COMMUNICATIONS
FROM THE
KONKOLY OBSERVATORY
OF THE
HUNGARIAN ACADEMY OF SCIENCES

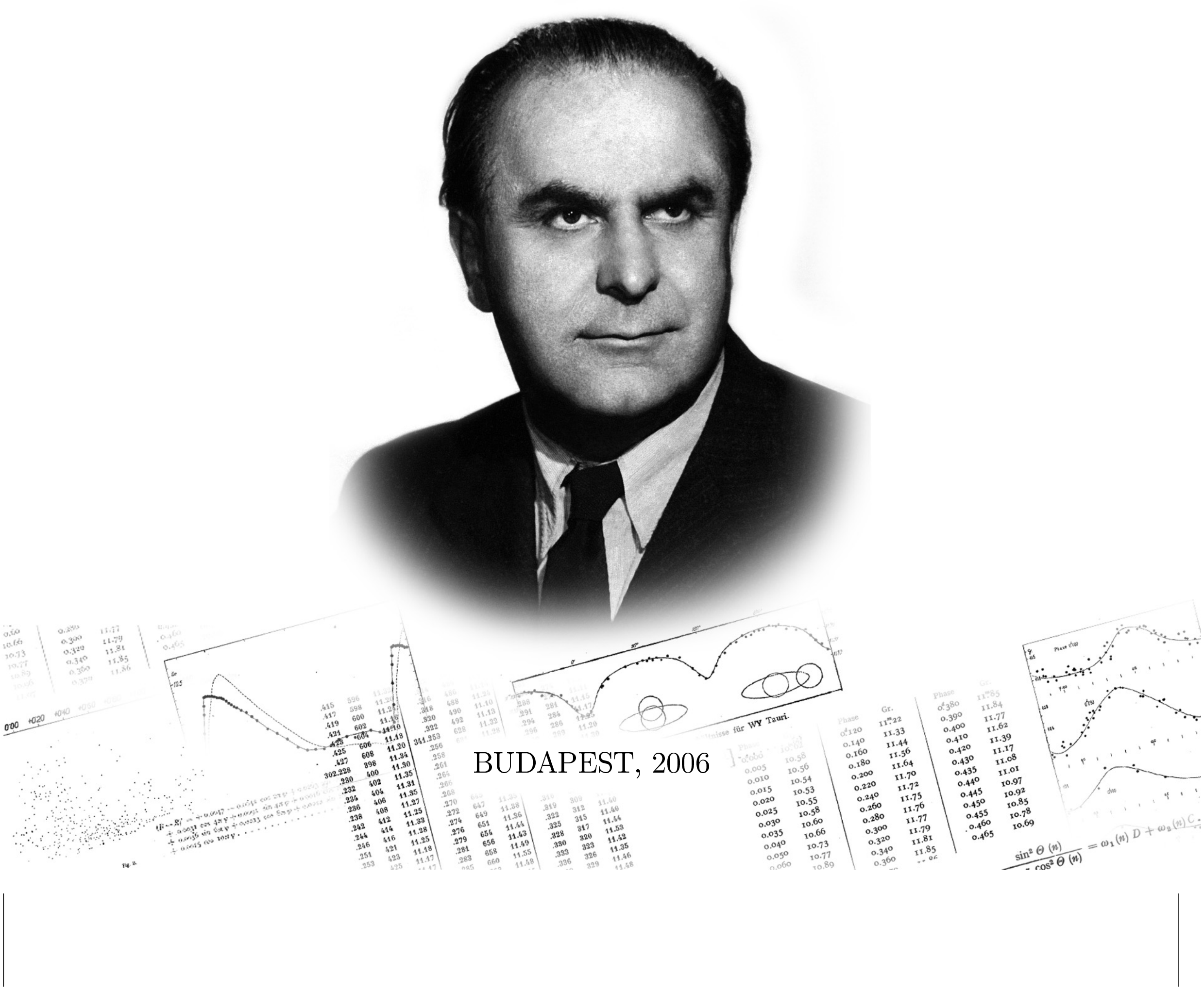
MITTEILUNGEN
DER
STERNWARTE
DER UNGARISCHEN AKADEMIE
DER WISSENSCHAFTEN

No. 104
(Vol. 13, Part 4)

Detre Centennial Conference

Proceedings

edited by: L. G. Balázs, L. Szabados, and A. Holl



BUDAPEST, 2006

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Foreword

The Astronomical Research Institute of the Hungarian Academy of Sciences commemorated the 100th anniversary of the birth of László Detre on 19th April, 2006. On the cosmic scale one hundred years is but a blink of an eye, but in the life of a research institute in Central Europe it is a very long time indeed, and the mere fact of its continued existence is, in itself, no mean achievement. In this context, existence does not not only mean having a pleasant building standing in a park in a pleasant area in the Buda Hills on a road named after its founder, behind a fence, displaying, for all to see, a board showing that this is indeed the Astronomical Research Institute of the Hungarian Academy of Sciences, but also that the creation of its founder is still an internationally acknowledged scientific workshop, producing work well up to the prevailing international standards. In Central Europe this cannot be taken for granted in our century. During this time the country (and within it the Institute – better known as the Konkoly Observatory) has managed to survive two World Wars, two revolutions, one world-wide economic crisis (and quite a few smaller ones), five changes of the political regime, and many smaller mishaps, not to be listed here.

As a scientist and the director of the institute, László Detre played a decisive role in the fact that our institute, despite all of the mishaps of the history in Central Europe, is respected worldwide. He was the most prominent representative of Hungarian astronomy in the 20th century. He got his PhD degree in Berlin (1929), having there such outstanding professors as Albert Einstein and Max Planck. Returning to Hungary he got a position at the Konkoly Observatory, Budapest, where he was active until his death in 1974.

He recognized that a small country, like Hungary, could carry out internationally high level research in the field of time-dependent astrophysical processes. Following his initiative, the mountain station at Piszkéstető was established and he passed away in 1974, just before the completion of the 1 m RCC telescope, the largest astronomical telescope in Hungary so far. There are no branches in the recent astronomical research in Hungary which do not go back to his organizational work.

Since László Detre played a significant role in the whole astronomical research in Hungary, the appropriate celebration of his centenary was a scientific colloquium giving a comprehensive overview of his scientific activity and its effect lasting until now. As he was member of the Hungarian Academy of Sciences we organized this colloquium under its auspices.

Although László Detre's scientific activity and achievements are well known abroad, he remained faithful to his country all the time and he did not leave it even in the hardest times. For him, his Hungarian nationality was very important and he emphasized it many times.

Taking into account all these circumstances, our Academy hosted a memorial colloquium on the significance of the work of László Detre on April 20, 2006. All the speakers knew him personally and remember him as a person who played a decisive role in their scientific career. A significant aim of the colloquium was to present a comprehensive overview also for young people who had no opportunity to know him personally.

This dedicated issue of the Communications from the Konkoly Observatory contains the talks presented at the memorial colloquium. We are thankful to our Academy for hosting the colloquium and to the speakers for their valuable contributions.

Lajos G. Balázs
Director

LÁSZLÓ DETRE

19 April 1906, Szombathely – 15 October 1974, Budapest

- 1924: Final exam in the Premonstratensian Secondary School in Szombathely
- 1924-1929: Studies at the Pázmány Péter University (Budapest) and Friedrich Wilhelm University (Berlin)
- 1929: PhD degree (Friedrich Wilhelm University)
- 1929-1974: Staff member in the Konkoly Observatory
- 1943-1974: Director of the Konkoly Observatory
- 1946-1949, 1955-1973: Corresponding member of the Hungarian Academy of Sciences
- 1961-1974: Editor of the Information Bulletin on Variable Stars
- 1964-1968: Head of the Department of Astronomy at the Loránd Eötvös University
- 1967-1970: President of the IAU Commission 27 (Variable Stars)
- 1968-1974: Honorary Professor of the Loránd Eötvös University
- 1970: State Prize awarded
- 1973-1974: Ordinary member of the Hungarian Academy of Sciences

László Detre and the Konkoly Observatory

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Prelude

In the seventh decade of the XIXth century changes occurred in astronomy, amounting to a revolution. Gustav R. Kirchhoff and Robert W. Bunsen discovered spectral analysis, which is the method whereby it is possible to draw valid inferences about the composition and physical properties of the emission source from its spectrum. Until then astronomy was to do mainly with measuring the time, the determination of the geographical position of earthly locations, that is with cartography and navigation or with mathematics through the study of celestial mechanics (for example Karl Friedrich Gauss was nominally earning his emoluments as the director of Göttingen Observatory).

The introduction of spectrum analysis into astronomy made it possible to study those physical processes, which produce the electromagnetic radiation observed through the telescopes. The epoch-making importance of this discovery was immediately recognized by Miklós Konkoly Thege, who decided right from the beginning to adopt observational astrophysics as the primary objective of his private observatory at Ógyalla established in 1871. He made regular observations of sunspots, organized a network for the observation of meteors, studied the structural changes visible on the surface of planets, and measured the spectra of some bright comets and stars. He was not satisfied with simply observing the phenomena, he also attempted to analyze them and find their explanation.

The 1860-1870s saw the beginning of the systematic study of stellar spectra. The Ógyalla Institute took the study of the spectra of stars brighter than 7.5 magnitude, and observable between -15° and 0° of declination as its contribution to the programme. Between the years 1882-1885, the lion's share of the work was done by Radó Kövesligethy, who was working at the institute as a graduate trainee, on secondment from the University of Vienna, where he was completing his studies. Later he became a professor at the University of Pest, acquiring a world-wide renown as an authority on seismology.

With the passing of the years, Konkoly became increasingly worried about the future of his institute. On the one hand, he was apprehensive – and rightly so – that after his death his stellarium may share the fate of similar initiatives in Hungary, that is falling standards and general decrepitation. On the other hand, he also appreciated the fact, that his financial resources were insufficient to finance a modern observatory in competition with the outside world, mainly America. Nationalisation appeared to be the only solution. He has already mooted a plan to this effect in the eighties, but it was not before 1899 that, using his parliamentary influence (in the interim he also became an MP), he could realize his intention. After the signing of the necessary papers on 16 May, 1899, the observatory became state property on 20 May, 1899. There were some people of the opinion, that Konkoly's timing was intentional. 21 May, 1899 was the fiftieth anniversary of Buda's liberation from the Austrians during the Hungarian War of Independence, that set the final seal on the sad fate of the observatory on St. Gellért's Hill.

The new National Observatory (full name: Royal Hungarian Astrophysical Observatory of the Konkoly Foundation) selected astronomical photometry as its principal field of exploration. Konkoly chose photometry as the principal field of study for his observatory because at the end of the XIXth century it became more and more obvious that, in the field of spectroscopy, even the state-financed establishment would be unable to keep pace with the rapidly growing observatories operating in the wealthy Western countries. To be able to employ the methods of photometry, it was necessary to establish a system of reference, covering the whole celestial sphere, which could serve as etalon for future measurements. The direction of this program went to the observatory of Potsdam, near Berlin. It was an international effort, and Ógyalla undertook to collect data on more than two thousand stars brighter than 7.5th magnitude, in the segment of declination -10° to 0°. Photometry was applied not only for creating the system of reference, but also for the study of stars of variable brightness. Konkoly realized that time passes equally fast for the rich and the poor, so, in some fields of study, the advantage of rich, well endowed observatories can be cancelled out, and more modestly equipped observatories could remain competitive. For this reason, the study of variable stars was chosen, in addition to contributing to the photometric reference system, as the primary task of the institute. This decision was to be the main determining factor in the further operation of the observatory.

At the First World War's end Hungary was also buried under the ruins of the defunct Austro-Hungarian empire, and both Ógyalla and the observatory found themselves under alien rule. By the end of 1918 the relevant ministries began to discern the victors' plans for the new Europe, so the Ministry of Education ordered the dismantling and repatriation of all the instruments and equipment in the state's possession. By January 1919 all the dismantled material was safely back in Hungary.

In 1921 the Hungarian government, acting on the recommendation of the Minister of Education, Dr. József Vass, accepted plans for a far-reaching program for the promotion of education and science. The observatory on the Svábhegy (Schwabian Hills) was built under the aegis of this programme. Budapest's local government voted to place twelve acres of land at the disposal of the state government with the proviso, that it may only be used for the building of the new observatory. Construction works started in the autumn of 1921, and one year later observations already started in the first dome. The order for the 24 inch reflector, sent originally to Heyde, but cancelled because of the war, was renewed. The installation of another dome was completed with the financial support of the Budapest local government in 1928. So, in the company of a 16 cm refractor from Ógyalla (in another, smaller dome), and of a meridian instrument, which was used among other things for providing accurate time-signals for the railways, the reincarnated Konkoly institute could also start its scientific work.

Next year, in 1929, László Detre joined the scientific staff of the institute.

Years of study

László Detre was born on April 19, 1906 in Szombathely (Steinamanger). His father, Dr. János Dunst (Detre changed his name in 1933) was a city councillor who died when Detre was only 2 years old. His mother educated him on her very modest widow pension. He studied in the secondary school of the Premonstratensers of Szombathely and had taken his final examination in 1924. Already in these years he showed a very keen interest in natural sciences and in the age of 13 he founded a study circle of natural sciences in his school. Above all, he was a skilled mathematician and he won a Hungarian contest in mathematics. As a consequence he was admitted to the Eötvös Collegium and studied at the Pázmány Péter University of Budapest between 1924-29. After completing three years at this University, he received a fellowship at the Friedrich-Wilhelm University in Berlin.

At that time this University had excellent professors in astronomy, mathematics and physics. According to Detre's university record he studied astronomy from Paul Guthnick, Ernst Kohlschütter and August Kopff. Albert Einstein and Max Planck were his professors in theoretical physics.

The 1920s were famous for the birth of quantum mechanics which made some kind of a revolution in physics. At the same time astronomy also experienced a revolutionary change. Following Hubble's discovery, the concept of the large stellar islands in the Universe, like our Milky Way, became widely accepted. These new results gave a new stimulus to the statistical studies of the space distribution of the stars.

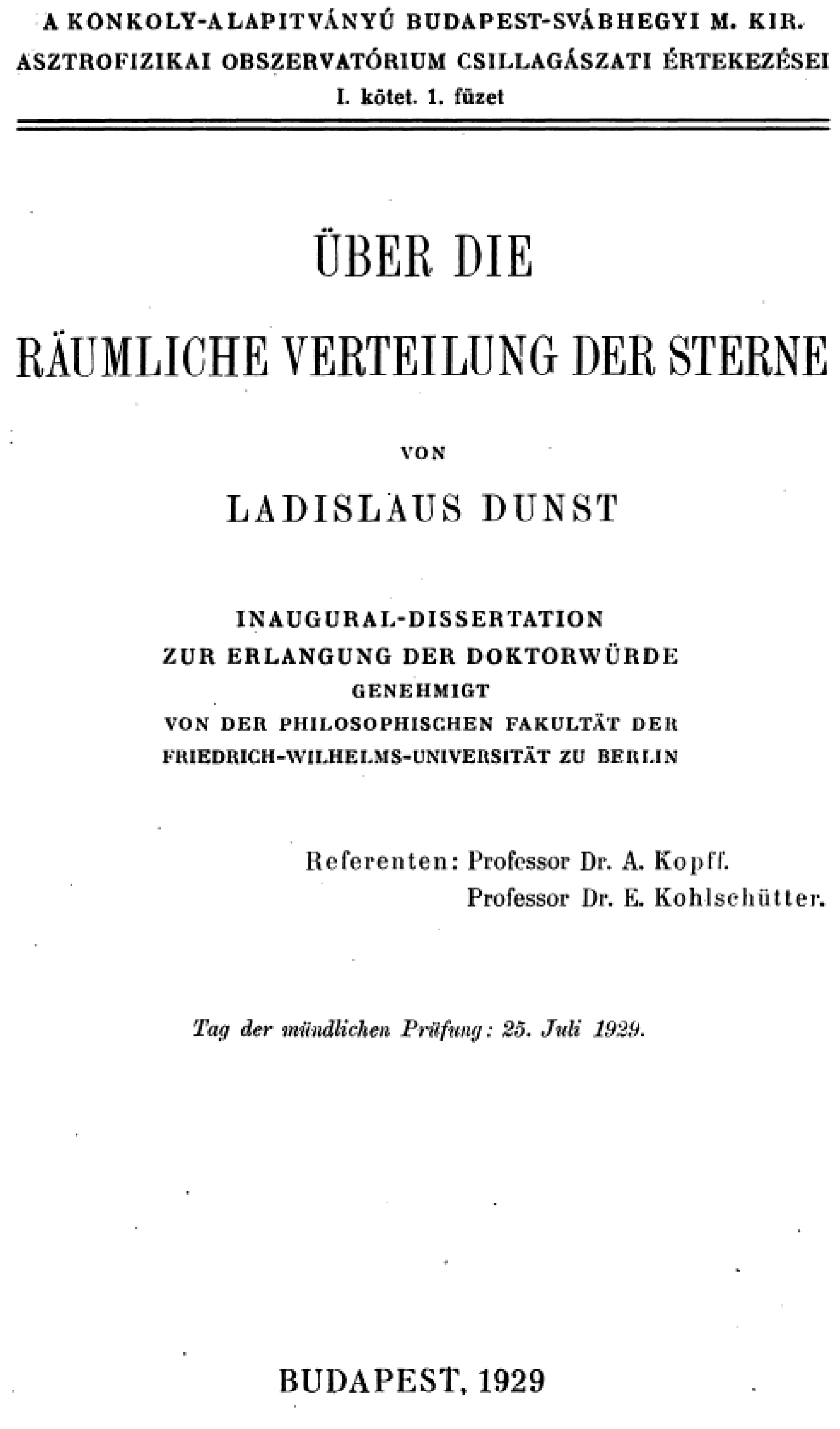
László Detre made acquaintance with these studies in Berlin and prepared his PhD theses on stellar statistics under the leadership of A. Kopff and E. Kohlschütter. He defended his Theses on July 25, 1929. His dissertation was published as the first issue of the institute's communications series (*Fig. 1*).

Before starting the regular work in the institute at the Svábhegy, he made six-month study trips in Vienna and Kiel.

Research fellow at Svábhegy

The science of astrophysics, born in the last three decades of the XIXth century continued its explosive growth all through the subsequent decades. This rate of growth was almost compatible with the growth of physics itself. In the 1920s it was proved by observational astronomy that stars tend to agglomerate in gigantic clusters (galaxies), and these galaxies are getting further away from each other at a rate proportional to their distance. This is a direct consequence of the relativistic models of the universe. The dynamic exploration of galaxies – including our own Milky Way system – also took place at an ever accelerating pace. The list of these achievements would not be complete without mentioning theoretical investigations on the internal structure of the stars, and their confirmation by observations.

Stars of variable brightness are important members of the family of stars. One of their important sub-groups is formed by those stars, whose changes of light emission are caused by oscillations propagating in the body of the star itself. When the oscillations reach the stellar surface, they cause a characteristic pattern of light changes, which carry important information about the internal structure of the stars. The first comprehensive treatment of this subject was the book written by Sir Arthur Eddington. He showed that the pulsation period of a star (P) and its average density (ρ) are related by a simple



A KONKOLY-ALAPITVÁNYÚ BUDAPEST-SVÁBHEGYI M. KIR.
ASZTROFIZIKAI OBSZERVATÓRIUM CSILLAGÁSZATI ÉRTEKEZÉSEI
I. kötet. 1. füzet

ÜBER DIE RÄUMLICHE VERTEILUNG DER STERNE

VON

LADISLAUS DUNST

INAUGURAL-DISSERTATION
ZUR ERLANGUNG DER DOKTORWÜRDE
GENEHMIGT
VON DER PHILOSOPHISCHEN FAKULTÄT DER
FRIEDRICH-WILHELMS-UNIVERSITÄT ZU BERLIN

Referenten: Professor Dr. A. Kopff.
Professor Dr. E. Kohlschütter.

Tag der mündlichen Prüfung: 25. Juli 1929.

BUDAPEST, 1929

Figure 1: Cover page of the first issue of the institute's communications series containing Detre's PhD Theses on the space distribution of stars.

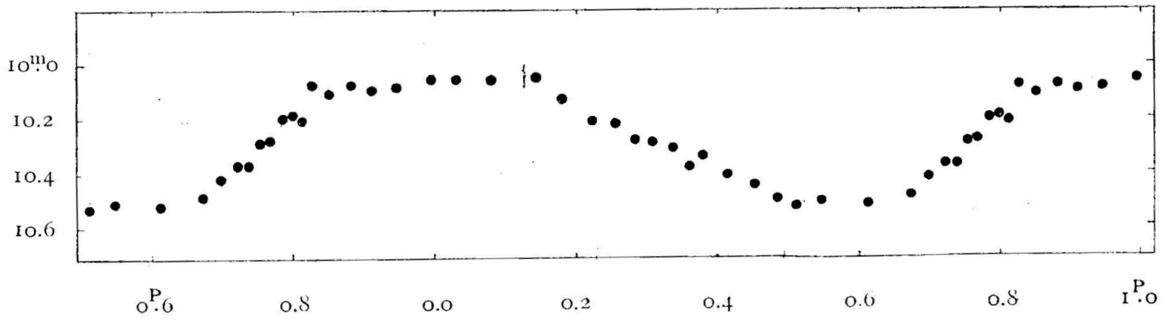


Figure 2: Light curve of RU Piscium as published in the Astronomische Nachrichten in 1931.

formula: $P\sqrt{\rho} = C$, where C is constant within the limits of the theory. Variable stars of short (0.5-1 day) period undergo several tens of thousands of periods during a generation. So their period can be measured to the accuracy of 10^{-5} s. Consequently, the processes, which would take several millions of years to complete, can cause an observable difference in the star's period in only a few decades. Research papers, devoted to the study of period changes caused by the evolution of stars, started to appear in the 1930s.

The Astronomische Gesellschaft, which was dominated by the Germans, held its 1930 General Meeting in Budapest, where some of the leading lights of the Anglo-Saxon astronomical community were also invited. Arthur Eddington was one of those invited, and he, according to the testimony of contemporary photographs, also paid a visit to the observatory in the Svábhegy. We do not know whether they discussed Eddington's new theories about the pulsation of variable stars and their observable consequences, but we know that, with the work of László Detre and later Júlia Balázs in the 1930s, the study of period and light curve variations of short period, RR Lyrae type pulsating variable stars, became one of the most important research fields of the institute at the Svábhegy.

It soon became obvious that the problem was not as simple as it first appeared, because there exist some period changes which cannot be attributed to the passage of time and the ageing of the star. The first task was to eliminate those from the changes studied. The study of variable stars provided decades of work for the institute, and it is still going strong.

I think it is not by chance that Detre changed his research field from stellar statistics to the study of period changes of short periodic pulsating variables. His first paper on this subject was published on the RR Lyrae star RU Piscium in 1931 in the Astronomische Nachrichten (*Fig. 2*). Detre used visual photometry in this work obtained with a Graff photometer attached on the 24 cm Heyde refractor (*Fig. 3*). In 1933 the visual technique was changed onto photographic observations. The 16 cm Merz was replaced by a 19 cm Cook refractor equipped with a 6 inch astrograph for photographic observations (*Fig. 4*). This instrument became the main observing facility for the further variable star research in the institute.

The photographic observation of globular clusters was another new departure for the institute which was initiated by Detre, made possible by the installation of the 24 inch telescope. In these clusters, hundreds of thousands of stars, among which there are many variable ones, are squeezed together in a relatively small volume. This makes it possible to record quite a few hundred variable stars on a single photographic plate. During the 1930s the globular clusters became very important. From their spatial distribution it became

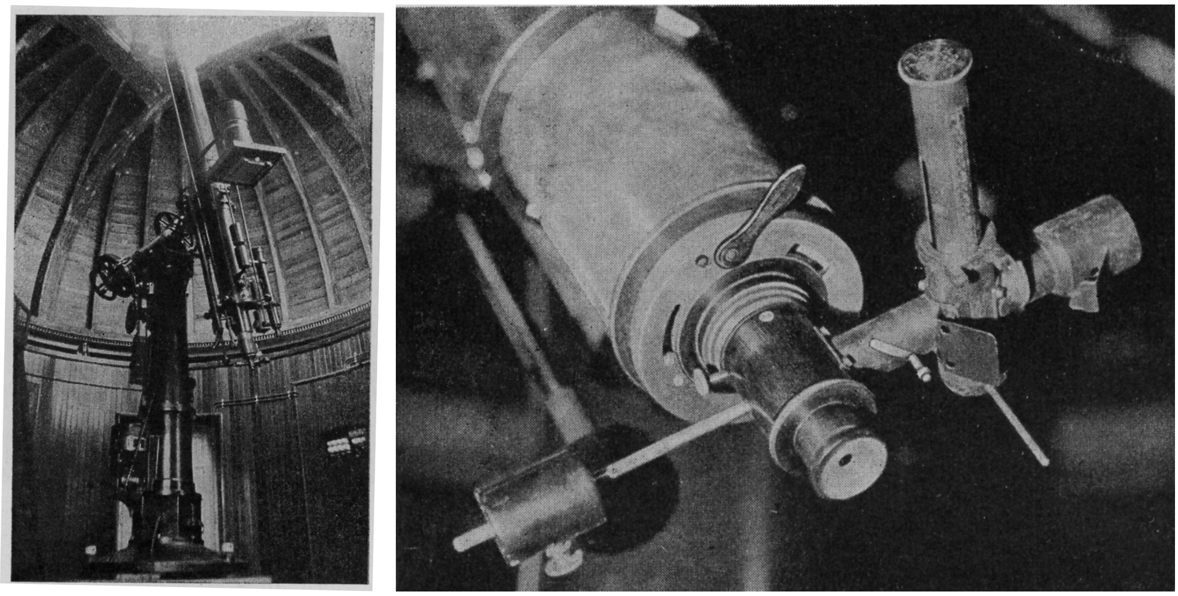


Figure 3: The 20 cm Heyde refractor of the institute (left) and the Graff visual photometer attached to the telescope (right).

possible to deduce the location and distance of the center of our Milky Way system. Subsequent studies revealed that, according to our present knowledge, these clusters are the oldest objects in the Universe, and their age is an excellent clue as to the verification of modern models of cosmological theories.

László Detre as director of the institute

On December 31, 1943 László Detre was appointed director of the institute.

The institute in the Svábhegy did not survive WWII without serious consequences. From 1943 onwards conditions rapidly deteriorated. Most of the periodicals and scientific publications published abroad failed to arrive. From the summer of 1944 the allied air offensive became more and more dangerous. On the top of Csillebérc, in the close neighbourhood of the institute, an AA battery was installed and, as it was a legitimate target, the director was, not unreasonably, worried about suffering collateral damage, should the allied flyers attempt a counterstroke. The 24 inch mirror was dismantled, but with the smaller telescopes observations continued until the early days of December, 1944. On the 25th of December, 1944 the institute was occupied by Soviet troops, specifically by a battery of field artillery, with the strength of about six hundred soldiers and one hundred horses. The soldiers were billeted in the main building, the domes were used as stables for the horses and as field kitchens.

Three days after the occupation Detre reached an agreement with the Soviet command, to the effect that the library and some of the laboratories were declared ‘off limits’ and free from billeting. When I was a young researcher, I heard some rumors about one of the Soviet officers having been a fellow astronomer and that the quick and favorable response to the institute’s request was due to his intervention. While we were preparing for the centenary of the institute in 1999, I tried to verify this story, but I could not find anybody either to confirm or to deny it.

Today it is with pride that we show our library to our visitors, and the exemption

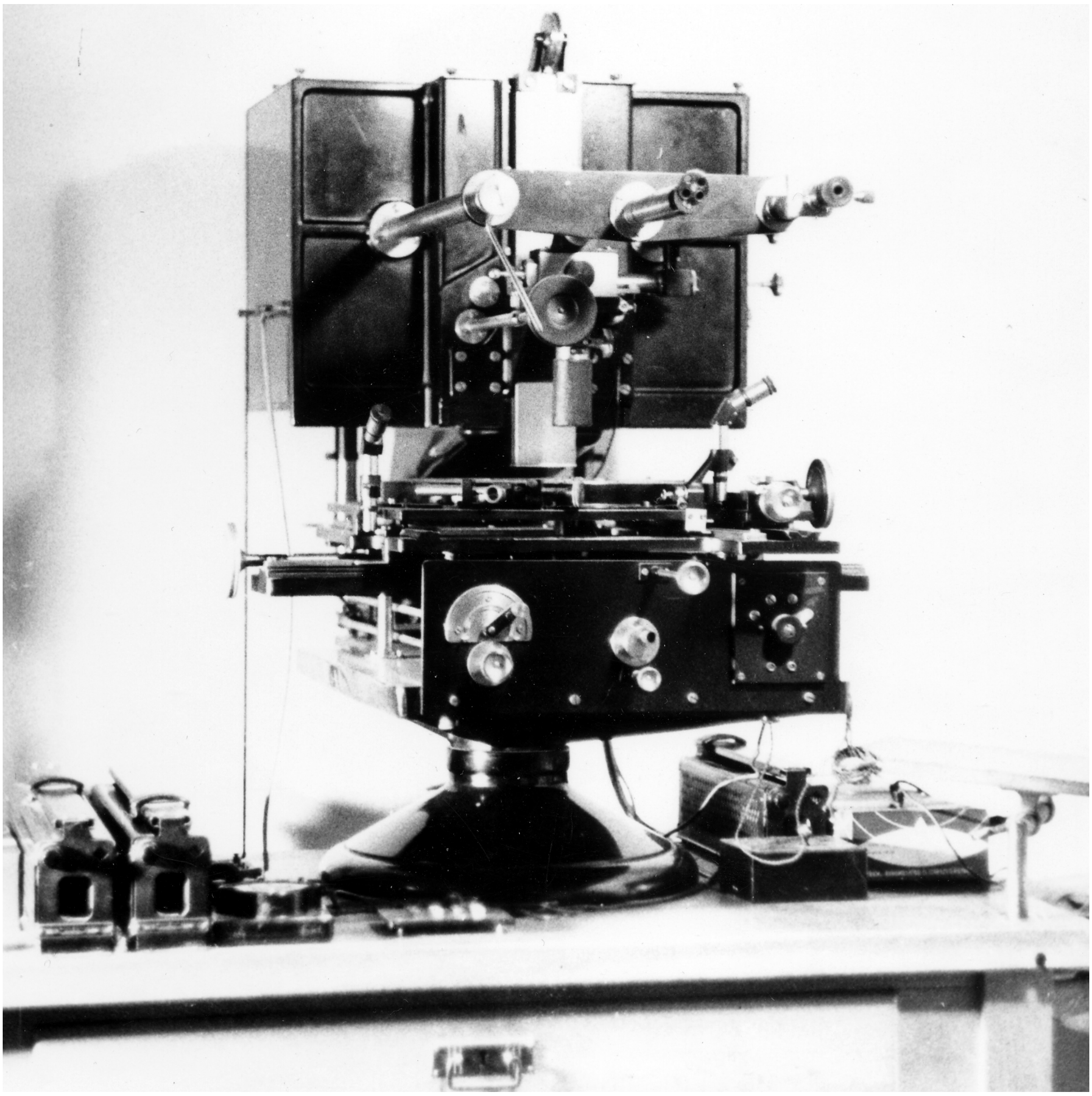


Figure 4: Photometer used for measuring the plates obtained with the 6 inch astrograph.

from billeting was a decisive factor in this. In spite of the turbulent history of Central Europe, complete sets of all the important astronomical publications (the Astronomische Nachrichten from 1823, the Astronomical Journal from 1851, etc.) can be found in our library. Publications not received during the war were successfully replaced soon. Thanks to the Rockefeller Foundation, the library received the missing volumes of the Astrophysical Journal and Astronomical Journal of 1941-46 and 1941-47 years, respectively.

As an acknowledgement of his internationally respected scientific results, László Detre was elected a corresponding member of the Hungarian Academy of Sciences in 1947.

In 1946 a decision was made on establishing a department of solar physics. For making heliophysical observations a photo-heliograph and Konkoly's 25 cm telescope were installed. The regular observations were started in March 1950. The whole solar disc and those parts covered with spots and prominences were regularly observed photographically. Based on their observations, the members of the department informed the National Meteorological Service by phone, when it was necessary, on the development of the solar activity. Beside the observations the statistical investigations made a significant part of the activity of the department. In 1957 a decision was made on moving the Department of Solar Physics into Debrecen where it started to work on January 1, 1958 as an independent institute on a location provided by the Kossuth Lajos University of Sciences.

Astronomical Institute of the Hungarian Academy of Sciences

At the foundation on the Svábhegy the institute belonged to the Ministry of Cultural Affairs but after that it joined the "Collection University" and in 1934 the Pázmány Péter University of Sciences. In 1948 the Ministry of Cultural Affairs received it back again. On the occasion of changing the political system, in 1948 a decision was made on establishing a network of research institutes, independent of the universities and organized within the framework of the Hungarian Academy of Sciences. On February 1, 1951 according to the 10/1951/I.6./M.T. decree of the Council of Ministers the Academy took over the institute under the name of Astronomical Institute of the Hungarian Academy of Sciences (widely known as the Konkoly Observatory abroad). Two departments were formed at the astronomical institute of the Academy: the astrophysical and the heliophysical.

After WWII the advance of astrophysics re-started at a very fast pace indeed. One of the most decisive factors in its advance was the appearance of radio astronomy. The discovery of the theoretically predicted radiation of the neutral hydrogen at the wavelength of 21 cm was its first great achievement. The appearance of computers also produced revolutionary changes. The traditional field of astronomy, optical observations were also significantly influenced by these changes. The giant 5 m reflector at Mt. Palomar started its operations in 1949. There was another reflector there with 180 cm mirror diameter. This telescope of the type Schmidt has a wide field of view (6.5°). With this instrument, the mapping of the whole firmament (up to about 21st magnitude) was completed in a few years. The result of this work, the Palomar Sky Atlas served as a starting point for many important explorations.

This rapid advance resulted in a dilemma for Hungarian astronomy. The problem was to find a compromise between the challenges presented by these advances, and the impoverished state of the Hungarian economy. One element of the solution was the introduction of photoelectric photometry. In the field of optical astronomy, the photoelectric multiplier played the leading role. In comparison with the conventional photographic plate, which

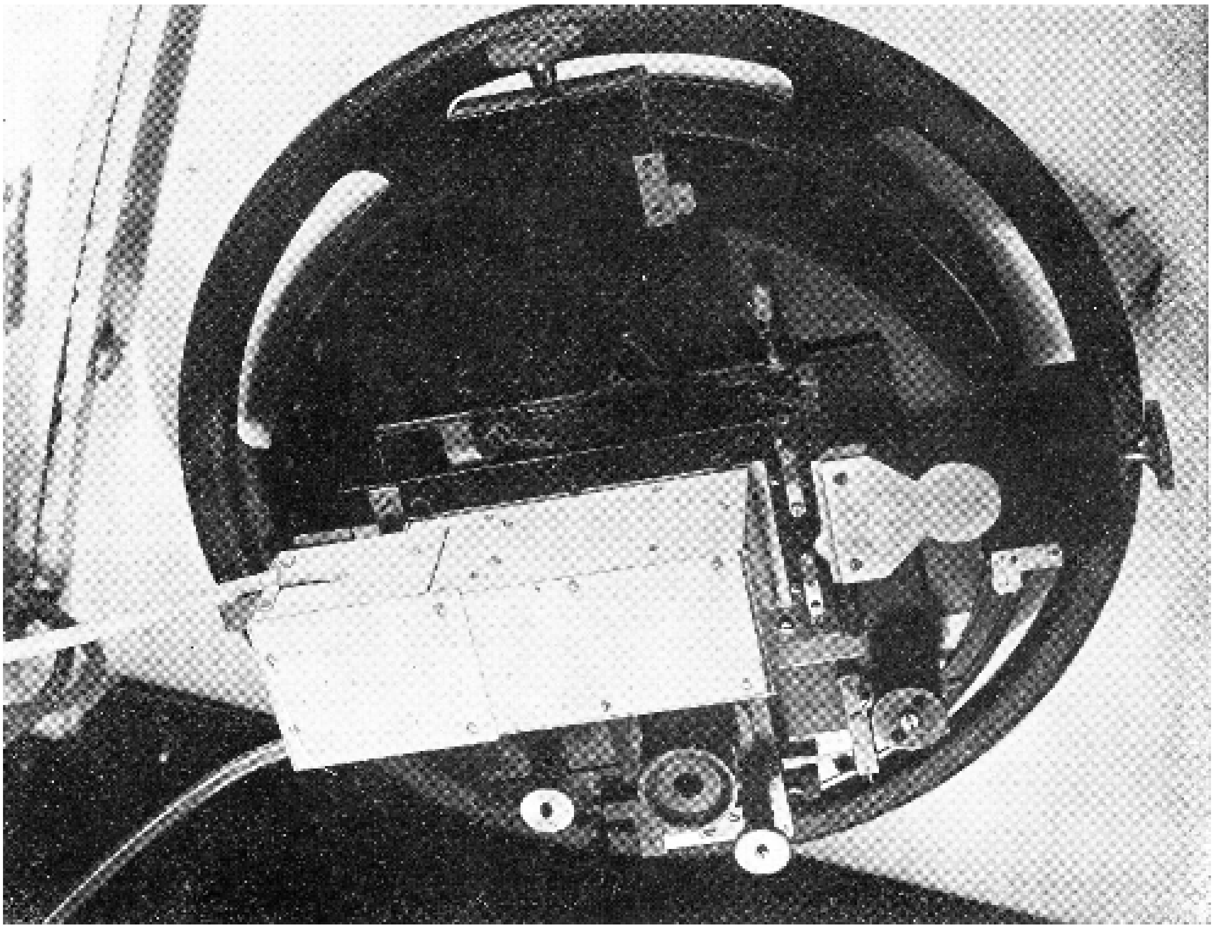


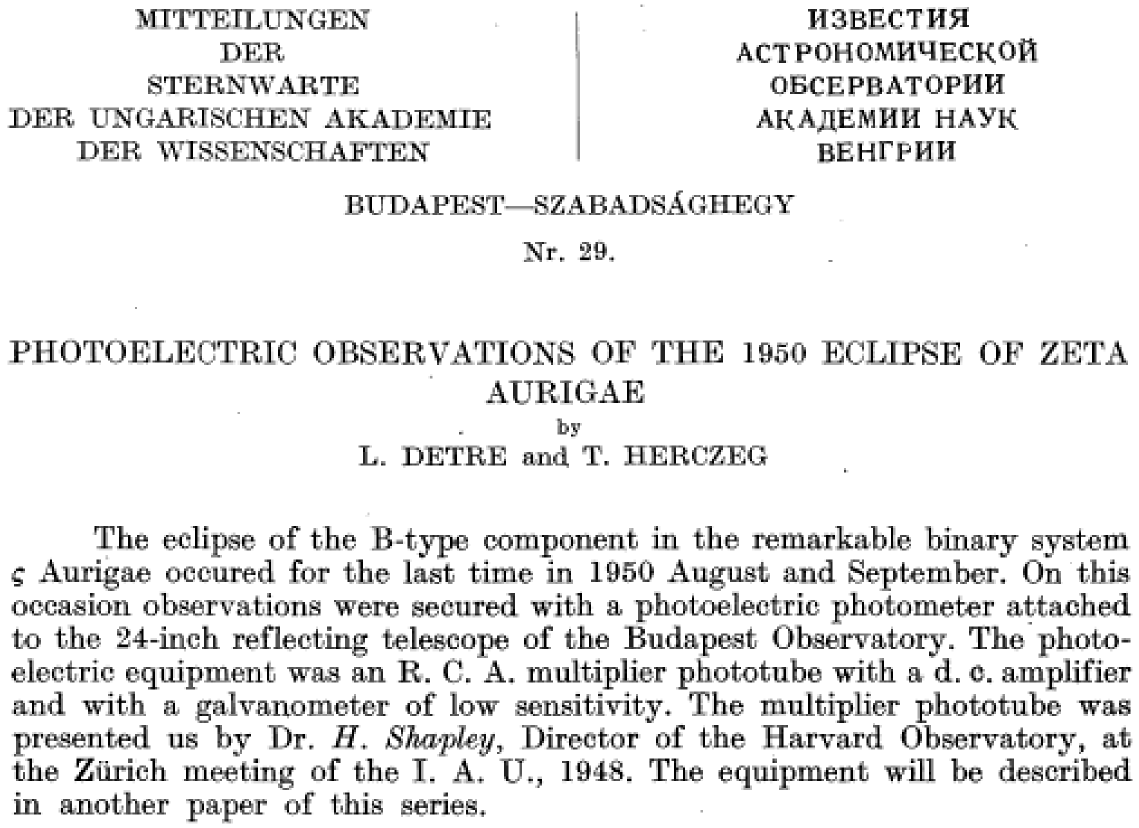
Figure 5: Photoelectric photometer attached on the Newtonian focus of the 60 cm telescope. The instrument used the 1P21 tube obtained from H. Shapley in 1948.

had the disadvantages of a less than one per cent quantum efficiency and the non-linear characteristics of its light sensitivity, the new instrument had a high quantum efficiency, linear characteristics and a much reduced level of noise.

After the war the institute and the firm 'TUNGSRAM Ltd.' conducted some joint experiments to develop a photomultiplier for astronomical purposes, but these failed to yield the desired results. In 1948 the then director of the institute, László Detre, received a 1P21 type multiplier from Harlow Shapley. This equipment made it possible to build a new photometer, which, fitted to the 24 inch telescope, enabled the institute to carry on with its work using really state-of-the-art technology (*Fig. 5.*). The first results were published on the photoelectric observations of the 1950 eclipse of ζ Aurigae in the No. 29 issue of the communications of the institute (*Fig. 6.*).

In 1954 they obtained a further 1P21 tube enabling them to observe down to 13th magnitude. Following the suggestion of the Dutch astronomer Theodor Walraven they rebuilt the amplifier of the photometer in 1955. Two further 1P21 tubes arrived in 1956 and László Detre received a further amplifier as a gift on the occasion of his visit in Leiden which made it possible to establish another photometric observing site based on a 25 cm reflector, so photoelectric photometry became one of the routine methods of observation.

Putting on orbit the first artificial satellite of the Earth in 1957, a new era started in the technical civilization which naturally had an impact on astronomical research.



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ИЗВЕСТИЯ
АСТРОНОМИЧЕСКОЙ
ОБСЕРВАТОРИИ
АКАДЕМИИ НАУК
ВЕНГРИИ

BUDAPEST—SZABADSÁGHEGY

Nr. 29.

PHOTOELECTRIC OBSERVATIONS OF THE 1950 ECLIPSE OF ZETA AURIGAE

by

L. DETRE and T. HERCZEG

The eclipse of the B-type component in the remarkable binary system ζ Aurigae occured for the last time in 1950 August and September. On this occasion observations were secured with a photoelectric photometer attached to the 24-inch reflecting telescope of the Budapest Observatory. The photoelectric equipment was an R. C. A. multiplier phototube with a d. c. amplifier and with a galvanometer of low sensitivity. The multiplier phototube was presented us by Dr. *H. Shapley*, Director of the Harvard Observatory, at the Zürich meeting of the I. A. U., 1948. The equipment will be described in another paper of this series.

Figure 6: The first published result based on photoelectric measurements carried out in the Konkoly Observatory

The Astrosoviet (Astronomical Council) of Moscow asked our institute to participate in the observations necessary for computing the orbits and donated 40 telescopes for visual observations well suited for installing a satellite tracking station. Besides Budapest such stations were installed in Baja, Miskolc and Szombathely which did not belong to the Academy, the professional coordination, however, was carried out by the institute. Following Detre's initiative, the station of Baja joined the institute but the others kept their independence.

In the field of artificial satellites the cooperations were realized within the framework of the INTERCOSMOS. In 1965 COSPAR had already two Hungarian members. The first computer program made in the institute in 1961 was related to the motion of the artificial satellites.

In 1970 László Detre received a State Award.

New station at Piszkéstető

The building of the observation station on Piszkéstető was a decisive impact of Detre's activity on the institute's life. The story of the Piszkéstető station had its commencement in the 1950s.

After the change of regime in 1948, a decision was made to set up of a network of research institutes under the general guidance of the Hungarian Academy of Sciences. One of the spectacular steps in this programme was the establishment of the Central

Research Institute for Physics. Following a decision made by the Council of Ministers, the Observatory in the Svábhegy also became part of this scientific network. In the context of the programme of extensive investment in science, it also became feasible for the institute to make a substantial capital investment.

At the beginning of the 1950s the improvements made to Budapest's public lighting and its increasing pollution made any further development of the observational facilities in the Svábhegy observatory pointless. In the early 1950s the Academy approved the acquisition of a wide angle telescope of the Sonnenfeld type, and the order was placed with Zeiss of Jena. Shortly afterwards the order was cancelled and a new order was placed for another wide angle telescope of the Schmidt type. This Schmidt telescope has a 900 mm mirror and a 600 mm correction plate, which makes her exactly half the size of the Mount Palomar Telescope, its sister, commissioned a few years earlier. The telescope was supplemented by the planned purchase of a 600 mm objective-prism, which was only marginally smaller than her biggest, 800 mm companion, the instrument installed at Hamburg. With the Schmidt telescope, Hungarian astronomy came again to possess a world-class instrument.

The Council of Ministers allocated nine million Hungarian Forints to astronomy. The construction of the new observatory started in 1958, at Piszkéstető, which is the third highest peak in the Mátra Mountains, 100 km NE from Budapest. The telescope itself became operational in 1962.

The development of astrophysics, that started after WWII, gained considerable momentum by the 1960s. In this, one of the decisive factors was the infusion of the revolutionary new microelectronics into the realms of astrophysics. With the appearance of electronic computers, numerical simulations (or modelling) became feasible. This enabled the scientists to replace their analytical approximations with more exact quantitative models, whose results could be directly compared to observational results. The turn of the 1950s saw the birth of models describing the evolution of stars. One of the interesting achievements of modelling techniques was, that with their help it was possible to verify the Hertzsprung-Russell diagram, which was discovered early in the century and relates the surface temperature of the stars to their absolute luminosity. Curve-fitting using these models can also yield the age of the cluster and its distance from Earth. The number of open, or galactic, clusters in our Milky Way system is estimated as several thousand. The examination of the HRD of these clusters is one of the important investigations carried out with the new telescope at Piszkéstető.

Perhaps the most spectacular touchstone of the stellar evolution theories was the theoretical clarification of the background to the explosion of supernovae. One of the most important problems concerning this subject is the determination of the stellar mass necessary to end up as a supernova. As the last supernova observed in our galaxy was observed by Kepler, our up-to-date knowledge must be based on observations of extragalactic supernovae. With the systematic survey of extragalactic events we might get a reasonable picture of the frequency of such events. With its 5° field of view, the Schmidt telescope at Piszkéstető is capable of regularly surveying areas rich in galaxies. It was in 1964 that the first supernova was observed. This was followed by the finding of 48 more, so it was at Piszkéstető, where almost ten per cent of the known supernovae were discovered in the era of photographic supernova patrols.

The Schmidt telescope also made the observation of special stars possible, such as the flare stars, showing sudden increases of light emission occasionally, or young stars at the beginning of their existence, showing a significant emission in the Hα line. The distribution of stars showing Hα emission yields important supporting data for the investigation of physical processes, occurring in molecular clouds active in the formation of new stars. In 1966 the Mátra station's instrument park was enriched by a Cassegrain-type telescope of 50 cm mirror diameter. The attachment of a photometer, developed within the institute, made it possible to utilize the favorable conditions prevailing around the Mátra station also in the field of photoelectric photometry.

At Piszkéstető the last and largest capital investment was the acquisition of an RCC telescope of 1 m diameter. In the beginning, the telescope was operated using CAMAC modules and a TPAi minicomputer, which were developed by the Central Research Institute for Physics. They were used for digitally positioning the telescope and collecting and storing the observed data. The telescope, augmented by the photoelectric photometer – developed by the institute – was in all respects up to contemporary world standards.

Unfortunately, László Detre did not live to see the inauguration of the RCC telescope at the end of 1974 since he died weeks before, on October 15.

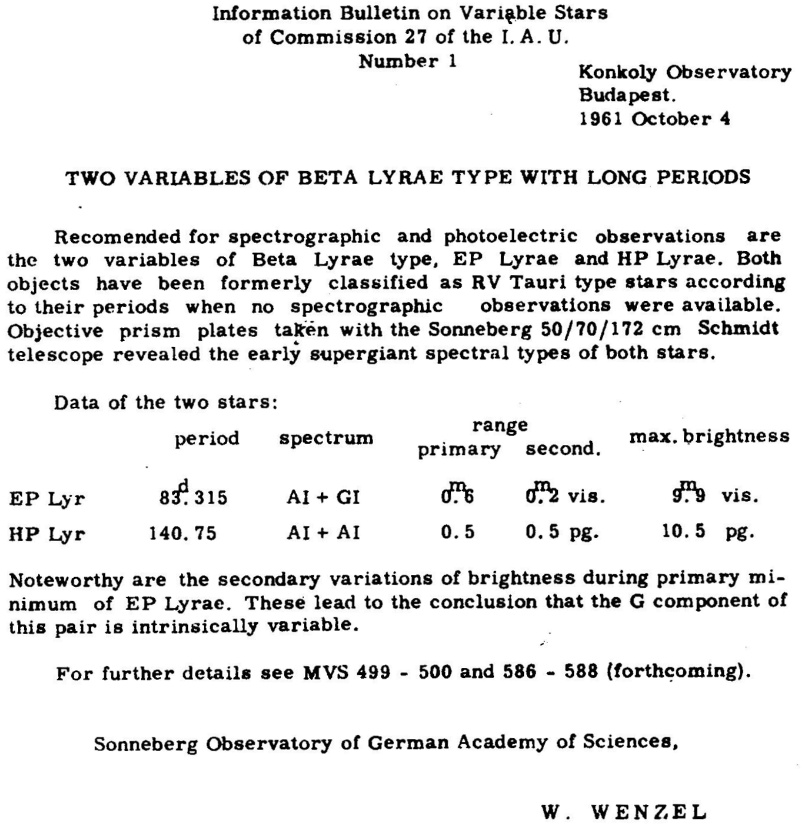
International relationships

The institute had traditionally good relationship with German astronomy. Until 1942 it issued a summary report on the annual work to the Vierteljahrsschrift published by the Astronomische Gesellschaft.

Following the World War I to compensate the international reputation of the AG, the Anglo-Saxon powers established the International Astronomical Union (IAU). Since Hungary was fighting on the defeated side, its researchers were excluded, along with the Germans. Our relationship to the IAU was normalized only after the World War II. Although there were some efforts to establish American relationships (e.g. on the occasion of a longer study visit of Károly Lassovszky, later director of the institute), the young researchers typically had fellowships at German institutes. Of course, there were some efforts on the part of the scientists to remove this discrimination. The AG had its general assembly on August 8-12, 1930 in Budapest with the participation of several distinguished scientists from Anglo-Saxon countries (e.g. Arthur Eddington, Otto Struve).

The international relations of the institute were changed drastically after the war. As an opening of the new era, László Detre was admitted to the IAU, as the first Hungarian astronomer. After the change of the political system in 1948 international relations started preferring the Soviet Union. Until this time Hungarian astronomers had little contact with their Soviet colleagues, but then it changed drastically. Short and longer study trips to the Soviet Union became regular. In 1950 Boris V. Kukarkin, having an international reputation in the field of variable star research, suggested to start a cooperation in the main research field of the institute. In 1952 the Institute of Theoretical Astronomy of Leningrad requested us to cooperate in the precise determination of positions of minor planets having uncertain ephemerides. Even in this year a third scientific department of the institute was founded under the leadership of István Földes. The Department of Positional Astronomy and Stellar Statistics, however, stopped its operation after two years, since due to the recession of the economy, the reduction of the staff was ordered in the institute. This was solved by putting an end to the young department in 1954 (by dismissing the head and two coworkers).

Due to the bilateral cooperation agreements between the Academies of the socialist countries, personal contacts also became possible in astronomy. As a natural consequence,



Information Bulletin on Variable Stars
of Commission 27 of the I. A. U.
Number 1

Konkoly Observatory
Budapest.
1961 October 4

TWO VARIABLES OF BETA LYRAE TYPE WITH LONG PERIODS

Recomended for spectrographic and photoelectric observations are the two variables of Beta Lyrae type, EP Lyrae and HP Lyrae. Both objects have been formerly classified as RV Tauri type stars according to their periods when no spectrographic observations were available. Objective prism plates taken with the Sonneberg 50/70/172 cm Schmidt telescope revealed the early supergiant spectral types of both stars.

Data of the two stars:

	period	spectrum	range primary	 second.		max. brightness	
EP Lyr	$83^{d}.315$	AI + GI	$0^{m}.6$	$0^{m}.2$	vis.	$9^{m}.9$	vis.
HP Lyr	140. 75	AI + AI	0. 5	0. 5	pg.	10. 5	pg.

Noteworthy are the secondary variations of brightness during primary minimum of EP Lyrae. These lead to the conclusion that the G component of this pair is intrinsically variable.

For further details see MVS 499 - 500 and 586 - 588 (forthcoming).

Sonneberg Observatory of German Academy of Sciences,

W. WENZEL

Figure 7: The first issue of the IBVS in 1961

not only our researchers travelled to these countries but a high number of colleagues visited our institute from there. In 1959 an opportunity was presented to establish contacts with Chinese astronomers. In the framework of this, the institute donated a photoelectric equipment to the Observatory of Nanjing. In order to strengthen the cooperation with Romanian astronomers, an 1P21 photoelectric multiplier was donated.

Starting in the second half of the fifties, the cold war started to turn milder and in the life of the institute an apparent sign for it was Detre's participation at the general assembly of the IAU in Dublin in 1955. The 27th Commission of the IAU (Variable Stars) supported the widening of the international cooperations in a special resolution.

A very high reputation of the Hungarian variable star research and the work of László Detre, was an international conference held in 1956 August 23-28 in Budapest dealing predominantly with period and light curve variations of RR Lyrae and δ Cephei stars.

The revolution in 1956 shocked the institute dramatically. The migration wave following the revolution resulted in the leave of three excellent researchers (Tibor Herczeg, Imre Izsák, and István Ozsváth) who started their career with great promise. Although, they were soon replaced by young people starting out on a career but the loss of their expertise had a long lasting effect on the institute.

It was an important milestone of the international appreciation when the IAU commissioned our institute to edit and publish the Information Bulletin on Variable Stars, on the occasion of the participation of László Detre at the IAU General Assembly in Berkeley in 1961 (*Fig. 7.*).

There were two further events of international importance in the life of the institute in the last years of Detre's directorship in which he played a leading role. In 1968 the Hungarian Academy of Sciences hosted an IAU colloquium on non-periodic phenomena in variable stars in Budapest. Following the initiative of Soviet astronomers, the scientific academies of the socialist countries signed a cooperation agreement on the physics and evolution of stars in 1974.

One has to pay special attention to the agreement with the Armenian Academy of Sciences. It was quite uncommon that a member republic of the Soviet Union established international relationships getting round Moscow. This agreement obviously was a tribute of Victor Ambartsumian, the president of the Armenian Academy of Sciences and an astronomer of very high international reputation. He visited our institute many times and also had a good personal relationship with László Detre and our researchers. Following this cooperation agreement, signed in 1968, the Armenian and Hungarian astronomers had a very tight contact until the collapse of the Soviet Union.

Epilogue

On the occasion of Detre's centenary, the drawing of conclusions and the recapitulation of the lessons learned is almost inevitable. Many of us are having our minds exercised by the problem of trying to find the source of strength that kept our institute in existence, in spite of the trials and tribulations it was exposed to. How typical was this of the intellectual and scientific life in Hungary? An important element of the success was the finding of a 'window of opportunity' between the international scientific challenges and the material resources of Hungary, but this is not the whole secret.

There is also an independent factor behind the success, which may be called the human factor. It is a loose concept and may include everything that happens inside us and influences our decisions, but remains invisible to the contemporary onlookers and even to history. I have been struck by an idea, found in the writings of István Bibó[1], that there is no natural law which could guarantee success in the development of human societies. The evolution of any social structure is a possibility, which can be achieved by making the right decisions, but the other outcome is also possible.

During the years of Detre's activity, the institute was faced with many crises, but managed to survive them successfully. Does this fact have a special meaning for the intellectual life of Hungary? It is my firm belief that the answer is an unqualified 'yes'. The other important question, which may be even more important than the first one is: Where to go and how to get there. Science will be one of the most important defining factors of any future society. The Hungarian society must develop the inner strength to answer this challenge. What this answer will be, and how effective it will be, is also going to be a determining factor for the future of the Konkoly Observatory, but the heritage of László Detre's work has a significant impact on it.

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[1] István Bibó, Hungarian social scientist, one of the spiritual fathers of the Hungarian revolution in 1956

Variable star research at the Konkoly Observatory
The first 75 years

Dedicated to László Detre's memory at the 100th anniversary of his birth

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Introduction

It is now evident that at some level, the light output of stars, including our Sun, varies over different length of time. Little wonder that the investigation of variable stars has a special place in astronomy. Almost all of our knowledge of stellar interior come from the study of pulsating variables. The observed surface luminosity, radius and colour variations probe into the stellar interiors in much the same spirit as in terrestrial seismology. The fact, that the light curve parameters and periods of pulsating stars are closely related to their physical state and are well measurable renders them as excellent calibration objects.

The study of other types of variable stars has also large impact on our knowledge about the physics of stars. The eclipsing variables tell us information about the size and mass of the stars. The observations of variable young objects enlighten the process of birth of stars and draw picture on the interaction between stars and interstellar matter. The cataclysmic variables (dwarf novae and their violent relatives, the novae and supernovae) are clue objects in a number of astrophysical problems. Stellar activity manifests itself in luminosity variability in a broad spectral range from X-ray to radio wavelength. The rapid rotation and the convective atmosphere of the cool-surfaced stars render the operation of dynamo possible, producing a magnetic field that drives spot formation and other phenomena of stellar activity. Spotted stars allow to directly measure the stellar rotation, even the differential rotation.

The start of the systematic study of variable stars goes back to the mid-19th century when F. W. A. Argelander's epoch-making paper was published in Schumacher's Jahrbuch

(1844). At that time only one and a half dozen stars of this type were known. This appeal for observing variable stars incited astronomers all over the world. By the end of the 19th century almost one thousand variables were already known mainly due to the rapid development of the photographic technique.

The light variation caused by eclipses of two stars orbiting each other was easy to explain as it was mainly an optical and mechanical problem. The understanding of the physics of intrinsic variables, however, proved to be more difficult. The pulsation theory was put forward as a hypothesis for discussion by H. Shapley[1] and soon the hypothesis for discussion to the rank of major astrophysical theory by A. S. Eddington[2]. The explanation of light variation of cataclysmic and related objects required more knowledge about energy production of stars and became reality only half a century later.

In the second half of the 19th century the observers in Hungary were rather interested in the objects of the Solar System, the planets and comets, so little wonder that records of star observations made here can hardly be met from this time. The first variable star observations in Hungary were made in 1879 by Friedrich Schwab, a German mechanician who worked for a while in our country[3]. Afterwards, apart from Miklós Konkoly's scarce spectroscopic observations no variable star research of scientific value was carried out in Hungary until the beginning of the 20th century.

Ó-Gyalla, after the nationalization

In 1899 Miklós Konkoly Thege handed over his private observatory at Ó-Gyalla to the Hungarian state. It was, indeed, a mile-stone in the history of the Hungarian astronomy. An institute run by the state had greater possibilities and a more prosperous future.

Konkoly Thege was keenly interested in the bodies of the Solar System, planets, comets, and meteors and was a passionate pioneer of photography and spectroscopy. Soon after the foundation of his private observatory regular sunspot observations had been performed. The change in the status of the observatory, however, necessitated the reconsideration of the scientific program and, in conformity with the scientific attitude of that time, a shifting of stress set in toward the study of the physics of stars. In view of the modest optical instruments available then at Ó-Gyalla, the photometric observation of variable stars was chosen as the principal program (Tass 1904b) but, of course, the traditional work had also been pursued. The 6 and 10 inch refractors of the observatory were used for the photometry. In 1901 and 1902 a wedge photometer manufactured in Töpfer's workshop in Potsdam was put to use for stellar brightness measurements. In order to eliminate the disturbing illumination of the scale of the wedge, its position was registered[4]. Later, from 1902, Zöllner-type photometers were mostly used for brightness measurements. The small Zöllner-type photometer was also acquired from O. Töpfer, in 1903. This photometer was then further developed in the workshop of Ó-Gyalla. Instead of paraffin flame (that was used before) an electric lamp provided the artificial star.

The variable star observations in Ó-Gyalla started on the evening of September 19, 1900. The permanent staff members of the observatory, baron Béla Harkányi, Antal

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[1] Astrophys. J., 40, 448, 1914

[2] Mon. Not. RAS, 79, 2 and 177, 1918

[3] P. Brosche & E. Zsoldos: Zwischen Handwerk und Wissenschaft: Friedrich Schwab (1858-1931), in: Beiträge zur Astronomiegeschichte, Acta Historica Astronomiae, 18, 182, 2003

[4] The flash of wit that a device should be used to register the wedge position instead of direct reading came from Jenő Gothard (Zeitschrift für Instrumentenkunde Jg. 1887, S. 347)

Tass and Lajos Terkán took part in the ambitious program. Later Emil Czuczi and Zsigmond Fejes joined forces with the principal observers for a while. Harkányi, Tass, and Terkán selected the program stars very carefully. They consulted with S. C. Chandler's "Third Catalogue of Variable Stars"[5], E. Hartwig's "Ephemeriden veränderlicher Sterne" regularly published in the "Vierteljahrsschrift der Astronomischen Gesellschaft" and E. C. Pickering's list published in a note on "Cooperation in observing variable stars"[6]. Of course, the selection of program stars was confined by the limited efficiency of the modest instruments and the latitude of the observatory.

The unfavorable air conditions in the surrounding of Ó-Gyalla very often made the observations difficult. Three rivers, Zsitva, Nyitra, and Vág met near Ó-Gyalla, and the Danube streamed close to it. Due to the frequent fog it rarely happened that photometric observations could be carried out on some consecutive nights.

Between September 19, 1900 and January 2, 1903, 22 variables such as miras, δ Cephei type stars, eclipsing variables, and a nova were observed on 116 nights with the wedge photometers. During this period 425 observations were collected.

Between April 12, 1903 and November 16, 1908, the Zöllner-photometer was used for the photometry of variables. On the whole 1870 observations were obtained on 372 nights. 129 variable stars, mostly miras, red semi-regular stars, cepheids and eclipsing variables were on the list of observation. After 1908 only sporadic observations (5 nights in 1909, one night in 1910 and 8 nights in 1913) could be made, for the principal observers (A. Tass and L. Terkán) had other task, the photometric survey of the southern sky from 0° to 15° southern declination was undertaken, a continuation and extension of the "Potsdam Durchmusterung" to the South. This program was only partly executed, the visual photometry of all stars of the BD down to the magnitude 7.5 in the zone from 0° to 10° southern declination had been carried out and published (Tass & Terkán 1916).

The variable star observations were published in a series of papers (Tass 1904a, 1904b, 1905b, 1906, 1908a, 1908b, Terkán 1905). While observing the program stars two stars were suspected to be variable. In Cassiopeia, near T Cas, the 8th magnitude star BD+54°49 (=190.1904 Cas) was one of the variable candidates (Tass 1905a, 1905c). J. G. Hagen[7], however, doubted its variability. It is worth mentioning that later the star was identified as Bamberg variable BV328 and classified as an eclipsing variable with a period of 0.602625 day and amplitude of 0.3 magn.[8]. The fact, however, is that neither the Hipparcos photometry nor the NSVS[9] prove the variability of the star with an amplitude larger than 0.03 magn.

Tass had hard luck with his other discovery, too. He noted that the star BD+22°1576 in Gemini, close to the program star R Gem, varied in brightness (Tass 1905d) and it received later the variable star name TW Gem. The observations of C. Payne-Gaposchkin[10], however, gave no indication of variability. R. Prager[11] summarized the behaviour of the M3 III type star as of small range and irregular, if it were variable at all.

On February 21, 1901 $14^{\mathrm{h}}40^{\mathrm{m}}$ GMT Th.D. Andersson[12] discovered a $2\overset{\mathrm{m}}{.}7$ bright new

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[5] Astron. J., 16, 145, 1896

[6] Astron. Nachrichten, 154, 405, 1901

[7] Astron. Nachrichten, 168, 11, 1905

[8] W. Strohmeier & R. Knigge, Veröffentl. Bamberg, 5, Nr. 6, 1960; W. Strohmeier, Inf. Bull. Var. Stars, No. 26, 1963

[9] P. R. Wozniak, W. T. Vestrand, C. W. Akerlof et al., Astron J., 127, 2436, 2004

[10] Harvard Ann., 118, No. 15, 1952

[11] Geschichte und Literatur des Lichtwechsels der Veränderlichen Sterne, 1, 109, 1936

[12] Astron. Nachrichten, 154, 363, 1901

star in Perseus. The new bluish-white variable received the provisional name 3.1901 Per and later the official variable star name GK Persei. On February 19, the star was invisible (fainter than 11^{m} magn.) and attained to its maximum brightness of about $0\overset{\mathrm{m}}{.}0$ around February 23. The observers at Ó-Gyalla (b. B. Harkányi, A. Tass, and L. Terkán) immediately commenced the observations of the new star on the first clear night (*Fig. 1*). Between February 28 and December 29, 1901 294 brightness measurements were made on 63 nights. The observations had been interrupted only in May and June, when the constellation Perseus was near the Sun, and in September due to technical problems. At the end of 1901 the star's brightness became fainter than 7th magnitude, the attainable limit of the 16 cm refractor with the wedge photometer. Throughout the observations the comparison stars were taken from the Potsdam Durchmusterung (Harkányi 1901a, 1901b, 1903). The Ó-Gyalla observations were in very good agreement with other observers' results indicating the high accuracy of the Ó-Gyalla photometry. The nova, during its descending phase, showed fast light fluctuations with amplitudes of 1-2 magn. This behaviour, first observed in GK Per is a characteristic feature of cataclysmic variables with rapid development. Nova GK Per is one of the best observed novae and the typical representative of its class.

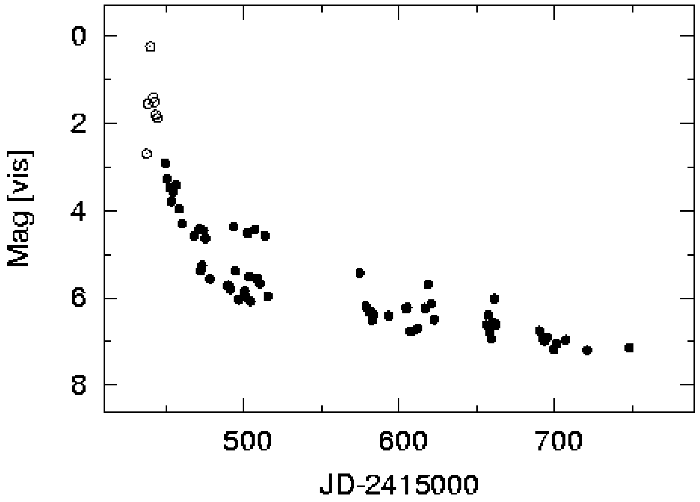

Figure 1: The nightly mean observations of GK Persei (Nova Per 1901) made at the Ógyalla observatory between 1901 February 28 and December 29 (filled circles). The nova, during its descending phase, showed fast, large light fluctuations. The observations of other observers before February 28 are also indicated (open circles).

Tass took part in the observations of another nova, too. Nova Aquilae 3 (=7.1918 Aql) was discovered on June 8, 1918 by L. Courvoisier[13]. The same night F. Schwab[14] estimated its brightness as 1st or 2nd magn. and remarked that is was "in Zunahme", still brightening. It attained the maximum brightness of −0.3 magn. on June 9. Tass (1918) observed the nova on June 14, 15, 16 and made 7 estimates both with the wedge and the Zöllner photometers on the 16 cm refractor. During these three nights the nova had been continuously fading from 0.74 to 2.18 magn.

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[13] Astron. Nachrichten, 207, 17, 1918

[14] Astron. Nachrichten, 207, 17, 1918

One hundred years ago the explanation of light variation of stars was certainly known only for the class of eclipsing variables. Little wonder, that the staff of Ó-Gyalla Observatory of Konkoly's Foundation actively took part in the observations of bright eclipsing variables. Terkán (1906a, 1906b) analyzed his photometry of β Lyrae obtained with the Zöllner photometer between July 14 and November 26, 1905 and determined the orbital elements of the system. This kind of investigation proved the applicability of the photometry for solving astrophysical problems, e.g. determining the size and mass of the stars.

At the very beginning of the 20th century, in line with the rapid development in physics (both experimental and theoretical) intensive investigations started around the world in order to get better insight into the problems of radiation and temperature (colour) of stars. At the same time, the use of photographic photometry just entered into astronomical application. This kind of investigations and works also started in Ó-Gyalla (Harkányi 1910, Terkán 1904, 1910). Terkán (1910, 1926) made an attempt at determining the colour and temperature variation of the eclipsing variables β Lyrae and β Persei.

The promising research was interrupted, the World War I broke out and the observatory got into a desperate situation. The comprehensive compilation of the variable star observations obtained at Ó-Gyalla could only be published later (Tass 1925). In consequence of the peace treaties, after the war Ó-Gyalla had belonged to Czechoslovakia, thus the staff left for and most of the instruments were transferred to Budapest. The Royal Hungarian Observatory of Konkoly's foundation found its new home on Svábhegy, a hill near Budapest.

The Start at Budapest-Svábhegy

In spite of the severe condition of the country, the Konkoly's Foundation reviewed in its new home near Budapest on Svábhegy, at an altitude of 470 m. The construction of the main building and domes was completed by 1929. The new 60 cm Newton-Cassegrain reflector was erected in a dome of 10 m diameter. The 20 cm Heyde refractor brought from Ó-Gyalla was housed in a 5 m dome and furnished with a new Graff-type wedge photometer. In 1932, the observation of bright stars using the Zöllner photometer attached to the 15 cm refractor that was also transferred from Ó-Gyalla to Budapest, was finished. Then, this telescope was dismantled and was replaced by a 17 cm Cook refractor from Kiskartal, from the private observatory of the Podmaniczky family. A 16 cm astrograph was fitted out to this telescope on purpose to start photographic photometry.

The scientific programs were essentially the same as those carried out at Ó-Gyalla. So, astrophotometry became the principal activity, with special emphasis on the photometry of variable stars. The regular observation of the Sun and shooting stars was, however, given up.

The visual observations of variable stars were already commenced with the Heyde refractor in 1929 and had been kept up as long as for 7 years, until 1936. Two ambitious astronomers, László Detre and Károly Lassovszky performed the variable star observations. Lassovszky took his doctor's degree at Pázmány University, Budapest in 1920 and then joined the staff of the reviving Konkoly Observatory. During time of the setting up of the observatory, he developed his knowledge at different North American and European astronomical institutes. Detre defended his doctoral dissertation at the Friedrich-Wilhelm University, Berlin in 1929 and, immediately after his returning, he started the research work at the observatory. Lassovszky took interest in eclipsing binaries in the first place, while Detre was keenly interested in pulsating variables. Nevertheless, both of them had either type of variables on their observing list. These years were very productive, a number of papers had been published mostly in the journal Astronomische Nachrichten. Detre and Lassovszky made the visual observations very carefully. Repeatedly, they checked the calibration of the wedge by measuring the stars of the North Polar Sequence or Pleiades. They found that the wedge-constant was not stable from night to night, therefore the sequence "variable + comparison stars" was chosen with great care. The linearity of the wedge, however, remained, which facilitated the reduction of the measurements. The main source of error of the Graff-type wedge photometer was, however, the inequality in the structure of the natural and artificial stellar images. The natural images heavily depended on the air conditions during the night (Lassovszky 1933c, Detre 1934c).

During the seven years, Detre and Lassovszky observed more than thirty stars visually and obtained more than 12000 observations. As mentioned Lassovszky was rather specialized in eclipsing binaries. He made extensive visual observations of four eclipsing variables. KR Cygni (Lassovszky 1936a) was observed on 81 nights and 1225 brightness estimates were obtained, while for AT Pegasi (Lassovszky 1935b) 1060 observations were collected during 59 nights. Similarly, for AB Persei (Lassovszky 1934) 718 visual observations were made on 115 nights, and for SV Tauri (Lassovszky 1938) 1260 observations during 100 nights. AT Peg, AB Per, and SV Tau are Algol type variables, while KR Cyg is of β Lyrae type. Lassovszky made an attempt at deriving the orbital parameters, furthermore the size of these stars. Of course, these results are outdated, but his photometry is still of high value and is used for studying these stars' period changes. In 1931 Lassovszky (1931b) made a short scientific visit to Babelsberg Observatory and measured some variables exposed on Ernostar plates with the 40 cm astrograph, but the observations were scarce to do rigorous investigation. Nevertheless, he discovered a new variable (Lassovszky 1931a,c), that received the preliminary name 381.1931 And, later the final name AP Andromedae. Then he made a series of exposures on Ernostar plates with the 40 cm astrograph and was able to derive the type and the period of the new variable. It proved to be an Algol type eclipsing variable with a period of 1.59 days. The star was, however, too faint for the Heyde refractor at Svábhegy, Budapest, and it could not be observed visually (Lassovszky 1932a).

Detre observed visually only one eclipsing binary, SV Cam (Detre 1932c, 1933b). During 34 nights he obtained 489 visual observations with the Heyde refractor. Some forty years later this star turned out to be a very interesting object. It is not only an eclipsing binary, one of its components is an active, spotted star. The visual observations, as a matter of course, did not reveal this behaviour.

Over and above the eclipsing variables, Detre and Lassovszky had 6 RR Lyrae stars and 8 Cepheids on their list of visual photometry. Detre observed SW Andromedae (Detre 1934c) on 38 nights (550 observations), W Canum Venaticorum (Detre 1935b) during 55 nights (369 observations), RZ Cephei (only the times of light maximum were published, Detre 1931, Balázs & Detre 1938) on 39 nights (590 estimates), XZ Draconis on 20 nights (344 observations) and RU Piscium (Detre 1934a) on 37 nights (472 observations). Of these RR Lyrae stars only short discussions about the period changes were published, since in 1934 Detre and his co-worker, Júlia Balázs decided to carry out a more detailed and thorough investigation of RR Lyrae stars (see next chapter). Here I only mention one result that shows how accurate Detre's visual observations were: several observers[15] thought that W CVn had light curve variations and short period waves were superimposed on the light curve. Detre's data, however, exhibited strictly repetitive character of light variation of the star. Several decades later, J. Tremko[16] investigated this variable and found that the star had stable and smooth light curve.

The visual observations of cepheids provided useful data to study the changes in periods of these stars. Both Detre and Lassovszky took part in the work and they collected 2515 observations for 8 cepheids. The program stars were YZ Aurigae (Detre 1935c, on 121 nights 239 observations), RW Cassiopeiae (Lassovszky 1932b, on 103 nights 520 observations), SZ Cassiopeiae (Detre 1933a, on 100 nights 344 observations), XY Cassiopeiae (Detre 1932a, on 87 nights 325 observations), SZ Cygni (Lassovszky 1933a, on 90 nights 265 observations), VY Cygni (Lassovszky 1933c, on 79 nights 240 observations), Z Lacertae (Lassovszky not published, on 93 nights 309 observations) and RR Lacertae (Lassovszky 1935a, on 92 nights 273 observations). Here only I mention two results. Lassovszky showed that the light curve variation of RW Cas suggested by M. Beyer[17] was not real. The data used by Beyer were inhomogeneous, simply they were obtained by different colour sensitive instruments (Detre & Lassovszky 1939). Detre investigating the behaviour of XY Cas presented arguments in favour of smooth changes in the period of the star rejecting the sudden change as propounded by L.V. Robinson[18].

The accurate visual observations of Detre and Lassovszky proved the constancy of some stars that were supposed to be variable by previous observers. These stars are X Canum Venaticorum (Detre 1932b), TV Cygni (Lassovszky 1933b), TW Geminorum (Detre 1936b), TZ Herculis (Detre & Lassovszky 1934b, Detre 1936b) and UY Herculis (Detre & Lassovszky 1934b, Detre 1936b).

Among the program stars there were several stars classified as semi-regular variables. The visual observations of two of them were published. UZ Aurigae was observed on 146 nights and 350 observations were obtained (Detre 1934b, 1935a). UU Herculis was also intensively observed, on 135 nights 517 estimates were made (Detre & Lassovszky 1934a, Detre 1936b). Some 50 years later this star turned out to be a very interesting object with alternating periods and it has been recognised that this supergiant star is a representative of a new class of variables.

The summary of the visual photometry carried out with the wedge photometer on the 20 cm Heyde refractor of Konkoly Observatory is found in one of the observatory's publications (Detre & Lassovszky 1938).

Károly Móra was associate professor at the Astronomy Department of Pázmány University, Budapest and took active part in the work of the observatory. In the middle of thirties he joined the staff of the observatory and became its director in 1936. He published important papers on R Scuti, an RV Tau-type variable (Móra 1930, 1934). This star's variability was discovered by E. Pigott[19] in 1795 and since that time a great number of observations had been published. Móra collected more than 13000 observations of R Scuti from different sources, from publications and archives, and even unpublished

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[15] E. Zinner, Astron. Nachrichten, 190, 379, 1912; ibid 202, 233, 1916; N. Bougoslawski, Astron. Nachrichten, 229, 203, 1927; F. C. Jordan, Allegh. Publ., 7, 1, 1929; L. V. Robinson, Harvard Bull., 876, 1930

[16] Mitteilungen Budapest, No. 67, 1974

[17] Astron. Nachrichten, 252, 85, 1934

[18] L. V. Robinson, Harvard Bull., No. 872, 1930

[19] Philosophical Transactions of the Royal Society, London, p. 133, 1797

data were included through correspondence. In this way, he was able to follow the star's behaviour throughout almost 340 pulsation cycles. Móra's work became significant half a century later when it was recognized that the star's pulsation was determined by low dimensional chaos.

Lassovszky, following the tradition of Ó-Gyalla, observed the bright Nova 605.1936 = CP Lac on 9 nights. The nova was discovered by A. V. Nielsen[20] on June 18, 1936, while on board "Strathaird" as a member of the eclipse-trip in Mediterranean.

The observations of Lassovszky were made on the nights June 20, 21, 22, 23, 25, 27, July 5, 6, and 7, with a Zeiss Petzval-7 cm Astrocamera on Eastman plates. During the two weeks of observation the photographic brightness of the nova dimmed from $2\overset{\mathrm{m}}{.}40$ to $5\overset{\mathrm{m}}{.}92$ (Lassovszky 1936b,c).

Detre's last visual observations were performed during a scientific visit in München (Detre 1942). Using the 10.5 inch telescope of the Universitäts-Sternwarte, München with a wedge photometer, he studied the brightness difference of binary components. Between the Right Ascensions 15^{h} and $0^{\mathrm{h}}30^{\mathrm{m}}$ and Declinations $-8°$ and $+47°$, he measured 173 pairs from the Aitken's catalogue[21] of visual binaries and 37 ones from other sources. On the whole he made 11570 estimates.

The RR Lyrae program

At the end of the 19th century, a great number of short period variable stars were discovered in globular clusters. Soon the first field variable star of this type was also discovered by W. P. Fleming[22] in the constellation Lyra. The star RR Lyrae has become the prototype of the class of variables of this type. The number of discovered RR Lyrae stars grew rapidly. At the beginning of the thirties, the number of known RR Lyrae stars brighter than 12^{m} was already several dozens.

In 1907 S. Blazhko[23] made an interesting discovery. He found that no constant period could satisfy the times of light maxima of RW Draconis (=87.1906 Dra), an RR Lyrae type star discovered in those days. He had to postulate periodic changes in the fundamental period with a secondary period of 41.6 days. Later Blazhko[24] carried out further studies on RR Lyrae stars and found that XZ Cygni changed its light curve from cycle to cycle with a secondary period of 57.4 days.

The striking changes in the maxima of the light curves of RR Lyrae that turned out to be periodic was first stated by H. Shapley[25] some 90 years ago. He obtained a secondary period of 40 days and an amplitude of 37 minutes for the time oscillation of the median magnitude of the ascending branch. This results were fully confirmed by E. Hertzsprung[26] in 1922.

Apart from the discoveries mentioned above, several observers fancied that other RR Lyrae stars also had irregularities, non-repetitive features, changing light curves, short term or sudden period changes etc. As the observational accuracy left much to be desired,

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[20] IAU Circ., No. 594, 1936

[21] R. G. Aitken, New General Catalogue of Double Stars within 120° of the North Pole. 1-2., Carnegie Inst. Washington, 1932

[22] E. C. Pickering, Harvard Circ., No. 54, 1901

[23] Astron. Nachrichten, 175, 325, 1907

[24] Annales de l'Observatorie de Moscou, 2-me série, Vol. VIII. No.2, 1922

[25] Astrophys. J., 43, 217, 1916

[26] Bull. Astron. Netherl., 1, 139, 1922

the observed and published irregularities were often doubtful. L. Detre strongly advised that the visual photometric observations were subject to significant systematic errors that could bring about ostensible light curve variations (Detre 1934c). Likely, the disputable irregularities stimulated Detre to conduct a systematic survey of "short periodic cepheids" and to scrutinize these objects. At that time, all pulsating stars with periods shorter than one day were called short period cepheids and no distinction was drawn between δ Scuti and RR Lyrae type stars. The very short periodic pulsating stars with period less than a quarter of a day, nowadays called HADS and SX Phe type stars also captivated Detre's interest.

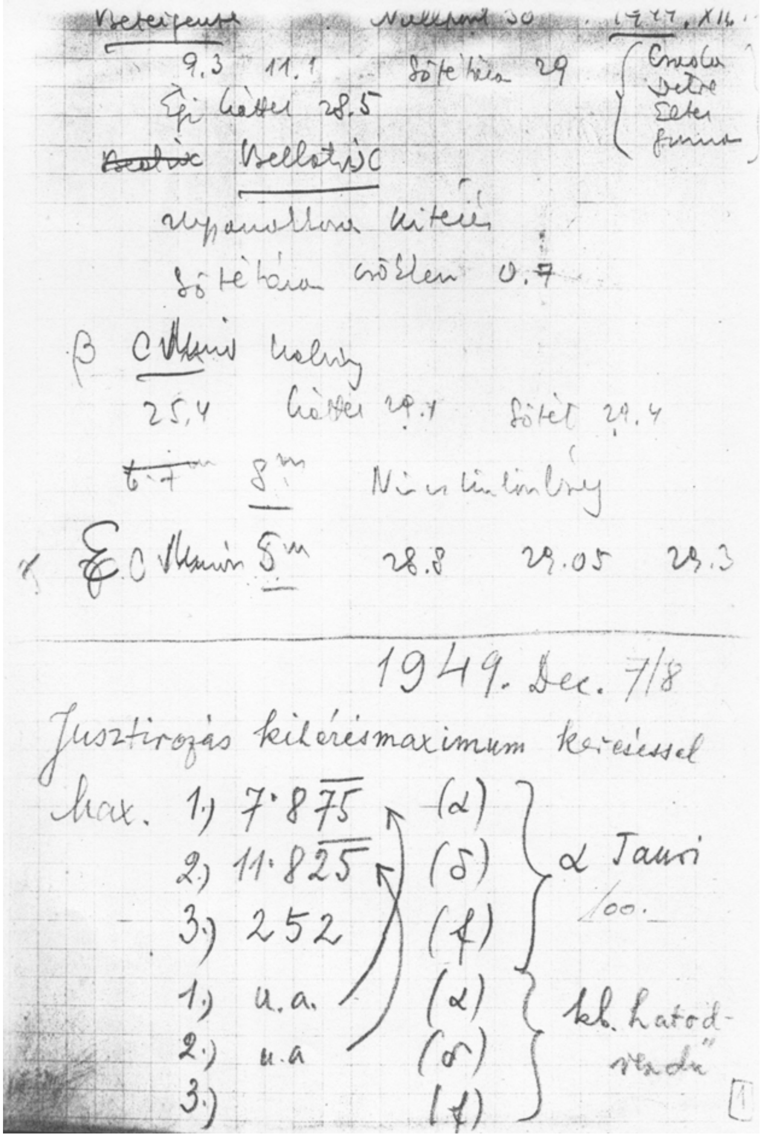
In the thirties, the photographic photometry was the most simple technique that provided accurate observations exempt from systematic personal errors and could be carried out in small institutes with modest instruments. Therefore, Detre and his associate, Júlia Balázs (his wife to be) decided to execute a comprehensive photographic observing program of RR Lyrae stars. An astrograph fitted out with a photographic doublet of Zeiss (16 cm diameter, f/14) and a Rosenberg type micro-photometer were at their disposal. They tested different kinds of emulsions, measured the limiting magnitude at different exposure times and the field correction by measuring a number of stars in Selected Areas, North Polar Sequence, Pleiades and Coma Berenices. Their experience was that under favorable conditions $0\overset{\mathrm{m}}{.}01$-$0\overset{\mathrm{m}}{.}02$ accuracy could be achieved, an accuracy that certainly hit the target set by themselves. The program and the results in general were described in several papers (e.g. Balázs 1963, Balázs & Detre 1961b, Detre 1957, 1960, 1965a, 1966a, 1967, 1970a, 1973).

The first variable photographed was XZ Cygni on July 20, 1934 and the last one VZ Herculis on July 8, 1958. During 24 years more than 50 variables were observed and about 60000 exposures were made on more than 3800 photographic plates. The exposition times were chosen between 30 sec and 5 min depending on the brightness of the stars. Several fellows, such as Imre Csada, Loránt Dezső, István Földes, István Guman, Tibor Kolbenheyer, and others joined forces with J. Balázs and L. Detre for a short while.

Detre always made great efforts to improve the accuracy of observations. During the General Assembly of IAU held in Zürich, in 1948, he received an 1P21 photoelectric multiplier tube from H. Shapley as a present. The experiments with this tube were started in December 1, 1949 (*Fig. 2*). The photometer was attached to the 60 cm telescope at its Newtonian focus. The measurements revealed some defects of the equipment, the stability and linearity of the amplifier were not always granted. The troubles with the electronics seemed insolvable since during the post-war and cold war time good-quality electronic parts were not to be had in Hungary. In the long run, Th. Walraven helped to overcome the difficulties. He gave an amplifier to the observatory constructed by himself. Then the photoelectric photometry of variable stars had been carried out unbroken until the eighties, when the reconstruction of the telescope and dome was started. The 60 cm mirror of the telescope was first aluminized in 1962 and afterwards, the three-colour (UBV) observations were routinish running. Later, on the mountain station of the observatory a 50 cm Cassegrain telescope was put into operation. The photometer to this telescope was constructed at the observatory's workshop by Géza Virághalmy.

In the photoelectric observations almost all staff members of the observatory took part. The list of program stars of the photoelectric photometry was essentially the same as was chosen for photographic photometry in 1934.

In the course of observations, it promptly turned out that a variable was misclassified as an RR Lyrae star, or in reality, it was an eclipsing or a variable of an other type or a



Betelgeuze Nullpont 30 1949. XII.

9.3 11.1 Sötétáram 29 [illegible] Detre [illegible] [illegible]

Égi háttér 28.5

~~[illegible]~~ [illegible]

[illegible] kitérés

Sötétáram csökken 0.7

β CMinoris halvány

25.4 háttér 29.1 sötét 29.4

~~6.7^m^~~ 8^m^ Nincs különbség

ξ CMinoris 5^m^ 28.8 29.05 29.3

1949. Dec. 7/8

Jusztirozás kitérésmaximum kereséssel

max. 1.) 7·875 (α)
2.) 11·825 (δ)
3.) 252 (f)
α Tauri /00.

1.) u.a. (α)
2.) u.a (δ)
3.) (f)
kl. katód-rácsú"

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Figure 2: The start of the photoelectric observations at the Konkoly Observatory: First page of the log-book.

non-variable star. In this case, the observations and analysis had been published and the object was crossed out of the program.

The first object that was scrutinized within the scope of the RR Lyrae program was AV Pegasi. 217 observations were obtained during five nights in 1935 and neither light curve variations nor short term period changes were detected (Balázs 1935).

In the pulsation of VZ Herculis secular period change and light curve modulation were found by N. F. Florja[27]. In order to investigate the reality of these findings, 335 exposures of this star were made on 12 nights in 1935. Júlia Balázs' result contrasted with that of Florja. She found no modulation in the light curves of the star. The height of light maxima was constant within the accuracy of photographic observation (Balázs 1936a).

The variability of RR Leonis was discovered in 1907. During the subsequent 30 years, a great number of both visual and photographic observations of the star were obtained. The

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[27] Leningrad Bull., 4, 1934

different observers[28] gave dissimilar light curve's amplitudes, and some of them referred to short term period changes. At the Konkoly Observatory 247 photographic observations of this star were secured during six nights in 1936. The investigation of the data unambiguously showed that RR Leo was a single periodic RR Lyrae star and its period was subject to only very slow secular change (Balázs 1937a).

BH Pegasi was also thought to be an RR Lyrae star with variable light curve by F. Lause[29]. In order to investigate the possible modulation of the light variation 249 observations with 3-5 minute exposures were obtained on 16 nights in the years 1934-1936. The results clearly refuted Lause's suggestion, BH Peg had a stable light curve. There was a very strong long lasting hump on the rising branch, probable this feature deceived the visual observers (Balázs 1937b).

DH Pegasi was observed on six nights in 1935 and 465 photographic observations were obtained. The star is of RRc type and has a stable character (Balázs 1937c).

The behaviour of AA Aquilae was also questionable. Both K. Bohlin[30] and N. Ivanov[31], based on their visual observations stated that this RR Lyrae star had strong light curve variations. As the inference drawn from visual photometry was many times not real, photographic photometry of the star was carried out at the Konkoly Observatory on 14 nights in the years 1935-1936. In all, 211 observations were obtained and six light maxima were well measured. The heights of light maxima were constant within the errors of photographic photometry. Neither light curve variations nor noticeable period changes were found (Balázs 1938).

In order to study the very short period pulsating variable RV Arietis, a number of photographic observations were made. One of the stars used as comparison proved to be variable in brightness. The new variable 624.1936Ari discovered by Detre received the final name RW Ari, a typical RRc star with a period of 0.3543 day (Detre 1937a, 1937b).

RU Piscium is also an RRc type star. There were hints in the literature on the unusual period behaviour of the star. Between 1936-1942, on the whole, 759 photographic observations were made and analyzed by Loránt Dezső (1945, 1949). He did not find any modulation in the light curve, only the period of RU Psc varied slowly. He suspected that this variation was periodic (with a period of three years and an amplitude of 0.0002 day). Later on, J. Tremko[32] pointed out that the variation in period of the star was more complicated and the existence of light curve modulation with a secondary period of 28.8 days was possible.

Although the variability of VZ Pegasi was discovered in 1921, and was considered as an eclipsing variable, only in the fifties S. Kato[33] suspected that the variable was in truth, an RR Lyrae star. To be sure of its real character, it was ranged among the RR Lyrae program stars. Photoelectric observations of three nights revealed that the star belonged to the homogeneous group of RRc type variables showing no sign of light curve variation (Barlai & Szeidl 1965).

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[28] C. Martin & H. C. Plummer, Mon. Not. RAS, 81, 458, 1921
F. C. Jordan, Allegh. Publ., 7, 34, 1929
P. Th. Oosterhoff, Bull. Astron. Netherl. 6. 39, 1930
L. V. Robinson, Harvard Bull. No. 867, 1930
L. B. Allen & F. F. Marsh, Harvard Bull. No. 888, 1932

[29] Astron. Nachrichten, 245, 333, 1932; ibid 249, 380, 1933

[30] Astron. Nachrichten, 221, 195, 1923; ibid 224, 403, 1925

[31] Astron. Nachrichten, 223, 287, 1924; ibid 228, 143, 1926

[32] Mitteilungen Budapest, No. 55, 1964

[33] Tokyo Astronomical Bull., Ser. II, No. 110, 1958

From his visual observations A. A. Batyrev[34] came to the conclusion that the RRab star AN Serpentis had strong light curve variation with a period of 22.94 days. On the one hand, this result was uncertain because of the large scatter of the visual observations, on the other hand, the short modulation period, if true, would make AN Ser an interesting object. Therefore, the photoelectric observations of the star were commenced at the Konkoly Observatory in 1967. Between 1967 and 1971 some 980 observations were obtained during 17 nights (Szeidl 1968b, Kanyó & Szeidl 1974). The results were disappointing, AN Ser was a single periodic RRab star.

AT Andromedae represented a similar case. O. V. Tchumak[35] stated that this star had strong light curve variation with a secondary period of 82.75 days. More than 1300 photoelectric observations were obtained at the Konkoly Observatory during 18 nights in 1974 and 1975 but no light curve variation was detected (Oláh 1974).

Those objects are also worth mentioning, which were erroneously classified as RR Lyrae stars and the Konkoly observations revealed their true nature.

The variability of WZ Cephei was discovered and mistakenly classified as an RRc star by H. Schneller[36]. Júlia Balázs obtained 206 photographic observations on eight nights in 1935 and showed that the star was, in fact, a W UMa type eclipsing binary (Balázs 1936c). L. Detre supplemented J. Balázs data with 208 measurements (five nights in 1939-1940) and analyzed the light curve and derived the system parameters (Detre 1940).

WY Tauri was also classified as an RR Lyrae star by A. S. Williams[37], the discoverer of the star's variability. Therefore, the variable was included in the list of program stars. From some nights' observations it was clear that the star was not of RR Lyrae type but a β Lyrae type eclipsing variable (Balázs 1936b). In order to analyze the light variation, additional observations were made (altogether 403 measurements on 16 nights during the years 1935, 1936, 1937 and 1939) and the period and light curve parameters, furthermore the system constants have been determined (Balázs & Detre 1940).

The classification of ZZ Persei was also questionable. K. Nakamura[38] suspected RR Lyrae, while V. M. Bodokia[39] suggested β Lyrae type light variations. 60 photographic observations were obtained in 1935 which did not show any noticeable variations within the error of measurements (about $0\overset{m}{.}02$-$0\overset{m}{.}03$), so the star could be regarded as constant (Lovas 1952).

A. G. Lange[40] suggested that AV Vulpeculae was an RR Lyrae star resembling AC Andromedae. 489 observations were obtained and the star proved to be a long period irregular variable (Guman 1952).

The Second Edition of GCVS (1958) classified both AT Herculis and BP Vulpeculae as RR Lyrae variables. AT Her was observed photoelectrically on 9 nights in 1960 but no light variation was detected. According to the spectrum, the star is of K0 V spectral type and is certainly not an RR Lyrae variable. The variability is questionable at all (Illés 1963). The photoelectric photometry of BP Vul was carried out during 11 nights in September and October 1959. It turned out that it is, in reality, an Algol type eclipsing binary (Illés 1960).

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[34] Peremennye Zvezdy, 12, 137, 1957; ibid 15, 278, 1964

[35] Peremennye Zvezdy, 15, 569, 1965

[36] Astron. Nachrichten, 233, 41, 1928

[37] Mon. Not. RAS, 87, 172, 1926

[38] Kyoto Bull., 8, 10, 1922

[39] Abastumani Bull., 1, 1937

[40] Astron. Tsirk., No. 20, 1943

A summary of the photometry of RR Lyrae stars made at the Konkoly Observatory until 1956 was presented by Detre at the Variable Star Colloquium held in Budapest, 23-28 August, 1956 (Detre 1957). Likewise, Detre gave a review on the photoelectric observations of RR Lyrae stars with stable light curve carried out at the Konkoly Observatory at the first Bamberg Variable Star Colloquium (Detre 1960). Here, he gave an account of an interesting connection between the length of the stillstand on the rising branch and the amplitude of RR Lyrae stars.

At first, the photoelectric observations were made only in two colours, then from the beginning of the sixties in three colours. These observations made the investigation of the position of RR Lyrae stars in the colour-colour and colour-magnitude diagrams possible. Such an investigation was made for the variables of ω Centauri based on photographic photometry (Geyer & Szeidl 1965, 1970).

The Blazhko effect

Since S. Blazhko was the very first to notice the periodic oscillation in the phase of light maximum of an RR Lyrae star (namely of RW Draconis) we refer to this periodic variation as Blazhko effect. Later H. Shapley demonstrated that the phase oscillation was accompanied by the periodic variation in the shape of the light curve and in the height of maxima with the same period in RR Lyrae.

In truth, the investigation of the amplitude and phase modulation of RR Lyrae stars, the Blazhko effect, has brought in the international reputation of the Konkoly Observatory. The results of these investigations have been published in a series of papers.

The planned research and the preliminary list of program stars were described in one of the first publications (Balázs & Detre 1938). The first program star to be studied in detail, was RW Draconis. During 143 nights in the years 1936-1938, 1941, 1942, 1944, 1945, 1947-1952 taken as a whole, 7210 photographic observations were obtained at the Konkoly Observatory. The old visual observations from 1907 made the investigation of long term variations in both the fundamental and the Blazhko period possible. The changes in the characteristics of Blazhko effect could also be studied. The amplitudes of both the phase and the amplitude modulation were the largest in 1937, 0.085 day $\approx$ 2 hours and $1\overset{\mathrm{m}}{.}0$, respectively. The amplitudes of modulation were much smaller after 1937, e.g. in 1941, 0.04 day $\approx$ 1 hour and 0.5 magn., respectively. The striking change in the effect had to take place around 1938-1939, but that time no observations of the star were made at the Konkoly Observatory. Fortunately, observations of RW Dra were obtained at the Leiden Observatory in 1938. These unpublished observations were placed at J. Balázs and Detre's disposal and it became clear that the sudden decrease in the effect took place in 1938 (*Fig. 3*).

Making use of unpublished photoelectric observations, the changes in both the main and secondary periods could be investigated for a time span of 60 years. The very strong change in the amplitude of the effect in 1938 was accompanied by a very large sudden change in both periods. These variations were anticorrelated, the O$-$C diagrams were mirror images to each other.

The photographic observations obtained at the Konkoly Observatory also made the detection of a small amplitude 120 day period (almost three times of the conspicuous 41.6 day Blazhko period) possible. This longer period variation clearly came in sight when the Blazhko effect was stronger than average. The investigation of the long term variation in the phase modulation revealed a 7.4 year period, that could be barely noticed in the O−C diagrams of the pulsation and Blazhko periods (Balázs 1957, Balázs, & Detre 1938, 1952, 1962).

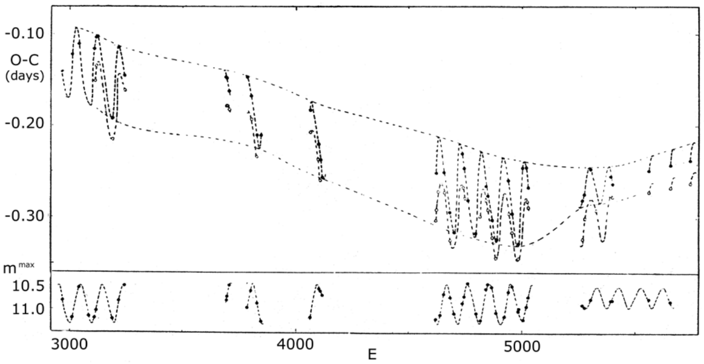

Figure 3: Sudden change in the Blazhko effect of RW Draconis in 1939 (after J. Balázs 1957).

The RR Lyrae stars with light curve modulation were usually observed only in a very limited phase interval of the pulsation period, during minimum, ascending branch and maximum light. J. Balázs and Detre carried out a comprehensive study of the Blazhko star AR Herculis: they covered the whole pulsation cycles at different phases of the secondary period, so thus they were able to construct the so-called light surfaces, the light curves at different fixed Blazhko phases. (More exactly, they gave the $m(\Phi, \Psi)$ brightness of the star in tabulated form, where Φ is the phase of the pulsation and Ψ is the phase of the modulation.) In this way, the study of the Blazhko effect on the whole pulsation cycle became possible. These results aroused the interest of variable star researchers, even Leon Campbell and Luigi Jacchia spent one page expounding these results in their well-known book The Story of Variable Stars (The Harvard Books on Astronomy, eds.: H. Shapley and B. J. Bok, 1941).

The phase modulation of light maximum of the 0.470 day period RR Lyrae star, AR Herculis was first noted by S. Blazhko[41], but apart from the scarce, mostly visual observations no serious investigation was devoted to the star before 1935. This is why J. Balázs and Detre decided to study it intensively. The photographic observations based on their investigation were made during 81 nights between 1935 and 1939. In all, 3363 observations were obtained and scrutinized.

The amplitude of the light variation varied between 0.90 and 1.77 photographic magnitudes during the 31.5 day Blazhko cycle, while the amplitude of the time oscillation of light maximum was 0.06 day ≈ one hour and a half (*Fig. 4*). During the modulation cycle the brightness of maximum was nearly the least when the momentary pulsation period was the longest (Balázs & Detre 1939).

Twenty years later Iván Almár repeated the investigation of AR Herculis on new extended photographic and photoelectric data sets. During the years 1946, 1948-1953, 1955-1957, 3511 photographic observations were obtained during 117 nights and, in the years 1958 and 1960, 1141 photoelectric measurements were made. These new data revealed that a 90.8 day period was also present (2.87 times longer than the 31.5 day Blazhko

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[41] Leningrad Eph. of short period Ceph., 1932

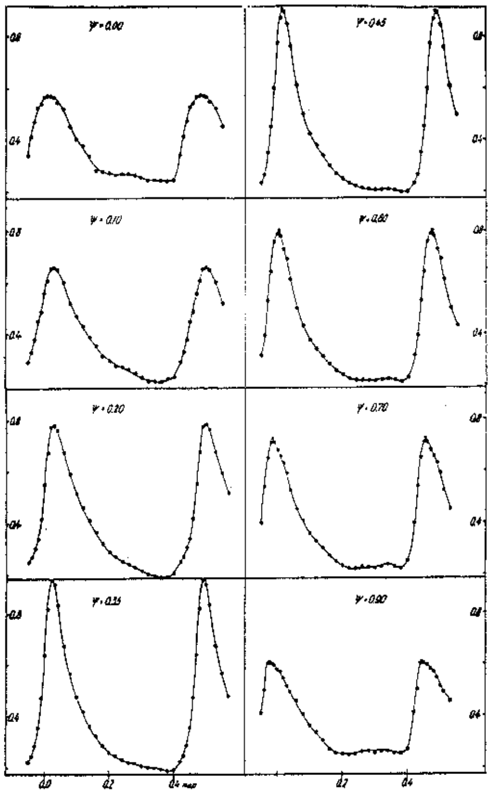

Figure 4: Light curves (light surfaces) of AR Herculis at different Blazhko phases (after Balázs & Detre 1939).

period). A comparison with the previous studies showed that in spite of the strong variations in the Blazhko effect during the decades the brightness of the brightest maximum in the modulation cycle practically had not changed and the form of the relation between the brightness and phase oscillation of light maximum was essentially the same for the different observing seasons. The amplitudes of the brightness and the phase oscillation of light maxima were subject to strong long term variations and between these variations no connection was found.

The new photometry and the published data made the investigation of the secular changes in both the fundamental and the modulation periods possible. Both of them exhibited perceptible changes: the pulsation period changed rather irregularly, the O−C diagram of the Blazhko period resembled a sine-like curve. Between the changes of the two periods no connection could be revealed (Almár 1961).

One of the most favorite Blazhko stars at the Konkoly Observatory was RR Lyrae itself. During the decades a large amount of observations of RR Lyr had been obtained by different observers at different sites, but the results were contradictory. H. Shapley[42] found a 40 days long modulation period, while A. de Sitter[43] gave a value of 38.21 days for it. T. E. Sterne[44] hinted at the possibility that de Sitter's result was affected by the selection of data. In order to clear up the matter in dispute, the star was intensively observed at the

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[42] see footnote 25

[43] Bull. Astron. Inst., 6, 215, 1932

[44] Harvard Circ., No. 387, 1934

Konkoly Observatory. During 27 nights in the years 1935, 1938, 1939, and 1941 as a whole, 6512 photographic observations were made. Their own observations and several thousand data (mostly photographic) published by 18 observers were reanalyzed. It became evident that in 1899 (at the discovery of the variability of RR Lyr) the modulation period was around 40.5 days and increased to 41 days up to 1943. During that time interval the pulsation period showed irregular changes. The amplitudes of oscillation in times and heights of maxima were fairly large around the end of the thirties: 0.055 day $\approx$ one hour and 20 minutes and 0.33 photographic magnitude (Detre 1943, Balázs, & Detre 1943, 1962).

The light curve variation of RW Cancri was discovered by S. Blazhko[45] in 1922 and he derived a modulation period of 87 days. The variable was also ranged among the program stars of J. Balázs and Detre. In the years 1938-1940 and 1950, 1210 photographic observations were collected at the Konkoly Observatory during 44 nights and 40 light maxima were observed. In the course of the analysis of the data RW Cnc proved to be one of the most interesting Blazhko stars. During the Blazhko cycle the brightness of light maxima changed between $10\overset{\mathrm{m}}{.}74$ and $11\overset{\mathrm{m}}{.}80$, while that of the minimum between $12\overset{\mathrm{m}}{.}55$ and $12\overset{\mathrm{m}}{.}34$. The highest maximum was always preceded by the deepest minimum, so thus the extreme values of amplitude of the light variation were 1.81 and 0.54 photographic magnitude. Such a large amplitude variation had never been observed previously in any other Blazhko star. Two modulation periods were present $P_{B1} = 29.9$ days and $P_{B2} = 91.1$ days, that were increasing. The fundamental period showed both increasing secular and cyclic variations with a suspected 25 year cycle length (Balázs & Detre 1950).

One of the most puzzling Blazhko stars is SW Andromedae. H. Shapley[46] stated that strong light curve variations were present, but no other visual observer mentioned it. Detre's visual observations showed $0\overset{\mathrm{m}}{.}07$ scatter in light maximum, that proved if Blazhko effect had existed in the star at all, it diminished to below the detectable limit. In order to reveal the real behaviour of the star 915 photographic observations were made on 23 nights in the years 1936, 1937, 1941, 1942, 1951 and 1952. These observations, however, could only be used to study the changes in the fundamental period, the accuracy of the photographic observations did not allow tracing the light curve variation. The pulsation period was steadily decreasing with a rate of 2 seconds in a century. The earlier assumption of an abrupt change in the period could not be confirmed.

In 1950 and 1953, 864 additional photoelectric observations were obtained on 22 nights. It was noticed that the length of the stillstand on the rising branch of SW And was changing with a period of 36.83 days, while the height of maximum varied $0\overset{\mathrm{m}}{.}03$ at the very most. This kind of light curve variation of SW And probably represents a specific type of Blazhko effect (Balázs & Detre 1954).

All the previous visual and photographic observers indicated that RV Ursae Majoris showed well-perceptible strong light curve variations, but were unable to establish the regularity of these variations.

In the years 1936, 1937, 1946-1952, 1229 photographic observations were obtained during 27 nights. From 1955 May to 1957 July RV UMa was observed photoelectrically on 35 nights and 1008 data were collected. The considerable part of the photoelectric observations were made in 1957, in all, 21 maxima were observed in that year, so thus the modulation period could easily be determined. The variable exhibited strong amplitude

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[45] Astron. Nachrichten, 216, 103, 1922

[46] Mon. Not. RAS, 81, 209, 1921

modulation, while the phase modulation of maximum was rather small. The variations could accurately be described by the combination of the 0.4680 day fundamental period with a secondary period of 90.1 days. The same periods were apparent in the earlier visual and photographic observations. Having used all the published observations, the O−C diagrams for both periods could be constructed. These diagrams contain cycles of the same length, but of opposite phase (Balázs & Detre 1957).

The investigation of RV Ursae Majoris proceeded at the Konkoly Observatory after 1957. In the years 1958, 1959, 1961-1965, 1968, and 1969, 5966 photoelectric observations (2378 in V, 2627 in B, and 961 in U band) were obtained on 150 nights.

As for the period changes the previous results were confirmed on a longer time base, the O−C diagrams of the pulsation and modulation periods run opposite in phase. During the Blazhko cycle there was no significant change in light curve in the phase interval 0.35-0.55. It was, however, a rather surprising discovery that, around phase 0.94, there was a point on the ascending branch that did not show any significant oscillation either (Kanyó 1976a).

Y Leonis Minoris was a known Blazhko variable. D. J. Martynov[47] derived its modulation period as $P_B = 33.4$ days. As the successive Blazhko cycles differed from each other both in shape and length, J. Balázs decided to reanalyze the published data, and came to the conclusion that the star had a second modulation period of 82.2 days, with a smaller amplitude ($0\overset{\mathrm{m}}{.}25$) and phase (0.016 day) modulation. The pulsation period was increasing and also showed a cyclic variation with a period of 7.7 years (Balázs 1955).

The search for light curve modulated RR Lyrae stars and determination of the accurate Blazhko periods were also an important part of the program.

M. Beyer[48], from his visual observations, suspected that XZ Draconis had light curve variation. Its photographic observation was commenced by J. Balázs in 1936. Using some observations obtained up to 1940, the Blazhko period turned out to be 76 days (Balázs & Detre 1941). The star has been kept observing photographically and photoelectrically later on.

V. P. Tsessevich[49] observed strong light curve variation in the RR Lyrae star DL Herculis and gave the modulation period as 49.1 days. Some 750 photoelectric observations were made of this star at the Konkoly Observatory on more than ten nights in 1963 and it turned out that the real value of the Blazhko period was 33.6 days. The modulation amplitude of the phase and height of light maximum were more than 0.02 day ≈ half an hour and about $0\overset{\mathrm{m}}{.}3$ in blue light, respectively (Szeidl 1963).

The earlier photographic observations made at the Konkoly Observatory indicated that Z Canum Venaticorum had Blazhko effect. The star was photoelectrically measured at the observatory in 1964 and almost 500 observations were made on 12 nights. From the analysis of these data the Blazhko period proved to be 22.75 days, a surprisingly short secondary period for a star with a fairly long, 0.6538 day pulsation period. The height of the light maximum varied $0\overset{\mathrm{m}}{.}45$ in B and $0\overset{\mathrm{m}}{.}38$ in V during the modulation cycle, while the amplitude of the phase oscillation of maximum was 0.04 day ≈ one hour (Kanyó 1966).

AR Serpentis was investigated by V. P. Tsessevich[50] who gave the element of its light variation and found strong fluctuation in the period, suggesting the presence of the Blazhko effect. In 1967, some 960 photoelectric observations were obtained in blue and

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[47] Engelhardt Obs. Bull., 18, 1940

[48] Astron. Nachrichten, 252, 85, 1934

[49] Odessa Isv., 3, 257, 1953

[50] Astron. Tsirk., No. 353, 3, 1966

yellow lights on 15 nights and a Blazhko period of about 105 days could be derived. The star possessed extremely strong light curve variation, the amplitude of the phase oscillation of maximum exceeded 0.12 day ≈ three hours, while the light amplitudes varied between $0\overset{m}{.}41$ and $1\overset{m}{.}09$ in V and $0\overset{m}{.}49$ and $1\overset{m}{.}32$ in B light (Szeidl 1967).

W. S. Fitch, W. Z. Wisniewski, and H. L. Johnson[51] observed a large sample of RR Lyrae star, among them TT Cancri as well. The observed light maxima differed from each other indicating that TT Cnc was a Blazhko star. From 1967 December up to 1968 April 1080 photoelectric observations were obtained in UBV colours. During this time interval 13 light maxima were observed. The modulation period turned out to be 89 days. The amplitudes of phase modulation of maximum light was 0.035 day ≈ 50 minutes and of the variations in height of light maxima were $0\overset{m}{.}30$ in V and $0\overset{m}{.}35$ in B light, respectively (Szeidl 1968a).

Inspired by a notice of L. J. Robinson[52] on a possible Blazhko effect in the light variation of SZ Hydrae, photoelectric observations were commenced by S. Kanyó at Catania Observatory during a scientific visit in order to determine the length of its secondary period. Although only four maxima could be observed, their favorable distribution in phase enabled the determination of the secondary period: $P_b = 25.8$ days (Kanyó 1970).

All the studies on Blazhko effect were focused on RRab stars. It was a question if RRc stars could also possess the effect. Detre observed TV Bootis, an RRc star, photoelectrically on several nights in 1955 and found that this star also showed light curve variation with a period of 33.5 days (Detre 1965b).

The globular clusters usually contain great number of RR Lyrae stars (e.g. Messier 3 contains over 200), therefore, their study is particularly suitable for determining statistical properties of Blazhko variables. It was concluded from the study of the variables in M3 that about 25-30% of the RRab stars showed the effect. A statistics of field RRab stars led a (less reliable) frequency of 15% (Szeidl 1965, 1973, 1976). As to the Blazhko stars in M3, another interesting observation was that for stars exhibiting variable light curves, the largest modulation amplitudes fitted the period-amplitude diagram valid for RRab stars with single period (Szeidl 1965). A definite negative correlation was found between the noise of pulsation period and the length of the Blazhko period (Kanyó 1976b).

During the years considerable knowledge accumulated at the Konkoly Observatory on the RR Lyrae stars with Blazhko effect. From time to time, it was summarized and published in review papers (Detre 1954, 1956a, 1957, 1962a, Szeidl 1976). In one of the reviews, Detre made an interesting observation. He arranged H. W. Babcock's[53] measures of the magnetic field intensity of RR Lyrae according to the phases of the pulsation and the Blazhko period. There was no correlation with the pulsation period, but a separation of positive and negative values was apparent in the course of the 41 day secondary period. Brightest maxima coincided with the largest negative, lowest maxima with the largest positive values of field intensity. As the number of the magnetic observations was small, the correlation could not be considered definitive (Detre 1962a).

Júlia Balázs propounded the oblique pulsator model as an explanation for Blazhko effect almost fifty years ago (Balázs 1960). If the magnetic axis inclines to the rotation axis of the pulsating star, then, depending on the geometry and the strength of the magnetic field, the Blazhko effect may have a natural explanation. If this hypothesis holds, then the Blazhko period equals to the rotation period. During the years, competitive theories

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[51] Commun. Lunar and Planetary Lab., No. 71, Vol. 5, Part 2, 1966

[52] Peremennye Zvezdy, 16, 62, 1966

[53] Astrophys. J. Suppl., 3, 141, 1958

have been advanced but we still lack for understanding of the Blazhko effect.

The situation became more complicated, when the 4-year cycle of RR Lyrae was discovered. After discussing and publishing their early photographic observations of RR Lyrae (Balázs & Detre 1943) its observation was kept on photographically, then photoelectrically from 1950. It seemed that the intensity of Blazhko effect had irregularly changed during the years. Detre wanted to mention it as an example for non-periodic effects in his introductory talk at the IAU Colloquium "Non-periodic Phenomena in Variable Stars" (Detre 1969c).

While preparing the figure of phase and amplitude modulation of RR Lyrae for different years by the author of the present review at Detre's request, it became conspicuous that the effect almost disappeared in the years 1963 and 1967, suggesting that the Blazhko effect might have a 4-year cycle. A very intensive observation of the star was started in 1969 and the transition between the new and old cycles was observed in 1971. At the end of the old 4-year cycle the phase variations during the 41-day Blazhko cycle died down almost completely and then, the new cycle started with a rapid increase of the amplitude. The amplitude of the maximum-variations was only $0\overset{\rm m}{.}07$ at the end of the old cycle, and then very rapidly became as large as $0\overset{\rm m}{.}16$ during 1971 and increased to $0\overset{\rm m}{.}27$ in 1972. The beginning of the new cycle was accompanied by a phase shift of 10 days, about a quarter in the phase of the 41-day Blazhko cycle (*Fig. 5*).

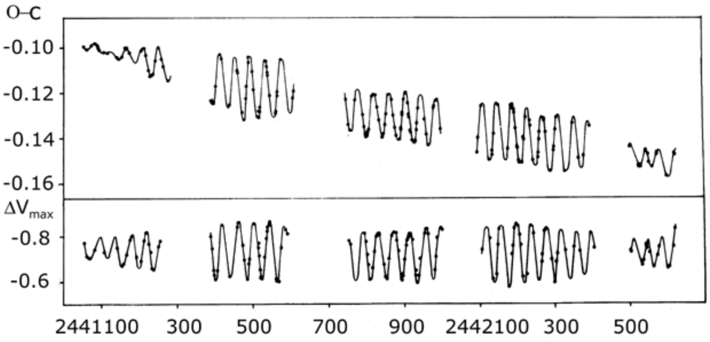

Figure 5: A whole 4-year cycle of RR Lyrae (after Szeidl 1976).

The Konkoly Observatory had almost forty thousand unpublished observations of RR Lyrae in 1972. Supplemented by others' photoelectric observations (1947: Th. Walraven[54], 1953: R. H. Hardie[55], 1955: P. Broglia & A. Masani[56], 1958-1959: G. Cocito & A. Masani[57], 1961-1962: B. Onderlicka & M. Vetesnik[58], 1962-1964: G. W. Preston, J. Smak, & B. Paczynski[59]) the 4-year (more exactly 4.3-year) cycle could be traced back to 1944 (Detre & Szeidl 1973a,b).

These results were fully confirmed by new observations, the transition from the old to the new cycle was also observed in 1975, and the phase discontinuity in the 41-day period was again about 10 days (Szeidl 1976).

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[54] Bull. Astron. Netherl., 11, 17, 1949

[55] Astrophys. J., 122, 256, 1955

[56] Contr. Oss. Astr. Milano-Merate, Nuova Serie, No. 105, 1957

[57] Contr. Oss. Astr. Torino, Nuova Serie, No. 27, 1960

[58] Astron. Inst. Univ. Brno (Czechoslovakia) Publ., No. 8, 1968

[59] Astrophys. J. Suppl., 12, 99, 1965

The identification of the 4-year cycle with magnetic cycle was very tempting and later it become the subject of heated debate.

Period Changes

W. Ch. Martin's[60] discovery, that the periods of the RR Lyrae stars in ω Centauri are predominately increasing, aroused the variable star astronomers' interest. Well it was thought that the O$-$C diagrams were simply accumulated evolutionary changes in the periods. Little wonder, then that the deviations of the epoch of variable stars from the linear elements were represented by second order equations, where the coefficients of the second order terms were supposed to describe the progressive changes in the periods. It was hoped that these coefficients would give some informations on the rate and direction of evolution of horizontal branch stars through the instability strip and would provide a strong test of the theory of stellar evolution. The study of RR Lyrae stars in globular clusters seemed to be particularly promising: at the same time, the period changes of a large sample of homogeneous group of RR Lyre stars could be investigated.

In 1937 L. Detre commenced the study of RR Lyrae stars of globular clusters M3 and M15 at the Konkoly Observatory. Later M. Lovas started the observation of RR Lyrae stars in M5 in 1951, and M56 and M92 were also included into the program. During the years 1937-1966 more than one thousand photographic plates were made on these clusters with the 60 cm Newton telescope. The plates were taken by Júlia Balázs, Katalin Barlai, L. Detre, G. Kulin, M. Lovas, I. Ozsváth, and B. Szeidl.

I. Izsák started investigating the period changes of the RR Lyrae stars in M15. The preliminary results were presented in the 1956 Budapest variable star conference (Izsák 1957). In the course of this study three new variable stars were discovered in M15 (Izsák 1952).

Between 1937-1951 115 plates of M56 were taken with 20 minutes exposure time. Júlia Balázs started analyzing the variables in this cluster. Comparing eight pairs of plates, she discovered two new variables (Balázs 1952a).

The study of period changes of RR Lyrae stars in M3 was started by I. Ozsváth. A short account on the preliminary results was given also at the 1956 variable star meeting (Ozsváth 1957).

For the final investigation of the variables of M3, 214 plates obtained at Budapest and 17 plates supplied by the Hamburg Observatory were used. 121 variables were measured with the microphotometers of the Konkoly Observatory and 13 variables (that could not be measured owing to crowding effect) were estimated. Out of the 134 objects measured, there were one red semiregular variable and one W UMa type eclipsing binary (RV CVn), a foreground star. As a whole, O$-$C diagrams of 125 RR Lyrae stars have been constructed, for most of them (116) for almost a 70 years timebase. Considering only the variables observed since Bailey's discoveries, the O$-$C diagrams could be fitted by a straight line for 8, by a positive parabola for 23 and by a negative parabola for 25 variables. No systematic trend was found in the direction of period changes. About half of the O$-$C diagrams could not be approximated by quadratic formulae. As a rule, the variables with secondary period had very complicated O$-$C diagrams. It was also an interesting observation that several RR Lyrae stars (both RRab an RRc) had sine-like O$-$C diagrams.

A review on the period changes of RR Lyrae stars in globular clusters was given by

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[60] Leiden Ann., 17, Part 2, 1938

Szeidl at the IAU Symposium on Variable Stars and Stellar Evolution held in Moscow in 1974. There were doubts about the character of the changes, whether the periods were relatively constant (apart from slow secular evolutionary changes) for long time intervals followed by brief intervals of spontaneous, abrupt changes or, whether the variations were relatively smooth. Two field RR Lyrae stars which were on the Konkoly Observatory's program provided examples for both cases. The period of RR Leonis (Balázs & Detre 1949) had increased smoothly, but the rate of change was not at all constant. On the other hand, the period of RR Geminorum changed suddenly around JD 2428900 within a brief interval. It was originally hoped that the period variations would depend on the positions in the colour-magnitude diagram, this expectation, however, was not fulfilled. We could not find any connection between the position of a star and its period change either in M3 or in M15. The final conclusion was that it was impossible to attach any evolutionary significance to the observed period change of an RR Lyrae star. Likely, ω Centauri is the only exception, in which some evidence for evolution effects may be present (Szeidl 1975).

L. Detre made an attempt at investigating the period changes of field RR Lyrae stars, but the sample was too small for drawing statistically significant conclusion (Detre 1955, 1970b). These studies, however, showed that, over and above evolutionary changes, some kinds of other effects exerted significant influence on the period causing period changes of different amount and of different direction.

Júlia Balázs and L. Detre called attention to mechanisms which were not connected closely with the physics of the star and could produce apparent period changes. If a variable moves as compared with the observers (even if in straight line with constant velocity) its observed period changes in consequence of the Doppler effect. In the case of constant velocity, the period is apparently increasing (Detre 1969b, 1970b). In a paper on period changes in variables and evolutionary paths in the Hertzsprung-Russell diagram Júlia Balázs and L. Detre applied the theory of random walk to the O−C diagrams of pulsating variable stars. If the period has random fluctuations, noise with σ standard deviation, then the O−C diagrams are random walks due to the cumulative nature of the fluctuations and do not represent real period changes. It was found that σ was an important parameter of variable stars and correlated with the rapidity of evolution (Balázs & Detre 1965).

Other pulsating variables

- δ *Scuti variables*

In the early days (in the thirties) δ Scuti stars were not distinguished from RR Lyrae stars, so it is not a wonder that they were also on the observing list at the Konkoly Observatory.

Immediately after the discovery of the variability of 391.1934 Aqr = CY Aquarii, its photographic photometry was commenced by J. Balázs and Detre. During nine nights in 1934, almost 200 observations were obtained and the elements of the light variation were derived. Nine maxima were observed that pointed to single periodic nature of the star (Balázs & Detre 1934, 1935). Later, it was observed photoelectrically that confirmed the previous results (Detre & Chang 1960).

Previous observers of XX Cygni referred to its light curve variations. Analyzing more than 300 photographic observations obtained in 1936, no sign of secondary periodicity was found (Detre 1936a).

Based on his visual observations, A. G. Lange[61] stated that RV Arietis exhibited irregular variations. About 300 photographic observations made in 1935-1936 during 16 nights revealed the star's real nature: a short period pulsating star (Detre 1936c, 1936d, 1936e, 1937b). Later, Detre succeeded in disclosing the double mode behavior of the star and determined its secondary period making use of the accurate photoelectric observations of P. Broglia and E. Pestarino[62] (Detre 1956b). It turned out that this variable belonged to the subgroup of AI Velorum stars. In order to get more accurate periods and the period ratio, new observations were made during nine nights in the years 1951, 1953, 1954, 1955, and 1956. As a whole, 261 photographic observations of RV Ari were obtained and discussed (Balázs 1956).

In the thirties, the question of multimode stellar pulsation aroused the interest of the variable star astronomers and captivated Detre's interest, too. He analyzed the photoelectric data set of δ Scuti obtained by E. A. Fath[63] and interpreted the star's secondary period as interference of two oscillations with close frequencies (Detre 1941).

At the Konkoly Observatory the observation of δ Scuti stars has proceeded forth photoelectrically (Detre 1957). I. Guman (independently from W. Fitch) discovered that VZ Cancri was also a double mode variable. He observed the star photoelectrically between April, 1951 and February 1954, and collected more than 1200 observations on 24 nights. The measurements were made without filter. The light curve variation and the differences in height of the 26 observed maxima were conspicuous. According to both the periods and the light variations the star behaved resembling AI Velorum and SX Phoenicis (Guman 1955a).

The variability of SZ Lyncis was discovered by C. Hoffmeister[64] and H. Schneller[65] classified it as a short period RR Lyrae star. In 1962 February and March 600 photoelectric B and V observations were collected and the period was derived. It was shown that the star was a single periodic dwarf cepheid (Gefferth & Szeidl 1962).

V. P. Tsesevich[66] called the attention to the possible light curve variation of the Bamberg variable BV92[67] = AE Ursae Majoris. More than one thousand photoelectric observations in two colours were made between January and April 1974 on 12 nights. The observed 18 maxima allowed to determine both the fundamental and first overtone periods. The period ratio 0.773 was very characteristic of the radially pulsating double mode δ Scuti stars. The light curve variations of AE UMa proved to be very strong, during a modulation cycle the height of maxima varied almost $0\overset{\mathrm{m}}{.}3$ while the phase of maxima almost 10 minutes (Szeidl 1974).

- *AC Andromedae*

Soon after P. Guthnick and R. Prager[68] discovered the variability of BD+47°4104 (= 9.1927 And) it became evident that the star (soon receiving its variable star name, AC

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[61] Tadjik Tsirk., 4, 1935

[62] Mem. Soc. Astr. Ital., 26, 429, 1955

[63] Lick Obs. Bull., No. 479, 1935; Lick Obs. Bull., No. 487, 1937

[64] Astron. Abh. (Erg.-H. zu den AN), 12, 21, 1949

[65] Astron. Nachrichten, 286, 102, 1961

[66] Astron. Tsirk., 775, 1973

[67] E. Geyer, R. Kippenhahn, & W. Strohmeier, Kleine Veröff. Bamberg, Nr. 11, 1955

[68] Astron. Nachrichten, 229, 455, 1927

And) is a unique variable. Through intensive observation, N. T. Florja[69] could derive the type of variability and periods of AC And. He could describe the light variation as superposition of two oscillations with periods 0.525 day and 0.711 day, and he interpreted this result in such a way that two RR Lyrae stars optically coincided with each other. Later, G. Münch[70] refuted this assumption on the basis of spectroscopic observations and suggested that AC And was rather of AI Vel type.

Little wonder, that the strange behavior of this star aroused L. Detre's interest and in 1935 he included AC And into the observing program of the Konkoly Observatory. Between 1935 and 1954, 5670 photographic observations were obtained that were later analyzed by I. Guman.

In order to get a real picture about the nature of the light variation of AC And, the star's intensive photoelectric photometry started in 1958 at the observatory. For the year 1962 Detre organized a campaign, too (Detre 1962b). In the long run, AC And was observed photoelectrically on a total on 78 nights in the years 1958, 1960, 1961, and 1962 and more than 10000 observations were secured in the Johnson U, B, and V bands. The analysis was, however, restricted to the 4662 yellow magnitudes, and revealed that AC And had its fundamental and first and second overtone radial pulsation modes, all excited and nonlinearly coupled. This variable star was found to have a mass of $M = 3.1 M_{Sun}$ and to be a high-mass analog of the δ Scuti stars, in the hydrogen-shell-burning and helium-core-contraction stage of evolution (Fitch & Szeidl 1976).

- *Cepheids*

In order to test the photoelectric photometer, L. Detre observed bright cepheids, such as FF Aql, η Aql, SU Cas, TU Cas, δ Cep, X Cyg, SU Cyg, S Sge, and T Vul, but these observations have not been published.

The long period cepheid CY Cas was investigated on Moscow archive plates and its period was corrected (Almár 1959).

The beat period cepheid TU Cassiopeiae was intensively observed by Erzsébet Illés in 1960-62 and by L. Szabados after 1971. The light-surface at different beat phases was constructed and the variation of the periods was studied (Illés 1968, Illés & Szabados 1976).

The Observatory's new photometer on the 50 cm Cassegrain telescope was put into operation in 1972. The instrument equipped with a UBV photometer made the expansion of the observatory's program possible. The observations of northern cepheids brighter than 12^{m} were started in 1972. One of the purposes of this observational program was the search for beat cepheids. One new double mode cepheid was discovered: BQ Serpentis had two periods, $P_0 = 4.271$ days fundamental and $P_1 = 3.012$ days first overtone, and $P_1/P_0 = 0.705$ period ratio (Szabados 1976a). Some results of the survey as by products were achieved right away. V445 Cas was wrongly classified as a cepheid, it is in reality an eclipsing variable of β Lyrae type (Szabados 1974a). V361 Per was catalogued as probable cepheid. It turned out to be an early type irregular variable (Szabados 1974b). The Bamberg variable BC Dra was assigned to cepheid. In truth, the star is an RR Lyrae variable of long (0.720 day) period (Szabados et al. 1976). J.D. Fernie and J.C.

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[69] Astron. Zhurnal, 14, 1, 1937

[70] Astrophys. J., 114, 546, 1951

Hube[71] reported BD+56°2806 as a probable cepheid. The observations showed that it was, indeed, a cepheid with short period (Szabados 1976b).

In 1966, S. Demers and J. D. Fernie[72] called attention to the strange behavior of the Population II cepheid RU Camelopardalis. The observations of this star started at the Konkoly Observatory already in August 1966 (Detre 1966b, Detre & Szeidl 1967, Detre 1969a, Szeidl 1969b).

- *β Cephei type*

RS Sextantis was identified as "related to the β Canis Majoris stars" by A.B. Underhill[73]. The projected velocity of rotation of RS Sex turned out to be fairly high, 260 km/s (Almár 1968).

- *Red variables*

On the plates taken for the RR Lyrae program, variable stars of other types may be found and could be investigated. BT Lyrae appeared on the plates (close to their edge) taken on the globular cluster M56 and its measurements showed that there were departures from regularities and the form of successive maxima and minima strongly varied. The period could be corrected to $P = 167.85$ days (Balázs 1952a). ST Draconis is near RW Dra. E. Hartwig[74] found it to be variable, but conformity with the photographic observations it proved to be constant within some hundredth of magnitude (Balázs 1952b).

On the plates taken for the study of AC And, two other variables could be found and measured. AI Andromedae is a Mira type variable and showed strong period variation (Guman 1952, 1955b). BE Andromedae is an M6 type semiregular variable. Its average period was newly determined, 157 days as against the previous value of 137 days, but the actual periods showed large fluctuations (Guman 1955b).

- *Cataclysmic variables and flare stars*

Nova Herculis 1963 was discovered by E. Dahlgren[75] on February 6, 1963. This object was observed at the Konkoly Observatory in three colours from February 9, 1963 to October 2, 1964. During 43 nights more than 900 observations were made and spanned almost 8^{m} of the brightness decrease. Rapid fluctuations in brightness and colour had been found (Almár & Illés 1966).

One of the light outbursts of the very interesting object Rosino-Zwicky near M88 was detected on plates taken by the observatory's 60/90 cm Schmidt telescope for the supernova search program. The object brightened by 6 magnitudes from the middle of March to the beginning of April 1965 (Lovas 1965). In the course of the flare statistics program, a new U Geminorum star was found in Cancer (Jankovics 1973).

The observatory took part in the photoelectric monitoring of flare stars. AD Leonis was observed and events were recorded (Szeidl 1969a, Barlai et al. 1972).

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[71] Astrophys. J., 168, 437, 1971

[72] Astrophys. J., 144, 440, 1966

[73] The Early Type Stars, D. Reidel Publ. Co. Dordrecht, p. 259, 1966

[74] Astron. Nachrichten, 177, 70, 1908

[75] BAV Rundbrief, 12, 3, 1963

- *Binary stars*

Although the observatory's main program was the study of intrinsic variables, some eclipsing and spectroscopic binaries were also investigated.

On the plates made for studying AV Vul, the β Lyrae type variable, CD Vulpeculae could also be measured. The amplitude of the primary minimum was about 1^{m}, and that of the secondary minimum about $0^{\mathrm{m}}\!.4$ (Guman 1951).

The long period eclipsing binaries Z Aurigae and 32 Cygni were photoelectrically measured (Detre & Herczeg 1952, Herczeg 1956a, 1956b).

The orbits of visual and spectroscopic binaries were also discussed in several papers (Batten & Szeidl 1972, Herczeg 1957a, 1957b).

In 1959, K. K. Kwee[76] organized an international campaign of observations of VW Cephei. In the frame of this program during seven nights in 1959 more than 1000 photoelectric observations were secured in U, B, V, and R bands (Detre & Kanyó 1961). In connection with this program photoelectric observations obtained previously at the observatory (in 1950, 1952, and 1959) were also published and discussed (Balázs & Detre 1961a).

Attempt was made to interpret the O$-$C diagrams of four eclipsing binaries (W Delphini, Z Draconis, TX Herculis, and RV Lyrae) with the effect of a hypothetical third body, and the mass functions and orbital elements were determined (Illés & Almár 1963a,b)

Putting into operation the 50 cm Cassegrain telescope, more telescope time was at disposal of the staff and the starting of new programs become possible.

The regular photoelectric observations of minima of eclipsing variables were commenced in 1973 (Patkós 1975, 1976).

Epilogue

In this review I made an attempt to summarize the results of variable star research at the Konkoly Observatory published until 1976. This date was chosen for the simple reason as I tried to stress the results and achievements "in which László Detre had a hand". Of course, there were research works commenced before 1976 and concluded and published later on. Here I quote only some examples.

The old photographic observations of AC And were measured and analyzed[77]. The photographic and photoelectric observations of nine single mode RR Lyrae stars (AT And, SU Dra, TW Her, VZ Her, RR Leo, TT Lyn, AV Peg, AR Per, and TU UMa)[78] and the Blazhko stars RW Dra[79], XZ Dra[80], and RR Lyr[81] were published and the basic parameters of the light curves (e.g. times of maximum light) were also given. Still we have old photographic (from the 1930-1950s) and photoelectric observations (from the 1950-1960s) of RR Lyrae stars not yet elaborated.

The period changes of single mode high amplitude δ Scuti stars (CY Aqr, YZ Boo, XX Cyg, DY Her, EH Lib, SZ Lyn, and DY Peg) were investigated also making use of the

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[76] Resolution on co-operative programs, IAU Comm. 42 Transactions of IAU, vol. 10, p. 638, 1958

[77] I. Guman, Budapest Mitt., Nr. 78, 1982

[78] K. Oláh & B. Szeidl, Budapest Mitt., Nr. 71, 1978; B. Szeidl, K. Oláh, & A. Mizser, Budapest Mitt., Nr. 89, 1986

[79] B. Szeidl, K. Oláh, K. Barlai, & L. Szabados, Budapest Mitt., Nr. 102, 2001

[80] B. Szeidl, J. Jurcsik, J.M. Benkő, & G. Bakos, Budapest Mitt., Nr. 101, 2001

[81] B. Szeidl, E. F. Guinan, K. Oláh, & L. Szabados, Budapest Mitt., Nr. 99, 1997

old photographic and photoelectric observations of the observatory[82]. The photoelectric observations obtained in the fifties and sixties were also included in the study of double mode HADS (RV Ari and AE UMa)[83].

The behaviour of the peculiar W Vir type star, RU Cam had been followed from 1966 during 16 years. The unique data set covered almost continuously the light variation for that time interval[84].

In the frame of the photographic observational program of RR Lyrae stars in globular clusters, a great number of plates were taken with the 60 cm telescope on different clusters from 1937 up to 1966. Measurements of variables in M15 were accomplished[85], but the investigation of RR Lyrae stars in M5 is still the task for the future.

In this review I have not alluded to two subjects, although both belong to the field of variable stars. In order to make the most the 60/90 cm Schmidt telescope, L. Detre initiated the search for extragalactic supernovae (Detre 1974) and for flare stars in galactic clusters[86]. The motive for setting aside these subjects was that the aim of the searches was the study of the frequency of supernovae and flare stars and not the study of physics of their variability.

The variable star research at the Konkoly Observatory had new perspective when the development of its mountain station was completed in 1975. The new 1 m RCC telescope was right away furnished with an uncooled UBV, and later on with a refrigerated photon-counting UBV$(RI)_C$ photometer[87], that made the broadening of the field of variable star research at the Konkoly Observatory possible. Based on the three photometric telescopes (60 cm Newtonian at Budapest, Svábhegy, 50 cm Cassegrain and 1 m RCC at Piszkéstető mountain station) the author of this review initiated the study of all types of variables in classical instability strip of HRD and of the phenomena of stellar activity. The 1 m telescope also proved to be an ideal equipment for the investigation of variables in globular clusters, to pursue our classical program. Large number of photographic plates were exposed on M3, M5, and M15 before the CCD era.

The variable star research at the Konkoly Observatory well-founded by L. Detre during his life has always had international reputation and the variable star community of the observatory has always taken active part in the international co-operation. Since 1961 the Information Bulletin of Variable Stars, the official publication of the IAU Commissions 27 and 42 has been issued by the observatory. The editors and co-editors were/are L. Detre (1961-1974), B. Szeidl (1968-1990), L. Szabados (1983-2000), Katalin Oláh (1990-) and Johanna Jurcsik (2000-). L. Detre and B. Szeidl fulfilled the duty of presidency of the IAU Variable Star Commission in the years 1967-1970 and 1985-1988, respectively. The observatory organized three international conferences on variable stars before 1976:

- Konferenz über veränderliche Sterne, Budapest, 23-28 August 1956
- Non-periodic Phenomena in Variable Stars, IVth Colloquium on Variable Stars, Budapest, 5-9 September 1968

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[82] H.A. Mahdy & B. Szeidl, Budapest Mitt., Nr.74, 1980; B. Szeidl & H. A. Mahdy, Budapest Mitt., Nr.75, 1981; B. Szeidl, Budapest Mitt., Nr.84, 1983

[83] B. Szeidl & G. Virághalmy, Budapest Mitt., Nr. 98, 2000; M. D. Pócs & B. Szeidl, Astron. Astrophys., 368, 880, 2001; M. D. Pócs, B. Szeidl, & G. Virághalmy, Astron. Astrophys., 393, 555, 2002

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In this short review I essayed to outline the first 75 years history of variable star research carried out at the Konkoly Observatory. Although the circumstances were not always favourable for research work, the accomplishment was impressive and has inspired, and may inspire the succeeding generations. The publications of staff members of the Konkoly Observatory on variable stars between 1901 and 1976 are given in the references section.

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The Piszkéstető Mountain Station of the Konkoly Observatory

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Overview

Under the directorship of *László Detre*, the Konkoly Observatory of the Hungarian Academy of Sciences has established a mountain station (on one of the highest points of Hungary) and has acquired three new telescopes. The building operations of the *Piszkéstető Mountain Station* (*Figs. 1-4*) started in 1958, their financial backing was provided by the Hungarian government. The completion of the main building took its turn in September 1960 and the dome of the Schmidt telescope was finished in 1961. The new telescope took up its duties in 1962. Detre was the originator and first leader of the Mountain Station. The realization of the project for itself was a great service to Hungarian science and it is really sorrowful that Detre could not live to see completion of this undertaking. The building up of the Station was finished in 1974 – with the installation of the 1 m RCC telescope – and since that time there has not been any significant astronomical building or instrumental investments in our country.

The 60/90 cm Schmidt telescope

The 120/180 cm Schmidt telescope of the Palomar Observatory was completed in 1948 (and for many years it was the largest Schmidt telescope in the world). One year later, the new wide-angle telescope starts the first Palomar Observatory Sky Survey, which maps the entire northern sky and a major share of the southern heavens as well (up to the 21st magnitude). The resulted Palomar Sky Survey Atlas is an indispensable tool of the astronomical investigations up to the present day.

This fact probably played a major role in the decision concerning the infrastructural facilities; consequently the first main acquisition was a 60/90 cm Schmidt telescope equipped with two (a 2° and a 5°) full aperture objective prisms (*Figs. 5-7*).

The installation of a 50 cm Cassegrain telescope was a logical extension of the instrumentation of the mountain station. The telescope arrived during the summer of 1966 and (as in the case of the Schmidt unit) it was assembled and examined by a team of Zeiss technicians in a new dome (*Figs. 8-9*). With the aid of a cooled *UBV* photoelectric photometer it became feasible to utilize the more favourable conditions of the mountain sky in the field of photoelectric photometry.

The 1 m Ritchey-Chrétien telescope

The last and at the same time largest building and instrumental investment at the mountain station was the installation of a 1 m RCC telescope (produced likewise by Carl Zeiss Jena). The guidance of the telescope and the data acquisition was solved by a CAMAC module and a small TPAi computer (KFKI products). The new facilities – including the 'home-made' photoelectric photometer – reassuringly matched the world-standard of that time and made possible the undertaking of more ambitious projects.

It is well known that Detre was fully aware of the importance of the observations. Perhaps observing was the only affair he took really seriously. But fate was not on his side: he could not live to see the completion of the truly remarkable 1 m RCC project. He died in 1974 when he was only at the age of 68. It is our honouring duty to worthily recall to mind the exceptional lifes work of László Detre, to keep his memory alive and continue his tireless efforts (*Figs. 10-13*).

The PPT version of the memorial lecture delivered is available at the author's home page: `http://astro.elte.hu/~bab/bb.html` .

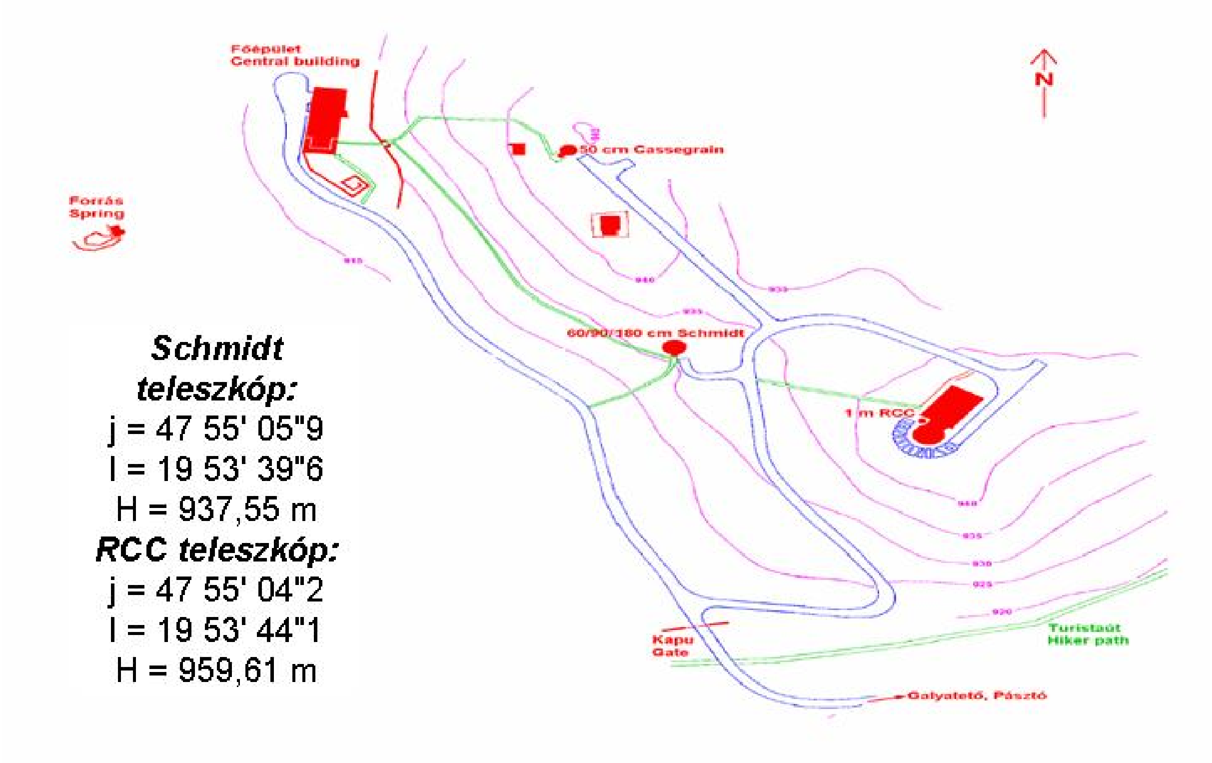

Figure 1: Sketch-map of the mountain station

Figure 2: Birds-eye view of the three domes of the mountain station

Figure 3: Aerial perspective of the main building

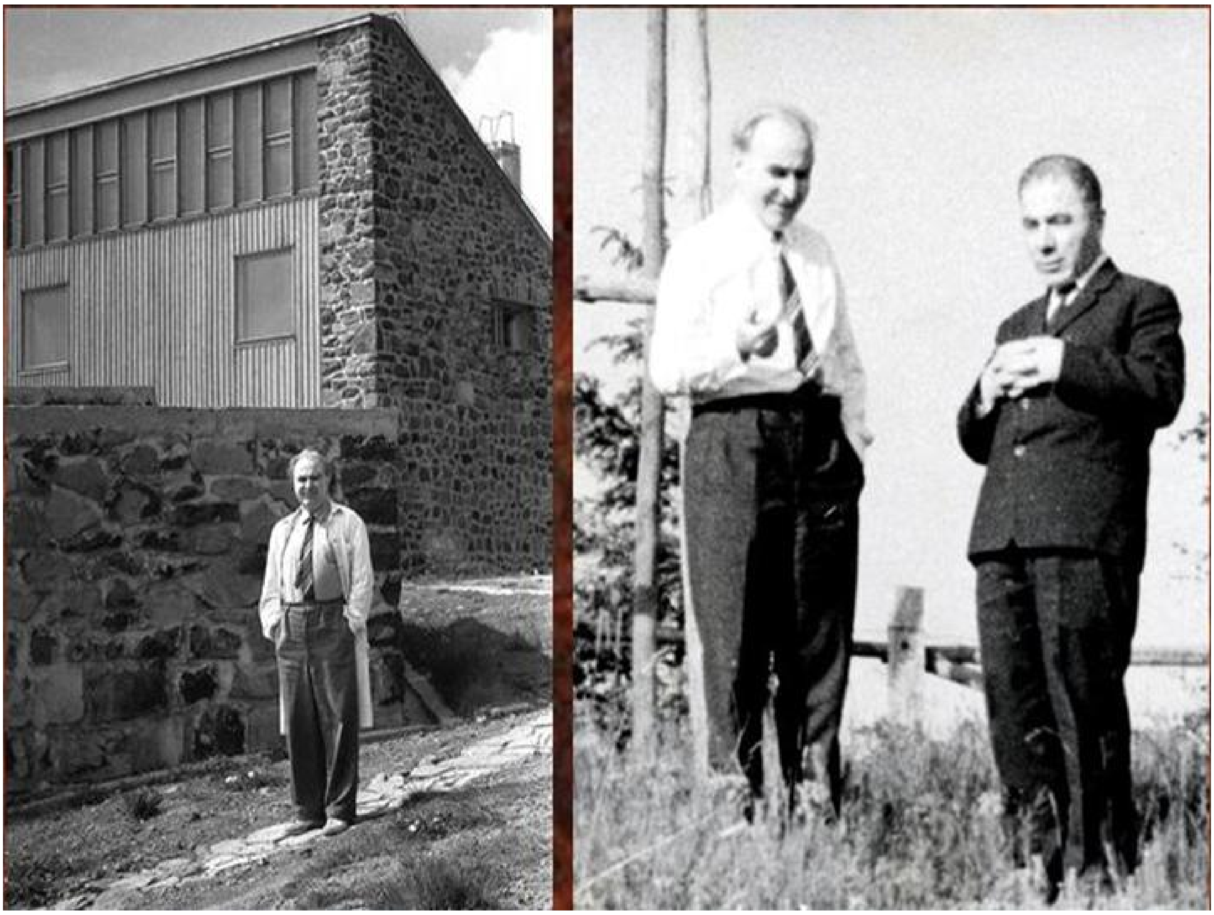

Figure 4: László Detre at the main building (*left*); László Detre and Viktor Amazaspovich Ambartsumian (president of the International Astronomical Union during 1961-1964) on the mountain station (*right*)

Figure 5: Four stages of the building process of the dome of the Schmidt telescope

Figure 6: László Detre (left), Viktor Ambartsumian (right), and the author in the Schmidt dome

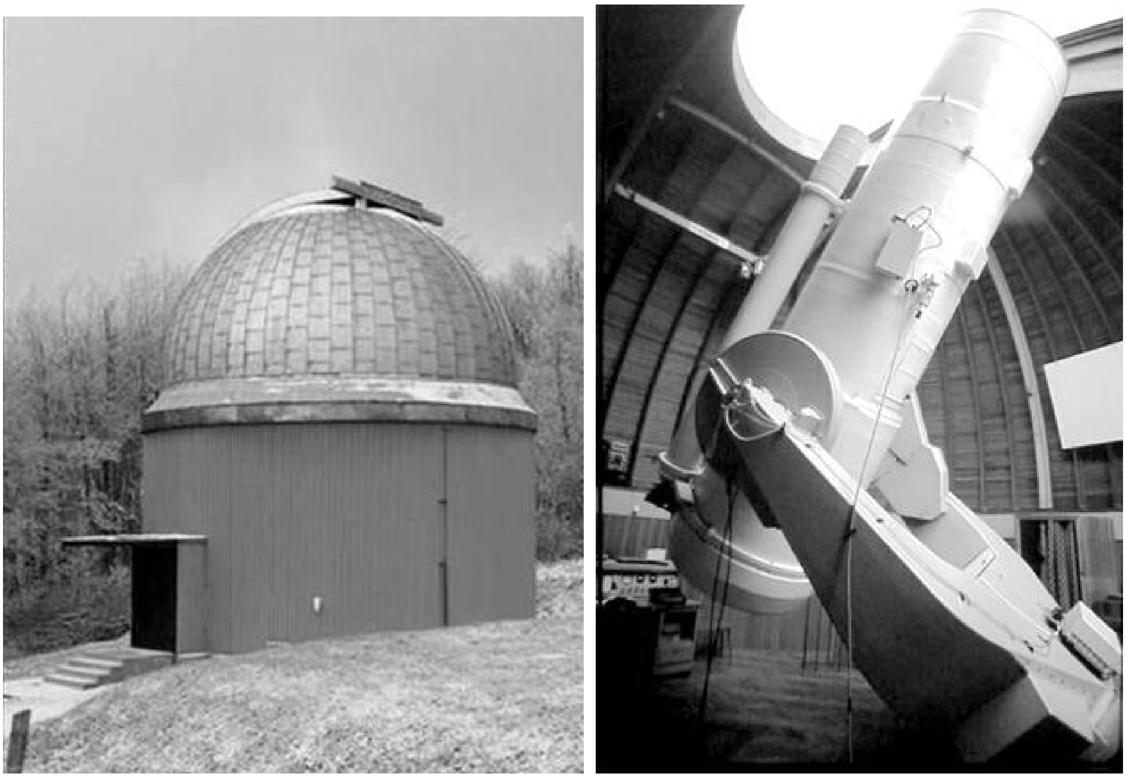

Figure 7: The Schmidt dome and the 60/90 cm Schmidt telescope. Main features: Manufacturer: Carl Zeiss Jena; Year of installation: 1962; Focal length: 1800 mm; Field: 5 degrees, 160×160 sq.mm; Optical instrumentation: 2° and 5° objective prism

Figure 8: The dome of the 50 cm telescope and its aerial view (with the main building)

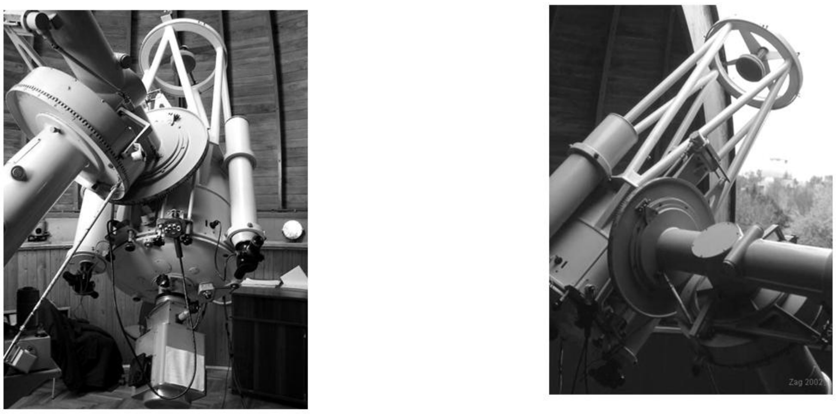

Figure 9: Two views of the 50cm Cassegrain telescope. Main features: Manufacturer: Carl Zeiss Jena; Year of installation: 1966; Focal length: 7500 mm

Figure 10: Two stages of the building process of the RCC facilities

Figure 11: Two views of the RCC building

Figure 12: The 1 m RCC telescope. Main features: Manufacturer: Carl Zeiss Jena; Year of installation: 1974; Focal length: 13500 mm

Figure 13: Unveiling ceremony of the Detre memorial at the Mountain Station. From left to right: L. G. Balázs, J. Balázs (sculptor), N. Kroó (General Secretary of the HAS), and Villő Detre

László Detre and the Department of Astronomy of the Loránd Eötvös University

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László Detre was appointed as professor and head of the Department of Astronomy of the Eötvös University from the 1st of August, 1964. Since he also was the director of the Astronomical Institute of the Hungarian Academy of Sciences, he served as a half time professor at the University. He was the leader of the Department of Astronomy until 1968 when, as a result of an agreement between the Academy and the University according to which a person cannot be a director of two institutes simultaneously, he resigned as head of department. He continued, however, giving lectures at the University as honorary professor until his death in 1974.

Before professor Detre the Department of Astronomy was led by István Földes, and Detre was followed as head by Béla Balázs.

The staff of the Department of Astronomy between 1964-1968 was
László Detre professor (in half time),
István Földes associate professor,
Béla Balázs associate professor (in half time),
Miklós Marik assistant professor.

Until 1967 the Department of Astronomy was in the main building of the Faculty of Natural Sciences at Múzeum Blvd. 6-8 on the first floor, where it had two rooms. Entering the department from the corridor there was a larger room which served as a seminar room and a library at the same time, and from here opened a smaller room for the staff, where in most of the cases only M. Marik could be met. Others came in just before their lectures.

In the early spring of 1967 the Department of Astronomy, together with other departments of the Faculty of Natural Sciences, moved to the building of the former Military Academy, the Ludovika, with the promise of being there just for a short transitory period, until the new campus of the Faculty would be built. This transitory period, however, lasted for more than three decades, and the author of this paper, who was a student of the department at the time of the movement, often thought that probably the department would still be in the Ludovika when he would retire.

In the building of the Ludovika the Department of Astronomy had a larger place and an astronomical research laboratory, supported both by the Academy and the University, could also be set up with the aim at reducing the large number of observations made by the Schmidt telescope of the Konkoly Observatory's Piszkéstető Mountain Station.

The regular astronomy education in the Eötvös University was initiated and organized by professor Detre. It began in the fall semester of the academic year 1965/1966. The Ministry of Education approved professor Detre's proposal according to which in each year four students, majoring either in physics, geophysics, or teaching of mathematics and physics, could also study astronomy from the third year as an additional major discipline, and after a successful state examination receive a university diploma in astronomy. Prior to this date astronomy could only be learned in special courses. The first diplomae in astronomy were issued in 1968.

While professor Detre was the head of the Department of Astronomy, among the students of the department were: Lajos Balázs, István Fejes, András Horváth, Péter Olaj, Koppány Thaly, József Abaffy, Szabolcs Barcza, István Jankovics.

Below is a (non-official) list of the students of astronomy with the year of the diploma whom professor Detre taught.

1968: Bálint Érdi, György Flórik, Lajos Galambos, László Varga;

1969: Barna Apagyi, Csaba Békássy, Sándor Nagy, Gyöngyi Rovó;

1970: Péter Horváth, Gábor Kilvády, Attila Matisz, Zoltán Nagy, Viktor Rónay;

1971: Lajos Márky-Zay, László Szabados, Gábor Szécsényi-Nagy, László Tihanyi;

1972: György Csaba, Mária Kun, László Patkós;

1973: József Csörgei, Pál Halász, János László Kókai, Anikó Paál;

1974: Lídia Gesztelyi, Attila Grandpierre, Katalin Oláh, Margit Paparó;

1975: Szaniszló Bérczi, Előd Both, Géza Kovács, Gábor Taracsák;

1976: András Bardócz, János Kelemen, Róbert Szabó, László Tóth, Márta Varga, Zsuzsanna Vizi.

Students who wanted majoring in astronomy from the third year, in the first two years had to take up an introductory course. In the following the schedule of astronomy courses is given. The numbers after the course names mean the number of hours per week, for example 2+1 means 2 hours lecture and 1 hour practice in a week. The lecturers' names are also given.

Figure 1: The main building of the Faculty of Natural Sciences on the Múzeum Boulvard, where the Department of Astronomy was until 1967.

Figure 2: The building of the Ludovika gave place for the Department of Astronomy from 1967 to 1998. Professor Detre held his lectures here in the period 1967-1974.

1st and 2nd years:
  Introduction to astronomy. 2+1, B. Balázs, M. Marik.
    1st semester: Astronomical objects of the Universe
    2nd semester: Spherical astronomy
    3rd semester: Elementary astrophysics
    4th semester: Structure of the Galaxy
3rd year:
  General astronomy. 2+1, L. Detre.
  Introduction to celestial mechanics. 2+1, I. Földes.
  Theoretical astrophysics. 2+0, M. Marik.
  Practical astronomy. 0+1, B. Balázs.
  Astronomical seminar. 0+2, L. Detre.
4th year:
  General astronomy. 2+1, L. Detre.
  Celestial mechanics. 2+1, I. Földes.
  Theoretical astrophysics. 2+0, M. Marik.
  Practical astronomy. 0+1, B. Balázs.
  Astronomical seminar. 0+2, L. Detre.
5th year:
  General astronomy. 2+1, L. Detre.
  Celestial mechanics. 2+0, I. Földes.
  Theoretical astrophysics. 2+0, M. Marik.
  Practical astronomy. 0+1, B. Balázs.
  Astronomical seminar. 0+2, L. Detre.
  Seminar on the diploma work. 0+10, L. Detre.

The course of general astronomy was developed by professor Detre. It included fundamental astronomy, physics of the Sun and the stars, and stellar systems. Beside these fields he also reviewed the latest results of astronomy in his lectures and seminars.

In the lectures on theoretical astrophysics by M. Marik mainly the theoretical methods were treated in the fields of the physics of stellar atmospheres and the interstellar matter, and cosmic electrodynamics.

Celestial mechanics was taught by I. Földes, more known in astronomical circles by his widespread interest in music, languages, and arts. His lectures covered the two-body problem, an introduction to the theory of perturbations, Delaunay's lunar theory, and somewhat surprisingly the theory of motion of artificial satellites.

Teaching of practical astronomy was the territory of B. Balázs. This included photographic and photoelectric photometry, techniques of astronomical instruments, and methods of evaluation of astronomical measurements. In the academic year 1967/1968, because of his research work in the USA, B. Balázs was substituted by Béla Szeidl who gave lectures on photoelectric photometry (fall semester) and on astronomical measuring technics (spring semester).

Professor Detre was internationally recognized for his variable star research. In his lectures, however, he covered all aspects of contemporary astrophysics not only the field of variable stars. He conveyed the most important recent results to his students and made them aware of the actual problems and main research directions. The years of the 1960's were especially rich in outstanding astronomical discoveries, several of them were later recognized by Nobel prize in physics. All these discoveries were discussed in detail in professor Detre's lectures. The main topics were the quasi stellar radio sources, the cosmic X-ray sources, the pulsars, the cosmic microwave background radiation, the beginning of infrared astronomy, and the observations of interstellar molecules. Throughout the years more and more information became available on these subjects, and he thoroughly followed the advance of all fields and was always up-to-date in the events, explanations and denials.

Interestingly, he lectured also on quite distant fields. He had several lectures on the phenomena of solar activity. In one year he gave a semester on supernova research. Years later, when I remember his lectures, the most interesting for me was that even he had given lectures on celestial mechanics. The difficult subject that I had heard from him as a student, later I recognized as the J_2 theory of the Earth's artificial satellites by the Poincaré–Zeipel method. This was undoubtedly due to his close relation to Imre G. Izsák, an internationally known expert of artificial satellite research at that time.

Professor Detre provided broad, comprehensive knowledge of astronomy and astrophysics to his students, many of whom became well known researchers of their fields playing leading roles in international bodies and organizations of astronomy.

László Detre had been a professor of the Eötvös University for ten years. His effect, however, has lasted longer than ten years, since the teaching of astronomy in the Department of Astronomy has been continued for decades, until very recently, on the bases established by him.

The University keeps memory of Professor Detre. A seminar room of the Department of Astronomy in the new university campus at Lágymányos has been named after him making Detre's name known and familiar for younger generations, and not only in astronomy. A bust of him has also been erected in the hall of the Faculty of Natural Sciences, among the busts of other great professors of the University.

Figure 3: The plaque of the Detre-room of the Astronomy Department in the new university campus at Lágymányos.

Figure 4: The bust of Professor Detre in the main hall of the Faculty of Natural Sciences at Lágymányos.

László Detre and German-Hungarian Relationships

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Institute for History of Science
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Introduction:
Konkoly and the Foundation of the Hungarian National Observatory

In the last quarter of the 19th century the Hungarian astronomy flourished and thanks to the activity of Nikolaus [Miklós] Konkoly Thege[1] (1842–1916) the German-Hungarian relationships in the field of astronomy could be activated.

Very clear is here the orientation of the periphery (Hungary) with respect to the center of development (Germany).[2] Astrophysics – with its topics: spectroscopy, photometry and photography – was born just before in Germany. Konkoly as an important scientist and organiser belonged to the few pioneers of astrophysics in the world. Already ten years after starting his astrophysical work he had an international reputation. Konkoly built up international contact through travelling, in order to get to know other astrophysicists and their observatories. There were especially good contacts to the Potsdam observatory. He had correspondence with astronomers everywhere in the world and scientists from abroad visited his observatory.

When Konkoly became director of the Hungarian National Institute for Meteorology and Terrestrial Magnetism in Budapest in 1890, he was so busy and had no time left for astronomical observations that he tried to get his observatory in O'Gyalla under state

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[1] Kenessey, K. von: Nikolaus v. Konkoly Thege, der Astronom. In: Kleine Veröffentlichungen der dem kgl. ung. Ministerium für Ackerbau unterstehenden kgl. ung. Reichsanstalt für Meteorologie und Erdmagnetismus Budapest. Neue Reihe No. 14 (1942), p. 26. – Steiner, Lajos: [Biographie von Konkoly]. Budapest. – Marik, Miklós: Konkoly Thege Miklós (1842–1916). In: Csillagászati évkönyv (1992), p. 145–147. Bartha, Lajos: Konkoly Thege Miklós emlékezete. Budapest 1992. Vargha, Magda; Patkós, László; Tóth, Imre (eds.): The Role of Miklós Konkoly Thege in the History of Astronomy in Hungary. Proceedings of the International Meeting "120th Anniversary of Konkoly Observatory" in Budapest, 5–6. Sept. 1991. Konkoly Observatory of the Hungarian Academy of Sciences, Monographs No. 1, Budapest 1992.

[2] This article is based on an earlier publication: Wolfschmidt, Gudrun: Deutsch-ungarische Beziehungen in der Astronomie und Astrophysik. In: Fischer, Holger (ed.): Deutsch-ungarische Beziehungen in Naturwissenschaft und Technik nach dem Zweiten Weltkrieg. München: Oldenbourg (Südosteuropäische Arbeiten, 103) 1999, p. 337–373. This research was supported by Prof. Tibor Herczeg, Oklahoma, and in Budapest by Prof. Béla Szeidl and Magda Vargha, librarian of the Konkoly Observatory and Prof. Béla Balázs of the Eötvös University.

control. This initiative for institutionalisation of Hungarian astronomy with the help of the Astronomische Gesellschaft was successful. Already in the following year 1899 O'Gyalla became a national institute with the name Royal Hungarian Astrophysical Observatory – Radó von Kövesligethy (1862–1934) was vice-director from 1899 to 1904.[3]

László Detre and the Study of Hungarian Astronomers Abroad

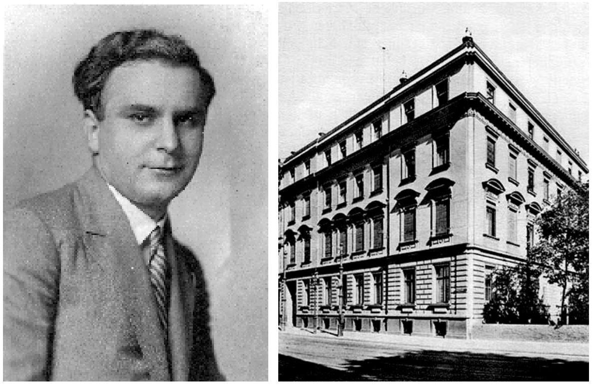

Figure 1: Left: László Detre (until 1933: László Dunst) (1906–1974). Right: Collegium Hungaricum in Berlin, founded in 1924

At the beginning of the 1920s, after WWI Hungary tried to get in closer connection to the cultural and scientific life in Europe: During the reign of the minister Kuno Graf Klebelsberg scientific and cultural institutes, the Collegia Hungarica, were opened in Vienna and Berlin in 1923/24. The Collegium in Berlin, Dorotheenstraße, under the director Professor Robert Gragger was in close cooperation with the Hungarian institute of Berlin university. The main task was the encouragement of talented young Hungarian scholars and artists. Living in Berlin, they should build up fruitful and long lasting contacts to Germany. Two decades very successful work was done until the building was destroyed in 1945.[4]

Like Konkoly in the 19th century also another director (since 1943) László Detre[5] [until 1933: László Dunst] (1906–1974) could get his scientific training in Germany, at the Collegium Hungaricum in Berlin, in 1927 to 1929 (*Fig. 1*).

After his dissertation he went to Kiel in 1929 and to Vienna in 1930.[6]

The whole staff in Budapest had got the training in Germany:

- Like Detre also his assistant Dr. Fr. Krbek studied in Berlin in 1927–29, then in Bonn in 1929–30 with Prof. Ernst Kohlschütter (1870–1942).
- The adjunct Dr. Károly Lassovszky got a grant for Babelsberg observatory in 1932 as a cooperator of Prof. Paul Guthnick (1879–1947).

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[3] Study in Vienna from 1881 to 1884, 1882–87 observer in O'Gyalla, 1899–1904 vice-director of O'Gyalla Observatory, in 1904 full professor and in 1910 director of the Seismographical Observatory, who had closest contacts to the German Seismological Observatories. Cf. Oltay, Karl: Radó v. Kövesligethy. In: Gerlands Beiträge zur Geophysik 43, Leipzig 1935, Heft 4, p. 337–339.

[4] Information from the "Haus der Ungarischen Kultur", Alexanderplatz, 1973–1989, Cultural institute "Haus Ungarn" since 1990.

[5] Szeidl, Béla: László Detre. In: Mitteilungen der Astronomischen Gesellschaft 38 (1976), p. 7–9.

[6] Cf. VJS 65 (1930), p. 110.

- The assistant Károly Móra (1899–1938) could go to Leipzig observatory in 1932 – Prof. Josef Franz Hopmann (1890–1975) – and then in 1933 to Heidelberg, Hamburg-Bergedorf and Göttingen.
- Also Loránt Dezső (1914-2003), the later leader of the Hungarian Heliophysical Observatory,[7] went to a German speaking country. He visited Prof. Max Waldmeier (1912–2000) in Zürich in 1939.

The result of Detre's long stay in Germany was not only that he made a lot of friends but also his research method and scientific work was influenced very much.

> *„Die Sternwarte von Budapest, eingerichtet als nationale Institution, nach Verlusten des Ersten Weltkrieges auf dem Schwabenberg, später Szabadsághegy (= Freiheitsberg) umbenannt, hatte einen langsamen Start. Das wohl einzige, nennenswerte wissenschaftliche Programm lief in den 1930er Jahren. Dr. L. Detre und seine Mitarbeiter begannen mit einer systematischen Studie der Perioden- und Lichtkurvenänderungen von RR Lyrae Veränderlichen. Die konsequente Überwachung einiger "Schlüsselobjekte" fand bald internationale Anerkennung. Julia Balázs' und L. Detres erste Publikation einer längeren Serie behandelte das Verhalten des kurzperiodischen Delta Cephei-Sterns RW Draconis [vgl. AJB 40 (1938), Nr. 8496, p. 270], die zweite das Verhalten des Veränderlichen AR Herculis (aufgrund von nicht weniger als 3363 photographischen Beobachtungen in fünf Jahren) [vgl. AJB 41 (1939), Nr. 8482, p. 213]. Das Beobachtungsprogramm lief zunächst auf zwei kleineren Astrographen, nach dem Krieg wurde auch der 60cm-Spiegel verwendet, um RR Lyrae Variablen in mehreren Kugelsternhaufen zu untersuchen.*
> *Dr. Detre promovierte 1929 in Berlin und seine persönlichen Beziehungen zu deutschen Astronomen waren ausgedehnt. Obwohl es nicht bekannt ist, ob das RR Lyrae-Programm aus Diskussion mit deutschen Astronomen geboren oder gar von ihnen vorgeschlagen wurde* (ich persönlich halte dies nicht für wahrscheinlich)*, durch Dr. Detres Person und seine ausgezeichneten Verbindungen hat die Forschung in Deutschland um 1925–30 bei der Geburt der Veränderlichenforschung (im weiteren Sinne der Astrophysik) in Ungarn sozusagen Pate gestanden.“*[8]

German-Hungarian Cooperation from 1870 to 1945

If you look at the graphic of cooperation (*Fig. 2*), you will see a large activity in the 1880s – in the time of Konkoly. Besides contacts inside of Hungary there were cooperations with Bothkamp near Kiel, Potsdam, Göttingen, and Leipzig. Abroad one should mention Vienna, Prague, Zürich, and Italy. In the eastern foreign countries there was only one cooperation with Russia on the occasion of a lunar eclipse.

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[7] The Heliophysical Observatory was in Budapest in the 1950s, then in Debrecen from 1958 on.

[8] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 26.8.1997. I am indebted to Professor Herczeg for giving me his report, and for proofreading my manuscript when we met in Gotha on 12 May 1998.

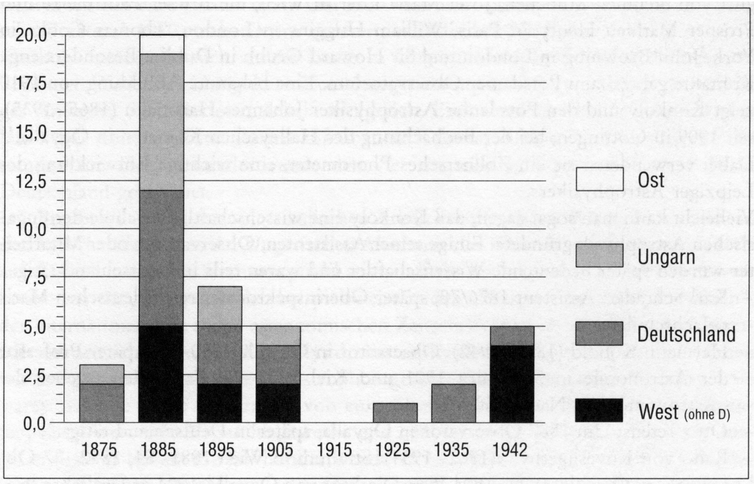

Figure 2: German-Hungarian cooperation from 1870 to 1945

- *German-Hungarian Cooperation from 1870 to 1919*

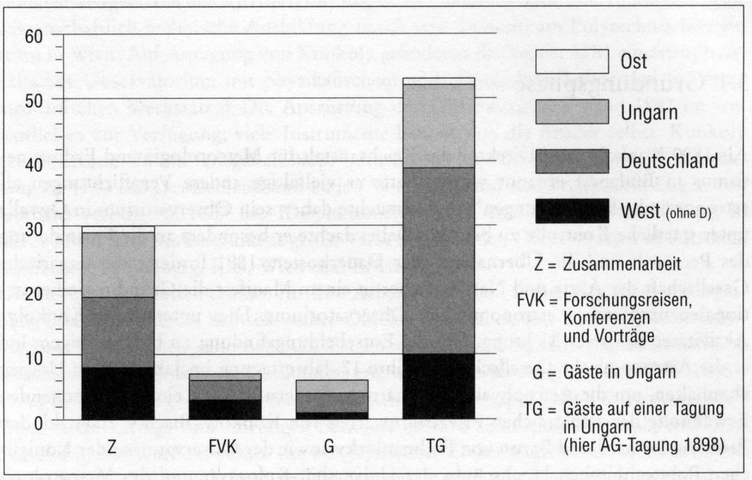

Figure 3: German-Hungarian cooperation from 1870 to 1899. Z: Cooperation, FKV: Scientific Travelling, Conferences and Lectures, G: Guests in Hungary, TG: Guests during a meeting in Hungary (here AG meeting 1898)

By analyzing the German-Hungarian contacts (cooperation, scientific travelling of Hungarians, guests from abroad in Hungary) from 1870 to 1899 (*Fig. 3*), one recognizes that Germany is in front compared to other western countries and there is only one example for a contact to eastern countries. During the meeting of the Astronomische Gesellschaft in 1898 in Budapest (cf. column TG) there were 53 astronomers: 29 Germans, 6 Austrians, 13 Hungarians and 5 more from Sweden, Russia, Denmark, and Italy. The executive council consisted of 4 Germans, one Austrian, one Swede, one Russian, and one Dutch in 1898.

It is obvious that the contacts decrease after the turn of the century (*Fig. 4*). But one has to consider that the annual reports given by Kövesligethy since 1900 are less detailed. And in addition there were no meetings in that time.

As honorary members of the Hungarian Academy of Sciences three Germans were

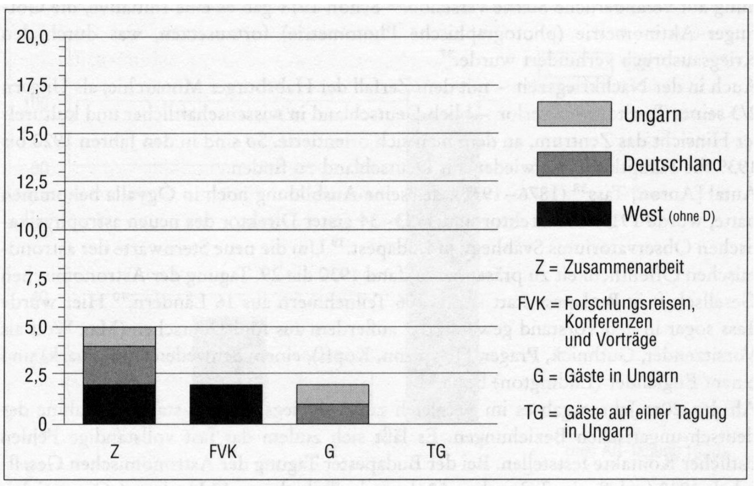

Figure 4: German-Hungarian cooperation from 1900 to 1919. The legend is explained in the caption to Figure 3.

elected until 1914: Arthur von Auwers (1838–1915), Berlin Academy of Sciences, in 1890, the director of Munich and Heidelberg observatories, Hugo von Seeliger (1849–1924), in 1899 and Max Wolf (1863–1932) in 1908 – in respect to their predicate to be president of the Astronomische Gesellschaft. These 3 astronomers from abroad in the Academy should be compared to 36 scholars from science (4 physicists, 6 chemists, and 7 mathematicians) and 60 scholars from the humanities.

- *Development in the 1920s and 1930s*

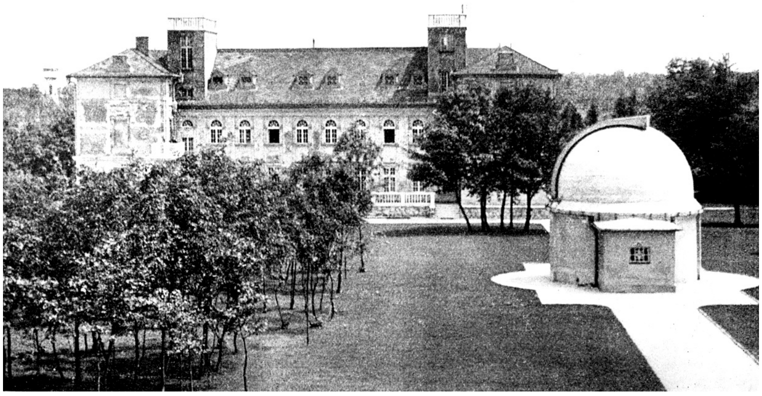

Figure 5: The Konkoly Observatory in Budapest, 1926

After WWI O'Gyalla was part of Czechoslovakia and was renamed to Stará Dala (today: Hurbanovo, Slovakia). Just in time – in 1921 – the instruments and the library of the observatory O'Gyalla could be transported to Budapest-Svábhegy. The building of the new National Observatory was finished in 1926 (*Fig. 5*).

The observatory in Budapest was named after its founder Konkoly.[9] The emphasis of the work was astrophysics, but in contrary to Konkoly's preference for spectroscopy since

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[9] Kelényi, B. Ottó: A magyar csillagászat története. Über die Geschichte der ungarischen Astronomie. In: Astronomische Abhandlungen des Kgl.-Ung. Astrophysikalischen Observatoriums von Konkoly's

the turn of the century and especially in the 1920s, the main topic became photometry and variable stars.[10] Already in 1914 there was an initiative to continue the “Göttingen Aktinometrie” (photographic photometry), a project which was stopped by the outbreak of WWI.[11]

In the postwar period – with the collapse of the Habsburg monarchy, when Hungary lost two thirds of its territory – Germany continued to be in scientific and cultural respect the orientation point. Thus in the years 1920 to 1939 the main contacts are to be found with Germany (*Fig. 6*).

Anton [Antal] Tass[12] (1876–1937), who got his scientific training in O’Gyalla, became vice-director in 1913 and first director from 1923 to 1934.[13] In order to present the new observatory to the astronomical public in 1930 the 29th meeting of the Astronomische Gesellschaft took place in Budapest with 106 participants from 16 countries.[14] During this meeting Tass was elected as member of the executive council which consisted of 5 Germans (Max Wolf as president, Guthnick, Prager, Hopmann, Kopff), one Swede (Lundmark) and one English (Eddington).

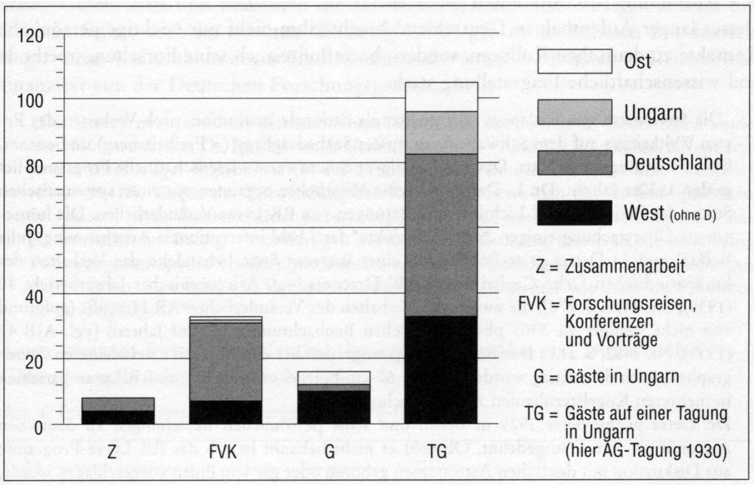

Figure 6: German-Hungarian cooperation from 1920 to 1945. The legend is explained in the caption to Figure 3.

Since the 1920s there was a prominent increase in the German-Hungarian relationships in comparison with the pre-war period. In addition one can recognize that contacts to eastern countries are practically totally missing. During the Budapest meeting (1930) (cf.

Stiftung in Budapest-Svábhegy Bd. 1 (1930), Nr. 2, p. 51–106 (in German). – Beckman, G.W.E.: Astronomie in Ungarn. In: Sterne und Weltraum 24 (1985), p. 439–443. – Herrmann, Dieter B.: Sternforscher und Sternfreunde in der VR Ungarn. In: Vorträge und Schriften der Archenhold-Sternwarte Berlin-Treptow Nr. 47 (1975), p. 1–16.

[10] In order to do photometry visual photometers were acquired in 1901–1903: a wedge photometer, a Zöllner photometer, a large astro photometer, all made by Toepfer in Potsdam, as well as a spectral photometer, made by Schmidt & Hänsch, Berlin, cf. VJS 36 (1901), p. 131, VJS 37 (1902), p. 143, VJS 38 (1903), p. 139.

[11] Cf. VJS 49 (1914), p. 186. An 8″, made by Heyde, Dresden, was used in combination with a Schwarzschild “Schraffierkassette” (like for the Göttingen Actinometry).

[12] Móra, K.: Anton Tass. In: VJS 73 (1938), p. 198–202.

[13] Tass was an assistant from 1899 and in 1902–13 observer in O’Gyalla, in 1913 vice-director of the O’Gyalla observatory.

[14] Bericht über die Versammlung der Astronomischen Gesellschaft zu Budapest 1930, August 8–12. In: VJS 65 (1930), p. 222–254, here p. 245.

column TG) there were 50 German participants, 13 Hungarians, 6 Austrians, and 27 other participants from western countries, here even from outside Europe: USA, Japan, and South Africa. Only 9 participants came from eastern countries: Soviet Union, Czechoslovakia, Poland, and Yugoslavia.

Even during WW II some cooperations with abroad existed: on one hand with Sweden where the "neutral bureau" was erected in Lund in order to keep up the exchange of important urgent astronomical information, but also on the other hand with Switzerland and the USA (Mt. Wilson Observatory) especially in the field of solar physics.

- *Visits of meetings and research travels until 1945*

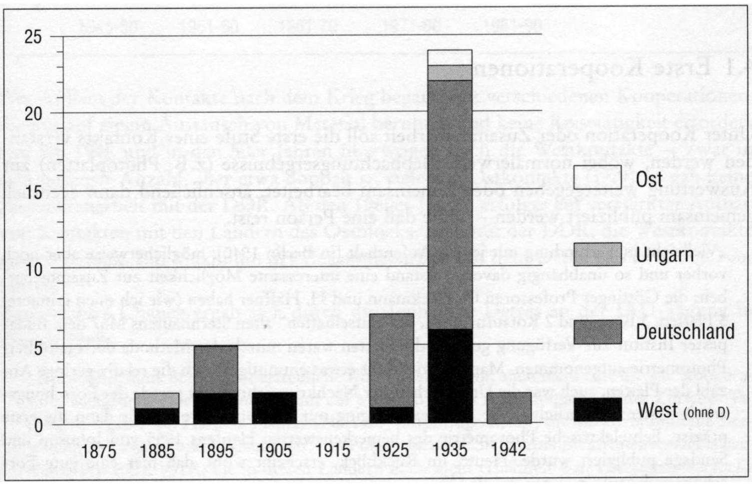

Figure 7: Research travels from 1870 to 1945

If one looks at the development of research travels, study visits and visits of meetings, one recognizes especially in the 1930s, in the period of Detre, a remarkable activity, especially visits in Germany, in the observatories Berlin-Babelsberg, Potsdam, Heidelberg, Göttingen, Hamburg, Bonn, Leipzig, and Munich and to the AG meeting in Danzig in 1939 (*Fig. 7*).

Travels to the western countries concern the meeting of the International Astronomical Union (IAU) in Stockholm, in addition visits in Vienna, Zürich, and Denmark. In the eastern countries only Kraków was visited in 1938.

László Detre and Júlia Balázs travelled in 1939 to Danzig to the meeting of the Astronomische Gesellschaft and visited the observatories Berlin-Babelsberg, Potsdam, and Leipzig.

Even during WWI (1940) there existed study visits of 5 month in Germany in the context of the German-Hungarian cultural agreement, financed by the Deutsche Forschungsgemeinschaft (DFG – German Research Organisation):

> *„Die letzten nennenswerten direkten Kontakte mit der Astronomie in Deutschland fanden um 1940 herum statt. Dr. Detre – noch nicht als Direktor – und Dr. Julia Balázs akzeptierten je ein kurzfristiges Stipendium (4–6–8 Monate?) zum Besuch der Münchner Sternwarte (1940 oder 1941?). Wegen der Entwicklung der Kriegslage erwies sich das als kein glücklicher Schritt und beide Wissenschaftler haben sich, Jahre später, wiederholt und mühsam – aber offensichtlich mit Erfolg – rechtfertigen müssen. (Wie behauptet, hatten sie die*

> *noch ruhige Forschungsatmosphäre des dortigen Instituts der von Befeindungen und Intrigen nicht ganz unbewährten Atmosphäre in Budapest (sowohl an der Universität wie auch am Schwabenberg) vorgezogen.“*[15]

A further research stay was given to Lassovszky and Detre in Göttingen in 1941.

Period of Isolation from 1945 to 1956/59

> *„Durch Detres Person haben ausgezeichnete Studien und konsequente Forschung viel von der besten deutschen Forschungstradition und Methoden auf dem “Schwabenberg” Wurzeln schlagen können.“*[16]

But the research stays, research travels, common meetings, and intense contacts to Germany and to abroad stopped completely after 1945.

- Scientific cooperation since 1945

Cooperation or team work should be understood as a first step of contacts; this could be the exchange of observing results – like photographic plates for reduction – or for discussion about the interpretation; finally the results can be published together – in this case there is no need that any person travels.

> *„Vielleicht in Verbindung mit jenem Aufenthalt [in Berlin 1940], möglicherweise aber noch vorher und so unabhängig davon, entstand eine interessante Möglichkeit zur Zusammenarbeit: die Göttinger Professoren O. Heckmann und H. Haffner haben (wie ich mich erinnere) 5 Platten, 3 Blau- und 2 Rotaufnahmen, des “rätselhaften” alten Sternhaufens M 67 dem Budapester Institut zur Verfügung gestellt; die Platten waren mittels der Methode der Halbfilter-Photometrie aufgenommen. Man war vielleicht etwas entmutigt durch die relativ geringe Anzahl der Platten, auch war die Unsicherheit der Nachkriegsjahre nicht gerade der Forschungsarbeit bestens förderlich – die Ausmessung ging nur schleppend voran, bis dann die erste präzise, lichtelektrische Photometrie des bemerkenswerten Haufens 1955 von Johnson und Sandage publiziert wurde. Heute, im Rückblick, erscheint wohl, daß hier eine gute Forschungsgelegenheit vertan wurde.“*[17]

The building up of contacts after the war started with different cooperations, which were only based on exchange of material; no travels were necessary. In the 1950s the contacts to the west dominated; it was only a small number but at least twice as much as the contacts to the east; there were no contacts to the GDR. Since the 1960s there existed a stronger contact to the countries of the Eastern European Bloc and also with the GDR; contacts with the west decreased. A maximum of cooperation with the east was reached in the 1970s (*Fig. 8*).

A further chance came up through Detre's participation, since 1943 director of the Konkoly Observatory, in the IAU meeting in Zürich in 1948:

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[15] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 26.8.1997. Cf. VJS 76 (1941), p. 85.

[16] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 14.9.1997.

[17] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 28.8.1997. – Johnson, H. L., Sandage, A. R.: ApJ 121 (1955), p. 616. Cf. VJS 70 (1935), p. 144 (Photographs of M 67, made with Göttingen's astrograph by Móra with agreement of Heckmann and Kienle).

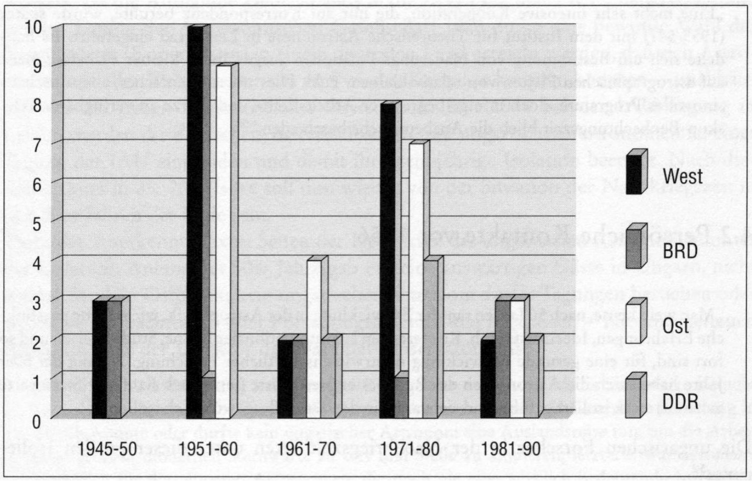

Figure 8: Cooperation from 1945 to 1990

> *„Diese Teilnahme brachte, als erfreuliche Konsequenz, wenn auch nicht eine direkte Kooperation, wenigstens eine Verbindung mit der amerikanischen Astronomie: Auf der Züricher Tagung übergab Prof. Harlow Shapley [Harvard, Cambridge/Mass.] für die astronomische Forschung in Ungarn (und – glaube ich – in Polen und der CSR) je eine Elektronenvervielfacherröhre Typ RCA 931A, die in diesen Ländern noch nicht erhältlich war. Die ersten Versuche am 60cm-Spiegel (die allerdings nur hellere Sterne bis zur 5. oder 6. Größenklasse erreichen konnten), verliefen 1949/50 mit der Unterstützung des Physikdozenten Péter Faragó; die erste kurze, aber erfolgreiche Messreihe bezog sich auf die August 1950-Bedeckung von Zeta Aurigae.“*[18]

In the beginning of the 1950s there existed a first cooperation with an Eastern partner:

> *„Eine nicht sehr intensive Kooperation, die nur auf Korrespondenz beruhte, wurde später (1953/54?) mit dem Institut für Theoretische Astronomie in Leningrad eingeführt. Es handelte sich um Bestimmung von Näherungs-Positionen ausgewählter kleiner Planeten, meist auf astrographischen Platten von relativ kleinem Feld. Dies war ein einfaches, aber durchaus sinnvolles Programm, doch infolge begrenzter Arbeitskräfte und Kürze an verfügbarer Teleskop-Beobachtungszeit blieb die Ausbeute sehr bescheiden.“*[19]

- *Personal Contacts before 1956*

> *„Man weiß heute, nach 50 Jahren rapider Entwicklung in der Astrophysik, wie wichtig persönliche Erfahrungen, Ideenaustausch, Konferenzen auf internationaler Ebene, Studienreisen und so fort sind, für eine gesunde Entwicklung naturwissenschaftlicher Forschung. Anfang der 50er Jahre haben sich die Astronomen der Budapester Sternwarte (jetzt auch Konkoly Sternwarte genannt) stark isoliert gefühlt und sie waren, in der Tat, außergewöhnlich isoliert.“*[20]

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[18] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 31.8.1997. Cf. Mitteilungen der Konkoly Sternwarte Nr. 29. (1952).

[19] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 31.8.1997.

[20] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil II: Isolation und erste Kontakte. Fax vom 2.9.1997.

The Hungarian scientists in the post-war time suffered from the large isolation:[21]

> *„In der ... [Nachkriegs-]Zeit sind wissenschaftliche Kontakte mit dem Ausland, insbesondere mit Deutschland, für fast zehn Jahre, praktisch auf Null gesunken. Man muß allerdings zwei wichtige Umstände beachten.*
> *1. Die Förderung der Bibliothek wurde aufrecht erhalten und die internationale Literatur stand uns immer prompt und ziemlich vollständig zur Verfügung.*
> *2. Ungarn wurde in der IAU [International Astronomical Union] zugelassen und Dr. Detre (der seit 1943 das Direktorat der Sternwarte innehatte) hatte an der Züricher IAU-Generalversammlung (1948) teilnehmen können.“*[22]

The affiliation of Hungary in the International Astronomical Union (IAU) already in 1948 was very different from the development after WW I, when besides Germany among others Hungary was also excluded from international societies during the 1920s.[23] Not only personal contacts of the scientists with foreign colleagues were made difficult, but also the official contacts during meetings. Because the affiliation of Germany was not successful in 1922 and 1925, one succeeded by choosing a meeting place (Copenhagen) in a neutral country for the meeting of the Astronomische Gesellschaft (AG) in 1926, that astronomers from all over the world met again and made contacts – independent of the new international society. Not before 1928 during the IAU meeting in Leiden the 10 year long isolation of the German, Austrian, and Hungarian astronomers was finished because they were accepted as participants. After this additional information about the situation in the 1920s, we look again what happened in the 1950s.

Inspite of acceptance by the IAU the Hungarian astronomers suffered due to the isolation. In the beginning of the 1950s there were no external guests in Hungary, not even from the Eastern Bloc; no Hungarian astronomer was allowed to travel to a meeting or to travel for an observation or research stay abroad – with one rare exception only the director:

> *„Von 1945 bis 1955 [hatte] kein einziger Kollege aus dem Ausland die Sternwarte besucht und – abgesehen von Dr. Detres glücklicher Teilnahme an der IAU Generalversammlung in Zürich, konnte oder durfte kein ungarischer Astronom eine Auslandsreise tun, um die Arbeit einer großen, modernen Sternwarte an Ort und Stelle zu studieren; letzteres war besonders hinderlich für die jüngeren Astronomen, die noch nie eine wirklich bedeutende Institution gesehen hatten. Ich nehme an, ein ähnliches Problem bestand auch für die Astronomen der DDR – aber dort waren doch immerhin mehrere Universitäten und mehrere aktive Observatorien vorhanden (insbesondere [Berlin-]Babelsberg, [APO Potsdam], Sonneberg, auch Jena, später Tautenburg), die ein Maß von innerem Verkehr und Austausch hätten ermöglichen können.*
> *Kontakte mit der Astronomie in der DDR aufzunehmen erschien aussichtslos. Selbst Versuche, Kollegen in den Nachbarländern zu treffen, führte zu keinem Ergebnis. Detre versuchte, zum Beispiel, den rumänischen Astronomen Dr.*

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[21] Contacts existed only in 1950 with the Astronomisches Recheninstitut in Berlin, further in 1952 with the Nautical Almanac in Washington, D.C., USA, and with Belgium, in 1953 with Leiden, Greenwich, and Mt. Wilson, USA (sunspots) as well as with Heidelberg in 1955.

[22] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 28.8.1997.

[23] Schröder-Gudehus, Brigitte: Deutsche Wissenschaft und internationale Zusammenarbeit 1914–1928. Ein Beitrag zum Studium kultureller Beziehungen in politischen Krisenzeiten. Genf 1966.

> *Armeanca (Cluj?) einzuladen – wie wir später erfuhren, hatte ihn die Einladung nie erreicht.*
> *Wir fanden auf jeden Fall die Situation, täglich und jahraus-jahrein, zum selben kleinen Kreis von 4 bis 5 Kollegen zurückzukehren, sehr frustrierend und sogar hinderlich, was die Qualität der Forschung betrifft. Gewiß, wir lasen mit großem Interesse die Forschungsberichte und versuchten uns daran zu orientieren, aber ein Durchbruch in der herkömmlichen Arbeit war nicht zu erwarten.*"[24]

The first meeting, which could be visited by many Hungarian astronomers, took place in Pulkovo Observatory near Leningrad, May 1954:

> „*Eine wesentliche Verbesserung der trostlos anmutenden Situation erfolgte jedoch im Jahr 1954, vielleicht Auswirkung der spürbaren (aber noch keineswegs einschneidenden) Änderungen im politischen System von Ost- und Mitteleuropa ("Tauwetter"). Im Mai 1954 erfolgte die Wiedereröffnung der im Krieg arg zerstörten, inzwischen neu aufgebauten Pulkowaer Sternwarte bei Leningrad. Aus diesem Anlaß hatte die Sowjetische Akademie der Wissenschaften eine viertägige Konferenz organisiert (20.–23.5.1954), mit unzähligen einheimischen Teilnehmern, aber auch mit großzügigen Einladungen aus dem Ausland. Eingeladen waren einige sehr bekannte, als "führend" geltende Astronomen aus dem Westen: die Professoren Oort [Holland], Danjon [Frankreich], Cowling [England], B. Lindblad [Schweden], Minnaert [Holland] unter anderen, Dr. Oosterhoff (Sekretär der IAU), Dirk Brower und D. Nassau aus den Vereinigten Staaten, weiterhin kleinere, 2- bis 9-köpfige Delegationen aus den sog. Volksdemokratien und 8 Astronomen aus China. Westdeutschland war leider nicht vertreten, die DDR mit drei Astronomen (J. Dick, C. Hoffmeister, O. Singer). Die Konferenz 1954 in Pulkowa war doch sehr wichtig sowohl für Ungarn als auch für die DDR.*
> *Nach der Eröffnung gab es eine Möglichkeit, Leningrad und Moskau zu besichtigen und interessierte Teilnehmer hatten auch eine Einladung bekommen, die totale Sonnenfinsternis am 30. Juni 1954 vom Nordkaukasus aus, unweit von Pyatigorsk, mit ihren eigenen, mitgebrachten Instrumenten zu beobachten. So ergab sich für viele Gäste die Gelegenheit, fast zwei Monate in der Sowjetunion zu verbringen. Obwohl die erstaunlich zahlreiche ungarische Delegation (6 Astronomen, ein Mathematiker, ein Höhenstrahlungsphysiker und ein Beamter der Akademie) eigentlich kein eigenes Instrument vorweisen konnte, sind sie ebenfalls mitgefahren, dabei waren sie häufig zusammen mit der DDR, auch mit der tschechischen Delegation. Wichtige persönliche Kontakte wurden dabei angeknüpft, die zwei Jahre später eine nicht geringe Rolle spielten.*
> *Dies war der Anfang der sich langsam normalisierenden internationalen Beziehungen.*"[25]

After the Leningrad meeting they had the possibility to travel to the total solar eclipse, June 30, 1954, in North Kaukasus.

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[24] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil II: Isolation und erste Kontakte. Fax vom 2.9.1997.

[25] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil II: Isolation und erste Kontakte. Fax vom 4.9.1997.

Two members of Konkoly Observatory, who were not present in Pulkovo, Júlia Balázs und I. Izsák, were allowed to visit in 1954 a Variable Star Conference in Moscow which lasted one week.

A real highlight was the travel of the director Detre to the meeting of the IAU in Dublin in 1955 and then a first travel to West Germany:

> *„... 1955 ... wurde ein überaus wichtiger Kontakt mit der Forschung in Deutschland endlich wiederhergestellt: Detre und Julia Balázs haben an der Tagung der AG [Astronomischen Gesellschaft] in Hannover teilnehmen können.“*[26]

Since 1956 the important tradition of the Variable Star Colloquia of the IAU has been started. During the first colloquium there were not yet western participants, but four from eastern Germany (Ahnert, Güssow, Hoffmeister, and Schneller); the total number was 29 participants.[27] These IAU Colloquia took place later in Budapest (1968, 1975) and in Bamberg (1959, 1965, 1977, and 1983).[28]

- *The events of the year 1956 – the Hungarian Revolution*

Starting with a student demonstration in October 23, 1956, a revolution all over Hungary against the regime developed quickly. With the second Soviet intervention in November 4, 1956 a mass escape began over the border to Austria. As a whole, more than 189,000 people left the country; half of them went overseas (mainly USA and Canada), the other half stayed in Europe, 20,000 in UK and 14,000 in Germany.

> *„Eine wichtige und zunächst ganz unerwartete Nebenwirkung der Konferenz [in Budapest 1956] war, daß die angeknüpften persönlichen Beziehungen sich in den Plänen der bald flüchtig gewordenen Sternwartenmitglieder deutlich bemerkbar machten. Dieser Exodus hat die Sternwarte und die ungarische Astronomie tief beeinflußt, später praktisch gespalten. Ihre Geschichte ist hier kurz skizziert wie folgt:*
> *Zunächst schien in der Sternwarte eine neue Epoche begonnen zu haben: man plante verschiedene Kooperationen, besonders mit den DDR-Sternwarten aber auch mit Italien (Asiago). Diese Pläne wurden aber durch die rasch anrollenden Ereignisse des Oktoberaufstandes in den Schatten gestellt. Die Sternwarte hatte einen recht bescheidenen, aber aktiven Anteil an den Ereignissen und nach der fatalen Rückkehr der sowjetischen Truppen am 4. November 1956 tauchte sehr bald die Idee einer Flucht aus dem Lande auf. Furcht vor Retorsionen aber auch die damals anscheinend hoffnungslose Lage für zukünftige Forschung machten dies hauptsächlich zu einem Problem der jüngeren Leute.“*[29]

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[26] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil II: Isolation und erste Kontakte. Fax vom 4.9.1997. The subsequent meeting of the Astronomische Gesellschaft took place in Bamberg in 1957.

[27] Participants of the 1956 conference: (IAU): 9 Hungary, 4 GDR, 5 GFR, 1 UK, 2 Netherlands, 1 Italy, 1 Belgium, 3 Poland, 1 Czechoslovakia, 2 China, and 5 USSR. The lectures were published in the Mitteilungen series of the Konkoly Observatory: Nr. 42, Budapest 1957.

[28] The meeting in Bamberg in 1977 was my personal first meeting and I got to know among others Prof. Herczeg and the participants from Hungary.

[29] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil III: Fluchtgeschichte. Fax vom 19.8.1997.

Figure 9: Left: Imre Izsák (1929–1965) – Right: Tibor Herczeg (* 1929)

Imre Izsák (1929–1965), a specialist for celestial mechanics (*Fig. 9*), was the first who left the country:[30]

> *„Der erste, der die chaotischen Zustände zu nützen wußte, war Imre Izsák. Sein Abgang war, sicherlich mit Dr. Detre's Hilfe, sehr "privat" organisiert. Er ging vermutlich sehr früh, vielleicht schon Anfang November (?): Wien, umgehend direkt nach Zürich, wo ihn Prof. M. Waldmeier offenbar sehr gerne empfangen hatte und ihm eine Forschungsstelle, hauptsächlich im Sonnenobservatorium Locarno-Monti geschaffen hat. Izsák beschäftigte sich mit den Bewegungen in Protuberanzen und publizierte darüber erfolgreich (in der "Zeitschrift für Astrophysik"). Sein eigentliches Interesse lag aber schon immer auf dem Gebiet der Himmelsmechanik, so hat er seine Stelle bei Prof. Waldmeier nach etwa zwei Jahren aufgegeben und ist in die Vereinigten Staaten übergesiedelt, zuerst nach Cincinnati, später nach der Harvard Sternwarte (oder Smithsonian Institution?). Er hat sehr bemerkenswerte Arbeit über die Bewegungen von Erdsatelliten geleistet."*[31]

Later four more members of the observatory fled, so that only half of the staff was left by the end of 1956.

> *„Der Weggang, besser gesagt die Flucht von weiteren drei oder vier jüngeren Mitgliedern der Sternwarte spielte sich unter wesentlich weniger Geheimhaltung ab, drei oder vier Wochen später. Auf jeden Fall wußte [der Direktor] Dr. Detre Bescheid und riet uns, zuerst nach Wien, in die Sternwarte zu gehen. Aus dieser Position wäre es möglich, wie es in der Tat möglich wurde, die neugewonnenen persönlichen Beziehungen zu deutschen Astronomen bestens zu nutzen. Zu dieser Gruppe gehörten die wissenschaftlichen Mitarbeiter T. Herczeg und I. Ozsváth, der "Aspirant" Karl Balogh und der Mechaniker István Vidéki. Die "Drehscheibe" des Unterfangens bildeten Balogh's Eltern, die nur 3 bis 4 km von der österreichischen Grenze, in dem früheren Grenzsperrgebiet wohnten. Durch diese Möglichkeit wurde die Flucht Anfang Dezember erfolgreich durchgeführt, so daß Herczeg, Ozsváth und Vidéki über die österreichische Grenze schlüpfen konnten und in 1 bis 2 Tagen Wien und*

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[30] Fred Whipple has written an obituary. Cf. also Marik, Miklós: Csillagászattörténeti életrajzi lexikon A-Z. Budapest 1982. A gondolat tükre. Izsák Imre élete (1929–1965). Zalaegerszeg 1997.

[31] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil III: Fluchtgeschichte. Fax vom 19.8.1997.

> *die Wiener Universitäts-Sternwarte erreicht haben. Die drei Ungarn aus der Sternwarte in Budapest wurden in der Wiener Sternwarte sehr freundlich, ja herzlich aufgenommen. (Balogh kehrte nach Budapest zurück, um seine Familie und Frau Ozsváth nachzuholen, fand aber dort eine wesentlich veränderte, schwierigere Situation vor und machte den "Sprung" nach Wien erst viel später – aber noch 1957 – möglich.)"*[32]

Neither Herczeg, nor Ozsváth wanted to stay in Vienna, but tried to reach West Germany:[33]

> *„Herczeg und Ozsváth erhielten ziemlich gute Stipendien von der Rockefeller Stiftung und fingen an, mit westdeutschen Kollegen in Verbindung zu treten, da sie nicht unbedingt in Wien zu bleiben gedachten. Ozsváth kontaktierte zunächst Dr. Julius Dick (Potsdam? Babelsberg?), mit dem er auf der Konferenz in Budapest eine gute Beziehung angeknüpft hatte. Dr. Dick nahm Verbindung mit einer Anzahl westdeutscher Sternwartdirektoren auf, unter Verwendung von Dr. Kahrstedts [Direktor des Astronomischen Recheninstituts] Postadresse in West-Berlin. (Dies geschah Jahre bevor der Berliner Wall gebaut wurde.) Aus dieser Hilfsaktion resultierten zwei wertvolle Forschungsgelegenheiten für die Flüchtlinge, an zwei wichtigen astronomischen Instituten der Bundesrepublik.*
> *Zuerst wurde Ozsváth eine Arbeitsmöglichkeit an der Hamburger Sternwarte in Bergedorf angeboten durch den Direktor Prof. O. Heckmann – schon im Februar 1957. Aus der ursprünglich bescheidenen Rechenarbeit am AG-Katalog wurde bald photographische Photometrie am großen Schmidt-Spiegel. Ozsváth promovierte 1959 an der Universität Hamburg mit einer photometrischen Studie des alten offenen Sternhaufens NGC 7789. Danach arbeitete er mit dem Theoretiker Dr. E. Schücking zusammen. Ihr wesentlicher Beitrag zur Kosmologie ("Finite rotating universe") wurde noch in Hamburg publiziert.*
> *Herczeg wurde im April 1957 unter etwas ähnlichen Umständen ein Arbeitsplatz an der Bonner Universitäts-Sternwarte zuteil, durch dessen damaligen Direktor Prof. Friedrich Becker. Herczeg sollte auf der Außenstation in der Eifel, auf dem Observatorium Hoher List, seine in Budapest begonnene lichtelektrische Arbeit fortsetzen. Er promovierte 1959 an der Universität Bonn mit einer 3-Farben-Photometrie des Algol-(β Per) Systems. Er arbeitete an mehreren Bedeckungssystemen mit Dr. Hans Schmidt zusammen. Später (1962) siedelte er an die Hamburger Sternwarte über, als Observator, dann als Hauptobservator, und er habilitierte sich 1966 mit einem Thema in Planeten-Kosmogonie. Als Beobachter war er spektroskopisch tätig, mit Hilfe des 1 m-Spiegels."*[34]

But there existed no possibility for both, to find a permanent position in Germany; finally they found a job in the USA:

> *„Bald danach (1962) gingen die beiden Forscher in die Vereinigten Staaten, Ozsváth zunächst nach Austin/Texas, dann nach Dallas, wo er bis heute als*

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[32] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil III: Fluchtgeschichte. Fax vom 19.8.1997.

[33] There existed generous support by the Lions Club and by the Rockefeller Foundation, about 1000.-DM per month, later 250.-DM by the Ford Foundation.

[34] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil III: Fluchtgeschichte. Fax vom 19.8.1997.

> *Professor der Mathematik an der University of Dallas (UTD) arbeitet. Vidéki verließ auch bald Wien und wanderte nach Kanada aus. Wo Balogh verblieb ist unbekannt.*
> *Herczeg akzeptierte 1970, endgültig 1971, eine Stelle als Professor of Physics and Astronomy an der University of Oklahoma in Norman/Oklahoma/USA. Es bestand für längere Zeit eine lebhafte, auch persönliche Verbindung zwischen dem kleinen Observatorium in Norman und der Bamberger Remeis-Sternwarte [Astronomisches Institut der Universität Erlangen-Nürnberg], gegründet auf verwandte Forschungsprojekte auf dem Gebiet der Veränderlichen Sterne, auch auf das Vorhandensein ausgedehnter Plattenarchive an beiden Instituten. Mehrere Mitglieder der Bamberger Sternwarte besuchten Norman, während Herczeg, aus Norman beurlaubt, vier Semester (1985–1987) in Bamberg bzw. an der Universität Erlangen verbracht hatte, als Vertreter für Prof. Jürgen Rahe (während seiner Beurlaubung zu NASA in Washington, D.C.).“*[35]

How is the escape mentioned in Detre's annual report of the Konkoly Observatory?

> *„In den letzten Jahren wurde allmählich eine Gruppe junger Astronomen zusammengestellt, die große Hoffnungen erweckt hat, was die Zukunft der ungarischen Astronomie betrifft. Die Vorkommnisse des Oktober/November 1956 veranlaßten die meisten jungen Mitarbeiter, das Land zu verlassen. Sie haben Arbeit in verschiedenen internationalen Institutionen übernommen. Die stellarstatistische Gruppe hat folgende Leute verloren: die wissenschaftlichen Mitarbeiter Izsák Imre, Herczeg Tibor und Ozsváth István, den "Aspiranten" Balogh Károly, die Aushilfskraft Miklós János und auch den Mechaniker Vidéki István.“*[36]

> *„Die zu Hause gebliebenen älteren Mitarbeiter haben den größten Teil ihrer Zeit dazu aufgewendet, die neuernannten Mitarbeiter einzuweisen. Weil uns die meisten jungen Forscher verlassen haben, war es nicht möglich, den internationalen Vereinbarungen nachzukommen, z. B. mit Izsák Imre waren die himmelsmechanischen Untersuchungen beendet, das Thema Doppelsterne von Herczeg wurde eingestellt. Zum Ausgleich konzentriert sich die Arbeit im Rahmen der IAU auf RR Lyrae.“*[37]

- *The Development after 1956*

In *Fig. 10* the three years from 1957 to 1959 are analyzed. The contacts to the Eastern bloc countries and to the GDR increased considerably, the contacts to the West and to the German Federal Republic were only possible in a restricted way.

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[35] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil III: Fluchtgeschichte. Fax vom 19.8.1997. Also me – as a student of the Remeis Observatory in Bamberg – visited Professor Herczeg in Oklahoma in December 1978 and made reduction of variable stars on photographic plates.

[36] Detre, L.: Jahresbericht für Jan. 1956 bis Sept. 1957. In: Évi jelentések 1940–1960, p. 92.

[37] Detre, L.: Jahresbericht für 1957. In: Évi jelentések 1940–1960, p. 98.

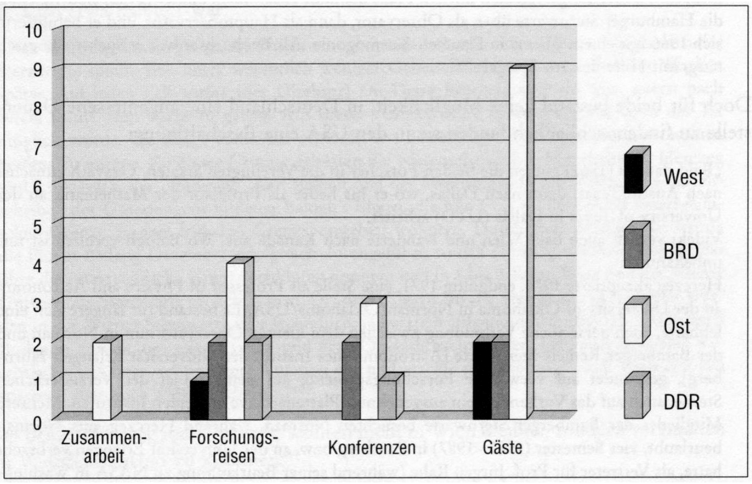

Figure 10: Cooperation, research travels, conferences, and guests after 1956

Scientific Cooperation from 1960 to 1990

- The Development in the 1960s

A large variety of sources was available for analyzing the development from the 1950s to the 1980s.[38]

After a certain transition time of a few years a positive development came up with the motto "Who is not against us, is for us". The rules were interpreted in a more liberal way; practically everybody was at least one time abroad, in the Western countries.[39] Especially in the field of science, where a strong interdependence from the modern development is obvious, there were only a few problems with travels from the 1960s on (*Figs. 11-12*). For travels to West Germany it was easier to get a permission, but for travels to the USA it was easier to get a grant (a financial support).

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[38] 1. Archive material in the Konkoly Observatory – offered by the librarian Magda Vargha:
– Annual reports of the Konkoly Observatory by Detre, from 1940 to 1973 (two volumes – typewritten with handwritten supplements)
– Annual reports of Debrecen by Dezső, from 1962 to 1982
– Guest book of the Konkoly Observatory
2. Handwritten supplements of Prof. Tibor Herczeg, transmitted by fax in Aug./Sept. 1997
3. Printed annual reports in Csillagászati évkönyv from 1959 to 1987, especially since 1974, written by Dr. Béla Szeidl, successor of L. Detre. – Printed annual reports in the Almanach MTA (1967–1980, 1985, 1991), in the Academy (1975–1980), in Meteor 1991–1997. – Printed annual reports of the University Budapest (ELTE) in Csillagászati évkönyv 1970–1992, written by Miklós Marik, later by Béla Balázs
4. Interview (Aug. 1997) with director Béla Szeidl, Konkoly Observatory, and Prof. Béla Balázs, Eötvös University, Budapest
5. Papers and documents of the Humboldt-Stiftung concerning I. Jankovics, director of the Gothard-Observatory in Szombathely, department of Budapest University
6. Annual reports of observatories in Western Germany, published in the Mitteilungen der Astronomischen Gesellschaft and discussions with German and Austrian astronomers.
7. Compilation of a data base with over 900 entries. The translation of the Hungarian material was done with the help of Andreas Korpas and typed in the data base by Celia von Lindern.

[39] Reported by Béla Balázs, in Aug. 1997. He spent one year (1961/62) in Hamburg and in 1964 again four months.

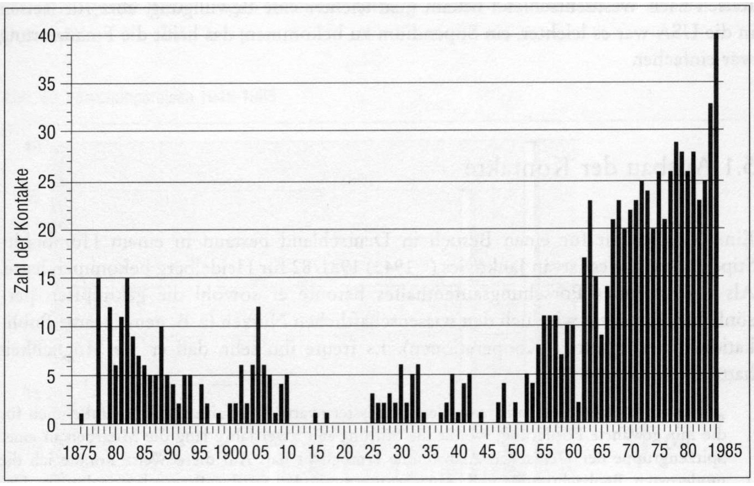

Figure 11: German-Hungarian relationships from 1874 to 1985

- *Extension of the Contacts in the 1970/80s*

One possibility for a visit in Germany was to get a Humboldt-Stipendium; this was given to István Jankovics (* 1943) in 1981/82 for Heidelberg. As a success of his research travel he emphasized the new personal contacts as well as the scientific profit (e. g. common publications and cooperations in the future). He reported: I was very glad, that I had the possibility,

> *„die schöpferische Atmosphäre an der Landessternwarte zu erfahren. Ich bedanke mich für die mir gewährte Förderung, womit die Stiftung mir zwei Jahre lang die Mitarbeit in einer Spitzengruppe der Deutschen Astronomie ermöglicht hat. Auf diese Weise konnte ich die modernsten Beobachtungs- und Auswertungsmethoden in der Praxis kennenlernen. Das führte dazu, daß mich mit den Kollegen nun nicht nur berufliche, sondern auch sehr gute persönliche Kontakte verbinden. ...Auch nach meiner Heimkehr bestehen gemeinsame Forschungsinteressen. Wir planen die langfristige spektroskopische und photoelektrische Überwachung junger Veränderlicher Sterne der Orion-Population. ...Für dieses Projekt ist eine Bildwandlerkamera geplant. Mit Heidelberger Kollegen werden gegenwärtig detaillierte Konstruktionspläne ausgearbeitet.“*[40]

The Budapest University (Béla Balázs) started official relationships to Jena University (Pfau, Zimmermann); already in the middle of the 1960s it became partner university.

In the 1970s and 1980s mainly the Soviet Union and the GDR were predominant for the studies and research travels. Thus Jankovics got a further grant in 1986/87 for Potsdam, GDR. Since 1992 he has been director in Szombathely, where he further on kept good relationships to Heidelberg – a tradition which has started already in the time of the Gothard brothers.

In the 1960s until the 1980s a permanent increase of the Eastern travels (maximum around 1980) is obvious; examples are visits, common projects for cooperation, travels for studying or astronomical observations. Already in the 1950s there existed more contacts in this field with the East and the GDR than with the West. Since the 1970s the travels to the German Federal Republic preponderated in comparison with travels to the GDR.

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[40] Jankovics, István: Bericht an die Humboldt-Stiftung vom 26.11.1983.

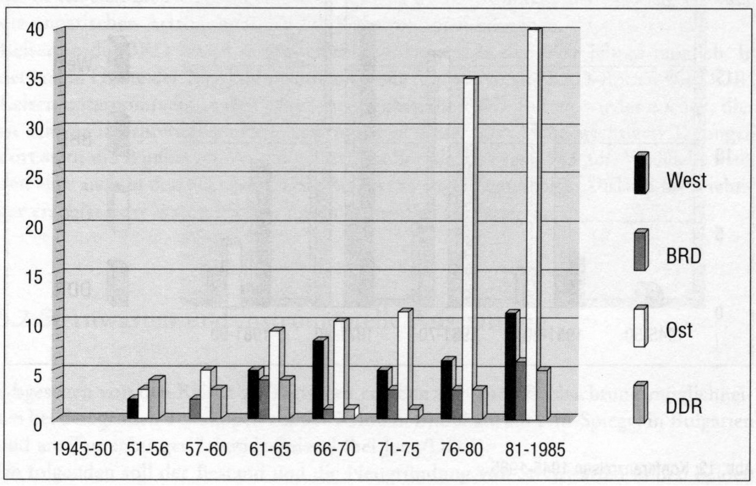

Figure 12: Research travels from 1945 to 1990

Regarding the travels one can recognise that the Hungarians preferred contacts with the GFR to the GDR.

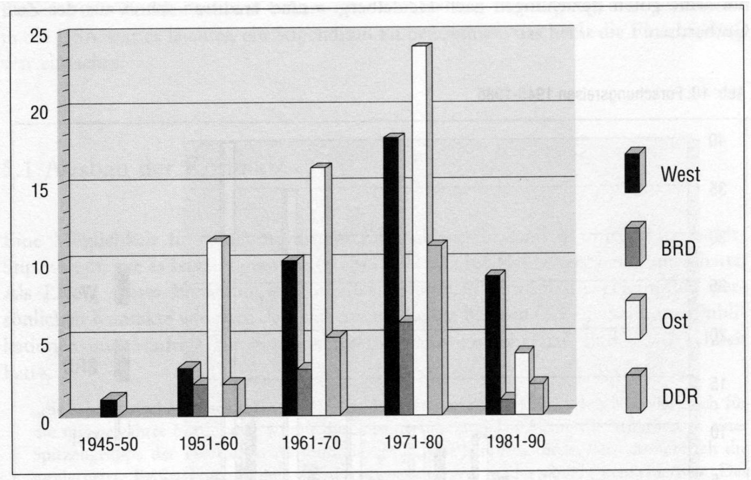

Figure 13: Guests in Hungary, 1945–1990

The guests from the Eastern Bloc increase from the 1950s until the 1970s; in the 1970s there is a maximum of guests from the GDR (three times more from the GFR) (*Fig. 13*). The interest of the Western side concerning visits in Hungary was relatively small in comparison to the East.

Detre as director of the Konkoly Observatory kept the contacts to the Western and Eastern astronomers, but also the international relationships. In September 1968 a meeting of the Commission 27 of the International Astronomical Union (IAU) took place in Budapest; there were 66 lectures and 93 participants: 7 GFR, 3 Austrian, 40 further participants from the West, 9 Hungarians, 9 GDR, and 26 from the East.[41] Detre was vice-president in 1964–67, in 1967–70 President of the Commission 27 of the IAU and founder and the first editor of the IBVS (Information Bulletin on Variable Stars).

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[41] The lectures were published: Detre, L. (ed.): Non-periodic Phenomena in Variable Stars. Budapest 1969.

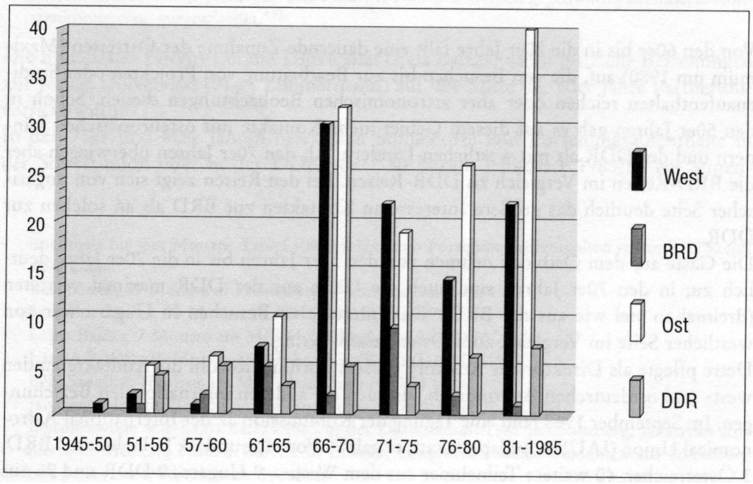

Figure 14: Conference travels, 1945–1990

In the 1950s the travels to the East predominated. In the middle of the 1960s there was a large increase of conference and lecture travels to the east, but also to the West. In the 1970s regular annual colloquia were introduced, where astronomers from the Eastern Bloc could meat each other, especially the Hungarian astronomers could meet the GDR astronomers (*Fig. 14*).

Travels to the German Federal Republic were possible in a larger amount not before the 1960s. In the first half of the 1970s twice more GFR-travels were undertaken as compared with the GDR-travels. In the 1980s the GFR-travels decrease; this is difficult to understand and to interpret, perhaps there are fewer important meetings in this time in the West; at least the Bamberg Colloquia on Variable Stars stopped in 1983.

Hungarian Members in the Astronomische Gesellschaft

Although the Astronomische Gesellschaft, founded in 1863, had its place of business and legal seat in Germany, but it represented with an amount of foreigners of 60% of the members the international astronomical society until the 1930s. The amount of Hungarians was from 1913 to 1935 around 2-3%, for example in 1913 there were 13 Hungarians in comparison to 421 members in the Astronomische Gesellschaft, in 1930 there were 16 Hungarians out of 509 members.

In the time after WW II the Astronomische Gesellschaft had lost its reputation as an international society, it included then mainly the German linguistic area; for example there were three Hungarians in 1962 (Detre (until 1974), Herczeg, and Ozsváth) out of 322 members (cf. six from Czechoslovakia, one Rumanian, and one Yugoslav) or in 1978 five Hungarians (Balázs B., Herczeg, Ozsváth, Pauliny-Tóth, Szeidl) out of 433 members, finally in 1996 six Hungarians (Balázs Béla, Herczeg, Jankovics, Kelemen János, Pauliny-Tóth, Szeidl) out of 793 members.

Language in the Publications

In Konkoly's time the German language was without concurrence the language of science. The publication series Mitteilungen der Konkoly-Sternwarte was published from the 1920s until around 1950 overwhelmingly in German.

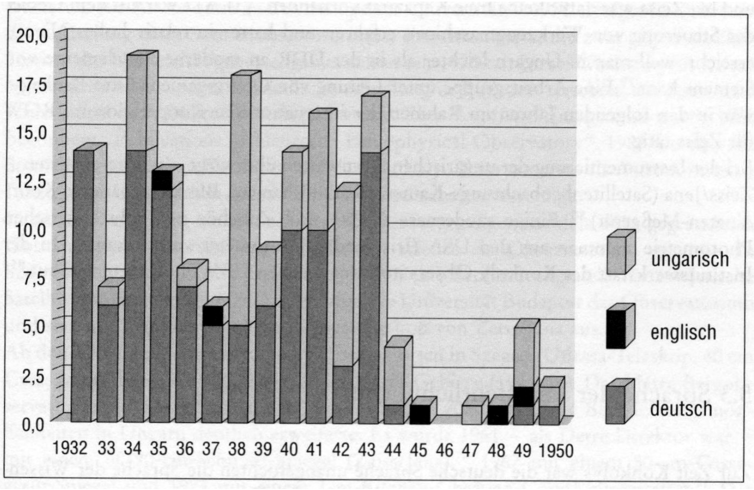

Figure 15: Language of the publications from 1932 to 1950

Regarding the histogram in *Fig. 15*, one can recognize, that until 1950 mainly German was used, practically no English; Hungarian was used especially in the case of popular astronomical journals.[42]

In the 1950s a discussion started, whether German is the suitable language for the publications further on.

> *„Die Publikation [über die Bedeckung von Zeta Aurigae] war die erste englischsprachige aus Budapest und auch der Titel der Reihe wurde zu "Contributions" geändert, allerdings als zweiten Titel "Mitteilungen" beibehaltend."*[43]

Since the middle of the 1960s one recognizes a strong increase of the English and thus a decrease of the German publications; a certain part of publications in Russian can also be found besides some Hungarian publications (*Fig. 16*).

Looking at the publications of Budapest University from 1978 to 1986, one recognizes English as the prominent language, but here no Russian is present (*Fig. 17*).

In analyzing the language used in meetings or for guest lectures (taken from the title of the lecture in the programme or in the annual report), one recognizes, that German played still an important role, but English increased in its significance. Only in the 1970s Russian was used several times; but it is not clear, whether the lecture was presented in Russian or it was translated (*Fig. 18*).

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[42] In 1924 the astronomical society "Stella" was founded by Antal Tass and József Wodetzky, "Almanach" appeared in 1924, the journal "Stella" in 1926 (it existed only until 1931 due to the unfavourable economic development). In 1933 the astronomical society "Stella" was changed into a section of the "Kgl. Ungarische Naturwissenschaftliche Gesellschaft" (Royal Hungarian Scientific Society). The Stella Almanach was merged with the yearbook of the "Naturwissenschaftliche Gesellschaft". Cf. VJS 70 (1935), p. 145–146.

[43] Herczeg, Tibor: Deutsch-ungarische Beziehungen, Teil I: Vorgeschichte. Fax vom 31.8.1997. Cf. Mitteilungen der Konkoly Sternwarte Nr. 29 (1952).

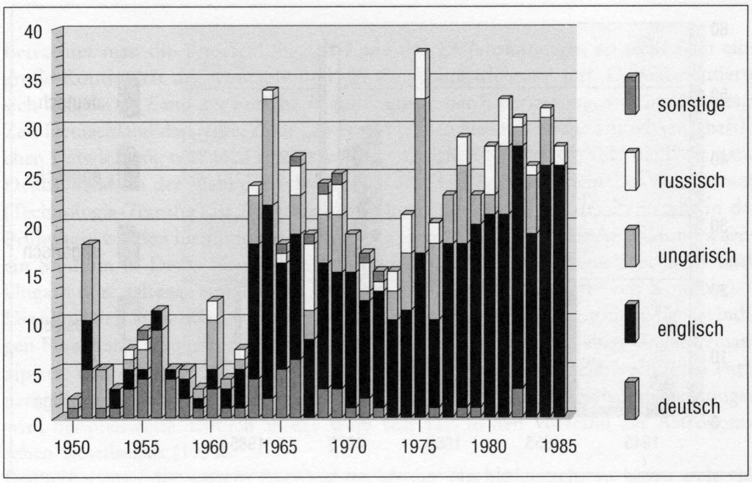

Figure 16: Language of the publications from 1950 to 1985

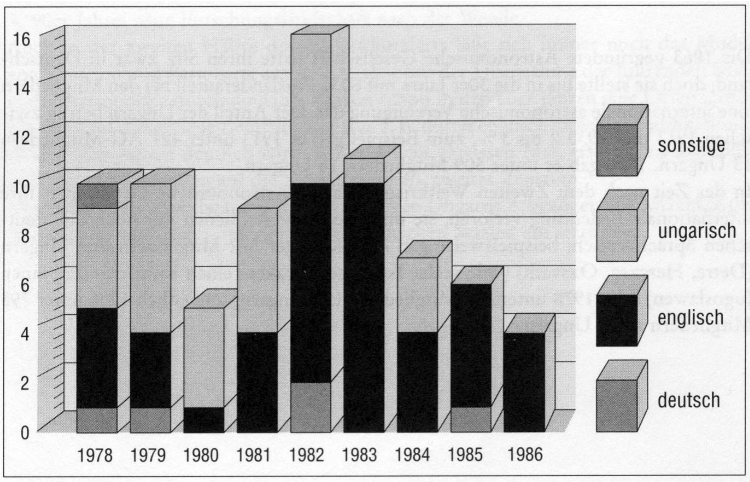

Figure 17: Language of the publications from 1978 to 1986, University Budapest

Observatories and Instrumental Equipment

- *Provenience of the Instruments from 1870 to 1945*

A compilation of the instruments used by Konkoly in his observatory O'Gyalla is given in *Fig. 19.* Around 66% came from German makers and 17% from abroad, half of them from England.[44] If you look in detail at the provenience of the instruments, one can recognize that in the beginnings of the 1870s – due to Konkoly's travels abroad – the English instruments have overweight in comparison to the German instruments. In the last two decades of the 19th century the amount of German instruments increases similarly

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[44] Today many of them are in the Technical Museum of Budapest. Cf. Wolfschmidt, Gudrun: Astronomical Instruments of the Era Konkoly in Respect to their Significance to Astrophysics. In: Vargha, Magda; Patkós, László; Tóth, Imre (eds.): The Role of Miklós Konkoly Thege in the History of Astronomy in Hungary. Proceedings of the International Meeting "120th Anniversary of Konkoly Observatory" in Budapest, 5.–6. Sept. 1991. Konkoly Observatory of the Hungarian Academy of Sciences, Monographs No. 1, Budapest 1992, p. 69–82. – Bartha, Lajos: Astrophysical Instruments in Hungary, 1871–1911. In: Journal for History of Astronomy 25 (1994), No. 2, p. 77–91.

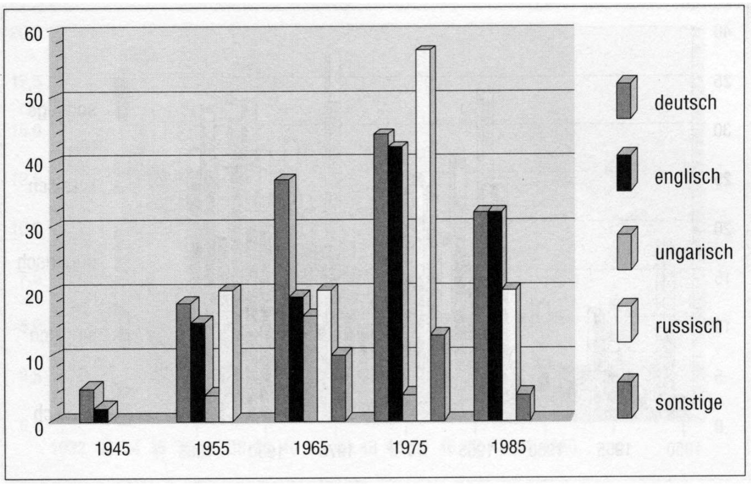

Figure 18: Comparison of the used languages during meetings from 1945 to 1985

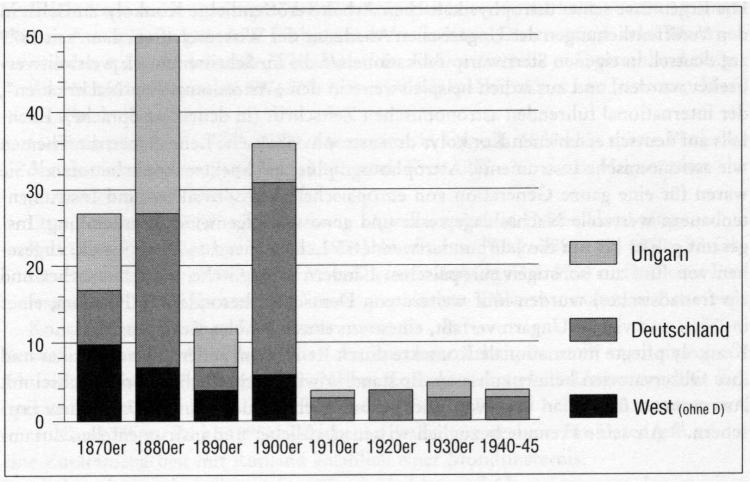

Figure 19: Origin of the instruments, 1870–1945

to the percentage of instruments, made in Hungary or especially in the workshops of the observatory. In 1900 the origin of the instruments is mainly Germany; from 1910 on there are no instruments from abroad any more.

- *Observatories since 1945 in Eastern-Western Comparison*

In the following the existing and newly founded observatories in the German states and in Hungary should be compared. In Germany there were 16 observatories around 1900 and this number did not change until 1945.

After WW II there existed eight observatories in West Germany (Bamberg, Bonn, Freiburg, Göttingen, Hamburg-Bergedorf, Heidelberg Landessternwarte, Kiel, München) and four in East Germany (APO Potsdam, Potsdam-Babelsberg, Jena, Sonneberg). In the GFR 14 institutes/institutions for astronomical research were founded,[45] but only one

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[45] Astronomisches Rechen-Institut (ARI) Heidelberg, Institut für Theoretische Astrophysik Heidelberg, Astronomisches Institut der Universität Tübingen, Lehr- und Forschungsbereich Theoretische Astrophysik der Universität Tübingen, Institut für Astronomie und Astrophysik der TU Berlin, MPI für Astrophysik München-Garching, MPI für Extraterrestrische Physik München-Garching, MPI für Astronomie

new institute in the GDR.[46]

In 1945 Hungary had the Konkoly Observatory as a national observatory and a chair for astronomy at Budapest University.[47]

In 1958 the institute in Debrecen was founded as a solar observatory (Dezső director). In 1982 this Heliophysical Observatory and the Konkoly Observatory were unified as the Astronomical Institute of the Hungarian Academy of Sciences.

- *Instrumental Equipment since 1960*

In the 1960s Szombathely, followed from Gothard's Observatory in Herény (founded in 1881), was used again as an observatory. In Szombathely an observing station was erected for tracking soviet satellites already in the 1960s. In 1977/78 the university of Budapest took over the observatory and bought a 60-cm-reflector from Carl Zeiss Jena.

Since the 1960s smaller observatories have been built in Szeged (Odessa-Telescope, 40 cm Cassegrain) and in Baja (1966).

The Piszkéstető Mountain Station (in the Mátra mountains) of the Konkoly Observatory is especially important, because it enlarged the possibilities of observation for Hungary considerably.

- As a first instrument in 1961 – when Detre was the acting director – a 60 cm Schmidt-telescope, correction plate 90 cm, was acquired from Zeiss of Jena.[48]
- In 1966 a 50 cm Cassegrain-reflector was delivered.
- In 1974 the observatory was provided with a 1 m Ritchey-Chrétien-Coudé.[49]

The 1 m telescope (1974) was made – according to an information from Hans G. Beck – in cooperation with the Hungarian firm VILATI, Institute for Electroautomatics, in Budapest.[50] In the following time VILATI built computer guiding devices for further nine 1 m telescopes, for the two 2 m telescopes for Bulgaria (Rozhen) and Ukraine (Kiev, Terskol), and for the horizontal solar research equipment. Also for the 2 m telescope in Ondřejov near Prague a VILATI guiding system was added during a modernisation.[51]

Heidelberg, MPI für Radioastronomie Bonn, Observatorium Hoher List (Bonn), Astronomisches Institut der Universität Münster, Astronomisches Institut der Universität Würzburg, 1. Physikalisches Institut der Universität Köln, Astronomisches Institut der Universität Bochum

[46] Tautenburg Observatory.

[47] Department of Astronomy at Péter Pázmány University in Budapest; since 1950 Eötvös Loránd Tudományegyetem (ELTE), headed by: Radó von Kövesligethy (1897–1933), Károly Móra (1933–1934), József Wodetzky (1934–1941), Károly Lassovszky (1942–1949, he had to change to "Amerikanistik" due to political reasons), István Földes (1949-1964), László Detre (1964–1968, at the same time director of the Konkoly Observatory), Béla Balázs (1968–1990), Marik Miklós (1990–1998), and Bálint Érdi (1998–). Cf. VJS 70 (1935), p. 138 and Csillagászati évkönyv (1970), p. 94–100.

[48] According to an information from Hans G. Beck (May 12, 1998), former head of the department astronomy of Zeiss in Jena, four such Schmidt-telescopes (technical dates: 600 mm, correction plate 900 mm, focal length 1800 mm) were made in the end of the 1950s and delivered apart from Budapest also to Jena, Torún [Thorn], and Beijing.

[49] According to an information from Hans G. Beck in Jena (May 12, 1998) the 1 m telescope with an English mounting EM 1 saw first light in 1974 thanks to Béla Balázs who was very active in getting this telescope for the observatory.

[50] Zeiss had made in advance two nearly identical telescopes and delivered to India (Nainital and Kavalur). For the telescope for Hungary already a digital guiding was introduced, while the telescopes for India had still analogue guiding.

[51] It was necessary to improve the electrical guiding system of the telescope and Zeiss had no free

Looking at the equipment of the Hungarian observatories, Zeiss of Jena – like you would expect – is dominating: Satellite observing cameras, Schmidt cameras, blink comparator, coordinate measuring machine.[52] Some more modern instruments and auxiliary equipment for photoelectric photometry were ordered in the USA (iris diaphragm photometer made by Askania). In the workshop of the Konkoly Observatory UBV photoelectric photometers were built.[53]

Observing possibilities for Hungarian astronomers existed also with the large telescopes on Crimea, in Byurakan, with the 2 m reflector in Bulgaria, and with the Schmidt reflector of Tautenburg Observatory near Jena, GDR.

Conclusion

At the end of the 19th century Hungary as a country at the periphery used as an orientation always a country in the center of scientific development – this was at that time Germany. The predominance of Germany in choosing the emphasis of fields of research is very easy to recognize and also in choosing the instrumental equipment (transfer of technology).

But the contacts had not only one direction; Hungary emancipated itself in scientific respect since the 1920s and developed in the direction to a scientifically equivalent partner by delivering important contributions. The appreciation of the Hungarian achievements is obvious in electing Tass in the managing committee of the Astronomische Gesellschaft in 1930.

Looking at the further development after WW II, where László Detre had an important influence, one can distinguish four periods:

from 1945 to 1956/59 – period of isolation

in the 1960s – starting of contacts

from the 1970s to the 1980s – extension of contacts

in the 1990s – new research landscape.

Also in the second half of the 20th century one can apply the model of center and periphery. With the taking over of the leading role in astronomy of the USA or in general the Western English speaking countries Hungary started already in the 1960s to use this development as an orientation. This is obvious already in the 1950s e. g. by starting to use the English language in the publications. But up to a certain point there was inevitably also an orientation towards the Soviet Union as a second center of scientific development. Apart from this orientation the relationships of Hungary were always – in respect to amount, continuity and intensity – the strongest with both German states.

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capacity at that time. VILATI had a lot of experience in the field of guiding of machine tools and had reached a relatively high standard. The reason was that it was easier in Hungary than in the GDR to get modern chips from Siemens. A team under leadership of the engineer Ottó Bánhegyi was active in the following years in the framework of international cooperation in the RGW for Zeiss.

[52] For the importance and development of the Zeiss works see e. g. Stolz, R., Wittig, J. (eds.): Carl Zeiss und Ernst Abbe – Leben, Wirken und Bedeutung. Jena: Universitätsverlag 1993. Dorschner, Johann: Astronomie in Thüringen. Skizzen aus acht Jahrhunderten. Mit besonderer Berücksichtigung der DDR-Zeit und der neuen astronomischen Forschungslandschaft im Freistaat Thüringen. Jenzig-Verlag 1998.

[53] A UBV photometer was built: in 1972 for the 50 cm reflector and in 1974 for the 1 m reflector in the Piszkéstető Mountain Station; in 1986 a new UBVRI photometer with photon counting device.

Figure 20: László Detre and Júlia Balázs

Astronomische Geräte von Carl Zeiss Jena in Ungarn

Hans G. Beck

Jena

Sehr geehrte Damen und Herren des Festkolloquiums zu Ehren von Herrn Professor László Detre!

Leider ist es mir aus gesundheitlichen Gründen nicht möglich, selbst einen Beitrag über die Beziehungen zwischen den ungarischen Astronomen und der Astro-Abteilung von Carl Zeiss Jena hier vorzutragen. Ich bedanke mich bei Herrn Professor Lajos Balázs für die Einladung und wäre gern nach über 30 Jahren wieder nach Budapest gekommen.

Die Beziehungen begannen bereits vor der Gründung der Abteilung durch freundschaftliche Kontakte und Lieferungen für das Privatobservatorium von Miklos von Konkoly-Thege in O´Gyalla. Pauly war ein Zeitgenosse Konkolys, beide waren etwa gleich alt. Als promovierter Chemiker leitete Pauly eine große Zuckerfabrik bei Mühlberg/Elbe mit bedeutendem Erfolg, insbesondere durch die Entwicklung neuer Technologien und Ausrüstungen für die Verarbeitung von Zuckerrüben. Pauly interessierte sich aber schon von Jugend an für die Astronomie und hatte nun finanzielle Mittel, sich intensiver mit dieser Wissenschaft zu beschäftigen. So baute er sich eine eigene Sternwarte auf, wobei ihn Konkoly unterstützte. Es gab zwischen beiden eine Art Seelenverwandtschaft, aus eigenen Kräften sich die Mittel für Forschung und Entwicklung zu schaffen.

Das besondere Interesse Paulys galt der Astro-Optik und er schuf eine leistungsfähige Optikwerkstatt mit einem großen Kundenkreis. Um 1890 lieferte er ein 6-Zoll-Objektivprisma und zwei 8-Zoll-Objektive nach O´Gyalla und nach Herény.

Große Aufmerksamkeit erregte Paulys Apochromat aus neuen Schott-Gläsern, den Professor Max Wolf von der Heidelberger Sternwarte auf dem Königstuhl als einen wesentlichen Fortschritt auf dem Gebiete der Fernrohroptik rühmte. Damit war eine Innovation entstanden, die die Grundlage für den Aufbau einer Werkstatt für astronomische Optik bei Carl Zeiss Jena bilden konnte.

Über dieses neue Objektiv und die neue Abteilung für astronomische Objektive berichtete Max Pauly auf der Tagung der Astronomischen Gesellschaft in Budapest im Jahre 1898, die von Konkoly organisiert worden war. An dieser Tagung nahm auch der Observator der Jenaer Sternwarte Otto Knopf teil, der von Ernst Abbe, dem führenden Wissenschaftler des aufstrebenden Weltunternehmens der Feinmechanik und Optik in Jena, mit den Geschäften der Astronomischen Lehre und Forschung betraut worden war.

Zu den Teilnehmern der Tagung der Astronomischen Gesellschaft in Jena im Jahre 1906 gehörte auch Konkoly, der sich von den Fortschritten in Jena überzeugen konnte. Aus der Werkstatt für astronomische Optik war eine Abteilung geworden, die bereits astronomische Groß geräte wie das 720-mm-Spiegelteleskop für Heidelberg und das 400-mm-Spiegel-teleskop für Innsbruck hergestellt hatte.

Solche Groß geräte zählten nicht zur Planung Konkolys, aber er erwarb die neue Zeiss´schen Wechselvorrichtung mit der bekannten Ringschwalbe für seine Teleskope, um beim Austausch von Nebengeräten die Beobachtungstätigkeit zu rationalisieren.

Mit der Übertragung der Konkoly´schen Sternwarte an den Staat im Jahre 1899 war deren Existenz für die Zukunft gesichert und wie wir mit Befriedigung feststellen können, selbst nach dem Untergang der K.u.K. Monarchie.

Die neue Sternwarte in Budapest erhielt 1928 ein großes Doppel-Teleskop mit einer Montierung von Heyde/Dresden mit einem 600-mm-Spiegelteleskop und einem 300-mm-Refraktor von Carl Zeiss Jena, das heute noch in modifizierter Form als automatisiertes Teleskop im aktiven Dienst steht. Auch zwei Kuppeln, verschiedene kleinere Teleskope und Auswertegeräte gehörten zu den Geräten von Carl Zeiss Jena.

Das Hauptarbeitsgebiet der Sternwarte blieb die von Konkoly intensiv betriebene Beobachtung veränderlicher Sterne, auf dem man auch mit kleineren Teleskopen, wie sie in Budapest vorhanden waren, erfolgreich tätig sein. In Deutschland gab dafür Cuno Hoffmeister in Sonneberg ein Beispiel. Nach Abschluß seines Studiums in Berlin im Jahre 1929 begann László Detre seine Forschungsarbeiten in der Konkoly-Sternwarte mit großem persönlichen Einsatz bei der Beobachtungsarbeit. Ähnlich wie bei Cuno Hoffmeister in Sonneberg wurde jede klare Minute zum Beobachten genutzt und eine große Zahl photographischer Himmelsaufnahmen gewonnen und ausgewertet.

Als László Detre 1943 Direktor der Konkoly-Sternwarte wurde, war überhaupt nicht daran zu denken, daß die ungarische Astronomie durch neue, leistungsfähigere Teleskope und Ausrüstungen die von Konkoly geschaffenen Grundlagen der Astrophysikalischen Forschungen weiter ausbauen könnte.

Es ist bemerkenswert, daß – ähnlich wie nach dem Ersten Weltkrieg – viele zerstörte Sternwarten wieder aufgebaut wurden und darüber hinaus neue Forschungsgeräte installiert wurden. Damit hatte auch die Astroabteilung von Carl Zeiss Jena eine Chance, im Rahmen des Wiederaufbaus des Zeisswerkes die Tradition der Astroabteilung fortzusetzen und sogar ein höheres Leistungsniveau anzustreben.

An vorderer Stelle standen die Schmidtspiegelteleskope und in Jena folgte dem 2-m-Universal-Spiegelteleskop mit dem größten Schmidtspiegelsystem der Welt, das Große Schmidtteleskop für die Sternwarte Hamburg-Bergedorf.

Die ersten Gespräche um eine Modernisierung und Vergrößerung der Ausrüstung der Sternwarte fanden 1956 anläßlich der Konferenz über Veränderliche Sterne statt. Es ging um ein Schmidtspiegelteleskop, das den in der Veränderlichforschung eingesetzten Astrographen überlegen war.

Es trat dann der günstige Fall ein, daß mehrere Sternwarten an einem Spiegelteleskop-Typ interessiert waren, der für die Ausbildung von Studenten in gleicher Weise wie für die Forschung geeignet war. Mit dem Teleskop, so war die Konzeption von Zeiss, sollte, ähnlich wie bei dem 2-m-Spiegelteleskop, das 1960 in Tautenburg in Betrieb genommen worden war, neben dem Schmidtsystem auch noch eine Cassegrainvariante Einzeluntersuchungen astronomischer Objekte ermöglichen.

An diesem Schmidtspiegelteleskop waren die Sternwarten Jena, Budapest, Poznan und Peking interessiert und so kam es zu einer intensiven Zusammenarbeit zwischen den Jenaer und den Budapester Astronomen. 1962 wurde das Schmidtspiegelteleskop 600/900/1800 auf der neuen Bergstation Piszkéstető in dem Mátra-Gebirge in Betrieb genommen. Ihm folgte 1966 ein 500-mm-Cassegrain-Teleskop.

In dieser Zeit waren in Jena die neuen 2-m-Spiegelteleskope für Schemacha (Aserbeidshan) und Ondrejov (CSSR) im Bau und zwei 1-m-Teleskope mit Ritchey-Chrétien-Spiegelsystemen für die indischen Sternwarten in Kavalur und Nainital in Entwicklung.

Dieser Teleskoptyp war für die Konkoly-Sternwarte ein optimaler Kompromiß zwischen Leistungsfähigkeit und Kostenaufwand verglichen mit einem 2-m-Teleskop. Zeiss hatte Vorteile mit einer weiteren Fertigung für Sternwarten in aller Welt. Durch die niedrigen Polhöhen der indischen Sternwarten war eine sogenannte Englische Montierung vorteilhaft, bei der die Stundenachse von zwei Pfeilern getragen wird. Für die Fertigung dieses Typs konnte eine Standardkonstruktion verwendet werden, die für den Kunden und den Lieferanten ökonomische Vorteile bot.

Damals entwickelte sich ein Umbruch in der Antriebs- und Steuertechnik der Teleskope, aber auch der gesamten Gerätetechnik des Zeiss-Fertigungsprogramms.

Die Astroabteilung von Carl Zeiss Jena stand vor einem Dilemma. Die bisherige Elektrotechnik war nicht mehr zukunftsträchtig, es gab aber keinen Partner mit entsprechenden Erfahrungen in der DDR für eine moderne Lösung.

Bei der Beratung dieser Problematik in Budapest ergab sich der Glücksfall, daß in der Budapester Firma VILATI ein potentieller Partner mit Erfahrungen auf dem Gebiet der Steuerung von Werkzeugmaschinen existierte, der zudem noch Zugriff auf moderne westliche Bauelemente der Elektronik hatte. Dank der Bemühungen von Prof. Béla Balázs und einer glücklichen Konstellation der kommerziellen Beziehungen zwischen Ungarn und der DDR im Rahmen der Gegenseitigen Wirtschaftshilfe konnte das Problem gelöst werden.

Die Zusammenarbeit mit den Spezialisten der Firma VILATI unter Leitung von Diplomingenieur Otto Bánhegyi war hervorragend und es gab keine Schwierigkeiten bei der Übertragung der Steuerung einer Werkzeugmaschine auf ein Teleskop.

Von besonderem Vorteil war, daß die erste neue Teleskopsteuerung in Ungarn zur Anwendung kam und die Betreuung des Teleskops gesichert war.

Das Teleskop wurde 1974 in Betrieb genommen.

Was zunächst nur als eine Lösung für das ungarische Teleskop angesehen wurde, entwickelte sich für Carl Zeiss Jena und die Firma VILATI zu einer Erfolgsgeschichte. Von dem 1-m-Teleskop-Typ wurden bis 1990 weitere 10 Geräte vor allem in den astroklimatisch günstigen Gebieten Mittelasiens in Betrieb genommen.

Inzwischen war auch die Digitaltechnik produktionsreif geworden und so konnte Carl Zeiss Jena dank der guten Zusammenarbeit mit der Firma VILATI auch auf diesem Gebiet mithalten und die Beobachtungsarbeit rationalisieren. Die mit dem 1-m-Teleskop gewonnenen Erfahrungen konnten auf die neuen 2-m-Ritchey-Chrétien-Teleskope für die Observatorien Roshen/Bulgarien und Terskol/Kaukasus übertragen werden.

Wie Sie sehen können, verdankt die Astroabteilung von Carl Zeiss Jena wesentliche Impulse ihrer Entwicklung der ausgezeichneten Zusammenarbeit mit bedeutenden ungarischen Astronomen und Institutionen. Es ist erfreulich festzustellen, daß Professor László Detre zur richtigen Zeit diese Impulse auslösen konnte. Persönlich freue ich mich, daß ich in meiner Funktion als wissenschaftlicher Leiter der Abteilung für Astronomische Geräte bei Carl Zeiss Jena diesen Aufbau fördern konnte. Ich hatte als Praktikant an der Sternwarte Sonneberg meine Lehrzeit als Astronom mit der Beobachtung von Veränderlichen Sternen begonnen ebenso wie mein engster Mitarbeiter Alfred Jensch, der dann Chefkonstrukteur der Astroabteilung wurde.

Ich wünsche der ungarischen Astronomie weiterhin eine gute Entwicklung und viele Erfolge.

Photographic observation of globular clusters in the Konkoly Observatory

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In the last years of the XIXth century Solon I. Bailey made photographic observations at Arequipa, Peru, at the observational station of the Harvard Observatory. He obtained long series of photographs on M3, M5, and ω Cen clusters and discovered hundreds of RR Lyrae variables on them.

About four decades later (1938) W. Christian Martin found increased periods based on new plates taken of ω Cen. This result made further research promising. They brought up the idea to grasp stellar evolution through period changes.

In Budapest the photographic observations of globular clusters span almost 30 years (1937–1966) (*Fig. 1*). These observations have been initiated by L. Detre. In the beginning he took the considerable part of plates at the Newtonian focus of the Observatory's 24" telescope. Later the program was continued by the staff members of the observatory. Júlia Balázs-Detre, Tibor Herczeg, György Kulin, Miklós Lovas, Béla Szeidl, and the author participated in the observations.

The globulars M3, M5, M15, M56, and M92 have been photographed systematically. The contribution by G. Kulin and M. Lovas has been extremely high to this plate collection. Apart from a few Kodak products and Agfa Astro special plates, the majority of the plates used were Guilleminot Superfulgur. With a few exception, exposition times extended 10-20 minutes. In course of these three decades hundreds of plates have been obtained on the clusters mentioned above.

In order to study the period changes, mean light curves and O$-$C diagrams have been constructed. Studies of this type have been published on about 60 RR Lyrae variables in M3 by István Ozsváth (1957) and 21 variables in M15 by Imre Izsák (1957). Further studies based on Budapest plates of M3 concerning 112 measurable variables were carried out and published (Szeidl, 1965) (*Fig. 2*). Later data on 54 RR Lyrae stars in the cluster M15 were published by the author (Barlai, 1989) (*Fig. 3*).

It is worth mentioning that the brightness of overwhelming majority of the RR Lyrae variables in M5 have been measured or estimated by M. Lovas. This database is to be analysed.

In 1975 a new 1-meter RCC telescope was installed at our Piszkéstető mountain station. Since then the photographic observations have continued there until the beginning of the 1990s. Several hundreds of plates have been obtained on M3, M5, and M15 globular

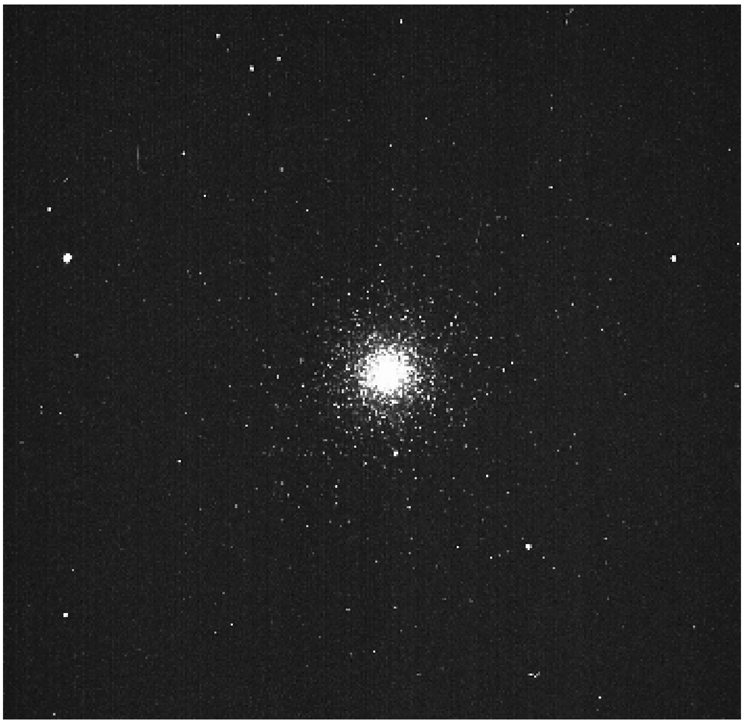

Figure 1: A "historic" photograph from the year 1950.

clusters. Due to the better resolution, further details can be revealed on the variables closer to the dense central region or the ones having close companions on the plates taken in Budapest with the Newtonian telescope. Analysis of their data means a task for the future.

Although the study of period changes did not fulfill the original expectations to show immediately the direction of cluster evolution still they and the numerous brightness data obtained gave us a deeper insight into the nature of RR Lyrae stars.

The new CCD technique made further photographic observation of globular clusters obsolete (*Fig. 4*). This "old" plate material, however, means a base for new approaches to these fascinating objects.

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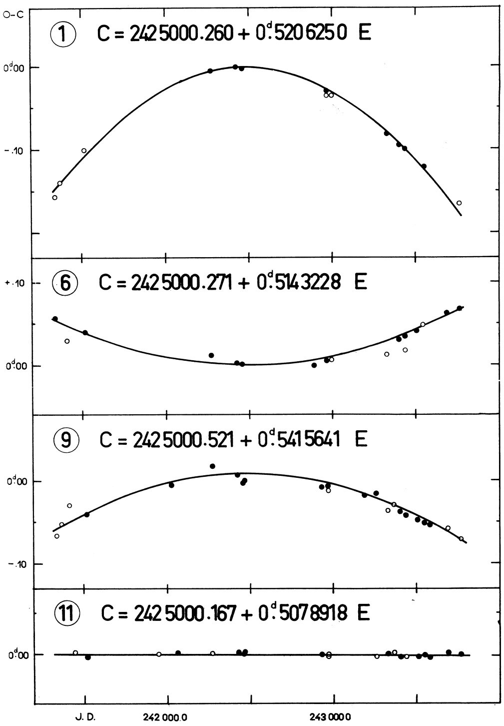

Figure 2: O−C diagrams of some RR Lyrae variables in M3. Increasing and decreasing periods can be seen and a constant period, as well (Szeidl 1965).

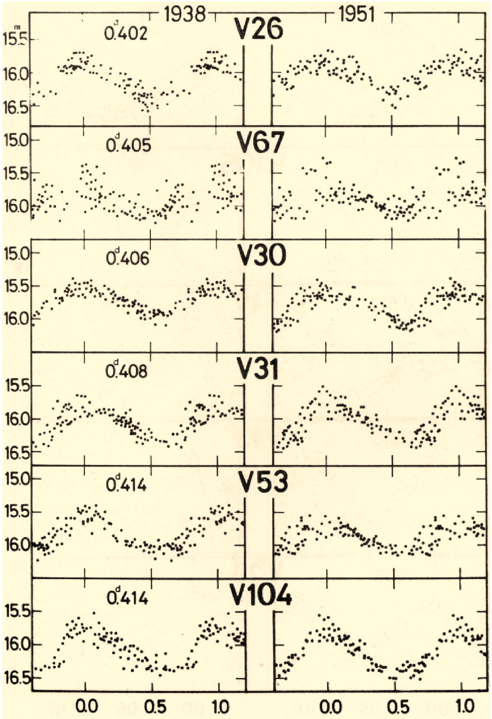

Figure 3: Some mean light curves of RR Lyrae stars in the globular cluster M15. Except V104 the other stars are of double mode nature or show suspect of Blazhko effect (Barlai 1989).

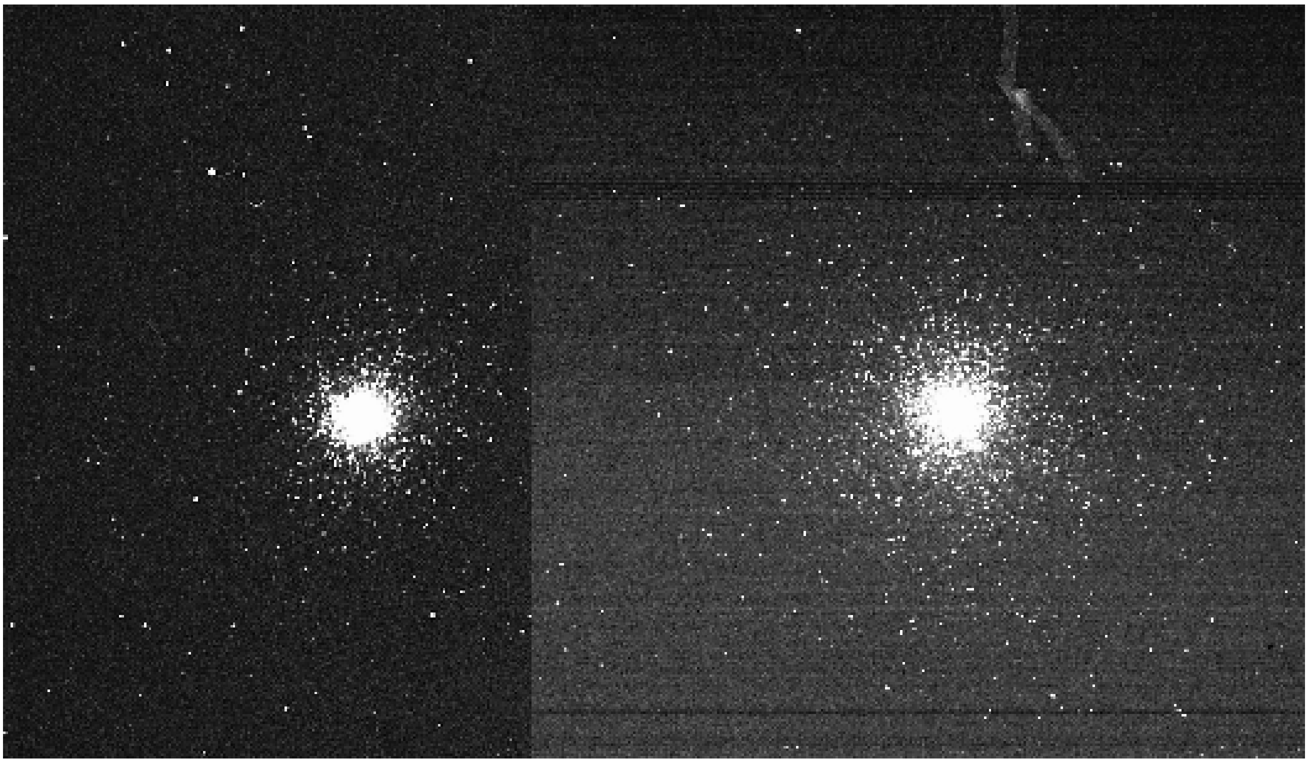

Figure 4: Image of M15 on the plates taken with the Newtonian telescope and with the RCC telescope, respectively. Casting a glance on the two photographs they clearly show the improvement in the resolution.

Conventional and new directions in studying Cepheids

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In the first part of this paper, traditional methods of studying Cepheids are summarized, mentioning Detre's contribution to this field. Then the new directions of Cepheid related research are reviewed with an emphasis on the problems concerning the period-luminosity relationship.

Introduction

Cepheids are supergiant stars that perform radial pulsation when they cross the classical instability strip in the Hertzsprung-Russell diagram during their post-main sequence evolution. It is the outer layers of Cepheids which oscillate, and the pulsation is maintained by the opacity changes in the partially ionised zones of neutral hydrogen and singly ionised helium capable for transforming heat into mechanical energy via the κ-mechanism (κ is the conventional sign of the opacity).

The mostly monoperiodic Cepheids may seem to be boring targets with respect to the multiperiodic radial and/or non-radial pulsating stars of different types but, in fact, Cepheids are neither perfectly regular, nor homogeneous. Subtle deviations from regularity and homogeneity result in important astronomical consequences. No wonder, Cepheids have remained in the forefront of the variable star studies in spite of the fact that a number of astrophysically important new types of variable stars emerged in the last decades. Due to variety and richness of the relevant studies, selected results are only mentioned in this review.

Traditional studies and Detre's contribution

The Cepheid pulsation is a free oscillation of the star whose frequency corresponds to the eigenfrequency of the stellar plasma sphere. The value of the frequency and its reciprocal, the pulsation period, is governed by the structure of the star, especially by the average density. This dependence gives rise to the well known period-luminosity relationship that exists for various types of pulsating stars. The period-luminosity (P-L) relationship was discovered a century ago by studying Cepheids in the Magellanic Clouds, and since that time this relationship has been instrumental in establishing the extragalactic distance scale.

By the time of mid-20th century, it became obvious that Cepheids are found in at least two varieties: the classical Cepheids belonging to Population I, and the older Type II Cepheids which are less luminous at a given pulsation period. In what follows, the term Cepheid covers classical Cepheids only.

The simplest observational study of Cepheids (and any other periodic variable stars) is to obtain photometric data from which the light curve can be constructed and long-term stability of both the light curve and the pulsation period can be investigated. László Detre also observed Cepheids – at the beginning of his career the Cepheids and the RR Lyrae type variables were not even strictly separated: the RR Lyrae type stars used to be referred to as short period Cepheids. Detre published three papers on classical Cepheids based on his visual photometric data. The targets of these studies were XY Cas (Dunst, 1932), SZ Cas (Dunst, 1933), and YZ Aur (Detre, 1935).

Two decades later, when the first photoelectric photometer was installed at the Konkoly Observatory, Detre included some bright Cepheids (FF Aql, SU Cyg, T Vul, and U Vul) in the observational programme. These photoelectric data were only published after Detre's death (Szabados, 1977, 1980).

Long-term changes in the pulsation period can be studied with the help of the O−C method. In the case of Cepheids, the amount and sign of the period variations can serve as an observational check of stellar evolutionary models. During the Cepheid stage of stellar evolution, the supergiant star crosses the instability strip in either direction. A monotonously increasing pulsation period reflects redward crossing of the instability strip, while the blueward transition results in continuously decreasing period. In reality, period fluctuations are often superimposed on the period changes of evolutionary origin. The erratic changes in the pulsation period reflect the physical conditions in the upper layers of Cepheids because this radial pulsation is an atmospheric phenomenon. Detre pioneered the study of period changes of regularly pulsating variable stars. His paper involving O−C diagrams for a number of Cepheids was published in 1970.

Role of Cepheids in astronomy

Importance of Cepheids in astronomy is twofold. In astrophysics they are *test objects for stellar evolution theory* (as mentioned above) and models of stellar structure. In extragalactic astronomy and cosmology, Cepheids are considered as *primary distance indicators* and the cosmic distance scale is chiefly based on Cepheids. They serve as standard candles because a close correlation exists between the pulsation period and stellar luminosity. The most recent review on the *period-luminosity relationship* is written by Sandage & Tammann (2006).

In addition to the P-L relationship, Cepheids obey a number of other relationships owing to regularity of their pulsation and some well-known physical principles (e.g. Stefan-Boltzmann law). Close relationships are valid between the period and the spectrum, the period and the radius, the period and the age of the Cepheid, etc.

Studies of Cepheids have been motivated mostly by the intention of improving any of these relationships either observationally or by theoretical calculations. Nevertheless, existence of period variations is already a hint that one cannot expect perfect regularity in the pulsation of Cepheids. Knowledge of the means how the individual Cepheids deviate from the regular behaviour and the physical explanation of these deviations is essential for the precise calibration of various Cepheid-related relationships, as well as from the point of view of astrophysics.

Recent developments

In spite of the fact that a number of methods suitable for extragalactic distance determination were devised in the last decades, the role of Cepheids as primary distance calibrators has not lessened. The interest in studying Cepheids has been facilitated by the rapid progress in both observational and theoretical astrophysics, especially by the following facts: availability of imaging detectors in the near infrared, existence of massive photometries (with the primary aim at detecting microlensing events), and the enormous increase in computing power.

The advantages of *observing Cepheids in infrared* are as follows:

- The photometric amplitude at near IR wavelengths is smaller than in the optical spectral region, therefore the mean brightness can be determined reliably from a few observations obtained at random phases. (In the optical band, at least 15-20 observational points are necessary for covering the light curve.) Thus projects aimed at determining extragalactic distances based on the P-L relationship of Cepheids are more feasible in the near IR.
- Infrared magnitudes are less affected by interstellar absorption. Thus the P-L relationship has a smaller scatter around the ridge line fit in the near IR photometric bands.
- The finite width of the P-L relationship at a given period is partly due to the temperature sensitivity of the pulsation period because the P-L relation is, in fact, period-luminosity-colour (P-L-C) relationship. At longer wavelengths, the monochromatic flux becomes less sensitive to temperature, thus the width of the P-L relation is reduced in the IR bands.
- Many Cepheids belong to binary systems whose secondary star is usually a less massive blue or yellow star on or near the main sequence. The photometric contribution from the companion is negligible in the near IR.
- The effects of metallicity are much reduced in the infrared as compared with the optical spectral region where metallic absorption lines dominate. Therefore, the Baade-Wesselink method of radius determination can be reliably applied in the near IR.

The main benefit from the *massive photometries*, especially MACHO, OGLE, and EROS, on Cepheid research is the availability of large body of homogeneous photometric data on Cepheids in both Magellanic Clouds. Using these databases, the period dependent behaviour of Cepheids can be studied much more precisely than before. In addition, many new Cepheids were discovered in both satellite galaxies including dozens of double-mode Cepheids (Alcock et al., 1995; Udalski et al., 1999a; Soszyński et al., 2000) and Cepheids which are members in eclipsing binary systems (Udalski et al., 1999c; Alcock et al., 2002). The Magellanic double-mode Cepheids outnumber their Galactic counterparts. Their simultaneously excited two modes can be either the fundamental mode and the first overtone, or the first and second overtones. Surprisingly, single-mode Cepheids pulsating in the second overtone have been also found in the Small Magellanic Cloud (Udalski et al., 1999b). Such stars are not known in our Galaxy, possibly because the mode identification for the Milky Way Cepheids is very difficult and uncertain.

The increasing number of large telescopes and very sophisticated auxiliary equipments facilitate the discovery of Cepheids in remote galaxies as well as deeper studies of individual Galactic Cepheids. In September 2006 Cepheids were *known in 76 galaxies.* Over 5000 Cepheids have been detected beyond the Magellanic Clouds, and about 400 such variables are known in various galaxies of the Virgo Cluster. The number of the known classical Cepheids in our Galaxy only amounts to about 6 per cent of the total known Cepheid sample.

The high precision photometric and deep spectroscopic studies of Galactic Cepheids facilitated a reliable determination of physical properties and surface chemical composition of a large number of these variables. With a spectacular progress in the last decade, *abundance determination* based on high resolution spectra has been already performed for more than 150 Cepheids (Kovtyukh et al., 2005 and references therein). The classical Baade-Wesselink method of *radius determination* has been replaced by the infrared surface brightness method (Welch, 1994). The estimated precision of radius determination of Cepheids was about 7 per cent several years ago (Gieren et al., 1999).

The long-lasting discrepancy between *Cepheid masses* derived by various methods was already resolved in early 1990es by using modified opacity values characteristic of stellar interior (Rogers & Iglesias, 1992; Seaton et al., 1994). Nevertheless, the agreement is not satisfactory yet. Now, the masses derived from stellar pulsation are smaller by about 10-20 per cent than the mass values deduced from evolutionary models. This problem can be resolved either by more appropriate stellar models or assuming a significant mass loss in pre-Cepheid evolutionary phases (Bono et al., 2006).

Quite recently, important observational results were achieved on the circumstellar environment of Cepheids: extended envelopes have been found around the brightest Cepheids from near-IR interferometric observations (Kervella et al., 2006; Mérand et al., 2006) testifying that *mass loss* occurred in the recent past.

The ample and precise observational data on Cepheids can be used even for studies of *star formation history* in particular stellar regions. The period distribution coupled with the period-age relationship is indicative of star formation in the recent past. For example, the period distribution of Cepheids in the Large Magellanic Cloud shows that star formation propagated along the bar of our largest satellite galaxy with a velocity of 100 $\mathrm{km\,s^{-1}}$ from SE to NW during the last hundred million years (Alcock et al., 1999).

Similarly, Cepheids are instrumental in following spatial motion of the point of intersection of two spiral arms in M31. The interaction point could be followed from the age, i.e. the period distribution of Cepheids (Magnier et al., 1997). The location of intersection now coincides with the superassociation NGC 206.

Moreover, some characteristics of star formation history in our own galaxy can be investigated, as well. The distribution of metallicity and its gradient as a function of galactocentric radius is an important feature determined from Cepheid studies (Kovtyukh et al., 2005).

In addition to investigations based on large numbers of Cepheids, *studies of individual Cepheid variables* have also resulted in spectacular results. There are quite a few Cepheids that exhibit peculiar behaviour. Polaris (α UMi), the brightest Cepheid, showed a secularly decreasing pulsation amplitude throughout most of the 20th century, but instead of ceasing pulsation, now it oscillates with an extremely small amplitude (Turner et al., 2005 and references therein). Strangely enough, the locus of Polaris in the H-R diagram is in the middle of the instability strip, so this Cepheid is not about leaving the instability region (Evans et al., 2002). Another example for secularly declining pulsation amplitude may be the case of Y Oph (Fernie et al., 1995). An even more strangely behaving Cepheid is V19 in M33 (Macri et al., 2001). The tremendous decrease in its pulsation amplitude was accompanied with increasing mean brightness during the 20th century.

In addition to these secular changes, important *periodic phenomena* also appear among Cepheids. V473 Lyrae, a very short period classical Cepheid (with a pulsation period of 1.491 days), cyclically varies its amplitude by a factor of about 15. The modulation period is as long as 1200 days (Burki et al., 1986 and references therein). The physical cause of this unprecedented behaviour has not been clarified yet.

Another type of independent periodicity is due to the orbital motion, if the Cepheid is a member in a binary system. The frequency of occurrence of *binaries among Cepheids* is as large as incidence of binarity among common stars in the solar neighbourhood, i.e. *exceeds 50 per cent* (Szabados, 2003). Such a high percentage was not foreseen earlier. Cepheids belonging to binary systems are key objects for determining the physical properties of Cepheid variables, including stellar luminosity which facilitates reliable calibration of the zero-point of the P-L relationship (e.g. Evans, 1992). Especially valuable are in this respect the eclipsing systems involving a Cepheid component, because the inclination of the orbital plane follows from the eclipsing nature, and knowledge of the inclination removes uncertainty in the mass determination. Unfortunately, such pairs have not been found in our Galaxy but three *eclipsing binary systems with Cepheid primaries* have been revealed in the LMC (Alcock et al., 2002; Udalski et al., 1999b).

The *pairs consisting of two Cepheid variables* are extremely interesting objects from the viewpoint of stellar evolution. In addition to the archetype, CE Cas, Alcock et al. (1995) revealed three such pairs in the LMC, while Udalski et al. (1999a) detected one pair in the SMC. Though the two components cannot be separated, it is clear from the period ratio of the two excited oscillations that the observed variations cannot be explained with double-mode pulsation of a solitary Cepheid in any of these cases.

In the *beat Cepheids*, the two excited oscillations are not independent of each other: they correspond to low order radial modes of stellar pulsation. Though a number of faint Galactic double-mode Cepheids have been discovered in the last decade, the number of such variables is only slightly over twenty, i.e. much less than their known counterparts discovered from the data collected during the photometries of either Magellanic Cloud. Quite recently, double-mode Cepheids were discovered in M33 (Beaulieu et al., 2006) among the huge sample of the photometric survey performed by Hartman et al. (2006). The survey covering the whole area of this more remote galaxy resulted in identifying about 2000 Cepheids in M33 (Hartman et al., 2006). There has been a spectacular *progress in modelling* double-mode pulsation in Cepheids, too. While purely radiative models have failed to reproduce simultaneous double-mode periodicity of Cepheids for decades, when taking into account turbulent convection in the hydrodynamic calculations, Kolláth et al. (2002) succeeded in obtaining a stable beat Cepheid behaviour.

Another major result among the Cepheid related theoretical investigations is the confirmation of existence of strange Cepheids. Stars performing surface mode pulsation were predicted by Buchler et al. (1997), and the first representatives of such short period, ultralow amplitude variables were discovered from the MACHO photometry of the LMC by Buchler et al. (2005). Discovery of non-radial oscillations as well as triple-mode pulsation in classical Cepheids were also announced based on the OGLE LMC data (Moskalik et al., 2004).

Problem of universality of the P-L relationship

There are quite a few effects that place the individual Cepheids scattered around the ridge line P-L(-C) relationship, thus resulting in a finite width of this plot. The most important effects being:
- interstellar reddening and absorption;
- presence of a companion star;
- mass loss;
- magnetic field;
- mode of pulsation;
- nonlinearity of the relation;
- differences in the chemical composition.

The amount and effects of interstellar absorption has been widely discussed and thoroughly studied in the Cepheid related literature. For Galactic Cepheids, the reddening correction and the intrinsic colour index is determined individually. In the case of extragalactic Cepheids, however, this is not a viable procedure, and, instead, the practically reddening-free Wesenheit function, W, is used (see Madore, 1976):

$$W = \langle V \rangle - R(\langle B \rangle - \langle V \rangle)$$

where R is the ratio of total-to-selective absorption. The assumption that R is constant throughout any galaxy is only a rough approximation. For extragalactic Cepheids, the absorption consists of two parts: internal absorption in the galaxy hosting the Cepheid and foreground absorption produced by interstellar matter along the given line of sight in our Galaxy. The effect of this latter component can be readily determined by multicolour photometry (Freedman & Madore, 1990 and references therein).

The photometric effect of possible companion stars (either physical or optical companions) is usually not taken into account. Neglect of binarity may lead to a systematic error in determining the luminosity of Cepheids useful for the calibration of the P-L relationship (Szabados, 1997), while line-of sight companions in crowded stellar fields of remote galaxies falsify the distance modulus derived for the given system.

Studies on the mass loss can gather a new impetus by recent discoveries of envelopes around bright Cepheids (Kervella et al., 2006; Mérand et al., 2006).

Existence of magnetic field and its effect on luminosity of Cepheids is a topic of worthy of closer attention from both theoretical and observational points of view.

The pulsation mode of extragalactic Cepheids can be determined relatively simply because stars oscillating in different modes are situated along distinct P-L relationships. In the case of Galactic Cepheids, however, the determination of the pulsation mode is not easy. There are contradictory propositions on the pulsation mode of some well studied bright Cepheids. Difficulties in the mode identification may also cause that no singly periodic Cepheid pulsating in the second overtone is known in our Galaxy, while a plenty of such stars have been found in the SMC (Udalski et al., 1999b).

Quite recently, it turned out that the P-L relationship of the LMC is nonlinear, showing a break at the pulsation period of about ten days (Sandage et al., 2004; Ngeow & Kanbur, 2006 and references therein). This effect is caused by nonlinearity of the period-colour relation and has its physical origin in the interaction of the hydrogen ionization front with the Cepheid photosphere. This interaction changes with the phase of pulsation and metallicity producing the observed changes in the Cepheid P-C and P-L relationships. Note that nonlinearity is characteristic of the relationships of the metal poor LMC, while the corresponding relations valid for the Milky Way galaxy are linear.

The role of *metallicity* in modifying the relationships valid for Cepheids is the key issue in the recent Cepheid related literature. The very precisely measurable period ratio of double-mode Cepheids clearly depends on the abundance of the heavy elements as shown by the comparison of Galactic beat Cepheids and their siblings in the Large Magellanic Cloud (Alcock et al., 1999). The [Fe/H] values of Galactic beat Cepheids determined individually from high resolution spectra also confirm existence of metallicity dependence of the period ratio (Sziládi et al., 2006). Moreover, Klagyivik & Szabados (2006) pointed out that some phenomenological properties of Cepheids, e.g. ratio of amplitudes of photometric and radial velocity variations also depend on the heavy element abundance, Z.

Nevertheless, the most important problem in this respect is the dependence of the zero point and the slope of the P-L relationship on metallicity. The era of contradictory results has not been over yet. A numerical parameter, γ, describing this metallicity dependence has been introduced by Sakai et al. (2004): $\gamma = \delta(m-M)/\delta \log Z$ where $\delta(m-M) = (m-M)_Z - (m-M)_0$ is the difference of distance modulus corrected for the effect of metallicity and the uncorrected value, and $\delta \log Z = (\log Z)_{LMC} - (\log Z)_{\mathrm{extragal}}$. The most recent studies (Sakai et al., 2004) resulted in $\gamma = -0.24 \pm 0.05$ mag/dex. It is worthy to mention that Freedman et al. (2001) used practically the same value of the γ in the final paper on the HST Key Project on the Hubble constant. However, theoretical models calculated by Romaniello et al. (2005), taking into account the variable He content, are not compatible with these observational findings.

In order to determine a reliable value of the distance modulus of the galaxy, at least the average metallicity of the host galaxy has to be known, in any case. Caputo et al.'s (2004) new method is a promising development in this respect. They pointed out that the luminosity difference between the RR Lyrae type variables and the more massive pulsators with the same period is a function of metallicity. The more massive, short period pulsators involved in this method are the so called *anomalous Cepheids.* According to the new paradigm, however, the anomalous Cepheids are classical Cepheids with extremely low metal content (Caputo et al., 2004; Marconi et al., 2004).

Knowledge of metallicity of Cepheids is, therefore, especially important for the precise calibration of the P-L relationship, i.e. to fix the bottom rung of the cosmic distance ladder.

Acknowledgements Cepheid related studies at the Konkoly Observatory are partly supported by the Hungarian OTKA grant T046207.

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Stellar activity and the Konkoly Observatory: the beginnings

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The early observational facts on stellar activity are discussed with special emphasis on L. Detre's interest in those results.

Introduction

The discovery of starspots has a long history. Curiously, the establishment of the class of active stars is strongly connected with Detre's Institute. The real discovery of starspots (on AR Lac) happened just in the middle of the XXth century by Kron (1947) and soon after on two other objects. But this discovery was forgotten for more than a decade. In 1965 Chugainov (1966) made a series of observations on HDE 234677 (BY Dra) and explained the resulting light curve by starspots. That paper was published in the *Information Bulletin on Variable Stars*, which has been edited by the Konkoly Observatory from the beginnings. At that time the editor was L. Detre. Observing flare stars became popular: during 1971 *Information Bulletin on Variable Stars* published about 100 issues, and 25% of those dealt with flare stars and related objects. In 1971 the *General Catalogue of Variable Stars* announced a new class of variables, the so-called BY Dra-type stars. The final step of establishing the class of active stars is connected with an IAU Colloquium held in Budapest in 1975, which will be mentioned in the Epilogue. The interested reader may find a thorough review about the discovery of starspots in Hall's (1994) excellent work. L. Detre has been interested in this new type of variables, as in every other novelties. In what follows, a few examples of this interest is presented.

Starspots and flares

In late 1960s and early 1970s, flare stars were increasingly observed. Beside flares, rotational modulations were revealed in several cases. Some stars, like BY Dra showed flares as well as rotational modulation. *Fig. 1* shows a light curve of HDE 234677 observed in 1966 by Krzeminski (1968), which appeared in a conference proceedings on the light variation of dM and dMe stars. At that time the star did not have a variable star designation, but slightly later aroused L. Detre's attention: he marked the name of the variable in the book. This variable was later observed with the 60-cm telescope in Budapest, and in 5 colours ($UBVR_CI_C$) with the 1-m telescope at Piszkéstető mountain station, which is also plotted in *Fig. 1.*

Photoelectric monitoring of flare stars were carried out as well in the late 1960s. Among the targets were BY Dra itself and also AD Leo. A huge flare observed in the latter object by Szeidl (1969) is shown in *Fig. 2.* These measurements clearly show, that L. Detre was interested in this new type of variable stars. At that time, in lack of clear definition, one could not call them a *new class* of variables.

Long-term variations: cycles

From the time of the discovery of starspots it was obvious to relate these features with those observed on the Sun for already centuries. Flares were thought to be huge eruptions on stellar surfaces, just like those detected on the Sun. The search for solar analogues on stars continued and Wilson (1968) initiated a long-term study for searching cycles of solar-type stars through measuring CaII H&K activity, which is continuing to date. But before this, already in 1966, L. Detre published a note of just once sentence, calling the attention on the possible presence of a spot cycle on BY Dra, as shown in *Fig. 3* (upper and middle panels). This small remark was surely among the first ones (if not exactly the first) suggesting cycles on other stars than the Sun.

In the lower part of *Fig. 3* the continuation of the long-term light variability of BY Dra is plotted. Clearly, cycles are present in the overall brightness of this system with quasiperiods of decades, about 14 and 3 years (see Oláh et al. 2000 for the details).

University classes

The author had the pleasure to attend L. Detre's classes of astronomy. Those lectures usually dealt with the newest results in variable star astronomy, which were found very useful even long after the graduation. Another topic of his lectures was solar physics, which is strongly connected with the active star research. *Figures 4* and *5* are examples of L. Detre's handwritten notes for the university lectures on the solar cycle and on the differential rotation.

Epilogue

L. Detre passed away on 1974 autumn. At that time the organization of the IAU Colloquium No. 29, *Multiple Periodic Variable Stars* which he initiated, was underway. His successor, B. Szeidl took over the conference organization, and among others, he invited Douglas S. Hall to give a review on *The RS CVn Binaries and Binaries with Similar Properties.* This talk and its published version became of fundamental importance in studying active stars: it determined the class of active stars and its subsystems, which is used (with later modifications) to date. The paper has more than 400 citations during the last 30 years by the ADS.

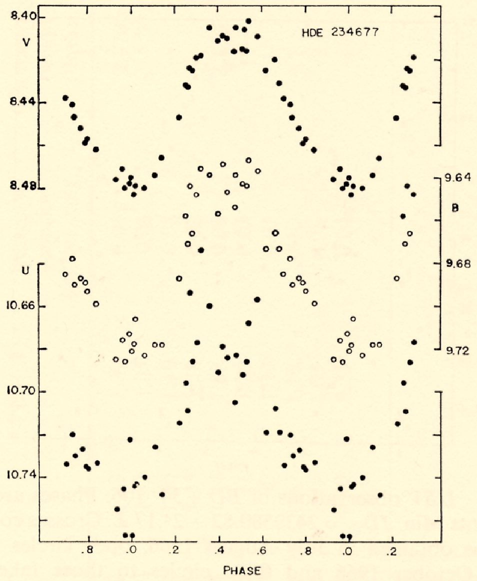

FIGURE 2 *UBV* observations of HDE 234677 in 1966. Phases are calculated from elements Min. $JD_{\odot} = 2439033.48 + 3^{d}.836\ E$.

BY Dra

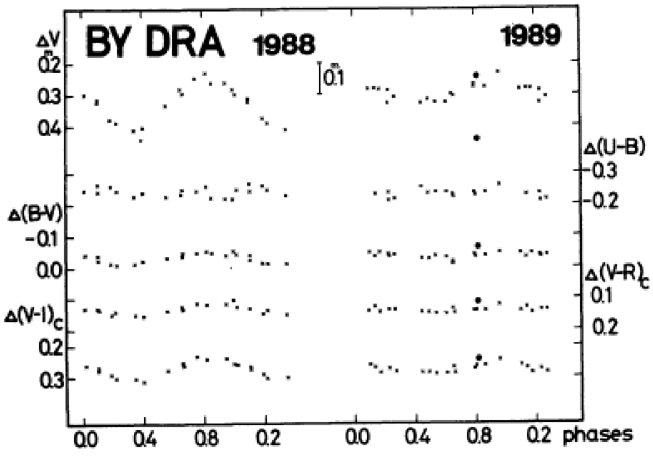

Figure 1: Top: An early light curve of HDE 234677 by Krzeminski (1968) from 1966. The star at that time did not have variable star designation. In the right corner L. Detre's handwriting is seen marking the name BY Dra of the variable. Bottom: Five colour observations of BY Dra with the 1 m telescope (see Pettersen et al. 1992).

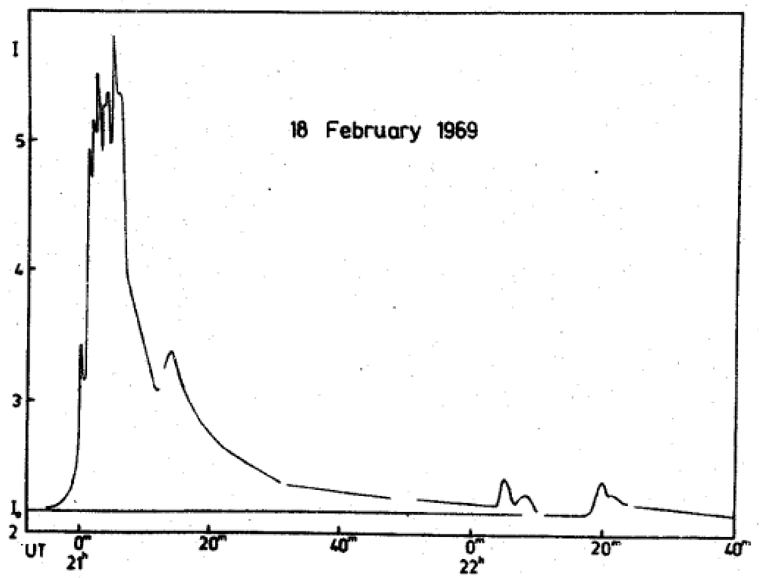

Figure 2: A flare of AD Leo observed by the 60-cm telescope of the Konkoly Observatory (Szeidl 1969).

Thus, the beginnings of stellar activity research is strongly connected with the Konkoly Observatory. It started with the rediscovery of starspots by Chugainov (1966) published in the *Information Bulletin on Variable Stars*, continued with publishing many observations there, and finished with Hall's (1976) historical talk. L. Detre played an active role in all of these.

Thirty years have passed already, and during all these years stellar activity research has been continuously developing. Simultaneously with the delivery of Hall's (1976) talk studying active stars began at the Konkoly Observatory as well, and the author of this paper, who talked about spotted stars with L. Detre as a student, finally got this subject as a lifetime project from B. Szeidl. It was a unique possibility to take part in a research field from its very beginning. At present, mapping stellar surfaces is a routine task. *Figure 6* shows the surface of an active giant star derived from spectral line profile analysis (Doppler imaging) and the modelled brightness variation from photometric measurements made in four colours by Oláh et al. (2002).

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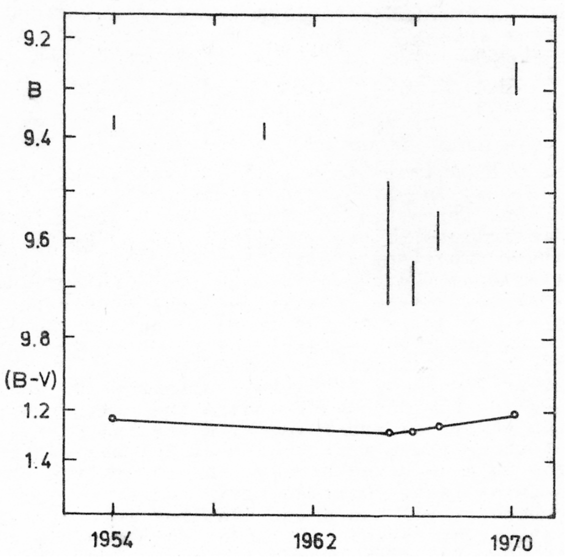
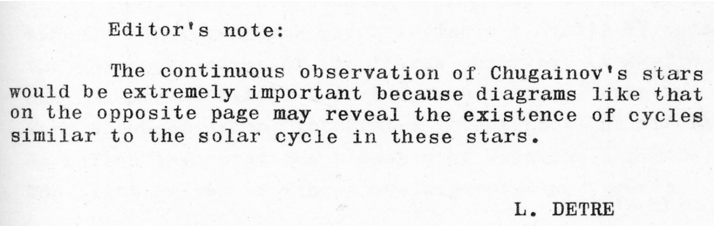



Editor's note:

The continuous observation of Chugainov's stars would be extremely important because diagrams like that on the opposite page may reveal the existence of cycles similar to the solar cycle in these stars.

L. DETRE

BY Dra light curve between 1964 - 1993

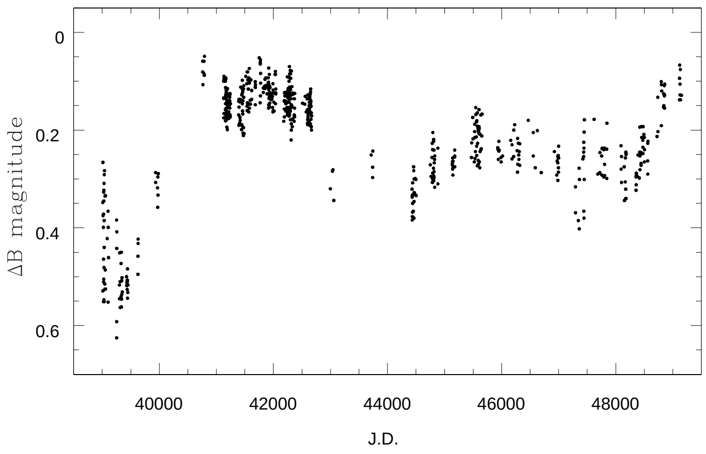
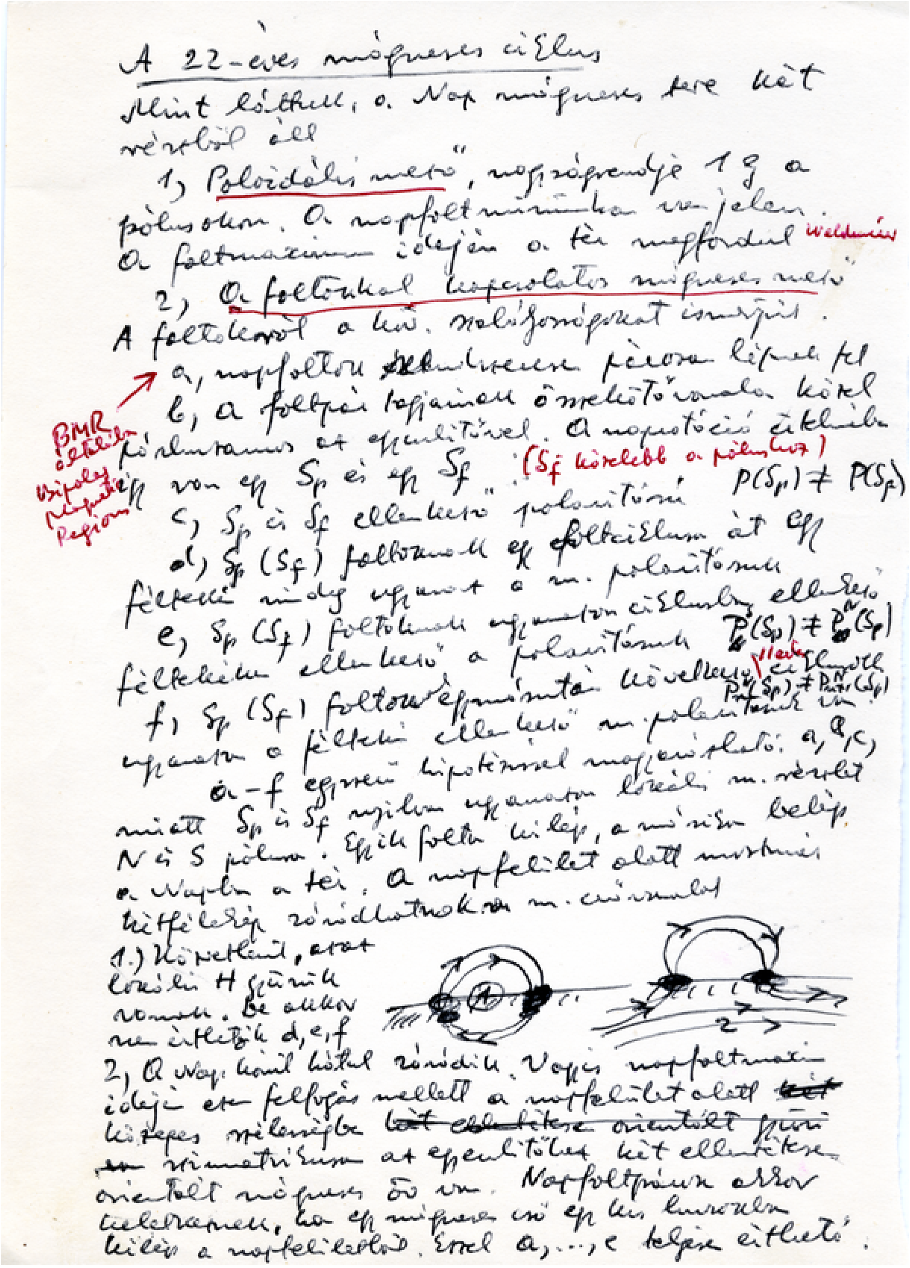


Figure 3: Top: Long-term brightness change of BY Dra by Chugainov (1971), and L. Detre's editorial note, commenting the figure. Bottom: the brightness change of BY Dra during almost 30 years, from the literature.



A 22-éves mágneses ciklus

Mint láttuk, a Nap mágneses tere két részből áll

1, Poloidális mező, nagyságrendje 1 g a pólusokon. A napfoltminimumkor van jelen. A foltmaximum idején a tér megfordul Waldmeier

2, A foltokkal kapcsolatos mágneses mező. A foltokról a köv. szabályszerűségeket ismerjük.

BMR
[illegible]
bipolar
magnetic
Region

a, napfoltok ~~[illegible]~~ [illegible] párosan lépnek fel

b, a foltpár tagjainak összekötő vonala közel párhuzamos az egyenlítővel. A [illegible] van egy S_p és egy S_f. (S_f közelebb a pólushoz) $P(S_p) \neq P(S_f)$

c, S_p és S_f ellenkező polaritású

d, S_p (S_f) foltoknak egy foltciklus át egy féltekén mindig ugyanaz a m. polaritásuk

e, S_p (S_f) foltoknak ugyanazon ciklusban ellenkező féltekén ellenkező a polaritásuk $P^N(S_p) \neq P^S(S_p)$

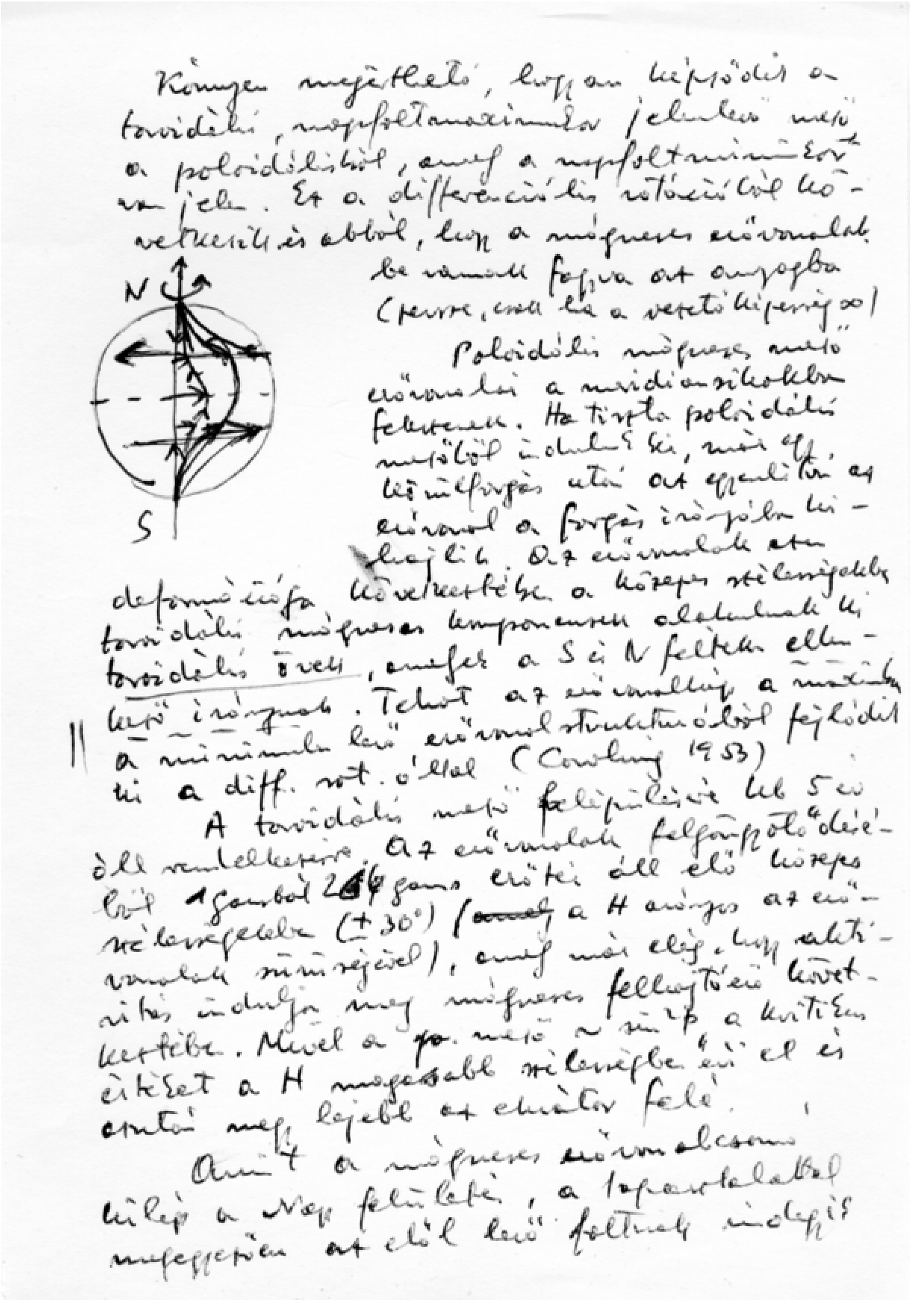
f, S_p (S_f) foltok egymásután következő ciklusokban Hale [illegible] $P_n^N(S_p) \neq P_{n+1}^N(S_p)$ polaritásuk van. ugyanazon a féltekén ellenkező m. polaritásuk [illegible] a, b, c,

a-f egyszerű hipotézissel [illegible] lokális m. [illegible] miatt S_p és S_f [illegible] ugyanazon [illegible] N és S pólus. Egyik foltnál kilép, a másiknál belép. [illegible] a Napban a tér. A napfelület alatt [illegible] kétféleképp származhatnak m. [illegible]

1.) Közvetlenül, azaz lokális H gyűrűk vannak. De akkor nem értelmezik d, e, f

2, A Nap körül [illegible] záródik. Vagyis napfoltmaximum idején [illegible] mellett a napfelület alatt ~~két~~ közepes szélességben ~~két ellentétesen orientált [illegible]~~ ~~[illegible]~~ szimmetrikusan az egyenlítőhöz két ellentétesen orientált mágneses cső van. Napfoltpárok akkor keletkeznek, ha egy mágneses cső egy kis hurokban kilép a napfelületből. Ezzel a,...,e teljesen érthető.

Figure 4: Excerpt from L. Detre's handwritten notes preparing the university classes, about the solar cycle (in Hungarian).



Könnyen megérthető, hogyan kifejlődik a toroidális, napfoltmaximumban jelentkező mező a poloidálisból, amely a napfoltminimumkor van jelen. Ez a differenciális rotációból következik és abból, hogy a mágneses erővonalak be vannak fagyva az anyagba (persze, csak ha a vezetőképesség ∞)

Poloidális mágneses mező erővonalai a meridiánsíkokban feküsznek. Ha tiszta poloidális mezőből indulunk ki, már egy körülfordulás után az egyenlítőn az erővonal a forgás irányában kihajlik. Az erővonalak ezen deformációja következtében a közepes szélességeken toroidális mágneses komponensek alakulnak ki, toroidális övek, amelyek a S és N féltekén ellenkező irányúak. Tehát az erővonalkép a maximumban
|| a minimumban levő erővonalstruktúrából fejlődik ki a diff. rot. által (Cowling 1953)

A toroidális mező felépülésére kb 5 év áll rendelkezésre. Az erővonalak felgombolyódásából 1 gaussból 24 gauss erőtér áll elő közepes szélességekben (±30°) (~~amely~~ a H arányos az erővonalak sűrűségével), amely már elég, hogy aktivitás induljon meg mágneses felhajtóerő következtében. Mivel a po. mező ~ sin²φ a kritikus értéket a H magasabb szélességben éri el és [illegible] meg lejjebb az ekvátor felé.

Amint a mágneses erővonalcsomó kilép a Nap felületén, a tapasztalattal megegyezően az elöl levő foltnak [illegible]

Figure 5: Same as *Fig. 4*, about the poloidal and toroidal magnetic fields, and the differential rotation of the Sun (in Hungarian).

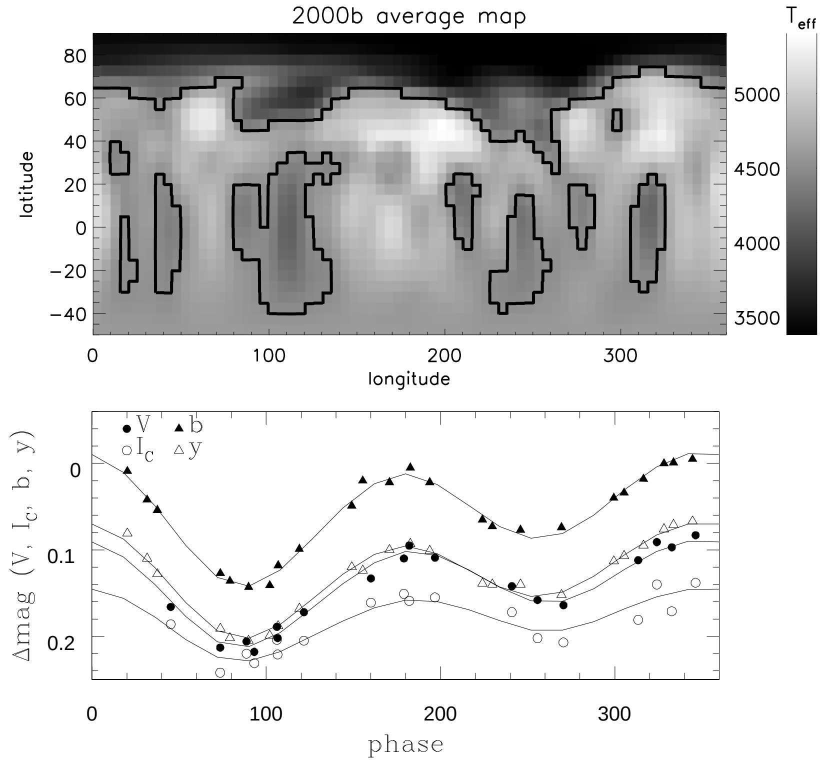


Figure 6: An example for the recent possibilities for modelling stellar surface structure: a surface temperature distribution map (Doppler image) of UZ Lib from high resolution spectra, and modelled light curves in 4 colours, for the same time interval (Oláh et al. 2002).

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Spectroscopic studies of star forming regions

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This paper reviews the results of studies of star forming regions, carried out at the Konkoly Observatory in the last two decades. The studies involved distance determination of star-forming dark clouds, search for candidate pre-main sequence stars, and determination of the masses and ages of the candidates by spectroscopic follow-up observations. The results expanded the list of the well-studied star forming regions in our galactic environment. Data obtained by this manner may be useful in addressing several open questions related to galactic star forming processes.

Introduction

The first instrument of the Piszkéstető Observatory, the 60/90/180 cm Schmidt telescope with two objective prisms has been a precious part of Detre's legacy. We inherited with this instrument a challenge to probe new paths of research, inspired by the attributes of the Schmidt telescope, and use techniques apparently very different from those of variable star researches, our most important scientific heritage.

The telescope with its field of view of 5 degrees was suitable for performing homogeneous, moderate-accuracy photographic photometry and low-dispersion slitless spectroscopy of large number of stars simultaneously. Traditional topics for Schmidt telescopes equipped with objective prisms included studying the space distribution of the stars and the light-absorbing diffuse matter in our galactic neighbourhood. Detre's early paper (Dunst, 1929) testifies that this subject was close to his scientific interest at the beginning of his career. Searching for objects of peculiar spectra in objective prism plates is another suitable project for this instrument. This kind of study has to be followed by slit spectroscopy of the selected objects, in order to establish their real nature. Galactic star forming regions, extending over large volumes of space and containing large amount of interstellar gas and dust, as well as young stellar objects of emission spectra are suitable targets for both kinds of Schmidt surveys. During the past two decades several star forming regions were discovered and studied using the Schmidt telescope with the 5-degree objective prism. The studies included distance determination and identifying optically visible pre-main sequence stars. The follow-up spectroscopic studies of the candidate pre-main sequence stars have been performed with larger telescopes available thanks to the OPTICON project. In this paper I introduce some star forming regions whose basic properties have been determined using the Schmidt telescope at Piszkéstető.

Star forming regions

- *Open issues of star formation*

Several important properties of the star forming processes can be understood only by comprehensive, large-scale, multi-wavelength studies of star forming regions. For instance, complete mapping and detailed photometric and spectroscopic studies of the young stellar population are required for establishing the stellar initial mass function, the age distribution of young stars, and studying the time scale of star formation. Both the star forming cloud and the stars born in it have to be mapped in order to study the efficiency of the star forming process and its propagation within the cloud.

Another group of open questions cannot be answered by detailed studies of a single nearby star forming region, but requires comparison of several regions. Which properties of molecular clouds influence the time scale and efficiency of star formation, the clustered and isolated modes, and the mass spectrum of the newborn stars? How does the early evolution of the stars depend on the environment of the star formation? Is star formation a fast and dynamic process governed by supersonic turbulence or rather a slow, quasistatic process controlled by static magnetic fields? To answer these questions, the stellar content of several star forming regions has to be assessed, and then the mass and age distributions of young stellar objects over the whole area of the star forming region, as well as the spectral energy distribution, characterizing the circumstellar environments of the young stars have to be determined.

- *Scope of our researches*

In the 1980's the development of the millimetre-wave radio astronomy led to the discovery of a large population of molecular clouds outside the galactic plane ($|b| > 10^{\circ}$). Part of them are smaller and more transparent than their galactic plane siblings. The discovery of the new molecular clouds aroused new problems: How far are the newly discovered molecular clouds from us? Do they form low-mass stars? Objective prism observations of the molecular cloud regions and follow-up spectroscopy provide the most suitable means of finding the answers to the questions.

We selected for studies molecular clouds which have already been mapped in ^{12}CO or/and ^{13}CO. Some of the target clouds also have shown evidence of low-mass star formation, e.g. embedded *IRAS* sources are associated with them. These clouds certainly contain a less conspicuous population of young pre-main sequence stars. The goal of our studies is to derive some basic properties of the selected star forming regions: to determine their distances, to assess the number of pre-main sequence stars, as well as to estimate their mass and age distributions. The first steps of the studies were based on objective prism observations using the 60/90/180 cm Schmidt telescope of the Konkoly

Observatory. Follow-up observations of the candidate pre-main-sequence stars have been carried out with various optical telescopes.

Methods

- *Distance determination*

In determining distances to nearby molecular clouds their interactions with the light of embedded or background stars can be utilized. While distances of normal stars can be determined from their apparent and absolute magnitudes (spectral types and colours), no properties of dark clouds indicate how far they are located from us. This is especially true for nearby clouds, whose galactic orbital velocities are close to the solar value. Neither the young, embedded stars are good distance indicators, because their luminosities strongly decrease during the pre-main sequence evolution. Extinction of starlight by the dust content of the cloud, interstellar absorption lines in the spectra of background stars, and embedded stars illuminating reflection nebulae can be used for distance determination. Distance is a basic data, which is important for determining the size and mass of the cloud, and the absolute luminosities of young stars.

In order to determine the distances of the selected clouds we examined the cumulative distribution of the field star distance moduli along the line of sight to the clouds. If $y = V - M_{\mathrm{V}}$ is the distance modulus of the stars, and $N(y)$ denotes the number of stars whose distance modulus is smaller than y (i.e. brighter than $V = M_{\mathrm{V}} + y$), then the distance modulus for distances smaller than that of the obscuring cloud can be written as $y = V - M_V = 5 \log r - 5$, whereas behind the cloud it is $y = 5 \log r - 5 + A_V$, where A_V is the visual extinction caused by the cloud. Thus the presence of a cloud along the line of sight shows up as a distortion in the shape of the $logN(y)$ *vs.* y curve (*Wolf diagram*), and its distance modulus can directly be read from the diagram.

The absolute magnitudes of stars were estimated from their objective prism spectral types. The spectra were obtained with the Schmidt telescope of the Konkoly Observatory equipped with a UV-transmitting objective prism having a refracting angle of 5° and a dispersion of 580 Å/mm at Hγ. The field of view of the telescope was 19.5 square degrees. Absolute magnitudes of stars belonging to different spectral classes were taken from Allen (1973) and Cox (1999). For calculating the apparent distance moduli $V - M_{\mathrm{V}}$ of the stars the V magnitudes listed in the *Guide Star Catalog* were used.

In this manner the distances of the dark clouds L 694 (Kawamura et al., 2001), L 1228, L 1235, L 1241, L 1251, L 1261 (Kun, 1998), L 1333 (Obayashi et al., 1998), and L 1340 (Kun et al., 1994) were determined. During this work spectral types of some 5000 stars have been determined visually, on objective prism plates.

An example for the Wolf diagram, showing the distribution of stellar distance moduli in the region of L1333, is shown in *Fig. 1.* The number of stars is normalized to one square degree. Filled circles connected by solid line show the cumulative distribution of distance moduli determined for a field of 19 square degrees centered on the cloud, and the dashed line is the reference curve displaying the same distribution without extinction at the galactic latitude of the cloud, +15°. The error of this kind of distance determination can be estimated as ± 10 percent, from the accuracy of spectral classification and the GSC magnitudes, as well as from the number of stars involved in the curves (Obayashi et al., 1998).

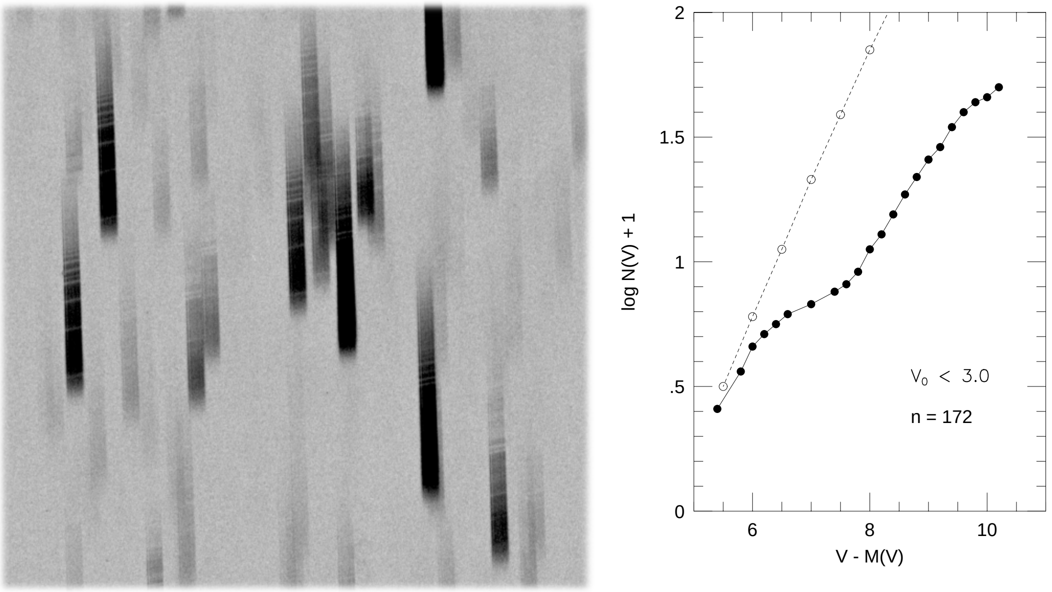

Figure 1: *Left*: Part of a blue-sensitive (emulsion type IIaO) objective prism plate obtained with the Schmidt telescope through the 5-degree prism. *Right*: Plot of $logN(V)$ vs. $V - M_V$ for the stars with $M_V < 3.0$. *N(V)* is the number of stars with apparent magnitudes brighter than V within 1 deg^2. The dashed line indicates the absorption-free reference curve.

- *Search for candidate pre-main sequence stars*

I have been searching for pre-main sequence star candidates using objective prism spectra taken with the Schmidt telescope through a red filter. The dispersion of the objective prism is about 2000 Å/mm at Hα. *Fig. 2* shows an example of a plate taken through a red (Schott RG 1) filter. *Fig. 3* shows examples of the objective prism spectra of various Hα emission objects obtained with the Photometrics CCD camera installed on the Schmidt telescope. The wavelength scale of the very low dispersion spectra was established in possession of the geometric and optical properties of the prism and camera, and using the atmospheric A-band at 7600 Å as reference wavelength. The quality of such a low dispersion slitless spectrum highly depends on the atmospheric conditions. This method is suitable for finding classical T Tauri stars, displaying strong Hα emission (EW(Hα) $\geq$10 Å). In addition to the objective prism spectra, infrared point sources of the *IRAS* Point Source Catalog and Faint Source Catalog were used to find further pre-main sequence stars born in the selected clouds.

- *Spectroscopic follow-up observations*

The real nature of the selected stars has to be established by medium-resolution spectroscopic follow-up observations. We performed spectroscopic observations of a few regions studied earlier with the objective prism using different telescopes and instruments: the *Intermediate Dispersion Spectrograph* on Isaac Newton Telescope, La Palma, *CAFOS* on the 2.2 m telescope of Calar Alto Observatory, as well as *ALFOSC* on the Nordic Optical Telescope. The spectra were used for determining the spectral types of the stars and

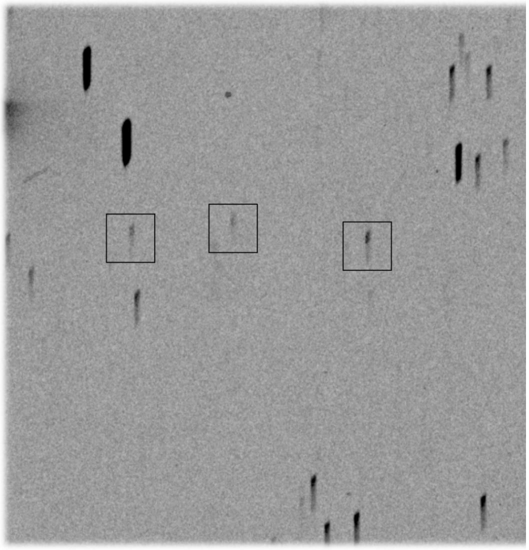

Figure 2: Objective prism image of the northern core of the dark cloud Lynds 1251. Part of a plate taken on Kodak 098-02 emulsion and through an RG1 filter with an exposure time 60 min. The images of three Hα emission stars are framed.

for establishing their pre-main sequence nature. Criteria for classification are described in Kirkpatrick et al. (1991), Preibisch et al. (2001), and Martín & Kun (1996). Several candidate pre-main sequence stars proved to be field stars without Hα emission. Nevertheless, a number of classical T Tauri stars were found in molecular clouds where no pre-main sequence stars had been identified earlier.

Results

- *Low-mass star formation in small molecular clouds*

Star forming molecular clouds tend to be parts of giant molecular complexes. The small translucent clouds found at high galactic latitudes usually are not associated with prominent signposts of star formation, such as far-infrared point sources. Our objective prism search for pre-main sequence stars at high galactic latitudes in most cases had negative results: spectroscopic follow-up observations have not confirmed the pre-main sequence nature of the candidate stars picked up from the photographic plates (Martín & Kun, 1996). The following sections show a few exceptions.

— *The Lynds 134 complex*

The members of this complex are the small dark clouds L 134, L 169, L 183, L 1780, located at a distance of 110 pc from us (Franco, 1989). No star formation was found earlier in the L 134 complex. The first star formation signpost in this region was the very low mass, young T Tauri star (spectral type: M 5.5IV) found during our survey (Martín & Kun, 1996) at an angular distance of 5 arcmin (0.16 pc) from the dense core L 183i (Laureijs et al., 1995). The radial velocities of the cloud and the star are close to each other, suggesting that the star was born in the cloud a few million years ago. The pre-protostellar condensations revealed recently in the same cloud by far-infrared and submm observations (Lehtinen et al., 2003) indicate ongoing star formation in L 183.

We found a binary system of very low mass, weak-line T Tauri stars (spectral types: M4V and M5IV) in the same region, to the west from the cometary cloud L 1780. The

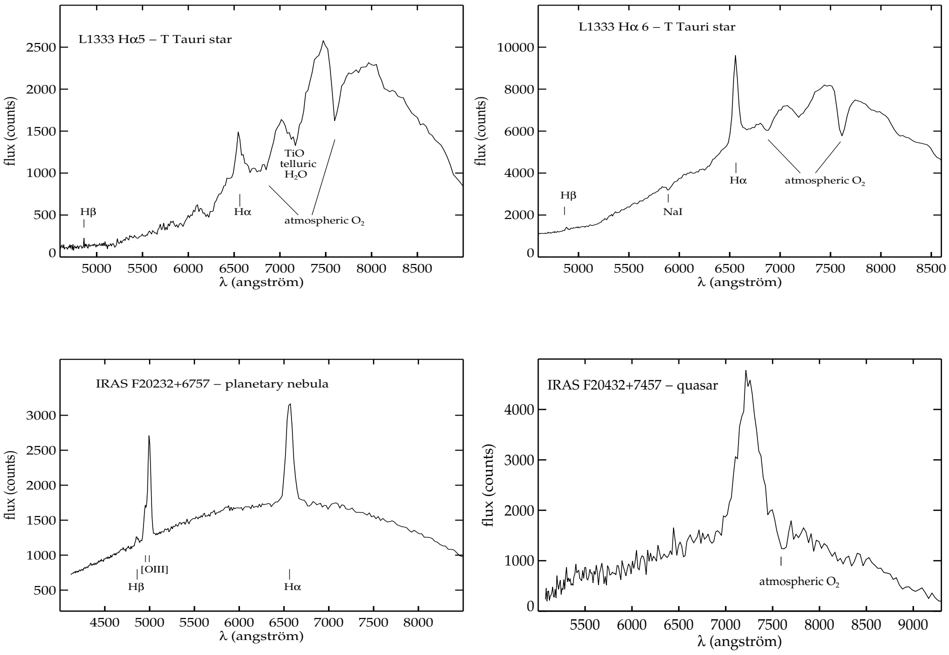

Figure 3: Objective prism spectra of various objects shown up as Hα emission stars. Position of the Hα line and the A-band of the atmospheric oxygen are indicated.

morphology of the region suggests that both the cometary shape of L 1780 and the formation of the low-mass stars were triggered by stellar winds form the Sco-Cen association (see Tóth et al., 2003).

— *IC 2118*

IC 2118 is an extended reflection nebulosity at high galactic latitude ($27^\circ < b < 33^\circ$), illuminated by β Orionis. It is situated at a distance of 210 pc from the Sun, and at some ten degrees to the west from the Orion star forming region. The bright nebula is associated by several small molecular clouds (Kun et al., 2001), among others MBM 21 and 22 (Magnani et al., 1995). Two young stellar object (YSO)-like *IRAS* sources, *IRAS* 04591$-$0856 and *IRAS* 05050$-$0614 are indicative of ongoing low-mass star formation in this region. Follow-up spectroscopic studies of our Hα emission stars selected as pre-main sequence star candidates, performed with the *ALFOSC* spectrograph on Nordic Optical Telescope, resulted in the discovery of five classical T Tauri stars (cTTS) projected on the molecular clouds (Kun et al., 2004). Their distribution is shown in the left panel of *Fig. 4*, overlaid on the *IRAS* 100μm image of the region. The spectra and the JHK photometric data of the 2MASS All Sky Survey (Cutri et al., 2003) made it possible to determine the effective temperature T_{eff} and luminosities $L/L_\odot$ of the young stars. The spectra of the T Tauri stars of IC 2118 are shown in the right panel of *Fig. 4*, and their positions in Hertzsprung–Russell diagram can be seen in *Fig. 5*.

The molecular clouds associated with IC 2118 are among the smallest known star form-

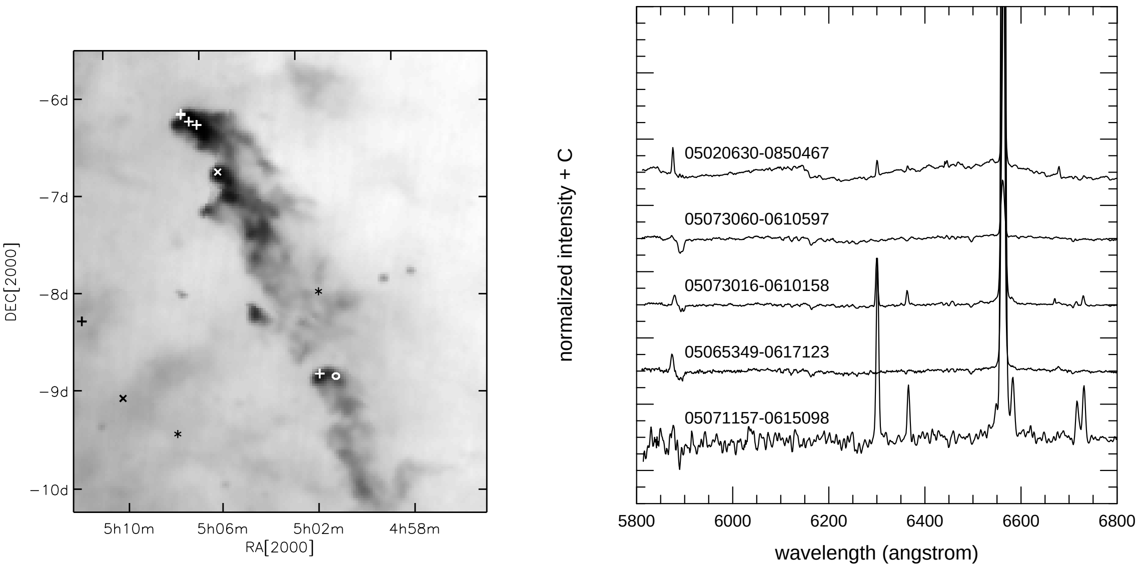

Figure 4: *Left*: Distribution of classical T Tauri stars on the 100μm IRAS map of IC 2118. *Right*: Optical spectra of classical T Tauri stars in IC 2118 over the wavelength region 5800–6800 Å.

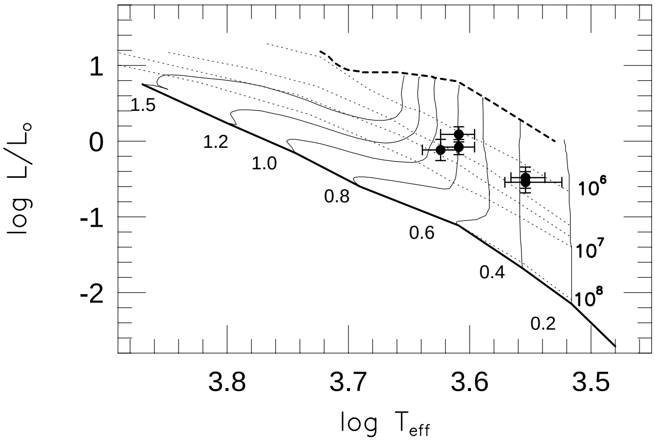

Figure 5: Location of the IC 2118 pre-main-sequence stars in the Hertzsprung–Russell diagram, together with the pre-main-sequence evolutionary tracks and isochrones published by (Palla & Stahler, 1999).

ing clouds. They probably lie near the surface of the *Orion–Eridanus Bubble*, being blown by the stellar winds and supernova explosions of the massive stars of Orion OB1 during the past ten million years. Given the large line-of-sight distance between the clouds and Orion OB1, star formation in this region propagates not only from the east to the west, but also towards us. The ages of the pre-main sequence stars found in the clouds are compatible with the assumption that star formation has been triggered by the superbubble. The complicated geometry and wind history of the OB association (Brown et al., 1995) hinders any detailed speculation on the exact position and age of the sources of trigger. Recently observations by the Spitzer Space Telescope revealed several very low mass young stars in these clouds.

- *L 1333*

L 1333 is a small dark cloud in Cassiopeia. The basic properties of the cloud and its environment were studied by Obayashi et al. (1998) within the framework of the collaboration between the Konkoly Observatory and the Radio Astronomy Laboratory of Nagoya University. We obtained a distance of 180 ± 30 pc for the cloud. ^{13}CO and C^{18}O observations revealed that the dark cloud is a part of a filamentary molecular complex, consisting of small dense clumps separated by some 6 pc from each other along a narrow line. The total mass of the complex, determined from the molecular observations, is about 720 $M_{\odot}$. Star formation is indicated by the protostellar-like *IRAS* source *IRAS* 02086+7600. Our objective prism and subsequent spectroscopic studies of L 1333 (Kun et al., 2006) revealed four classical T Tauri stars in the region of L 1333, associated with the *IRAS* sources F02084+7605, 02103+7621, and 02368+7453. One of the *IRAS* sources, *IRAS* 02103+7621 (OKS Hα6 in Obayashi et al., 1998) proved to be a visual binary, whose both components are cTTS, separated by about 1.8 arcsec (corresponding to $\sim$ 320 AU at 180 pc).

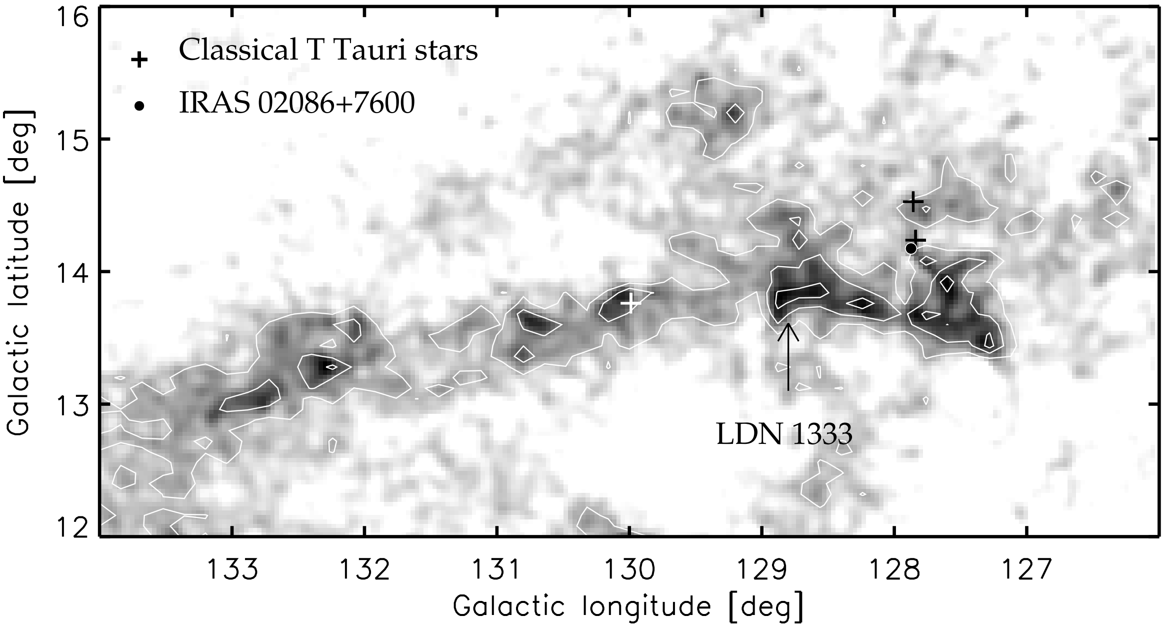

Figure 6: Distribution of the visual extinction and the young stars in the region of L 1333.

The positions of the young stars mark two star-forming clumps along the filamentary cloud complex. Compared to other nearby star forming regions these star forming clumps are very small, similar to those found at high galactic latitudes (24 $M_{\odot}$ and 15 $M_{\odot}$, respectively; Obayashi et al., 1998). The filamentary morphology of the cloud complex resembles the L 1495–B 211–B 213–B 216 system in Taurus, but the separation of dense clumps along the filament is larger, and the star formation efficiency is smaller in L 1333 than in Taurus. *Fig. 6* shows the distribution of the visual extinction in the region containing L 1333 (Dobashi et al., 2005). The position of the dark cloud and the young stellar objects are marked. *Fig. 7* shows the optical spectra of the young stars, obtained with the Nordic Optical Telescope, as well as their positions in the $\log T_{\mathrm{eff}}$ vs. $\log L$ diagram.

Like in IC 2118, the star forming cores of L 1333 are significantly smaller than those of other well known nearby star forming regions (e.g. Taurus, Ophiuchus, Chamaeleon, Lupus). Interestingly, the young stars are located on the high galactic latitude side of the

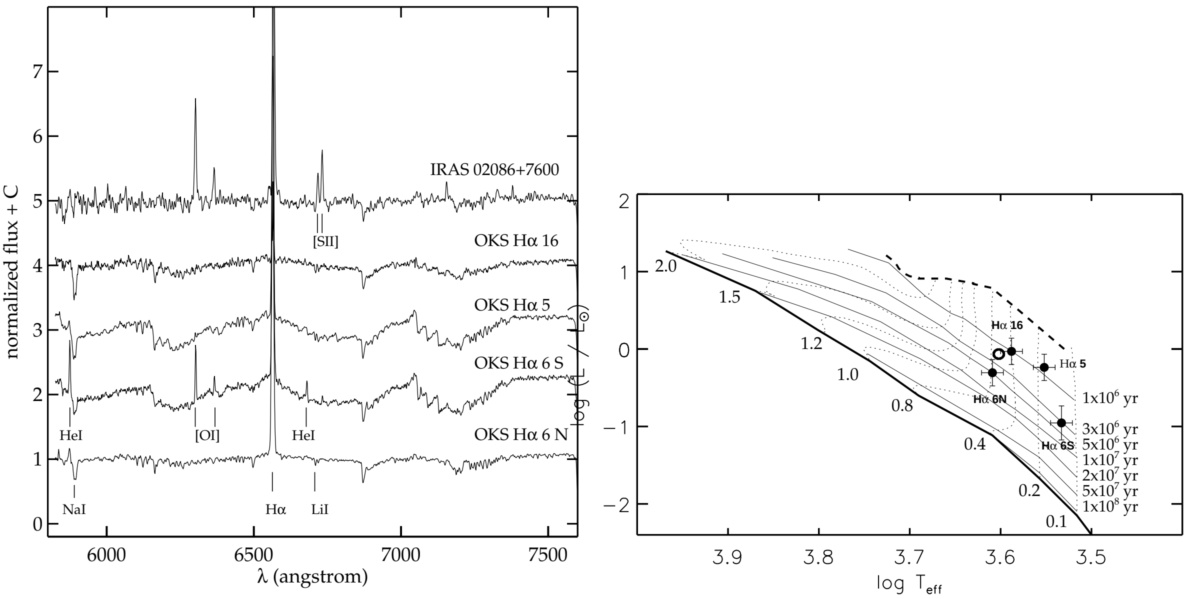

Figure 7: *Left*: Optical spectra of the young stellar objects in Lynds 1333. *Right*: Location of the same stars in the HRD, together with the pre-main-sequence evolutionary tracks and isochrones published by Palla & Stahler (1999).

cloud, so that the oldest member of the group lies farthest from the cloud. Star formation in such small clumps is thought to be assisted by an external trigger. The observed morphology of the L 1333 region suggests that the source of the trigger lies probably at the higher galactic latitudes (Kun et al., 2006).

- *The Cepheus flare giant molecular complex*

The interstellar matter in the Cepheus at $100^\circ < l < 120^\circ$ and $b > 10^\circ$ is distributed over large spatial and velocity range (see e.g. Heiles, 1967; Lebrun, 1986; Yonekura et al., 1999). Molecular gas has been observed in the radial velocity interval $-15\,\mathrm{km\,s^{-1}} < v_{LSR} < +5\,\mathrm{km\,s^{-1}}$ (Grenier et al., 1989; Yonekura et al., 1999). The nearby giant molecular complex of the Cepheus flare is comparable in mass with the Taurus, Ophiuchus, and Chamaeleon complexes.

I determined the distances of the absorbing clouds using optical star counts (Kun, 1998), and found three absorbing layers, located at 200, 300 and 450 pc from the Sun, and equally at $z \approx 90$ pc from the galactic plane. Farther away, at 600–800 pc from us, the outer regions of the associations Cep OB2 and Cep OB3 are projected on the southern part of the Cepheus flare. Our study of A-type stars of the region having far-infrared excess confirmed this space distribution of the clouds (Kun, Vinkó, & Szabados, 2000). This morphology suggests that the clouds are part of a larger interstellar structure parallel to the galactic plane. Recently, Olano, Meschin, & Niemela (2006) have shown that the interstellar matter in the Cepheus flare is distributed over the surface of an expanding shell. The presence of the shell can account for the different distances of the dark clouds of the region.

I detected more than a hundred candidate pre-main-sequence stars over an area of some 200 square degrees, covered by the clouds. Their distribution suggests that the three cloud complexes differ from each other in star forming activity. No high-mass star formation can be observed in the Cepheus flare region. Low-mass YSOs can be found in the component at 200 pc (L 1228) and in the 300 pc component (NGC 7023, L 1235, L 1251). The most distant component of the region can be found at the southern boundary of the complex. We searched for intermediate-mass pre-main sequence stars among the A and B type stars of the region exhibiting infrared excess, and identified a new Herbig Ae star, BD +68°1118 (Kun, Vinkó, & Szabados, 2000). This star, together with a neighbouring HAe star HD 203024, is projected on a relatively transparent region of the cloud complex close to the star forming globule L 1177 (CB 230).

Spectroscopic follow-up observations of the candidate pre-main sequence stars were carried out using the 2.2 m telescope of Calar Alto Observatory. BVR_CI_C photometric observations of the same stars are in progress. The first results are published by Eredics & Kun (2003).

- *L 1340: A region of intermediate-mass star formation*

It is well known that high mass stars are born as members of dense clusters in giant molecular clouds, whereas small, cold cores give birth to one or a few solar type stars. The transition from isolated to clustered mode of star formation occurs smoothly in molecular clouds forming intermediate mass stars.

Lynds 1340 is a molecular cloud in Cassiopeia, near (l,b)=(130,11), and associated with the reflection nebula DG 9 (Dorschner & Gürtler, 1966) illuminated by B and A-type stars. The small nebulosities RNO 7, 8, and 9 (Cohen, 1980), associated with the cloud, are probably signposts of recent star formation. We studied the structure and young stellar objects of Lynds 1340 in order to find how this birthplace of Herbig Ae/Be stars fits into the sequence of star forming environments.

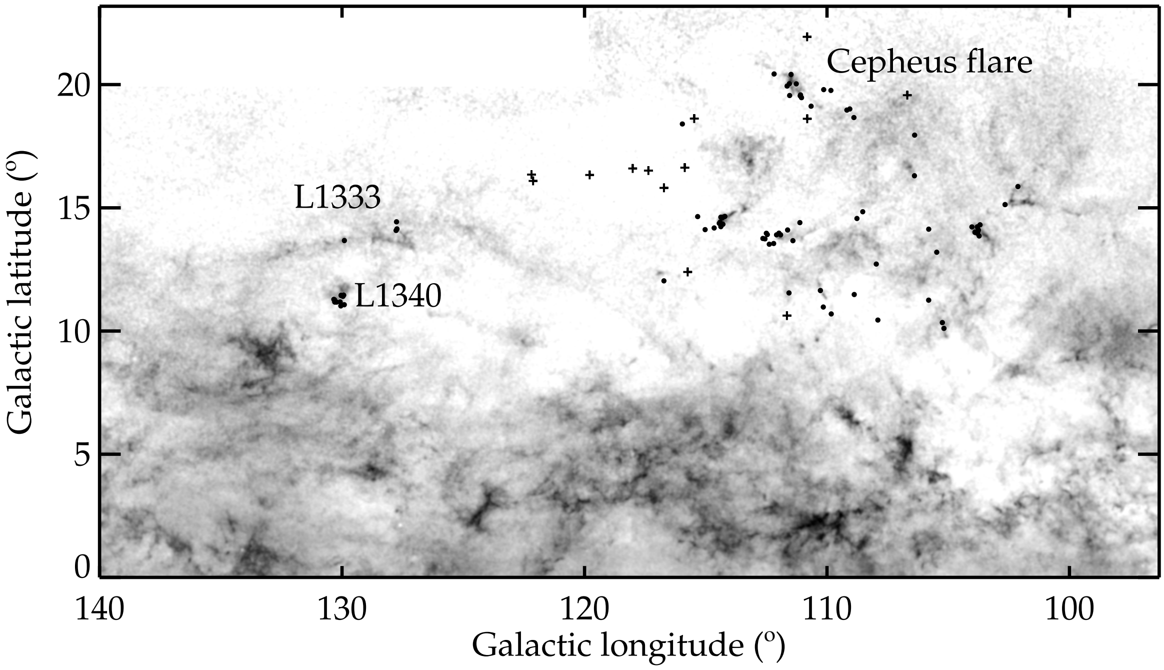

Figure 8: Distribution of the visual extinction and the young stars in the Cepheus–Cassiopeia region.

The basic properties of the cloud are studied within the framework of the collaboration between the Konkoly Observatory and the Radio Astronomy Laboratory of Nagoya University (Kun et al., 1994). ^{13}CO and C^{18}O maps of the cloud, obtained with the 4-m radio telescope of Nagoya University, distance determination, and a list of the candidate young stellar objects have been presented. The distribution of ^{13}CO has revealed three clumps within the cloud, each associated with a number of *IRAS* point sources and Hα emission stars. The total mass of the molecular cloud is some 1300 $M_{\odot}$. Follow-up spectroscopic, as well as optical and infrared photometric observations of L 1340 revealed that a star as massive as some 6 $M_{\odot}$ has been born in the cloud. This Herbig Be star is a member of the embedded cluster RNO 7, consisting of some 25 stars. Follow-up radio observations in the 1.3 cm inversion lines of the ammonia molecule have shown that several dense cores, future sites of star formation are embedded in L 1340 (Kun et al., 2003). Our results inspired several further studies of this interesting star forming region. For instance, Nanda Kumar et al. (2002) and Magakian et al. (2003) discovered several Herbig–Haro objects powered by the young stars embedded in the cloud. Submillimeter observations by O'Linger et al. (2006) revealed protostellar objects at very early stages of star formation.

The surface distribution of the young stellar objects in the Cepheus–Cassiopeia region at latitudes $b > +10^{\circ}$, discovered with the Schmidt telescope, is displayed in *Fig. 8* on the large-scale extinction map of the region (Dobashi et al., 1995).

Future prospects

The newly discovered nearby star forming regions are good targets for more sensitive observations, aimed at revealing the whole stellar populations born in them. Their comparison with the few well-known nearby star forming regions (Orion, Taurus, Chamaeleon, Lupus) may shed light on hidden laws of star forming processes. Further spectroscopic and photometric studies of the pre-main-sequence stars discovered will allow us to study some environmental effects of early stellar evolution.

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Flare star investigation – two decades of cooperative observational study in Budapest and Byurakan

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In 1969, when I got acquainted with the questions of flare phenomena, the investigation of these eruptive stars was over on the early stages of research. The first known flare star, DH Carinae, was discovered by E. Hertzsprung in 1924. Hertzsprung took plates for finding variable stars in the region of Carina and a flare of 1.8 magnitude was observed. Hertzsprung (1924) wrote in his note: “After the outburst, which took place on the third plate, the star lost about a magnitude in brightness in the course of about 1.3 hours.” This observation had been forgotten and only after the discovery of the UV Ceti was it brought to the center of attention. It is interesting that Hertzsprung tried to consider a mechanism which could explain the phenomenon: “A rough estimate indicates that a fall into the star of a body like a small planet would yield sufficient energy for an outburst as observed...”

In the following 15 years a whole range of authors reported on accidentally observed flare events. For example, in the Orion nebula several stars showing similar changes of brightness have also been discovered. Among the numerous reports on extremely sudden increase in the brightness of some stars Wachmann’s (1939) article was the first note on a flare event observed spectroscopically.

The star is now designated as V371 Ori. The lines of Balmer series were seen during the flare and the first small part of the trailed spectrogram was very intense followed with an abrupt drop in the spectroscopic continuum during the last part of the spectra (Wachmann, 1939).

Many of the flare stars were discovered during observations aimed at finding high proper motion stars. So the existing early data on the accidentally discovered flare stars are of a heterogeneous origin. The first observed flare stars were large proper motions objects in the vicinity of the Sun. They are low luminosity dwarf stars with spectral types of M0 or later and they have emission lines mainly of H and CaII during the normal state. The similarity of the observed features led van Maanen (1945) first to the idea that these stars may belong to the same class.

The field of flare star research really took off with the discovery of flares on Luyten 7268. The star had been known for its high proper motion and on 7 December 1948, E.F. Carpenter in Tucson made a multiple exposure plate for parallax purposes (see

Luyten, 1949). There are five consecutive exposures on the plate, each exposure took 4 minutes, while the total observation lasted about 20 minutes. The rapid increase in brightness of about two magnitudes, followed by a decrease of the same amount and all this happened in a 20 minute interval. From this moment it was clear that a new and until then unknown form of the brightness variation had happened and a new type of variable stars had been discovered. Today, the star is known as UV Ceti, the prototype of the flare stars. I have to mention, that three months earlier, even in September, Joy & Humason (1949) recorded the spectrum of UV Ceti during an eruptive change of brightness.

Also, as a class, the flare stars have spectral types of late M through late K, corresponding to the effective temperatures between about 2500 to 4000 K. They often have detectable emission lines of hydrogen and calcium in their spectra, indicating chromospheric activity. They have masses between 0.1 and 0.6 solar masses. Variability in the flare stars is characterized by rapid, irregular, large amplitude increases in stellar brightness, followed by a much slower decay (from minutes to hours) back to a quiescent level. Before the abrupt changes, a smooth light enhancement occurs in the continuum brightness. After this the really flare up takes only several seconds. The first part of the decay is also steep but slower than the brightening, which is followed by a longer lasting, quasi exponential part. The strongest variations occur in the blue and in the UV range: a flare may cause a one magnitude change in the V band, but more magnitudes in the U band. And during the flare event the star makes a loop on the colour-colour diagram. From the spectroscopic point of view, flares are typically accompanied by brightening of the emission line spectra of the star, particularly of the Balmer series of hydrogen, and the appearance of ionized helium lines as well. Flares have also been observed in the radio and X-ray regions of the spectrum, though they are not necessarily coincident with optical flares.

In 1945 Alfred Joy published a pioneering paper that initiated the study of emission-line stars associated with nebulosity. Ambartsumian (1947) showed that the bright-line variables are concentrated in certain regions where the star density is ten to one hundred times larger than in the neighbouring stellar fields. From this evident clustering of these objects Ambartsumian concluded that these stars had a definite genetic relationship and perhaps a common origin. Ambartsumian called these regions T-associations.

In 1953 Haro and Morgan reported on three rapid variables discovered in the Orion nebula. In rapid succession flare stars were found in other stellar aggregates and clusters of different ages – for example in NGC 2264, Pleiades, Coma, Praesepe, and Hyades clusters.

These flare stars in stellar aggregates radically changed the earlier picture based on the UV Ceti variables in the solar vicinity. Flares have been observed not only in Me dwarfs but also in stars of spectral type as early as K0, or earlier, and the absolute luminosities of these stars during quiescence correspond to cool subgiants as well as to dwarfs.

The *great flare hunting* started at the end of the 1960s. It was begun by Haro and his collaborators in Tonantzintla, and followed at Asiago – by Rosino –, in Byurakan – by a whole group of observers –, and in Budapest. The most intense observing campaign took place at the Byurakan observatory.

The Byurakan Astrophysical Observatory was founded in 1946 on Victor Ambartsumian's initiative. He became the first director of the observatory, and the main direction of astrophysical investigations – observational and theoretical aspects of stellar evolution – was determined by him. The scientific results came just after the foundation of the Byurakan Observatory. New type stellar systems, the stellar associations were discovered.

It was proved that stars are formed by groups. During 15 years intense observing campaign (until 1980) with wide-angle telescopes at the observatories Tonantzintla, Asiago, Byurakan, and Budapest for about 4000 hours of effective time of photographic observations nearly one thousand flare stars were discovered in several stellar aggregates of different ages. My contribution to this observational study was the comparative analysis of Pleiades and Praesepe clusters with about 400 hours effective exposure time, between 1971 and 1980. Photographic methods are usually unsuitable for photometric and colorimetric investigations of rapid variables. Nevertheless, a great number of flare events had been observed by this method. On the one hand, the multi-exposure plates taken with wide-field cameras are excellent means to discover that a change of brightness has taken place but it is not possible to determine the real amplitude of the flare event nor the correct light curve. On the other hand, the data obtained by the photographic method can be used excellently *for statistical investigations.*

Ambartsumian (1969) published the results of first statistical study based on the data of the first 60 Pleiades flare stars published by Haro. Suppose that the sequence of flares of any flare star is of the type of Poissonian stationary process with some mean frequency of occurrence, ν. Then it can be shown that the expected value, n_k of the number of stars that have flared k times during the total duration of observations, follows the relation:

$$n_k = \frac{n_{k+1}^2}{2n_{k+2}}$$

According to the definition, n_0 is the expectation of the number of flare stars that have not flared during the whole time of observation. In fact, it is the number of stars that are not yet discovered. Therefore adding this n_0 to the sum $n_1 + n_2 + ...$ of all stars observed in flares (this is the number of discovered flare stars), we can obtain the total number, N of flare stars in the given stellar aggregate:

$$N = \sum_0^\infty n_k$$

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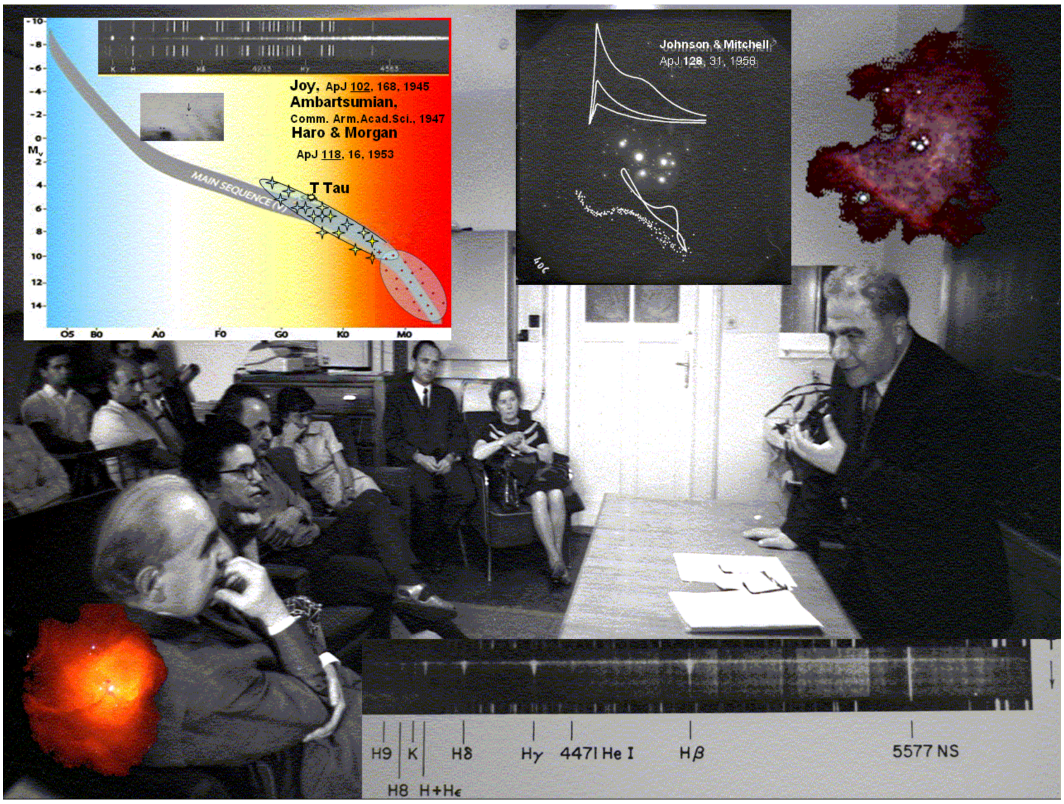

Figure 1: Ambartsumian's lecture for the staff of the Konkoly Observatory in 1969.

Active binary stars

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The study of active binary stars at the Konkoly Observatory started in the early 1970's. The director of the observatory *László Detre* and my chief *Béla Szeidl* proposed me to deal with binary stars. At that time it was possible to get one week observational time at the Piszkéstető Mountain Station each month. This possibility could be best used for stars with assumed characteristic light-curve changes on time scales of months. For variable star research we had the 50 cm Cassegrain telescope equipped with the photoelectric photometer designed and built by *Géza Virághalmy.* I prepared a list of eclipsing binaries with possible period and light-curve changes. This list contained more than a hundred items. In one week observational time – according to the given weather conditions – about three clear nights were expected. This means, that to get a complete light curve, the ideal orbital period of the target binary had to be near 0.5 days. For the optimal use of the one week per month observational possibility the whole year over, stars with high declination were preferred. Further point of view was that the target star should not be too bright, nor too faint for the given telescope-photometer combination.

The binary system SV Camelopardalis was on top of my list with nearly 10 mag brightness, 0.6 day orbital period, 82° declination and with suspected irregular period and light-curve changes on month's time scales. SV Camelopardalis is one of the closest systems of the short period group of RS CVn binaries. Basic data of the system are: $P_{\rm orb} = P_{\rm rot} = 0.5930$ day, $a = 4R_\odot$, $i = 89.6^\circ$, $r_2/r_1 = 0.64$, $r_1 = 1.3R_\odot$, $T_1 = 5750$K, $T_2 = 4500$K, $d = 74$ pc.

SV Cam proved to be a good choice. The system has been monitored at the Konkoly Observatory for more than 30 years, and the system did show interesting features like migration waves, optical flare events, moving dark and bright spots on the stellar surfaces. According to our measurements, the presence of a third component is also possible in the system.

The migrating distortion wave

Due to the close monitoring of the system it turned out that the reported "irregular light-curve changes" were not irregular. It turned out that there exists a distortion wave, rapidly moving with advancing phase. Former studies could not find this, as the observations were not frequent enough, and because the distortion wave was not always present in the system.

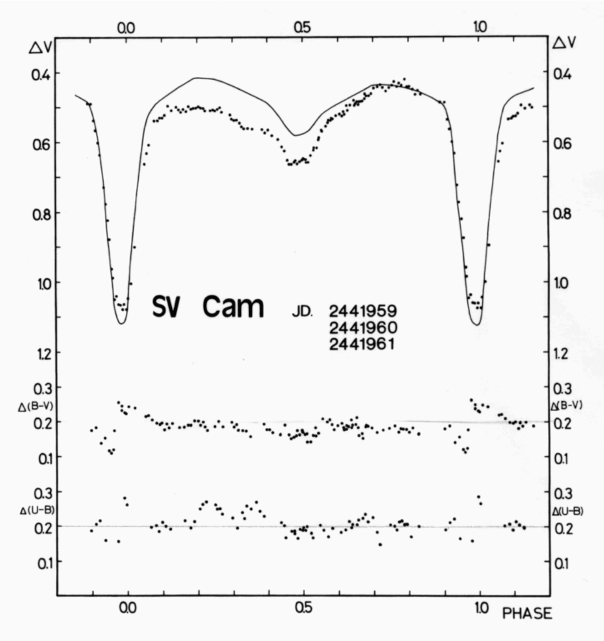

Figure 1: Light curve of SV Cam. The solid curve represents the unspotted reference curve, the points represent the observed brightness of the system. The measured points are below the reference curve, because large dark spots on the surface dim the brightness of the star. The centrum of the distortion wave is before phase 0.5.

The distortion wave is caused by dark spots on the surface of the brighter component of the binary star. In a close binary system – like SV Cam – the stellar rotation is synchronized to the orbital period. But differential rotation is also present. As there exists a co-rotational latitude, the forming distortion wave will move according to or against phase, depending on whether the spots are at higher or lower latitude than the co-rotational latitude. In the case represented in *Figs. 1* and *2* the distortion wave moved with growing orbital phase. This means, that the centrum of the spots which caused the wave was below the co-rotational latitude, consequently, the spots that caused the distortion were near the equator.

The amplitude of the observed waves sometimes exceeded 0.1 mag. (According to my observations migration waves in the system SV Cam do not always move as fast as in this example, and in the same direction either.)

Flare events in the optical range

Monitoring the system SV Cam – for the first time – optical flare events were measured in an RS CVn system. Optical flare events are very rare in RS CVn systems. Another example is the one observed by Zeilik et al. (1983) in the system XY UMa, which also belongs to the short period group of RS CVn systems.

I observed another optical flare event in the system SV Cam, but the three most pronounced events were observed in a single night at J.D. 2444582 during the whole – more than 30 years long – observational period (*Fig. 3*). This means, that the system was in an extraordinary enhanced activity phase around J.D. 2444582. The observed flare curves seem to be less asymmetric than usual, although the first one (near phase 0.6) was obviously the superposition of several different flares.

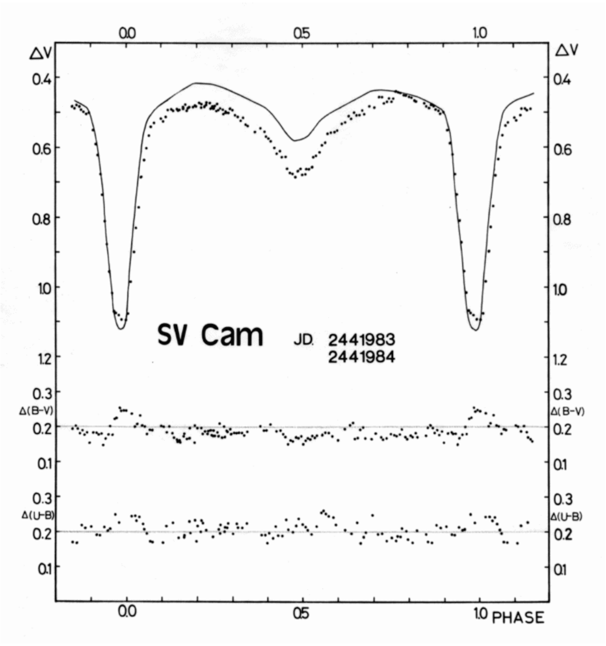

Figure 2: Just 3 weeks later, the centrum of the distortion wave is already near phase 0.5

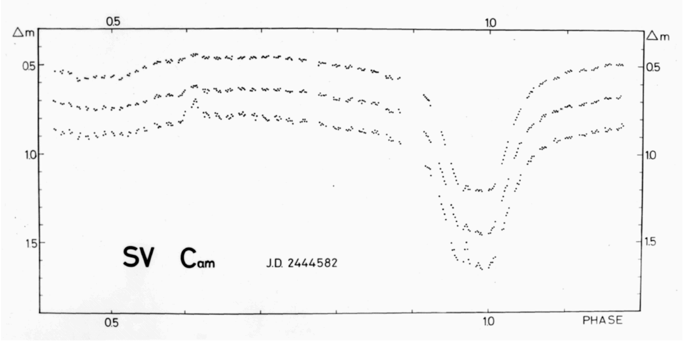

Figure 3: Three flare events on a single night (J.D. 2444582). The three (shifted) light curves are in V, B, and U band respectively. One (complex) flare was near the phase 0.6, the second and the third one at the bottom of primary minimum. The amplitudes were the largest in U and the smallest in V.

Bight spots on the primary component

As the migrating distortion wave was caused by dark spots on the stellar surface, all the observational points had to be below the reference curve which represents the totally unspotted case.

At J.D. 2442405 there were no spots on the stellar surface, measured light curve data fitted the reference curve. At J.D. 2442432 (one month later) the measured points still fitted the reference curve, but after another month points in the phase interval 0.2-0.7 were significantly higher. This means that the system suffered an exceptional brightening. This peculiar brightening was confirmed by the light curve observed five days later (at J.D. 2442466, *Fig. 4*).

After another two months (at J.D. 2442523) some residual brightening was still visible near the phase 0.5. The spot that might caused the brightening significantly diminished. In the light curve obtained four months later (at J.D. 2442634) we can see the start of a

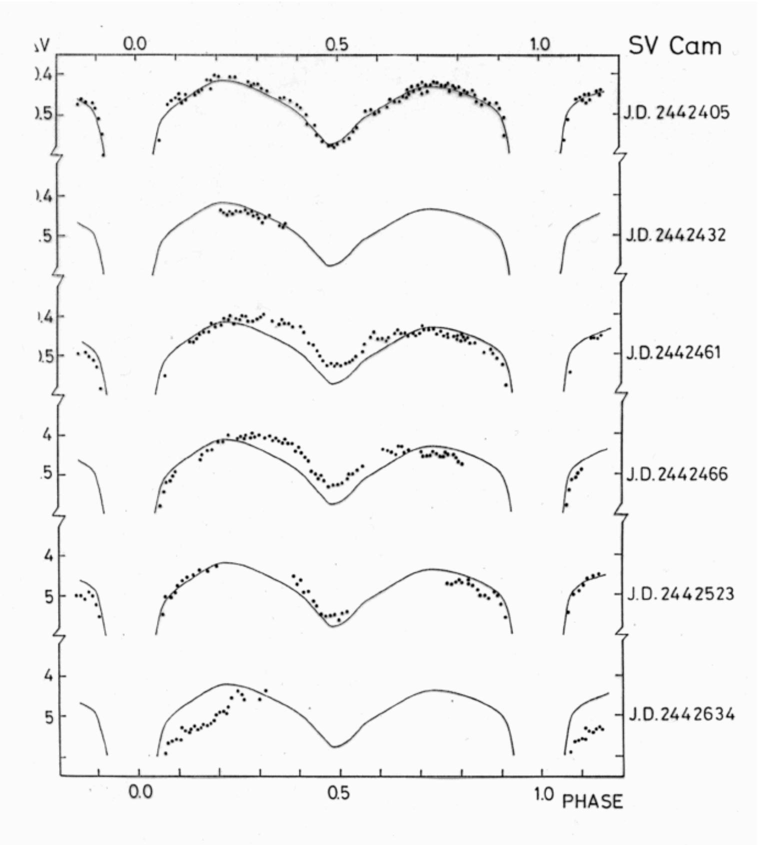

Figure 4: Parts of the light curves between J.D. 2442405-J.D. 2442634. (Points at or near the primary minimum are not plotted).

new distortion wave.

We analyzed the unusual brightening of SV Cam. A temporarily existing bright spot was supposed which appeared on the primary star of the binary system. A location near the stellar equator and the spot radius were derived. According to the analysis, the temperature difference between the spot and its surroundings was up to 110 K.

The existence of the spot might be related to an observed change of the orbital period. The suspected period change is depicted in *Fig. 5.*

Assuming that the observed phenomena were caused by an episodic mass transfer from the secondary to the primary component – the direction of the period change (period increase) is adequate. However, according to our own (Patkós & Hempelmann 1994) and other (e.g. Özeren et al., 2001; Albayrak et al., 2001; Kjurkchieva et al., 2002) investigations the Roche lobe of the secondary component of SV Cam was not completely filled.

Since 1973 the appearance of the bright hot spot on SV Cam around J.D. 2442461 was a particular event. But there are some other indications that bright spots do exist on the surface of the primary component. My observations indicate another (significantly less bright) spot (*Fig 6.*) at around J.D. 2441963-J.D. 2442019.

During the primary minima of SV Cam, the smaller, darker secondary component is moving in front of the larger and brighter primary. In that case a small part of the primary surface dominates the system's brightness. In contrast to this reduced brightness relatively smaller spots can be noticed. This was the case in the interval J.D. 2441963-2441984. At J.D. 2441963 a bright spot appeared near the edge of the visible part of the

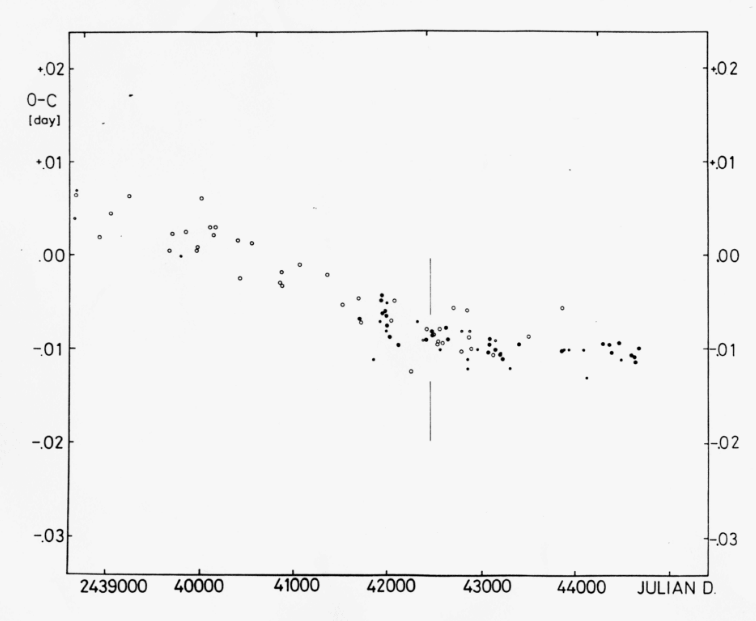

Figure 5: Part of the O−C diagram of the system SV Cam. Moment of the peculiar brightening is denoted by a vertical line. This seems to coincide with a break in the O−C curve. Black dots are minima measured by Patkós, open circles are minima from the literature.

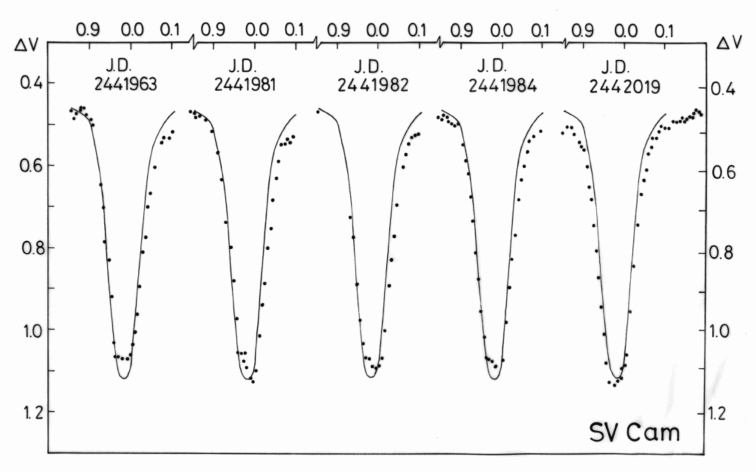

Figure 6: Primary minima of the SV Cam light curves between J.D. 2441963-J.D. 2442019. Solid lines represent the reference curve. At the bottom of the observed curves the measured points were higher than the reference curve at J.D. 2441963. At J.D. 2441981, 2441982, and 2441963 there was a significant step at the bottom. At J.D. 2442019 the points were again at the normal low level.

primary surface. This spot was present during the whole transit. The bottom of the primary minimum was therefore a bit brighter. Some days later (J.D. 2441981, 2441982, 2441984) the spot moved towards the central meridian. As result there was an abrupt step at the bottom of the primary minima when the dark secondary disk eclipsed the spot. Some days later the small bright spot moved further towards the central meridian and the bottom brightness of the system slid back to its original level.

In conclusion, bright spots do exist on the surface of the primary component of SV Cam, but they are not always bright enough to measure them against the whole stellar disk.

Activity minimum in the system SV Cam

The typical light curve of SV Cam is the one with the migrating distortion wave. It is a normal eclipsing light curve, but the measured points – in some phase interval – are below the usual brightness level because of the dark spots somewhere on the stellar surface. With the help of different spot solution methods (e.g. Wilson-Devinney code) it is possible to determine the parameters of the dark spots on the stellar surface. Then subtracting the effects of the dark spots we can get the unspotted eclipsing light curve suitable for the determination of the system parameters.

In the case of SV Cam – due to the data from the 33 years long monitoring – it was possible to choose a light curve (*Fig. 7*) which was almost completely free of maculation. (Stellar activity was at minimum or at least near to minimum). With the help of this light curve we could determine system parameters with a sufficient precision.

Photospheric-coronal connections in SV Cam

An important question in RS CVn studies is whether photospherically observed spots correlate with observed phenomena at other layers of the stellar atmosphere. To study spatial connections to other atmospheric layers we needed additional spectroscopic (Doppler imaging) and X-ray observations. As a result we could establish clear spatial correlations between the photosphere and corona.

We organized simultaneous X-ray, spectroscopic and optical observations of SV Cam. An international team was formed to establish spatial connections between photosphere and corona. Members of the group were A. Hempelmann (Astrophysikalisches Institut Potsdam, Germany), A.P. Hatzes (McDonald Observatory, The University of Texas at Austin, U.S.A.), M. Kürster (Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany), and L. Patkós (Konkoly Observatory of the Hungarian Academy of Sciences, Hungary).

We observed SV Cam photometrically between J.D. 2449254-J.D. 2449257 with the 50 cm telescope at Piszkéstető Mountain station of Konkoly Observatory. A second complete light curve was observed with the same instrument at J.D. 2449310-J.D. 2449311 (*Fig. 8*).

We observed SV Cam with the ROSAT PSPC in the X-ray spectral region 0.1-2.4 keV. The total exposure time, 35.5 ksec, between J.D. 2449225-J.D. 2449229 was split into eleven half-hour exposures and seven exposures lasting only a few minutes. The main part of these observations covered 3.5 consecutive binary orbits of SV Cam. The spectroscopic observations were carried out at Sandiford Cassegrain Echelle spectrograph of the 2.1 m telescope of McDonald Observatory. Because of some technical difficulties,

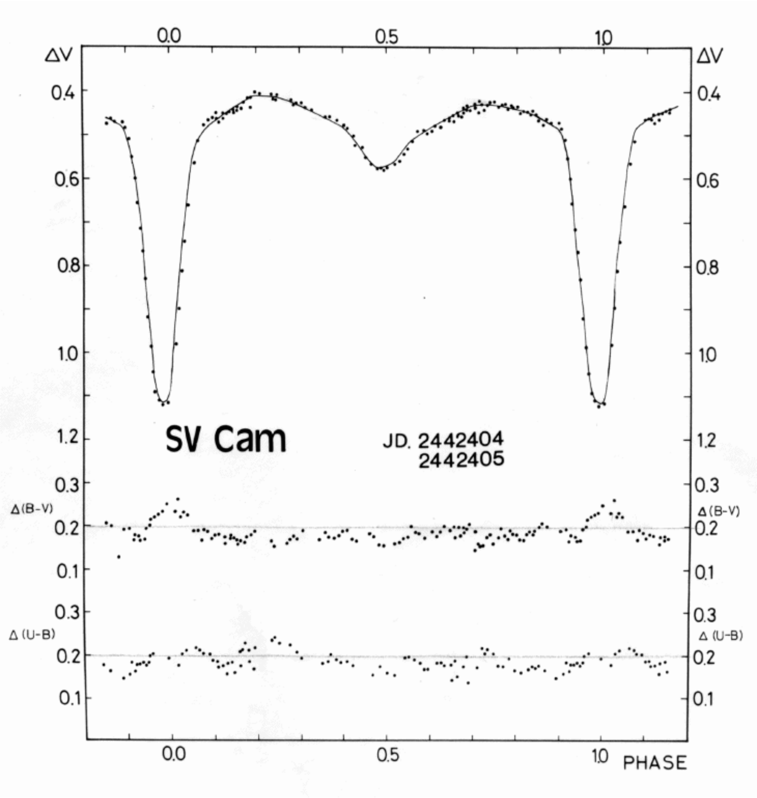

Figure 7: Light curve of SV Cam at J.D. 2442404-2442405. Measured brightness points nearly fit the unspotted reference curve.

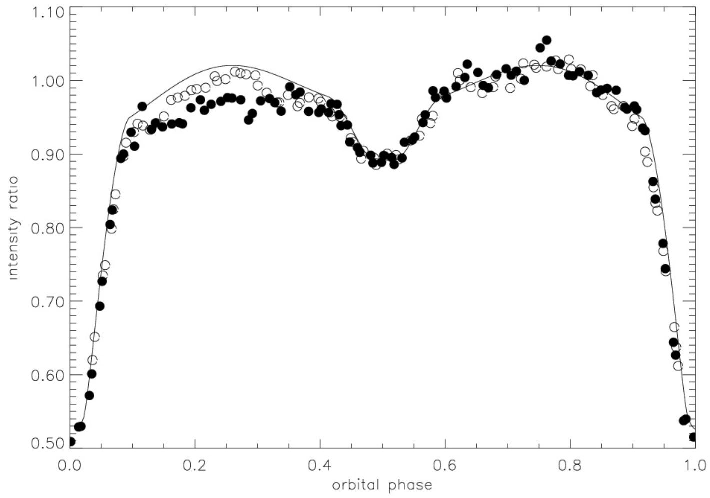

Figure 8: Photoelectrically observed light curves of SV Cam at J.D. 2449254-J.D. 2449257 and at J.D. 2449310-J.D. 2449311.

our spectroscopic observations (J.D. 2449288-J.D. 2449357) were delayed in comparison to the X-ray and optical observations. We obtained 13 spectra well distributed in phase. Exposure times were limited to 20 min to minimize phase smearing.

In the optical light curve it was obvious that there was a significant deviation from the unspotted light curve. This deviation was more pronounced in the J.D. 2449254-J.D. 2449257 light curve than the one obtained two months later at J.D. 2449310-J.D. 2449311. We assumed photospheric spots only on the surface of the primary star, because the possible contribution of spots over the secondary star was too small to account significantly to the light curve changes.

According to our analysis in the case of the first light curve there was a round dark spot with a radius of $27^\circ \pm 12^\circ$ at latitude $50^\circ \pm 20^\circ$ and longitude $78^\circ \pm 2^\circ$. In the light curve at J.D. 2449310-2449311 the maculation effect was much smaller. In that case we could not do detailed spot model analysis. We could determine the latitude of this smaller spot to be around 37°.

To produce the X-ray light curve we binned photon counts into time intervals of maximum 200 sec. To reduce scatter we binned the observational points in phase intervals of about 0.02.

We modeled the X-ray light curve with two coronal emission regions over the primary star. The X-ray spectrum of SV Cam could be explained by two different temperatures of $T_1 = 3 \times 10^6$ K and $T_2 = 1.5 \times 10^7$ K.

As SV Cam is a single lined binary, the mutual blending of the absorption systems originating from the second component is therefore no problem. But because of the high rotational velocity neighboring lines can blend each other significantly. We had to use only lines which seemed to be blend-free. Our analysis was based on four absorption lines: CaI 610.28 nm, CaI 612.20 nm, Fe I 640.00 nm, and CaI 643.91 nm.

We obtained independent Doppler images of the four lines (*Fig. 9*). The maps we got were not identical, but were very alike, and they agreed well with the map obtained analyzing the photometric data (*Fig. 10*).

Notice that the photometric spot analysis and the Doppler imaging are two completely different methods based on different data. It is very important that even in the case of a nearly 90° inclination the two methods yielded the same result.

According to the average picture, we got a spot distribution which was dominated by a strong circular spot at around latitude 60° and longitude 75°. There seemed to exist also an appendage to this spot with a longitude similar to the one we got from the J.D. 2449310-2449311 optical light curve. This also coincides with the position of one of the derived coronal X-ray emission regions. One possible explanation could be that the spot observed at J.D. 2449254-2449257 might have vanished by J.D. 2449310 or drifted to a new position. As the spectroscopic observations were done later (between J.D. 2449288 and J.D. 2449357) – a new strong spot might have emerged at the original position.

This kind of rapid spot evolution seems to be the regular behavior of SV Cam (Patkós, 1982; Zeilik et al., 1988). Note that we cannot distinguish between spots on the "upper" and "lower" hemispheres. The spots might be on either or both hemispheres. It could be that the above mentioned spot and its appendage were not connected, they might be at different hemispheres, and therefore physically not related.

A third active region was also derived from the spectroscopic observations. It seemed to be near the equator at around latitude 270°. It had a lower contrast in our Doppler image map. Despite this, it had a position near the second coronal X-ray source which we derived from the ROSAT light curve. This indicates a complete magnetically active region

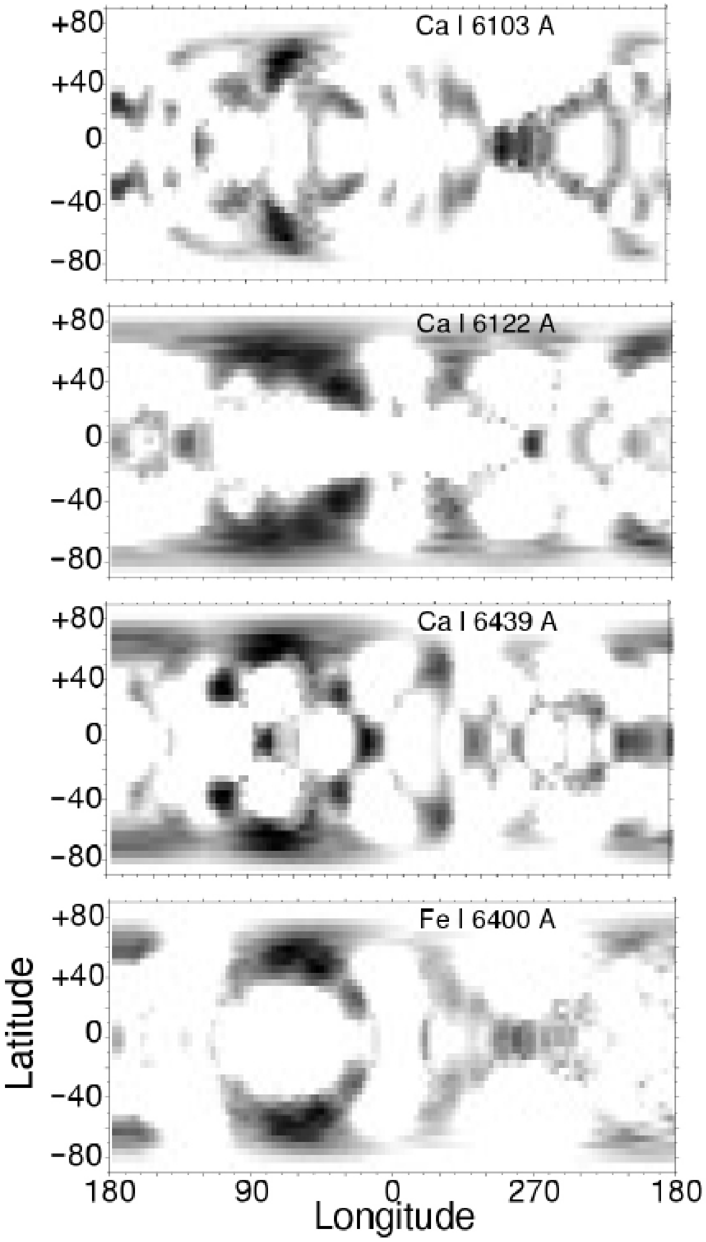

Figure 9: Four Doppler imaging results of SV Cam. Stellar longitude vs. latitude of the primary component.

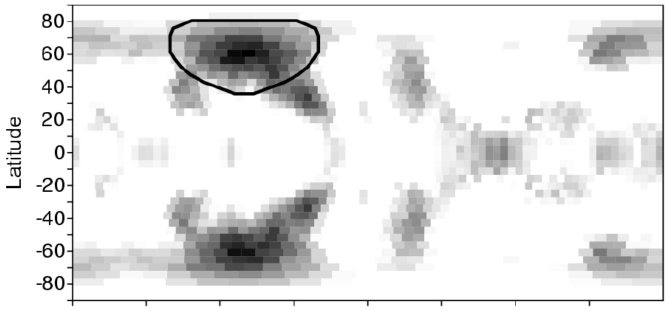

Figure 10: Averaged Doppler imaging result and the result of the independent photometric spot solution (solid circle).

at this position. Reality of this spot is further strengthened by the fact, that surface spots have been frequently observed at the same position (see e.g. Zeilik et al., 1988).

The large wavelength coverage of the Sandiford Echelle Spectrograph made it possible to acquire data simultaneously in Hα. These spectral profiles were examined to see if any rotational modulation – which may be an indication of a surface plage – could be detected. There was a strong distortion (pseudo-emission bump) in the red wing of the line at the phase of 0.004 that might be due to the secondary. The secondary star with an estimated spectral type of K4 is considerably cooler than the primary and when it transits it appears as a dark spot against the primary's surface. It thus produces a pseudo-emission distortion in the spectral line profile in the same manner as a cool surface spot.

The X-ray light curve could be explained with a model of two localized coronal sources in the binary system. One source was located closer to the primary star (most probably 0.8 $R_\odot$ above its surface), the other source was in the middle between the two stellar components. It remained unsolved whether this source has its origin in magnetism of either component or whether it results from an interaction of the two stellar magnetospheres.

On the primary star we found two photospheric active regions. The first active region has been exhibited by Doppler tomography to be of complex nature. Its main structure is a large spot of almost circular shape. This spot was also found from optical light curve analysis. The optical light curve was completely explained with this spot alone. However, the Doppler image showed an additional feature in this active region: an appendage to the circular spot. The whole region looks similar to a spot group on the Sun although one has to keep in mind that there is latitude ambiguity with respect to the equator, so that the circular spot may be in the one hemisphere while the appendage might be in the other hemisphere.

The presence of this appendage (a second spot inside a common active region) produces a noticeable change in the light curve and this would have been detected by the photometric measurements. There are, two explanations to solve this contradiction. The first but less likely possibility is that it was an artifact in the Doppler image resulting from observational errors and noise. However, this feature is evident in all four spectral lines analyzed. Hence, we felt its existence was real. The other possibility was the assumption of a temporary development of an active region. The spectrograms were obtained one month later than the light curve. Such rapid changes of spottedness might not be abnormal in case of SV Cam as some of the figures by Patkós (1982) demonstrate.

Finding of spots exclusively on the primary star does not imply inactivity nor absence of spots on the secondary star. Normally they cannot be seen in broad-band light curves, nor in the absorption lines outside the primary eclipse because of a too little contribution of the secondary star to the total light output. However, this may not be the case during primary eclipse when all the photospheric lines in the primary show absorption features that are believed to come from the secondary star. However, no such absorption feature is seen in the Hα profile, which should be present if the secondary were an inactive K4 star. The implication is that at primary eclipse the light from the secondary (at the wavelength of Hα) is predominantly continuum or possibly even in emission.

Further evidence of such activity was seen at secondary eclipse. The Hα line strength of the primary increased at this phase. This was expected because outside eclipse light from the secondary filled in the absorption lines of the primary making them shallower. However, the increase in Hα line strength was a factor of 1.6 larger than that expected from the continuum (near 656.3 nm) from the secondary for its spectral type. Again the conclusion is that the secondary is chromospherically active.

The Hα variations showed rotational modulation with a maximum near phase 0.8 and minimum near phase 0.3. It is not known whether the origin of this variation – if it were real – originated with surface features on the primary or secondary stars. If the chromospheric plages which might be responsible for this variation were located on the primary, then they might be associated with the large photospheric spot found by Doppler imaging and photometry. If the secondary star produced this variation, then the stellar surface region below one X-ray source was the more active one. In each case, the conclusion is that the strong spot on the primary star, the enhanced chromospheric activity of the secondary star and an intermediate coronal X-ray source were correlated with each other physically.

The light from the secondary could have strong influence on the Hα line strength and this complicates interpretations of the Hα variations.

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Fundamental parameters of pulsating stars from atmospheric models

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A purely photometric method is reviewed to determine distance, mass, equilibrium temperature, and luminosity of pulsating stars by using model atmospheres and hydrodynamics. T Sex is given as an example: on the basis of Kurucz atmospheric models and $UBVRI$ (in both Johnson and Kron-Cousins systems) data, variation of angular diameter, effective temperature, and surface gravity is derived as a function of phase, mass $\mathcal{M} = (0.76 \pm 0.09)\mathcal{M}_\odot$, distance $d = 530 \pm 67$ pc, $R_{\rm max} = 2.99 R_\odot$, $R_{\rm min} = 2.87 R_\odot$, magnitude averaged visual absolute brightness $\langle M_V^{\rm mag} \rangle = 1.17 \pm 0.26$ mag are found. During a pulsation cycle four standstills of the atmosphere are pointed out indicating the occurrence of two shocks in the atmosphere. The derived equilibrium temperature $T_{\rm eq} = 7781$ K and luminosity $(28.3 \pm 8.8) L_\odot$ locate T Sex on the blue edge of the instability strip in a theoretical Hertzsprung-Russell diagram. The differences of the physical parameters from this study and Liu & Janes (1990) are discussed.

Introduction

Except for supergiants and cool stars with effective temperature $T_{\rm e} < 4000$K a large grid of model atmospheres is available in the literature (Kurucz, 1997 for the latest versions). The conversion of theoretical fluxes to observational magnitude and colour indices has been solved (e.g. for Johnson and Kron-Cousins photometries, Castelli, 1999) opening the way to a determination of the atmospheric parameters effective temperature, $T_{\rm e}$, and surface gravity if broad band photometry is available for the target star.

The stellar angular diameter can be derived in the following manner from atmospheric models. Monochromatic flux $\mathcal{F}_\lambda(0)$ of the models at optical depth $\tau = 0$ is given in tabular form for a large grid of $T_{\rm e}$, g, metallicity $[M]$, etc., furthermore, by integrating $\mathcal{F}_\lambda(0)$ for a number of photometric systems the fluxes $\mathcal{F}_X(0)$ were computed in physical units $\mathrm{erg\,s^{-1}\,cm^{-2}}$ as well, and the corrections from interstellar absorption, reddening were included (Kurucz, 1997). X represents the photometric band, e.g. V in the Johnson system. On the other hand, observed physical fluxes, $\mathcal{I}_X$, of stars in band X can be derived by using the absolute flux calibration of Vega (Tüg et al., 1977). If the interstellar extinction is A_X magnitude, the half angular diameter of a spherical (i.e. non-distorted) star can be derived from the simple formula

$$\vartheta = R/d = [10^{A_X/2.5}\mathcal{I}_X/\mathcal{F}_X]^{1/2} \tag{1}$$

where d is the distance to the star, R is the radius of $\tau = 0$ (Barcza, 2003).

For giant, main sequence, or white dwarf stars the stellar atmosphere is a thin layer in comparison with R. The gravitational acceleration

$$g(r) = -G\frac{\mathcal{M}}{r^2} = \varrho^{-1}(r)\nabla p(r) \tag{2}$$

is practically constant in the atmosphere, i.e. at $r \approx R$, where $\varrho(r)$, $p(r)$, $\mathcal{M}$, G are density, pressure, mass, and the Newtonian gravitational constant, respectively. The surface gravity, $g(R)$, is an important parameter of the static atmospheric models given conventionally as $\log|g|$ and it can be used to weigh a star if the stellar radius, R, is known. Relation (2) was applied for a number of non-variable stars enhancing our knowledge on stellar masses: e.g. for white dwarfs purely from $\log|g(R)|$ of model atmospheres and R $\mathcal{M}_{\mathrm{wd}} = 0.480 \pm 0.014$ average mass was derived (McMahan, 1989) for a sample of 53 stars while other methods gave somewhat larger mass, $\mathcal{M}_{\mathrm{wd}} = 0.58 \pm 0.10$ for 64 stars (Koester et al., 1979).

Problems, dependence of g, ϑ, $\mathcal{M}$ on $E(B-V), [M]$ were discussed in numerous papers, e.g. Kinman & Castelli (2002), Decin et al. (2003). Accuracy of the data from broad band photometry is inferior to that from fine analysis of spectra or interferometry, respectively, and $\mathcal{M}$ can be determined much better from binary orbits. However, if the more accurate methods are not available, the photometric determination of g, ϑ, and $\mathcal{M}$ must be appreciated.

Implementation for $UBV(RI)_{\mathrm{C}}$ photometry

The main parameters of atmospheric models are T_{e}, g, $[M]$, and in addition to them the interstellar reddening, extinction (e.g. $E(B-V)$, A_X) must be known. From observational point of view colour indices, $C_i, (i = 1, 2, ...)$ are the input parameters and the inverse problem of ordering a model to them must be solved. In optimal cases the typical errors of interpolation are 0.1 in $\log|g|$ while a few hundredth in $\mathcal{F}_X$, respectively, however, the successful solution depends on the shape of the functions $T_{\mathrm{e}}(C_1, ...)$ and $\log|g(C_1, ...)|$. The final step is that theoretical $\mathcal{F}_X(C_1, ...)$ belonging to the selected model must be compared with $\mathcal{I}_X$ from observed magnitudes according to (1).

From inspecting the Kurucz tables some general rules can be inferred, we mention a few of them. For main sequence or giant stars UBV photometry must be preferred if $7000 < T_{\mathrm{e}} < 10^4$ K while for cooler stars BVI_{C} gives reliable results as well. Below $T_{\mathrm{e}} = 9000$ K the dependence of $\log|g|$ on $U-B$ becomes more pronounced, $U-B$ itself is sensitive to $[M]$ because of the appearance of metallic lines in ultraviolet. In favourable cases T_{e} and g can be determined from a two colour diagram if $[M]$, $E(B-V)$ were already known while the procedure is more uncertain if $[M]$ and $E(B-V)$ must be estimated from colour indices as well, in this case more than two colour indices are necessary.

Table 1: Half angular diameter of some stars from intensity interferometry (ϑ_{HB}) and V, $B-V$, $U-B$ of Kurucz models (ϑ), the units are 10^{-9}. The mass was calculated from the *Hipparcos* parallax π (ESA, 1997) and using $R = 3.086 \times 10^{13}\vartheta/\pi$ in (2).

HR	V	$B-V$	$U-B$	ϑ_{HB}	ϑ	π	$\mathcal{M}_{\odot}$
2421	1.93	0.00	0.04	$3.37 \pm .21$	3.55	0.031	1.51
2491[1]	−1.46	0.00	−0.05	$14.28 \pm .39$	14.31	0.379	3.47
2943[2]	0.38	0.42	0.02	$13.47 \pm .42$	11.80	0.286	1.7
3685	1.68	0.00	0.03	$3.85 \pm .17$	3.89	0.029	4.07
4534	2.14	0.09	0.07	$3.22 \pm .24$	3.33	0.090	1.70
6556	2.08	0.15	0.10	$3.95 \pm .31$	3.79	0.070	2.24
7001	0.03	0.00	−0.01	$7.85 \pm .11$	7.97	0.129	2.47
7557[3]	0.77	0.22	0.09	$7.22 \pm .34$	7.65	0.194	1.18
8728	1.16	0.09	0.08	$5.09 \pm .34$	5.29	0.130	1.55

1: The uncertainty of the mass values is indicated by $3.47_{\odot}$ for Sirius (HR 2491) in contrast with $2.143_{\odot}$ from binary orbit (Gatewood & Gatewood, 1978). This severe discrepancy is caused by the steep function $\log|g(U-B, B-V)|$ if $T_{\mathrm{e}} > 9800$K: small shifts $U-B = -0.05 \rightarrow -0.04$ or $B-V = 0.00 \rightarrow -0.01$ would result in $\log|g| = 4.52 \rightarrow 4.3$ i.e. $3.47_{\odot} \rightarrow 2.4_{\odot}$ with unchanged ϑ.

2: In the effective temperature range of Procyon (HR 2943) ($T_{\mathrm{e}} \approx 6600$ K) the dependence $\Delta\log|g|/\Delta[M] \approx 1.5$ is strong, $[M] = 0.4$ must be taken to reproduce the mass $\mathcal{M} = 1.75$ from binary orbit solution, in spite of the solar atmospheric composition (Drake & Laming, 1995). The change $B-V = 0.42 \rightarrow 0.43$ could lead to $\vartheta \approx \vartheta_{\mathrm{HB}}$.

3: The difference of ϑ and ϑ_{HB} exceeds the error for Altair (HR 7557). Its rotational oblateness (Belle et al., 2001) may be responsible because both ϑ and ϑ_{HB} assume spherical symmetry of the visible disc of the star. From $R/d = (ab)^{1/2} = (7.85 \pm 0.27) \times 10^{-9}$ a better agreement could be obtained where a, b are the visible minor and major axes, respectively.

To demonstrate reliability of the method, some date are given in Table 1: ϑ was derived from observed V, $B-V$, $U-B$ (Hoffleit, 1982) by using $\mathcal{F}_V(U-B, B-V)$ of the Kurucz models while for comparison the value ϑ_{HB} is given from intensity interferometry corrected for limb darkening (Hanbury Brown et al., 1974). Using the *Hipparcos* parallaxes (ESA, 1997) $R = 3.086 \times 10^{13}\vartheta/\pi$ km was calculated and the mass was obtained by (2) from $\log|g(U-B, B-V)|$. It can be noted that the weakest sampling of the spectrum is provided by $(U-B, B-V)$ since the wavelength interval $\approx 360 - 540$ nm is covered in this case. Of course an inclusion of other colour indices could improve the values of $\vartheta, \log|g|$.

For pulsating stars with periods exceeding 0.1 day the characteristic time of changes of the main atmospheric parameters $T_{\mathrm{e}}, g_{\mathrm{e}}, \mathcal{F}_X$ is long in comparison with the formation of radiative (and convective) equilibrium, therefore, the static atmospheric models account satisfactorily for the changes of g_{e} and ϑ as a function of pulsation phase φ (Buonaura et al., 1985). The subscript in $g_{\mathrm{e}}(= -\varrho(r)\nabla p(r) > 0)$ indicates that this is an effective outward acceleration produced by the pressure gradient in the atmosphere. On appropriately selected two colour diagrams the loop of a variable star gives $\log g_{\mathrm{e}}(\varphi), T_{\mathrm{e}}(\varphi), \mathcal{F}_X(\varphi)$ etc. of the models while photometric observations can be reduced to $\mathcal{I}_X(\varphi)$ giving finally $\vartheta(\varphi)$ by (1).

- *Mass and distance from $\vartheta(\varphi)$, $g_{\rm e}(\varphi)$ by using the radial momentum balance in the pulsation*

If $\vartheta(\varphi_j), j = 1, 2, ..., N$ points are available in a sufficient number to numerical differentiation of $\vartheta(\varphi)$ the angular acceleration can be converted to $\ddot{R}(t) = \ddot{\vartheta}(t)d$, $t = \varphi P$, where P is the period in seconds. Numerical experience showed that $N \approx 500$ or more points gave reliable $\ddot{R}(\varphi)$ if they were distributed uniformly in $0 \leq \varphi \leq 1$.

Now the main innovation is that $\ddot{R}(\varphi_j)$, $g_{\rm e}(\varphi_j), j = 1, 2, ...$ are introduced in the radial component of the Euler equation of hydrodynamics and we exploit that the atmosphere must be in standstill at least twice in a pulsation cycle. At these phases $\varphi_i (i = 1, 2)$ the radial component of the non-linear term vanishes: the non-radial motions are expected to contribute negligibly to the momentum balance in radial direction, therefore, $(\mathbf{v}, \nabla)\mathbf{v} \propto \dot{R} \approx 0$ and we have the equations:

$$\ddot{\vartheta}(\varphi_i)d = -\frac{G\mathcal{M}}{[\vartheta(\varphi_i)d]^2} + g_{\rm e}(\varphi_i), \quad i = 1, 2. \tag{3}$$

The fundamental stellar parameters: distance and mass

$$\begin{aligned} d &= \frac{g_{\rm e}(\varphi_1) + \ddot{R}_a(\varphi_1) - [g_{\rm e}(\varphi_2) + \ddot{R}_a(\varphi_2)][\vartheta(\varphi_2)/\vartheta(\varphi_1)]^2}{\ddot{\vartheta}_0(\varphi_1) - \ddot{\vartheta}_0(\varphi_2)[\vartheta(\varphi_2)/\vartheta(\varphi_1)]^2}, & (4) \\ \mathcal{M} &= [g_{\rm e}(\varphi) - \ddot{\vartheta}(\varphi)d]\vartheta^2(\varphi)d^2/G & (5) \end{aligned}$$

(Barcza, 2003) follow from (3) by elementary operations. The apparent accelerations $\ddot{R}_a$ can be neglected if the characteristic spatial extension of the atmosphere – i.e. the size of the interval $0 \leq \tau_{\rm Rosseland} \leq 1$ varies slightly during the whole pulsation cycle. If there are more than two standstills, then $i \geq 3$ in (3). Eventual different values of $\mathcal{M}, d$ from $i = 1, 3$, $i = 2, 3$ etc. can indicate e.g. non-radial pulsation because radial pulsation was assumed throughout the procedure outlined here.

The fundamental stellar parameters equilibrium luminosity and temperature (Carney et al., 1992) are obtained from $\vartheta(\varphi), T_{\rm e}(\varphi), d$ by

$$\begin{aligned} L_{\rm eq} &= 4\pi\sigma\langle\vartheta^2(\varphi)d^2T_{\rm e}^4(\varphi)\rangle, & (6) \\ T_{\rm eq} &= \{L_{\rm eq}/4\pi\sigma[\langle\vartheta(\varphi)\rangle d]^2\}^{1/4} = \langle\vartheta^2(\varphi)T_{\rm e}^4(\varphi)\rangle^{1/4}\langle\vartheta(\varphi)\rangle^{-1/2} & (7) \end{aligned}$$

where σ is the Stefan-Boltzmann constant, $T_{\rm eq}$ differs slightly from the average effective temperature $\langle T_e(\varphi)\rangle$. $L_{\rm eq}, T_{\rm eq}$ allow to locate a variable star in theoretical Hertzsprung-Russell diagram: of course on the basis of [colours $- T_{\rm e}, \mathcal{F}_X$] calibration of the used atmospheric models.

— *Comparison with the Baade-Wesselink method*

The determination of $\vartheta(\varphi)$ is common in both methods. The difference lies in its further use.

In the BW method the radius change is derived from integrating the radial velocity curve and it is equated with ϑd. The kinematic equation

$$\vartheta(\varphi)d = R_0 + \delta R = R_0 + \int_{\varphi_0}^{\varphi P} p_{\rm p}(t)[v_\gamma - v_{\rm radial}(t)]{\rm d}t \tag{8}$$

must be solved for d where p_{p} is the projection factor of converting radial to pulsation velocity and v_γ is the barycentric velocity of the star. Physical input comes from the time-dependent projection factor. A much more serious uncertainty of kinematic nature is imported in this procedure by the error Δv_γ. If $\Delta v_\gamma \ll \overline{|v_\gamma - v_{\mathrm{radial}}(t)|}$ a negligible error is propagated into δR, however, it is problematic to achieve this desired accuracy because the observed radial velocities are an integral of the radial component of true, non-uniform motions in the atmosphere contaminated by apparent velocity changes from varying opacity during phases of different compression. The difficulties from the uncertain value of v_γ could be circumvented by differentiating $p_{\mathrm{p}}(t)v_{\mathrm{radial}}(t)$ and substituting it for $\ddot{\vartheta}d$ in (3). However, because of low number, large scatter of the observed radial velocities, and eventual time dependence of $p_{\mathrm{p}}(t)$ this principally correct use of (3) cannot result in $d, \mathcal{M}$ of acceptably small error.

By using $\vartheta, \ddot{\vartheta}, g_{\mathrm{e}}$ in (3) radial velocity observations and their problematic conversion to radius changes are not necessary at all at the price of differentiating $\vartheta(\varphi)$ twice plus more physical input: $g_{\mathrm{e}}(\varphi)$ and the assumption of radial momentum balance must be used. Finally d and $\mathcal{M}$ are obtained by solving algebraic equations. The method was described in detail and applied for the $\mathrm{RR_{ab}}$ star SU Dra by Barcza (2003). We mention two remarkable details from this study. (i) At minimum radius, i.e. at maximum compression in the atmosphere, $g_{\mathrm{e}} = 50.1\,\mathrm{ms}^{-2} \gg G\mathcal{M}/R^2 \approx 8\,\mathrm{ms}^{-2}$ reduces (3) to $d < g_{\mathrm{e}}/\ddot{\vartheta}$ giving $d < 718\mathrm{pc}$. This upper value is very close to $d = 647\mathrm{pc}$ from the solution of (3) for three observed standstills. From them the unequivocal $d, \mathcal{M}$ show that a non-radial mode, if there is any, is negligible in comparison with the radial oscillation of SU Dra. (ii) During a time interval t the small uncertainty $\Delta v_\gamma \approx +5.9\mathrm{kms}^{-1} \approx 0.04 v_\gamma$ (Liu & Janes, 1990 vs. Oke et al., 1962) leads to a phase dependent error $\Delta R = p_{\mathrm{p}} \Delta v_\gamma t \leq 3.43 \times 10^5\mathrm{km}\,(\approx (R_{\max} - R_{\min})/2!)$ which has a considerable effect on d. If the method by Liu & Janes (1990) is followed to solve the kinematic equation, the increment of d is 1.26 from $\Delta v_\gamma = 5.9\ \mathrm{km\,s}^{-1}$. This results in correction $\langle M_V^{\mathrm{mag}} \rangle = 0.78 \to 0.28$ for the magnitude average absolute magnitude. (Roughly this is the difference between the short and long extragalactic distance scales – Gratton, 1998. The distance 815 pc corresponding to the long distance scale is ruled out by $d < 718\mathrm{pc}$.)

Application to T Sex

Now we apply the method for the RRc variable T Sex. Good quality photoelectric observational material was collected from the literature, the sources are given in Table 2.

- *Period, $O - C$, average light and colour curves*

The periods given by TS58, PP64, EE73, BM88, LJ89 indicated period changes of $\mathrm{O}(10^{-6})$. To clarify it string length minimization (SLM) was applied, since good conversion of the observations to average light curve and colour-colour loops is crucial to determine $\vartheta(\varphi), g_{\mathrm{e}}(\varphi)$. (The adaptation of SLM to pulsating stars was described by Barcza (2002), the notation of this paper will be used here. The essence of SLM is that first the segments $k = 1, 2, \ldots$ of the observed V magnitudes are projected onto the phase axis $\varphi, 0 \leq \varphi \leq 1$ by the saw tooth function which is perturbed by a term $\delta_k \equiv (O-C)_k \ll P_0$ accounting for the phase shift of segment k and next the neighbouring points are con-

Table 2: $V, UBV, BVRI, UBV(RI)_C$ data of T Sex used for constructing average light and colour curves, k is the serial number of the segment, n_k is the number of V points in the segment, δ_k, E_k are the phase shift and epoch in (9)

k	HJD − 2400000	n_k		δ_k	E_k	Source
1	34311.8675 − .9315	31	V	−0.0160	6	TS58
2	34350.8051 − .9402	66	V	−0.0247	126	TS58
3	34363.7245 − .8531	64	V	−0.0300	166	TS58
4	34508.5948 − .6598	10	V	−0.0766	612	TS58
5	35190.7392 − .8208	2	UBV	0.0593	2712	TS58
6	35191.6423 − .8871	72	UBV	0.0586	2715	TS58
7	35195.6440 − .9000	106	UBV	0.0470	2727	TS58
8	35513.7227 − .9620	40	UBV	−0.0286	3707	TS58
9	35514.6815 − .9477	60	UBV	−0.0275	3710	TS58
10	35516.6802 − .9387	73	UBV	−0.0272	3716	TS58
11	38017.9584 − 8.0870	43	UBV	0.0322	11417	PP64
12	38035.8141 − .9985	55	UBV	0.0280	11472	PP64
13	38038.8007 − .8928	28	UBV	0.0227	11481	PP64
14	40678.6990 − .7931	10	V	0.0778	19610	EE73
15	40680.6390 − .7382	8	V	0.0757	19616	EE73
16	41013.7358 − .7565	4	V	−0.0127	20641	EE73
17	43525.792 − 56.694	11	V	0.0588	28418	E94
18	45387.7850 − .9212	76	$BVRI$	0.0010	34109	BM88
19	45388.6578 − .7634	69	$BVRI$	0.0026	34112	BM88
20	45389.6382 − .8760	113	$BVRI$	0.0029	34115	BM88
21	45393.7134 − .8596	98	$BVRI$	0.0000	34127	BM88
22	45400.6689 − .7235	45	$BVRI$	−0.0021	34149	BM88
23	46845.6886 − .7489	6	$UBV(RI)_\mathrm{C}$	0.0540	38598	LJ89
24	46846.8005 − .8859	7	$UBV(RI)_\mathrm{C}$	0.0429	38601	LJ89
25	46847.6521	1	$UBV(RI)_\mathrm{C}$	0.0480	38604	LJ89
26	46848.6547 − .9614	25	$UBV(RI)_\mathrm{C}$	0.0432	38607	LJ89
27	47197.7625 − 8.0035	16	$UBV(RI)_\mathrm{C}$	−0.0301	39682	LJ89
28	47226.6368 − .9153	3	VR_C	−0.0258	39771	LJ89
29	47488.8955 − .9059	7	$BVRI$	−0.0881	40578	BM92

nected by straight strings. Finally the normalized sum νl of the string lengths is minimized numerically as a function of period P_0 and phase shifts $\delta_1, ...)$

The V file contains 1149 observations in 29 segments, SLM gave for the maxima

$$\mathrm{HJD}_{\max} = 2434310.035 + P_0 E_k + \delta_k \tag{9}$$

with $P_0 = 0.3247796 \pm 0.0000032$ and the values δ_k in Table 2. The summed string length was $\nu l_0(P_0, \delta = \mathbf{0}) = 0.330$ with standard deviation SD $= 0.069$ magnitude, the folded light curve belonging to it is plotted in *Fig. 1a.* Applying the values δ_k of Table 2 reduced $\nu l(P_0, \delta)$ to 0.062 with $\mathrm{SD}(P_0, \delta) = 0.012$ mag, dots of *Fig. 1b* are a plot of the folded light curve, its SD $= 0.012$ does not exceed the expected random error of a V point, it is lower than the claimed amplitude 0.028, 0.015 mag for the second and third periods of T Sex (Hobart et al., 1991). Thus, the conclusion must be drawn that between HJD 2434311-2447488 the light curve of T Sex can perfectly be reproduced if the light curve segments in *Fig. 1a* are shifted to the $\mathrm{HJD}_{\max}$ given by (9). The colour indices were shifted by δ_k of the segment, *Figs. 1c-f* are their plots. The line in *Figs. 1b-f* was obtained by fitting high order (≤ 9) polynomials to the points. These drawn light and colour curves were used to construct colour-colour loops and to interpolate the physical parameters of the Kurucz models.

Two remarks on the homogenization of the colour curves. (1) In $U - B$ of segments 5,6,7 a zero point correction +0.08 was applied while for 8,9,10 it was +0.05 in order to bring the TS58 observations in coincidence with those of PP64 and LJ89. (2) The Johnson $V - R, V - I$ colours of BM88 and BM92 were converted to $V - R_{\mathrm{C}}, V - I_{\mathrm{C}}$ by Taylor's (1986) empirical formulae.

- *The physical parameters*

The colour-colour loops $(U-B, B-V), (U-B, V-R_{\mathrm{C}}), (U-B, V-I_{\mathrm{C}}), (B-V, V-I_{\mathrm{C}})$ could be used to interpolate $T_{\mathrm{e}}(\varphi)$, $\log g_{\mathrm{e}}(\varphi)$, $\mathcal{F}_V(\varphi)$, $\mathcal{F}_{R_{\mathrm{C}}}(\varphi)$, $\mathrm{BC}(\varphi)$. Using a midpoint formula the half angular velocity $\dot{\vartheta}$ and acceleration $\ddot{\vartheta}$ were determined from $\vartheta(\varphi)$. *Fig. 2* is a plot of the results for $E(B-V) = 0.095, [M] = -1.2$. From the different loops the scatter of $\log g_{\mathrm{e}}$ was the largest: $\pm 0.11, \pm 0.03$ at $\varphi = 0.3, 0.9$, respectively, the scatter in $\mathcal{F}_V, \mathcal{F}_{R_{\mathrm{C}}}, T_{\mathrm{e}}$ was ≤ 0.02. Therefore, $\log g_{\mathrm{e}}, \vartheta, T_{\mathrm{e}}$ were averaged at each φ from the four loops. The scatters result in an error of ≈ 0.15 for the derived mass and distance if one pair of standstills is used.

- *Distance, mass, equilibrium luminosity and effective temperature*

The standstills of the atmosphere were found at $\varphi \approx 0.31, 0.56, 0.65, 0.90$ by searching for zero average angular velocity $\overline{\dot{\vartheta}(\varphi)} \approx 0$. $\ddot{\vartheta}, \log g_{\mathrm{e}}$ were averaged here in an interval $\Delta\varphi \approx 0.02$ (i.e. ≈ 10 min). Table 3 reports the results for some values of $E(B-V) = 0.095, [M] = -1.2, -1.0$.

The characteristic size of the atmosphere is $\approx 10^4$ km, $\ddot{R}_a \ll g_{\mathrm{e}}$, therefore, $\ddot{R}_a$ can be neglected.

$\langle T_{\mathrm{e}}(\varphi)\rangle, T_{\mathrm{eq}}$ and from pairs of standstills AD,BD,CD the average d, $\mathcal{M}$, R, L_{eq} are given in Table 4 to some values of $E(B-V)$. The estimated errors from the averaging are in accordance with that of the interpolation of $\log g_{\mathrm{e}}$, the other quantities propagate negligible errors in (4),(5).

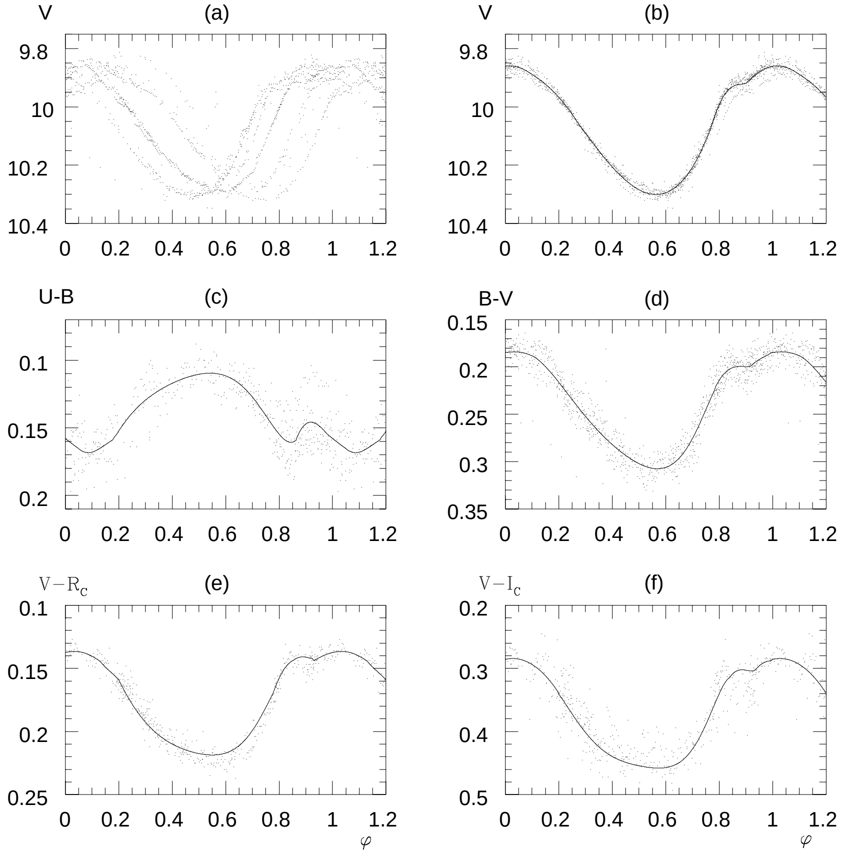

Figure 1: Panel (a): 1149 V observations folded by $P_0 = 0.3247796$ days, $\delta = \mathbf{0}$. Panels (b)-(f): dots: $V, U-B, B-V, V-R_{\mathrm{C}}, V-I_{\mathrm{C}}$ observations folded with the values δ_k given in Table 1. Lines: High order polynomial fitting curves.

Table 3: Average ϑ, $\ddot{\vartheta}$, $\log g_{\mathrm{e}}$ at $\varphi = 0.31,\ 0.56,\ 0.65,\ 0.90$ for $E(B-V) = 0.095, [M] = -1.2, -1.0$. The units are: radian, radian s^{-2}, $\mathrm{cm\,s}^{-2}$.

	φ	$\vartheta \times 10^{10}$	$\ddot{\vartheta} \times 10^{18}$	$\log g_{\mathrm{e}}$
$[M] = -1.20$				
A	0.31	1.273	$-0.334 \pm .013$	$3.38 \pm .11$
B	0.56	1.242	$0.189 \pm .012$	$3.37 \pm .10$
C	0.65	1.247	$-0.257 \pm .020$	$3.36 \pm .07$
D	0.90	1.222	$1.56 \pm .02$	$3.71 \pm .03$
$[M] = -1.00$				
A′	0.31	1.264	$-0.331 \pm .013$	$3.45 \pm .10$
D′	0.90	1.217	$1.58 \pm .02$	$3.74 \pm .03$

Table 4: Average physical quantities from the pairs of standstills AD,BD,CD assuming $M = -1.20$ and different reddenings. The units are: K, K, pc, solar mass, radius, and luminosity. Our final choice is $E(B-V) = 0.095$.

$E(B-V)$	$\langle T_{\rm e}\rangle$	$T_{\rm eq}$	d	$\mathcal{M}$	$\langle R\rangle$	$L_{\rm eq}$
0.08	7607	7625	452 ± 73	$0.37 \pm .06$	2.54	19.6 ± 6.9
0.09	7712	7728	514 ± 84	$0.55 \pm .08$	2.86	26.5 ± 9.4
0.095	**7765**	**7781**	$\mathbf{530 \pm 67}$	$\mathbf{0.76 \pm .09}$	**2.93**	$\mathbf{28.3 \pm 8.8}$
0.10	7816	7834	558 ± 65	$1.06 \pm .16$	3.07	31.9 ± 6.9
0.105	7871	7886	892 ± 130	$3.04 \pm .44$	4.89	84 ± 26

Discussion

- *Dependence of the physical quantities on reddening*

The strong dependence of $T_{\rm e}(\varphi), \log g_{\rm e}(\varphi)$ and the derived $d, \mathcal{M}$ on $E(B-V)$ is a surprising result of this study while the value of $[M]$ is of secondary importance. $E(B-V) = 0.05 \pm 0.02$ by Liu & Janes (1990) gives very small $d, \mathcal{M}$ which cannot be reconciled with our present day theoretical knowledge on RR Lyrae or other type of pulsating stars. Reddening $E(B-V) = 0.07$ and 0.09 were suggested by Hobart et al. (1991) and Hemenway (1975), respectively, our finding is that $E(B-V) = 0.09 - 0.1$ is the only possible choice.

- *Effective temperature, surface gravity*

$T_{\rm e}(\varphi), \log g_{\rm e}(\varphi)$ of the present study are significantly higher by some 650 K and ≈ 0.4 than those of Liu & Janes (1990). Since essentially the same Kurucz tables were used we attribute the difference to the different philosophy of the interpolation procedure:

> Liu & Janes (1990) determined $g_{\rm e}(\varphi) = 0.6\mathcal{M}_\odot G/R^2(\varphi)$ from kinematics with assuming the canonical mass $0.6\mathcal{M}_\odot$ of RR Lyrae stars. Next, one arbitrarily chosen colour index, $V-K$ was taken as sole source of $T_{\rm e}(\varphi)$ belonging to $\log g_{\rm e}(\varphi)$ from the kinematics and $T_{\rm e}(\varphi)$ from the other colour indices were neglected leading to their very low $\langle T_{\rm e}\rangle = 7137$ K. To check this procedure their $T_{\rm e}(B-V), T_{\rm e}(V-R_{\rm C}), T_{\rm e}(V-I_{\rm C}), T_{\rm e}(V-K)$ tables were all used for $\log g_{\rm e} = 3, 3.5$: according to our opinion no reason can be found to reject any $T_{\rm e}$ since the difference was ≤ 250 K with no systematically decreasing trend when going more and more to the infrared indices. Therefore, averaging could have been more appropriate. Theoretical colour indices differing systematically from the observed ones by $0.02 - 0.04$ mag correspond to their lower $\log g_{\rm e}(\varphi)$ values.
>
> In the present study two colour diagrams were used to determine a pair of $T_{\rm e}(\varphi)$, $\log g_{\rm e}(\varphi)$ simultaneously taking into account the dependence of $T_{\rm e}(\varphi)$ on $\log g_{\rm e}(\varphi)$ automatically and the small differences (≤ 250 K in $T_{\rm e}$, ≤ 0.11 in $\log g_{\rm e}$) from the four colour-colour loops justified averaging. This is a self-consistent procedure trusting on the Kurucz models exclusively. By using four colour-colour loops, different parts of the whole spectrum $\mathcal{F}_\lambda(0)$ were sampled in the λ interval $360 - 1000$ nm.

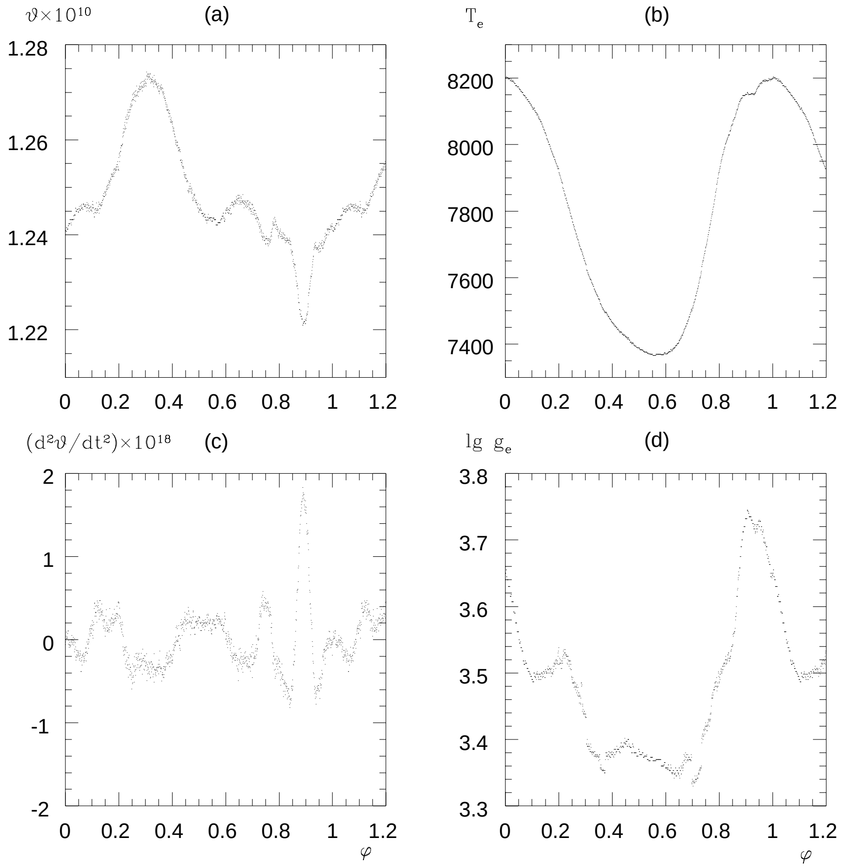

Figure 2: The average variable parameters of T Sex for $E(B-V)=0.095, [M]=-1.2$ from the loops $(U-B, B-V), (U-B, V-R_C), (U-B, V-I_C), (B-V, V-I_C)$. The outlier points of panels (a,c,d) at $\varphi \approx 0.36, 0.72-0.76$ are artifacts of interpolation, they were not smoothed out to show the effect of eventual uncertainties in the interpolation.

- Position in a theoretical HRD, absolute brightness

The values of the fundamental parameters $\log T_{\rm eq}=3.891$, $\log L_{\rm eq}=1.452$, $\mathcal{M}=0.76_\odot$ for $E(B-V)=0.095$ place T Sex just to the blue edge of the instability strip given by Tuggle & Iben (1972) and Lee et al. (1990). This position is expected for an $\rm RR_c$ variable and it was our main argument to accept the large reddening. With distance $d=530$ pc we get $R(\varphi=0.31)=2.99R_\odot, R(\varphi=0.91)=2.87R_\odot$, and magnitude averaged visual absolute brightness $\langle M_V^{\rm mag}\rangle = 1.17\pm0.26\,{\rm mag}$. These values come purely from atmospheric models which are trustable to a few percent level and verify figures from stellar structure calculations. The values $d=578.5$ pc and $\langle M_V^{\rm mag}\rangle=1.06\pm0.38$ of Hobart et al. (1991) agree with the present results within the quoted errors. The physical parameters of Liu & Janes (1990), $(0.47\mathcal{M}_\odot$, $d=667$ pc, $\langle T_{\rm e}\rangle=7137$ K, $\langle R\rangle=4.05R_\odot$, $\langle M_V\rangle=0.76\pm0.27$ mag $\langle \log g_{\rm e}\rangle=2.98)$ are unreliable.

Figs. 3a-c are plots of the variable acceleration, velocity, radius in absolute units for a pulsation cycle if $d=530$ pc. The sharp undulation of the curves in $0.72<\varphi<0.78$ is not real, it originates from the interpolation artifact indicated in the caption to *Fig. 2.*

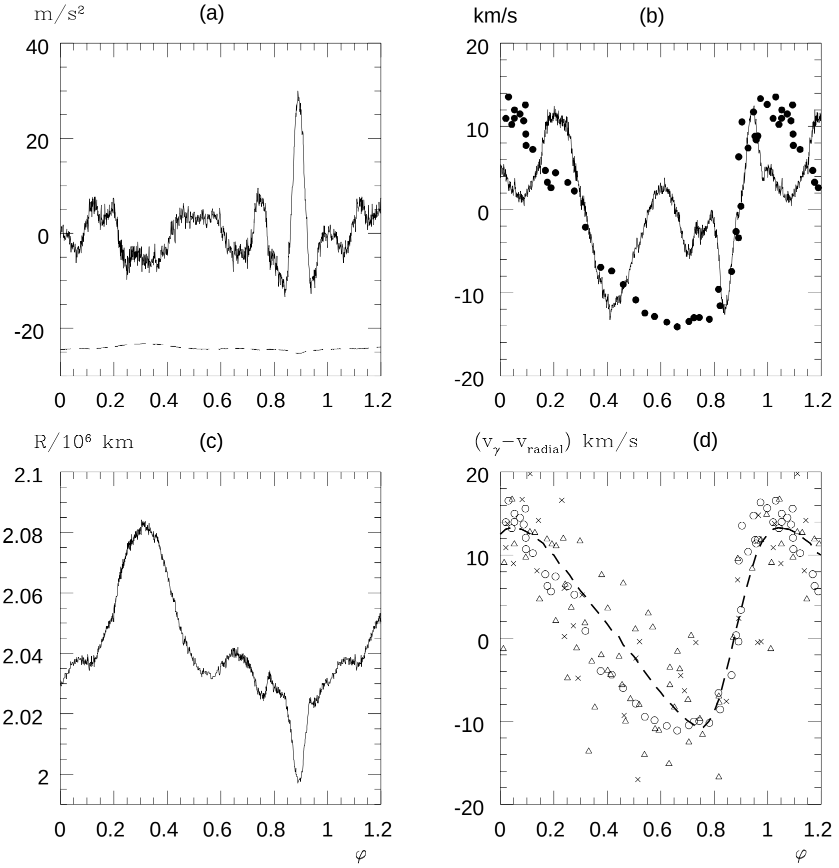

Figure 3: Panel (a): line: $g_{\mathrm{e}}(\varphi)$, dashed: $-0.76\mathcal{M}_{\odot}G/R^2(\varphi)$. Panel (b): $\dot{R}(\varphi)$, filled circles: $25 - v_{\mathrm{radial}}(\varphi)$ from Liu & Janes (1989). Panel (c): $R(\varphi)$. Panel (d): circles: $28 - v_{\mathrm{radial}}(\varphi)$ from Liu & Janes (1989), triangles: $38 - v_{\mathrm{radial}}(\varphi)$ from Barnes et al. (1988), crosses: $38 - v_{\mathrm{radial}}(\varphi)$ from Tifft & Smith (1958), dashed line: mean of $38 - v_{\mathrm{radial}}(\varphi)$ from Barnes et al. (1988). The outlier points of panels (a)-(c) at $0.72 < \varphi < 0.78$ are artifacts of interpolation, they were not smoothed out to show the effect of eventual uncertainties in the interpolation.

- *Open problems*

There is a systematic difference in the $v_{\mathrm{radial}}(\varphi)$ curves of Barnes et al. (1988), Tifft & Smith (1958), and Liu & Janes (1989): $v_\gamma = 38$, and 28.0 ± 1.4 km s^{-1}, respectively, which exceed the expected observational errors. On the basis of *Fig. 3b* $v_\gamma = 25$ km s^{-1} seems even more probable. The amplitudes $28, 24, 24$ km s^{-1} of TS58, BM88, LJ89 do not differ significantly. *Fig. 3d* shows that subtracting $v_{\mathrm{radial}}(\varphi)$ from the different barycentric velocities does not bring the different observations to full coincidence. The stability of the light and colour curves is, however, obvious from *Fig. 1*, therefore, secular change of the shape of $v_{\mathrm{radial}}(\varphi)$ seems to be improbable. A variable v_γ i.e. duplicity cannot be excluded in spite of the large scatter of $v_{\mathrm{radial}}(\varphi)$ of TS58, BM88, furthermore, the scatter of δ_k is some 3 hours. This is significantly higher than the imaginable error of a δ_k value and for its explanation barycentric motion i.e. light-time effect can even be considered.

On speculation level the extreme sensitivity of the BW method on Δv_γ may be guessed as the main source of the discrepant d of Liu & Janes (1989) which was propagated into their $\mathcal{M}$, $\langle R\rangle$, $\langle M_V\rangle$. Since the radial amplitude of T Sex is only some $\delta R = 80000$ km for a BW analysis v_γ ought to be known by an accuracy $\mathrm{O}(100)\mathrm{m\,s}^{-2}$ which was obviously not reached, another factor is their low $T_\mathrm{e}(\varphi)$. (Their quoted error $\Delta v_\gamma = \pm 1.4\ \mathrm{km\,s}^{-1}$ leads to an error $\approx \pm 18000$ km in δR resulting in an error $\Delta d/d \approx 0.21$.)

The product $p_\mathrm{p}[v_\gamma - v_\mathrm{radial}(\varphi)]$ is the comparable quantity with $\dot{R}$ plotted in *Fig. 3b.* The spectral lines originate from $0 < \tau_\mathrm{Rosseland} < 0.4$, therefore, we expect $p_\mathrm{p}|v_\gamma - v_\mathrm{radial}(\varphi)| < |\dot{R}(\varphi)|$. It is satisfied if $p_\mathrm{p}(t) \approx 1$, however, the large scatter of the radial velocities gives weak basis for this very small value. Remarkable is that the most accurate radial velocities i.e. those of Liu & Janes (1989) show small humps at the extreme values of $\dot{R}$ at $\varphi \approx 0.2, 0.4, 0.6$ and $\dot{R}_\mathrm{max} - \dot{R}_\mathrm{min}$ agrees better with the extreme values of $v_\gamma - v_\mathrm{radial}$ if $v_\gamma = 25\ \mathrm{km\,s}^{-1}$.

The rather loose correlation of $\dot{R}$ and $25 - v_\mathrm{radial}(\varphi)$ is similar to that found in SU Dra (Barcza, 2003) and it raises a serious question concerning the basic equation (8) of the BW method. A qualitative explanation can be guessed from gas dynamics and the technique of measuring radial velocity.

> $\dot{\vartheta}(\varphi), \dot{R}(\varphi)$ reflect the motion of $\tau = 0$ while the spectral lines originate from the surroundings of $\tau_{\lambda_\mathrm{line}} \approx 0.3$. Non-negligible velocity gradient is definitely present in an RR Lyrae atmosphere (e.g. Oke et al., 1962) and the limb darkening integrates the non-uniform motion of the layers $0 < \tau < 0.5$ into a single value $v_\mathrm{radial}(\varphi)$. (Dynamical atmospheric models are not available to treat quantitatively the conversion of the pulsation velocity to $v_\mathrm{radial}(\varphi)$.)
>
> CORAVEL technique is itself accurate for stars of non-variable spectra while applying it for a variable spectrum may result in systematic errors which are not easy to survey. The coarse agreement of $v_\mathrm{radial}(\varphi)$ from spectroscopy and CORAVEL is obvious in *Fig. 3d*, however, the large scatter indicates that some caution is appropriate, especially, since fine details of $\vartheta(\varphi)$, $v_\mathrm{radial}(\varphi)$ play some role in a BW analysis.

Conclusions

The purely photometrically derived fundamental parameters of T Sex (see Table 4) have been found from ATLAS atmospheric models of Kurucz (1997) and their calibration to stellar photometric systems (Castelli, 1999). They have been found to be in consensus with our knowledge on stellar models and pulsation theory of asymptotic giant branch stars. In addition to bridging over these remote branches of astrophysics some details have been revealed on RR Lyrae type pulsation: at the RRc variable T Sex fine structure, definite footprint of two shocks have been found in the variable stellar radius $R(\varphi)$ (i.e. in the distance of zero optical depth from the stellar centre). In a previous study of SU Dra similar details were found concerning the fine structure of the atmospheric pulsation: there is at least one pair of temporal, intermediate, minor standstills of the pulsating atmosphere between maximum and minimum extension. This seems to be a common feature of RRab and RRc stars at phase ≈ 0.55, it was not considered (or it was smoothed out) in the previous BW studies, presumably because it is a sub-oscillation in the upper stellar atmosphere which is scarcely reflected in the radial velocities. (The radial velocities give information on the motion of the deeper layers.) To derive the fundamental parameters the less accurate radial velocity observations and their problematic conversion to radius changes had not to be used at all, however, an indication of eventual variable barycentric velocity of T Sex has arisen.

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Formation of the Supercluster-Void Network

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A review of the study of superclusters based on the 2dFGRS and SDSS is given. Real superclusters are compared with models using simulated galaxies of the Millennium Run. We show that the fraction of very luminous superclusters in real samples is about five times larger than in simulated samples. Superclusters are generated by large-scale density perturbations which evolve very slowly. The absence of very luminous superclusters in simulations can be explained either by non-proper treatment of large-scale perturbations, or by some yet unknown processes in the very early Universe.

Introduction

Superclusters are the most extensive density enhancements in the Universe of common origin. Investigation of large systems of galaxies was pioneered by the study of the *Local Supercluster* by de Vaucouleurs (1953) and by Abell (1961) and using rich clusters of galaxies by Abell (1958) and Abell et al. (1989). Superclusters consist of galaxy systems of different richness: single galaxies, galaxy groups and clusters, aligned in chains (Jõeveer, Einasto, & Tago, 1978; Gregory & Thompson, 1978; Zeldovich, Einasto, & Shandarin 1982).

New deep galaxy surveys, such as the Las Campanas Galaxy Redshift Survey, the 2 degree Field Galaxy Redshift Survey (2dFGRS, Colless et al., 2001, 2003), and the Sloan Digital Sky Survey (SDSS, Adelman-McCarthy et al. 2006) cover large areas in the sky and are almost complete up to fairly faint apparent magnitudes. Thus these surveys are convenient to detect superclusters using both galaxy and cluster data. This possibility has been used by Basilakos (2003), Basilakos et al. (2001), Erdogdu et al. (2004), Porter & Raychaudhury (2005), and Einasto et al. (2003a, 2003b, 2005, 2006a).

The goal of the present review is to analyse properties of superclusters based on the 2dF Galaxy Redshift Survey and the Sloan Digital Sky Survey Data Release 4 by Einasto et al. (2006a, 2006b, 2006c), and to compare properties of real superclusters with theoretical models. 2dFGRS and SDSS supercluster catalogues have been compiled using group catalogues of 2dFGRS and SDSS DR4 surveys, found by Tago et al. (2006a, 2006b). For comparison we use the superclusters found for the Millennium Run mock galaxy catalogue by Croton et al. (2006), that itself is based on the Millennium Simulation of the evolution of the Universe by Springel et al. (2005).

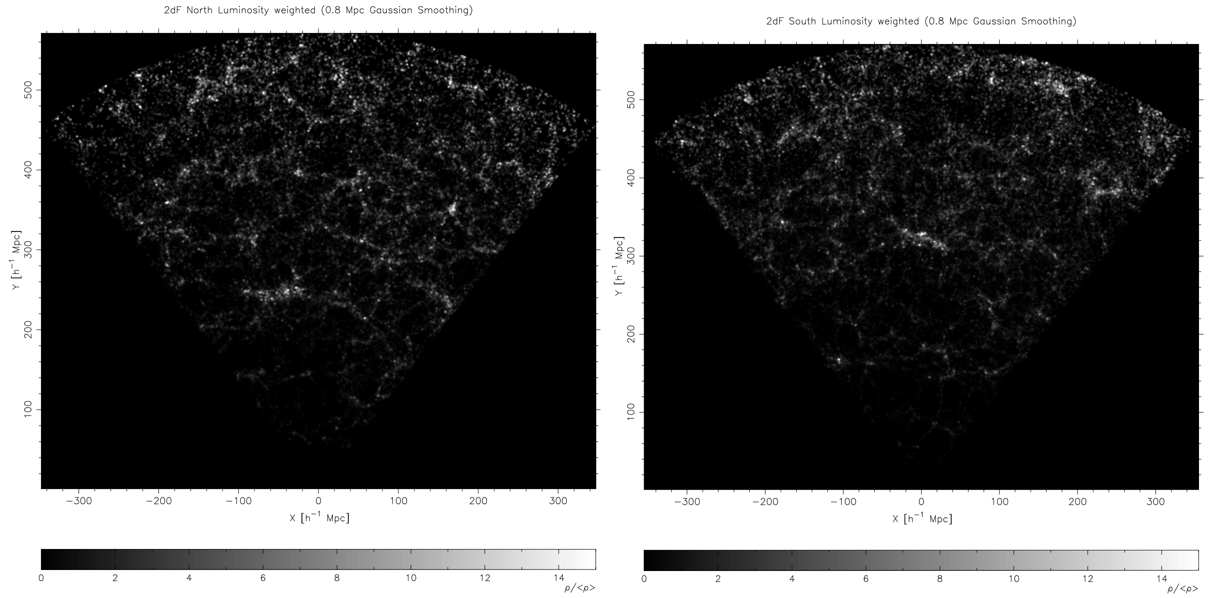

Figure 1: The high-resolution 2-dimensional density fields of the Northern and Southern parts of the 2dF redshift survey are shown in the left and right panels, respectively. The samples are conical, i.e. their thickness increases with distance, thus at large distances from the observer we see many more systems of galaxies. The richest supercluster in the Northern region is SCL126 in the list by Einasto et al. (1997), also called the Sloan Great Wall by Vogeley et al. (2004); the richest Southern supercluster is SCL9 by Einasto et al. (1997), or the Sculptor Supercluster.

Superclusters in the 2dF and Sloan surveys and in the Millennium simulation

Both real and model superclusters were found using the luminosity density fields calculated using Epanechnikov smoothing with a radius of 8 h^{-1} Mpc. Superclusters were defined as connected non-percolating systems with densities above a certain threshold density. These density fields were normalized to identical mean levels, and all regions above a threshold density 6 (in units of the mean density) were considered as superclusters. The density fields were calculated for a grid step of 1 h^{-1} Mpc, which allows to investigate the detailed spatial structure of superclusters. The 2dFGRS superclusters were found separately for the Northern and Southern regions of the 2dF Survey, and SDSS superclusters – for the high-declination region of the SDSS DR4 Survey in the Northern hemisphere. The 2dF Northern and Southern regions together contain 544 superclusters, the SDSS Northern survey has 911 superclusters. The comparison model samples have 1733 and 1068 superclusters (the full model sample and the simulated 2dF sample, respectively).

In *Figs. 1* and *2* we show high-resolution density fields on the 2dFGRS and SDSS surveys. All wedges are about 10 degrees thick, thus near to the observer they are thin. These figures show the cosmic web – a continuous network of galaxy systems of various

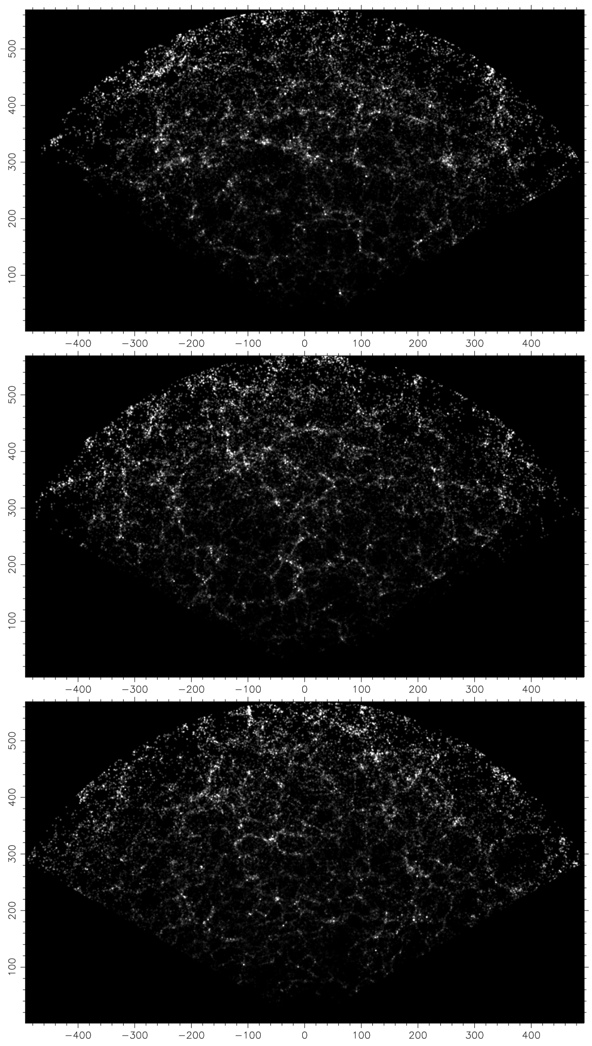

Figure 2: The high-resolution 2-dimensional density field of the SDSS DR4 Northern high-declination region. The wedges are drawn in rectangular coordinates based on the SDSS survey coordinates η and λ, and have a thickness of 9.33 degrees in λ; the panels from bottom to top correspond to increasing λ values. Note the presence of rich superclusters in all wedges.

luminosity densities, and voids between them. All luminous regions seen in these figures are superclusters. We see that they have very different richness, some are very small and resemble the Local Supercluster around the Virgo cluster, some are large and very rich.

For all superclusters their geometric and physical properties were found. Among the geometrical properties are the position (RA, DEC, and distance), the size, and the offset of the geometrical center from the dynamical one, defined as the center of the main (most luminous) cluster. The physical properties are the mean and maximum luminosity densities, the total luminosity and the luminosity of the main cluster and of the main galaxy (the brightest galaxy of the main cluster).

Comparison of properties of model superclusters with properties of real superclusters shows that they are very similar. Superclusters consist of several chains (filaments) of galaxies, groups, and clusters. These chains have various length, thus superclusters are asymmetrical in shape. The degree of asymmetry is higher in rich superclusters. Rich superclusters are also denser and contain luminous knots – high-density nuclei.

Rich superclusters in real data and models

One important property of superclusters is different in real and model samples – the supercluster richness. To characterise the richness we used two independent characteristics: the total luminosity and the number of rich clusters, i.e. the multiplicity.

The multiplicity was derived from the number of high-density knots of the density field. We call these knots DF-clusters. The spatial density of DF-clusters is about twice that of Abell clusters in the same volume, thus the expected number of DF-clusters in superclusters is about twice the number of Abell clusters. Both functions were determined separately for the 2dFGRS and SDSS superclusters, and for the total observational sample.

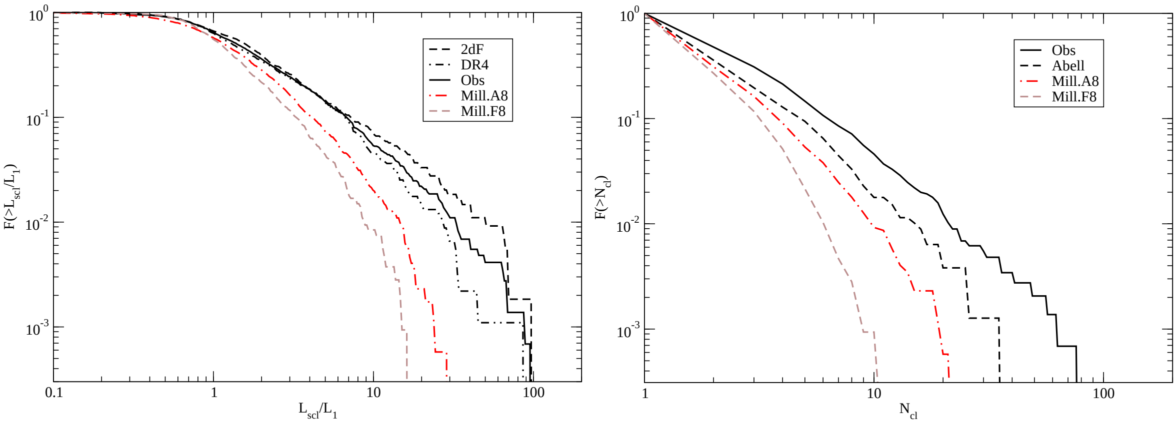

Figure 3: Comparison of relative luminosity functions and multiplicity functions of observational and model supercluster samples (in left and right panels, respectively). The spatial density of superclusters is expressed in terms of the total number of superclusters in a sample to avoid small differences due to different mean supercluster number densities in different samples. In the left panel we show the relative luminosity functions separately for the observational samples SDSS DR4, 2dF, and for the combined sample Obs, in the right panel we use the combined observational sample Obs, and the Abell supercluster sample (here the multiplicity is defined by the number of Abell clusters, and isolated Abell clusters are considered as richness class 1 superclusters). Mill.A8 and Mill.F8 denote the full and simulated 2dF Millennium supercluster samples, respectively.

The total luminosity was calculated by summing the luminosities of galaxies and clusters of galaxies inside the density contour, which defines the boundary of the supercluster. In our case the threshold density was chosen to be 6 (in units of the mean density). In calculating total luminosities we used weights for galaxies which take into account the galaxies outside the observational luminosity window of a survey. To avoid complications due to the use of different color systems and mean luminosities, we used *relative* luminosities, normalized by the mean luminosity of poor superclusters, i.e. the superclusters that contain only one DF-cluster.

For model samples we calculated these functions for two cases. One sample uses all model galaxies and can be considered as the “true” model sample. The second model sample simulates the 2dF sample, where an “observer” was put into one corner of the sample, and only these galaxies were included, which satisfy the same selection criteria as used in the real 2dF sample.

The luminosity and multiplicity functions of real and model samples are compared in *Fig. 3*. We see that both functions show much more rich superclusters for real samples than for model samples. This difference is the major cosmological result of the analysis of our supercluster survey. The presence of very rich superclusters in our vicinity is well known; good examples are the Shapley Supercluster and the Horologium-Reticulum Supercluster (see Fleenor et al., 2005; Proust et al., 2006; Nichol et al., 2006; Ragone et al., 2006, and references therein). But until recently the number of such extremely massive superclusters was too small to make definite conclusions about their abundance.

When comparing models with observations we have to use the simulated 2dF sample, which is formed using the same selection criteria as used for the observational sample. The most luminous simulated superclusters of this sample have a relative luminosity of about 15 in terms of the mean luminosity of richness class 1 superclusters, whereas the most luminous superclusters of real samples have a relative luminosity about 100, i.e. they are about 6 times more luminous. The richest model superclusters have a multiplicity of 10, whereas the multiplicity of the richest real superclusters is over 70. The number of Abell clusters in the richest Abell supercluster is 34 (Einasto et al., 2001).

Figures 1 and *2* show that very luminous superclusters are located in *all subsamples* (the Northern and Southern regions of the 2dFGRS, and in subregions of the SDSS DR4 sample, if divided into 3 wedges of equal width). These subsamples have characteristic volumes of about 10 million cubic h^{-1} Mpc, whereas model samples of 10 times larger volume have no extremely rich superclusters.

Formation of the supercluster-void network

To check these results we used a number of independent numerical simulations, carried out for simulation boxes of size of 500 h^{-1} Mpc and 768 h^{-1} Mpc, using 512^3 Dark Matter particles. We found DM-halos in simulations, and used them to calculate the smoothed density field as for real and Millennium Simulation. For all simulations we then found simulated superclusters as previously, and found the distribution of dense knots (simulated rich clusters). These calculations confirmed our previous result: the number of dense knots in simulated superclusters is much smaller than in real superclusters.

This striking conflict between model and reality needs explanation. In order to understand the formation of rich superclusters we used wavelet analysis to investigate the role of density waves of different scales. The á trous wavelet technique we used allows to divide the density field into components of various wavelength bands, so that the field is restored by summing all components. The wavelet analysis was carried out both for real and model samples.

Our results show that in all cases superclusters form only in regions where *large density waves combine in similar local phases to generate high density peaks.* Very rich superclusters are objects where density waves of all large scales (up to a wavelength $\sim$ 250 h^{-1} Mpc) have similar phases. The smaller is the maximum wavelength of such phase synchronization, the lower is the richness of superclusters. Similarly, large voids are caused by large-scale density perturbations of wavelength $\sim$ 100 h^{-1} Mpc, here large-wavelength modes combine *in similar local phases to generate under-densities.*

Superclusters of galaxies are formed by density perturbations of large scales. These perturbations evolve very slowly. As shown by Kofman & Shandarin (1988), the present structure on large scales is built-in already in the initial field of linear gravitational potential fluctuations. Actually they are remnants of the very early evolution and stem from the inflationary stage of the Universe (see Kofman et al., 1987). The distribution of luminosities of superclusters allows us to probe processes acting at these very early phases of the evolution of the Universe.

There are two possible explanations for the large difference between the distribution of luminosities of real and simulated samples. One possibility is that in present simulations the role of very large density perturbations, responsible for the formation of these very luminous superclusters, is underestimated. The other feasible explanation of the differences between models and reality may be the presence of some unknown processes in the very early Universe which give rise to the formation of extremely luminous and massive superclusters.

Conclusions

1. Geometric properties of superclusters are well explained by current models.
2. There are much more very rich superclusters than models predict.
3. Large perturbations evolve very slowly and represent the fluctuation field at the epoch of inflation.
4. The difference between observations and models can be explained in two ways:
   large-scale perturbations are not incorporated in the models, i.e. models need improvement;
   there occurred presently unknown processes during inflation.

The present review is based on talks held in Budapest on April 20, 2006 in Detre Centenary, in Uppsala University on April 27, 2006, and in Aspen Workshop on Cosmic Voids on June 6, 2006. I thank my collaborators Maret Einasto, Enn Saar, Erik Tago, and Volker Müller for permission to use results of our common work in this review. We are pleased to thank the 2dFGRS and SDSS Teams for the publicly available data releases. The present study was supported by Estonian Science Foundation grants No. 4695, 5347, and 6104, and Estonian Ministry for Education and Science support by grant TO 0060058S98. I thank Astrophysikalisches Institut Potsdam (using DFG-grant 436 EST 17/2/05) and Uppsala University for hospitality where part of this study was performed. 2dFGRS supercluster catalogues are available at `http://www.aai.ee/~maret/2dfscl.html`, Sloan DR4 supercluster catalogues at `http://www.aai.ee/~maret/SDSSDR4scl.html`.

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