ASTRONOMY IN TORUŃ NICHOLAS COPERNICUS' NATIVE TOWN

Nicholas Copernicus, the famous Polish astronomer, was born five hundred years ago in Toruń, an old town situated on the board of Vistula, in the North of Poland. Copernicus was the first scientist, who not only conceived the idea of heliocentric motions in the planetary system, but also proved by mathematical arguments, that his system was in agreement with his observations.

In the astronomer's native town a new university bearing his name was organized in 1945. The history of the Astronomical Observatory of the Nicholas Copernicus University is told in this booklet. The reader will find some details about the difficult beginnings and further development of the Observatory, and the research activities of the Toruń astronomers.

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edited by

CECYLIA IWANISZEWSKA

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The photograph on the cover:
Nicholas Copernicus, anonymous painting from the XVI c.

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„Among the numerous and various arts and sciences evoking our love and supplying food to the human mind, those — in my opinion — that have a bearing on things more beautiful and more worthy of knowledge than others, call for our attention most of all and should be cultivated with the utmost zeal. Such are the sciences concerned with the wonderful revolutions occuring in the Universe and the course of stars, their size and distances, their rising and setting as well as with the causes of all other phenomena in the Heavens, for they, finally, explain the whole system of the world. And what is there more beautiful than the Heavens which indeed embrace everything that is lofty and beautiful?"

Nicholas Copernicus. *De Revolutionibus.* Book I

1. Town-Hall at Toruń, originally built in XIII c., rebuilt and renovated in XVII, XVIII, XIX c.

2. Old city of Toruń, seen from the Vistula

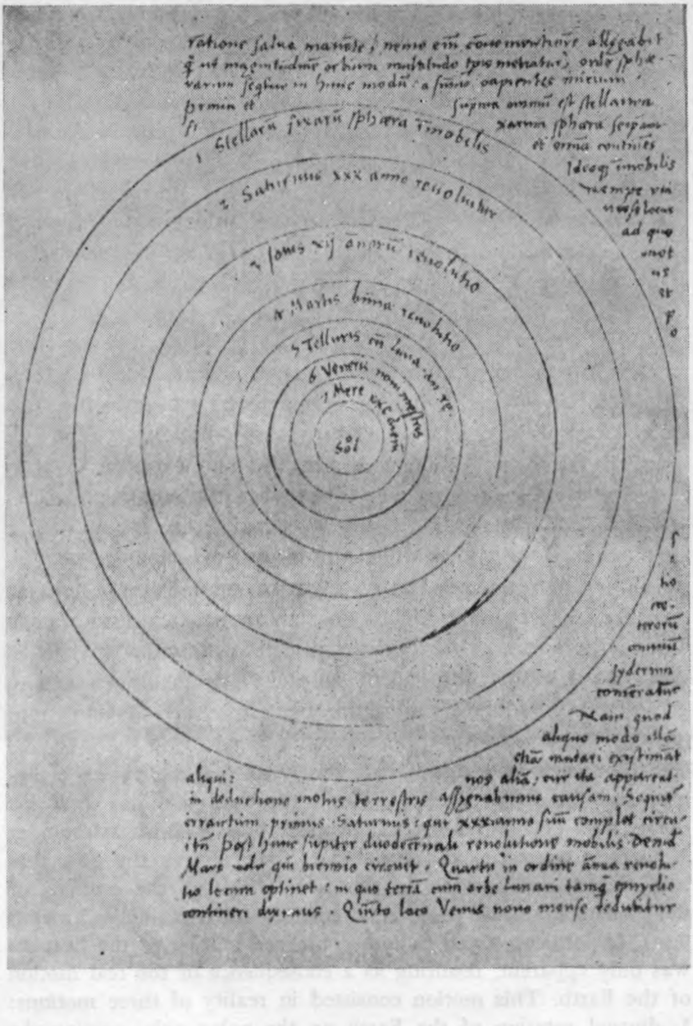
NICHOLAS COPERNICUS FOUNDER OF MODERN ASTRONOMY

Astronomy is one of the oldest sciences known to mankind. Every civilization and culture of which we have records has had its own conception of cosmology, has had its own answer to the important question: „What is the shape of the Universe?" These answers had to be in accordance with the observed aspects of the heavens, no wonder then that in most cosmological theories the theory of geocentric (in Greek „gê" means Earth) motions prevailed. The Moon, Sun and planets were believed to revolve around the Earth, since people observed the apparent motion of the heavens around the Earth.

COPERNICUS' HELIOCENTRIC THEORY

The first scientist who not only conceived the idea that the planets and the Earth revolve around the Sun, but also gave his theory very detailed theoretical support, was a Polish astronomer Nicholas Copernicus (1473—1543). Since it was the Sun that held the central position in this new Universe, the motions of the planets were said to be heliocentric (in Greek „helios" means Sun). Copernicus stated that the observed motion of the heavens was only apparent, resulting as a consequence of the real motion of the Earth. This motion consisted in reality of three motions:

1. diurnal rotation of the Earth on the polar axis, causing the apparent rotation of the heavens;
2. annual revolution of the Earth around the Sun, causing the change of seasons, since the Earth axis is inclined to the plane of the terrestrial orbit;



3. The heliocentric system, drawn by Copernicus himself on the manuscript of *De Revolutionibus*

3. precessional motion of the Earth's polar axis around an axis perpendicular to the plane of the terrestrial orbit, causing the motion of the equinoxes.

Of course, if the Earth was set in motion by Copernicus' theory, the author of this theory had to revise the existing theories of planetary motions, to get their positions in accordance with observations made from a rotating and revolving Earth.

Nicholas Copernicus was born on February 19th, 1473 in Toruń, of a merchant family. He studied at the University of Cracow from 1491 to 1495, and later in Italy, where he stayed in Bologna, Padua, and Ferrara from 1496 to 1503. From 1510 until his death in 1543 Copernicus held a position of a Canon of the Chapter of Warmia in Frombork, a little town in the North of Poland, where he spent most of his time working out his theory. To test this he made many astronomical observations, using very simple wooden instruments (with no lenses since these were not invented until a hundred years later).

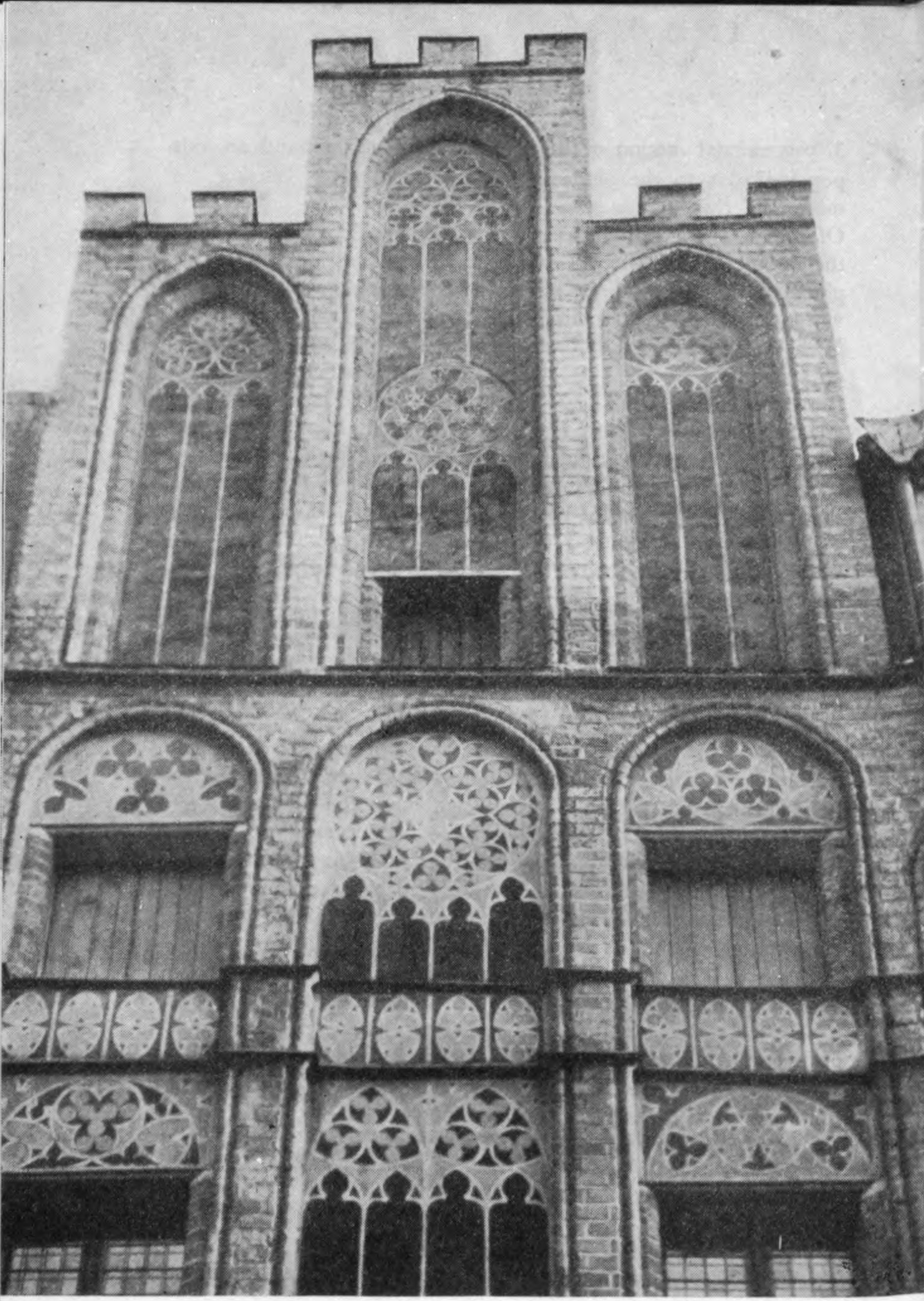
COPERNICUS' MOTIVES

A short report on his new theory was written as a letter by Copernicus himself (between 1510 and 1515) and circulated in handwritten copies among astronomers. From the first words of the text it was called *Commentariolus* — Commentary. But it took Copernicus many years of constant work to give the final form to his principal work — the detailed theory of motions in a heliocentric system. His friends and his only pupil, a young mathematician from Nuremberg, Joachim von Lauchen, known as Rheticus, urged Copernicus to publish his theory, to which he agreed at last in 1539. Finally, in the autumn of 1541 Rheticus took the Latin manuscript to Nuremberg, where the work was printed in 1543 under the title given by the editors:

NICOLAI COPERNICI TORINENSIS
DE REVOLUTIONIBUS ORBIUM COELESTIUM LIBRI SEX

which means:

„NICHOLAS COPERNICUS OF TORUŃ
ON THE REVOLUTIONS OF THE HEAVENLY SPHERES, SIX BOOKS".



4. The house where Copernicus was born, renowated in 1964

It is not sure whether this was the original title proposed by Copernicus himself, most probably it was to be only „ De Revolutionibus" — „On the Revolutions", or „Liber Revolutionum" — „Book on the Revolutions".
The arguments which led Copernicus to the discovery of a new Universe, were given by the author himself in a prefatory letter to his work, dedicated to Pope Paul III:

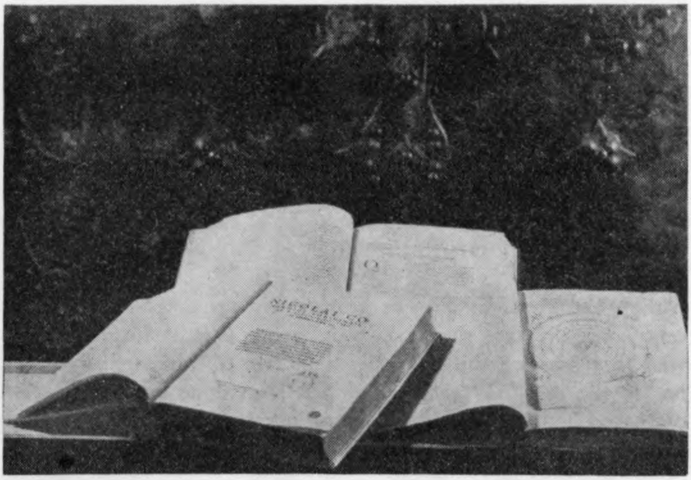
„...I was induced to think of a method of computing the motions of the spheres by nothing else than the knowledge that Mathematicians are inconsistent in these investigations. For, first, the mathematicians are so unsure of the movements of the Sun and Moon, that they cannot even explain or observe the constant length of the seasonal year. Secondly, in determining the motions of these and of the other five planets, they use neither the same principles and hypotheses nor the same demonstrations of the apparent motions and revolutions [...] Nor have they been able thereby to discern or deduce the principal thing — namely the shape of the Universe and the unchangeable symmetry of its parts...".
These last words were very characteristic of Copernicus' way of thinking, of his opinion of the harmony of the whole Universe. He stated further in Chapter X of Book I, that in his system:

„We find underlying this ordination an admirable symmetry and a clear bond of harmony in the motion and magnitude of the spheres such as can be discovered in no other wise..".
But let us look further at Copernicus' preface, in which he wrote about his own preparations to start the elaboration of his theory as follows:
„...I took pains to read again the works of all the philosophers on whom I could lay hands to seek out whether any of them had ever supposed that the motions of the spheres were other than those propounded by the mathematical schools [...]
Taking advantage of this I too began to think of the mobility of the Earth, and though the opinion seemed absurd, yet knowing now that others before me had been granted freedom to imagine such circles as they chose to explain the phenomena of the stars, I considered that I also might easily be allowed to try whether, by assuming some motions of the Earth, sounder explanations than theirs for the revolution of the celestial spheres might so be discovered.

Thus assuming motions, which in my work I ascribe to the Earth, by long and frequent observations I have at last discovered that, if the motions of the rest of the planets be brought into relation with the circulations of the Earth and be reckoned in proportion to the circles of each planet, not only do their phenomena presently ensue, but the orders and magnitudes of all stars and spheres, nay the Heavens themselves, become so bound together that nothing in any part thereof could be moved from its place without producing confusion of all the other parts and of the Universe as a whole".

THE CONTENTS OF *DE REVOLUTIONIBUS*

The first book was directed to laymen, to people without a profound mathematical or astronomical training, while the other five books were to be presented to mathematicians.
Copernicus stated in the first chapters, that the universe is spherical, and the Earth is also spherical, for which he gave many arguments; that the Earth motion should be circular (because the circle was considered as a most perfect figure), and, finally, that the real motion of the Earth is the cause of the apparent motion of the celestial sphere.
„...If then any motion of the Earth be assumed it will be reproduced in external bodies, which will seem to move in the opposite direction. Consider first the diurnal rotation. By it the whole Universe, save Earth alone and its contents, appears to move very swiftly. Yet, grant that Earth revolves from west to east, and you will find, if you ponder it, that my conclusion is right. It is the vault of Heavens that contains all things and why should not motion be attributed rather to the contained than to the container, to the located than the locater?"
Still further, Copernicus stated that the size of the Earth's orbit in relation to the size of the whole Universe, to the distances of stars, is found to be so small, that the changes in the positions of the Earth do not give any apparent shifting of the stars on the celestial sphere. In reality such a parallactic shifting was discovered only several centuries later, when optical telescopes had become available.
According to Copernicus the planets had to revolve around the Sun in the following order:



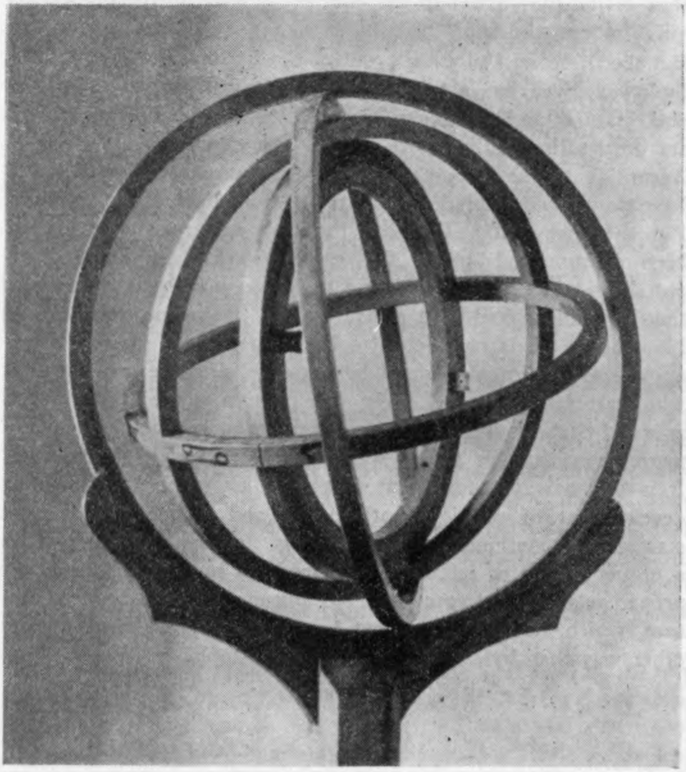
5. The oldest editions of *De Revolutionibus* (Nuremberg 1543, Basel 1566, Amsterdam 1617)

„Most distant of all is the sphere of the fixed stars [...] Next is the planet Saturn, revolving in 30 years. Next comes Jupiter, moving in a 12-year circuit; then Mars, who goes round in 2 years. The fourth place is held by the annual revolution of the sphere in which the Earth is contained, together with the sphere of the Moon as on an epicycle. Venus, whose period is 9 months, is in the fifth place, and sixth is Mercury, who goes round in the space of 80 days.
In the middle of all the Sun sits enthroned. Could we place this luminary in any better position then in this most beautiful temple from which he can illuminate the whole at once?".
In the Copernican system the observed westward and retrograde motions of the planets were accounted for by changes in the respective positions of the planet and of the observer, situated on a moving Earth. The planetary orbit was a circle, but Copernicus had to introduce a system of supplementary circles (similar to those in the Ptolemaic system), in order to account for the discrepancies between the observed and circular motions. A smaller circle, called epicycle, moved on a bigger one, the deferent, and

the planet had to move on the epicycle. These two kinds of circles, introduced to planetary motions many centuries earlier, were finally dropped only in the beginnings of the seventeenth century, after Kepler's discovery of elliptical planetary orbits.
The other books of *De Revolutionibus* are full of mathematical considerations and arguments; they comprise many astronomical definitions and auxiliary tables, a detailed theory of the Earth revolution around the Sun, the motions of the Moon and planets, a catalogue of positions and brightness of over one thousand stars.
Although Copernicus is more known as a promoter of the heliocentric system, one should bear in mind, that it was also him, who first ascribed the precessional motion to the Earth axis and not to the celestial sphere as it had been done before. He also compared long series of planetary observations and concluded from them that the apside lines of planetary orbits are shifting.

THE SIGNIFICANCE OF COPERNICUS' THEORY FOR THE DEVELOPMENT OF ASTRONOMY

All the events observed on the celestial sphere could be connected with the terrestrial ones, since according to Copernicus the Earth was one of the planets, and so the terrestrial physical laws could also be applied outside the Earth.
The introduction of relative motions, already known in Optics, to the theory of planetary motion was one of Copernicus' achievements. It should also be pointed out, that in *De Revolutionibus* there are no speculations not based upon facts, all the arguments are well connected with astronomical observations.
The Copernican universe was still in many aspects very traditional. The Sun, lying in its centre, was not yet a star; the sphere of unmovable stars was considered the limit of the universe; the planetary motions could be explained only by means of epicycles and deferents. Many propositions coming out of this theory were found much later by Copernicus' successors, when more accurate observations became available.
Sixty years later the Italian mathematician and astronomer, Galileo Galilei, was the first who found observational arguments for Copernicus' theory. Using the first astronomical telescope, he



6. One of Copernicus' instruments – the astrolabe (reconstruction)

discovered in 1609 four satellites of Jupiter. The motions of these satellites around Jupiter were quite similar to those of the planets around the Sun in the Copernican system. He also saw that Venus shows phases similar to those of the Moon but in such succession which proves its revolving around the Sun, not around the Earth.

It was also about that time that Johan Kepler in Prague discovered his famous laws of planetary motions, and in 1687 Isaac Newton published his law of gravitational attraction of bodies, thus giving the answer to the question: „Why do the planets revolve around the Sun?"

But the first direct physical proof of the Earth motion around the Sun was given by James Bradley, when in 1728 he found the aberration of light, a slight displacement of the direction to the star in the direction in which the Earth is moving.

According to the Copernicus' theory the nearest stars ought to have parallactic displacements, arising from their finite distances. But the first stellar distances, the first stellar parallaxes have been measured only in the XIX c. by Wilhelm Struve and Friedrich Bessel and they were found to be so small, that no wonder that Copernicus could not measure them, having no telescope.

Nonetheless he is considered to be the father of modern astronomy and the founder of modern science, since he was the first who started to think in a right way relative to the Universe and proved by laborious mathematical arguments, as much as he could prove then, that his system was in agreement with observations. It is by no way an accident that with his work a tremendous development of physics, mathematics and all natural sciences started and continues up to our days. Placing the observer in a proper system of reference he helped his successors to discover proper relations between observed phenomena, the laws of nature, which, he showed, cannot be successfully explained in any other way than by applying mathematical tools.

HISTORY OF THE TORUŃ OBSERVATORY

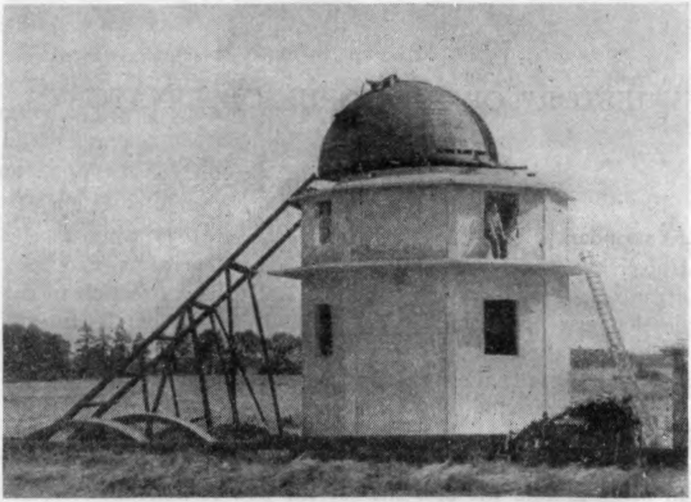
THE BEGINNINGS

Astronomical activities in Toruń began in 1945 when a new University, bearing the name of Nicholas Copernicus, had been organized. It was considered appropriate to pay attention to the development of astronomy in the native town of Copernicus. Hence two astronomical chairs were established at the Faculty of Sciences. These chairs were headed, one by professor Władysław Dziewulski, director of the Observatory till 1952, the other by professor Wilhelmina Iwanowska, the succeeding director of the Observatory and presently of the Astronomical Institute.

In order to find the best site for the new Astronomical Observatory both professors explored the neighbourhood of Toruń, and finally decided upon the village Piwnice, situated 12 km North-West of the town and separated from it by woods. The geographical coordinates of the Observatory are: 53°06′ N, 1^h14^m E and 90 m altitude.

There was no way to have a telescope built in Poland, or to buy it from abroad. The only way to obtain a telescope in those difficult postwar days was to borrow one from older and richer Observatories. Thanks to the kindness of professor Harlow Shapley, director of Harvard College Observatory, their 8-inch astrograph with two objective prisms was sent to Poland, reaching Toruń in June, 1947. It was the famous Draper astrograph, which served Miss Cannon in her spectral classification many years ago. Installed in a 5 m dome built by a local firm, the astrograph began its work in 1949. The first research plate was taken in Piwnice on July, 24, 1949, it was a region of Aquila for the Milky Way program. Many years later, in 1964, when professor Shapley visited the Toruń Observatory he said:

„After the First World War I have lent an 8-inch astrograph to Poland, to the Cracow Observatory. After the Second World War I lent an 8-inch to your Observatory. Now, there can't be a third War because we have no more 8-inch astrographs at Harvard!"



7. The erection of the first astronomical building in 1948 - the five meter dome constructed in Toruń, brought to Piwnice and mounted on top of the building

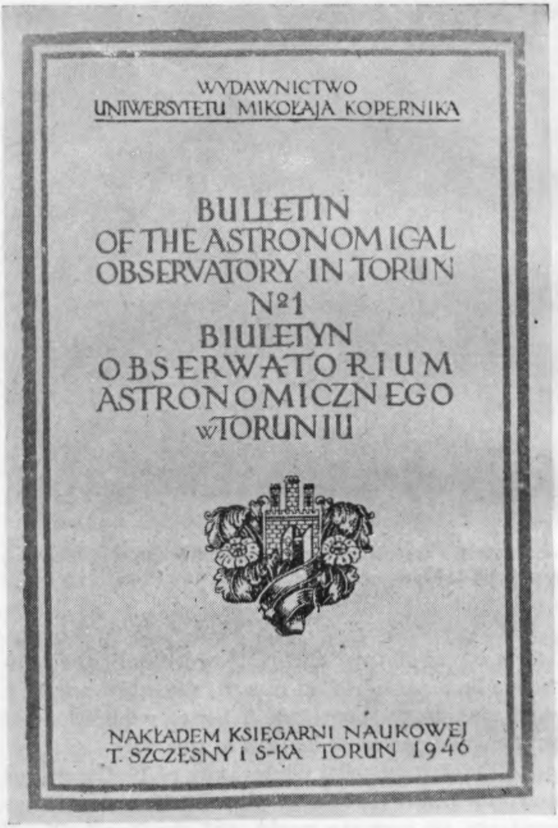
The next two small telescopes were assembled in the Observatory workshop: the optics were acquired at a very low price in Sweden, with the help of professor Bertil Lindblad, director of the Saltsjöbaden Observatory; the mounting, from an English firm. In such a way the Observatory came into the possession of a 35 cm Schmidt camera and a 25 cm parabolic reflector, both equipped with objective prisms. These instruments were put into operation in 1958, after the new domes had been constructed. But the Schmidt camera had already been working since 1953 in a provisional wooden hut built by the astronomers themselves.
Although the first astronomical plates were obtained in 1949, the first astronomical publications of the Observatory had appeared much earlier. In June 1946 the first „Bulletin of the Astronomical Observatory of Nicholas Copernicus University in Toruń" was published. The papers printed in this issue were based upon observational data collected before the Second World War by professors Iwanowska and Dziewulski at their former post — the Wilno University Observatory. The „Toruń Bulletin" appears irregularly, there are usually about two issues per year. Papers printed in various Polish scientific journals are bound together

8. A visit to Piwnice (1964) – two eminent astronomers professor Shapley (first from the left) and professor Lindblad (right) with professor Iwanowska

to form successive copies of the Bulletin. Fifty issues of the „Toruń Bulletin" have been published up to now, the list of scientific papers published runs up to about 250. A list of publications of the Toruń astronomers is given at the end of this book.
The „Bulletins of the Astronomical Observatory of N. Copernicus University in Toruń" have been sent since 1946 on exchange basis to observatories all over the world, and the Toruń Observatory is receiving in exchange many valuable scientific publications.

TEACHING ACTIVITIES

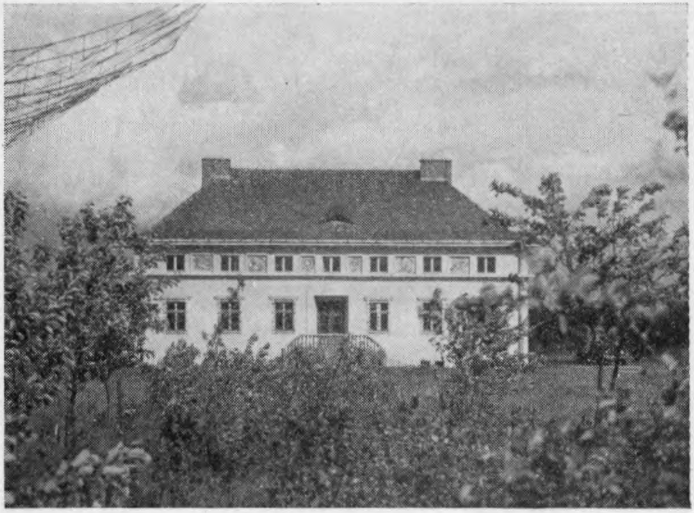
At the University of Nicholas Copernicus young people can obtain their degree of Master of Science in astronomy, after five years of study not only of astronomy, but mathematics as well as physics. The students can specialise in one of the four fields of astronomy: astrophysics, stellar astronomy, radioastronomy, celestial mechanics.



9. The front-cover of the first issue of the „Bulletin of the Astronomical Observatory of Nicholas Copernicus University in Toruń"

The first M. S. diploma in astronomy in Nicholas Copernicus University was given in 1950. Up to 1971, sixty more were given. The graduates are working at the Toruń Observatory, in High Schools and Universities, in research institutes, scientific libraries etc.

Besides teaching their own students, the Observatory staff has held summer courses for students from other Polish universities, as well as courses for young astronomers from other countries.

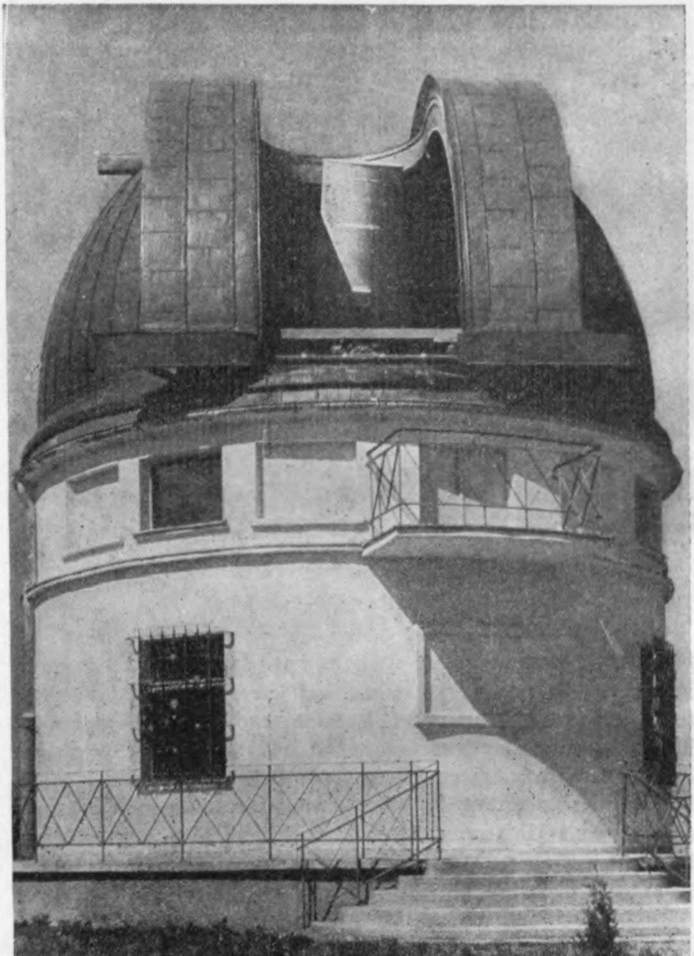


10. The main Observatory building in Piwnice, finished in 1957, comprising offices, laboratories, workshops

Since 1947, undergraduate students have been engaged to work in the Observatory as assistants, and later, after obtaining doctor's degree, as astronomers, lecturers and associate professors. The first doctor's degrees were taken in 1959. Up to 1971 sixteen degrees have been given. There is in Poland a third degree following the doctorate for obtaining a teaching permit (*veniam legendi*) at a University. Seven such degrees have been obtained in astronomy up to 1971.

FURTHER DEVELOPMENT OF THE OBSERVATORY

In 1957 the main Observatory building in Piwnice was finished. It comprises offices, laboratories, a small workshop, bedrooms.
In the late fifties radio observations were begun at the Toruń Observatory, the solar radio emission is recorded regularly since 1958.
Finally, in 1962 the Observatory got a telescope of a bigger size.



11. The dome of the Schmidt-Cassegrain telescope, built in 1962

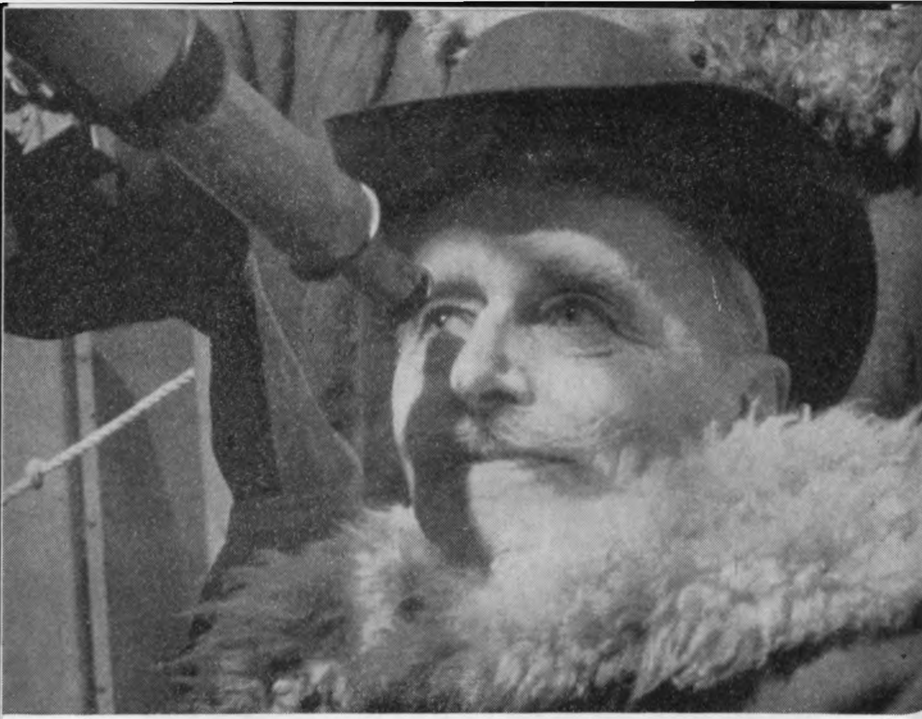
12. Professor Bertil Lindblad, a few moments after obtaining the first honorary doctor's degree of Nicholas Copernicus University in 1959

It was a Schmidt-Cassegrain telescope, with a mirror of 90 cm diameter, bought by the Ministry of Education and the Polish Academy of Sciences at the workshops of Carl Zeiss, Jena, East Germany.

Since 1957 there has been in Toruń and Piwnice an Astrophysical Laboratory of the Astronomical Institute of the Polish Academy of Sciences directed by professor Iwanowska.

Astronomers from the University Observatory as well as from the Academy Laboratory take part in scientific conferences held abroad. Many of them had Predoctoral or Postdoctoral Fellowships at different Observatories. Following countries have been visited by the Toruń astronomers: Australia, Belgium, Canada, Czechoslovakia, France, German Democratic Republic, German Federal Republic, Hungary, Italy, Netherlands, Sweden, Switzerland, United Kingdom, USA, USSR.

Astronomers from foreign countries visit the Toruń Observatory, coming from: Australia, Belgium, Bulgaria, Canada, Czechoslo-



13. Professor Władysław Dziewulski, the first director of the Observatory, at the Draper telescope

vakia, France, German Democratic Republic, Hungary, Italy, Netherlands, Sweden, U. K., USA, USSR, Yugoslavia.

Professor Lindblad was given the first honorary doctor's degree of Nicholas Copernicus University in 1959.

The Toruń astronomers are members of the International Astronomical Union, of the Polish Astronomical Society, as well as of the Toruń Scientific Society, in whose publications many astronomical papers have been printed.

WŁADYSŁAW DZIEWULSKI (1878–1962) THE FIRST DIRECTOR OF THE OBSERVATORY

When speaking about the first years of the Toruń Observatory, one has to mention its first Director — professor Władysław

Dziewulski. When he came to Toruń in 1945, he was already in the age of retirement. But in spite of his age, he was still full of energy and spent the first postwar years in organizing the new University, of which he became Vice-Rector, and also organized the new Astronomical Observatory. For fifteen years he was actively involved in scientific research, teaching as well as organizing work. He had always been very modest and approachable, had a special gift of understanding other people, and the faculty of teaching young people in their beginnings of scientific activity. The scientific papers of professor Dziewulski, nearly 200, have appeared in print. They are concerned with three main astronomical domains: celestial mechanics, stellar astronomy, photometry. In the first group are studies of disturbances in the motion of minor planets caused by the action of major planets. Statistical studies of motions of different groups of stars, in particular, motions of the local group — represent the domain of stellar astronomy. In photometry professor Dziewulski's investigations are concerned with photographic observations of variable stars, and also visual observations of these stars, which were conducted for many years. Such detailed observations of variable stars are indispensable when studying the elements of light variation of these stars.

Professor Dziewulski was a member of the Polish Academy of Sciences, of the Royal Astronomical Society, of the International Astronomical Union, of many other scientific associations here and abroad. In 1961 he received an honorary doctor's degree from Nicholas Copernicus University. He received many marks of dictinction and decorations for his merits in the development of Polish Science.

He died on February 6, 1962.

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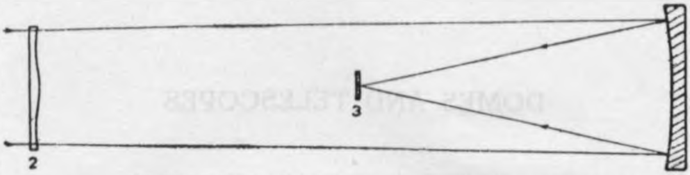
DOMES AND TELESCOPES

THE SCHMIDT-CASSEGRAIN TELESCOPE

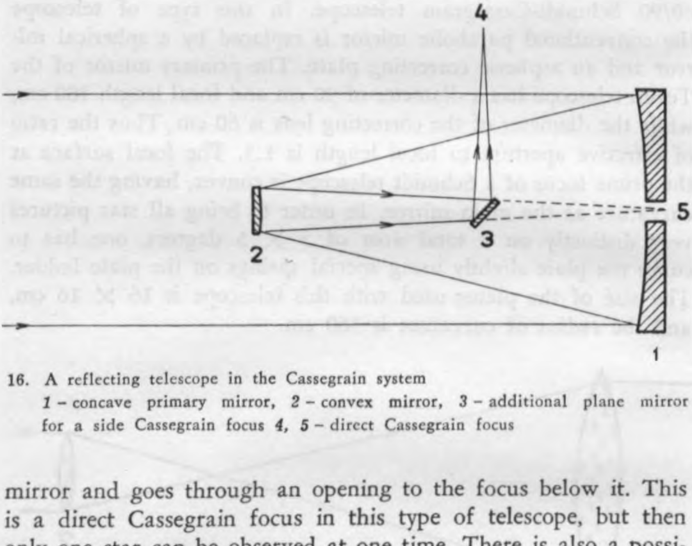
The principal instrument of the Toruń Observatory is the 60/90 Schmidt-Cassegrain telescope. In this type of telescope the conventional parabolic mirror is replaced by a spherical mirror and an aspheric correcting plate. The primary mirror of the Toruń telescope has a diameter of 90 cm and focal length 180 cm, while the diameter of the correcting lens is 60 cm. Thus the ratio of effective aperture to focal length is 1:3. The focal surface at the prime focus of a Schmidt telescope is convex, having the same curvature as the main mirror. In order to bring all star pictures very distinctly on a total area of 5 × 5 degrees, one has to curve the plate slightly using special springs on the plate holder. The size of the plates used with this telescope is 16 × 16 cm, and the radius of curvature is 360 cm.

14. A classical astronomical telescope
1 – objective, *2* – eye-piece

The Toruń Schmidt telescope has two objective prisms, yielding stellar spectra in dispersions of 250 or 550 Å/mm.
If one takes off the correcting plate, and puts a small convex mirror in front of the primary focus, the focal length of the telescope increases to 13.5 m and the focal ratio is 1:15. The light beam is then reflected back to the primary mirror by the small



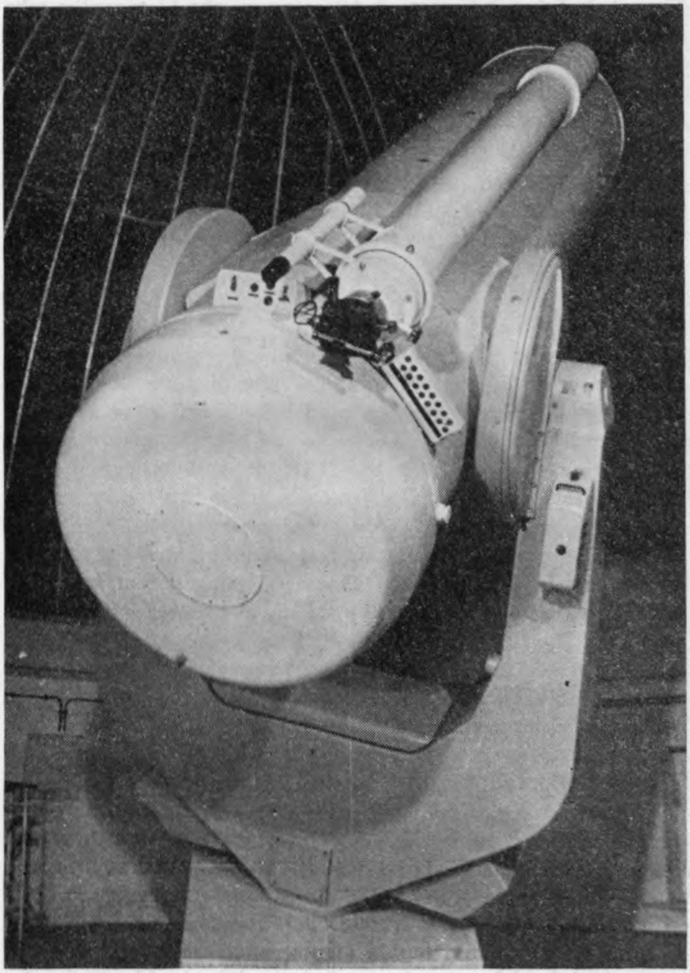
15. A Schmidt telescope
1 – spherical primary mirror, *2* – correcting plate, *3* – focal surface



16. A reflecting telescope in the Cassegrain system
1 – concave primary mirror, *2* – convex mirror, *3* – additional plane mirror for a side Cassegrain focus *4*, *5* – direct Cassegrain focus

mirror and goes through an opening to the focus below it. This is a direct Cassegrain focus in this type of telescope, but then only one star can be observed at one time. There is also a possibility to reflect the light beam to a side Cassegrain focus with the aid of an additional small plane mirror. The light beam then goes through a hole in the declination axis and is focused at the top of the fork mounting.

The light coming from the star is gathered here ordinarily by a photoelectric photometer hung at one side of the fork mounting. There ought to be a slit spectrograph attached to the other side of the mounting. With this auxiliary equipment one should be able to get spectra of single stars in greater dispersion and better resolving power. Such an instrument would be of special value when observing on hazy nights, which are quite frequent in Poland.

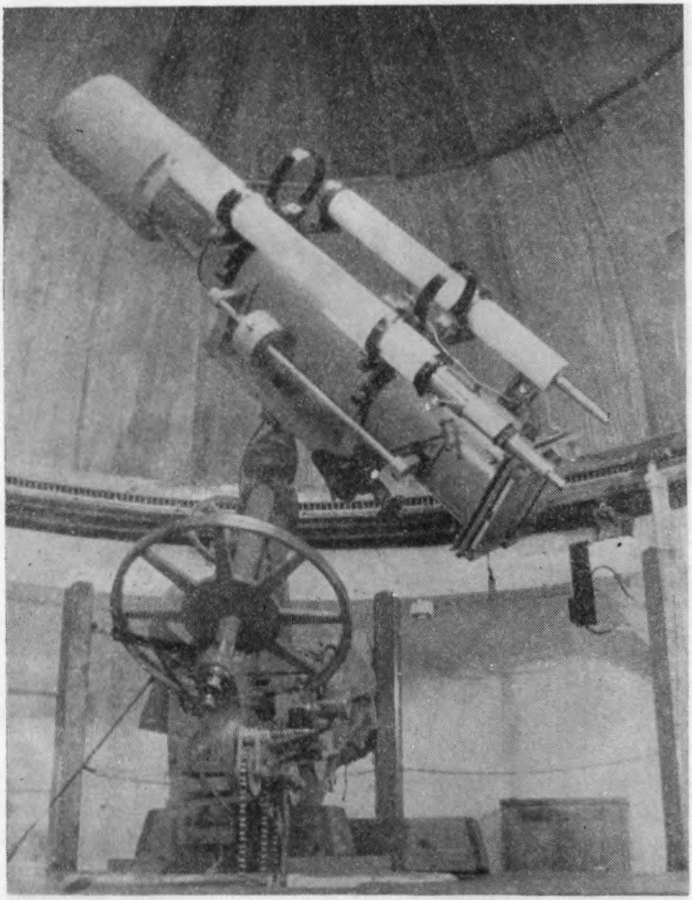


17. The Toruń 90 cm Schmidt-Cassegrain telescope, Poland's largest instrument

The whole Schmidt-Cassegrain telescope weighs 14 tons, the tube with the mounting 6 tons only. Friction is reduced to minimum and all parts are well balanced, so that the driving of the telescope is done by an electric motor of 35 W power. The telescope and its 8 m dome were manufactured by Zeiss, Jena.
The Schmidt-Cassegrain telescope is Poland's largest instrument, it is used in stellar astronomy studies not only by the Toruń astronomers, but also by all Polish astrophysicists.

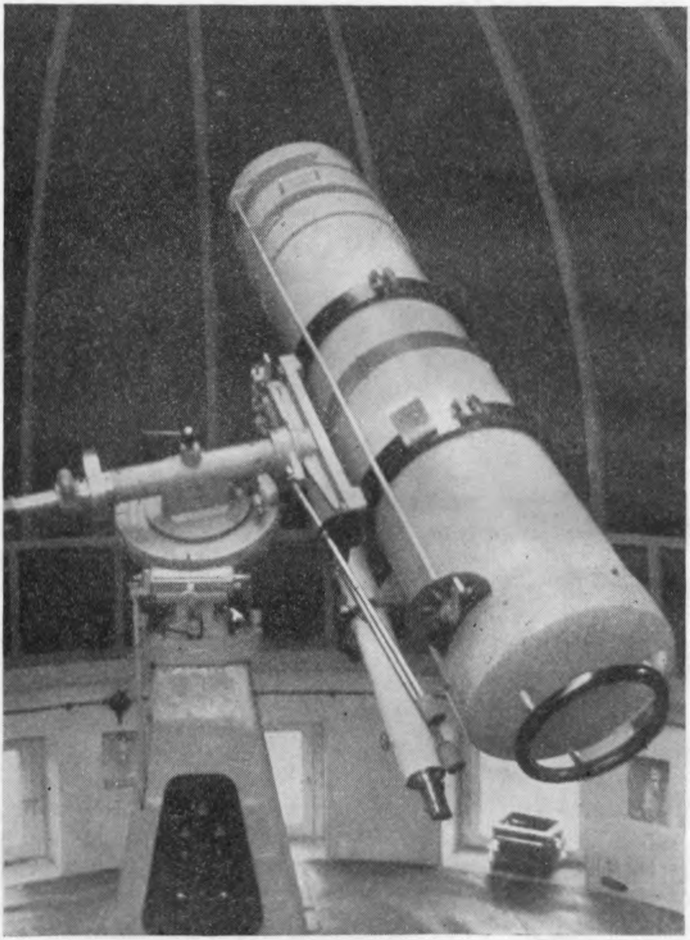
SMALLER TELESCOPES

The Draper astrograph is a photographic telescope. Its objective has 4 lenses of the Petzval type of 20 cm diameter and 126 cm focal length. The instrument is mechanically driven by a weight, controlled by a pendulum. There are two objective prisms as well as a grating, that may be put in front of the objective.
The Draper astrograph has a famous past: it was the instrument used in Harvard College Observatory for pioneer studies in astrophysics at the beginning of this century. With its help the first spectral catalogue, the Henry Draper Catalogue containing classified spectra of over 225 000 stars up to the 9 magnitude was produced. The first photographic standard catalogue of the North Polar Sequence and other fundamental works were made with the aid of this instrument. The Draper astrograph beats the world record of plates taken — 59 000 plates at Harvard and over 5 000 in Piwnice.
The Observatory possesses a smaller Schmidt telescope with a 35 cm mirror and 30 cm correcting plate. Its focal length is 75 cm. This instrument is being used only with an objective prism. The spectra of stars are taken on films of 8 cm diameter, placed in the primary focus. The optics were acquired in Sweden, while the mounting came from Irving, England.
A third smaller photographic telescope has a 25 cm parabolic mirror and focal length 140 cm. It is used in the Newtonian focus: a small plane mirror placed at an angle of 45° reflects the converging beam from the primary mirror to focus at the side of the tube. The telescope is used with an objective prism, the spectra obtained have a dispersion of about 200 Å/mm.
The last two telescopes have identical small domes of 5 m diameter.



18. The first Toruń telescope – the famous Draper astrograph

Finally, a visual Zeiss telescope „comet finder" is installed in a small building, with no dome, only an opened roof. Its objective has a diameter of 20 cm and the focal length is 133 cm. The magnifying power is from 21 to 220 times. Actually this telescope is used with a single-channel photoelectric photometer.



19. A smaller Schmidt telescope with a 35 cm mirror, in operation since 1953

20. Zeiss microphotometer for stellar spectra measurements

AUXILIARY EQUIPMENT

Most of the observations made by means of the above mentioned telescopes are photographic ones. The obtained plates and films with stellar images or stellar spectra on them are treated in the Observatory photographic laboratory and then examined and measured for the intensity of light or its wavelength with the aid of proper instruments.

There is a measuring machine of the Abbe type of Zeiss, and two microphotometers, one a Hilger, the other a Zeiss, projecting arrangements, microscopes, desk calculators and so on.

21. Western view of the Astronomical Observatory at Piwnice

RESEARCH WORK

Since 1969 the Universities in Poland underwent new schemes of organization, based on Institutes concentrating teaching and research work in different disciplines. The former chairs of Astronomy and Astrophysics at the Nicholas Copernicus University in Toruń were reorganized into an Institute of Astronomy with the following sections:

Astronomical Observatory at Piwnice
Section of Astrophysics and Stellar Astronomy
Section of Radio Astronomy
Section of Celestial Mechanics.

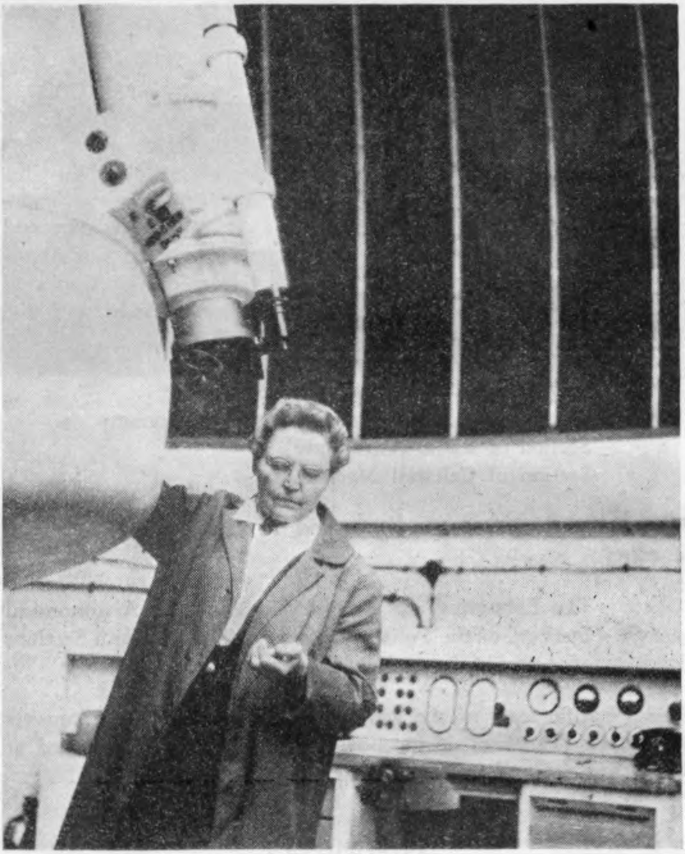
Within the University Institute and in close cooperation with it exists

The Laboratory of Astrophysics I of the Astronomical Institute of the Polish Academy of Sciences with Sections of Astrophysics and Radio Astronomy

The scientific staff of the astronomical centre in Toruń consists at present (1972) of 26 persons, 18 of them being appointed at the University and 8 — at the Academy.

ASTROPHYSICS

Astrophysics is a branch of astronomy aimed at investigations of the physical state and the chemical composition of matter in the Universe. Its development started effectively at the turn of this century, when physics attained a proper level and modern astronomical instruments went into operation. Nevertheless astrophysics like the whole of modern astronomy and the whole of modern science has its roots in the work of Nicholas Copernicus. In fact, astrophysics is an extension of physics into the Universe, where the same laws apply as those on the Earth, but acting on a much greater scale. Matter appears in an enormous range of densities



22. Astrophysicist professor Wilhelmina Iwanowska, co-organizer of the Toruń Observatory, director of the Institute of Astronomy of Nicholas Copernicus University, at the Schmidt-Cassegrain telescope

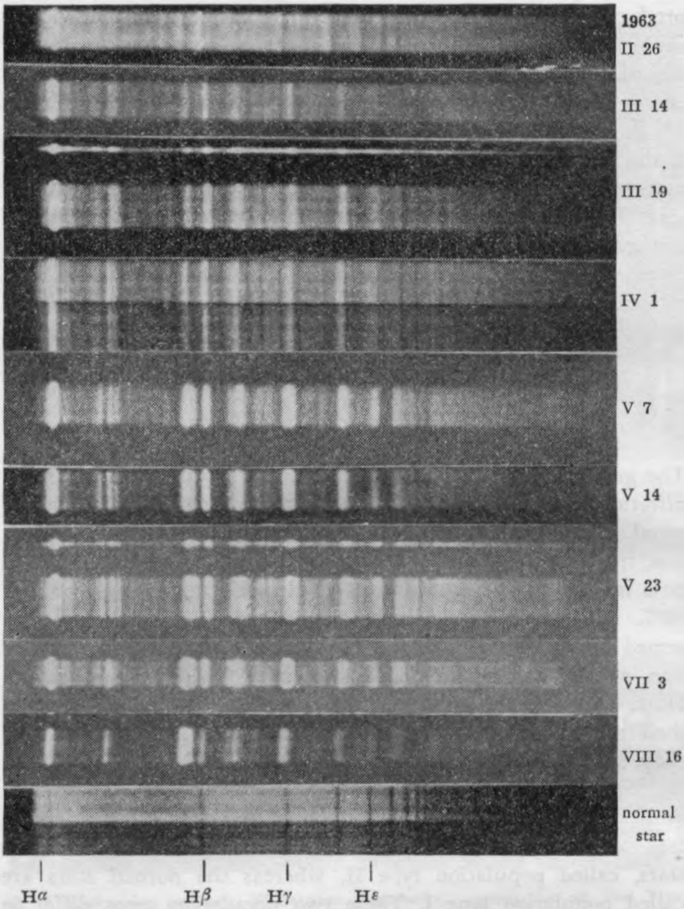
from superdense neutron stars recently dicovered in pulsars to almost ideal vacuum in the vast interstellar and intergalactic space. However, this almost empty space is very interesting since most energetic particles, called cosmic rays are present there. Not hampered by collisions ionized atoms are being accelerated to enormous velocities even by very weak magnetic fields. Peaceful production of nuclear energy takes place inside stars, but violent explosions happen in some of them, called novae or supernovae according to the scale of the event. Still much greater outputs of energy have been discovered recently in quasars, which probably are the result of a collapse and explosion of a whole galaxy. This is the macrocosmos of astronomy. There is also a microcosmos: planets with their satellites, comets and meteors revolving around stars like our Sun, are also being investigated by astrophysical methods either from the Earth, or, more recently, from the interplanetary rockets.

Fifteen astronomers in Toruń are working in astrophysics and stellar astronomy. Their main interests are concentrated on the following problems of astrophysics.

Investigations of peculiar stars

The great majority of stars constitute a family of „normal" stars, differing in mass and temperature among themselves but nearly equal in chemical composition. Their main constituent is hydrogen, the lightest element yielding about 70% of stellar mass; the next is helium, the second lightest element amounting to about 28%. All remaining elements, called heavy elements are represented by as little as about 2%. This is the composition of our Sun, as well as of most of the stars in the solar neighbourhood. However, there are exceptional stars, called peculiar, differing in their spectra from normal stars. The nature and the cause of these peculiarities is a problem to be solved.

A frequent kind of peculiarities in stellar spectra are weak lines of heavy elements which indicate that these elements constitute less, sometimes much less than 2% in the atmospheres of these stars, called population type II, whereas the normal stars are called population type I. These two population types differ in their distribution in our Galaxy and in their motions, the population II stars form a more loose, less flattened and slowly rotating subsystem. This lag in rotation around the centre of the Galaxy makes it appear that population II stars seem to move fast relatively to our Sun, therefore they are called high velocity stars though, in fact, they are slowly moving stars. The astronomers in Toruń have established criteria based on statistical probability, which enable them to state to which population type a given star belongs if its position and motion is known. These



23. Spectra of Nova Herculis 1963, taken with the Schmidt-Cassegrain telescope from 26 II to 16 VIII 1963. A spectrum of a „normal" star with hydrogen absorption lines is given below

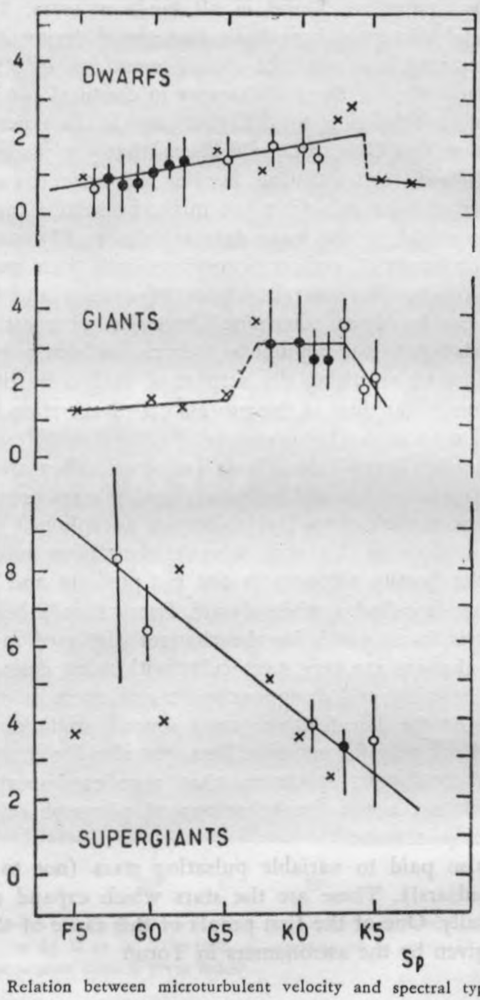
criteria called statistical population indices have been calculated for more than 4000 stars of different mass and temperature ranges. According to these indices stars representing both population types are selected for comparative spectroscopic studies, which also have been made here for many kinds of stars. Representants of both population types are found in all kinds of stars. This disproves the widely accepted hypothesis that the differing content of heavy elements is a result of the different age of stars. A search for other causes of these differences in chemical composition between stars belonging to different population types is being undertaken at this Observatory; it seems that gravitational separation of elements concentrating heavier elements towards the galactic center and the galactic plane might be such a cause. Another peculiarity exhibited by some stars are abnormally strong lines of helium or bands of carbon. Sometimes both these peculiarities appear jointly. The overabundance of carbon and the ratio of its isotopes has been determined here for some carbon stars and their relation to the population indices has been examined. The possibility of acquiring the surplus of carbon by these stars from the interstellar dust in the process called accretion has been investigated with encouraging results.

A most intriguing peculiarity among stars are novae. They are by no means new born stars, but suddenly brightening stars because of violent ejections of their outer layers. For yet unexplained reasons some stars explode in this way, whereas their inner core is shrinking until the density amounts to one ton per ccm and the star becomes what is called a white dwarf. Every time a bright nova appears, it is investigated for the changes displayed in its spectrum. These changes are very spectacular with many emission lines appearing, growing and disappearing to give room to new systems of lines. At the Toruń Observatory several bright novae were investigated not only for emission lines, but also for changes occuring in the continuous spectrum, that supplies important additional information about the behaviour of photospheres of novae during their outbursts.

Attention was also paid to variable pulsating stars (not to be confused with pulsars!). These are the stars which expand and contract periodically. One of the first proofs of this cause of their variability was given by the astronomers in Toruń.

A Study of Motions in Stellar Atmospheres

Like our terrestrial atmosphere, the outer layers of stars are more or less violently agitated. In particular, convection currents are active in those layers of a star where a strong temperature gradient is present. Random motions of greater or smaller volumes



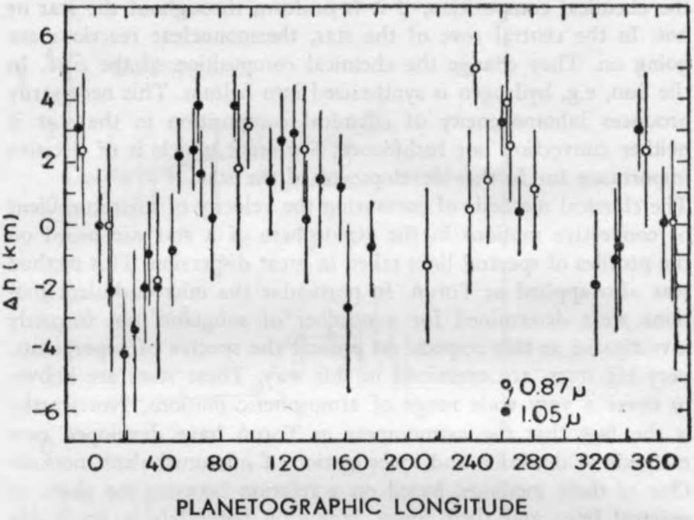
24. Relation between microturbulent velocity and spectral type for dwarfs, giants and supergiants

of gases, called respectively macro or microturbulence, may be present in stellar atmospheres as well. It is very important to know the state of motion of a stellar atmosphere in order to correctly know its structure called its model, as well as to infer on

the chemical composition, if it is uniform throughout the star or not. In the central core of the star, thermonuclear reactions are going on. They change the chemical composition of the core. In the Sun, e.g. hydrogen is synthesized into helium. This necessarily produces inhomogeneity of chemical composition in the star if neither convection nor turbulence is present which is of decisive importance for further development of the star.
The classical methods of measuring the velocity of microturbulent or convective motions in the atmosphere of a star are based on the profiles of spectral lines taken in great dispersion. This method was also applied in Toruń. In particular the microturbulent motions were determined for a number of subgiants not formerly investigated in this respect. At present the spectra of supergiants, very big stars, are examined in this way. These stars are known to cover a very wide range of atmospheric motions. Noteworthy is the fact that the astronomers in Toruń have developed new methods of detection and investigation of microturbulent motions. One of these methods, based on a relation between the shifts of spectral lines and their lower excitation potentials is applicable to spectra of high dispersion and consists in precise measuring the positions of lines. Another makes use of the fact that lines sensitive to microturbulence are not uniformly distributed along the spectrum. This last method is adapted to spectra of low dispersion like those which are taken in great numbers at this Observatory with Schmidt telescopes and objective prisms.

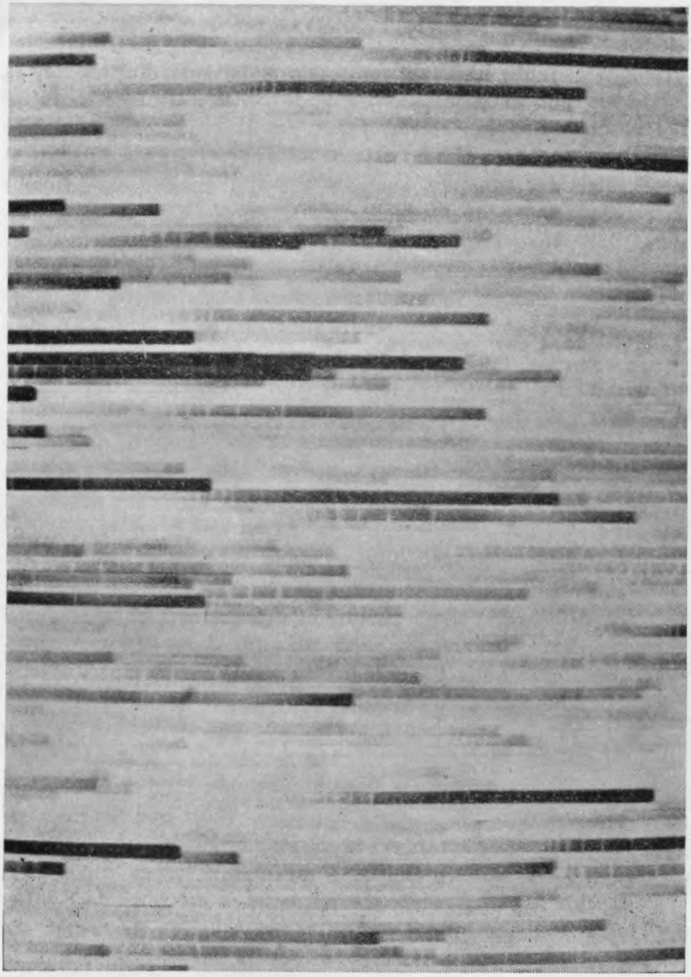
Explorations of Planets and Comets

Since 1969 studies of the physical state and chemical composition of planetary atmospheres started at this Observatory when spectra of Mars and Venus secured in high dispersion at the McDonald Observatory became available. It is surprising how many important informations on these planets can still be obtained from the Earth-bound observations now, in the era of interplanetary rockets. E.g. the amount of carbon dioxide, the main constituent of the Martian atmosphere was determined by one of our astronomers over different areas of the planet. Therefrom the elevation differences of these areas were obtained. They reach up to 10 km and are not correlated with the colour or the brightness of their surface.



25. Spectrographic profile of Martian topography centered on about 10° N, obtained from observations of 0,87 μ and 1,05 μ bands during the 1969 opposition

A group of our astronomers is active in spectroscopic investigations of comets. Every time that a bright comet appears it is observed with the objective prism and Schmidt telescope arrangement giving spectra in small dispersion. Spectra of high resolution are being obtained occasionally from abroad. Comets are loose swarms of stones, dust and gas of very small total mass. They move in very elongated orbits around the Sun and are visible at the time of their approach to the Sun, at the perihelia of their orbits. Then they undergo considerable changes of their state: they begin to emit radiation consisting of bands of molecules present, e.g. C_2, CN and others. At the same time they develop tails of different and changing shapes under the action of corpuscular streams emitted by the Sun. Comets are regarded as natural probes crossing the circumsolar space and showing what is going on in this space. Spectral analyses made of many comets by the Toruń astronomers, produced much new knowledge of their chemical composition, the mechanism of their radiation and the processes connected with solar activity.

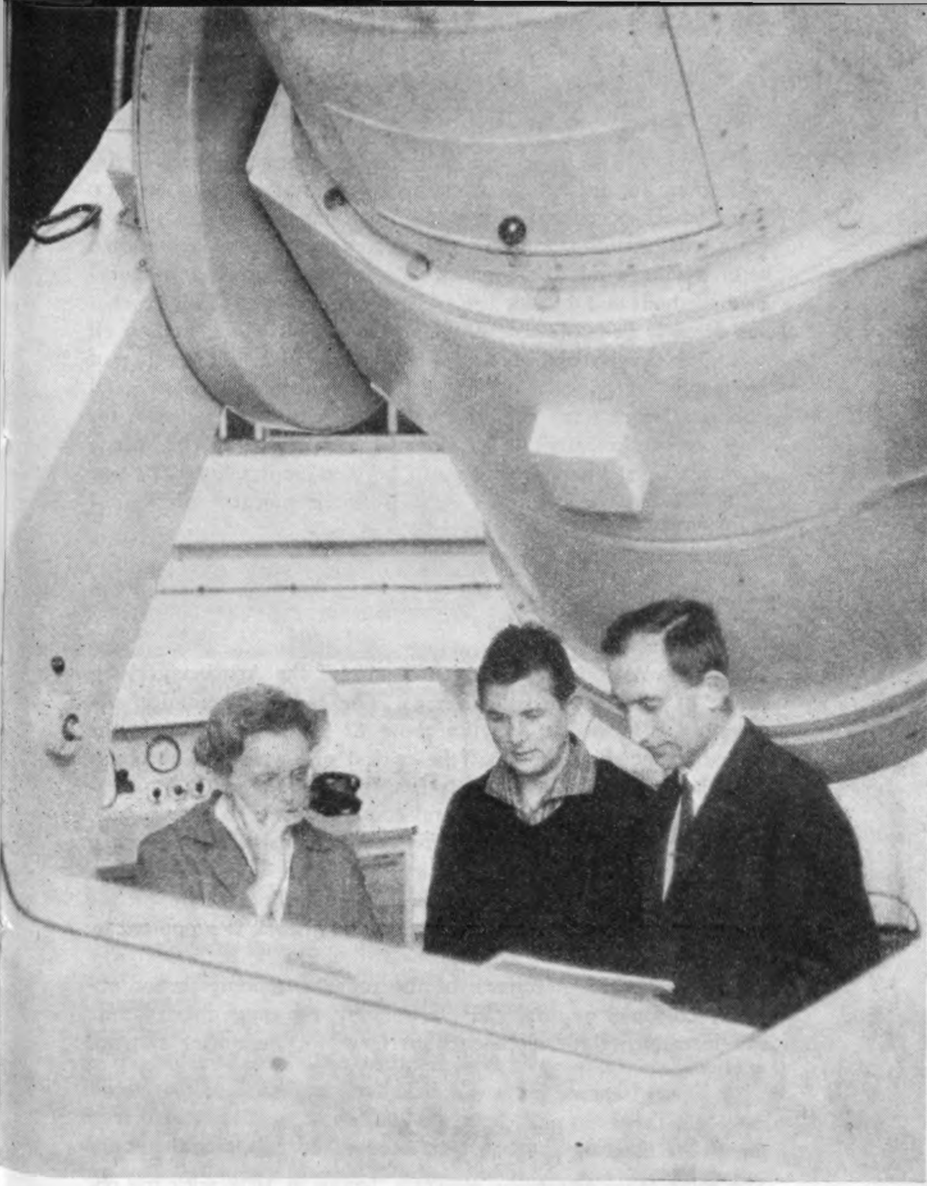


26. Objective prism spectra taken with the Schmidt-Cassegrain telescope

Whereas astrophysics examines single stars, stellar astronomy is interested in their ensembles. It is known that stars are not scattered uniformly in the Universe, they are concentrated in separate galaxies, huge ensembles containing, like our Galaxy, up to 2.10^{11} stars. Stellar astronomy analyses the distribution of different kinds of stars and of interstellar matter in our Galaxy, their motions, their ages, the mutual interaction between interstellar matter and stars, which, it is believed, are formed out of condensations of this matter. Interstellar magnetic fields, cosmic rays, belong to stellar astronomy as well. Investigations of galaxies belong to galactic astronomy and the structure and evolution of the whole Universe are the subjects of cosmology.

The telescopes equipped with objective prisms installed at the Toruń Observatory, giving hundreds or thousands of spectra in one exposure are particularly suited to stellar statistical studies of our environment in the Galaxy. Methods are being developed here that will make it possible to get as much information of these low-dispersion spectra as possible. This is called spectral classification of stars. The first fundamental work in this field was accomplished at the beginning of this century at the Harvard College Observatory mostly with the aid of the Draper astrograph which is being utilized presently in Toruń. Spectral classification consisted then in determining stellar temperatures from low-dispersion spectra and this was done for more than 225 000 stars contained in the famous Henry Draper Catalogue. This number of stars was accessible for the 20 cm Draper astrograph reaching to the ninth stellar magnitude. With our Schmidt telescope we can reach stars up to 12 magnitude, about four times further and take spectra of tens of millions of stars. This is what is being done in time when the telescope is not busy with other programs. A collection of spectral plates covering the whole sky accessible from our geographic latitude is growing. Our aim in spectral classification is to extract more than one parameter, the temperature, from these spectra. By spectrophotometric methods we are able to get the information also on the pressure in stellar atmospheres and on the chemical composition, namely the ratio of heavy elements to hydrogen. Efforts are also being made to get information on the motions in stellar atmospheres from our

 low-dispersion spectra with the aid of one of the methods men-



27. Discussion at the Schmidt telescope

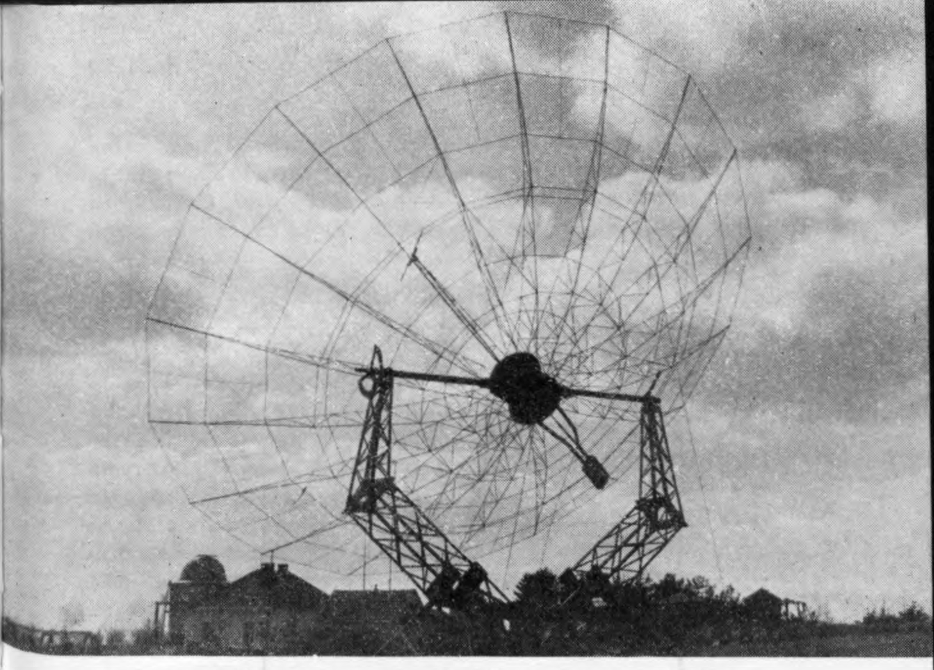
tioned above. This is what is called multiparametric spectral classification. In order to deduce many parameters from spectra, more laborious, spectrophotometric methods are needed. Classifying tens of millions of spectra involves much more labour than before. This would be impractical were not authomatic numerical methods suitable for use of computers applied. This is what has recently been started at this Observatory. When having all accessible sky on our spectral plate collection and disposing of spectrophotometric automatic methods of multiparametric spectral classification of stars we shall be able to get these parameters for any star of these tens of millions present on our plates. Many problems of stellar astronomy can be then undertaken. The one in which we are interested now is the chemical evolution of matter in our and other galaxies.

RADIO ASTRONOMY

The Radio Astronomy Section is a part of the Astronomical Institute of N. Copernicus University. The radio astronomical observatory is located at Piwnice about 12 km from Toruń in the immediate neighbourhood of the optical observatory. The observing site at Piwnice is relatively free from man-made radio interference because it is a small rural community.
The staff of the Radio Astronomy Section consists of more than a dozen people, two thirds being graduates in astronomy or physics; the rest have technical training. Almost half of the staff and a considerable part of the research work is supported by the Polish Academy of Sciences.
The present field of interest of the radio astronomy section covers such topics as solar radio astronomy, the outer solar corona and instrumental developments for large interferometer systems.

Research Activity

The solar radio astronomy program, begun in 1958 with the observations of the solar radio emission at 127 MHz using a 12 m dish. In 1960 a 127 MHz low-resolution interferometer, took over the solar routine observations. The results of these observations have been used for the study of the correlation of: the 127 MHz

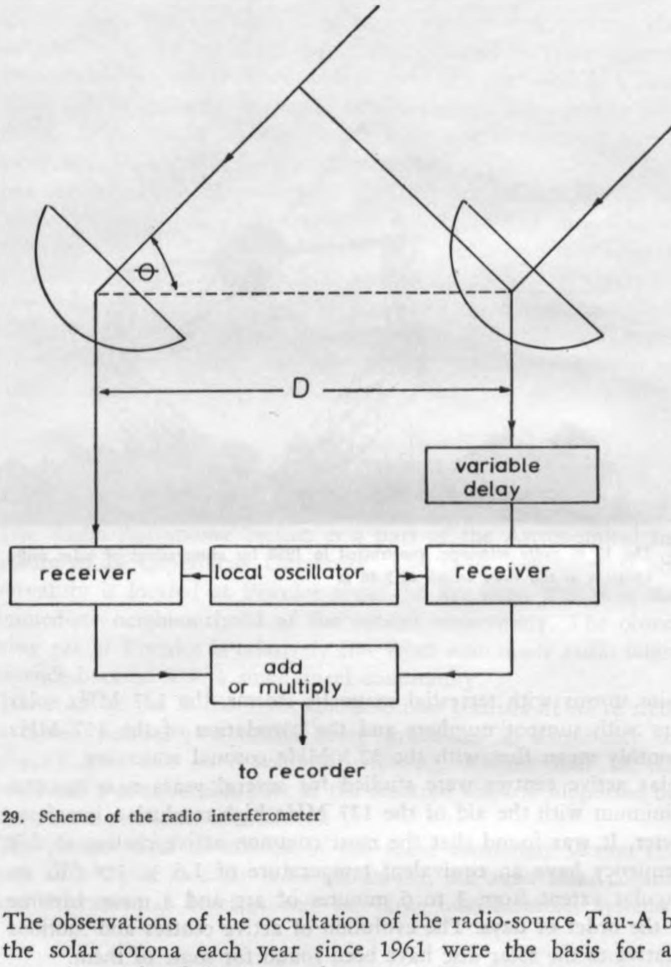


28. The 12 m radio telescope, constructed in 1958 for observations of solar radio emission at the vawe length of 2,36 m

noise storms with terrestial magnetic storms, the 127 MHz solar flux with sunspot numbers and the correlation of the 127 MHz monthly mean flux with the 32.5 MHz coronal scattering.

Solar active centres were studied for several years near sunspot minimum with the aid of the 127 MHz high-resolution interferometer. It was found that the most common active centres at this frequency have an equivalent temperature of 1.6×10^6 °K, an angular extent from 3 to 6 minutes of arc and a mean lifetime of the order of days. The evolution of active centres and motions relative to the solar disc have been found for some of them.

Several solar eclipses have been observed. The results of the solar eclipse observations of February 15, 1961, were used to derive the radiobrightness distribution on the solar disc at 127 MHz and 327 MHz. It was found that the observed limb brightening at 327 MHz is much lower than the theoretical value. This result was later explained as the scattering of solar radio waves by the coronal electron irregularities.



29. Scheme of the radio interferometer

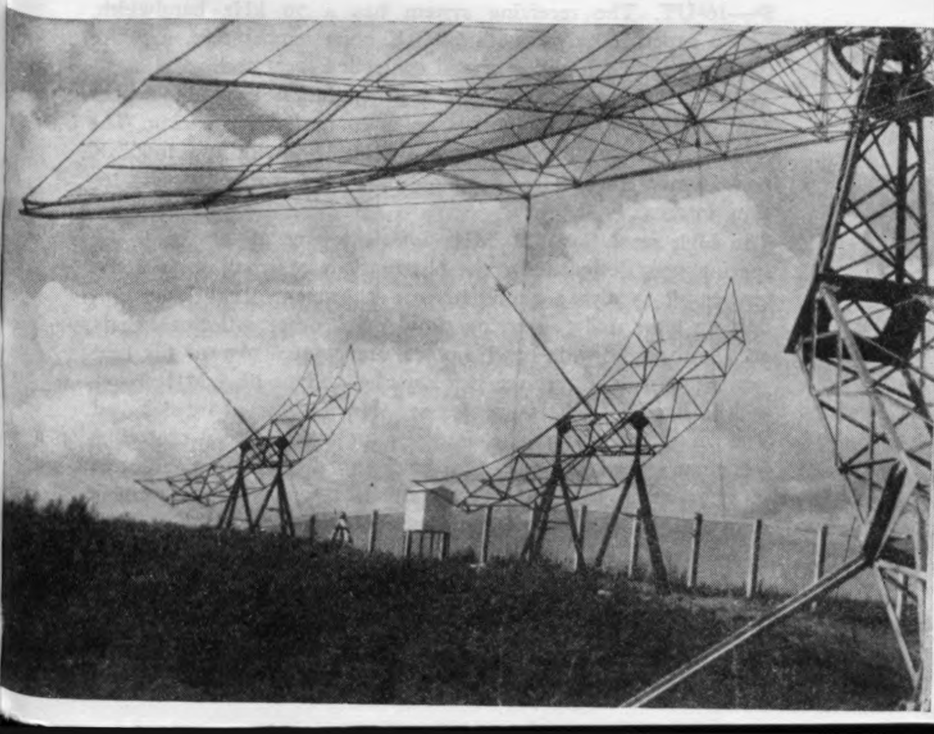
The observations of the occultation of the radio-source Tau-A by the solar corona each year since 1961 were the basis for an extensive study of the outer solar corona. The main research activity concentrated on the following topics: variation of the coronal scattering with the distance from the Sun and the phase of the sunspot cycle as well as shape and spatial orientation of the outer corona and the properties of unusual scattering events. A number of unusual scattering events were found that can only be explained as an increase of the observed Tau-A flux. These flux increases, also reported by other observers, have been explained as reflections of radio waves from large sporadic coronal electron irregularities. Such a large coronal irregularity was also seen later in our observatory by the refraction effects on the Tau-A radiation.

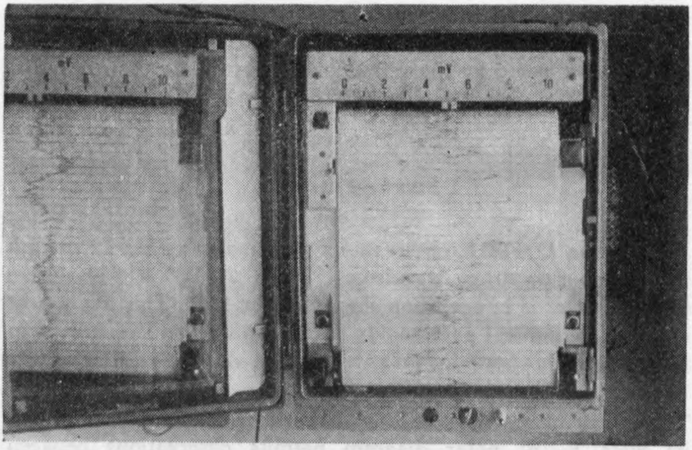
Instruments

Initially the 127 MHz observations were made with a 12 m dish useful down to 50 cm wavelength. The 127 MHz low-resolution interferometer is in operation since October 1960. This instrument uses two cylindrical paraboloids, tiltable in declination, 8 by 4 m in size with horizontally polarized folded dipoles with reflectors in the focus.

The interferometer has an E—W baseline of 24 m spacing, and its wide E—W polar diagram permits observations between

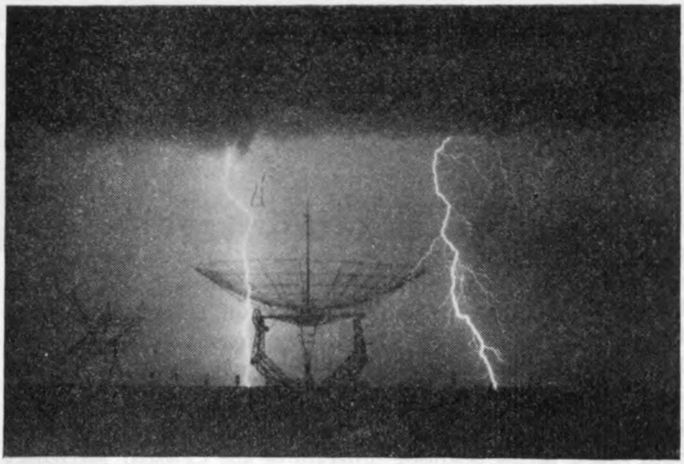
30. The small interferometer of the Toruń Observatory, in operation since 1960 (solar routine observations)





31. The recording of the transit of radio-source Virgo A, observations with the three aerial interferometer

8^h—16^hUT. The receiving system has a 50 kHz bandwidth, uses a superheterodyne with 520° K noise temperature, a Dicke type crystal switch and a crystal controlled local oscillator.
The 327 MHz interferometer is in operation since November 1961 and employs two aerials on a 20 m E—W spacing. The receiver is phase switched, has a 4 MHz bandwith and 1500° K noise temperature. The observing time also covers the 8^h—16^h time interval.
The high resolution 127 MHz interferometer of 220 m E—W spacing was designed for the observations of small solar active centres. It is also a meridian transit instrument but has only half an hour daily observing time. Two corner reflector aerials, each with eight wide band dipoles, are pointed toward the celestial equator. The receiver is a superheterodyne of 4 MHz bandwidth, has 700° K noise temperature and is phase-switched. The minimum observable intensity of solar active centres is less than 1% of the quiet Sun level and the positional accuracy in hour angle is about one minute of arc. The instrument is calibrated in phase and amplitude against the radio-sources Tau-A and Vir-A.



32. Radio telescopes in the light of lightnings

The 32.5 MHz interferometer has a 1400 m E—W spacing since May 1961 and was later extended with the addition of a north aerial to a 3 element interferometer. Two aerials of this interferometer have 240 m E—W length and one 80 m. All are corner reflectors with full wave dipoles. The phase switched superheterodyne receivers have variable bandwidth from 10 to 200 kHz and 600° K noise. The time service is based on a fully transistorized quartz crystal clock with an accuracy of several parts in 10^9.
The routine solar observations of the 127 MHz flux and distinctive events as well as the 327 MHz solar emission are fully automatically recorded and controlled by clock derived signals.
An instrumental study extending over a two year period culminated, by the end of 1970, in the design of a large interferometer system for the Toruń Observatory. The instrument should consist of five fully steerable 25 m diameter paraboloids arranged on a 3 km E—W baseline, an on-line computer, multichannel radio spectrograph, and a flexible solid state receiver of unique design.

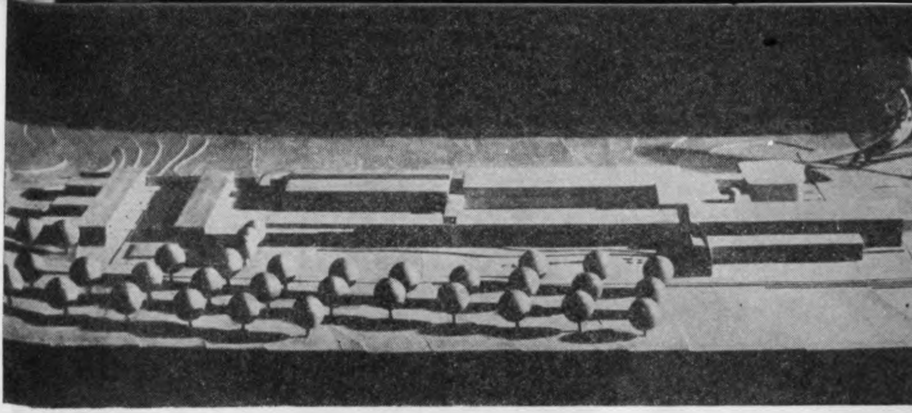
The aim of celestial mechanics, as well as that of dynamics of stellar systems, is to investigate the dynamics of heavenly bodies using mathematical methods. Mathematics and mechanics are closely connected. Many mathematical ideas that would seem purely abstract at first, proved to be very useful in celestial mechanics. On the other hand, it is mechanics which presents many new problems to be solved by mathematicians. For instance, integral calculus was invented by Newton in order to describe planetary motions. Nearly all modern distinguished mathematicians have also done some work in the field of celestial mechanics. It was so with Newton, Gauss, Lagrange, Laplace, Poincaré, Ljapunow, and actually — with Kolmogorov, Siegel, Moser and Arnold.

Problems related to celestial mechanics and mathematics are both found in the scientific program of the Celestial Mechanics Section of Astronomical Institute of Nicholas Copernicus University in Toruń. The staff of this section consists of three persons, two astronomers and one mathematician.

It was professor Dziewulski who first investigated the problem of instability of orbits of minor planets, arising from the action of Mars. It has been shown that these of the minor planet orbits which intersect the orbit of Mars, can undergo considerable changes nothwithstanding the small mass of Mars. Professor Dziewulski and his collaborators studied this problem using numerical methods, by means of a simple desk calculator and logarithmic tables.

A more cosmological aspect of the problem of minor planets is now under investigation at the Celestial Mechanics Section. It is a study of the origin of all minor bodies in the planetary system: minor planets, comets, all kinds of meteors, since this problem has not satisfactorily been solved as yet. Some statistical relations are being established and their theoretical meaning is also being discussed.

The main results can be summarized as follows: very characteristic features of the orbital elements distributions are the dispersions of these elements. These dispersions show high stability with respect to time as they are not susceptible to the perturbing action of other planets.



33. Photograph of a mock-up of the buildings of the radioastronomy centre, planned at Piwnice

The relations between the dispersions of orbital inclinations and mean distances to the Sun, calculated for several distance intervals, were found to be extremely interesting. They led to the supposition, that all minor bodies have a common origin and that they were formed through the desintegration of Mars. According to this hypothesis Mars initially had a greater mass and had to revolve around the Sun at a greater distance (1.9 astronomical units instead of 1.5) than actually observed. At some critical moment of its life, the planet underwent a cataclysm, some of its mass fell off and produced minor bodies, but the main bulk of the planet remained in the form as it is observed now. A theoretical support to this hypothesis has also been found by excluding the possibility that the relations mentioned above might be caused by the perturbing action of other planets, e.g. Jupiter. It has been proved that, if the initial distribution of orbital elements of minor planets has been totally random, then the gravitational action of the major planet — Jupiter could not bring them to the distribution actually observed.
A relation between the mean mass of minor bodies and the dispersions of their orbital inclinations near a solar distance 1.9 a.u. was found. It is hoped that this will be very useful for the calculation of the initial mass of Mars.
Another problem worked out at the Celestial Mechanics Section is more mathematical. It is the problem of periodical solutions in the theory of orbits and of their application to the motion of artificial satellites.

34. Eastern view of the Astronomical Observatory at Piwnice

The motion of a satellite can be represented by a set of differential equations which have no solutions in a general form. There are, however, two possible ways out of it: either to get numerical solutions, or periodical ones. Numerical solutions can be obtained when using huge computers, but the results thus obtained can not be generalized, whereas periodical solutions can be attained by analytical methods. The periodical motion of an artificial satellite in a gravitational field of a dynamically symmetric planet has been worked out. The radius of convergency of the obtained series has also been determined. Another theory of periodical solutions is under consideration.

The third research problem of the Celestial Mechanics Section is a purely mathematical one. All the differential equations used in celestial mechanics are classified in view of their analytical as well as numerical solvability. The aim of this investigation is to find such methods which will make the description of phenomena possible without a full knowledge of the complete solution. Such are the quantitative methods of investigating dynamical processes.

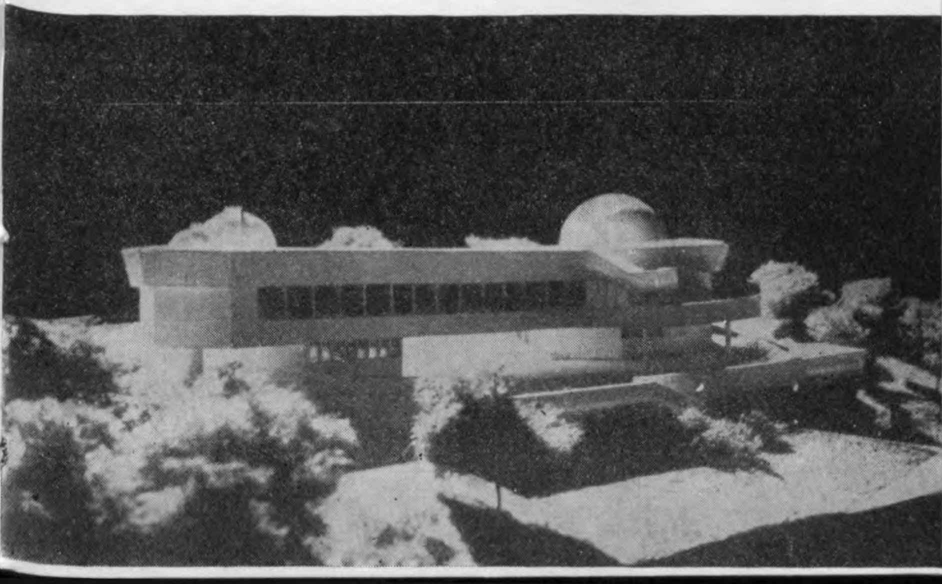
GENERAL EDUCATION ACTIVITES

The astronomers of Nicholas Copernicus University are also carrying on a program for the general public. Every year they give public lectures in the schools and cultural institutions of Toruń and the neighbourhood. They also write popular books and articles in magazines.

The Astronomical Observatory of Nicholas Copernicus University in Piwnice is open to visitors from spring till autumn. Groups of high school students as well as the general public, attending lectures or a telescope show at the Observatory, are seen nearly every week. The number of visitors runs up to 2000 persons yearly.

There is a Scientific Association of Astronomy Students connected with the Nicholas Copernicus University. Its members organize special lectures during the academic year and courses in observational astronomy in high mountain camps during the holidays. There is also a branch of the Polish Amateur Astronomers So-

35. Photograph of a mock-up of the buildings of the Popular Observatory and Planetarium, planned at Toruń



ciety, founded in Toruń in 1952. This branch had in 1971 over 120 members. It organizes public lectures (565 up to 1970), shows of astronomical or astronautical motion pictures (over 100 shows), and also night-sky shows by means of a small portable telescope. Each year the Copernicus anniversary is commemorated by a special meeting, organized by the Society and the local Museum, held in the Town Hall. Once a month a special astronomical lecture is given for Society members as well as for the general public. The speakers are Toruń astronomers or prominent scientists from other universities.

To meet the increasing interest of the general public in astronomy — the Polish Amateur Astronomical Society proposes to build a Popular Observatory and Planetarium in Toruń.

36. Scientific staff of the Institute of Astronomy of Nicholas Copernicus University and the Laboratory of Astrophysics of the Polish Academy of Sciences
Sitting from the left are: A. Burnicki, J. Smoliński, Z. Turło, B. Wikierski, A. Stawikowski, A. Woszczyk. Standing from the left are: R. Tylenda, L. Dybkowski, S. Kasperczuk, J. Strobel, A. Kaczor, A. Strobel, J. Sikorski, S. Krawczyk, J. Krełowski, N. Maron, J. Hanasz, S. Grudzińska, A. Wolszczan, S. Gorgolewski, H. Wełnowski, W. Iwanowska, A. Kus, C. Iwaniszewska, E. Basińska, J. Krempeć, B. Krygier, S. Gąska.

PUBLICATIONS

Most of the papers of the astronomers of Toruń are published in Studia Societatis Scientiarum Torunensis, Sectio F (Astronomia), published by the Scientific Society of Toruń (abbreviated in the list given below — St.) or Acta Astronomica, published by the Polish Academy of Sciences (abbreviated — AA). Their reprints appear as Bulletin of the Astronomical Observatory of N. Copernicus University in Toruń (abbreviated — Bull.).

I. ASTROPHYSICS AND STELLAR ASTRONOMY

1. Galactic Structure

A Study of Galactic Structure in Four Selected Fields in Aquila-Sagitta and Cassiopeia

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