Radio astronomy in Poland 2.

The new astronomical observatory in Toruń

A.Kus[1)], Wielebinski, R.[2)]

1. Uniwesytet Mikołaja Kopernika, Toruń, Poland
2. Max-Planck-Institut für Radioastronomie, Bonn , Germany

Abstract: The development of radio astronomy in Poland took some time in view of the destruction in the country during World War II. The shift in the country's borders in favor of the Soviet Union led to the loss of two important astronomy observatories: historic centers of astronomy in Wilno and Lwów. The relocation of these important astronomical centers to Toruń and Wrocław in the West needed considerable effort. Radio astronomy was hence the second priority, the optical people had to be made operational first. Nevertheless in 1950s the groups in Kraków and Toruń started with erection of radio telescopes. In Kraków Solar radio astronomy became established. In Toruń after experiments with low frequency antennas dishes became the main instruments. First, a 15m dish was built, later a 32m dish became operational. In Kraków the Solar patrol continued and a LOFAR station was added. Contacts with radio observatories in the whole world were established. In Zielona Góra a new regional university was established and a group involved in pulsar research was built up.

1. Introduction

Astronomy in Poland has a long history. The foremost historical astronomer is Nicolaus Copernicus (Mikołaj Kopernik) (1473-1543) who was the initiator of the heliocentric theory that placed the Sun in the Centre of our planetary system. Kopernik was born in Toruń, studied at the Jagiellonian Univeristy in Kraków, later in Italy, lived until his death in the lands of the Teutonic Order (Frombork). Other important astronomer was: Johannes Hevelius in Danzig (Gdańsk) (1611-1687). The age of observatories begun with the creation of the first observatory in Wilno (now Lithuania) in 1753. This observatory was moved to Toruń in 1945. The Kraków observatory was inaugurated in 1792. The Lwów observatory founded in 1912 had to move to Wrocław, since Lwów became a part of USSR. Several additional observatories were constructed in Poznań, Lublin, just to name the larger units. The important observatories in the Polish capital Warszawa (Warsaw), founded in 1825, were destroyed in the war. However the creation of the Polish Academy of Sciences made this town an important centre of astronomy to the present day.

Polish astronomy was in a bad shape in 1945. Two main pre-war observatories (Wilno, Lwów) were lost due to the border changes in the East. Some of the staff from these observatories were forced to move to cities Toruń and Wrocław in the West. In Toruń a new Univeristy was established: Uniwersytet Mikołaja Kopernika. This development of the astronomy faculty was forced by Prof. W. Dziewulski and Prof. Wilhelmina Iwanowska. The observatory in Poznań was not destroyed and started teaching duties in 1945 already. The head of the Poznań observatory Prof. J. Witkowski started to push for a national astronomy centre that became a part of the Polish Academy of Sciences (PAN) in Warszawa. The Kraków observatory became active with Prof. Tadeusz Banchewicz as the director. The astronomers from Lwów settled in Wrocław reconstructing the ruins of the former German university observatory.

The major problem, plaguing all astronomical observatories in Poland in the early times (after 1945), was the political insistence of the Polish Government ''to learn from USSR'. This was the political pressure not to have contact to western institutes. This also led for a long time to travel difficulties to western countries.

2. The new astronomical observatory in Toruń

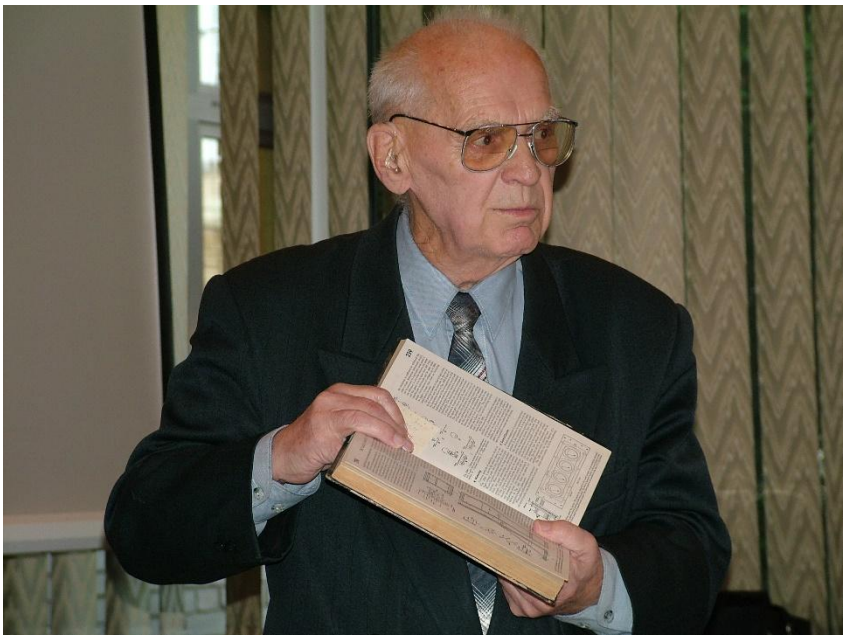
The Nicolaus Copernicus University (Uniwersytet Mikołaja Kopernika; UMK) in Toruń was founded in August 1945. The astronomers from the Stefan Batory University in Wilno were expelled by the Soviets and settled after some argumentation in Toruń, attracted by the historical fact that this was the birth city of Copernicus. The teaching in astronomy could start in December 1945 already. Prof. Władysław Dziewulski became the founding professor of the astronomy department. Prof. Wilhelmina Iwanowska was responsible for the astrophysics section of the department. Both persons were actively involved in the foundation of the astronomical faculty in the Nicolaus Copernicus University. In addition to working space in the town Toruń they searched for land that would be suitable for an observatory. This was found in Piwnice, some 12 km from the town. The first building in Piwnice constructed in 1948 was a 5m dome for the 8-inch Draper astrograph, a present of the Harvard College Observatory. Further optical instruments were installed at Piwnice through the support of Prof. B. Lindblad from Sweden. Prof. W. Iwanowska had good contact to astronomical institutes and managed to visit the USA on an IAU scholarship. Prof. W. Dziewulski attended the 1948 IAU General Assembly in Zurich. To balance the political needs Prof. Iwanowska led an expedition in 1954 to observe a Solar Eclipse in Caucasus (USSR).

Prof. Wilhelmina Iwanowska (1905-1999)

Prof. Iwanowska came from Wilno and was instrumental in the development of radio astronomy in Torun.
She was also a vice-president of the International Astronomical Union and very supportive for contacts to other institutes.

The first contacts with radio astronomy were made by H. Iwaniszewski with a 1956 visit to the Crimean Radio Astronomy Observatory. However radio astronomy was considered a military secret in the USSR. A proposed visit by Stanisław Gorgolewski to the Crimean Radio Observatory was refused, because he expressed the wish to become familiar with electronics, again a top secret in USSR.

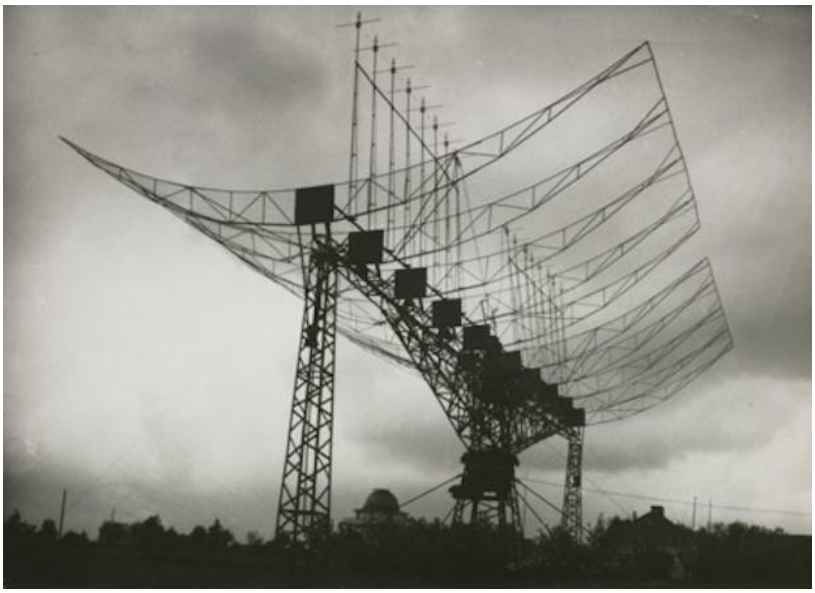
The Polish Academy of Sciences (PAN) was formed in 1953. In January 1957 the Academy established its astronomical institutes with branches in Warszawa, Borowiec and in Toruń. One branch became the Laboratory of Astrophysics in Toruń. A close cooperation between the staff members of the UMK observatory and the PAN laboratory was established. The International Geophysical Year (IGY) that started in August 1957 led to many efforts to improve the observational possibilities of the UMK observatory. The launching of Sputnik in 1957 clearly pointed to the need to become involved in radio astronomy. Prof. Iwanowska organized a visit of Prof. K. Grzesiak to the Nancy Radio Observatory. Dr. Stanisław Gorgolewski was transferred from the Physics Department to her Astrophysics Chair. The first solar radio receiver (containing more than 100 valves) was completed in June 1957. Also in 1957 the first radio telescope, the RT-1 cylindrical reflector (12m x 26m) was completed. This instrument made successful observation of the Sun. Good contacts to the Warsaw Polytechnik University and Telecommunication Institutes were established. It was a momentous task to build up the technical laboratories needed for support of radio astronomy in such a new regional university.



Prof. Stanisław Gorgolewski (1926 – 2011) Long time director, was responsible for constructing technical observing facilities for the Toruń radio astronomy group. He was instrumental in the construction of the 32m dish.

In spite of political difficulties, with great support by Prof. W. Iwanowska, international contacts were established to radio astronomy institutes in western countries. In 1957 Prof. A. Woszczyk went to Liege on a Belgian Scholarship. In 1958 Dr. Stan. Gorgolewski won a British Council Scholarship and went to the Cavendish Laboratory, Cambridge, to work under the supervision of Prof Sir Martin Ryle and Prof. Anthony Hewish.

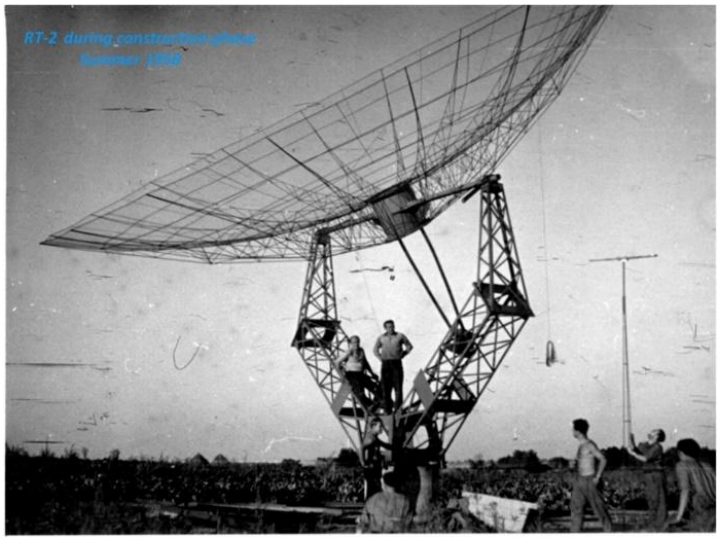
On return from Cambridge in 1960 Stan (as he was called) came back with electronic devices and started to construct first receivers at various low frequencies. He was impressed by the string, wax and plastic tape methods that he experienced in Cambridge. He worked with Anthony Hewish in Cambridge and was fascinated by the possibilities of doing state of art research with simple instruments. Antennas for observations of Jovian bursts were constructed, at low radio frequencies. Also interferometric studies of the Solar Corona were published (Gorgolewski & Hewish, 1960; Grogolewski et al., 1962). At one stage three antennas were connected as interferometer for solar research. Cooperation with Dr. Jan Hanasz, from the Polish Academy Toruń Unit, was established, later extended to a space radio astronomy project. Also a 12m dish was constructed and used for Solar patrol observations.



The RT-1 Radio telescope.

12m x 26m cylindrical reflector

New young people were joining the radio astronomy group bringing in their new ideas. One person who deserves special mention is Dr. Zygmunt Turło, a physicist, with good knowledge of electronics. Since the political situation did not give much financial support to science projects Dr. Z. Turło decided to construct a 15m dish antenna that could be included in European VLBI observations. First a 12 m dish was constructed in 1959, named RT-2. This was a change in thinking: away from the low frequency antennas – off to the future of European radio astronomy. This was followed by the RT-3 dish.



The 12m radio telescope RT-2

This was a major step for the Toruń radio astronomers to move to higher radio frequencies

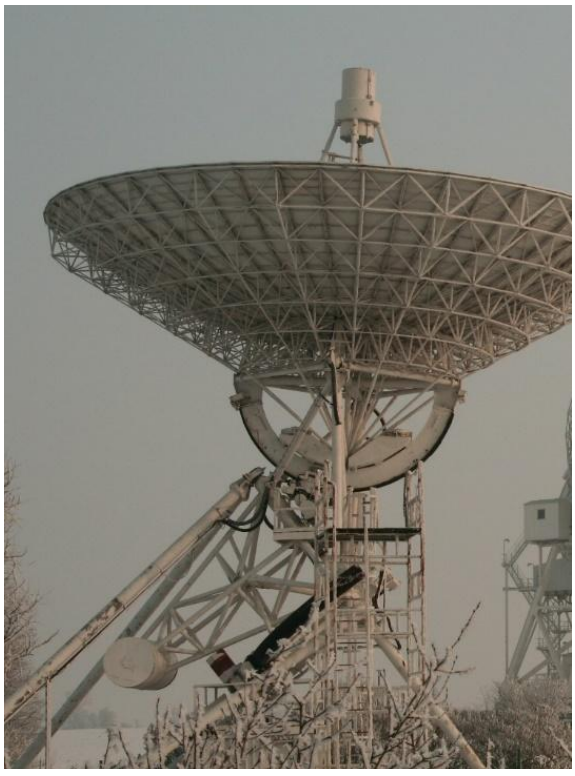
To extend their knowledge all Toruń radio astronomers were supported, in particular by Prof. W. Iwanowska, to make visits to other radio astronomy institutes in the world. Also small technical improvements, such as the move to semiconductors instead of valve electronics, took place. New young people such as A. Kus, A. Wolszczan joined the radio astronomy effort in Toruń. The visits to other radio astronomy institutes led to a regular visits of A. Wolszczan, starting in 1972, to the Max-Planck-Institute for Radio Astronomy in

Bonn. Early papers were published (e.g. Wolszczan et al., 1974, 1981, Wolszczan, 1980; Nowakowski, et al., 1982, Hewish, et al., 1985) with emphasis on pulsar scintillations. A. Kus went to Cambridge in 1973 and worked on the 5C6 and 5C7 surveys of radio sources (Pearson & Kus, 1978). Also contacts were made by A. Kus with the Jodrell Bank Observatory in this time, this became the basis for further developments, i.e. A.Kus got postdoc position at IBO in 1979, where he made first ever maps of OH maser shell around IR star using MERLIN array (Booth et al. 1981).

Next, a 15m antenna, named RT-3, became operational in 1977. First tests of VLBI, with a locally built terminal MkIIc, between Toruń and the Effelsberg 100m radio telescope took in 1982 place in June 1981. First pulsar observations in Poland were made with the RT-3 telescope, radio spectroscopy observations followed in 1984. Several papers were published describing the characteristics of the RT-3 telescope (Kus, A.J, et al. 1983; Szymczak, M., et al. 1983). Associate membership of the European VLBI Network (EVN) was signed on 5th November 1985.

.

.



The RT-3, a 15m dish, resulted in Toruń joining the European VLBI network.

The need for modern observational facilities became urgent. A group of planers started to urge the university authorities to build laboratories and working space in Piwnice. At first the Polish Academy of Sciences (PAN) was involved in the planning, however the PAN withdrew from financial participation. The coming of an important historical event in 1973: the 500th birthday anniversary of Copernicus, helped to get some financial support. A few days before

the IAU special colloquium in Toruń on September 1973 took place, the new office and laboratory buildings for radio astronomers were ready. However, the hope for financial support for new instruments was not realized.
In conjunction with the Copernicus anniversary the Soviet Academy and the Polish Academy suggested the joint construction of a space experiment. The solar "Intercosmos-Kopernik 500" spectrograph was constructed under the management of Toruń radio astronomers. Both Prof. S. Gorgolewski and Dr. J. Hanasz were involved. The strict completion date led to considerable problems for both the Radio Astronomy group and the Toruń Academy astronomy unit. The satellite was launched, on time, in April 1973. The anniversary IAU symposium in 1973 led to the creation of three Honorary Doctors at the Copernicus University, Toruń: Prof. Martin Ryle (Cambridge), Prof. Jaan Oort (Leiden) and Prof. Wilhelmina Iwanowska (Toruń).

Prof. S. Gorgolewski was the Director of the Institute of Astronomy in 1977-1979. Toruń Radio Astronomy Observatory (TRAO - formally Chair of Radio Astronomy) became an independent unit at Faculty of Physics in 1979 with Prof. S. Gorgolewski as TRAO Director until 1991.
The directorship of the TRAO was transferred to Prof. A. Kus in 1992 until May 2006. From 2006 to 2011 the lead of the Department of Radio Astronomy was taken by Prof. Szymczak, then later by Prof. K. Katarzynski (2012-2014) and Prof. A. Marecki (2015-2019).

In late 80-ties big efforts were undertaken to obtain funds for a larger radio telescope in order to get full participation in European and global VLBI Networks. Prof. S. Gorgolewski was instrumental in the political discussion that finally led to the agreement to fund a 32m radio telescope construction. Contacts were made to various firms capable of designing various sections of a large radio telescope. To ensure that the whole system would be manageable tests of VLBI functionality were made in 1994 between the 15m RT-3 Telescope in Piwnice and the 100m radio telescope in Effelsberg, Germany. It became clear that a bigger dish antenna in Poland was needed to become a full participating member of the European VLBI Network (EVN). The political situation was ripe to bring in a bigger project in the ministry. Also a steel construction designer was found with great enthusiasm for radio astronomy: Engineer Z. Bujakowski. Through good contacts Eng. Z. Bujakowski travelled to several institutes with advanced radio telescopes and used his findings in the 32m dish design. This radio telescope, designed as RT-4, became operational in 1996. Full membership of the (EVN) was achieved in 1998. This development allowed Torun to become truly an European radio astronomy Centre. Honorary doctorate were given to Prof. R.Wielebinski and Prof. R. Booth in 1993. Another Dr. h.c. was bestowed later on Prof. P.N. Wilkinson in 2010.
The RT-4 and the infrastructure around, it had been the largest and the most expensive investment for astronomy in Poland ever made. It had great impact on future research development of RA in Poland and had significantly contributed to international co-operation, participating in many EVN key programs.

The 32m dish radio RT-4 radio telescope in Piwnice. Near Toruń
Inaurgurated 1996
Prof. S. Gorgolewski was the driving force in the design and in political negotiations.

A modern computing centre, equipped with Convex-C120 (replaced later by Sun work stations), was commissioned in Piwnice in 1990. This was needed for the throughput of considerable data material in various observational projects.

In 1996 the two independent astronomy units, TRAO and Institute of Astronomy, were united under new name Torun Centre for Astronomy (TCfA), it consisted of two Departments (optical and radio groups) which formed one entity. The TCfA was directly protected by the University Rector. The position of TCfA Director was held by Prof. A. Wolszczan (Jan 1997 - Dec 2000), then by Prof A. Kus (Jan 2001 – Dec 2010), followed by Prof. M. Hanasz (Jan 2011 - May 2019), Prof. K. Katarzynski (2019). The new Center was organized and important strategic directions of research defined by Prof. Alex Wolszczan. The decisions taken helped to integrate dispersed community and to concentrate on advanced modern research targets.

3. The New Horizons in Toruń

Starting in 1996 the development of active research groups, able to complete in research on the world level, became possible. Also a competent electronics group was installed to match the antenna with other similar instruments in Europe. Here a special mention must be made to E. Pazderski, an astronomer, exceptionally talented in electronics, who designed and built cryogenic receivers, digital backends, also made software for RT-4 telescope control, and led

very competently the electronics laboratory for many years. Support was received from other European institutes like Jodrell Bank, MPIfR, Astron, and NRAO. First VLBI fringes were received with the RT-4 telescope and a Mark III P&G terminal in May 1996.

A long term cooperation in the pulsar research was organized by Prof. A. Wolszczan, first at Arecibo and later from the Penn State University. Numerous important publications in Wolszczan's life (e.g. Wolszczan et al 1980, 1981, 2000, 2002, Cordes & Wolszczan, 1986, Wolszczan & Cordes, 1987, Wolszczan & Frail, 1992) date to this time.
Prof A. Wolszczan organized at Toruń a research group studying neutron stars. Building up on his experiences in Effelsberg, Arecibo and Penn State University he concentrated on studies of neutron star timing, in cooperation with doctoral students. The timing program at 1.7 GHz on RT-4 started in June 1996 , using Penn State Pulsar Machine II. Main goal of this program was the search for planetary companions around neutron stars, however the database was also used for interstellar scintillation analysis, study of average pulse stability and timing noise properties for more over a hundred pulsars (Jacoby et al., 1997, Konacki et al., 1999, Redmerska et al., 2000, Lewandowski et al. 2000, 2004). In particular a detailed study of the pulsar B1257+12 (with planets) led to a very exciting development. The cooperation with Arecibo and Effelsberg continues, more recently with optical studies (exoplanets search) on the SALT telescope in South Africa and on HET of McDonald Observatory. Large scale exoplanets search continues within Pen State - Torun University program (e.g. Niedzielski et al., 2007).

Prof. A. Kus led a group that concentrated on studies of active galactic nuclei (AGNs) using the VLBI system. The variable structures of CSO (Compact Symmetrical Object) and CSS (Compact Steep Spectrum) AGNs were observed regularly. This aspect of research is important since the activity of AGNs is repeatable and their evolution trucks are complex (Katarzynski at al., 2001). Super Luminal Motion was detected in 3C309.1, and the youngest ($\ll 10^4$ years) classical double lobe CSOs were found. (Kus et al., 1981, Owsianik & Conway, 1998, Owsianik et al., 1998, Marecki et al., 2003, Kunert-Bajraszewska, et al., 2005, Gawronski et al., 2006). The CSO and CSS sources studied at Torun are at early stages of their development or at a reborn phase. The results lead to a new, modified model of AGN evolution. According to this, objects with low radio brightness will expire at an early stage of evolution, and are short lived once. Such short episodes of radio activity can happen many times before radio structure finally escapes the host galaxy and evolves to the size of large-scale FRI or FRII. The work also suggest that the population of such short-lived objects is large, and radio-strong CSS and GPS (Gigahertz Peak Sources) sources are only a small percentage of them. Studies using SALT, Chandra X-ray and most recently LOFAR as complementar5y to VLBI were also carried out.
In cooperation with JIVE (Garrett at al., 2001) studies of AGNs in the Hubble field were made. The Torun team had also been involved in space VLBI programs: VSOP and Radio Astron (Fomalont et al., 2000, Kovalev Y.Y. et al., 2020)

Some VLBI research was expanded to mm wave range and detailed studies were made at 3mm and 7mm using dedicated global array of ultra high frequency telescopes (Baath et al. 1992, Krichbaum et al. 1990). The observations reviled earlier unknown sub-parsec scale substructure close to the central Black Hole.

In cooperation with Prof. R. Booth (OSO), Prof. A.Kus initiated spectral program to study methanol maser sources, later Prof. M. Szymczak took the lead and organized a group that carried out studies of new star formations areas and stars in the late stages of evolution. A survey of the galactic plane methanol clouds were of significant importance. The first result of this research was the publication of a survey of the 6.7 GHz methanol line for a large sample of star forming regions selected from their infrared color indicators (Szymczak, et al. 2000). Subsequently, a blind survey of a narrow strip of the Galactic plane revealed more methanol maser sources associated with massive stars in the early stages of their evolution (Szymczak, et al. 2002).
Detailed study of the physical properties of these objects was undertaken using VLBI (Bartkiewicz et al. 2009). The discovery of ring-like morphological structures with a well-defined velocity gradient demonstrated that the 6.7GHz maser radiation of methanol is produced in molecular disks, where the kinematics of individual clouds is determined by accretion processes or outflows. The studies of magnetic fields in clouds surrounding the masers were also successful.
In the years 2009-13, a key spectral EVN program for monitoring the variability of methanol masers, led to discovery of periodic objects and the reconstruction of the 3D disk structure. One of the more serious results was the finding of the periodic alternating variability of emissions in the methanol and water vapor lines (Szymczak et al. 2016).
The second known transition line of methanol (at 12.2 GHz) had also been surveyed with RT-4 and spectra were analysed in comparison with the main 6.7 GHz lines (Błaszkiewicz & Kus, 2004). With all these activity, Torun become the leading centre for cosmic methanol maser study on Europe.

Prof. A.Kus, in cooperation with Prof. P. Wilkinson and Prof. I. Brown (Jodrell Bank Observatory), originated the One Centimetre Receiver Array (OCRA) project. The initial aim was to operate a 16 channel multi-beam receiver on the RT-4 radio telescope at ~9mm wavelengths. The prototype two horn OCRA-p receiver was installed on RT4 in December 2002. OCRA-f an eight beam receiver of a half part of full OCRA was installed three years later. With co-workers (E.Pazderski, R.Feiler), and students several steps in the development of this difficult technical project were made. Improved radio telescope properties, via holographic measurements of antenna surface panel adjustment, as well as the antenna pointing correction table, had been gained.
The scientific plan aimed towards a deep surveys of a small selected areas of the sky, to search for the S-Z effect, the absorption of 2.7K CMB radiation in galaxy clusters, and also to study AGNs variability, and Planetary Nebulae physics. Results from OCRA program can be seen in: Pazderska et al. (2009), Gawronski, et al. (2010), Lancester, et al. (2011). The OCRA

project had also tremendous impact on RT-4 performance in sensitivity, stability and precision tracking.
In parallel to OCRA cosmology results Prof. B. Roukema with Dr. A.Marecki build up studies of the large-scale universe. Detailed analysis of the WMAP observations were the basis of these theoretical studies. (Roukema et al., 2004).

The participation in the SALT optical telescope project, and interest in radio polarization measurements with RT-4 led effectively to Torun's group involvement into RoboPol optical polarimetry program (e.g. Ramaprakach et al. 2019, Blinov et al. 2015, Pavlidou V., et al. 2014) .The project aimed towards collecting observational data (i.e. Blinov, et al., 2021) on selected sample of Fermi sources (AGNs), which allowed to conduct statistical studies of connections between observational properties of sources observed in extremely large range of wavelengths. The critical results on fast rotation of ***E*** vector were obtained for regions close to the Black Hole, that improved our understanding of emission processes, jet physics, and allowed to track complex evolution of active regions in blazars. The research is being done in close cooperation of TCfA RA group with teams from CALTECH, MPIfR, UoC, IUCfAA. Torun group was led by A. Kus and included E.Pazderski and R.Feiler.

The Department of Radio Astronomy had been the implementer of several European Union FP projects. Just some examples: "Infrastructure Cooperation Network in Radio Astronomy", "FARADAY" – Focal-plane Arrays for Radio Astronomy. "RADIONET" – A large project involving cooperation in VLBI (EVN) and the development of modern technologies, and observation methods of radio astronomy, "PHAROS" - the development and construction of a prototype multi beam antenna systems for use on single parabolic antennas. These programs cemented scientific and technology cooperation among European Radio Observatories.
Recently some of present research activities of the RA group members have expanded to high energy astronomy (H.E.S.S. and CTA), theoretical astrophysics and cosmology however, the radio spectroscopy of cosmic masers and VLBI with EVN on AGNs remain the most solid continuation of the original long term Radio Astronomy team programs.

The period of 1996-2020 was scientifically fruitful time for TCfA Radio Astronomy. The team developed advanced international co-operation and gained recognition as a high standard European research and education centre in Eastern Europe.
Great help and advice had been received over many years from the major observatories and institutes (MRAO, JBO, MPIfR, OSO, Astron, NRAO, Caltech, JIVE), several top class scientists were personally involved in Torun Radio Astronomy development.

Special acknowledgements and thanks are deeply expressed to Sir. M. Ryle, Sir B. Lovell, Prof. R. Wielebinski, Prof. R. Booth, Prof. P. Wilkinson, Prof. A. Readhead, Prof. I. Brown, Prof. R. Schilizzi, and to many others colleagues not mentioned here by name from the above Observatories.

4. **References Toruń**

Gorgolewski, S., Hewish, A.: 1960, The irregular structure of solar corona during 1959 June. The Observatory, 80, 93-103.

Gorgolewski, S., Hanasz, J., Iwaniszewski, H., Turło, Z.: 1962, Interferometric Investigations of the outer Corona at the 32.1 MHz band. Acta Astronomica, 12, 75-83.

Gorgolewski, S.: 1965, Recent radio observations of the outer solar corona. Acta Astronomica, 15, 261- 271.

Gorgolewski, S.: 1970, A possible detection of thermal radio emission from Callisto. Astrophys. Letters, 7, 37.

Wolszczan, A., Hesse, K.H., Sieber, W.: 1974, Observations of pulsar spectra at 1420MHz. Astron. Astrophys., 37, 285-290.

Pauliny-Toth, I.I.K., Witzel, A., Gorgolwski, S.: 1974, The brightness temperatures of Ganymede und Callisto at 2.8cm wavelength. Astron. Astrophys., 34, 129-132.

Pauliny-Toth, I.I.K., Witzel, A., Gorgolwski, S.: 1977, Observations of Ganymede and Callisto.
Astron. Astrophys., 58, L27-L28

Pearson, T.J., Kus, A.J.: 1978, The 5C6 and 5C7 surveys of radio sources. Mon. Not. R. astr. Soc. 182, 273-274.

Wolszczan, A.: 1980, A correlation of the P_3 periods of pulsars with their magnetic field age. Astron. Astrophys., 86, 7-10.

Wolszczan, A., Bartel, N., Sieber, W.: 1981, Spectrum of the interstellar turbulence of the pulsar PSR0329+54. Mon. Not. R. astr. Soc., 196, 473-480.

Booth, R.S., Kus, A.J., Norris, R.P., Porter, N.: 1981, Observations of a circumstellar shell around the OH/IR star OH127.8-0.0. Nature, 290, 5805, 382-384.

Kus, A.J., Wilkinson, P.N., Booth, R.S.: 1981, The radio structure of 3C309.1 determined by multi-baseline interferometry. Mon. Not. R. astr. Soc. 194, 527-535.

Nowakowski, L., Usowicz, J., Wolszczan, A., Kępa, A.: 1982, A multi-frequency fluctuation analysis in nine pulsars. Astron. Astrophys., 116, 158-163.

Szymczak, M., Kus, A.J., Gawronska, G.: 1983, Parameters of the RT-3 radio telescope. Postępy Astron., 30, 307-314.

Kus, A.J., Gorgolewski, S., Kempa, A., Krygier, B., Mazurek, J., Pazderski, E.: 1983, Receivers for RT-3 radio telescope. Postępy Astron., 31, 303-314.

Hewish, A., Wolszczan, A., Graham, D.A.: 1985, Quasi-periodic scintillation patterns of pulsars 1133+16 and 1642-03. Mon. Not. R. astr. Soc., 213, 167-179.

Krygier, B.: 1985, 25 lat radioastronomii w Toruniu, (in polish). Kwartalnik HNIT, 3-4, 761-776.

Cordes, J.M., Wolszczan A.: 1986, Multiple imaging of pulsars by refraction in the interstellar medium. Astrophys. Journal, 307, L27-L31.

Wolszczan, A., Cordes, J.M.: 1987, Interstellar interferometry of pulsar PSR1237+25. Astrophys. Journal, 320, L35-L39.

Ananthakrishnan, S., Kulkarni, V. K., Ponsonby, J. E. B., Spencer, R. E., Graham, D. A., et al. (12 authors): 1989, VLBI observations of the nuclei of a mixed sample of bright galaxies and quasars at 327 MHz. Mon. Not. R. astr. Soc. 237, 341-354.

Krichbaum, T. P., Witzel, A., Booth, R. S., Kus, A. J., Ronnang, B. O., et al. (20 authors): 1990, 43 GHz VLBI observations of 3C273 after a flux outburst in 1988. Astron. Astrophys., 237, 3-11.

Bååth, L.B., Rogers, A. E. E., Inoue, M., Padin, S., Wright, M. C. H., et al. (20 authors): 1992, VLBI observations of active galactic nuclei at 3mm. Astron. Astrophys., 237, 31-46.

Wolszczan, A., Frail, D.A.: 1992, A planetary system around the millisecond pulsar PSR1257+12. Nature, 355, 145-147.

Owsianik, I. and Conway, J. E.: 1998, First detection of hotspot advance in a Compact Symmetric Object. Evidence for a class of very young extragalactic radio source. Astron. Astrophys., 337, 69–79.

Owsianik, I., Conway, J. E., and Polatidis, A. G., 1998, Renewed Radio Activity of Age 370 years in the Extragalactic Source 0108+388. Astron. Astrophys., 336, L37–L40.

Konacki, M., Lewandowski, W., Wolszczan, A., Doroshenko, O., and Kramer, M.: 1999, Are There Planets around the Pulsar PSR B0329+54? Astrophys. Journal, 519, L81–L84.

Marecki, A., Falcke, H., Niezgoda, J., Garrington, S. T., and Patnaik, A. R.: 1999, "Gigahertz Peaked Spectrum sources from the Jodrell Bank-VLA Astrometric Survey. I. Sources in the region 35degr <= DEC <= 75degr", Astron. Astrophys. Suppl., 135, 273–289.

Szymczak, M., Hrynek, G., Kus, A.J.: 2000. A survey of the 6.7 GHz methanol maser emission from IRAS sources. Astron. Astrophys. Suppl., 143, 269-301.

Wolszczan, A. Doroshenko, O., Konacki, M., Kramer, M., Jessner, et al. (9 authors): 2000, Timing observations of four millisecond pulsars with the Arecibo and Effelsberg radio telescopes. Astrophys. Journal, 528, 907-912.

Browne, I. W., Mao, S., Wilkinson, P. N., Kus, A. J., Marecki, A., and Birkinshaw, M., (6 authors): 2000, OCRA: a one-centimeter receiver array, in Radio Telescopes. Proc. SPIE, 4015, 299–307.

Katarzyński, K., Sol, H., Kus, A.J.: 2001, The multi-frequency emission of Mrk 501. Astron. Astrophys., 367. 809-925.

Garrett, M. A., Muxlow, T. W. B., Garrington, S. T., Alef, W., Alberdi, A., et al., (13 authors): 2001, AGN and starbursts at high redshift: High resolution EVN radio observations of the Hubble Deep Field. Astron. Astrophys., 366, L5–L8.

Szymczak, M., Kus, A.J., Hrynek, G., Kępa, A., Pazderski, E.: 2002, 6.7 GHz methanol masers at sites of star formation. Astron. Astrophys., 392, 277-286.

Marecki, A., Barthel, P. D., Polatidis, A., and Owsianik, I.: 2003a, 1245+676 - A CSO/GPS Source being an Extreme Case of a Double-Double Structure. Publications of the Astronomical Society of Australia, 20, 16–18.

Marecki, A., Spencer, R. E., and Kunert, M.: 2003b, Location of Weak CSS Sources on the Evolutionary Path of Radio-Loud AGN. Publications of the Astronomical Society of Australia, 20, 46–49.

Błaszkiewicz, L. and Kus, A. J.: 2004, 12.2 GHz survey towards 6.7 GHz methanol masers. A comparison of 12.2 GHz and 6.7 GHz spectra. Astron. Astrophys., vol. 413, pp. 233–240.

Lewandowski, W., Wolszczan, A., Feiler, G., Konacki, M., Sołtysiński, T: 2004, Arecibo timing and single-pulse observations of 18 pulsars. Astrophys. Journal, 600, 905L.

Roukema, B. F., Lew, B., Cechowska, M., Marecki, A., and Bajtlik, S.,: 2004, A hint of Poincaré dodecahedral topology in the WMAP first year sky map. Astron. Astrophys., 423, 821–831.

Szymczak, M., Pillai, T., Menten, K.M.: 2005, Masers as signposts of high-mass protostars. . Astron. Astrophys., 434, 613-621.

Kunert-Bajraszewska, M., Marecki, A., Thomasson, P., and Spencer, R. E.: 2005, FIRST-based survey of Compact Steep Spectrum sources. II. MERLIN and VLA observations of medium-sized symmetric objects. Astron. Astrophys., 440, 93–105.

Dąbrowski, B. P., Rudawy, P., Falewicz, R., Siarkowski, M., and Kus, A. J.: 2005, Millisecond radio spikes in the decimetre band and their related active solar phenomena. Astron. Astrophys., 434, 1139–1153.

Kunert-Bajraszewska, M., Marecki, A., and Thomasson, P.: 2006, FIRST-based survey of compact steep spectrum sources. IV. Multifrequency VLBA observations of very compact objects. Astron. Astrophys., 450, 945–958.

Gawroński, M.P., Marecki, A., Kunert-Bajraszewska, M., Kus, A.J.: 2006, Hybrid morphology of *r*adio sources from the FIRST survey. Astron. Astrophys., 447, 63-70.

Lowe,S.R., Gawronski,M., Wilkinson,P.N. Kus,A.J., Browne, I.W.A., et al. (9 authors): 2007, 30 GHZ flux density measurements of the Caltech-Jodrell flat-spectrum sources with OCRA-p. Astron. Astrophys., 474, 1093-1100.

Lancaster, K., Birkinshaw, M., Gawroński, M.P., Browne, I.W.A., Feiler, R., et al., (8 authors):, 2007, Preliminary Sunyaev-Zel'dovich observations of galaxy clusters with OCRA-p. Mon. Not. R. astr. Soc., 378, 673-680.

Niedzielski, A., Konacki, M., Wolszczan, A., Nowak, G., Maciejewski, G., et al., (9 authors): 2007, A Planetary-Mass Companion to the K0 Giant HD 17092. The Astrophys. Journal, 669, 1354–1358.

Pazderska, B.M., Gawroński, M.P, Feiler, R., Birkinshaw, M., Browne, I. W. A., et. al. (12 authors): 2009, Survey of planetary nebulae at 30 GHz with OCRA-p. Astron. Astrophys., 498, 463-470.

Gawroński, M.P., Peel, M.W., Lancaster, K., Battye, R. A., Birkinshaw, M., et al., (19 authors): 2010, 30 GHz observation of sources in the Very Small Array field. Mon. Not. R. astr. Soc., 406, 1853-1864.

Lancaster, K., Birkinshaw, M., Gawroński, M.P., Battye, R. A., Browne, I. W. A., et al. (18 authors): 2011, Sunyayev_Zeldovich observations of a statistically complete sample of galaxy clusters with OCRA-p. Mon. Not. R. astr. Soc., 418, 1365-2966.

Pavlidou, V., Angelakis, E., Myserlis, I., Blinov, D., King, O. G., et al. (20 authors): 2014, The RoboPol optical polarization survey of gamma-ray - loud blazars. Mon. Not. R. astr. Soc., 442, 1693P.

Blinov, D., Pavlidou, V., Papadakis, I., Kiehlmann, S., Panopoulou, G., et al., (29 authors): 2015, RoboPol: first season rotations of optical polarization plane in blazars. Mon. Not. R. astr. Soc., 453, 1669-1683.

Blinov, D., Pavlidou, V., Papadakis, I. E., Hovatta, T., Pearson, T. J., et al., (29 authors): 2016, RoboPol: optical polarization-plane rotations and flaring activity in blazars. Mon. Not. R. astr. Soc., 457, 2252B.

Ramaprakash, A. N., Rajarshi, C. V., Das, H. K., Khodade, P., Modi, D., et al. (20 authors): 2019, RoboPol: A four-channel optical imaging polarimeter. Mon. Not. R. astr. Soc., 485, 2355R.

5. **Personal biographies**

Professor Andrzej Kus was born in Krakow, Poland in June 21st of 1944. After the war the family migrated to new settlement in a city of Slupsk (Pomerania). This is the place where he got the basic education up to mature exams. His interest in astronomy triggered a decision to study at the Nicolaus Copernicus University in Torun. He was graduated in astronomy with master degree in 1967. The same year he was employed as a young assistant in the Institute of Astronomy to work under supervision of Prof. S.Gorgolewski in radio astronomy group. In 1973, thanks the support of Prof. W.Iwanowska he received the British Council one year scholarship to study at Cambridge University. There he worked in Mullard Radio Astronomy Observatory under supervision of Prof. Sir M.Ryle. This had been unique opportunity to learn and practice radio interferometry and aperture synthesis techniques. After return to Torun he defended his doctorate in 1975. The habilitation degree was obtained in 1991 and then the associate professor position offered at the Nicolaus Copernicus University in 1993. He received his full academic professor title in 2003.

Andrzej Kus spent over six years working in leading research centers in Europe (JBO, MPIfR, OSO, Astron, Jive, ESO) and in the USA (Caltech, MIT, NRAO). He has been elected as the Associate Member of the Royal Astronomical Society in 1995 A::Kus was awarded highest prize in astronomy by *Polska Academia Umiejetności PAU* in Krakow in 2005 for leading a research team of radio astronomers from NCU who prepared instrumentation and made methanol maser sources survey of the Milky Way. After retirement he received honorary professorship from the Nicolaus Copernicus University (2015). Currently he is engaged in ongoing polarization program (RoboPol) and also shares his time with amateur astronomers and the public outreach promoting research in astronomy.

Professor Richard Wielebinski was born in Pleszew, Poland in 1936. The family were evicted from their house in December 1939 already, as part of the ethnic cleansing. The family spent ten years being moved to various camps In Poland and Germany. Finally the Wielebinski family emigrated to Australia, arriving in Hobart, Tasmania in 1949. Richard at the age of 14 could attend a school for the first time in his life, but had to learn English first. After Hobart High School Richard studied Electrical Engineering at the University of Tasmania. During his university studies Richard worked for Grote Reber who came to Tasmania and was installing low frequency antennas. After the completion of Bachelor of Engineering and Master of Engineering Science (1957) degrees Richard worked for the Postmaster-General Department, constructing a TV transmitter on Mt. Wellington above Hobart. Having won a Shell Postgraduate Scholarship, Richard was accepted in 1960 as a PhD student by Marin Ryle in Cambridge. In 1963 Richard moved to a lectureship in the Electrical Engineering department at the University of Sydney. Here in addition to lecturing he conducted sky surveys with the Parkes radio telescope, pulsar observations in Molonglo as well as doing antenna studies for the Arecibo telescope. In 1966 Richard was invited by Prof. Hachenberg as guest professor to Bonn University. The contacts were active after this visit and in 1969 an invitation came from the Max-Planck-Gesellschaft to become a director at the Max-Planck-Institut für Radioastronomie (MPIfR) in Bonn. The 100m Effelsberg radio telescope was under construction and Richard took charge of the Electronics Division. In the following 35 years, in addition to the Electronics Division Richard built up an active research group studying cosmic magnetic fields and pulsars. For the studies of magnetic fields he was awarded in 2017 the Karl-Schwarzschild Medal by the Astronomische Gesellschaft. The MPIfR moved to mm research in collaboration with France (later Spain) leading to the installation of the IRAM institute in Grenoble. A sub-mm project with the Steward Observatory led to the construction of the HHT telescope on Mt.Graham in Arizona.

Richard Wielebinski holds honorary professorships in Bonn University, the Chinese Academy of Sciences University, Beijing and the University of Southern Queensland in Toowoomba. He is a member of several academies and holds four Dr.h.c. degrees from: Nicolaus Copernicus University, Toruń, the Jagiellonian University in Kraków, the University of Tasmania and the University of Zielona Góra. After retiring in 2004 Richard became involved in the History of Radio Astronomy. He is still active in this field, was the Chairman of the IAU Working Group on History of Radio Astronomy.