Bohdan Paczyński (1940-2007)

Wojciech Dziembowski[1]

1. Nicolaus Copernicus Astronomical Center
Bartycka 18, 00–716 Warszawa, Poland

Paczyński's death in 2007 has been a great loss for the world astronomy. He was one of the most influential personalities in our field. His original ideas presented in numerous seminal papers opened new directions in astrophysics. He was an excellent teacher, who guided many students and young scientists to the right track in their research. For many astronomers of his generation he was an unforgettable friend.

Bohdan Paczyński was born on February 8, 1940, in Vilnius (Lithuania). The city, called Wilno in Polish, belonged to Poland until September 19, 1939, when it was invaded by Soviet Army. In June 1940, Vilnius became the capital of the Soviet Republic of Lithuania. Bohdan parents were graduates of Vilnius University (then Stefan Batory University). Bohdan's father (Jan) was a lawyer and his mother (Helena) a Polish literature teacher. The family survived the German occupation (1941-1944) in Lithuania. After the Soviets took control over the region, the family, including Bohdan's younger sister Ewa, moved to Poland. Until 1947 they lived in Cracow, where Bohdan's father became the head of a publishing house. Later he got a job in Moscow and the whole family moved there. Thus, Bohdan began his school education in Russian. By the end of 1949 the family returned to Poland to settle in Warsaw.

In 1954, Professor Włodzimierz Zonn, a friend of the Paczyński, brought Bohdan to the Warsaw University Astronomical Observatory in Ostrowik near Warsaw. There he met astronomy students, some of which became his life-long friends. They invented his popular nickname *Bep*. Soon after the first visit to Ostrowik, he started his own visual observations of variable stars. The data on minima of eclipsing binaries he has observed were published *Acta Astronomica* (AcA, 1958). His brilliance in math showed up also early. He was the runner-up in the national competition in mathematics for high school students.

In 1957, Paczyński enrolls at the Faculty of Mathematics and Physics of the Warsaw University. He graduates in 1962. Part of his thesis required for the Polish equivalent of the M.Sc. was published in his second research paper (AcA, 1962). The work concerned interstellar matter. His advisor (also for the Ph.D.), Professor Stefan Piotrowski, quickly recognized Bep's unusual talent. A research stay in the US was a must for Piotrowski's students. Bohdan went there for one year before getting Ph.D. to become a night assistant in the Lick Observatory. The product of his stay was a number of still frequently quoted papers on RR Lyrae stars and eclipsing binaries (e.g. AJ, 1964, ApJ 1964, ApJ 1965, ApJS 1965), some coauthored by George Herbig, George Preston and his older colleague from Warsaw, Joe Smak.

In the fall of 1963, Bep completed his Ph.D. and defended it in the early 1964. In the same year he married Hanna (called Hania by him and friends) Adamska, his class-mate from the secondary school. Their daughter Agnieszka was born in 1967 and son Marcin in 1974. He always tried to take his family for his longer stays abroad.

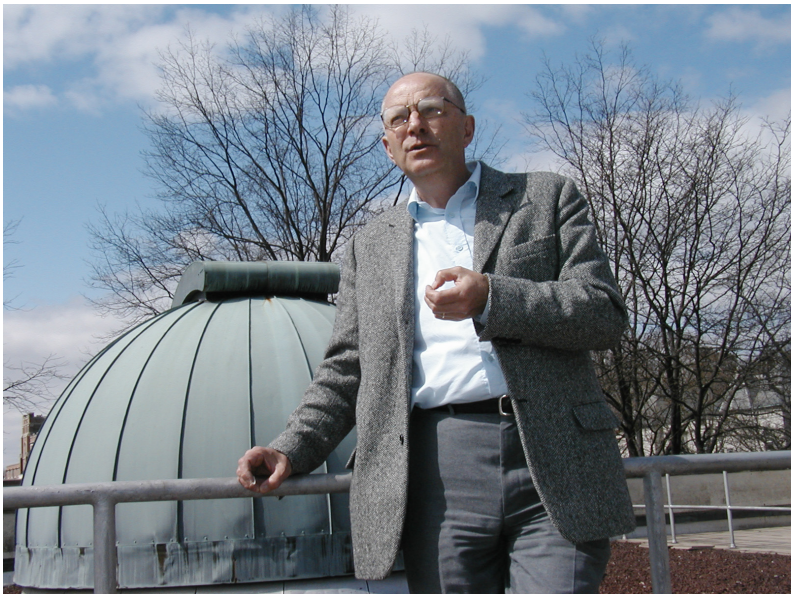

Fig. 1: Bogdan Paczyński on the rooftop of Peyton Hall in 2002. Photo by Evelyn Tu.

However, under the system we lived until 1989, getting passports for whole families was not easy and he did not always succeed.

The topic of his Ph.D. thesis was distribution of interstellar matter in the Milky Way. The new results were published in a largely ignored paper (AcA 1964), which however should not escape attention of Paczyński's biographers. Firstly, because this is the most mathematic paper he ever published. Secondly, because the presented numerical results were obtained with an electronic computer based on electron-tubes which was the first and the only application of such a computer in Polish astronomy. In 1965, Warsaw University purchased a Danish computer GIER, based on transistors. This computer became an essential tool for his research until 1968. As talented as Bep was to mathematics, he treated it mainly as a tool for solving problems posed by astronomical observations. He never learned it beyond his current needs. The same was true about computer programming. He never tried new programming languages merely because they were developed. He would say that he works only on easy problems. In fact, many problems he solved might have appeared easy once he solved them but somehow nobody did it earlier.

Paczyński was interested in the whole astrophysics but from the mid-sixties to the end of seventies his own research was focused on the theory of stellar evolution. Achievements in this field brought him world-wide fame. His work began with writing his stellar evolution code which presented a challenge because the GIER computer had only 1024 directly addressable words. To run the full version of the code, he had to go abroad. The calculation reported in a series of papers *Evolution of Close Binaries.* I - V (AcA 1966-1967) were performed with the IBM 7040 computer of the Paris Observatory in Meudon. This series of papers was his dissertation for the higher degree (*doctor habilitatus*), a prerequisite for further promotions. He was then 27, which is unusually young age for this degree. These papers together with nearly

contemporaneous papers of Kippenhahn and Weigert led foundations of the theory of stellar evolution in close binary systems.

Paczyński published ten other papers between 1965 and 1967. Among them, the one entitled *Gravitational Waves and the Evolution of Close Binaries* (AcA 1967), which is most remarkable. He showed there that evolution of short period binaries WZ Sge and HZ29, may be considerably affected by gravitational radiation and thus data on such objects may yield an indirect test of its reality of such a radiation, which was then controversial. Note that the paper was published well before the more direct evidence from data from the binary pulsar was put forward. The coauthor of three papers from this period is the first Bep's Ph.D. student, Janusz Ziółkowski, who received his degree in 1969. The review paper *Evolutionary Processes in Close Binary Systems* published by Paczyński in 1971 in Annual Review of Astronomy and Astrophysics, which contains references to his original works, is one the most often used astronomical papers (over 950 citations).

In 1968 Paczyński is granted a JILA Fellowship in Boulder. The year spent there, he devoted mainly to developing a new version of stellar evolution code (known as the Paczyński code). The goal was to model evolution of single stars from ZAMS to the white dwarf or carbon ignition. The main results obtained with this code were published in the series of papers entitled *Evolution of Single Stars I-VI* (AcA 1970 - 71). Even with the powerful CDC 6400 computer, treatment of the phase of helium shell flashes was not possible but for his aims not essential. He realized that the mean evolutionary track may be approximated with the stationary shell models, whose structure he described analytically (Paper II). In the process, he discovered a remarkably simple formula for stellar luminosity as a function of the core mass.

A problem that arose from his studies of stellar evolution, the thermal instability, gave rise to a series of five papers entitled *Linear series of stellar models* (AcA 1972-76) coauthored with his Ph.D. students Maciej Kozłowski and Michał Różyczka. The papers addressed the matter of uniqueness of stellar models which Bep encountered in numerical calculation and tried to understand. These are rather rare examples of his work that had a pure theoretical motivation. The next student of Bep was Anna Żytkow, who got her degree in 1972 for the work on stationary mass outflow from massive stars. In Caltech, where Bep spent a year (1975-76) as a Sherman Fairchild Distinguished Scholar and Anna was a postdoc, they worked on hydrogen shell flashes in mass accreting white dwarfs.

Paczyński's professional career proceeded very quickly. In 1974 he becomes an associate and in 1979 a full professor in the Copernicus Astronomical Center (until 1977 the Institute of Astronomy) of the Polish Academy of Sciences (PAS). Earlier, at an unusually young age of 36, he is elected a corresponding member of PAS. In the same period came the first signs of the international recognition. In particular, he is elected President of IAU Comission 35 for the 1976-79 term. At the 1979 IAU General Assembly in Montreal, he gave one of the three Invited Discourses. The other two were given by the Nobel Prize winners, Chandrasekhar and Herzber. Would he be one too, had he lived longer? Bep started his talk *Stellar evolution and close binaries* with dedication to his professors Zonn and Piotrowski stressing their role in attracting him to astronomy and the binary star research.

An unexpected opportunity for the development of Polish astronomy appeared in 1972. The US Special Committee for the Celebration of the Copernicus Quincentennial has been considering a gift for Poland. One of the Committee members, the well-known astronomer Robert O'Dell from the University of Chicago, decided to ask

his Polish friends Joe Smak and Bep for their suggestions. The idea came from their memorandum on the future of Polish astronomy published in the semi-professional journal *Postępy Astronomii*, where they argued that public money will be better spent on an institute for theoretical astronomy rather than on a big telescope, as originally planned. O'Dell liked the idea and, surprisingly, American NSF accepted the plan for committing its available funds in Poland for construction of a spacious building for the Copernicus Astronomical Center of the PAS.

Bep did not like administrative duties but could not totally avoid them. Piotrowski ended his term as the director of the Insititute in 1976, Joe was about to go to Ohio State for one year and Bep was the only choice. He had to take up the job. The construction of the building was proceeding slowly but this was the matter beyond his control. The task that could not wait was purchasing the computer - a separate gift worth 140K$ of the US National Academy of Sciences, on the same occasion. Bep carried negotiations with companies and selected the brand. His choice was PDP 11/45. This computer had 32k directly addressable memory and truly revolutionized our work. As soon as Joe returned, Bep gladly ceded the directorship to him and focused on expanding research field in the Copernicus Astronomical Center by attracting physics graduates to work on astrophysics.

Throughout the 1970s, stellar evolution dominates in Paczynski's research but this was also the time when he begins to work on quite different problems. In 1974, he publishes his first papers on gravitational lensing by extragalactic objects and three years later first papers on accretion discs. His collaborators are Michał Jaroszyński, his new Ph.D. student - now a professor at the Warsaw University Observatory, and Marek Abramowicz, now an emeritus professor of Göteborg University. They developed thick disk models (AcA 1980), well-known as *Polish donuts*. The decade of 1970s is also the time of his shorter visits to the US, mainly to Princeton. He has his first young American collaborators (Charlse Alcock, Scott Tremaine, Virginia Trimble, Paul Wiita). Some of them were visitors to the newly opened Copernicus Center. One of the most cited Paczyński paper arose from his collaboration with Wiita. Their paper *Thick accretion disks and supercritical luminosities* (A&A 1980) gathered over 930 citations. The reasons for this high popularity is undoubtedly the ingenious expression for the pseudo-Newtonian potential, which very-well mimics effects of the General Relativity.

When on December 13, 1981, the Law Martial was declared in Poland, Bep with his family is in Pasadena again as a Fairchild Fellow at Caltech. Expecting the worst, they decided to stay in the US. From a number of job offers he accepted a professorship in the Department of Astrophysical at Princeton University, which becomes his second and the last home institution. Polish authorities regarded his stay in the US as illegal and his passport became shortly invalid. It took seven years before he received a new passport and could visit Poland. Bep was unhappy but his scientific productivity was not affected. He worked on a large variety of topics from stellar evolution to cosmology with a number of, both, American and Polish collaborators. His invitations to Princeton were of great help Polish astronomers.

The gamma bursts (GRB) were in the center of Bep's interest for a long time. In 1986 he published in ApJL a brief but influential paper providing simple arguments that their sources are at cosmological distances. He defended this view in the debate that took place in 1995 in Chicago, marking the 75th anniversary of the famous debate between Harley Shapley and Herbert Curtis on the distance to M31. Paczyński's opponent was Donald Lamb, who opted for sources located in the Galactic halo. The

moderator, sir Martin Rees, declared the debate undecided. Soon, however, observations showed that it was Paczyński who has been right. Still, he often expressed skepticism regarding reality of detailed models of GRB sources, including those proposed by himself. His models involved not only neutron but also quark stars, which he considered in two papers published in 1990 and 1991. He kept continuing his search for adequate models of GRB sources. In a reaction to the observation of the optical afterglow of the gamma-ray burst GRB 970508 in 1998, he publishes an ApJL paper where he argues that the source is a hypernova explosion and outlines a possible model of the phenomenon. In one of his last papers, he came back to the quark star connection.

In the same year, Paczyński published in ApJL another seminal paper, *Gravitational Microlensing by the Galactic Halo*, which inspired first massive photometry projects, a new field in observational astrophysics. The original motivation was a search for the baryonic dark matter in the Galactic Halo. He calculates probability of lensing by hypothetical massive objects and concludes that there are reasonable chances of detecting them by monitoring light changes of few millions of the Magellanic Cloud stars. He knows that the Halo may consist of exotic particles not of individual massive object and he is well aware of observational difficulties but encourages undertaking the effort with these words: "a systematic discovery of variable stars in a nearby galaxy is attractive, even if no lensing events is discovered". In fact, such events were discovered, but the outcome of first variability surveys (EROS, MACHO, OGLE) went far beyond it. Years later, asked by a journalist which of his works he regards most important, he points to these two 1986 papers.

Paczyński initiated the OGLE project, originally as the Warsaw-Princeton-Carnegie collaboration putting in charge Andrzej Udalski, then a young staff member of the Warsaw University Observatory. This was an excellent choice. Andrzej is a very bright astronomer and a genius in instrument building, the gift that Bep did not have. He spoke often with great respect about Andrzej's work. Among spectacular achievements of the OGLE team are first discovery of microlensing events toward the Galactic Center (1993), first binary lens(1998), and first microlensing by planetary companion (2004). A possibility of discovery distant planets in searches for microlensing events has been first considered by Paczyński and his Ph.D. student Shude Mao in (ApJ 1991).

At a number of occasions, he emphasized importance of collecting light curves for various variable stars. All three microlensing projects provided a wealth of such data, which find applications in studies of stellar pulsation and evolution, galactic structure, and distance scale in the universe. The OGLE team spectacular achievement was the detection of planets by observations of transit. A number of his students, in particular two Warsaw University graduates Krzysztof Stanek and Przemysław Woźniak, were involved in analyses of the OGLE photometry data. The matter of distance scales was addressed in several Paczynski's papers. His inspiration is behind the ongoing DIRECT collaboration aimed at distance determination to nearby galaxies through analyzes the light and radial velocity curves for detached binaries Cepheids. The collaboration involves American and Polish astronomers from the Copernicus Center (Janusz Kałużny, Barbara Mochejska).

It seems that the all-sky patrolling with small telescopes occupied most of Paczyński's mind in his last ten years. In 1996 he gave an invited talk *The future of Massive Variability Searches* at the 12th IAP Colloquium in Paris, where he presented the motivation. In the same year, he approached with this idea Grzegorz Pojmański,

another staff member of the Warsaw University Observatory, and again this is a very good choice. Working for most of the time alone, Grzegorz designed the instruments and data reduction procedures for the project known All Sky Automated Survey (ASAS), which started operation in 2000. Bep's support for the project continued almost up to his last days. Even being very ill he often contacted Pojmański in ASAS matters. The ASAS station at Las Campanas led to identification of large number ($\sim 10^5$) of bright variables of various types in the Southern Sky. First observations of rare events include comets, novae, and supernovae.

During his work in Poland, Paczyński received his first honors and prizes for achievements in astronomy. In 1974 he becomes a member of the German Academy of Science Leopoldina and two years later a corresponding member of the Polish Academy of Science. In 1980 he gets Polish State Prize. A true flood of honors and prizes came after he moved to Princeton. In 1984 he becomes a Foreign Associate of the US National Academy of Sciences. In 1985 he receives Medaille l'Adion from the Nice Observatory. The Royal Astronomical Society prizes him with its Eddington Medal (1987), the George Darwin Lecture (1996) and the Gold Medal (1999). In 2002 Oxford University awards him with the Halley Lecture. Dannie Heineman Prize for Astrophysics, which he received in (1992) opens the list of American prizes: Moris Loeb Lectures (Harvard, 1995), Russel Marker Lecture Series (Penn State, 1996), Henry Draper Medal (1997), The Antoinette de Vaucouleurs Medal (1998), Sackler Lectureship (Berkeley, 1999), Thomas Gold Lectureship (Berkeley, 1999), The Marc Aaronson Lectureship (Arizona, 1999), Rossi Prize (2000), Catherine Wolfe Bruce Gold Medal (2002), and Sayfert Lecture (Vanderbilt, 2003), Russel Lecture (AAS, 2006). After 1989, there was time again for Polish honors: he receives Marian Smoluchowski Medal (Polish Physical Society, 2000), becomes a full member of the Polish Academy of Science (2001), gets honorary degrees from Wrocław University (2004) and Nicolaus Copernicus University (Toruń, 2005).

The whole summer of 2003 Bep spent in Poland. He was as always enthusiastic and busy inventing and supervising research projects. We did not notice any sign of the coming disease. The terrible news about his malicious brain tumor came few months after his return to Princeton. The experimental treatment stopped tumor growth. Although he remained partially paralyzed he could return to work. The therapy gave him three years which he filled up with an intense research activity. NASA's Astrophysics Data System lists his 31 publications dated between 2004 and 2007. The range of topic covers nearly the whole of his research activity. In a letter to Montly Notices published in 2005, Paczyński and Paweł Haensel connect Gamma Ray Bursts with quark stars, as they first did in their pioneering 1991 paper. The work has been inspired by the data on GRBs associated with powerful SN Ic. They proposed that powerful long GRBs associated with SNIc resulted from the formation of a quark star.

In several papers Bep returned to variable star research, the field in which he started his astronomy. He collaborates with two Pojmański's students, Dorota Szczygieł and Bogumił Pilecki. Dorota and Ryszard Sienkiewicz coauthored in the paper devoted to modeling the contact binary AW UMa, which he discovered in 1963 during his stay at the Lick Observatory. The two Pojmański's students and Igor Soszyński of Udalski's team witnessed the last months of Paczyński's work. He was very ill but still showed a vivid interest in their work. He died one month after the last of the young visitors returned to Warsaw.

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