Bohdan Paczyński (8 February 1940 – 19 April 2007)

To a generation of stellar evolution practitioners, he was "The Paczyński Code", but by the time he died on 19 April 2007 in Princeton, New Jersey, Bohdan Paczyński was even better known as a very early, persistent advocate of extragalactic origin for the gamma ray bursts and as the father and godfather of several projects that have succeeded in finding gravitational lensing of stars by other stars (some with planets) and in setting firm upper limits to the numbers of dark lenses in the galactic halo. And there was yet another community who, if asked "Where did you first learn about binary star evolution?" would say "From the Paczyński (1971 ARA&A 9, 183) review article", which has reached the criterion for Science Citation Index citation classic status several times over. His death had been inevitable from the time of diagnosis of an inoperable brain tumor three years earlier, but a very new experimental treatment provided a couple of extra years, a large fraction of them spent on astronomy. He said that among his motivations for trying to do well was the doctor wanting so badly for his experiment to succeed.

BRIEF BIOGRAPHY

Bohdan (to those who could pronounce it) or Bep (to many of us who could not) was born in Wilno, Poland (now Vilnius, Lithuania) on 8 February 1940. The family moved west with the border in 1945, and thus his degrees were from Warsaw University (MA 1962, PhD 1964, dr. hab. and Docent 1967). That the Allies permitted Russia to shove Poland westward in this fashion was one of very few things that Bohdan seriously resented. The family however spent some time in Moscow, and Bohdan retained serviceable Russian the rest of his life. Curiously, as the growing brain tumor gradually eroded his ability to recall words and put them together, he said that Polish and English were about equally difficult, but that Russian was a little easier. He married Hania (Hanka – a characteristic Polish diminutive) Adamska in 1964, and their children Agnieszka and Marcin (later Martin) were born in 1966 and 1974. They moved permanently to the US in 1982 but maintained close personal and professional ties with Poland. Toward the end, Bep regretted that he had not been able to make one last trip back to Poland, perhaps as much to see his beloved mountains as anything (both his and Hanka's parents being long gone). But he was able to visit the Canadian Rockies as part of the trip to give the Russell Lecture at the American Astronomical Society meeting in Calgary in June 2006.

EARLY CAREER

By age 15, Paczyński was an amateur astronomer, with his first publication on eclipsing variables at age 18 (and his last posthumous). His first overseas post (1962 – 63) was a pre-doctoral position at Lick Observatory as an observer and, sometimes, night assistant

(e.g. to Gerald Kron). Most of those data appeared in PASP and AJ, with George Herbig and George Preston as early co-authors. A left-over subset popped up very recently in AJ 128, 1233 (Table 4, 2004).

During the Lick year, Bep learned to drive (the railings on the road up Mt. Hamilton may still bear the scars) and developed his unique, instantly recognizable, style of English. His own description was that he had learned how many articles (a, an, the; Polish and Russian have none) a typical paragraph should contain, but not where they should go. There were also shorter observing visits to Beograd, Haute Provence, and Meudon.

His PhD dissertation (Acta 14, 157) used star counts to probe interstellar absorption, and, with 205 equations, may well have set a record for both the journal and the author. As a new postdoc, Paczyński turned (temporarily!) from observations to theory, and his dr. hab. thesis, completed under Stefan Piótrowski, on evolution of binary stars, began to appear in the 1966 and 1967 volumes of Acta Astronomica (16, 231; 17, 1 the most frequently cited portion; 17, 8, etc). This quickly made Acta a must-read journal for stellar astronomers. It happened again from the mid 1990s to the present, because many of the results from the OGLE and ASAS microlensing searches have been published there, especially the ones dealing with variable stars, stellar population statistics, galactic structure, planet transits, and so forth that have turned out to be by-products of these searches of at least as much importance as the original goal.

LATER CAREER

Paczyński remained primarily in Warsaw for 15 years post-docent-degree, becoming an assistant professor in 1969, associate in 1974, and professor in 1979 at the Institute of Astronomy, eventually renamed the Copernicus Astronomical Center. Visiting appointments included 1968-69 at JILA, University of Colorado (where The Code was largely developed), Fairchild appointments (1975-76 and 1981-82) at the California Institute of Technology, and shorter terms at Cambridge University, Trieste, Princeton (University and Institute for Advanced Study), the Astronomical Council in Moscow, Harvard, CNRS Paris, and Tokyo. He had intended never to leave Poland except temporarily, but as the political situation there deteriorated, he accepted a professorship in the Department of Astrophysical Sciences at Princeton University in 1982, becoming the Lyman Spitzer, Jr. professor in 1989. It was a decision made not without regret, and he later said he would not have left Warsaw if he had known how quickly things would improve there.

HONORS, AWARDS, AND APPRECIATIONS

Paczyński was the only astronomer ever to make a clean sweep of the major awards given by the Royal Astronomical Society (London) – the Eddington Medal (1987), the George Darwin Lectureship (1995, lecture given in 1996), and the Gold Medal (1999). A complete list of other awards takes a full page, but it includes the Karl Schwarzschild

Lecture (Astronomische Gesellschaft, Germany, 1981), the Heineman Prize (American Institute of Physics, 1992), the Henry Draper Medal (US National Academy of Science 1993), the Rossi Prize (American Astronomical Society High Energy Astrophysics Division 2000), the Halley Lecture (Oxford 2002), the Bruce Gold Medal (Astronomical Society of the Pacific 2002), the Henry Norris Russell Lecture (AAS 2006), and a number of honors from Polish organizations, ending with the Smoluchowski Medal of the Polish Physical Society (2000). He was a member of the Polish Academy of Sciences (Corresponding 1976, full 1991), a foreign associate of the Royal Astronomical Society (1997), and a Foreign Associate of the US National Academy of Sciences (1984). Astronomical leadership can be exercised in many ways, both formal and informal. Bep's were mostly informal and attested to in comments from Polish and American colleagues in other obituaries, tributes, and press releases. Indeed the only formal position of this sort he appears to have held (and it does not appear on his official CV) was as President of Commission 35 (Stellar Constitution) of the International Astronomical Union. This came as part of a curious succession: Alla Massevich (USSR 1970 – 73), Leon Mestel (UK 1973 – 76), BP (Poland 1976 – 79), and Roger Tayler (UK 1979 – 82) and at a particularly difficult time for free communication between east and west. Paczyński later gratefully and cheerfully acknowledged that Tayler had actually done most of the work during his term, including the compilation of the commission reports for the 1979 Montreal IAU General Assembly (where Paczyński gave an invited discourse), which are signed by both of them. The “cheerfully” was characteristic. A Polish exit passport in those days was not a right but a mysterious commodity, which might or might not appear in time for a scheduled departure, because, said Bep, there are many low-level functionaries whose only pleasure in life is the arbitrary power of saying yeay or nay.

Bohdan's early co-authors included six women astronomers at a time when there were very few of those anywhere. It would be unfair to say that they were all in love with him, but four out of six isn't bad.

Everyone who ever met him (and perhaps some who did not) has a Paczyński story, and many appear in other tributes. A large fraction falls somewhere between tongue-in-cheek self-deprecation and real modesty. His style of research, described to Princeton colleague J.P. Ostriker as “mostly common sense”. His leadership method as having the knack for persuading people to get together and do what they should probably be doing anyway. More subtly on his linguistic abilities, which were enormous, though he often didn't get jokes, “Never mind. I have no sense of humor in Polish either” (which he would actually apologize for speaking with colleagues in the presence of anyone who couldn't as “Sorry for Polish.”)

But there could be a bit of a sting as well. Concerning an astronomer who shall remain nameless and had been suggested as one of very few first-rate scientists who was also a more or less normal human being, he responded, “It is two o'clock in the morning. We have all been eating and drinking since six. And X is still talking about galaxies. Do you think that is normal?”

THE SCIENCE

This is a reasonably serious, if not always solemn, attempt at cataloguing most of the insights, ideas, projects, and all for which the community honors and will remember Bohdan Paczyński. Some items are mentioned only by name, others with considerable elaboration. The list is meant to be chronological by first paper on a topic, and the citations (run into the text and abbreviated) are typically to that first paper and perhaps a couple later and more frequently cited ones. The total publication list exceeds 280 items, the vast majority of which can be located in Science Citation Index and ADS. The two commonest misnomers under which citations occur are Paczynsky, B. and Paczynski, B.E. (an inevitable but incorrect back-formation from the Bep nickname, and if you wish to ask "Did Paczyński have a middle name?" the only possible answer is "Why would he need one?" He once claimed the Polish equivalent of Christopher, but in a context that makes it slightly suspect).

A very major omission here is a complete list of students and postdocs on both sides of the Atlantic. Such a list should appear in the PASP obituary being compiled by W. Dziembowski or the BAAS one coming from D.N. Spergel and other Princeton colleagues. Many names of students and postdocs appear here in parentheses as part of paper citations. If no other names are mentioned, the paper is by BP as sole author. Remember, the traditional Polish (and German) keyboard has y and z interchanged from the American and British ones.

- Observations of eclipsing variables (Acta 9, 48, l958, J. Ginter, A. Wernik).

- Selective absorption in the ISM (Acta 12, 206, 1962).

- Observations of RR Lyrae (pulsating) variables (ApJ 140, 181, l964, G.W. Preston).

- Nova-like variables as short-period EBs (ApJ 141, 617, 1965, G.H. Herbig, G.W. Preston, J. Smak).

- Evolution of close binaries (Uccle B17, 111, 1967; IAU Highlights v. 1, 409, 1968; Acta 16, 231, 1966; Acta 17, 1, 1967, the most often cited; Acta 17, 8, 1967 J.Ziółkowski, and more). This was Paczyński's break-out into international astronomy, and it was partly the fortuitous location of the 1967 IAU GA in Prague that led to his being asked to speak at length on binary evolution. This also led to his discovery that sometimes new territory is mined, when Anne Underhill rose in wrath at the idea that Wolf-Rayet stars could have been stripped of their hydrogen envelopes by mass transfer to a close companion. There are, she said, more models that aren't stars than there are stars that aren't models.

  In addition to the WR explanation, early results included the fact that a supernova in a binary would not unbind the system because the exploding star would by then be the less massive and the possibility of forming binaries from coagulation of a

disk around a single star during formation with rotation (both ARA&A 1971). So far ahead of its time that even BP had to rediscover it was the realization that gravitational radiation from cataclysmic binaries will drain enough angular momentum to shrink the orbit and drive mass transfer (Acta 17, 287, 1967). The rediscovery is ApJ 248, L27, and 268, 825, 1982 (R. Sienkiewicz) and includes the idea that the distribution of CV periods – the minimum P near 80 minutes and the gap in N(P) between 2 and 3 hours – results from such evolution.

The origin of CVs requires removal of a great deal of angular momentum if the stars were ever far enough apart for one to be a red giant. How it happens and the name "common envelope" binaries appear in IAUS 73, p. 75, 1976).

- Violation of the Russell-Vogt theorem (IAUS 34, 396, 1968; Acta 18, 225, 1968, J. Ziółkowski). This is a prequel to the next major topic, recognizing that total mass and radial distribution of composition are not sufficient to determine the structure of a star, because extended red supergiant envelopes actually have total positive energy (when you include the ionization) and so are separated from planetary nebulae plus nuclei only by an exoergic instability. The idea is developed at greater length in 4 papers on linear series of stellar models, ending with Acta 23, 263, 1973 (M. Kozłowski & K. Popova).

- Evolution of single stars (and the Paczyński code). A curious title for a series of papers (Acta 20, 47, 1970, most often cited, and five following) until you remember that his first series was "evolution of close binaries". The result most often mentioned is perhaps that the cores of stars between about 3 and 7 solar masses converge to very similar behavior (leading to PNe and WDs, not to explosive carbon ignition, we now know). More massive stars sometimes looped back to the blue during advanced evolution and sometimes not. It was the existence of the code in two forms, for IBM and DEC machines with 8 and 12 significant figure precision, that revealed the cause was (real or numerical) sharp edges in composition left beyond by main sequence hydrogen burning in convective cores, when these were overtaken by later nuclear reactions.

  Several things about the code made it available and used by dozens of other astronomers, right down to a CD inside the back cover of a 2004 textbook by Carl Hansen et al. The first was Bohdan's incredible generosity. You could have a copy for the cost of the mag tape to put it on. But the format was also unusually flexible in comparison with what other theorists had been doing. A Schwarzschild-style part produced an initial ZAMS model, in about five minutes of main frame time, which was then evolved forward, Henyey-style, by a separate program that used the previous time step as the trial solution for the next one. Perhaps most important, the three auxiliary quantities you need to solve the four differential equations (nuclear energy generation rate, opacity, equation of state) were stored in tables calculated in advance for the range of temperature, density, and composition you expected to encounter, rather than having to figure them out afresh at every time step. This also permitted great flexibility in choice of

composition and prescriptions for opacity and convective flux, so that the code could be applied to odd things like helium red giants (A&A 22, 9, 1973, V. Trimble), massive population II stars (A&A 25, 35, 1973. V. Trimble, B. Zimmerman), carbon burning with the URCA process (Acta 24, 1 E. Ergma), and helium shell flashes (Liège Colloq. 335, 1975, I.J. Sackmann-Christy), as well as to assemblages of commoner sorts of stars.

- Stellar ideas BP was first or among the first to enunciate, but which do not appear in the main paper series include FU Ori stars as accretion/excretion disk phenomena (QJRAS 17, 31, 1976), FK Comae stars as the products of binary mergers, R CrB stars as a natural product of vigorous mass loss, and merger of white dwarf binaries as the origin of Type Ia supernovae.

- Properties of astrophysical black holes, including a quasar mass limit (Nature 249, 329, 1974), X-ray sources in multiple star systems (ApJ 189, L17, 1974, J.N. Bahcall, F.J. Dyson, J.I. Katz), and, most cited, a firm lower limit to the mass of the compact component of Cygnus X-1, via analysis of the geometry of the Roche lobes, and putting it firmly in the black hole regime (A&A 34, 161, 1974).

- Gravitational lensing by whole galaxies (IAU Regional Meeting, Trieste, 673, 1975, J. Jaroszyński) and very much more about gravitational lensing about 10 years ahead.

- Geometrically thick and/or self-gravitating accretion disks, particularly as a way of allowing AGNs to radiate more than the Eddington limiting luminosity (Acta 28, 91, 1978; Acta 30, 1, 1980, M. Jaroszynski & M.Abramowicz; A&A 88, 23, 1980, P. Wiita). The Paczyński-Wiita potential is a Newtonian mimic of the GR equations of motion around a Schwarzschild black hole widely used in modeling BH accretion where one needs to find the last stable orbit and such.

- Testing GR and black hole properties with a pulsar near Sgr A* (IAUS 84, 401, 1979, V. Trimble) and with QPOs (Nature 327, 303, 1987).

- An observational test for the existence of a non-zero cosmological constant (then thought nearly impossible to separate from the other parameters) that uses very many lensed QSOs to determine how the volume of space depends on redshift (Nature 281, 358, 1979, C. Alcock). About one was known at the time. ApJ 248, L101, 1981 (K. Górski) added another. And we are still probably not quite half way to the 100+ needed for the test.

- Gravitational lensing. That mass could bend light was known to Einstein, Eddington, Zwicky, and many others. Paczyński was, however, instrumental in recognizing in three different contexts that lensing could reveal an enormous amount about the Galaxy, the Universe, and their contents. The first of these was single luminous arcs superimposed on images of clusters of galaxies (Nature 325,

572, 1987), a case where it is at least possible that he understood what was going on slightly in advance of the observers who had obtained the images.

Second is the lensing of and by an ensemble of galaxies that we now call weak lensing, which is a vital prong of the fork of determining the full set of cosmological parameters. Calculations were done by Zel'dovich in 1964 and by Gunn in 1966, but those by Paczyński and his collaborators came along just as giant surveys were beginning to provide data to be interpreted this way (ApJ 317, 11, 1987, N. Katz; ApJ 357, 32, 1990, M.H. Lee; ApJ 337, 581, 1989, J. Wambsganss; ApJ. 365, 22, 1990, J. Jaroszyński, C.B. Park, R. Gott).

Gravitational microlensing of one star by another is the third and perhaps most spectacular case. BP's critical inspiration (ApJ 301, 503; 304, 1, 1987) was that CCD detectors and rapidly advancing computational power, attached to something like a 1-m telescope, would make it possible to monitor the 10 million or more stars needed to catch a few events per year with magnification ratios of 2-3 or more, assuming that the dark halo of the Milky Way consists of stellar mass objects, when you look toward the LMC, or rather more events due to Galactic bulge stars when you look toward the center. Best known of the projects Paczyński inspired was MACHO, but the first reported event (Acta 43, 289, 1993, A. Udalski and 6 others) actually came from the Warsaw-Carnegie-Princeton OGLE collaboration. More events followed, very few from the halo (ruling out MACHOs as most of the dark matter), and the total data base is now at least as valuable for other purposes.

- Planets can show up in two ways, transiting and dimming their host stars (Acta 52, 1, 2002, Udalski and 7 others) and as distortions of a lensing light curve (Acta 52, 361, 2002, J. Jaroszyński, plus many other papers with numerous authors, a fairly sudden change in BP's pattern of co-authorships). Inevitably the programs have revealed many other kinds of variable stars, including eclipsing binaries (MNRAS 368, 1131 2006, D.M. Szczygieł, B. Pilecki, G. Pojmański) and Cepheids (ApJ 533, L103, B. Pindor), and also a good deal about galactic populations and structure (MNRAS 337, 895, 2002, S. Mao; ApJ 485, 611, 202 M. Kiraga & K.Z. Stanek).

- Gamma ray bursts as extragalactic. In the first few years after the 1973 announcement, at least six different extragalactic models appeared. Then there was a decade of absolute certainty that GRB events happened in the Milky Way, probably on old neutron stars. BP (ApJ 308, L43, 1986) was the first, and for long the only, astronomer to revive the idea of very rare, very bright events that we see coming from a large fraction of the observable universe. He gradually became more confident of this (Acta 41, 257, 1991) and put forward a model of colliding neutron stars from a binary (Taos symposium, p. 67, 1992). He has said that he was led in that direction by thinking that the observered flux distribution N(S) had turned over slightly brighter than eventually proved to be the case. The conclusion was nevertheless, of course, correct, and when the first extragalactic optical

identifications appeared, the flavor of "I told you so" was gentle (Nature 386, 650, 1997, R. Wijers; Nature 389, 548, 1997, C. Kouveliotou). He embraced the association with powerful supernovae or hypernovae as well (4th Huntsville GRB Symposium, 783, 1998, and several abstracts etc. about SN 2001em).

Lest you suppose Bohdan never made a mistake, here are a few of the less successful ideas:

- A sun with metal-depleted core as cause of the solar neutrino deficit (ApJ 326, 392, 1988, R. Sienkiewicz, S. Ratcliff).
- The possibility that the 600 km/sec CMB dipole, generally blamed on our motion, might have a cosmological component (ApJ 364, 341, 1990, T. Piran).
- A white dwarf behaving like a pulsar to explain the X-ray source 1E 2259+586 (ApJ 365, L9, 1990).

This overview began with Paczyński studying eclipsing binaries and will end with his desire to continue to do so, on the grounds that a clean, double-lined spectroscopic eclipsing binary is the only truly direct, geometric way to measure astronomical distances beyond the range of heliocentric parallax, other methods being mere "indicators". This appears first in the 1997 proceedings of an STScI conference (CUP, p. 273) and then in Nature 401, 311 (1999), AJ 121 3089 (2000 I.B.Thompson and 6 other authors), Acta 53, 209 (2003), and IAUS 240, 50 (2006, Richichi and 3 others). And he was very much looking forward to PanSTARRS, LSST, and other future programs that might pin down the scales of the universe is this way.

I am most grateful to George Herbig and Wojtek Dziembowski for information not readily available elsewhere, to Mindy Lipman at Princeton for providing a copy of Bep's CV to replace the one I foolishly discarded after nominating him for one of the prizes mentioned above, and to Stephen Maran for extracting from the AAS picture archives the accompanying photo, taken at the June 2006 AAS meeting in Calgary.

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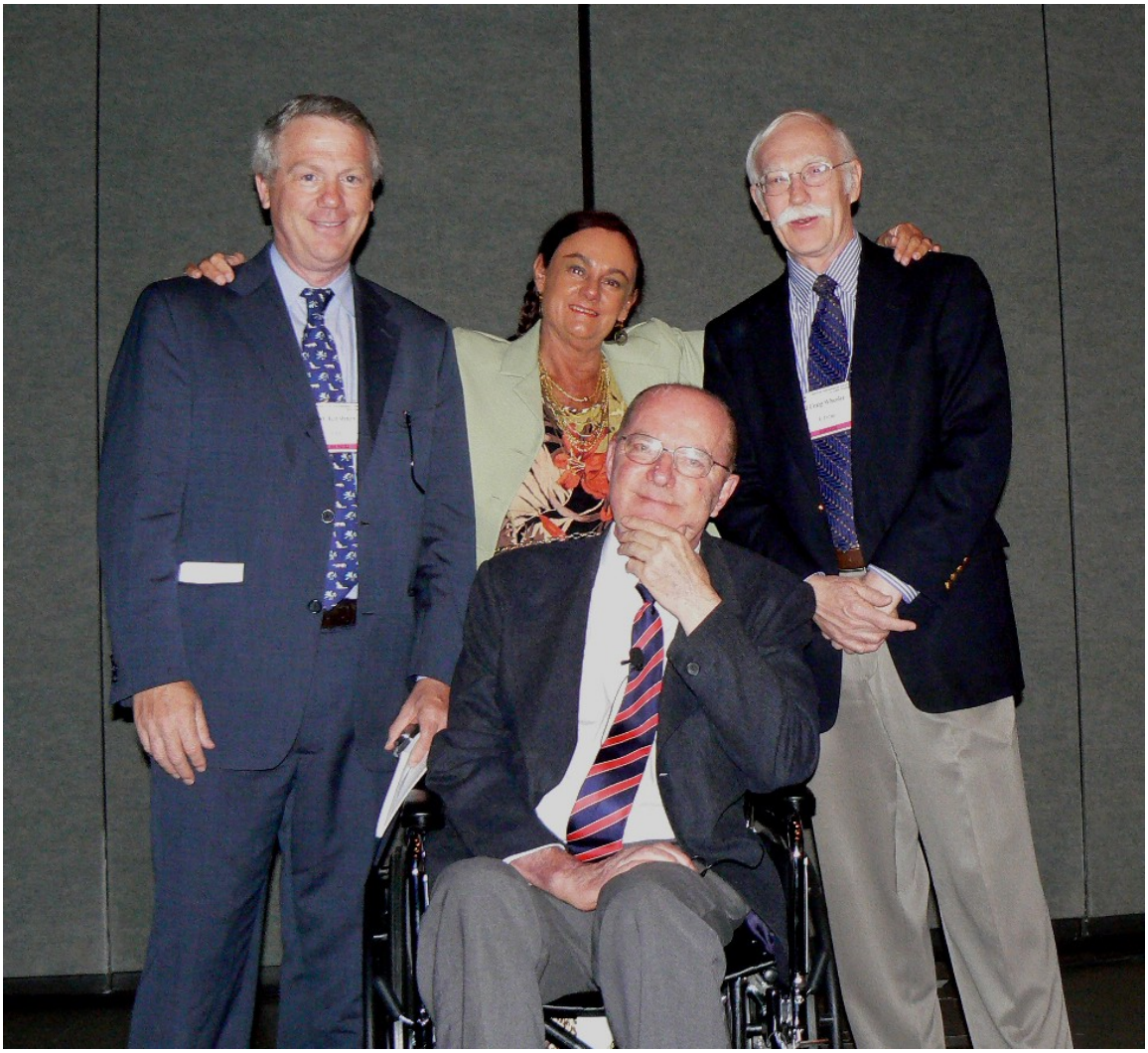

Bohdan Paczyński at the June 2006 Calgary meeting of American Astronomical Society just before giving his Russell lecture. Behind him are Robert Kirshner, outgoing AAS president (you can see the check in his pocket), the author, and Craig Wheeler, incoming AAS president. AAS photo by Richard Dreiser, ©2006 American Astronomical Society.