FORWARD: Introductory remarks delivered at the opening session

TIMOTHY H. HANKINS
Very Large Array, National Radio Astronomy Observatory
and Department of Physics, New Mexico Institute of Mining and Technology

Welcome

On behalf of the Scientific Organizing Committee it is my pleasure and an honor to welcome you to IAU Colloquium Number 128, *The magnetospheric structure and emission mechanisms of radio pulsars.* For most of you, getting here will have been less than half of the fun. My own trip was long but, thankfully, uneventful. I look forward to an exciting week of discussion about many aspects and ideas about pulsar magnetospheres.

Let us now ask, "Why are we here?" My answers: To learn about the pulsar magnetosphere and to try to understand why it produces sufficiently varied radio emission to keep 100 of the world's best scientists busy and excited for more than 20 years. Does that mean that there have been only 2000 man-years devoted to the study of pulsars? Does it mean that one person would have to study radio pulsars for 2000 years to learn all that is currently known about them? Maybe so, but I am sure that it would take far less time for the best of you to learn and understand all that is *important* about radio pulsars. Part of my objective for this meeting is to form some conclusions about what is important to understand. I am also here to make new acquaintances, to renew old friendships, and to try new arguments on long-standing controversies.

Reflections

It is clear that we think we know and understand far more than we did, say 16 years ago when some of us met at the Stanford Pulsar Symposium hosted by Peter Sturrock in 1974, and more than we did 10 years ago when we met at IAU Symposium No. 95 hosted by Wolfgang Sieber and Richard Wielebinski at the Max Planck Institute for Radio Astronomy in Bonn.

Let me reflect on those two meetings for a moment. At the Stanford Pulsar Meeting there were 31 participants. Eight of those are attending this meeting, and I might point out that though several have been inactive in the field for some time, none have retired (though M. M. Komesaroff, who contributed one of the most solid and long-standing ideas about pulsar magnetospheres, passed away a few years ago.).

I would like to quote the introductory paragraph from Dick Manchester's report on the meeting (Manchester 1974).

> A great deal of progress has been made toward reaching an understanding of pulsars since their initial discovery in 1967. For example, their identification with rotating neutron stars possessing strong magnetic fields is now generally accepted. However, no consensus has been reached on the mechanism by which the rotational energy is transformed into the presumably beamed radiation that we observe as pulses. The purpose of this symposium was to provide a forum for the discussion of the various models for the emission mechanism that have been proposed and to decide which observations or 'critical experiments' are likely to be the most important in choosing among these proposed models.

At the Stanford meeting we compiled a standard list of observed properties common to nearly all pulsars, plus a list of important properties found in some but not all. Most of these in the first category can now be found in introductory astronomy textbooks. The properties in the second category now seem nearly trivial—in the category of "Oh—everyone knows that."

We chose a list of "standard pulsars": if you wanted to learn about drifting subpulses, then study PSR 0031−07; if microstructure, then PSR 0950+08; if double profiles, then PSR 1133+16 or PSR 0525+21; PSR 0823+26 as a "single integrated profile", and so forth. Well, many of us have studied these objects in more detail since then and we have found in nearly every case that upon close scrutiny, each of these "standard pulsars" is an "odd ball"—it exhibits some kind of strange behavior that makes it not so standard after all.

https://doi.org/10.1017/S0002731600154617 Published online by Cambridge University Press

The title of the Stanford meeting was *Pulsar Radiation Mechanisms: What are the Critical Experiments?* (Perhaps this title started a trend of inserting a colon and question mark in titles. Several subsequent pulsar paper titles used this format, including one that Jim Cordes and I wrote. I regret that IAU Colloquium No. 128 breaks no new ground in this area.)

We compiled a list of 8 critical experiments: "... experiments which have the potential of defining the pulse emission process in pulsars." Looking at the list of contributions to our meeting here in Poland, one sees that we are still working on these experiments. I should comment on one of these as an example of the kind of pulsar work that has led to understanding in other areas: One of the critical experiments was to understand the long-term intensity variations in pulsars. In the early 1980's Wolfgang Sieber recognized that the long term variability on the scale of days, weeks or months was a propagation effect rather than an intrinsic emission phenomenon. Barney Rickett, who wrote the first Ph. D. thesis on pulsars that I know of, subsequently identified these long term propagation induced intensity fluctuations as refractive scintillations, and this has had a strong effect on the understanding of low-frequency variability of other radio sources.

Now may I quote from Tony Hewish's introductory review published in the proceedings of the 1980 IAU Symposium No. 95 *Pulsars* (Hewish 1981):

> During the 13 years [since pulsars were discovered] a great deal has been discovered, but the jig saw puzzle of the pulsar model is still in pieces. Some of these have intriguing shapes and seem to fit together, but they do not yet indicate what the picture will be.

Somewhat later in his talk Hewish noted, "Only two pulsars have been found in binaries". That has changed. Nearly anyone would now predict that the number will soon be uncountable on the fingers of two hands. Alex Wolszczan at Arecibo recently said to me that the finding of pulsars in globular clusters has become a cottage industry—implying that the limit to how many he can produce is only limited by the time it takes to analyze the data to pull them out. I merely note here that Don Backer's discovery of the millisecond pulsar and the discovery of a whole new class of "recycled pulsars" in globular clusters, plus the two eclipsing pulsars in short-period binary orbits have had an enormous impact on the general interest of pulsars, though they have not facilitated the answers to questions we are trying to find at this meeting.

Hewish also notes in his remarks,

> Radio energy accounts for but a small fraction of the spindown energy $I\Omega\dot{\Omega}$ the neutron star, typical fractions being 10^{-3} to 10^{-8}.

In their review article, Taylor and Stinebring (1986) continue this idea with,

> Thus the radio emissions always play a negligible role in the energy budget of a pulsar. For this reason, and also because of the astonishing variety of observed emission characteristics, it is perhaps not surprising that a convincing model for the radio emission mechanism has been hard to produce.

There are two points to be made about this comment:

1. Some theoreticians seem to have taken the point of view that since the radio emission is such a small fraction of the total energy budget, it is insignificant, and therefore unimportant. But it is by the radio emission that we know pulsars. It is hard to predict, but if Jocelyn Bell and Tony Hewish had not discovered pulsars, it seems unlikely that they would have been found in other wavelength regions. So I feel that an understanding of their radio emission mechanism is essential for the full pulsar picture. It has been quoted practically to the point of banality. The quotation is attributed to Sandra Faber:

> We know why pulsars pulse, but not why they shine.

Rankin and Gil have put it another way in their recent note to *Comments in Astrophysics* (Rankin and Gil 1989):

> We have a theoretical myth of pulsar emission—that is a wise and unverified tale—rather than an observationally grounded theory.

2. The other point was made long before Taylor and Stinebring wrote their review. In fact, Stinebring was probably still in high school when Geoffrey Burbridge said to me in 1970 or 1971, "Pulsars are too complicated to understand. I am going back to work on quasars where there is much less data."

https://doi.org/10.1017/S0002731600154617 Published online by Cambridge University Press

It is no wonder that the pulsar machine is difficult to understand. They are not like Cepheid variables which, if you know their pulsation period you know it all. Pulsar periods have a range of 3000; luminosities and magnetic fields a range of 10000; and age, a range of 100000. The parameter space is huge!

The point is that there are a bewildering number of observational facts known about pulsars. In 1974 we tried to establish which ones were important for understanding pulsar radio emission. By 1980 we had made considerably more observations and the theory had progressed as well. After the Bonn meeting, many of us continued making more and more sophisticated observations—all the easy things had long since been done. Improved instrumentation meant we could do more and do it faster. We have in American slang: "pushed the envelope" to wider observing bandwidths, better time resolution, higher sensitivity. Some interesting if not significant things have been found. Then the discovery of the millisecond pulsar in 1982 and another in 1983 gave a great boost to pulsar astronomy, though some theoretical work was diverted from the emission mechanism to the evolutionary story of the millisecond pulsars.

Future

What are we of the Scientific Organizing Committee asking for? We want each person, this week, to listen, to evaluate, to test new ideas. Compare them with your own. Draw your own conclusions—perhaps new ones—or perhaps you are right after all! Then take away new ideas which you can test. Keep in touch with us—all of us—it is much easier now. Though some of you may have reason to doubt it, I exchanged more than 400 electronic mail messages concerning this meeting just since Christmas. Our timing of this meeting is fortuitous for improved communication among our Chinese, Polish, Soviet, and Western colleagues.

One aspect of our profession which I have particularly enjoyed is that radio astronomy knows no political boundaries. It is true that bureaucracy has occasionally slowed things down for us, but the rapid political changes we see in the world appear to be going in the direction to facilitate better communication and collaboration among us.

Look now 10 years ahead. When we get together for a pulsar meeting in the year 2000, will we be able to look back and see the questions we ask at this meeting answered in astronomy textbooks? That is a lot to hope for; ours is a mature science now, and the easy things have been done. But let us see if by Saturday, we can formulate and clarify a set of significant questions to answer in the next decade.