Part 12
Summary

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IAU 177 — A week in review

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1. Introductory Remarks

The onerous task of summarising meetings such as these falls traditionally on some poor unsuspecting soul. Having accepted this duty (and I still can't believe I ever agreed to it!) it's now time to look back on what has been one of the most enjoyable meetings I've had the good fortune to attend.

As always on these occasions, the conference summariser is given a free rein to review the meeting as he/she feels appropriate. As we all know, this often results in a significant deviation from the "ideal conference summary" — an unbiased account of the proceedings. This review is no exception and, as is the tradition, I shall make it very clear from the start that the following paragraphs only scratch the surface of the many varied topics discussed at this meeting. I choose to concentrate on the topics I was most interested in, and the new results that really caught my attention. As such, the many excellent presentations on pulsar emission theory are therefore not mentioned here (see however the preceding review by Melrose). My apologies to all such participants who do not get a mention in this review. This merely reflects my personal bias as an observer who takes the "black-box" approach to pulsars and life in general.

In all we listened to 95 contributed talks and pondered over 180 posters. Topics covered included pulsar surveys, the interstellar medium, anomalous X-ray pulsars, magnetars, single pulse studies, radio emission phenomenology, pulsar timing, supernova remnants, interactions with companion stars, high energy observations, neutron star emission theories, fundamental astrometry, general relativity, neutron star demography, plasma physics and the future of the field. Many of us also heard the excellent public lecture given by Jocelyn Bell-Burnell (a *tour de force* presentation of astronomy to the general public) as well as additional evening sessions discussing orthogonal polarisation modes and magnetars. There is clearly much to talk about and, without further ado, I will begin.

2. Meeting Highlights

2.1. Pulsar Surveys

The week got off to a fine start with talks by Camilo and Manchester on the latest results from the Parkes Multibeam survey. With 13 λ 21-cm 25 K receivers on the sky, along with $13 \times 2 \times 288$-MHz filterbanks, the system is presently making major contributions in a number of different pulsar search projects. In its main use for the Galactic plane survey described by Camilo, the system achieves a sensitivity of 0.15 mJy in 35 min and covers about one square degree of sky per hour of observing — far beyond the capabilities of any other system at present.

The staggering present total of 439 new pulsars from an analysis of just under half the total data leads the team to predict that the final body count should be over 600. Such a large haul is resulting in significant numbers of interesting individual objects: Several of the new pulsars are observed to be spinning down at high rates, suggesting that they are young objects with large magnetic fields. The inferred age for the 400-ms pulsar J1119−6127, for example, is only 1.6 kyr. Another member of this group is the 4-s pulsar J1814−1744, an object that may fuel the ever-present "injection" controversy surrounding the initial spin periods of neutron stars. Further studies of these objects to look for extended radio/optical emission (i.e. supernova remnants/bow shocks) will undoubtably help us to understand the birth properties of pulsars.

A number of the new discoveries from the survey have orbiting companions. Several low-eccentricity systems are known where the likely companion is a white dwarf star. Two probable double neutron star systems are presently known: J1811−1736 is in an 18-d highly eccentric orbit, while J1141−65 has a lower eccentricity but with an orbital period of only 4.75 hr. The fact that J1141−65 may have a characteristic age of just over 1 Myr implies that the likely birth-rate of such objects may be large. Whilst it is premature to start speculating on statistics of one object, it is clear that these binary systems and the many which will undoubtably come from this survey will teach us a lot about the still poorly-understood population of double neutron star systems.

The most massive binary system from the multibeam survey to date is J1740−3052, whose orbiting companion must be at least 11 $M_{\odot}$. As Manchester mentioned, recent optical observations reveal a K-supergiant as being the likely companion star in this system. With such high-mass systems in the Galaxy, not to mention the massive X-ray binary systems, surely it is only a matter of time before a radio pulsar will be found orbiting a stellar-mass black hole. Future searches for these elusive beasts in globular clusters, where long integration times are common, would do well to utilise Ransom's novel technique to detect short orbital period binary systems.

We also heard during the meeting that the Parkes multibeam system has not only been finding young and distant pulsars along the Galactic plane. Two other search projects were described in the posters by Edwards et al. and Freire et al. Edwards et al. have been using all 13 beams to do a "quick" (5 min per pointing) search at intermediate Galactic latitudes ($5° \leq |b| \leq 15°$). The discoveries of 8 "recycled" pulsars during this search, not to mention 50 long-period objects, strongly support a recent suggestion by Toscano et al. that an L-band search of intermediate latitudes is an excellent means of finding millisecond pulsars which, as they and others demonstrated (see Kramer's review) now appear to have significantly flatter spectra than previously thought.

Freire et al., on the other hand, have used only the central beam to search for new pulsars in the globular cluster 47 Tucanae. This has revealed no less than 10 new binary millisecond pulsars, bringing the total number of pulsars in this cluster to 21! The new discoveries include a 95-min binary system. This is presently the shortest orbital period for a radio pulsar binary. Clearly these are exciting times for the pulsar hunting community and the coming months will undoubtably throw up further surprises.

2.2. Gravitational Wave Astronomy

While pulsar searches in the radio and X-ray regimes are enjoying a renaissance due to new instrumentation and advances in sensitivity, our colleagues in the gravitational wave community are about to open a whole new window on the Universe. As Schutz reported during his talk, a number of sensitive detectors are about to come on-line. Specifically, these are the two LIGO sites in the US, the GEO detector in Hannover (a joint German/UK project) and, later, the Italian VIRGO project. Possible events that are being targeted by these detectors include: (1) compact object mergers at cosmological distances; (2) continuous emission from spinning neutron stars (though detecting even nearby pulsars will challenge the limits of present sensitivity); (3) stellar collapse in the Galaxy. Millisecond pulsar timing still remains an attractive means of probing the long-wavelength regime, with space interferometers still some way off.

In anticipation of the data that will soon be pouring off these detectors, astronomers at various institutes around the world have been putting a tremendous effort into understanding the numerous signal processing/detection hurdles they face. As always, the main problem is one of sensitivity... astronomers are trying to measure events that produce a detector "strain" of order 10^{-23} or less! In addition, as we heard, analyses of 10^7 s time series are required with the initial detector systems. The requirement to deal with time series of this length is prompting novel techniques to enable even present state-of-the-art computers analyse the data within a Hubble time. Radio and X-ray pulsar hunters would do well to stay in touch with this exciting field for new tricks in the future.

2.3. Radio-Quiet Neutron Stars and Supernova Remnants

The so-called "radio-quiet neutron stars" were the subject of a number of presentations during this meeting. This term includes the soft gamma-ray repeaters (SGRs; thought to be magnetars) and the anomalous X-ray pulsars (AXPs) and the enigmatic Geminga pulsar (see below). One significant advance in the high energy observations has been in the timing analyses that are now possible. The new Rossi X-ray phase-coherent timing observations of two AXPs by Kaspi et al. provide a nice confirmation that these neutron stars are spinning down in a similar manner to most radio pulsars. Whilst there seems to be overwhelming evidence that the AXPs are young neutron stars at the centres of supernova remnants (see e.g. the contributions by Gotthelf and Gaensler) I certainly got the impression during some of the discussions that whilst the evidence associating SGRs with supernova remnants is tantalising, it is presently only circumstantial.

Part of the problem in making the link arises because of uncertainties in independently measuring the distances to the remnants and the SGRs. An interesting development in this regard is the detection of dispersed low-frequency radio pulses from SGR 1900+14 by Shitov and collaborators. The dispersion measure obtained implies a distance of 6 kpc for the most recent electron density model. Future combined radio and high-energy timing analyses to monitor the spin-down of this magnetar will be most interesting, particularly if e.g. regular radio observations reveal magnetar glitches. It presently remains a mystery why this pulsar and Geminga are not detected at higher radio frequencies e.g. 430 MHz, this is despite numerous observing campaigns at Arecibo, Jodrell Bank and the VLA (see Kassim & Lazio's poster and references therein).

2.4. Pulsar Timing

A number of recent and interesting pulsar timing results were presented during the week. High-precision timing of millisecond pulsars continues to demand careful attention to understanding the properties of the telescope and data taking system in order to reap the wealth of astrophysical information that these clocks have to tell us. This was well highlighted during Britton's study of the systematic effects of polarisation on the Parkes timing model residuals obtained for the bright, nearby millisecond pulsar J0437−4715. The clever use of the "invariant profile" (Stokes $I^2-Q^2-U^2-V^2$, as opposed to the total intensity) in the timing analysis is an elegant means (for weakly polarised pulsars) to circumvent the many non-trivial steps in a proper polarisation calibration analysis. The quality of the residuals obtained via this relatively simple analysis should inspire other observers to try this technique as a means of improving their timing precision.

Recent results from timing observations that have (finally!) resumed after the Arecibo upgrade include further confirmation of the orbital decay of the binary pulsar B1913+16 predicted by general relativity (see Taylor's paper), as well as a continuing study of the pulse profile evolution of this pulsar caused by geodetic precession of the orbit (see Weisberg's paper). Post-upgrade Arecibo observations of the "planets pulsar" B1257+12, when combined with Effelsberg and pre-upgrade Arecibo observations, and a clever perturbation analysis, have permitted the orbital inclination of two of the planets and hence their absolute masses to be determined (see papers by Wolsczcan and Konacki).

On the subject of planets, a long-awaited update on the timing of the pulsar B1828−11 was presented by Lyne. The curious behaviour of this system was first reported by Bailes et al. in the proceedings of the "Planets around Pulsars" meeting back in 1992 where the timing residuals showed a strong periodicity indicative of a sum of three sinusoids that could be attributed to the Doppler shifting of the pulsar period by orbiting planetary bodies. The new results presented here show a strong correlation between pulse profile changes and the periodic oscillations seen in the timing residuals. Whilst this would rule out a planetary origin, an interesting twist in the story is that the phases of the sinusoids sum to a constant value — as seen in e.g. the Jovian satellites. Presently, the most plausible explanation seems to be free precession of the neutron star. If correct, this would be the first clear detection of such an effect. It remains a mystery why similar behaviour is not seen in other young pulsars.

The very useful contributions that can be made by smaller radio telescopes, which are being used to perform intense observing campaigns on selected objects, was highlighted several times during the week. Wolszczan and collaborators have now been performing regular timing observations with the 32-m telescope in Torun for several years. Their growing database of observations is being used to search for planets around pulsars, and to investigate pulsar scintillation (see papers by Lewandowski et al). The Crab pulsar still continues to surprise astronomers after almost 30 years of regular monitoring with the remarkable echoing events (ghost pulse profile components) seen in observations made using the 85-foot telescope at Green Bank by Backer and the 42-foot telescope at Jodrell Bank (Smith & Lyne). Current interpretations of the echos, which have now been seen on several occasions, are that they are caused by ionised shells drifting around the nebula, or intrinsic to the pulsar magnetosphere.

2.5. Neutron Star Demography

Significant progress in our understanding of the Galactic population of neutron stars is being made, and Cordes' presentation summarised the present status of an ambitious attempt his group is making to model the population. A big improvement that this model has over previous studies is the use of a self-consistent beaming model. Assuming that the core-cone model of the radio beam is correct, and Desphande and Rankin's polar cap maps seem to be confirming this, apparent pulse shapes can be simulated and compared to those that we observe. I look forward to seeing the full results of this study in the near future. A useful check of this model would be to simulate the Parkes multibeam survey.

As emphasised by Cordes, even non-detections from pulsar surveys are interesting results and pulsar hunters at all wavelengths should continue to write up their negative results (boring though the task of writing them may be!) for use in likelihood analyses. A good example in this regard is the modelling of the gamma-ray pulsar luminosity function based on OSSE and EGRET results presented by McLaughlin. This study provides a novel means of constraining a number of population parameters, such as the initial spin period of pulsars.

Our understanding of poorly-sampled subsets of the Galactic population, such as the double neutron star systems, is receiving a significant boost from the work presented by Kalogera. This population is presently dominated by two objects: the original binary pulsar B1913+16 and B1534+12. Kalogera and Narayan are presently addressing the burning question "how representative are these pulsars of the underlying sample of objects?" — a novel approach to this is to create a model population (whose underlying parameters are well understood) and estimate the size of the underlying sample based on a few objects. It turns out that there is a significant bias which can be derived from this model, and applied to the true sample of objects to infer the Galactic population. This is an important new result and could also be applied to other small samples.

One such application is the population of long-period pulsars. We heard from Young that the period of PSR J2144−3933, originally discovered in the Parkes Southern Sky Survey, is 8.5 s — three times that previously thought. This is presently the longest period for a radio pulsar. Young et al. make the valid point that such pulsars could be very numerous in the Galaxy since they have very narrow emission beams and therefore radiate to only a small fraction of the celestial sphere. Why this pulsar is radiating at all challenges some current neutron star emission theories and equations-of-state.

Theoretical studies concerning globular cluster pulsar demography and dynamics are beginning to become popular again. As we heard during Rasio's talk, the recent flurry of new discoveries in 47 Tucanae and improved timing solutions are allowing more detailed studies to be carried out. The radial distribution of pulsars in this cluster out to a few core radii seems to be consistent with an isothermal sphere. 47 Tucanae is a cluster that has not yet gone through a core collapse phase and is supporting itself by "burning" binaries (thereby releasing kinetic energy) in the core. Among the questions posed is why there are so many short-period binaries in 47 Tucanae but relatively few low-mass X-ray binaries. In addition, there is a distinct absence of long-period ($\gtrsim$ 3 day) binaries. Presumably, the latter objects get quickly disrupted during exchange interactions, which may in turn result in short-period binaries and solitary millisecond

pulsars. Fossil evidence for such interactions may be the small, but significant, eccentricities now measurable for some of the binaries in 47 Tucanae.

3. The Future

This review has (shamelessly!) focused on radio pulsar astronomy — a classic summariser selection bias. Whilst the current status of this field is alive and well, giant leaps are anticipated in the future with the Square Kilometer Array. Funding and radio frequency interference permitting, there should be no shortage of tasks to be carried out in the near and long-term future of this field. High energy astronomy is already embarking on a busy period with the new generation of satellites, in particular CHANDRA, as we heard is already producing fantastic results. As already discussed, gravitational wave astronomy should be increasingly augmenting the science presented at these meetings in future as new detectors come on-line. In short, the future of pulsar astronomy looks well set.

4. And finally...

The friendly atmosphere which prevailed during the week inevitably included some lighthearted moments. Three particularly memorable quotes from the speakers are listed below for posterity:

"*The only good pulsar is a dead pulsar!*" — G. Pavlov

"*We obtained a good fit to the data with only 18 free parameters.*" — A. Somer

"*We have convinced ourselves that this will probably work.*" — J. Cordes

Joking and back-slapping aside, I'm sure that these proceedings will serve as a useful testament to the events of this meeting and a snap-shot of the field as it stands. This is particularly important not only for researchers wanting to catch up on the latest results, but also for the continual influx of young researchers to pulsar astronomy, many of whom were present at this meeting.

Und *dat*, as they say in Rheinland, war es denn. I'd like to close by saying what a pleasure it was to participate in this meeting — not only because of all the hot scientific results being discussed, but also because of the efficient way in which it was organised and run throughout the week. Whilst many would expect nothing less from a conference held in Germany, nevertheless the standard set here will be hard to surpass in future meetings. On behalf of all of the participants, I'd like to thank all the members of the Local Organising Committee who put themselves at our disposal during this week. In particular, hearty thanks go out to Michael Kramer, Norbert Wex, Gabi Breuer, Ute Runkel and Richard Wielebinski, all of whom must have breathed a sigh of relief, perhaps even saying "*nie wieder!*", when the meeting was over and the last participant had shuffled out of the building. They can pride themselves on a job well done and be assured that we are all eagerly looking forward to another pulsar IAU meeting in Bonn at some point early in the next millennium!