Planets around Pulsars

Michael Kramer

MPI für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

Abstract. In 1992 the first extrasolar planets were discovered. But unlike expected, these planets were not located around normal stars. The central object of the system that is now known to consist of (at least) three planets, is a radio pulsar. This discovery was possible due to the unique precision of pulsar timing which allows us to detect even asteroid-sized bodies around pulsars. If sensitivity is not a problem, where are the other systems? Only one further pulsar planetary system is known, raising the question about the formation processes of pulsar planets and their conditions. In the future, we can expect to perform a 'complete' census of pulsar planets in the Galaxy, promising to answer the open questions once and for all.

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INTRODUCTION

It is remarkable that the first planets outside the solar system have been discovered around some unusual objects, consisting of the most extreme matter in the observable Universe: Pulsars! Pulsars are generally believed to be born in supernova explosions of massive stars at the end of their lifetime, so that the formation of planets around such extreme objects is at least surprising. On the other hand, the precision that can be achieved when measuring the orbits of pulsars is so good that even small asteroids can be discovered rather easily, raising the opposite question why the number of pulsar planetary systems is actually very small. In this review, we summarise the detection techniques, the made discoveries and briefly discuss the formation scenarios. We will give a glimpse into latest results and will conclude with an outlook into a bright future which promises to settle all open questions.

DETECTING SMALL ORBITING BODIES

Pulsars are very stable cosmic clocks. Admittedly, we do not yet know how their radio emission is actually produced. However, the fact that they act as lighthouses in space, storing rotational energy as massive, city-sized fly-wheels of about $1.4M_\odot$, allows precision experiments based simply on measuring their pulse arrival times on Earth (e.g. Lorimer & Kramer 2005). If the pulsar happens to have one or more companions, this precision allows us to detect them in a variation of those arrival times. As the pulsar timing technique is fundamentally different from just measuring variations in radial velocity commonly used to search for optical planets, we will explain this "ranging" method and its application in some detail.

The Power of Pulsar timing

A pulsar is a neutron star that emits a visible radio pulse by virtue of its rotation. The emitted pulse propagates through the interstellar medium (ISM), interacts with the ISM in form of dispersion and multi-path scattering, before it reaches a radio telescope on Earth. Here, the electromagnetic wave of the pulse is detected digitised and split into frequency components in order to correct for dispersion. Nowadays, it is common practice to perform this "de-dispersion" coherently in phase (of the electromagnetic signal), i.e. to fully restore the original pulse shape (e.g. Lorimer & Kramer 2005). The data are time-stamped with an atomic clock synchronised to an international time standard via GPS and then recorded to disk.

Usually off-line, the data are folded given a pulse period and the resulting average pulse shape is matched to a high-signal-to-noise standard "profile" or "template" to derive a "time-of-arrival" (TOA). The TOA is compared to a predicted arrival time using a timing model that includes all astrometric parameters, all possible binary parameters, dispersion delays and also takes into account that all pulsars slow down due to the loss of rotational energy, which is converted into electromagnetic radiation. The deviations between the TOAs and the timing model are minimised by a least-squares fit for the timing model parameters. The result are "post-fit residuals" that are inspected for possible systematic trends that may, for instance, reflect the effect of an unmodeled binary companion or planet. See Lorimer & Kramer (2005) for more details.

The secret of the power of pulsar timing lies in the fact that the timing model refers the TOAs to the rotational phase of the pulsar, i.e. a "coherent" timing model tracks the phases and hence the number of each single rotation of the neutron star. This phase connection is vastly superior than simply studying the orbital variation of the pulse period and improves the precision of all involved parameters by many orders of magnitude compared to a simple Doppler method. As a recent example we refer to the observations of PSR J1012+5307 by Lazaridis et al. (2010). The authors measured the pulse period of this pulsars to a $P = 0.005255749014115410 \pm 0.000000000000000015$ s, demonstrating that we can refer every single TOA ever measured for this pulsar uniquely to one of the ~ 100 billion rotations since its discovery.

Unmodeled or incorrectly described effects lead to characteristic variations in the post-fit residuals. Examples of those are shown in Fig. 1. The presence of a companion to the pulsar manifests itself in a periodic variation of the TOAs due to a Roemer delay in the pulsar binary (or planetary) system. For the best pulsars with a timing precision of better than 100 ns, path-length differences of only about 50 m can be detected. This can be translated directly into a sensitivity to small-mass orbiting bodies as shown in Figure 2. The best timing precision shown in this plot of 1 μs is typical (and easy to achieve) for a large number of millisecond pulsars and allows us to detect moon-like bodies. Using pulsars with even better timing precision obviously allows the detection of even smaller, asteroid-like bodies.

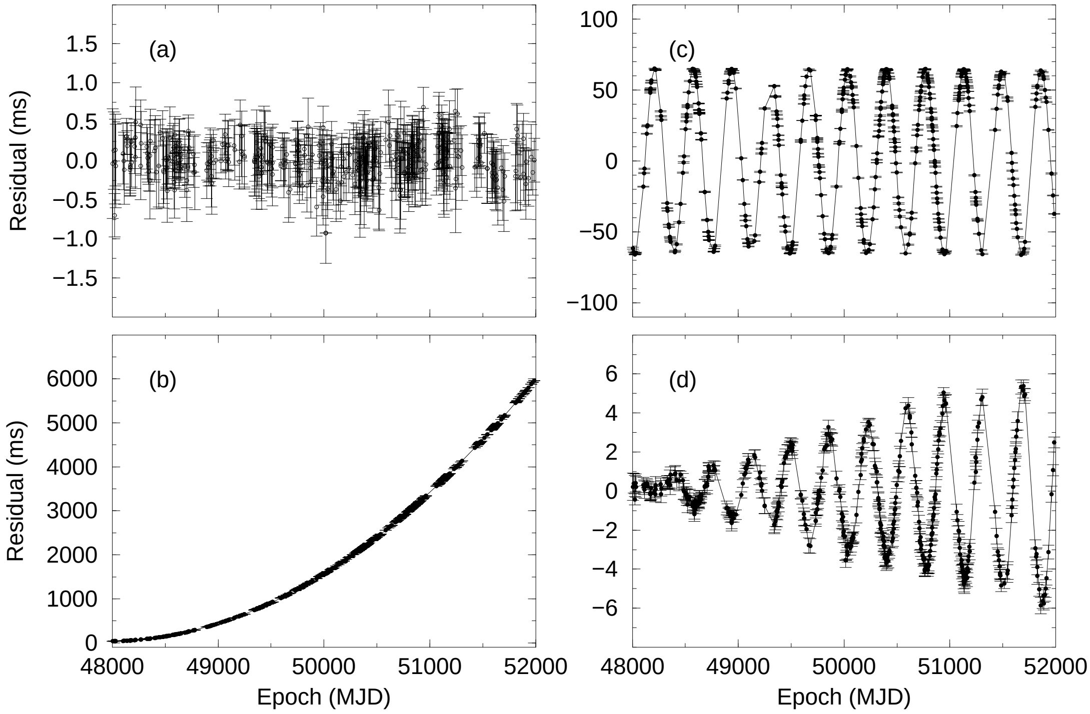

FIGURE 1. (a) Post-fit timing residuals for the 1.19 s pulsar B1133+16. A fit of a perfect timing model should result in randomly distributed residuals. (b) A parabolic increase in the residuals is obtained if $\dot{P}$ is underestimated, here by 4 per cent. (c) An offset in position (in this case a declination error of 1 arcmin) produces sinusoidal residuals with a period of 1 yr. (d) The effect of neglecting the pulsar's proper motion, in this case $\mu_T = 380$ mas yr^{-1}. In all plots we have set the reference epoch for period and position to the first TOA at MJD 48000 to show the development of the amplitude of the various effects. Note the different scales on each of the vertical axes.

Population of pulsars and their companions

The previous section clearly demonstrates that pulsar timing is a very sensitive tool to detect binary companions to pulsars. Currently, about 150 binary pulsars are known whereas nearly all types of stars are represented in the sample, i.e. main sequence stars, white dwarfs, neutron stars and planets. One system exists that has two pulsars orbiting each other (Burgay et al. 2003; Lyne et al. 2004). The shortest orbital period found is 95 min (PSR J0024−7204R), while the longest is 5.3 yr (PSR J1638−4725). Despite this variety of companions and the sensitivity of pulsar timing, only two planetary systems are known (but see also later). We discuss both systems in detail later, but we mention here that both systems are quite different in their evolutionary history, one being located in the plane of the Galaxy while the other is in a globular cluster.

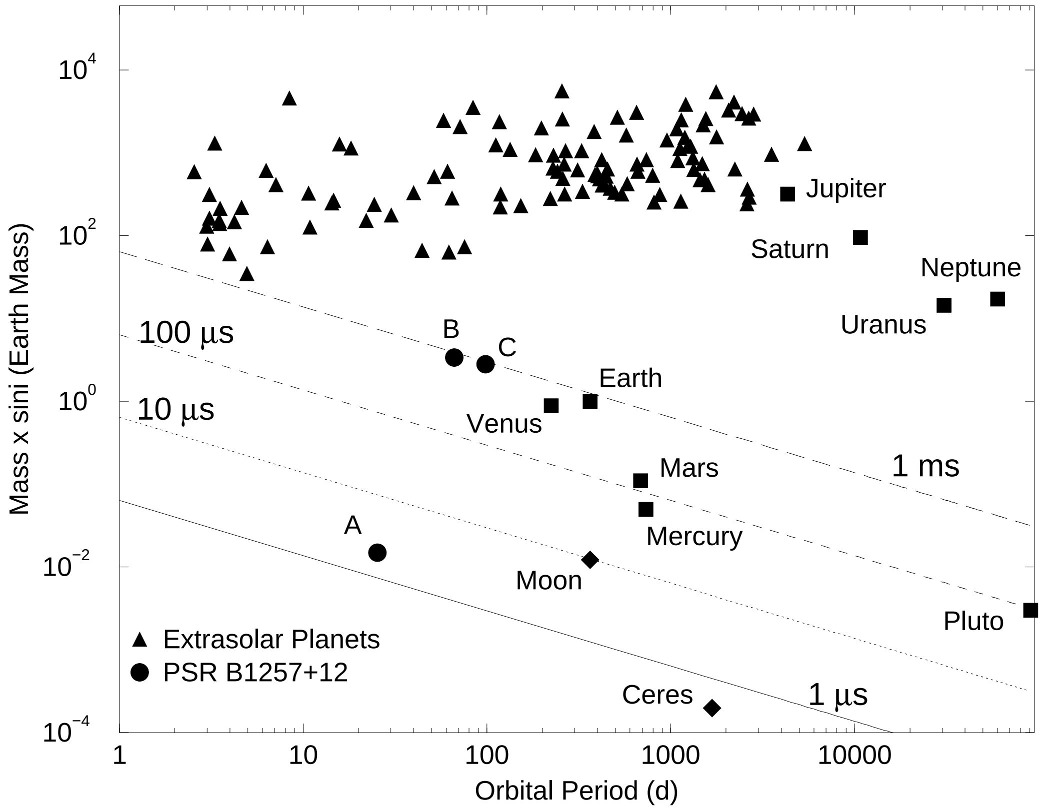

FIGURE 2. Phase space for planetary companions that can be probed by pulsar timing assuming precisions of 1, 10, 100 and 1000μs. The parameters of the solar system planets and those of PSR B1257+12 are compared to those of the some known extrasolar planets discovered by optical spectroscopy. Note that current technology provides a timing precision for some pulsars as small as 50 ns. Sensitivity lines scale appropriately.

Looking for periodicities

The most effective to look for undetected companions is to do a spectral analysis of the (usually) unevenly sampled timing data. A standard method is, for instance to compute Lomb-Scargle spectra for the obtained TOAs. The results can be directly converted into limits for any planetary companion (for details see Freire et al. 2003)

Starting with the definition of the mass function, we have

$$m_c \sin i = a_p \sin i \left(\frac{4\pi^2 m_p^2}{G P_b^2} \right)^{1/3}, \tag{1}$$

where m_p and m_c are the pulsar and companion masses, i the inclination of the orbit with respect to the plane of the sky, P_b is the orbital period, G is the gravitational constant and a_p is the semi-major axis of the pulsar's orbit about the common centre of mass.

Assuming a pulsar mass of $m_p = 1.4 M_\odot$ we obtain

$$m_c \sin i = 1.42 \times 10^{-4}\, a_p \sin i P_b^{-2/3}, \tag{2}$$

with P_b expressed in days, $a_p \sin i$ in m and $m_c \sin i$ in Earth masses.

The Lomb-Scargle periodograms of N timing residuals result in a distribution of power as a function of orbital frequency, $\mathscr{P}(\nu_i \equiv 1/P_{b,i})$. As shown by Scargle (1982), an unmodeled harmonic signal present in the timing residuals of the form

$$x(t) = x_0 \sin(2\pi/P_{b,i} t + \phi_0) \tag{3}$$

will cause a signal in the power spectrum of magnitude

$$\mathscr{P}(\nu_i) = N \left(\frac{x_0}{2}\right)^2. \tag{4}$$

Note that N (the number of timing residuals) is usually much smaller than the number of frequency points in the periodograms.

From the power spectrum $\mathscr{P}(\nu_i)$, we can infer an upper limit for the amplitude of any possibly existing harmonic signal. Using Eqn. 4, we find

$$x_0 \leq 2\sqrt{\frac{\mathscr{P}(\nu_i)}{N}}. \tag{5}$$

We can identify the amplitude x_0 of a signal hidden in the TOAs as the light travel time across the orbit, i.e., $a_p \sin i = c\, x_0$. Using Eqn. 2, we obtain

$$m_c \sin i \leq 1.42 \times 10^{-4} x_0\, c\, P_b^{-2/3}. \tag{6}$$

As the power in the spectrum scales with x_0^2 it is essential to use consistent units for this back transformation from spectral values into the time domain. Computing spectra from timing residuals measured in microseconds, we finally obtain with Eqn. 5

$$m_c \sin i \leq 0.0852 \sqrt{\frac{\mathscr{P}(\nu_i)}{N}} P_b^{-2/3}, \tag{7}$$

where units of m_c and P_b are again Earth masses and days, respectively. Finally we can use Eqn. 7 to convert our computed Lomb-Scargle periodograms into diagrams presenting upper limits of an unknown companion mass as a function of orbital period. During this procedure, one should realize that there is a strong covariance between the orbital period of a planet and the period derivative of the pulsar. In order to account for that, on should multiply the limits for periods of 1 year or longer with P_b^3. An example for such a computation is presented in Fig. 3 where TOAs from PSR B1257+12 clearly show the presence of (at least) two planetary mass companion.

Planets closer to home

It is possible to demonstrate the power of pulsar timing also at planets in our own solar system. This is possible as the first step of a pulsar timing analysis involves the

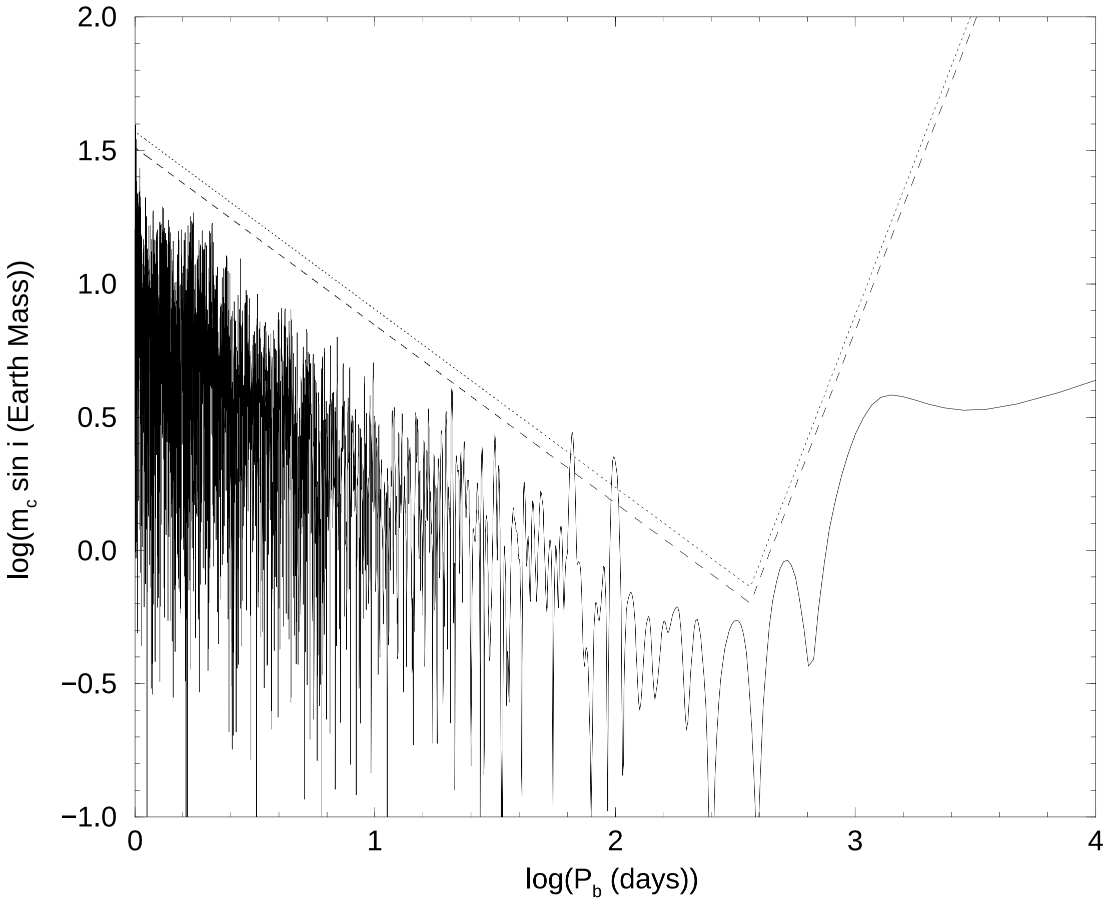

FIGURE 3. Results of a spectral analysis of a sample of timing residuals obtained for PSR B1257+12. This diagnostic plots reveals the presence of two significant periodic signals exceeding the threshold lines drawn for 95% and 99% confidence limits as dashed and dotted lines, respectively. The two signals are related to planets B and C with orbital periods of 66 and 98 days. Also the masses can be read off easily.

transformation of the TOAs at the telescope on Earth to a theoretical arrival time at the solar system barycentre as the closest approximation to an inertial reference frame available to us. Such a transformation requires planetary ephemerides and hence the position of all major planets in the solar system. Getting these positions or the masses of the planets wrong, the arrival time at the solar system barycentre will be wrong also and the resulting post-fit residuals will have a characteristic periodicity at the orbital frequency of the planets. This consideration can be used to also 'weigh' the planets in our solar system using pulsar timing. That this is possible has been recently demonstrated by Champion et al. (2010) who indeed measured the mass of the Jovian system using this effect to a better accuracy than it was possible with the fly-bys of Pioneer and Voyager. While currently the precision of the measurement is a few $10^{-10}M_{\odot}$, regular biweekly measurements of 20 pulsars with a timing precision as expected for Pulsar Timing Array experiments (e.g. Stappers et al. 2006) should lead to measurement precisions 100 times better after 5 to 10 years of observing time.

The importance of the correct treatment of the Solar system, including that of the Earth orbit, was especially highlighted with the report by Bailes et al. (1991) about the first discovery of an extra-solar planet around PSR B1829−10. The authors reported a planetary companion with an orbital period of 184.4 ± 0.9 days. This period was, in hindsight, suspiciously close to 0.5 years and also the inferred orbital velocity was quite close to that of the Earth in its orbit around the Sun. At the end, it was the authors themselves who discovered quickly that they had had an unfortunate software problem for this particular source which essentially ignored the small but non-zero eccentricity of the Earth's orbit. After Andrew Lyne announced this mistake promptly and directly to the scientific community, the coincidence of a second planet announcement, immediately following the retraction of the "first" one, was eyed with caution. This one, however, turned out the be correct.

THE FIRST PLANETS

In 1992 Alex Wolszczan and Dale Frail announced the discovery of the first extrasolar planets (Wolszczan and Frail 1992). They had discovered a planetary system around the millisecond pulsar PSR B1257+12. This 6.2-ms pulsar was apparently orbited by two planets with a mass of (at least) $2.8M_{\rm Earth}$ and $3.4M_{\rm Earth}$ with orbital periods of 98.2 and 66.6 days, respectively. The relative distances to the pulsar were measured to be 0.47 AU and 0.36 AU, respectively. Given the previous experience, people suggested alternative explanations for the observed variation in the TOAs, e.g. a potential free precession of the neutron star (Gil et al. 1993). However, the 3 : 2 ratio of the orbital periods allowed for some interesting verification method, as pointed out first by Rasio et al. (1992). Due to the near commensurability of the periods, the mutual gravitational perturbations of the two planets were expected to produce not only small secular changes, but also larger periodic changes in the orbital elements. They predicted that the changes in the eccentricities and orbital periods should become measurable within a few years and would allow for a measurements of the planet masses and the orbital inclination angles. This predictions were not only found to be correct, but continued observations also revealed a third Moon-sized planet in the system. A summary of the determined parameters was presented recently by Wolszczan (2008) and are listed for completeness in Table 1. Renaming the planets to "A", "B" and "C" corresponding to their distance from the pulsar, the planetary system has the configuration as shown in Figure 4. Interestingly, the relative distance of the planets to the central object corresponds to the same relative distances of the three inner-most planets in our Solar system. Speculations as to whether such a configuration is therefore natural and should be expected in all planetary systems, were later found to be wrong as the many discoveries of optically-detected planetary system showed later.

AN OLD PLANETARY SYSTEM: EARLY FORMATION?

Not very long after the discovery of the planets to PSR B1257+12, another millisecond pulsar, PSR B1620−26 discovered in 1988 in the globular cluster M4 (Lyne et al.

TABLE 1. Parameters of the PSR B1257+12 planetary system as published by Wolszczan (2008). Numbers quoted in parentheses denote the error in the last digit of the preceding parameter value.

Parameter	Planet A	Planet B	Planet C
Projected semi-major axis, x (ms)	0.0030(1)	1.3106(1)	1.4134(2)
Eccentricity, e	0.0	0.0186(2)	0.0252(2)
Orbital period, P_b (d)	25.262(3)	66.5419(1)	98.2114(2)
Mass (M_{Earth}	0.020(2)	4.3(2)	3.9(2)
Semi-major axis, a_p (AU)	0.19	0.36	0.46

1988) was suggested to have a planetary companion. Backer et al. (1993) presented timing data of PSR B1620−26 that suggested that the pulsar does not only have one stellar-mass companion, presumed to be a white dwarf, in a 191-day orbit, but it had a second companion of planetary mass. Despite initial doubts about this interpretation (e.g. Thorsett et al. 1993 or Rasio 1994), continued timing observations confirmed this unusual configuration (Backer and Thorsett 1995; Arzoumanian et al. 1996). In 2003, the stellar companion was clearly identified using observations with the Hubble Space Telescope, indicating that it was white dwarf with a mass of $(0.34 \pm 0.04) M_{\odot}$ and an inferred age of 480 ± 140 Myr (Sigurdsson et al. 2003). This result placed constraints on the history of this triple system, supporting a scenario in which the present configuration is the outcome of a dynamical exchange interaction in the cluster core. This implied formation scenario of the triple system, combined with the relatively large age of the white dwarf suggests that planetary systems could have been formed at a rather early stage.

In the current configuration, the planet has a mass of $(2.5 \pm 1.0) M_{\rm Jupiter}$ and a semi-major axis to the central pulsar of 23 AU. The formation is a direct consequence of its location in the globular cluster and is quite different to the formation of the B1257+12 system that we will discuss later. The suggested formation scenario (e.g. Sirgudsson et al. 2003) goes as follows: At first the Jovian planet forms around a Sun-like star in the outskirts of M4 at a rather early age of about 13 billion years ago. Together with its parent star, the planet travels to the dense core of the globular cluster where exchange interactions are common. Indeed, the system is drawn toward a neutron star and its companion. The still slowly spinning neutron star captures the star and its planet, while the original partner is ejected from the system. Some time later, the star evolves, fills its Roche-lobe and a "standard" recycling process (e.g. Phinney & Kulkarni 1994) spins up the neutron star to millisecond periods. The companion stars eventually sheds its envelope and exposes its inner core as the white dwarf observed today. During this process, the planetary companion continues to orbit about the centre of mass relatively undisturbed and forms the current system: a Jovian planet that orbits a pulsar - white dwarf system in its centre.

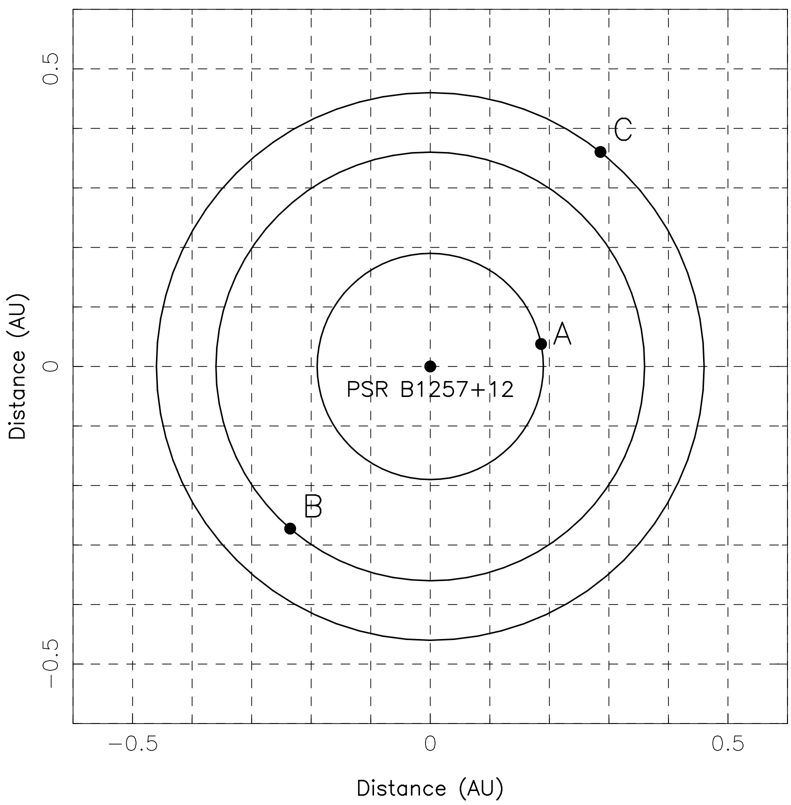

FIGURE 4. Schematic plot of the configuration in the PSR B1257+12 system.

FORMATION SCENARIOS

From an evolutionary point of view, considering the birth of the PSR B1257+12 system is much more interesting. At its location in the Galactic disk, we cannot rely on interchange interaction to obtain a planetary companion but we have to address the question on how a planetary disk can be formed around a pulsar. Essentially, the two scenarios put forward soon after the discovery are still the ones to be discussed (see e.g. Podsiadlowski 1993).

In the first scenario, the planetary disk forming the planet is the result of material from the supernova that created the pulsar. In this case, not all material cleared the gravitational potential of the star and falls back to form a metal-rich planetary disk.

In the second scenario, the supernova destroys the binary companion either via tidal forces or even with a kick imparted on the newly formed neutron star right into the companion. During this event, the neutron star "takes along" material from the companion which then forms a "tidal disruption disk" of solar-like material.

In order to decide which of these scenarios is the correct one, we can look at the current and past system parameters and also study if we find evidence of fall-back disks around other pulsars.

Firstly, it is peculiar that with 200 millisecond pulsars known and a routine timing precision that allows us to detect even asteroids, PSR B1257+12 is the only planetary system known in the disk.[1] Furthermore, PSR B1257+12 is also peculiar in the way that it has a transverse space velocity that is surprisingly large for a recycled pulsar, i.e. 300 km s^{-1}. Both facts are consistent with the tidal/kick disruption disk scenario: on one hand, the probability for the neutron star to be kicked in exactly the right direction is sufficiently small to explain the small number of pulsar planets known. On the other hand, the large space velocity could indeed be the direct result of a powerful kick. Therefore, the observed properties may represent literally the “smoking gun” of an assault on the original companion star but they are far from being the proof.

For the second scenario to be viable, we would expect fall-back disks also to be observed around other neutron stars but evidence had been missing for while. In 2006, Wang et al. (2006) presented observations that they interpreted as the result of a fall-back disk around the cool isolated X-ray pulsar 4U 0142+61. Depending on orbital parameters, distance, flux etc, they derive an upper limit on the disk mass of $M_{\rm disk} < 3 \times 10^{-3} M_{\odot}$.

The interpretation of the data of 4U 0142+61 may not be unique, in particular given the fact that we have failed to detect similar disks around millisecond pulsars, in particular around PSR B1257+12 (see Wolszczan (2008)). Nevertheless, perhaps the detection of 25 X-ray photons (!) from the B1257+12 system with CHANDRA may be an indication that circumstellar material is still present around the pulsar (Pavlov et al. 2007). These authors point out that the X-ray luminosity is rather smaller than usual and that its small value could be caused by X-ray absorption in circum-pulsar matter, speculated to be perhaps the remnants of the debris disk.

It is clear that more planetary systems around pulsars are needed to settle the question about the formation process.

WHERE ARE THE OTHER PLANETS?

The main question remains: where are the other planetary systems when we have the sensitivity – even for slowly rotating normal pulsars – to discover them in abundance? Could it be that we have unknown selection effects that prevent a detection? Or are pulsar planets simply rare?

There have been other claims of planet detections in the past, mostly about normal, slow pulsars which do not have the timing precision as recycled millisecond pulsars. Moreover, these pulsars are relatively young and the spin-down is not as smooth as for millisecond pulsars, so that their timing residuals often show (quasi)-periodic structure. If the time baseline of observations is too short, such variations could be easily mistaken for the effects of orbiting bodies. The best example is perhaps PSR B0329+54, which was claimed to harbour a planetary system by Shabanova (1995). Continued observations by Konacki et al. (1999) however clearly demonstrated that the observed periodic variation of the TOAs was in fact long-term timing noise as the observed trend did not continue.

Recent observations by Lyne et al. (2010) show that if the timing baseline is long

[1] In fact, this statement has been superseded by the time of writing and will be discussed in brief later.

enough, even normal timing noise can manifest itself in a rather periodic fashion and can mimic the effect of planets. Rather the variation in the timing being caused by the gravitational pull of a companion, it was shown by a discovered correlation between pulse profiles and spin-down properties that switches in the magnetospheric currents are responsible. These changes in the current cause an alternating torque contribution to the spin-down, so that we observe a systematic change in spin-down period derivative, i.e. in the amount of neutron star braking. What exactly causes the currents to alter or why this often happens in a (quasi-) periodic fashion is far from clear, but it is established that it is related to the phenomenon of intermittent pulsars (Kramer et al. 2006) and pulsar moding (Backer 1970a) and nulling (Backer 1970b).

Interestingly, thanks to the correlation between pulse profile and spin-frequency derivative, high-sensitivity observations of pulsars will offer the possibility to identify the corresponding spin-down state and hence to successfully correct even the “noisy pulsar clocks” (Lyne et al. 2010).

RECENT RESULTS AND THE FUTURE

As indicated earlier, the discovery of more pulsar-planet systems in the Galactic disk is required to make progress in answering the question about the formation process. Two ways can and are being employed. Continued timing observations of known normal and millisecond pulsars should reveal more systems. However, given that we have not found more convincing cases in the already known sample of pulsars suggests the other, perhaps rather usual approach: find more pulsars – some of which will then possibly harbour a further planetary system!

A new planetary system!?!

At the moment the first true all-sky survey is being conducted at the Parkes telescope in the South and the Effelsberg telescope in the North. Combined they provide a state-of-the art census of the dynamic radio sky with unprecedented time and frequency resolution. This “High Time Resolution Universe” (HTRU) survey has already, at the time of writing, discovered about 70 pulsars including 10 millisecond pulsars. This unusually large fraction of millisecond to normal pulsars in a blind survey is obtained by a deeper penetration in the Galactic volume due to the improved time and frequency resolution.

In this HTRU survey, we discovered very recently a 5.8-ms pulsar in compact 2.2-hr orbit with a light companion with a mass of only $1.2M_{\rm Jupiter}$. Optical observations with the Keck telescope are on-going and may yield a detection of the companion (van Straten et al., in prep.) If the planetary nature of the companion can be confirmed, it will raise interesting questions about the survival of a planet in such a short compact orbit about a powerful high-energy source.

The ultimate answer: the SKA

The immediate success of the HTRU survey demonstrates clearly the potential of new pulsar surveys to turn up new pulsar - planet systems. Therefore, the ultimate answer to our questions on how many pulsar planets exist and how they form can be given if we find all pulsars in the Galaxy – or at least those, which point their radio beam towards Earth! This is possible.

The biggest telescope on Earth, the Square-Kilometre Array (SKA), is being planned by a consortium of currently 19 nations to construct a multi-purpose radio telescope from many elements, both dishes and aperture arrays, leading to a total collecting area approaching 1 million square metres[2]. The SKA will perform a Galactic census of pulsars (Cordes et al. 2004) and will also allow us to time pulsars with a precision that exceeds even today's standard by about a factor of 50 to 100 (Kramer et al. 2004).

The Galactic census will eventually yield a population of 20,000 or more radio pulsars across the Galaxy including about 1000 millisecond pulsars (Smits et al. 2009) . With the leap in timing precision even for normal pulsars, aided by the described way to correct now for timing noise, we should routinely detect asteroids, debris disks and planets around pulsars. With this sample at hand, we will finally, for sure, answer the question on how common pulsar planets are.

CONCLUSIONS

What are the lessons from our very small but intriguing sample of pulsar planets? Do they matter in the big context and among the ever increasing sample of other extra-solar planets. This is for the reader to decide but the answer of a (hopelessly biased, of course) pulsar astronomer is very clear (cf. Wolszczan 2008):

Firstly, it is fascinating to see that the physical process of "pre- and post-death" planetary formation can be rather similar. This is a rather surprising result and should be viewed with the recognition in 1992 that planets are more common than previously thought in the past. It is an extraordinary fact that planets were first discovered around neutron stars, a rather unusual place to look for planets. In hindsight, of course, the reason is clear: planets were not discovered first around pulsars because pulsar planets are very common, but simply because pulsar astronomers have had (and still do) a vastly superior sensitivity. Simply this larger parameter space had enabled Wolszczan and Frail to make their discovery. Increasing the parameter space even further with new instruments at radio and optical wavelengths will naturally lead to new discoveries in the near future.

The B1257+12 system provided further lessons: Resonances due to a special arrangements of orbital periods lead to characteristic changes in the orbital elements and can be measured and exploited to provide a complete picture of the planetary system. Similar resonances may be also found in optically discovered planets, providing therefore useful information about the systems. A regular monitoring of the planetary movements and,

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[2] For more details, visit `www.skatelescope.org`

probably, better measurement accuracy is needed to have success though.

The other planetary system, the triple pulsar B1620−26 also seems to tell us something: apart from having a system that was formed at an early stage, the fact that we detected a Jovian planet in an extremely metal-poor environment of a globular cluster may cast doubt on any link between the occurrence of planets and the metallicity of their parent stars. In reality, the conditions for the formation of planets, at least in globular clusters, may be complicated as the unsuccessful but careful search for planets in the many millisecond pulsars of 47Tuc seems to suggests (Freire et al. 2003).

It is clear that we need a larger sample. The SKA will provide us with this sample and hence the answer to a very interesting astrophysical mystery.

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