# PSR B1937 + 21

PSR B1937 + 21 is a pulsar located in the constellation Vulpecula a few degrees in the sky away from the first discovered pulsar , PSR B1919 + 21 . The name PSR B1937 + 21 is derived from the word " pulsar " and the declination and right ascension at which it is located , with the " B " indicating that the coordinates are for the 1950 @.@ 0 epoch . PSR B1937 + 21 was discovered in 1982 by Don Backer , Shri Kulkarni , Carl Heiles , Michael Davis , and Miller Goss . It is the first discovered millisecond pulsar , with a rotational period of 1 @.@ 557708 milliseconds , meaning it completes almost 642 rotations per second . This period was far shorter than astronomers considered pulsars capable of reaching , and led to the suggestion that pulsars can be spun @-@ up by accreting mass from a companion .

The rotation of PSR B1937 + 21 , along with other millisecond pulsars discovered later , are very stable in their rotation . They are capable of keeping time as well as atomic clocks . PSR B1937 + 21 is unusual in that it is one of few pulsars which occasionally emits particularly strong pulses . The flux density of the giant pulses emitted by PSR B1927 + 21 are the brightest radio emission ever observed . These properties of PSR B1937 + 21 , and its unexpected discovery , are credited with helping revitalize research on pulsars .

## Background

The first pulsar was discovered in 1967 by Jocelyn Bell and her PhD supervisor Antony Hewish using the Interplanetary Scintillation Array . Shortly after the discovery of pulsars , Franco Pacini and Thomas Gold independently suggested that pulsars are highly magnetized rotating neutron stars , which form as a result of a supernova at the end of the life stars more massive than about 10 times the mass of the Sun . The radiation emitted by pulsars is caused by interaction of the plasma surrounding the neutron star with its rapidly rotating magnetic field . This interaction leads to emission " in the pattern of a rotating beacon , " as emission escapes along the magnetic poles of the neutron star . The " rotating beacon " property of pulsars arises from the misalignment of their magnetic poles with their rotational poles .

## Discovery

In the late 1970s , the radio source 4C21.53 captured the attention of radio astronomers , " because of its anomalously high level of interplanetary scintillation . " As interplanetary scintillation is associated with compact radio sources , the interplanetary scintillation observations suggested that 4C21.53 might be a supernova remnant , but a pulsar survey carried out at Arecibo Observatory in 1974 by Russell Hulse and Joseph Taylor in the region did not discover a pulsar associated with 4C21.53. With the lack of success in finding a pulsar in the region , other explanations for the scintillation were explored , including suggestion of entirely new classes of objects . After realizing in 1982 that previous searches for a pulsar in the region of 4C21.53 were not sensitive to periods short enough to produce the observed scintillation , Don Backer initiated a search in the area that would be sensitive to a wide range of pulse periods and dispersion measures , including very short periods . The initial search plan was to sample at a rate of 500 Hz , which would have been insufficiently fast to detect a pulsar spinning at 642 Hz . To simplify the search apparatus , Backer 's then student , Shri Kulkarni , sampled as quickly as was possible , and time averaged the signal over a period of 0 @.@ 4 milliseconds , thus effectively sampling at 2500 Hz . As a result , Backer et al. determined in November 1982 that the source was a pulsar rotating every 1 @.@ 558 milliseconds , a rate far beyond anything that astronomers studying pulsars had expected .

## Characteristics

### Age and spin down rate

When Backer et al. reported their finding in November 1982 , they found that the rotation period of PSR B1937 + 21 was decreasing at a rate of 3 × 10 @-@ 14 seconds per second . Pulsars are expected to slow over time , as the energy that they emit is ultimately drawn from the rotational energy of the pulsar . Using the initially observed values for the period and spin down rate , and assuming a minimum period of 0 @.@ 5 milliseconds for pulsars , the maximum age for PSR B1937 + 21 was found to be about 750 years old . The estimate of the minimum possible period is obtained from the centrifugal break @-@ up limit , which is the rotational period at which the centrifugal force and the self @-@ gravity of the pulsar are equal . The value of the minimum rotational period depends upon the neutron star equation of state , with different models giving values between 0 @.@ 3 and 1 millisecond , which corresponds to a rotation frequency of 1 @-@ 3 kilohertz . There may be mechanisms such as gravitational radiation which keep the pulsar from reaching this absolute limit , but pulsars can spin no faster .

An age of no more than 750 years for the PSR B1937 + 21 was at odds with the observations of the region in other wavelengths . No optical supernova remnant , nor bright x @-@ ray source , had been observed in the vicinity of the PSR B1937 + 21 . If PSR B1937 + 21 was that young , it would not have had time to move far from the site at which it formed . As neutron stars are formed as the result of supernova explosions , evidence of the explosion should be nearby for a young pulsar . If it was that young , it would also be expected to still be hot , in which case the thermal radiation from PSR B1937 + 21 would be observable at x @-@ ray wavelengths . Venkatraman Radhakrishnan and G. Srinivasan used the lack of observed supernova remnant to argue that PSR B1937 + 21 had not formed with such a fast period , but instead had been " spun up " by a companion star which essentially gave the pulsar its angular momentum , a mechanism now generally used to explain millisecond pulsars . They also made a theoretical estimate of the necessary spin down rate to be 1 × 10 @-@ 19 seconds per second . Backer et al. revised their estimate of the upper limit of the spin down rate just a month after the initial discovery , to 1 × 10 @-@ 15 seconds per second , but the currently measured value is more nearly in line with the theoretical estimate , at 1 @.@ 05 × 10 @-@ 19 seconds per second . The age of PSR B1937 + 21 was also later determined to be 2 @.@ 29 × 108 years , a value which is consistent with the observational evidence .

The companion which is supposed to have spun @-@ up PSR B1937 + 21 is no longer present , making it one of few millisecond pulsars which does not have a stellar mass companion . The generally high occurrence of companions to millisecond pulsars is to be expected , considering a companion is necessary to spin @-@ up millisecond pulsars to their short periods . However , millisecond pulsars do not actively accrete matter from a companion , but instead need to have only done this at some time in the past , and thus the lack of companion for PSR B1937 + 21 is not seen as a being in disagreement with the spin @-@ up model . Possible mechanisms for creating isolated millisecond pulsars include evaporation of the donor star or tidal disruption of the system .

= = = Pulses = = =

During one period of rotation for PSR B1937 + 21 , there are two peaks observed , known as the pulse and interpulse . PSR B1937 + 21 is unusual among pulsars in that it occasionally produces pulses far brighter than an average pulse . Until 1995 , the sole other pulsar known to produce giant pulses was the Crab pulsar , and by 2006 , there were 11 pulsars that had been observed to produce giant pulses out of more than 1500 known pulsars . The giant pulses of PSR B1937 + 21 were first observed in 1984 , shortly after its discovery , but difficulty in observing single pulses of PSR B1937 + 21 due to its fast period meant that the pulses were not studied in more depth until a decade after they were first observed . In more recent follow up observations , more giant pulses have been found . These giant pulses have been observed to occur at the trailing edge of both the pulse and interpulse . The duration of these giant pulses is short compared to the period of the pulsar , lasting on the order of 10 nanoseconds . The flux density of observed pulses is somewhat variable , but has been observed to be as high as 6 @.@ 5 × 10 ? 22 Wm ? 2Hz ? 1 ( 6 @.@ 5 × 104 janskys ) . The brightness temperature of a pulse with such high flux density and such low duration exceeds 5 × 1039 Kelvin , making the pulses of PSR B1937 + 21 the brightest radio emission ever observed . PSR B1937 + 21 is intrinsically the most luminous millisecond pulsar . In addition to the radio pulses observed , pulses have been detected at x @-@ ray wavelengths , which show the same pulse and interpulse pattern .

## = = Evidence for companions = =

After the discovery of planetary mass companions around PSR B1257 + 12 in 1990 by Aleksander Wolszczan , data for PSR B1937 + 21 and other pulsars were analyzed for the presence of similar companions . By 1994 , an upper limit of about one thousandth of the mass of Earth was determined for any companion of PSR B1937 + 12 within 2 astronomical units . In 1999 , Aleksander Wolszczan reported variations in the times of arrival of pulses from PSR B1937 + 21 , as well as previous analysis by Tokio Fukushima which suggested that these timing variations could be caused by a dwarf planet around the pulsar . The data were consistent with a companion having a mass similar to Ceres and located at 2 @.@ 71 astronomical units from the pulsar , but data over a longer period of time are required in order to verify the proposed companion . More recent observations have not detected any regular periodic signal associated with this companion , but argue that the slight variations in pulse arrival times are consistent with an asteroid belt having a total mass less than 0 @.@ 05 that of the Earth , but acknowledge that the detection of periodicity in pulse timing variations associated with individual asteroids is necessary to confirm the possible asteroid belt .

## = = Significance = =

Until the discovery of PSR J1748 @-@ 2446ad in 2006 , which spins 716 times per second , PSR B1937 + 21 was the fastest spinning neutron star known . As of 2010 , PSR B19371 + 21 remains the second fastest spinning pulsar known . In addition to extending the range of periods observed in pulsars by a factor of 20 , it also extended the range of magnetic fields observed by a factor of 100 , with a magnetic field of 4 @.@ 2 × 108 gauss ( 42 kT ) .
As the first discovered millisecond pulsar , PSR B1937 + 21 " sparked a ' theory frenzy ' " by providing a new laboratory in which to study pulsars , neutron stars more generally , and perhaps even some other astrophysical problems such as gravitational waves . For instance , as the density required to spin at such high rates are comparable to nuclear densities , the fastest spinning millisecond pulsars are important in understanding how matter behaves at such densities . The initially high estimate of the spin down rate was also intriguing , as it implied a signal that could be directly detected by gravitational wave detectors , but the actual spin down rate put the expected signal below the sensitivity of current detectors . The currently accepted value spin down rate corresponds to a change in the rotational period of 1 @.@ 5 Hz over the course of one million years . The stability of rotation of PSR B1937 + 21 is of the same order of the stability of the best atomic clocks , and is thus a tool used in establishing ephemeris time .
The discovery of B1937 + 21 launched " extensive pulsar surveys at all major radio observatories " and " happened to revitalize pulsar astronomy at a time when most people thought the field was moribund . "