Pulsar searching with Arecibo - the world's largest radio telescope

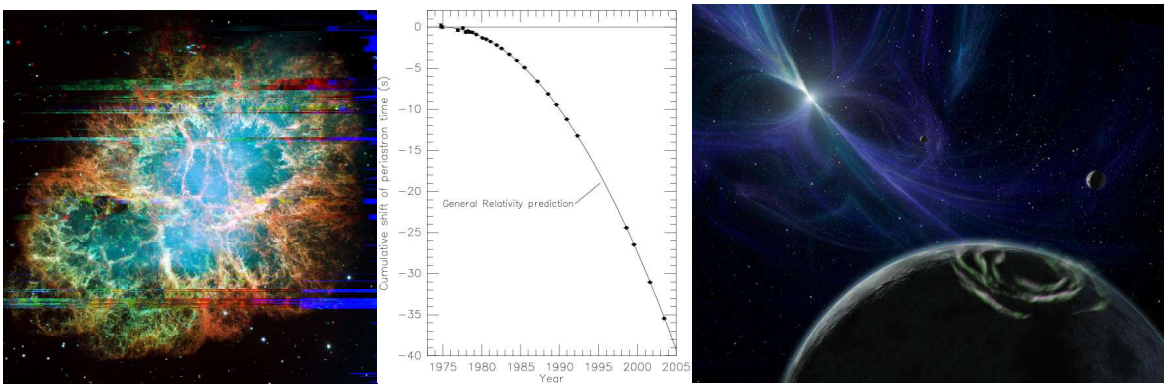
Pulsars – rapidly rotating highly magnetized neutron stars – are compact stellar cores produced during supernova explosions of massive stars. Their radio beams sweep the sky like a lighthouse resulting in pulses of radiation once per rotation. Measured rotation periods currently span the range 1.4 ms – 8.5 s. These cosmic clocks are unique astrophysical laboratories with a wide variety of applications ranging from testing Einstein's general theory of relativity to constraining the equation of state of superdense matter. Searches for new and exotic pulsars drive this high-profile research field. The unparalleled sensitivity of the 305-m Arecibo telescope has kept it at the forefront of pulsar astronomy for the past 40 years.

Radio pulsars are unique astrophysical objects which can be used to uniquely:

- TEST relativistic theories of gravity in the strong-field regime.
- CONSTRAIN the equation-of-state of superdense matter.
- SEARCH for low-frequency gravitational radiation in the Universe.
- PROBE the ionized and magnetized interstellar medium in our Galaxy.

Arecibo has provided a number of key discoveries in this field, including:

- the identification of 33-ms pulsations from a pulsar in the Crab nebula, providing strong support for the rotating neutron star model to describe the pulsar phenomenon.
- the first binary pulsar system from which Arecibo measurements of the orbital decay provided unambiguous confirmation of the existence of gravitational radiation.
- a "millisecond pulsar" spinning at 642 Hz which was the prototype of a large population of hitherto overlooked objects which now serve as exquisite celestial clocks.
- the first extra-solar planetary system.



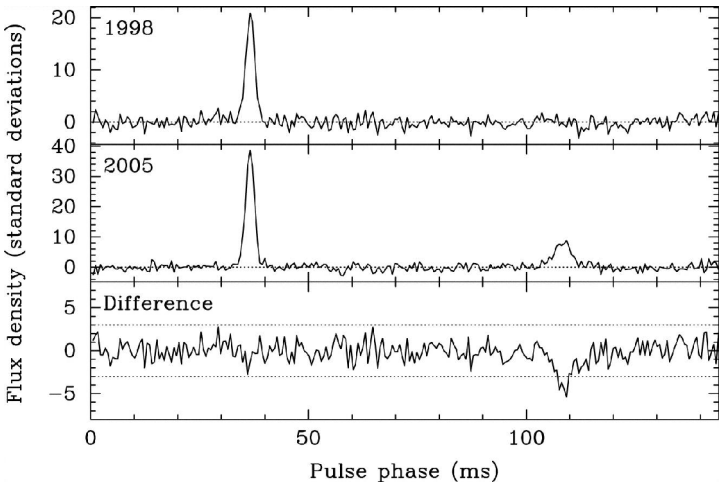
Left: optical image of the Crab nebula. The Arecibo telescope identified a 33-ms pulsar in 1968. Center: orbital decay of the binary pulsar as measured by 30 yr of Arecibo timing observations. Right: artists impression of the pulsar planetary system discovered by Arecibo.

Pulsar surveys with Arecibo continue to reveal unique and exotic systems to probe fundamental physics that are beyond the reach of all current and planned telescopes.

Since 2004, astronomers have been using a state-of-the-art receiver known as the Arecibo L-Band Feed Array (ALFA) which allows the telescope to look at 7 different regions of sky at once. The ALFA survey expects to find several hundred pulsars which are too faint to be found with other telescopes and provide a rich census of the Galactic population. So far, we have discovered over 50 pulsars, among which two unique finds are highlighted below:

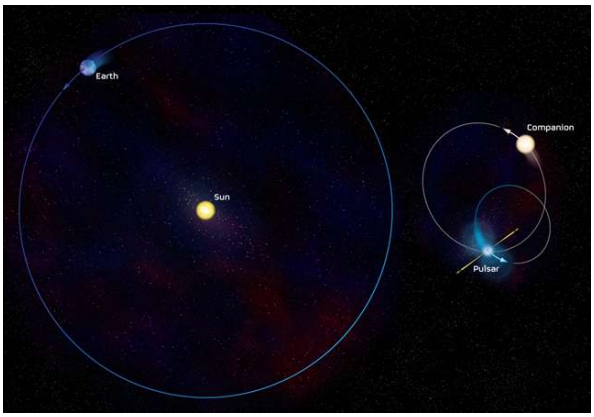
A young pulsar in a relativistic binary system

PSR J1904+0746 spins on its axis almost 7 times every second and is in a binary orbit around another neutron star which it orbits every 4 hr. Unlike other systems known of this kind, this Arecibo discovery is much younger and implies a large birthrate of similar objects in our Galaxy. A number of general relativistic effects have so far been observed including the rare phenomenon of geodetic precession which causes the pulsar's profile to change (right figure) due to space-time curvature in the orbit.



An eccentric millisecond pulsar binary system

As recently reported in *Science*, we found a 2.15-ms pulsar in a 95-day orbit around a solar mass companion. What is unprecedented for this system is the highly elliptical shape of the orbit (shown to scale with the Earth's orbit around the Sun in the graphic). This orbit can not be explained by any existing model and is providing unique new insights into the origin and evolution of binary stars.



For pulsar searching, it is crucial to keep Arecibo operational because it is:

- the only telescope currently capable of finding large numbers of highly dispersed millisecond pulsars.
- the most sensitive telescope to short-period binary systems which are the most exciting for tests of fundamental physics.
- able to find the faintest pulsars currently known. Therefore, extracting the scientific output from many of the exciting discoveries can only be followed up by Arecibo.