An Introduction to Pulsars, NANOGrav, and Gravitational Waves

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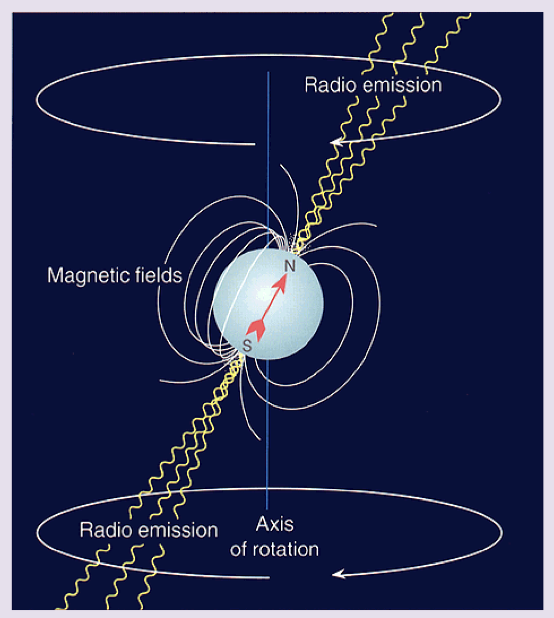
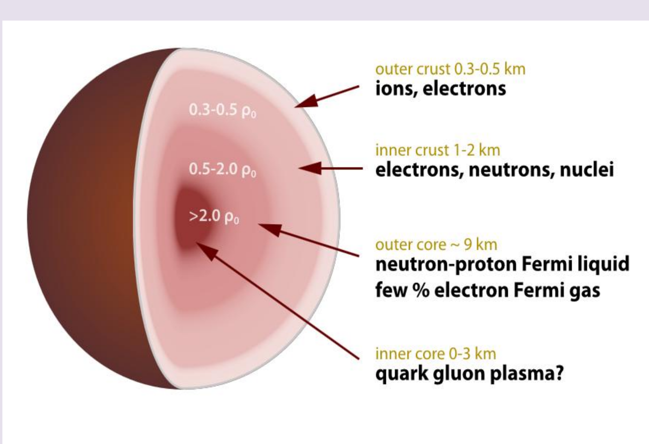
Pulsars and Millisecond Pulsars



http://www.nobelprize.org/nobel_prizes/physics/laureates/1993/illpres/discovery.html

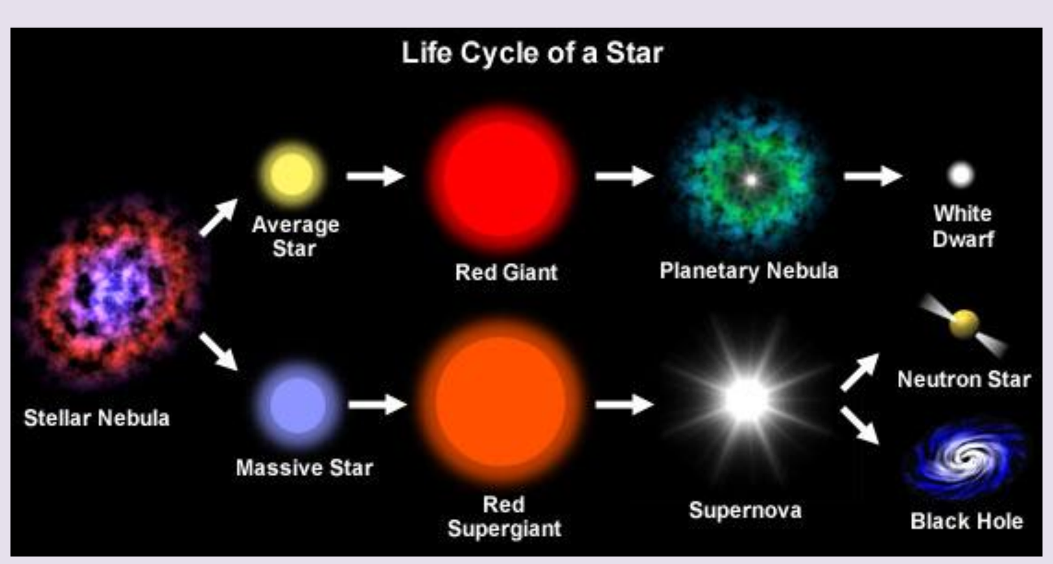
Pulsars are extremely dense neutron stars that form from the supernova of other stars. They are special types of neutron stars that emit periodic radio signals (Data used in this project were collected between 400 and 2000 MHz.). These signals are emitted from the star in what are called light cones, which are aligned with the star's north and south magnetic poles.

A pulsar's emission can be compared to a lighthouse: every time a lighthouse rotates, observers see flashes of the continuous beam of white light that is being emitted, which carry light of many frequencies. Like the lighthouse, emissions from pulsars can only be seen when the pulsar is in a certain point of its rotation relative to an observer.

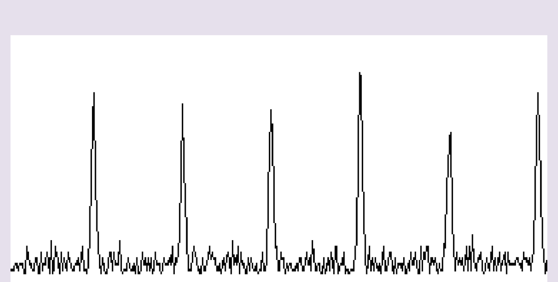


typical pulsar : mass ~ 1.4-3.2 solar masses
density ~ 10^{17} kg/m^3
http://upload.wikimedia.org/wikipedia/commons/thumb/9/9e/Neutron_star_cross_section.svg/1280px-Neutron_star_cross_section.svg.png

Pulsars have periods ranging from 1.5 ms to 8 s. Our particular focus was upon millisecond pulsars, which are fairly old neutron stars. These stars were able to gain enough angular momentum to rotate over 100 times per second by accreting mass and angular momentum from companion stars in binary orbits.



http://www.schoolsobservatory.org.uk/astro/stars/lifecycle


Example of a pulsar signal
http://www.uni.edu/morgans/astro/course/Notes/section2/new10.html

Pulsars are predictable objects with extremely steady rotational periods, which allows the pulses' arrival times to be measured to precision of 100s of nanoseconds or less. Because of this, scientists are able to detect slight perturbations in the arrival time of signals they receive.

NANOGrav

Arecibo Telescope – Arecibo, Puerto Rico

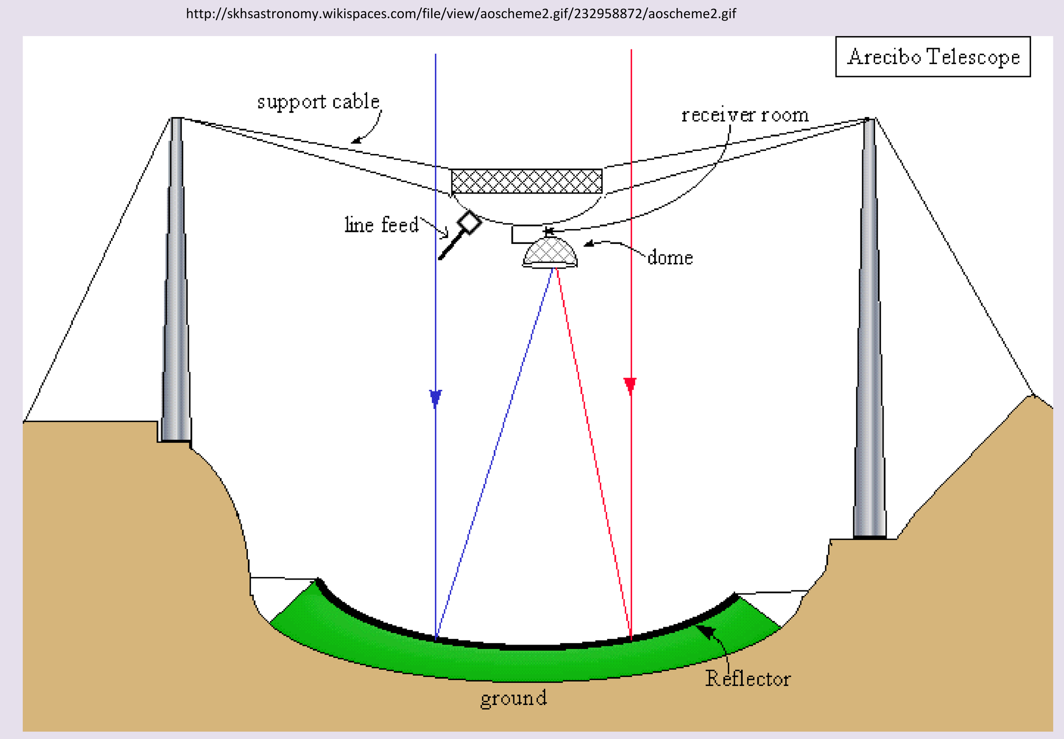

http://www.puertoricoblogger.com/arecibo-observatory-in-puerto-rico/

Our work is part of the NANOGrav project, which stands for North American Nanohertz Observatory for Gravitational Waves. NANOGrav is a collection of physicists from around the world with one main goal in mind: the detection and study of gravitational waves.

Green Bank Telescope – Green Bank, West Virginia
http://www.umich.edu/~lowbrows/reflections/2008/mdeprest.30a.jpg

NANOGrav uses two main telescopes for data collection: Arecibo and Green Bank. The telescopes have various receivers that collect data at different frequencies. Arecibo's data acquisition system used for this project is called PUPPI, and Green Bank's is called GUPPI.

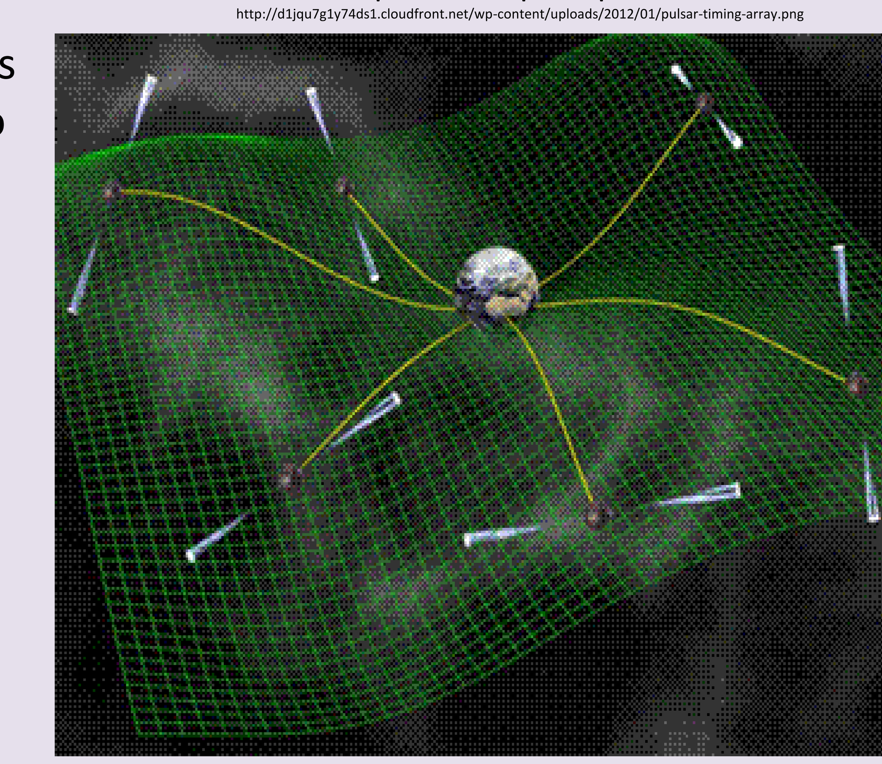
Mechanism of how radiation is collected at Arecibo
http://skhsastronomy.wikispaces.com/file/view/aoscheme2.gif/232958872/aoscheme2.gif



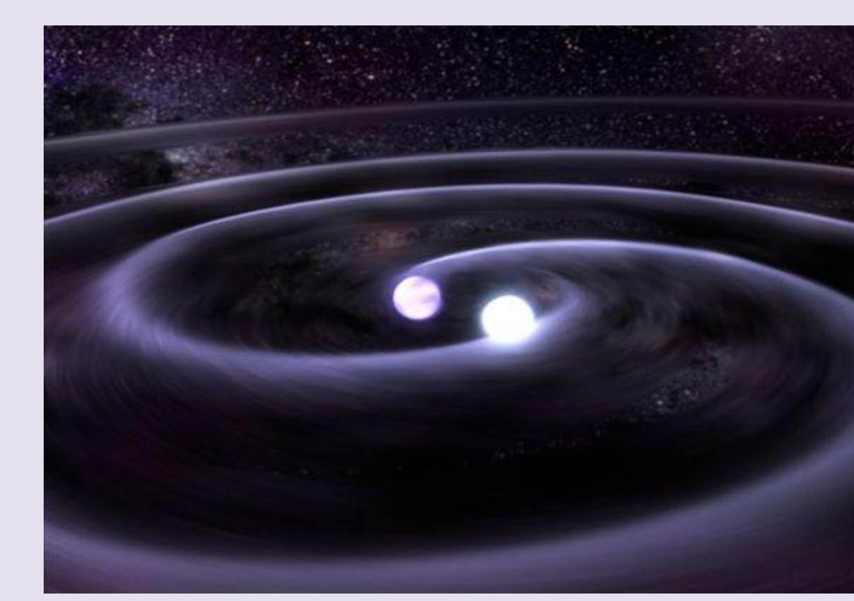
Gravitational Waves

The ultimate goal of measuring these pulsars with high precision is to detect gravitational waves, which would cause pulses to arrive earlier and later than expected. Predicted by Einstein's Theory of General Relativity, gravitational waves are ripples in space that could give a new window through which to study some of the most energetic systems in the Universe, such as binary orbits of supermassive black holes, and even to probe the early stages of the Universe itself..

Example of warped space-time
http://d1jqu7g1y74ds1.cloudfront.net/wp-content/uploads/2012/01/pulsar-timing-array.png



Binary system of pulsars
http://2.bp.blogspot.com/-S3XFWREfFdk/Tpw0Yml9FRI/AAAAAAAABII/ulNz9_PJCCY/s1600/swirling-binary-stars-system-5-minute-interval_16585_600x450.jpg



Gravitational waves are very difficult to detect because their effect on spacetime is very small. Theoretical estimates suggest that they should perturb distances by about 1 part in 10^{15} as they pass by. The NANOGrav collaboration is studying pulsars in order to detect gravitational waves, which warp spacetime. This creates a greater distance for pulsar signals to travel, thus delaying the their times of arrival. If these delays are detected, gravitational waves could be responsible.

Sources:
"North American Nanohertz Observatory for Graviational Waves." *NANOGrav*. 29 July 2014. Web. <http://nanograv.org/>.
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"Pulsar Properties." *NRAO*. National Radio Astronomy Observatory., 2009. 29 July 2014. Web. <http://www.cv.nrao.edu/course/astr534/Pulsars.html>

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