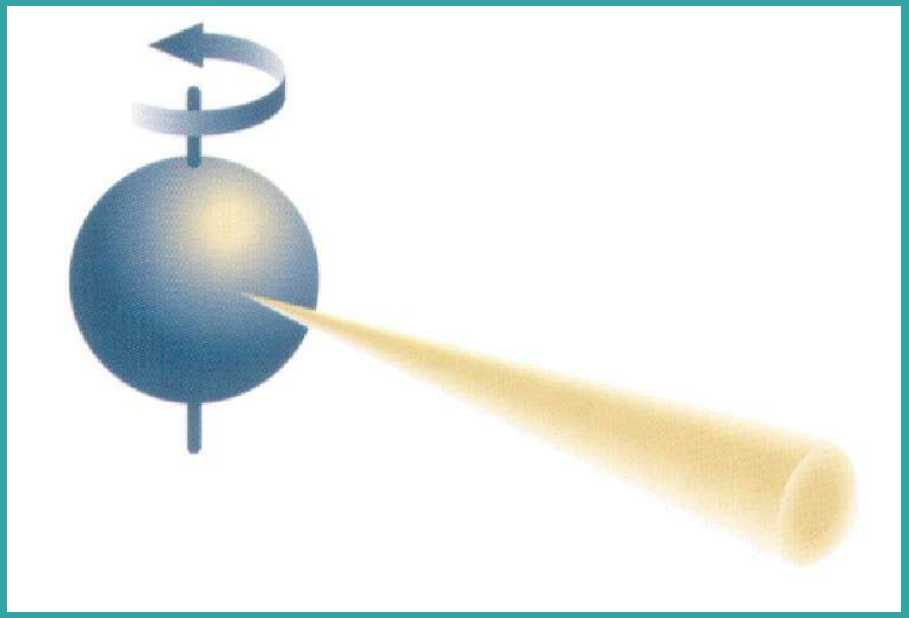
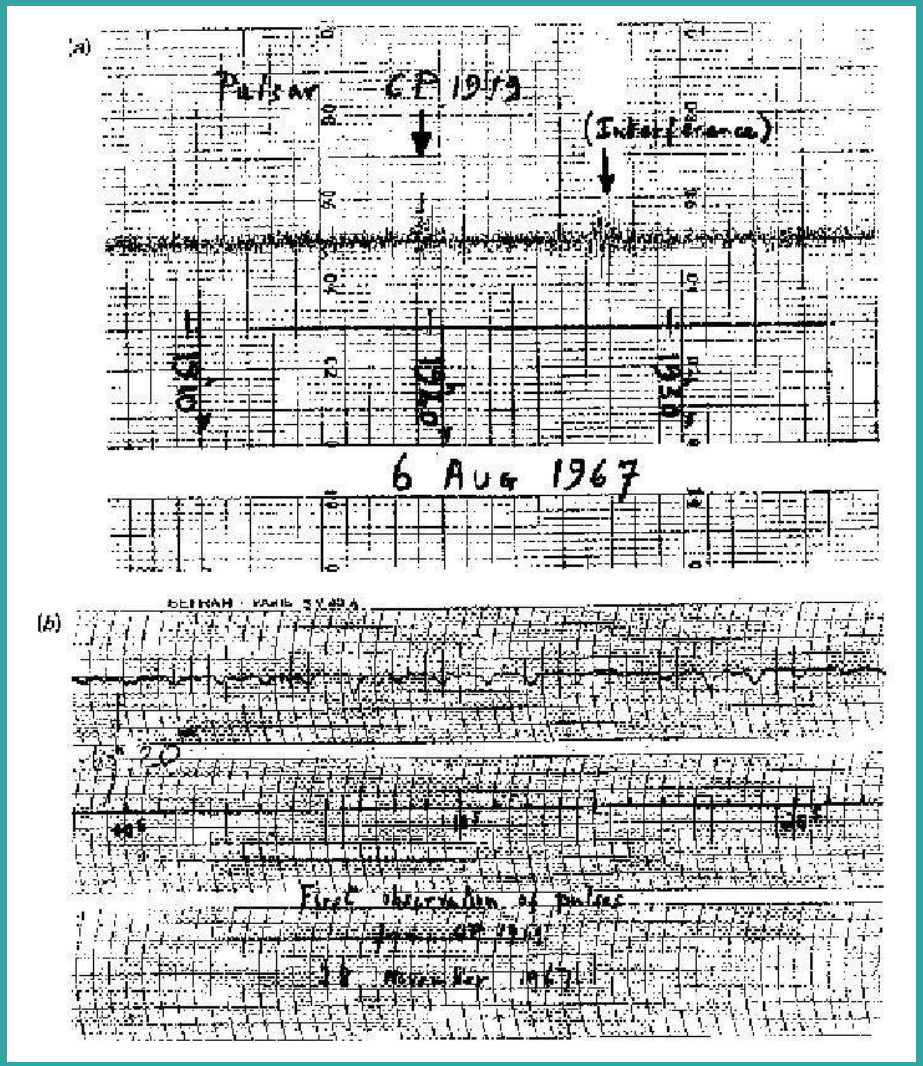
Pulsars: Precise Probes of the Universe

Ingrid Stairs
UBC TRIUMF lecture
March 18, 2006



Cambridge, 1967...



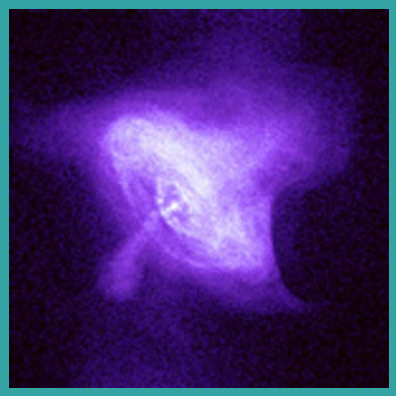
Interference?
Little Green Men?
Astronomical
Source?

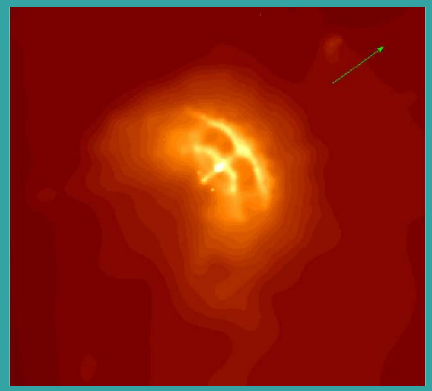
Supernova 1987A: Before and after!

Pulsars born in Supernovas?

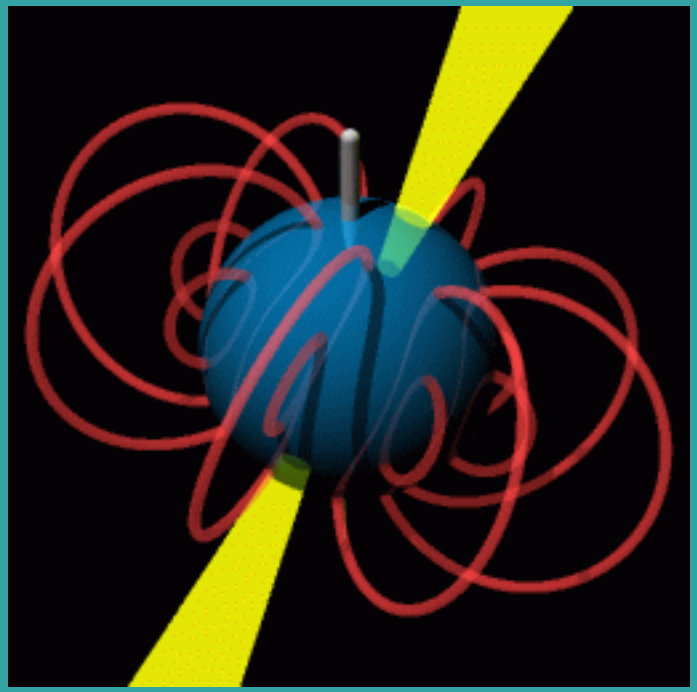
Pulsars found in
Crab and
Vela supernova
remnants...

confirmation that
this is the birthplace
of pulsars!

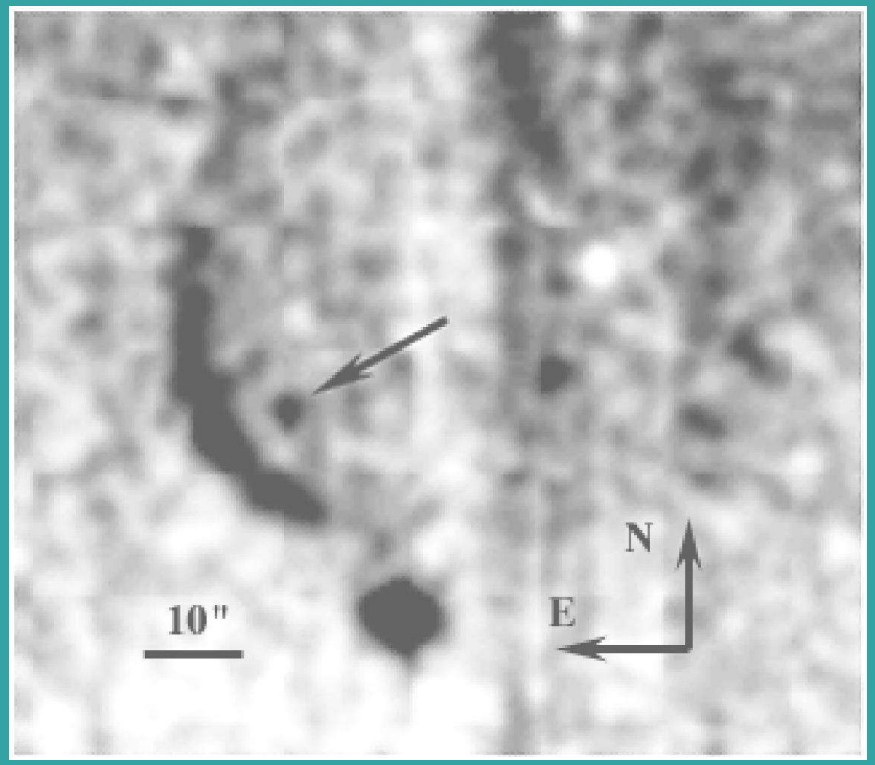




Crab period of 33 milliseconds:
has to be a neutron star!
Predicted by Baade and
Zwicky in 1934!



Pulsars are high-speed objects!



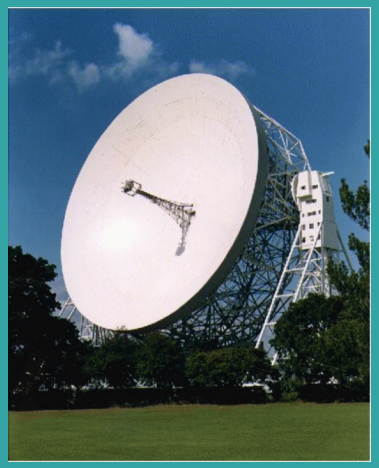
But images are a very small part of the story...

Telescopes that I've used to observe pulsars

Arecibo, Puerto Rico

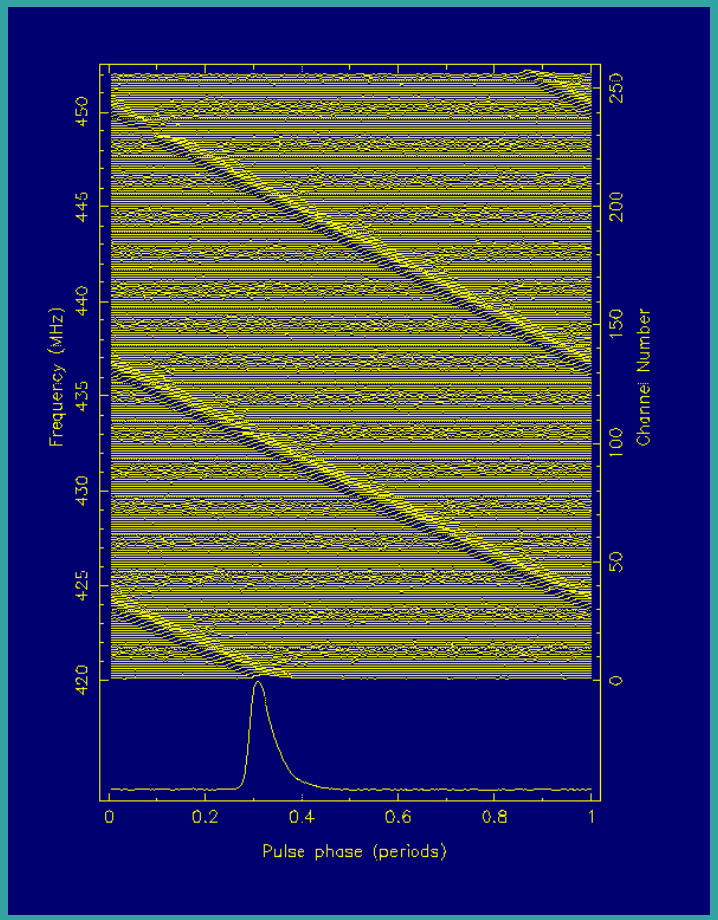
Parkes,
Australia

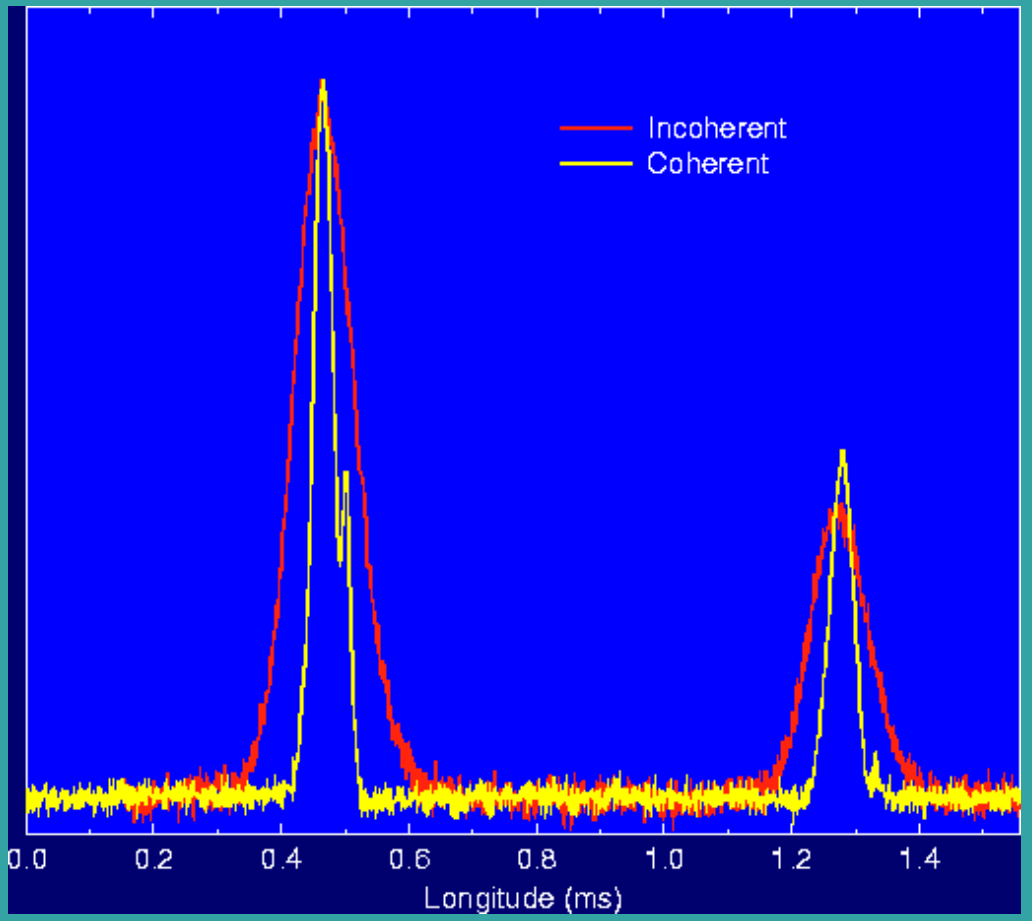
Green Bank, WV



Jodrell Bank, UK

Dispersion and its Removal

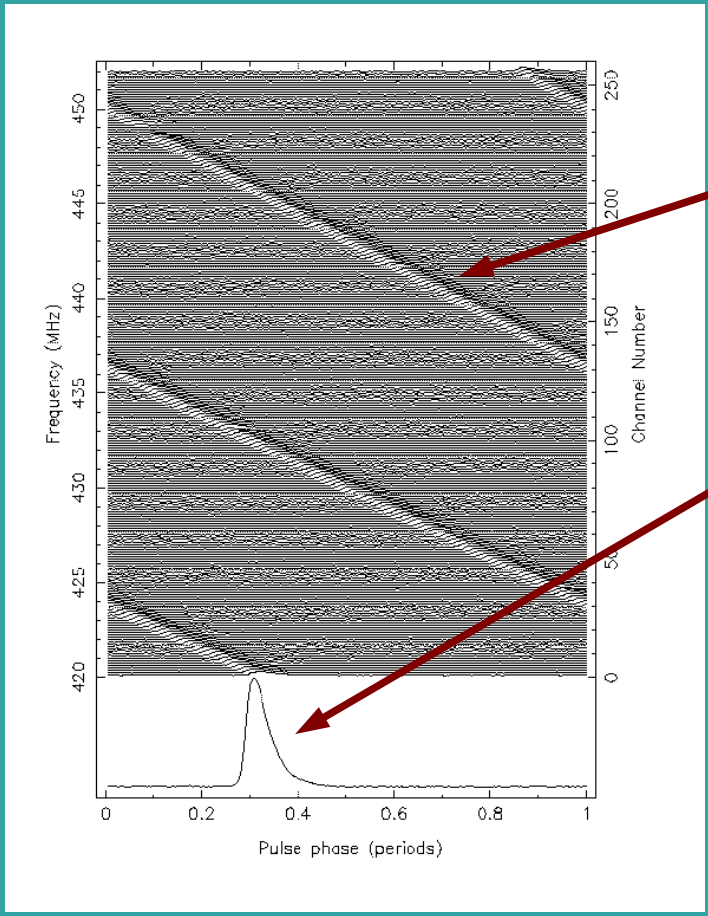




Filterbank:
lots of smearing

Coherent Dedispersion:
better profiles, better timing!

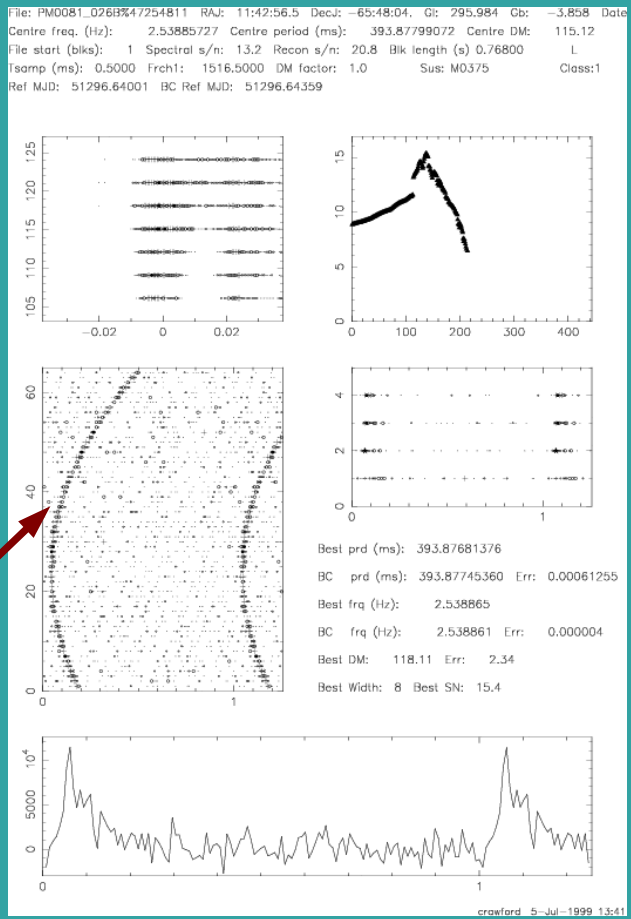
How to search for pulsars: need lots of computing power!



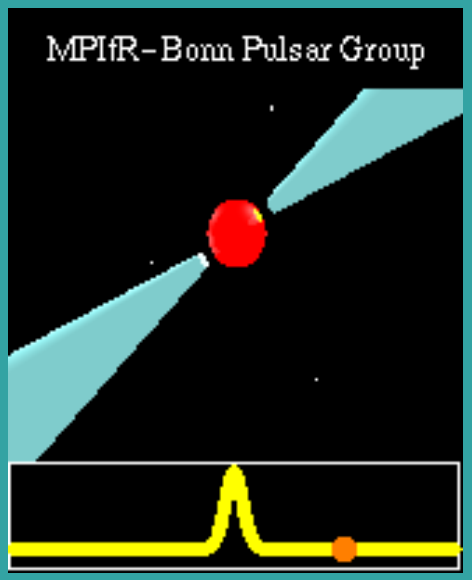
Dispersion Measure

Periodicity

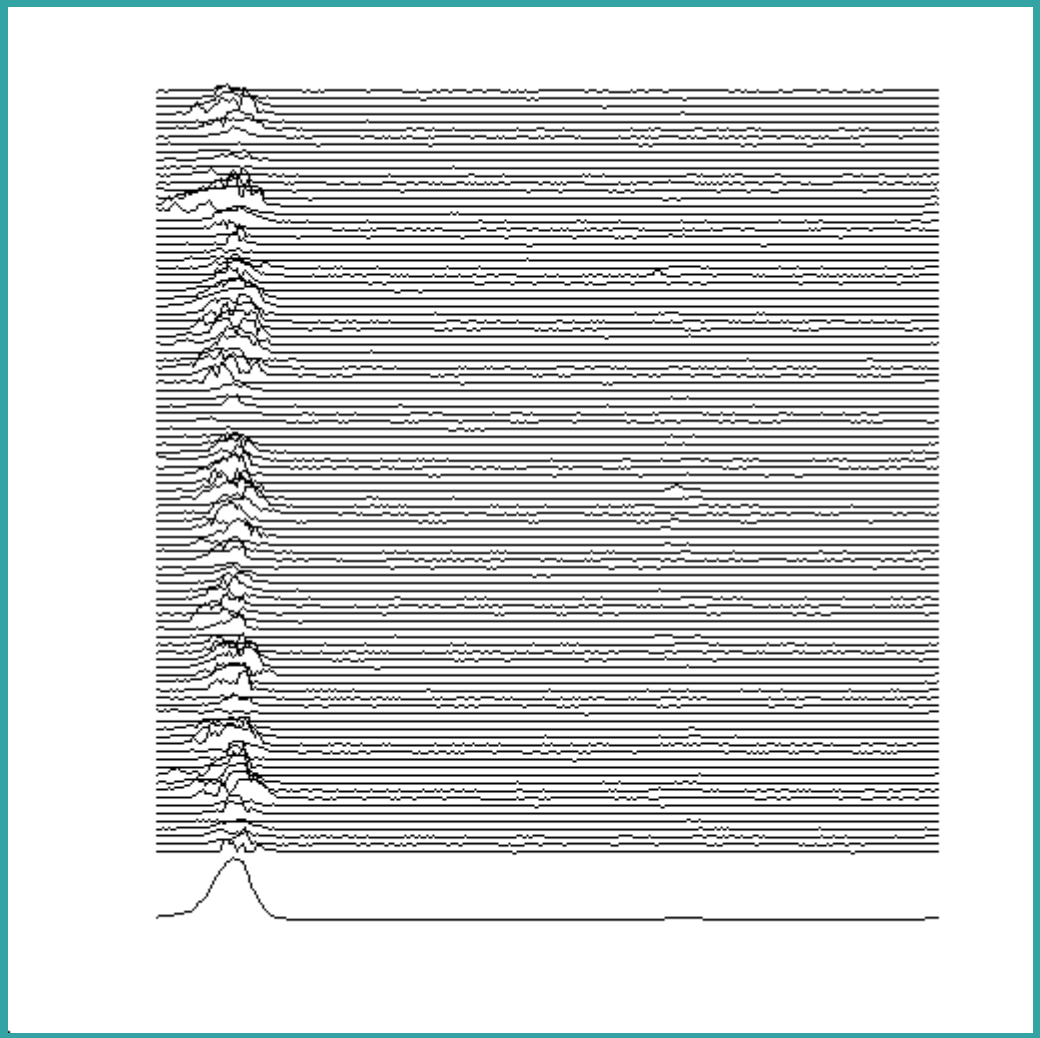
Acceleration



Pulse-to-pulse variations

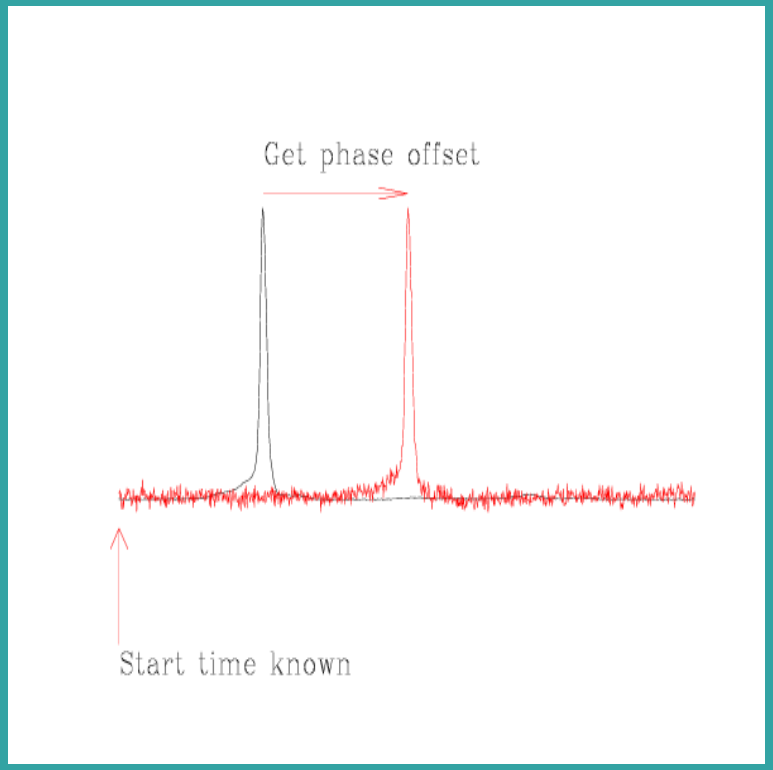


Lighthouse model



Integrated profile

Cross-correlation with standard profile: Time-of-Arrival (TOA)



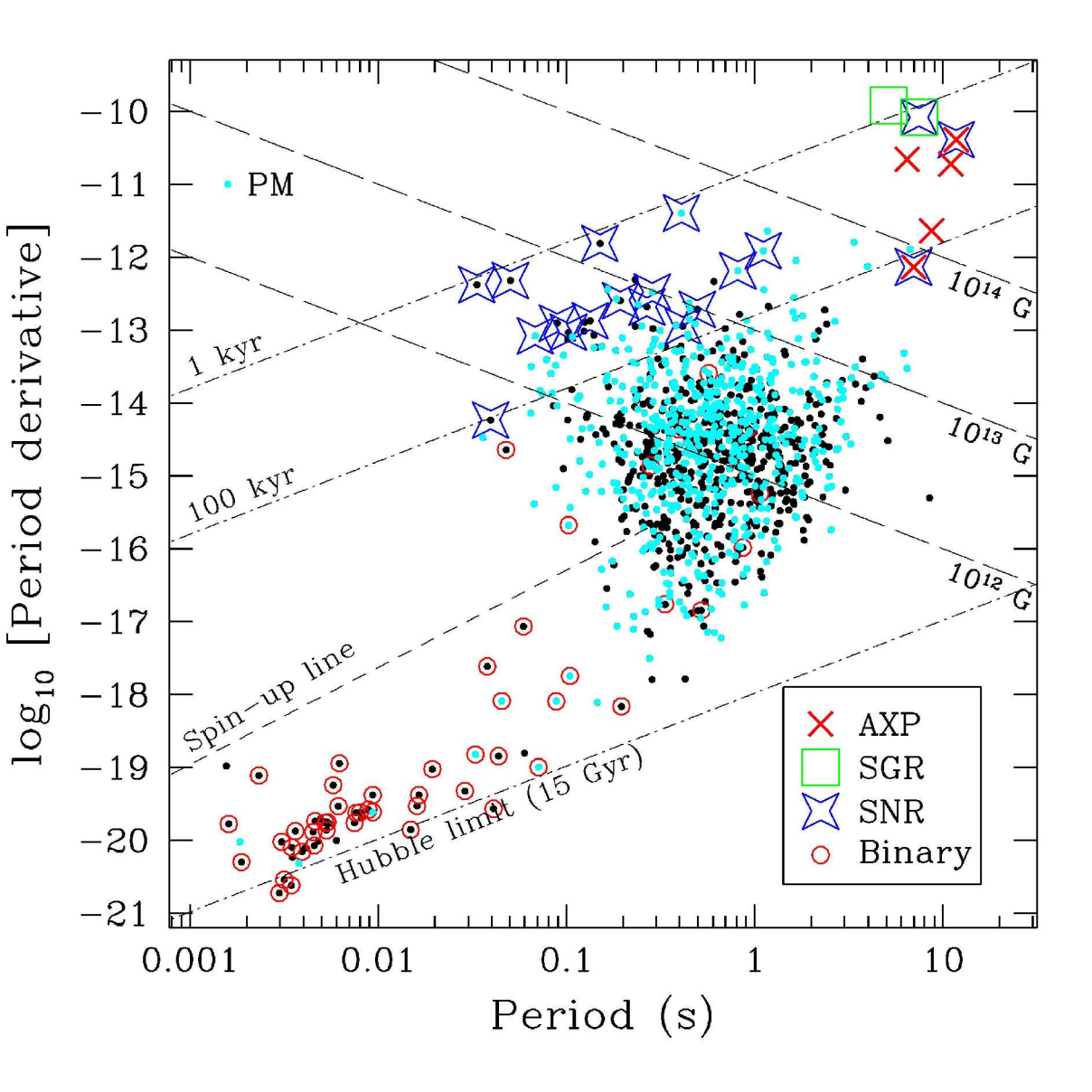
PSR B1534+12: between
23 Aug. 1990 20:56:17.030
and
9 March 2006 09:00:16.722
there were exactly
12 939 121 017 pulses.

High-precision timing

The Pulsar Population

$$\tau = \frac{P}{2\dot{P}}$$

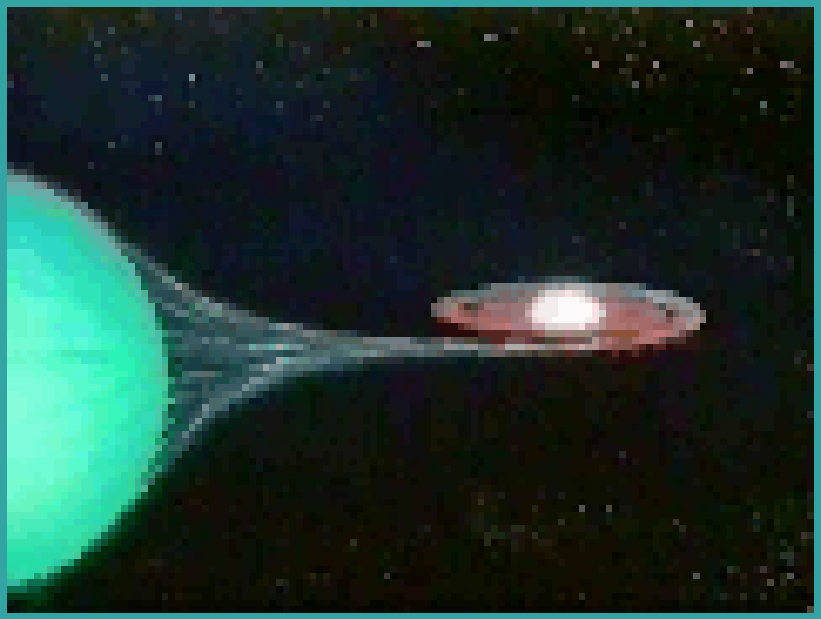
$$B = 3.2 \times 10^{19} \sqrt{P\dot{P}}$$

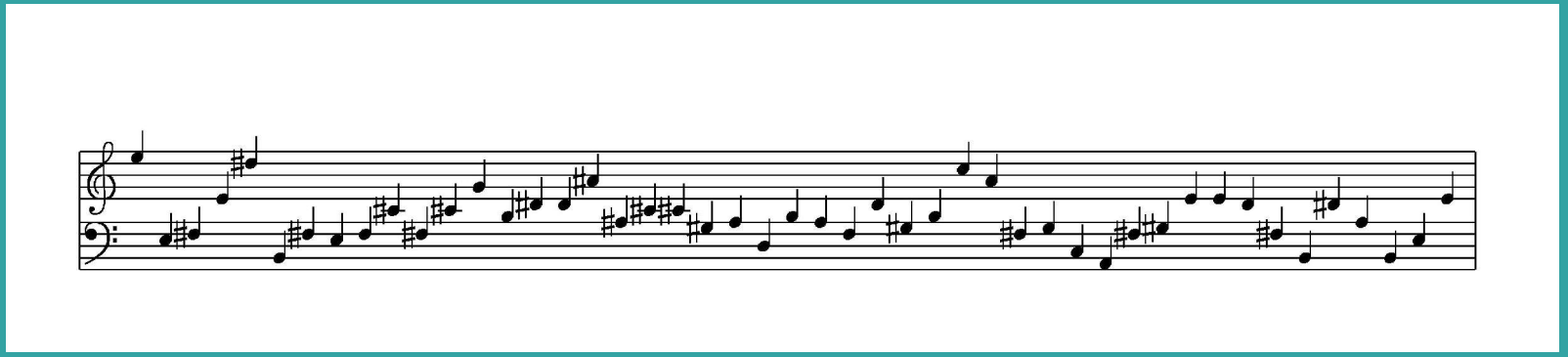


- Crab
- Vela
- B0329+54
- B1937+21

Spinning-up a pulsar:

transferring matter and spin from an evolving companion



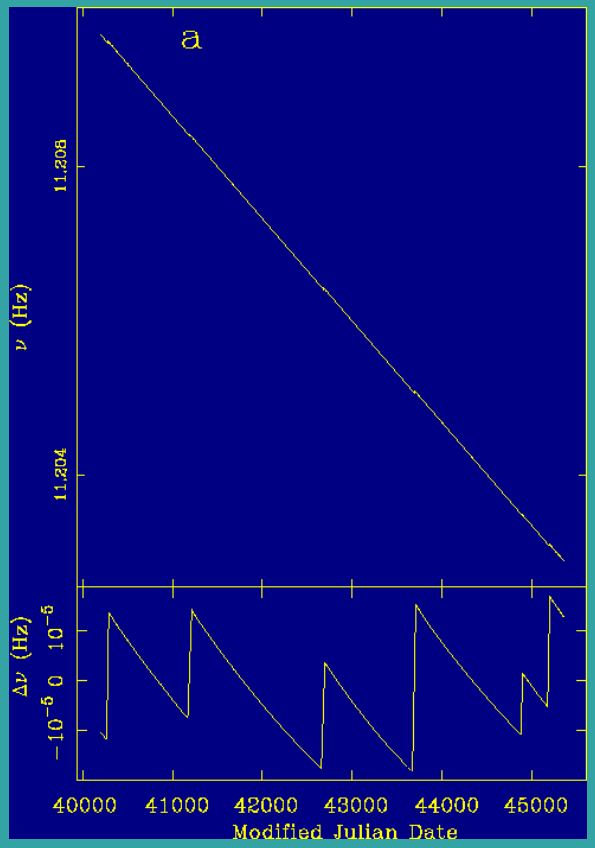


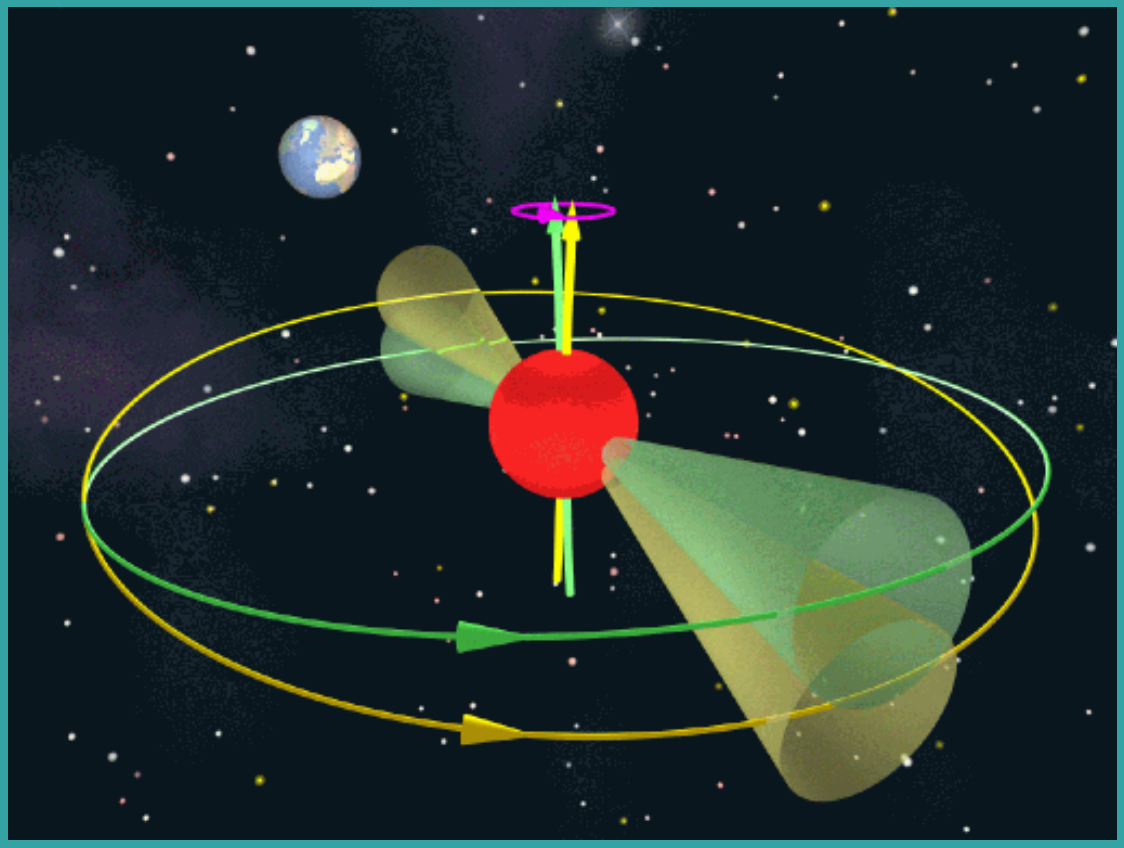
Recently we found the fastest-spinning pulsar: 716 Hz, or just above F5.

Some science to be learned from pulsars....

Properties of neutron stars
Pulsar emission process (difficult!)
Structure of our Galaxy
Pulsar companions and evolutionary history
Gravity-wave background
Tests of General Relativity

Neutron Star Interiors

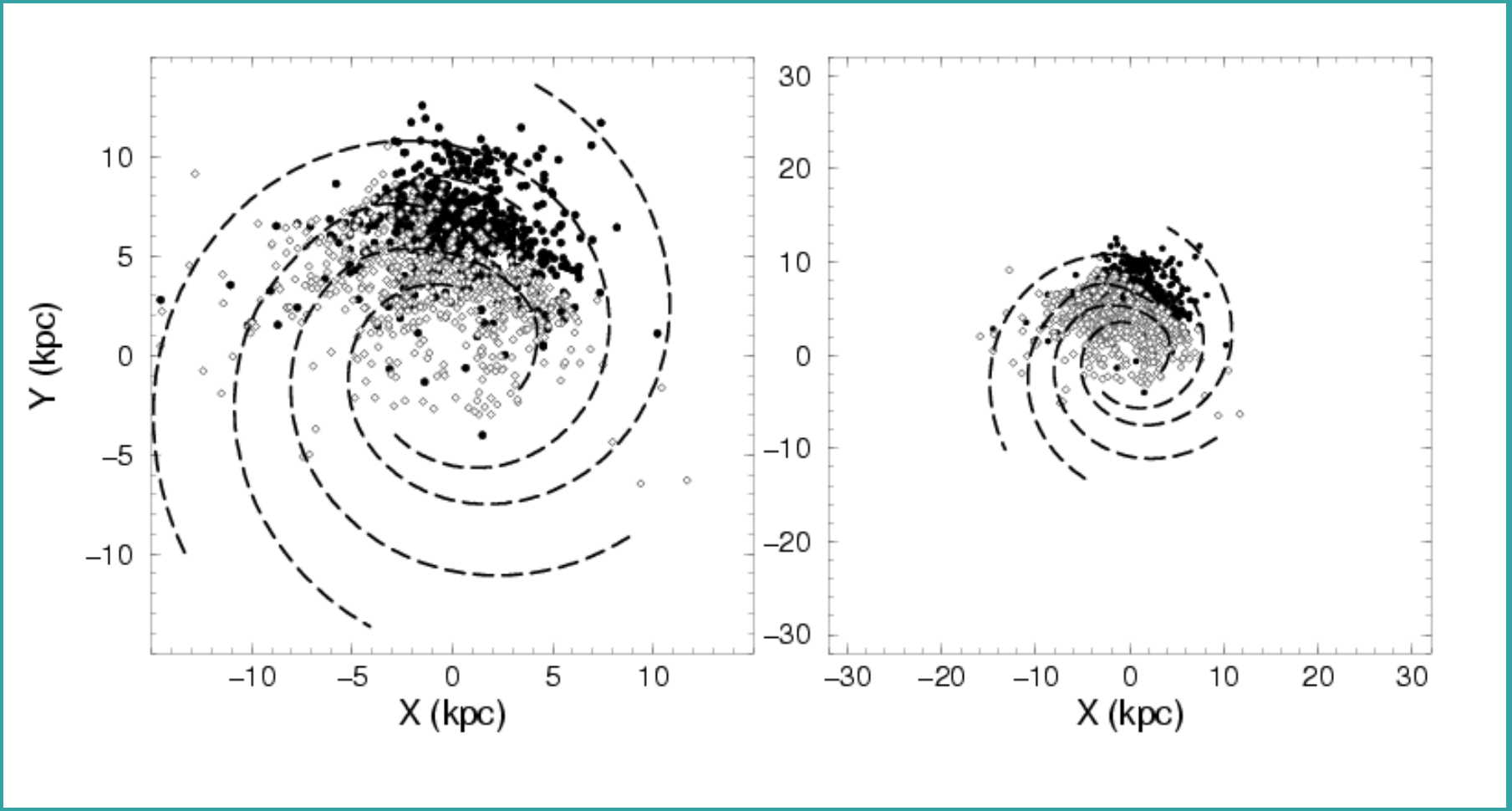




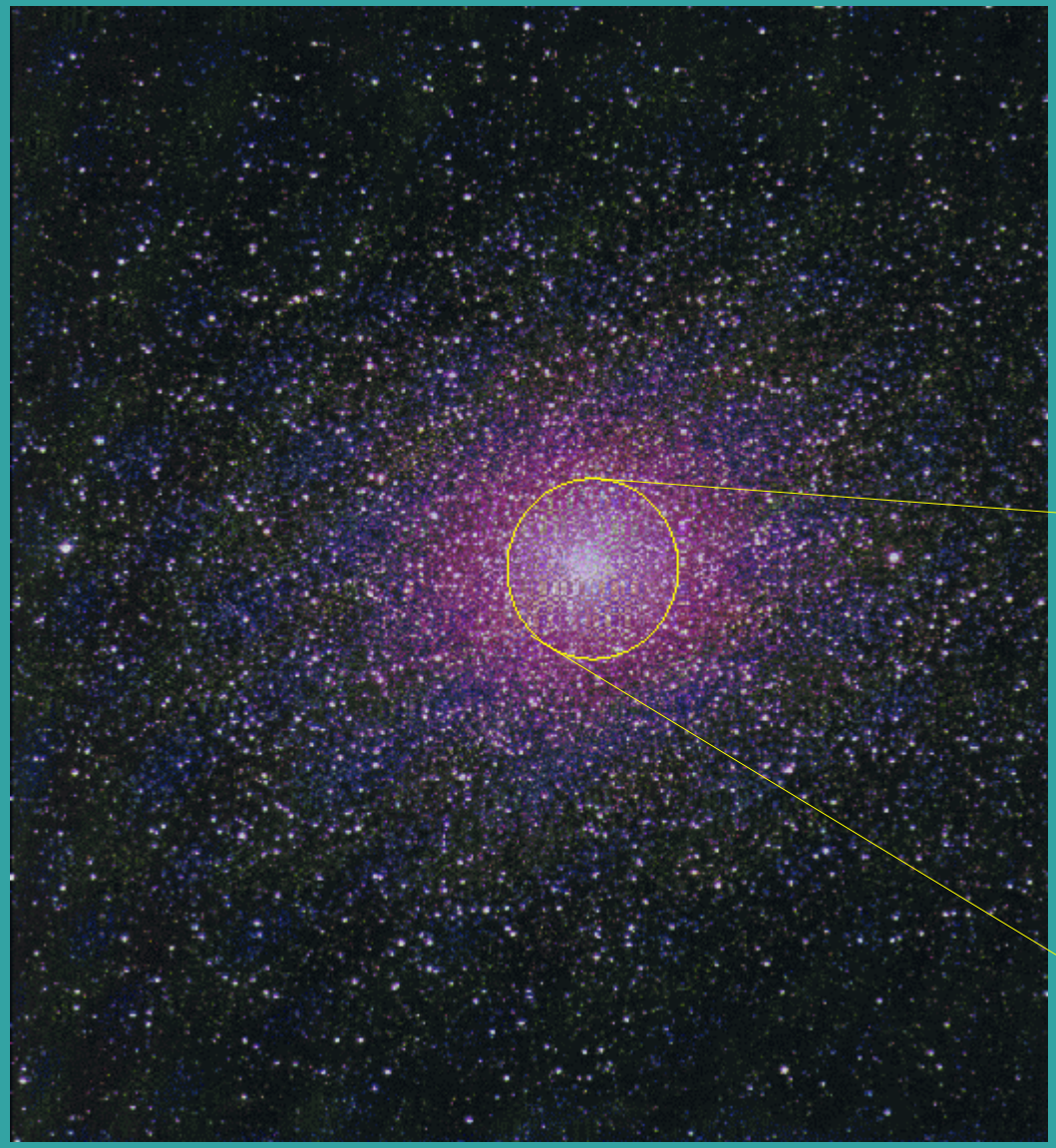
Glitches

Free precession

Pulsars in the Galactic Plane

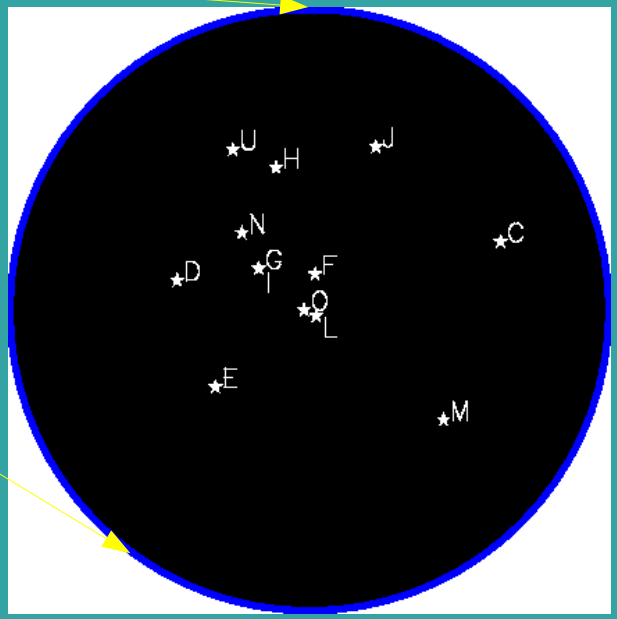


Pulsars in Globular Clusters

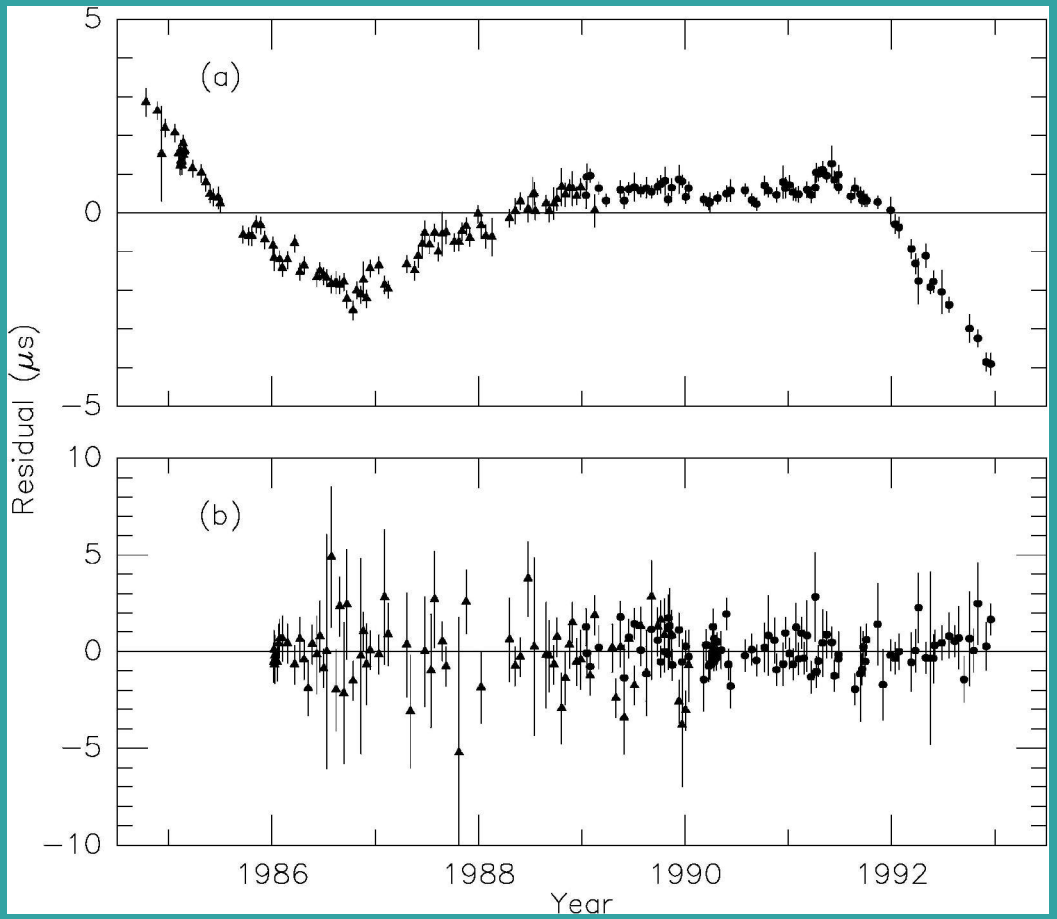


- 47 Tucanae -
  22 millisecond pulsars!

  Terzan 5: 33 pulsars!



Timing Residuals: Actual TOAs – Predicted

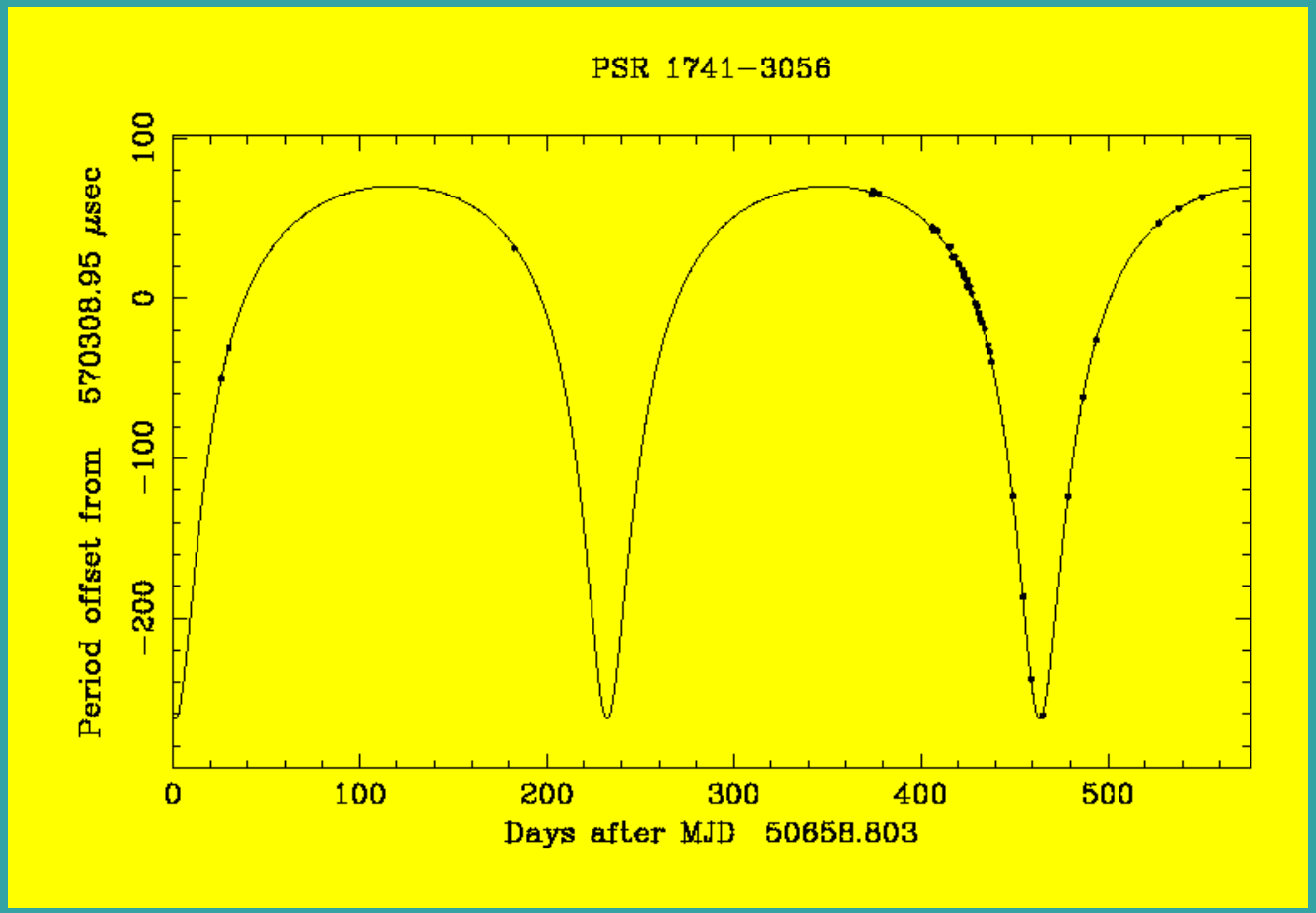


PSR B1937+21

PSR B1855+09

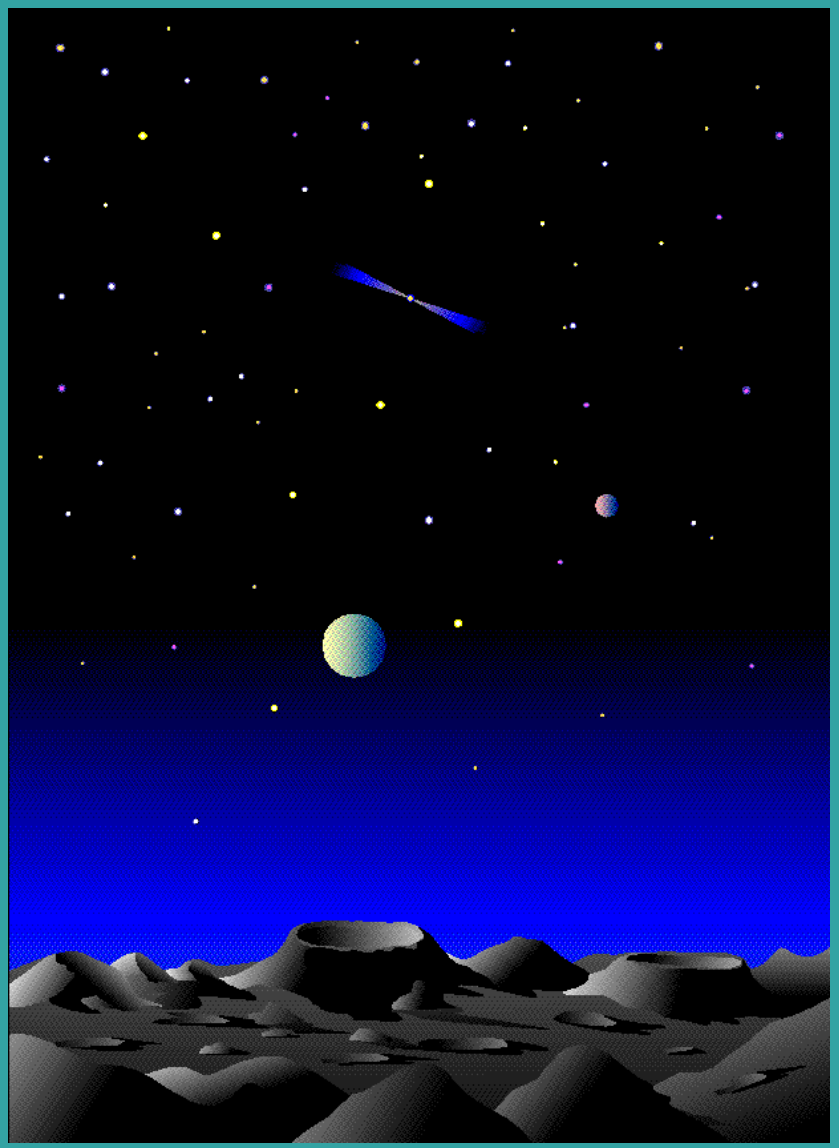
Millisecond pulsars: limits on a gravitational-wave background

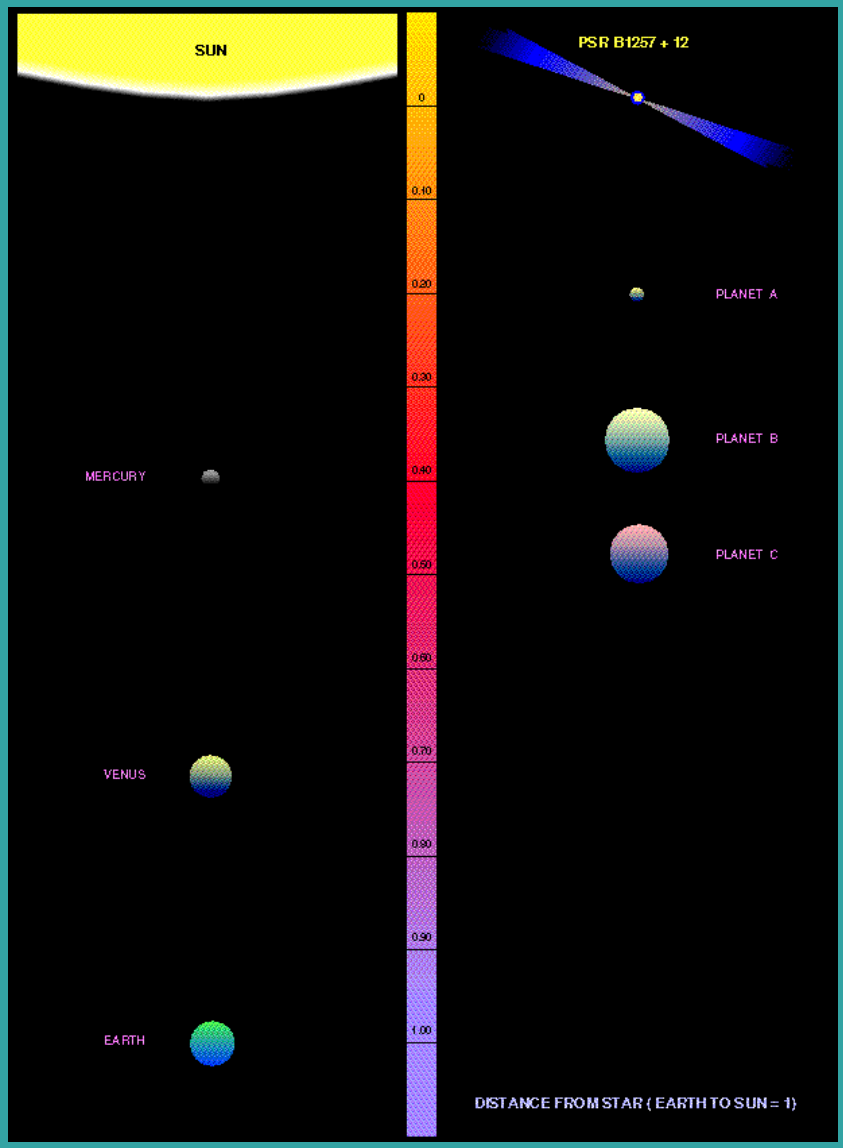
Binary Pulsars



Companions: white dwarfs, neutron stars,
main-sequence stars, planets.... someday black holes??

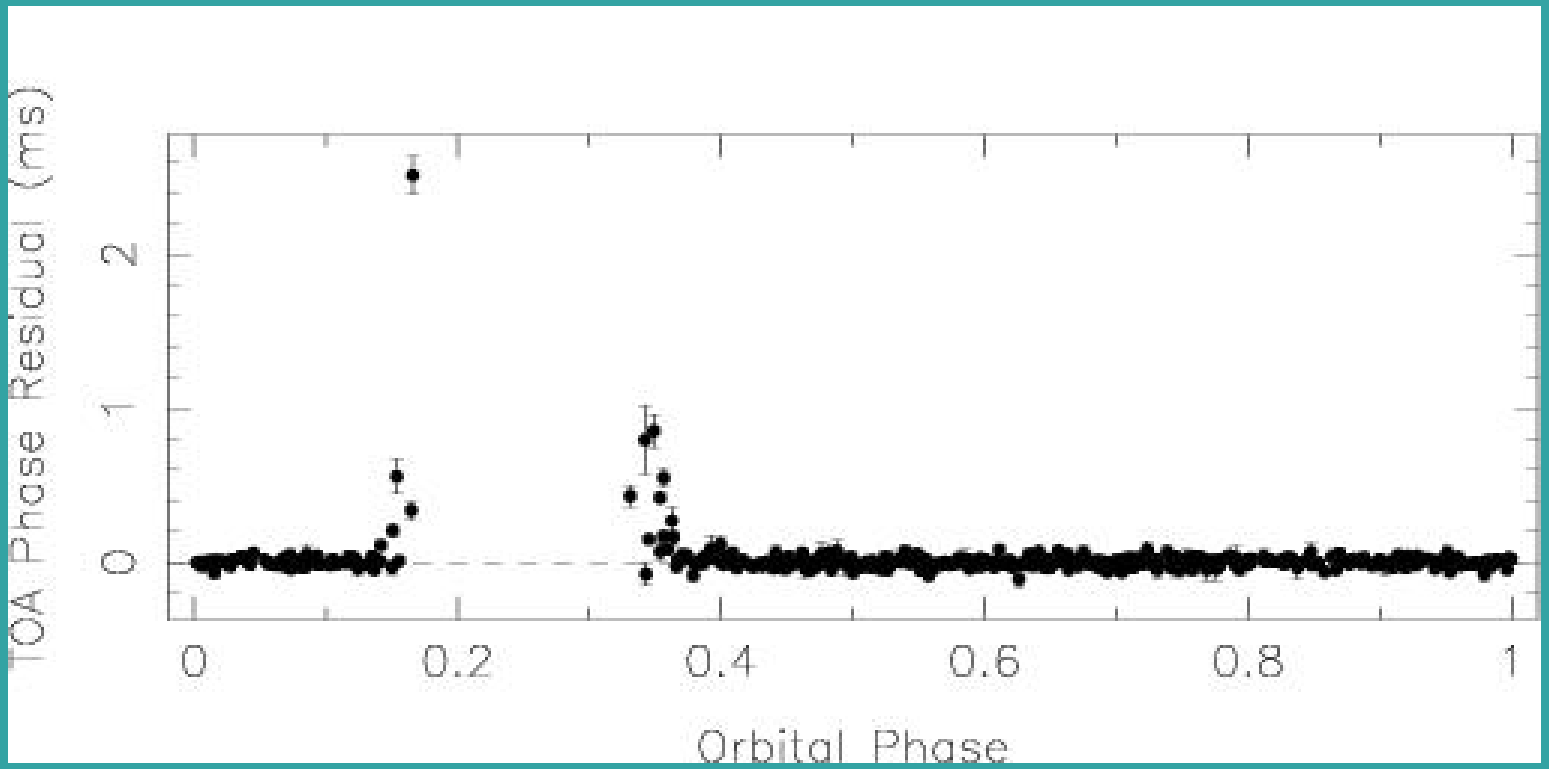
Planets around PSR B1257+12



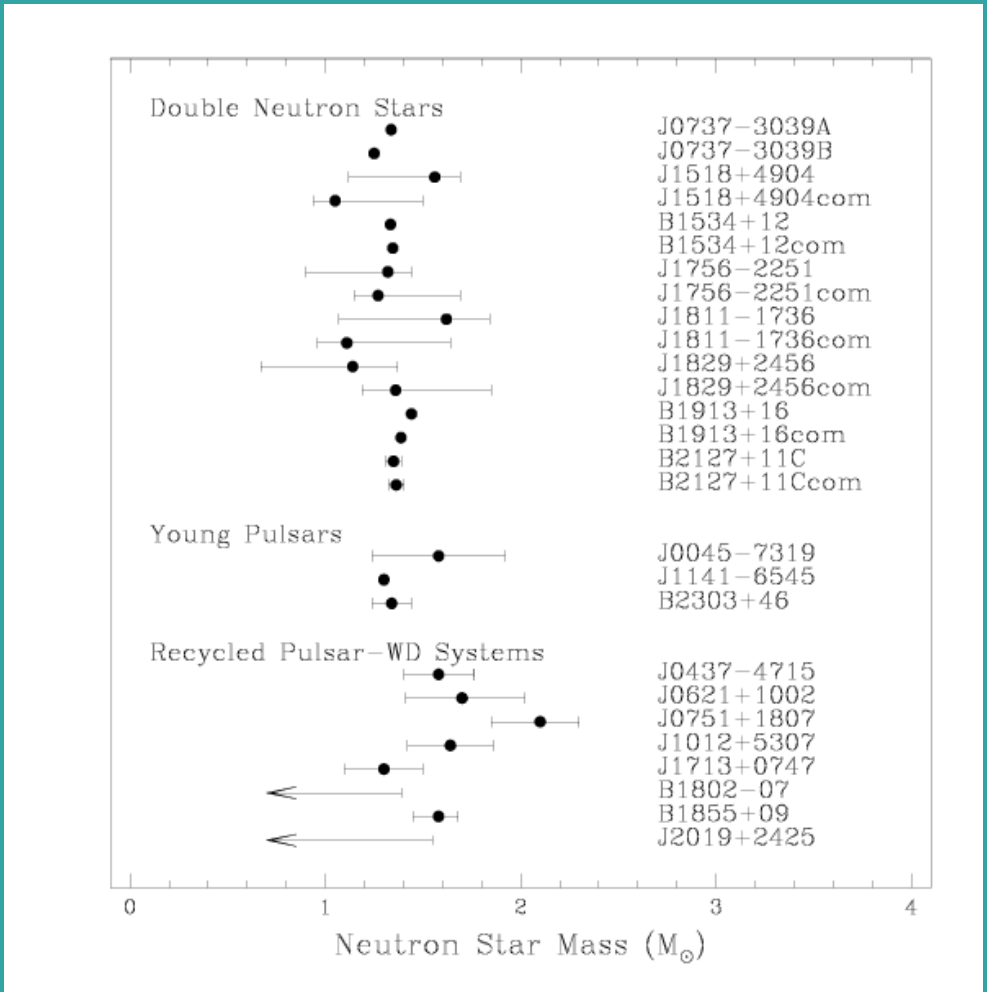


Eclipsing Systems

Pulsars destroying their companions

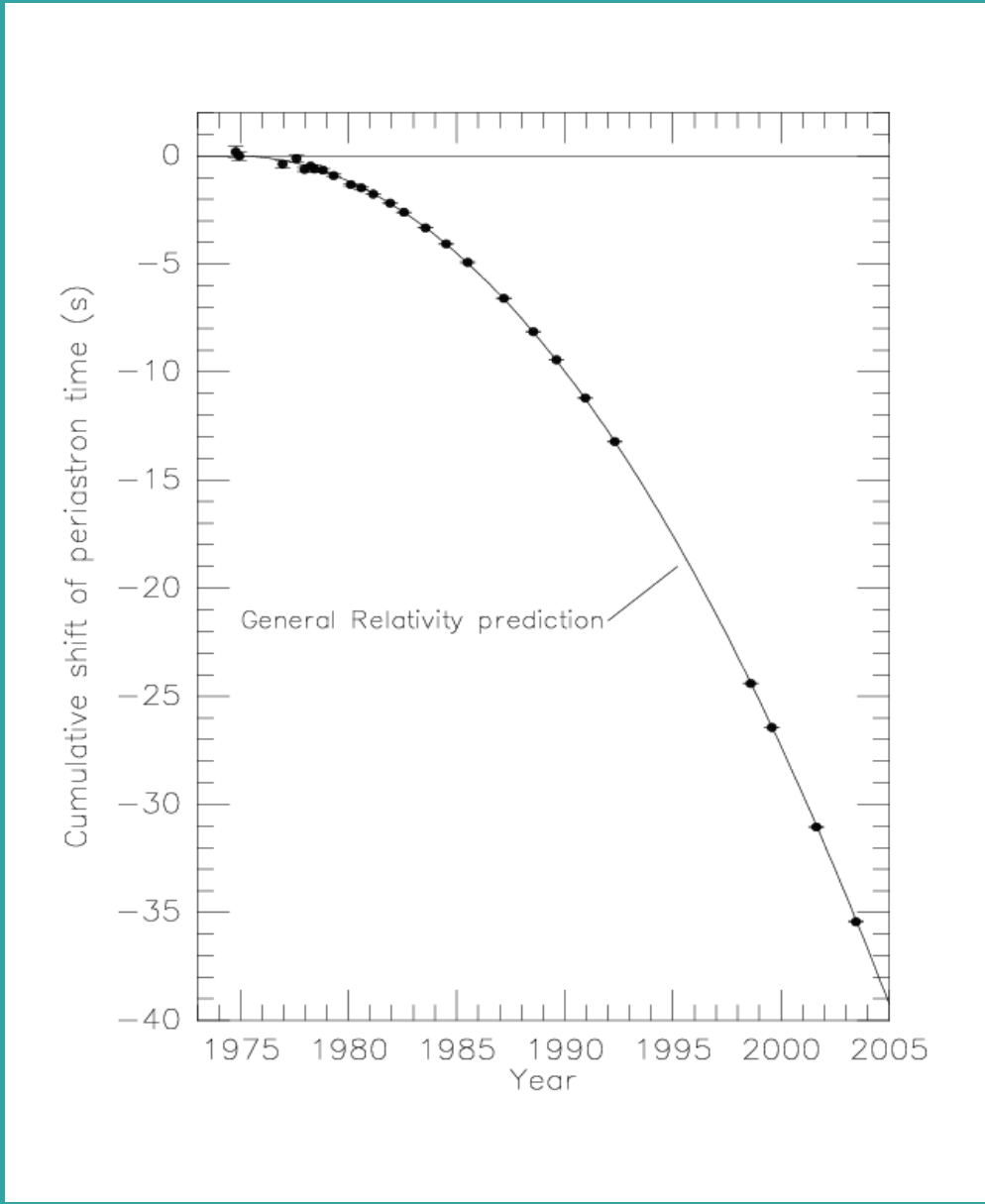


Neutron Star Masses



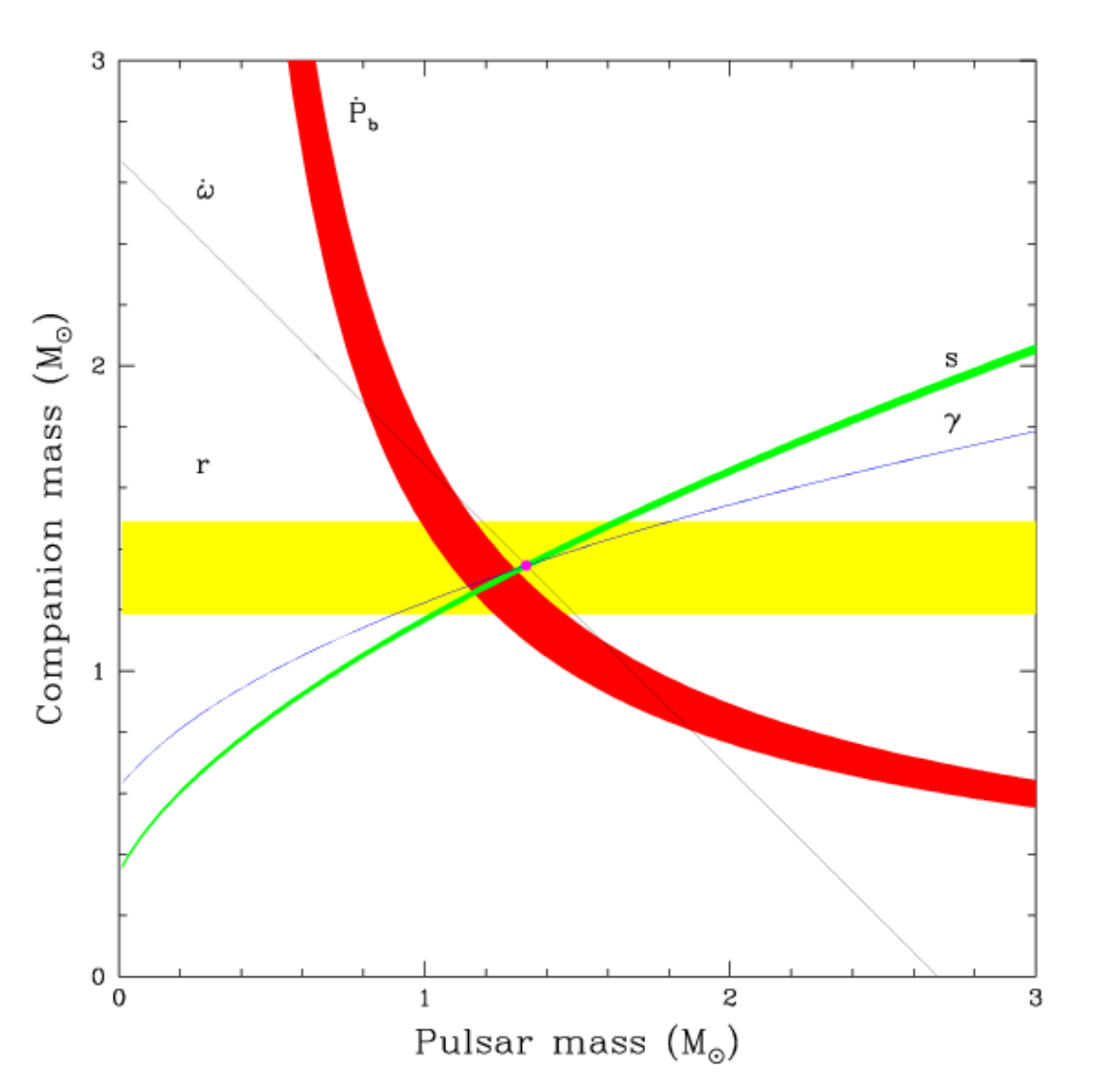
Differences due to evolution? We're working on it!

Double-NS Systems: Tests of GR



PSR B1913+16:
Nobel Prize in
1993 for
Joe Taylor
and
Russell Hulse

PSR B1534+12

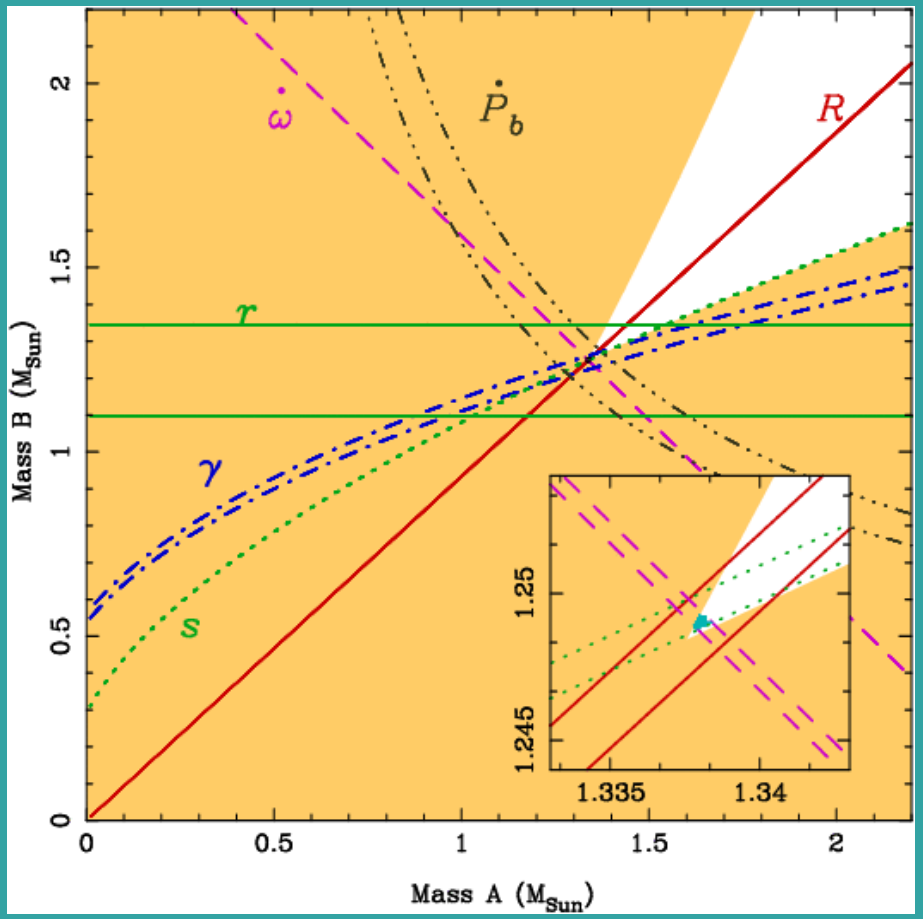


Measure more parameters than for 1913+16, including Shapiro delay

Complementary test of GR

New distance to the pulsar

Amazing new system: the double pulsar!

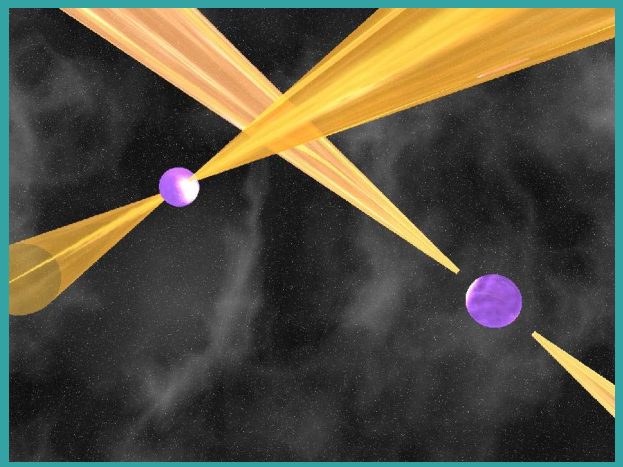


Measure ratio of orbital sizes

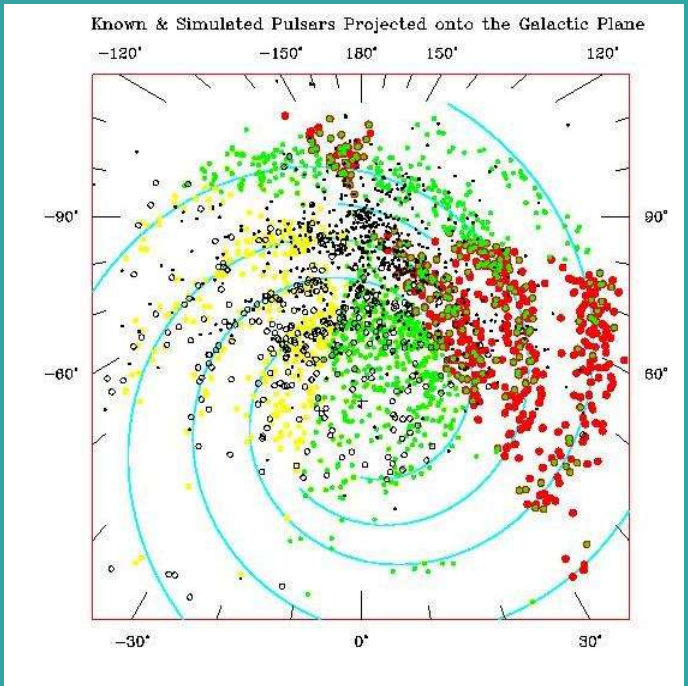
$m_1 a_1 = m_2 a_2$

==> mass ratio

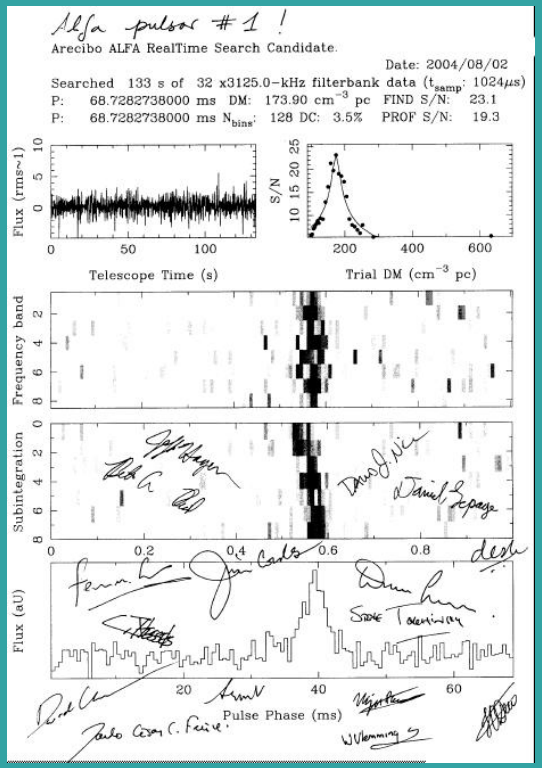
==> completely new test of GR!



What to expect next?

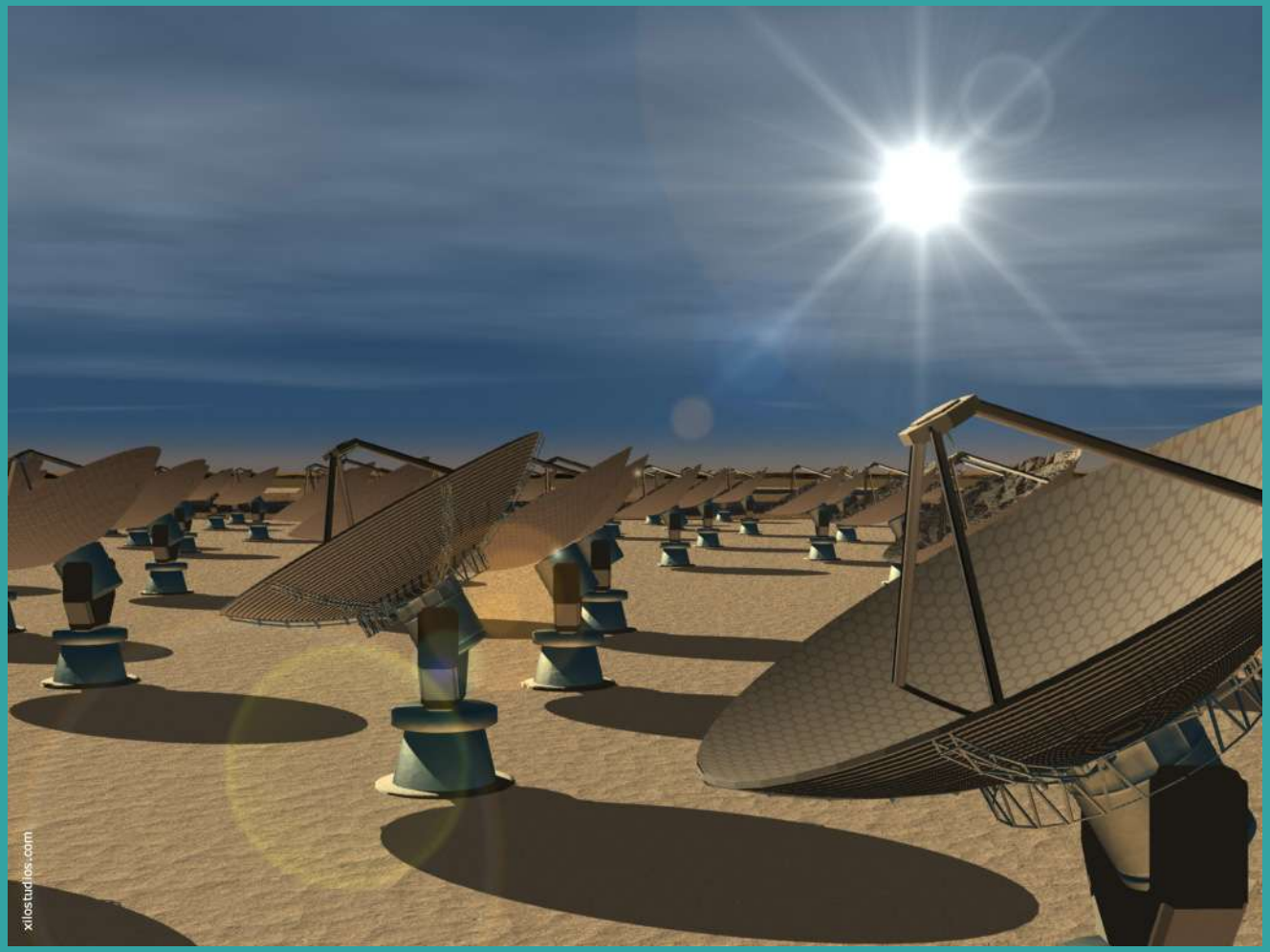


ALFA: Arecibo multibeam surveys – 500-1000 pulsars, very sensitive to ms pulsars. ==> populations, Galaxy



High-precision timing follow-up ==> NS, binary, GR science – We've already found one relativistic system!

Longer term: Square Kilometre Array (SKA)



And will we find that pulsar-black hole system that “must” be out there somewhere??