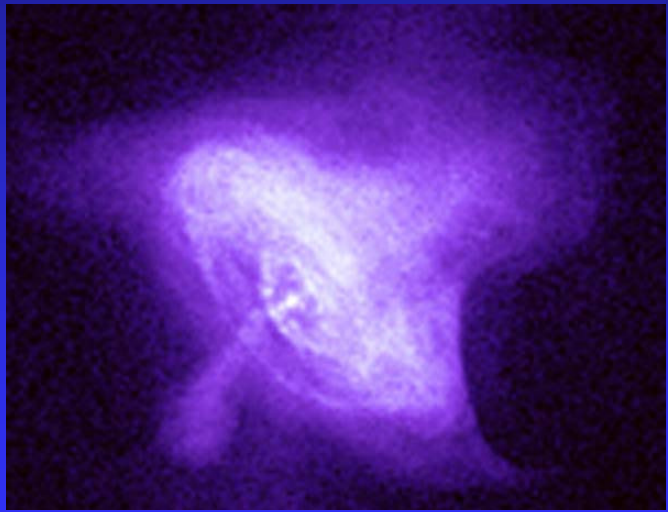
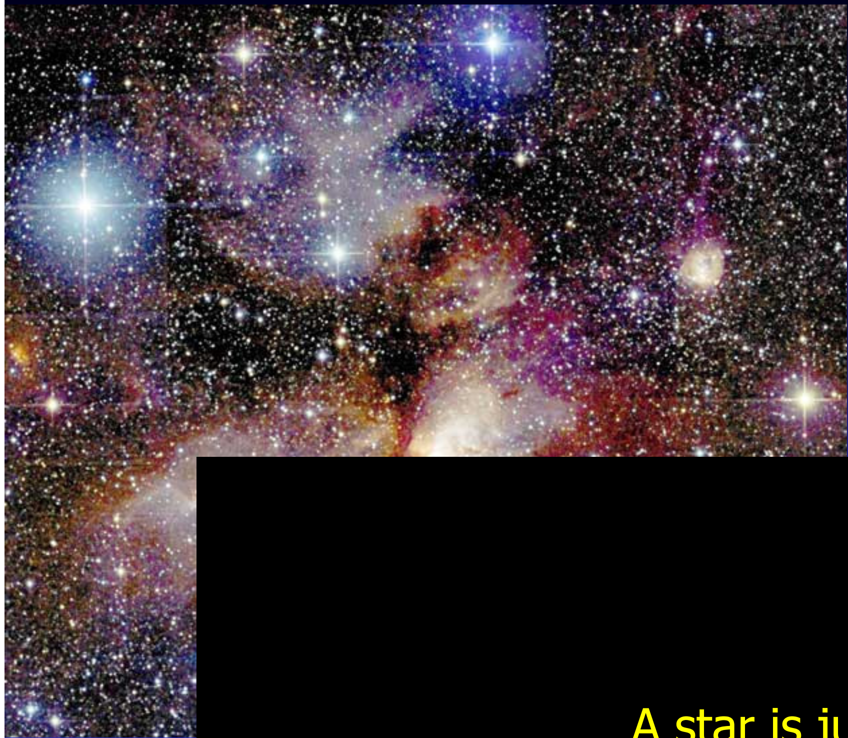
Observations and characteristics of Radio Pulsars

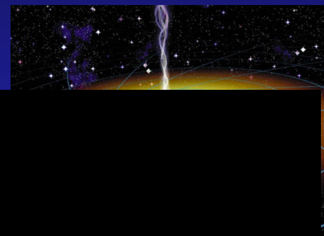


Thomas Tauris

Open Cluster (RCW38) 5500 light years away



Formation of compact objects (stellar death....)



n:

A star is just an intermezzo in the transition from a gas cloud to a compact object!

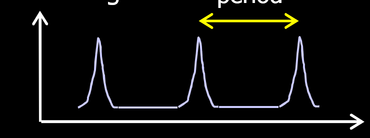
black hole

neutron star

white dwarf

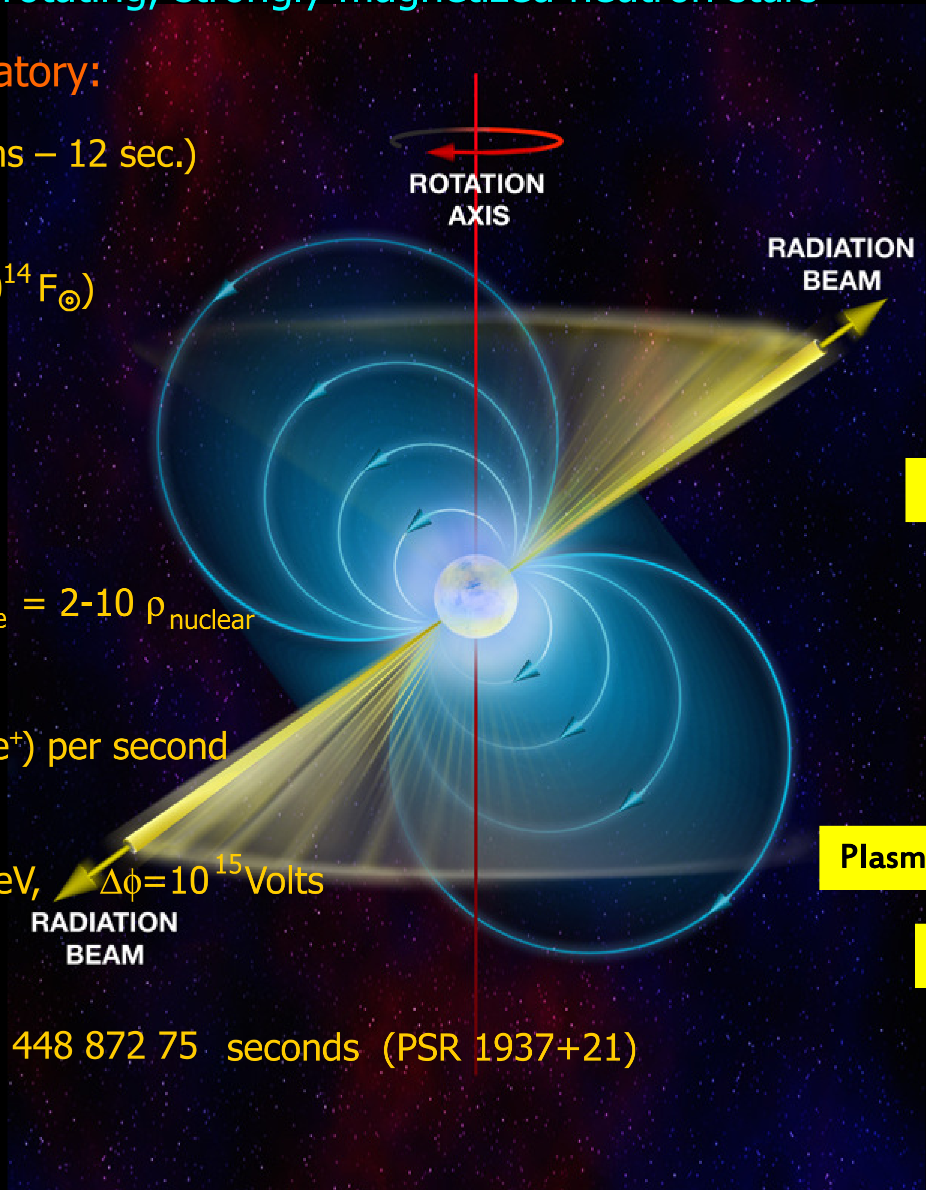
Radio Pulsars

- rotating, strongly magnetized neutron stars



A perfect physics laboratory:

- ✓ ν = 700 Hz (P=1,4 ms – 12 sec.)
- ✓ B = 10^{13}G
- ✓ $\dot{E}_{rot} = 10^{5}\,L_{\odot}$ ($F = 10^{14}\,F_{\odot}$)
- ✓ M = 1.4 $M_{\odot}$
- ✓ R = 10 km



Giant atomic nucleus:

- ✓ A=10^{57} baryons, $\rho_{core} = 2\text{-}10\,\rho_{nuclear}$

Magnetosphere:

- ✓ production of 10^{38}(e^{-} e^{+}) per second
- ✓ TeV γ-rays
- ✓ e^{-} accelerated to 10^{15} eV, $\Delta\phi=10^{15}$Volts

Perfect clock:

- ✓ P= 0.001 557 806 448 872 75 seconds (PSR 1937+21)

Particle physics

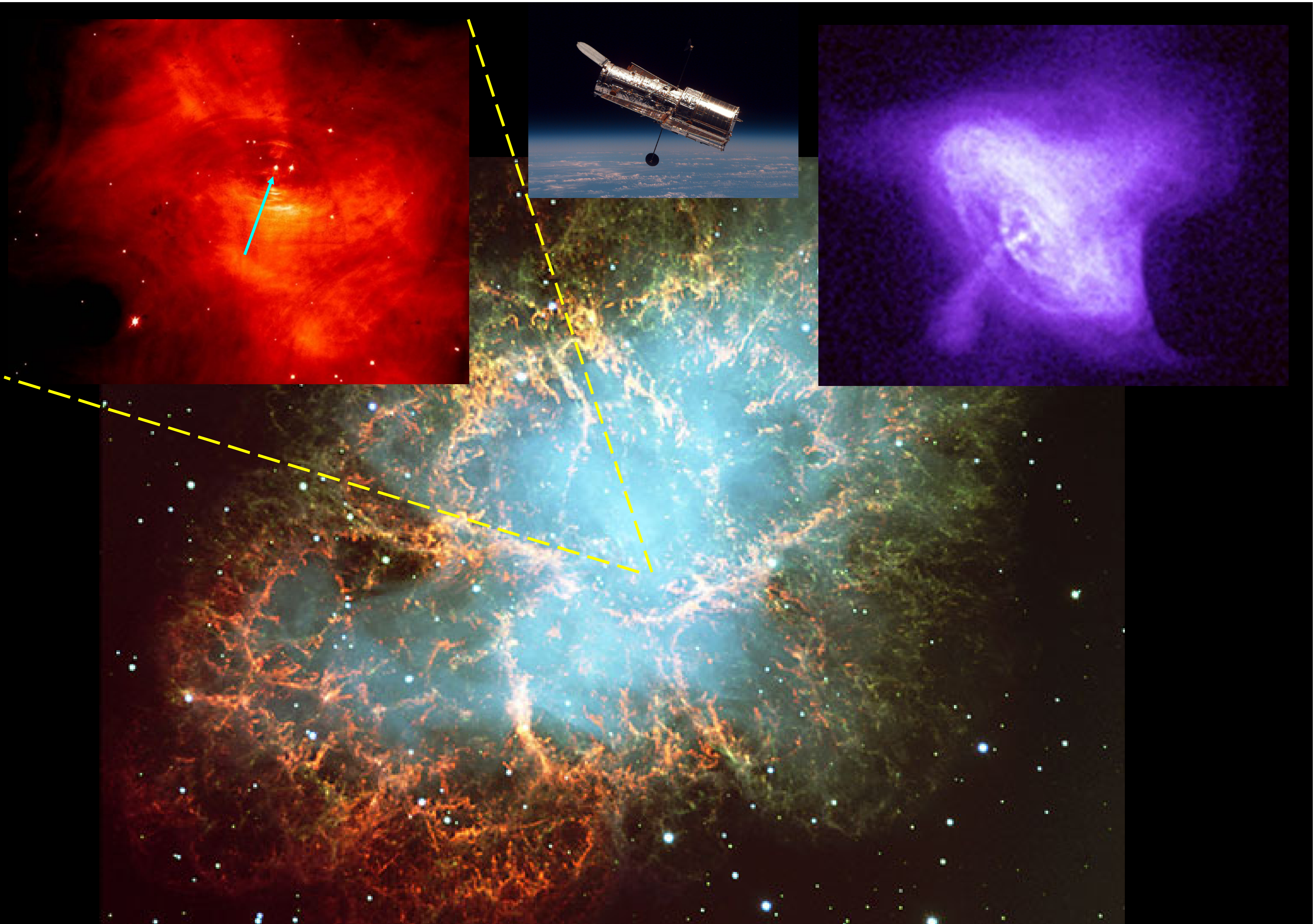
Nuclear physics

Solid state physics

Atom physics

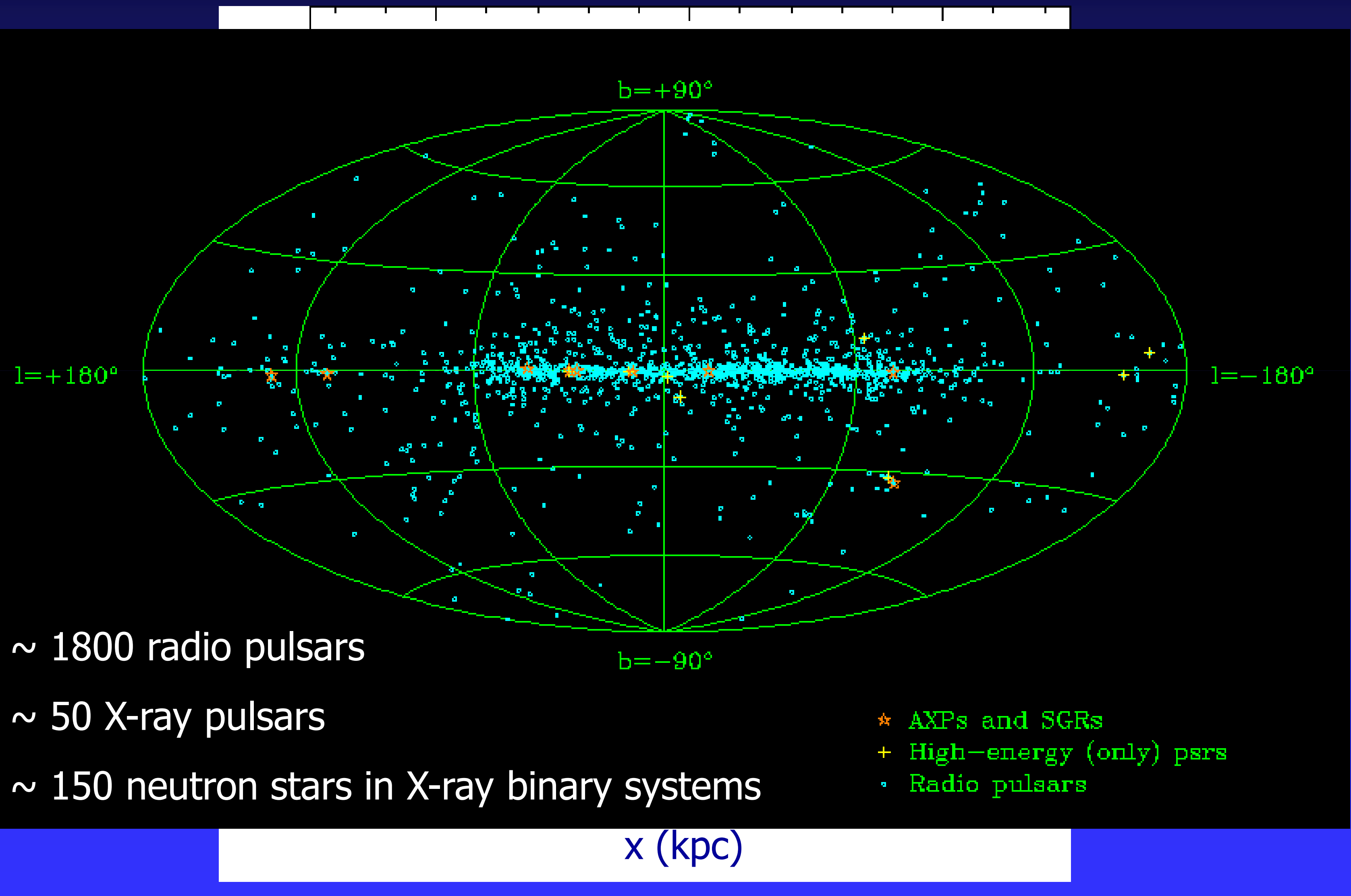
Plasma physics

Relativity



This supernova was observed by Chinese astronomers in 1054 a.d.
Today we observe a rapidly rotating neutron star (pulsar) with a period of 33 ms.

Detected radio pulsars in our Milky Way:



~ 1800 radio pulsars

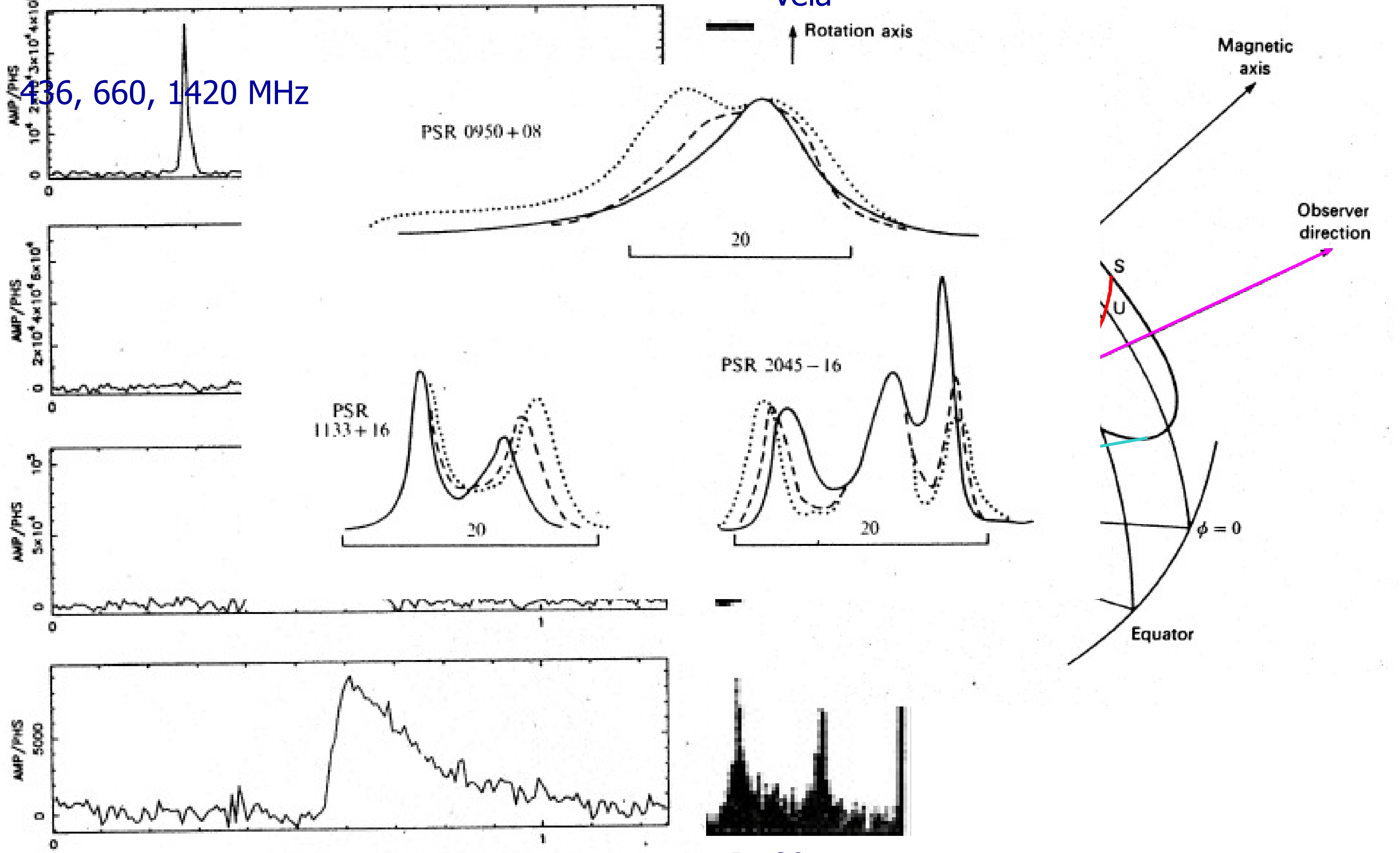
~ 50 X-ray pulsars

~ 150 neutron stars in X-ray binary systems

Pulsar pulse profiles

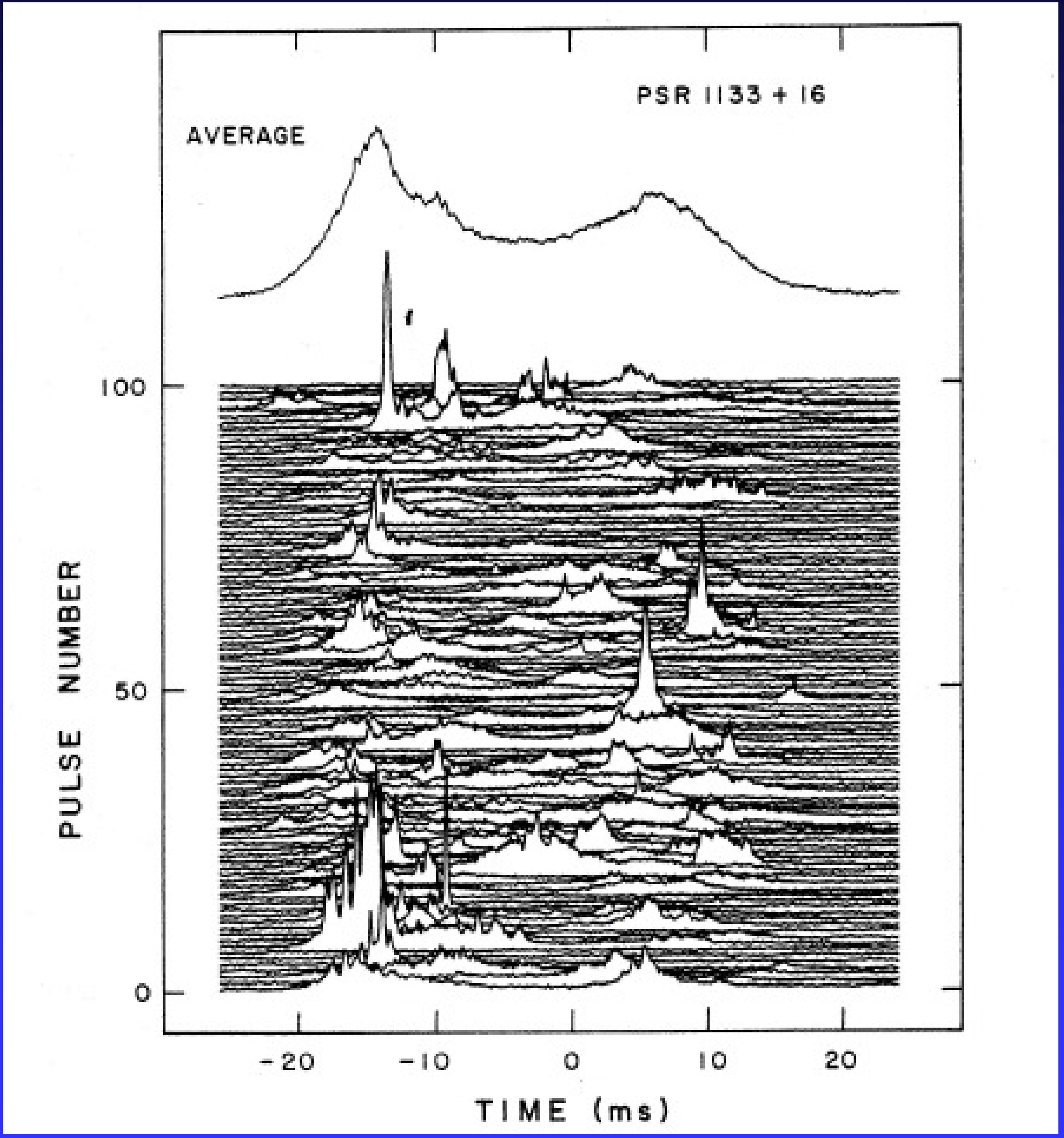
Vela

436, 660, 1420 MHz

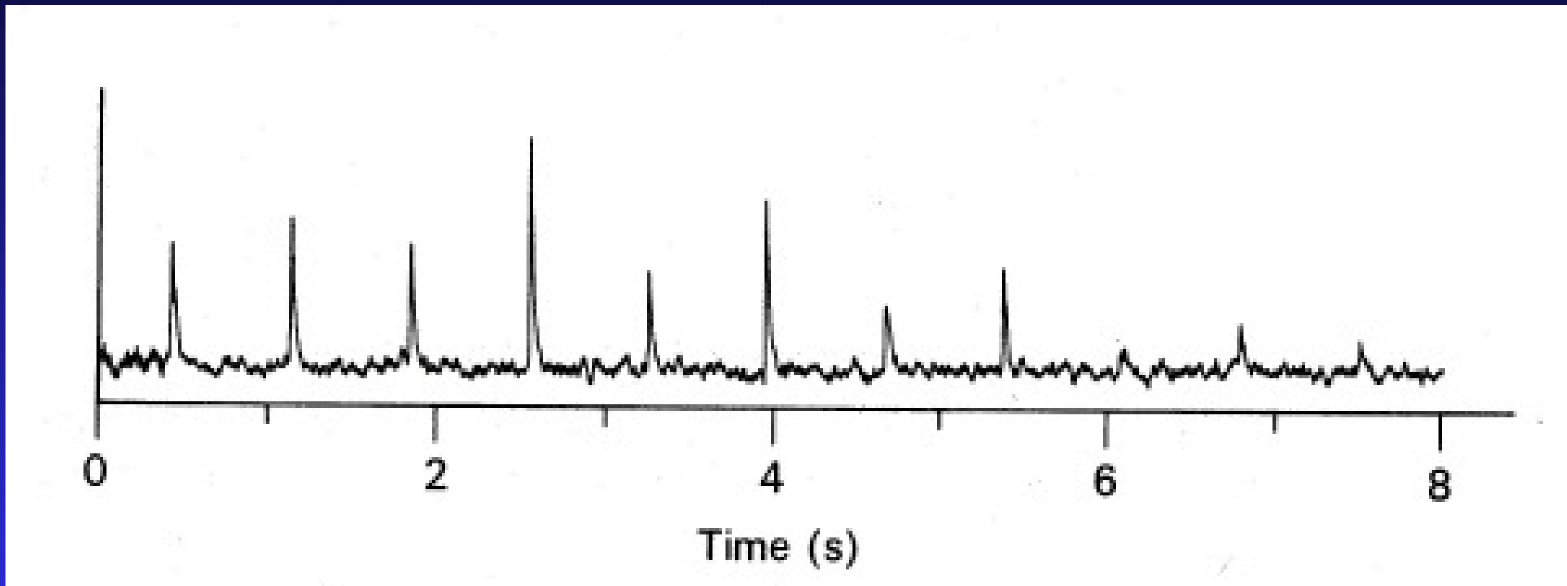


P=89 ms.

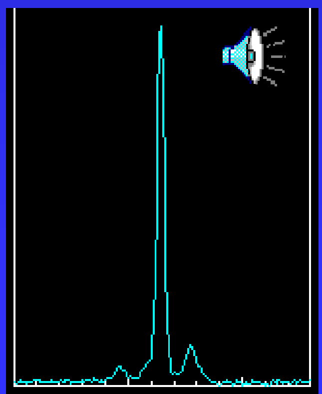
Pulsar pulse profiles



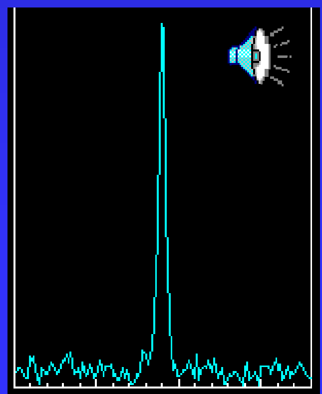
Pulsar pulse profiles



PSR 0329+54

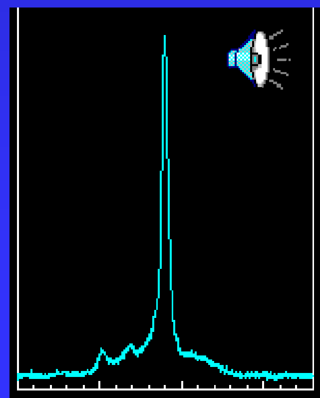


Vela

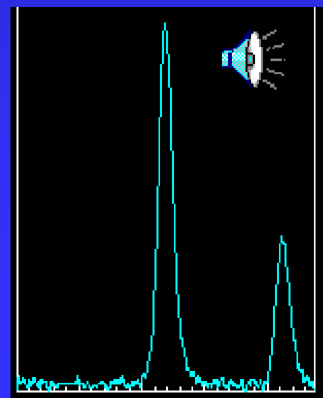


Crab

PSR 0437-4715

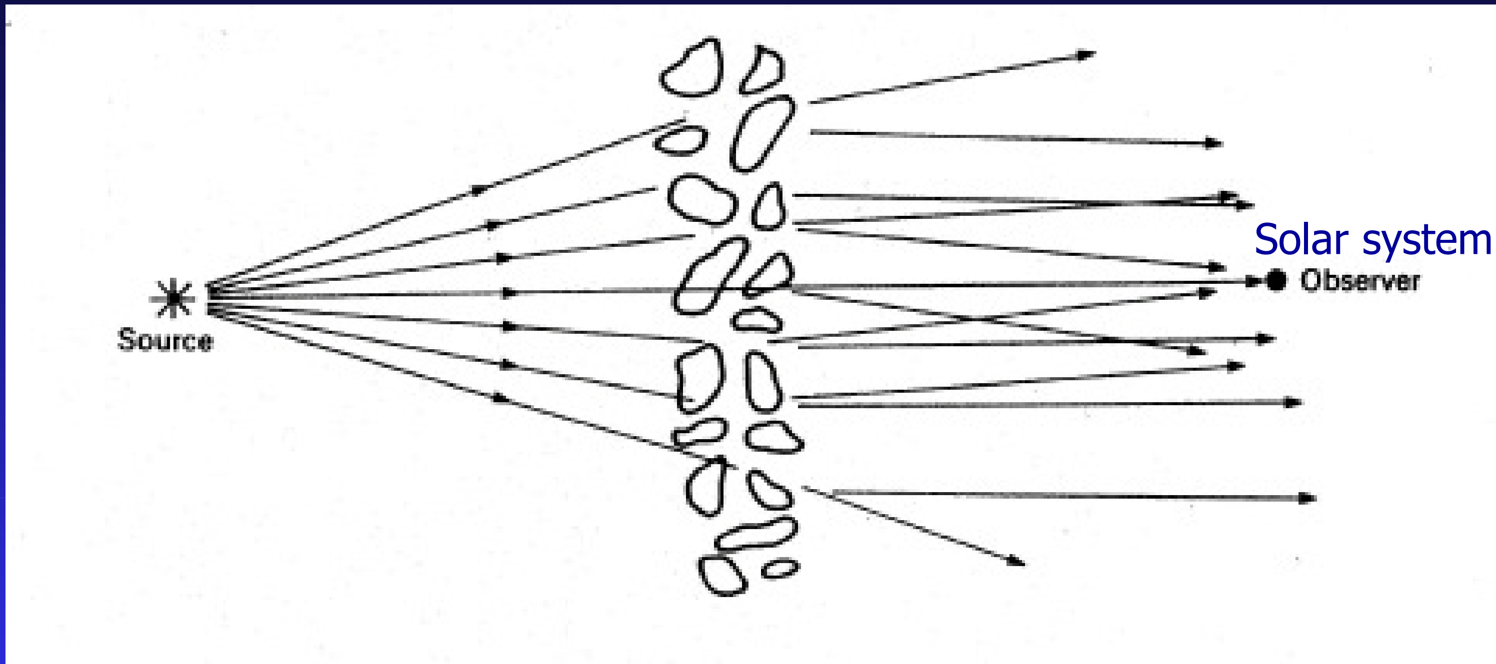


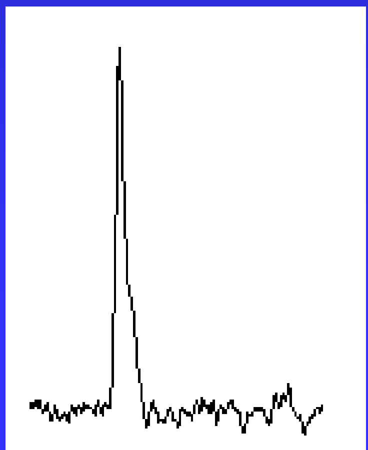
PSR 1937+21



Cosmic orchestra in 47 Tuc

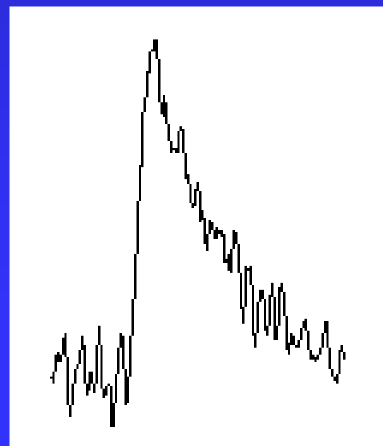
Scintillation (interstellar weather)





emitted pulse

observed pulse



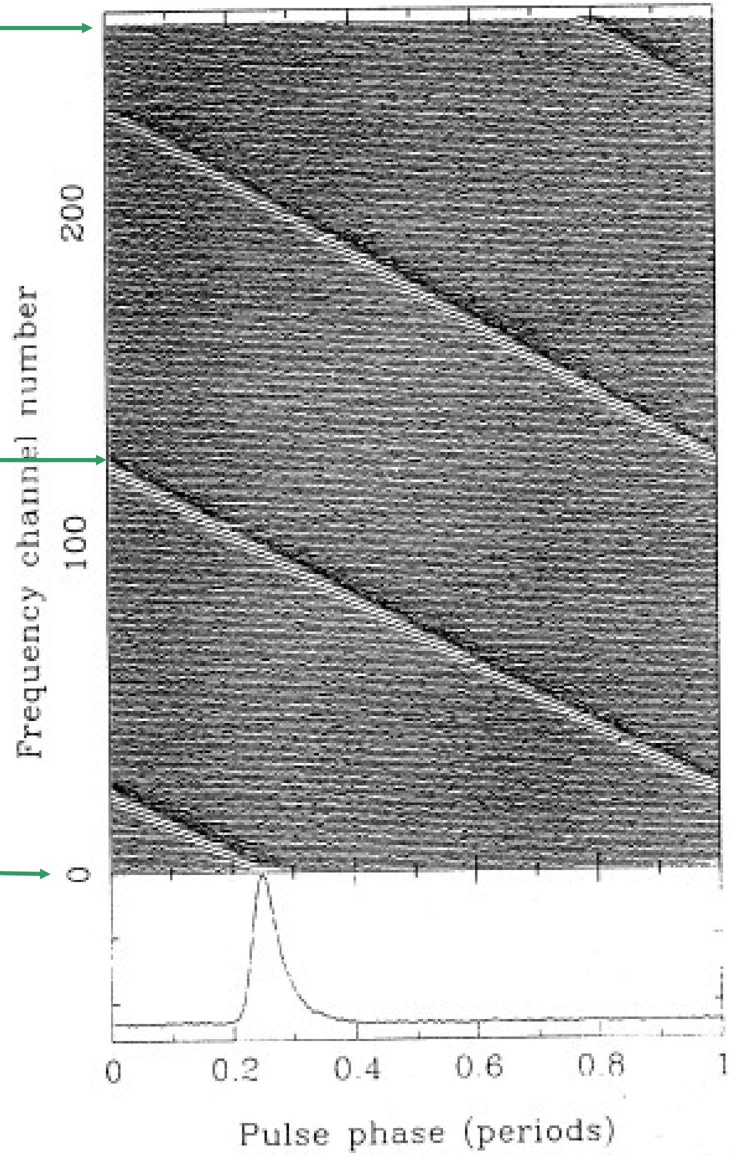
Distance determination of pulsars

452 MHz

256 channels
* 125 kHz

436 MHz
(70 cm)

420 MHz

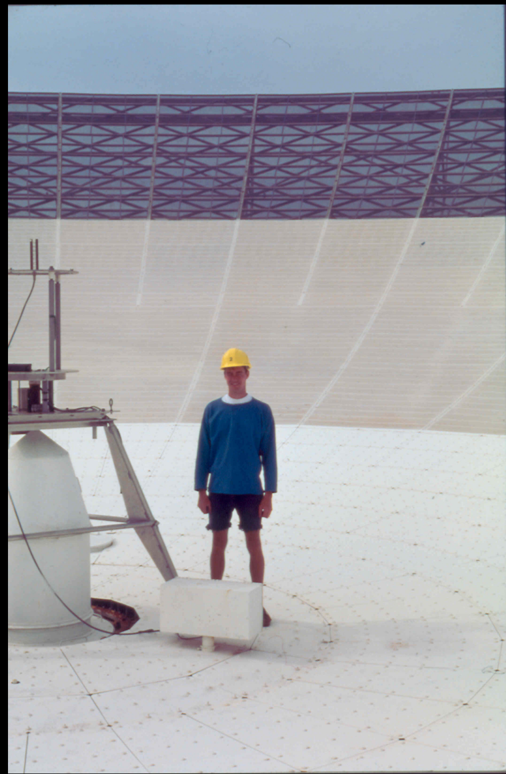


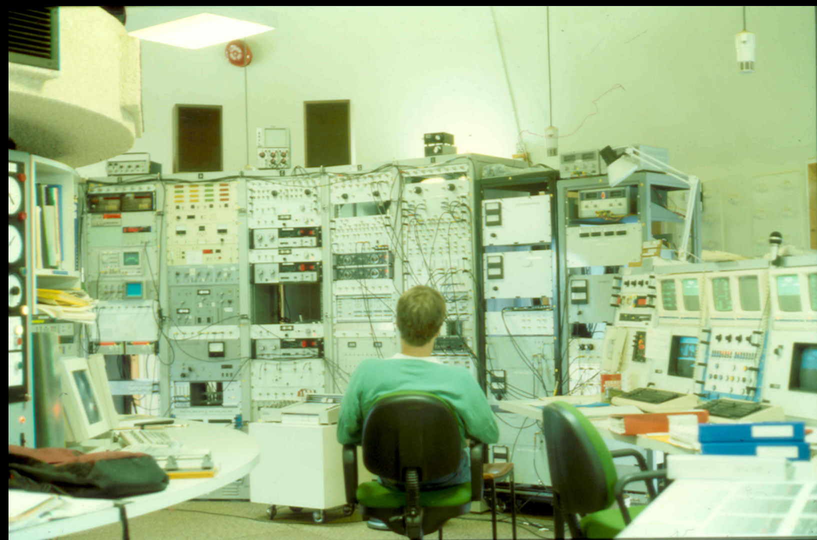
$$\frac{\Delta t_a}{\Delta \omega} = -\frac{4\pi e^2}{m_e c\, \omega^3} DM$$

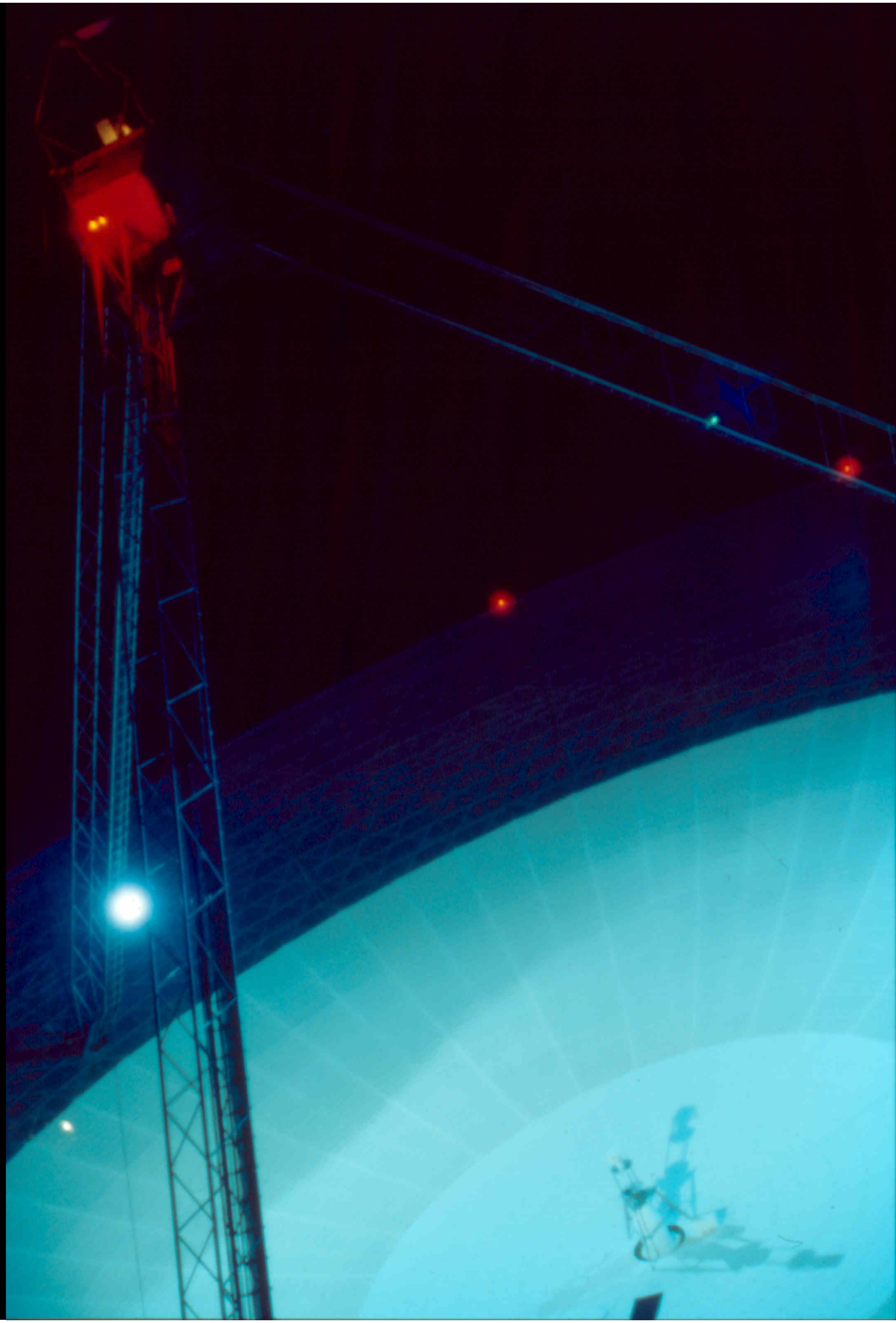
$$DM = \int_0^L n_e\, dl = \langle n_e \rangle L$$

slope α 1/distance


Parkes (64 meter)
Radio Telescope
(NSW, Australia)





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ATCA, Narrabri
(NSW, Australia)
6 km. baseline

The spin evolution of pulsars!

Radio pulsar $(P,\dot{P})$ diagram

The magnetic-dipole model:

$$\dot{E}_{dipole} = -\frac{2}{3c^3}|\ddot{m}|^2$$

$$|\ddot{m}| \sim BR^3\Omega^2 \sin\alpha$$

$$E_{rot} = \frac{1}{2} I_{NS}\Omega^2 \quad (\Omega = 2\pi / P)$$

$$\dot{E}_{rot} = I_{NS}\Omega\dot{\Omega}$$

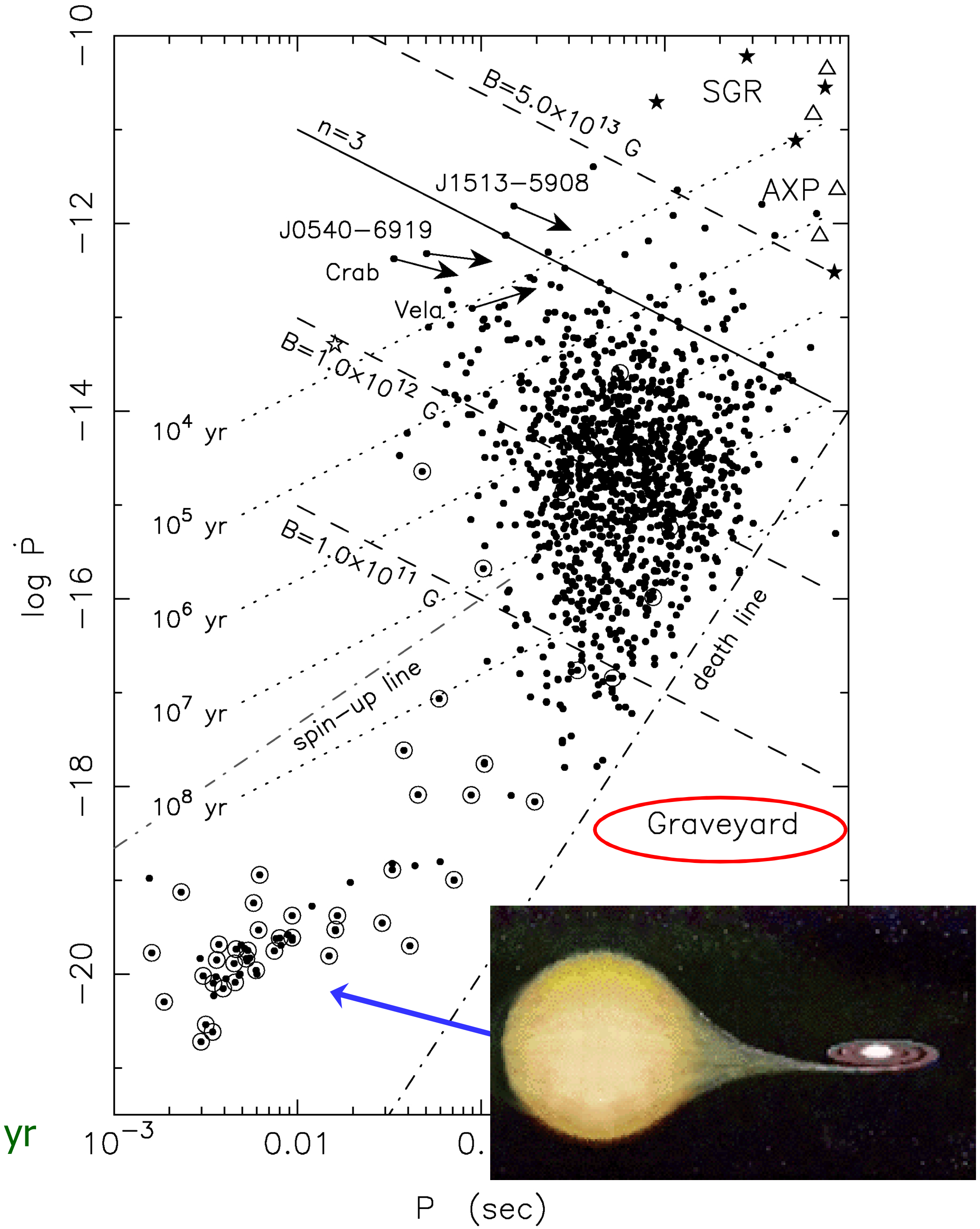
$\Updownarrow$

$$B = \sqrt{\frac{3c^3 I_{NS}}{8\pi^2 R_{NS}^6} P\dot{P}}$$

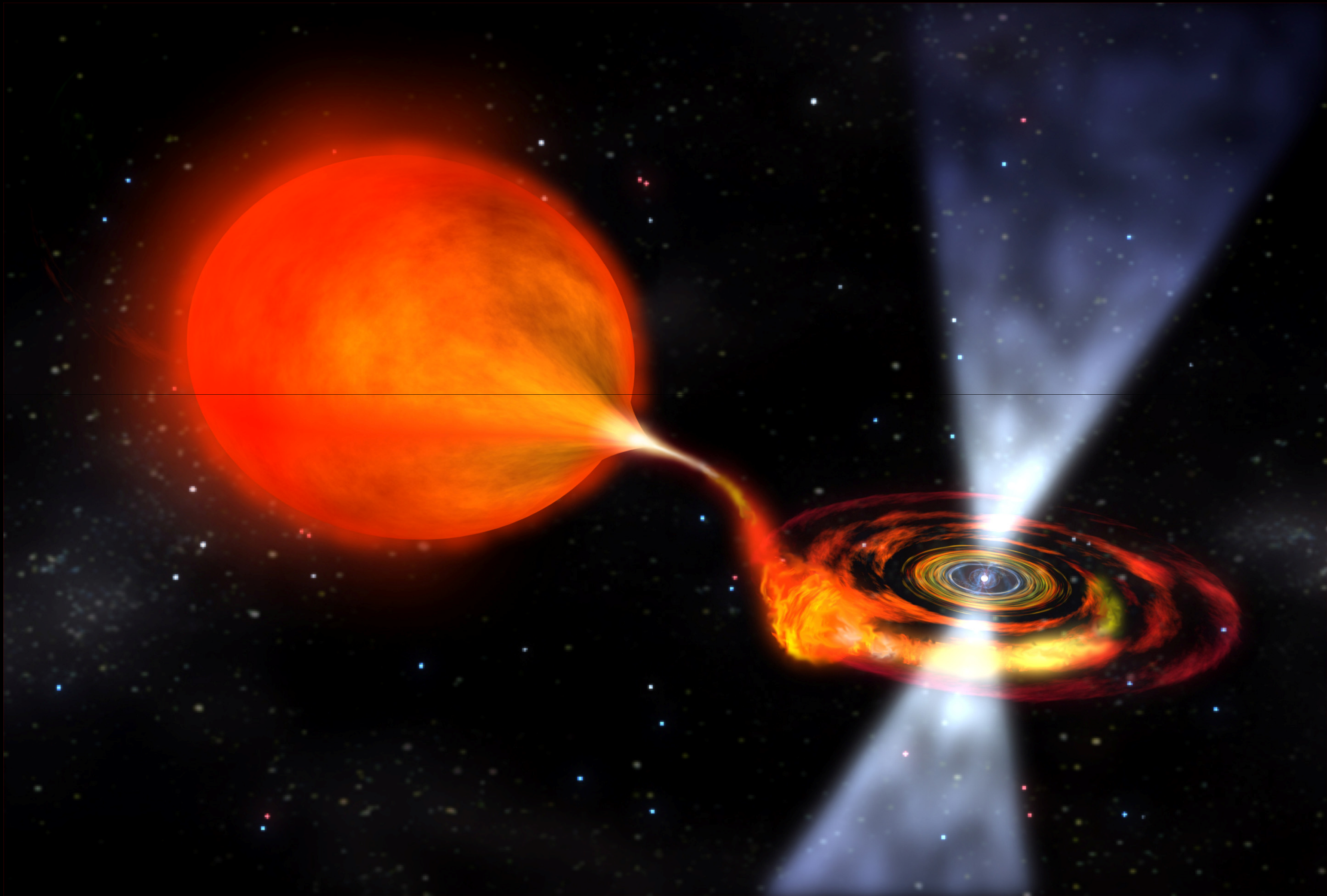
$$\tau \equiv \frac{P}{2\dot{P}}$$

Characteristic age

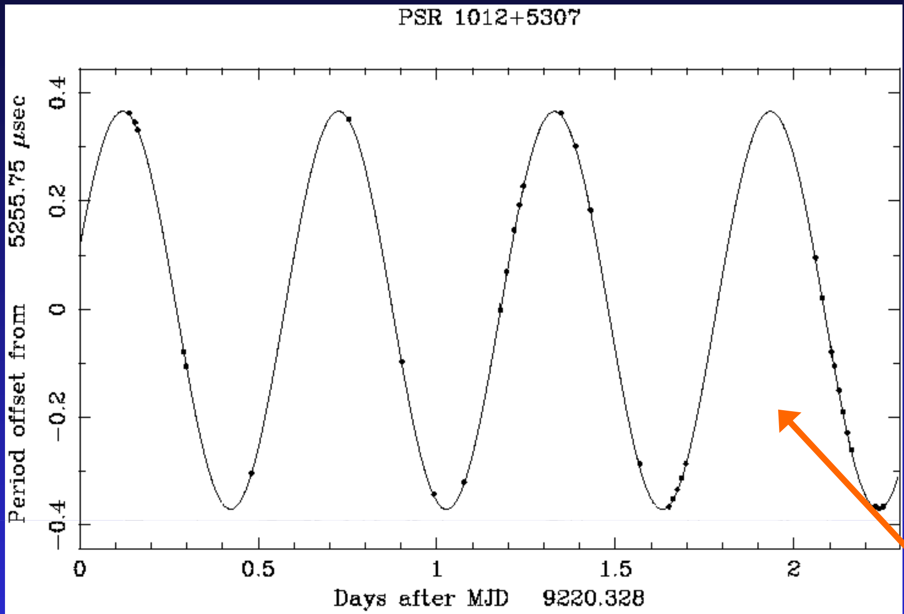
Active pulsar lifetime: 10-50 million yr

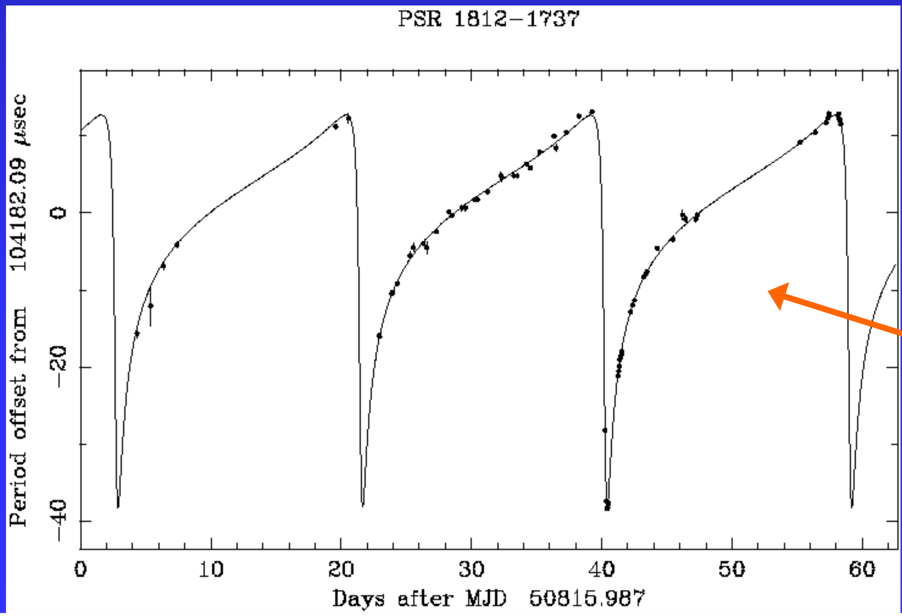


Spin-up of a neutron star

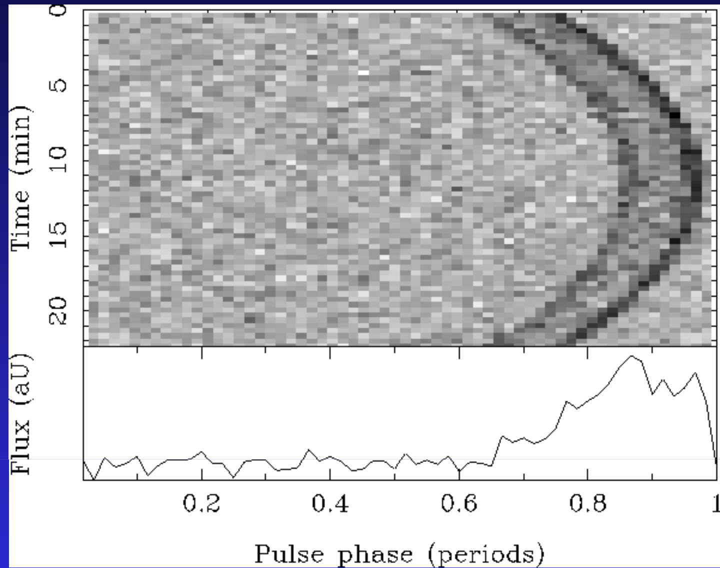


Detection of binary pulsars





binary pulsar

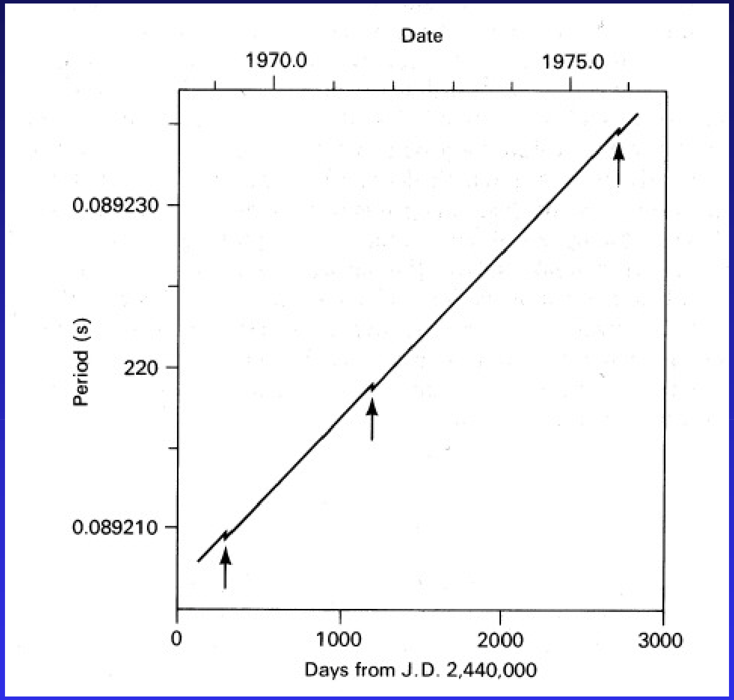


Dopplershift of signal

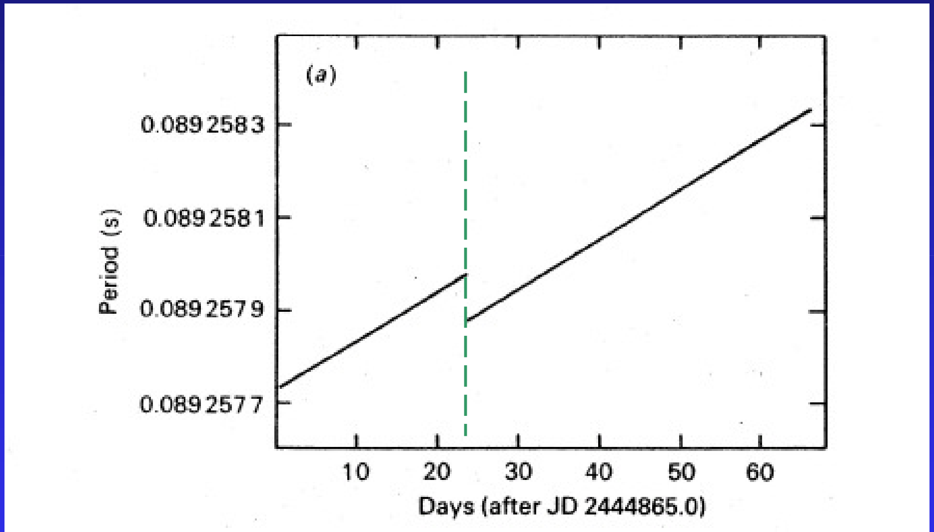
circular orbit
(NS + WD system)

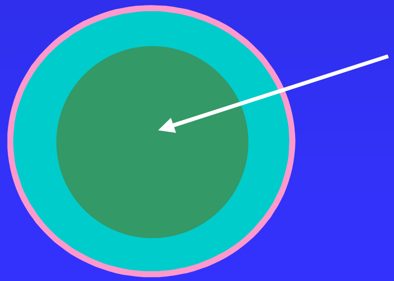
elliptical orbit
(double NS system)
PSR J0737-3039

Glitches (*star quakes* in neutron stars)



Vela (89 milliseconds)





Core of superfluid neutrons

Rarotonga


SUN = 100 × EARTH
MOON = 1/4 × EARTH
4500 000 000
COMET
METEOR
VENUS
MERCURY
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
1 A.U.
100 000 000 000
BIG BANG
NEAREST STAR: 270 000 A.U
NEW ZEALAND