Title: Victoria Kaspi: The Cosmic Gift of Neutron Stars

Date: Feb 03, 2016 07:00 PM

URL: http://pirsa.org/16020084

Abstract: Neutron stars are a celestial gift to scientists. These incredibly dense collapsed stars act as very precise cosmic beacons that help shed light on some of the most challenging problems in modern physics.

In her Feb. 3 talk at Perimeter Institute, astrophysicist Victoria Kaspi will explore these strange objects, explain how astronomers are using them to study issues ranging from the origins of the universe to the very nature of matter, and even let the audience hear the cosmic symphony they create.

Arecibo Radio Telescope in Puerto Rico

Diameter: 305 m

Pulsar “Sounds”


PSR B0329+54 P=0.7s

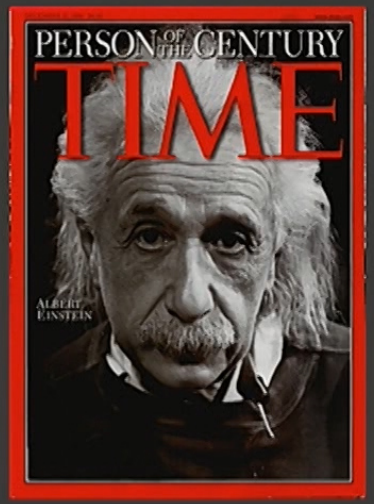

PSR B0833-45 P=0.089s

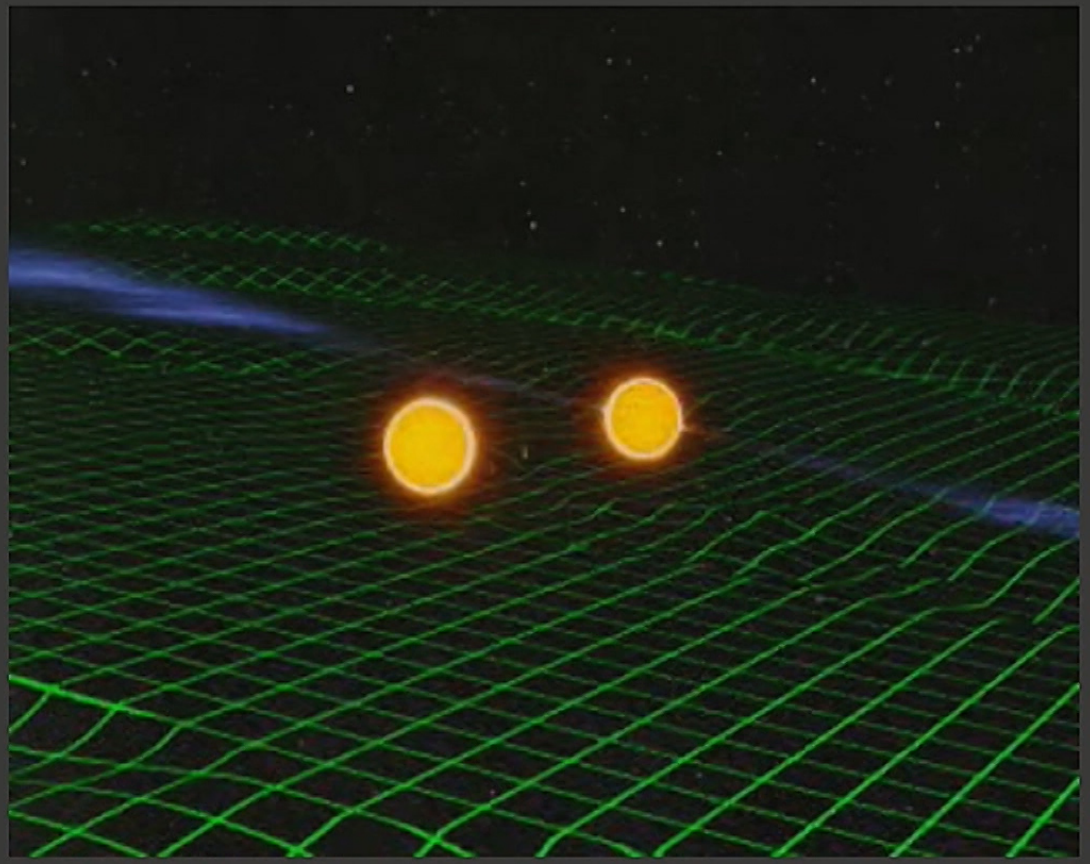

PSR B0531+21 P=0.033s

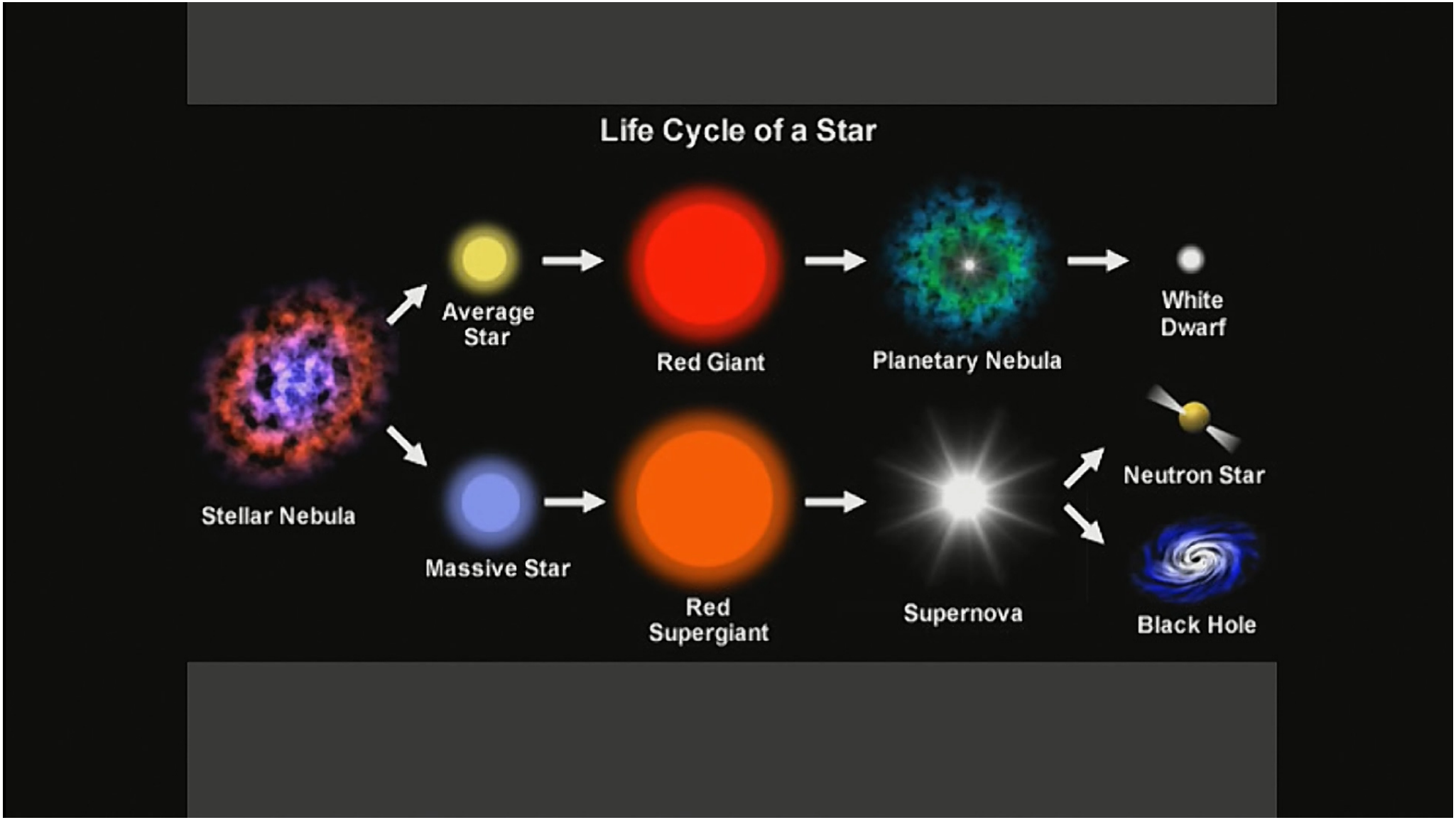

PSR B1937+21 P=0.0015s

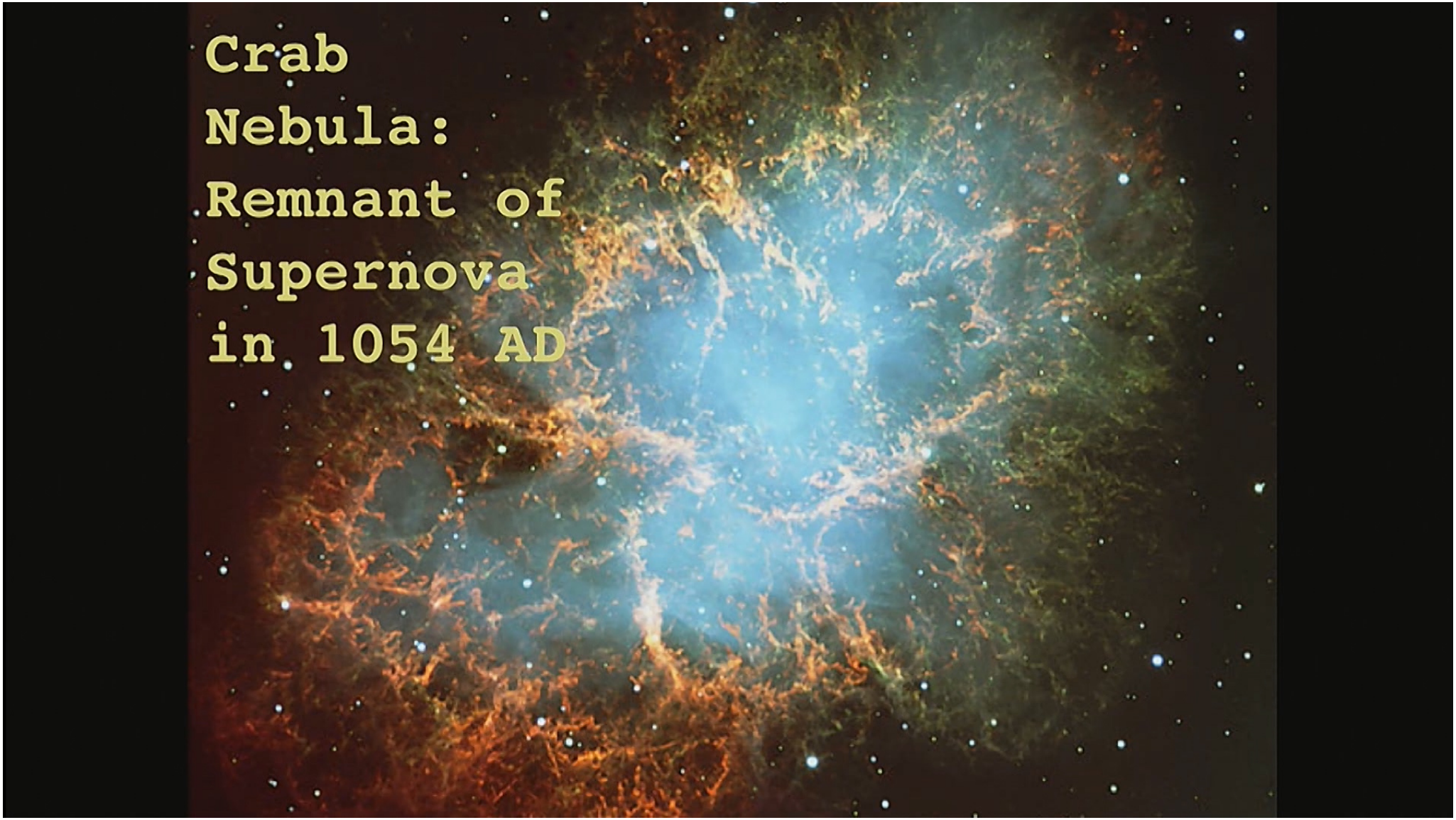
Binary Pulsar and Gravitational Waves

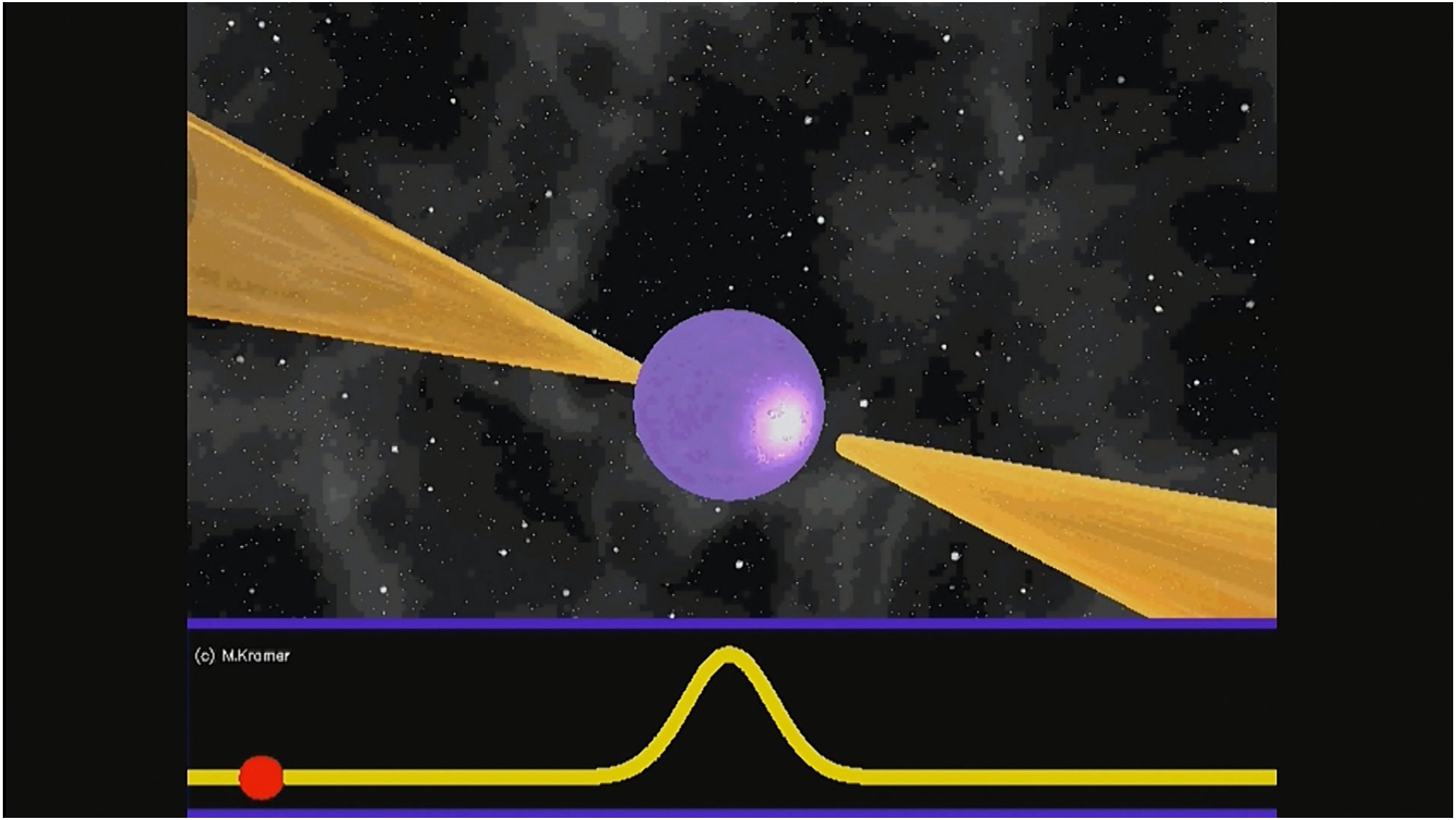
Pulsar orbit should decay!

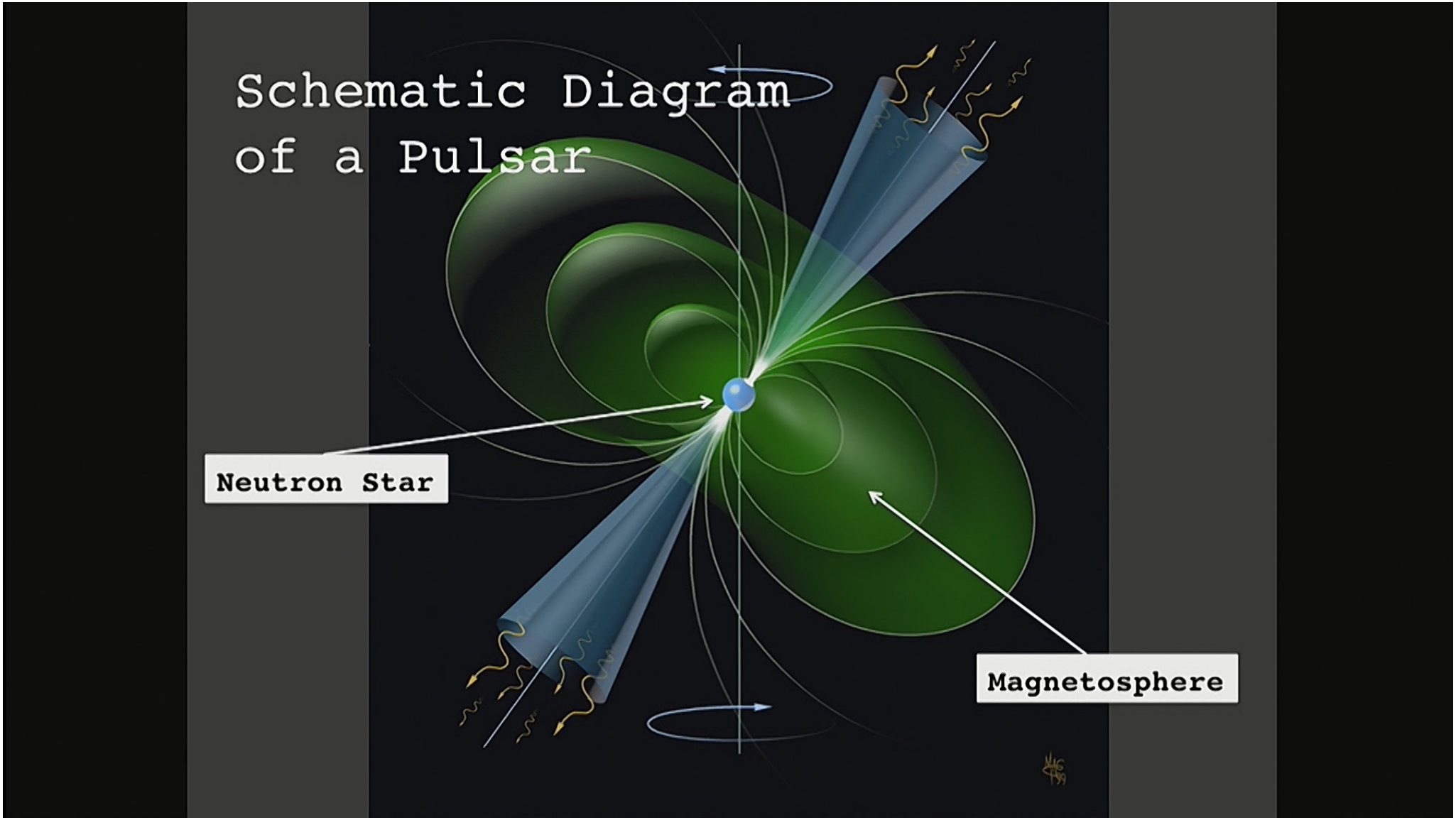





Life Cycle of a Star
Average Star
Red Giant
Planetary Nebula
White Dwarf
Stellar Nebula
Massive Star
Red Supergiant
Supernova
Neutron Star
Black Hole


Crab
Nebula:
Remnant of
Supernova
in 1054 AD


(c) M.Kramer


Schematic Diagram
of a Pulsar
Neutron Star
Magnetosphere

Neutron Star Rotation

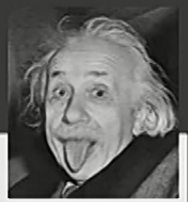
- Conservation of Angular Momentum
- Progenitor star's spin gets amplified in collapse

Vita-mix 5000:

"fastest blender on Earth"

Maximum 625 rps

What is the speed at the surface of a millisecond pulsar?



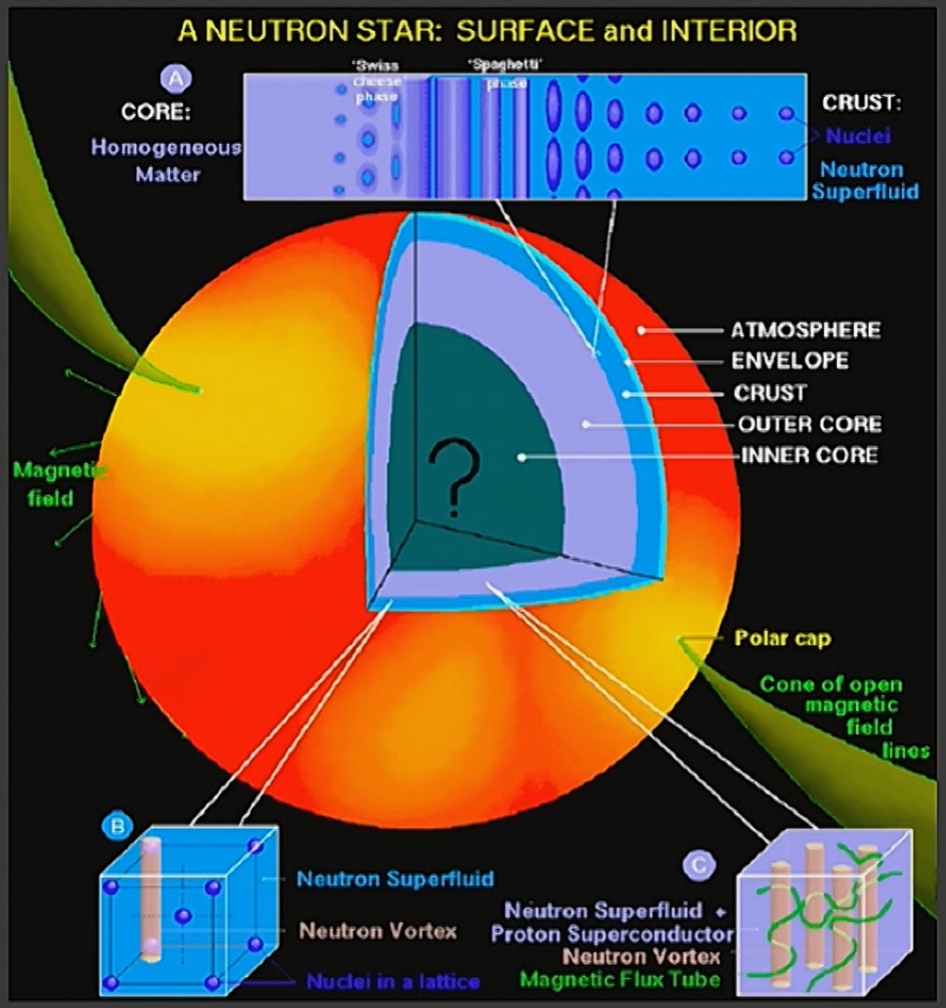
$$v = \frac{2\pi R}{P} = \frac{2\pi 10000}{0.0014} = 4.5 \times 10^7 m/s = 0.15c$$

velocity

very fast!

HOW FAST CAN A PULSAR SPIN?

What's Inside a Neutron Star?



Arecibo Radio Telescope in Puerto Rico

ameter:

5 m

Fastest Pulsar Yet!

ASTRONOMY

A Neutron Star in F-sharp

Jonathan E. Grindlay

Millisecond pulsars are extreme examples of what can happen when stars evolve into neutron stars in compact binary systems. These rotating objects are spun up by accretion of matter from their binary companions, producing luminous x-ray emission, and later become detectable as pulsars with periods of a few milliseconds (*1*). As a result, these "fast pulsars" may offer some of the best probes to study matter and space in the relativistic regime of strong gravity. On page 1901, Hessels *et al.* (*2*) report the discovery of pulsar PSR J1748-2446ad in the dense globular cluster Terzan 5 (Ter5-ad). This object, detected with the Green Bank radio telescope, holds the new record for the fastest spinning neutron star (or, indeed, any object of stellar mass or larger). Its spin p 1.396 ms, even shorter than that of B first millisecond pulsar discovered ms. With a rotation frequency of 71 reaches a new high note for the celestial spheres—between F a whereas B1937+21 (at 642 Hz) can between D-sharp and E.

Since their discovery in 1967, been the gateway to the study o energy at the extremes found on stars (*4*). Such stars are nature's la posts of matter and are only a larger in radius than an object th lapse to a black hole. With ~1 masses ($M_\odot$) packed into a radius km, neutron stars are the ultimate for the astrophysics and physics of Neutron stars can exhibit magnetic 10^{15} times that of Earth, as reve

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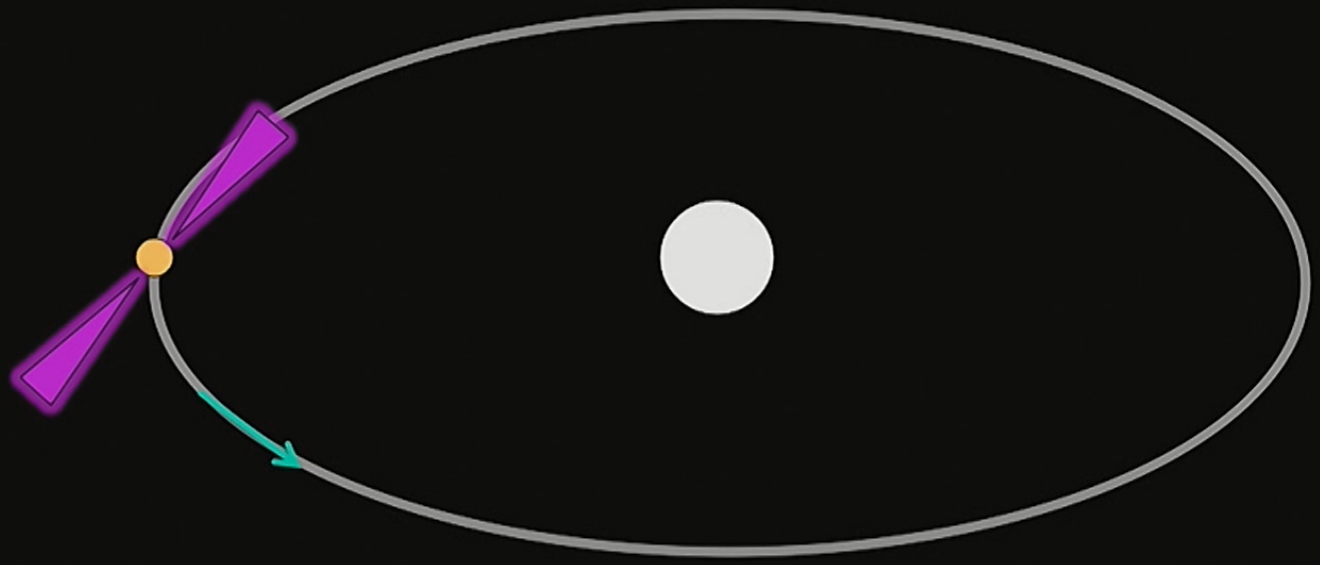
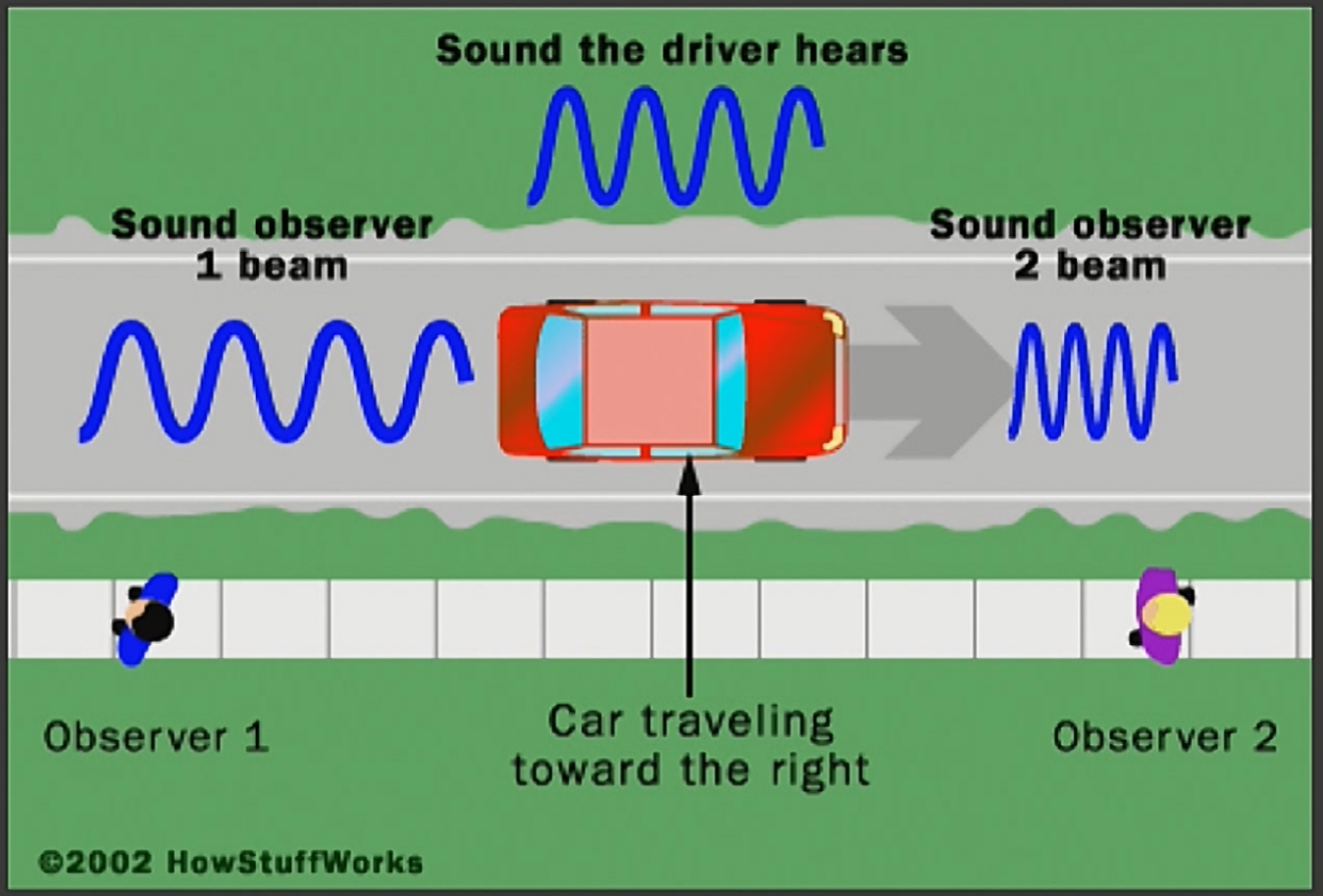
Binary Pulsars

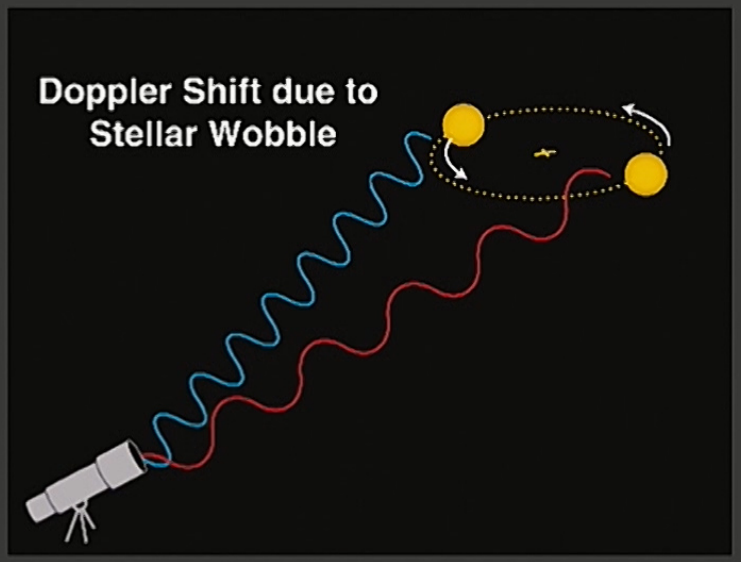


The pulsar orbits another star

Doppler Shift

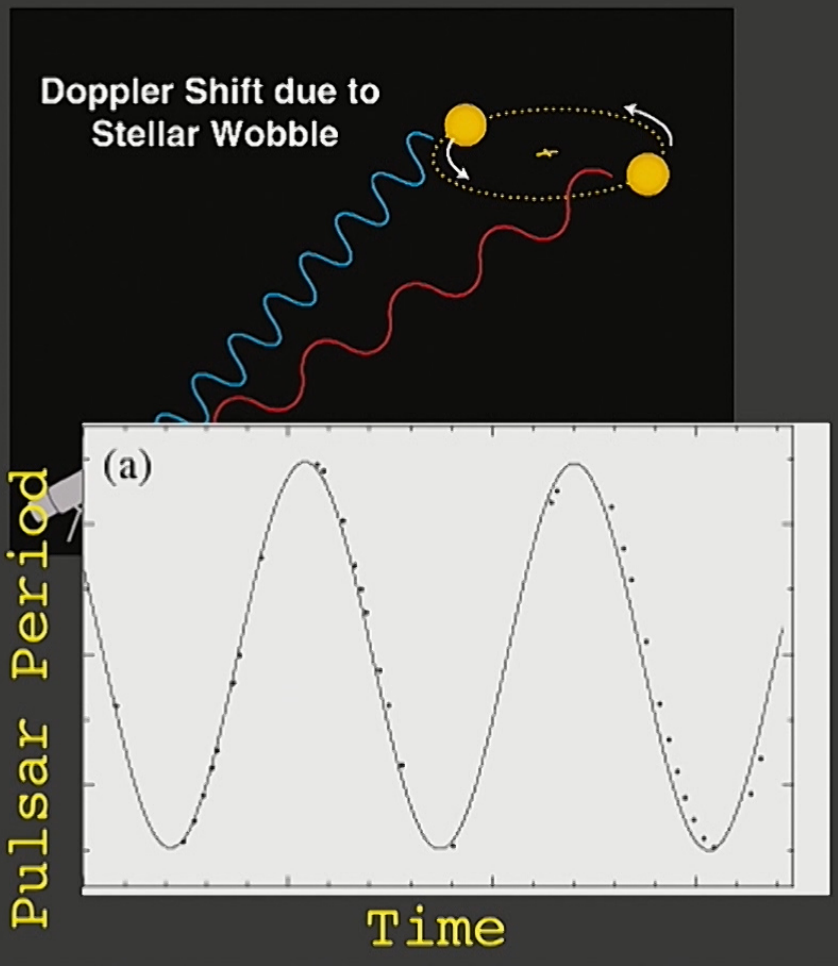


Doppler Shift in Binary Stars



- Pulse period in binary system changes!
- Can study binary motion with *exquisite* precision

Doppler Shift in Binary Stars



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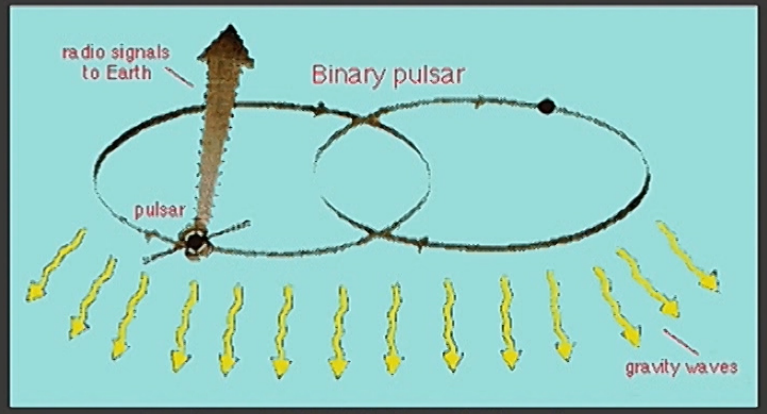
1974: Discovery of first Binary Pulsar



- PSR B1913+16 in orbit around a second neutron star that is not a pulsar

Russell Hulse Joe Taylor

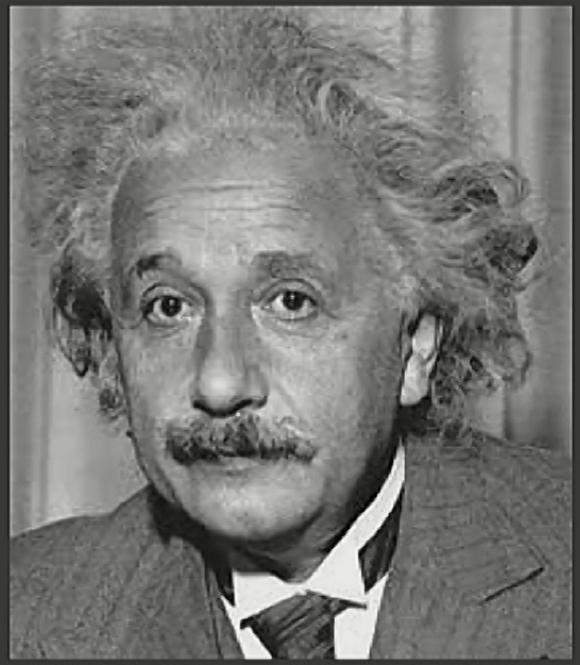
PSR B1913+16:Orbital period 8hrs!

HIGHLY RELATIVISTIC

Classical Dynamics

$F=ma$

Relativistic Dynamics



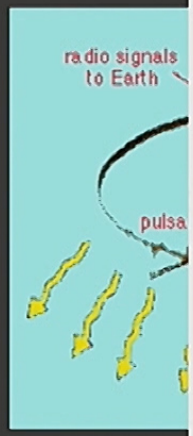
Einstein's Equation:

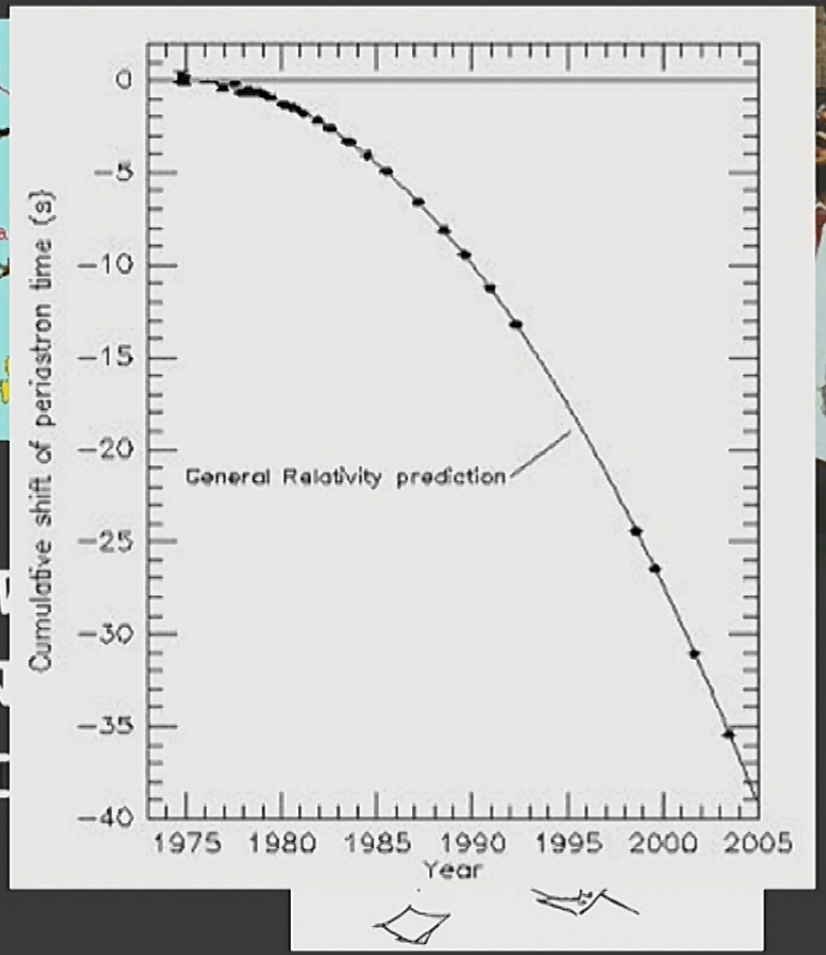
$$R^{\mu\nu} - (1/2)(g^{\mu\nu}R) + \Lambda g^{\mu\nu} = 8\pi G T^{\mu\nu}$$

$$ds^2 = [1 - (\Lambda/3)r^2 - r_s/r]\, dt^2 - [1 - (\Lambda/3)r^2 - r_s/r]^{-1}\, dr^2 - r^2(d\theta^2 + \sin^2\theta d\varphi^2)$$

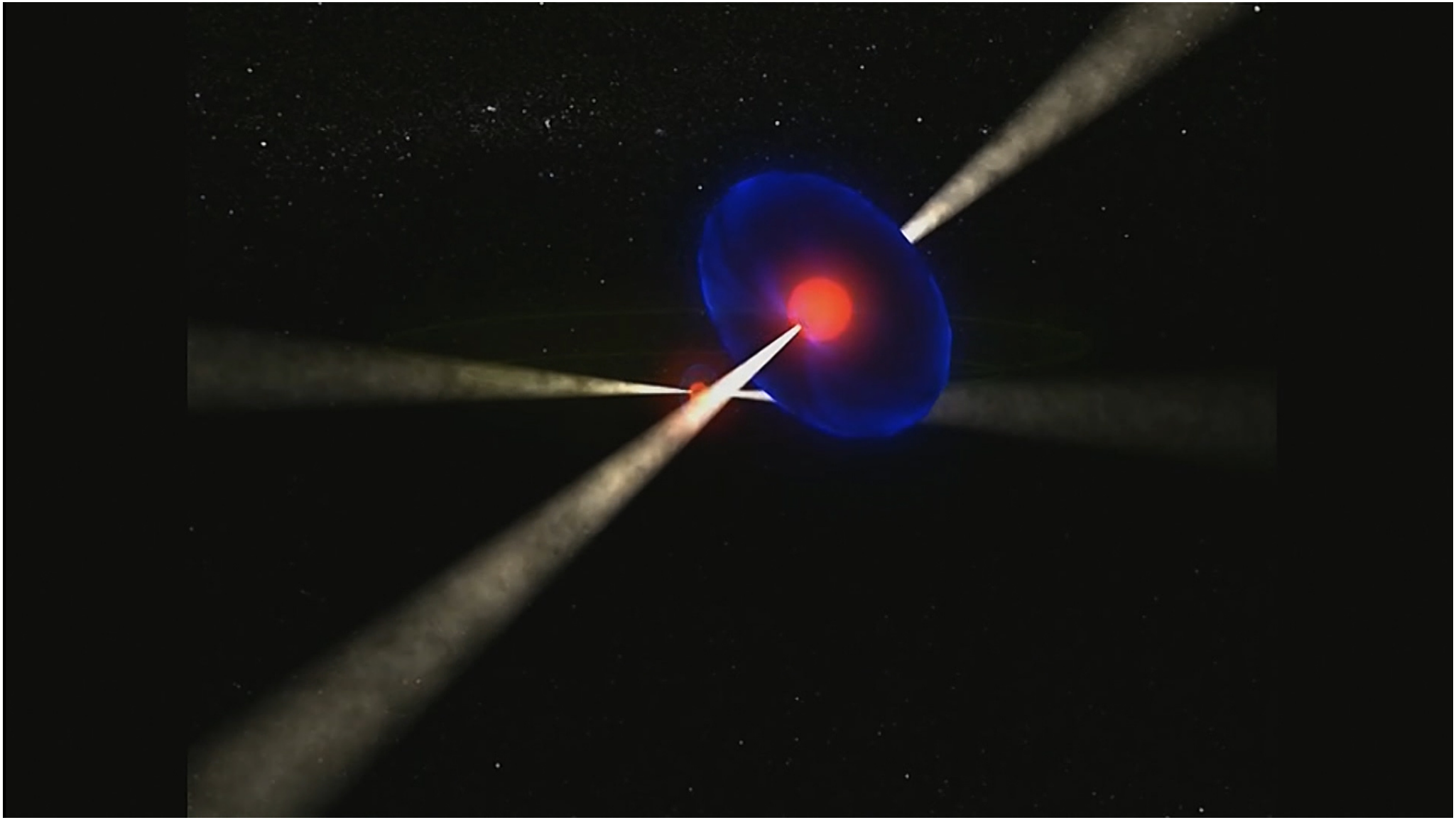
Schwarzschild metric with a cosmological constant

Binary Pulsars and Einstein



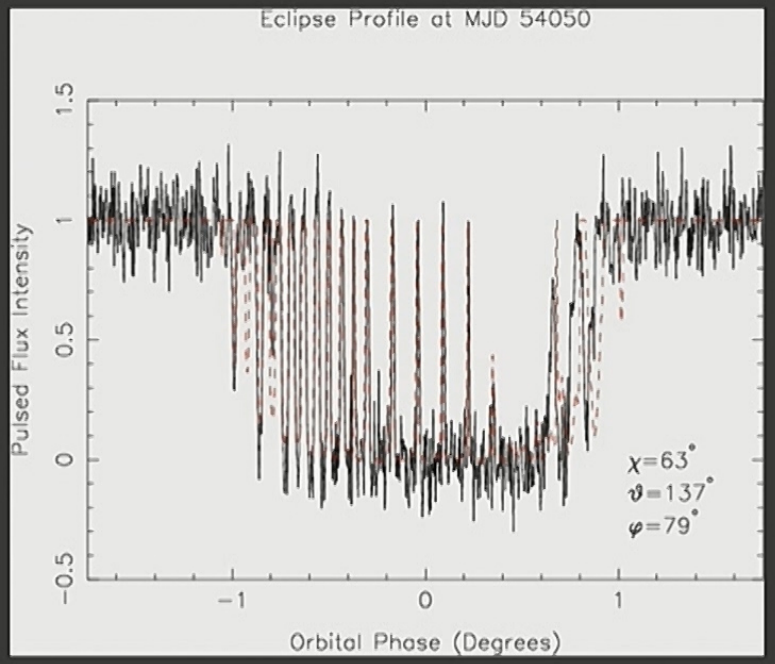


EIN
RI



Double Pulsar: GR Laboratory

- Unparalleled lab for GR
- Use eclipses of pulsar A to study B's orientation in space
- GR:B should change if GR correct



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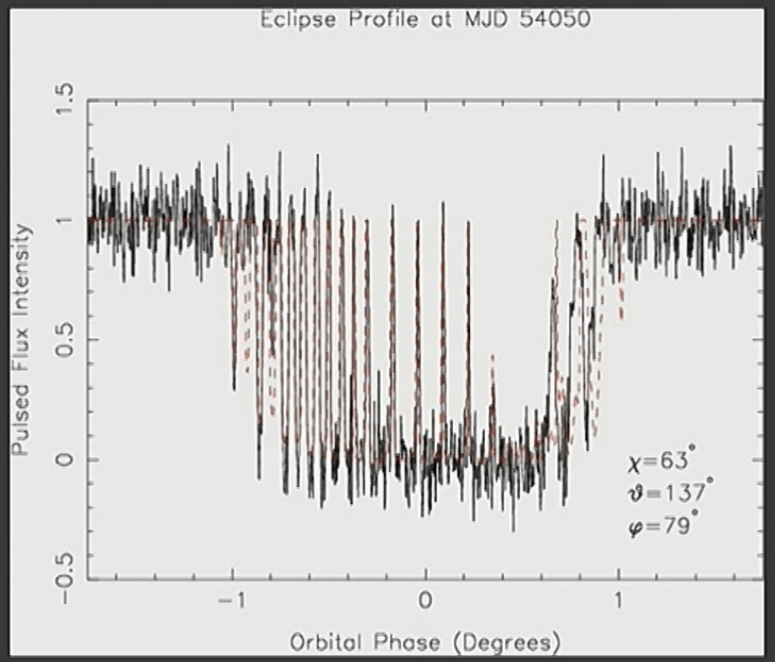
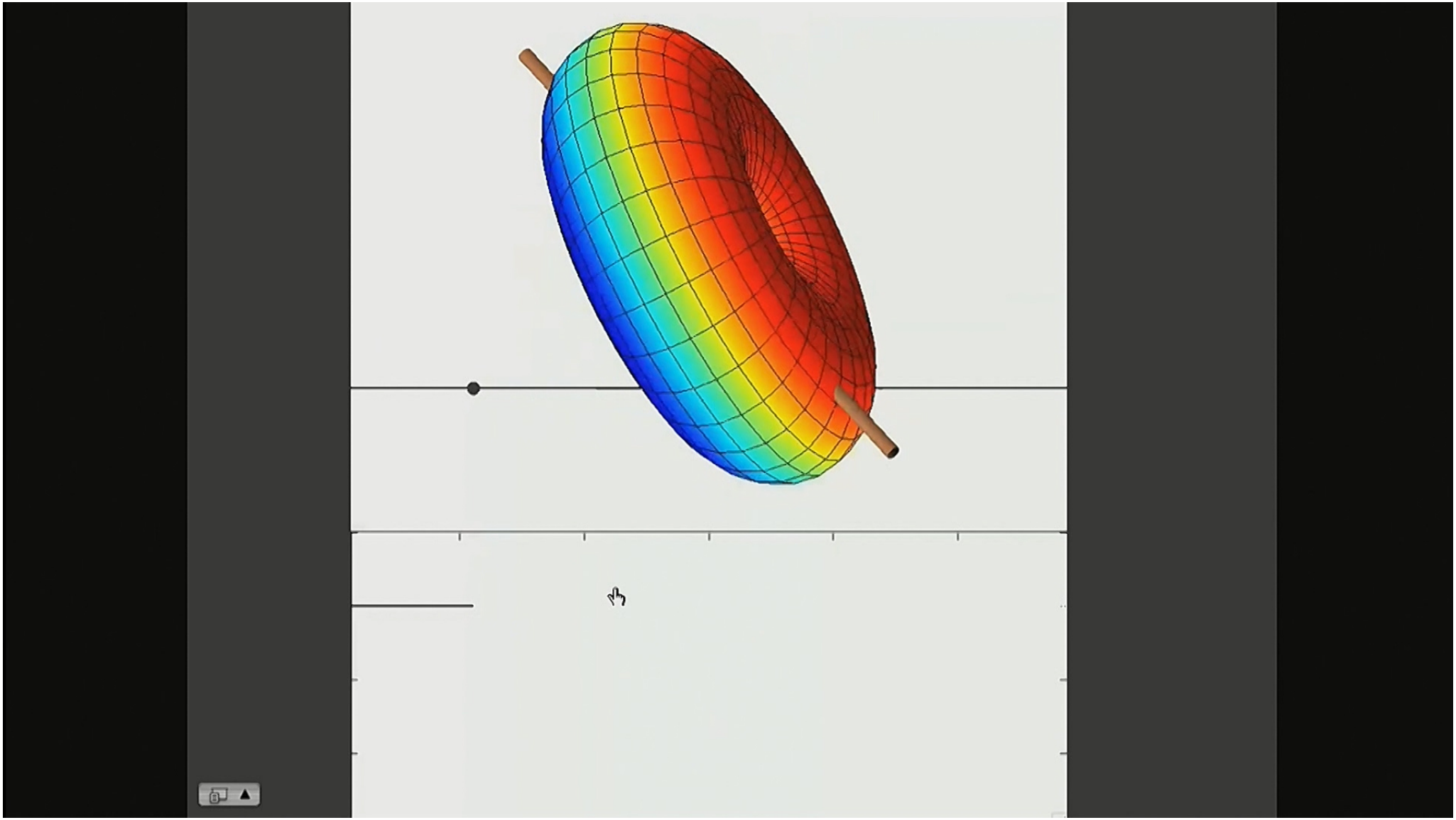
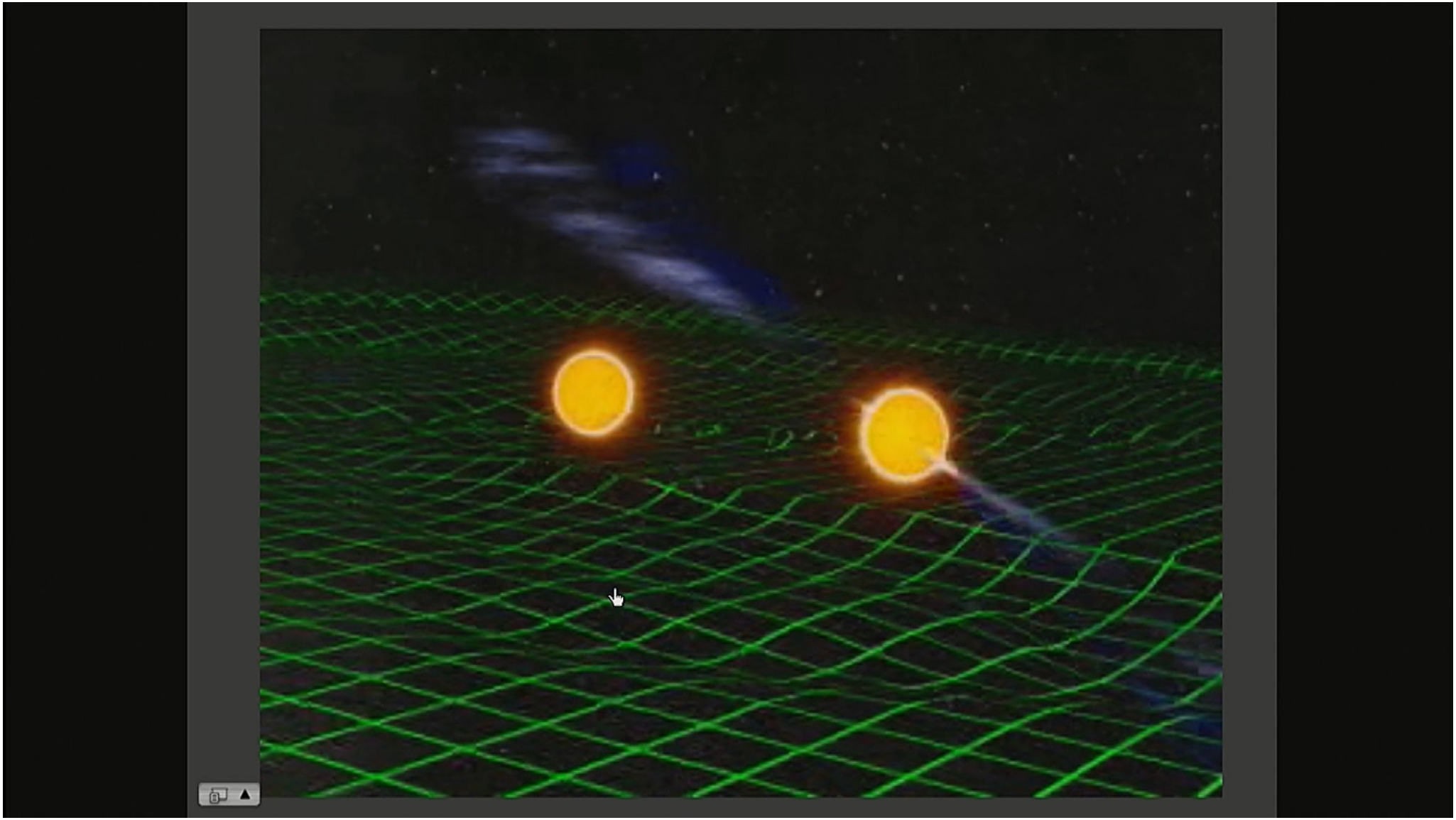


PhD thesis of Rene Breton, McGill U.





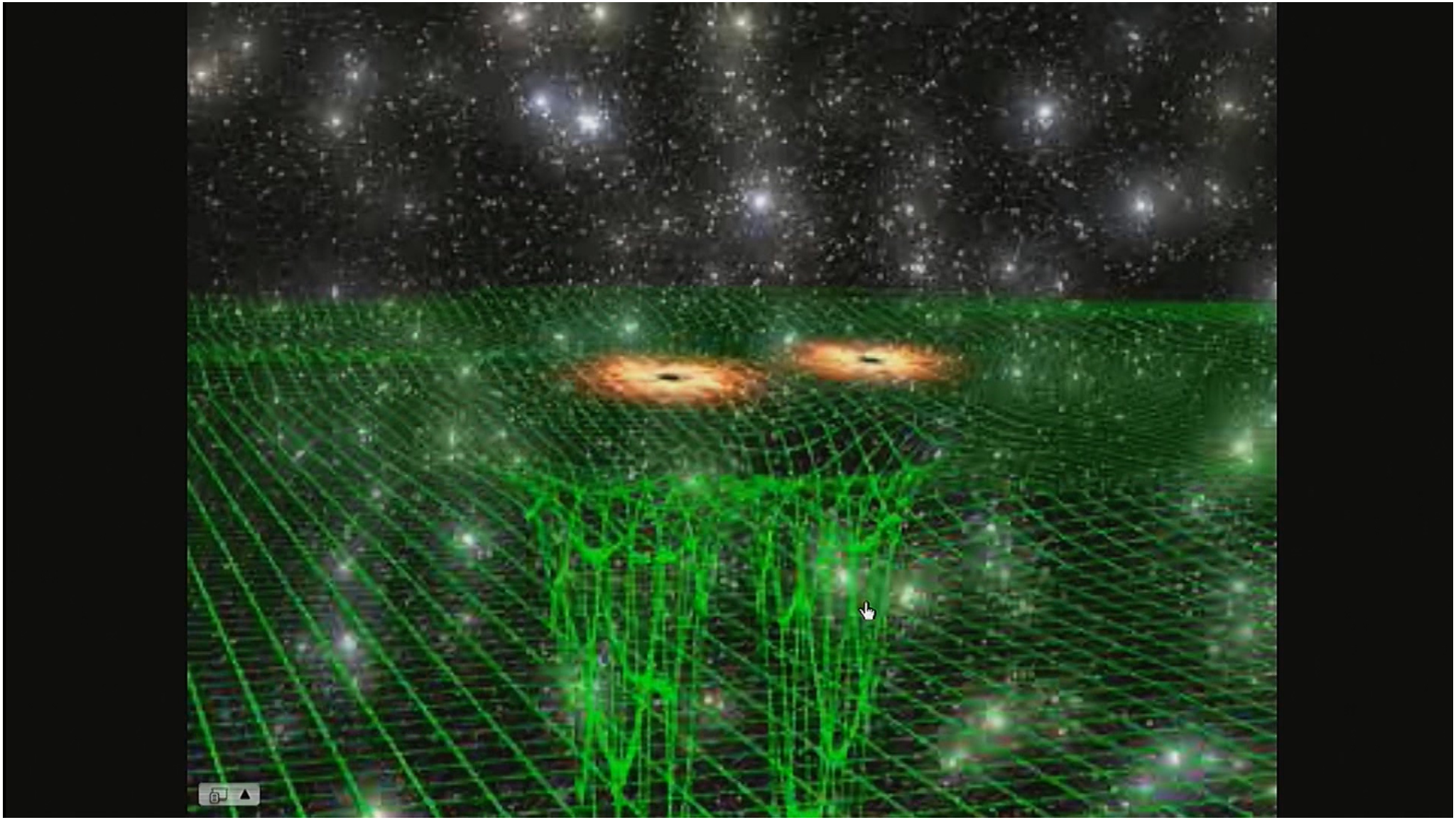
Neutron Stars: Gifts that Keeps Giving

- Pulsars are sources of gravitational waves...and
- Pulsars can be detectors of gravitational waves!
  - Pulsars' signals affected by other sources of gravitational waves
  - Example: merging supermassive black holes

Merging Galaxies

Optical image of merging galaxies "The Mice"

Computer Simulation of merging galaxies



Cosmic Gifts from Pulsars

- Pulsar music
- Perfect clocks
- Binary pulsars
- Tests of Einstein's theories
  - Indirect detection of gravitational waves
- Double pulsar
- Soon to come: the next gift?
  - Direct detection of gravitational waves from supermassive black holes?

McGill Pulsar Group

Institut Spatial de McGill
McGill Space Institute

NSERC CRSNG

Fonds de recherche Nature et technologies Québec

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