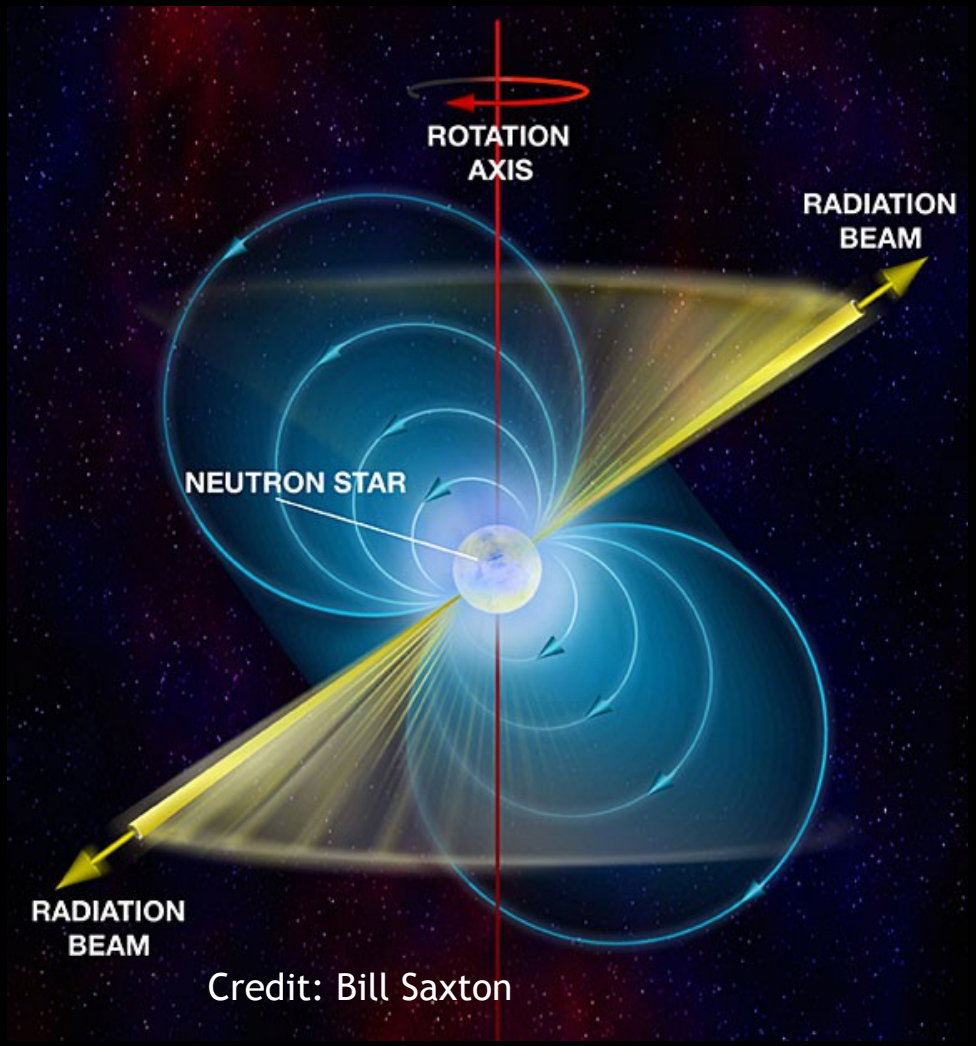
Pulsars, flickers and cosmic flashes (the transient radio universe)

Duncan Lorimer, Dept. of Physics and Astronomy, West Virginia University



Credit: Bill Saxton


Credit: Swinburne

* Introduction
* Pulsars
* Fast radio bursts
  (more on these tomorrow)

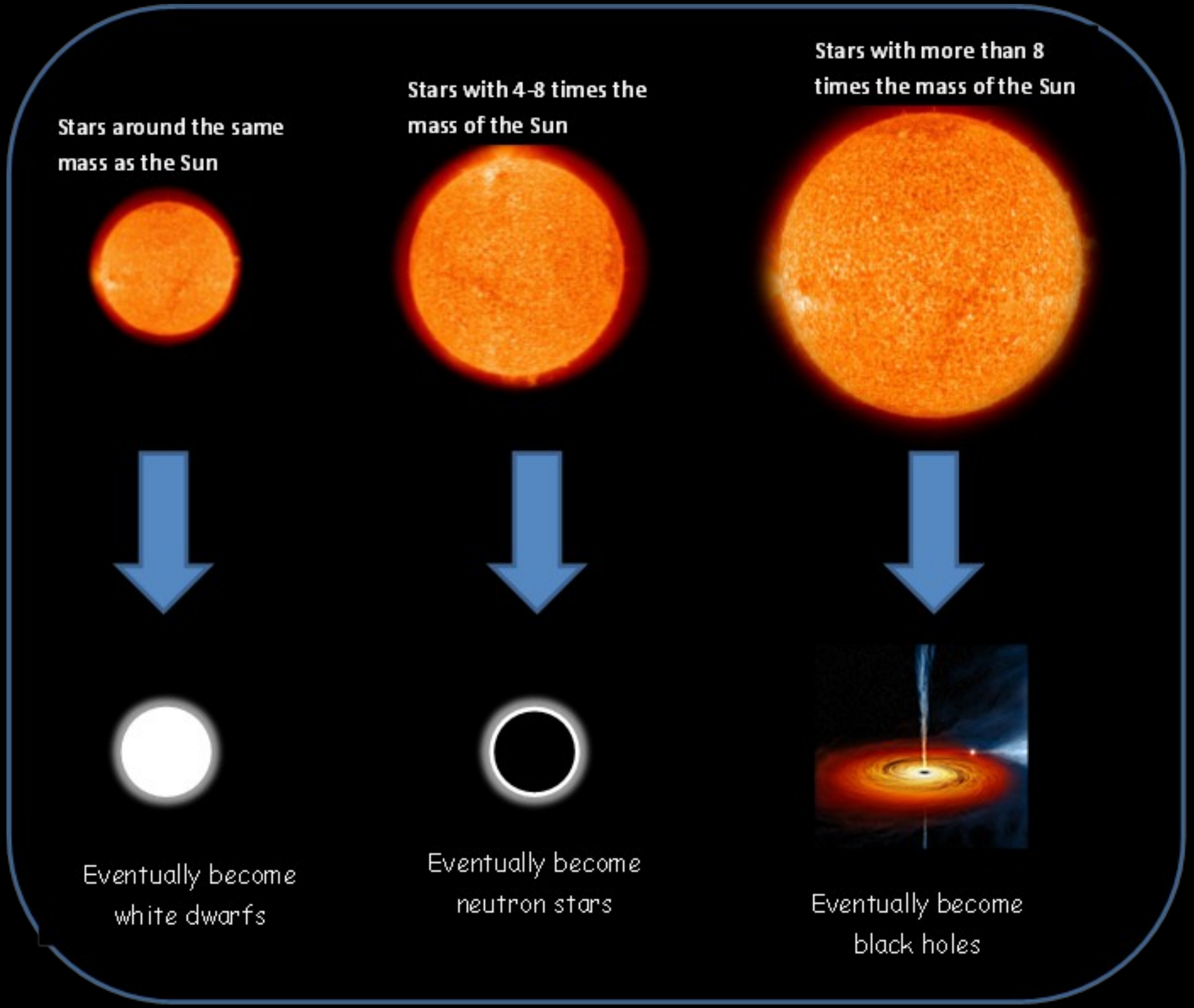
Photograph by Miloslav Druckmüller

MAGELLANIC CLOUDS. DECEMBER 201


1987

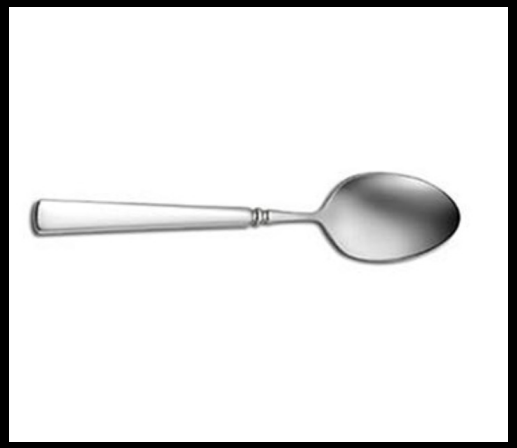
Dr Fritz Zwicky

Walter Baade, fizikus

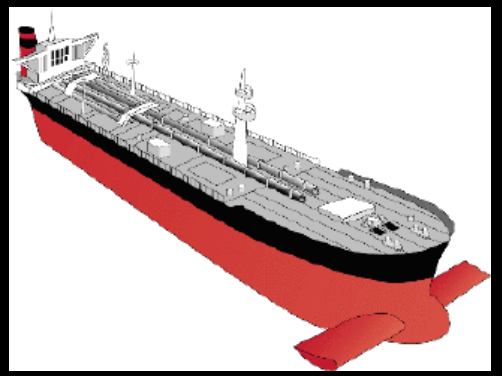

Stars around the same mass as the Sun
Stars with 4-8 times the mass of the Sun
Stars with more than 8 times the mass of the Sun
Eventually become white dwarfs
Eventually become neutron stars
Eventually become black holes
Credit: CTA-UK

Neutron stars are EXTREME objects!

Extremely dense - 100,000,000,000,000,000 kg m^{-3}



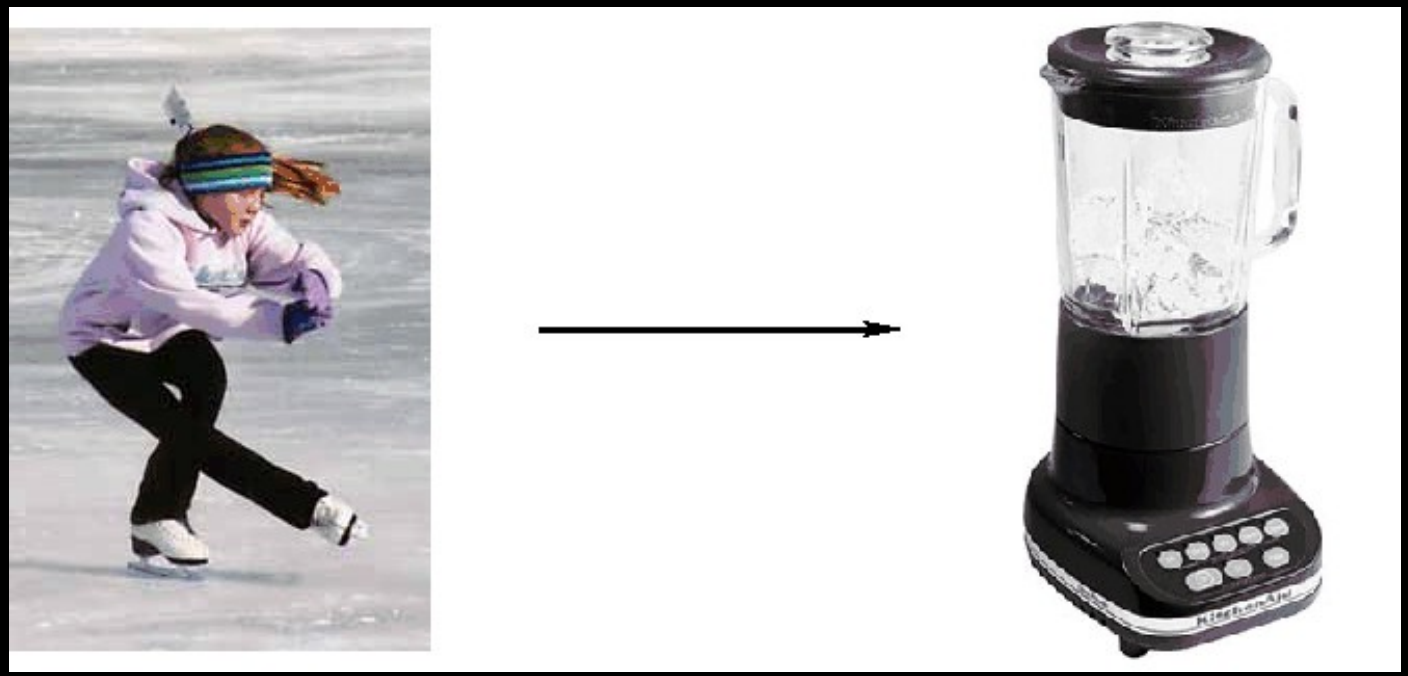
=



Neutron stars are EXTREME objects!

- Extremely dense - 100,000,000,000,000,000 kg m^{-3}

Very rapid rotation - up to 700 Hz

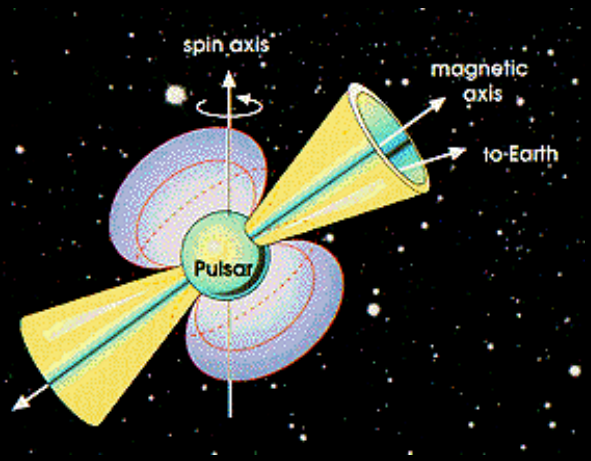


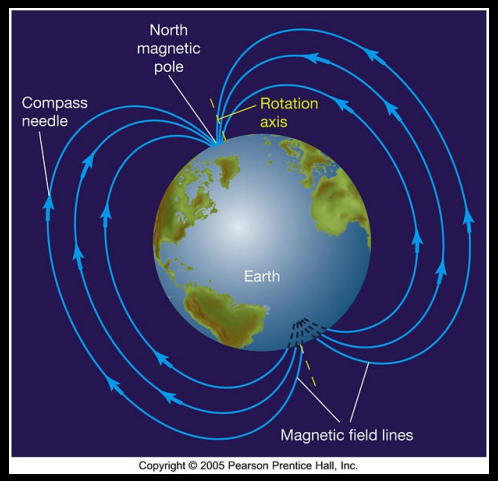
Neutron stars are EXTREME objects!

- Extremely dense - 100,000,000,000,000,000 kg m^{-3}

Very rapid rotation - up to 700 Hz

Ultrahigh magnetic fields - 1,000,000,000,000 times Earth's





Neutron stars are EXTREME objects!

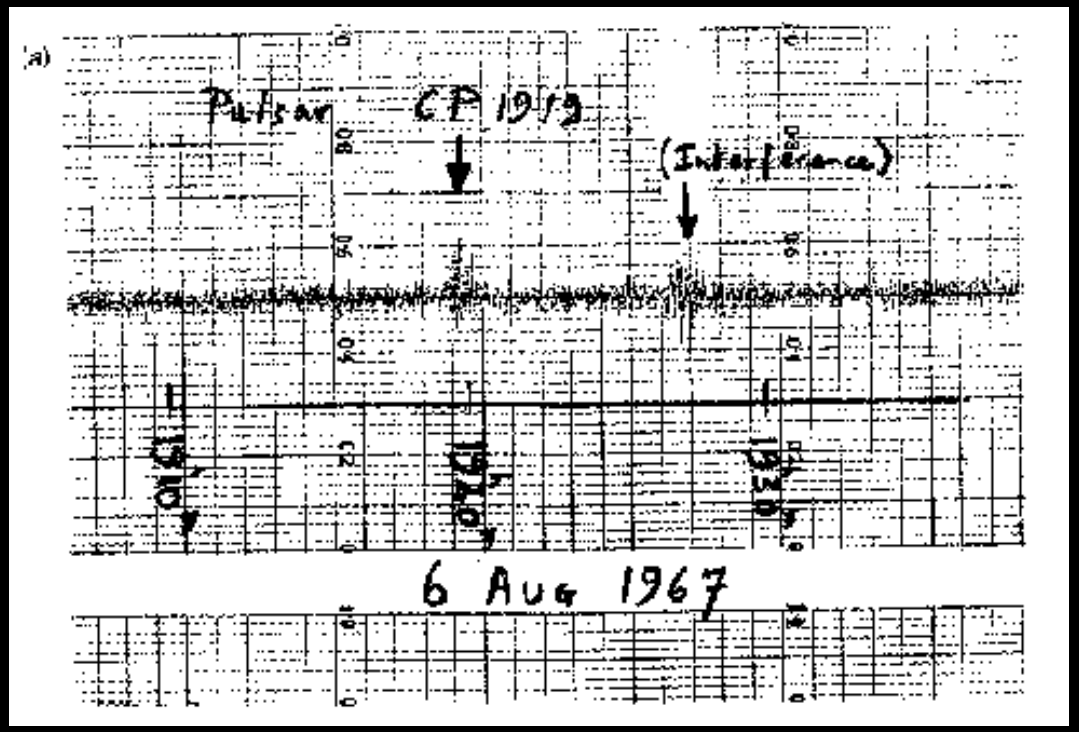
Extremely dense - 100,000,000,000,000,000 kg m^{-3}

Very rapid rotation - up to 700 Hz

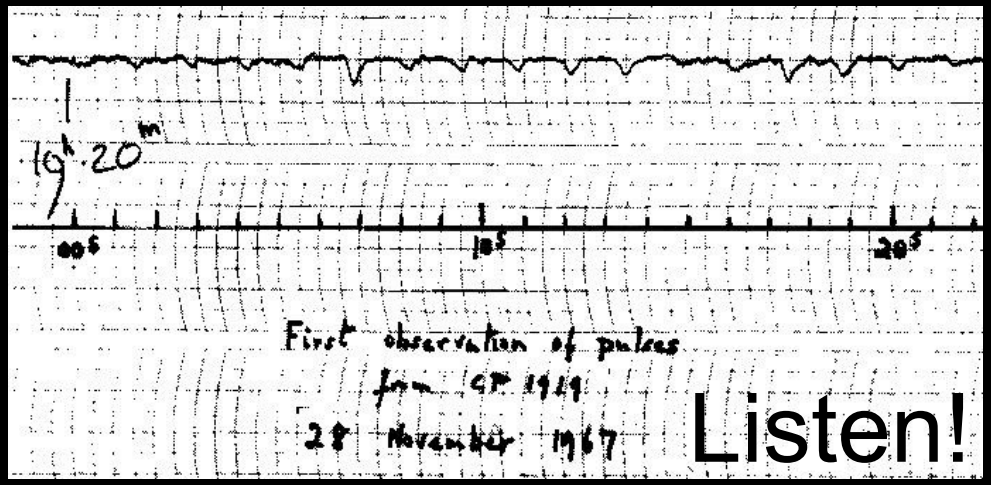
Ultrahigh magnetic fields - 1,000,000,000,000 times Earth's

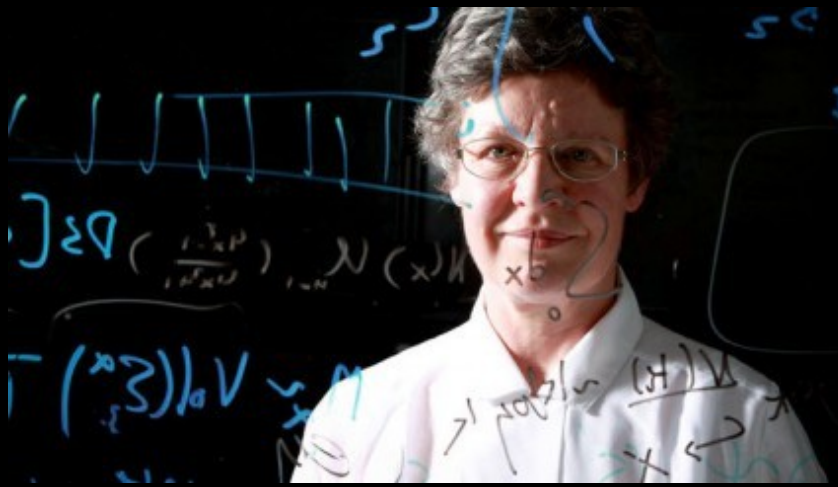
High space velocities - up to 1,000 km/s

- sprinter - 10 m/s
- f1 car - 100 m/s
- normal stars - 10 km/s

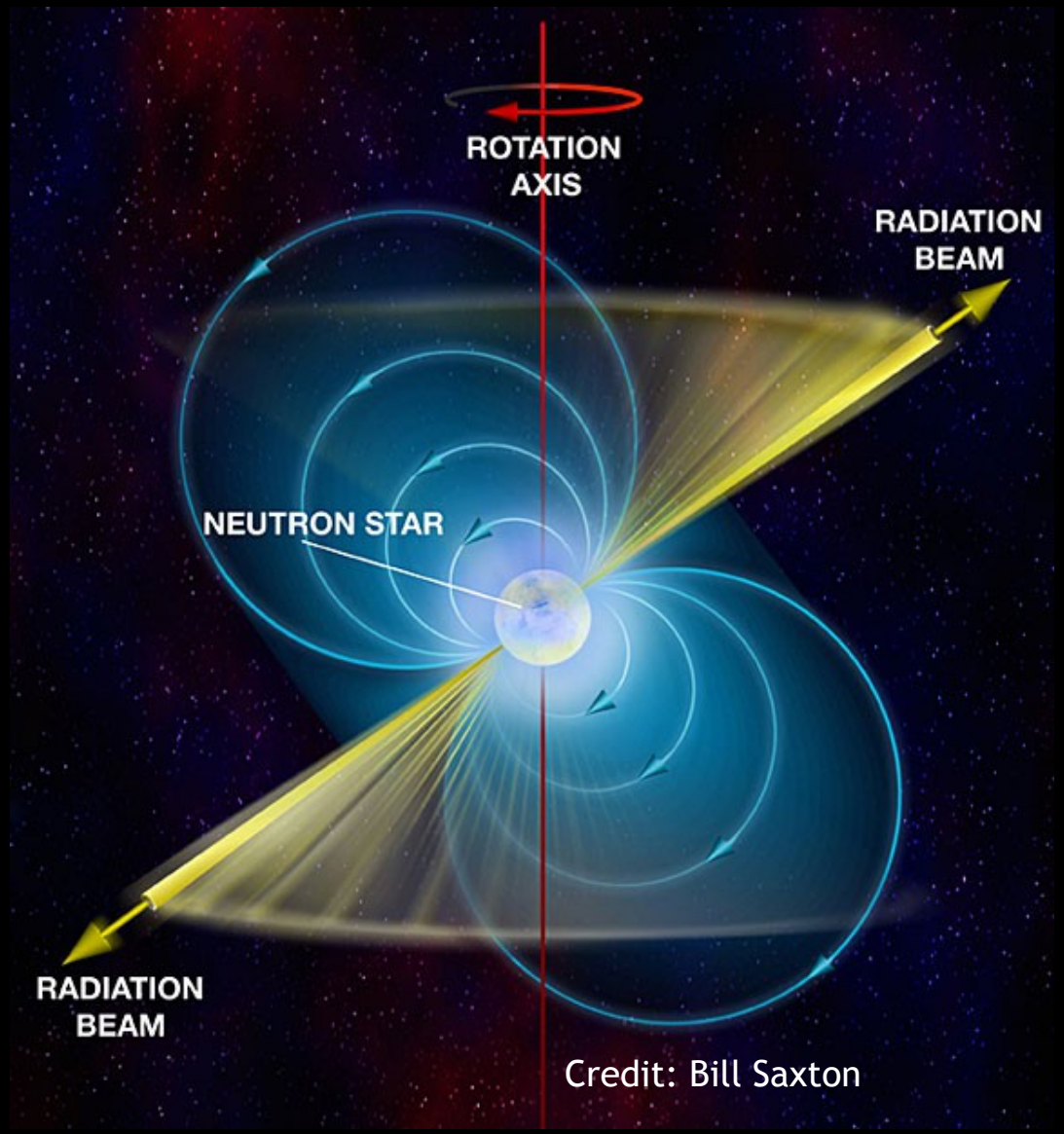

(a)
Pulsar CP 1919
(Interference)
6 Aug 1967

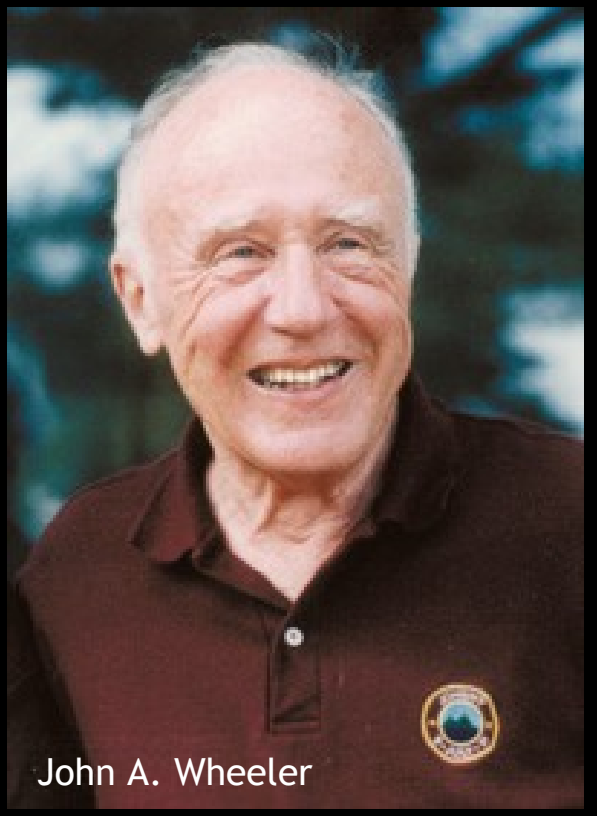

1967


19h 20m
00s
10s
20s
First observation of pulses
from CP 1919
28 November 1967
Listen!

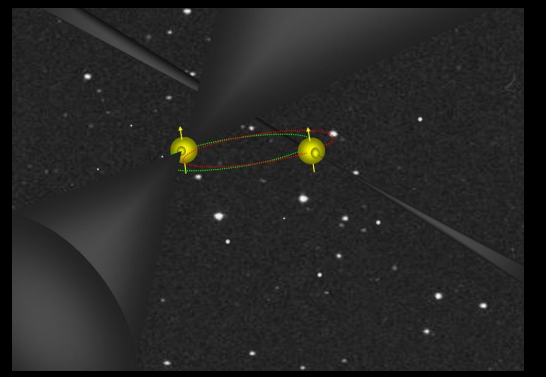


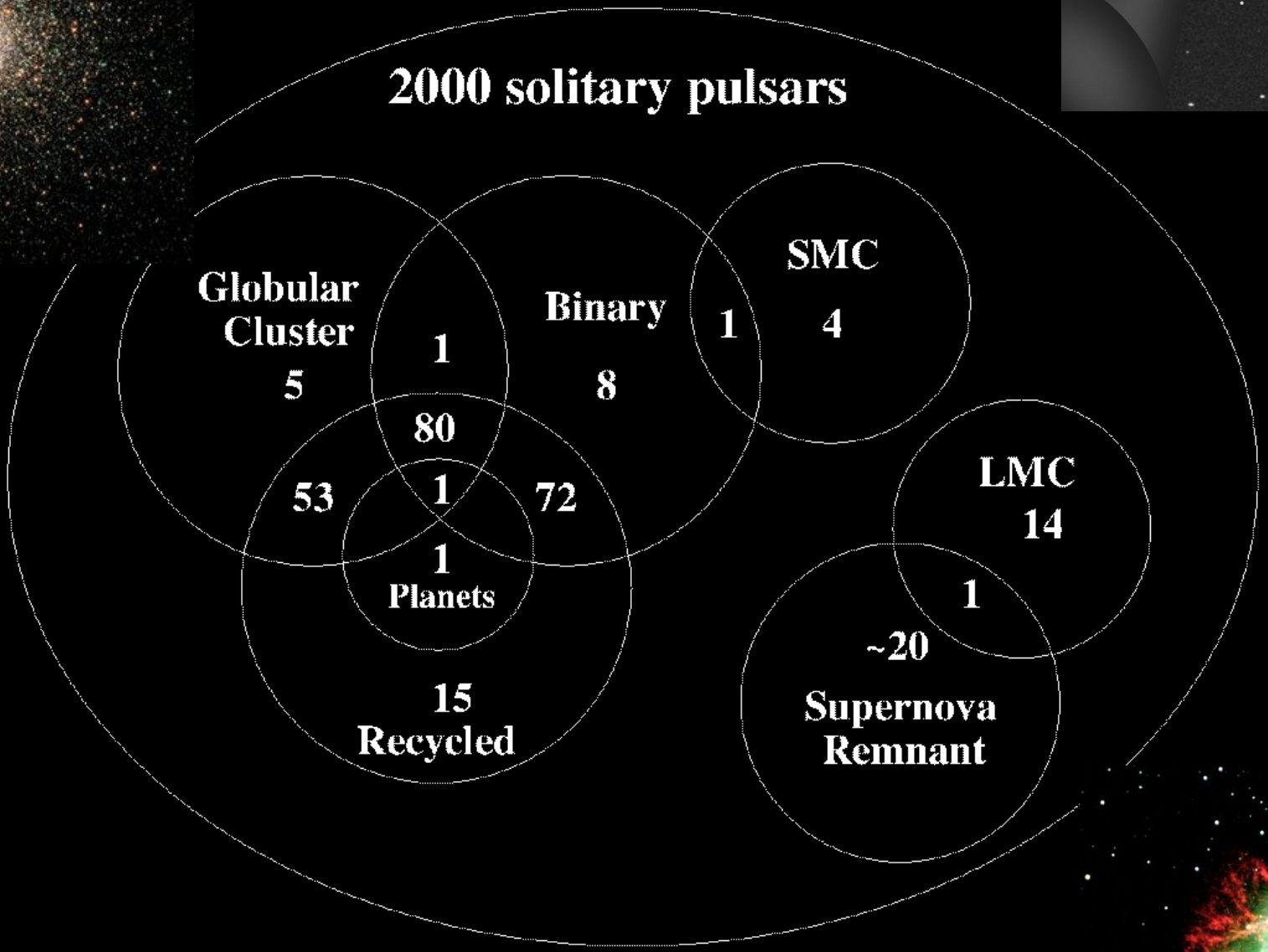
"it was not realized that neutron stars would come equipped with a handle and a bell!" --- John A. Wheeler

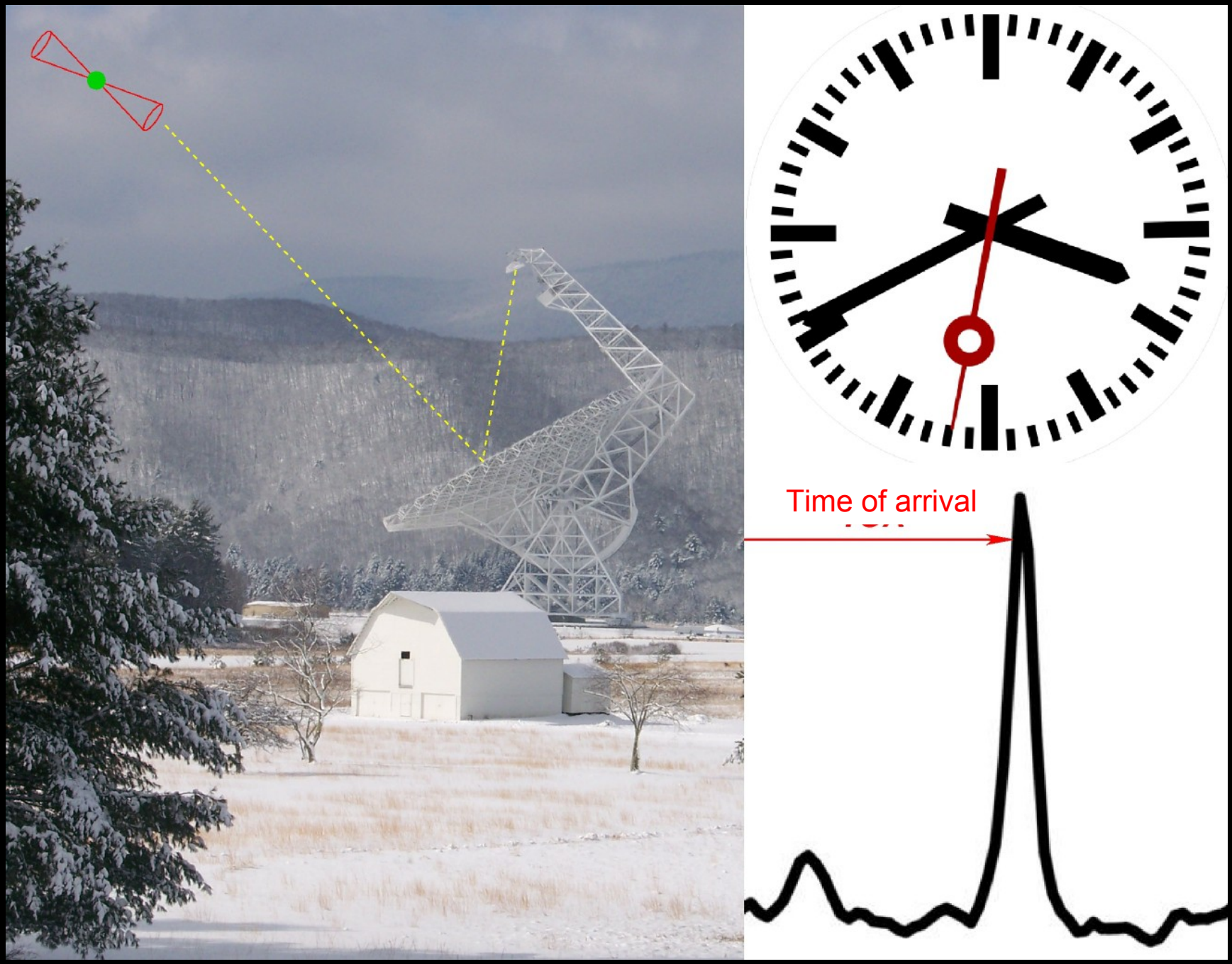


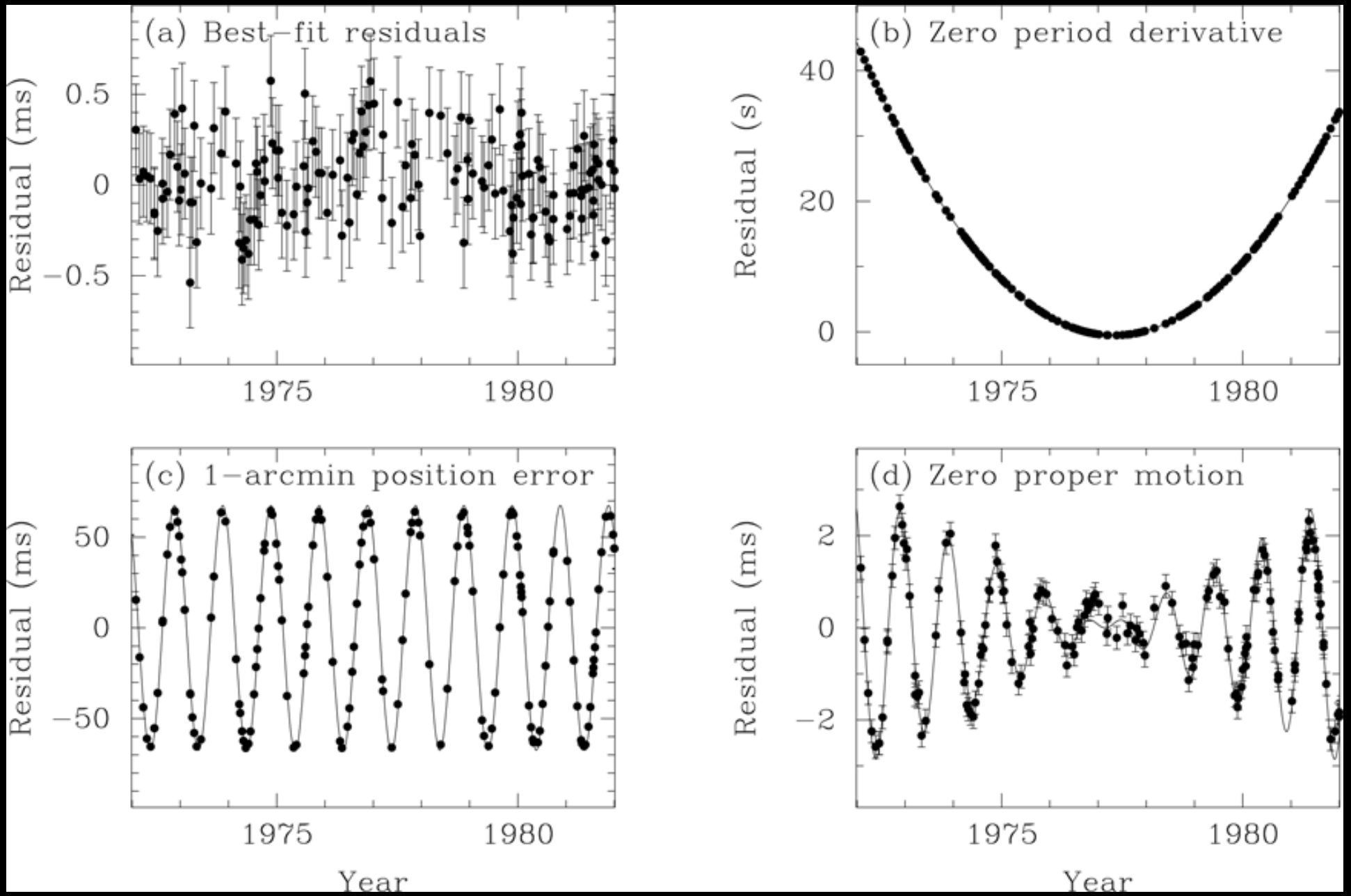

John A. Wheeler

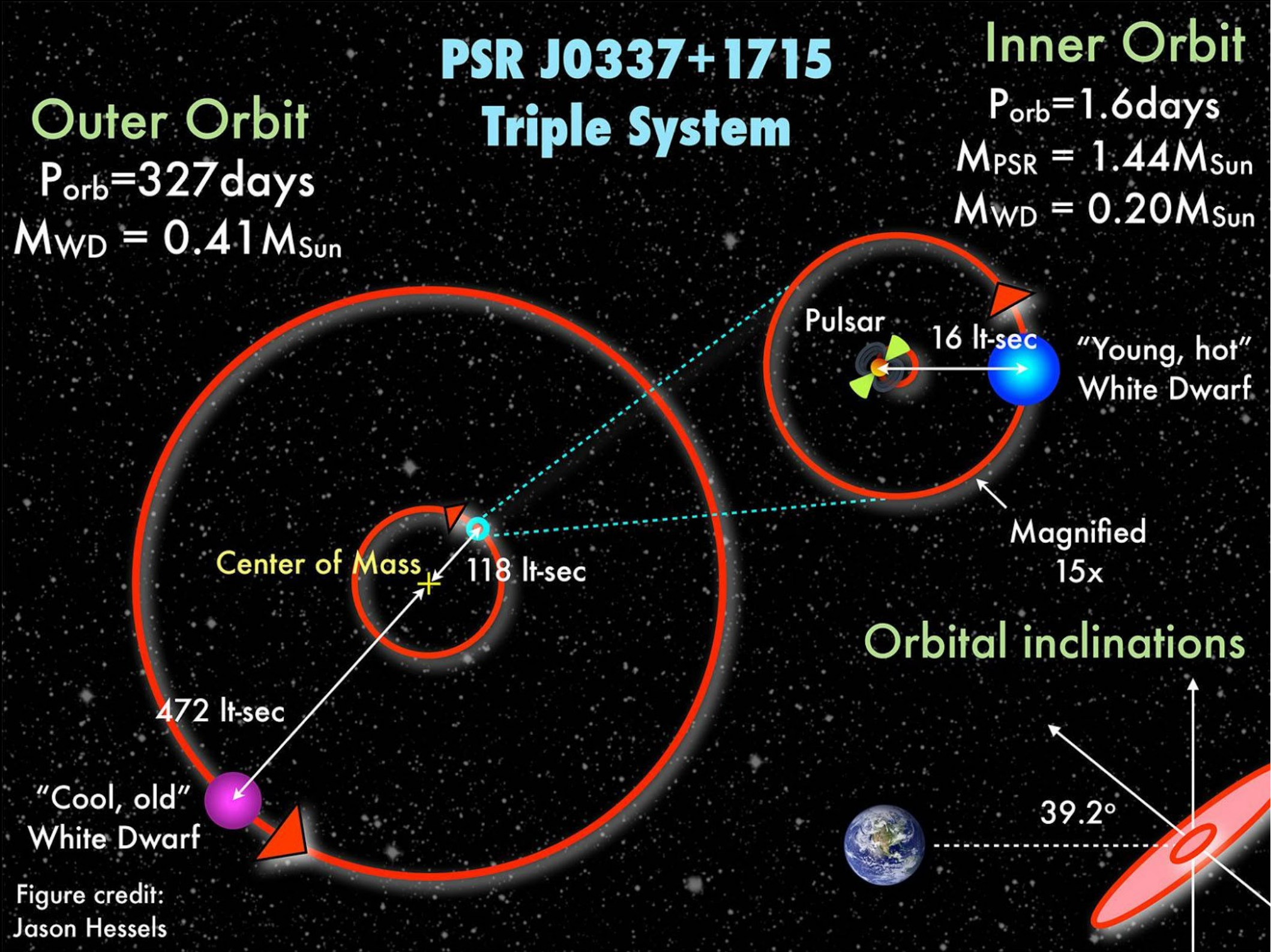
This is known as the "light house" model for pulsars!



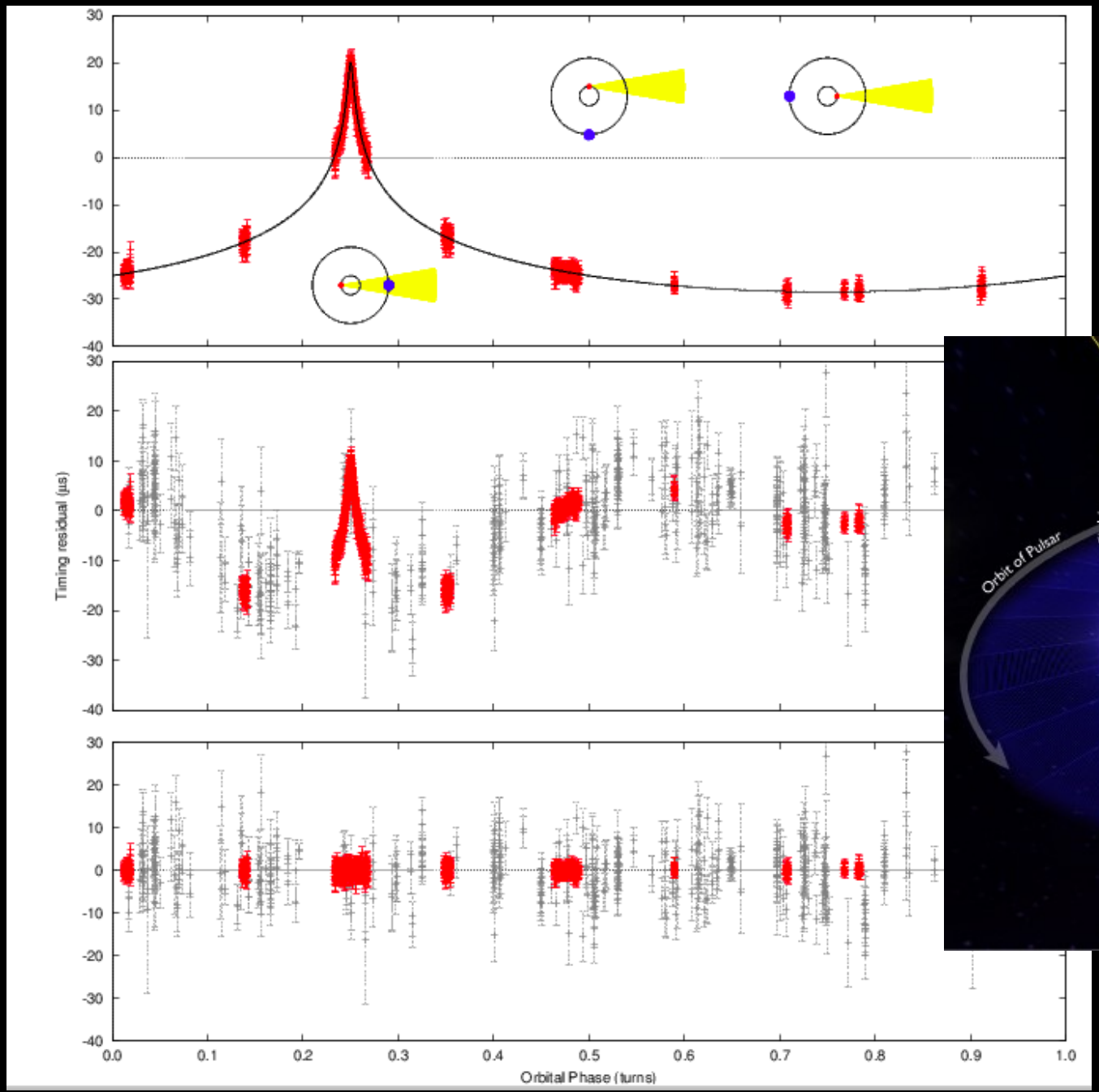

2000 solitary pulsars
Globular Cluster
5
1
Binary
8
1
SMC
4
80
53
1
72
1
Planets
LMC
14
1
~20
Supernova Remnant
15
Recycled


Time of arrival

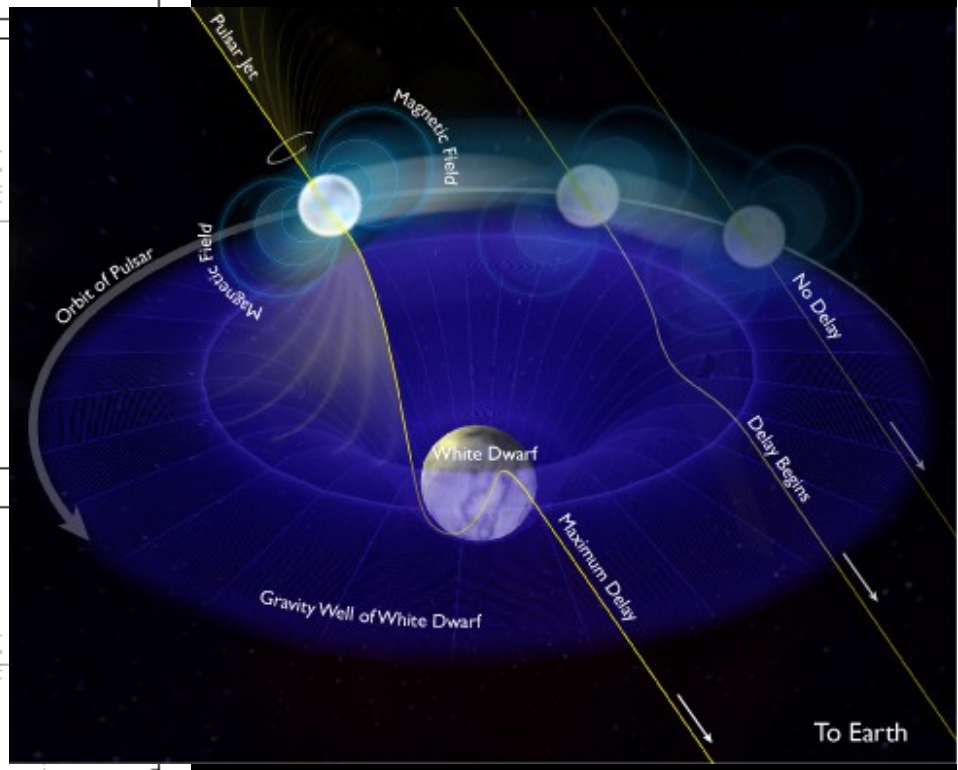

(a) Best−fit residuals
Residual (ms)
0.5
0
−0.5
1975
1980
(b) Zero period derivative
Residual (s)
40
20
0
1975
1980
(c) 1−arcmin position error
Residual (ms)
50
0
−50
1975
1980
Year
(d) Zero proper motion
Residual (ms)
2
0
−2
1975
1980
Year


PSR J0337+1715
Triple System
Outer Orbit
Porb=327days
MWD = 0.41MSun
Inner Orbit
Porb=1.6days
MPSR = 1.44MSun
MWD = 0.20MSun
Pulsar
16 lt-sec
"Young, hot"
White Dwarf
Magnified
15x
Center of Mass
118 lt-sec
472 lt-sec
"Cool, old"
White Dwarf
Orbital inclinations
39.2°
Figure credit:
Jason Hessels

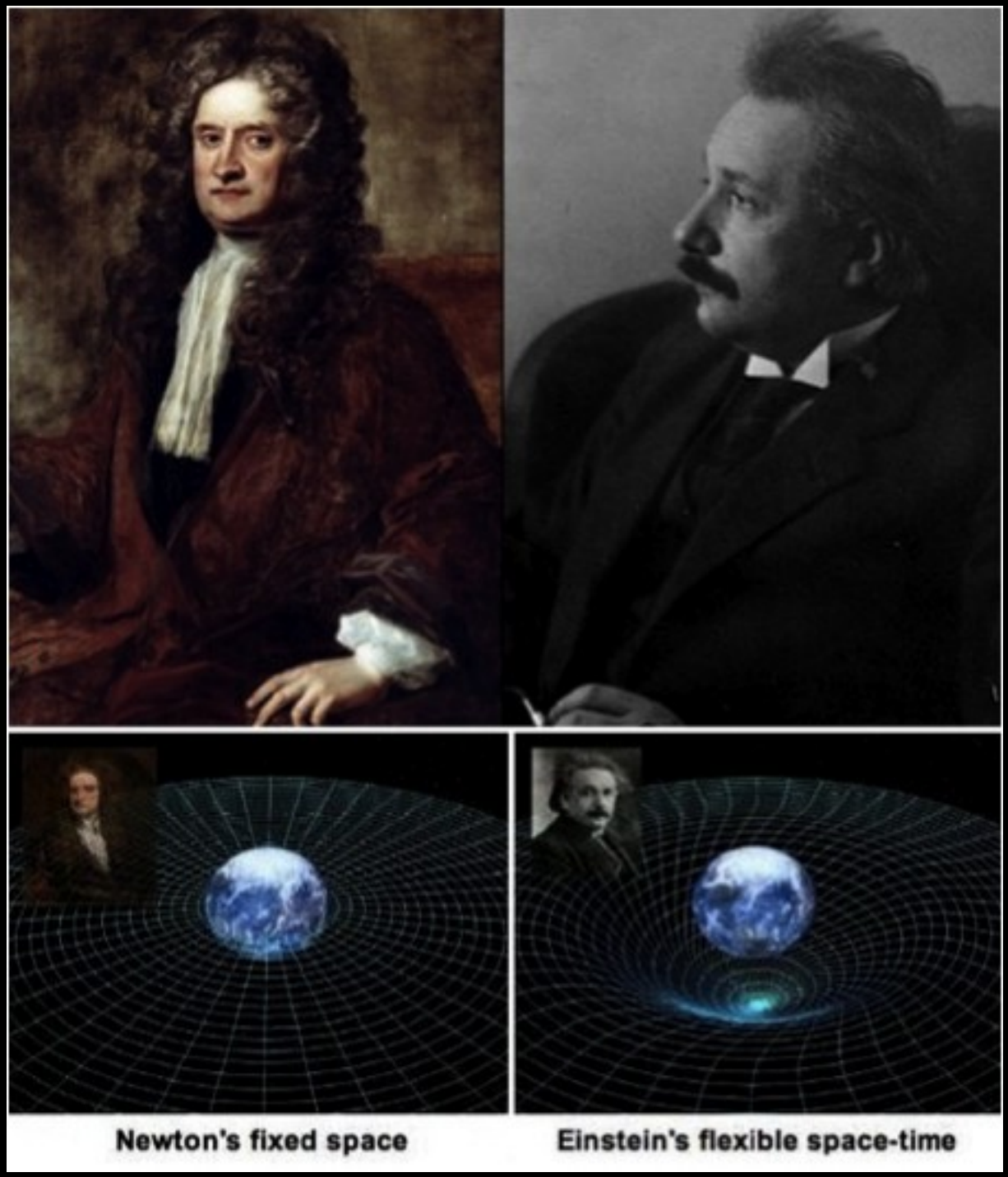
A two solar mass neutron star!

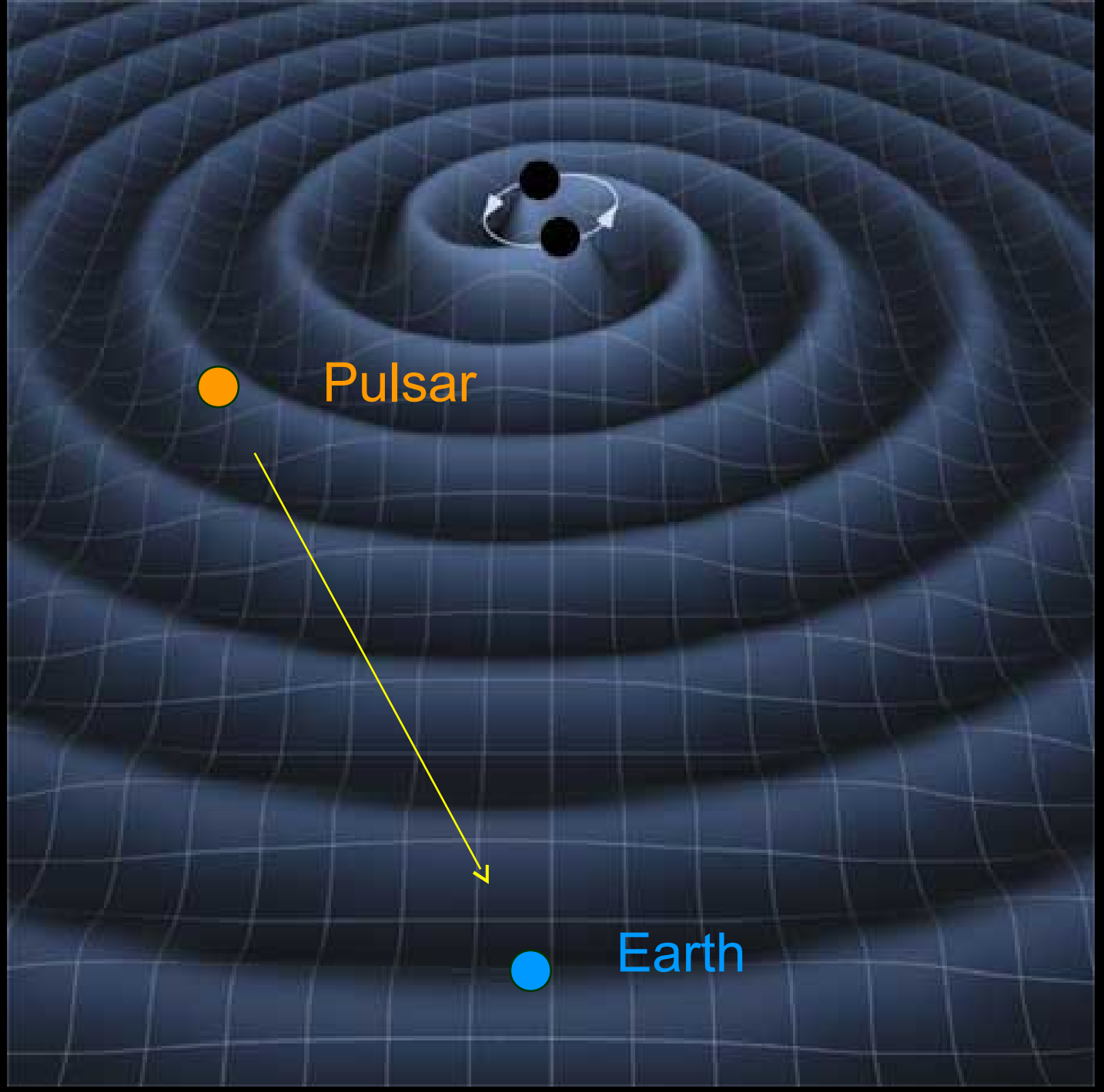


PSR J1614-2230
Spin = 3.15 ms
Orbit = 8.7 days
M = 1.97(2) Msun

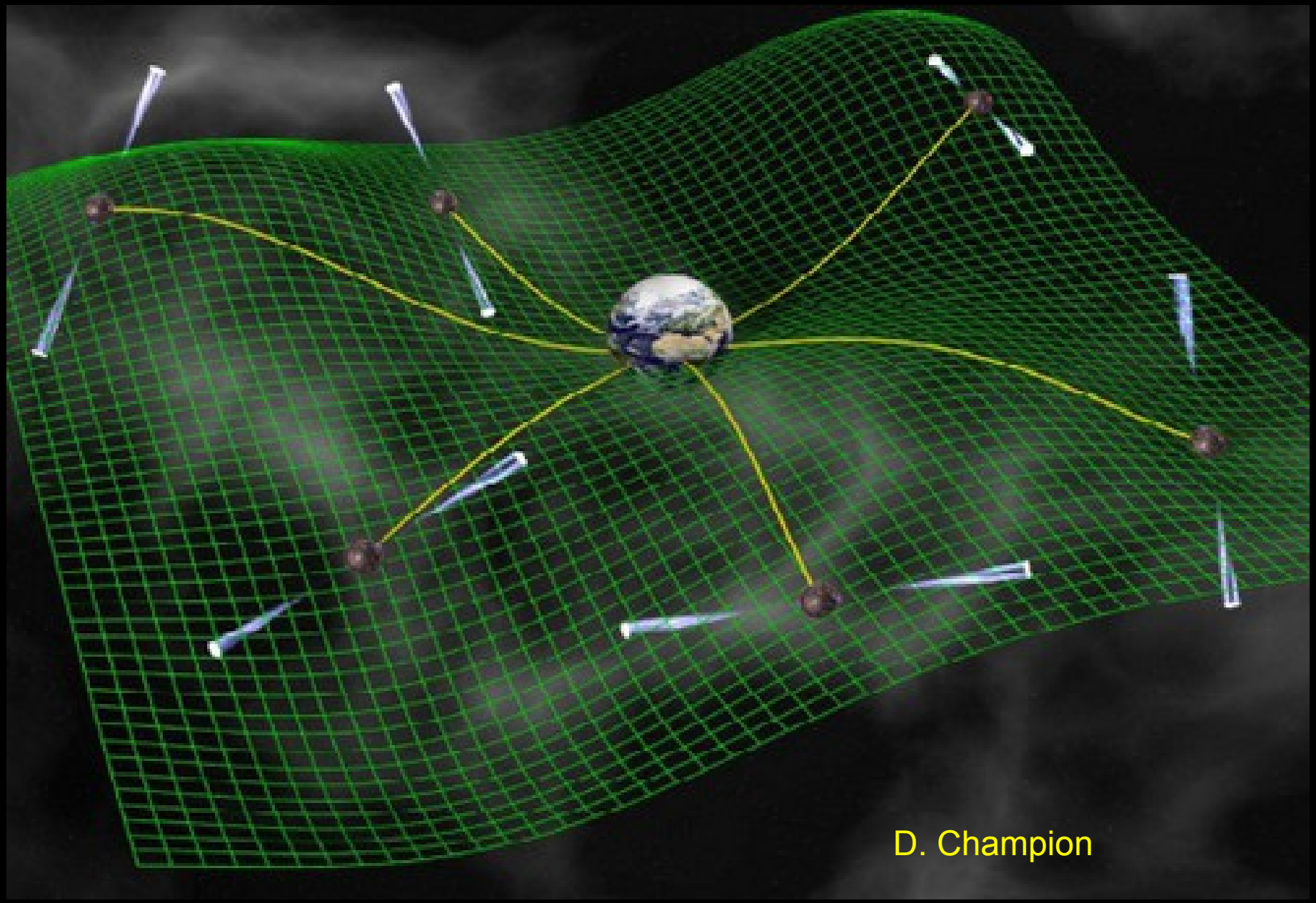


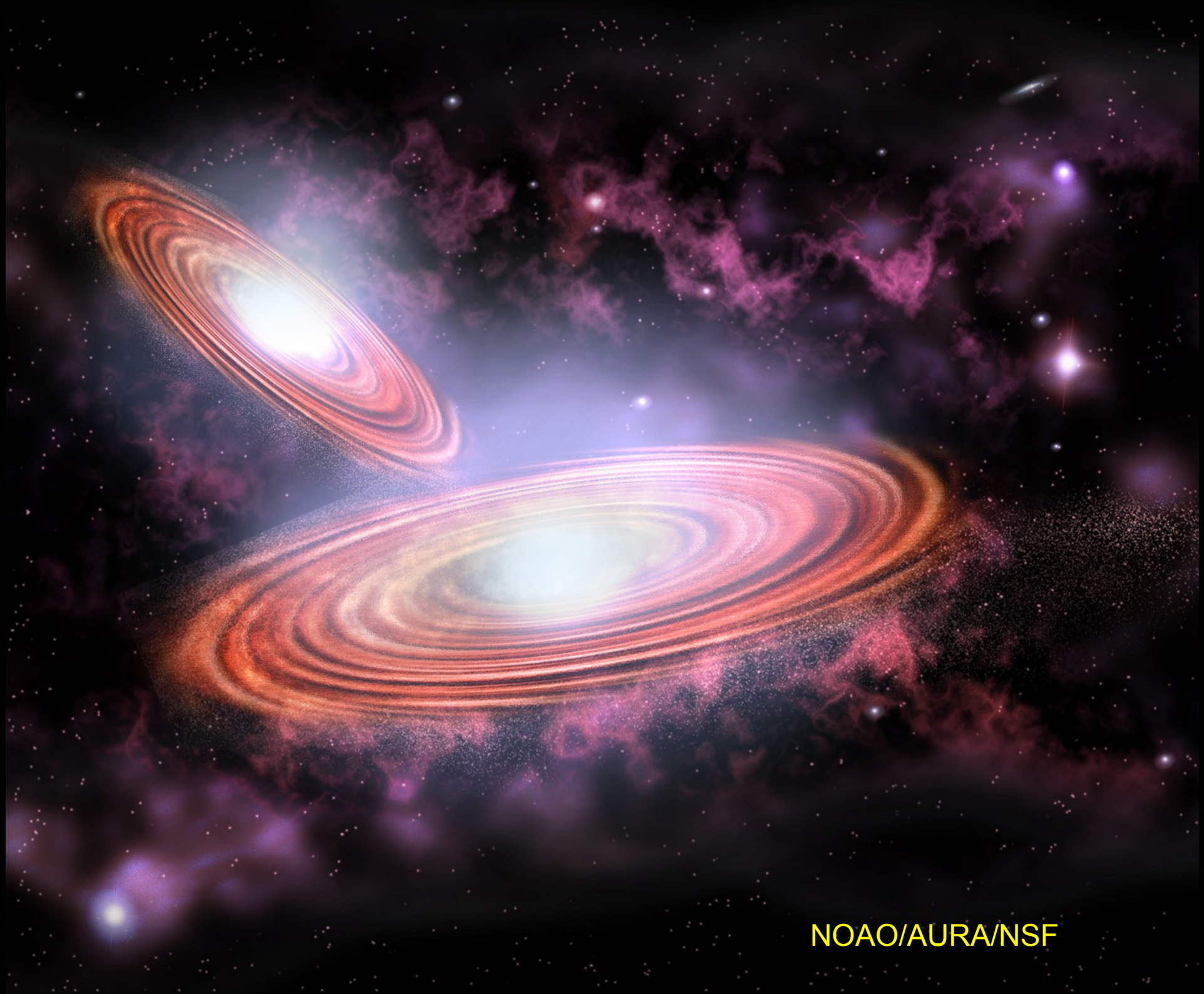
Demorest et al. (2010)


Newton's fixed space
Einstein's flexible space-time



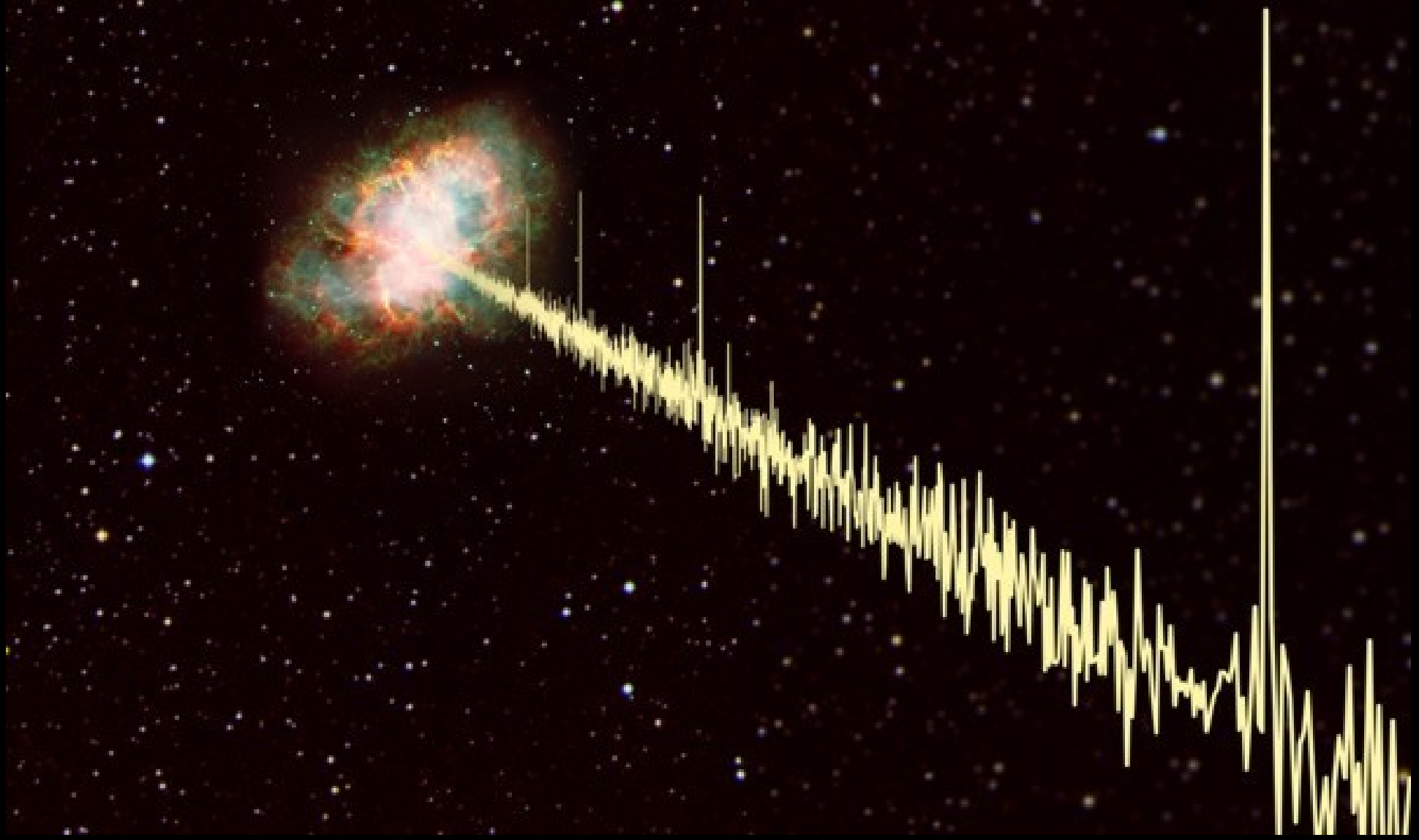
Credit: Don Backer / NASA


D. Champion


NOAO/AURA/NSF


Green Bank, West Virginia
Westerbork, The Netherlands
Effelsberg, Germany
Pune, India
The race is on!!!
Arecibo, Puerto Rico
Cheshire, United Kingdom
Nancay, France
Parkes, Australia

And now for something different...



Credit: Joeri van Leeuwen

DISCOVERY OF 14 RADIO PULSARS IN A SURVEY OF THE MAGELLANIC CLOUDS

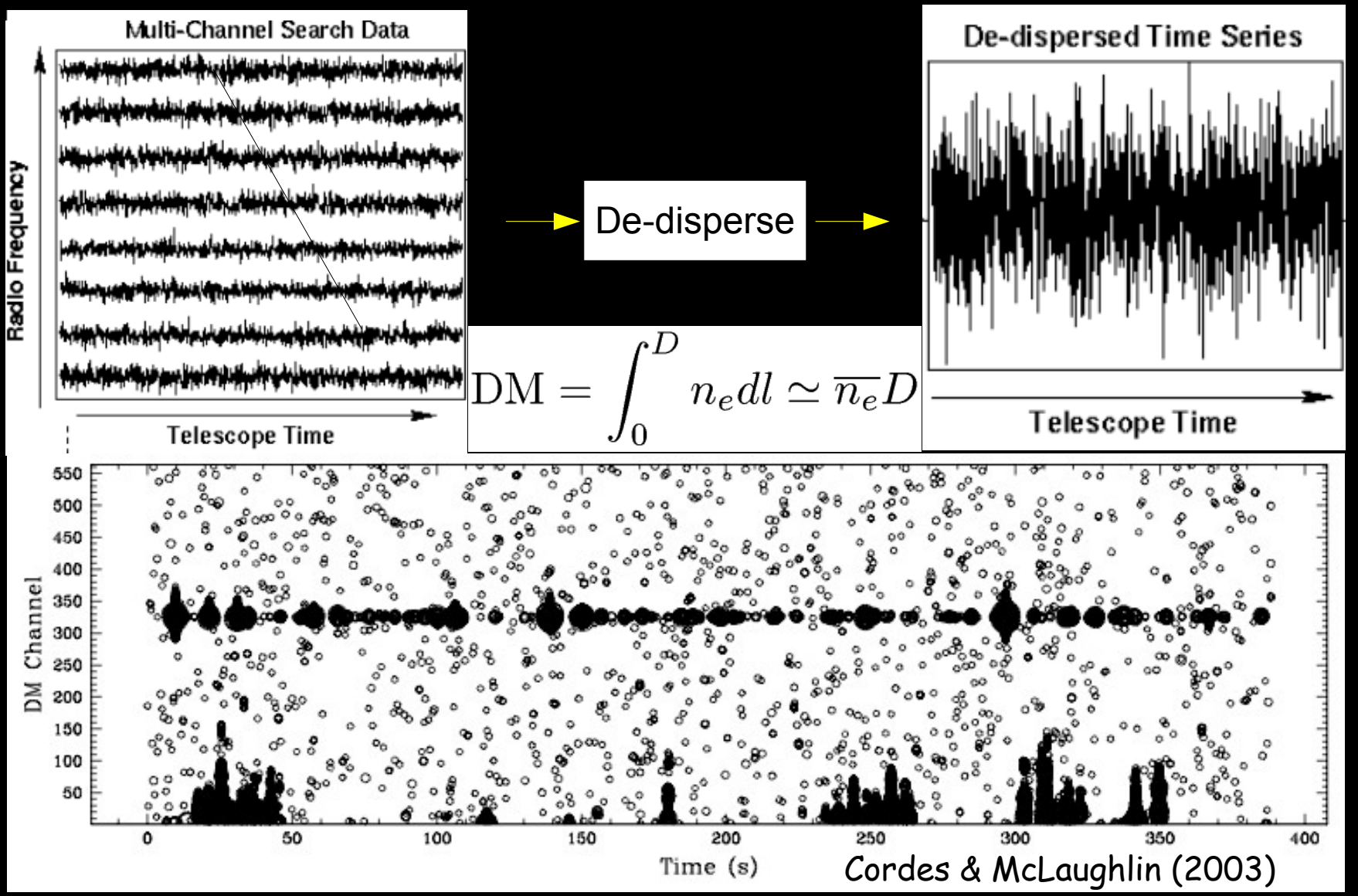
R. N. MANCHESTER,[1] G. FAN,[2,3] A. G. LYNE,[4] V. M. KASPI,[3] AND F. CRAWFORD[5]

Received 2006 February 23; accepted 2006 April 19

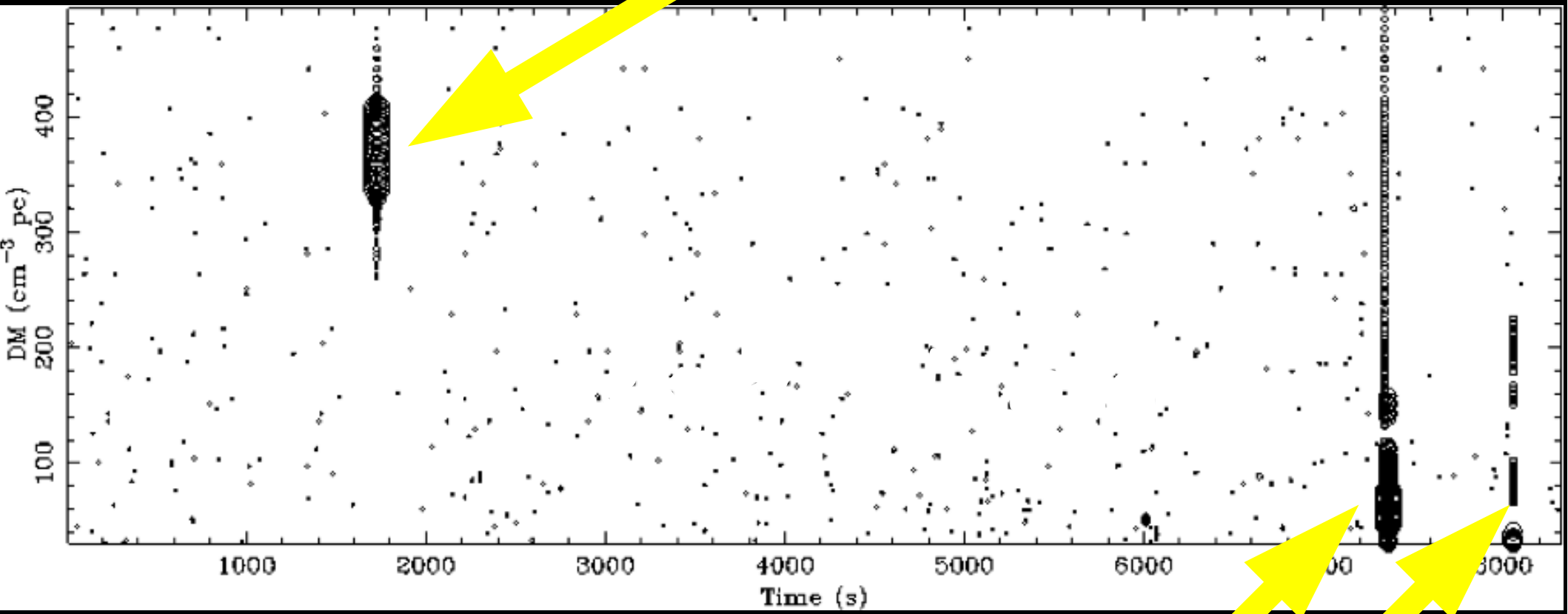
2006

Figure credits:
ATNF (left)
Astropixels (right)

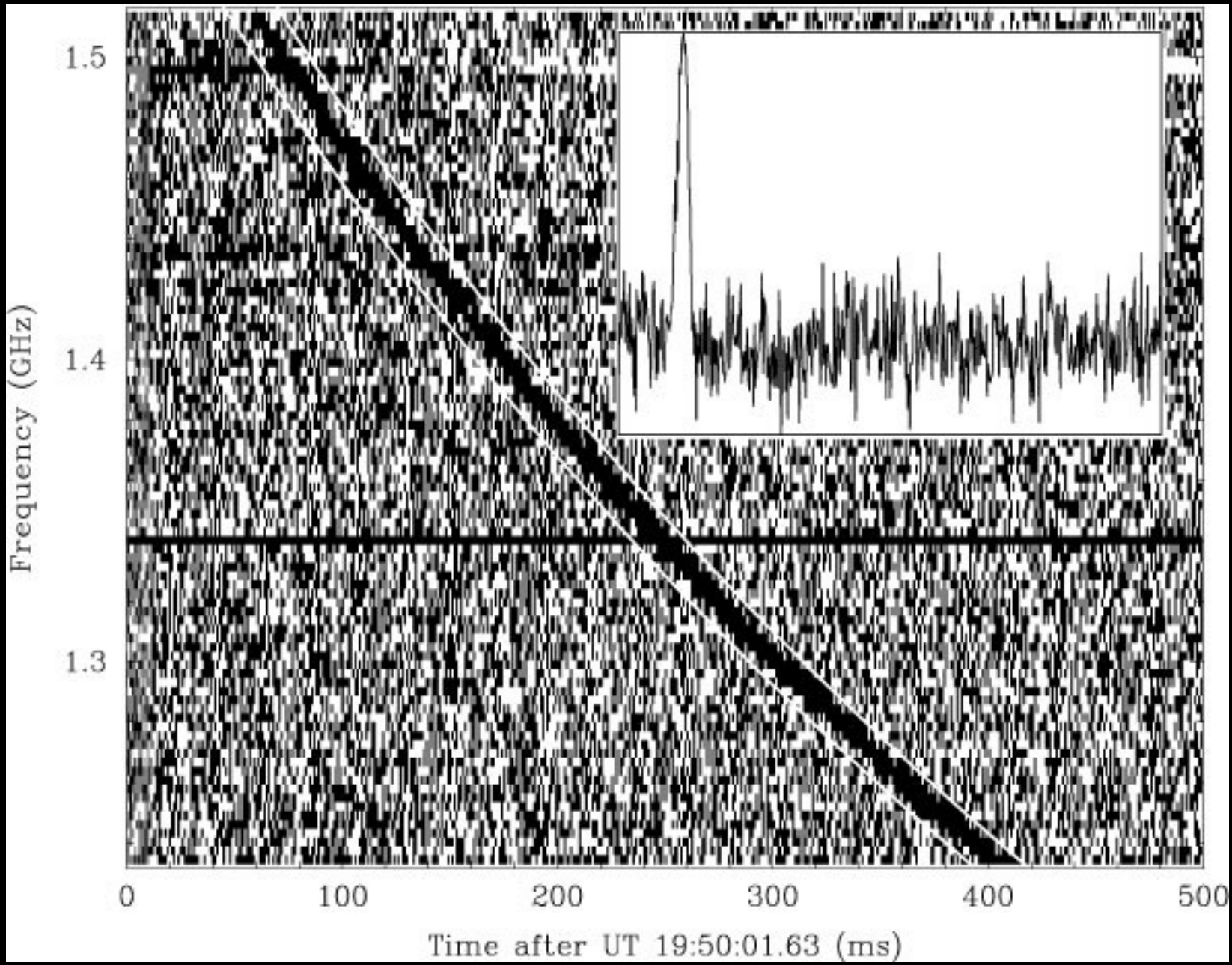
Single-pulse search



An unexpected signal!



Interference


1.5
1.4
1.3
Frequency (GHz)
0
100
200
300
400
500
Time after UT 19:50:01.63 (ms)

A Bright Millisecond Radio Burst of Extragalactic Origin

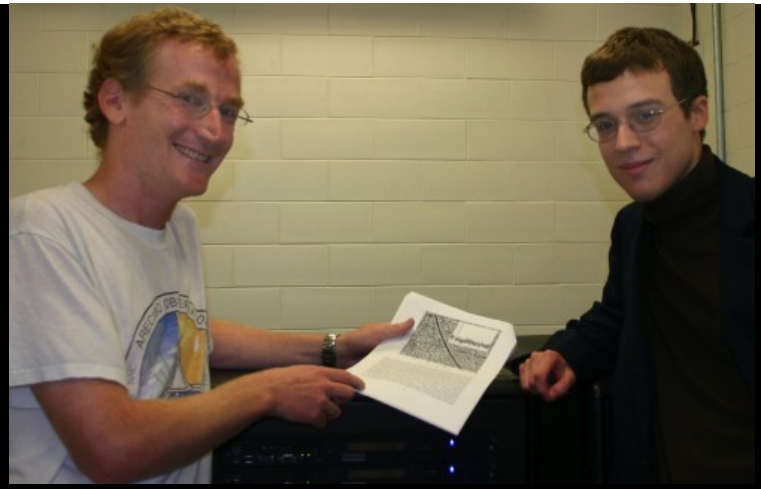
2007

D. R. Lorimer,[1,2]* M. Bailes,[3] M. A. McLaughlin,[1,2] D. J. Narkevic,[1] F. Crawford[4]

Pulsar surveys offer a rare opportunity to monitor the radio sky for impulsive burst-like events with millisecond durations. We analyzed archival survey data and found a 30-jansky dispersed burst, less than 5 milliseconds in duration, located 3° from the Small Magellanic Cloud. The burst properties argue against a physical association with our Galaxy or the Small Magellanic Cloud. Current models for the free electron content in the universe imply that the burst is less than 1 gigaparsec distant. No further bursts were seen in 90 hours of additional observations, which implies that it was a singular event such as a supernova or coalescence of relativistic objects. Hundreds of similar events could occur every day and, if detected, could serve as cosmological probes.

Questions:

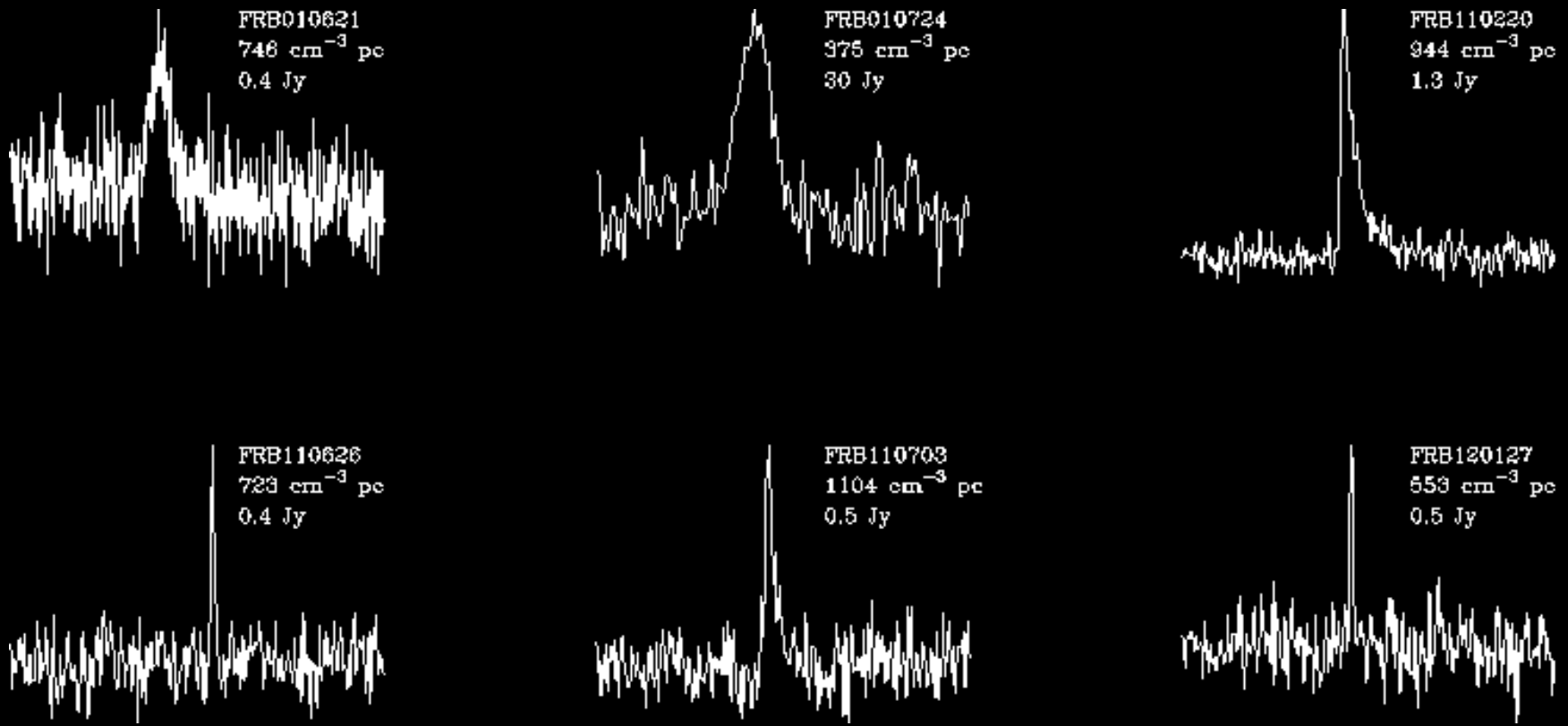
* Why so bright?
* Why no weaker events?
* Detectable in other surveys?



A Population of Fast Radio Bursts at Cosmological Distances

2013

D. Thornton,[1,2*] B. Stappers,[1] M. Bailes,[3,4] B. Barsdell,[3,4] S. Bates,[5] N. D. R. Bhat,[3,4,6] M. Burgay,[7] S. Burke-Spolaor,[8] D. J. Champion,[9] P. Coster,[2,3] N. D'Amico,[10,7] A. Jameson,[3,4] S. Johnston,[2] M. Keith,[2] M. Kramer,[9,1] L. Levin,[5] S. Milia,[7] C. Ng,[9] A. Possenti,[7] W. van Straten[3,4]



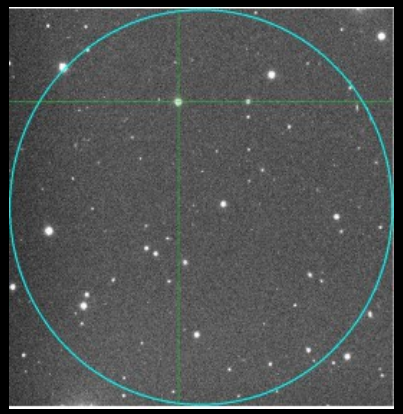
What could they be?

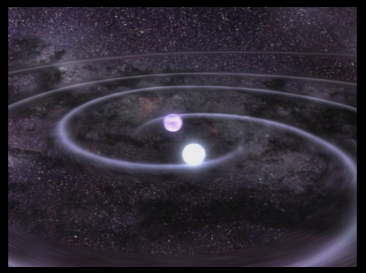
- Extra-terrestrial
  - Alien signals

    (Luan & Goldreich 2014)
- Galactic
  - Flare stars

    (Loeb et al. 2014)
- Extragalactic
  - Favored cosmic catastrophe

    (Cobbly et al. 2014)





What are people doing

- Searching archival data
- Follow-up on existing bursts
- Realtime detectors on large/small dishes
- Staring at the sky with interferometers

(My) bold predictions

- 2015: counterparts found
- 2020: 100s FRBs found
- 2025: 1000s of FRBs known
- 2030: FRBs essential cosmological tools