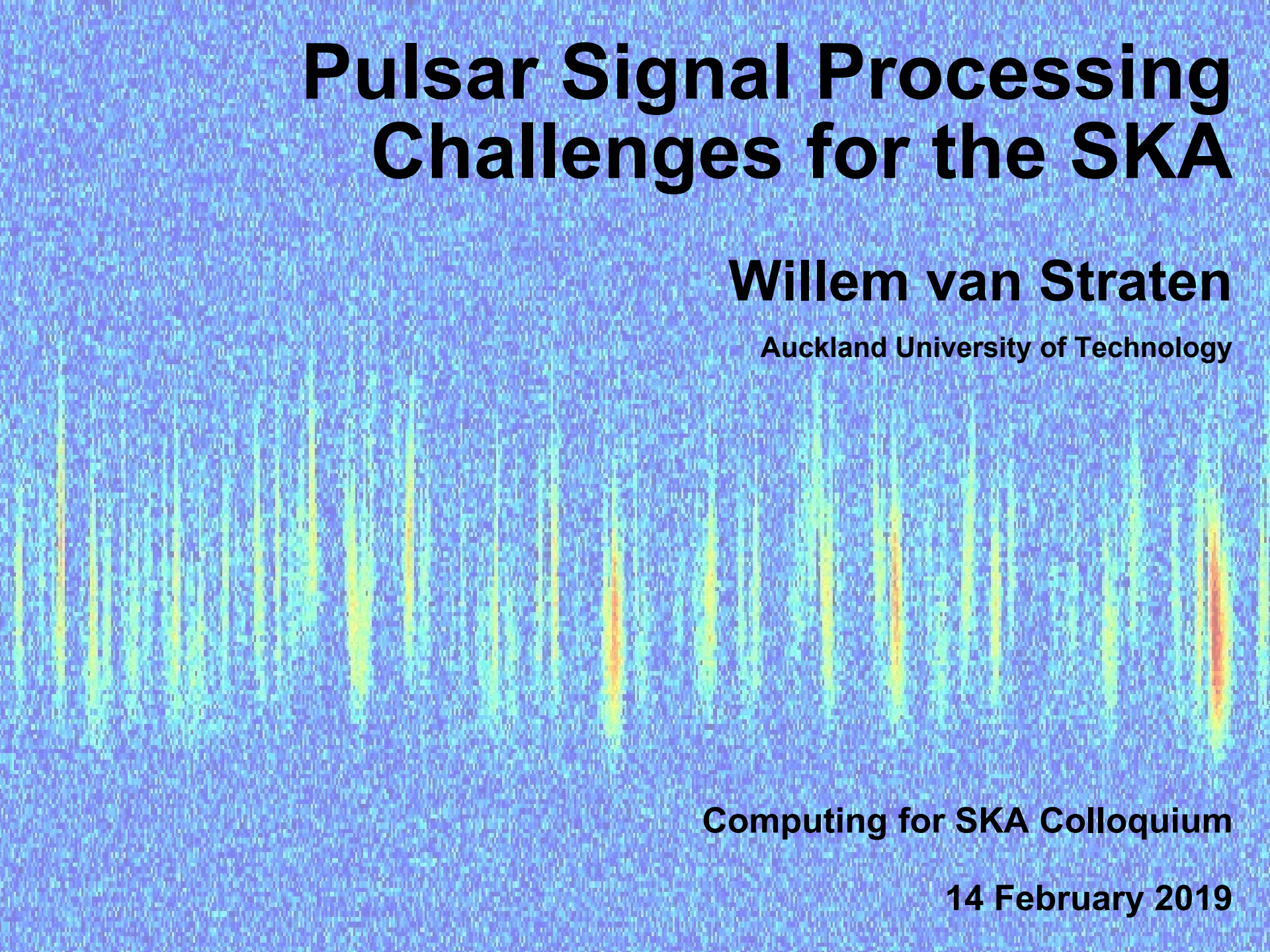
Pulsar Signal Processing Challenges for the SKA

Willem van Straten

Auckland University of Technology



Computing for SKA Colloquium

14 February 2019

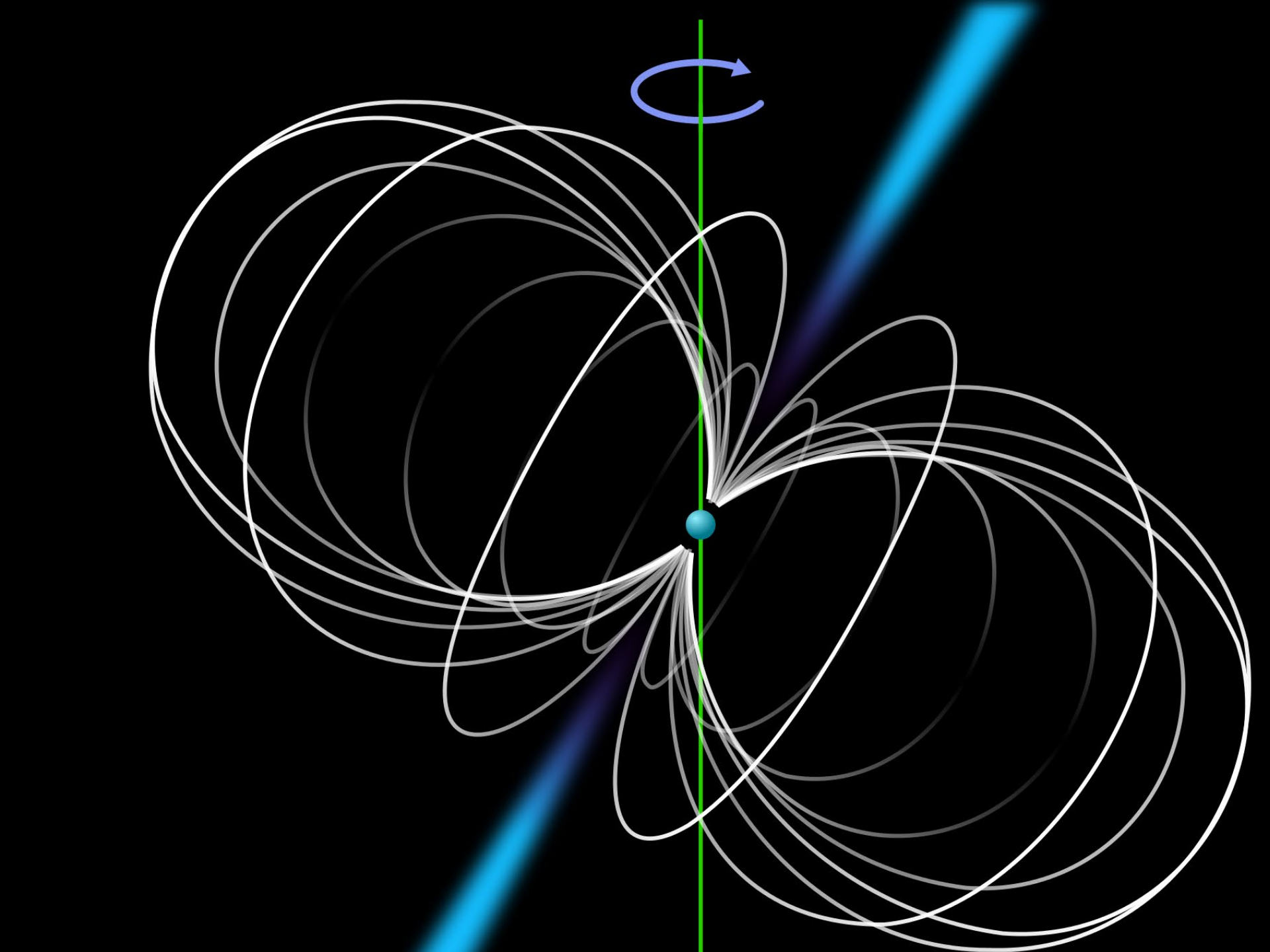


Image credit: Jonathon Green

Pulsars: Fundamental Physics

- Precision tests of General Relativity
- Search for nHz gravitational waves
- Relativistic plasma physics
- Equation of state of ultradense matter
- Superfluid and superconducting interior

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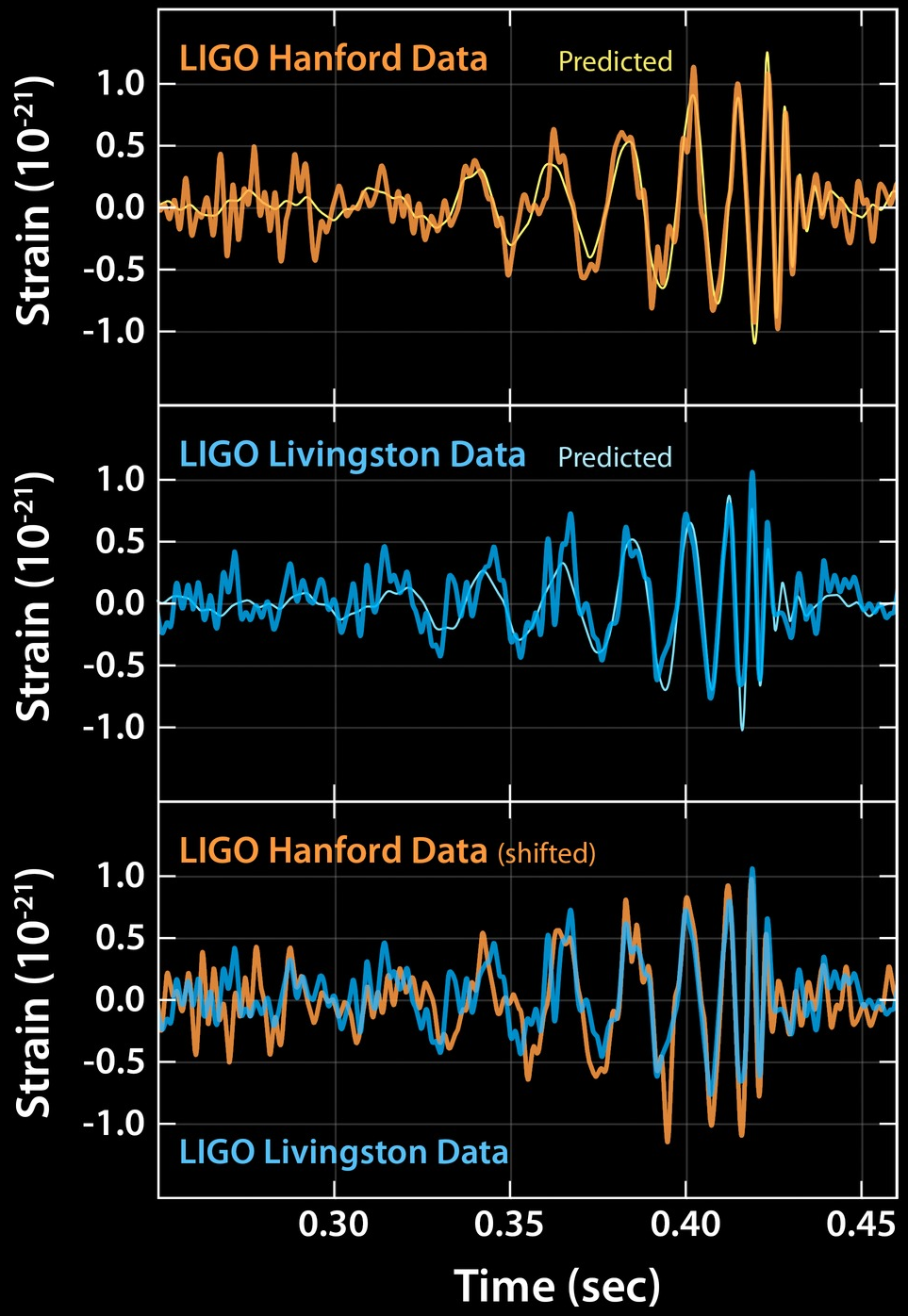
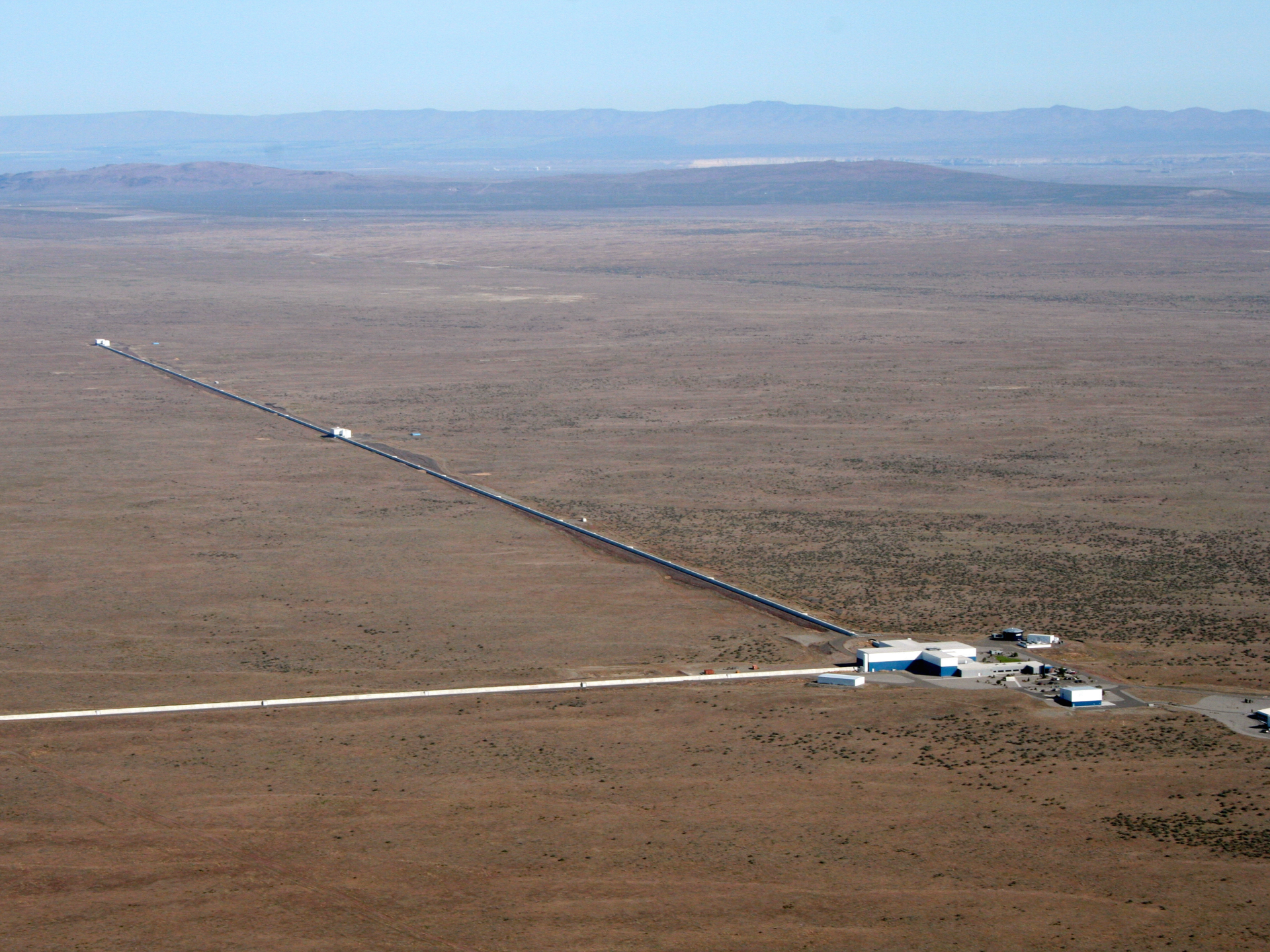
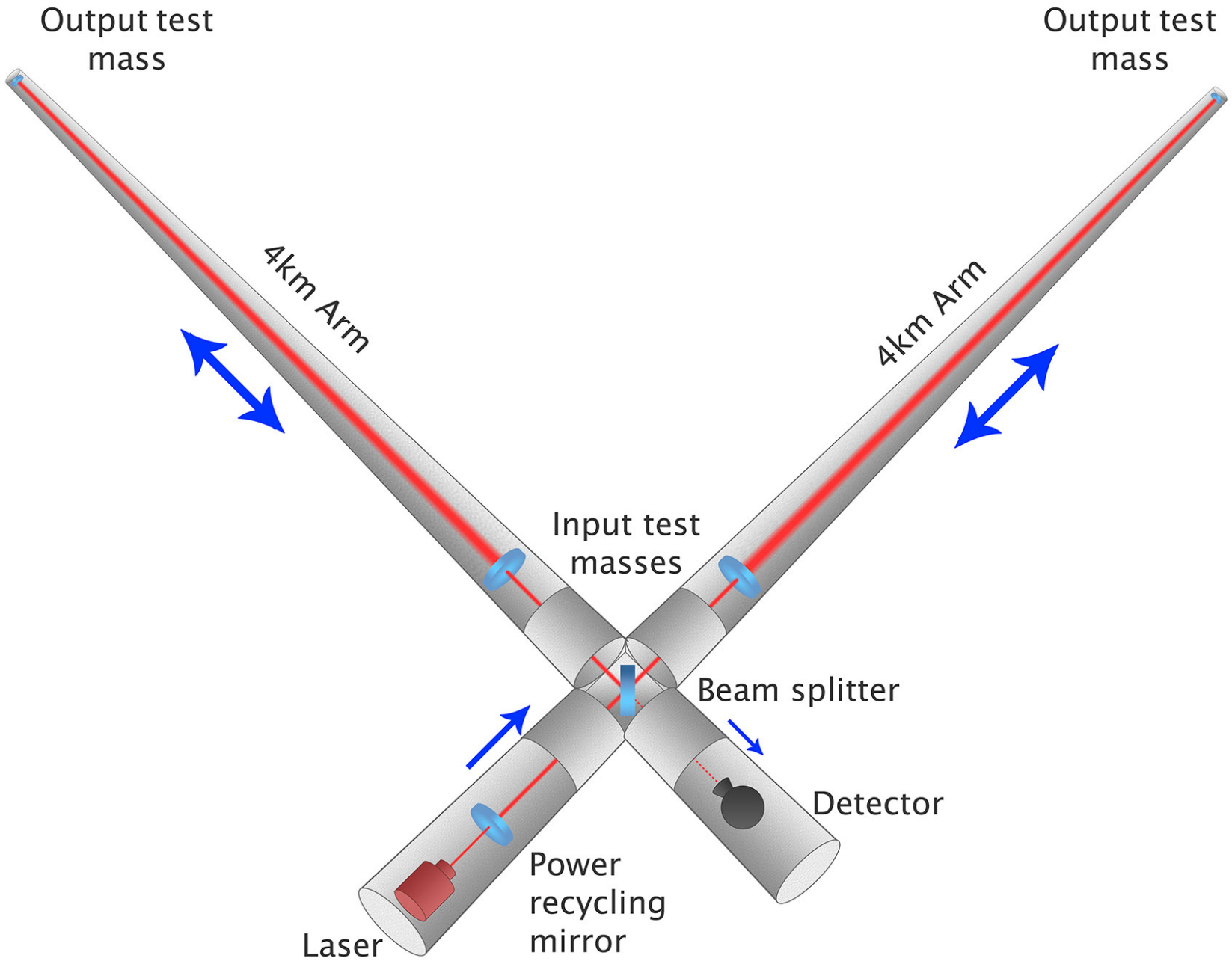


Abbott et al. (2016)



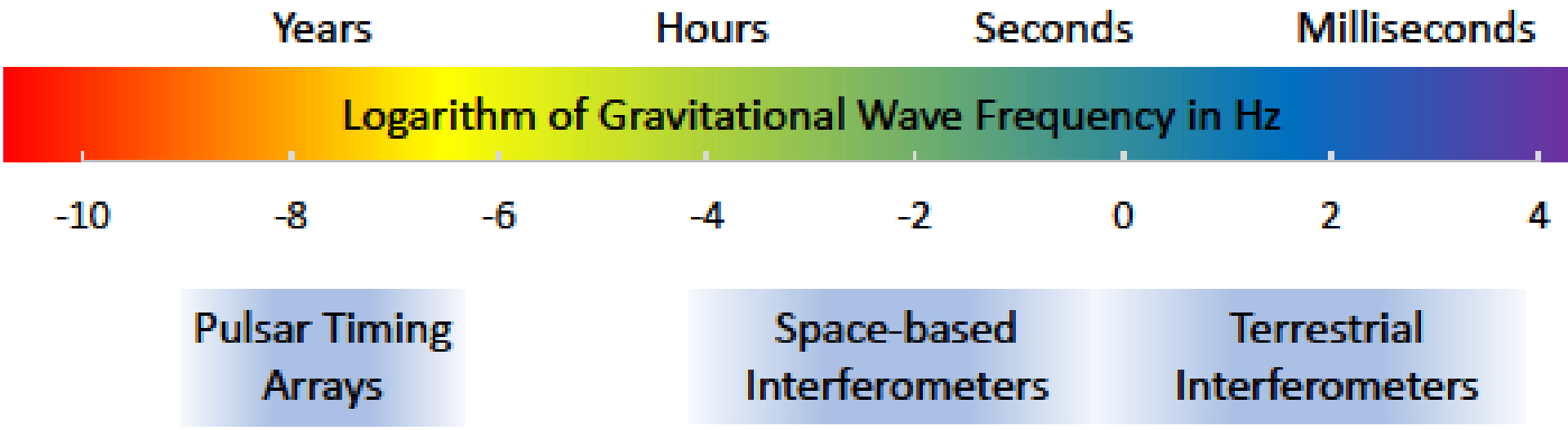

Output test mass
Output test mass
4km Arm
4km Arm
Input test masses
Beam splitter
Detector
Power recycling mirror
Laser

Gravitational Wave Sources

Supermassive Black Hole Binary Systems

Compact Objects Binary Systems

Compact Objects and Supermassive Black Holes

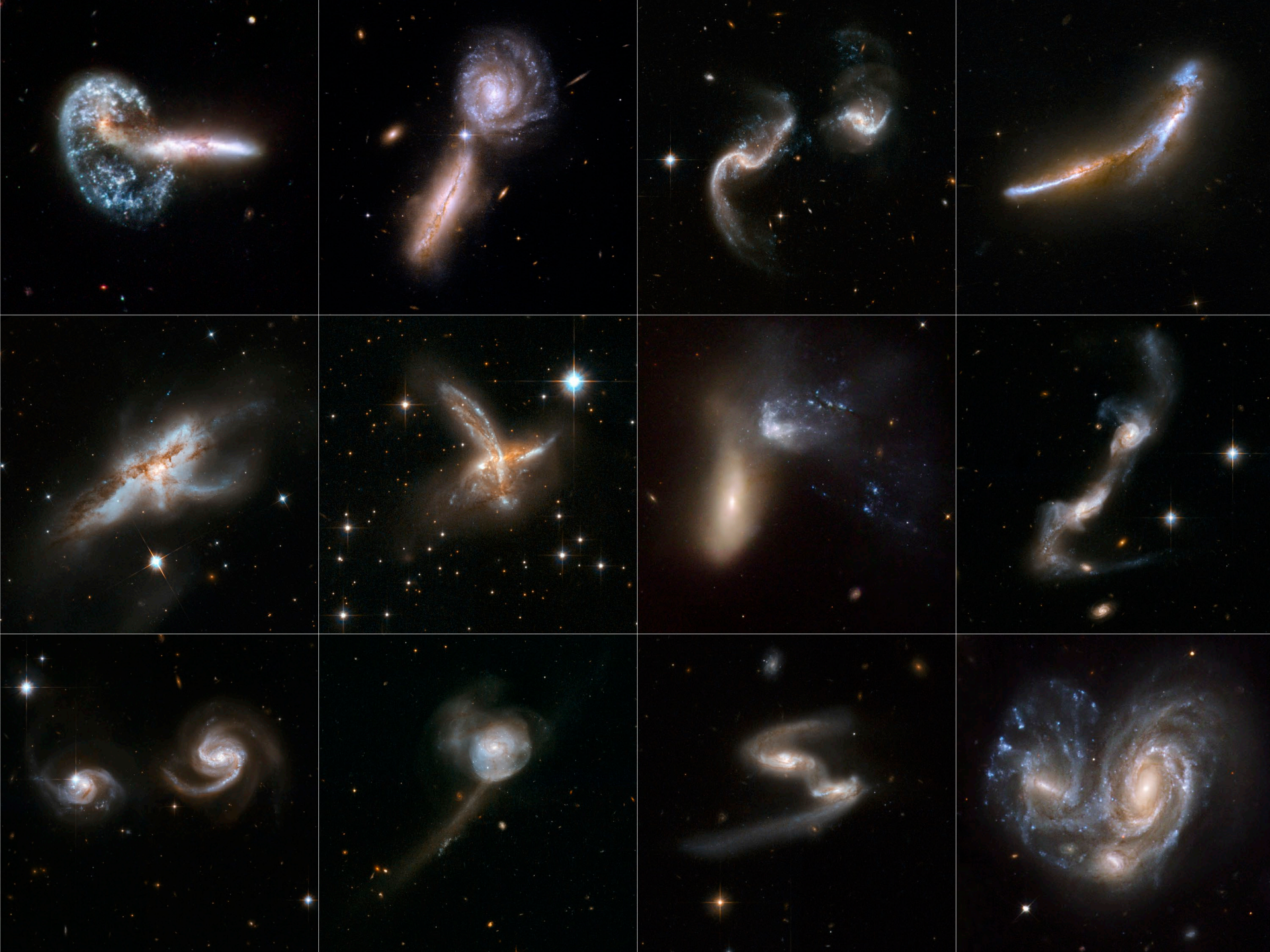


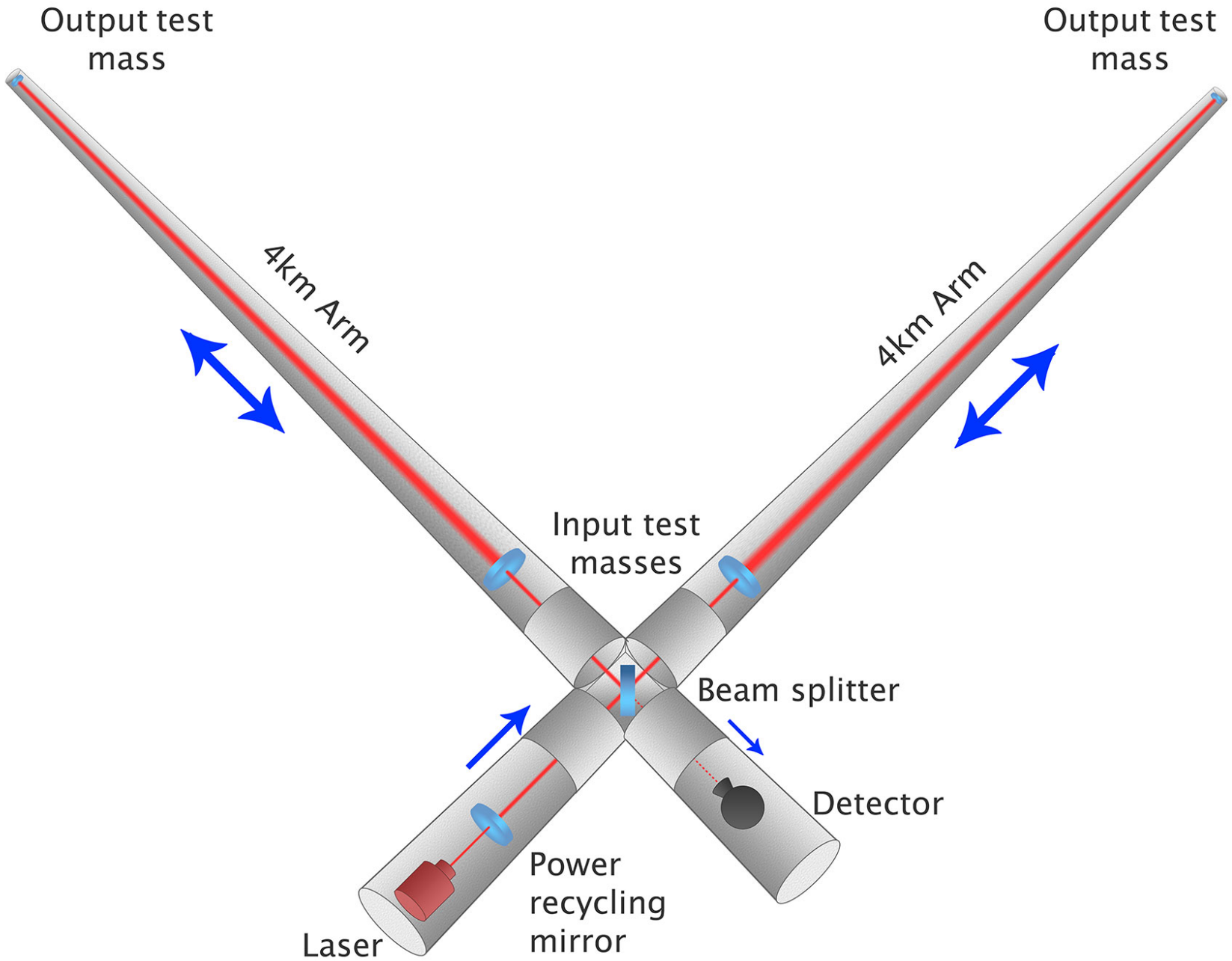
Pulsar Timing Arrays

Space-based Interferometers

Terrestrial Interferometers

Detection Methods

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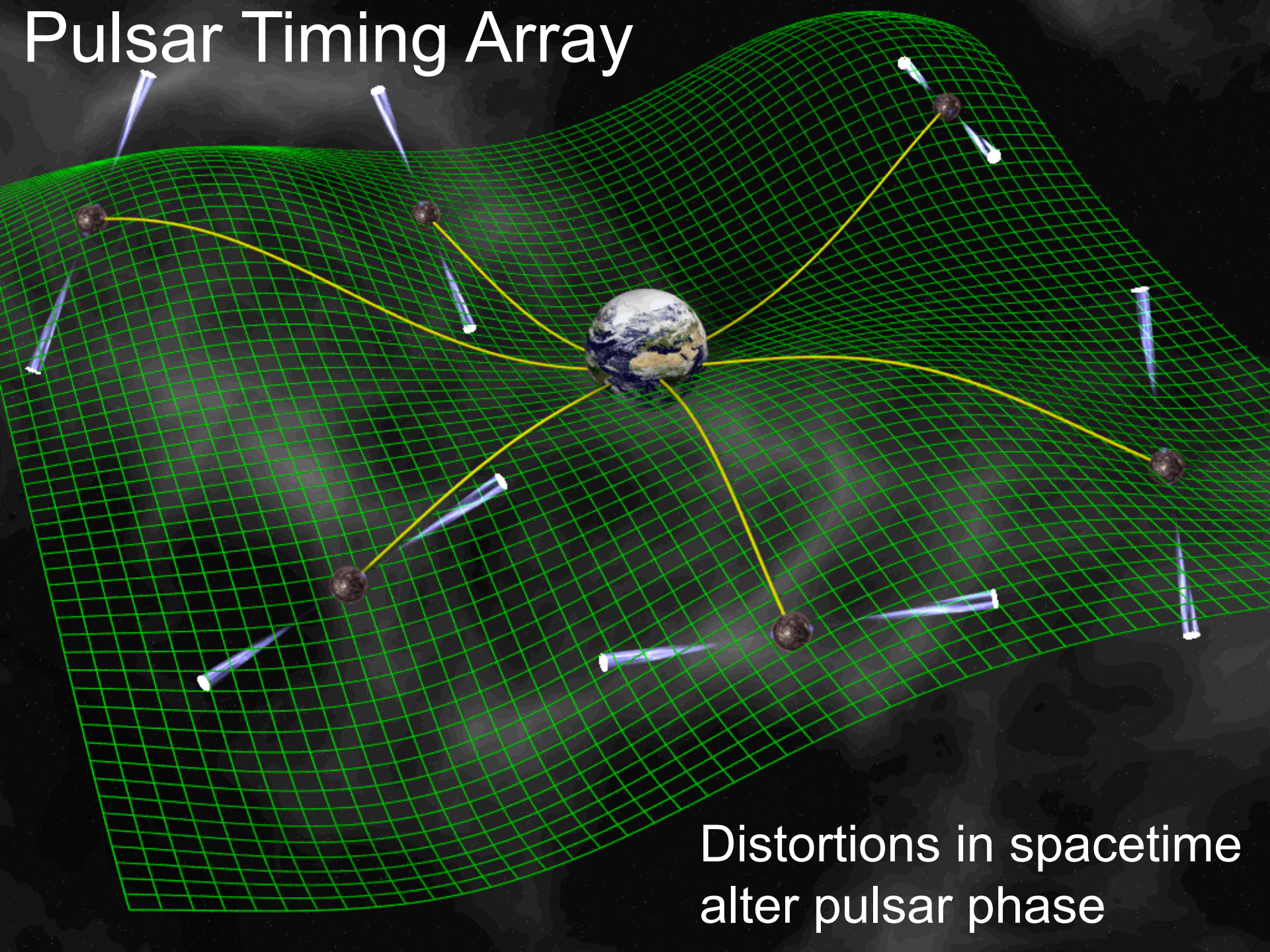
Pulsar Timing Array



Distortions in spacetime alter pulsar phase

Gravitational Wave Detection is Challenging

- Pulsar intrinsic
  - Stochastic impulsive emission (white noise)
  - Spin irregularity (red noise)
- Interstellar medium
  - Variations in electron density along line of sight (red)
  - Multipath propagation (scattering)
- Within solar system
  - Errors in the solar system ephemeris (dipolar)
  - Errors in the definition of time on Earth (monopolar)

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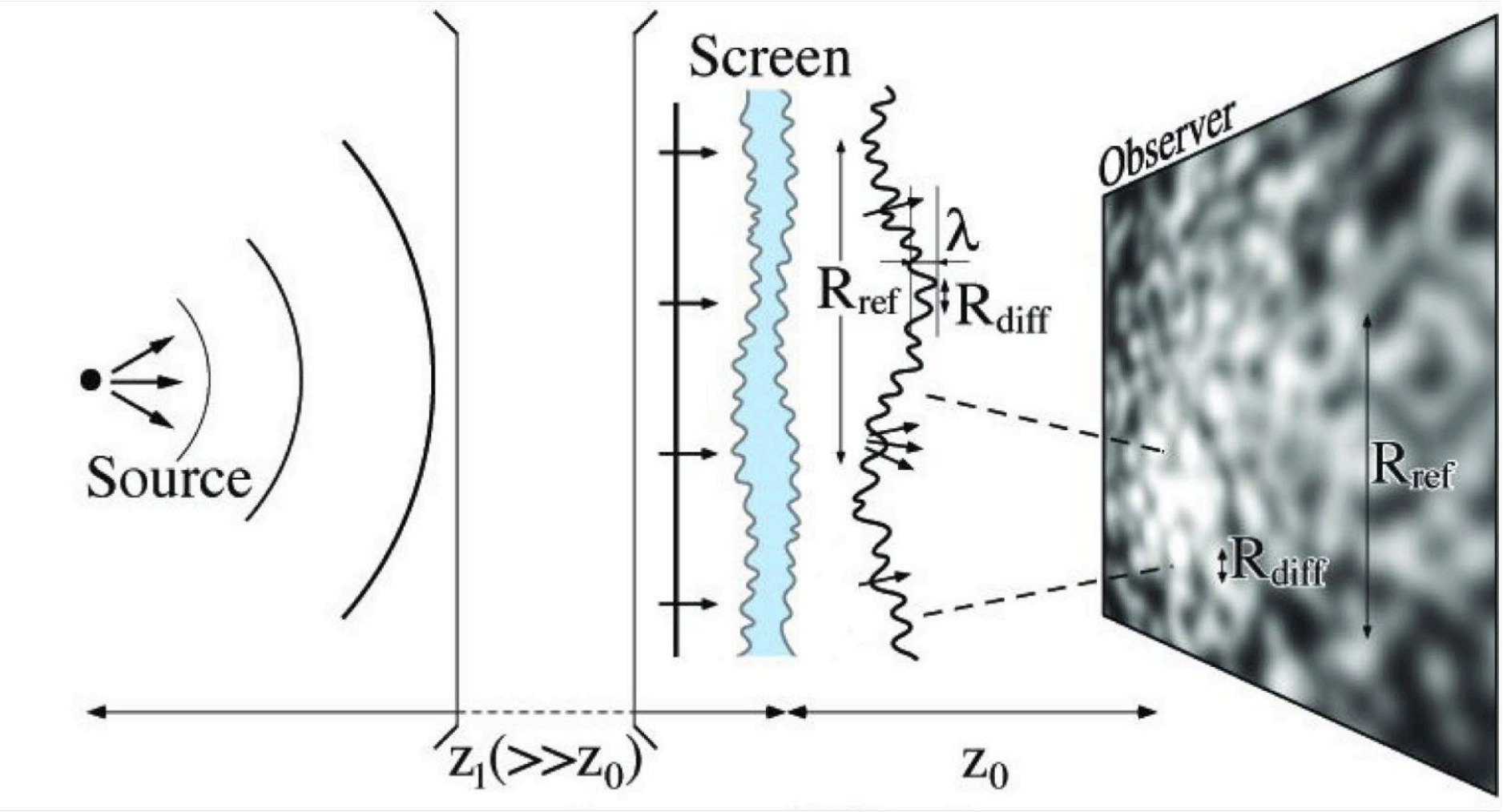
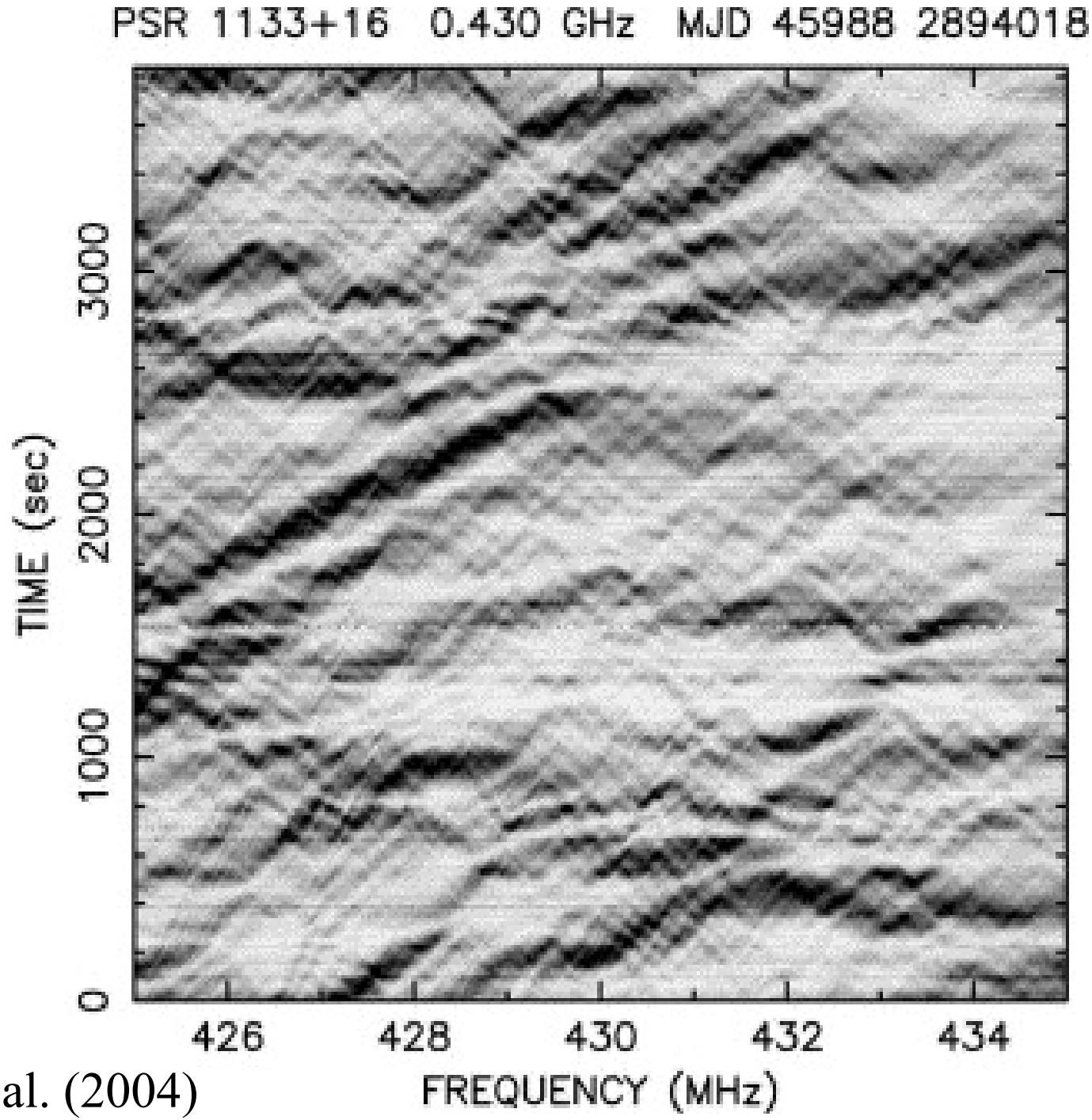
Multipath propagation

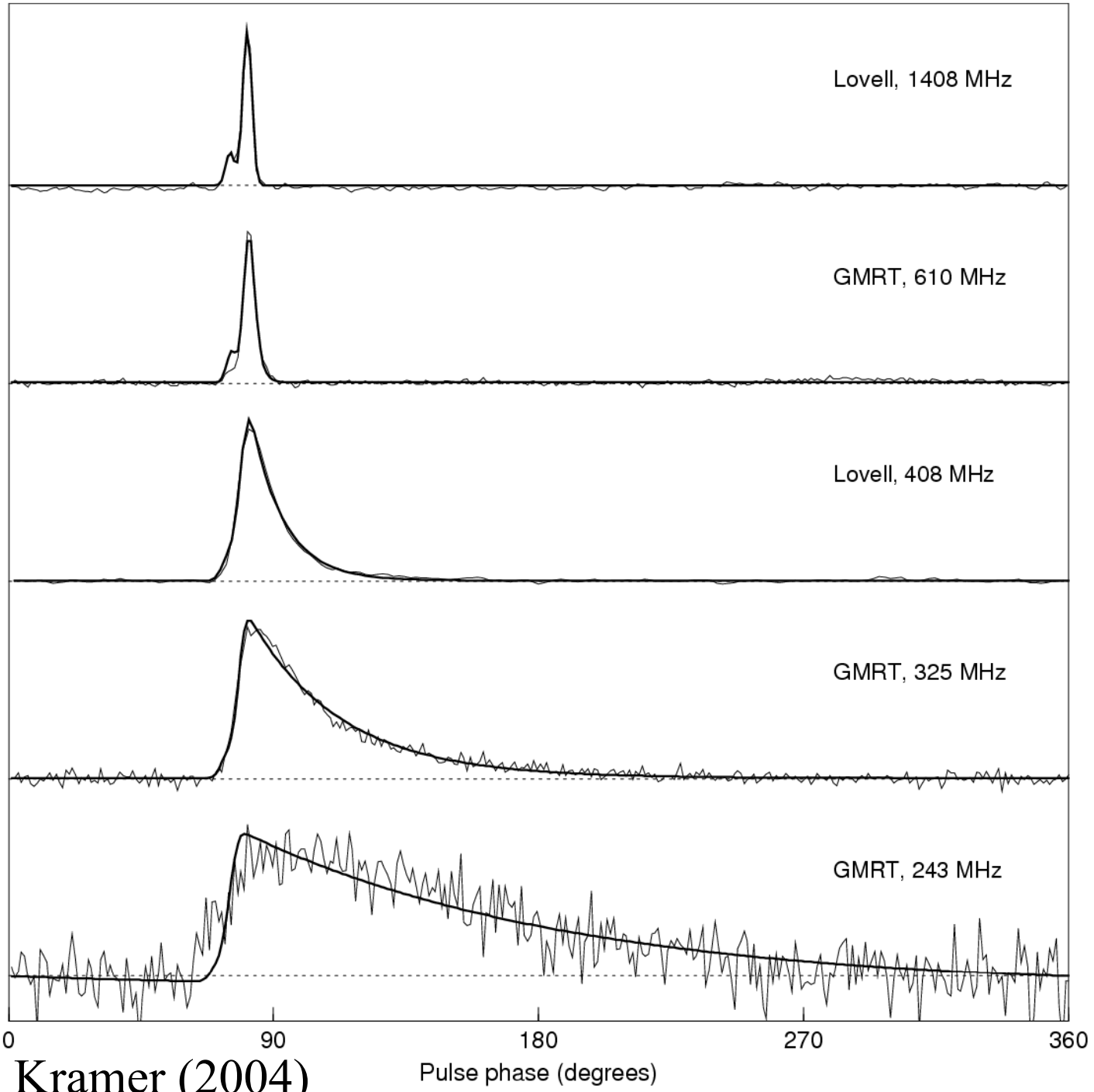
NASA, ESA and J. Hester (ASU)



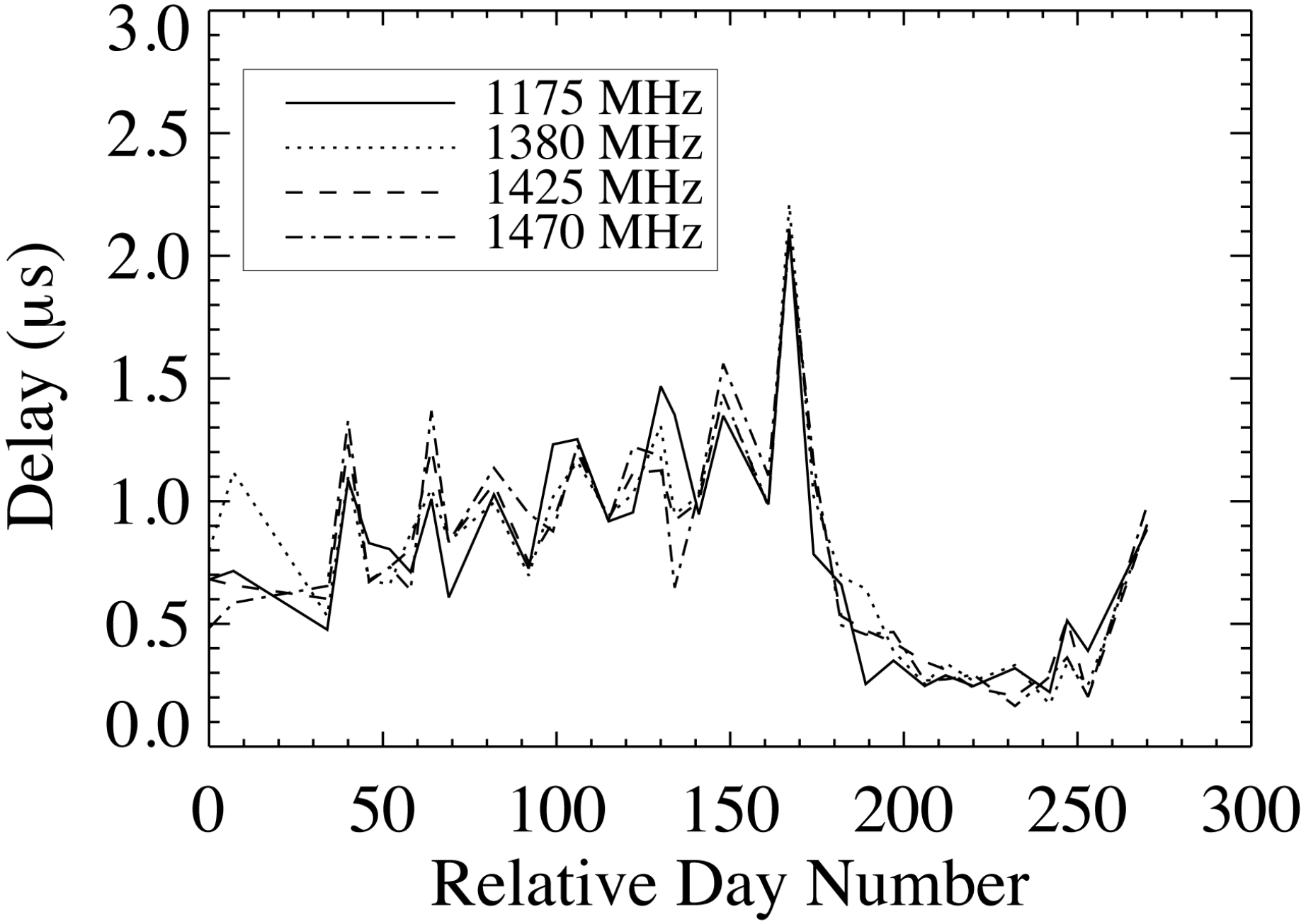
Habibi et al. (2011)



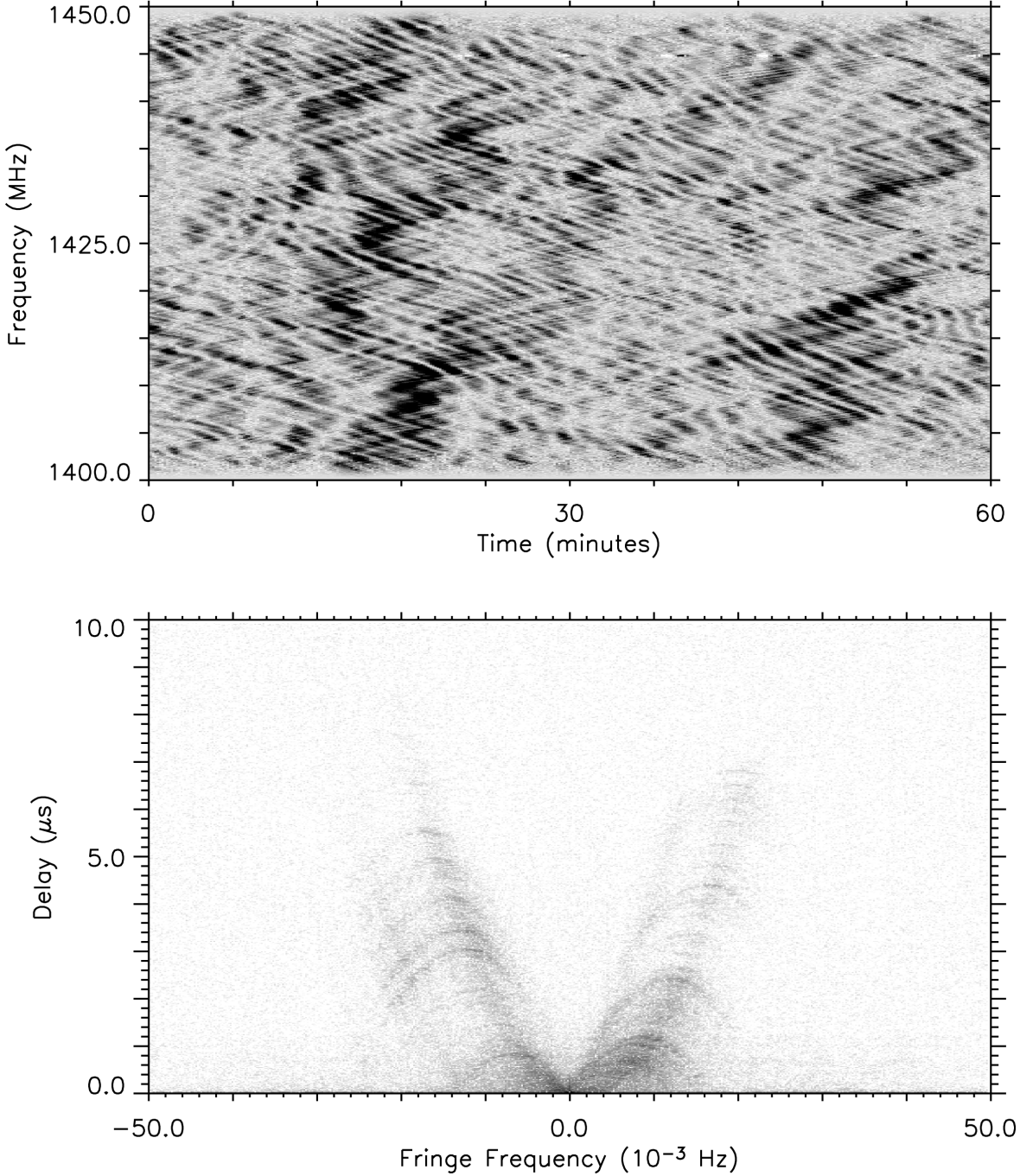
Lazio et al. (2004)



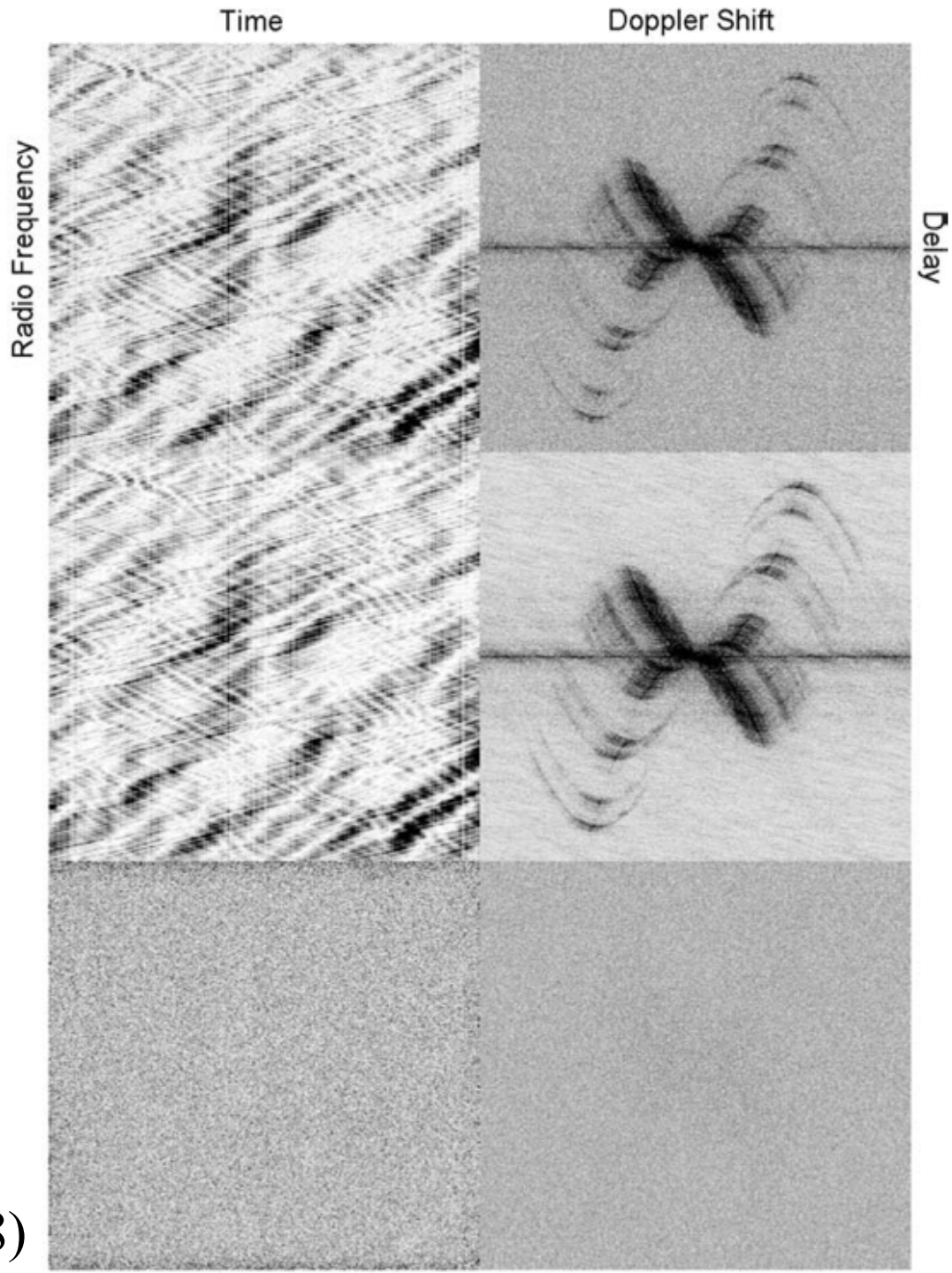
Lorimer & Kramer (2004)



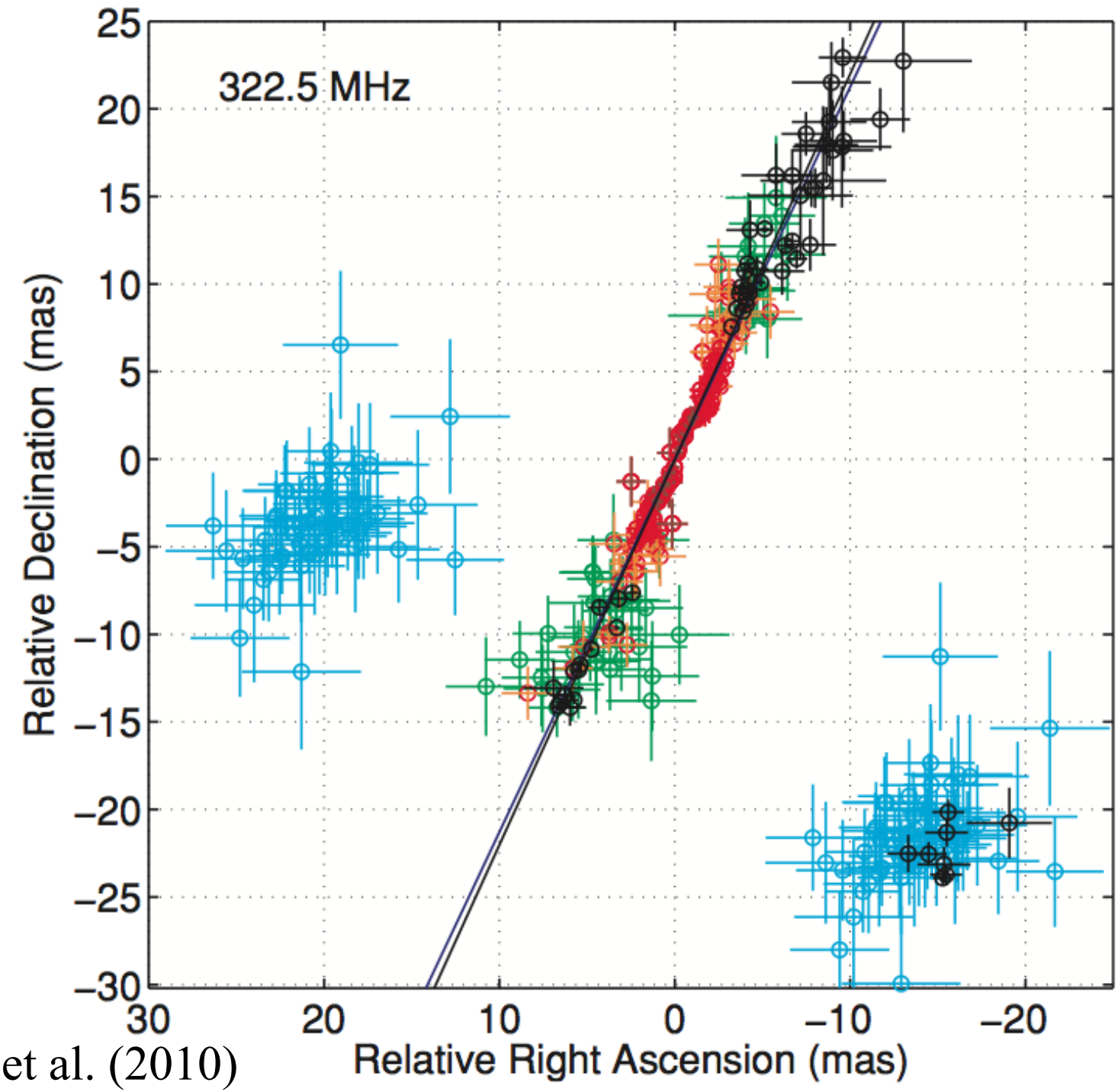
Hemberger & Stinebring (2008)



Credit: Dan Stinebring



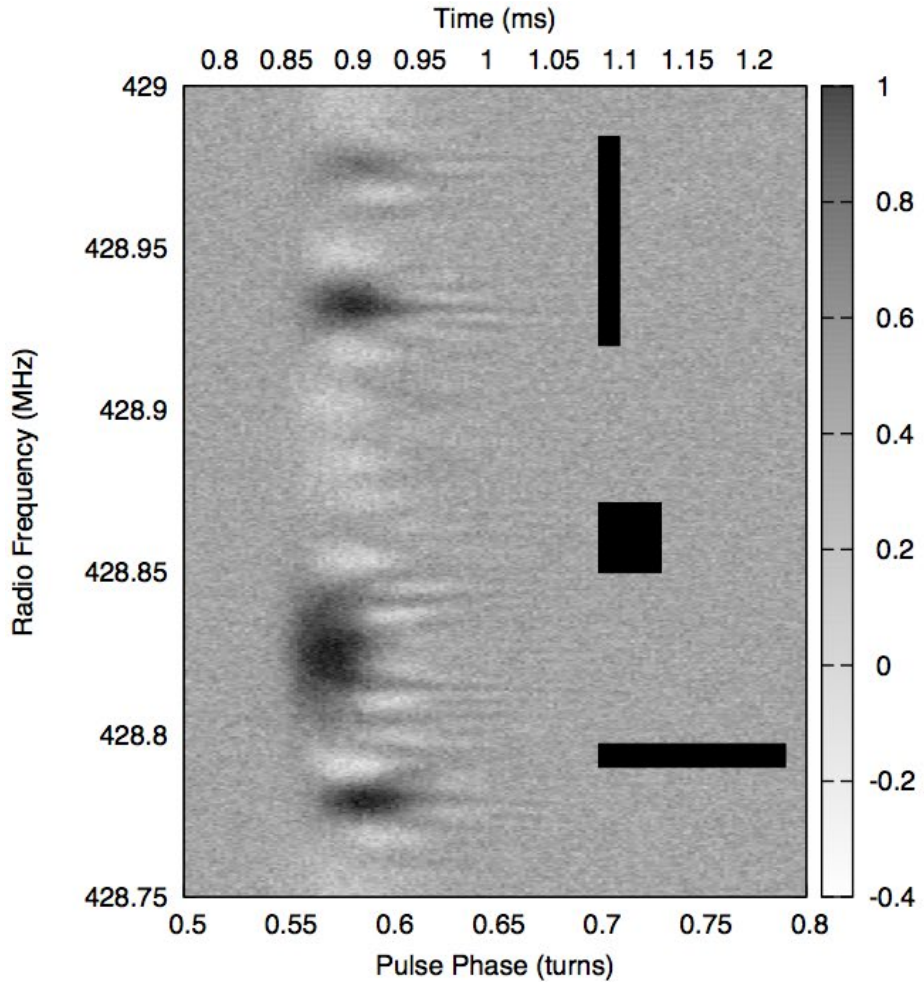
Walker et al (2008)

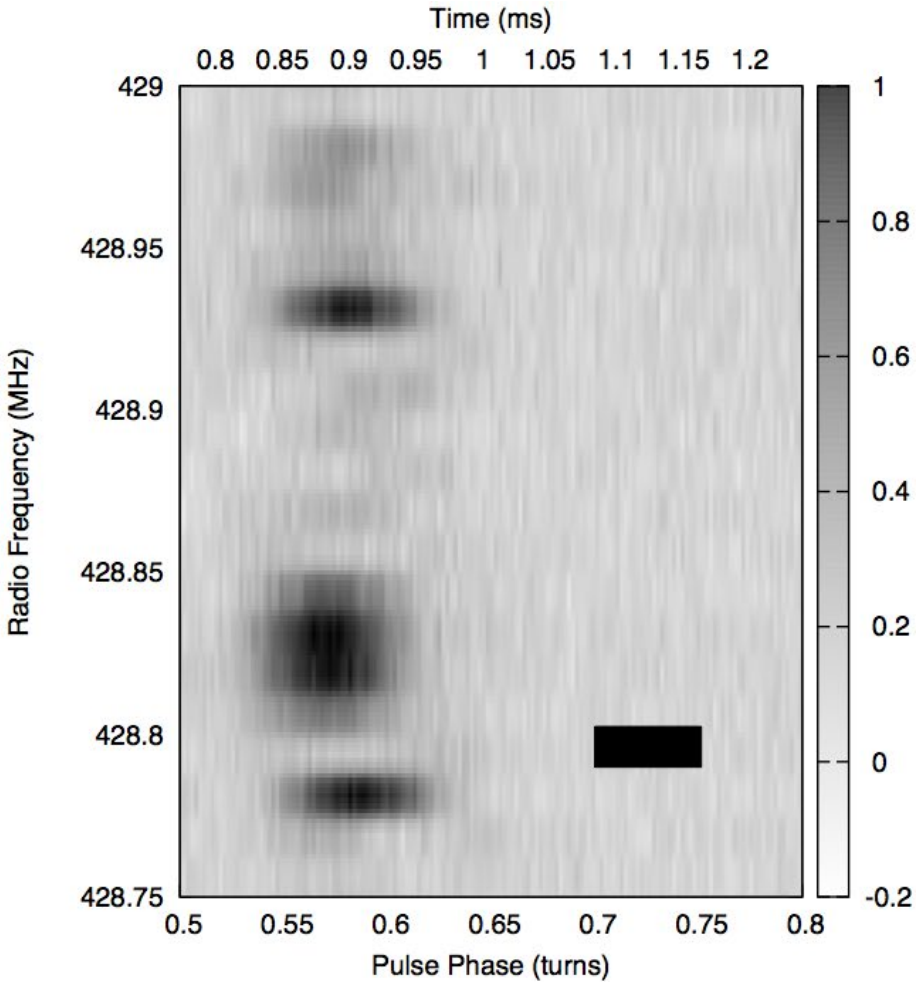


Brisken et al. (2010)

Helix Nebula Detail HST • WFPC2

PRC96-13b · ST ScI OPO · April 15, 1996 · C.R. O'Dell (Rice Univ.), NASA





Demorest (2011)

Adaptive Optics for Pulsars

Cyclic spectrum	SKA1-Low	SKA1-Mid B1
Bandwidth (MHz)	300	700
# phase bins	1024	1024
# taps interpolate	7	7
# polarizations	4	4
TMACs	**9.2**	**21.5**

De-dispersion	SKA1-Low	SKA1-Mid B1	SKA1-Mid B5
Bandwidth (MHz)	300	700	2500
Input Res. (kHz)	32	49	49
Output Res. (MHz)	0.25	1	1
Max DM	300	3000	3000
GMACs	**175**	**379**	**750**

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55%

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Square Kilometre Array

- Cyclic spectroscopy
  - computationally prohibitive
  - SKA1-Low: divide band over 16 nodes
- Interstellar holography
  - propagation delay monitor for PTAs
  - ~ AU structure of magnetoionic ISM


Thank you!