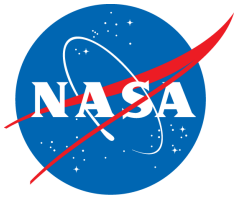


Using the Deep Space Network as a Gravitational Wave Observatory

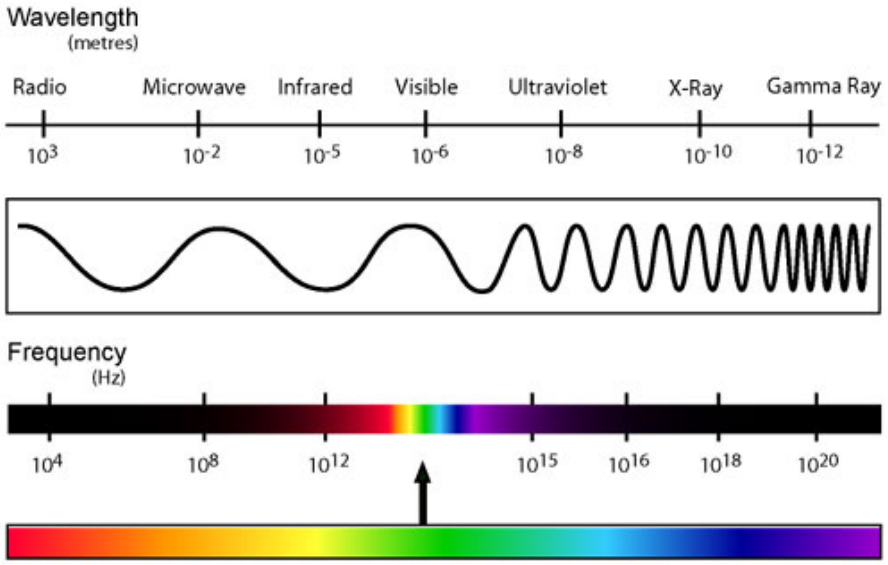
Joseph Lazio

Sarah Burke-Spolaor, Walid Majid, Michele Vallisneri, John Armstron, Curt Cutler, Thomas Kuiper

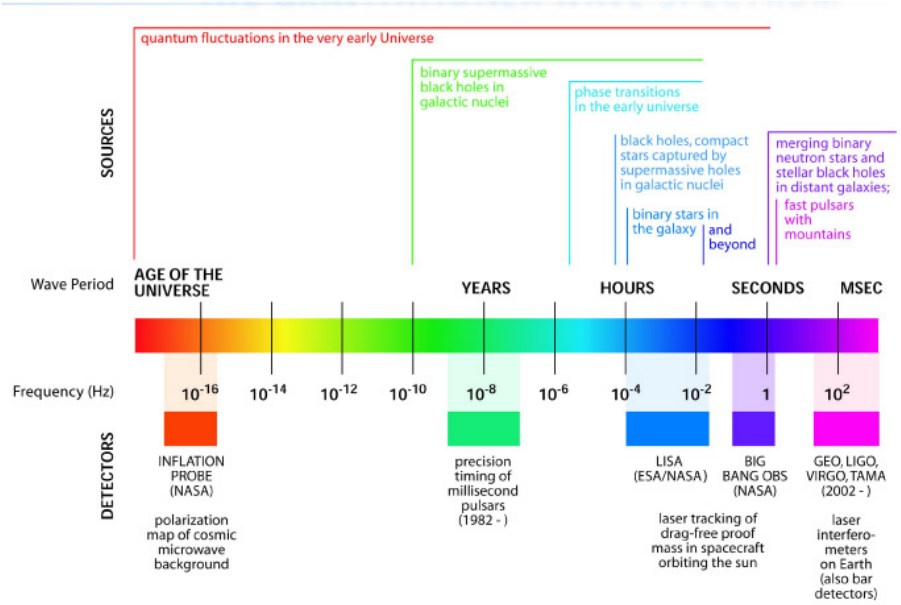
(Jet Propulsion Laboratory, California Institute of Technology)

Gravitational Waves

Electromagnetic Spectrum



Gravitational Wave Spectrum

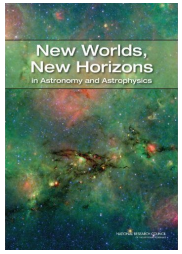


Gravitational Waves
Who Cares?

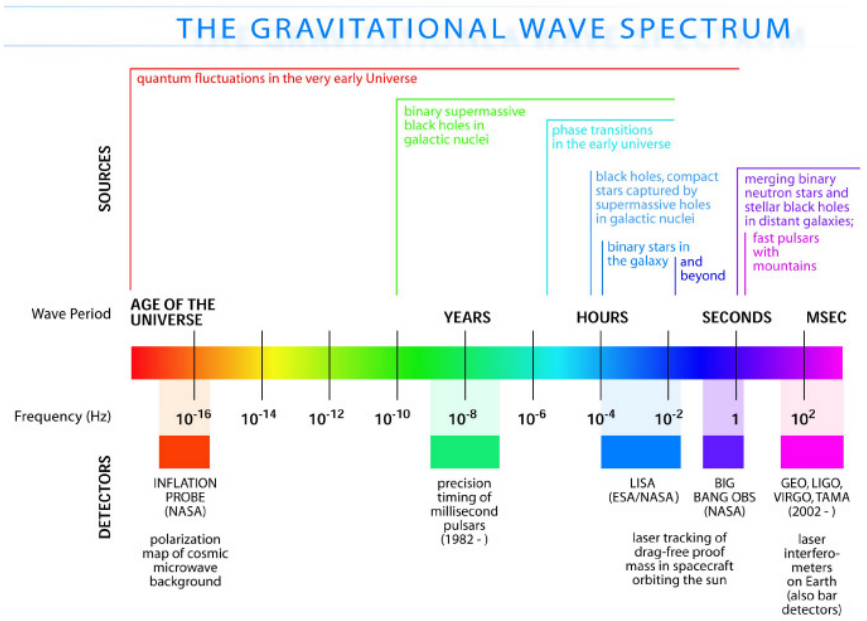
- One of the final untested predictions of Einstein's Theory of General Relativity

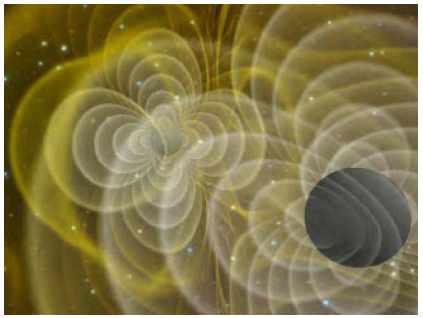
  Initial work already yielded one Nobel Prize in Physics

- Identified by U.S. astronomy community as one of the "science frontier discovery areas" for this decade *(U.S. National Academy of Sciences)*



- Probes most extreme environments in Universe

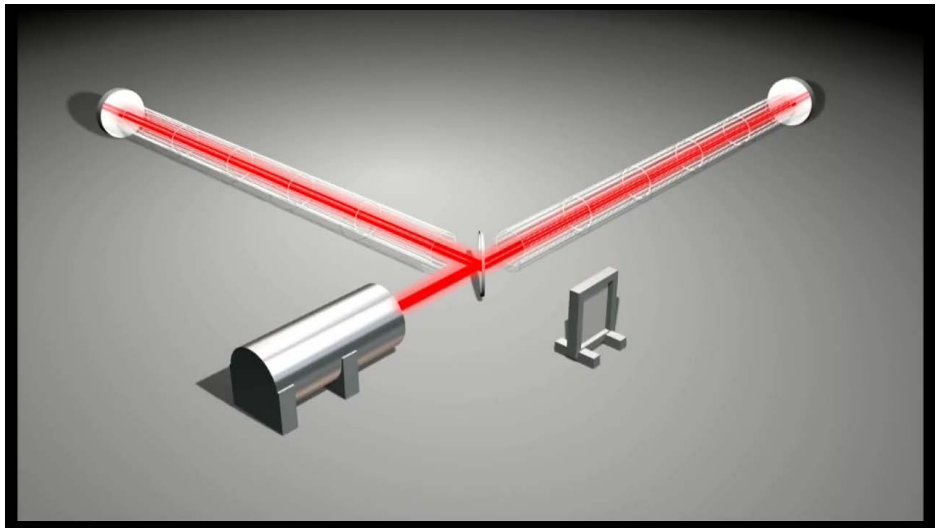


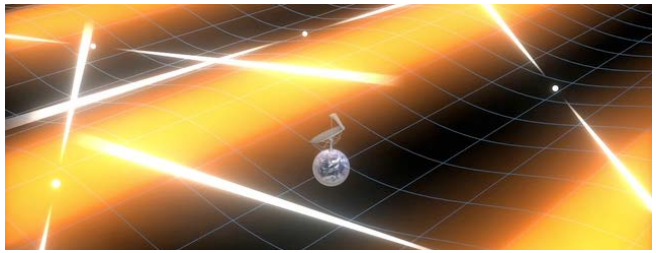


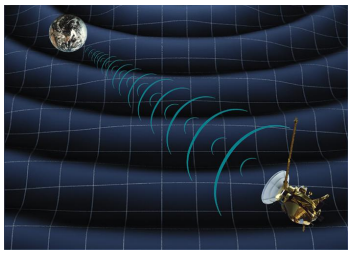
Gravitational Wave Detectors

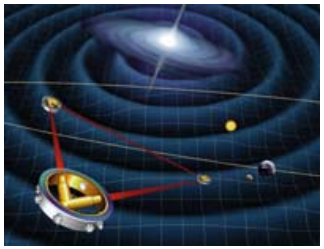
All modern gravitational wave detectors use same principle

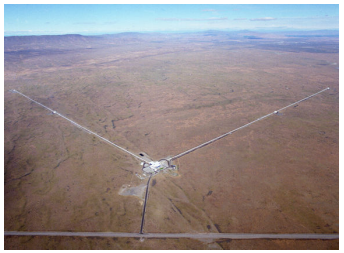
- Gravitational wave modifies distance (a.k.a. spacetime metric)
- Measure the distances between a collection of objects (test masses)
- Changes inferred to result from passing gravitational wave











Deep Space Network

- Three major tracking sites around the globe, with 16 large antennas, provide continuous communication and navigation support for the world's deep space missions
- Currently services ~ 35 spacecraft both for NASA and foreign agencies

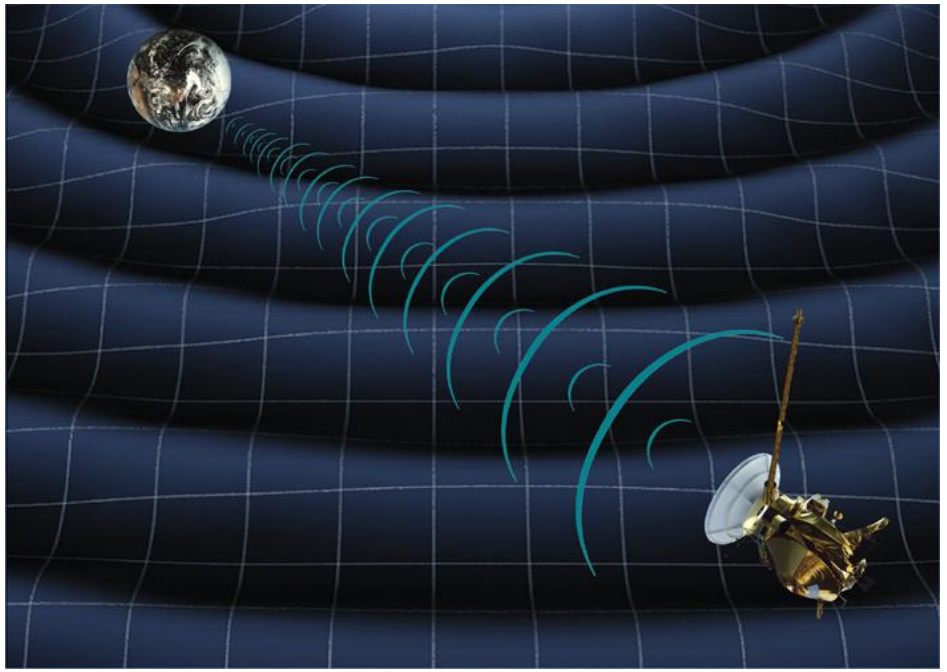
  Includes missions devoted to planetary, heliophysics, and astrophysical sciences as well as to technology demonstration
- Spigot for science data from most spacecraft instruments exploring the solar system, as well as a critical element of radio science instruments
- $2B infrastructure that has been critical to the support of 10's of $B of NASA spacecraft engaged in scientific exploration over the last few decades

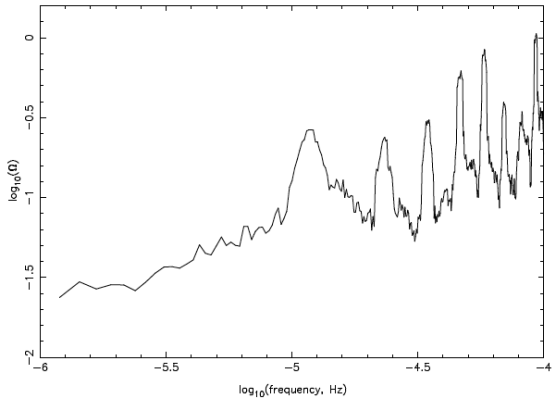
Spacecraft Tracking and Gravitational Waves

Spacecraft-Earth forms gravitational wave detector.

- First suggested by Estabrook & Wahlquist (1975), both **JPL**
- DSN has long history, beginning with Pioneer, Viking
- Most recent efforts with *Cassini*
- DSN-*Cassini* limits ~ 1000× better than previously obtained

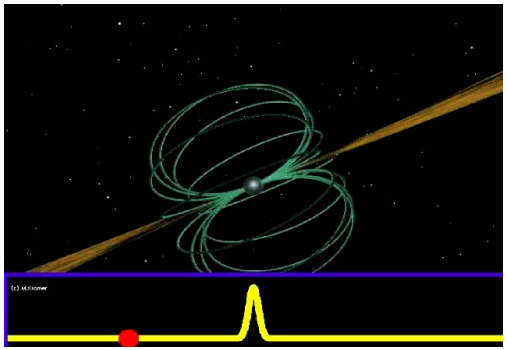
  … for low-frequency gravitational wave background



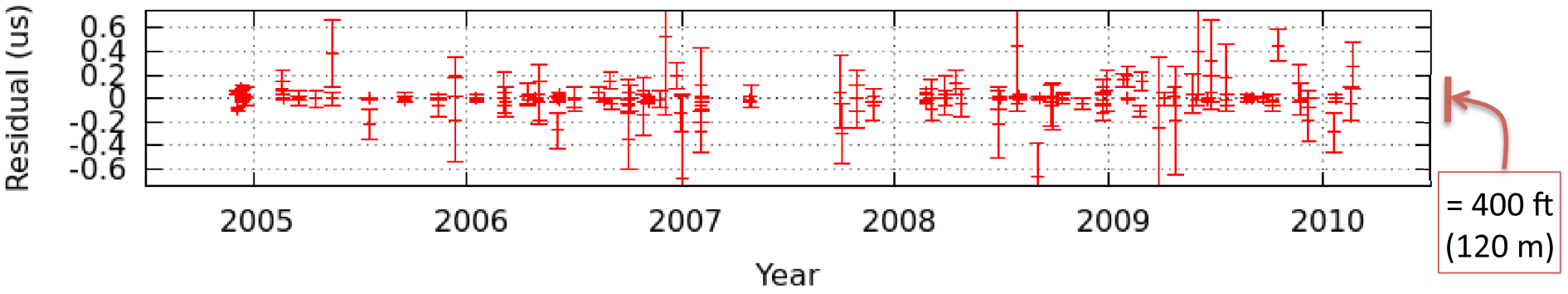


Radio Pulsars

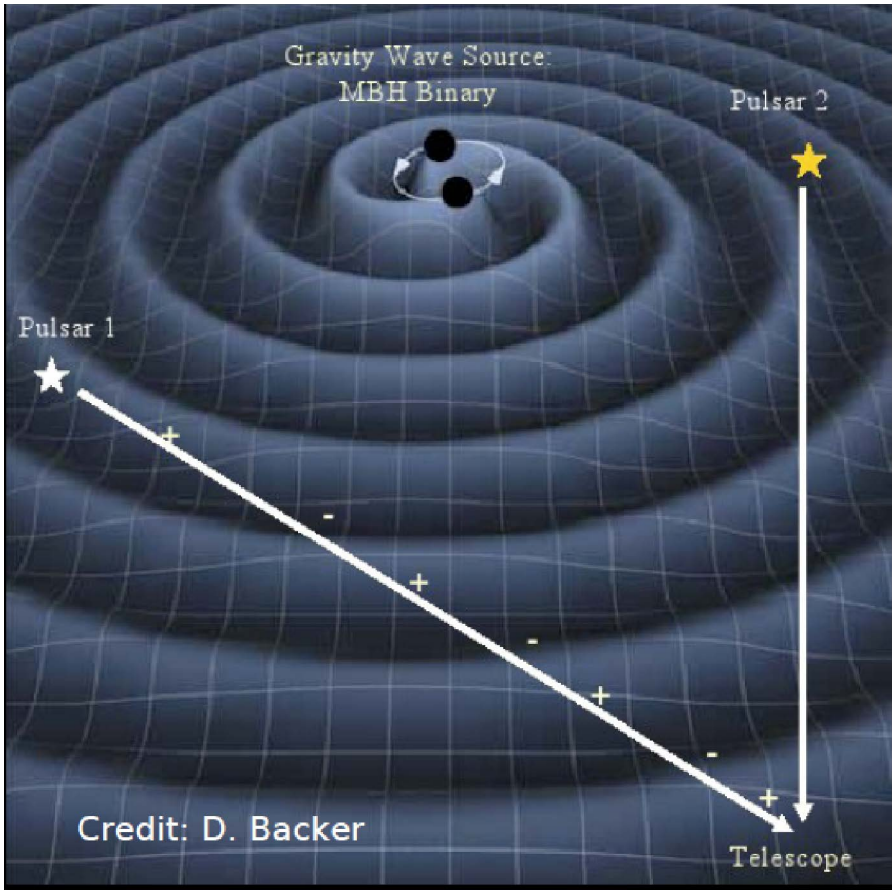
- Compact, rotating remnants of stars more massive (> 8×) than the Sun
- Strong magnetic fields produce pulsed radio emission
  Lighthouse-like
- Use world's largest radio telescopes to keep track of when pulses arrive at Earth …



J1713+0747



Radio Pulsars, DSN, and GWs



Technique first proposed by Hellings & Downs (JPL)

Searching for gravitational waves emitted by supermassive black holes at the centers of galaxies as they in-spiral together ….

International Pulsar Timing Array

NANOGrav

EPTA

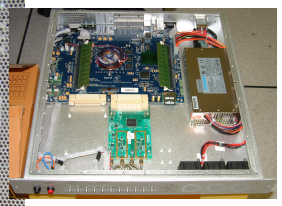
PPTA

+ Deep Space Network?

Why the DSN?

1. **Sensitive telescopes, particularly in southern hemisphere**
   - Developing precision pulsar timing capability for DSN telescopes, with initial support from **JPL's R&TD** program
   - Progress through first 6 months

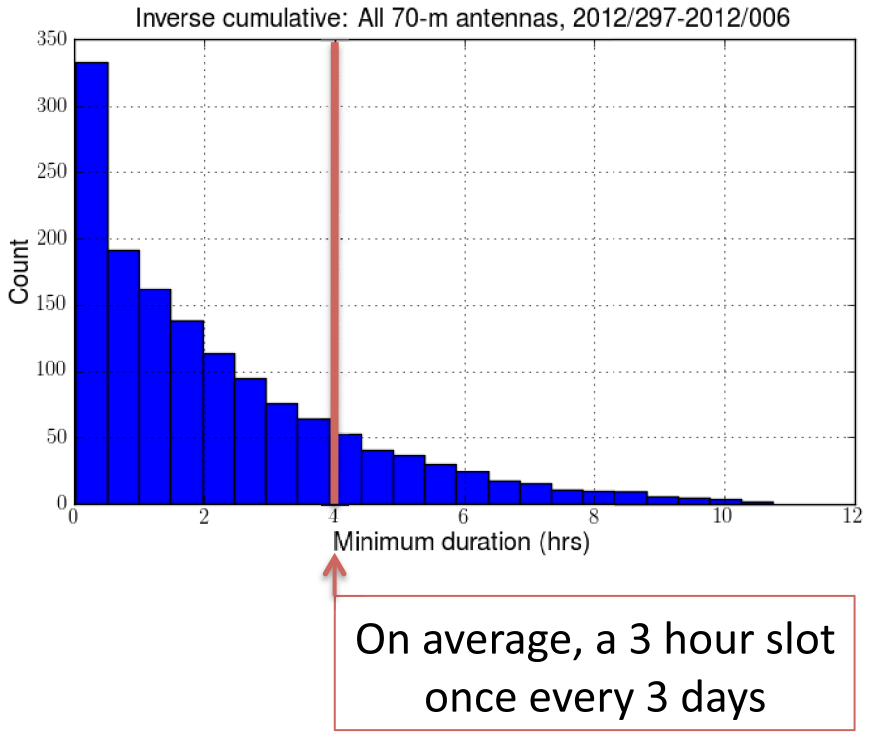
     completed signal processing architecture, procurement of hardware, FPGA firmware development, partial completion of monitor & control
   - Future
     - remainder of FY13: GPU software development for real-time processing, first light at Goldstone complex
     - FY14: Continuing system tests in the field, GPU development of cyclic spectroscopy techniques to obtain scatter corrected TOAs, timing pipeline development, begin timing campaign
2. Potential availability



Why the DSN?

1. Sensitive telescopes, particularly in southern hemisphere
2. **Potential availability**
   - Scheduling gaps that could be used for science!
   - cf. typical pulsar timing program acquires measurements only once per month

➢ DSN provides ~ 2--10× improvement over current activities



Gravitational Waves and the Deep Space Network







- Gravitational wave astronomy is emerging frontier
- JPL and Deep Space Network already have made substantial contributions
- Engaged in ensuring that Deep Space Network has valuable role in growing International Pulsar Timing Array