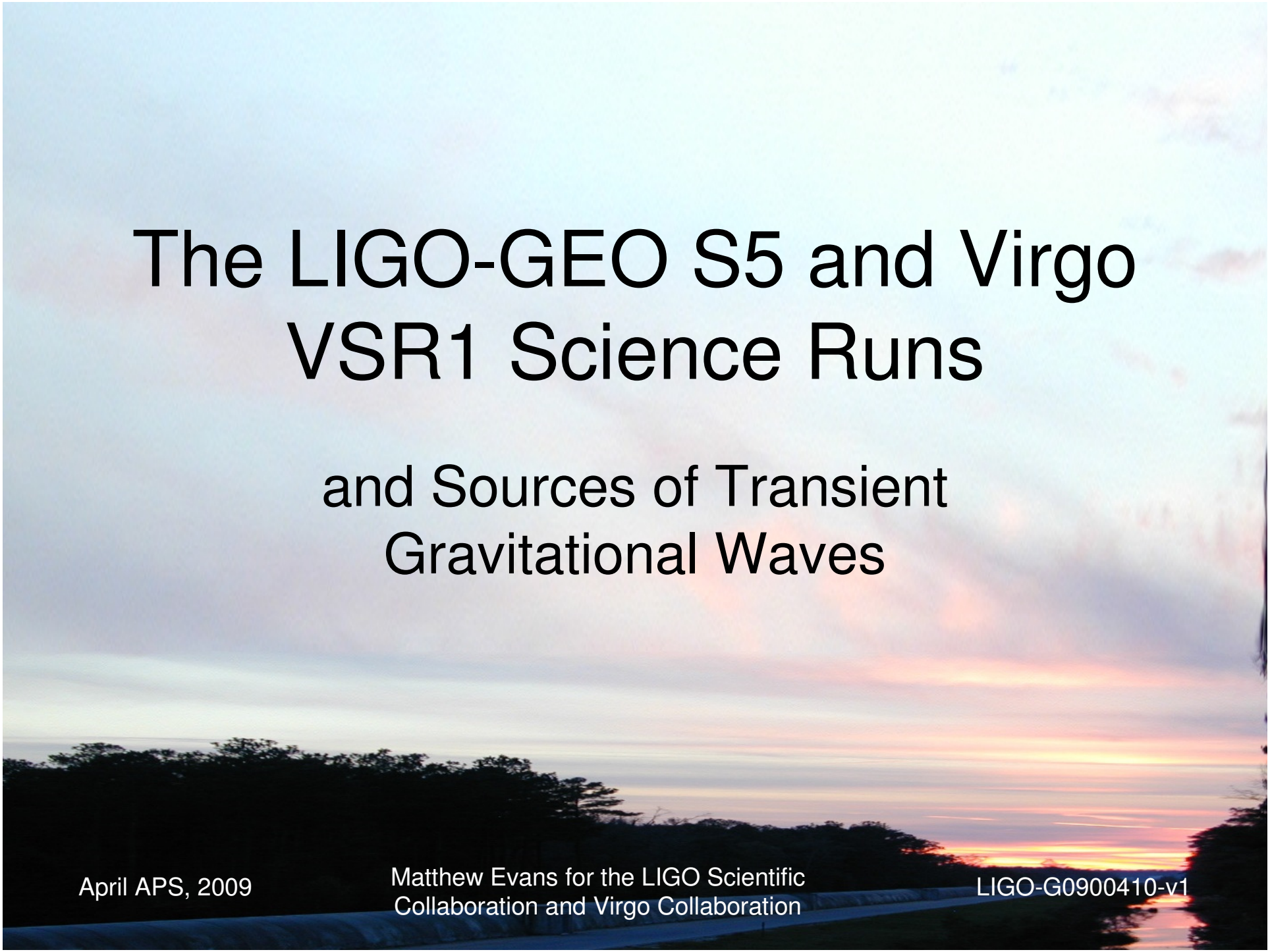


The LIGO-GEO S5 and Virgo VSR1 Science Runs

and Sources of Transient Gravitational Waves

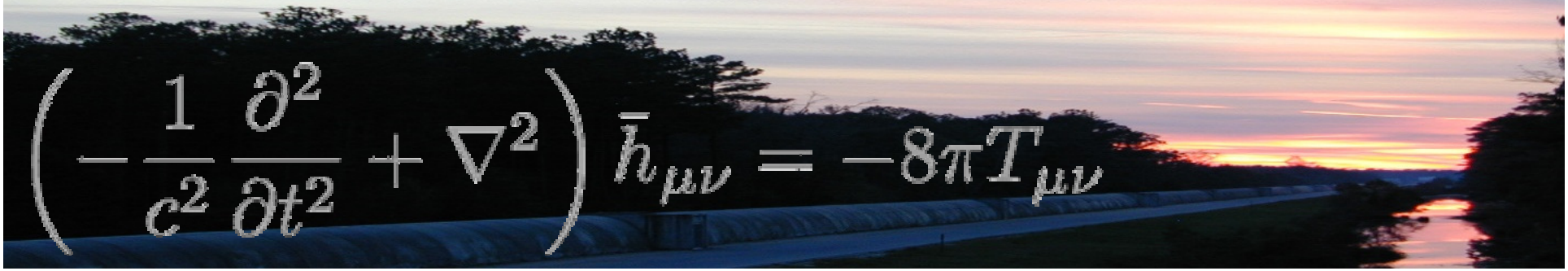
Matthew Evans for the LIGO Scientific Collaboration and Virgo Collaboration

April APS, 2009

LIGO-G0900410-v1

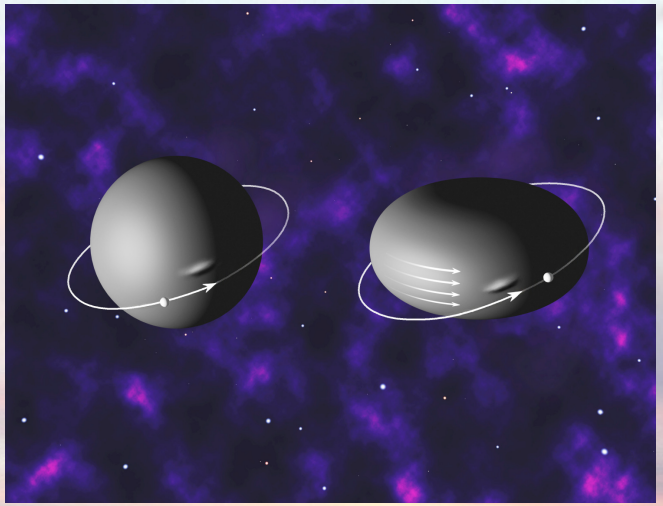
Outline

- What are gravitational-waves?
- Where do they come from?
- How can they be detected?
- What is the state of the world's gravitational-wave detector network?
- How much data has been taken?
- What have we found?



Gravitational Waves

- Caused by moving masses
  (mass distributions with changing quadrupole)
- Distortions of space-time
  - linearization of GR gives wave equation
  - propagate at speed of light
  - 2 polarizations



$$\left(-\frac{1}{c^2}\frac{\partial^2}{\partial t^2}+\nabla^2\right)\bar{h}_{\mu\nu}=-8\pi T_{\mu\nu}$$

Gravitational Waves

- Waveform and amplitude determined by source mass
  - Potential for excellent source distance measurement
- Weak interaction with matter
  - Astrophysical sources are unscreened by intervening matter
  - Hard to detect

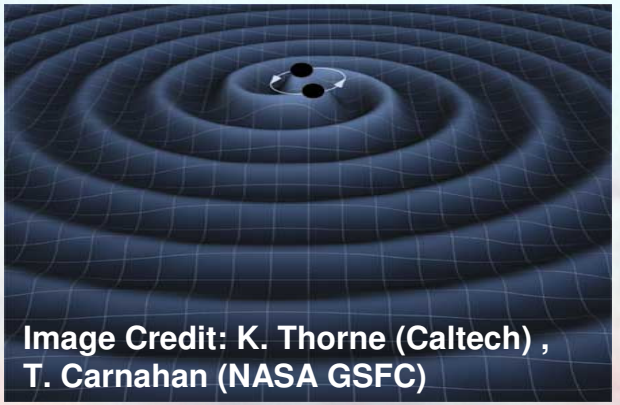


Image Credit: K. Thorne (Caltech) , T. Carnahan (NASA GSFC)

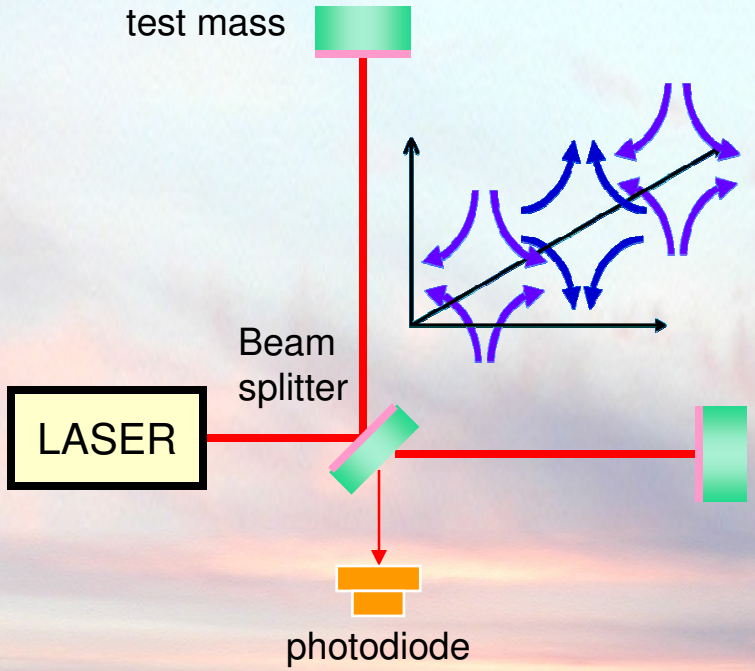
$$h_{\mu\nu} \approx \frac{1}{r}\frac{2G}{c^4}\int T_{\mu\nu} d^3 r$$

Gravitational Wave Detection

- Interferometers
- How sensitive?
  - For a binary neutron star coalescence…

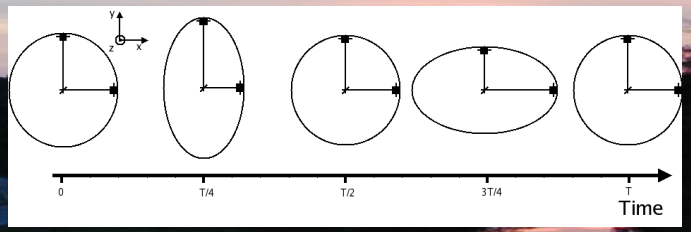
$$h_{\mu\nu} = \frac{2G}{c^4 r}\ddot{I}_{\mu\nu} \Rightarrow h \approx \frac{4\pi^2 GMR^2 f_{orb}^2}{c^4 r}$$

I =quadrupole mass distribution of source

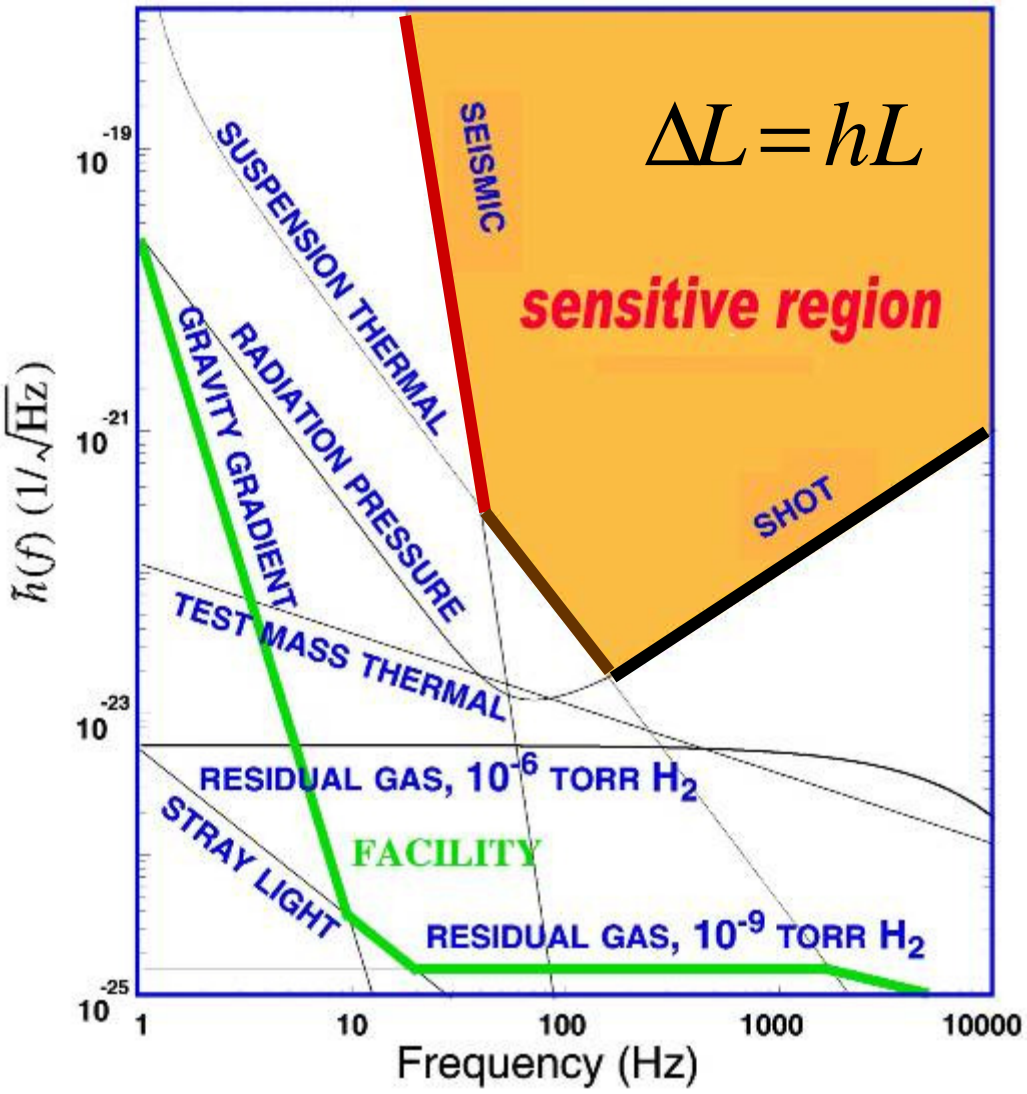


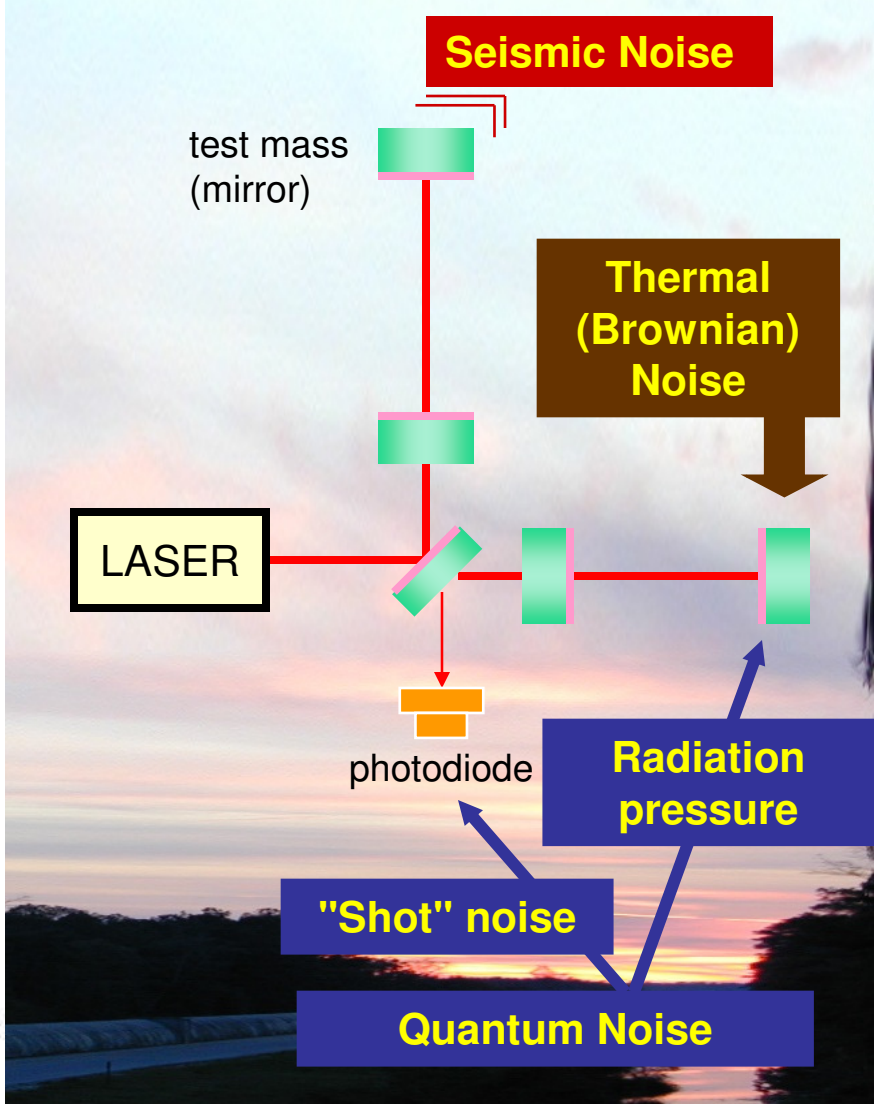
M ≈ 6x10^{30} kg ≈ 3 M solar
R ≈ 20 km
F ≈ 100 Hz
r ≈ 10^{23} m ≈ 3 Mpc

➡ $h \sim 10^{-22}$



Basic Detector Noises



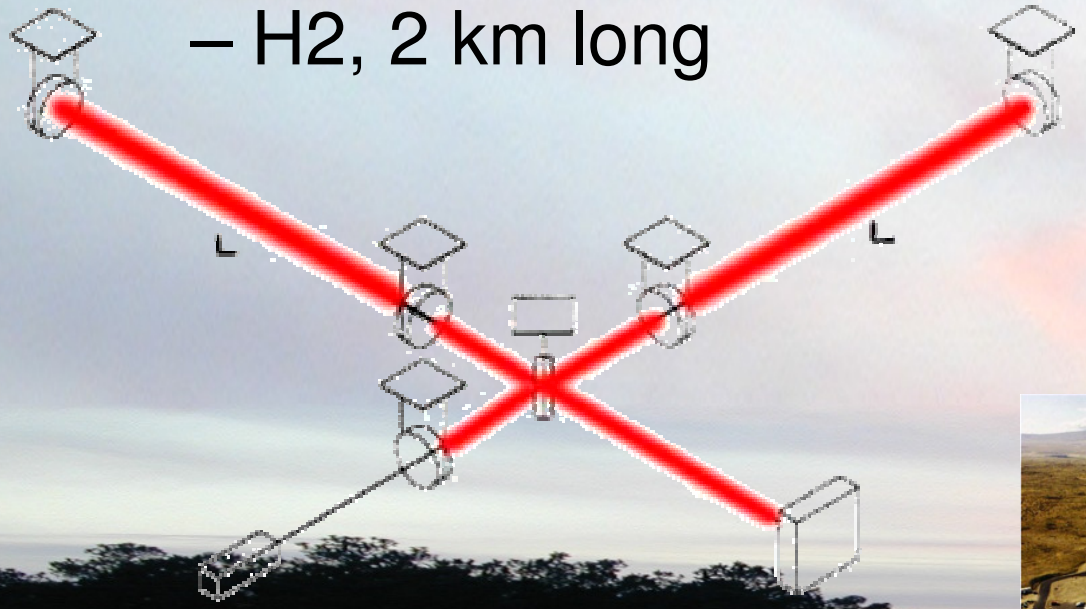


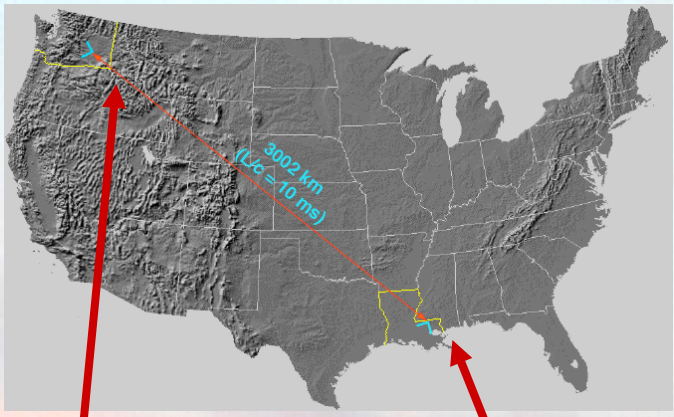
Operating Detectors

LIGO

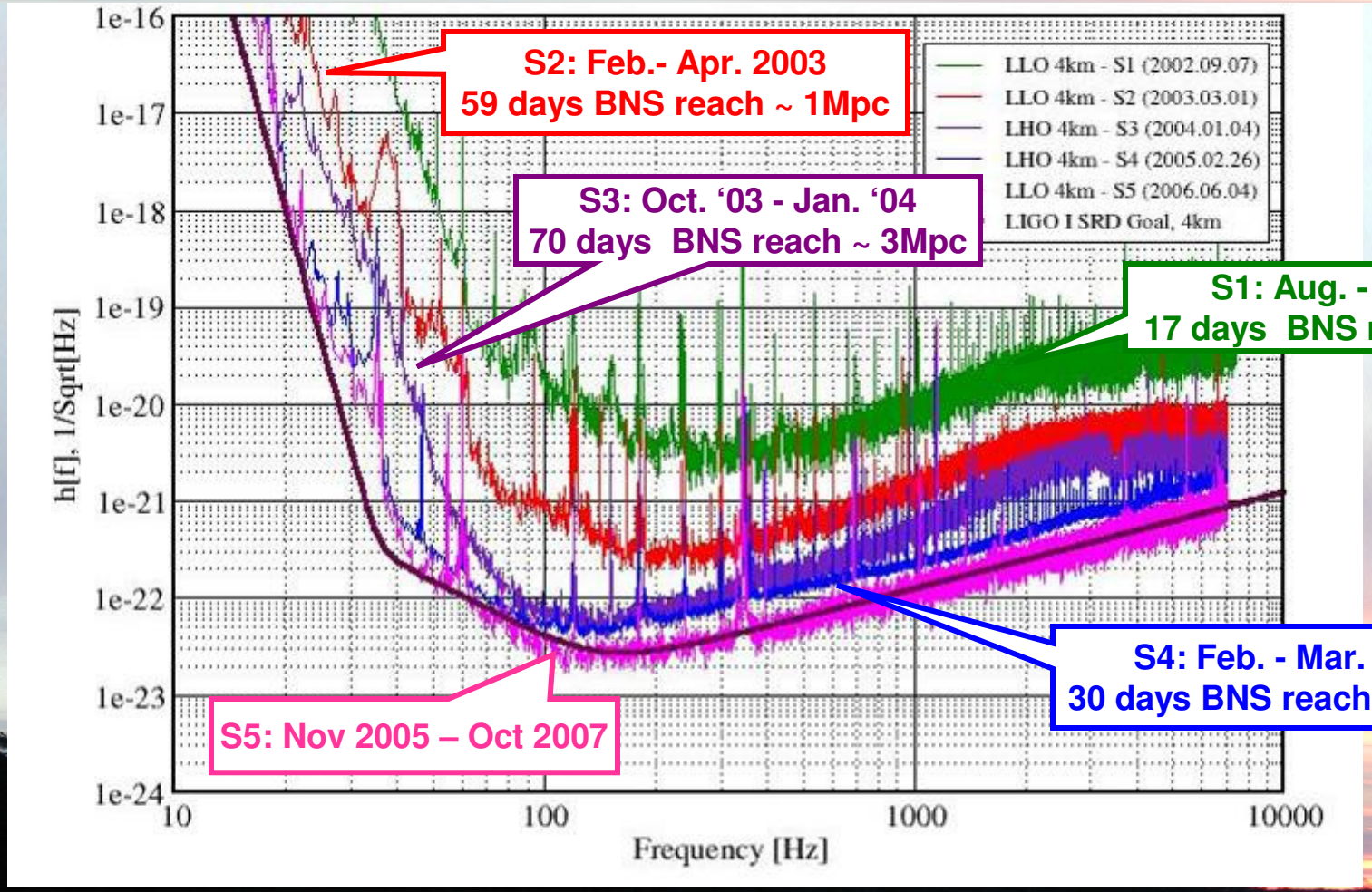
LIGO: Sites

- 3 interferometers
  - H1 and L1, 4 km long
  - H2, 2 km long



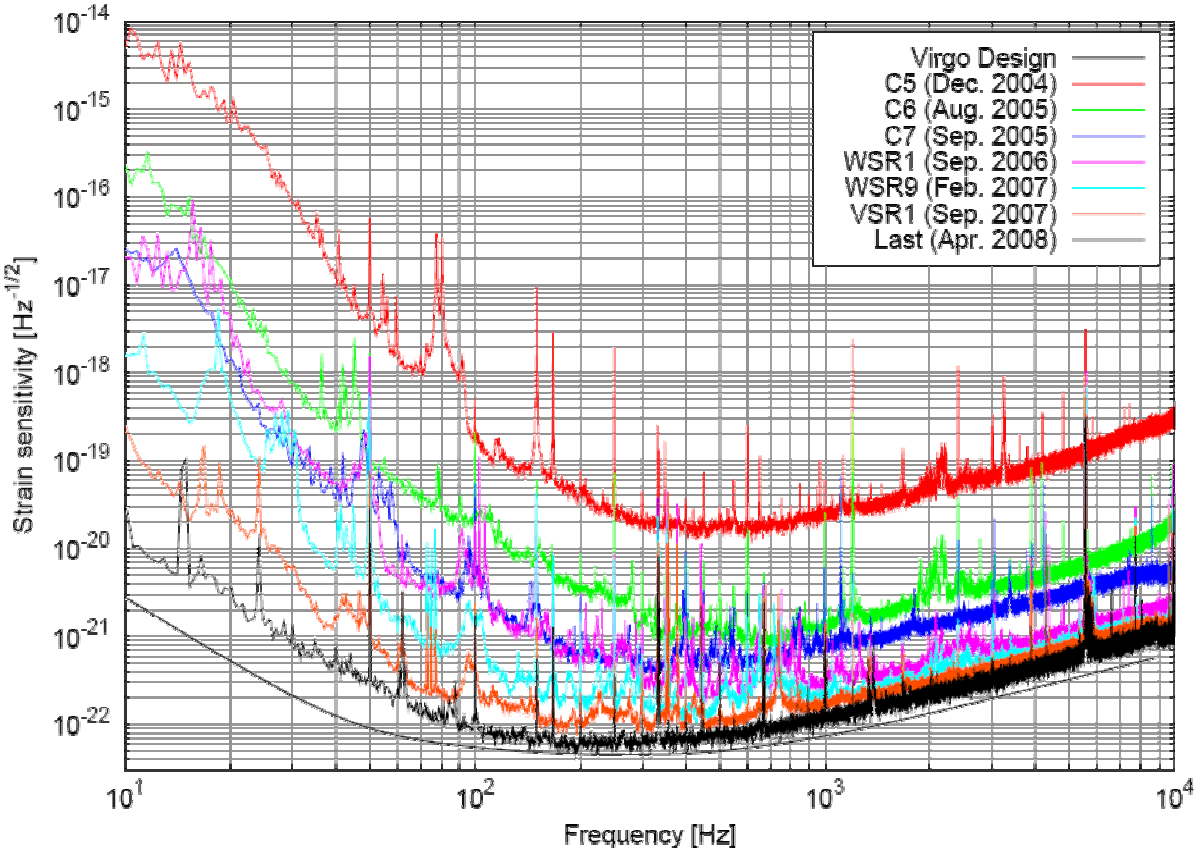


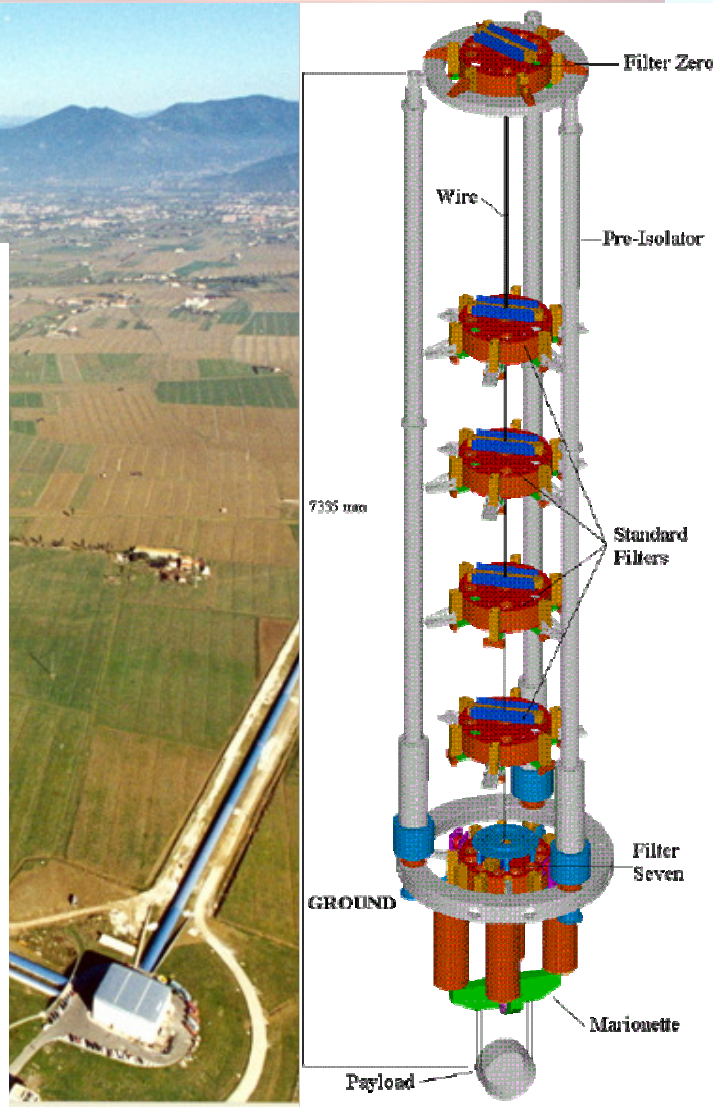
LIGO: Sensitivity Progress



Virgo

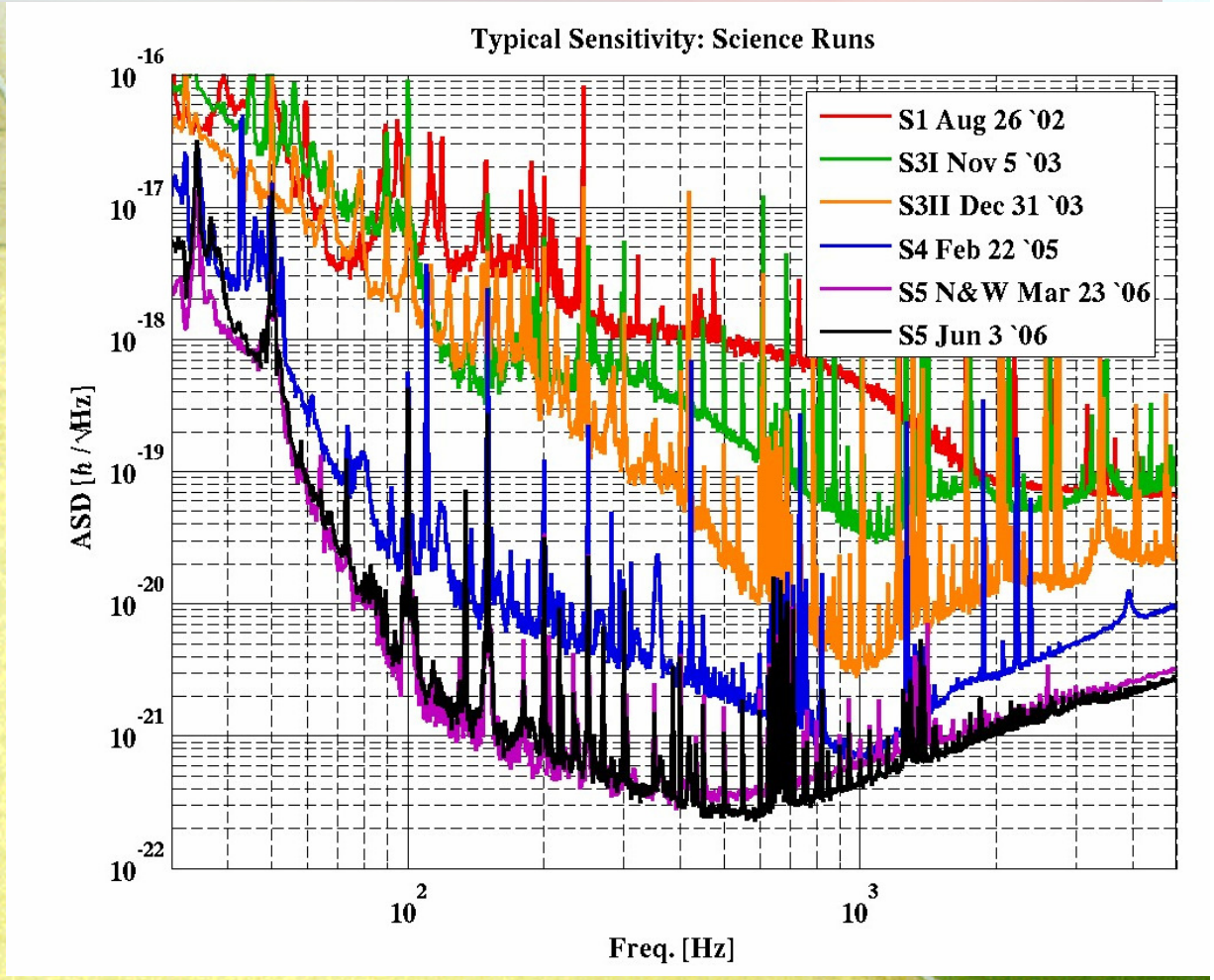
- LIGO like optics, 3 km long
- Advanced suspensions



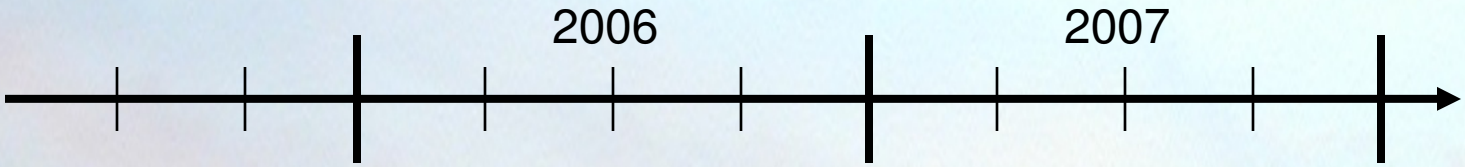


GEO 600

- 600m long
- Advanced optical configuration



The S5/VSR1 Science Run

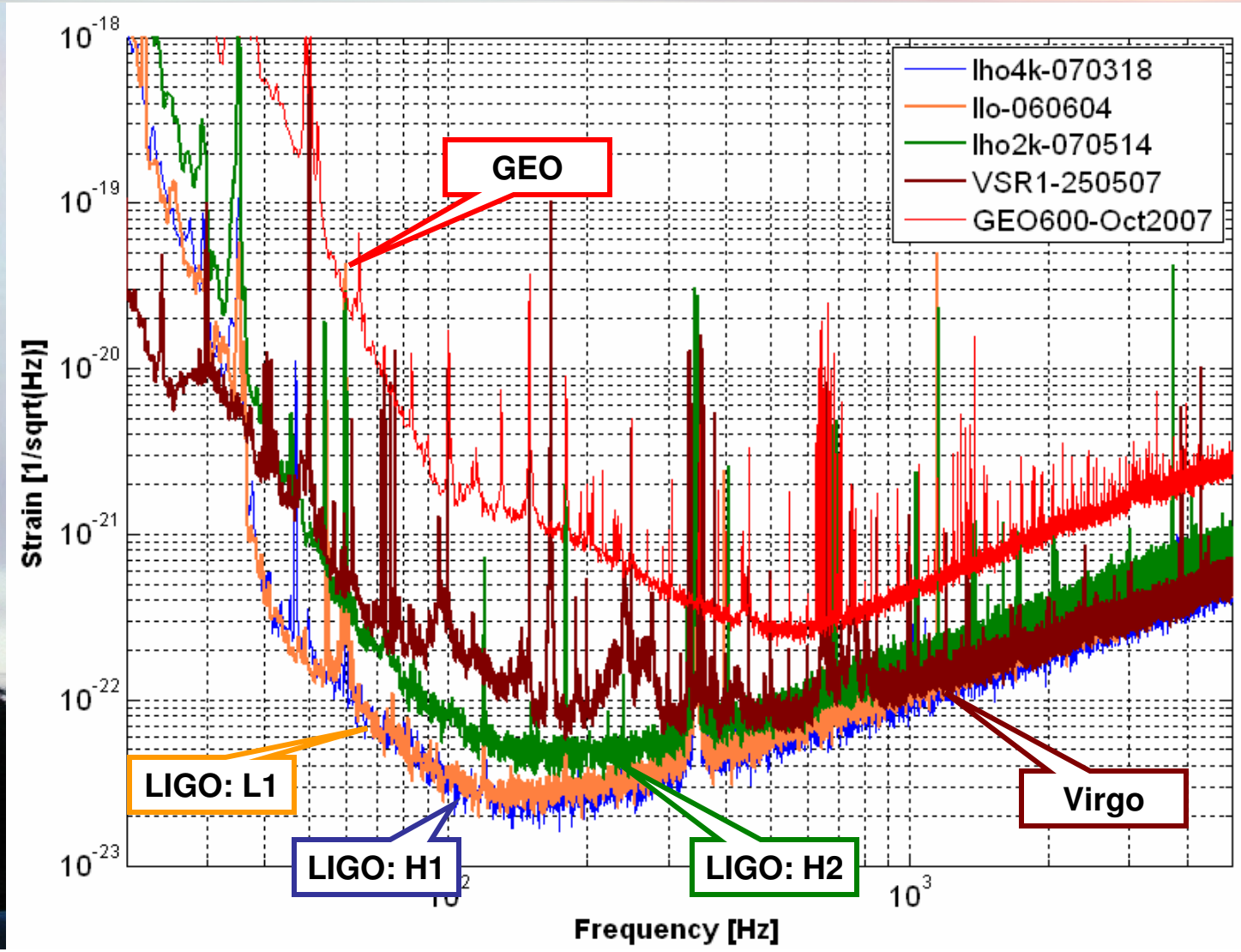


91% duty cycle

81%

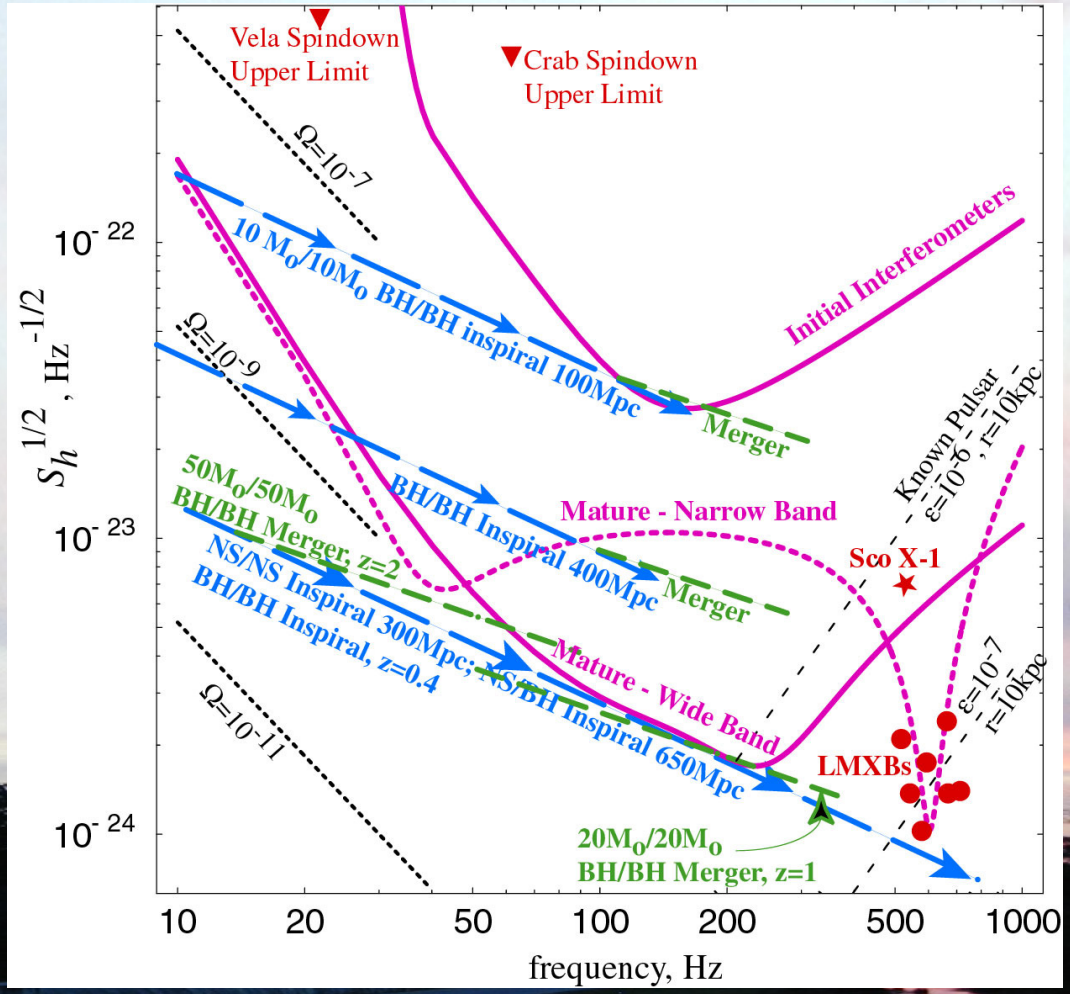
75% single detector, 53% triple coincident

The S5/VSR1 Science Run



Source Magnitudes

- Compact binary coalescence
- Supernovae
- Continuous wave sources
- Cosmic GW background
- Things that go bump…



Talks to Come in this Session

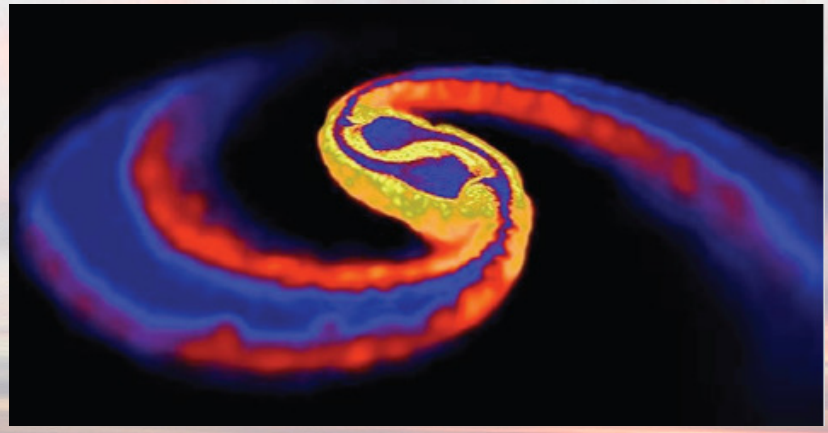
- Black Hole Collisions!
  - All sky, untriggered search
  - 25 to 100 solar mass systems
  - Waveforms powered by numerical relativity

- Evan Ochsner

If you could not hear...

Talks to Come in this Session

- Short Gamma-Ray Bursts
  - Triggered search (time and sky location)
  - Multi-messenger astronomy
  - Predicted waveforms from modeled sources

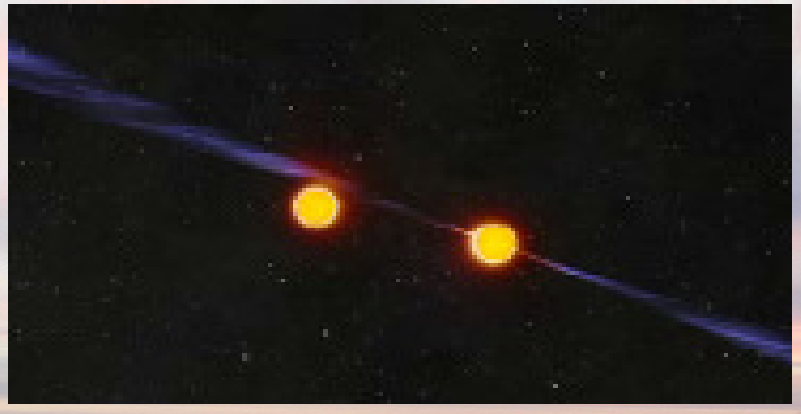


- Nick Fotopoulos

had never heard a sound in your life,

Talks to Come in this Session

- The Inspiral Search
  - All sky, untriggered search
  - 2 to 35 solar mass systems
  - Neutron star binaries!

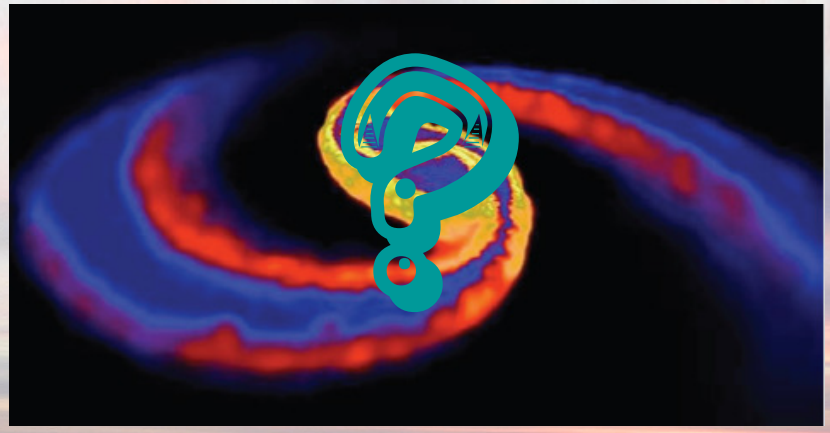


- David McKechan

but had to guess what you might hear

Talks to Come in this Session

- Gamma-Ray Bursts, long and short
  - Triggered search (time and sky location)
  - Unknown waveforms from unmodeled sources



- Isabel Leonor

based only on what you see

Talks to Come in this Session

- The Burst Search
  - Anything and Everything
  - All sky, untriggered search
  - Unmodeled sources
  - 64 Hz to 2kHz
- Michele Zanolin

think of all the sounds

Talks to Come in this Session

- The High Frequency Search
  - All sky, untriggered search
  - Unmodeled sources
  - up to 6kHz
- Brennan Hughey

that you would never imagine.


The End
If you could not hear…
had never heard a sound in your life,
but had to guess what you might hear
based only on what you see
think of all the sounds
that you would never imagine.