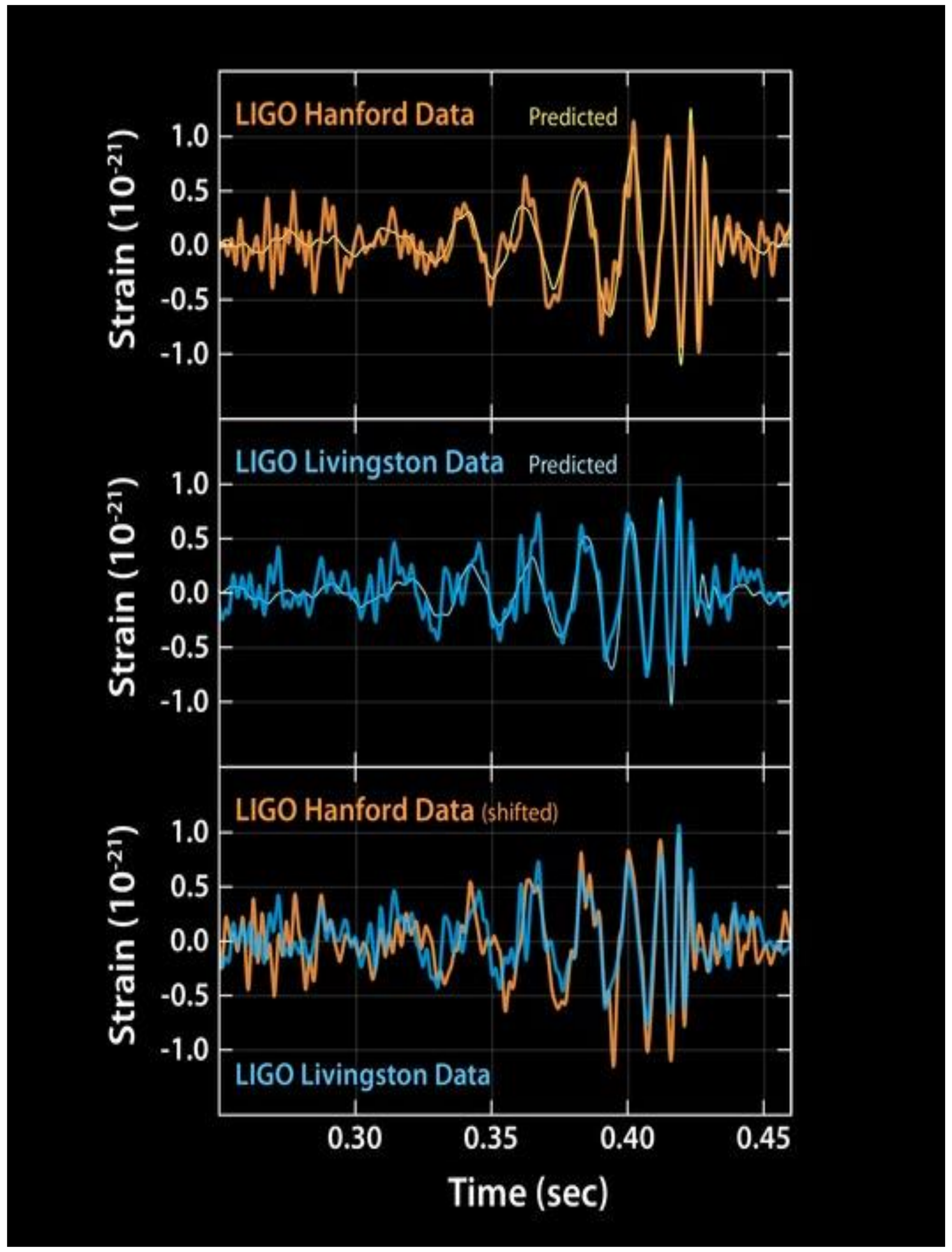
A review of the detection of gravitational waves by laser interferometers

Liam Horst
Advisor: Dr. Pedrotti
University of Dayton

Introduction

- Emitted by accelerating masses like black hole mergers
- First detected by LIGO (Laser Interferometry Gravitational-wave Observatory) in 2016*
- Carries info not carried by E&M waves
  - Not trapped by black holes
  - Not blocked by celestial bodies
- LIGO has currently detected compact binary inspiral gravitational waves



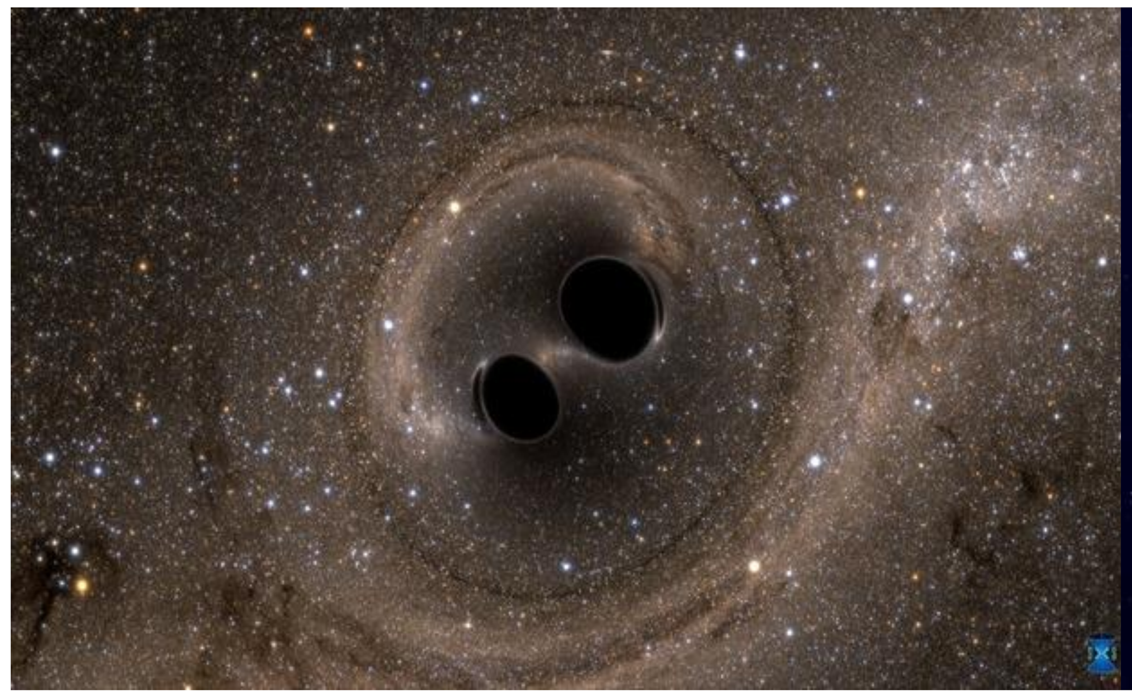
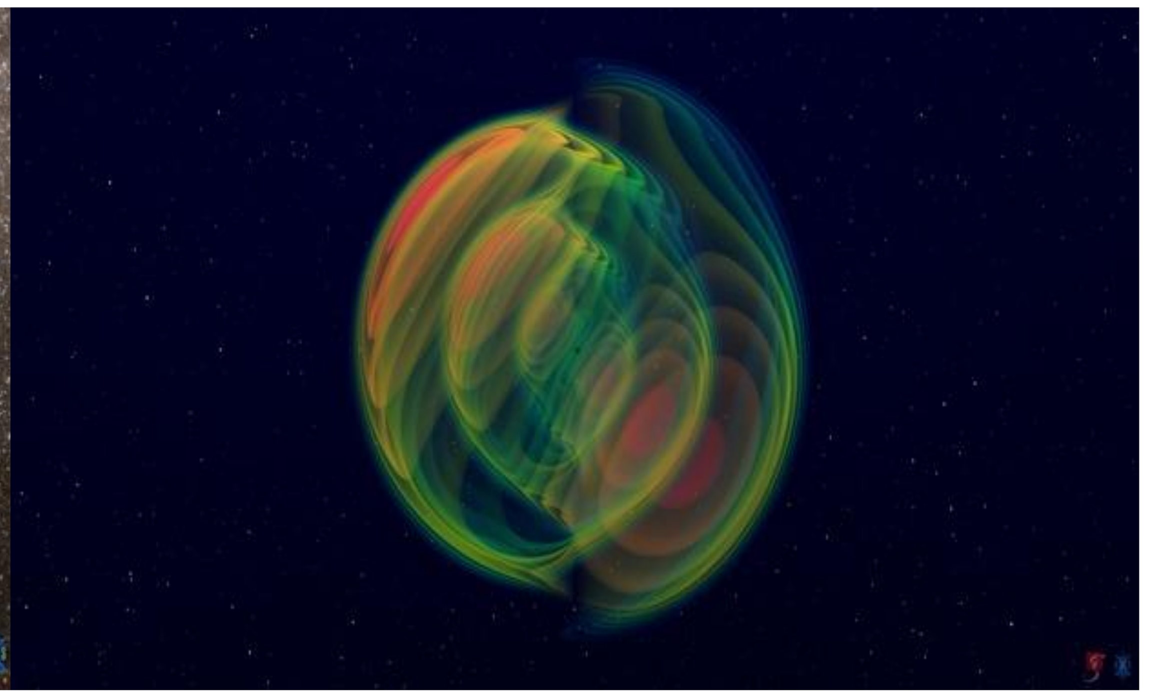
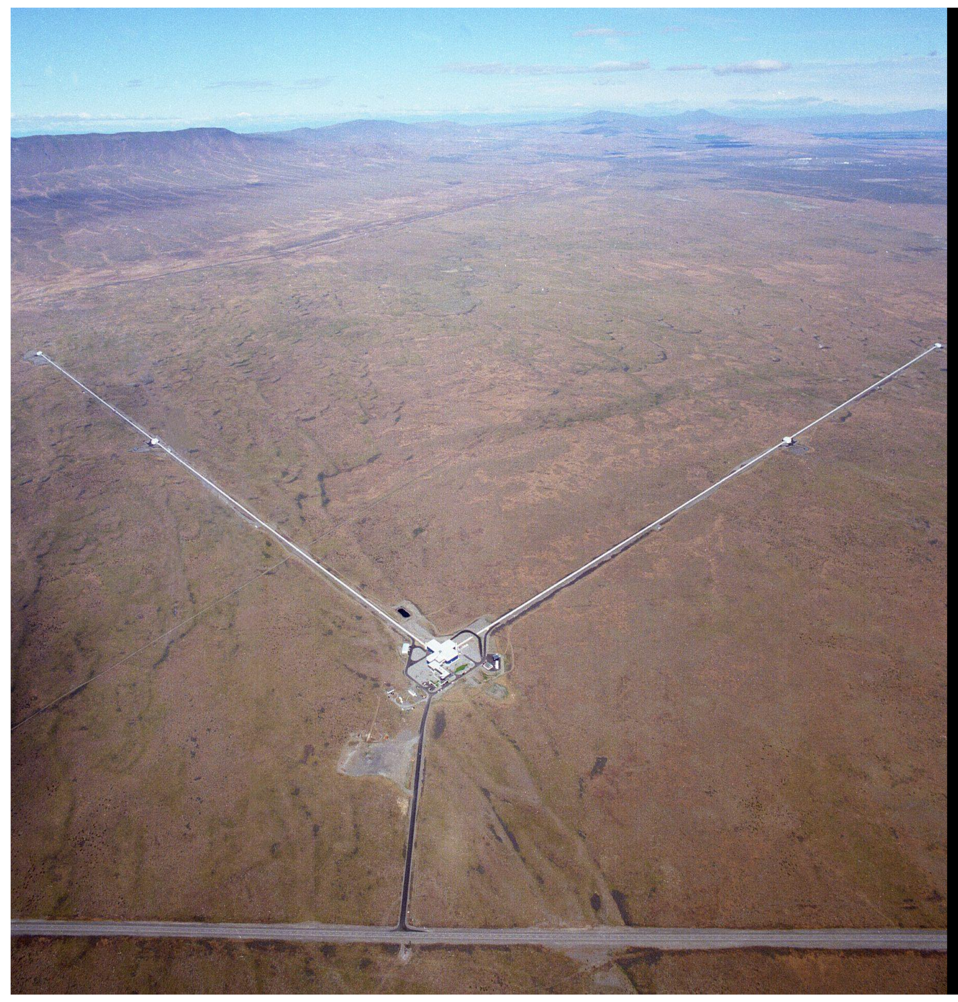


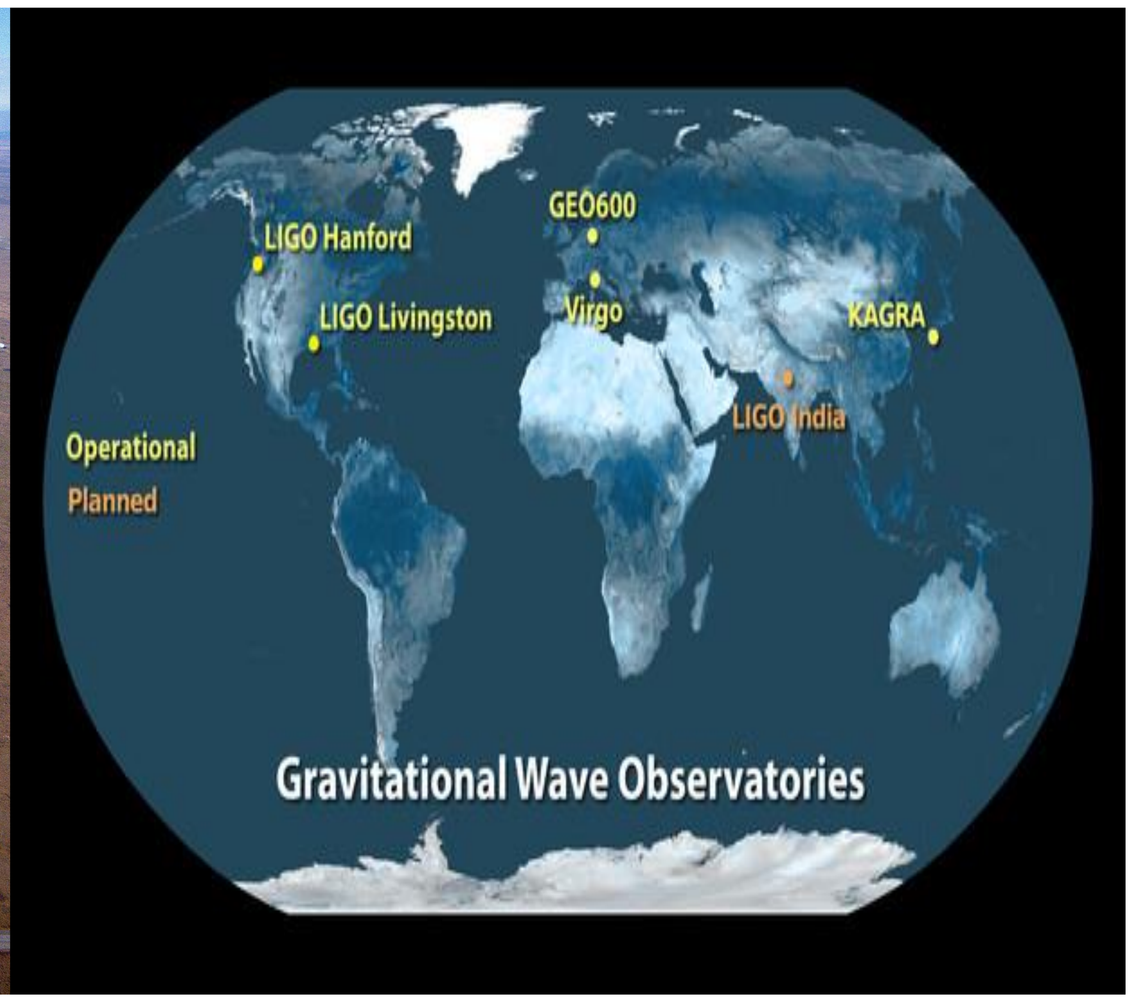
Image of blackhole binary merger



Simulation of blackhole binary merger



LIGO Hanford Observatory



Map of Gravitational wave observatories as of February 2016

Theory

- Metric: $ds^2 = g_{\mu\nu} dx^\mu dx^\nu = \eta_{\mu\nu} + h_{\mu\nu}$

$$h_{\mu\nu} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & h_+ & h_x & 0 \\ 0 & h_x & -h_+ & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \cos(\omega t - kz)$$

- Strain equation: $\frac{\Delta L}{L} = h_+ \cos(\omega t - kz)$
- Change in length is much smaller than the diameter of a proton!

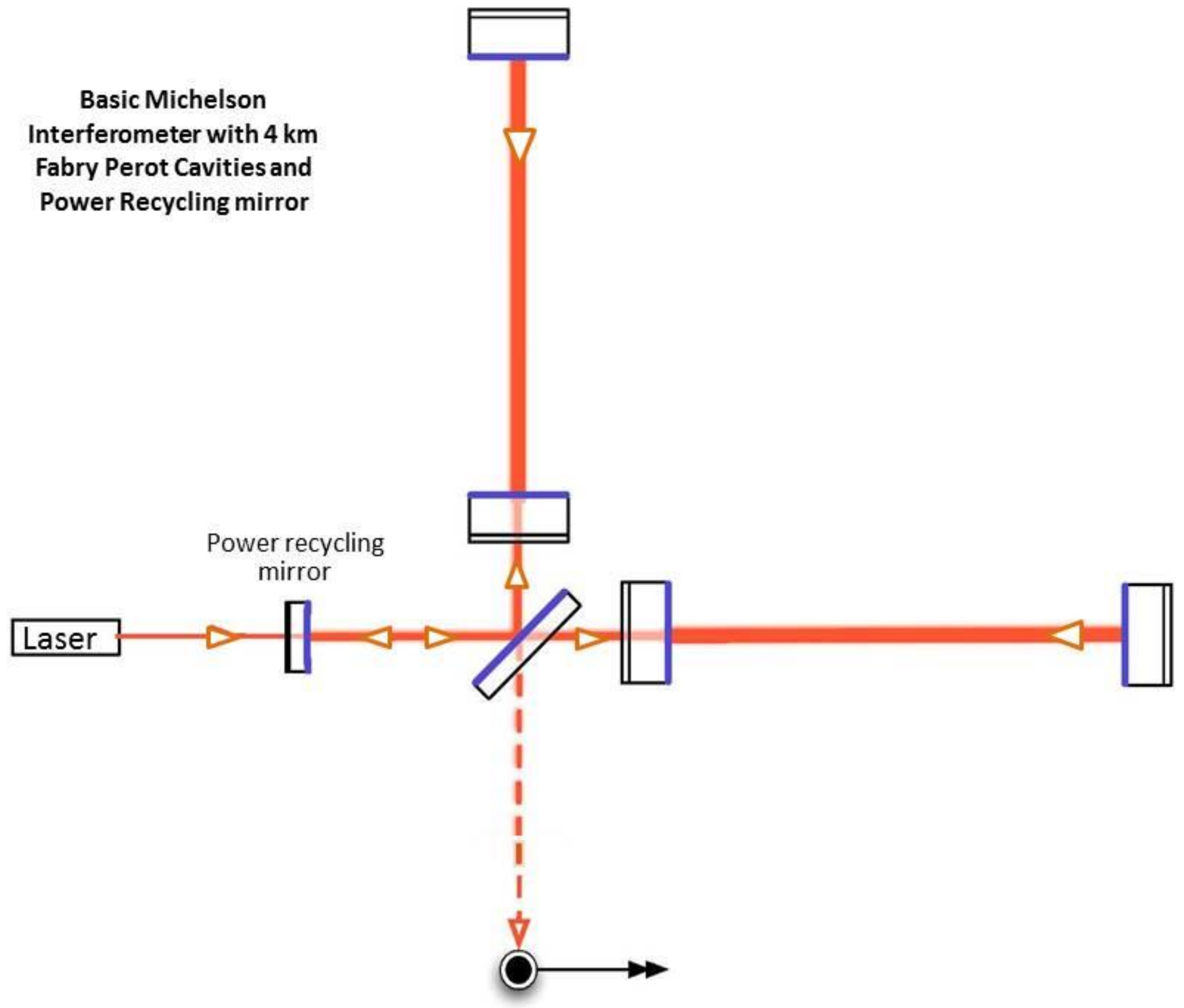
Michelson Interferometer

- Change in arm lengths alter the irradiance at the detector

$$I_D = \frac{I_L}{2}\left(1 - \cos\left(\frac{2\pi}{\lambda}(2\Delta L)\right)\right)$$

LIGO Modifications:

- Fabry Perot Cavities
- Power recycling mirrors
- Seismic isolation system
- Vacuum chamber



Conclusions

- Over 150 black hole and neutron/black-hole mergers detected
- Observation at multiple observatories increases detection sensitivity
- Provides check on predictions of the Theory of General Relativity and new information on BH/BH-NS mergers.
- Next stage observations might be able to detect less dramatic events (ex. binary star system and stochastic background)

All images Courtesy Caltech/MIT/LIGO Laboratory

* B. P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration) Phys. Rev. Lett. 116, 061102 – Published 11 February 2016