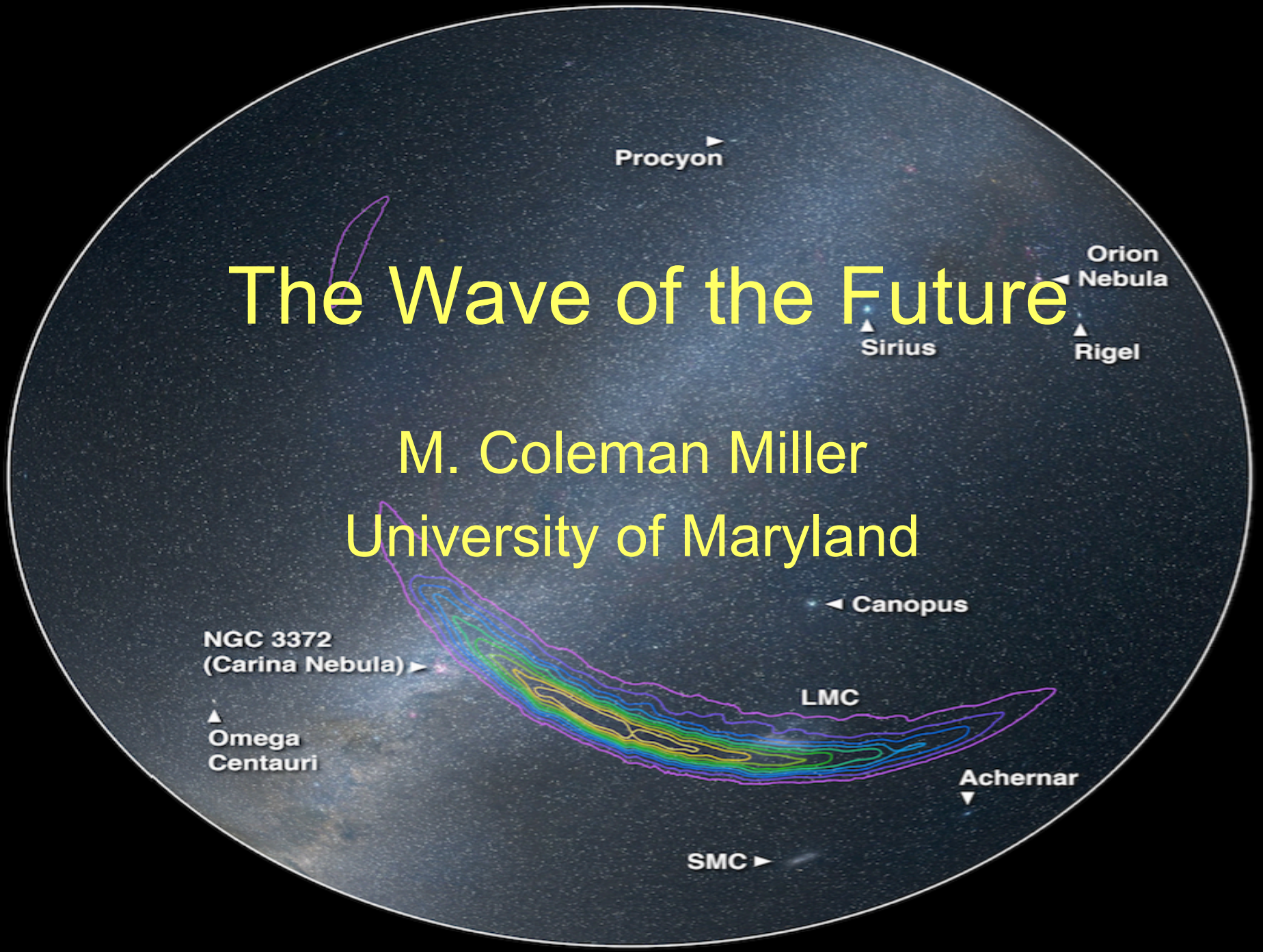


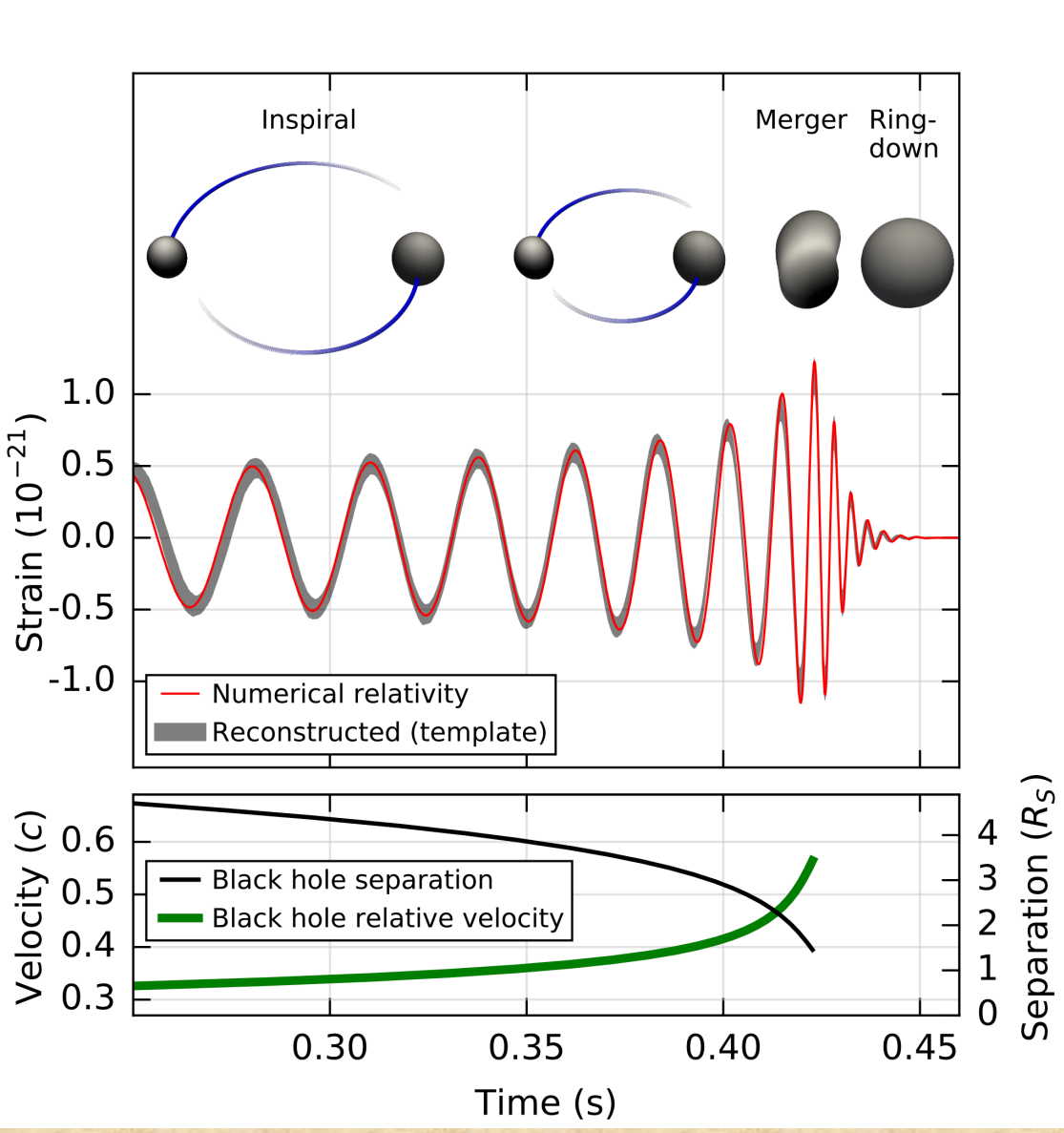
The Wave of the Future

M. Coleman Miller
University of Maryland

General Perspectives

- Limited set of deep-space messengers
  Photons, ν, CR; now GW added!
- Can now see very energetic but previously invisible events
  During merger, GW150914 produced ~50x as much energy as all stars in the visible universe combined over that time!
- These weren't minor events we were missing...

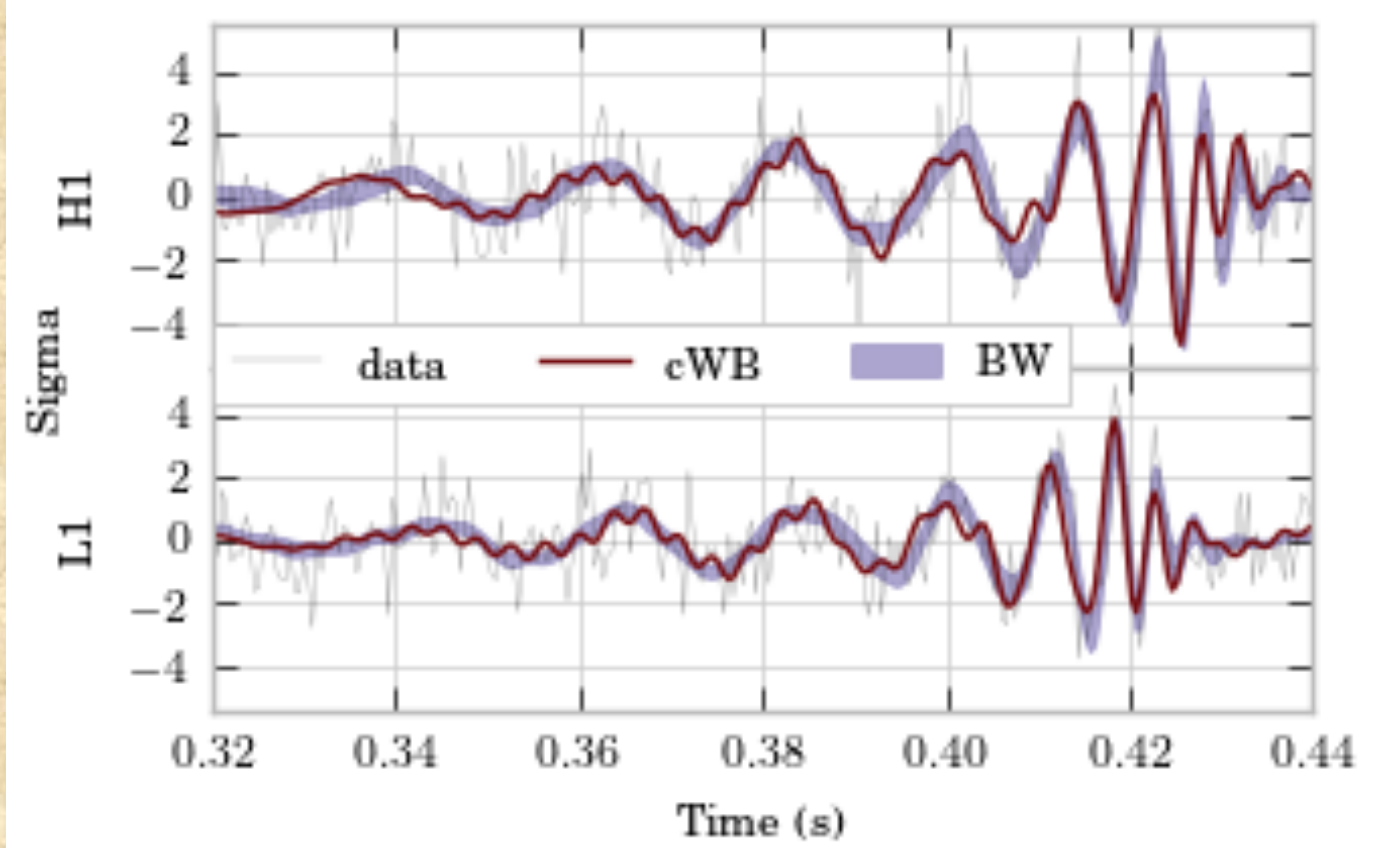
What Happened?



Inspiral of two ~30 M_{sun} black holes. Waveform matches the expectation from general relativity to within the accuracy of the data

LIGO Scientific Collaboration, Virgo Collaboration 2016

The Actual Signal

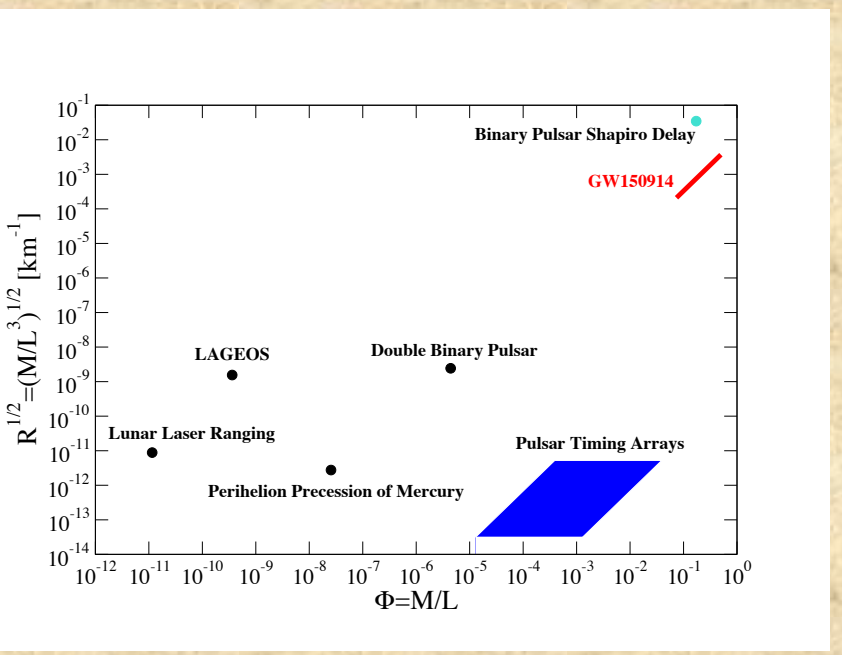


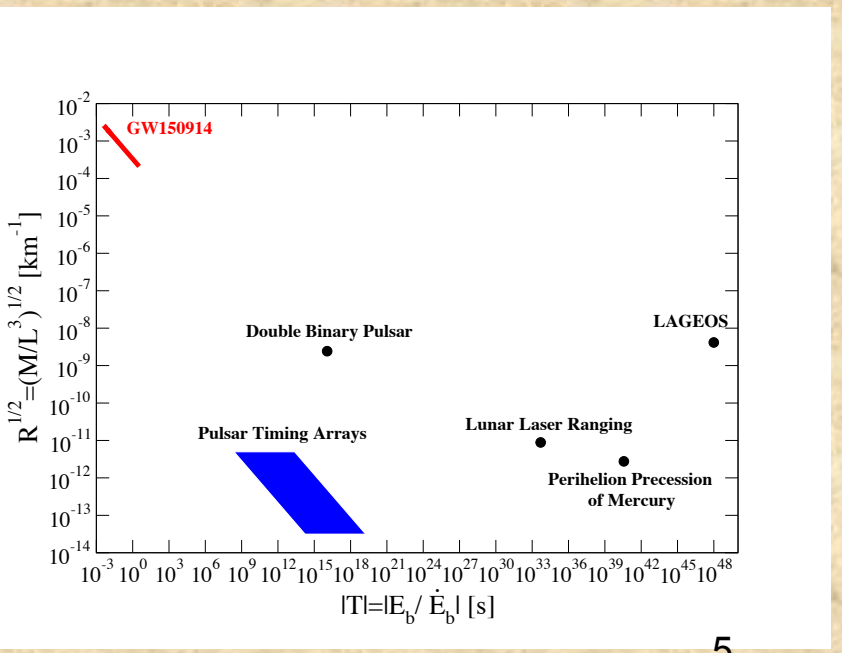
Note the delay between the signals from the sites; this is the difference in the light travel times (7 ms). Helps localize the burst.

LIGO Scientific Collaboration, Virgo Collaboration 2016

Extreme Gravity

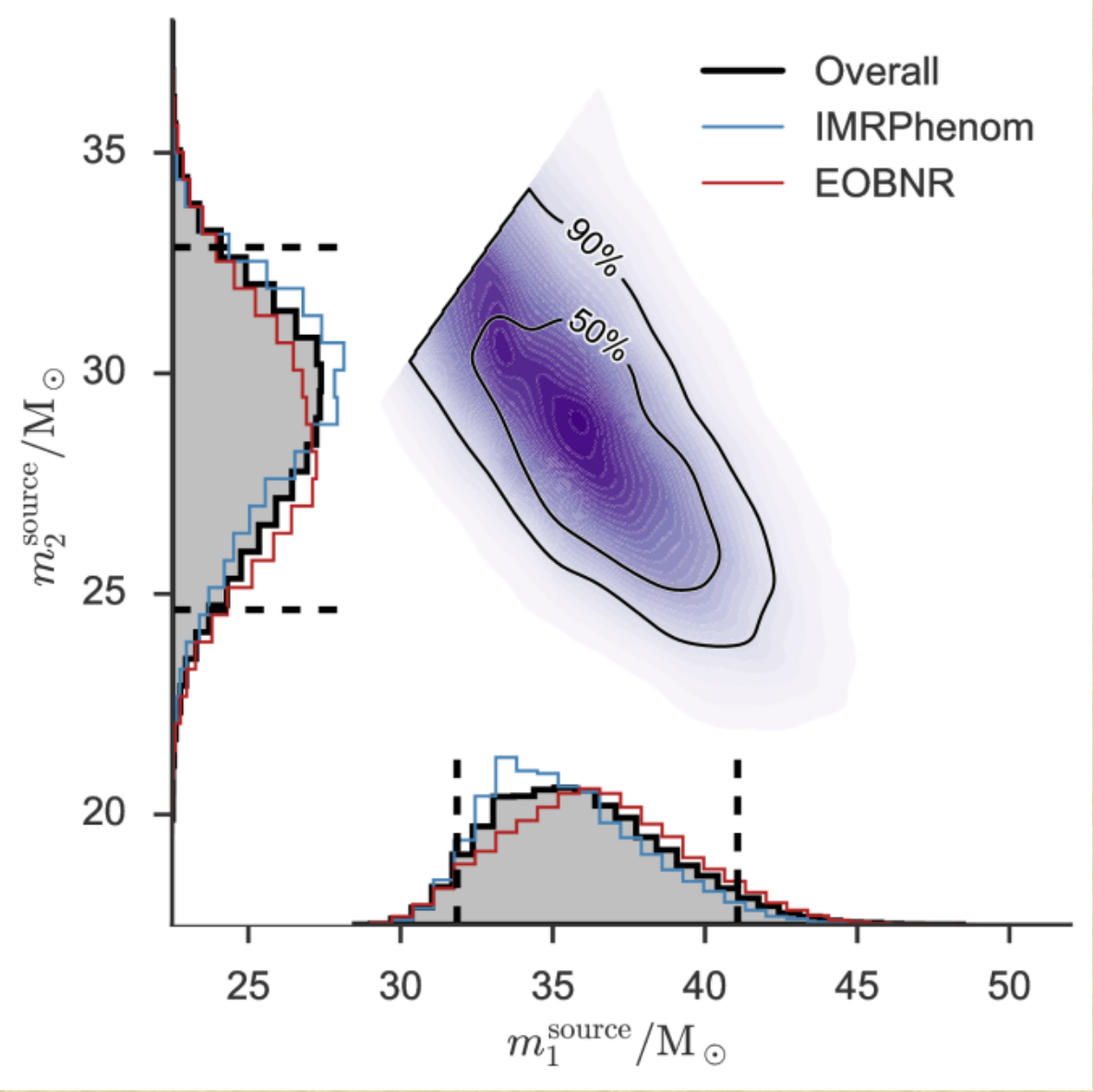
- GW150914 can be used to test gravity in qualitatively new ways
- Currently, we are limited by lack of understanding of what mergers would be in different theories
- <4% of signal is non-GR





Yunes, Yagi, Pretorius 2016

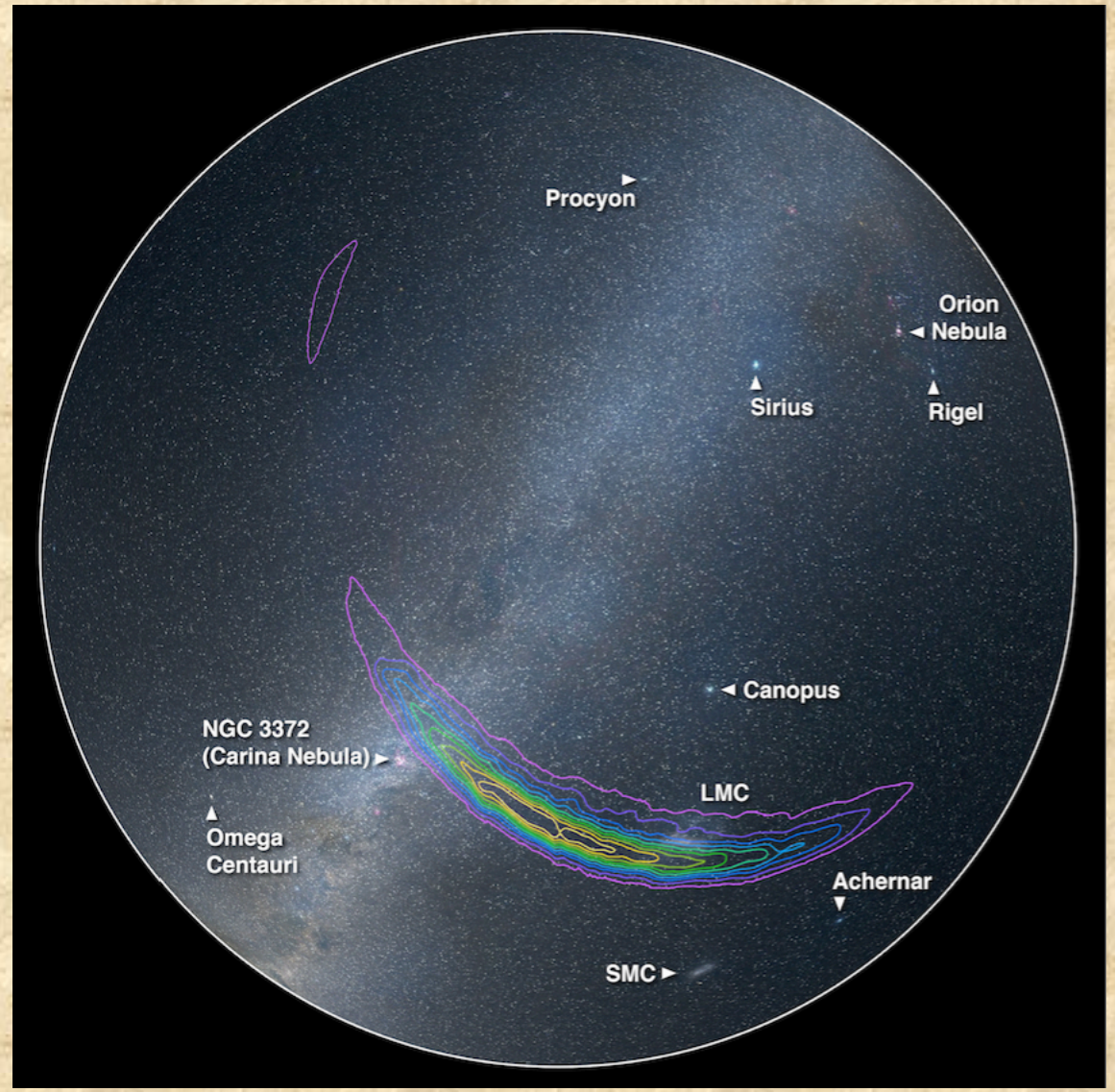
The Masses



The previous highest definitively established mass for a stellar-mass black hole was ~15 M_{sun}. The two here had masses of ~29 M_{sun} and ~36 M_{sun}. When they merged, the mass was ~62 M_{sun}.
Tip of the iceberg?

LIGO Scientific Collaboration, Virgo Collaboration 2016

The Localization

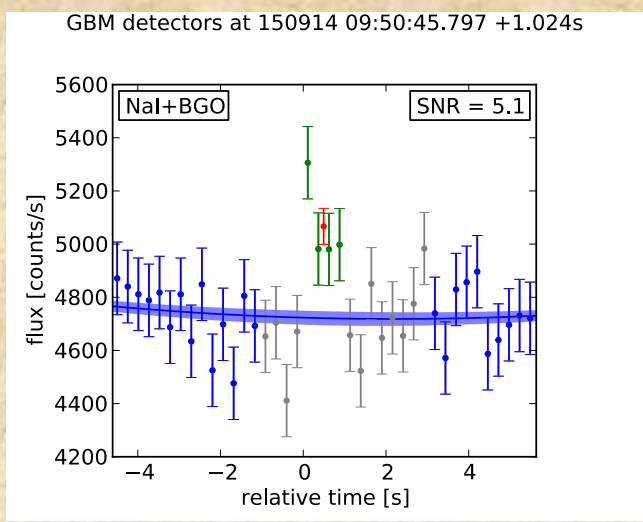


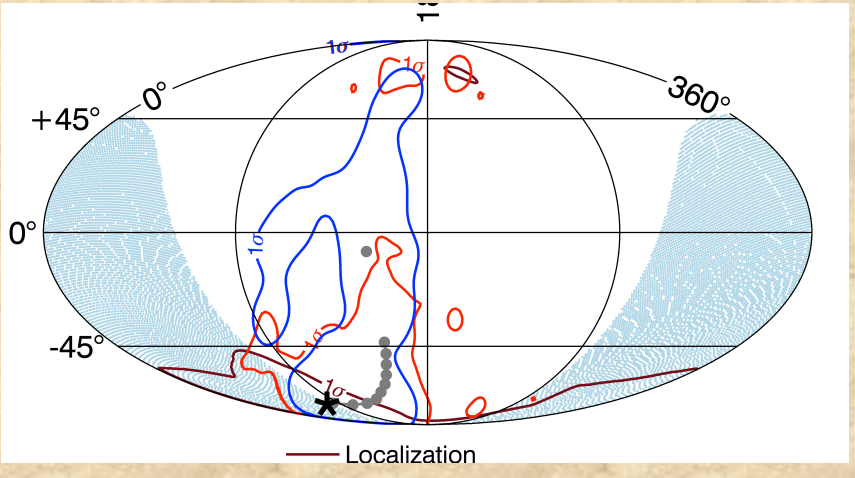
Only two detectors (Hanford, Livingston) were observing. Thus constraint on sky is mainly an arc, of 600 sq degrees.
With third detector (e.g., Virgo), the localization would be much better.
Also better if EM counterpart, but unlikely with BH-BH

LIGO Scientific Collaboration, Virgo Collaboration 2016

And yet...

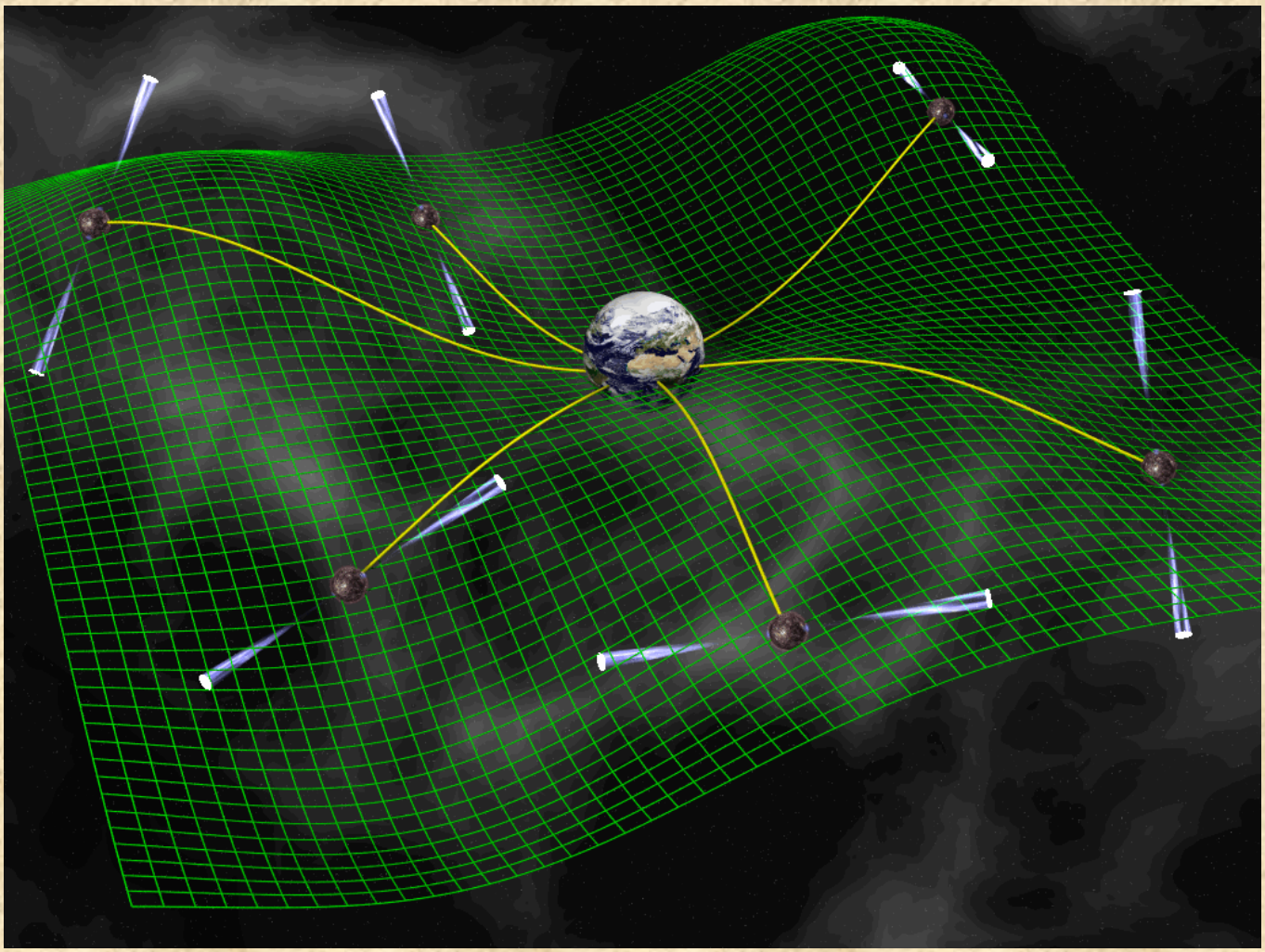
- Fermi event: ~1 sec long, 0.4 sec after GW event
- Chance prob 0.002
- Associated? If so, amazing and revolutionary
- Prob. unassociated, but more events will tell





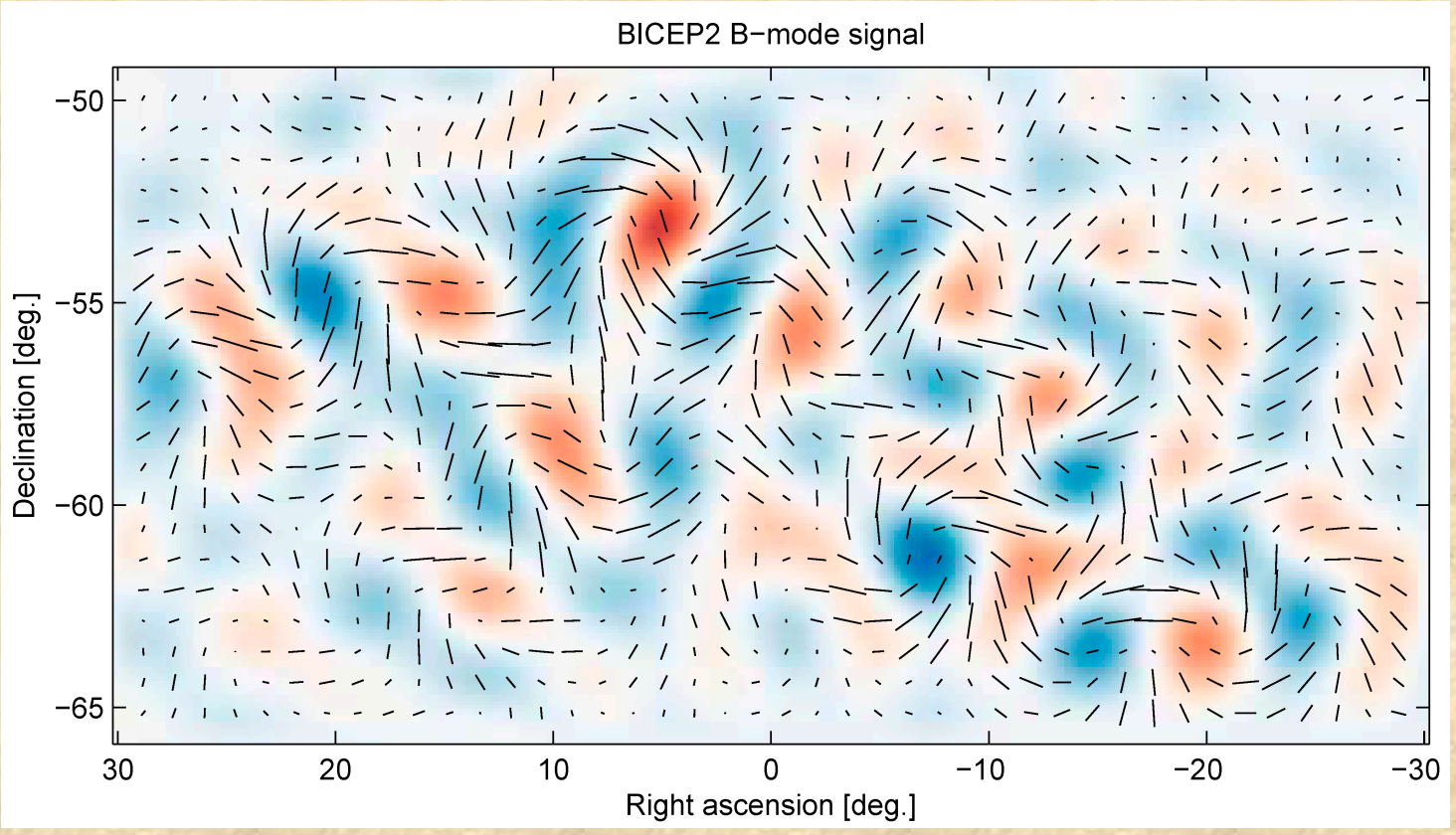
Connaghton et al. 2016

Pulsar Timing Arrays



Looking for signals at 1/months – 1/years
Detection of stochastic signal; 5 years?

B-mode Polarization from CMB



- BICEP2 signal was actually dust
- More sensitive experiments coming
- But no guarantee of detection

LISA: GW Detection in Space

- ESA launch: 2034
- Frequency 10^{-4} to 10^{-1} Hz
- Sources: SMBH, extreme mass ratio inspirals, WD binaries
- High precision!