



# GWIC

Gravitational Wave International Committee

## SCIENCE CASE FOR 3G

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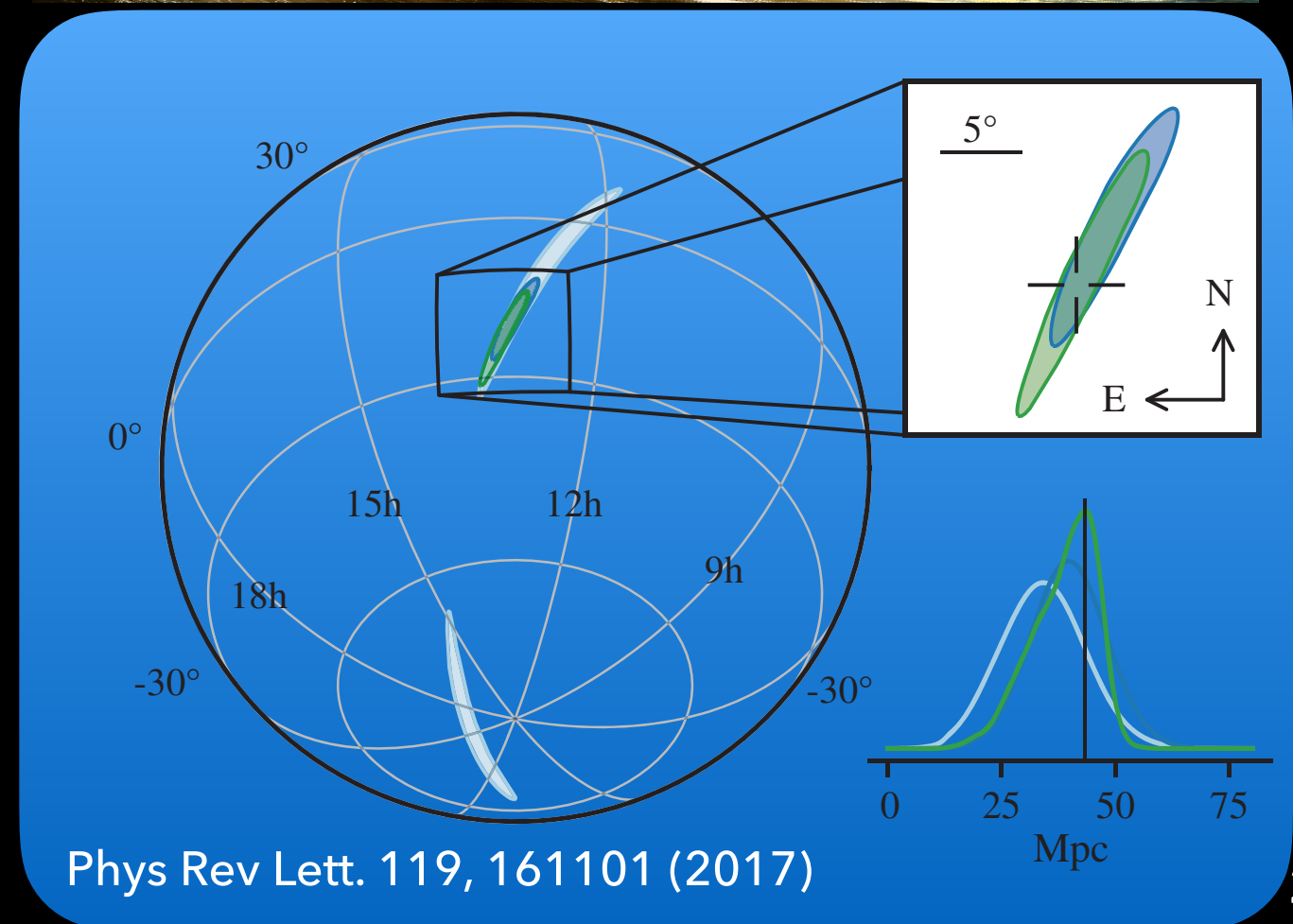
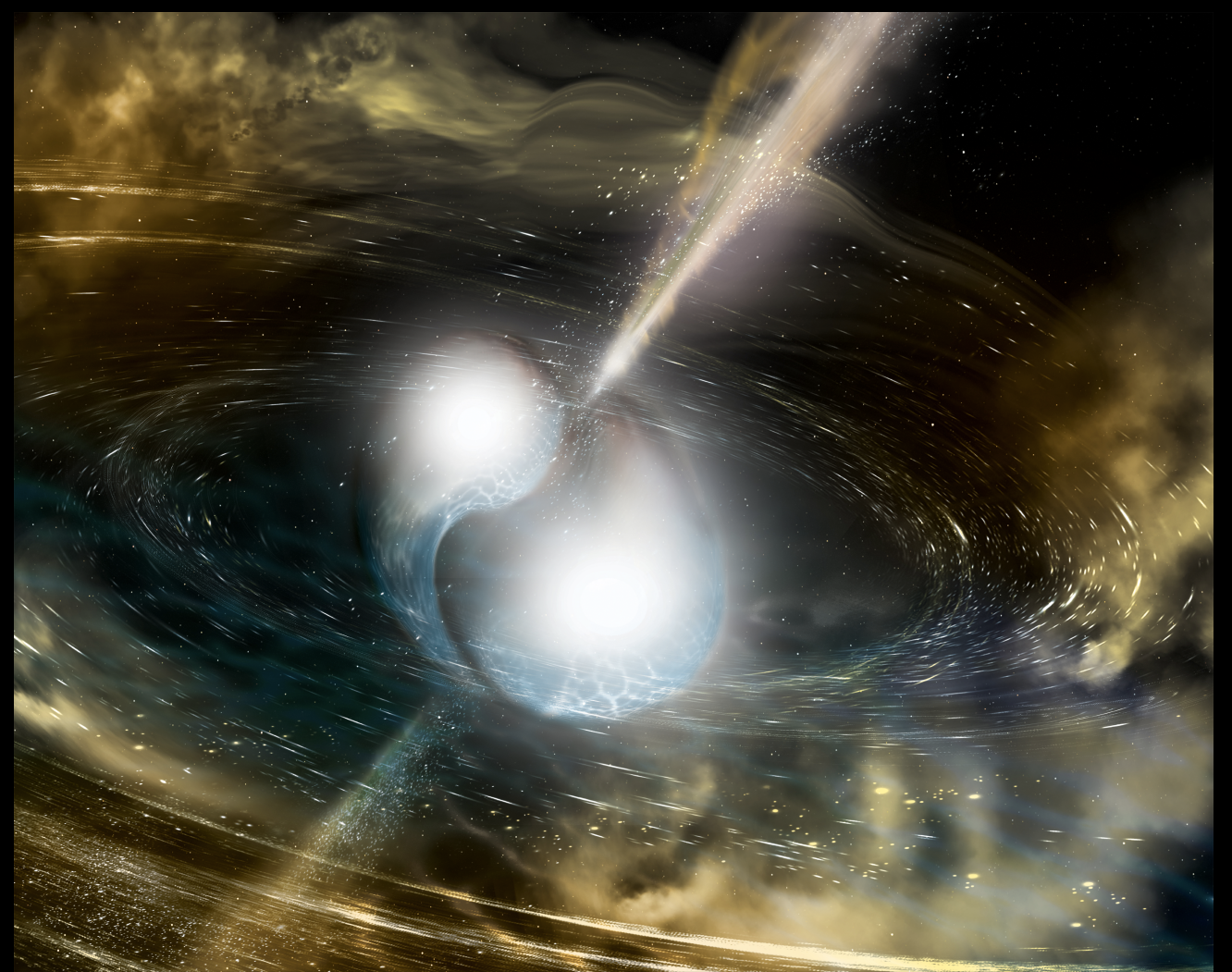
ON BEHALF OF

GWIC 3G COMMITTEE & 3G SCIENCE CASE TEAM



# CONTEXT

- ❖ gravitational wave observations have ushered in a new era of scientific discovery
- ❖ will advance the exploration of extremes of astrophysics and gravity
- ❖ solve open questions in fundamental physics and astronomy
- ❖ provide insights into most powerful events in the Universe
- ❖ boost the impact of multi-messenger astronomy
- ❖ likely to reveal new objects and phenomena





# WHY 3G, WHY NOW?

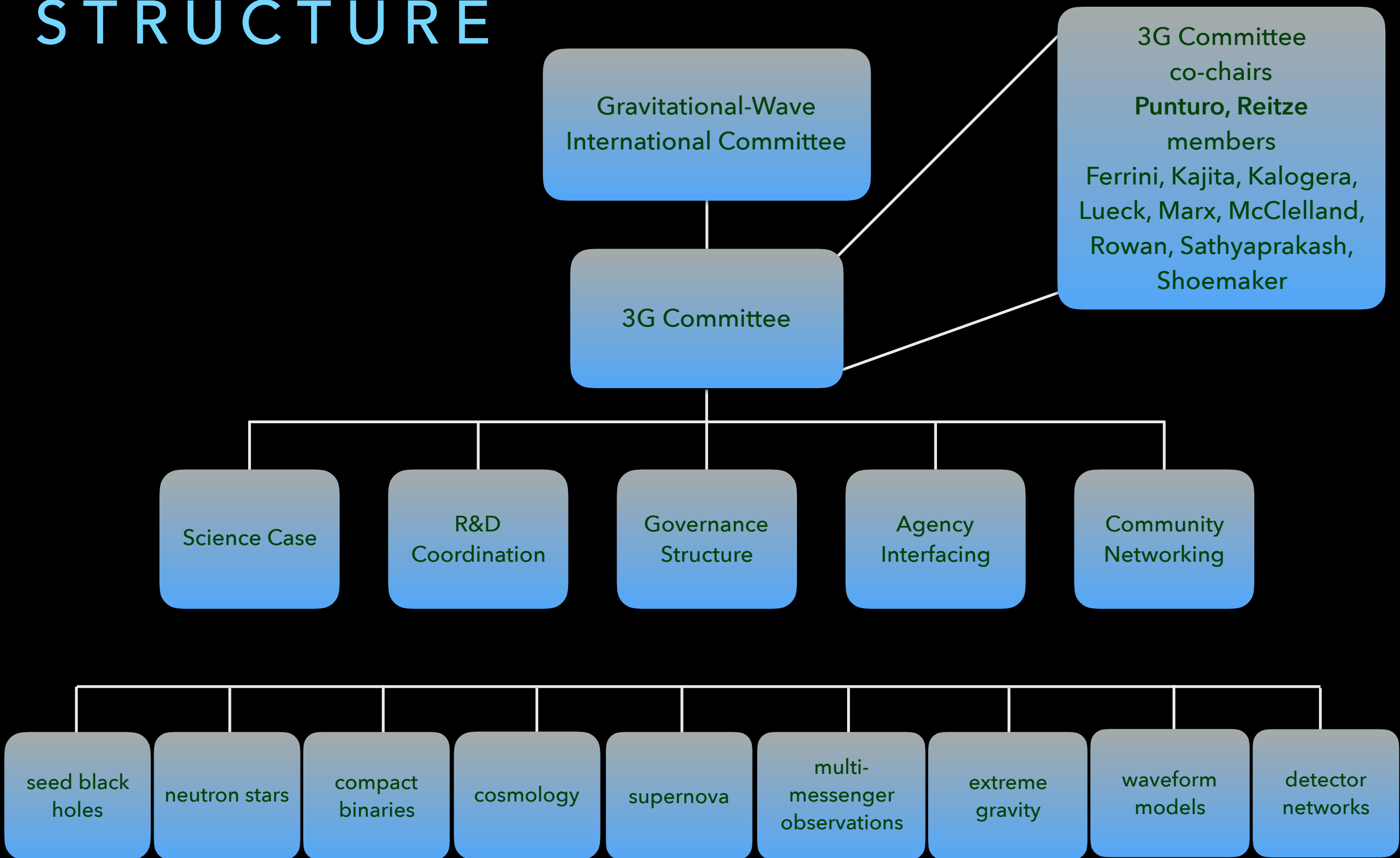
- ❖ LIGO and Virgo both have facility-imposed limits on sensitivity
  - ❖ at most, x 3 improvements in strain sensitivity possible, gravity gradient noise limits sensitivity below 10 Hz
  - ❖ there is a compelling case to build detectors that can observe deeper into the cosmos
- ❖ LIGO and Virgo took ~ 15 years each for initial and advanced configuration
  - ❖ vision to build a facility that's good ~30-40 yrs after construction
  - ❖ need to explore/understand funding scenarios in different regions
- ❖ to succeed it is critical to have a common/shared global vision
  - ❖ articulate for the excellent science we know is possible from a strong platform

# SCOPE

- ❖ to fully exploit the GW window we will need new facilities
- ❖ GWIC formed a subcommittee to develop a vision for the next generation of ground-based detectors
- ❖ one of the charges to the GWIC subcommittee is:
  - ❖ *"commission a study of ground-based gravitational wave science from the global scientific community, investigating potential science vs. architecture vs. network configuration vs. cost trade-offs, ..."*
  - ❖ GWIC subcommittee has constituted five 3G subcommittees:
    - ❖ (1) Science Case Team (3G-SCT), (2) R&D Coordination, (3) Governance, (4) Agency Interfacing, (5) Community Networking
- ❖ the Science Case will be developed by an international consortium of scientists under the leadership of the 3G-SCT (18 members)



# STRUCTURE



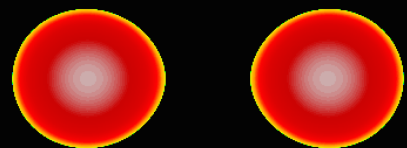
for membership of committees see: <https://gwic.ligo.org/3Gsubcomm/>

Working Group	Co-chairs
Extreme Gravity	Buonanno and Van Den Broeck
Neutron Stars	Papa, Reddy, Rosswog
Compact Binaries	Bailes, Kalogera, Mandel
Seed Black Holes	Colpi, Fairhurst
Supernova	Bizouard, Burrows
Cosmology	Mandic, Sathyaprakash
Waveforms	Buonanno and Lehner
Detector Networks	Evans, Fairhurst, Hild
Multi-messenger Observations	Bailes, Kasliwal



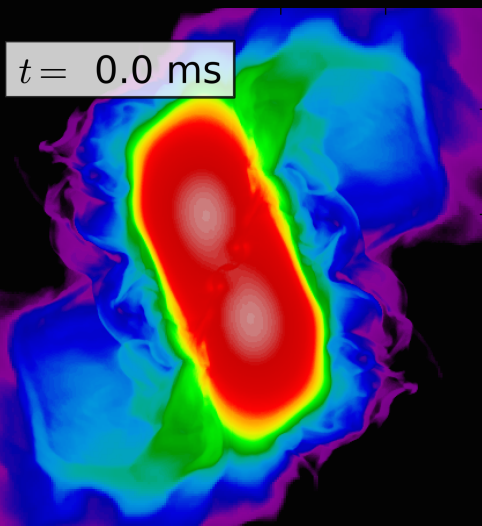
# KEY QUESTIONS THAT MOTIVATE THE SCIENCE CASE

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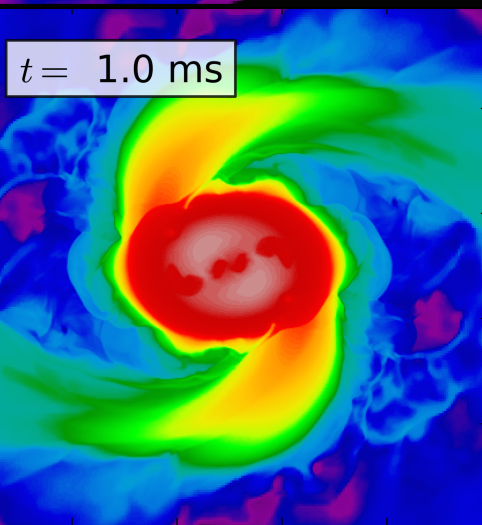


# EQUATION OF STATE OF DENSE NUCLEAR AND OTHER EXTREME MATTER

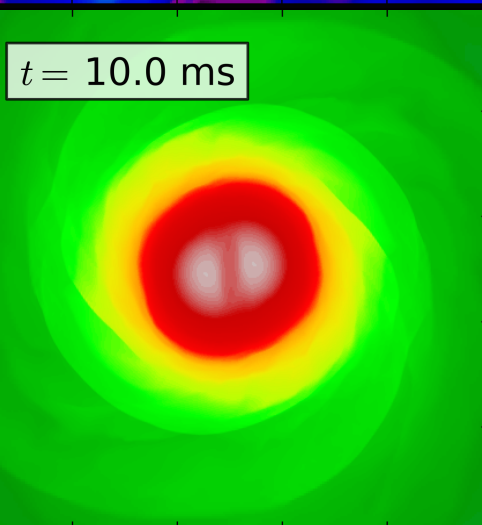
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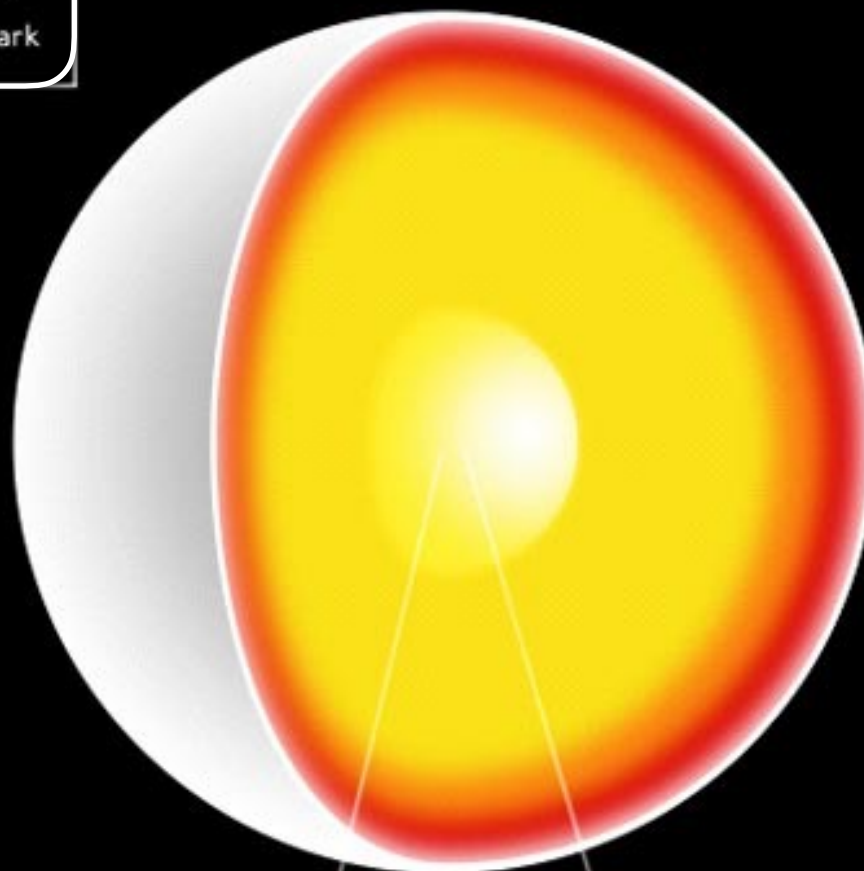
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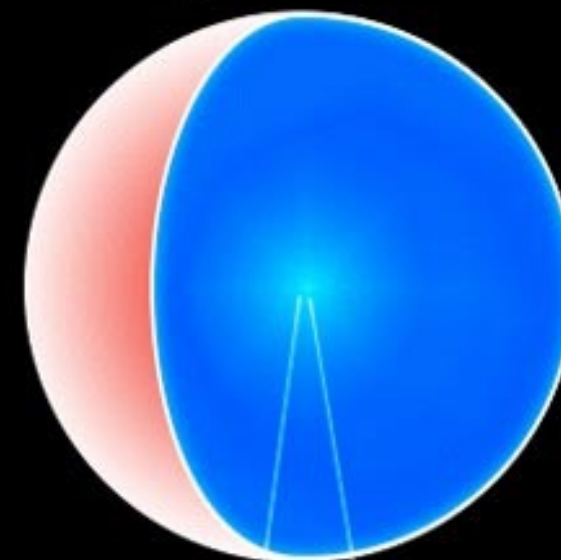
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Neutron Star



Strange Quark Star

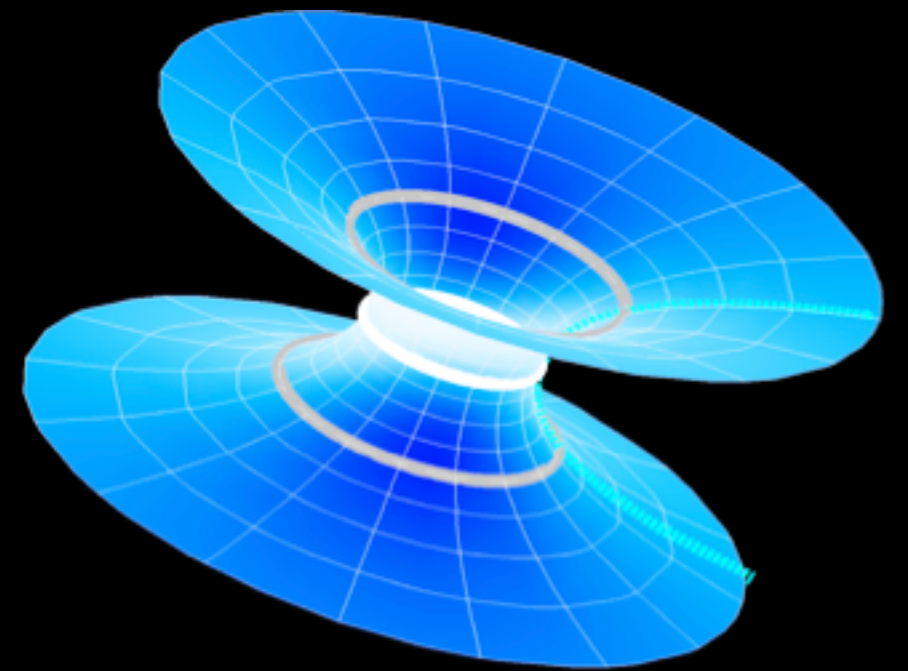
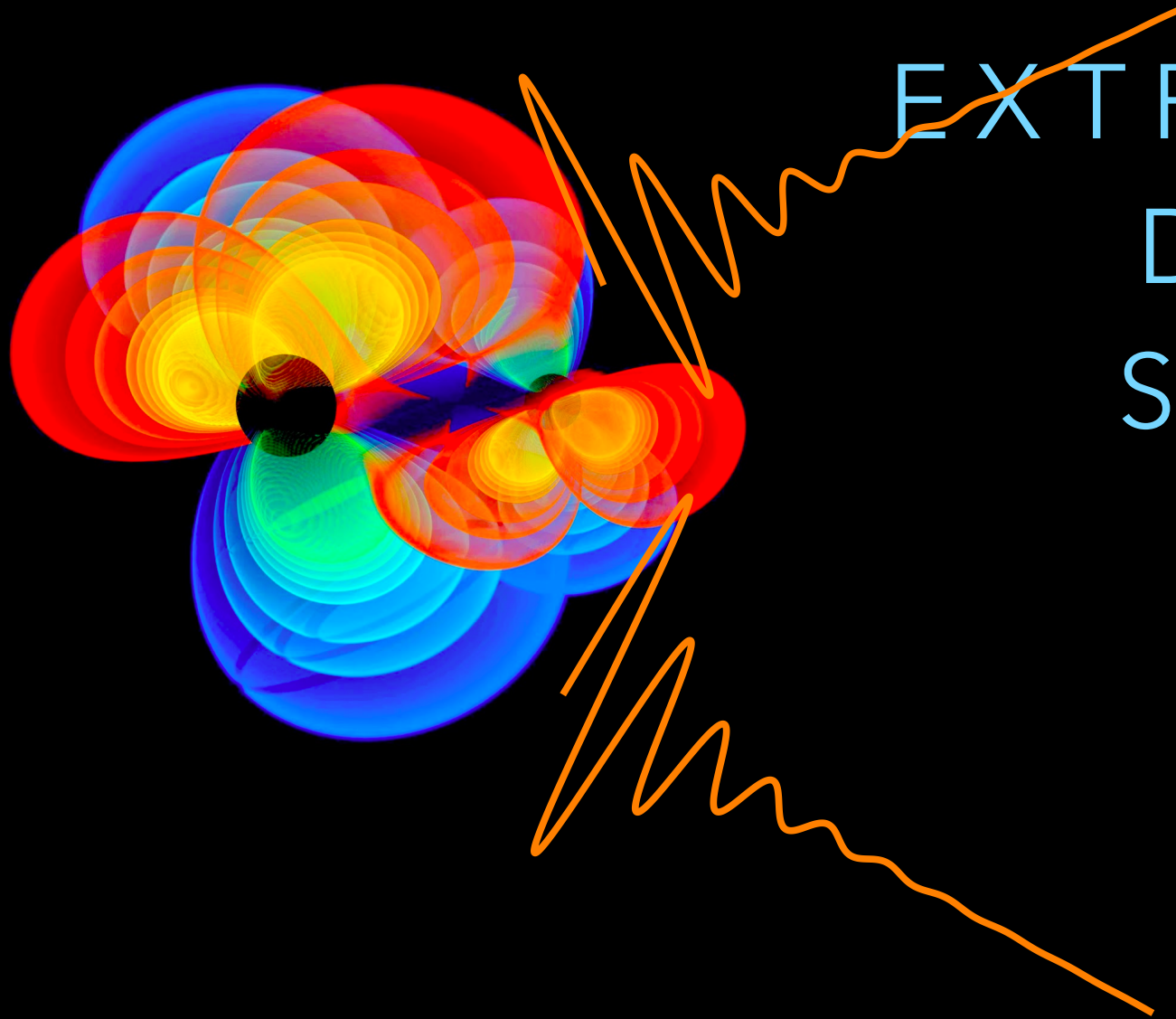


Densities  $\sim 4 \times 10^{17} \text{ kg/m}^3$

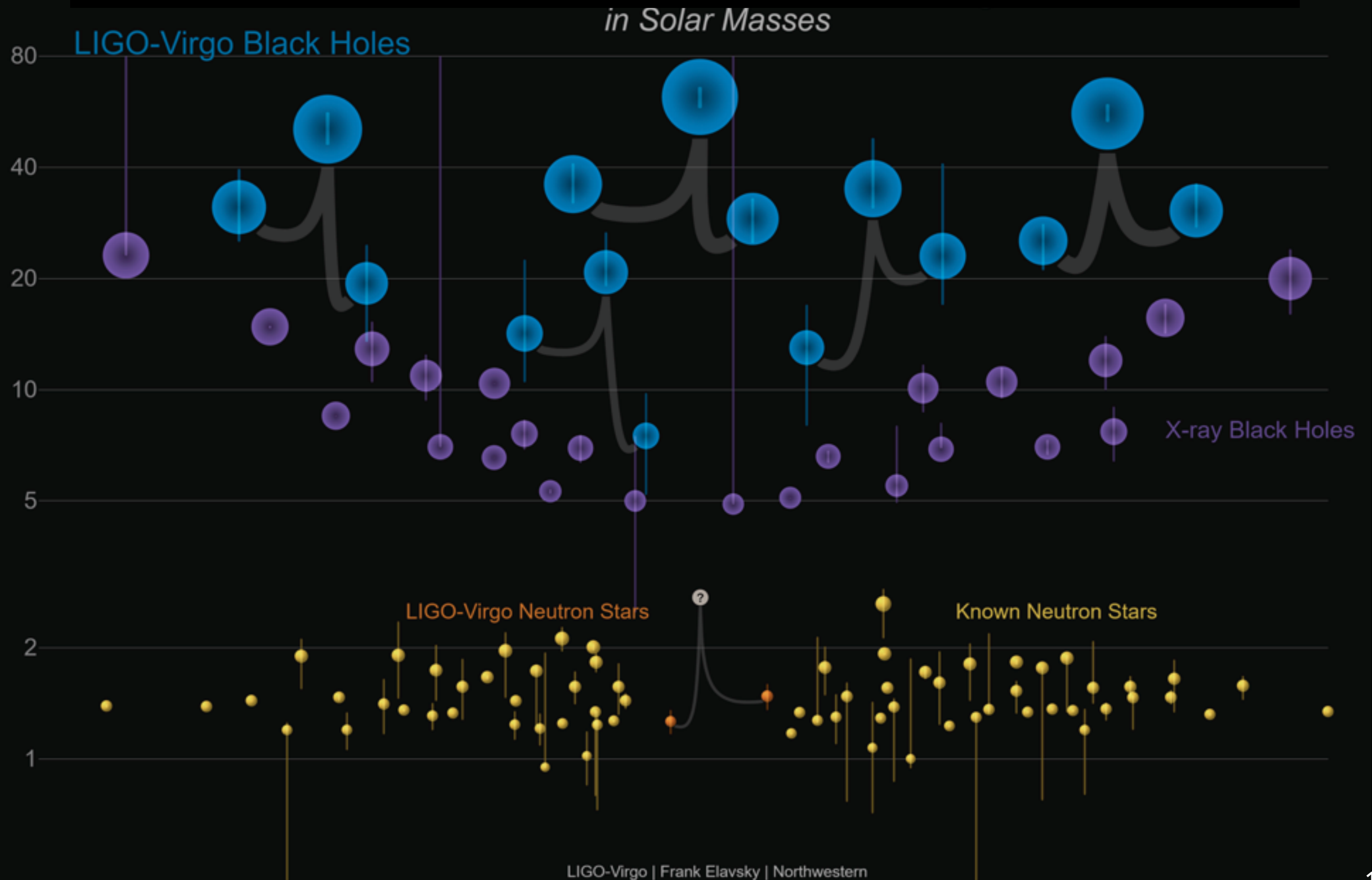




# EXTREME GRAVITY, DYNAMICAL SPACETIMES



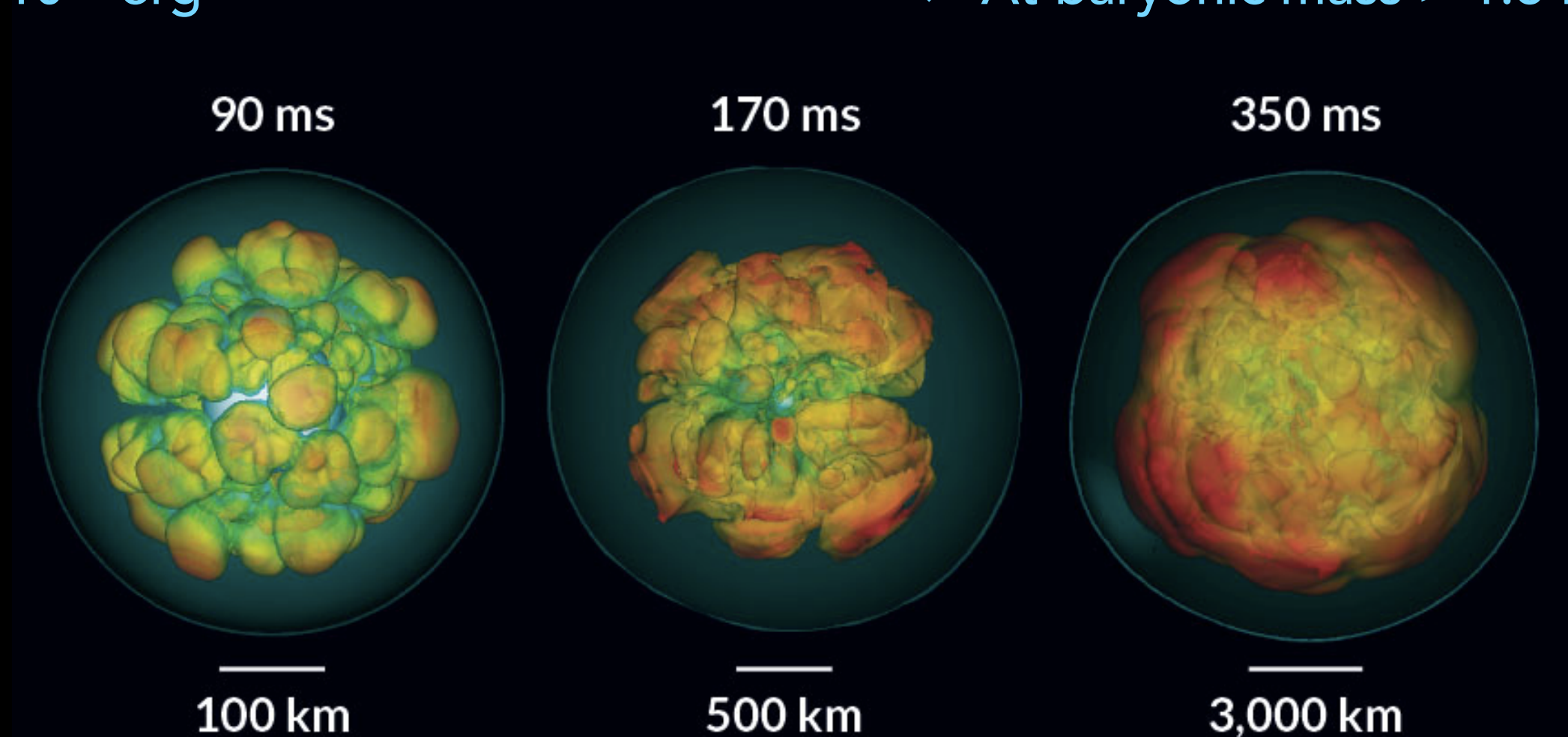
# FORMATION AND EVOLUTION OF COMPACT BINARIES





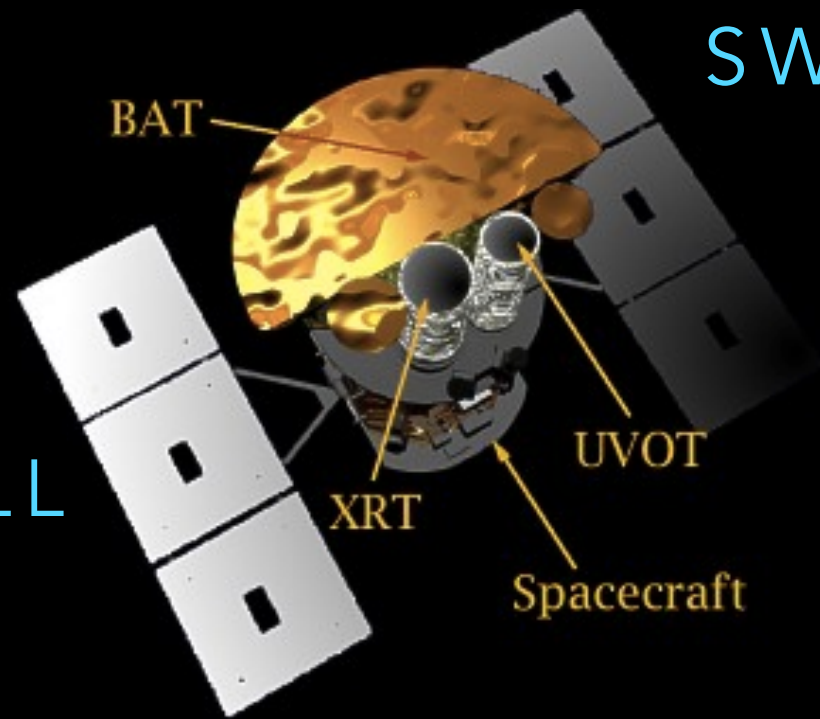
# ASTROPHYSICS OF STELLAR COLLAPSE AND SUPERNOVAE

- ❖ Energy reservoir
  - ❖  $\text{few} \times 10^{53} \text{ erg}$
- ❖ Explosion energy
  - ❖  $10^{51} \text{ erg}$
- ❖ Time frame for explosion
  - ❖ 300 - 1500 ms after bounce
- ❖ Formation of black hole
  - ❖ At baryonic mass  $> 1.8\text{-}2.5 M$



# MULTI-MESSENGER ASTROPHYSICS: SYNERGY BETWEEN GW-EM

SWIFT - BAT



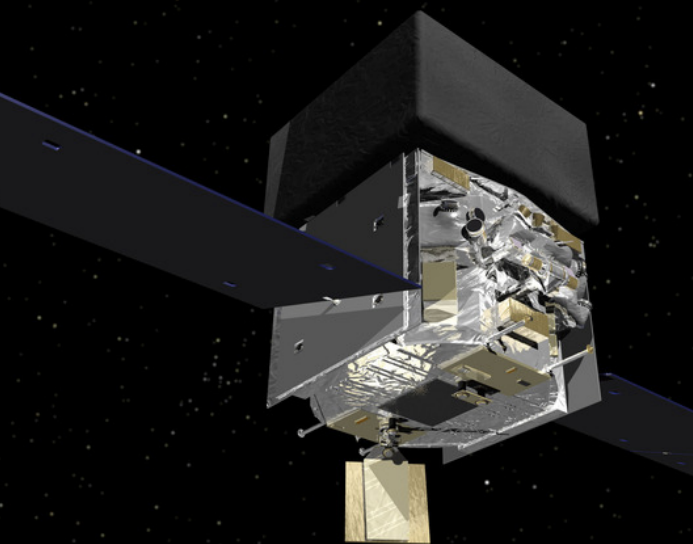
KECK



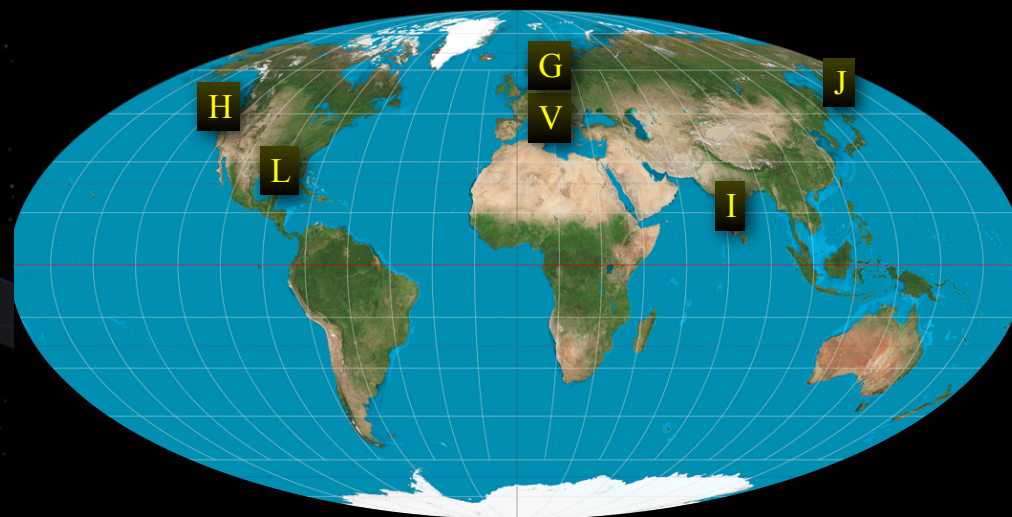
PARKES RADIO  
TELESCOPE



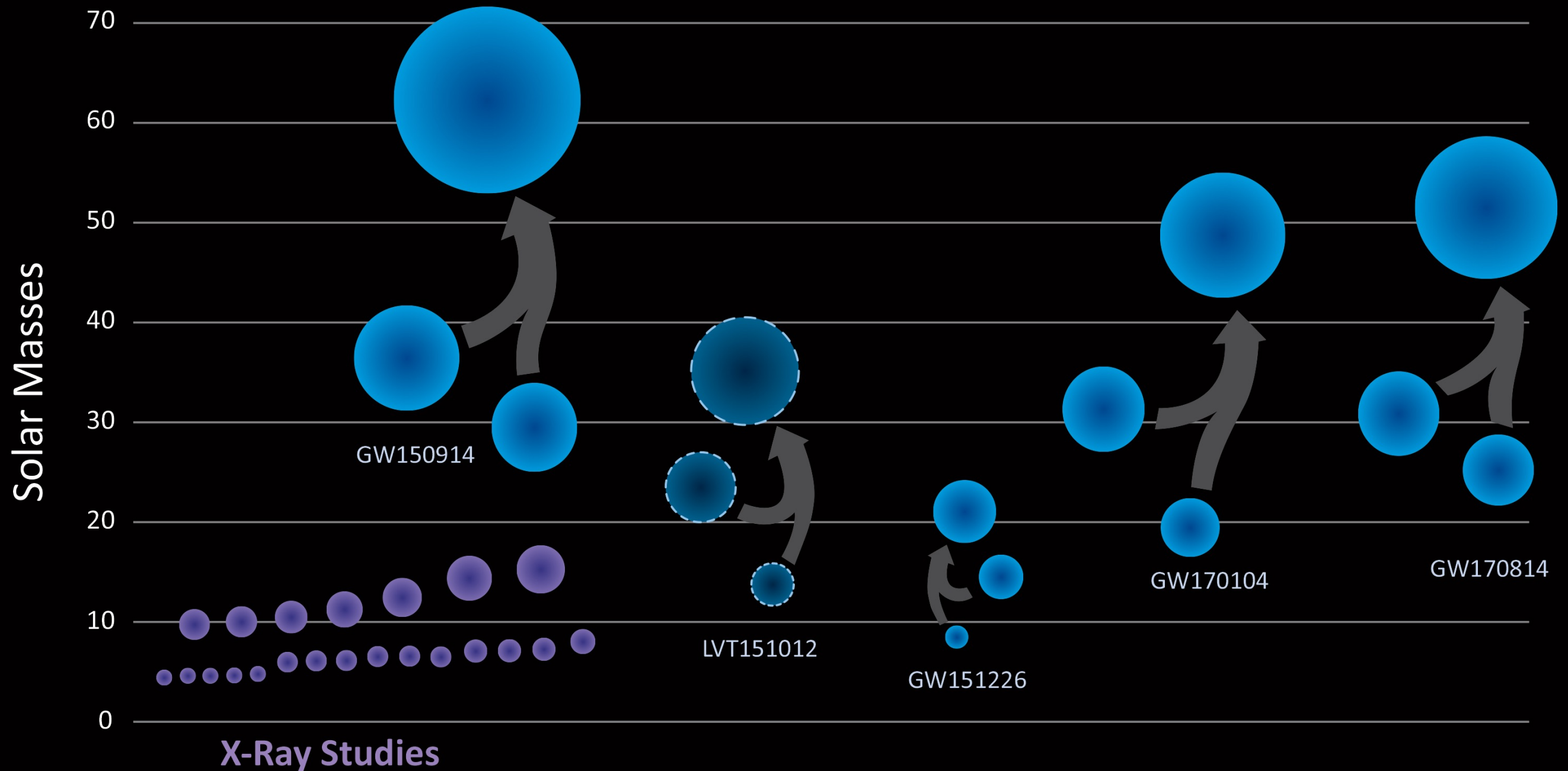
FERMI GBM - ALL  
SKY



GW NETWORK - ALL SKY



# FORMATION AND EVOLUTION OF LIGHT SEED BLACK HOLES AND THEIR GROWTH



graphic: LSC and Aurore Simonnet



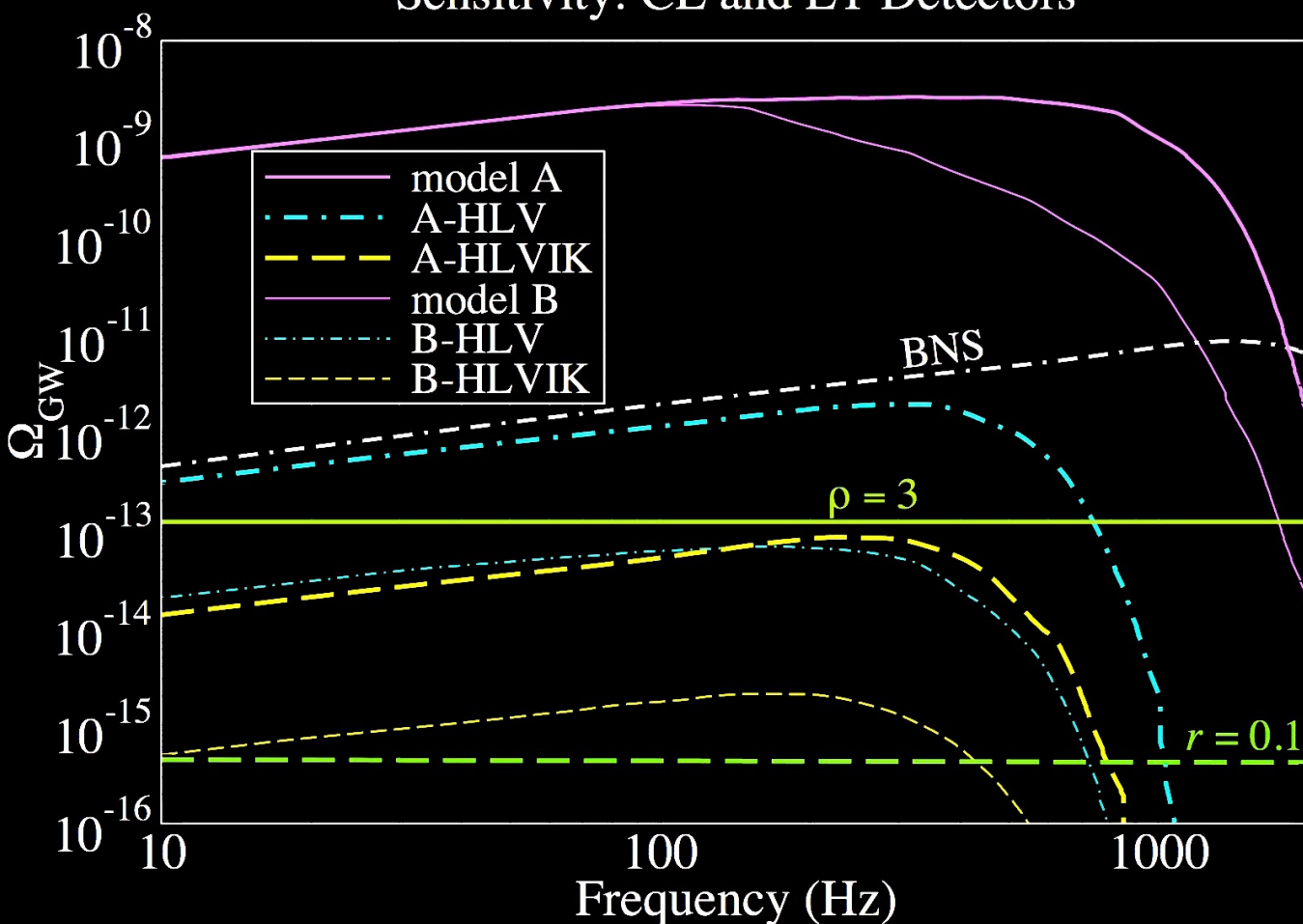
# STANDARD SIREN COSMOLOGY

- ❖ Compact binaries are standard sirens; GW observations can measure the luminosity distance
- ❖ Can measure distance **and** redshift from GW observations of binary neutron stars

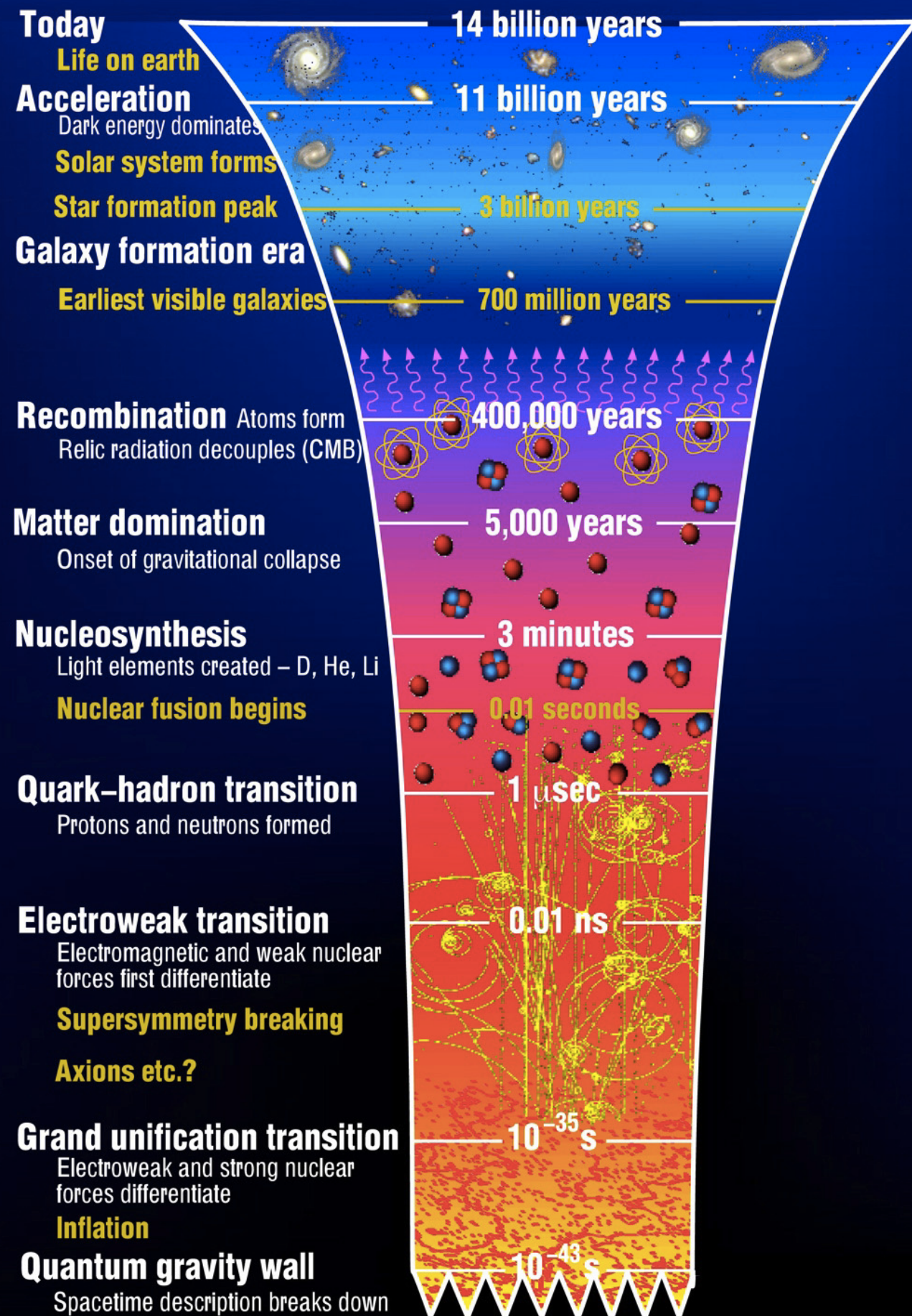


# ASTROPHYSICAL AND PRIMORDIAL STOCHASTIC BACKGROUNDS

Sensitivity: CE and ET Detectors

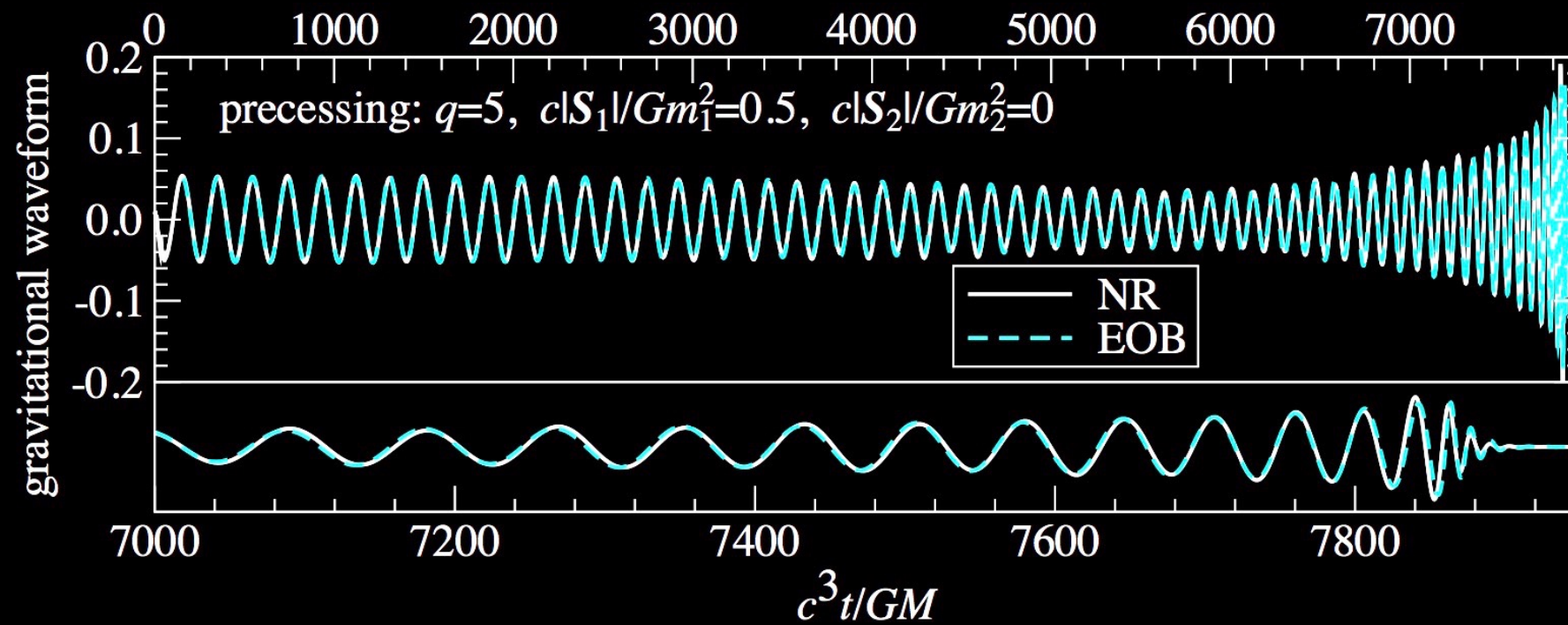


Regimbau+ PRL 2017





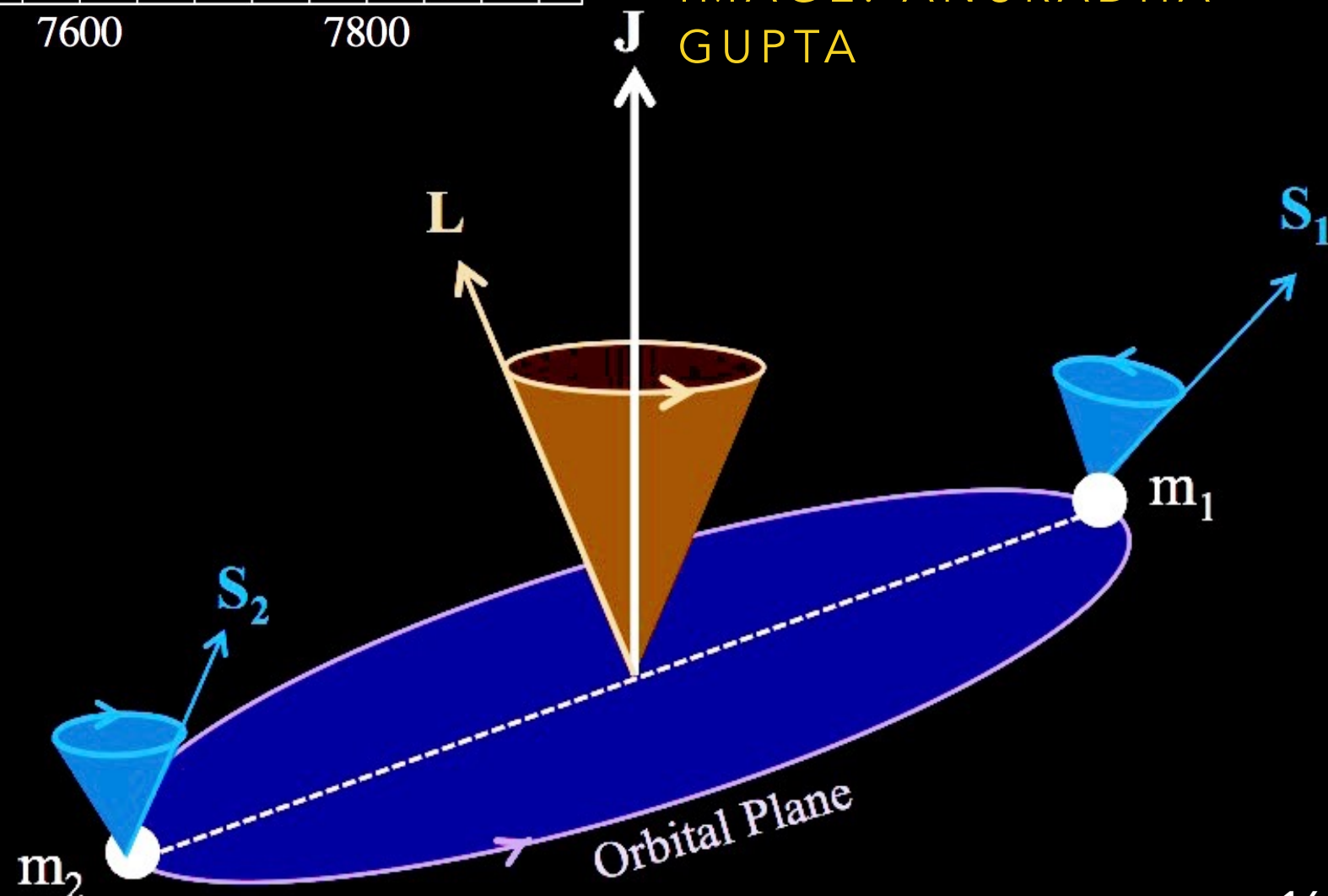
# NUMERICAL RELATIVITY SIMULATIONS AND ANALYTICAL RELATIVITY THEORY



WAVEFORM: SXS,  
FROM BUONANNO  
AND SATHYAPRAKASH

IMAGE: ANURADHA  
GUPTA

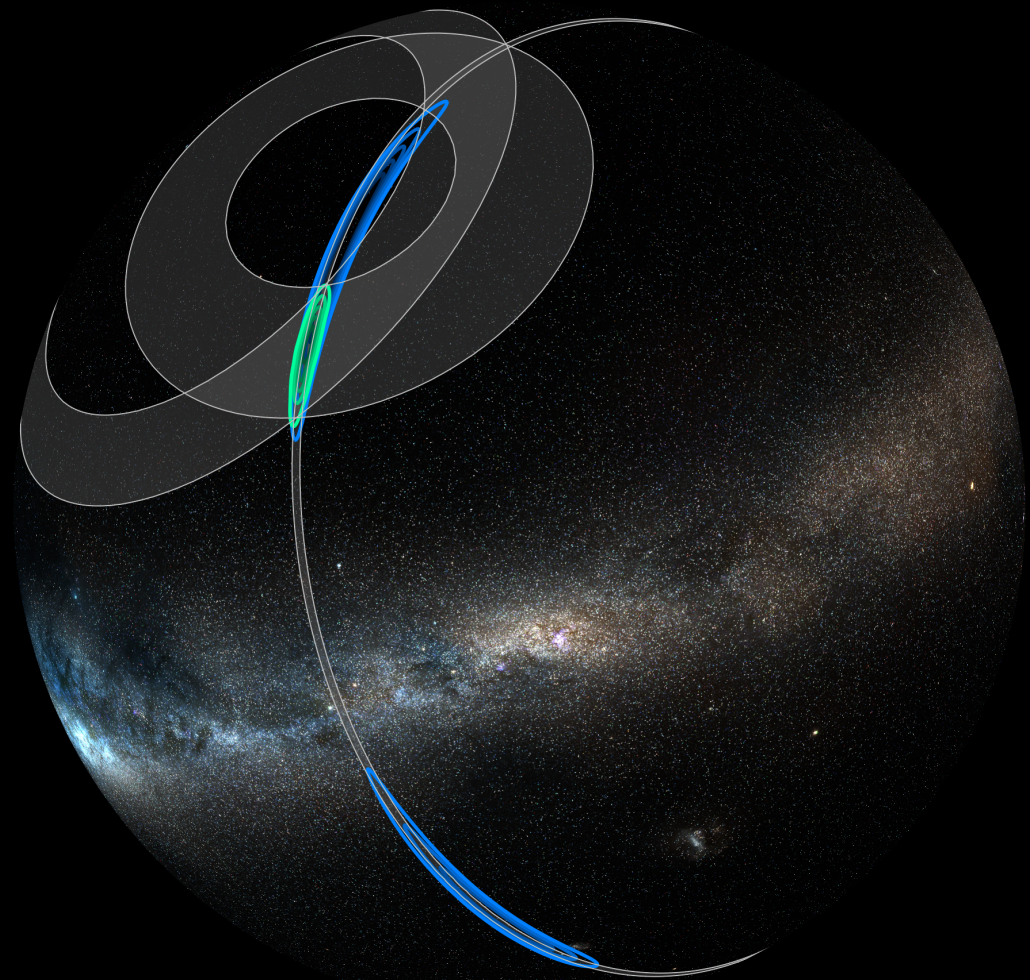
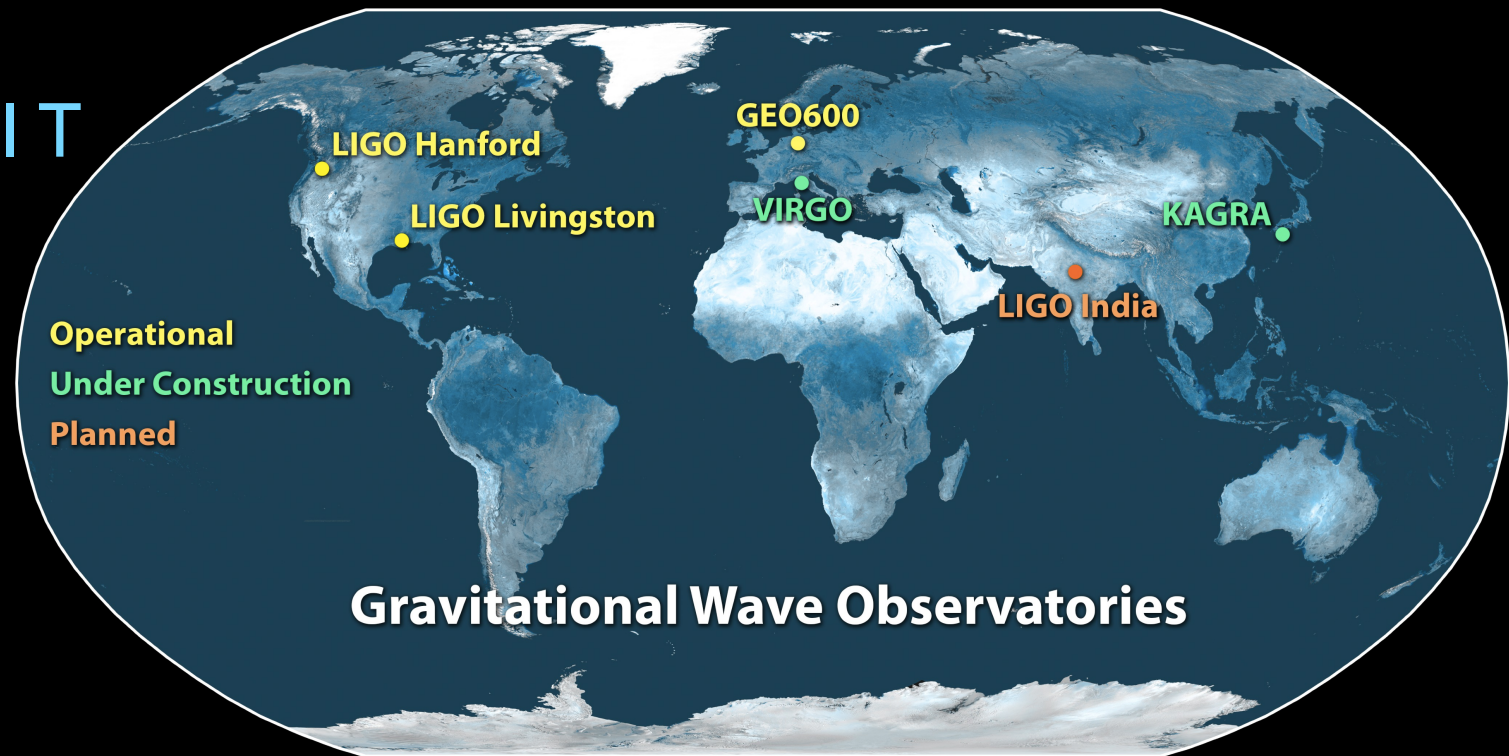
- ❖ challenges in waveform modelling:
  - ❖ relativistic effects in binary black holes
  - ❖ matter effects in binary neutron stars
  - ❖ supernova signals





# DETECTOR NETWORKS AND FIGURES OF MERIT

- ❖ detector networks
  - ❖ how many detectors do we need
- ❖ heterogeneous detector networks
  - ❖ what is the role of less sensitive detectors
- ❖ what are the different figures-of-merit to sum-up detector performance?
  - ❖ distance reach, angular resolution, ability to measure specific parameters, ...



# JOINING THE 3G SCIENCE CASE CONSORTIUM

- ❖ open to anyone who wishes to contribute to the development of the science case for 3G
- ❖ send a one-page CV and research interests relevant to 3G to:
  - ❖ B.S. Sathyaprakash [bss25@psu.edu](mailto:bss25@psu.edu) or Vicky Kalogera <[vicky@northwestern.edu](mailto:vicky@northwestern.edu)>