OVERVIEW OF COSMIC PROBES: GRAVITATIONAL WAVES

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#127: SEARCHES FOR DARK SECTORS:

TUESDAY 1400, ZOOM 1

- **Early Universe Phase Transitions**
  - Gravitational Wave as a probe of phase transitions during inflation Haipeng An, Lian-Tao Wang
  - Complementarity between collider and gravitational wave signatures of a first-order electroweak phase transition Michael Ramsey-Musolf, Ashutosh Kotwal
  - Probing the Electroweak Phase Transition with Exotic Higgs Decays Marcela Carena
  - Phase Transitions: Precision Calculations of Gravitational Wave Spectrum and Thermal Parameters Huai-Ke Guo
  - Composite Higgs: Collider Signals and Electroweak Phase Transition Da Liu
  - Gravitational Waves from Low Energy Supersymmetry Breaking Nathaniel Craig
- **Primordial Black Holes**
  - Gravitational waves from primordial black holes Sebastien Clesse
  - Electromagnetic Probes of Ultralight Primordial Black Holes Ranjan Laha

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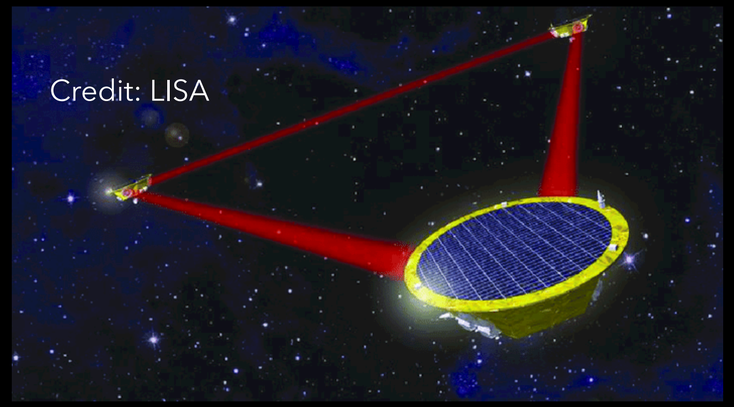
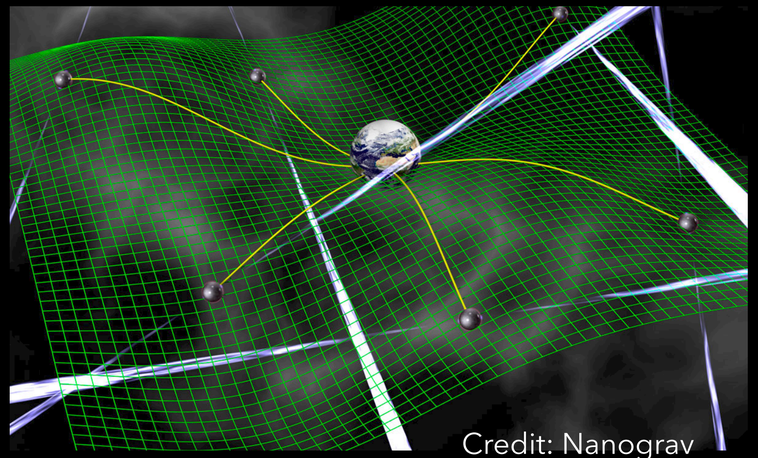
TUESDAY 1400, ZOOM 1

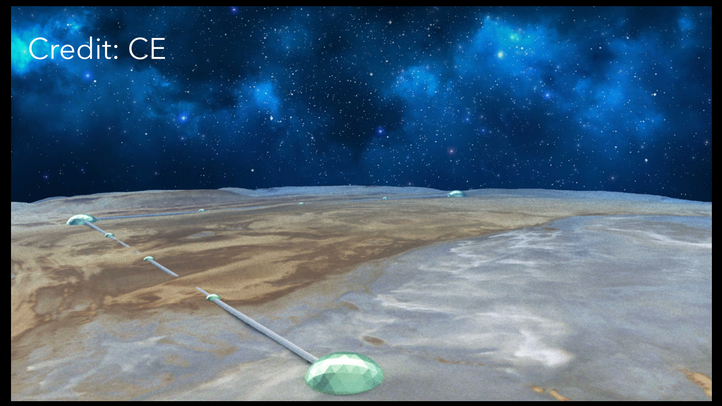
- **Stochastic Backgrounds**
  - The Stochastic Gravitational Wave Background as a Probe of New Physics from the Early Universe Robert Caldwell
  - Correlating Stochastic Gravitational Wave Background with Electromagnetic Observations Light Fields Vuk Mandic
- **Fundamental Physics**
  - Fundamental physics with gravitational wave detectors Emanuele Berti
  - Probing Fundamental Physics using the Stochastic Gravitational Wave Background from the Early Universe Yue Zhao
  - Fundamental Physics with Pulsar Timing Arrays Xavier Siemens
  - Gravitational Wave Propagation as a Probe of Fundamental Physics Jay Tasson
  - Search for gravitational waves from ultralight boson clouds around black holes Ling Sun

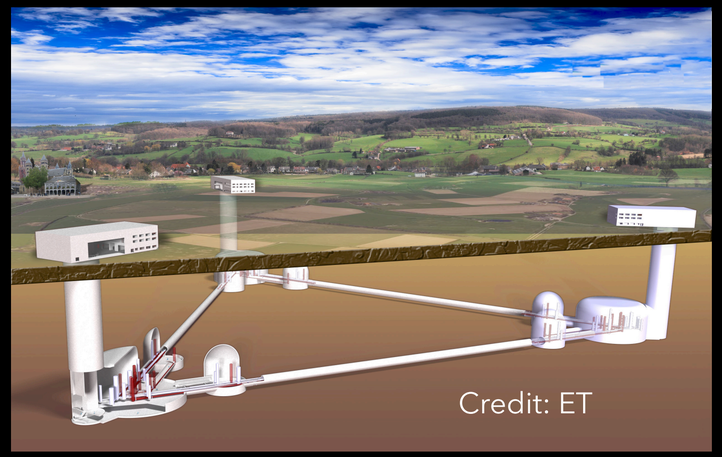
FUTURE GRAVITATIONAL-WAVE OBSERVATORIES

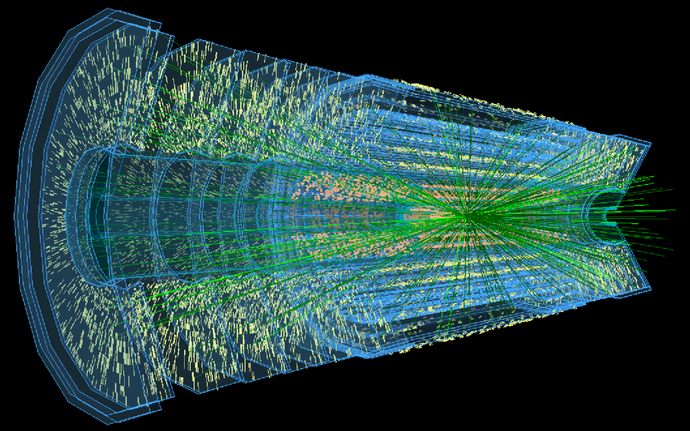


- LIGO/Virgo: black holes and neutron stars are fundamental physics laboratories
  - upgrades: A+, Voyager, KAGRA, LIGO-India (2025)
- Future Observatories
  - **High-f:** NEMO, Einstein Telescope, Cosmic Explorer (2030+)
  - **Mid-f:** MAGIS, AION, AEDGE, DECIGO
  - **Low-f:** LISA, Tianqin (mid-2030s)
  - **Ultra-low-f:** Pulsar Timing Arrays, Nanograv, PPTA, EPTA, SKA (on going)
  - **Future colliders:** High Luminosity LHC (mid 2020s)









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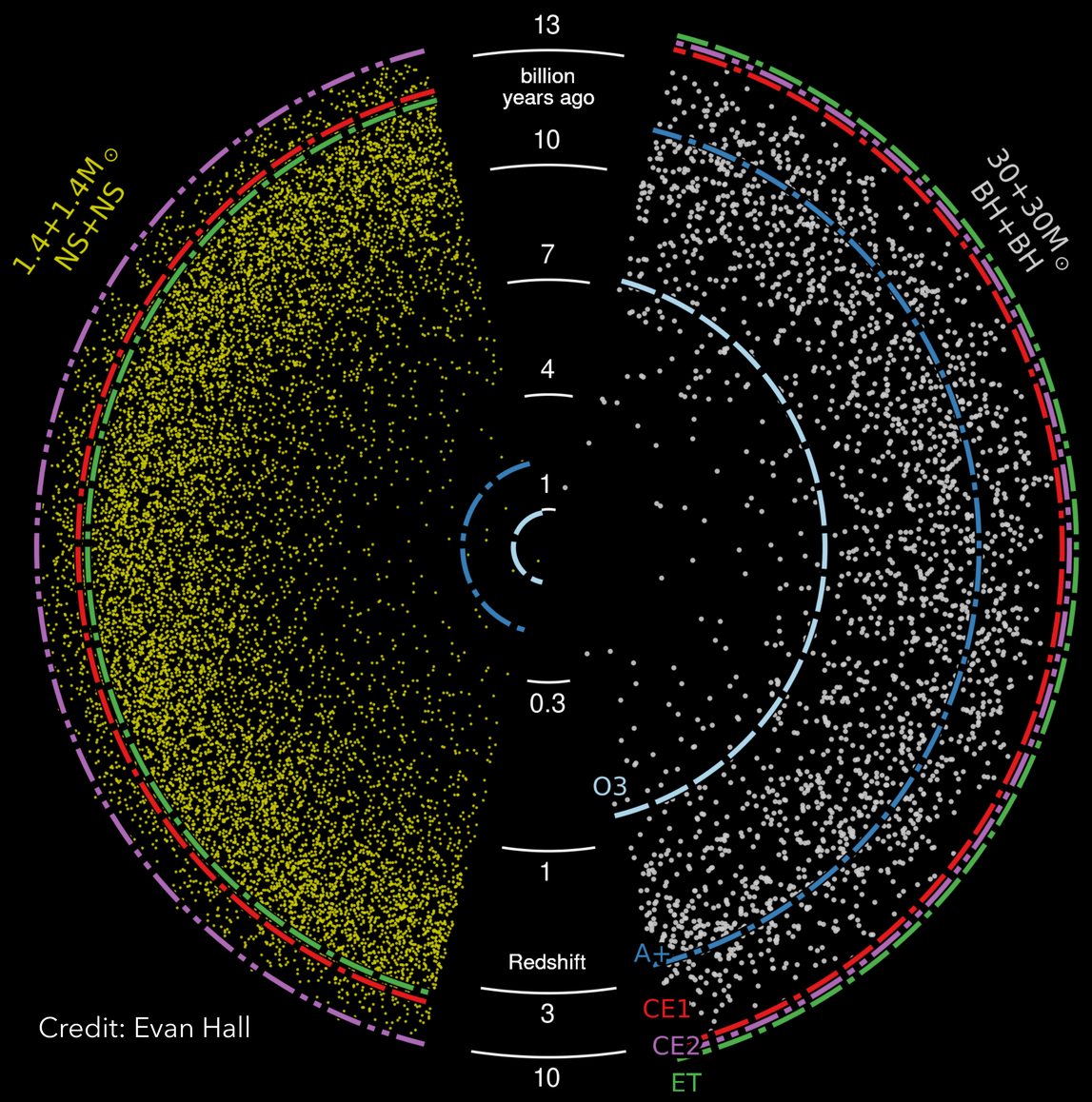
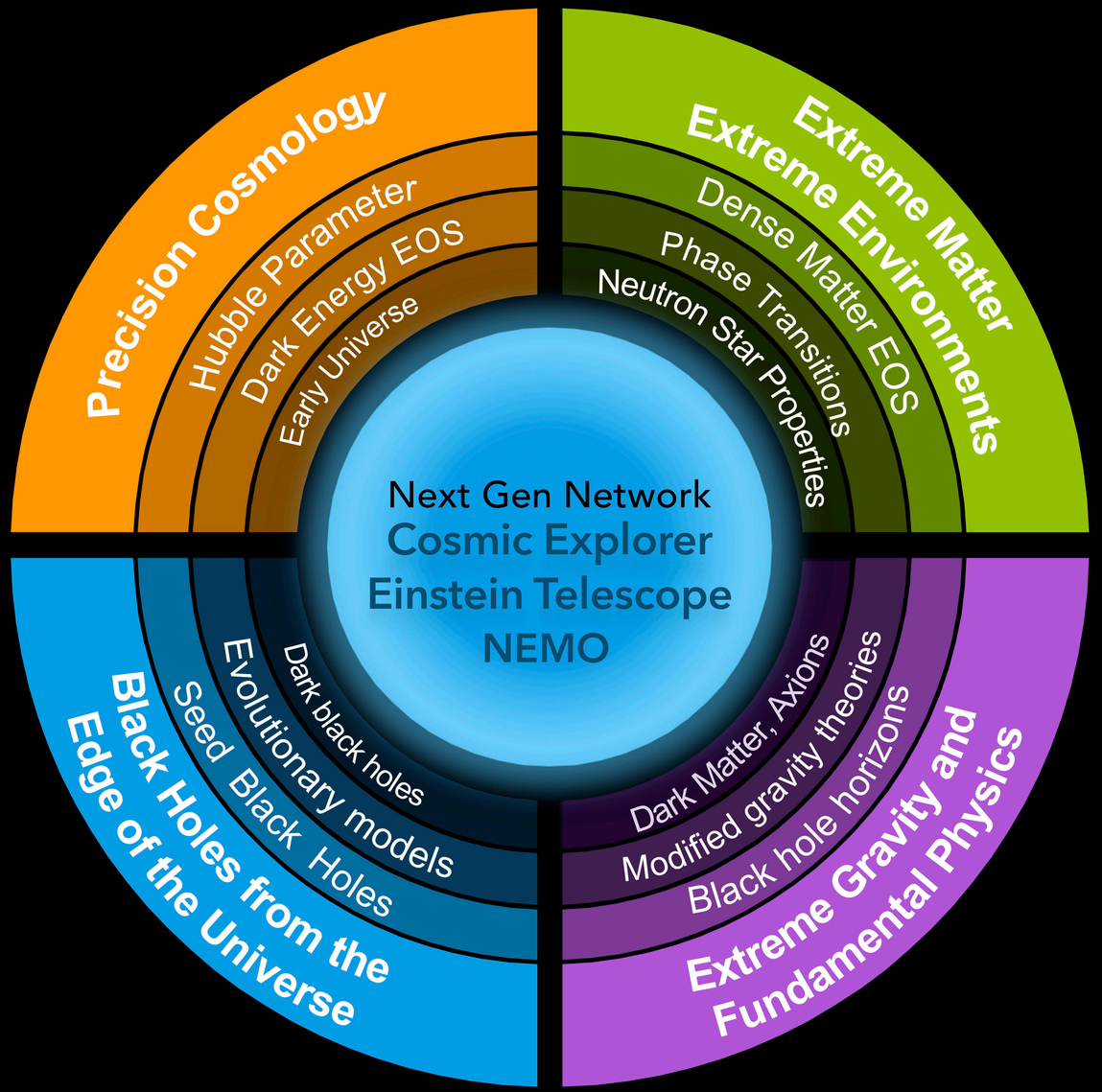
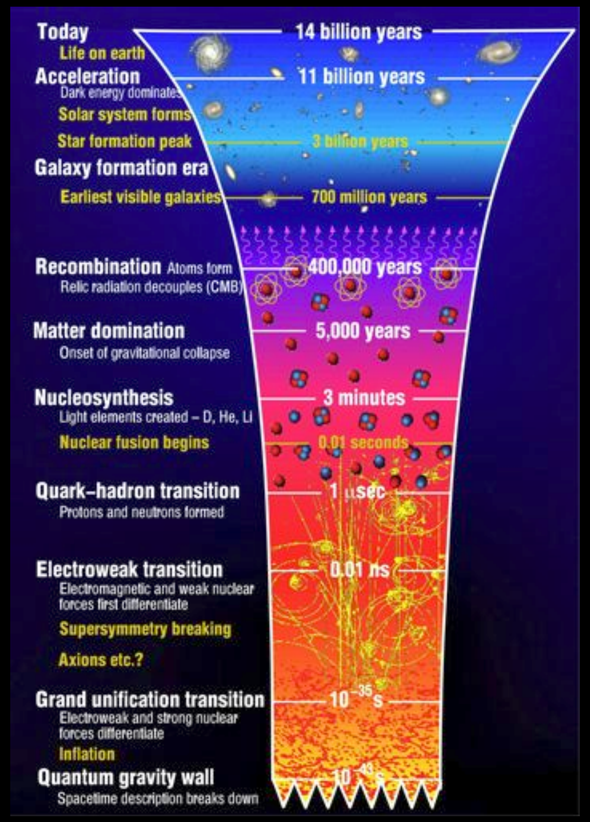


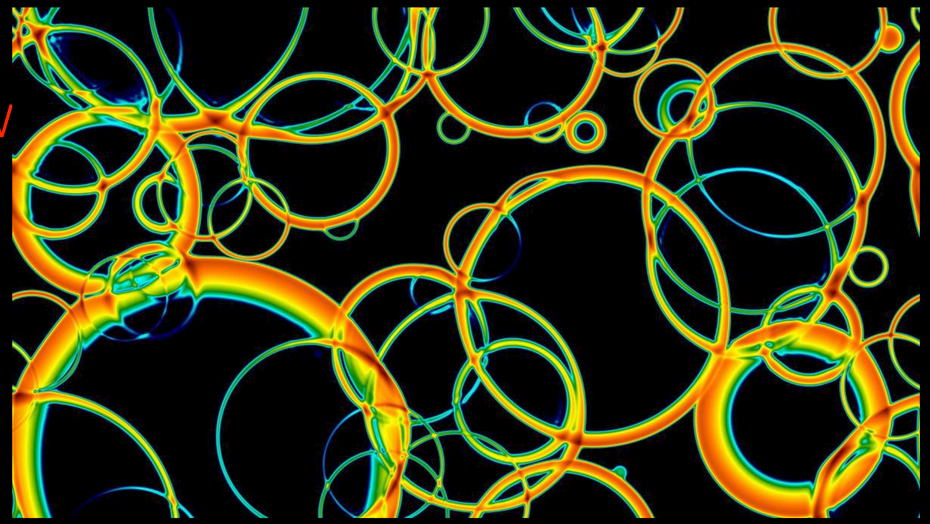
Credit: Evan Hall



EARLY UNIVERSE PHASE TRANSITIONS

- bubble collisions during phase transitions could produce observable gravitational waves
  - energy scale determines the frequency at which they might appear
- beyond standard model physics
  - mass-gap between BSM particles and EW scale
    - e.g. SUSY phase transitions
  - is the Universe natural?
  - what order is the EW phase transition?
  - first order phase transitions in the Higgs condensate
    - presence of new physics could alter the thermal history of the EW symmetry breaking
    - to what extent do future GW observatories probe EW phase transitions?
- slow roll inflation produces primordial stochastic background
  - observable in CMB B-modes



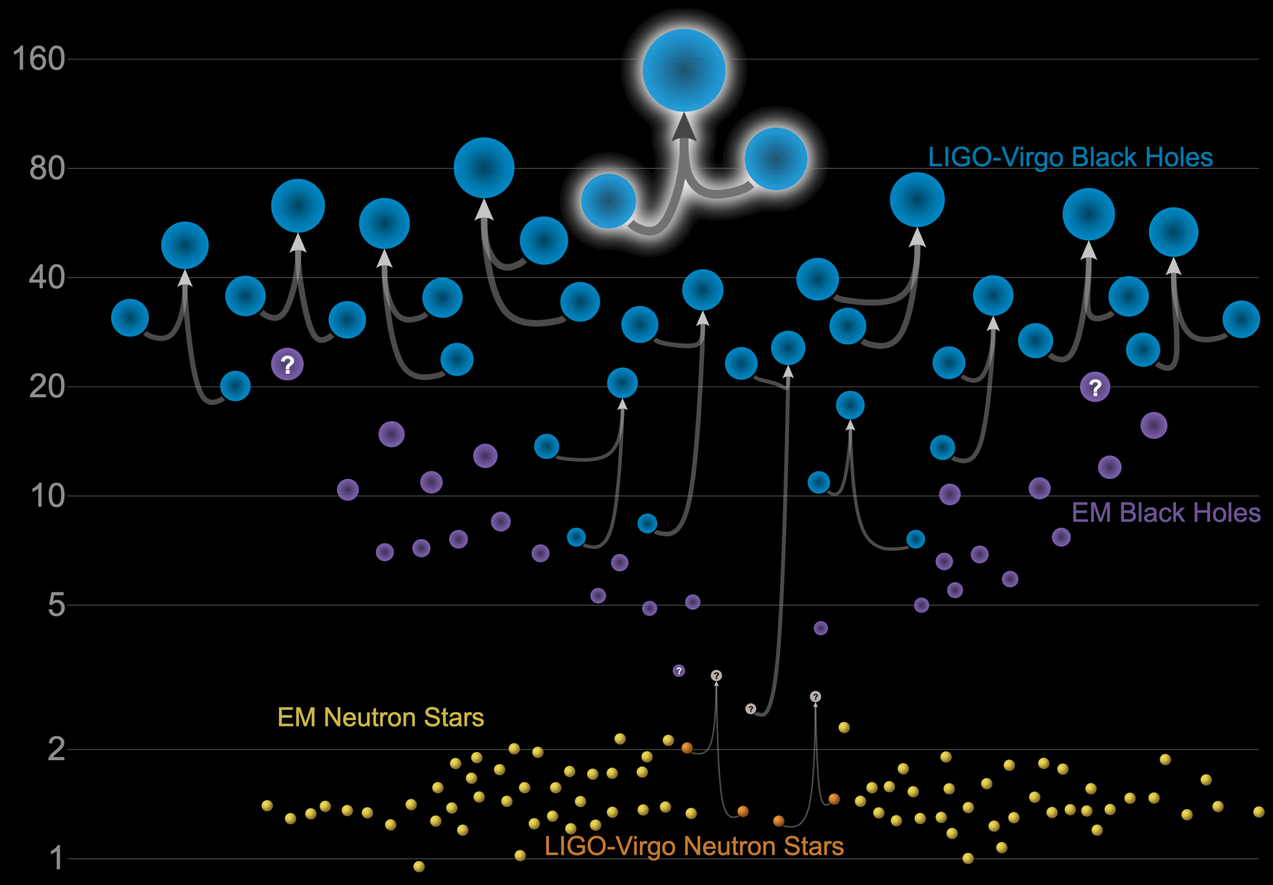


Credit: D. Weir, University of Helsinki.

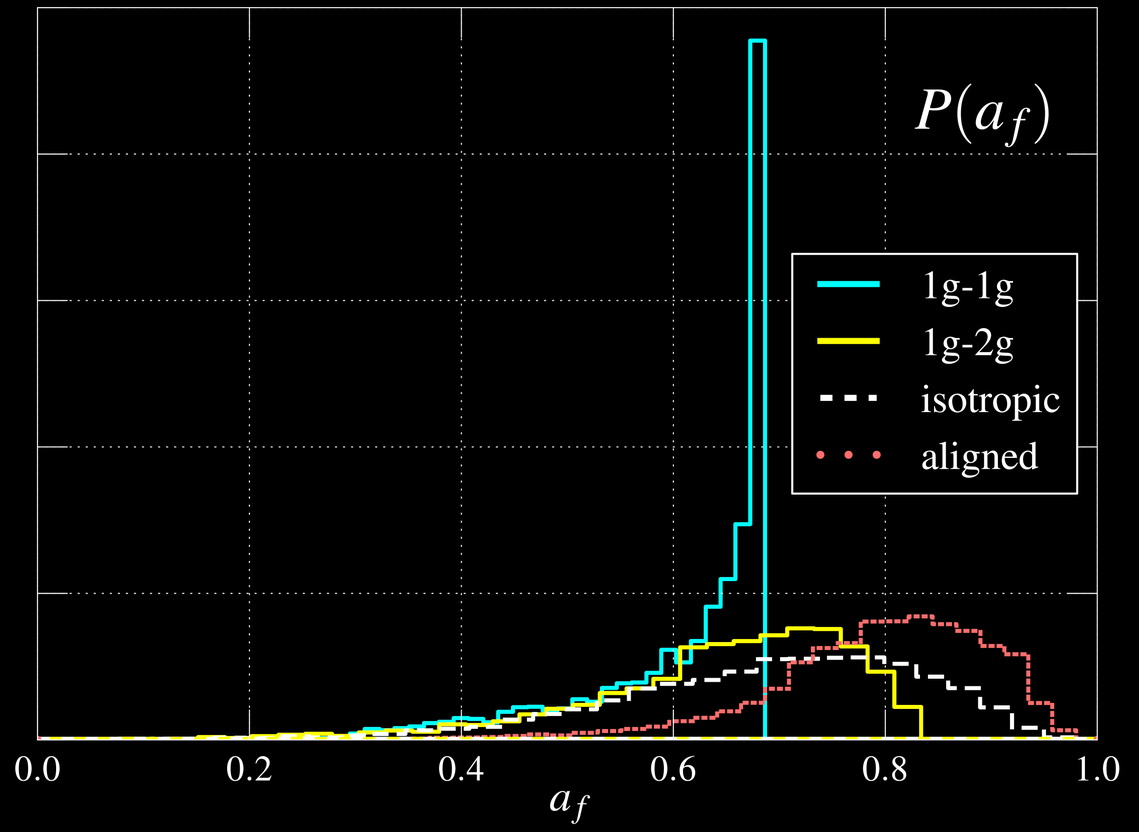
PRIMORDIAL BLACK HOLES

- masses of companion black holes in the first GW discovery was far greater than what **most** astrophysical models predicted
  - however, some models with low metallicity do accommodate the existence of such ‘heavy’ black holes
- recent discoveries are challenging stellar formation scenarios
  - light companion of GW190814, primary companion of GW190521
  - some of LIGO-Virgo black holes might well be primordial in origin
- how can we ascertain that black holes are not of stellar origin or merger products?
  - detection of sub-solar mass black holes
  - black holes spins that are essentially zero

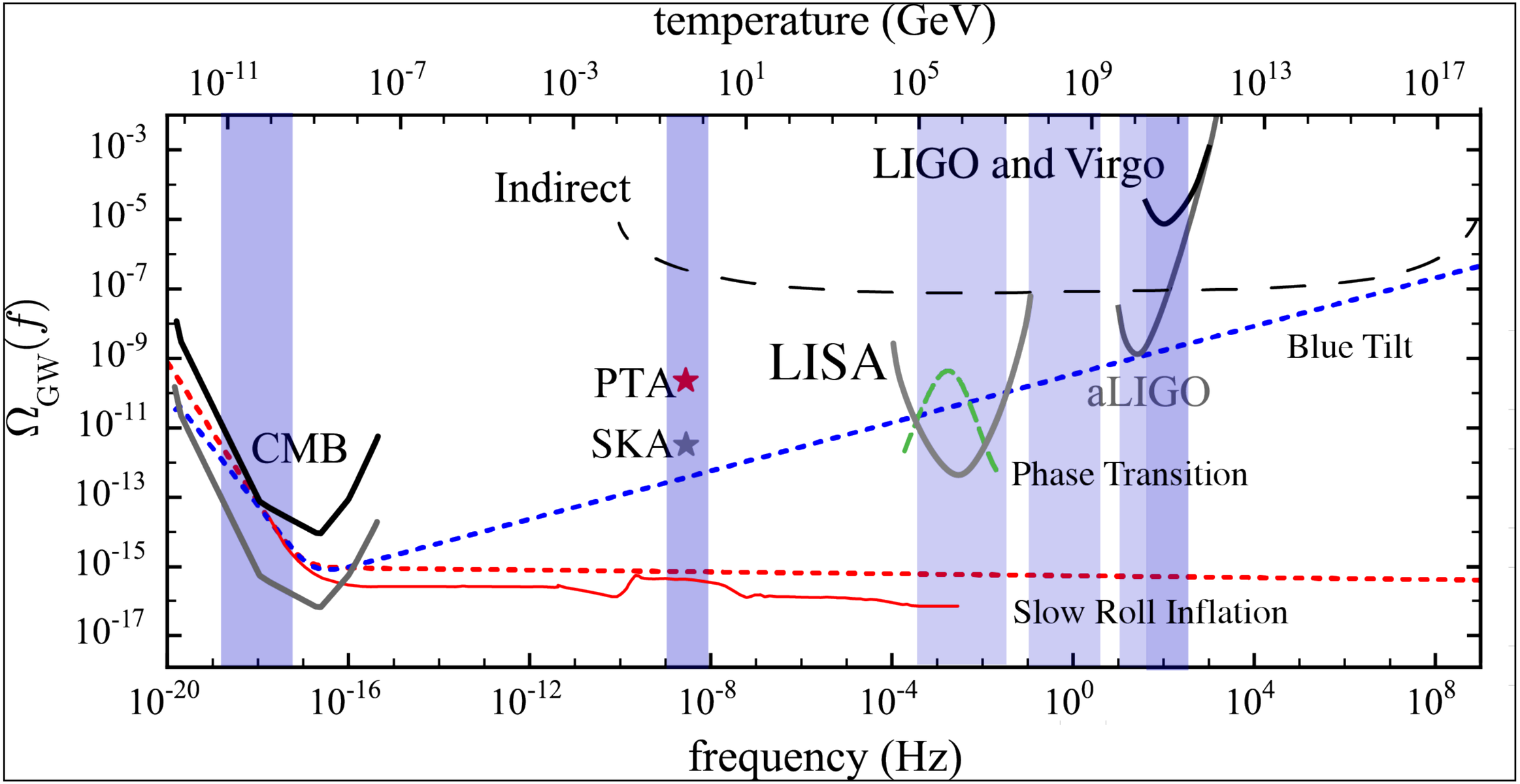
PRIMORDIAL BLACK HOLES



Updated 2020-09-02
LIGO-Virgo | Frank Elavsky, Aaron Geller | Northwestern



STOCHASTIC GRAVITATIONAL-WAVE BACKGROUNDS



FUNDAMENTAL PHYSICS

CF7,CF3 TF1,TF9,TF10,TF1

- Black hole horizons, quantum gravity, information paradox
  - black hole spectroscopy, multipolar structure, quantum modifications at horizon scales?
- Corrections to general relativity
  - additional fields, modifications of inspiral radiation
  - black hole uniqueness theorems violated: exotic compact objects?
- Probing dark matter
  - primordial black holes?, mini-charged dark matter, ultralight boson clouds, bosenovas, EM signatures?
- Gravitational-wave propagation and graviton mass
  - GW170817: constraints on Lorentz violation in the gravitational sector, Dispersion: graviton mass, extra dimensions, parity violation