NS Mergers White Paper Summary

E Burns. on behalf of

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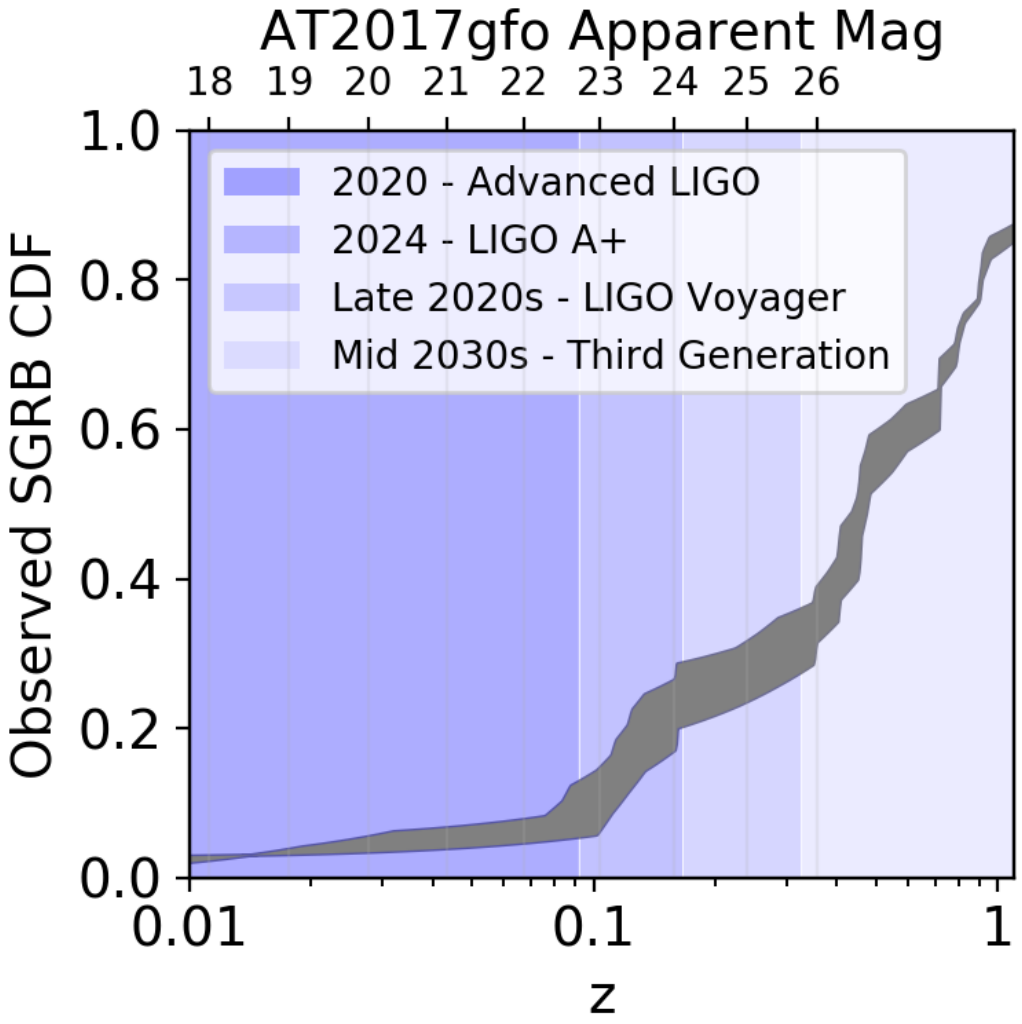
The Future of GW-EM Observations

Interferometer Generation	Start Year (approx.)	Range (Mpc)	BNS Rates (1/year)
Advanced LIGO	2020	175	2-50
LIGO A+	2024	325	10-300
LIGO Voyager	**~2030**	**~1,050**	**>1,000**
3rd Generation	**~late 2030s**	**~4,200**	**~100,000**



Astrophysics

Short Gamma-ray Bursts

- What is the prompt emission mechanism of SGRBs?
- What are the progenitors of GRBs?

Kilonovae

- What is the diversity of kilonova?
- The distribution of heavy element production

Both

- How do their intrinsic properties affect EM observables?
- How do BNS and NSBH mergers differ?
- When do NSBH mergers cause SGRBs or kilonovae?

Fundamental Physics

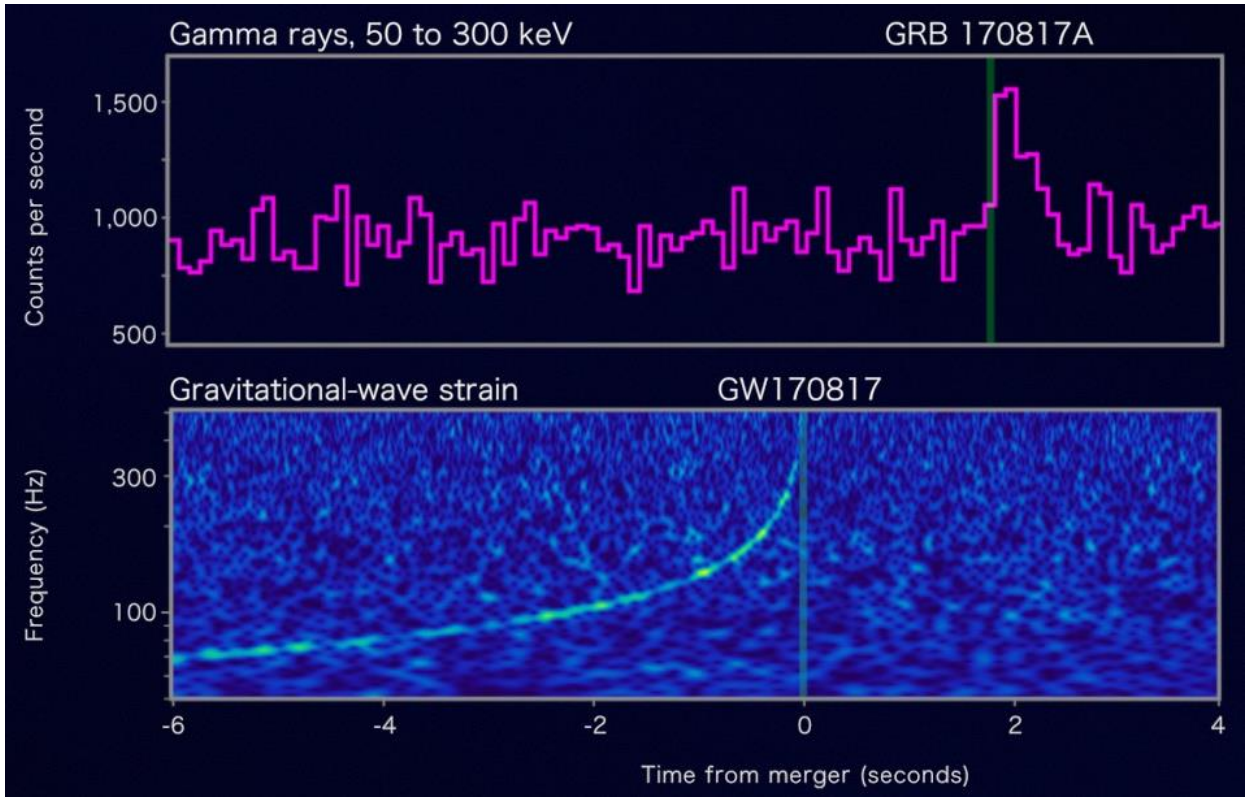
Measure:

- Speed of gravity
- Relative violations of
  - The Weak Equivalence Principle
  - Lorentz Invariance Violation
- (Absolute Lorentz Invariance Violation)

Largest Discovery Space / Tightest Constraints on:

- **The Special Theory of Relativity**
- **(Non)-Metric Theories of Gravity**
- **The General Theory of Relativity**
- **Quantum Gravity**

The seconds variability over cosmological baselines enables unique tests of fundamental physics

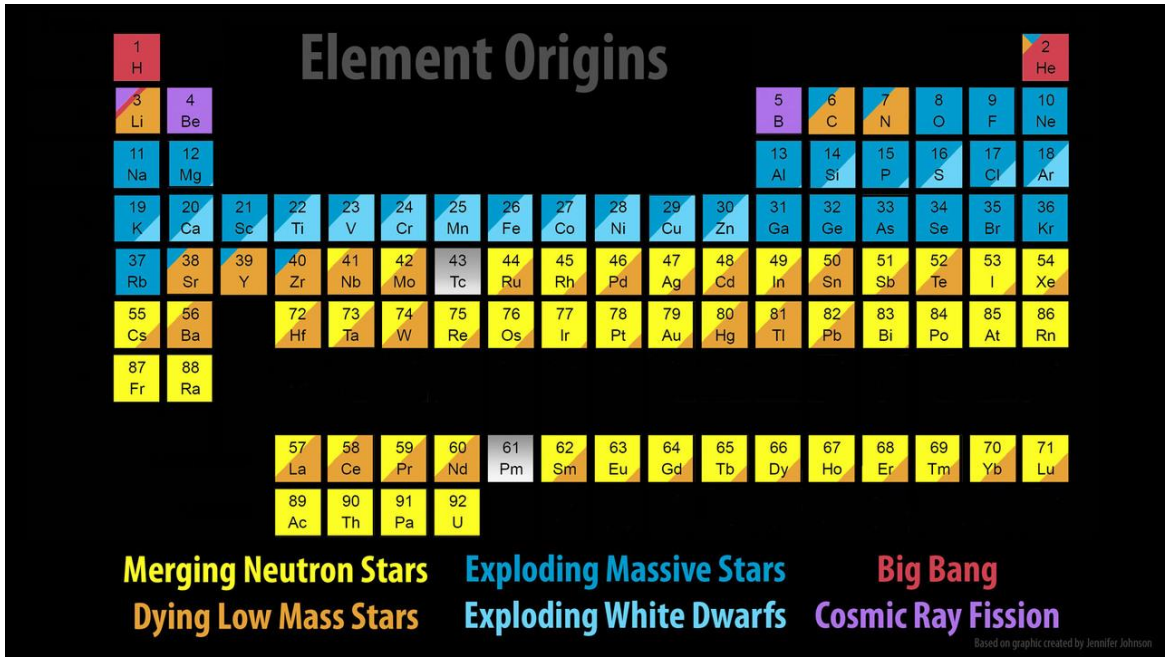


Astrophysical Jets

- What is the structure of ultrarelativistic jets?
  - The effect of their environments?
- How do jets form?
  - Blandford-Znajek, neutrino-antineutrino annihilation?
- Do relativistic jets require an event horizon to form?
  - Can they form around magnetars? Other central engines?
- How is energy carried in relativistic jets?
  - Through baryons or Poynting flux? Both? What's the fraction?
  - Also informed through joint neutrino detections

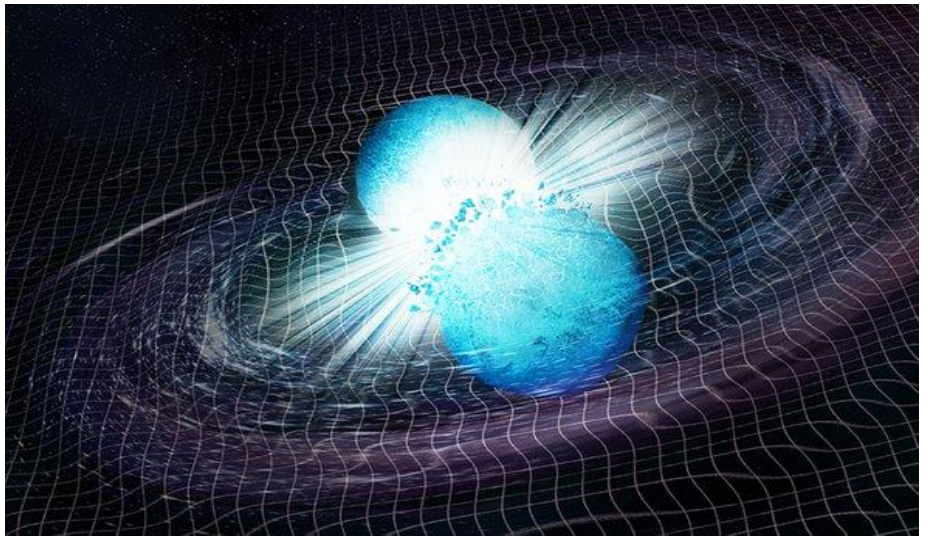
Heavy Element Enrichment through Cosmic Time

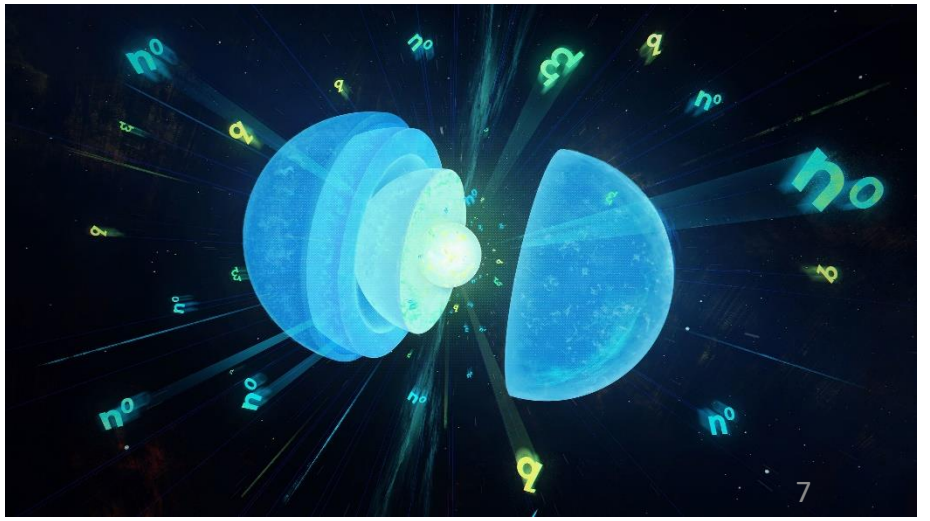
- R-process nucleosynthesis occurs in NS mergers and core-collapse Sne.
- Both should track the stellar formation rate, modulo inspiral time for NS mergers
- Uncovering the redshift distribution of NS mergers determines their source evolution, and the lanthanide/actinide enrichment history of the universe



The EOS of Supranuclear Matter

- Neutron stars achieve densities and temperatures entirely unobtainable on Earth.
- Understanding the NS EOS can constrain the phase diagram of quantum chromodynamics and enable more accurate QCD predictions
- MMA studies of NS Mergers measures:
  - The radii and mass of NS
  - Constrain metastable NS masses and lifetimes



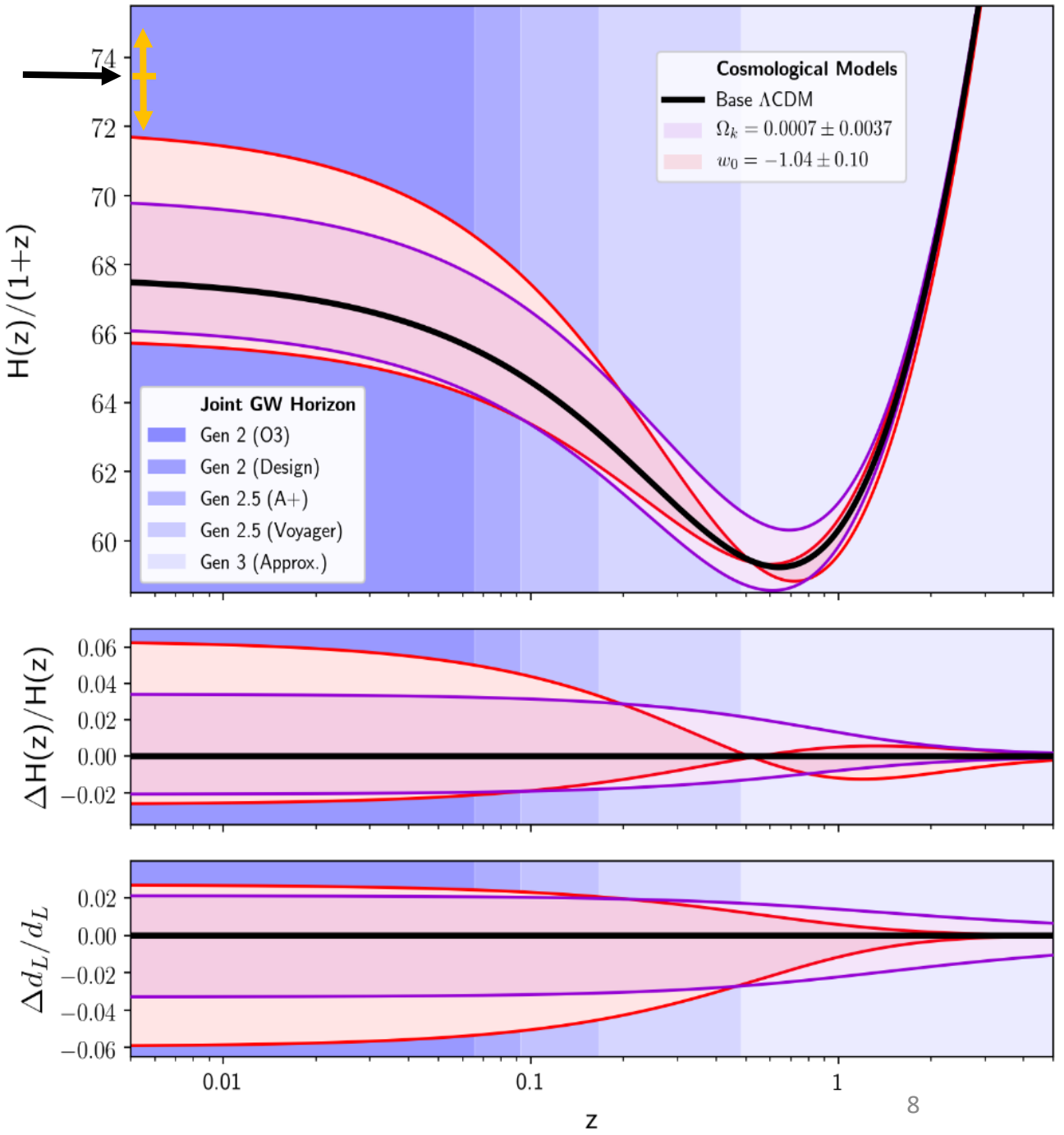


Cosmology

Riess et al. 2018
Type Ia measure

Standard sirens have luminosities predicted by GR. They will:

- Resolve the H_0 controversy
- Calibrate the cosmological ladder
- When combined with CMB+BAO:
  - Resolve the neutrino mass hierarchy (determine the neutrino mass eigenstates?)
  - Constrain/measure the number of effective neutrino species
  - Constrain the equation of state of dark energy
- With CMB+BAO and WFIRST/LSST/EUCLID:
  - Enable sub-percent precision cosmology throughout the universe
  - Measure multi-parameter extensions to ΛCDM



NS Merger Science

- The physics of SGRBs
- Astrophysical Jets
- Fundamental Physics
- Origin of the Elements
- Cosmology
- Identification and classification of GW sources

NS Merger Recommendations

General: Upgraded GW interferometers

Next 5-10 years

- Extension of the Fermi and Swift missions
- Develop suitable replacements with small-scale missions
- IceCube Gen-2 upgrade
- Allocation of observing time and ToO programs on all necessary telescopes
- Greater NSF-NASA collaboration

10+ years

- Design large-scale missions for this era
- A large-scale gamma-ray observatory with ~keV-MeV sensitivity and a wide field of view
- Appropriately matched X-ray/UVOIR/radio telescopes

E. Burns et al. “A Summary of Multimessenger Science with Neutron Star Mergers” https://arxiv.org/abs/1903.03582
R. Foley et al. “Gravity and Light: Combining Gravitational Wave and Electromagnetic Observations in the 2020s” https://arxiv.org/abs/1903.04553
B.S. Sathyaprakash “Multimessenger Universe with Gravitational Waves from Binary Systems” Astro2020 WP (no arXiv link)