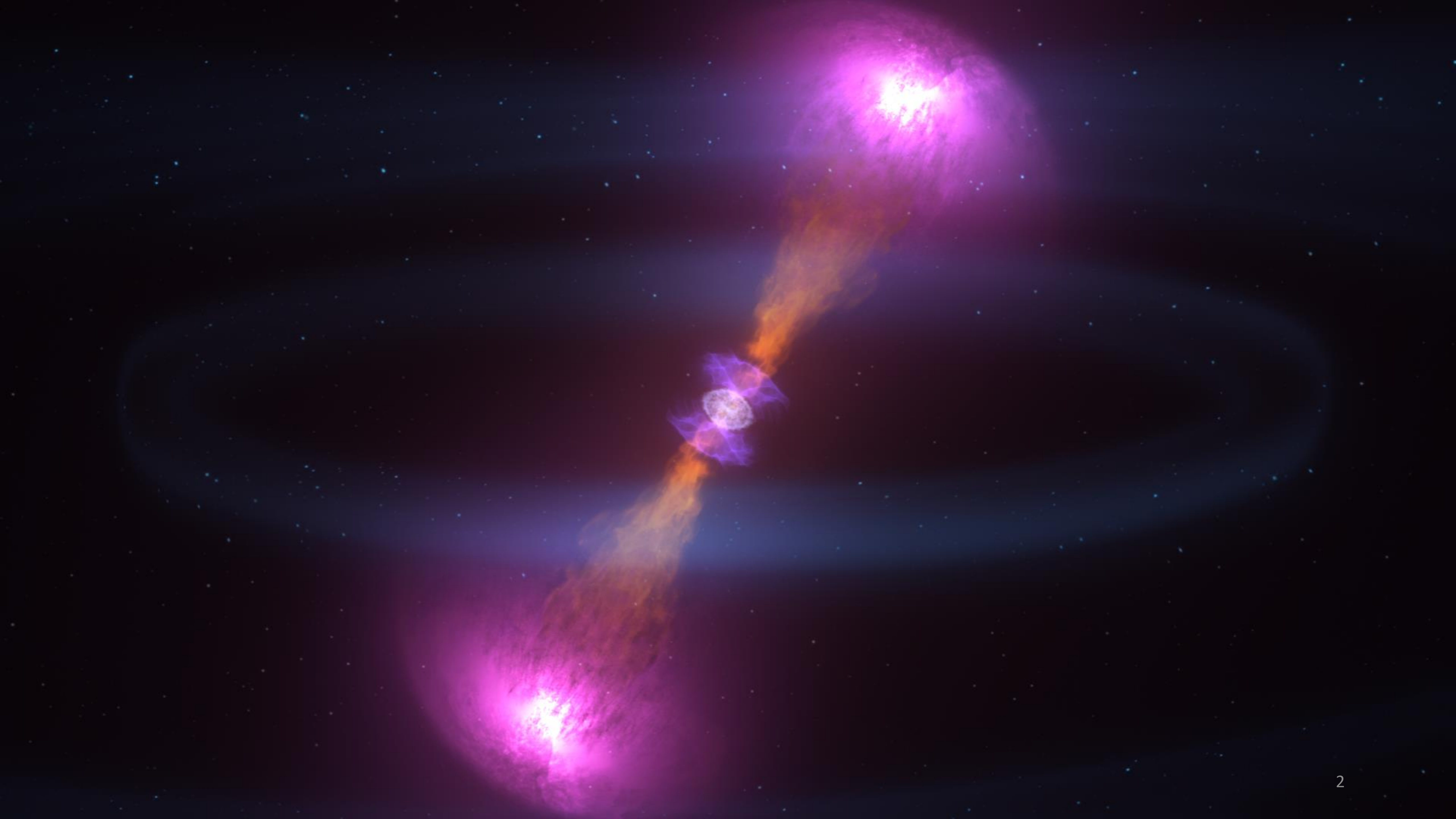
Gravitational Waves and AMEGO

E. Burns instead of D. Kocevski

On behalf of the AMEGO Team



GW170817, GRB 170817A, AT2017gfo

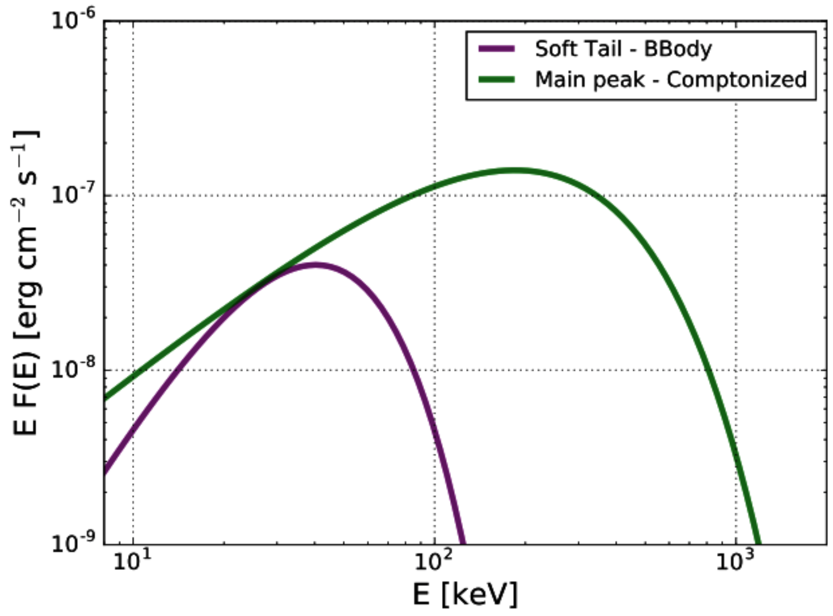
- Confirmed binary neutron star (BNS) mergers cause short gamma-ray bursts (SGRBs) and kilonova

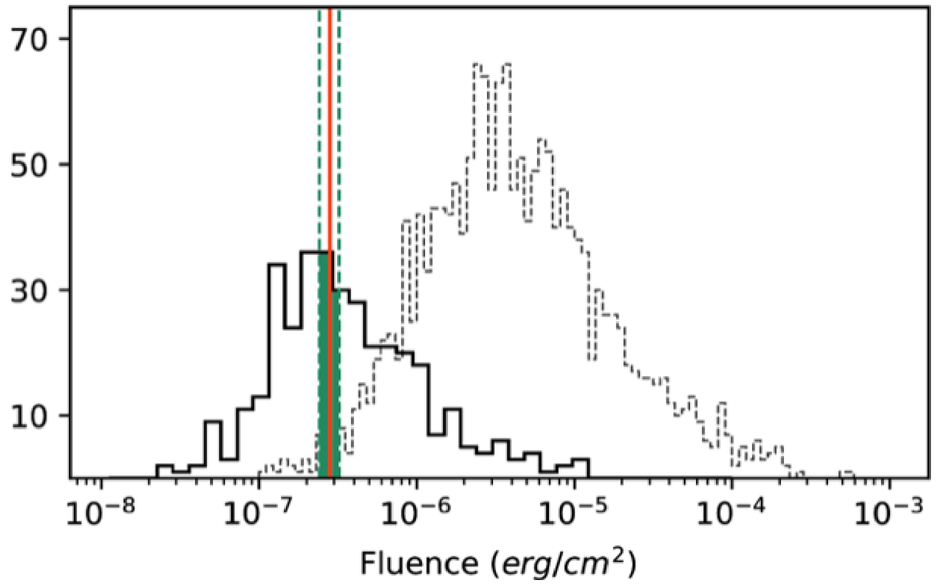
- The SGRB was unusual. The kilonova had unexpected UV emission

- Had implications for several fields of physics

GRB 170817A

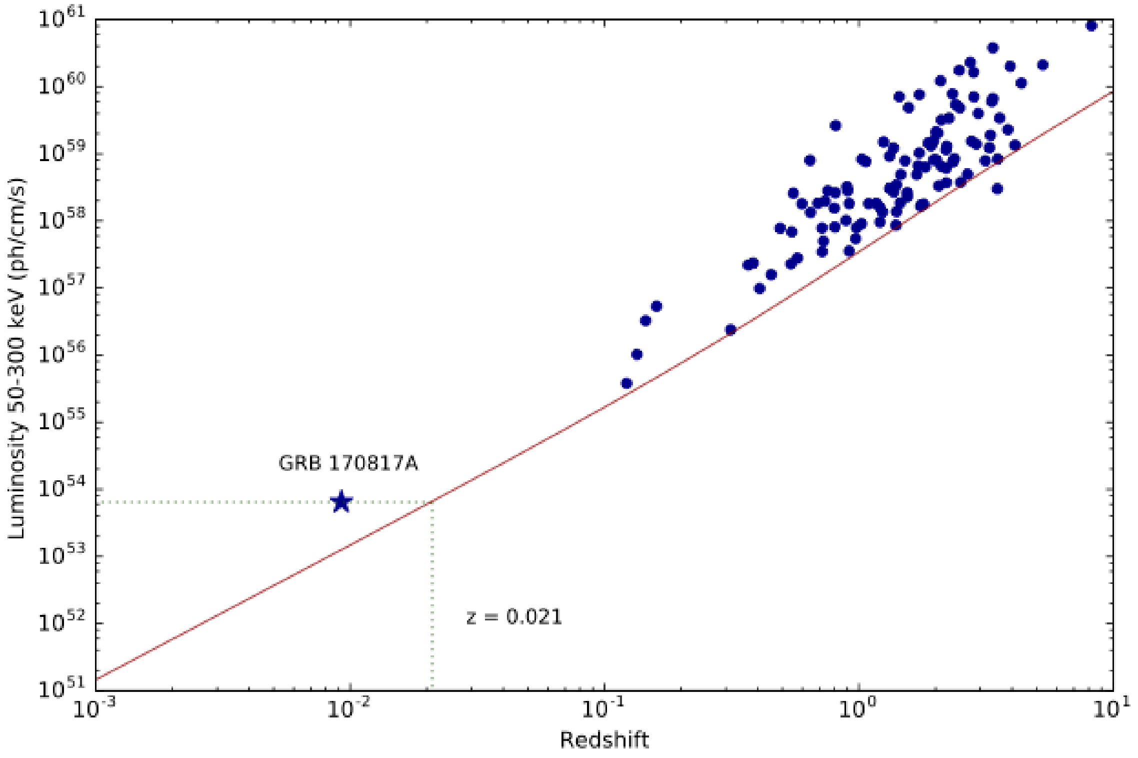
- GRB 170817A appeared as a normal GRB to Fermi GBM. The only exception is a distinct soft tail.
- It is only with the distance information from GW observations that we realized it was severely subluminous





GW-GRB Detectability

- GRB 170817A was near the on-board detection threshold of Fermi-GBM
- We can already detect NS mergers in GWs beyond where GRB 170817A is detectable

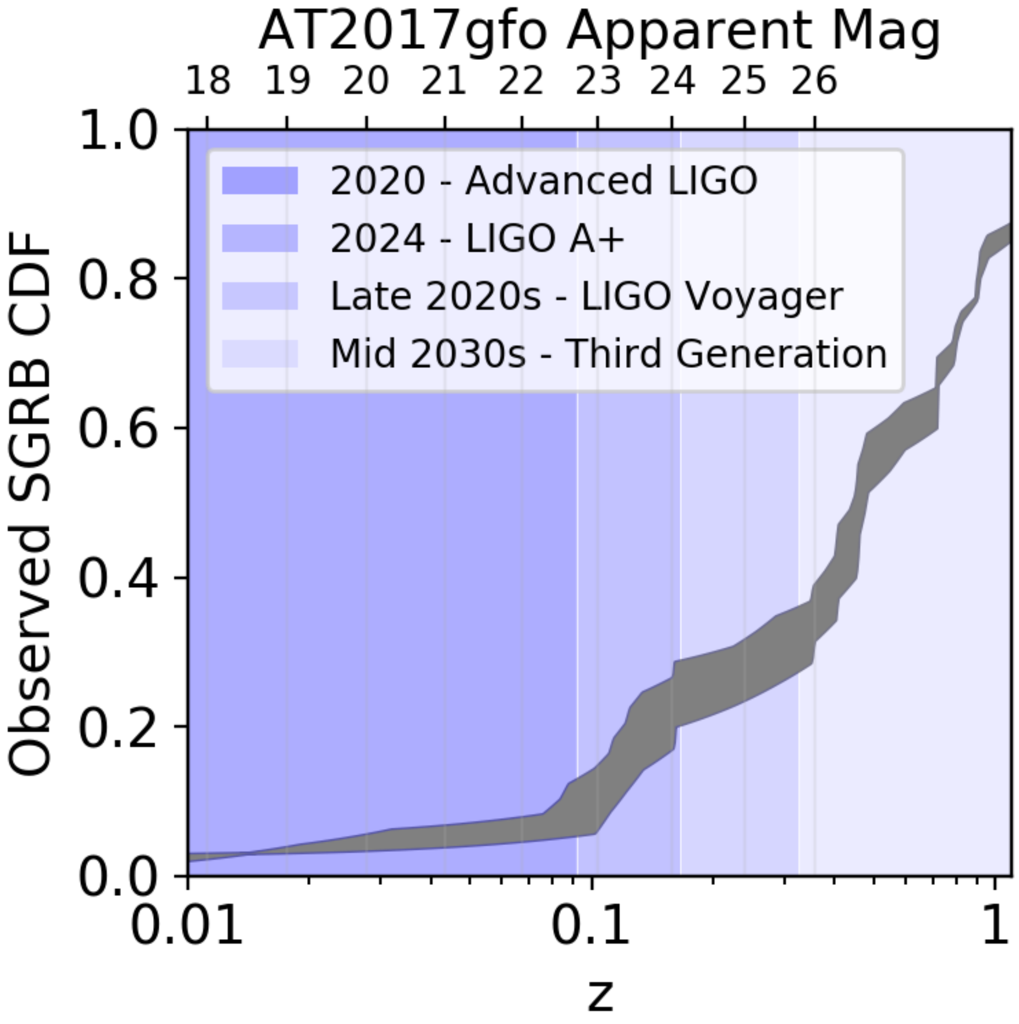


- **GW SNR scales as r^{-1}, (most) EM SNR scales as r^{-2}. We will quickly enter an era where we fail to detect most SGRBs from GW-detected NS mergers**

The Future of GW-GRB 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	>10,000

- **We increase our GW-GRB detection rate by detecting more SGRBs.**
- **AMEGO would trigger on-board to ~80 SGRBs/year, possibly more (with reduced localization capability)**



Direct AMEGO Science with NS Mergers

- **An understanding of SGRBs**
- **Relativistic Jets and Particle Acceleration**
- Fundamental Physics

Short Gamma-ray Bursts

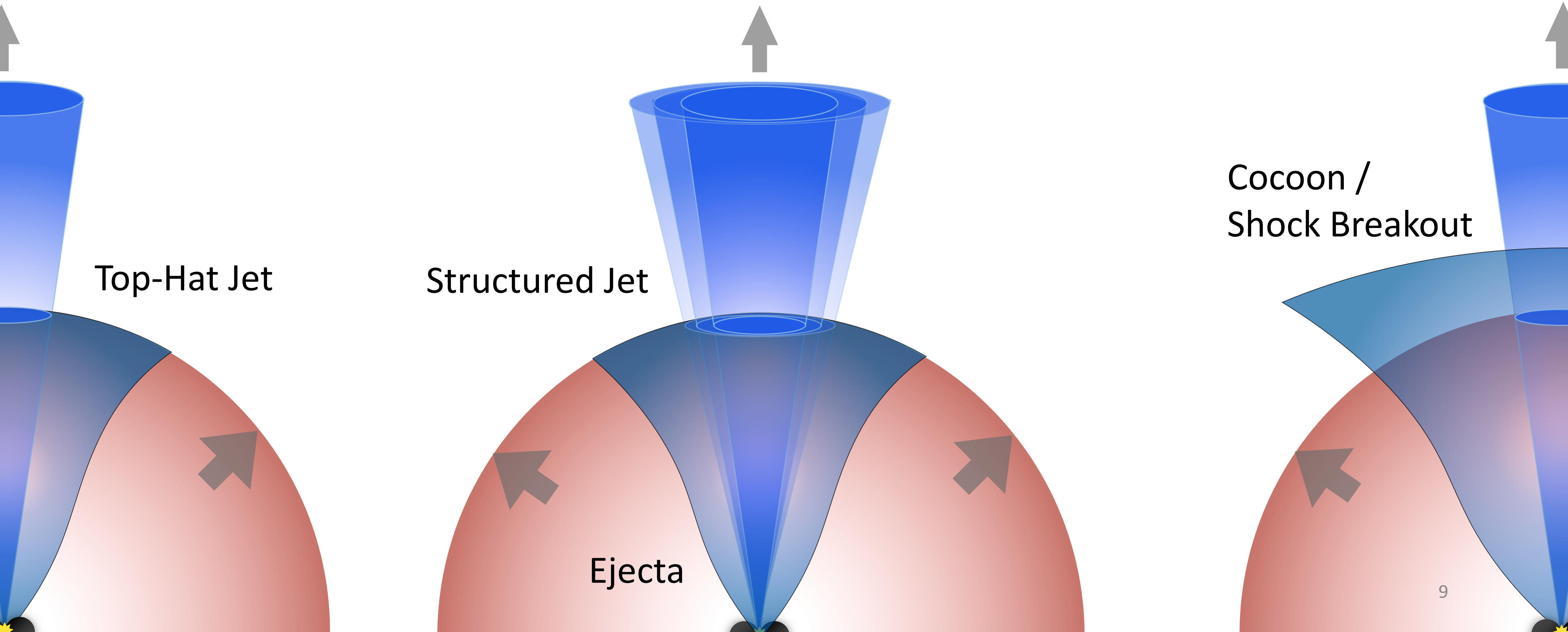
- What is the prompt emission mechanism of SGRBs?
  - GRBs are the most luminous events in the universe, but we do not fully understand how they work

- What are the progenitors of GRBs?
  - Do SGRBs also arise from neutron star-black hole (NSBH) mergers?
  - What is the fraction of SGRBs from BNS vs NSBH mergers?
  - Which GRBs arise from mergers? Which from collapsars?

- How do SGRBs vary with relation to intrinsic parameters?
  - How do the mass and spin of the progenitors affect the SGRB?
  - How do BNS and NSBH mergers differ?

Astrophysical Jets - Structure

The structure of relativistic jets is largely unknown. GW-SGRB observations will determine their intrinsic structure and the effect of their interaction with surrounding material



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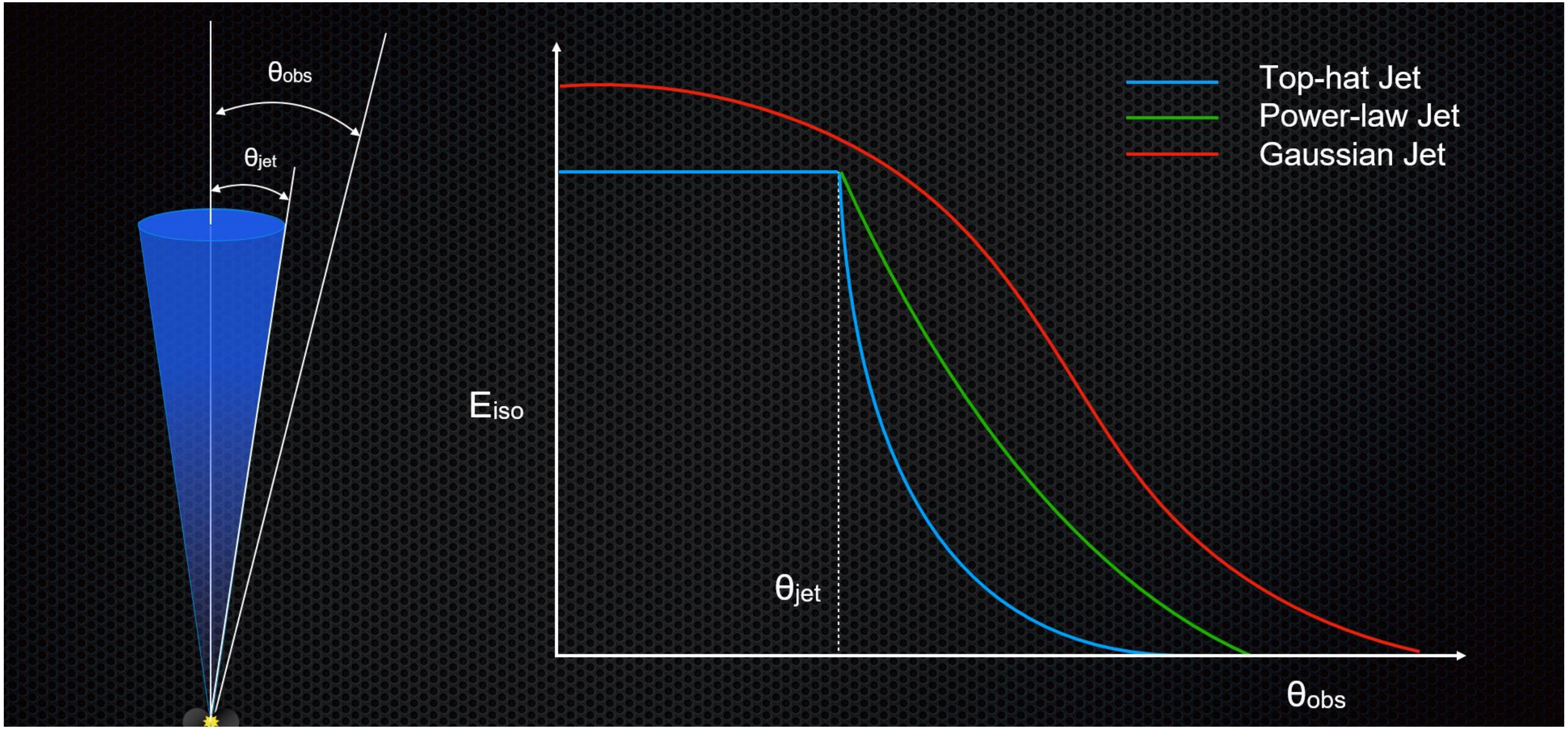


Astrophysical Jets

- How do jets form?
  - Blandford-Znajek, neutrino-antineutrino annihilation?

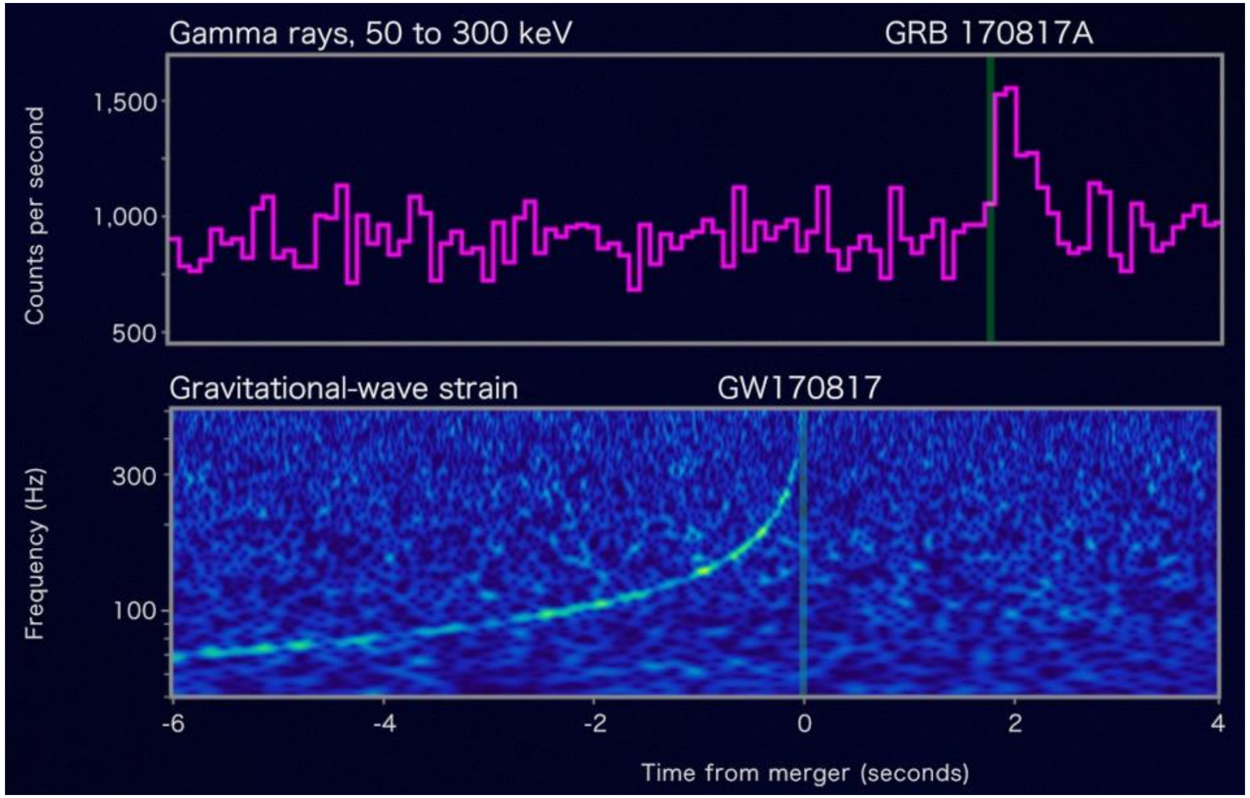
- Do relativistic jets require an event horizon to form?
  - Can they form around magnetars? Other central engines?

- How is energy carried in relativistic jets?
  - Through baryons or Poynting flux? Both? What’s the fraction?
  - Also informed through joint neutrino detections

Fundamental Physics

The seconds variability over cosmological baselines enables unique tests of 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**

Science from NS Mergers Enabled by AMEGO

GW-AMEGO Searches:

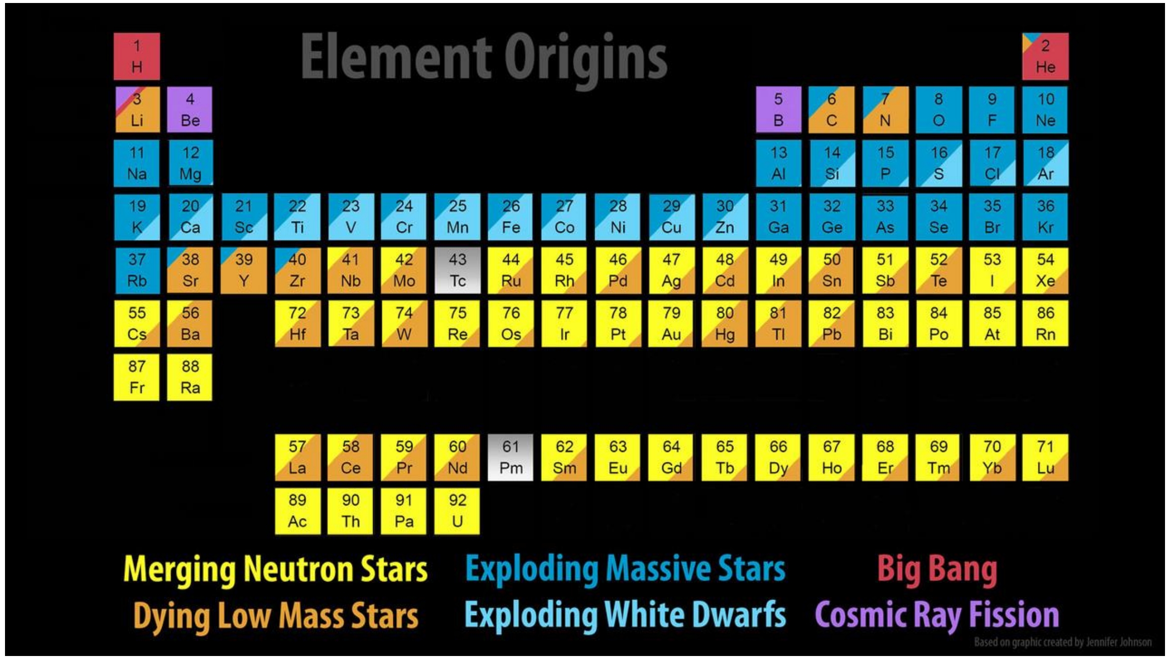
- Increase the number of detected GWs
- Increase the effective GW-detection distance
- ~<deg localizations just after merger time, which enables
  - Early follow-up detections
  - Sensitive follow-up
  - Association of EM counterparts

Which enables studies on:

- Stellar formation and evolution
- The equation of state (EOS) of supranuclear matter
- Heavy element enrichment
- Cosmology

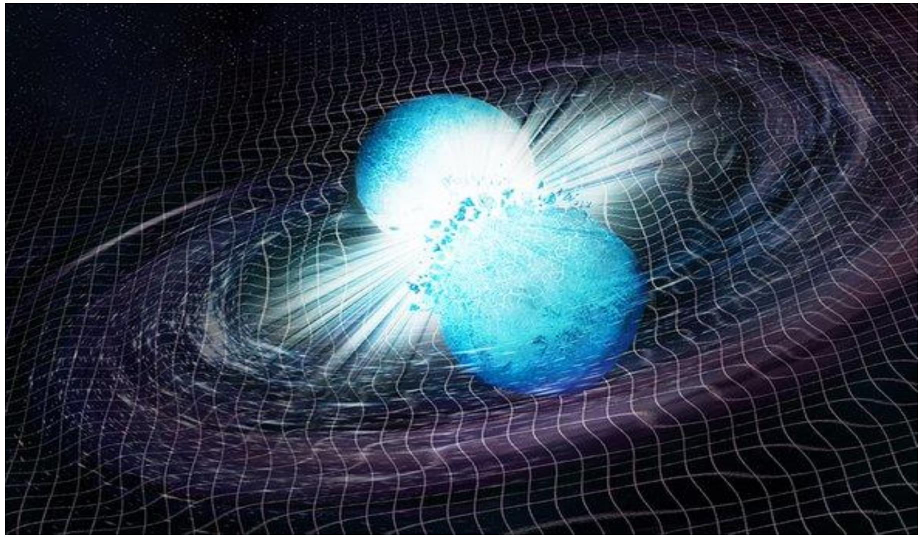
Heavy Element Enrichment through Cosmic Time

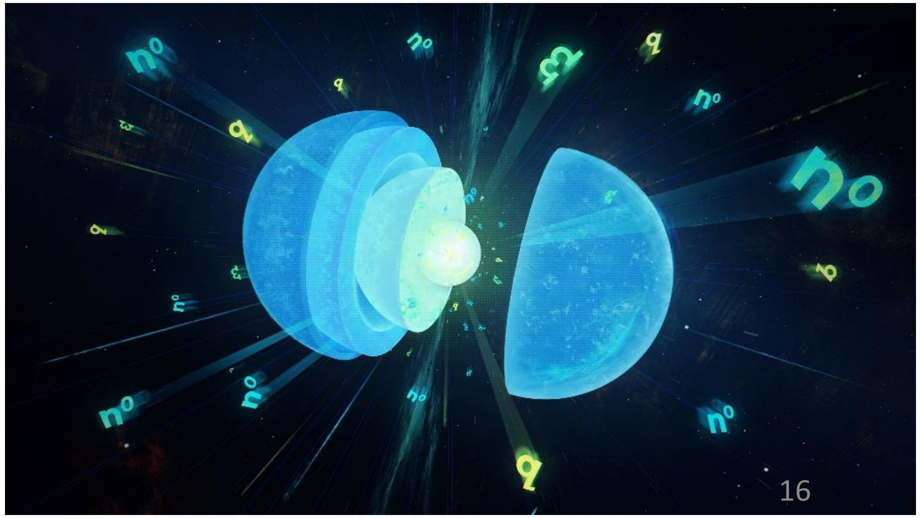
- R-process nucleosynthesis occurs in NS mergers and core-collapse Sne.
- Both should track the stellar formation rate, modulo inspiral time for NS mergers
- Uncovering the redshift distribution of NS mergers determines their source evolution, and the lanthanide/actinide enrichment history of the universe



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

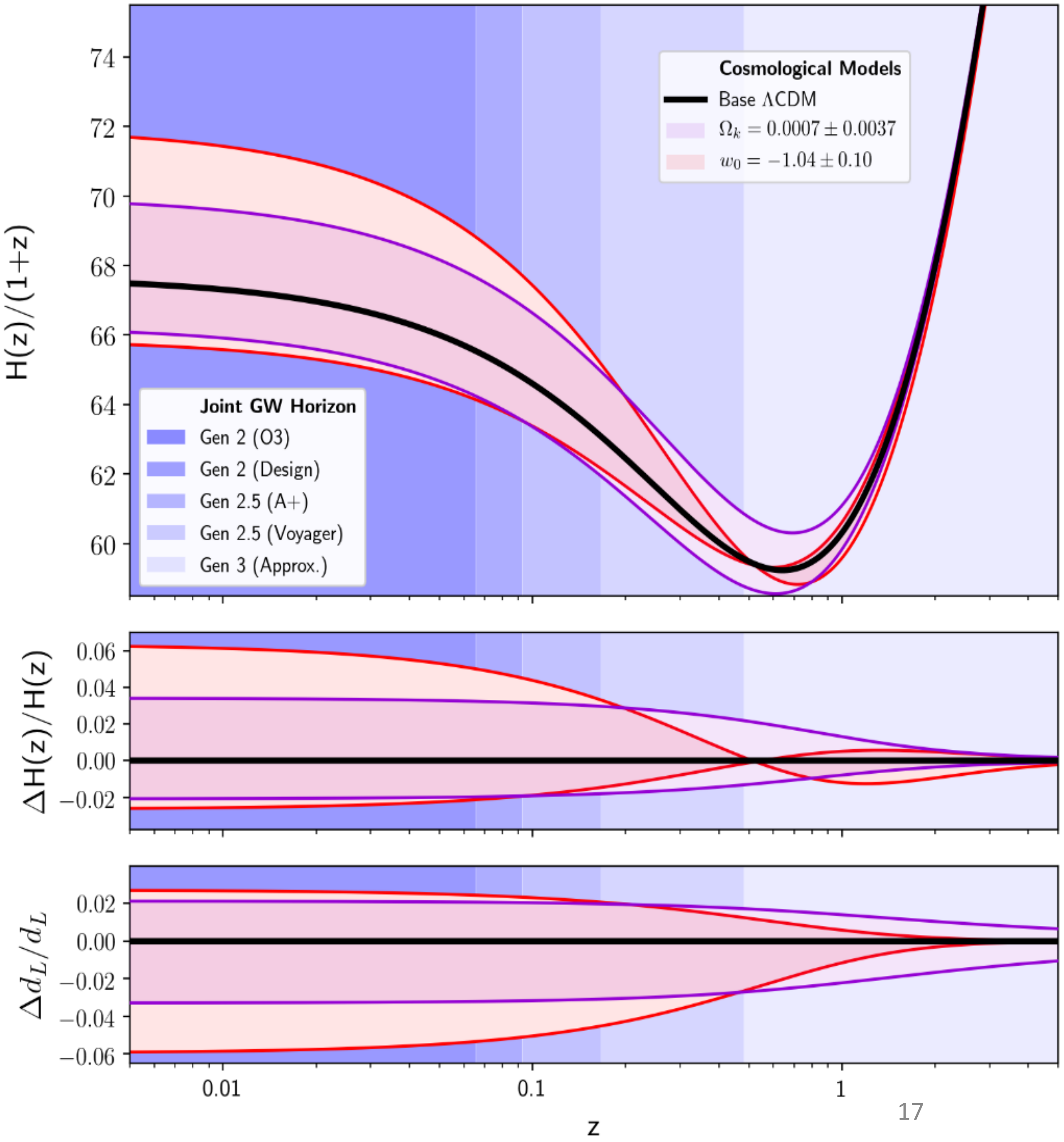




Cosmology

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



Identifying GW Sources

- GW Bursts:
  - Unmodeled GW transients – maybe long GRBs, giant magnetar flares, etc
  - Gamma-ray all-sky monitors can classify these events and possibly assign to known systems at event time
- Intermediate Duration GWs:
  - GW transients that last ~hours to ~months. New searches being developed
  - Transitional pulsars, accreting pulsars, magnetar ringdown, etc
- Continuous GWs:
  - Emission from continuously emitting sources (>years)
  - Pulsars, AGN, etc
- Pulsar Timing Arrays:
  - Fermi can be used in existing PTAs. AMEGO pulsar observations should be used similarly (though with perhaps higher photon statistics)

GWs and AMEGO

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