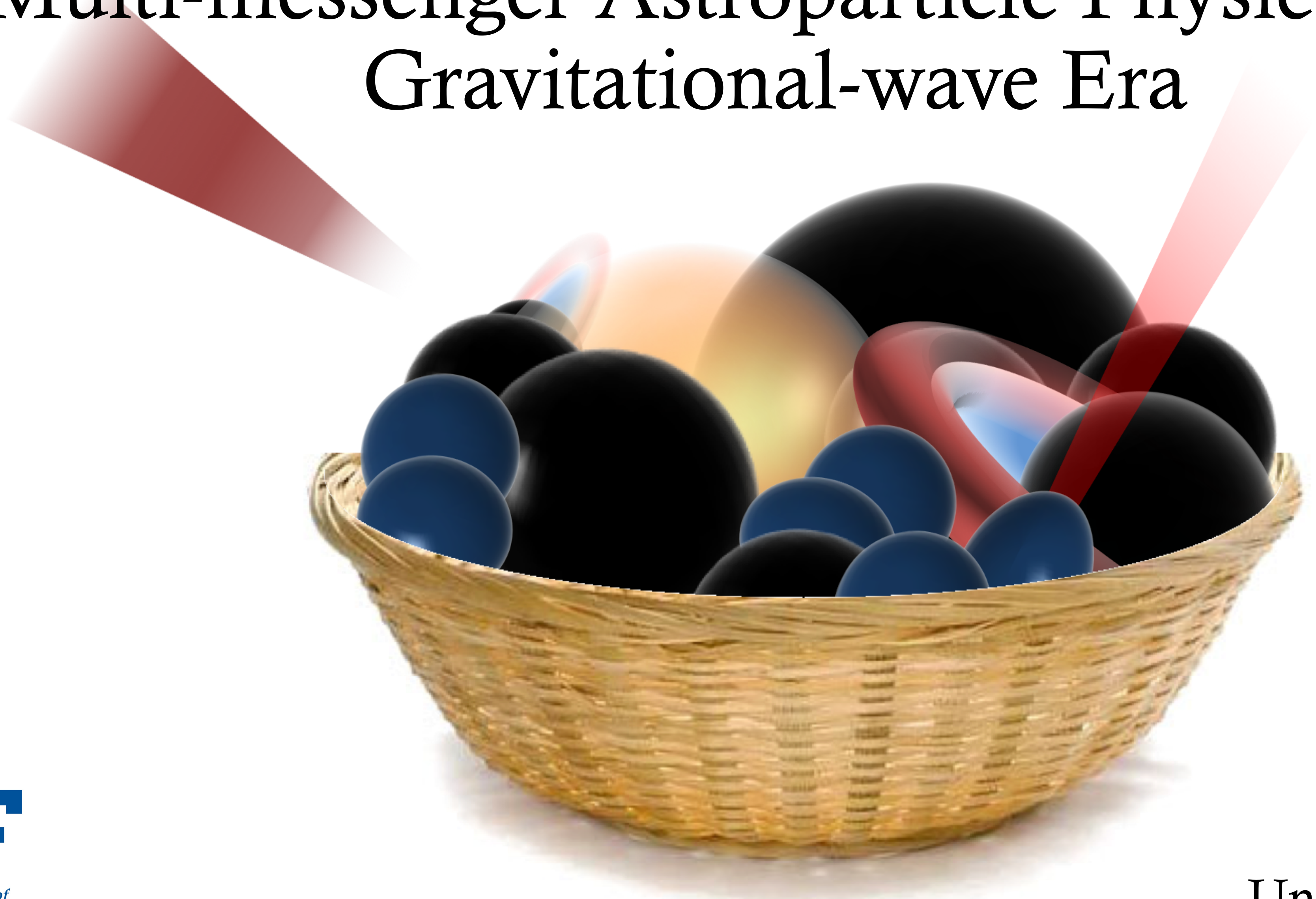
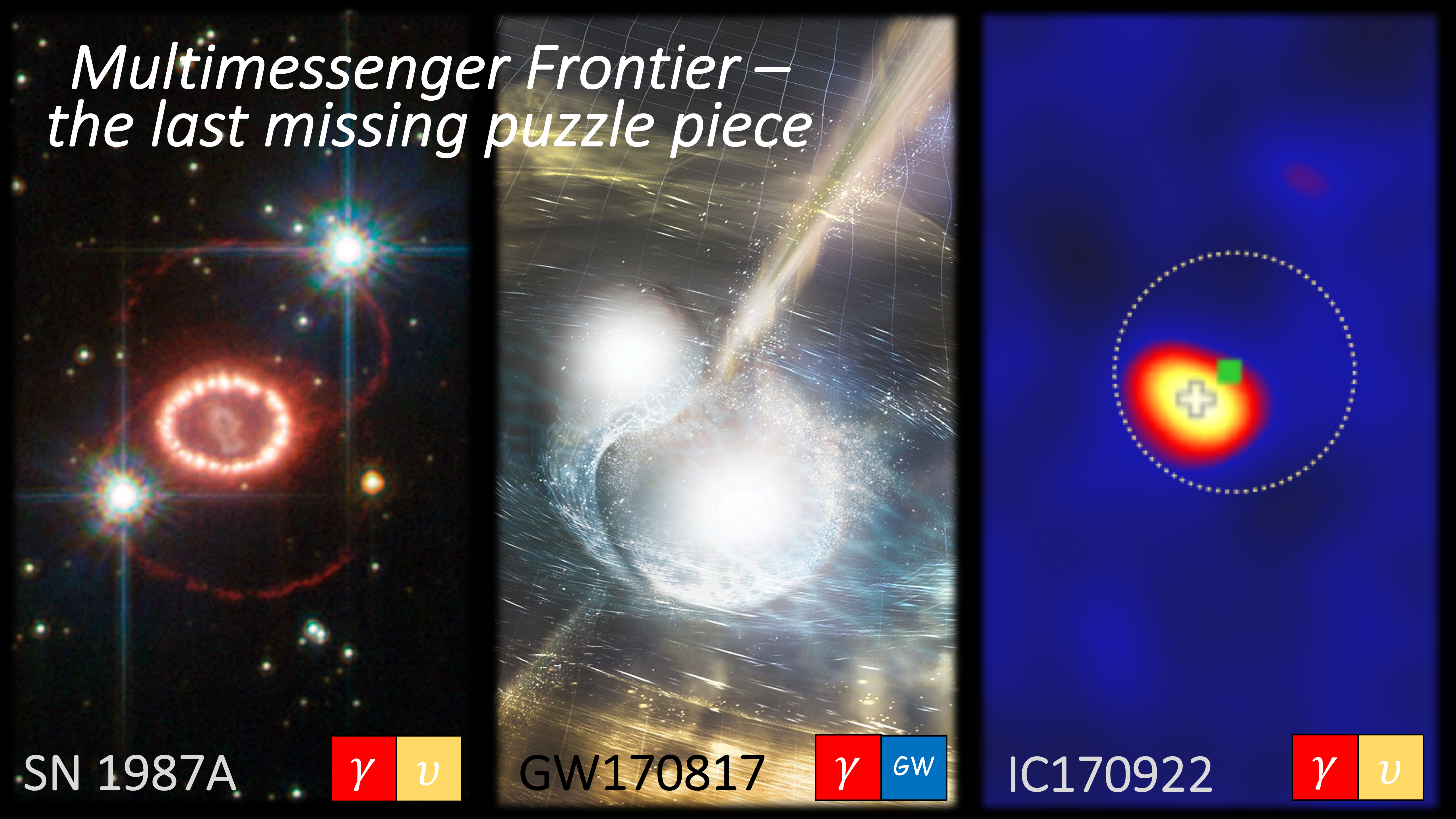
Multi-messenger Astroparticle Physics in the Gravitational-wave Era



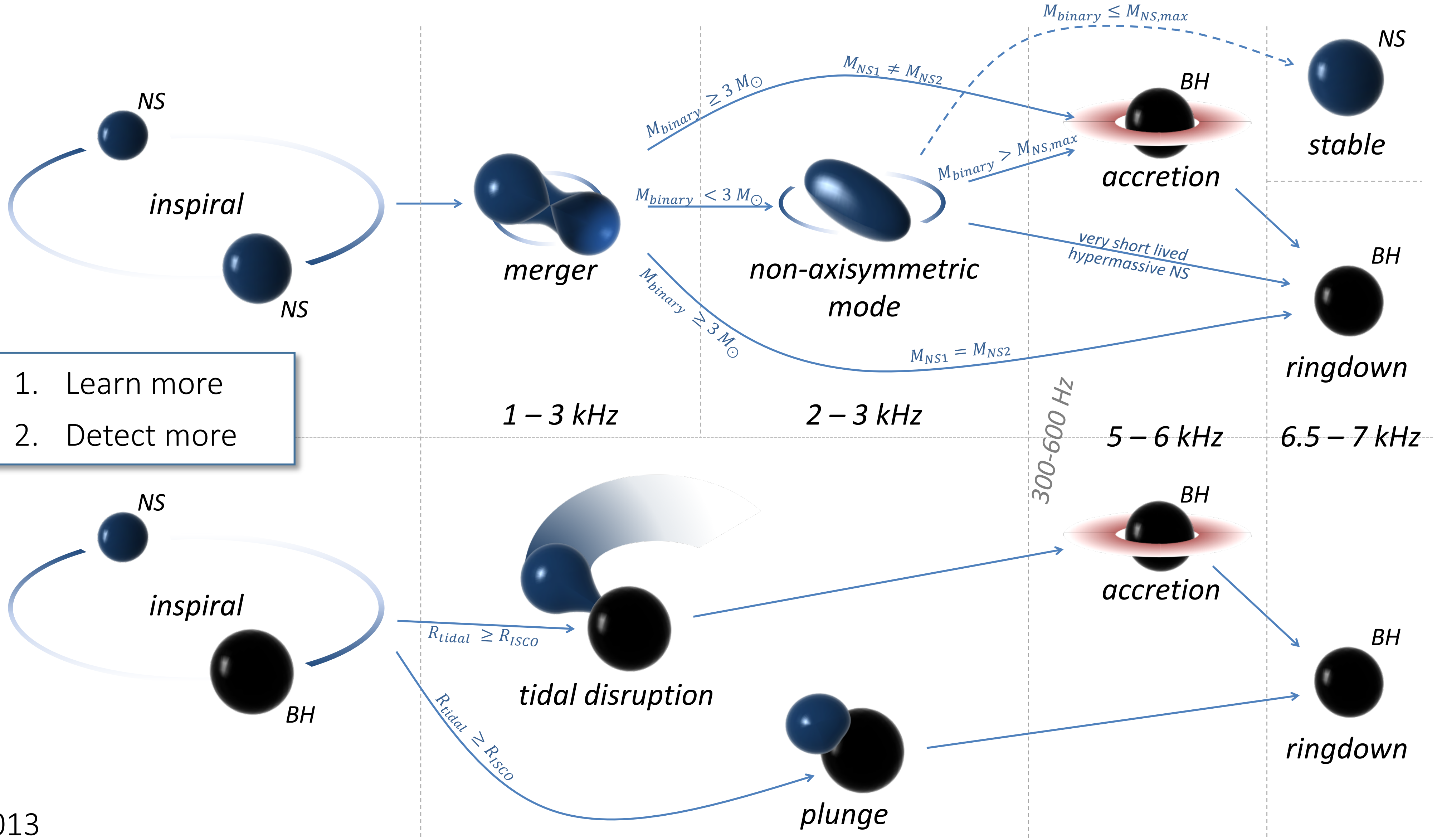
UNIVERSITY of FLORIDA

Imre Bartos
University of Florida

ASTERICS Symposium | 03.28.19


Multimessenger Frontier –
the last missing puzzle piece
SN 1987A
γ
υ
GW170817
γ
GW
IC170922
γ
υ

Compact binary mergers



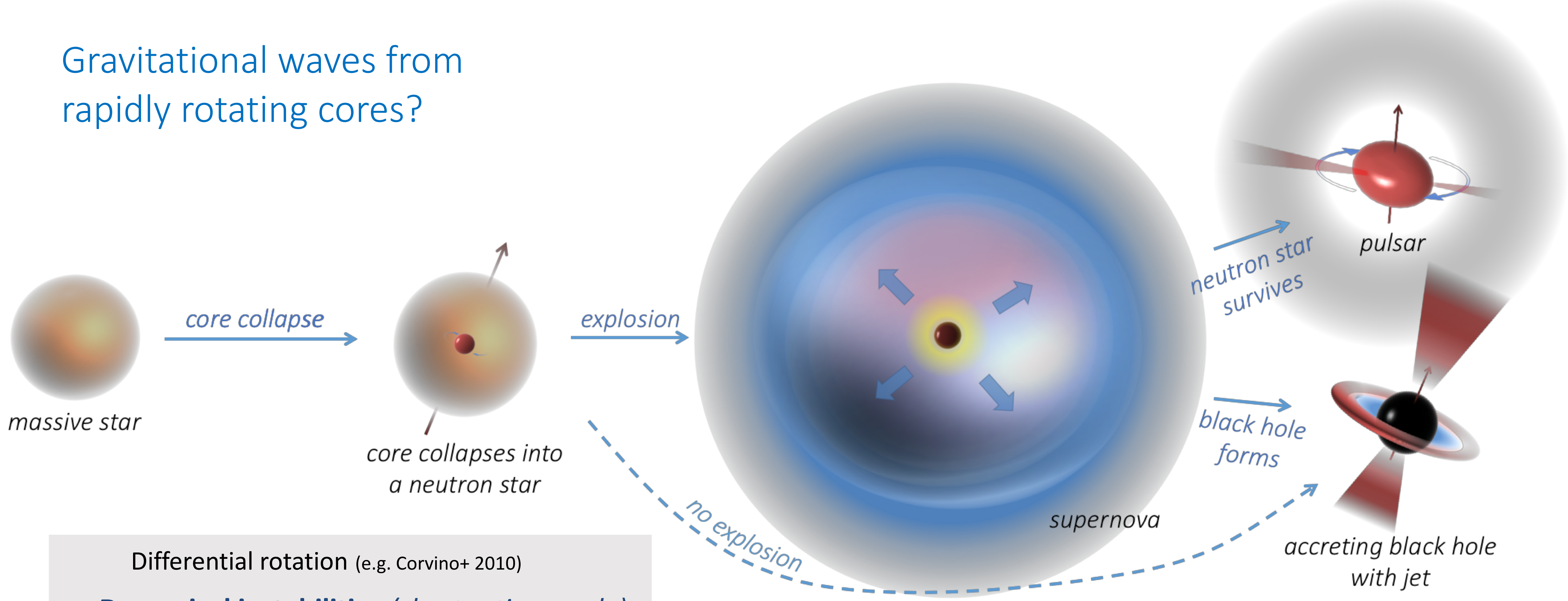
Goals:

1. Learn more
2. Detect more

Bartos+ 2013

Stellar core collapse

Gravitational waves from rapidly rotating cores?

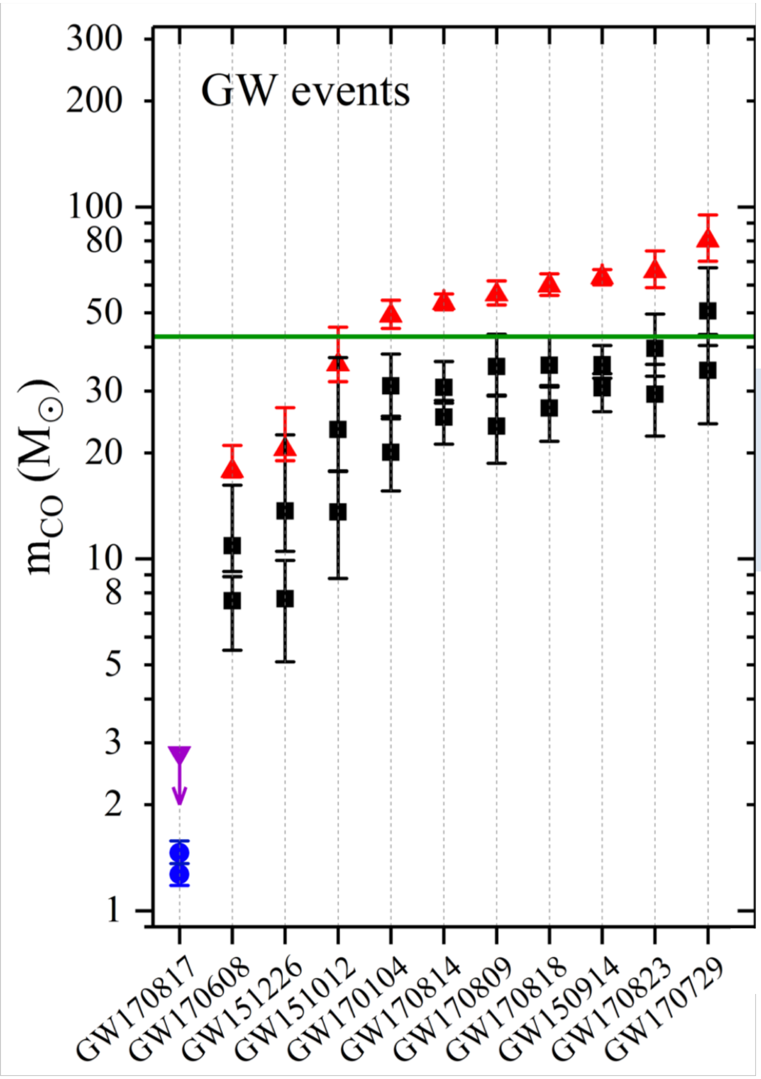


Differential rotation (e.g. Corvino+ 2010)

- **Dynamical instabilities** *(shorter time scale)*
- **Secular instabilities** *(longer time scale)*
- **Magnetic distortion**

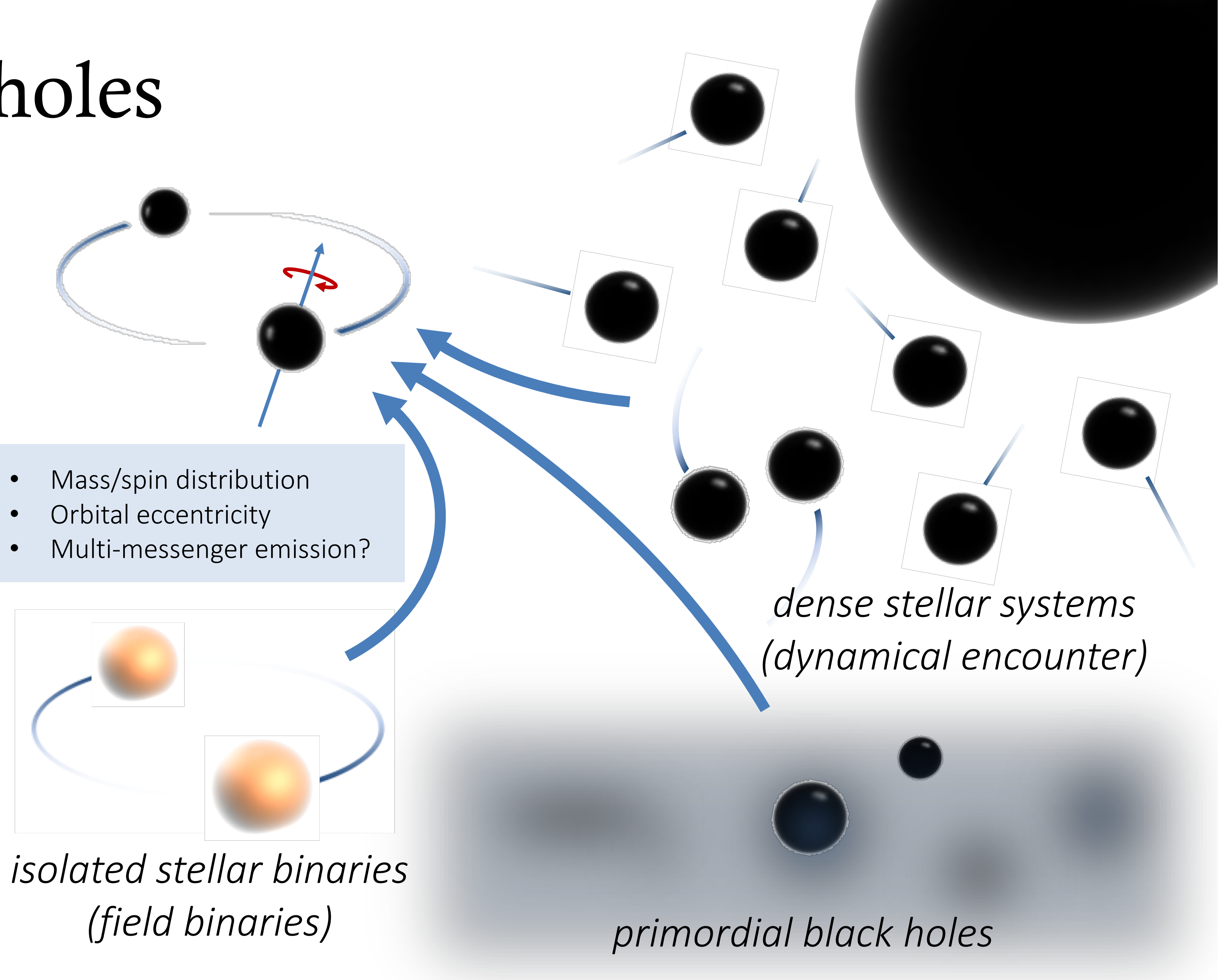
Fallback accretion? *(Piro & Thrane, 2012)*

Binary black holes

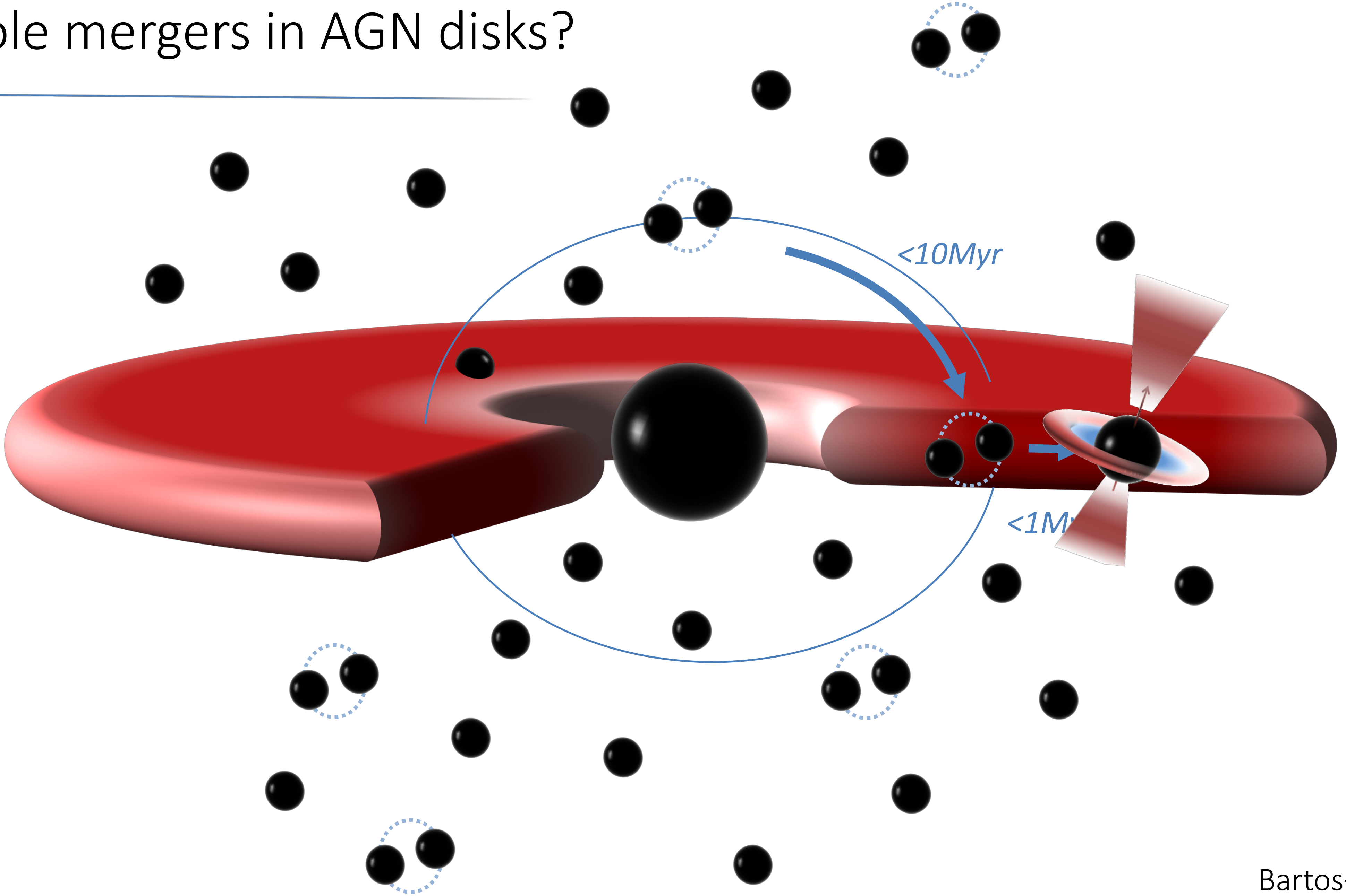


LIGO+Virgo 2018

- Mass/spin distribution
- Orbital eccentricity
- Multi-messenger emission?



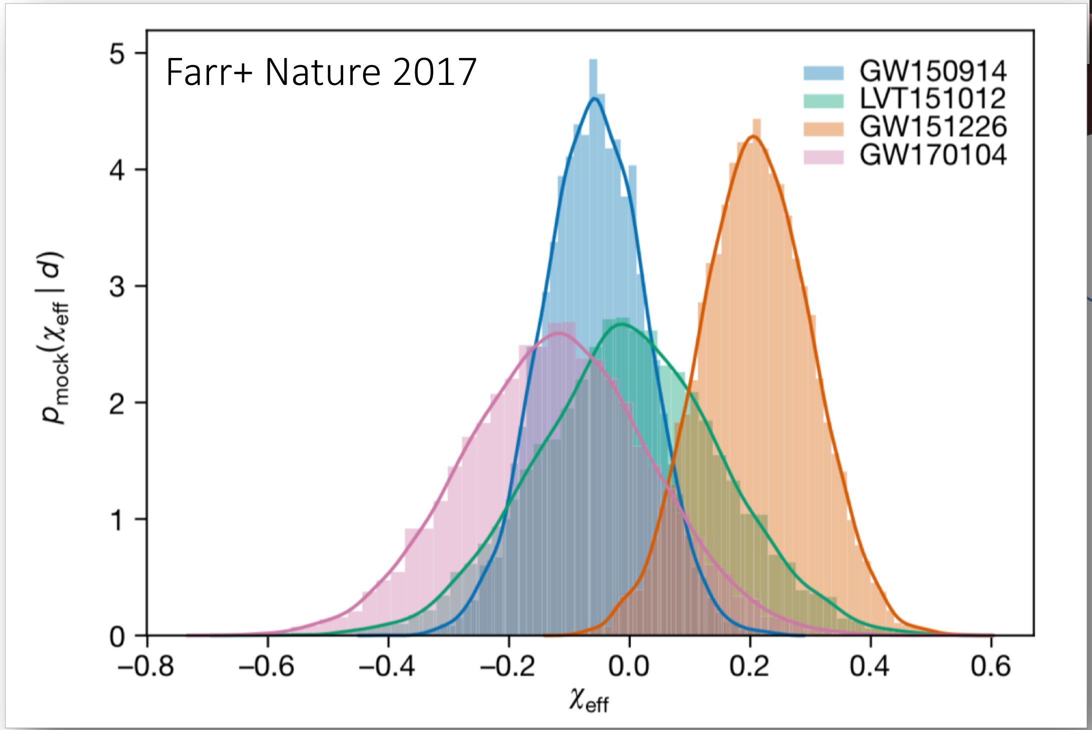
Black hole mergers in AGN disks?

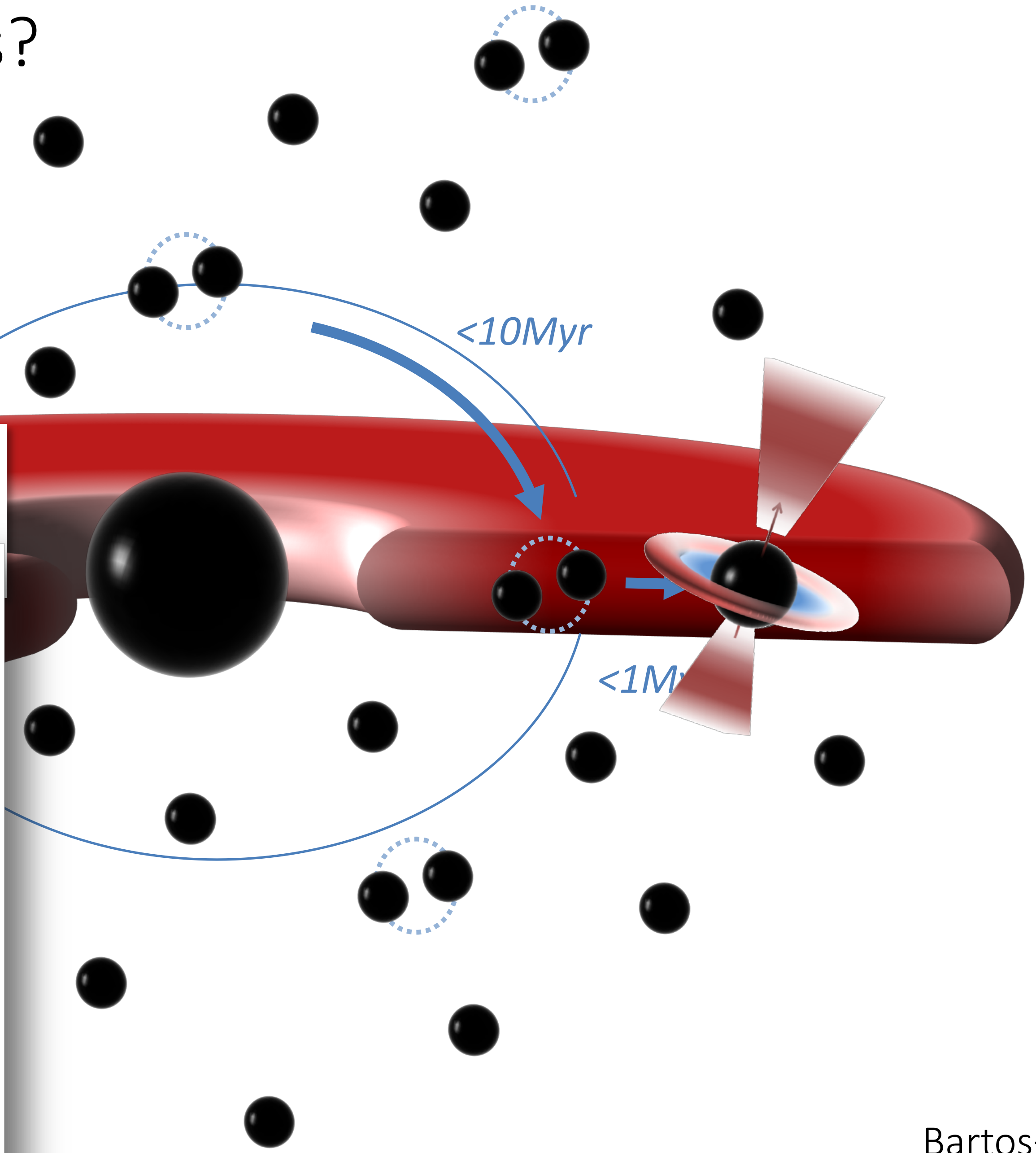


Bartos+ ApJ 2017

Black hole mergers in AGN disks?

Black hole spin distribution consistent with "chance-encounter" origin.



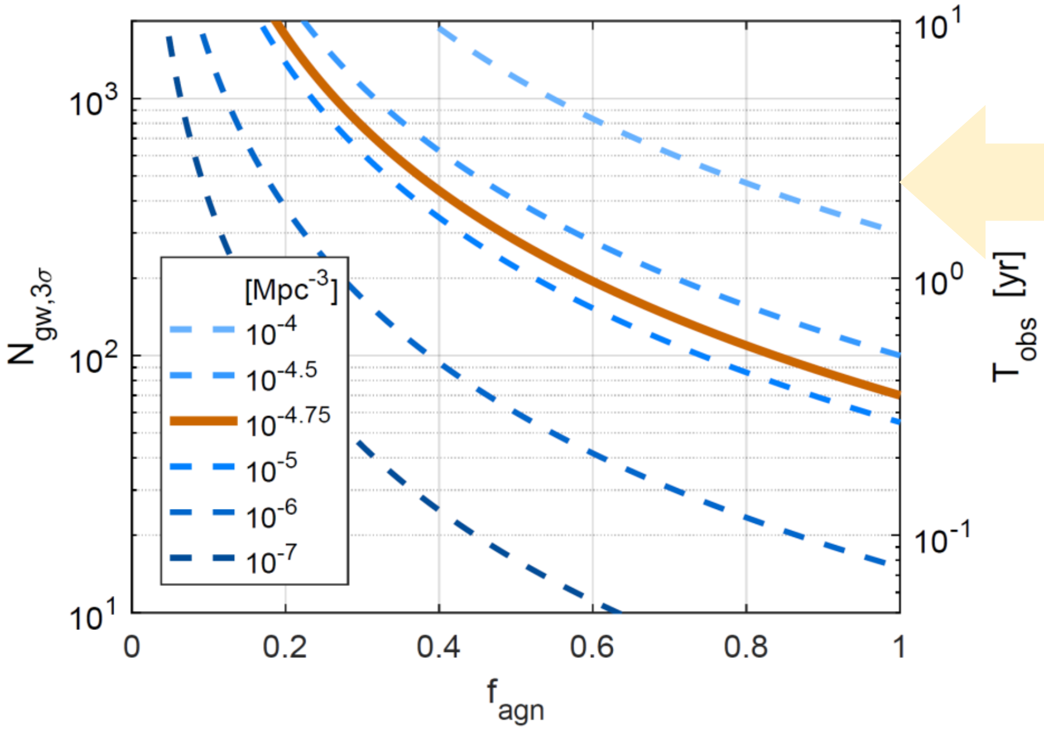


Bartos+ ApJ 2017

The 5th messenger – galaxies

<u>Host galaxies:</u>

- ✓ Enable preferential pointing
- ✓ Reduce background
- ✓ Astrophysical information on source



Bartos+ Nature Comm. 2017

<u>NGC4993</u>: has no star formation
→ binary likely billions of years old.

<u>Cosmology:</u> Redshift of host galaxy + GW luminosity distance
→ cosmic distance ladder (LIGO+Virgo Nature 2017)

<u>Binary black hole mergers</u> – statistical galaxy distribution → redshift

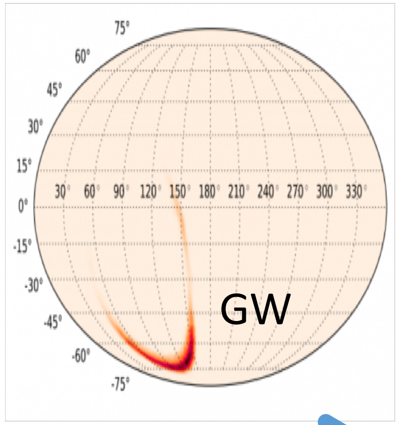
Could help distinguish BBH formation channels

Galaxy catalogs are incomplete beyond ~100 Mpc.

- Galaxy surveys on the fly (Bartos+ ApJ Lett. 2015)
- Deep galaxy surveys
  (e.g. Dark Energy Spectroscopic Instrument, DESI)

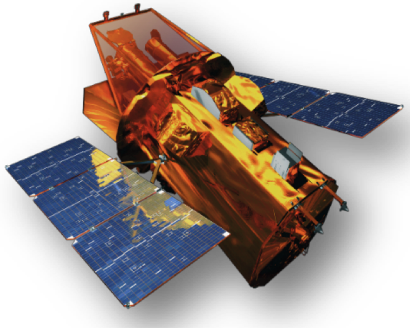
Multi-messenger follow-up

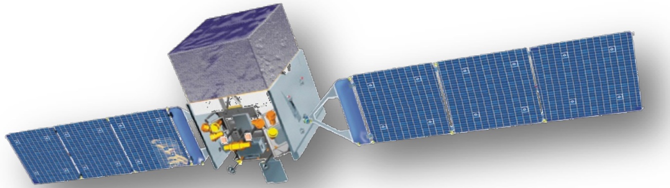
Gravitational waves

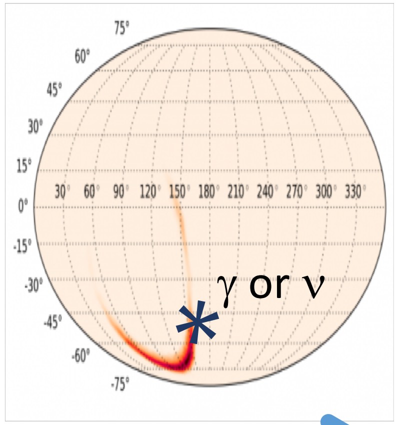


"all-sky" observatories

Gamma-ray + neutrinos

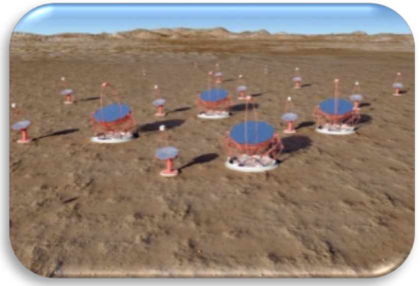






follow-up

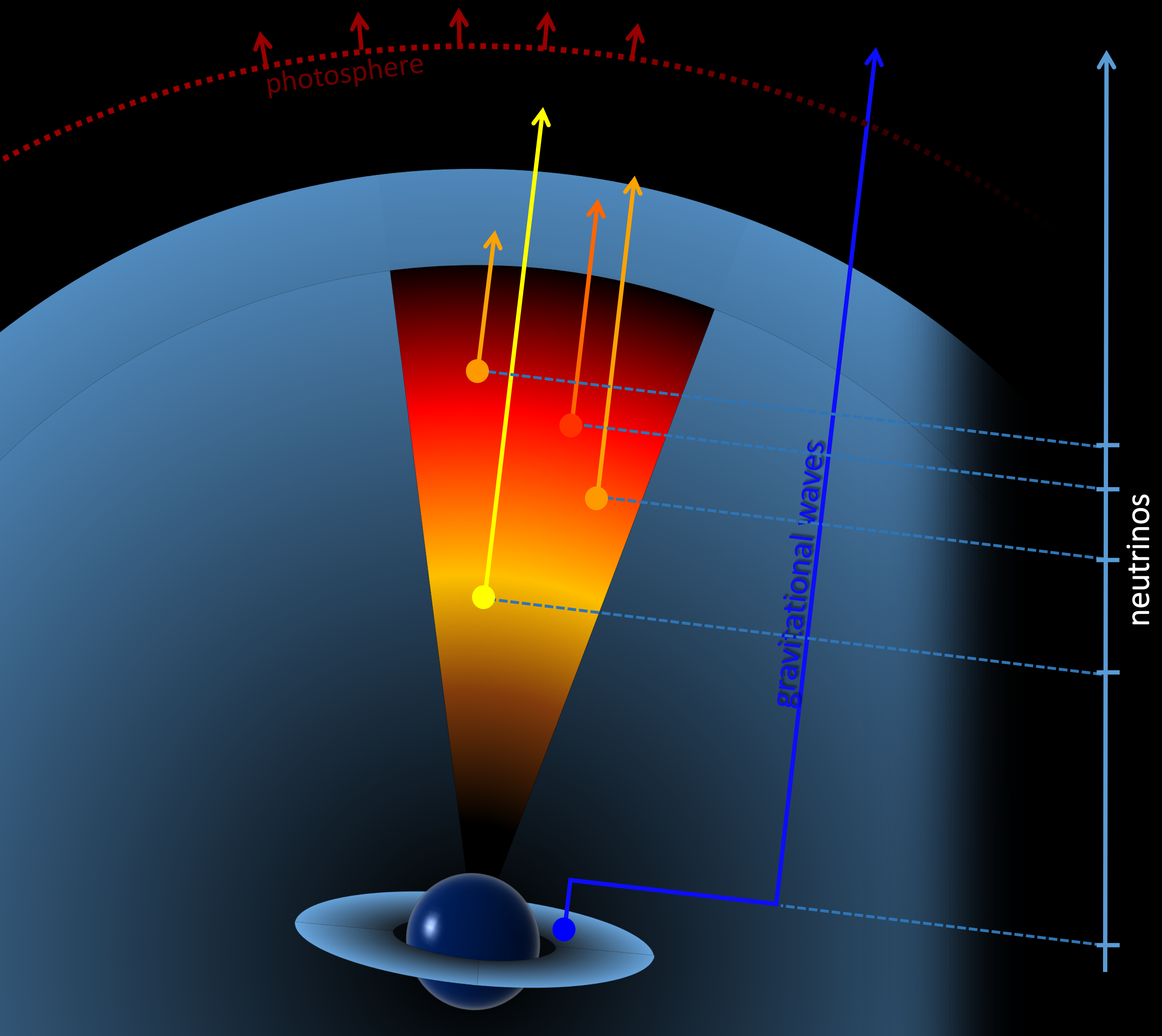
Optical / X-ray / radio

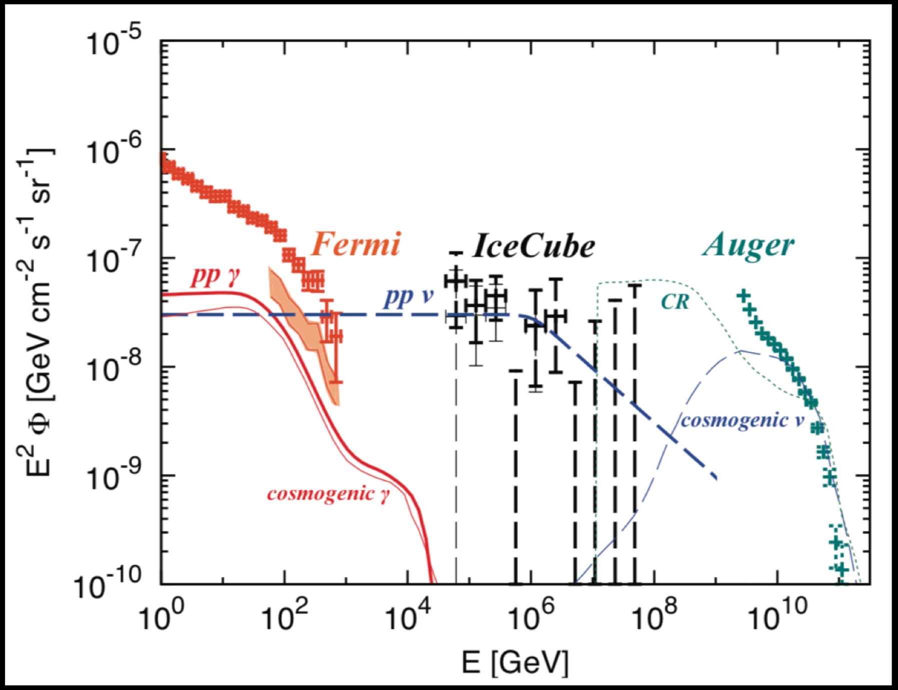


Pre-merger GW detection

Bartos 2017

Hidden cosmic accelerators?

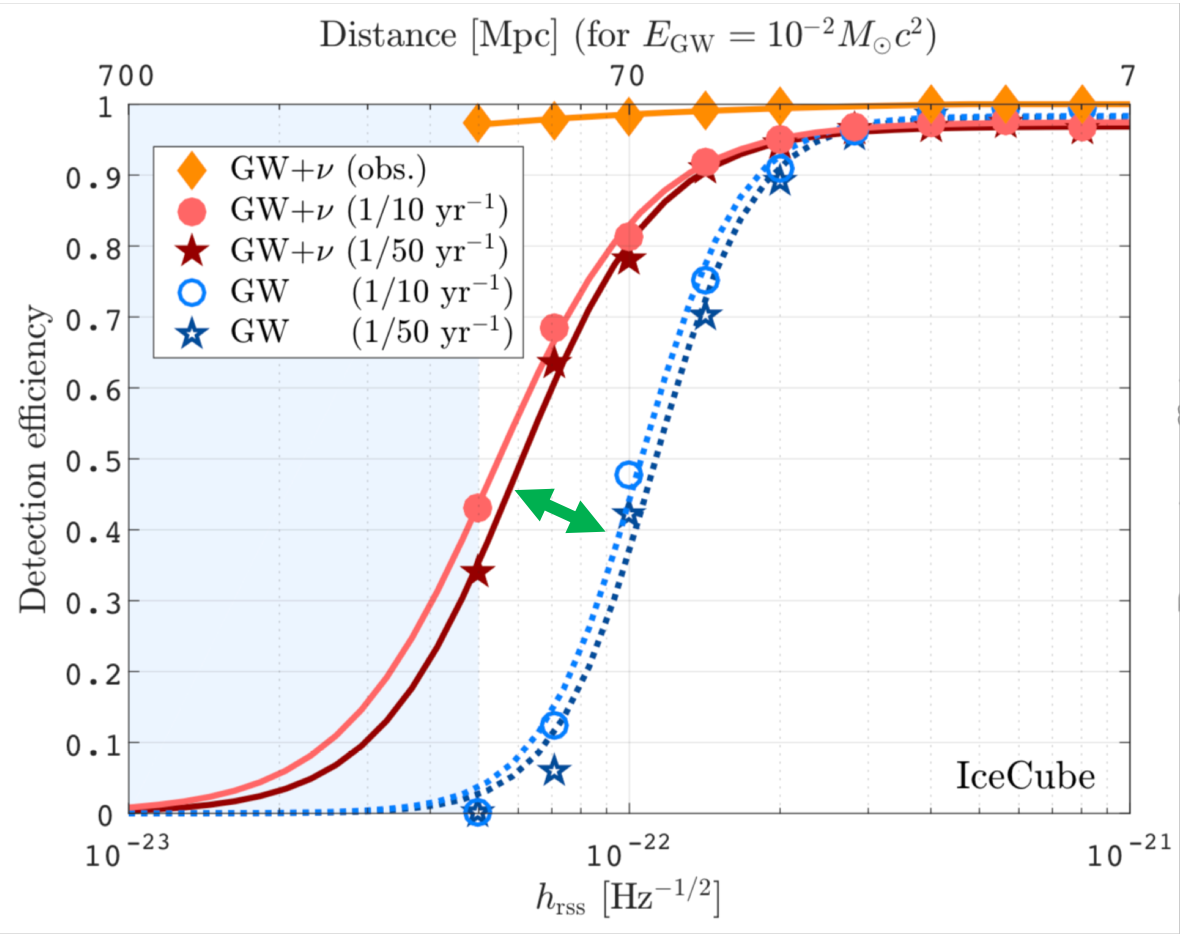


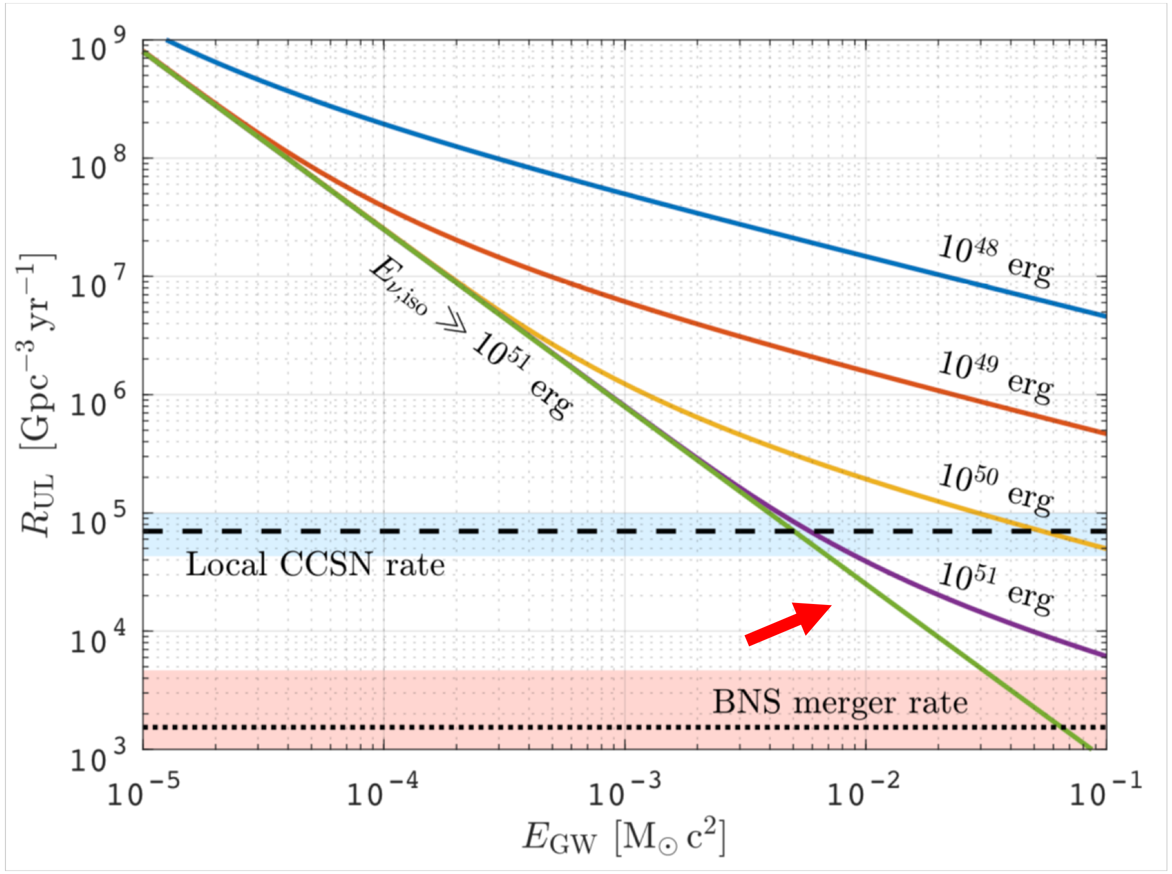


Murase & Waxman 2016

Razzaque+ 2003
Bartos+ 2012
Murase+ 2013, 2015

Sub-threshold searches



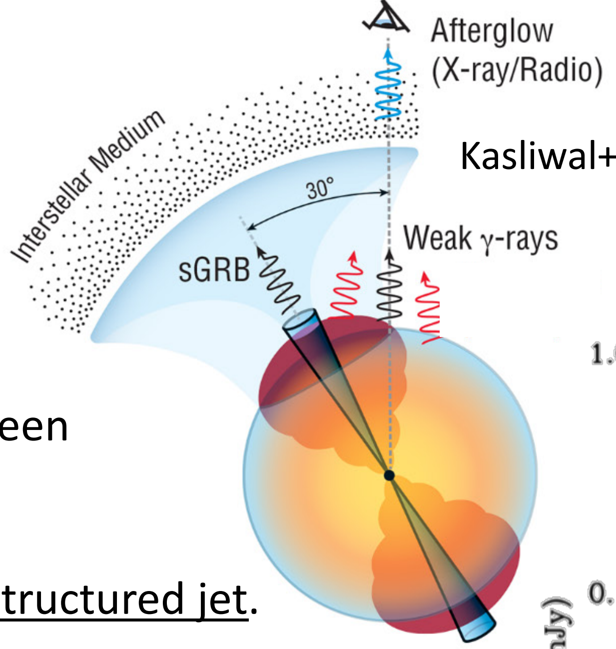


- Neutrinos improve GW sensitive volume by x10.
- Sub-threshold search in 2019 is x500 improvement over 2014.

ANTARES, IceCube, LIGO, Virgo ApJ 2019

Consequences:

Structured jet

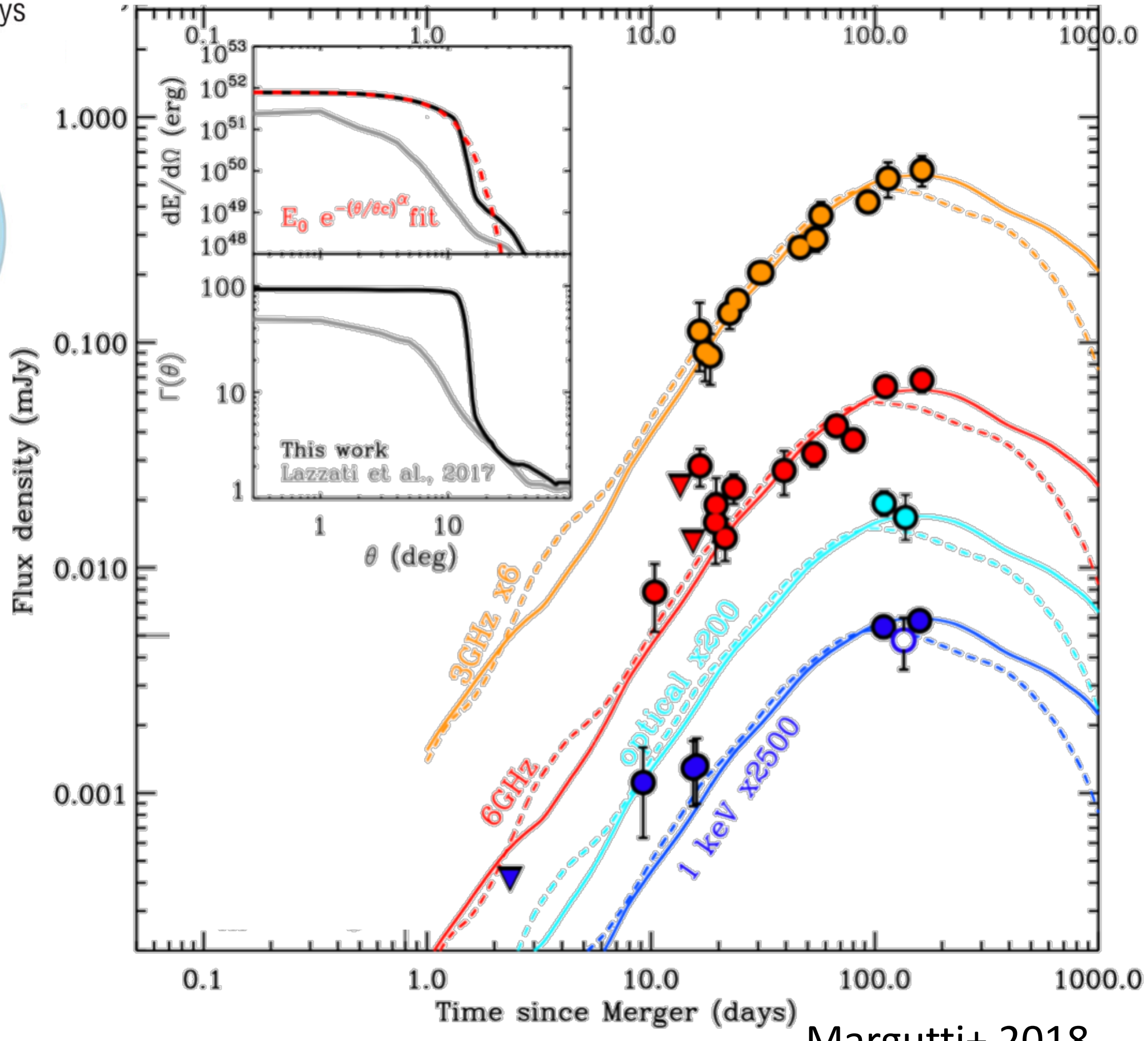


Kasliwal+ 2017

- Joint GW + GRB detection have been mostly considered unlikely.
- Afterglow observations point to structured jet.
- Based on cosmological GRB beaming observations, GRB 170817A should be highly atypical (Beniamini+ 2018).

- But what if GRB 170817A is typical?
- Taking structured jet models (Margutti+ 2018) at face value:
  - ✓ up to 30% of GWs from BNS will have GRB counterpart.
  - ✓ Significant fraction (10%) of GRBs should be nearby.
  - ✓ BNS merger rate lower end of range (500 Gpc^{-3} yr^{-1})

(current LIGO/Virgo estimate: 100-4000 Gpc^{-3} yr^{-1})



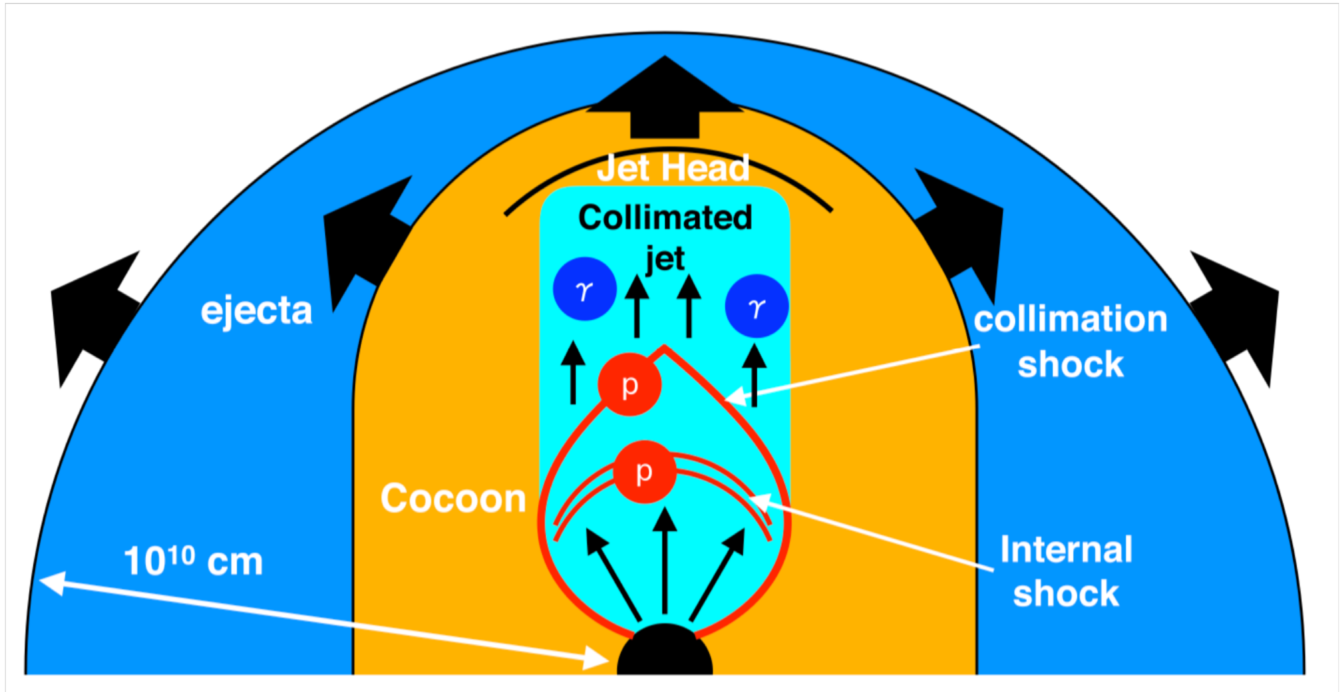
Margutti+ 2018

Gupte & Bartos 2018

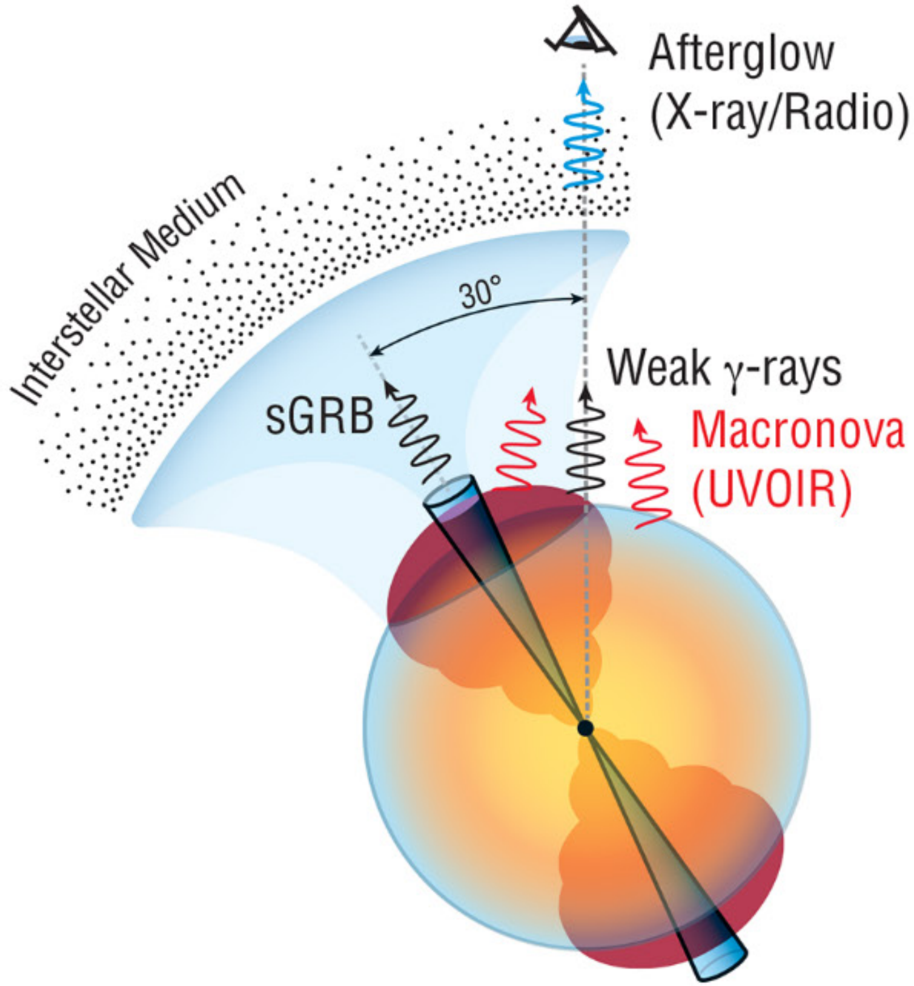
Interaction between jet and relativistic outflow (GW170817)

- Not considered prior to GW170817.

- Relativistic outflow will interact with slower ejecta
  → alter neutrino emission
  → attenuate observable gamma-ray flux
  → can probe jet structure.

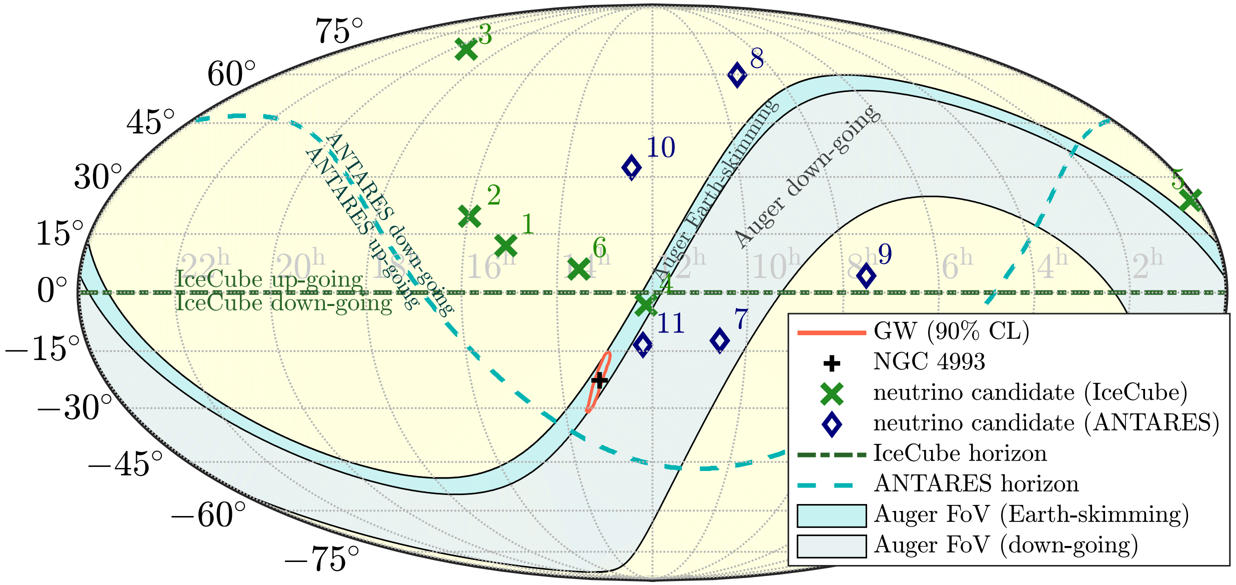


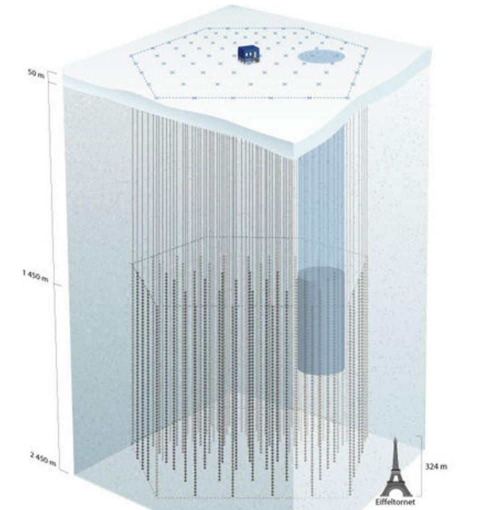
Kimura, Murase, Bartos, Ioka, Heng, Meszaros 2018



Kasliwal+ 2017

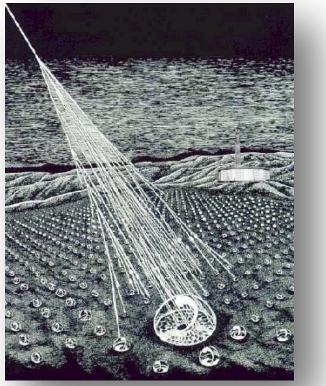
Search for ultrahigh-energy emission (neutrinos)



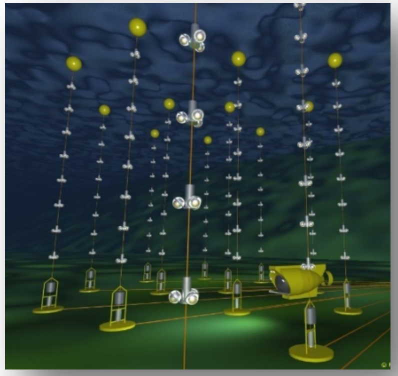


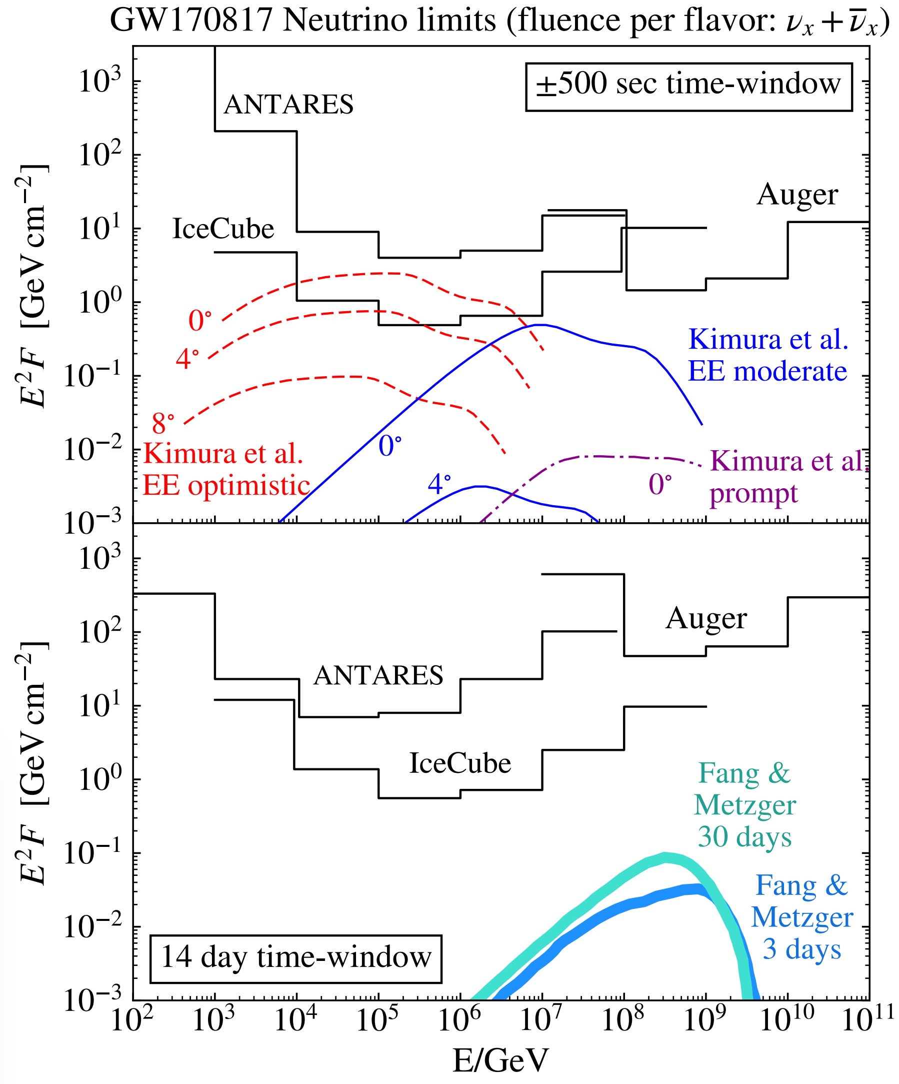
IceCube

Pierre Auger

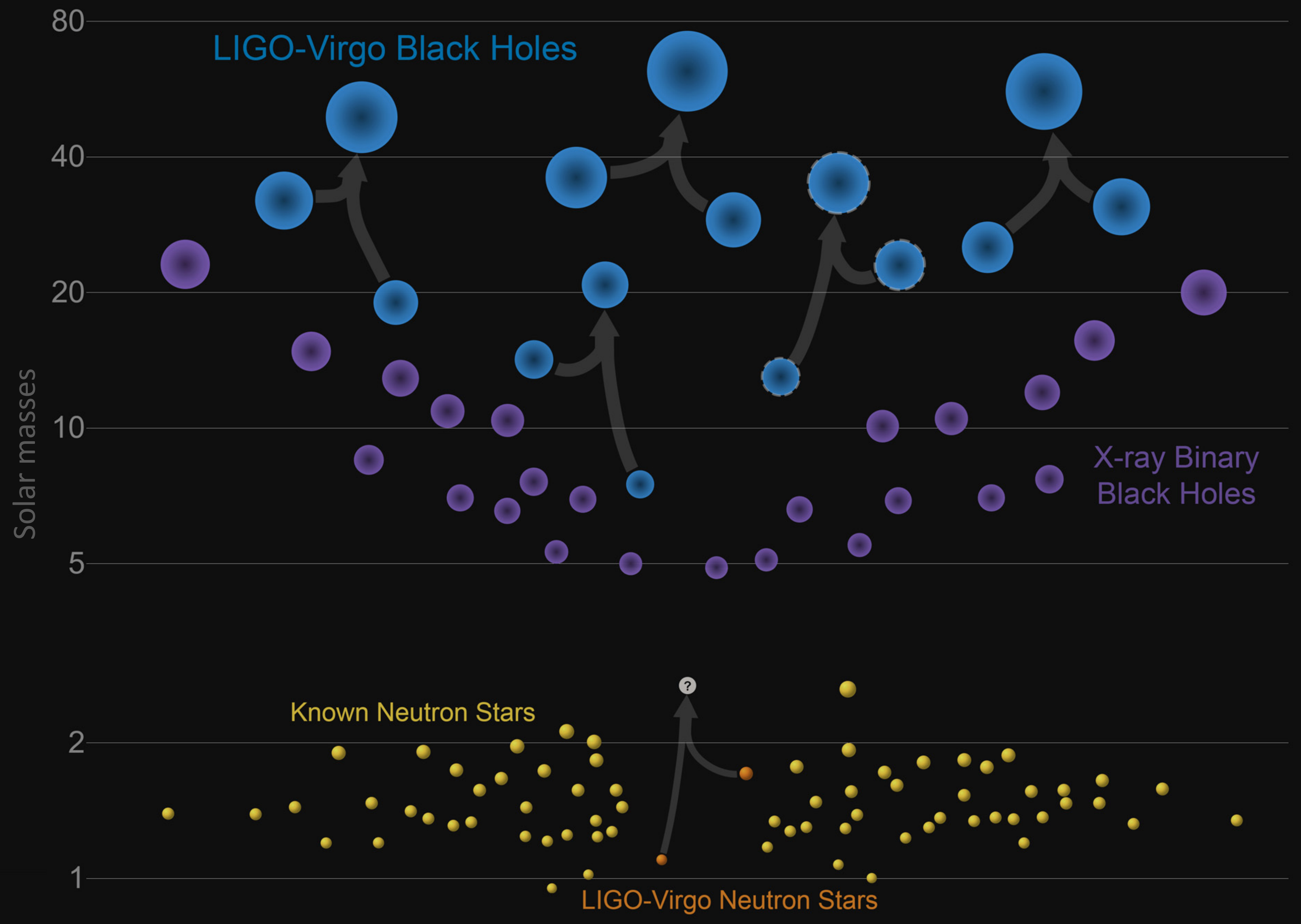


ANTARES





Auger, IceCube, ANTARES, LIGO, Virgo
ApJ Lett. 2017



Credit: LIGO-Virgo/Frank Elavsky/Northwestern University