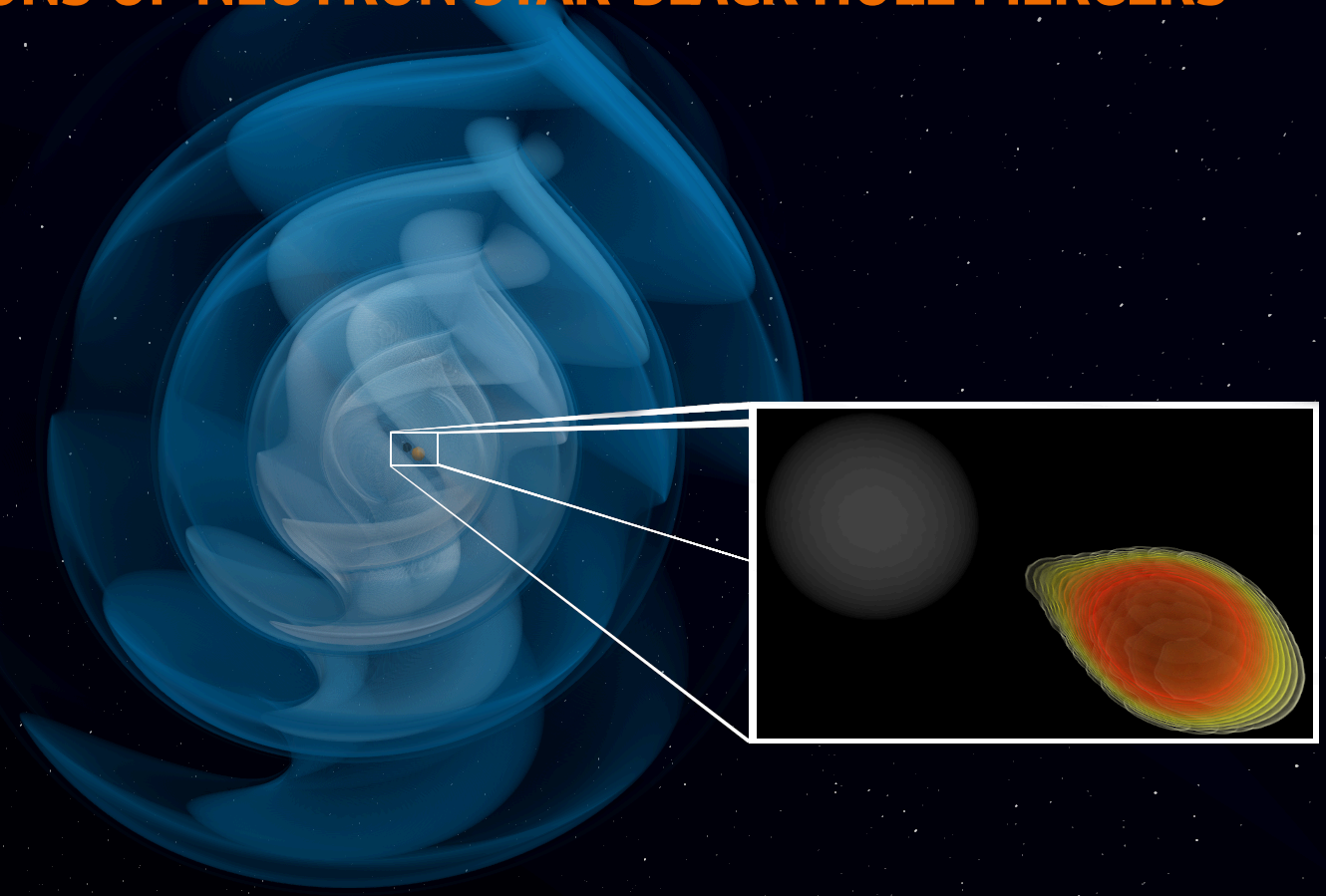
FIRST DETECTIONS OF NEUTRON STAR-BLACK HOLE MERGERS



VIRGO

LSC LIGO Scientific Collaboration

KAGRA

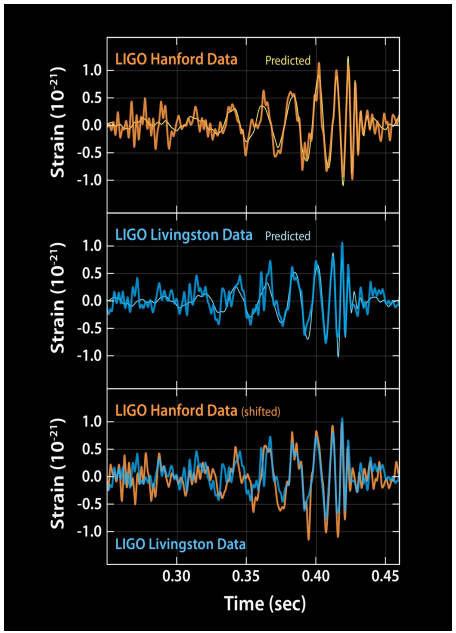
Astrid Lamberts - Observatoire de la Côte d'Azur

GDR OG-12/10/21

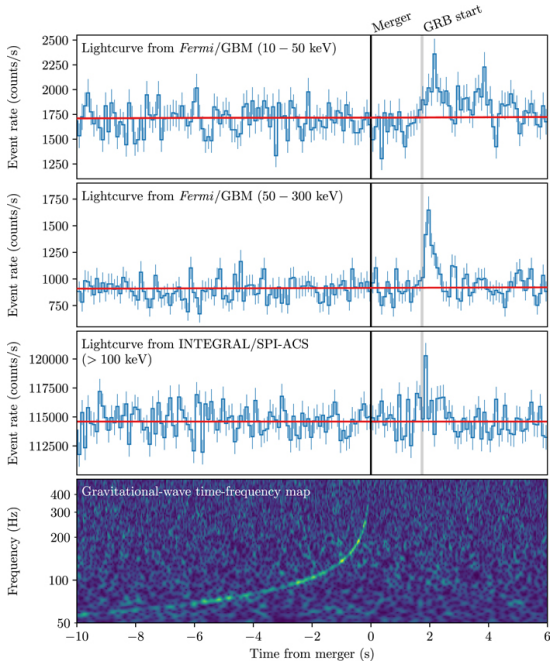
Visualisation: T. Dietrich, N Fischer, S. Ossokine; AEI, UP

THE « MISSING » GW SOURCE

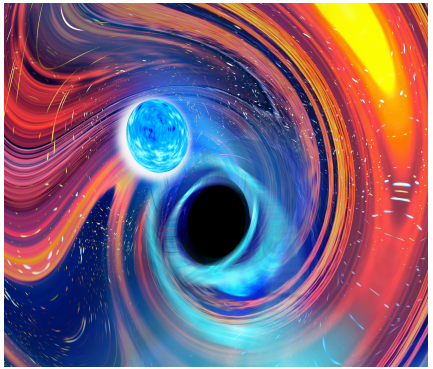
GW150914: BBH



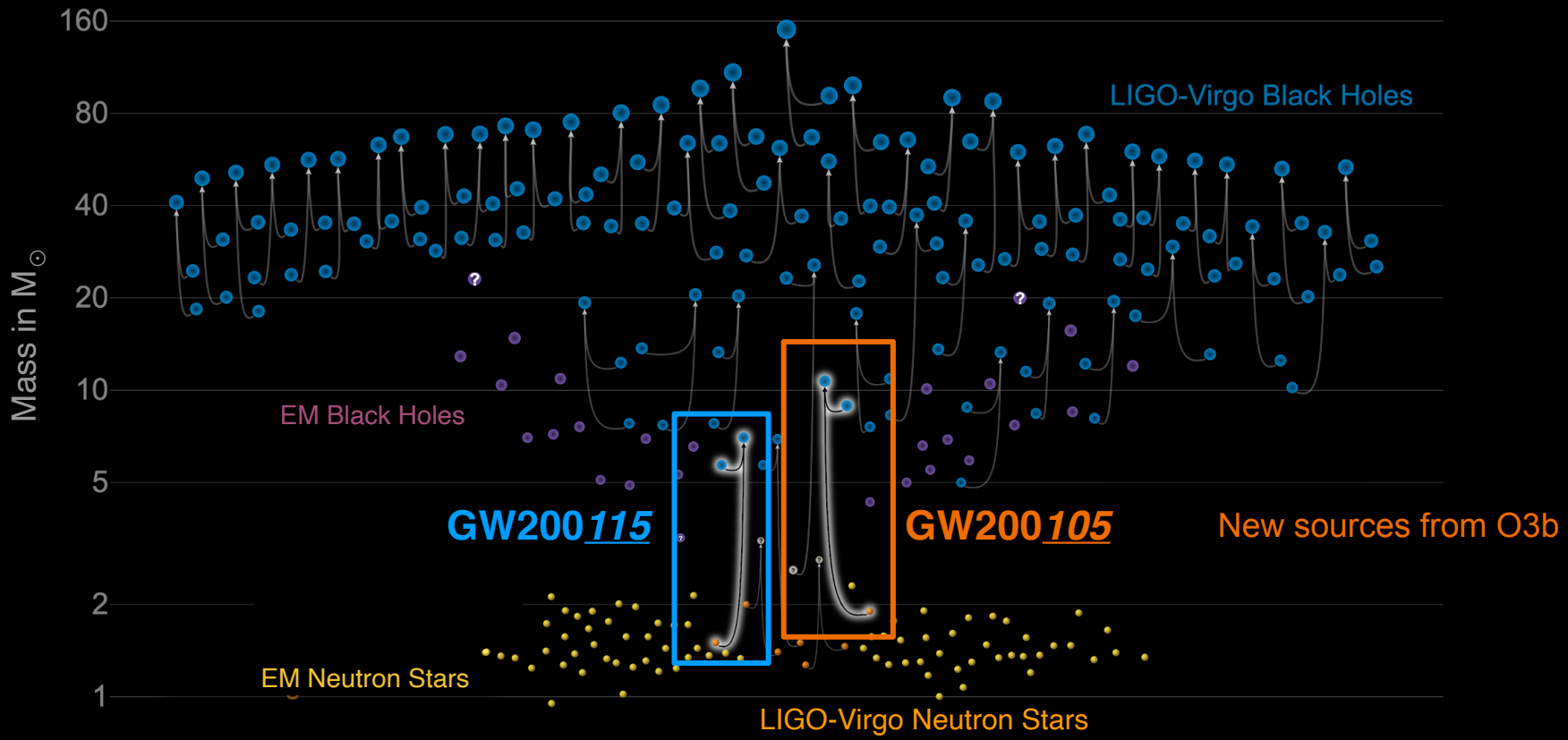
GW170817: BNS



2020: NSBH

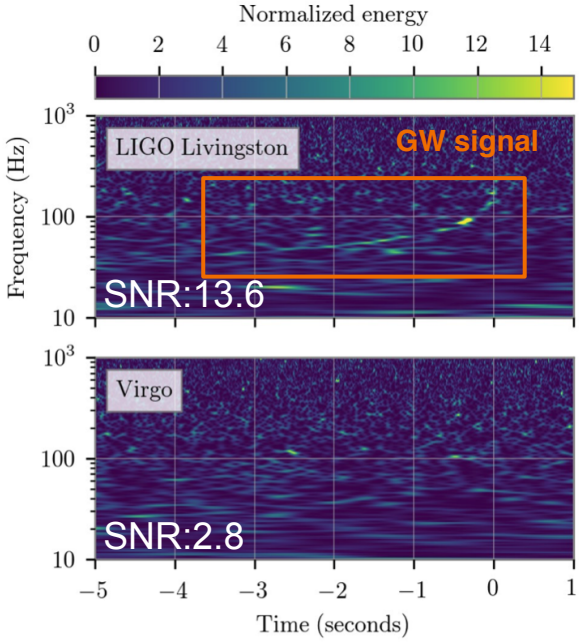


THE GWTC2.0 CATALOG

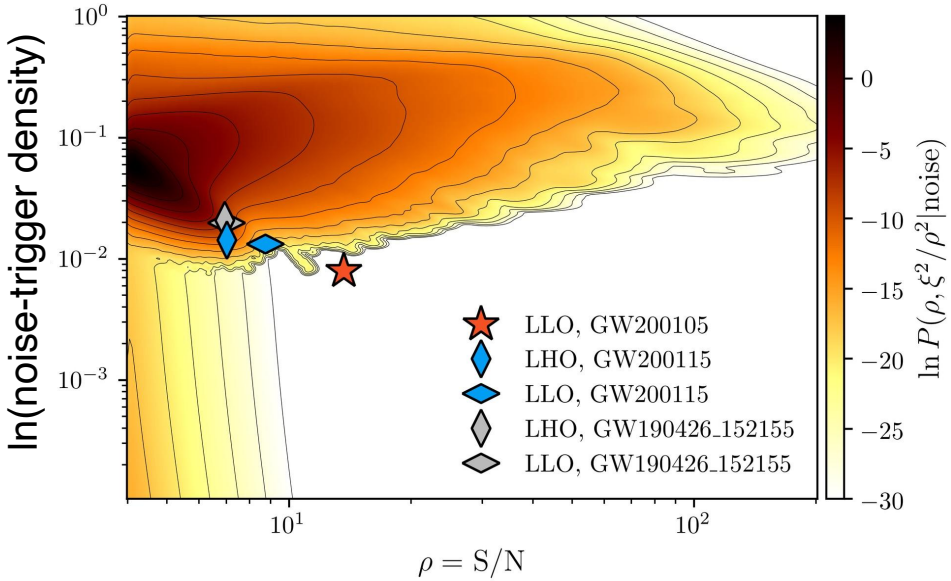


GWTC-2 plot v1.0
LIGO-Virgo | Frank Elavsky, Aaron Geller | Northwestern

GW200105: A SINGLE DETECTOR EVENT



Joint SNR–ξ^2 noise probability density function

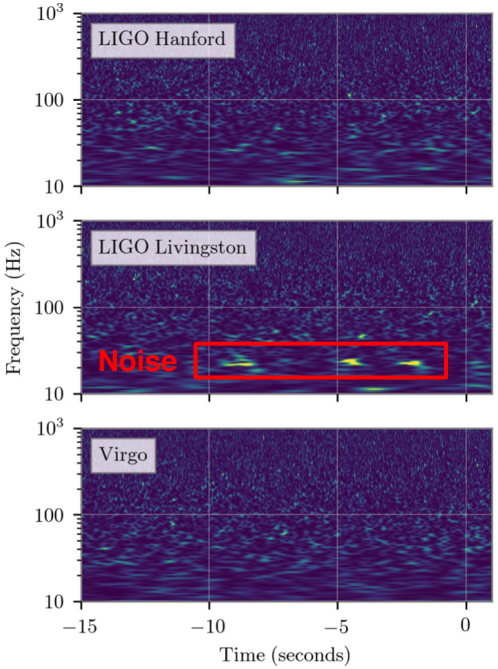


False alarm rate: 1/3 yrs: how to establish confidence? -> distinctly separate from noise

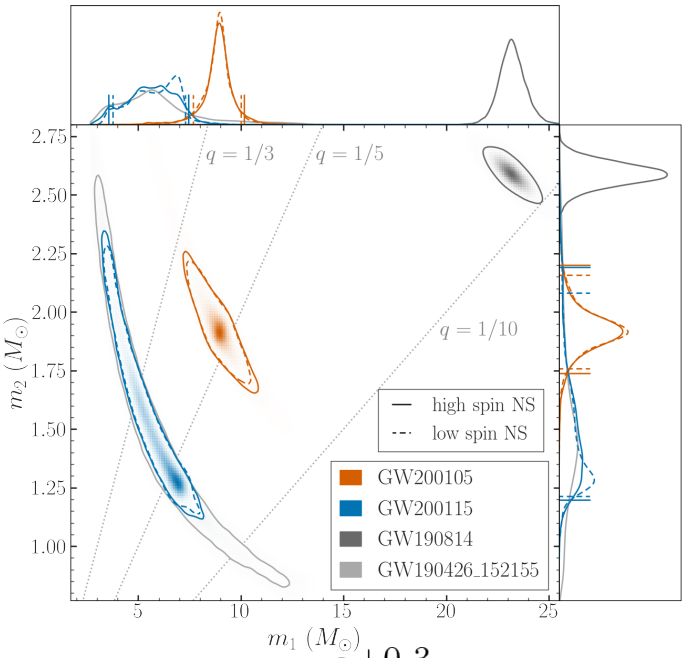
GW200115: COINCIDENT MULTI-DETECTOR OBSERVATION

- **GW200115**: A **coincident** event
- H1 or L1: Do not stand out individually (SNR~11)
- Significance (**F**alse **A**larm **R**ate):

  From **1/ (182 yr)** to less than **1 / (10^5 yr)**

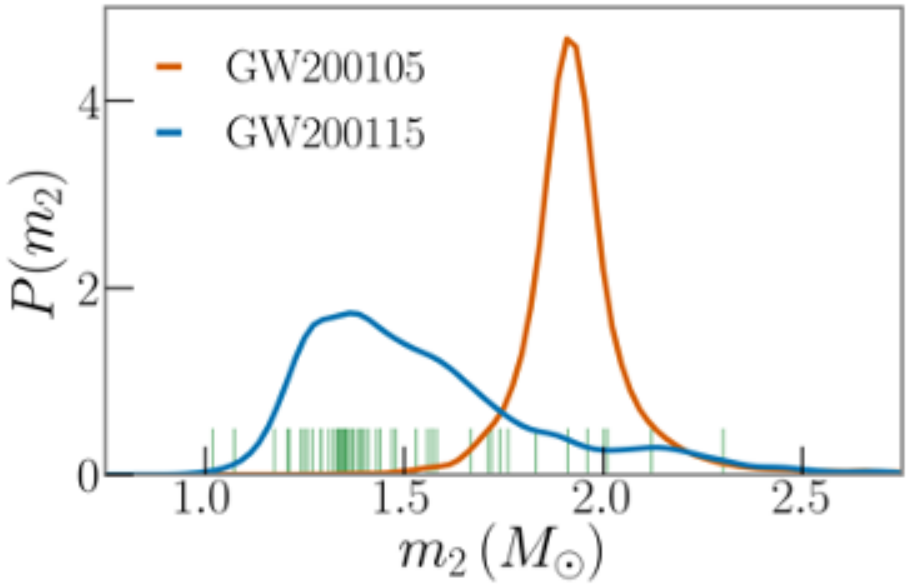


FIRST PROOF OF EXISTENCE OF NS-BH BINARIES



GW200105 m2 = $1.9^{+0.3}_{-0.2} M_\odot$

GW200115 m2 = $1.5^{+0.7}_{-0.3} M_\odot$

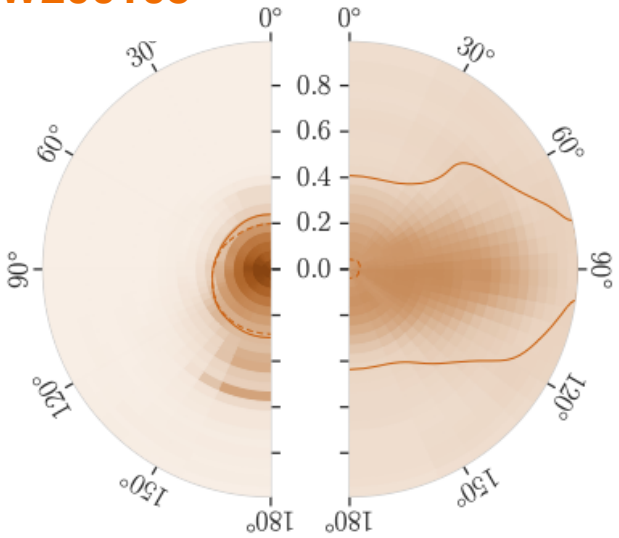


2 populations of NS?

Consistent with EM observations

PRIMARY SPINS

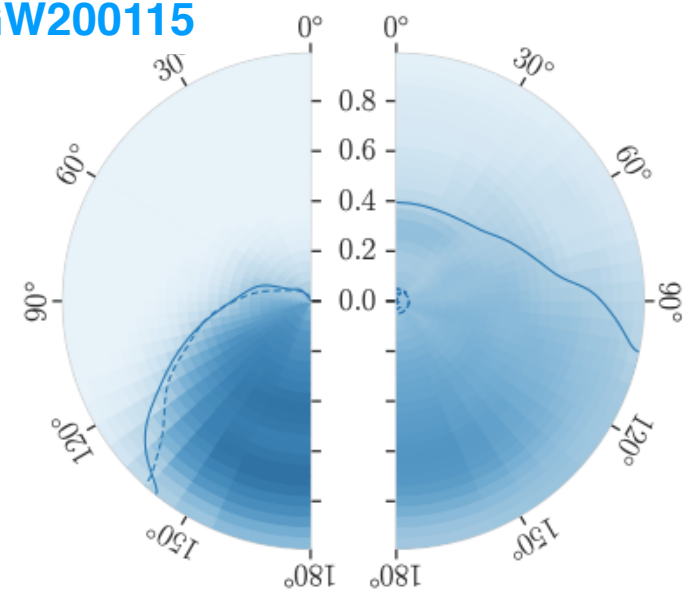
GW200105



$|\vec{\chi}_1| < 0.23$ (90% confidence)

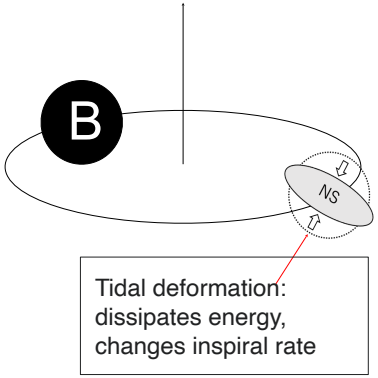
Small spin magnitude

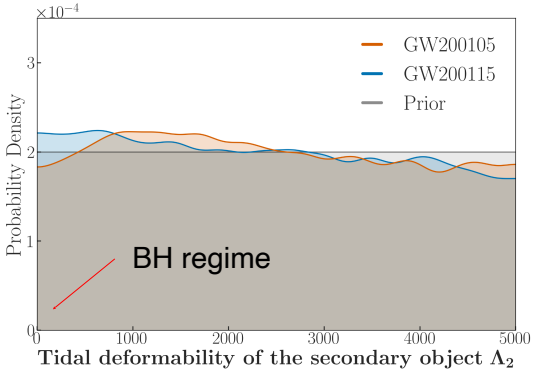
GW200115



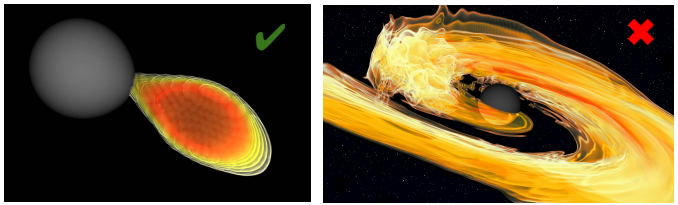
Possibly misaligned spin

PROVING THE PRESENCE OF NS





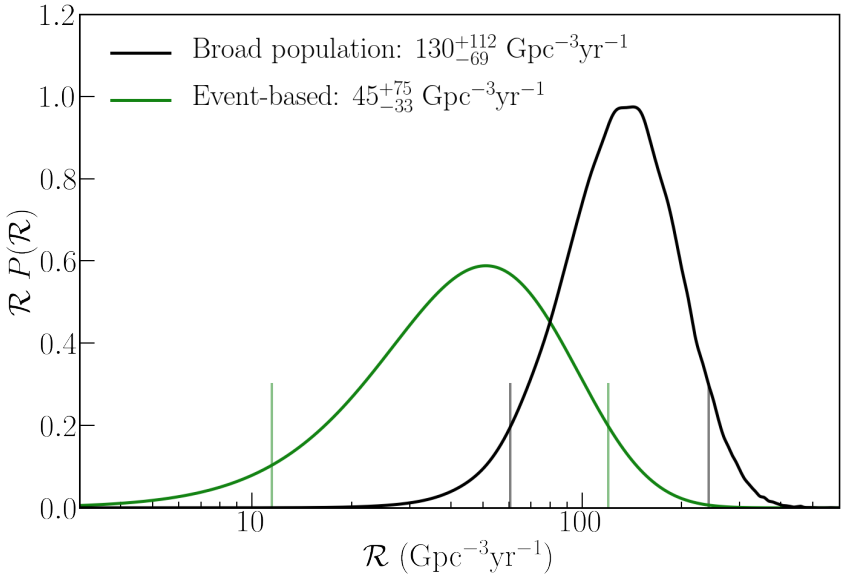
No information
recovered
from GWs (expected)



No EM counterpart (expected)

BUT ~95% probability of NS by comparison with known NS masses

FIRST EMPIRICAL INFERENCE OF NSBH MERGER RATE



Assuming one detection of each type:

- **12-120 Gpc^{-3} yr^{-1}**

Accounting for less significant triggers:

- **61-242 Gpc^{-3} yr^{-1}**

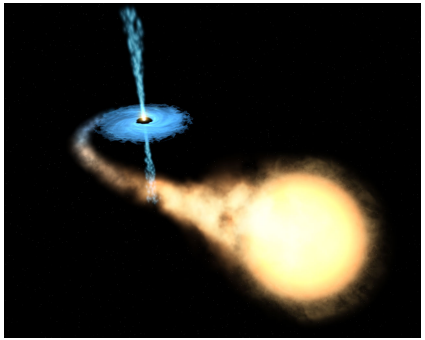
All merger rates now empirically measured -> time for models!

NSBH	BNS	BBH
12-242 Gpc^{-3} yr^{-1}	80-810 Gpc^{-3} yr^{-1}	15-38 Gpc^{-3} yr^{-1}

FORMATION CHANNELS

Isolated binary evolution

- Merger rate **~0.1-800 Gpc^{-3}yr^{-1}**
- Large uncertainties due to treatment of **supernova kicks**, **common envelope** treatment
- Masses compatible with measurements



Credit: European Space Agency, NASA, and Felix Mirabel

NGC 4755 Credit: ESO

Young star clusters

- Merger rate **~0.1-100 Gpc^{-3}yr^{-1}**
- Most NSBHs ejected before undergoing dynamical exchanges, merge in the field
- Encompasses contribution from **isolated binary evolution**
- Masses compatible with measurements

FORMATION CHANNELS

Credit: ESA / NASA / Hubble / Rosario et al.

AGN disks

- Merger rate ≲**300 Gpc^{-3} yr^{-1}**
- Depends on contribution of AGNs to overall merger rate-> large uncertainties

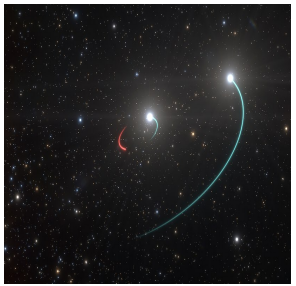
Globular clusters

- Merger rate **~0.01 Gpc^{-3} yr^{-1}** (NS get kicked out)

Credit: ESA / NASA / Hubble

Hierarchical triples

- Merger rate **~0.001-0.01 Gpc^{-3} yr^{-1}**
- Enhanced if no supernova kicks



Credit: ESO / L. Calçada

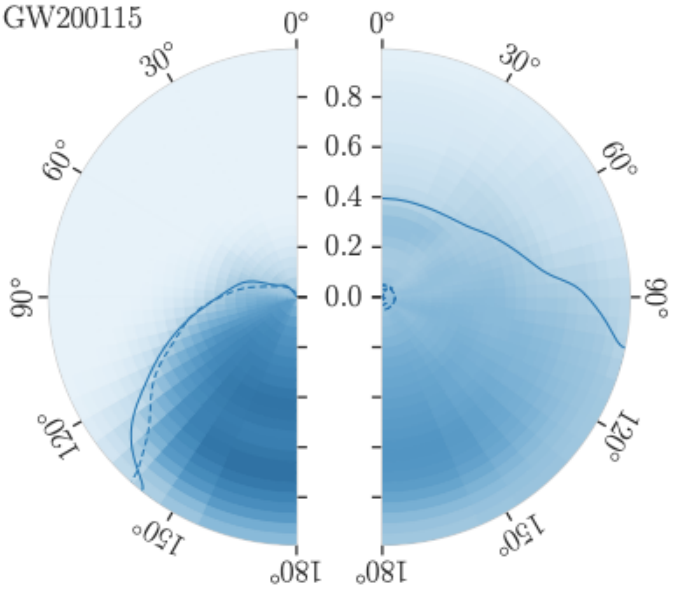
GW200115: MISALIGNED SPIN WITH MASS GAP PRIMARY?

Black hole masses

- GW200115 BH may be in the lower mass gap
  - P(mass gap) ≈ 30%
  - Correlated with negatively-aligned primary spin
- Very difficult to form:
  - Very high NS kick (Fragione+21, Zhu+21)
  - Combined with very efficient common envelope?
  - Very high BH kick (Gompertz+21)

Degeneracy between m1 and spin for low SNR

Analysis with (astrophysical) low spin prior: m1~7 Msun, no spin (Mandel+21)



SUMMARY: FIRST NSBH OBSERVATIONS

GW200105 **~ 1.9 and 9 $M_\odot$** (two detectors)

GW200115 **~ 1.5 and 6 $M_\odot$** (three detectors)

No definite proof of nature of secondary, but **suggestive**

- Secondary masses smaller than maximum NS mass
- Masses consistent with known galactic NS and formation scenarios

NS-BH merger rate of **~100 Gpc^{-3} yr^{-1}** consistent with several formation scenarios.