Synergies with ground based laser interferometers

Stephen Fairhurst

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Fourth Observing Run (O4)

GraceDB Public Alerts Latest Search Documentation Login

https://gracedb.ligo.org/

Please log in to view full database contents.

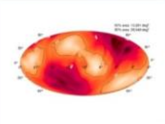
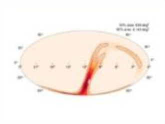
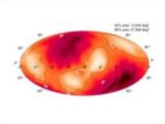
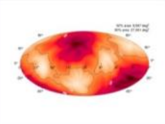
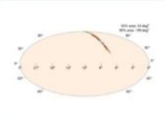
O4 Significant Detection Candidates: **81** (92 Total - 11 Retracted)

O4 Low Significance Detection Candidates: **1612** (Total)

Show All Public Events

Page 1 of 7. next last »

SORT: EVENT ID (A-Z)

Event ID	Possible Source (Probability)	Significant	UTC	GCN	Location	FAR	Comments
S240109a	BBH (99%)	Yes	Jan. 9, 2024 05:04:31 UTC	GCN Circular Query Notices | VOE		1 per 4.3136 years	
S240107b	BBH (97%), Terrestrial (3%)	Yes	Jan. 7, 2024 01:32:15 UTC	GCN Circular Query Notices | VOE		1.8411 per year	
S240104bl	BBH (>99%)	Yes	Jan. 4, 2024 16:49:32 UTC	GCN Circular Query Notices | VOE		1 per 8.9137e+08 years	
S231231ag	BBH (>99%)	Yes	Dec. 31, 2023 15:40:16 UTC	GCN Circular Query Notices | VOE		1 per 3.7932e+06 years	
S231226av	BBH (>99%)	Yes	Dec. 26, 2023 10:15:20 UTC	GCN Circular Query Notices | VOE		1 per 2.8446e+42 years	

Results from O3: Populations

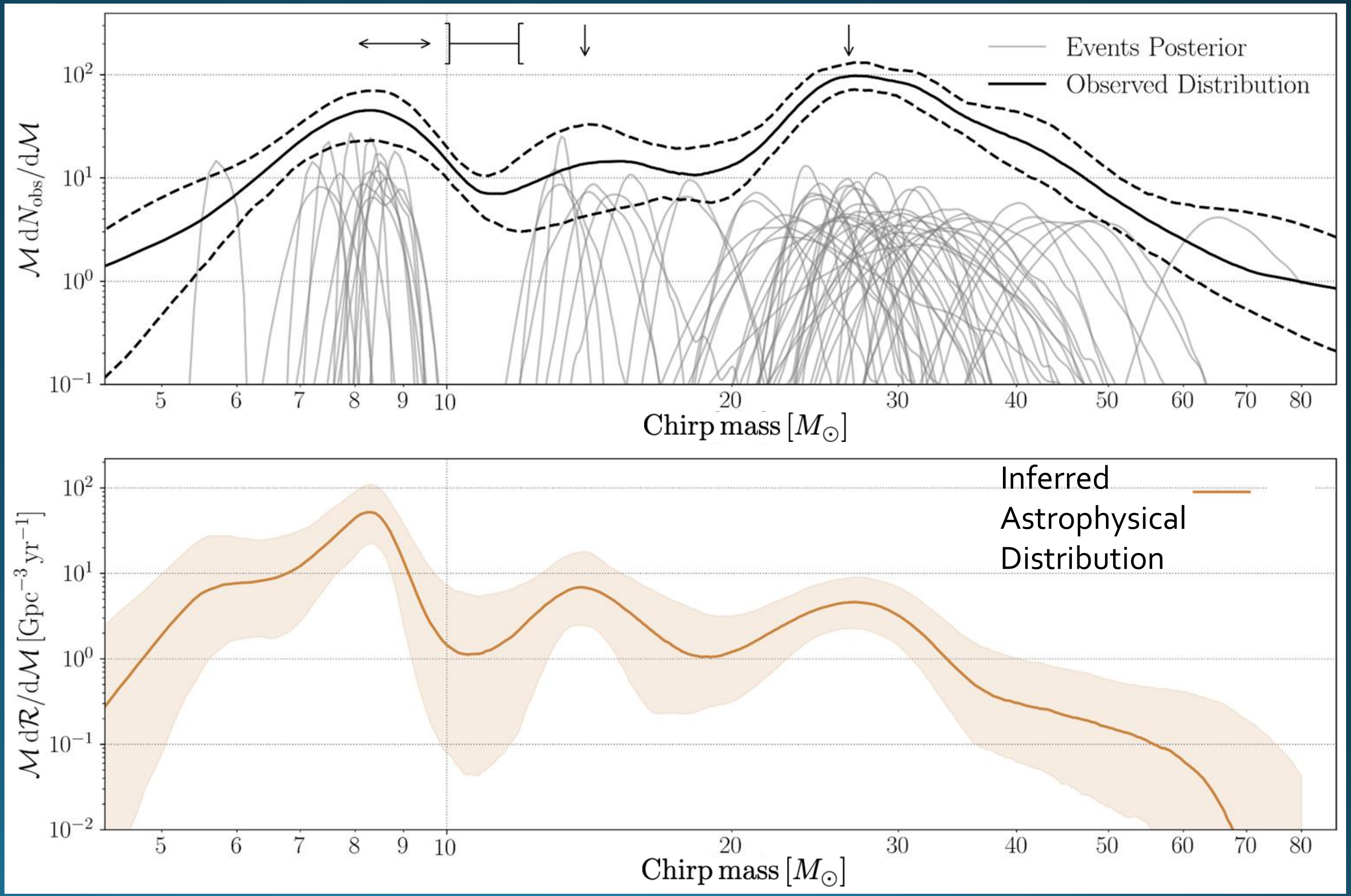
Features in the mass spectrum

Over-density between $8M_\odot$ and $10M_\odot$ and around $26M_\odot$.

- A **weaker feature** present at around $14M_\odot$

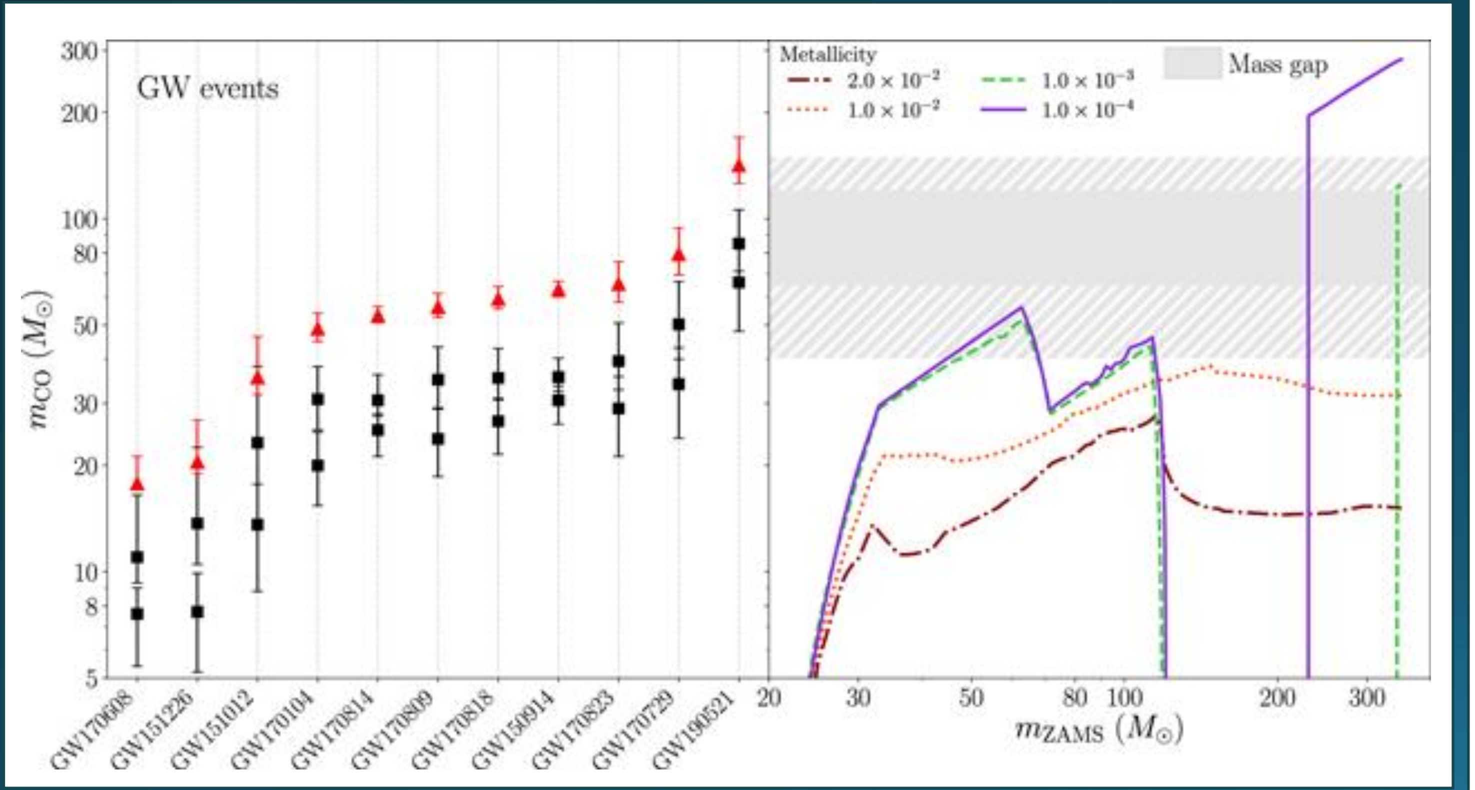
- **Absence** of mergers with chirp masses between $10M_\odot$ and $12M_\odot$.

From Abbott et al, arXiv: 2111.03634
First discussed in Tiwari and Fairhurst, arXiv: 2011.04502

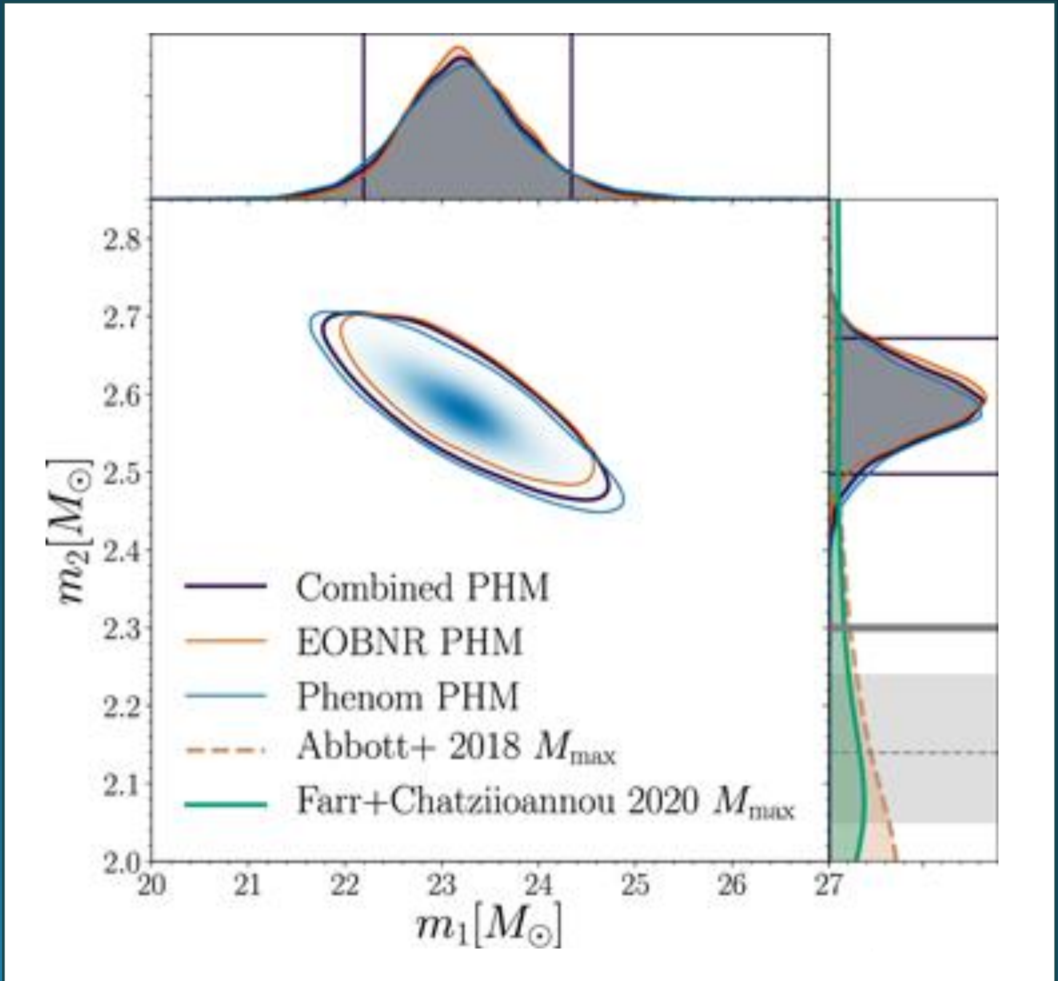


Results from O3: Unexpected Events

GW190521



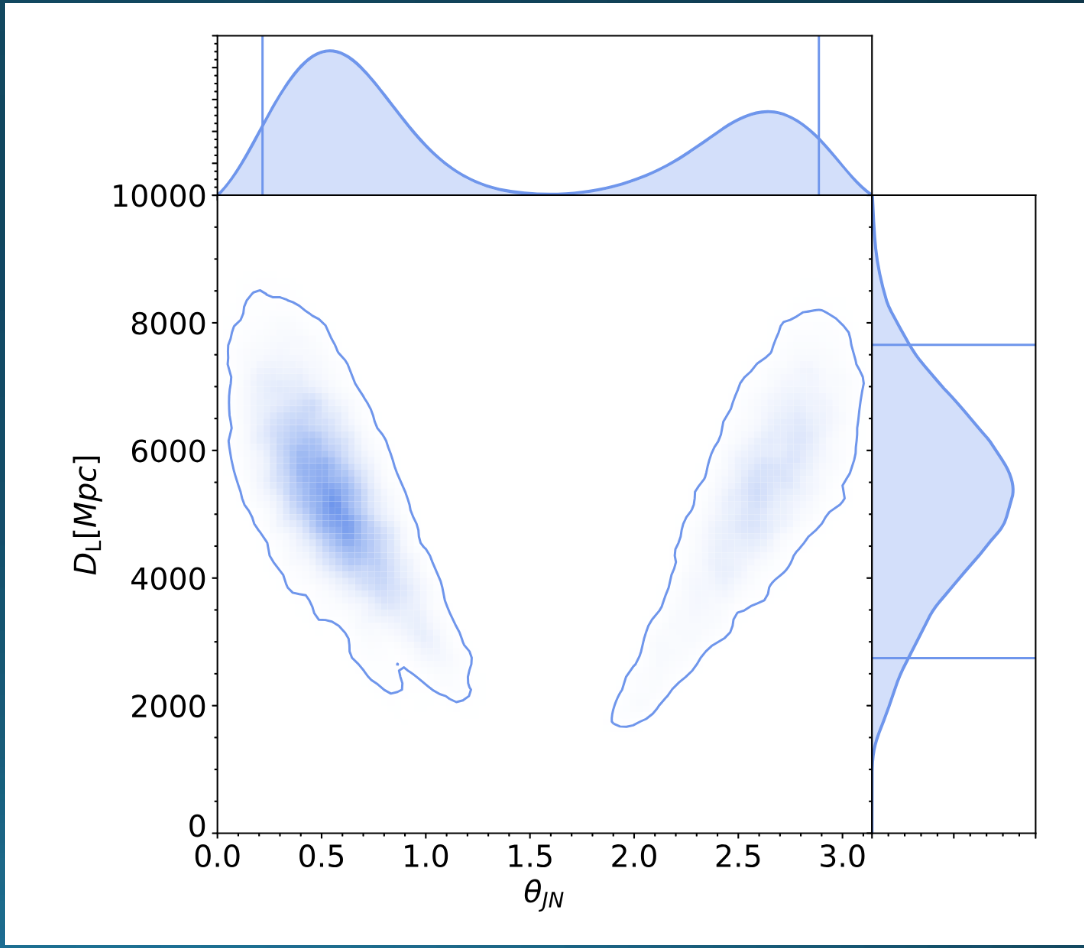
GW190814



Abbott et al, arXiv: 2009.01075, 2006.12611

Challenge: Accurate measurement of mass and redshift

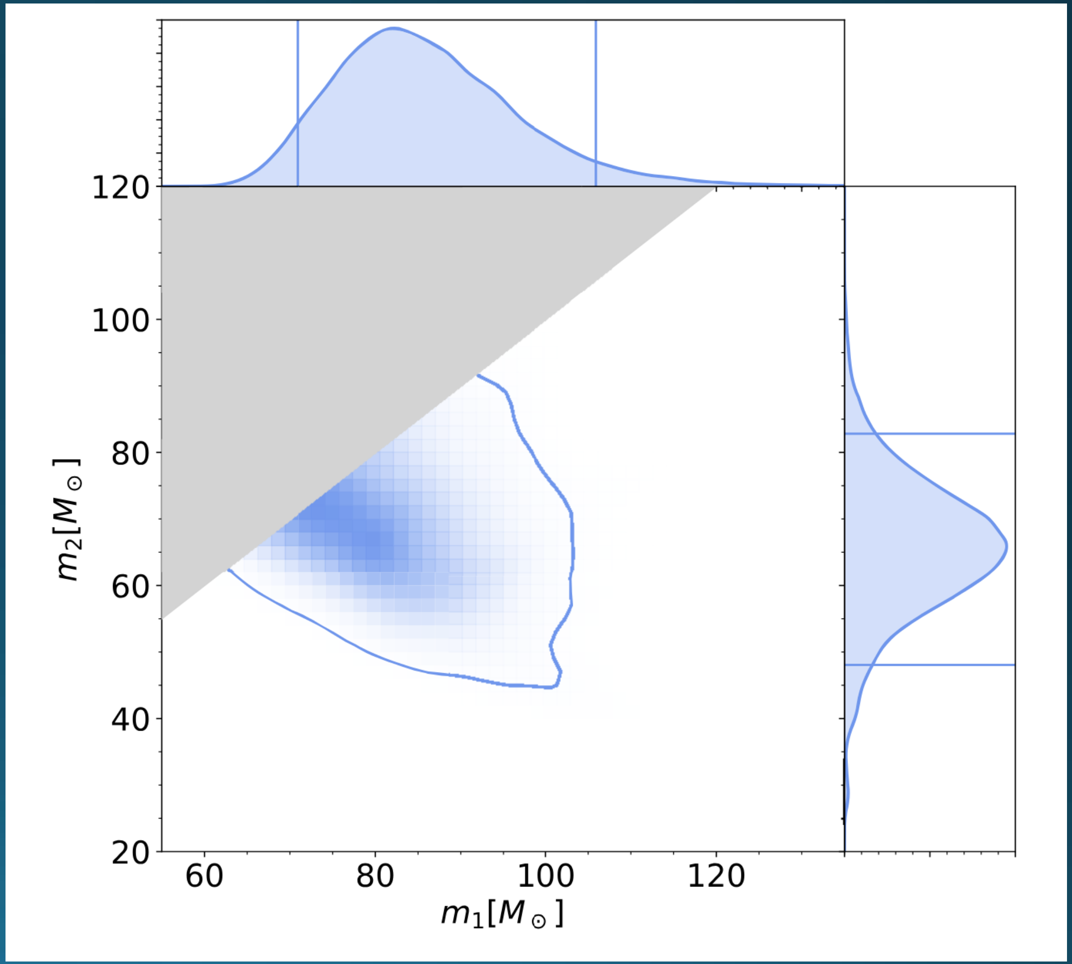
- Example: GW190521
- Distance uncertain to a factor of 2 largely due to degeneracy with orientation.
- Corresponding redshift uncertainty: $0.5 < z < 1.1$.
- GW measurements give $M(1 + z)$, so distance uncertainty contributes to mass uncertainty



Abbott et al, arXiv: 2009.01075

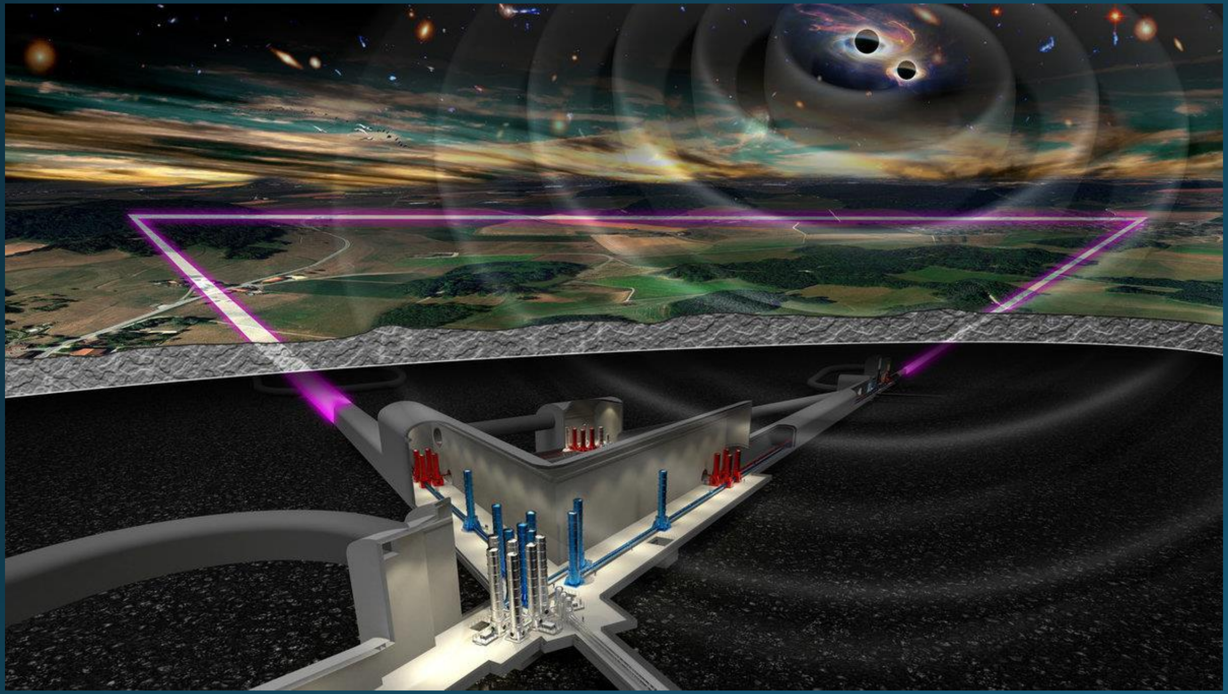
Challenge: Accurate measurement of mass and redshift

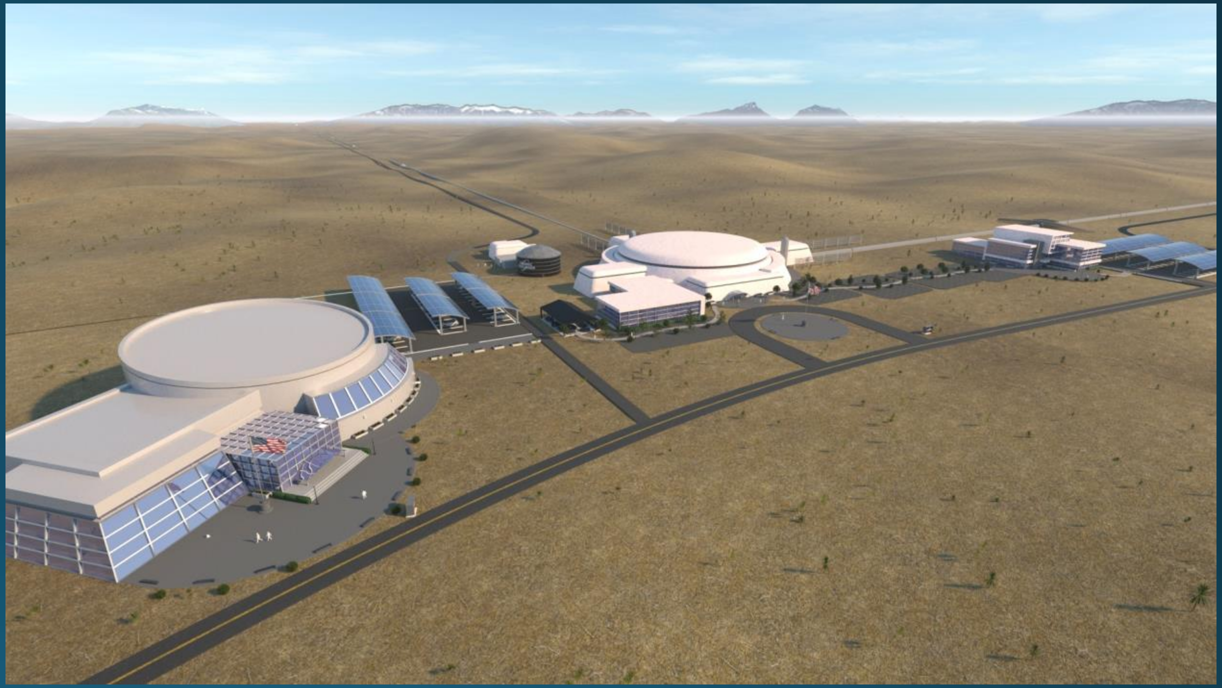
- Example: GW190521
- Distance uncertain to a factor of 2 largely due to degeneracy with orientation.
- Corresponding redshift uncertainty: $0.5 < z < 1.1$.
- GW measurements give $M(1 + z)$, so distance uncertainty contributes to mass uncertainty
- More pronounced at high z



Abbott et al, arXiv: 2009.01075

Einstein Telescope and Cosmic Explorer





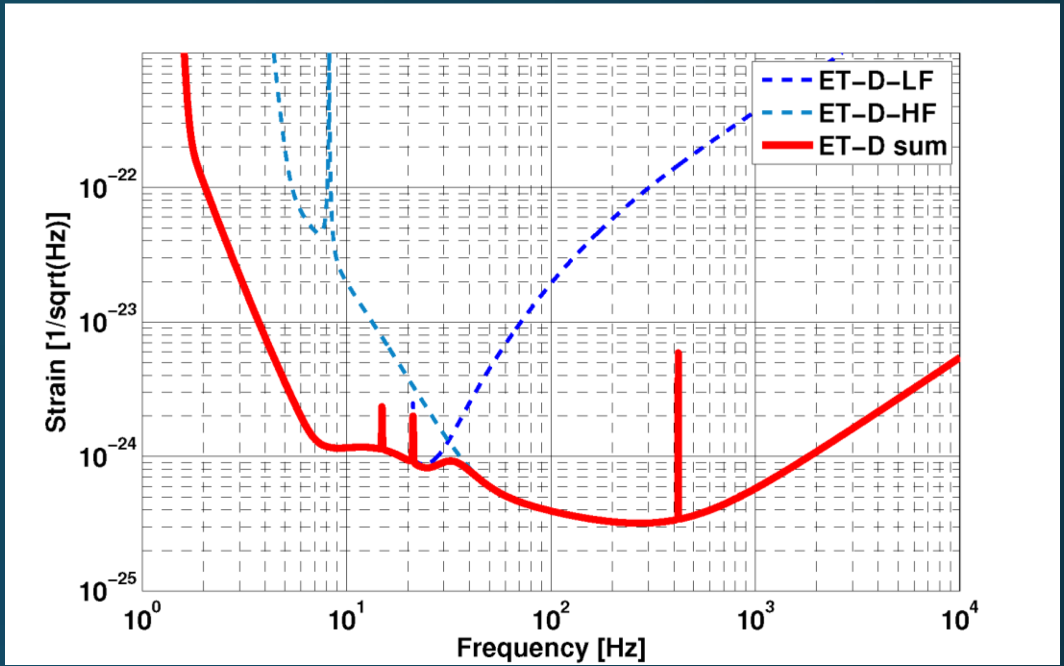
Maggiore et al. https://arxiv.org/abs/1912.02622

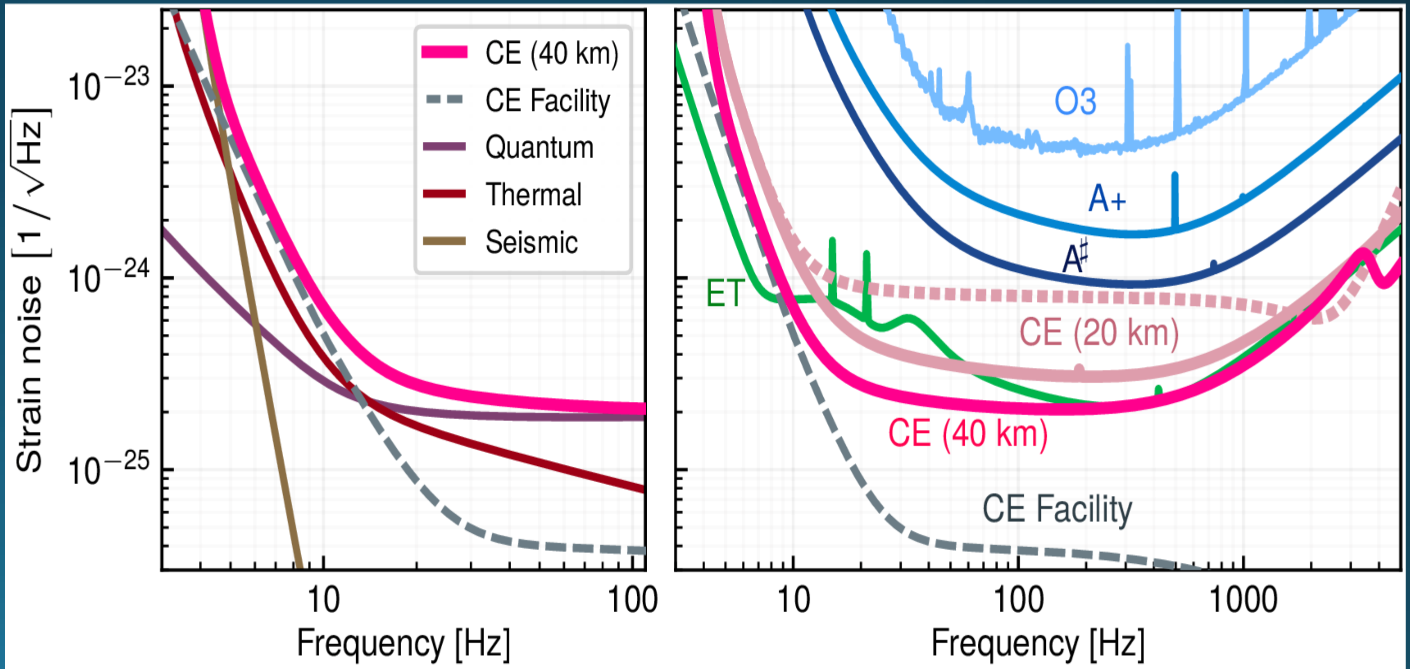
Evans et al. https://arxiv.org/abs/2109.09882

Next Generation GW Observatory Science Book
https://gwic.ligo.org/3Gsubcomm/documents.html

Sensitivity

- Both Cosmic Explorer and Einstein Telescope target a 10x sensitivity improvement and a broader frequency range
- Achieved through longer arms, improved seismic isolation

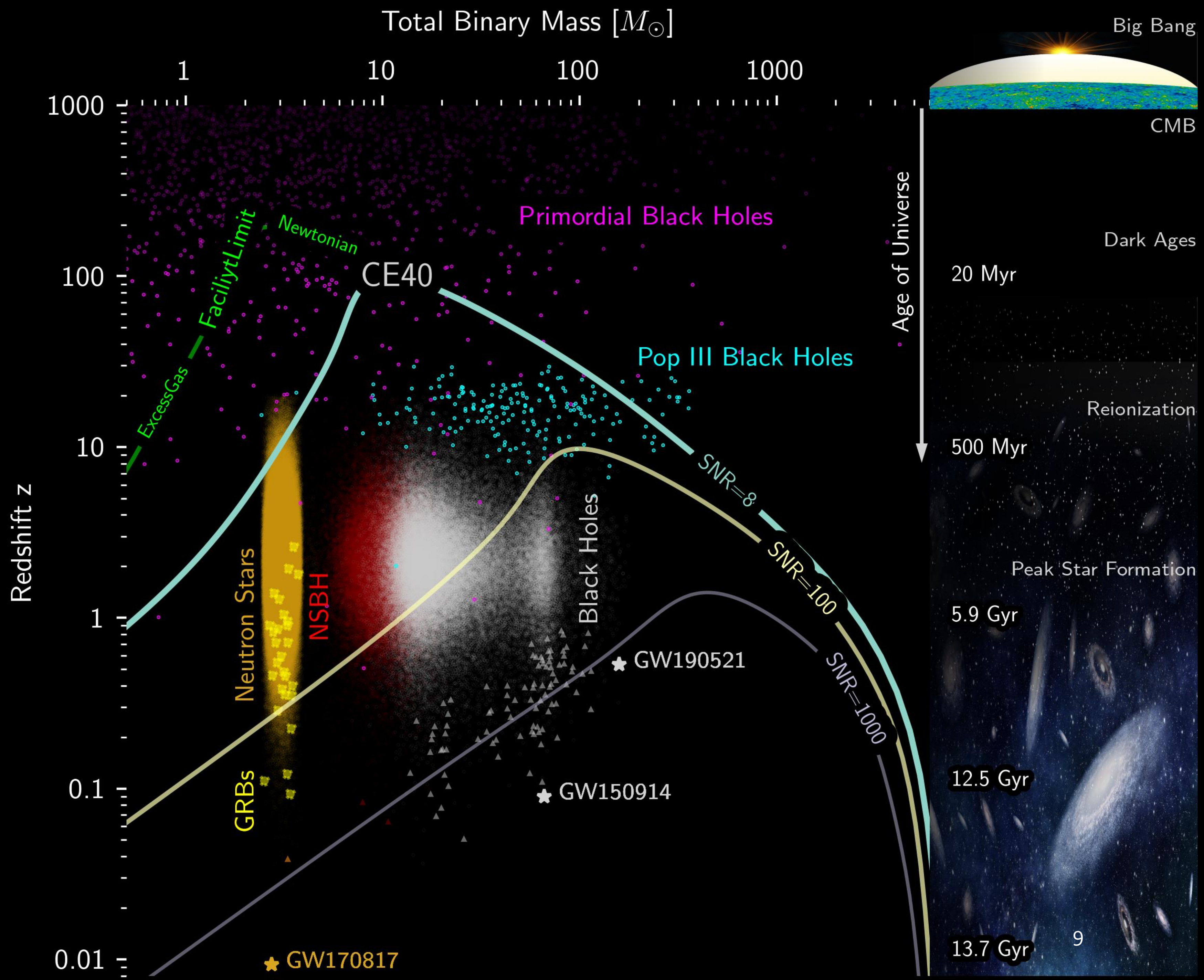




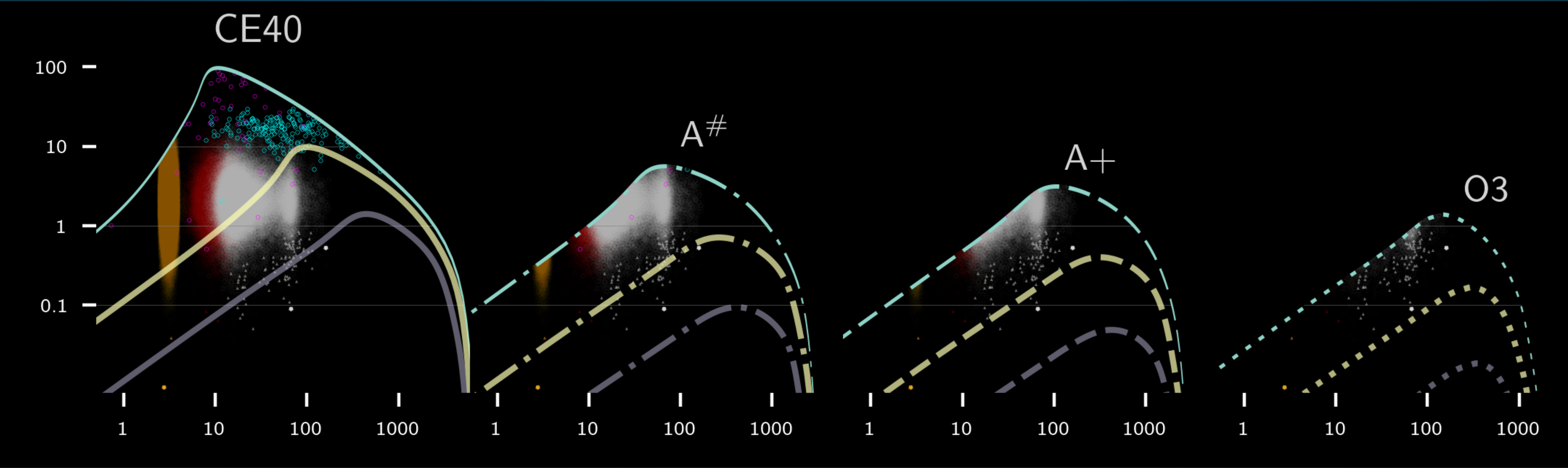
Science Reach

Sensitivity to Black Hole and Neutron Star mergers

From Cosmic Explorer white paper: Evans et al, arXiv:2306.13745

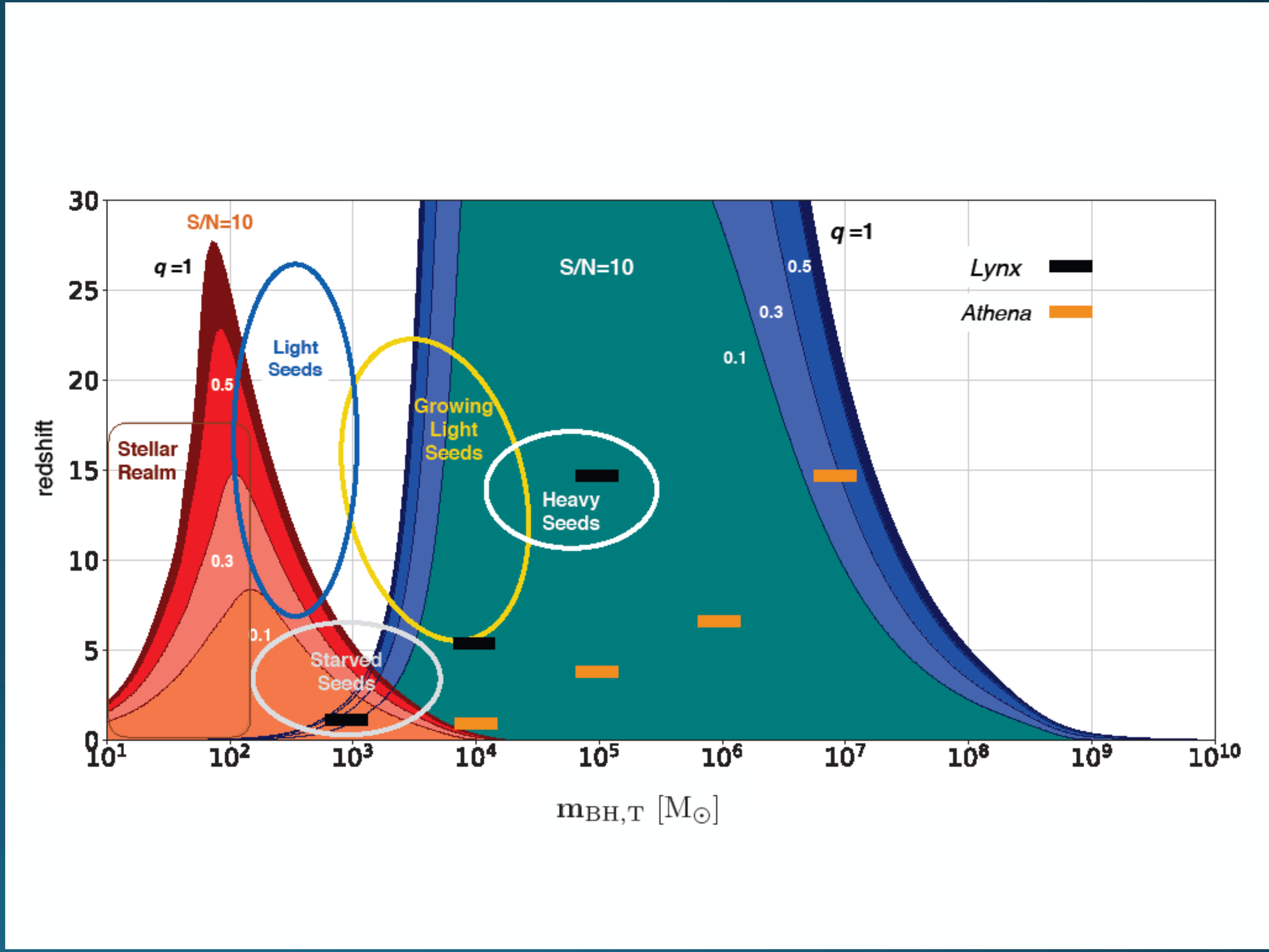


Evolution of detector sensitivity



Seed black holes

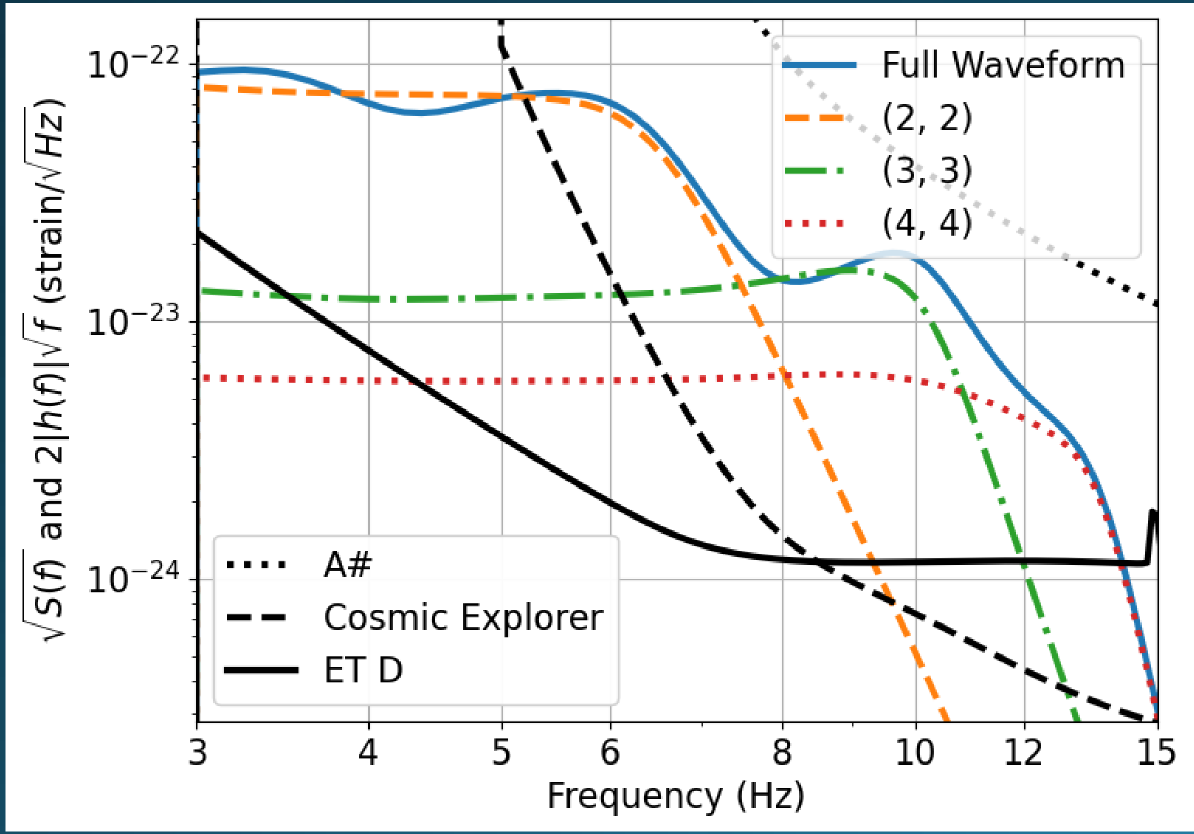
- Quasars observed at redshift z > 7 [less than 1 billion years after the big bang] are powered by black holes with mass > 10^9 $M_\odot$
- Likely population of seed black holes at high redshifts that grow through accretion and mergers to form supermassive black holes
- Light seeds will be observable to next-generation GW observatory
- Challenging to accurately measure masses and redshift

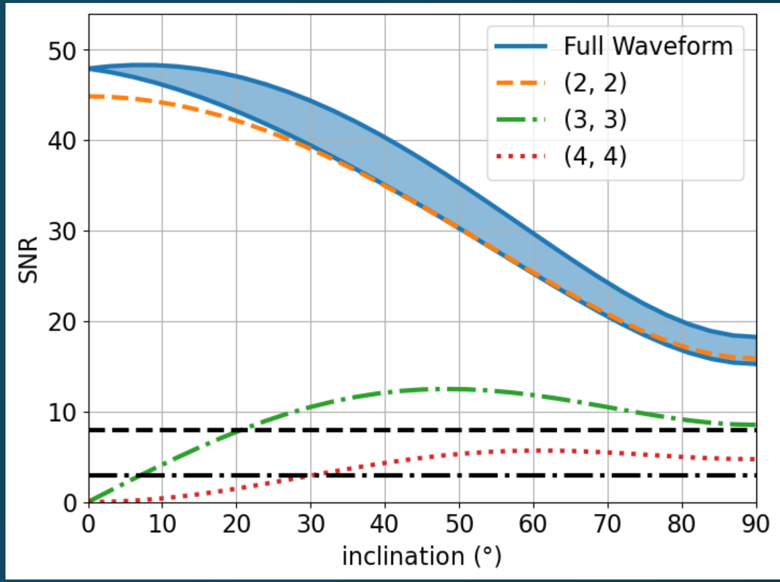


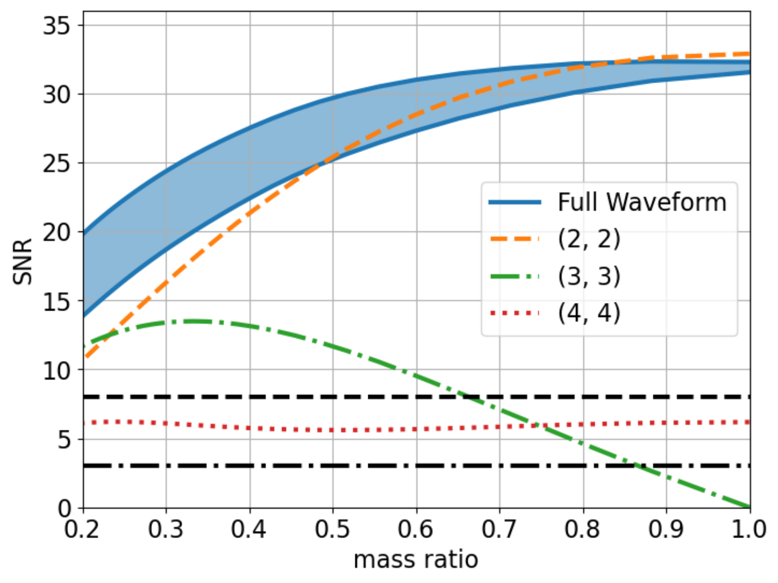
From Valiante et al https://arxiv.org/abs/2010.15096

GW multipoles

- Break distance-orientation degeneracy by measuring additional GW multipoles
- Example: 120-60 $M_\odot$ BBH at z=14

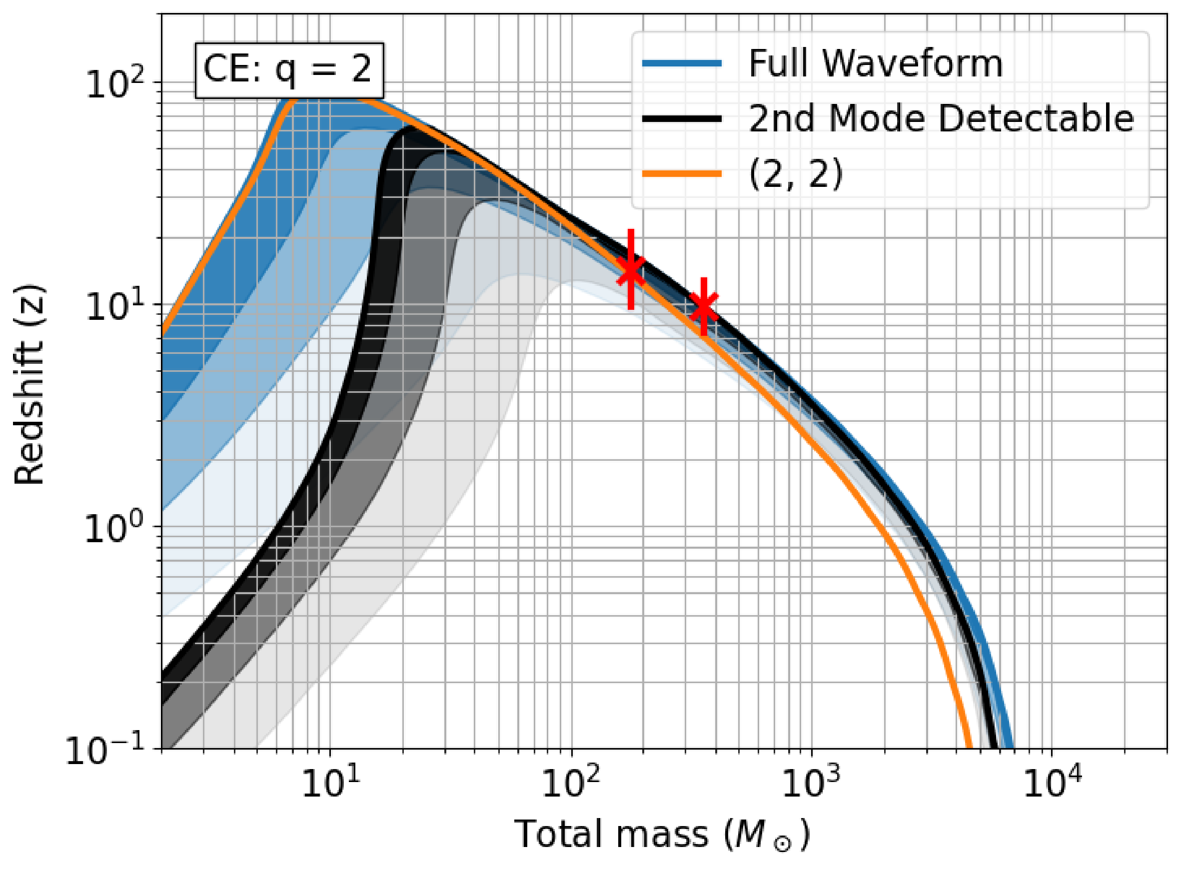


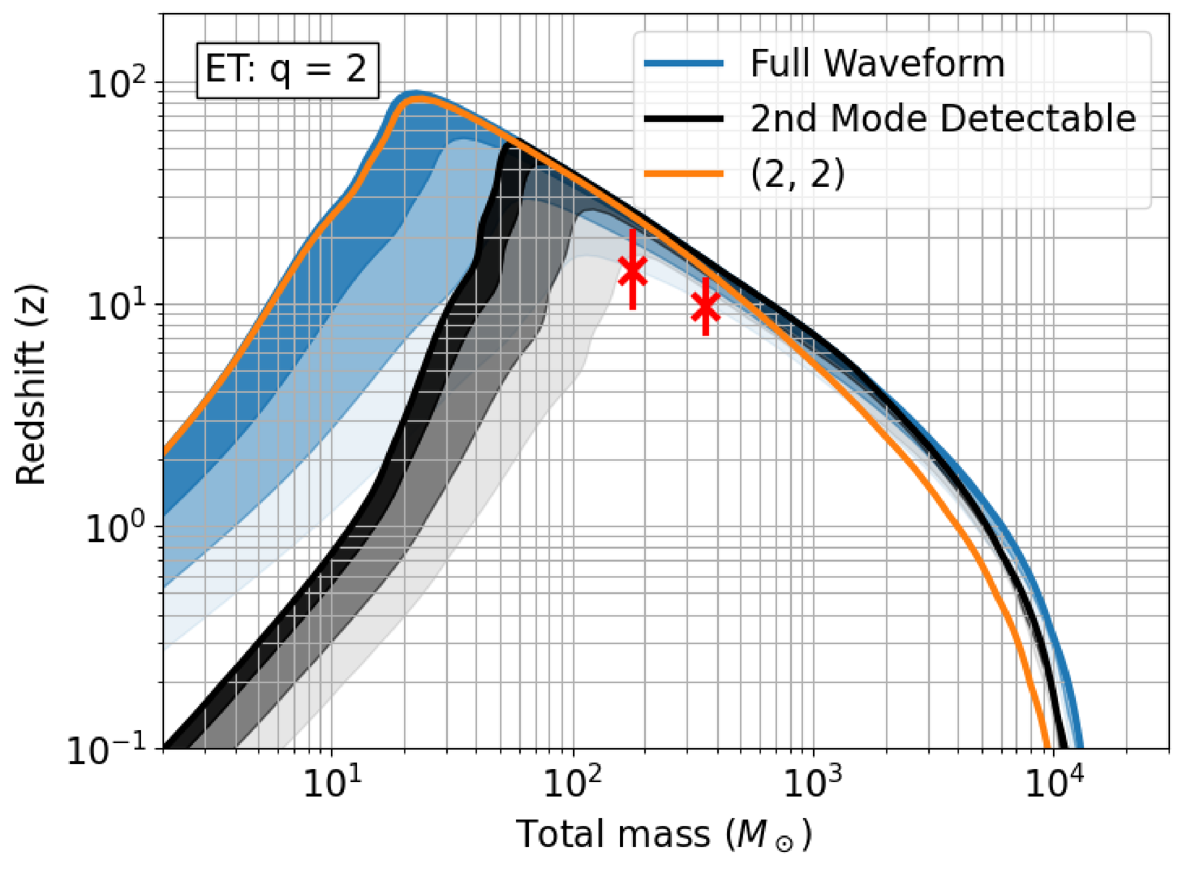




From Fairhurst et al, arXiv: 2310.18158

Observability of GW multipoles



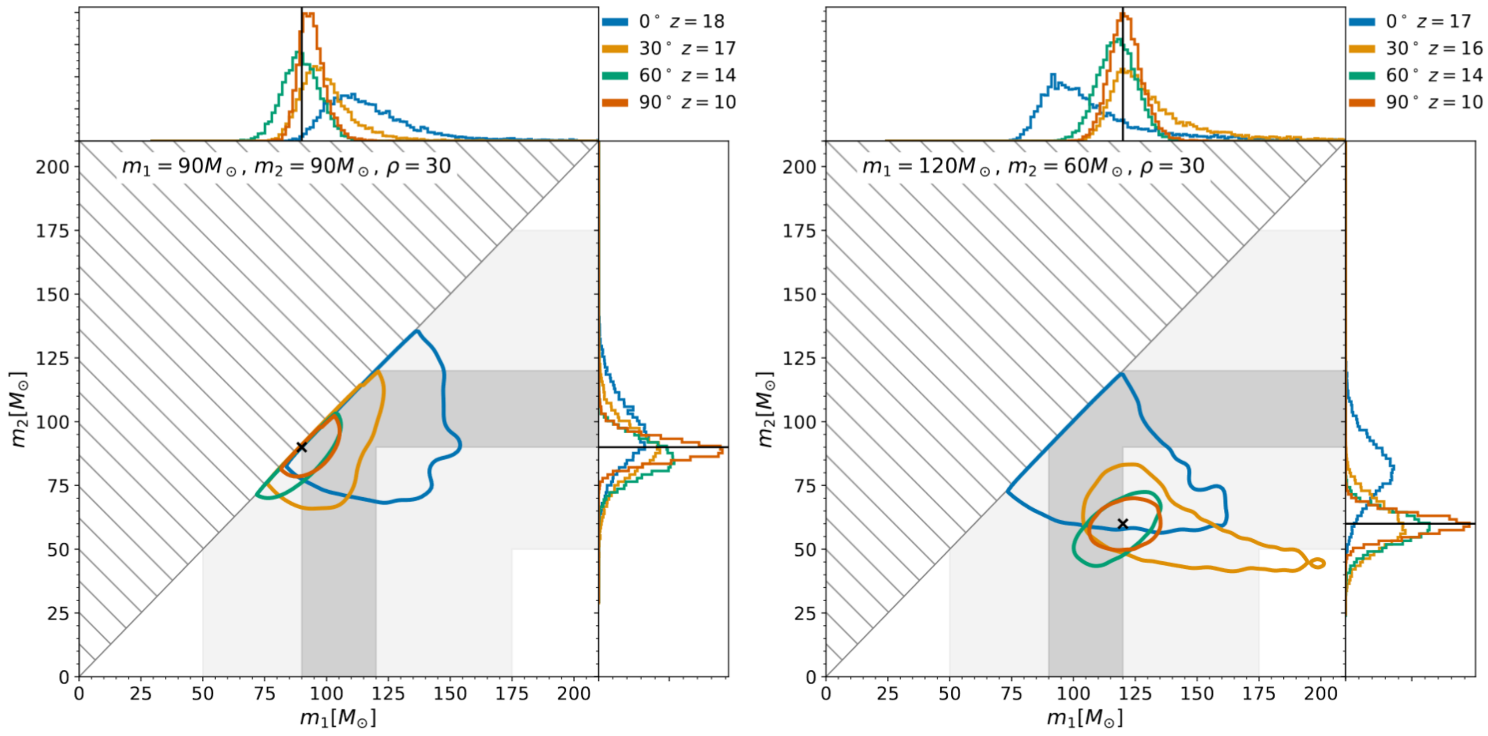


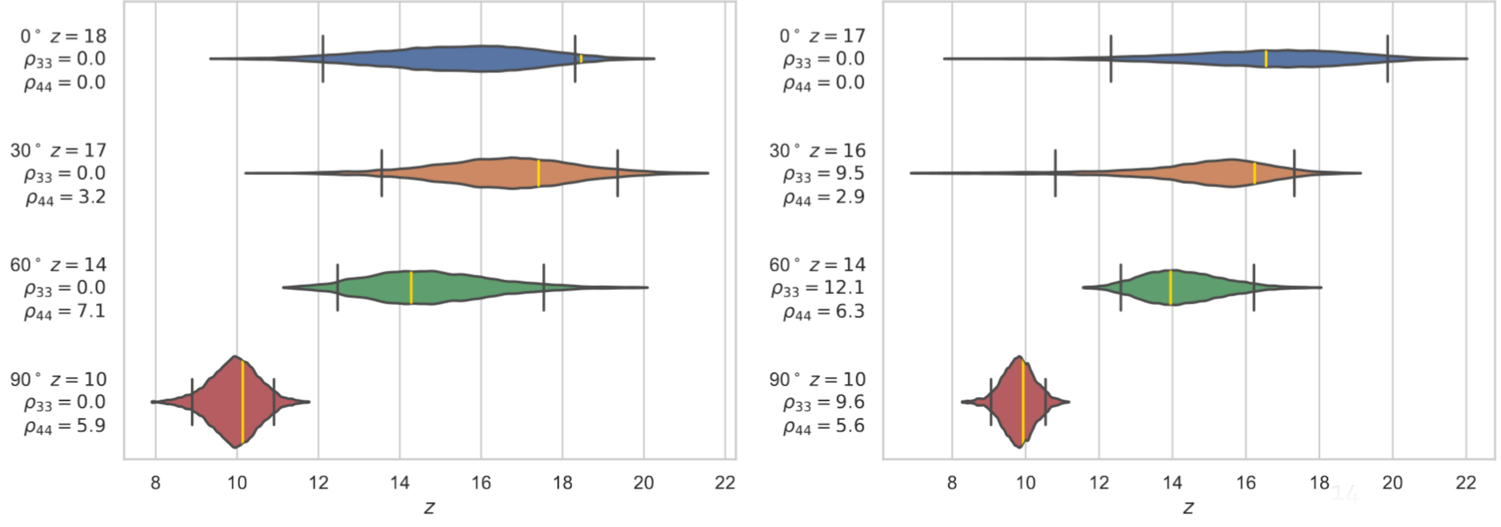
From Fairhurst et al, arXiv: 2310.18158

Observing high-mass, high-z BBH

- Can extract masses and redshift of black holes from GW signals
- Observation would provide evidence for 'light seeds'
- Can also investigate location of BH mass gap

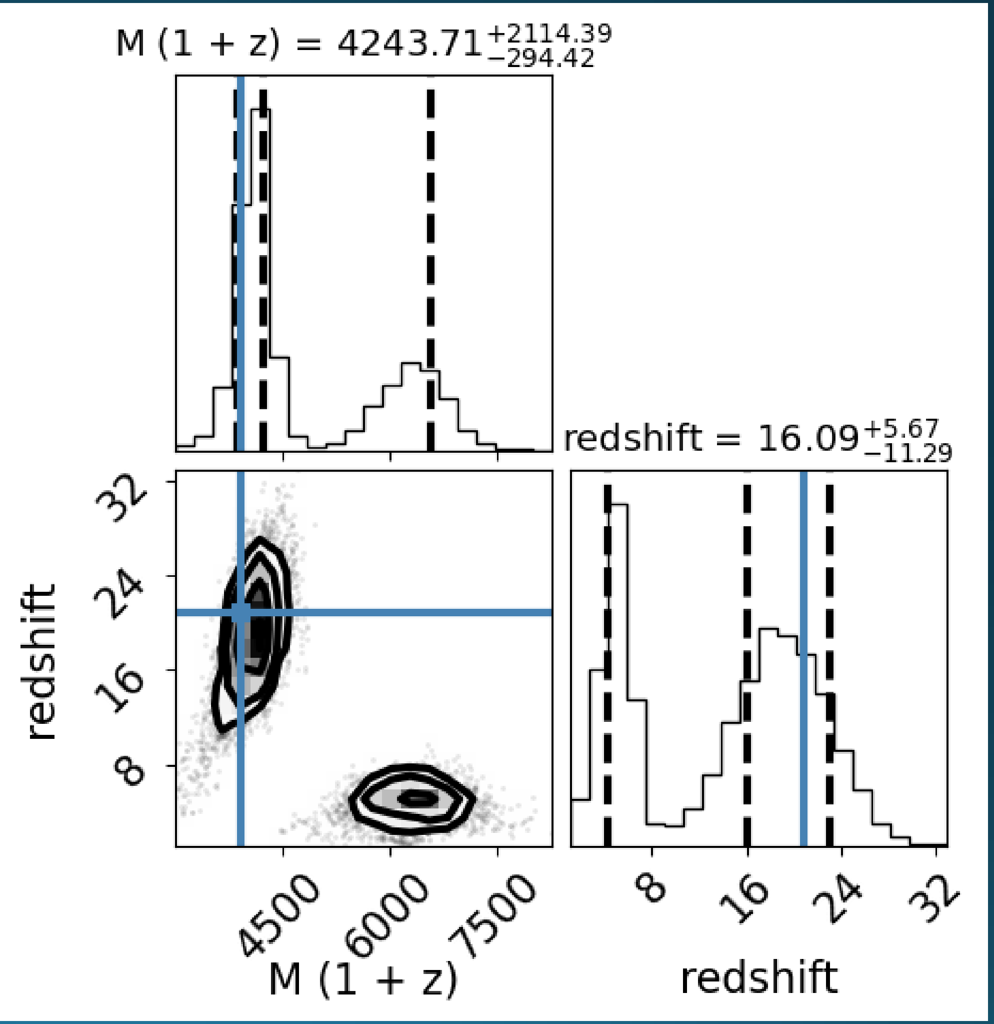
From Fairhurst et al, arXiv: 2310.18158





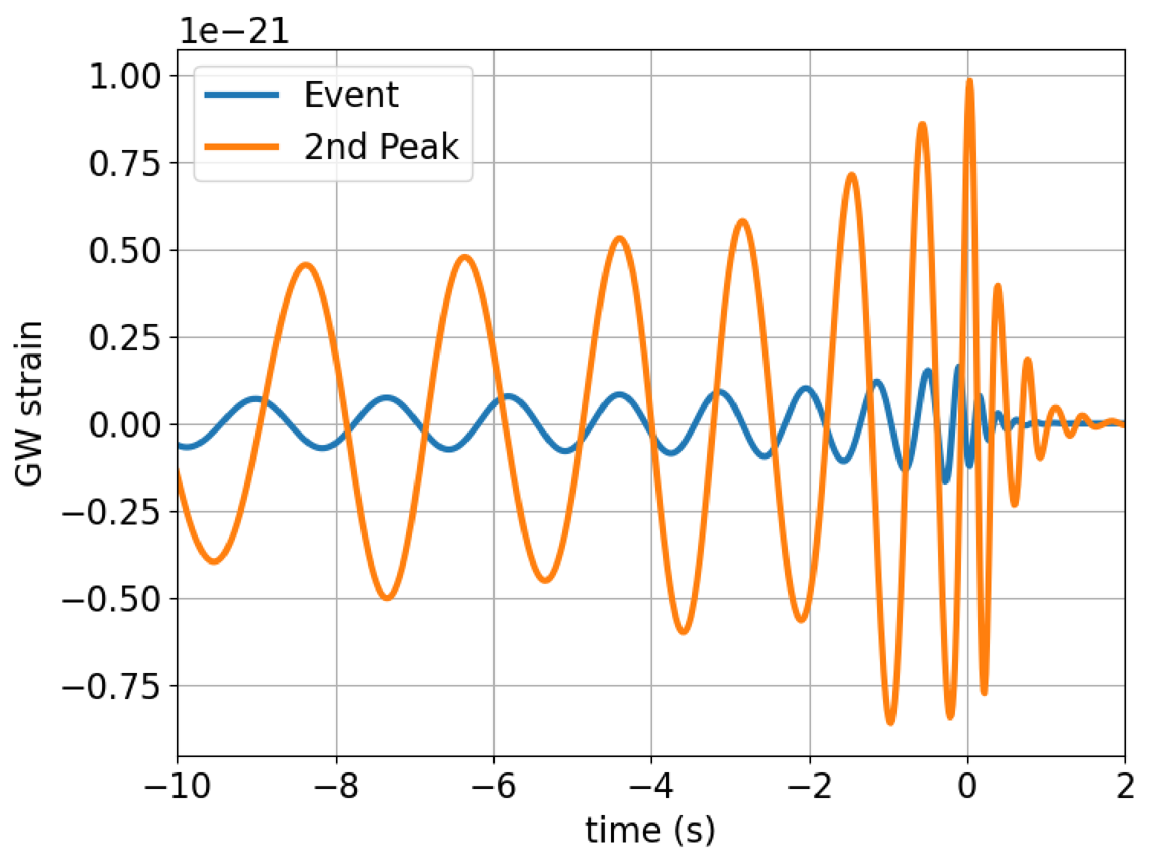
Challenges in Observing high mass BBH

- Example: 120-60 $M_\odot$ BBH at z=21
- Can't accurately measure mass/redshift. Could be
  - (2, 2) mode of 120-60 $M_\odot$ BBH at z=21 or
  - (3,3) mode of 600-300 $M_\odot$ BBH at z=5



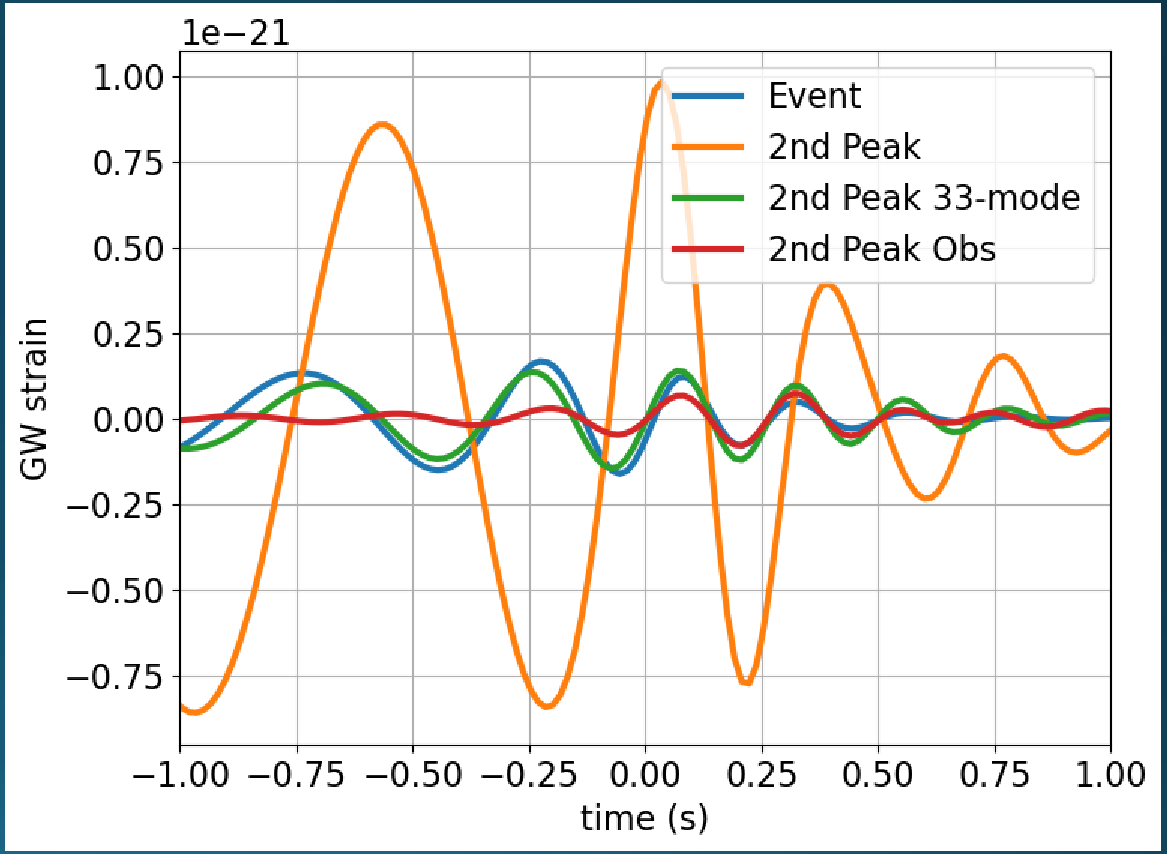
Challenges in Observing high mass BBH

- Example: 120-60 $M_\odot$ BBH at z=21
- Can't accurately measure mass/redshift. Could be
  - (2, 2) mode of 120-60 $M_\odot$ BBH at z=21 or
  - (3,3) mode of 600-300 $M_\odot$ BBH at z=5



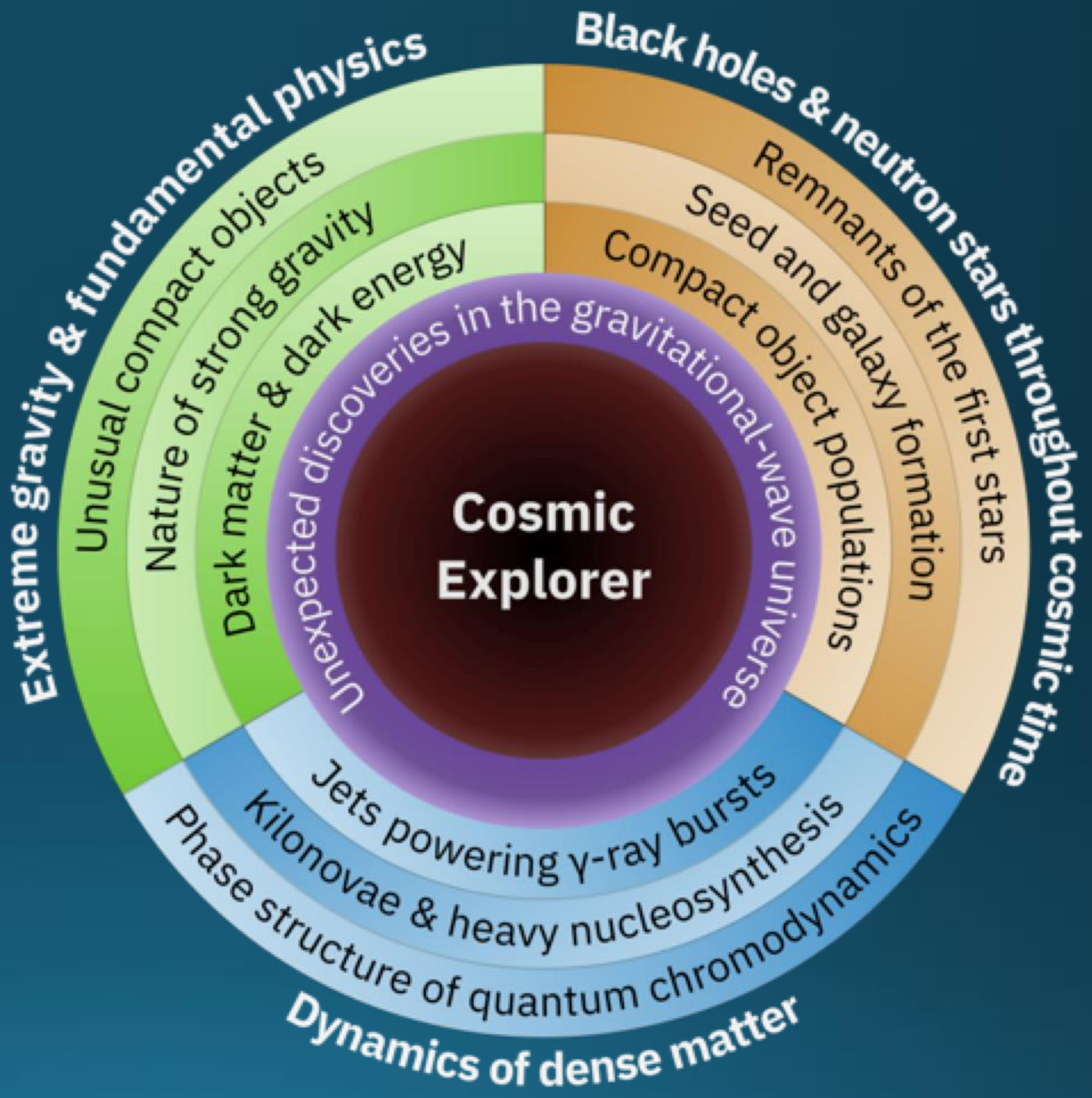
Challenges in Observing high mass BBH

- Example: 120-60 $M_{\odot}$ BBH at z=21
- Can't accurately measure mass/redshift. Could be
  - (2, 2) mode of 120-60 $M_{\odot}$ BBH at z=21 or
  - (3,3) mode of 600-300 $M_{\odot}$ BBH at z=5



Conclusions

- LIGO-Virgo-KAGRA are unveiling the population of neutron stars and black holes
- Next generation gravitational-wave observatories are entering conceptual design phase
- Observatories will provide a unique view of the universe
- Observation of high-mass, high-redshift black holes will provide insights into seed black holes and black hole mass gap
  - Highly dependent on low frequency sensitivity



Evans et al. https://arxiv.org/abs/2109.09882