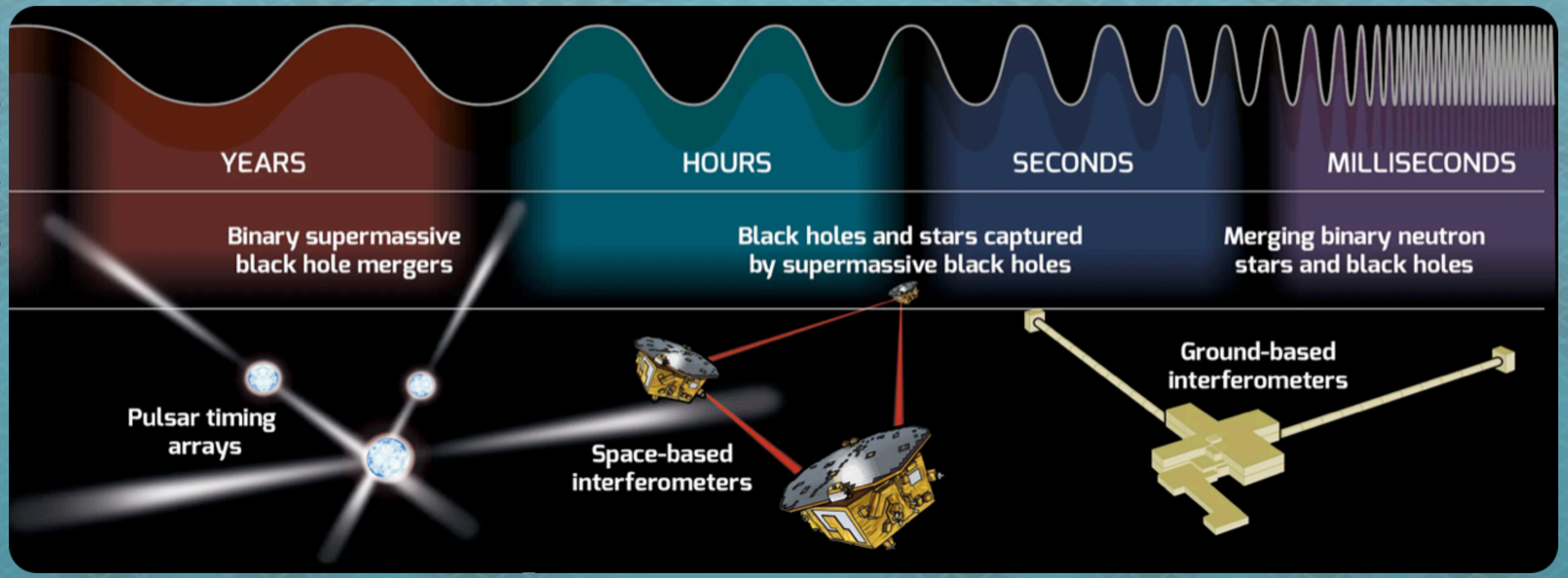
Multi-Messenger Astronomy in the Era of Gravitational Waves

AG du GDR OG - Lyon - 2026

S.D. Vergani

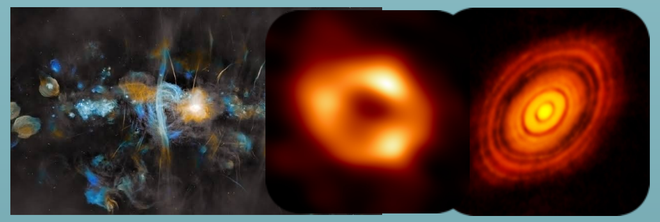


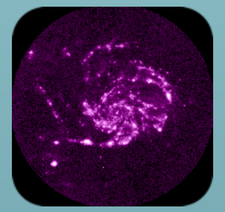
Gravitational Wave Astrophysics



Credits: Ben Gilliland

Multi-wavelength Astrophysics





INFRARED OPTICAL UV X-rays GAMMA




SKAO

ALMA

NASA | ESA | CSA jwst

ROMAN SPACE TELESCOPE

VERA C. RUBIN OBSERVATORY

ULTRASAT Ultraviolet Transient Astronomy Satellite

UVEX

einstein probe 爱因斯坦探针 exploring the dynamic x-ray universe

Swift

SVOM

Fermi Gamma-ray Space Telescope

CTAO

ESO

esa newathena

Multi-messenger astrophysics

Not only

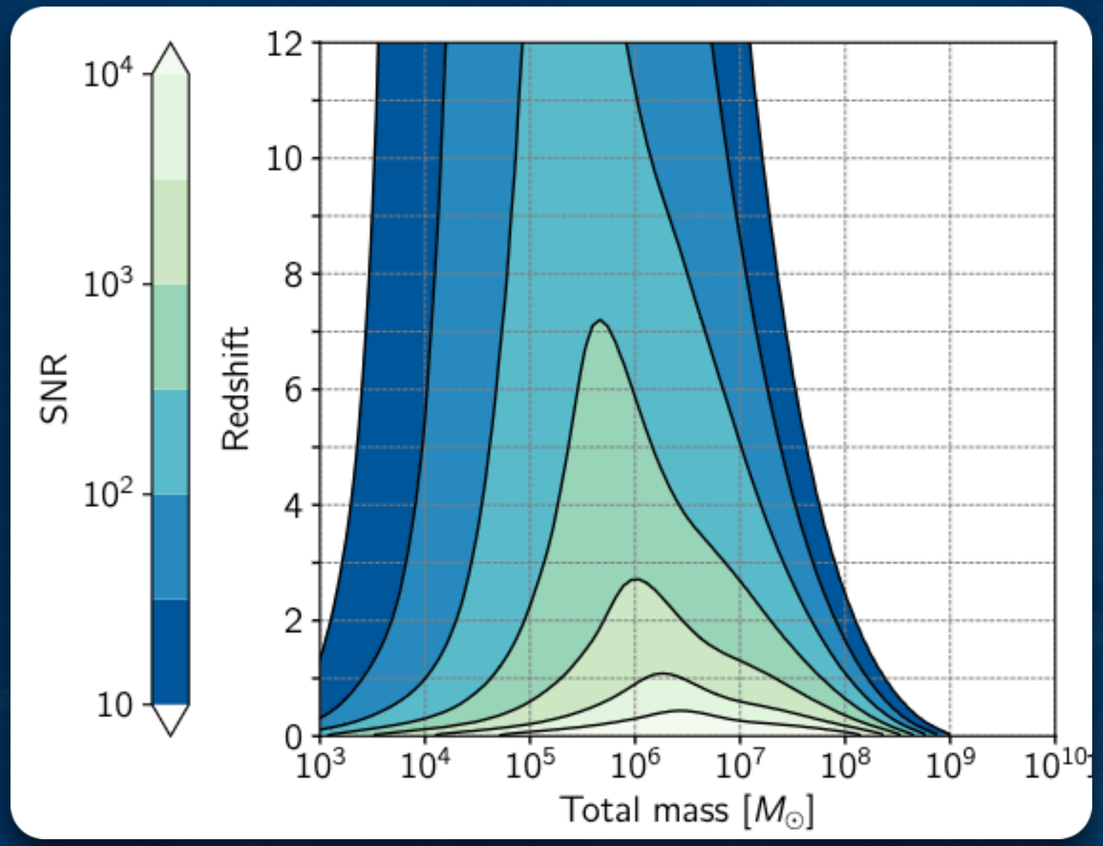
EM and GW detection of the same “event”

but more globally

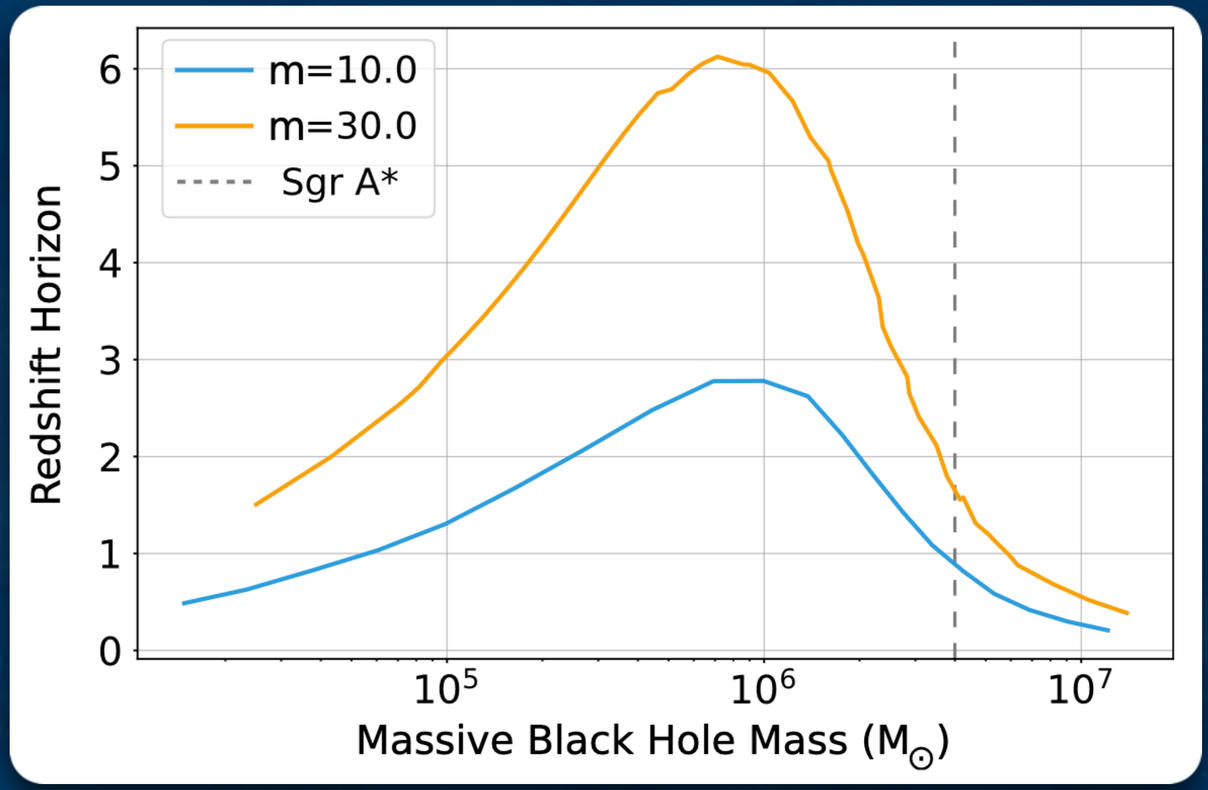
Exploring & Understanding the Universe
with the help of both messengers

Gravitational Wave Astrophysics: LISA

MBH

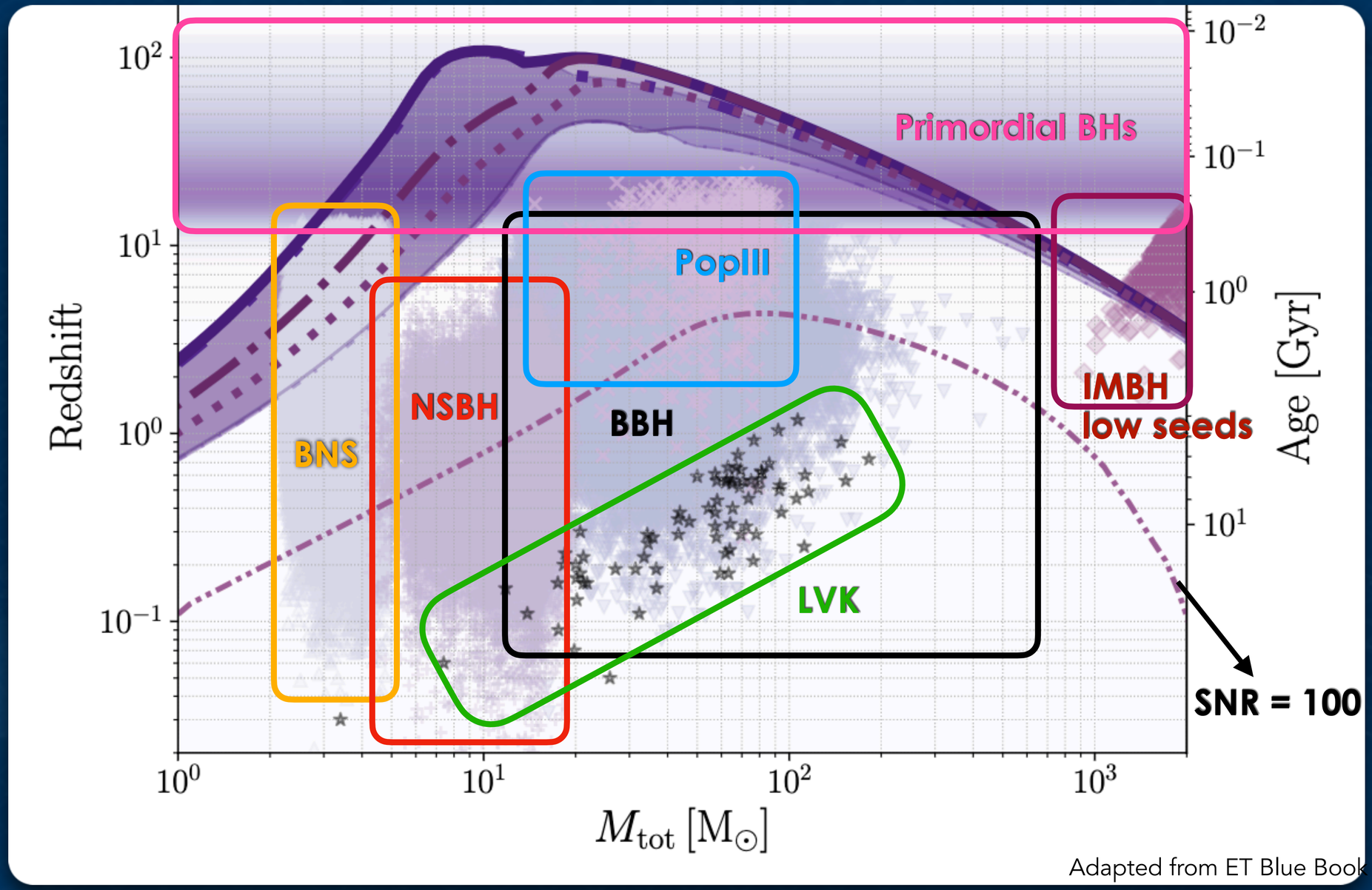


EMRI



LISA DSR 2023

Gravitational Wave Astrophysics: ET

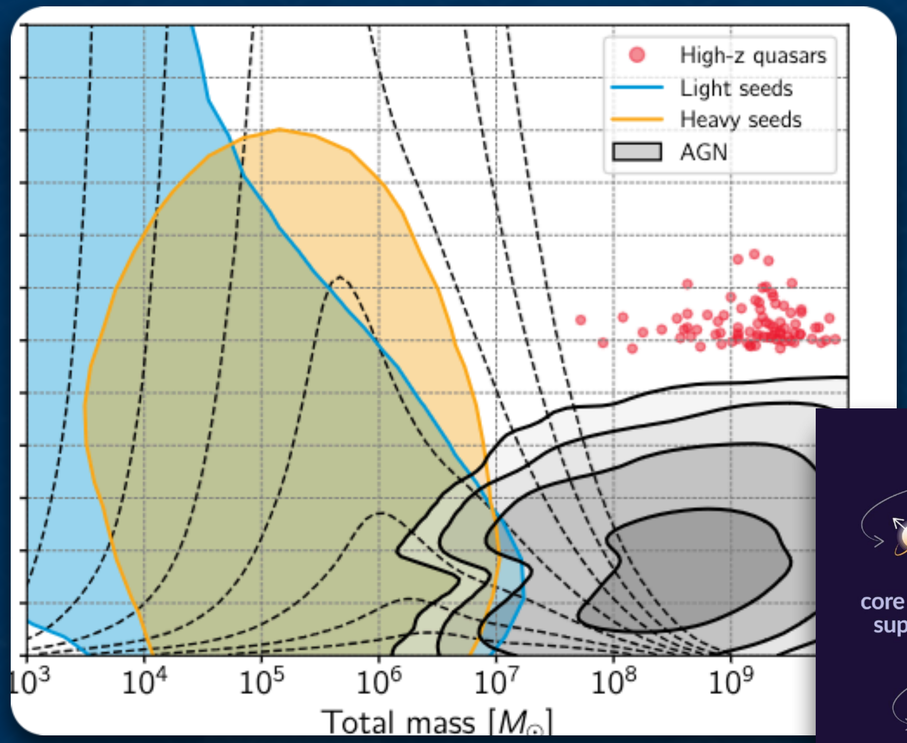


ET Blue book arXiv:2503.12263

Adapted from ET Blue Book

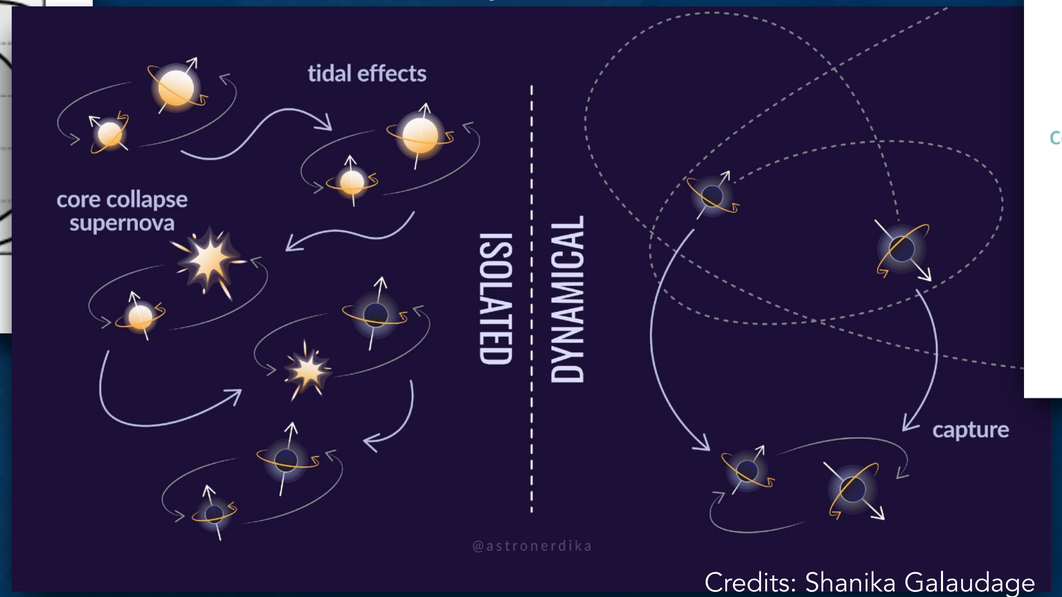
Formation & evolutionary channels

How were MBHs born and how did they grow?



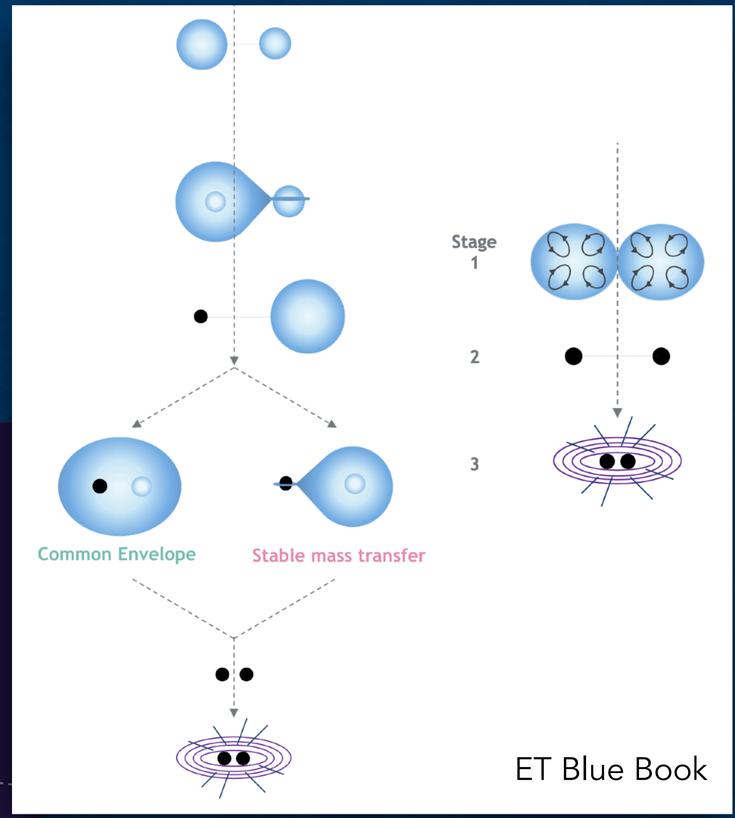
LISA DSR 2023

Isolated vs Dynamical channels



Credits: Shanika Galaudage

Common envelope vs Chemical Homogeneous Evolution



ET Blue Book

Multi-messenger astrophysics

- What are the properties of primordial BH (mass, spin, evolution,…)?
- What are the properties of PopIII stars?
- How was the Universe enriched of heavy elements?
- How do galaxies evolves?
- Cosmological constants
- …?

Multi-messenger astrophysics

EM will be the bottleneck!

Not only

EM and GW detection of the same “event”

but more globally

Exploring & Understanding the Universe
with the help of both messengers

EM counterparts

Can I potentially detect it?

Distance —> faintness

sensitivity

Can I detect it?

Error region

Telescope reaction

Telescope time

Large FoV

Am I able to identify it?

Distance —> larger volume —> more numerous

Distance —> faintness —> more numerous

Error region —> more numerous

sensitivity

Large FoV

Telescope time

Multi-wavelength

Spectroscopy

Models

Multi-object

Catalogues

Am I able to study it?

Distance —> faintness

sensitivity

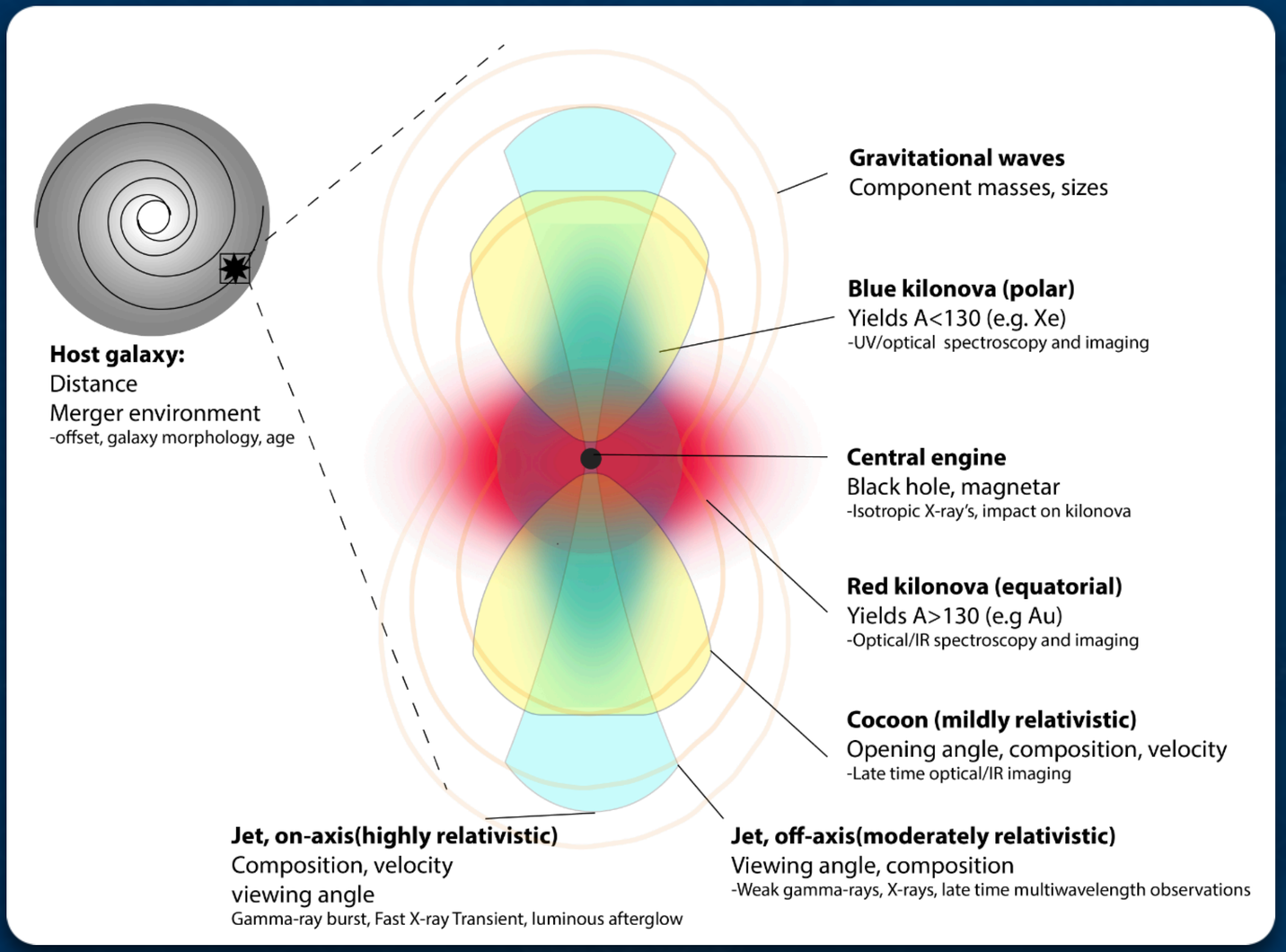
Telescope time

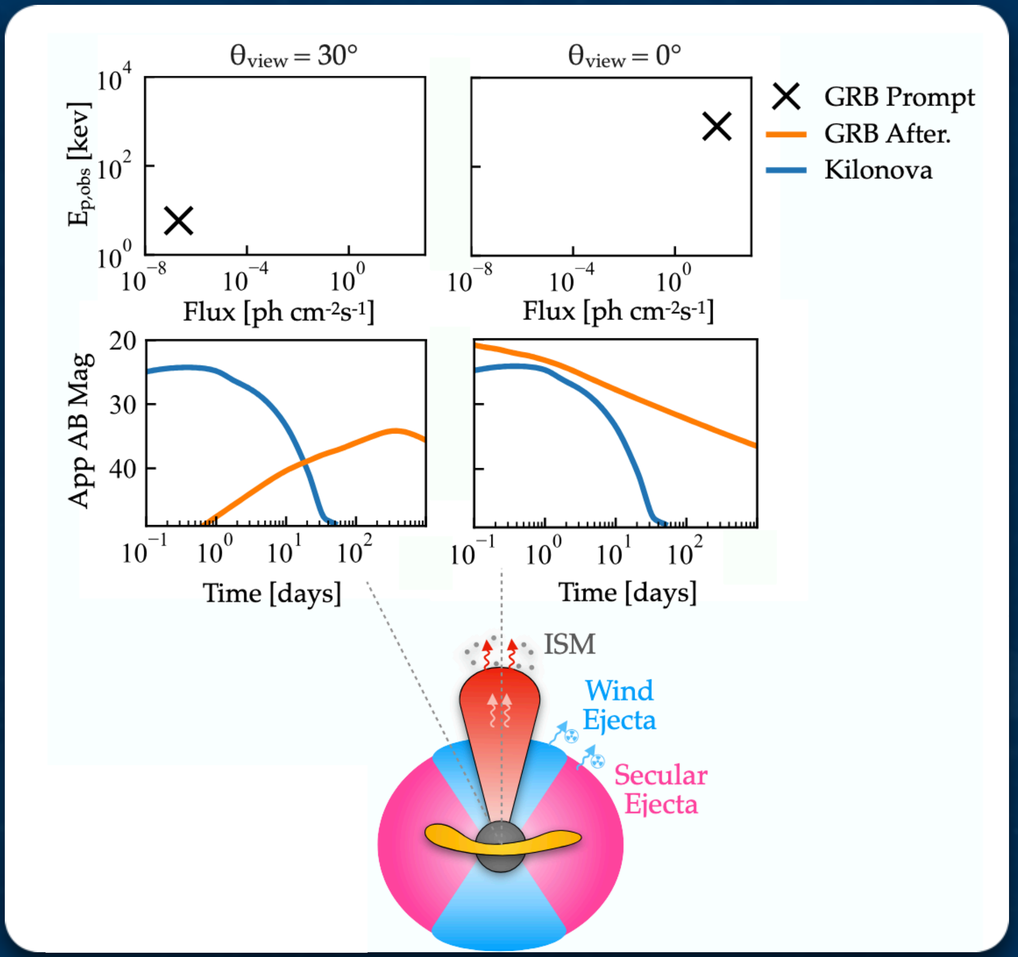
Models

Spectroscopy

Multi-wavelength

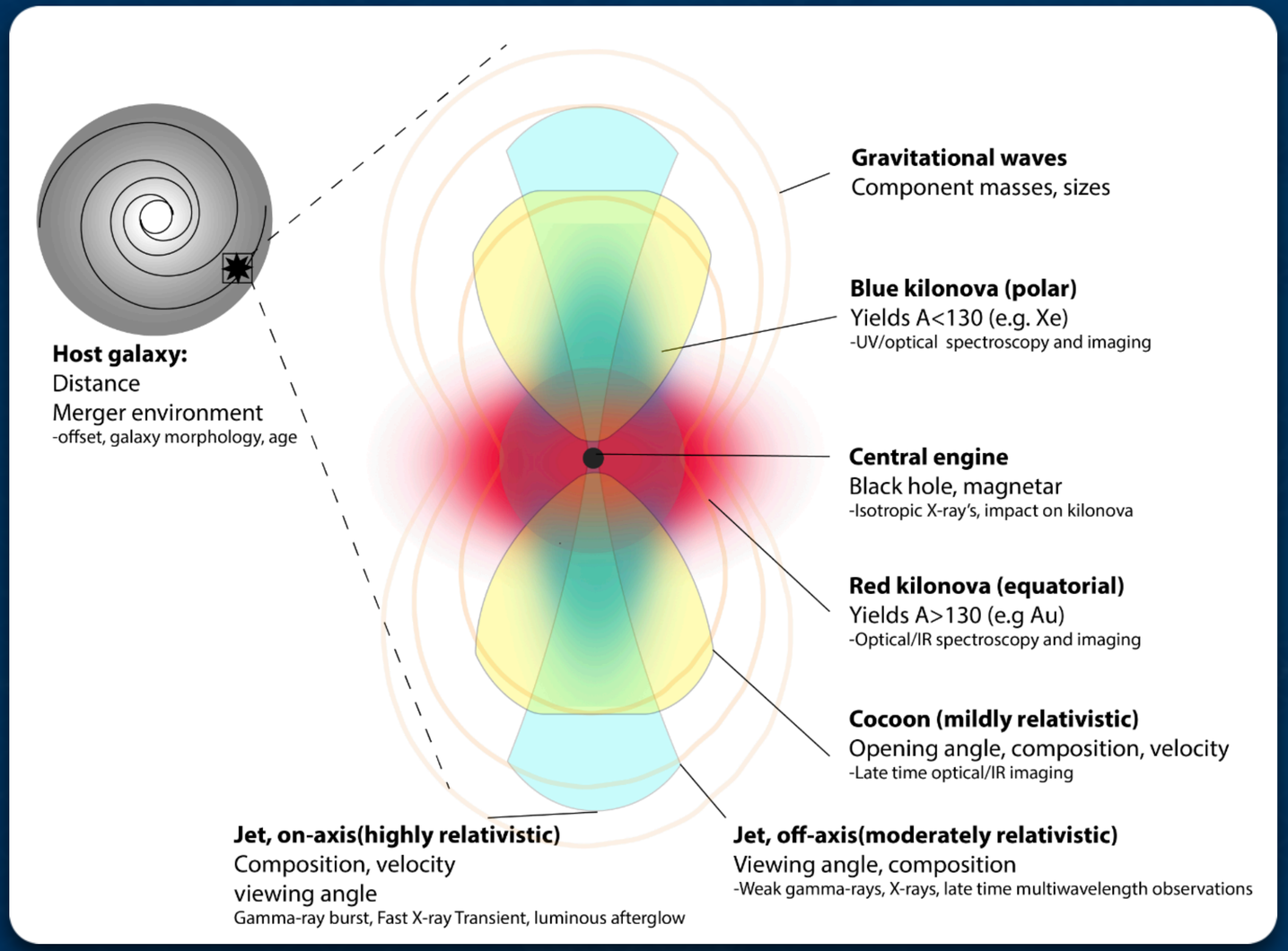
GW & EM BNS (and NSBH) mergers

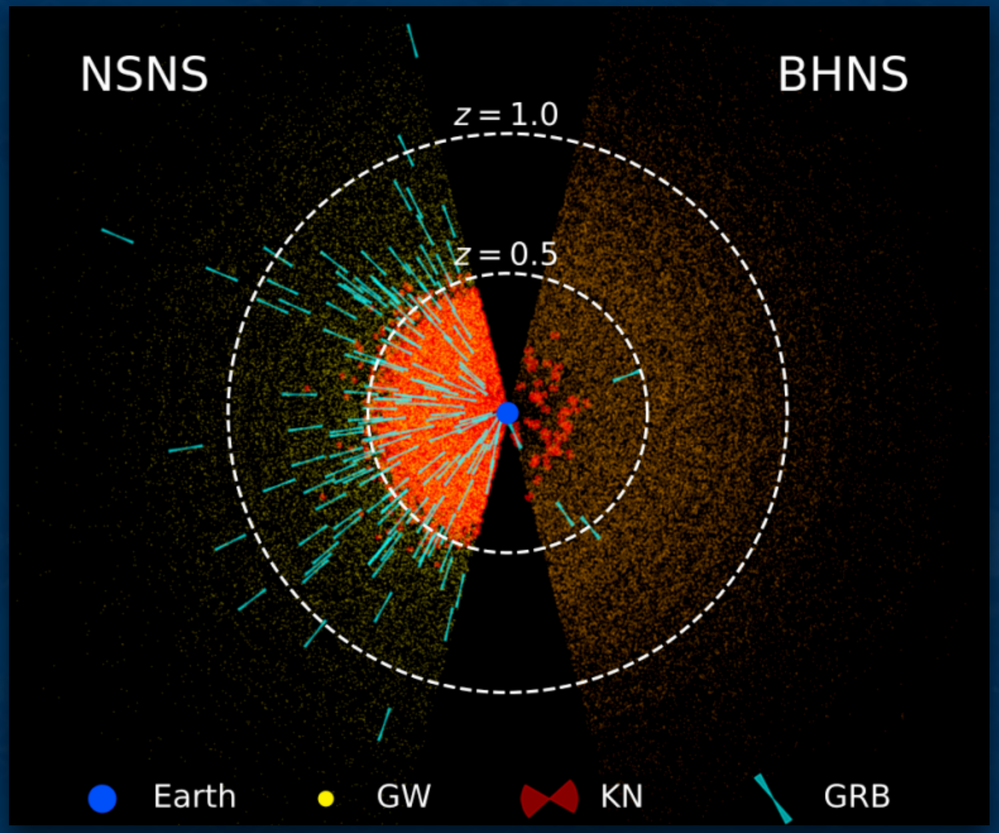




ET Blue book arXiv:2503.12263

GW & EM BNS (and NSBH) mergers

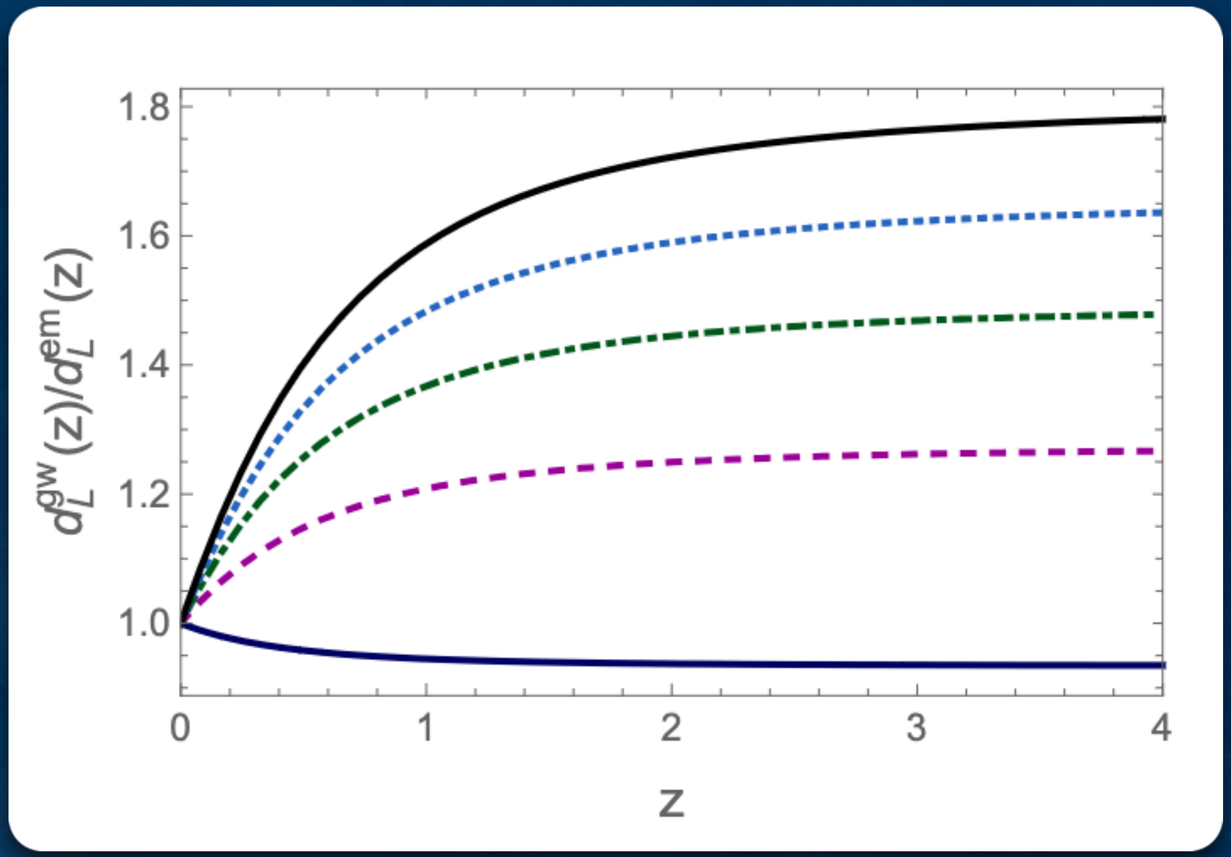




ET Blue book arXiv:2503.12263

Cosmology : modified gravity

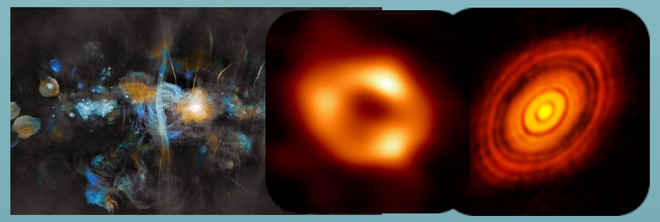


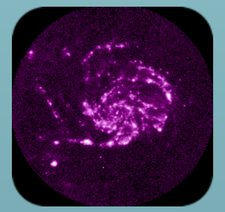


ET Blue book arXiv:2503.12263

Even 1 event at high-z can discriminate!

Electromagnetic Astrophysics





INFRARED OPTICAL UV X-rays GAMMA



SKAO

ALMA

NASA | ESA | CSA

jwst

ROMAN SPACE TELESCOPE

VERA C. RUBIN OBSERVATORY



ULTRASAT
Ultraviolet Transient Astronomy Satellite

UVEX

einstein probe 爱因斯坦探针
exploring the dynamic X-

SVOM

Fermi Gamma-ray Space Telescope

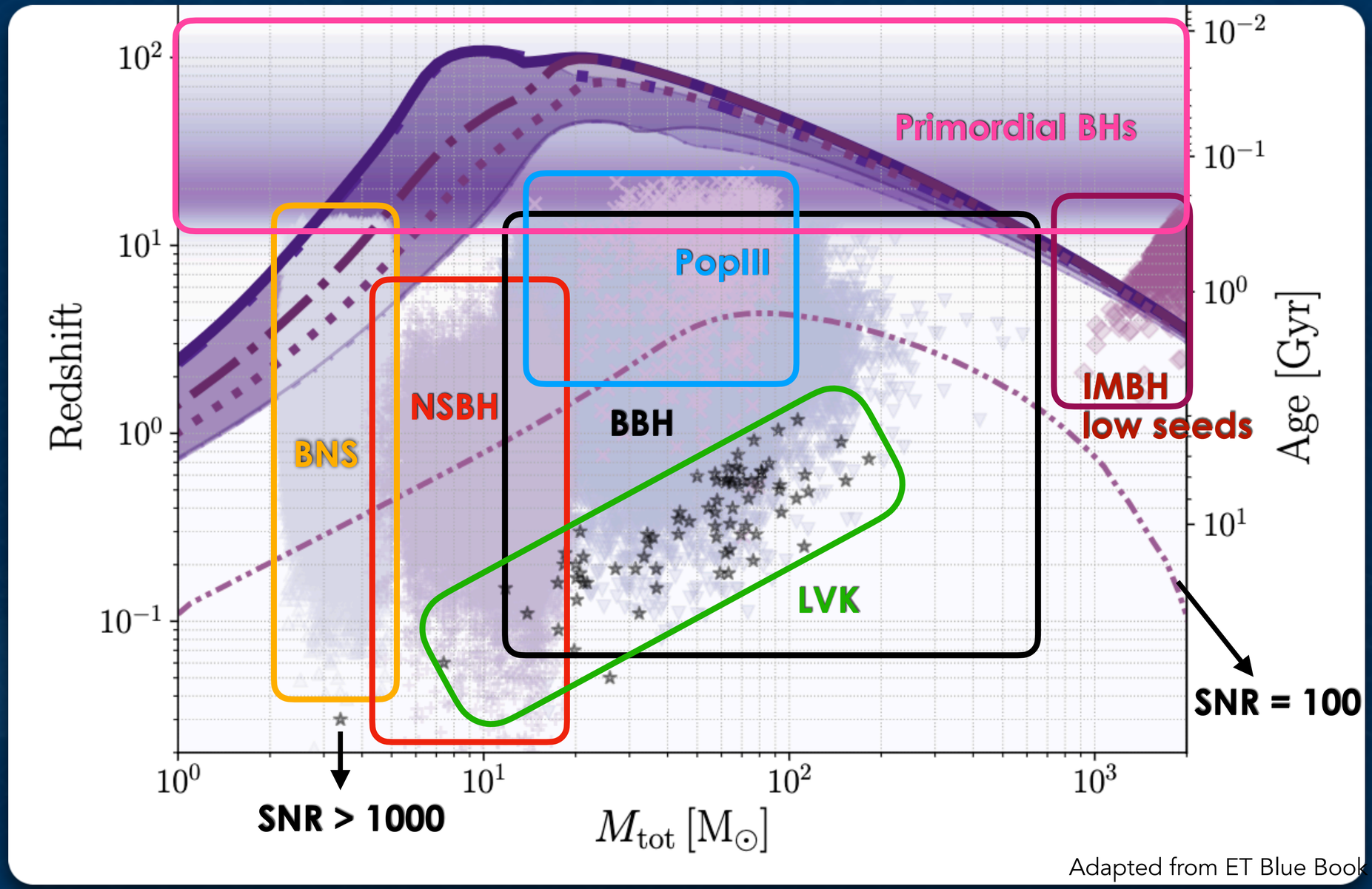
CTAO

ESO

esa newathena

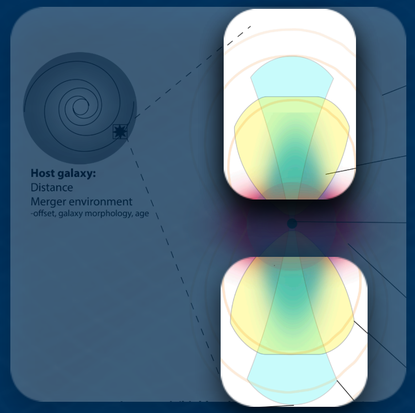


Gravitational Wave Astrophysics: ET



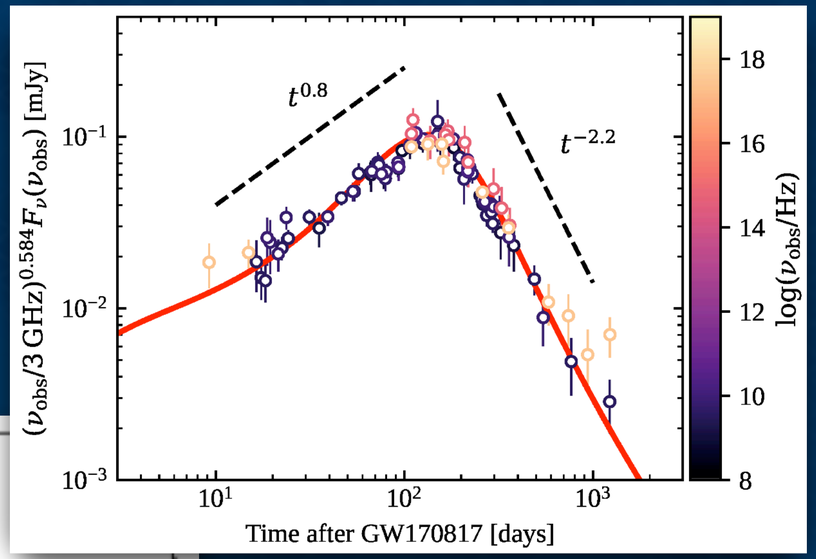
Adapted from ET Blue Book

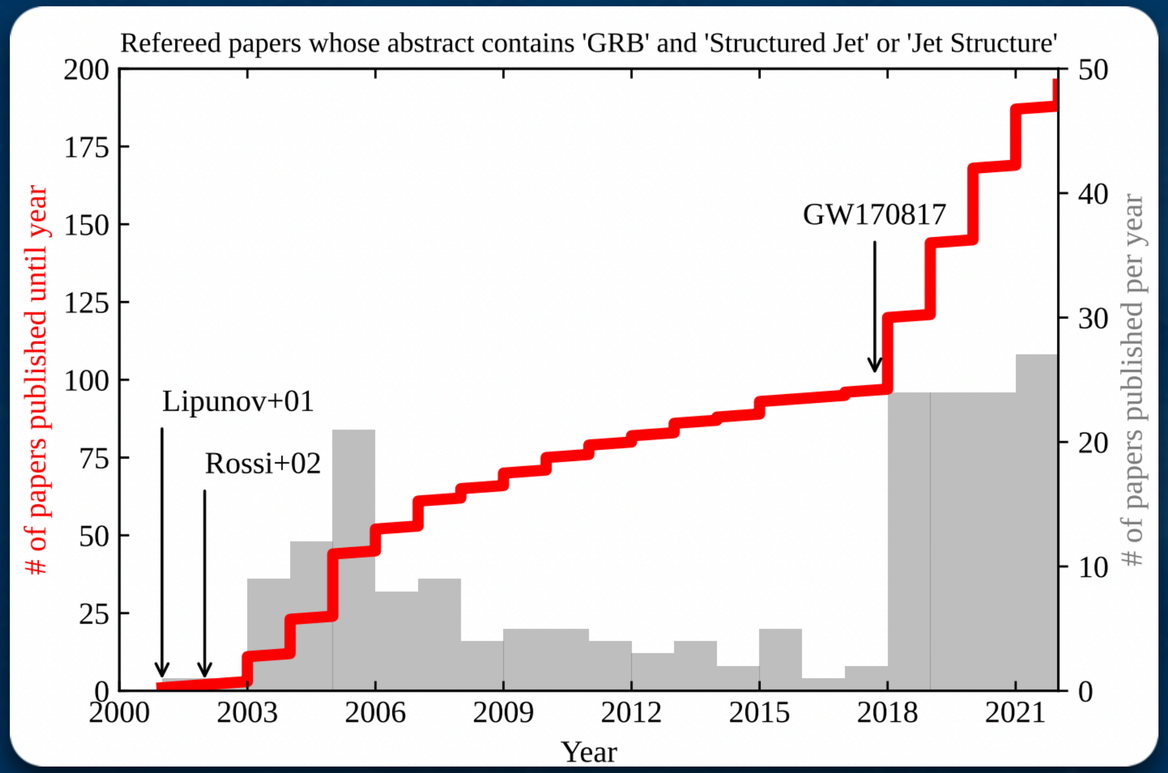
Jets



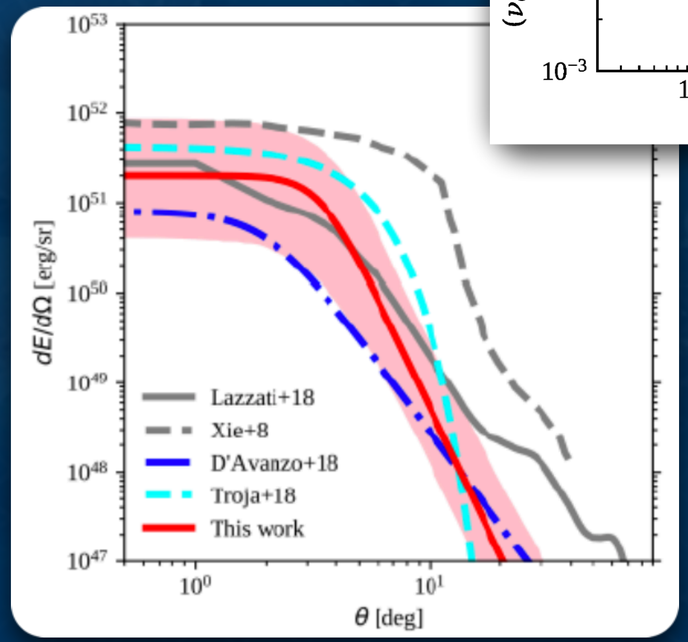
- What is the structure of BNS merger jets?
- How do jets expand in the BNS environments?
- How are afterglows produced?

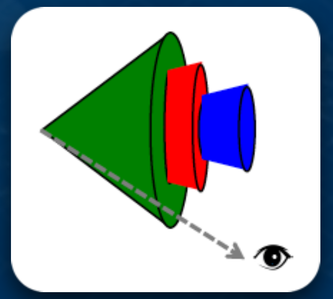
Off-axis GRB afterglow





Salafia+22

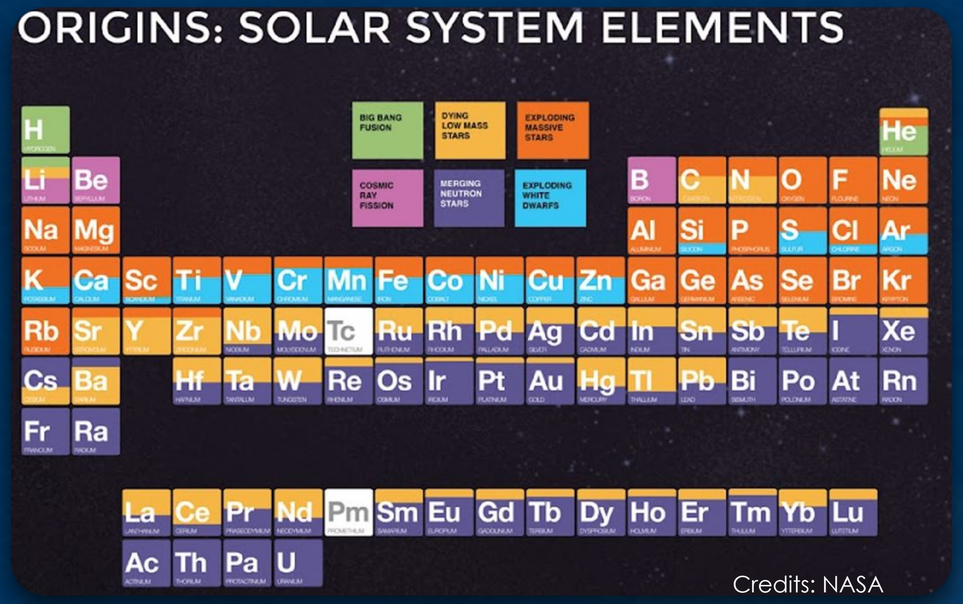


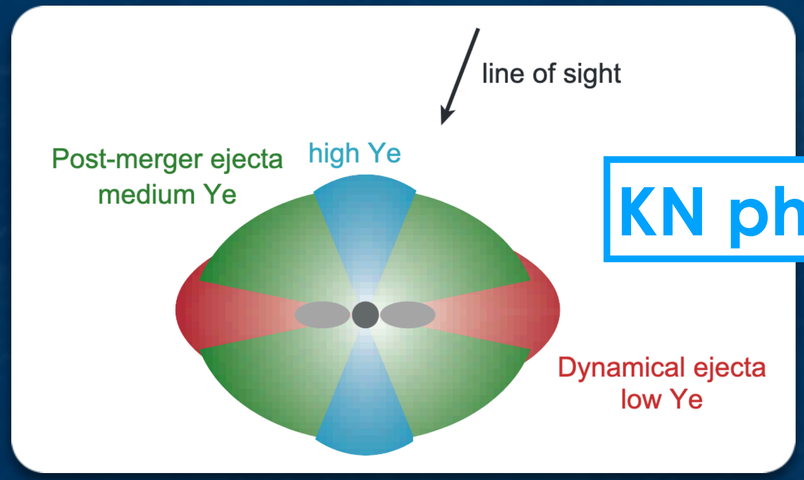


Ghirlanda et al. 2019

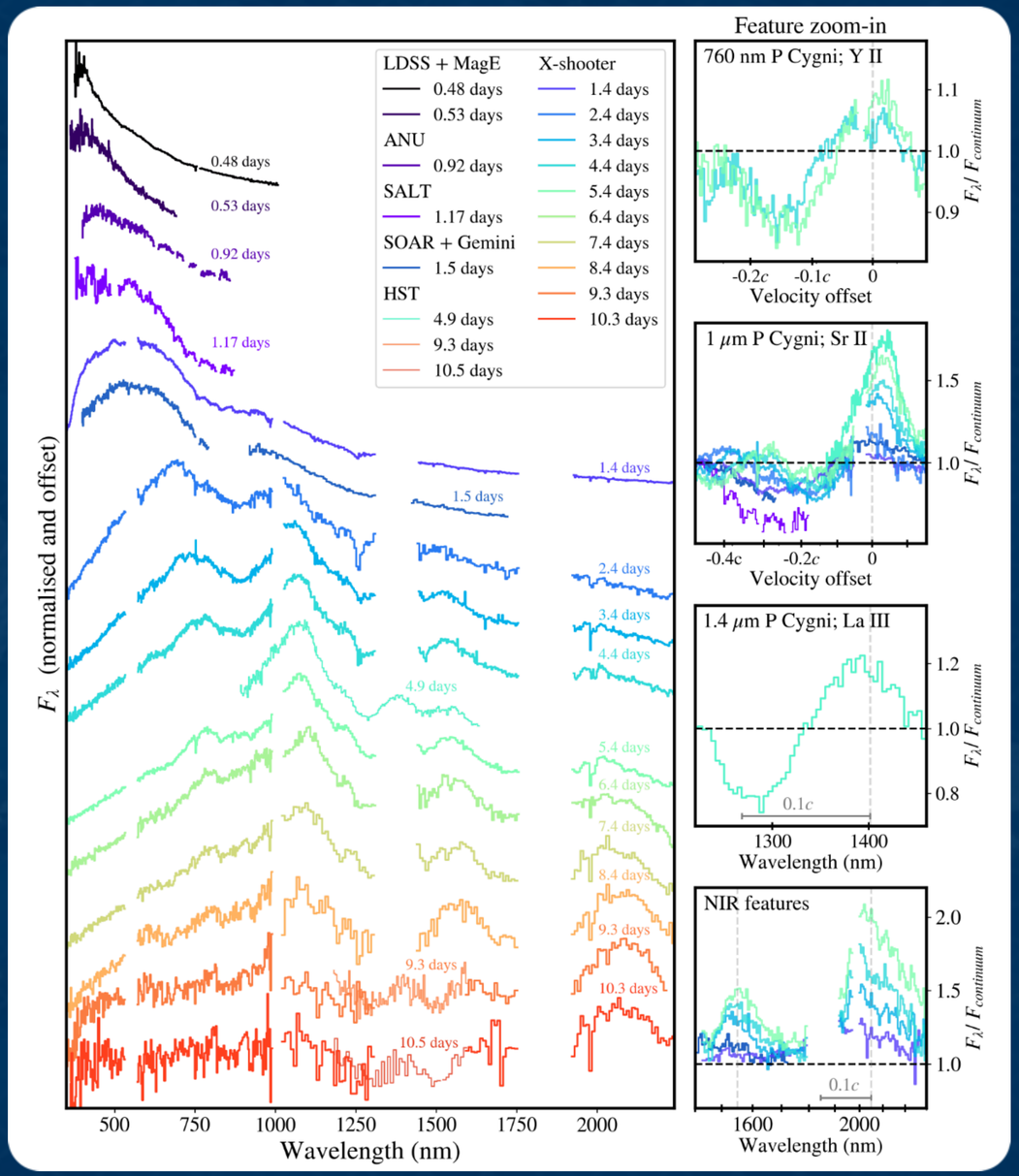
Kilonova







KN physics

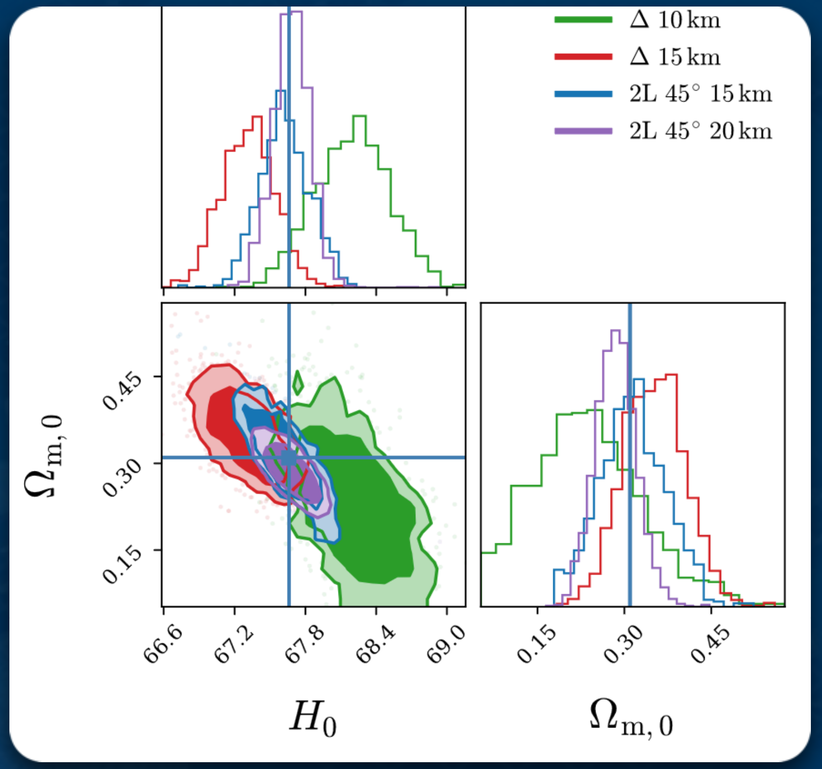


Sneppen et al., see also Pian et al. Gillanders et al. Hotokezaka et al,...



Cosmology : H_0

< 2% precision with ~50 events in total



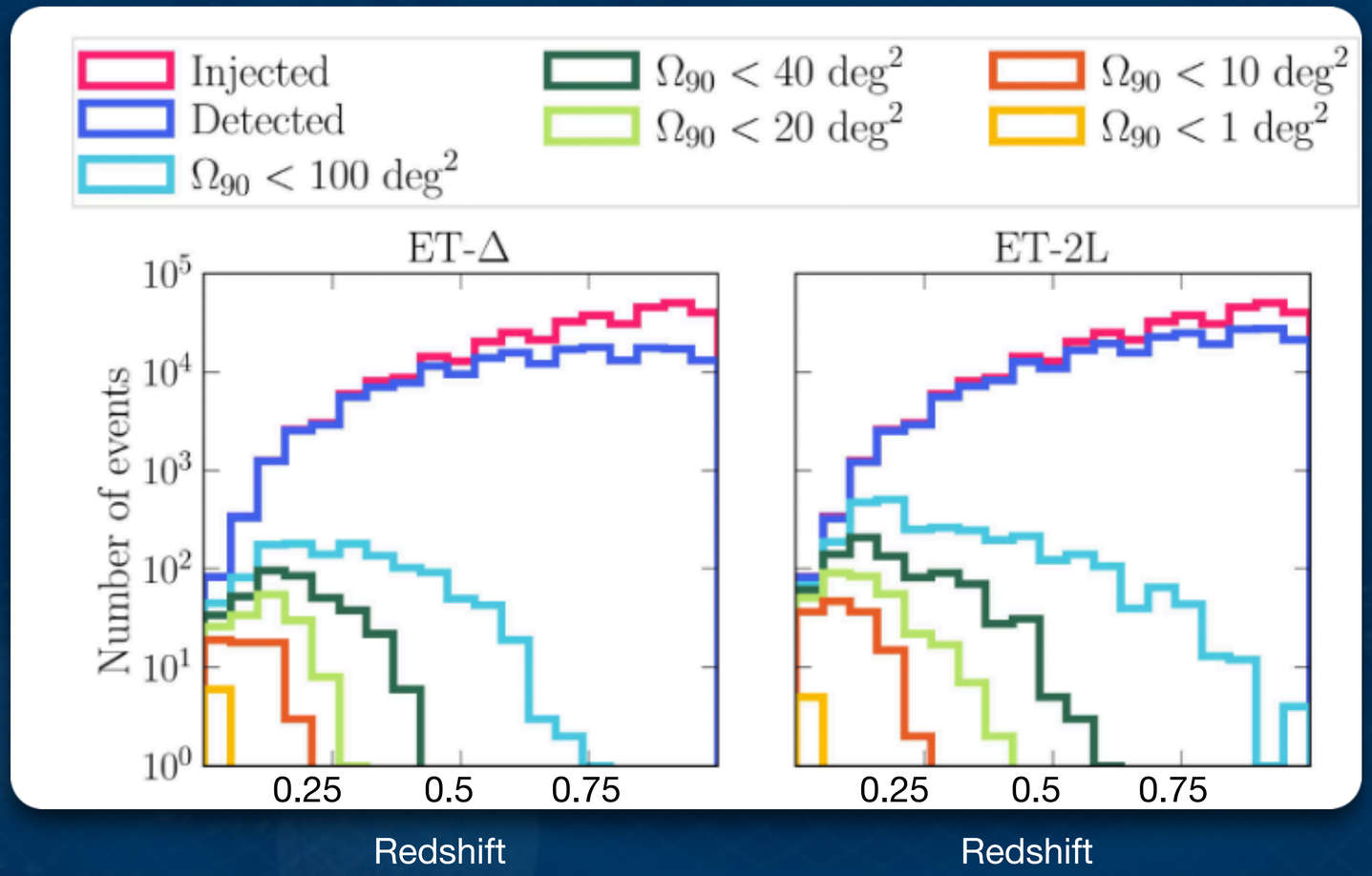
~40 events per year with redshift

Configuration	$\Delta H_0/H_0$
Δ-10km	0.009
Δ-15km	0.007
2L-15km-45°	0.006

Branchesi et al. 2023

GW & EM BNS (and NSBH) mergers

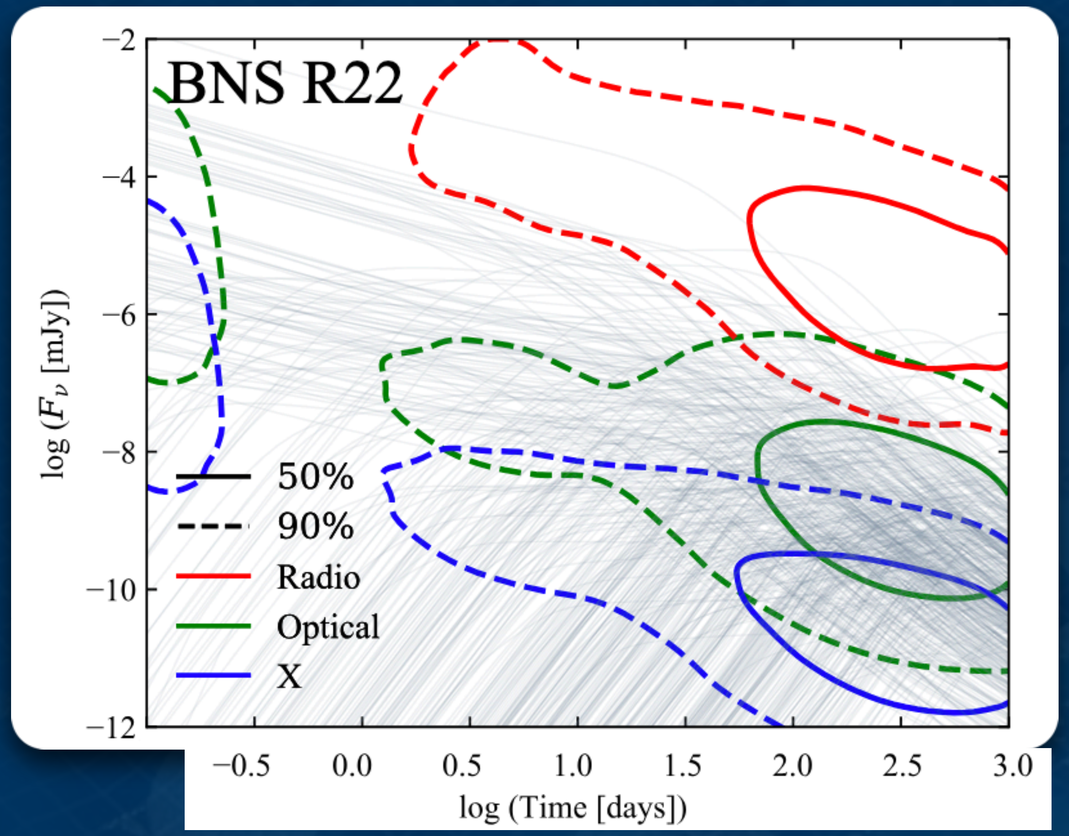
Loffredo et. al. 2025



sky-loc < 100 deg^2

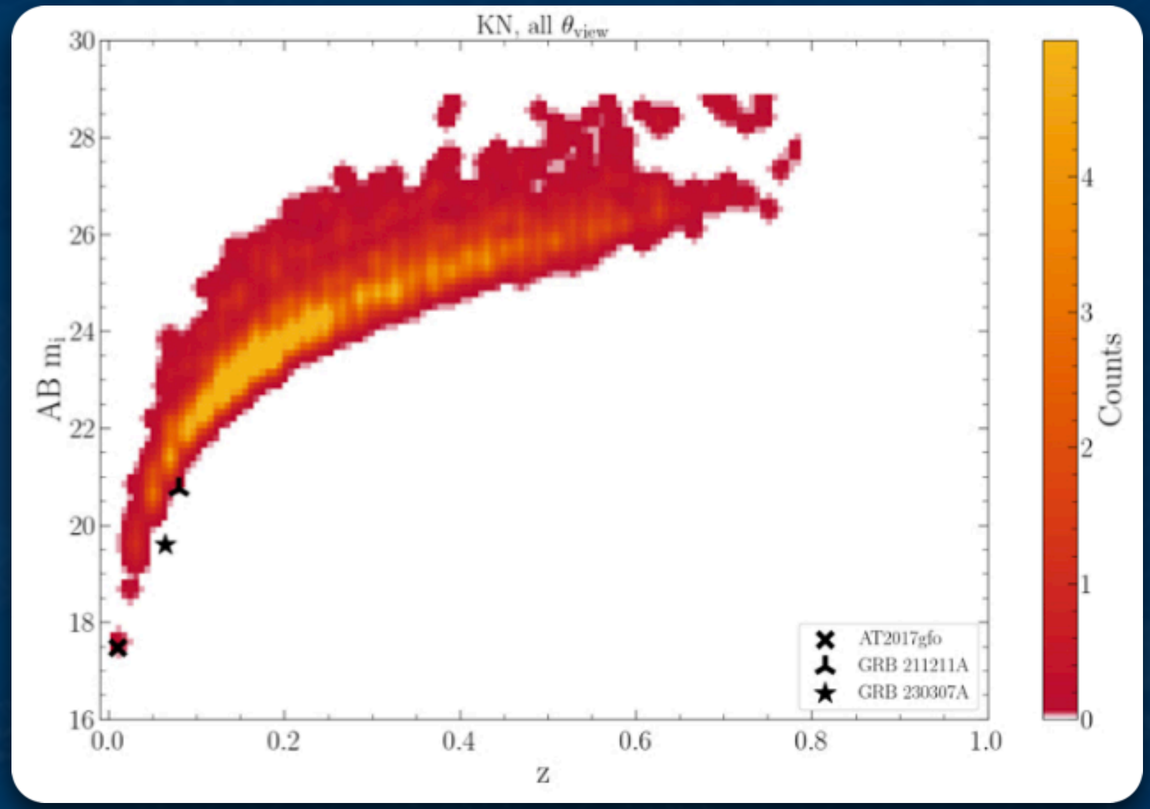
GW & EM BNS (and NSBH) mergers

Afterglows



ET Blue book arXiv:2503.12263

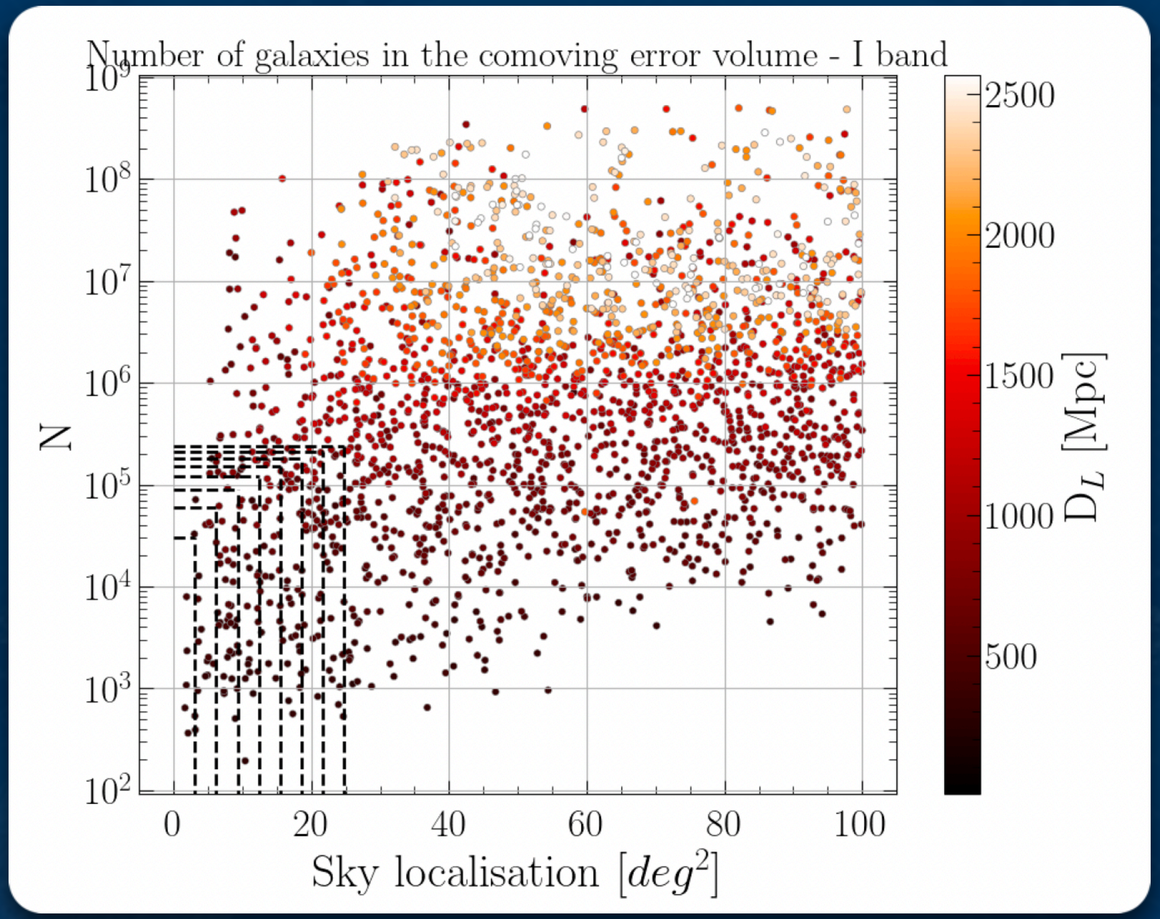
Kilonovae



Bisero et al. 2026

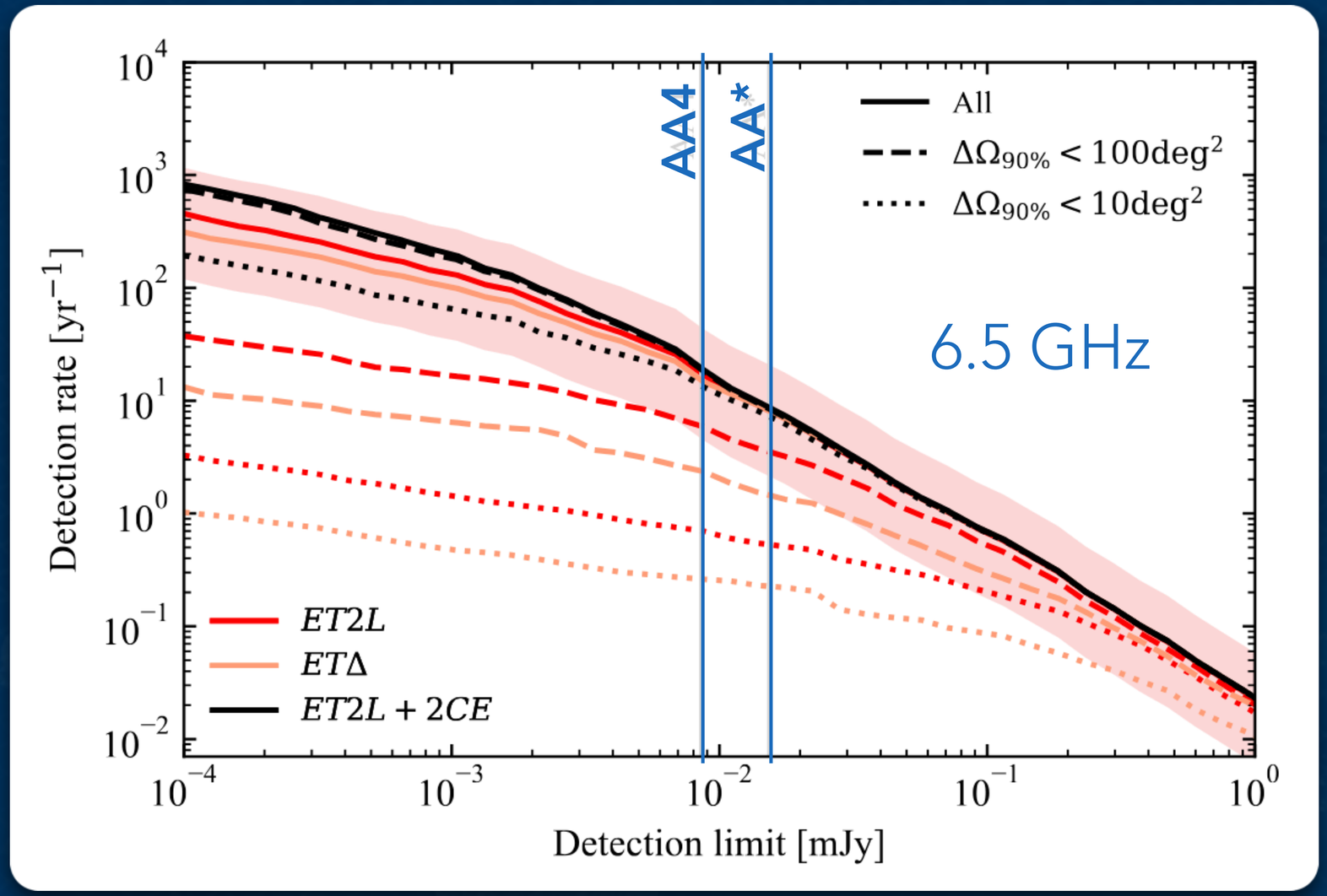
GW & EM BNS (and NSBH) mergers

Galaxy targeted searches



Bisero et al. 2026

Afterglow: radio



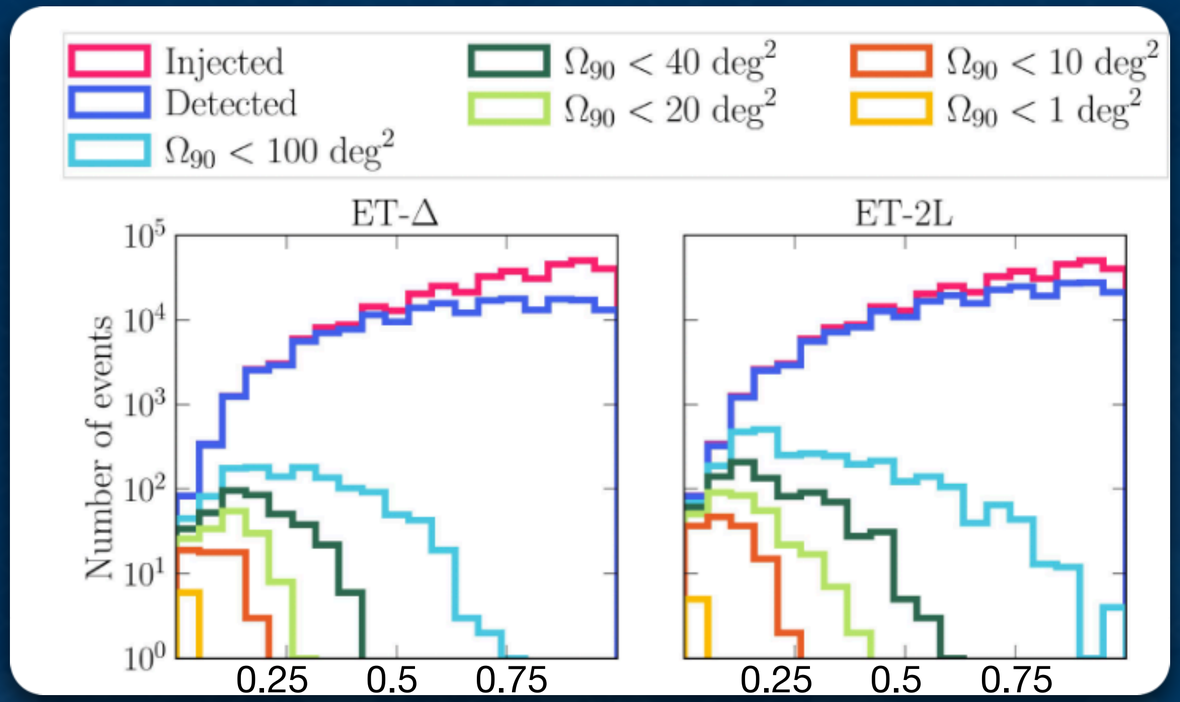
Colombo, Giroletti, Vergani et al. Advancing Astrophysics with SKA

10-min SKAO-AA4 sensitivity 5σ (8.5 μJy)

10-min SKAO-AA* sensitivity 5σ (15.25 μJy)

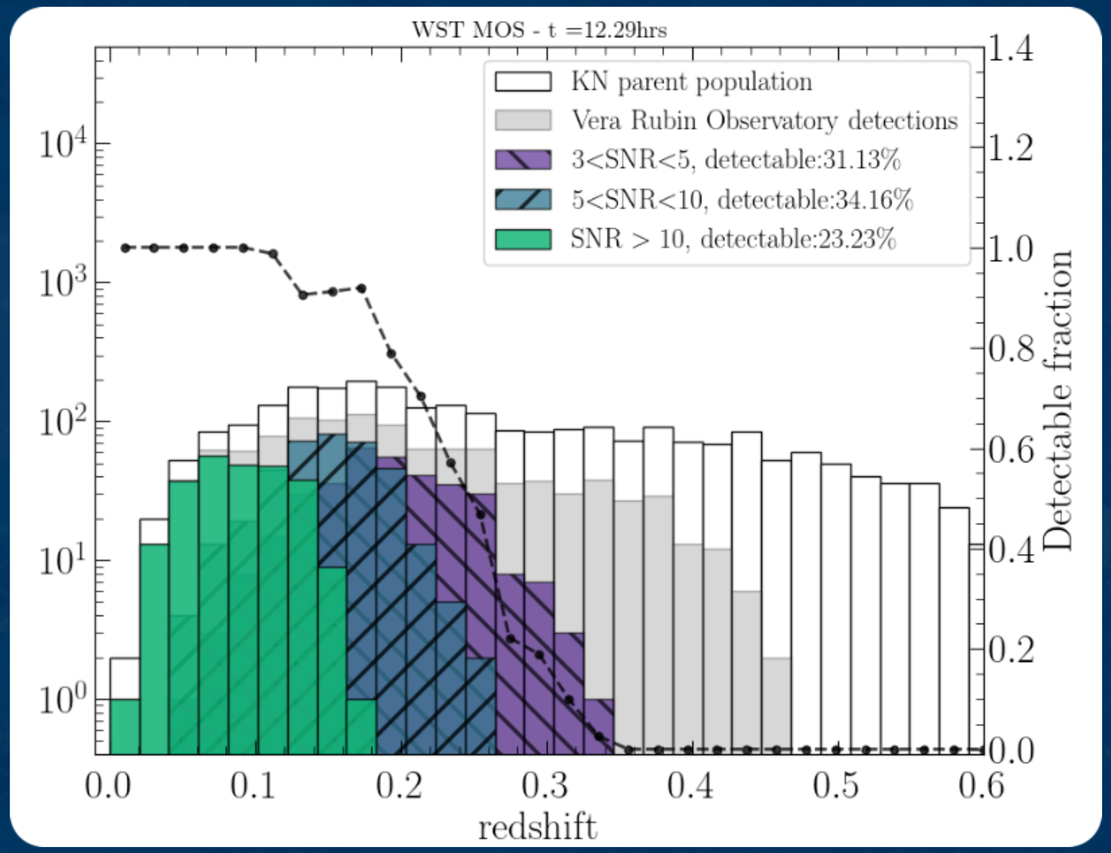
Detect!

Kilonova: Vera Rubin Observatory



Loffredo et. al. 2025

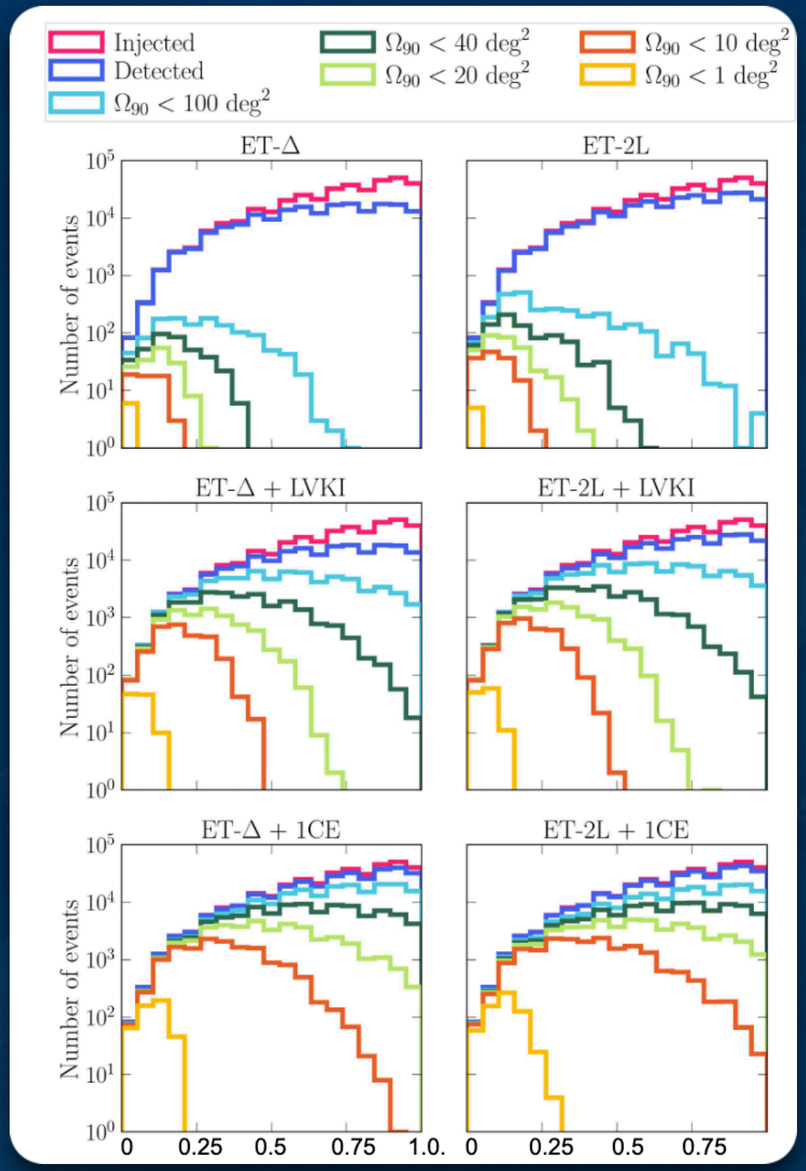
ET+VRO 8 – 50 KNe per year



Bisero et al. 2026

Detect!

GW & EM BNS (and NSBH) mergers



Loffredo et. al. 2025

ET+VRO 8 – 50 KNe per year

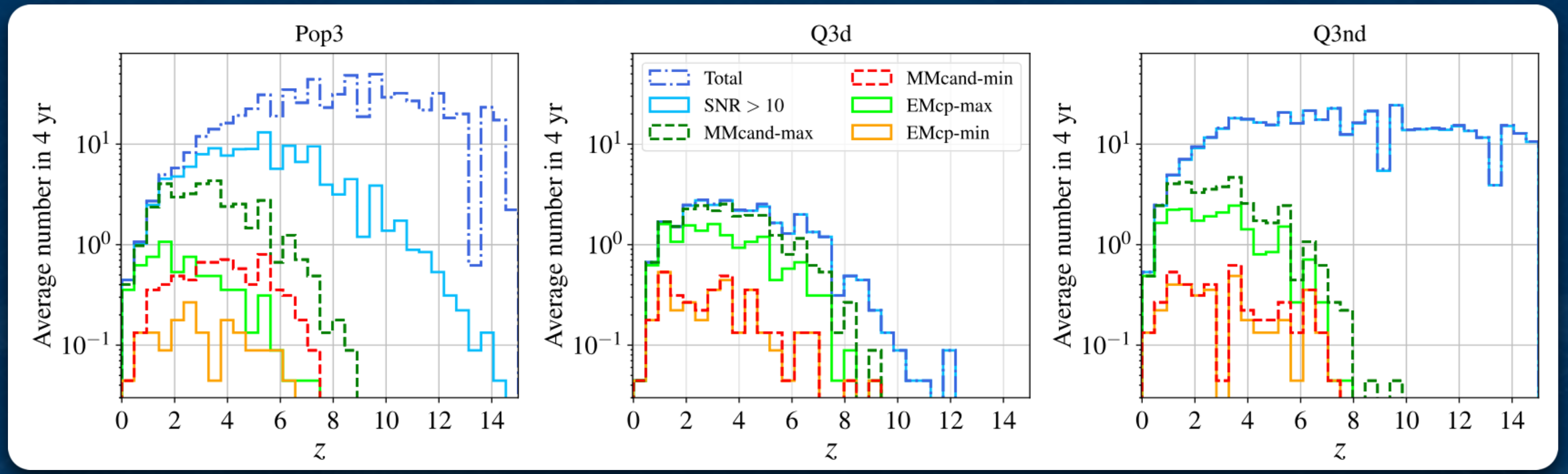
x 10 for ET-LVKI+VRO

x 3 ET-CE+VRO

GW & EM MBH mergers

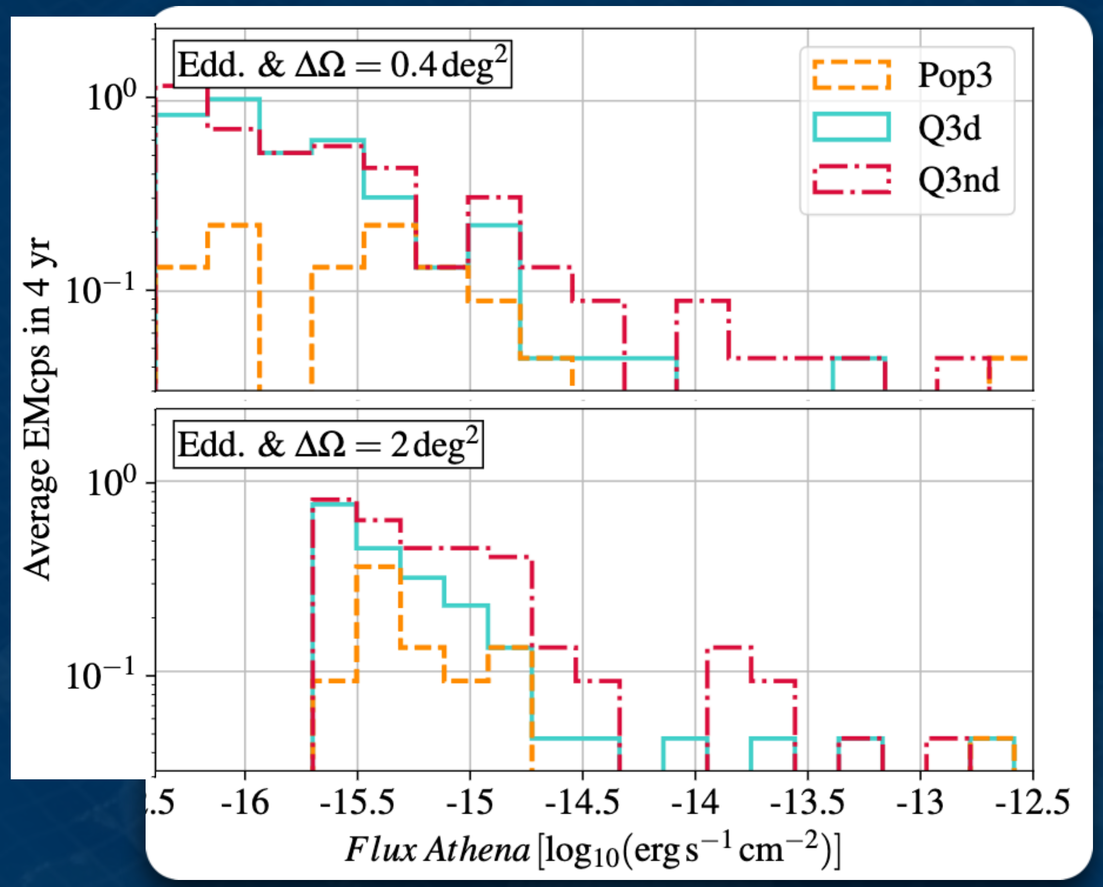
MBHs

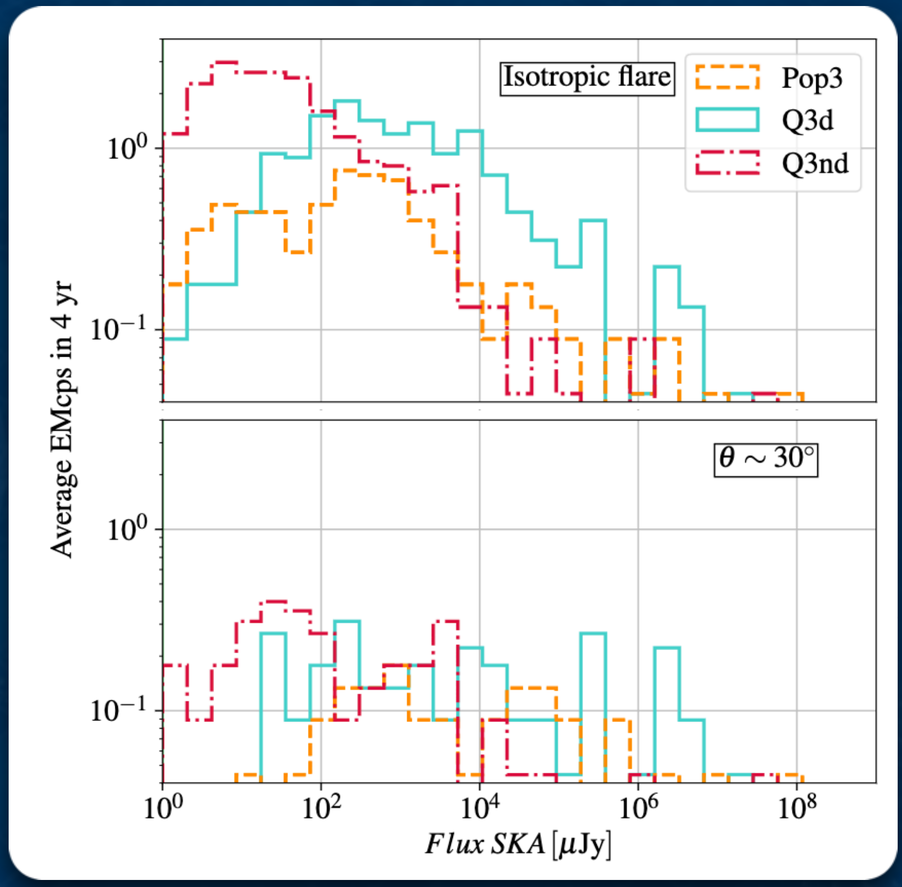
Mangiagli et al. 2022



GW & EM MBH mergers

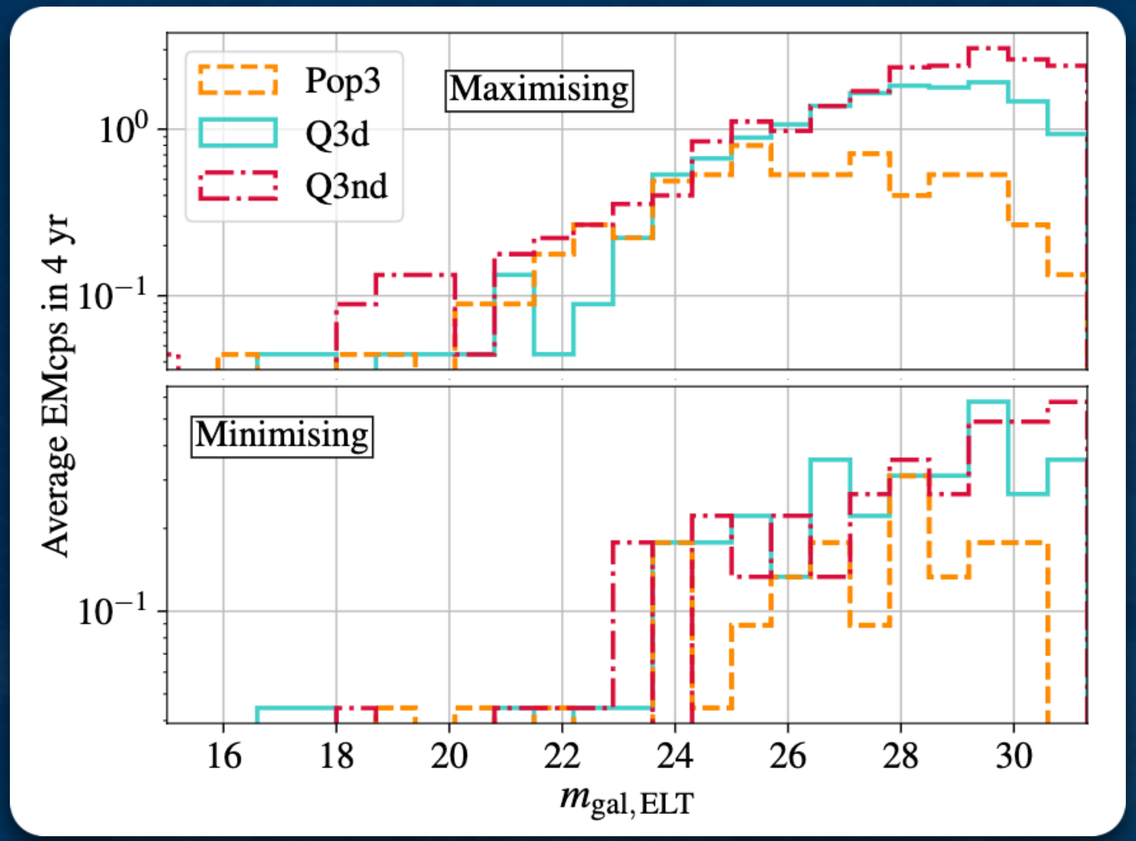
Mangiagli et al. 2022

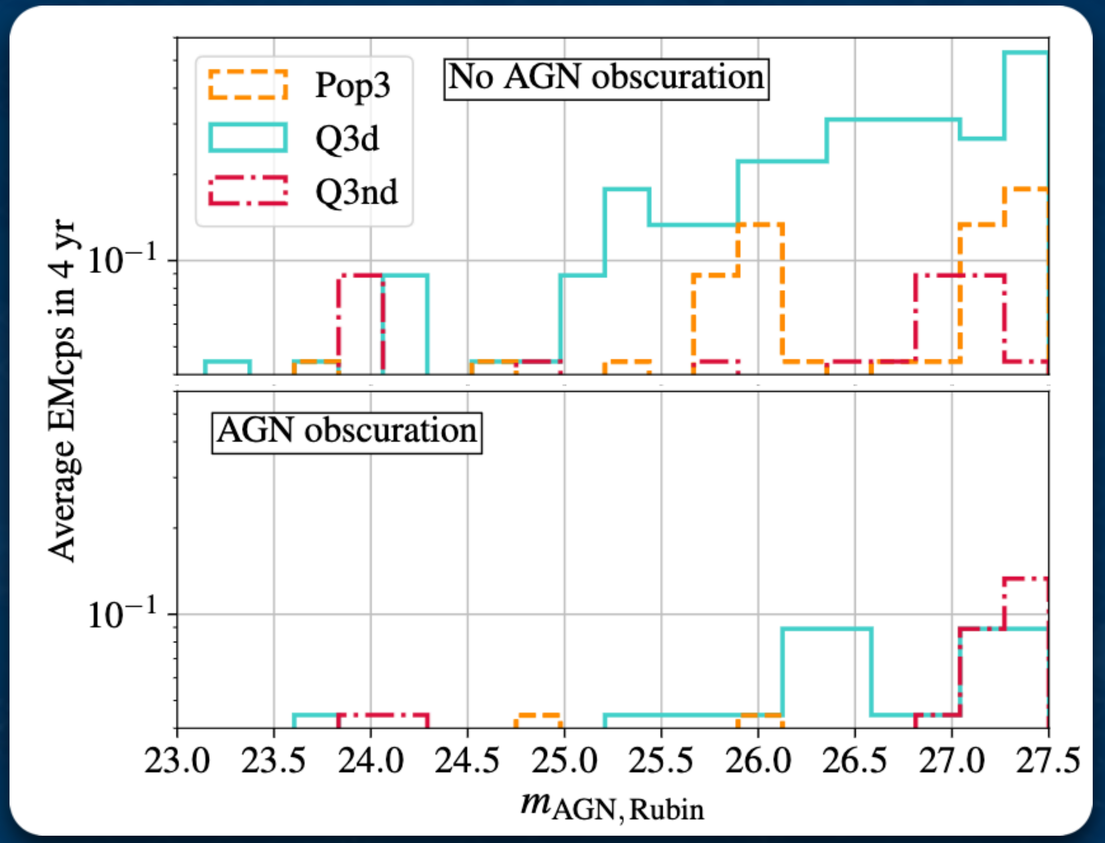




GW & EM MBH mergers

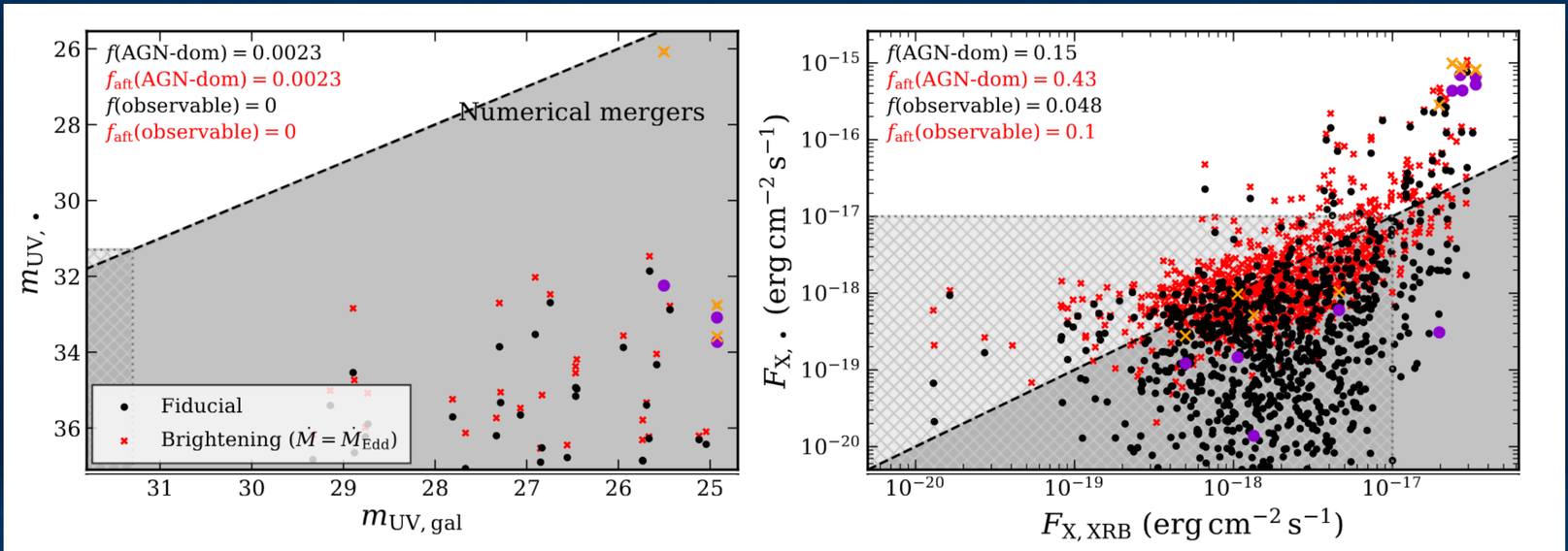
Mangiagli et al. 2022





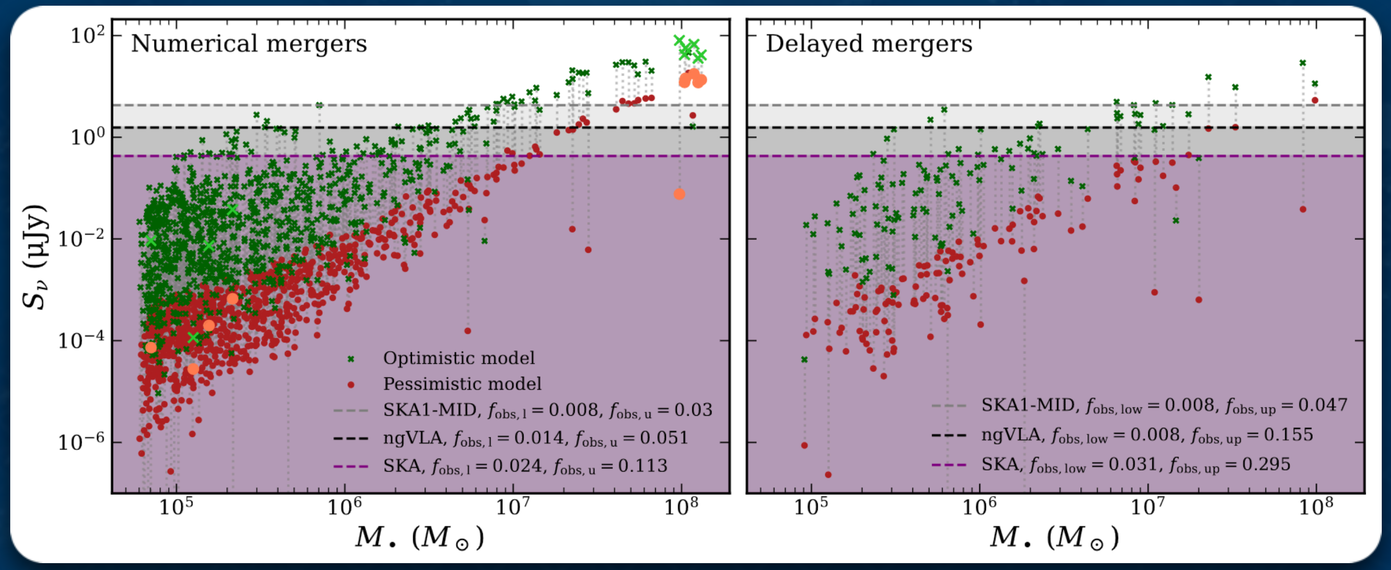
GW & EM MBH mergers

UV



X-rays

Radio

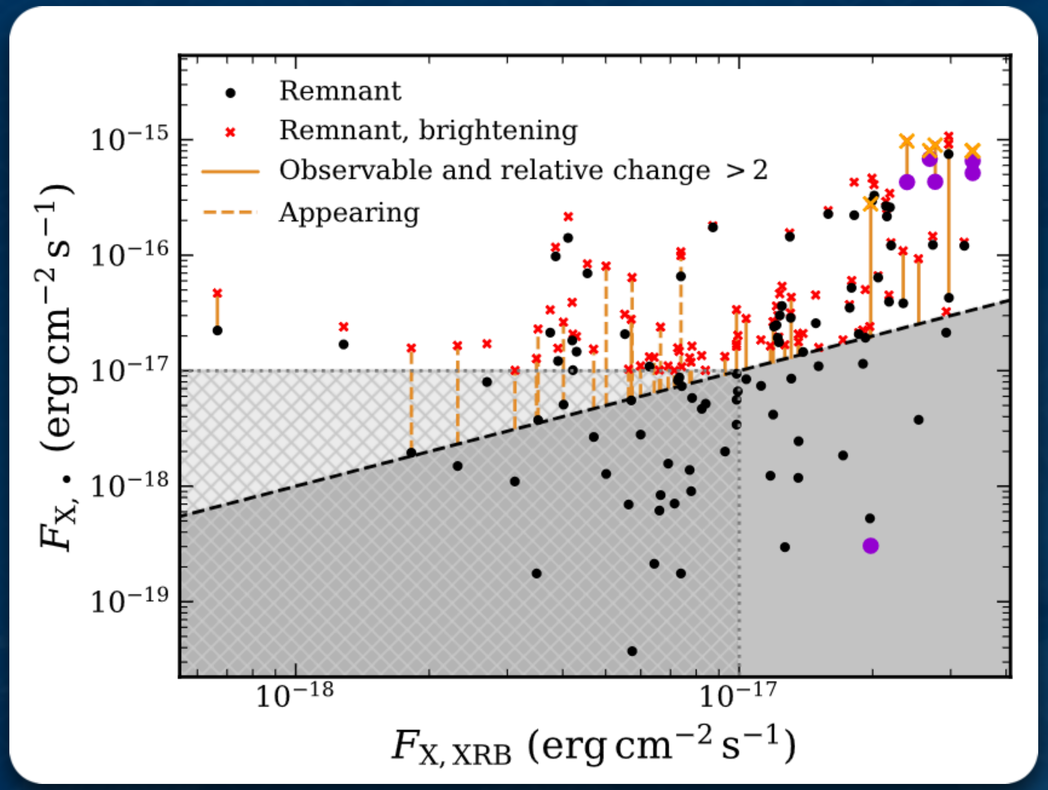


Dong-Paéz et al. 2023

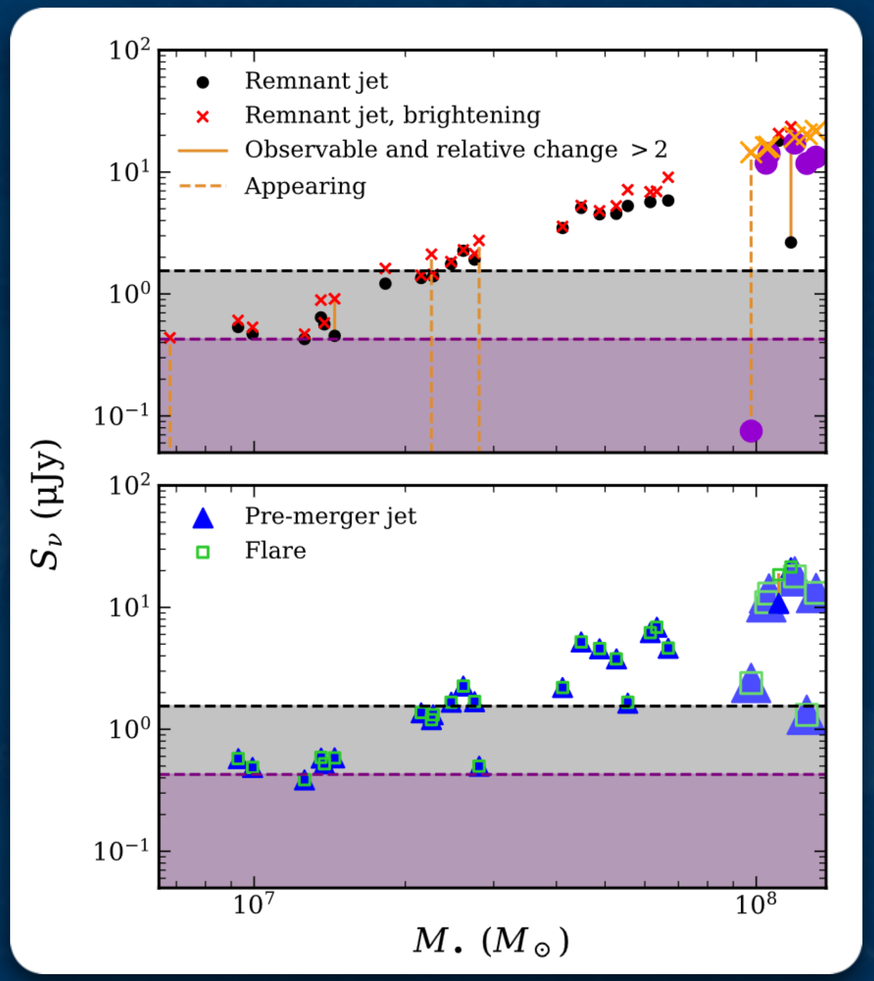
z > 3.5

GW & EM MBH mergers

Dong-Paéz et al. 2023



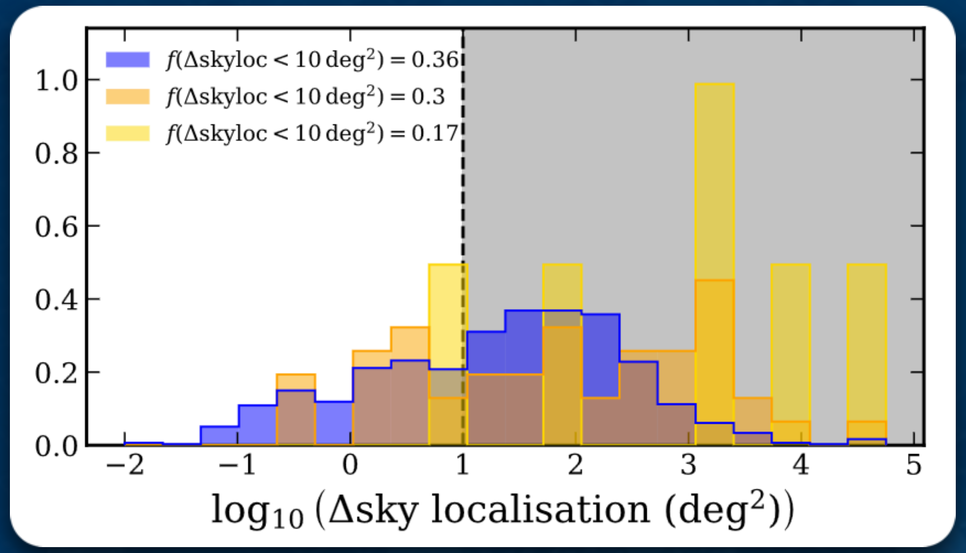
X-rays

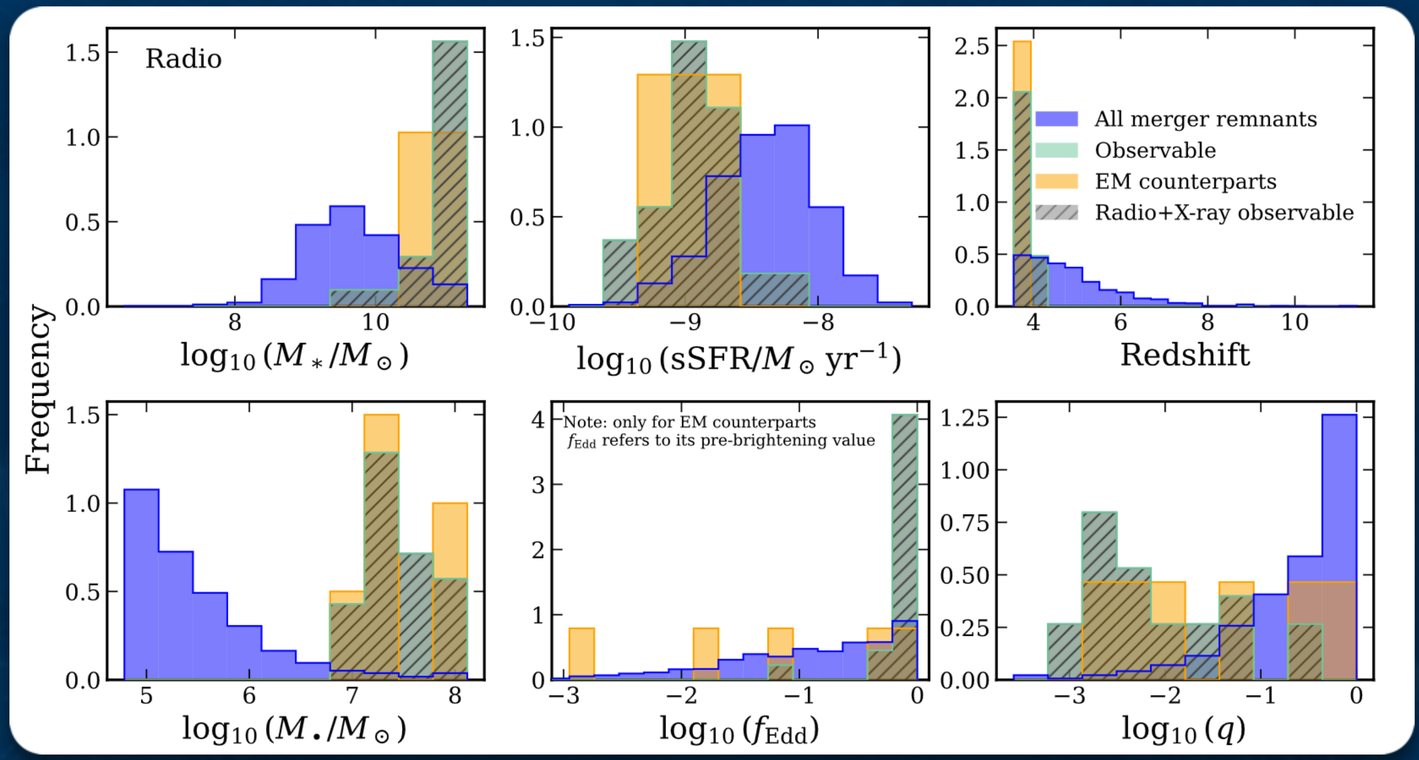


Radio

GW & EM MBH mergers

Dong-Paéz et al. 2023

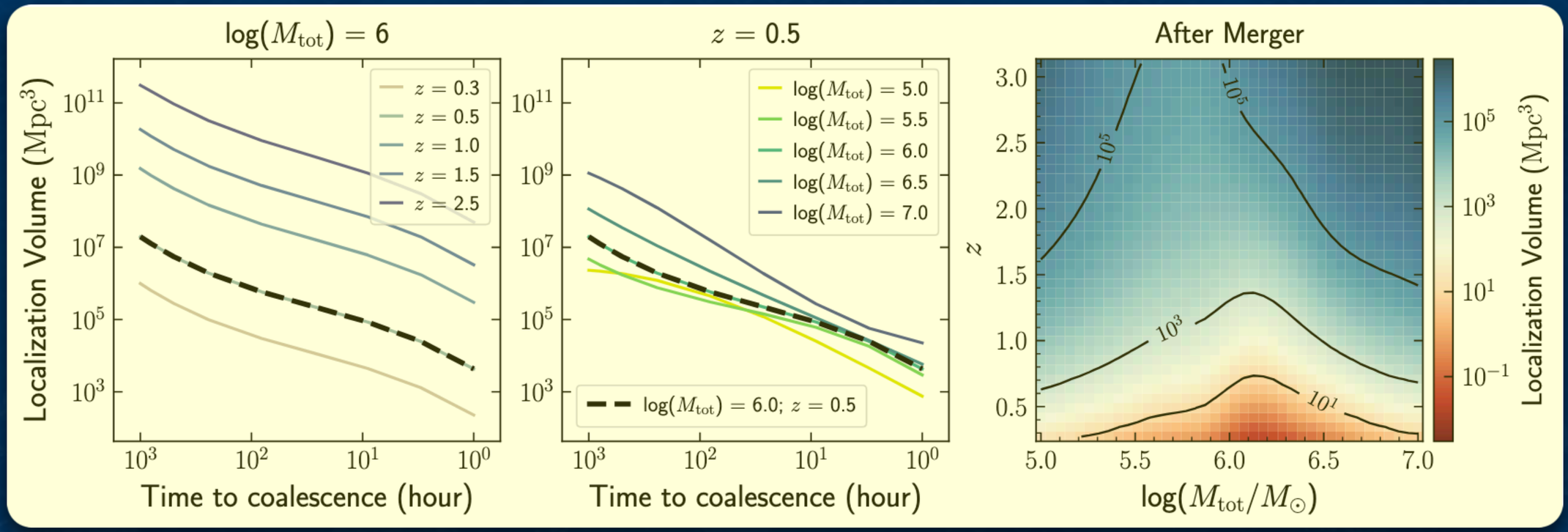




Bias!

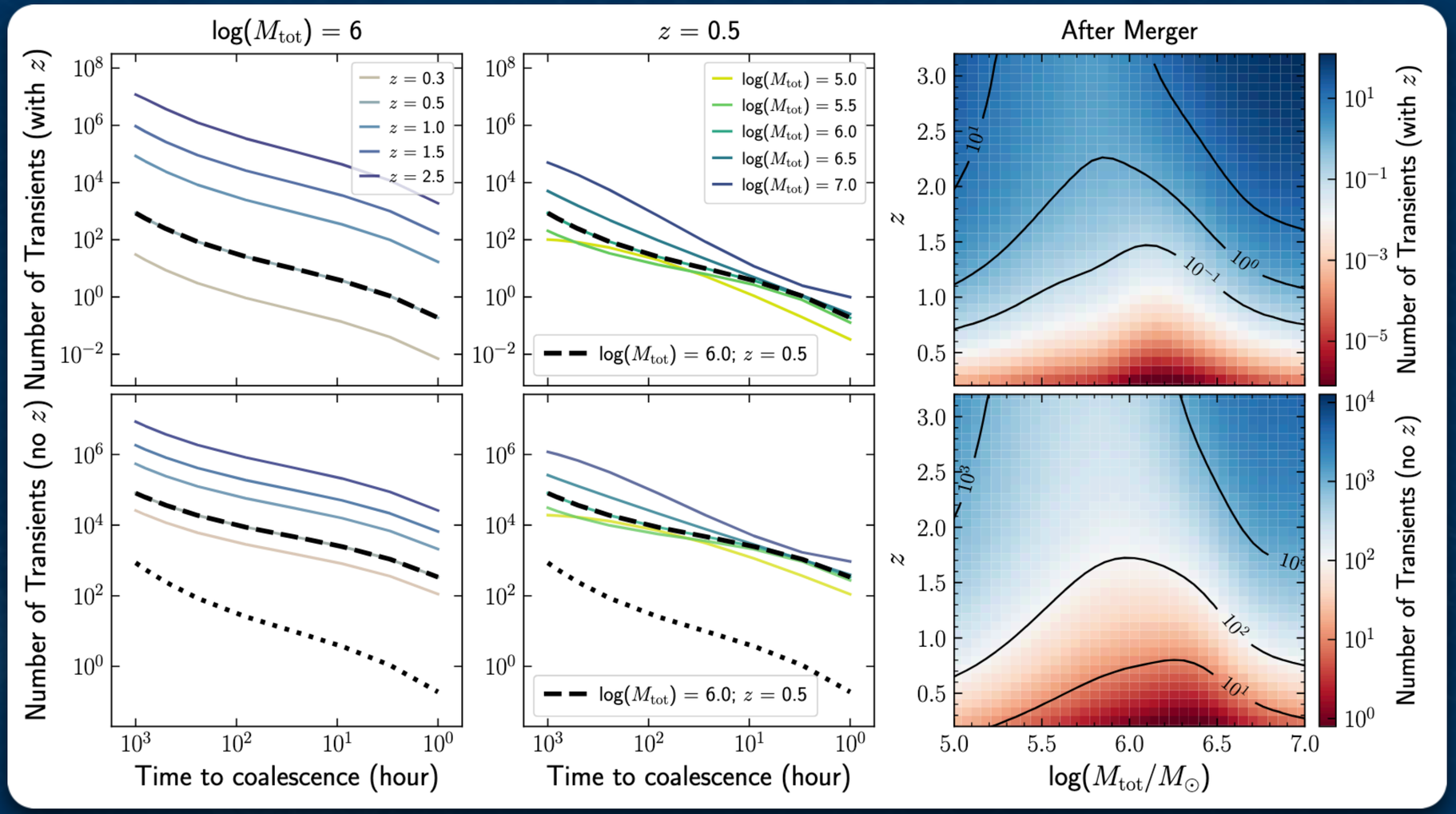
GW & EM MBH mergers

Yu et al. 2025



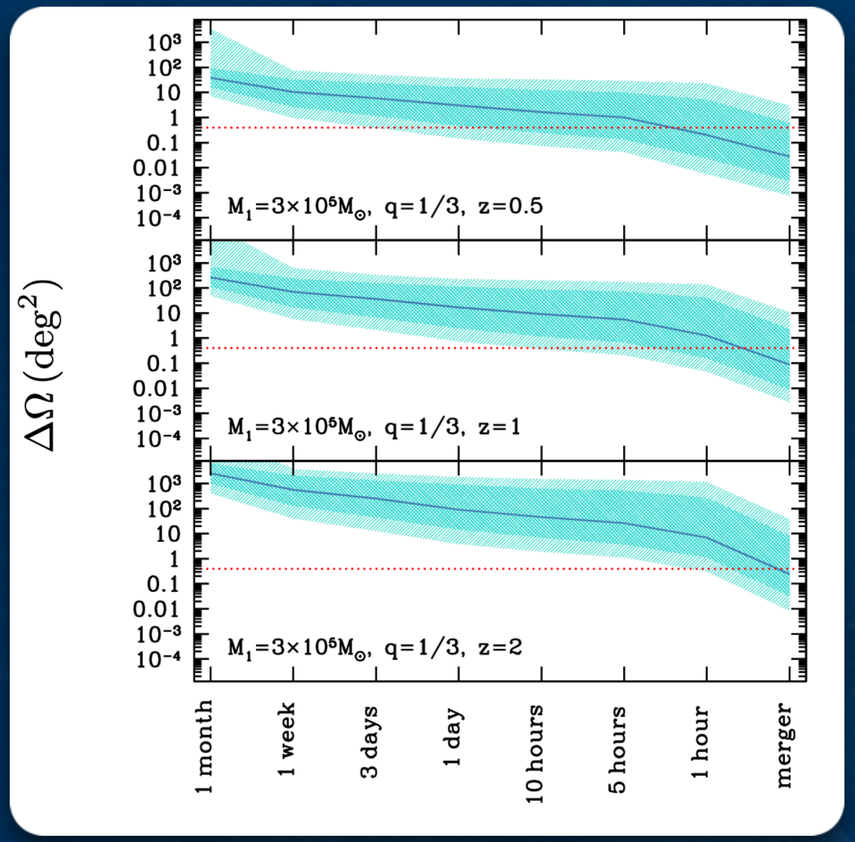
GW & EM MBH mergers

Yu et al. 2025

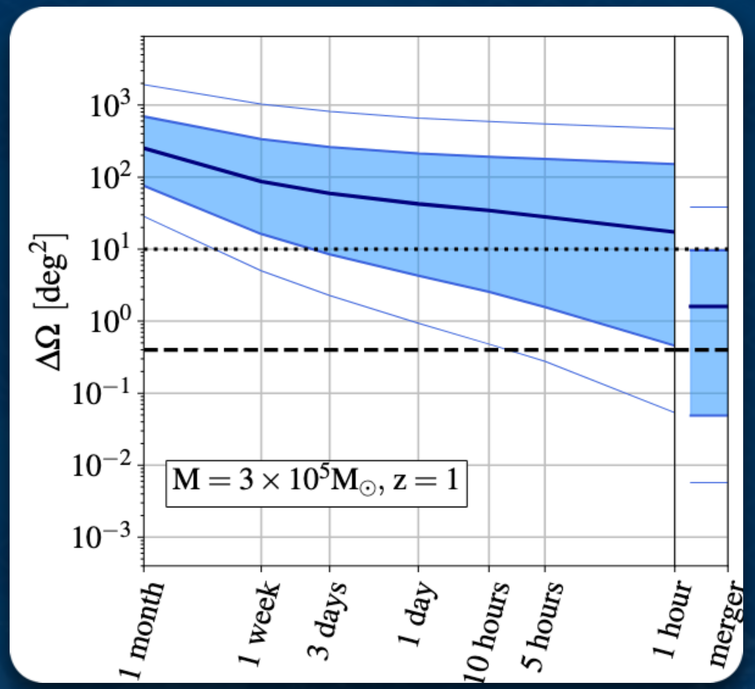


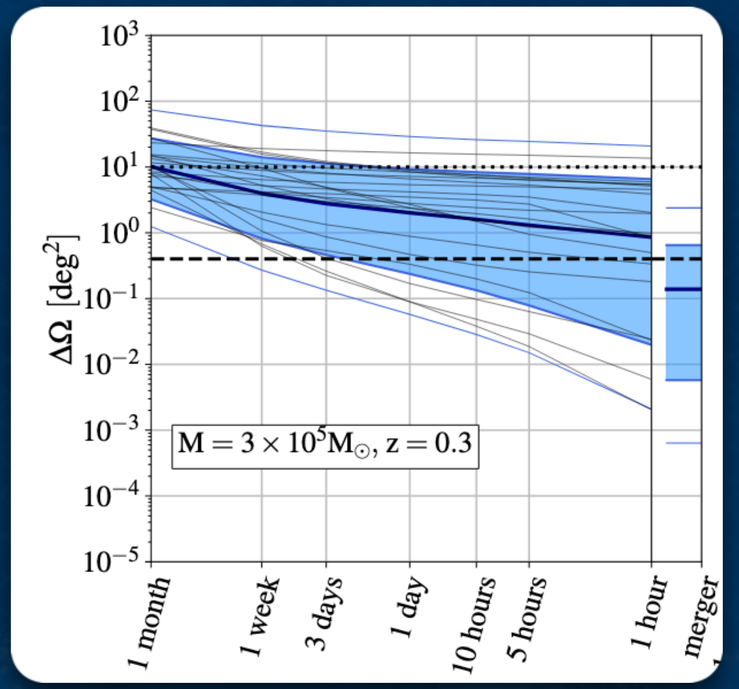
GW & EM MBH mergers

From ATHENA-LISA synergy



Piro et al. 2023





Platinum cases very well localized
Most sensitive telescopes on target

Athena, SKA
ELT/MOSAIC?

Merci !

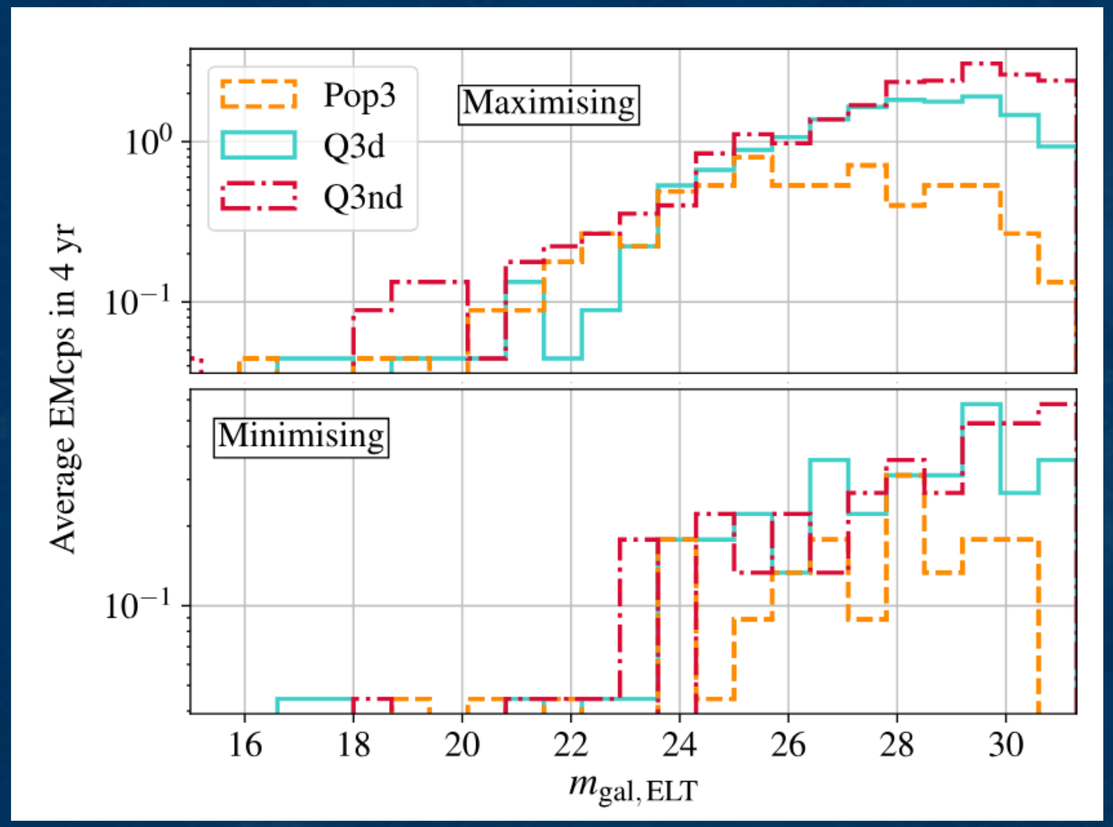
AG du GDR OG - Lyon - 2026

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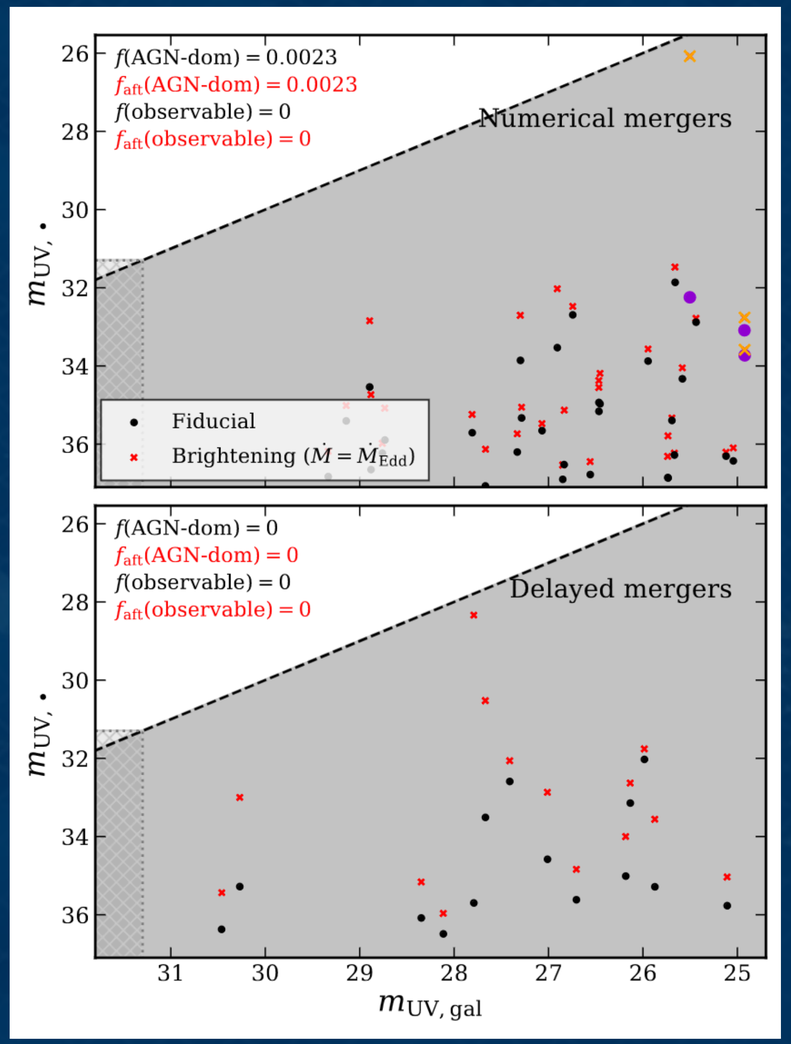


MBHs

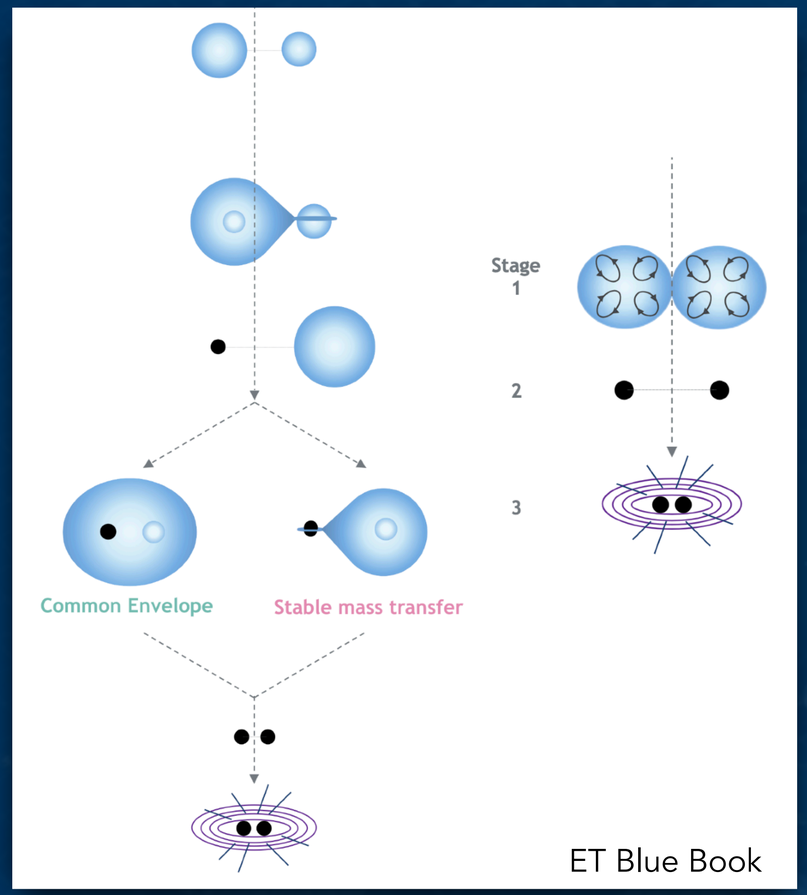
Mangiagli et al. 2022



Dong-Paéz et al. 2023

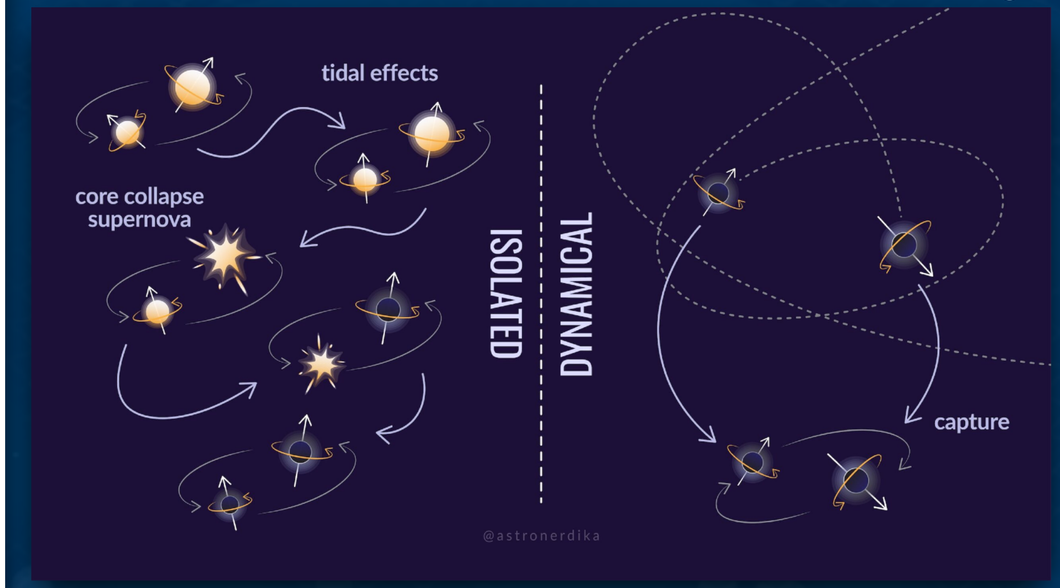


Stellar evolution & formation of compact binaries



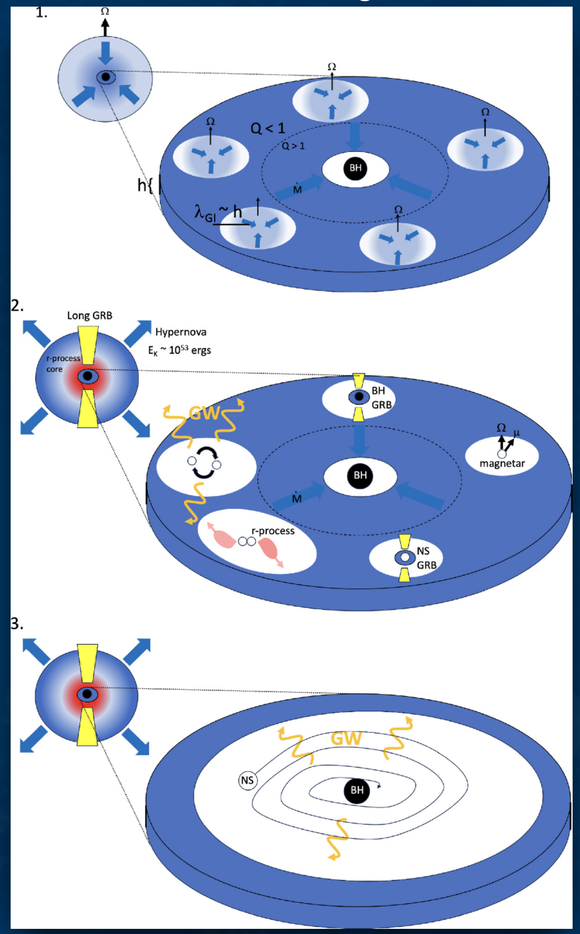
Common envelope vs
Chemical Homogeneous Evolution

Credits: Shanika Galaudage

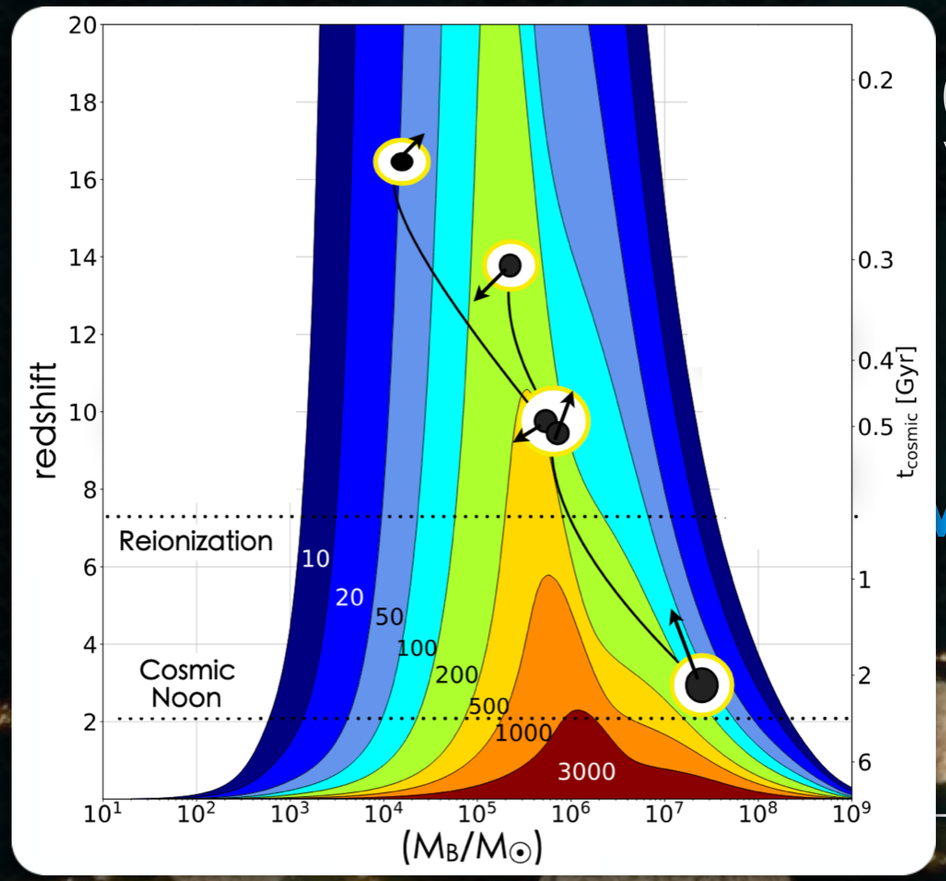


Isolated vs Dynamical channels

Metzger et al. 2024



Fragmentation



ger science with third generation Wave detectors

workshop

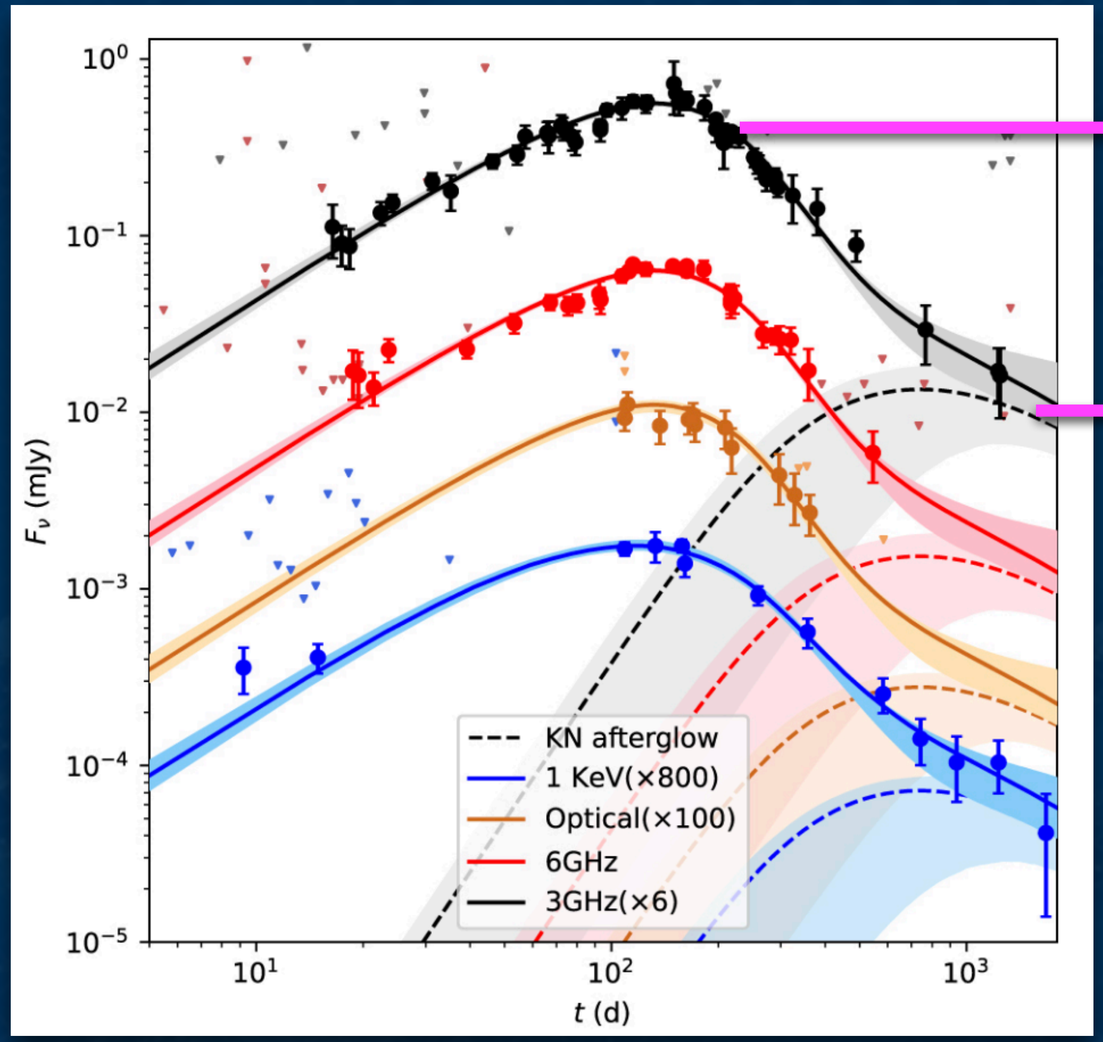
Telescope - 2026, JCAP, arXiv:2503.12263

S.D. Vergani

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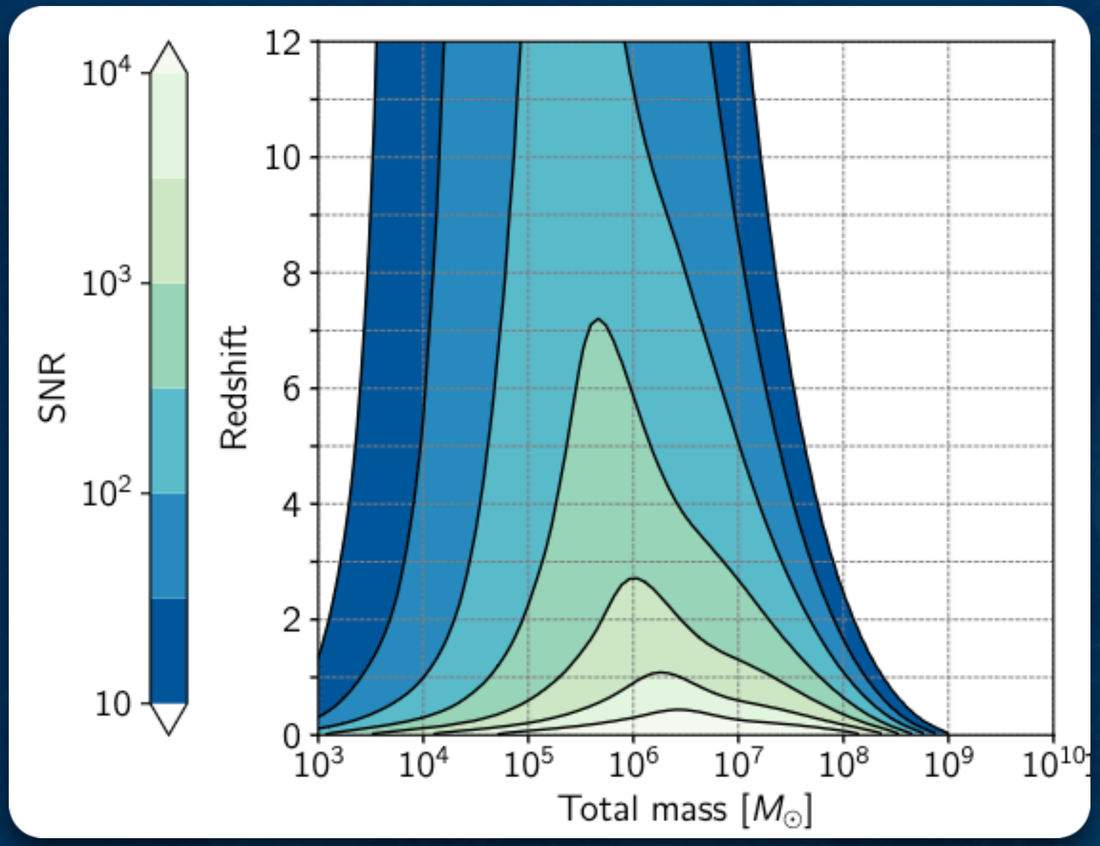
adapted from Wang et al. 2023

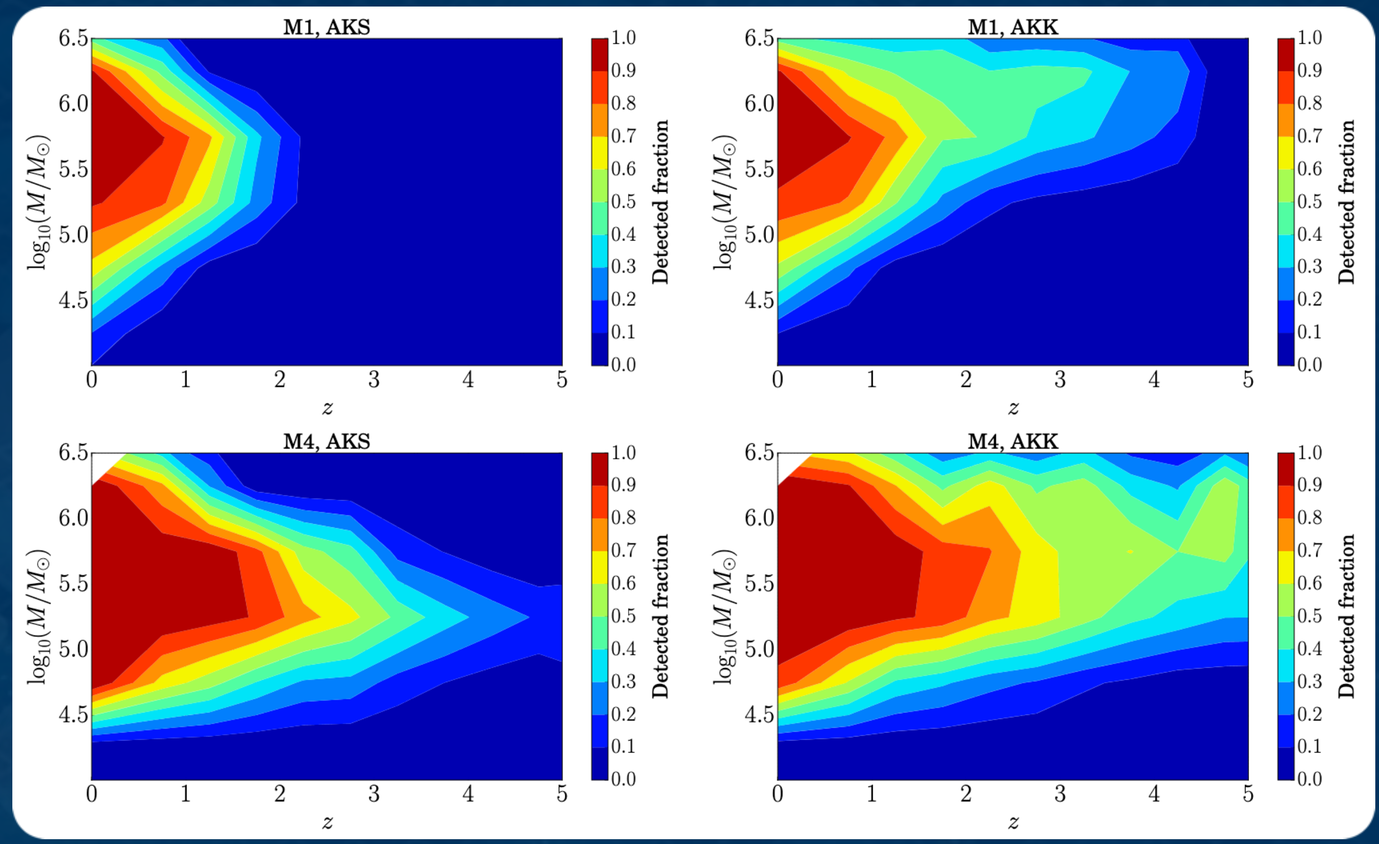


Off-axis afterglow

Kilonova afterglow?

Gravitational Wave Astrophysics: LISA





LISA DSR 2023