

Gravitational wave detectability range informed by external messengers

(aka Targeted Detectability Range, TDR)

S. Ronchini, A. Chopra, T. Dal Canton, B. Banerjee, A. L. De Santis, M. Branchesi

5th Astro-COLIBRI workshop, 12-16 Oct. 2026



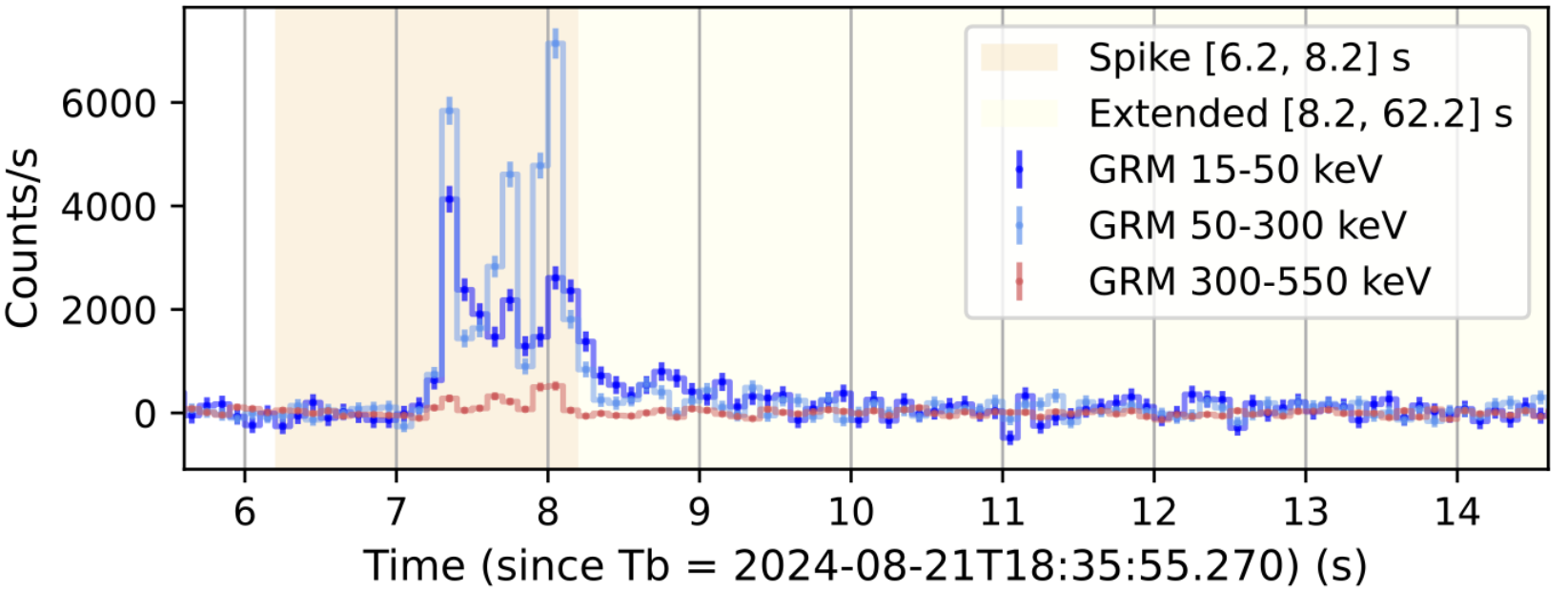
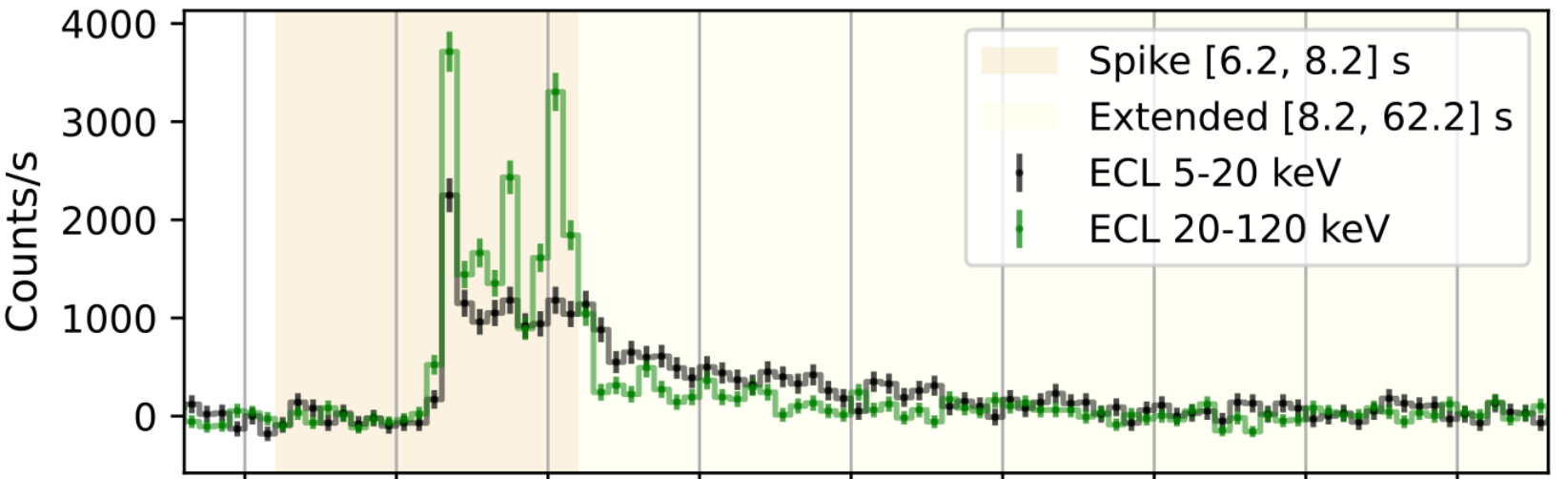
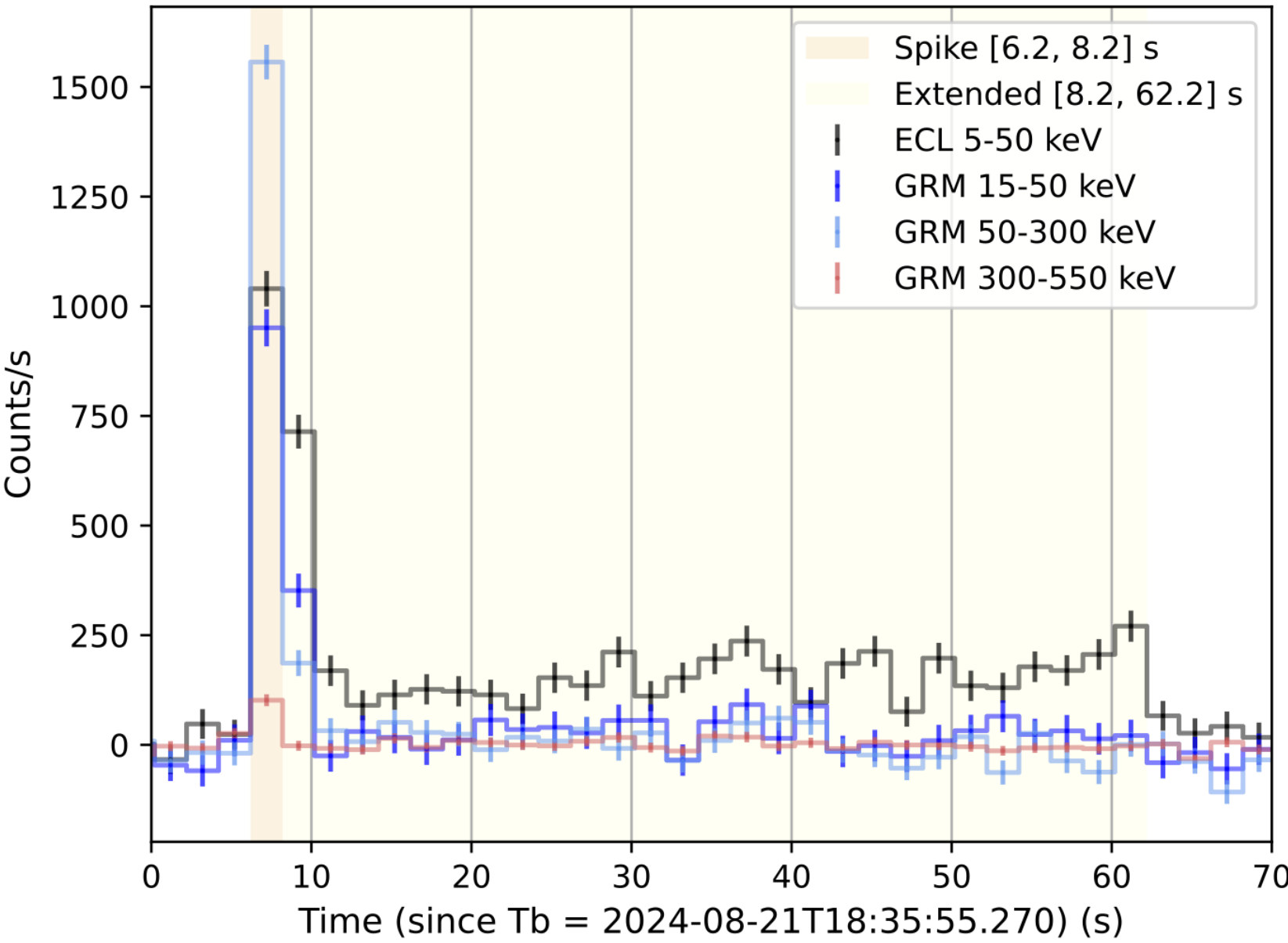
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Starting point

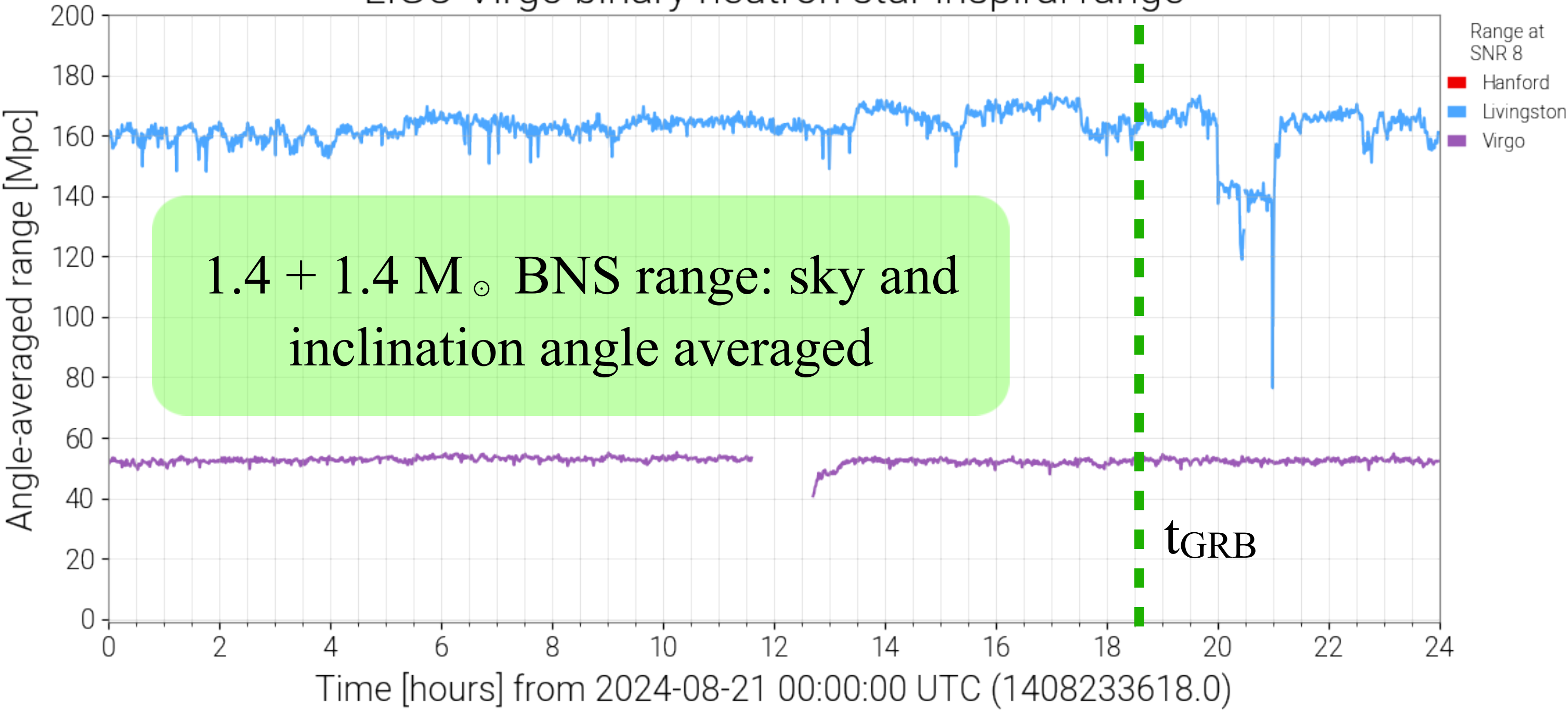
GRB 240821A, $z = 0.238$

- Short GRB with extended emission, detected by SVOM-ECLAIRs: **optimal merger-driven candidate**
- **Any GW candidate** close in time? No
- **Up to which distance** we would have detected a GW?
- Can GW exclusion distance **facilitate EM follow up?**

Daigne+26



LIGO-Virgo binary neutron star inspiral range



GW Targeted Detectability Range

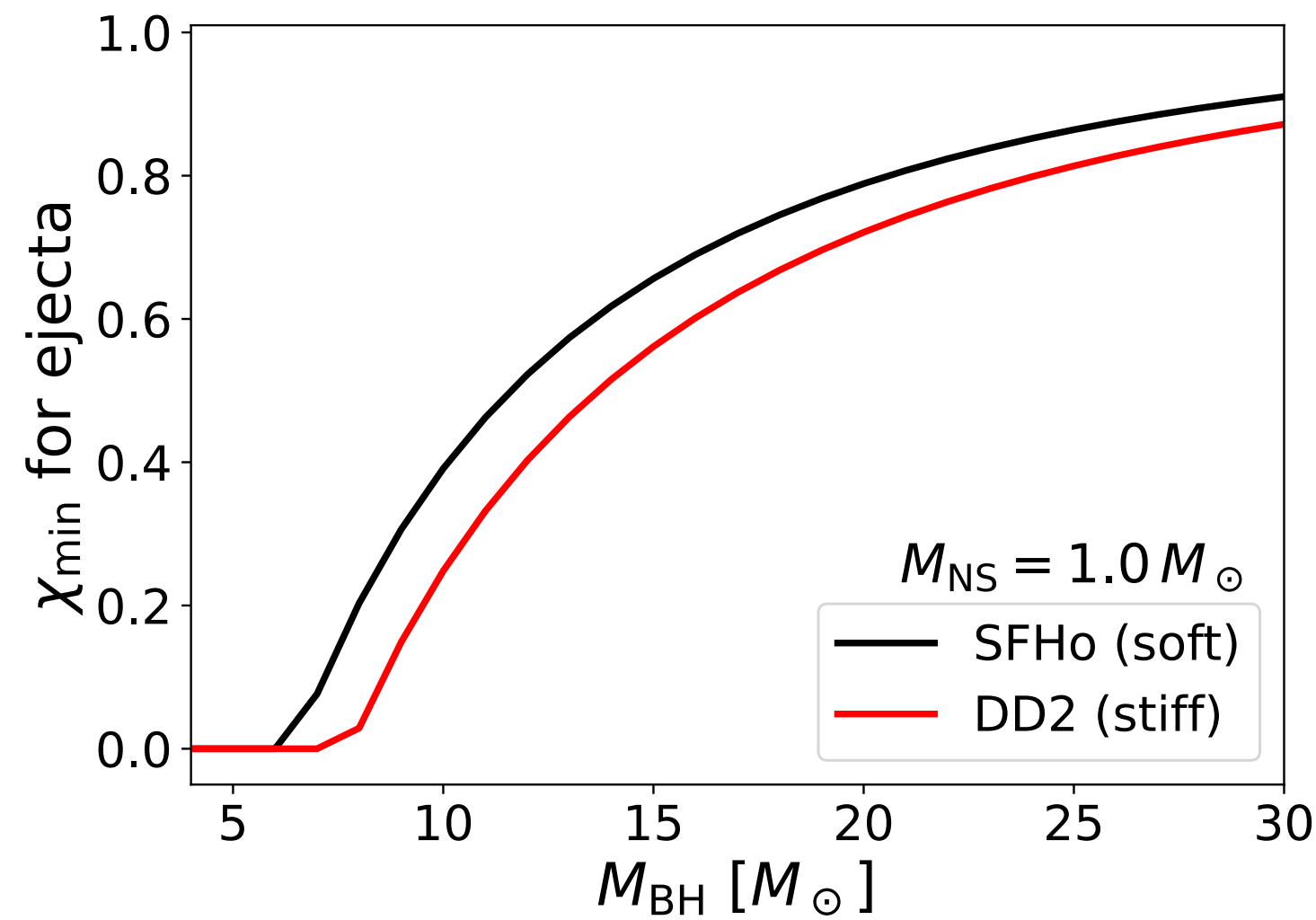
1. Check the interferometer (IFO) online at t_0
2. Inject BNS and NSBH sources according to EM priors (on **sky localization, inclination angle and masses**)
3. Compute GW network Signal to Noise Ratio (**SNR**) as a function of distance
4. Define D_{90} as the distance where **90% of the injected sources have matched-filter $SNR > SNR_{min}$** (tuned to have optimal match with PyGRB exclusion distances)
5. We can interpret D_{90} as a 90% exclusion distance under the condition that **no all-sky, all-time search found any GW candidate online in temporal proximity to the external trigger**

Runs in few minutes, once the data frames are available, complementing the more accurate exclusion distance given by CBC-modeled GW targeted searches (e.g. PyGRB), which are more computationally expensive

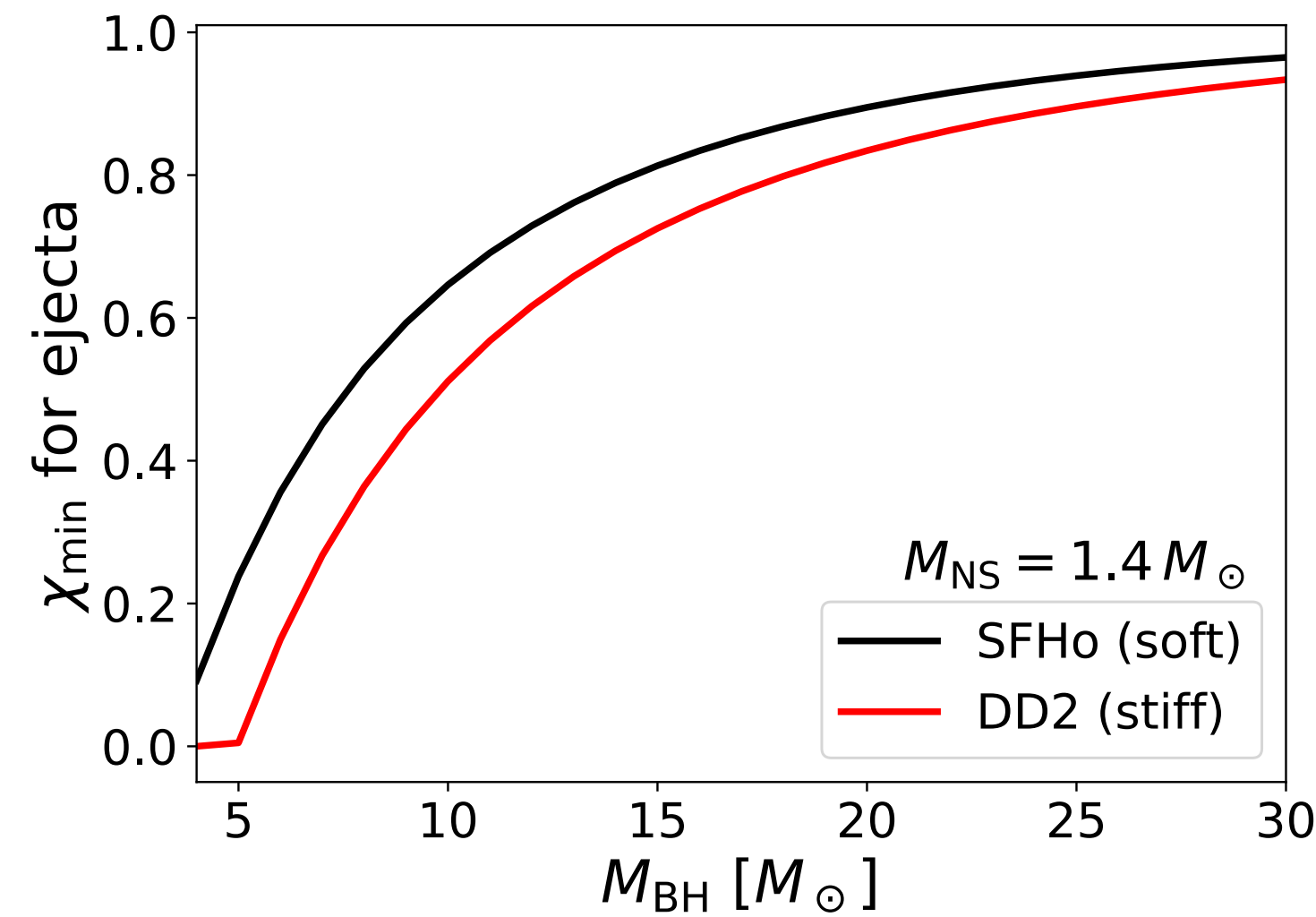
Incorporating electromagnetic (EM) priors

$$M_{\text{rem}} > 0$$

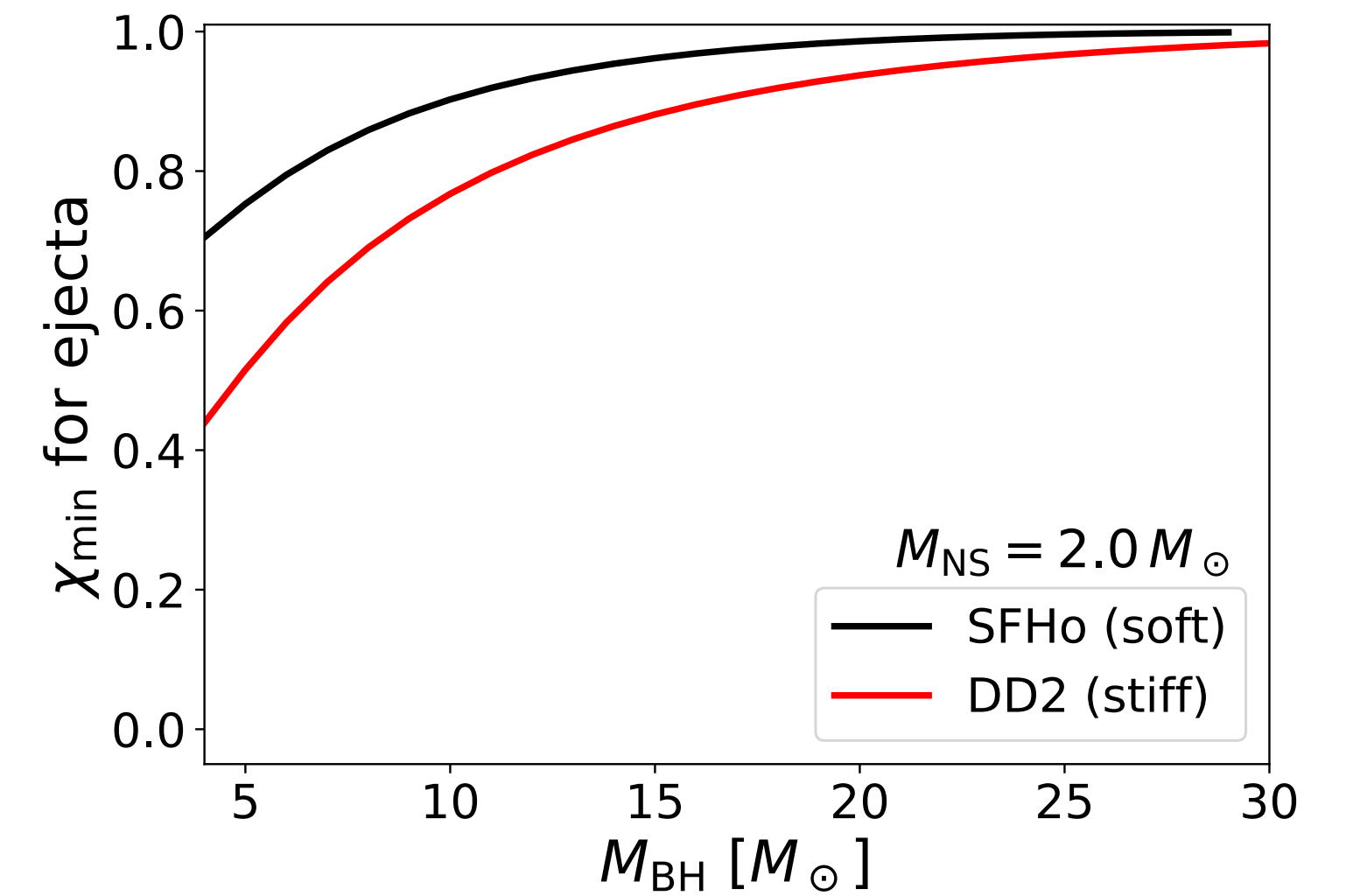
	Masses	Waveforms
BNS	$[M_{\text{NS}}, M_{\text{NS}}] = [1, 1] M_{\odot}$ $[M_{\text{NS}}, M_{\text{NS}}] = [1.4, 1.4] M_{\odot}$ $[M_{\text{NS}}, M_{\text{NS}}] = [2.0, 2.0] M_{\odot}$	TaylorF2
NSBH	$[M_{\text{NS}}, M_{\text{BH}}] = [1, 5] M_{\odot}$ $[M_{\text{NS}}, M_{\text{BH}}] = [1.4, 10] M_{\odot}$ $[M_{\text{NS}}, M_{\text{BH}}] = [2.6, 20] M_{\odot}$	IMRPhenomNSBH with SFHo and DD2 EOSs



$$\chi_{\text{BH}} > 0$$

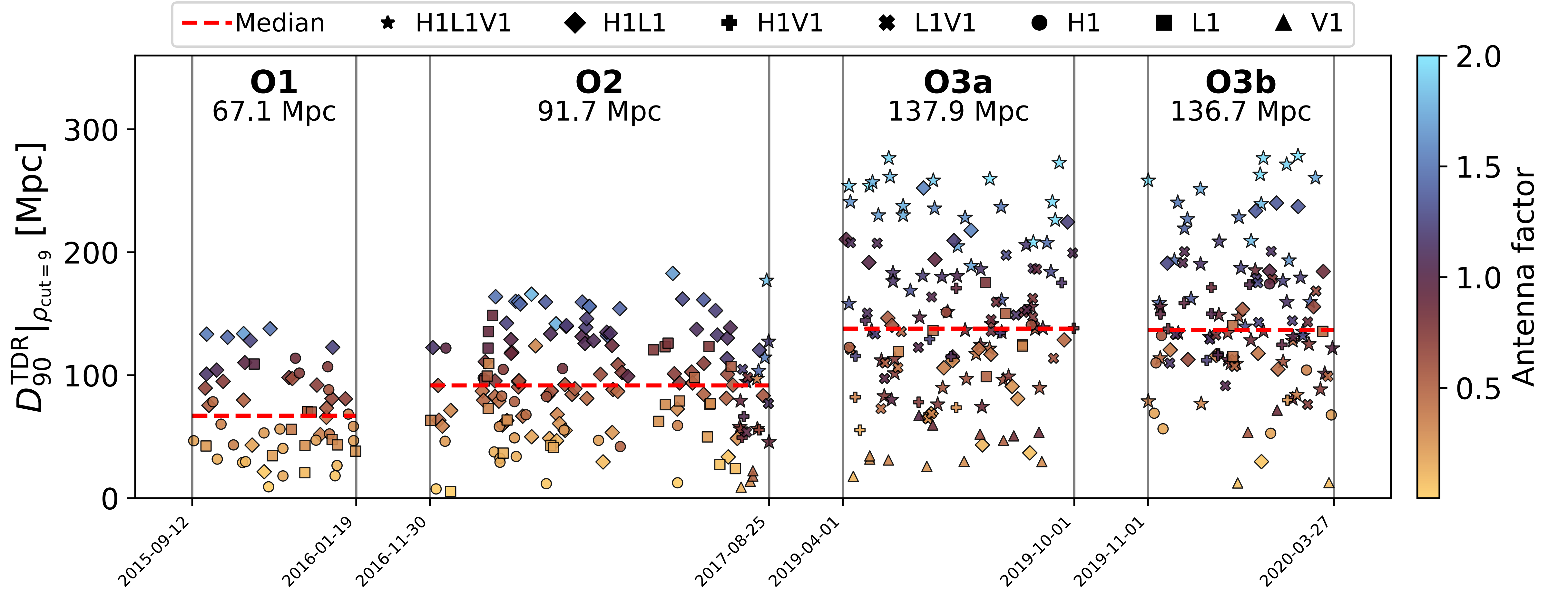


$$\chi_{\text{BH}} > 0.5 - 0.6$$



$$\chi_{\text{BH}} > 0.90 - 0.95$$

TDR for all the short- and long-GRBs during first 3 LVK observing runs



Adopting an **SNR cut of 9 (matched-filter)**, we find that for **70% of the cases** the relative **mismatch** between the TDR D_{90} and the PyGRB D_{90} is **less than 20%**

Standard TDR products: example for GRB 240821A

[TDR Web Runner](#) [Runner](#) [Docs](#) [GitHub](#)

GW targeted detectability range

Submit and monitor TDR runs from this web interface.

Input Parameters

Transient Name Run label, e.g. GRB_WEB	Trigger Time (t0) Use GPS seconds or ISO UTC, e.g. 2020-03-26T12:24:47.903
240821A	2024-08-21T18:36:02.000
SNR Threshold Typical values are in the range 8-12	SNR Type Choose matched filter (mf) or optimal (opt)
9	matched filter (mf)
lota Min (deg, optional)	lota Max (deg, optional)
0	45
Localization Source	
☒ Use RA/DEC	
☐ Use sky map file	
RA (deg)	DEC (deg)
354.23	-10.18

Start Run

Cancel Job

Standard TDR products: example for GRB 240821A

Job Status

STATE **COMPLETED**

JOB ID e74cdfed31

RETURN CODE 0

COMMAND Input parameters used: transient=240821A; t0=2024-08-21T18:36:02.000; snr_threshold=9.0; snr_type=mf; localization=coords (ra=354.23, dec=-10.18); iota=default 0-45, 0-90 deg

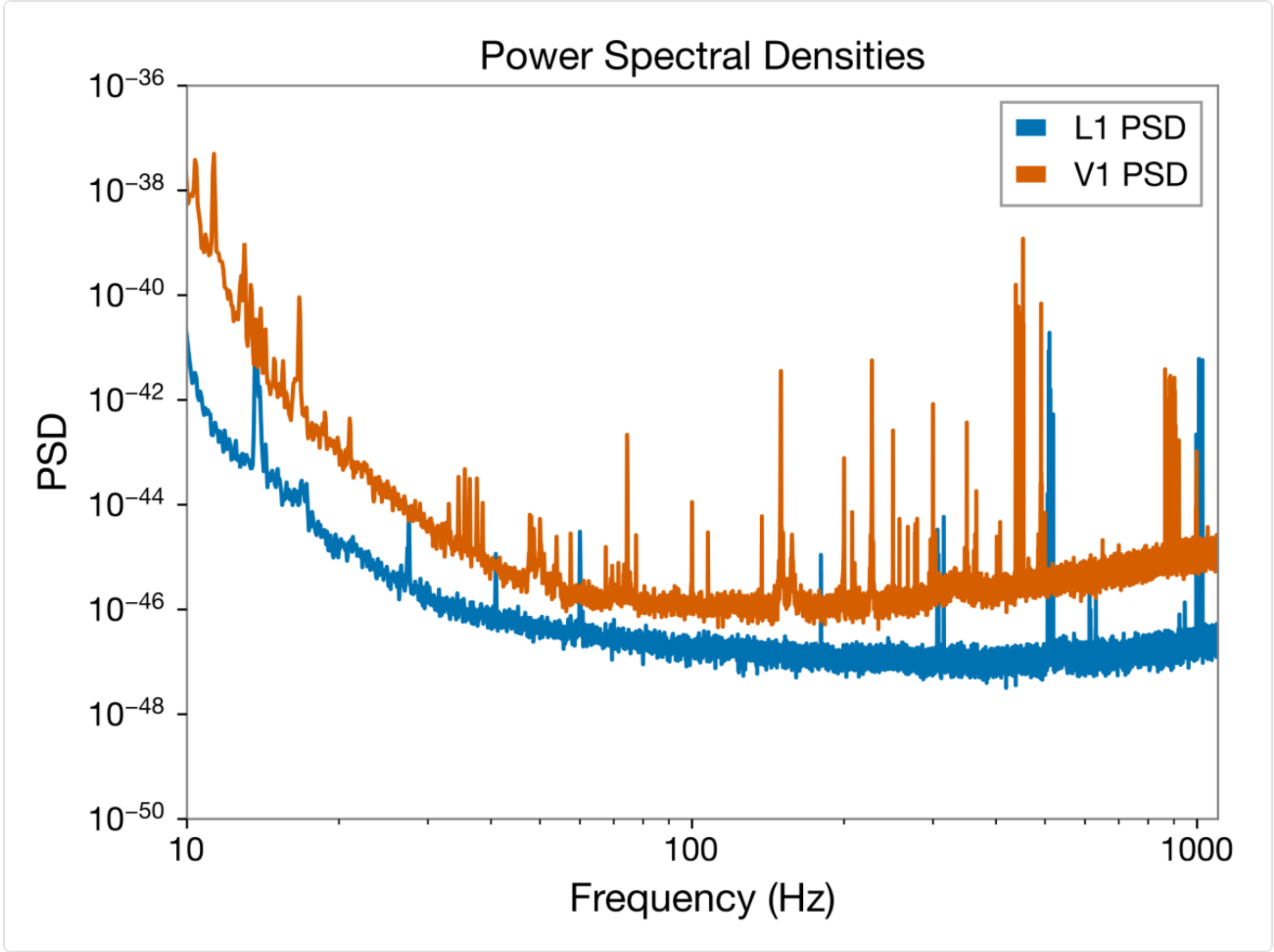
OUTPUT FOLDER gw_tdr_results/240821A

Live Log

```
Input parameters used: transient=240821A; t0=2024-08-21T18:36:02.000; snr_threshold=9.0; snr_type=mf; localization=coords (ra=354.23,
dec=-10.18); iota=default 0-45, 0-90 deg
2026-08-02 11:13:35 (5.60 MB/s) - 'gw_tdr_results/_gwosc_cache/L-L1_GWOSC_04b_4KHZ_R1-1408299008-4096.hdf5.part' saved
[95042278/95042278]
IFOs with available strain data: L1,V1
IFOs used in the analysis:      L1,V1
setting the output map dtype to [dtype('float64')]
INFO:targ_range:240821A: finished compute_range
INFO:targ_range:240821A: starting plot_final
INFO:targ_range:240821A: finished plot_final
INFO:targ_range:240821A: completed analysis
[240821A] DONE in 130.69 s (2.18 min)
ANALYSIS COMPLETE in 131.09 s (2.18 min)
```

Standard TDR products: example for GRB 240821A

PSD plot

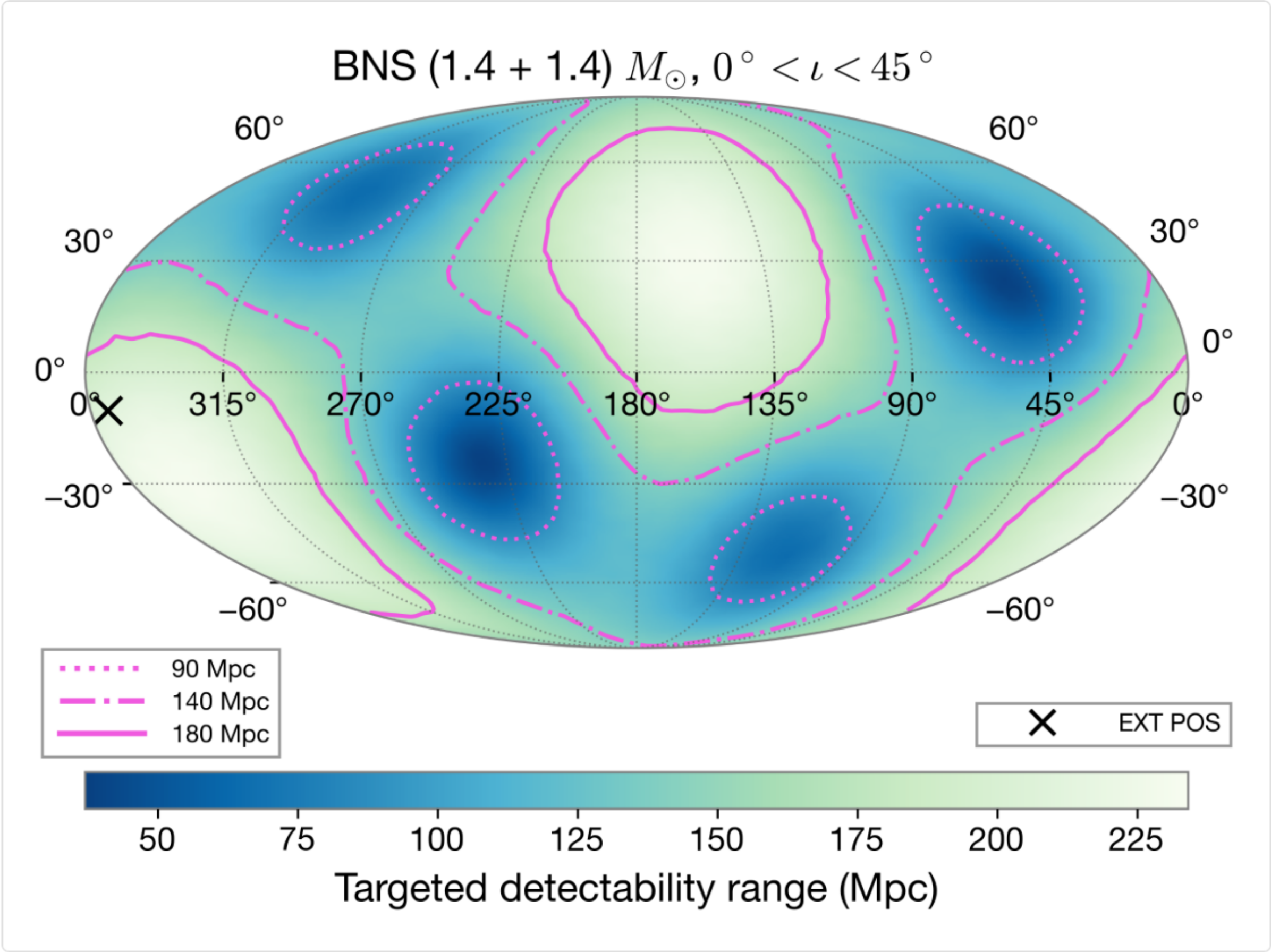


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ONLINE IFOS

L1, V1

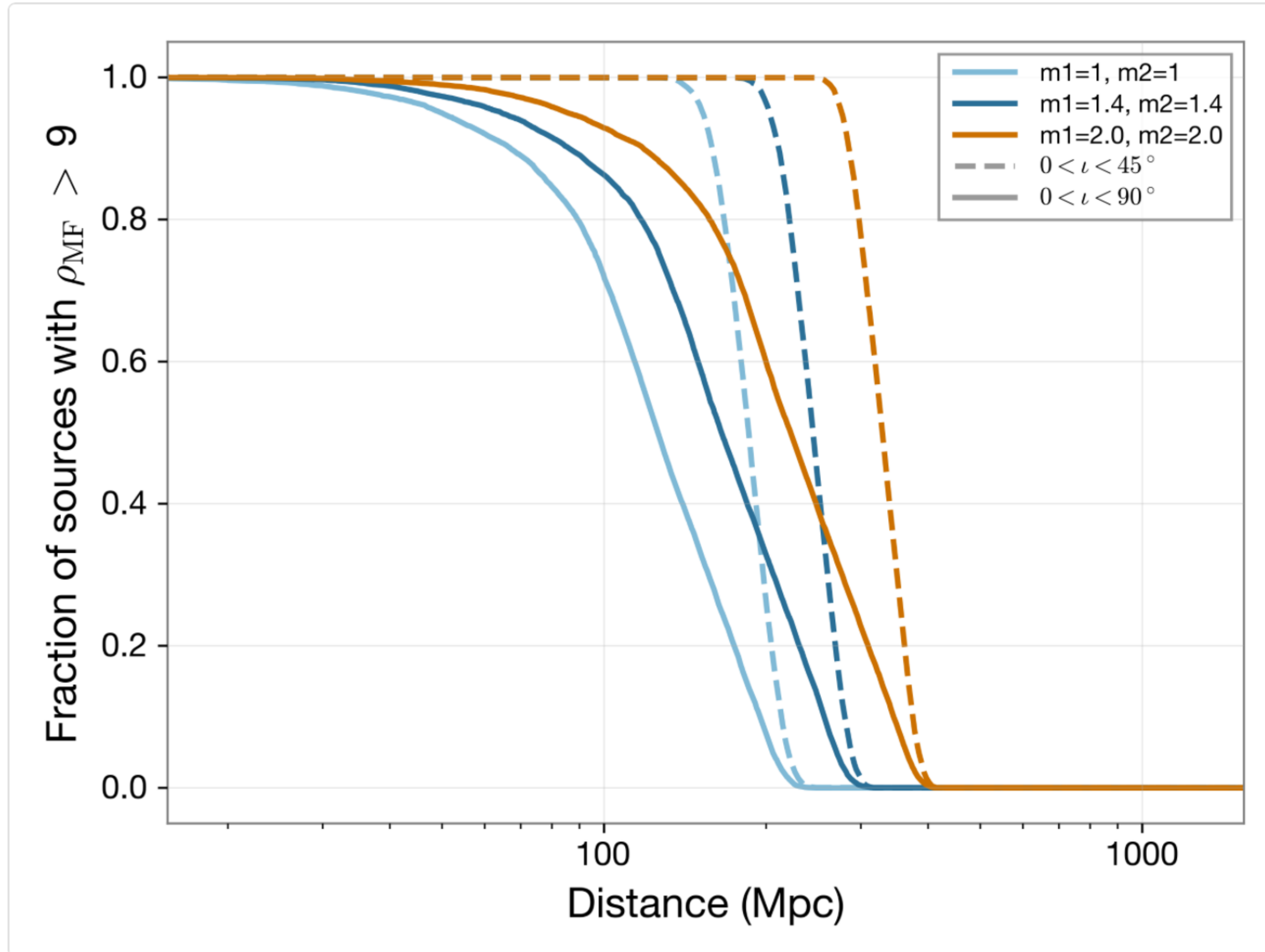
TDR map



[Open](#) [Download](#)

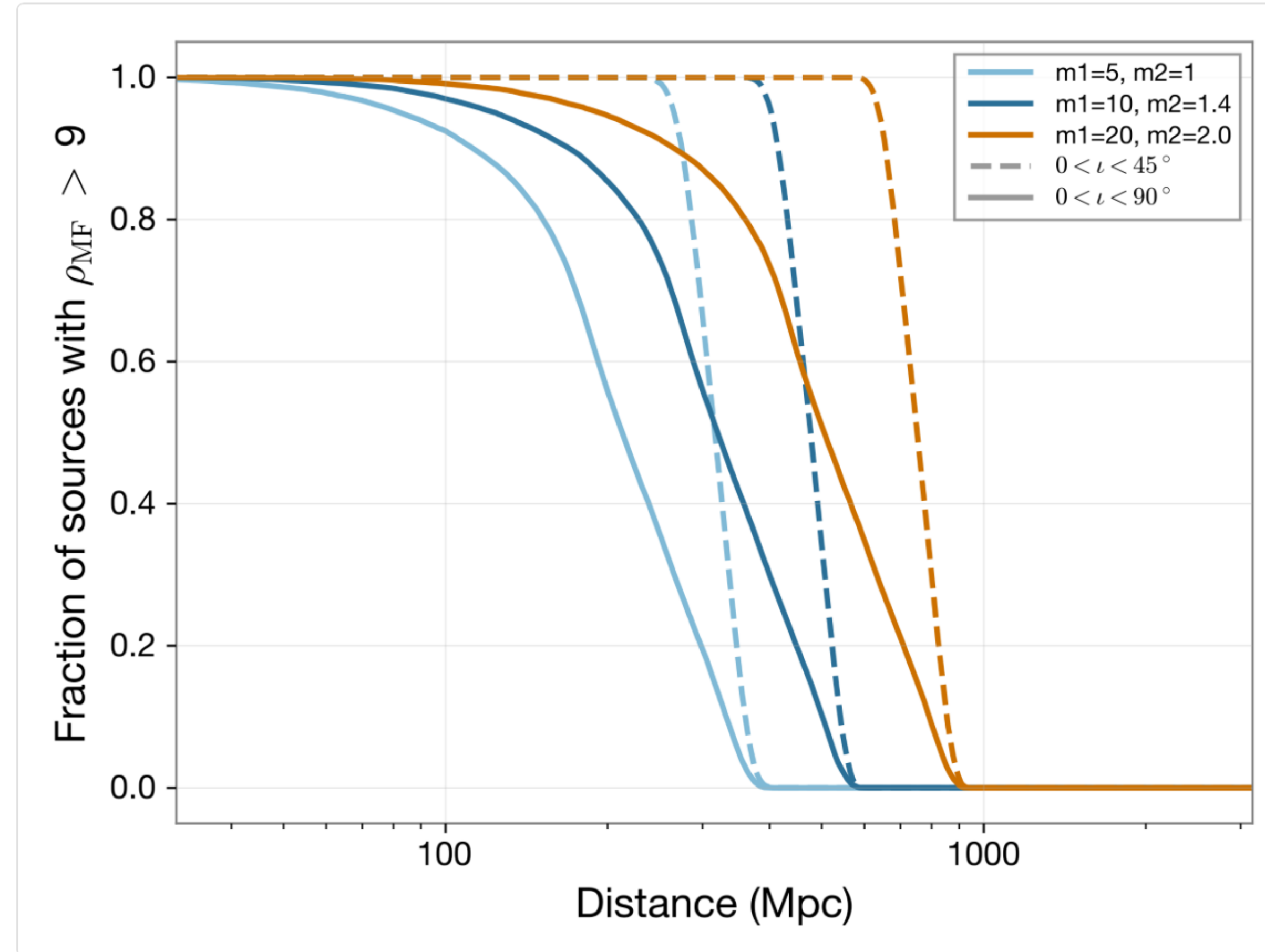
Standard TDR products: example for GRB 240821A

BNS efficiency curve



[Open](#) [Download](#)

NSBH efficiency curve



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Standard TDR products: example for GRB 240821A

Results Summary

Showing default iota ranges 0-45 and 0-90 deg for each mass combination.

BNS [Download JSON](#)

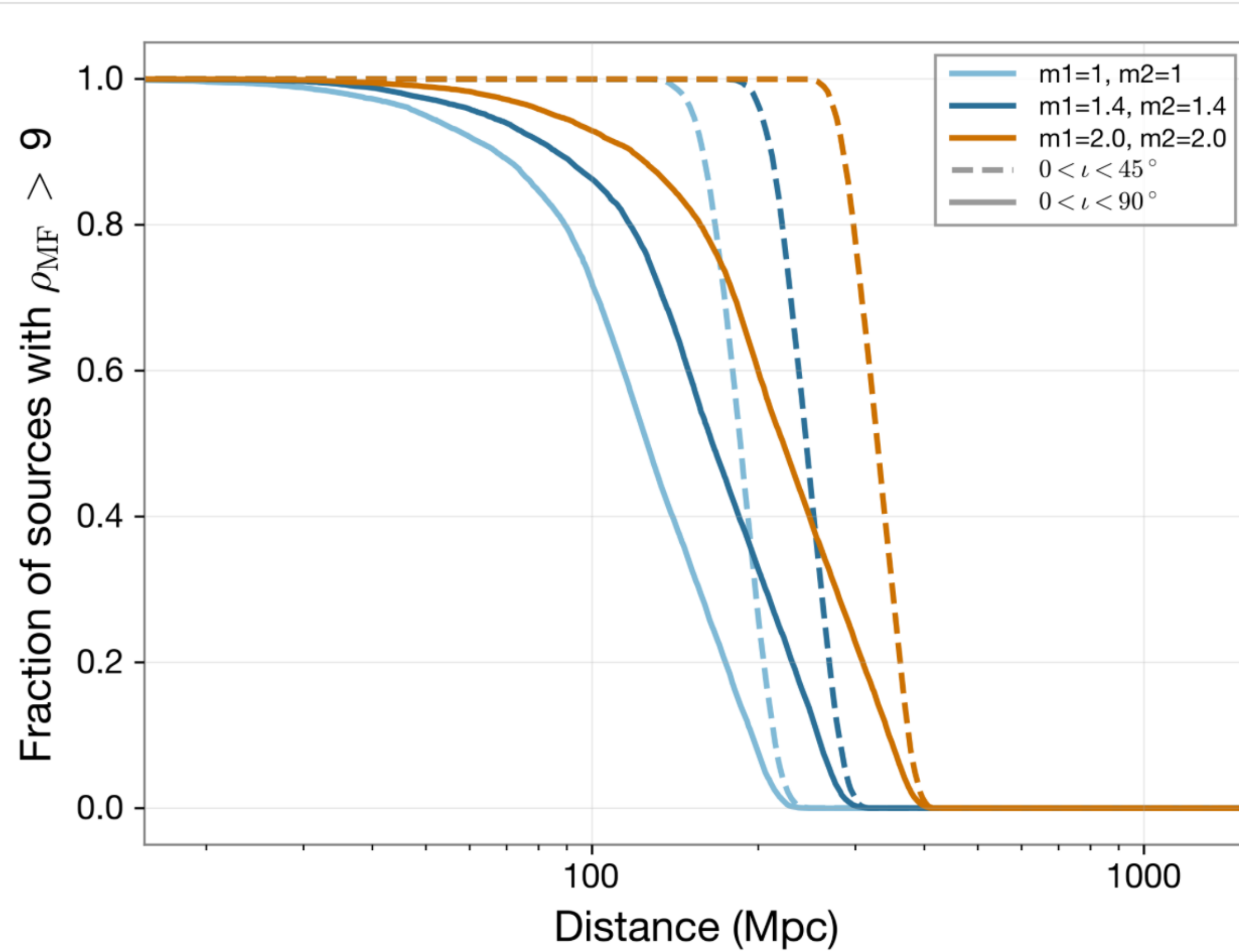
MASS COMBINATION	D ₉₀ 0-45 DEG (MPC)	D ₉₀ 0-90 DEG (MPC)
M ₁ , M ₂ = [1,1] M _⊙	159.0	67.0
M ₁ , M ₂ = [1.4,1.4] M _⊙	211.3	86.2
M ₁ , M ₂ = [2,2] M _⊙	285.2	118.4

NSBH [Download JSON](#)

MASS COMBINATION	D ₉₀ 0-45 DEG (MPC)	D ₉₀ 0-90 DEG (MPC)
M ₁ , M ₂ = [5,1] M _⊙	274.9	112.4
M ₁ , M ₂ = [10,1.4] M _⊙	415.2	170.0
M ₁ , M ₂ = [20,2] M _⊙	657.2	266.6

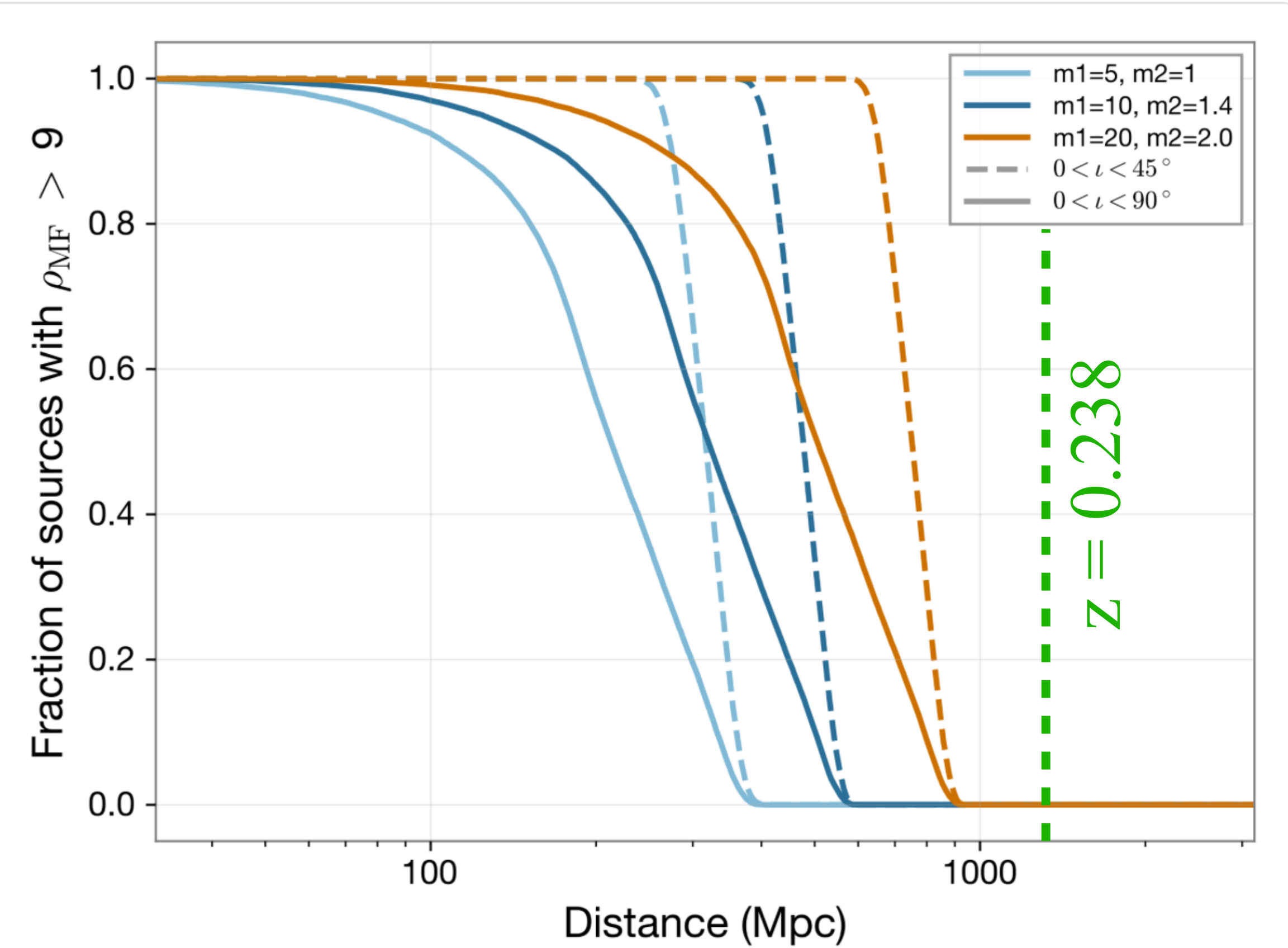
Standard TDR products: example for GRB 240821A

BNS efficiency curve



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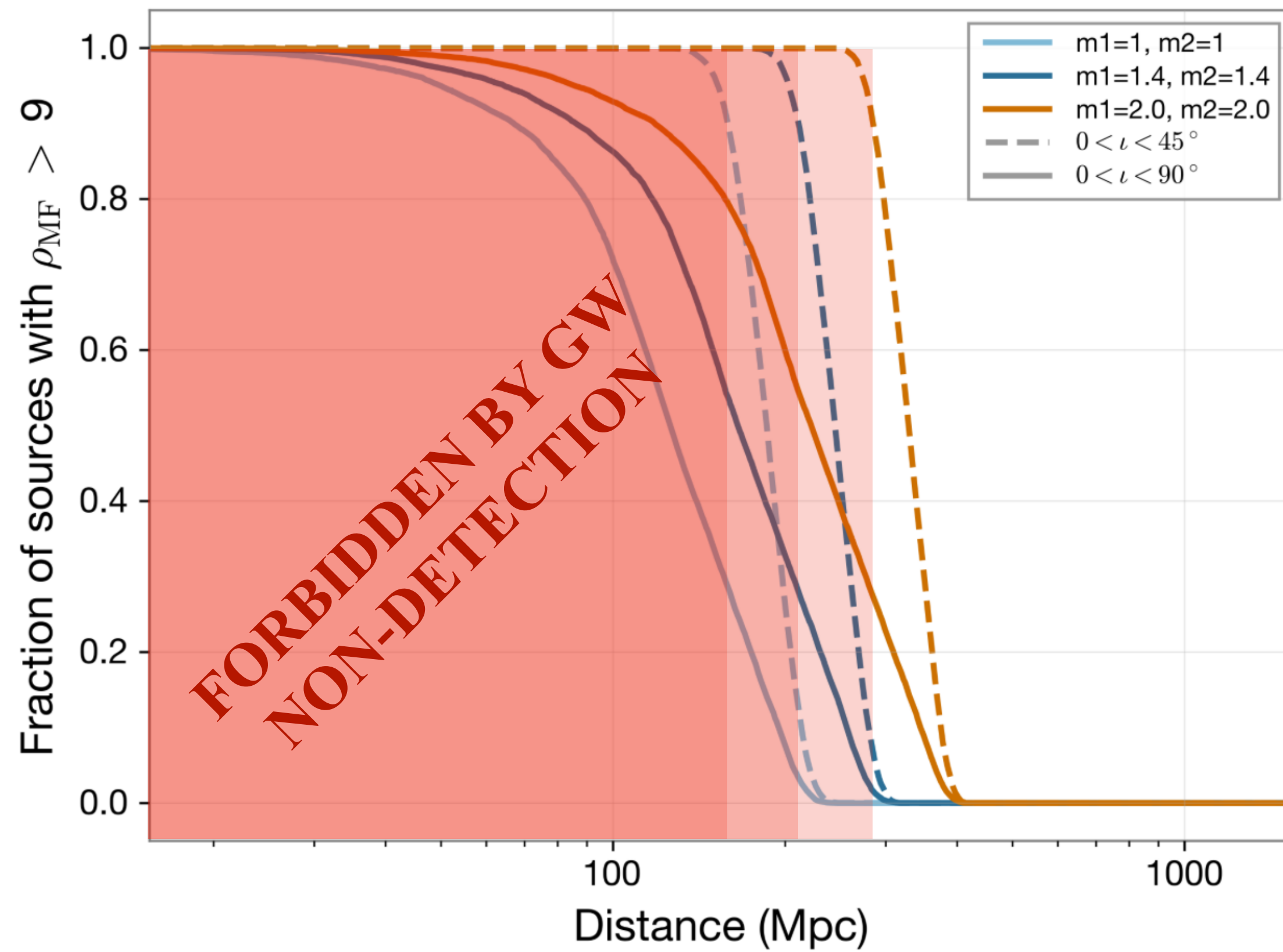
NSBH efficiency curve



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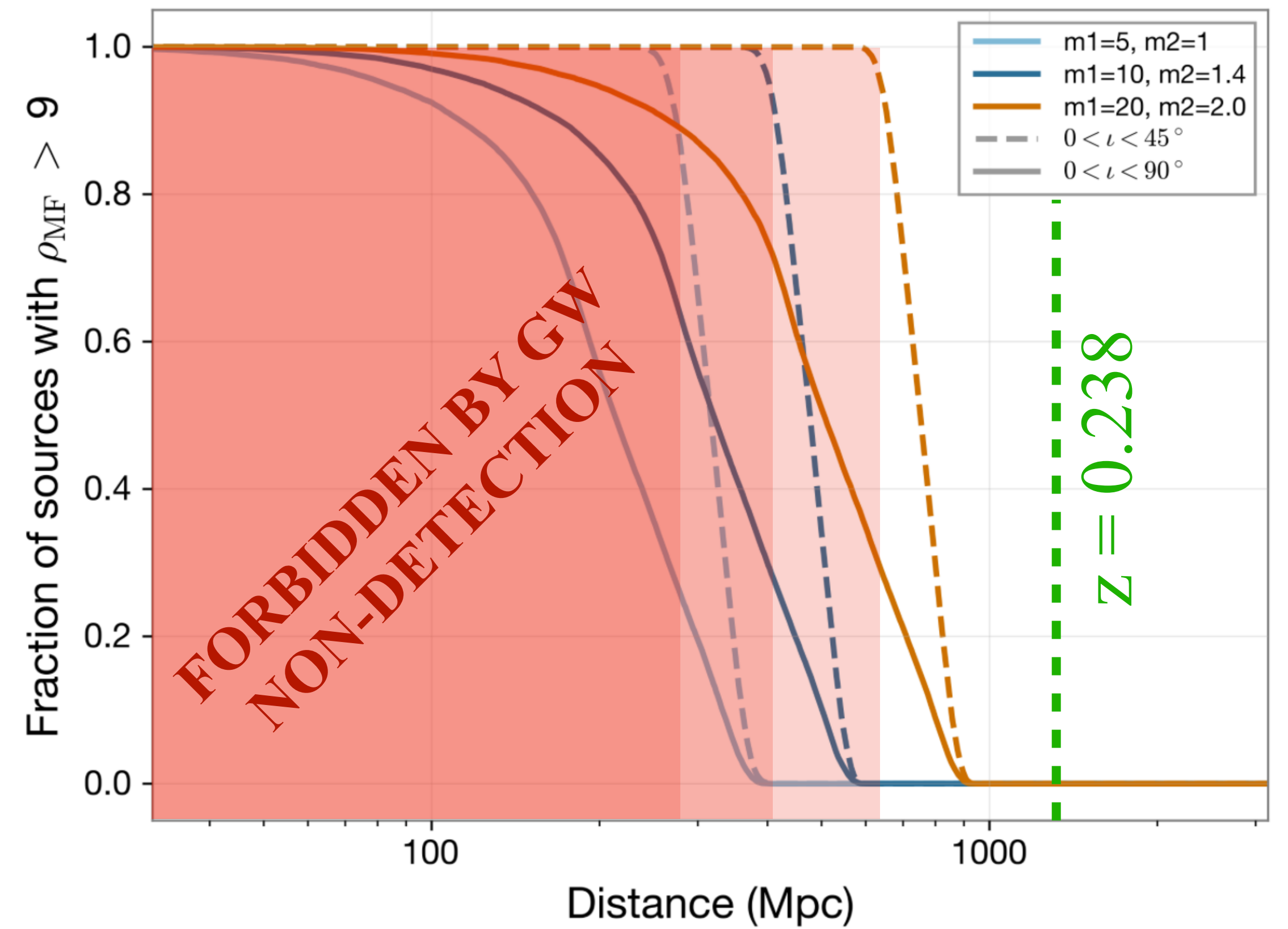
Standard TDR products: example for GRB 240821A

BNS efficiency curve



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NSBH efficiency curve

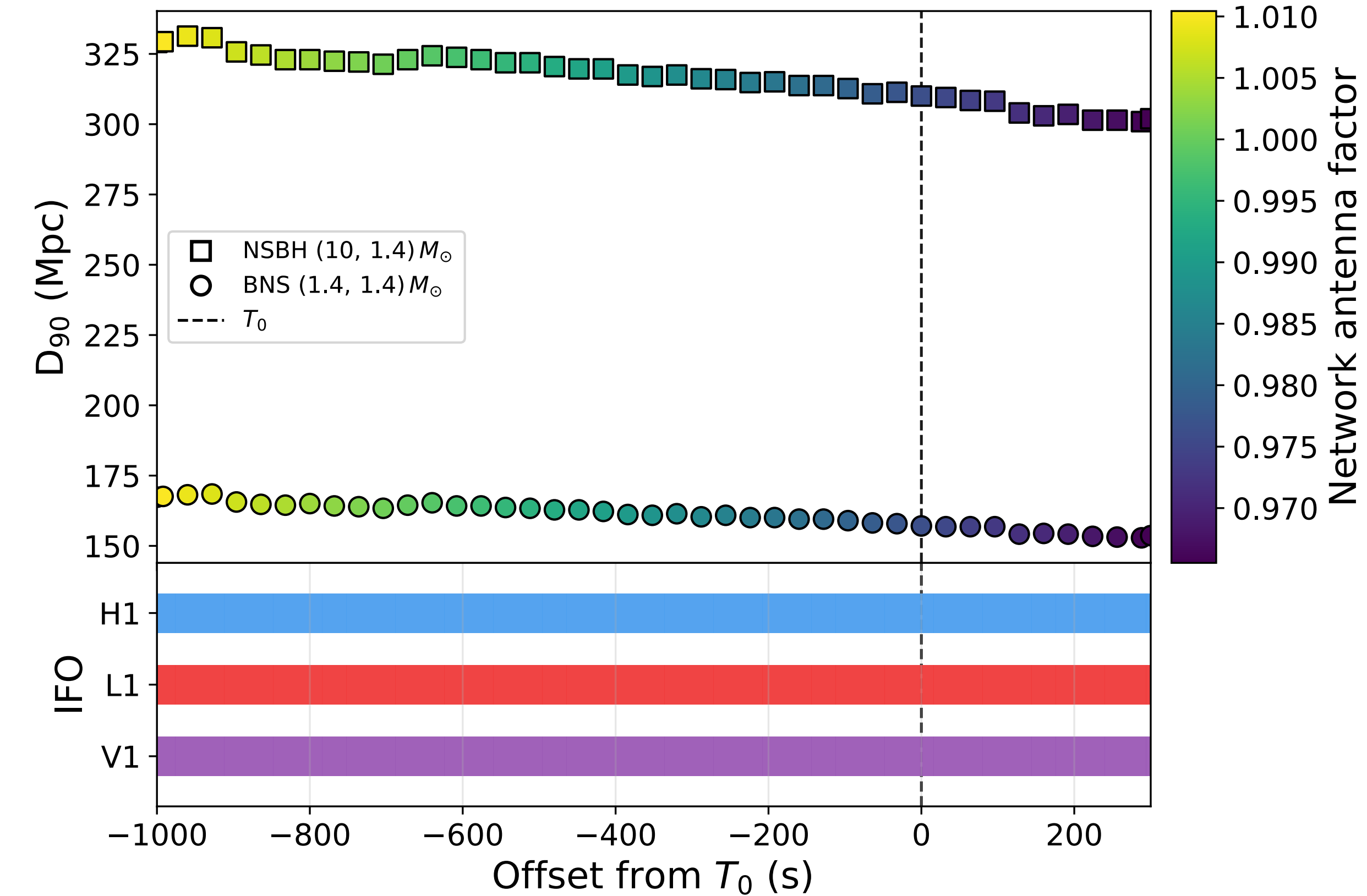


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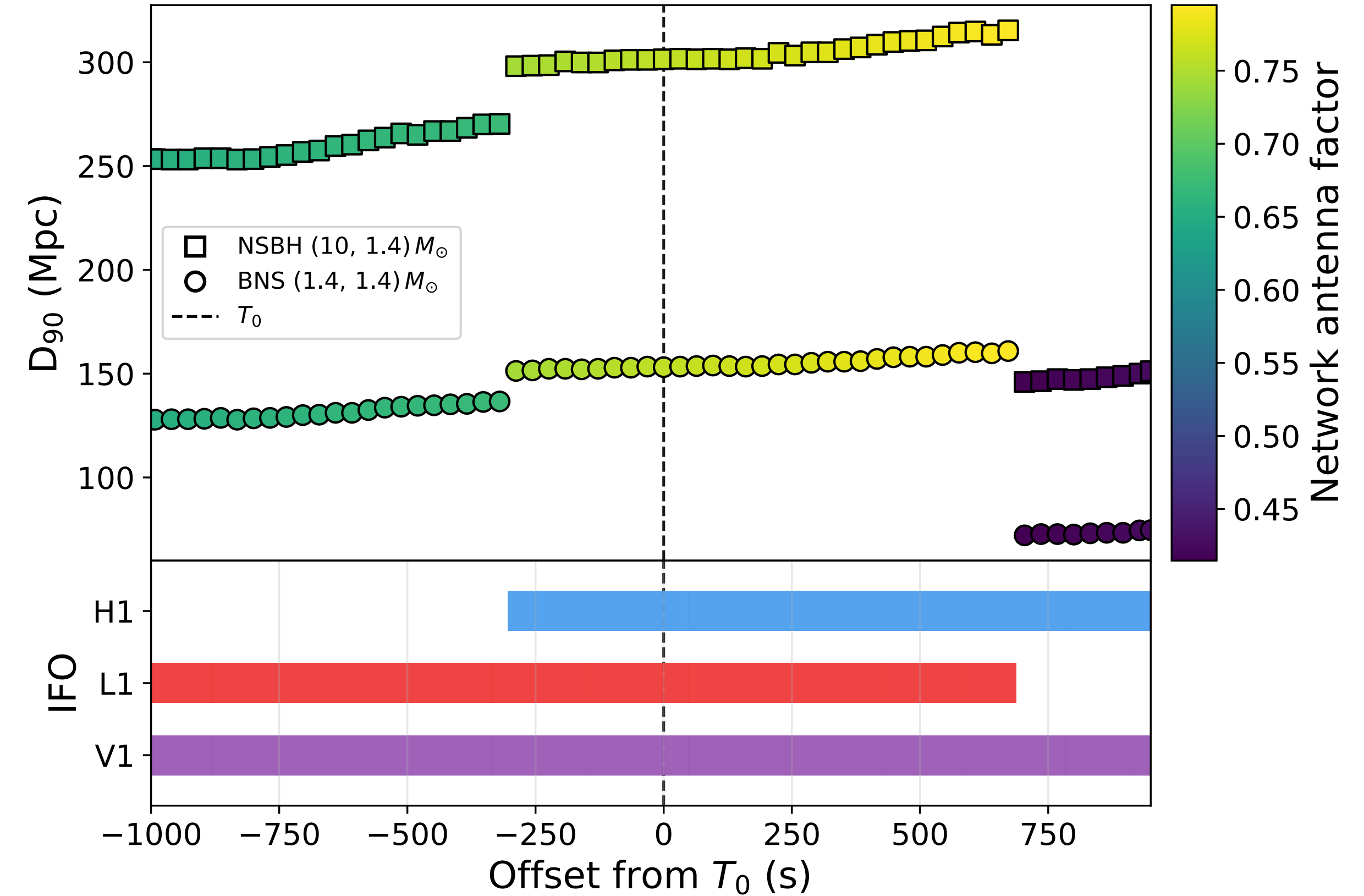
How the TDR can work also on loose constraints on the t_0

Chopra A., **SR** + 26

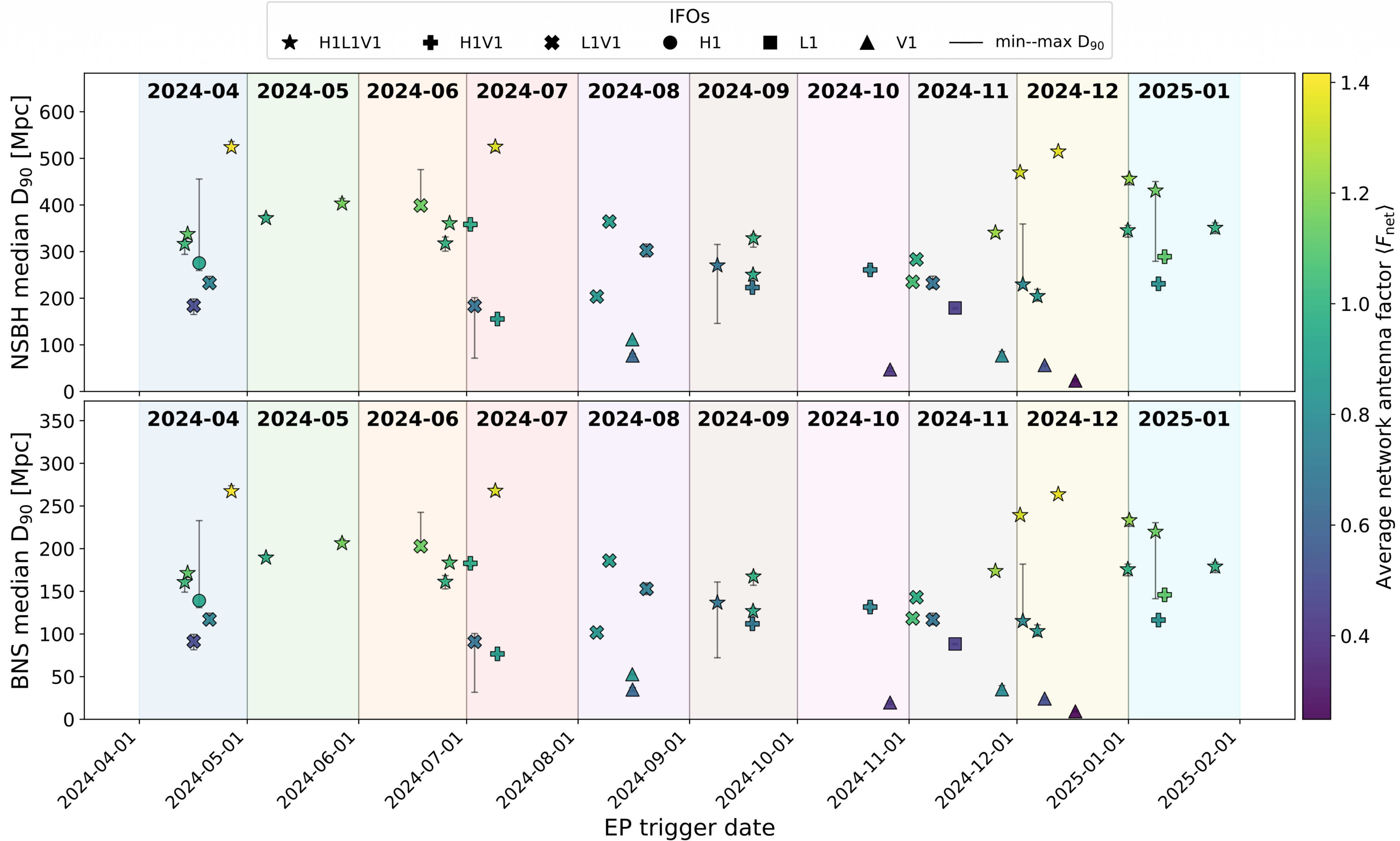
Effect of Earth motion



Sensitive to change of IFOs online



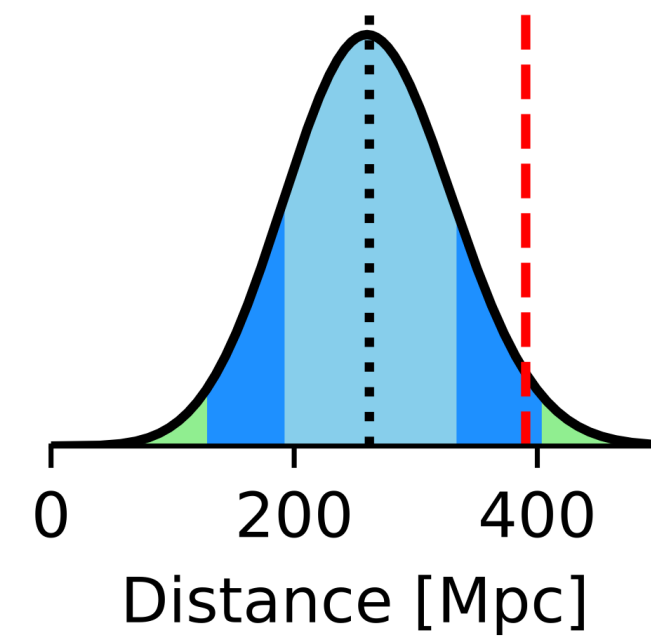
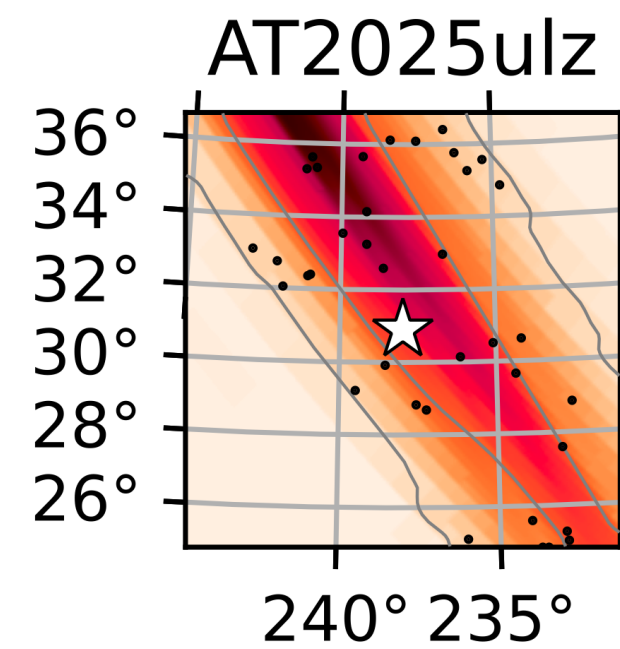
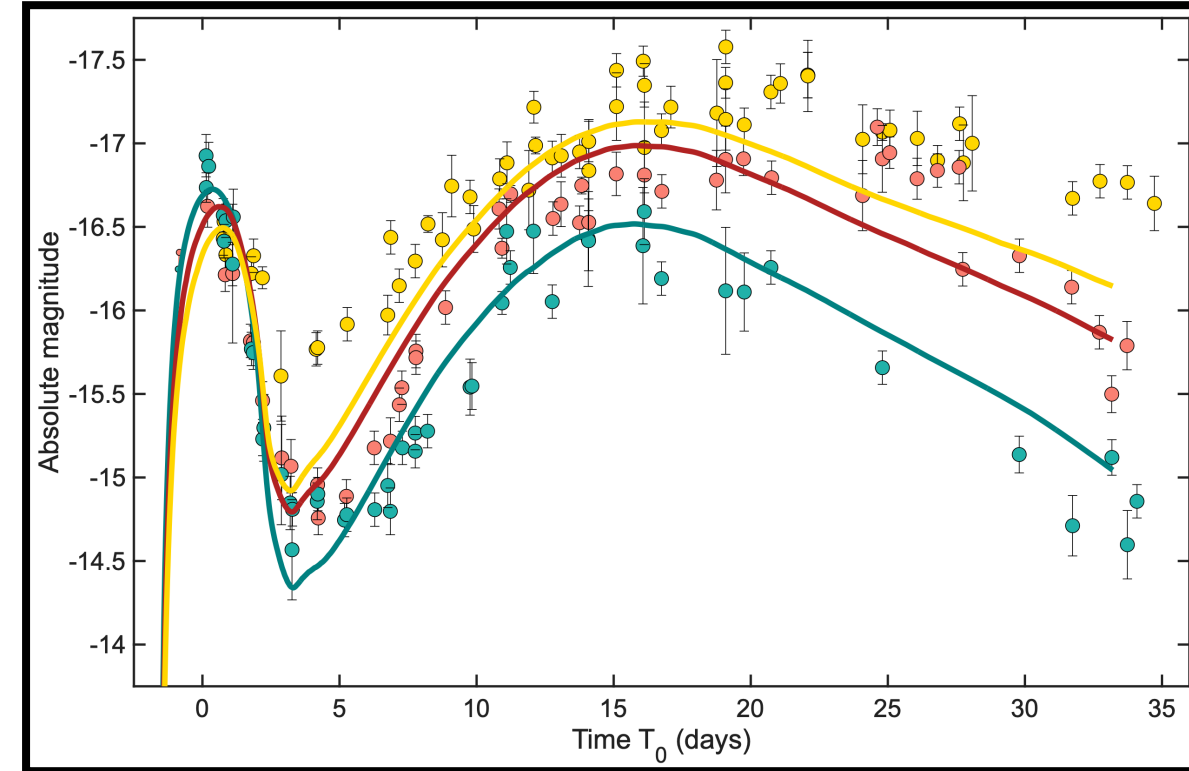
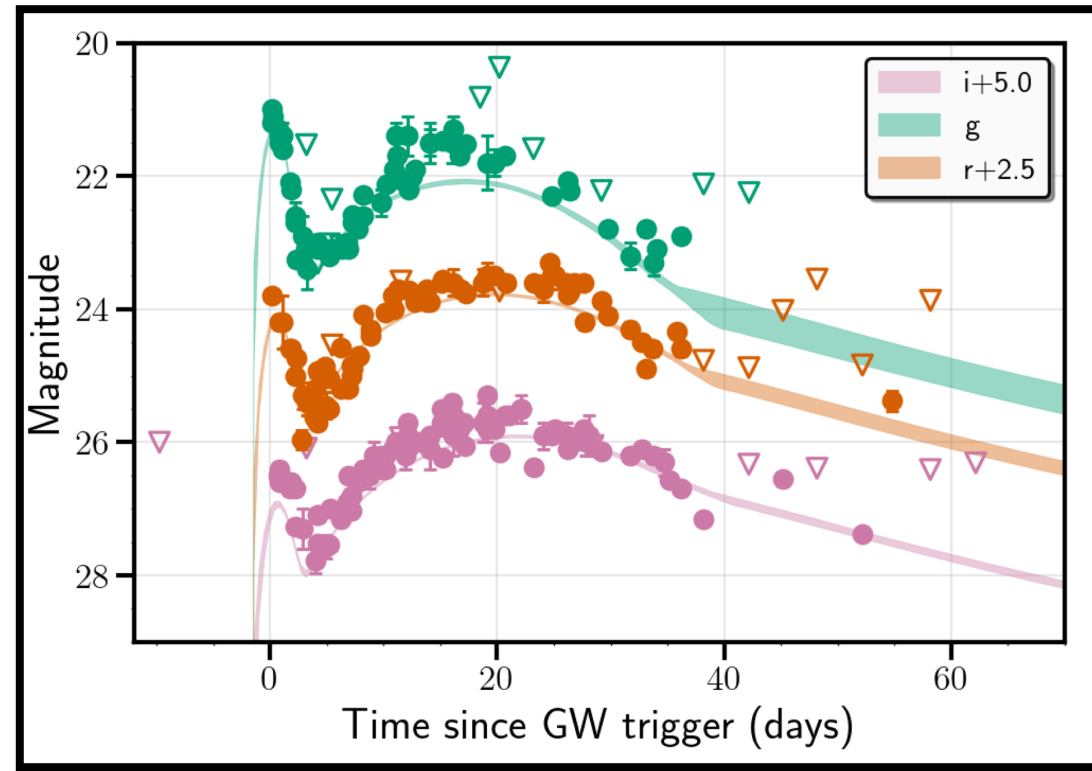
How the TDR can work also on loose constraints on the t_0



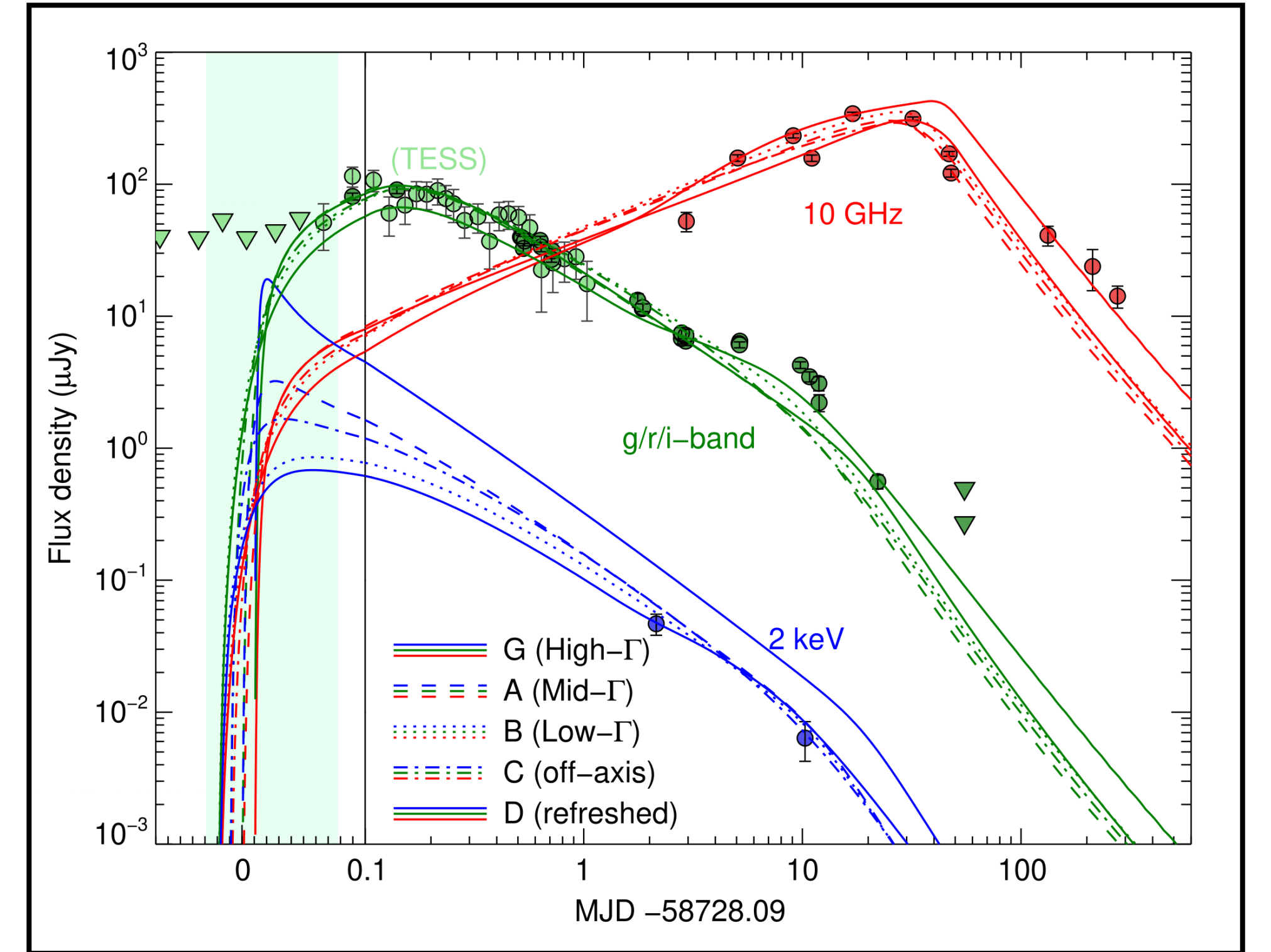
Chopra A., SR + 26

Possible science cases where TDR can make the difference

KN candidates that have an estimate of t_0



Orphan afterglows that have an estimate of t_0



Down to few 10^2 s of uncertainty on t_0

Stein et al. 2025; Gillanders et al. 2025; Kasliwal et al. 2025;
O'Connor et al. 2025; Ackley et al. 2026

e.g., Xu et al. 2023; Srinivasaragavan et al. 2025;
Perley et al. 2025; Li et al. 2025

GW Targeted Detectability Range

🕒 **Fri 23 Oct 2026, 10:00 - 16:00**

📅 Calendar

Hands-on sessions

Description

Starting from the basic principles of gravitational-wave (GW) detection and data analysis, this tutorial shows how to derive a GW detection probability informed by the observational properties of an astronomical transient potentially associated with a compact binary coalescence. We will discuss how this information is exploited as a prior in computing the GW Targeted Detectability Range (TDR, Ronchini et al. 2026), with the method applied to BNS and NSBH mergers. Participants will become familiar with the tool both through a publicly accessible web interface and via a local installation. We will show the TDR applied to GRBs and to fast X-ray transients, extending its applicability to cases where the delay between the GW signal and the first photons is not well predictable a priori. The tutorial will conclude with an introductory discussion of GW targeted searches (modeled and unmodeled) and how they compare with the TDR tool. Tutor: Samuele Ronchini
Node: GSSI

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Oct

23

Friday

Oct **GW Targeted Detectability Range**

23 Fri 23 Oct, 10:00 - 16:00

Conclusions

- **The Targeted Detectability Range (TDR) provides in low-latency a fast computation of GW detection range, informed by EM priors**
- **Computationally cheap version of the more robust estimate given by offline GW targeted searches (PyGRB)**
- **If there is a nearby, potential host galaxy of an EM transient, possibly merger driven, TDR can disfavor/keep viable the association**
- **If an EM transient has a confirmed host, and hence redshift, TDR can disfavor/keep viable the merger origin**
- **Now TDR is available for offline use only (on all LVK data already released), but a low-latency implementation would help prioritizing EM follow-up**
- **The low computational cost allows to run TDR on wide time ranges, ideal for EM transients where the EM-GW time delay is not well known a priori (e.g. Fast X-ray Transients, Kilonovae, high-energy neutrinos)**



method paper



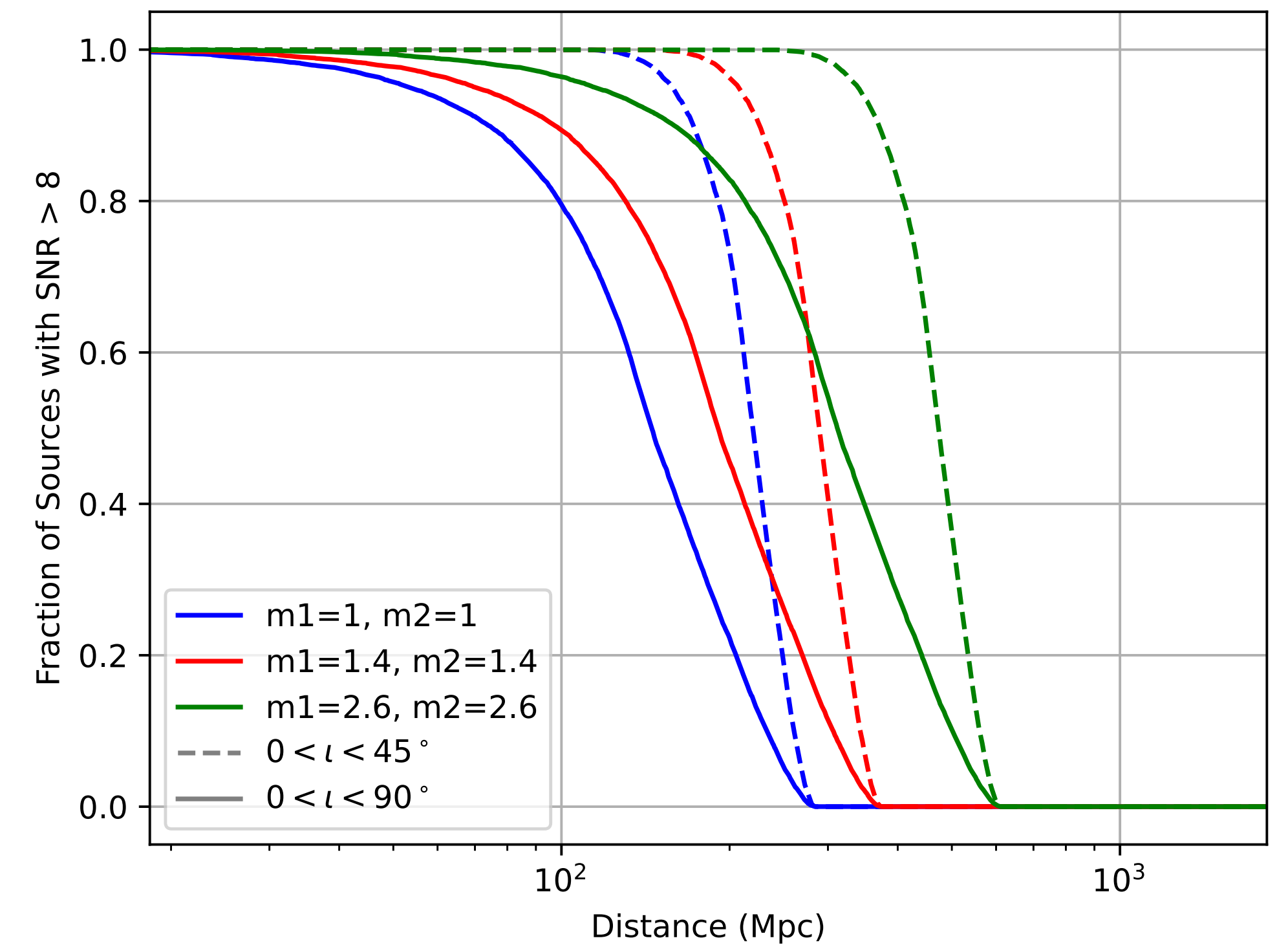
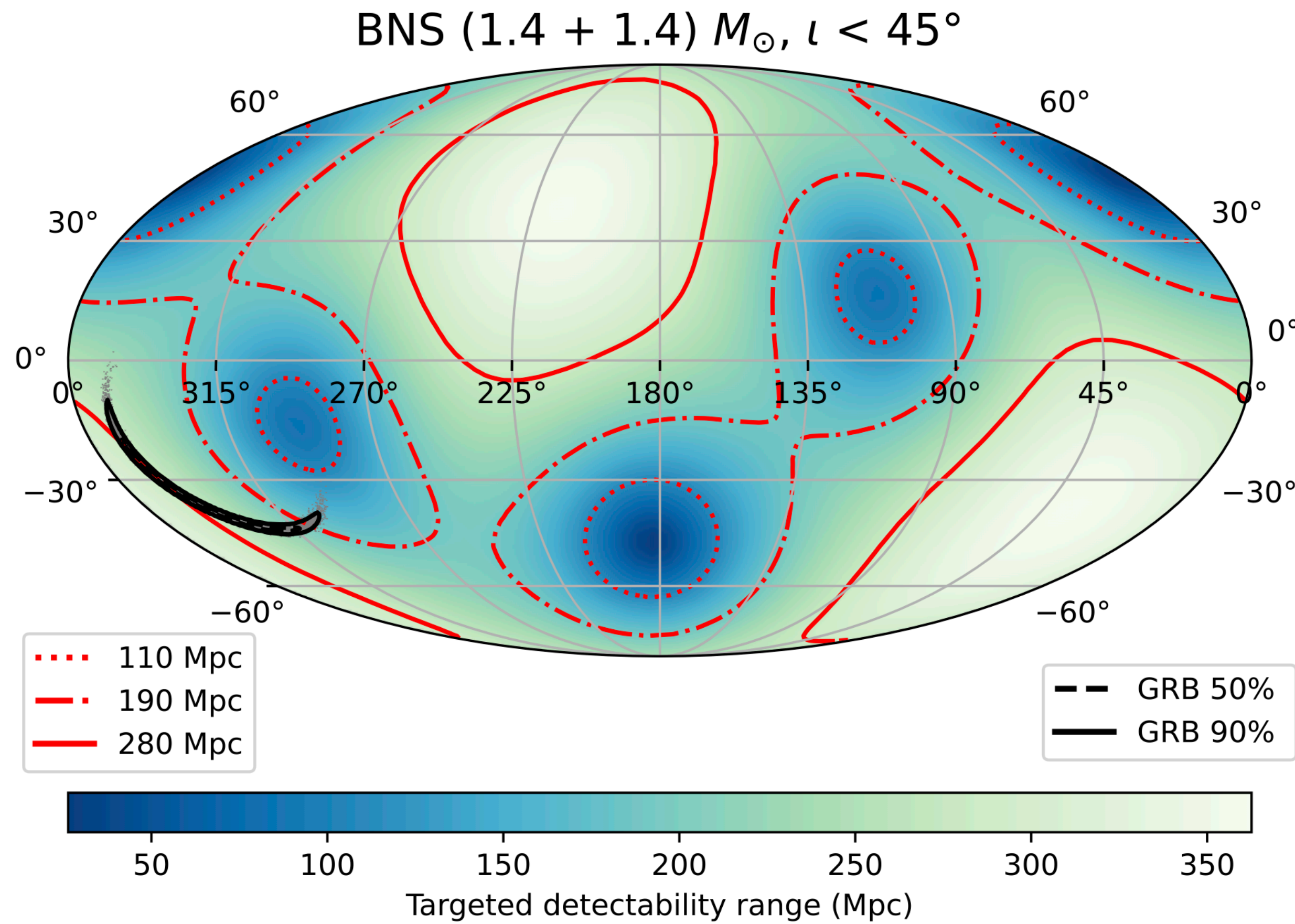
web tool



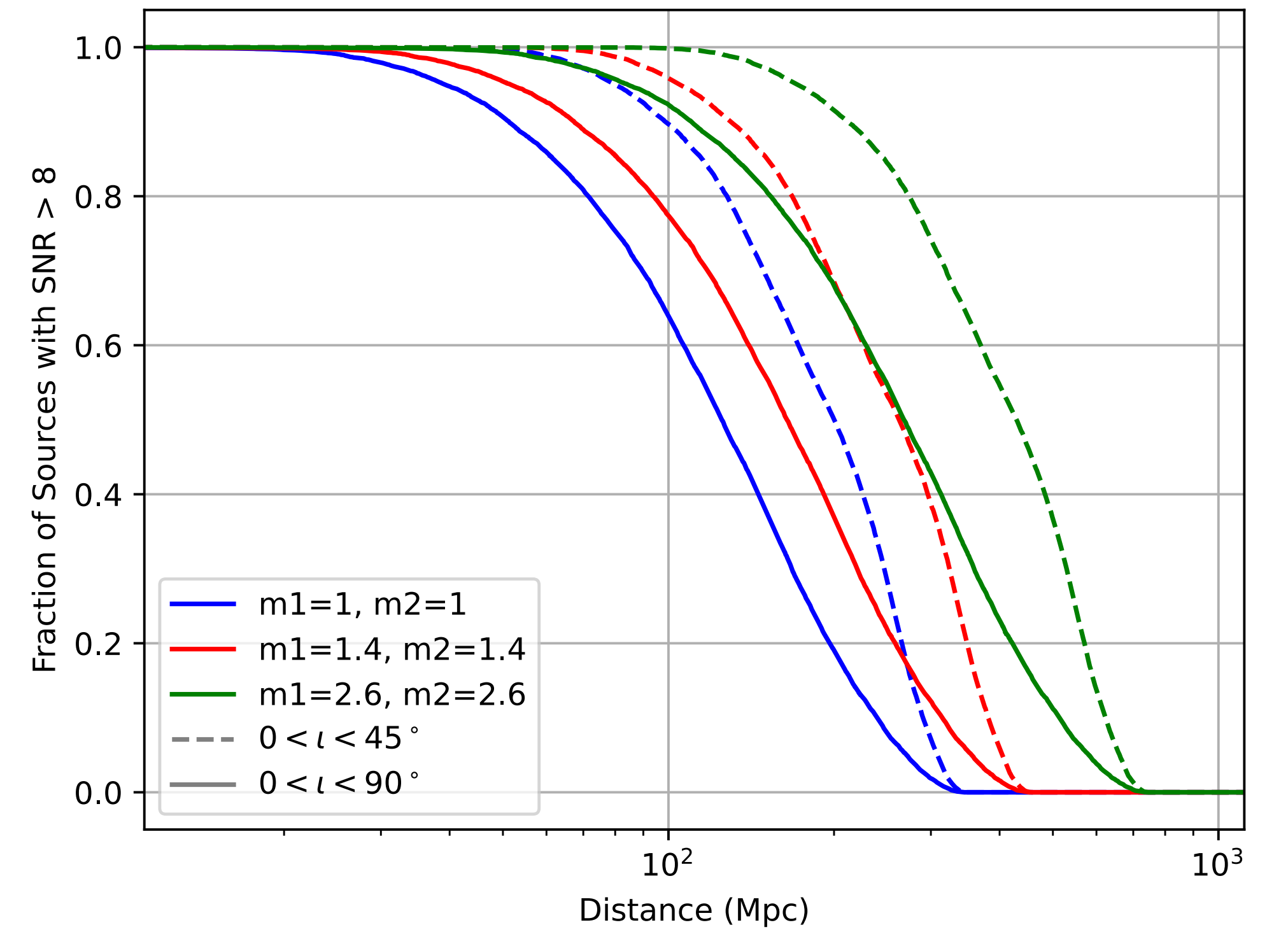
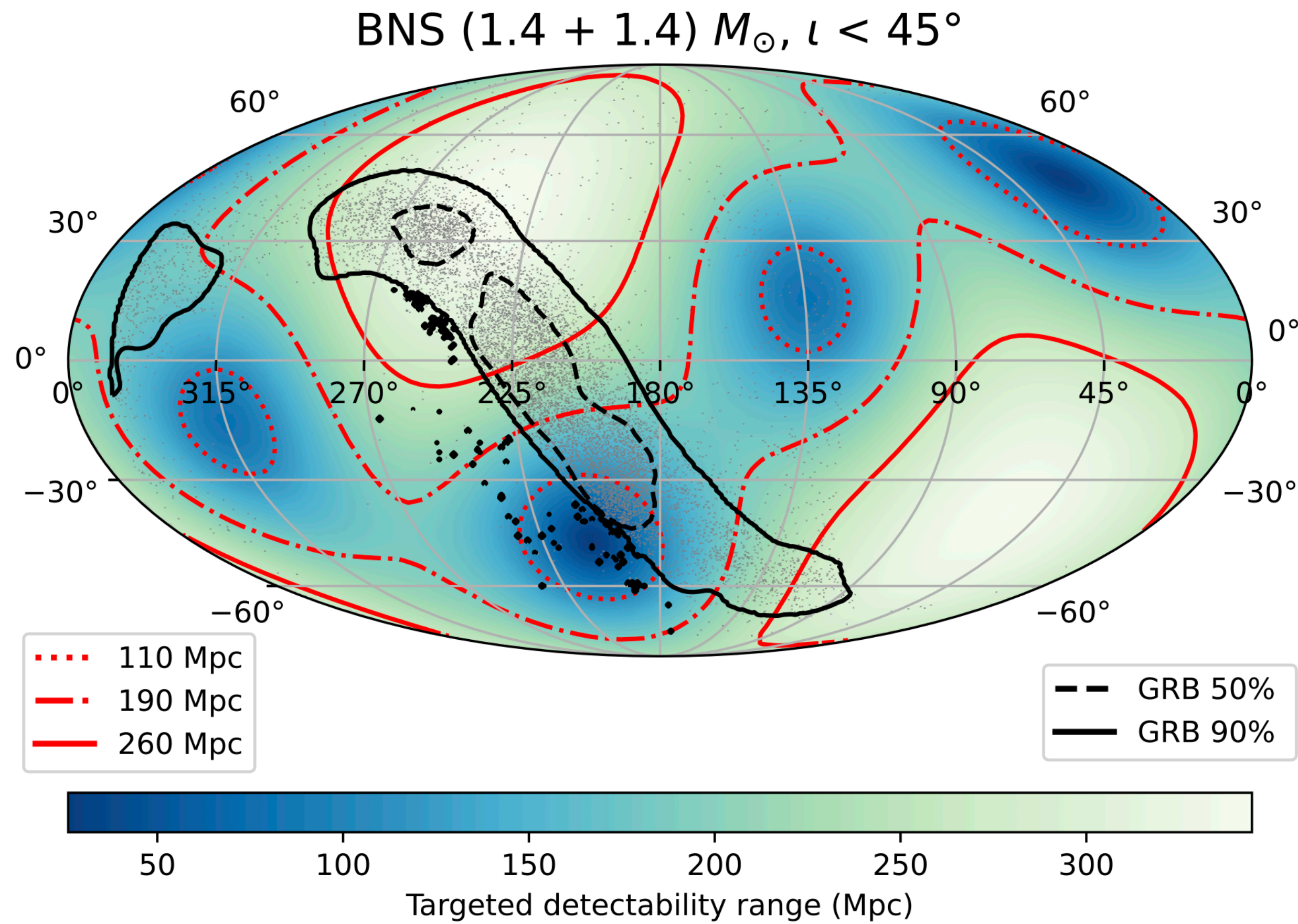
EP paper

Backup

IPN localization

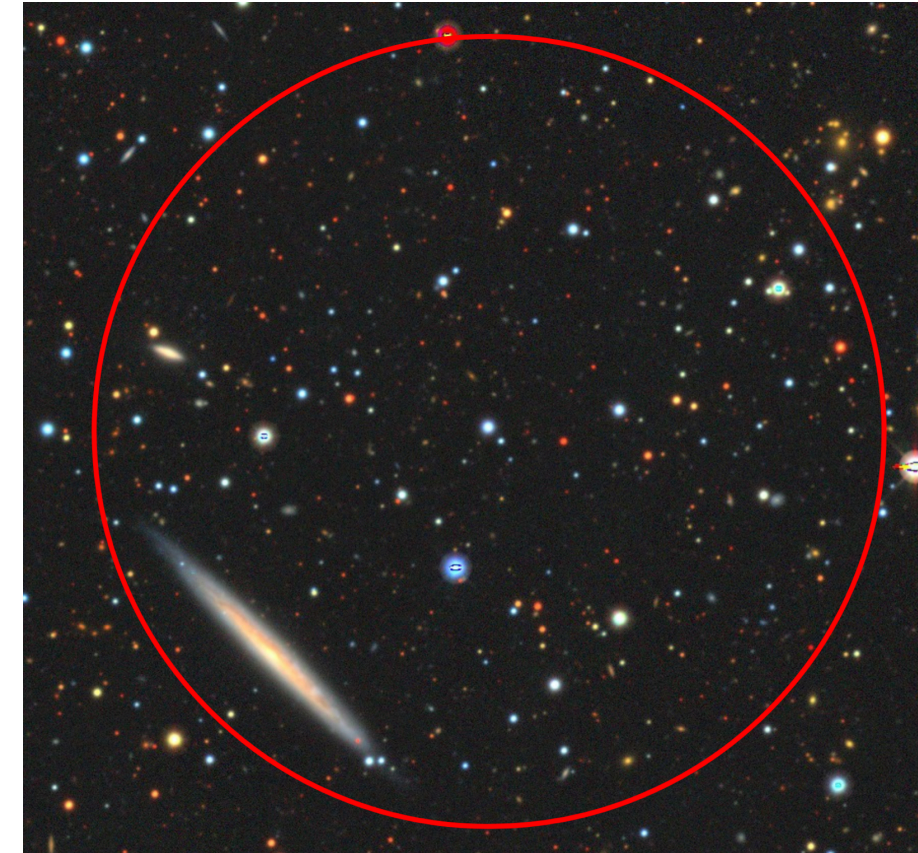


Sub-threshold Swift localization



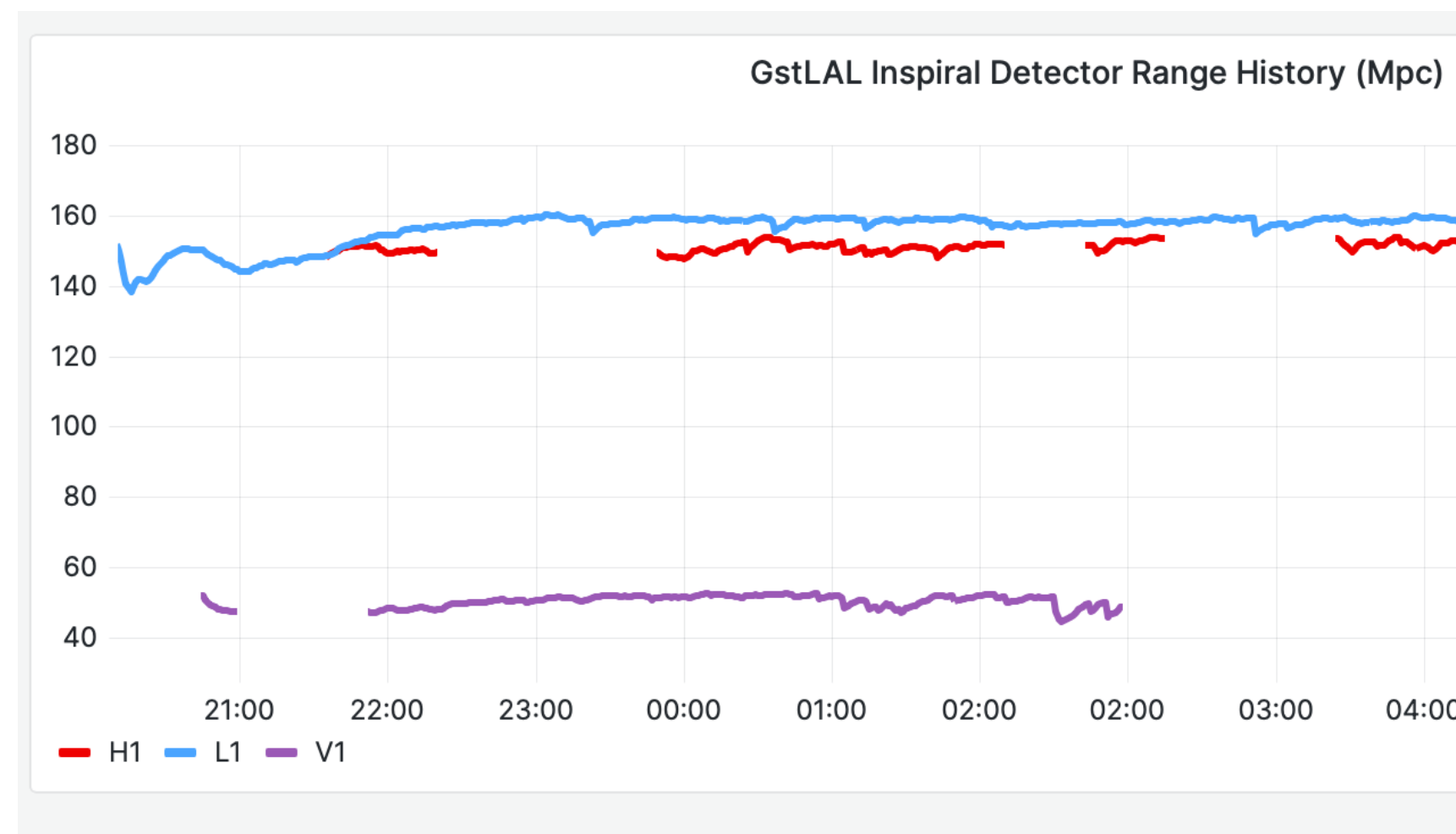
GRB 250225B

- Galaxy at 78 Mpc inside the Swift-BAT error region
- **0.9% probability** to have by chance a galaxy at $d < 80$ Mpc inside a circle of 3 arcmin
- **Can it be merger-driven? Are GW interferometers online? What is their detection range?**
- **Do we want to activate EM follow-up?**
- ...
- GCN 40024 finally confirmed the host is likely at $z = 0.950$, ruling out the local galaxy



GRB 211211A and GRB 230307A

- **First confirmed long GRBs associated to Kilonova**
- No IFO was online
- Some models involve NSBH merger
- If any IFO was online, **a statement about BNS/NSBH detectability could have disfavored/excluded possible scenarios**



https://gwosc.org/detector_status/

