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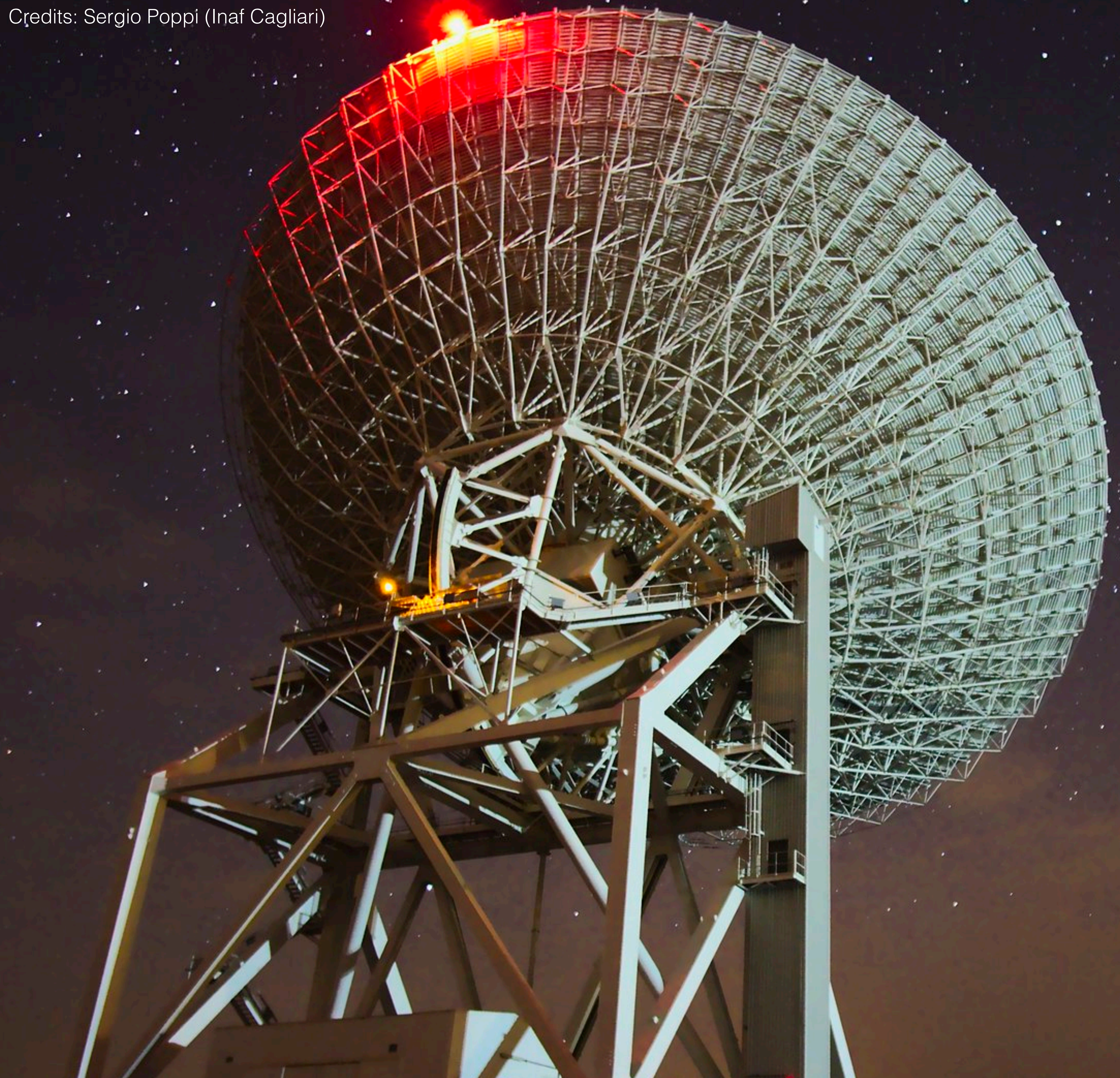
DI ASTROFISICA

The revolution of the SKA on GRB studies

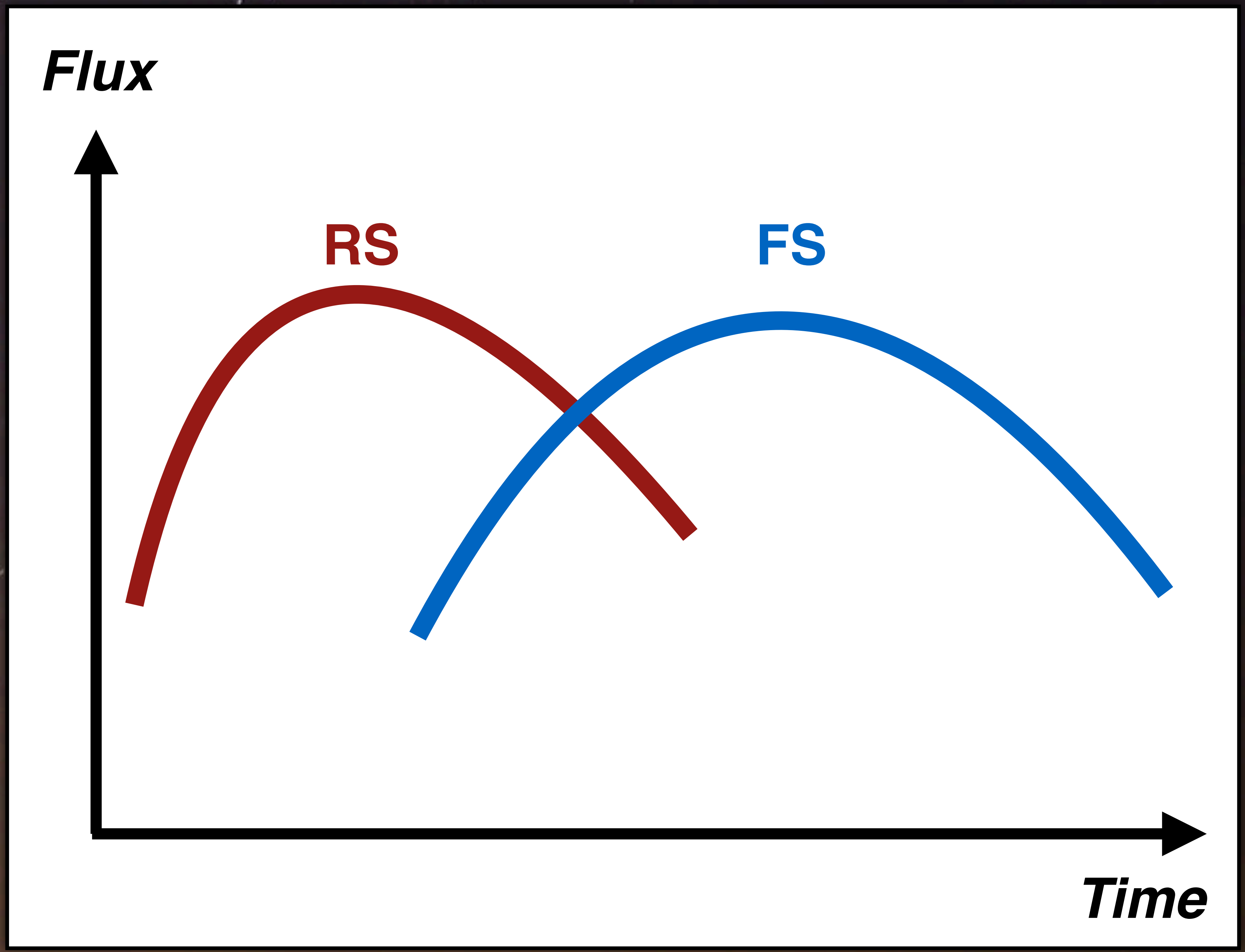
Credits: Sergio Poppi (Inaf Cagliari)

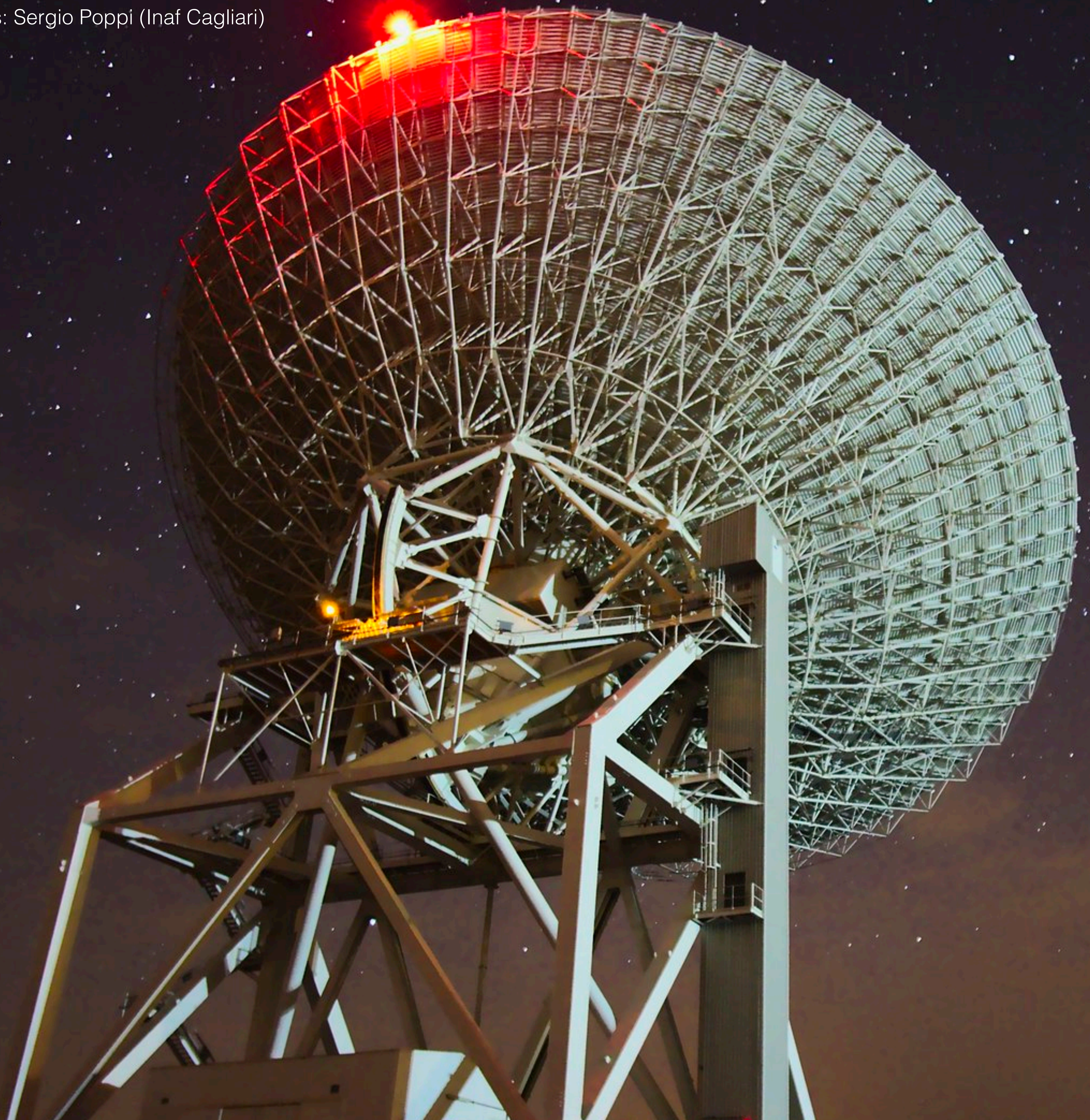


GRBs in Radio

Emission mechanism

Forward vs Reverse shocks





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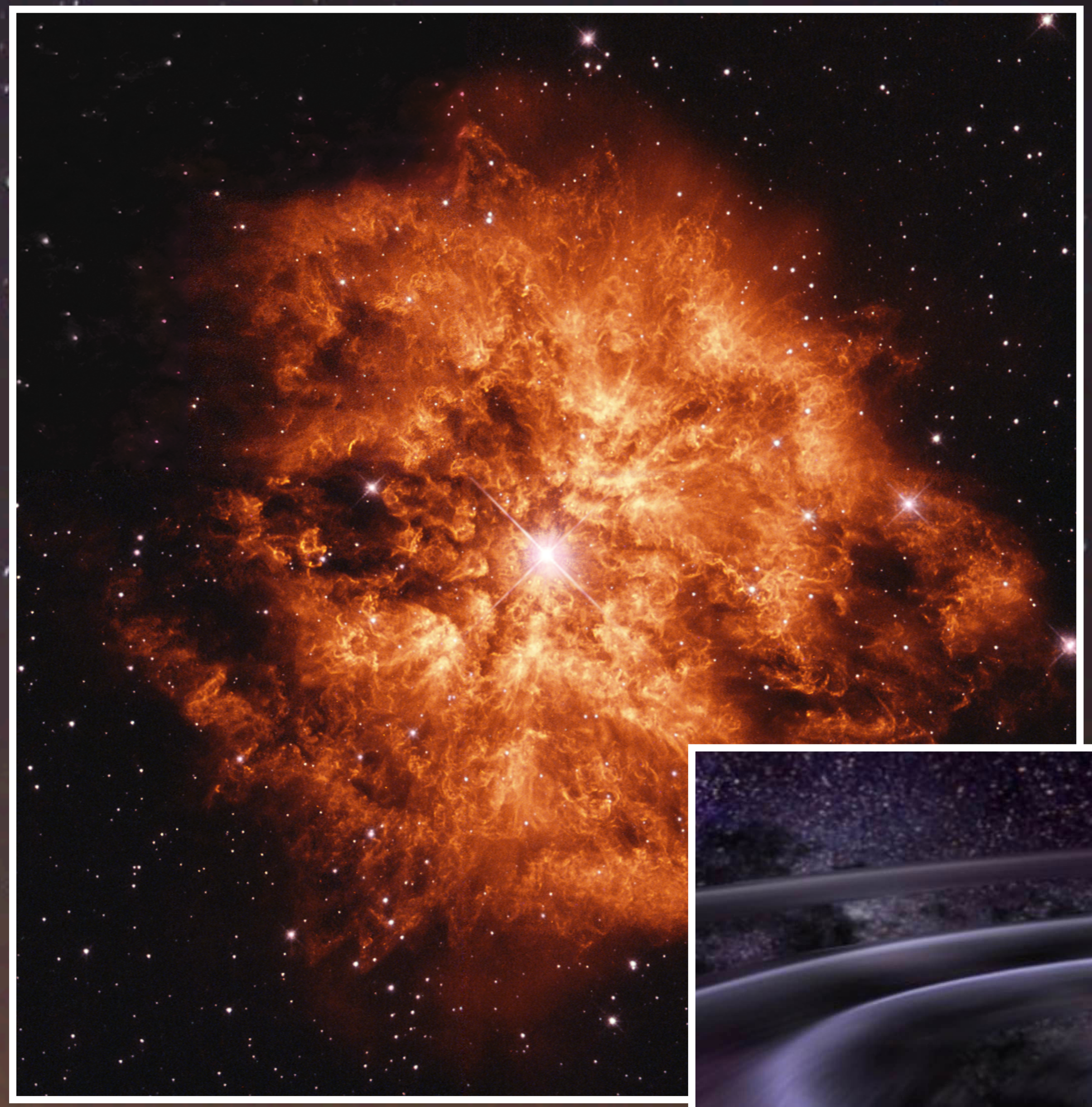
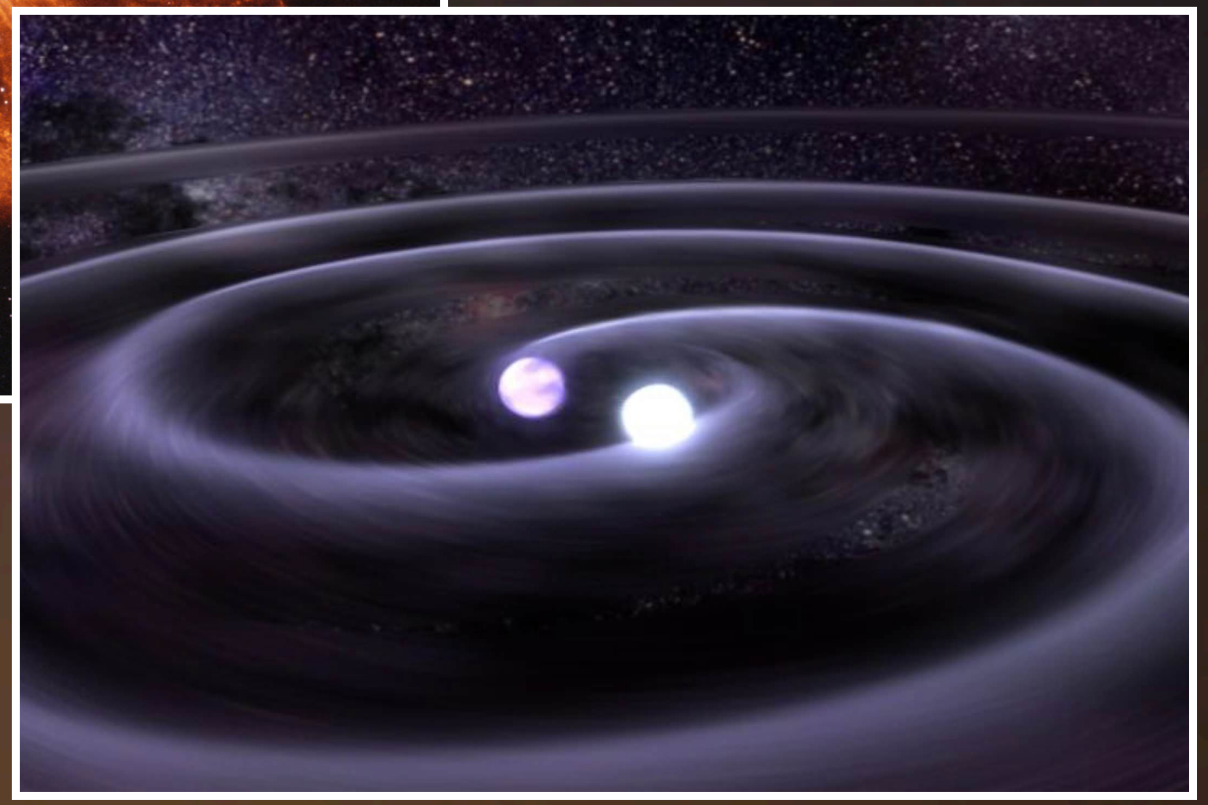
GRBs in Radio

Progenitors

Circum-burst density profile





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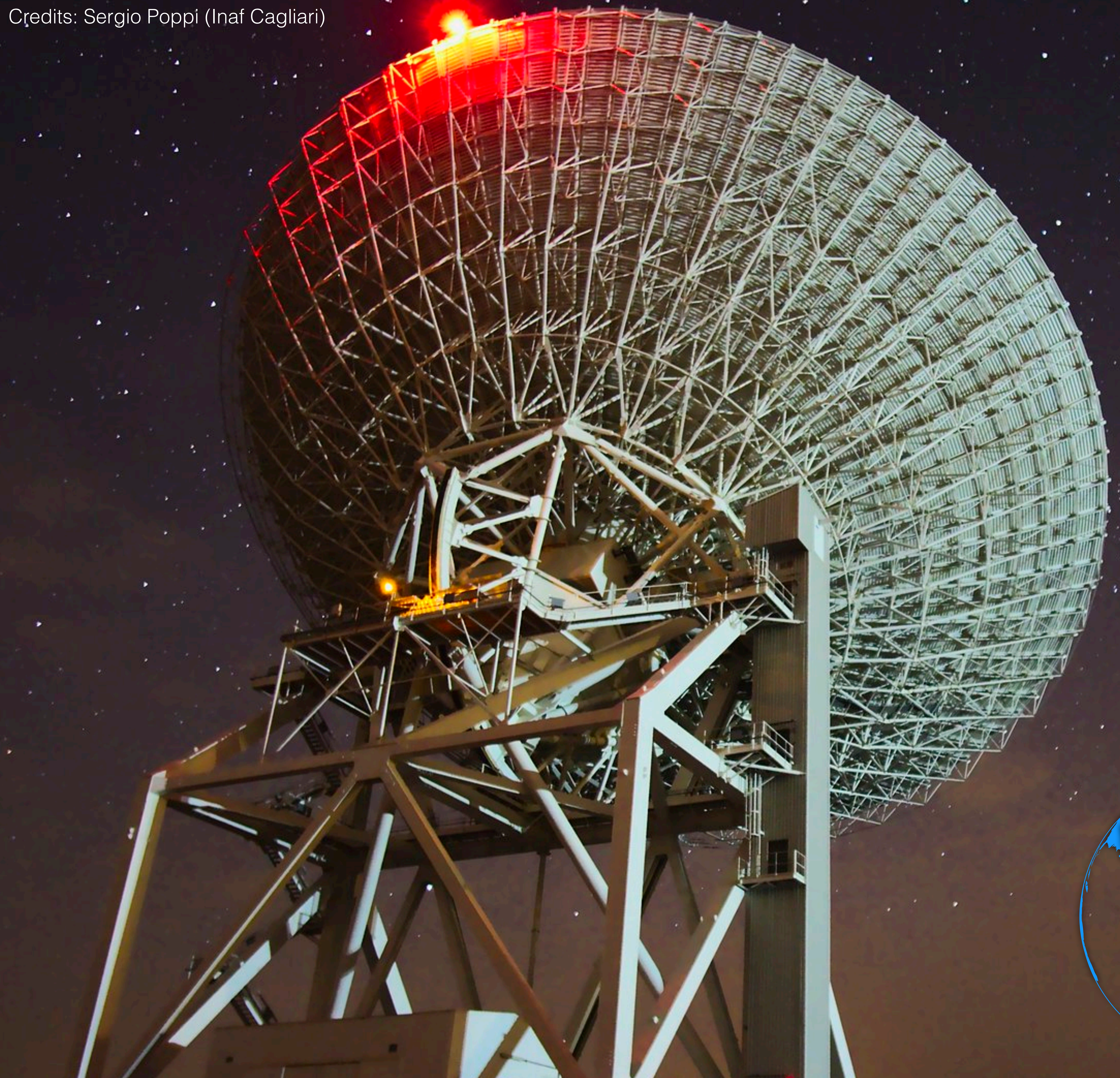
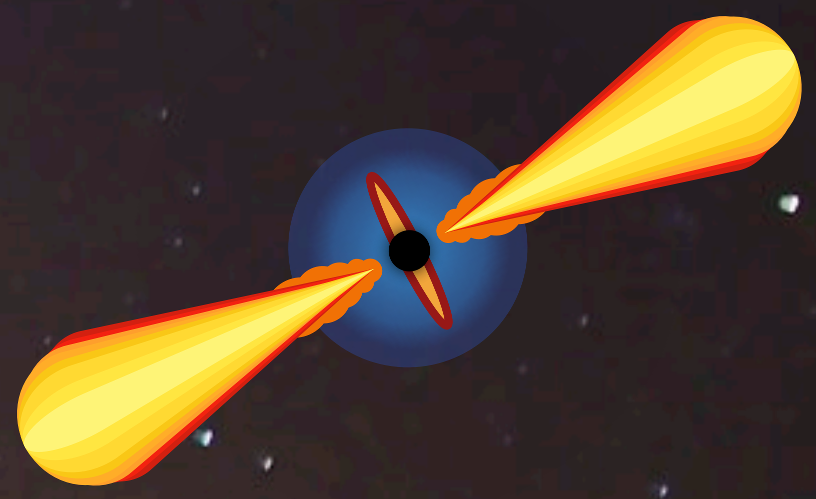
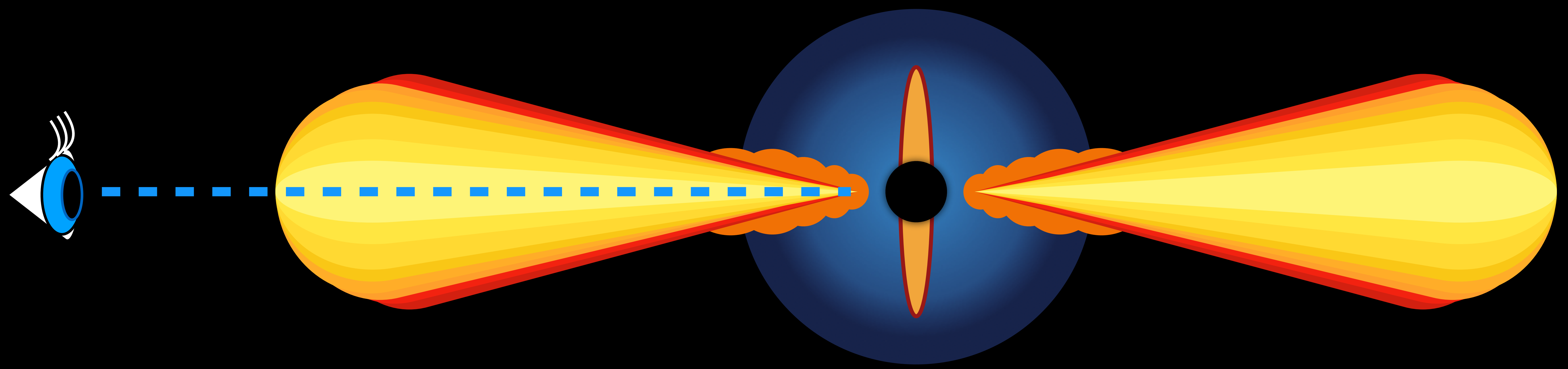


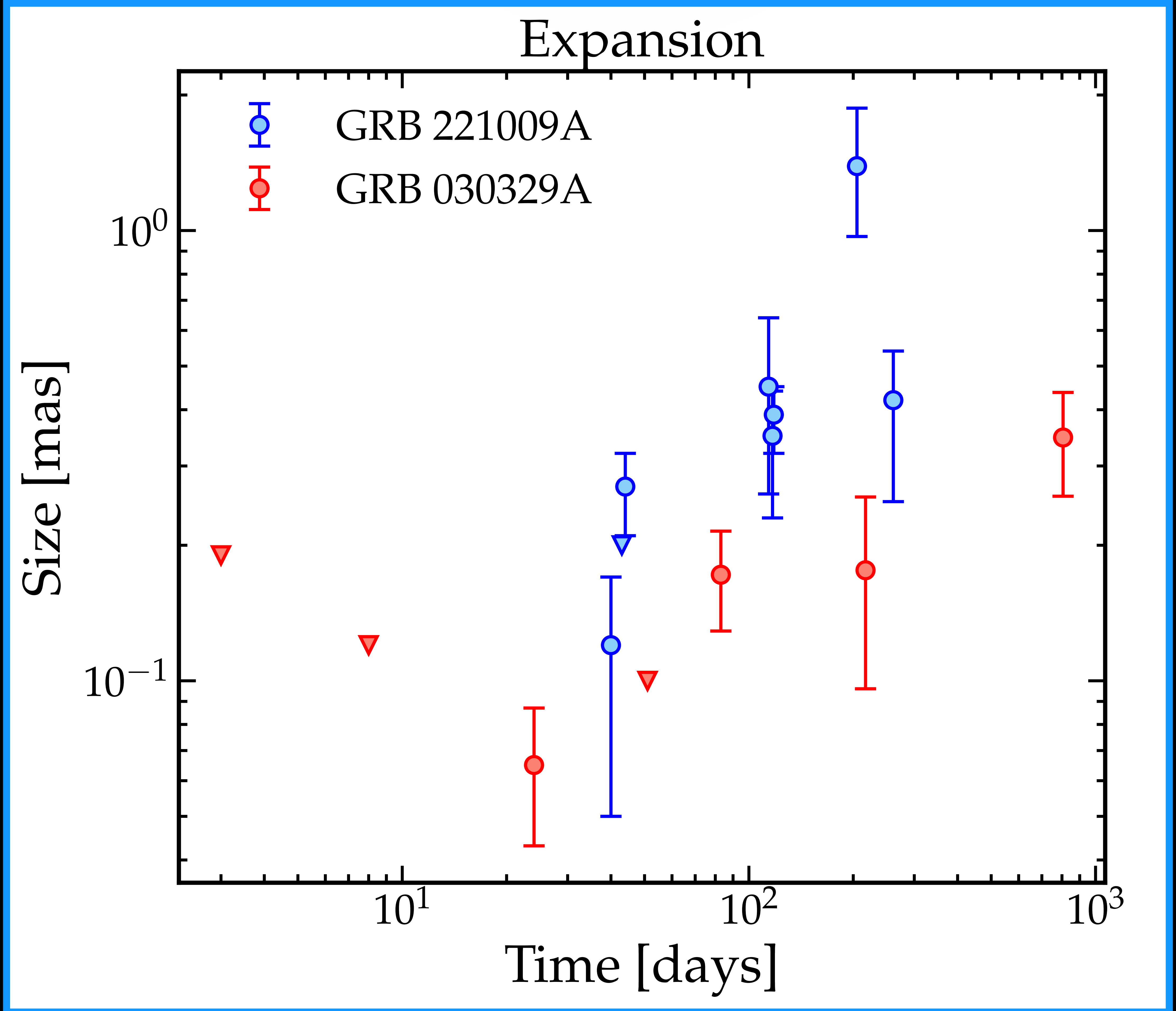
GRBs in Radio

Geometry

Viewing angle
Collimation angle
Size and structure

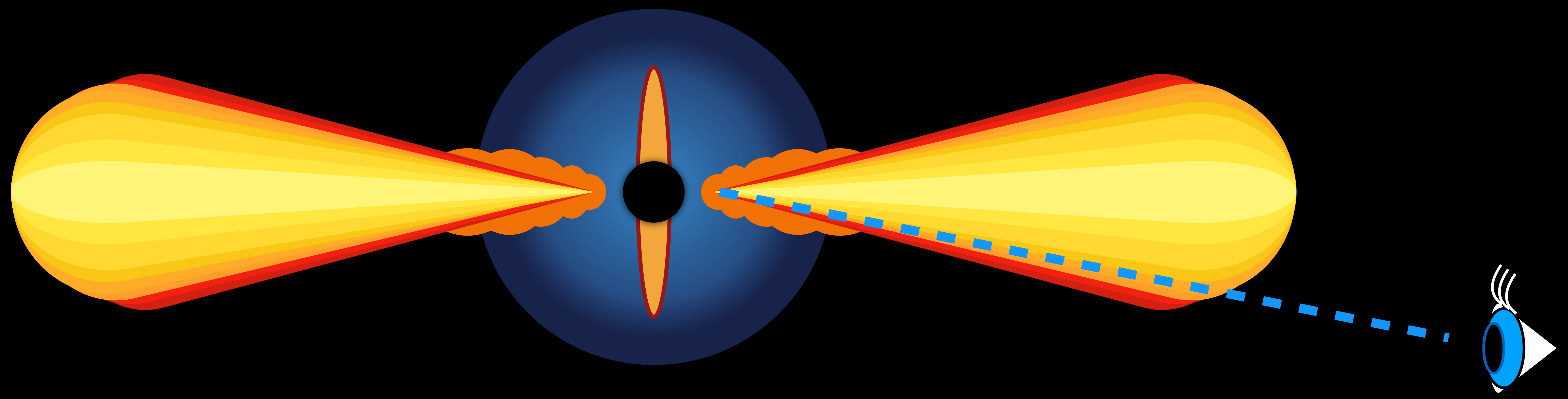


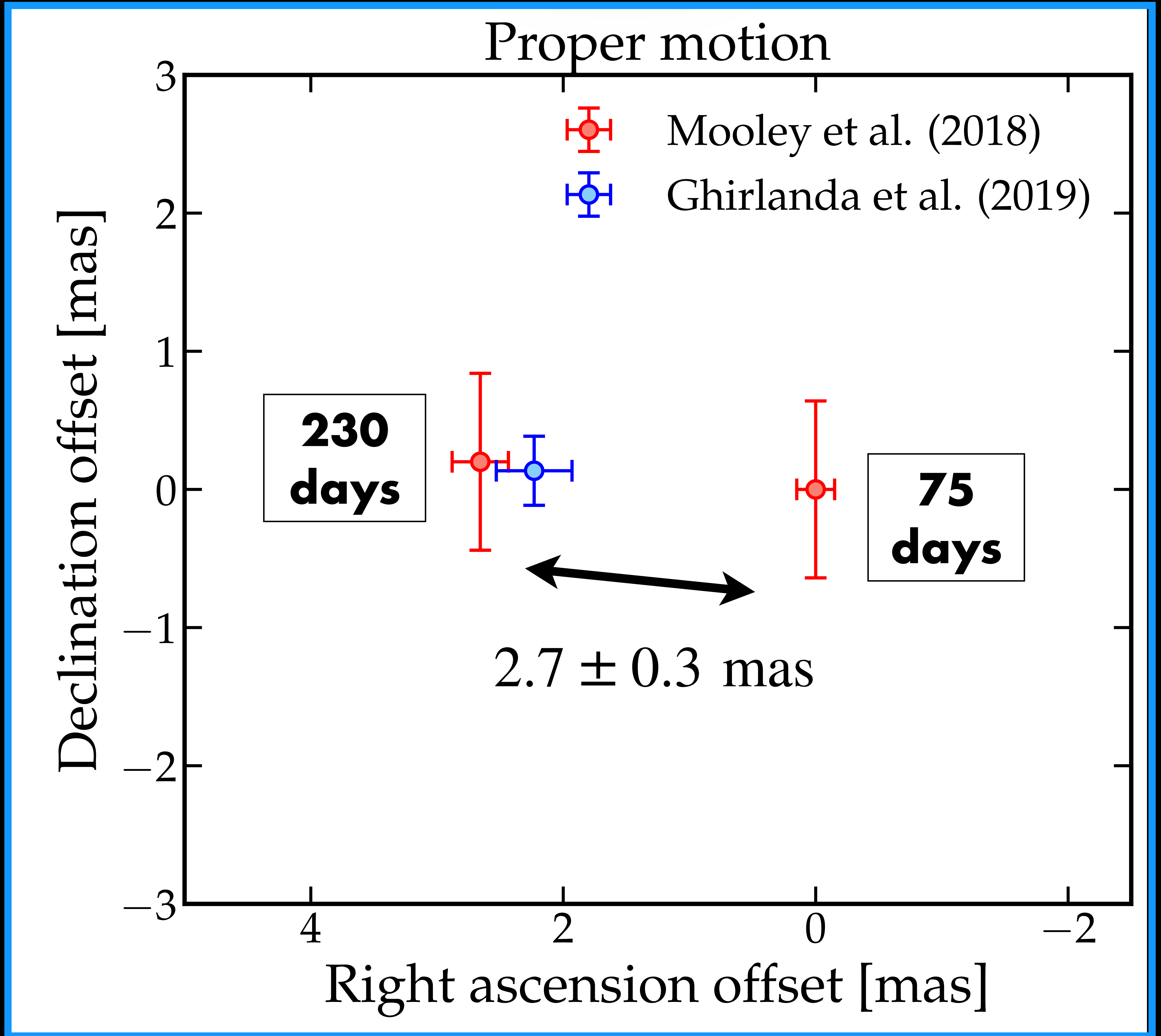




Adapted from
Giarratana et al. (2024)

First direct proof of (apparent) superluminal expansion

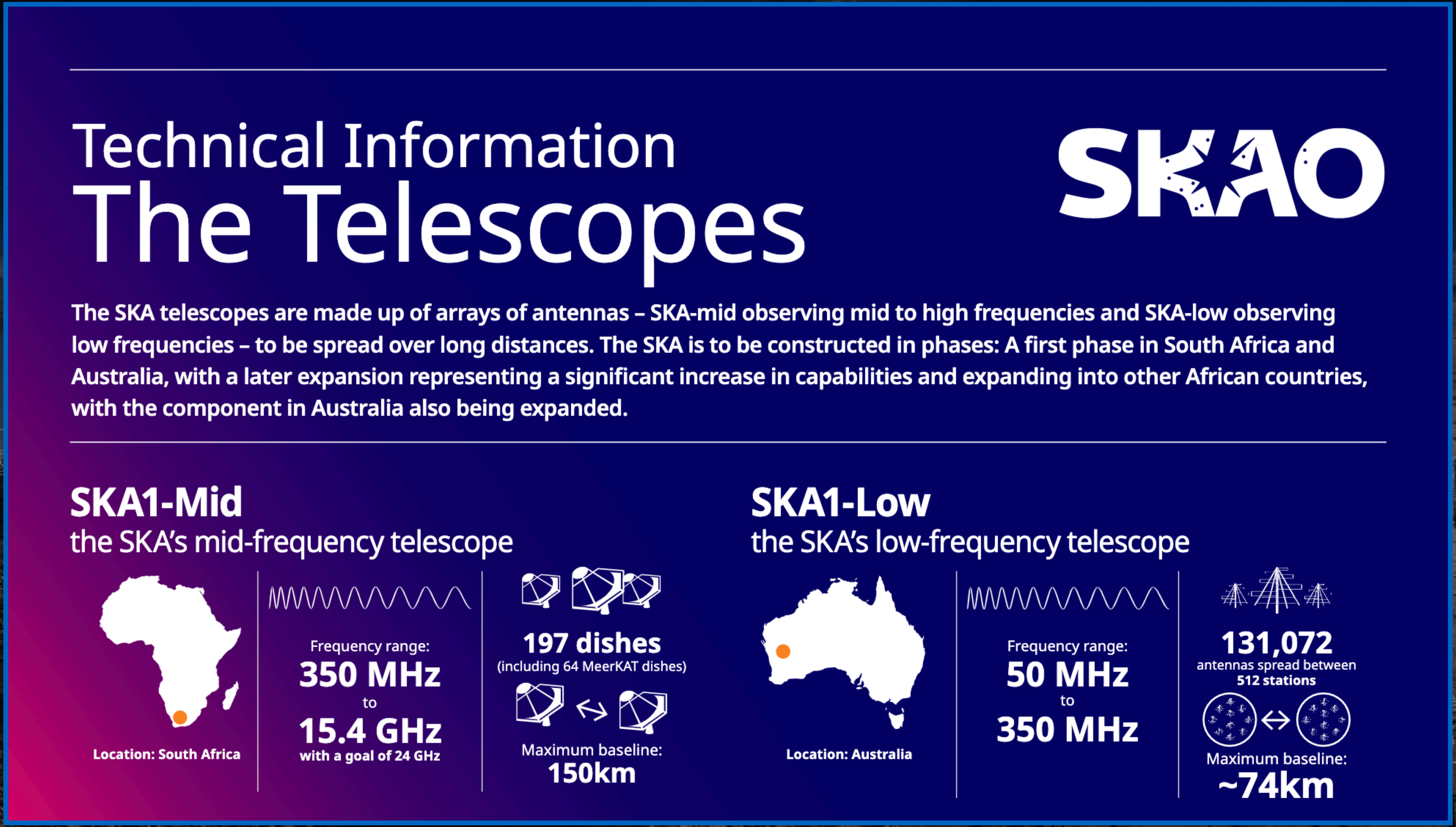




Adapted from *Mooley et al. (2018)*; *Ghirlanda, Salafia et al. (2019)*

First proof of successful jet from a BNS merger

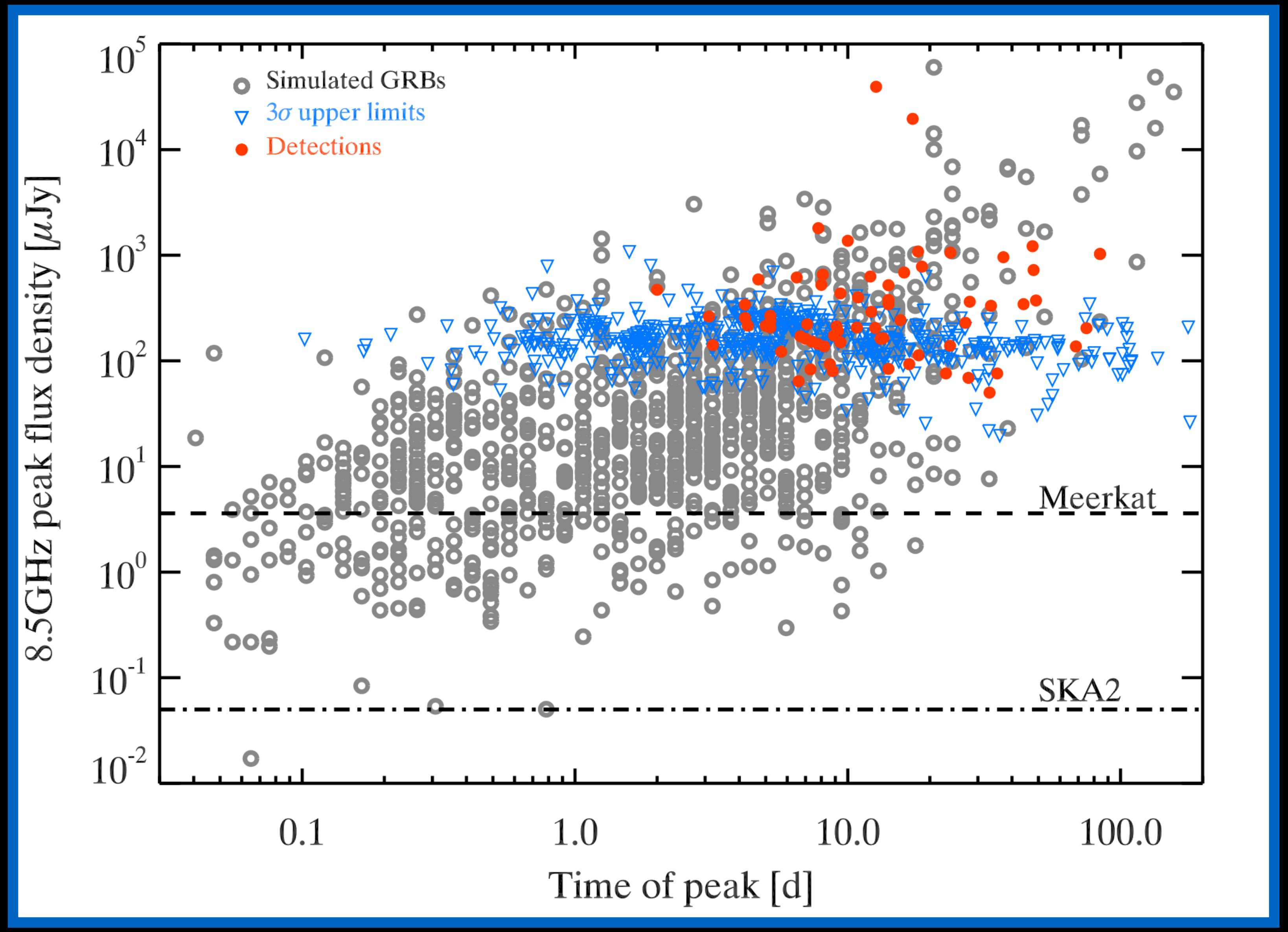
The Square Kilometer Array



SKA info sheet from the public SKAO website

GRBs in the SKA era

To be updated!



Adapted from *Ghirlanda et al. (2013)*

From 30% to almost 100% of detection rate

GRBs in the SKA era

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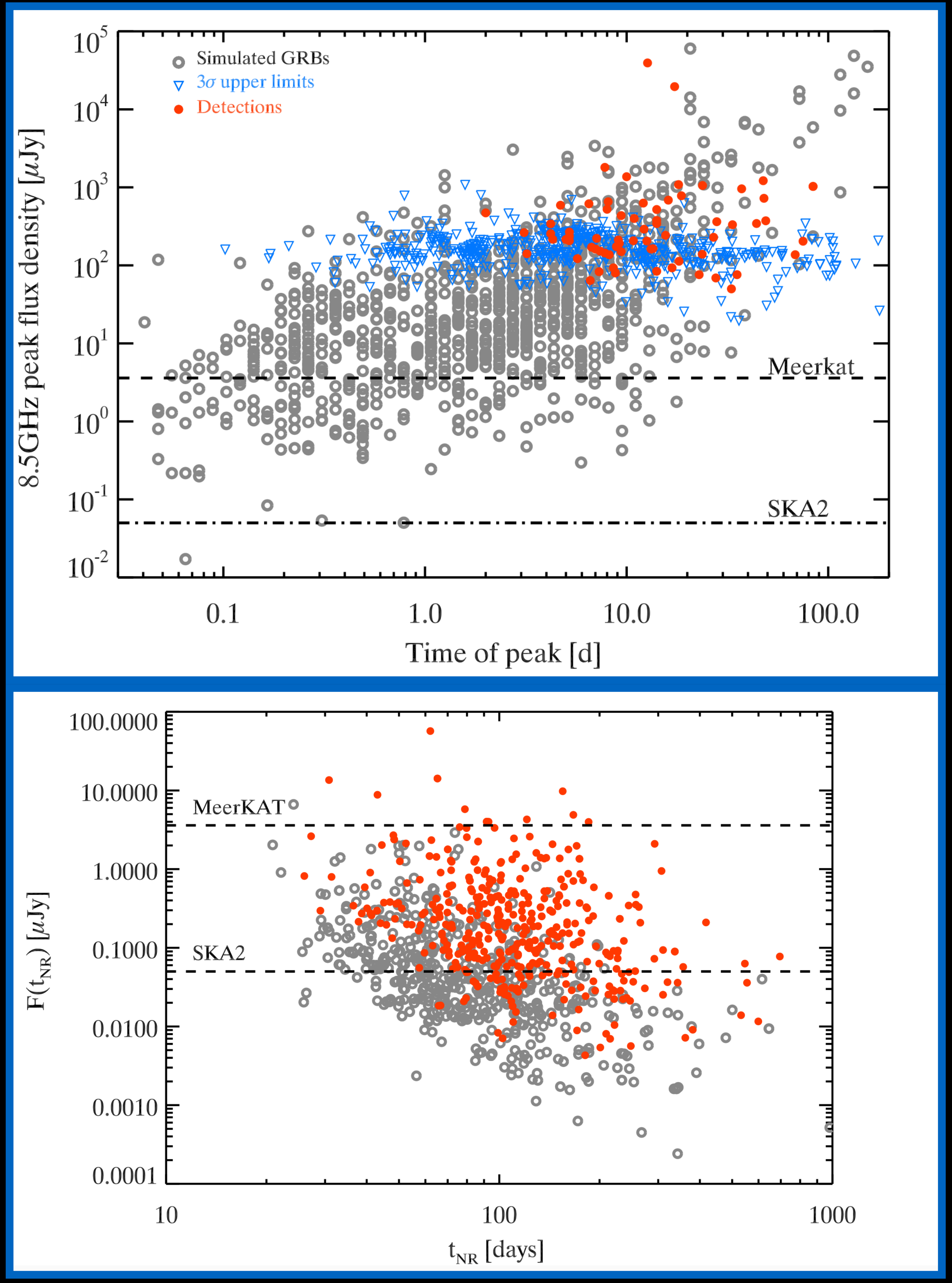

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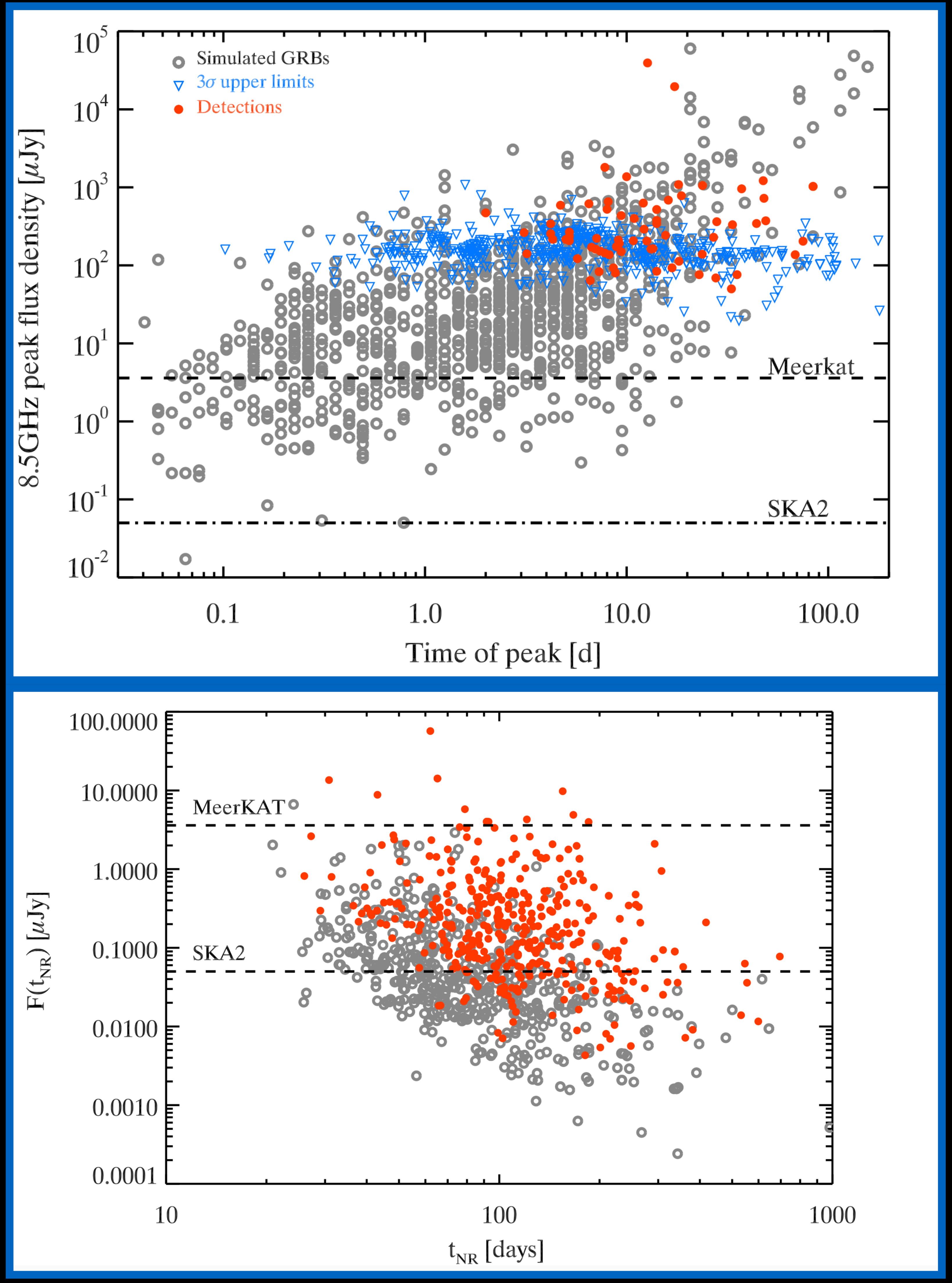
From 30% to almost 100% of detection rate

From <15% to almost 50% of detections at the transition time

GRBs in the SKA era

To be updated!



Adapted from *Ghirlanda et al. (2013)*

From 30% to almost 100% of detection rate

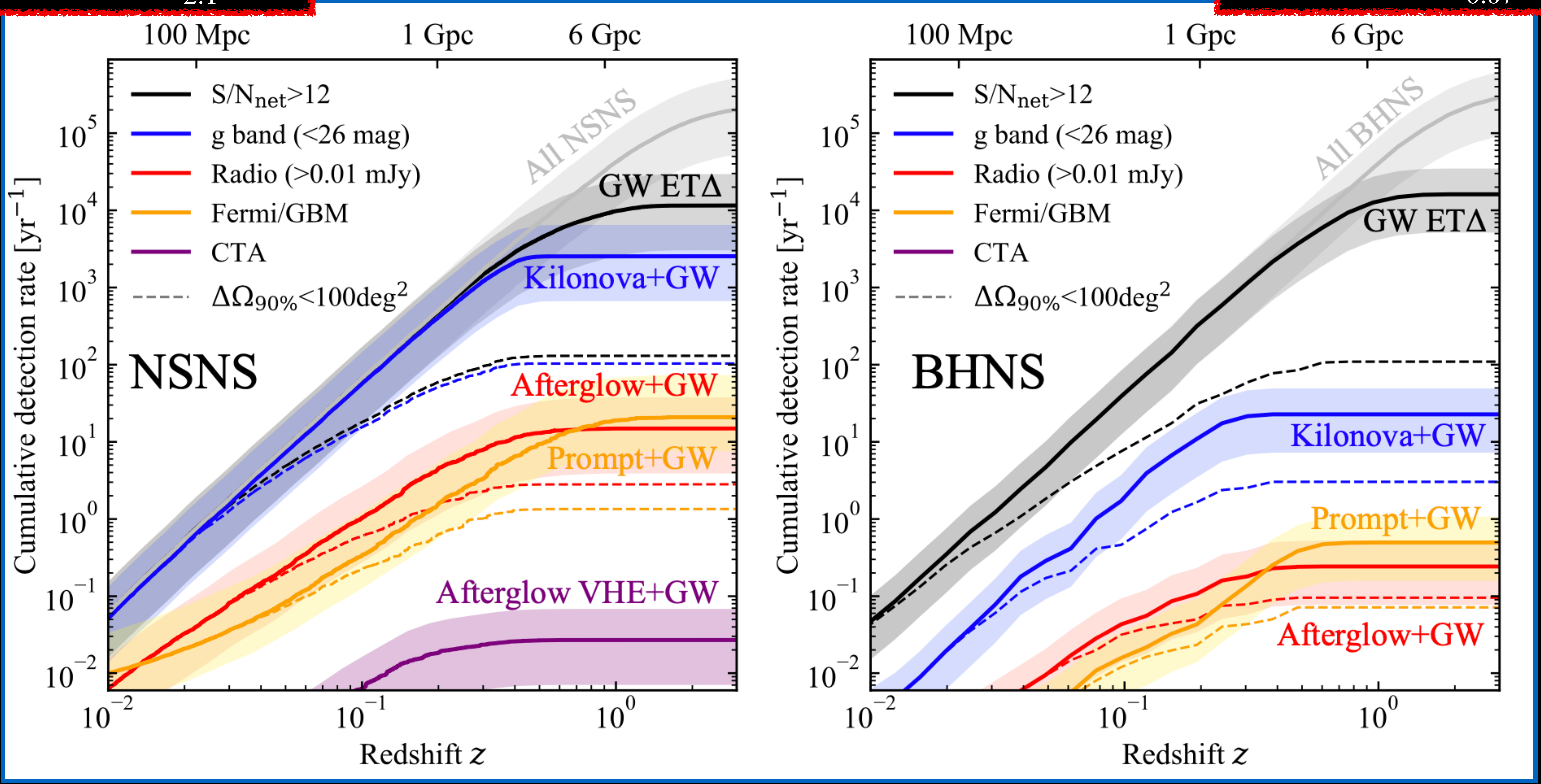
From <15% to almost 50% of detections at the transition time

+**VLBI**: structure and geometry

GW counterparts in the ET era

$\mathrm{NSNS} = 2.8^{+4.4}_{-2.1}\,\mathrm{yr}^{-1}$

$\mathrm{BHNS} = 0.11^{+0.10}_{-0.07}\,\mathrm{yr}^{-1}$

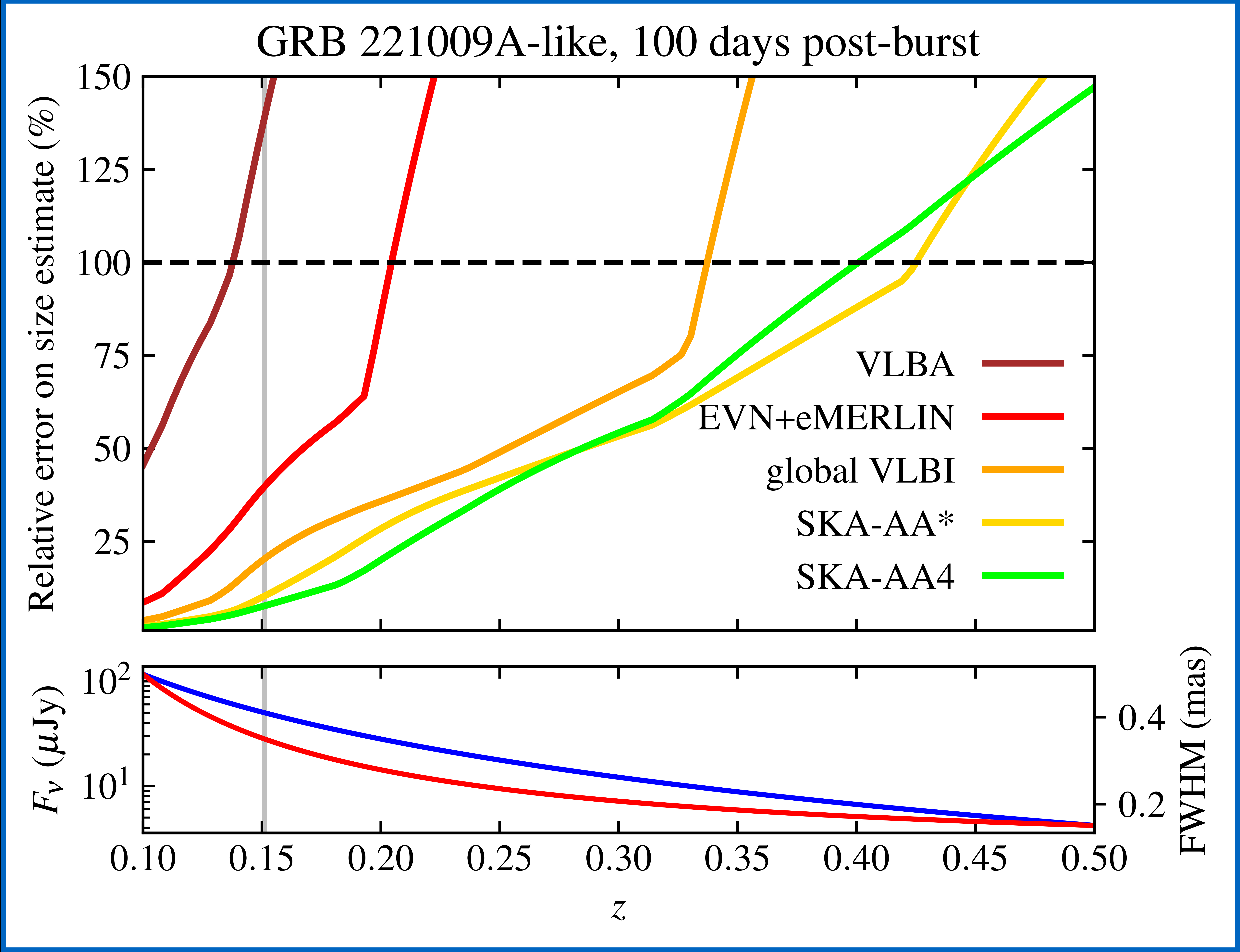


From *Colombo et al. (2025)*

SKA-VLBI: size measurements

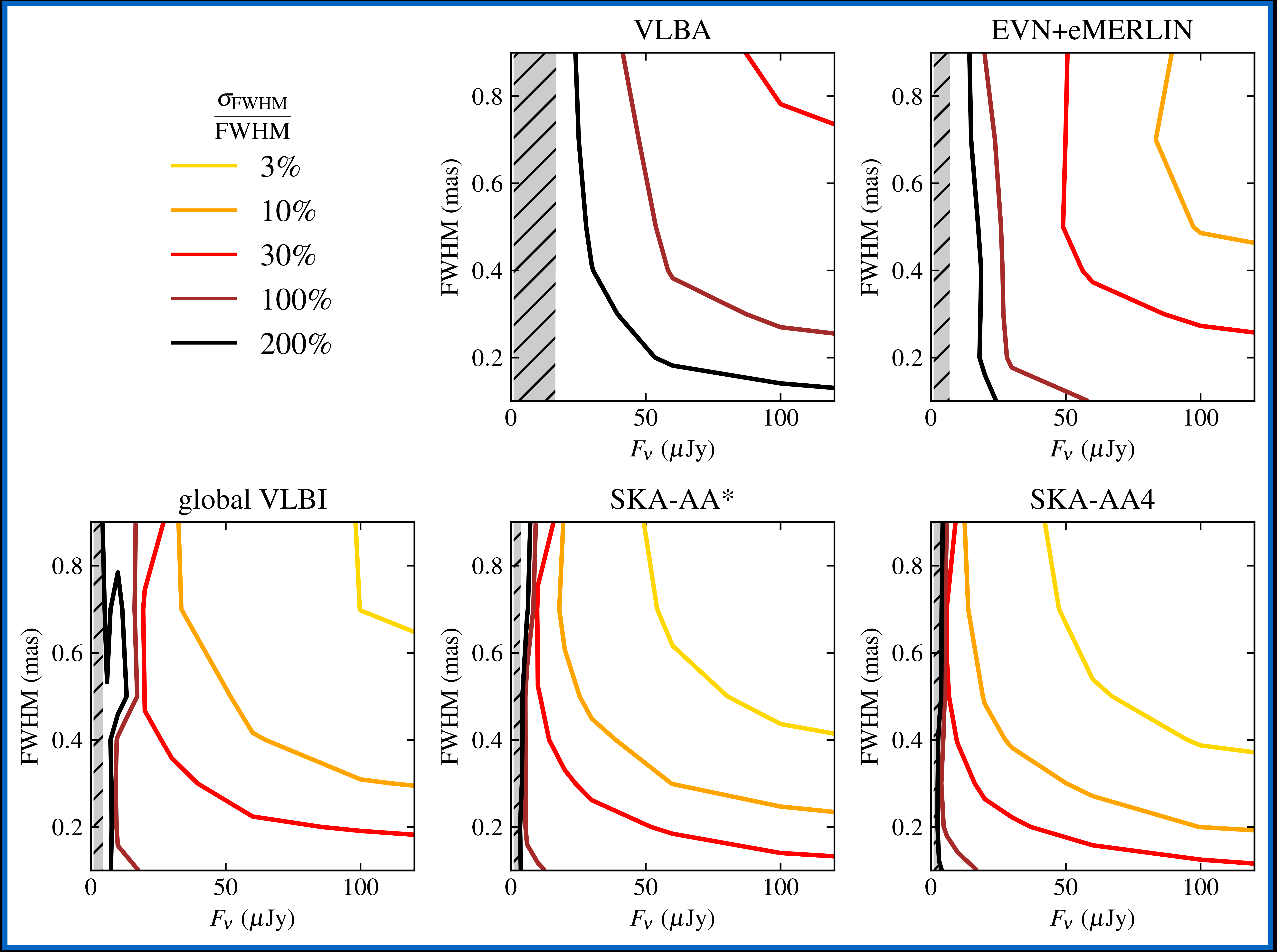
From $z \simeq 0.16$ to $z \simeq 0.25$

Constraining the size 2 times better



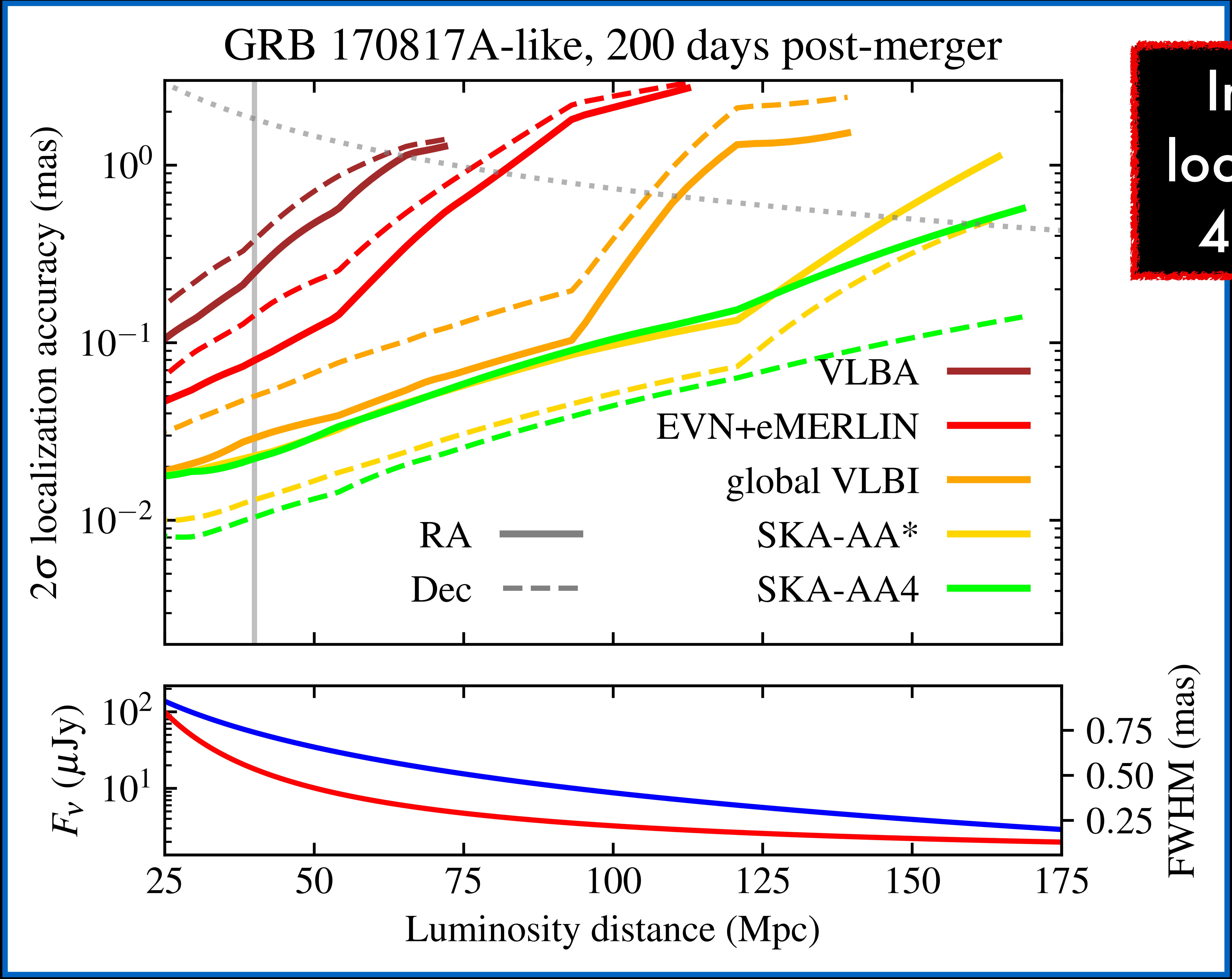
From *Giarratana et al. (under review)*

SKA-VLBI: resolving powers



From *Giarratana et al. (under review)*

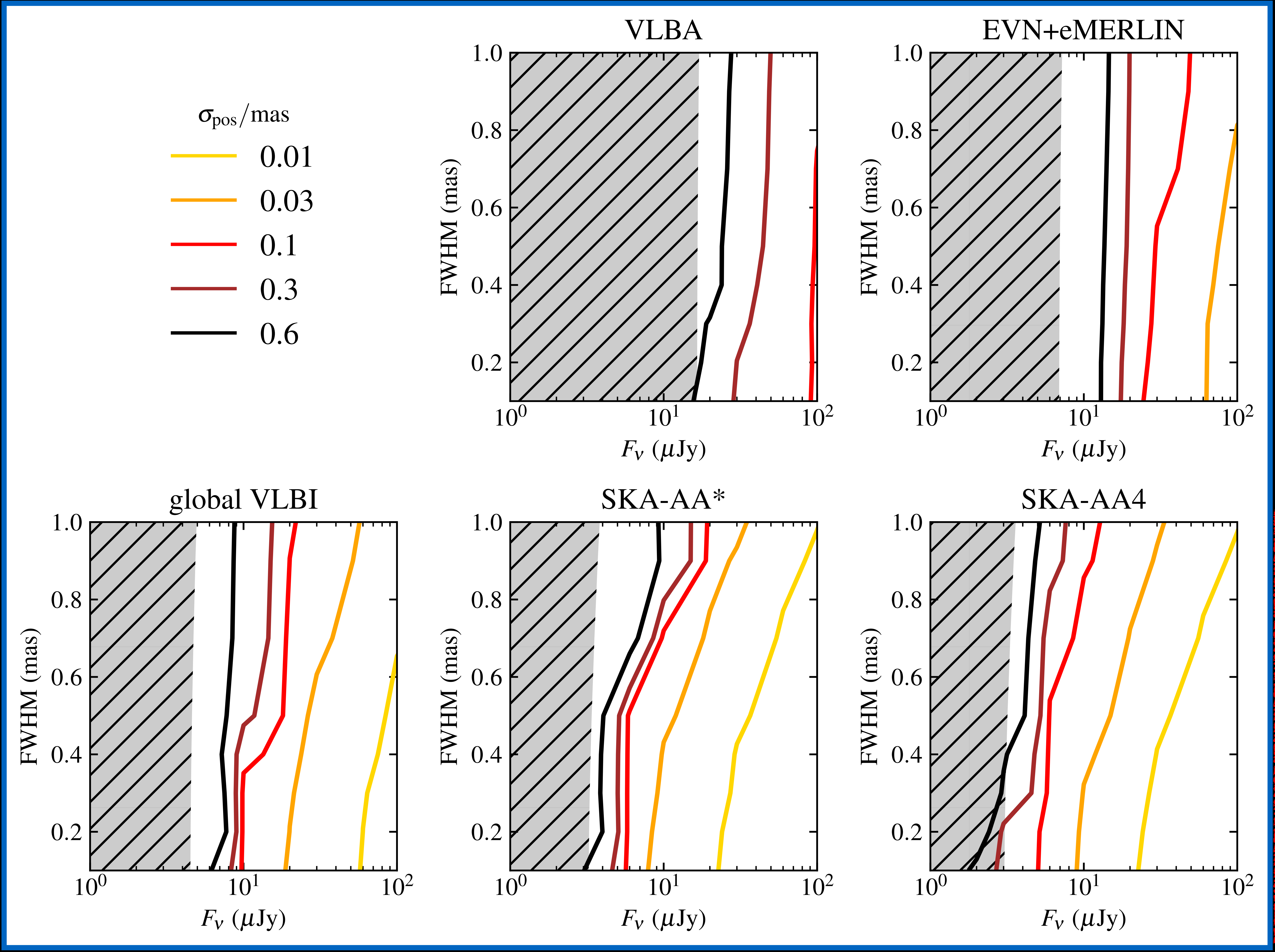
SKA-VLBI: localisation accuracy



Improving Dec localisation from 4 to 30 times!

From *Giarratana et al. (under review)*

SKA-VLBI: astrometry



3x confidence level for apparent proper motion

From *Giarratana et al. (under review)*

Conclusions

- **SKA** will detect:
  . almost 100% of radio afterglow (at the peak)
  . $2.8^{+4.4}_{-2.1}\,\mathrm{yr}^{-1}$ BNS and $0.11^{+0.10}_{-0.07}\,\mathrm{yr}^{-1}$ BHNS

- **SKA-VLBI** will provide:
  . size measurements up to $z \simeq 0.25$
  . 2x better constraints on size estimate
  . 4x - 30x better precision in Dec
  . 3x confidence level for detection of proper motion

Conclusions

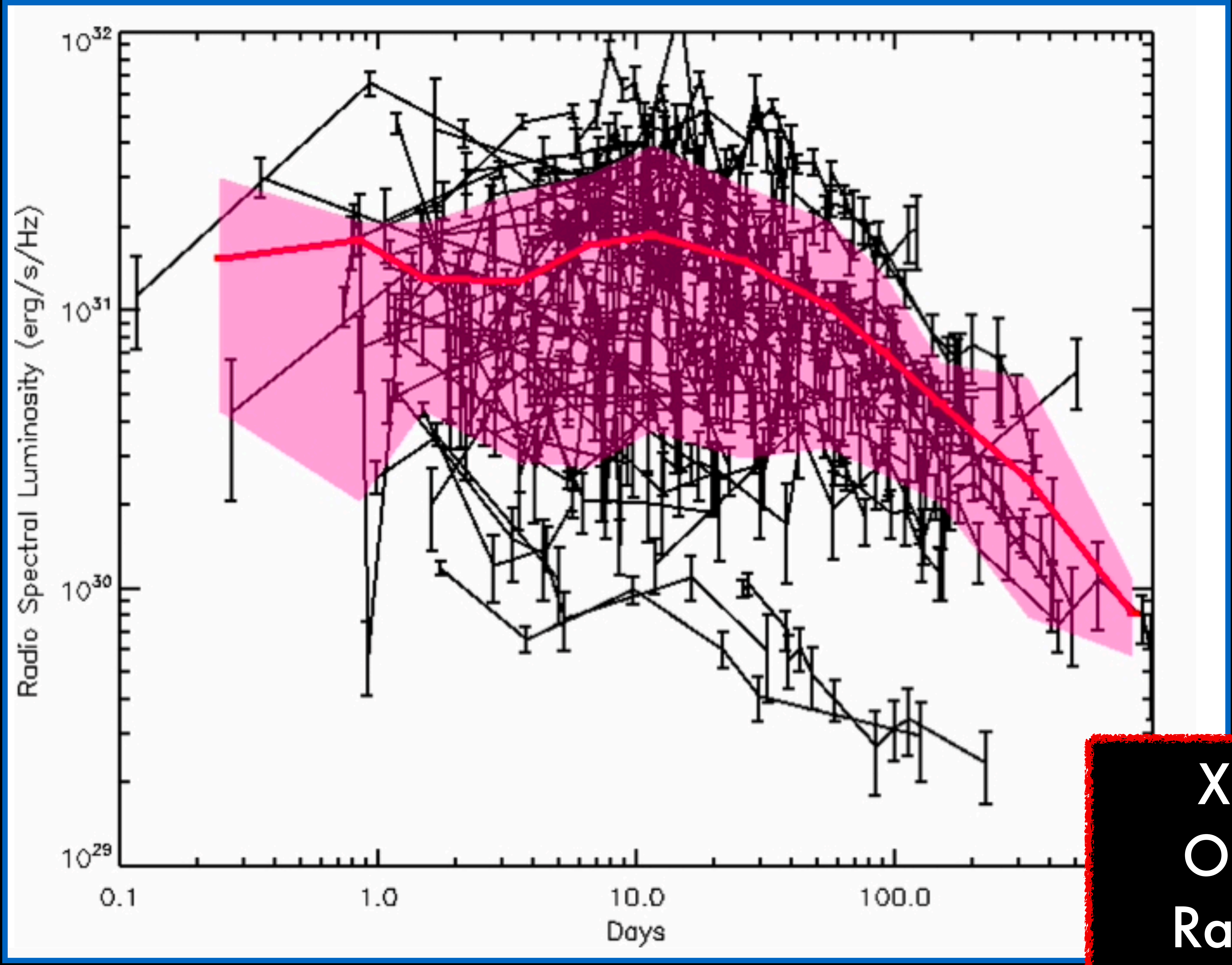
- **SKA** will detect:
  - . almost 100% of radio afterglow (at the peak)
  - . $2.8^{+4.4}_{-2.1}\,\mathrm{yr}^{-1}$ BNS and $0.11^{+0.10}_{-0.07}\,\mathrm{yr}^{-1}$ BHNS

- **SKA-VLBI** will provide:
  - . size measurements up to $z \simeq 0.25$
  - . 2x better constraints on size estimate
  - . 4x - 30x better precision in Dec
  - . 3x confidence level for detection of proper motion

Thank you!

Backup Slides

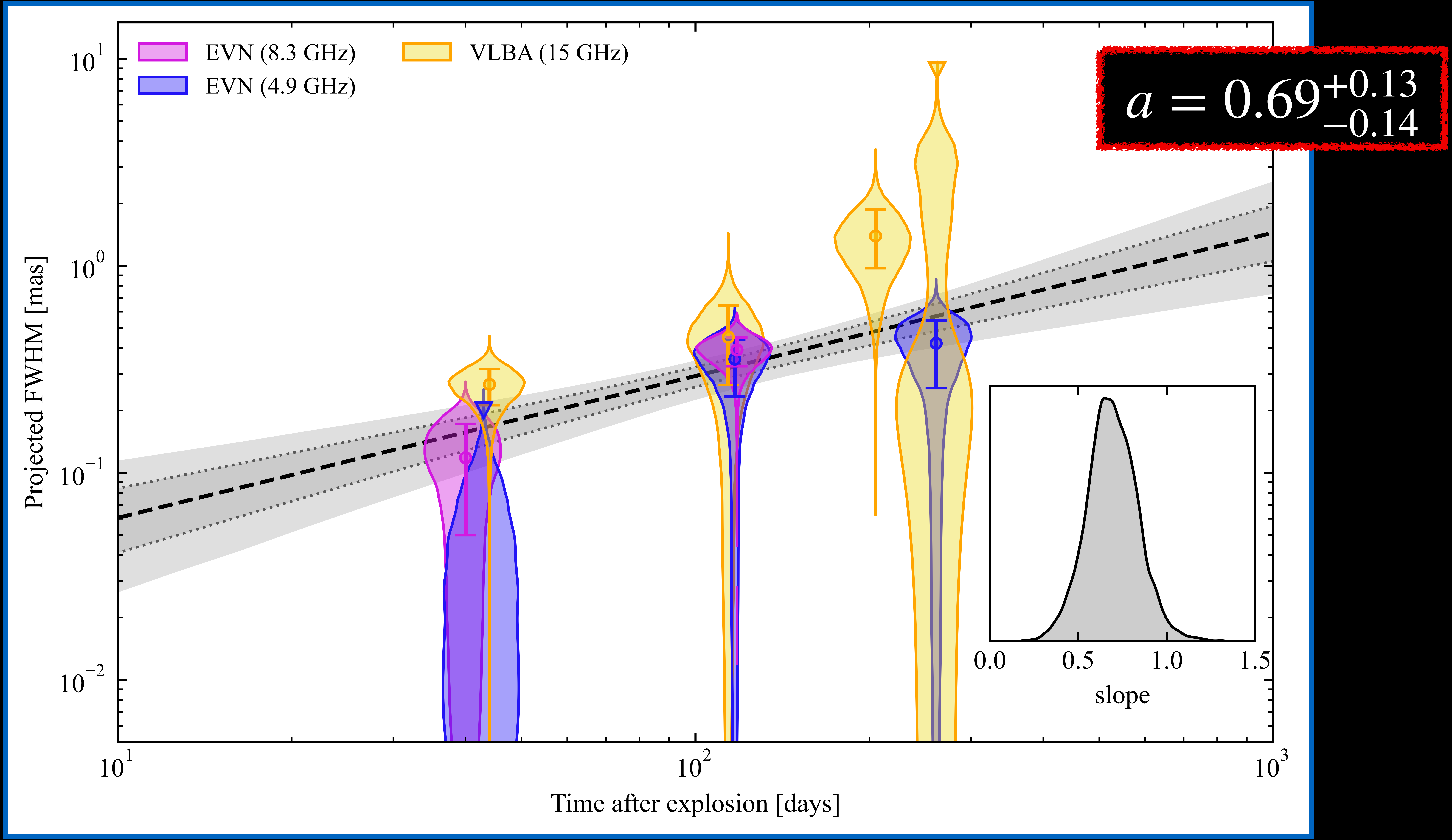
Radio emission from GRBs



X-rays: 95%
Optical: 70%
Radio: 31% (*)

From *Chandra & Frail (2012)*

GRB 221009A



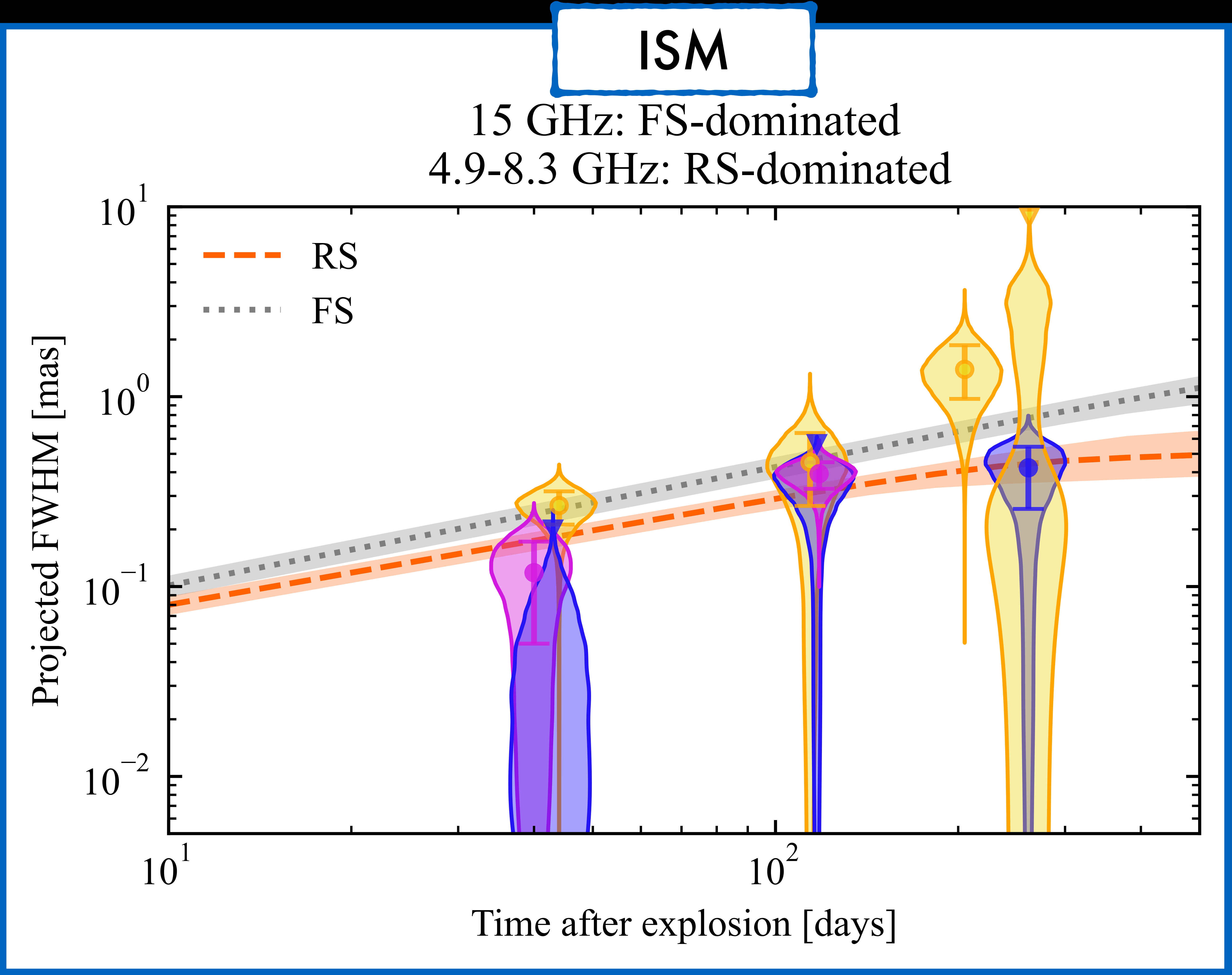
Apparent size evolution.
From *Giarratana et al. (2024)*

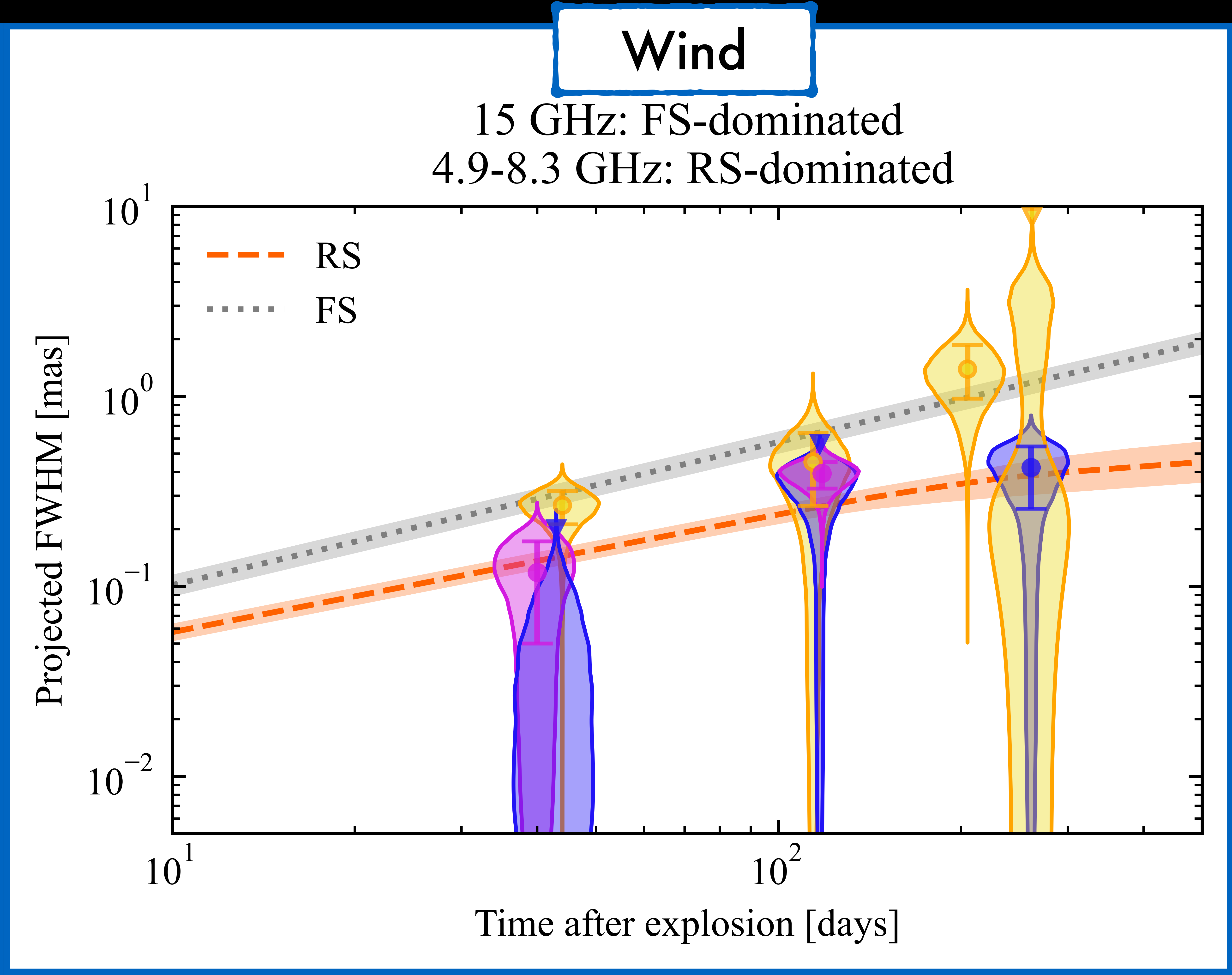
Hint for different size evolutions

Forward vs Reverse shocks?

From *Giarratana et al. (2024)*

GRB 221009A



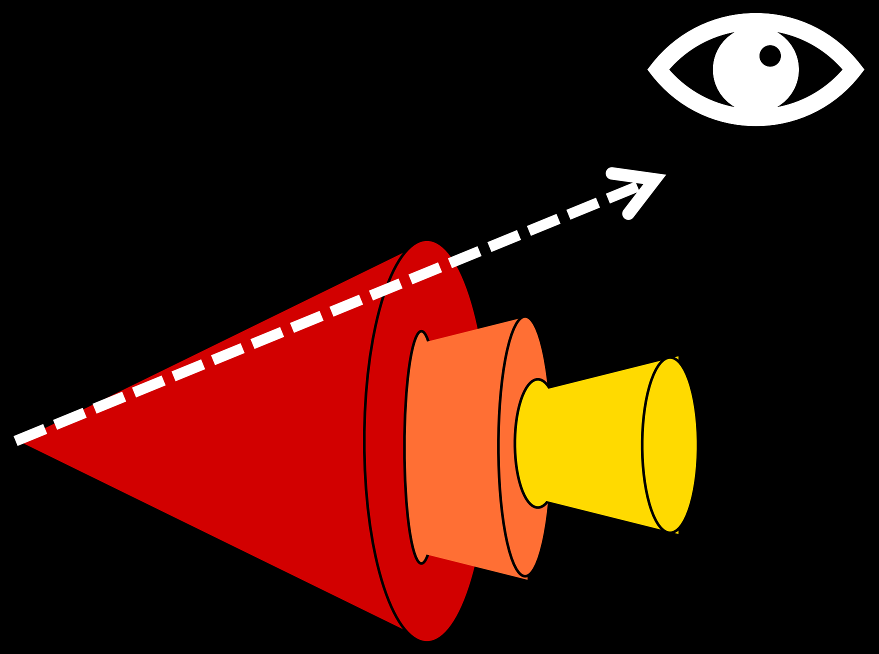


$E/A \simeq 10^{57}\ \mathrm{erg\,cm^{3}}$
$\theta_j \simeq 21^\circ$

Model size evolution in a FS + RS scenario.
From *Giarratana et al. (2024)*

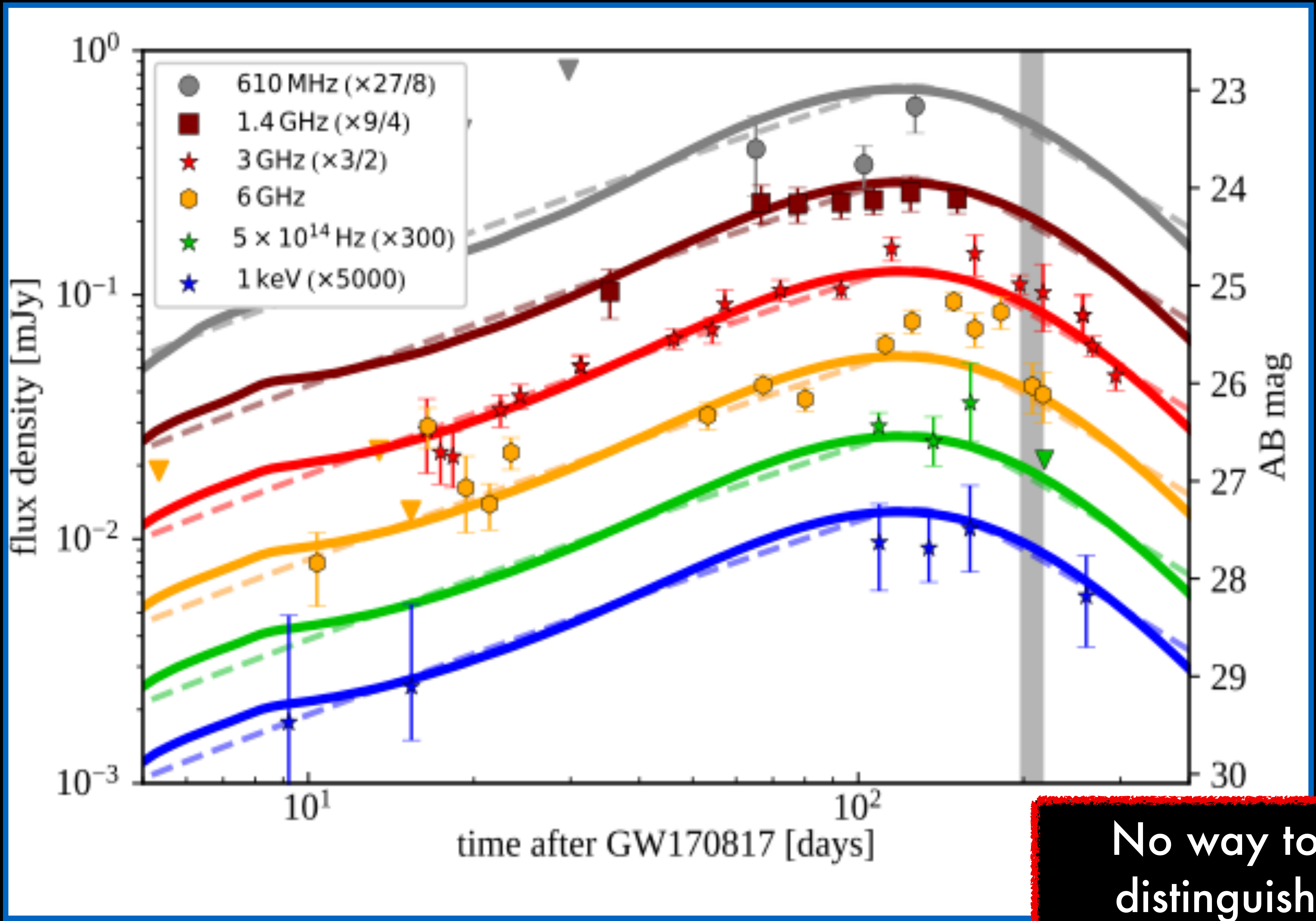
$E/A \simeq 10^{55}\ \mathrm{erg\,cm^{3}}$
$\theta_j \simeq 23^\circ$

GRB 170817A

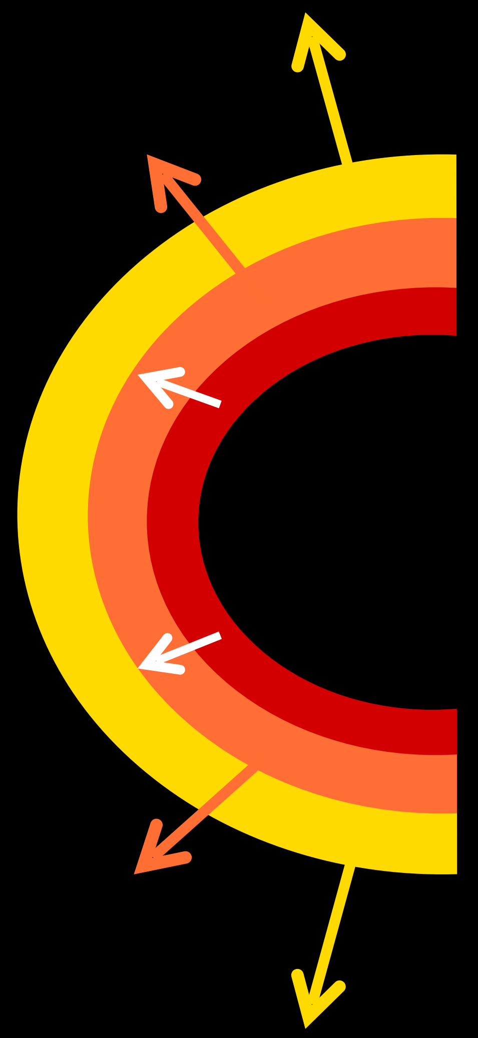


$\Gamma_1 < \Gamma_2 < \Gamma_3$

$E_1 < E_2 < E_3$



From *Ghirlanda, Salafia et al. (2019)*

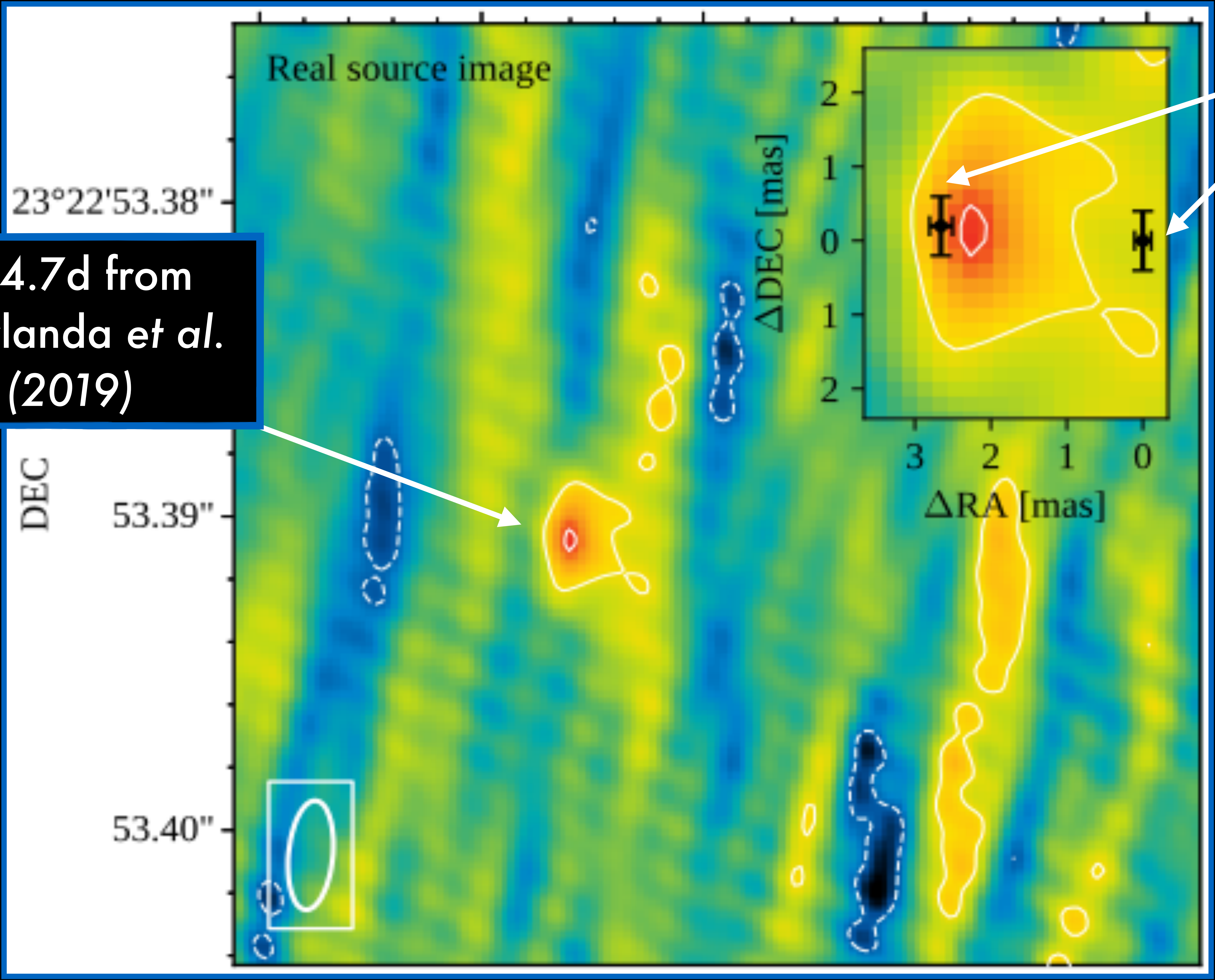


$\Gamma_1 < \Gamma_2 < \Gamma_3$

$E_1 > E_2 > E_3$

No way to distinguish between models!

GRB 170817A



75d & 230d from *Mooley et al.* (2018)

204.7d from Ghirlanda *et al.* (2019)

From *Ghirlanda, Salafia et al.* (2019)

First proof of successful jet from a BNS merger

The SKA

Milestones	Mid (end-date)	Low (end-date)
AA0.5 • 4 Mid dishes • 4 Low stations	2026 Jan	2024 Dec
AA1 • 8 Mid dishes • 18 Low stations	2026 Aug	2025 Nov
AA2 • 64 Mid dishes • 64 Low stations	2027 Jul	2026 Oct
AA* (staged delivery plan) • 144 Mid dishes • 307 Low stations	2028 May	2028 Jan
Operations Readiness Review	2028 Aug	2028 Apr
Formal end of construction (including schedule contingency)	2029 Mar	
AA4 (design baseline) • 197 Mid dishes • 512 Low stations	TBD	

Telescope	Maximum baseline length		
	AA2	AA*	AA4
Low	39.0 km	73.4 km	73.4 km
Mid	108.0 km (36.0 km, excluding dish SKA008)	108.0 km (36.0 km, excluding dish SKA008)	159.6 km

Timeline and maximum baseline length.

The SKA

SKA1 Telescope Expected Performance – Imaging

Nominal frequency	110 MHz	300 MHz	770 MHz	1.4 GHz	6.7 GHz	12.5 GHz
Range [GHz]	0.05-0.35	0.05-0.35	0.35-1.05	0.95-1.76	4.6-8.5	8.3-15.4
Telescope	Low	Low	Mid	Mid	Mid	Mid
FoV [arcmin]	327	120	109	60	12.5	6.7
Max. resolution [arcsec]	9.7	3.5	0.7	0.3	0.06	0.03
Max. bandwidth [MHz]	300	300	700	810	3900	2 x 2500
Cont. rms, 1hr [μJy/beam] [a]	26	14	4.4	2	1.3	1.2
Line rms, 1hr [μJy/beam] [b]	1850	800	300	140	90	85
Resolution range for cont. & line rms [arcsec] [c]	12-600	6-300	1-145	0.6-78	0.13-17	0.07-9
Channel width (uniform resolution across max. bandwidth) [kHz]	5.4	5.4	13.4	13.4	80.6	80.6
Narrowest bandwidth, zoom mode [MHz]	3.9	3.9	3.1	3.1	3.1	3.1
Finest zoom channel width [Hz]	226	226	210	210	210	210

a. Continuum sensitivity at nominal frequency, assuming fractional bandwidth of $\Delta\nu/\nu = 0.3$

b. Line sensitivity at nominal frequency, assuming fractional bandwidth per channel of $\Delta\nu/\nu = 10^{-4}$ ($>10^{-6}$ will be possible]

c. The sensitivity numbers apply to the range of beam sizes listed

For more details refer to the document "Anticipated SKA1 Science Performance" (SKA-TEL-SKO-0000818 available on astronomers.skatelescope.org and at arxiv.org/abs/1912.12699)

SKA info sheet from the public SKAO website.