

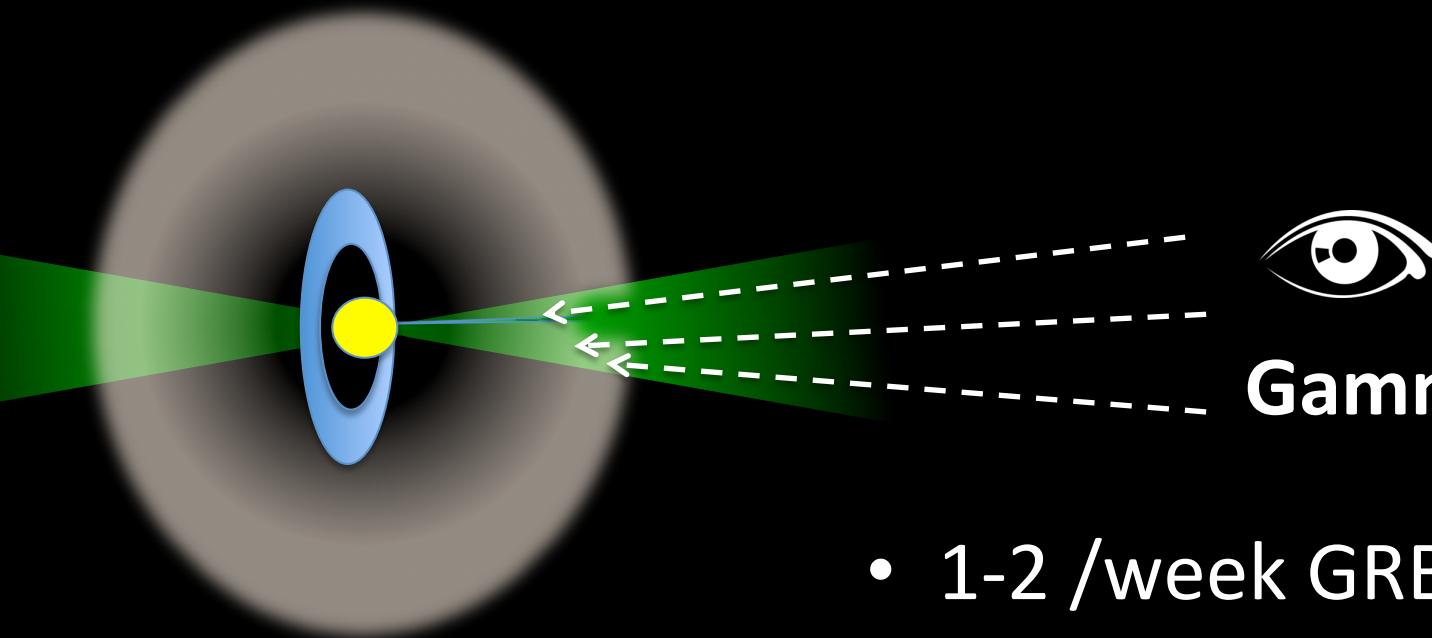
# Gamma Ray Bursts studies with the Square Kilometer Array (SKA)

*Giancarlo Ghirlanda*

*INAF-Osservatorio Astronomico di Brera (Milano-Italy)*

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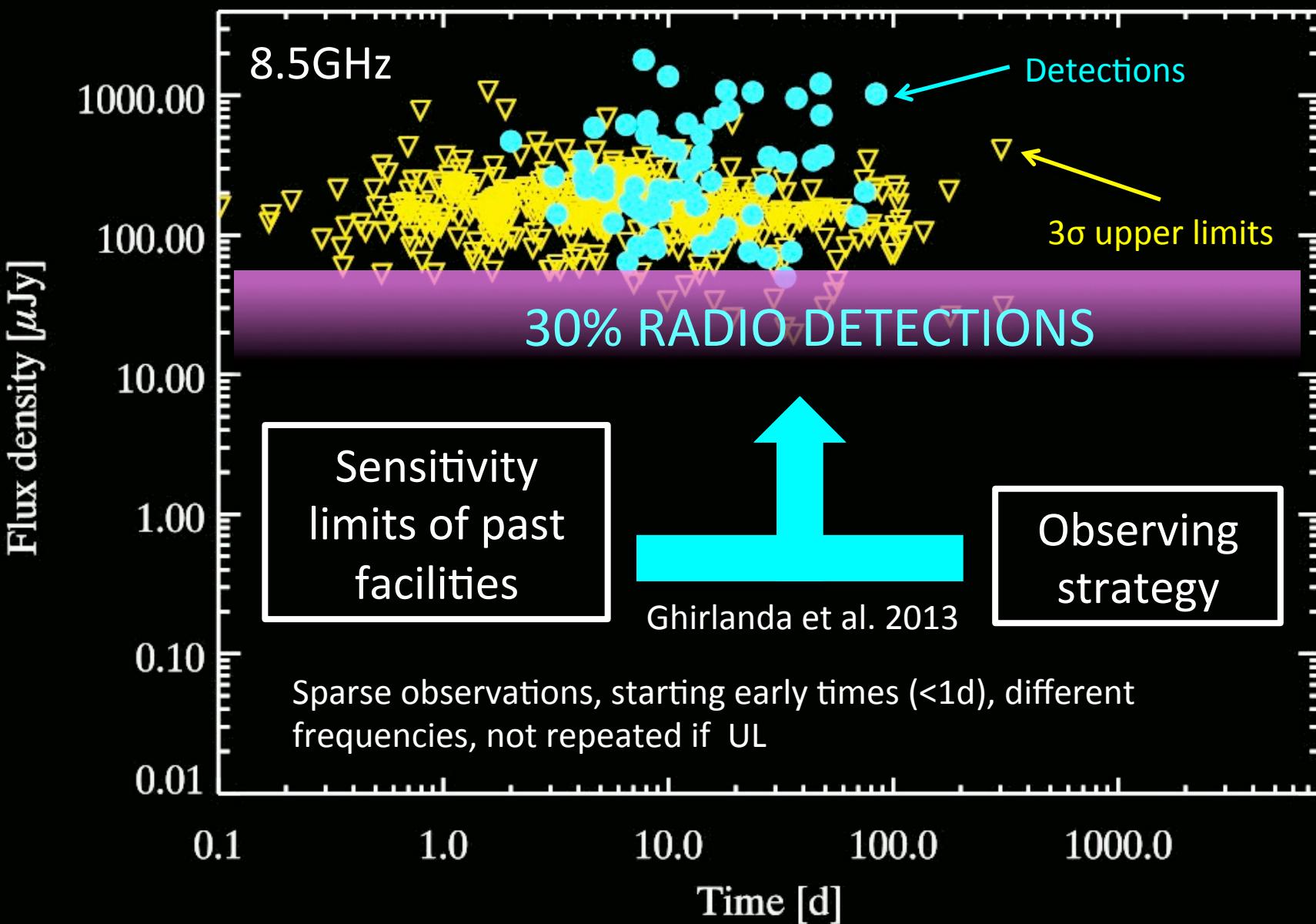
M. G. Bernardini, D. Burlon, S. Campana, S. Covino, P. D'Avanzo,  
V. D'Elia, G. Ghisellini, A. Melandri, T. Murphy, L. Nava, I. Prandoni,  
R. Salvaterra, L. Sironi, G. Tagliaferri, S. Vergani, A. Wolter



## Gamma Ray Burst

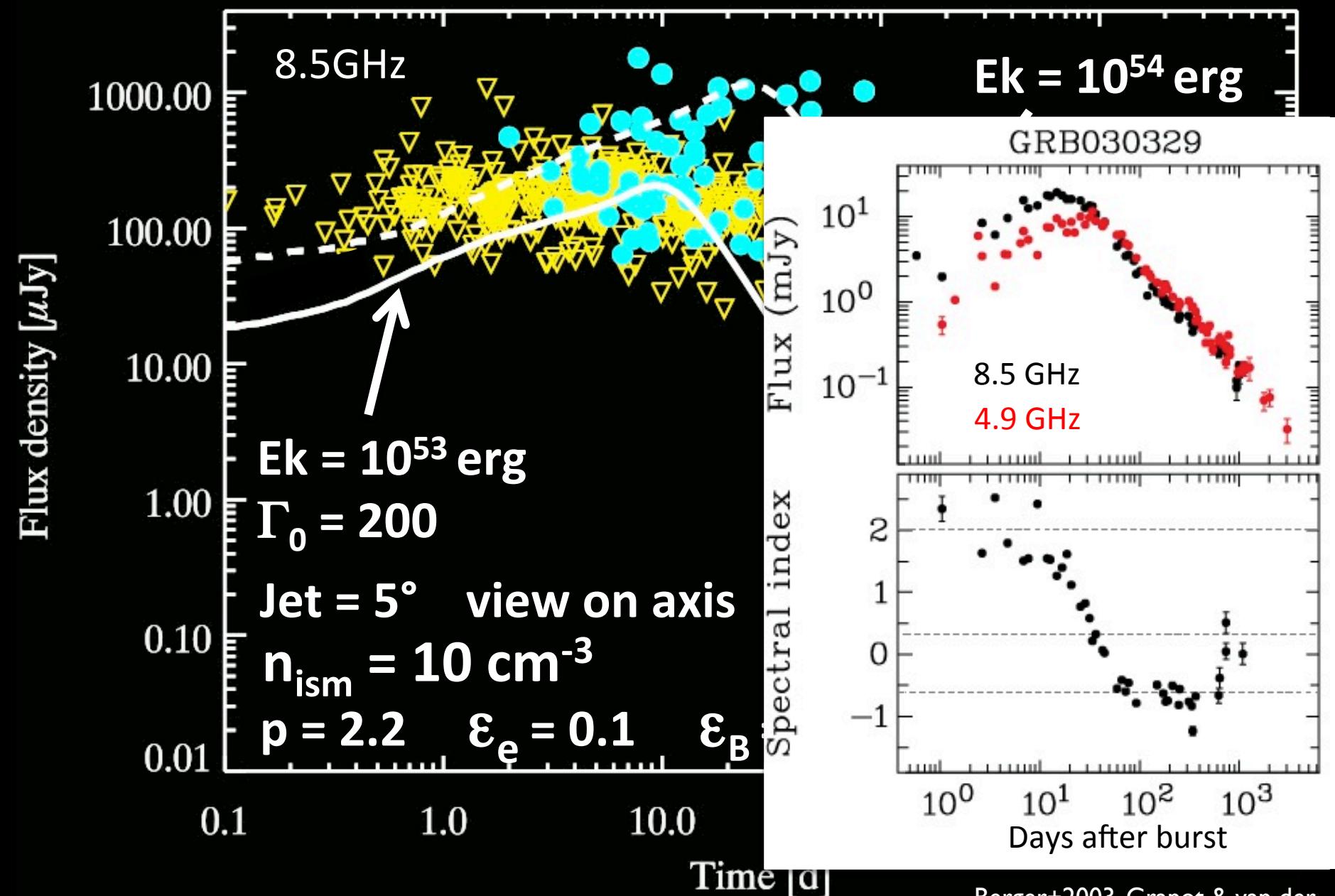
- 1-2 /week GRBs (detected)
- 99% X-ray afterglows
- 70% Optical/NIR afterglows
- **30% Radio afterglows**  
[Chandra & Frail 2012]

# Current status of radio observations of GRBs



Adapted from Chandra & Frail 2012

# The tip of the icerbeg of the GRB population



Berger+2003, Granot & van der Horst 2014

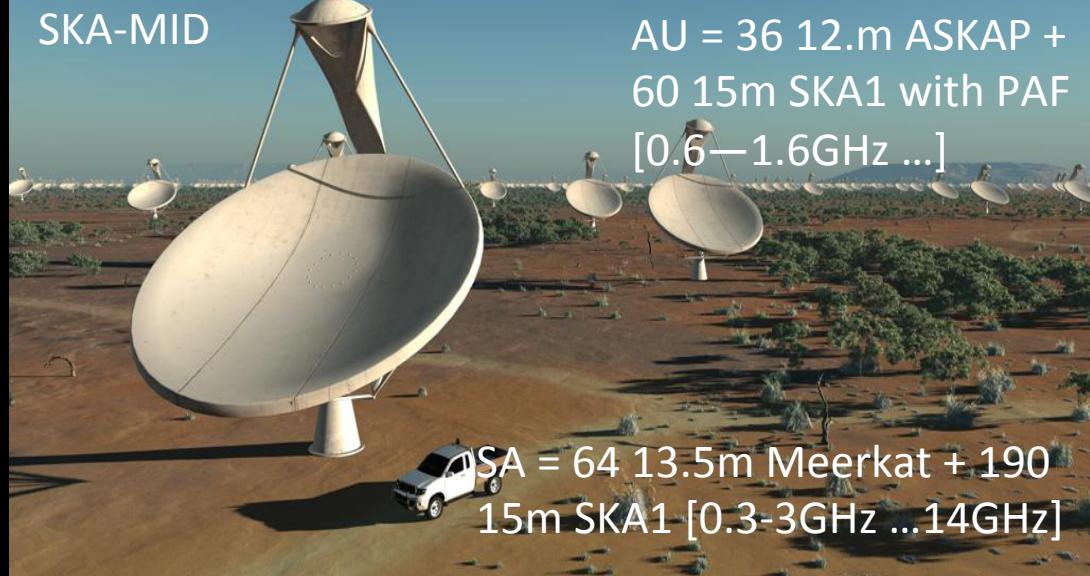
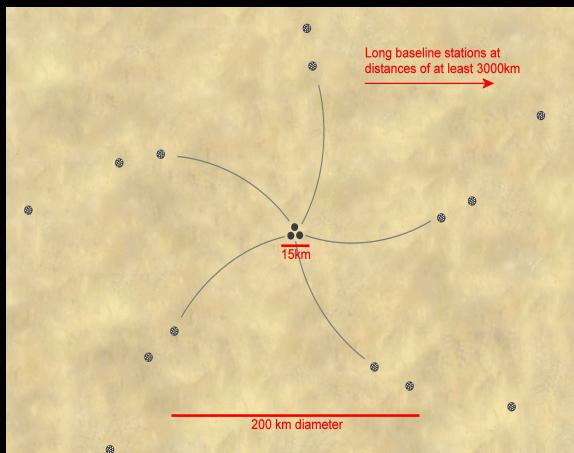
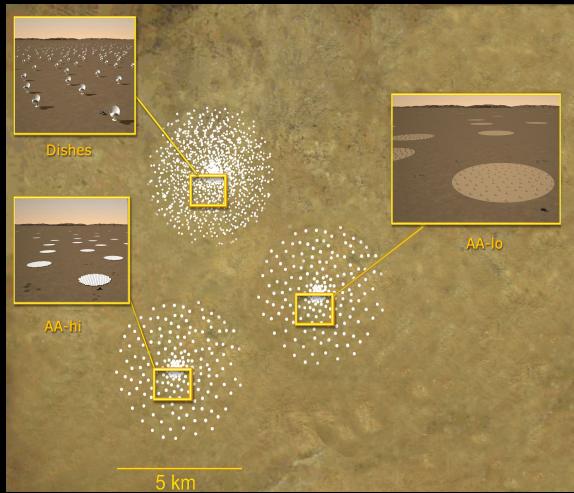
# The role of radio GRB observations

OBSERVATION	PHYSICS	
Scintillation	Dynamics of the jet (confirm relativistic)	970508 ... Frail+1997
Light curve flattening (t~100d) (980703,000418 ...)	Transition non relativistic Test jet expansion Alternatives	Frail+2004 Berger+2005
Calorimetry	Jet true energy (collimation indep. energy budget) ISM structure and density	030329, 970508, 980703 Frail+2005; Van der Horst +2005,2008 ;Berger+2004
Multiwavelength	Shock micro-physics	Taylor+2005
Early time monitoring	Test Reverse Shock	e.g. 130427 A ... Toma+2010; Chandra+2012; Laskar et al. 2013, Anderson et al. 2014
Monitor parent SN pop & transitional objects	Constrain GRB/SN assoc.	Berger+2003 Soderberg+2006,2009
Host galaxy	Access the obscured SFR Host properties	Stanway+2010 Hatsukade+2012 Zauderer+2012



**SQUARE KILOMETRE ARRAY**  
Exploring the Universe with the world's largest radio telescope

# The Square Kilometer Array



Sparse Aperture Array

Dish Array

Hyp:

1) comoving frame clustering [gg+12]

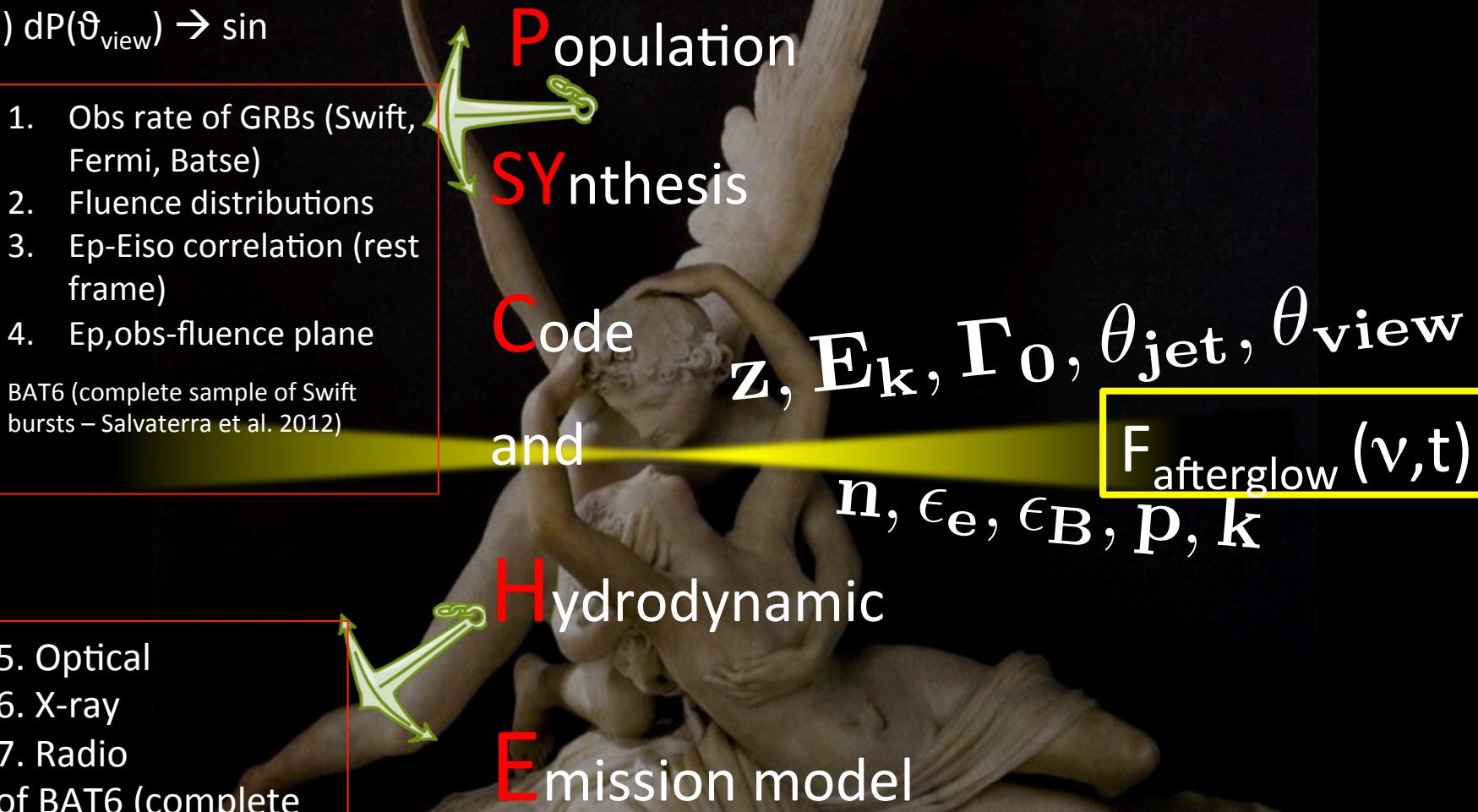
2)  $f(z)$  [Hopkins & Beacom 06; Li 08]

3)  $dP(\vartheta_{\text{view}}) \rightarrow \sin$

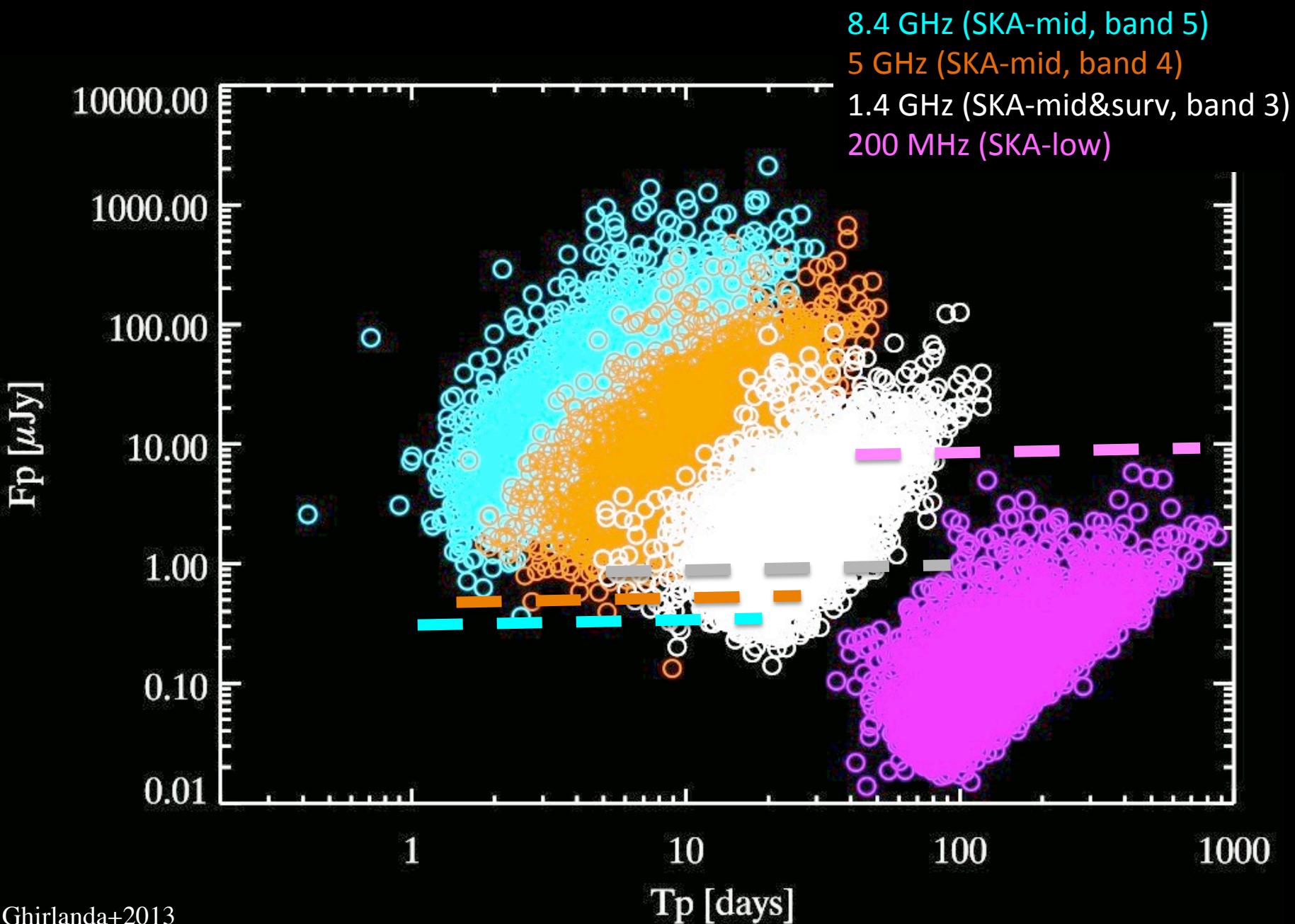
1. Obs rate of GRBs (Swift, Fermi, Batse)
2. Fluence distributions
3. Ep-Eiso correlation (rest frame)
4. Ep,obs-fluence plane

BAT6 (complete sample of Swift bursts – Salvaterra et al. 2012)

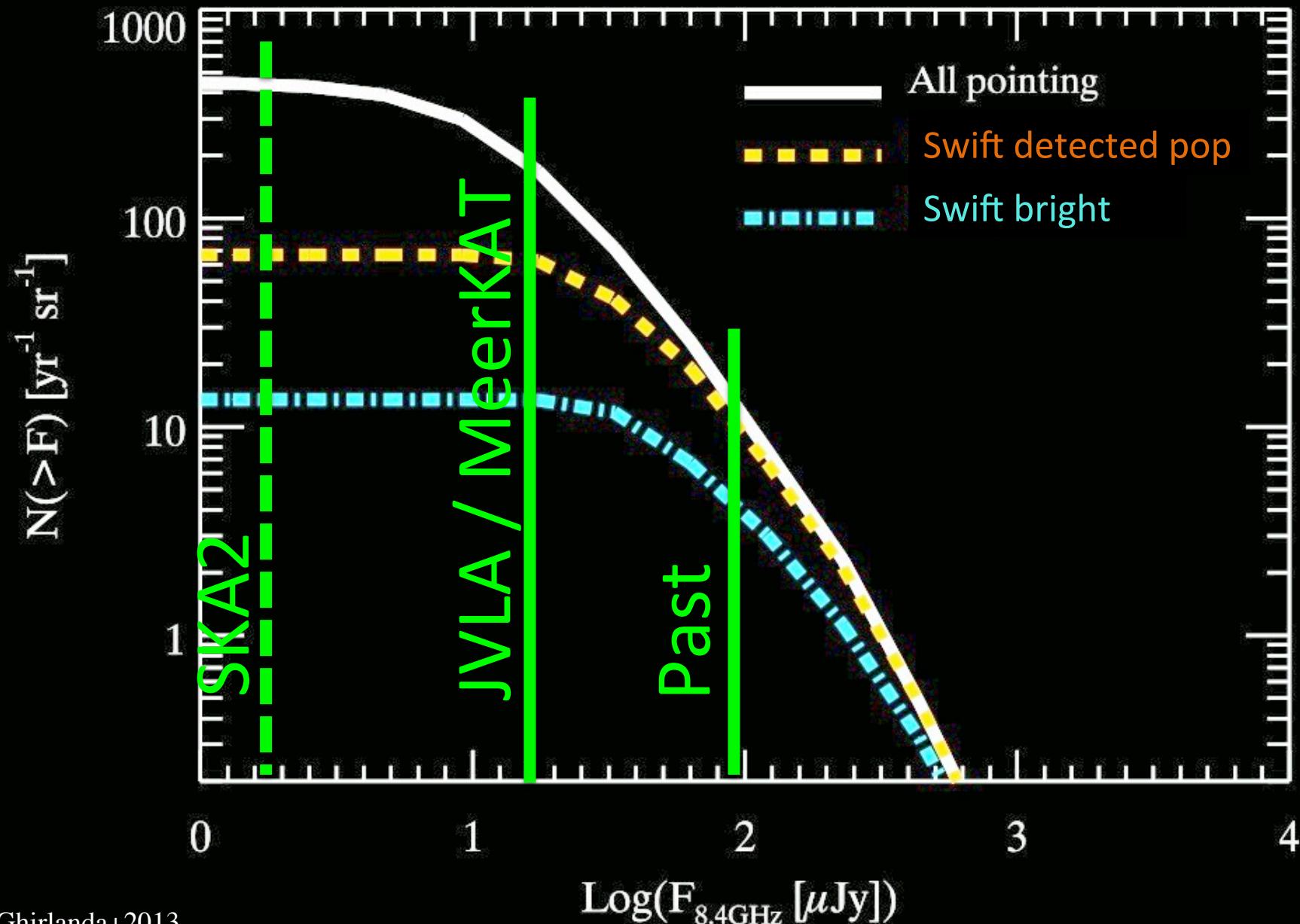
5. Optical
  6. X-ray
  7. Radio
- of BAT6 (complete flux limited sample of Swift bursts)



Ghirlanda+2012, MNRAS  
Ghirlanda+2013, MNRAS  
Ghirlanda+2014, PASA



# 8.5GHz flux @ 5 days



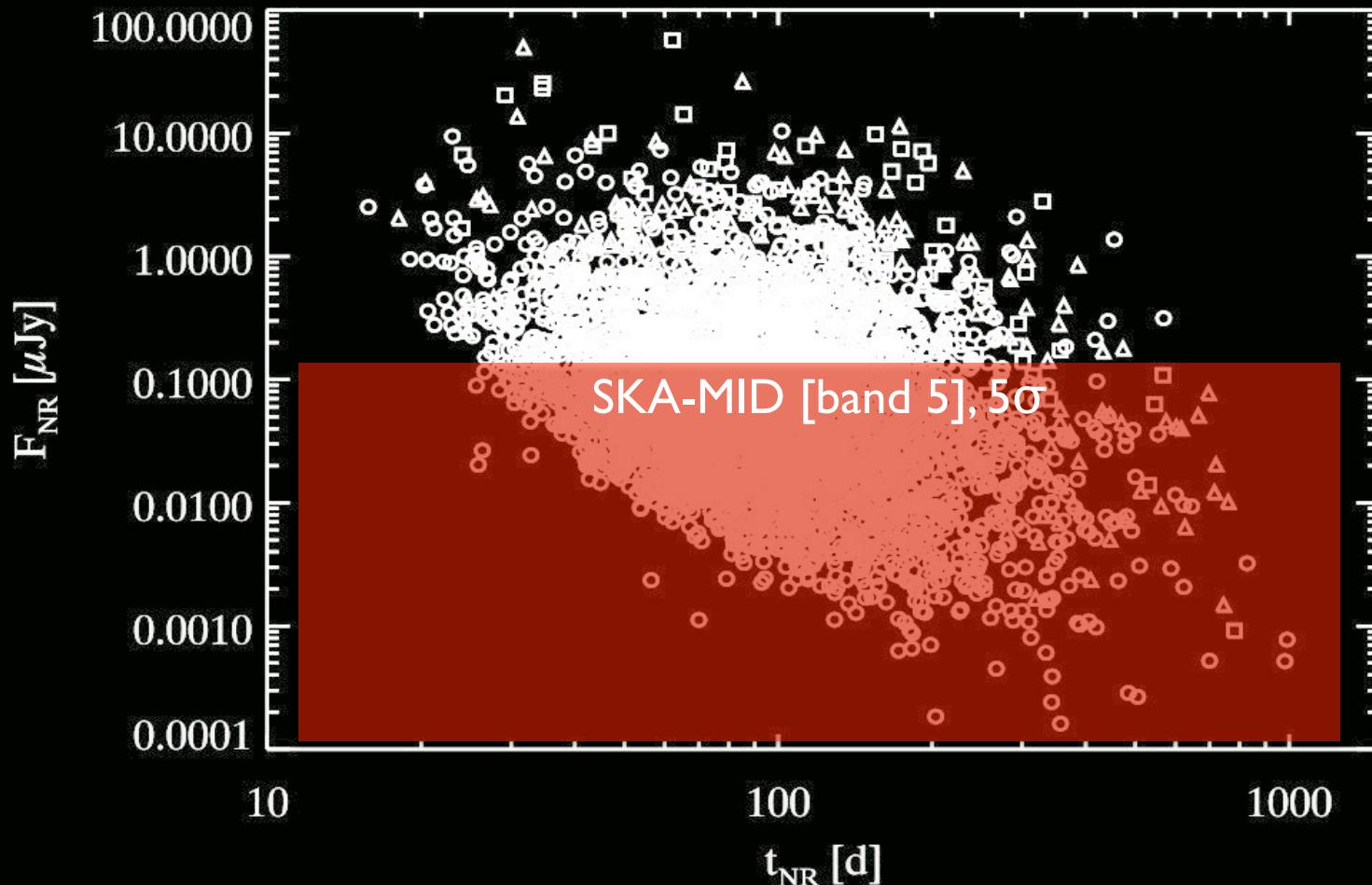
Trans Relativistic (late times) when  $\Gamma=1$

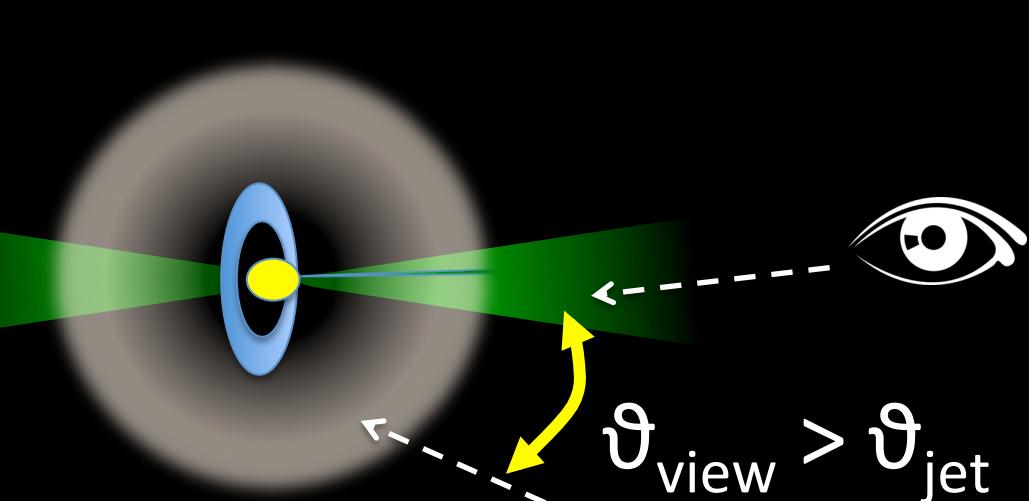
## GRB calorimetry

Prompt emission gives the isotropic equivalent proxy

$$E_{\text{kin, true}} = E_{\text{iso}} \theta^2 / \eta$$

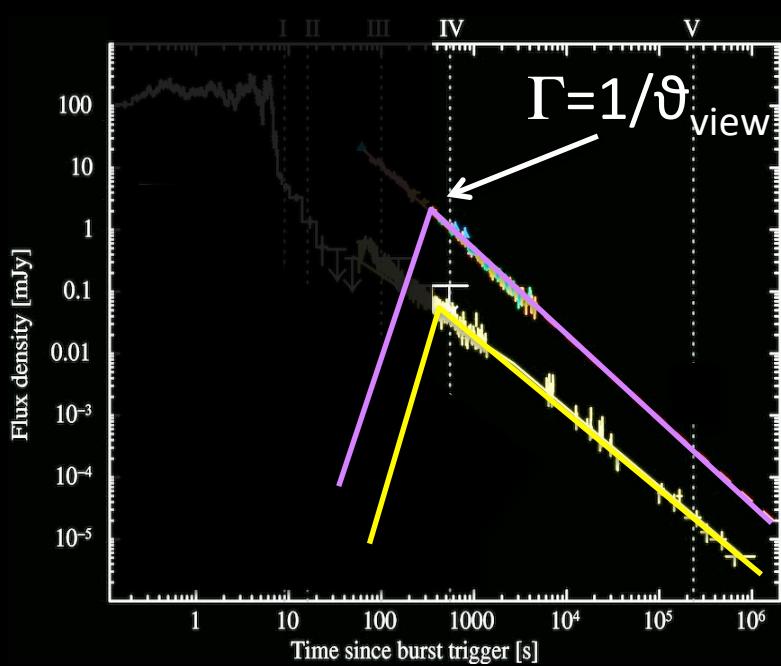
- true (collimation and beaming indep.) energy of GRBs
- Probe microphysics
- Probe SIM structure



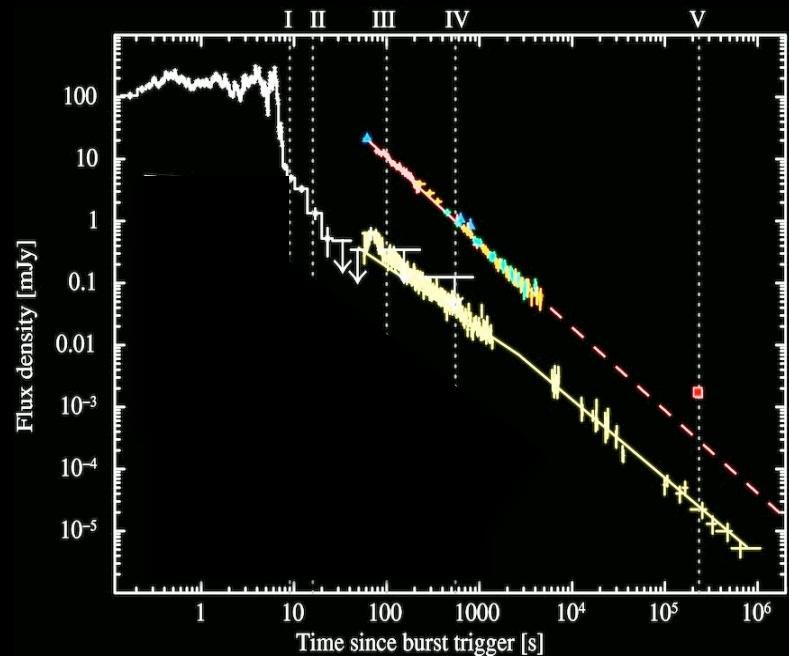


**ORPHAN**

**Afterglow**



**GRB + Afterglow**



$$N_{\text{orph}} \sim \frac{2}{\theta_{\text{jet}}^2} N_{\text{GRB}}$$

$\theta_{\text{jet}} = 5^\circ$  for each GRB  $\rightarrow \sim 260$  Orphans

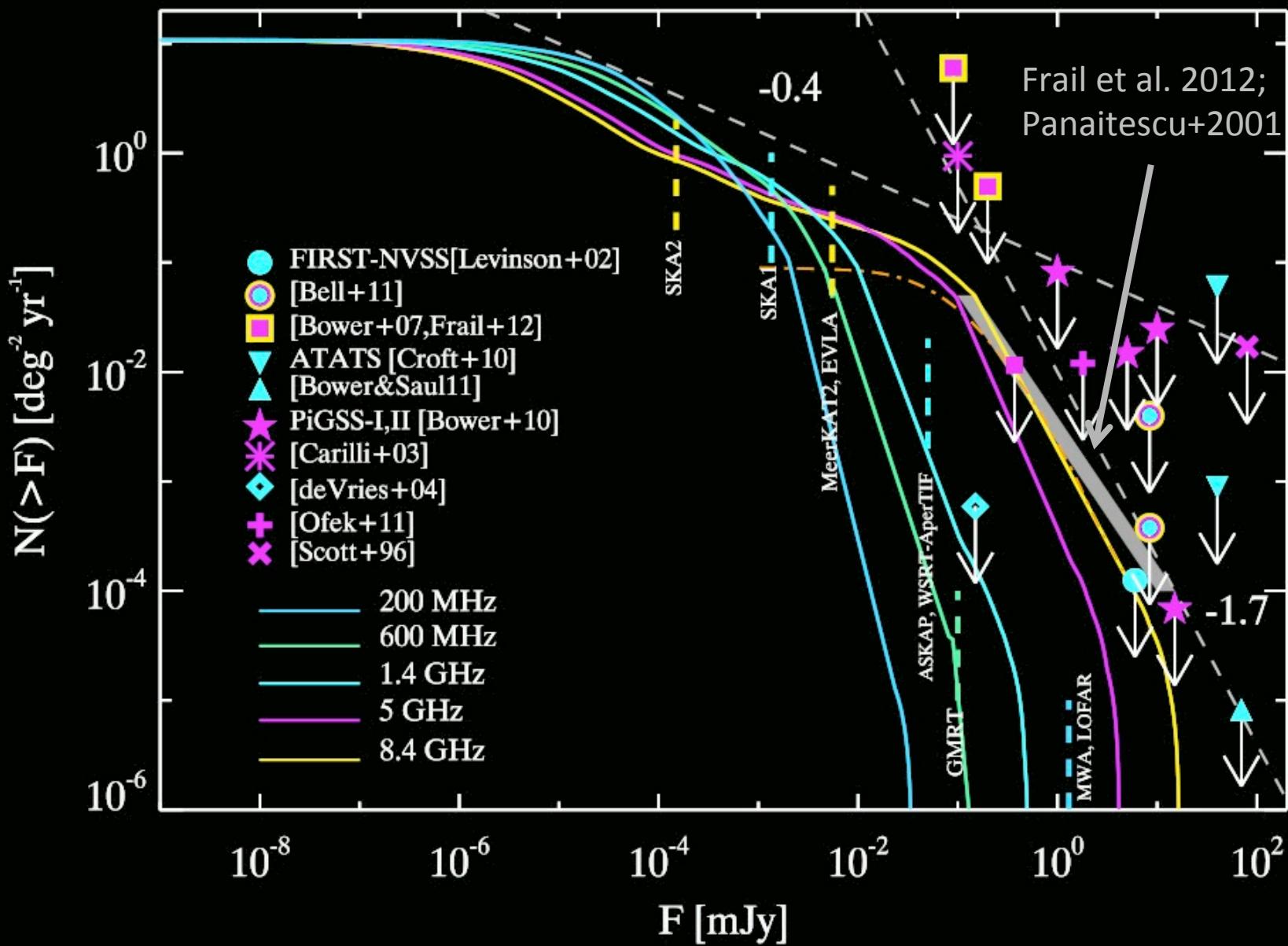
# Orphan afterglows searches as transients in (blind) surveys

Band	Ref	Results
X-ray	Grindlay 1999; Greiner et al. 2000	23 → flare stars
Optical/NIR	Rau et al. 2006 (12 deg <sup>2</sup> , R=23)	4 → flare stars
	Malacrino et al. 2007 (490 deg <sup>2</sup> , r=22.5) CFTHLS	3 → flare stars
Radio	Levinson et al. 2002 (1.4 GHz NVSS vs FIRST, 6000 deg <sup>2</sup> )	9 candidates → 5 false positive, 2 non transients (Gal-Yam et al. 2006)

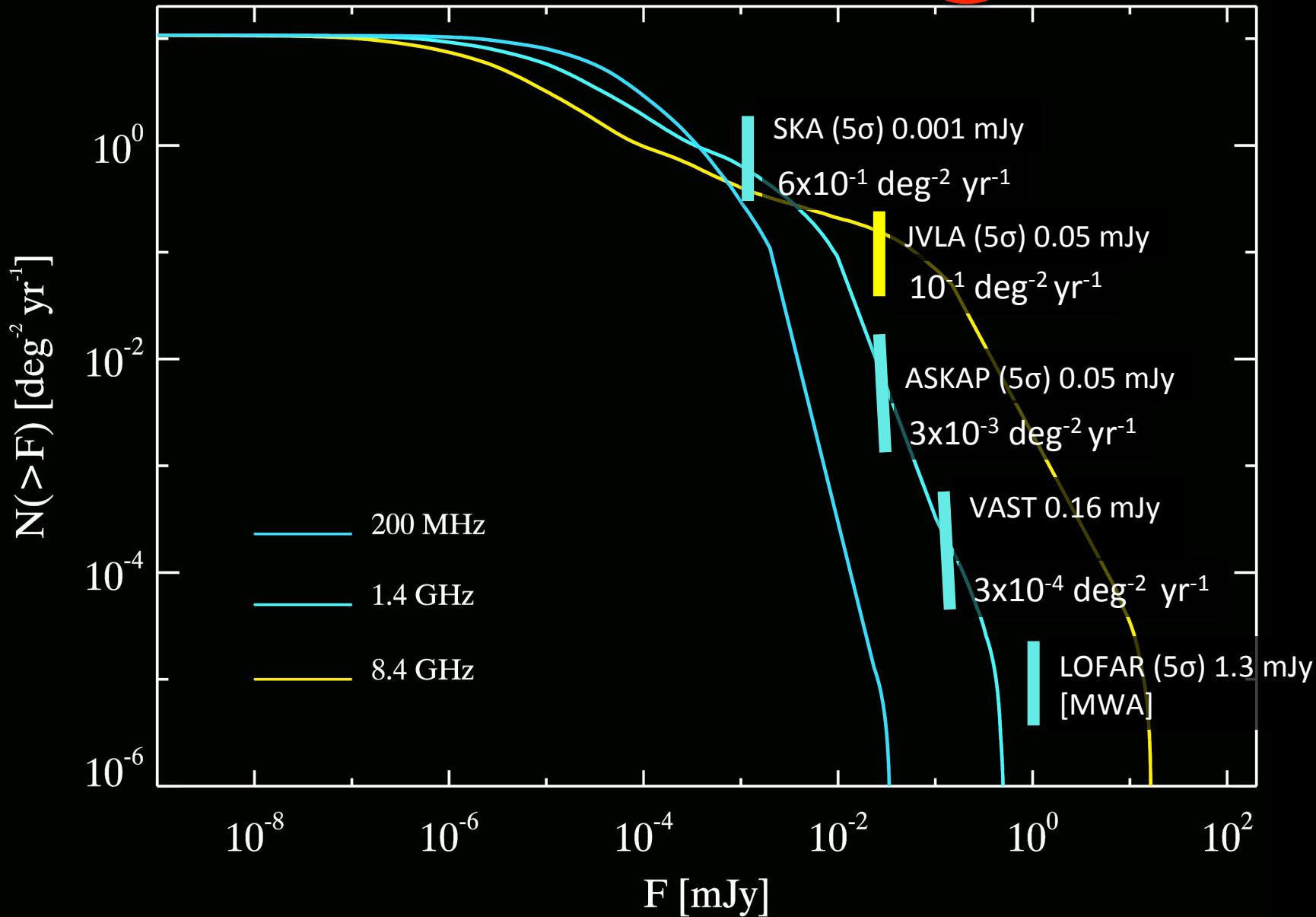
Table 3: Summary of snapshot rates for transient and variables radio sources reported in the literature. The results are organised according to upper limits based on non-detections (top section); transient detections (middle section); and detections of highly variable radio sources (bottom section).

Survey/Reference	S <sub>Min</sub> (mJy)	S <sub>Max</sub> (mJy)	Rate (deg <sup>-2</sup> )	Timescale	Frequency (GHz)	Epochs (N)
Bower et al. (2007)	>0.09	—	<6	1 year	4.8 & 8.4	17
Bower et al. (2007) & Frail et al. (2012) <sup>†</sup>	0.2	—	<3	2 months	4.8 & 8.4	96
Bower et al. (2007) & Frail et al. (2012) <sup>†</sup>	>0.37	—	< 6 × 10 <sup>-1</sup>	20 mins - 7 days	4.8 & 8.4	944
PiGSS-I/Bower et al. (2010)(A)*	>1	—	<1	1 month	3.1	75
PiGSS-II/Bower et al. (2011)(B)*	> 5	—	<0.18	1 month	3.1	78
FIRST-NVSS/Gal-Yam et al. (2006)	>6	—	<1.5×10 <sup>-3</sup>	days to months	1.4	2
Bell et al. (2011)	>8 (8 $\sigma$ )	—	<0.032	4.3 - 45.3 days	1.4, 4.8 & 8.4	5037
PiGSS-I/Bower et al. (2010)(A)*	>10	—	<0.3	1 month	3.1	75
PiGSS-II/Bower et al. (2011)(B)*	> 15	—	<0.025	1 day	3.1	78
ATATS - I/Croft et al. (2010)	>40	—	<0.004	81 days - ~ 15 years	1.4	12
Bower & Saul (2011)(A)*	>70	—	<3×10 <sup>-3</sup>	1 day	1.4	1852
ATATS - II/Croft et al. (2011)	>350	—	<6×10 <sup>-4</sup>	minutes to days	1.4	12
Bower & Saul (2011)(B)*	>3000	—	>9×10 <sup>-4</sup>	1 day	1.4	1852
Lazio et al. (2010)	>2.5×10 <sup>6</sup> (5 $\sigma$ )	—	<9.5×10 <sup>-8</sup>	5 mins	0.0738	~1272

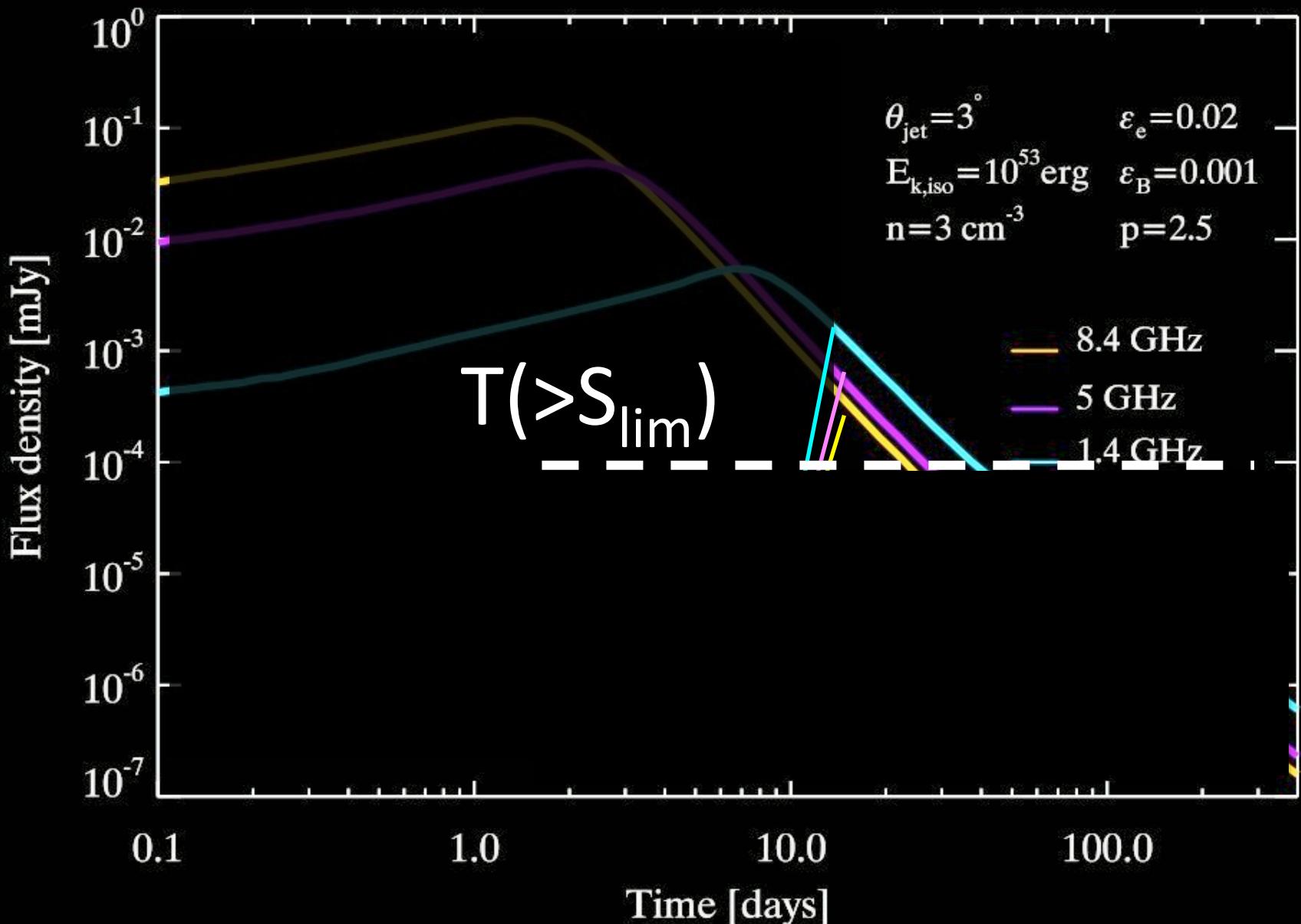
# RADIO: Orphan flux



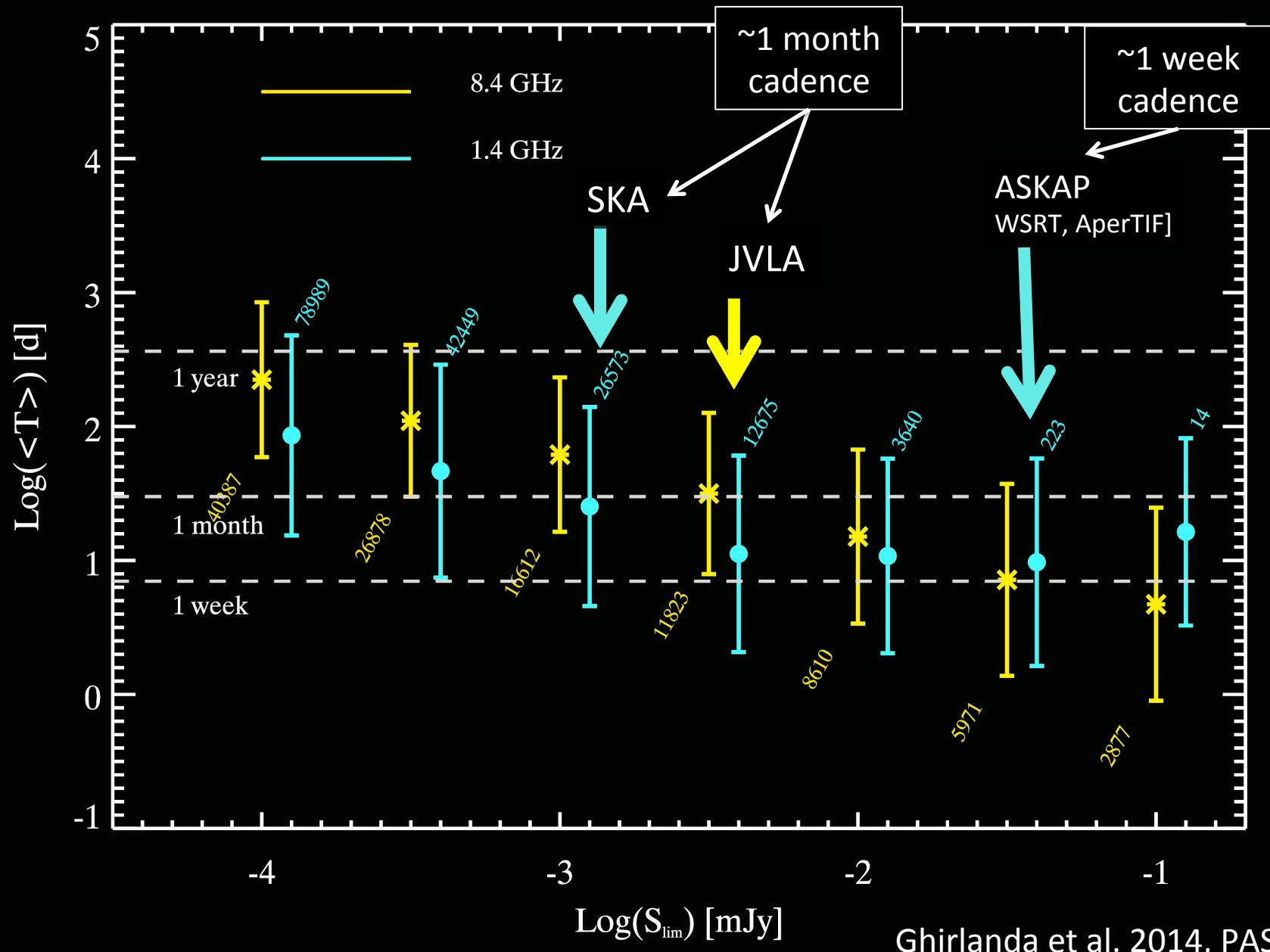
# RADIO: Predictions $\leftarrow \rightarrow$ Survey $S_{\text{lim}}, \Omega, \Delta T, \dots$



# Survey flux limit ( $S_{\text{lim}}$ ) → timescale



# Survey flux limit ( $S_{\text{lim}}$ ) $\rightarrow$ timescale



# Conclusions

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In the SKA era we will be able to

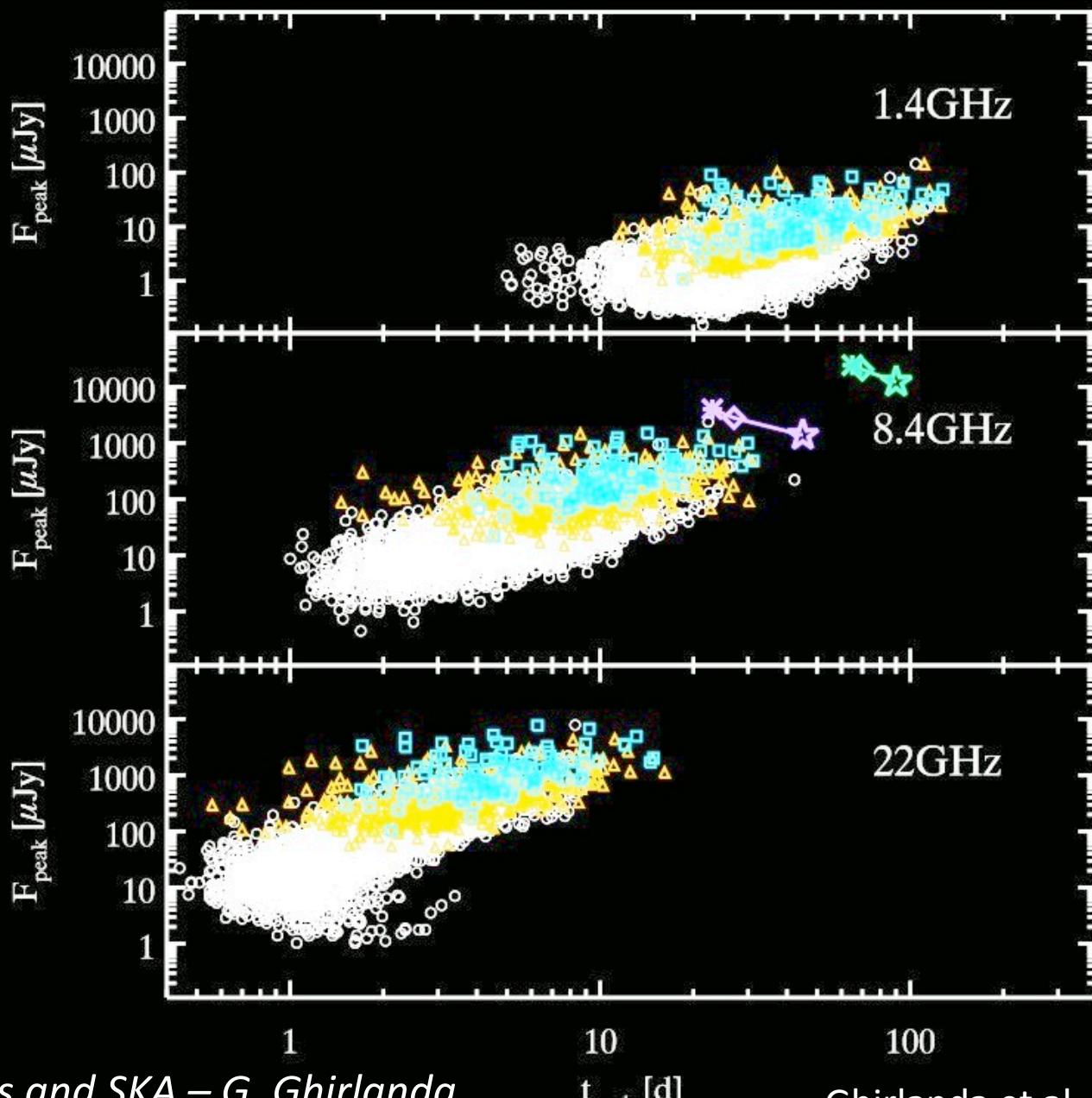
- ✓ densely sample (>1GHz) the lightcurve of **all GRB** with a  $\gamma$ -ray trigger (radio obs strategy)
- ✓ routinely perform **calorimetry** → estimate true energetics, independently constrain jet structure/evolution and shock efficiency
- ✓ chase down the elusive **orphan afterglow** population (relatively slow transients)

The performances that are key to GRB science are

- ✓ flexible use of the different bands → “**GRB large programs**”
- ✓ sensitivity of the higher  $\nu$  bands
- ✓ deep all-sky survey with cadence sensitive to slow transients

# When and Where?

Peak flux vs  
peak time  
@  $\neq$  v



# An International Mega-Project



- 20 countries
- \$450m AUD current investment
- \$3 billion AUD total cost
- Needs ~\$200 million AUD per year to run
- Full operations by 2025 – lifetime of 50+ years