Deciphering the puzzle of GRB170817 and SKA studies of Gamma Ray Bursts

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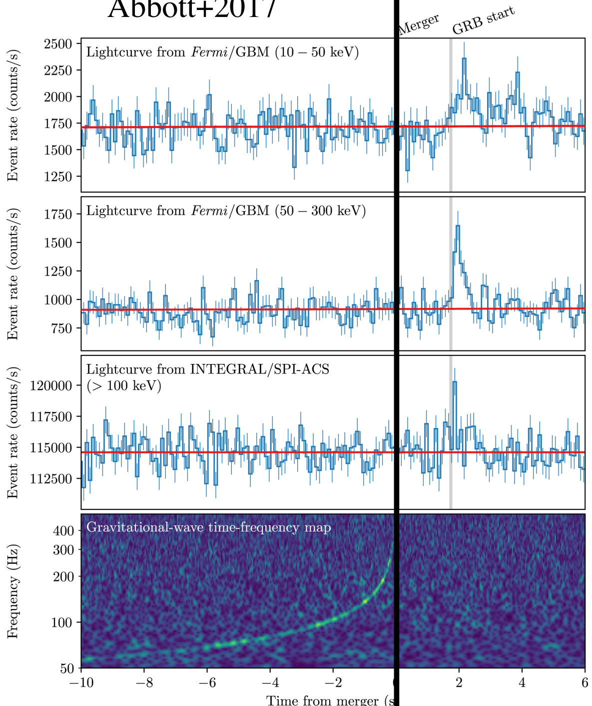
Salafia, Paragi, Giroletti, Yang, Marcote, Blanchard, Agudo, An, Bernardini, Beswick, Branchesi, Campana, Casadio, Chassande–Mottin, Colpi, Covino, D'Avanzo, D'Elia, Frey, Gawronski, Ghisellini, Gurvits, Jonker, van Langevelde, Melandri, Moldon, Nava, Perego, Perez-Torres, Reynolds, Salvaterra, Tagliaferri, Venturi, Vergani, Zhang

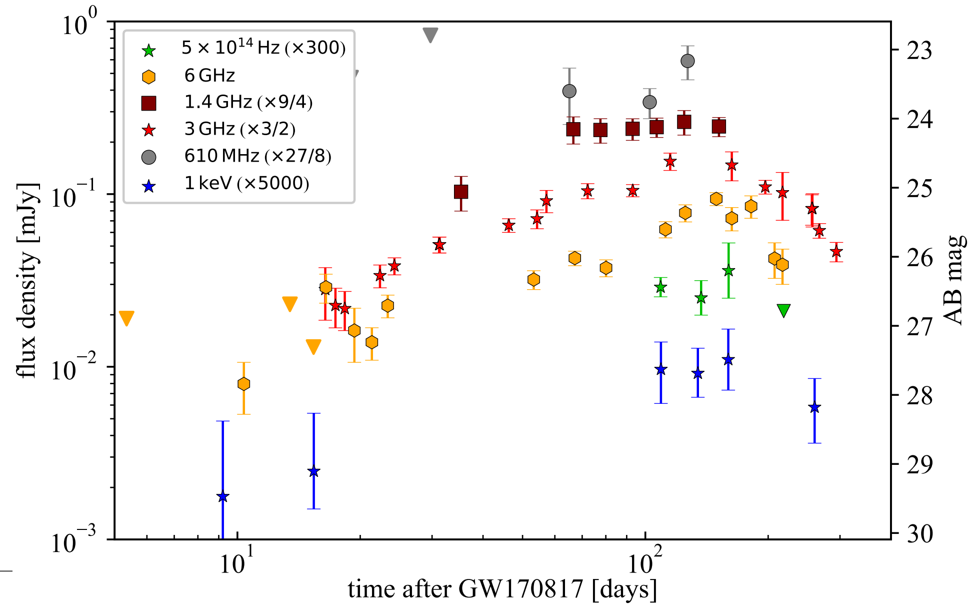
arXiv:18081.00469

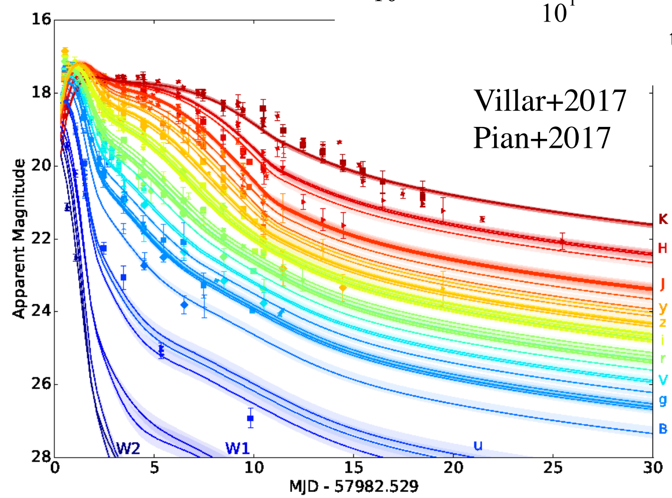
1. **GRB/GW170817: a relativistic structured jet emerged**
2. **Three SKA on-going projects**

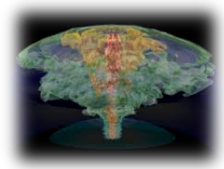
ID: GW/GRB170817

Abbott+2017









T=0

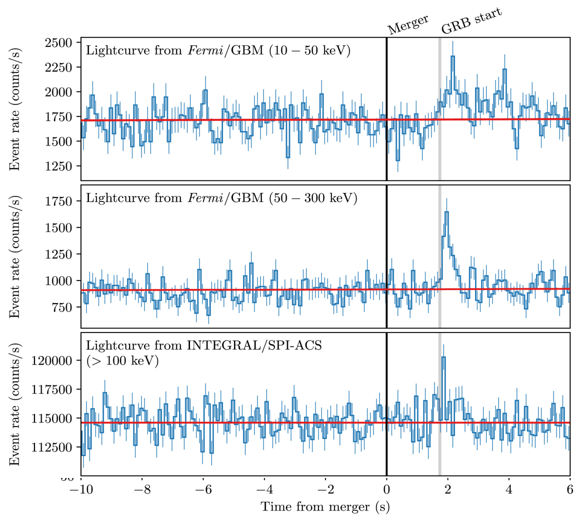
GW Phase
seconds

γ-rays
seconds

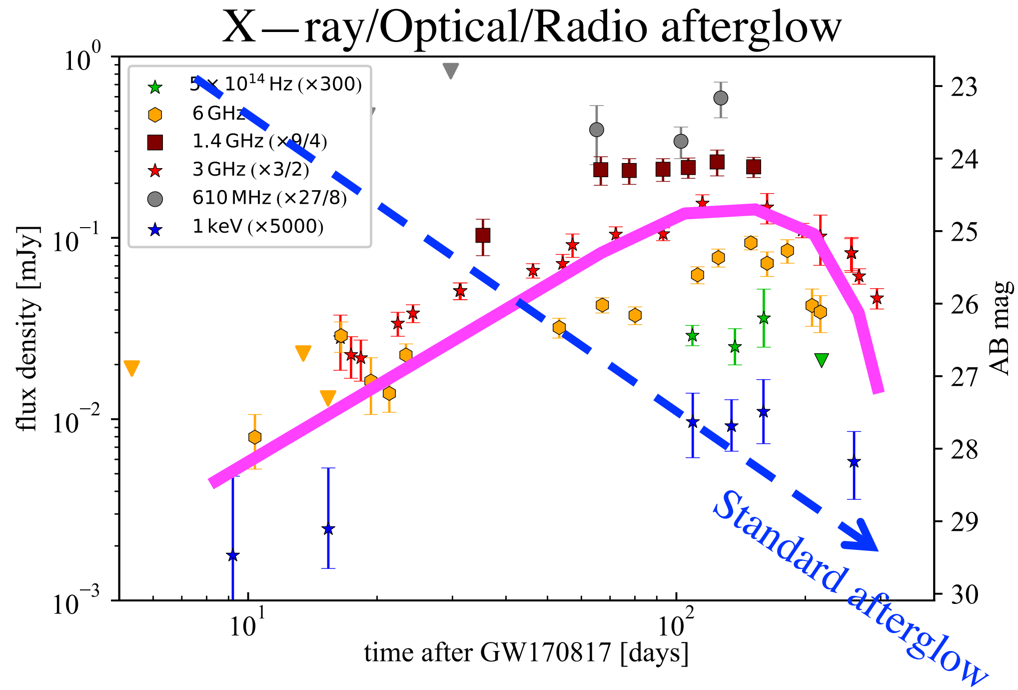
Optical (0.5 - 27 days)

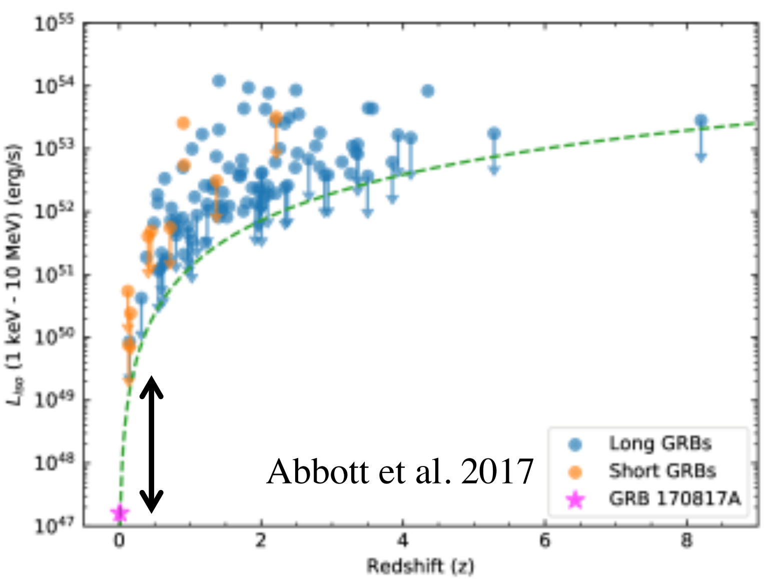
X—ray & Radio (10 - 300 days)

GRB170817: non-thermal components



Prompt Gamma Ray Burst





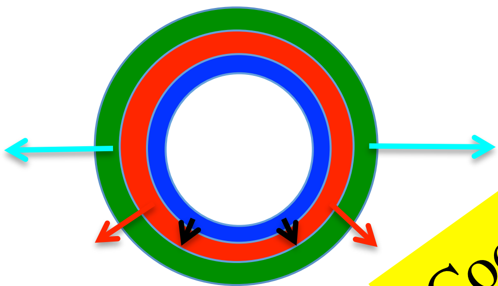
- 3-4 orders of magnitudes less luminous
- Afterglow: increasing with time rather than decreasing as standard GRBs

Standard jet seen at large angles
(aka off-axis standard jet)

BUT … rise is too shallow ($t^{0.8}$)

Need/origin of structure

Isotropic blast wave



Cocoon

+ radial structure

$\Gamma_1 < \Gamma_2 < \Gamma_3$

$E_1 > E_2 > E_3$

$E_{jet} < E_{ejecta}$

Choked jet (not sucessful)

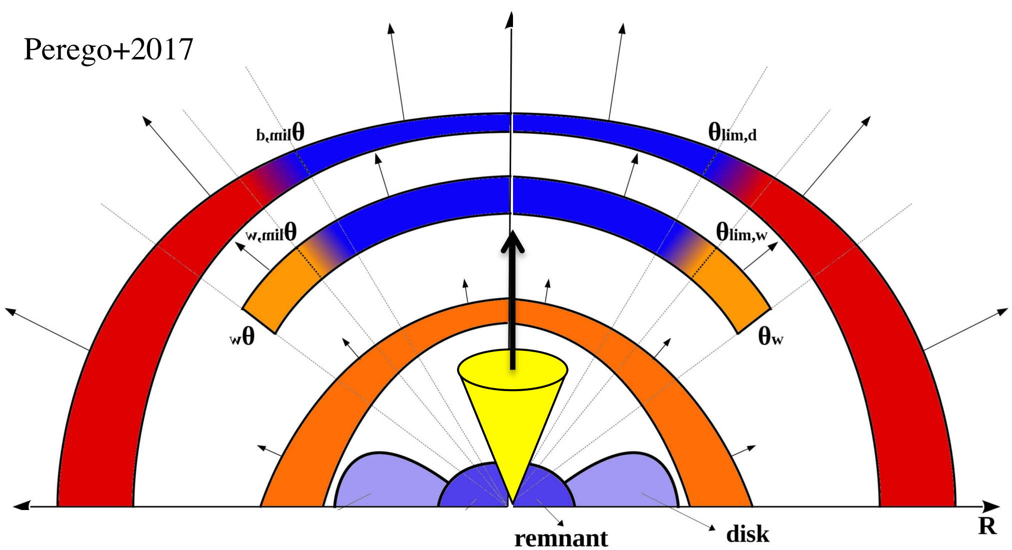
with some degree of anisotropy

Solve the probability issue

Account for the low luminosity

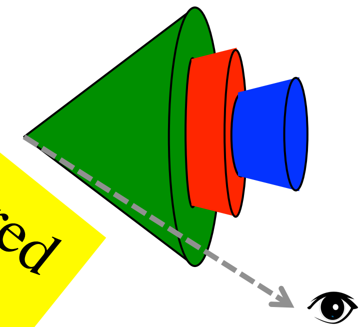
Shallow rise phase as $t^{0.8}$

Perego+2017



In both cases the radial or angular structure may be due to the interaction of the jet head with the merger ejecta

Off-axis structured jet



Structured jet

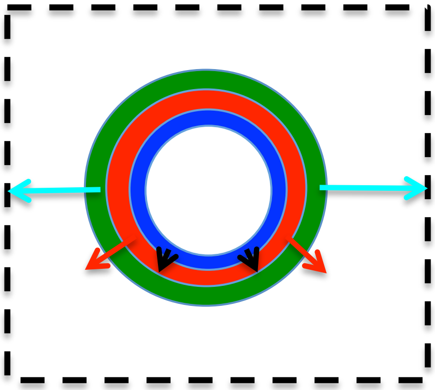
+ angular structure

$\Gamma_1 > \Gamma_2 > \Gamma_3$

$E_1 > E_2 > E_3$

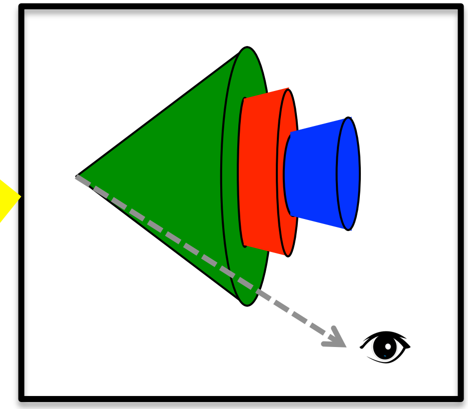
$E_{jet} < E_{ejecta}$

Structured Jet (sucessful)



Cocoon

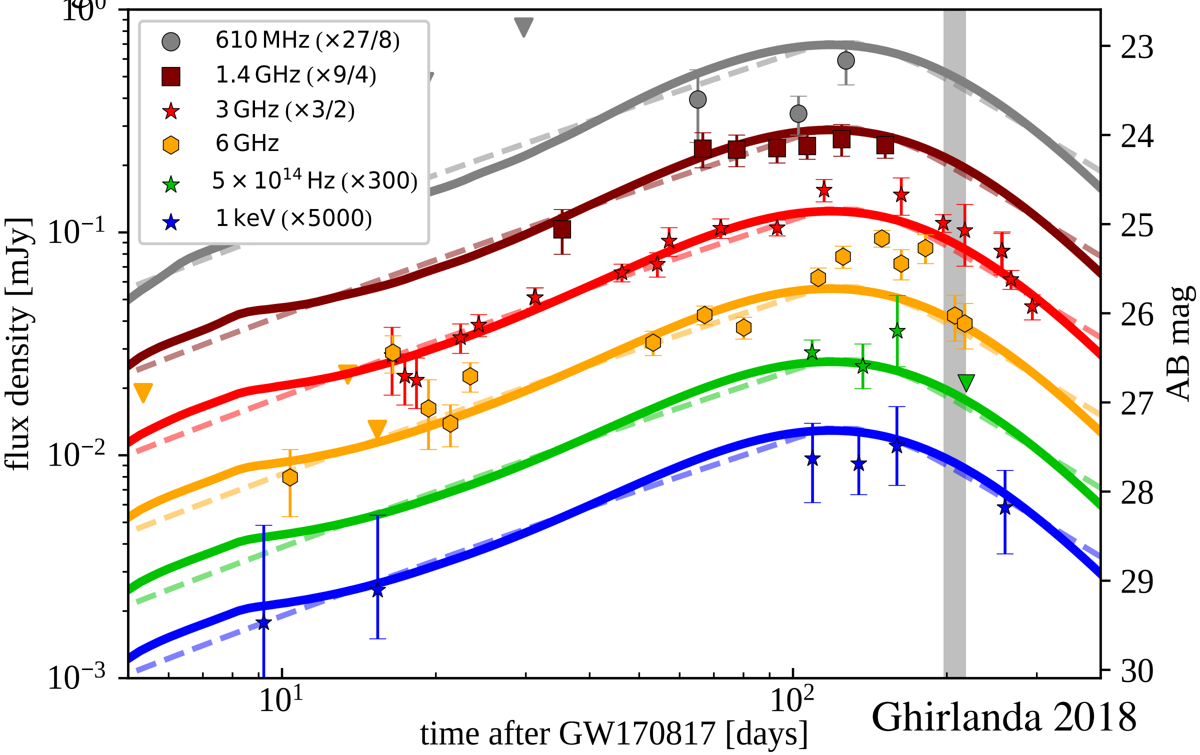
Structured jet



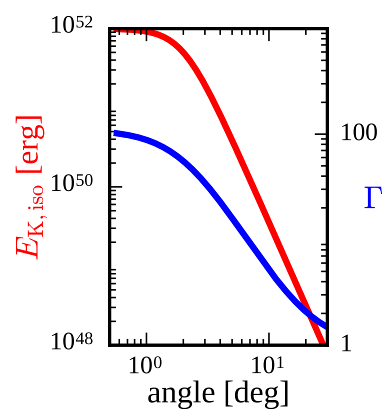
$E_0 = 1.5 \times 10^{52}$ erg
$\alpha = 6$
$\Gamma_{max} = 6$
$\Theta = 30, 45, 60$ deg

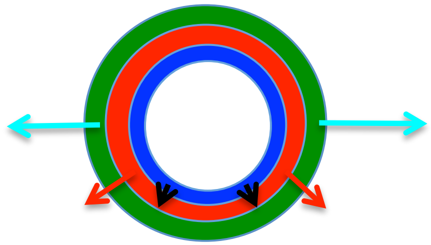
$p=2.15$; $\epsilon_e=0.1$; $\epsilon_B= 10^{-4}$

$E_{core}=2.5 \times 10^{52}$ erg ; $s_1=5.5$;
$\Gamma_c = 250$; $s_2=3.5$; $\vartheta_{core}=3.4$ deg
$n_{ism}=4 \times 10^{-4}$ cm^{-3} ; $\vartheta_{view}=15$ deg



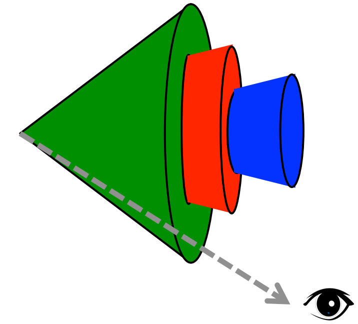
Ghirlanda 2018





Cocoon

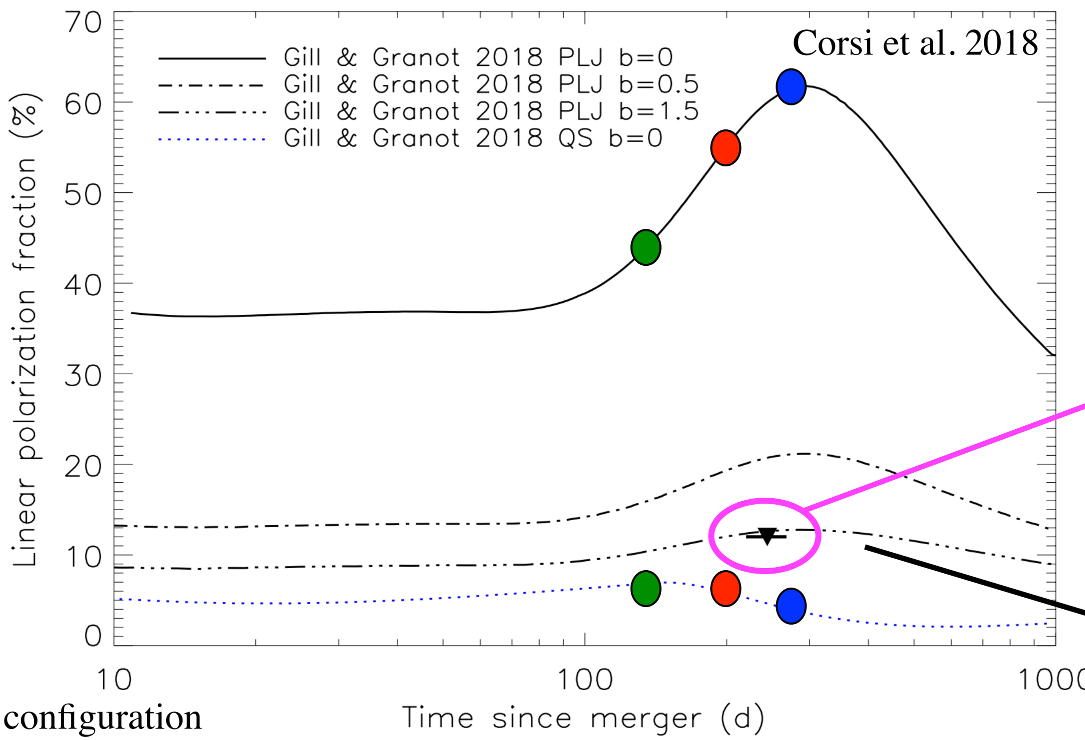
Structured jet



Polarization

[Rossi+2004 … Gill & Granot 2018; Nakar+2018; Lazzati+2018]

$$b = 2\frac{< B_\perp >}{< B_\parallel >}$$



JVLA @ 244d, 2.8 GHz

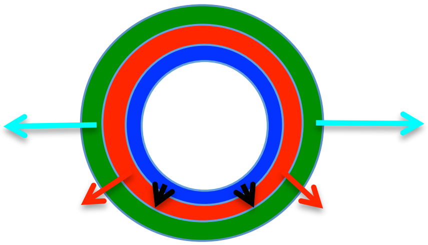
Π<12% (90%)

Corsi et al. 2018

Still compatible with a structured jet with B component perp. shock

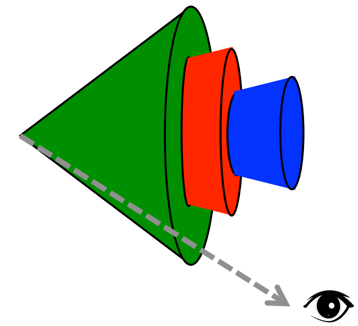
Contribute:

1) Magnetic field configuration (randomness & compression)
2) Γ
3) Geometry (ϑ_{jet} ; ϑ_{view})
4) Emission mechanism



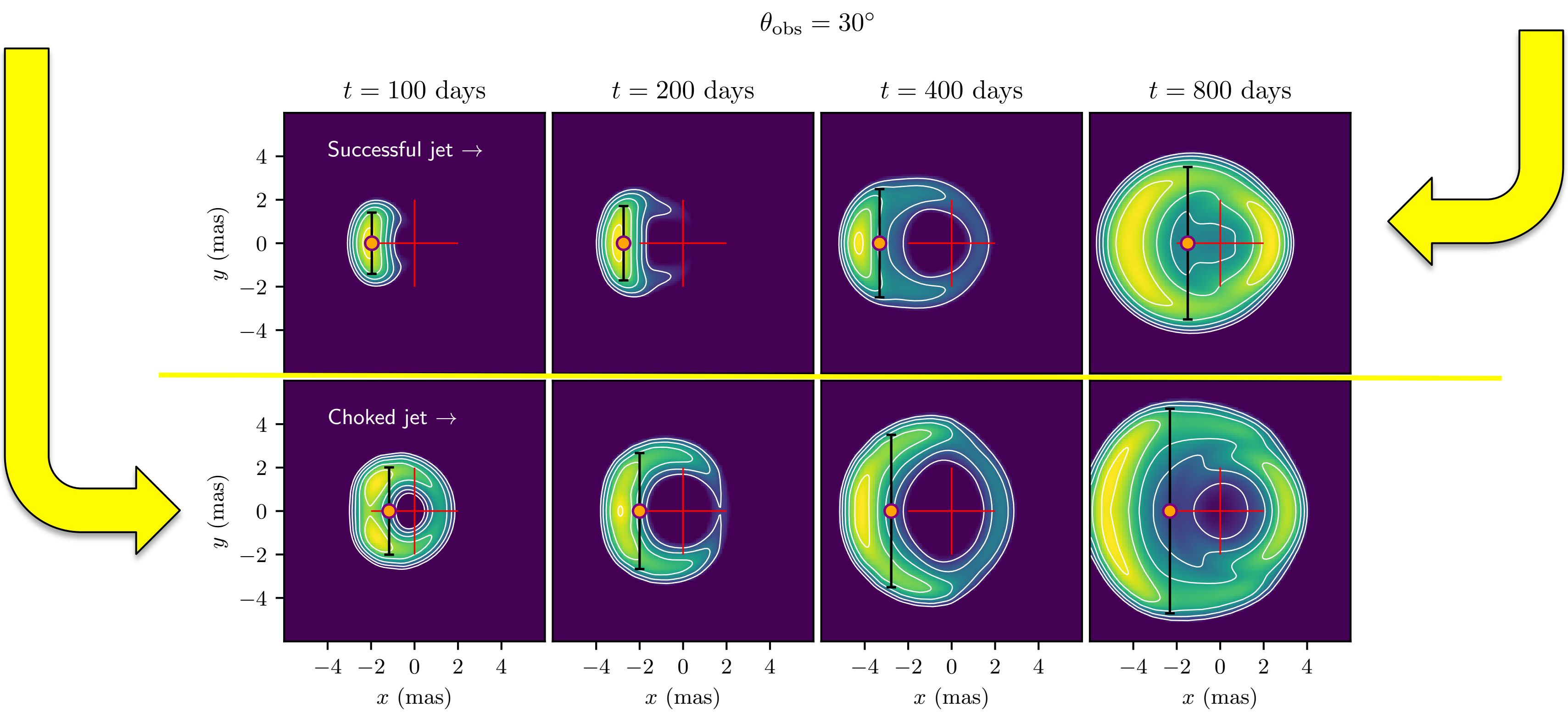
Cocoon

Structured jet

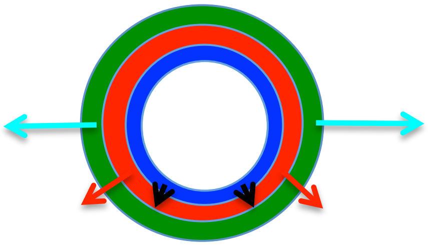


Imaging

[Gill & Granot 2018; Nakar+2018; Zrake+2018; Mooley+2018; Ghirlanda+2018]



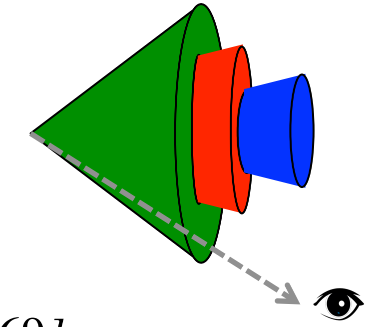
Structured jet has larger displacement and smaller size than cocoon



Cocoon

Imaging

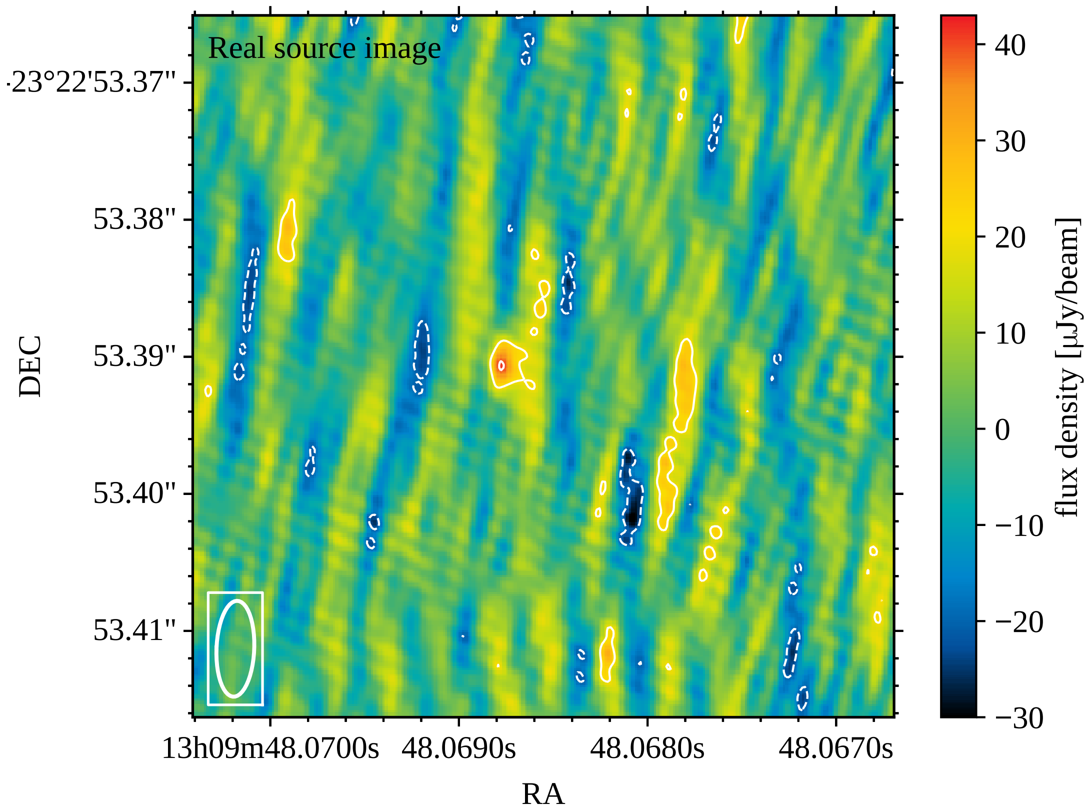
Structured jet



(I) Size constraint *[Ghirlanda+2018* arXiv:18081.00469*]*

Global-VLBI EVN project (GG084) +
eMERLIN (CY6213) {+ EVN (RG009)}

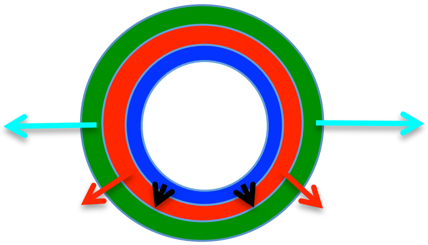
12-13 March 2018 = 207.4 days @ 5 GHz (32 ant. but VLA)



8 μJy/beam rms

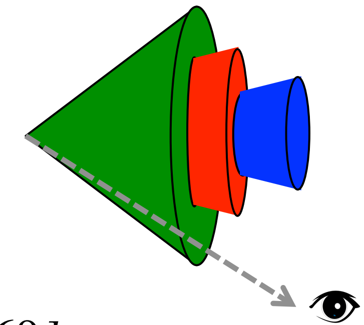
Peak brightness 42 ± 8 μJy/beam
[cnst. interpolating closest JVLA F=47±9 μJy]
8-22 March (12 runs) eMERLIN
F_p < 60 μJy/beam

Size = 2.5 mas
Consistent with structured jet model



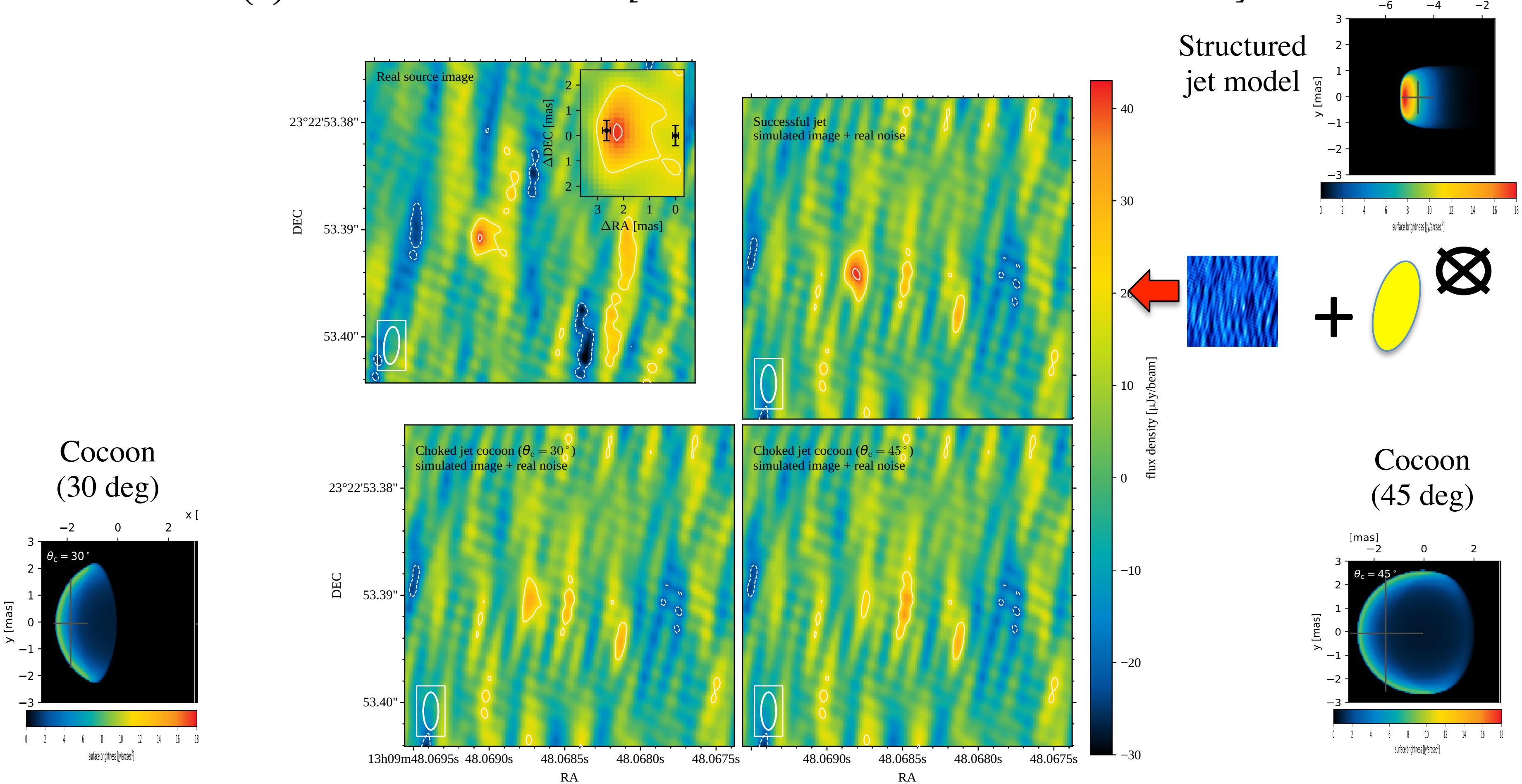
Cocoon

Structured jet



Imaging

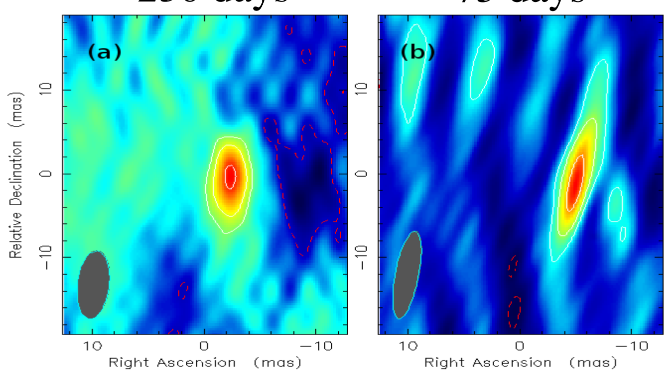
(I) Size constraint *[Ghirlanda+2018* arXiv:18081.00469*]*



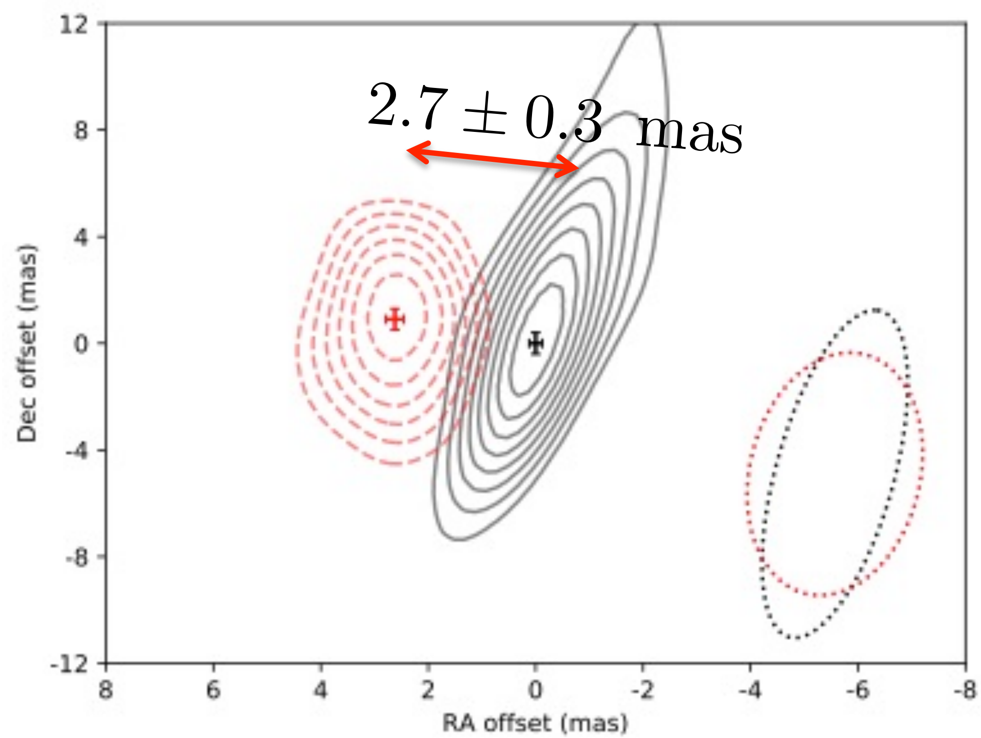
Imaging

(II) apparent motion *[Mooley+2018]*

230 days 75 days



VLBA + VLA + GBT: 2/4 epochs (Sept 2017 – Apr. 2018, L,S,C,C) @ <75d> and <230d> (4.5 GHz)

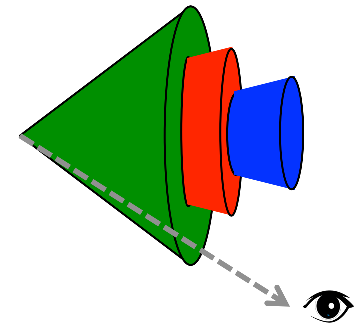


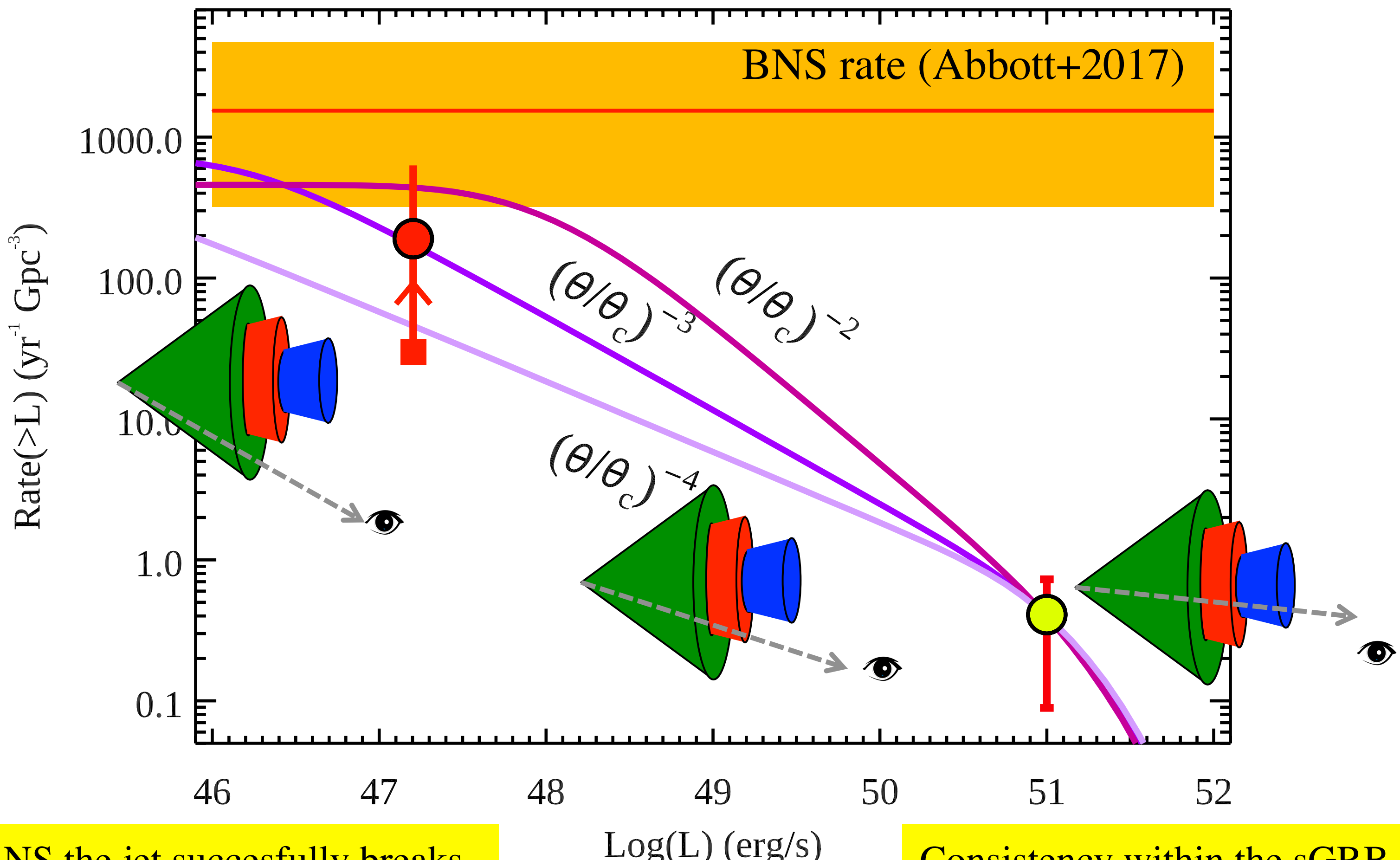
Rates and Luminosity

Structured jet

Structured jet model (universal structure) → Luminosity function
(Pescalli et al. 2015; Salafia et al. 2015)

$$N_{sGRB}(GBM) = \frac{\Omega_{GBM} T_{GBM}}{4\pi} \rho_{0.SGRB} V_{\max} \geq 1$$

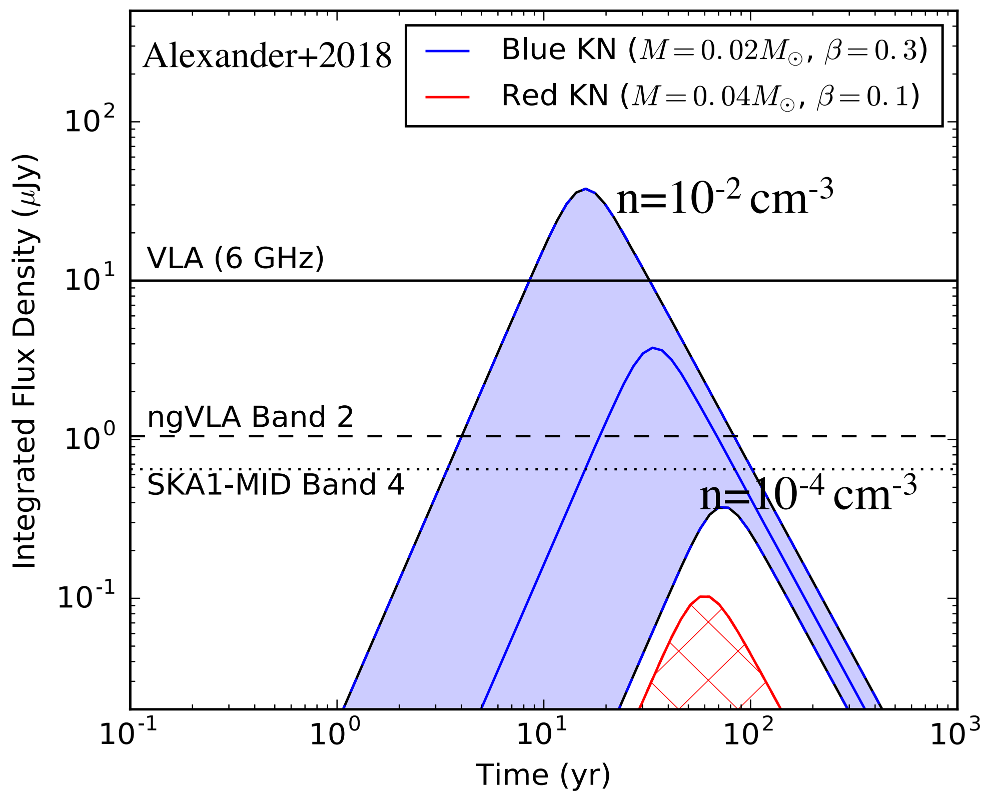




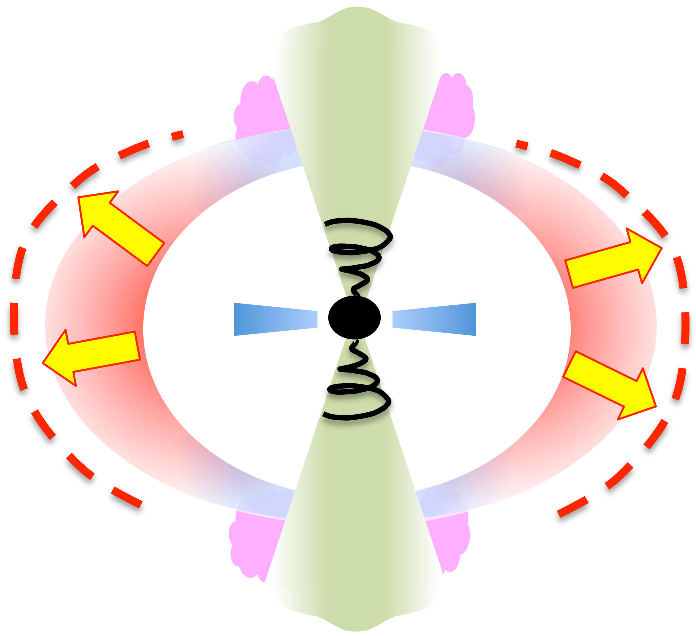
In at least 10% of BNS the jet succesfully breaks out of the merger ejecta

Consistency within the sGRB pop with a single structure

SKA: late non-thermal emission component



Kilonova ejecta deceleration



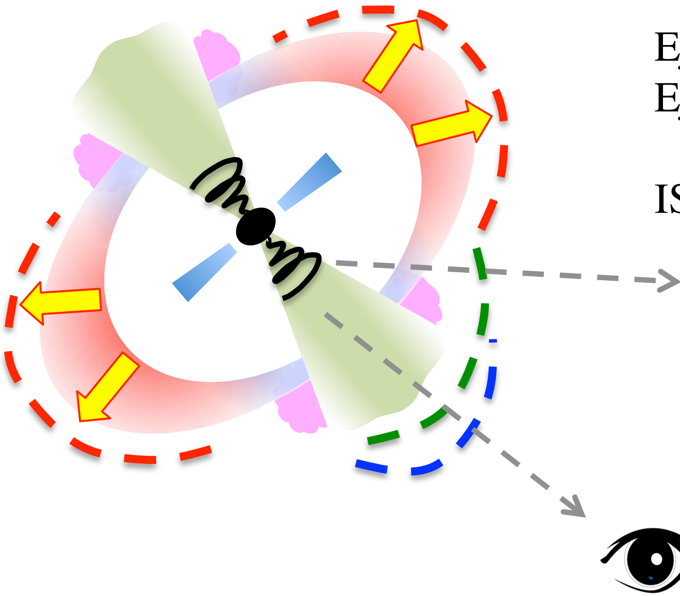
Ejecta mass and velocity distribution [Hotokezaka+2018, Kuici+2018]

External ISM density

Shock microphysical parameters

SKA project (I)

KN (non-th) emission: Energy, β (structure), ISM density

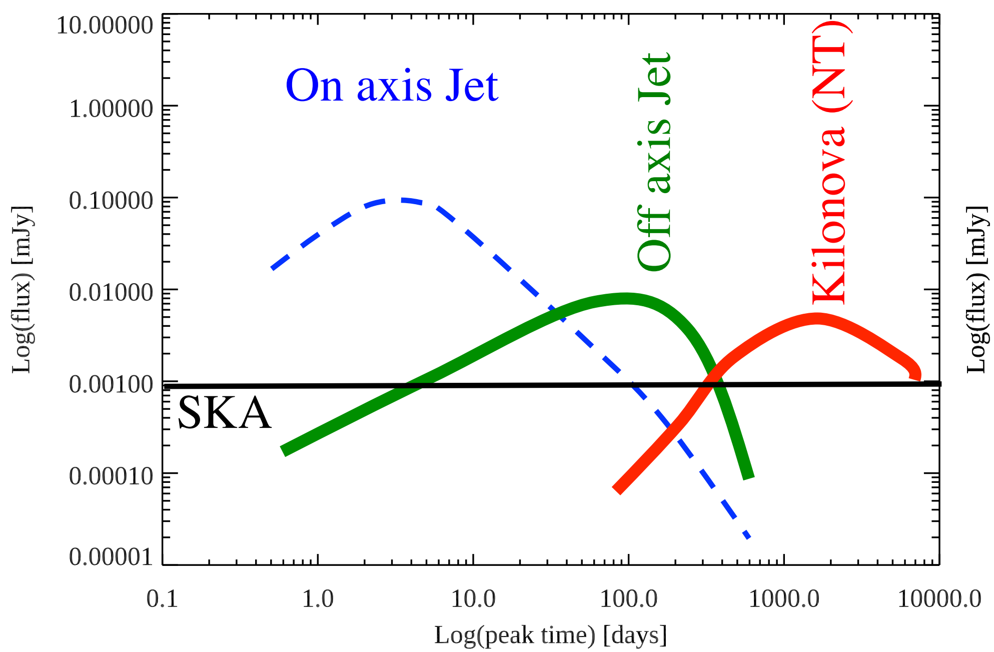


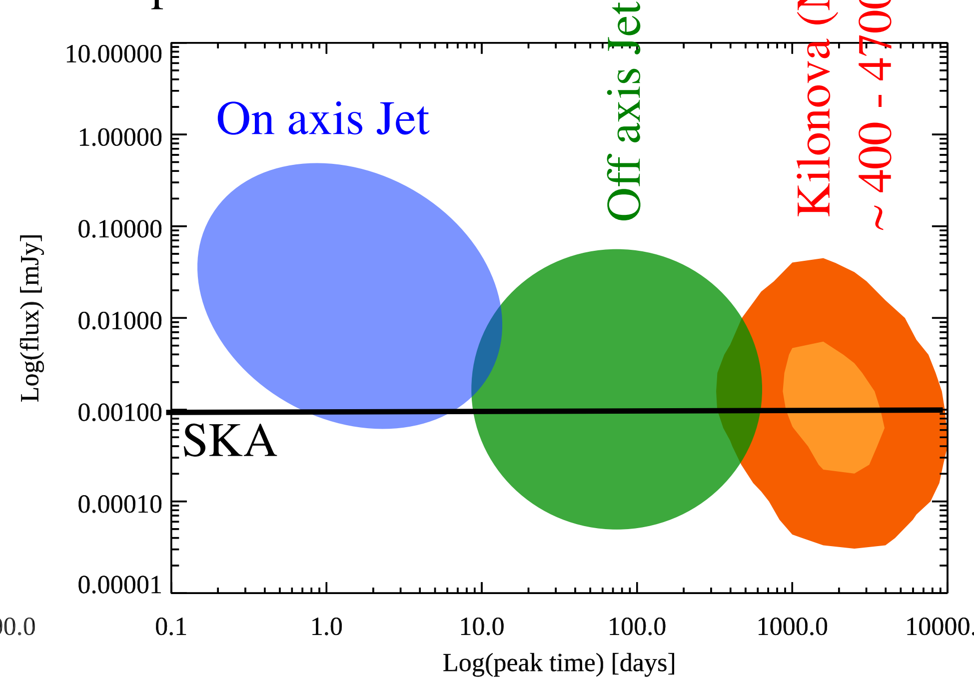
Ejecta mass(es)
Ejecta velocity → Dynamics: NS shocks & tidal effects

ISM density → Population (primordial vs dynamic channel)

Jet (non-th) emission: Energy (structure), ϑ_{view}/ ϑ_{jet}, ISM density

@ ~ 200 Mpc

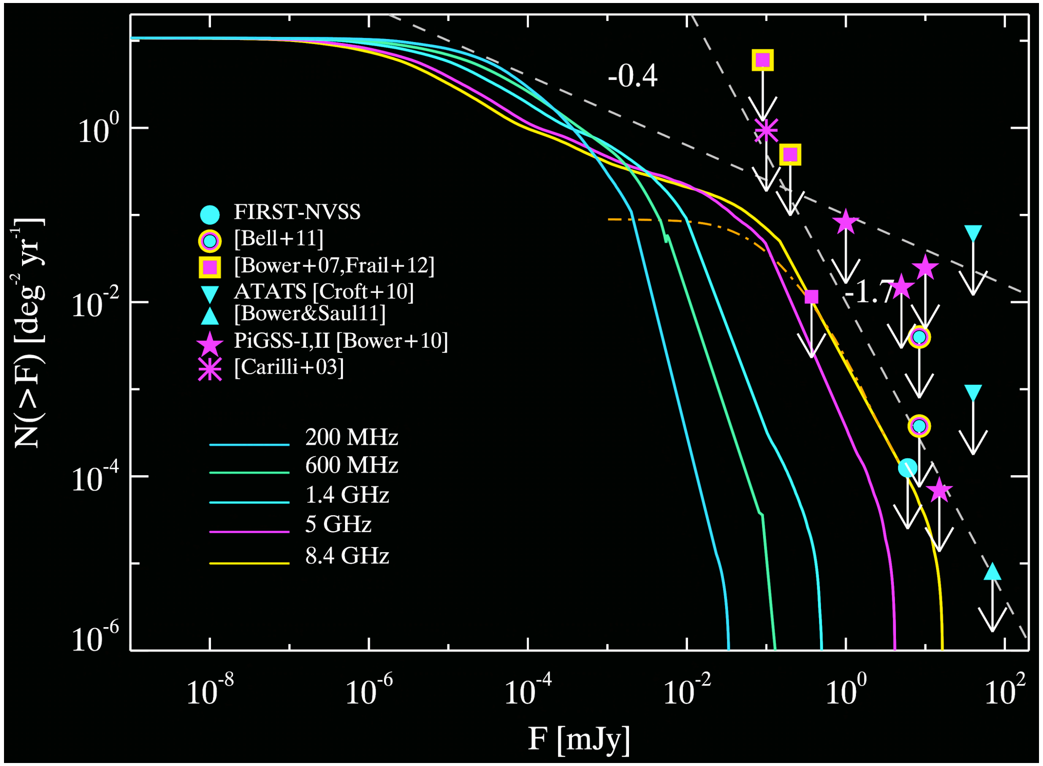




SKA project (II)

SKA: revealing the parent population of cosmological GRBs

Ghirlanda+2014; 2015; Burlon, Ghirlanda et al. 2016



Telescope name	ν [GHz]	$S_{\rm lim}$ [mJy]	Rate [$\deg^{-2}$ $\rm yr^{-1}$]
ASKAP	1.4	0.05	3×10^{-3}
MeerKAT/Ph1	1.4	0.009	10^{-1}
MeerKAT/Ph2	8.4	0.006	3×10^{-1}
SKA/Ph1	1.4	0.001	6×10^{-1}
SKA/Ph2	1.4(8.4)	0.00015	$1.5(2 \times 10^{-1})$
WSRT/AperTIF	1.4	0.05	3×10^{-3}
EVLA	8.4	0.005	3×10^{-1}
LOFAR	0.2	1.3	...
MWA	0.2	1.1	...
GMRT	0.6	0.1	10^{-5}
GMRT	1.4	0.15	2×10^{-4}

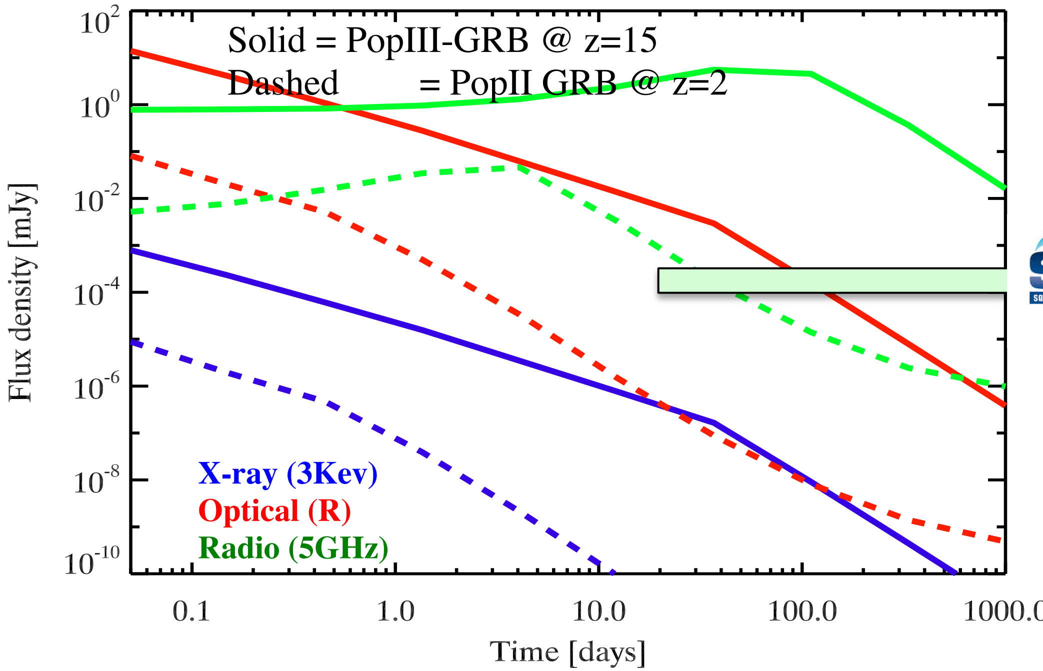
Revision of our MW predictions with:

1) One possible detection (Metzger et al. 2018)
2) New population models
   - different jet structures – Salafia et al. 2015, Pescalli et al. 2016
   - different methods – MCMC (Ghirlanda+2016)

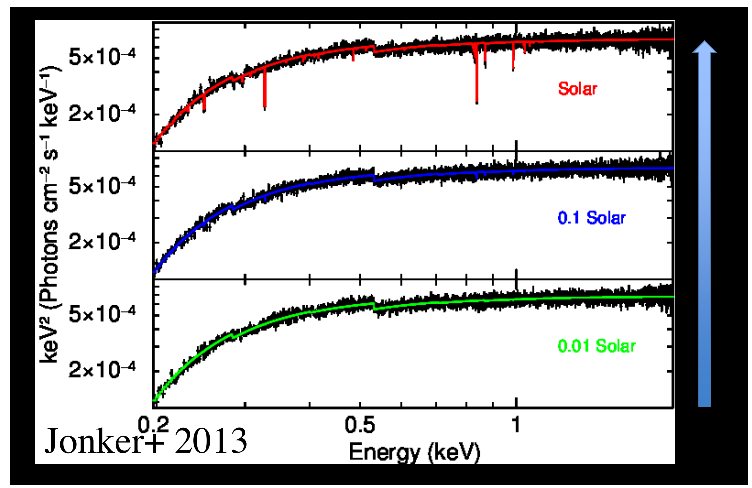
SKA-Athena synergy project (III)

GRBs from Massive Pop-III – diagnostic tools

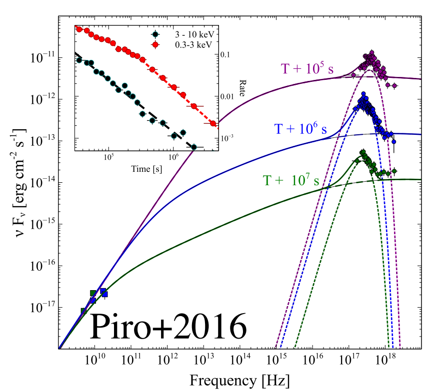
Nakauchi+2012; Ghirlanda+2013; Burlon+2014; Mesler 2014



Late time radio monitoring
+
X-ray high resolution spectroscopy (mettalicity constraints +thermal component)



Proposed to the SKA-Athena synergy SWG



Conclusions

- GW/GRB170817: relativistic narrow jet or cocoon?
  - L(t) (10-240 days) cannot tell apart the two scenarios.
  - High resolution radio observations:
  - ✓ Imaging:
    1. Size < 3 mas (95%) @ 207.4 days (EVN global VLBI)
    2. Proper motion 2.7 mas @ 75-230 days (HSA)

  ⇒ Relativistic structured jet

- 10% of BNS: jet breaks out the merger ejecta.
- Jet (gaussian) universal structure due to interaction with merger ejecta

- SKA (I) survey can detect the KN radio emission → dynamic ejecta and progenitor origin
  - Jet/KN ejecta interaction from BNS and BHNS (project within Prometeo group Unimib+Brera)

- SKA (II) can detect the Orphan GRB afterglow population
  - On-going refinement of the population for Long and Short cosmological GRBs
- SKA – Athena (III) synergies to unveil Pop-III GRB progenitors