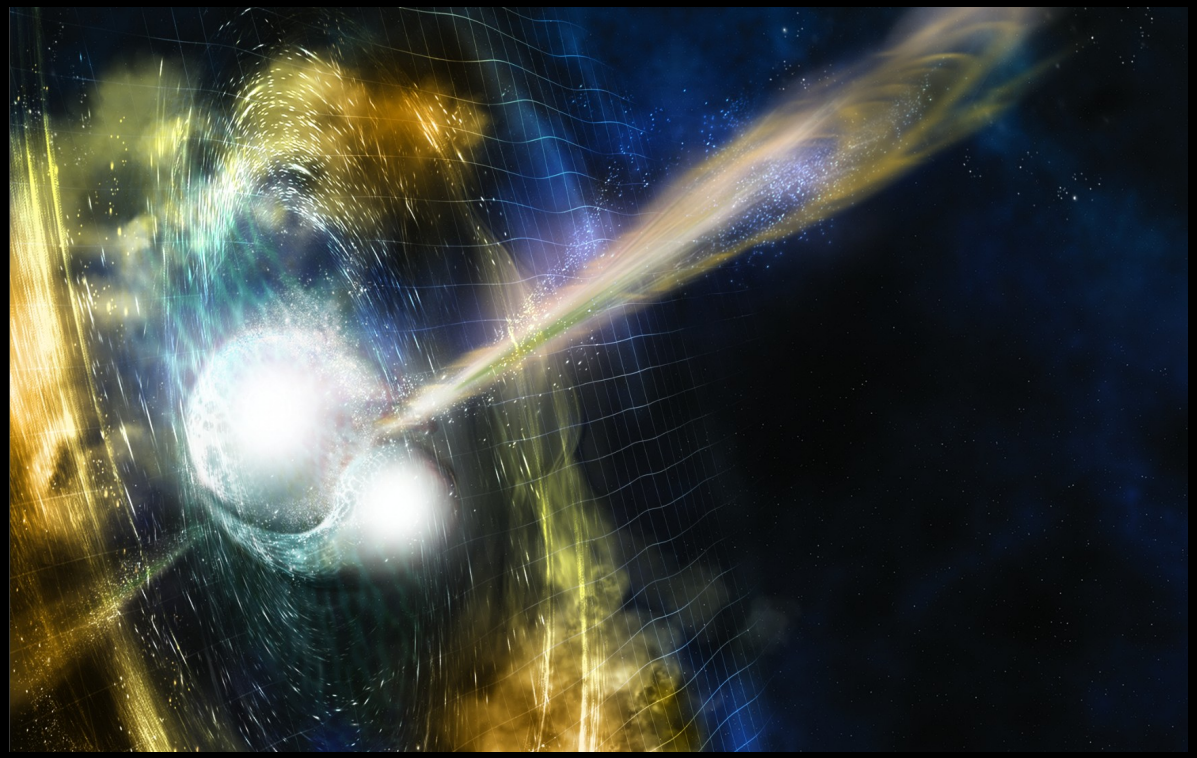
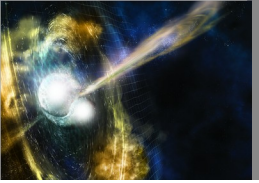
RADIO OBSERVATIONS OF GW170817: PROBING THE STRUCTURE OF RELATIVISTIC JETS



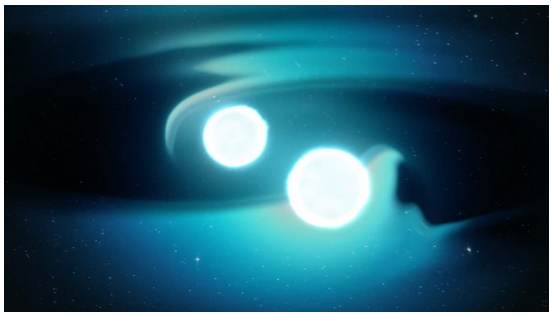
Kate D. Alexander

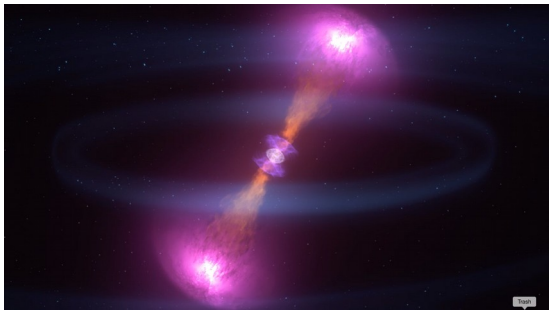
Einstein Symposium

October 2, 2018

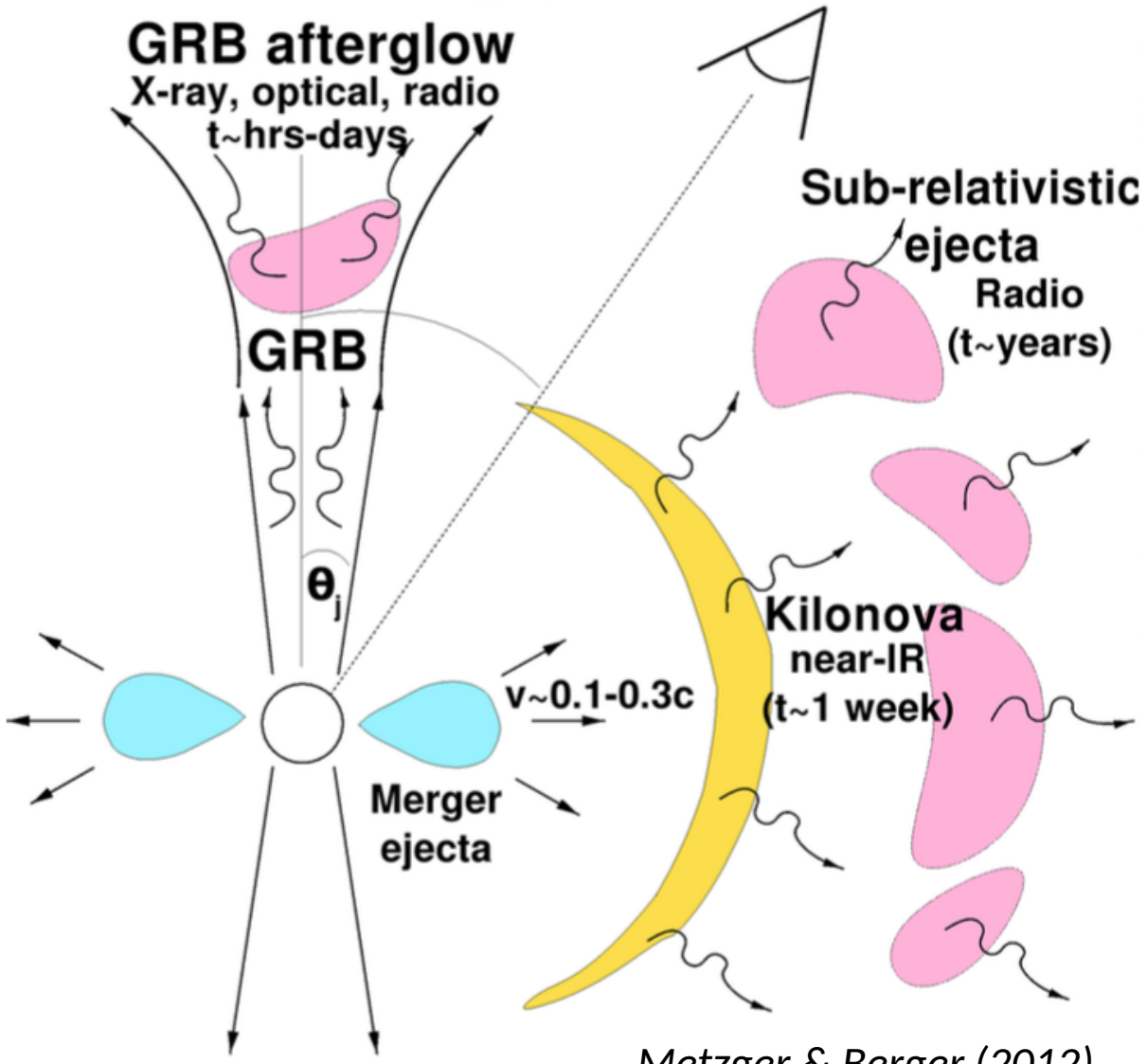


Portrait of a BNS Merger





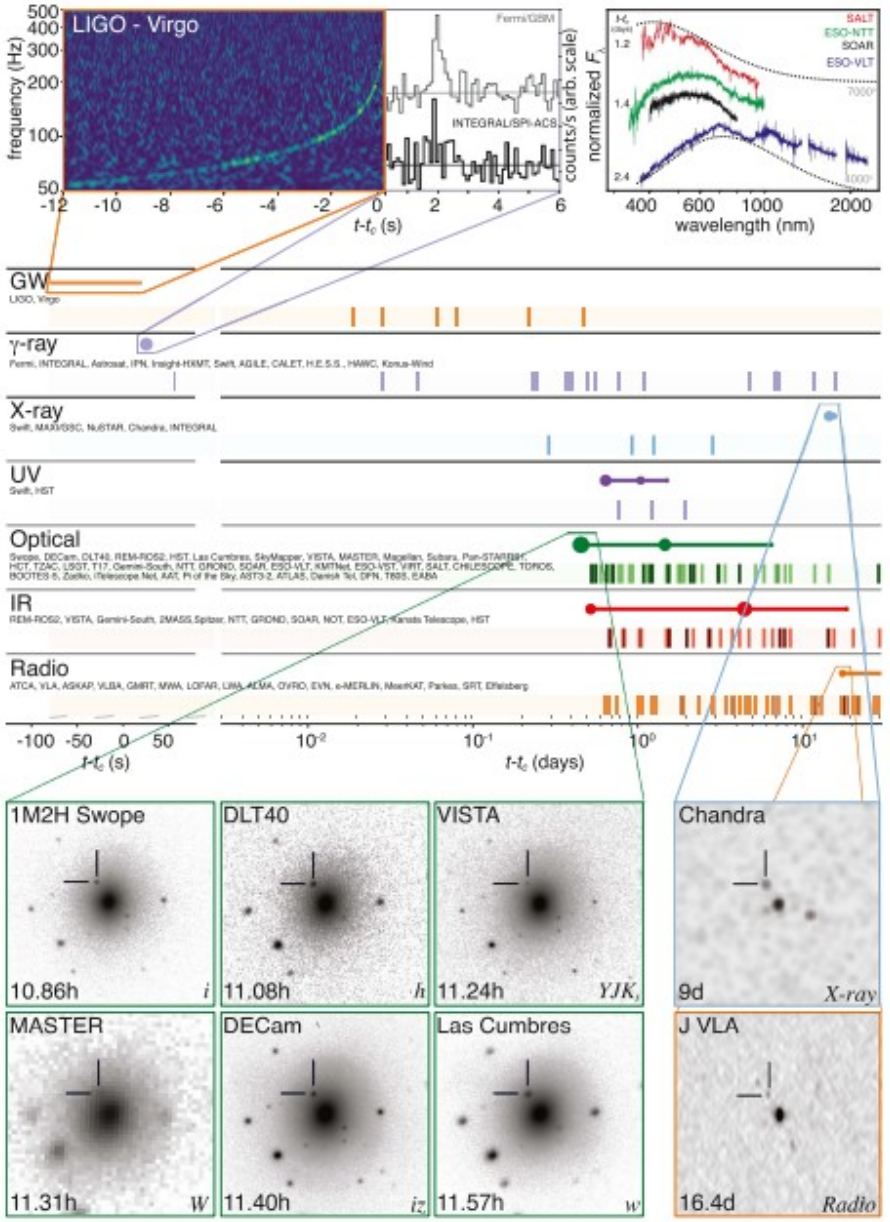
NASA



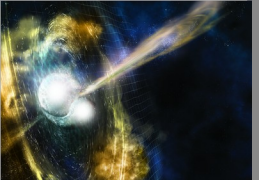
Metzger & Berger (2012)

GW170817: Hitting the EM Jackpot

- GW170817 exhibited all predicted EM counterparts for binary neutron star mergers:
  - Kilonova (optical/IR)
  - Short gamma-ray burst (SGRB)
  - **synchrotron afterglow (X-ray + radio)**

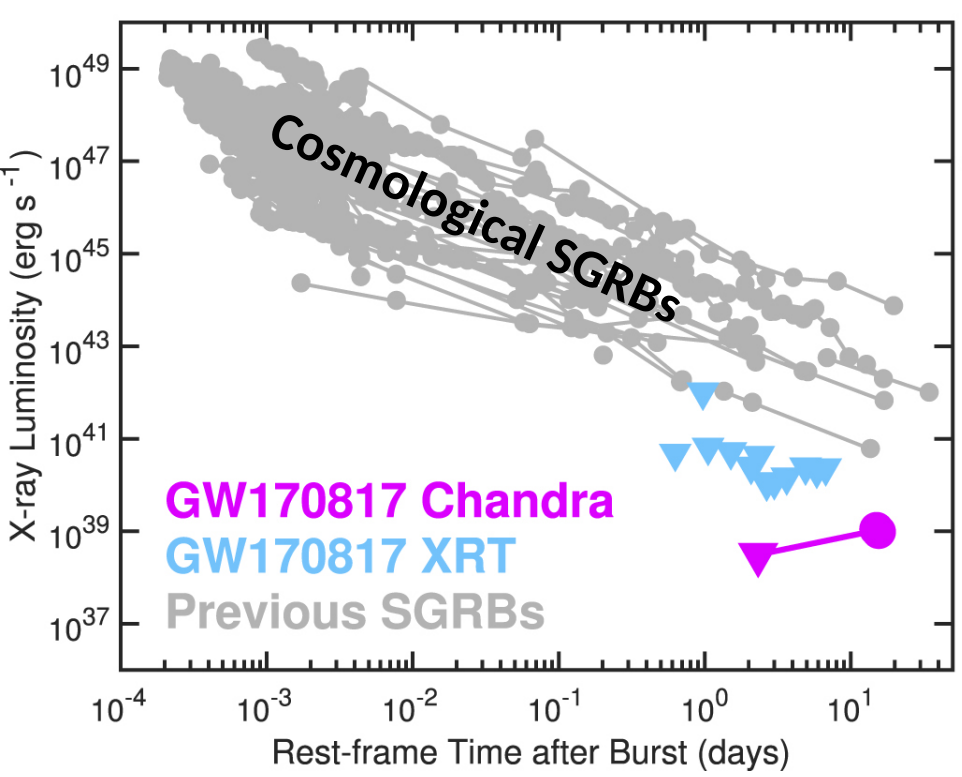


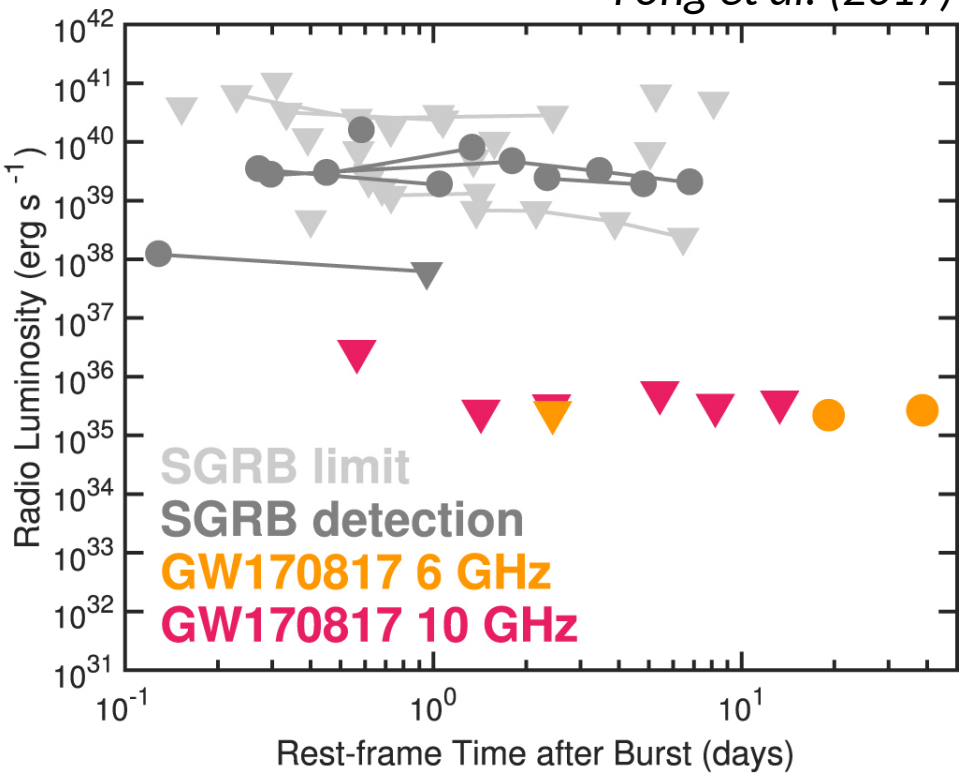
Abbott et al. (2017)



Early comparison to known SGRBs

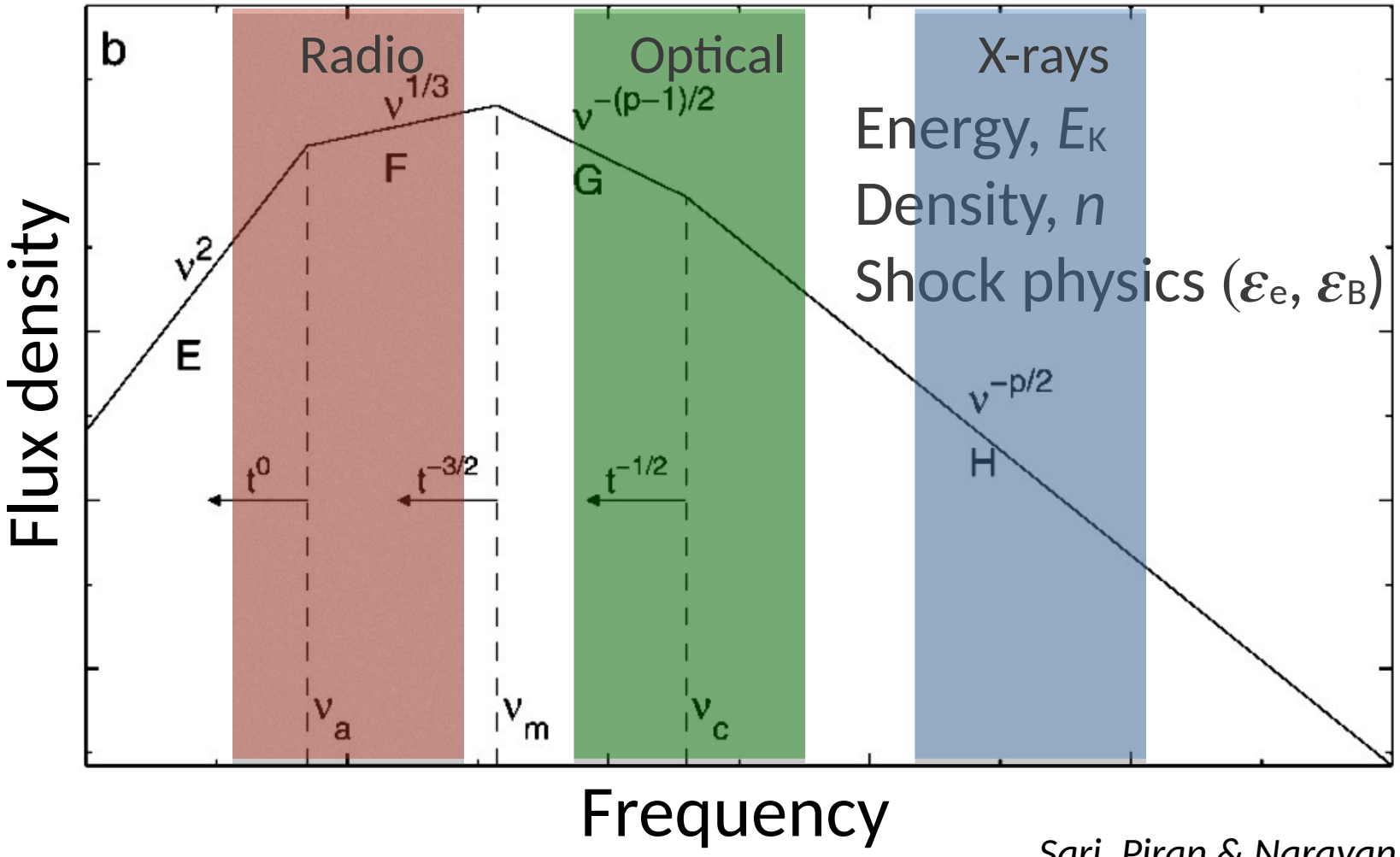
Fong et al. (2017)





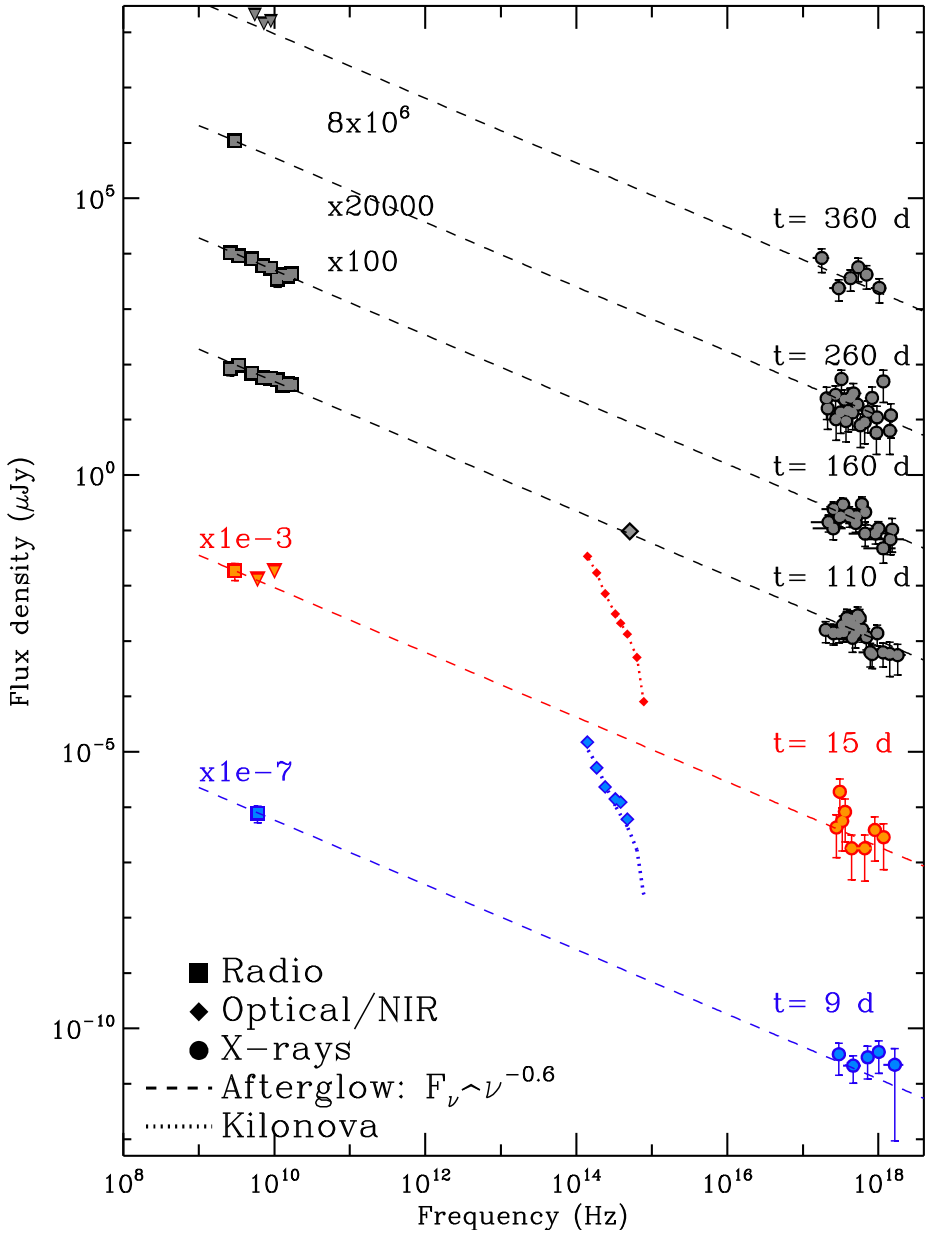
- Faint rising X-ray and radio emission first detected at 10 days and 16 days respectively: very different from cosmological SGRBs.
- A SGRB-like on-axis jet is RULED OUT.

Outflows Generate Synchrotron Emission



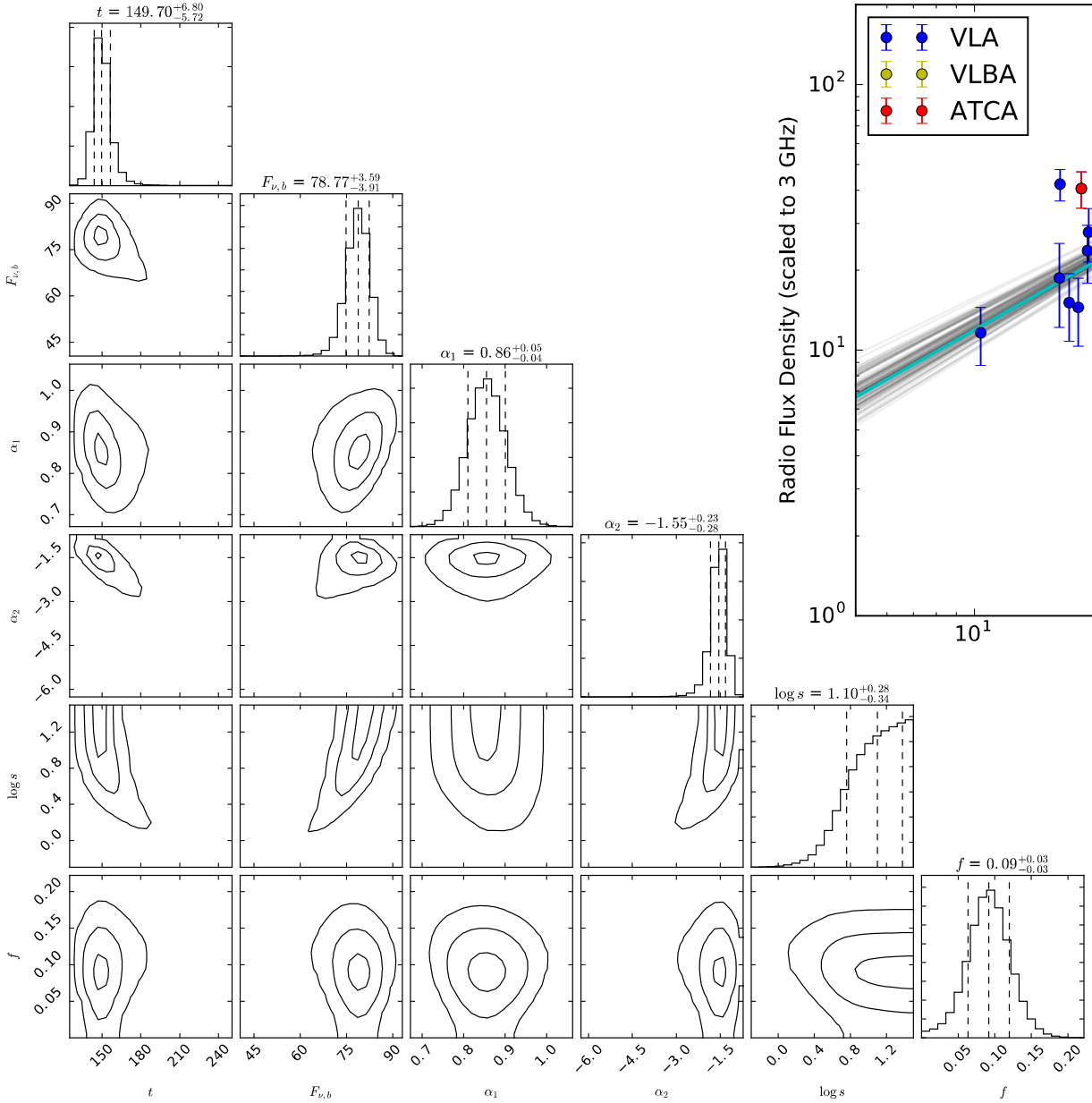
Sari, Piran & Narayan (1998)
Slide courtesy T. Laskar

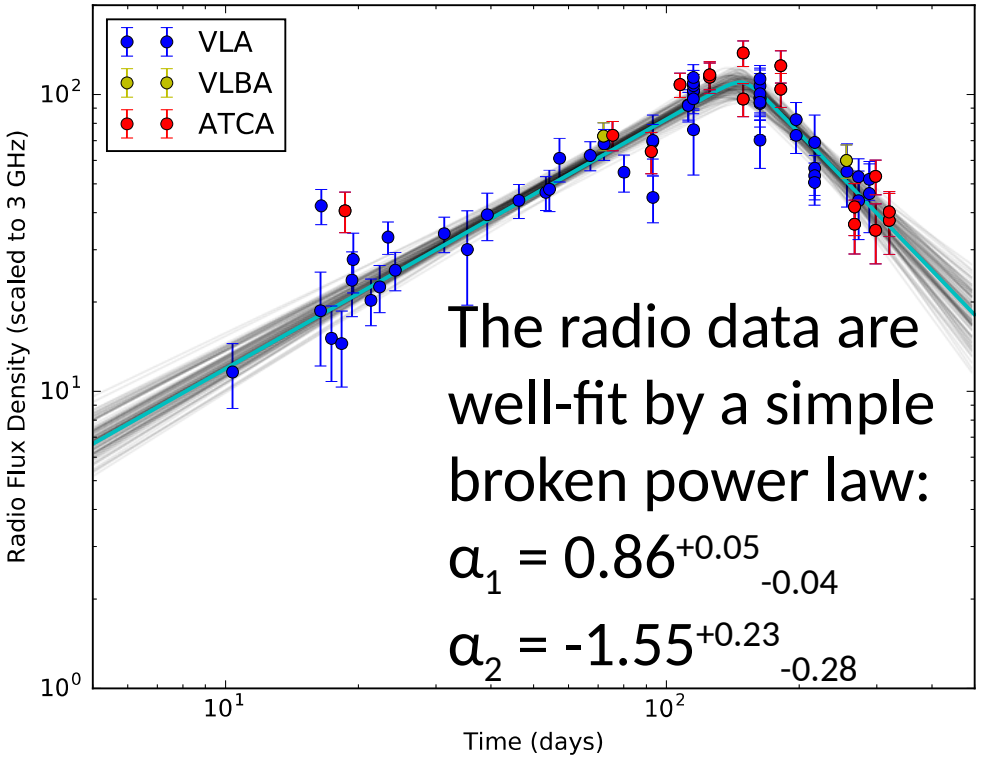
SED: A perfect power law



Plot credit: Raffaella Margutti (updated from Margutti, Alexander et al. 2018)

Light curves: Achromatic peak at t~150





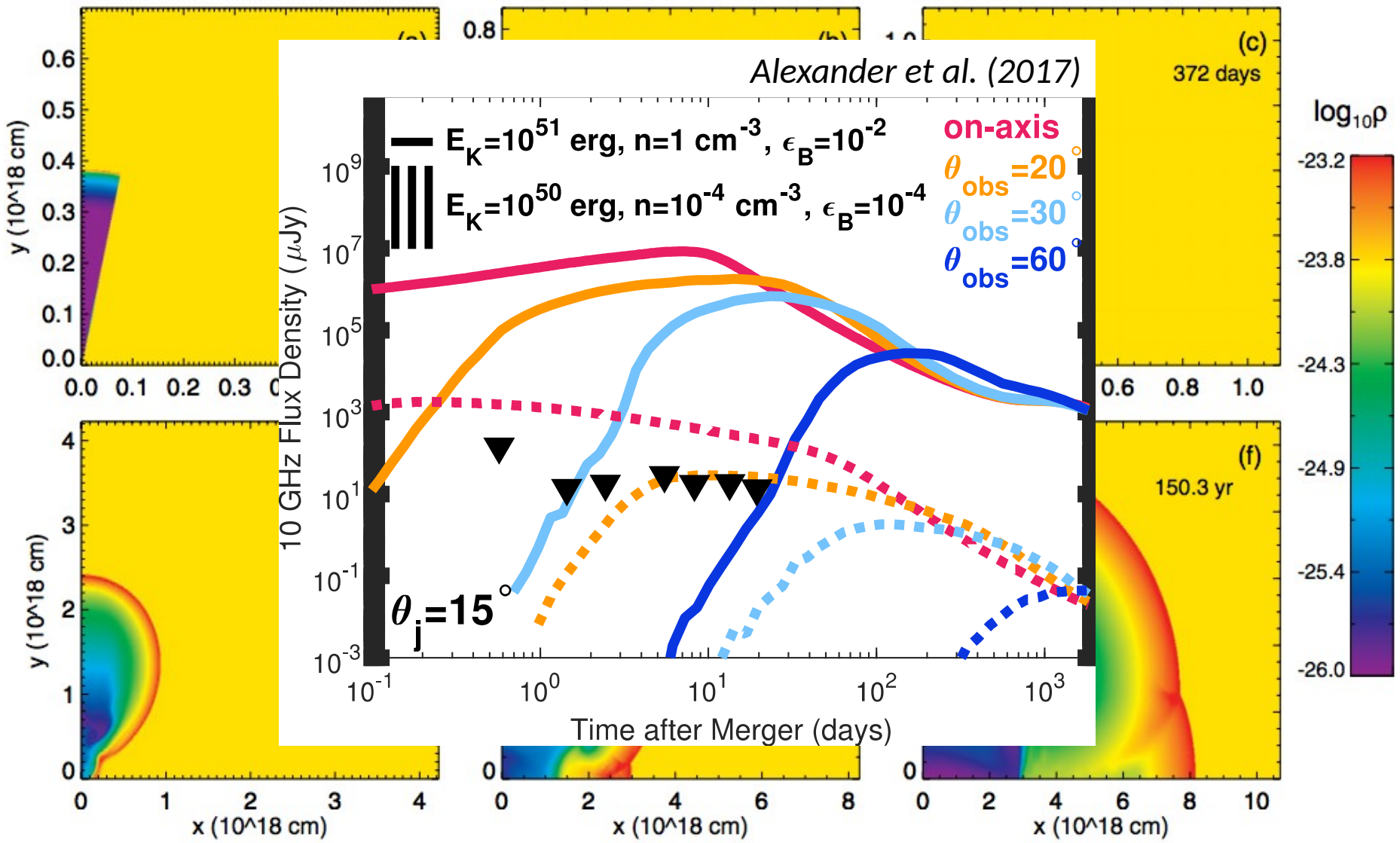
The radio data are well-fit by a simple broken power law:

$\alpha_1 = 0.86^{+0.05}_{-0.04}$

$\alpha_2 = -1.55^{+0.23}_{-0.28}$

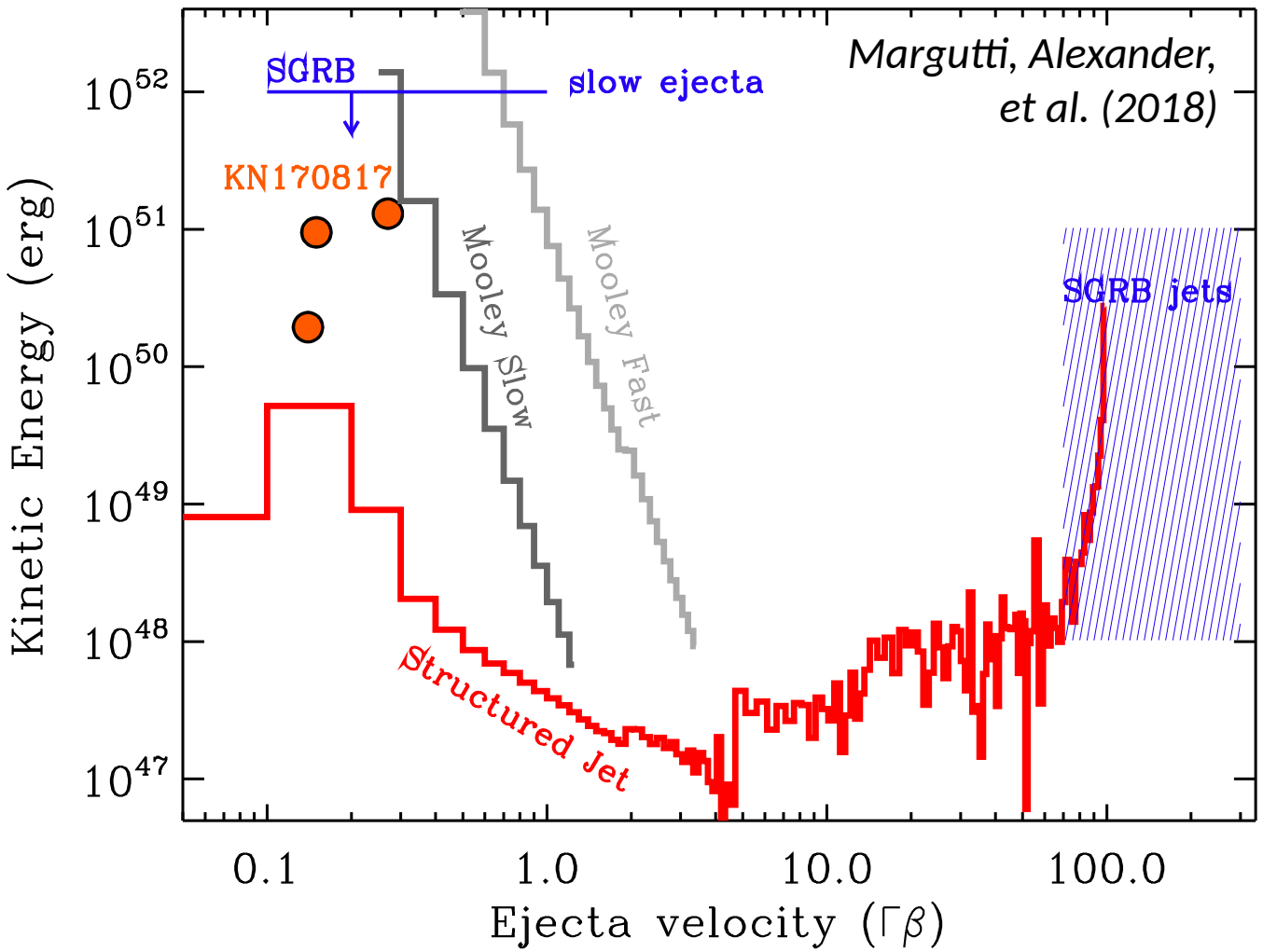
Alexander et al. (2018)

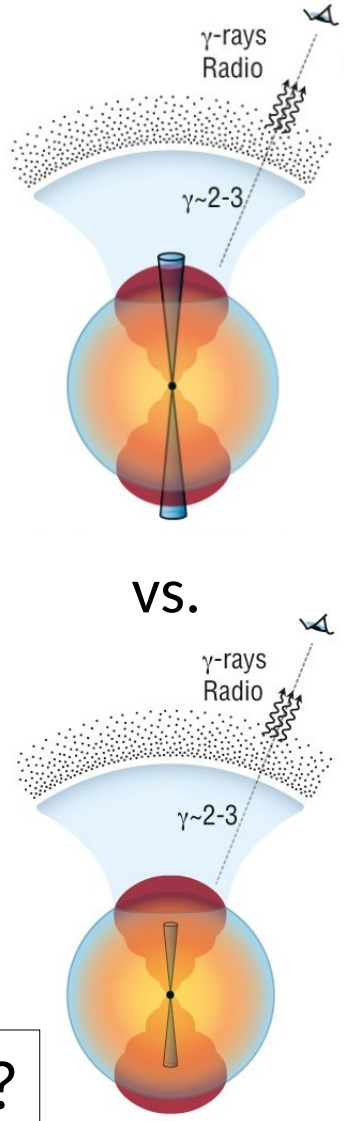
Light curves: ejecta structure, viewing angle



Zhang & MacFadyen (2009)

Real jets are not uniform



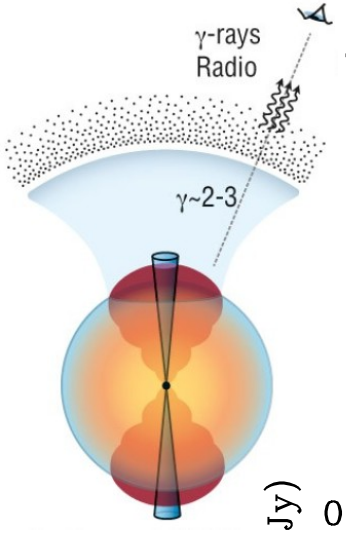


Key question: was a successful jet produced, or not?

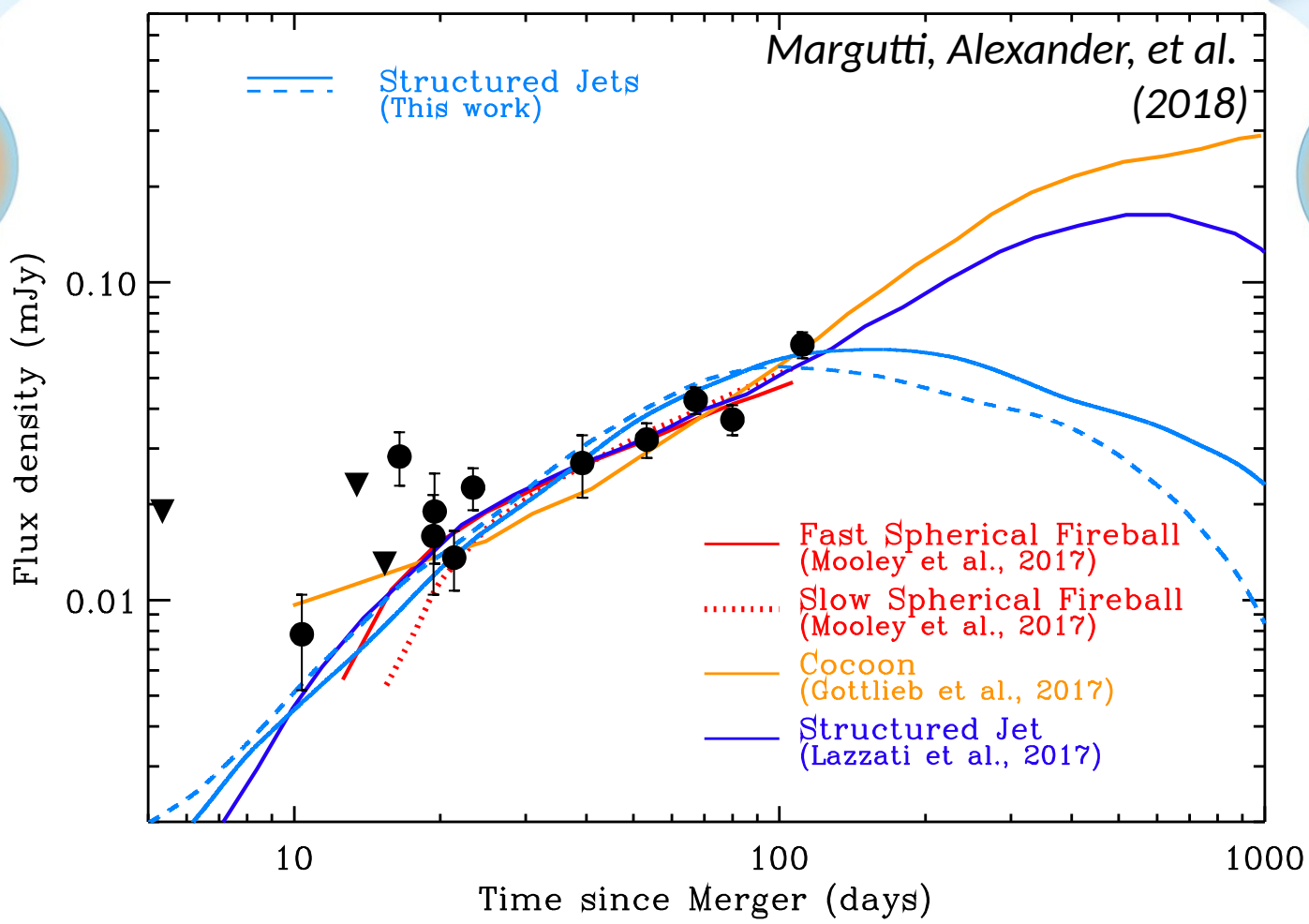
Mooley et al. (2018)

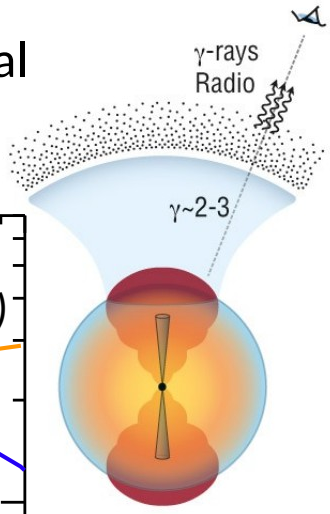
Light curves probe ejecta structure

The early emission is dominated by mildly-relativistic material (Γ ~ 3-10): either wings of a structured jet or a cocoon.



Successful structured jet model

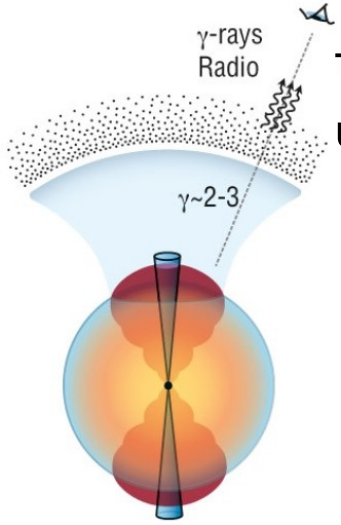




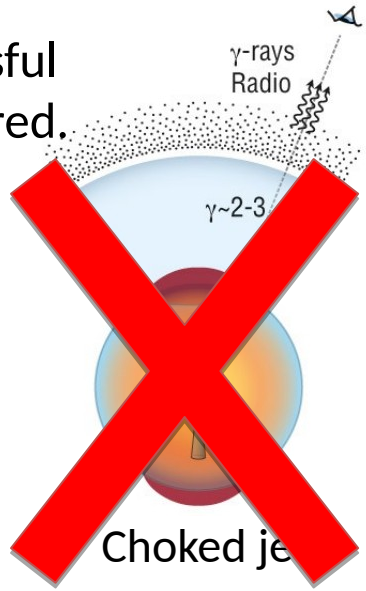
Choked jet/cocoon model

Light curves probe ejecta structure

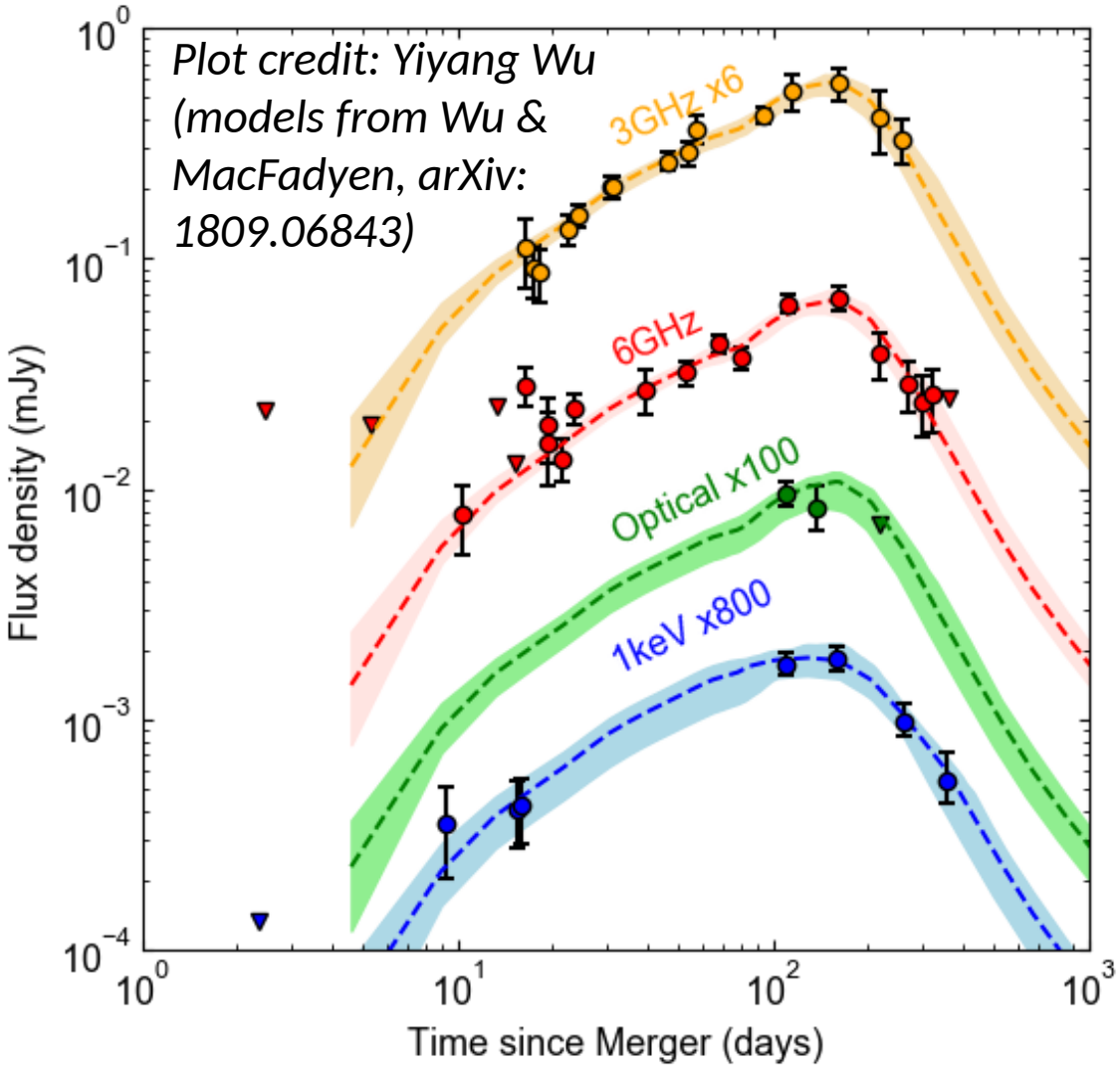
The rapid late-time decline requires a narrow (~5°), successful ultrarelativistic jet (Γ ~ 175): a choked jet/cocoon is disfavored.



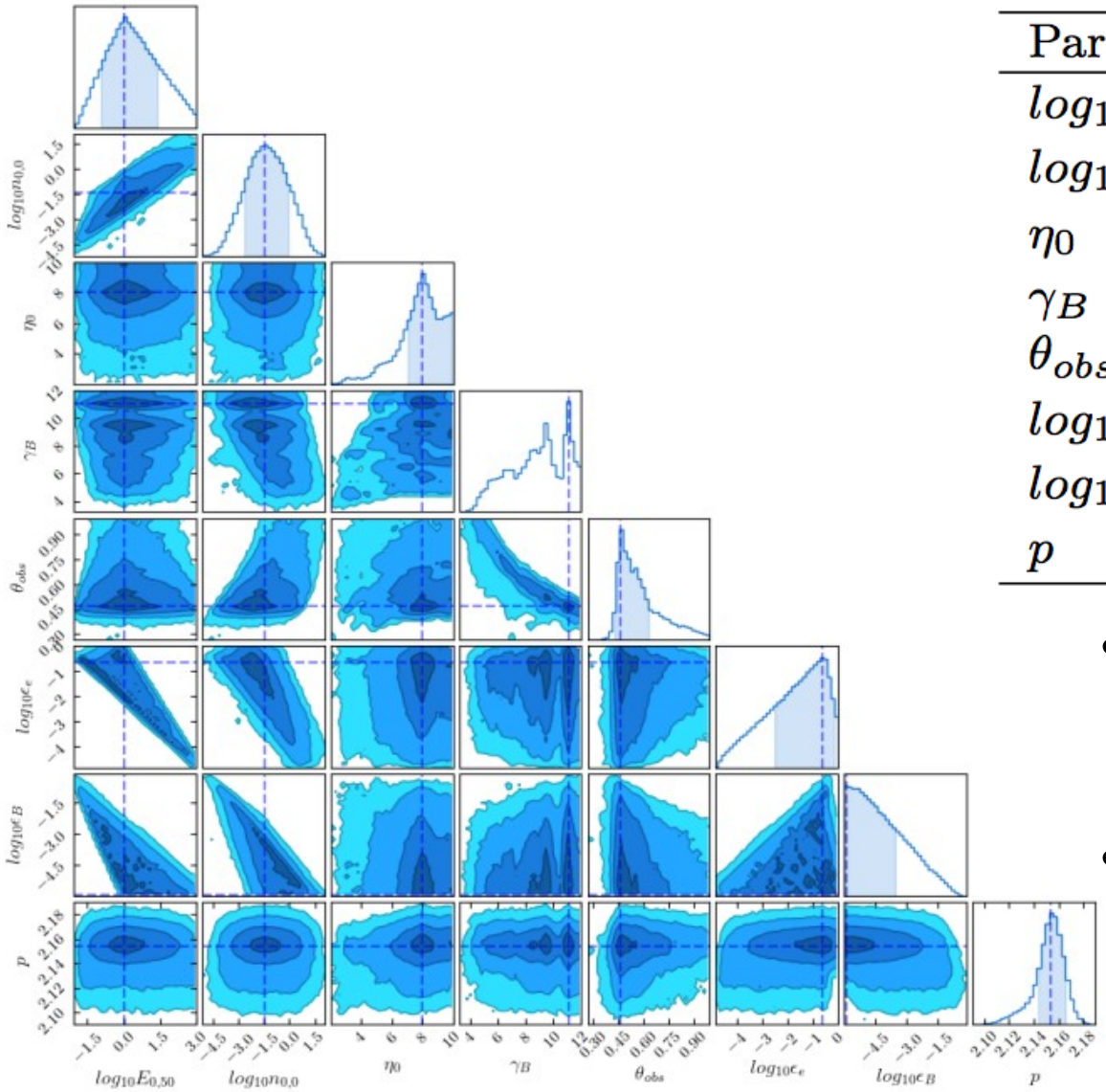
Successful structured jet model



Choked jet cocoon model



Physical properties of the jet



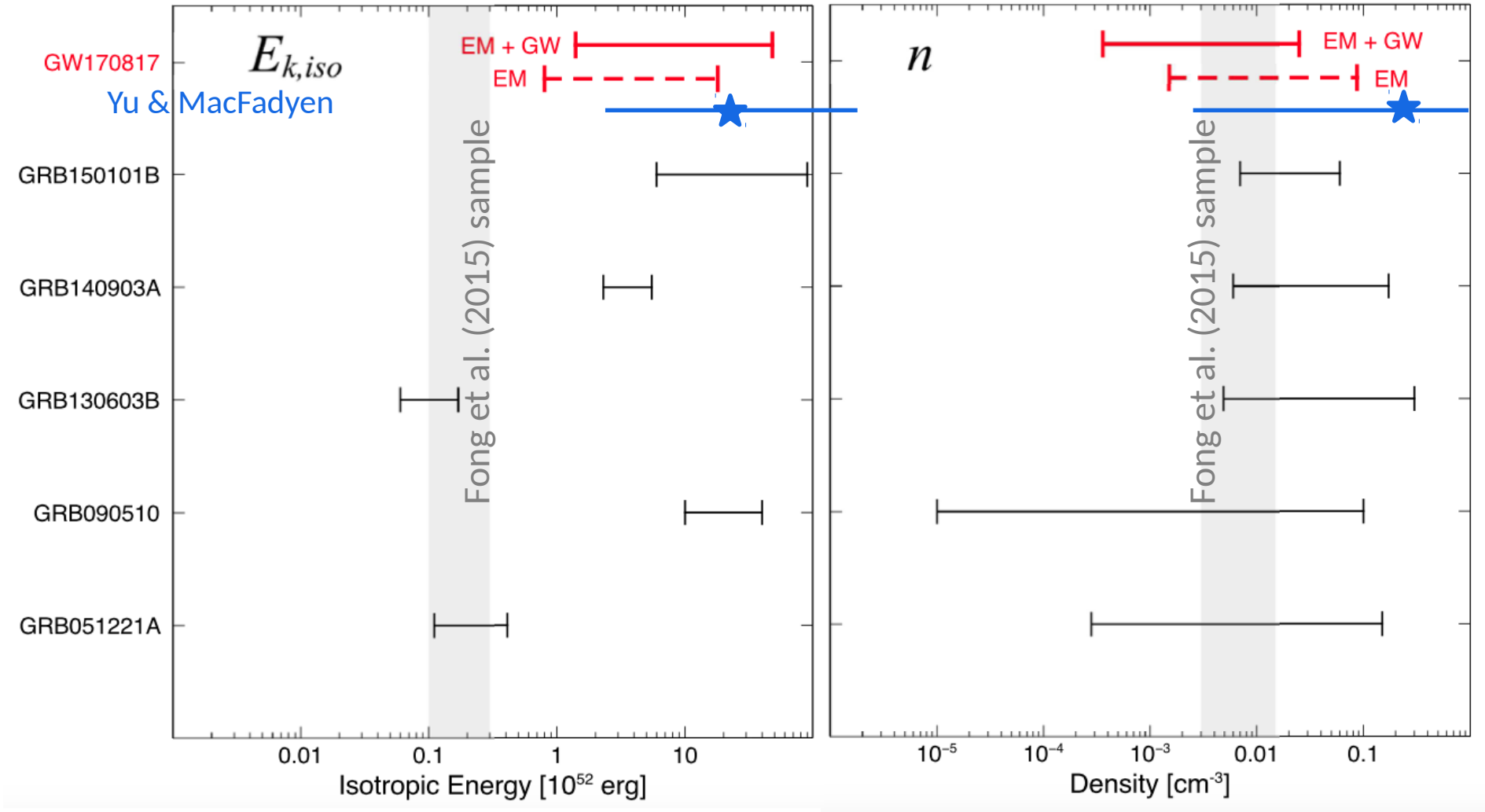
Wu & MacFadyen (arXiv:1809.06843)

Parameter	Median
$log_{10}E_{0,50}$	$0.04^{+1.36}_{-0.98}$
$log_{10}n_{0,0}$	$-1.4^{+1.4}_{-1.2}$
η_0	$8.00^{+1.88}_{-0.94}$
γ_B	11.06
θ_{obs}	$0.47^{+0.17}_{-0.05}$
$log_{10}\epsilon_e$	$-0.65^{+0.49}_{-1.87}$
$log_{10}\epsilon_B$	$-5.9^{+2.4}_{-0.0}$
p	$2.154^{+0.012}_{-0.010}$

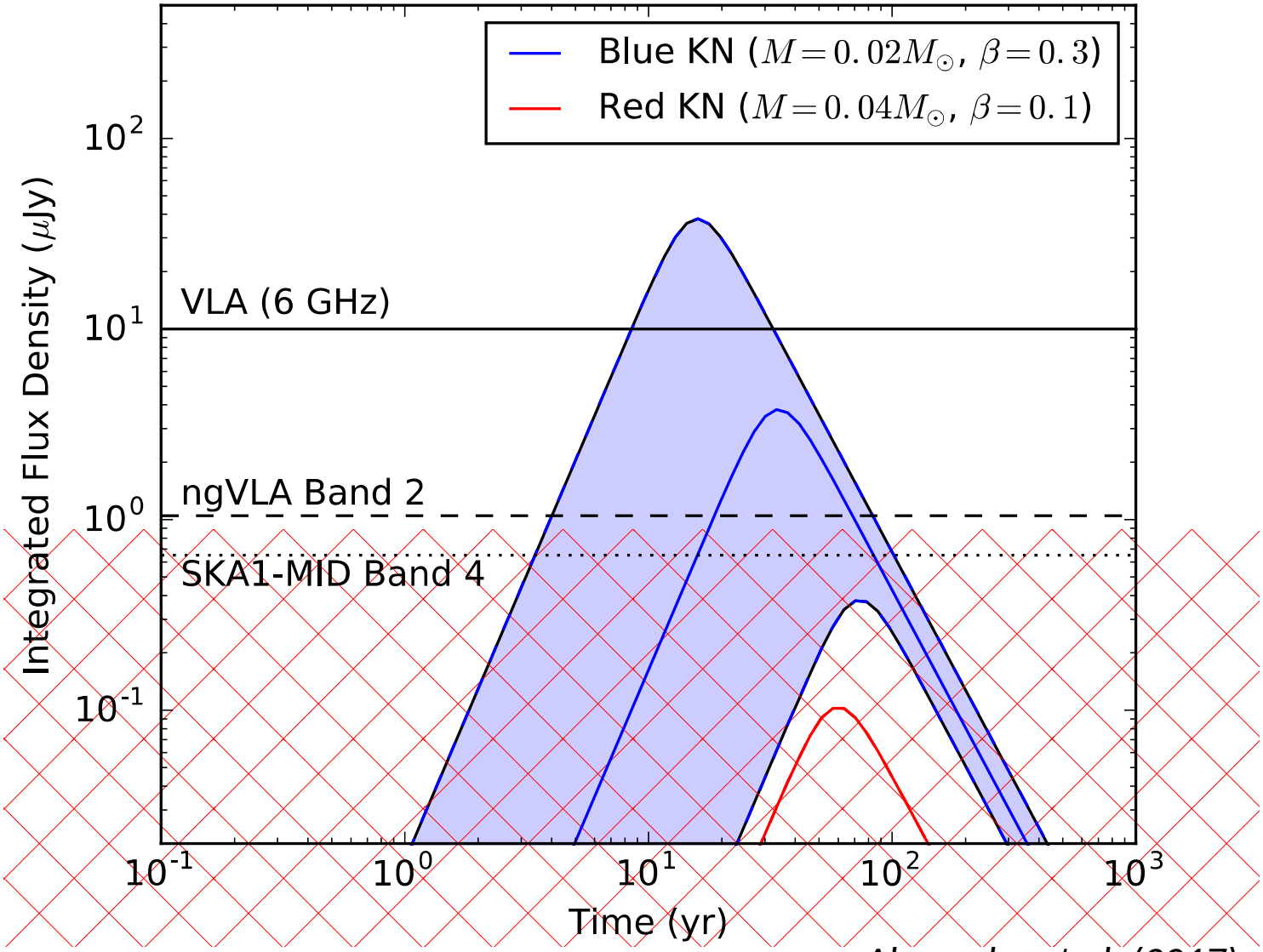
- Best-fit viewing angle ($\theta_{obs}=27^{+9}_{-3}$ deg) agrees with GW constraint
- Other physical params (energy, density, ϵ_e, ϵ_B) are degenerate/loosely constrained

Comparison to SGRBs

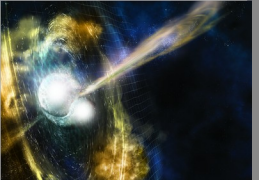
Adapted from Troja et al. (arXiv:1808.06617)



A long-term rebrightening? KN ejecta



Alexander et al. (2017)



Conclusions

- The radio and X-ray observations of GW170817 are broadly consistent with a structured **off-axis relativistic jet** similar to those seen on-axis in SGRBs
  - The jet core is narrow (5°) and the energy & circumburst density are ~consistent w/cosmological SGRB population
  - A choked jet/cocoon scenario is disfavored by new late-time observations
- More broadly-beamed, mildly-relativistic material dominates the early emission, boding well for future radio and X-ray detections of GW events
- Ongoing radio monitoring will (eventually) provide independent constraints on the kilonova ejecta