Punching through the diversity of γ-ray burst jets

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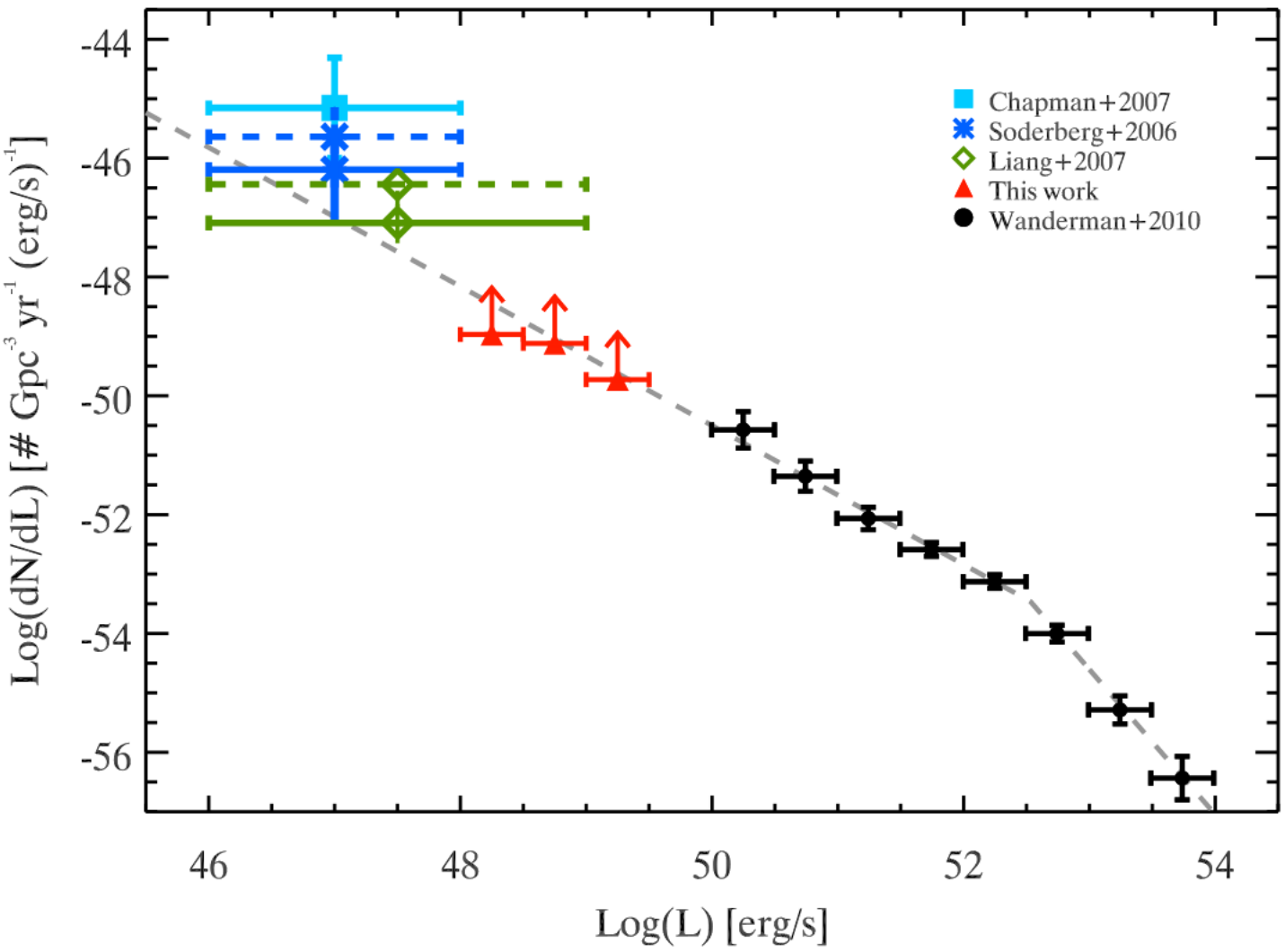
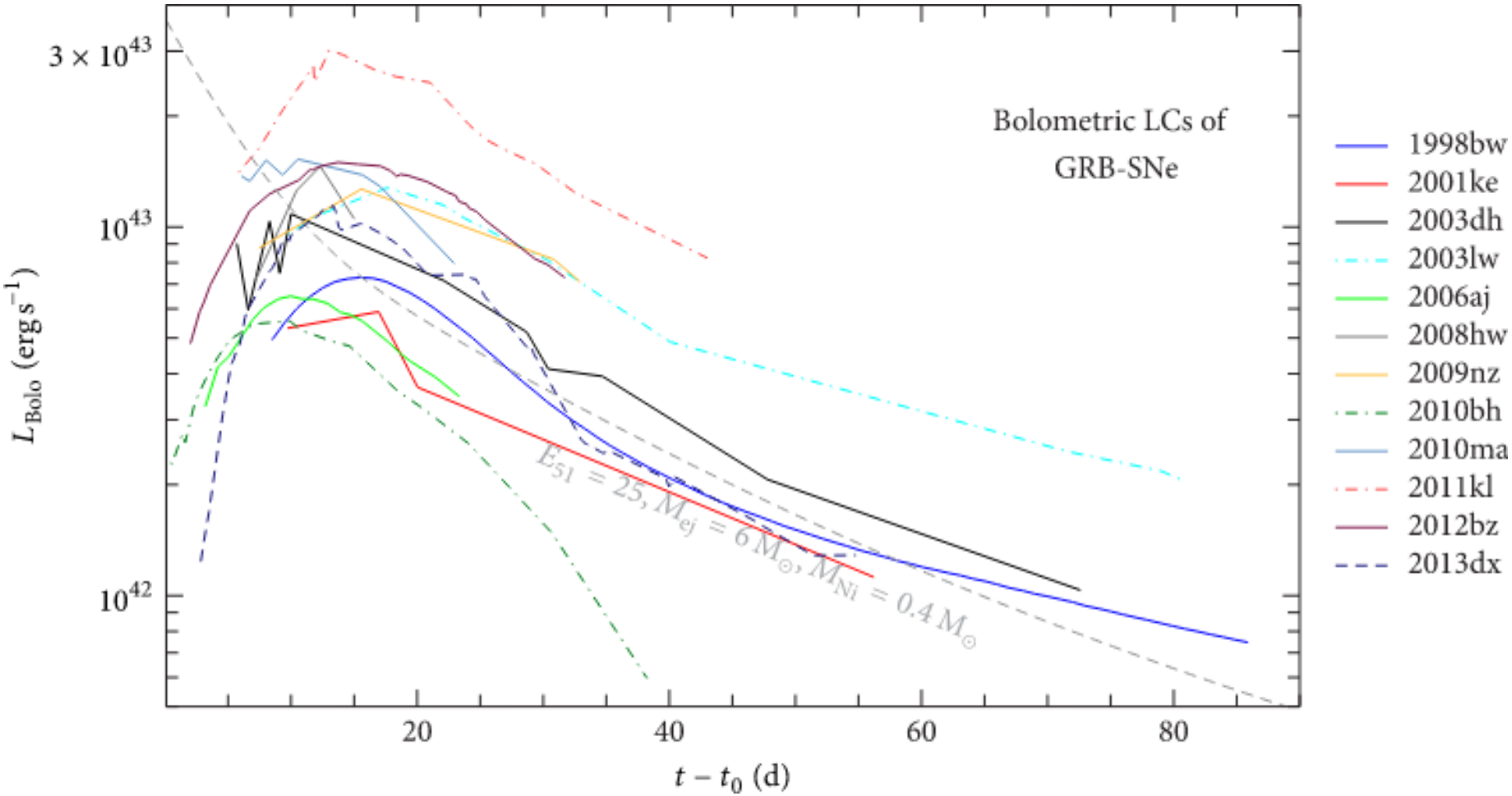
GRB luminosity distribution



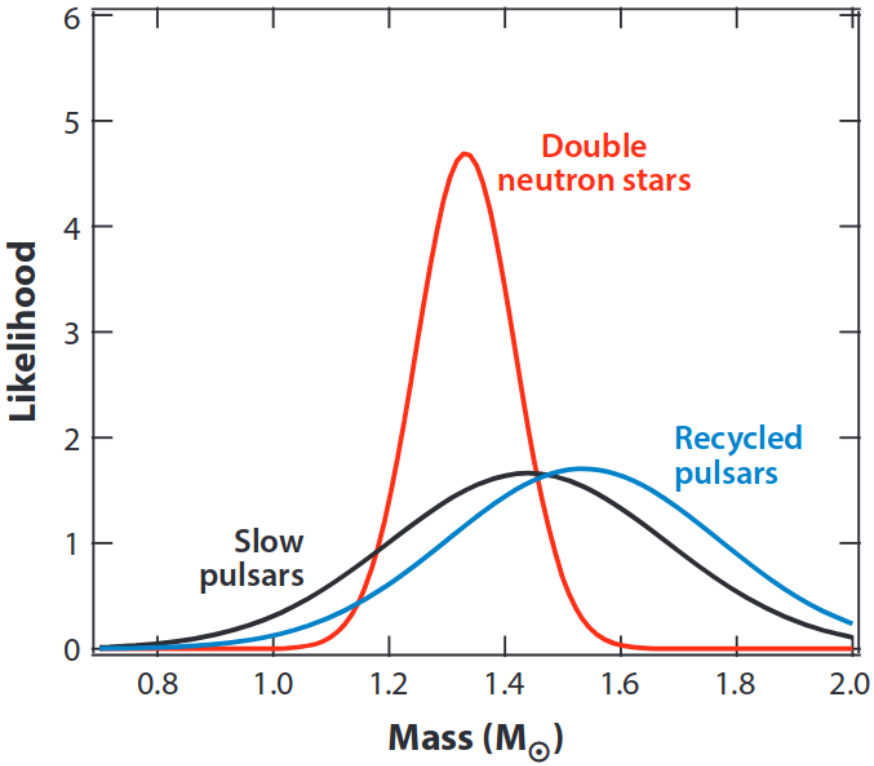
[Pescalli+15]

GRB-SNe hint at similar LGRB progenitors

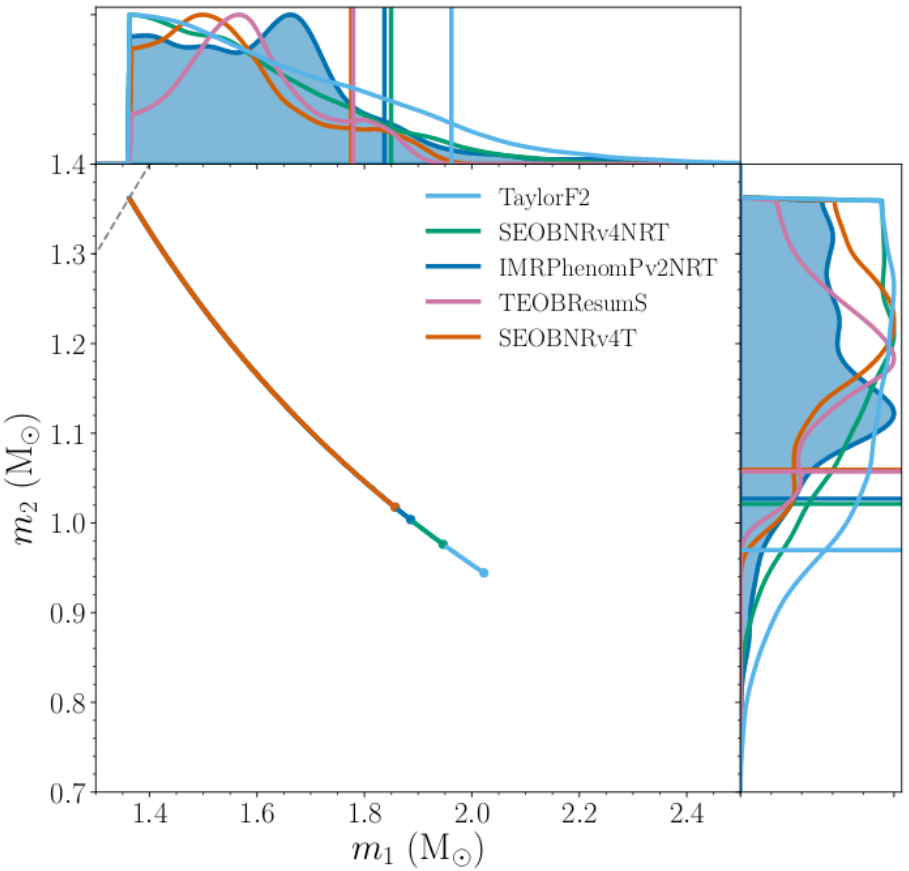


[Cano+17]

Galactic NS masses hint at similar SGRB progenitors

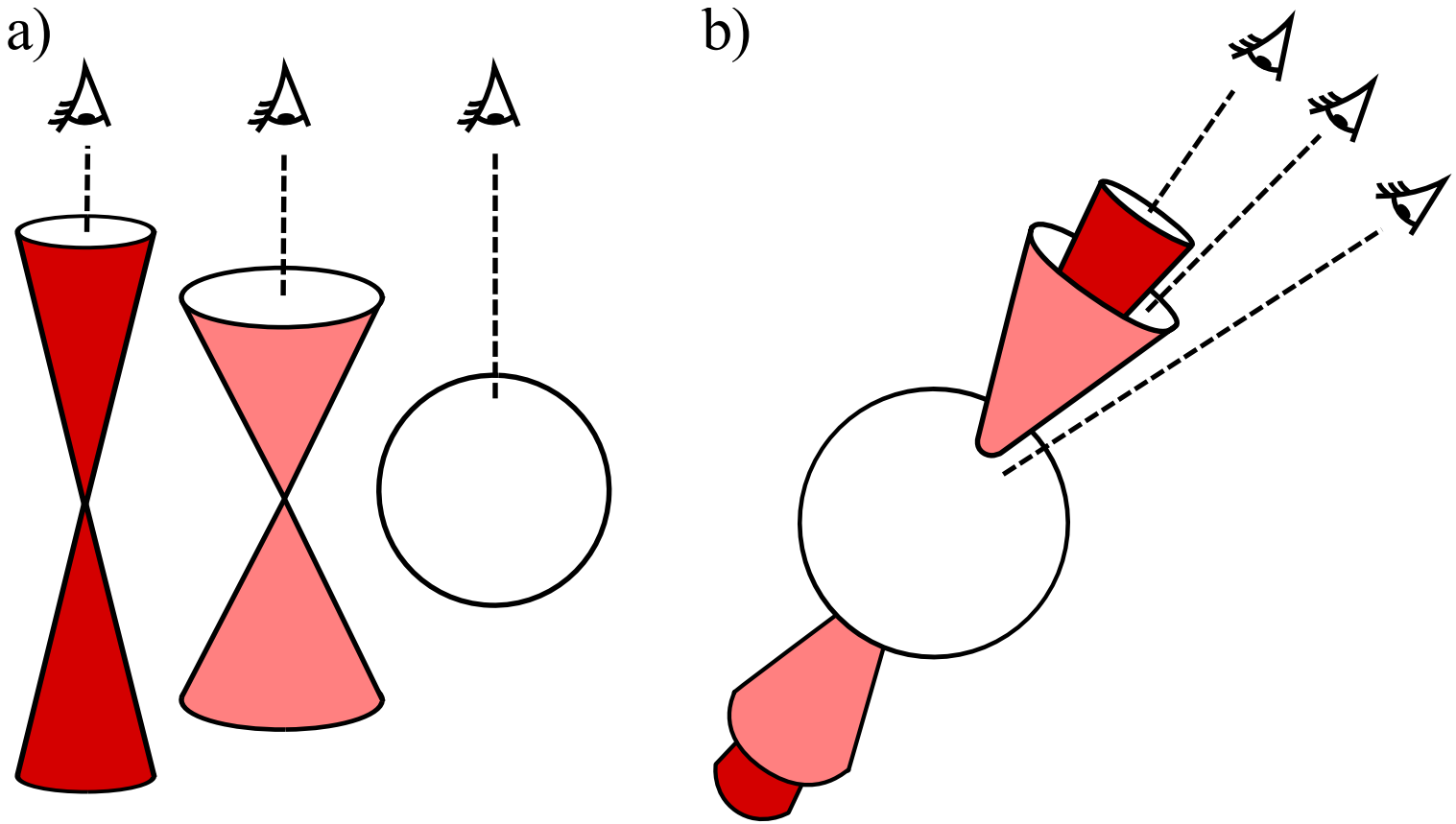


[Ozel+16]



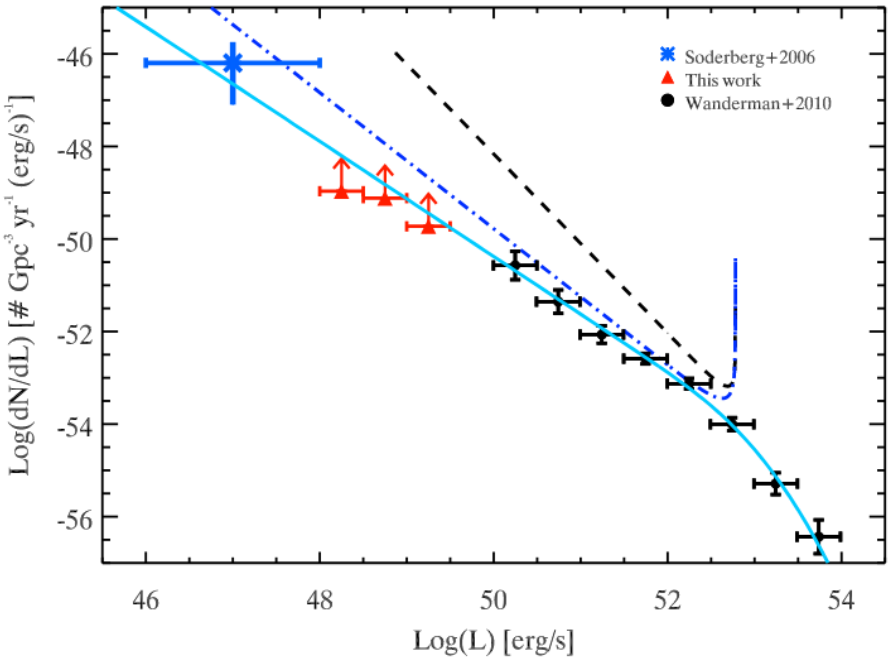
[Abbott+18]

Jet structure

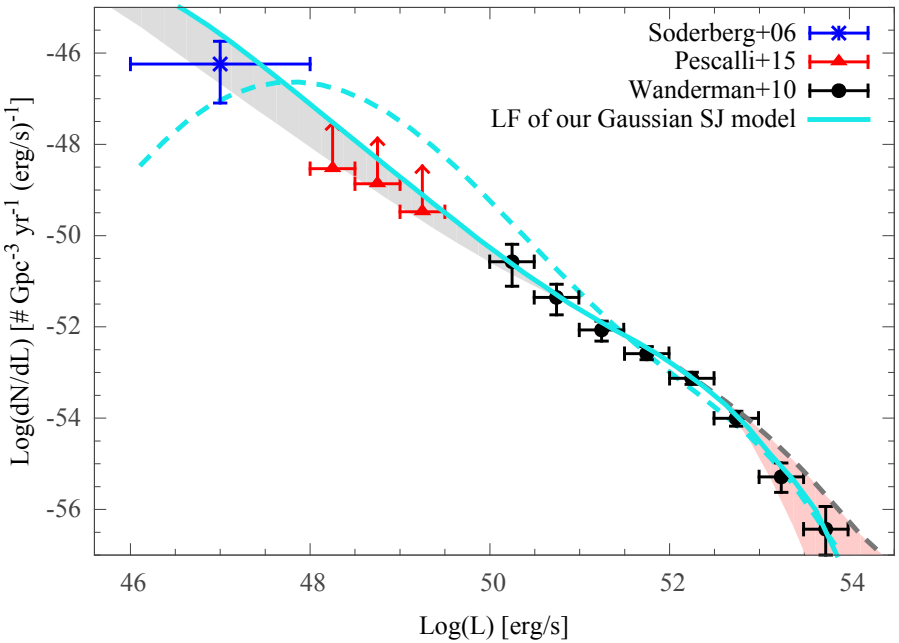


[Lipunov+01]

Different luminosity = different viewing angle?

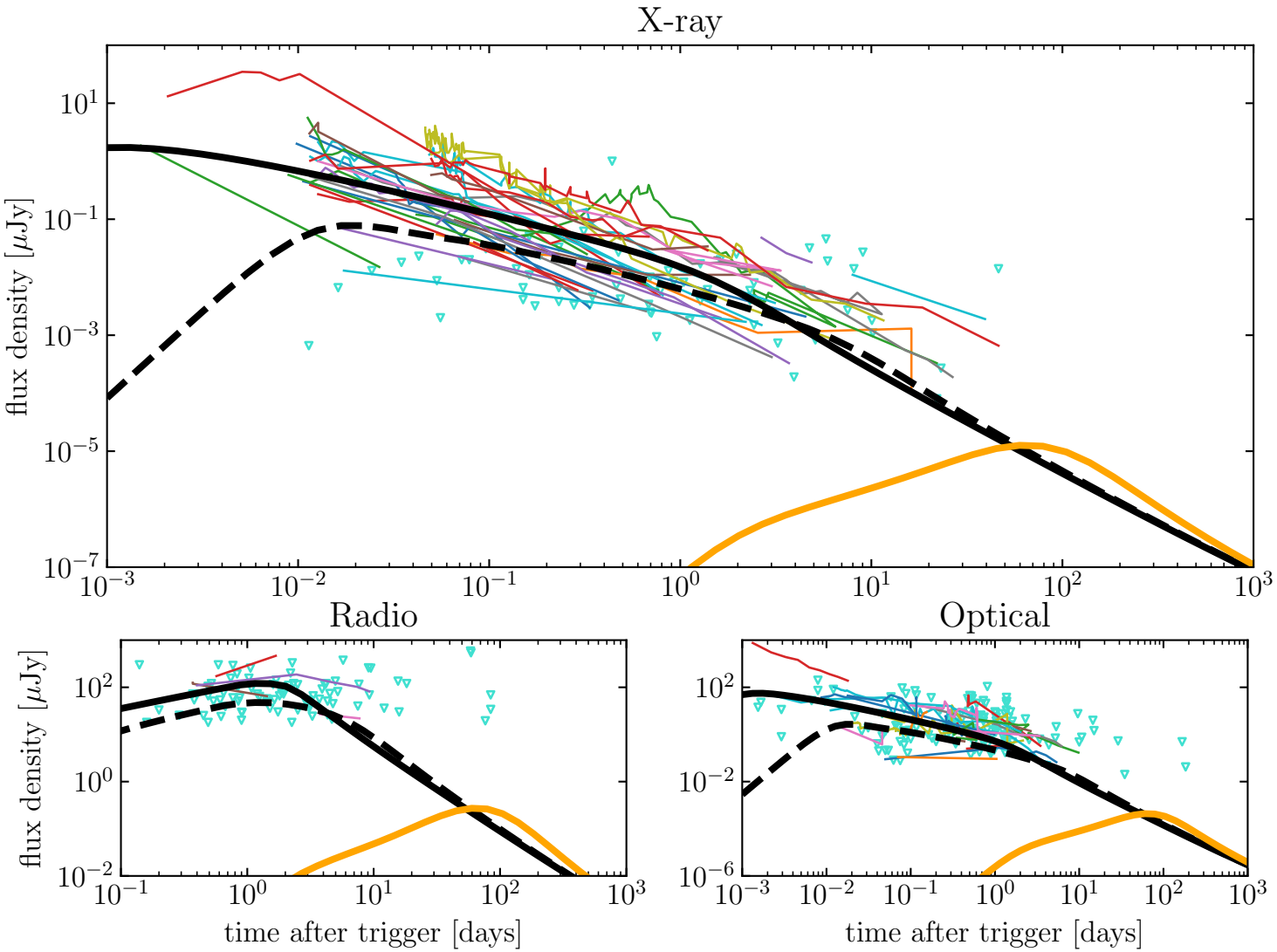


[Pescalli+15]



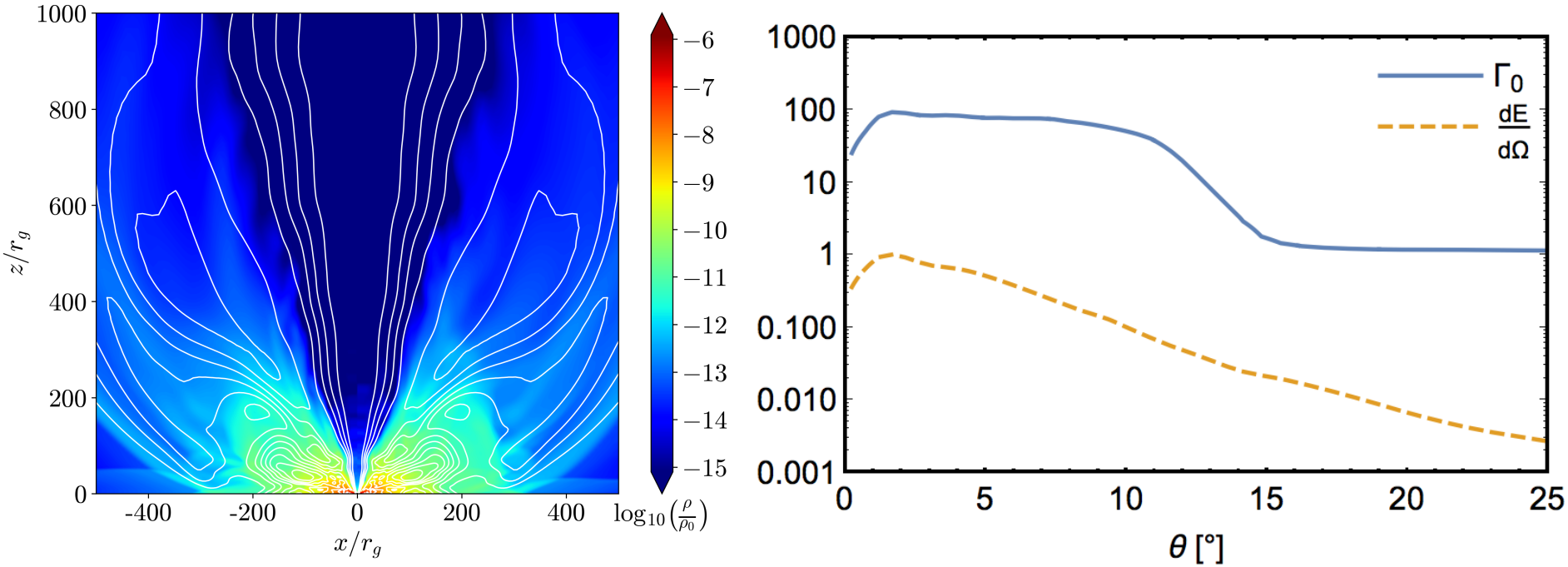
[Salafia+15]

The on-axis view of GRB 170817A



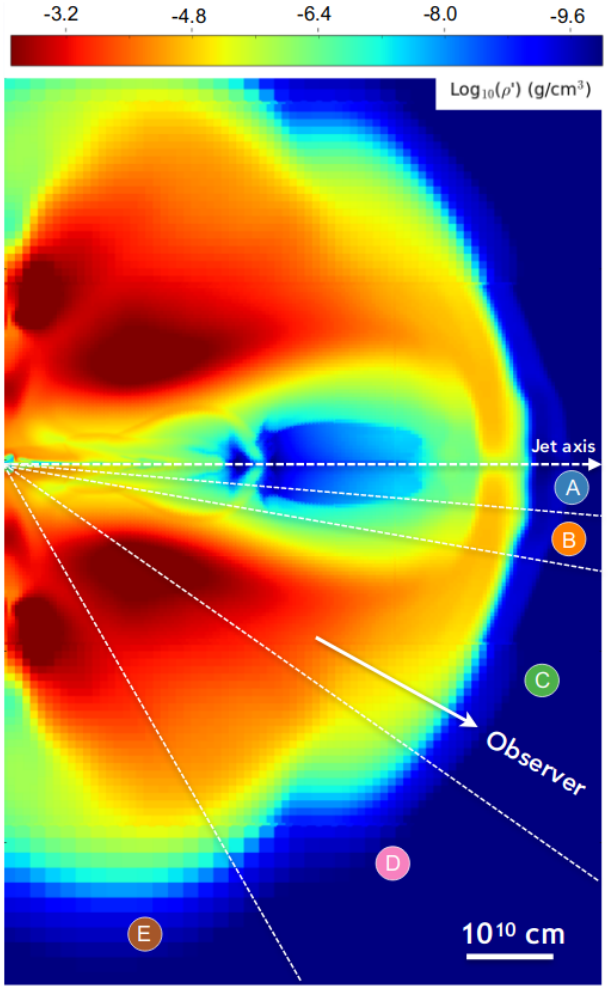
[Salafia et al. 2019]

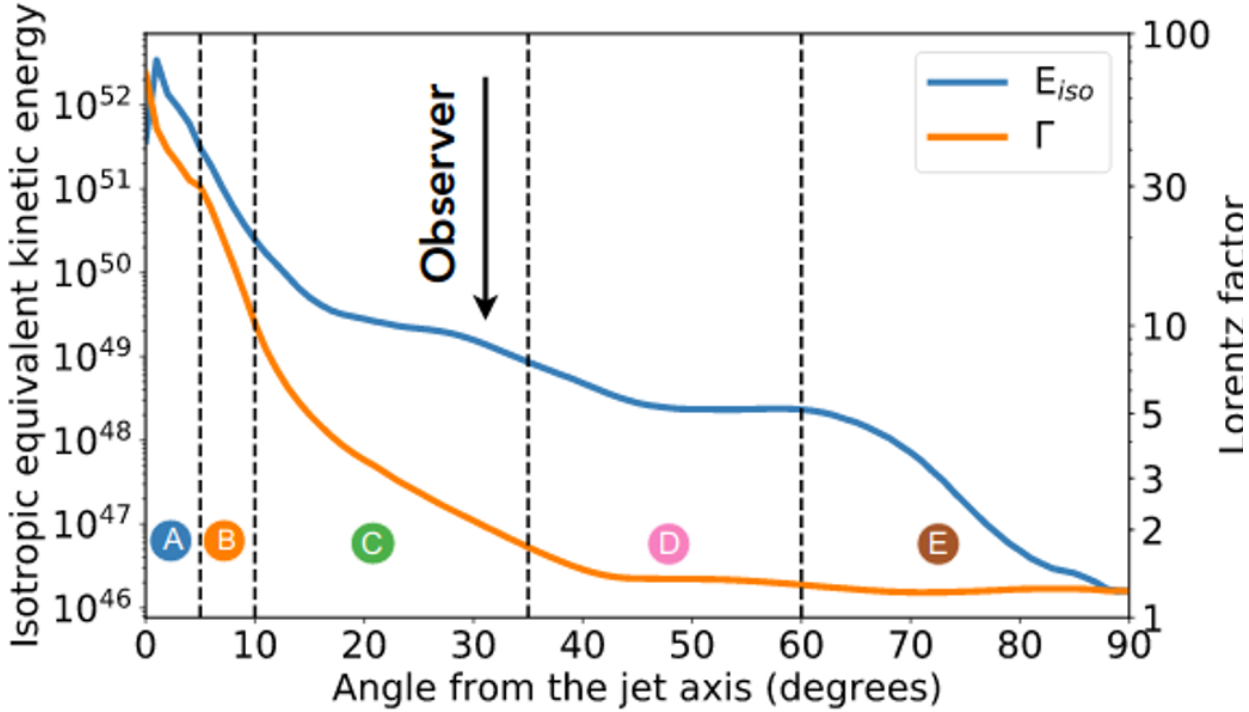
Jet structure at launch



[Kathirgamaraju+19]

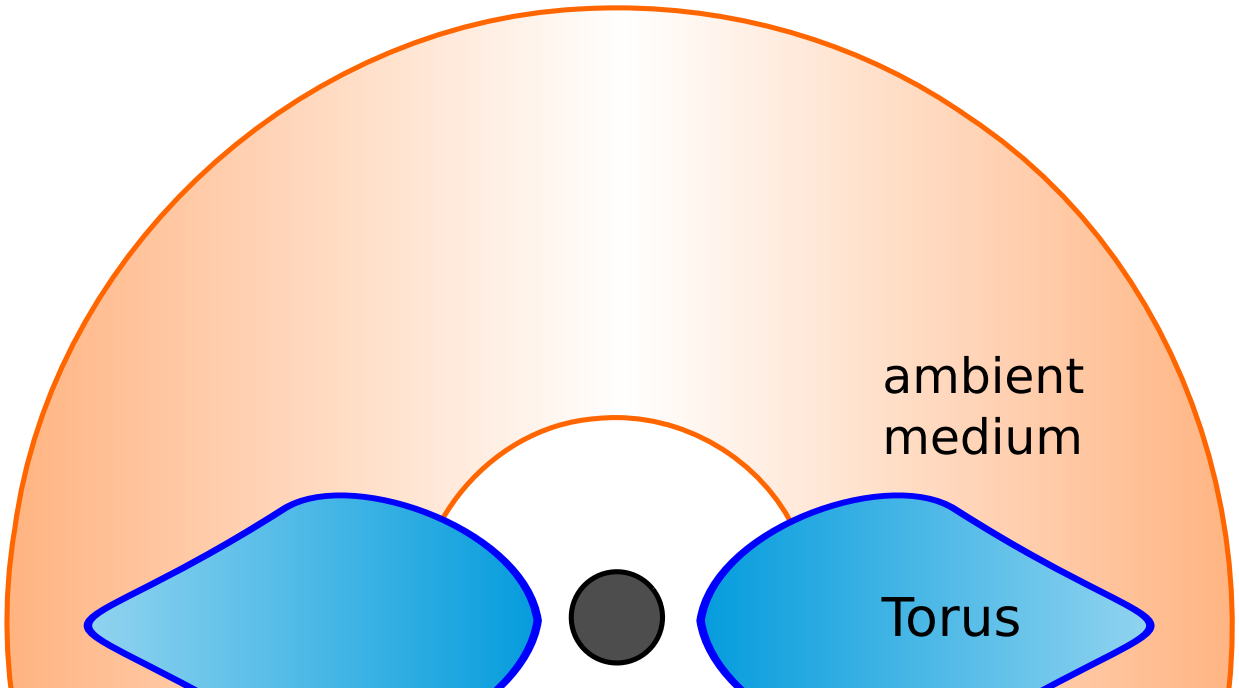
Jet structure from interaction with ambient medium



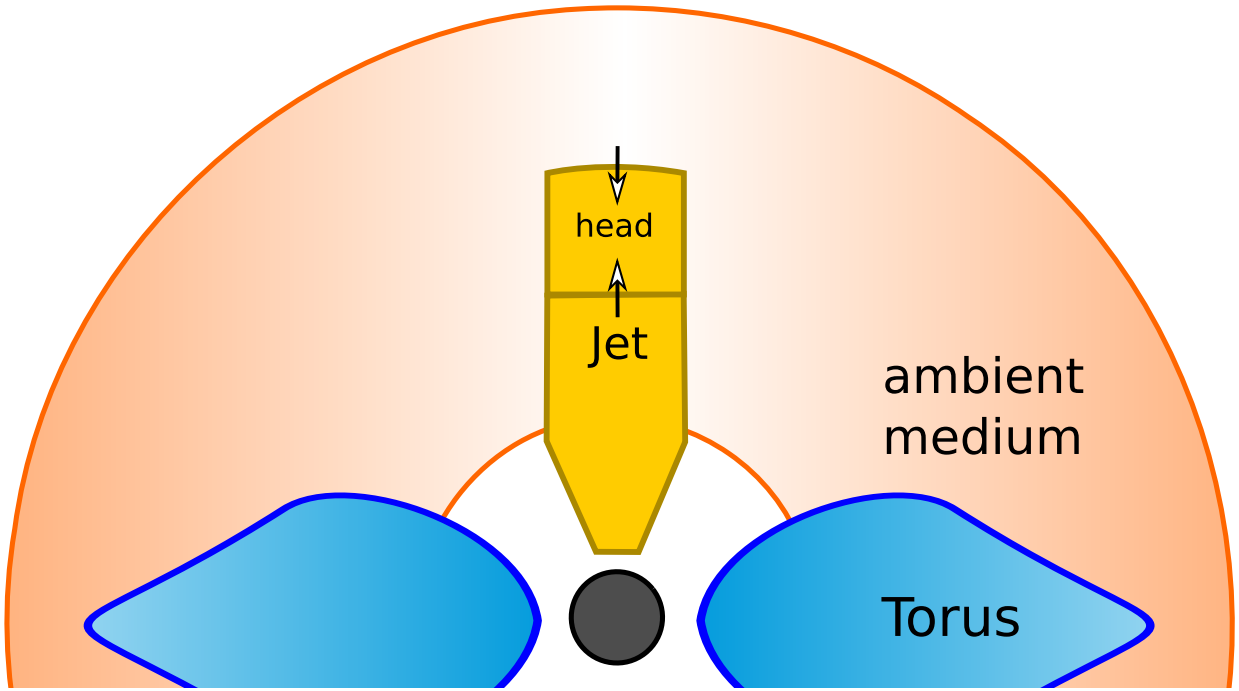


[Lazzati+18]

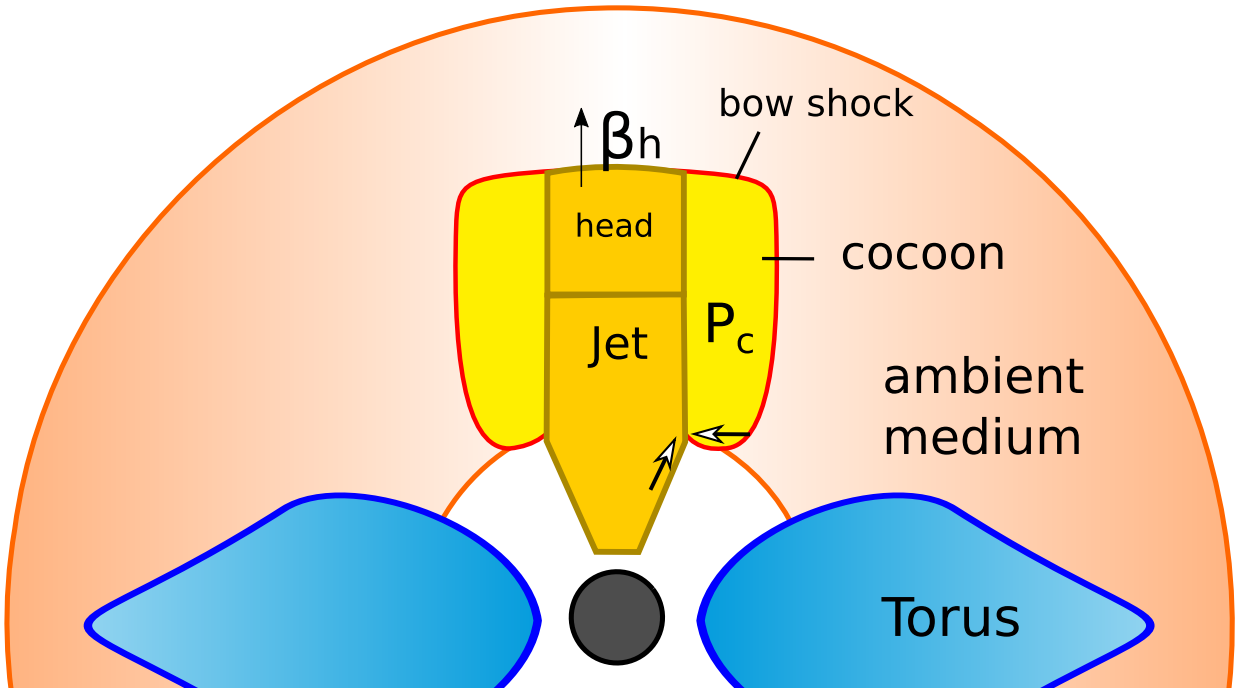
The scenario



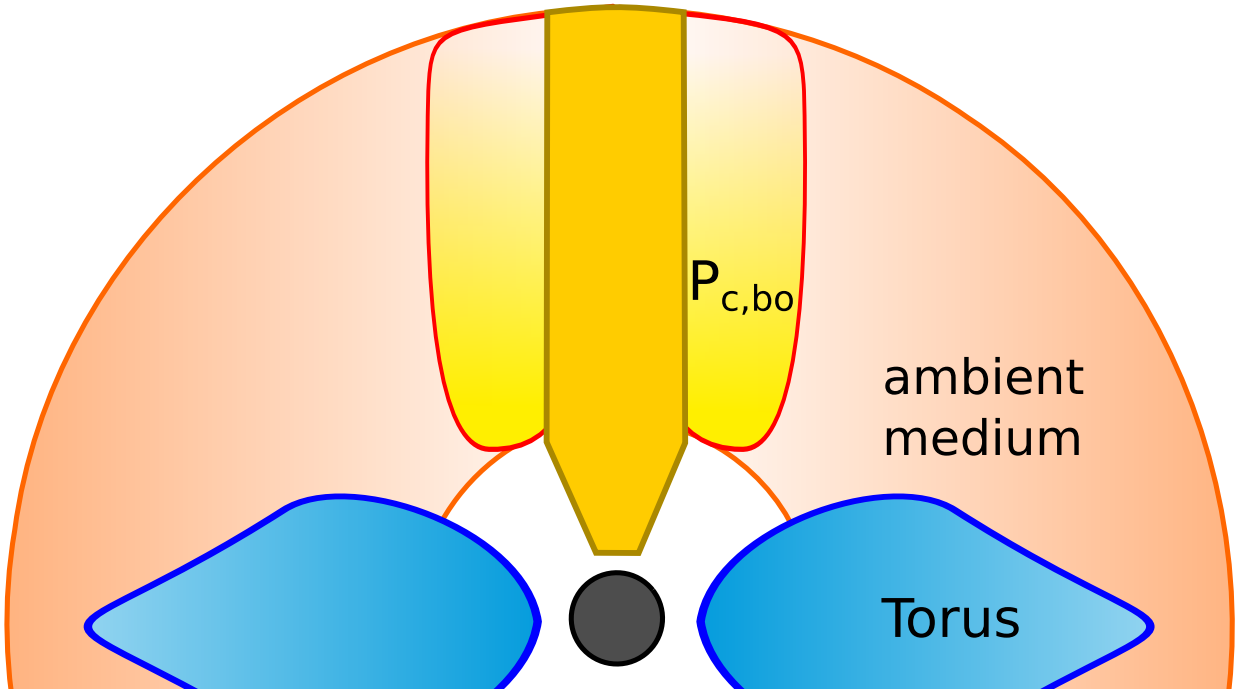
The scenario



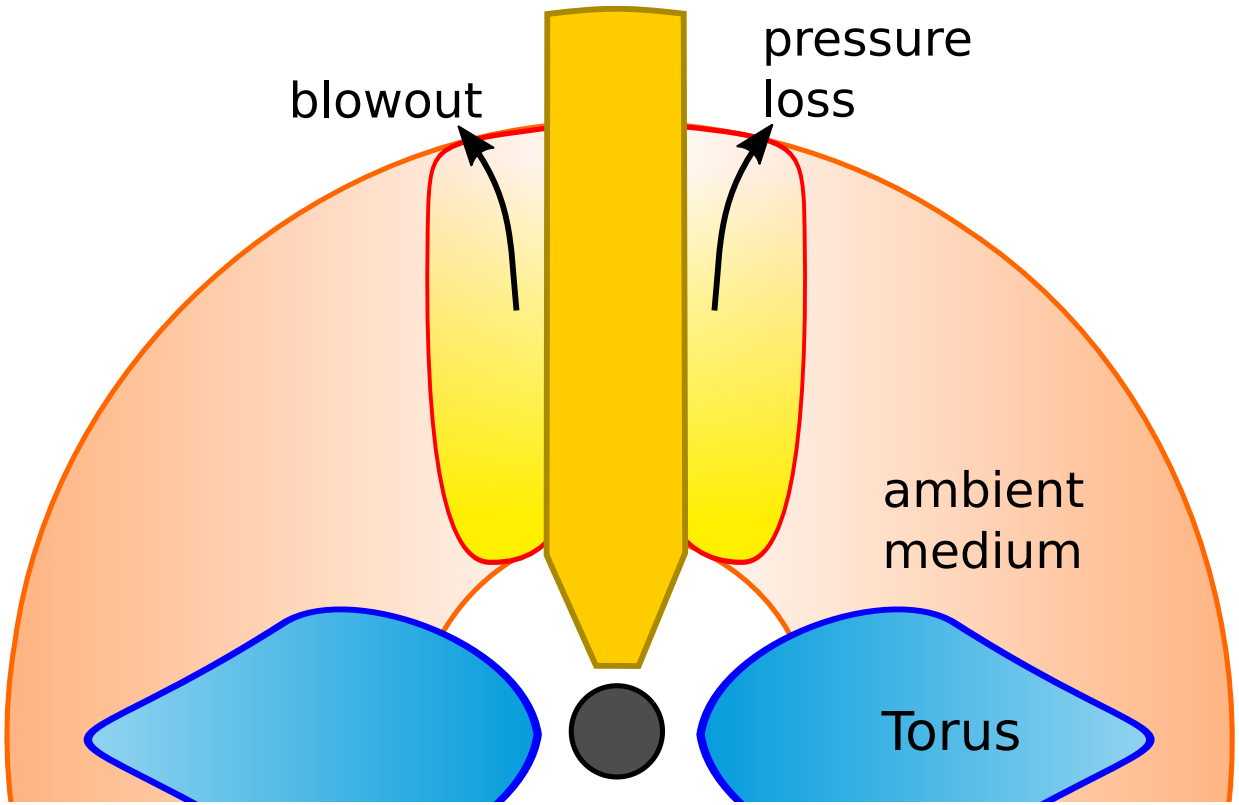
The scenario



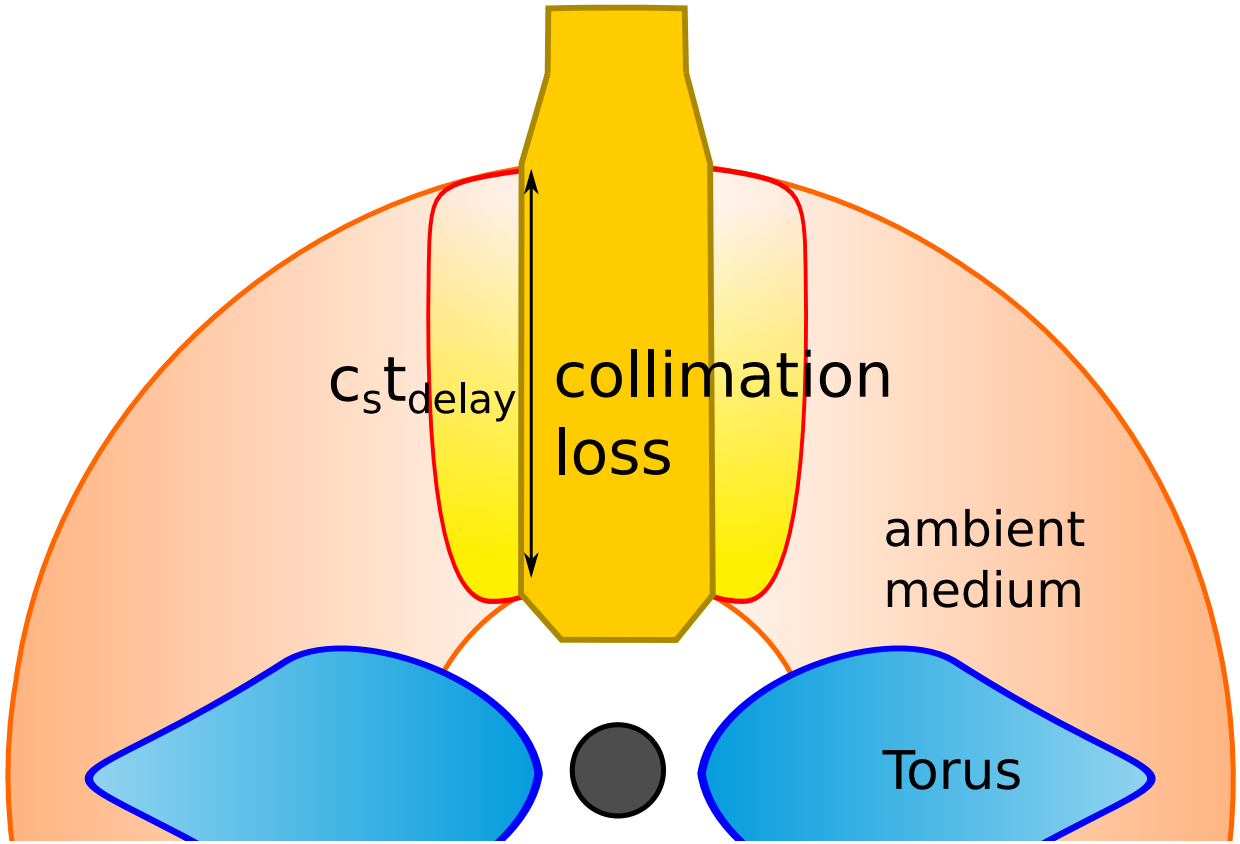
The scenario



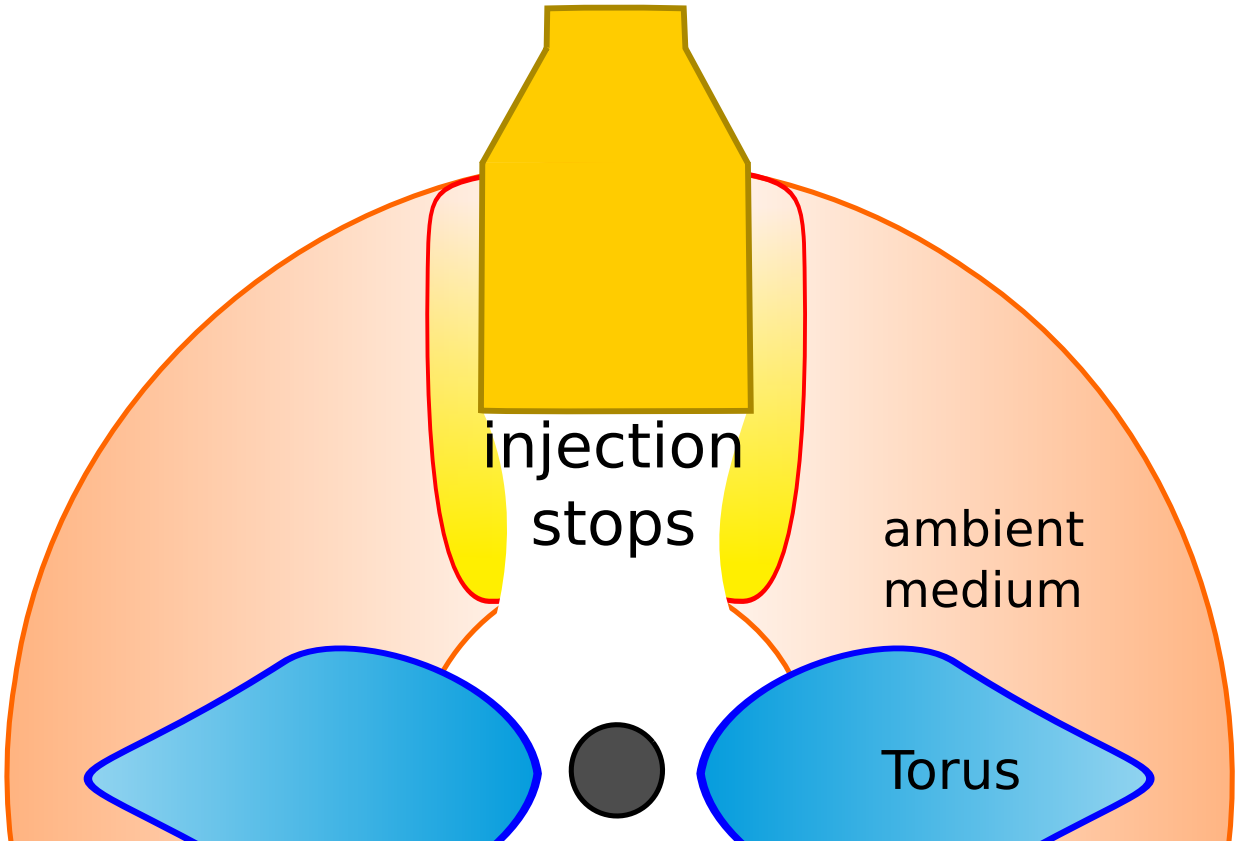
The scenario



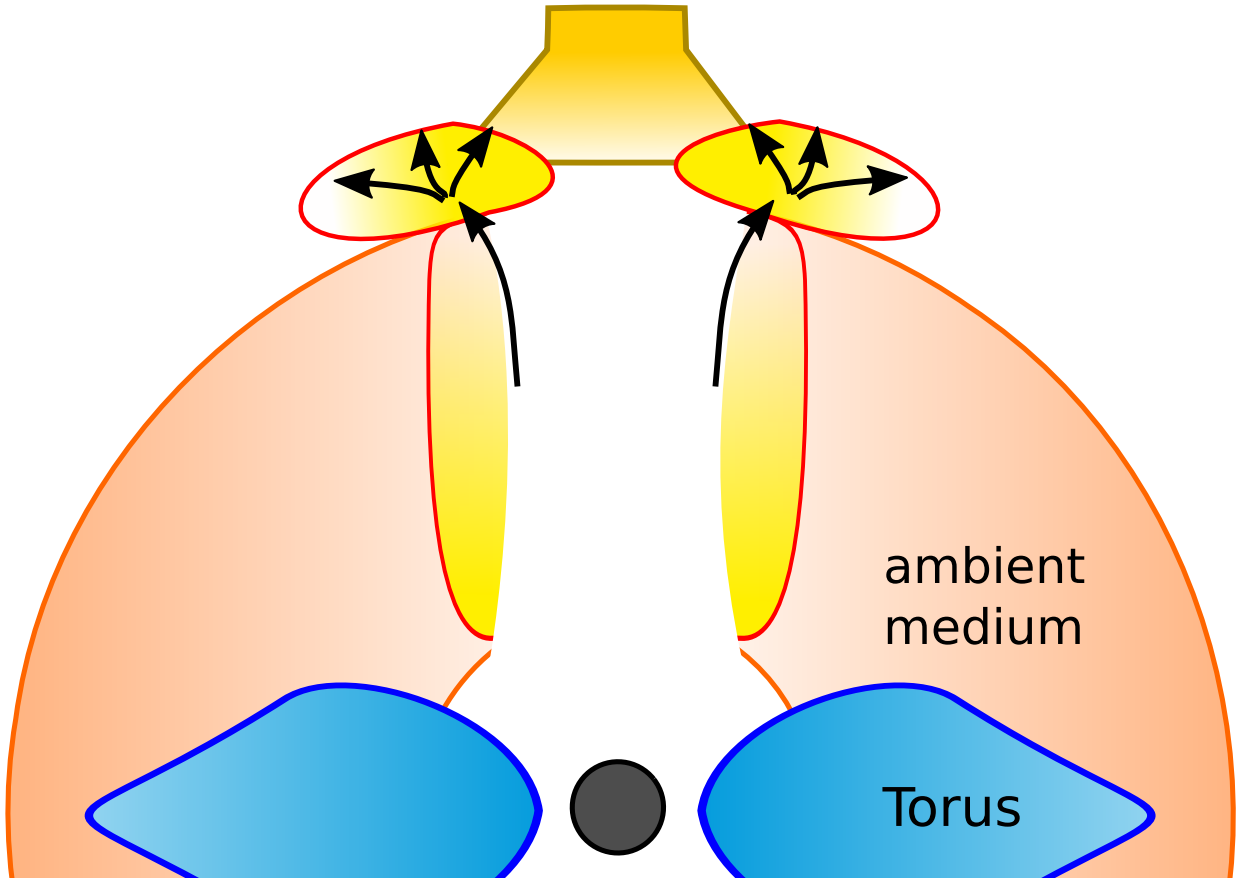
The scenario



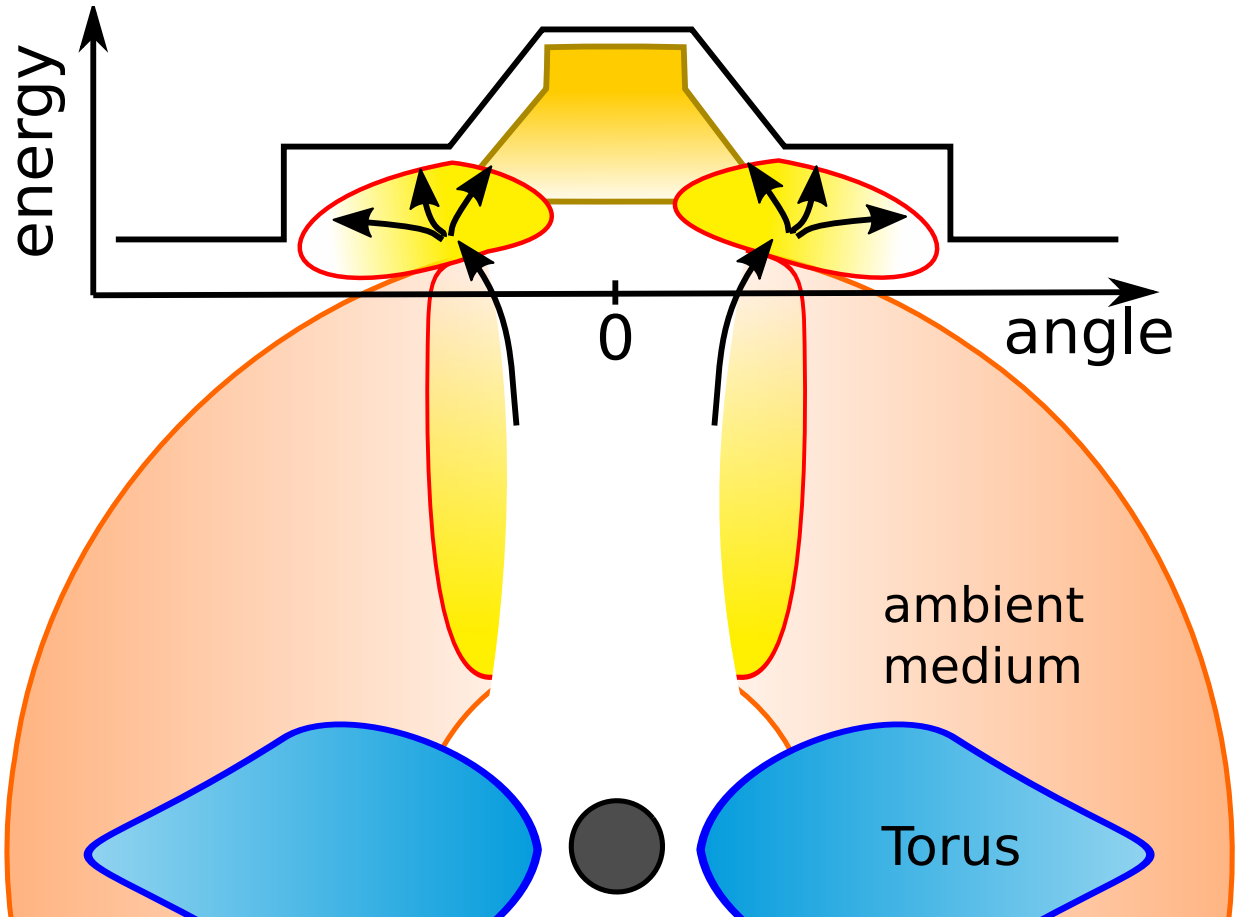
The scenario



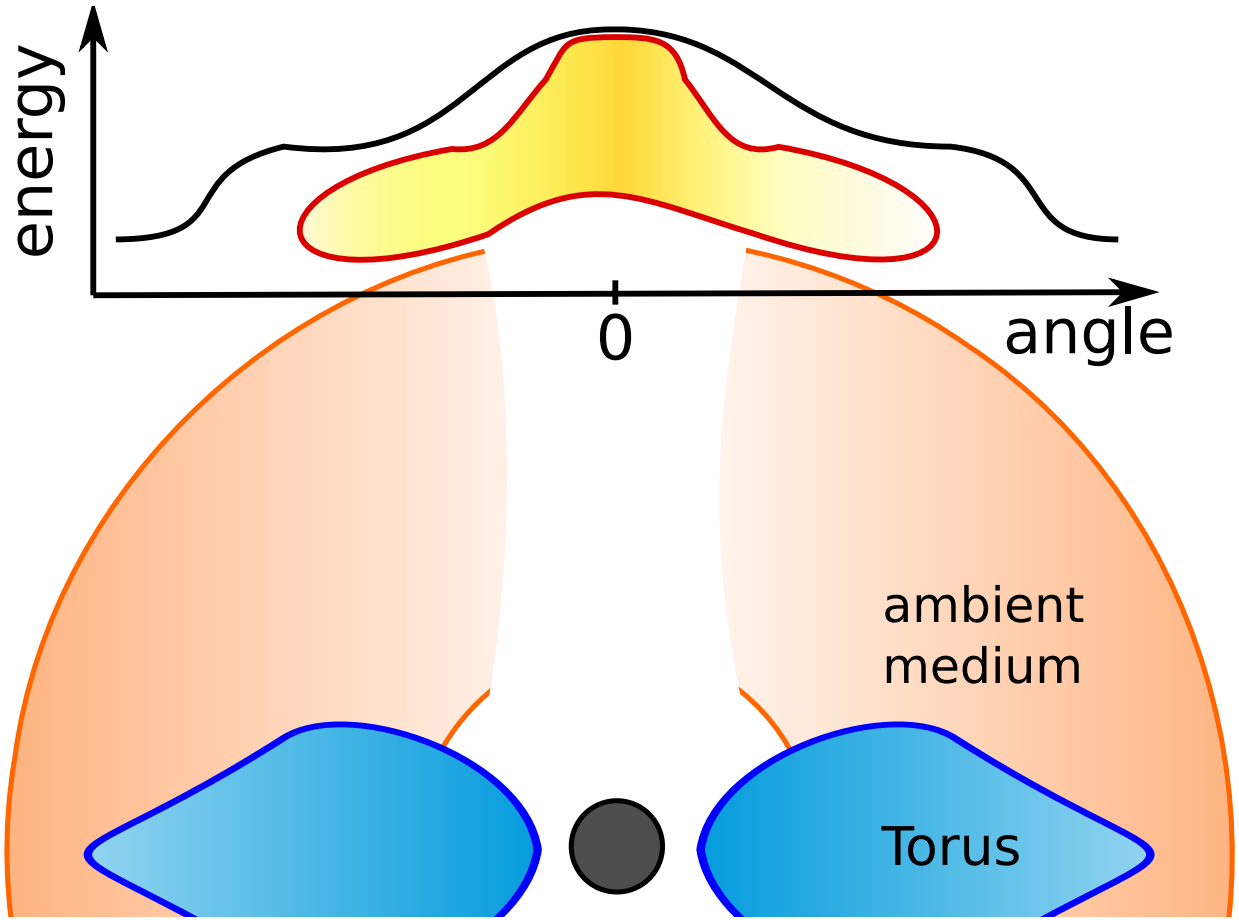
The scenario



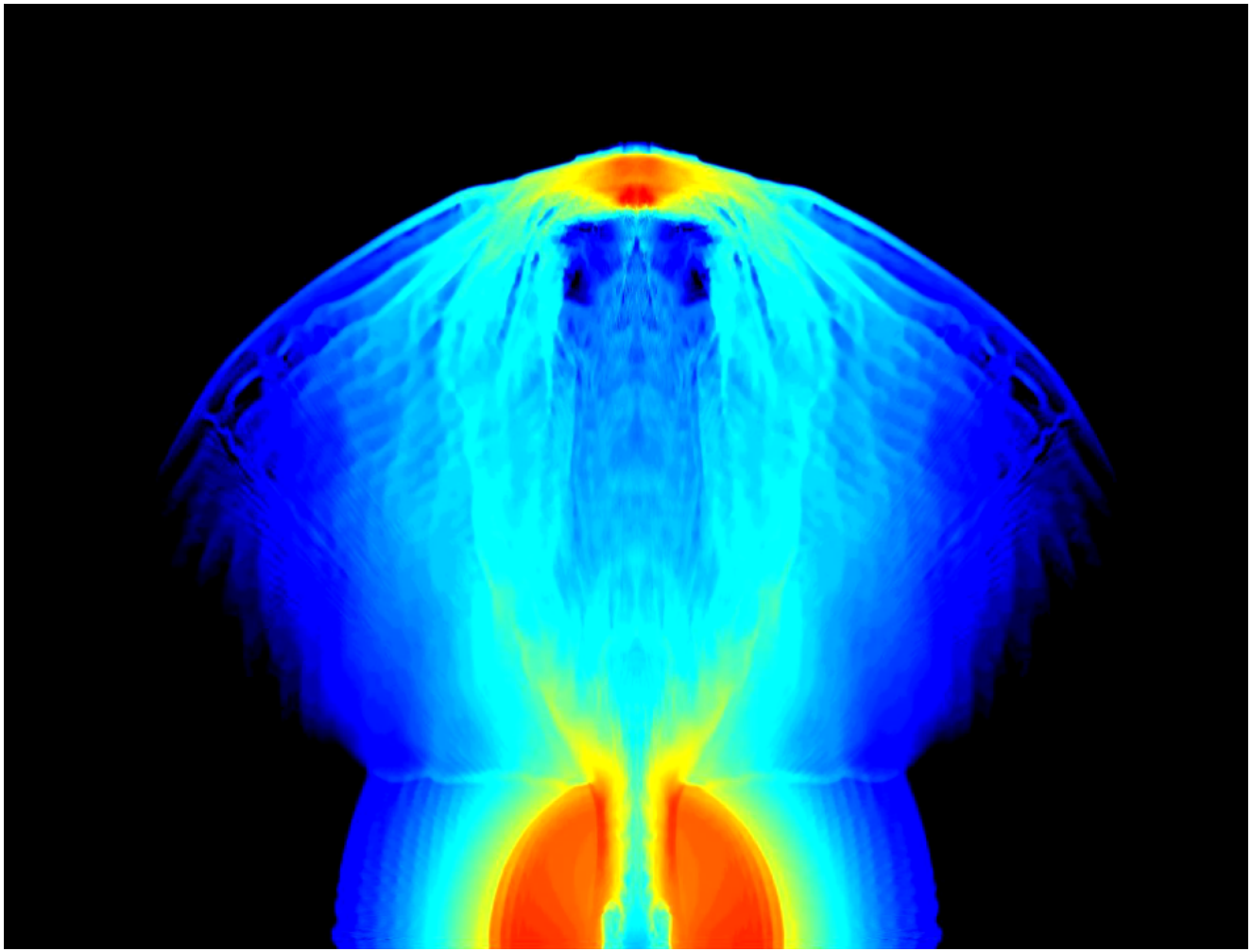
The scenario



The scenario



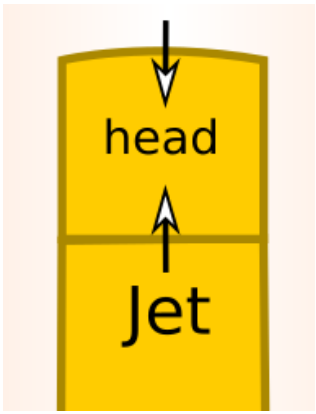
The scenario



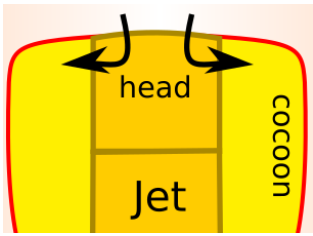
[Gottlieb & Nakar]

Head propagation & collimation: (semi-)analytical modelling

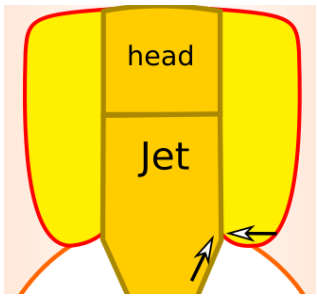
Ram pressure balance at head
(accounting for ambient velocity)



Energy flow to cocoon
(accounting for head/cocoon relative velocity)

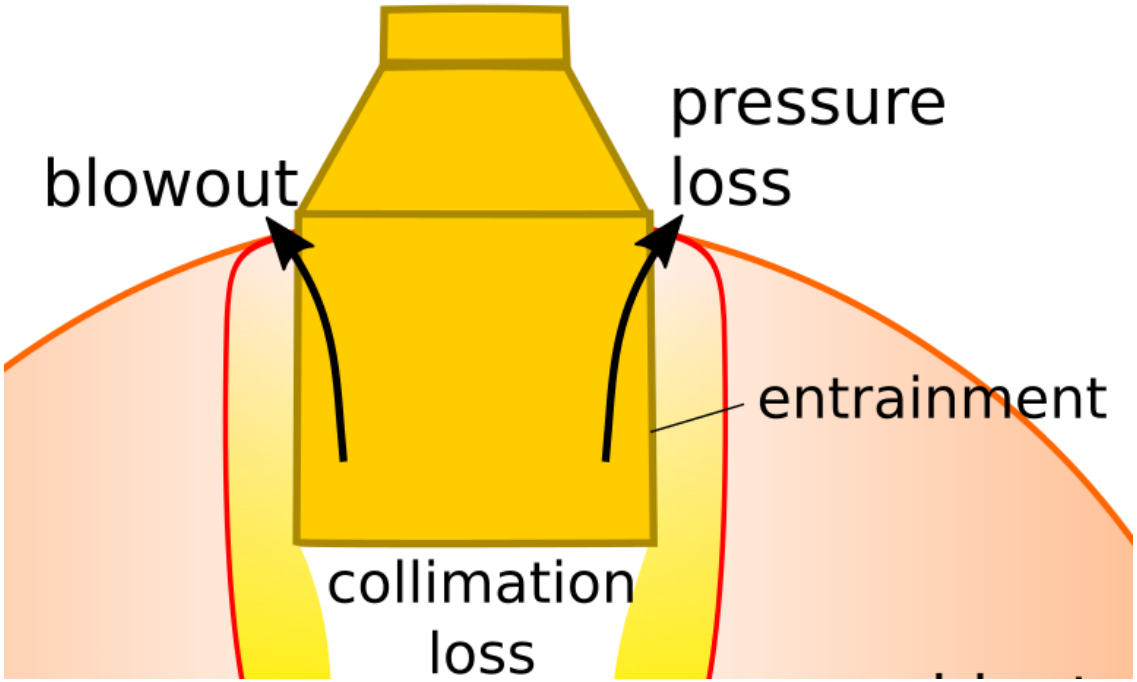


Collimation
(accounting for jet pressure)



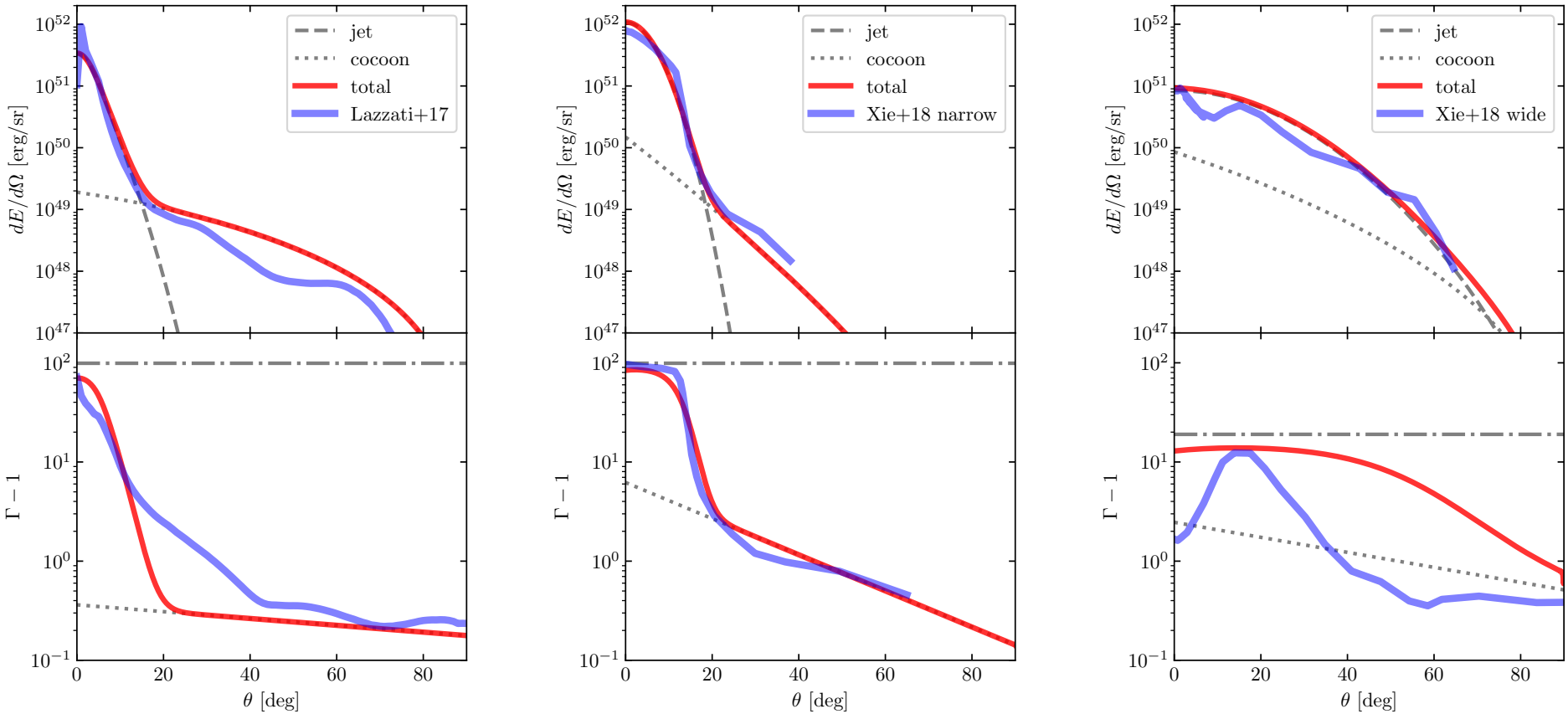
[Salafia & Barbieri in prep., building on Begelman+1995, Komissarov+1998, Matzner 2003, Bromberg+2011, Murguia-Berthier+2017, Harrison+2018]

Structure development



[Salafia & Barbieri in prep., building on ideas from Lazzati & Begelman 2005 + insight from published numerical simulations; similarities with Lazzati & Perna 2019]

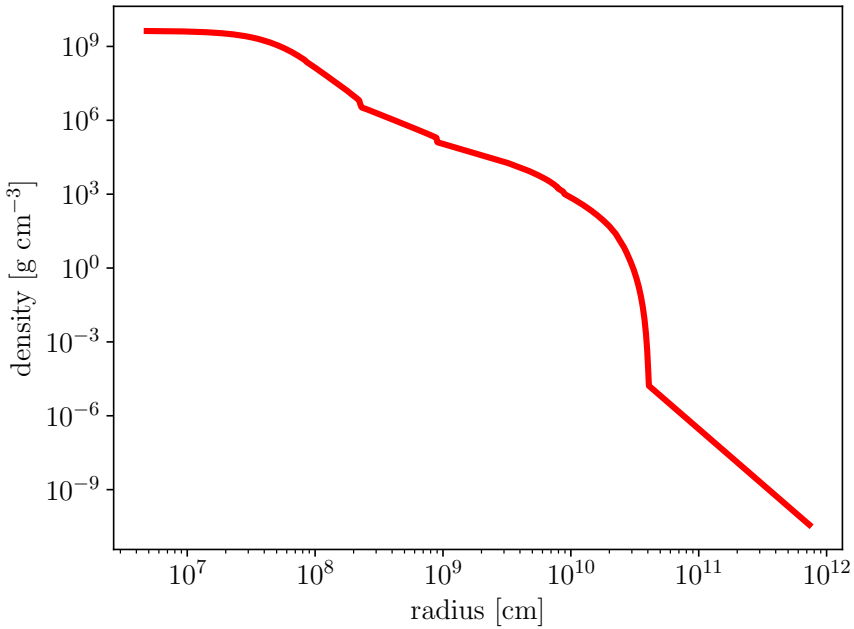
Structure: comparison with simulations



[Salafia & Barbieri in prep., comparison with Lazzati+17, Xie+18]

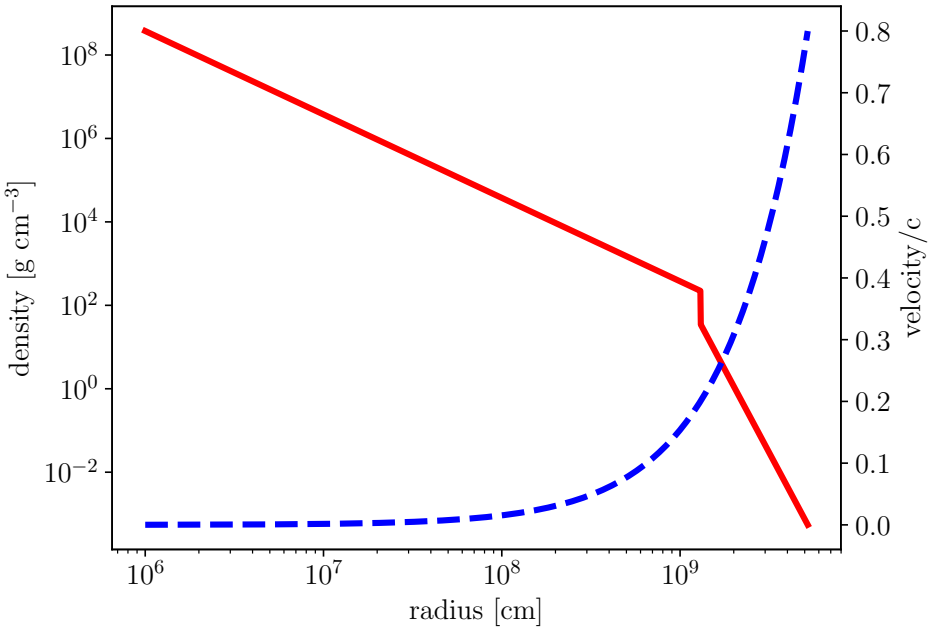
Population: progenitor density & velocity profiles

LGRB



Woosley & Heger's 16TI model (pre-supernova low-metallicity rotating massive star)

SGRB



Post-NS-merger ambient medium (Kasliwal+17, Gottlieb+18, Xie+18)

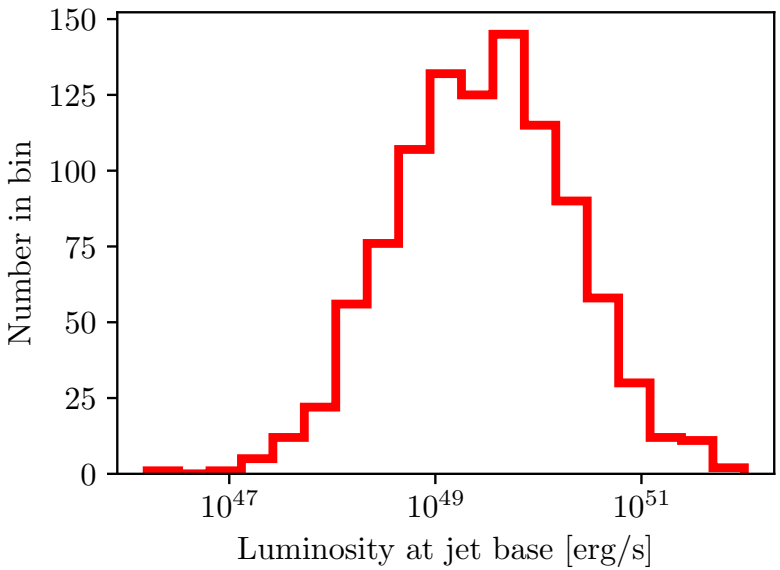
[Salafia & Barbieri in prep.]

Population: LGRB jet propoerties at launch

Half-opening angle: fixed at $\theta_{\rm j,0} = 0.25\,{\rm rad}$

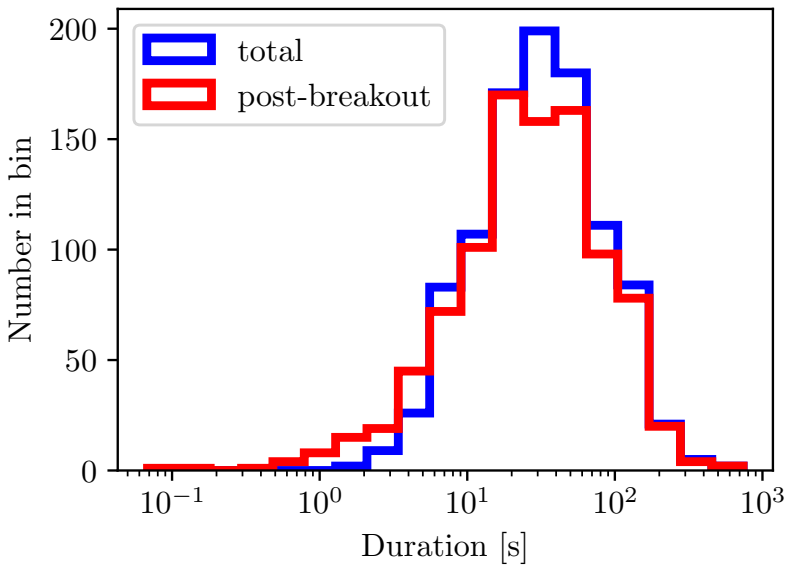
Luminosity: lognormal

$\mu = 3 \times 10^{49}\,{\rm erg/s},\ \sigma = 0.85\,{\rm dex}$



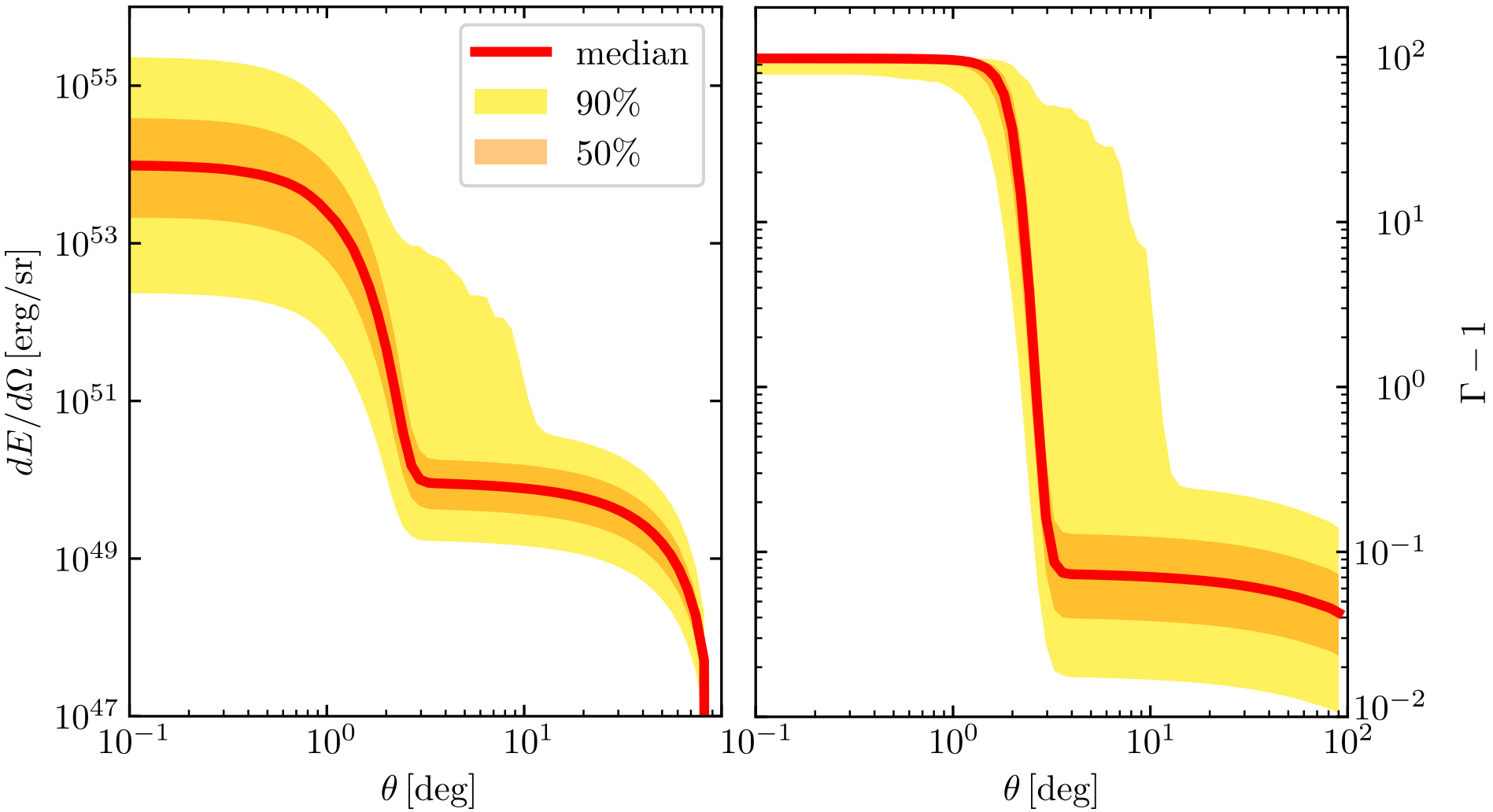
Duration: lognormal

$\mu = 30\,{\rm s},\ \sigma = 0.45\,{\rm dex}$



[Salafia & Barbieri in prep.]

Result: LGRB structures

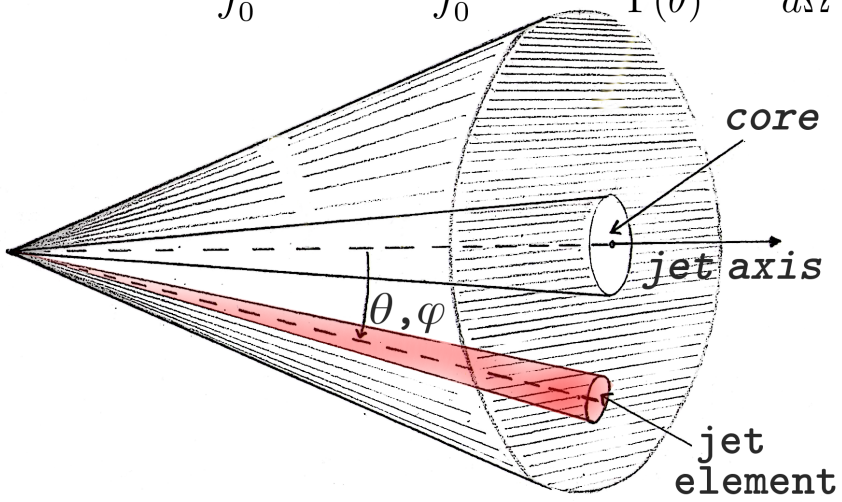


[Salafia & Barbieri in prep.]

Prompt emission luminosity

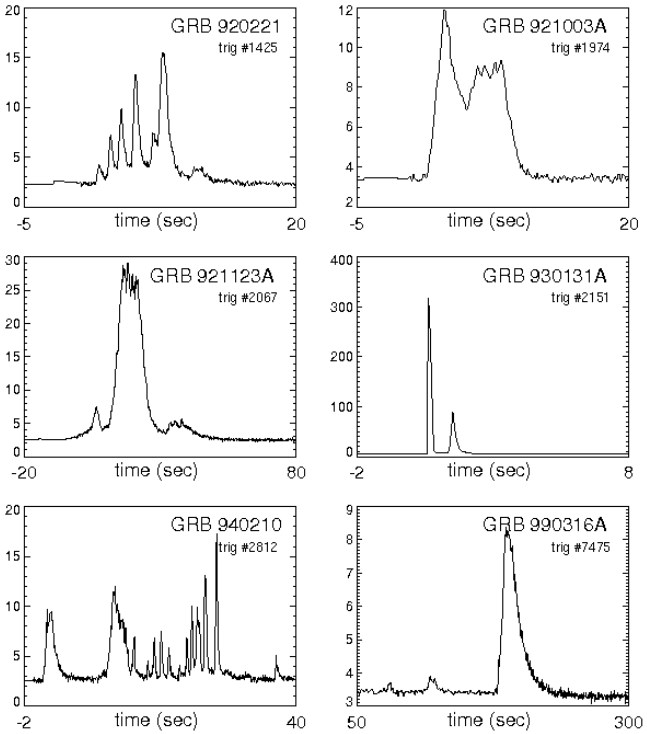
1) sum de-beamed emission from all jet

$$E_{\rm iso}(\theta_{\rm v}) = \eta \int_0^{\pi/2} d\cos\theta \int_0^{2\pi} d\phi \, \frac{\delta^3(\theta,\phi,\theta_{\rm v})}{\Gamma(\theta)} \frac{dE_{\rm K}}{d\Omega}(\theta)$$

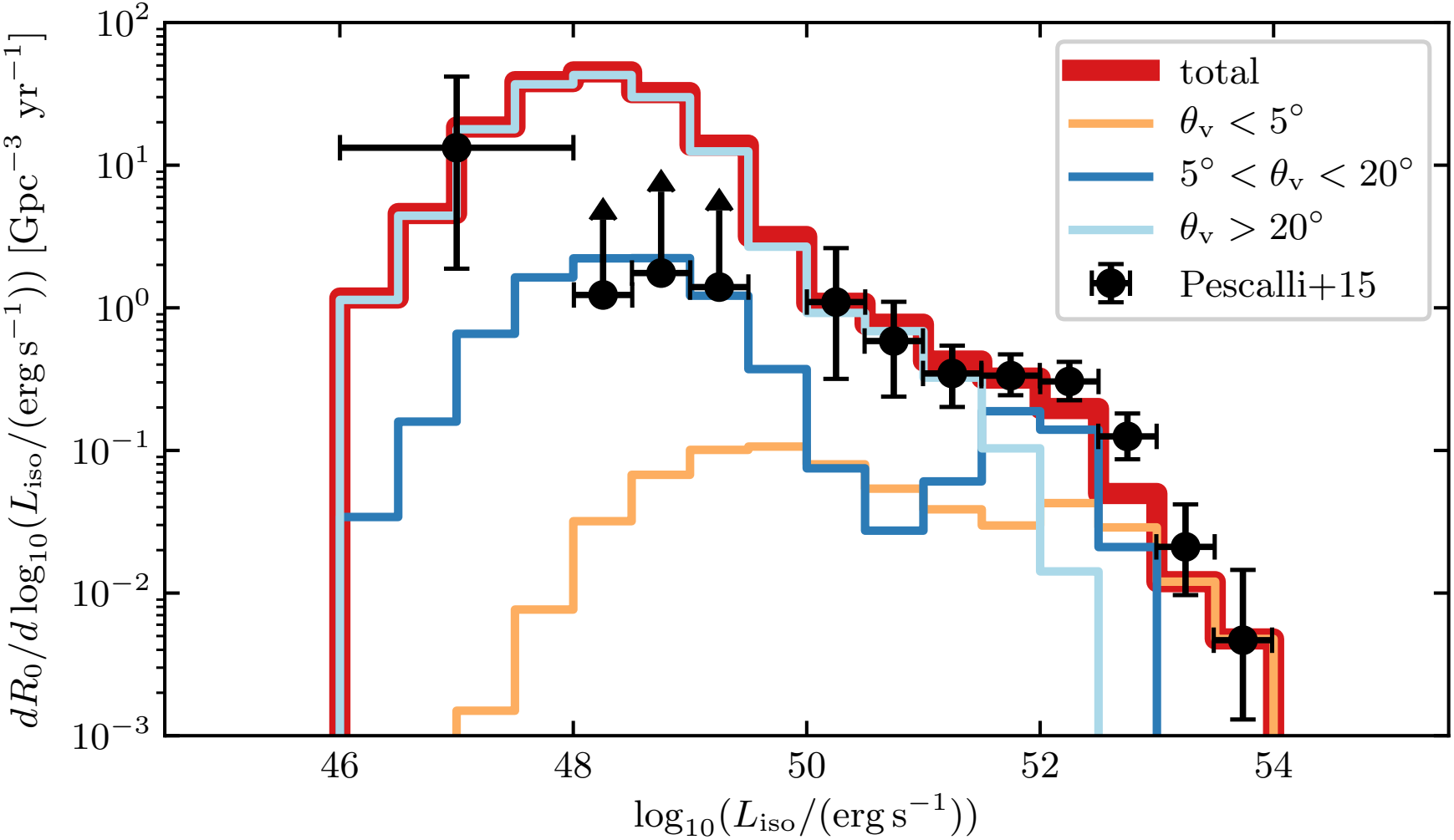


[Salafia+15, Salafia+19]

2) $L_{\rm iso} = 2(E_{\rm iso}/T_{\rm GRB})$



Result: LGRB luminosity distribution



[Salafia & Barbieri in prep.]

Population: SGRB jet propoerties at launch

Half-opening angle: fixed at $\theta_{\rm j,0} = 0.25\,{\rm rad}$

Luminosity: lognormal

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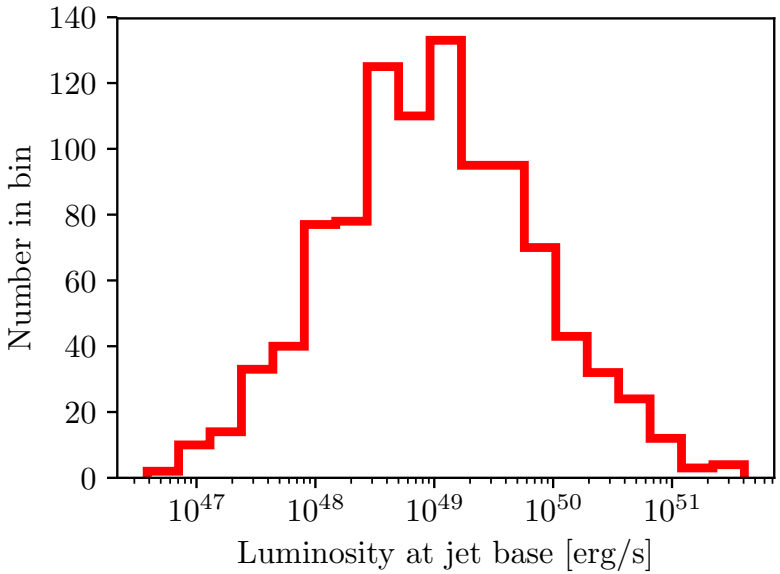
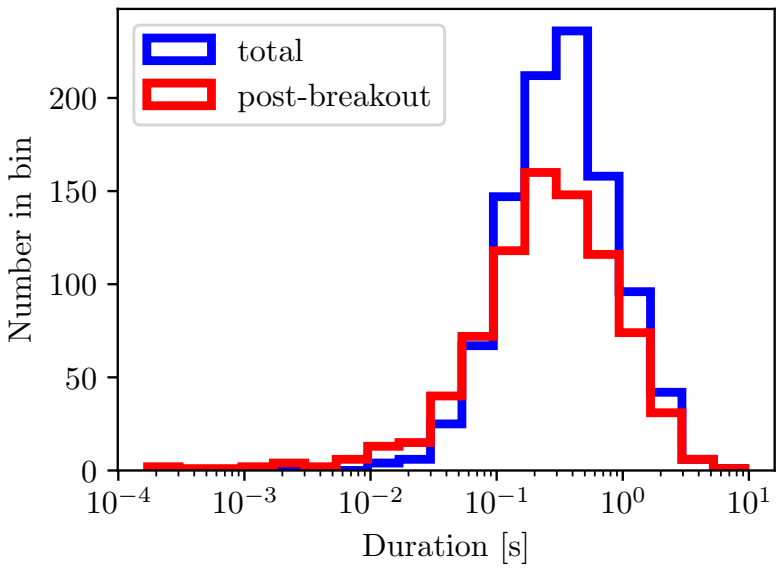


Duration: lognormal

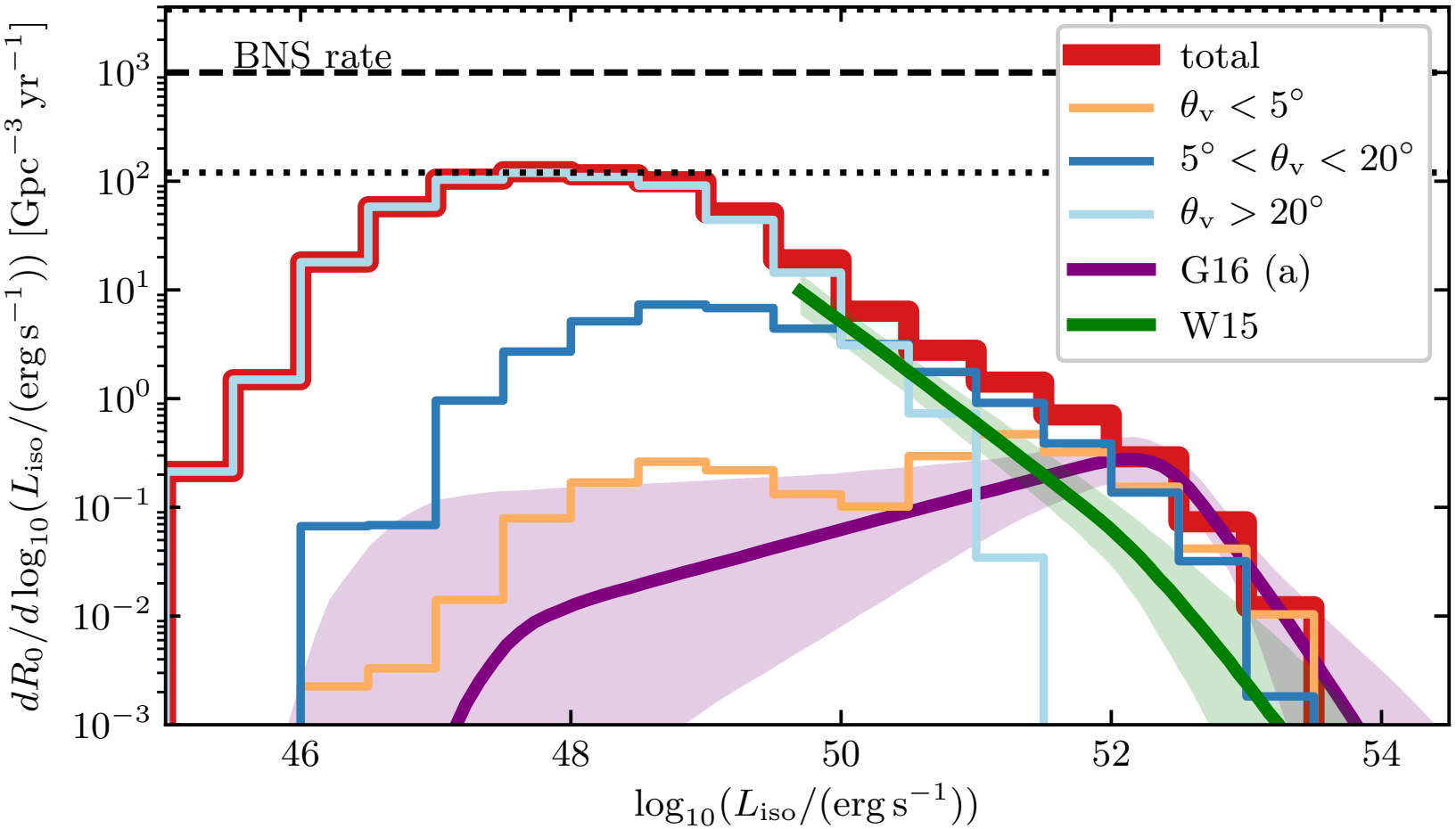
$\mu = 0.3\,{\rm s},\ \sigma = 0.45\,{\rm dex}$



[Salafia & Barbieri in prep.]

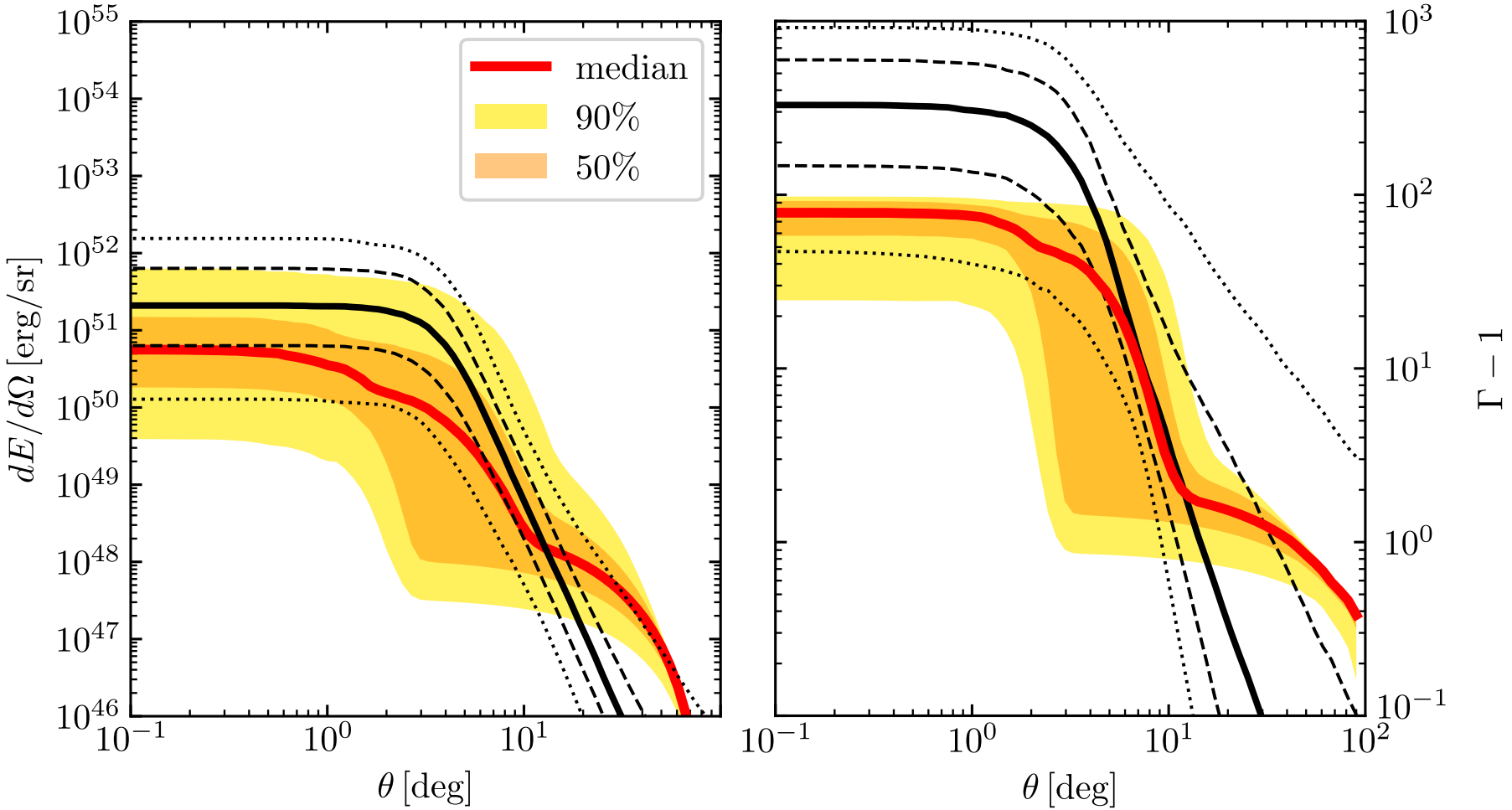
Result: SGRB luminosity distribution (PRELIMINARY)

$$R_0 = 300\,\mathrm{yr}^{-1}\,\mathrm{Gpc}^{-3}$$



[Salafia & Barbieri in prep., lum. functions from Wanderman+15 and Ghirlanda+16]

Result: SGRB structures (PRELIMINARY)



[Salafia & Barbieri in prep.]

Caveats

Luminosity computation

- angle-independent efficiency: likely not realistic
- angle-independent emission duration: likely not realistic
- (let aside that we don't actually know the emission process)

Progenitors

- intrinsic progenitor diversity? (for SGRBs in particular)

Structure development

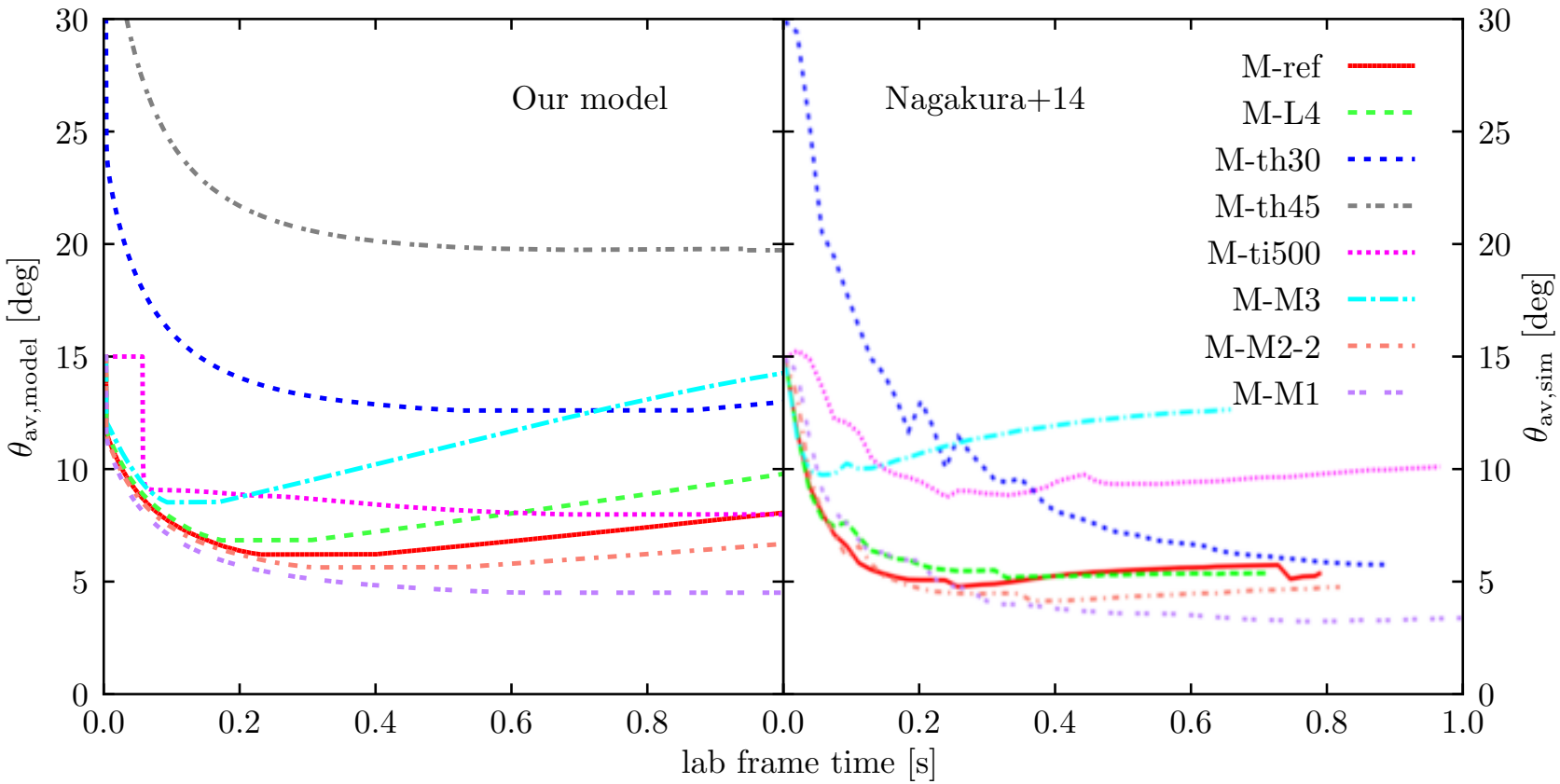
- only tested on a handful of simulations: need to perform large number of dedicated runs

Conclusions

- simple semi-analytical modeling of jet/ambient interaction $\rightarrow$ reproduce L distribution for both SGRB & LGRB (but thousands of caveats!)
- $\rightarrow$ observed heterogeneity could be traced back to extrinsic differences $\rightarrow$ jets intrinsically similar
- stay tuned for future improvements & more detailed comparisons with observations

Thank you!

Collimation: comparison with simulations



[Salafia & Barbieri in prep., comparison with Nagakura+14]