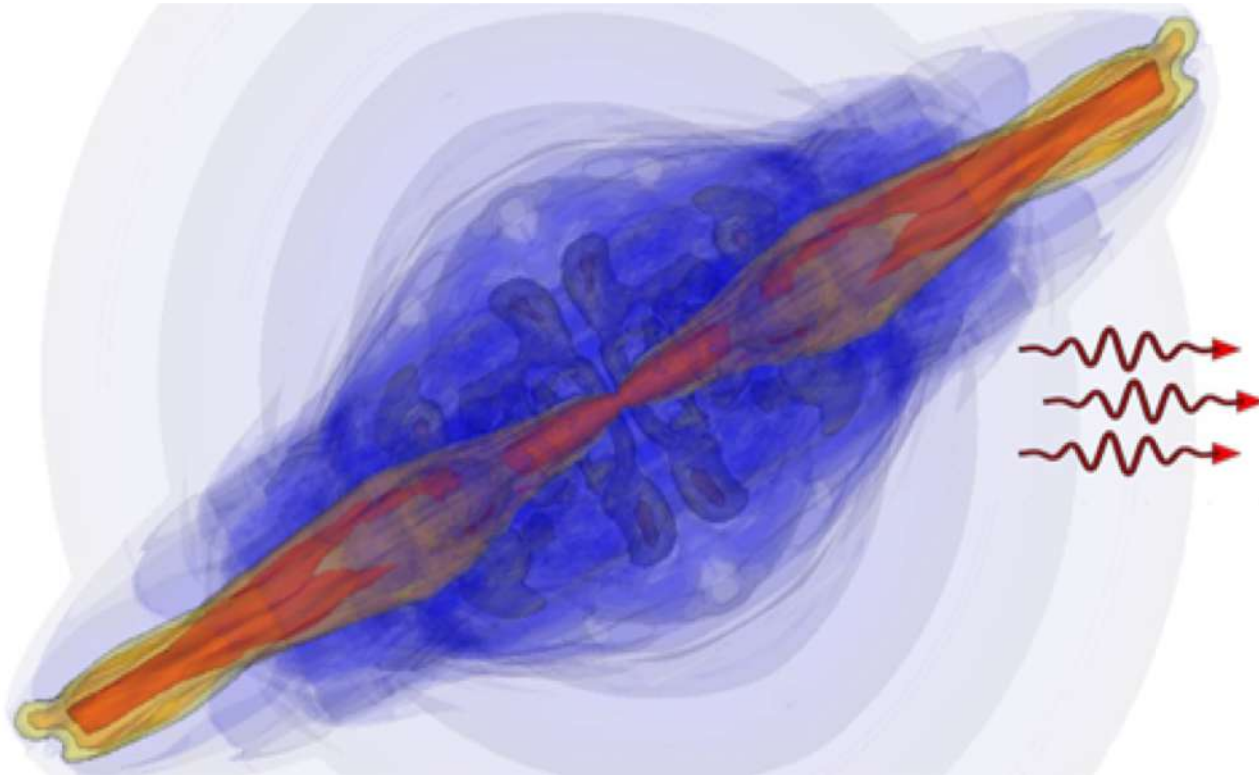


# Evolution of a 3D short GRB through the NS-NS post merger ejecta

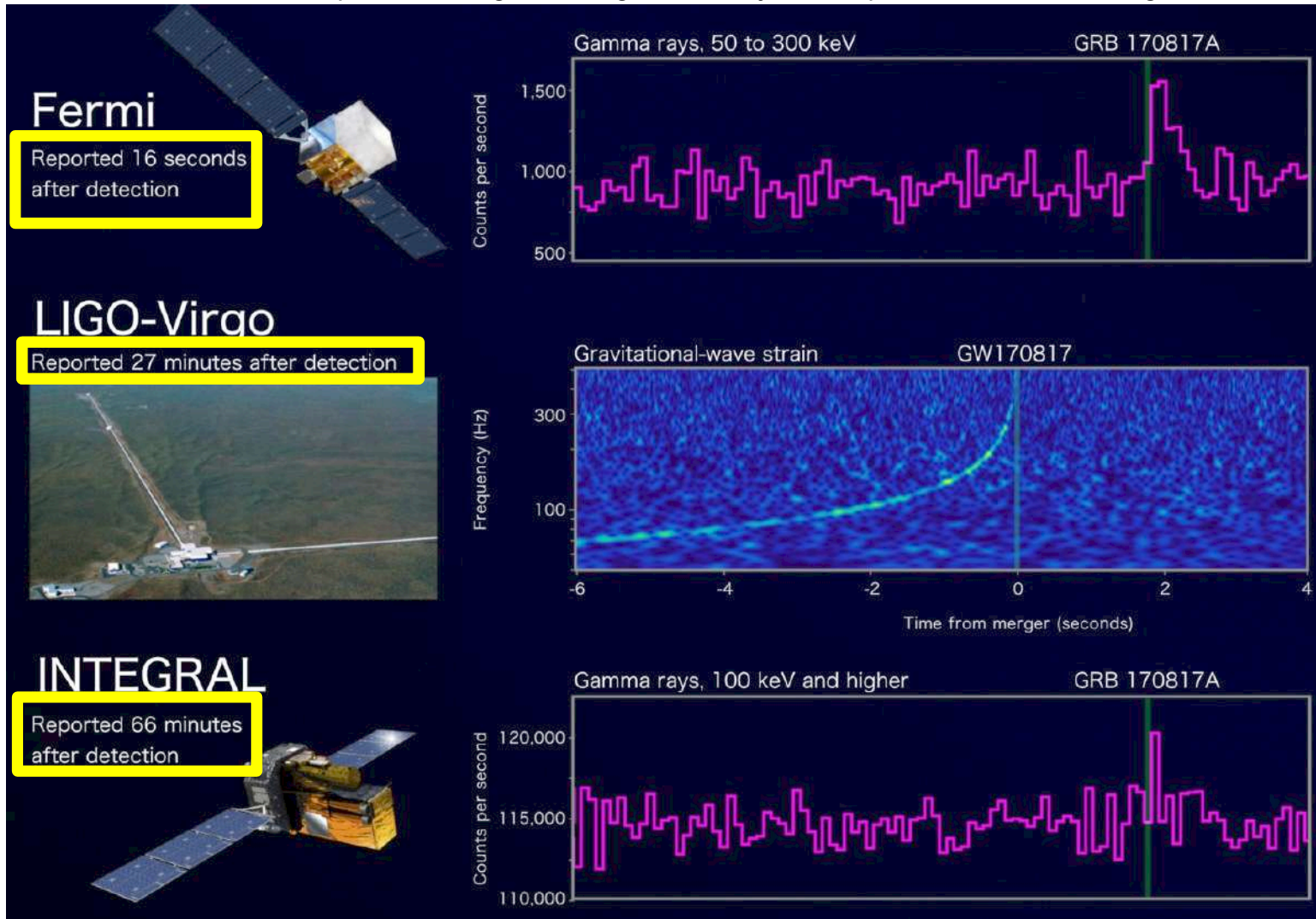


**Diego López-Cámara (IA-UNAM)**

Davide **Lazzati**, Rosalba **Perna**, Brian **Morsony**, Matteo **Cantiello**, Ricardo **Cioffi**,  
Bruno **Giazomazzo**, Jaled **Workman**

# GW170817/GRB170817A...

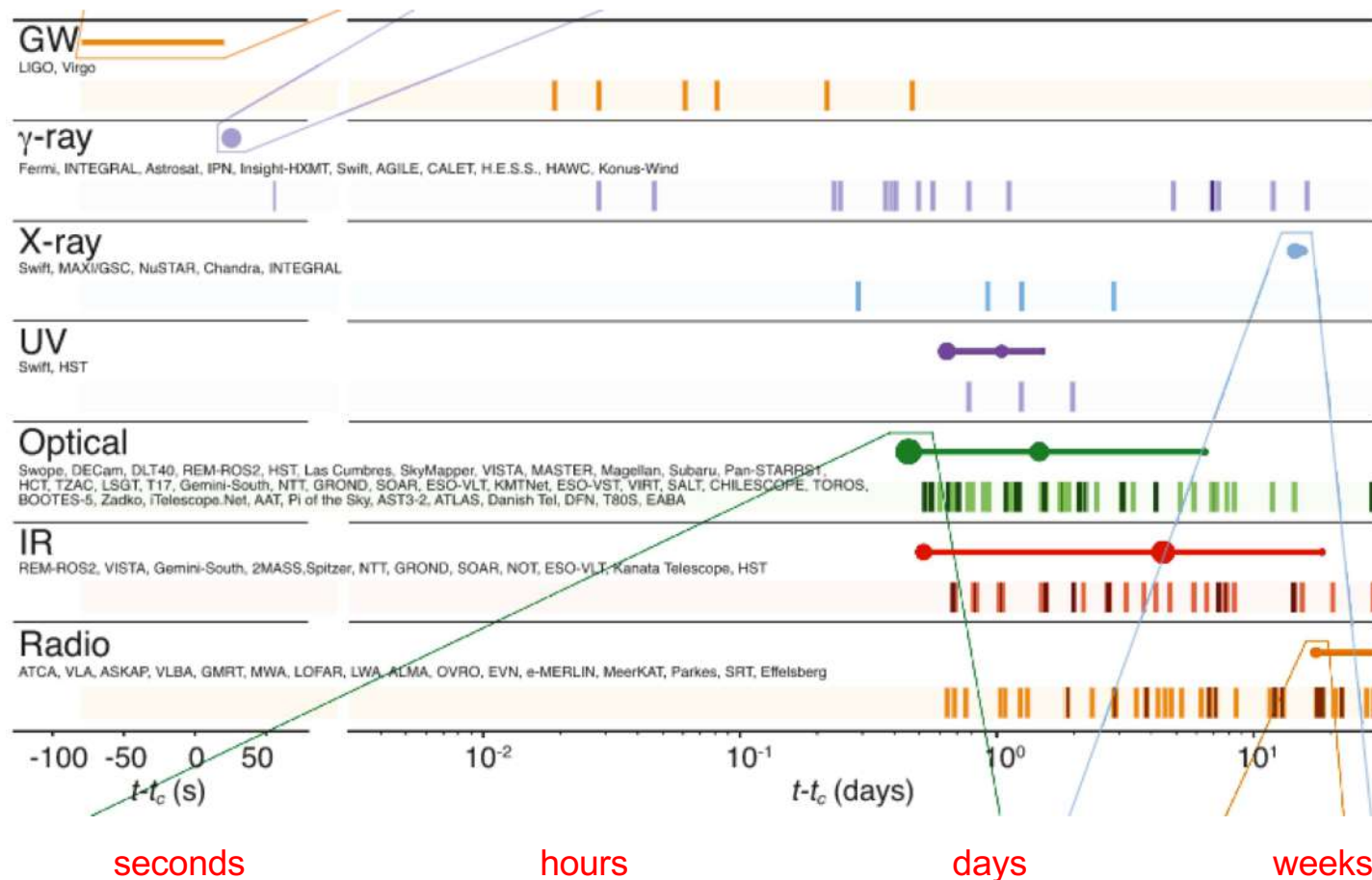
<https://heasarc.gsfc.nasa.gov/docs/objects/heapow/archive/transients/gw170817.html>



17th of August 2017

# GW170817/GRB170817A...

Celestial object/phenomena that has been observed by the most amount of satellites/detectors/telescopes at  $t =$  in history ( $\sim 100$ )





# GW170817/GRB170817A...

Celestial object/phenomena that has been observed by the most amount of satellites/detectors/telescopes at t= in history (~100)

THE ASTROPHYSICAL JOURNAL LETTERS, 848:L12 (59pp), 2017 October 20

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<https://doi.org/10.3847/2041-8213/aa91c9>



## **Multi-messenger Observations of a Binary Neutron Star Merger\***

LIGO Scientific Collaboration and Virgo Collaboration, Fermi GBM, INTEGRAL, IceCube Collaboration, AstroSat Cadmium Zinc Telluride Imager Team, IPN Collaboration, The Insight-HXMT Collaboration, ANTARES Collaboration, The Swift Collaboration, AGILE Team, The 1M2H Team, The Dark Energy Camera GW-EM Collaboration and the DES Collaboration, The DLT40 Collaboration, GRAWITA: GRAvitational Wave Inaf TeAm, The Fermi Large Area Telescope Collaboration, ATCA: Australia Telescope Compact Array, ASKAP: Australian SKA Pathfinder, Las Cumbres Observatory Group, OzGrav, DWF (Deeper, Wider, Faster Program), AST3, and CAASTRO Collaborations, The VINROUGE Collaboration, MASTER Collaboration, J-GEM, GROWTH, JAGWAR, Caltech-NRAO, TTU-NRAO, and NuSTAR Collaborations, Pan-STARRS, The MAXI Team, TZAC Consortium, KU Collaboration, Nordic Optical Telescope, ePESSTO, GROND, Texas Tech University, SALT Group, TOROS: Transient Robotic Observatory of the South Collaboration, The BOOTES Collaboration, MWA: Murchison Widefield Array, The CALET Collaboration, IKI-GW Follow-up Collaboration, H.E.S.S. Collaboration, LOFAR Collaboration, LWA: Long Wavelength Array, HAWC Collaboration, The Pierre Auger Collaboration, ALMA Collaboration, Euro VLBI Team, Pi of the Sky Collaboration, The Chandra Team at McGill University, DFN: Desert Fireball Network, ATLAS, High Time Resolution Universe Survey, RIMAS and RATIR, and SKA South Africa/MeerKAT  
(See the end matter for the full list of authors.)

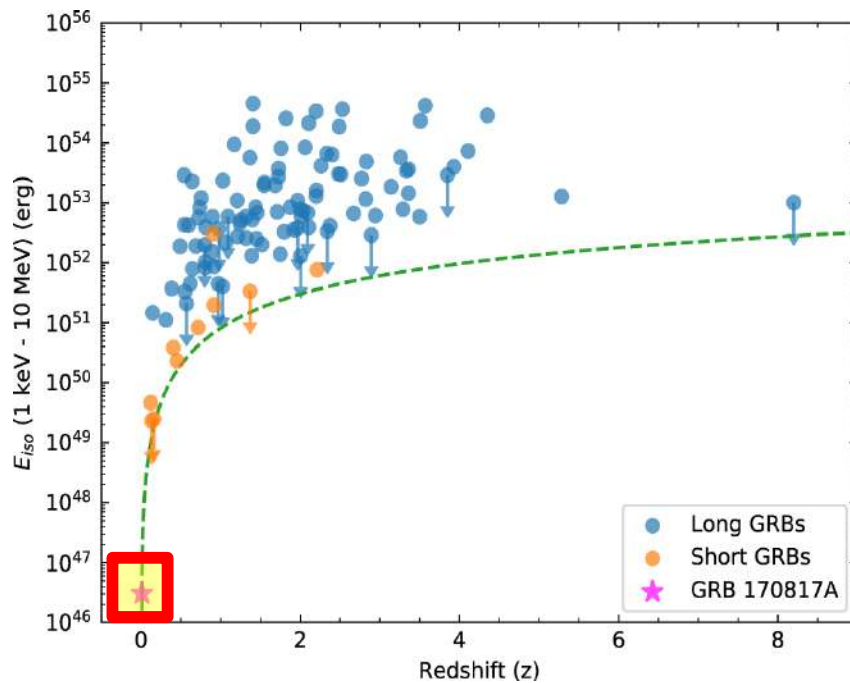
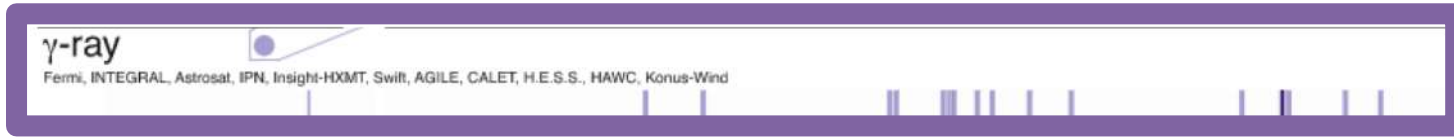
*Received 2017 October 3; revised 2017 October 6; accepted 2017 October 6; published 2017 October 16*

(953 institutions, ~ 3000 co-authors)

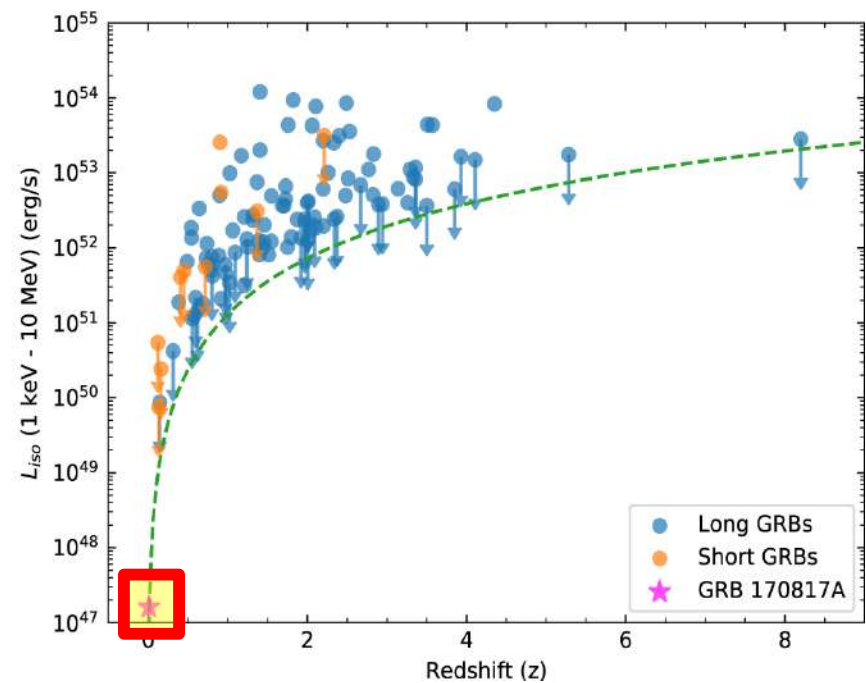
(Abbot et al. 2017a)

# GRB170817A...

Thanks Frédéric



$$E_{\text{iso}} = (3.1 \pm 0.7) \times 10^{46} \text{ erg}$$



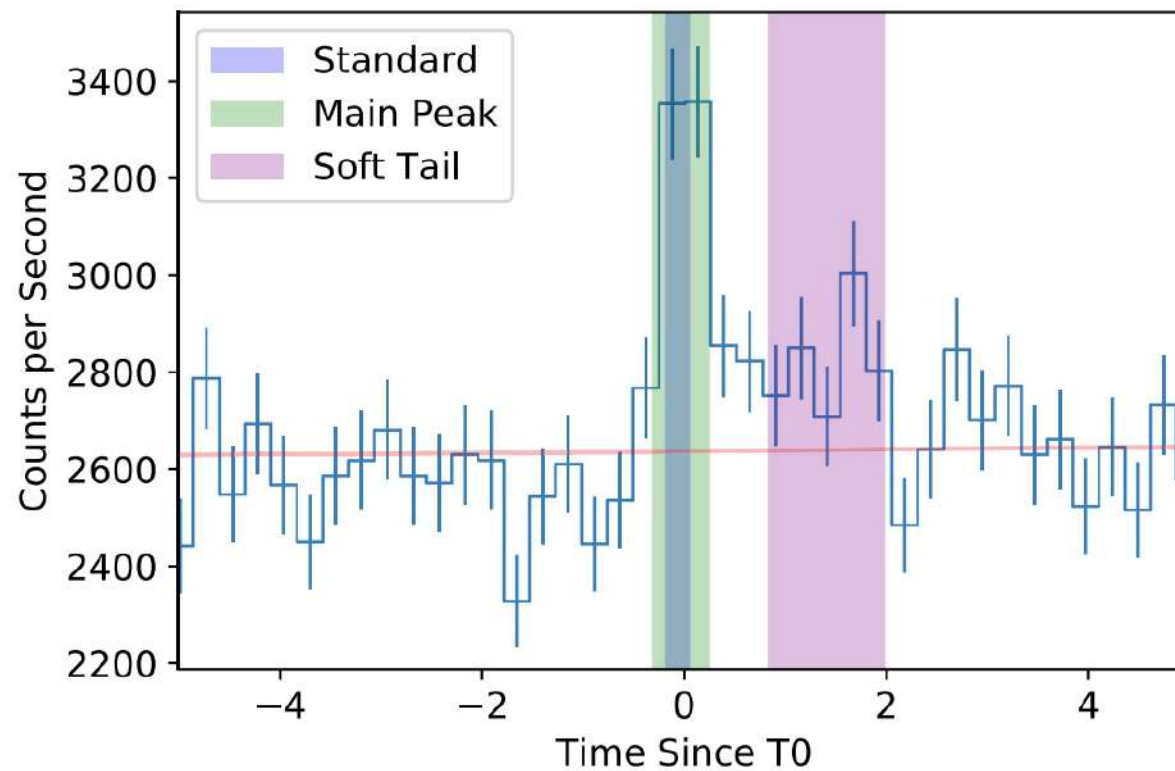
$$L_{\text{iso}} = (1.6 \pm 0.6) \times 10^{47} \text{ erg s}^{-1}$$

Atypical #1:  $E_{\text{iso}}$  y  $L_{\text{iso}}$  very low

(Abbot et al. 2017b)

# GRB170817A...

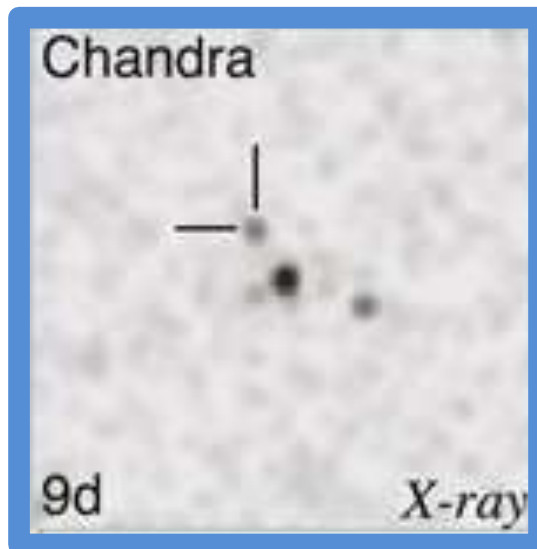
Thanks Frédéric



Goldstein+ 2017

Atypical #1:  $E_{\text{iso}}$  y  $L_{\text{iso}}$  very low + main peak + soft tail

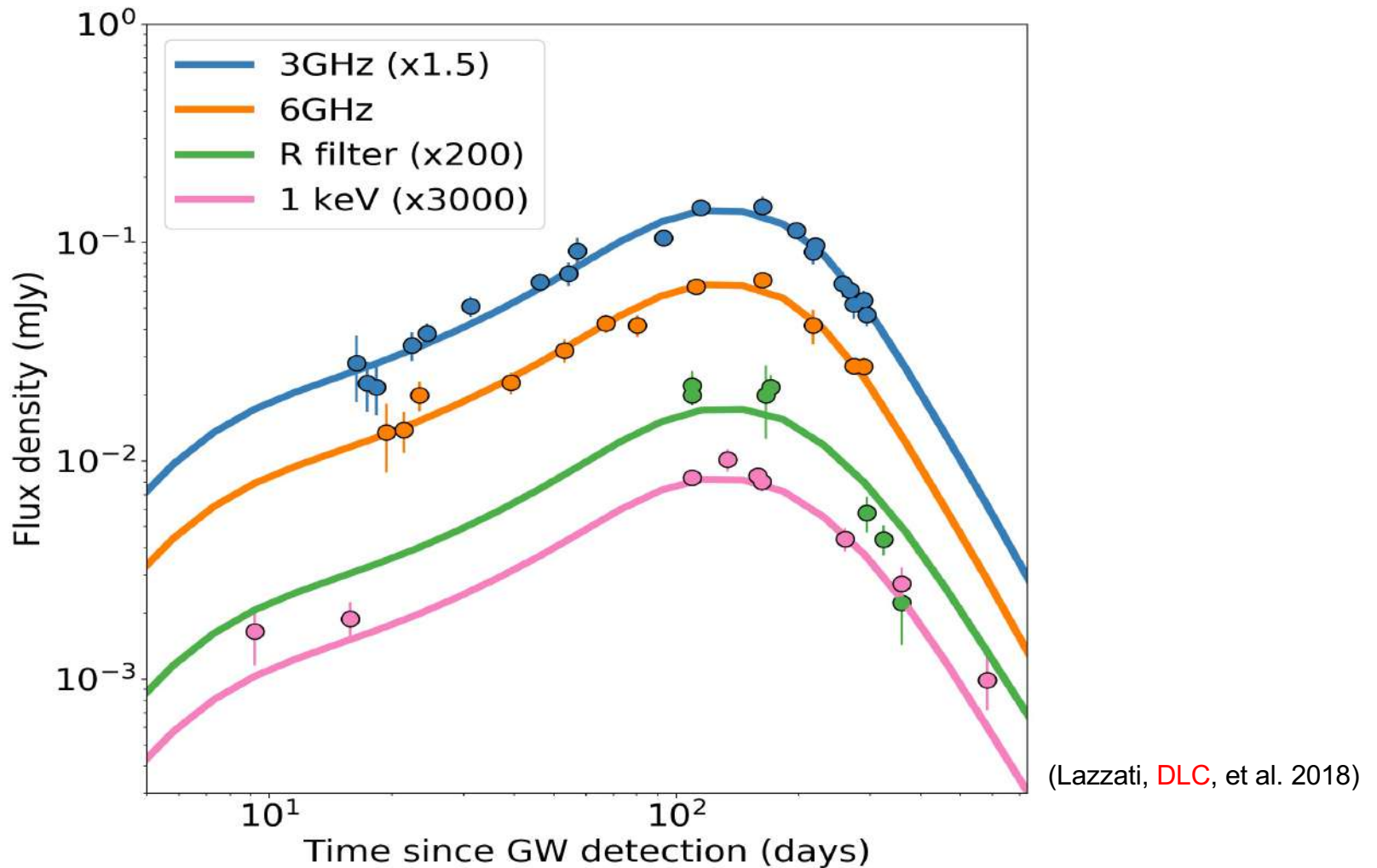
# GRB170817A...



Atypical #2: No X-rays until after 9 days.

# GRB170817A...

Thanks Frédéric



Atypical #3: X, optical, and radio for up to ~2 years



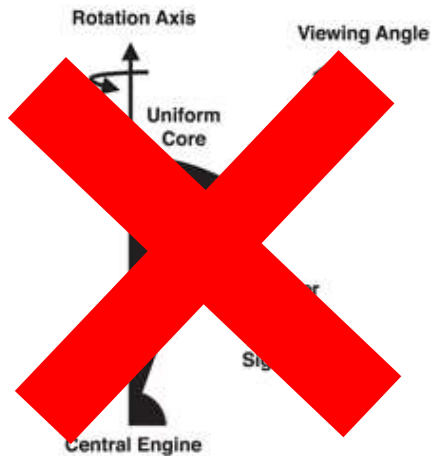
# GRB170817A...

¿Is GRB170817A a new kind of phenomena?

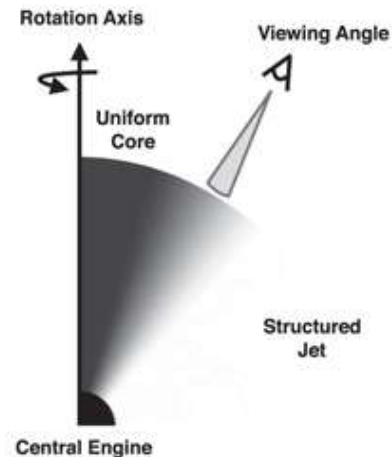
# GRB170817A... (initial models)

~~On axis jet not favored (X ray would be visible at t < hours)~~

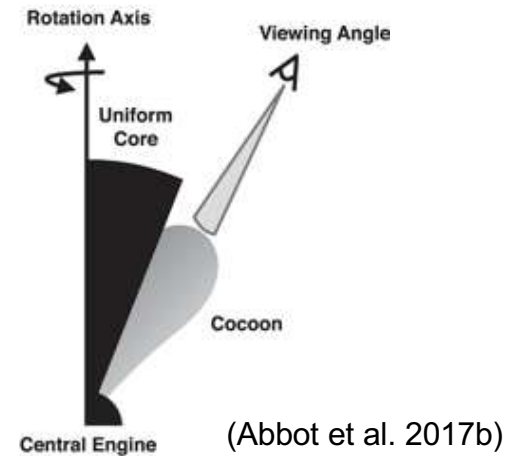
Scenario i: Uniform Top-hat Jet



Scenario ii: Structured Jet



Scenario iii: Uniform Jet + Cocoon



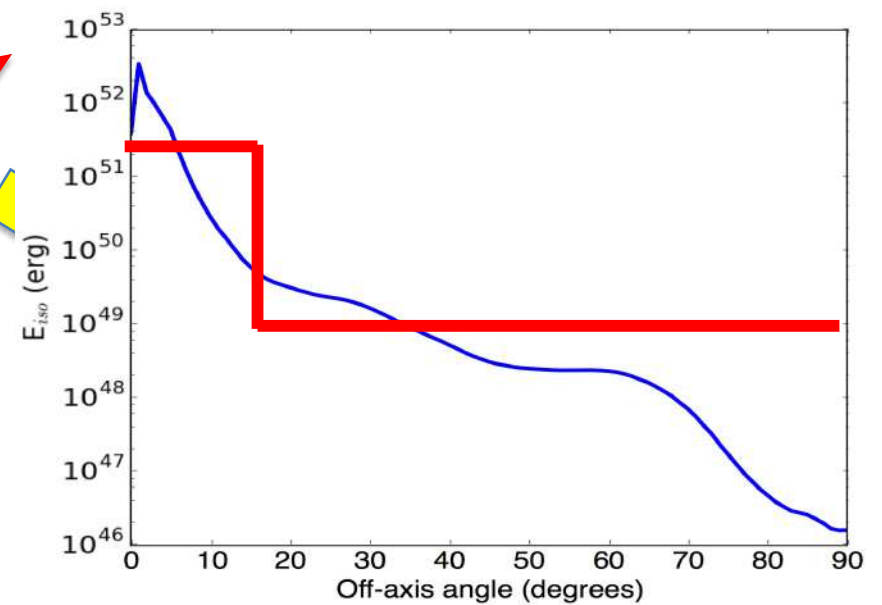
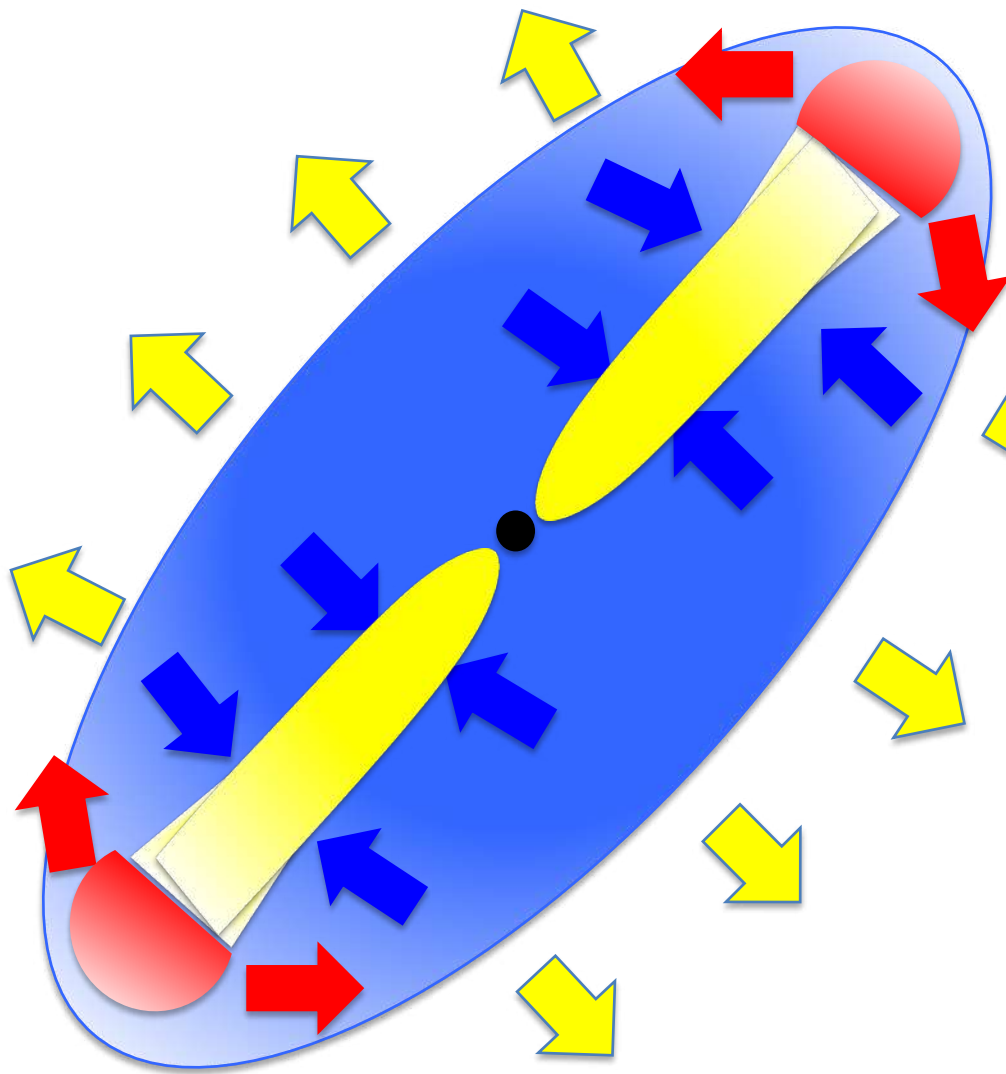
Scenario iv. Explosión isotrópica



Confusion between  
“structured” and jet+cocoon

# GRB170817A... (initial models)

Thanks Fabio



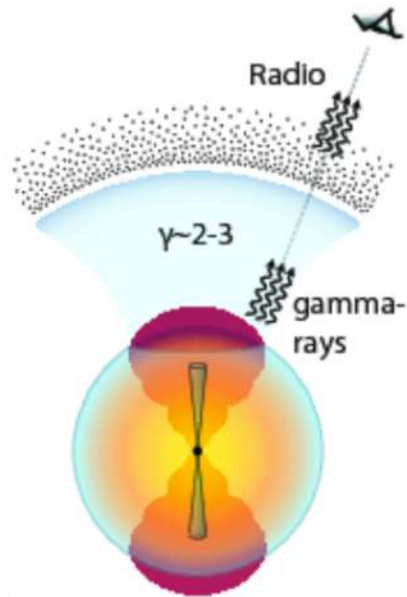
structured jet = jet+cocoon

# GRB170817A... (initial models)

Successful

vs

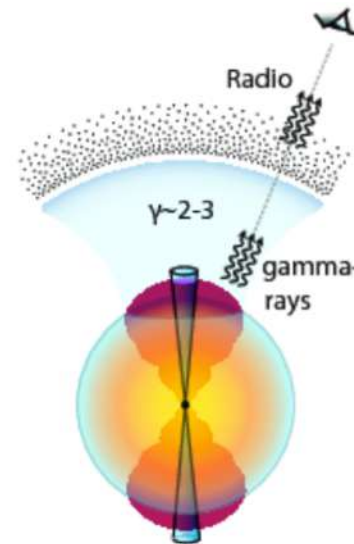
choked



4

C. Choked Jet  
Cocoon gamma-rays  
and afterglow

Mooley et al. 2017  
Gottlieb et al. 2017



E. Successful hidden Jet  
Cocoon gamma-rays  
and afterglow

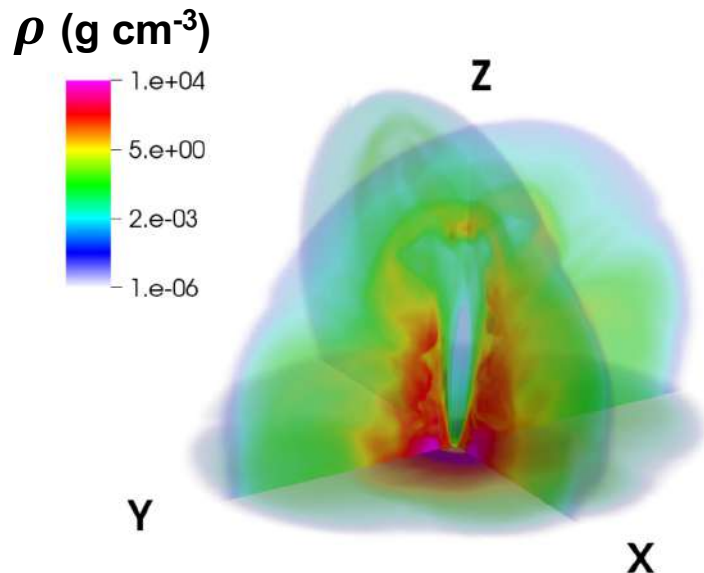
Lazzati et al. 2018  
Kathirgamaraju et al. 2018



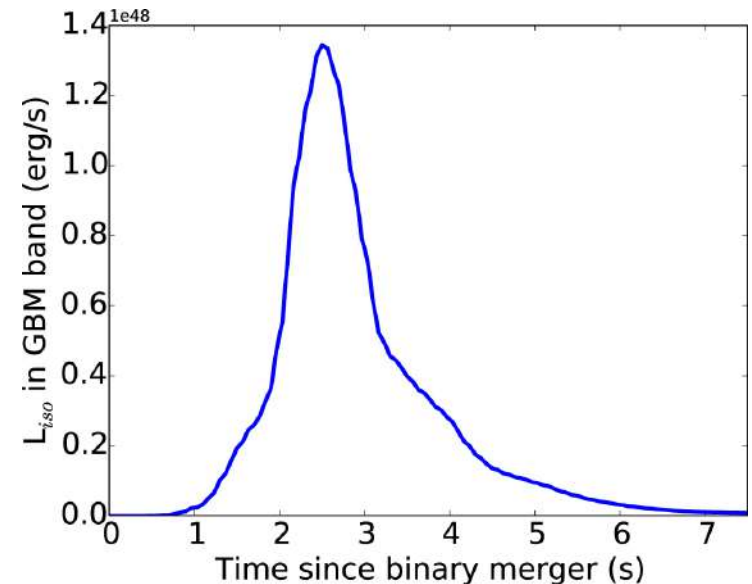
# GRB170817A... (jet+cocoon)

During the 17/08/17 gossip...

3D/2DRHD study of the prompt emission of the jet+cocoon of a sGRB  
(photospheric)



3D sGRB over post NS-NS ISM  
( $\rho_{ism} = 10^{-3} M_{\odot}$ ,  $t = 0.25 \text{ s}$ ,  $D \sim 1.5 \times 10^{10} \text{ cm}$ )



Fermi's light curve...  
( $\theta_{obs} = 30^\circ$ ,  $D \sim 40 \text{ Mpc}$ )

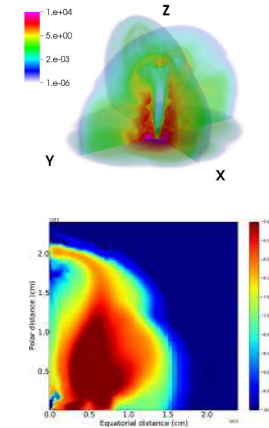
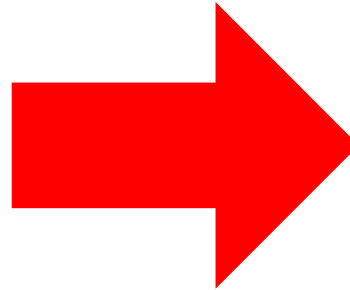


# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB

GRB170817A  $t_{90} = 2\text{s}$   
GRB170817A  $E_{\text{iso},K^*} = 10^{50} \text{ erg}$   
~sGRB  $\Gamma_{\text{jet}} = 5$  ( $\Gamma_{\infty} = 300$ )  
~sGRB  $\theta_{\text{jet}} = 16^\circ$



3D

2D

GRB170817A  $d = 40 \text{ Mpc}$   
MCMC

$(\theta_{\text{obs}}, \epsilon_e, \epsilon_B, p_e, n_{\text{ISM}})$

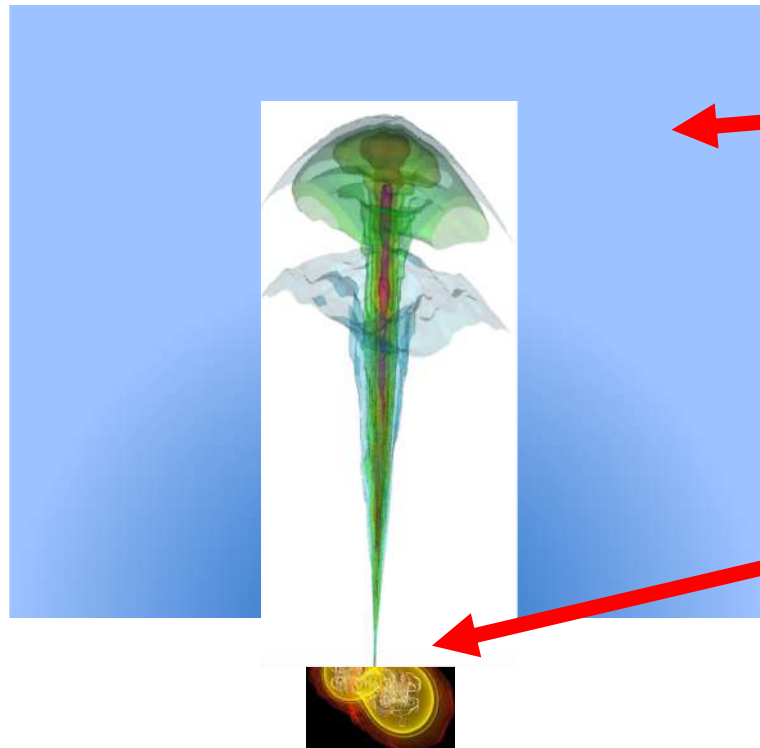


vs observations

# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB



Spherically radially  
decreasing ISM ( $\sim$ post NS-NS)

$$t_{90} = 2\text{s}$$

$$E_{\text{iso},K^*} = 10^{50} \text{ erg}$$

$$\Gamma_{\text{jet}} = 5 \quad (\Gamma_{\infty} = 300)$$

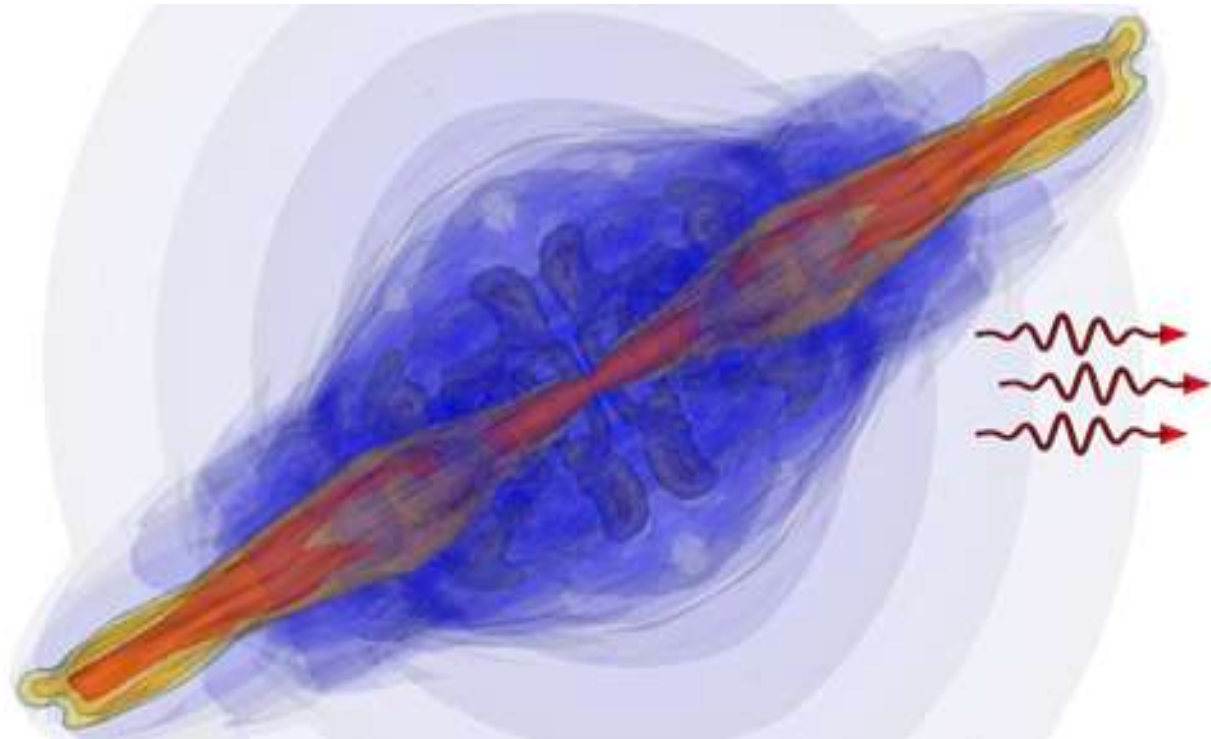
$$\theta_{\text{jet}} = 16^{\circ}$$

# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB

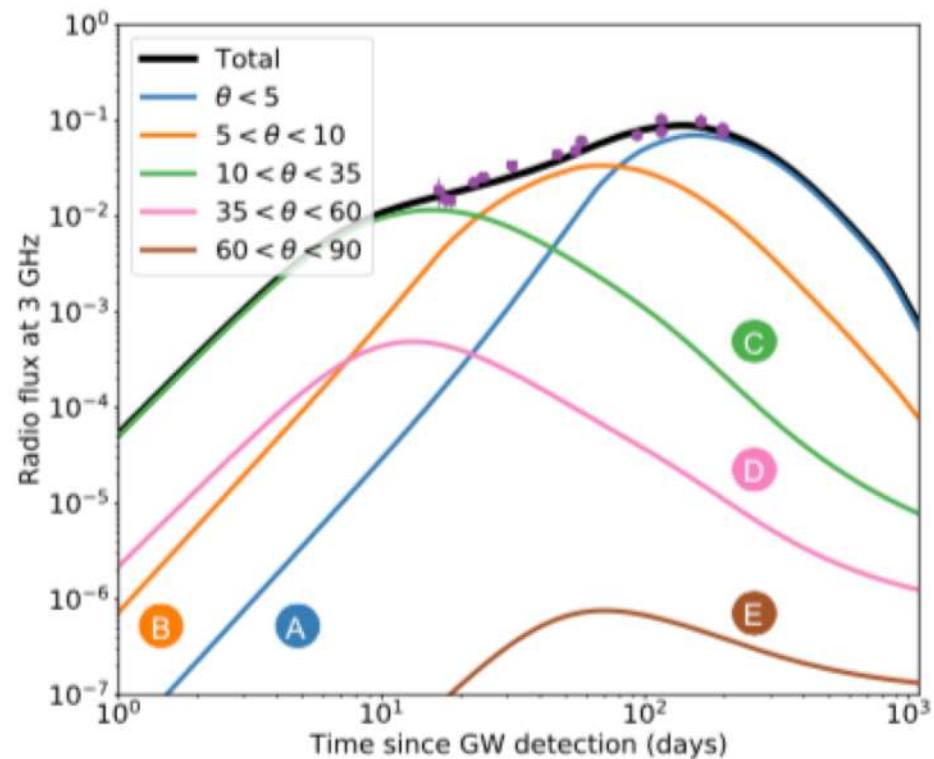
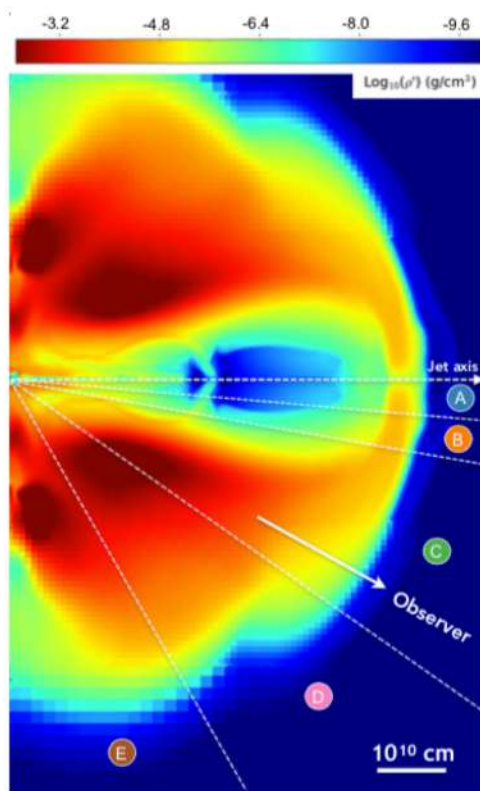
Jet  
+  
Cocoon  
+  
Seen off-axis



# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

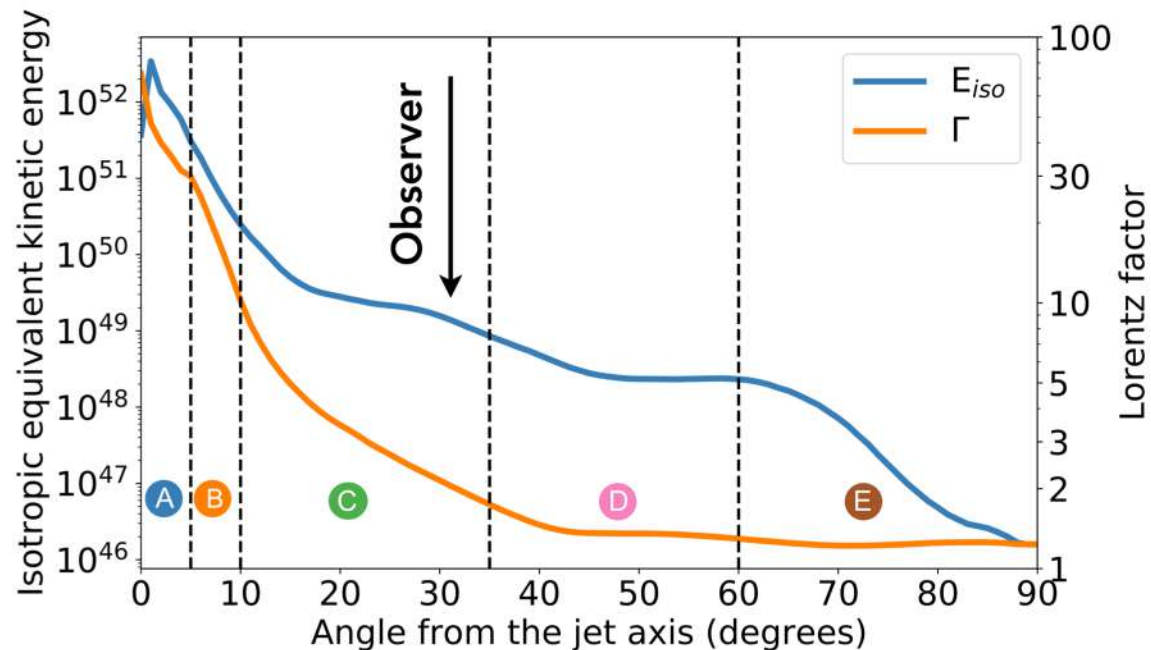
3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB



# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB



$$E_{iso} = (3.1 \pm 0.7) \times 10^{46} \text{ erg}$$

$$L_{iso} = (1.6 \pm 0.6) \times 10^{47} \text{ erg s}^{-1}$$

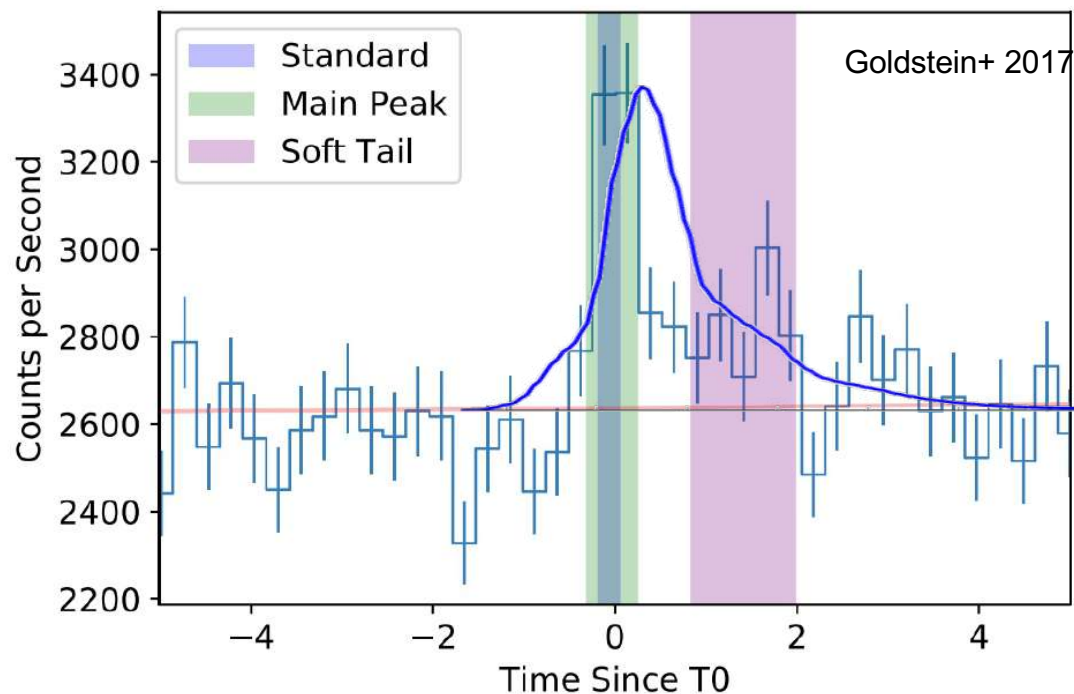
(atypical #1 ✓)



# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB



~ main pulse + soft tail

(atypical #1 ✓✓)

# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB

$$t_{90} = 2\text{s}$$

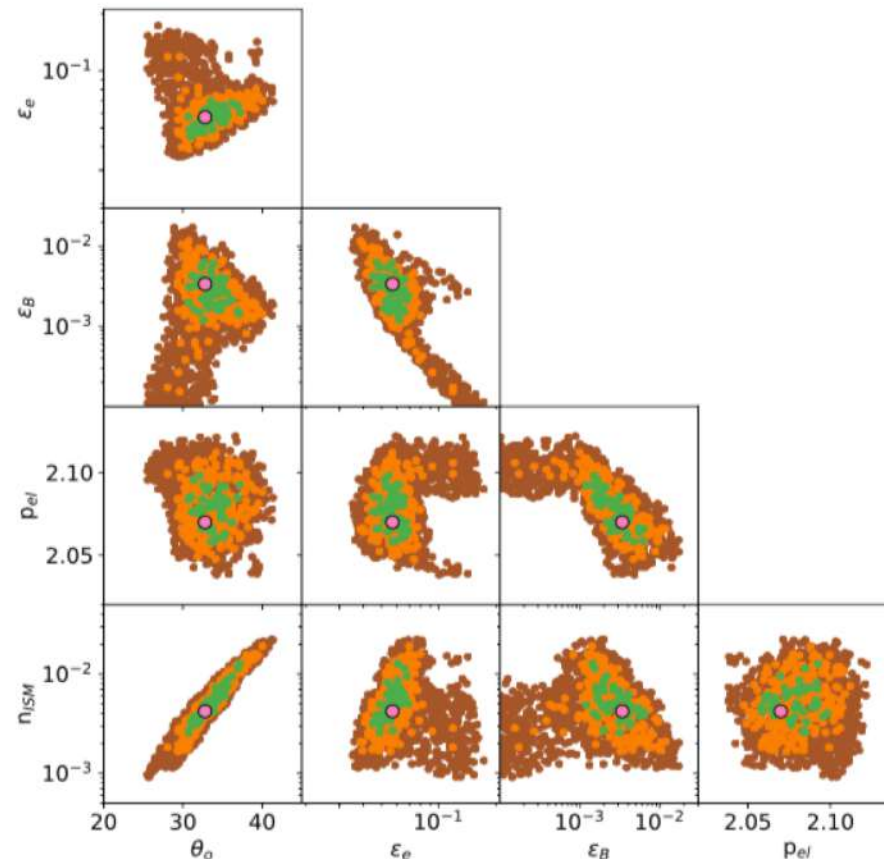
$$E_{\text{iso},K^*} = 10^{50} \text{ erg}$$

$$\Gamma_{\text{jet}} = 5 (\Gamma_{\infty}=300)$$

$$\theta_{\text{jet}} = 16^\circ$$

$$d = 40 \text{ Mpc}$$

$$\Theta_{\text{obs}}, \epsilon_e, \epsilon_B, p_{\text{el}}, n_{\text{ISM}}$$



# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB

$$t_{90} = 2\text{s}$$

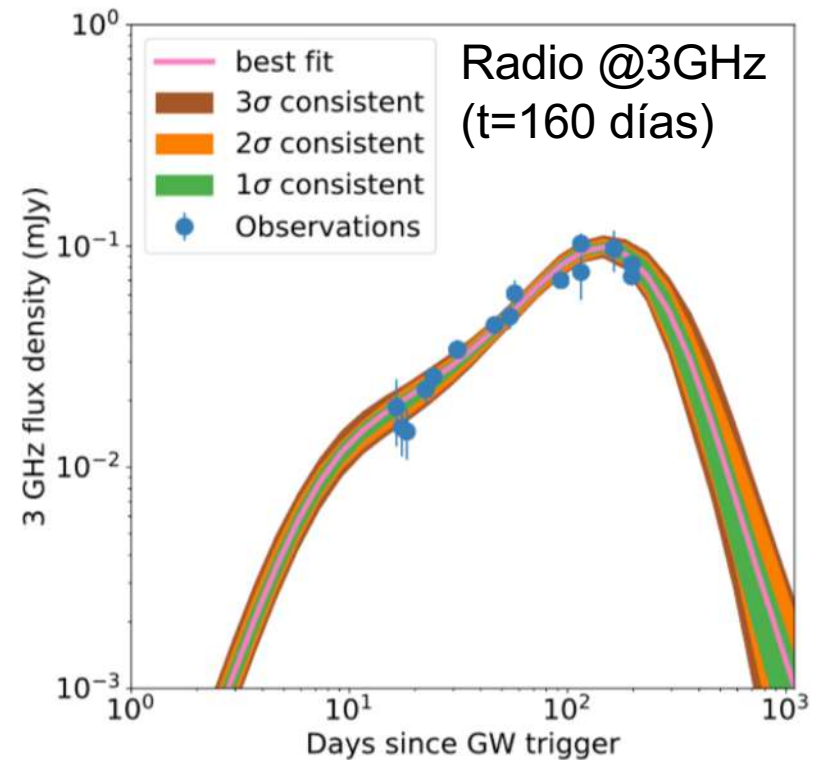
$$E_{\text{iso},K^*} = 10^{50} \text{ erg}$$

$$\Gamma_{\text{jet}} = 5 (\Gamma_{\infty}=300)$$

$$\theta_{\text{jet}} = 16^\circ$$

$$d = 40 \text{ Mpc}$$

	Structured
$\chi^2/\text{d.o.f.}$	69/56
probability	0.11 ( $1.6\sigma$ )
$E_{\text{iso}}$ (erg)	—
$\Gamma_0$	—
$\theta_j$ (degrees)	—
$\theta_o$ (degrees)	$33^{+4}_{-2.5}$
$\epsilon_e$	$0.06 \pm 0.01$
$\epsilon_B$	$0.0033 \pm 0.002$
$p_{\text{el}}$	$2.07 \pm 0.01$
$n_{\text{ISM}}$ ( $\text{cm}^{-3}$ )	$(4.2^{+8.5}_{-1.6}) \times 10^{-3}$



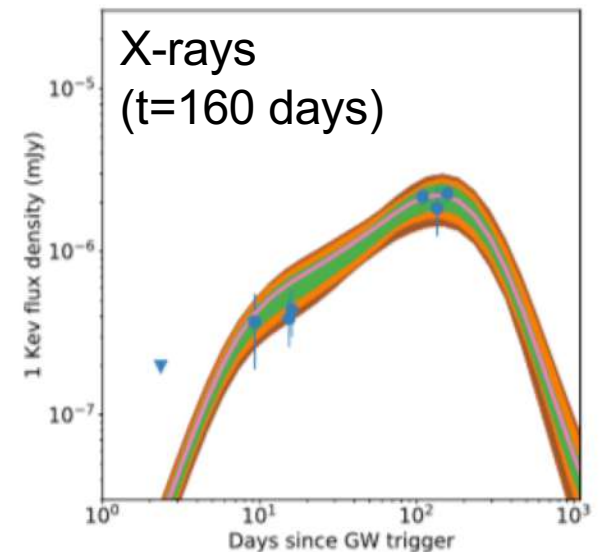
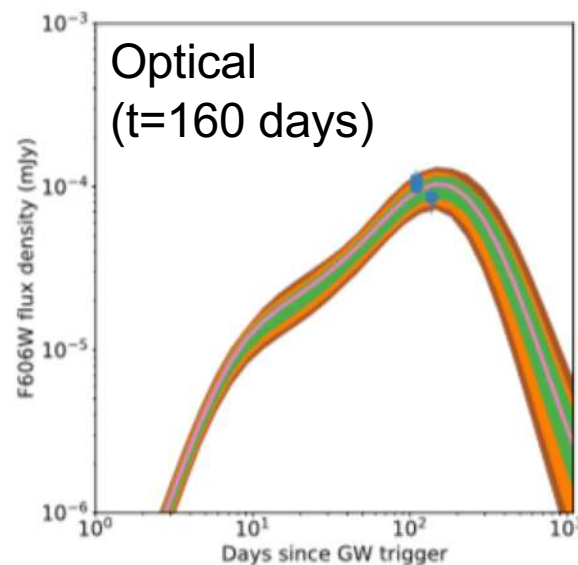
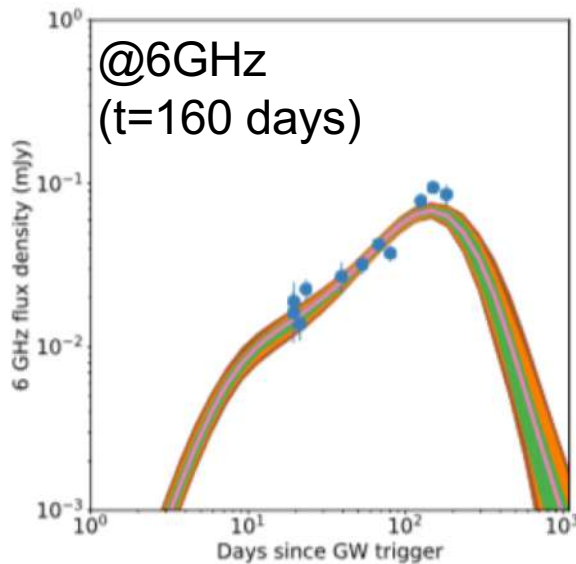
(atypical #3 )

# GRB170817A... (jet+cocoon)

After the 17/08/17 news...

3D/2DRHD+MCMC study of the afterglow of the jet+cocoon of a sGRB

X-rays after 9 days

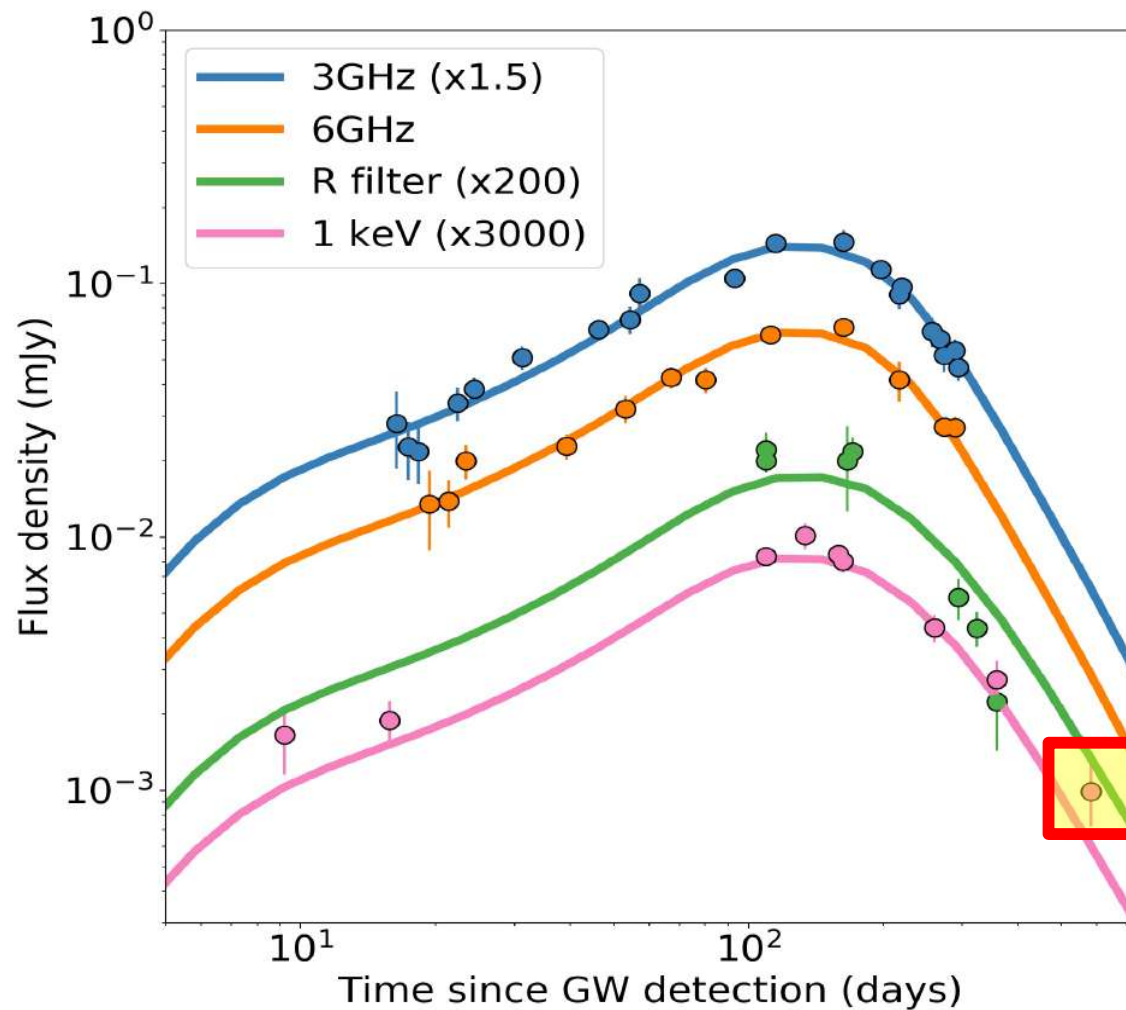


(atypical #3 ✓)

(atypical #2 ✓)  
(atypical #3 ✓)

# GRB170817A... (jet+cocoon)

Thanks Nissim



Still room for more fun:

Cocoon dominates...

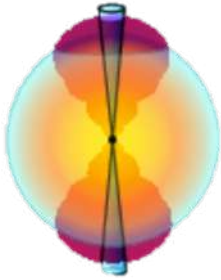
Then jet dominates...

Then cocoon dominates (again)?

(Nissim + DLC)



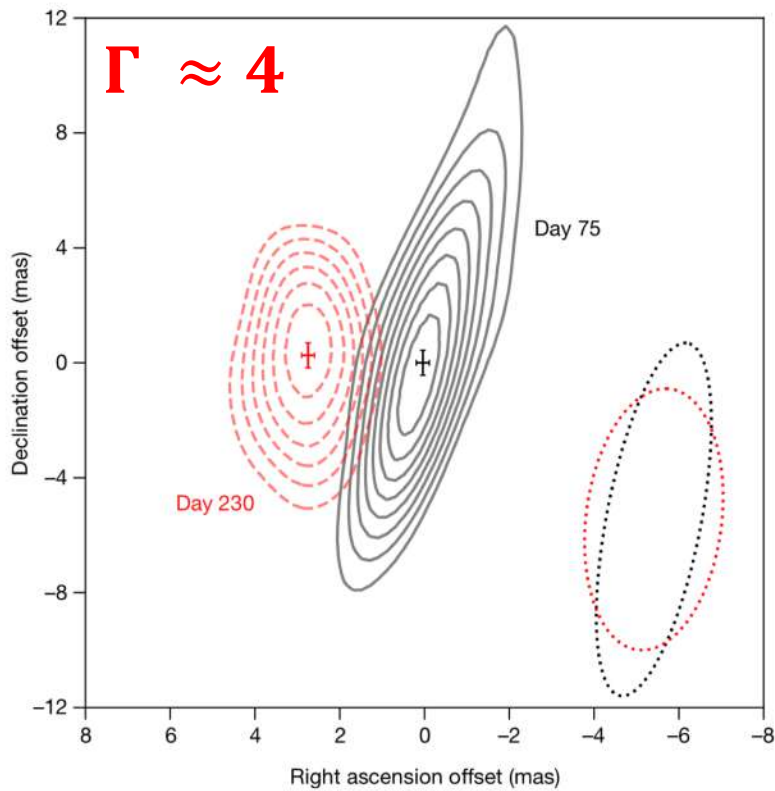
**GRB170817A... (successful or failed)**



# Jet + cocoon ("sucessfull")

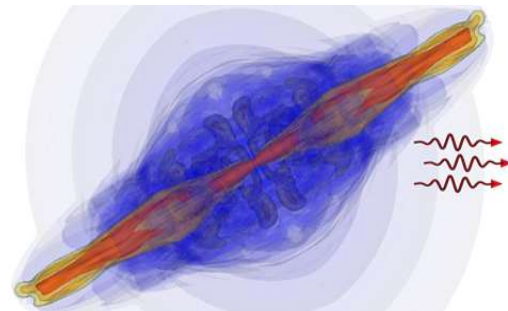
**VS**

Jet + co  
("failed")



# Superluminal motion!

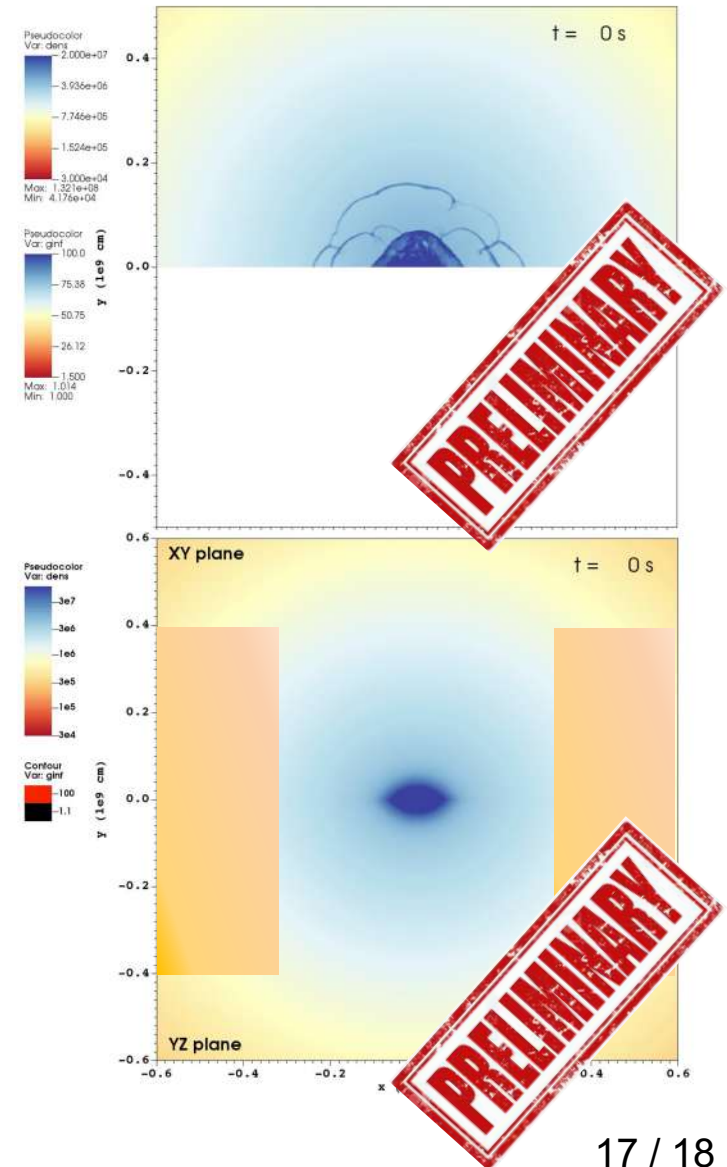
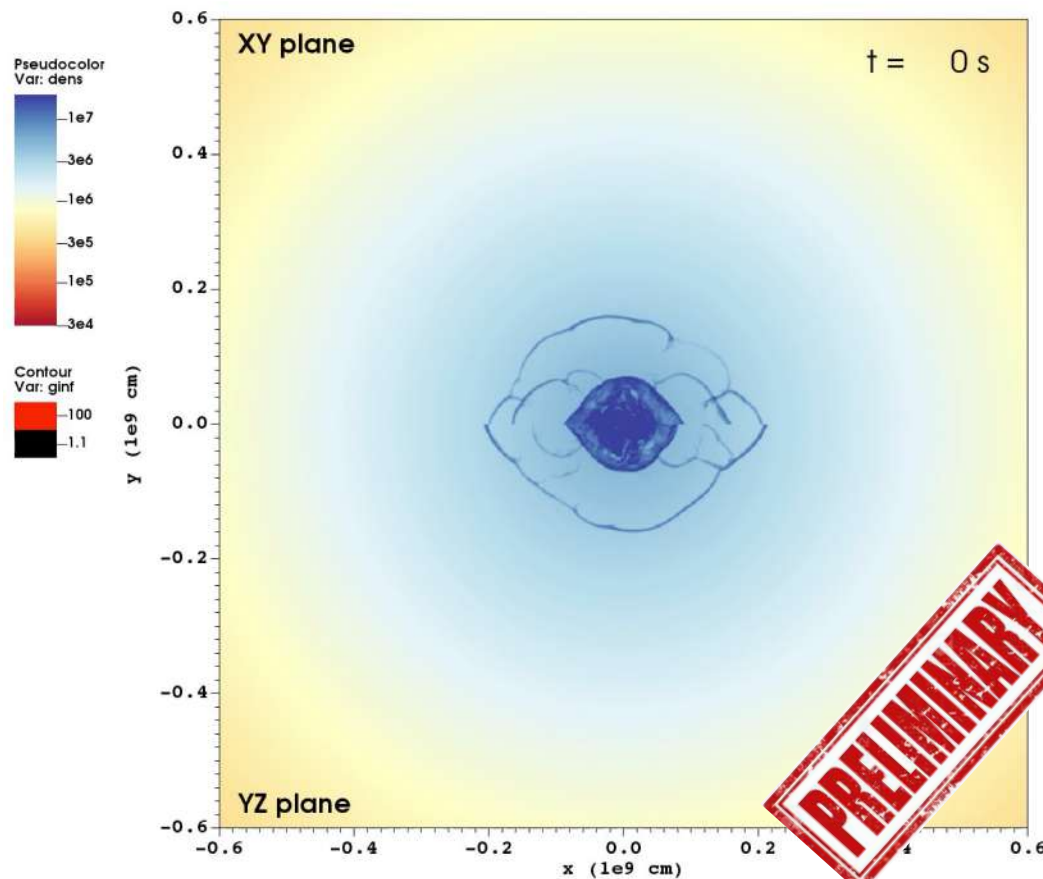
# JET!



# GRB170817A... (out of the oven results)

... we launch a 3D sGRB.

$t_{\max} \ 0.2 \text{ s} = 10^6 \text{ cpu-h} (\sim 4000 \text{ cpus} \times 1 \text{ month})$



# Conclusions

GRB170817A = sGRB (successful jet + cocoon + seen off-axis)

