GRB 170817A Associated with GW170817: Multi-frequency Observations, Modeling, and Prediction of the second peak in its afterglow

Maxim Barkov

Purdue University

ABBL RIKEN

Theoretical slides

Numerical slides

Observational slides

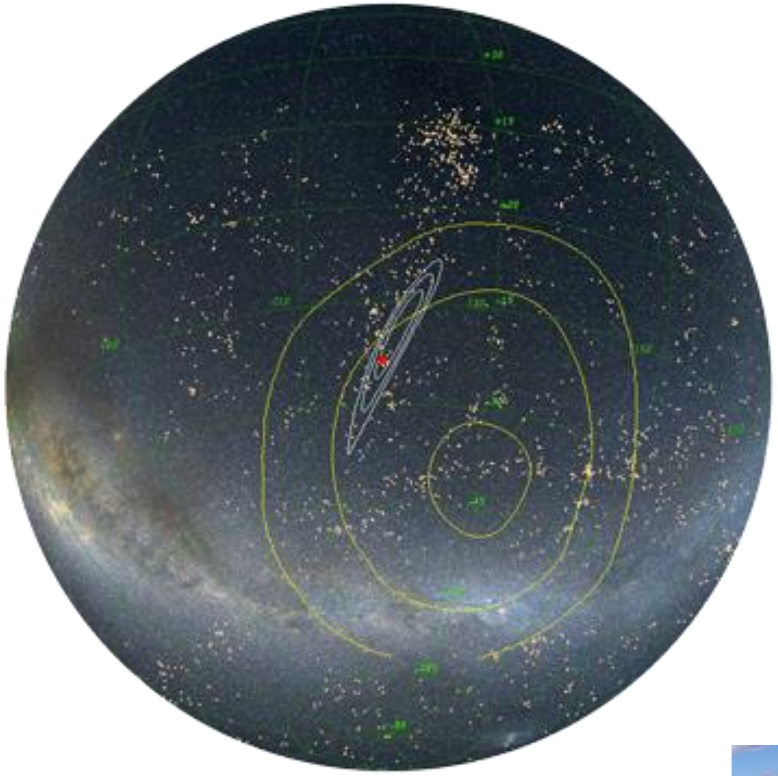
Collaborators:

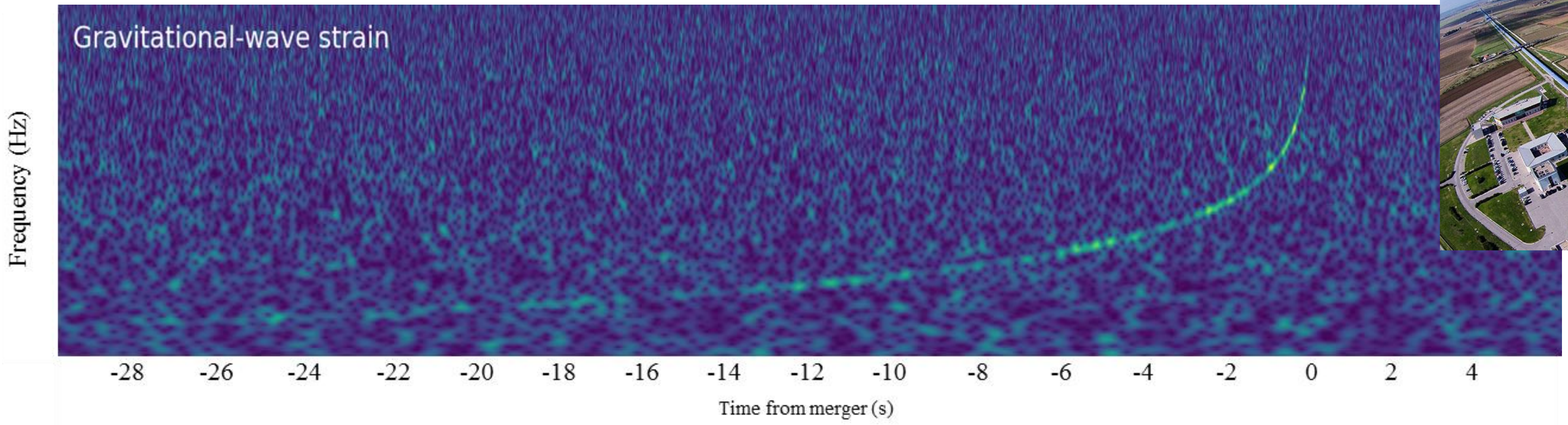
- Pozanenko A. S.; Minaev P. Yu.; Volnova A. A.; Mazaeva E. D.; Moskvitin A. S.; Krugov M. A.; Samodurov V. A.; Loznikov V. M.

- Kathirgamaraju Adithan; Luo Yonggang; Lyutikov Maxim; Giannios Dimitrios

Once upon a time in galaxy far far away

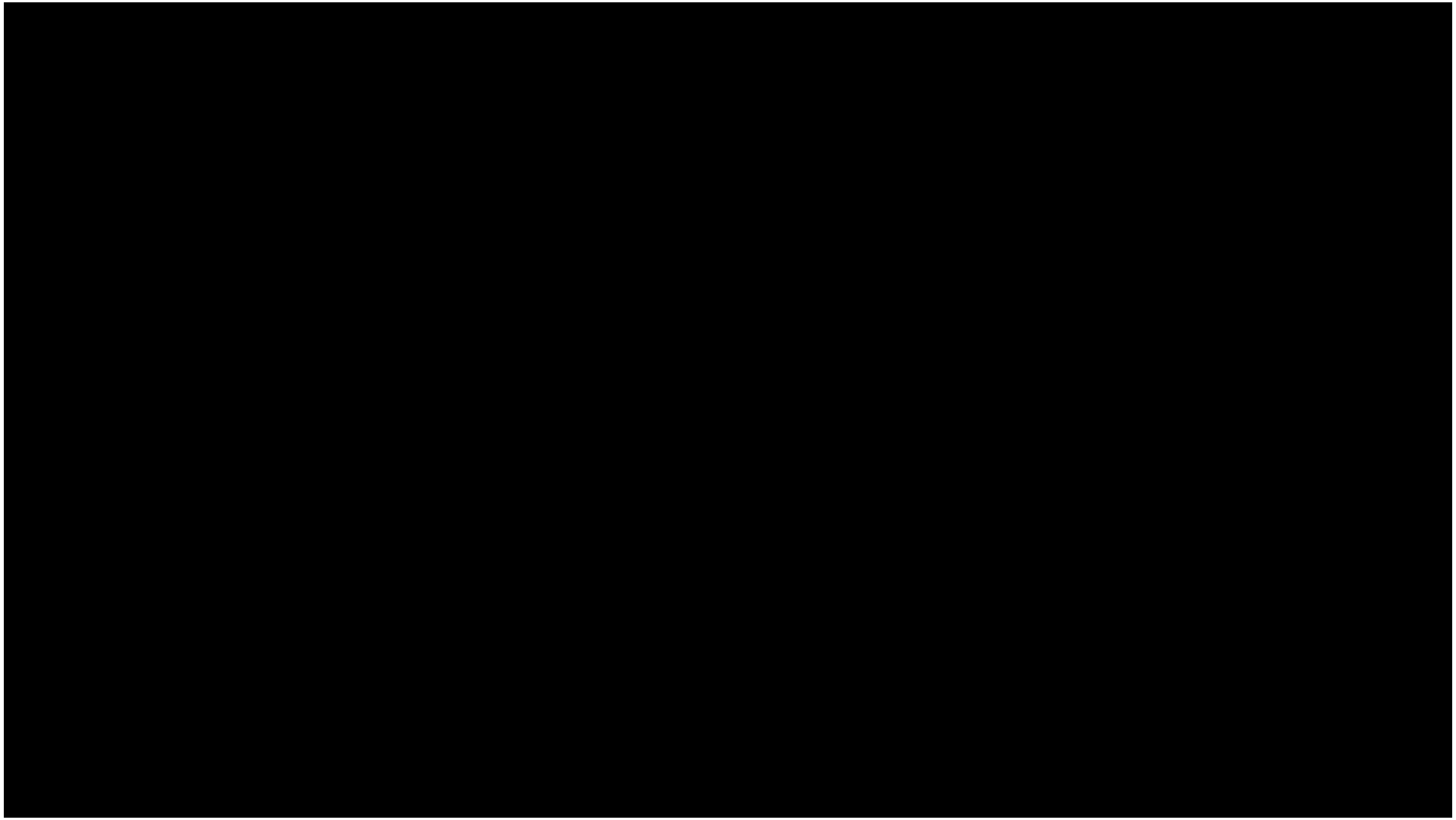
- August 17 2017…

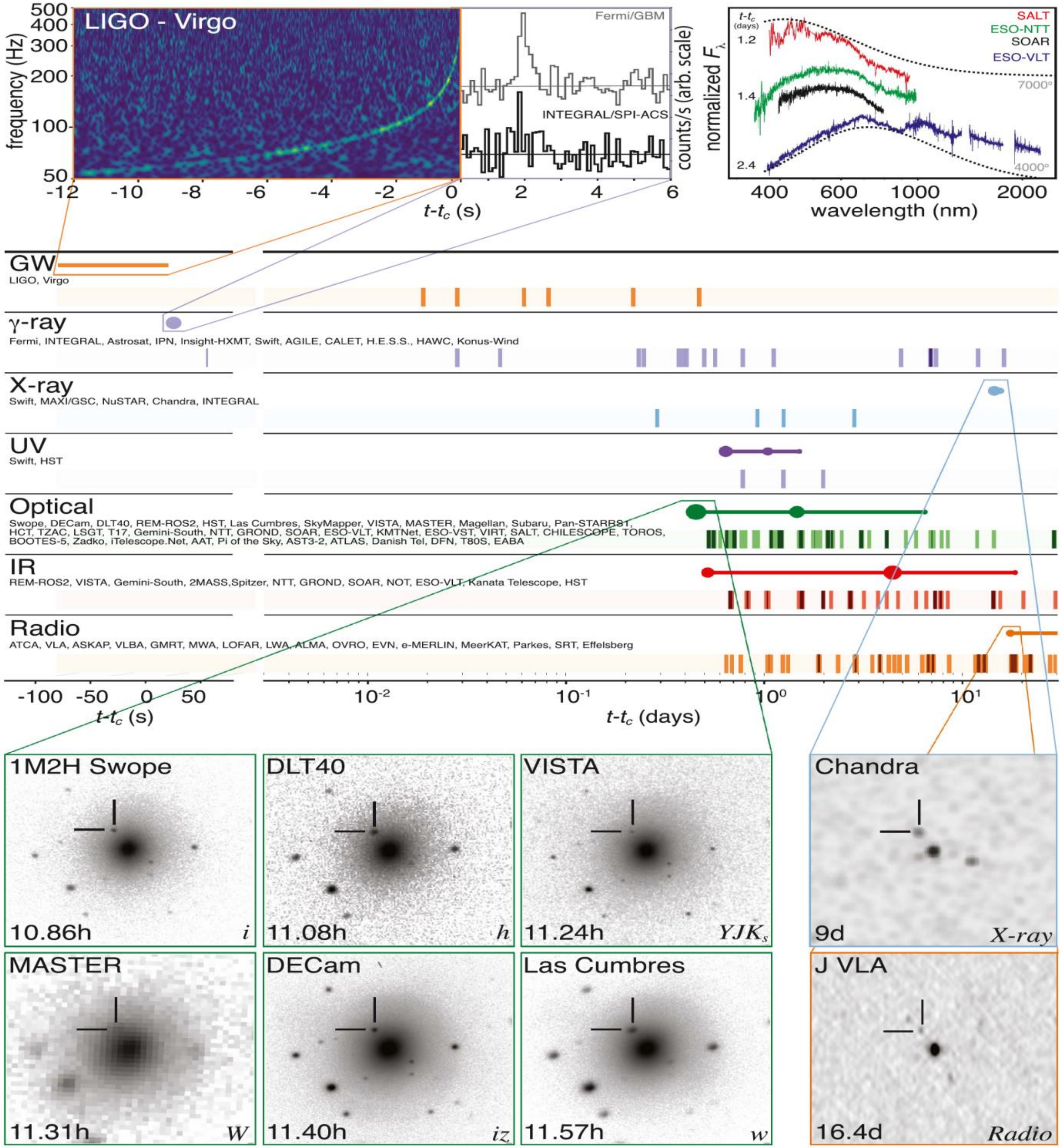


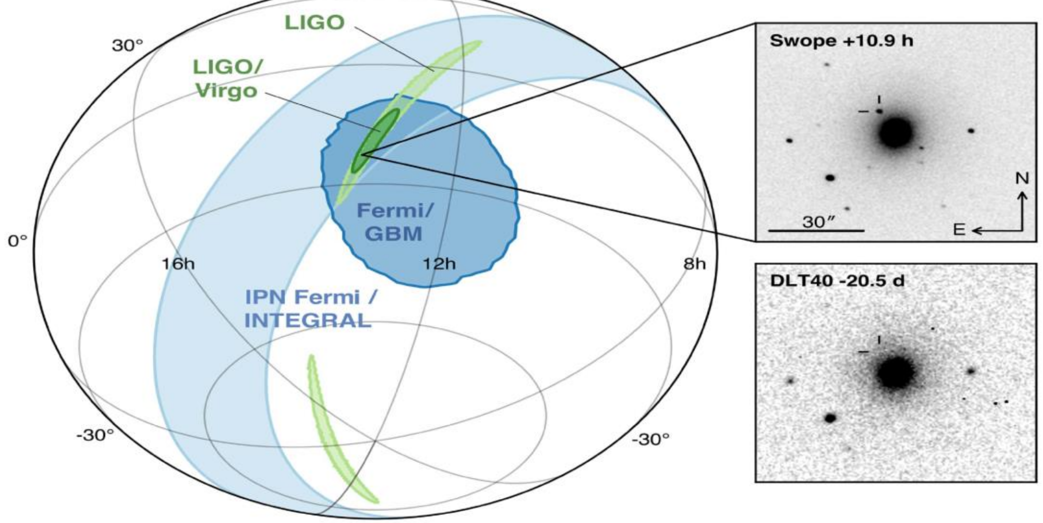


Omega Scan of LIGO's First Neutron Star Merger Detection

How the sort gamma ray burst happens







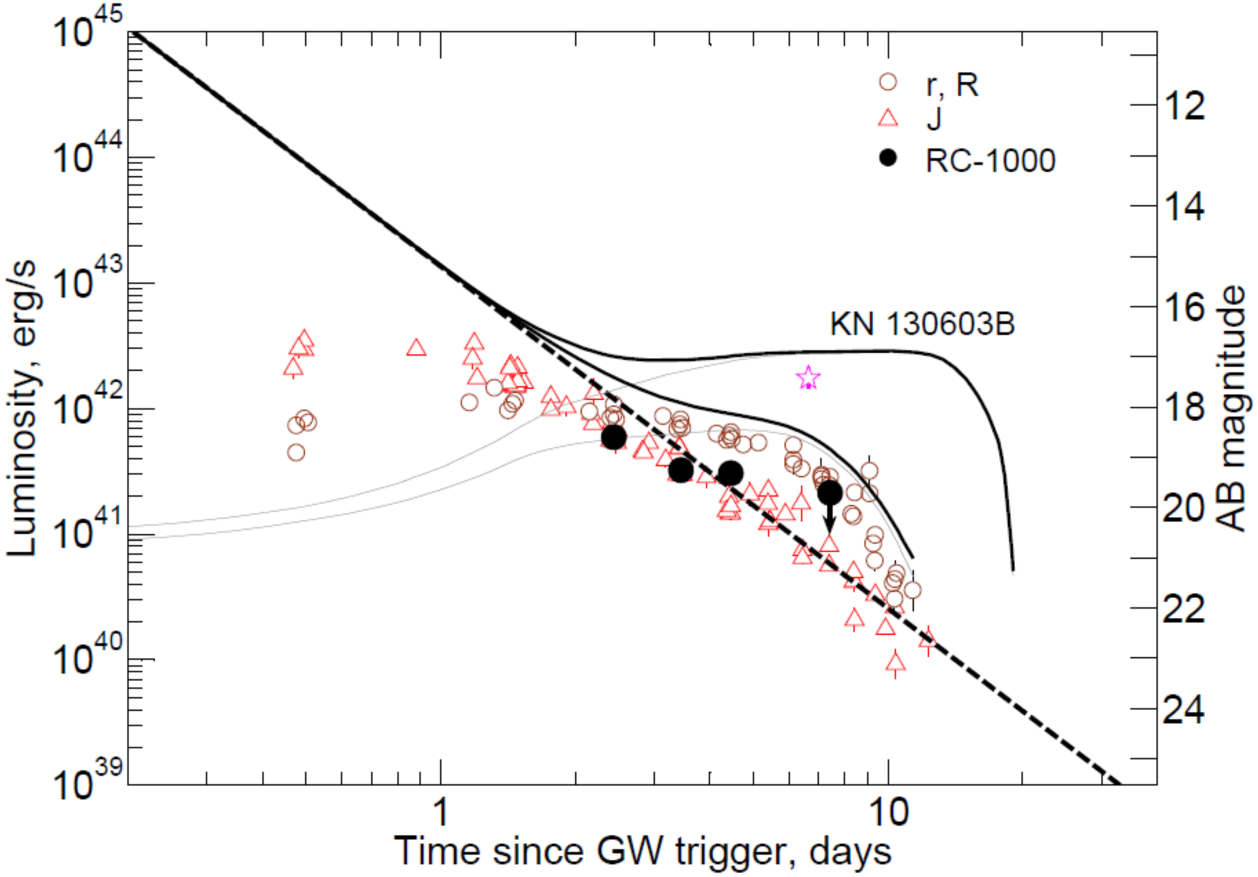
From LIGO Scientific Collaboration and Virgo Collaboration, Fermi GBM, INTEGRAL, IceCube Collaboration, AstroSat Cadmium Zinc Telluride Imager Team, IPN Collaboration, The Insight-Hxmt Collaboration, ANTARES Collaboration, The Swift Collaboration, AGILE Team, The 1M2H Team, The Dark Energy Camera GW-EM 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 ApJL 848:L12 (2017)

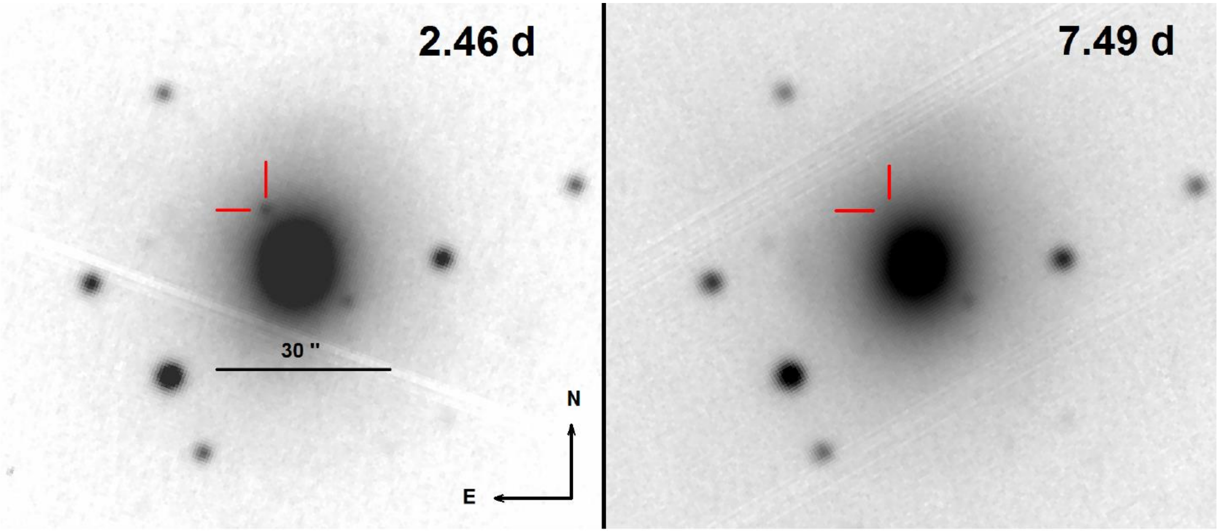
- Observations

Pozanenko et al (ApJ 852, L30, 2018)

Pozanenko et al (ApJ 852, L30, 2018)

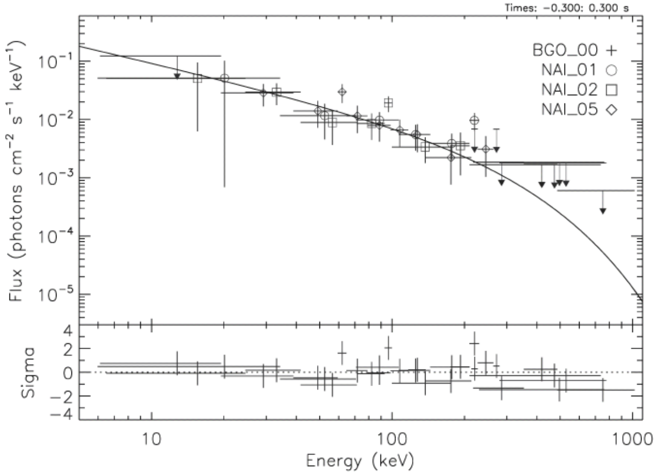
Optical observatins RC-1000 telescope

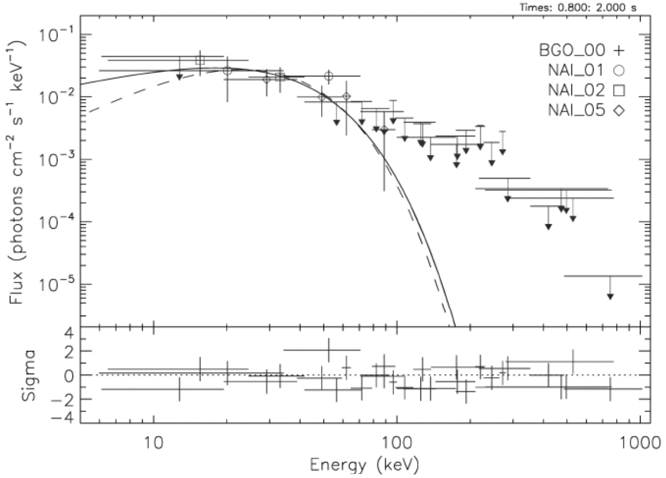


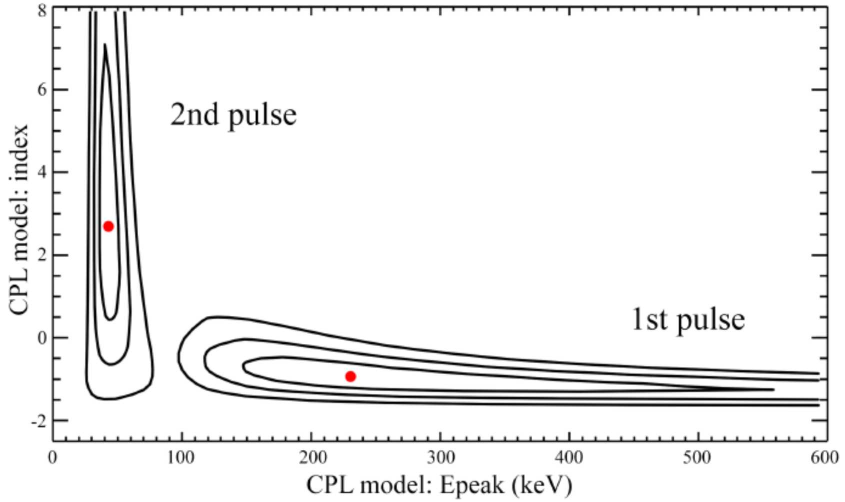


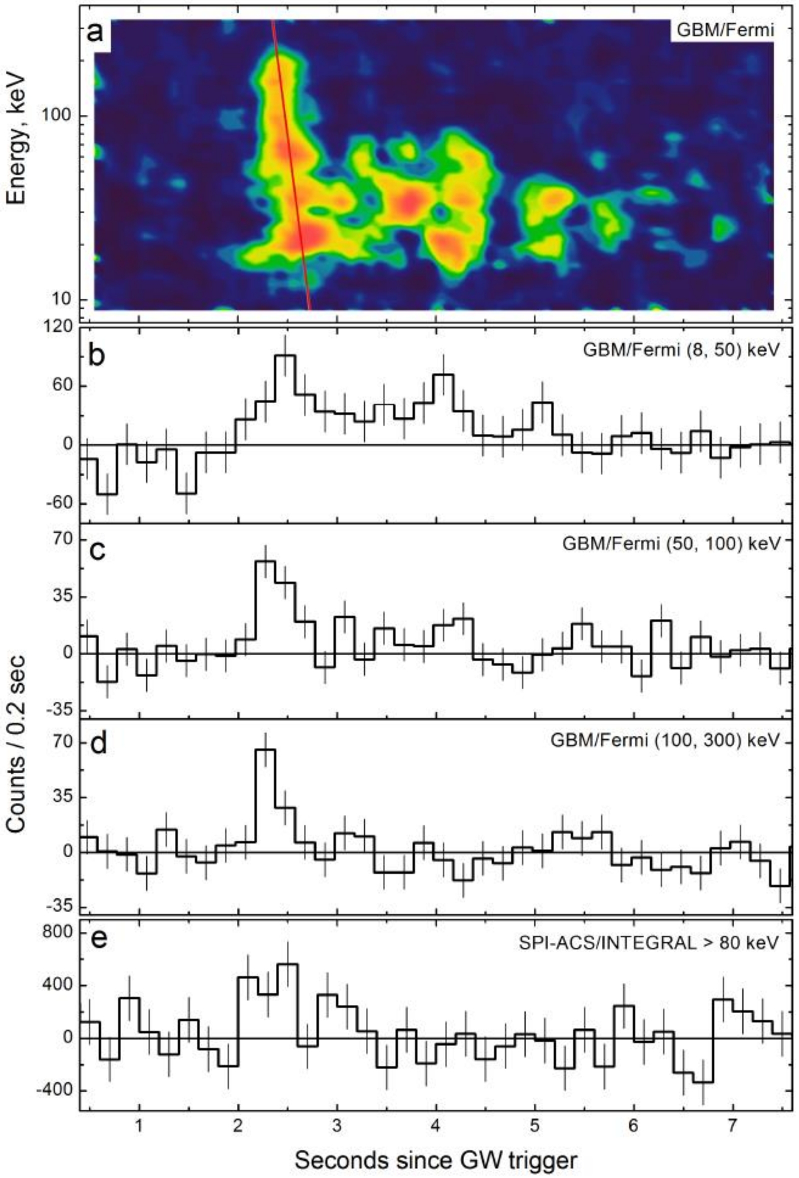
Fermi/GBM and SPI-ACS/Integral

Pozanenko et al (ApJ 852, L30, 2018)





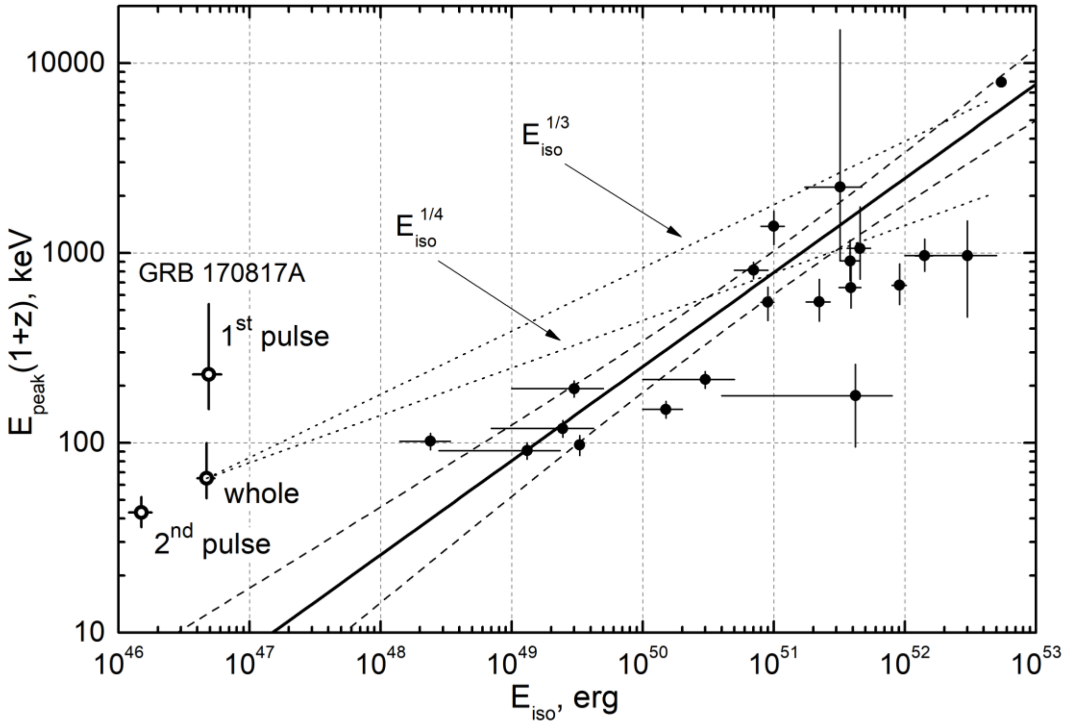




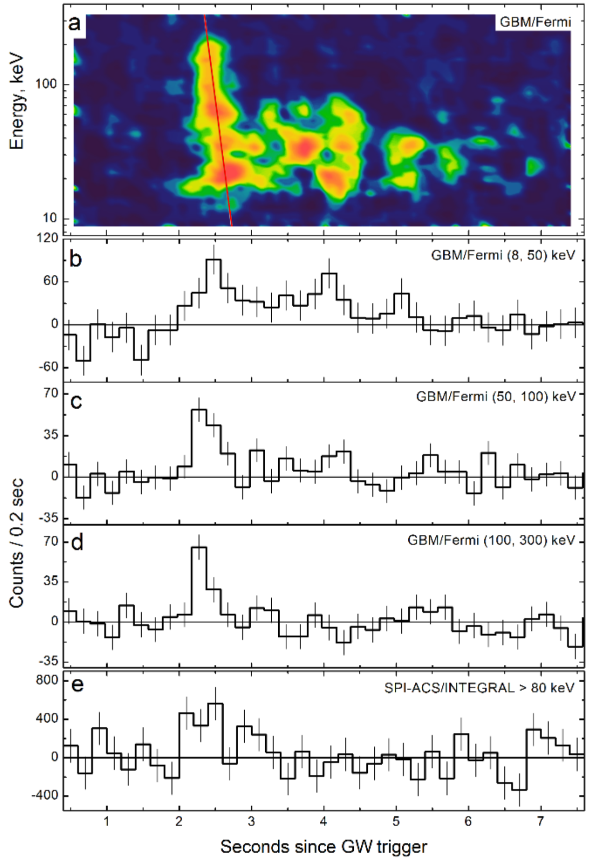
Pozanenko et al (ApJ 852, L30, 2018)

GRB170817A is a not normal sGRB!

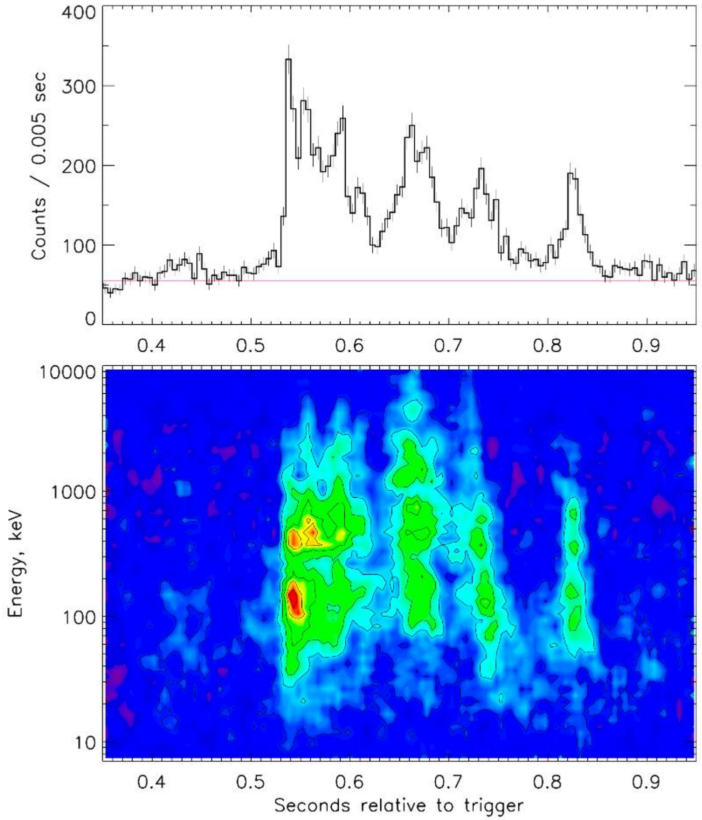
Amati relation



GRB 170817A

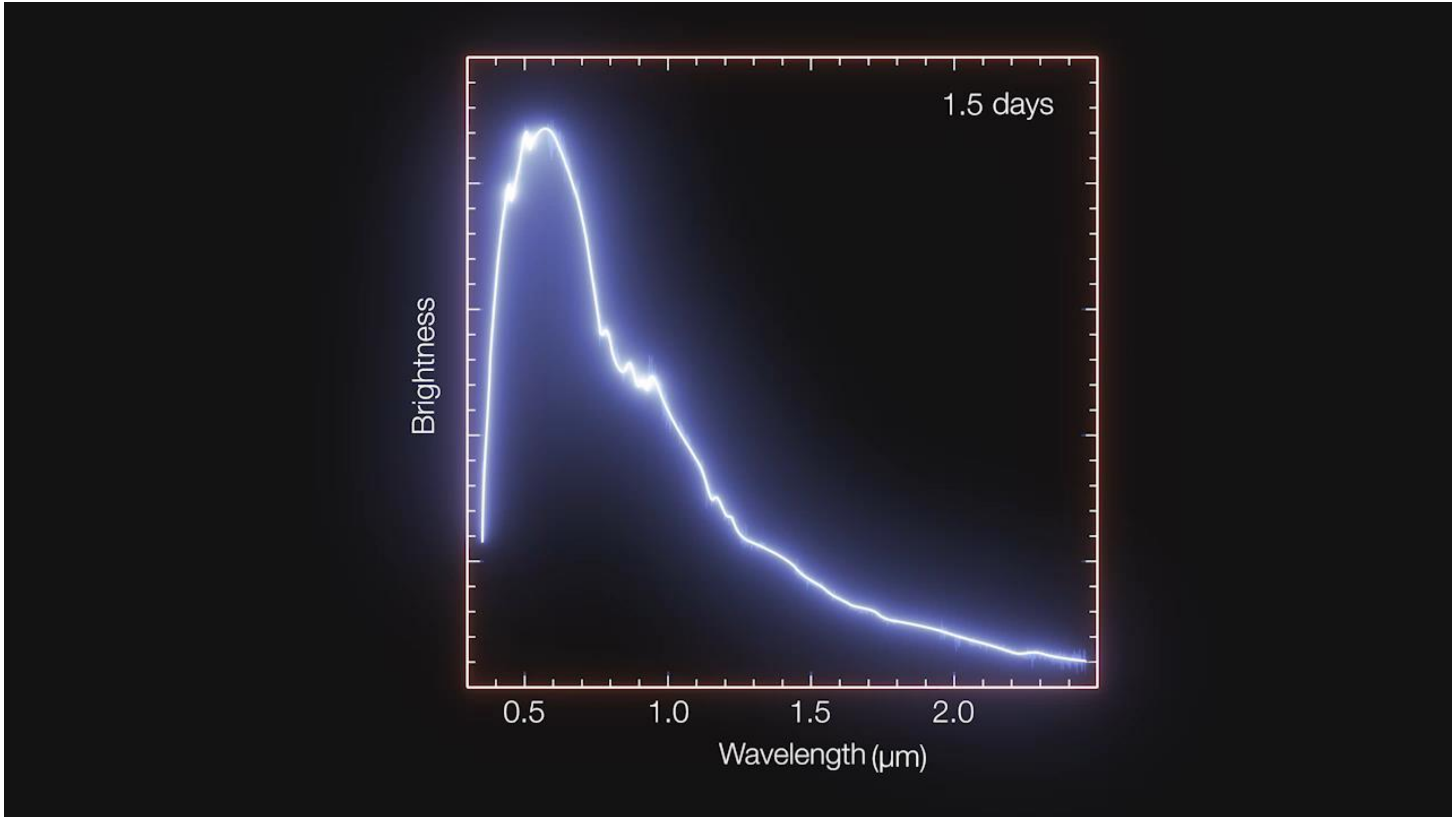


GRB 090510

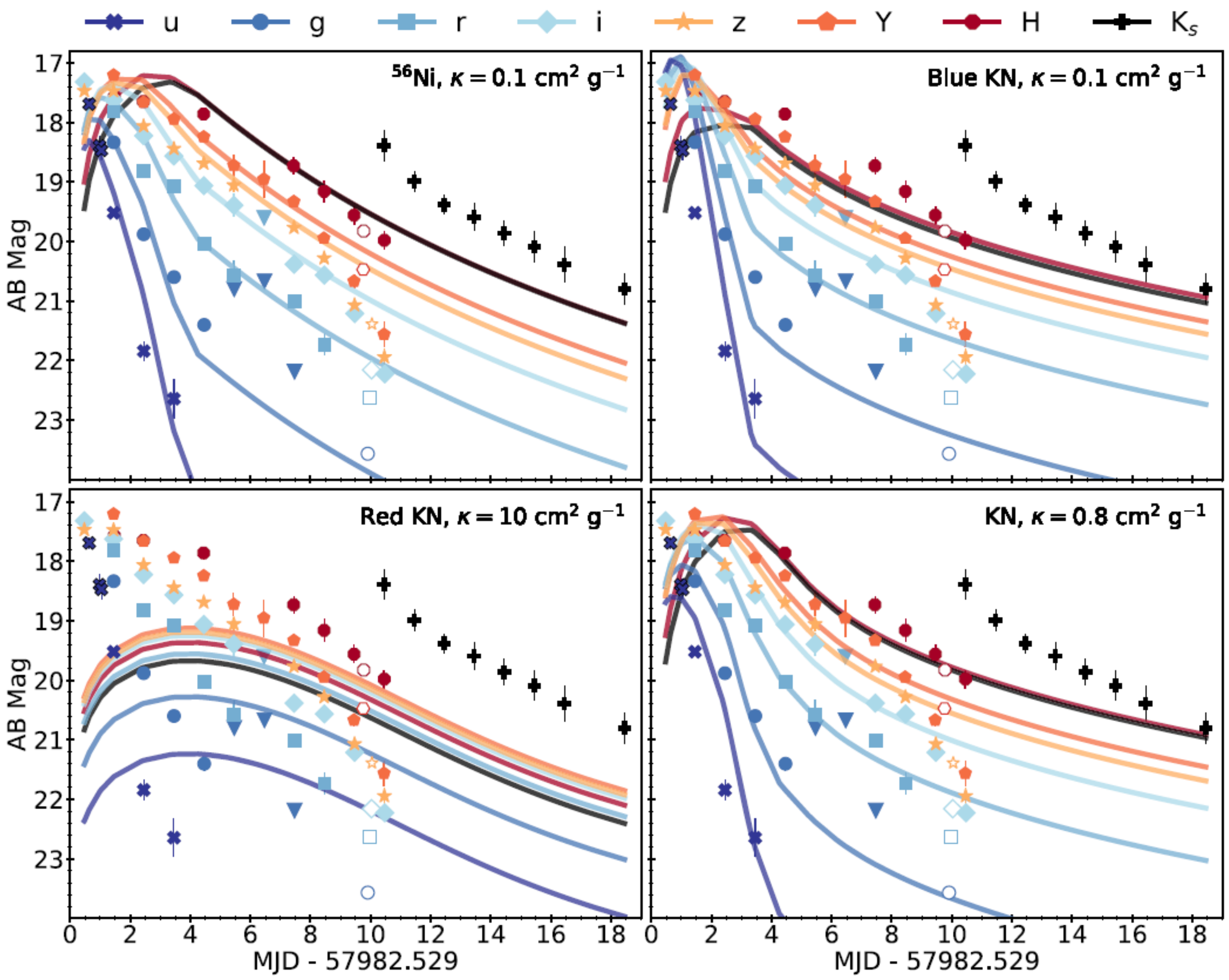


- A few comments about kilonova

VLT ESO

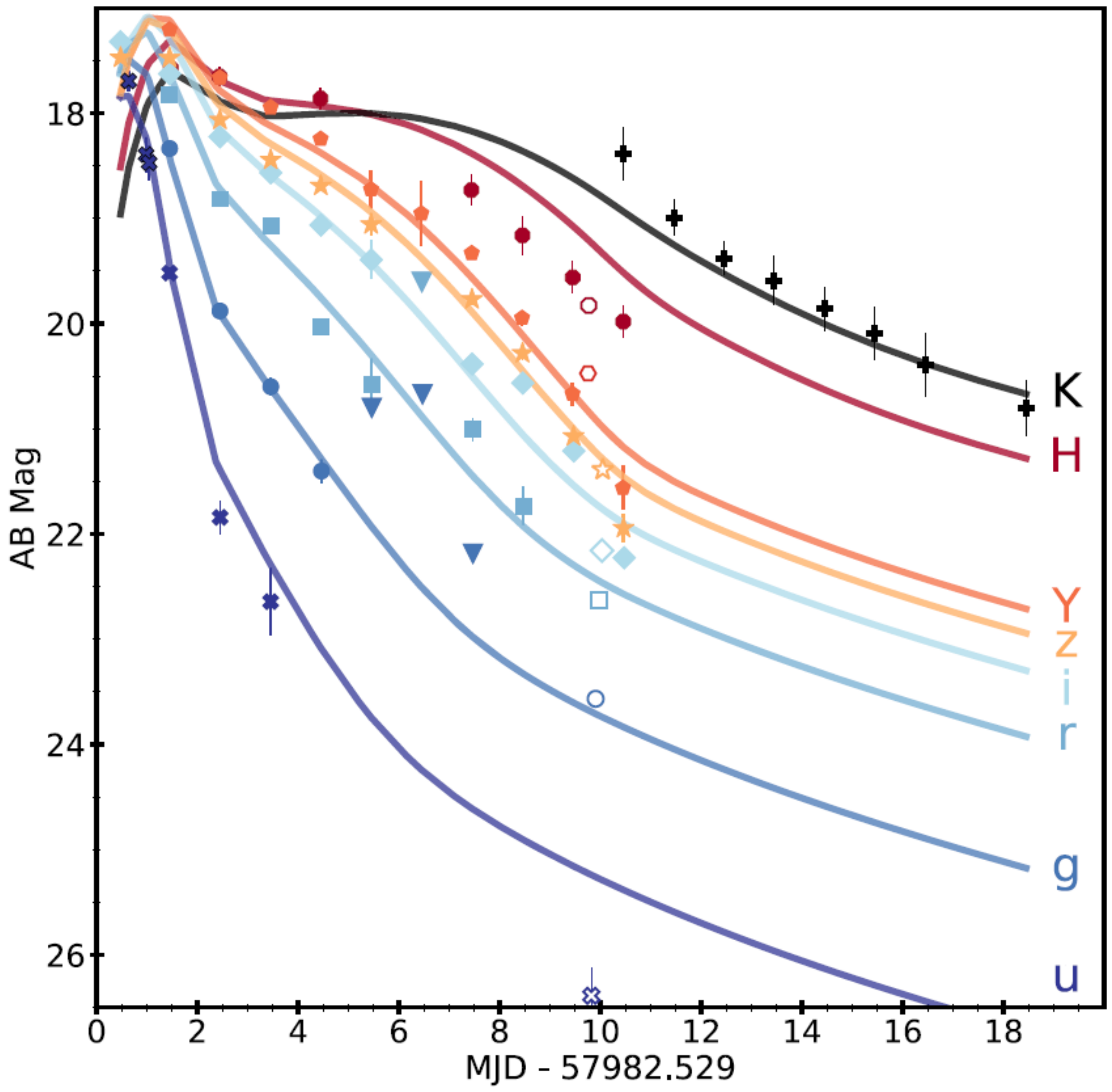


Multiple components!



From Cowperthwaite et al., ApJL 848:L17 (2017)

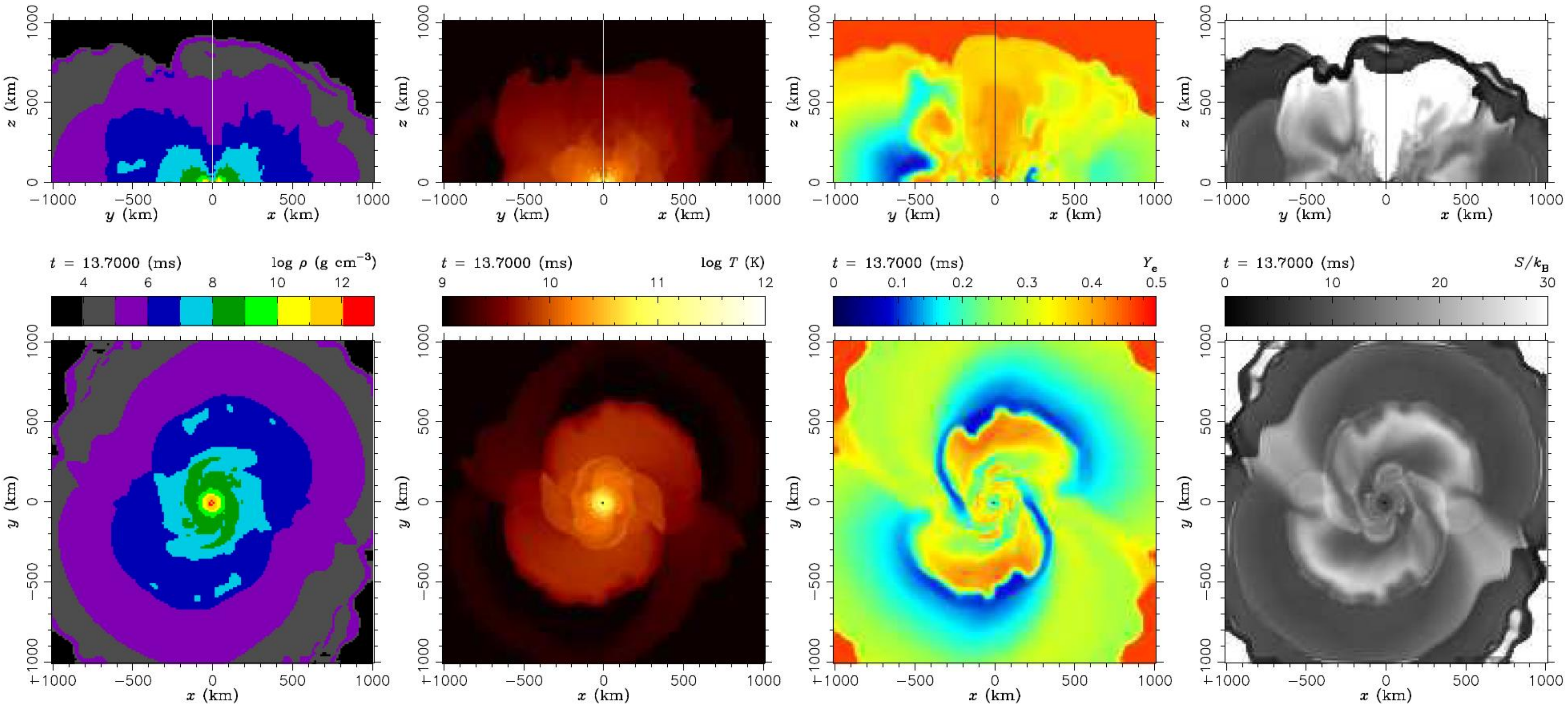
Multiple components!



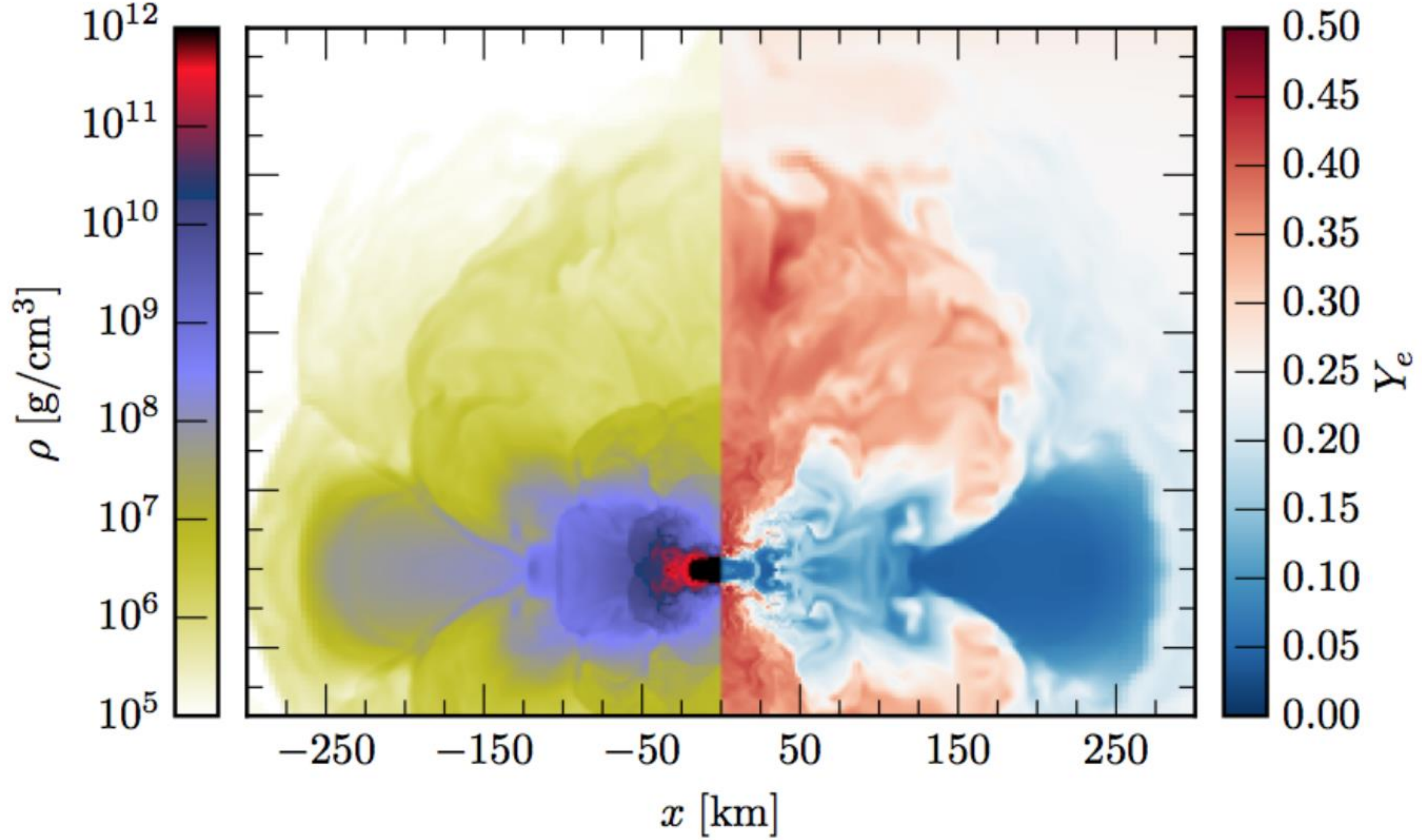
From Cowperthwaite et al., ApJL 848:L17 (2017)

NS merging modeling

Wanajo et al (2014)

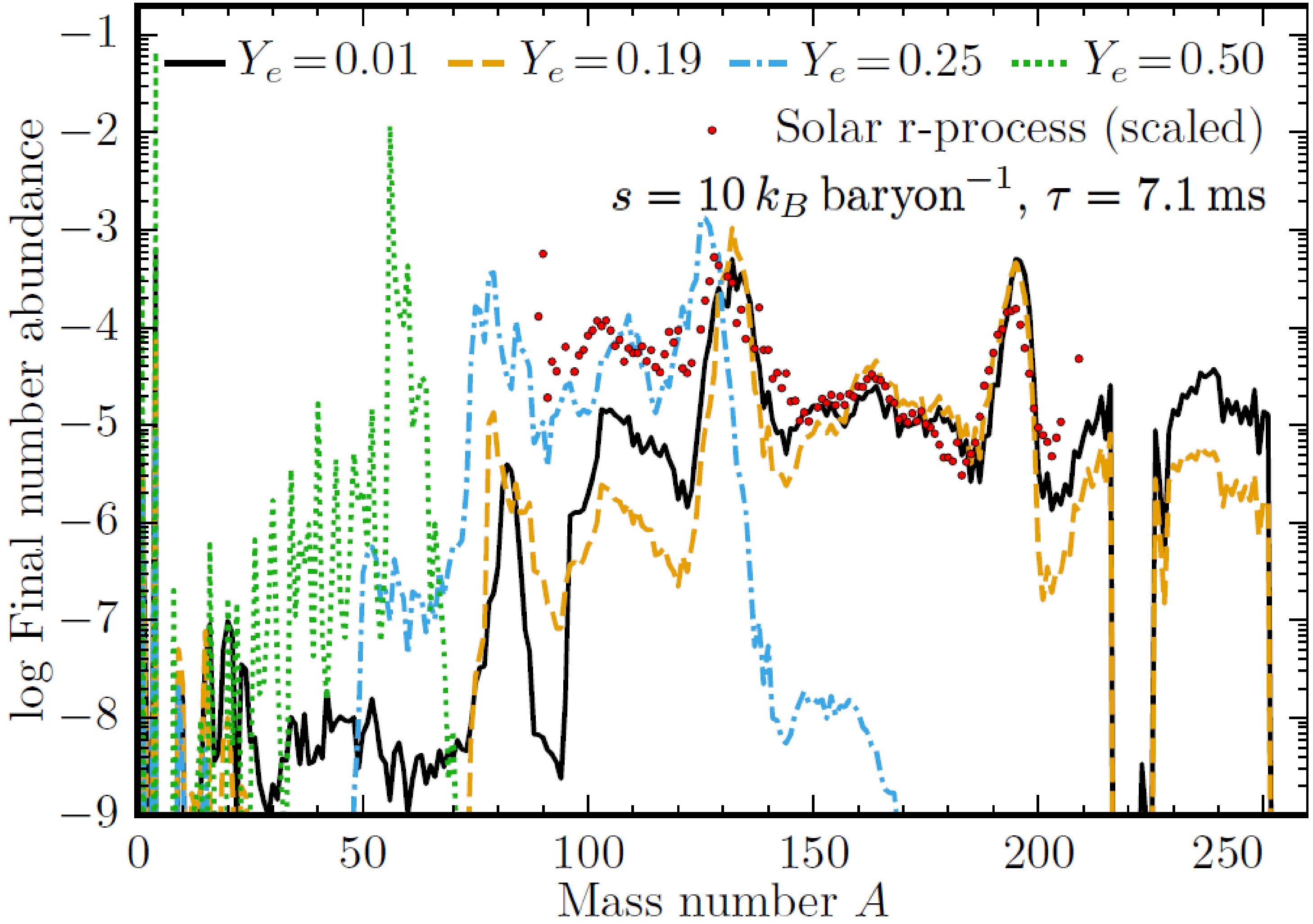


Neutron reach outflow



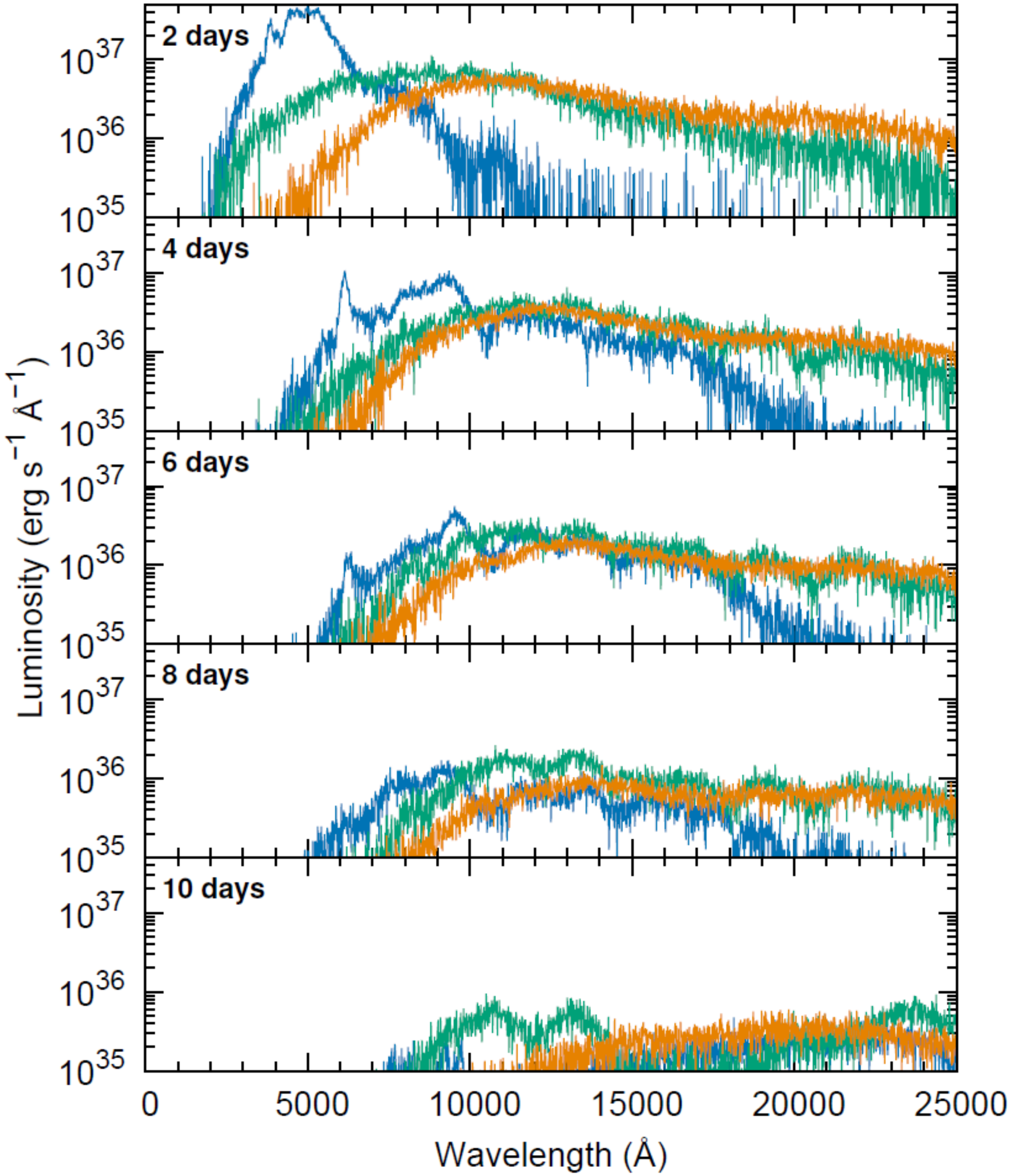
Radice at al. (2016)

Chemical composition

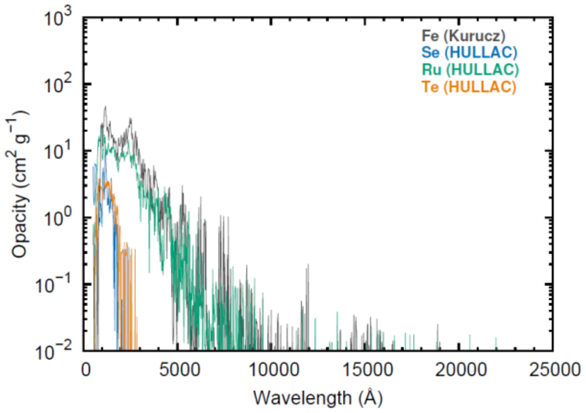


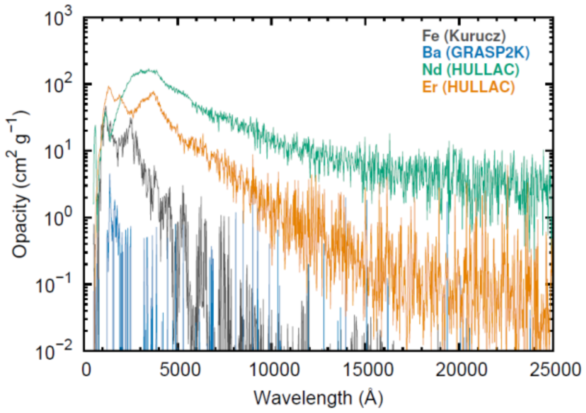
Lippuner & Roberts (2015)

Wanajo et al (2018)



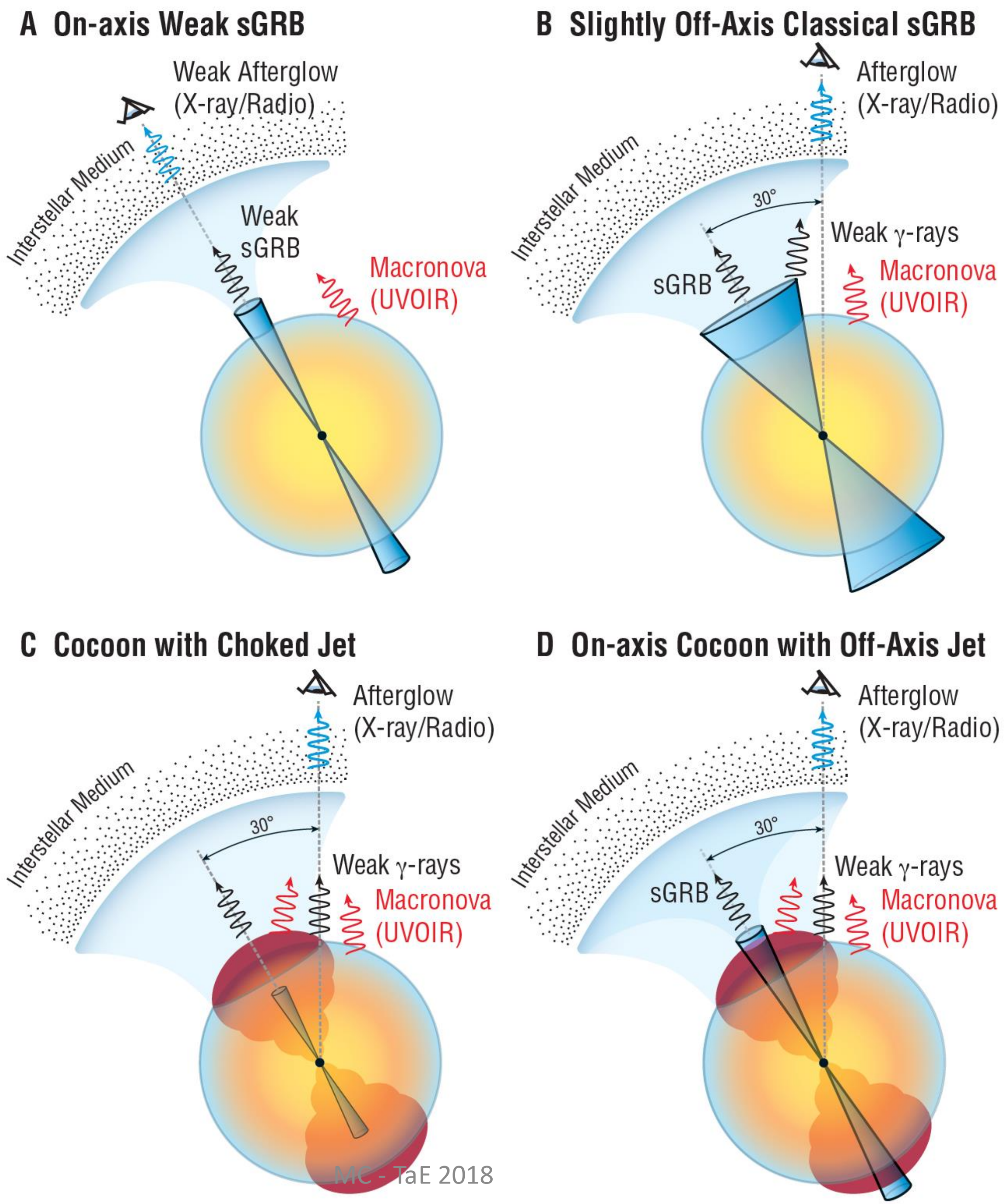
The opacities are very sensitive to the chemical composition. It leads to strong spectral evolution of kilonova.





- The model of the prompt emission

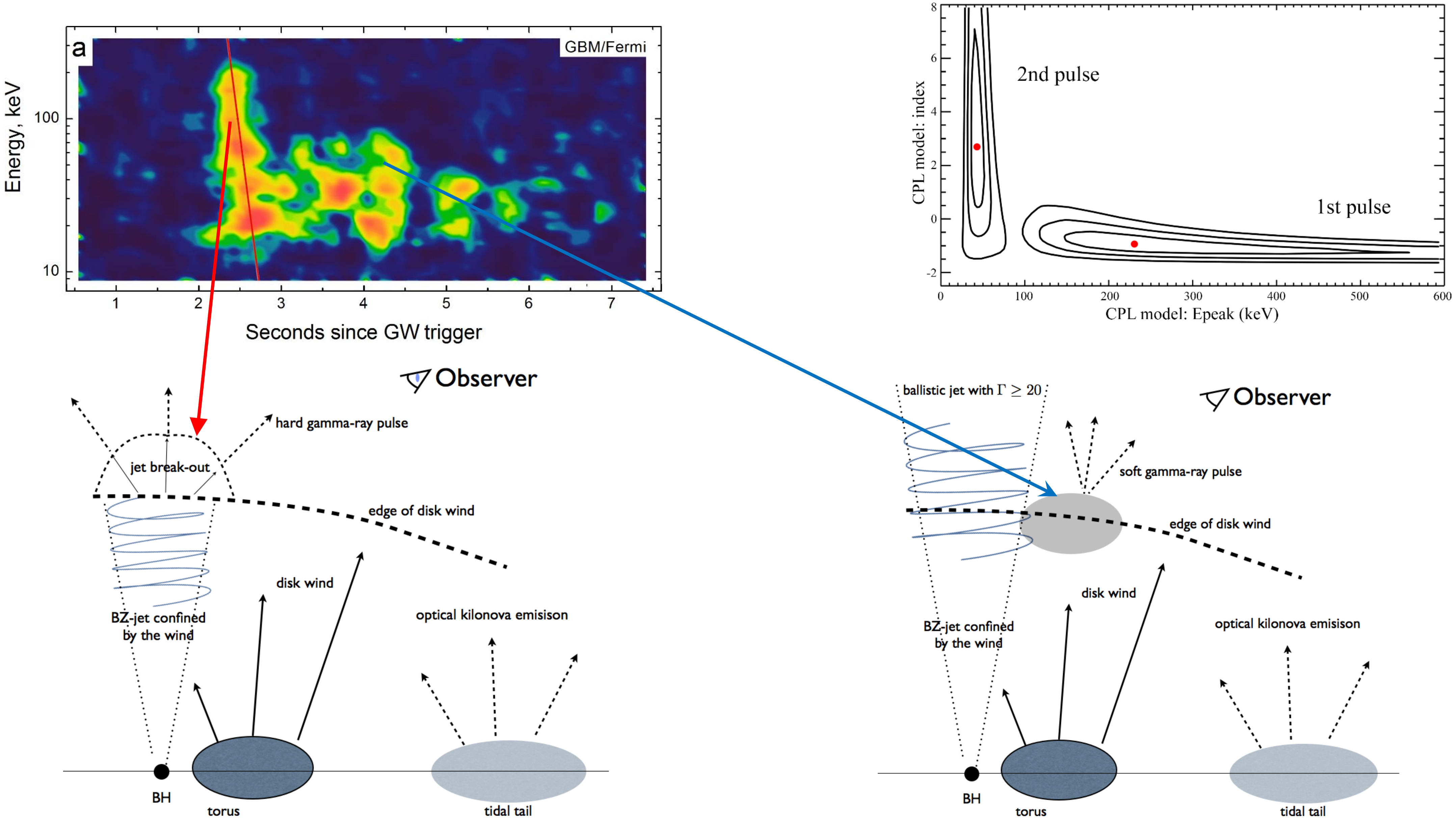
Models:



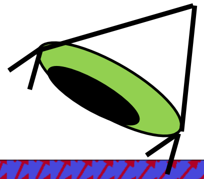
Kasliwal el al (2017)

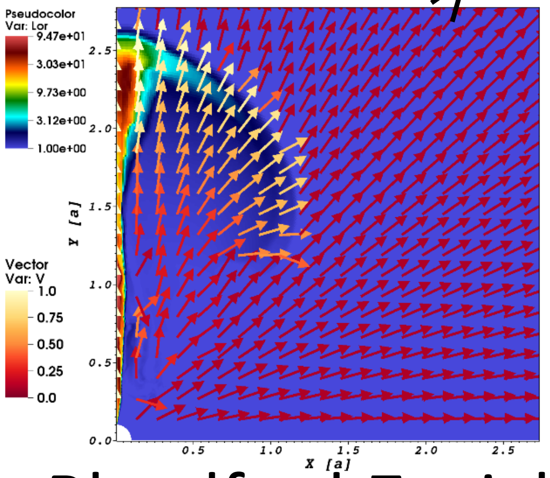
Our model:

Pozanenko et al (2018)



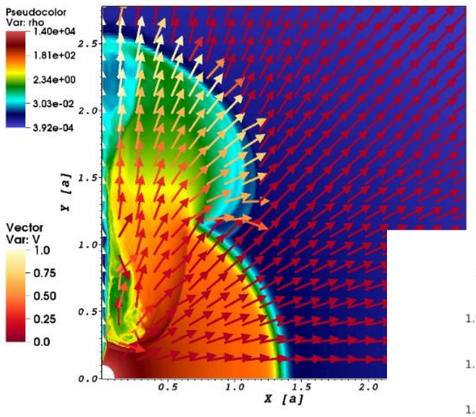
Lorentz Factor



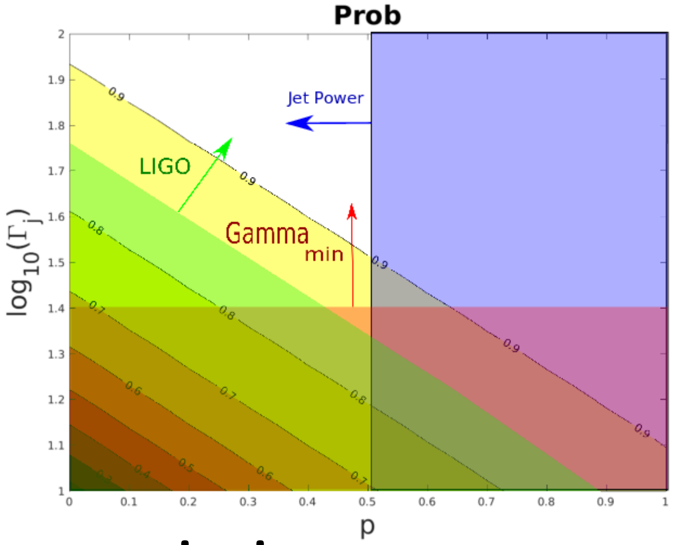


The model

Log Density

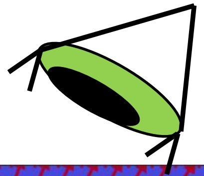


Pozanenko et al (2018)

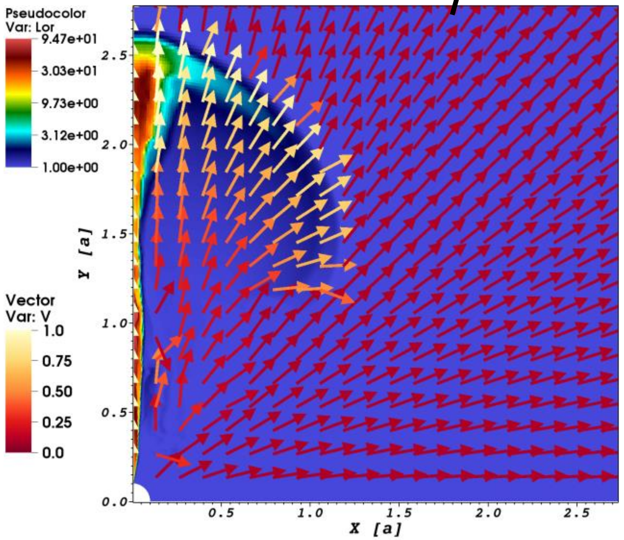


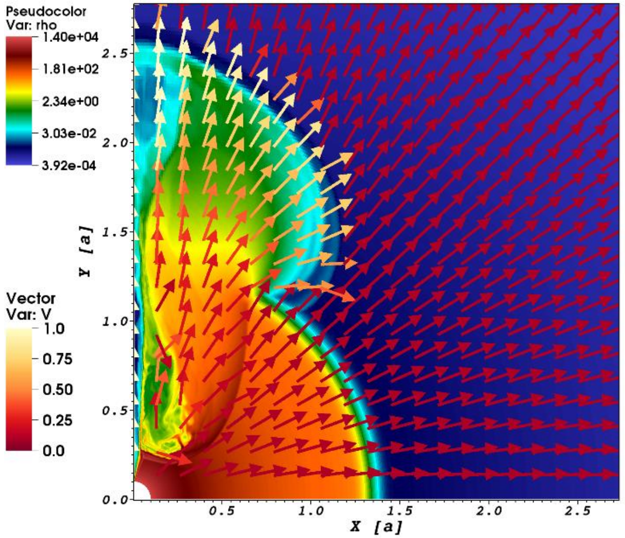
- The jet is launched by Blandford-Znajek (BZ) mechanism
- Accretion rate and jet power decrease as a power low
- We see cocoon emission as a prompt (first pulse)
- Hot shocked wind forms second extended pulse of prompt emission
- Jet is long-lived but ultra relativistic, so we do not see it due to off-axis
- The observed ~2 sec lag results from both the delay of activation of BZ-jet and the jet propagation through expanding envelope

Preliminary results: 2D RHD



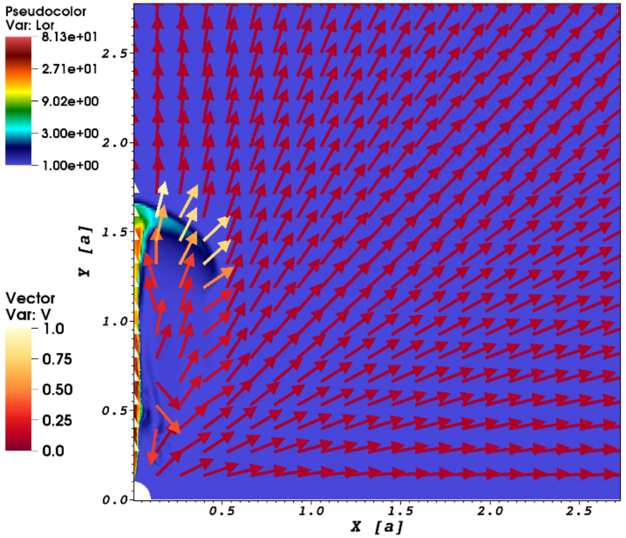
Lorentz Factor

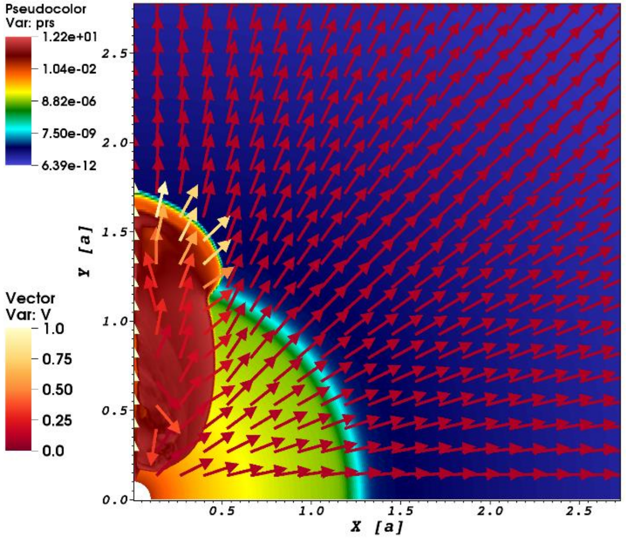




Log Density

Lorentz Factor



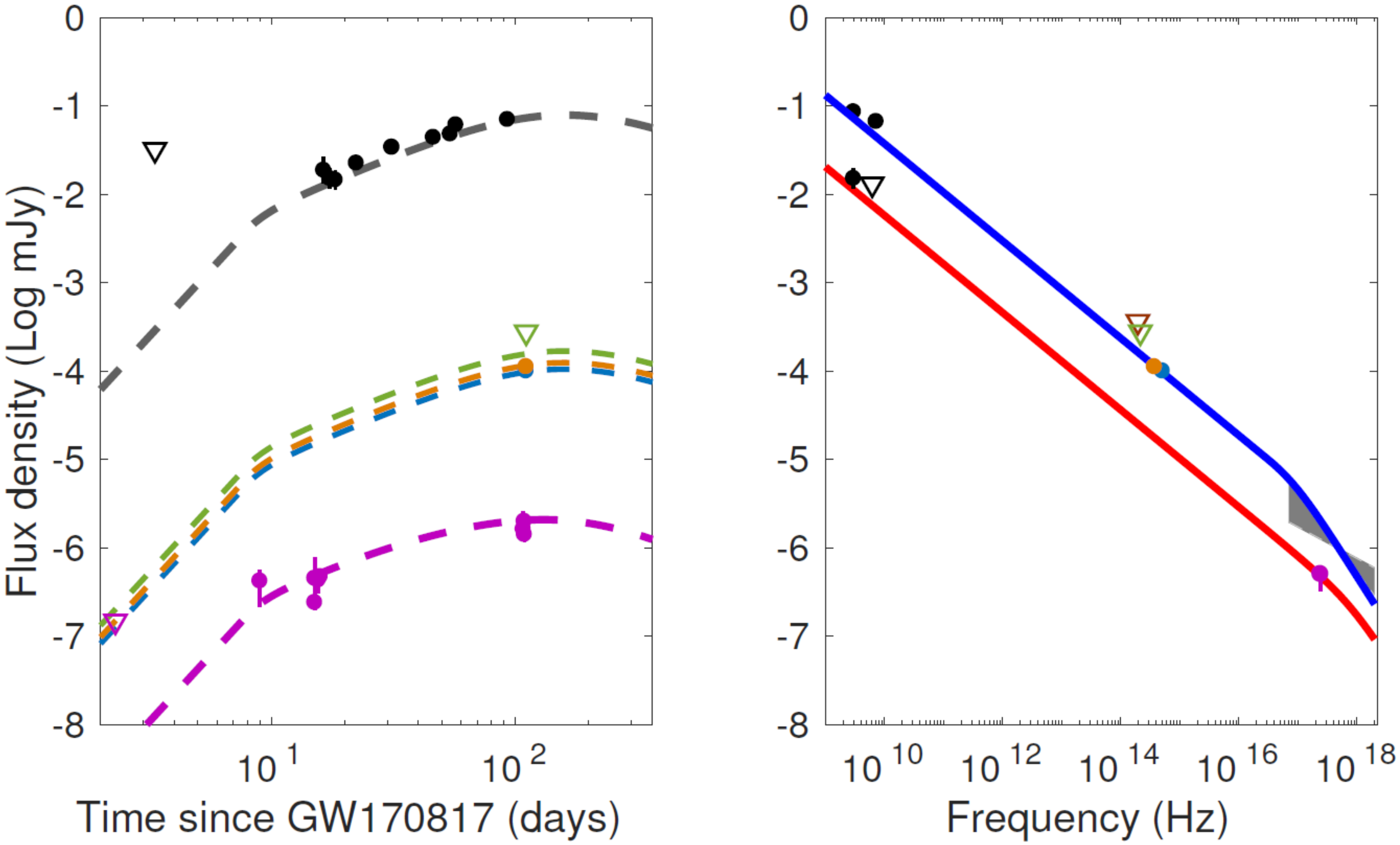


Log Pressure

- Afterglow

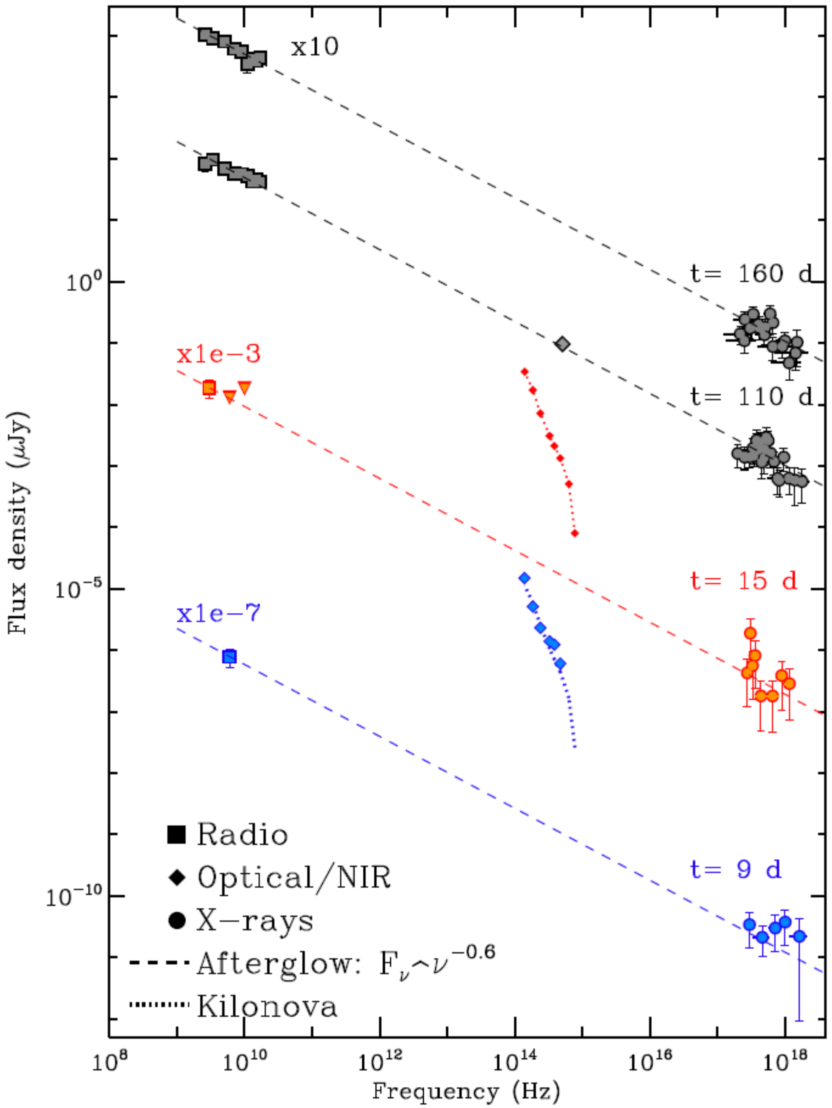
Afterglow:

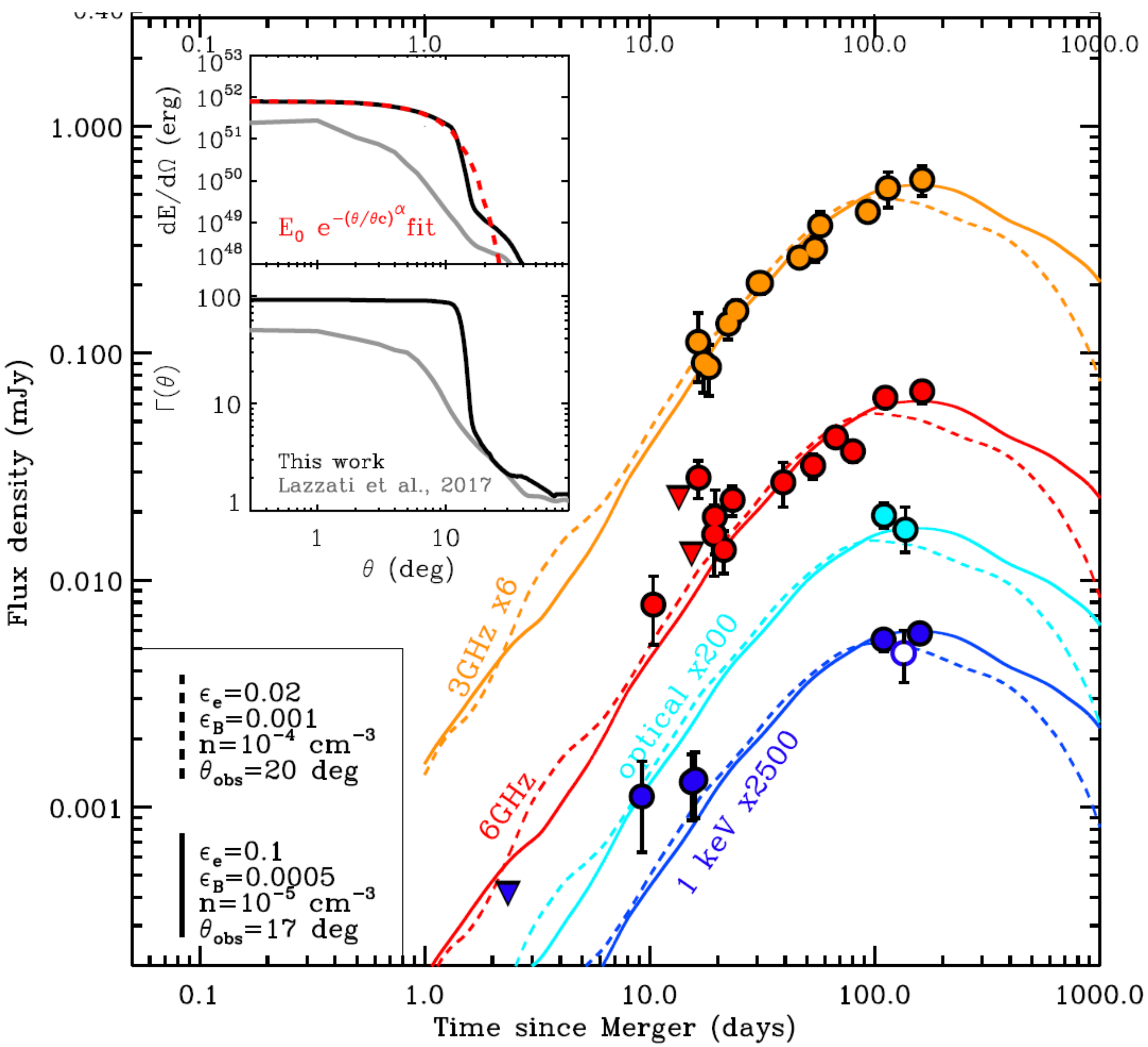
Lyman et al (2018)



Afterglow:

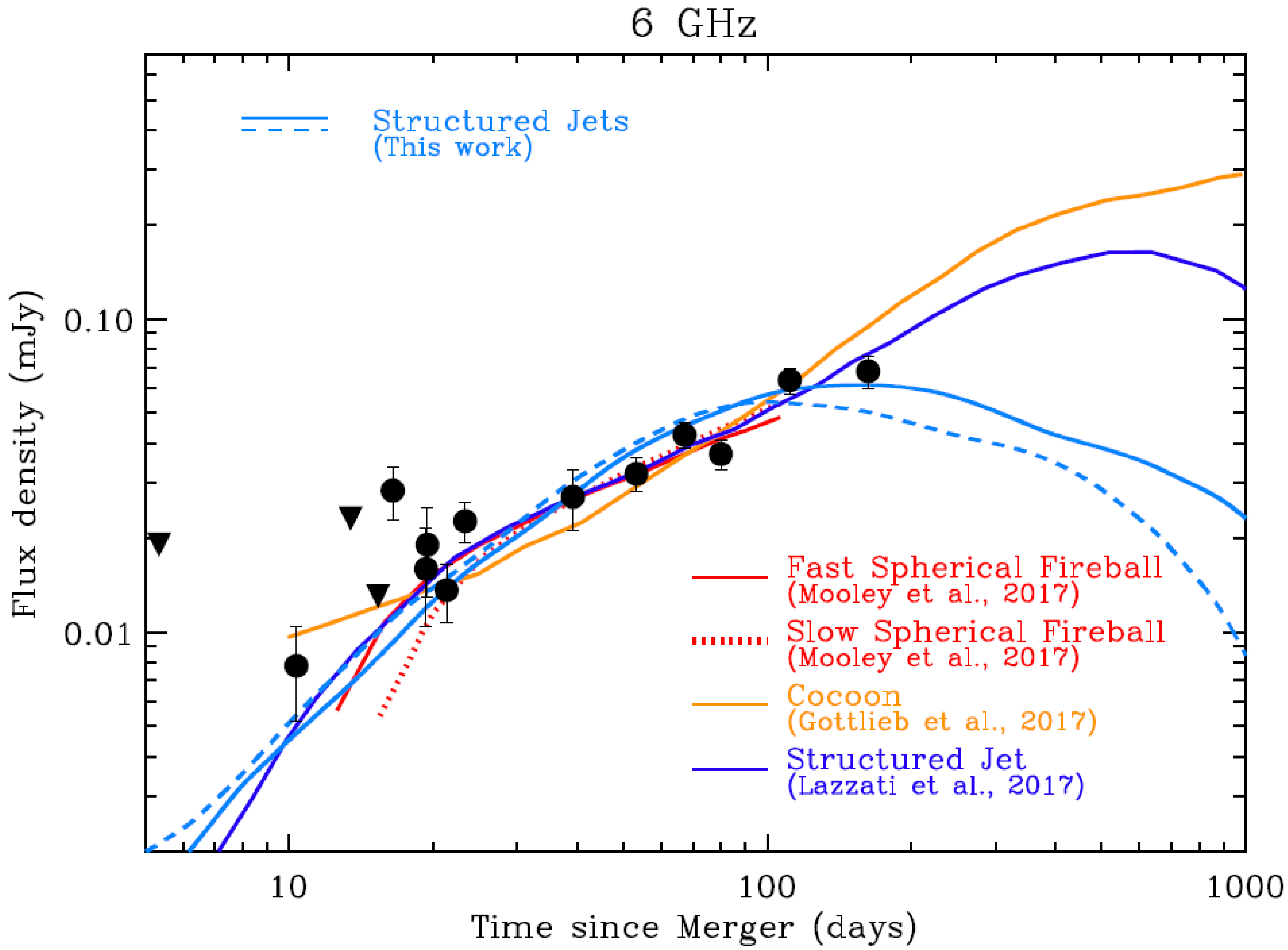
Margutti et al (2018)





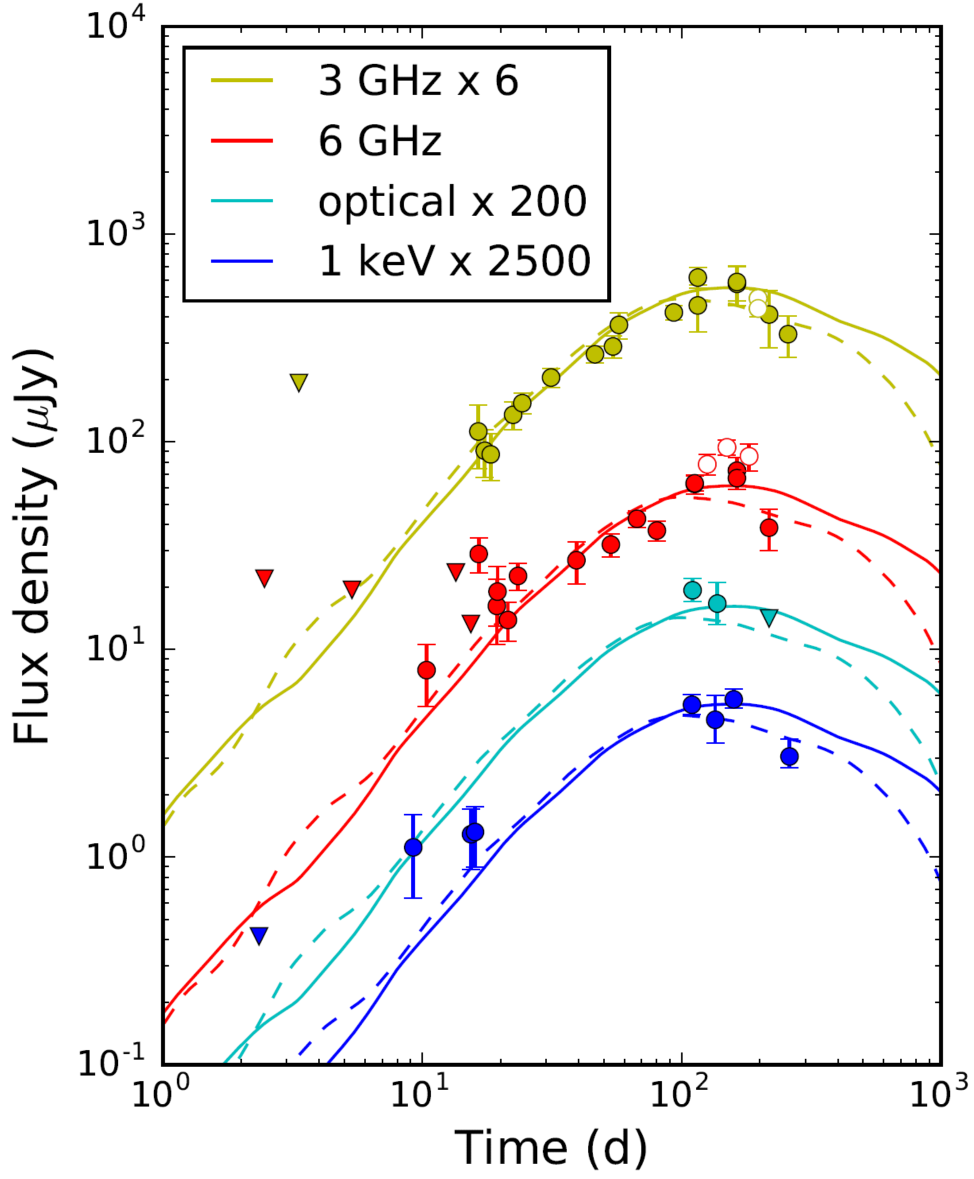
Afterglow:

Margutti et al (2018)



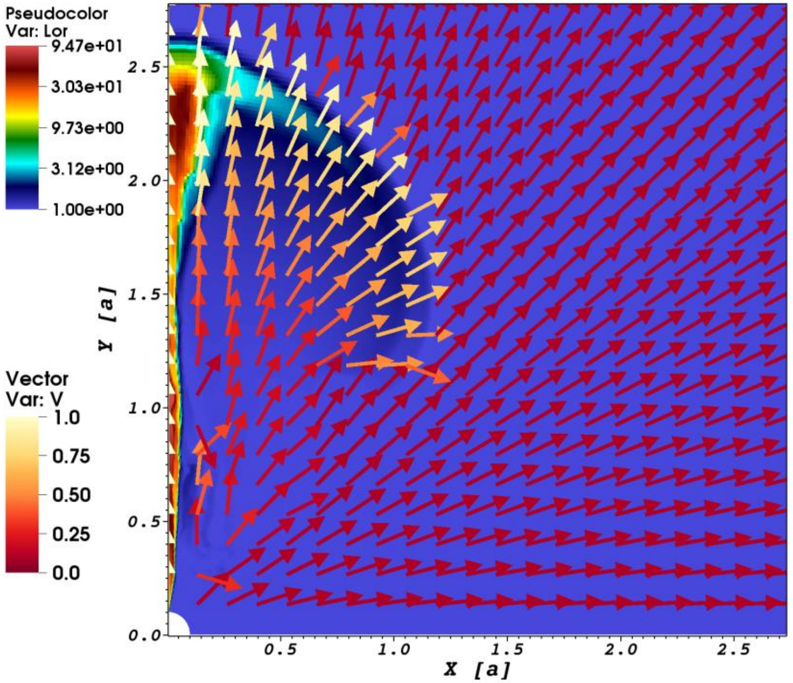
Afterglow:

Alexander et al (2018)

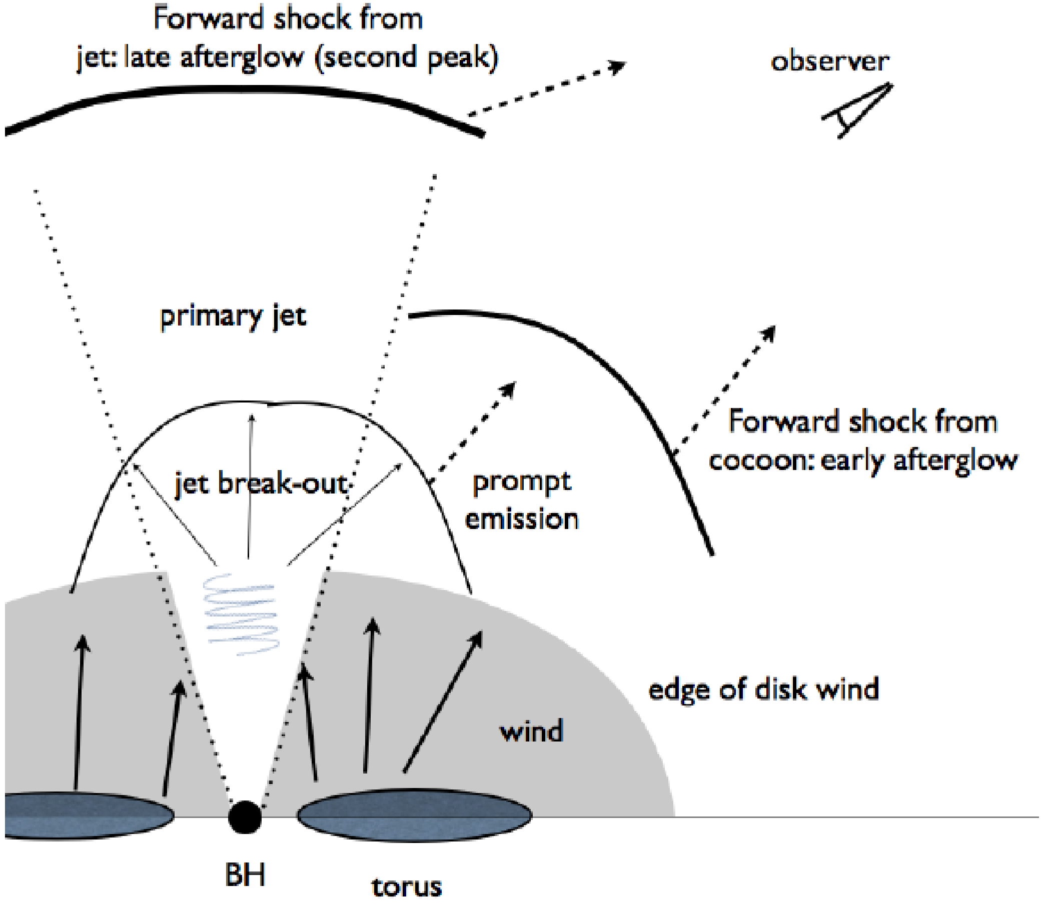


- The second bump in the afterglow

An Idea:



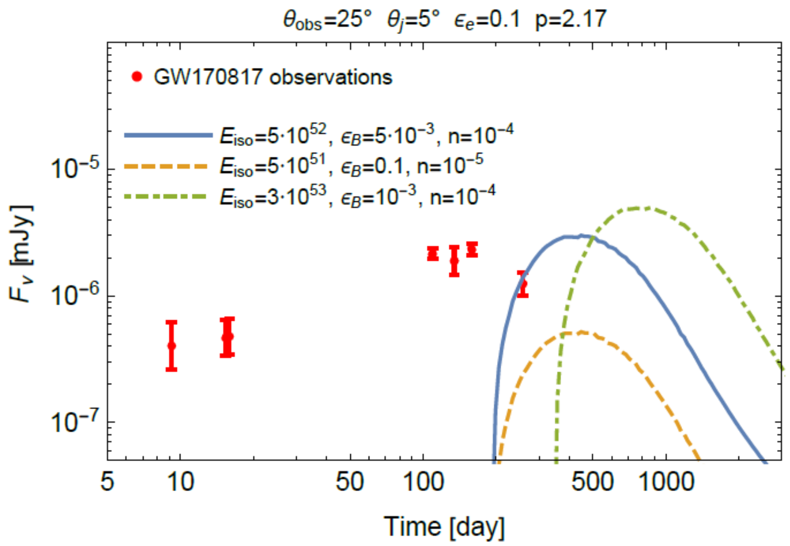
Pseudocolor
Var: Lor
9.47e+01
3.03e+01
9.73e+00
3.12e+00
1.00e+00
Vector
Var: V
1.0
0.75
0.50
0.25
0.0
Y [a]
X [a]

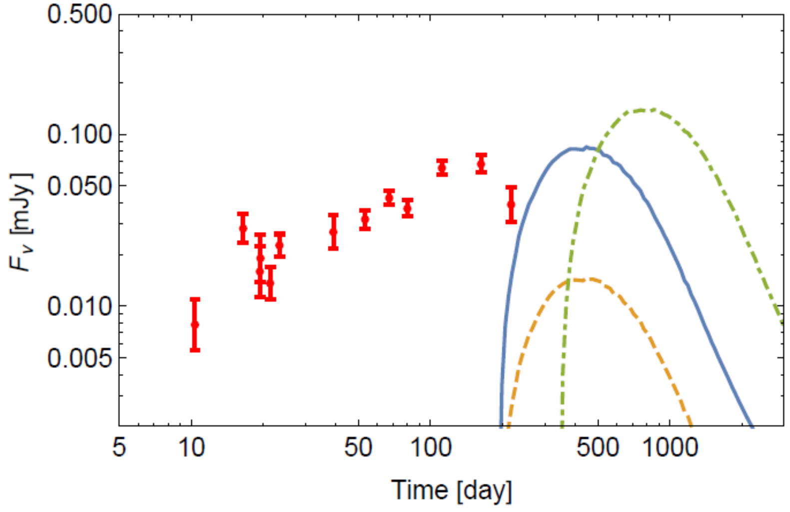


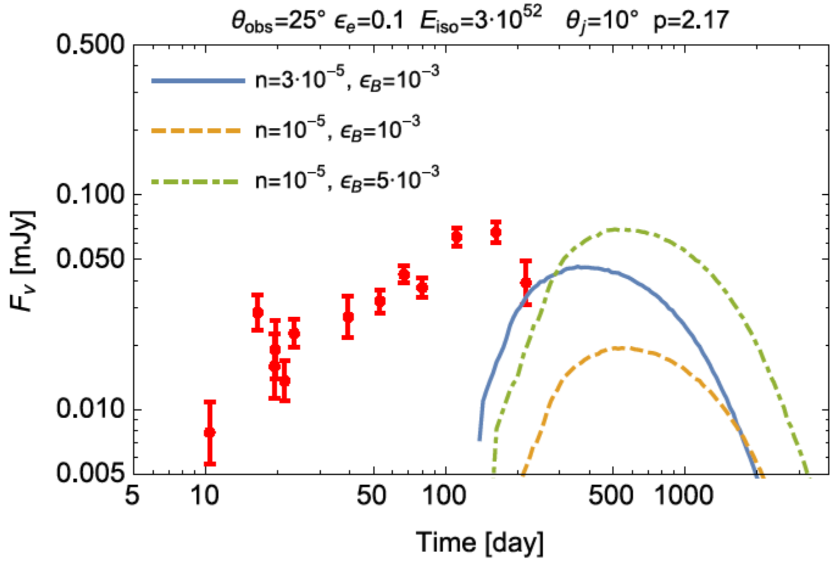
Forward shock from
jet: late afterglow (second peak)
observer
primary jet
jet break-out
prompt
emission
Forward shock from
cocoon: early afterglow
edge of disk wind
wind
BH
torus

BoxFit model:

Barkov et al (2018)



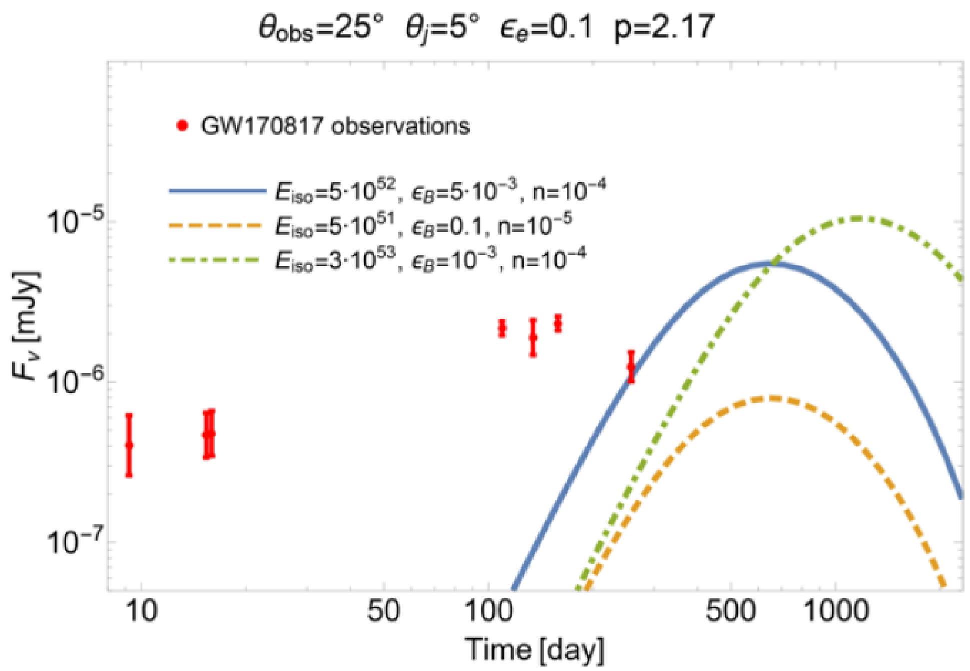


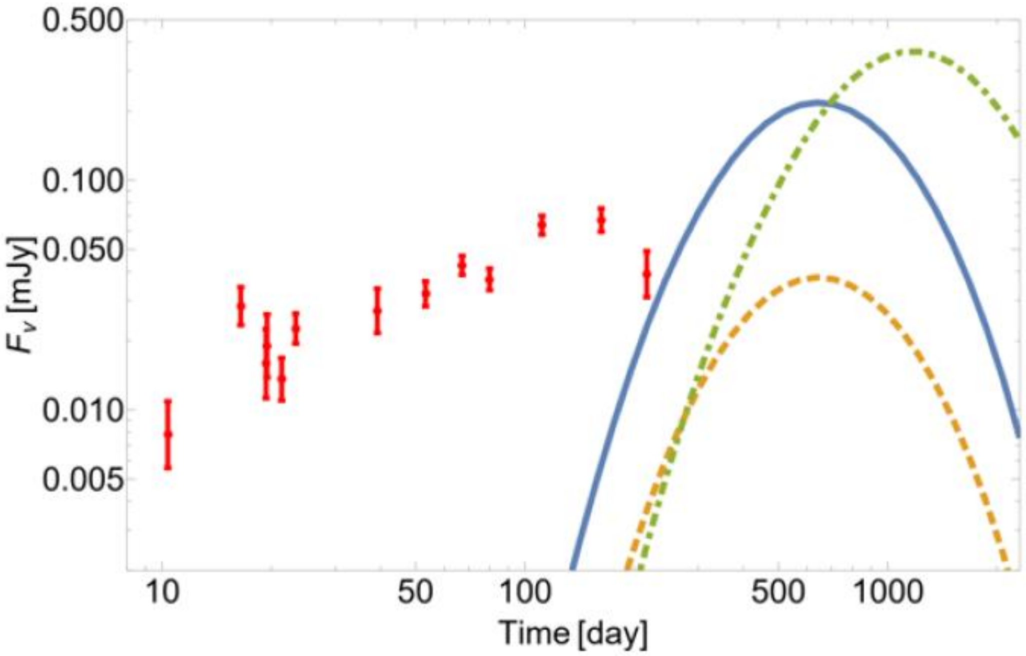


BoxFit model van Eerten&McFadyen (2012)

”Synchrotron” model:

Barkov et al (2018)

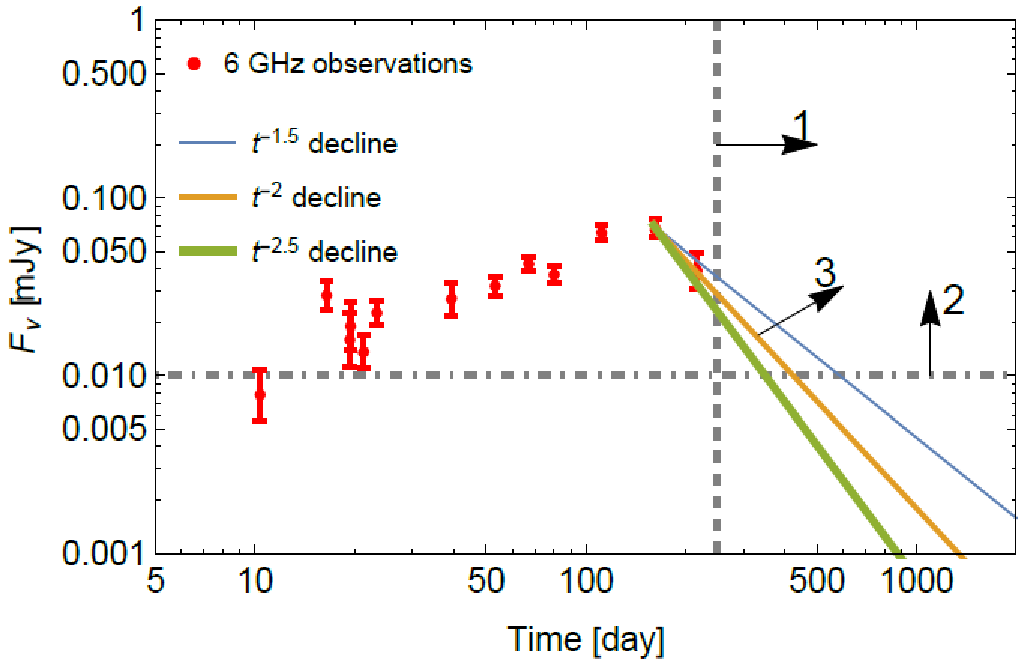


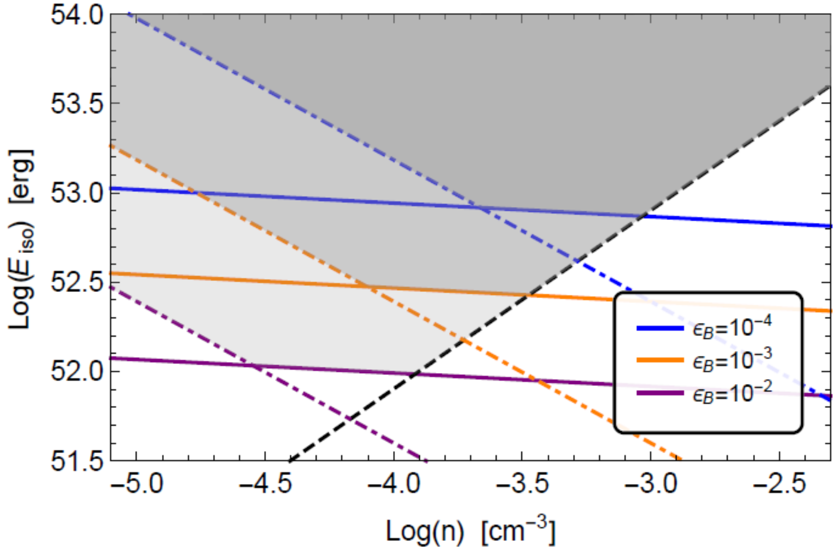


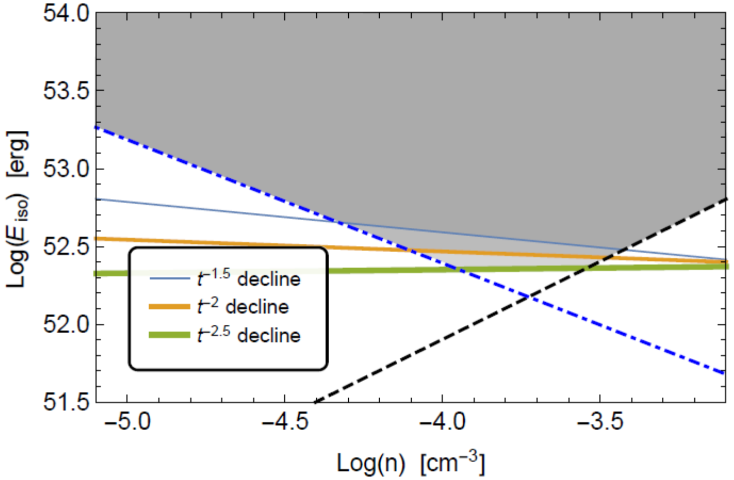
Synchrotron model is based on Blandford&McKee (1976)

Analytical restrictions:

Barkov et al (2018)







Based on Granot et al (2017)

Conclusions:

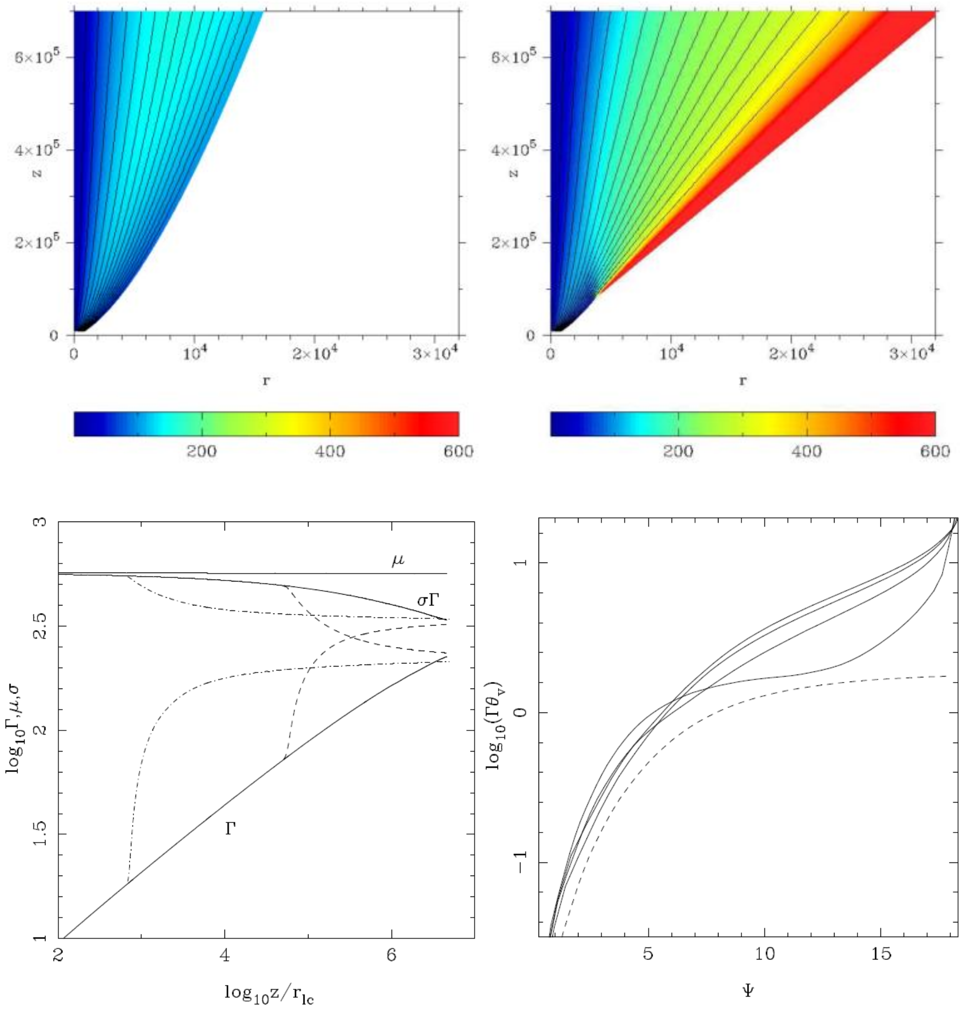
- We successfully observe GW optical counterpart
- Our analysis show unique properties of prompt emission of GRB170817
- We suggest the new model for explanation of prompt emission
- We predict formation of second bump in the afterglow (from radio till X-ray)

- [Rarefaction acceleration]()

$$\Gamma \sim \Gamma_n \sqrt{\sigma_n}$$

The rarefaction acceleration mechanism allows to reach wider opening angles of the Jets

$$\theta\Gamma >> 1$$



Tchekhovskoy A. et al. (2010) NewA 15, 749

Komissarov S. et al. (2010) MNRAS 407, 17

Off-axis short GRBs from structured jets as counterparts to GW events

Adithan Kathirgamaraju[1⋆], Rodolfo Barniol Duran[2⋆], Dimitrios Giannios[1⋆]