The dawn of a new astronomy

Transient Universe 2023

GEV EXCESS DETECTED IN A MERGER-DRIVEN GRB

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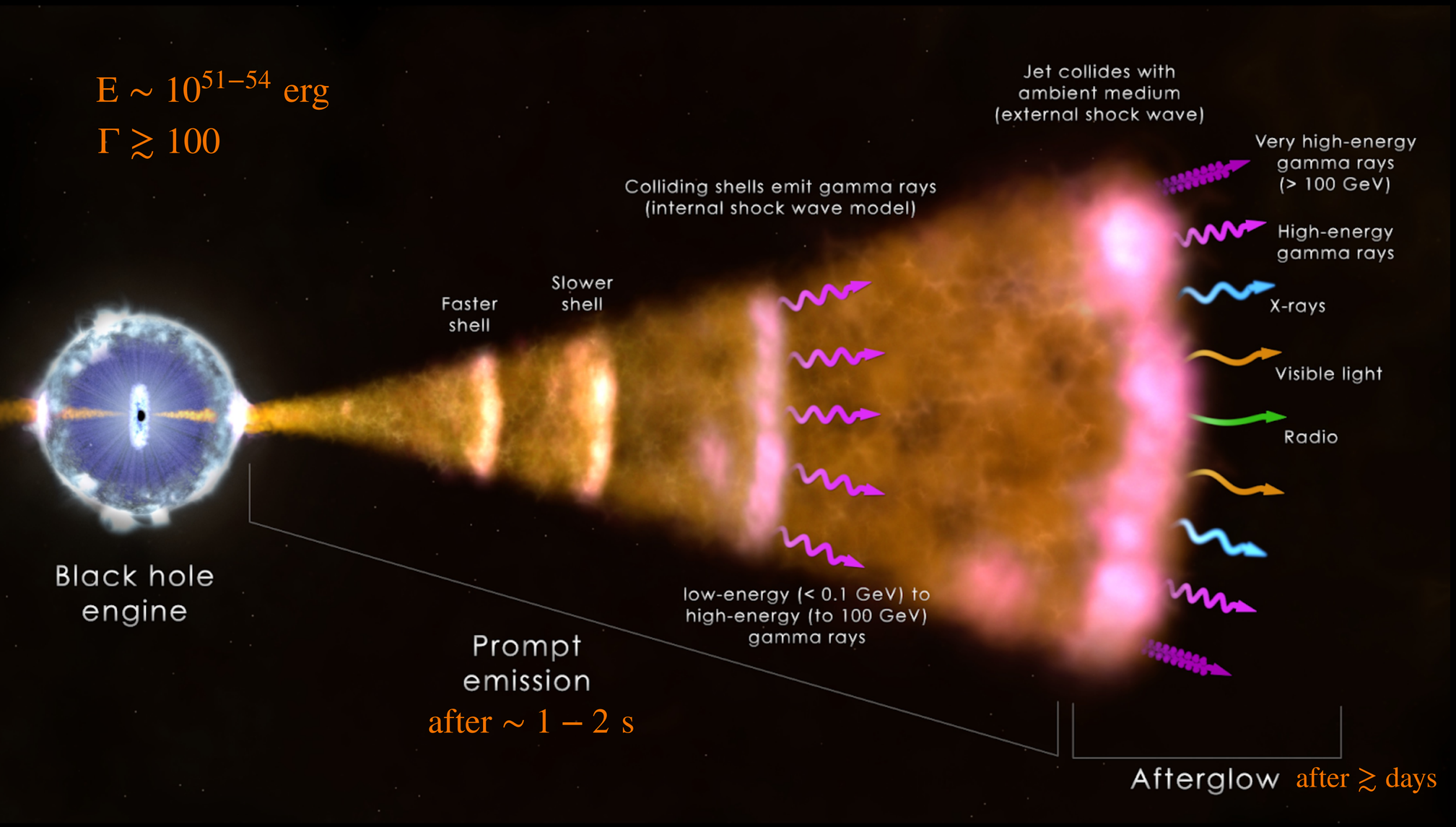
Credits to NASA's Goddard Space Flight Center

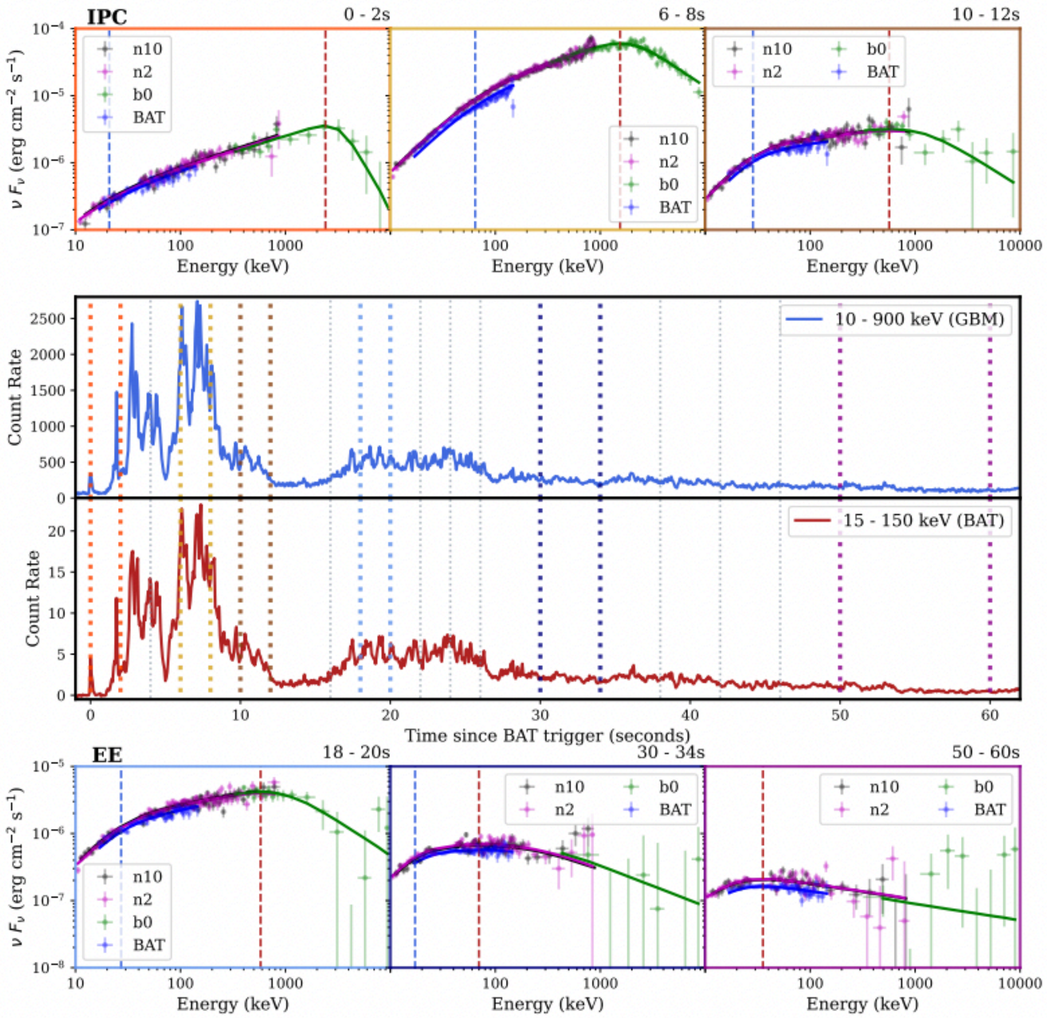
The fireball model

$E \sim 10^{51-54}$ erg

$\Gamma \gtrsim 100$



GRB211211A: long merger-driven GRB



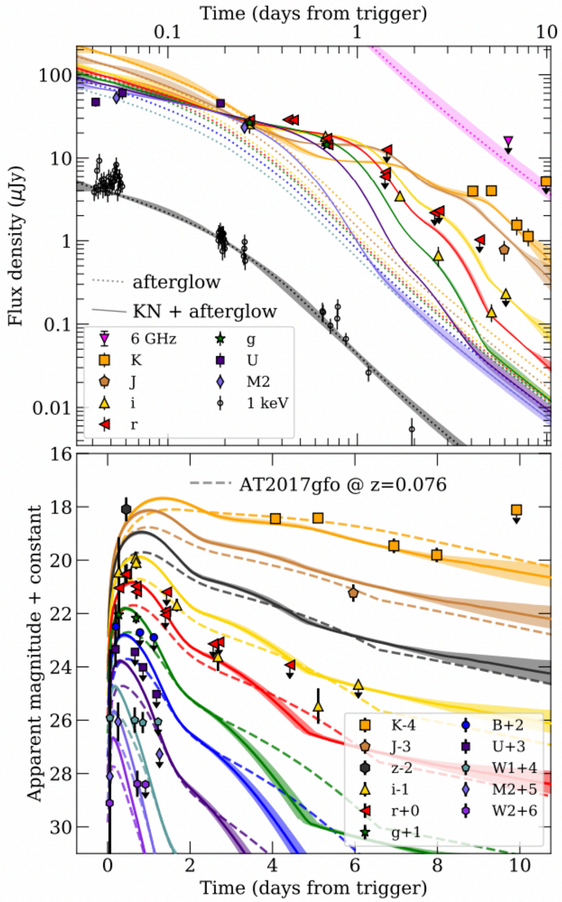
Gompertz et al. 2022

- On Dec. 11, 2021 a bright gamma-ray emission triggered Fermi/GBM (10 keV - 40 MeV) and Swift/BAT (15-150 keV).
- The duration of the prompt emission of this GRB is $T_{90} \simeq 34$ s
- Presence of a softer extended emission at later times (up to ~60 s)

Long merger-driven GRB!

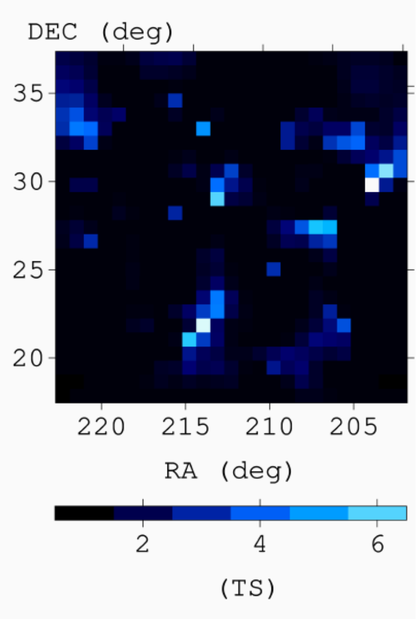
Rastinejad et al. 2022

(but see also Troja et al. 2022)

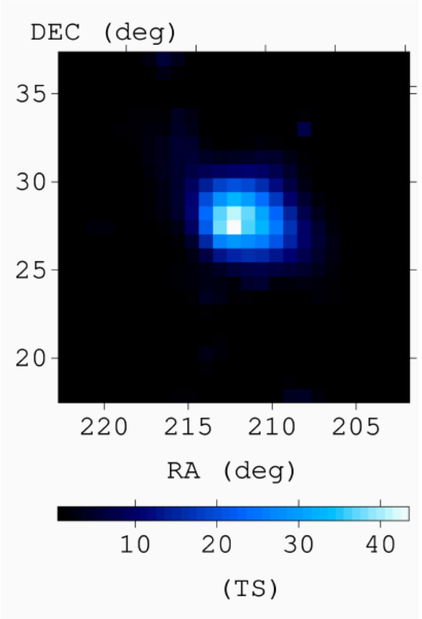


HE emission at late times

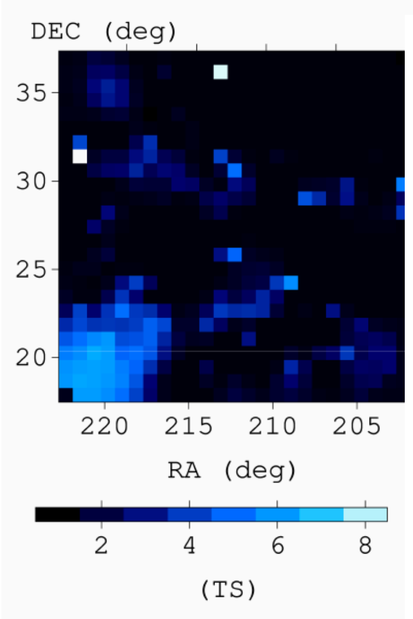
Mei et al. 2022



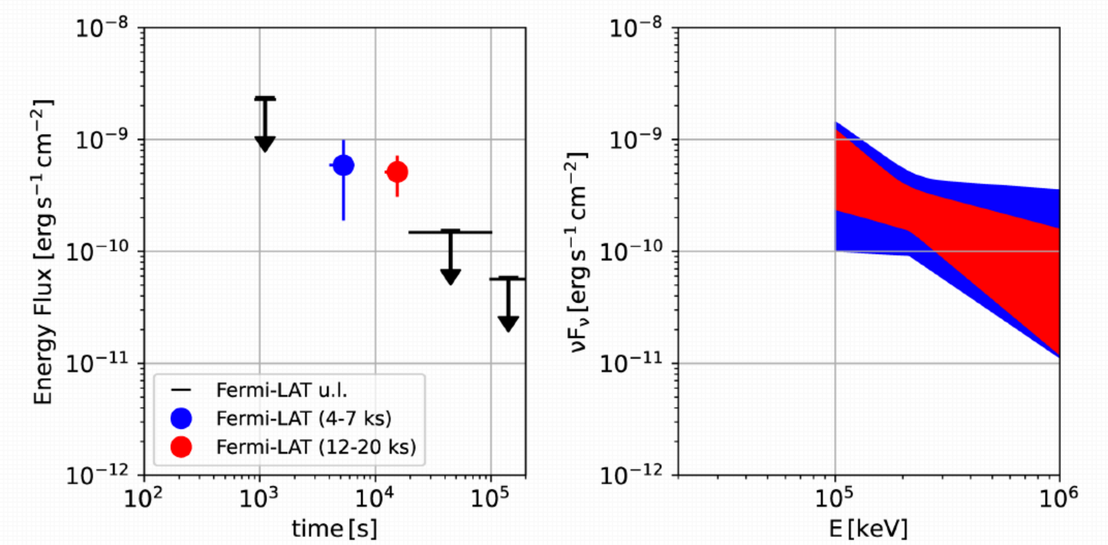
(a) t_0-1 d to t_0



(b) t_0 to t_0+20 ks



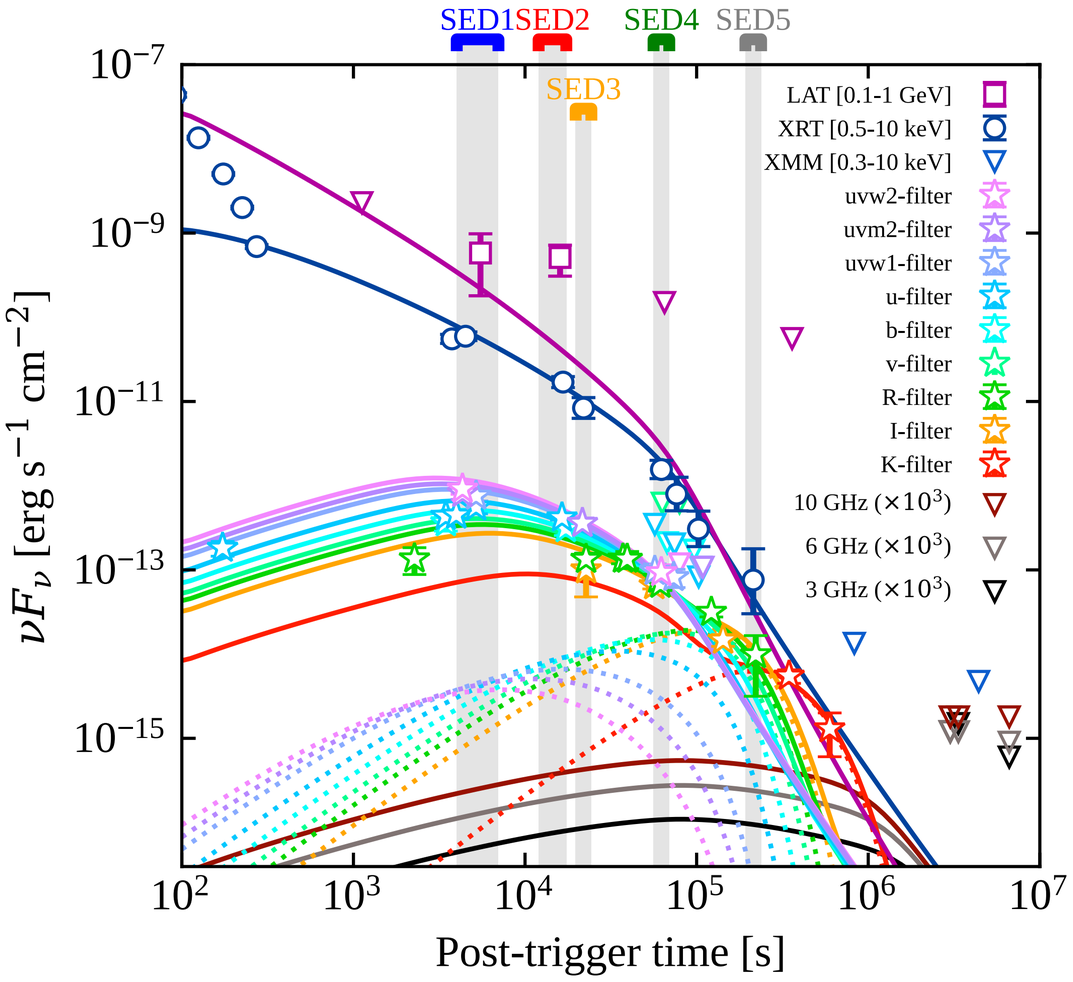
(c) t_0+1 d to t_0+2 d



(d) t_0 to t_0+2 d

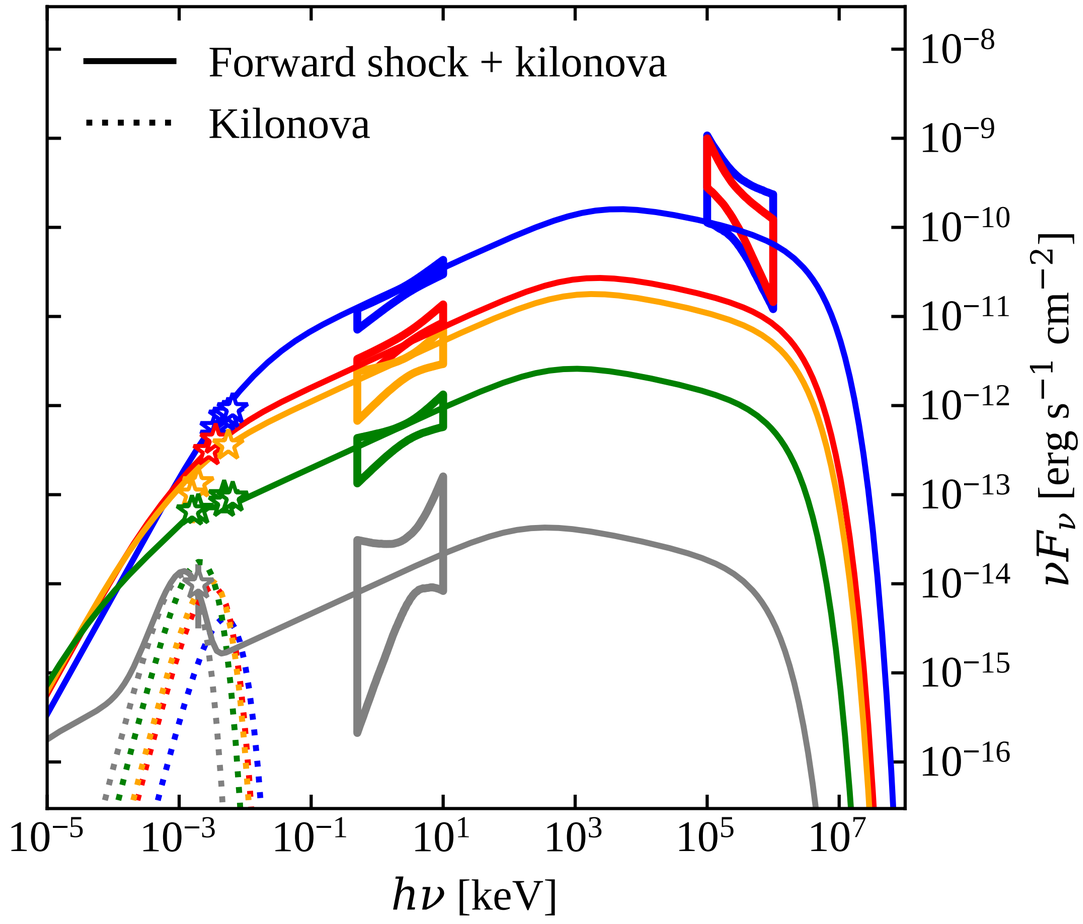
HE excess at late time

Light curves



(a)

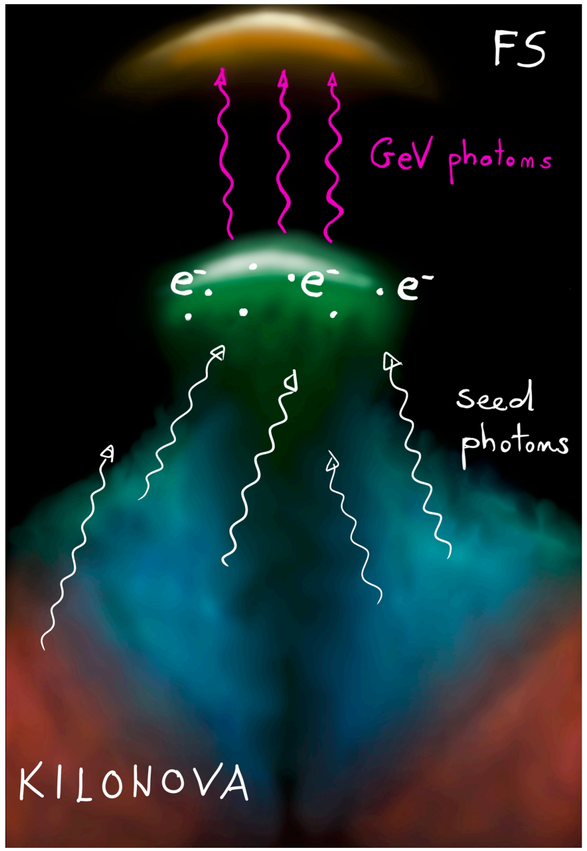
Spectra (SED)



(b)

Low power jet-KN EIC

De-beamed scenario ($R_j > R_{KN}$)



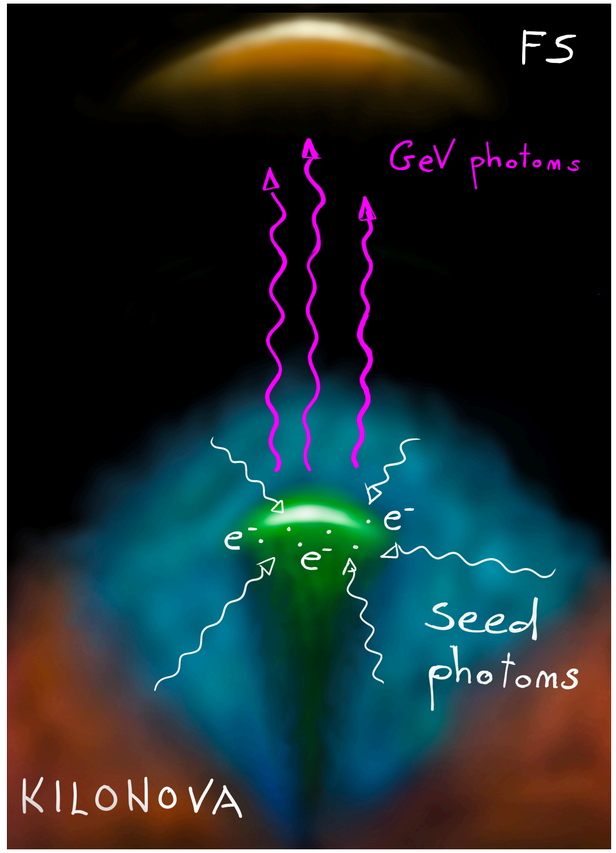
Credits: S. Ronchini

$T_0 + 10^4$ s

- If the hot electrons are **above** the kilonova photosphere, the photons are **de-beamed** in the jet comoving frame.
- This scenario requires an unrealistically low jet magnetisation ($\epsilon_B \lesssim 3 \times 10^{-10}$)

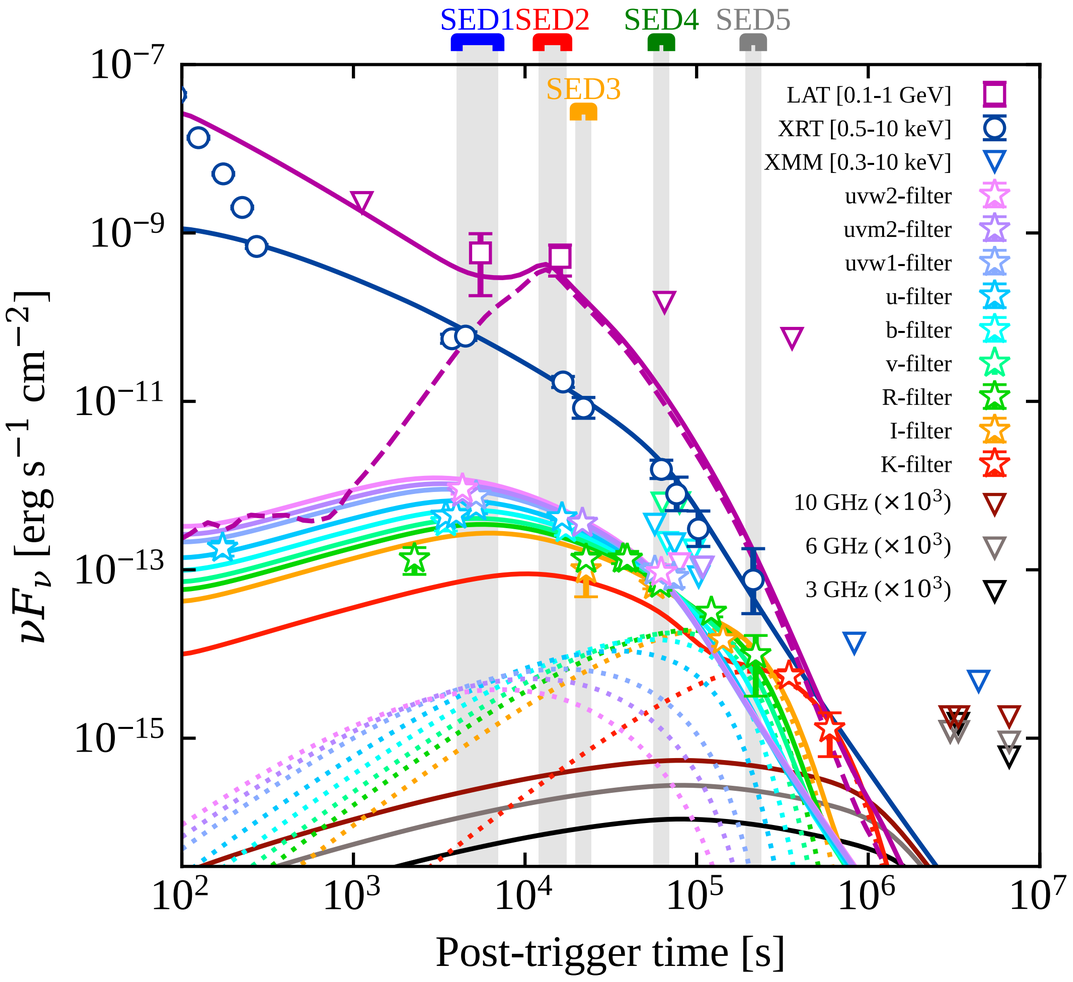
- If the hot electrons are **below** the kilonova photosphere, the photons are **beamed** in the jet comoving frame.
- This scenario requires a low, but reasonable, jet magnetisation ($\epsilon_B \lesssim 8 \times 10^{-6}$)

Beamed scenario ($R_j < R_{KN}$)



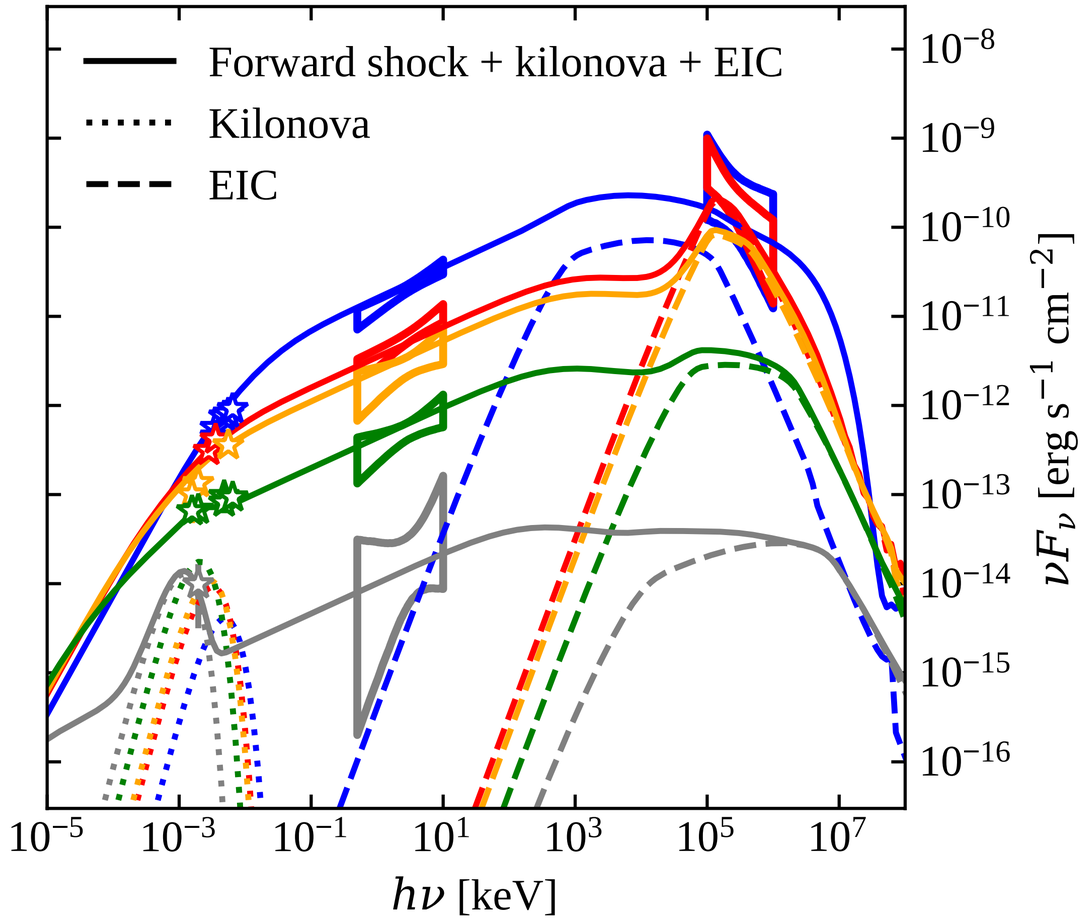
External Inverse Compton component

Light curves



(a)

Spectra (SED)



(b)

Conclusions

- GRB 211211A is a bright long GRB likely produced, together with a kilonova emission, by the merger of two Neutron Stars.

- We have observed for the first time a late GeV emission coming from a compact binary merger, in clear excess with respect to the synchrotron emission from external shock-accelerated electrons.

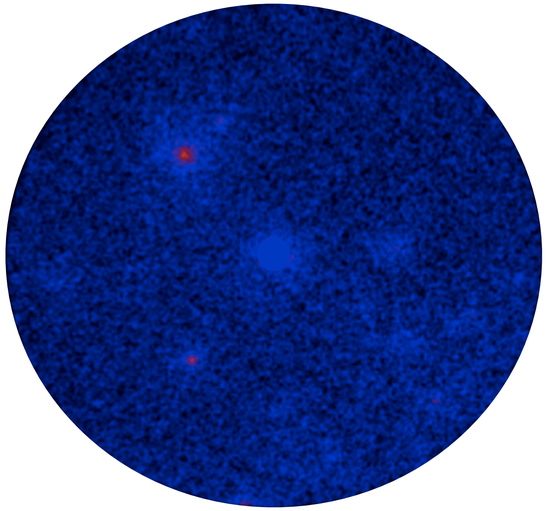
- We show that such emission can be matched by External Inverse Compton interaction between the optical Kilonova photons and the hot electrons accelerated in a low-power jet.

- This discovery opens a new observational channel for GRBs, Kilonovae, and GW counterparts, possibly detectable at late times in the high energy band!

BACKUP SLIDES

Source detection with Fermi/LAT

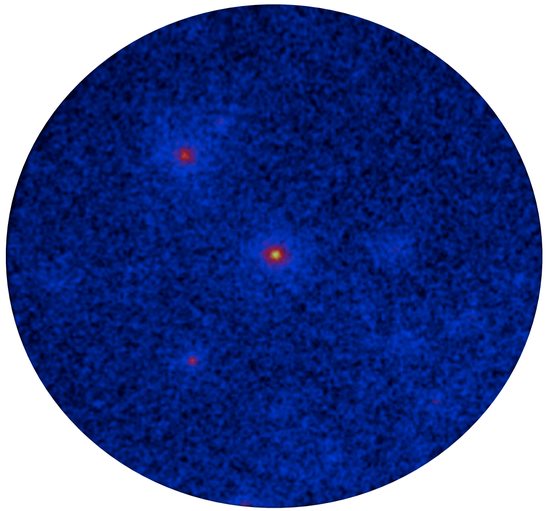
Likelihood ratio test (LRT) → $\mathrm{TS} = -2\log\left(\frac{\mathscr{L}_0}{\mathscr{L}_1}\right) \approx (\text{detection significance})^2$



$\mathscr{L}_0$

Null model

(Observation without source)



$\mathscr{L}_1$

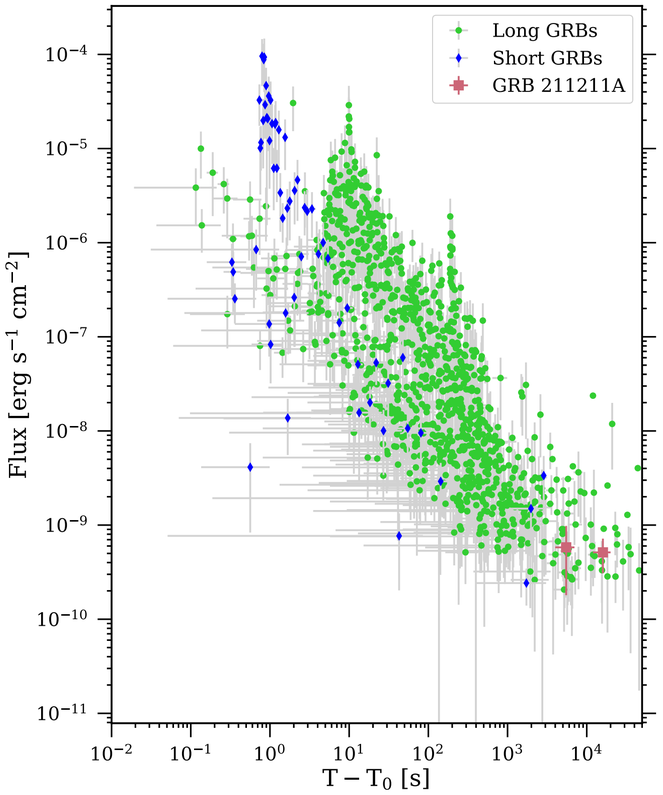
Alternative model

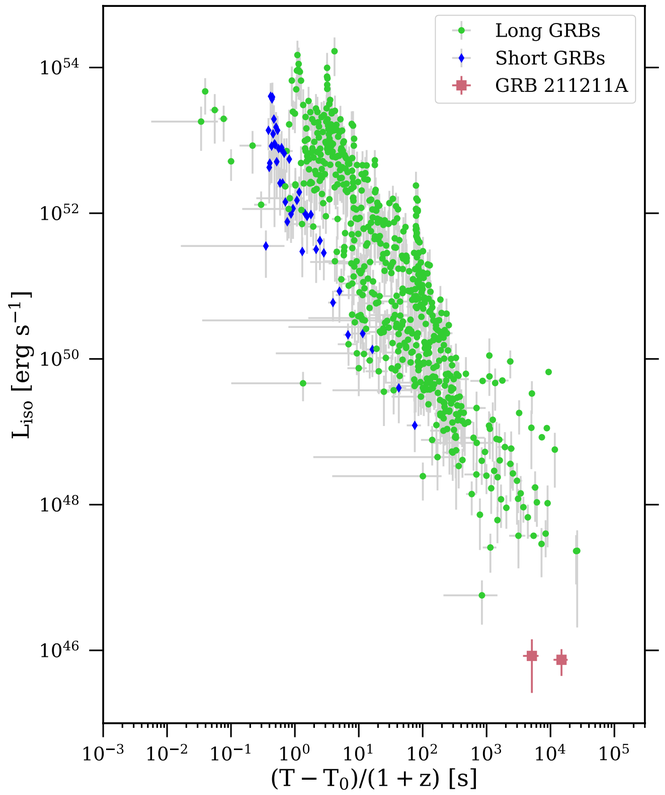
(Observation with source)

- We define a Region of Interest (ROI) of 12 deg around the GRB position.
- We account for the isotropic particle bkg, galactic and extragalactic high energy components from Fermi 4th catalog (F4GL).
- We assume a PL spectral model for the GRB as well as for the other sources in the ROI, the latter with fixed normalisation and spectral index.
- We assess the improvement of the fit following the introduction of the GRB in the model through LRT.

Comparison with other sources

2nd Fermi/LAT GRB catalog (Ajello et al. 2019)



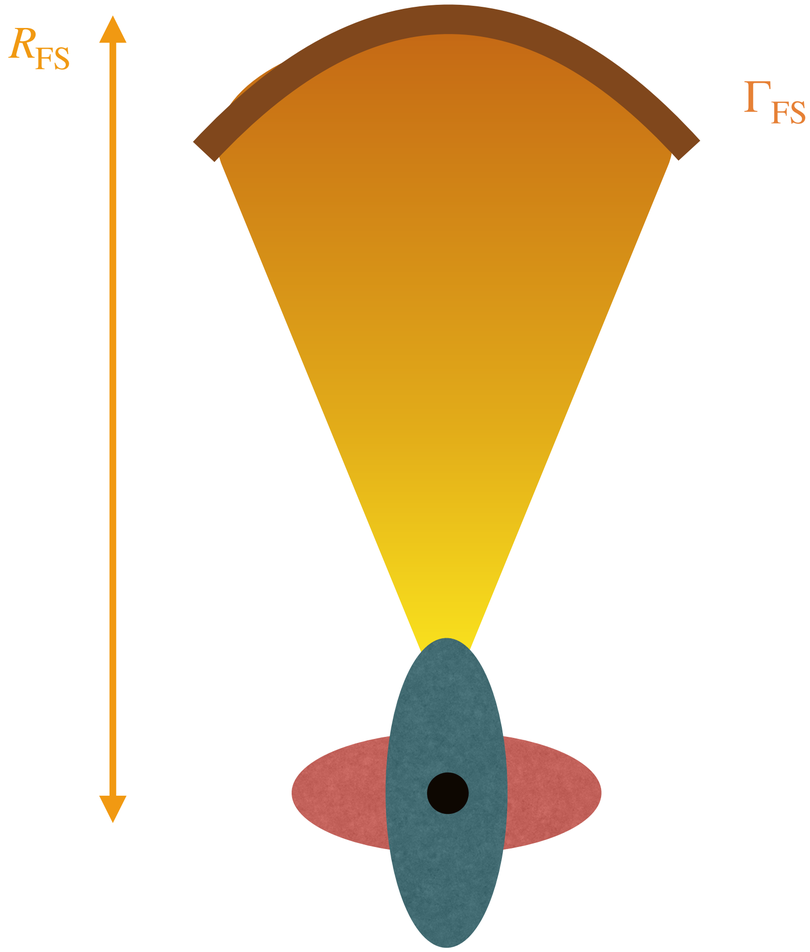


- GRB 211211A is intrinsically faint in the LAT energy band ($L_{iso} \sim 10^{46}$ erg/s).
- It is observable thanks to its proximity to Earth! (~350 Mpc)
- No other GRB with $d \lesssim 350$ Mpc shows significant LAT emission.
- GRB 170817A would be a good candidate, but no LAT observation due to South Atlantic Anomaly before 1ks, while after 1ks there is no detection (TS<9).

Low power jet at late times

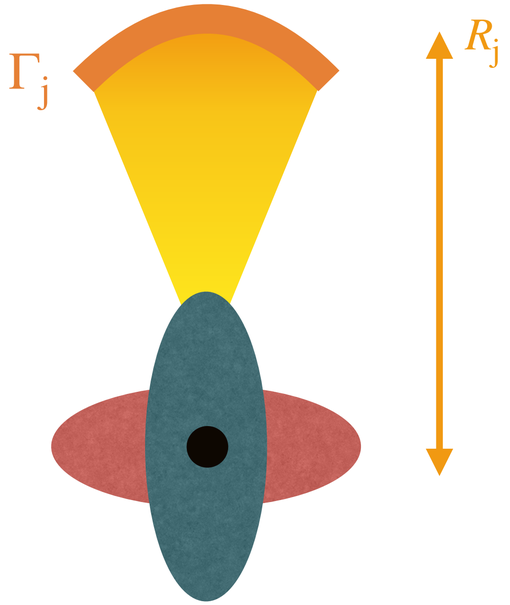
Deceleration phase $T_1 > T_0$

Late-time activity $T_2 = T_0 + 10^4$ s

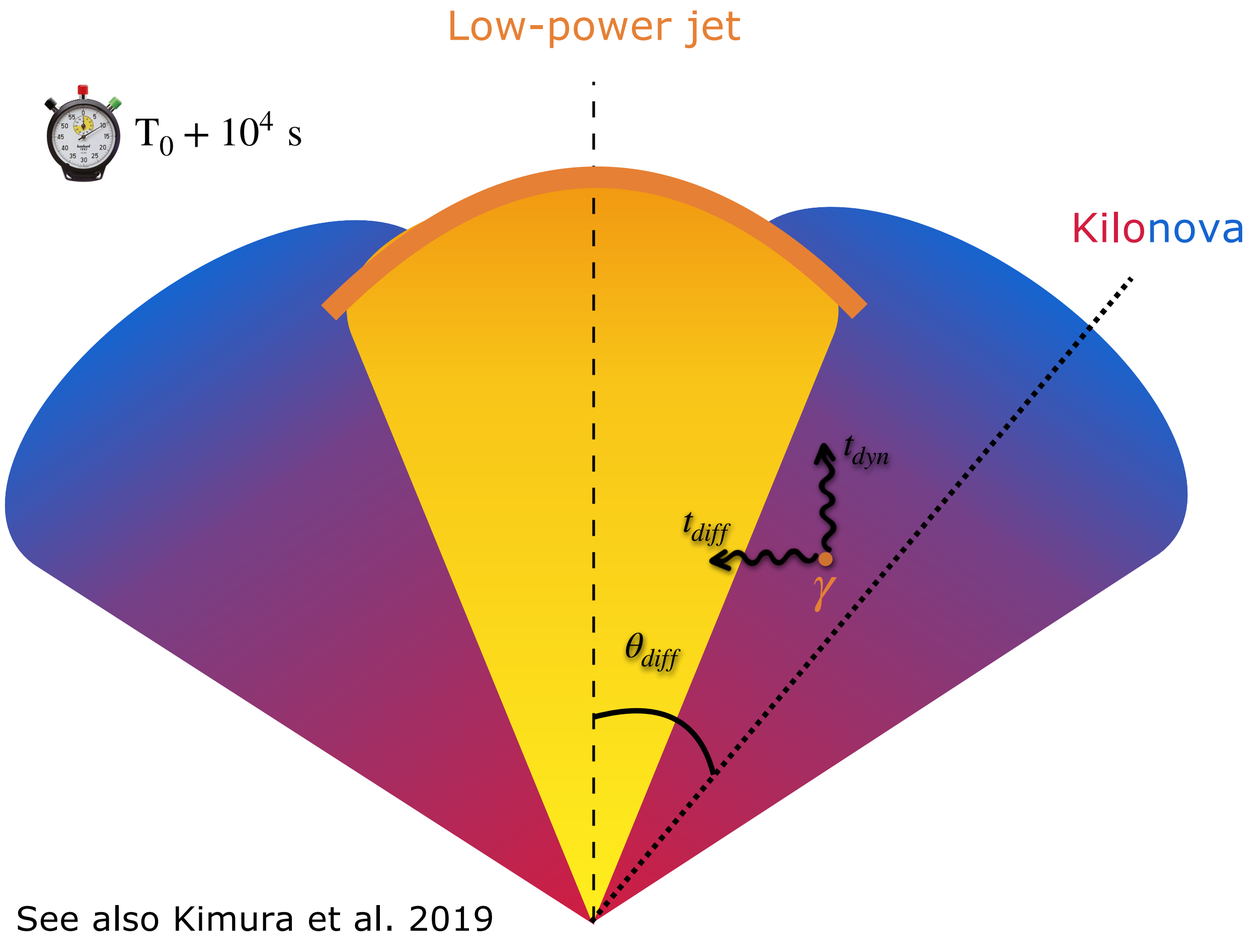


Accretion onto the newly born compact object:

$$\dot{M} \propto t^{-5/3}$$



Low power jet-KN interaction



See also Kimura et al. 2019