Can the Thermal Evolution of the Fireball alone explain the GRB 171227A?

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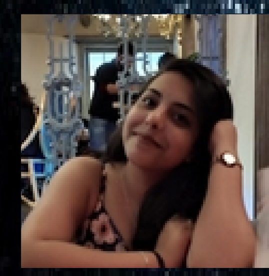
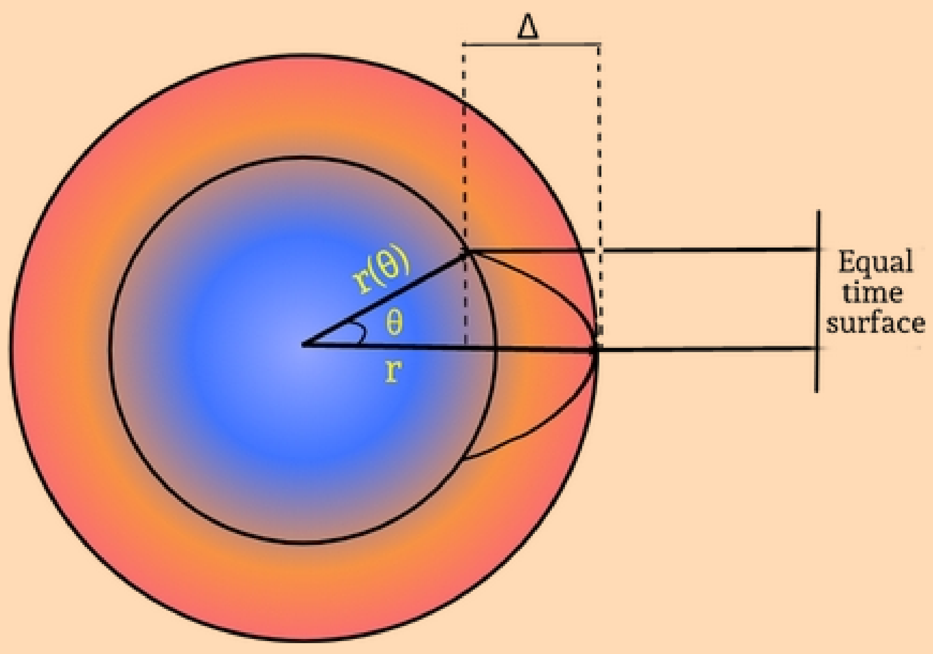


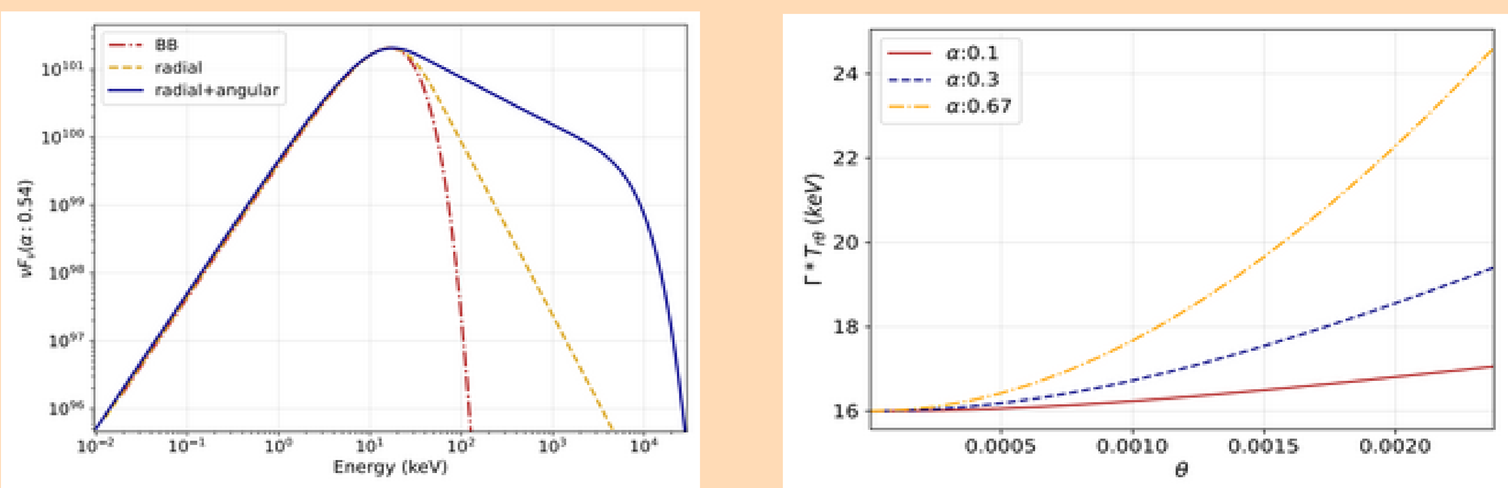
- Majority of GRBs spectra are well-fitted with an empirical Band function.
- We propose a multi-temperature blackbody (mBB) spectrum which manifests the photospheric emissions from the different radii and angles under the relativistic fireball formalism.
- To better understand the GRB evolutionary process, we perform a detailed study of this model with its temperature decreasing as a function of its radius.
- A numerical code developed under this scenario is employed to reproduce the spectrum of the GRB 171227A during its bright phase.
- The spectral fitting is performed by coupling this numerical model with the statistical fitting package XSpec.
- From the best-fit parameters, we analyze the evolutionary behaviour of the fireball and check for its physical consistency.

EXPANDING FIREBALL



- Considering the evolution of temperature with the radius (expansion)
- High Lorentz factor leads to the angle dependence of the Doppler shift
- The equator emission follows after the high latitude emission.
- Hence the off axis emission will be hotter than the on-axis emission

$$T_\theta = T_r\left[\frac{r}{r_\theta}\right]^\alpha = T_r\left[\frac{1-\beta\cos(\theta)}{1-\beta}\right]^\alpha = T_{ph}\left(\left[\frac{r_{ph}}{r}\right]\left[\frac{1-\beta\cos(\theta)}{1-\beta}\right]\right)^\alpha$$



$$F_\nu = \int I_\nu \cos(\Theta)d\Omega \qquad F_\nu = Cr^2\nu^3\int_{\cos\phi}^{1}\frac{\mu}{(1-\beta\mu)^2}\frac{1}{\left[\exp\frac{h\nu}{\Gamma kT_{ph}}\frac{(rr[1-\beta])^\alpha}{(1-\beta\mu)^\alpha(1+\beta\mu)}-1\right]}d\mu$$

$$\phi = MIN\left[\frac{1}{\gamma}, \cos^{-1}\left(\frac{1}{\beta}\left[1-rr(1-\beta)\right]\right), \cos^{-1}\left(\frac{1-(rr/SW)*\beta}{\beta[1-(rr/SW)]}\right)\right]$$

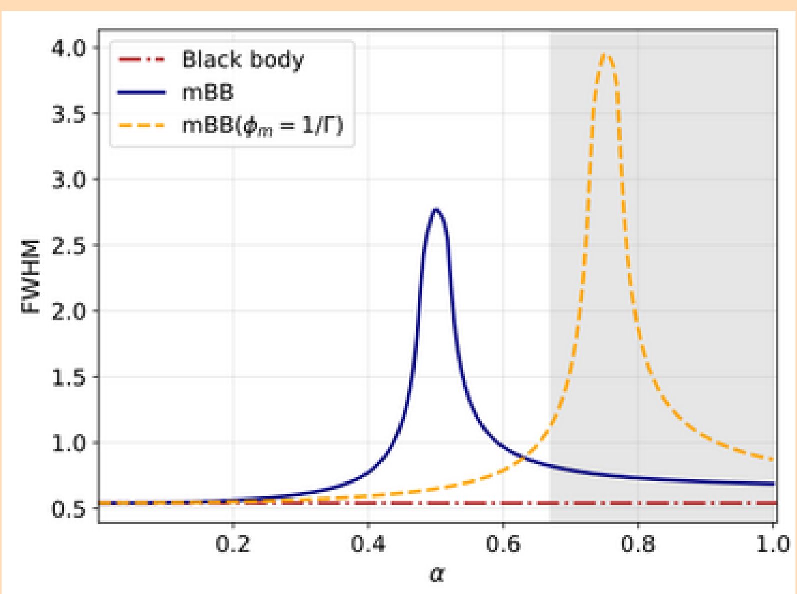


Fig: The variation of spectral width with α for Black Body(red), mBB(blue) and mBB when angle of the radiation cone is 1/Γ(yellow)

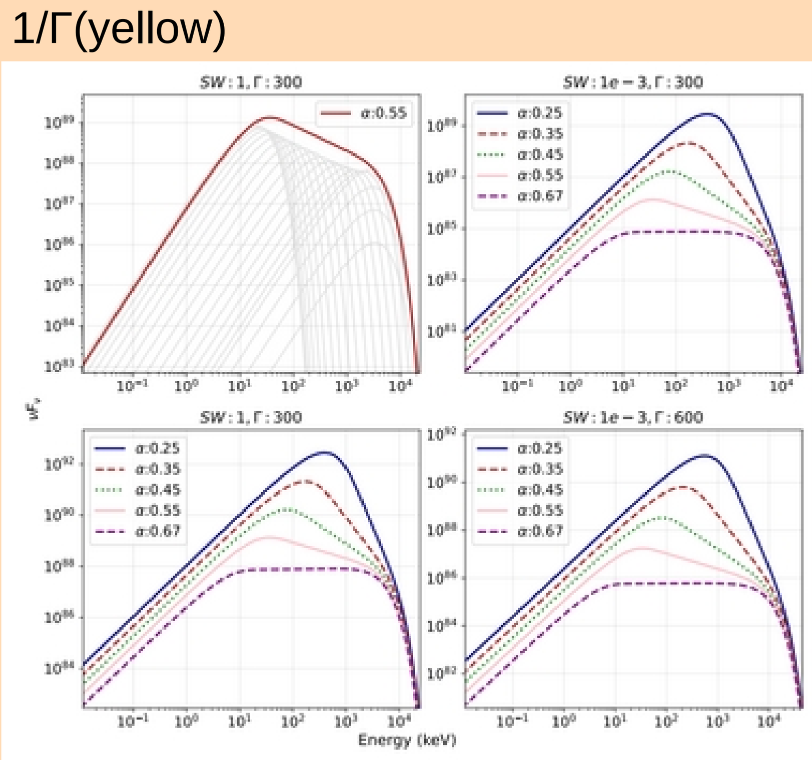


Fig: The variation of spectral shape and width for different Γ, SW and α

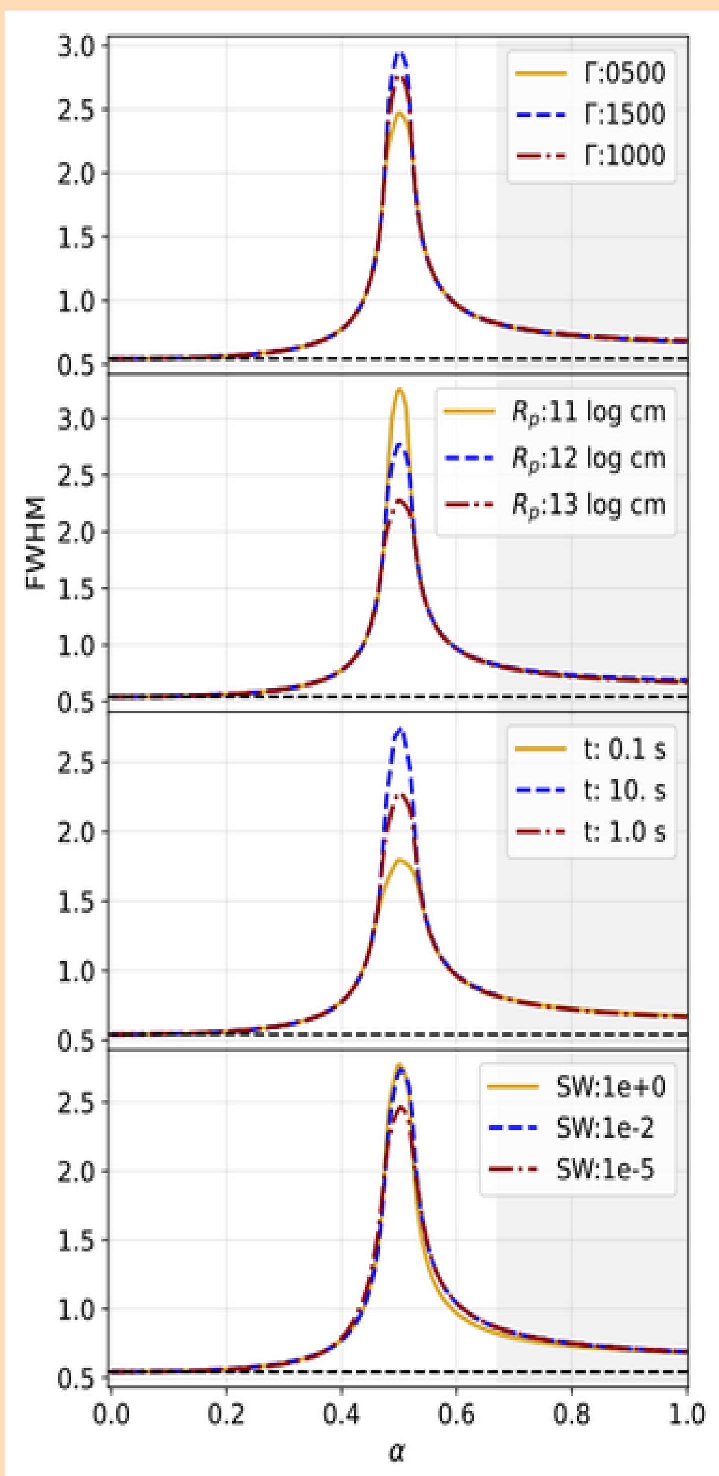
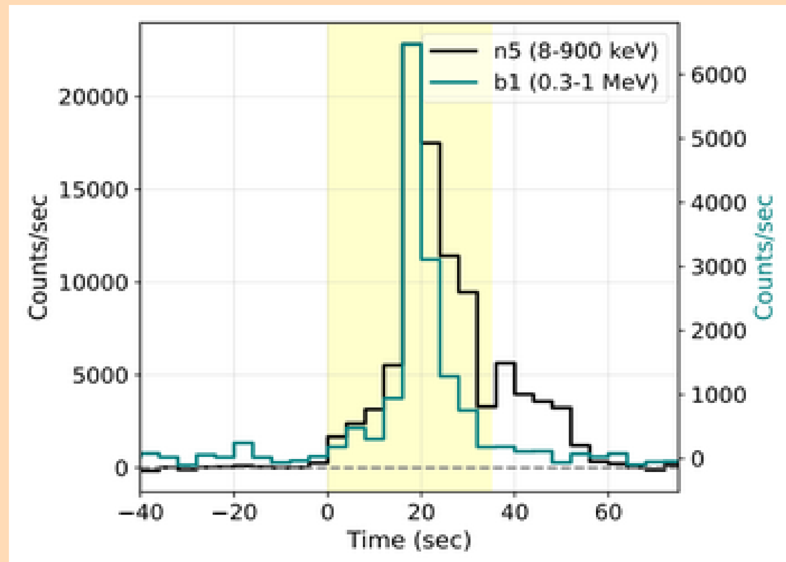


Fig: Variation of Spectral width with α by varying different physical parameters

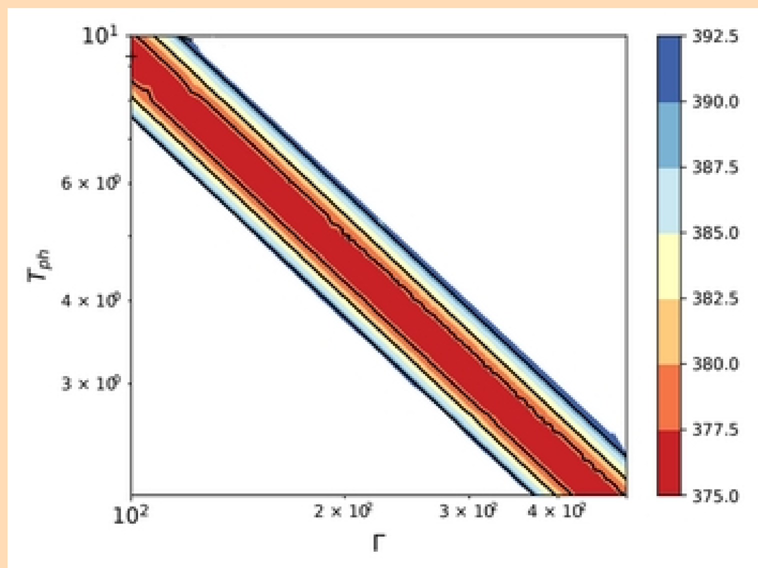
GRB 171227A SPECTRAL ANALYSIS



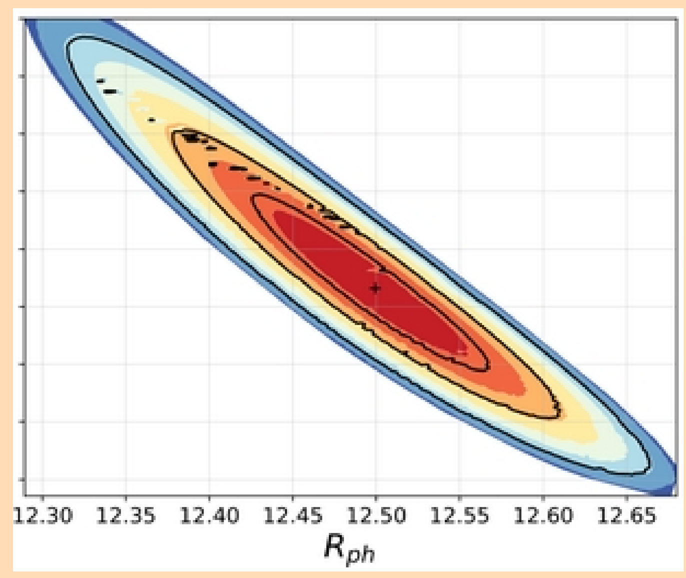
- Data used : Fermi GBM
- Detectors: NaI 5 and BGO 1
- One of the Bright burst
- T_{90}: 35.0 sec burst (T_0-T_0+35.0)
- Unpolarised Burst reported by Chattopadhyay et al 2022

We coupled the numerical mBB model with the XSpec and the fitting is performed for the GRB 171227A.

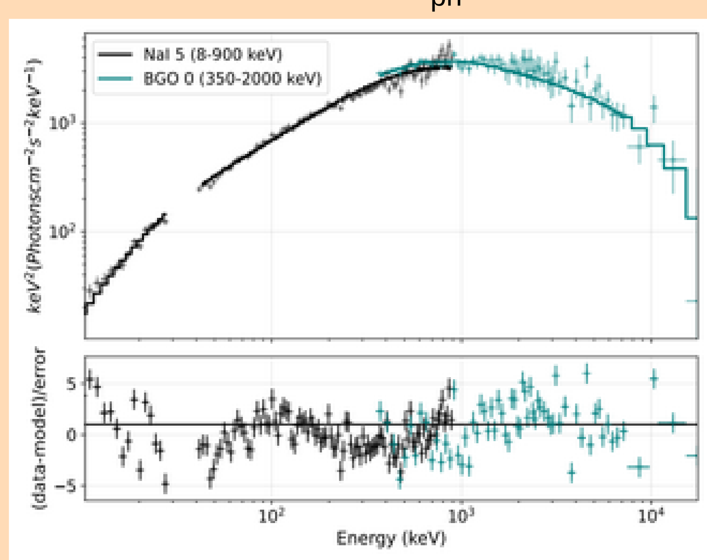
$$\mathscr{F} = \frac{\int_{r_1}^{r_2} F_\nu(r)dr}{r_2 - r_1}$$



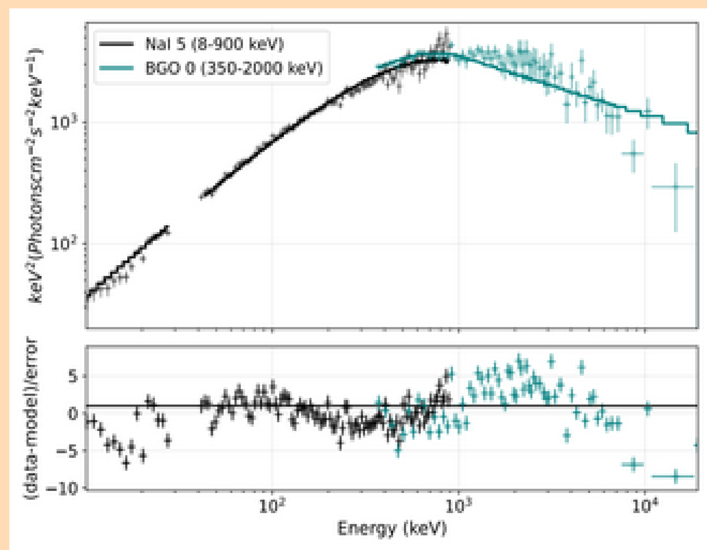
Degenracy observed between Γ and T_{ph}



Confidence Interval for R_{ph} and T_{ph}



mBB Model



Band model

SUMMARY

- Under the fireball interpretation of GRB, the spectral width of the time averaged spectrum can indicate the evolution of temperature.
- A numerical model is developed to imitate the expanding fireball model and applied on the bright GRB 171227A.
- The spectra of GRB 171227A is well fitted with the mBB model.
- There was degeneracy found between the photospheric temperature and bulk Lorentz factor.
- This supports the previos polarisation study by Chattopadhyay et al 2022, where this burst was reported to be unpolarised.
- The mBB model is capable to explain different shapes and widths of the spectrum.

REFERENCES

- Broadening of the thermal component of the prompt GRB emission due to rapid temperature evolution, Bharali et.al. 2017
- Photospheric emission in gamma-ray burts, Peer et.al, 2016
- Multi color Black body emission in GRB 081221, Hou et al, 2018

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