Photospheric emission in GRBs

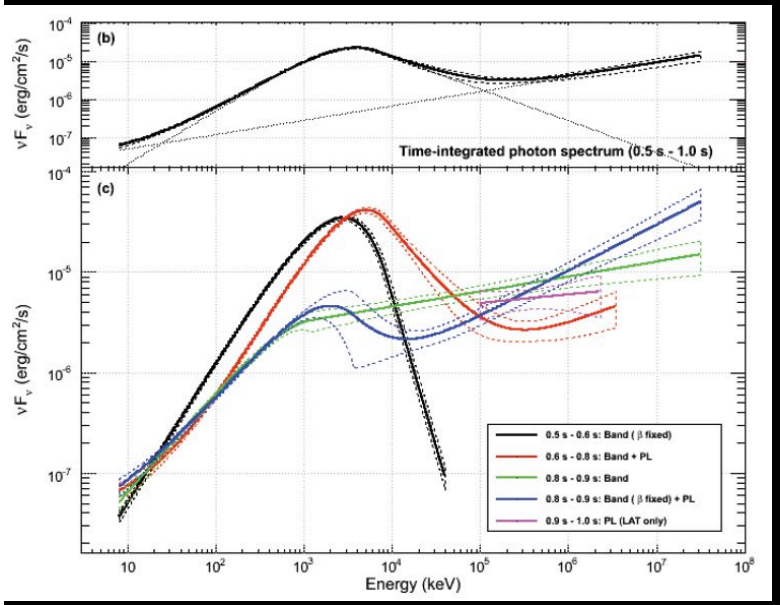
Bottom line(s)

1. There are evidence for a thermal emission during the prompt phase of many GRBs.

2. It is not possible to analyze the prompt phase using the same tools as for the afterglow !

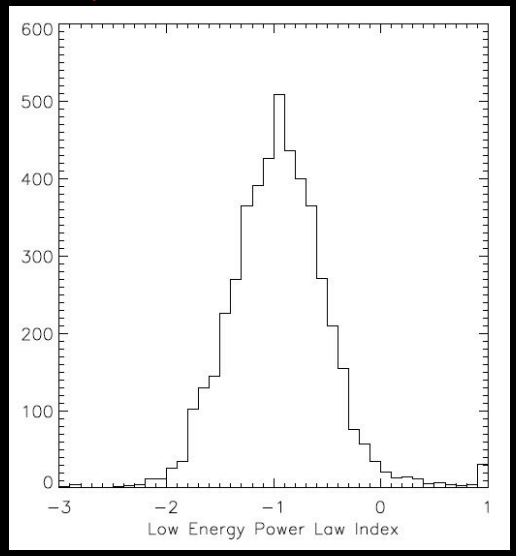
3. Thermal emission can be used to extract physical information on the outflow & progenitor
   -> Deduce Poynting dominated outflow

Why thermal emission ? - Observations



Synchrotron: AG;

"Synchrotron line of death"

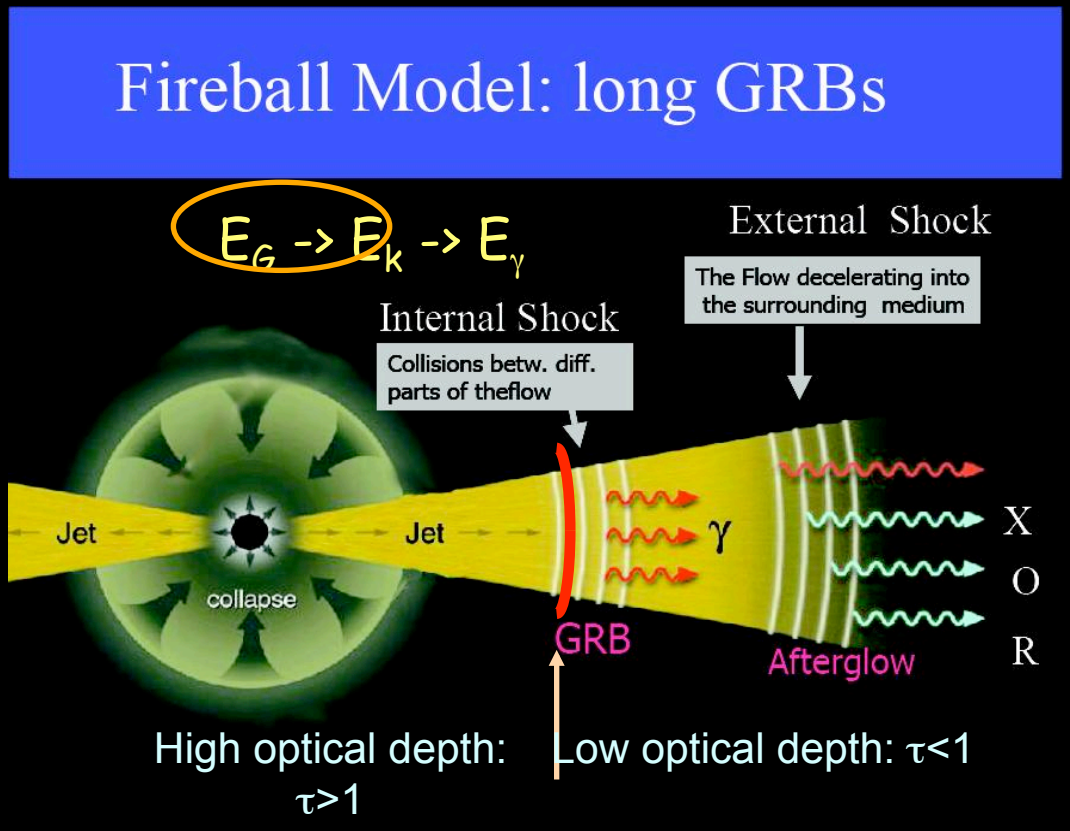


Why thermal emission ? - theory

TWICE:

1)

2) (Efficiency problem)

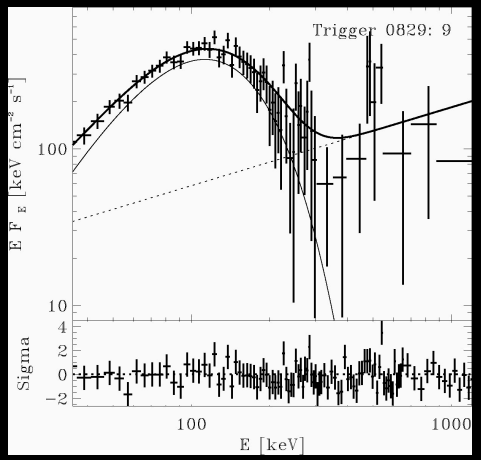


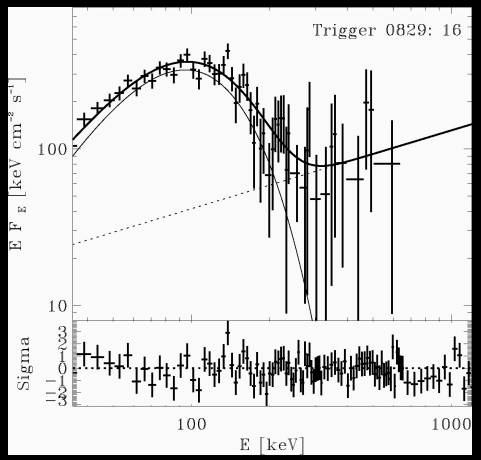
inevitably thermalize !

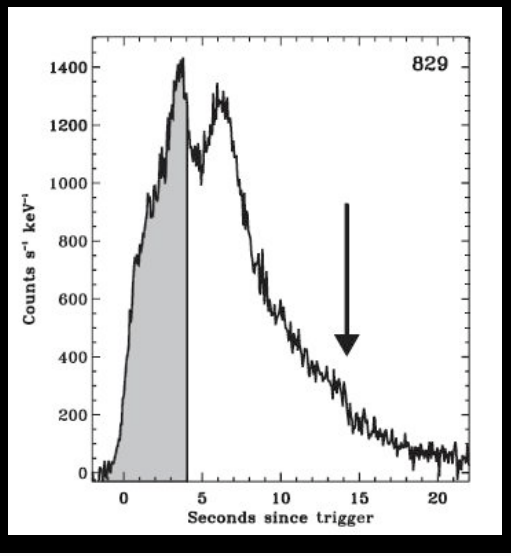
Natural outcome of fireball !

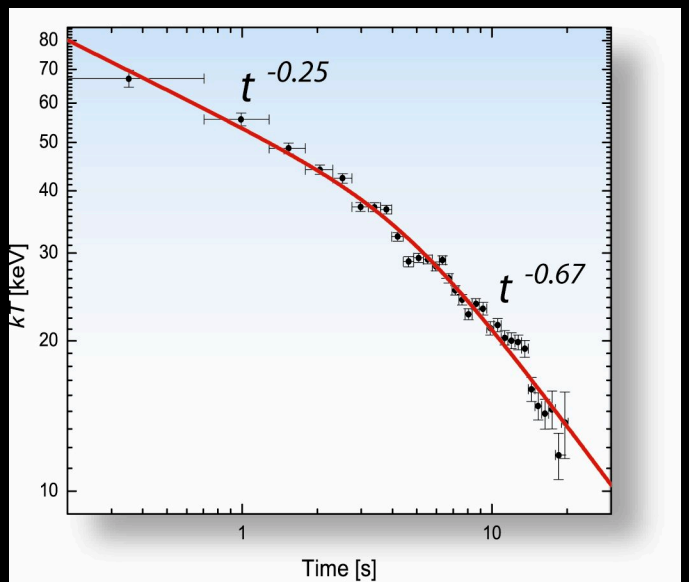
In search for thermal emission

Problems:







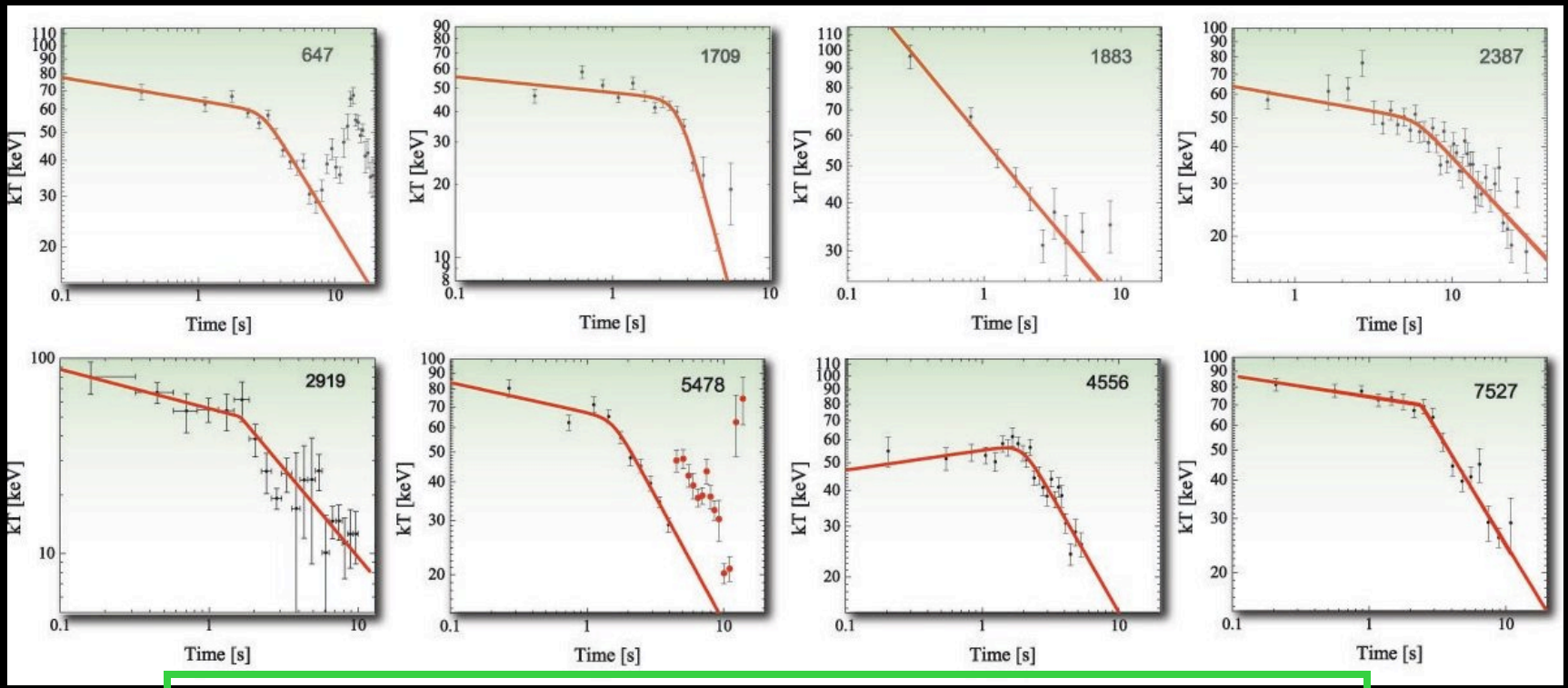


consistent physical interpretation !

In search for thermal emission (2)

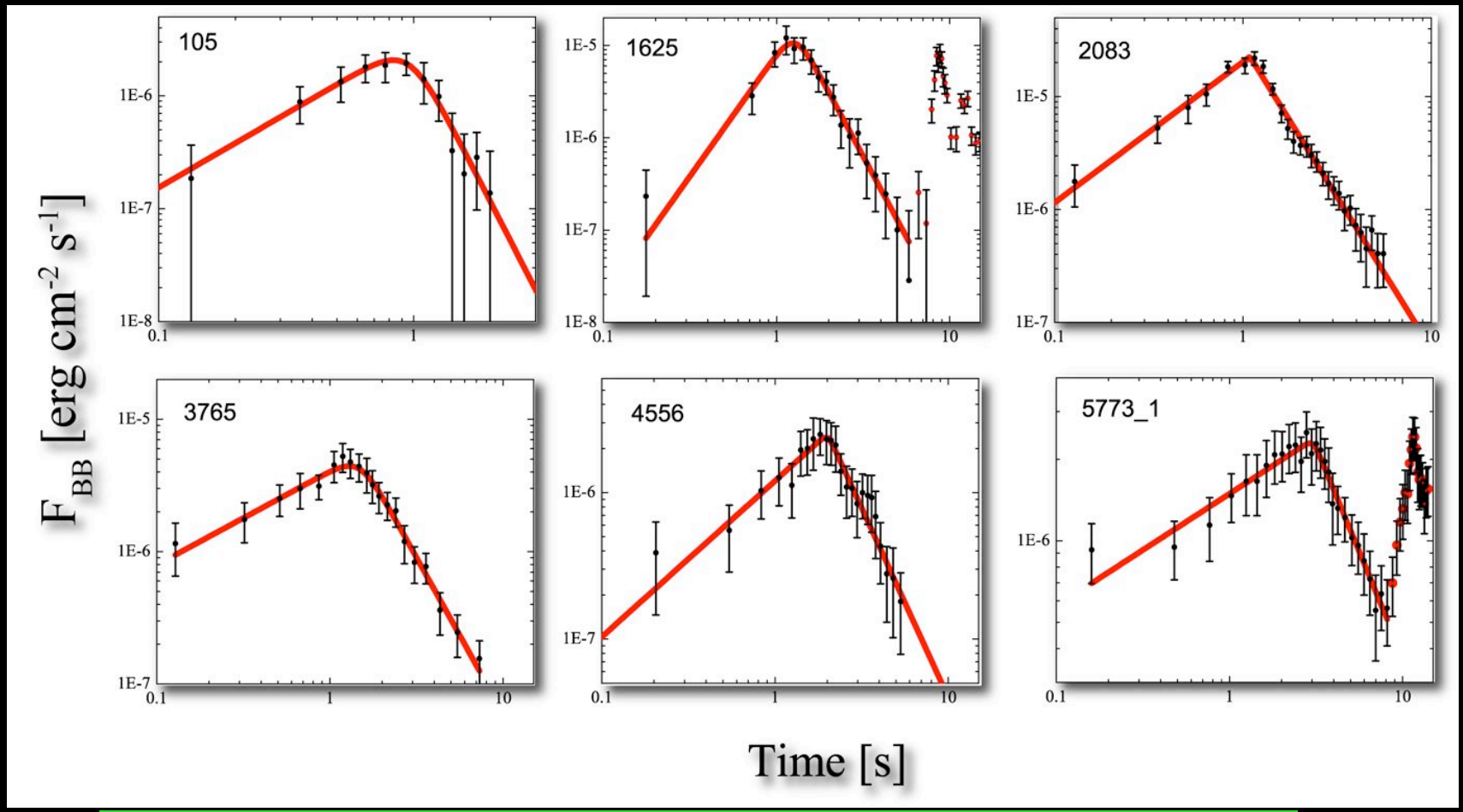
Major findings:

1) **Identify thermal emission**
2) **Characteristic behaviour:** (both Temperature and Flux)
   decreases as a broken power law



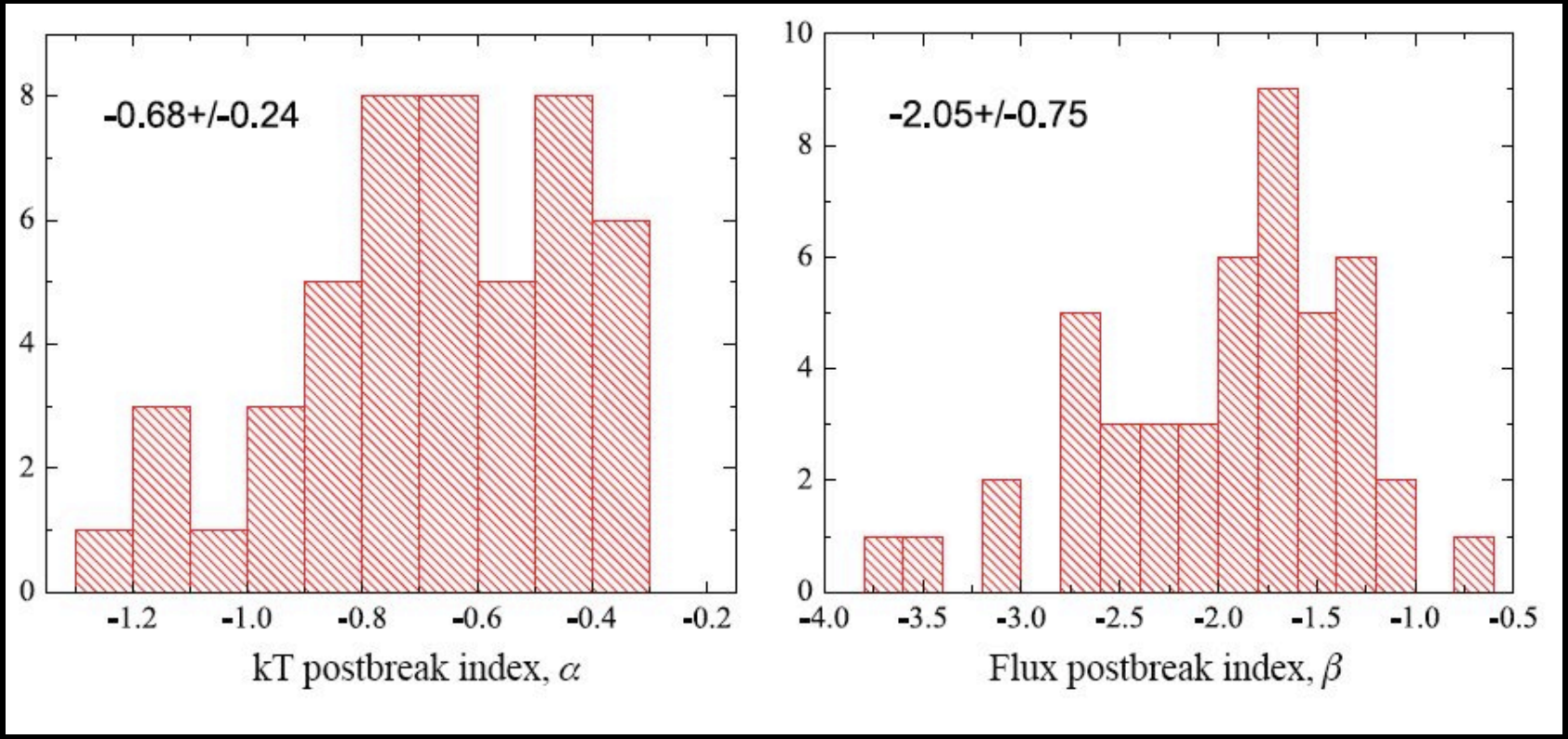
In search for thermal emission (3)

Thermal flux decay



also shows broken power law behaviour

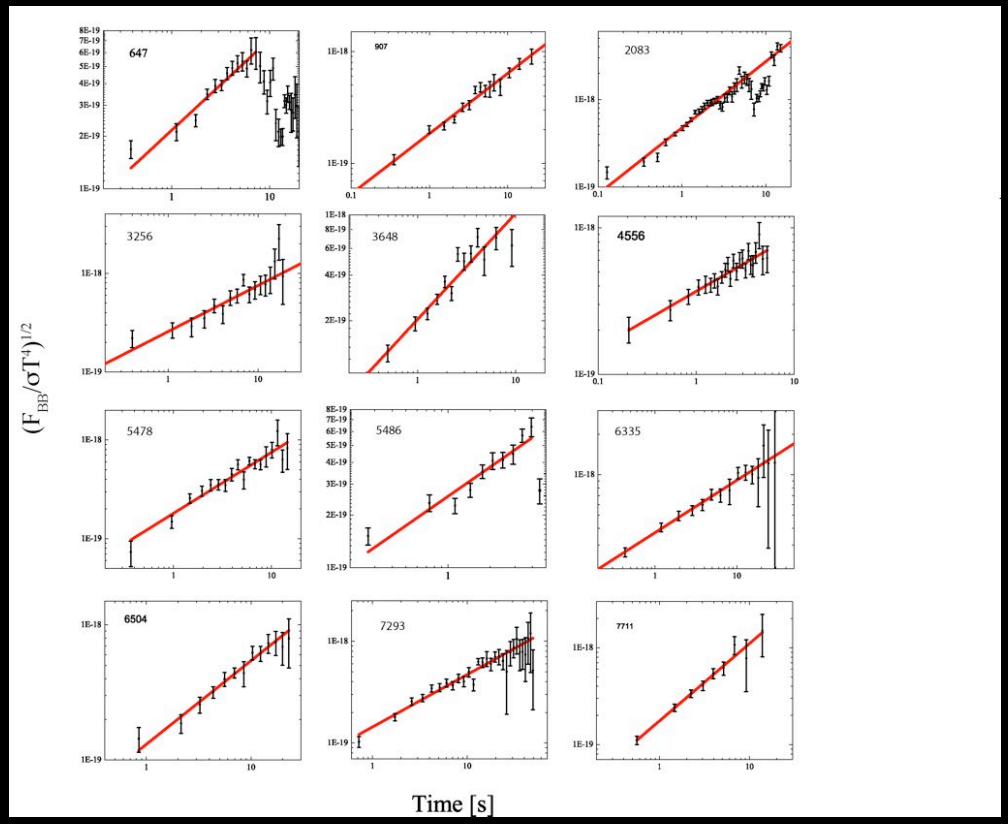
Histograms of late-time decay power law indices (56 bursts)



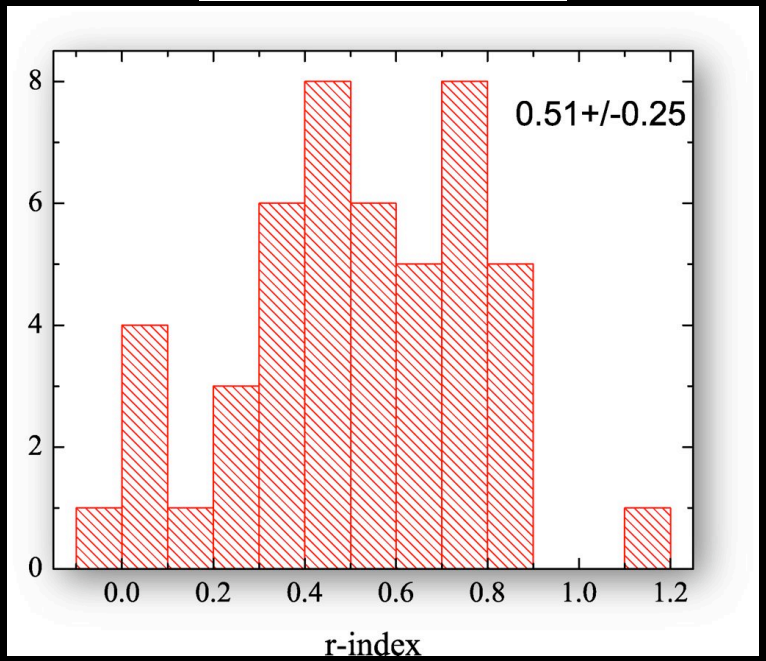
Power law decay of Temperature and Flux are ubiquitous !!!

In search for thermal emission (4)
Characteristic behaviour of the photosphere

The ratio between F_{bb} and σT^4 : $\mathcal{R} \propto t^{\beta}$, $\beta \cong 0.3 - 0.7$:

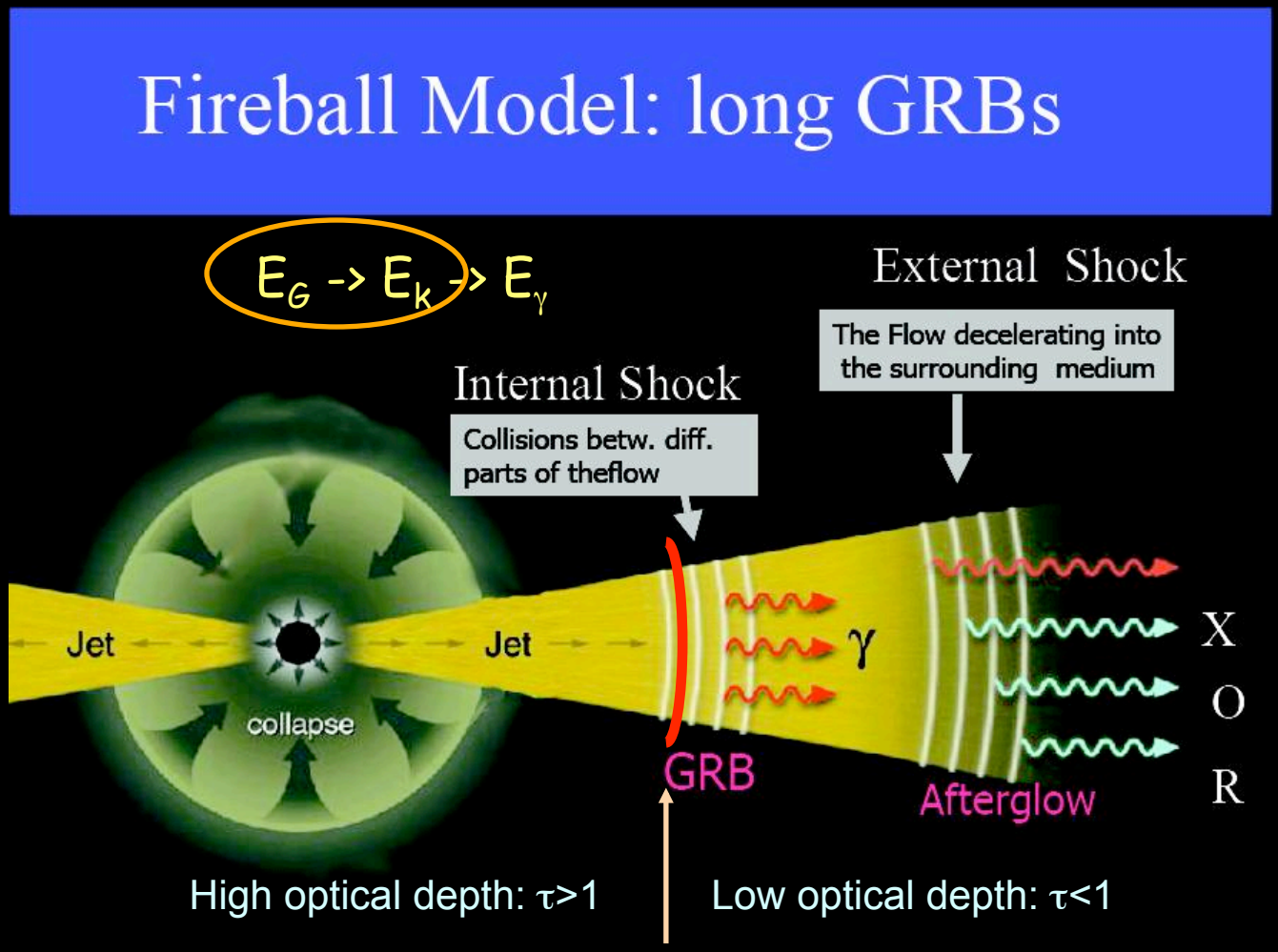


$$\mathcal{R}(t) \equiv \left(\frac{F(t)}{\sigma T(t)^4} \right)^{1/2}$$

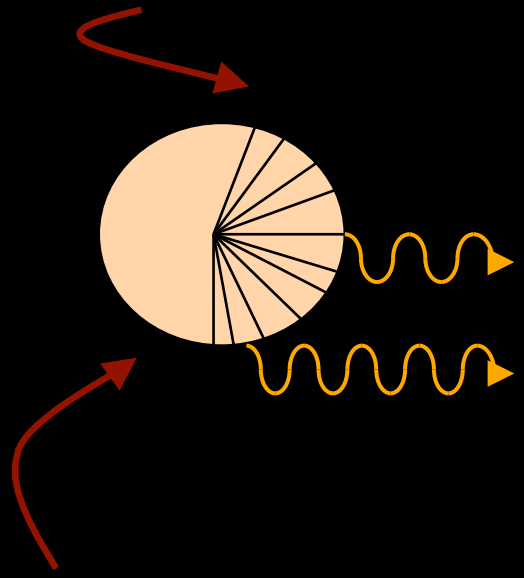


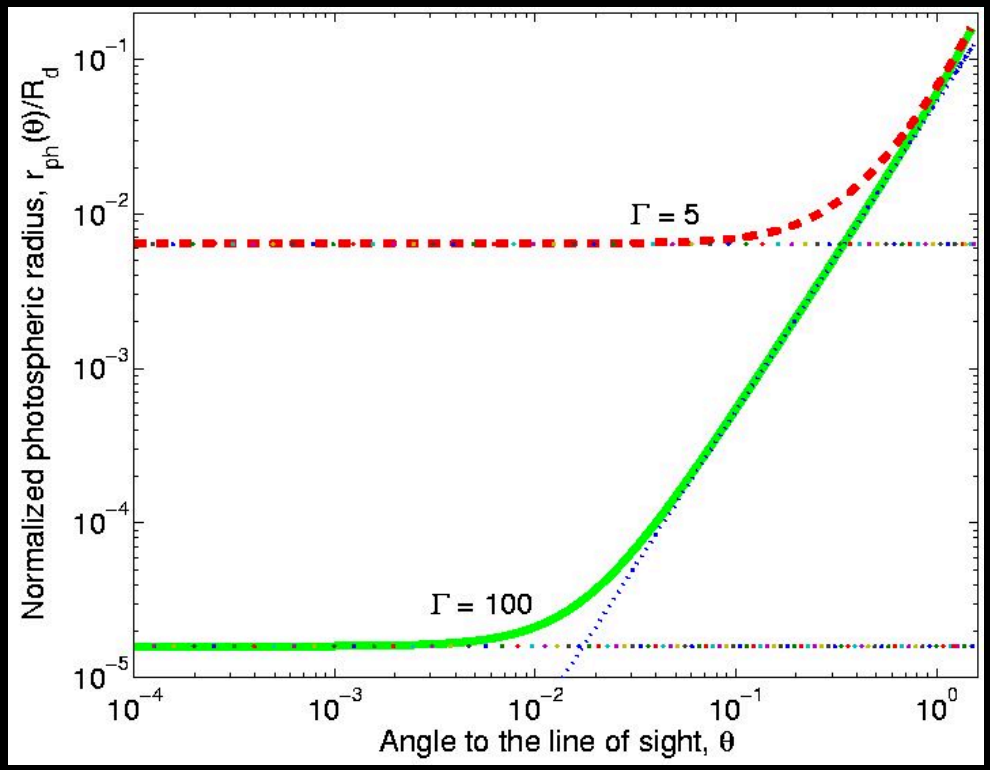
Theoretical interpretation

Thermal emission must originate from the photosphere



Photosphere in relativistically expanding plasma is θ- dependent





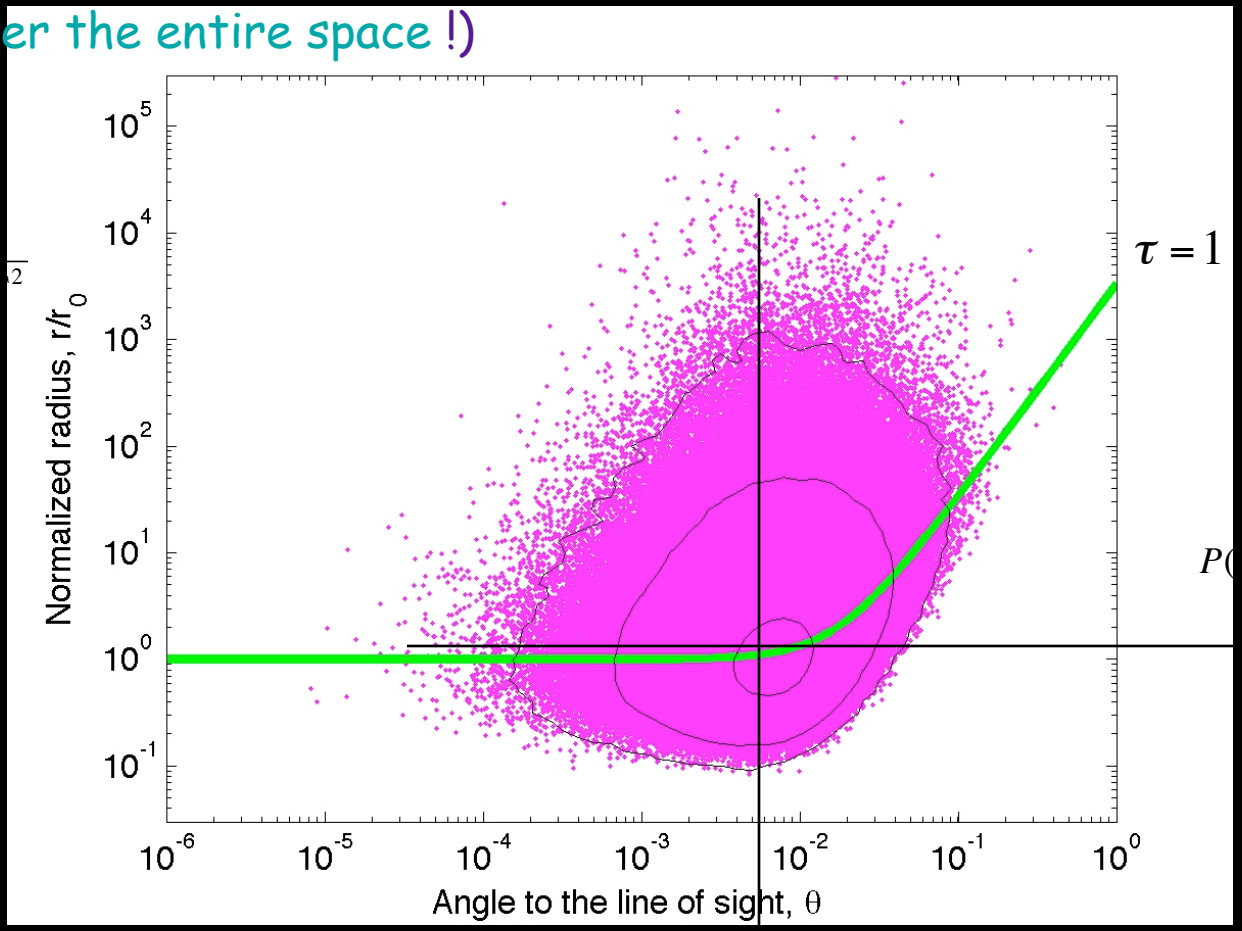
Thermal emission is observed up to tens of seconds !

Extending the definition of r_{ph}

Thermal photons escape from a range of radii and angles

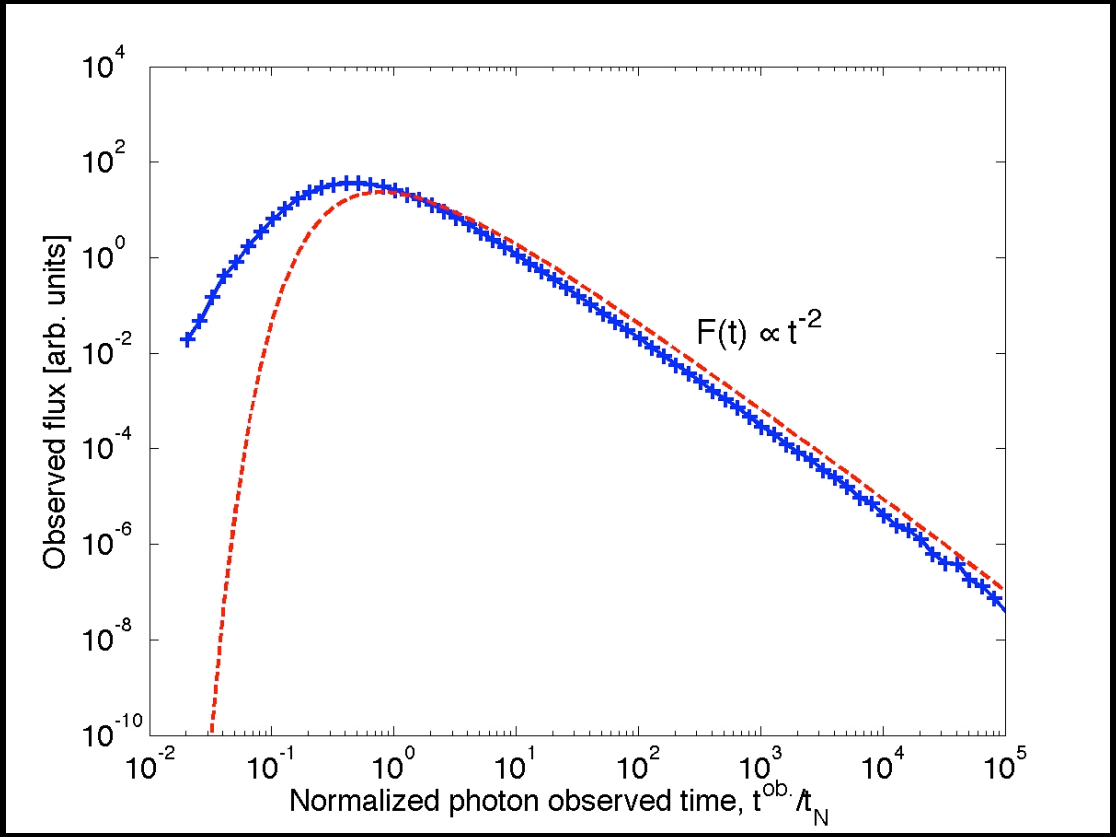
Photons escape radii and angles - described by probability density function

(Integrate over the entire space !)

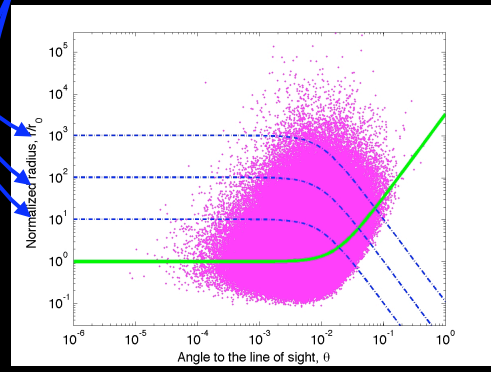


Late time temporal behavior of the thermal flux

(for a δ-function injection)

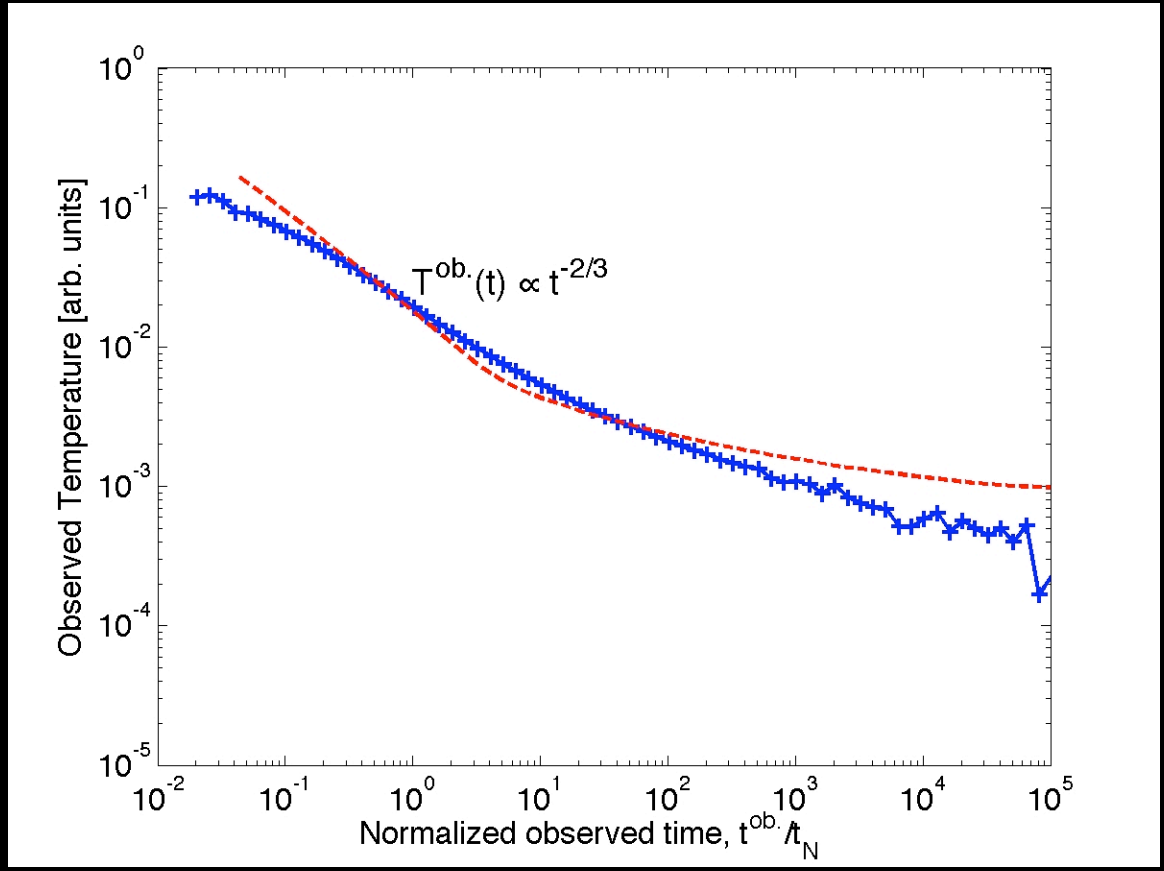


Equal arrival time contours



Thermal flux decays at late times as t^{-2}

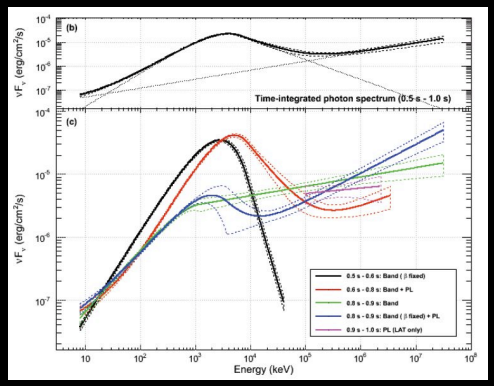
Temporal behavior of T and $\mathcal{R}$



Temperature decays as

So, are we seeing thermal emission ?

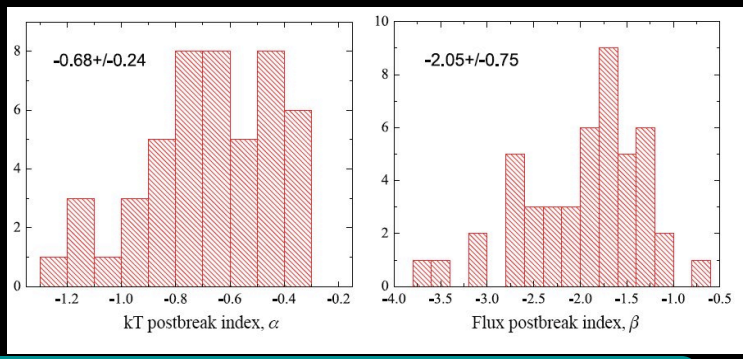
We can interpret what we see in many ways !



Thermal emission:

Histograms: $\langle T^{ob.} \rangle \propto t^{-0.68}$; $\langle F_{BB} \rangle \propto t^{-2.05}$;

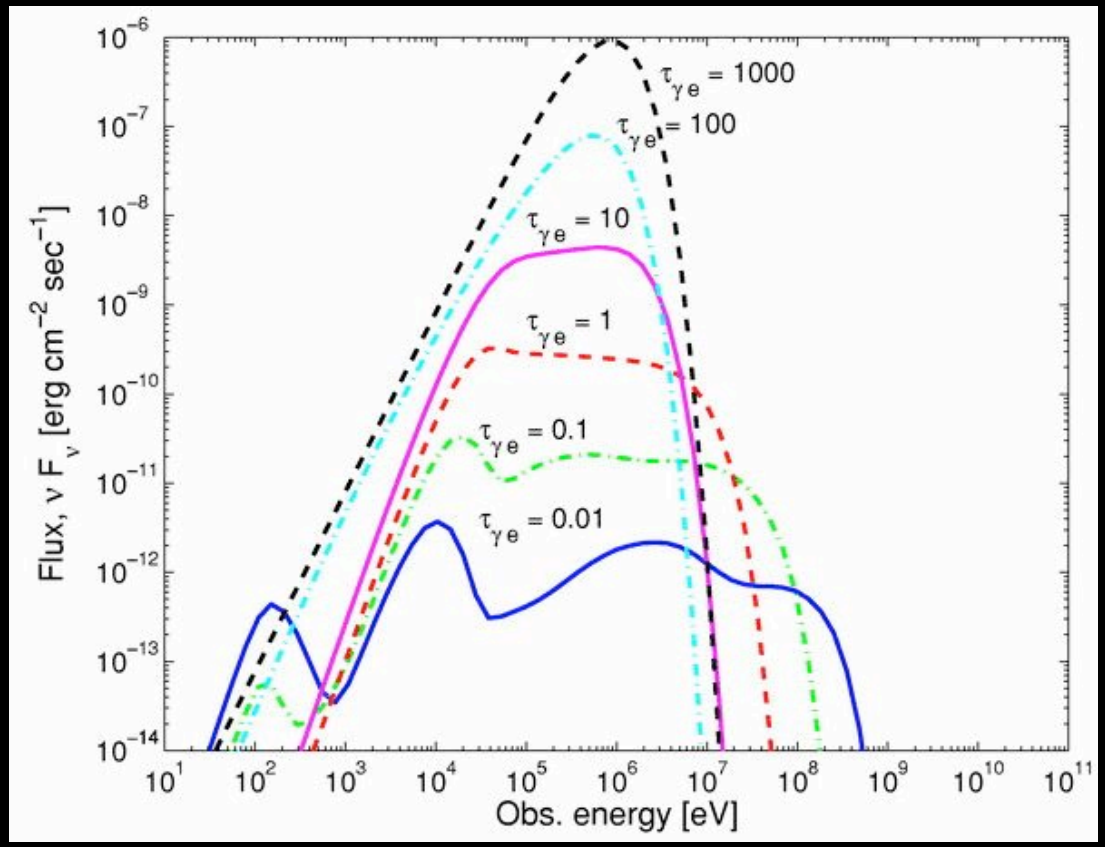
Theory: $T^{ob.} \propto t^{-2/3}$; $F_{BB} \propto t^{-2}$



Provides consistent physical interpretation to (part of) the spectrum

Implication of thermal component

a. complex relation between thermal and n.t. emission



Thermal photons serve as seed photons for IC - **Electrons rapidly cool**

"Quasi steady state": **Electrons distribution is not power law**

Real life spectra is not easy to model !! **NOT**

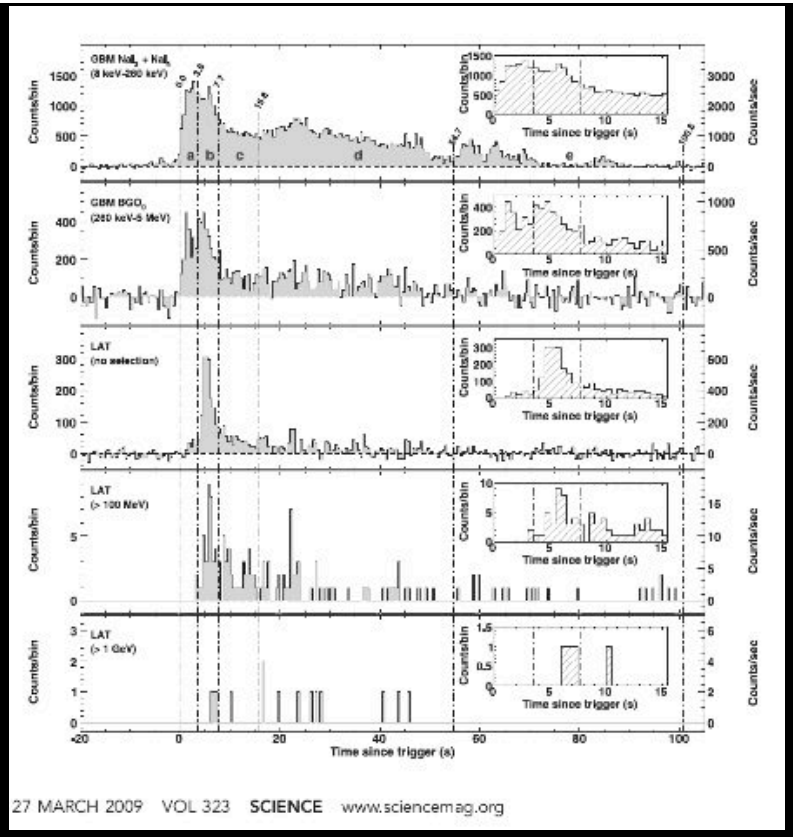
b. Implication of Non-detection of thermal component

RESEARCH ARTICLES

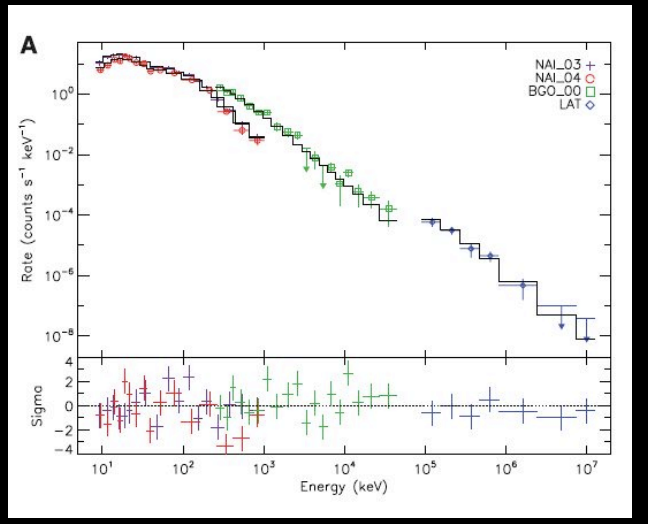
Fermi Observations of High-Energy Gamma-Ray Emission from GRB 080916C

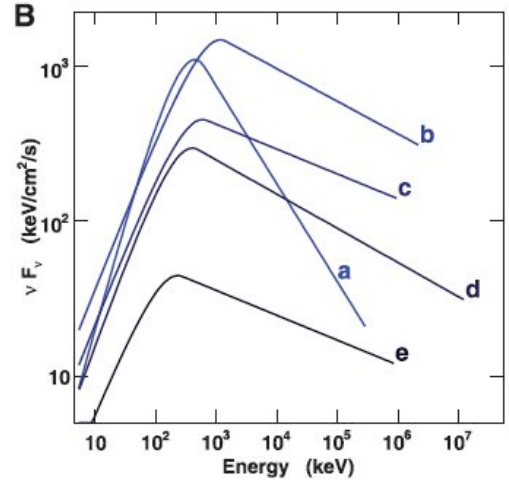
The Fermi LAT and Fermi GBM Collaborations*

- energetic (E_{iso} ~ 9 x10^{54} erg)
- High energy emission: 13.2 GeV
- No evidence for thermal emission



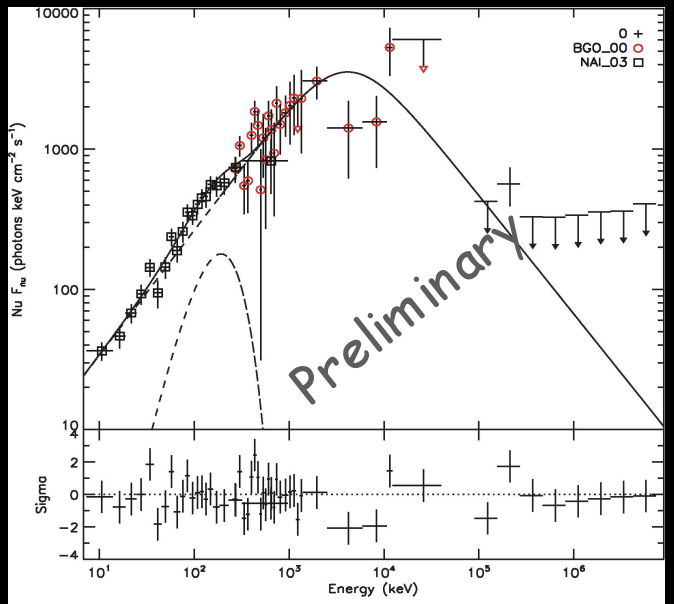
27 MARCH 2009 VOL 323 SCIENCE www.sciencemag.org

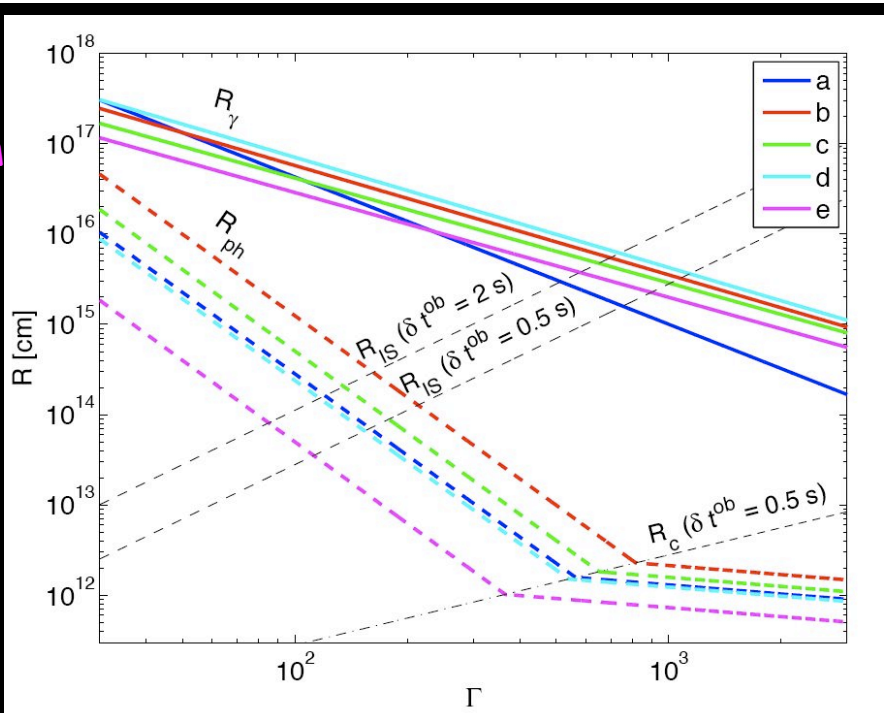


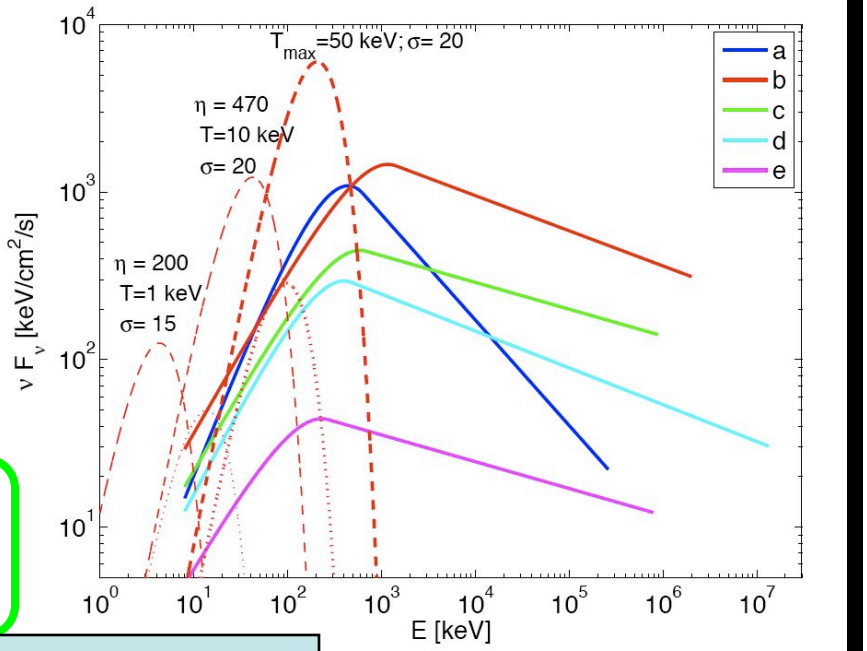


→ lower limit on emission radius, R_γ ~10^{15}-10^{17} cm
→ Not from the photosphere !

→ T^{ob} <~50 keV, F_{th} are known;
..but not seen







Additional source of energy between R_{ph} and R_γ !

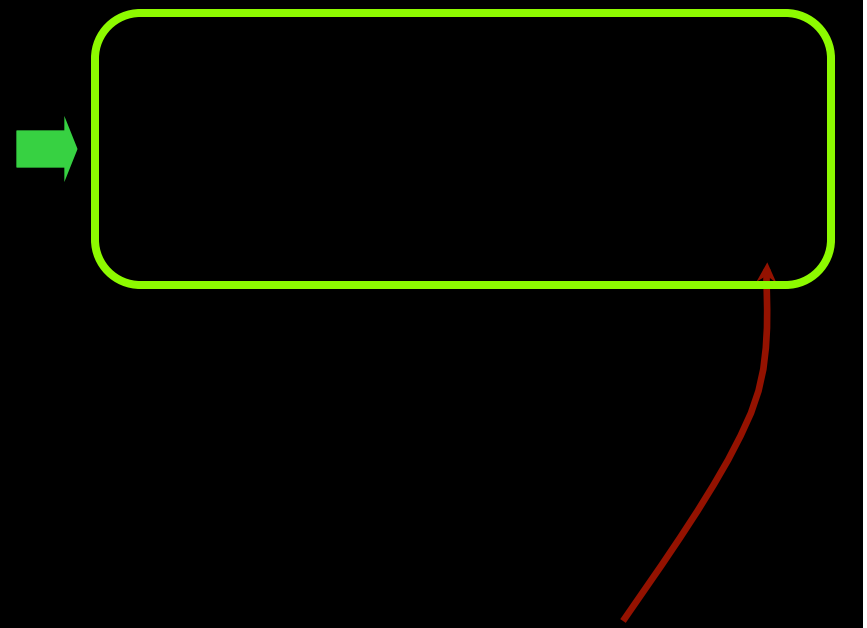
No time - skip to summary

c. Using thermal emission to measure outflow parameters

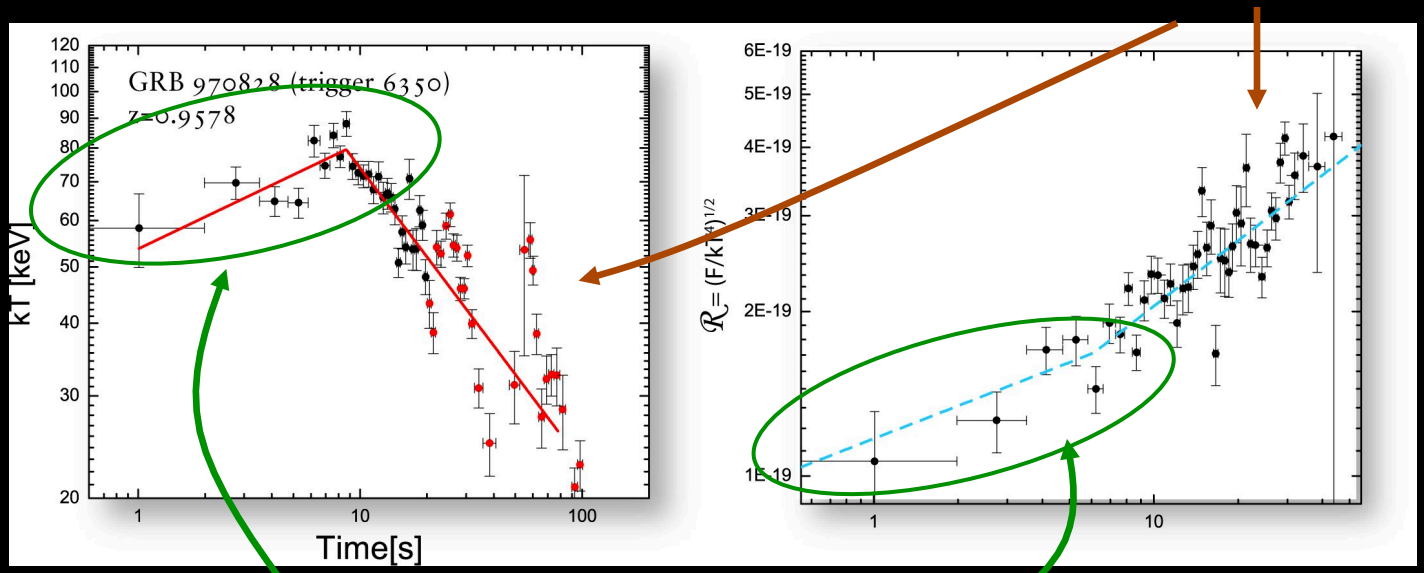
Why $\mathcal{R}$: (Thermal) emission from wind inside a ball

wind

Photospheric radius



Measuring physical properties of GRB jets - I



Emission is dominated by on-axis photons

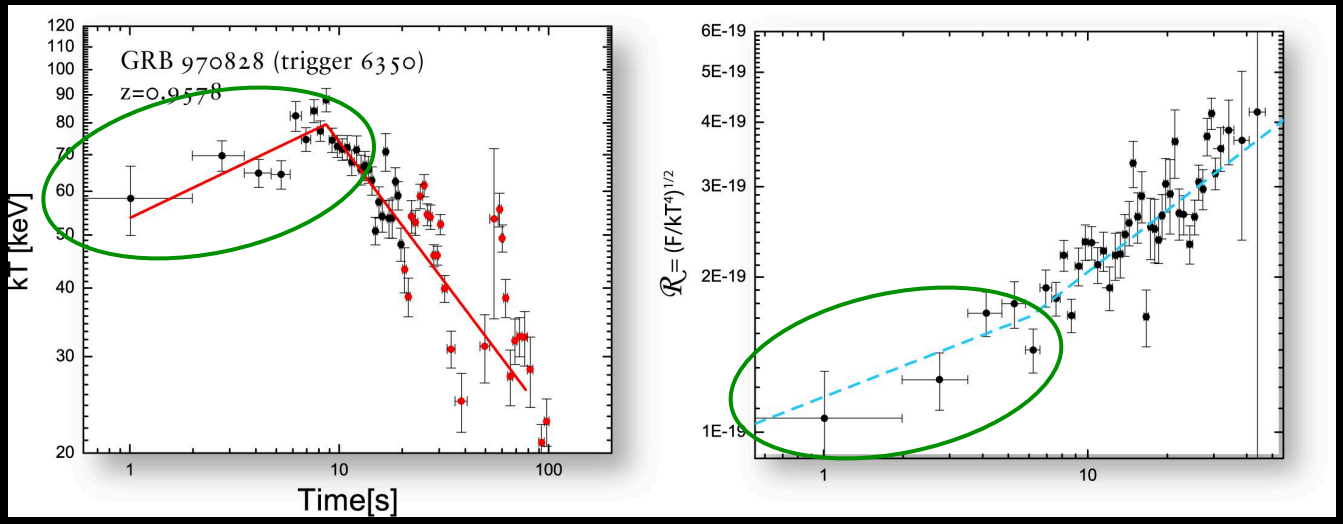
Known:

Unknown:

Measuring physical properties of GRB jets - II

Measuring quantities below the photosphere

r_0 = size at the base of the flow



Specific example:

GRB970828 (z=0.96)

Γ=305±28

r_0=(2.9±1.8)×10^8 cm

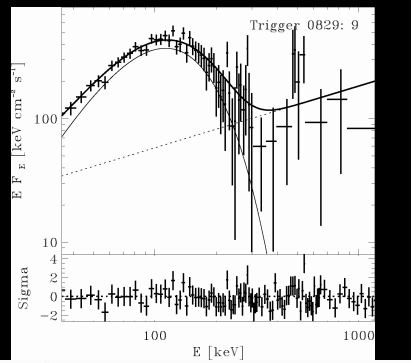
So what does it mean ? (general thoughts)

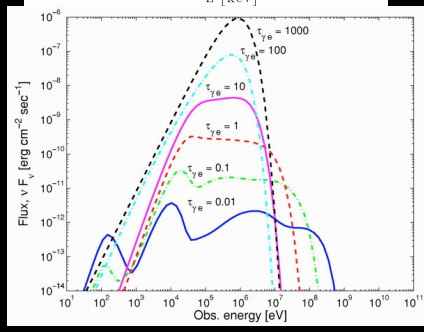
-
-
-

Bottom lines & summary

- **There are evidence for a thermal emission during the prompt phase of many GRBs.**

  Based on:
  a) Repetitive behavior;
  b) agreement between theory & obs.





- **It is not possible to analyze the prompt phase using the same tools as for the afterglow !!!**

- **Thermal emission can be used to extract physical information on the outflow & progenitor**

  a direct measurement

  Evidence for non-baryonic composition

GRB970828 (z=0.96)

Γ=305±28

$r_0=(2.9\pm1.8)\times10^8$ cm