# A model of the extended emission of short duration Gamma-ray bursts


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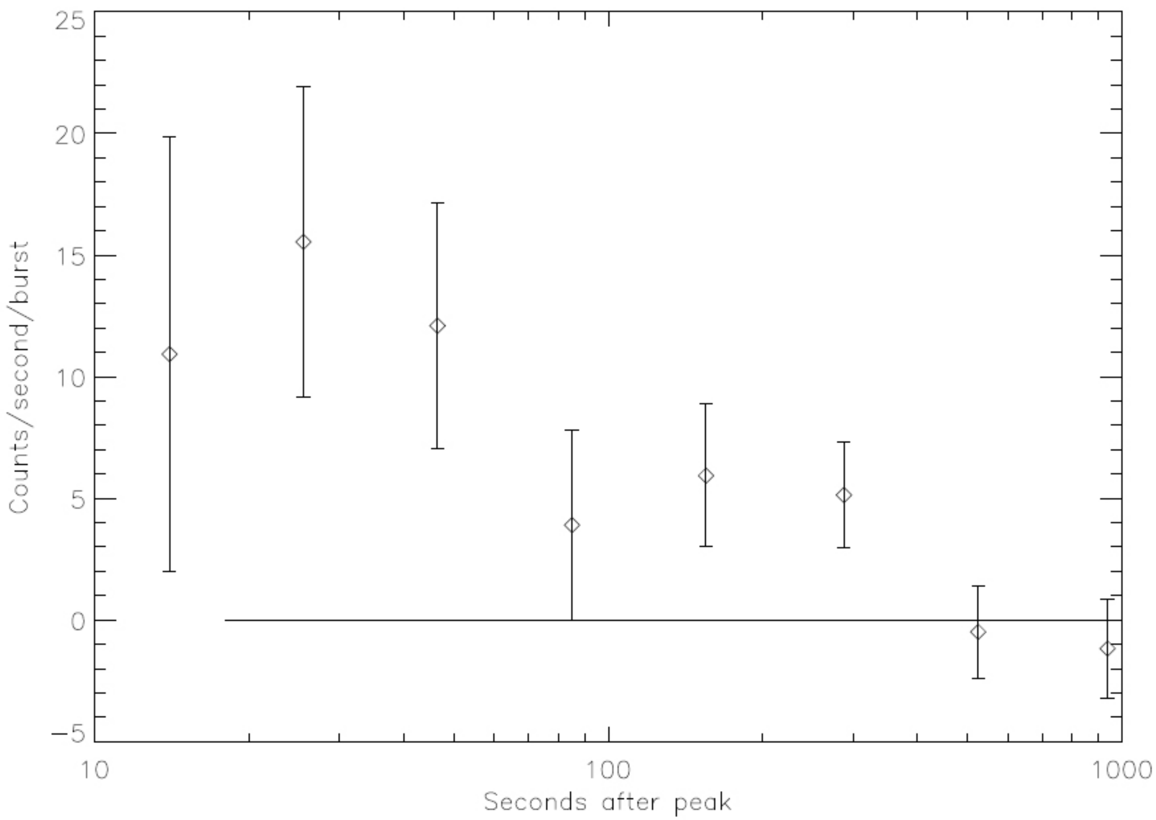
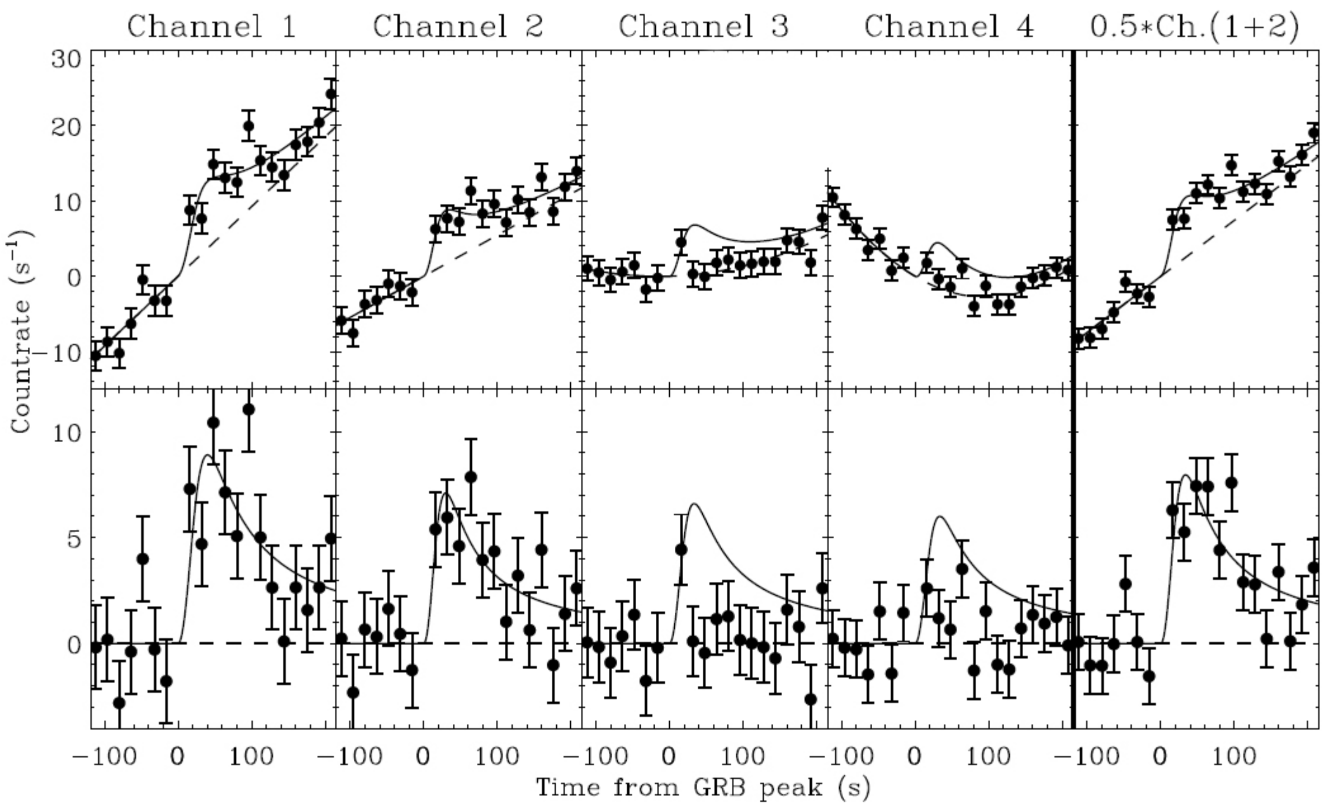
# Extended emission of Short GRBs (I) Ensemble of short GRBs




**BATSE**

Connaughton (2002)

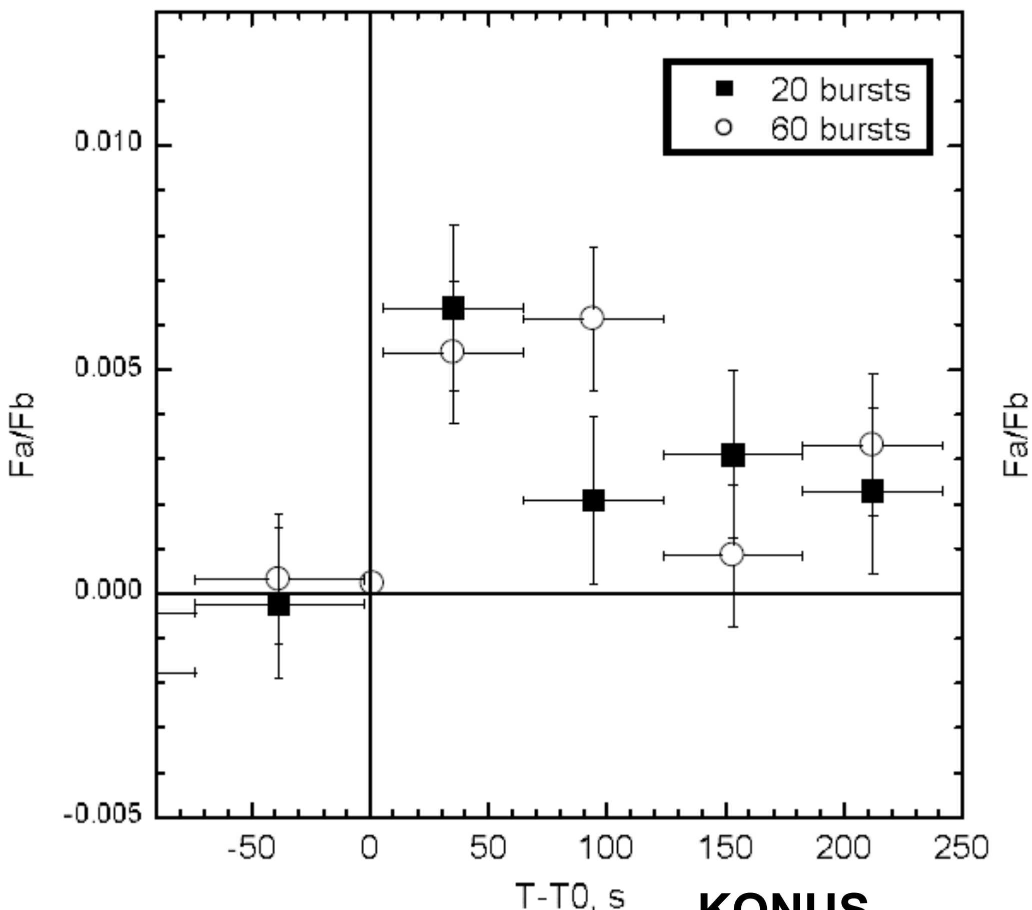
# Extended emission of Short GRBs
# (I) Ensemble of short GRBs




**BATSE**

Lazzati et al. (2001)

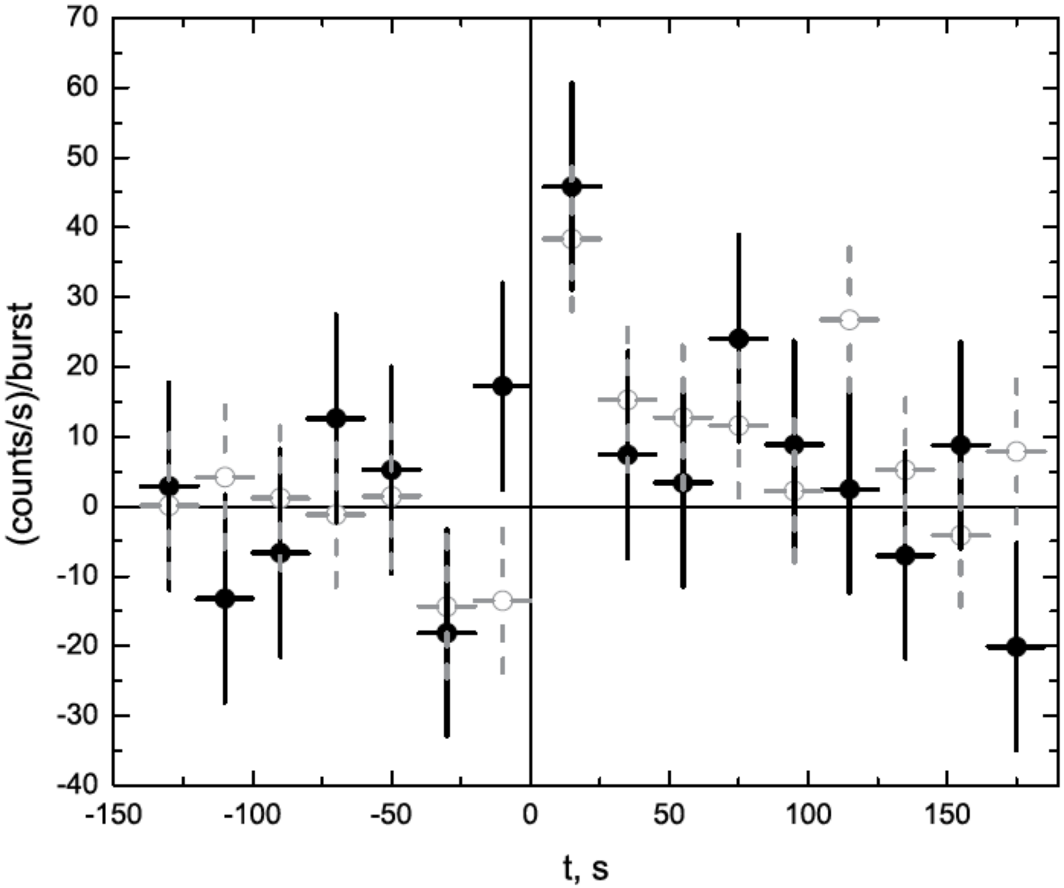
# Extended emission of Short GRBs
# (I) Ensemble of short GRBs




**KONUS**

Frederiks et al. (2004)

# Extended emission of Short GRBs (I) Ensemble of short GRBs




**SPI-ACS/INTEGRAL**

Minaev et al. (2010)

. Extended emission in the averaged light curve of short GRBs

| Experiment | Energy range, keV | Number of investigated GRBs | Emission duration, s |
|---|---|---|---|
| BATSE | 25-110 | 76 | 100 [1] |
| BATSE | 50-300 | 100 | 100 [2] |
| Konus | 10-750 | 125 | 100 [3] |
| BeppoSAX | 40-700 | 93 | 30 [4] |
| INTEGRAL | $> 80$ | 53 | 25 [5] |
| INTEGRAL | $> 80$ | 43 | 125 [6] |

[1] - Lazzati et al. (2001).
[2] - Connaughton (2002).
[3] - Frederiks et al. (2004).
[4] - Montanari et al. (2005).

See also Posters:

**P-II-3 Fitzpatrick et al (BAT/Swift)**

# What is the extended emission: rising afterglow or prolonged activity of a central engine?

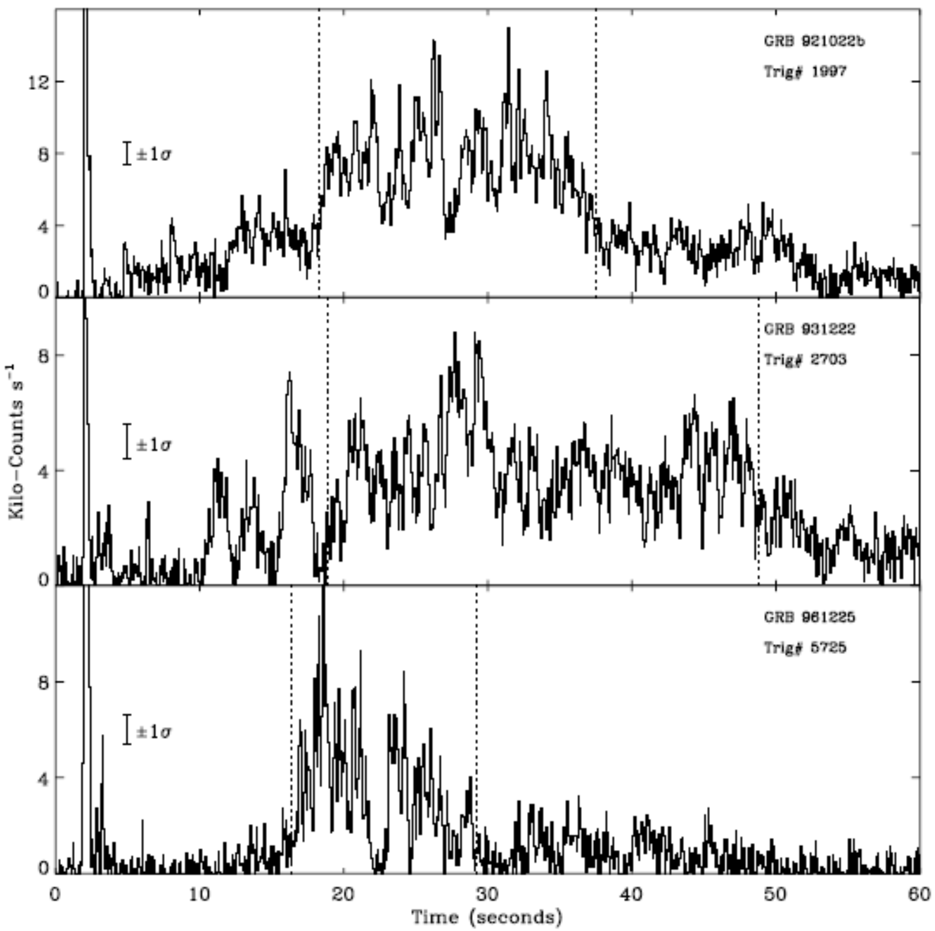
Prolonged activity?

Pros: Extended emission found in energy range > 80 keV. However, it is softer, than main peak (IPC)

Cons: ???

# Extended emission of Short GRBs?

## (II) Long GRBs which look like short GRB o




No spectral lag

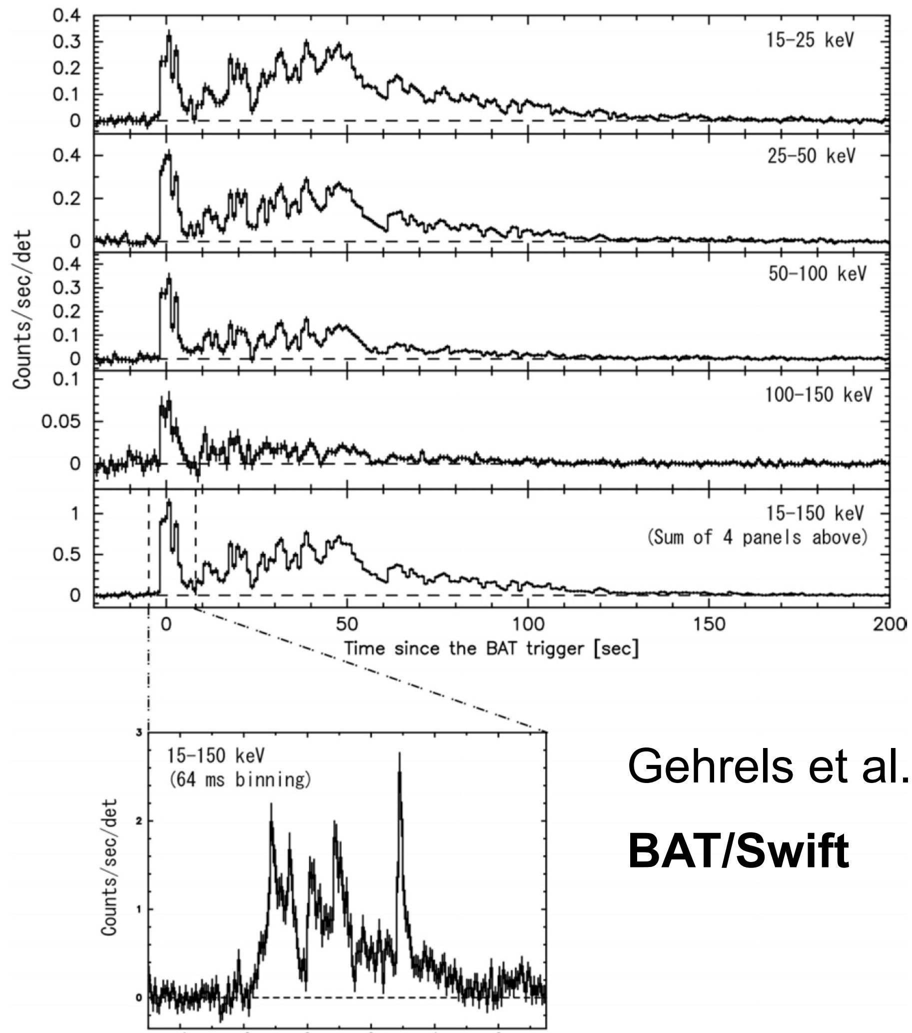
Fluence ratio of main peak and extended emission ~ 1

**BATSE**

Norris & Bonnell (2006)

# Extended emission of Short GRB?

## (III) GRB 060614 – ultimate example of long ($T_{90}$ ~ 100 s) GRB which looks like short one




z=0.125

No Supernova!

No spectra lag!

Fluence ratio of main peak and extended emission < 1

Peak flux ratio ~ 1

Gehrels et al., 2006

**BAT/Swift**

# Extended emission of Short GRB?

Sakamoto et al, **The Second Swift BAT Gamma-Ray Burst Catalog: ~2% of Short GRB with EE**

See also Posters:

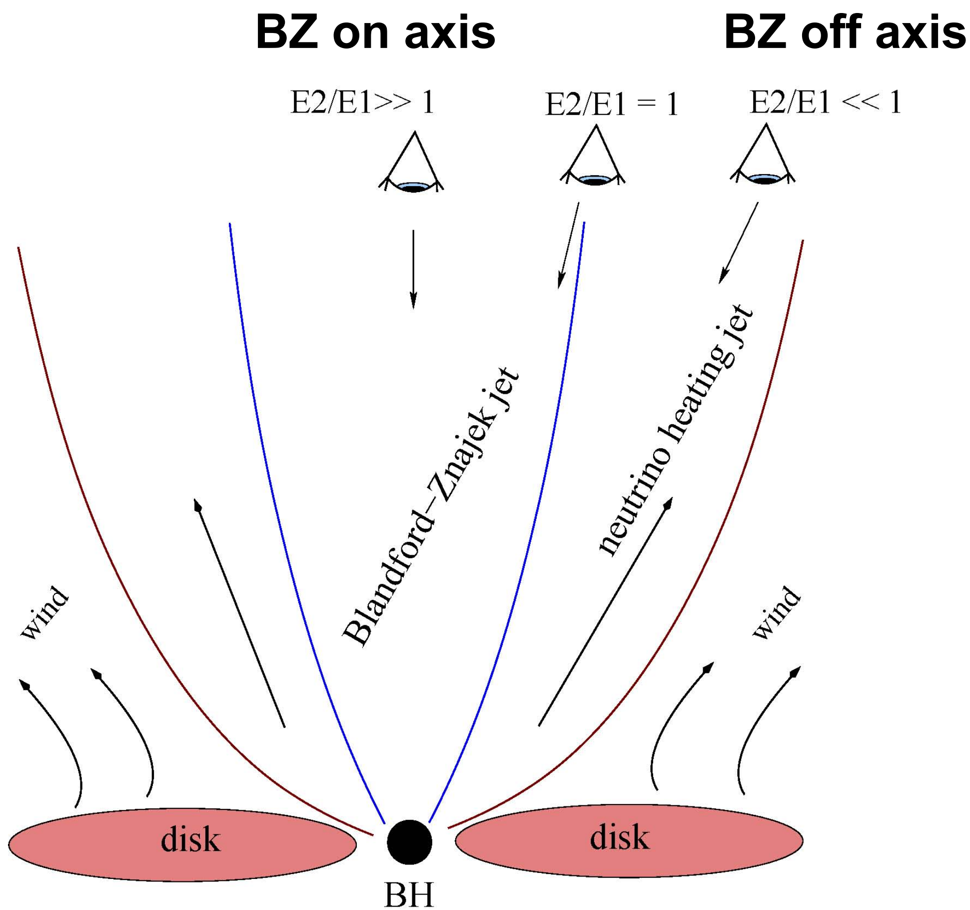
P-II-4 Bostanci et al (BATSE GRB with EE)

Are the cases above (I – III) the same phenomenon?

Otherwise, is it necessary to introduce new groups of the bursts, i.e. Short burst with Extended Emission?

# Two jets model

## Barkov&Pozanenko MNRAS.417.2161B

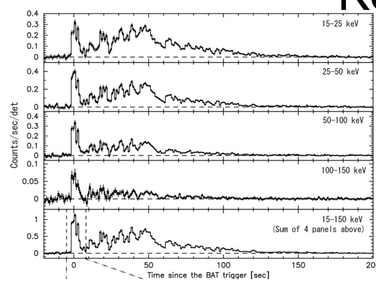


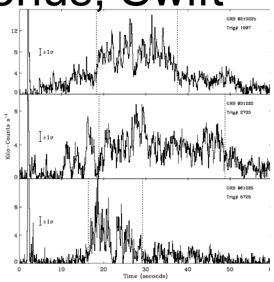
# Two jets model

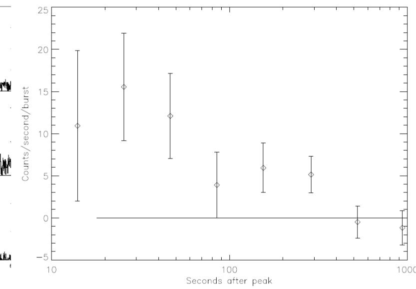
1-3% of BATSE, Konus, Swift

GRB 060614

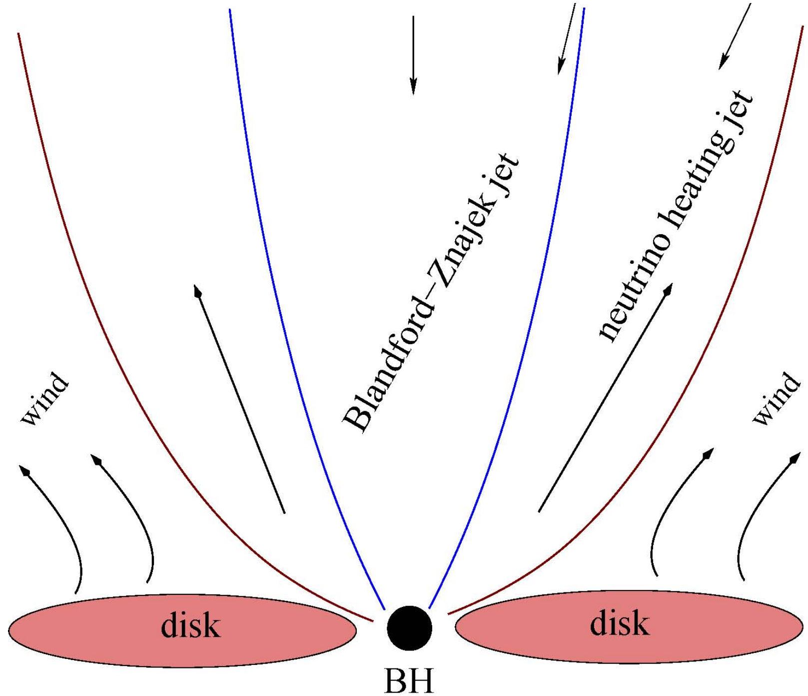
unique




All Short GRBs aligned against main peak

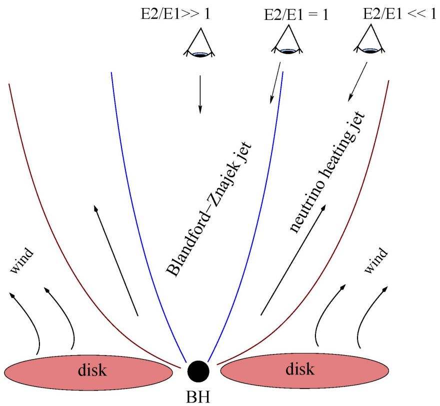


# Two jets model (1)

We suggest a two component model with a neutrino heating (Woosley 1993) and an electromagnetic Blandford-Znajek mechanism (Blandford & Znajek 1977). Main short peak (~ 1 s) is a result of fast short accretion period (Popham et al. 1999), when the accretion rate is higher then ~ $0.05 M_{\odot}$ $s^{-1}$. While the accretion rate becomes lower, the efficiency of neutrino heating drops dramatically (Zalamea & Beloborodov 2010). However the low accretion rate can keep the central machine activity at the observable level due to BZ mechanism (Lee et al. 2000; Mizuno et al. 2004; Barkov & Komissarov 2008, 2010).

# Two jets model (2)

- It is essential that opening angle $\theta_{BZ}$ (~1/Γ) of BZ-jet (Komissarov et al. 2009) is smaller than the opening angle $\theta_{\nu\tilde{\nu}}$ ~ 0.1 of neutrino powered jet (Aloy et al. 2005; Harikae et al. 2010).



# Extended emission vs. Initial peak

- What can be calculated numerically?
- (neutrino heating, BZ initial jet development)
- What can be estimated?
- (energy release in jets)
- And what cannot be done?
- (numerical selfconsistent calculations beyond ~1 s)

# What can be estimated?

Luminosity of BZ mechanism (Komissarov & Barkov 2010; Barkov 2010):

$$L_{BZ} \approx \frac{0.05}{\alpha_{-1}\beta_1}\dot{M}_{in}c^2 \approx 10^{48}\alpha_{-1}^{-1}\beta_1^{-1}\dot{M}_{in,-5} \text{ erg s}^{-1}$$

Luminosity due to neutrino heating (Zalamea & Beloborodov 2010):

$$L_{\nu\nu} \approx 3\times 10^{50}\left(\frac{R_{ms}}{4R_g}\right)^{-4.7}\left(\frac{M_{BH}}{3M_\odot}\right)^{-3/2}\left(\frac{\dot{M}_{in}}{M_\odot \text{ s}^{-1}}\right)^{9/4} \text{ ergs s}^{-1}$$

$\theta_{BZ}$ is opening angle of-BZ jet, and $\theta_{\nu\tilde{\nu}}$ is opening angle of neutrino heated jet

$$\frac{L_{BZ}}{L_{\nu\tilde{\nu}}} = \left(\frac{\theta_{BZ}}{\theta_{\nu\tilde{\nu}}}\right)^2 \frac{t_{\nu\tilde{\nu}}}{t_{BZ}} \sim 3\times 10^{-4}$$

# The both jets in one GRB?

**Parameters of the BZ and neutrino heated jets**

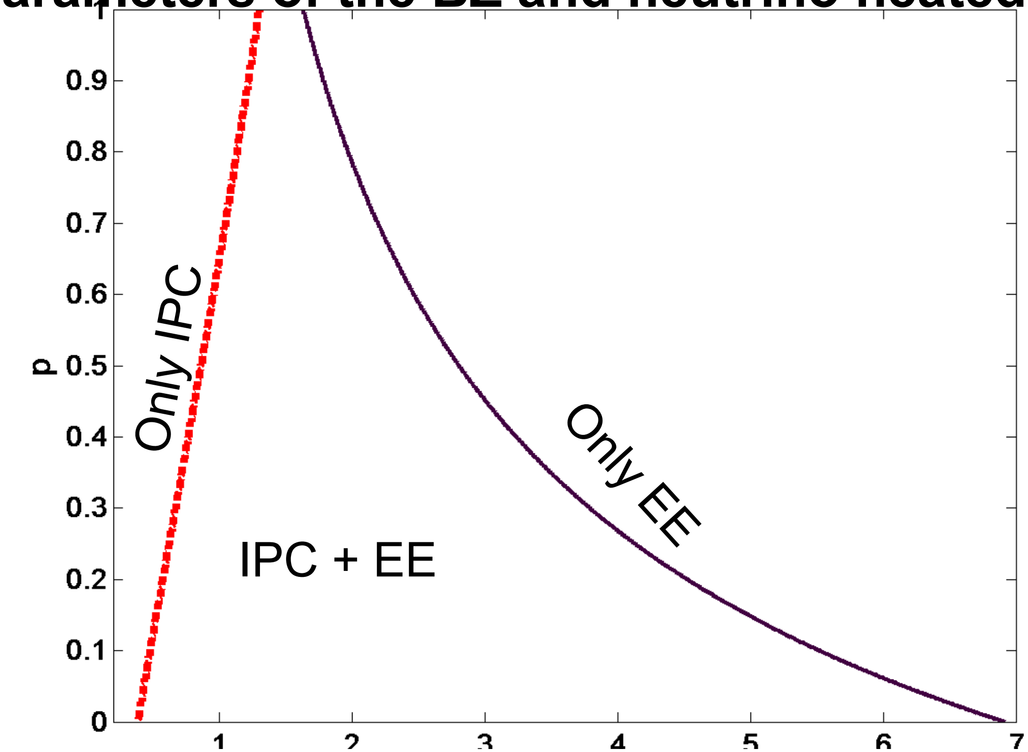
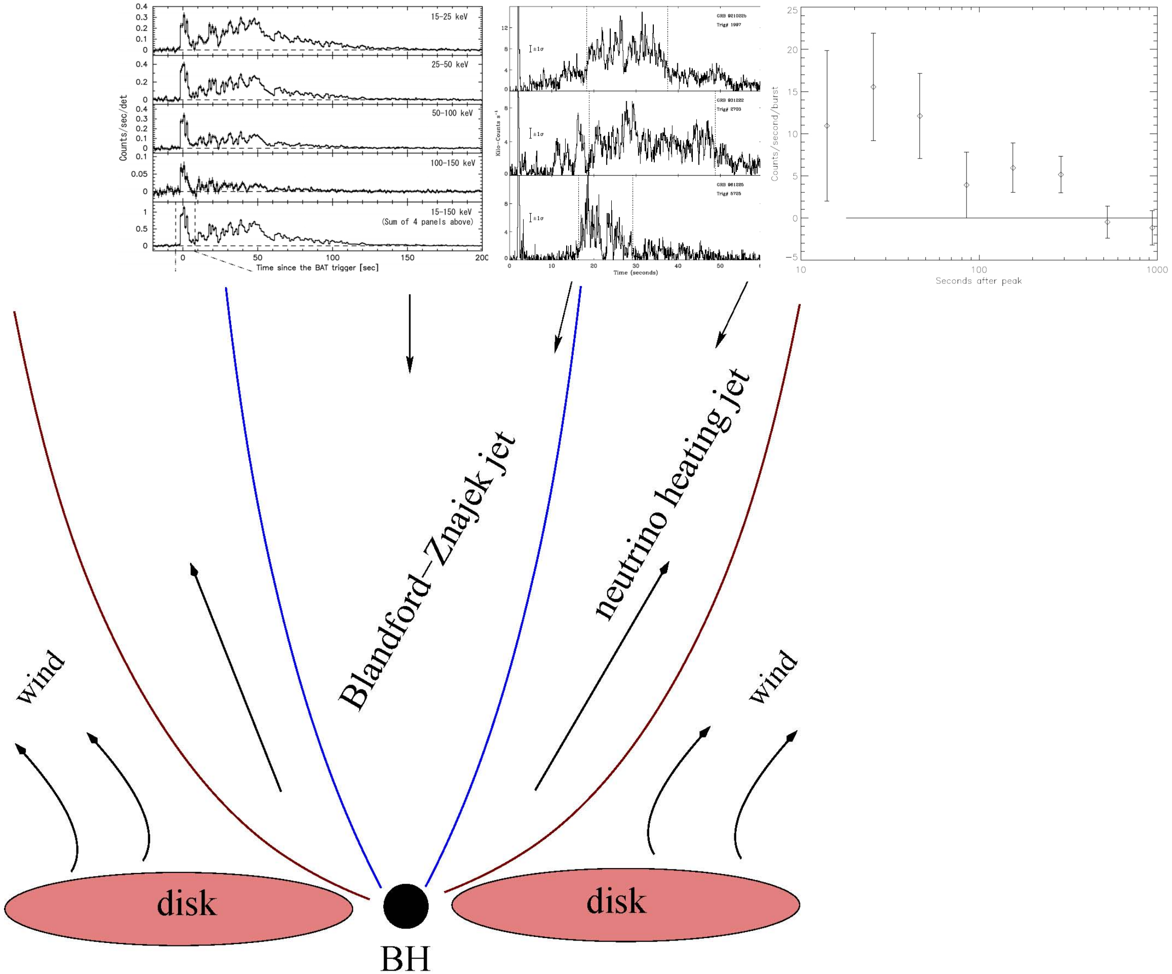



**Figure 4.** The first episode of short emission and EE is observable if initial parameters $p$ and $R_{\rm d,0}$ are between the lines. We take the initial mass of the accretion disc equal to $M_{\rm d,0} = 0.1\,{\rm M_\odot}$, $a = 0.5$, the duration of the IPC and the EE is $t_{\nu\tilde{\nu}} = 1$ s and $t_{\rm BZ} = 100$ s. The area to the right of the thick line corresponds to $L_{\rm BZ} \geq 3 \times 10^{-4} L_{\nu\tilde{\nu}}$. The area to the left of the thin line represents the initial accretion rate $\dot{M}_{\rm in} > 0.05\,{\rm M_\odot\,s^{-1}}$.

# Summary

- Two jets is a plausible model to explain the extended emission of the ensemble of short GRBs and small portion of individual burst with EE (e.g. GRB 060614)
- From observations one can estimate some parameters of the model, e.g. a ratio of the fluxes in main peak (IPC): The distribution of ratio should be continuous
- Statistical investigation of intensity of the Extended Emission and can reveal the ratio of the opening angles of the two jets and verify the proposed two jets model

# Thank you!



Blandford–Znajek jet
neutrino heating jet
wind
wind
disk
disk
BH