Testing a two-jet model of short Gamma-ray bursts

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Galaxies meet GRBs, Cabo de Gata, September 23-27

Outline

< How we can test them observationally? >

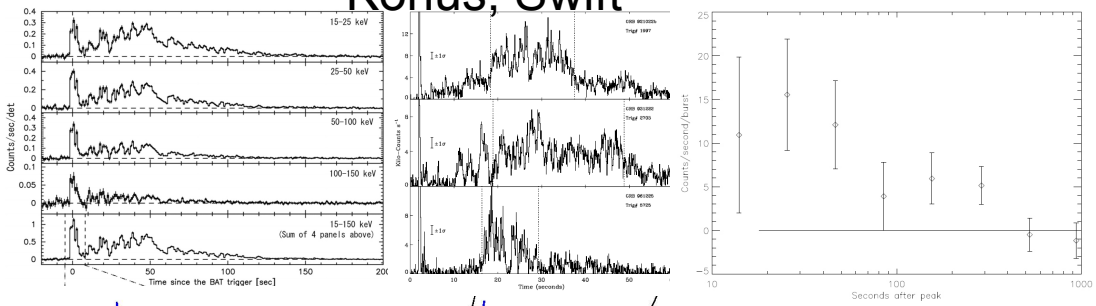
- Two jets model
- Observational properties of the model
- Feasible tests

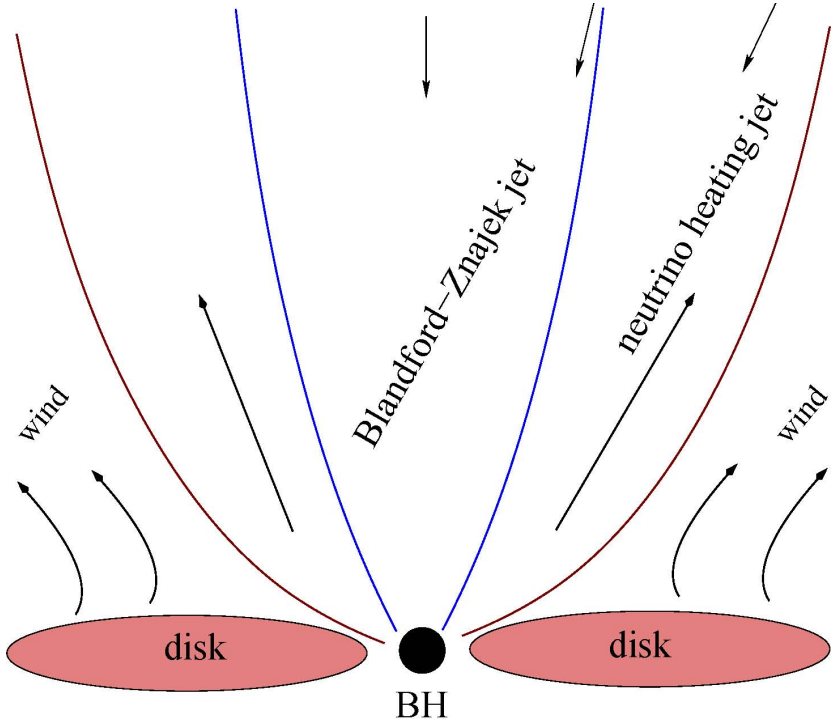
Two-jet model (Barkov & Pozanenko 2011)

1-3% of BATSE, Konus, Swift

GRB 060614

unique





Short GRBs aligned against main peak

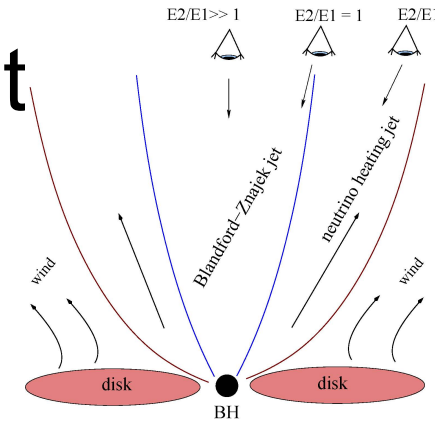
Two-jet model(1)

Two component model with a first component of neutrino heating (Woosley 1993) jet, and second jet based on electromagnetic Blandford-Znajek mechanism (Blandford & Znajek 1977). Main short peak, called IPC (~ 1 s) is a result of fast short accretion period (Popham+ 1999), when the accretion rate is high, more ~ $0.05 M_{\odot}$ 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+ 2000; Mizuno+ 2004; Barkov & Komissarov, 2008, 2010).

Two-jet model (2)

- It is essential that opening angle θ_{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). It is why t ΞE



Observational tests (I)
power law decay index

Mass accretion rate (and decay time profile of the EE) depends on wind parameter and in two extreme cases p=0, and p=1

$$\dot{M} \sim t^{-4/3} \text{ and } \dot{M} \sim t^{-8/3}$$

One can model the tail of the EE

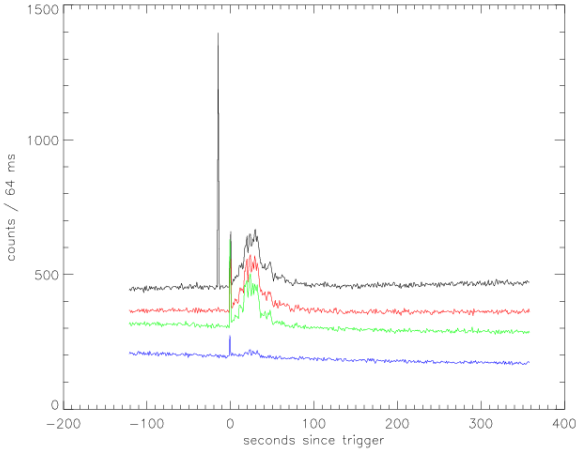
Power law index distribution

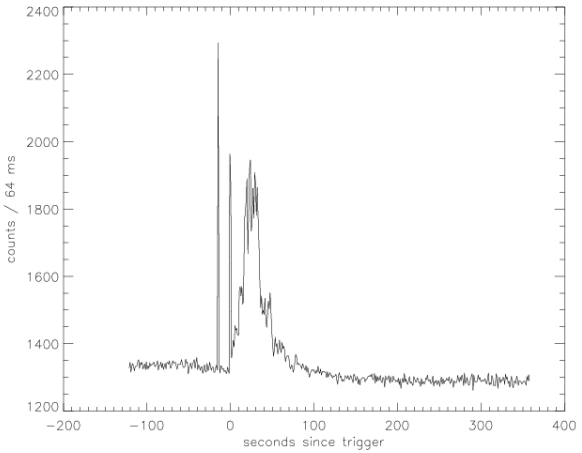
- BATSE list of short GRBs with the EE compiled from Norris & Bonnell, 2006 and Bostancı+, 2012

- BATSE trig. ## 503, 1088, 1626, 1997, 2436, 2703, 3853, 5725, 7446, 7647, 7936

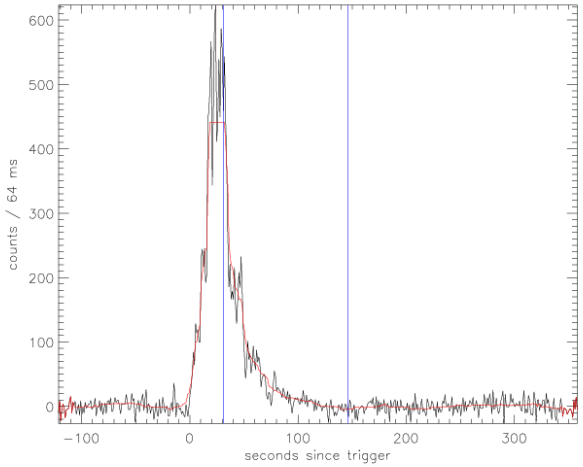
Example of lc fitting

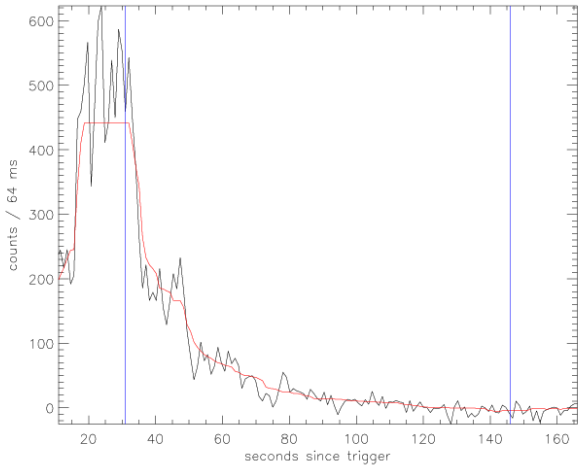
BATSE Trig.#1997



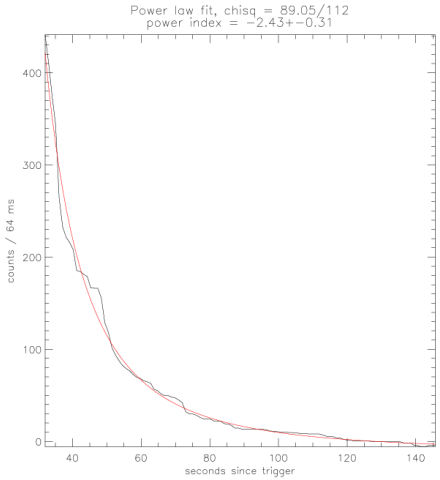


Original time profile





Bgd. subtracted time profile, IPC suppressed



Power law fitting

Observational tests (II)?

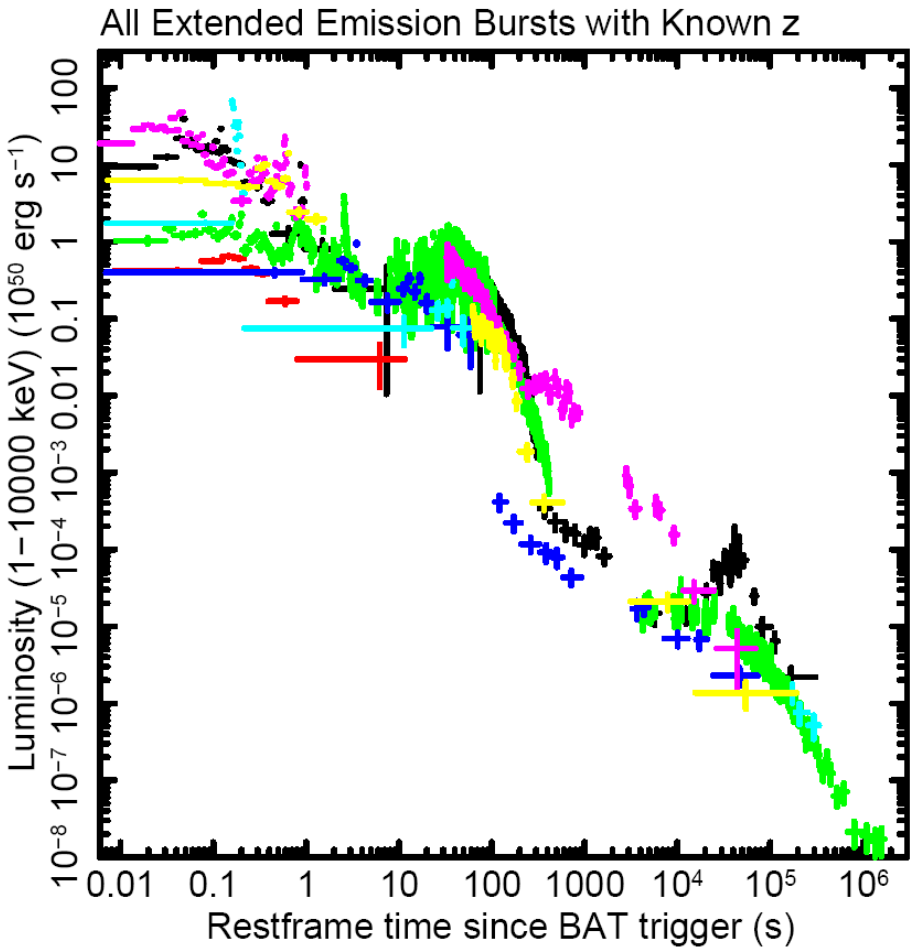
Absence of jet break in lc of afterglow:
Indeed for the BZ-jet opening angle is valid

$$\theta_{BZ} \sim 1/\Gamma$$

It might be if a fluence of the EE >> IPC

Observational tests (II)?

No immediate jet break in XRT afterglow



Swift/XRT- afterglow of short GRB with the EE

Gompertz+, 2013

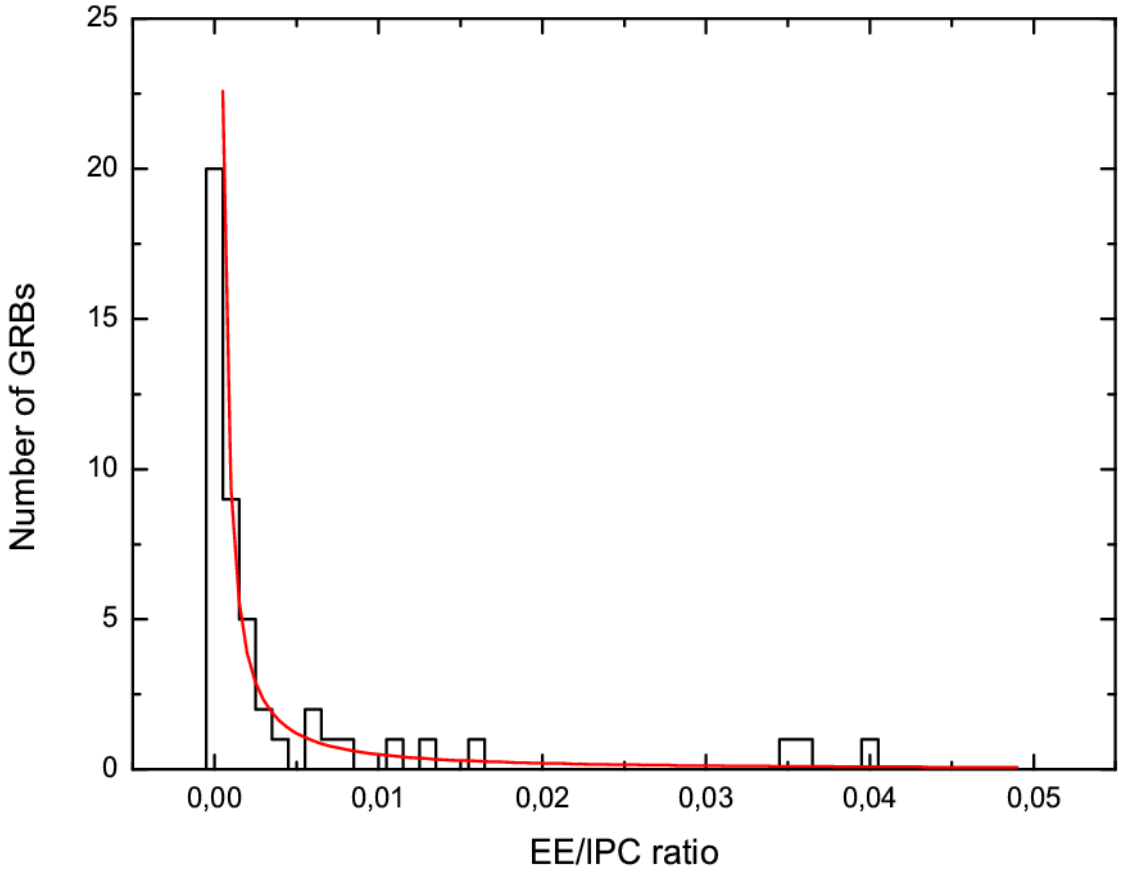
Observational test (III)
Polarization of the EE

- Due to domination of regular toroidal magnetic filed in the BZ-jet, one can expect high degree of polarization of the Extended Eemission

Observational tests (IV)?

Number density of ratio EE and IPC

(based on BAT/Swift, Norris+, 2010)



No clustering in groups -> in **favor of the two-jet model?**

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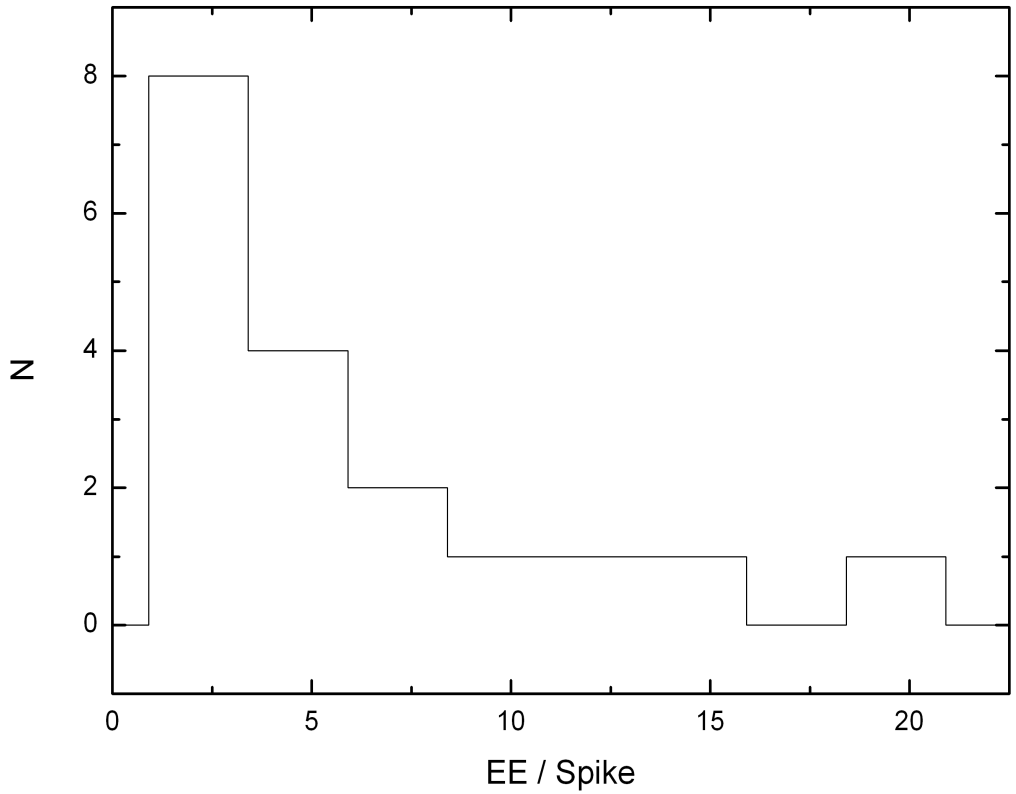
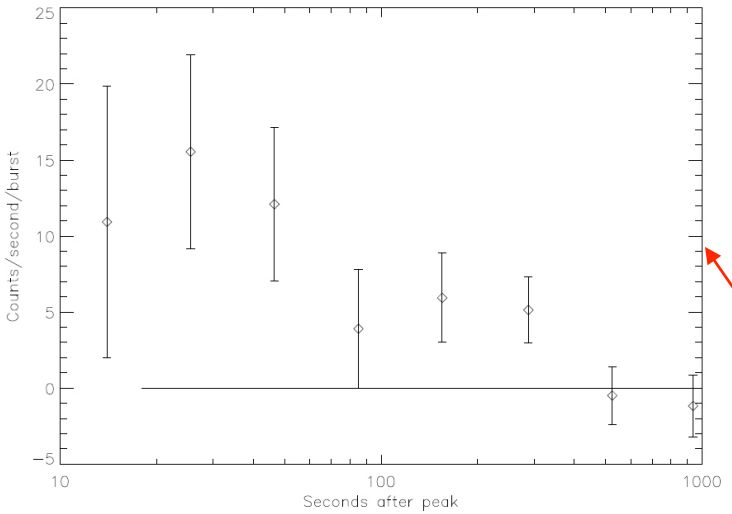


No clustering in groups -> in **favor of the two-jet model ?**

A problem of dichotomy (IV)

On the one hand there is the EE in BATSE, Konus, SPI/INTEGRAL



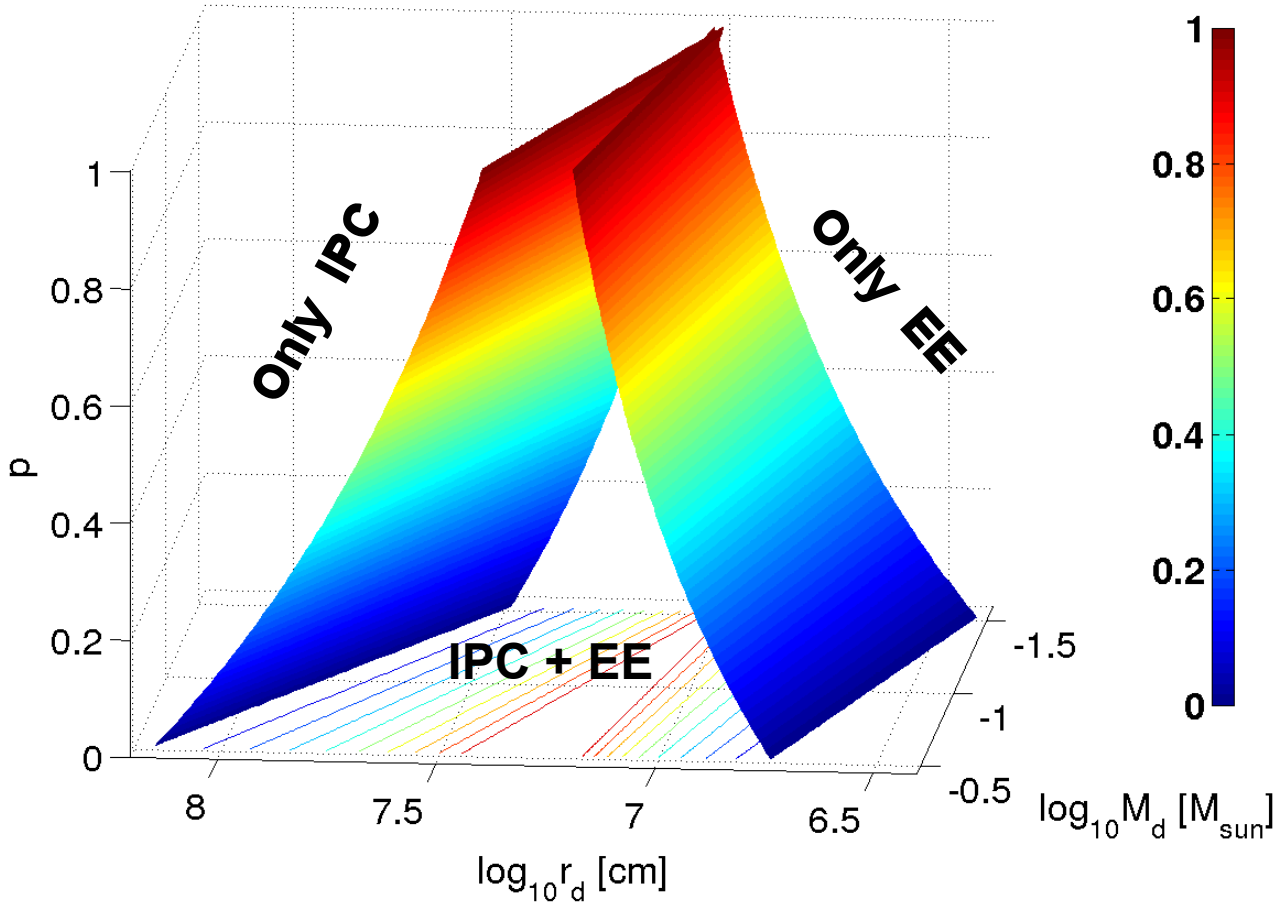
. Extended emission in the averaged light curve of short GRBs

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]

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

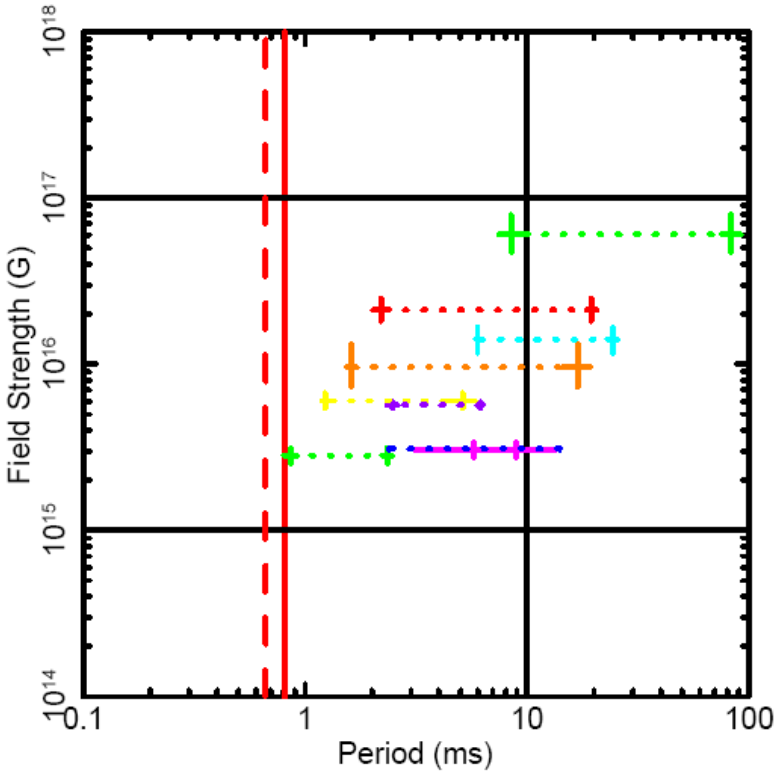
However Norris+ 2010 found nothing about the EE in an ensemble of "carefully" selected short GRBs w/o EE of BAT/Swift

The both jets in one GRB source?



Search for periodicity in prompt emission in the range of 1-100 ms (V)

It was modeled (Gompertz+ 2013) that magnetars (periods 1 – 100 ms) can feed (Zhang & M´esaros 2001) the EE



Gompertz+, 2013

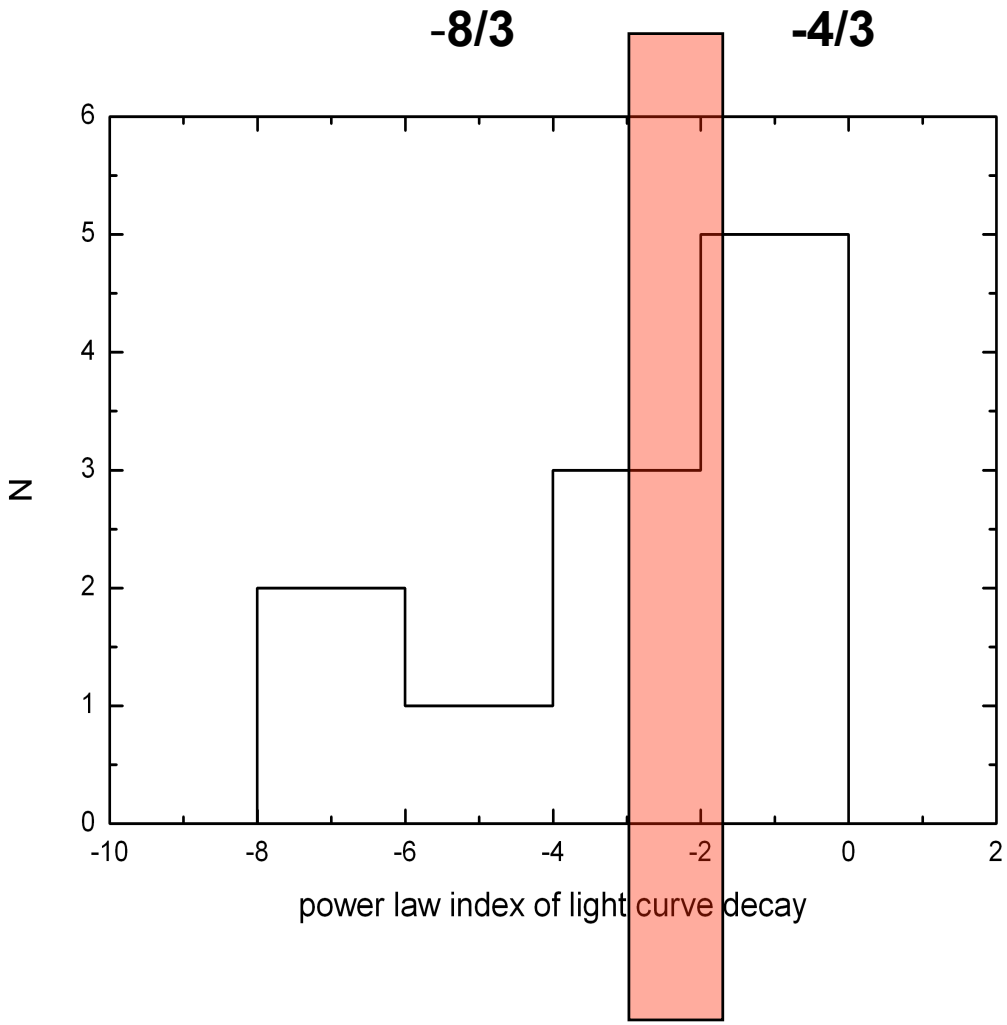
Search for periodicity in prompt emission in the range of 1-100 ms (V)

- We found neither coherent, nor QPO in the range of 1-100 ms in our list of BATSE GRBs with the EE (based on TTE data).

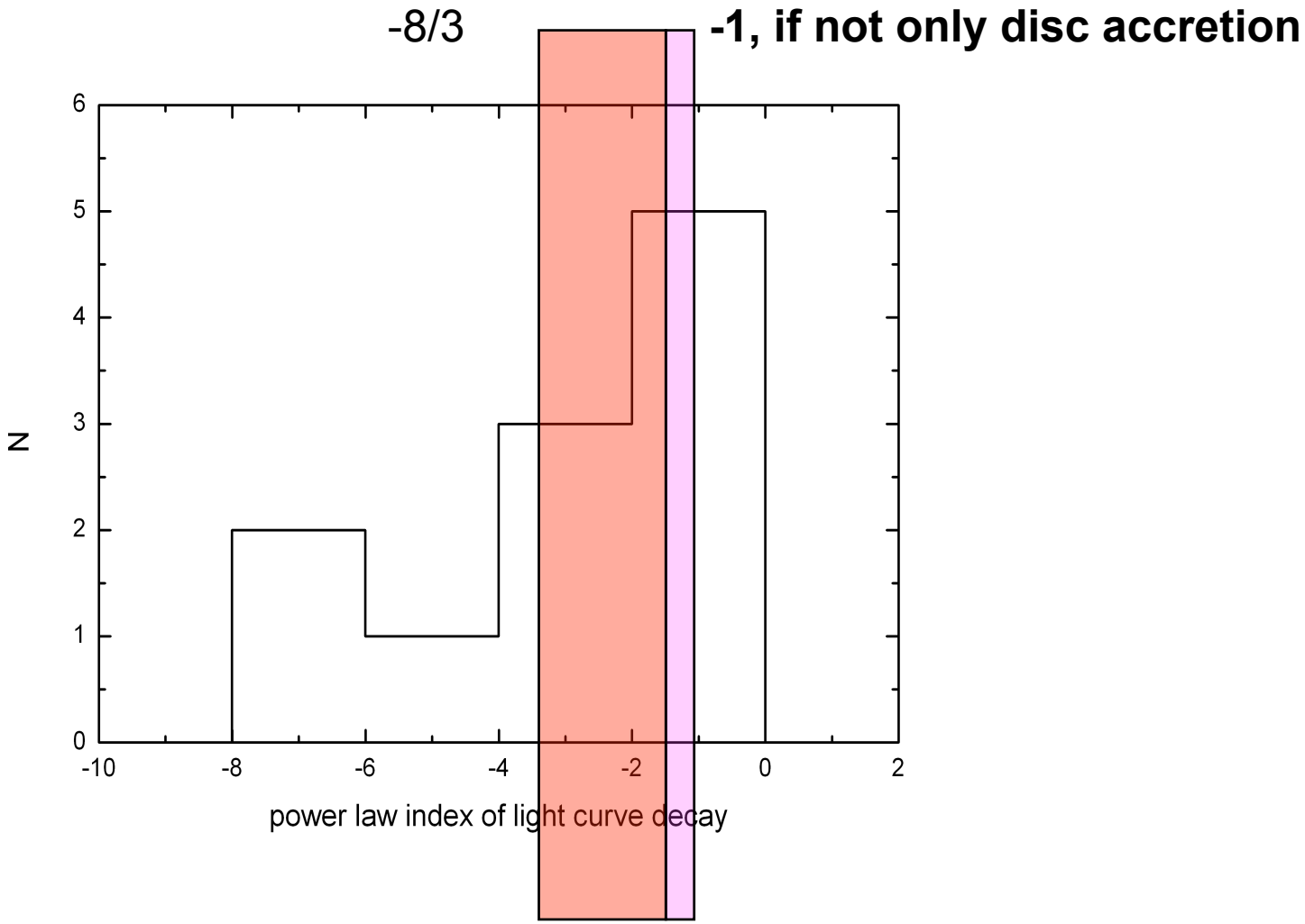
Summary

- **The Extended Emission (EE) exists**
- **Two jets is one of plausible model to explain the EE of different intensity (e.g. GRB 060614 and the EE of ensemble of short GRBs)**
- **There are tests which could help us to discriminate the two-jet model and other models of the EE**
- **In particular not all GRBs with the EE can be described by a simple accretion model**
- **Also we expect strong polarization of the EE emission**
- **It is not clear yet if the EE is a property of each short GRB or there are two classes of short bursts, i.e. "true" short bursts and short burst with EE**
- **All considerations above are valid also for the EE in ****long duration****** GRBs if the EE of long burst is due to BZ-jet**

Power law index distribution



Power law index distribution



Power law index distribution

Less -8/3 , if magnetic flux is unchained with M_dot, and rate of magnetic flux generation due to dynamo is variable…

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