Konus-Wind gamma-ray bursts: temporal characteristics, hardness, and classification

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Outline

- Physical classification
- Konus-Wind experiment
- Duration
- Hardness
- Lags
- Comparison of classifications
- Conclusions

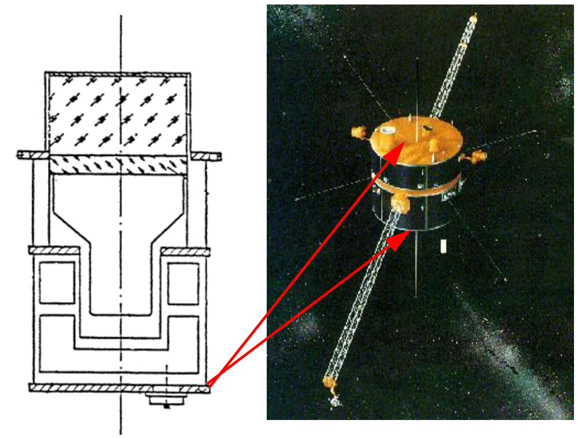
Physical classification

	Type I	*Type II*
Prompt emission (γ-rays)	short	long
X-ray afterglows	not always observed; about 10 times weaker; X-ray flares	always observed; X-ray flares
Optical afterglows	rarely observed; weak	observed for most of bursts
Host galaxies	early- and late-type galaxies; large offsets from their host centers	late-type galaxies; burst sources reside in the most bright blue regions
Supernova	never observed; hard upper limits	observed (types Ib/c)
Redshift (median)	~0.3	~1.8
Suggested source	Coalescence of NS-NS or NS-BH	Collapse of massive stars ~> 100 M_{sun}

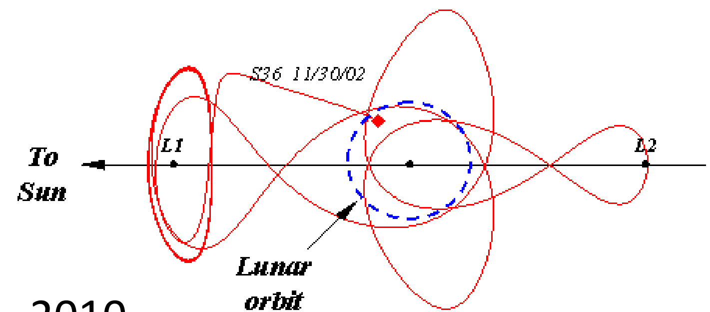
Zhang et al., 2006, 2007, 2009

Konus-Wind

- Two detectors NaI(Tl) 4π FoV total, S_{eff} ~80–160 cm^2
- Time history
  - recorded in 12 – 50 keV (G1), 50 – 200 keV (G2), 200 – 760 keV (G3)
  - Two modes: waiting (resolution 2.944 s) and triggered (2 ms –256 ms, from T_0-0.512 s to T_0-230 s)



- Spectral measurements in the 20 keV -15 MeV band
- Very stable background (up to few days)



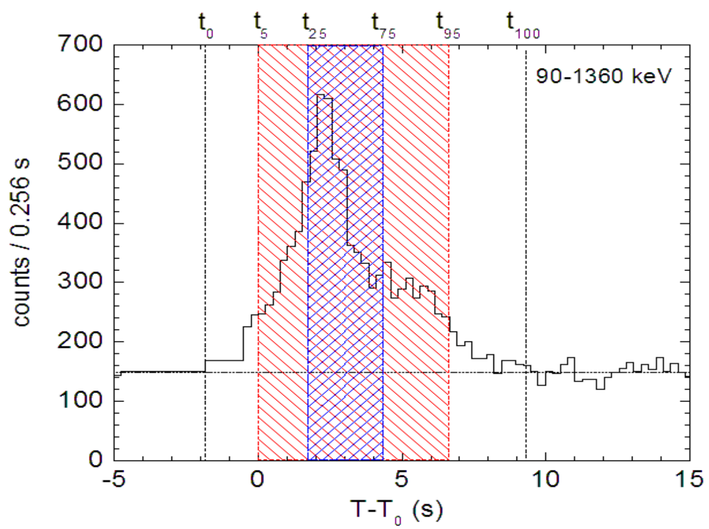
- We have analyzed 1834 GRBs detected during 1994 – 2010.
- Among them 84 with measured redshift (Tsvetkova talk)

Duration

- Durations are calculated in 80-1400 keV (G2+G3) band
  - Energy of the most GRBs is hard E_p (max EF_E) >80 keV
  - in G1 (20-80 keV) background is less stable
  - onset of X-ray afterglow in G1 can bias a duration

- Burst begin (t_0) and end (t_{100}) are calculated at 5σ level.

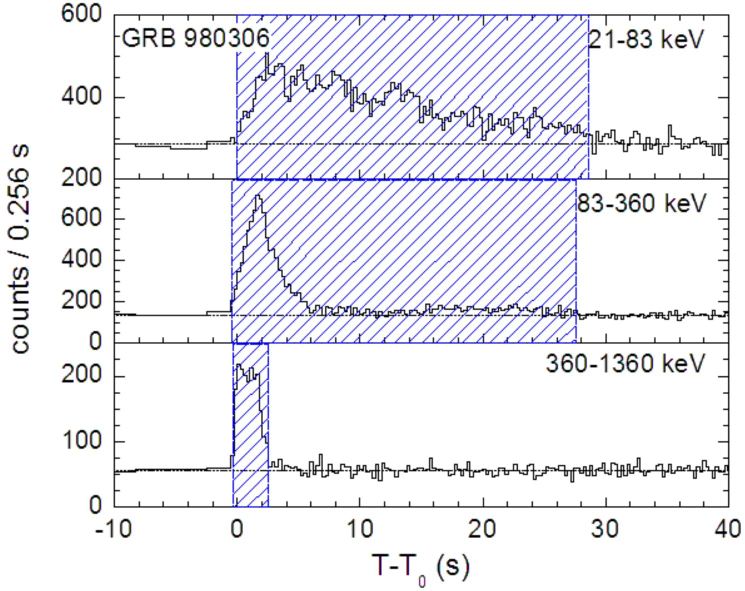
- T_{50} и T_{90} – intervals of accumulation of 50% и 90% burst counts in a detector

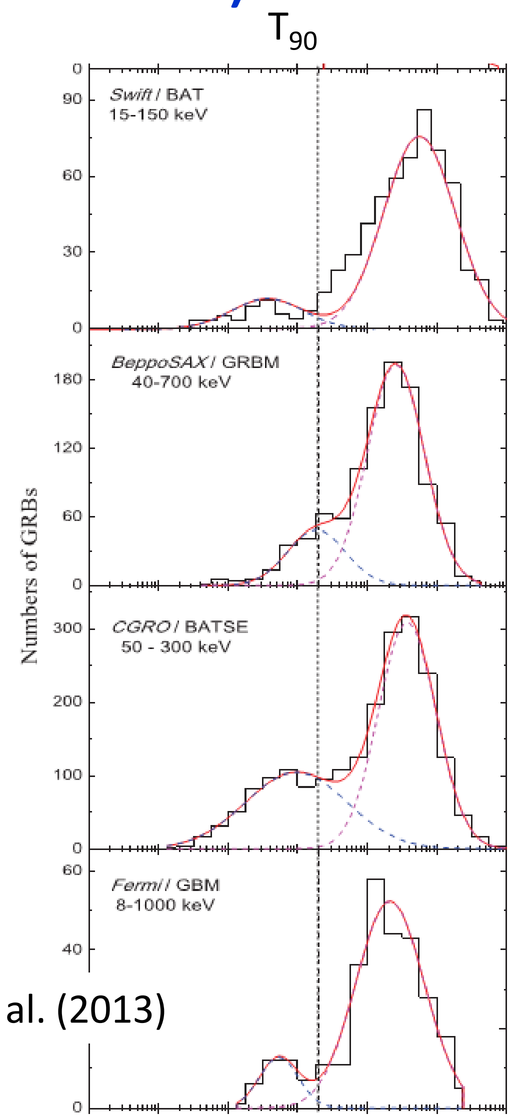


T_{50} = 2.6 ± 0.2 c
T_{90} = 6.7 ± 0.4 c

Durations (systematic effects)

- Signal-to-noise ratio (S/N; Bonnell et al. 1997)
- Cosmological time dilation
- Energy band (Fenimore 1995)
- Trigger algorithm

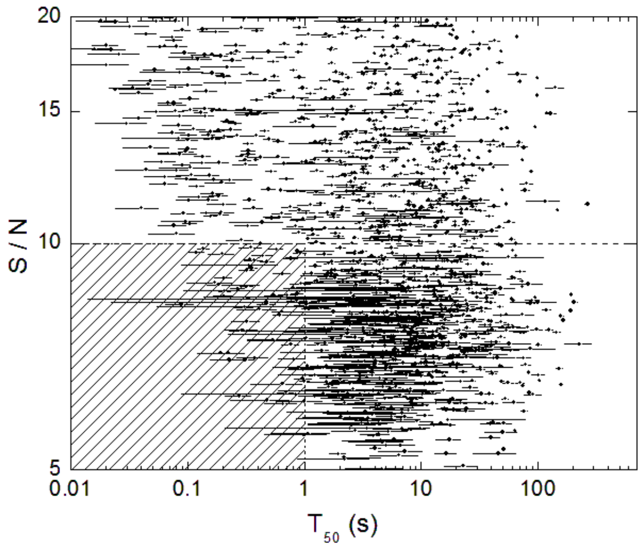


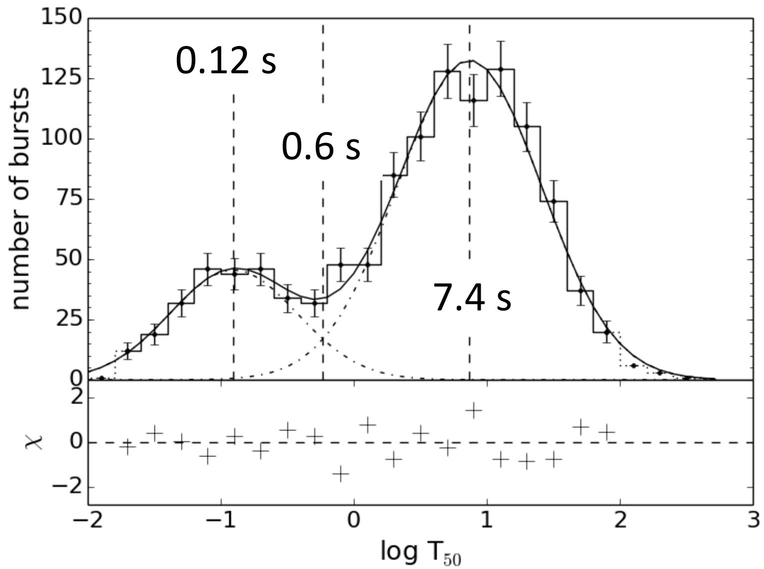


Qin et al. (2013)

T_{50} and T_{90} distributions

- The burst sample contains 1834 GRBs (1994 -2010)
- Parameters of T_{50} distribution is less sensitive to the search threshold.
- T_{50} was used for the classification.
- The sample is biased: lack of weak short GRBs (S/N<10, T_{50} <1 s)
- We used unbiased sample of 1168 GRBs with S/N>10. The boundary between long and short bursts is T_{50} = 0.6 s
- The fraction of short GRBs (T_{50} < 0.6 s) in the unbiased sample - 22%, in the full sample – 15% (BATSE -32%; Swift-BAT -8%; Fermi-GBM – 15 %)



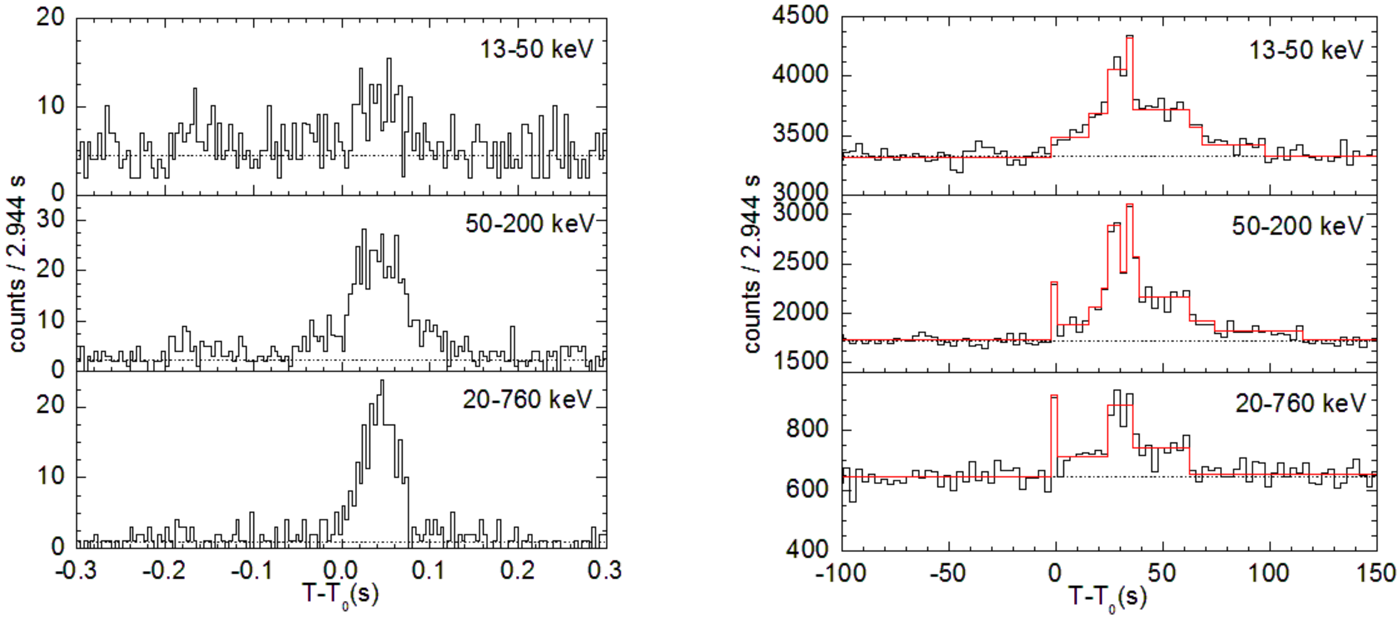


χ^2 = 9.3 (13 d.o.f)

Short GRBs with EE

- Morphology: short initial pulse, long, low intensity tail up to ~100 s
  (Lazzati et al., 2001; Connaughton, 2002; Frederiks et al., 2004; Norris & Bonnell 2006; Norris et al., 2011)
- 23 candidates to short GRBs with EE found in KW data
- Fraction among short GRBs:
  Konus-Wind – 8% (23/296); BATSE – 25% (64/256); Swift – 23% (12/52).

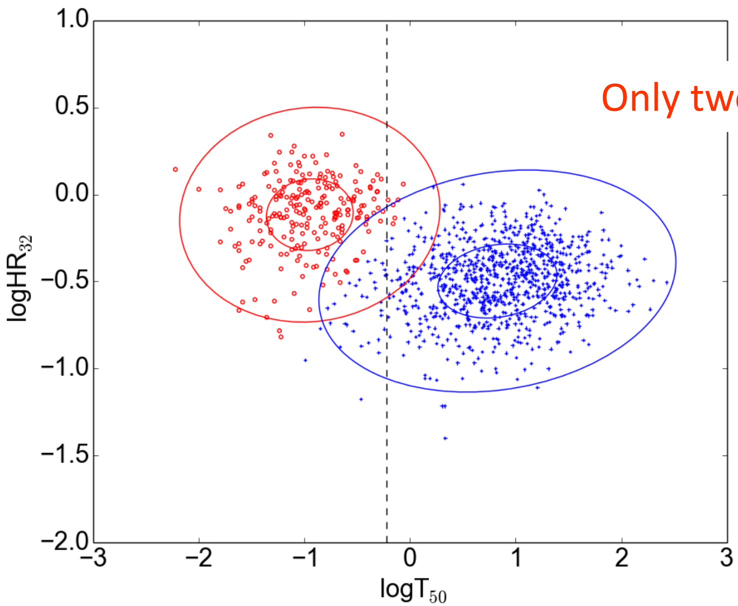
GRB 950503 T_0 = 66971.838 s



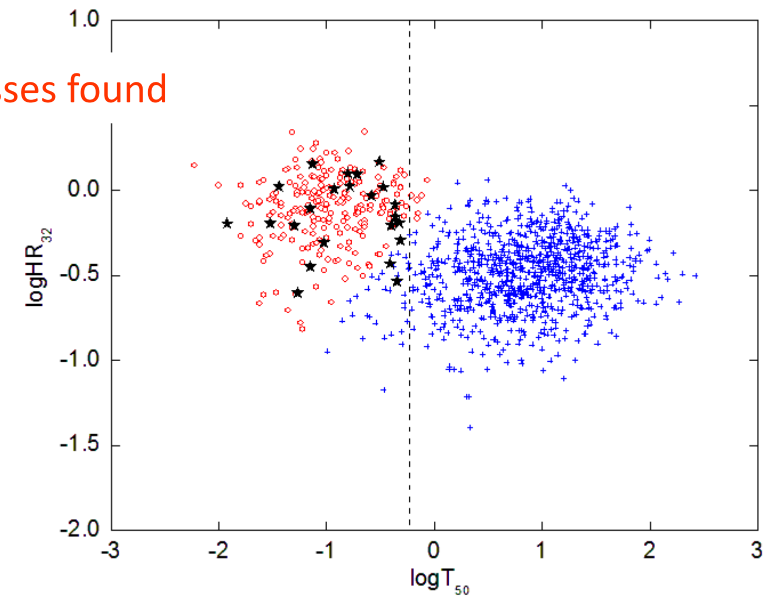
Hardness

- Hardness – ratio of count accumulated during burst in G3 and G2 (HR_{32}=G3/G2)
- We have analyzed 1143 GRBs
- The log T_{50} – logHR_{32} distribution was fitted with two 2D Gaussian distributions.

- The fraction of short GRBs (T_{50} <0.6 s) in long/soft GRB cluster is 13%.
- Among 23 short GRBs with EE, initial pulses of *two* bursts are in long/soft GRB cluster .



Only two classes found



Hardness

- 2D Gaussian distribution ($x=\log T_{50}$; $y=\log HR_{32}$)

$$p(x,y|l) = \frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-r^2}} \times \exp\left[-\frac{1}{2(1-r^2)}\left(\frac{(x-a_x)^2}{\sigma_x^2} + \frac{(y-a_y)^2}{\sigma_y^2} - \frac{C}{\sigma_x\sigma_y}\right)\right],$$

где

$$C = 2r(x-a_x)(y-a_y)$$

- Likelihood

$$L = \sum_i \ln p(x_i, y_i),$$

$$p(x,y) = \sum_l p(x,y|l)p_l$$

- Indicator function

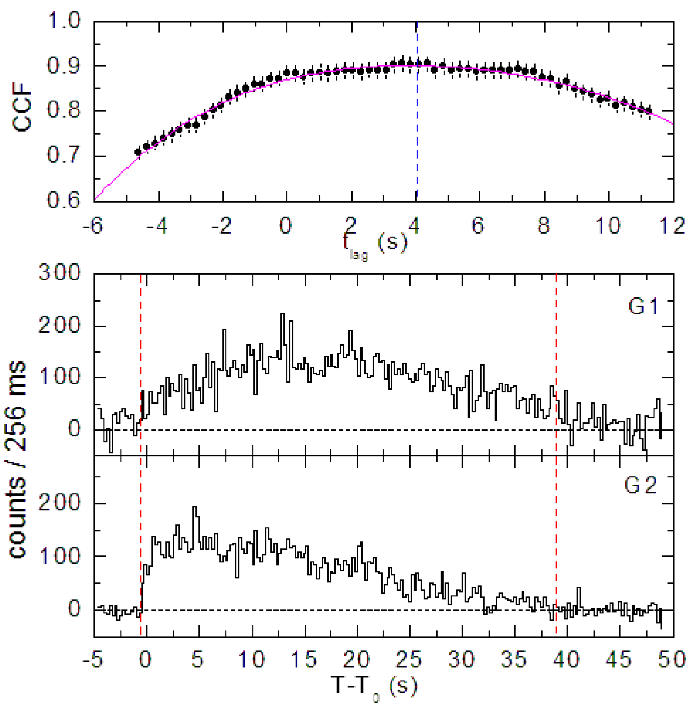
$$I_l = \frac{p_l p(x,y|l)}{\sum_l p(x,y|l)}$$

- Cluster parameters

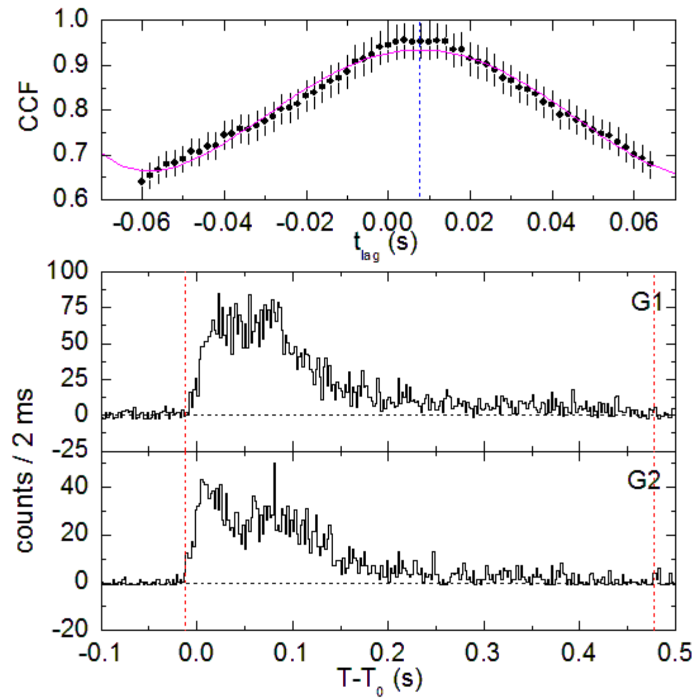
l	a_x	T_{50c}, s	a_y	HR$_c$	σ_x	σ_y	r	p_l
1	$-0.940^{+0.032}_{-0.012}$	$0.115^{+0.009}_{-0.003}$	$-0.124^{+0.011}_{-0.019}$	$0.752^{+0.020}_{-0.032}$	$0.442^{+0.033}_{-0.015}$	$0.221^{+0.008}_{-0.010}$	$0.020^{+0.041}_{-0.056}$	$0.210^{+0.011}_{-0.003}$
2	$0.835^{+0.017}_{-0.005}$	$6.834^{+0.265}_{-0.081}$	$-0.499^{+0.001}_{-0.002}$	$0.317^{+0.001}_{-0.002}$	$0.560^{+0.003}_{-0.019}$	$0.216^{+0.003}_{-0.003}$	$0.176^{+0.006}_{-0.008}$	$0.791^{+0.002}_{-0.012}$

Spectral lags

- Spectral lag (t_{lag}) is a measure of spectral evolution
- t_{lag} is calculated using a fit for cross correlation function (CCF) with 4^{th} degree polynomial
- Confidence interval (68% CL) is calculated using bootstrap method



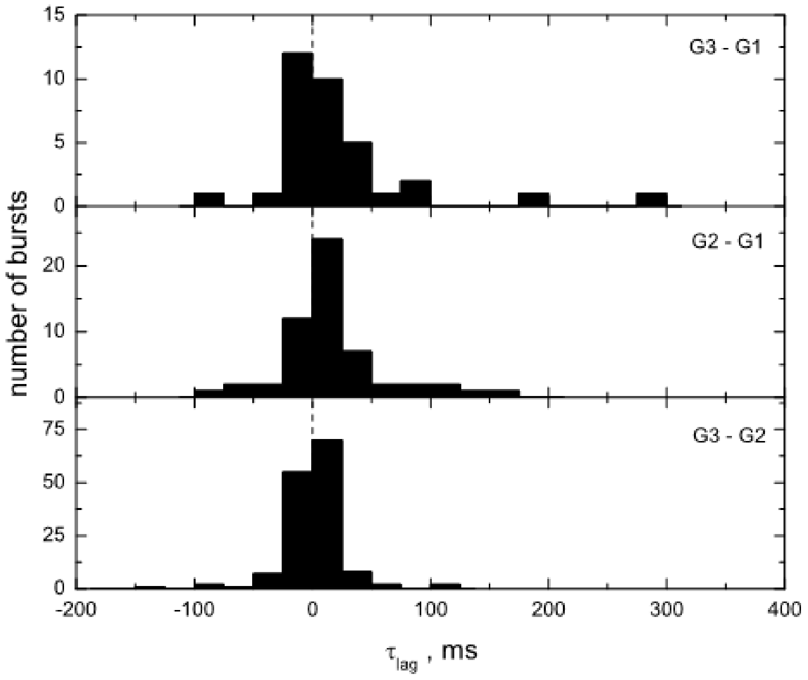
GRB 090618 $t_{lag} = 4.0 \pm 0.4$ s

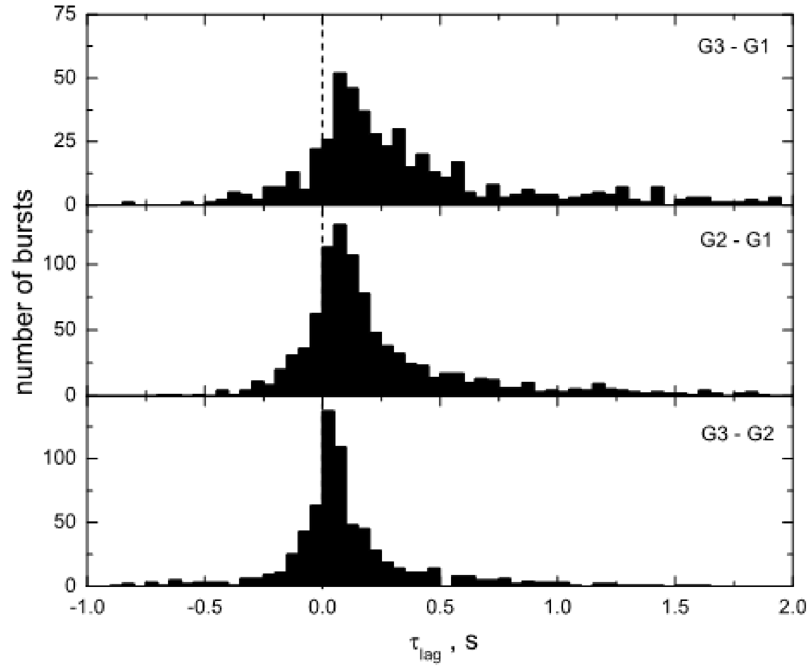


GRB 120323A $t_{lag} = (5.\ 4 \pm 1.3) \times 10^{-3}$ s

Spectral lags

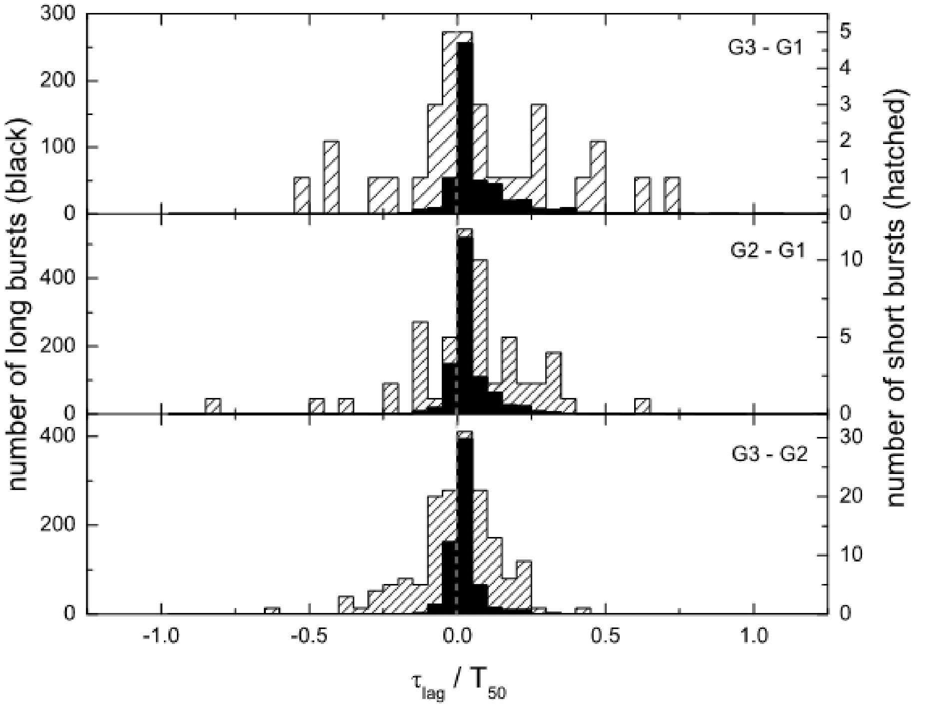
- Most of the short GRBs have $|t_{lag}|$<50 ms
- Long GRBs t_{lag} distribution peaks at ~75 ms
- Among long GRBs ~20% have $|t_{lag}|$<50 ms





Spectral lags

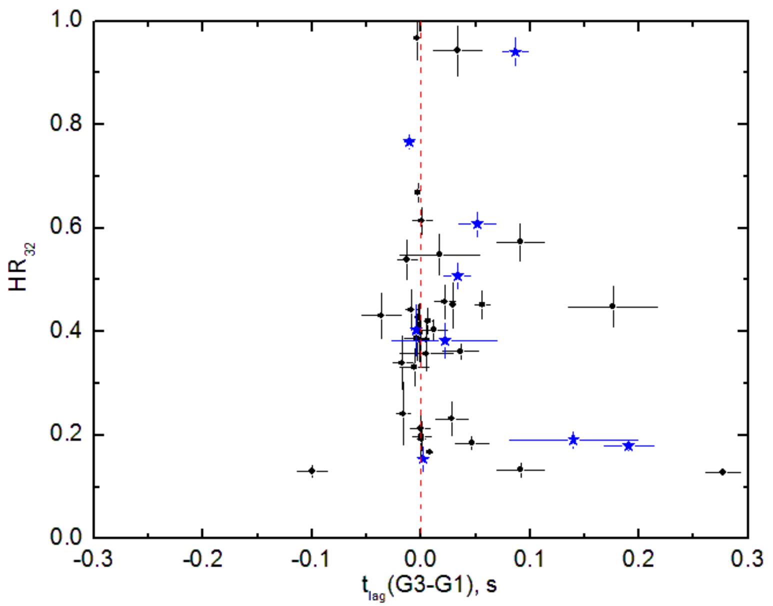
parameter, p	channels	D_{KS}	P_{KS}
τ_{lag} (s)	G3-G1	0.678	8.5e-14
τ_{lag}/T_{50}		0.297	5.5e-03
τ_{lag} (s)	G2-G1	0.566	1.1e-15
τ_{lag}/T_{50}		0.245	2.7e-03
τ_{lag} (s)	G3-G2	0.568	2.2e-35
τ_{lag}/T_{50}		0.307	1.3e-10

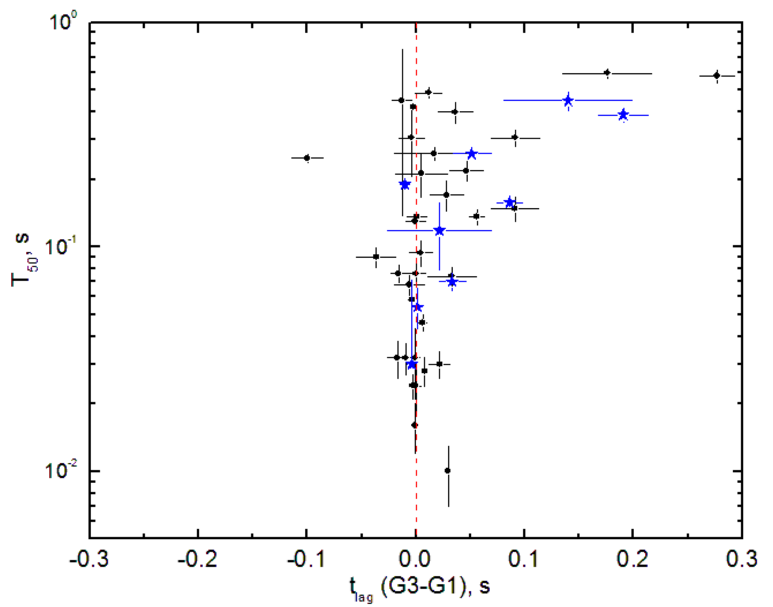


Spectral lags of short GRBs

- 5 soft GRBs with T_{50} <0.6 s have significant lags (t_{lag} >100 ms) and reside in the long/soft cluster.
- 2 GRBs classified as short GRB with EE reside in the long/soft cluster having t_{lag} >100 ms.

- Softer and longer bursts tend to have longer lags

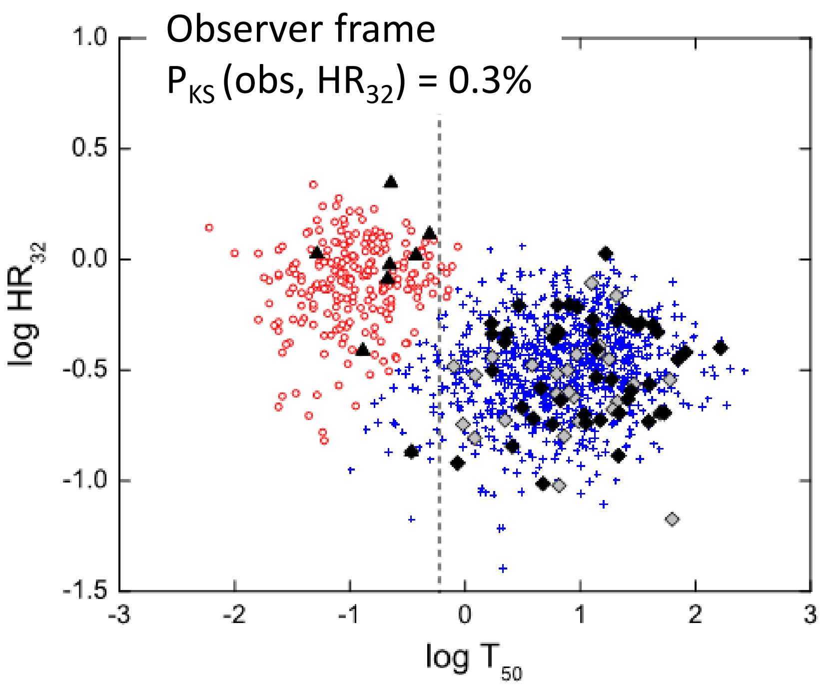


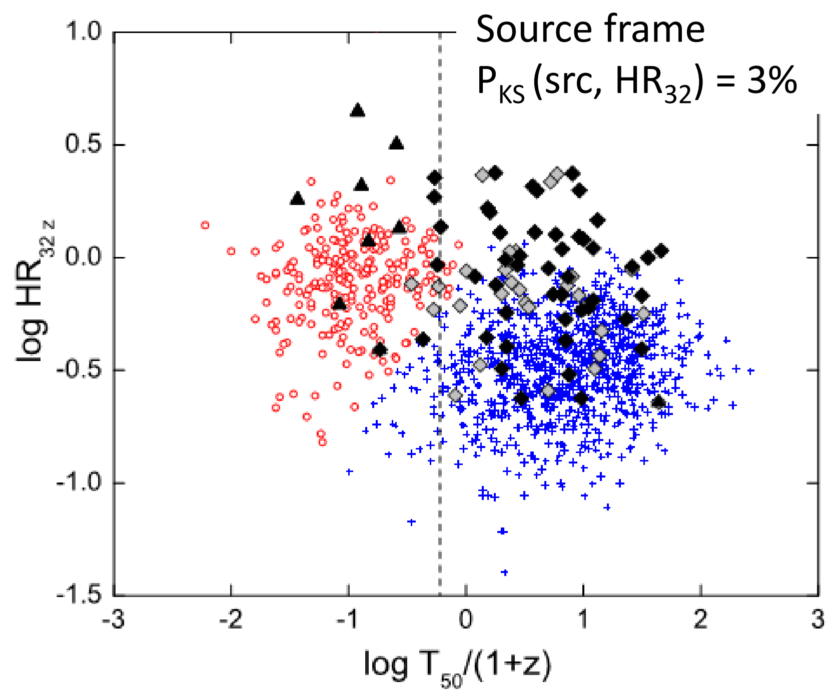


Comparison of classifications

- Konus-Wind sample contains 84 GRBs with measured z (detected up to the end of 2010)

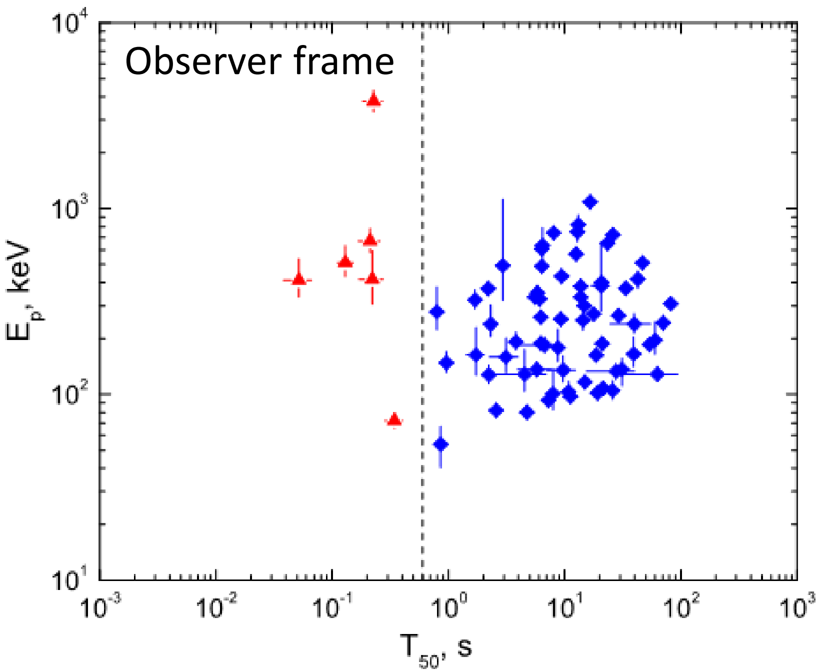
- Type I – 8 GRBs (7 short GRBs + GRB 060614)
- Type II – 48 GRBs (Zhang et al., 2009; Kann et al., 2010, 2011)
- 28 unclassified with measured redshift

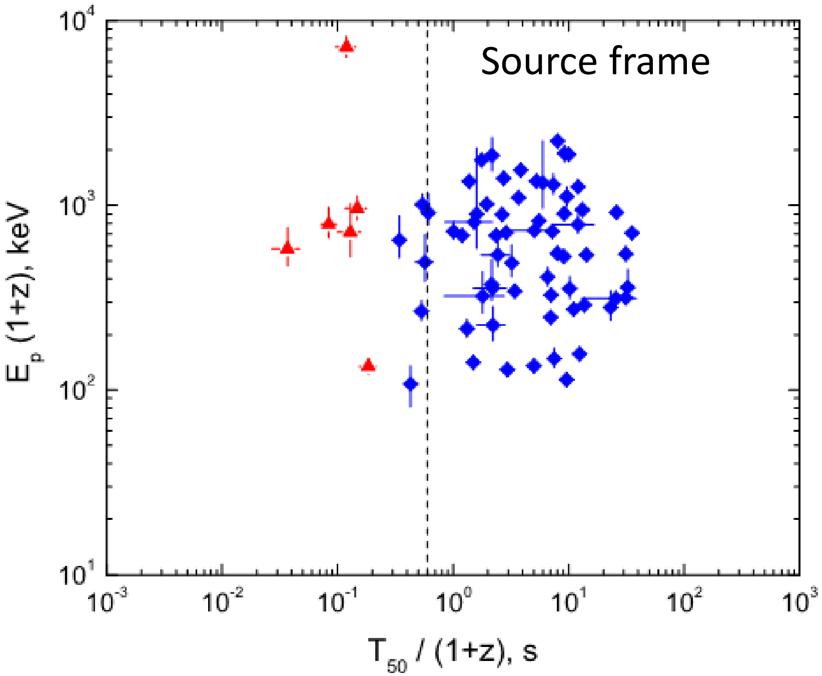




Comparison of classifications

- Konus –Wind GRB redshifts
  - short < z > = 0.6
  - long < z > = 1.5
- Only one out of 6 short GRB has E_p > 1 MeV, while 16 out of 65 long GRBs have E_p > 1 MeV.





Conclusions

- Using the unbiased T_{50} distribution we derived the boundary between short and long KW GRBs T_{50} = 0.6 s with a fraction of short GRBs of 22%. The total number of short GRBs – 296.
- Cluster analysis of KW GRBs suggests the existence of only two GRB classes: short/hard and long/soft.
- Spectral lag distributions of short and long GRBs differs significantly.
- Physical GRB types I and II corresponds to short/hard low-lag GRB and long/soft GRB classes, respectively.
- The hardness difference of the two GRB classes can be attributed to the difference of average source distances. Long bursts tend to be detected at large distances.
- The results were used in
  Pal'shin et al., Interplanetary Network Localizations of Konus Short Gamma-Ray Bursts, 2013
  The second Konus catalog of short GRBs, in prep.

Thank you!