Konus-Wind observations of ultra-long GRBs

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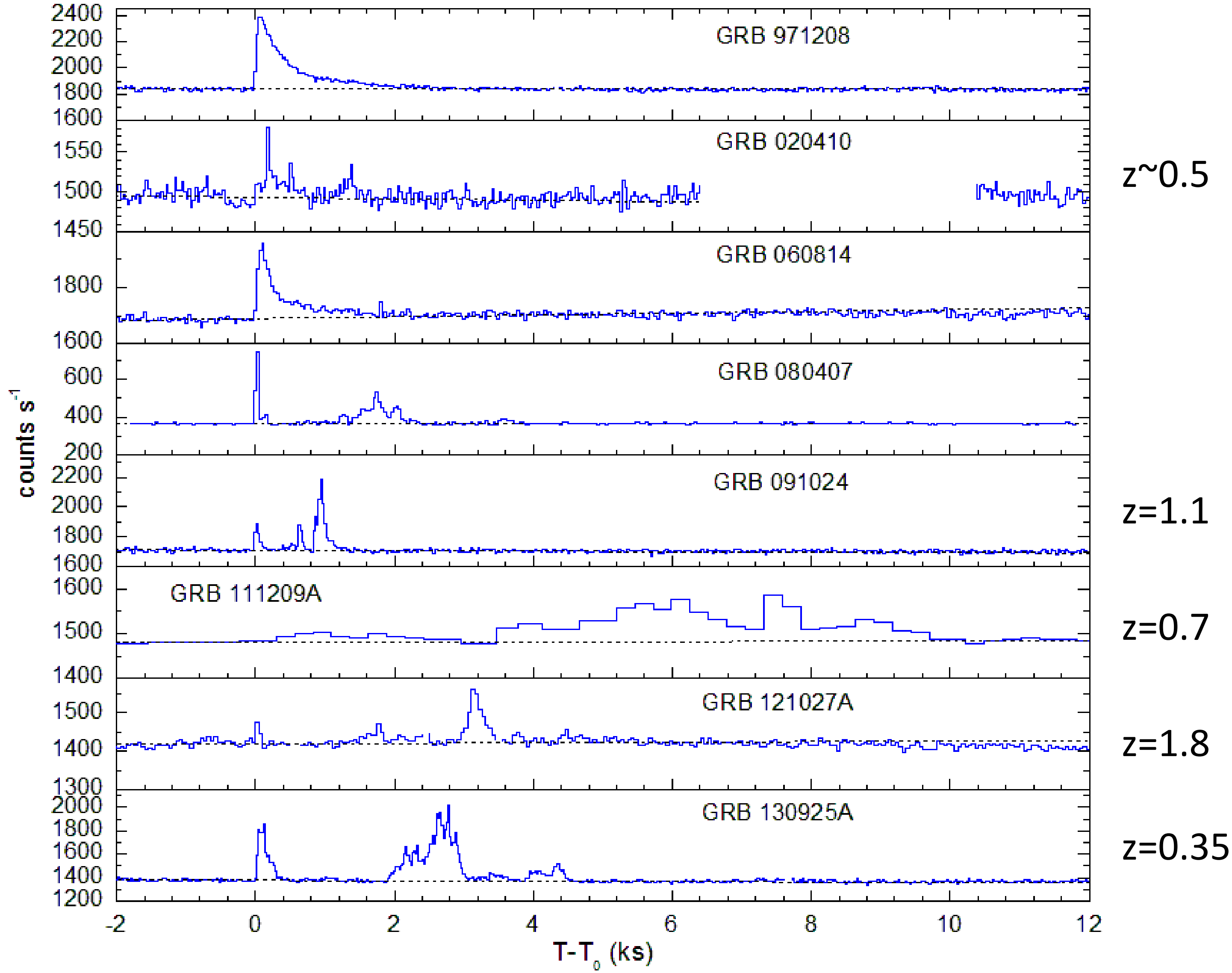
Ioffe Workshop on GRBs and other transient sources: 25 Years of Konus-Wind Experiment

Known ultra-long GRBs observed by Konus-Wind



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Very long GRB data

Instrument	Energy band*, keV	Number of bursts	
		T_{90}>250 s	T_{90}>~1000 s
CGRO-BATSE	**50 - 300**	**22**	**1******
BeppoSAX-GRBM	**40 - 700**	**7**	**0**
Swift-BAT	**15 - 150**	**58**	**~20**
Fermi-GBM	**50 - 300**	**30**	**0**
Konus-Wind	**50 - 1500**	**~100**	**~20 this work**

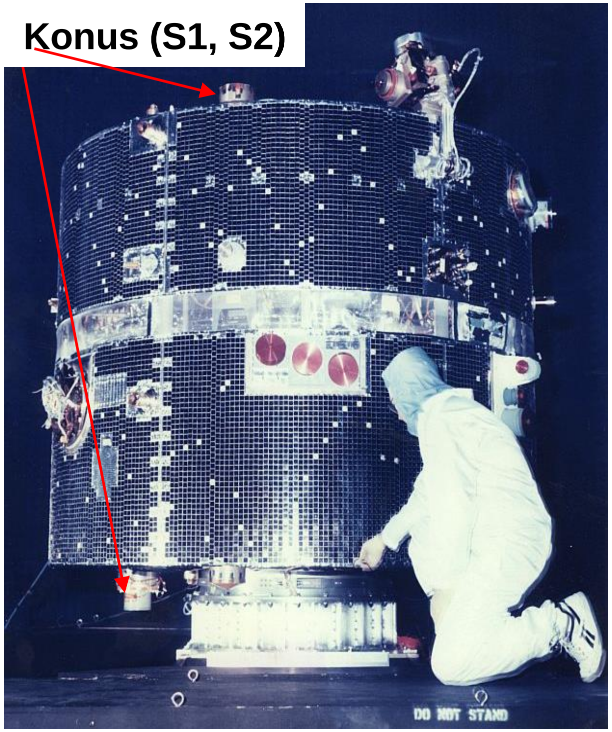
*used for duration calculation

** GRB 970315

Meegan et al. BATSE current GRB cat.; Frontera et al., 2009; Lien et al., 2016; Bhat et al., 2016

Joint Russian-US Konus-Wind experiment

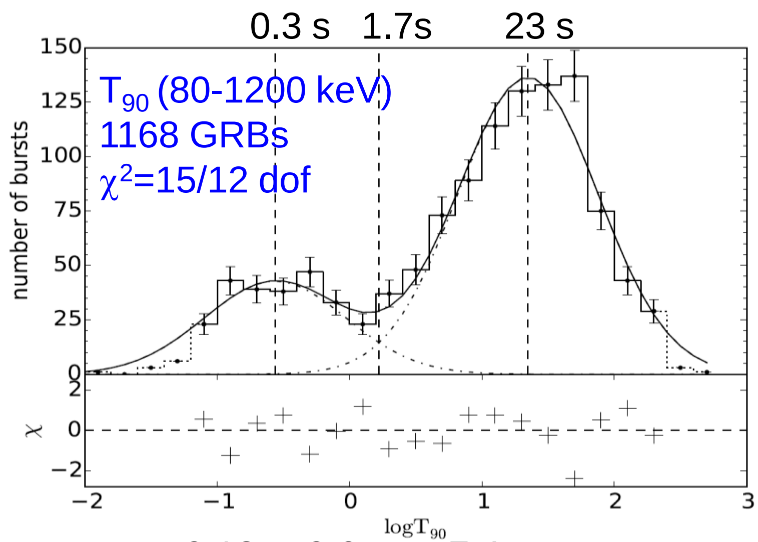
- Launch 1994 - 24+ years of continuous operation;
- Waiting mode – continuous record of count rates in the 20-80 keV (G1), 80-350 keV (G2), and 300-1200 keV (G3) bands with 2.944 s resolution;
- Advantages:
  - stable background (up to a few days),
  - 2 ×2 π FoV,
  - duty circle ~95%,
  - observes all bright transients;

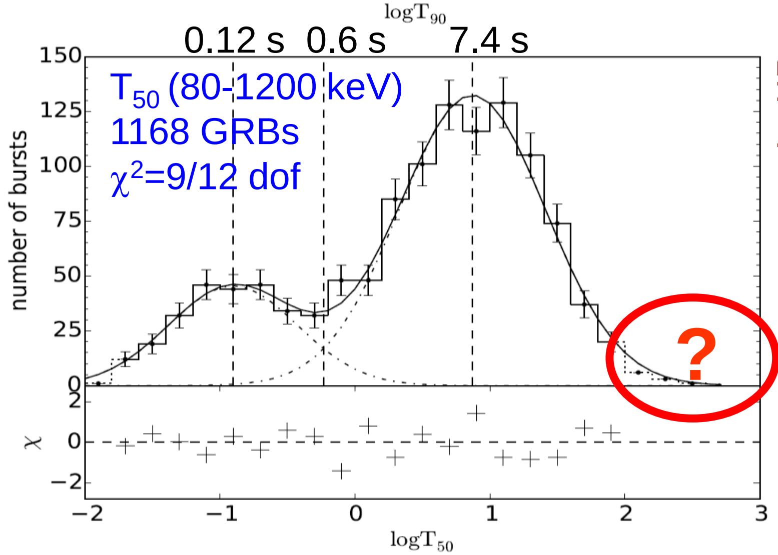


- Extremely useful for a search of very log duration transients.

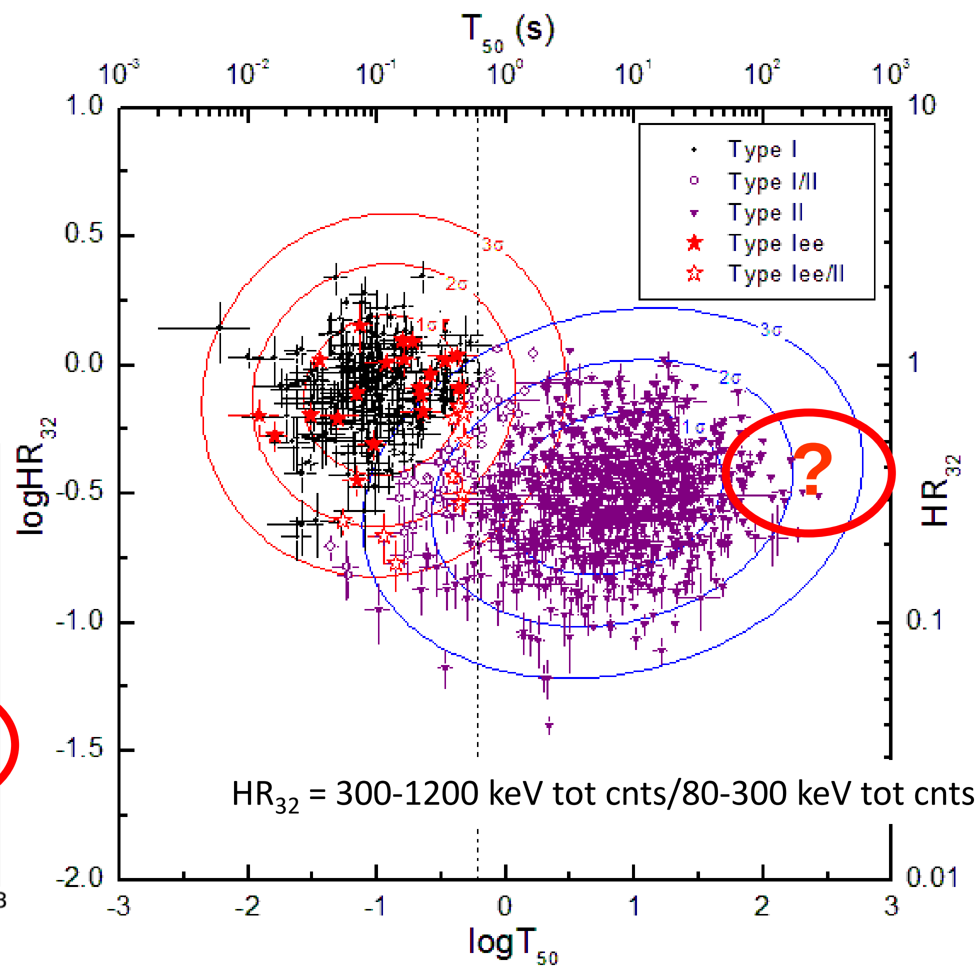
Konus-Wind triggered GRB classification

- The boundary between “short” and “long” GRBs was adopted to be T_{50}=0.6 s: 15% - short GRBs
- Hardness-duration distribution is well fitted wit 2 2D Gaussians.



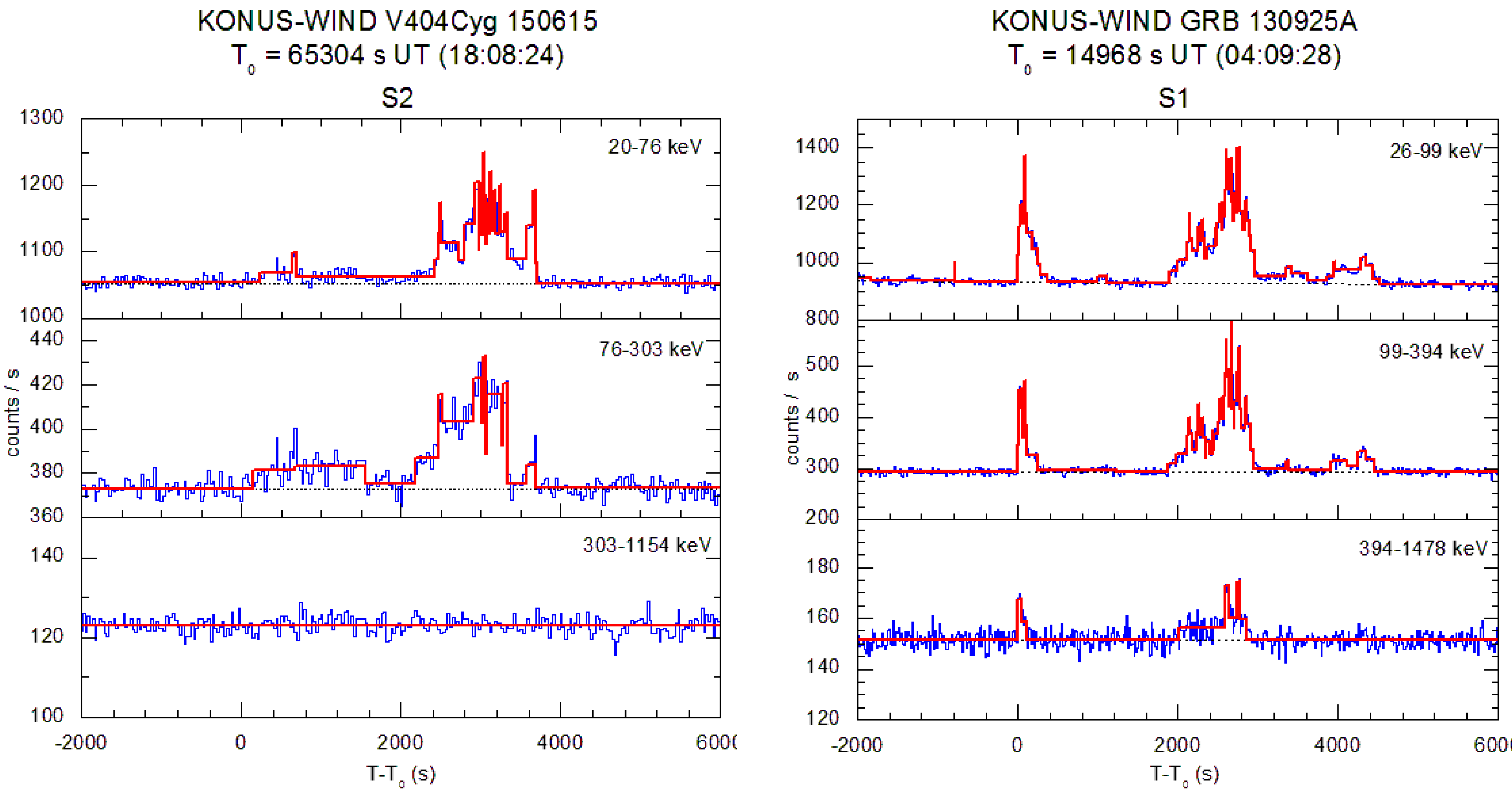


- Classification using the fit:
  18% - Type I(short/hard), 78% - Type II (long/soft), for 4% the type is uncertain (I or II).



Konus-Wind waiting mode event search

- Bayesian block decomposition of KW waiting mode time history 1994-2017;
- Selection of transients occurred in both detectors and/or at least in two energy bands;
- Preliminary event classification: GRB, Solar flare, hard X-ray transient (e.g. Cyg -X1, V404 Cyg), particle event (using Wind-3DP particle monitor), or instrument glitch;



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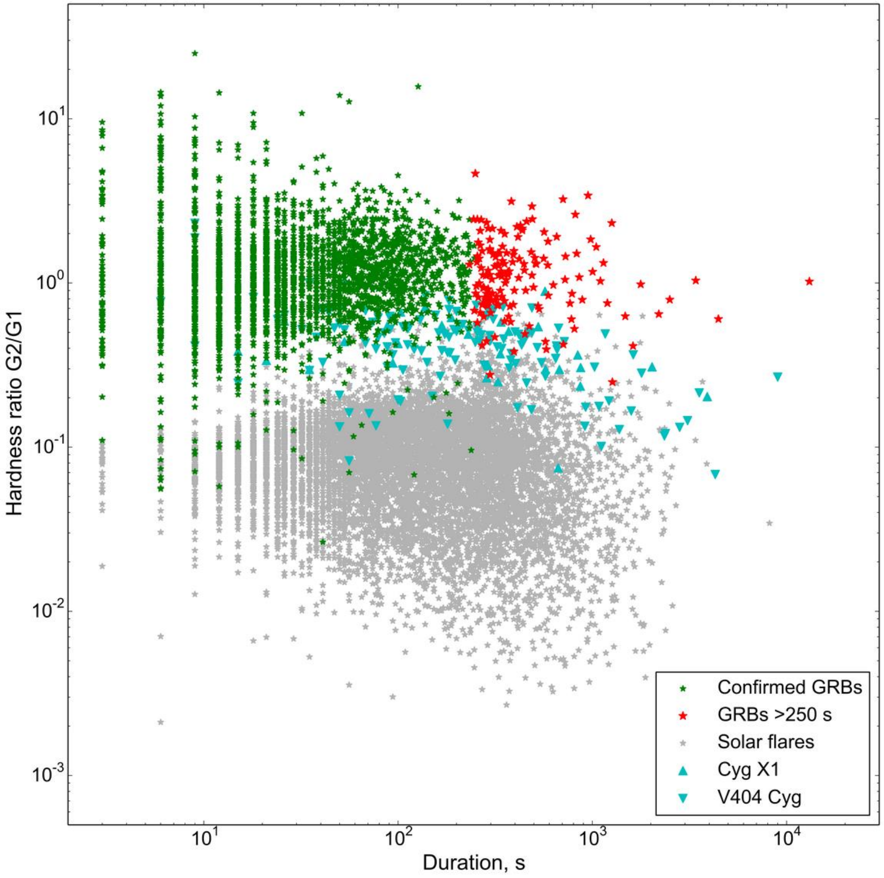
KW waiting mode event search results



Event type	Number
Solar Flares	**~12 000**
GRB candidates + Other transients	**~9 000**
Confirmed GRBs	**~5 000**
Total	**~26 000**

- The confirmed and unconfirmed GRBs include ~120 events with T_{100} > 250 s and S/N > 10 (at T_{100}) which allow to analyze the tail of the KW GRB duration distribution.

HR_{21} = 80-300 keV peak. rate /20-80 keV peak. rate

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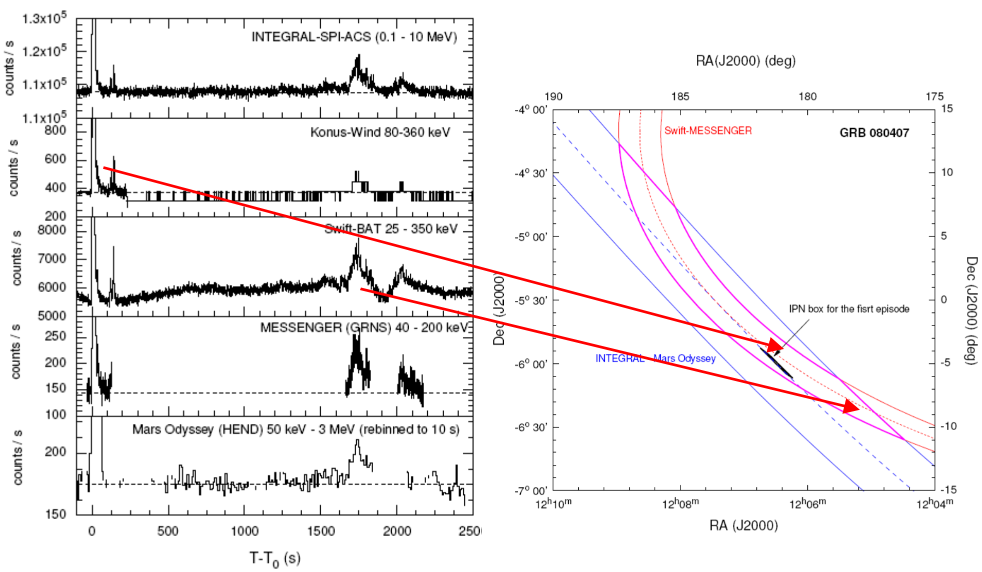
Confirmation of multi-episode GRBs

- Association of close in time events with a single source using detections by other instruments (Inter Planetary Network, IPN).

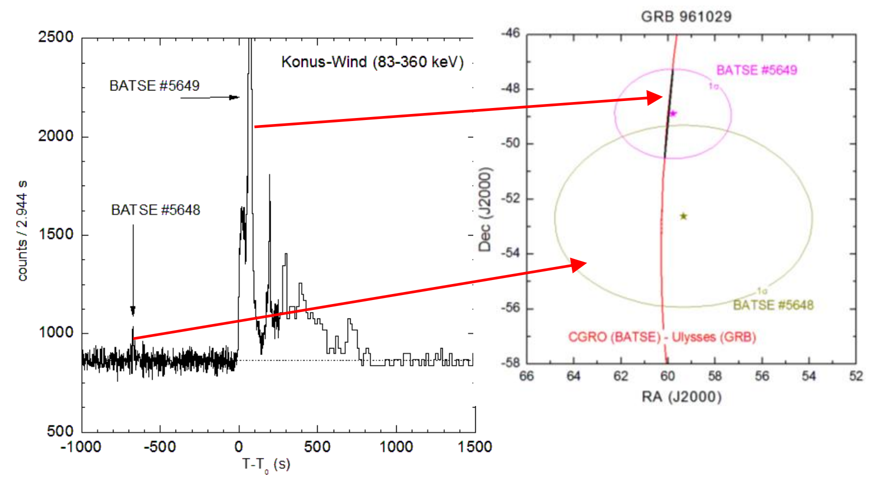
- **The IPN instruments used**: CGRO-BATSE, Fermi-GBM, Swift-BAT (at low earth orbit);
INTEGRAL-SPI-ACS (at the elongated oribit up to 0.5 lt-s);
Ulysses-GRB (670 -3180 lt-s); Mars Odyssey-HEND (Mars, up to 1200 lt-s);
MESSENGER-GRNS (Mercury, up to 700 lt-s)

- **Confirmed**: 99 GRB candidates (single and multi-episode) $T_{100} > 250$ s,
17 u-long GRB – $T_{100} > 1000$ s (including 8 known KW u-long GRBs and 9 new candidates).

GRB 080407; Pal'shin et al., 2012



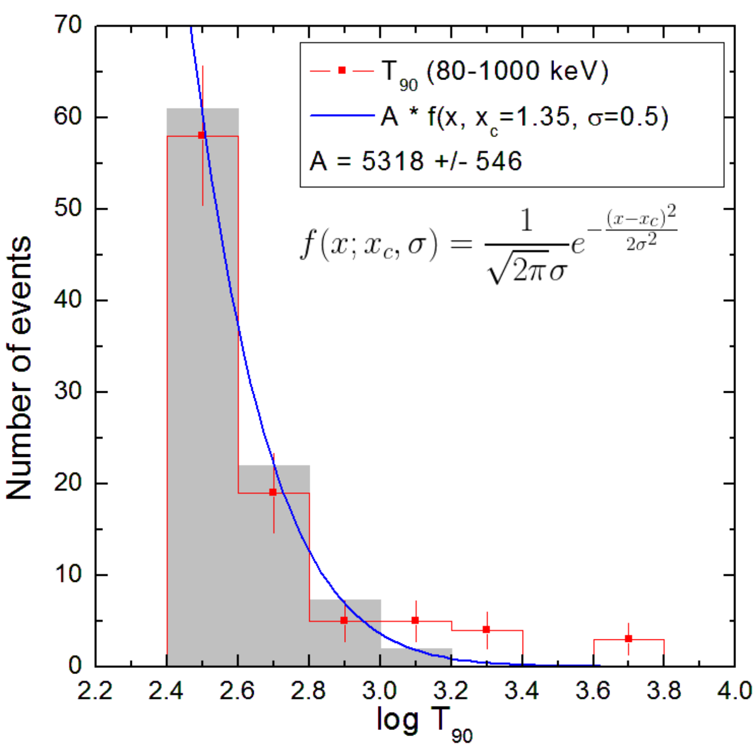
GRB 961029 - detected by KW, BATSE, and Ulysses

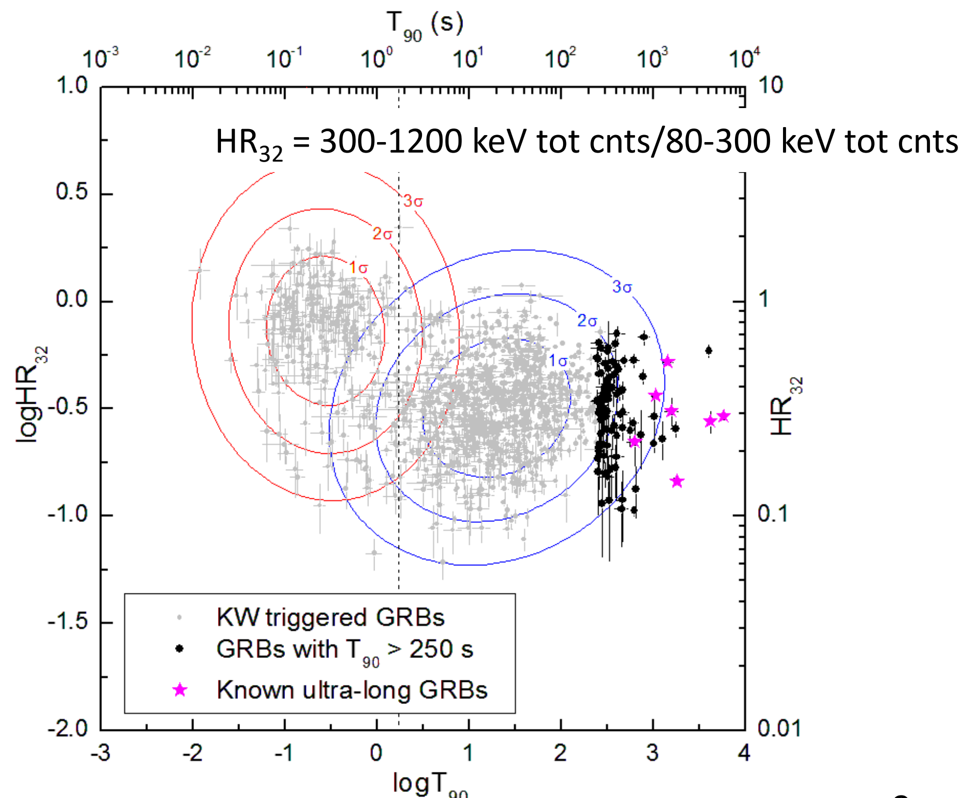


U-long GRBs.
Duration and hardness.

- The T_{90} distribution of the GRBs with 250 s < T_{90}< 1000 s is consistent with a tail of the triggered GRB population with P_{KS}=30%.
- There is an excess of bursts in the tail (T_{90}> 1000 s) with $P_{chance}=3\times10^{-6}$.

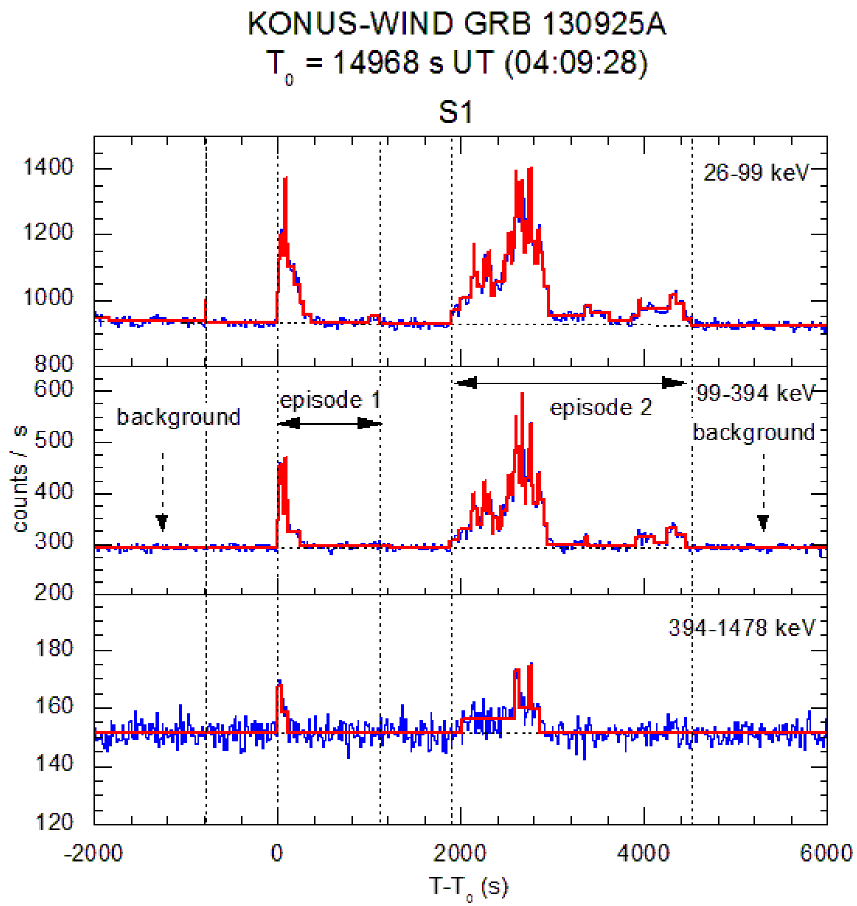
- Ultra-long GRBs extend the softer/longer part of the long GRB distribution.

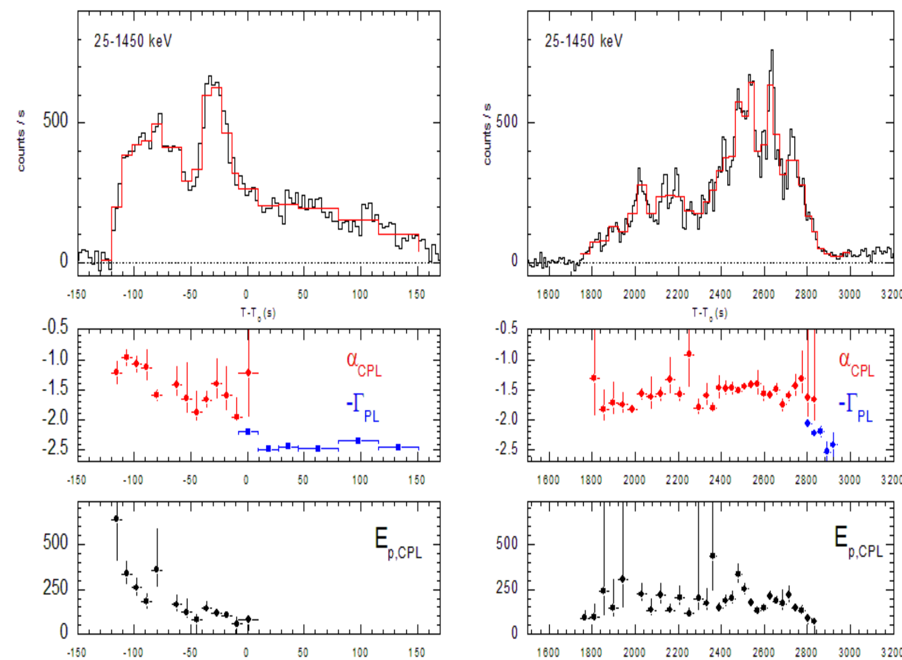




Spectral analysis

- KW waiting mode is a continuous 3-channel spectrum in the ~20—1500 keV band.
- Up to 3 model parameters (including normalization) may be estimated:
  PL (1 d.o.f.), Cutoff PL, Band function with one fixed parameter (i. e., beta).





Ultra-long GRB 130925A; Frederiks et al., 2014

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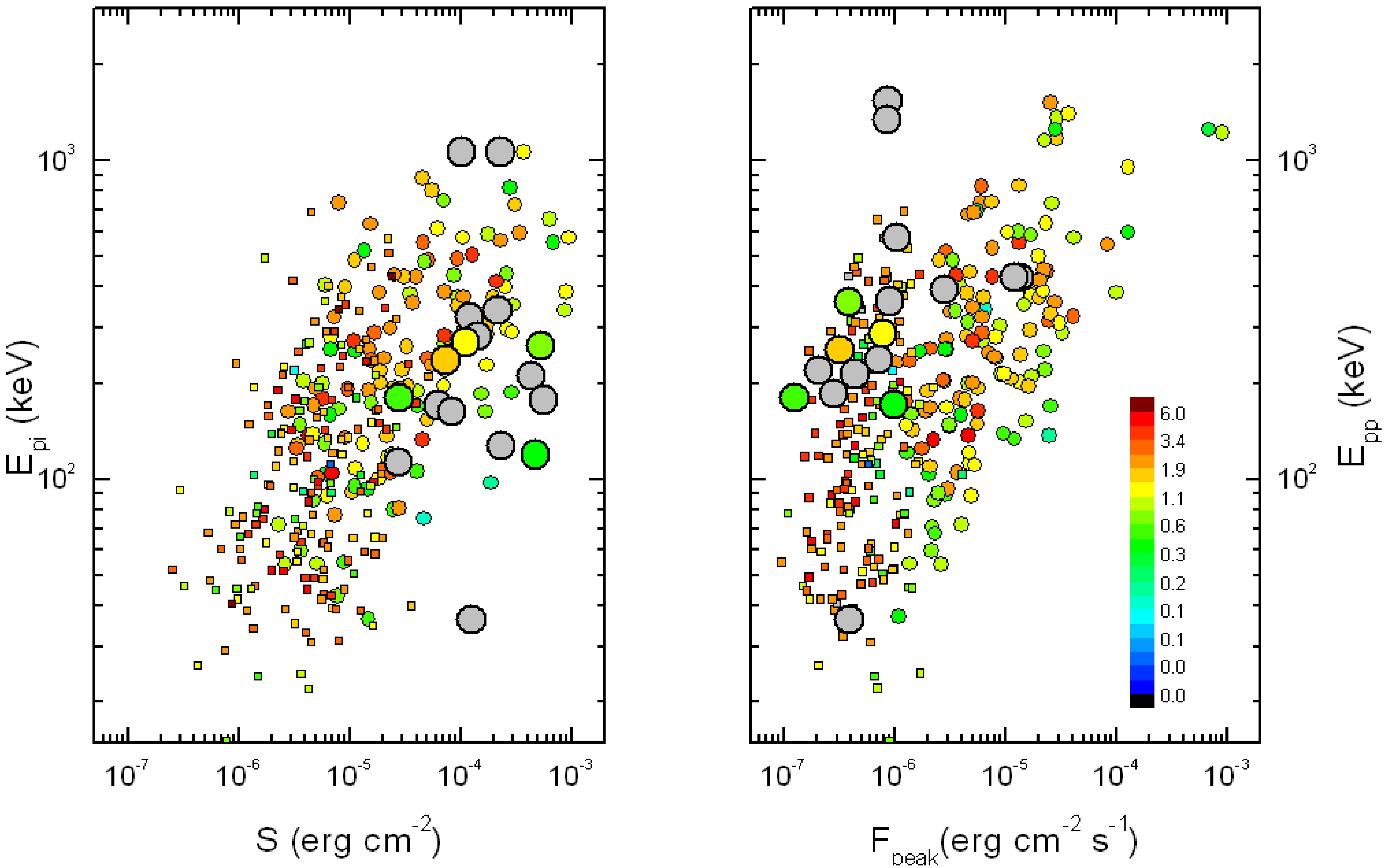
Spectral analysis results

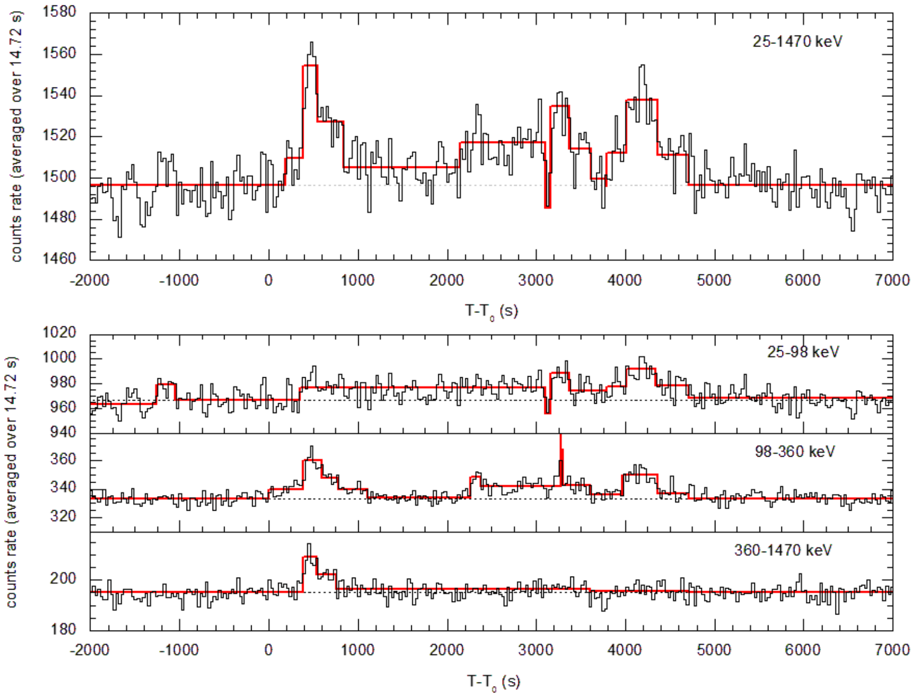
- 17 GRBs with T_{100} > 1000 s
- Most of E_{peak} are in the ~100-300 keV range with 2 hard (~1 MeV) and 1 soft (~40 keV) outliers.
- U-long GRBs are consistent with other bursts in terms of fluence and peak flux.



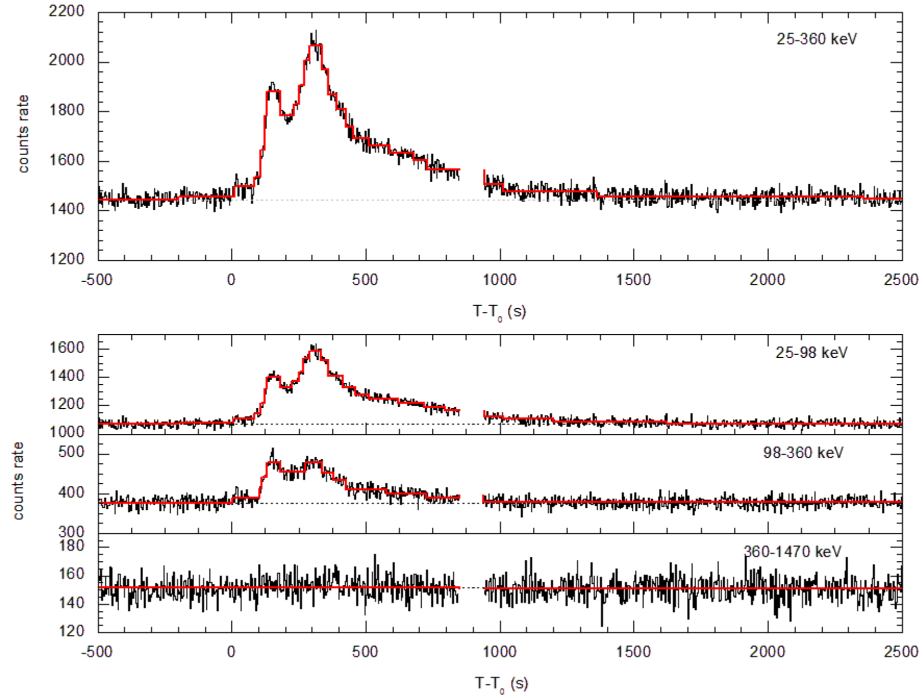
Discovered KW ultra-long GRBs

The hardest and the softest discovered burst

KONUS-WIND GRB 161103
T_0 = 81691 s UT (22:41:31)
S1



KONUS-WIND GRB 130527
T_0 = 39662 s UT (11:01:02)
S2

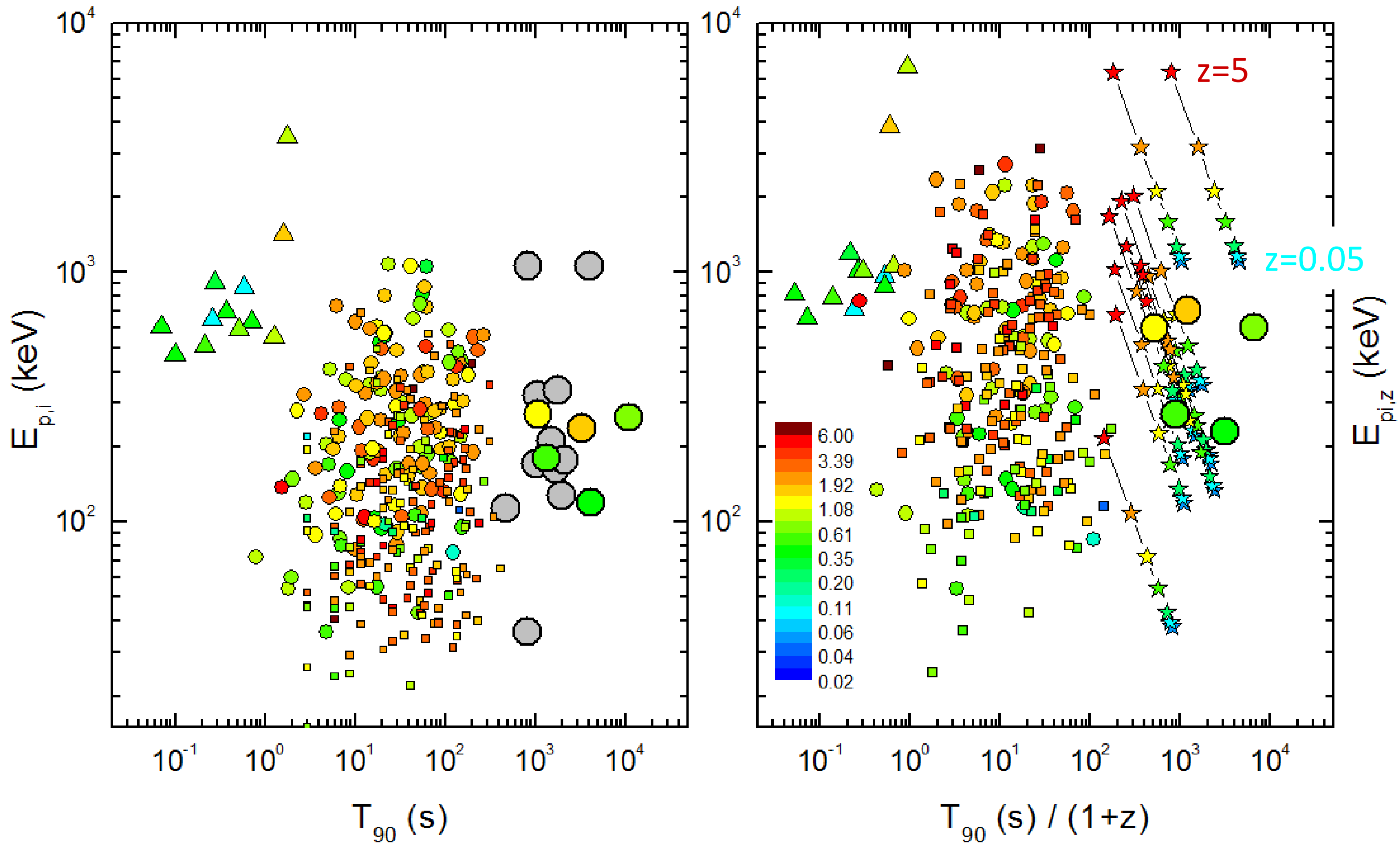


T_{100} = 4380 s (25-1470 keV)
T_{90} = 4001 ± 164 s; T_{50} = 3053 ± 134 s
time averaged: **Ep =1.06 (-0.27,+0.68) MeV**

T_{100} = 1348 s; (25-1470 keV)
T_{90} = 824 ± 38 s; T_{50} = 306 ± 7 s
time averaged: **Ep =36 (-21,+24) keV**

KW Ulong GRBs in the rest frame: Hardness-duration distribution

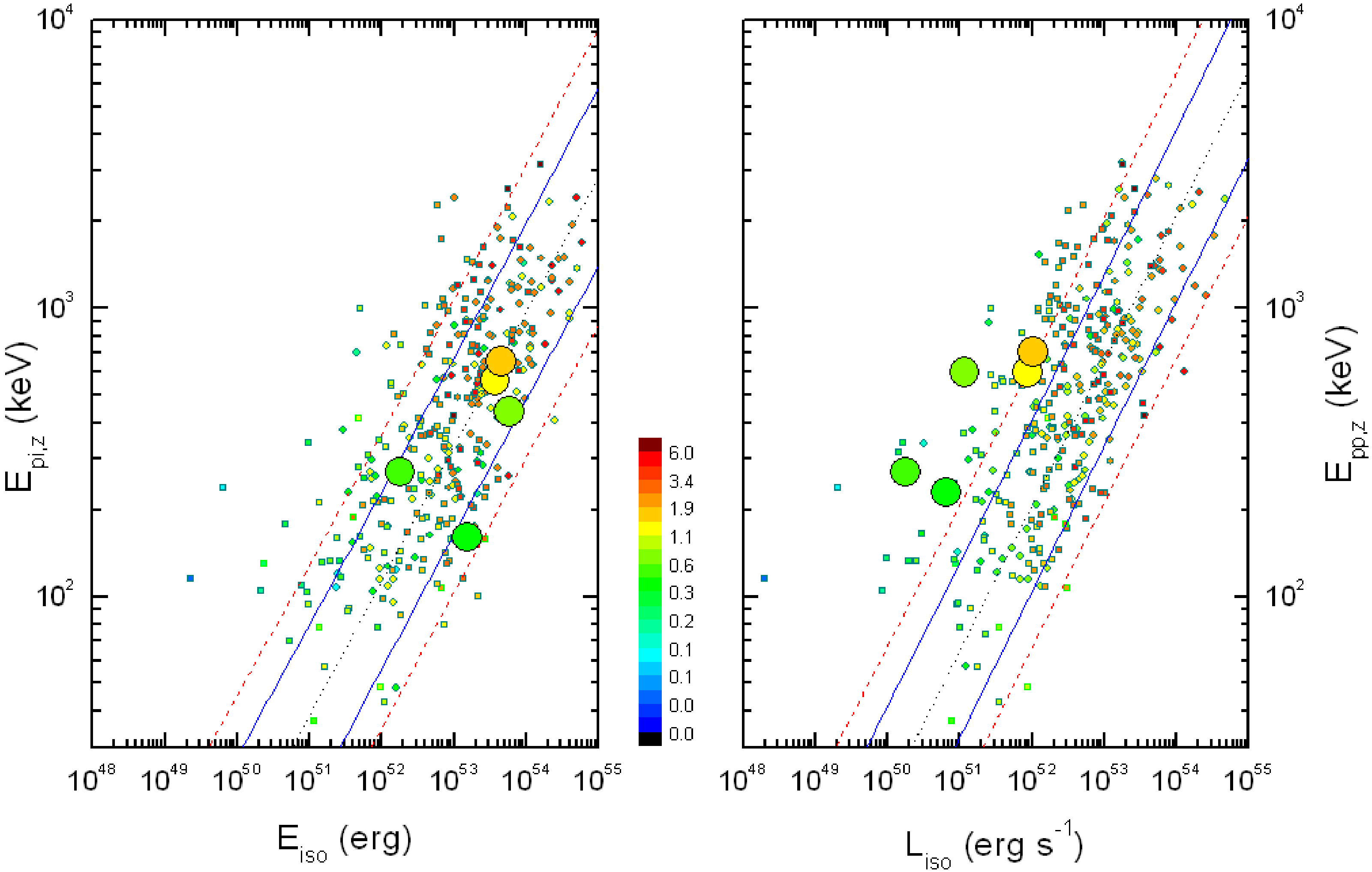
- Konus-Wind has detected **337** GRBs with known redshifts (**Anastasia Tsvetkova talk on Wednesday**)
- U-long GRBs are still the longest bursts in the rest frame.



Tsvetkova et al., ApJ 850, 161, 2017

KW Ulong GRBs in the rest frame: Amati and Yonetoku relations

- U-long GRBs nicely follow the Amati relation for 'classic' long GRBs and reside on the low luminosity side of the Yonetoku relation.



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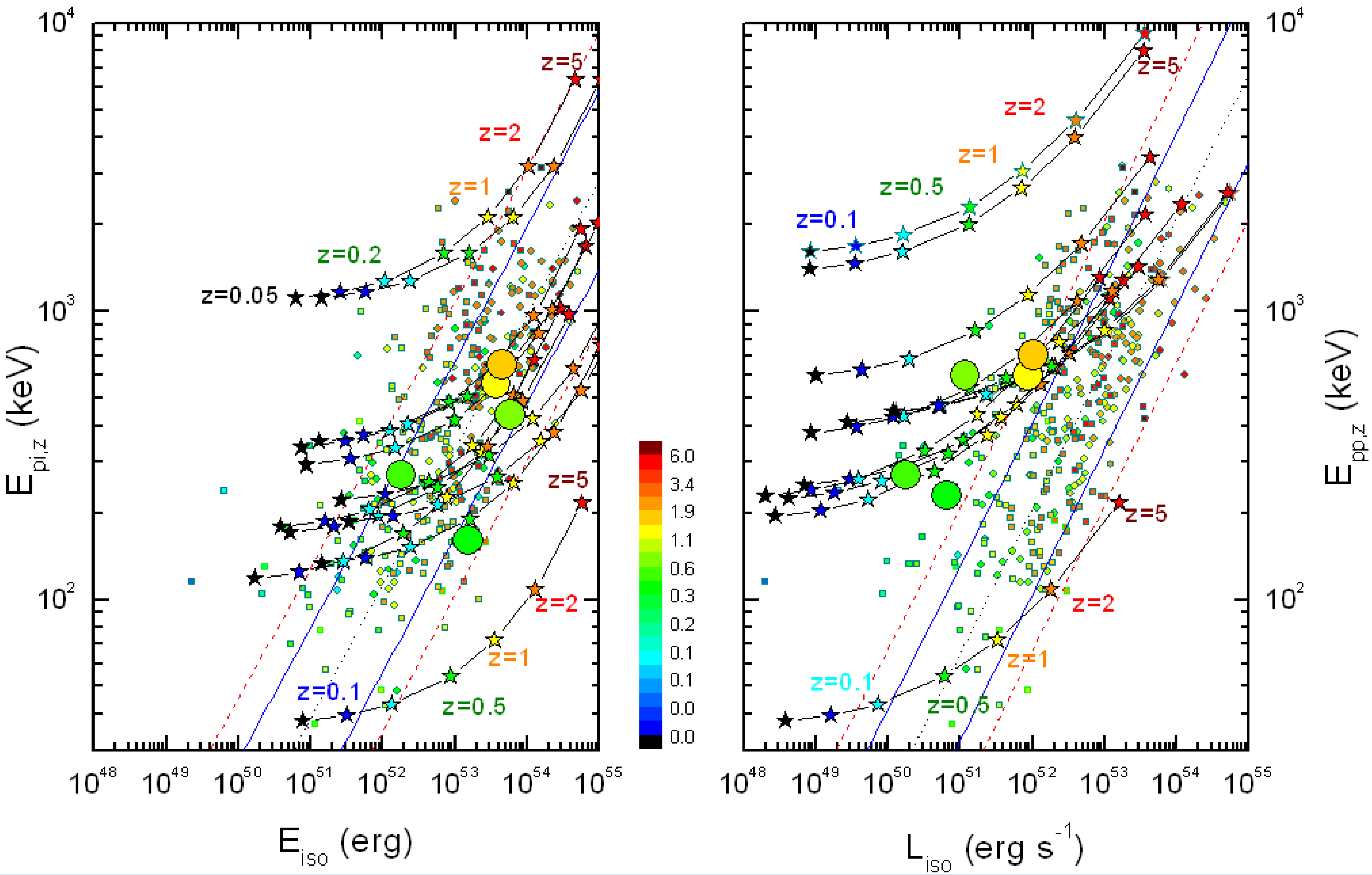
KW Ulong GRBs in the rest frame

There are 12 u-long GRB candidates with unknown z. What we can learn about them?

- Most of the found u-longs may originate at a broad range of z > ~0.2
- U-long GRBs seem to be inhomogeneous in hardness also in the rest frame.



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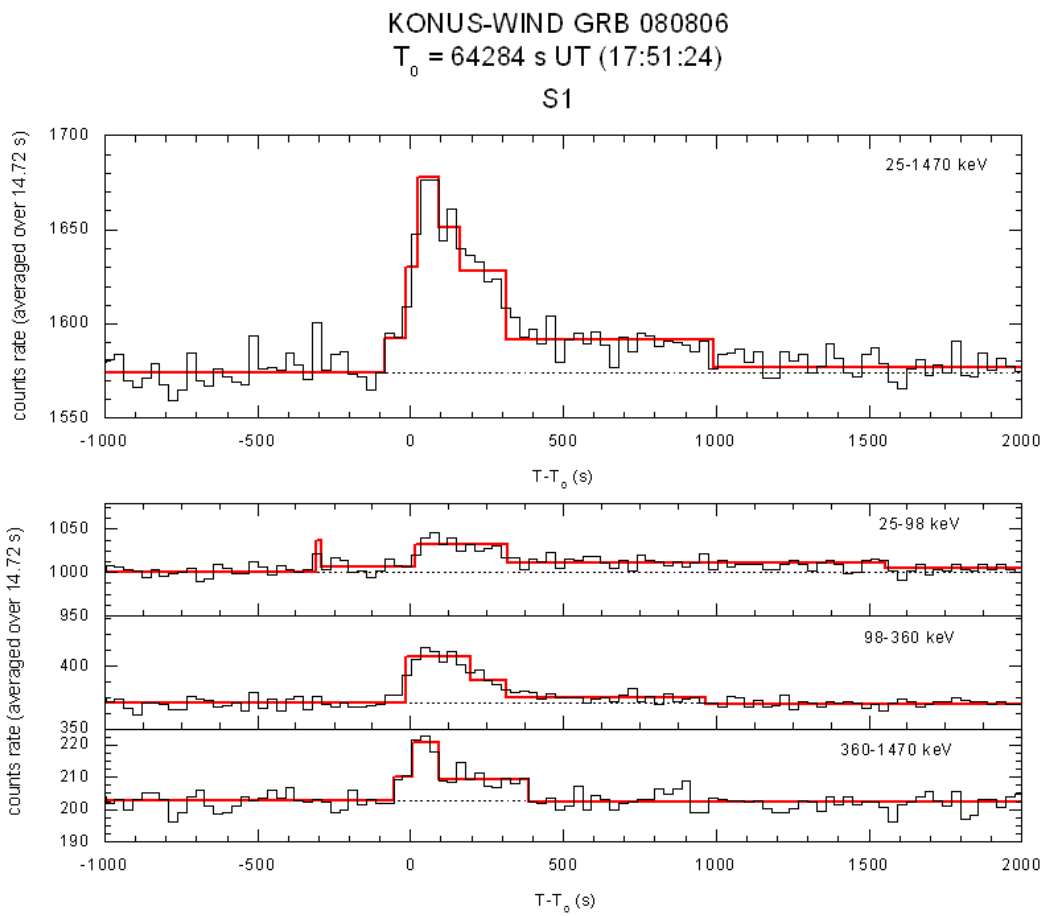
Summary

- KW provides an excellent opportunity to observe prompt emission of ultra-long GRBs for their whole duration.
- We have found 9 new u-long GRB candidates with durations in the range ~1000 – 4500 s.
- A hint of excess was found in the T_{90} distribution at T_{90}>~1000 s above the log-normal fit derived for classical long GRBs.
- Spectral analysis of KW u-long GRBs shows that most of the events have E_{peak} in the range of 100-300 keV with one soft and two hard outliers.
- The u-long GRBs with unknown redshifts nicely follow the Amati relation for ‘classic’ long GRBs and reside on the low luminosity side of the Yonetoku relation.
- U-long GRBs seem to be inhomogeneous in hardness also in the rest frame.

Thank you!

Work is supported by RSF (grant 17-12-01378)

Discovered KW ultra-long GRBs



T_{100} = 1007 s (25-1470 keV)
T_{90} = 830 ± 116 s; T_{50} = 277 ± 51 s
time averaged: **Ep =1.06 (-0.4,+1) MeV**

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Konus-Wind ultra long GRBs

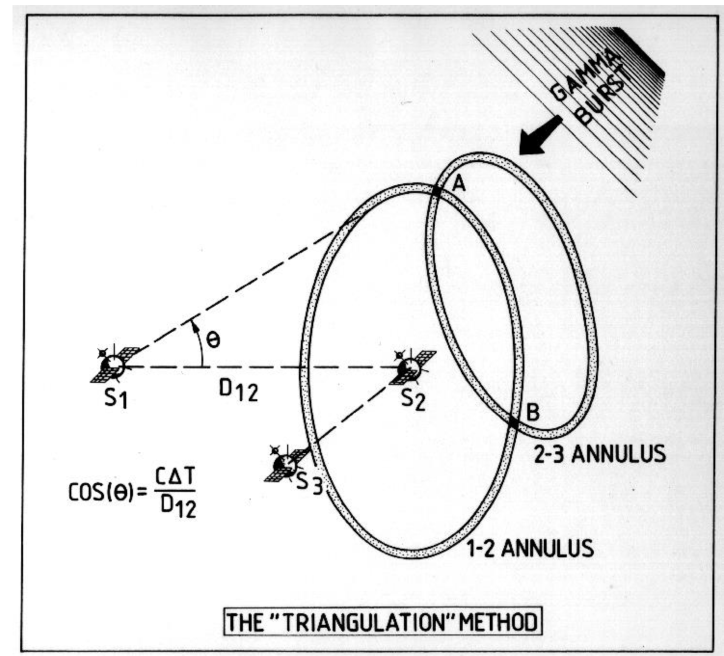
GRB	z	dT (s)	LC shape	E_{peak} (keV)	Fluence (erg cm^{-2})	E_{iso} (erg)
971208[a]	--	~2500	FRED	~144	~2.6x10^{-4}	~6.9x10^{53}**
020410[b]	~0.5[f]	~1600	Multi-episode	~180	~2.8x10^{-5}	~1.8x10^{52}
060814B[a]	--	~2700	FRED	~340	~2.4x10^{-4}	~6.4x10^{53}**
080407[c]	--	~2100	Multi-episode	~290*	~4.5x10^{-4}	~1.2x10^{54}**
091024[d]	1.1[d]	~1200	Multi-episode	~280	~1.3x10^{-4}	~4.5x10^{53}
111209A[e]	0.7[g]	~10000	Multi-episode	~310	~4.9x10^{-4}	~5.8x10^{53}
121027A	1.8[h]	>3500	Multi-episode	~300	~7.4x10^{-5}	~5.9x10^{53}
130925A	0.35[e]	~5000	Multi-episode	~152	**~6.2x10^{-4}**	**~1.9x10^{53}**

* 1st pulse
** at z=1

[a]Pal'shin+2008, [b]Nicastro+2004, [c]Pal'shin+2013, [d]Virgili+2013, [e]Golenetskii+2011, [f]Levan+2005, [g]Vreeswijk+2011, [h]Tanvir+2012, [e]Vreeswijk+2011

GRB episode association using InterPlanetary Network

- The 3rd IPN is in operation since 1990
- At present time consists of 7 s/c:
  AGILE, Fermi, RHESSI, and Swift (at low earth orbits); INTEGRAL (at the elongated oribit up to 0.5 lt-s);
  Wind (up to 7 lt-s) and
  Mars Odyssey (Mars, up to 1200 lt-s)
- Included also: MESSENGER, Suzaku, BATSE, Ulysses, etc.
- Continuous full sky monitor with sensitivity of ~10^{-6} erg cm^{-2}
  (1 phot. cm^{-2} s^{-1})



K. Hurley,
http://www.ssl.berkeley.edu/ipn3/

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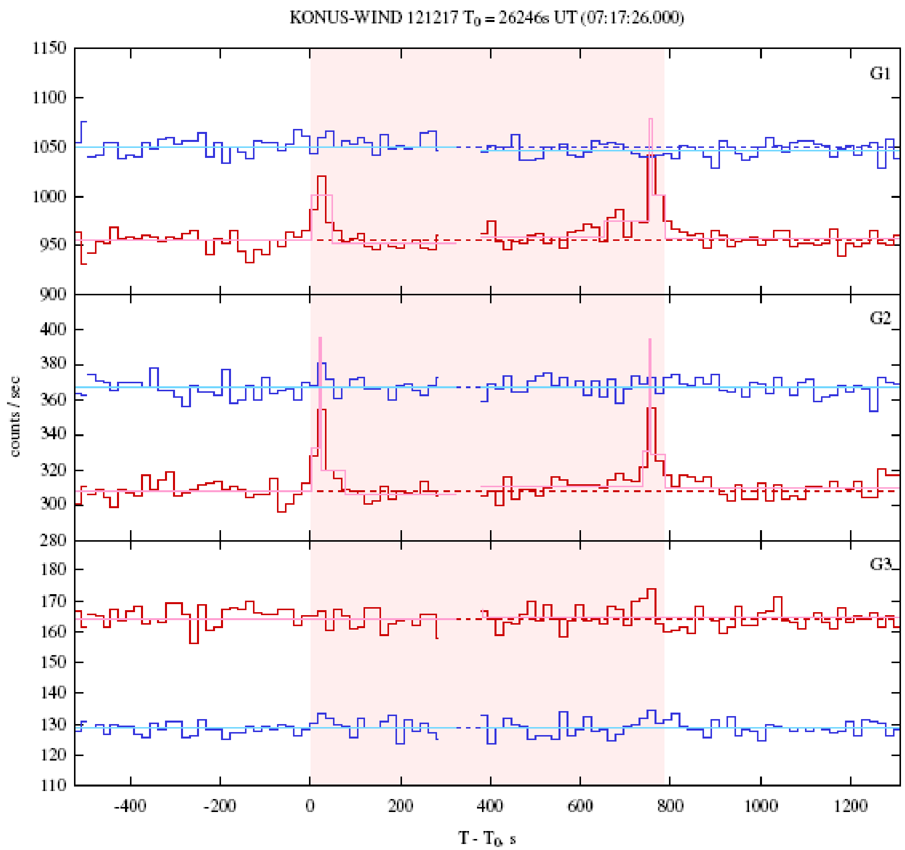
IPN detections

GRB 121217A, observed by Fermi and Swift



T_{100} = 748 s;

T_{90} = 741 ± 7 s; T_{50} = 730 ± 12 s

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IPN detections