A search for ultra-long gamma-ray bursts in the Konus-Wind data

D. Svinkin, D. Frederiks, R. Aptekar, S. Golenetskii, M. Ulanov, A. Tsvetkova, A. Lysenko, A. Kozlova
Ioffe Institute, St.Petersburg, Russia

T. L. Cline
NASA Goddard Space Flight Center; Emeritus,

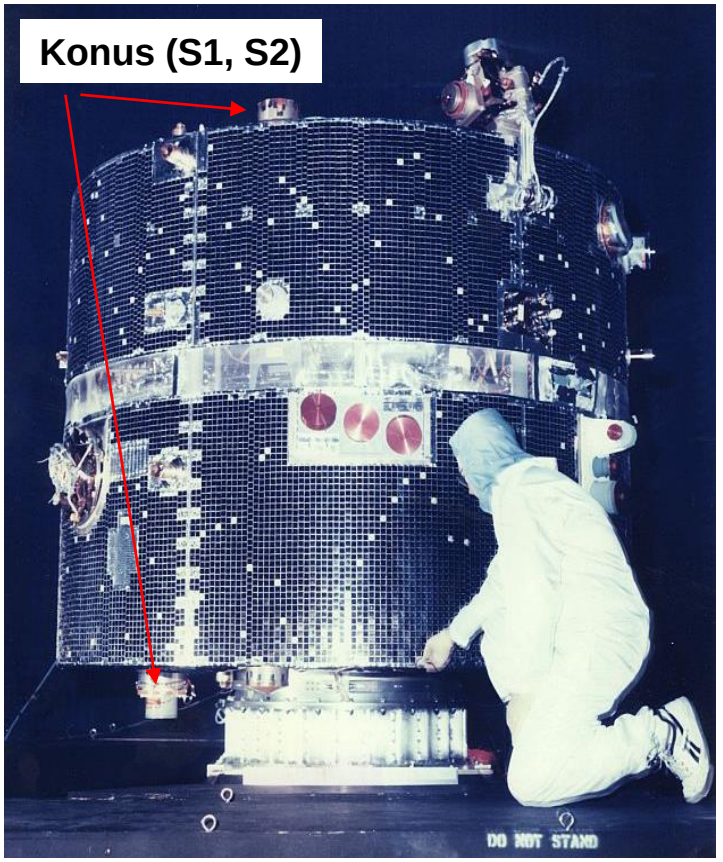
and
K. Hurley
Space Sciences Laboratory, University of California, Berkeley

Joint Russian-US Konus-Wind experiment

- Launch 1994 - 23+ years of continuous operation,
- Now in orbit near L_1 up to 1.5 million km,
- Two NaI(Tl) spectrometers 130×75 mm,
- 20 keV – 15 MeV, S_{eff}~100-160 cm^2
- Burst mode:
  - light curve resolution 2-256 ms
  - 128 channel spectra
- Waiting mode:

  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 (at few ks interval),
  - 2 ×2 π FoV,
  - duty circle ~95%,
  - observes all bright events



- Observation statistics (triggers):

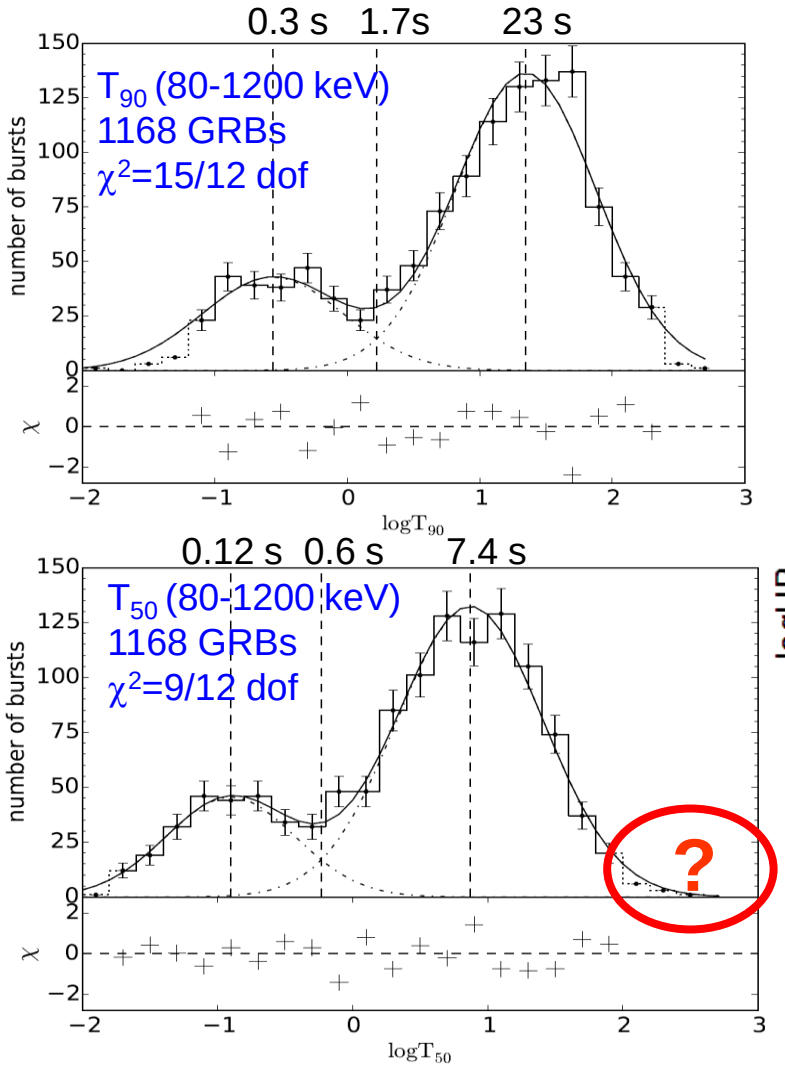
  3000 – GRBs (Fermi ~2400, BATSE ~2700)

  250 – SGRs

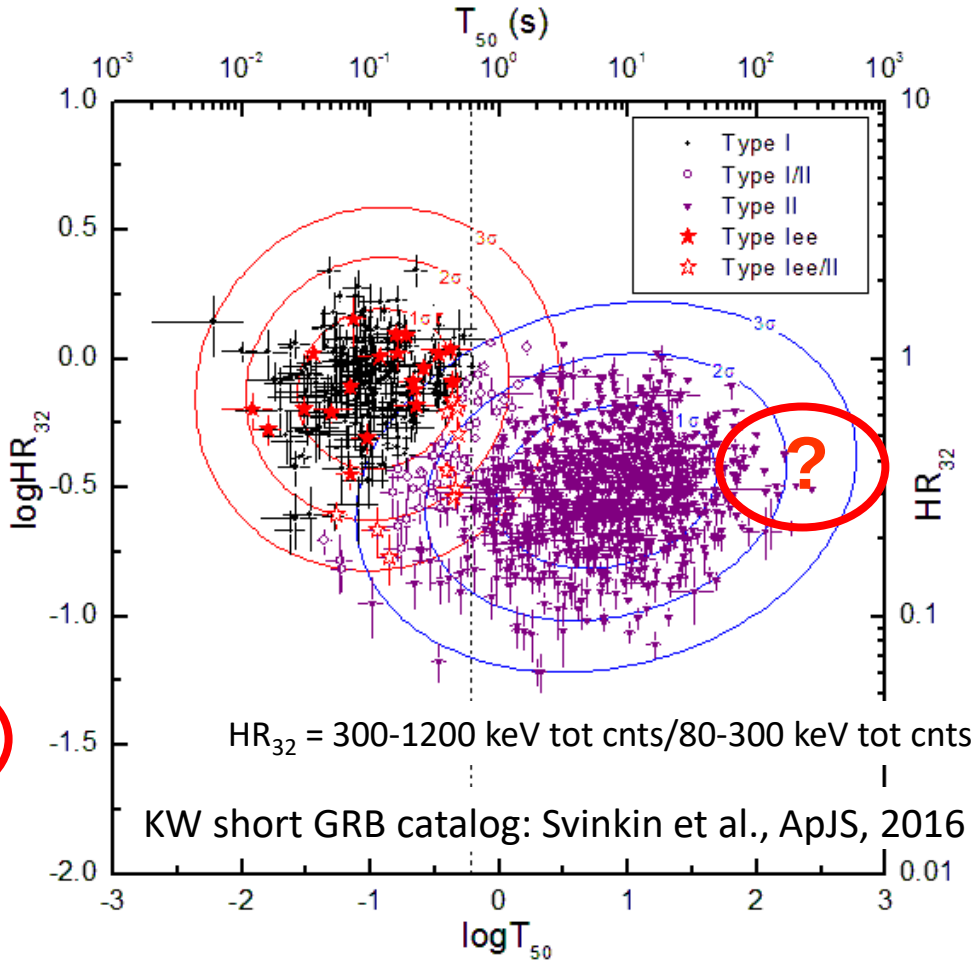
  1000 – Solar flares

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 with 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).



HR_{32} = 300-1200 keV tot cnts/80-300 keV tot cnts

KW short GRB catalog: Svinkin et al., ApJS, 2016

Very long GRB data

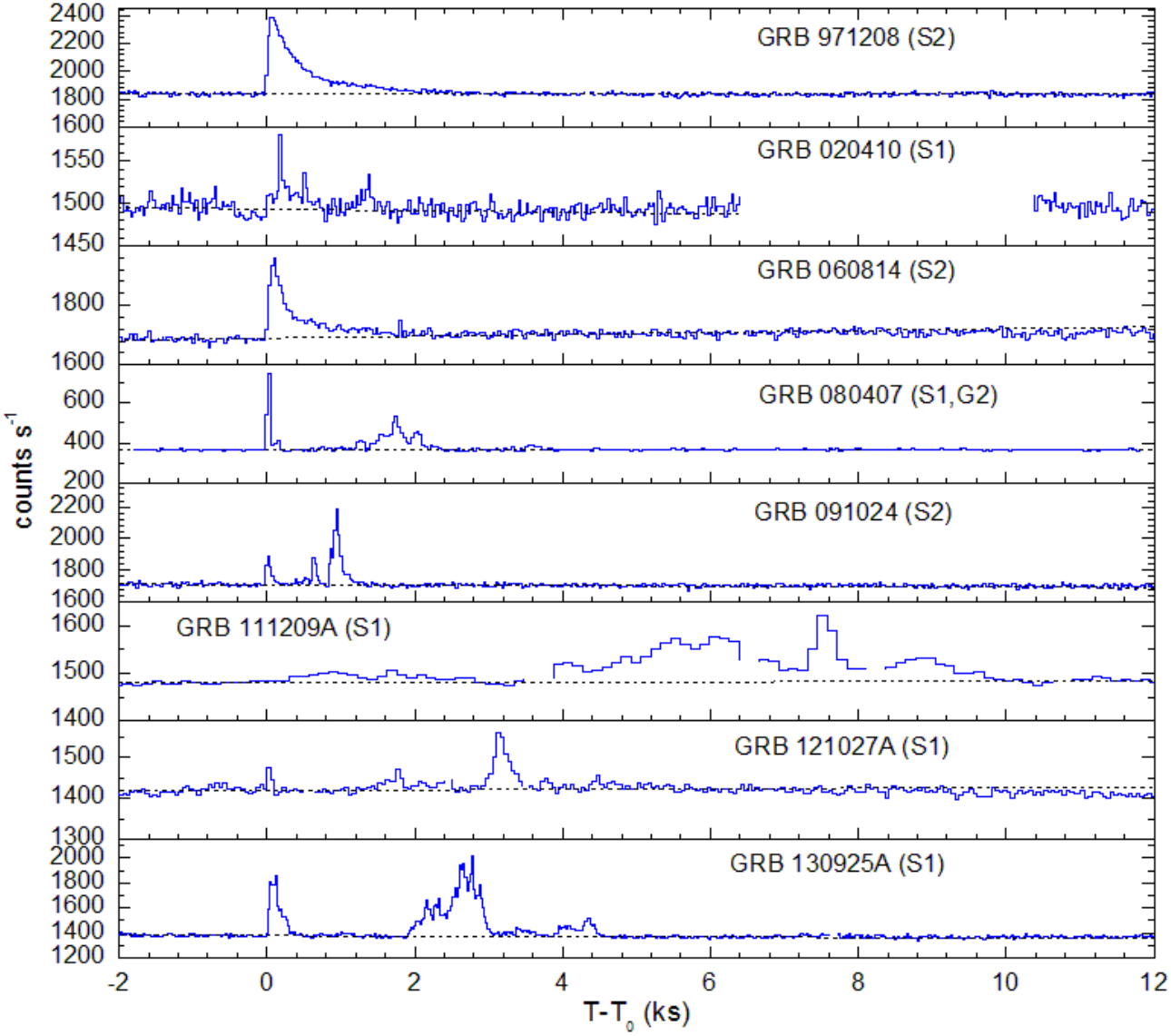
Instrument	Energy band, keV	Number of bursts	
		T_{90}>250 s	T_{90}>1000 s
CGRO-BATSE	**50 - 300**	**22**	**1***
BeppoSAX-GRBM	**40 - 700**	**7**	**0**
Swift-BAT	**15 - 150**	**58**	**15**
Fermi-GBM	**50 - 300**	**30**	**0**
Konus-Wind	**50 - 1000**		**8****

* GRB 970315

** reported, so far

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

Known Konus-Wind ultra-long GRBs



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}**

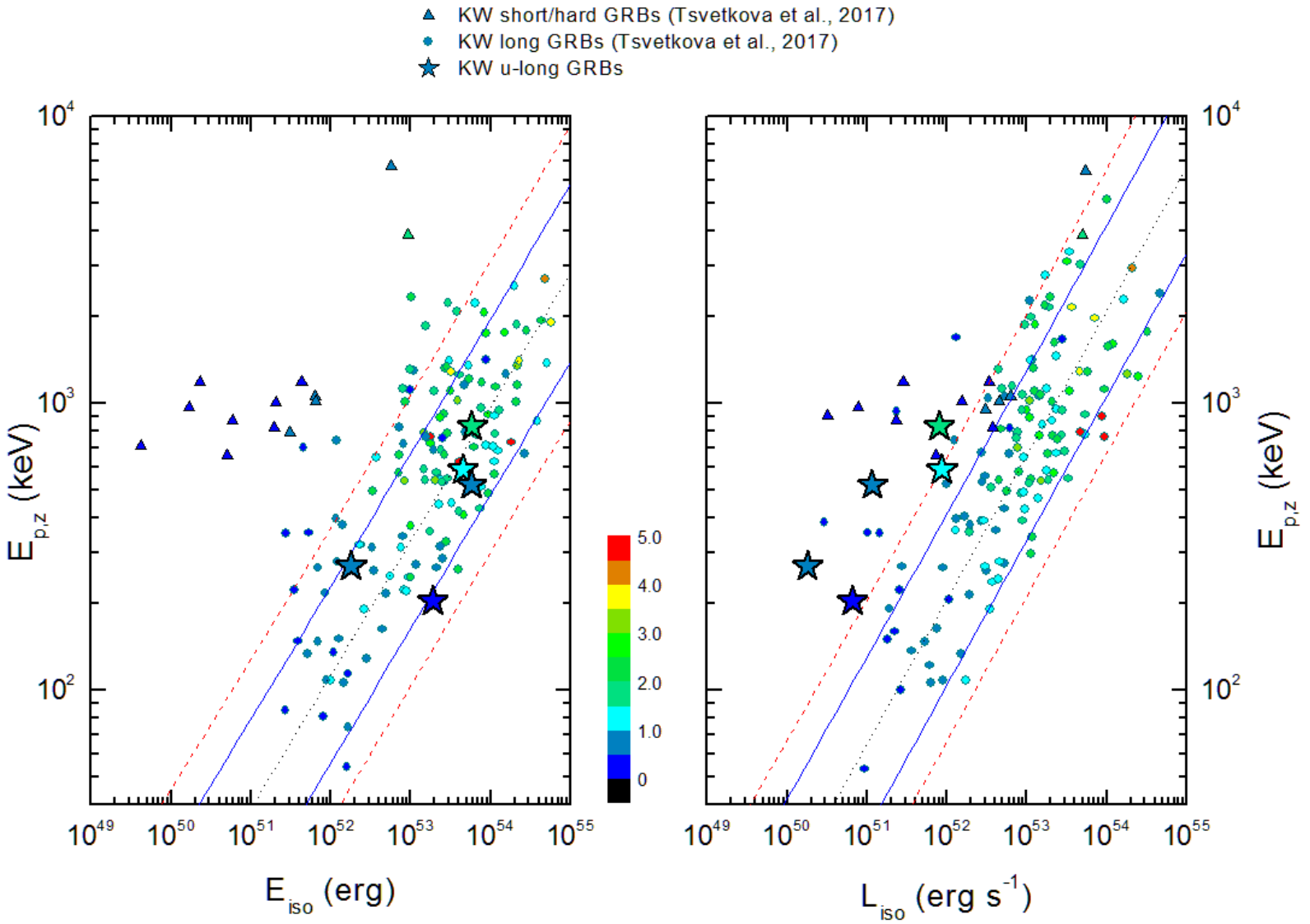
* 1st pulse

** 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

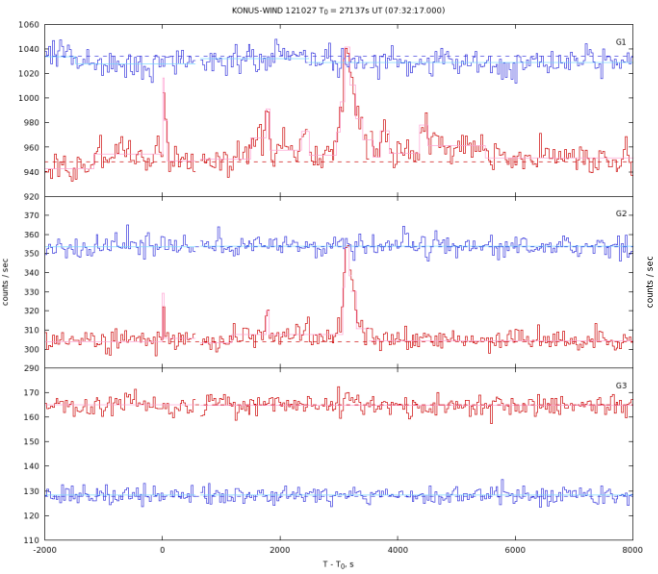
Known Konus-Wind ultra-long GRBs

- Konus-Wind GRBs with known redshifts include 5 u-long GRBs.

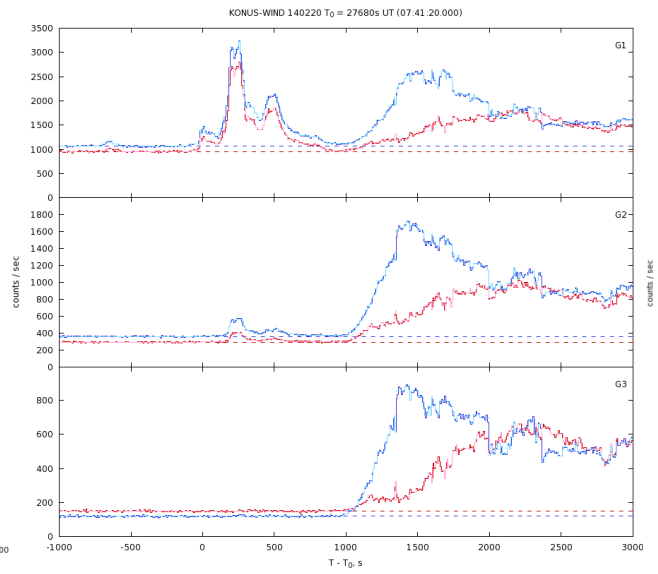


Konus-Wind waiting mode event search

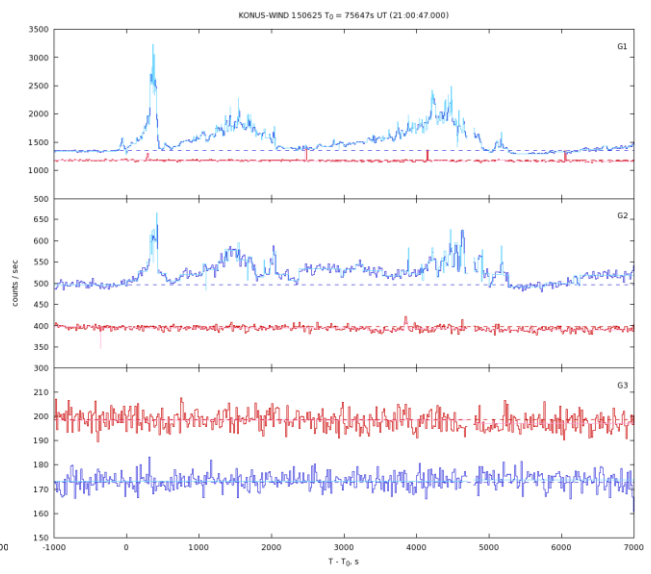
- Bayesian block decomposition of KW waiting mode time history 1994-2017;
- Selection of transients occurred in both detectors and/or at least in two energy bands;
- Preliminary event classification: GRB, Solar flare, hard X-ray transient (e.g. Cyg -X1, V404 Cyg), particle event (using Wind-3DP particle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



GRB 121027A



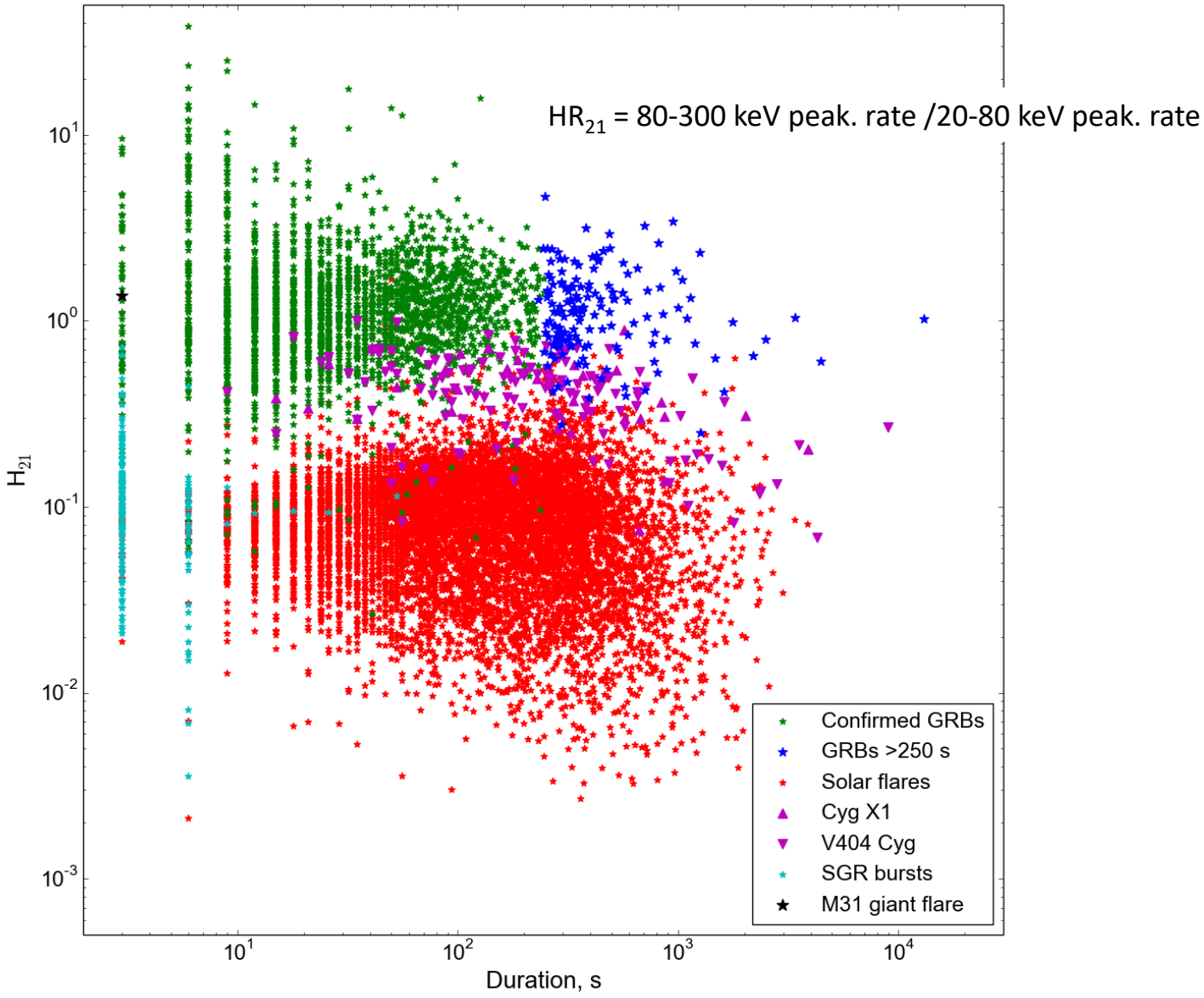
Solar flare M3.0, followed by energetic solar particles



V404 Cyg

red / blue – S1/S2 KW detector, count rate and Bayesian blocks

KW waiting mode events



The search results

Event type	Number
Solar Flares	**~14 000**
GRB candidates	**~12 000**
Other transients	**~1 000**
Energetic particle events	**~2 000**
Data artifacts	**~2 000**
Total	**~31 000**

Very long GRB candidates

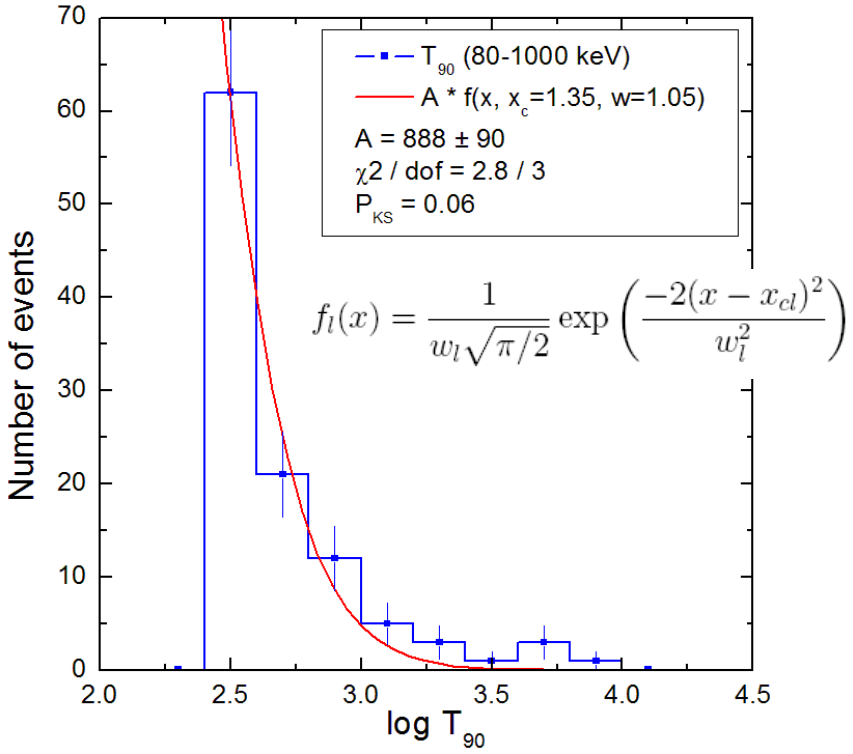
- Long burst selection criteria: $T_{90} > 250$ s, S/N > 10 (at T_{100})

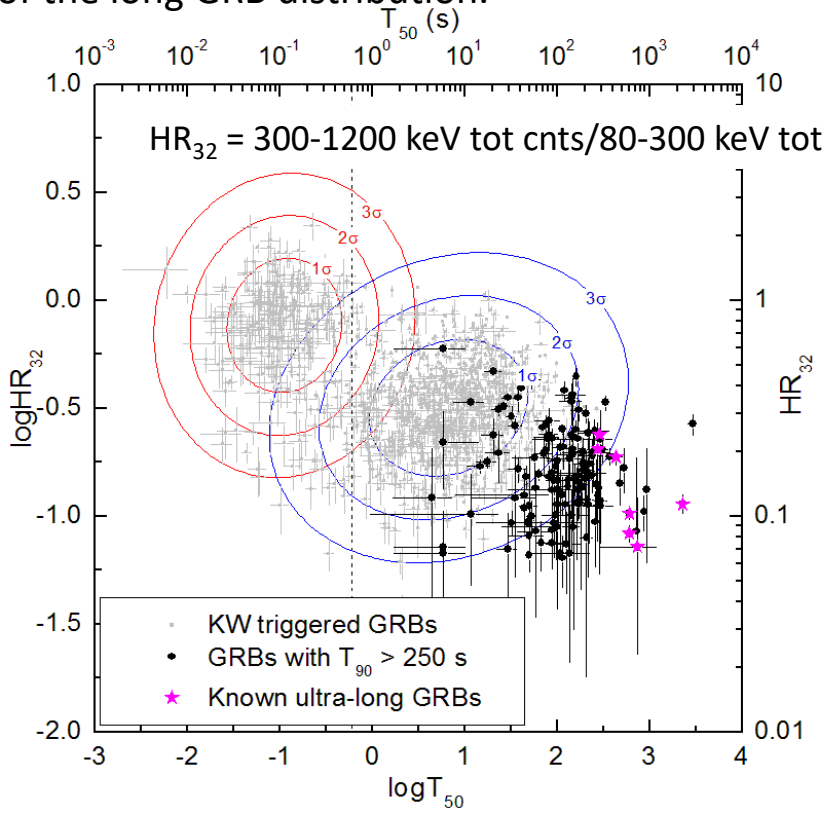
Total found:

- 120 GRB candidates (single and multi-episode),
- 13 – $T_{90} > 1000$ s (including 5 known KW u-long GRBs and 7 new candidates).

Very long GRBs. Duration and hardness.

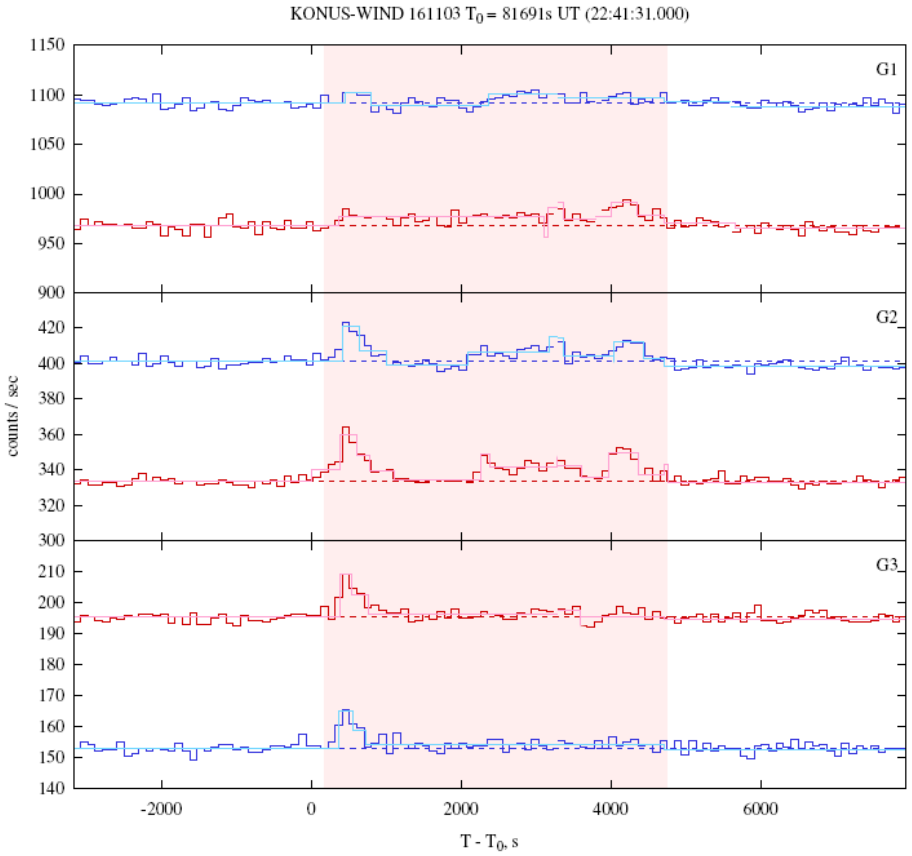
- The T_{90} distribution of the KW very long GRBs is consistent with a tail of the triggered GRB population. Log-normal function with x_c and w fixed to those for the triggered GRBs fits the tested distribution with **P_{KS}=6%.**
- The number of observed u-long GRBs (T_{90}> 1 ks) is consistent with one expected from the fit (within 3σ conf.).
- Ultra-long GRBs extend the softer/longer corner of the long GRB distribution.

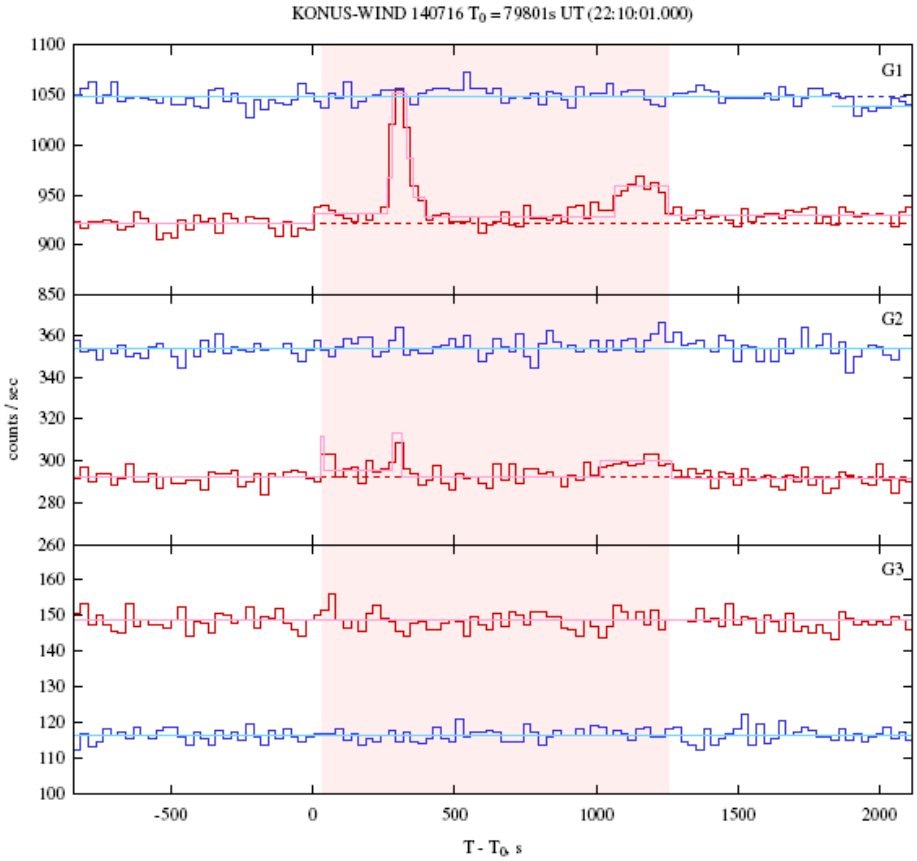




Discovered KW ultra-long GRBs

Both seen in the KW data only





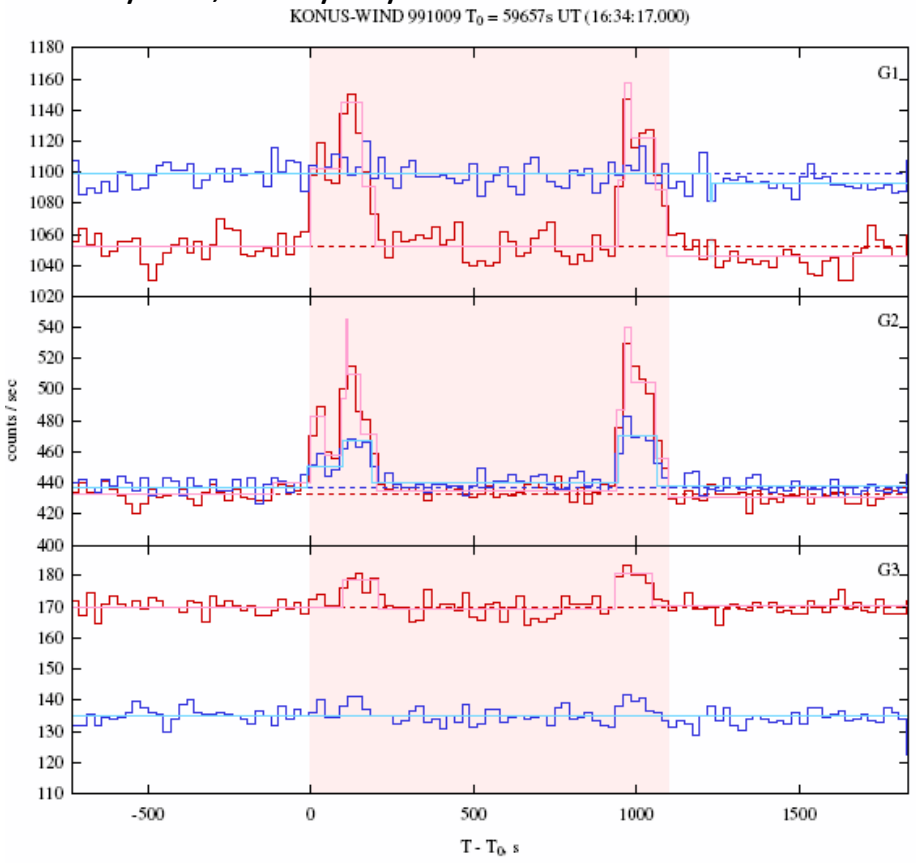
T_{100} = 4751 s (G1+G2+G3);
T_{90} = 4098 ± 248 s; T_{50} = 2938 ± 336 s

T_{100} = 1334 s;
T_{90} = 1272 ± 791 s; T_{50} = 939 ± 82 s

red / blue – S1/S2 KW detector, count rate and Bayesian blocks

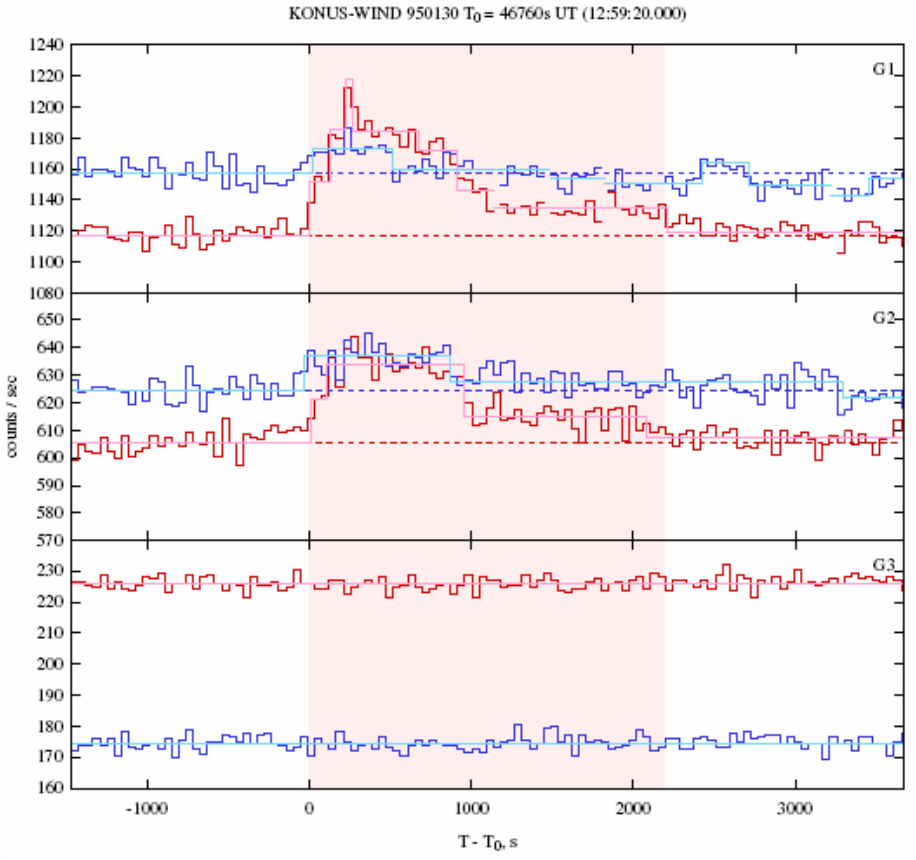
Discovered KW ultra-long GRBs

GRB 991009, 1st pulse observed by Ulysses, 2nd by Ulysses and BATSE



T_{100} = 1098 s;
T_{90} = 1027 ± 23 s; T_{50} = 874 ± 12 s

GRB 950130, observed by KW only

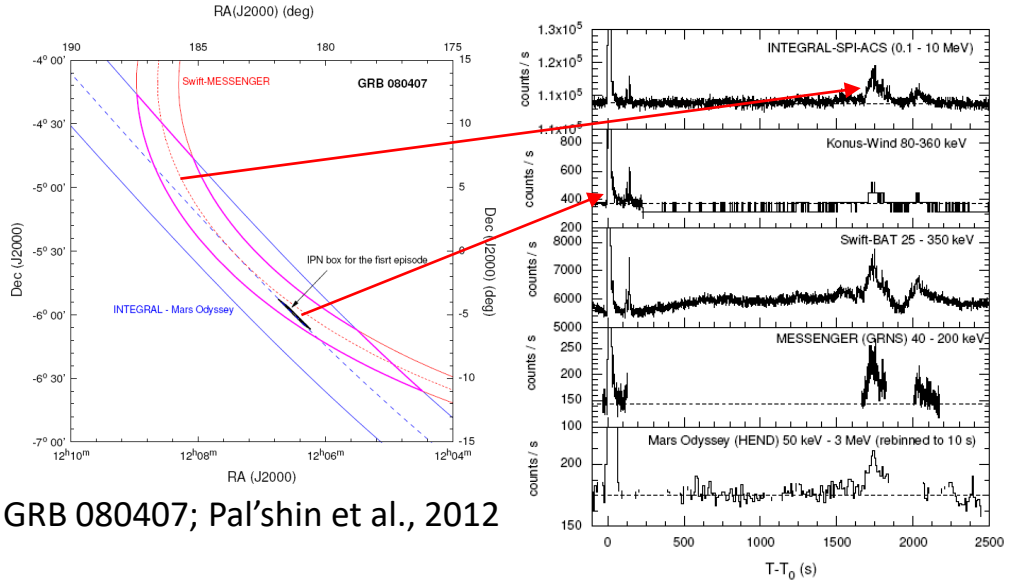


T_{100} = 2302 s;
T_{90} = 1805 ± 224 s; T_{50} = 668 ± 112 s

red / blue – S1/S2 KW detector, count rate and Bayesian blocks

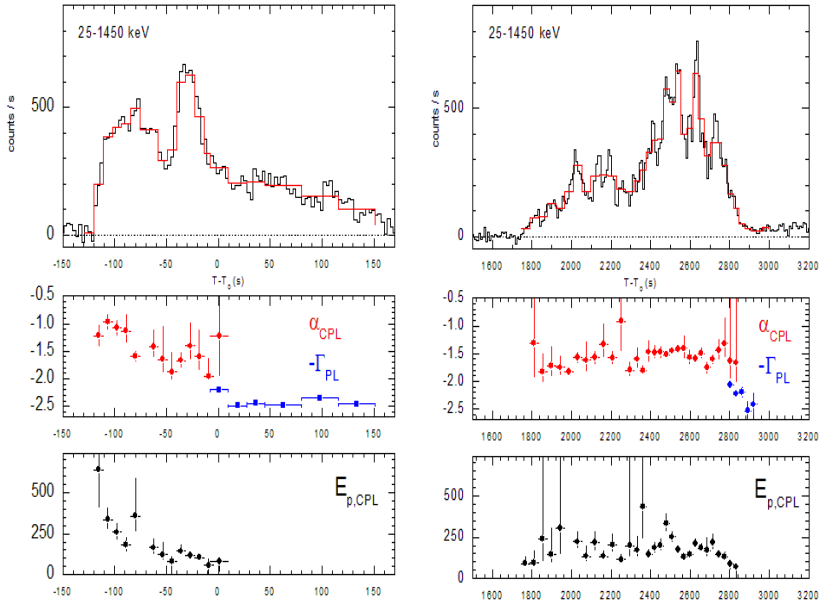
Prospects

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



GRB 080407; Pal'shin et al., 2012

- Spectral analysis of ultra-long GRBs.
  - KW waiting mode data form a continuous 3-channel spectrum in the 20—1450 keV range.
  - Spectral models with up to 3 parameters (including norm.) can be tested: e.g. PL (1 d.o.f.), Cutoff PL, Band func. with fixed parameter (e.g. beta).



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

Summary

- KW provides an excellent opportunity to observe prompt emission of ultra-long GRBs for their whole duration.
- Konus-Wind analysis of previously known u-long GRBs shows that with the exception of their duration, the KW u-long GRBs look not much different (spectrum, energetics) from “regular” KW-detected long GRBs.
- The Kons-Wind data search for the ultra-long GRBs reviled ~100 rather bright GRBs longer than 250 s, including ~30 (T_{90}>500 s) and 7 new u-long candidates (T_{90}>1000 s).
- The T_{90} duration distribution of very long GRBs seems to follow the log-normal law derived for “regular” long GRBs.
- The candidate list will be further refined using InterPlanetary Network detections. The spectral analysis of the new u-long GRBs is ongoing.
- All recent GRBs found with the presented search procedure are published at Ioffe web site http://www.ioffe.ru/LEA/kw/wm/ and IPN master list http://www.ssl.berkeley.edu/ipn3/masterli.html

Ioffe Institute

NASA Goddard SPACE FLIGHT CENTER

Thank you!

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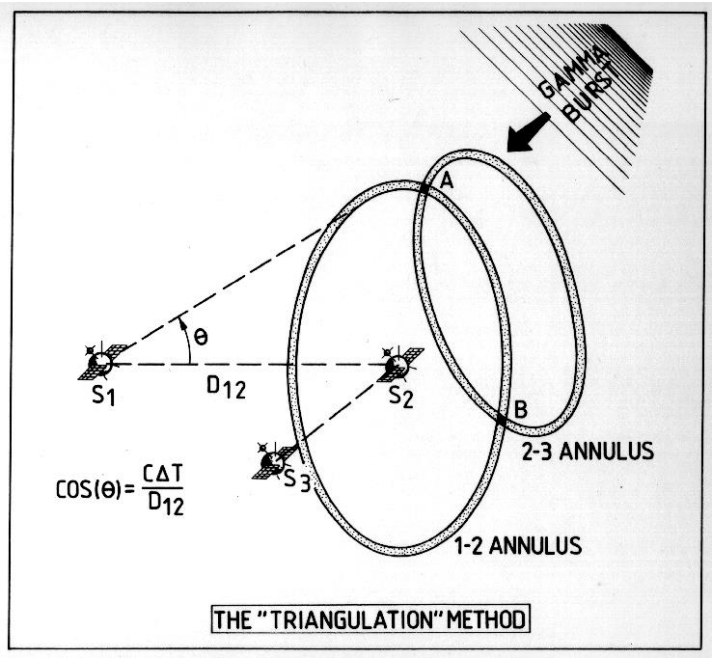
Backup: Inter Planetary Network

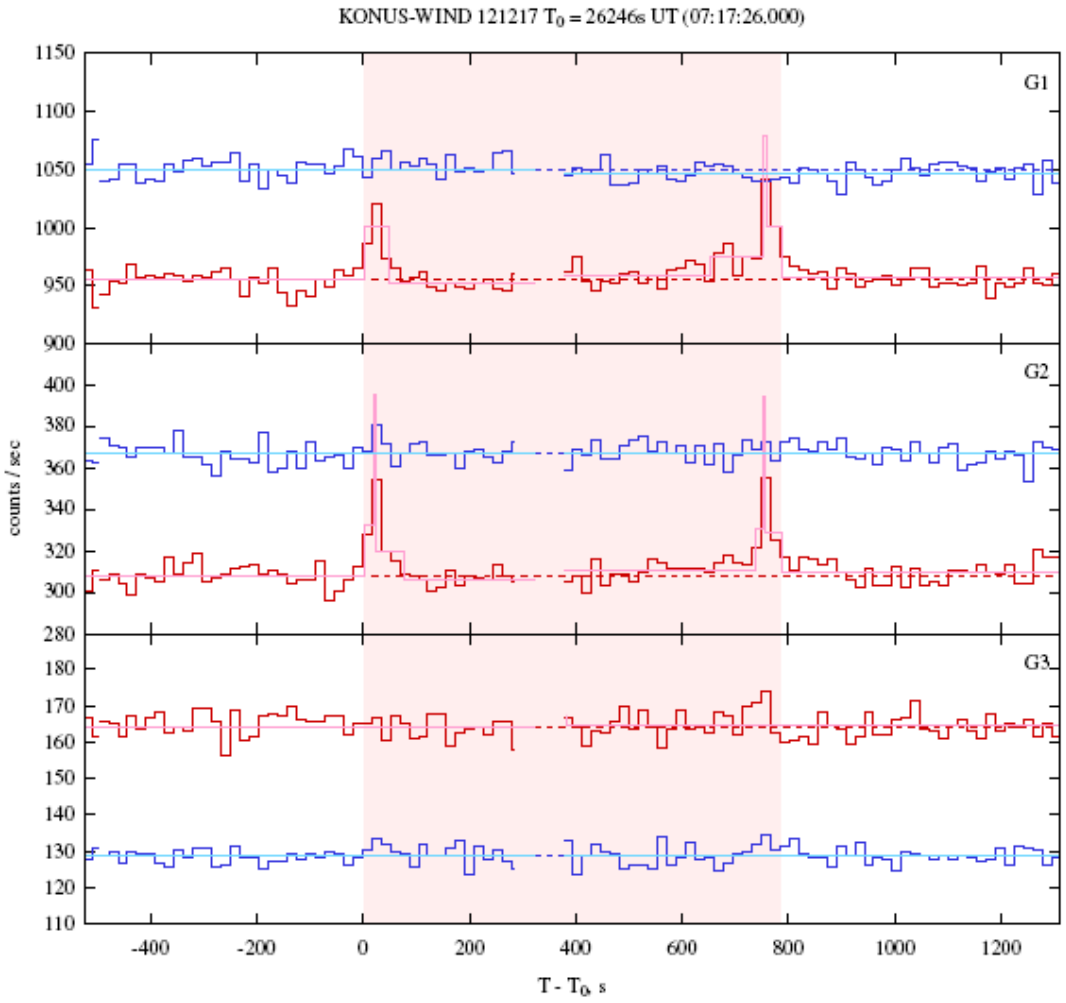
- The 3rd IPN is in operation since 1990
- At present time consists of 7 s/c:
  AGILE, Fermi, RHESSI, and Swift (at low earth orbits); INTEGRAL (at the elongated oribit up to 0.5 lt-s);
  Wind (up to 7 lt-s) and
  Mars Odyssey (Mars, up to 1200 lt-s)
- Included also: MESSENGER, Suzaku, BATSE, Ulysses, 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/

Backup: IPN detection example

GRB 121217A, observed by Fermi and Swift



T_{100} = 748 s;

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