

# GRB 130925A and other ultra-long GRBs observed by Konus-Wind

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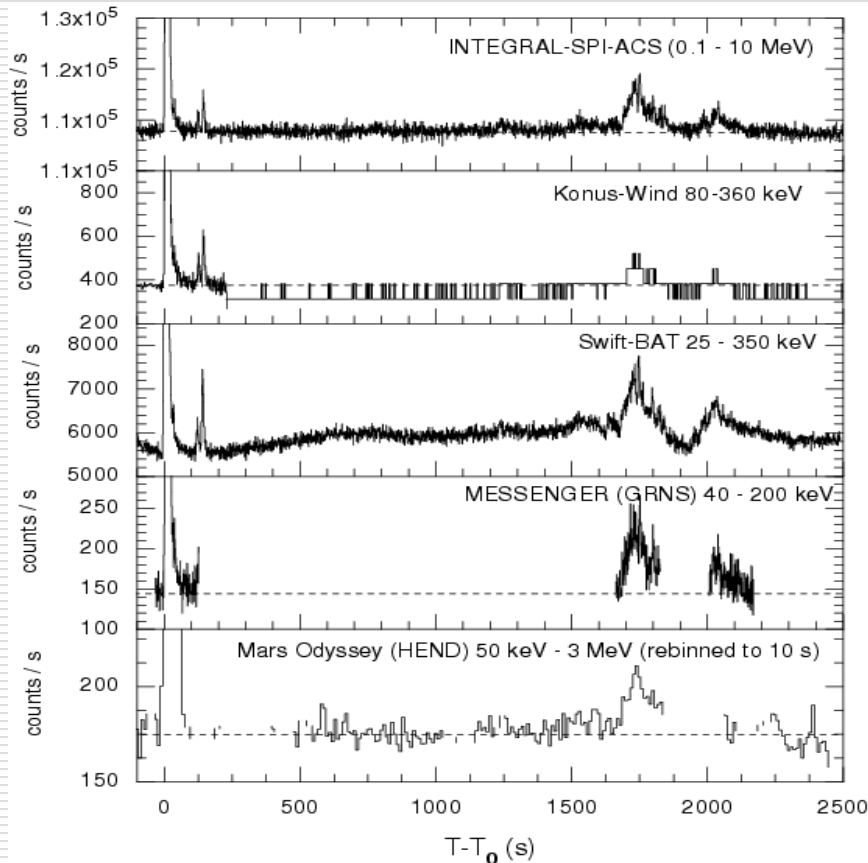
GRB-2014, St.-Petersburg, Russia

# Ultra-long GRBs

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- Ultra-long (u-long) GRB criteria:
    - very long prompt emission duration (e.g.  $dT > 1000$  s)
    - hard energy spectrum (typical of GRBs)
  
  - Less than a dozen confirmed events is known
  - A variety of light-curve morphology (single FRED-like pulse, continuous multi-pulse emission, interrupted ...);
  - Durations up to several hours ( $\sim 10^4$  s),
  - Moderate intensity, high typical fluence  $S \sim 10^{-4}$  erg/cm<sup>2</sup>
  
  - Low or moderate redshift, if measured ( $z < 1.8$ ),
  - Typical  $E_{\text{iso}} \sim 10^{53}$  erg
  
  - Progenitors: Andrew Levan's talk
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# KW detection of u-long GRBs



- KW detected eight confirmed >1000 s GRBs so far

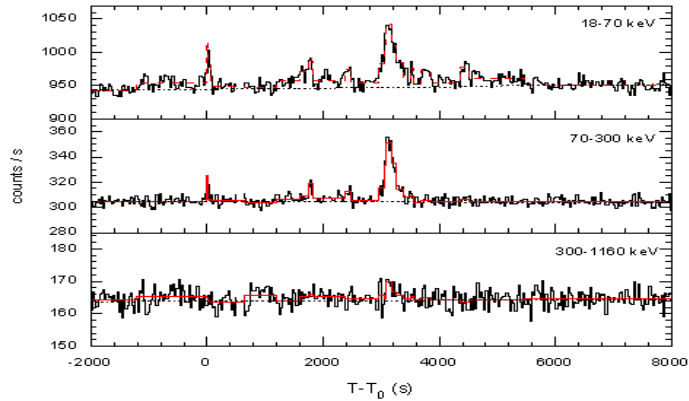
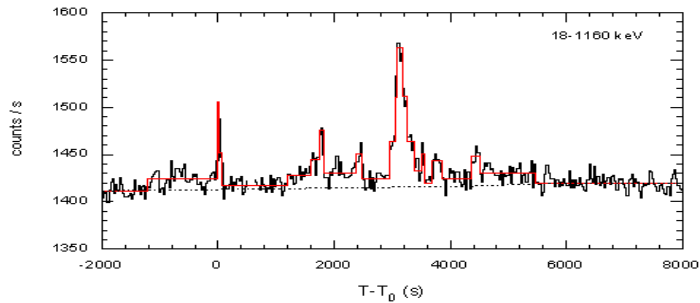
Confirmation of the common source of separate pulses is very important - imaging instruments, standalone localization, Earth/planet occultation, IPN triangulation

- KW triggered mode (rare u-long GRBs with bright initial phase) disadvantage - one hour gap for data transfer.

At this time only spare channel with very limited throughput is available (G2 band, 3.68 s binning, rough CR discretization)

# KW detection of u-long GRBs (ii)

KONUS-WIND GRB 121027  
 $T_0 = T_0(\text{BAT}) = 27149 \text{ s UT (07:32:29)}$   
S1



□ Waiting mode (more typical for u-long GRB detection):

- continuous G1, G2, and G3 lcs with 2.944 s binning

- limited spectral analysis is possible in  $\sim 20 \text{ keV} - 1.5 \text{ MeV}$  band

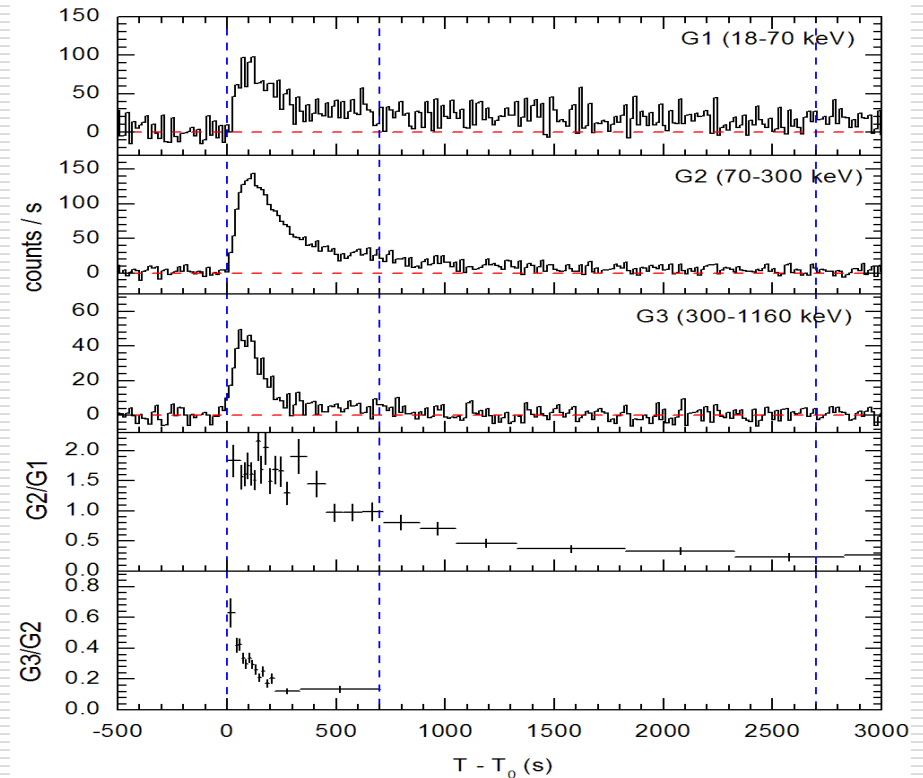
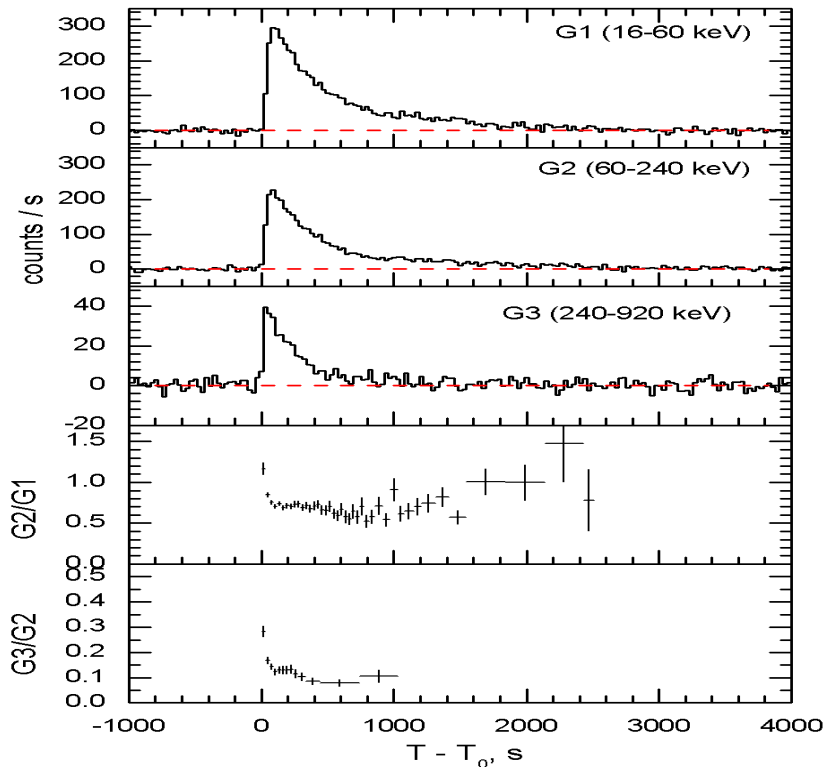
- observations of such long event benefit from the lack of occultation and stable s/c background

GRB 121027A (Starling et al., in preparation)

# U-long GRB zoo

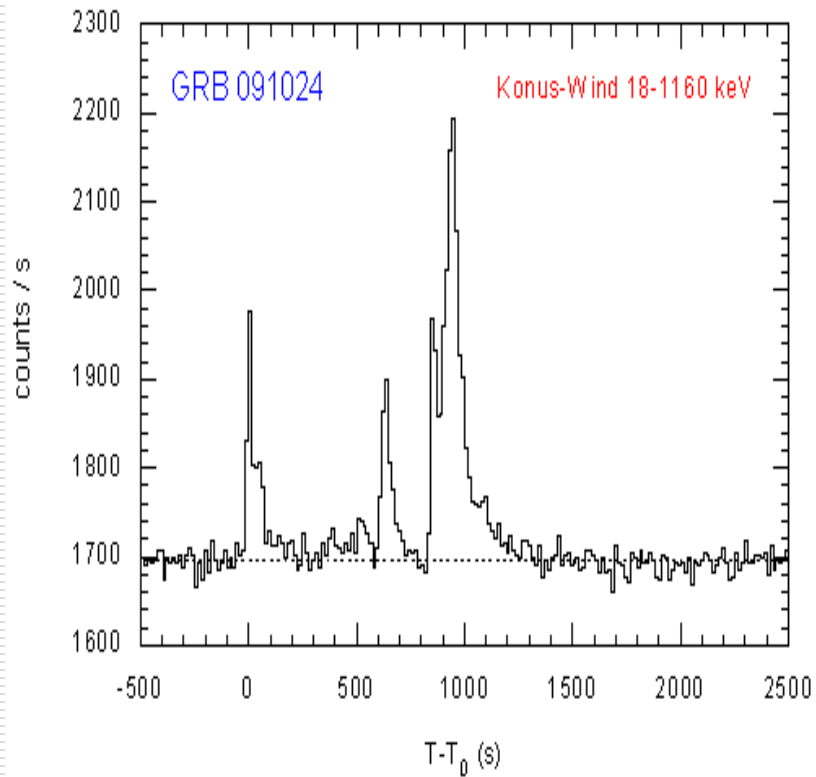
□ GRB 971208: +BATSE,  $\Delta T \sim 2500$  s  
 $S \sim 2 \times 10^{-4}$  erg  $\text{cm}^{-2}$   $E_p = 144 \pm 12$  keV

□ GRB 060814B: +Suzaku-WAM,  $\Delta T \sim 2600$  s  
 $S \sim 2 \times 10^{-4}$  erg  $\text{cm}^{-2}$   $E_p = 341 \pm 62$  keV



# U-long GRB zoo

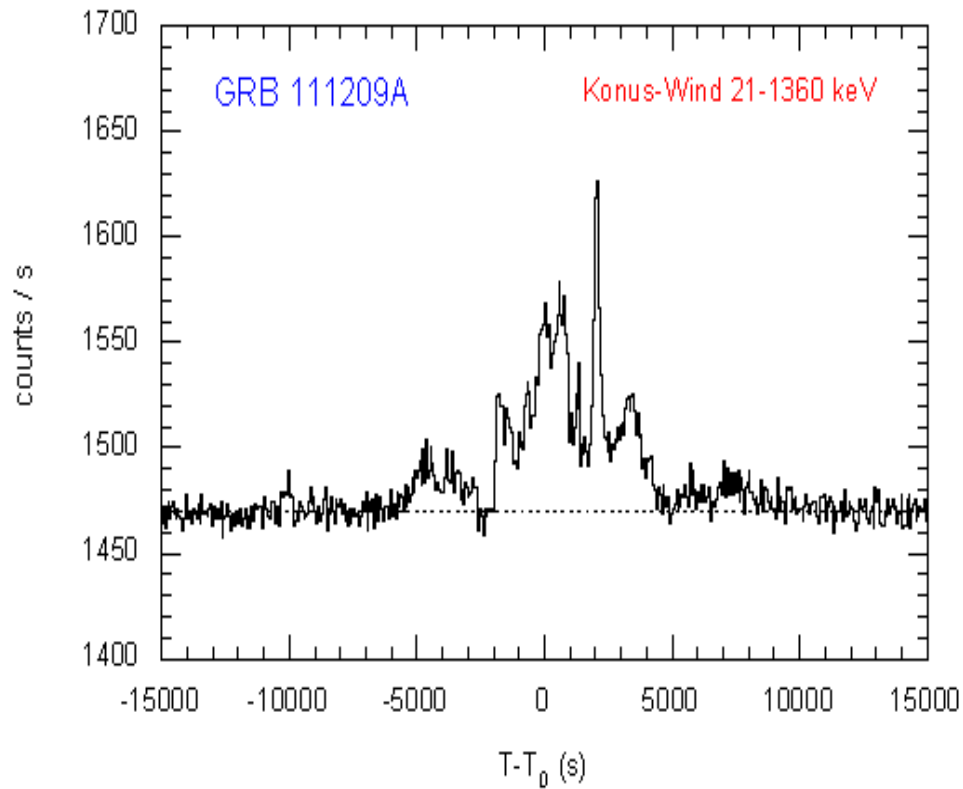
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- GRB 091024 ( $z=1.092$ )  
Duration  $\sim 1200$ s  
 $S \sim 1 \times 10^{-4}$  erg cm $^{-2}$   
 $E_{\text{iso}} \sim 1 \times 10^{53}$  erg

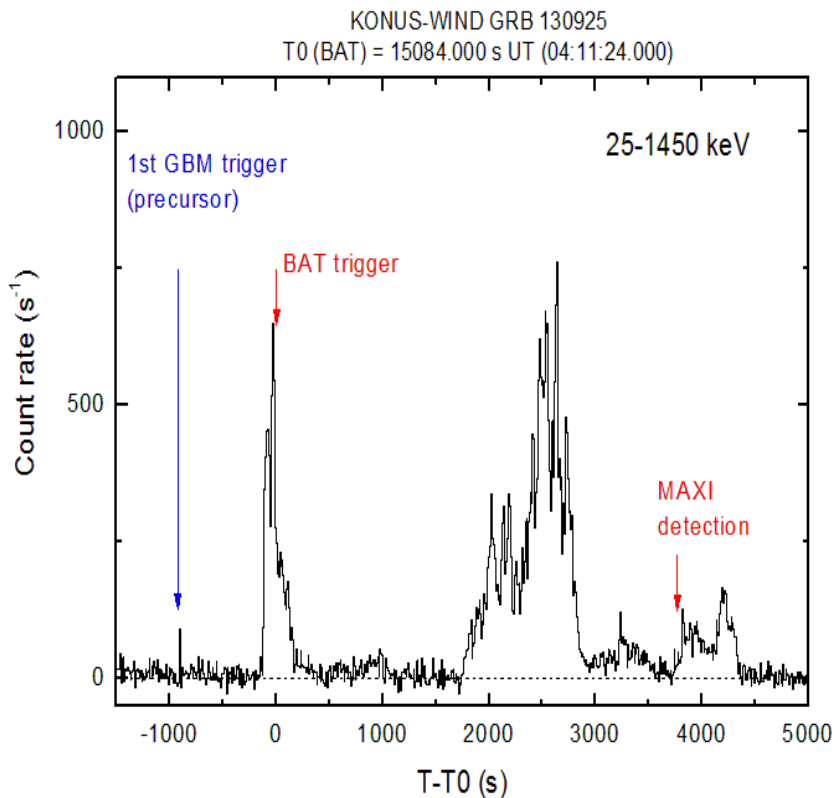
# U-long GRB zoo

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- GRB 111209A ( $z=0.677$ )  
Duration  $\sim 10$  ks!  
Fluence  $\sim 5 \times 10^{-4}$  erg  $\text{cm}^{-2}$   
 $E_{\text{iso}} \sim 6 \times 10^{53}$  erg

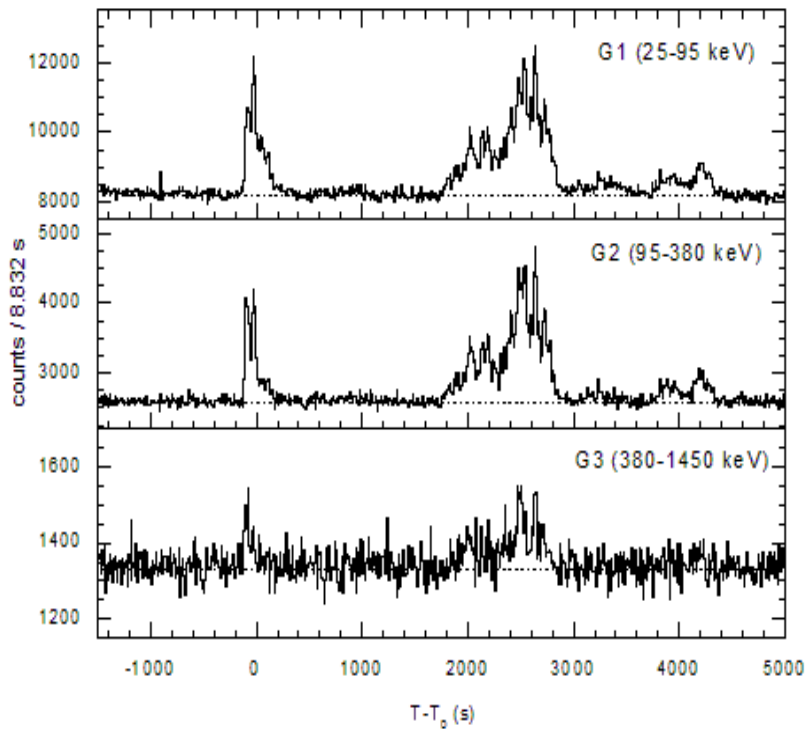
# GRB 130925A – recent 5 ks event



- ❑ Two Fermi/GBM triggers (Fitzpatrick, 2013)
- ❑ Swift/BAT trigger & bright XRT source (Lien+2013)
- ❑ MAXI/GSC detection (Suzuki+2013)
- ❑ INTEGRAL SPI-ACS detection, 3 episodes, 5ks (Savchenko+2013)
- ❑ Konus-Wind observation (Golenetskii+2013)
- ❑ IPN (Hurley+2013), 8 s/c (incl. RHESSI, Suzaku, Mars Odyssey and MESSENGER) data confirmed common origin of the pulses
- ❑ No UVOT detection, but very red optical/IR source (GROND, Sudilovsky+2013a)
- ❑ UVES (Vreeswijk+2013) and X-Shooter (Sudilovsky+2013b) spectroscopy yields  $z=0.347$
- ❑ Highly variable X-ray flaring (6 hrs!) initially suggested a TDE, like Swift J1644+57 (Burrows+2013)
- ❑ Late-time HST obs: source offset  $\sim 600$  pc from the host galaxy center (Tanvir+2013)
- ❑ Late-time ( $>10^5$ s) X-ray lc resembles a GRB afterglow ( $10^7$  s total!)

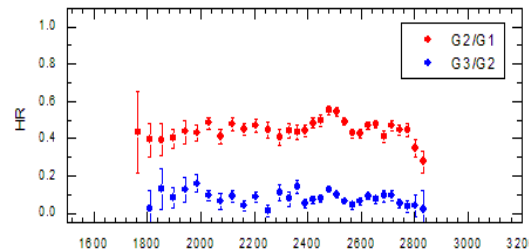
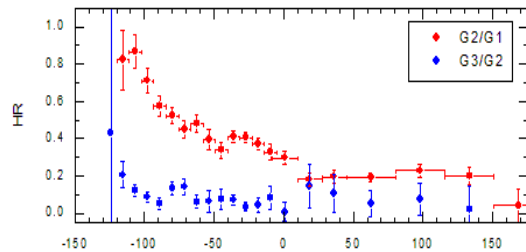
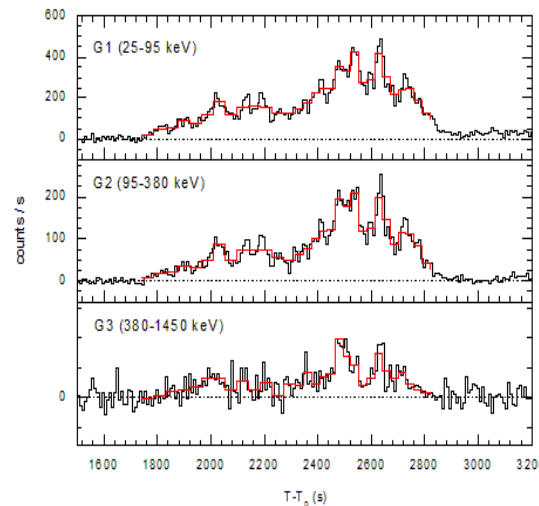
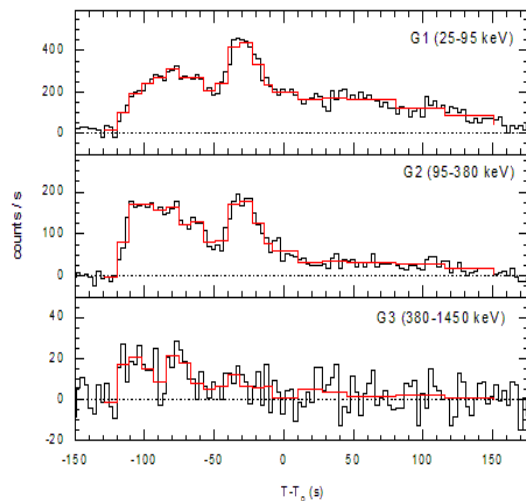


# GRB 130925A- prompt Ic overview



- Weak, soft precursor,  $dT < 10$  s from  $\sim T_0 - 900$  s, triggered GBM
- 1<sup>st</sup> major episode,  $dT \sim 300$  s from  $\sim T_0 - 130$  s, triggered GBM and BAT
- 2<sup>nd</sup> major episode,  $dT \sim 1200$  s from  $\sim T_0 + 1750$  s, was seen by KW and SPI-ACS only
- 3<sup>rd</sup> major episode,  $dT \sim 650$  s from  $\sim T_0 + 3730$  s, KW + SPI-ACS + GBM
- Weak inter-pulse emission

# GRB 130925A- two major episodes



- 1<sup>st</sup> episode (~300 s):
  - resembles typical long GRB
  - apparent hard-to-soft evolution from burst onset to  $\sim T_0(\text{BAT})$
  - spectral lag
    - $\tau^*_{G2-G1} = 4.6 \pm 0.6 \text{ s} (!)$
- 2<sup>nd</sup> episode (~1200 s):
  - less prominent evolution, a hint of HIC
  - $\tau_{G2-G1} = (0.5 \pm 0.5) \text{ s}$

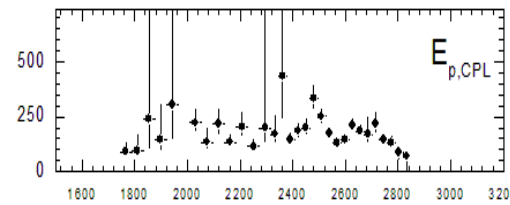
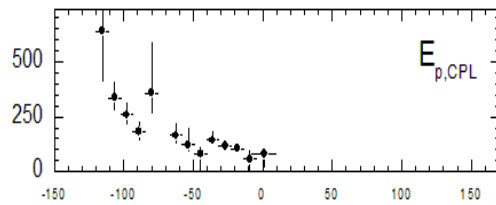
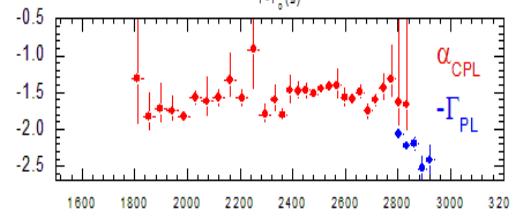
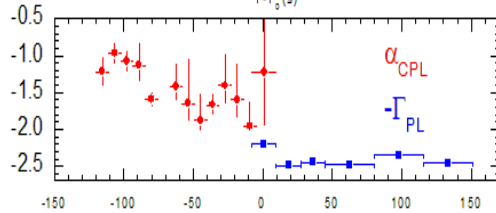
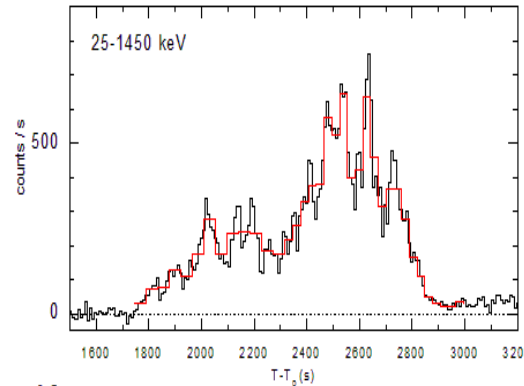
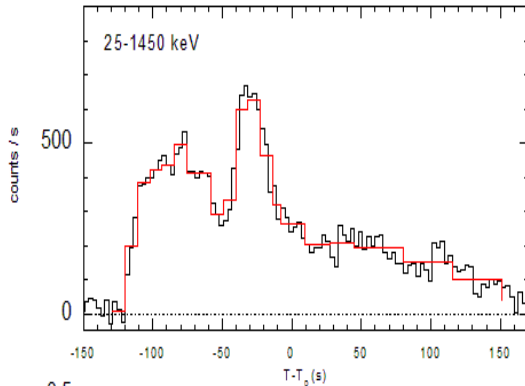
\*CCF analysis (Norris+2000)

# Spectral analysis of KW 3-channel data

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- Background-subtracted count rates in the (G1, G2, G3) bands form a continuous, 3-channel spectrum in the 20–1450 keV range
  - Counts are grouped in the time domain and the spectral analysis is performed with XSPEC and/or KW-specific software using a 3-channel DRM
  - Spectral models with up to 3 parameters (incl. norm.) can be tested: e.g. PL (1 d.o.f.), cutoff PL, Band func. with fixed parameter (e.g. beta) etc.
  - Parameter errors (conf. ranges) are estimated from M-C simulations (bootstrap)
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# GRB 130925A- time-resolved spectral analysis



- Precursor - PL,  $\Gamma \approx 2.7$
- 1<sup>st</sup> episode:
  - decaying  $E_{\text{peak}}$
  - evolves to PL,  $\Gamma \approx 2.5$
- 2<sup>nd</sup> episode:
  - less prominent evolution
  - $E_{\text{peak}} \sim 100\text{-}250$  keV
  - evolves to PL,  $\Gamma \approx 2.5$

$F_{\text{max}} = (1.2 \pm 0.3) \times 10^{-6} \text{ erg cm}^{-2} \text{ s}^{-1}$   
 @T0(BAT)+2550 s  
 20 keV – 10 MeV

# GRB 130925A - time-averaged spectra and fluence

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Episode	Model	Photon index	$E_{\text{peak}}$ (keV)	Fluence* (erg cm <sup>-2</sup> )
Precursor	PL	-2.7 (-0.5,+0.9)		$7.2(-2.5,+4.2)\times 10^{-7}$
1 <sup>st</sup>	CPL	-1.8 (-0.1,+0.1)	107 (-19,+17)	$(0.95 \pm 0.07)\times 10^{-4}$
2 <sup>nd</sup>	CPL	-1.59 (-0.05,+0.05)	179 (-11,+13)	$(3.9 \pm 0.1)\times 10^{-4}$
3 <sup>rd</sup>	CPL	-1.8 (-0.2,+0.4)	103 (-40,+22)	$(0.6 \pm 0.1)\times 10^{-4}$
Whole GRB	CPL	<b>-1.77 (-0.05,+0.05)</b>	<b>152 (-13,+12)</b>	<b><math>(6.2 \pm 0.3)\times 10^{-4}</math></b>

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\*20 keV–10 MeV band

# Prompt emission properties of KW u-long GRBs

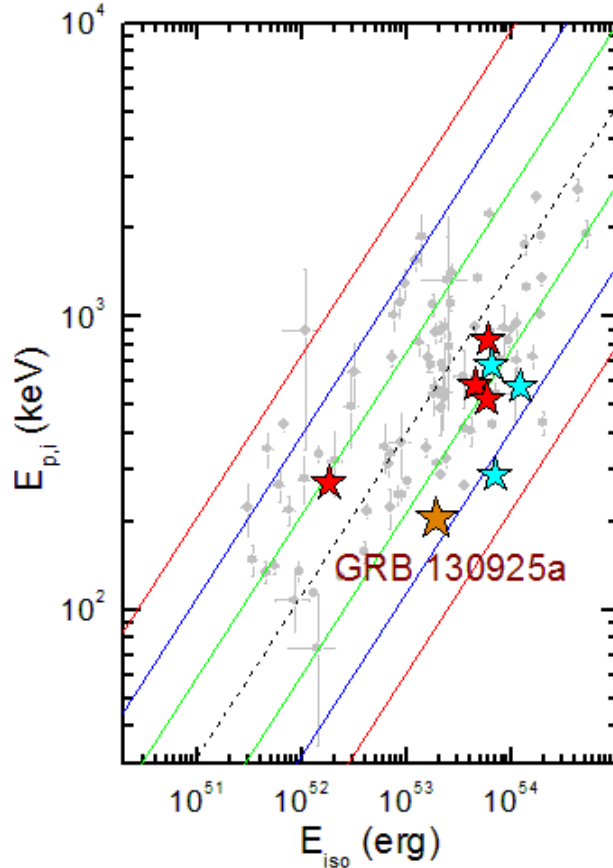
GRB	z	dT (s)	LC shape	E <sub>peak</sub> (keV)	Fluence (erg cm <sup>-2</sup> )	E <sub>iso</sub> (erg)
971208 <sup>a</sup>	--	~2500	FRED	~144	~2.6x10 <sup>-4</sup>	~6.9x10 <sup>53**</sup>
020410 <sup>b</sup>	~0.5 <sup>f</sup>	~1600	Multi-episode	~180	~2.8x10 <sup>-5</sup>	~1.8x10 <sup>52</sup>
060814B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

\* 1st pulse

\*\* at z=1

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

# GRB 130925A in the rest frame



- $z=0.347$
- $E_{iso} = (1.9 \pm 0.1) \times 10^{53}$  erg
- $L_{iso,peak} = (4.4 \pm 1.5) \times 10^{50}$  erg
- $E_{peak,i} = (205 \pm 17)$  keV

# Concluding remarks

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- KW provides an excellent opportunity to observe prompt emission of u-long GRBs for their whole duration
- The recent, 5000 s long, low-redshift GRB 130925A is the most fluent u-long GRB observed so far
- With the exception of their duration, the KW u-long GRBs look not much different from “regular” KW-detected long GRBs

Please welcome Jochen's and Phill's talks on GRB 130925A, which also incorporate the KW observation

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