Non-homogeneities in gamma-ray bursts afterglow light curves

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We discuss the non-homogeneous behavior of GRB afterglow light curves in optical range. By the non-homogeneous behavior we mean flashes, slow deviations from power law, bumps and wiggles in the light curve. We use several well sampled light curves of GRB afterglows. In particular we describe phenomenology, compare optical light curves with X-ray ones obtained by XRT/Swift and classify the non-homogeneities.

1. Synchronous Gamma-ray Burst Counterparts Observations

The light curves in **Fig.1-5** are observations by ground based optical and X-ray space telescopes.

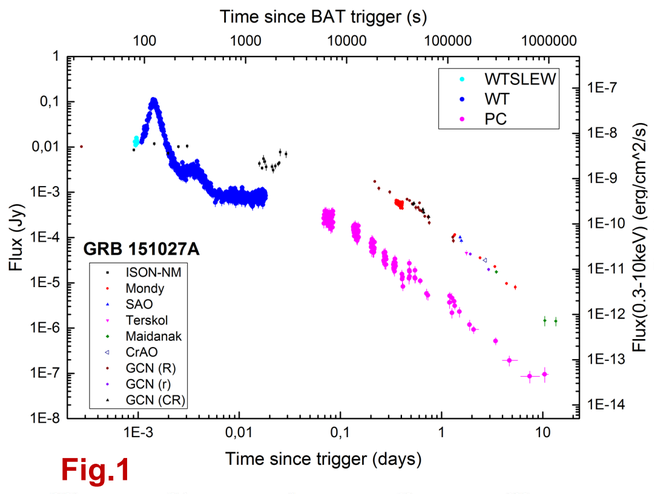

Fig.1

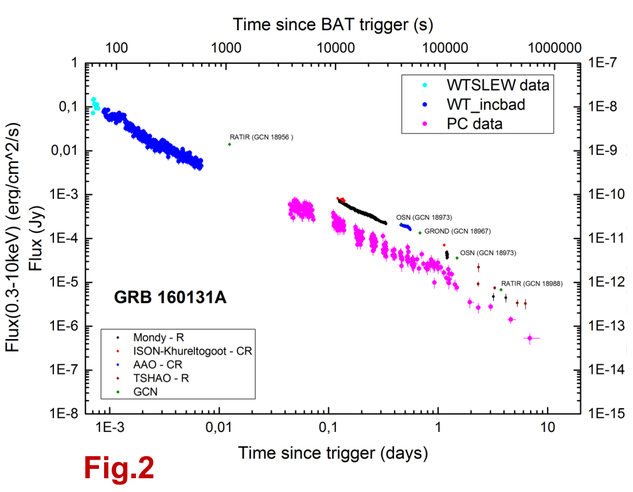

Fig.2

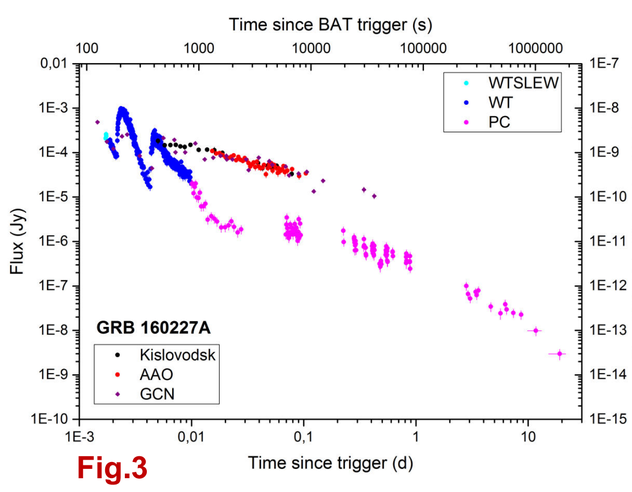

Fig.3

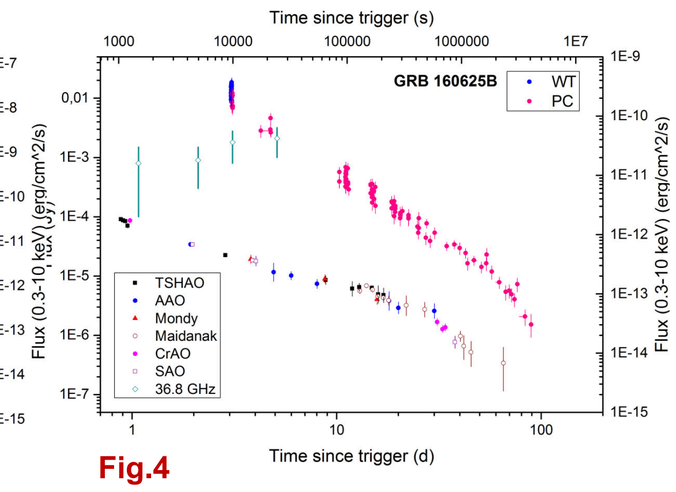

Fig.4

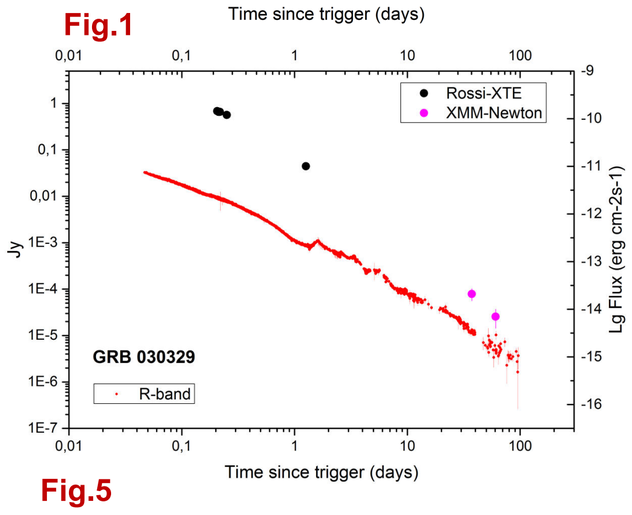

Fig.5

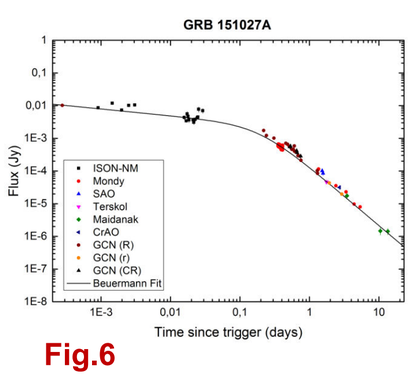

Fig.6

$$F = F_0 \left[\left(\frac{t}{t_b}\right)^{\alpha_1 w} + \left(\frac{t}{t_b}\right)^{\alpha_2 w} \right]^{-1/w} \quad (1)$$

2. Extraction of non-homogeneities

Light curves described by a broken power-law decay (for example **Fig.6**, broken power-law function is **(1)**). The optical light curves reveal a array of variations, superposed over the mean power-law decay. The variations were approximated by polynomials from 3 to 9 degrees (in more detail see **Table.1**).

Table 1. Non-homogeneities in gamma-ray bursts afterglow light curves

GRB	Tmax-t0 (days)	FWHM (days)	Amplitude (Jy)	Delta (mag)	%	Shape	X-ray and optical variations correlation?	Type	Fig. #
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
030329	0.08826	0.03242	3.954E-04	0.02	2.0	poly9	no data	Wiggles	8
030329	0.14657	0.04640	-3.200E-04	-0.03	-2.6	poly9	no data	Wiggles	8
030329	0.23522	0.08627	2.123E-04	0.03	2.6	poly9	no data	Wiggles	8
030329	1.60190	0.24504	2.700E-04	0.32	33.7	poly9	no data	n/d	13
030329	2.62084	0.14206	1.111E-04	0.21	21.8	poly9	no data	n/d	-
030329	3.39444	0.41709	1.358E-04	0.35	38.0	poly9	no data	n/d	-
030329	3.61772	0.33584	9.724E-05	0.28	29.8	poly5	no data	n/d	-
030329	5.67352	1.15475	8.522E-05	0.45	51.2	poly9	no data	n/d	-
030329	8.79820	0.41162	1.292E-05	0.15	15.0	poly5	no data	n/d	-
030329	9.76593	0.37217	1.829E-05	0.24	24.9	poly3	no data	n/d	-
030329	10.76485	0.91008	1.590E-05	0.24	25.1	poly5	no data	n/d	-
030329	11.72378	0.65981	1.145E-05	0.20	20.5	poly5	no data	n/d	-
030329	12.58917	0.41100	1.332E-05	0.26	26.6	poly5	no data	n/d	-
151027A	0.5369	0.22988	2.17E-04	0.53	62.6	poly5	yes	Flare	7.1
151027A	2.66541	1.41120	9.51E-06	0.38	41.8	poly3	yes	Flare	7.2
160131A	0.16648	0.04802	-1.756E-05	-0.04	-3.5	poly4	no	Wiggles	9
160131A	0.24792	0.05253	8.993E-06	0.03	2.9	poly4	no	Wiggles	9
160131A	0.16764	0.01142	1.097E-05	0.03	2.3	poly3	no	n/d	12
160131A	0.52016	?(>0.05)	5.774E-05	0.13	12.3	poly3	no	Bump	11
160227A	0.00190	0.00078	-2.153E-04	-1.06	-62.2	poly3	yes	Flare	7.3
160227A	0.00397	0.00145	-2.079E-04	-3.12	-94.4	poly4	yes	Flare	7.4
160625B	14.44238	2.19765	1.395E-06	0.26	27.5	poly3	no	Bump	10

3. Classification

We extracted non-homogeneities superposed over the mean power-law decay. Some possible classification of the non-homogeneities is following. Optical variations coincide in time with flare in X-rays are named as ‘flares’, e.g. **Fig.7**. Wave-like variations with small amplitude (several millimags) of the early afterglow (up to ~ 0.5 days since GRB trigger) can be detected in a dense photometric data (‘wiggles’, see **Fig.8-9**). Variations with a positive residual, and probably asynchronous with the pulses of X-rays, we classified as the ’bumps’. The remaining variations are named as "non-classified“. Variance characteristics are indicated in **Table 1** and **Fig. 14-15**.

3.1 Flares

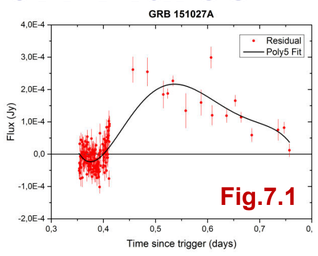

Fig.7.1

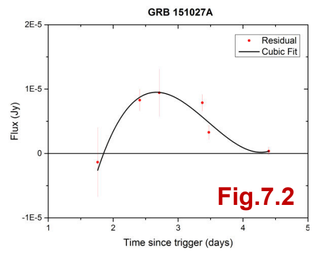

Fig.7.2

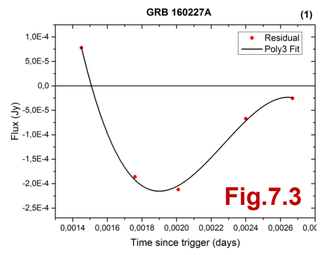

Fig.7.3

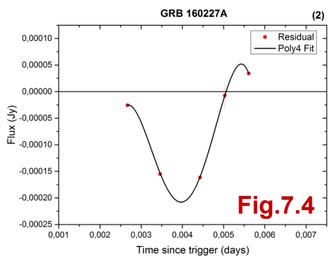

Fig.7.4

Fig.7

3.2 Wiggles

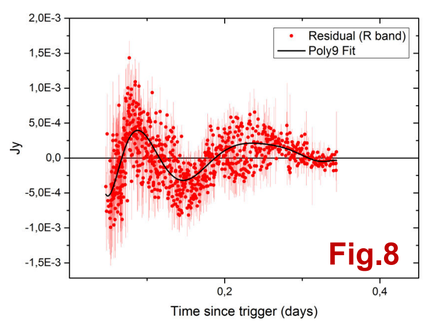

Fig.8

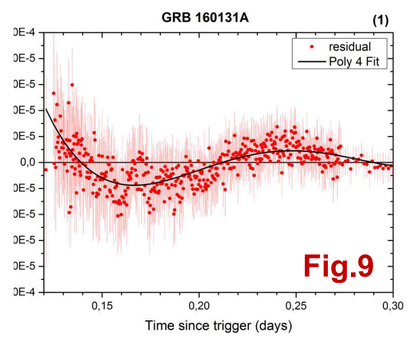

Fig.9

FWHM of the wiggle features (**Fig.8-9**) increases with time for each next episode (see **Table.1**).

3.3 Bumps

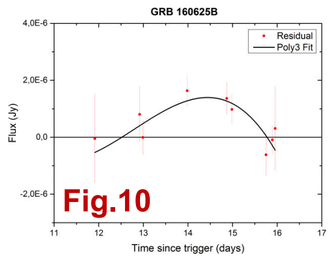

Fig.10

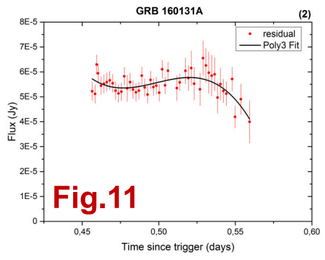

Fig.11

3.4 Non-classified features

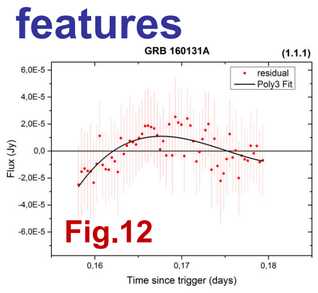

Fig.12

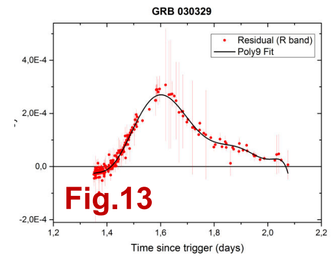

Fig.13

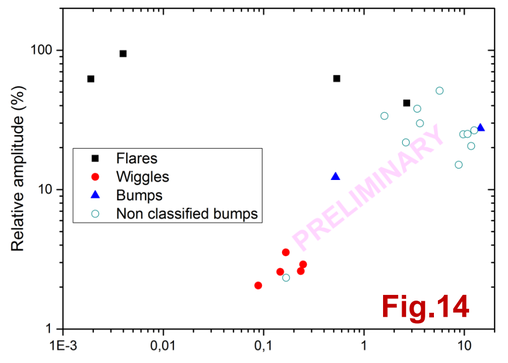

Fig.14

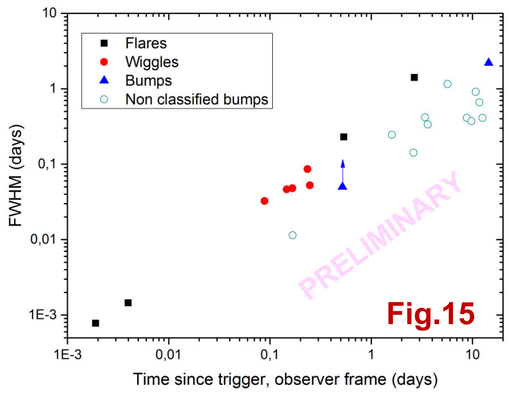

Fig.15

References

GCN: 18485 18491 18495 18503 18503 18513 18515 18515 18518 18518 18519 18521 18521 18537 18537 18567 18567 18567 18567 18567 18567 18567 18567 18609 18609 18609 19116; Lipkin et al. (2004), Beuermann et al. (1999)