

Search for fast optical activity of SGR 1806-20 at the SAO RAS 6-m telescope

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Received: 18 July 2006 / Accepted: 29 October 2006 / Published online: 20 March 2007
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Abstract The region of SGR 1806-20 localization was observed during its gamma-ray activity in 2001. The observations have been performed on the 6-meter telescope of the Special Astrophysical Observatory, using the Panoramic Photometer-Polarimeter (PPP). The search for variability was performed on the 10^{-6} –10 s time scale, and its results were compared to the properties of corresponding X-ray flares.

Keywords Methods: data analysis · Objects: SGR 1806-20

PACS 95.75.-z · 95.75.Wx · 95.85.Kr · 97.60.Jd

1 Introduction

There is now increasing evidence that the soft repeater SGR 1806-20 hosts a magnetar, i.e. a neutron star with an anomalously high magnetic field $B > 10^{14}$ Gs (Duncan and Thompson 1992; Woods and Thompson 2004). The SGR 1806-20 is the most active among soft gamma repeaters and is characterized by the emission of short sporadic flashes of soft gamma rays with characteristic durations of 10 ms–1 s and luminosities of 10^{39} – 10^{42} erg/s.

(Gogus et al. 2001; Hurley 2000). They are detected during sporadic periods of the object's activity lasting from days to months. Pulsations of the persistent X-ray flux of SGR 1806-20 with a period of 7.47 s were discovered (Kouveliotou 1998). The culmination of the long period of its activity that started in the end of 2003 was a giant flare of 27th December 2004 (Borkowski et al. 2004; Mazets et al. 2004; Golenetskii et al. 2004). During the main spike that lasted 0.2–0.5 s, about 10^{47} ergs above 50 keV was emitted for a distance of 15 kpc (Palmer et al. 2004; Mereghetti et al. 2005; Schwartz et al. 2005; Terasawa et al. 2005). The long part of the flare showed a pulsation with the period of 7.57 s during about 300 s (Borkowski et al. 2004).

Unfortunately, even the minimal estimation of the distance to SGR 1806-20 is 6 kpc (while the most reasonable one is 15 kpc), and the absorption reaches $A_V \sim 30$ m (Eikenberry et al. 2004; McClure-Griffiths and Gaensler 2005), so there is not much hope of detecting its optical emission, even though its infrared counterpart seems to have been found, with a magnitude of $K = 21.6$ m (Israel et al. 2005).

However, we have carried out a set of observations of the location of SGR 1806-20 in the optical band with 1 μ s temporal resolution to try to detect very short and strong optical spikes. The epoch of the observations has been chosen in relation to the increase of γ -ray activity of the source, according to HETE data (Ricker et al. 2001a, 2001b).

We have reported the preliminary results of our monitoring in earlier papers (Beskin et al. 2001, 2003). In the present work we describe the process of observation, the equipment, and we present a more detailed analysis of the acquired data.

This work has been supported by the Russian Foundation for Basic Research (grant No 04-02-17555), Russian Academy of Sciences (program "Evolution of Stars and Galaxies"), and by the Russian Science Support Foundation. The authors would also like to thank the anonymous referee for his/her valuable comments.

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2 Observations, hardware and software

The field of SRG 1806-20 has been observed using the 6-meter telescope of the Special Astrophysical Observatory. Observations were carried out with Panoramic Photometer-Polarimeter (PPP) with high time resolution (Plokhotnichenko et al. 2003) in the telescope prime focus on June 20 2001 (2 days after HETE trigger), and on August 22 2001 (15 hours after HETE trigger) (Ricker et al. 2001a, 2001b).

The main part of PPP is the Positional Sensitive Detector (PSD), which consists of a vacuum tube with a standard S20 photocathode, a set of microchannel plates and a four-electrode anode. The pixel size of the detector is $0''.21$, the FOV is a circle of about $1'.5$, and the time resolution (dead time) is $1 \mu s$ (Debur et al. 2003).

For the determination of the photon arrival times and coordinates, and for the storage of the whole data set, a special “time-code” converter “Quantochron 4-48” connected to the PC in realtime has been used. The information on the observations is summarized in Table 1.

The search for variability has been performed in the region centered on the IPN localization of the source (Hurley et al. 1999). The statistical properties of the photon lists have been studied separately for 9 square boxes with the size of $6''.5$ covering the localization region (see Fig. 1).

As an indicator of the variability we used the function y_2 , defined as the ratio between the distributions of the photon arrival time intervals for the source and background (Schvartsman 1977). It is:

$$y_2(\tau) = \frac{P_s(\tau) - P_b(\tau)}{P_b(\tau)}, \tag{1}$$

where τ is the interval between the times of arrival of successive photons, while $P_s(\tau)$ and $P_b(\tau)$ are the distribution functions of τ for the source and background boxes, respectively.

We used the following definitions and relations: $I(t)$ —intensity variation during the flare and its mean value:

$$\langle I \rangle = \frac{1}{\langle \tau \rangle} = \frac{1}{T} \left[I_0 + \int_0^T I(t) dt \right], \tag{2}$$

where τ is the mean interval between the arrival times of successive photons, T —mean time between the flares and I_0 —persistent emission intensity; I_{\max} —maximum intensity of the flare; characteristic time scale of the variability:

$$\tau_{\text{var}} = \frac{1}{I_{\max}} \int_0^T I(t) dt; \tag{3}$$

relative amplitude of the intensity variations $A \equiv \frac{I_{\max}}{\langle I \rangle}$, and relative power of the variable emission component

$$S = \frac{1}{\langle I \rangle T} \int_0^T I(t) dt = \frac{I_{\max} \tau_{\text{var}}}{\langle I \rangle T} = FA, \tag{4}$$

where $F = \tau_{\text{var}}/T$ —the flares duty cycle.

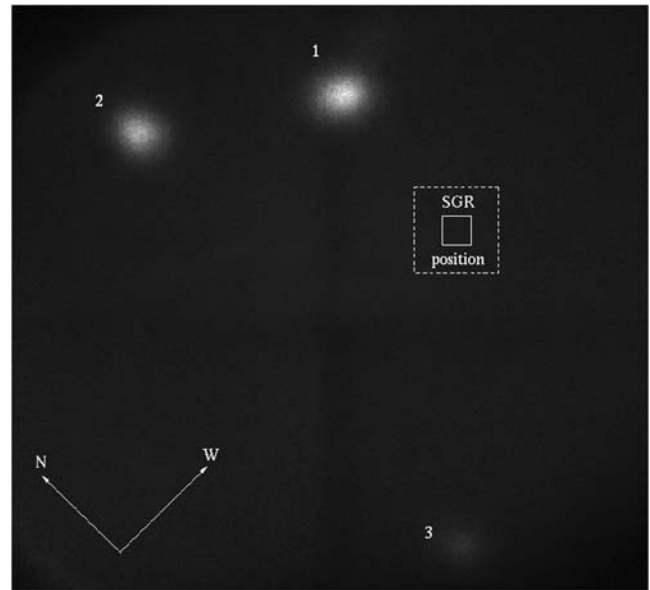


Fig. 1 Observed field of SGR 1806-20. Numbered stars are listed in Table 2

The function y_2 is related to the variability parameters defined above (Schvartsman 1977) as

$$y_2(\tau \ll \langle \tau \rangle, \tau_{\text{var}}) \approx \frac{kS^2}{F}. \tag{5}$$

where $k = \frac{1}{\langle I \rangle T} \int_0^T I^2(t) dt$ —flare shape coefficient. For example, sinusoidal flares have $k = 0.25$, triangular ones have $k = \frac{2}{3} - 2\beta + 2\beta^2 \approx 0.2-0.7$.

From the registered photon lists it is easy to compute $y_2(\tau)$, from which S follows:

$$S(\tau) \approx \sqrt{\frac{y_2(\tau)F}{k}}. \tag{6}$$

The absence of variability is rejected if $S(\tau) > 3\sigma_S(\tau)$, where

$$\sigma_S(\tau) = \left(\frac{1}{P_b(\tau)N} \right)^{\frac{1}{4}}, \tag{7}$$

and N is the number of photons detected (Plokhotnichenko 1992, 1983).

3 Results of observations

Using the arrival times of 10^6 photons, detected in each sub-box of the SGR 1806-20 localization, the distribution function of intervals between the following photons has been built. The mean background intensity has been 152 counts/s with nearly Poissonian statistics.

Table 1 Observations details

Date	Start time (UT)	Exposure time (s)	Zenith distance	Filter
20.06.2001	19 ^h 58 ^m	4544.6	67.°1	B
22.08.2001	20 ^h 31 ^m	800.33	77.°7	B

Table 2 USNO-A2.0 stars in the field of SGR 1806-20

N	R.A. J2000*	DEC. J2000	Bmag	Rmag
1	18 ^h 08 ^m 39. ^s 42	−20°24′11.″74	14.6	13.7
2	18 ^h 08 ^m 41. ^s 13	−20°24′02.″29	15.5	14.6
3	18 ^h 08 ^m 41. ^s 47	−20°25′12.″61	16.5	15.9

*Monet D.G., 1998, BAAS 30, Vol. 4, 120.03

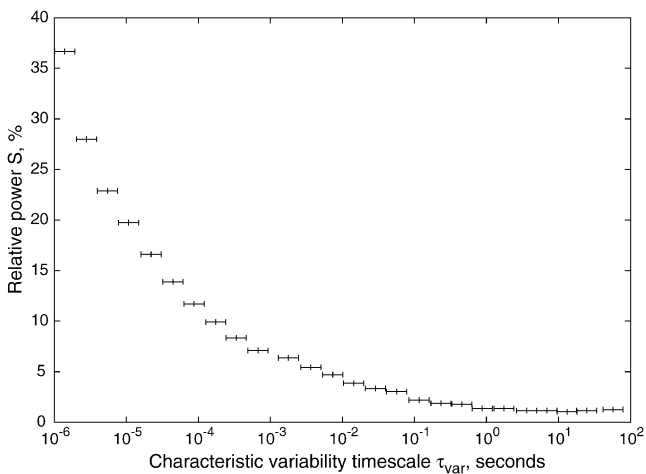
**Fig. 2** Upper limits for the relative power of the variable emission

Figure 2 shows the upper limits for the relative power S of the variable emission component derived using (1–7). The model of triangular flares with the duty cycle of 0.1 was used.

We used the information on flares detected in gamma and X-ray bands (see, for example, Woods and Thompson 2004 and Götz et al. 2006).

For the photometric calibration, the stars listed in Table 2 have been used.

So, the upper limits for flashes with the duration of $\sim 10^{-2}$ s (similar to the parameters of γ -ray flashes) will be about 20 m. For very rare flashes with the duty cycle of 10^{-4} , the upper limits will be thirty times better—we should be able to detect events of 23–24 m.

Unfortunately, even having good upper limits for the variable optical component, due to huge absorption it is impossible to derive a reasonable estimate of the luminosity. Assuming $A_V \sim 20$ m and a distance of 6 to 15 kpc (Eikenberry et al. 2004; McClure-Griffiths and Gaensler 2005), we have for the upper limits of flaring optical luminosity of SGR 1806-20 values ranging from 7×10^{46} erg/s to 4×10^{47} erg/s. These values are similar to the peak luminosity of the object in the γ -ray band, i.e. to the values registered during the giant flare. This means that very short and very rare “giant optical flares” could be detected.

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