BVR_cI_c photometry of GRB970508 optical remnant: May-August, 1997

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Abstract. We present the results of photometric observations of the variable optical source associated to the remnant of the gamma-ray burst GRB970508 performed at the Special Astrophysical Observatory of the Russian Academy of Science (SAO RAS) from May to August 1997. The observations were carried out with the standard (Johnson-Kron-Cousins) photometric BVR_cI_c system using the 1-meter and 6-meter telescopes. The brightness of the optical source increased from R_c = 21.19 ± 0.25 (May 9.75 UT) to R_c = 19.70 ± 0.03 (May 10.77 UT), whereupon it was decaying in all the four BV R_cI_c bands during about one month after the burst. Between the 3rd and the 6th night after the GRB970508 event, the flux decrease of the optical source follows an exponential law in all the four bands. In that period the broad-band spectrum of the object does not change and can be approximately described by the power law F_ν ∝ ν^{-1.1}. The subsequent observations in BVR_cI_c bands have shown a reduction of the source brightness decrease rate. The source flux decay after the maximum in the R_c band is well described by a single power-law F ∝ t^{-1.171(±0.012)} for the whole set of observations during 86 days. In the other bands the decay seems to slow down from the 31th day onwards. In particular, in the I_c band the source magnitude is about 23.1 from the 36th day after the GRB to the end of the observations (August 4, 1997).

Key words: gamma-rays: bursters – optical transients, CCD photometry

1. Introduction.

Since their discovery in 1969 (Klebesadel et al. 1973) the gamma-ray bursts (GRBs) phenomenon is the subject of intensive observational and theoretical studies. The basic problem before 1997 was the lack of reliable counterparts to the sources of GRB (in quiet or transient state) in wave bands other than gamma-rays and, as a consequence, the total uncertainty of their distance. The situation changed after the Gamma-Ray Burst of February 28, 1997, GRB970228 (Costa et al. 1997a) detected by the Italian-Dutch satellite BeppoSAX (Boella et al. 1997). Thank to the fast and accurate positioning of GRBs (a few arcminutes) obtainable through the combined capabilities of the Gamma-Ray Burst Monitor (GRBM) and Wide Field Cameras (WFCs) onboard this satellite, an X-ray and optical afterglow were observed for the very first time (Costa et al. 1997b, van Paradijs et al., 1997).

However, as was found out later, the optical data on the first GRB afterglow in the history were obtained with different instruments and in different photometric conditions and refer to different photometric systems and bands. The source brightness in different filters was determined at different times and besides, only a few reliable brightness determinations (not upper limits) have been gained while the object was bright enough. In the end, it led to the uncertainty in the interpretation of optical observations (see for example Sahnu et al. 1997, Galama et al. 1997 and the Proceedings of the 4th Huntsville GRB Symposium). But at least, one thing became clear after GRB970228: the optical source – a gamma-ray burst remnant (GRBR) – can be observed during rather a long period, from one to several days, in sufficiently bright phase, with the brightness of V < 23.

By the end 1997, the optical afterglow of GRBs was reliably detected in 3 cases: GRB970228, GRB970508, GRB971214. While the first and third optical transient sources (OTs) were not observed at SAO RAS close to their maximum brightness, for the second OT, related to GRB970508 reported by the BeppoSAX team (Costa et al. 1997b; Piro et al. 1998) essential optical data helping to elucidate common observational signs of optical...
GRBRs have been obtained at SAO with the 1-m and 6-m telescopes. The second GRB with an optical afterglow was in a very favorable place in the northern sky (in the Camelopardalis constellation). The high declination of around +79° allows us to observe this object at SAO at all dates being at a zenith distance of less than 57°.

Preliminary results of multi-color photometry of the GRB970508 optical remnant were reported elsewhere (Sokolov et al. 1997). In this paper we report the results of $BVRcIc$ photometry from May to August 1997 discussing the correlation between the features of the optical light curves and those observed at other wavelengths. The second section deals with the search and detection of this optical source with the SAO telescopes and describes the $BVRcIc$ photometry with the 1-m and 6-m telescopes. The third section is dedicated to the results of CCD photometry in the phase of the source brightness maximum and to the following brightness fading in different filters up to the 87th day after the burst. The fourth section is dedicated to the discussion of the results and to the comparison of the optical light curves with those in X-ray and radio.

2. GRB970508 optical counterpart search.

The alert of a new GRB detection by BeppoSAX reached SAO only 3.5 hours after the high energy event (May 8.904 UT). Due to morning twilight, follow-up observations could start at the 1-m telescope on May 9.74 UT. The 5′ WFC error box was completely covered with the CCD mosaic of 29 images in $Rc$ band with 300 and 600 sec exposure times. The 1-m (Zeiss-1000) telescope is equipped with a CCD photometer ISD015A, $520 \times 580$ pixels corresponding to the field of view $2.0'' \times 3.7$'. The images from the 1-m telescope were compared to the corresponding fields of the Digitized Sky Survey (DSS). No new bright object was found up to the DSS limit for this field.

On the next night, May 10/11, a refined WFC error circle position was available: $\alpha_{2000} = 06^h53^m28.3^s$; $\delta_{2000} = +79^\circ17.4'$ with a 3′ error radius (99% confidence level). Photometric observations of GRB970508 field were then continued with the 6-m telescope. The 1040 × 1160 pixel CCD chip “Electron ISD017A” installed at the Primary Focus has a field of view of 2.′38 × 2.′66. A 2 × 2 binning mode was employed, so that each of the $520 \times 580$ zoomed pixels has angular size of 0.′′274 × 0.′′274. The gain is $2.3e^-$ per DN (Data Number). The readout noise is about 10$e^-$.

The first image at the 6-m telescope was obtained on May 10.76 UT and a variable object was discovered by comparison with the image taken the night before. Its brightness, from May 9.85 UT to May 10.76 UT, increased of about 1.5 magnitudes. This object was first reported by Bond (1997) as a possible optical counterpart of GRB970508 and was independently found in our data only about 0.5 day later. The summary of the observations carried out at SAO during the first week after the GRB is reported in Table 1. The exposure times in seconds are shown for each filters.

| night  | UT (May) | telescope | $B$ (s) | $V$ (s) | $Rc$ (s) | $Ic$ (s) |
|--------|----------|-----------|--------|--------|---------|---------|
| 09/10  | 09.75    | 1-m       | 300    |        |         |         |
| -      | 09.85    | -         |        |        | 600     |         |
| 10/11  | 10.77    | 6-m       | 300    | 200    | 100     | 300     |
| -      | 10.93    | -         | 300    | 200    | 100     | 300     |
| 11/12  | 11.76    | -         | 450    | 300    | 150     | 450     |
| 12/13  | 12.87    | -         | 450    | 600    | 150     | 900     |
| 13/14  | 13.88    | -         | 1200   | 600    | 450     | 450     |

Table 1. First week observations of GRB970508 optical remnant.

Table 2. Secondary photometric standards in the OT GRB970508 field.

| #    | $\alpha_{2000}$ | $\delta_{2000}$ | $B$ | $V$ | $Rc$ | $Ic$ |
|------|-----------------|-----------------|-----|-----|------|------|
| 1    | 06:53:37.19     | 79:17:30.7      | 20.44 | 19.14 | 18.31 | 17.53 |
| 2    | 06:53:36.31     | 79:15:30.3      | 19.93 | 19.17 | 18.71 | 18.27 |
| 3    | 06:53:39.23     | 79:15:21.1      | 17.94 | 17.40 | 17.06 | 16.71 |
| 4    | 06:53:48.50     | 79:16:32.7      | 21.93 | 20.43 | 19.49 | 18.53 |

Observations were carried out with filters closely matching the $BVRcIc$ Johnson-Kron-Cousins system. The data were processed using the ESO-MIDAS software. Standard data reduction includes bias subtraction, flat-fielding and cosmic particle traces removal. Photometric conditions remained stable during two nights of May 13/14 and May 21/22.

Four bright stars (Fig. 1) in the GRB970508 field were used as secondary photometric standards. Magnitudes of these stars were determined on the night of May 13/14 with good photometric conditions using four standard stars in the field of PG1657+078 (Landolt, 1992). Zero-point errors are better than 0.05m. Coordinates and magnitudes of secondary photometric standards are given in Table 2. Our $Rc$ magnitudes of stars 2, 3, 4 are 0.20 ± 0.01 higher than the magnitudes measured by Schaefer et al. (1997). The application of the analogous photometric procedure in $BVRcIc$ Johnson-Kron-Cousins system, used at SAO RAS, is given in details in the paper by Kurt et al. (1998).
3. The brightness maximum phase and following source fading

We define as source brightness maximum phase the period when the optical object brightness increased to the maximum (or close to the maximum) and then began to drop down to $V \approx 21.5$ and $R_c \approx 21.1$. It corresponds approximately to the first week of observations after the GRB when the optical source could still be observed with many telescopes - big and medium ones. The results of the observations performed during these nights at SAO together with those from Palomar and Loiano are shown in Fig. 2. Many more observations other than those from Palomar and Loiano were performed, but the different photometric systems used and relatively smaller accuracy of the measurements do not allow a better evaluation of the OT behavior.

Johnson-Kron-Cousins magnitudes in the $BVR_cI_c$ bands with the associated errors for GRB970508 optical counterpart are given in Table 3. Given the BeppoSAX/GRBM trigger time $t_0 = \text{May 8.904 UT}$, we note (see Fig. 2):

1) from $t - t_0 = 0.226$ to $t - t_0 = 0.944$ the $R_c$ brightness of the object seems to remain constant (Castro-Tirado et al. 1997; Djorgovski et al. 1997);

2) from $t - t_0 = 0.944$ to $t - t_0 = 1.866$ the $R_c$ brightness increased of 1.5 mag. The magnitude increase rate using our 1-m data and the data from Palomar (Djorgovski et al. 1997) was about 0.12 mag per hour;

3) at $t - t_0 = 1.866$ the $R_c$ magnitude reached the brightness maximum of 19.70 and from that date a decline of brightness began;

4) the magnitude decrease during the beginning (2–5 days) of the fading phase follows an exponential law in all four bands:

$$
B = 19.689(\pm 0.036) + 0.452(\pm 0.014)(t - t_0)
$$
$$
V = 19.264(\pm 0.053) + 0.449(\pm 0.020)(t - t_0)
$$
$$
R_c = 18.874(\pm 0.029) + 0.443(\pm 0.011)(t - t_0)
$$
$$
I_c = 18.355(\pm 0.050) + 0.450(\pm 0.019)(t - t_0)
$$

A power law did not fit the data for the brightness fading after the maximum. For example for the $R_c$ data it is $\chi^2_n = 0.97$ for the exponential fit while it is $\chi^2_n = 4.5$ for the power law. All the $R_c$ data from $t - t_0 = 1.866$
Fig. 2. The light curves of GRB970508 optical counterpart during 5 days after the burst. SAO RAS (filled symbols), Loiano (Mignoli M. et al. 1997, $t - t_0 = 1.95$) and Palomar (Djorgovski et al. 1997, transformed to $R_c = r - 0.34 + A_r$) (open triangles) magnitudes with their errors are shown. Lines correspond to equations (1) of exponential decline of brightness reported in the text. For $R_c$ also the best fit power law is shown (dotted line).

$$
\begin{align*}
\alpha_B &= -1.200(\pm 0.019) \\
\alpha_V &= -1.144(\pm 0.018) \\
\alpha_{R_c} &= -1.171(\pm 0.012) \\
\alpha_{I_c} &= -1.184(\pm 0.026),
\end{align*}
$$

neglecting the fact that for the first 5 days the light curve decay is better described by the exponential law in all the 4 bands. Figure 3 shows this averaged power-law light curve for the $R_c$ band up to about 84 days ($t - t_0 = 83.940$) after the burst.

Starting from the $\approx 36$th day after the burst, the object did not show the further fall of the brightness in the $I_c$ filter up to $t - t_0 = 87.085$. The magnitude of the object in the $I_c$ filter in that period was stable around $I_c = 23.07$.

Figure 4a shows the light curves in the $BVRcI_c$ bands up to day 87.085.

4. Discussion. Comparison of optical, X-ray and radio brightness curves

The data obtained with the SAO RAS 1-m and 6-m telescopes allow us to divide the GRB970508 brightness change curve into three stages (Fig. 2, 4 and Table 3):

1) the increase of brightness on time scale of about one day;
2) the exponential brightness fall during about 4 days with

$$
\begin{align*}
B &= 19.713(\pm 0.139) + 3.000(\pm 0.048) \times \log(t - t_0) \\
V &= 19.323(\pm 0.135) + 2.860(\pm 0.046) \times \log(t - t_0) \\
R_c &= 18.865(\pm 0.092) + 2.927(\pm 0.031) \times \log(t - t_0) \\
I_c &= 18.313(\pm 0.151) + 2.961(\pm 0.066) \times \log(t - t_0)
\end{align*}
$$

with

$$
\begin{align*}
\alpha_B &= -1.200(\pm 0.019) \\
\alpha_V &= -1.144(\pm 0.018) \\
\alpha_{R_c} &= -1.171(\pm 0.012) \\
\alpha_{I_c} &= -1.184(\pm 0.026),
\end{align*}
$$

and the following color indeces:

$$
(B - V) = 0.43, \quad (V - R_c) = 0.39, \quad (R_c - I_c) = 0.52
$$

After the 5th day the decline of brightness is slowed down. In the $BVRc$ bands during about 85th day and $I_c$ band until the $\approx 36$th day, the light curve can be described by a power-law relation,

$$
\begin{align*}
B &= 19.713(\pm 0.139) + 3.000(\pm 0.048) \times \log(t - t_0) \\
V &= 19.323(\pm 0.135) + 2.860(\pm 0.046) \times \log(t - t_0) \\
R_c &= 18.865(\pm 0.092) + 2.927(\pm 0.031) \times \log(t - t_0) \\
I_c &= 18.313(\pm 0.151) + 2.961(\pm 0.066) \times \log(t - t_0)
\end{align*}
$$

...
a stable broadband power-law spectrum;
3) the further brightness fading according to a power law. Nevertheless, from the 36th day after the burst the object did not show the further fall of the brightness in the $I_c$ filter. After 87 days, the deviation from the average power law (2) achieved already $\approx 1$ mag.

As Figure 3 shows, our observations with the 6-m telescope alone can be approximately described by a single law in the $R_c$ filter, but in the phase of brightness maximum (Fig. 2), when all fluxes were measured with the smallest errors, we see the same deviations from the “average” power law in all 4 bands. Garsia et al. (1997) also mention that the brightness fading after the maximum cannot be well described by a single power law.

As discussed by Piro et al. (1998), after about 30 seconds from the high energy event, the GRB970508 X-ray flux began to fall according to a power law with a slope of $-1.1 \pm 0.1$. Nevertheless, in about 16.6 hours after the GRB the flux decay showed a temporal behavior analogous to the optical one during the first hours after the GRB (Pedersen et al. 1998). (We did not observe at that time, but in the R band the optical flux was either stable or showed a slow decrease in the first 8 hours after the GRB.) The features of the optical curves immediately after the maximum (May 10.77 UT) correlate with those of the X-ray transient light curve (Piro et al. 1998).

In Figure 4 the SAO RAS $BVR_cI_c$ brightness curves are presented together with the radio at 8.46 GHz (Frail et al. 1997) and the X-ray (BeppoSAX NFIs, Piro et al. 1998). Apparently, the most interesting moment in this phase was the sharp fall of the X-ray flux and its subsequent fast increase which was observed in details in the BeppoSAX MECS range 2–10 keV, but unfortunately no simultaneous optical observations were performed. The subsequent optical brightness increase which was observed also at SAO (Fig. 2) began with a small ($\approx 5.5$ hours) delay. (Though now it can be supposed that before that moment there was a genuine optical brightness minimum missed by the observers.) Piro et al. (1998) notice that the following behavior of X-ray flux deviates from the power law. In the X-ray range this deviation, lasting about 4 days, took about 30% of the energy released in the “afterglow” part of the power-law drop. It is about 10% of the gamma-ray energy itself. During the same period the optical decay does not follow a power-law too, but the exponential one (Fig. 2 and 3). This is in favor of a common origin of the X-ray and optical events. Taking into account the ratio of X-ray to optical flux during the 4 days after the optical maximum, more than 16% of the energy of the GRB event itself was released in optical together with X-rays. Thus, it is believable indeed that the energy of the GRB remnant is not only determined by the afterglow, but there is also an intrinsic burst activity of the source which has an energy comparable to that of the burst in a time scale 10,000 times longer than the duration of the GRB itself.

When comparing the radio and optical behavior of the source (Frail et al. 1997; Taylor et al. 1997) after the brightness maximum phase, the attention is immediately drawn to the fact that the decrease of the “twinkling” am-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Fig3.png}
\caption{\textit{R}$_c$ light curve of the optical counterpart of GRB970508 during $\approx 86$ days after the burst. SAO RAS (filled marks) and Palomar (Djorgovski et al. 1997), Loiano (Mignoli et al. 1997), HST (Fruchter et al. 1997), Keck II (Metzger et al. 1997) (open squares, transformed from Schaefer’s photometric system to ours) magnitudes are shown. Lines correspond to power (up to $t - t_0 = 83.940$) and exponential law (dashed) for fading brightness.}
\end{figure}
Table 3. GRB970508 OT photometry results

| UT       | $t - t_0$ | B     | V     | $R_c$  | $I_c$  |
|----------|-----------|-------|-------|--------|--------|
| 9.75 May | 0.841     | 20.50 | 20.06 | 21.19  | ±0.25  |
| 9.85     | 0.944     | 20.26 | 20.22 | 21.13  | ±0.18  |
| 10.77    | 1.866     | 20.50 | 20.06 | 19.70  | ±0.03  |
| 10.93    | 2.026     | 20.60 | 20.22 | 19.80  | ±0.03  |
| 11.76    | 2.856     | 21.03 | 20.52 | 19.30  | ±0.03  |
| 12.87    | 3.966     | 21.48 | 21.10 | 19.58  | ±0.04  |
| 13.88    | 4.976     | 21.92 | 21.47 | 20.19  | ±0.06  |
| 20.795   | 11.891    | 21.92 | 21.47 | 20.58  | ±0.09  |
| 20.875   | 11.971    |       |       | 21.81  | ±0.10  |
| 20.970   | 12.066    |       |       | 21.27  | ±0.13  |
| 21.892   | 12.988    | 23.12 | 22.09 | ±0.07  |
| 21.908   | 13.004    |       | 22.18 | ±0.14  |
| 21.942   | 13.038    |       |       | 21.96  | ±0.13  |
| 07.917 Jun. | 30.085 |       |       | 23.66  | ±0.10  |
| 08.964   | 31.060    |       |       | 23.84  | ±0.24  |
| 08.980   | 31.075    |       |       | 23.54  | ±0.20  |
| 08.991   | 31.087    |       |       | 23.34  | ±0.22  |
| 10.928   | 33.024    |       |       | 24.08  | ±0.25  |
| 10.940   | 33.036    |       |       | 23.09  | ±0.35  |
| 10.945   | 33.041    |       |       | 23.09  | ±0.35  |
| 13.954   | 36.050    |       |       | 23.42  | ±0.14  |
| 13.966   | 36.061    |       |       | 23.30  | ±0.35  |
| 13.992   | 36.088    |       |       | 24.17  | ±0.16  |
| 27.865   | 49.961    |       |       | 23.88  | ±0.16  |
| 27.873   | 49.969    |       |       | 24.08  | ±0.20  |
| 27.893   | 49.980    |       |       | 24.08  | ±0.20  |
| 27.910   | 50.006    |       |       | 24.08  | ±0.20  |
| 07.946 Jul. | 60.042 |       |       | 24.08  | ±0.20  |
| 07.961   | 60.057    |       |       | 24.08  | ±0.20  |
| 31.843   | 83.940    |       |       | 24.54  | ±0.25  |
| 31.857   | 83.952    |       |       | 24.60  | ±0.24  |
| 31.862   | 83.958    |       |       | 23.08  | ±0.23  |
| 02.807 Aug. | 85.902 |       |       | 24.28  | ±0.35  |
| 02.825   | 85.920    |       |       | 24.28  | ±0.35  |
| 02.852   | 85.950    |       |       | 24.59  | ±0.25  |
| 03.989   | 87.085    |       |       | 25.32  | ±0.25  |

The amplitude of the point-like radio source begins approximately from the 35th day. The radio fluxes in 8.46 and 4.86 GHz VLA bands show the tendency to stabilization. The stabilization of the radio fluxes began approximately at the same time of the deceleration fading we see in the $I_c$ filter ($\approx 8000 \, \AA$). The “radio plateau” was lasting till about the 65th day after the GRB. Then the flux decreased at both frequencies to $\approx 0.4 \, \text{mJy}$ by the 87th day. (The flux in the 1.43 GHz band also approached the same value.) Thus, in spite of sharp flux variations in the beginning of observations, about one month after the burst the radio source considerably calms.

We note here that HST/NIMCOS flux measurements (Pian et al. 1998) in $H$ band gave $6.2 \pm 1.5 \, \mu\text{Jy}$, and not $3 \pm 1 \, \mu\text{Jy}$, as was expected for power-law brightness fading in ground-based $I$ and $K$ bands. It was necessary to extrapolate these data to the $H$ band assuming the same power-law spectrum slope which was observed in the brightness maximum phase (Metzger et al. 1997a; Sokolov et al. 1997). We note that the date of the HST observation and this deviation from the expected averaged power law in the HST/NIMCOS $H$ band are close to the beginning of the deviation from the power law decay in our $I_c$ band (Fig. 4) and to the “twinkling” amplitude decreasing date of the point-like radio source.

Pedersen et al. (1998) were the first to report about the deviation from the average power law. These authors find $R = 24.28 \pm 0.10$, 96 days after the high energy event, which gives a deviation from the power law decay of $\approx 0.6$ mag. From the HST observation (on June 2, 1997) we see that the object retained the point-like appearance with a possible contribution of an underlying “compact galaxy”
with FWHM = 0″.15 and with $R \geq 25.4$. The possible deceleration of brightness fading rate in HST/NIMCOS $H$ band and the observed flattening of the light curve in the $I_c$ filter 36 days after the GRB might be interpreted as a sign of the detection of such a galaxy. (This would imply a quite red object for $z = 0.835$, but we do not discuss this implication in this work.)

On the other hand, the multi-wavelength (optical, X-ray, radio) behavior we observe can also be explained by some intrinsic features of GRB970508 OT, rather than by the manifestation of an host galaxy. For example, it is possible to suppose that we observe the formation of a jet-like structure related to the activity of a stellar mass compact object, i.e. a \textit{gamma-ray burster}. The possibility of explanation of all the observational data by the intrinsic
5. Summary

The variable optical source associated to GRB970508 was observed with the 1-m and 6-m telescopes of SAO RAS from May 9 to August 4, 1997. The details of temporal changes of brightness in the $BVRI$ bands were compared with observations in X-ray and radio bands. We confirm the burst activity of the object detected by Piro et al. (1998) in X-rays in the first week after the high energy event. We notice also that the further brightness fading of the point-like object deviates from the average power law. This behavior was clearly seen at $\approx 8000 \, \text{Å}$ when, approximately 36 days after the GRB, a period of constant brightness starts.

Taking into account the global multi-wavelength behavior of GRBR 970508, it is presumable that the burst activity and subsequent deceleration of the brightness fading of the optical stellar-like source is caused by some intrinsic features of the object itself. Alternatively we probably observe the displaying of a dwarf underlying host galaxy with $I_c \approx 23.1$. To be certain of the absence of appreciable variability of a conjectural constant source further observational monitoring of a “quiet state” of the GRBR 970508 could give crucial inputs to the solution of this mystery.

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References

Boella G., et al., 1997, A&AS 122, 299
Bond H.E., 1997, IAU Circ No. 6654
Castro-Tirado A. J., et al., 1997, IAU Circ No. 6657
Costa E., et al., 1997a, IAU Circ No. 6649
Costa E., et al., 1997b, Nat, 387, 783
Dar A., 1997 [astro-ph/9709233]
Galama T., et al., 1997, Nat, 387, 479
Garcia M.R., et al., 1997, ApJL (submitted; astro-ph/9710346)
Djorgovski S., et al., 1997, Nat 387, 876
Klebesadel R.W., et al., 1973, ApJ 182, L85
Kurt V.G., et al., 1998, A&A (in press., astro-ph/9706076)
Landolt A.U., 1992, AJ 104, 340
Metzger M.R., et al., 1997, AJ 104, 340
Sokolov V., et al., 4-th Huntsville’s Symp. 1997 [astro-ph/9709093]
van Paradijs J., et al., 1997, Nat 386, 686
Taylor G.B., et al., 1997, Nat 389, 263
Frail D.A., et al., 1997, Nat 389, 261
Fruchter A., et al., 1997, IAU Circ No. 6674
Paczyn’ski B., 1997 [astro-ph/9710086]
Pedersen H., et al., 1998, ApJ 496 (in press, March 20)
Pian E., et al., 1998, ApJ 492, L103 [astro-ph/9710334]
Piro L., et al., 1998, A&A 331, L41 [astro-ph/9710355]
Sahu K.C., et al., 1997, Nat 387, 476
Schafer B., et al., 1997, IAU Circ No. 6658
Sokolov V., et al., 4-th Huntsville’s Symp. 1997 [astro-ph/9709093]