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Archival searches for transient optical emission in the error box of the 1991 January 22 gamma-ray burst

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Abstract. We present here the results of a study carried out at the Harvard College Observatory Plate Collection. We examined 3995 plates covering the error box of the gamma-ray burst GRB 910122, over a time span of 90 yr (from 1889 to 1979). The total exposure time is $\sim$ 0.55 yr. No convincing evidence of optical transient emission was found within the GRB 910122 IPN error box. However, a possible OT was found *outside* the GRB 910122 error box. Optical ground based observations have revealed a V$\sim$22.3 object consistent with the position of the new object. The colours of the object are typical of a K7/M0 star or a reddened galaxy, which could have caused the OT, but the fact that the object is far away from the GRB error box makes both events unrelated.

Key words: gamma rays: bursts

1. Introduction

In spite of the exciting progresses carried out recently, the central engine that powers gamma-ray bursts (GRBs) remains unknown. Following the detection of an absorption system in the optical spectrum of the optical transient (OT) related to the gamma-ray burst GRB 970508 (Metzger et al. 1997), it is believed now that most GRBs, if not all, arise at cosmological distances. However, the mechanism responsible for the emission is not yet known, and it could be still possible the existence of recurrent transient optical emission.

If this is the case, archival searches are extremely important, because they will allow to search for the possible recurrent optical emission. The detection of optical transient emission for GRB 970228 (van Paradijs et al. 1997, Guarnieri et al. 1997) and GRB 970508 (Bond 1997, Djorgovski et al. 1997, Castro-Tirado et al. 1998) confirms this fact. However, for some other bursts no optical emission was detected although prompt and deep follow up observations were carried out (Castro-Tirado et al. 1997, Groot et al. 1998).

Several OTs have been already found by means of archival searches. However, the confirmation of optical recurrent emission associated to GRBs is still unclear. Among them, OT 1901, OT 1928 and OT 1944 (Schaefer 1981, Schaefer et al. 1984) are located inside small GRB error boxes. For instance OT 1928 is a prominent object 5.8 mag over the plate limit, within a 8 arcmin^2 error box. But the reality of these objects has been under debate (Żytkow 1990, Hudec et al. 1994a). Other firm candidates are the three objects found by Hudec et al. (1990), at the same position of the sky. They are well above the plate limit and the structure is compatible with a star-like object in all three cases. However, they are outside the GRB 790325b error box.

Moskalenko's object (OT 1959, Moskalenko et al. 1989) was found inside the GRB 791101 error box as a 13 mag stellar image (or 6.6 mag if a 1-s flash is assumed) on two different plates (B and V filters) taken simultaneously. A double exposure cannot be ruled out because both plates were taken with cameras on the same mount. Moreover, the low quality and the steepness of the image profile cast doubts about the reality of the object (Greiner and Moskalenko 1994).

The OT reported by Greiner et al. (1991), represents one of the best candidates detected so far. It was found on three plates taken simultaneously in 1966 in the GRB 781006b error box. The magnitudes of the objects are similar to Moskalenko's one, at $\sim$ 13.1 mag (or 6.3 mag if a 1-s flash is assumed). Although some preliminary explanations were given (asteroids, satellite glints, head-on meteors, aircraft air lights or a dwarf nova), spectroscopic observations provided evidence that the OT was due to a large amplitude flaring dMe star, probably unrelated to the GRB (Greiner and Motch 1995).

The only OT found near-simultaneous to a GRB event, is the one reported by Borovička et al. (1992). They found a star-like object at the edge of the GRB 790929 error box on a plate taken only 7.1 h after the high energy event. Also, two additional objects were found at the same position on another plates. The objects are consistent with the star HDE 249119, but are relatively faint (at the utmost 1 mag above the plate limit), so a plate fault or a grain cumulation cannot be completely excluded. Further optical studies detected additional optical eruptions of HDE 249119, reporting ten optical brightenings with amplitudes greater than 0.5 mag (Štěpán and Hudec 1996).

Besides the above-mentioned OT candidates, Hudec et al. (1994b) reported the presence of a very bright OT (5 mag above the plate limit) inside GRB 910219 WATCH/*Granat* error box

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Table 1. The most exhaustive GRB archival searches carried out to date.

Plate collection	Number of boxes	Total monitoring time (yr)	Reference
Ondřejov Sonneberg Bamberg	22	∼12	Hudec et al. (1987, 1988, 1991, 1994b)
Harvard	16	4.25	Schaefer et al. (1984, 1990)
Sonneberg	15	2.6	Greiner et al. (1987, 1990b, 1990c)
Harvard ROE	2	1.65	Gorosabel & Castro-Tirado. (This paper and 1998a)
Odessa	40	1.26	Moskalenko et al. (1989, 1992)

Table 2. The 7 HCO Plates examined for GRB 910122.

Plate series	Limiting magnitude	Number of plates	Total exposure time (hr)	Number of plate faults	Faults rate (mm^{-2})
A	16.5	16	23	1	$5.0\ 10^{-5}$
AM	14.1	3001	4078	94	$1.2\ 10^{-3}$
B	15.2	277	78	8	$1.6\ 10^{-4}$
Damon	15.2	254	285	5	$1.1\ 10^{-4}$
MF	16.4	135	82	6	$2.1\ 10^{-4}$
RB	14.8	312	282	11	$9.8\ 10^{-4}$

Table 3. The 7 HCO plates containing objects selected for a deep study.

Plate ID number	Plate Series	exposure (minutes)
2027	Damon Blue	30
299	Damon Yellow	120
24633	AM	90
24098	AM	60
24589	AM	90
108	AM	63
45398	B	10

(Sazonov et al. 1998) coincident with the position of a confirmed quasar with redshift z=1.78 (Vrba et al. 1994). However the position of the object is not consistent with the small error box derived by the third Interplanetary Network (hereafter IPN, Hurley 1997).

More recently Hudec et al. (1997) reported two OTs that may be connected to GRB 910522 and GRB 920406. In the former case the OT seems to be related to a dMe flare star whereas a quiet counterpart with colours consistent with a quasar/AGN was found in the second one.

Other OT candidates have been found (Scholz 1984, Greiner and Flohrer 1985, Flohrer et al. 1986, Greiner et al. 1987, Hudec et al. 1987, Hudec et al. 1988) but none of them can be conclusively proven as a real OT. Therefore, despite strong efforts carried out during the last two decades there is no a convincing prove that OTs found in plate archives and GRBs are related to the same physical phenomenon. Comprehensive reviews on OTs found so far can be seen in Hudec et al. (1993a, 1993b, 1994c, 1995).

The most recent archival search has been performed by Gorosabel and Castro-Tirado (1998a). They have examined 8004 plates at the Harvard College Observatory Plate Collection searching for optical transient emission from the gamma-ray burst GRB 970228. This has been the first archival search carried out so far for a gamma-ray burst with known transient optical emission. The total exposure time amounted to ~ 1.1 yr. No convincing optical activity has been found above 12.5 mag at the expected position of the GRB 970228 optical counterpart. Table 1 displays a summary of the most exhaustive archival searches performed to date.

GRB 910122 is one of the GRBs with a very small error box (see Fig. 1). The X-ray fluence in the 8-20 keV range, as seen by WATCH (Castro-Tirado 1994) was 2.1×10^{-6} erg cm^{-2}, and the γ-ray fluence (E $>$ 100 keV) was 6.77×10^{-5} erg cm^{-2} (Therekov et al. 1994). The detection of GRB 910122 by the IPN (that included *Ulysses*, SIGMA/*Granat* and *PVO* spacecraft) allowed the intersection of three annuli which determined a tiny error box of ~ 20 arcmin^2 (Hurley et al. 1993). The position of the error box was afterwards improved, being shifted from the previous IPN position $4'$ to the west (Hurley 1997). The new IPN error box is consistent with that provided by WATCH/*Granat* and is the basis of our study.

In this paper we report the results of a study carried out at several plate archives, looking for optical transient emission from GRB 910122. Preliminary results have been published elsewhere (Guziy et al. 1997).

2. Observations and results

2.1. No optical transient found within the IPN error box

Both the small size of the GRB error box and the low surface density of stars ($b^{\rm II} = -30°$) made the search at the Harvard College Observatory Plate Collection (HCO) very suitable. A total of 3995 plates were examined (see Table 2). A region ~ 100 times larger than the 3σ error box around the GRB position was visually inspected, that was used to estimate the star-like plate faults rate (see Table 2). The total exposure time for GRB 910122 amounts to $\sim$ 0.55 yr.

In this study 125 suspicious objects were found, being 118 easily discarded using amplification lenses. The remaining 7 objects (see Table 3) were checked using the reflected-transmitted light microscope. None of the 7 objects are located *within* the 910122 IPN error box. Most of them are located far away from the error box. Only the closest object to the GRB error box (on plate AM 24589) was considered for further study.

Additional plates taken at the UK Schmidt Telescope (UKST) in Australia were blinked at the Royal Observatory of Edinburgh (ROE). No object varying by more than 0.2 mag

Table 4. The 18 UKST plates examined at ROE.

Plate ID number	Date	Exposure time (s)
UB 53	730727	200
J 897	740908	400
J 916	740916	450
J 1751	750807	700
J 1758	750808	700
J 1791	750829	700
HA 2560	760829	1300
HA 2585	760912	2400
BJ 4251	780506	150
J 7019S	810511	600
J 7024	810512	700
J 7192	810917	100
UJ10444P	850911	250
B11967	870622	150
U11968	870622	600
OR14496	910831	650
OR15122	920821	600
I15763	930912	1200

was found near or inside the IPN error box above the plate limit, 20-21 mag. Table 4 displays the plates examined at ROE.

2.2. *An object found on plate AM 24589 close to the error box*

The plate AM 24589 is a 90-min blue exposure taken in 1945 May 18 where the object appears as a 13.5 ± 0.5 mag star, or ~ 0.6 mag above the plate limit. The object is lightly more compact than the stars on the plate. The plates taken close in time to AM 24589 were AM 24582 (exposed the night before) and AM 24591 (exposed 3.05 hr after). None of them showed something at the object position (Fig. 1). Like AM 24589, both plates were exposed for 90 minutes, thus the limiting magnitude is the same (B ~ 14.1).

2.3. *Optical observations of GRB 910122 error box*

Optical observations were performed in 1996-1997 during three observing runs on the Danish 1.54-m Telescope at ESO La Silla Observatory. The DFOSC instrument provided a field of view of $13'.3 \times 13'.3$. The CCD was a backside illuminated Loral/Lessler chip with 2052×2052 pixels.

All observations were made using UBVR (Bessel) and I (Gunn) filters. Photometric calibrations were made using the Landolt field Mark A (Landolt 1992), and the standard stars HD 84971 and HD 121968 at different air masses and filters. Limiting magnitudes for the co-added images are I=22, R=23.5, V=24, B=24.5, U=22. Table 5 displays the observing log.

The IPN error box contains $\sim$ 150 objects brighter than V$\sim$22 mag. There are two bright stars (V$\sim$10) within the error box. None of the $\sim$ 150 objects contained in the error box seem to be elongated, although in the surrounding area, close to the edge of the error box, there are four galaxies with V$\leq$19. At first sight there are no objects within the IPN error box with anomalous colours. A detailed study about the content of the error box will be published elsewhere (Gorosabel, Castro-Tirado and Lund 1998).

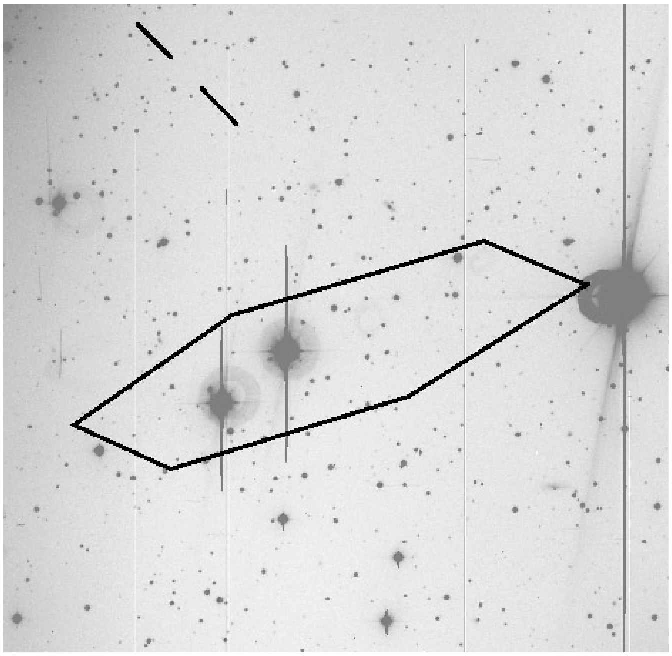

Fig. 1. A B-band image obtained with the 1.54-m Danish Telescope at La Silla. The improved error box of GRB 910122, provided by the third interplanetary network (Hurley 1997), and the location of the possible optical transient are shown. The field of view is $12'.6 \times 12'.6$. North is at the top and east to the left.

Table 5. Log of observations covering the GRB 910122 position with the 1.54-m Danish Telescope.

Date	Exposure time (s)				
	U	B	V	R	I
12 Sep 1996	1200	-	-	-	-
13 Sep 1996	-	-	500	-	400
12 March 1997	1800	1200	900	600	600
15 March 1997	-	1800	900	600	600
16 March 1997	6925	1800	900	600	600
26 June 1997	-	3000	-	-	-
27 June 1997	4800	-	-	-	-
28 June 1997	4800	-	-	-	-
29 June 1997	2400	-	2700	1200	1200
4 July 1997	4500	-	-	-	-
5 July 1997	-	-	-	-	6000
Total: 15.59^{hr} =	26425^s+	7800^s +	5900^s+	3000^s +	9400^s

3. Discussion

3.1. *Reliability of the object*

There are different theories regarding the kind of silver grains structure that OTs should leave in the emulsion. Schaefer (1981) suggested that flash images on large exposure plates are expected to be shallower than those of stars, which can be attributed to the failure of the law of reciprocity in photographic

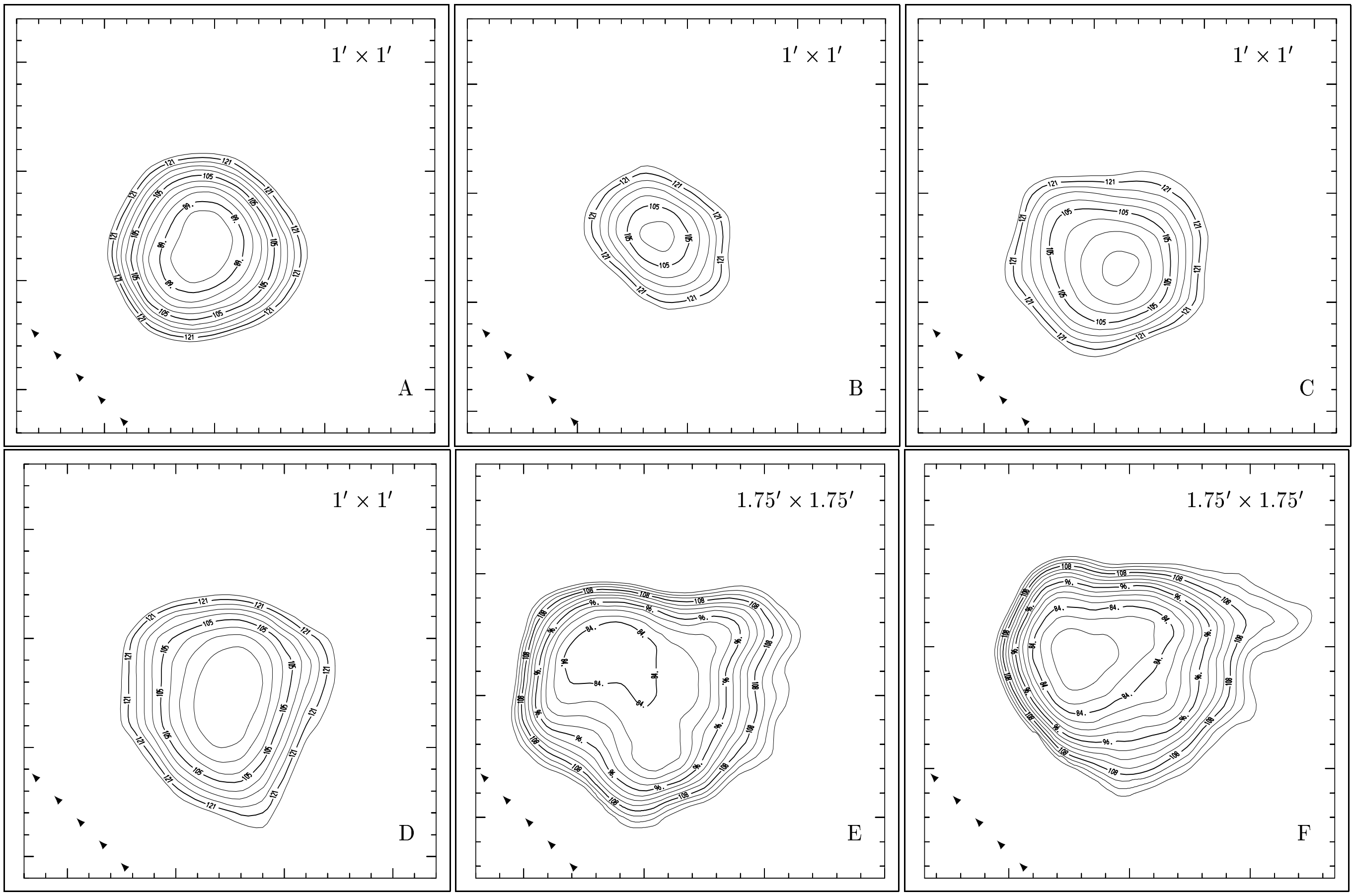

Fig. 2a–f. Image "A" shows the equidensity profiles as detected by the transmitted light microscope for the object found on the plate AM 24589. The remaining images show equidensity diagrams for nearby stars on the same plate. Images "B", "C" and "D" show the profiles for faint stars (B∼13-14), whereas the contours of two bright stars (B∼9-10) are shown in "E" and "F". The contours are labeled in arbitrary units which are directly related to the intensity of the light measured by the CCD at the microscope. The direction towards the plate centre is indicated by the arrows. Fields of view are indicated at the upper right corners. As it is shown, the object found on the plate AM 24589 shows similar profiles to those measured in stars with similar magnitudes to it. North is at the top and east to the left.

emulsions. Other authors claim that inadequate guiding or variations in the atmospheric turbulence, could make the flash images steeper (Moskalenko et al. 1989, Varady and Hudec 1992). However if the object image was produced by a long lasting (∼ hours) optical counterpart similar to OT/GRB 970228 and OT/GRB 970508, the structure of the object would be indistinguishable from that of the stars on the plate.

When half of the plate AM 24589 was blinked, other two bright star-like objects were found. However, taking into account the star-like faults rate for AM series shown in Table 1, we would expect ∼10 star-like images, which is comparable to the number of spots found in the blinking test. Furthermore, the observing log does not contain any indication of a double exposure, therefore a double exposure can be excluded with a high probability.

Changing the focal length of the microscope, we were able to examine the object at different deepness. In spite of its faintness, we realized that the silver grains are geometrically extended in a cylinder shape up to the emulsion/glass boundary, decreasing the density of grains for deeper regions. This is consistent with the structure of grains for real images (Greiner et al. 1990a, Żytkow 1990). We also detected a marginal deposition of silver grains above the gelatine surface as it is expected for exposed regions (Lau and Krug 1957). Furthermore the inspection by means of reflected light microscopy did not reveal distortions on any side of the emulsion as it was detected in some plate faults (Greiner et al. 1990a).

The bright stars show coma distortion towards the centre of the plate, however neither the object nor the faint stars showed any distortion (see Fig 2). In order to determine if the object shape was different than that from the stars, the equidensity profiles of the object and the surrounding stars were compared. As it is shown in Fig 2, the object seems lightly steeper than the stars. However, the profile of the object is very similar to the faint stars, without coma distortion towards the plate centre. Thus, we conclude that the study of the profiles does not show a significant difference between the faint stars and the object. *Therefore we have considered the star-like object as real, although the fault origin cannot be completely excluded.*

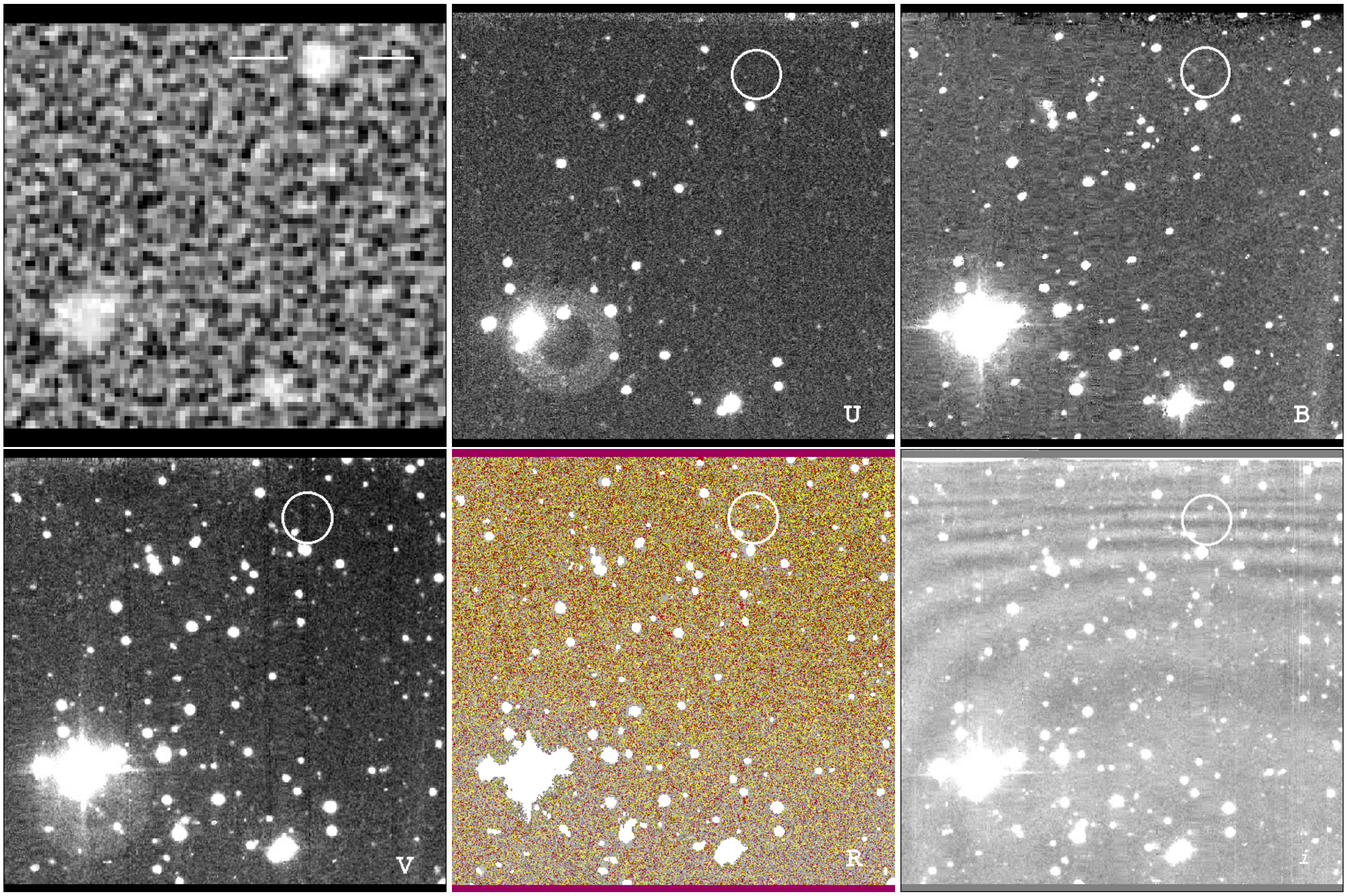

Fig. 3. A set of images near the GRB 910122 field. The first image is a microscope image of plate AM 24589, showing the object (indicated between lines). The remaining 5 images were obtained with the Danish 1.54-m Telescope at ESO La Silla Observatory in the U, B, V, R and I bands. The circle represents the 1σ astrometrical error box at the object position. North is at the top and east to the left.

3.2. The flash parameters

For a given intensity I and exposure time T, the photographic density D is expected to follow the Schwarzschild's reciprocity law (Schwarzschild 1900), $D = I^qT$, where q is a function of the exposure time T (with $q \leq 1$ for a short flash and $q \geq 1$ for a long one, following Eastman Kodak, 1935).

If we assume that q does not vary strongly with T, the limiting magnitude m_{flash} for a flash lasting T_{flash} on a plate of limiting magnitude m_{plate} and exposure time T_{plate} is:

$$m_{flash} = m_{plate} - (2.5/q)\ log\ (T_{plate}/T_{flash})$$

According to this formula, assuming the value of q calculated by Schaefer et al. (1981), and taking into account the magnitude of the object on the plate (B $\sim$ 13.5 mag) and the exposure time of the plate (90 min), the expected magnitude for a 1-s flash would be $\sim$ 6.0 mag. We note that OT 1959 (Moskalenko et al. 1989), OT 1966 (Greiner et al. 1991), OT 1901 (Schaefer et al. 1984), OT 1946 and OT 1961 (Hudec et al. 1990) reached analogous magnitudes.

We still cannot rule out that the object on AM 24589 may have been caused by a head-on meteor. If we assume a flash duration of $\sim$1 s, the probability that the object found on the plate AM 24589 is due to a head-on meteor can be roughly estimated;

Although the rate of meteors below 4 mag is not very well measured, it has been estimated that the frequency of $\sim$ 6 mag meteors is at most $\sim$10 h^{-1} sr^{-1} (Karnashov et al. 1991). Thus, the probability of detecting a $\sim$6 mag meteor inside the GRB 910122 IPN error box (area $\sim$20 arcmin^2) on a plate like AM 24589 exposed 90 minutes, is $< 3 \times 10^{-5}$. However, as it is shown in the "A" plot of Fig 2, the object is not trailed with an upper limit of 10 arc sec trailing. So, the meteor should have approached within 10 arcsec off the vertical. Taking into account the estimation made by Schaefer et al. (1981) for OT 1928 (an upper limit of 3 arc sec trailing), the probability that a meteor will travel inside a cone with an aperture of 10 arc sec would be $\sim 10^{-7}$.

Therefore, the joint probability of both having on a AM plate a head-on meteor and detecting the meteor in the IPN error box is at most $\sim 3 \times 10^{-12}$. Taking into account that the monitoring time of the examined AM plates amounts to $\sim 4 \times 10^3$ hr , the total probability of finding a $\sim$6.0 mag head-on meteor in the GRB 910122 IPN error box in any AM plate used in this study, is below $\sim 10^{-8}$. Considering that a region $\sim$ 100 times larger than the 3σ error box was visually inspected, an upper limit to the probability of finding a ~6.0 mag head-on meteor around the GRB position is $\sim 10^{-6}$, which is negligible.

We would like to point out that the former calculation has been performed assuming the plate scale and the monitoring time of the AM series, which represents a 84.5% of the total monitoring time. Other series would impose lower upper limits to the probability because of their larger plate scale in comparison to the AM series.

On the other hand, the possible presence of a minor planet has been checked using data of the Minor Planet Center. As expected by the high ecliptic latitude of the GRB ($\beta = -32°$) there is no known minor planet $15'$ around the error box at the time of plate AM 24589 (Williams 1998). The plate AM 24589 was taken in 1945, so any relationship with satellite glints is obviously excluded. Astrometry of the object yielded: $\alpha_{2000} = 19^h47^m23^s \pm 2^s, \delta_{2000} = -70°33'7.3'' \pm 9''$.

If the object is due to optical emission from the source that produced GRB 910122, and assuming a 1-s duration flash and the same gamma-ray fluence in 1945 and 1991, the corresponding gamma to optical (B band) fluences ratio is $S_\gamma/S_{opt} \sim 3 \times 10^3$, and the X-ray to optical (B band) fluences ratio is $S_x/S_{opt} \sim 10^2$.

3.3. A search for the quiescent optical counterpart of the object

We have tried to correlate the position of the object with catalogues of sources (from X-rays to radio wavelengths), by means of the SIMBAD, HEASARC and NED databases. The result is that no sources are found within 30” from the object position. Only the infrared source IRAS 19419-7038 is located 118” away. Taking into account that the IRAS angular resolution at 12 μm is 45” (Beichman et al. 1987), we conclude that the relationship between this infrared source and the object is unreliable.

UBVRI images of the field containing the OT are shown in Fig. 3. The content of the 3σ astrometrical error circle is shown in Fig. 4. Magnitudes and positions of all objects are displayed in Table 6. Photometrical errors in the magnitudes are overestimated due to the presence of several bad CCD columns. Object # 1 seems to be the most interesting object within the 1σ error circle, with U > 22, B = 23.9 ± 0.5, V = 22.3 ± 0.2, R = 21.15 ± 0.15, I = 20 ± 0.15. The colours are consistent with that of a K7/M0 dwarf star or a K5/M1 giant, although they could be also consistent with a reddened galaxy (see Fig 5).

The object on plate AM 24589 appears to be ~ 0.6 mag over the plate limit and is absent on plate AM 24592 (obtained 3 hours and 5 minutes after). Therefore, the object should have declined at a rate of ≥ 0.2 mag/hr, which is similar to same decline rates in flares stars. Could object #1 be classified as a flare star?.

To estimate the probability of having a K7/M0 dwarf star or a K5/M1 giant coincident with the 1σ astrometrical error is difficult because of various statistical biases in star catalogues.

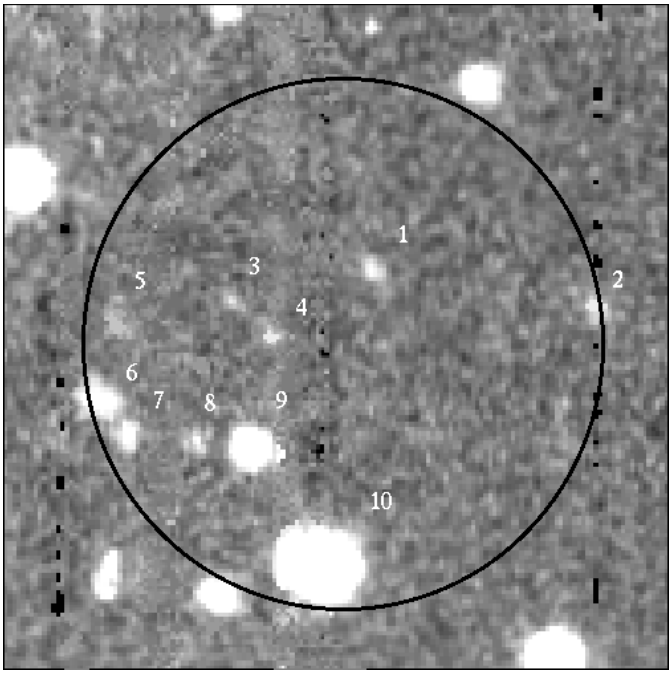

Fig. 4. The circle represents the 3σ astrometrical error circle around the position where the object was found on plate AM 24589. Ten sources are consistent within the object error circle. Only the objects # 1, 3, and 4 are within the 1σ object error circle. The image is a combination of the U,B,V,R and I-band frames. Magnitudes and coordinates are given in Table 6.

Taking into account the number of stars per square degree of magnitude B=22 at galactic latitude $b^{\rm II} = -30°$ and the fraction of K7/M0 spectral-type main sequence and K5/M1 giant stars (Allen 1973), we expect $\sim 10^{-2}$ K7/M0 main sequence stars and $\sim 10^{-4} - 10^{-5}$ K5/M1 giants within a $9''$ error circle (the size of the 1σ astrometrical error radius). Therefore, in the absence of stronger constraints we cannot prove that this star has caused the object detected on the plate AM 24589.

Considering that in the solar neighbourhood the fraction of M0-M1 type stars that can be considered as flare stars is 5% (Shakhovskaya 1994, Mirzoyan 1994), the probability that a M0-M1 flare star is located by chance inside the 1σ astrometrical error would be $\lesssim 5 \times 10^{-4}$. Therefore, if object #1 was a flare star, it is likely to be the responsible of the object found on the plate AM 24589. In this case, the flare amplitude would be $\Delta B \sim 10$ mag which is slightly higher than the extreme flares of the CZ Cnc stars (Greiner and Motch 1994, Toth et al. 1996). It should be noted that M flare stars have been found at OTs position inside two GRB error boxes (Greiner and Motch 1995, Hudec et al. 1997). In any case an optical spectrum would be desirable in order to clarify its nature.

3.4. The lack of OTs within the GRB 910122 error box.

OTs have been found at the edge or slightly outside GRB error boxes, like GRB 910219 (Hudec et al. 1994b), GRB 790325b (Hudec et al. 1990) or GRB 791006b (Greiner et al. 1991). In fact

Table 6. Magnitudes and positions for objects within the 3σ astrometrical error circle of the possible OT found on the plate AM 24589.

Object	Coordinates		Magnitudes					Proposed
number	$\alpha(2000)$	$\delta(2000)$	U	B	V	R	I	class
1	$19^h47^m22.36^s$	$-70°33'0.9''$	> 22.0	23.9 ± 0.5	22.30 ± 0.20	21.15 ± 0.15	20.00 ± 0.15	K7/M0 V K5/M1 III
2	$19^h47^m25.03^s$	$-70°33'4.7''$	> 22.0	24.0 ± 0.5	23.30 ± 0.30	23.36 ± 0.30	> 22.00	
3	$19^h47^m18.56^s$	$-70°33'3.9''$	> 22.0	23.4 ± 0.4	22.89 ± 0.25	21.35 ± 0.30	20.20 ± 0.25	
4	$19^h47^m24.35^s$	$-70°33'5.7''$	> 22.0	24.0 ± 0.5	23.05 ± 0.25	22.01 ± 0.10	21.50 ± 0.30	
5	$19^h47^m26.91^s$	$-70°33'4.6''$	> 22.0	> 24.2	23.50 ± 0.50	23.30 ± 0.40	21.70 ± 0.40	
6	$19^h47^m27.42^s$	$-70°33'11.8''$	> 22.0	22.5 ± 0.3	21.40 ± 0.20	21.20 ± 0.15	20.80 ± 0.25	
7	$19^h47^m26.79^s$	$-70°33'14.9''$	> 22.0	22.9 ± 0.3	22.10 ± 0.30	22.10 ± 0.30	21.80 ± 0.45	
8	$19^h47^m25.52^s$	$-70°33'15.3''$	> 22.0	23.5 ± 0.5	23.10 ± 0.25	21.50 ± 0.30	20.60 ± 0.25	
9	$19^h47^m24.65^s$	$-70°33'16.1''$	> 22.0	21.5 ± 0.2	20.00 ± 0.20	19.04 ± 0.15	18.60 ± 0.20	K2/K4 III
10	$19^h47^m23.47^s$	$-70°33'26.7''$	17.7 ± 0.2	17.9 ± 0.2	17.05 ± 0.15	16.50 ± 0.15	16.20 ± 0.15	F5/F8 V ?

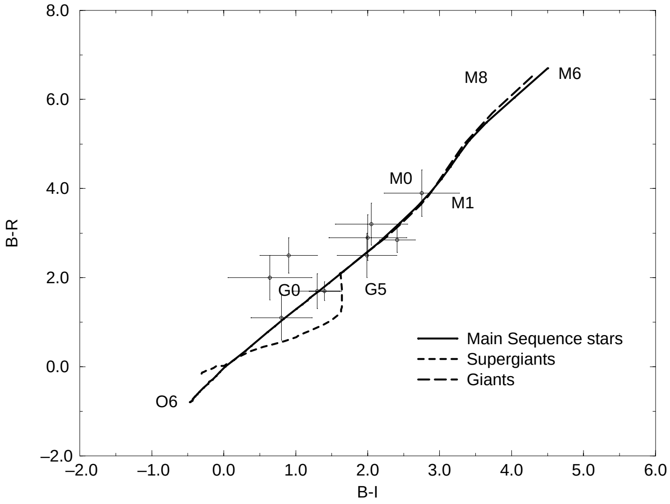

Fig. 5. Colour-colour diagram for the objects inside the 3σ error box shown in Fig. 4. The upper one is object # 1 which is consistent with a K7/M0 star. Magnitudes are uncorrected for interstellar extinction.

several authors suggest a strong relationship between quasars and OTs (Vrba et al. 1994, Hudec et al. 1997), but statistical studies do not show a convincing correlation between quasars and GRBs (Gorosabel et al. 1995, Schartel et al. 1997, Gorosabel and Castro-Tirado 1998b, Gorosabel and Castro Tirado 1998c, Hurley et al. 1998).

The object is inside the WATCH error circle (Sazonov et al. 1998), but $5'$ outside the improved IPN error box for GRB 910122 (Hurley et al. 1997) and not included in any of the three annuli determined by the *Granat*, *PVO* and *Ulysses* spacecraft. Even if we assume an extended halo radius equal to 150 kpc and a high-velocity neutron star (at 1000 km/s), its apparent motion on the sky would be only ~ 0.14" in 100 yr. Therefore, theories based on high-speed neutron stars in the halo will not allow to place the optical source that far away the IPN error box (Li and Dermer 1992). The maximum allowable distance to detect such proper motion of $5'$ in 46 yr (from 1945 to 1991) would be 35 pc, but such a nearby neutron star would have been easily detected in previous all-sky X-ray surveys.

Therefore we can set a lower limit of 0.55 yr for any recurrent optical transient activity (above 14.1 mag) related to GRB 910122. This can be compared with the 2.1 yr in the case of GRB 910219 (Hudec et al. 1994b). Further results on the optical content of the GRB 910122 IPN error box will be published elsewhere (Gorosabel, Castro-Tirado and Lund 1998).

4. Conclusions

We have examined ~ 3995 plates at HCO for GRB 910122 covering ~ 0.55 yr. No convincing evidence of optical transient emission was found within the GRB 910122 error box. Additional plates at ROE did not show any suspicious object either. However, a possible OT was found at HCO on the plate AM 24589, located $5'$ outside the improved error box provided by the IPN.

Multicolour optical observations were carried out, finding 3 sources consistent, within the 1σ object astrometrical error box. One of them shows colours typical of a M dwarf star or a reddened galaxy. In any case it seems to be unrelated to the GRB because of its location outside the IPN error box.

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