

ISO observations of the environment of the soft gamma-ray repeater SGR 1806-20

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Abstract. Observations at near⁵ and mid-infrared wavelengths (1–18 μm) of SGR 1806-20 suggest that it is associated with a cluster of giant massive stars which are enshrouded in a dense cloud of dust. The centre of the best sky position of the gamma-ray source (Hurley et al. 1999) lies on top of the dust cloud at only 7 arcsec (~ 0.5 pc at a distance of 14.5 kpc) from the star cluster, and 12 arcsec (~ 0.85 pc) from a Luminous Blue Variable Star (LBV) which had been proposed to be associated with the SGR (Kulkarni et al. 1995). The bright cloud of interstellar gas and dust observed with ISO (Infrared Space Observatory) is probably the birth site of the cluster of massive stars, the LBV star, and the progenitor of the soft gamma-ray repeater pulsar. The presence of such a young star formation region is compatible with the current interpretation of soft gamma-ray repeaters as young neutron stars. The SGR 1806-20 compact source is unlikely to form a bound binary system with any of the infrared luminous massive stars, since no flux variations in the near-infrared were detected from the latter in an interval of 4 years. The ISO observations were made over two epochs, 11 days before and 2 hours after a soft gamma-ray burst detected with the Interplanetary Network, and they show no enhanced mid-infrared emission associated to the high energy activity of the SGR.

Key words: stars: individual: SGR 1806-20 – stars: peculiar – stars: pulsars: individual: SGR 1806-20 – gamma rays: bursts – infrared: stars – X-rays: stars

1. Introduction

Soft Gamma-ray Repeaters (SGRs) are transient γ -ray sources that are distinguished from classical Gamma-Ray Bursts (GRBs) by their short duration (~ 0.1 s), softer γ -ray spectra and recurrent activity of their outbursts (Golenetskii et al. 1984). SGRs randomly undergo quiescent periods and intervals

of intense activity with up to hundreds of bursts. The latter can appear as single short (less than 10 ms) bursts, or complex events lasting hundreds of milliseconds.

Only four SGRs have been found so far:

- SGR 1806-20: associated with an X-ray source coinciding with the radio peak of the supernova remnant (SNR) G10.0-0.3 which is a plerion: a non-thermal radio nebula powered by a central pulsar (Kulkarni et al. 1994). Recently, Hurley et al. (1999) applied a statistical method to derive very precise location for SGRs, and found this SGR's most likely position significantly displaced from this radio peak. Pulsations in the persistent X-ray flux were discovered with a period of 7.47 s and a spin down rate of $8.3 \cdot 10^{-11} \text{ s.s}^{-1}$ (Kouveliotou et al. 1998a).
- SGR 1900+14: associated with a soft X-ray source lying close to the SNR G42.8+0.6. It has entered a new phase of activity in 1998 after a long period of quiescence. Pulsed emission with a 5.16 s period and a secular spindown at an average rate of $1.1 \cdot 10^{-10} \text{ s.s}^{-1}$ was detected (Kouveliotou et al. 1999).
- SGR 0525-66: a soft X-ray counterpart with an 8 s period (but this source appears to be time variable), lying on the northern edge of the SNR N49 in the Large Magellanic Cloud. No optical, infrared or radio point source counterpart was found (van Paradijs et al. 1996; Fender et al. 1998).
- SGR 1627-41: near SNR G337.0-0.1 and recently discovered (Kouveliotou et al. 1998b). It indicates weak evidence of 6.7 s pulsations (Dieters et al. 1998).

The association between SGR and young (less than 10 000 years old) SNR, and the detection of pulsations strongly support the argument that SGR sources are young neutron stars (Kouveliotou et al. 1998a). However, their rarity suggests unusual physical characteristics: if the secular spindown is due to magnetic dipole radiation, then the corresponding dipolar magnetic field would be in excess of 10^{14} Gauss (Kouveliotou et al. 1999). Thus these young neutron stars are called 'magnetars' (Thompson & Duncan 1995). They are different from normal pulsars; for example their X-ray and particle emissions are powered not by rotation but by decaying magnetic field (Kulkarni

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⁵ Based on observations collected at the European Southern Observatory, Chile (proposal ESO N°59.D-0719)

& Thompson 1998). This involves both internal heating and seismic activity that shakes the magnetosphere and accelerates particles. This gradual release of energy is punctuated by intense outbursts that are more plausibly triggered by a sudden fracture of the neutron star's rigid crust caused by magnetic stresses (Kouveliotou et al. 1998a).

A core-jet geometry has been reported by Vasisht et al. (1995) and Frail et al. (1997) in 3.6 cm radio continuum images. Since SGRs are recent remnants of massive stars, they can be surrounded by dust and gas. If a source of X-rays and/or relativistic jets, such as SGR 1806-20, is inside or near interstellar gas clouds, then a large fraction of the energy radiated by the X-rays and/or injected in the form of relativistic particles could be dissipated by heating of the interstellar material. Thus thermal emission from dust may be expected. Mid-infrared observations can be used to test this possibility, and also to identify possible counterparts embedded in dense dust clouds.

2. Previous observations of SGR 1806-20

SGR 1806-20 is the most prolific soft gamma-ray repeater with more than a hundred bursts (Hurley et al. 1994) since its discovery (Atteia et al. 1987; Laros et al. 1987). Within its localization box, Kulkarni & Frail (1993) pointed out an amorphous radio nebula G10.0-0.3 classified as a supernova remnant. Conducting a multi-band radio observation of this SNR using the Very Large Array (VLA), Kulkarni et al. (1994) found a compact nebula superimposed on an extended plateau of emission. Cooke (1993), with the ROSAT X-ray telescope, discovered an X-ray source coincident with this compact nebula within an $11''$ error box. This was confirmed by Murakami et al. (1994), who were fortunate to detect an X-ray burst, simultaneously detected by BATSE as a γ -ray burst, and a point-like source (designated AX 1805.7-2025) in the same observation with the X-ray satellite ASCA. The burst was coincident with the steady source and both were coincident with the centroid of the compact radio nebula. This SNR (see top of Fig. 1) has strong emission from the central region, and a hierarchical structure culminating in a central peak, suggesting a compact object located at this radio core. This morphology is typical of a plerion, where the radio emission is synchrotron radiation powered by the relativistic wind of a central pulsar. In addition, Murakami et al. (1994) argued that the radio and the X-ray spectra are consistent with a synchrotron source such as the Crab nebula, and the similarity of the radio/X-ray flux ratio is consistent with a source powered by a pulsar from radio to X-ray wavelengths. The pulsar model for SGR 1806-20 was confirmed later with the discovery of 7.47 s pulsations in its persistent X-ray flux (Kouveliotou et al. 1998a). Still, the measured period increase implies a magnetic field stronger than 10^{14} Gauss, and the rotational energy of the neutron star with its present period is too small to power the X-ray and particle emission (Kouveliotou et al. 1998a), so the magnetar model becomes more plausible.

Thanks to the precise location of SGR 1806-20 from the radio data, it was possible to search for optical or infrared counterparts. Kulkarni et al. (1995) detected a highly reddened lumi-

nous supergiant star coinciding with the radio peak of G10.0-0.3, whose reddening is consistent with the high extinction inferred for AX 1805.7-2025 ($A_V \sim 30$ mag). Spectroscopic observations by van Kerkwijk et al. (1995) classified this star as a Luminous Blue Variable (LBV) candidate of spectral type O9-B2. LBVs are among the most luminous and massive stars. They can show no detectable variability ($\Delta M < 0.1$ mag), or either they can be very variable ($\Delta M > 3$ mag) on different timescales, and they eject large amount of matter (their mass loss rate can be as high as 10^{-5} to $10^{-4} M_{\odot} \text{ yr}^{-1}$). Only a dozen LBVs are known in the local group of galaxies so they presumably represent a very short ($< 10^5$ yr) stage of some rare, massive stars' life. This peculiar LBV is one of the brightest in our Galaxy with a bolometric luminosity greater than $10^6 L_{\odot}$. Although it is still not clear what is the physical connection between the SGR source and this LBV, the chance coincidence probability of this kind of object with the radio position is exceedingly small ($\sim 2 \cdot 10^{-5}$ from Kulkarni et al. 1995). According to Corbel et al. (1997) the SNR G10.0-0.3 is very likely associated with one of the brightest H II regions in the Galaxy: W31, on the edge of a giant molecular cloud, at a distance of 14.5 ± 1.4 kpc with a visual extinction of 35 ± 5 mag. The LBV's characteristics are consistent with this region, thus leading to nearly $5 \cdot 10^6 L_{\odot}$ for its luminosity. During the last period of activity of SGR 1806-20 in 1996 November, Castro-Tirado et al. (1998) performed follow-up observations of the LBV. They suggested that no strong additional IR emission appears during the active period, nor any variation larger than 0.1 mag in the K-band in 1 s timescale can be attributed to an X/ γ -ray burst. So this luminous blue variable does not seem to exhibit any variability greater than 0.1 mag even during the bursts, which tends to disprove the accreting binary model for a physical link between the LBV and the pulsar.

3. Infrared observations

Observations of the mid-infrared environment of SGR 1806-20 were carried out on 1997 April 3 (with the LW2 (5.0–8.5 μm) filter) and April 14 (with the other filters) by the ISOCAM instrument (Cesarsky et al. 1996) aboard the Infrared Space Observatory (ISO) satellite. By chance, a soft gamma-ray burst was detected by the Interplanetary Network on 1997 April 14 (Hurley et al. 1999). So the LW2 image was taken 11 days before, and all the other ISOCAM observations were made only between 1.6 and 3.5 hours after this burst. The images were taken in the 5–18 μm range with several wide-band filters (LW), with a 1.5 arcsec pixel field of view for LW2 (5.0–8.5 μm) and a 3 arcsec pixel field of view for the other filters. The data were reduced using the "CIA" package to correct the dark current, the glitches, the flat field and the detector transient behaviour (see Ott et al. 1997).

We also monitored the field of SGR 1806-20 in the near-infrared, at the European Southern Observatory (ESO), with the ESO/MPI 2.2 m telescope with the IRAC2b camera. The most complete observations were made on 19 July 1997, in the J ($1.25 \pm 0.30 \mu\text{m}$), H ($1.65 \pm 0.30 \mu\text{m}$) and K' ($2.15 \pm 0.32 \mu\text{m}$) bands. The IRAC2b camera was mounted at the F/35 in-

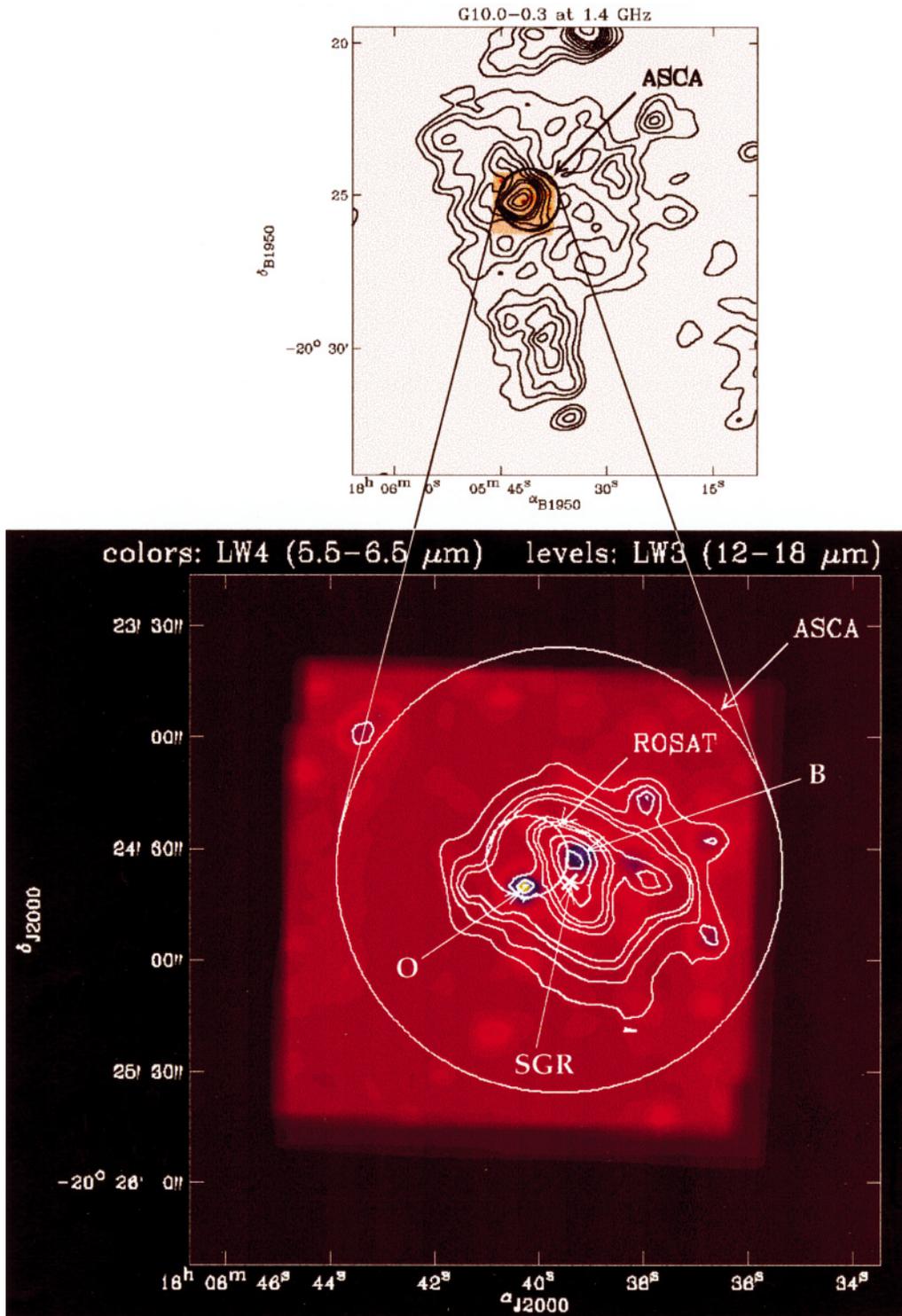


Fig. 1. *Top:* Radio image of the supernova remnant G10.0-0.3 at 1.4 GHz (from Kulkarni et al. 1994) with the ISOCAM LW4 (5.5–6.5 μm) color image superimposed on it. The circle marks the location of the steady ASCA X-ray source (Murakami et al. 1994) considered as the counterpart of SGR 1806-20. *Bottom:* The best fit position of SGR 1806-20 (Hurley et al. 1999) marked as a white cross, the 1' ASCA circle and the 11'' localization circle of the X-ray source by ROSAT, are shown superimposed on our observation of this region with ISOCAM. The levels of the LW3 (12–18 μm) image are superimposed on the LW4 (5.5–6.5 μm) color image, both have $3 \times 3 \text{ arcsec}^2$ per pixel field of view. Contour levels are: 15, 17, 19, 20, 30, 35, 41, 61, 81, 127 mJy, and the images were smoothed using a bilinear interpolation. A Luminous Blue Variable (LBV) star, named “O”, is on the south part of the ROSAT circle, and to the west, there is a cluster of giant massive stars, named “B” (see Fig. 2). Note that the coordinates drawn on this image are not precise.

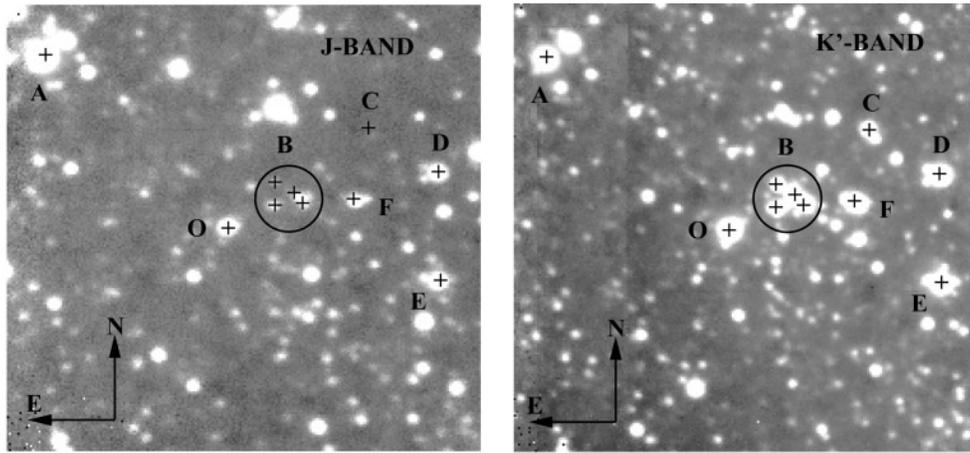


Fig. 2. J-band ($1.25 \pm 0.30 \mu\text{m}$) and K'-band ($2.15 \pm 0.32 \mu\text{m}$) images of the field surrounding SGR 1806-20 obtained with IRAC2b on the ESO/MPI 2.2 m telescope with a $0.5 \times 0.5 \text{ arcsec}^2$ per pixel field of view. The global field shown is roughly the same as in the ISOCAM images: $\sim 2' \times 2'$. The objects clearly seen with ISOCAM are marked. The LBV is marked “O”. Except for “A”, the extinction is greater in the J-band than in the K'-band. The extinction of “B” in the J-band image suggests that it is a cluster of hot giant massive stars behind or still partly embedded in their “placental” dusty cloud, visible in the LW9 ($14\text{--}16 \mu\text{m}$) and LW3 ($12\text{--}18 \mu\text{m}$) images in Fig. 4.

frated adapter of the telescope. This camera is a Rockwell 256×256 pixels Hg: Cd:Te NICMOS 3 large format infrared array detector. It was used with the lens C, providing an image scale of $0.49 \text{ arcsec/pixel}$ and a field of $136 \times 136 \text{ arcsec}^2$. The typical seeing for these observations was 1.2 arcsec . Each image taken at la Silla is the median of 9 images exposed for 1 minute, four of these images offset by $30''$ to the North, East, South and West, to allow subtraction of a blank sky. The images were further treated by removal of the bias, the dark current, and the flat field, and we carried out absolute and relative photometry to look for small variations of the luminosity of SGR 1806-20. This work was performed with the IRAF procedures, using the DAOPHOT package for photometry in crowded fields.

The ISO absolute astrometry is not very precise, so we used the relative positions of the sources visible on our ISOCAM images to identify them with the ones on the J, H and K' images. For the ISOCAM images displayed in this paper, we corrected their astrometry using the LBV's position given by Kulkarni et al. (1995) as a reference for the center of the corresponding ISO source. However, the accuracy of the displayed coordinates is still about $2''$.

4. Results and discussion

We can summarize the aforementioned information and our observations of SGR 1806-20 in Fig. 1. The top represents the radio image of the SNR G10.0-0.3 at 1.4 GHz presented by Kulkarni et al. (1994) with the ASCA $1'$ radius error circle centered on the steady X-ray source. The bottom shows the same circle surrounding the ISOCAM view of this region with the 3 arcsec pixel field of view, and we overlaid the $11''$ radius localization circle of the X-ray source by ROSAT. Fig. 2 shows J-band and K'-band images roughly corresponding to the ISOCAM field of view. The objects clearly seen on the ISOCAM images are marked; “O” is the LBV supposed to be the IR counterpart of

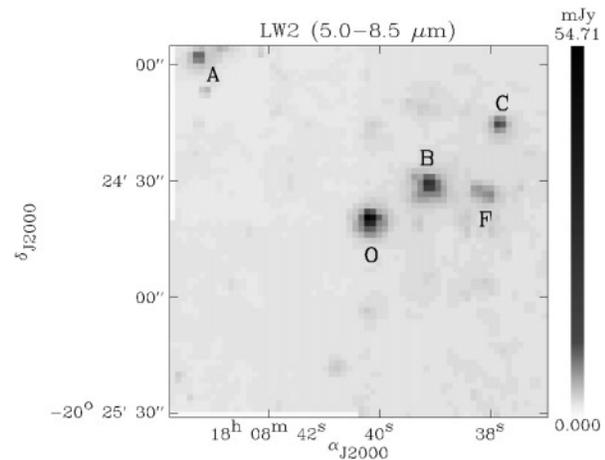


Fig. 3. ISOCAM LW2 ($5.0\text{--}8.5 \mu\text{m}$) image of SGR 1806-20 taken with the $1.5 \times 1.5 \text{ arcsec}^2$ per pixel field of view lens. The global field of view is $\sim 1.5' \times 1.5'$, smaller than the field of the other ISOCAM images ($\sim 2' \times 2'$), so only “O”, “B”, “C”, “F” and “A” are visible. Even with this finer resolution, the stars of the cluster “B” are not resolved.

SGR 1806-20, in Fig. 1 it is the bright color point on the south part of the ROSAT circle. “B” is a cluster of stars in Fig. 2, but it is seen as an unresolved source with the lower resolution (3 arcsec per pixel) of the ISOCAM LW4 ($5.5\text{--}6.5 \mu\text{m}$) color image. Even with the 1.5 arcsec pixel field of view, the stars of this cluster are not resolved between 5.0 and $8.5 \mu\text{m}$, the range of the LW2 image (see Fig. 3).

Fig. 4 shows how the infrared field of view surrounding SGR 1806-20 changes depending on the wavelength. At $6 \mu\text{m}$ the LBV is the brightest star and nearly all the sources look point-like on the LW4 image (see Fig. 1 and Fig. 4). “B” becomes brighter compared to “O” as the wavelength increases, and a cloud is clearly visible in the LW3 ($12\text{--}18 \mu\text{m}$) image where it strongly dominates the observed flux. From the super-

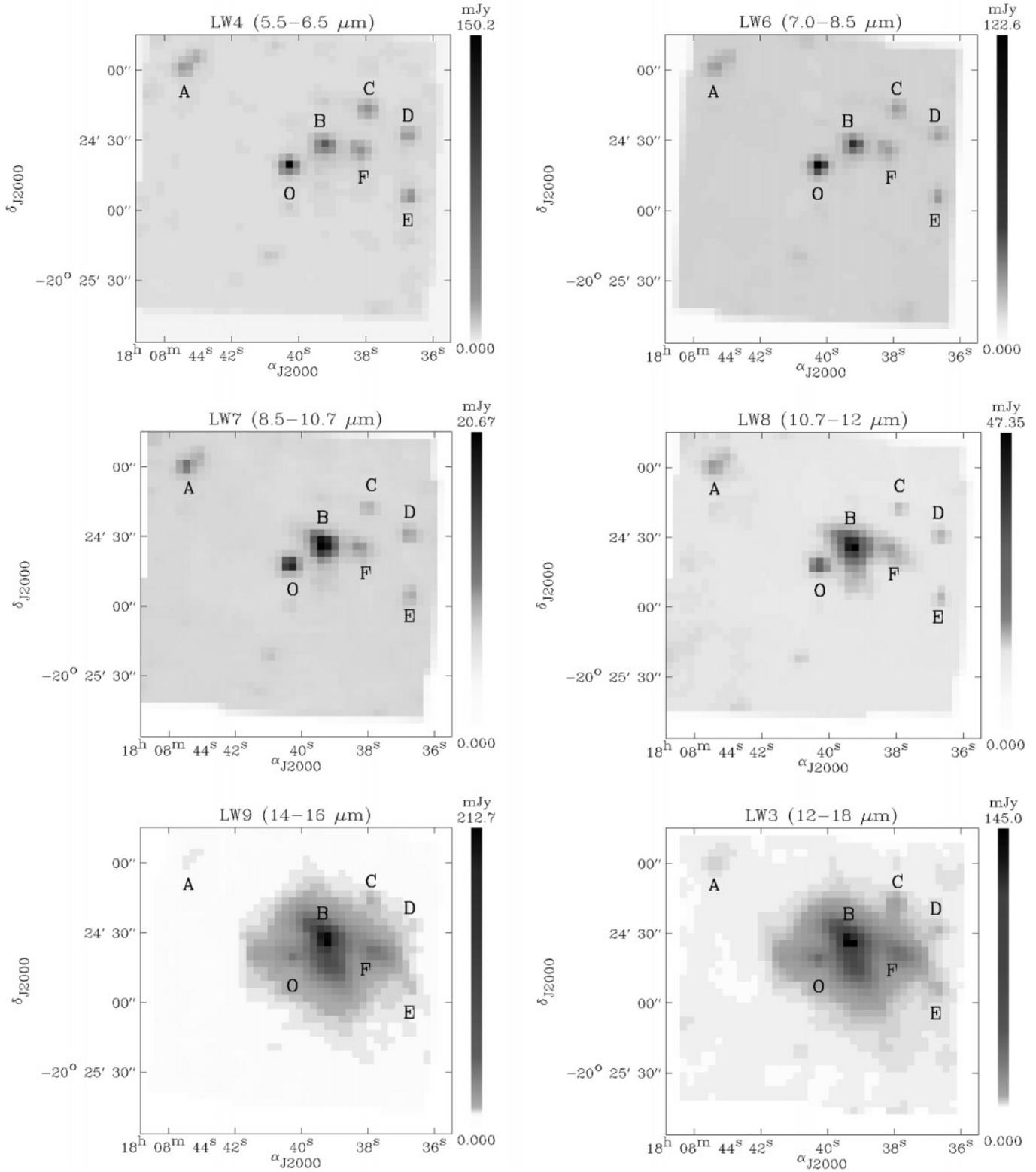


Fig. 4. Continuum images of the environment of SGR 1806-20 as seen by ISOCAM wide band filters with 3×3 arcsec² per pixel field of view. The global field of view is $\sim 2' \times 2'$. At $6 \mu\text{m}$ the LBV dominates and all the sources are point-like, except “B” (see Fig. 2): the individual stars are not resolved but the cluster seems to be dominated by the flux of the central star. With the increasing wavelength the presumed dust cloud appears and its peak seems located on the south-east star of the cluster (see Fig. 1). Stars “O” (the LBV), “C”, “D”, “E”, and “F” seem to be in or behind this cloud.

imposed LW3 level image with the LW4 color image in Fig. 1, the cloud appears to be centered on the south-east star of the “B” cluster. From this spectral evolution and the extinction of “B” and the other stars (except “A”) in the J-band image compared to the K’-band one, we suggest that this is a dust cloud, birth place of the cluster “B” which is probably composed of hot giant massive stars. These stars are behind or still partially embedded in this cloud and heat it up, so it appears bright around $15\ \mu\text{m}$. “O”, “C”, “D”, “E” and “F” seem to be in or behind this cloud, but “A” seems to be a foreground star.

This assumption is supported by the spectral energy distribution of these objects. In Fig. 5 we show the observed flux densities in the J, H and K’ bands, and in the large ISOCAM filter bands (see Fig. 4 for the corresponding wavelengths). We overplotted in each case an approximate fit for the data (solid lines) which is the sum of a “hot” black body (dashed lines) and a “cold” one (dotted lines), both attenuated by the interstellar extinction law of Rieke & Lebofsky (1985). As we have already noticed, “B” is a cluster of resolved stars in the J, H and K’ images, but is unresolved in the ISOCAM images. So for its photometry in the near infrared, we integrated the flux density over a circle surrounding the four stars of this cluster. For $\lambda < 10\ \mu\text{m}$ the spectra are consistent with those of hot supergiant stars through the interstellar absorption $A_V \sim 30\ \text{mag}$, except for “A” whose spectrum corresponds more likely to $A_V \sim 14\ \text{mag}$, indicating that “A” is a foreground star. For $\lambda > 10\ \mu\text{m}$, the flux of the dust cloud, presumed to be heated by these hot stars, is dominant. For “O”, “C” and “F”, closer to the “B” cluster than “D” and “E”, the dust cloud is fitted by a hotter black body (150 K and 160 K) than for “D” and “E” (120 K and 130 K). The rough black body model fits our data well for “O”, “B”, “C” and “F” (see Fig. 5). The absorption $A_V \sim 30\ \text{mag}$ appears to be the same for these stars, so they are probably embedded in the cloud.

“O” is very luminous, as expected from an LBV candidate. But the stars in the “B” cluster are also luminous. A simple estimate of their individual mean luminosities in our observational wavelength range shows that each is comparable to the LBV’s estimated luminosity in the same range. We can compare the LW2 ($5.0\text{--}8.5\ \mu\text{m}$) image taken 11 days before the 1997 April 14 burst reported in Hurley et al. (1999), and both the LW4 ($5.5\text{--}6.5\ \mu\text{m}$) and LW6 ($7.0\text{--}8.5\ \mu\text{m}$) images, taken only 2 hours after this burst. No new source appears on the latter images, and for each observed source, the fluxes in the three bands are consistent with each other, within the 20% typical error due to ISOCAM photometry. Thus, there is no evidence of additional heating by the high energy activity of SGR 1806-20, before or right after this burst.

Concerning the LBV “O” flux, our observed near-infrared magnitudes are: $J = 13.72 \pm 0.15$, $H = 10.49 \pm 0.13$ and $K' = 8.76 \pm 0.12$. If we compare these to our previous observations in July 1994 (Chaty 1998), the flux variation in the J and K’ bands is less than 0.1 mag. These values and the mid-infrared ones are consistent with the previous published infrared measurements (see Kulkarni et al. 1995; Castro-Tirado et al. 1998, and Smith et al. 1997). So the J, H and K’ magnitudes show no significant variation greater than 0.1 mag over an interval of four years.

Table 1 summarizes the observation dates of the SGR 1806-20 soft gamma-ray bursts and its infrared counterpart during this time interval. We have also checked the near-infrared flux of stars “B” and “F” in 1994 and in 1997. Again the variation is less than 0.1 mag, the typical error in the flux. So there appears to be no variable source in the vicinity of the SGR 1806-20 radio core.

Now, let us suppose that the LBV is the physical counterpart of SGR 1806-20 and that they were born in the dust cloud at $\sim 15''$ from their present location. The plerions’ characteristics imply that they fade rapidly (Kulkarni et al. 1994) so the maximum pulsar age is $t_p \sim 10^4\ \text{yr}$. Then, at a distance of 14.5 kpc, the pulsar would have a minimum transverse velocity $v_p \sim 100\ \text{km.s}^{-1}$, and it would be a runaway neutron star. If the LBV is the donor, it is not fully understood how such a massive binary would have acquired this peculiar velocity without being disrupted.

Moreover, a recent paper by Hurley et al. (1999) presents a new estimate of SGR 1806-20’s location. Its most likely position would have a small displacement from the radio core of the SNR G10.0-0.3 coinciding with the LBV. This observation is consistent with our data showing no evidence of any binary activity. Hurley et al. (1999) propose that the neutron star’s progenitor and the LBV initially formed a binary system, which became unbound following the supernova explosion. It is possible that the radio core is due to the huge mass loss of the LBV, while the rest of the plerion is the remnant of the progenitor’s supernova explosion. As shown in Fig. 1, the new neutron star’s location is closer to the cluster of massive stars called “B” in this paper ($\sim 7''$ corresponding to $\sim 0.5\ \text{pc}$ at a distance of 14.5 kpc) than to the LBV ($\sim 12''$ corresponding to 0.85 pc). “B” lies at the edge of the 3σ equivalent confidence contour of SGR 1806-20’s position, presented in Hurley et al.’s (1999) paper, whereas the LBV is well outside this contour. This implies that the birth place of the SGR’s progenitor has an equal probability of being in the cluster, as near the actual LBV’s location. The argument for an alignment between SGR 1806-20 and a very luminous star such as an LBV, to that of other stars in the cluster is equally justified, since the mean luminosities of the stars are comparable with that of the LBV.

5. Conclusion

SGR 1806-20 is an X-ray pulsar, lying close to the radio core of the plerion G10.0-0.3 (Kulkarni et al. 1994). From the latest models, this neutron star is surely a magnetar (Thompson & Duncan 1995) with its unusual physical characteristics leading to the gamma-ray outbursts. The previous search for a counterpart inside the ASCA and ROSAT error boxes led to the discovery of a luminous blue variable (LBV) star, a quite unusual star belonging to the brightest stars in the Galaxy, coinciding with the radio peak of the supernova remnant.

We have observed with ISOCAM the luminous blue variable star that was previously associated with SGR 1806-20, and a dust enshrouded cluster of equally luminous massive stars, which heat a dust cloud that appears very bright at $12\text{--}18\ \mu\text{m}$.

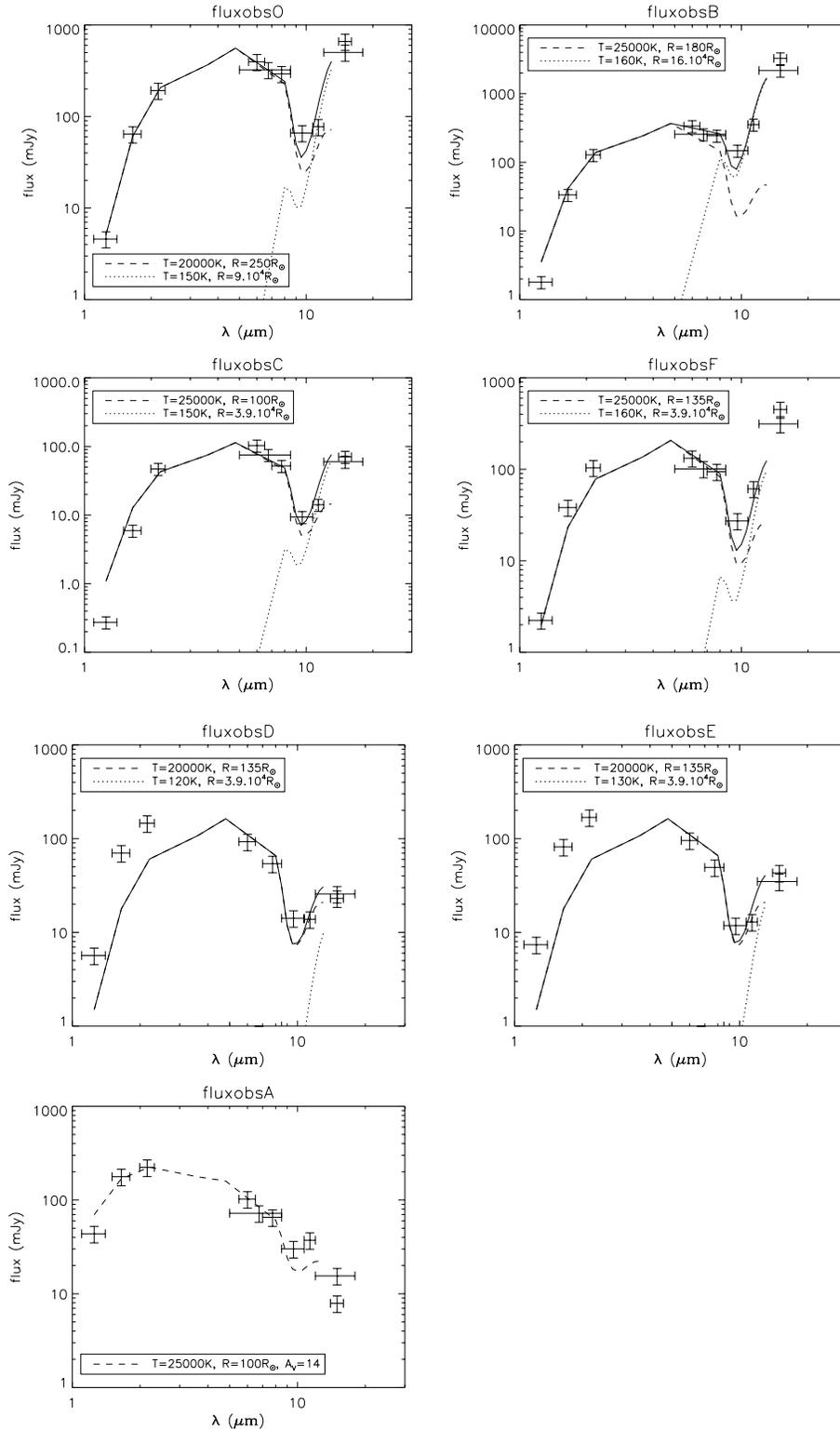


Fig. 5. Observed flux densities of “O”, “B”, “C” and “F” in the J, H and K' bands, and in the large ISOCAM filter bands (see Fig. 4 for the corresponding wavelengths). We overplotted in each case an approximate fit for the data (solid lines) which is the sum of a “hot” black body (dashed lines) and a “cold” one (dotted lines), both attenuated by the interstellar extinction law of Rieke & Lebofsky (1985) with $A_V = 30$ mag, except for “A” whose spectrum corresponds more likely to $A_V = 14$ mag. So “A” is a foreground star. For each fit, the presumed temperature and radius (in solar radius unit R_{\odot}) of the emitting region are noted down. “B” is a cluster of resolved stars in the J, H and K' images, but is unresolved in the ISOCAM images. So for its photometry in the near infrared, we integrated the flux density over a circle surrounding the four stars of this cluster. “D” and “E” are at the edge of the dust cloud showed in the LW3 image (see Fig. 4), it may explain that they are less attenuated in the J, H and K' bands than the others stars and thus that their flux densities are below the fit in these bands.

This infrared luminous cloud was probably the formation site of the cluster of hot stars, the LBV, and the progenitor of SGR 1806-20. For the region where these objects lie, there is excess emission at 12–18 μm , but there is no evidence of heating by the high energy SGR activity, although the observations were made only

2 hours after a soft gamma-ray burst (reported in Hurley et al. 1999).

J, H and K' bands observations of all the massive stars close to the SGR 1806-20 position show no significant flux variations greater than 0.1 magnitude over a time interval of four years. Therefore, the compact source SGR 1806-20 does not

Table 1. Chronology of the soft gamma-ray bursts and the infrared observations of SGR 1806-20 for the late 1993–1999 epoch.

X/ γ -ray	Infrared	Instrument and/or wavelengths	References
1993 Sept 29		BATSE	Kouveliotou et al. 1993
	1993 Oct 4-5	Palomar 1.5 m; I (0.90 μm)	Kulkarni et al. 1995
	1993 Oct 8	Hale 5 m; J (1.25 μm), H (1.65 μm), K (2.2 μm), L' (3.7 μm)	Kulkarni et al. 1995
1993 Oct 9		BATSE & ASCA	Tanaka 1993
1993 Oct 11		ASCA	Tanaka 1993
	1994 Jun 1	Hale 5 m; optical	Kulkarni et al. 1995
	1994 Jul 7	ESO/MPI 2.2 m; K' (2.15 μm)	Chaty 1998
	1994 Jul 8	ESO/MPI 2.2 m; J (1.25 μm), K' (2.15 μm)	Chaty 1998
	1994 Aug 19	UKIRT ^a ; K spectrum: 2.02–2.22 μm	van Kerkwijk et al. 1995
	1994 Oct 18	Hale 5 m; J spectrum: 1.19–1.33 μm , H spectrum: 1.54–1.78 μm	van Kerkwijk et al. 1995
	1995 Sept 24	JCMT ^b ; 800 μm	Smith et al. 1997
	1995 Sept 25	JCMT ^b ; 450 μm , 800 μm	Smith et al. 1997
1995 Sept 30		BATSE	Kouveliotou et al. 1995
	1996 Jul 3	GSCAO ^c 1.2 m; H (1.65 μm), K (2.2 μm)	Castro-Tirado et al. 1998
1996 Oct 30–31		BATSE	Kouveliotou et al. 1996a
1996 Nov 5–6	1996 Nov 6	RXTE / TCS ^d 1.5 m; K (2.2 μm)	Kouv96b ^e /C-T98 ^f
	1996 Nov 10	TCS ^d 1.5 m; J (1.25 μm), H (1.65 μm), K (2.2 μm)	Castro-Tirado et al. 1998
1996 Nov 19		Ulysses & BATSE	Hurley et al. 1996
1996 Nov 23		BATSE	Hurley et al. 1996
1996 Dec 30		IPN ^g	Hurley et al. 1999
1997 Jan 24		IPN	Hurley et al. 1999
	1997 Apr 3	ISOCAM; 6.75 μm	this paper
1997 Apr 14	1997 Apr 14	IPN/ISOCAM; 6 μm , 7.75 μm , 9.6 μm , 11.35 μm , 15 μm	Hurley et al. 1999/this paper
	1997 July 19	ESO/MPI 2.2 m; J (1.25 μm), H (1.65 μm), K' (2.15 μm)	this paper
1997 Aug 27		IPN	Hurley et al. 1999
1997 Sept 2		IPN	Hurley et al. 1999
1998 Aug 5		IPN	Hurley et al. 1999
1999 Feb 5		IPN	Hurley et al. 1999

^a United Kingdom Infrared Telescope, Mauna Kea, Hawaii

^b James Clerk Maxwell Telescope

^c German-Spanish Calar Alto Observatory

^d Carlos Sánchez Telescope, Observatorio del Teide (Canary Islands)

^e Kouveliotou et al. 1996b

^f Castro-Tirado et al. 1998

^g Interplanetary Network, consisting of BATSE, Ulysses, and KONUS-WIND

form a bound binary system with any of these massive stars. This is consistent with the magnetar model (Thompson & Duncan 1995) which can explain the bursts without accretion from a companion donor star.

According to the latest results (Hurley et al. 1999), the SGR's location appears to be closer to the cluster of giant massive stars than to the LBV. Emission from the LBV's mass ejections could be superimposed on the radio emission of the plerion, explaining the location of this star at its radio core. SGR 1806-20 appears as an isolated pulsar, whose progenitor could have been formed as a single star or in a binary system, either with the LBV or in the cluster of massive stars.

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