Mid-infrared observations of the SGR 1900+14 error box

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Abstract. We report on mid-infrared observations of the compact stellar cluster located in the proximity of SGR 1900+14, and the radio/X-ray position of this soft-gamma repeater. Observations were performed in May and June of 2001 when the bursting source was in an active state. At the known radio and X-ray position of the SGR we did not detect transient mid-IR activity, although the observations were performed only hours before and after an outburst in the high-energy band.

INTRODUCTION

Recent deep, high-resolution multi-wavelength timing observations of SGRs led to significant progress in our understanding of these enigmatic sources [1, 2]. Key goals in current SGR studies include the identification of their counterparts at long-wavelengths and a better understanding of their past and future evolutionary states (e.g., [3]). Of particular interest is their possible relation to the class of anomalous X-ray pulsars [4].

From the point of view of ground-based astronomy, among the known four (perhaps five) soft gamma-ray repeaters [1] SGR 1900+14 has the advantage that it (or better, its error box) is observable from the northern as well as the southern hemisphere. This increases the opportunities to monitor this source in the optical/infrared bands whenever it is in an active state. During its recent activity cycle in spring/summer 2001 we observed the SGR 1900+14 error box with the ESO 3.6-m telescope using the newly commissioned TIMMI 2 mid-infrared camera. The campaign covered the position shortly after and before an outburst in the high-energy band.

OBSERVATIONS

TIMMI 2 (Thermal Infrared Multi Mode Instrument) is a thermal infrared camera designed for direct imaging at 5, 10, and 17 microns. This instrument is the successor of TIMMI 1 which was decommissioned in 1999. TIMMI 2 uses a 240 × 320 pixel AsSi BIB detector [5], the scale is 0.3 arcsec per pixel for observations in the N band. The field of view is 96′′ × 72′′. An overview of TIMMI 2 is given in [6], and some early observational results are presented in [7].

Our first observing run was performed on May 22, about 1 month after the giant gamma-ray flare detected from SGR 1900+14 on April 18 [8], and also about 1 month before the detection of the next high-energy outburst from this source [9]. A second observing run, again using TIMMI 2 at the ESO 3.6-m telescope, was carried out on June 28, now only about 9 hours after and 6.5 hours before a gamma-ray outburst [9, 10]. All observations were performed using the N11.9 filter. N11.9 is a narrow-band filter centered at about 11.6 microns (FWHM of ∼1.2 microns). We selected this filter, because it offers the highest sensitivity [5].

RESULTS AND DISCUSSION

With a flux density limit of about 3 mJy our observations represent the deepest mid-infrared observations of the SGR 1900+14 field performed to date. Furthermore, with a delay of only 9 hours after a high-energy outburst our observations probe the SGR environment at a time when it could still be affected by the energy input from the burst. However, we do not detect any mid-IR flux that would indicate an energizing interaction between the burst and the circum-burster medium.

Basically, there are two issues that can be addressed with our observations. The first one is the relevance
FIGURE 1. Deep I-band image of the compact stellar cluster in the proximity of SGR 1900+14 with the position of its two most prominent members, two nearly identical M5 supergiants, indicated as A, B. In order to identify the cluster the M5 supergiants and star C have been psf subtracted. Also indicated is the putative radio/X-ray position of SGR 1900+14 suggested in [11, 12]. Adapted from [13]. To provide a scale, star B is separated by 11.8 arcsec from this radio position [14].

FIGURE 2. Part of van Paradijs’ published countour plot of their mid-infrared observations with TIMMI 1 (top; [15]) compared to our TIMMI 2 image (May 2001; bottom). The stars A and B refer to Fig 1. Contour levels correspond to 28, 56, 112, 224, 448 and 896 mJy per square arcsec (top panel) and also include 14 mJy in the bottom panel. The point-spread function of the 3.6-m telescope is known to deviate slightly from circular.

The compact stellar cluster

To our knowledge, the only mid-infrared observations of the SGR 1900+14 error box to date were performed by van Paradijs et al. in July 1995 [15]. These authors used the ESO 3.6-m telescope equipped with the TIMMI 1 camera. At the time of their observations neither a radio transient nor an underlying compact stellar cluster was known, so their main focus was the bright M5 supergiants discovered in the arcmin-sized SGR error box ([16, 17]; Fig. 1).

Based on the earlier observations, our primary attention focused on potential evidence for long-term variability in the interstellar medium surrounding the bursting source, including any gas associated with the M5 supergiants (Fig. 2). Van Paradijs et al. measured a flux density of stars A and B in the \( N \) band of about 1.64 and 0.86 Jy, respectively [15]. On our May 22 image we measure a flux density in the N11.9 filter of 2.11 and 0.90 Jy, respectively. Since the spectrum of these stars is rapidly rising in the mid-infrared (see figure 5 in [17]), these measurements are not in conflict with each other. Furthermore, they are in agreement with recent observations of this region by the MSX satellite during its Galactic Plane survey (Fig. 3; see the MSX database at [18]): For the D-band image taken at 12.13 microns we measure a total flux density of the unresolved A+B stars of 2.97 Jy.

A comparison between our two observing runs seems to reveal a slight short-term variability of star B. We consider this not surprising, however, since supergiants are known to exhibit some optical variability [17]. Spots on the stellar surface, for example, could be responsible for variations of a cool supergiant [19]. Van Paradijs et al. found evidence for a possible component of extended diffuse emission surrounding the M5 supergiants [15]. Such a component is not apparent in our data, although
our observations are more sensitive. The non-detection of a diffuse emission component is interesting because it constrains the amount of hot dust within the stellar cluster. Moreover, a large local flux of UV photons could produce emission from PAHs of which one feature falls into our chosen filter band. We do not detect this feature. Although we have not yet performed detailed simulations, we believe that this non-detection indicates that there are no strong UV sources within this cluster. This is in agreement with the non-detection of radio continuum emission from this cluster [20]. Obviously this is a stellar cluster where high-mass star-formation stopped $\gtrsim 10^7$ years ago.

The recent discovery of a compact stellar cluster underlying the M supergiants [13], and the discovery of a similar stellar cluster close to SGR 1820–20 [21], raises the question of what role such clusters might play in the formation of SGRs. In the case of SGR 1900+14 there is an extensive debate in the literature of whether the cluster and the SGR are indeed physically related or whether they are located at very different distances in the Galactic Plane and only appear to be connected by random projection. Recently, the debate has focused on the different interstellar extinction measured towards the M supergiants on the one hand [17], i.e. the most luminous members of the stellar cluster, and toward the quiescent X-ray counterpart of the SGR on the other hand [20]. Since the former is several magnitudes higher than the latter, this seems to argue against a physical relationship between the cluster and the SGR.

In principle, mid-infrared observations could be used to constrain the distance of the stellar cluster, because they are less affected by interstellar extinction. Assuming that star C in Fig. 1 is either a member of this stellar cluster or seen in front of this cluster, we can place a lower limit on the distance of the cluster by the fact that we do not detect this star on our frames. The spectral type of this star was determined by Vrba et al. to be M2 III [17]. Its predicted $N$-band luminosity [22, 23] together with our non-detection of it places this star at a distance of $d \gtrsim 8$ kpc, in agreement with constraints deduced from earlier optical observations [17]. A similar derivation of an upper limit on the cluster distance based on our observations is more uncertain. Although the spectral type of the supergiants seems to be relatively secure (M5; [17, 24]), there is still the question of their absolute luminosity in the N band. Although theoretical $V - N$ colors are available in the literature, the observational basis of mid-infrared observations of supergiants is still very small. This makes it difficult to estimate the uncertainty that can be attributed to the choice of a certain $N$-band luminosity for these stars.

Although we cannot provide a strong upper limit on the distance of the stellar cluster based on our mid-infrared observations, we draw attention to the following issue concerning the extinction measured toward the M supergiants [17]. In light of the recent discovery of an underlying compact stellar cluster [13] the possibility remains that the measured extinction is the sum of ordinary interstellar extinction and intrinsic extinction within the compact stellar cluster. The observed scatter in the $I - J$ colors of the cluster stars [13] significantly exceeds their uncertainties, indicating that several stars in this cluster suffer significant intracluster extinction. Not only that, but the spread of the ($I - J$) color of the cluster stars takes up about one half of the $\Delta(I - J)$ between the supergiants A and B and the least reddened star at about $I - J \approx 6.7$ (table 1 in [13]). Naturally, there is no ad hoc reason to assume that the M supergiants, the brightest beacons of this cluster, are by chance located in front of the stellar cluster. We discuss this point further elsewhere [25].

**FIGURE 3.** The SGR 1900+14 error box was also imaged by the Midcourse Space Experiment (MSX satellite) in 1996/97 [18]. Shown is the image obtained at 8.28 microns. Note that the MSX satellite did not resolve the stellar cluster. The image appears extended along the scan direction of the satellite.
ment. Because of the possible presence of fossil accretion disks around SGRs, and their potential AXP relatives, we modeled the spectral energy distribution (SED) of such a disk following Perna et al. [26]. At first glance, mid-infrared observations are very promising for detecting such disks since their SEDs can peak in the infrared. However, even if we include 10 to 20 magnitudes of optical interstellar extinction ($A_V$) toward SGR 1900+14, compared to deep near-infrared observations [20] our flux density limit does not provide a strong constraint on any persistent accretion disk. We can report, however, that if any such a disk exists around SGR 1900+14 then hours before and after a high-energy burst its flux density in the $N$ band does not exceed 3 mJy.

**CONCLUDING REMARKS**

The issue of whether or not SGR 1900+14 and the compact stellar cluster its proximity are physically related is crucially linked to the very uncertain distances. Are these objects located at the same distance or not? In this particular case, this question could be answered if a better understanding of the measured extinction toward the M supergiants and toward the SGR is achieved. The former might profit from deeper mid-infrared observations, the latter might gain from the recent discovery [27] of a persistent dust-scattered X-ray halo around the quiescent X-ray counterpart of the SGR, which could lead to a direct measurement of the extinction by the scattering dust along the line of sight [28]. The non-detection of any signal from the SGR might not be surprising if there is no accretion disk at all around the burster, as indicated by the observations performed to date [20]. But should one expect to detect any non-gamma-ray signal from the burster within hours of a high-energy outburst? This question remains to be addressed by further theoretical studies, but we note that there are now two cases where mid-IR observations were performed only a few hours after a SGR outburst (the other case is SGR 1820–20 [21]) and no signal from the burster or the ambient interstellar medium was detected down to a flux density limit of a few mJy. Future observations need to further push the sensitivity limit, and also sample more closely in time. Truly simultaneous coverage would require robotic observations, similar to those used in the search for prompt optical emission [29, 30].

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