Where is SGR1806-20?

T. Cline[1], C. Kouveliotou[2], E. Mazets[3], and S. Golenetskii[3]
[1] *NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA*
[2] *USRA - MSFC, Huntsville, AL 35812, USA*
[3] *Ioffe Physico-Technical Institute, St. Petersburg 194021, Russia*

Abstract

We have derived a new, precise position for the Soft Gamma Repeater SGR1806-20 by triangulating eight bursts observed by *Ulysses*, BATSE, and KONUS-WIND. The resulting error box, although within the radio contours of the Galactic supernova remnant G10.0-0.3, is significantly displaced from its core. Although this can be explained by a high velocity neutron star, it raises interesting questions about the model of SGR emission from this object.

1 Introduction:

The four known soft gamma repeaters (SGRs) are neutron stars in radio or optical supernova remnants. SGR1806-20 was discovered in 1986 (Laros et al. 1986) and underwent a period of intense activity in 1987 (Laros et al. 1987, Kouveliotou et al. 1987) which led to a relatively precise localization of the source by triangulation (Atteia et al. 1987). Based on this position, Kulkarni & Frail (1993) suggested that the SGR was associated with the Galactic radio supernova remnant (SNR) G10.0-0.3. This was confirmed when the ASCA spacecraft observed and imaged the source in outburst, leading to a ~1' radius error circle (Murakami et al. 1994). ROSAT observations of the quiescent X-ray source associated with SGR1806-20 confirmed the ASCA data (Cooke 1993; Cooke et al. 1993). It is believed that the SGRs may be 'magnetars', i.e. objects in which the magnetic field energy dominates all other sources of energy, including rotation (Duncan & Thompson 1992). In the case of SGR1806-20, evidence for this model comes from observations of the period and period derivative of the quiescent soft X-ray emission (Kouveliotou et al. 1998).

Studies of the radio nebula show evidence for changes in the contours on ~year timescales, and suggest that the neutron star may be located at the nonthermal core of the radio emission (Frail et al. 1997). The position of the core also coincides with that of an unsual star, identified as a luminous blue variable (van Kerkwijk et al. 1995). However, the connection between this object and the SGR is unclear.

SGR1806-20 has remained active over the past several years, and many bursts have been detected by the Interplanetary Network (IPN), consisting primarily in this case of BATSE, *Ulysses*, and KONUS-WIND. However, only eight events have been intense enough to trigger both *Ulysses* and a near-Earth spacecraft, resulting in high time resolution data (the other bursts were recorded with lower time resolution). It is these triggered events which lead to the most precise determination of the source position by triangulation

2 Observations:

The eight triggered bursts occurred over the period November 1996 - February 1999. In each case, triangulation using *Ulysses* and either BATSE or KONUS results in a single annulus of width ~30 - 45" which defines the possible arrival direction for the burst. Two such annuli define an error box, if the angular separation between their centers is sufficient to prevent the annuli from intersecting at grazing incidence. Over the ~2 yr period analyzed here, the *Ulysses*-Earth vector moved sufficiently to define a non-degenerate error box. With three or more annuli, the problem of defining the source location becomes overdetermined, and we can use a statistical method to derive the most probable source location. Briefly, this consists of defining a chisquare which is a function of an assumed source position in right ascension and declination, and of the parameters describing the eight annuli. The assumed source position is varied to obtain a minimum chisquare.

Figure 1 shows the ASCA, ROSAT, and IPN locations for SGR1806-20, along with the radio contours of G10.0-0.3. The ASCA error circle radius is 1', and is quoted as a systematic error, with no confidence limit given (Murakami et al. 1994). The ROSAT PSPC error circle radius is 11", with no confidence limit quoted (Cooke et al. 1993); we are currently reanalyzing the ROSAT data to establish it. An asterisk indicates the center of the non-thermal core, whose position coincides with that of the luminous blue variable. Another asterisk shows the position which is the best fit to the eight IPN annuli. The chisquare for the best fit position is 10.7 for 6 degrees of freedom (i.e., eight annuli minus the two fitting parameters, right ascension and declination). The non-thermal core has a chisquare of 96. The separation between the two positions is ~17".

3 Discussion:

In the magnetar model, the neutron star may be born with a high kick velocity (Duncan & Thomson 1992). In the case of SGR1900+14, there is evidence that neutron star transverse velocity may be as high as several thousand km/s. If the distance to SGR1806-20 is 14.5 kpc (Corbel et al. 1997) and its age is taken to be 10,000 y, the implied lower limit to the transverse velocity of the neutron star is a rather modest 113 km/s. Although this does not strain the magnetar model, the fact that the source lies outside the nonthermal core poses an interesting question for the specific model of SGR1806-20. The changes in the radio structure of the nonthermal core have been interpreted by Frail et al. (1997) as being due to the sudden deposition of relativistic particles and fields from the neutron star. However, if the neutron star does not lie in the nonthermal core, this model, while probably not ruled out, becomes less likely. Another interpretation suggests itself.

We speculate that the luminous blue variable, which may be driving a wind with a velocity ~500 km/s (van Kerkwijk et al. 1995), is instead responsible for the changes to the radio nebula. The neutron star progenitor may once have been in orbit about this massive star. Much of the energy imparted to it in the supernova explosion may have been expended overcoming the gravitational potential of this star, resulting the low implied transverse velocity of 113 km/s. At this point, however, we caution that such speculations still require more detailed examination and calculations.

4 References:

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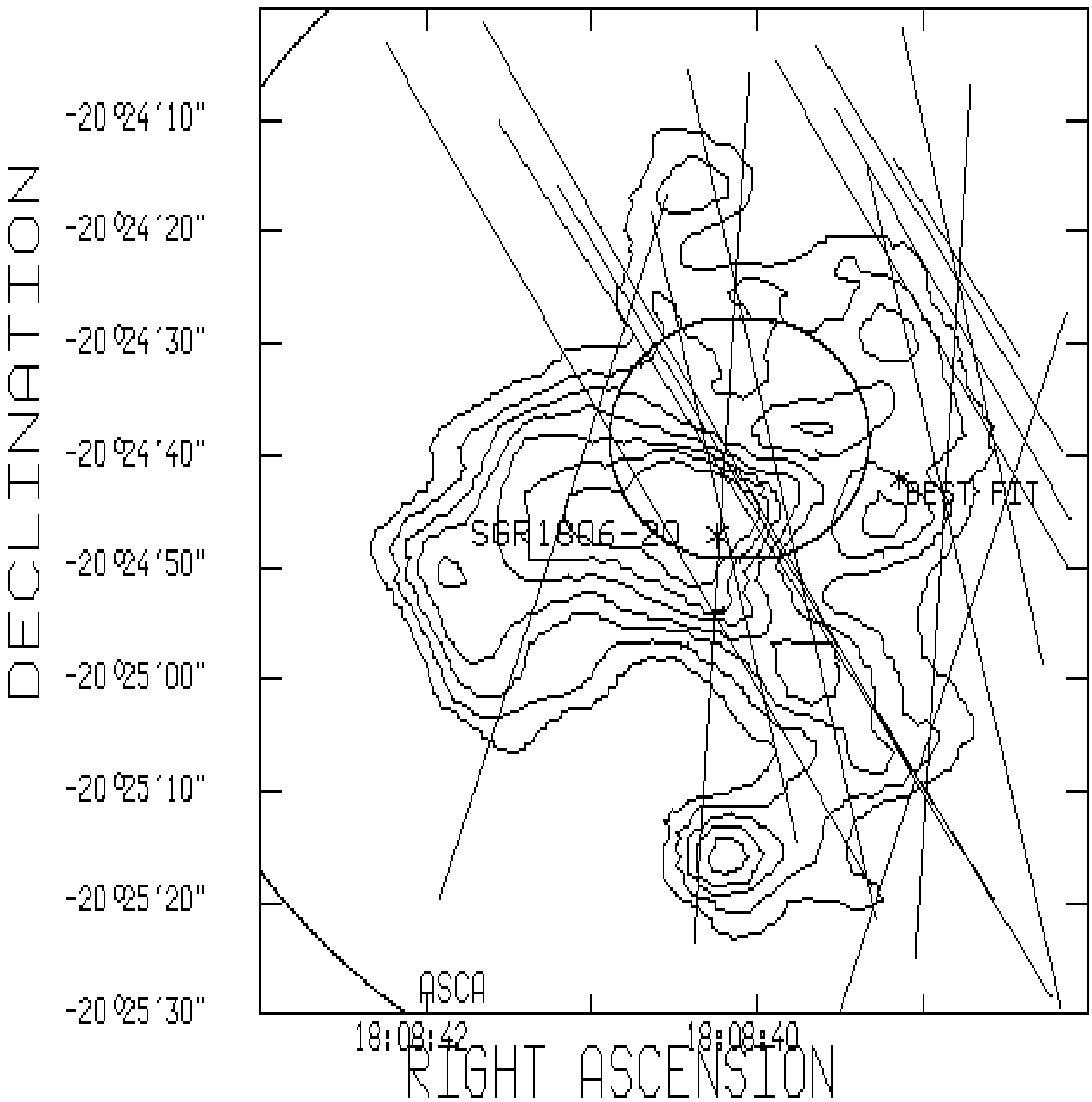

Figure 1. Localizations and radio contours of SGR1806-20. The ASCA error circle is just visible in the lower left and upper left corners. The smaller circle towards the center of the figure is the ROSAT error circle. The parallel lines represent the locations given by the 9 IPN annuli. The best fit position derived from them is indicated with an asterisk. The radio contours are also shown. The center of the non-thermal core, which has been suggested to be the location of the neutron star, is shown with an asterisk and labeled SGR1806-20.