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ROSAT Imaging of GRB920525 and GRB930118

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For this effort we requested ROSAT images of two small gamma-ray burst (GRB) error boxes. Our goal was to search for sources that might be associated with the quiescent site of a GRB. More than 1000 GRBs have been detected in the twenty five years since their discovery, yet their origin remains a mystery. No real-time or quiescent counterparts at any wavelength have been identified as sources of GRBs despite considerable follow-up efforts. Ground based campaigns to examine GRB error boxes shortly after the bursts have revealed no transient, or highly variable objects at optical and radio wavelengths in the time period >7 hours after the burst. Due to the heavy demand on X-ray satellite time, and the difficulty of re-scheduling observations, rapid follow-up observations at high energies have not been obtained as quickly as the ground based-efforts. In fact, X-ray images of GRB error boxes are normally obtained months-years after burst detection. The current fastest X-ray response time is over two weeks.

Deep imaging of GRB error boxes at X-ray wavelengths is an additional observational approach that can be used to constrain models of the origin of GRBs. In the extragalactic scenario for the origin of GRBs, the existence of X-ray emitting remnants appears unlikely. For instance, in the commonly favored scenario where the merging of two neutron stars is responsible for the GRB, nothing remains after the burst to cause long-lived emission. In galactic theories for the origin of GRBs, the favored sources are isolated neutron stars. Isolated neutron stars would be faint at both optical and radio frequencies, and thus escape detection even in deep GRB error box surveys. At X-ray energies, however, neutron stars could be quite bright. It is the search for these objects that has driven X-ray studies of GRB error boxes.

We requested ROSAT time to image two small GRB error boxes, but only one localization, that for GRB920525 was granted. This observation consisted of a 9.7 ksec HRI image of a 0.5° diameter field centered on the interplanetary network GRB error box. The field

center was $\alpha_{2000} = 20^h03^m28.7^s$ $\delta_{2000} = -42°34'12.0"$. The ROSAT HRI image was obtained 860 days after the GRB event and reached a 3σ flux level of $F_x \geq 4 \times 10^{-14}$ ergs cm^{-2} s^{-1}. Four X-ray point sources were identified by the ROSAT software, two of these, however, were only significant at a flux level below 3σ. None of these sources were within the confines of the IPN error box. On the digitized sky survey, faint ($m_p \geq 16$) stars are visible within the HRI error boxes of three of the four identified sources. No optical candidate was visible at the remaining HRI detection location.

We combined the results of our investigation of the GRB920525 error box with that of a prior ROSAT PSPC observation of GRB910814 and submitted them for publication. This paper was accepted and appeared in the July edition of the *Astronomical Journal* (T.E. Harrison, B.J. McNamara, C.L. Williams, and R.M. Wagner 1996 *AJ* 112, 216). In that paper (copy attached) we also reviewed past deep X-ray observations of GRB error boxes. We noted that 11 small GRB error boxes have now been imaged to sensitive levels ($F_x < 10^{-11}$ ergs cm^{-2} s^{-1}), and no unambiguous quiescent GRB sites have been identified. Our ROSAT observations, combined with these earlier observations, rule out a nearby population of hot neutron stars as GRB sites. The current X-ray limits do not, however, rule out cooler galactic neutron stars, or neutron stars located in the galactic halo. Unfortunately it will take X-ray observations that are more than an order of magnitude more sensitive than those obtained to date to detect such objects. Deep observations of this type can only be made of the very smallest error boxes, as the confusion rate at such faint flux levels ($N_{Sources} > 1000$ deg^{-2} at $F_x = 10^{-16}$ ergs cm^{-2} s^{-1}) would be considerable.

We conclude that based upon our efforts and those of others, deep X-ray observations obtained long after the GRB are not likely to yield further productive results until smaller GRB error boxes become available. It may be possible to obtain such small error boxes in the near future from XTE, HETE and an augmented IPN.