UNCOVERING THE PROPERTIES OF YOUNG NEUTRON STARS AND THEIR SURROUNDING SUPERNOVA REMNANTS

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Annual Report

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The subject grant provides funding through the NASA LTSA program. This five-year grant involves the study of young neutron stars, particularly those in supernova remnants.

In the second year of this program, the following studies have been undertaken in support of this effort:

3C 391

Our investigations of archival data from this centrally-brightened SNR reveal that the centrally-bright X-ray emission is thermal in nature, perhaps the result of evaporating clouds in the remnant interior. The remnant appears to be interacting with a molecular cloud to the northwest, and we show evidence of variable absorption consistent with this scenario. This work was published in *The Astrophysical Journal* under the title "ASCA Observations of the Thermal Composite Supernova Remnant 3C 391." The ADS abstract is attached.

G292.0+1.8

In our previous work on this SNR, we discovered a young neutron star and its associated pulsar wind nebula. We have carried out an investigation of the X-ray emission from the SNR itself in order to probe the properties of the progenitor that produced the compact object. Our investigations reveal ejecta synthesized in the progenitor as well as filaments of normal composition material which we interpret as shock-heated regions of a circumstellar shell produced by strong winds in the red/blue supergiant phases of progenitor evolution. This work, entitled "The Structure of the Oxygen-rich Supernova Remnant G292.0+1.8 from Chandra X-Ray Images: Shocked Ejecta and Circumstellar Medium" was published in ApJ Letters. The ADS abstract is attached.

3C 58

Our *Chandra* observations of this Crab-like SNR revealed the presence of a young, rapidly rotating pulsar. Follow-up archival investigations of *RXTE* observations recovered the period, and provided a measurement of the pulsar spin-down properties. We find that the pulsar has a magnetic field strength of 3.6×10^{12} G, typical of young pulsars. Association with the historic supernova of 1181 requires that the pulsar was born spinning at nearly the current observed rotation rate. This work has been accepted for publication in ApJ Letters. The ADS abstract for the work, entitled "Discovery of X-ray Pulsations from the Compact Central Source in the Supernova Remnant 3C 58" is attached.

In addition to the pulsation study, we have identified a central compact nebula around the pulsar in 3C 58 which we interpret as a toroidal structure associated with the pulsar wind termination shock. Spatial modeling of this emission allows us to constrain the total flux from the neutron star itself. Associating the pulsed component with emission from the pulsar magnetosphere, our modeling provides an upper limit to the surface temperature of the neutron star itself. This upper limit falls below predictions from standard cooling models, and implies the presence of exotic particles (such as pion condensates) or other processes that increase the neutrino production rate in the interior. A seminar on these results was presented at the Institute for Advanced Study (Princeton, NJ), and a manuscript summarizing the results is in preparation for submission to ApJ Letters.

RX J1856.5-3754

This isolated neutron star was observed for 450 ks with *Chandra* Director's Discretionary Time in an effort to search for spectral features associated with the stellar atmosphere. We pursued a different investigation with these data, performing an exhaustive search for pulsations. Our upper limit of 4.5% to the pulsed fraction from this neutron star sets strong

constraints on either the geometry (requiring the spin and magnetic axes to be aligned, or our line of sight to be very nearly aligned with the spin axis) or the mass-to-radius ratio. We show that, barring special geometric orientations, the lack of pulsations are suggestive of an extremely compact star, even by normal neutron star standards. This work, entitled "A Deep Search for Pulsations from the Nearby Isolated Neutron Star RX J1856.5-3754" has been accepted for publication in ApJ Letters. A copy of the ADS abstract is attached.

Workshop on Neutron Stars in Supernova Remnants

With colleague B. M. Gaensler, the Principal Investigator organized an international seminar on the subject of "Neutron Stars in Supernova Remnants" held in Boston, MA, in August 2001. This highly successful 4-day meeting attracted over 100 participants from around the world. The proceedings are in preparation for publication by the Astronomical Society of the Pacific (eds. P. O. Slane and B. M. Gaensler).