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INFRARED STUDIES OF SUPERNOVA REMNANTS WITH THE IRAS

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Abstract: A comparative study of the infrared and X-ray fluxes and morphologies of supernova remnants (SNR) can yield valuable information on their evolution and on their interaction with the ambient interstellar medium (ISM).

Infrared observations of SNR: The infrared observations used in this study were obtained with the Infrared Astronomical Satellite (IRAS) which performed an all-sky survey at 12, 25, 60, and 100 microns. Galactic remnants detected in the IRAS survey include the historical remnants: Cas A, Tycho, Kepler; and the adiabatic remnants: IC 443, Puppis A, RCW 86, and the Cygnus Loop. Among those not detected are SN 1006 and RCW 103.

Infrared emission mechanisms: Mechanisms operating within a SNR that can contribute to the observed infrared (IR) emission are: synchrotron emission from accelerated electrons; infrared line and free-free emission from shocked optical nebulosities; and thermal emission from dust. Thermal dust emission can arise either from interstellar or circumstellar dust swept up by the expanding supernova (SN) shock, or from circumstellar or supernova dust that is swept up by the reverse shock that propagates through the ejecta.

Comparison of IR to X-ray cooling of SNR: Thermal dust emission is the dominant source of IR radiation in all the detected remnants listed above. A comparison of the IR and X-ray morphologies of the extended remnants shows that they are spatially well correlated, suggesting that the IR emission arises from collisionally heated dust that resides in the X-ray emitting plasma. For a given dust-to-gas mass ratio and dust model the ratio of infrared to X-ray cooling of a remnant (hereafter the IRX ratio) is then only a function of gas temperature. We calculated this ratio for all remnants listed above, and compared it with the theoretically predicted value (Figure 1). We found that: 1) the observed IRX ratio follows the general theoretical trend of decreasing IRX ratio with increasing remnant age; and 2) the IRX ratio is significantly larger than unity for all remnants, suggesting that gas-grain collisions are the dominant cooling mechanism of the shocked gas. The enhanced cooling resulting from gas-grain collisions will, however, have a negligible effect on the dynamical evolution of the remnants considered here.

Interaction with the ISM: Some remnants have IRX ratios that deviate significantly from the theoretical value. These deviations can be shown to result from varying conditions in the ambient ISM.

Nature of the emitting dust: A detailed analysis of the spectrum of Cas A (Dwek, Dinerstein, Gillett, Hauser, and Rice; submitted to Ap. J.; see Figure 2), and a preliminary study of that of Tycho and Kepler indicate that the IR spectrum from these remnants arises from an interstellar mixture of silicate and graphite dust. The excess 12 microns emission, over that expected from a standard MRN grain size distribution, suggests the presence of very small dust particles in the ISM which are stochastically heated by the shocked gas.

Figure 1: The IRX ratio of selected SNR

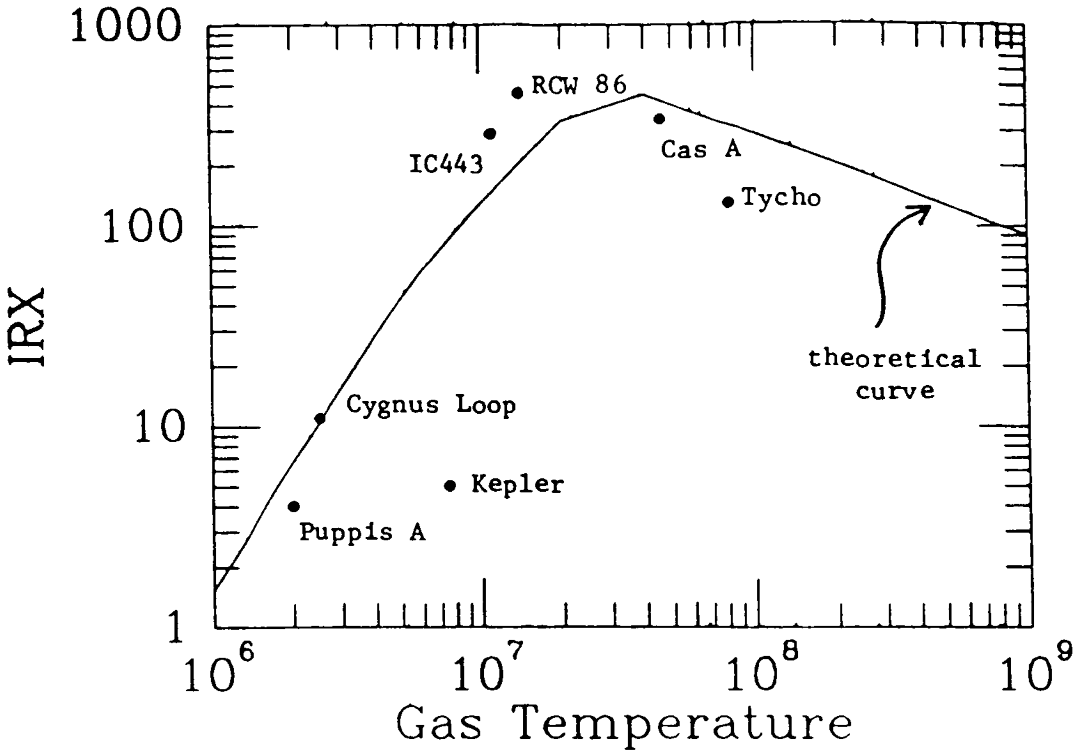

Figure 2: The infrared spectrum of Cas A