Infrared Spectroscopy of Supernova Remnants

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Infrared emission lines of [Fe II] and molecular hydrogen (H_2) falling in the atmospheric windows between 1 μm and 5 μm offer great potential for the study of moderate to low velocity (< 100 km s^{-1}) shocks, particularly those propagating in relatively dense regions where optical lines may be either not excited or obscured by dust. Such regions include the surroundings of forming stars, galaxy nuclei and supernova remnants. The new infrared grating/array spectrometer IRSPEC (Moorwood et al., 1986) at the ESO 3.6-m telescope is well suited to such observations and we report here some preliminary results for SNR's obtained with this instrument.

For diagnostic purposes, Fe^+ is of particular interest because of the possibility of determining N_e, T_e and A_v, in addition to its relative abundance, from lines of a single ion. The first detection of [Fe II] lines in the infrared in a SNR was reported by Seward et al. (1983) who observed the 1.644 μm and 1.600 μm transitions in the high density remnant MSH 15–52 with a low resolution filter spectrometer.

Figure 1 shows IRSPEC spectra of the [Fe II] 1.644 μm and 1.256 μm lines on the Large Magellanic Cloud remnant N 49. These lines originate from the same upper level and the observed 1.256/1.644 ratio of 1.3 in this relatively unobscured remnant agrees with that expected from the latest ratio of transition probabilities (Nussbaumer and Storey, private communication). Because remnants in the LMC subtend smaller angular sizes than those in the Galaxy they can be mapped more easily and, for N 49 and N 63 A, we have determined the total [Fe II] (1.644 μm) luminosities to be in excess of 200 $L_\odot$, a result of particular relevance to separate observations and interpretation of this line in galaxy nuclei which are beyond the scope of this article.

Exploratory spectra have confirmed that the 1.664 μm and 1.256 μm lines are the brightest [Fe II] lines observable from the ground between 1 μm and 5 μm. IRSPEC is more sensitive at 1.644 μm and this line has been detected in all the galactic SNR's observed so far (Puppis A, Kepler and RCW 103) as well as N 49, N 63 A and N 103 B in the LMC. The highest surface brightness is exhibited by RCW 103 in which the 1.644 μm line could be "peaked-up" and a region of ~ 30 × 70″ mapped with 5″ resolution by stepping the telescope to produce the false colour [Fe II] image reproduced in Figure 2. An H band (1.5 μm–1.8 μm) spectrum on the peak is shown in Figure 3. In addition to the prominent 1.644 μm line this also reveals several other lines attributable to [Fe II] including the 1.60 μm line which is shown at higher s/n ratio in the insert spectrum, made with a longer integration time in order to determine the density sensitive 1.60/1.64 line ratio. From this and the 1.26/1.64 ratio we obtain values of $N_e \simeq 4.10^3$ cm^{-3} and $A_v \simeq 6$ mag. respectively which are somewhat higher but still consistent within the uncertainties with earlier estimates by

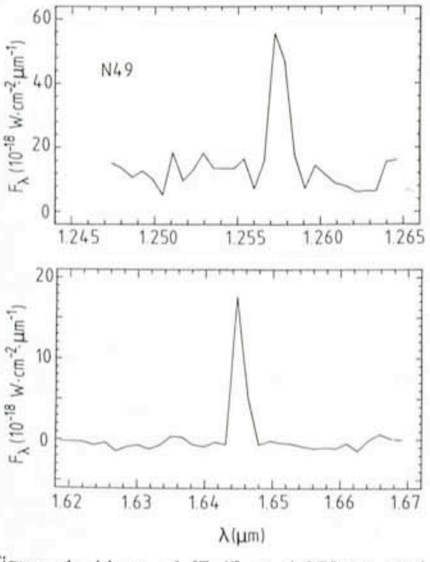

Figure 1: *Lines of [Fe II] at 1.256 μm and 1.644 μm in the Large Magellanic Cloud supernova remnant N 49. These lines originate from the same upper level and their ratio is thus a measure of the extinction.*

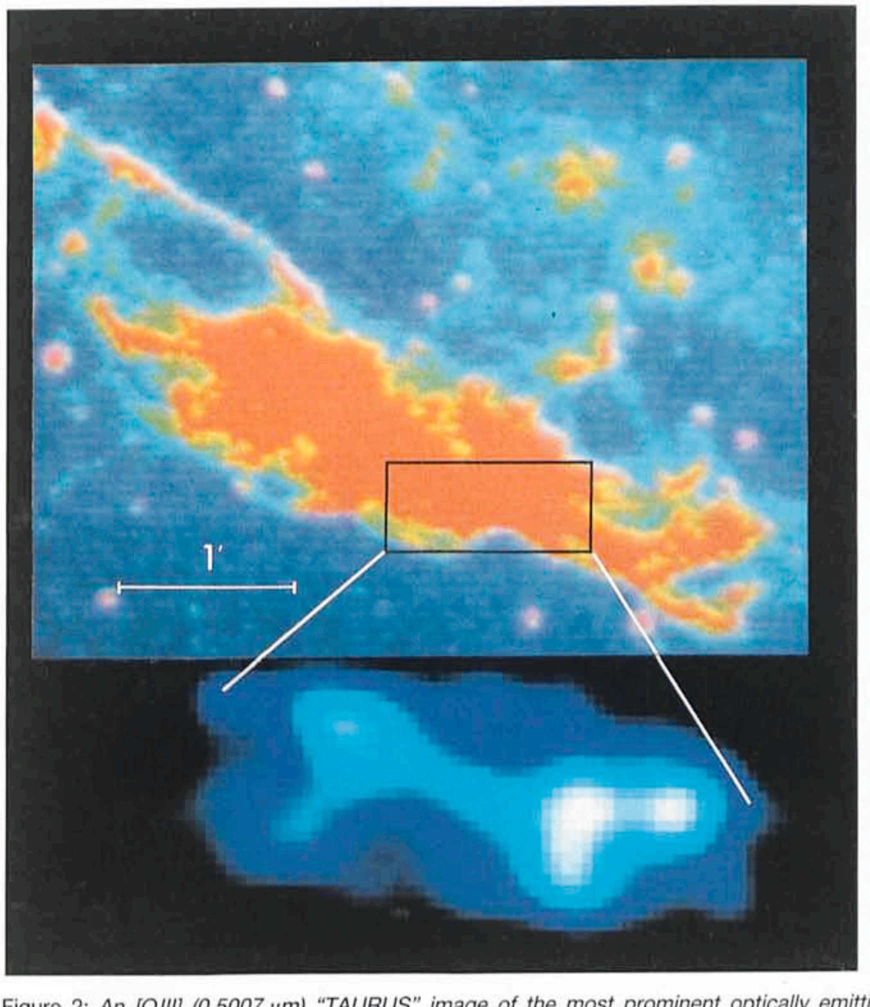

Figure 2: *An [O III] (0.5007 μm) "TAURUS" image of the most prominent optically emitting region of the galactic supernova remnant RCW 103 and, below, an [Fe II] (1.644 μm) image of the portion indicated, obtained by mapping with IRSPEC.*

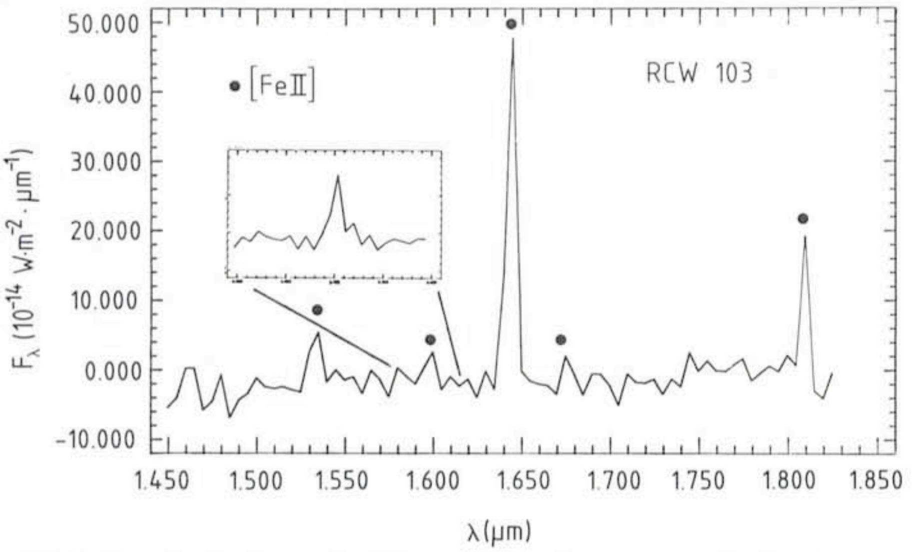

Figure 3: *An H band spectrum on the position of peak [Fe II] (1.644 µm) emission in RCW 103 (white in Fig. 2). Several other [Fe II] lines are present including one at 1.60 µm whose intensity relative to the 1.644 µm line is density sensitive. The insert spectrum shows a better measurement of this line made with a longer integration time.*

Leibowitz and Danziger (1983) based on optical [S II] lines and the Balmer decrement.

In addition to [Fe II], lines of H I (Brγ at 2.165 µm) and H_2 (1–0 S(1) at 2.12 µm) have also been detected in RCW 103 at 2% and 6% respectively of the 1.644 µm line intensity. To our knowledge, H_2 has only been detected previously in IC 443 which is known to be associated with a molecular cloud (Treffers, 1979). From the 1.644/Brγ ratio we derive $Fe^+/H^+ \simeq 5.10^{-5}$ assuming a Case B recombination hydrogen spectrum. Further interpretation of this quantity is model dependent due to the unknown ionization structure. Simple models however give $Fe^+ \simeq Fe$ and $H^+ \leqslant 0.1\,H$ implying $Fe/H \leqslant 5.10^{-6}$ or a depletion factor of > 0.8 for Fe and hence relatively little grain destruction. Of great interest in the future therefore is to see how this ratio varies from remnant to remnant.

We consider these first results to be encouraging both from the point of view of demonstrating the detectability of useful infrared lines and as an observational test of the available Fe^+ atomic data. Further attempts to exploit their astrophysical potential are clearly warranted as is their inclusion in future theoretical shock models.

References

Leibowitz, E.M., and Danziger, I.J.: 1983, *Mon. Not. R. astr. Soc.*, **204,** 273.

Moorwood, A.F.M., Biereichel, P., Finger, G., Lizon, J.-L., Meyer, M., Nees, W., and Paureau, J.: 1986, *The Messenger*, **44,** 19.

Seward, F.D., Harnden, Jr., F.R., Murdin, P., and Clark, D.H.: 1983 *Astrophys. J.*, **267,** 698.

Treffers, R.R.: 1979, *Astrophys. J.*, **233,** L 17.

NEWS ON ESO INSTRUMENTATION

F/35 Infrared Photometer at the 2.2-m Telescope

An infrared system consisting of an infrared photometer/adaptor, detector units and an F/35 chopping secondary mirror was installed and tested on the 2.2-m telescope in March 1987 in a collaboration with Heidelberg's Max-Planck-Institut für Astronomie.

MPIA developed and built the chopping mirror and its associated functions for focus and rotation. As can be seen in Figure 1, this infrared secondary is mounted in the original Coudé ring and, therefore, a change from visible (F/8) to infrared (F/35) observing requires a change of toprings.

The infrared photometer is a duplicate of that at the 3.6-m telescope, as described in the *Messenger* No. 39 by A. Moorwood and A. van Dijsseldonk. It is equipped at present with bolometer and InSb detector units which are basically identical to those offered at the 1-m and 3.6-m telescopes.

This new instrument has been offered

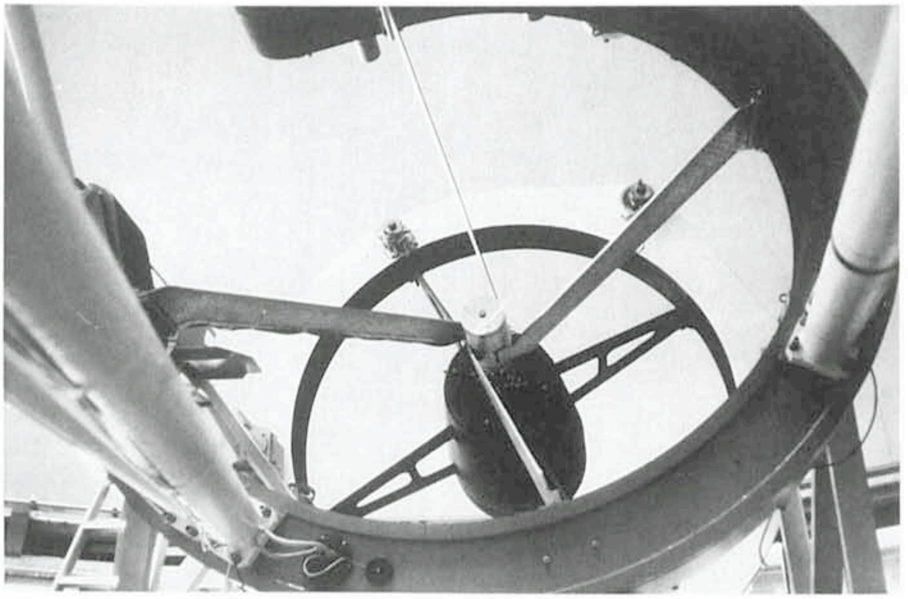

Figure 1: *F/35 infrared chopping secondary mirror mounted on the 2.2-m telescope. The mirror is only 21 cm in diameter. Behind is the "normal" F/8 front ring which has just been exchanged with the coudé ring used to support the infrared secondary.*