SOME RECENT INFRARED SPECTROSCOPY OF INTERSTELLAR PROCESSES

T. R. Geballe
U. K. Infrared Telescope; Hilo, Hawaii

I. Introduction

The intent of this paper is to demonstrate the potential which infrared spectroscopic techniques provide for studying interstellar processes. Several examples are given. The data were obtained at UKIRT, using its frequency-chopped Fabry-Perot spectrometer and its seven-channel cooled grating spectrometer.

II. Shocked Molecular Hydrogen

The emission from the V=1-0 S(1) line of H_2 has been mapped over a large portion of the supernova remnant IC443 by Burton et al. (1986, in preparation). A section of this map is shown in Fig. 1. The emission is clumped along a ridge where the expanding shell of the SNR has interacted with a molecular cloud. The clumps may be density enhancements in the molecular cloud or be the result of fragmentation caused by the shock. The observed intensity ratios of the 2μm lines imply that the H_2 is collisionally excited and that the extinction to the shocked gas is 2 mag at 2μm. The total luminosity from H_2 lines is about 1000 $L_\odot$, making IC443 one of the most luminous galactic H_2 line sources. The mass of hot, shocked gas is ~0.2 $M_\odot$.

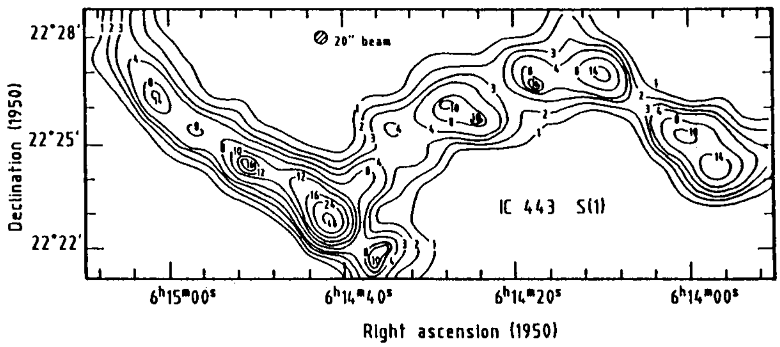
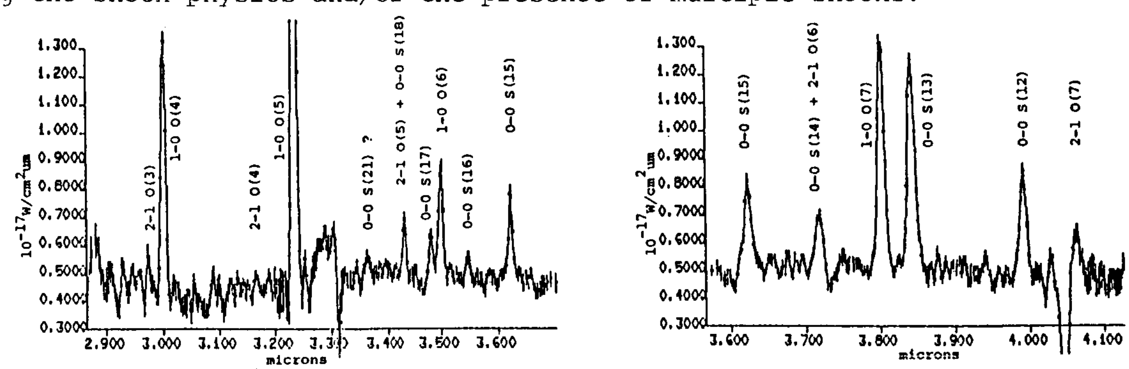


Fig. 1

Figure 2 shows a 3-4μm spectrum of Pk 1 in Orion (Wade and Geballe, 1986, in preparation). Numerous H_2 lines are easily seen. The most highly excited of these is the 0-0 S(17), whose upper level energy (T = 25,500 K) is the highest yet detected from H_2 in a shocked region. The even higher excitation S(21) line at 3.37μm may also be detected. Excitation temperatures derived from pairs of highly excited lines in this spectrum are typically 2700 K, considerably higher than those determined from the strong, but lower excitation 2μm lines. This result is expected for H_2 undergoing post-shock cooling. Accurately determined intensity ratios and velocity profiles of high and low excitation lines may yield important information concerning the shock physics and/or the presence of multiple shocks.

Fig. 2

Orion Pk 1



II. Molecules in Grain Mantles

Ice band spectra at resolving powers of 100 have been in existence for many years. The combination of observations from Mauna Kea and higher spectral resolution allow a significant increase in information. Figure 3 shows the ice band of GL2136

(Greenberg et al.; 1986, in preparation), obtained at a resolving power of ~350. For the most part the profile is smooth, but several distinctive structures are seen. These are: a narrow maximum in optical depth at 3.09µm, a shoulder at 3.25µm, and (possibly) a shallow feature at 3.4µm. All have been seen in spectra of other sources. No sharp features have been detected on the long wavelength wing.

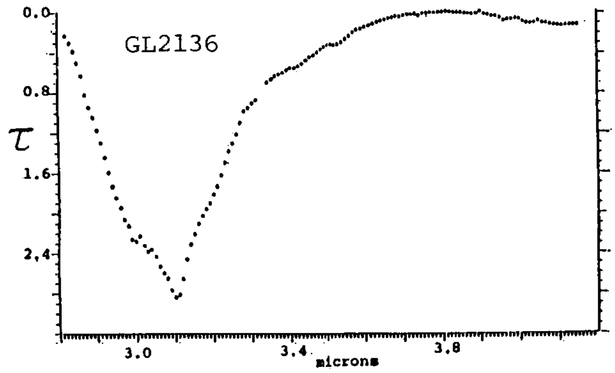


Fig. 3

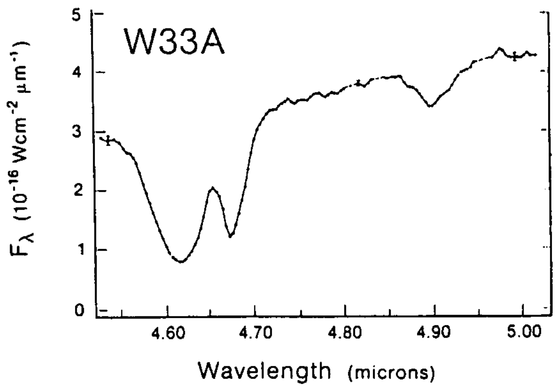


Fig. 4

The infrared source W33A is perhaps the most important astronomical resource for the study of grain mantles. Its 4.5-5.0µm spectrum (Geballe et al., 1985, Astron. Ap., 146, L6) contains three strong absorptions (Fig. 4). The narrowest of these, at 4.67µm, due to solid CO, has been detected in many obscured sources. The others, at 4.62µm and 4.90µm, have not been clearly detected elsewhere. Work by the Laboratory Astrophysics group (Leiden Univ.) indicates that their carriers are, respectively, unidentified C≡N - and sulfur - bearing molecules which are produced on the mantles by UV-photolysis.

III. Unidentified Emission Features

Recent spectroscopy of the well-known 3µm unidentified emission features has resulted in 1) accurate characterizations of their spectral shapes, 2) proof of the existence of source-to-source variations in their relative strengths, and 3) the discovery of several new emission features. Figures 5 and 6 are a good example of the range of phenomena which has been found. The planetary nebula BD +30 3639 exhibits a strong 3.3µm feature, a weak or absent 3.40µm peak, and a "plateau" of emission extending to 3.6µm (Geballe et al., 1985, Ap. J., 292, 500). In contrast the source IRAS 21282+5050 has, in addition to a strong 3.3µm feature and plateau, a strong 3.40µm feature and additional peaks at 3.46, 3.51, and 3.56µm (de Muizon et al., 1986, Ap. J. Letters, in press). The variety and wavelength range of the 3µm features appears to be consistent with their being emitted by PAHs (some with molecular subgroups attached), but specific identifications have not yet been made.

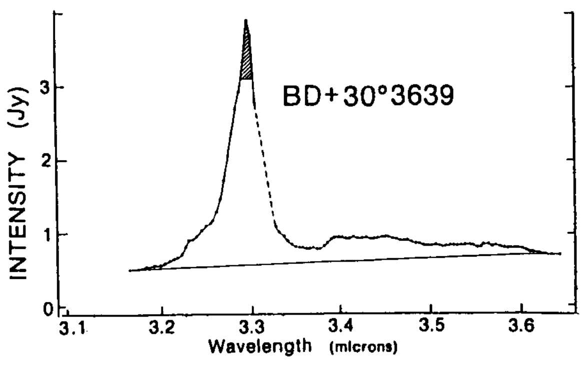


Fig. 5

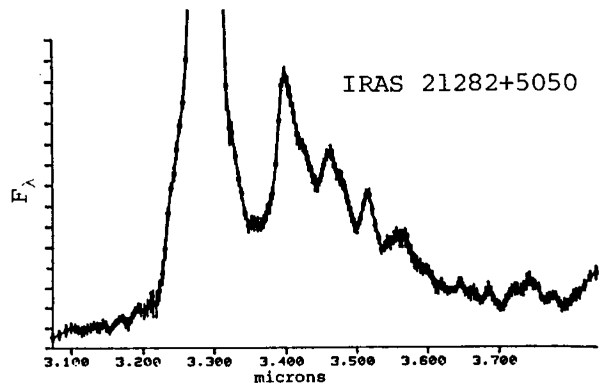


Fig. 6