PAH EMISSION FROM NOVA CEN 1986

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ABSTRACT. We report the discovery of broad emission features between 3.2μm and 3.6μm in the spectrum of Nova Cen 1986 (V842 Cen) some 300 days following outburst and remaining prominent for several months. The general characteristics of these features are similar to those attributed to PAH molecules in other dusty sources, although the relative strengths are different, and these observations provide the first clear evidence for molecular constituents other than graphite particles in the ejecta of novae.

1. INTRODUCTION

Since the original discovery of a dust emission phase in FH Ser (Hyland and Neugebauer 1970), and subsequent investigations which show that a dust phase is common to many novae (Ney and Hatfield 1978, Gehrz et al. 1980 a, b 1988), it has been realised that novae provide unparalleled opportunities for the investigation of the formation and dispersal of dust particles into the interstellar medium. Studies of the nature of the dust found in novae outbursts should provide clues on the abundance characteristics of the ejecta, and of the physical conditions existing during dust formation and destruction.

Photometric infrared studies of several novae have been reported in the literature (Ney and Hatfield 1978, Gehrz et al. 1980 a,b, 1988, Geisel, Kleinmann and Low 1970, Mitchell et al, 1985). Although these show remarkable similarities in the infrared secular development of novae, with a number of intermediate speed novae exhibiting strong dust emission, there exist wide differences in the optical depth of dust formed.

Little definitive information regarding the nature of the dust particles has so far been obtained, and the determination of the relative contributions of various dust constituents in novae ejecta remains one of the key issues to be addressed. The smooth black-body nature of the continua and apparent lack of silicate or other emission features in the 8-13μm region as determined from broad and intermediate-band photometry (other than in Nova Aql 1982, Bode et al. 1984) has led to a consensus view of dust in most novae as carbon particles, probably in graphitic form (see Bode and Evans 1983 for a discussion of this point). It might be expected that the UV radiation field experienced by carbon rich dust in novae ejecta would be conducive to the excitation of PAH type molecules if they are present in the outflow. However, data of sufficient resolution to determine whether weak dust emission features are present in novae ejecta have not been available. Infrared spectroscopic observations have been at a premium and have not had the time coverage of the photometric data. One of the key motivations for the present program of observations has been to obtain secular spectroscopic data in the 1-5μm region with sufficient resolution to determine if and when dust emission signatures reveal themselves.

2. THE SPECTRAL DEVELOPMENT OF NOVA CEN 1986

Nova Cen 1986 (V842 Cen) was discovered in 1986 November several days before maximum light (McNaught 1986). Because of its brightness, position, and the availability of previously scheduled time, Nova Cen has provided us with one of the best opportunities yet for significant secular studies of the infrared spectrum development of a nova. The first spectrum was obtained on 1986 December 19, and since then data has been obtained at roughly regular intervals for about 18 months.

Spectroscopic and photometric infrared data have been obtained with the cooled grating spectrometer (CIGS) and photometric systems on the ANU 2.3m telescope at Siding Spring Observatory, and also with the infrared spectrometer (FIGS) on the Anglo-Australian telescope. Wherever possible, spectroscopic data were obtained with a resolving power of $\lambda/\delta\lambda \sim 500$, covering the 1-5μm windows. A selection of spectra in the 2.9-4.1μm wavelength range obtained on five different occasions between 1986 December and 1988 January is shown in Figure 1.

Early spectra of the nova, taken some 30 days after outburst, when no dust emission was evident,showed the presence of strong emission lines of H, He, OI as well as CO first overtone emission similar to that seen in NQ Vul (Ferland et al. 1979). In the three micron region, strong atomic emission lines mask the appearance of any dust or molecular features. As expected for this relatively slow nova, by analogy with FH Ser, dust formation occurred around 55 days following outburst, and produced an optically thick dust shell which lasted for some 75 days. The dust emission dominated all wavelengths longer than the J(1.25μm) band until early 1988. Spectra taken soon after the formation of the dust shell (1987 January) show the presence of an extremely smooth dust continuum with a blackbody temperature of about 650K (Hyland and McGregor, 1987). Examination of the spectrum in the three micron region, where dust and molecular signatures are expected, showed no significant features against the smooth continuum.

However, spectra taken in 1987 September, when the shell temperature was closer to 800K, and subsequent measurements up to 1988 May, all show the presence of broad spectral features between 3.25 and 3.5μm with characteristics similar to those of the proposed PAH bands. We believe that this is the first time that such features have been seen in the spectrum of a nova.

The absolute integrated strength of the feature in 1987 September ($\sim 1.2 \times 10^{-17}$ W/cm^2), was such that it would not have been visible against the continuum when the dust shell first formed, and so it is not possible to say whether the PAH molecules formed simultaneously with the graphitic like dust, or was formed subsequently by processing of the dust. By 1987 July it should have been possible to measure a feature with the strength of that found in September, although this is greatly hampered by imperfect division of telluric features close to 3.3μm. Nevertheless, it appears (Fig. 1) that the 3.4μm emission was not present in July, and we favor the formation of molecules by the processing of existing graphitic grains.

The integrated strength of the features decreased by a factor of ~2.5 between 1987 September, and 1988 January, while the continuum dropped by a factor of ~6 during the same period as the dust became progressively more optically thin. This can be attributed to an increase in the relative number of excited PAH type molecules.

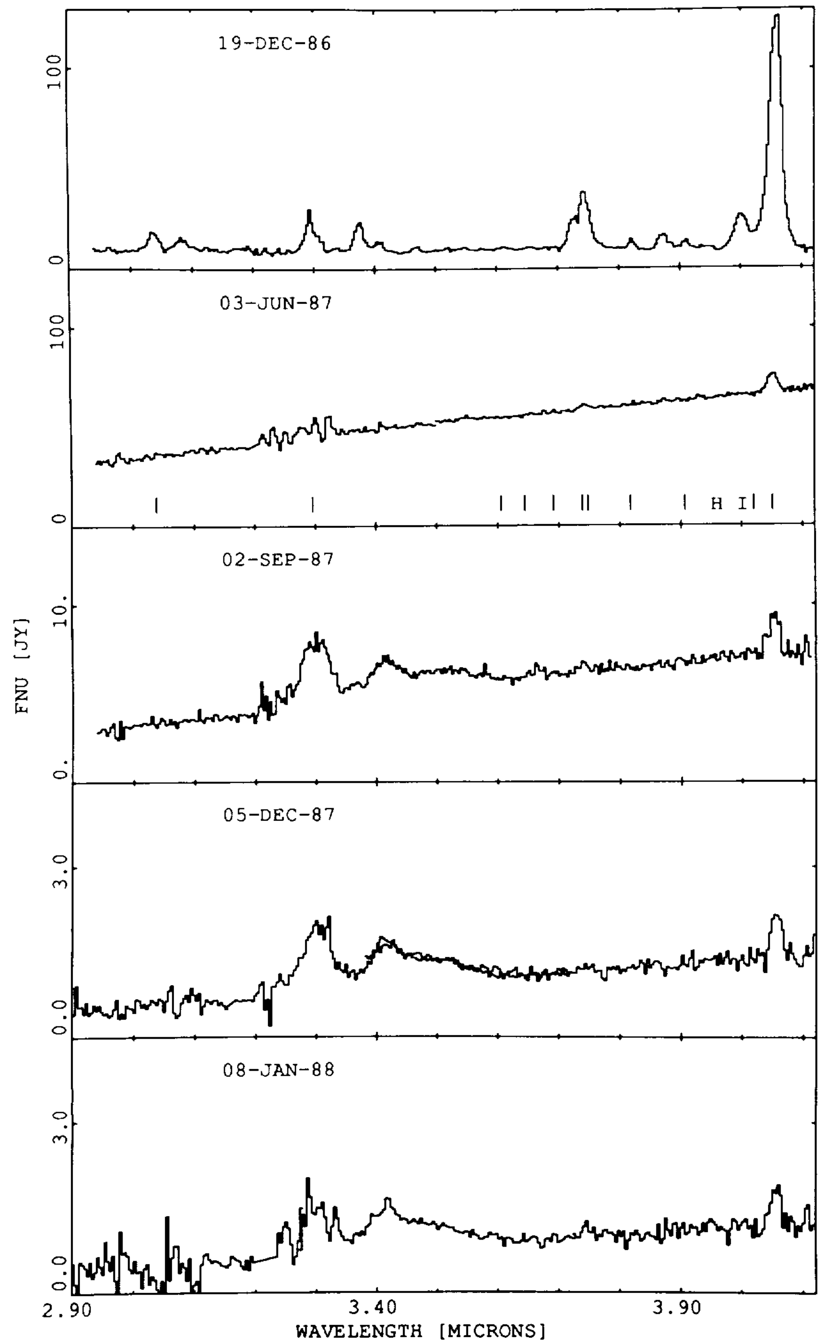

Fig. 1 Spectra of V842 Cen from 2.9-4.1μm obtained on five different occasions showing the development of the 3.3 and 3.4μm features. The top three spectra were obtained with CIGS on the MSSSO 2.3m telescope, while the remainder were obtained with FIGS on the AAT.

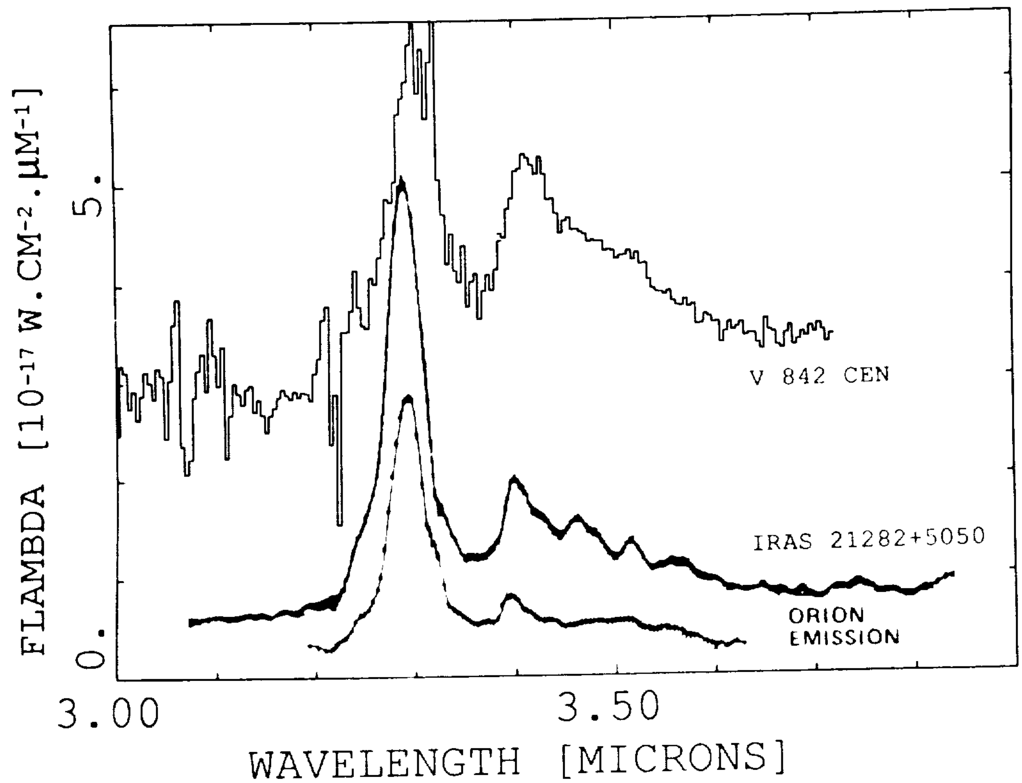

Fig. 2 A comparison of the observed 3μm spectrum of V842 Cen with spectra of IRAS 21282+5050 and the Orion Bar (see text). The spectrum of the nova has been arbitrarily shifted by the addition of a constant (10^{-17}).

3. PAH CHARACTERISTICS

The emission features observed in V842 Cen are compared with observations of PAH features in IRAS 21282+5050 (de Muizon et al. 1987) and the Orion Bar (Allamandola et al. 1987) in Fig. 2. Despite considerable similarities of the emission features in these three sources, V842 Cen also differs significantly from the other two sources in two respects. These are, 1) the relative strength of the 3.28μm feature to the blended group between 3.4 and 3.6μm is much lower in V842 Cen and 2) the feature seen strongly in 21282+5050 at 3.45μm is either absent or weak in the nova, rendering the shape of the feature between 3.4μm and 3.6μm intermediate between that of the two comparison objects. These characteristics should be diagnostic of the conditions and relative number densities of various molecular species in the nova ejecta. For example, it is possible that the relative strength of the 3.28μm and 3.4-3.6μm features is directly related to the temperature of the molecular species. Allamandola et al. (1987) have pointed out that a change from 400 to 480K is sufficient to alter the relative strengths of these features in observed char spectra remarkably in the sense that the longer wavelength features are enhanced at lower temperature. On the other hand, the exact wavelength of the C-H stretching vibration depends on the precise nature of the molecules involved (see de Muizon et al. 1987), and the relative strength of the features at different wavelengths may provide important constraints on the exact mix of molecular species. The 3.28μm feature is dominant in aromatics, while in saturated hydrocarbons such as alkanes the C-H mode lies in the 3.4-3.6μm range, and depends upon whether the C-H bond is in CH_3, CH_2, or CH. The 3.46μm feature is thought to be due to a C-H bond in CH. It is possible therefore, that the weakness of the 3.28μm feature relative to those between 3.4-3.6μm may be due to a low ratio of unsaturated to saturated hydrocarbons. At the present time we have no explanation for the apparent differences in the feature at 3.45μm. Clearly the use of features in the 3μm region as molecular diagnostics in dust spectra has great potential, but at present is still in its infancy and will require both high quality astronomical and laboratory data for further advances to be made.

REFERENCES:

Allamandola, L.J., Tielens, A.G.G.M. and Barker, J.R.: 1987,in *Polycyclic Aromatic Hydrocarbons and Astrophysics*, eds. Léger, A., Hendecourt, L.B. d', and Boccara, N., (D. Reidel Publishing Co., Dordrecht), p. 255.

Bode, M.F. and Evans, A.: 1983, *Q.J.R.A.S.*, **24**, 83.

Bode, M.F., Evans, A., Whittet, D.C.B., Aitken, D.K., Roche, P.F. and Whitmore, B.: 1984, *M.N.R.A.S.*, **207**, 897.

Ferland,G.J., Lambert, D.L., Netzer, H., Hall, D.N. and Ridgway, S.T.: 1979, *Ap. J.*, **227**, 489.

Gehrz, R.D., Grasdalen, G.L., Hackwell, J.A. and Ney, E.P.: 1980a, *Ap. J.*, **237**, 855.

Gehrz, R.D., Hackwell, J.A., Grasdalen, G.L., Ney, E.P., Neugebauer, G. and Sellgren, K.: 1980b, *Ap. J.*, **239**, 570.

Gehrz, R.D., Harrison, T.E., Ney, E.P., Matthews, K., Neugebauer, G., Elias, J., Grasdalen, G.L. and Hackwell, J.A.: 1988, *Ap. J.*, **329**, 894.

Geisel, S.L., Kleinmann, D.E. and Low, F.J.: 1970, *Ap. J.*, **161**, L101.

Hyland, A.R. and Neugebauer, G.: 1970, *Ap. J.(Letters)*, **160**, L177.

Hyland, A.R. and McGregor, P.J.: 1987, in *Infrared Astronomy with Arrays*, eds. Wynn-Williams, C. G. and Becklin, E.E., (University of Hawaii, Honolulu), p.388.

McNaught, R.H.: 1986, *IAU Circular* 4274.

Mitchell, R.M., Robinson, G., Hyland, A.R. and Neugebauer, G.: 1985, *M.N.R.A.S.*, **216**, 1057.

Muizon, M. de, Hendecourt, L.B.d' and Geballe, T.R.: 1987, in *Polycyclic Aromatic Hydrocarbons,* eds. Léger, A., Hendecourt, L. d' and Boccara, N., (D. Reidel Publishing Co., Dordrecht, Holland), p. 287.

Ney, E.P. and Hatfield, B.F.: 1978, *Ap. J. (Letters)*, **219**, L111.