3.3-μm Spectroscopy with IRSPEC

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IRSPEC is a cooled grating spectrometer in service at ESO since October 1986. It is equipped with a linear array of 32 InSb detectors and with two back-to-back-mounted gratings; in its present stage, it permits spectroscopy in the 1–5 μm region at a spectral resolution ($R = \lambda/\Delta\lambda$) of 1,000 to 2,000, depending on grating, order and wavelength. A description of it and a report on its performances can be found in Moorwood et al. (1986).

Although, in principle, data can be acquired at any wavelength between 1 and 5 μm, astronomical observations in some spectral regions (for instance, 1.35–1.45 μm or 2.5–3.0 μm) are impossible due to the large atmospheric extinction. There are regions (e.g., 1.10–1.18 or 3.1–3.5 μm) where atmospheric transmission is not zero, but still poor. There is great interest in performing spectroscopy in the 3.0–3.5 μm range. Such observations are difficult, not only due to the bad atmospheric transmission, but also due to the thermal background which rises in this range. Not much can be done by regular users on the thermal background issue and, hereafter, only the first source of difficulties will be addressed.

Figure 1 shows the raw (3.15 – 3.45 μm) spectrum of a K2III star. This spectrum was obtained in May 1988 during a good photometric night; relative humidity at ground level was ~10%. It has been acquired by stepping the grating at three different positions; the spectrum segments are contiguous and do not overlap. Spectral resolution is ~1,100. At this resolution and in this range, a K2III star is not expected to present any strong spectral feature and, therefore, what is presented in Figure 1 is basically the atmospheric transmission. One notes many absorption features, some of which are due to several overlapping lines and could be resolved at higher resolution. A feature at 3.318 μm is particularly deep and strongly affects observations even at low resolution. A low resolution spectrum (R ~80) of the atmospheric extinction can be found in Martin (1987); this spectrum, obtained with a circular variable filter (CVF), shows a peak around 3.3 μm. It is interesting to study this kind of spectrum before considering observations in the 3.0–3.5 μm range. As several atmospheric lines of different intensities (some of which are even saturated) affect the same spectral element, it is of prime importance to observe scientific target and comparison star at airmasses as close as possible; using the comparison star spectrum as a template allows, in principle by simple division, to correct the target spectrum for all its atmospheric features. However, experience shows that even during good nights, atmospheric absorption in the 3.0–3.5 μm range is not always stable with time. Therefore, it appears advisable to select a comparison star as nearby in the sky as possible from the object, and to observe it before and after in order to control the stability of the atmospheric transmission. Also, to avoid variation in airmass during exposure, one should observe preferentially around the meridian. It is only by carefully applying such guidelines that the observer might be able to cancel atmospheric features in its spectra. This advice is relevant to medium resolution spectroscopy with IRSPEC and, *a fortiori*, to low resolution spectroscopy with CVF's.

Among the most exciting observations to perform in the 3.0–3.5 μm region are those designed to study the so-called unidentified infrared emission features. The most prominent one is centred at 3.3 μm and has long been observed without being satisfactorily explained. Leger and Puget (1984) have proposed a consistent physical interpretation of it in terms of polycyclic aromatic hydrocarbon (PAH) molecules. Another feature, generally less intense, is observed at 3.4 μm. These two features are, in general, correlated with others found at 6.2, 7.7, 8.6 and 11.3 μm which may, therefore, have a similar origin. However, till now, most of the astrophysical observations have been done at low resolution (R ~80) with CVF's, and do not permit profile study of these features. With the availability of grating spectrographs like IRSPEC, physical studies based on medium resolution spectroscopy are feasible; also, now, comparison with laboratory data should be more meaningful in identifying the carriers. For instance, working at a resolution of 400, de Muizon et al. (1986) have observed structures in the 3.3-μm and in the 3.4-μm features and have discovered three new features at 3.46, 3.51 and 3.56 μm; accurate wavelengths, profiles and relative intensities of these different features give information on particle size, chemical composition, ionization state, etc. of the carriers.

To illustrate more specifically the potential offered by IRSPEC, a spectrum in the range 3.15–3.55 μm of Hen 1044 is presented by a WC star. Its progenitor is probably an intermediate mass ($1\,M_\odot < M < 9\,M_\odot$) star evolving from the Asymptotic Giant Branch (AGB) to the white dwarf stage. The high excitation of the nebula is clear from its H-band spectrum where Brackett lines up to (20-4) can be seen. Cohen et al. (1985) studied its IRAS low resolution spectrum (LRS); they show that, in addition to features at 7.7 and 11.3 μm, this

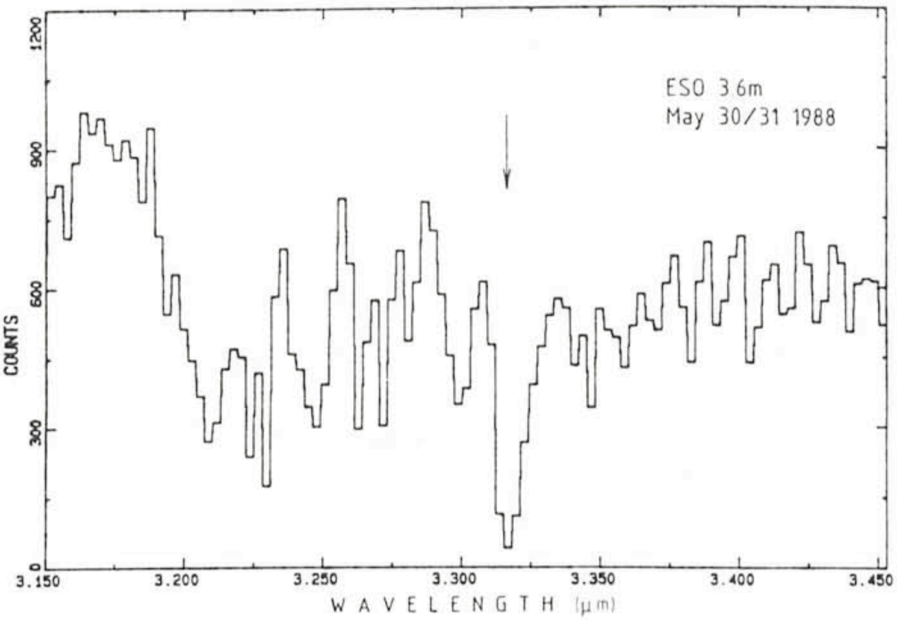

Figure 1: *Raw spectrum of a K2III star. The strong telluric feature at 3.32 μm, due to Methane, is indicated by an arrow.*

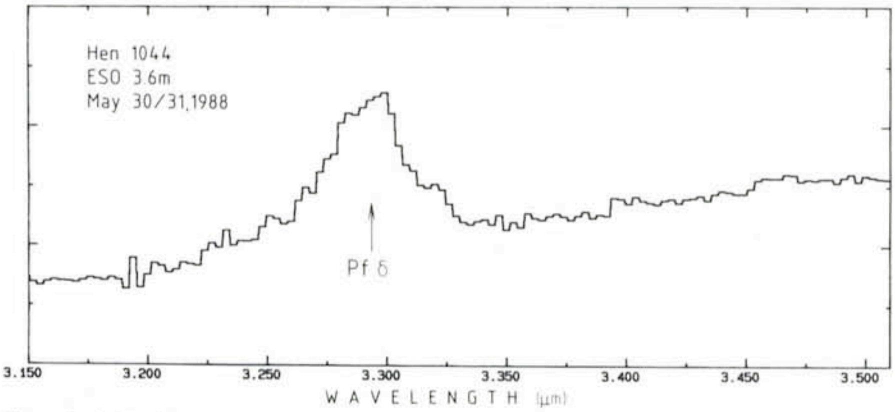

Figure 2: *3.15–3.50 μm spectrum of Hen 1044. The expected position of Pf δ at 3.296 μm is indicated by an arrow.*

source presents a plateau of emission extending from 11.3 to 13.0 μm. They discovered this new feature in the LRS's of 20 IRAS sources which exhibit emission at 7.7 and 11.3 μm and attributed it also to PAH's.

The spectrum presented in Figure 2 has been corrected for atmospheric extinction as explained above; no other treatment of the data (smoothing, etc.) has been performed and its resolution is exactly the one given by IRSPEC in this wavelength range (i.e., R ~1100). As the object is bright (L ~4.3), the noise in the final spectrum is mainly due to imperfect cancellation of atmospheric features. The 3.3-μm emission is clearly seen in the Hen 1044 spectrum; the feature is resolved and presents asymmetric wings. Adjusting it with a gaussian profile (which is somewhat equivalent to degrading the resolution of the spectrum), one finds a central wavelength of 3.292 μm and width of .044 μm. However, as the contribution of the Pfund δ hydrogen line (9-5) at 3.296 μm might not be completely negligible, a careful analysis is needed; this line is expected to affect at most two contiguous pixels. An interesting characteristic of this spectrum is the total absence of feature at 3.4 μm and longwards. The clear absence of emission at 3.4 μm suggests that the features at 7.7 and 11.3 μm and the plateau at ~12 μm are not correlated with it. Such recognition of correlation (or absence of correlation) between features, in combination with laboratory studies, will allow to constrain the identification of the different PAH's existing in astrophysical environments (see, for instance, de Muizon et al., 1986). The complete infrared spectrum as well as a discussion of all the data acquired on this interesting object will be presented elsewhere.

In Figure 3, the spectrum of Hen 1379 (another post-AGB object studied by the author) is presented. Most atmospheric features are well cancelled, except the strong telluric absorption at 3.318 μm which varied during the observations in such a way that an "emission line" appears around 3.3 μm. At CVF resolution, such an effect may mimic the unidentified 3.3-μm emission; with the resolution of IRSPEC, there is no ambiguity on its telluric origin: the 3.3-μm feature is clearly absent from the spectrum of Hen 1379. Some reported detections of the 3.3-μm feature with CVF's have not been confirmed later; the reason may simply be a rapid variation of the atmospheric absorption around 3.3 μm.

In conclusion, spectroscopic observations in the range 3.0–3.5 μm are feasible at La Silla using the 3.6-m telescope equipped with IRSPEC and promising prospects are offered by the utilization of this instrument. However, a careful preparation of the observations is required to get useful data; the observing planning should not be improvised at the telescope. Such a preparative work is surely time consuming and painful, but, at the end, it may make the difference between a successful mission and an unsuccessful one.

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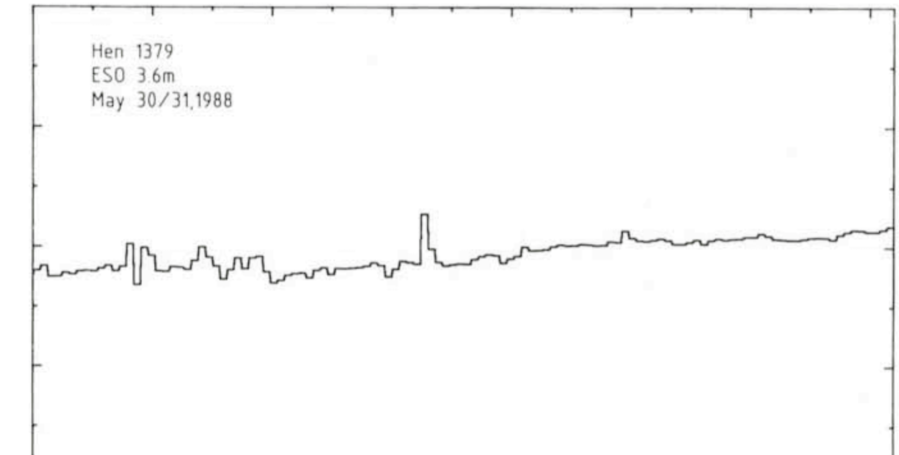

Figure 3: *3.15–3.50 μm spectrum of Hen 1379. The "emission line" at 3.32 μm is an artifact due to atmospheric Methane (see Figure 1).*

STAFF MOVEMENTS

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PIENEMAN, Hendrik (NL), Accounting Assistant
PIRENNE, Benoit (B), Fellow (Science Archive Software Specialist)
PRIEUR, Jean-Louis (F), Fellow
VAN RIJN, Gunilla (NL), Administrative Assistant
WALLANDER, Anders (S), Software Engineer
WIELAND, Gerd (D), Procurement Officer