High Resolution Spectroscopy of Symbiotic Stars

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Introduction

A high resolution spectroscopy survey of symbiotic stars is conducted in the southern hemisphere by the authors, using the Coudé Echelle Spectrograph (CES), equipped with a CCD at the ESO Coudé Auxiliary Telescope (CAT), and concurrently in the northern hemisphere by Bode, Evans, Meaburn and collaborators, using the UK facilities at La Palma. So far, more than 400 spectra of about 70 stars have been obtained, mostly during 1988 and 1989. The southern part of the work will be described below.

The discussion of symbiotic stars in the context of novae is not far-fetched. A number of symbiotics are known to have nova-like outbursts, and several novae are not easily distinguished from symbiotic stars. A noteworthy example is the most recently recognized recurrent nova, V745 Sco, first observed by Liller on July 24, 1989. It is described here, both because in late decline it represents a link between novae and symbiotic stars, and because of its current interest.

A link between novae and symbiotic stars

Fig. 1 shows a low dispersion spectrum of V745 Sco. The deep TiO bands which began to appear 2 weeks after outburst, and which dominate the spectrum taken on August 24, 1989, are characteristic of spectral type M6 - M6.5 III (Turnshek *et al.* 1985). The emission lines and some line ratios are reminiscent of symbiotic stars.

The 683 nm band, frequently and almost uniquely found in symbiotic stars and attributed to Raman scattered ultraviolet O IV (Schmid 1989), is clearly present in the spectra of V745 Sco taken in mid-August (not shown here). In Fig. 1, it appears almost drowned in the strong red continuum. Another common feature is the broad base of Hα. The line ratio He I 587.6 nm to He I 667.8 nm is relatively small, suggesting densities characteristic of symbiotic stars, recurrent novae and very slow novae. Lines of [O I] are strong, of [O III] much weaker, no lines of [N II] are found. Their absence is another characteristic common to recurrent novae (with the exception of T Pyx) and most S-type symbiotic stars, and clearly distinguishes them from classical novae. The small ratio He II 468.6 nm to Hβ indicates the relatively low temperature of the central source.

Observations of symbiotic stars

The CES is used with the short camera giving a typical resolving power of about 60 000 or 0.2 to 0.3 nm mm^{-1} reciprocal dispersion. The CCD has 1024 pixels of size 15μm $\times$ 15μm providing a spectral coverage of about 5 nm per exposure at a resolution of $\approx$ 3.5 pm pixel^{-1}. Exposure times are generally between $5^{\rm m}$ and $1^{\rm h}$, yielding signal to noise ratios of 10 to 200 in the emission lines. Stars down to B = 17.2 were observed successfully in the Magellanic clouds.

The lines observed in most of the stars are: Hα 656.3 nm (+ [N II] 654.8/658.4 nm), [O III] 500.7 nm, He II 468.6 nm, and He I 667.8 nm + He II 668.3 nm, in some objects also He I 1083.0 nm, Ca II 854.2 nm, Hβ 486.1 nm and Hγ 434.0 nm + [O III] 436.3 nm.

Preliminary results

Typical Hα profiles observed in S-type and D-type symbiotics are shown in Figs. 2 and 3.

All Hα lines show structure, including asymmetrical central reversals. Broad symmetric wings characterize the lines in S-types, while the dusty, presumably more evolved stars have noticeably smaller wings. Not shown here is the absence of [N II] lines in the S-type objects in our galaxy. The unusually strong [N II] lines in Sanduleak's star in the LMC indicate an approximately 100-fold nitrogen overabundance (Kafatos *et al.* 1983).

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The [O III] lines have multiple components; the dominant double peak may be interpreted in terms of shell geometry.

The high resolution spectra for which examples are given here will be used to derive physical, kinematical and statistical parameters of symbiotic stars and to study links to related objects. Model computations for comparison with the observed Hα profiles include self-absorption or combinations of broad emission lines and P-Cygni profiles, and electron scattering in order to model the wings. The different contributors characterize physically and geometrically different regions of the object. The forbidden line components with high accuracy radial velocity data should reveal the kinematics and geometry of the tenuous gas. Line fluxes from corroborating observations will be used to combine the optical results with observations in other wavelength regions.

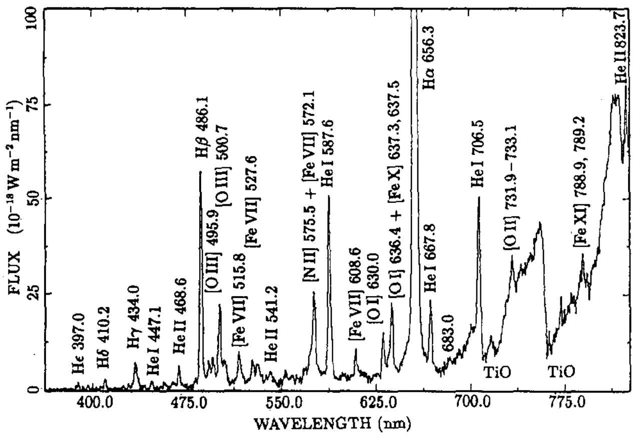

Fig. 1. Spectrum of the recurrent nova V745 Sco, taken 1 month after outburst with EFOSC II at the ESO 3.5m NTT, resolution ≈ 0.35 nm pixel^{-1}.

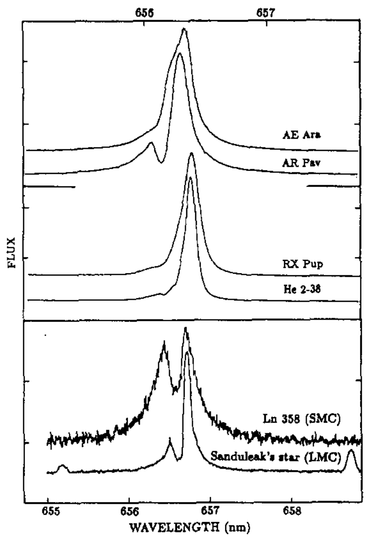

Fig. 2. a) Normalized Hα-profiles of two S-type symbiotics;
b) Normalized Hα-profiles of two D-type symbiotics;
c) Normalized Hα profiles of the two symbiotics in the Magellanic Clouds which are not of C-type.

Wavelength positions slightly adjusted. Note the strong [N II] lines in Sanduleak's star.

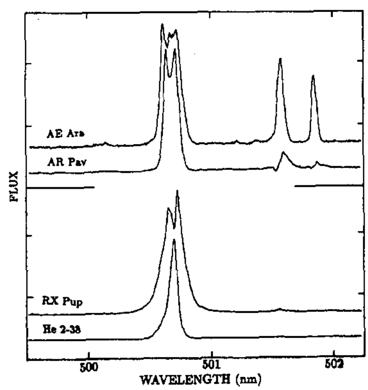

Fig. 3. a) Normalized [O III] 500.7 nm-profiles of two S-type symbiotics;
b) Normalized [O III] 500.7 nm-profiles of two D-type symbiotics.

Wavelength positions slightly adjusted.

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