

K 3–22: a D-type symbiotic star[★] (Research Note)

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ABSTRACT

A goal of the IPHAS survey is to determine the frequency and nature of emission-line sources in the Galactic plane. According to our selection criteria, K 3–22 is a candidate symbiotic star, but it was previously classified as a planetary nebula. To determine its nature, we acquired a low-resolution optical spectrum of K 3–22. Our analysis of our spectroscopy demonstrates that K 3–22 is indeed a D-type symbiotic star, because of its high excitation nebular spectrum and the simultaneous presence of Raman-scattered O VI emission at 6825 Å and 7082 Å, which is detected primarily in symbiotic stars.

Key words. binaries: symbiotic – planetary nebulae: general

1. Introduction

While analysing the data of the the INT Photometric H α Survey of the northern Galactic plane (IPHAS, [Drew et al. 2005](#)), we noticed that a point source included in the main list of Galactic planetary nebulae ([Acker et al. 1992](#)), namely PN G045.6+01.5 (also called K 3–22), had optical and near-infrared colours typical of symbiotic stars rather than planetary nebulae ([Corradi et al. 2008, 2010](#)). We therefore decided to investigate the nature of the source via optical spectroscopy. This demonstrates that K 3–22 is indeed a symbiotic star, as described in the following.

2. Spectroscopic observations

The spectrum of K 3–22 was obtained on 2 September 2009 at the 2.5 m Isaac Newton Telescope using the IDS spectrograph. Grating R300V was used, which gives a reciprocal dispersion of 1.9 Å per pixel, and a spectral coverage from 4300 to 8500 Å. The slit width was 1''1, providing a spectral resolution of 5.0 Å. The total integration time on target was 80 min, which was divided into two exposures of 40 min each. The 2 k \times 4 k IDS EEV CCD is affected by fringing redward of \sim 7000 Å. In addition, flux calibration is uncertain above 7500 Å because of second-order contamination as well as significant optical aberrations at the edge of the large-format CCD used with IDS. Two

spectrophotometric standards were observed during the night to help us perform a relative flux calibration. Reduction was completed using IRAF¹ in a standard fashion.

3. A symbiotic star's spectrum

Figure 1 shows the optical spectrum of K 3–22, which is dominated by emission lines of both low (e.g., [O I], [Fe II], [S II]) and high ([O III], He II, [Ca V], [Fe VII]) ionization species. H I and He I emission is strong, and He II relatively fainter. Line identification and fluxes are listed in Table 1. Line fluxes F_{obs} are given relative to $F_{\text{H}\beta} = 100$, and the estimated H β flux is 6.5×10^{-15} erg cm⁻² s⁻¹, with an error of 20% caused by a lack of precise absolute flux calibration for these data. The errors in the quoted relative fluxes are \sim 5% for lines stronger than $0.2 F_{\text{H}\beta}$, and are larger for fainter lines. The H α and in particular the [N II]6583 fluxes are affected by an additional amount of uncertainty because of their blending.

Relatively strong O I emission at 8446 Å is also detected, but this line is outside the spectral range with reliable flux calibration. The continuum is weak and slowly rising, with no evidence of the absorption bands of a red giant. However, the clear detection of the Raman-scattered O VI broad emission at 6825 Å and the fainter line 7082 Å ([Schmid 2001](#)), in addition to high excitation lines, proves its nature as a symbiotic star according to the criteria defined in [Belczyński et al. \(2000\)](#). The full width at half maximum (*FWHM*) of the Raman-scattered lines is 15 Å. The classification of K 3–22 as a symbiotic star is also supported by the large observed H α /H β flux ratio, of the order of 50, which is typical of symbiotic binaries.

[★] Based on observations obtained at the 2.5 m INT telescope of the Isaac Newton Group of Telescopes in the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofísica de Canarias. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

¹ IRAF is distributed by the NOAO which is operated by AURA under contract with NFS.

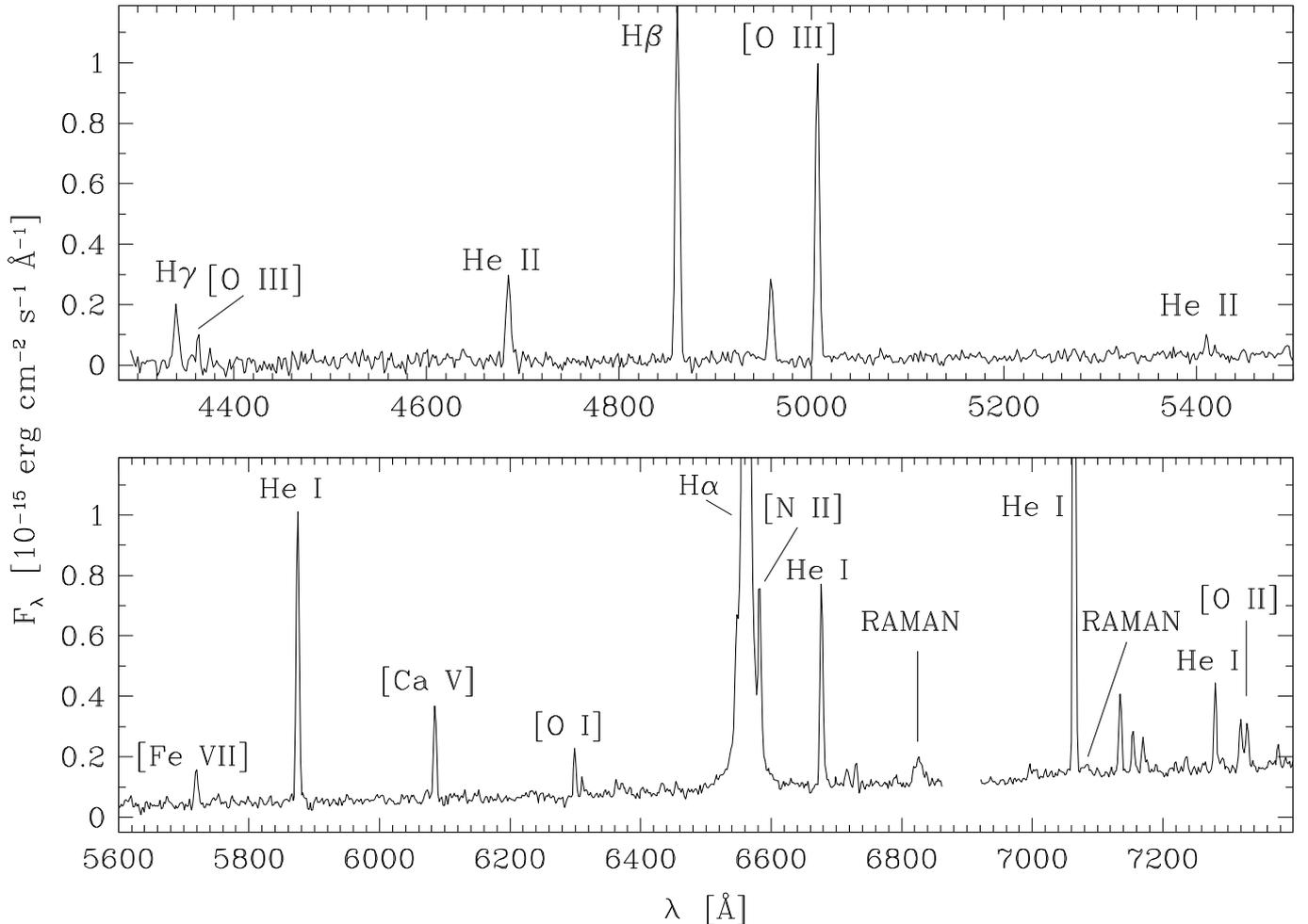


Fig. 1. The spectrum of K 3–22 in the range with reliable flux calibration. The main spectral features are labelled. The region around 6870 Å containing the telluric O₂ atmospheric absorption *B* band is not plotted.

The broad wings of the H α line profile of K 3–22, which extend well beyond the [N II] doublet (see Fig. 1) with a total width at zero intensity of 4500 km s⁻¹, are also characteristic of symbiotic stars (van Winckel et al. 1993), and might also have been produced by Raman scattering (Nussbaumer et al. 1989).

The situation is similar to that of other symbiotic systems, such as He 2-104, where the red giant is not visible in the optical, and only shows up in the near-IR either spectroscopically via its characteristic CO absorption bands in the *K* band, or by photometric variations typical of pulsating AGB stars (Santander-García et al. 2008). These systems generally belong to the class of “dusty” (D-type) symbiotic stars, because their near-IR colours are indicative of a reddened Mira-type giant surrounded by a large amount of warm ($T \sim 1000$ K) dust. This is also true for K 3–22: its 2MASS magnitudes are $J = 12.34$, $H = 10.33$, and $K = 8.82$ mag, which mean that the source is at the top-right of the locus defined by D-type symbiotic stars in the 2MASS colour-colour diagram (Corradi et al. 2008).

Therefore these observations resolve the previous uncertainty about the nature of K 3–22: the source was included in the list of true or probable planetary nebulae (PNe) in the Strasbourg–ESO catalogue but with the note “possibly an H II region” (Acker et al. 1992), classified as a possible planetary nebula (Kohoutek 2001), or considered as an object of uncertain nature (Acker et al. 1987).

To summarise, K 3–22 is one of a group of elusive D-type symbiotic stars for which the red giant in the optical range is only indirectly detected by the excitation of the circumstellar nebula, which allows the formation of Raman-scattered emission thanks to the simultaneous presence of high energy photons from the hot white dwarf companion and neutral material in the red-giant extended atmosphere. The observational frontier between these systems and a number of PNe is poorly defined; in both cases, the optical spectrum is dominated by the ionized nebula, and the central star(s) are highly obscured by dust. Both classes also often display extended ionized nebulae with similar bipolar morphologies (Corradi 2003). The near-IR can provide clues about their symbiotic nature, but not without difficulties (cf. Santander-García et al. 2009). Even the presence of the Raman-scattered O VI broad emission at 6825 Å is not a property exclusive to symbiotic stars: it has also been detected in bipolar PNe with massive neutral envelopes such as NGC 6302 (Groves et al. 2002) and NGC 7027 (Zhang et al. 2005), although in the latter objects they are much fainter than the nebular emission lines. Unveiling the true nature of these and other well-studied nebulae such as M 2–9 or Mz 3 (see Corradi 1995), or of certain newly discovered candidate PNe (e.g. Viironen et al. 2009), remains a difficult task, but is of vital importance to understanding the physical processes at work in forming and shaping the outflows from evolved stars.

Table 1. Emission line identification and fluxes, relative to $F_{H\beta} = 100$.

Identification	$\lambda[\text{\AA}]$	F_{obs}
H I	4340.5	18
[O III]	4363.2	*
He II	4685.7	26
H I	4861.4	100
[O III]	4958.9	24
[O III]	5006.8	81
He II	5411.5	5
[Fe VII]	5720.9	11
He I	5875.6	80
[Ca V]/[Fe VII]	6086	26
[O I]	6300.3	11
[S III]	6312.1	4
H I	6562.8	5500:
[N II]	6583.4	60:
He I	6678.2	55
[S II]	6716.4	5
[S II]	6730.8	4
Raman	6825	19
He I	7065	218
Raman	7082	6
[Ar III]	7135.8	20
[Fe II]	7155.1	11
[Fe II]	7172.0	9
[Ar IV]	7236.0	4
He I	7281.4	21
[O II]	7319	16
[O II]	7330	13

Notes. (*) Marginal detection; (:) uncertain flux because of blending.

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