THE CLASSIFICATION OF FAINT Be STARS

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(Paper read by J. P. Swings)

Abstract. Faint emission-line stars found on Hα surveys are usually classified as planetary nebulae or Be stars on rather arbitrary criteria. A comparison of spectra of such stars with their optical and infrared properties suggests that a next step in their classification can be made quite rapidly by photometry. In particular the more unusual specimens can be readily isolated.

Paul Merrill was the first person to engineer a systematic Hα survey of the northern sky as a means of identifying Be stars. That his technique was successful is beyond question; the three volumes of the MWC (Merrill and Burwell, 1933, 1943, 1949) testify to that.

But Merrill was bedevilled by one problem: how to distinguish his cherished Be stars from the chaff of emission-line objects that litter the sky. Nebulous objects – compact H II regions and large planetary nebulae – he could hope to isolate simply by their extended nature; stellar objects – T Tauri stars, symbiotic stars, Me stars, compact planetary nebulae, Wolf-Rayet stars etc. – could be distinguished only spectroscopically. On the original objective-prism plates this was feasible, and was indeed undertaken, for the brightest sources, but it became increasingly difficult as the plate limit was neared. Merrill's solution was to publish a list of additional stars (the AS; Merrill and Burwell, 1950) about which he could say no more than that they had Hα emission. This is an admirable approach which has subsequently been shunned by the majority of Hα surveyors who seem to prefer risking errors of commission to making admissions which might be construed to imply inadequacy. Thus, rather than hiving off a 'don't know' group *qua* the AS, most recent Hα surveys have turned up only 'Be stars' or 'planetary nebulae'. The reasoning seems to be either: I see a continuum, ergo this is a Be star or: I see no continuum; this object *has* no continuum, ergo it is a planetary nebula. The outcome of this approach is to cram the Be star lists with T Tauri and even later-type stars, and the planetary nebula catalogues with the most bizarre assortment of objects, including even some M stars with pure absorption spectra (Allen and Fosbury, 1975).

Even the impeccable MWC includes a number of stars Merrill chose to classify as Be but which could now better be described as forbidden-line stars. I refer to objects like MWC 17 (Swings and Struve, 1941), MWC 342 (Swings and Struve, 1943), MWC 645 and MWC 819 (Swings and Allen, 1973) in which low-excitation forbidden lines dominate the emission spectrum and there is a strong continuum offering little or no evidence of an underlying B-type star. The study of these enigmatic objects would be greatly benefited by their isolation from Be catalogues, but this was not always possible from the original Mount Wilson plates.

A problem therefore exists. The promulgators of objective prism surveys in the main seem unable or unwilling to classify their discoveries into more than two loosely defined categories. To do so spectroscopically requires an inordinate amount of

A. Slettebak (ed.), Be and Shell Stars, 229–231. *All Rights Reserved*

telescope time and offers a low yield of the frontier-pushing astronomy we are supposed to be pursuing. How should we proceed?

A solution offered here is photometry which, by dint of its inherently wider bandpass, is considerably faster than spectroscopy and can be performed on a smaller telescope. Considering first the optical, filter combinations which have already proved successful and which could serve usefully in the classification of emission-line stars include the Hβ/[O III] and the TiO/CaH sets. The first of these combinations was used by Webster (1966) to examine the stellar planetary nebulae of Henize's (1967) survey. On this basis she isolated 15 which had at best only very weak [O III] emission and which therefore merited at least a more thorough examination before they were accepted as genuine planetary nebulae. Two thirds of these have since been shown not to be planetary nebulae, and several of them would more properly be classed as Be stars. An Hβ/[O III] photometric survey of all the objects classified as stellar or compact planetary nebulae would therefore aid in cleaning up this group. Late type stars – M, Me and symbiotic stars – can be identified by the TiO/CaH photometry practiced by Jones (1973), or by similar filter combinations. Many emission-line stars are quite heavily reddened, so working in the red has obvious advantages. Since late-type stars are present in both samples, all faint emission-line stars found by objective prism surveys would need to be examined.

1–4 μm infrared photometry offers another, and perhaps a superior, means of separating the various emission-line objects (Allen and Swings, 1972). At the time of writing, most infrared observations of emission-line stars have been made with PbS cells; the advent of InSb, which is nearly an order of magnitude more sensitive, will considerably speed up this type of work. The standard Johnson filters at 1.25 (J), 1.65 (H), 2.2 (K) and 3.5 μm (L) have been used. At these wavelengths three types of continuum can be identified, and these are listed in Table I.

TABLE I

The three varieties of infrared continua in emission-line stars

Type	Typical colour indices (magnitudes)				Emission-line objects represented
	$J-H$	$H-K$	$K-L$	$V-K$	
i Blue continuum, stellar or free-free	≲0.3	≲0.4	≲0.6	~2	Be stars; planetary nebulae; most Wolf-Rayet stars
ii Late-type star	1.0	0.4	0.4	3–15	M, Me stars; most symbiotic stars; VV cephei stars except that $K-L$ is usually larger. Stars of type (i) if $A_V \simeq 10$ mag.
iii Dust emission at colour temperatures 700–1500 K	Colours depend on dust temperature	>0.6	>0.9		Some dense planetary nebulae; some symbiotic stars; T Tauri stars; forbidden-line stars; compact H II regions; pre-main-sequence Ae and Be stars

https://doi.org/10.1017/S0074180900011402 Published online by Cambridge University Press

The technique so far adopted (Allen, 1974; Allen and Glass, 1974, 1975) was to integrate for 5 minutes at 2.2 μm using a PbS detector on a 1 or 1.2-m telescope. In this time the majority of the late-type and dust emission objects will have been detected. Other wavelengths may then be tackled to derive colours. A one-minute integration with an InSb cell would go deeper, and hence find the fainter late-type and dust emission stars. Five minutes integrating on a similar aperture telescope would reach the continuum of many of the faint Be stars and planetary nebulae. Thus infrared photometry offers a particularly rapid diagnostic for faint emission-line stars and serves to isolate the more unusual and peculiar specimens for further study. The data in Table II indicates the numbers of misclassified objects isolated by the author

TABLE II

Proportion of type (ii) and type (iii) infrared continua amongst emission-line stars fainter than about 13th magnitude

	Total sampled	%(ii)	%(iii)
Classed as Be	85	32	36
Classed as planetary nebulae	376	21	10

in his various infrared surveys of Be stars and compact planetary nebulae, and illustrates the magnitude of the misclassification problem. The use of InSb detectors on the sources undetected with PbS cells would probably lead to an increase in the percentages of misclassified sources, especially amongst planetary nebulae.

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