

The Search for Post-AGB Stars With Dusty Discs

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Abstract

A systematic search has been made for stars of a subset of the presumed post-AGB population, which are characterised by their RV Tauri-like spectral energy distributions in the 1-60 micron range as well as by near-solar spectral types. Data from several large surveys have been combined to find such stars, which include classical RV Tauri stars, stars which lie outside the Type II Cepheid instability strip and have at most small-amplitude pulsations, and stars such as U Equ, which have superimposed absorption features which arise in cool circumstellar gas. All are thought to have dusty circumstellar discs.

Introduction

Stars with dusty discs have distinctive colours, with infrared excesses which start in the near infrared and continue to longer wavelengths so that they have distinctive colours in several 2-colour diagrams which may be constructed from near-IR and IRAS photometry^{1,2,3}. The star will be seen largely by reflection from material out of the plane of the disc, if the disc is seen nearly edge-on⁴, when resonance emission lines and bands may appear^{2,5,6}. Alternatively, sharp absorption bands of TiO have been seen in two cases^{7,8}. The nearly edge-on objects have especially large colour indices and appear very faint⁹ and so are hard to find.

Evolved stars known to have dusty discs include some M giants, carbon stars, stars with strong H-alpha emission and RV Tauri stars². The characteristic colours of their dusty discs have indeed been used to search for new RV Tauri stars¹⁰. It is also possible to locate new RV Tauri stars by their colours in lists of variable stars which have been misclassified, usually as semiregular variables.

Methods. Four main searches have been carried out.

1. Stars which have RV Tauri-like colours in the IRAS [12]-[25], [25]-[60] diagram were observed spectroscopically and by JHKL photometry.
2. JHK data from the 2MASS catalogue were combined with IRAS photometry to select stars with red [12]-[25], an excess at K and a large K-[12] value, reproducing the photometric characteristics of the stars selected earlier except for the lack of L and 60 micron measurements.
3. A comparison of 2MASS with stars which the General Catalogue of Variable Stars classified as RV Tauri, SR, SRD or Cep.
4. Some newly-classified SRD variables were checked in ROSAT as well as in 2MASS.

Using IRAS with 2MASS

A renewed survey of the IRAS Point Source Catalog, to fainter magnitudes than done previously², has been carried out with the aid of the 2MASS catalogue of JHK photometry. We cross-correlated this with the IRAS PSC, and extracted stars with IRAS [12]-[25] greater than 0.9, K-[12] greater than 5.0 as a rule, and a position to the right (red) of the line passing through J-H = 1.0, H-K = 0.7 and J-H = 2.0, H-K = 1.7. The latter condition removed such objects as Mira variables. We also excluded stars with J-H less than 0.9. These fainter stars generally lacked reliable 60 micron fluxes, which provided the principal search criterion for the original survey².

Figure 1 shows the location in the J-H, H-K diagram of the stars which we observed spectroscopically, as well as some known objects.

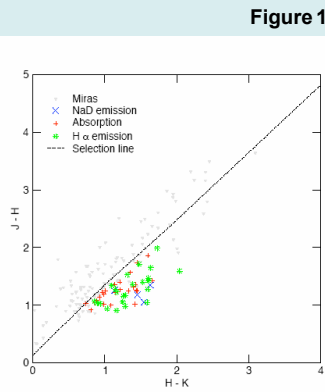


Figure 1

Spectroscopy

Spectra of likely stars were taken during two observing runs in 2004 and 2005 with the Cassegrain spectrograph on the 1.9m telescope of the South African Astronomical Observatory. One or more of three grating/grating angle combinations were used, giving 6Å resolution 3600 – 7600Å, 4Å resolution 4500 – 7100Å or 4Å resolution 6400 – 9000Å. In practice the blue spectra were useful for classifying the minority of less-reddened stars, the middle range spectra were well suited to detecting NaD emission and other exotic features, while the red spectra were the most useful for classifying the majority of the stars observed.

Figure 2 shows some sample spectra in the yellow spectral region, and Figure 3 shows some in the red.

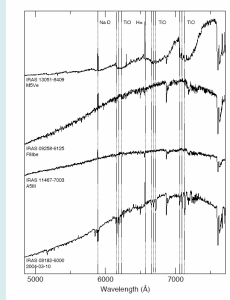


Figure 2

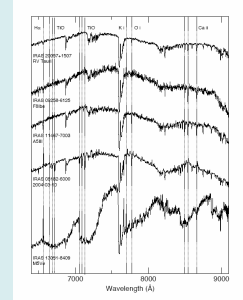


Figure 3

Results

Survey 1 identified new RV Tauri and related stars, as well as hot emission line stars and M stars with excesses at L^{2,10}. The cooler stars identified in Survey 2 include four new cases with NaI and sometimes KI resonance lines in emission, indicating that the disc is nearly edge-on, but none with molecular bands arising in cool circumstellar material. The stars with NaD emission are a mixed group, including a possible T Tauri star of spectral type M. The high luminosity stars, of class Ia or Ib, are confined to the narrow range of spectral type F5 – G1. One of them, IRAS 20057+1507 (V1095 Aql), has been shown from ASAS-3 photometry to be an RV Tauri of period 87 days. The relative lack of similar (but non-variable) stars with spectral types between early G and late K as the precursor of the RV Tauri stars in their presumed evolution across the Cepheid instability strip towards higher temperature¹⁰ is not understood.

Surveys 1 and 2 together indicate that among the stars of near-solar temperature, RV Tauri stars generally have K-[12] greater than 5, stars with NaI or KI emission have K-[12] greater than 6 and those with prominent molecular bands arising in circumstellar material have K-[12] greater than 7.

Study of Known Variables.

The General Catalogue of Variable Stars contains large numbers of variables whose nature is as yet unknown. We have used IRAS, 2MASS and ROSAT data to investigate those stars added to the GCVS since 1985 and classed SRD. Many are stars of smaller amplitude than the well-known stars of this type, and were discovered by the HIPPARCOS satellite and TYCHO photometer. Figure 4 shows the location in the J-H, H-K diagram; stars which were too bright to have satisfactory 2MASS photometry are not considered farther. Most fall into one of three groups: stars already recognised as Post-AGB stars, some of which may be stars with dusty discs³; stars with strong X-ray emission; and stars which are probably red variables of small amplitude, classed as SRD because they are of spectral type K rather than the more common M.

The ratio of X-ray to optical flux in the stars denoted by X in Figure 4 is comparable to that of chromospherically-active stars, and at least an order of magnitude more than that of most stars in the Bright Star Catalogue. We conclude that they are also chromospherically-active, and that their optical variability is probably the result of rotation of a spotted star.

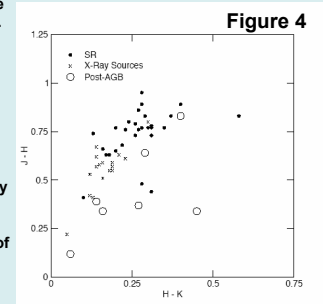


Figure 4

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