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Optical identification and BVRI photometry of a few 'unidentified' IRAS sources of a late type stellar nature

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Abstract. A search for the optical counterparts of 21 'unidentified' IRAS sources was carried out using the POSS, ESO and SERC Sky Survey prints. The sources selected for study were of a late type stellar nature with circumstellar dust shells as revealed by their flux densities in the IRAS survey bands. CCD photometric observations of these IRAS sources were carried out in the *BVRI* bands with the 1.02 m telescope at the Vainu Bappu Observatory (VBO), of the Indian Institute of Astrophysics (IIA) at Kavalur. Spectroscopic observations of three of the brighter sources (viz., 04184 + 2008, 07593 − 1452 and 12387 − 3717) were carried out in the wavelength range 6300-11000 Å using the 2.3 m telescope of IIA at VBO, Kavalur.

BVRI photometric measurements aimed towards understanding the evolutionary stage of these sources indicate that they have higher values of $B - V$ for their $V - I$ colours compared to those of main sequence and giant stars indicating their advanced stage of evolution associated with a high mass loss rate and the consequent high extinction experienced by them in the B band, due to circumstellar dust. Colour-colour diagrams of [12] − [25] versus $V - I$ and [25] − [60] versus $V - I$ show that they can be used to distinguish proto-planetaries and planetaries from sources with continuously falling spectra as they exhibit distinctly higher [12] − [25] and [25] − [60] at all $V - I$.

Key words : 'unidentified' IRAS sources—*BVRI* photometry—CCD detector—spectroscopy

1. Introduction

We have carried out *BVRI* photometry of 21 'unidentified' IRAS sources of a late type stellar nature using the CCD camera with the 1.02 m telescope of the Vainu Bappu Observatory (VBO), Kavalur. These observations were undertaken with the aim (i) of identifying the optical counterparts of these sources (where they exist), (ii) to obtain their *BVRI* photometric magnitudes and (iii) to undertake low resolution spectroscopic observations of the brighter sources from among them, to elucidate their evolutionary stage. The CCD camera for these observations uses a Thomson CSF Th7882 CCD chip (384 × 576 pixels) , which has a special coating for providing enhanced ultraviolet sensitivity. It is mounted in a liquid-nitrogen cooled dewar. This CCD system together with the controller and the data acquisition system were obtained in an integrated form from Photometrics Ltd., U.S.A. The CCD in its imaging mode at the *f*/13 Cassegrain focus of the 1.02 m telescope of VBO (at a scale of 0.357 arcsec per pixel) covers a total field of 137 arcsec × 206 arcsec. We used standard *B*, *V*, *R* and *I* filters to carry out the photometric observations. Nightly extinction coefficients were determined by observing standard stars. The observed instrumental magnitudes (at zero air mass) were transformed to standard magnitudes by observing several equatorial photometric standards.

Spectroscopic observations of three of the brighter sources were also carried out using a Boller Chivens spectrograph at the 2.3 m telescope at VBO, Kavalur with a CCD Camera.

2. Observations

BVRI photometric observations were carried out on January 1, January 24, March 8, December 26 and 27, 1992. The sky conditions were more photometric on the nights of December 26 and 27 than on the other nights of our observations. We report here the preliminary results of our photometric observations on only the nights of December 26 and 27, 1992.

The spectroscopic observations of the 'unidentified' IRAS source 07593 – 1452 was carried out on the night of January 5, 1993 and those of 04184 + 2008 and 12387 – 3717 on the night of January 6, 1993. These observations were obtained using a grating of 830 lines per mm at 4 different settings (orientations) to cover the wavelength ranges λλ 6300-7100 Å, λλ 7100-7900 Å, λλ 7900-8700 Å and λλ 9100-10100 Å. The spectral data were reduced using the RESPECT software package (Prabhu, Anupama & Giridhar 1987). The steps followed for the reduction scheme were : (i) correction of the raw data for readout and dark noise, (ii) conversion of the two-dimensional image to a one-dimensional one, (iii) flat field correction and (iv) wavelength calibration.

3. Data analysis and results

The method of analysis and the procedure adopted to extract magnitudes from the raw CCD images is as described by Mayya (1991). Preliminary results from the observations of December 26 and 27, 1992 are listed in table 1 along with data on these sources from IRAS PSC, which we hereafter refer to as 'programme' sources. The sources listed in table 1 belong to two distinct groups of objects : (i) those whose flux densities monotonically decrease with (increasing) wavelength and (ii) those whose flux densities show a maximum in the 25 μm band of the IRAS survey instrument. The former are stars with circumstellar dust shells which account for most of the observed far-infrared emission from these sources and the latter are sources similar to those identified with proto-planetary nebulae and planetary nebulae which generally show enhanced emission in the 25 μm and 60 μm bands of the IRAS survey instrument.

We present in figure 1, $V - I$ versus $B - V$ of the programme sources along with those of Main Sequence and Giant stars (Johnson 1966). It is seen that in general the programme sources have higher values of $B - V$ for their $V - I$ colours compared to those of Main Sequence and Giant stars indicating their advanced evolutionary state associated with a high mass loss rate and the consequent high extinction (due to circumstellar dust), experienced by them in the *B* band.

We present in figure 2 the colour-colour plots of [12] – [25] versus $V - I$ and [25] – [60] versus $V - I$ of the programme sources. It will be seen that both the [12] – [25] as well

Table 1. Log of *BVRI* photometric observations along with data from IRAS PSC

Date of observation	IRAS name	Photometric mag. *B*	*V*	*R*	*I*	Data from IRAS PSC Var.	[12] – [25]	[25] – [60]
27-12-1992	00408 + 5933*	13.0	10.7	9.4	8.3	0	1.48	1.46
26-12-1992	04179 + 4145*	18.4	14.3	12.3	10.4	9	0.14	0.30
26-12-1992	04184 + 2008*	12.9	11.0	9.5	7.0	9	0.34	0.03
27-12-1992	04278 + 2253@	18.5	16.4	14.5	13.0	2	1.75	1.43
27-12-1992	04296 + 3429@	16.3	14.3	13.0	12.0	1	2.95	0.70
26-12-1992	05067 + 2942*	16.4	14.9	14.1	13.5	7	0.34	0.25
27-12-1992	05235 + 1129@	14.7	13.0	11.8	10.8	1	2.05	2.40
26-12-1992	06426 – 0825*	18.2	17.7	16.1	14.6	9	0.21	–0.02
27-12-1992	06510 + 1200*	16.7	13.0	10.9	9.7	0	0.12	0.13
26-12-1992	07430 + 1115@	14.3	12.5	11.5	10.5	0	3.04	0.76
26-12-1992	12387 – 3717*	12.8	10.9	9.1	6.5	0	1.07	–0.38

Notes : Symbol * refers to sources whose flux density decreases with increasing wavelength in the IRAS survey bands and symbol @ refers to sources whose flux density peaks in the 25 μm IRAS survey band. The error on the *B* magnitudes is estimated to be $\lesssim$ 0.15 mag and on the *V*, *R* and *I* magnitudes ≈ 0.1 mag.

as the [25] – [60] colours of sources of a proto-planetary and planetary nature (i.e., those sources which exhibit a maximum in their flux density at 25 μm or 60 μm of the IRAS survey bands) have on an average [12] – [25] and [25] – [60] colours higher than sources with continuously falling spectra (in the IRAS survey bands). Thus the differences in the

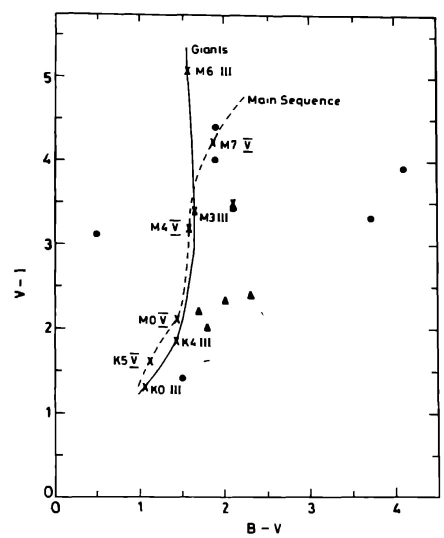

Figure 1. *V* – *I* versus *B* – *V* for (i) Main Sequence stars—dashed line, (ii) Giants—solid line, (iii) • of programme sources whose flux density continuously decreases with wavelength in the IRAS survey bands and (iv) ▲ of programme sources whose flux density peaks at 25 μm in the IRAS survey bands.

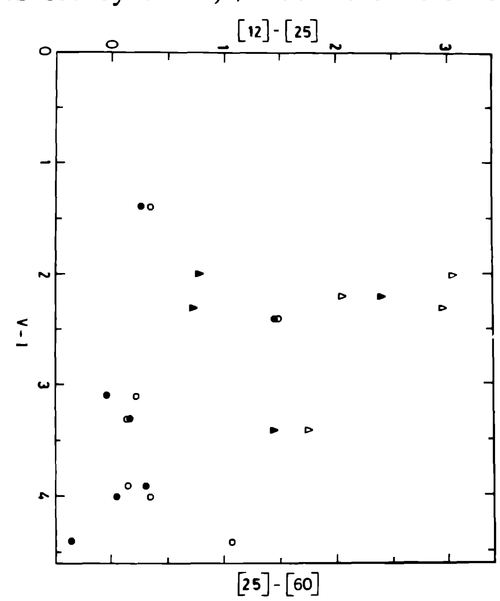

Figure 2. [12] – [25] versus *V* – *I* and [25] – [60] versus *V* – *I* of the programme sources. The ordinate scale is the same for [12] – [25] and [25] – [60] colours. Symbol O and • refer to [12] – [25] versus *V* – *I* and [25] – [60] versus *V* – *I* respectively, of programme sources whose flux density continuously decreases with increasing wavelength (in the IRAS survey bands) and Δ and ▲ refer respectively, to the same two quantities for sources whose flux density exhibits a maximum at 25 μm in the IRAS survey bands.

dependence of the [12] – [25] and [25] – [60] colours of these two types of sources can be used to distinguish between them.

The spectra of 04184 + 2008 and 12387 – 3717 in the λλ 6300-7400 Å and λλ 7800-9000 Å interval and those of 07593 – 1452 and 12387 – 3717 in the λλ 7000-8200 Å show strong absorption features. The work of identifying the atomic and molecular species and their transitions responsible for these absorption features is in progress.

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