J. Astrophys. Astr. (1986) **7,** 237–240

Is IRAS 03134 + 5958 a Herbig-Haro Object?

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Received 1986 May 5; accepted 1986 June 27

Abstract. The source IRAS 03134 + 5958 identified by Iyengar & Verma (1984) on the Palomar Observatory Sky Survey (POSS) prints with a nonstellar optical object with $[P - R] \simeq 5.3 \pm 1.5$ is near the edge of Lynds dark cloud No. 1384 and is either embedded in or behind the cloud. The galactic latitude of this source ($b^{\mathrm{II}} = 2^\circ\!.3$), its position *vis-a-vis* the Lynds dark cloud, its nonstellar appearance, high $[P - R]$ colour and its far-infrared spectrum, all suggest the possibility of its being a Herbig-Haro (HH) object. To test this possibility we undertook measurements of its proper motion and variability (two of the characteristic properties of HH objects). These yield $\mu_\alpha = (3.6 \pm 2.3)$ arcsec/century and $\mu_\delta = (-1.2 \pm 2.0)$ arcsec/century for its proper motion. The source reveals large variation in brightness between 1950 and 1954. Optical line studies of the source are required to confirm its classification as an HH object.

Key words: infrared sources—Herbig-Haro objects—stars, proper motion—stars, variability

1. Introduction

In the course of their work on the optical identification of the unidentified sources in IRAS Circulars 2–4 (Habing & Neugebauer 1983 a, b, c) using POSS prints, Iyengar & Verma (1984) identified the IRAS source 0313 + 599PO2 with an optical object at R.A. (1950) = $03^{\mathrm{h}}\,13^{\mathrm{m}}\,25^{\mathrm{s}}\!.2$ and Dec (1950) = $59^\circ\,58'\,45''$. Its angular separation from the optical object was 44 arcsec. The more accurate position now available for this source designated as IRAS 03134 + 5958 in the IRAS Point Source Catalog (Beichman *et al.* 1984) is within 3 arcsec of the optical position. Assuming the validity of the diameter-magnitude relations given for POSS prints by King & Raff (1977), we estimate $m_{\mathrm{p}} = 13.8$ and $[P - R] \simeq 5.3 \pm 1.5$ corresponding to a large value of $[P - V] \simeq 3.3 \pm 1$. The optical counterpart of the IRAS source (hereafter referred to as the programme object) appears nonstellar in the POSS prints. Its high $[P - R]$ colour, and its location near the edge of Lynds dark cloud No. 1384 (R.A. (1950) = $03^{\mathrm{h}}\,16^{\mathrm{m}}\!.0$, Dec (1950) = $+\,59^\circ\,50'$, area = 0.068 deg^2 and opacity = 4; Lynds 1962) led us to examine the possibility of its candidacy for an HH object. HH objects are known to exhibit large proper motions, light variations of 2–3 mag on a timescale of 5–10 yr and have strong emission lines with weak continuum emission. In this note, we present results on the proper motion and variability of the object based on measurements of plates from the Harvard collection and POSS prints.

2. Data and Discussion

We obtained contact negatives of plates from Harvard plate collections covering this region of the sky in order to measure the proper motion and variability of the programme object. Plates MC 2028, MC 28535, MC 36685, and MC 36689 from the Harvard collections corresponding to the epochs 1912 October 6,1936 October 21/22, 1949 December 14/15,1949 December 15/16 and the POSS O plate corresponding to the epoch 1954 January 27/28, were used for this purpose. Figs 1 a–f show on a magnified scale the optical candidate of the IRAS source as seen on the Harvard plates and POSS blue and red prints. We measured the positions of the programme object

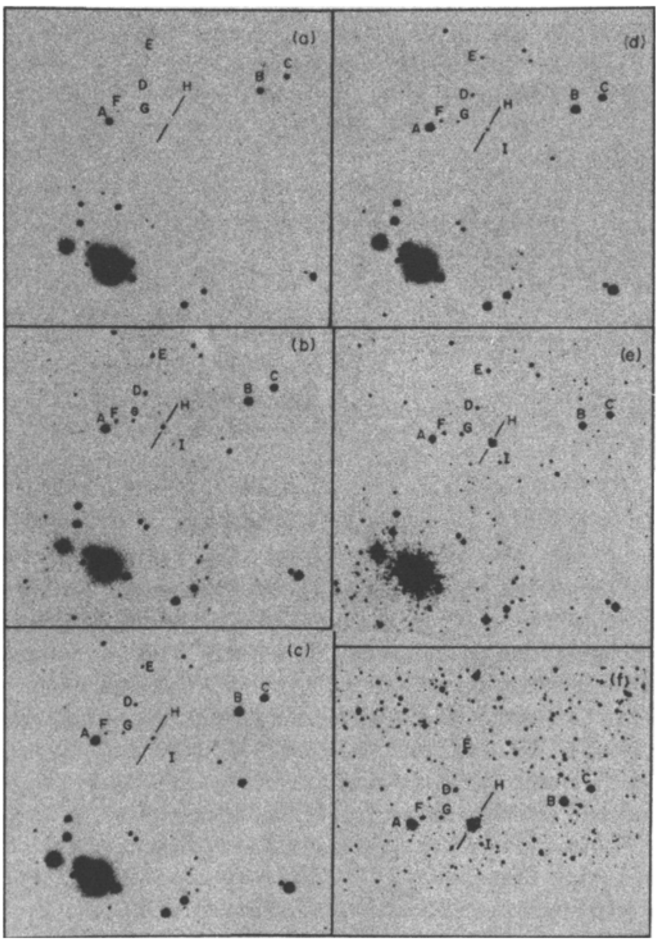

Figure 1. Enlarged prints of the Harvard plates MC 2028, MC 28535, MC 36685 and MC 36689 and the POSS blue and red prints corresponding to the epochs of (a) 1912 October 6; (b)1936 October 21/22; (c) 1949 December 14/15; (d) 1949 December 15/16; (e) blue POSS print of 1954 January 27/28; (f) red POSS print of 1954 January 27/28. In these prints east is to the right, and north is at the top. H indicates the programme object on these prints. A–I are objects around the programme object within a radius of 6 arcmin which encompass the brightness range the programme object underwent during the epoch interval 1912–1954.

Using Ascorecord, the Zeiss coordinate measuring machine. We chose as reference stars, 18 SAO starts with *P* magnitude in the range 9.5–10.2 surrounding the programme object. Also the plates were measured in direct and reverse orientations to eliminate systematic errors of a physiological nature. Corrections were made for the known proper motions of reference stars and the coordinates of the programme object were reduced to the equator and equinox of 1950.00. From a linear least-squares fit to these data we obtained μ_α = (3.6 ± 2.3) arcsec/century and μ_δ = (–1.2 ± 2.0) arcsec/century for the proper motion of the programme object. If the object is indeed an HH object, it belongs to the category of HH objects with low proper motion.

In order to measure the variability of the programme object, we need to eliminate effects arising from different exposures of plates as well as from possible difference in the effective bandwidths for the Harvard and POSS plates. For this purpose, we measured the diameter of the object with respect to several nearby objects. These objects A–I including the programme object designated as H are marked in Figs 1 a–f. From a careful study of the diameters of these objects, we conclude that the diameters of A, D and E changed by < 5 per cent. These were, therefore, used as calibration objects. Measurements on A, D, E and H were used to determine the relative diameter of H with respect to E. These relative diameters are plotted as a function of time in Fig. 2. It is seen that the programme object is variable. It has brightened considerably in 1954. The increase in diameter by a factor of 1.6 in 1954, corresponds to a brightening

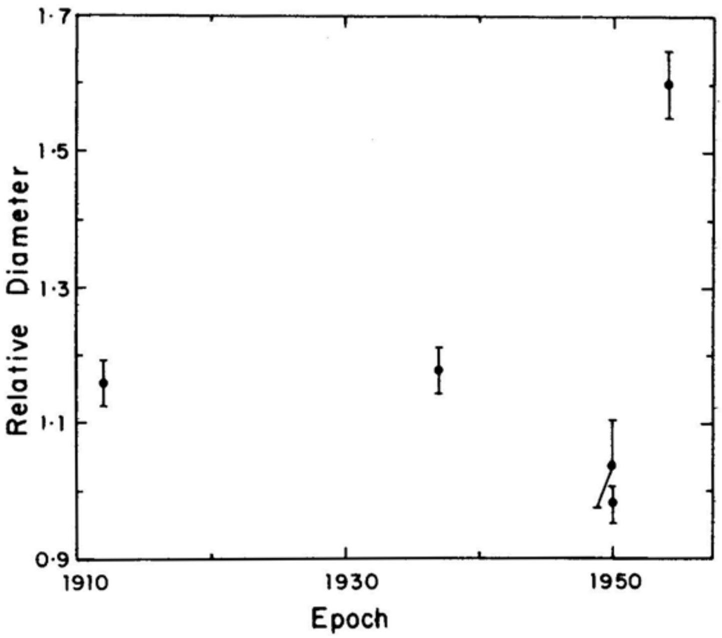

Figure 2. The relative diameter of the programme object versus the epoch of observation. The diameters of objects A, D and E changed by < 5 per cent during the epoch interval 1912–1954 and were therefore used to determine the relative diameter of the programme object on any plate with respect to the diameter of E on the same plate. The errors shown are rms deviation of measurements with respect to A, D and E.

by 2.4 magnitude in *P*. In 1950, the object seems to have reduced in brightness as compared to earlier times.

From IRAS observations the flux densities (colour corrected) of the programme object are found to be 1.78,2.09,9.19 and 35.80 Jy in the four IRAS bands of 12,25,60 and 100 μm respectively. IRAS data on other HH complexes such as HH 1, HH 11, HH 46–47, L 1551 NE and L 1551 IRS-5 (Beichman *et al.* 1984; Emerson *et al*. 1984) also indicate flux densities increasing with wavelength. However, there is a large spread in their [12–25] and [25–60] colours, which seem to depend strongly on their environments. The 100 μm flux densities being subject to cirrus contamination cannot be very effectively used. Thus, the far-infrared spectrum of the programme object, though a strong supportive indicator, cannot uniquely identify it as an HH object.

The object is not listed by Coyne & MacConell (1983) suggesting that it does not a e the strong Hα emission characteristic of an H-H object. On the other hand, low di per i deep objective prism spectrum of the core of the nebula taken at the Warner and Swasey observatory's Schmidt telescope shows (a) no evidence of strong hydrogen or nebular emission lines in the $\lambda\lambda$ 4550–5050 range, (b) no evidence of TiO or other strong absorption bands in the $\lambda\lambda$ 6800–8000 range indicating that it is not a late M or carbon star (N. Sanduleak, personal communication). Higher dispersion spectra of the object are required to resolve the conflicting evidence on its possible classification in the Herbig-Haro category.

Acknowledgements

We thank Dr Martha Hazen for access to Harvard plate collection and Dr G. Melnick for help in copying the plates.

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