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# IRAS 17340−3757: A Newly Identified Unusual Carbon Star *

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**Abstract.** During a program to discover new YSO candidates, we have serendipitously discovered IRAS 17340−3757 to be a hitherto unknown J-type carbon star with, to our knowledge, unique properties. The central star is surrounded by a strikingly symmetric, bipolar, reflection nebula, visible at optical and near-infrared wavelengths. Mid-infrared imaging and spectroscopy show that the central point-source possesses a large infrared excess. New mm-wave spectroscopy in the $J$ = 1–0 and 2–1 pure rotational transitions of CO reveals a strong, very fast (> 50 km s$^{-1}$) outflow, from which we derive a mass loss rate $\dot{M} > 1.2 \times 10^{-4}$ M$_\odot$ yr$^{-1}$. Both the existence of a prominent reflection nebula and the presence of such a strong outflow are highly unexpected, since one would expect the central carbon star to be on the AGB, but one would only expect to see the optically bright nebula after the star has become a protoplanetary nebula. Peculiarly, the central star also shows O I absorption and we discuss a tentative detection of an infrared band due to water ice in the spectral energy distribution. Possibly we are witnessing a product of binary evolution in this enigmatic object.

**Key words.** Stars: Carbon – Stars: IRAS 17340−3757 – Stars: AGB, post-AGB – Reflection nebulae – Infrared: Stars

## 1. Introduction

All low and intermediate mass stars end their life on the so-called Asymptotic Giant Branch (AGB) where they lose their entire hydrogen-rich envelope through a slowly expanding, dusty stellar wind. Mass loss rates can reach values as high as $10^{-5}$ to $10^{-3}$ M$_\odot$ yr$^{-1}$ which implies that this is a short-lived but crucial phase in stellar evolution. The physical mechanism driving the outflows of AGB stars is probably related to a combination of stellar pulsations and the formation of dust in the inner regions of the cooling envelope. At the end of the AGB phase, mass loss drops to low values and the AGB remnant begins to expand while the central star becomes visible and increases its effective temperature. During this post-AGB phase often a double-peaked spectral energy distribution is observed, in the optical dominated by the post-AGB star, and in the IR by thermal emission from dust in the AGB remnant heated by the star. The AGB remnant is often found to be spatially extended at mid-IR wavelengths on scales of $\sim 10^{15}$–$10^{16}$ cm (see e.g. Meixner et al. 1997).

The mid-IR images of post-AGB shells show that AGB winds are axi-symmetric at the very end of the AGB. The origin of this deviation from spherical symmetry is not well understood, and several suggestions have been made; e.g. axi-symmetric mass loss, or the effect of a (stellar or planetary) companion. The presence of a companion near the dust condensation region will probably affect densities and thus the dust formation process. Since mass loss depends critically on the density in the dust forming layer, this could cause a (strong) latitude dependence of the mass loss rate. There is accumulating observational evidence that binarity can substantially alter the outcome of AGB

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evolution (see e.g. Jorissen & Mayor 1992), with the binary surviving the AGB. The RV Tau stars with weak metallic lines are suspected to be wide binaries (with orbital periods between a few 100 to ∼ 1500 days; Van Winckel et al. 1999) of which one component has recently left the AGB. These stars are surrounded by a circum-companion disk or a circum-binary disk which is probably the result of mass transfer and/or mass loss processes.

A second group of post-AGB stars with weak metal lines was also found to consist of wide binaries with circum-binary disks (Van Winckel et al. 1995). The most famous object in this group is HD 44179, the central star of the Red Rectangle. The Red Rectangle has a complicated chemical structure in its circumstellar matter, showing evidence for both oxygen-rich and carbon-rich dust. These observations have been interpreted in terms of the chemical evolution of the more massive star in the system from an O-rich M giant to a C-rich AGB star (Waters et al. 1998). The O-rich dust was ejected when the star was still an M-giant and was stored in a long-lived disk. The AGB star then evolved to a C star. A possible progenitor system to the Red Rectangle and similar objects is IRAS 09425−6040 (Molster et al. 2001), a C-rich AGB star surrounded by an oxygen-rich cold dust shell, which likely has the geometry of a (stationary) disk.

In this paper we report on the discovery of a peculiar AGB star which is surrounded by an extended, highly bipolar reflection nebulosity, IRAS 17340−3757. The object was found on the basis of optical and infrared searches for young stellar objects: the *IRAS* colors resemble those of optically thick dust disks surrounding young pre-main-sequence stars (Magnier et al. 1999). However, subsequent optical and infrared spectroscopy showed that the central star is in fact an evolved carbon star, thus ruling out a young stellar object. Thus, IRAS 17340−3757 seems to share properties of AGB stars (the star) as well as of post-AGB stars (the extended bipolar nebula). This paper is organized as follows: in Sect. 2 and 3 we present and analyse our observations; in Sect. 4 we discuss the possible evolutionary status of IRAS 17340−3757 and its link to other peculiar evolved stars.

## 2. Observations

### 2.1. Imaging

CCD images of IRAS 17340−3757 through Bessel $V$ (5442 Å), Bessel $R$ (6481 Å) and Gunn $i$ (7972 Å) filters were obtained with the Dutch 92 cm telescope (TEK $512^2$ detector, $0''.44$ pixel scale) at the European Southern Observatory, La Silla, Chile, on September 14, 1996. Exposure times were five minutes per CCD frame. The source was imaged three times in each filter. These three exposures were subsequently averaged, rejecting outliers in the image due to cosmic ray impacts on the detector. The resulting images were bias subtracted, flatfield corrected and positionally calibrated.

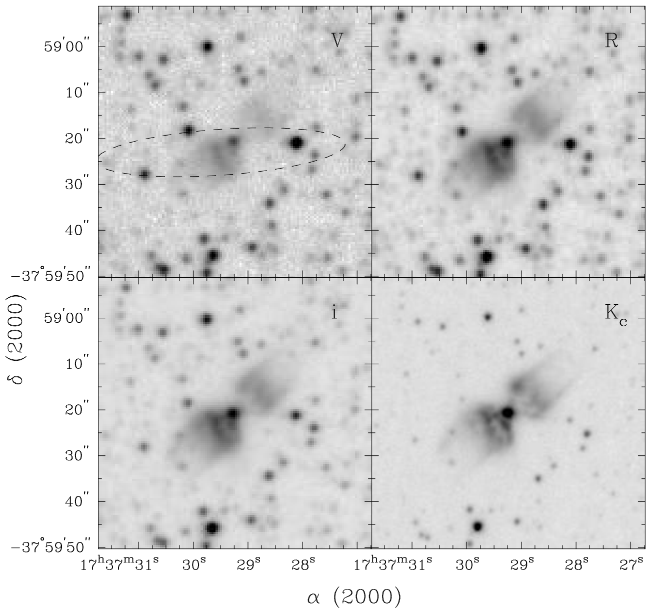


**Fig. 1.** Optical ($VRI$) and near-IR ($K_c$) broadband images of IRAS 17340−3757. Intensities are scaled logarithmically to grey-scales. The dashed curve in the $V$-band image shows the IRAS Point Source Catalogue error ellipse for this source.

Synthetic aperture photometry of the point-like source in the center of the bipolar nebula visible in the images was performed using a 5 pixel ($2''.2$) radius circle centered on the point-source. A 5 pixel wide circular annulus starting at 15 pixels ($6''.6$) from the point-source was used to compute the background. A sigma-clipping algorithm was applied to this background annulus to eliminate any emission from compact sources. Different choices of the radii hardly affect our results, leading us to believe that the presence of extended nebulosity did not greatly influence the results. Our photometry was flux-calibrated and transformed to the Cousins $VRI$ system using images from standard stars in the E1 and E7 regions (Graham 1982). The resulting magnitudes for the point-like source in the center of the IRAS 17340−3757 nebula are $V = 19^{\rm m}.1$, $R_c = 16^{\rm m}.9$ and $I_c = 15^{\rm m}.1$. We estimate the errors in these magnitudes, mainly due to the uncertainties in the absolute calibration of the images, to be around $0^{\rm m}.1$.

A near-infrared $K'$-band image of IRAS 17340−3757 was taken in non-photometric conditions with the SOFI instrument with $1024^2$ NICMOS3 detector ($0''.3$ pixel size) at the 3.5 m ESO New Technology Telescopy (NTT) on July 24, 1999. The total integration time of the image was 20 seconds. The resulting image was dark subtracted, flatfield corrected and positionally calibrated. The central part of this image is shown along with the optical images in Fig. 1.

Mid-infrared $L'$ (3.84 $\mu$m), $M$ (4.80 $\mu$m), $N$ (10.6 $\mu$m) and $Q$ (18.0 $\mu$m) images of IRAS 17340−3757 were taken on August 11 and August 14, 2001 with the University of Arizona/Smithsonian Astrophysical Observatory Mid-IR Array Camera (MIRAC3; Hoffman et al. 1998) on the 6.5 m Magellan I Walter Baade telescope. A 128 × 128

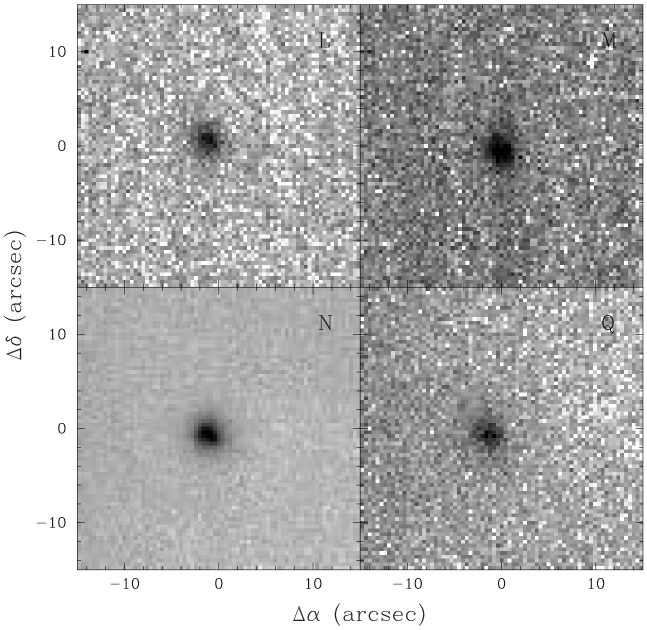


**Fig. 2.** Mid-infrared broadband ($L'MNQ$) images of IRAS 17340−3757 obtained with MIRAC on Magellan. Intensities are again scaled logarithmically to grey-scales.

Boeing HF-16 arsenic-doped silicon-impurity-band hybrid array was used as the detector. The pixel scale was set to 0.″38, resulting in a 49″ × 49″ field of view. Subtraction of the thermal emission from the sky, as well as the telescope itself, was achieved by chopping in the East-West direction with a chop throw of 30″, and nodding the telescope in the North-South direction by 30″. The chopping frequency was 3 Hz, whereas the nodding sequence was repeated every 30 seconds. Total integration times were 1, 1, 5 and 10 minutes per night for the $L'$, $M$, $N$ and $Q$ bands, respectively. The mid-infrared standard stars HD 169916 and HD 175775 (August 11) or HD 169916 and HD 196171 (August 14), observed just before and after the science observation, were used to flux calibrate the data and as point spread function (PSF) reference stars. After a standard data reduction consisting of co-adding of frames, flat fielding and bad pixel removal, the chopped and nodded images of IRAS 17340−3757 were combined into one single frame per filter, shown in Fig. 2. In all four filters, IRAS 17340−3757 appears point-like. By comparison with our PSF reference stars, we derive upper limits of 0.″7, 0.″8, 0.″4 and 1.″2 on the spatial extent of this compact source in $L'$, $M$, $N$ and $Q$. No extended emission could be detected in any of the mid-infrared images. Synthetic aperture photometry was performed on the point source using a circular aperture of 20 pixels (7.″6), with a 5 pixel wide annulus surrounding this aperture used to subtract any background residuals. Again different choices of the radii did not significantly alter our results. The results were also within errors identical in both nights for which we have data. Averaged magnitudes for the central source of IRAS 17340−3757 are listed in Table 1.

**Table 1.** Photometry of IRAS 17340−3757.

| Instrument | Band | λ [μm] | magnitude | $F_\nu$ [Jy] |
|---|---|---|---|---|
| Dutch | $V$ | 0.55 | 19.1 ± 0.1 | $(8.4 \pm 0.7) \times 10^{-5}$ |
| | $R_c$ | 0.64 | 16.9 ± 0.1 | $(5.2 \pm 0.5) \times 10^{-4}$ |
| | $I_c$ | 0.79 | 15.1 ± 0.1 | $(2.3 \pm 0.2) \times 10^{-3}$ |
| 2MASS | $J$ | 1.25 | 11.16 ± 0.05 | 0.056 ± 0.003 |
| | $H$ | 1.65 | 10.50 ± 0.06 | 0.070 ± 0.004 |
| | $K_s$ | 2.17 | 9.95 ± 0.08 | 0.070 ± 0.005 |
| MIRAC | $L'$ | 3.84 | 6.91 ± 0.05 | 0.43 ± 0.02 |
| | $M$ | 4.80 | 5.61 ± 0.05 | 1.00 ± 0.05 |
| | $N$ | 10.6 | 2.88 ± 0.04 | 2.44 ± 0.09 |
| | $Q$ | 18.0 | 1.53 ± 0.05 | 3.09 ± 0.16 |
| TIMMI2 | $N'$ | 11.9 | 3.10 ± 0.10 | 1.99 ± 0.19 |
| MSX | $B_2$ | 4.25 | – | < 9.63 |
| | $A$ | 8.28 | – | 2.16 ± 0.11 |
| | $C$ | 12.1 | – | 1.98 ± 0.15 |
| | $D$ | 14.7 | – | 3.96 ± 0.19 |
| | $E$ | 21.3 | – | 6.22 ± 0.49 |
| IRAS | [12] | 11.8 | – | 2.77 ± 0.19 |
| | [25] | 24.4 | – | 6.91 ± 0.55 |
| | [60] | 58.6 | – | 43.3 ± 5.2 |
| | [100] | 101 | – | 27.0 ± 2.7 |

Additional $N'$-band (11.9 μm) images of IRAS 17340−3757 were obtained on May 16 and May 17, 2001 using the TIMMI2 instrument (Reimann et al. 2000) at the ESO 3.6 m telescope. The pixel scale on the 320 × 240 Raytheon Si:As array was set to 0.″202, providing a total field of view of 64″ × 48″. Sky subtraction was achieved by chopping in the North-South direction with an amplitude of 15″ followed by a nodding pattern with the same direction and amplitude. The infrared standard star HD 169916 was observed both before and after each program star observation as a flux and PSF calibrator. In the resulting images, with a total integration time of 15 minutes, IRAS 17340−3757 appears as a point source (size < 0.″6) at 11.9 μm as well. No extended emission was detected at the position of the optical nebula. Photometry of the central source, obtained using the same procedure as for the MIRAC observations, is listed in Table 1.

For detection of large-scale thermal emission from dust, we created maximum entropy 12, 25, 60 and 100 μm *IRAS* maps of 32′ × 32′ centered on IRAS 17340−3757 using the HIRAS image restoration technique (Bontekoe et al. 1994). In all four *IRAS* bands, IRAS 17340−3757 appears as a strong point-like infrared source. It is clearly much redder than the other point-sources in the field, which are visible only in the 12 and 25 μm images. No extended emission is visible in any of these infrared images, demonstrating that the source is rather isolated from any plausible star forming region.

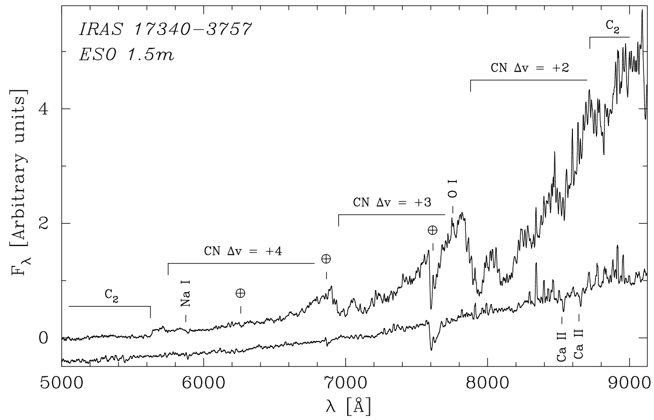


**Fig. 3.** Optical spectra of the point-source (top curve) and the nebula (bottom) associated with IRAS 17340−3757. For clarity, the nebular spectrum was shifted and multiplied by a factor of 10. Telluric absorption features are marked with ⊕.

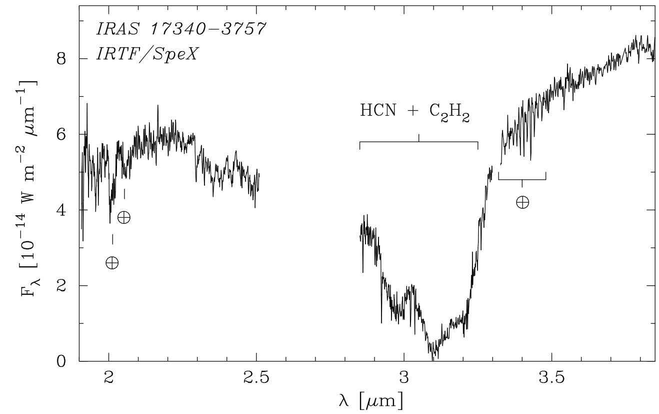


**Fig. 4.** 1.9–3.9 $\mu$m spectrum of IRAS 17340−3757 obtained with SpeX on the IRTF. Spectral regions corresponding to strong telluric absorption features have been removed from the spectrum. Other, weaker, remnants of telluric absorption are marked by the ⊕ symbol. Note the prominent HCN + $C_2H_2$ absorption feature due to between 2.7 and 3.4 $\mu$m.

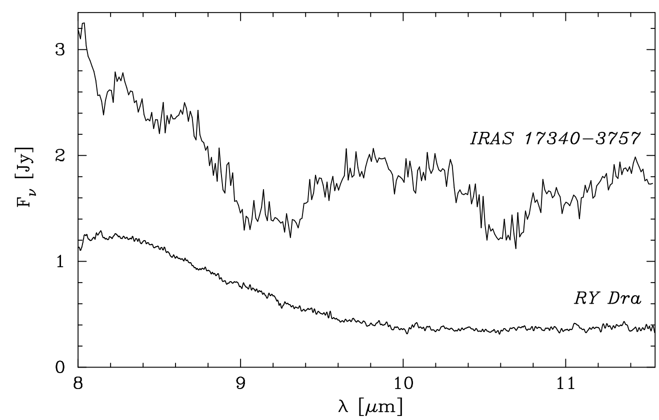


**Fig. 5.** $N$-band (8–11.6 $\mu$m) TIMMI2 spectrum of IRAS 17340−3757. Note the strong absorption structure visible at 9.0 and 10.6 $\mu$m. For comparison we also show the spectrum of the J-type Carbon star RY Dra, obtained with the *Infrared Space Observatory* (Yamamura et al. 2000), shifted for clarity.

## 2.2. Optical Spectroscopy

Low-resolution (2.8 Å pix$^{-1}$) long-slit spectra of IRAS 17340−3757 in the wavelength region of 3400–9200 Å were taken with the Boller & Chivens spectrograph at the ESO 1.52 m Telescope at La Silla during the nights of June 28 and 29, 1996. The exposure time for both observations was 60 minutes. The orientation of the slit over the nebula was chosen to be perpendicular to the nebula on June 28, whereas on June 29 the slit was oriented over the central axis of the nebula. The spectra were reduced with the usual steps of bias subtraction, flatfielding, background subtraction using a polynomial fitted over the spectrum on both sides of the source, spectral extraction, and wavelength and flux calibration. In Fig. 3 we show the spectrum obtained for the central source on July 2. Apart from a multiplicative factor, which may be due to the fact that the nights in which these observations were taken were not of photometric quality, it appears identical to the spectrum of the central point-like source in the July 3 observation. Also shown in Fig. 3 is the averaged spectrum of the nebula on both sides of the central source, obtained from the July 3 CCD frame. For this nebular spectrum, the night sky emission was subtracted using linear interpolation between the left- and rightmost 4 pixels in the CCD frame. The sharp apparent emission lines seen in the nebular spectrum could very well be artefacts resulting from this necessarily crude background subtraction.

## 2.3. Infrared Spectroscopy

Near-infrared (1.9–4.0 $\mu$m) spectoscopy of IRAS 17340−3757 system was obtained on June 28, 2002, at Mauna Kea Observatory with the SpeX spectrograph (Rayner et al. 2003) attached to the 3.0 m NASA Infrared Telescope Facility (IRTF). The slit, with a width of 0.8″ and aligned east-west, was centered on the central point-source of the nebula seen in the $K$-band image (Fig. 1). A spectrum of the reference star HR 5881 (A0 V) was also obtained just before the IRAS 17340−3757 observation, Data were reduced using the SpexTool software package (Cushing et al. 2003), after they were corrected for telluric absorption and flux-calibrated by dividing the IRAS 17340−3757 spectrum by the ratio of the HR 5881 spectrum to a Kurucz (1991) model for the photosphere of this star. The resulting spectrum is shown in Fig. 4. Since there was a small difference in airmass between the IRAS 17340−3757 and HR 5881 observations, some residuals of atmospheric absorption are visible in this near-infrared spectrum. These are marked by the ⊕ symbols in Fig. 4.

An $N$-band (8.0–11.6 $\mu$m) spectrum of IRAS 17340−3757 was obtained on May 16, 2001 using the TIMMI2 instrument on the ESO 3.6 m telescope. The same detector parameters and background subtraction procedure as followed for the TIMMI2 $N'$-band imaging were also used for the spectroscopic observations. The to-

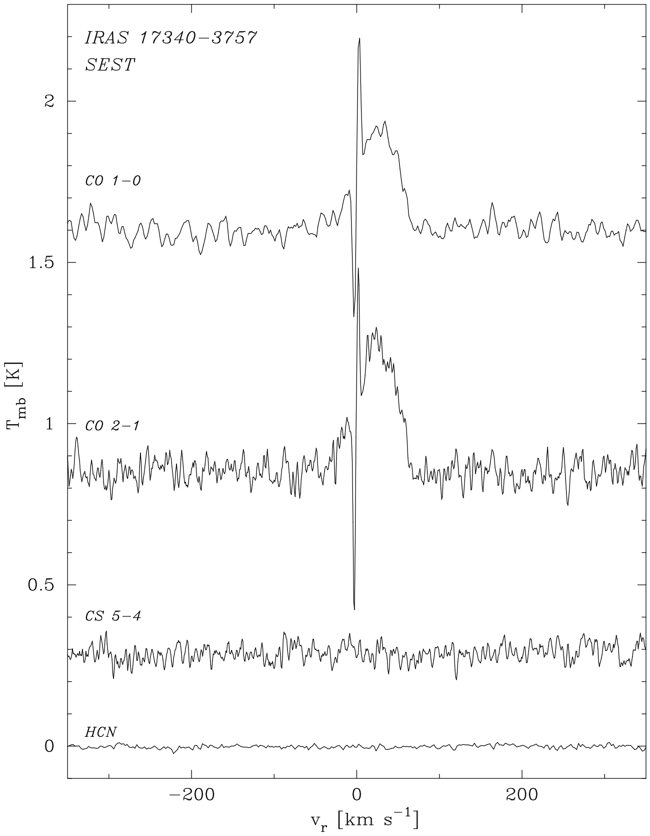


**Fig. 6.** Submm spectra of IRAS 17340−3757. From top to bottom CO 1–0, CO 2–1, CS 5–4 and HCN are shown. The vertical axis of each spectrum is shifted by an arbitrary amount.

tal integration time was 30 minutes. The slit, with a width of 3.″0, was centered on the compact source detected in the $N'$-band image, thereby suppressing any nebular emission. A spectrum of the reference star HD 169916 was also obtained before and after the IRAS 17340−3757 observation. Data were reduced using the usual steps of background subtraction, spectral extraction, and wavelength calibration. Correction for the telluric ozone absorption bands, as well as absolute flux calibration were achieved by ratioing the IRAS 17340−3757 spectrum to that of HD 169916, flux-calibrated using the spectral templates by Cohen et al. (1999). The resulting spectrum is shown in Fig. 5.

### 2.4. Submillimeter Spectroscopy

CO $v$ = 1–0 (115 GHz), CO $v$ = 2–1 (231 GHz), CS 5–4 (245 GHz) and HCN (89 GHz) spectra of IRAS 17340−3757 were obtained with the LR1 and LR2 wide-band receivers on the Swedish-ESO Submillimeter Telescope (SEST) on La Silla on March 16, 2001. Integration times were 6, 6, 8, and 34 minutes for CO 1–0, CO 2–1, CS 5–4 and HCN, respectively. Cancellation of the sky background was achieved by chopping the telescope's secondary mirror with a frequency of 8 Hz and an amplitude of 60″. All submm spectra of IRAS 17340−3757 are shown in Fig. 6.

## 3. Analysis

### 3.1. Imaging

The optical and near-infrared images of IRAS 17340−3757 shown in Fig. 1 show a red point-like source surrounded by a nebula with a strikingly bipolar appearance. In sharp contrast to this, the mid-infrared images displayed in Fig. 2 only show evidence for a point source. The morphology of the source, as well as the fact that the nebula shows a similar brightening with wavelength as the point source leaves little doubt as to the fact that the two are physically connected. Both the optical/near-infrared point-source and the south-eastern lobe of the nebula are located within the *IRAS Point Source Catalogue* error ellipse and could be responsible for the *IRAS* flux at longer wavelengths.

The point-like source is positioned slightly to the south-east of the apex of both lobes of the nebula. The south-eastern lobe of the nebula is distinctly brighter than the north-western lobe in both the optical and the near-infrared. In the $K'$ band image, which has the highest spatial resolution, several bright knots are visible in the south-eastern lobe of the nebula, suggesting the presence of clumps of matter, or perhaps even a ring of material. More filementary linear structures, similar to the streamers seen in some planetary nebulae, extend further from the central star and appear to trace the edges of the nebulosity.

The optical and near-infrared morphology of the system is compatible with that of two cones of material, perhaps moving away from the star. The colour dependence in the optical to near-infrared, as well as the absence of nebular emission in the mid-infrared, shows that this is a reflection rather than an emission nebula. The outer rim of both lobes appear brighter and can be seen at greater distance from the central source than the central parts of both lobes, suggesting an hourglass-like morphology.

### 3.2. Optical Spectroscopy

The optical spectrum of the central point-source (Fig. 3) is dominated by broad, strong absorption features which we identify with the molecular bands of CN. No flux was detected below 5630 Å, where a discontinuity is visible in the spectrum. This is indicative of strong absorption due to $C_2$, unambiguously establishing this object as a J-type Carbon star (Barnbaum et al. 1996). No H$\alpha$ or Ba II $\lambda$ 6142, 6595 is visible in the spectrum, indicative of a rather low effective temperature. The only strong narrow lines in the spectrum are due to the resonance lines of Na I at 5890 and 5896 Å and O I at 7776 Å. By comparison of our spectrum to the spectral atlas of Carbon stars by Barnbaum et al. (1996), we estimate the spectral type of the central star of IRAS 17340−3757 to be C-J4 in the classification scheme devised by these authors. By comparison, the nebular spectrum shown in Fig. 3 looks smooth and featureless. Apart from the telluric bands, the only absorption features in the red continuum that are visible are the Na I doublet at 5890, 5896 Å and the Ca II triplet at 8500, 8542, 8662 Å.

The striking morphology of IRAS 17340−3757 strongly suggested a physical connection between the nebula and the point-like source. This is further confirmed by our spectroscopy, which showed the central source to be a C-star. The probability of a chance aligment between two such rare objects is neglegible. The smooth appearance of the nebular spectrum is somewhat surprising. Possibly we are seeing the presence of extended red emission (ERE), similar to that seen in some other reflection nebula, diffuse clouds and the interstellar medium (e.g. Gordon et al. 1998). The absorption lines observed in both the nebular spectrum and the spectrum from the central star, most likely interstellar of origin, suggest the system to be rather distant. From our spectrum we measure a combined equivalent width for the Na I doublet of 6.5 Å, corresponding to a total Na I column of $8.4 \times 10^{13}$ cm$^{-2}$ (assuming a $D_1/D_2$ ratio of 1.1, corresponding to the high-column density limit). With the relation between $N$(Na I) sin $|b|$ and $d$ by Sembach & Danks (1994) we determine this Na I column towards IRAS 17340−3757 to be compatible with any distance larger than 1 kpc.

### 3.3. Infrared Spectroscopy

The SpeX spectrum of IRAS 17340−3757 (Fig. 4) is dominated by a strong, broad absorption feature ranging from 2.7 to about 3.4 $\mu$m. This feature starts at wavelengths that are too short, and has too steep a shoulder on its long-wavelength side to be due to the familiar 3 $\mu$m water-ice band. Instead we identify the feature seen in IRAS 17340−3757 with a blend of gaseous HCN and $C_2H_2$ absorption such as is also seen in Carbon stars in the galaxy and the Magellanic Clouds (e.g. Yamamura et al. 2000; Matsuura et al. 2002). The “double-peaked” structure of the absorption minimum around 3.1 $\mu$m is in agreement with that expected for this band (e.g. Cernicharo et al. 1999). Additional HCN aborption around 3.55 $\mu$m is possibly present in IRAS 17340−3757, but the S/N of our current spectrum is insufficient to firmly establish its presence.

The Equivalent Width (EW) of the 3.1 $\mu$m band seen in our IRAS 17340−3757 spectrum is 0.52 $\mu$m; much higher than found for galactic Carbon stars of similar $K-L$ colour (Matsuura et al. 2002). If we assume that no other species contribute to the 3.1 $\mu$m feature, the HCN and/or $C_2H_2$ abundance in IRAS 17340−3757 must be much above the average galactic value of a few times $10^{-8}$ for both species. This could be a possible indication for an anomalously high C/O ratio in this system (Matsuura et al. 2002).

The 8.0–11.6 $\mu$m spectrum of IRAS 17340−3757 shown in Fig. 5 shows a smooth continuum, with strong spectral features in the 8.8–10.8 $\mu$m range. By comparing the spectrum of IRAS 17340−3757 with those of the other stars for which spectra were obtained during this observing run, we exclude the possibility that such prominent features could be residuals of the correction for atmospheric extinction. No similar features have been found in the infrared spectra of other evolved stars (e.g. Waters et al. 1998, Yamamura et al. 2000).

The simplest explanation for the spectral structure might be to infer the presence of two broad features centered at 9.2 and 10.6 $\mu$m. The width (FWHM) of the 9.2 $\mu$m feature would be around 0.3 $\mu$m, whereas the width of the 10.6 $\mu$m feature is 0.2 $\mu$m. However, to our knowledge currently no dust species have been identified which could cause such spectral features. Therefore we consider as an alternative explanation for the observed mid-infrared spectral structure the presence of a broad absorption band ranging from 9.0 to 10.8 $\mu$m, which has been filled in with a broad emission band from 9.4 to 10.4 $\mu$m. The familiar 10 $\mu$m band due to the Si–O bending mode in amorphous silicates, although unexpected around a C-rich star, may be the prime candidate for the observed broad absorption. The narrower (FWHM $\sim$ 0.8 $\mu$m) emission component could not be identified with any known spectral features.

### 3.4. Submillimeter Spectroscopy

The CO 1–0 and 2–1 spectra of IRAS 17340−3757 reveal a strong (peak brightness 0.3 K), very broad (FWHM $\approx$ 100 km s$^{-1}$) line centered at +26 $\pm$ 5 km s$^{-1}$. A narrow line (FWHM $\sim$ 1.5 km s$^{-1}$) is seen to be superimposed on this broad feature at a velocity of about +1 km s$^{-1}$, accompanied by a similarly narrow absorption line at −1 km s$^{-1}$.

No lines were detected in the SEST CS and HCN spectra of IRAS 17340−3757. The absence of the density-sensitive CS 5–4 or $HCO^+$ 6–5 (close to the HCN rest frequency) lines suggest that the molecular material must be spread out over a large volume of space. This is consistent with the non-detection of IRAS 17340−3757 in OH maser emission by te Lintel Hekkert & Chapman (1996). The broad line shape of the CO lines as well as the absence of significant amounts of dense gas are more compatible with a wind-like geometry than with an origin in a circumstellar disk.

We therefore interpret the broad CO emission feature as indicative of a very fast ($v_s \lesssim 50$ km s$^{-1}$) molecular outflow. We note that the speed of this outflow in IRAS 17340−3757 is unusual: only a handful of other galactic sources are known to possess such broad CO lines, none sharing the other observational characteristics of IRAS 17340−3757. The narrow lines also seen in CO may easily be explained by the presence of an extended molecular cloud in our beam. The presence of the narrow absorption feature, most likely caused by the presence of CO emission in our chopping position 60″ from the central source, shows that this structure must be more extended than our chopping throw. It may be a molecular cloud unrelated to

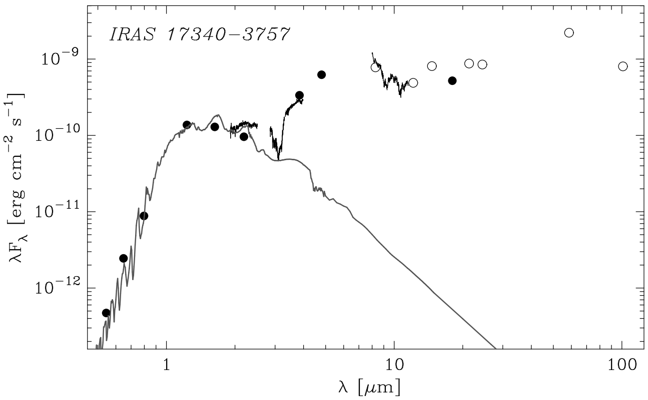


**Fig. 7.** Spectral Energy Distribution of IRAS 17340−3757. Observations with sufficient spatial resolution to exclude the nebular emission are shown as filled dots, whereas *MSX* and *IRAS* data, which include emission from both central point-source and nebula, are shown as open circles. Also shown are the SpeX and TIMMI2 spectra (three upper lines) of IRAS 17340−3757 and a synthetic model energy distribution for the central C-J4 star (lowest curve).

IRAS 17340−3757. The absence of strong HCN emission may suggest that the outflow of IRAS 17340−3757 is O- rather than C-rich.

The CO 1–0 and 2–1 lines appear equally strong, suggesting that these lines are optically thick. Therefore the peak line flux (0.33 K) and half line width (65 km s$^{-1}$) of the CO 1–0 line constrain the stellar mass loss rate. Using the formula by Knapp & Morris (1985), a CO over $H_2$ abundance of $8 \times 10^{-4}$, appropriate for Carbon stars, and the 1 kpc lower limit to the distance derived in Sect. 3.2, we compute $\dot{M} > 1.2 \times 10^{-4}$ M$_\odot$ yr$^{-1}$. This lower limit to the mass loss rate places IRAS 17340−3757 among the evolved stars with the highest mass loss rates. This would indicate that the current episode of mass loss in IRAS 17340−3757 has only started recently. This is in agreement with the rather small size of the reflection nebula seen in the optical images. If this nebula has been formed by the same outflow seen in the CO lines, its kinematic age would be only 1400 years for an expansion velocity of 50 km s$^{-1}$.

### 3.5. Spectral Energy Distribution

Using our newly obtained $VRIL'MNQ$ photometry, $JHK$ magnitudes of the central source obtained from the 2MASS Survey, as well as data from the *MSX Point Source Catalogue* (Egan et al. 1999) and the *IRAS Point Source Catalogue* (2$^{\rm nd}$ ed), we constructed the Spectral Energy Distribution (SED) of IRAS 17340−3757, shown in Fig. 7. As can be seen from this plot, the optical and near-infrared fluxes of IRAS 17340−3757 form the smooth curve that one may expect from the photosphere of a cool star. To characterize this, we also show a PHOENIX (Allard & Hauschildt 1995; Hauschildt et al. 1997) synthetic model atmosphere with $T_{\rm eff} = 4000$ K, $\log g = 3.5$ and a carbon to oxygen ratio of 1.02, believed to be appropriate for a J4-type carbon star, reddened by the $A_V$ of $4\overset{\rm m}{.}0$ indicated by the 2MASS $J - K$ colour of IRAS 17340−3757 (the intrinsic near-infrared colours of carbon stars are rather homogeneous; Knapik & Bergeat 1997).

At wavelengths longward of 2.2 $\mu$m, a large infrared excess above the levels indicated by the PHOENIX model atmosphere is visible in the SED. The *MSX* and *IRAS* data points between 8 and 15 $\mu$m show a deep absorption, compatible with the TIMMI2 spectrum discussed in section 2.3. The ground-based $Q$ band data point appears significantly lower than the interpolated *MSX* $D$ and $E$ band fluxes. This may either be due to a strong absorption feature in the 18 $\mu$m region (e.g. due to the O–Si–O bending mode in amorphous silicates), or it could be the result of the difference in spatial resolution between the *MSX* and ground-based observations. If the latter is correct, deeper $Q$-band imaging should be able to resolve extended emission surrounding the central point source.

At longer wavelengths, the IRAS 60 $\mu$m point appears to be much stronger than the interpolated 25 and 100 $\mu$m fluxes. The *HIRAS* images demonstrate that this behaviour cannot be due to confusion by nearby extended emission, but must reflect the presence of a strong spectral feature in the *IRAS* 60 $\mu$m band. This anomalously high 60 $\mu$m flux is reminiscent of that of the O-rich protoplanetary nebula Frosty Leo (IRAS 09371+1212), which shows a very prominent emission band due to crystalline water ice from 50 to 80 $\mu$m (Forveille et al. 1987; Omont et al. 1990). In analogy with this object, we suggest that the nebula surrounding IRAS 17340−3757 may contain a significant amount of crystalline water ice.

Using our lower limit of 1 kpc for the distance and the SED data presented in Fig. 7 we compute the bolometric luminosity of IRAS 17340−3757 to be > 120 L$_\odot$. Interestingly, the bulk (93%) of this luminosity is radiated at wavelengths that can not be dominated by the photosphere of the central carbon star. The radiation at the long wavelengths may be easily explained by thermal emission from circumstellar dust, heated up by the central star. However, the rather modest ($A_V \approx 4\overset{\rm m}{.}0$) extinction towards the central star combined with the observation that the total system luminosity is dominated by the infrared excess, will pose stringent constraints on any scenario in which circumstellar dust is to be responsible for the mid-infrared emission as well. The only possibility to reconcile these two observations would be to pose that the circumstellar dust responsible for the mid-infrared emission is optically thick and primarily concentrated outside of our line-of-sight towards the central star. A circumstellar disk could satisfy both criteria. Alternatively, one could hypothesize that an additional source of energy, for example in the form of an embedded companion, to be present to explain the unusual energetics of the system.

## 4. Discussion and Conclusions

In the previous sections we have seen a large number of sometimes conflicting observations regarding the nature of

IRAS 17340−3757. The absence of hydrogen atoms or hydrogen bearing molecules such as CH in the optical spectrum of IRAS 17340−3757 excludes a possible YSO nature of the central point-source. The very unusual spectrum displayed by the point-like source, as well as the fact that the point-source appears well-centered on the nebula, show that the two must be physically connected and that we are not merely seeing a late-type foreground star projected onto the nebula. Therefore we must conclude that the selection criteria outlined by Magnier et al. (1999) do not only select transitional YSOs, but that they also select an hitherto unrecognized class of evolved stars.

The nature of the member of this new class of objects studied in this paper, IRAS 17340−3757, immediately raises some challenges to the standard picture of late stages of stellar evolution. The central star is clearly C-rich and very cool, which would suggest that it is already on the Asymmetric Giant Branch (AGB). This would be compatible with the presence of a strong outflow. However, the star also already possesses an optically bright, strikingly symmetric, nebula, which one would only expect to see after the star has become a protoplanetary nebula.

The chemistry of the IRAS 17340−3757 system is equally unusual. The central star is evidently C-rich, but also contains some O in its immediate surroundings, as evidenced by the presence of O I in the optical spectrum. Furthermore, the possible presence of silicates in absorption, the absence of sub-mm HCN emission and the tentative detection of water ice all suggest that at least some parts of the nebula may be O-rich rather than C-rich. This would suggest that IRAS 17340−3757 is related to the group of silicate carbon stars: J-type Carbon stars which show prominent silicate emission features in the infrared (e.g. Waters et al. 1998; Yamamura et al. 2000). In these systems it is believed that the dust disk is a remnant of a previous phase of mass-loss when the central star was O-rich. However, none of these stars is known to harbour an optically bright reflection nebula, making IRAS 17340−3757 unique.

IRAS 17340−3757 may also be related to peculiar objects as IRAS 09425−6040 and the RR. Both objects harbour a C-rich AGB or post-AGB star and show mixed chemistry consistent with the presence of an O-rich long-lived (circum-binary) disk. It is tempting to place IRAS 17340−3757 between IRAS 09425−6040 and the Red Rectangle. Note however that the expansion velocity of the bipolar nebula of the Red Rectangle is much smaller than the high velocities seen in IRAS 17340−3757.

To some degree, the properties of IRAS 17340−3757 are reminiscent of those of OH231.8+4.2 (the rotten egg nebula). This is a late M Mira star with a similar high velocity outflow and a prominent bipolar outflow, seen e.g. in HST NICMOS images. Zijlstra et al. (2001) explained the appearance of accelerating outflows in OH/IR stars as due to an outer AGB wind, swept up by a faster post-AGB wind, with either the AGB- or post-AGB wind being non-spherically symmetric. The detection of an unusually fast CO outflow in IRAS 17340−3757, a source with an extremely bipolar reflection nebula, fits in nicely with this general picture. It could be that IRAS 17340−3757 is the evolutionary successor to the OH/IR stars with bipolar outflows, which means that the high velocity CO outflow would continue throughout the main part of the AGB (it takes time for a star to evolve to the C-star phase through thermal pulses).

Binarity may be the key to understand the unusual properties of all these objects. A binary nature may be essential to generate the non-spherically symmetric wind required in the Zijlstra et al. (2001) model. Some authors even speculate that *all* bipolar nebula must be the product of binary evolution (Morris 1987; Livio 1993; Soker & Harpaz 1992; Soker 2001). The binary hypothesis could also explain the unusual energetics and chemistry of IRAS 17340−3757 if its mid-infrared emission were to be dominated by an embedded companion. This companion could also be responsible for (part of) the radiation field illuminating the reflection nebula. Also, AGB stars in binaries may develop a high velocity CO outflow at any time during their evolution, depending e.g. on the properties of a hypothetical companion star, which would explain the small kinematic age of the nebula. Time-resolved optical or near-infrared spectroscopy of the central star of IRAS 17340−3757 would be a valuable tool to test this hypothesis further.

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