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IRAS 03201+5459: a C–rich AGB star with silicate absorption ⋆

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Abstract. IRAS 03201+5459 is a late–type star with a circumstellar envelope according to its IRAS color. It has no identification at optical or near–infrared wavelengths. A full ISO–SWS spectrum between 2.3 and 43 μm was taken at the resolution of about ∼300 to investigate its nature. The spectrum shows the 9.7 μm feature in absorption usually seen in O–rich envelopes, and the 3 μm feature in absorption related to C–rich late–type stars. Furthermore, modeling of the spectral energy distribution indicates the necessity of C–based dust. To understend the conflicting spectral features, we have estimated interstellar extinction by means of different methods in direction of IRAS 03201+5459. In no case we can get $A_{\rm V}$ sufficiently large to explain the observed strength of the 9.7 μm absorption feature. Therefore, we have investigated the hypothesis that a central C–rich star is surrounded by an inner C–rich shell and an outer O–rich shell (the object may be at the transient stage of evolution from an O–rich to C–rich star). However, the required very short timescale of star life as a C–rich and at the same time similarity between IRAS and ISO spectra makes this hypothesis rather weak. **On the other hand, O–rich material around C–star IRAS 03201+5459 could be confined into more stationary disk–like configuration which is seen (almost) edge–on.**

Key words: Stars: AGB and post–AGB – circumstellar matter – stars: chemically peculiar – Stars: individual: IRAS 03201+5459

1. Introduction and conclusion

IRAS 03201+5459 (hereafter IRAS 03201) was first detected by the IRAS satellite (see The IRAS Point Source Catalogue) (PSC 1988). Fluxes at 12 and 25 microns are 13.77 and 5.14 Jy, respectively, which are of good quality. The resulting color $C_{12} \equiv \lg(F_{25}/F_{12})$ is equal to −0.43 which is typical for a late–type star with circumstellar envelope, posssibly optically thin and warm if the star is located in region II, or cold if source position coincides with region VIa on the IRAS color–color diagram (van der Veen & Habing 1988). Due to the low quality of the IRAS flux at 60 μm (only upper limit values are available for the 60 and 100 μm fluxes) it is difficult to judge the property of the object solely by its C_{12} IRAS color.

As the flux at 12 micron is relatively high, the Low Resolution Spectrum (LRS) between 7 and 23 μm was also obtained by the IRAS. Due to a clear absorption feature around 10 μm it was classified as LRS 32 (Olnon et al. 1986). However, it is worth noting that Kwok et al. (1997) put this LRS spectrum into unusual (U) group according to an eye classification scheme developed by Volk & Cohen (1989). It was assumed to be a carbon–rich source with silicate absorption due to interstellar extinction. This possibility will be discussed in more detail in Sect. 3.

After the discovery of this source during the IRAS mission, follow–up identification attempts were carried out, but no object from the exisiting catalogues was associated with this source. Optical identification in POSS R plate gave a negative result (Jiang & Hu 1992), so the object is fainter than 21st magnitude in the R band. Moreover, there was no detection of signal in near–infrared (IR) at the limit of magnitude 8 at K band, i.e. the flux at 2.2 μm is less than 0.4 Jy. The steep increase between the near–IR such as K band and the mid–IR (e.g. 12 μm) may indicate strong emission in this range, for which ISO Short Wavelength Spectrometer (SWS) observation was proposed. Searches for the molecular maser emissions from OH (Galt et al. 1989), H_2O (Zuckerman & Lo 1987) and SiO (Jiang et al. 1996) all failed to find any maser lines. In consequence, no more measurements were available aside from the IRAS photometry and spectroscopy.

1.1. Two–dust–component model

The thinner C–rich shell close to the central star extends up to about 0.15 $R_{\rm max}$ and the geometrically thicker O–rich shell is located in the outer part. The expansion velocity is assumed to be 15 km s^{-1} and to be the same for the two types of circumstellar shells so that the ages of the two shells are 31 yrs and 180 yrs, respectively. In other words, the C–rich stellar wind started 31 years ago if expansion velocity is 15 km s^{-1}

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Table 1. Key parameters for two–dust (AC1+silicate) model

Parameter	Value
$T_{\rm eff}$	2800 K
$L_{\rm star}$	8000 $L_\odot$
d	4.2 kpc
$T_{\rm inn}$	800 K
R_{inn}	$4.2\,10^{14}$cm
$R_{\rm out}$	$1.0\,10^{16}$cm
t_{dyn}	$2.11\,10^{2}$ yr
$R_{\rm AC1shell}$	0.06–0.15 $R_{\rm out}$
$R_{\rm silicateshell}$	0.15–1.00 $R_{\rm out}$
$\dot{M}$	$1.1\,10^{-5}$ $M_\odot$/yr
Dust–to–gas ratio (AC1 shell)	$5.0\,10^{-3}$
Dust–to–gas ratio (silicate shell)	$8.0\,10^{-3}$
A_V	21.6

or about 50 years ago if $V_{\rm exp}$ = 10 km s^{-1} and the O–rich stellar wind started 211 years if $V_{\rm exp}$ = 15 or about 300 years ago if $V_{\rm exp}$ = 10 km s^{-1}. The end of the O–rich wind and the start of C–rich wind occured in our model at the same time. The time seems short for the O–rich mass loss process. Increasing the outer radius of the model would result in a longer life of O–rich mass loss phase although the far–infrared radiation would increase at the same time if the density distribution remains the same. A possible explanation is that the density distribution of the O–rich shell decreases steeper with radius than the assumed power law with index -2 (which corresponds to increasing mass loss rate with time). More steeply decreasing distributions of the density of the shell would enlarge the outer radius of the shell keeping the far–infrared radiation almost unchanged. If the dust–to–gas ratios for O–rich and C–rich stellar winds were the same then the O–rich mass loss rate would be 1.6 times that for C–rich case.

Early in 1986, Little–Marenin (1986) and Willems & de Jong (1986) found nine stars which showed silicate emission at 9.7 μm but were optically identified with carbon stars. Some of these sources may be mis–identified, but several others seem to have both the silicate and C–rich features real (see e.g. Kwok et al. 1997 for one of the most recent lists of such sources). Because the majority of these silicate carbon stars are ^{13}C–enhanced J–type (Lambert et al. 1990, Le Bertre et al. 1990, Lloyd–Evans 1990), a binary model was proposed. However the presence of a mass–losing O–rich companion was ruled out observationally for a number of silicate carbon stars (Noguchi et al. 1990; Engels & Leinert 1994). In addition, an object with both O–rich and C–rich spectral features has been found in LMC (Trams et al. 1999). In a single–star model, such silicate carbon stars would have experienced O–rich mass loss which formed the O–rich shell that has already expanded to become optically thin at 9.7 μm, producing the emission feature. Their central stars have become C–rich after the third dredge–up process ejected the freshly produced C from the burning shell to the photosphere. Note, however, that Jura & Kahane (1999) found narrow emission lines of CO from two carbon–stars with oxygen–rich envelopes, which can be interpreted as an evidence of long–lived reservoir of orbiting gas. This gas, if O–rich **and not completely seen edge–on** could give observed silicate emission.

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