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The Chemical Classification of the AGB Star IRAS 17515–2407 *

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Abstract The chemical classification of IRAS 17515–2407 has been debated for a long time. Up to now there are two contenders, oxygen-rich or carbon-rich. We believe that IRAS 17515–2407 is an oxygen-rich source: because (i) it shows the silicate self-absorbed emission; (ii) in the near infrared-IRAS diagram it is located in the oxygen-rich object region and (iii) particularly, it has detected SiO maser emission.

Key words: stars: AGB – stars: chemical classification – stars: maser – infrared: stars

1 INTRODUCTION

Stars on the asymptotic giant branch (AGB) are divided into three main groups, M, S and C. It is well known that the M stars (oxygen-rich) have $C/O < 1$, the S stars, $C/O \approx 1$ and the C stars, $C/O > 1$ (Iben & Renzini 1983; Chen & Kwok 1993). Before the advent of infrared astronomy, the identification of M, S and C stars was based exclusively on typical molecular features in the optical: the M stars show TiO and VO molecular bands, the S stars display ZrO and LaO molecular bands, and the C stars are easily recognized by the presence of CN and C_2 bands. However, with large infrared surveys becoming available (IRC, AFGL, IRAS and recently 2MASS and DENIS) it has become clear that there are a lot of AGB stars that are so obscured by circumstellar shells that they are faint or even invisible in the optical region. For these stars, there are no traditional ways of determining their chemical composition and other methods based on their properties in the infrared or/and radio bands have to be used.

After the IRAS mission, the IRAS low-resolution spectra (LRS) have become an important tool for discriminating between the carbon stars and M stars. The silicate features at $10\,\mu$m and $18\,\mu$m in emission or in absorption are indicators of the oxygen-rich M stars, while the silicon carbide (SiC) feature at $11.2\,\mu$m is a good indicator of the carbon-rich stars (Olnon & Raimond 1986; Kwok et al. 1997). However, there is one exception in that some carbon stars do display silicate emission features at $10\,\mu$m and these are now known as silicate carbon stars

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(Little-Marenin 1986; Willems & de Jong 1986; Kwok et al. 1997; Yamamura et al. 2000). In addition, a lot of AGB stars do not exhibit clearly any of the above features in their LRS spectra (e.g., Omont et al. 1993; Chan 1994). Moreover, the majority of IRAS sources have no LRS observations due to their low fluxes in the LRS band at 7–23 μm and, in fact, only about 1/20 of them have the LRS spectra available (Kwok et al. 1997). Therefore, sometimes infrared two color diagrams are used for discriminating between the carbon stars and the M stars. One such diagram commonly used is the [25]–[60] vs. [12]–[25] diagram proposed by van der Veen & Habing (1988). Another is [12]–[25] vs. K-L or [12]–[25] vs. L-[12] suggested and used by Epchtein et al. (1987, 1990), Fouque et al. (1992) and Guglielmo et al. (1993, 1997, 1998).

In addition, as Raid & Moran (1981) and Habing (1996) pointed out, the SiO maser phenomenon is a common property of oxygen-rich late-AGB stars and the SiO maser emission is generated just above the stellar photosphere within about two to four times the stellar diameter. On the other hand, although OH and H_2O maser emissions have been found in some silicate carbon stars, no SiO maser emission has been detected in any of the silicate carbon stars (Little-Marenin et al. 1994). Hence, SiO maser emission is a good indicator of oxygen-rich late-AGB stars.

In this paper we review the available observations of IRAS 17515–2407 and demonstrate convincingly that this object is an oxygen-rich star rather than a carbon-rich star which was originally suggested by the automatic LRS classification.

2 DATA ANALYSIS AND DISCUSSION

In 1973 the first catalog for galactic carbon stars: the General Catalogue of Cool Carbon Stars was published, mainly based on spectral observations in the optical (Stephenson 1973). In 1989 Stephenson (1989) published the second edition of the galactic carbon star catalog: the General Catalog of Cool Galactic Carbon Stars, in which 176 infrared carbon stars selected by Little-Marenin et al. (1987) on the basis of the 11.2 μm SiC emission feature being present in the IRAS LRS spectra were added. Very recently, Alksnis et al. (2001) published the third edition of the galactic carbon star catalog: General Catalog of Galactic Carbon Stars by C. B. Stephenson. In this catalog, many sources identified with the infrared two color method proposed by Epchtein et al. (1987) and Fouque et al. (1992), were further added. IRAS 17515–2407 does not figure in all of these catalogs, but its "object class" in the Simbad database is given as C*.

IRAS 17515–2407 was first considered as a very dusty carbon-rich AGB star by Jura & Kleinmann (1990) according to its LRS number classification in the LRS Atlas (Olnon & Raimoud 1986). Shortly after te Lintel Hekkert et al. (1991) and Le Squeren et al. (1992) separately made OH maser emission observations at 1612 MHz and both obtained negative results. These results made it seem likely that IRAS 17515–2407 is a carbon-rich object. Allen et al. (1993), for the same reasons as Jura & Kleinmann (1990), also assumed that this star is a carbon-rich object. Even until very recently Groenewegen et al. (2002) still considered it to be an infrared carbon star, although their millimeter observations did not detect CO (1–0), CO (2–1) and HCN. The latter authors did not comment, however, on the proposal by Kwok et al. (1997) that IRAS 17515–2407 be classified as an oxygen-rich object.

It is well documented that in some cases the automated LRS classification in the LRS Atlas gives unreliable results. In particular, there are cases in which the LRS spectra with weak silicate emission were classified as 4n (e.g., Little-Marenin et al. 1987; Walker & Cohen 1988;

Chan & Kwok 1990; Volk et al. 1991 and Groenewegen et al. 1992). Fortunately, Kwok et al. (1997) re-sorted out the raw database of the IRAS LRS spectra and published a new IRAS LRS database with the letter classification proposed by Volk & Cohen (1989). It is expected that most mistakes which were present in the original version of the LRS catalogue have been corrected by this new classification scheme. In fact, Kwok et al. (1997) classified IRAS 17515–2407 as an oxygen-rich object. Figure 1 shows the LRS spectrum of this star. It can be seen that from about $8\,\mu$m to about $12.5\,\mu$m there is a wide emission feature. In addition, it can be seen that a weak absorption feature around $10\,\mu$m is superposed on the emission feature. As Sloan & Price (1998) pointed out, the whole feature could be considered as silicate self-absorbed emission and such spectra are usually classified as E type (oxygen-rich) by Volk & Cohen (1989) and Kwok et al. (1997).

Furthermore, Guglielmo et al. (1993) made the near infrared photometry and gave $K = 4.94$ and $K - L = 2.51$ for IRAS 17515–2407. They also used the near infrared-IRAS diagram proposed by Epchtein et al. (1987) to classify IRAS 17515–2407 as an oxygen-rich object in their table 3a. The standard near infrared-IRAS diagram is plotted in Fig. 2, in which the line BB indicates the blackbody line; the line AA is the line $[12] - [25] = 0.42(K - L) + 0.10$; the line CC is $K - L = 0.7$. According to Epchtein et al. (1987) and Guglielmo et al. (1993), the upper region between the line AA and the line CC is the location of the oxygen-rich objects. It can be seen that IRAS 17515–2407 is located right in the region typical for the oxygen-rich objects.

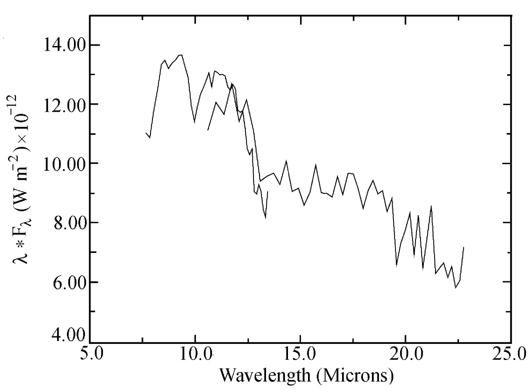

Fig. 1 LRS spectrum of IRAS 17515–2407.

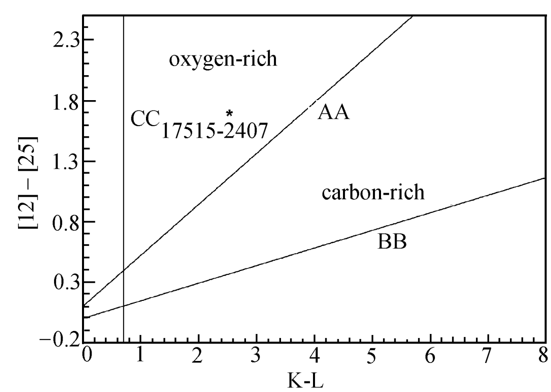

Fig. 2 IRAS 17515–2407 in the standard near infrared-IRAS diagram.

The most important fact that testifies that IRAS 17515–2407 is an oxygen-rich object is the observations of the maser emissions. Although as mentioned above, IRAS 17515–2407 has no OH maser emission detected so far, it does show SiO maser emission. Deguchi et al. (2000) made the SiO maser observation at 43 GHz and detected the SiO maser of $(J = 1 - 0, v = 1)$ with $T_a(K) = 1.084$ and $S(\text{K km s}^{-1}) = 3.198$, and of $(J = 1 - 0, v = 2)$ with $T_a(K) = 1.075$ and $S(\text{K km s}^{-1}) = 2.798$.

3 CONCLUSIONS

According to the original LRS classification, IRAS 17515–2407 was classified as a carbon-rich object. This classification has been adopted by Jura & Kleinmann (1990), Allen et al. (1993)

and more recently by Groenewegen et al. (2002). However, the original LRS classification is probably incorrect. Observational facts, collected by us for IRAS 17515–2407, namely, (i) an LRS spectrum with self-absorbed emission around 10 μm; (ii) a position in the near infrared-IRAS diagram typical for oxygen-rich object; and (iii) the detection of SiO maser emission, demonstrate that this star is an oxygen-rich object.

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