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On the Carbon-Star Status of Five Stars in a New Carbon Star Catalog

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Abstract We find that five sources listed in the new carbon star catalog are not really carbon-rich objects but oxygen-rich stars, because they all have the prominent 10μm silicate features in absorption and the 1612 MHz OH maser emission or/and the SiO molecular features. These objects were considered as carbon stars in the catalog based only on their locations in the infrared two-color diagram. Therefore to use the infrared two-color diagram to distinguish carbon-rich stars from oxygen-rich stars must be done with caution, because, in general, it has only a statistical meaning.

Key words: stars: AGB — stars: carbon — infrared: stars

1 INTRODUCTION

Stars in the asymptotic giant branch (AGB) are divided into three main groups of M, S and C according to their spectral types. It is well known that the AGB stars have the evolutionary sequence of M–MS–S–SC–C (Iben & Renzini 1983; Chen & Kwok 1993). Before the advent of infrared astronomy, the identification of M, S and C stars was based exclusively on some typical molecular features in the optical spectra with moderate resolution. M stars show TiO and VO molecular bands, S stars display ZrO and LaO molecular bands, and carbon stars are easily recognized by the presence of CN and C_2 bands. However, with the large infrared surveys (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 become faint or even invisible in the optical region. For these stars, there are no traditional ways available to discriminate them and other methods based on their infrared properties have to be employed.

After the IRAS mission, the IRAS low-resolution spectra (LRS) has become the most important tool in the infrared for discriminating between carbon stars and M-stars. The silicate features at 10μm in emission or in absorption and 18μm in emission are indicators for oxygen-rich stars (M-stars) and the silicon carbide (SiC) feature at 11.2μm is an indication for carbon-rich stars (Olnon & Raimoud 1986; Kwok et al.1997). However, some exceptions exist. One

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case is that some carbon stars do display silicate emission features at 10μm and these are now known as silicate carbon stars, but so far no silicate carbon stars have been found with the silicate features in absorption (Little-Marenin 1986; Willems & de Jong 1986; Kwok et al. 1997; Chen et al. 1999). Another case is that some M-stars and OH/IR stars may have carbon-rich shells with SiC features at 11.2μm (Skinner et al. 1990; Groenewegen 1994; Selvester 1999; Chen et al. 2001a; Chen et al. 2001b). However, a lot of AGB stars do not exhibit any of the above features clearly 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 7–23μm and only for about 1/20 of them the LRS spectra are available (Kwok et al. 1997). Therefore sometimes an infrared two-color diagram is used as a reference for discriminating between carbon stars and M-stars. The one common used is [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 by Epchtein et al. (1987) and Fouque et al. (1993).

In 1973 was published the first catalog for the galactic carbon stars: the *General Catalogue of Cool Carbon Stars* (hereafter CCCS). It is mainly based on spectral observations in the optical and it contains 3219 carbon stars (Stephenson 1973). In 1989 Stephenson (1989) published a second version, the *General Catalog of Cool Galactic Carbon Stars* (hereafter GCGCS) by adding some new carbon stars discovered with the optical method from 1973 to 1989 and also 176 IRAS sources given by Little-Marenin et al. (1987) based on the presence of the SiC emission feature at 11.2μm in their IRAS LRS spectra. The GCGCS records 5987 carbon stars. Very recently Alksnis et al. (2001) published a third version: the *General Catalog of Galactic Carbon Stars by C.B. Stephenson* (hereafter CGCS). In this catalog are added not only new carbon stars discovered by the optical and IRAS LRS methods from 1989 to 2000, but also many sources identified with the infrared two-color method proposed by Epchtein et al. (1987) and Fouque et al. (1993). In this catalog the number of carbon stars is increased to 6891.

In this paper we shall show that five new sources given in the CGCS are definitely NOT carbon stars. We shall also point out that caution should be exercised when using the infrared two-color diagrams, such as [12]–[25] vs. K-L or [12]–[25] vs. L–[12], to identify carbon stars, because such diagrams have only a statistical meaning.

2 DATA PROCESSING AND RESULT

Compared to the GCGCS, the CGCS has a further addition of 924 new sources (Alksnis et al. 2001). We have made cross-identification between these sources and the IRAS sources by using the *IRAS Point Source Catalog* (1988, hereafter PSC) according to the method proposed by Chen (1995). The main point of this method is as follows. From the 95% –confidence, positional error ellipse given for each IRAS source in the PSC (1988, PSC) and from the position and error range given for each star in the CGCS, we confirm that there is association between the CGCS star and the IRAS source if the CGCS star is located in the error ellipse of the IRAS source or if their error ranges overlap; otherwise we say there is no association. We then extracted, for the sources with positive identifications, their IRAS low-resolution spectra classifications from Kwok et al. (1997). We clearly found that among the sources, IRAS 16105–4205=CGCS 6623, IRAS 17277–2356=CGCS 6676, IRAS 17528–1503=CGCS 6689, IRAS 18298–2111=CGCS 6749 and IRAS 20547+0247=CGCS 6879 all belong to the group A in the LRS. This means that they all have the silicate feature in absorption at 10μm and they should be oxygen-rich stars, and not carbon-rich stars. The LRS spectra from Kwok et al. (1997) for these five objects are

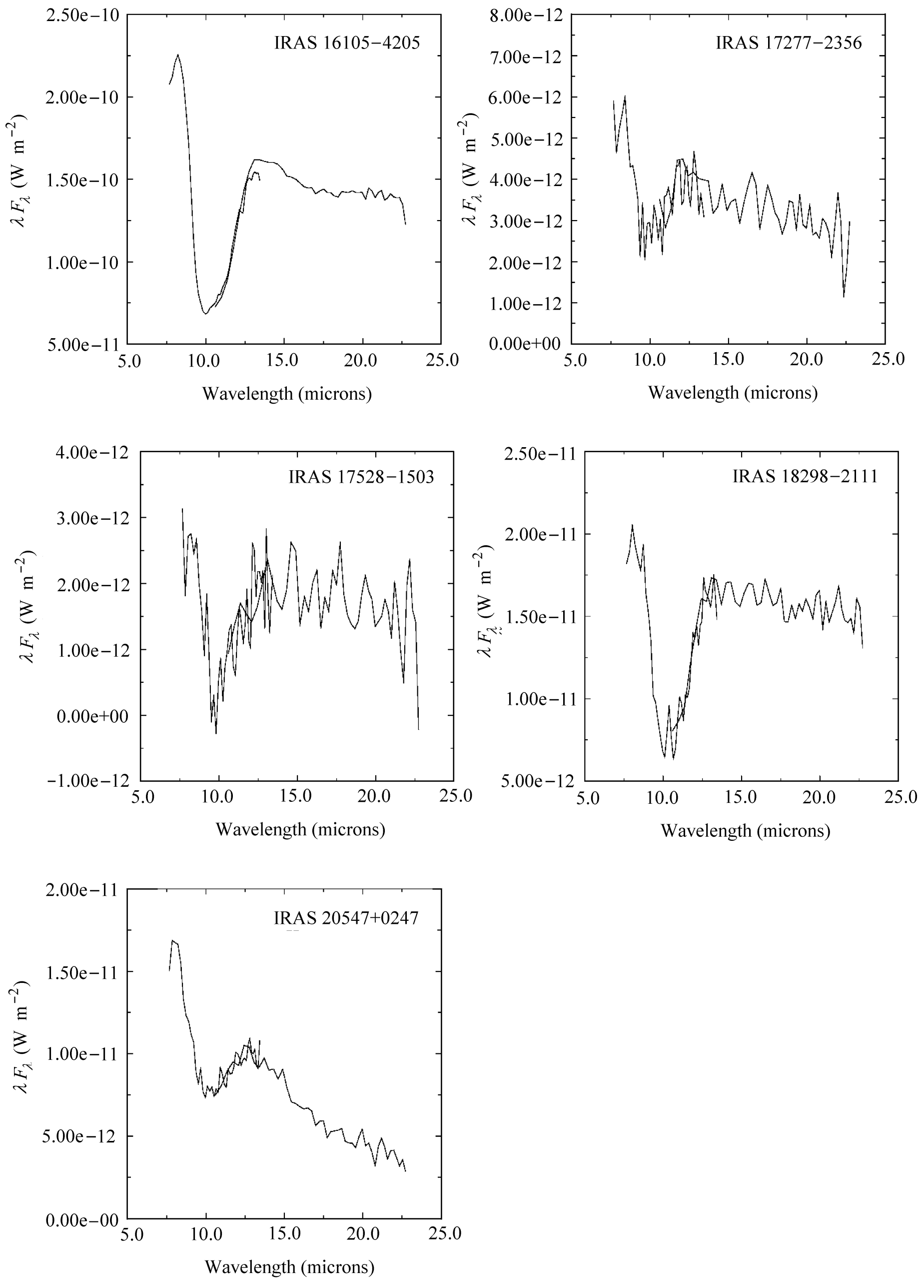

Fig. 1 IRAS LRS Spectra for IRAS 16105–4205, 17277–2356, 17528–1503, 18298–2111 and 20547+0247

displayed in Fig. 1, from which it is obvious that the silicate absorption features are prominent in all the five sources. To obtain further information, the observations by the Infrared Space Observatory (ISO) were checked for these five sources (ISO Archive); unfortunately, no data are available from ISO for these sources.

Four of the five sources (IRAS 16105–4205, 17528–1503, 18298–2111, 20547+0247) were listed as OH/IR stars in one of our recent papers (Chen et al. 2001a). It was found that the OH maser emission at 1612 MHz has been recorded 4 times in IRAS 16105–4205 (Garlard & Whitelock 1988; Garlard et al. 1989; te Lintel Hekkert et al. 1991; Silva et al. 1993), 2 times each in IRAS 17528–1503 (te Lintel Hekkert et al. 1988; te Lintel Hekkert et al. 1991) and IRAS 20547+0247 (Sivagnanam et al. 1990; Chengalur et al. 1993), and 3 times in IRAS 18298–2111 (te Lintel Hekkert et al. 1988; Likkel 1989; David et al. 1993). Furthermore, the spectral type of IRAS 16105–4205 in the Simbad database is M and the SiO maser ($J = 1 - 0$, $v = 2$) was detected for IRAS 18298–2111 (Nyman et al. 1998). Barnbaum et al. (1996) from their very detailed study of IRAS 20547+0247 (= U Equ, we have checked the positions of these two objects and found them to be within $2''$ of each other), found it to have many striking molecular lines of TiO, AlO and VO in the spectral range from 4500Å to 7100Å, as is typical of M star. For IRAS 17277–2356, although no detection of the OH maser emission has been reported so far, the detection of SiO ($J = 1 - 0$, $v = 1$ and 2) was reported by Izumiura et al. (1995). Thus, it is proved that these sources are oxygen-rich and should be excluded from the carbon star category.

These five sources were first identified as carbon-rich stars by Fouque et al. (1993) according to the method proposed by Epchtein et al. (1987). In the method the star distributions in the two-color diagram, [12]–[25] vs. K-L or [12]–[25] vs. L–[12], was used to separate the oxygen-rich and carbon-rich stars, and the carbon stars so identified were put in the class 'c'. However, Epchtein et al. (1987) pointed out "if an object belongs to the class 'c', it is *very likely* to be a carbon star". It means that this method is not always right and may have exceptions. The above sources are just such cases. The use of this method to distinguish carbon-rich stars from oxygen-rich stars must therefore be done with caution.

3 CONCLUSIONS

(1) It is likely that IRAS 16105–4205=CGCS 6623, IRAS 17277–2356=CGCS 6676, IRAS 17528–1503=CGCS 6689, IRAS 18298–2111=CGCS 6749 and IRAS 20547+0247=CGCS 6879 are NOT carbon stars and we suggest that they should be removed from the new carbon star catalog: *General Catalog of Galactic Carbon Stars* by C. B. Stephenson (Alksnis et al. 2001).

(2) When we use an infrared two-color diagram, [12]–[25] vs. K-L or [12]–[25] vs. L–[12], to distinguish carbon-rich stars from oxygen-rich stars this must be done with caution, because the star distributions in these diagrams have only a statistical meaning. For the identification of an individual star, we would recommend that some other methods are also used to verify any results from the infrared two-color method.

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