Chin. J. Astron. Astrophys. Vol. 1, No. 4, (2001) 344–348
(*http://www.chjaa.org* or *http://chjaa.bao.ac.cn*)

Chinese Journal of
Astronomy and
Astrophysics

IRAS 19111+2555 (=S Lyr): A Possible Silicate Carbon Star

Pei-Sheng Chen⋆ and Xun-Hao Wang

Yunnan Observatory and Joint Laboratory for Optical Astronomy, CAS, Kunming 650011
National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012

Received 2001 April 5; accepted 2001 June 4

Abstract The properties and classification of IRAS 19111+2555 have so far not been well determined. We collect all the available information and data of this star, and take the data obtained by IRAS LRS and ISO SWS to discuss its properties and classification. The star is found to have a 3.1μm feature in absorption and a 10μm feature in emission, so it is possibly a new silicate carbon star.

Key words: stars: AGB and post-AGB — stars: carbon — infrared: stars

1 INTRODUCTION

Stars in the asymptotic giant branch (AGB) are divided into three groups of M, S and C and their intermediates MS and SC according to their spectral types. It is well known that the sequence M-MS-S-SC-C is an evolutionary sequence (Iben & Renzini 1983; Chen & Kwok 1993). Before the advent of infrared astronomy, the identification of M, S and C stars was based exclusively on optical spectra: M stars show TiO bands, S stars display ZrO and LaO bands, and carbon stars are easily recognized by the presence of CN and C_2 bands. In addition, there is a group of peculiar carbon stars called ^{13}C-rich or J-type carbon stars that do not exhibit the enhancement of the s-process elements that the normal carbon stars do, and it seems quite difficult to separate the J-type and SC stars based only on optical spectroscopic observations (Lorenz-Martins 1996; Ohnaka & Tsuji 1999). 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 are faint or even invisible in the optical region. For these stars, the traditional way of discrimination is not available and other methods based on their infrared properties have to be employed.

After the IRAS mission, the IRAS low-resolution spectra (LRS) have become the most important tool in the infrared for discriminating between carbon- and M-stars. The silicate feature at 10 and 18μm are indicators for oxygen-rich stars (M-stars) and the silicon carbide (SiC) feature at 11.3μm is one for carbon-rich stars (Olnon & Raimoud 1986; Kwok et al. 1997). However, some exceptions exist: some carbon stars display the silicate feature and these are known as silicate carbon stars (Little-Marenin 1986; Willems & de Jong 1986; Kwok et

⋆ E-mail: iras@public.km.yn.cn

al. 1997; Chen et al. 1999) and some M-stars are surrounded by carbon-rich shells (Skinner et al. 1990; Groenewegen 1994). In addition, many silicate carbon stars observed have been identified as belonging to the J-type (Ohnaka & Tsuji 1999). Moreover, 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). Furthermore, Chen & Kwok (1993) showed that some S stars given in the *General Catalog of Galactic S Stars* (Stephenson 1984, hereafter GCGSS) have the silicate emission feature; however, Lloyd Evans & Little-Marenin (1999) pointed out that some of these stars are not real S stars but M or MS stars, and that S stars should not show the silicate feature.

Another method for distinguishing carbon stars from S or M stars is the photospheric 3.1μm absorption feature due to HCN and/or C_2H_2 (Ridgway et al. 1978): this is observed in carbon stars (Merrill & Stein 1976; Noguchi et al. 1977; Groenewegen et al. 1994), but not in M or S stars (Noguchi et al. 1977, 1981 and 1993). In addition, the silicate carbon stars observed all show this feature (Noguchi et al. 1990). Therefore the 3.1μm absorption feature is a promising characteristic to discriminate carbon stars from S stars and M stars, irrespective of whether the carbon star is a normal carbon star or a silicate carbon star.

In this paper we collect all the information and data observed for IRAS 19111+2555, and take the IRAS LRS data and ISO SWS (Infrared Space Observatory, Short Wavelength Spectrum) data to discuss its properties and classification on the basis of the above description.

2 OBSERVED DATA OF IRAS 19111+2555

The position of IRAS 19111+2555 (=S Lyr) is given in the *HST Guide Star Catalog* (1989, hereafter GSC) and the *IRAS Point Source Catalog* (1989, hereafter PSC) as R.A.=191109.01, Dec.=255517.9 and R.A.=191108.3, Dec.=255516 for the epoch 1950. The *General Catalogue of Variable Stars* (Kholopov et al. 1985-1987) records it as a Mira variable with magnitude 9.8–15.6 in V, period 438.4 d and spectral type SCe. In 1968 it was observed with an infrared objective prism which showed the ZrO and infrared CN bands that had become strong near the light maximum (Terrill, 1968). Its spectral type was first determined as SC using a Coudé Spectrograph with dispersion 13–82 Åmm^{-1} (Catchpole & Feast 1971). Catchpole and Feast pointed out that like the typical SC star, UY Cen, S Lyr has a strong sodium D line which is often present in carbon stars, and that it also has the ZrO bands with heads at 6473 Å and CN lines particularly at 6478.5 Å. In the *General Catalogue of S Stars*, (Stephenson 1976, hereafter GCSS) and *General Catalog of Galactic S Stars* (Stephenson 1984, hereafter GCGSS), its spectral type is also listed as SC. Little-Marenin et al. (1988) suggested: "it appears to be more closely related to S star since no obvious carbon star characteristics are present and its 10.8μm feature can be matched by 45% silicate + 55% SiC". Noguchi et al. (1991) classified it as SC star and gave $J = 5.86$, $H = 4.73$, $K = 3.80$ and $L = 1.84$. However, Walker (1979) who made photometric observations, treated it as a carbon star. Jura et al. (1990) considered it as a very dusty carbon star. Thus, its characteristic is still being argued about in the literature.

3 IRAS AND ISO OBSERVATIONS

The IRAS PSC gives good quality fluxes at 12, 25 and 60μm for IRAS 19111+2555: $F_{12} = 42.08$, $F_{25} = 20.21$ and $F_{60} = 5.047$ Jy. On the standard IRAS two-color ([12]-[25], [25]-[60]) diagram from van der Veen & Habing (1988), IRAS 19111+2555 is plotted as an open circle in Fig. 1. It is clearly seen that IRAS 19111+2555 is located in region VII. According to van der Veen & Habing (1988), this region is the location of those variable stars with more evolved carbon-rich circumstellar shells.

The IRAS also has a low-resolution spectrum (LRS) for this star. According to Kwok et al. (1997), its LRS classification is E, which means this star has the silicate emission around 10μm and/or 18μm. In addition, Sloan et al. (1998) classified its infrared spectrum as SE2 which also indicates the silicate emission. The LRS spectrum of IRAS 19111+2555 is plotted in Fig. 2, in which the silicate emission around 10μm is indeed shown, but no clear emission feature can be found around 18μm due to the poor signal to noise ratio.

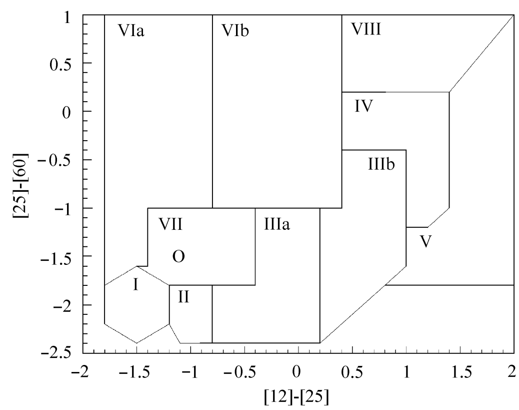

Fig. 1 [12]-[25] [25]-[60] diagram for IRAS 19111+2555

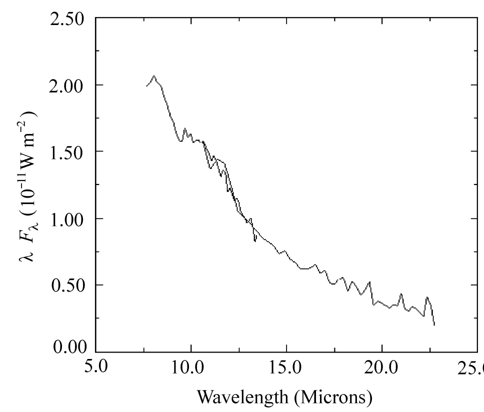

Fig. 2 The IRAS LRS spectrum of IRAS 19111+2555

Furthermore, the ISO made short wavelength spectral (SWS) observation in 2–45μm for this star in the SWS01 mode on April 19, 1997 (ISO data archive, http://www.iso.vilspa.esa.es). The ISO SWS of IRAS 19111+2555 is plotted in Fig. 3. It can be seen from Fig. 3 that between 10 and 11μm and around 18μm there seems to be some traces of emission features, despite the poor signal to noise ratio. A very important feature is present around 3.1μm; this is enlarged in the upper-left corner of Fig. 3. This is a very deep absorption feature that is present only in carbon stars due to C_2H_2 and HCN, as described in Section 1. It is noted that Noguchi et al. (1993) made spectral observation of this star in the near infrared and pointed out: "it has a peculiar spectrum that shows a rapid flux increase toward longer wavelength between 3–4μm and there is a dip between 2.5–3μm". But they did not discuss this spectral peculiarity in any detail. In fact, Noguchi et al. (1993)'s observation was ground-based and the wavelength range around 2.7μm is strongly obscured by terrestrial water vapor. Therefore they did not reach any conclusion about the feature around 3.1μm, although their observation indeed revealed a possible trace of absorption feature there.

In addition, the ISO SWS observed only two known silicate carbon stars, namely, IRAS 00519+5817=W Cas and IRAS 20350+5954=V778 Cyg (ISO data archive). IRAS 00519+5817 was first identified as a silicate carbon star with the spectral type of C7,1e by Kwok et al. (1993). For comparison with IRAS 19111+2555, the ISO SWS spectrum of IRAS 00519+5817 in the range of 2–45μm is included in Fig. 4 (ISO data archive). Comparing the two SWS spectra, it is found that, in general, IRAS 19111+2555 has some features similar to IRAS 00519+5817.

In particular, as Aoki et al. (1998) pointed out that among these features the most prominent ones identified are the HCNν_1 (+C_2H_2) absorption at 3.1μm, and the HCN$\nu_2 + \nu_3$ absorption at 3.56μm. (see the enlarged part of Fig. 3) and the HCN$\nu_1 - \nu_2$ absorption at 3.9μm. Again these features indicate that IRAS 19111+2555 is carbon-rich.

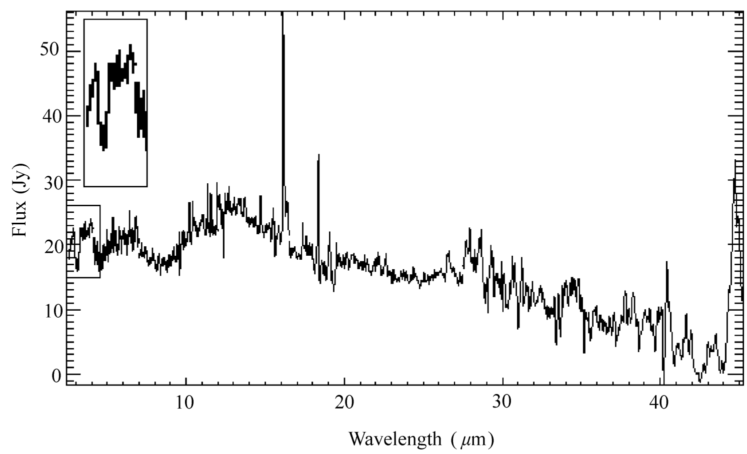

Fig. 3 The ISO SWS observation of IRAS 19111+2555

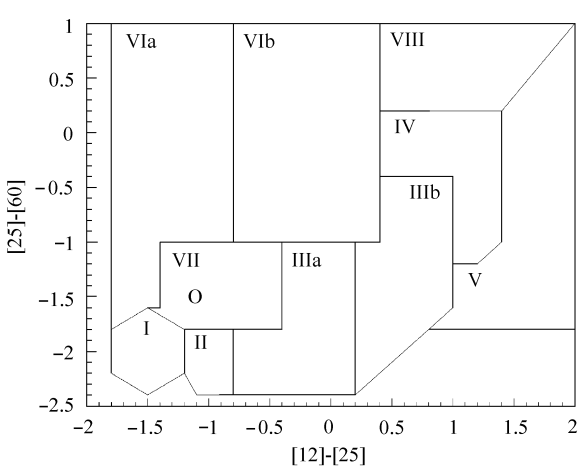

Fig. 4 The ISO SWS observation of IRAS 00519+5817

4 SUMMARY AND CONCLUSION

From the discussions above, in particular the observational results from the IRAS and ISO, it can be concluded that:

(1) IRAS 19111+2555 (=S Lyr) has strong carbon star characteristics and is an evolved carbon star because of the definite absorption features around 3.1μm, 3.56μm and 3.9μm due to HCN.

(2) IRAS 19111+2555 (=S Lyr) has the silicate emission features revealed in the IRAS LRS and possible ISO SWS spectra, so it may be a new silicate carbon star.

(3) Because the spectral type of IRAS 19111+2555 was determined as type SC, and type SC stars are difficult to distinguish from J-type stars from optical spectroscopy alone, it is possible that the star may also belong to J-type, as do many silicate carbon stars.

(4) From the points above the conclusion is that IRAS 19111+2555 (=S Lyr) may be a silicate carbon star with the J-type spectrum.

Acknowledgements We are grateful to the referee for his/her helpful suggestions. This work is supported by the National Natural Science Foundation of China and the Chinese Academy of Sciences. This work has made use of NASA's ADS database.

References

Aoki W., Tsuji T., Ohnaka K., 1998, A&A, 340, 231
Catchpole R. M., Feast M. W., 1971, MNRAS, 154, 197
Chan S. J., 1994, MNRAS, 268, 113
Chen P. S., Kwok S., 1993, ApJ, 416, 769
Chen P. S., Wang X. H., Wang F., 1999, Acta Astronomica Sinica, 40, 33
Groenewegen M. A. T., de Jong T., Geballe T. R., 1994, A&A, 287, 163
Groenewegen M. A. T., 1994, A&A, 290, 207
HST Guide Star Catalog, 1989, STScI (GSC)
Iben I. Jr., Renzini A., 1983, ARA&A, 21, 271
IRAS Point Source Catalog, 1989, Joint IRAS Science Working Group, Version 2 (Washington, DC: GPO) (IRAS PSC)
Jura M., Kleinmann S. G., 1990, ApJ, 364, 663
Koholopov P. N. et al., 1985–1987, General Catalogue of Variable Stars ($4^{\rm th}$ ed.; Moscow: Nauka) (GCVS)
Kwok S., Chan S. J., 1993, AJ, 106, 2140
Kwok S., Volk K., Bidelman W. P., 1997, ApJS, 112, 557
Little-Marenin I. R., 1986, ApJ, 307, L15
Little-Marenin I. R., Little S. J., 1988, ApJ, 333, 305
Lloyd Evans T., Little-Marenin I. R., 1999, MNRAS, 304, 421
Lorenz-Martins S., 1996, A&A, 314, 209
Merrill K. M., Stein W. A., 1976, PASP, 88, 285
Noguchi K., Maihara T., Okuda H. et al., 1977, PASJ, 29, 511
Noguchi K., Kaware K., Kabayashi Y. et al., 1981, PASJ, 33, 373
Noguchi K., Murakami H., Matsuo H. et al., 1990, PASJ, 42, 441
Noguchi K., Sun J. H., Wang G., 1991, PASJ, 43, 275
Noguchi K., Kobayashi Y., 1993, PASJ, 45, 85
Ohnaka K., Tsuji T., 1999, A&A, 345, 233
Olnon F. M., Raimoud E., 1986, A&AS, 65, 607
Omont A., Loup C., Forveille T. et al., 1993, A&A, 267, 515
Ridgway S. T., Carbon D. F., Hall D. N., 1978, ApJ, 225, 138
Skinner C. J., Griffin I., Whitmore B., 1990, MNRAS, 243, 78
Sloan G. C., Price S. D., 1998, ApJS, 119, 141
Stephenson C. B., 1976, Pub. Warner & Swasey Obs., 2, 23 (GCSS)
Stephenson C. B., 1984, Pub. Warner & Swasey Obs., 3, 1 (GCGSS)
Terrill C. L., 1968, AJ, 74, 413
van der Veen W. E. C. J., Habing H. J., 1988, A&A, 194, 125
Walker A. R., 1979, SAAOC, 1, 112
Willems F. J., de Jong T., 1986, ApJ, 309, L39