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New infrared carbon stars in the IRAS point source catalog⋆,⋆⋆

F. Guglielmo[1,2], N. Epchtein[2], F. Arditti[3], and F. Sèvre[4]

[1] Leiden Observatory, NL–2300 RA Leiden, The Netherlands
[2] Observatoire de Paris, Département de Recherche Spatiale, URA CNRS 264, F–92195 Meudon Principal Cedex, France
[3] Université de Paris X–Nanterre, F–92000 Nanterre Cedex, France
[4] Institut d'Astrophysique de Paris, CNRS UPR 341, F–75014 Paris, France

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Abstract. We present new results of a search for infrared carbon stars (IRCS) based on the combination of IRAS and near infrared colours. A sample of 207 stars with IRAS colours that characterize IRCS is selected and measured in the $JHKL$ photometric bands. Using a $[12-25]$ vs. $K-L$ colour diagram, 20 new IRCS candidates are proposed. Medium resolution spectra in the $\sim 6000-9000$ Å range of 8 of these candidates confirm their carbon rich nature. In addition we propose a few stars with LRS class "4n" as oxygen–rich candidates, and a few stars with LRS classes "0n" and "1n" as carbon–rich.

Key words: stars: carbon — stars: late-type — stars: AGB and Post-AGB — galaxy: stellar content — infrared: stars — stars: circumstellar matter

1. Introduction

Carbon stars have been, so far, mainly identified on objective prism survey plates (e.g., Stephenson 1989, hereinafter GCCCS). More recently, C–rich stars surrounded by a circumstellar dust shell (CDS) that blocks most of the optical radiation, have been recognized thanks to the emission feature of the SiC grains which are contained in their envelopes. A large number of these so–called Infrared Carbon Stars (hereinafter, IRCS) have been found by inspection of the Low Resolution Spectra that were obtained during the IRAS mission (LRS, IRAS Science Team 1986 and works by Volk & Cohen 1989 and Volk et al. 1992a). Most of them have been classified in the *"4n"* class of the LRS.

Epchtein et al. (1987) have shown that IRCS can also be reliably identified through the location of their representative points in a colour–colour diagram that combines a near–IR colour (e.g., $K-L$), and the IRAS colour $[12-25]$. In these diagrams C-rich and O-rich stars with circumstellar envelopes clearly break out, while they do not in a pure IRAS colour–colour diagram (e.g., van der Veen & Habing 1988, hereinafter VH).

The efficiency of this method has been demonstrated on a large sample of IRAS objects whose LRS exhibit the SiC feature (Epchtein et al. 1990), and has been successfully applied to various samples of IRAS Point Sources without LRS spectra, and has lead to the identification of more than 100 new IRCS, mainly in the southern sky (Guglielmo et al. 1993, Paper I).

In the present paper we present an extension of this search to a sample of 172 IRAS stars selected randomly in the area of the IRAS colour–colour diagram where the proportion of C-rich stars has been shown to be the largest (region VII of VH), or, which have a $[12-25]$ colour index that corresponds to this region when the 60 μm IRAS flux measurement is either absent or of bad quality. A few additional stars (35) already known as carbon stars or with uncertain IRAS LRS spectra have been also observed.

2. Near infrared observations

The near infrared observations have been carried out with an InSb photometer built by Observatoire de Paris and modified by the Institut d'Astrophysique de Paris and the Bureau des Longitudes to include a CCD Thomson camera in the focal plane that allows field recognition and provides approximate photometric measurements in the R and I bands. Standard $JHKL$ filters were used. The field aperture of the IR photometer represents 30″ on the sky and the beamswitching is made in east–west direction

Send offprint requests to: FG [2], "guglielmo@obspm.fr"

⋆ Based on observations obtained at the Observatoire de Haute Provence, France.

⋆⋆ Tables 2 and 3 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

at a frequency of 10 Hz, with a beamthrow of 45″. This instrument was attached at the f/15 cassegrain focus of the 80 cm telescope of Observatoire de Haute Provence, France (OHP) during 4 periods in 1992 and 1993 (Table 1). The CCD camera was only available in periods 2 and 3 and was only used for field recognition.

Table 1. Journal of observations

Column 2 in Table 2	Epoch
1	27-01-92 to 04-02-92
2	02-08-92 to 17-08-92
3	19-11-92 to 01-12-92
4	14-02-93 to 26-02-93

To pick up the IRAS source, the telescope was pointed by offseting from nearby stars of the Guide Star Catalogue (Space Telescope Science Institute, 1992, hereafter GSC) and the objects were searched for in the K band. Owing to the large field aperture, in most cases, the infrared sources were immediately detected. In a few peculiar cases, however, the CCD image obtained in real time was used to identify the location of the IRAS sources with respect to the field stars. Their optical counterparts, if visible, were identified by simple comparison between GSC charts and the observed field images (Fig. 1). In addition, these CCD images (typically, the $m_{\rm I}$ limit of detection is about 16-17 mag) allow to check a possible confusion with closeby field stars that might influence the IR photometric measurements.

The $JHKL$ photometry was derived with the help of frequent measurements of standard stars (Blackwell et al. 1979; Engels et al. 1981; Koornneef 1983; Campins et al. 1985) at similar air–masses and as close as possible to the observed source. An average accuracy of $+/-0.05$ magnitude in the JHK bands and $+/-0.1$ magnitude in L was achieved most of the time for objects brighter than $JHK = 7$ and $L = 3.5$.

The new infrared photometric data, are summarized in Table 2, where Col. 1 gives the IRAS name, Col. 2 refers to the epoch of the observations, Cols. 3 to 6 list the photometric data, Cols. 7 to 9 the IRAS colours[1] and LRS types, Cols. 10 and 11 the classification in our system (Epchtein et al. 1988) and in the VH system, respectively. Column 12 contains flags that indicate that the objects have an entry in one or several of the following catalogs: the GCCCS (flag *C*), *"a general catalog of S stars"* (Stephenson 1976) *(S)*, the GSC *(G)*, another stellar catalog *(I)* quoted in the IRAS PSC, or have been detected in one or several radio lines: CO/HCN (Loup et al. 1993), H_2O maser (Comoretto et al. 1990), OH maser (te Lintel–Hekkert et al. 1989) (*M*). More detailed information is given in Table 3.

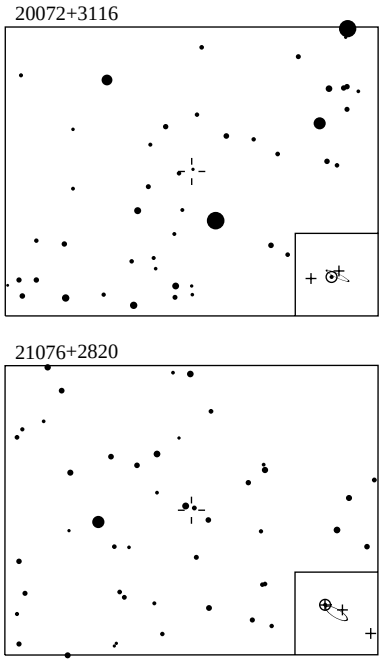

Fig. 1. Identification charts ($\approx 18' \times 14'$) of IRAS 20072+3116 and IRAS 21076+2820. Dots represent the GSC stars. Zooms of $2' \times 2'$ around the IRAS positions are plotted at the bottom right of these diagrams. The GSC positions are represented by crosses, the IRAS positions by their ellipses of uncertainty, and the near–IR sources by dot-circles. In both cases, the near-IR positions and the IRAS ellipses coincide. One notice that 21076+2820 is associated with a GSC star although 20072+3116 is not

Despite our large aperture, none of the measurement seems to be significantly contaminated by the emission of a nearby star. Out of the 84 stars observed when the CCD camera was available, only 9 of them, namely, 03118+6144, 03174+5247, 06234+0612, 06360+3335, 19122+2318, 20072+3116, 21131+3215, 21254+5709, 21309+6507 have a field star located at less than 15″, but, in all cases they are much fainter than the main source in the near-IR. This has been systematicallly checked by centering the photometer successively on the 2 objects and comparing the 2 fluxes. In two cases the fluxes may, however, have been contaminated by a nearby star, *i)* a GSC star of $m_V \sim 8.5$ is located at 19″ of the IRAS position of 05581+2232, *ii)* 06523+2437 is close to 2 GSC stars.

3. Identification of C-rich star candidates

The colours of the observed objects have been plotted in a $[12-25]$ vs. $K-L$ diagram (Fig. 2), in order to discriminate between oxygen and carbon rich stars. Following our classification method (Epchtein et al. 1987), the

[1] The IRAS colours are defined using the magnitude scale given in the IRAS Explanatory Supplement (IRAS Science Team 1988).

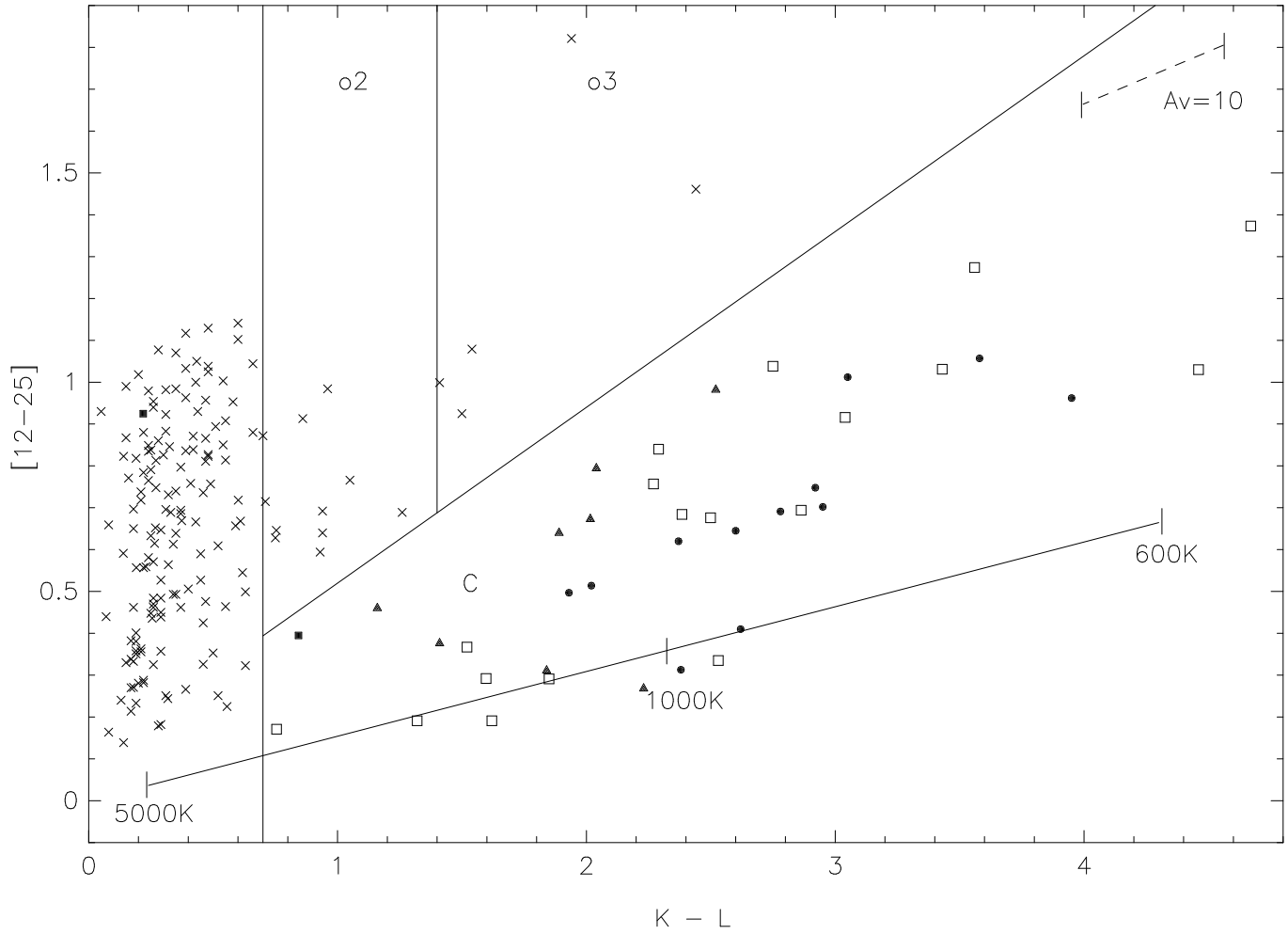

Fig. 2. $[12-25]$ vs. $K-L$ diagram for the 199 observed stars in the K and L bands. The triangles represent the 8 new infrared stars confirmed by spectroscopic measurements, the dots, the 12 other new carbon star candidates, the open squares the stars previously known as carbon stars through their optical spectra (GCCCS) or their IRAS low resolution spectra, the filled squares, the 2 objects which might be contaminated by a nearby star, and the crosses, the other stars. The black–body line, the areas defined by Epchtein et al. (1987) and the reddening vector corresponding to $A_V = 10$ are also drawn

objects can be roughly splitted into 3 main groups. One group is located along a vertical strip at low $K-L$ and corresponds to O–rich stars surrounded by a thin dust shell, a second group follows a sequence located above the blackbody line and corresponds to C–rich stars (region *c*), finally, a few objects with larger colour indices correspond to oxygen stars with thick dust shells (region *o2* and *o3*). The numbers of objects that belong to each of these classes are given in Table 4. The brightest stars in our sample have a thin CDS ($K-L<0.7$). It is among them that the percentage of carbon stars is the lowest. Most of them are listed in the GSC, and their m_K range approximately between 3 and 5. The 8 stars that were not observed in the L band are unlikely to be IRCS according to their location in other two–colour diagrams such as $[12-25]$ vs. $J-K$. They are likely to be M stars with thin CDS.

The complete list of the 20 new IRCS candidates that we propose is given in Table 5. All of them were discovered by IRAS, but were, so far, of unknown nature, i.e. not already identified as carbon stars (not in the GCCCS, not LRS "4n"). Flag *"C"* in Col. 3 indicates that their carbon rich nature has been confirmed by optical spectroscopic observations (see Sect. 4). The 3 objects with LRS "0n" or "1n" included in this list have LRS of too poor quality to identify their chemical type. The 17 others have no LRS. Only, 06000+3445 has a GSC counterpart. According to our previous studies, since these objects have $\sim 1 < K-L <\sim 4$ (Fouqué et al. 1992) and are not located at the edge of the class *c* area, their probability of being IRCS is very high (Paper I). Two IRCS 18240+2326 and 21489+5301 have a $K-L$ slightly larger than 4 in the "4n" samples. 21489+5301 has been already pointed out

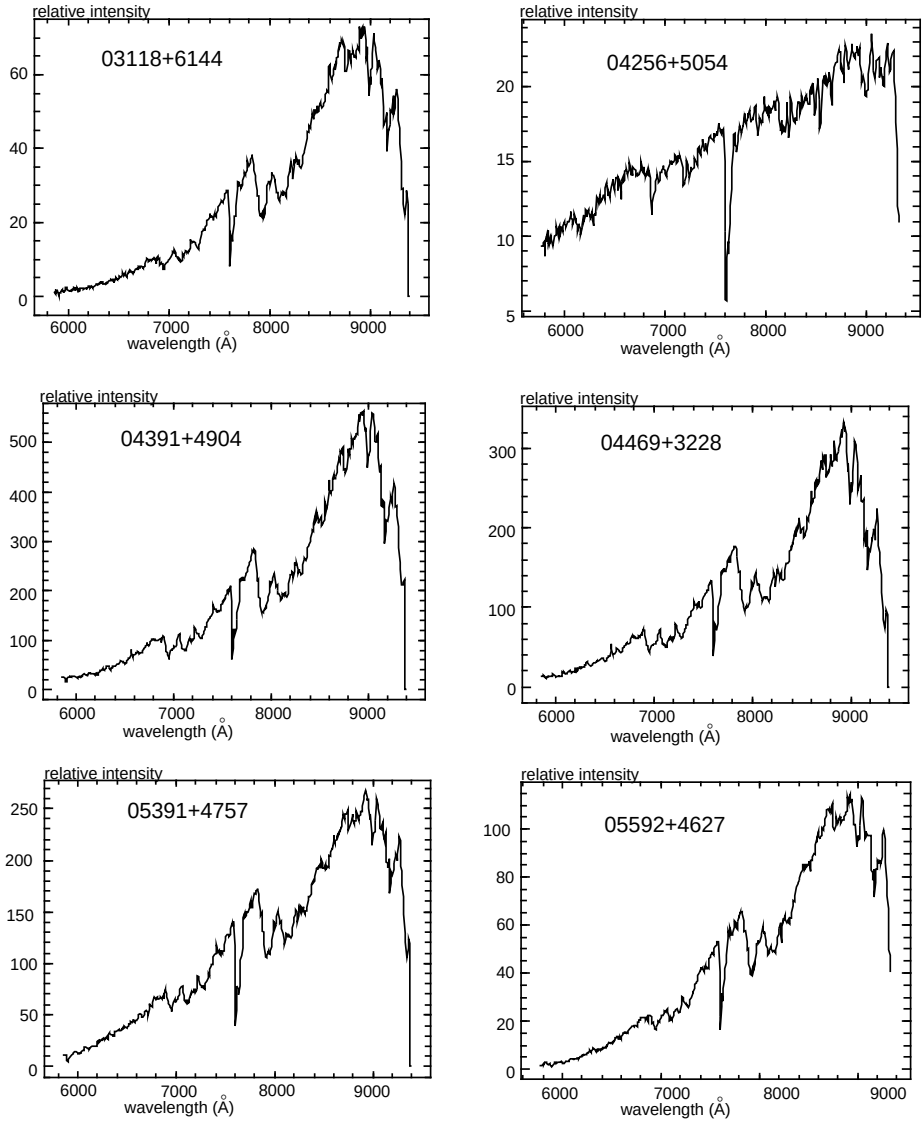

Fig. 3. Red spectra of 10 objects (03118+6144, 04256+5054, 04391+4904, 04469+3228, 05391+4757, 05581+2232, 05592+4627, 06175+2347, 07152+1228, 19580+2552). The spectrum of 06175+2347 is represented to illustrate the typical features of a carbon star obtained with the same instrumentation. Some of the CN band heads as well as the NaD doublet and H_α are indicated. Some of the band heads of TiO characteristics of M type star are indicated on the spectrum of 05581+2232

as a candidate of extreme carbon star (Volk et al. 1992b, and Omont et al. 1993).

4. Spectroscopic observations

A follow–up programme of spectroscopic observations of the C-rich star candidates has been initiated in order to confirm the chemical nature of stars observed in near IR photometry. Medium resolution spectra in the far red ($\sim$ 6000 − 9000 Å) have been obtained for a subsample of 10 candidates, namely 03118+6144, 04256+5054, 04391+4904, 04469+3228, 05391+4757, 05581+2232, 05592+4627, 06175+2347, 07152+1228, 19580+2552, with the CARELEC spectrograph (OHP publication, 1986) attached to the 193 cm telescope of Observatoire de Haute Provence during 2 periods (November 28 to December 3, 1992 and November 20 to November 25, 1993). These spectra are displayed in Fig. 3.

This spectral range has been chosen because it allows to measure the reddest objects optically identified (m_R brighter than $\sim$ 17), and because many molecular features that characterize late giant stars (e.g.,

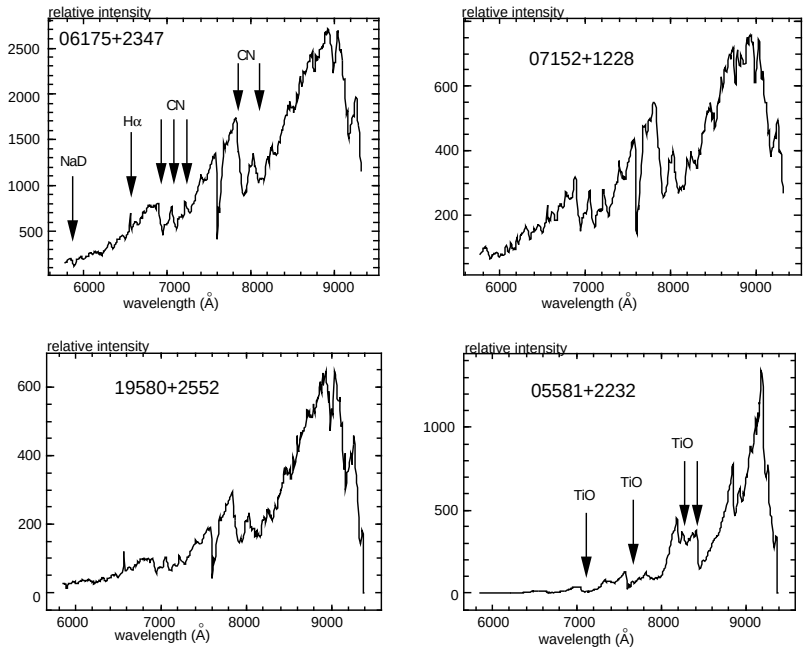

Fig. 3. continued

Table 4. The number of observed stars according to various classifications: LRS, VH, Epchtein et al. (1987), GCCCS

	total	$K-L<0.7$		$K-L>0.7$		
		all	GCCCS	all	*"o2-o3"*	IRCS
LRS "4n"	18	6	1	12	2	10
LRS "0n" & "1n"	13	5	1	8	2	6
region VII (VH)	119	85	0	34	12	22
same $[12-25]$ as region VII	49	48	2	1	0	1
Total	199	144	4	55	16	39

Turnshek et al. 1985) are located in this spectral range. The spectra of 9 objects definitely confirm that they correspond to *bona fide* C-rich stars, since all of them exhibit the CN bands that unambiguously characterize them. Among these objects, only 06175+2347 has a LRS spectrum (code *17*), which clearly exhibits a SiC feature. As concerns the spectrum of 05581+2232, it shows TiO bands that characterize O–rich stars, but the near–IR photometric data might be inaccurate because of contamination by a nearby star.

5. Concluding remarks

The method that combines near-IR and IRAS photometric data is used successfully on a new sample and has lead to the identification of 20 new infrared carbon star candidates. The nature of 8 out of them, measured in optical spectroscopy is confirmed. In addition, a few stars with LRS "4n" are found to be oxygen rich while a few "0n" and "1n" stars are carbon rich.

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Table 5. List of the 20 new infrared carbon star candidates

IRAS Name	Spectrum LRS	opt.
03118+6144		C
03311+5623		
04096+5443		
04223+4312		
04256+4435		
04256+5054		C
04391+4904		C
04469+3020		
04469+3228		C
05391+4757		C
05438+2337		
05592+4627	15	C
06000+3445		
06280+3133		
06360+3335	01	
07152+1228		C
19580+2552	05	C
20259+5151		
21290+4919		
21533+5844		

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