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A search for peculiar objects in young open clusters

II. A new Be star, the optical counterpart of IRAS 19564+3224 and a new open cluster in Vulpecula*

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Abstract. A serendipitous sky field in Vulpecula was observed with Johnson BVR photometry and slitless spectroscopy in the 5600–8000 Å range, looking for emission line and late spectral type stars. We discovered that the B2V star LS II +32° 9, most probably a member of the Vul OB4 association, is now an Hα emitter. Furthermore, we identified the optical counterpart of the IRAS source IRAS 19564+3224 as a C star. Photometric study of the surrounding stellar field revealed that this object lies inside the sky area of a previously undetected open cluster of intermediate age. We discuss the possible cluster membership of the Carbon star and its implications. Some hints about the galactic structure along the line of sight of the observed field are also given

Key words. stars: carbon stars – stars: evolution – stars: emission-line, Be – stars: individual (LS II+32° 9) open clusters and associations

1. Introduction

The search for high-mass stars, presented in Bernabei & Polcaro (2001, thereafter Paper I), follows two observational strategies. In general, a young association or cluster is selected on the basis of the proven presence of at least one high mass star and it is then surveyed by means of slitless spectroscopy, looking for stars showing previously unreported emission lines or late spectral type. In addition, all the available slitless spectrocopy images taken during any other kind of research on low galactic latitude fields are also examined.

We present here the results obtained on a serendipitous field located inside the Northern part of Vulpecula ($l = 64.68°$, $b = +1.75°$). This field was firstly observed in the framework of the successful search for the optical counterpart of the X-ray source 1WGA J1958.2+3232 (Israel et al. 1999).

This sky region is extremely complex, since it contains three distinct young stellar groups (Vul OB1, Vul OB2 and Vul OB4) projected on the same sky area, but located at distances of 2, 4 and 1 kpc respectively (Ruprecht 1966; Turner 1980, and references therein). Furthermore, the reddening in Vulpecula is high and largely inhomogeneous and the distance scale is quite uncertain (e.g. FitzGerald 1968; Thé & van Paradijs 1971). Fresnau & Monier (1999) further investigated the so called "Vulpecula Rift" by using photographic proper motions and B and V magnitude of 50 000 stars in this sky region and argued that the interstellar clouds, linked to the Vul OB stellar associations, give a total extinction up to ∼1.5 mag at a distance of only 0.3 kpc.

2. Observations

The $13' \times 13'$ field, centred on RA = 19h 58m 14s, decl = $32°33'04''$ (J2000) and including the error box of the 12 min X–ray pulsator 1WGA 1958+3232 (Israel et al. 1998 and references therein), was observed on 30 July 1998. We performed Johnson R filter photometry and slitless spectroscopy in the range

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* Based on data collected at 1.52 m "Cassini" telescope of the Loiano Observing Station, Bologna Astronomical Observatory.

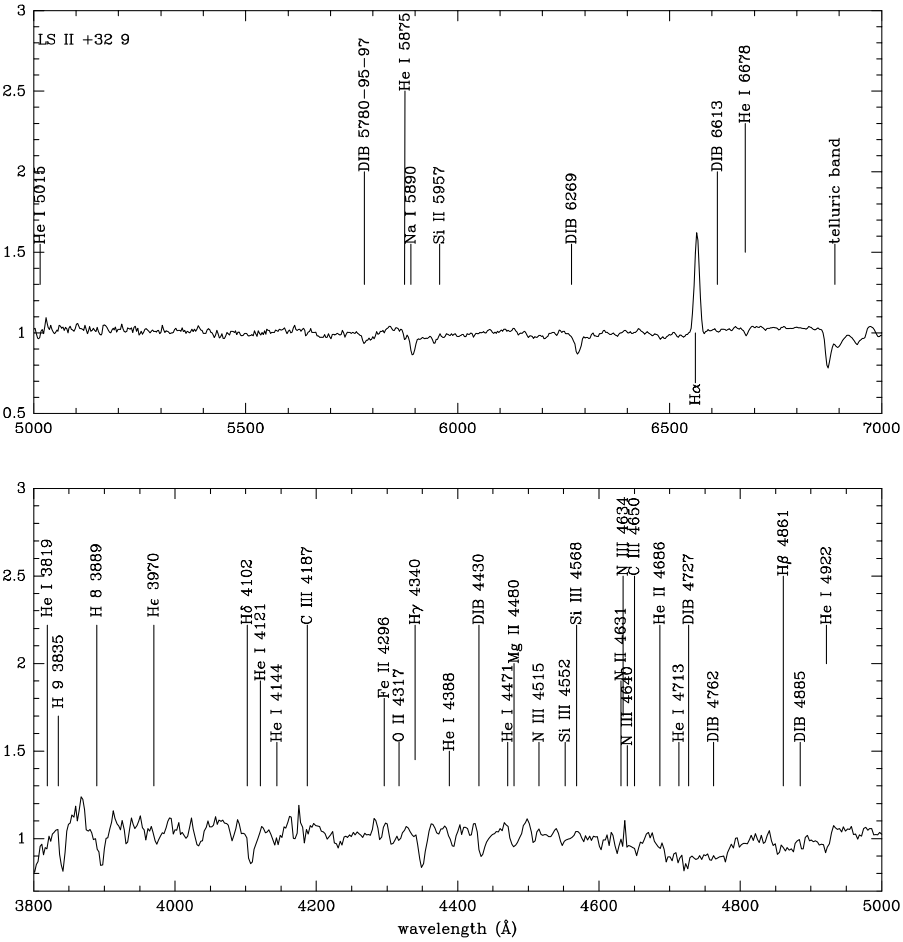

Fig. 1. The rectified slit spectrum of LS II $+32°$ 9 in the 3800–7000 Å range

5500–8000 Å at the 1.52 m "Cassini" Telescope of the Bologna Astronomical Observatory equipped with the Bologna Faint Object Spectrometer and Camera (*BFOSC*, Merighi et al. 1994). The instrumental set-up and the technique described in Polcaro & Viotti (1997) and in Paper I was employed. Apart from the objects present in the 1WGA J1958.2+3232 error box, analysed by Israel et al. (1999), only two stars showed peculiarities in our slitless spectral images and were further studied with slit spectroscopy.

Low resolution ($\Delta\lambda = 5.7$ Å) slit spectra in the 3500–9000 Å range of these two objects were taken in the following nights. On the same dates, intermediate resolution spectroscopy ($\Delta\lambda = 3$ Å) in the 6300–8000 Å range was also performed. Low and intermediate dispersion spectra of the star, that later resulted to be the optical counterpart of IRAS 19564+3224, was also obtained in July 1999.

Johnson B, V, R filter photometry of a partially overlapped field, centred on the optical counterpart of 1WGA 1958+3232 (RA = 19h 58m 14.4s, decl = $32°32'42''$; J2000), taken on 12 July 1999, was also used. Table 1 gives the observation log.

Data were reduced and analysed using standard *IRAF* procedures. The spectra were compared with the spectral atlases listed in Paper I for spectral classification. All the available information on the selected objects were collected by using the *SIMBAD* database at the CDS (Strasbourg).

3. Results

Table 2 reports the positions, B, V, R magnitudes, and our proposed spectral classifications of the two peculiar stars that we have found.

We will examine these objects in detail in the following

3.1. LS II $+32°$ 9

A single reference on the star LS II $+32°$ 9 is available on *SIMBAD*. The object was observed by Forbes (1984) in the framework of a study of distant early-type stars as tracers of the local spiral structure of the Galaxy. In that paper, the star is reported to have $V = 11.56$, $B - V = 0.82$ $U - B = -0.05$ and a B2V spectral type; no emission features are reported. From our photometry, performed on 30 July 1998, we obtained $R = 12.41$.

Figure 1 shows our rectified slit spectrum of the star in the 3800–7000 Å range, where the signal-to-noise ratio (S/N) is higher than 10, reaching $\sim$100 at $\lambda \geq 6000$ Å.

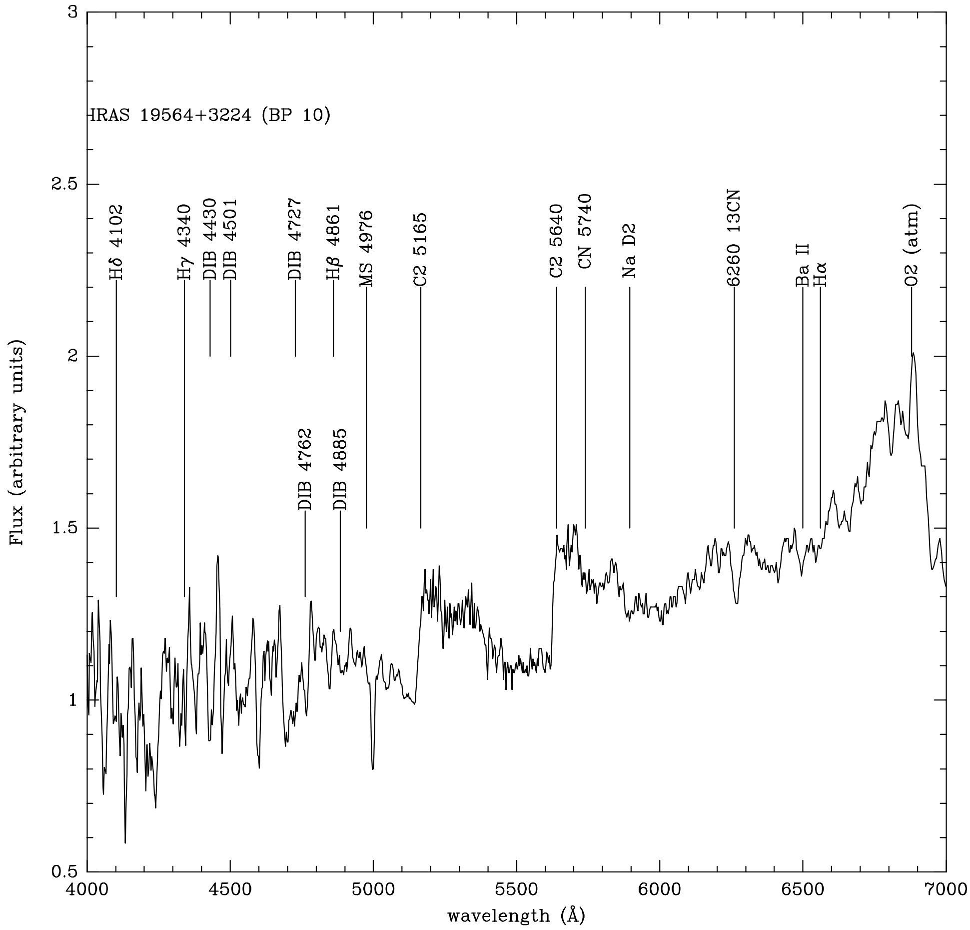

Fig. 2. The spectrum of BP10 (IRAS 19564+3224) in the 3500–9000 Å range. The spectrum is only corrected for instrumental response

We can clearly notice the Hα emission, with equivalent width $EW = 8.7$ Å, while the Hβ emission is filling-in the photospheric absorption. Central emission peaks in higher Balmer lines should be present, but the low resolution and the low S/N at blue wavelengths do not allow us to decide on the matter.

Since the spectrum of Forbes (1984) was obtained in the 3700–4900 Å range, with S/N ratio and spectral resolution higher than our ones, it is unlikely that the lack of the Hβ line was unnoticed, if it was present at this epoch. We must thus argue that the star entered in the present Be phase after the time of Forbes observations (1979–1981).

In our spectrum of LS II +32° 9, the HeII lines are very faint (i.e. HeII λ4686 Å) or undetectable, while HeI is quite strong and many lines of CIII, NII, NIII, OII and SiIII are clearly visible, but the SiIV lines are lacking. The B2 spectral type assigned to the star by Forbes (1984) is thus fully confirmed. It is quite difficult to assign a precise luminosity class to a Be star, being the most reliable luminosity indicators (based on the Balmer lines absorption shape and depth) inapplicable. We thus assume the Forbes (1984) luminosity class, which was determined when the object was not active, and classify the star as B2Ve.

The contribution of the circumstellar disk to the star V magnitude is ≃0.01 mag, from the Hα EW measured in 1998 and the formula given by Fabregat & Reglero (1990). Unfortunately, we cannot check if the stellar continuum is intrinsically constant or variable, since LS II +32° 9 was outside our B, V and R images taken in 1999.

The stellar spectrum is clearly strongly reddened. From the equivalent width of the diffuse interstellar band at 5797 Å ($EW_{5797} = 0.19$ Å), a colour excess $E(B-V) = 1.55$ can be derived (Chlewicki et al. 1986). Assuming this interstellar reddening (the one due to the circumstellar disk is negligible) and an absolute magnitude $M_V = -2.4$ for the B2V spectral type from the Schmit-Kaler's main sequence, a distance of ∼0.95 kpc is derived from the $V = 11.6$ measured by Forbes (1984). Considering the uncertainties in EW_{5797} and the actual spread in the M_V of the early main sequence stars (see, e.g. Jaschek & Gómez 1998), this distance is compatible with that of Vul OB4. We can thus assume that LS II+32° 9 is a member of this association, deeply embedded in a local cloud. Vul OB4 has been to date poorly studied and even its actual separation from Vul OB1 has been questioned by Thé & van Paradijs (1971). However, assuming that the ages of these two association is similar (i.e., ∼10^7 y, Turner 1980 and references therein) we can argue that LS II+32° 9 is

Table 1. Observation log

photometry					
date		exp. (min)	UT beg (hh:mm)	filter	magnitude limit
1998 July 30		2.0	20:10	R	22
1998 July 30		2.0	20:15	R	22
1999 July 12		2.0	23:31	B	20
1999 July 12		2.0	23:20	V	21
1999 July 12		2.0	23:49	R	22
slitless spectroscopy					
date	object	exp. (min)	UT beg (hh:mm)	sp. range (Å)	res. (Å)
1998 July 30		10	20:25	5600–8000	20
slit spectroscopy					
date	object	exp. (min)	UT beg (hh:mm)	sp. range (Å)	res. (Å)
1998 July 31	BP10 (IRAS 19564+3224)	20	20:15	3500–9000	5.7
1998 July 31	BP10 (IRAS 19564+3224)	20	20:45	6300–8000	3.0
1998 July 31	BP10 (IRAS 19564+3224)	30	21:15	3500–9000	5.7
1998 July 31	BP10 (IRAS 19564+3224)	20	22:40	6300–8000	3.0
1998 August 1	LS II+32° 9	30	20:15	3500–9000	5.7
1998 August 1	LS II+32° 9	30	20:15	6300–8000	3.0
1999 July 20	BP10 (IRAS 19564+3224)	20	20:15	3500–9000	5.7
1999 July 20	BP10 (IRAS 19564+3224)	20	20:45	6300–8000	3.0

Table 2. New peculiar stars in Vulpecula

name	alternative names	spectral type	RA (2000)	Decl (2000)	B	V	R
BP 10	IRAS 19564+3224, CGCS 4585	C-R2 MS1	19h 58m 21.0s	32°32′25″	16.64	14.28	11.88
LS II +32° 9		B2Ve	19h 58m 54.1s	32°32′36′09″	12.38(*)	11.56(*)	12.41

(*) *from* *Forbes (1984)*

a relatively high mass object ($M_0 \simeq 10\ M_\odot$), not far from the ZAMS. However, given the uncertainties on the luminosity class of the object and on the distance scale in the Vulpecula region, we cannot completely rule out the possibility that the star could be a farther giant located close to the TAMS, as it was found out in the case of many Be stars (see, e.g., Fabregat & Torrejon 2000).

3.2. The optical counterpart of the IR source IRAS 19564+3224

In our slitless spectroscopic image, a very red star with strong absorption bands was evident. The following low and intermediate resolution spectroscopy allowed the discovery of clear bands of C_2, CN and SiC_2, the so called Merril-Sanford (MS) bands. TiO bands are lacking, while at least Hα and Hβ Balmer lines are surely present (see Fig. 2). Thus, following Barnbaum et al. (1996), the star can be classified as a *C-R2 MS1* carbon star.

No references to optical objects were present in *SIMBAD* data base corresponding to the star position. It was thus named BP10, following the numbering of Paper I. However, full positional coincidence was found with the IR object IRAS 19564+3224. Since most carbon stars are strong IR sources, it is obvious to consider BP10 as the optical counterpart of the IRAS source. Actually, the ratio of the detected IRAS fluxes at 12 μm and 25 μm, after dereddening with $E(B-V) = 0.33$ (see next paragraph), gives an intrinsic temperature of the infrared source of 2500 K (Beichman et al. 1988), that perfectly fits the carbon star temperature, as can be argued from its spectrum (see Fig. 3).

It was later found out that BP10 corresponds to the object CGCS 4585 in the *General Catalogue of Cool Galactic Carbon Stars (2nd edition)* (Stephenson 1989), although

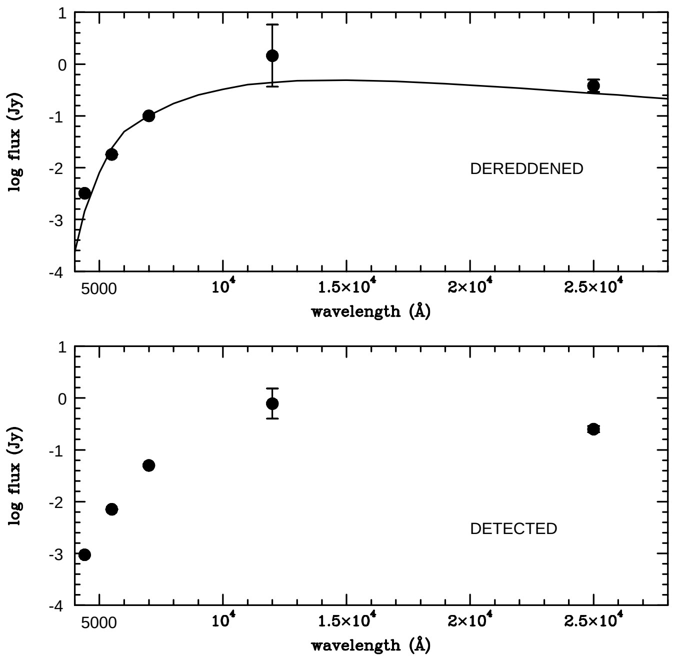

Fig. 3. The combined energy distribution of BP 10 and IRAS 19564+3224. Lower panel: measured. Upper panel: dereddened with $E(B-V) = 0.33$. A 2500 K black body, normalised to the R band flux, is also shown. The error bars on the measured IRAS fluxes correspond to the figures quoted in the IRAS catalogue; those on the dereddened fluxes take also into account the uncertainties in the value of the reddening. Error bars on B, V, R fluxes are smaller than the symbols size in both cases

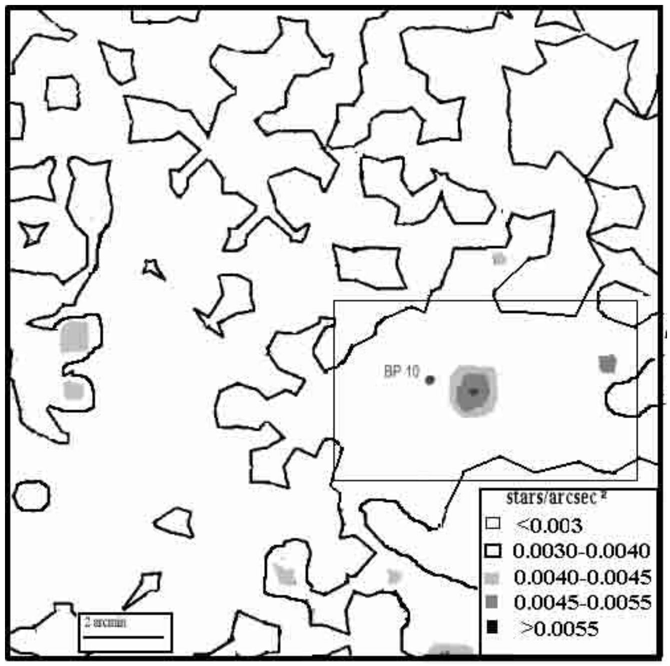

Fig. 4. Map of the density of stars brighter than the 17th magnitude from our July 1998 $13'\times 13'$ R image. Star census is averaged on $25''\times 25''$ square cells. N is at the top, E is at the left. The position of optical counterpart of the IRAS source 19564+3224 (BP10) is indicated by a dot. The rectangle gives the boundaries of the sky area represented in Fig. 5

the coordinates are slightly different (CGCS 4585: RA = 19h 58m 21.3s, decl = +32°32′29″, J2000) and this star does not show up in *SIMBAD*

3.3. The Loiano 1 open cluster

The presence of a carbon star in such a young stellar region as the Vulpecula Rift is quite unusual. We thus first checked the position of the star in the POSS digitised sky atlas, to look for a possible proper motion. However, no displacement greater than 1″ was found on a time scale of ~50 years. We can thus exclude that BP10 is a run-away star.

In order to understand the physical connection between the C star and its environment, we studied the B, V and R photometric data of our field. It is very crowded: more than 16 000 stars are present in the whole $13'\times 13'$ R image. On the other hand, only 522 stars of those are brighter then the 17th magnitude, corresponding to an average star density of $\sim$0.001 $\mathrm{stars}_{R<17}/\mathrm{arcsec}^2$. However, a slight enhancement in this figure is visible not far from the position of the C star, reaching a maximum of $\sim$0.0055 $\mathrm{stars}_{R<17}/\mathrm{arcsec}^2$ around the position of the optical counterpart of 1WGA 1958+3232 (see Fig. 4).

We thus deeply investigate a $6.5'\times 4'$ field surrounding BP10 (see Fig. 5), where 75 stars up to $R = 17$ are present.

The V vs. $(V-R)$ CM diagram of these stars is shown in Fig. 6. Apart from the peculiar objects 1WGA 1958.2+3232 and ICP99C, which were discovered and discussed by Israel et al. (1999) and are not further analysed here, we can see that all stars seem to be members of a single population, with some spread. Notice that the situation is definitely different if we consider the whole $13\times 13''$ field, whose CM diagram is shown in Fig. 2 of Israel et al. (1999).

The V vs. $(B-V)$ CM diagram of the objects included in the field shown in Fig. 5 also suggests the presence of a single main-sequence (see Fig. 7).

It is certainly possible that the better definition of the Main Sequence in the $6.5'\times 4'$ field, with respect to that of the whole one, is partly due to the smaller number of stars, which diminishes the scatter. Part of the residual scatter may also be due to binarity, since a possible parallel sequence about 0.75 mag brighter than the ZAMS should be visible in Fig. 7. However, because of the enhancement in the density of stars with $R < 17$ near to BP10, we considered the possibility that a small open cluster, overlapped to a different population, is located in this sky area.

In order to check this hypothesis, we used the following procedure. It is well known that the intrinsic colours of normal stars are related each other. For instance, Slivan (1998) found, from a best fit of the intrinsic colours of all the main-sequence stars listed in the *UBVRI Standard*

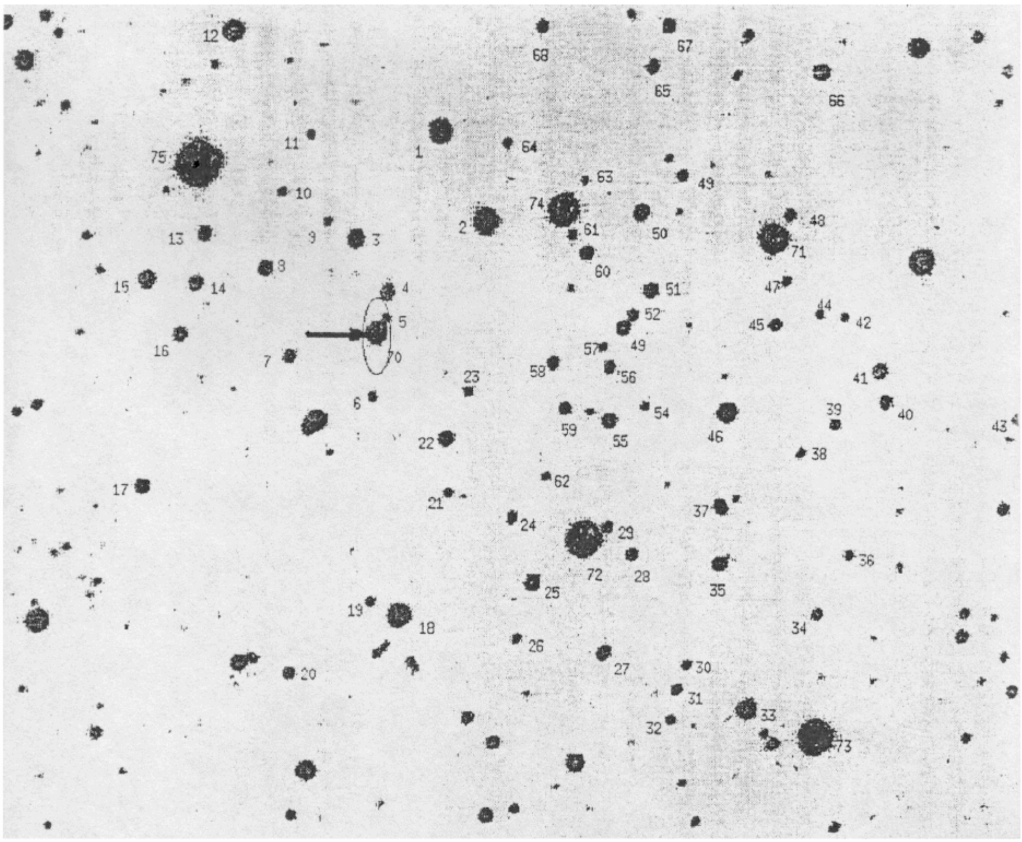

Fig. 5. The central (6.5′×4′) region of the Vulpecula field from our July 1999 R image, including the newly detected open cluster Loiano 1. N is at the top, E is at the left. Star numbers refer to Table 3. The optical counterpart of the IRAS source 19564+3224 (No. 70) is indicated by an arrow. The error ellipse of the IRAS source is also shown

stars" list published in the Astronomical Almanac, the relationship:

$$(B-V) = -0.104 \times (V-R)^2 + 1.355 \times (V-R) - 0.080$$

with a fit error of 0.04 mag.

Since the R band is much less affected by interstellar reddening than the V band and this one is less affected than B band, we used the previous relationship to evaluate a "computed" $(B-V)$ colour for each star corresponding to the measured $(V-R)$. In this way, a first approximation $E(B-V)$ was obtained for each star. Dereddened B, V and R magnitude were than computed from this colour excess, using the relationships given by Cardelli et al. (1989). The procedure was then repeated up to the convergence to zero of the residual colour excess, that was reached only with three iterations for all stars of the field at the same time. The total colour excess $E(B-V)$ value was then computed. We have confidence on these figures, since they are in agreement (within ± 0.1 mag) with the values obtained by Israel et al. (1999) for 1WGAJ 1958+3232, IPC99A and IPC99E on the base of the interstellar features equivalent width and with the values estimated by us from the analysis of archive intermediate resolution slit spectra of the B stars identified by the Nos. 71 and 74 in Fig. 5, that was taken in 1996, in the framework of the search for the optical counterpart of the X-ray source.

Table 3 gives the measured B, V, R magnitude of each star in the field, numbered as shown in Fig. 5, as well as the computed $E(B-V)$. The mean value of this parameter was found to be 0.43. All stars with reddening lower than 0.1 mag respect to this average were considered foreground objects: their $E(B-V)$ values seem to cluster around $\sim 0.2 \pm 0.04$ mag, suggesting the presence of a second population, most probably related to Vul OB4, despite the significant angular distance respect to the main part of this association. Among the other 60 objects, whose average $E(B-V)$ is 0.47, only 5 (stars Nos. 1, 5, 23, 72 and 74) show a reddening significantly greater than the average. They can be either background objects or reddened by local nebulosity. Excluding these 5 object, the average $E(B-V)$ is again 0.44.

Figure 8 gives the histogram of the computed $E(B-V)$ of the stars brighter than $R = 17$ present in the $6.5' \times 4'$ field studied.

It is interesting to notice that most of the stars with higher reddening do not spread on the whole field, but 4 of these 5 stars are located near to the void surrounding star No. 2 (that is a foreground object). It looks thus logical to suppose that this void is generated by the presence of a cloud, sited on the line of sight and that stars Nos. 1, 5, 23 and 74 are seen through its boundaries. Figure 9 gives the M_V vs. $(B-V)_0$ diagram of the stars of this field

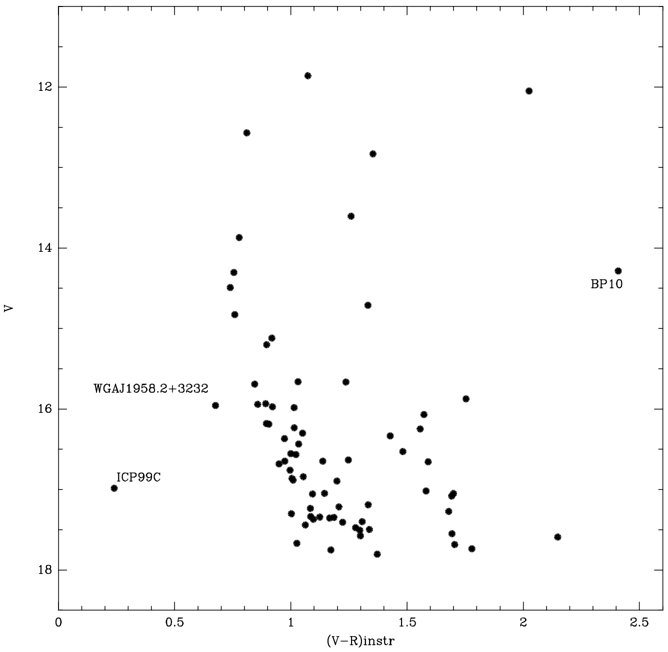

Fig. 6. The V vs. $(V-R)_{\rm instrumental}$ diagram of the objects present in the field shown in Fig. 5

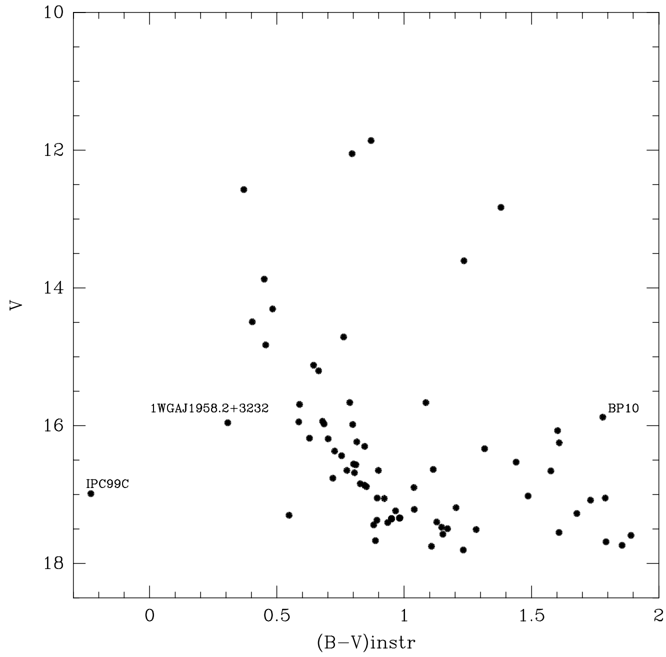

Fig. 7. The V vs. $(B-V)_{\rm instrumental}$ diagram of the objects present in the field shown in Fig. 5

with $0.33 \le E(B-V) \le 0.53$. The absolute V magnitude M_V is computed on the base of the evaluated reddening and of a distance of 2.7 kpc (see later). As can be seen, apart from the peculiar objects 1WGA 1958.2+3232 and ICP99C (Israel et al. 1999), all stars fit a single main sequence, but for star No. 73 and BP 10 (star No. 70). Four objects, fitting a parallel sequence about 2.5 mag brighter than the ZAMS, are most probably binaries.

We can thus argue that we are actually observing a previously unknown open cluster, with $E(B-V) \simeq 0.44$, a region of reddening excess and a number of peculiar members, though its angular dimension is difficult to measure, due to the high faint star density in the whole field.

We named this cluster Loiano 1.

From the fit of its M_V vs. $(B-V)$ diagram with the Schaller et al. (1992) isochrones, an age of ~250 My and a distance of 2.7 kpc can be argued. This distance is greater than that evaluated on the base of the cluster colour excess, that is of order of ~1 kpc, assuming the average galactic reddening. On the other hand, the cluster coordinates correspond to the "Zone 17" of FitzGerald (1968), where the reddening seems to remain constant to a value of $E(B-V) \simeq 0.5$ for distances between ~1 kpc and ~4 kpc (FitzGerald 1968; Thé & van Paradijs 1971).

4. Discussion and conclusions

The problem now rises of the real membership of BP10 to the Loiano 1 cluster. Actually, the computed reddening of the C star is only marginally compatible with the average $E(B-V)$ of the whole cluster. However, we have to bear in mind that the relationship used to evaluate the reddening of each star has been obtained from data related to main sequence stars, while the colours of a C star are, obviously, anomalous: greater uncertainties must thus be taken into account. On the other hand, it is impossible to accurately measure the interstellar features in such a complex spectrum as the BP10 one. It is also difficult to evaluate the star distance from photometric data, since the few R stars, whose parallaxes have been measured by Hipparcos satellite, have a large spread in absolute magnitude ($-3.8 \le M_V \le 4.8$) and intrinsic $(B-V)$ differing each other of ~1.4 mag ($2.0 \le (B-V)_0 \le 3.4$; Alksnis et al. 1998).

From an evolutionary point of view, it is easier to consider the C star a member of the 250 My old cluster Loiano 1 than of the much younger population of the foreground Vul OB4 and Vul OB1 associations. It is also interesting to notice that the age of Loiano 1 is rather similar to that of NGC 2533, Jaffner 14 and Lodén 1409: all these three clusters have log(age) $\simeq$ 8.2 and are positively associated with C stars (Jorgensen & Westerlund 1988). If the distance and the average reddening of the cluster is assumed also for the C star, we derive its absolute magnitude $M_V = 0.8$ and its intrinsic colour $(B-V)_0 = 1.91$. These figures, although acceptable for a carbon star, are still outside from the cluster isochrone (though the correction is in the right direction), but we have to consider that BP10 lies near to the void centred around star No. 2, so that a greater reddening is possible. On the other hand, a disagreement between theoretical prediction and measured luminosities for carbon stars is not too rare (see e.g. Jorgensen & Westerlund 1988; Frogel et al. 1981). If BP10 is a foreground star belonging to the Vul OB4 or Vul OB1 association, the only possible explanation is that this star is a post-main sequence, high initial mass object, formed from an interstellar medium strongly enriched

Table 3. Photometry of the field shown in Fig. 5

star	B	V	R	$E(B-V)$	comments
1	15.47	14.71	13.38	0.90	background?
2	14.84	13.61	12.35	0.27	foreground
3	15.76	15.12	14.20	0.48	
4	16.78	15.98	14.97	0.44	
5	19.48	17.59	15.44	0.63	background?
6	18.32	17.34	16.22	0.38	
7	17.75	16.63	15.39	0.39	
8	16.89	16.19	15.28	0.40	
9	19.59	17.74	15.96	0.19	foreground
10	18.67	17.50	16.16	0.45	
11	18.73	17.58	16.28	0.42	
12	14.79	14.30	13.55	0.43	
13	17.10	16.37	15.40	0.46	
14	17.86	16.25	14.69	0.21	foreground
15	15.87	15.20	14.31	0.43	
16	17.15	16.30	15.25	0.44	
17	16.61	15.94	15.04	0.41	
18	14.32	13.87	13.09	0.50	
19	18.32	17.34	16.25	0.33	
20	17.97	16.53	15.05	0.32	foreground?
21	18.34	17.41	16.18	0.57	background?
22	16.66	15.97	15.05	0.44	
23	17.85	17.30	16.30	0.69	background?
24	18.39	17.19	15.86	0.40	
25	16.45	15.66	14.63	0.47	
26	18.53	17.40	16.09	0.46	
27	17.05	16.23	15.22	0.42	
28	17.48	16.76	15.76	0.50	
29	18.26	17.22	16.01	0.43	
30	18.31	17.36	16.19	0.47	
31	17.74	16.88	15.87	0.37	
32	18.95	17.27	15.59	0.29	foreground
33	14.90	14.49	13.75	0.50	
34	18.51	17.02	15.44	0.40	
35	17.67	16.07	14.50	0.24	foreground
36	18.20	17.24	16.15	0.35	
37	17.36	16.56	15.56	0.42	
38	19.16	17.55	15.86	0.39	
39	17.94	17.05	15.90	0.51	
40	17.38	16.57	15.54	0.44	
41	17.65	15.87	14.12	0.26	foreground
42	19.04	17.81	16.43	0.42	
43	17.42	16.65	15.68	0.41	
44	18.62	17.48	16.20	0.40	
45	17.67	16.84	15.79	0.46	
46	15.28	14.83	14.07	0.47	
47	18.30	17.35	16.16	0.50	
48	17.93	16.90	15.70	0.42	
49	16.75	16.99	16.75	0.47	ICP99C
50	16.28	15.69	14.85	0.44	ICP99A
51	16.26	15.96	15.28	0.51	1WGAJ 1958.2+3232
52	18.84	17.05	15.35	0.17	ICP99D foreground
53	16.81	16.18	15.29	0.47	
54	18.56	17.67	16.64	0.36	
55	16.53	15.94	15.09	0.46	
56	18.81	17.08	15.39	0.24	foreground
57	19.48	17.69	15.98	0.17	foreground
58	18.23	16.66	15.07	0.30	foreground
59	17.49	16.68	15.73	0.35	ICP99E
60	17.65	16.33	14.91	0.40	
61	18.26	17.37	16.27	0.44	
62	18.79	17.51	16.21	0.26	foreground
63	18.86	17.75	16.58	0.30	foreground
64	18.32	17.44	16.38	0.41	
65	17.55	16.65	15.51	0.49	
66	16.75	15.67	14.43	0.41	
67	17.19	16.44	15.40	0.51	
68	17.71	16.86	15.86	0.38	
69	17.98	17.06	15.96	0.41	
70	16.64	14.28	11.88	0.33	BP10
71	14.21	12.83	11.48	0.22	foreground
72	12.85	12.05	10.03	1.79	background?
73	12.73	11.86	10.79	0.44	
74	12.94	12.57	11.76	0.63	background?
75					saturated

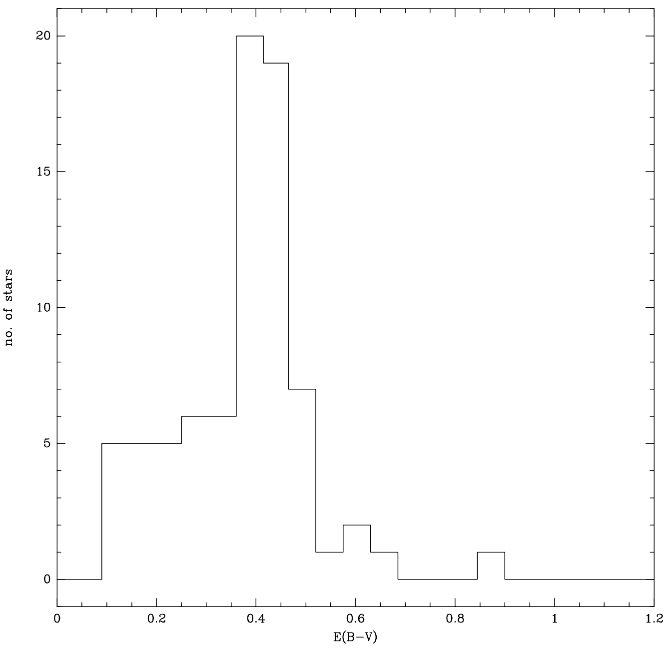

Fig. 8. The histogram of the computed $E(B-V)$ of the 75 star up to $R = 17$ present in the $6.5' \times 4'$ field shown in Fig. 5

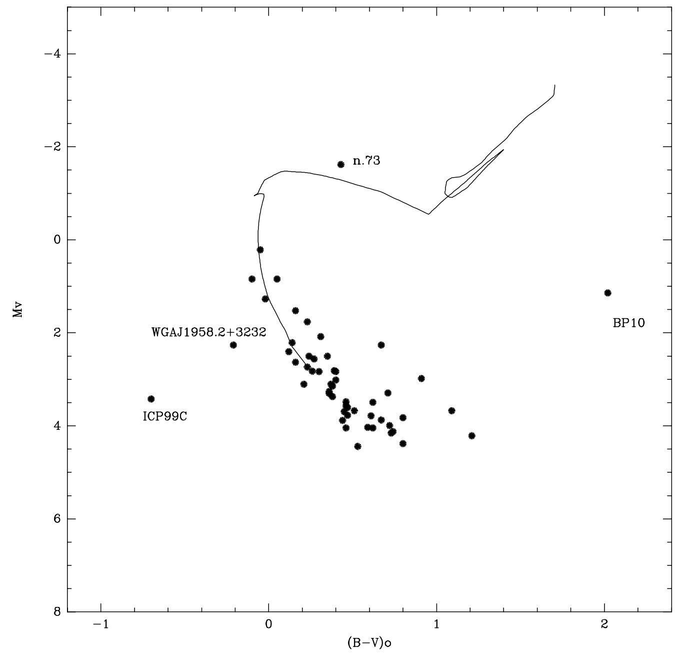

Fig. 9. The M_V vs. $(B-V)_o$ diagram of the field shown in Fig. 5; a distance of 2.7 kpc has been assumed and stars with $\Delta E(B-V) > \pm 0.1$ mag respect to the average colour excess (0.43) are excluded. The Schaller et al. (1992) 251 My isochrone is also shown

in carbon due to the effect of a previous generation of carbon stars and WCs (Chieffi, private communication). Actually, the Vul OB2 region is known to have a peculiar chemical composition of the interstellar matter (e.g. Krelowsky et al. 1999; Guetter & Vrba 1989), but no similar claim has been done to date for other Vulpecula OB associations: we thus do not consider this possibility very likely. A last problem concerns the nature and the distance of the dark matter cloud that is present in the cluster field. Since it does not affect the brightness of star No. 2, while it strongly reddens the overlapped area of the cluster, its distance must be evaluated between 1 and 2.7 kpc. We favour the longer distance, since no contribution from this cloud seems to come to the IR source IRAS 19564+3224 (no flux was detected in the IRAS longer wavelength channels, as can be expected from cold matter). Actually, Turner (1986) found out a distance of 2.5 kpc for the large globule Lynds 810 and argued that this globule is likely to belong to the Vul OB1 complex. We can thus reasonably suppose that the cloud that we detected is also a member of the same complex and lies at similar distance.

The experimental evidence that we have presented suggests a very complex situation: the nearby young stars related to Vul OB4 are followed by a substantially empty space, where only some residual matter connected with the Vul OB1 star forming region and a much older open cluster, not related to the Vulpecula OB associations chain, can be found. The bright and strongly reddened star No. 72 and, possibly, a few of the stars with $E(B-V) \geq 0.53$ listed in Table 3, should be the only representative of the farther Vul OB2 association visible in our field.

However, further spectroscopic and photometric measurements on this interesting sky area are needed in order to evaluate the Loiano 1 boundary since this cluster does not appears very concentrated and it is possible that its size is much larger than the enhancement in the star density shown in Fig. 4 and even of the $6.5' \times 4'$ field shown in Fig. 5. These studies are also needed in order to recognise the exact nature and evolutionary state of the C star BP10.

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