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# **A** CGPS **view of the** ISM **towards** HD **192281**

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**Abstract.** Massive stars are known to have a profound impact on their surroundings through their high ionizing radiation, their strong stellar winds, and their eventual final explosion as supernova. Within the area surveyed by the CGPS project there are 87 O-type stars and 36 galactic Wolf-Rayet stars. Therefore, the CGPS is an ideal database tu study, in a large number of stellar targets, the interaction of massive stars (and its descendants) with their surroundings. In this paper we report on the study carried out towards the massive stars HD 192281. A shell like structure, detectable at radio continuum, infrared and neutral hydrogen emissions, is found to be associated with this star.

## 1. Introduction

Massive stars inject large amounts of mechanical energy into their surrounding interstellar medium (ISM) via their powerful stellar winds and their final explosion as supernova. These stars also play an important role in shaping large scale properties of spiral galaxies, for they may be one of the major sources of turbulent energy input into the ISM.

Based on early works of Avedisova (1972) and Weaver et al. (1977), it was soon realized that massive stars can give rise in their local ISM to structures generically known under the name of *interstellar bubbles* (IB). Under very simple assumptions (e.g. the star is at rest with respect to its surroundings; the stellar mass loss rate is isotropic; the ISM is homogeneous; both the mass loss rate ($\dot{M}$) and the wind terminal velocity ($v_\infty$) are constant throughout the stellar evolution; magnetic fields effects are neglected) an IB should be a spherically symmetric region, centred at the stellar position, of low density (n$\sim 10^{-2}$ to $10^{-3}$ cm$^{-3}$) and high temperature (T$\sim$$10^{6-7}$ K) which is surrounded by a complex of expanding shells of gas that after cooling down may be observable in the neutral hydrogen (HI) $\lambda$ ~21-cm line. Since dust particles are mixed with gaseous matter, after being heated by the stellar radiation, the dust particles may emit at infrared wavelengths and the overall IR emission may also depict a shell-like morphology. When observed at short wavelengths, the central part of this idealized IB is expected to be detectable as a source of diffuse X-ray emission, while when viewed in the HI line emission at $\lambda \sim$ 21-cm , this central part should be detectable, in a limited velocity range, as an HI minimum. In the event that either the innermost shell of shocked HII gas (the shell originated by the expansion of the shocked stellar wind region) or the outer shock of interstellar gas (originated by the expansion of the photoionized HII region) (Freyer et al. 2003) may become optically thick to the stellar ionizing radiation field, the central HI minimum may be surrounded by ring-like features of radio continuum, infrared and/or neutral gas.

Though most of the simplifying assumptions made in the original IB models have been relaxed and dealt with in several papers (Weaver, McCray, Castor, Shapiro, & Moore 1977; Wilkin 1996; Garcia-Segura & Mac Low 1995; Freyer, Hensler, & Yorke 2003, 2006), the agreement between observations and model predictions is highly variable. On one hand, the case of the IB associated with the Wolf-Rayet (WR) star LS 16 is almost a textbook example, with a well defined central cavity surrounded by a shell like feature that is seen in the continuum at radio and IR wavelengths, as well as in the emission of the HI. On the other hand, there are several examples of massive stars that: *i)* are surrounded, totally or partially, by shells of neutral gas, that lack a radio continuum or infrared counterpart (Cazzolato & Pineault 2000); *ii)* are well off-centered with respect to the centre of the HI minimum (Arnal 1992); *iii)* show an unexpected dual-lobe geometry within a larger HI minimum (Arnal & Roger 1997); *iv)* exhibit such a large spatial velocity (~200 $\mathrm{kms}^{-1}$ for 209 BAC) that the IB related to the star is totally distorted and better understood in terms of a bow shock (Cichowolski et al. 2008).

Therefore, it can safely be concluded that in most cases the matter distribution observed in the neighbourhood of massive stars is quite complex and do not conform to theoretical predictions. Furtheremore, the study of the interaction of massive stars with their surroundings may help us to better understand the role played by early type stars, either individually or collectively, in shaping the large scale properties of the ISM. Morerover, these studies may also have an impact in our understanding of supernova remnant evolution (supernova type II explosions are likely to take place inside an IB created by the previous evolutionary stages of massive stars) and may shed some light on the role played by this interaction in triggering those processes that may end up forming new generations of stars.

From an observers's perspective, a way to better understand all these phenomena would be to increase the sample of massive stars whose local ISM is studied at arcmin resolution in different wavelength regimes.

## 2. The Canadian Galactic Plane Survey contribution

Among these surveys the CGPS is a project that " *combines radio (both HI line and continuum), millimeter and infrared surveys of the Galactic Plane to provide arcminute scale images of all major components of the* ISM" (Taylor et al. 2003). The CGPS extends from 55° $\leq l \leq$ 192° and -3°.5 $\leq b \leq$ +5°.5, and has a high latitude extension up to $b$= 17°.5 between 110° $\leq l \leq$ 117°.

Within the area surveyed by the CGPS there are 87 catalogued O-type stars (Maíz-Apellániz et al. 2004) and 36 galactic Wolf-Rayet (WR ) stars (van der Hucht 2001). Among the O-type stars, 58 are situated at galactic latitudes $|b|\geq$ 1°.0, while 21 WR stars fulfilled the same condition. Therefore, a sizable fraction of the O- and WR-type stars known in the Milky Way, fall within the boundaries of the region covered by the CGPS and have a galactic latitude high enough to minimize the confusing effects arising from the overall galactic HI emission.

Summing up, due to both the large number of O- and WR-type stars that are present within the sky area surveyed by the CGPS, and the large galactic latitude coverage of this survey, the CGPS is a very well suited database to considerable increase the number of early type stars (and its descendants) whose local ISM can be studied with high resolution at widely different wavelengths.

## 3. The ISM towards HD 192281

### 3.1. Basic stellar properties

HD 192281 [$(l, b) = (77\overset{\circ}{.}12, +3\overset{\circ}{.}40)$] is a member of the OB-association Cyg OB8, has a spectral type O5 Vn((f))p (Walborn 1972), and is a fast rotator with $V \sin i = 270$ $\mathrm{kms}^{-1}$ (Conti & Ebbets 1977). Distance determinations for this star vary between 1.55 kpc (Stone 1978) and 2.4 kpc (Humphreys 1978). Its radial velocity is -23.1 ± 8 $\mathrm{kms}^{-1}$ (De Becker & Rauw 2004), and its proper motions are $(\mu_\alpha \cos\delta, \mu_\delta) = (-8.0 \pm 0.7, -2.0 \pm 0.8)$ mas $\mathrm{yr}^{-1}$ (Zacharias et al. 2010). Moffat et al. (1998) claimed that this star has significant peculiar proper motions, supporting a possible run-away nature for this star.

Neither the mass-loss rate ($\dot{M}$) nor the wind terminal velocity ($v_\infty$) are known for this star. We shall adopt for HD 192281 $\dot{M} = 7 \times 10^{-7}$ $M_\odot \mathrm{yr}^{-1}$ and $(v_\infty) = 2700$ $\mathrm{kms}^{-1}$. These values are those of HD 14434, a star whose spectral type is similar to the one of HD 192281. Under this assumptions, the total mechanical energy injected into its local ISM along the stellar lifetime is $\sim 2 \times 10^{50}$ ergs. The total number of ionizing photons ($N_{Lyc}$) emitted by a star like HD 192281 is $N_{Lyc} \sim 5 \times 10^{51}$ $\mathrm{s}^{-1}$ (Martins et al. 2005).

### 3.2. The ISM around HD 192281

HD 192281 is located $\sim 1\overset{\circ}{.}7$ away of the young SNR G78.2+2.1 (Fig. 1). This remnant is very young (4000 to 7000 years, Mavromatakis (2003)) and is a very strong radio source at 1.4 GHz ($S_{1.4} = 226 \pm 19$ Jy, Kothes et al. (2006)). HD 192281 is seen projected onto a faint shell of radio emission observed towards the north-west of the SNR. Ladouceur & Pineault (2008) interpreted this feature either *as a probable breakout of the SNR* or *a simple line of sight coincidence*.

Due to the high dynamic range of the CGPS, the continuum emission arising from this faint shell clearly stands out from the noise, in spite of the presence of a very strong source (G78.2+2.1) in the vicinity.

This faint shell is also detected at both higher radio continuum frequencies, namely 2.695 GHz (Reich et al. 1984), 8.35 GHz and 14.35 GHz (Langston et al. 2000) and lower frequencies (0.408 GHz, CGPS database). Flux density determinations at these are consistent with a thermal nature for this source, for its spectral index is $\alpha = -0.11 \pm 0.02$ ($S_\nu \propto \nu^\alpha$).

At infrared wavelengths, from 8.7$\mu$m (MSX Band A) up to 100 $\mu$m (IRIS), the continuum shell has a clear infrared counterpart (Fig. 2) whichh is almost a mirror image of the radio continuum emission. From a fit of a modified Planckian function of the form $\nu^m \times B_\nu(T_d)$ to the measured flux densities at 60 and 100$\mu$m (adopting an index $m = 1.5$), we derived a dust temperature of $T_d = 24 \pm 4$ K. This value is typical of dust in HII regions (Fich & Terebey 1996).

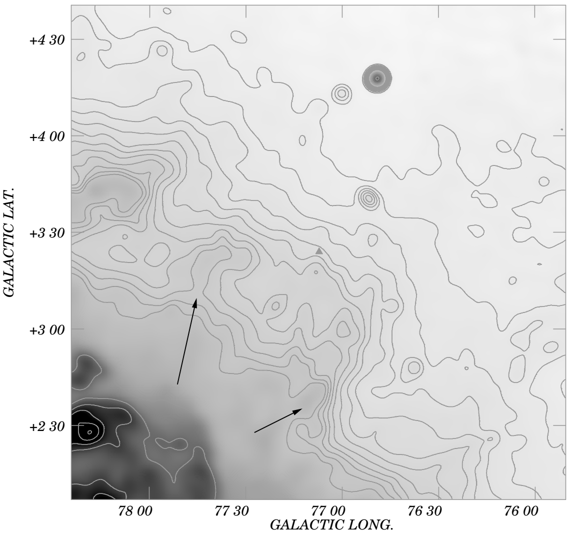

Figure 1. CGPS 1.42 GHz radio continuum emission towards HD 192281. The strong emission seen in the lower left corner of the image corresponds to the galactic supernova remnant G78.2+2.1. The arrows indicate the location of the faint shell-like feature. The position of HD 192281 is marked by a triangle symbol.

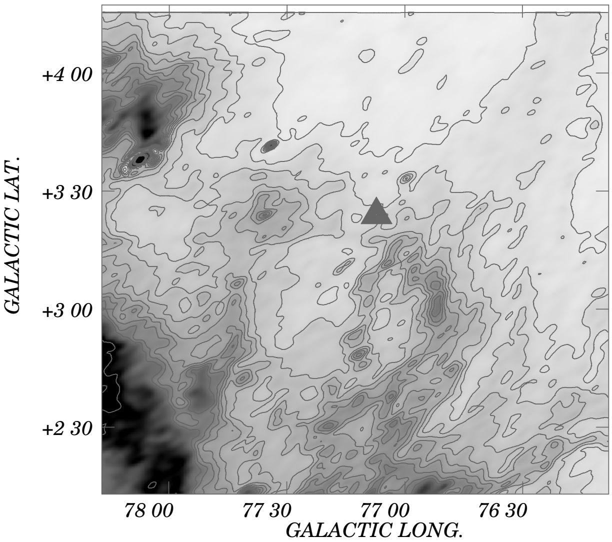

Figure 2. Extended IR emission towards HD 192281 at 60$\mu$m. The position of HD 192281 is signaled by a triangle.

Analysis of the entire HI data cube discloses a neutral gas structure (Fig. 3) that is very likely is associated with HD 192281. The velocity range covered by this feature is from -14.7 to -5.6 kms$^{-1}$.

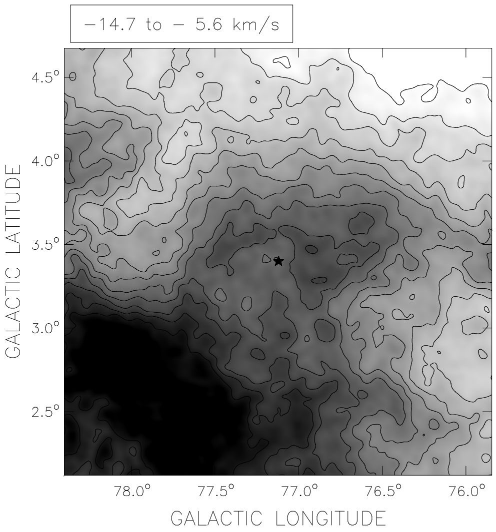

Figure 3. Average HI brightness temperature in the velocity range -14.6 to -5.6 $\mathrm{kms}^{-1}$. The stellar location is indicated by a star symbol.

## 4. Is HD 192281 related to G78.2+2.1?

Since the direction of the stellar proper motion of HD 192281 when extrapolated backwards in time interceps the centre of G78.2+2.1, it may be worth further exploring the possibility of a phyhsical association between them. A very simple reasoning indicates that this is impossible. Indeed, based on the angular distance between both objects, roughly ~ 1.°7, and the range of ages accepted for the SNR, a physical association between both objects would require, in order to explain the present position of HD 192281 with respect to G78.2+2.1, that the stellar proper motion should be around ~ 1.0 arcsec/year. This figure is almost two orders of magnitude larger than the observed one.

## 5. Discussion and Conclusions

Following the procedures outlined by van der Sluys & Lamers (2003) and Cichowolski et al. (2008) , and adopting for HD 192281 a distance of 1.5 ± 0.3 kpc, the total *peculiar* velocity ($V_p$) of this star turns out to be $V_p$= 39 ± 10 $\mathrm{kms}^{-1}$. Adopting the criterion of Cruz-González et al. (1974), HD 192281 very likely is a run-away star, in agreement with the conclusions drawn by Moffat et al. (1998). According to Weaver et al. (1977) a star moving with such a high velocity with respect to its surroundings will create an IB whose geometry departs from the spherical one, being distorted along the direction of the stellar motion. Based on van der Sluys & Lamers (2003) only two angles, denominated $i$ and $\phi$, are needed to completely define the spatial orientation of the structure created by a fast moving star. The angle $i$ is measured from the line of sight towards the observer, whilst $\phi$ is measured on the plane of the sky, counterclockwise from the tip of the peculiar velocity vector (van der Sluys & Lamers 2003).

In the case of HD 192281 the angles are $i$=114° ± 18° and $\phi$= -24° ± 21°. Therefore, the star is moving towards the observer and towards low galactic longitudes and high galactic latitudes. Based on the Hı data, a bow shock interpretation is favoured. In this context the infrared and radio continuum data may be interpreted as originated in the surface defining the bow shock downstream from the apex.

Based on above, it can be concluded that:

*a)* The weak continuum feature detected north-west of G78.2+2.1 is not a blow-out feature of this SNR.

*b)* The above feature is thermal in nature and very likely powered by the radiation field of HD 192281.

*c)* There are infrared and atomic gas (Hı) counterparts to the shell-like continuum feature.

*d)* HD 192281 is very likely a run-away star.

*e)* A bow-shock geometry best fits the observed Hı distribution likely to be related to HD 192281. The radio continuum and infrared emission can also be understood in this context.

*f)* The large spatial motion of HD 192281 is not associated with the supernova explosion that originated SNR G78.2+2.1.

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