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DISCOVERY OF A NEW BIPOLAR H II REGION IN CYGNUS

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RESUMEN

La nueva estructura dipolar, descubierta en los datos de radio continuo y línea de H I de Pineault & Chastenay (1990), es consistente con una región H II producida por una estrella central. Si la fuente está a su distancia cinemática de 10 kpc, se necesitaría una estrella O6 V para producirla. En cambio, si se halla a una distancia más cercana de 2 kpc (posiblemente relacionada con la asociación Cygnus OB1/OB3), sería suficiente una estrella B0 V para ionizar la estructura.

ABSTRACT

A new bipolar structure found in the continuum and H I line radio data of Pineault & Chastenay (1990) is shown to be consistent with a bipolar H II region powered by a central star. If at its kinematical distance of 10 kpc, an O6 V star is required. However, if at a closer distance of 2 kpc, possibly related to the Cygnus OB1/OB3 association, a B0 V star is sufficient to ionize the structure.

Key words: **INFRARED: ISM: CONTINUUM — ISM: H I, H II REGIONS, STRUCTURE — RADIO CONTINUUM: ISM**

1. INTRODUCTION

The source G74.5+0.9 was first noticed by Pineault & Chastenay (1990) as displaying a morphology reminiscent of an extragalactic double-lobe radiogalaxy with a jet-like core. It was pointed out however that its rather flat radio spectral index and far-infrared to radio ratio were more typical of an H II region. Analysis of aperture synthesis neutral hydrogen observations by Pineault, Gaumont-Guay, & Madore (1996) showed the presence of a double-minimum cavity in a velocity interval of about $8\,\mathrm{km\,s^{-1}}$ centered at about $-70\,\mathrm{km\,s^{-1}}$ (LSR). This strongly argues for a galactic origin and I suggest that G74.5+0.9 is a bipolar H II region powered by a central star.

2. THE DATA

Fig. 1 shows the source region in the radio continuum at 1420 MHz, at 60 μm in the IR and in the H I line. I refer to the associated bright compact source as the "central" source (even though it is slightly off center) and discuss both its properties and those of the extended emission. Gaussian fitting (at 1420 MHz) to the central source produces a best-fitting size of $1.4' \times 0.7'$ at a position angle PA, measured E of N, of 95°. The extended continuum emission is *not* limb-brightened and there is *no* evidence of an H I shell. Background/foreground emission is severe in this direction and it is somewhat difficult to unambiguously define the extension of the source. For the sake of the discussion, whenever integrated quantities are used in the remainder, they refer to the polygon (defined from the 1420 MHz continuum emission) shown as a dot-dashed line in Fig. 1(*c*).

3. THE CONTINUUM SPECTRUM

The physical properties of the source are derived on the basis of the data in Fig. 1, together with new radio observations at 327 MHz (Taylor et al. 1996) and 4.85 GHz (Condon et al. 1994) as well as *HIRES* infrared (IR) data (Fowler & Aumann 1994). Table 1 shows the radio and IR fluxes and colors. Both the central source and the extended emission are characterized by a rather flat radio spectral index (the central source is confused

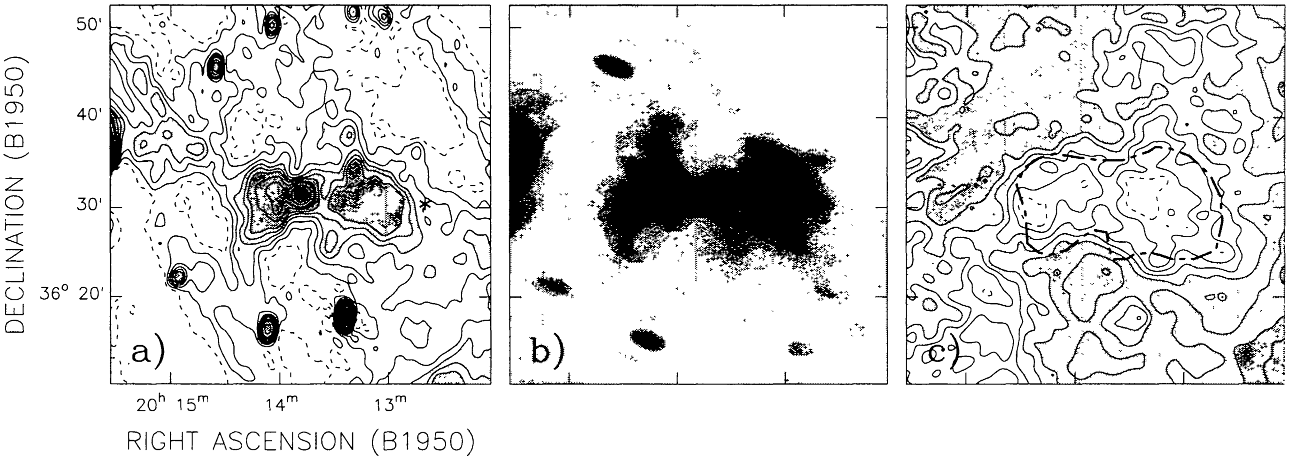

Fig. 1. (*a*) Radio continuum emission at 1420 MHz (Pineault & Chastenay 1990). Resolution is $1' \times 1.7'$ (EW $\times$ NS). Contour levels are at 7.5 (dashed) to 10 K in steps of 0.5 K, then at 11, 12, 14, 16, 18 and 24 K in brightness temperature. Grayscale steps occur at 8, 9 10, 16 and 24 K. The asterisk marks the position of the star WR 137. (*b*) *IRAS* (*HIRES*) emission at 60 μm. Resolution (variable over the field) is about $95'' \times 58''$ at a PA of 65°. Shadings run smoothly from -7.5 to 120 MJy sr^{-1}. (*c*) Neutral hydrogen emission (Pineault, Gaumont-Guay, & Madore 1996) averaged over an 8.25 km s^{-1} bandwidth centered at $v_{\rm lsr} = -69.6$ km s^{-1} and smoothed to a resolution of $2'$. The average of the emission over the field is 49.7 K. Contour levels, referred to this mean value, are at $-18, -15, -12, -9, -6$, 0, 6, 12, 18, and 24 K. Grayscale steps occur at $-18, -12, -6$, 6, 18 and 24 K. The dot-dashed line represents the source boundary as inferred from Fig. 1(*a*).

with the eastern lobe on the 4.85 GHz map and could not be measured). The IR data show that the colors of the central and extended emission are also rather similar yielding an average dust temperature $T_{\rm d} \approx 31$ K (Pineault 1998). These colors are typical of galactic nebulae or normal galaxies (Helou 1986).

4. BIPOLAR H II REGION

As a model for the source, we adopt that of a bipolar H II region and use standard techniques to derive the physical parameters (details and references in Pineault 1998). For simplicity, the ionized gas parameters are derived by modelling the source as two spherical regions of uniform density lying on either side of the central source (Mezger & Henderson 1967). We consider two possible distances for the source.

For a flat rotation curve model with $R_0 = 8.5$ kpc and $V_0 = 220$ km s^{-1}, the distance-velocity relation gives a kinematical distance of $d \approx 10$ kpc (Pineault, Gaumont-Guay, & Madore 1996). However, the kinematics in this direction of the Galaxy is affected by the presence of the Cyg OB1 and OB3 associations (Lozinskaya & Repin 1990) and the presence of large negative velocities has been demonstrated in the spectra of a number of stars in this direction, notably the stars WR 134 and WR 137 (Treffers & Chu 1982; St-Louis & Smith 1991;

TABLE 1

RADIO AND IR FLUX DENSITIES AND COLORS

	Radio flux density (Jy)			IR flux density (Jy)				IR color $C_{i,j}$		
	327	1420	4850	12	25	60	100	12,25	25,60	60,100
Central	0.21	0.20	...	5.97	13.0	116	196	0.34	0.95	0.23
Extended	1.56	1.62	12.4	35.9	62.8	528	833	0.24	0.92	0.20

Note. – For radio data, the flux densities refer to the frequency in MHz. For IR data, the flux densities refer to the wavelength in μm, the IR colors are defined as $C_{i,j} = 2.5 \log (S_j/S_i)$ and the errors in the flux densities are 44, 20, 21 and 32 % (Fich & Terebey 1996).

TABLE 2

DERIVED PHYSICAL PROPERTIES OF EXTENDED STRUCTURE

d (kpc)	$L_{IR}/L_\odot$	$M_d/M_\odot$	$M_{H\,I}/M_\odot$	n_e (cm^{-3})	$M_{H\,II}/M_\odot$	N_u (s^{-1})	Type	$L_*/L_\odot$
2	5.1×10^3	1.1	32	$12 \rightarrow 20$	95	3.5	B0 V	5.2×10^4
10	1.3×10^5	27	810	$5.2 \rightarrow 8.8$	5290	127	O6 V	4.2×10^5

Nichols & Fesen 1994; Esteban & Rosado 1995). The distance to the latter stars is 2.1 and 1.8 kpc (van der Hucht et al. 1988). A large negative velocity is thus compatible with the bipolar source being part of a feature expanding toward us away from, and in front of, the Cyg OB1/OB3 associations (Pineault & Terebey 1997), in which case a distance of $d \approx 2$ kpc is suggested. For reference, a source of angular extent θ_{am} arcmin at a distance $d = d_{kpc}$ kpc has a linear size $l = 0.29\, d_{kpc}\theta_{am}$ pc.

Table 2 shows the derived physical parameters (see Pineault 1998 for details of the derivation) of the extended bipolar source for the two cases. These parameters are the total IR luminosity L_{IR}, dust mass M_d, H I mass M_{HI}, electronic number density n_e (the two values refer to the two separate lobes), ionized mass gas M_{HII}, number of ionizing photons per second N_u, stellar type and stellar luminosity L_*. Note that $M_{HI} < M_{HII}$ and that the inferred ratio of gas to dust mass is reasonable, varying between 30 and 200 depending on whether one takes the neutral or ionized mass estimate for the gas. And finally the inferred infrared luminosity satisfies $L_{IR} < L_*$.

5. CONCLUSION

Considering the various assumptions entering into the estimates of the source properties and the errors inherent in the determination of the true size of the extended emission, we conclude that the IR, radio continuum, and neutral hydrogen observations are all consistent with the model of a bipolar H II region ionized by the UV flux of the central object. Source parameters have been derived for two distances. For the nearer distance, a B0 V star is sufficient to ionize the bipolar source, its total length is about 12 pc and the central (compact) source has dimension 0.8 pc $\times$ 0.4 pc. For the farther distance, the corresponding parameters are an O6 V star, a total length of 60 pc and a central source size of 4 pc $\times$ 2 pc.

The lack of limb brightening (radio continuum and infrared) and of an H I shell bordering the cavity argues against significant wind action which would have left a hot low-density cavity surrounded by a denser shell, although the central (compact) source, if it is indeed extended as show the 1420 MHz observations, could mark the boundary of a wind-shocked region. However, its small size sets severe constraints on the age or duration of the wind having caused it (Pineault 1998).

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