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VLA RADIO CONTINUUM OBSERVATIONS OF THE EXTENDED ENVELOPES SURROUNDING 16 UC HII REGIONS

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I. INTRODUCTION

Ultracompact (UC) HII regions are very small (D $\lesssim$ 0.1 pc), dense ($n_e > 10^4$ cm^{-3}), and bright (EM $\gtrsim$ 10^7 pc cm^{-3}) radio and infrared sources that are still embedded in their parental molecular cloud (Churchwell 1990). These objects represent an early stage of massive-star evolution. Koo et al. (1996) showed that G5.48−0.24, known as UC HII region, is indeed a large (~40 pc) HII region complex which has structures at diverse length scales ranging from ~ 0.01 pc to ~ 40 pc. The presence of the extended envelope implies that there are much more ionizing photons than what would have been estimated from the compact core alone. In G5.48−0.24, the spectral type of exciting star turned out to be O5 ZAMS instead of O8 of Wood & Churchwell (1989: hereafter WC89) and the fraction of UV photons absorbed by dust grains mixed with ionized gas turned out to be ~40% instead of 95% of WC89. The extended diffuse emission could be also a direct evidence supporting that the UC HII regions are significantly older than ~ 3×10^4 yrs. The results on G5.48−0.24 showed that the observation of the extended envelope is essential in understanding the nature of HII regions. What is the physycal relationship between the extended envelope and an UC HII region? They could have been produced by the same ionizing source as in Champagne flow model (Tenorio-Tagle 1982 and references therein; Joncas et al. 1985), or by separate ionizing sources at different ages as in sequential star formation model (Elmegreen & Lada 1977; Campbell & Persson 1988). We report here radio continuum obervations, made with the Very Large Arry (VLA), toward 16 UC HII regions. The observations were designed to search for the extended envelopes associated with UC HII regions and to investigate the relationship between the two.

II. OBSERVATIONS

The radio continuum observations of 16 UC HII regions were made with $40'' \times 20''$ angular resolution at 20 cm using the VLA (C/D array) in 1995 February. The sixteen UC HII regions were selected from WC89 catalog of UC HII regions because of their large ($\geq$10) ratio of single-dish to VLA fluxes. They are composed of five cometary, one shell-type, two core-halo type, two spherical, and six irregular (or multiply peaked) UC HII regions. The flux density was refered to 3C 286, which was assumed to have flux density of 14.64 Jy at 1.465 GHz. The data were edited and calibrated following the standard VLA program in AIPS.

Table 1. Observed Parameters

Source	Size (′)	Flux (Jy)	N_{core}[a]	Type
G5.89−0.39	14.4 × 9.0	20.86	2	shell
G5.97−1.17	14.5 × 10.7	48.29	1	core-halo
G6.55−0.10	30.9 × 12.6	40.36	1	irregular
G8.14+0.23	6.9 × 2.8	6.67	1	irregular
G10.15−0.34	10.9 × 6.7	55.22	2	irregular
G10.30−0.15	12.8 × 4.6	15.92	2	cometary
G12.21−0.10	4.7 × 3.4	3.06	3	cometary
G12.43−0.05	3.0 × 2.2	0.69	1	cometary
G23.46−0.20	8.8 × 5.8	11.31	3	spherical
G23.71+0.17	2.9 × 1.8	1.93	1	core-halo
G23.96+0.15	3.1 × 1.5	2.13	1	irregular
G25.72+0.05	3.2 × 2.5	1.74	1	spherical
G27.28+0.15	2.6 × 1.4	0.96	1	irregular
G29.96−0.02	6.3 × 5.2	12.69	2	cometary
G35.05−0.52	3.7 × 3.1	1.64	2	irregular
G37.55−0.11	2.1 × 1.8	1.12	1	core-halo

[a]The number of radio-continuum compact cores.

III. RESULTS AND DISCUSSION

We have detected diffuse emission in all sixteen UC HII regions. There were one to three compact cores and several less compact clumps in each extended envelope. Most of the extended envelopes associated with the core-halo type and irregular UC HII regions have one compact core. UC HII regions were located in the compact cores except G23.46−0.20 and G25.72+0.05. These two spherical UC HII regions have no associated compact core and are located near the edge of extended envelopes. On the other hand there appears to be no relationship between the morphology of UC HII region and the size of extended envelope. The basic observed parameters of the individual sources are summarized in Table 1.

We have derived the physical parameters of the ionized gas using the observed integrated flux densities reported in Table 1 and assuming that the HII region is spherical symmetric, optically thin, homogeneous, dust-free, and ionization-bounded (Panagia & Walmsley 1978). In the calculation of physical parameters we used the distances and electron temperatures given by Downes et al (1980) and Wink et al. (1982) who observed radio recombination line emission. The results are summarized in Table 2. The last column of Table 2 lists the spectral type of the ionizing star (Panagia 1973) required to produce the Lynman continuum photon flux, N_c, of each source. This assumes that a single star is responsible for the ionization. The spectral types are approximately four subclasses earlier than those of

Table 2. Derived Physical Parameters

Source	d (kpc)	n_e[a] (cm^{-3})	M_{HII} ($M_\odot$)	Spectral Type
G5.89−0.39	2.6	64	480	O6 (O9)
G5.97−1.17	1.9	98	380	O6 (B0)
G6.55−0.10	16.7	67	1970	O4.5 (O8.5)
G8.14+0.23	4.2	111	200	O6 (B0)
G10.15−0.34	6.0	99	3800	O4 (O8)
G10.30−0.15	6.0	64	1830	O4.5 (O8.5)
G12.21−0.10	16.1	46	3550	O4 (O6.5)
G12.43−0.05	16.7	44	1030	O6 (O9)
G23.46−0.20	9.0	49	3710	O4 (B0)
G23.71+0.17	9.0	112	290	O6 (O9)
G23.96+0.15	6.0	146	100	O6.5 (O9.5)
G25.72+0.05	14.0	63	1100	O5 (B0)
G27.28+0.15	15.2	82	570	O5.5 (O9)
G29.96−0.02	9.0	71	2780	O4 (O5.5)
G35.05−0.52	12.7	50	1160	O5.5 (O9)
G37.55−0.11	12.0	96	330	O6 (O7.5)

[a]Averaged over the area of the entire source.

WC89, which are given in parentheses.

Figure 1 is a plot of electron density against diameter for the compact cores (crosses) and extended envelopes (circles). There is a strong correlation between the two physical parameters. A least-square fit yields $n_e = 1200\ D^{-1.1}$. A similar relation was found for the more compact HII regions including the UC HII regions of WC89 (Garay et al. 1993). If the number of ionizing photons is constant, $n_e \propto D^{-1.5}$. We can think of two possible explanations for the less-steep power-law. One is that the more smaller HII regions are excited by less luminous stars. Or, alternatively, the larger HII regions contain more numerous stars. The other is that only a fraction of UV photons emitted from ionizing stars is used to excite compact HII regions. This case includes the possibility that some compact cores are externally-ionized density inhomogeneities within larger HII regions.

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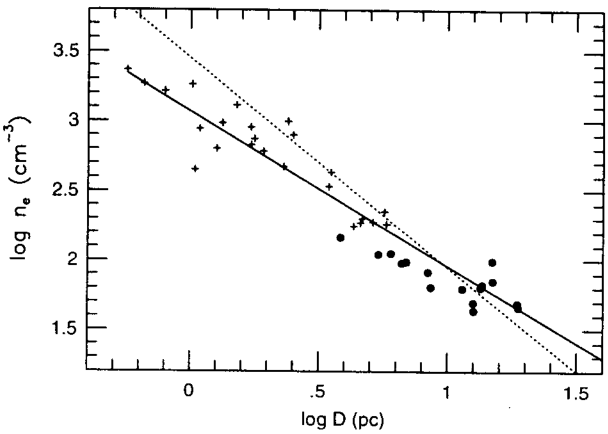

Fig. 1.— RMS electron density vs. linear diameter for the compact cores (crosses) and extended envelopes (circles). A linear fit gives a correlation coefficient of −0.95. The solid and dotted lines represent the fitted relation and a line of constant excitation parameter ($U = 10^2$), respectively.

REFERENCES

Campbell, B. & Persson, S. E. 1988, AJ, 95, 1185

Downes, D., Wilson, T. L., Bieging, J., & Wink, J. 1980, A&AS, 40, 379

Churchwell, E. 1990, Astron. Astrophys. Rev., 2, 79

Garay, G., Rodríguez, L., Moran, J. M., & Churchwell, E. 1993, ApJ, 418, 368

Joncas, G., Dewdney, P. E., Higgs, L. A., & Roy, J. R. 1985, ApJ, 298, 596

Elmegreen, B. G., & Lada, C. J. 1977, ApJ, 214, 725

Koo, B.-C., Kim, K.-T., Lee, H.-G., Yun, M.-S., & Ho, P. T. 1996, ApJ, 456, 662

Panagia, N. 1973, AJ, 78, 928

Panagia, N., & Walmsley, C. M. 1978, A&A, 70, 411

Tenorio-Tagle, G. 1982, in *Regions of Recent Star Formation* , ed. R. S. Roger & P. E. Dewdney (Dordrecht:Kluwer), p. 1

Wink, J. E., Altenhoff, W. J. & Mezger, P. G. 1982, A&A, 108, 227

Wood, D. O., & Churchwell, E. 1989, ApJS, 69, 831