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UCH II REGIONS WITH EXTENDED ENVELOPES

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RESUMEN

Presentamos observaciones de radio, en líneas de recombinación y el contínuo, de 16 UCH II con cocientes de flujo, en una antena a VLA, grandes. Excepto por una, todas las fuentes están físicamente asociadas a la emisión extendida y posiblemente son excitadas por la misma fuente. Entonces, casi ninguna de las fuentes observadas son regiones UCH II reales, sino núcleos de regiones H II extendidas. Consideramos el origen de la emisión extendida y discutimos sus implicaciones en el problema de las edades de regiones UCH II.

ABSTRACT

We present radio continuum and recombination line observations of 16 UCH II regions with large ratios of single-dish to VLA fluxes. All the sources but one are physically associated with extended emission. The UCH II regions and their extended envelopes are likely to be excited by the same ionizing sources. Therefore, almost all the observed UCH II regions are not likely to be real UCH II regions but ultracompact cores of more extended H II regions. We consider the origin of extended emission and discuss its implications on the age problem of UCH II regions.

Key Words: **H II REGIONS — STARS: FORMATION**

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1. INTRODUCTION

Ultracompact (UC) H II regions represent an early evolutionary stage of massive stars (Wood & Churchwell 1989a; Kurtz, Churchwell, & Wood 1994). One of the most interesting issues related to these objects is the "age problem", i.e., too many UCH II regions are observed in the Galaxy, compared to that expected from other indicators of massive star formation rate based on their dynamical age (Wood & Churchwell 1989b). In order to resolve this problem, several different models were proposed (see Churchwell 1999 and references therein). These models suggest that H II region expansion is constrained by various mechanisms in the UC phase for a long ($>10^5$ yr) time.

On the other hand, extended emission was observed around a few tens of UCH II regions (Garay et al. 1993; Koo et al. 1996; Kurtz et al. 1999), suggesting that the ultracompactness arises from the missing short baseline of interferometric observations. However, the relationship between UCH II regions and the surrounding extended emission remains unclear. In this contribution, we answer the following questions (see Kim & Koo 2001 for details):

Do most UCH II regions have extended emission?

What is the physical relationship between the two?

What is the origin of extended emission?

2. OBSERVATIONS

We observed 16 UCH II regions in radio continuum and radio recombination line (RRL). The continuum observations were made with about $40'' \times 20''$ angular resolution at 21 cm using the VLA (DnC array) in 1995 February. The sources were selected from the catalog of Wood & Churchwell (1989a) because of their simple morphology and large ($\gtrsim$10) ratios of single-dish to VLA fluxes (simple means that they are not resolved into two or more distinct components). The observations were sensitive to structures up to $15'$ in size. The H76α RRL observations were done with $2'$ angular resolution using the Green Bank 43-m telescope in 1997 February and June. We made observations at 1–13 positions including the radio continuum peaks in each source except two (G5.89–0.39 and G5.97–1.17). The two sources were mapped in full-beam spacing.

3. RESULTS AND DISCUSSION

We detected extended emission in all sources. The extended envelopes are $2'-12'$ (4$-$19 pc) in angular extent, and their morphologies range from simple structures with a single peak to a complicated structures with several compact ($\sim 1'$ or 0.5$-$5 pc) components. All the UCH II regions but two are located in the compact components, where the UCH II regions always correspond to their peaks. We derived the ratios of single-dish to VLA fluxes for 52

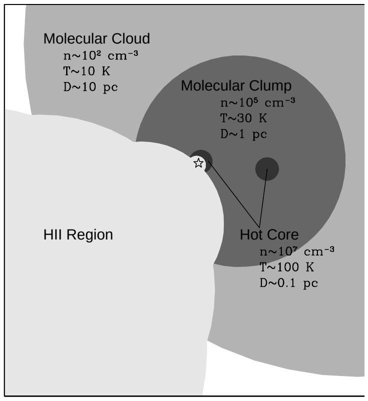

Fig. 1. Schematic diagram of our model. The ionizing star is marked by a star symbol. This figure is not scaled.

UCH II regions with simple morphology in the catalogs of Wood & Churchwell (1989a) and Kurtz et al. (1994), and found that most of them have large ratios. For instance, about 70% have ratios > 5. Thus, most UCH II regions are likely associated with extended emission, analogous to our sources.

H76α line emission was detected in all sources except G12.43−0.05. We could not find any significant velocity difference between the spectrum observed toward each UCH II region and the average spectrum of its extended envelope with one exception (G25.72+0.05), although some local motion was observed in 7 sources. This indicates that the two components are physically associated. Furthermore, there are no large differences between our H76α line velocities and the molecular line velocities taken from the literature. So, the UCH II region, compact component(s), and extended envelope may be physically associated in almost all (15/16) of our sources.

As noted above, the UCH II regions correspond to the peaks of their associated compact components in all the sources. Moreover, the compact components with UCH II regions are usually smaller and denser than those without UCH II regions. If they are ionized by separate sources, one would not expect these correlations. Hence, the UCH II region and its associated compact component is probably excited by the same ionizing source.

Molecular clouds are clumpy at all observable length scales. Thus it is not surprising that H II regions have substructures as in our sources. Recent high-resolution studies of massive star-forming regions have revealed 'molecular clumps' and 'hot cores' therein (see Kurtz et al. 2000 and references therein). Hot cores are believed to be the sites of massive star formation, and the sizes of the hot cores and molecular clumps agree roughly with those of UCH II regions and their associated compact components, respectively. Based on these observations, we propose a simple model in which the existence of the extended emission around UCH II regions can be explained by combining the Champagne flow model with the hierarchical structure of massive star-forming regions. Figure 1 is a schematic representation of our model. We consider the case where a massive star forms off-center within a hot core with $n_{\rm H_2} \sim 10^7$ cm^{-3} and $M \sim 100 M_\odot$, which is placed in a molecular clump of $n_{\rm H_2} \sim 10^5$ cm^{-3}. In this case, the H II region continues to be ultracompact within the hot core for a long ($> 10^5$ yr) time, while it could grow up to a few 1 pc outside the core (Whitworth 1979; Tenorio-Tagle 1979). We have found the champagne flows in several sources, based on the velocity gradient of H76α line emission and/or the morphology of radio continuum image, and the larger line width of RRLs in the compact components. Theses observations are consistent with our model. In conclusion, most sources known as UCH II regions may not be real UCH II regions but rather ultracompact cores of more extended H II regions.

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