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Hydrocarbons in Massive Star Forming Regions: C_2H Observations

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Abstract. In order to better understand the chemical conditions and evolutionary properties of massive star-forming regions, and to explore the physical and chemical behavior of simple hydrocarbon molecules, we have used telescopes such as CSO, JCMT, CARMA and SMA, to map the multi-transitions of C_2H and HC_3N. The column densities and abundances are compared with chemical models to gain some diagnostic of the environment of the regions.

Keywords. astrochemistry – ISM: abundances – molecular processes – stars: early-type – stars: formation – stars: individual (G10.6-0.4, ON1, W33, and AFGL 490)

1. Introduction

The evolutionary phases of massive star is still not well understood due to the short timescales and high extinction, and extensive theoretical (physical and chemical) models have been dedicated to address the evolutionary questions. For example, an evolutionary sequence of high mass stars have been proposed in Beuther *et al.*(2007). Other than physical approaches, astrochemical diagnosis has been adopted to study the properties of star-forming regions. Observing molecular clumps and cores with multi-species and multi-transitions, would help diagnose the history of cloud collapsing and the early phase of star formation during the embedded phases, as well as constraining the chemical models.

The representative hydrocarbon, C_2H (Ethynyl radical), is found to be ubiquitous and abundant in the ISM, and is a good tracer of Photon-Dominated Regions (PDRs). Cuadrado *et al.*(2014) have conducted a systematic study of small hydrocarbons. It has been suggested that C_2H is a good tracer of cold molecular gas linked to the early phase of star formation (Beuther *et al.*2008, Padovani *et al.*2009).

2. Observations and Implications

Our work consists of multi-transitions observations of hydrocarbons using a variety of facilities. A systematic survey of C_2H 1-0 and HC_3N 10-9 toward a sample of 27 Galactic OB cluster forming regions were implemented using the PMO 14-m telescope (Li *et al.*2012). The sample represents different evolution stages (UCHII, extended HII and YSO). C_2H 4-3 emission in 14 of the sample have been mapped (map sizes $\sim 2'' \times 2''$ or $3'' \times 3''$) using HARP on JCMT (programs m15ai46 and m15bi042), and OTF maps of C_2H 3-2 in four targets were obtained with the CSO also in 2015. Follow-up high-resolution observations have also been implemented towards four selected targets: C_2H 1-0 and HC_3N 10-9 were observed by the Combined Array for Research in Millimeter-wave Astronomy (CARMA) in 2014, and C_2H 3-2 by the Submillimeter Array (SMA, Jiang et al. 2015).

Our results (Fig. 1) clearly show that, C_2H follows the molecular gas envelops in some sources (G10.6-0.4 and W33 Main as examples in Fig. 1), while on small scales ($\sim$ 0.1 pc) the peaks of C_2H are offset from the core center traced by the mm continuum (See Jiang et al. 2015 for more details). Our new JCMT mapping also shows that, on larger scales ($\sim$ pc) the distribution of C_2H is different from that obtained by the interferometries. The difference might be a result from the different transitions we observed, but it is possible that the interferometries missed the diffuse C_2H emission so the maps exhibit such different distributions (data still being reduced).

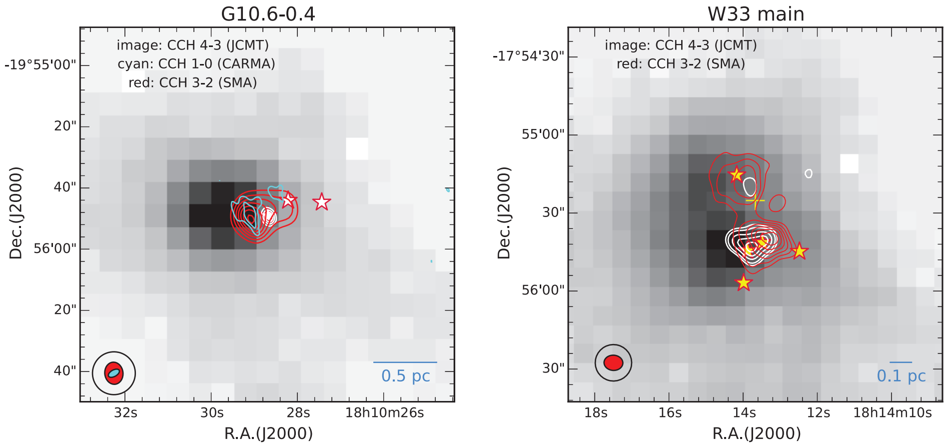

Figure 1. Maps of multiple transitions of C_2H lines in the massive star-forming region G10.6-0.4 (left) and W33 Main (right). The greyscale images are C_2H 4-3 obtained by HARP on JCMT . Overlaid are C_2H 1-0 by CARMA (thick cyan contours, data being reduced), and C_2H 3-2 by SMA (thin red contours, from Jiang *et al.* 2015). Their corresponding resolutions (beam sizes) are indicated on the lower left corners. The yellow stars are HII regions near the core center (small white contours), which is 1.1 mm continuum emission by SMA.

These results indicate that while C_2H is closely linked to the gas illuminated by the PDRs around star forming regions, it is weaker in the star forming core centers. Its chemical behaviors might be a good probe of the conditions of these regions. The data will allow us for a systematic analysis of C_2H and HC_3N, and provide detailed comparison with models (Pilleri et al. 2013, Le Petit *et al.*2006). Finally we aim to bridge the connection in this understanding of characteristic molecules to those detected in external galaxies (Jiang *et al.*2011). Although CARMA and CSO have been shutdown, new facilities like ALMA will be able to support and extend such astrochemical research in more Milky Way and extragalactic sources.

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