Multiplicity of OB Stars in UCHII Regions Using Mid & Far IR Imaging

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summary Ultra-compact (UC) HII regions are ionized by at least one O or early B star, but their multiplicity is not established. We present Cycle-2 Spitzer/MIPS data at 70µm of 30 Galactic UCHII regions in order to clarify their OB star multiplicity. We use dust radiative transfer models to determine the 70µm contribution to the integrated infrared (IR) luminosity. Comparison of the IR luminosity with a radio derived Lyman continuum flux enables one to distinguish between a single OB star or multiple OB stars. The most massive star dominates the Lyman continuum flux whilst other luminous stars (if present) also contribute to the IR luminosity. This work capitalises on the high spatial resolution of MIPS relative to IRAS to produce refined IR luminosities which in general support the idea of UCHII regions containing multiple OB-stars, although exceptions exist. Further evidence for this is demonstrated with high resolution VLT & Gemini mid-IR narrow-band imaging of the UCHII regions which indicates the embedded location of individual OB stars.

1. Data

Our sample comprised the VLA selected UC HII regions identified by Wood & Churchwell (1989, hereafter WC89) and Kurtz et. al (1994, hereafter KCW94) for which Crowther & Conti (2003) provide IRAS and MSX fluxes. Images at infrared and radio wavelengths are presented in figure 1 for a representative case.

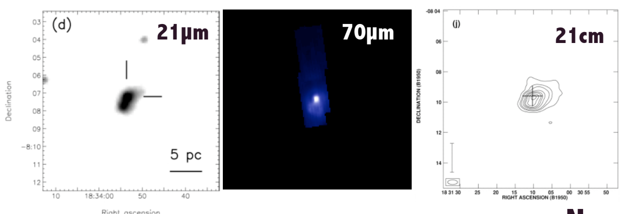

figure 1. 10x10 arcmin images of G23.711+0.171. left: 21µm MSX (Crowther & Conti 2003); centre: 70µm MIPS image; right: 21cm VLA image (Kim & Koo 2001). N is up, E to left throughout.

2. Analysis

SEDs of UCHII regions require the use of 3D dust radiative transfer models, which account for varying extinction along different lines of sight due to clumping (Indebetouw et al., 2006). Figure 2 shows different sightlines for a clumpy 3D model UC HII region, demonstrating the potential variability in flux at mid-IR wavelengths. Using these SEDs, we estimate the contribution of the 70µm flux to the integrated infrared flux as being 1/17. These models are tested by predicting sub-mm fluxes, and comparing them to observed fluxes from Thompson et al. (2006).

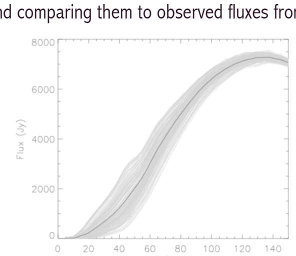

figure 2. 200 SEDs from different sightlines in a clumpy 3D model (Indebetouw et al., 2006). The solid line represents the 'mean' SED.

The predicted 850µm fluxes are in agreement with observations within a factor of 2.2±0.2 (predicted/measured). Lyman continuum fluxes were calculated from original fluxes in Kim & Koo (2001) and Araya et al. (2002) which sample the same spatial scale as the MIPS data. To complete the sample, high resolution radio data from Wood & Churchwell (1989) and Kurtz et al. (2004) was used.

For comparison of Lyman continuum flux and infrared luminosity, we use properties of O stars (Martins et al., 2005; Conti et al., 2008) and cluster population modelling using a Kroupa IMF to provide theoretical infrared luminosities and Lyman continuum fluxes for both single stars and clusters.

3. Results

In calculating the theoretical infrared luminosity and Lyman continuum flux, we take $\xi = 0.9$, as the fraction of ionizing radiation which ionizes the gas. A value of $\xi = 0.1$ results in the data points being unphysical- having too much Lyman continuum flux for their luminosity. Taking just the sources with radio data spatially comparable with MIPS (black triangles), we see that 6/14 sources are consistent with hosting a cluster of massive stars, assuming all far ultraviolet radiation goes into heating the dust. As a secondary diagnostic, we look at cluster masses, which are derived using sub-mm flux, from the SCUBA observations of Thompson et al. (2006), which assumes a star formation efficiency of 30%.

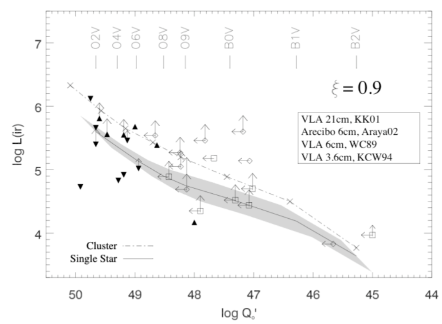

figure 3. Comparison of Lyman continuum log flux and IR luminosity of UC HII regions. Dotted and solid lines represent theoretical values for a cluster or single star, respectively. Key shows origin of radio data.

To confirm the presence of a cluster, we look at the estimated cluster mass, and compare it with the expected Lyman continuum flux from such a cluster (the crosses on cluster line show the values for the 8 theoretical clusters). If the UCHII region has the appropriate Lyman continuum flux for a given mass, then it is assumed to have a normal Kroupa IMF, and is thus a cluster.

Using this two-edged analysis, we finally conclude that 11 out of 14 UCHII regions host a cluster, and one is consistent with hosting an 'isolated' O-star (no other stars more massive than B2V). For the other two objects, no firm conclusions can be drawn. For those UCHII regions deduced as hosting a cluster from the cluster mass only (i.e. object lies below single star in Fig 3), we reconcile the infrared luminosity by requiring that a significant fraction of far-ultraviolet photons escape the nebula without contributing to heating dust.

4. The Future...

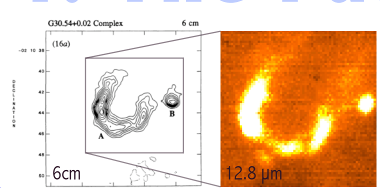

figure 4. left- a 6cm continuum map of G30.535+0.021 from Wood & Churchwell (1989), sampling the free-free emission ; right- a NeII image of the same object, taken with VLT/VISIR, sampling the dust plus the nebula emission at a similar spatial resolution.

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