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CHARACTERIZING THE FORMATION OF THE MOST MASSIVE STAR CLUSTERS IN THE MILKY WAY

Roberto Galván-Madrid[1], Hauyu B. Liu[2], Adam Ginsburg[3], and Jaime E. Pineda[4]

We give an update on our comprehensive gas surveys of some of the most luminous ($L_{\rm bol} > 10^5$ to 10^7 $L_\odot$) deeply embedded – optically obscured – star formation regions in the Milky Way, which are the local cases of massive star clusters and/or associations in the making. Our approach emphasizes multi-scale, multi-resolution imaging in dust and gas in its different phases through a combination of data taken with ALMA, JVLA, SMA, Herschel, and single-dish telescopes including the LMT in Mexico.

We highlight our results on W49A, the most luminous star formation region in the Galactic disk ($L_{\rm bol} \sim 4 \times 10^7$ $L_\odot$, Lin et al. 2016). Our multiscale mapping (Galván-Madrid et al. 2013) reveal that the entire Giant Molecular Cloud (GMC) is very massive ($M_{gas} \sim 1.1 \times 10^6$ $M_\odot$) and concentrated. The inner $r < 6$ pc of the GMC (which extends to $r \sim 60$ pc), often referred to as the 'ministarburst' W49N, contains a mass $M_{gas} \sim 2 \times 10^5$ $M_\odot$. The GMC is distributed in a network of filaments with similar structure from ~ 100 to 1 pc, and appears to converge toward a 'hub' at the known cluster with dozens of young massive stars in W49N (De Pree et al. 1997). Feedback from the forming cluster – which already has a stellar mass $M_\star > 7 \times 10^4$ $M_\odot$ – is still not enough to disrupt the GMC: only 1 % of the gas mass in W49N is ionized and the luminosity Eddington ratio is < 0.1. The final stellar content will probably remain as a bound star cluster for Gyr timescales, since it satisfies several theoretical conditions: the current star formation efficiency is SFE> 10 %, the gas-dispersal timescale is > 1 Myr, most of the forming stellar content is in a compact volume ($r < 6$ pc), and the gas mass surface density within the entire W49N 'ministarburst' is $\Sigma > 1000$ $M_\odot$ pc^{-2} (Galván-Madrid et al. 2013).

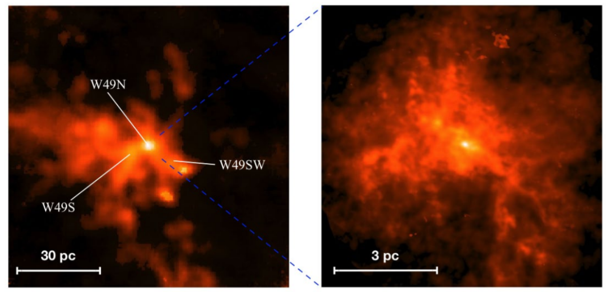

Fig. 1. Mass surface density maps obtained isotopologue line ratios. The left panel shows the zoomed-out measurement from the PMO-14m telescope CO and ^{13}CO 1–0 maps. The right panel shows the zoomed-in measurement from the SMA mosaics combined with IRAM-30m telescope maps of ^{13}CO and C^{18}O 2–1. The embedded OB cluster-forming regions W49N, W49S, and W49SW are marked (Galván-Madrid et al. 2013).

Further mapping of other highly-luminous cluster formation regions in the Milky Way also reveal filamentary structures, even in the form of spiral arms, converging toward a central hub where the most massive stars are forming (G33.92+0.11; Liu et al. 2015). These filaments tend to fragment into cores that are dynamically unstable, but are either in an earlier stage or forming less massive stars than those in the central hub. The cluster forming GMCs show significant chemical stratification within different subregions (Immer et al. 2014, Liu et al. 2015).

The entire gas reservoirs do not necessarily end up in stars. In W49A and W51A, the copious feedback from the young/forming massive stars is not enough to halt star formation locally, but may shut-off the replenishment of gas from larger scales (Ginsburg et al. 2016). At parsec scales, there is still a large fraction of the dense gas that appears to be the main ingredient for massive star (cluster) formation (Ginsburg et al. 2015).

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[1]Instituto de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Campus Morelia, Apartado Postal 3–72, 58090 Morelia, Michoacán, Mexico (r.galvan@irya.unam.mx).
[2]European Southern Observatory (ESO).
[3]National Radio Astronomy Observatory (NRAO), USA.
[4]Max Planck Institute für extraterrestrische Physik (MPE), Germany.