
The first Galaxy scale hunt for the youngest high-mass protostars

http://researchonline.ljmu.ac.uk/2509/

Citation (please note it is advisable to refer to the publisher’s version if you intend to cite from this work)


LJMU has developed LJMU Research Online for users to access the research output of the University more effectively. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LJMU Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The version presented here may differ from the published version or from the version of the record. Please see the repository URL above for details on accessing the published version and note that access may require a subscription.

For more information please contact researchonline@ljmu.ac.uk

http://researchonline.ljmu.ac.uk/
THE FIRST GALAXY SCALE HUNT FOR THE YOUNGEST HIGH-MASS PROTOSTARS


Abstract. The origin of massive stars is a fundamental open issue in modern astrophysics. Pre-ALMA interferometric studies reveal precursors to early B to late O type stars with collapsing envelopes of 15–20 M⊙ on 1000–3000 AU size-scales. To search for more massive envelopes we selected the most massive nearby young clumps from the ATLASGAL survey to study their protostellar content with ALMA. Our first results using the intermediate scales revealed by the ALMA ACA array providing 3–5" angular resolution, corresponding to ∼ 0.05–0.1 pc size-scales, reveals a sample of compact objects. These massive, dense cores are on average two-times more massive than previous studies of similar types of objects. We expect that once the full survey is completed, it will provide a comprehensive view on the origin of the most massive stars.
1 Introduction

The origin of stellar masses, in particular of massive stars, is one of the most fundamental open issues of modern astrophysics. In spite of recent progress in our understanding of high-mass star-formation, a coherent picture is still lacking of the earliest evolutionary stages, i.e., the onset of collapse and the initial fragmentation of massive, dense cores (MDCs) (e.g. Tan et al. 2014). Potential precursors of early B to possibly late O stars with $M_{\text{env}} \sim 10 - 20 M_\odot$ have been frequently revealed (e.g. Bontemps et al. 2010, Zhang et al. 2009, Rathborne et al. 2011, Wang et al. 2011, Longmore et al. 2011, Palau et al. 2013, Beuther et al. 2013). Their typical sizes of 1000–3000 AU and low bolometric luminosities make them excellent analogs for the low-mass Class 0 stage (Duarte-Cabral et al. 2013).

The larger effective Jeans masses of these protostars can be explained by a combination of turbulence and magnetic fields at small scale (McKee & Tan 2003), or by collapse from larger scales at which Jeans masses are larger due to lower average densities (e.g. Hennebelle & Chabrier 2009). Recent numerical models reproduce up to $10 M_\odot$ fragments from a $100 M_\odot$ collapsing core (Commerçon et al. 2011), further suggesting that the combined effect of magnetic fields and radiative feedback determines the early fragmentation of massive cores (see also Krumholz et al. 2009). To test formation scenarios the precursors of the more massive objects need to be revealed, which becomes now feasible by performing statistical studies using the capabilities of the Atacama Large Millimeter/submillimeter Array (ALMA).

2 A sample of the brightest ATLASGAL sources

The ATLASGAL survey (Schuller et al. 2009, Csengeri et al. 2014) is the most sensitive and extensive ground-based unbiased survey of the inner Galaxy at submillimeter wavelengths, and provides an unprecedented view on all stages of massive star formation. Over 10000 compact sources have been identified (Csengeri et al. 2014), and we have made substantial progress in characterising various evolutionary stages of massive clumps by using ancillary radio and mid-infrared data (e.g. Urquhart et al. 2014), and assigned distances to a large number of sources (Wienen et al. 2015). Given its higher angular resolution (19\arcsec) compared to Herschel at submillimeter wavelengths, the ATLASGAL survey is better suited to disentangle the more evolved from the pristine cold sources.

Selected from ATLASGAL, we identified a complete sample of 45 objects which are massive ($>650 M_\odot$) and dense, with surface density exceeding the theoretical $1 \text{ g cm}^{-2}$ threshold (Krumholz et al. 2009) for forming high-mass stars. In addition they lack bright mid-infrared embedded objects, suggesting that they are in their earliest evolutionary phase. Our selection of these mid-infrared quiet massive clumps is complete within 4.5 kpc, and to date represents the best potential sites to host the next generation of the most massive stars currently forming in our Galaxy.
We used ALMA to perform the first systematic survey at high angular-resolution to look for high-mass protostars in this sample of massive clumps. As a first step we present here the results of the Atacama Compact Array (ACA) observations, which provides a 3–5" angular resolution corresponding to \( \sim 0.05–0.1 \) pc physical scales (Fig. 1). This size-scale shows the fragmentation from clump to core scales, and reveals a sample of MDCs.

The first result of this survey is to confirm the presence of compact embedded sources towards our selection of mid-infrared quiet ATLASGAL clumps. Only one source out of the entire survey is found to be resolved out lacking embedded compact objects, while the rest all shows at least one centrally concentrated fragment.

Interestingly, the sample shows limited fragmentation, with only 2–3 MDCs revealed per clump, which is similar to earlier findings by Motte et al. (2007) and Bontemps et al. (2010) in the systematic study of the Cygnus-X region. A first mass estimate shows, however that they are on average twice as massive as the MDCs in Cygnus-X. Among them we also find several candidates to be the most massive MDCs known to date (Csengeri et al. in prep).
4 Conclusions and Outlook

A first analysis of fragmentation on intermediate scales reveals a large number of MDCs within the sample of mid-infrared quiet ATLASGAL sources targeted with ALMA. They are extreme in terms of their mass and surface density, potentially hosting the precursors of the most massive stars in our Galaxy. Complementary molecular line data will be used to further investigate the nature of their embedded sources. The full capacities of ALMA requested for this survey will provide 0.6" angular resolution, corresponding to individual protostars. This dataset will ultimately provide a comprehensive view of the earliest phase of the formation of high-mass protostars.

References

Tan, J. C.; Beltrán, M. T.; Caselli, P. et al. 2014, PPVI, University of Arizona Press, Tucson, 49-172