**A Comprehensive ATCA Census of High-Mass Clumps:
Converting Turbulent Structure into Stars on Sub-parsec Scales**

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Scientific aims: The conversion of turbulent structures within molecular clouds into high-mass stars and star clusters, the relation between Galactic and extragalactic star formation, and the effects of Galactic environment on star formation are fundamentally important, yet unsolved problems in astrophysics. The two major theories for high-mass star formation, "competitive accretion" and "turbulent core accretion," make distinct predictions about the initial conditions within star-forming clumps and how the gas on ~1 pc "clump" scales affects the accretion history of individual stars on ~0.05 pc "core" scales at which individual stars and binary stars form.

A number of recently completed dust continuum (HiGAL, ATLASGAL, BGPS) and molecular line (MALT90, HOPS) surveys toward thousands of dense molecular clumps have characterised their physical and chemical conditions on pc scales. *After decades of effort, we have finally located the sites of all current and future Galactic high-mass star formation.* Now that pc "clump" scale conditions have been measured, in order to directly test the theories, we require observations of the smaller size scales down to 0.05 pc "core" scales. These observations will be used to characterise the turbulent structure within the clumps and to directly measure the locations, temperatures, masses, temporal sequence, and kinematics of their individual ~0.05 pc size star-forming cores.

To achieve this, we propose a comprehensive Compact Array survey of clump sub-structure on ~2'' (0.05 pc) to 40'' (1 pc) scales from a large, well-characterised sample of clumps. By targeting these clumps, we will obtain *a complete census of all 4^{th} quadrant high-mass star-forming cores in a broad range of evolutionary states and Galactic environments*. We will image the NH_3 (1,1) to (6,6) inversion line emission, H_2O and CH_3OH maser emission, and the H67α recombination line toward all 4^{th} quadrant clumps with masses > 1,000 $M_{\odot}$ (which will form the highest mass stars). The NH_3 lines probe the dense gas associated with star-forming regions and provide robust estimates of the structure, gas temperature, and the kinematic state (especially the velocity dispersion and the virial parameter). We will measure: (1) robust gas temperatures throughout the clumps, (2) the specific angular momentum of cores, (3) the mass accretion rate per free-fall time, (4) the fragmentation properties as a function of clump environment, (5) the maximum mass of cores, especially in the early cold phases, and (6) the ionizing flux. The multi-billion dollar ALMA and SKA facilities will perform exquisite measurements of star-forming clumps at high angular resolution. Yet, because intermediate spatial scales remain poorly explored, this survey is critical to identify the key targets for these future high-resolution studies. *ATCA is the only telescope capable of surveying clumps' sub-pc structure and gas temperatures throughout the 4^{th} quadrant. It will identify the key targets for studies of individual objects with ALMA and SKA.*

Legacy Value: This project will provide a complete census of high-mass cores and will identify the rare, elusive objects to target for future detailed ALMA and SKA studies. Indeed the survey will discover at least 1,000 star-forming cores spanning a large range of evolutionary states and Galactic environments.

Since ALMA and SKA will reach ~10 pc size-scales in galaxies in the next decade, Galactic surveys like this are the only means to provide the key spatial information on smaller scales to guide our understanding of extragalactic star-formation. An especially important outcome will be robust measurements of gas temperatures on these unexplored scales. Temperatures are critical for reliably interpreting any future ALMA data (e.g., Jeans masses, internal and external heating, temperature gradients, etc.) The ATCA survey data will be archived and provide value-added legacy data products to the community.

Number of objects: We propose to observe all known 4th quadrant clumps with M > 1,000 $M_\odot$, a total of about 300 clumps. This mass limit was chosen to target the highest mass clumps, which give rise to the highest mass stars. These clumps span the complete range of evolutionary states: from cold quiescent clumps, to those containing embedded high-mass young stellar objects, and on to those containing H II regions (indicating OB stars on the main sequence). They have roughly equal numbers (~100) in each of the broad evolutionary stages (quiescent, protostellar, and H II region). This enables us to build a robust temporal sequence for the evolution of gas within these clumps. In addition, these clumps reside in a range of Galactic environments: disk spiral arms, the Galactic Bar, and the Outer Galaxy, allowing us to directly compare the key parameters for star forming clumps across a range of environments. Because these data will be similar to the CMZ SWAG survey, we can also directly compare the Milky Way clump star-formation properties to those in the CMZ and other galactic nuclei. This survey will provide statistically robust samples of clumps in all of the important temporal and environmental categories.

LST ranges: The clumps are in the Milky Way's 4th quadrant, from LST of ~12^h30^m to ~17^h30^m.

Frequencies: The frequencies of the NH3 (1,1) to (6,6) inversion lines are ~23.7 GHz. In addition we will survey H_2O (22.2 GHz) and CH_3OH (24.0 GHz) masers, CCS the H67α recombination line.

CABB modes: CFB 64M-32k is necessary to obtain sufficiently high velocity resolution (0.4 km/s) for all of our target lines.

Array configuration: H214 + H168 + H75 + 750. Since turbulent structures produce complex structures with a broad range of angular scales, we require good *u,v* coverage and four array configurations. This combination allows us to probe all physical scales from the clump scale (1 pc) to the core scale (0.05 pc).

Observing strategy: We will image 4 clumps per 8 hour track (a total of 2 hours per source; including overheads) in 4 configurations. Since the clumps are close on the sky we can use the same phase, flux, and bandpass calibration for each of the four clumps in each track.

Required Sensitivity: The dense substructures are expected to be moderately optically thick (τ >~1) and to have minimum excitation temperatures of ~10 K. Thus we require a brightness sensitivity of ~1 K, sufficient to detect ~5 $M_\odot$ cores for typical distances.

Approximate number of hours in total, and per semester: The total observing time is estimated to be ~8 hours per clump x 300 clumps, for a total of 2,400 hours, or 800 hours in each of 3 winter semesters.

Indicative resources/Representative team members & skills available: Current team members include those from the MALT90, HOPS, and MMB surveys. As such, a large portion of the team has expertise in conducting large-scale surveys. Many team members are also seasoned ATCA observers. The team has broad experience in observations, theory, and simulations of high-mass star-forming regions.