

Do Galactic Center Stars Form Under Unusual Conditions?

Our current picture of the molecular gas in the central 500 parsecs of our Galaxy (hereafter, ‘GC’) has largely been determined using low-resolution surveys. The derived physical conditions, averaged over the 3-5 pc scales of GC molecular clouds, are starkly different than typical conditions in Galactic disk clouds. Gas in the GC is hotter ($T = 50\text{--}300\text{ K}$, Güsten et al. 1985; Mauersberger et al. 1986; Hüttemeister et al. 1993) and more turbulent ($\Delta v \sim 30\text{ km s}^{-1}$, Bally et al. 1987) than molecular gas in the disk. GC molecular clouds also achieve higher average densities ($10^4 - 10^5\text{ cm}^{-3}$) than those in the disk, while remaining largely quiescent (Longmore et al. 2012).

Based on these average gas properties, it has been predicted that the resulting stellar initial mass function (IMF) may differ from the typical form (Morris 1993). However, thus far a deviant IMF has only been measured in the central parsec (Maness et al. 2007; Bartko et al. 2010)—present-day mass functions in other GC clusters also show higher fractions of massive stars, but this may be an effect of their dynamical evolution (Kim et al. 2006; Hußmann et al. 2012). The absence of an unusual IMF throughout the GC suggests that these cloud-averaged gas properties do not represent the conditions on the scales of star-forming clumps. If the GC IMF is in fact typical, this would suggest the physical conditions on the smallest scales in most GC clouds are actually comparable to those found in the disk.

As an ESO fellow, I will take advantage of the newly-available capabilities of ESO facilities such as the Atacama Large Millimeter Array (ALMA) and other cutting-edge, open-access instruments such as the Karl G. Jansky Very Large Array (VLA) to make the first survey of physical conditions in Galactic center clouds on sub-parsec scales. These observations will provide the strongest constraints to date on the extent to which the Galactic center IMF may be expected to deviate from the standard form.

Measuring Physical Conditions on Sub-parsec Scales

The evolution of dense clumps in GC clouds is determined by their physical conditions: this determines the characteristic Jean’s mass for collapse, whether the cores are virialized, and whether the pressure supporting these cores is thermal or turbulent. Identifying whether the higher temperatures, turbulence, and densities persist on the smallest spatial scales can then provide insight into the nature of the future star formation in this gas.

High temperatures and turbulence: Models of supersonic flows in giant molecular clouds predict that stars will only form in clumps where thermal pressure dominates over turbulence (Gong & Ostriker 2009, 2011). By measuring temperatures in a sample of clumps I will compare the expected thermal line widths to the observed line widths in order to determine the relative contributions of thermal and turbulent pressure, and search for variation of this ratio which may indicate evolution.

High densities: Using spatially-resolved measurements of the density structure within GC clouds, I will also make the first clump mass function (CMF) for the GC. Recent observations suggest that the CMF maps directly to the stellar IMF (Lada et al. 2008; Enoch et al. 2008). By comparing the GC CMF to those derived in disk environments, I will perform a unique test of existing hypotheses that the GC environment causes the initial stellar mass function to differ from that in the disk. By measuring the detailed velocity structure, I will further test whether the observed dense clumps are virialized (and likely pre-stellar), in a stable pressure equilibrium, or transient.

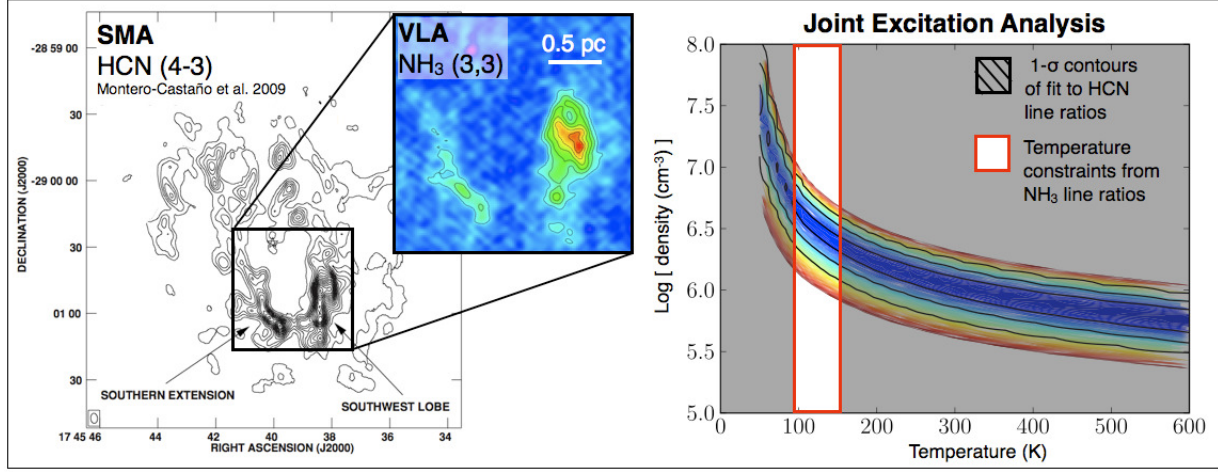


Fig. 1.— *High-resolution observations of density and temperature tracers can be used together to make extremely accurate measurements of the physical conditions. Here, an analysis using HCN constrains the gas density to within two orders of magnitude. However, by adding temperature constraints derived from NH_3 (PI: Mills, 2012), the density is constrained to within a factor of 2.*

A Comprehensive High-Resolution Survey of GC Gas

Measuring temperatures with the VLA: I already have data from an existing high-resolution (0.1 pc) VLA study of NH_3 and HC_3N in five of the most massive GC clouds (PI: Mills, 2012). The multiple observed transitions of NH_3 will yield measurements of the temperature structure in the interiors of Galactic center clouds.

Measuring densities with ALMA and APEX: For the same region covered in the VLA survey, I will conduct high-resolution ($\gtrsim 1000$ AU) ALMA follow-up of multiple higher transitions of HC_3N as well as other density tracers such as CS and HCN. The combination of density limits from these molecules and temperatures derived from the VLA survey will yield tight constraints on the physical conditions in these cores (Figure 1). I have already proposed an ALMA Cycle 1 pilot study to do this analysis for the GC Circumnuclear disk. The measured physical conditions will also be compared to those derived from lower-resolution APEX observations of the same sources. The degree to which the derived conditions differ will provide a useful constraint on how well the physical conditions determined from low-resolution (e.g., extragalactic) observations represent the actual conditions in the unresolved, pre-stellar clumps.

Data from these cutting-edge ESO facilities combined with the VLA will build an unprecedented high-resolution picture of the physical conditions in the Galactic center that will identify the influence of the unique gas properties of the GC on star formation in this region.

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