# NGVLA Observations of Dense Gas Filaments in Star-Forming Regions

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**Background**: *Herschel* and JCMT continuum observations of nearby star-forming regions have revealed that filaments are ubiquitous structures within molecular clouds (André et al. 2014). Such filaments appear to be intimately connected to star formation, with those having column densities of $A_V > 8$ in particular hosting the majority of prestellar cores and protostars in clouds (Könyves et al. 2015). This "threshold" can be explained simply as the result of supercritical cylinder fragmentation (cf. Inutsuka & Miyama 1992). Though gravity and turbulence are likely involved, specifically how star-forming filaments form and evolve in molecular clouds remains unclear. Kinematic probes are needed to understand how mass flows both onto and through filaments, leading to star formation.

**Current Observations**: We show here preliminary results from the recent GAS (PIs: R. Friesen & J. Pineda) and KEYSTONE (PI: J. Di Francesco) surveys that have used the Green Bank Telescope's K-band Focal Plane Array to map $NH_3$ emission from dense gas in nearby star-forming regions. As a tracer of gas of density $> 10^3$ cm$^{-3}$, $NH_3$ emission can reveal filament kinematics, dynamics, and kinetic temperatures from line velocities, widths, and ratios, respectively.

## GAS: Filaments of NGC 1333 in Perseus:

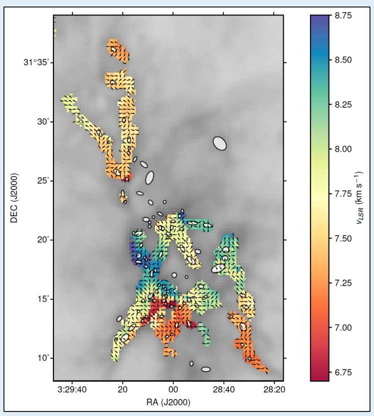


*Figure 1*: line velocities ($V_{LSR}$; color scale) of NGC 1333 dense gas filaments obtained from a single-component fit to observed $NH_3$ (1,1) emission. The grey scale background indicates Herschel 250 μm continuum emission. Arrows denote directions of local $V_{LSR}$ gradients normalized here to unity for clarity. Ellipses correspond to dust continuum sources identified in JCMT SCUBA-2 850 μm continuum maps (Chen et al. 2018, in preparation).

GAS has obtained dense gas maps in Orion, Perseus, Ophiuchus, Serpens, Cepheus, IC 5146, the Pipe, and Taurus at $A_V > 5$ that show filaments and cores (Friesen et al. 2017).

## KEYSTONE: DR 21 Ridge in Cygnus X North:

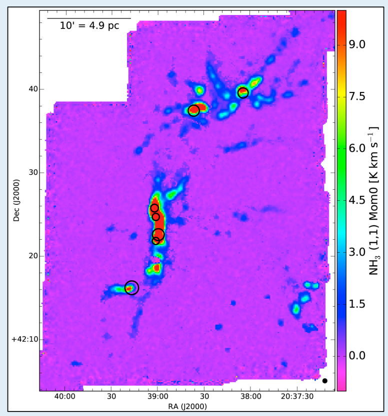


*Figure 2*: integrated intensities of $NH_3$ (1,1) emission (Moment 0; color scale) of the DR 21 Ridge and its associated filaments. Mapping of this region is still in progress. Circles indicate the locations of $H_2O$ $6_{16}$-$5_{23}$ maser line emission observed simultaneously with the $NH_3$ emission. Circle size indicates relative brightness of the maser emission (Keown et al. 2018, in preparation).

KEYSTONE is obtaining dense gas maps in Cygnus X, W3, W48, Mon R1, Mon R2, NGC 2264, NGC 7538, Rosette, M16, and M17 at $A_V > 10$, also revealing filaments and cores.

## Wide-field Ammonia Emission Mapping with the Next Generation Very Large Array

The GAS and KEYSTONE data from GBT have native spatial resolutions of 33" FWHM, e.g., 0.04 pc in NGC 1333 and 0.27 pc in DR 21. For context, the characteristic width of filaments and the size of cores is 0.1 pc. Higher resolution data are critical to probe motions onto and through filaments to cores. We are currently exploring limited Jansky VLA follow-up observations in 18A.

Relative to the Jansky VLA, the potentially smaller antenna sizes and greater collective surface area of an Next Generation Very Large Array (NGVLA) will uniquely allow high sensitivity and high resolution observations of $NH_3$ emission over wide mosaics.

The final number and size of NGVLA antennas are not fixed but we assume here 150 × 18-m antennas are placed within a 1 km maximum baseline, as in the Jansky VLA D-configuration. Such an array would provide a factor of ~10 improvement or more in mapping speed over current facilities.

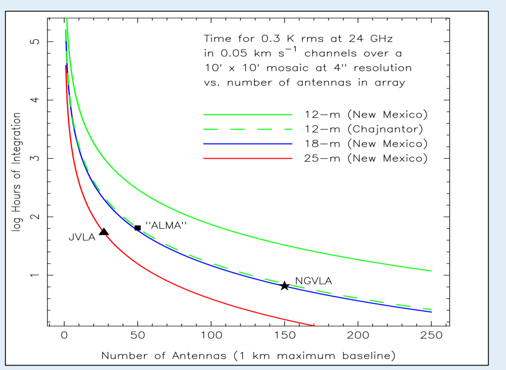


*Figure 3*: Time required to observe a 10' × 10' mosaic at 4" FWHM resolution at 24 GHz to 1 σ = 0.3 K rms in 0.05 km s$^{-1}$ channels vs. number of antennas of a given diameter. Time estimates are determined using NRAO's online VLA Exposure Calculator and are scaled by the standard $N^2 D^4$ mapping speed metric where $N$ = antenna number and $D$ = antenna diameter. Values for 12-m, 18-m, and 25-m antennas are shown in green, blue, and red, respectively. Note that ALMA does NOT observe at 24 GHz but its performance here is estimated based on its opacities and aperture efficiencies relative to those of the Jansky VLA.

*References*: André et al. 2014, PPVI, p.27; Friesen et al. 2017, ApJ, 843, 63; Inutsuka & Miyama 1992, ApJ, 388, 392; Könyves et al. 2015, A&A, 584, 91

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