VLA study of temperature and velocity structure in IRDCs

Sarah Ragan (MPIA), Edwin Bergin (Michigan), Fabian Heitsch (UNC-CH), David Wilner (SAO)
email: ragan@mpia.de

Infrared-dark clouds (IRDCs) represent an important phase in the early stages of massive star and cluster formation, thus understanding their internal physical conditions is crucial to constraining the initial conditions of this process. I present the results of a high-resolution NH_3 (1,1) and (2,2) study of six IRDCs from the Ragan et al. (2009) sample using the Very Large Array (VLA). I show strong evidence for complex kinematical structure within IRDCs using ammonia observations, which also serves as a gas thermometer.

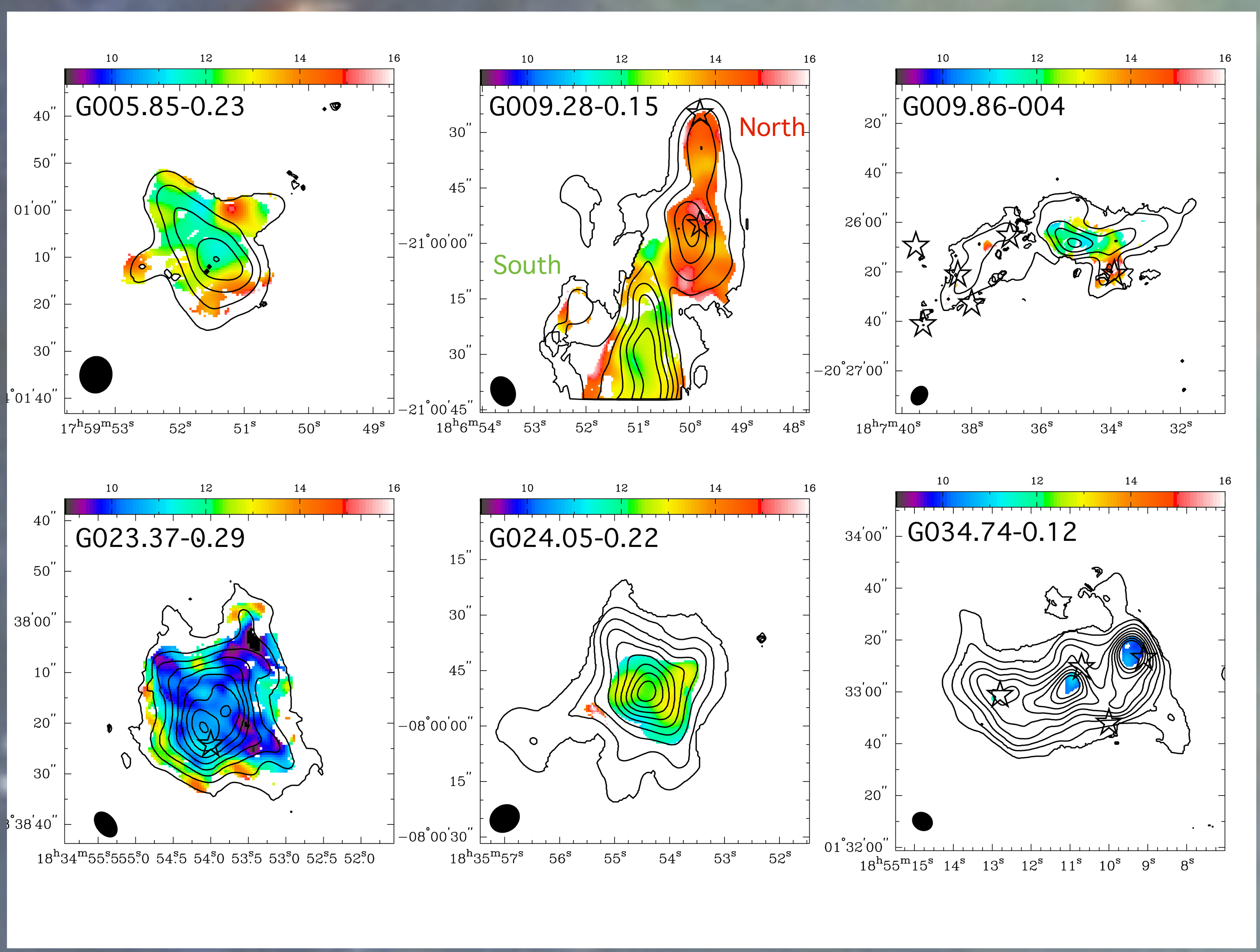

Figure 1: Kinetic temperature maps (color) with contours of NH_3 (1,1) integrated intensity overplotted. Star symbols indicate the location of 24um point sources detected with Spitzer.

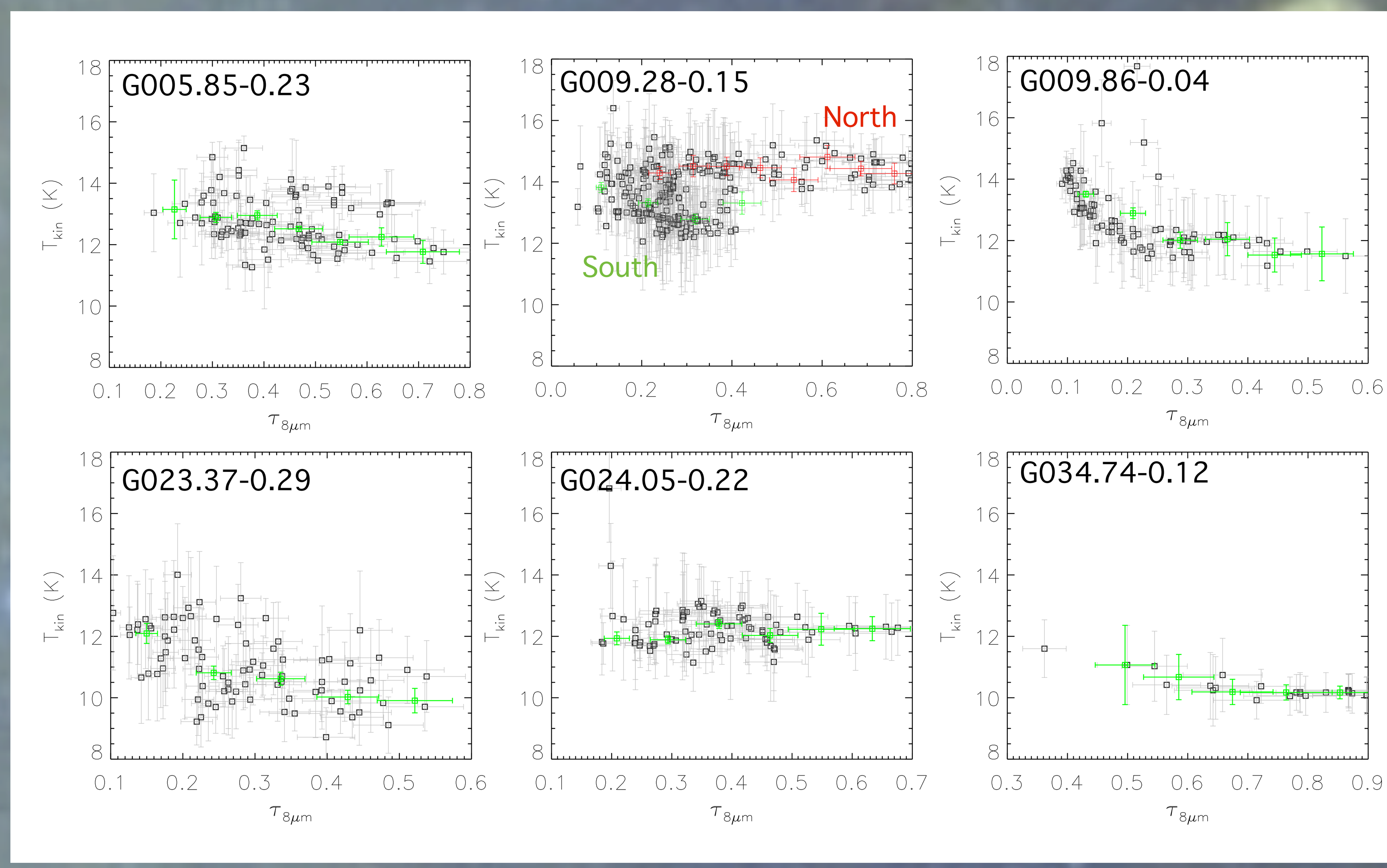

Figure 2: Kinetic temperature plotted as a function of 8um optical depth. The green squares show the weighted average per $\Delta\tau \sim 0.1$ bin. In the case of G009.28-0.15, the red is the weigthed average of the northern part of the cloud, and the green corresponds to the south.

Kinetic temperature in IRDCs

IRDCs show very little variation in temperature, even on the 4 – 8'' level (10x higher resolution than Pillai et al. 2006a study). The gas kinetic temperature (Tk) maps are shown in Figures 1 and 2. In the four cases in which we have 24um point sources directly associated with the IRDC gas, the temperature increases only by 1-2 K in the vicinity. If indeed these point sources are embedded protostars within the IRDC, the heated envelope is small (D < 20000 AU), and the bulk gas is largely unaffected.

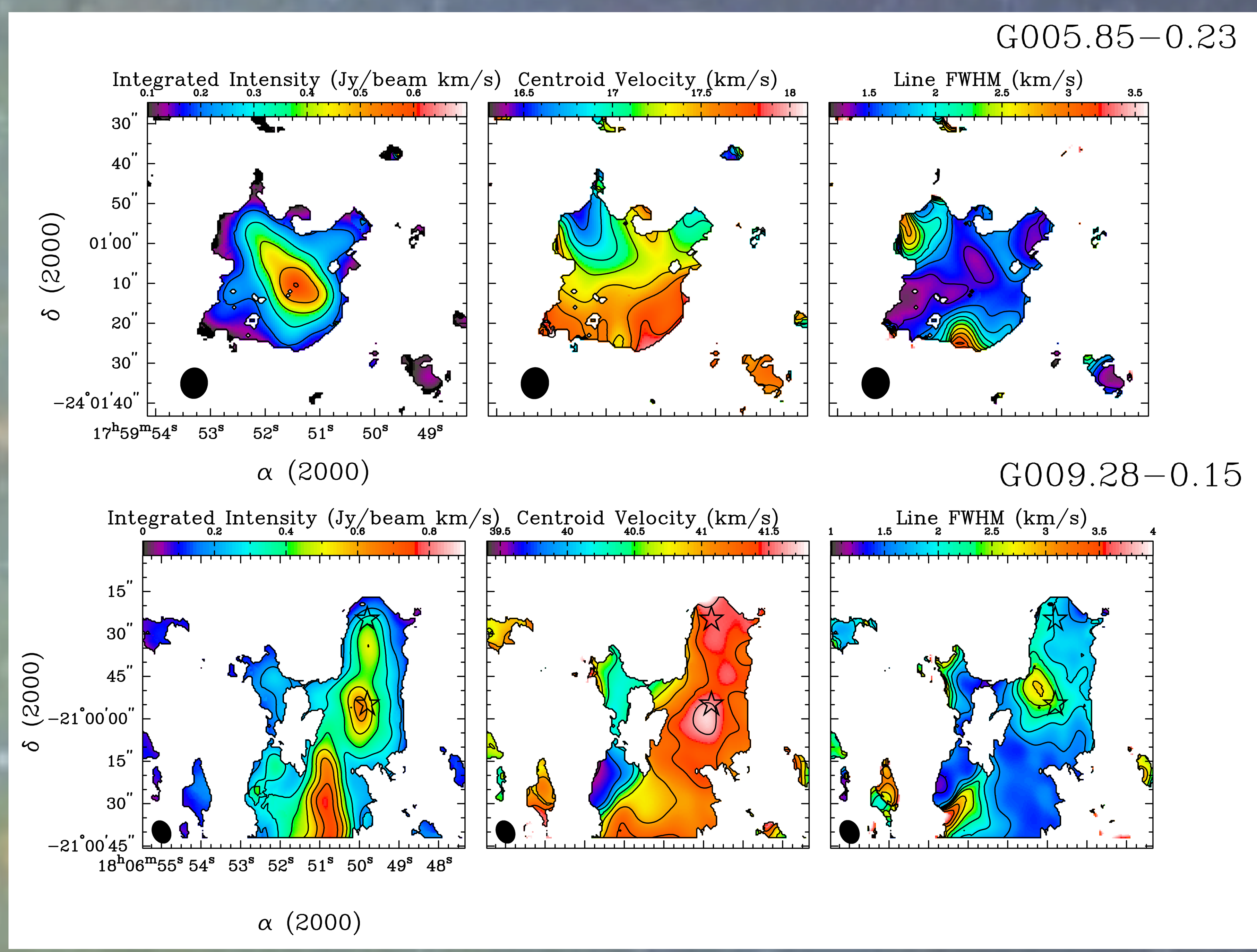

Figure 3: Spectral moments of NH_3(1,1) for IRDCs G005.85-0.23 (top) and G009.28-0.15 (bottom). Left panel shows the integrated intensity; central panel shows the centroid velocity of the main line; right panel shows the main line FWHM. Star symbols indicate the location of 24um point sources.

Velocity structure in IRDCs

These maps are a powerful tool to examine the dynamical environment within IRDCs. We find complex internal velocity structure (see Figure 3). The presence of 24um point sources is accompanied by an enhancement in linewidth (as also seen in Wang et al. 2008) and shift in centroid velocity. While we cannot rule out the interpretation that this signature is an imprint of cloud formation, it is suggestive that we are seeing the effect of outflows from young embedded protostars.

In the sources lacking 24um point sources (G005.85-0.23 and G024.05-0.22), the FWHM maps appear the most quiescent, despite a still dominant non-thermal component of the linewidth ($\Delta v_{th} \sim 0.2$ km s^{-1}, $\Delta v_{nt} \sim 1.5 - 2$ km s^{-1}). Smooth gradients in centroid velocities are suggestive of systematic motion (e.g. rotation, sheer). Steeper velocity gradients toward cloud edges are possibly signatures of interaction with the surrounding envelope.

Summary and Prospectus.

IRDCs exhibit complex velocity structure, reflecting a combination of effects from embedded protostellar objects and cloud formation. Despite the significant dynamical effect of young stars, the gas temperature does not vary appreciably, though observations of more highly excited molecular transitions could uncover a more compact region of warm gas (e.g. Pillai et al. 2006b). Many factors can contribute to the dominant non-thermal component to the linewidth, including turbulence, ordered motions, clumpy substrucutre, etc. ALMA promises to be crucial to understanding the formation and dynamical state of IRDCs in detail.

References

Pillai et al. 2006a, A&A, 447, 929
Pillai et al. 2006b, A&A, 450, 569
Ragan et al. 2009, ApJ, 698, 324;
Wang et al. 2008, ApJ, 672, L33