Are **massive dense clumps** truly **sub-virial**? A new analysis using Gould Belt ammonia data

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INTRODUCTION

The stability of star-forming regions is calculated by comparing gravitational and kinetic energies as a virial ratio:

$$\alpha \equiv \frac{2\mathcal{T}_{\rm cl}}{|\mathcal{W}_{\rm cl}|}$$

The clouds are considered stable at α = 2. The regions with α > 2 are unbound. Cores with α < 2 are super-critical .

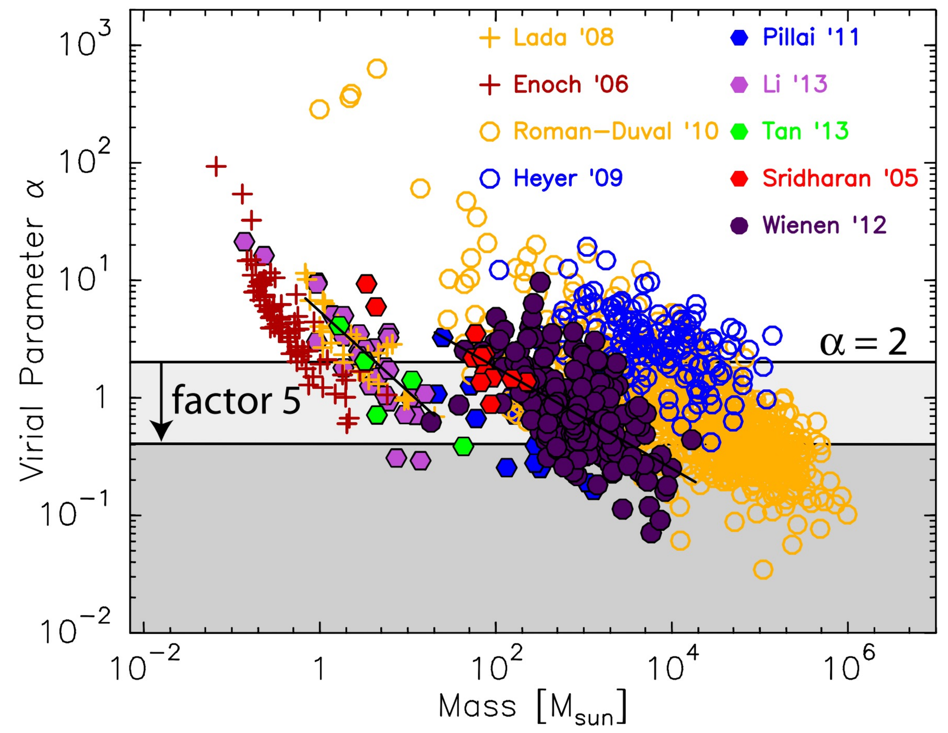

Fig. 1: Kauffmann et. al. (2013) present the results from various studies that show the virial parameter of 1325 fragments.

In practice, this is s estimated by virial parameter introduced by Bertoldi & McKee (1992), **BM92**, using only cloud's mass M_{cl} , effective radius R_{cl} , and line-of-sight velocity dispersion $\sigma_{cl,z}$.

$$\alpha_{\rm BM92} \equiv \frac{5\sigma_{\rm cl,z}\, R_{\rm cl}}{G\, M_{\rm cl}}$$

Kauffmann et. al. (2013) shows low virial parameter for high mass clumps (See Fig. 1). This can indicate the rapid collapse of cores or the presence of strong magnetic fields.

DATA

We have identified 89 individual cores from 12 different molecular cloud complexes for the purposed of this study. The slide show presents a few of these regions with contoured cores.

- For the gravitational component, we are using **H_2 column density maps** generated by fitting a spectral energy distribution (SED) to continuum data from **Hershel Space Observatory** at 160, 250, 350 and 500 µm.

- Kinetic energy is calculated using the line tracer date of **Ammonia from the Green Bank Ammonia Survey** (GAS) (Friesen et al. 2017).

OUR APPROACH

In Singh et. al. (2019), **SMJ19**, we present a new technique that allows us to estimate the viral ratio by directly estimating the gravitational and kinetic energy. There are three main components to our method.

- Calculating the **gravitation energy from the column density map**. It is 2/π times the gravitational energy of a cloud if it were to collapse into a thin sheet. This corrects for the fact that we are using 2D column density maps to estimate 3D gravitational energy.
- Including **bulk kinetic energy** (See Fig. 2).
- Using **Able transformation** (Abel 1926) to extract clump from the cloud. This takes into consideration the effects of limb-brightening on the edges. It provides a better estimate of the mass (See Fig. 3).

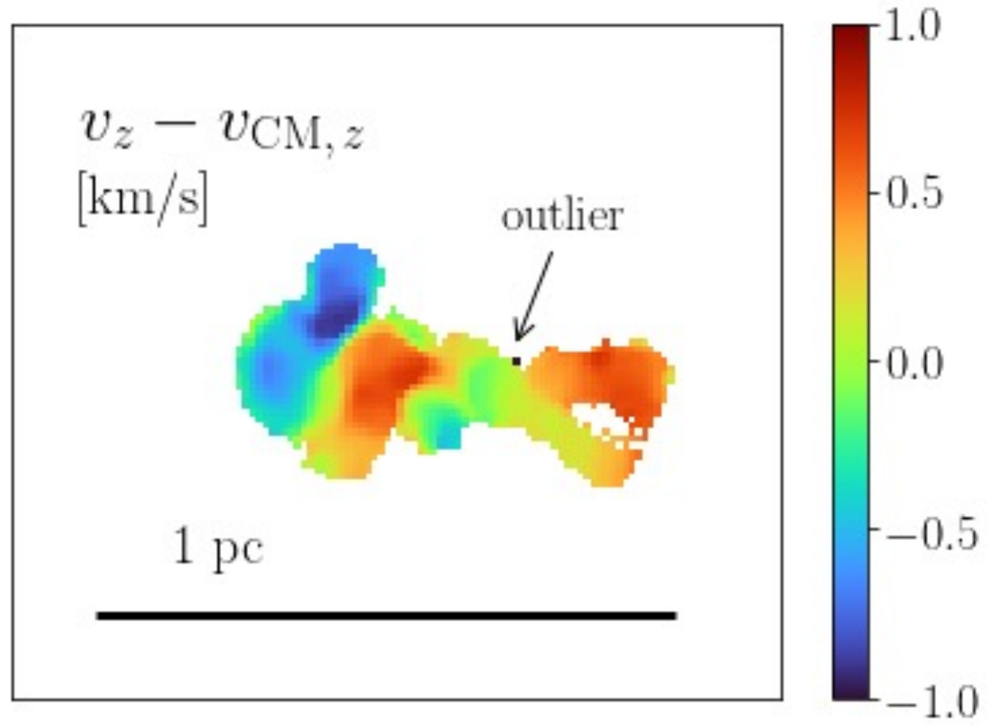

Fig. 2: Map of a clumps that shows line of sight velocity v_z, relative to the center-of-mass velocity $v_{CM,z}$ within the original clump boundary. This contributed to bulk motion.

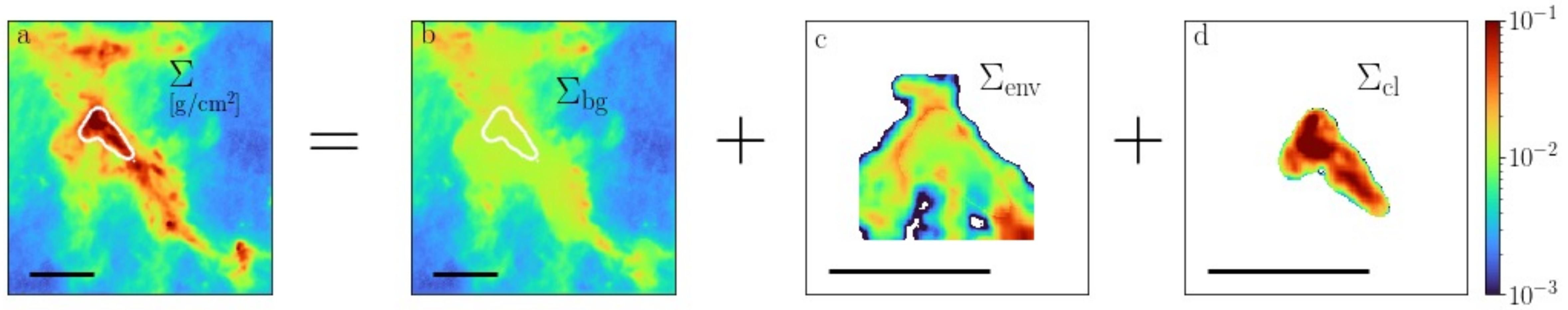

Fig. 3: Clump in Perseus B1 extracted using Abel reconstruction. Left to right panel: a) Total H_2 column density, b) contribution from the background and foreground, c) clump envelope and d) the clump.

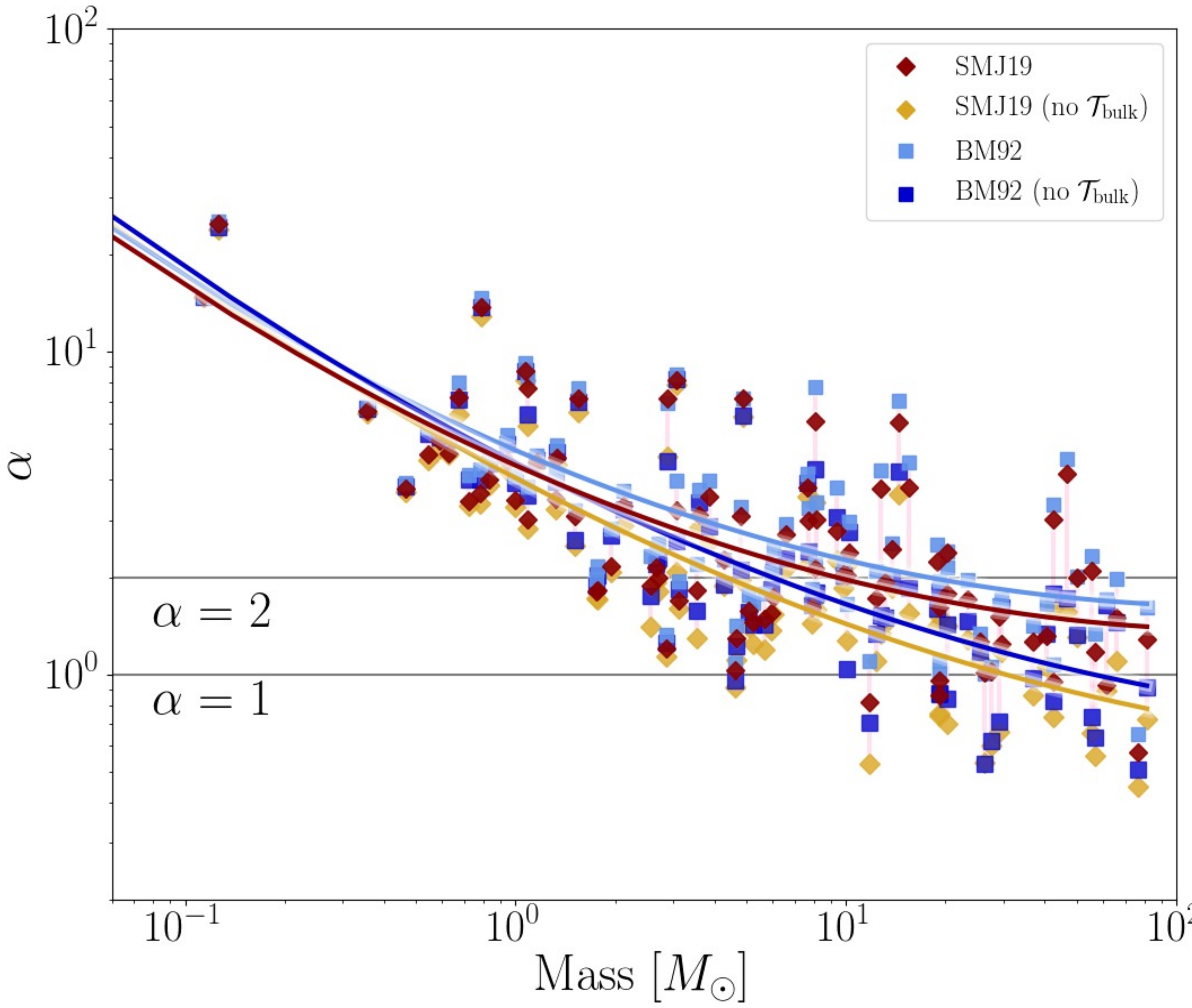

Fig. 4: Virial stability using our method (SMJ19) and BM92 of 89 clumps.

RESULT

For the high mass cores as shown in Fig. 4, the viral ratio with the bulk kinetic energies is significantly larger than without, whereas it is comparable at low mass cores. This indicated that at high masses, the kinetic energy is dominated by the bulk motion. **As a result, the clumps have virial motion rather than sub-virial.**

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