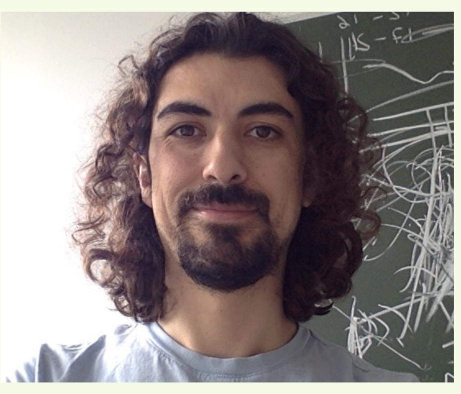
Max-Planck-Institut für extraterrestrische Physik

On the fragmentation of filaments and the origin of wide separation multiples

Pineda et al. 2015, Nature, 518, 213



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A critical test for formation of multiples

Most stars are found in multiple systems, although this depends critically on the mass of the primary stellar component (Duchene & Kraus 2013).

Several options have been proposed to form binaries: prompt fragmentation, disk fragmentation, stellar capture, and turbulent fragmentation (see Reipurth+2014, PPVI).

However, large separation multiples (>1,000 au) are still difficult to explain, and two possibilities have been proposed:

(a) formation of a compact triple system (<500au), which is later unfolded by dynamical interactions (Reipurth & Mikkol 2012)
(b) formation of wide separation system in-situ by the collapse of over-densities generated by turbulence (Offner+2010)

Here we present observations that support the second scenario of wide separation multiple stellar systems,

The Barnard 5 Dense Core

Barnard 5 is a dense core in the Perseus cloud (~250 pc, ~40M_{sun}) and it hosts a single Class I YSO. The velocity dispersion from a high-density tracer (NH_3) shows subsonic turbulence within the dense core (Pineda+ 2010).

Two narrow filaments were revealed with high-resolution JVLA + GBT NH_3 data (Pineda+ 2011). New (deeper) observations reveal the presence of condensations (smaller than classical pre-stellar cores), see Fig. 1.

We identify 3 bound condensations in the filaments with separations >3,000 au. Together with the YSO it could provide the youngest wide separation multiple ever observed

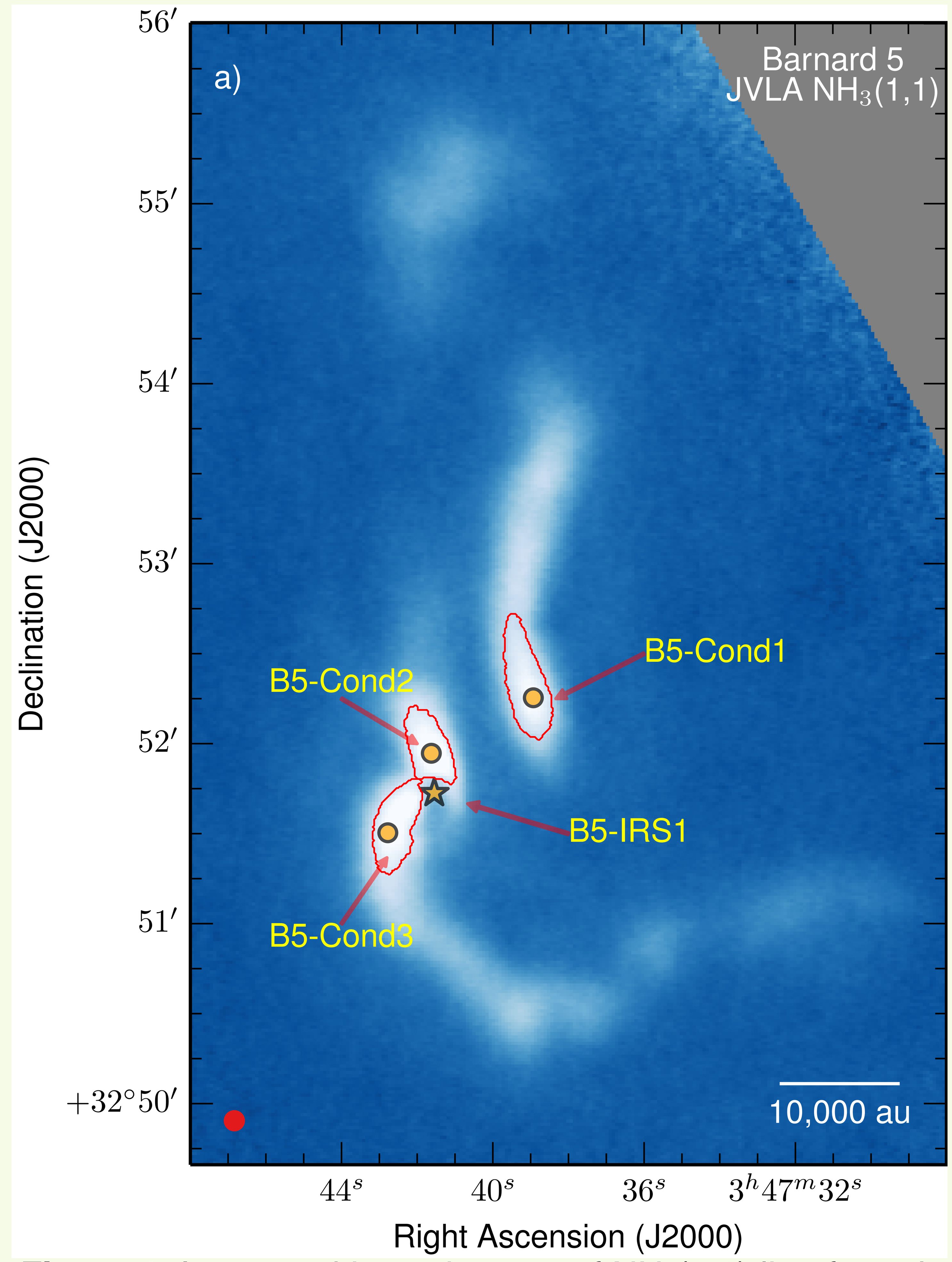

Figure 1: Integrated intensity map of $NH_3(1,1)$ line from the new JVLA+GBT observations. The filaments are clearly identified with some evident sub-structure. Red contours show the 3 identified condensations identified using dendrograms and the filled circles mark their center. The Class I YSO is shown by the star.

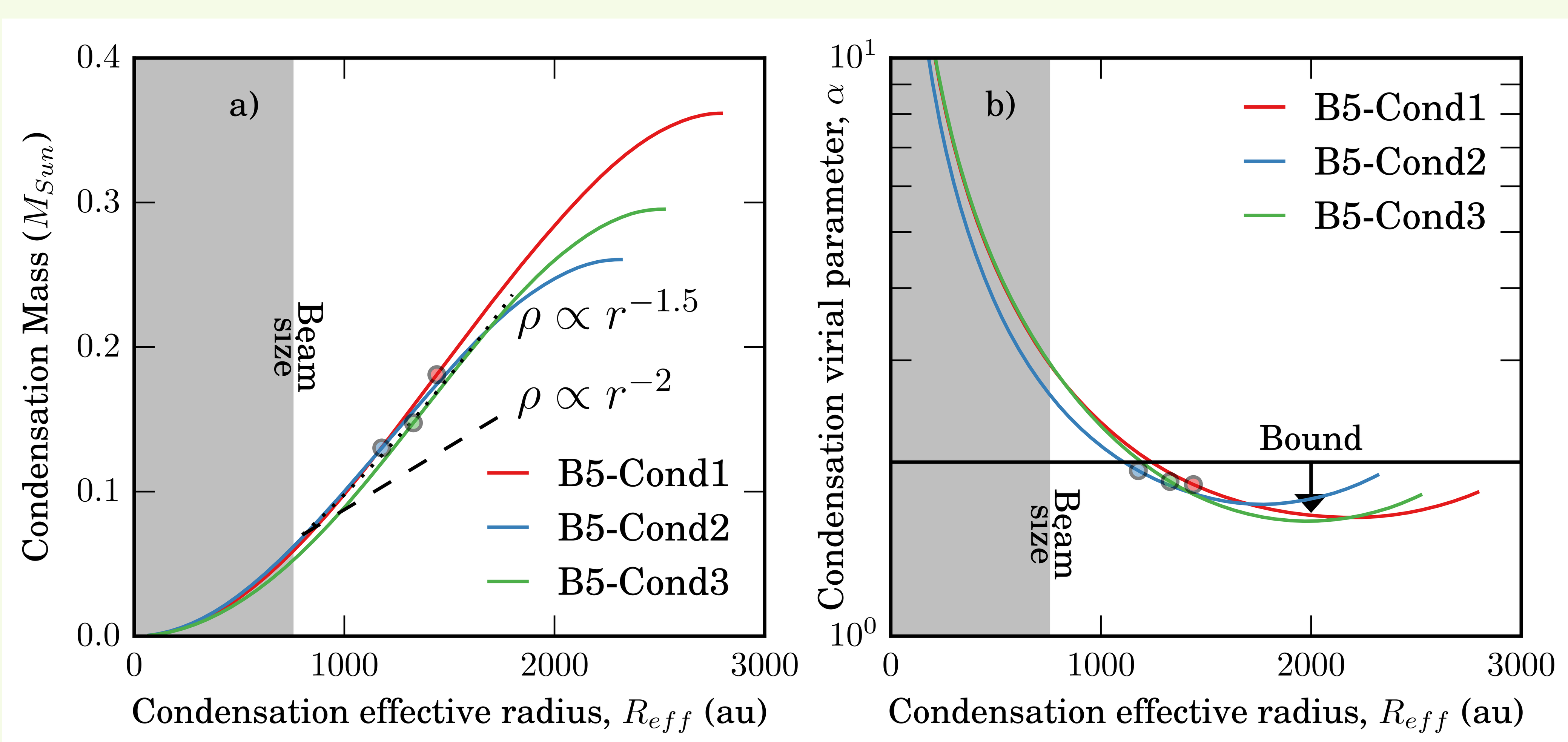

Figure 2: *Left*: Enclosed mass as a function of effective radius for all there condensations. Notice that their mass profiles are consistent with density profile $r^{-1.5}$, and not with hydro-static equilibrium solution r^{-2}. *Right*: Virial parameter as a function of effective radius for all condensations. It shows that they are mostly bound, except for the region <1,000 au, where the mass determination is affected by high optical depth.

The free-fall time is only 40,000 yrs!

What is the final outcome?

Condensations are bound and with a short free-fall time (Fig 2), therefore they will form stars.

The closest binary (B5-IRS1 and B5-Cond2, separation >3,500 au) is bound, regardless of the spatial configuration assumed (Fig 3) and without considering the gravitational potential of gas.

The final quadruple system is probably unstable, and it will likely evolve into a triple system (ejecting one star).

Wide separation multiple systems can be formed through turbulent fragmentation, by the fragmentation of filaments

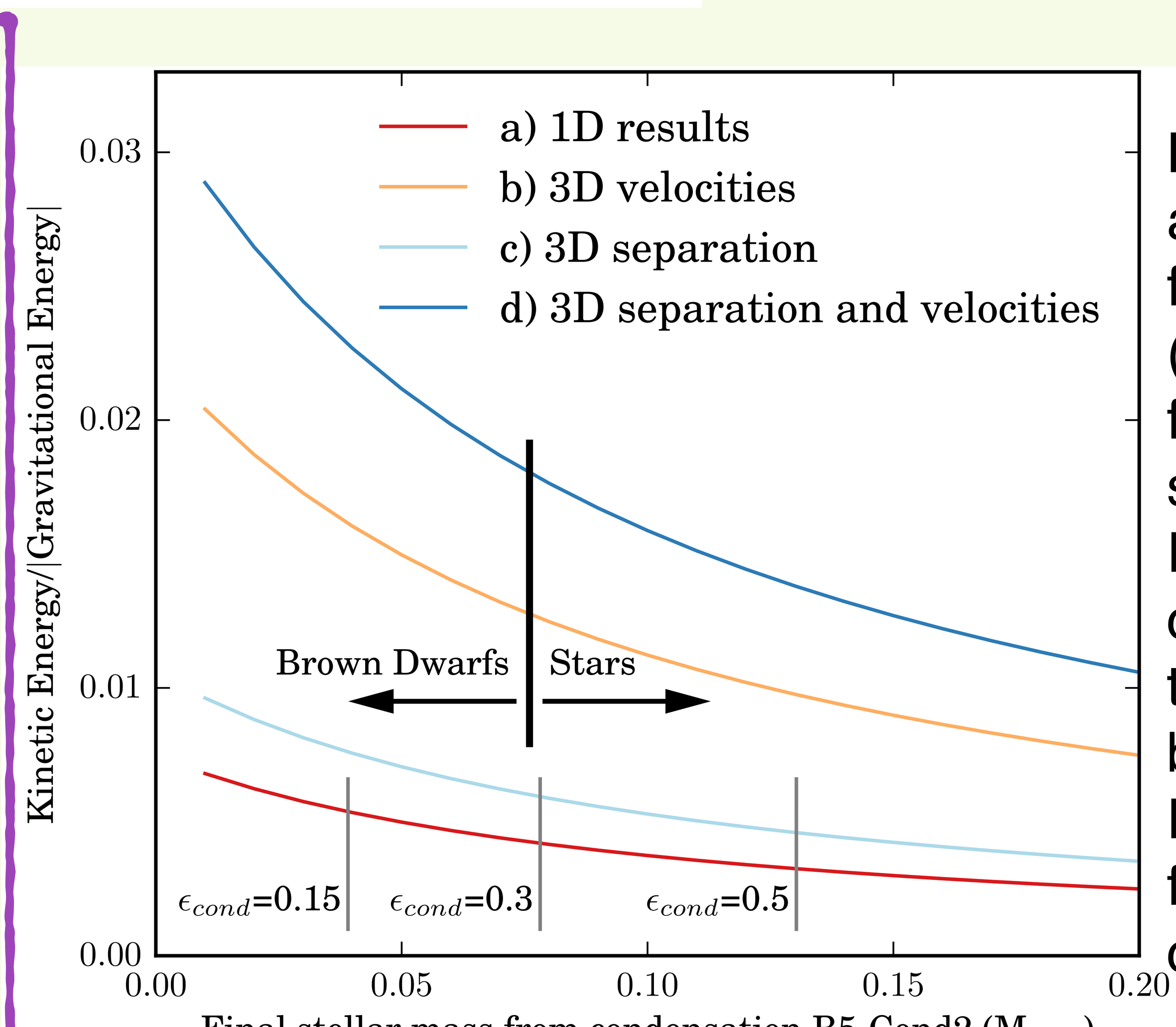

Figure 3: Ratio of kinetic and gravitational energy for the closest binary (B5-IRS1 & B5-Cond2), for different possible spatial configurations. Regardless of the configuration assumed, the system is always bound (energy ratio < 1). Even for a low star formation efficiency in cores.

References: Duchêne & Kraus 2013A RA&A 51 269 * Offner et al. 2010, ApJ, 725, 1485 * Pineda et al. 2010, ApJ, 712L, 116 * Pineda et al. 2011, ApJ, 739L, 2 * Pineda et al. 2015, Nature, 518, 213 * Reipurth & Mikkol 2012, Nature, 492, 221 * Reipurth et al. 2014. PP VI. 267