A Detailed Look at the Perseus Molecular Cloud with *Herschel*

Sarah Sadavoy (UVic), James Di Francesco (NRC)
Philippe André (Saclay), Stefano Pezzuto (INAF-IAPS),
and the *Herschel* Gould Belt Survey collaborators

Introduction

The Perseus molecular cloud is an active star-forming region, forming both low- and intermediate-mass stars within several complexes (Bally et al. 2008), hereafter clumps (Figure 1). At a distance of ~ 235 pc (Hirota et al. 2008), *Herschel* observations of Perseus have sufficient resolution (< 0.04 pc) to characterize the dense cores in each clump. Using these observations, we compare and contrast the clumps in Perseus.

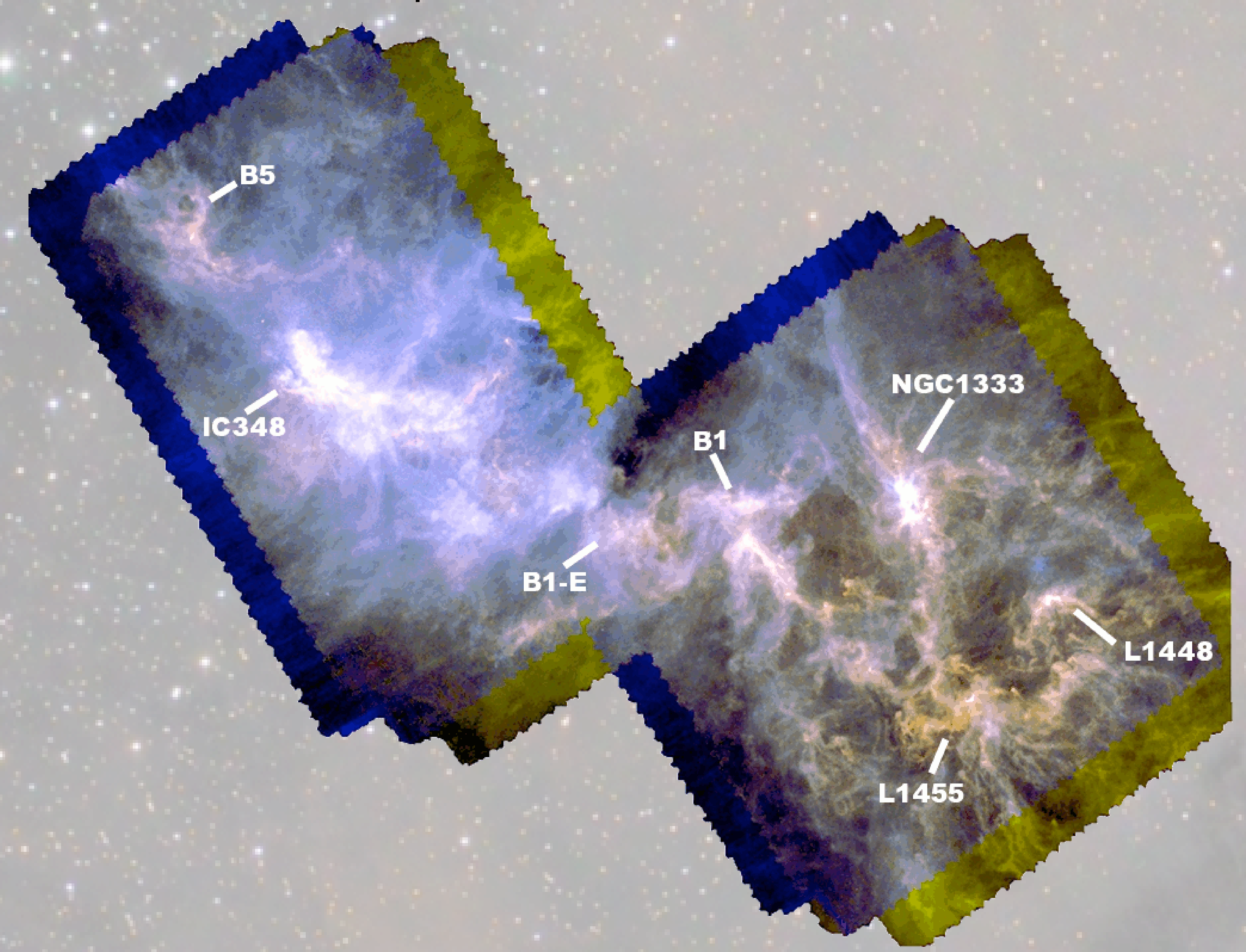

Figure 1 – Colour image of the Perseus molecular cloud highlighting 160 μm (blue), 250 μm (green), and 350 μm (red) *Herschel* observations. The seven main clumps are also highlighted.

Core Formation in the B1-E Clump

Herschel observations of B1-E have revealed substructures within this starless clump for the first time (see Sadavoy et al. 2012). Figure 2 shows the *Herschel*-derived column density map of B1-E. The nine highest column density substructures appear similar to prestellar cores.

Using the GBT, most substructures were found to have broad NH_3 (1,1) emission, suggesting they are unbound. Only one source (B1-E2) was likely bound. We propose that B1-E is fragmenting into a first generation of cores and B1-E2 is a prestellar core precursor.

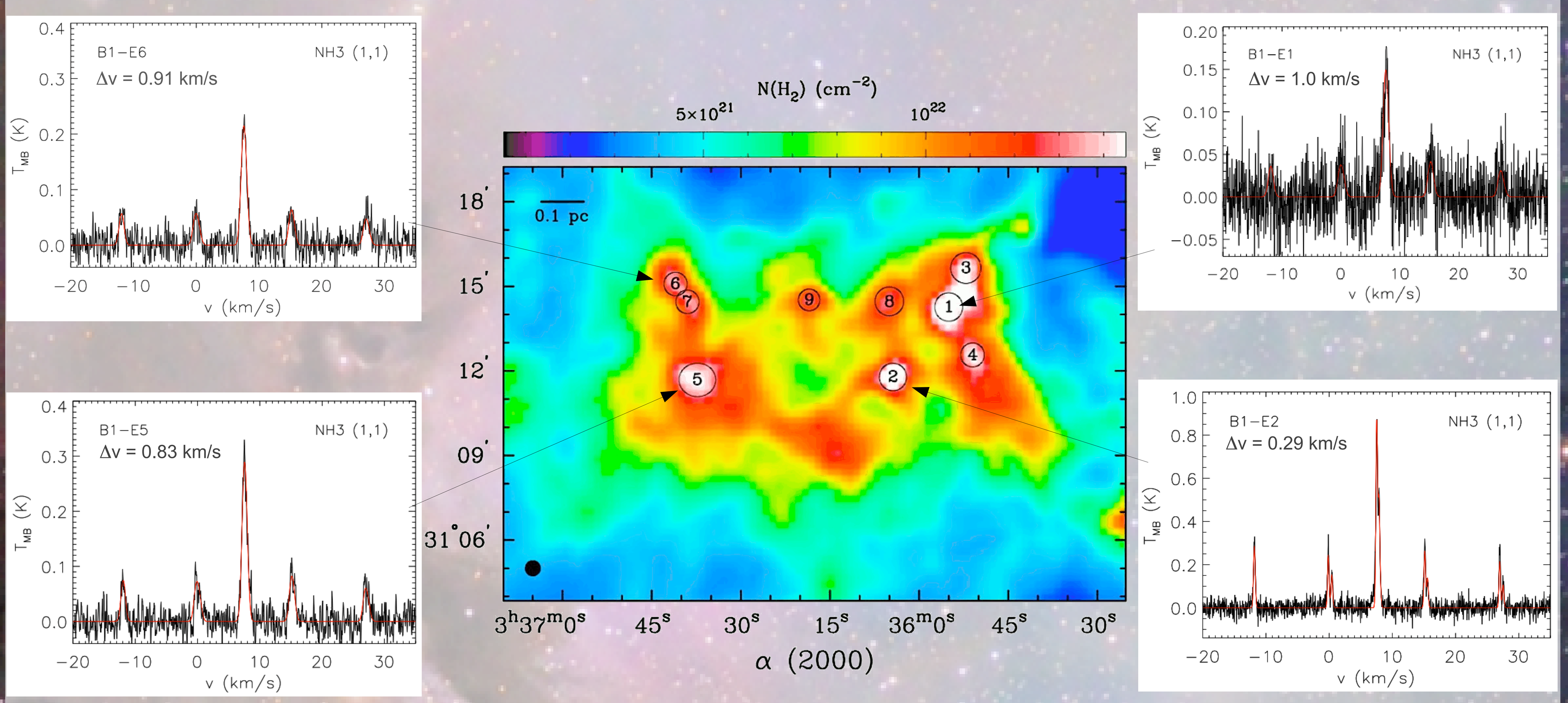

Figure 2 - Column density map of B1-E obtained from fitting SEDs to *Herschel* data at 160 – 500 μm and assuming β = 2. The nine highest column density substructures are shown as circles and labelled in order of decreasing peak column density. Sample NH_3 (1,1) spectra towards these substructures are also given. Most substructures had supersonic turbulent velocities and are gravitationally unbound. Only B1-E2 had subsonic turbulence and appears gravitationally bound.

Dust Evolution in the B1 Clump

Dust opacities vary with dust grain properties (Ossenkopf & Henning 1994). For cold clumps and cores, *Herschel* data alone cannot constrain well the dust emissivity index, β. Using complementary 850 μm data from SCUBA-2, we can constrain β better.

Figure 3 compares the β distributions when the 850 μm data are (a) included or (b) excluded. We find that β is constrained better with the H+850 bands and that β is lower towards the dense cores, suggesting that their dust grains have evolved (grown).

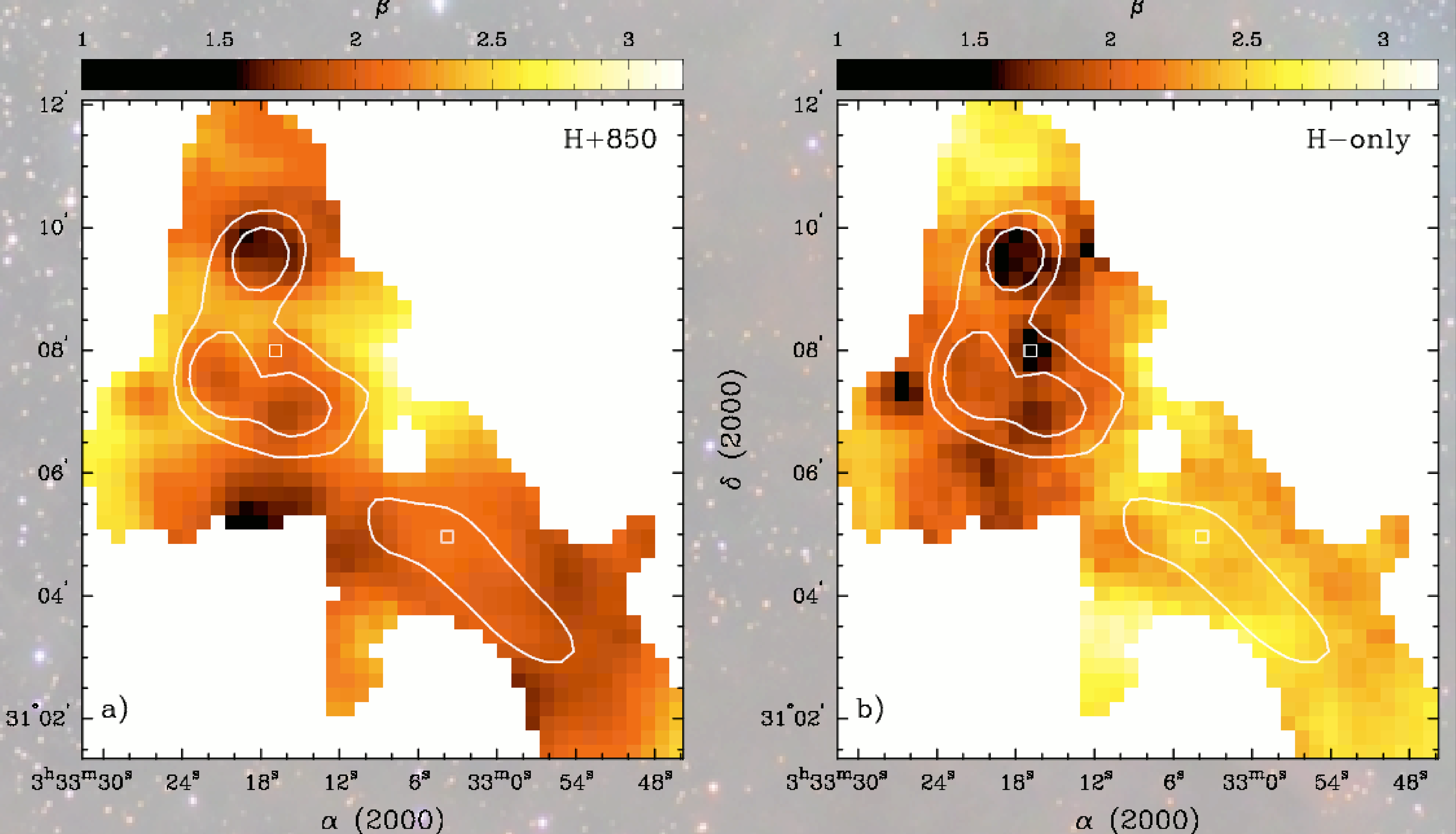

Figure 3 – Dust emissivity index (β) in B1 from SED fitting of (a) the *Herschel* and 850 μm data (H+850) and (b) the *Herschel* bands alone (H-only). In both cases, the *Herschel* data were filtered using the SCUBA-2 pipeline. We find that β is constrained better by roughly a factor of 2 with the H+850 data over the H-only data. For more details, see Sadavoy et al. (2013).

Comparison of Perseus Clumps

We used *getsources* (Men'shchikov et al. 2012) to extract sources from the *Herschel* data. We used archival catalogues of young stellar objects (YSOs) from Evans et al. (2009) and Gutermuth et al. (2009) to classify these sources as starless or protostellar. Figure 4 shows the relative fractions of each population type.

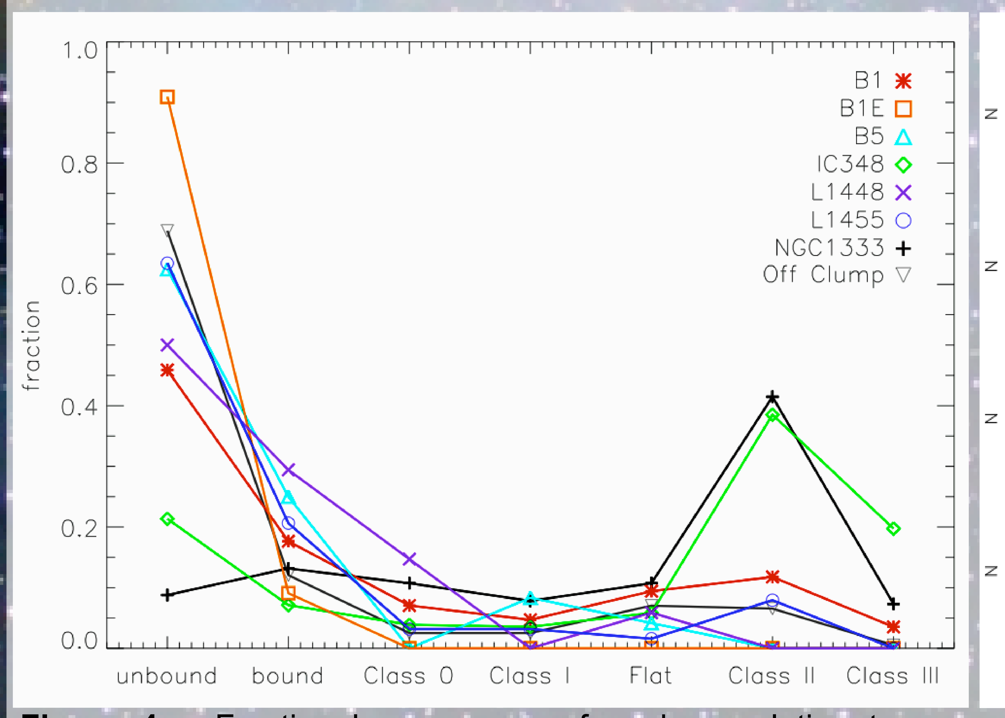

Figure 4 – Fractional occurrence of each population type plotted for each clump in Perseus. Fractional occurrence is measured as the instances for each classification normalized by the total number of detections in the clump.

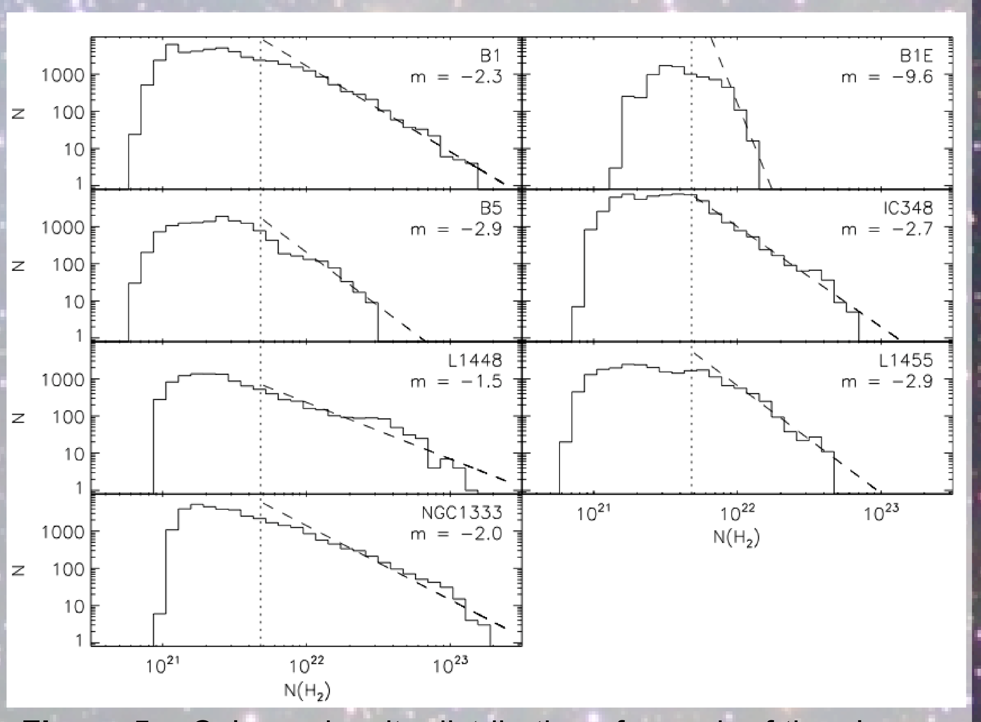

Figure 5 – Column density distributions for each of the clumps. The dashed lines give the best fit slope to the high column density tails (slope is also labeled).

We found that IC348 and NGC1333 have high fractions of Class II (and Class III) YSOs, suggesting that these clumps formed their YSOs first. Conversely, L1448 has the highest fractions of young sources (bound starless cores and Class 0 YSOs) and B1-E has a relative overabundance of unbound starless cores. B1-E also has the steepest "high column density" tail (see Figure 5), which suggests that it lacks the necessary dense material to form stars.

Star Formation and Column Density

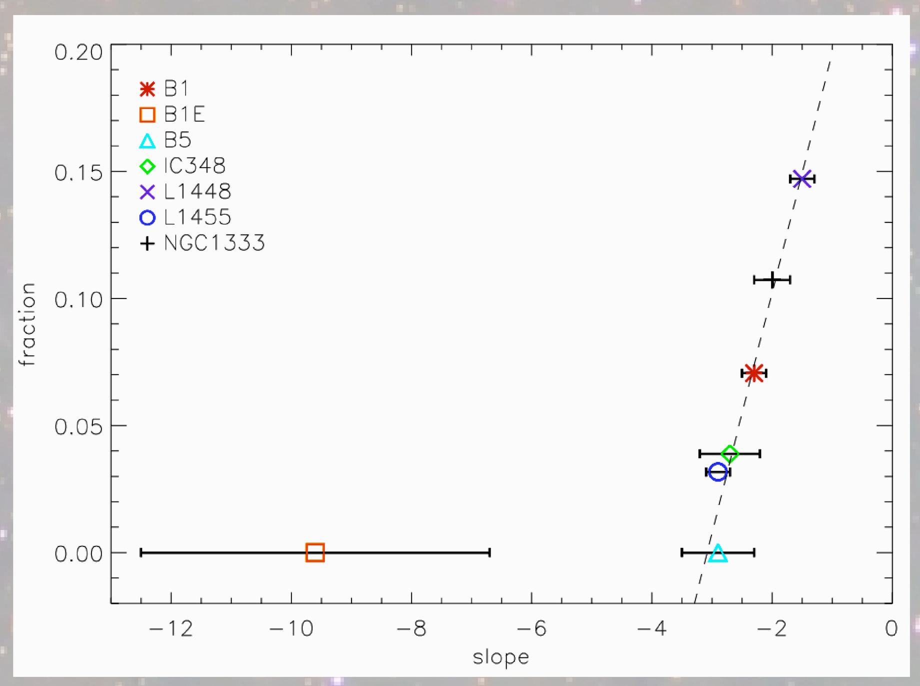

Figure 6 – Relation between the high column density slope and fraction of Class 0 YSOs in each clump.

Active star-forming regions generally have prominent high column density tails (e.g., Kainulainen et al. 2009). Figure 6 shows a strong correlation between the high column density slope (Figure 5) for each clump with their fraction of Class 0 YSOs (Figure 4), which suggests that the **high column density tail correlates with *recent* bursts of star formation** and not the total star formation history of the clump. Furthermore, we find that a minimum quantity of high column density material (slopes > -0.3) is necessary to form new stars.

Acknowledgements & References

This work is supported by funding from an NSERC CGS award, with additional support from the CSA and an NSERC Discovery grant. All *Herschel* maps were created using *scanamorphos*, developed by H. Roussel (2012). *Herschel* is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA. These observations are part of the *Herschel* Gould Belt key program (PIs Ph. André and P. Saraceno; André et al. 2010). This poster is presented with thanks to the ESA Student Sponsorship program.

André et al. 2010, A&A, 518, L102 || Bally et al. 2008, Handbook of Star Forming Regions v1, 308 || Evans et al. 2009, ApJS, 181, 321 || Gutermuth et al. 2009, ApJS, 184, 18 || Hirota et al. 2008, PASJ, 60, 37 || Kainulainen et al. 2009, A&A, 508, L35 || Men'shchikov et al. 2012, A&A, 530, 133 || Ossenkopf & Henning 1994, A&A, 291, 943 || Roussel 2012, ArXiv:1205. 2576 || Sadavoy et al. 2012, A&A, 540, 10 || Sadavoy et al. 2013, ApJ, 767, 126