# High-fidelity view of the massive, filamentary IRDC G11.11-0.12:

## Two modes of fragmentation

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**Summary:** We analyze the fragmentation characteristics of a massive, filamentary infrared dark cloud in an unprecedentedly high spatial resolution (2"), over a wide dynamic range of column densities ($N_H$ = 4-200 x $10^{21}$ cm$^{-2}$). We achieve this by employing a novel dust extinction mapping technique that combines near- and mid-infrared data. We show that at size-scales above $l$ > 0.5 pc the fragmentation of G11 is in agreement with that of a self-gravitating filament. However at smaller scales, the fragmentation agrees better with spherical Jeans' fragmentation. This implies that at scales smaller than 0.5 pc, the fragmentation depends only on the local properties of the cloud, while at larger scales also the filamentary morphology plays a role.

**A new view of infrared dark clouds:** Infrared dark clouds (IRDCs) are the best current candidates to harbor the initial conditions of high-mass star and star cluster formation. However, these objects are located at distances greater than $d$ > 2 kpc, and therefore, our knowledge on their internal mass distributions and fragmentation is very scarce. Reaching the Jeans' scale at the distance of the IRDCs requires arcsecond-scale resolution that has so far been possible only to interferometers. Interferometers, however, cannot probe the diffuse envelopes of the clouds in which most of their mass resides.

We have recently developed a novel dust extinction mapping technique that allows probing the mass distributions in IRDCs in high spatial resolution (2") over a relatively wide dynamic range of columnd densities (Kainulainen & Tan 2013). The technique allows us, for the first time, to probe the internal mass distributions of IRDCs from the diffuse envelope material to the dense cores.

**Fragmentation of G11:** We employed the new technique to derive a dust extinction map of a remarkably filamentary cloud IRDC G11 (Fig. 1). The technique resulted in column density data that was in excellent agreement with Herschel-derived column densities (Fig. 2). With the help of these data and a wavelet-based multiscale analysis, we analyzed the fragmentation of the cloud between 0.1-10 pc size-scales.

Our analysis showed that at size-scales larger than ~0.5 pc, the fragmentation of the cloud is in agreement with that of an infinite, self-gravitating cylinder (Fig. 3). However at smaller scales ($l$ < 0.5 pc), the fragmentation characteristics match better spherical Jeans' fragmentation. This curious change in the fragmentation characteristics can be understood in terms of sizescale-dependent collapse time-scales (Pon et al. 2011). The results show that there exists a sizescale (~0.5 pc) below which only local properties of the gas affect the collapse. Above that sizescale, the filamentary nature of the cloud dominates the fragmentation mode.

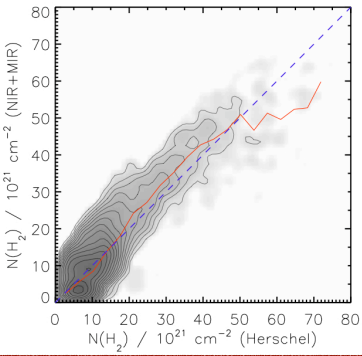


**Fig. 2:** Relationship between the column densities derived from dust extinction (see Fig. 1) Herschel dust emission data. The red line shows the median relationship. The blue line shows one-to-one correlation.

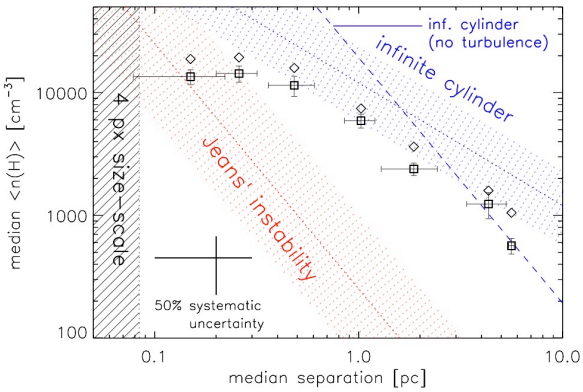


**Fig. 3:** Multi-scale fragmentation analysis of G11 showing the mean density of fragments as a function of their separation. The boxes show the values calculated assuming spherical symmetry and diamonds assuming cylindric symmetry. The theoretical prediction for Jeans' fragmentation is shown with red and the one for cylinder fragmentation with blue (Kainulainen et al. 2013).

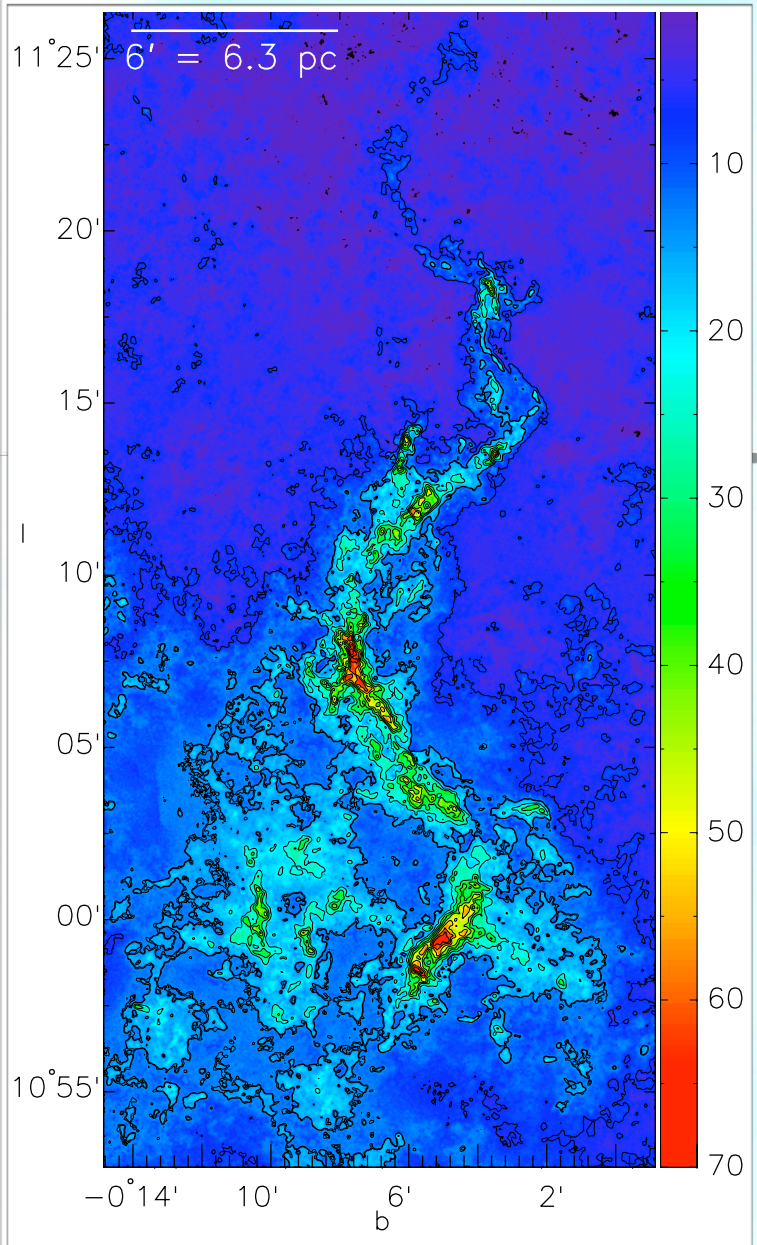


**Fig. 1:** High-fidelity dust extinction map of the IRDC G11.11-0.12 (Kainulainen et al. 2013). The resolution of the map is 2" and it covers the column density range $N_H$ = 4-200 x $10^{21}$ cm$^{-2}$.

References:

*Kainulainen J. & Tan J., C., 2013, A&A, 549, 53*

*Kainulainen J., Ragan S. E., Henning T., Stutz A., 2013, acceptd to A&A, arXiv: 1305.6383*

*Pon A., Johnstone D., Heitsch F., 2011, ApJ, 740, 88*