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A CENSUS OF DENSE CORES IN AQUILA FROM *HERSCHEL* GOULD BELT SURVEY OBSERVATIONS

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Abstract – Introduction

The main scientific goal of the ***Herschel* Gould Belt survey** (HGBS, André et al., 2010) is **to elucidate the physical mechanisms of the formation of prestellar cores out of the diffuse ISM**, which is crucial for understanding the origin of stellar masses.

Among our target clouds the **Aquila Rift** complex (d~260 pc) is a rich, unexplored complex with well-known clusters, and serves as a "case study" for the main objectives of the HGBS (Könyves et al., 2010; 2014 in prep.).

In Aquila, we have identified a complete sample of ~600 starless cores, > 65% of which are gravitationally bound dense prestellar cores. We find a **strong correlation between the spatial distribution of prestellar cores and the densest filaments** observed with *Herschel*, and also confirm the existence of a **threshold background column density** of ~7×10^{21} cm^{-2} (or A_V ~ 7), above which prestellar cores are forming.

The prestellar core mass function (CMF) is very similar in shape to the stellar initial mass function (IMF), confirming earlier findings on a much stronger statistical basis. Our "filamentary" results support a picture where **the gravitational fragmentation of marginally critical filaments produces the peak of the CMF**.

The global shift in mass scale between the CMF and the IMF is consistent with a typical **SFE of ~30% for an individual core**. By comparing the numbers of starless cores in various density bins to the number of Spitzer YSOs, we find that the **lifetime of prestellar cores is ~3 core free-fall times** (André et al., 2014; Könyves et al., 2014 in prep.).

Source extraction with *getsources*

Compact sources were extracted from the SPIRE/PACS images (500–70 μm) using *getsources*, a multi-wavelength source-finding algorithm (Men'shchikov et al., 2012).

Core selection and classification

We set selection criteria based on: Significance – S/N ratio – peak/total flux – source size/elongation – quality of the SED fit.

Deriving core properties

SEDs of the extracted sources are constructed from the integrated flux densities measured by *getsources*.

Zoom in on cores

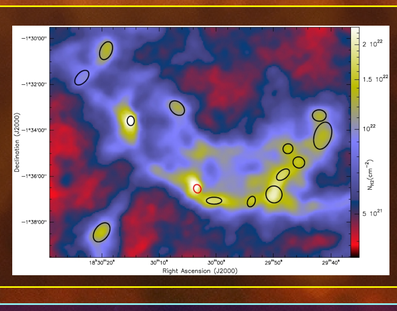


Fig. 2: Selected prestellar cores (black) and a protostar (red) in a subfield of the Aquila N_{H_2} map. The ellipses represent FWHM sizes derived by *getsources*.

Core formation threshold

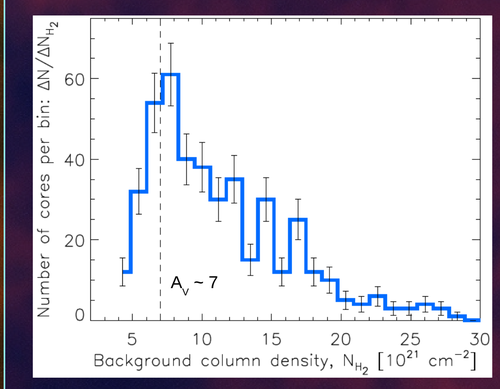


Fig. 3: Distribution of background cloud column densities for the Aquila candidate prestellar cores (André et al., 2014; Könyves et al., 2014 in prep.).

Our *Herschel* observations confirm that there is a **critical threshold of ~7 × 10^{21} cm^{-2} (or A_V ~ 7) for prestellar core formation** (André et al., 2010, 2014, Könyves et al., 2014 in prep.).

About **85% of the *Herschel*-identified prestellar cores are found above this threshold** background column density, and a similar high fraction of them are also located within supercritical filamentary structures.

Interpretation:

Invoking the typical filament width ~0.1 pc (Arzoumania et al., 2011), the observed N_{H_2} core formation threshold corresponds –within a factor of 2– to the threshold above which interstellar filaments become gravitationally unstable: $M_{line,crit} = 2c_s^2/G$ ~ 16 $M_\odot$/pc, with c_s~0.2 km/s for T~10 K (André et al., 2014, Könyves et al., 2014 in prep.).

Core lifetime estimates

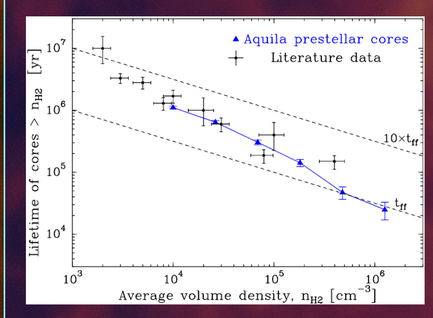
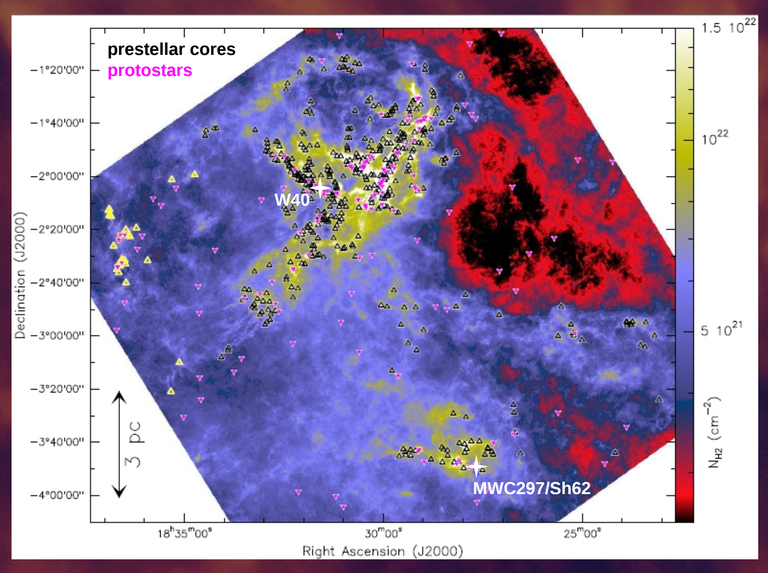


Fig. 5: Estimated lifetime against average core density for the prestellar and starless core population identified with *Herschel* in Aquila (André et al., 2014, Könyves et al., 2014 in prep., plot after Jessop & Ward-Thompson 2000).
The dashed lines correspond to the free-fall timescale (t_{ff}) and a rough approximation of the ambipolar diffusion timescale (10 × t_{ff}).

We derive statistical estimates of the lifetimes of dense cores by comparing the number ratios of observed sources at different stages of star formation, using *Herschel* cores, and *Spitzer* YSOs. ⇨ $t_{prestellar}$ ~ 3 t_{ff}

Cores and filaments on column density maps



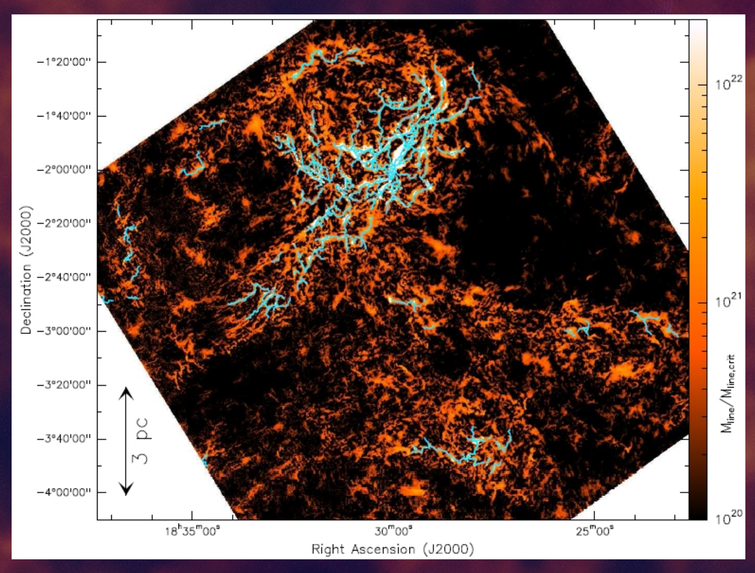


Fig. 1: (a) H_2 column density map of Aquila at 18.2" angular resolution, derived from HGBS SPIRE/PACS data. Black triangles mark ~450 prestellar cores, and magenta stars indicate ~200 protostars. Additional yellow triangles locate cores where there is potential contamination by CO emission.
(b) Filamentary structure of Aquila, traced by the curvelet transform component (cf. Starck et al., 2003) of the *Herschel* N_{H_2} map. This is also equivalent to a map of the mass per unit length along the filaments, given their typical width of ~0.1 pc (Arzoumanian et al., 2011). The white areas show the likely gravitationally unstable filaments (see Fig. 4). The overplotted blue skeletons mark the ridges of supercritical filaments selected from DisPerSE (Sousbie, 2011).

Omnipresent filamentary structure – Relation with dense cores

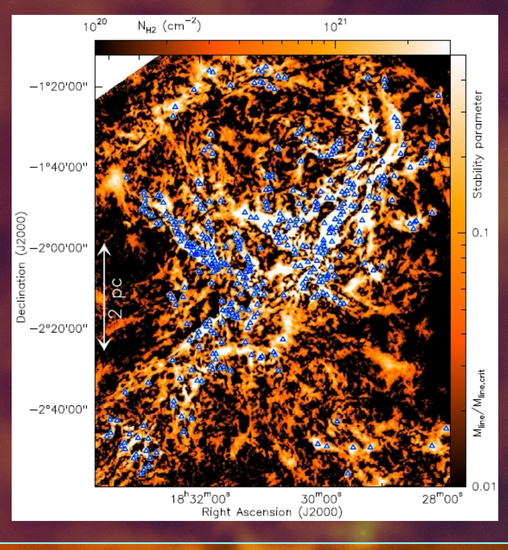


Fig. 4: This column density map is equivalent to a stability parameter (mass per unit length) along the filaments (similarly as in Fig. 1b). White color shows the gravitationally unstable areas, where the filaments have a mass per unit length larger than half the critical value ($M_{line,crit} = 2c_s^2/G$, cf. Inutsuka & Miyama, 1997). Blue triangles mark the bound prestellar cores in the main field of Aquila (André et al., 2010; Könyves et al., 2014 in prep.).

In the Aquila complex, **~50% of the dense gas mass is estimated to be in the form of filaments**.

We find a **strong correlation between the spatial distribution of prestellar cores and the densest filaments** observed with *Herschel* (see section 'Core formation threshold').

About 80% of the *Herschel*-identified prestellar cores are located within filamentary structures with supercritical masses per unit length ≳ 16 $M_\odot$/pc.

Core mass function in Aquila

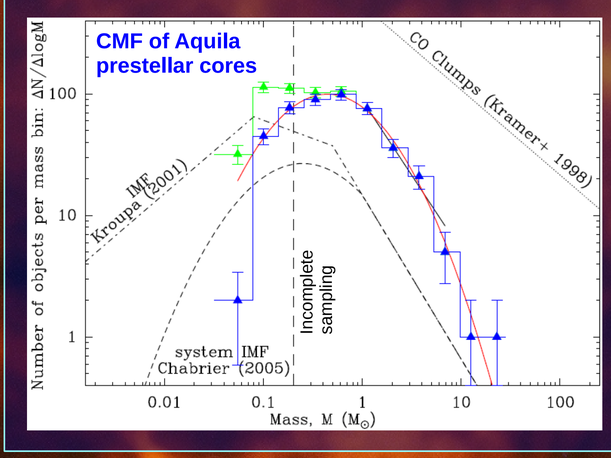


Fig. 6: Differential mass function of ~600 starless cores in Aquila (green histogram), and that of ~450 prestellar cores (blue hist.). The latter is approximated with a lognormal fit (red curve) with a peak at ~0.5 $M_\odot$. The high-mass end of the CMF is fitted by a power-law ($dN/d\log M \propto M^{-1.16\pm0.26}$). The observed core sample is estimated to be **complete down to ~0.2 $M_\odot$**, derived from completeness analysis on a set of simulated cores (André et al., 2010; Könyves et al., 2010; 2014 in prep.).

Aquila results support a picture according to which the cores making up **the peak of the CMF result primarily from the gravitational fragmentation of marginally critical filaments**.

The **local efficiency in Aquila is high**: $\epsilon_{core} \equiv M_*/M_{core}$ **~ 20–40%**.

Only a **small fraction** (10-15%) **of the gas mass is in the form of prestellar cores** above the column density threshold (André et al., 2014; Könyves et al., 2014 in prep.).

References

André et al. 2010, A&A 518, 102 — André et al. 2014, PPVI chapter, astro-ph/1312.6232 — Arzoumanian et al. 2011, A&A 529, 6 — (SPIRE:) Griffin et al. 2010, A&A 518, 3 — Inutsuka & Miyama 1997, ApJ 480, 681 — Jessop & Ward-Thompson 2000, MNRAS 311, 63 — Könyves et al. 2010, A&A 518, 106 — Men'shchikov et al. 2012, A&A 542, 81 — (*Herschel*:) Pilbratt et al. 2010, A&A 518, 1 — (PACS:) Poglitsch et al. 2010, A&A 518, 2 — Sousbie 2011, MNRAS 414, 350 — Starck et al. 2003, A&A 398, 785