A physically motivated dense-core extraction technique applied to Herschel/Planck observations

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Dense cores connect cloud structure to star formation.

protostars

Großschedl+ (subm.)
Dense cores connect cloud structure to star formation.

Alves+ (2007)

André+ (2010)
Sub-mm dust emission observations

- Dust opacity (column density) & effective dust temperature
- Available for many nearby molecular clouds

Noise, line-of-sight confusion, dust properties $\rightarrow$ physical interpretation?

1) e.g. HP2 survey in Orion (Lombardi+2014), Perseus (Zari+2016), California (Lada+2017), Pipe nebula (Hasenberger+2018, in press)
2) Shetty+ (2009a,b)
Effective dust temperatures in cores

- 97% of cores show significant anticorrelation between column density and temperature

**Thermodynamics of cores:** heating by ISRF & shielding by surrounding medium
What is a core?

Using algorithms based on morphology only, derived core boundaries potentially depend on the data resolution and chosen input parameters.³

³ Pineda+ (2009), Smith+ (2008)
What is a core?

Core extraction technique that...

... is based on physical properties of the cloud medium.

... can be applied to a variety of nearby molecular clouds.

→ **GRID core-finding technique**⁴ (isocontours of the gravitational potential and balance between $E_{\text{grav}}$ and $E_{\text{th}}$) on dust emission observations

⁴ Gong+ (2011)
From flux maps to cores

\[ \lambda_1 \rightarrow \lambda_2 \rightarrow \lambda_3 \rightarrow \lambda_4 \]

Core boundaries

\[ \tau \rightarrow \Theta \rightarrow \Phi_{\text{grav}} \rightarrow E_{\text{th}} \]

GRID
From flux maps to cores
Estimating 3D flux distributions: AVIATOR

A Vienna Inverse-Abel-Transform based Object Reconstruction algorithm

Abel transform:
\[ F_{2D}(x, y) = F_{2D}(\rho) = \int g_{3D}(r) \, dz \]

Inverse Abel transform (spherical geometry):
\[ g_{3D}(r) = -\frac{1}{\pi} \int_{r}^{\infty} \frac{dF_{2D}(\rho)}{d\rho} \frac{d\rho}{\sqrt{\rho^2 - r^2}} \]

Our scheme:
- Decompose 2D flux images into flux levels
- Apply variant of inverse Abel transform

\[ g_{3D}(r) = \sum_{i} \frac{1}{\pi} \frac{1}{\sqrt{R_i^2 - r^2}} \]

5) Abel (1826) deduced from morphological analysis
Examples for 3D flux estimates

Extent along LoS ~ Extent in plane of the sky
Validation of estimated 3D temperatures

\[ T_{d}^{2D}, T_{d}^{3D}, T_{NH3} \]
AVIATOR/GRID cores in a Pipe nebula subregion

gravitational potential
cores (GRID definition)
bound cores (GRID definition)
cores (clumpfind, Rathborne+2009)
Summary

• **Dust emission observations allow us to investigate the thermodynamics of dense cores:** In the Pipe nebula, the dominant processes are heating by the ISRF and shielding by the surrounding medium.

• **The AVIATOR algorithm is an innovative tool to estimate 3D flux distributions from observations:** Estimates of dust temperature using the AVIATOR algorithm are in good agreement with molecular line measurements of NH$_3$ for most cores in the Pipe nebula.

• **The AVIATOR/GRID-core technique allows us to define physically motivated core boundaries and yields results different from morphology-based algorithms:** In the Pipe nebula, only few individual gravitational wells contain bound material, and the relation to cores derived by clumpfind is generally not straightforward.