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A physically motivated core definition applied to dust emission observations of the Pipe nebula

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Abstract. Dense cores represent a critical stage in the star-formation process, but are not physically well-defined entities. We present a new technique to define core boundaries in observations of molecular clouds based on the physical properties of the cloud medium. Applying this technique to regions in the Pipe nebula, we find that our core boundaries differ from previous analyses, with potentially crucial implications for the statistical properties of the core sample.

Keywords. methods: data analysis, ISM: clouds, (ISM:) dust, extinction, ISM: structure, ISM: individual (Pipe nebula), submillimeter

1. Introduction

The investigation of dense cores allows us to gain insights into the physical mechanisms that are relevant at the early stages of the star-formation process. Observationally, cores are commonly defined by their 2D morphology in maps of molecular clouds – without explicitly imposing constraints on the physical properties of the region defined as a core (Pineda *et al.* 2009, Smith *et al.* 2008). We develop a core extraction scheme that is physically motivated and thus requires us to go beyond projections in the plane of the sky. Dust emission observations of the Pipe nebula are a suitable basis for our study due to the quiescent nature of the region and the quality of the available data (Hasenberger *et al.* 2018, Forbrich *et al.* 2009, Alves *et al.* 2008).

2. Estimating 3D density and temperature

We utilise *Herschel-Planck* flux maps of the Pipe nebula region (Hasenberger *et al.* 2018) for our analysis. From these maps, we estimate 3D flux distributions based on two assumptions: For each structure at each flux level, a) the extent along the line of sight is similar to the extent in the 2D projection, and b) the 3D radial distribution is approximated well by applying a variant of the inverse Abel transform (Abel 1826) to the 2D projection. The overall 3D flux distribution is then the sum of the contributions from each structure in each flux level. We derive estimates for the 3D density and temperature distributions by fitting the 3D flux distributions with a modified blackbody spectrum.

We applied this method to a number of subregions in the Pipe nebula. As a first test of our technique, we compare temperatures in dense cores derived from NH_3 line emission observations (Rathborne *et al.* 2008), the 2D dust map, and the 3D dust map (see Fig. 1). We generally find good agreement between the line-emission and 3D dust values, corroborating our assumptions and technique.

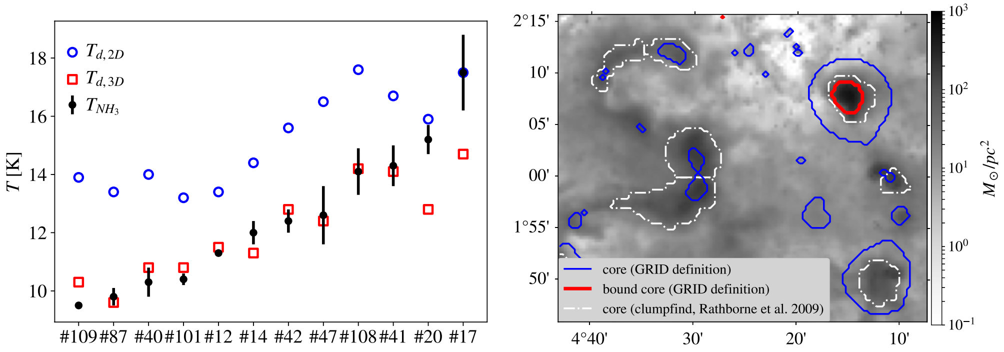

Figure 1. *Left:* Comparison of core temperatures derived using different methods, with the x-axis indicating the core number as given by Alves *et al.* (2007). *Right:* Map of the column-density distribution derived from the 3D density estimate for the Smoke subregion of the Pipe nebula, with different core boundary definitions shown as contours.

3. Physically motivated core boundaries

With 3D density and temperature estimates at hand, we are able to construct 3D maps of gravitational (E_g) and thermal energy (E_{th}). Following the gravitational identification (GRID) procedure (Gong *et al.* 2011), GRID cores are defined as individual wells in the gravitational potential, and bound GRID cores as areas where $E_g > E_{th}$. A preliminary analysis of the subregions indicates that only few areas in the Pipe nebula qualify as bound GRID cores (see Fig. 1), which might have critical implications for the statistical properties of the core sample, for example the core mass function.

4. Conclusions and outlook

We use dust emission observations of the Pipe nebula to develop a new, physically motivated core extraction scheme. By estimating the 3D distribution of density and temperature, we are able to define core boundaries based on the balance between gravitational and thermal energy. Our preliminary analysis suggests that this method yields a core sample significantly different from the results of traditional core-extraction techniques. In order to deepen our understanding of dense cores, we aim to apply this procedure to the entire Pipe nebula and other molecular clouds in the future.

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