Mem. S.A.It. Vol. 88, 737

Memorie della

Towards a physically motivated core definition: the Pipe Nebula as seen in Herschel-Planck emission and NIR extinction

B. Hasenberger[1], M. Lombardi[2], J. Alves[1], J. Forbrich[3,4], A. Hacar[5], and C. J. Lada[4]

[1] Department for Astrophysics, University of Vienna, Türkenschanzstraße 17, 1180 Vienna, Austria, e-mail: `birgit.hasenberger@univie.ac.at`
[2] University of Milan, Department of Physics, via Celoria 16, 20133, Milan, Italy
[3] Centre for Astrophysics Research, University of Hertfordshire, Hatfield AL10 9AB, UK
[4] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[5] Leiden Observatory, Leiden University, PO Box 9513, NL-2300 RA Leiden, the Netherlands

Abstract. We construct high-resolution column-density and effective-temperature maps for the Pipe nebula region based on sub-mm/far-infrared and near-infrared data. Based on these maps, we show that the slope of the relation between column density and temperature can be used to distinguish dense from diffuse regions in the cloud. Therefore, temperature information could be employed in one of the criteria to define cores in a physically motivated fashion.

1. Introduction

The study of dense cores allows us to gain insights into the physical mechanisms that are relevant at the early stages of the star formation process. Algorithms commonly used to extract cores from observational data (e.g., Williams et al. 1994), are however associated with complications regarding, e.g., the choice of input parameters (e.g., Pineda et al. 2009) and do not impose explicit constraints on the physical properties of the region defined as a core.

This study explores the possibility of using temperature information derived from multi-wavelength sub-mm/far-infrared observations as an additional dimension when defining regions of dense matter, and by that takes a first step towards a physically motivated core definition. Due to the quality of the available data and its quiescent nature, the Pipe Nebula is a suitable target for our study (Alves et al. 2008; Forbrich et al. 2009).

2. Data and results

To construct maps of column density A_K and effective dust temperature T (see Fig. 1), we employ data from the *Herschel* Gould Belt Survey (André et al. 2010), *Planck* thermal dust emission maps (Planck Collaboration et al. 2014), and an extinction map based on 2MASS (Kleinmann et al. 1994; Lombardi 2009). The latter is used to calibrate optical depth measurements τ derived from the combined *Herschel* and *Planck* data to yield A_K. We follow the same reduction procedure as described by Zari et al. (2016).

We utilise the T map by studying the relation between τ and T. Shielding from the interstellar radiation field allows the densest parts

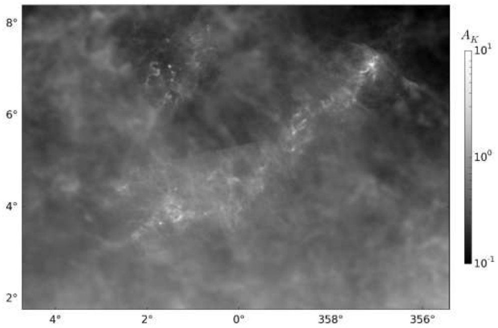

Fig. 1. Map of A_K in Galactic coordinates.

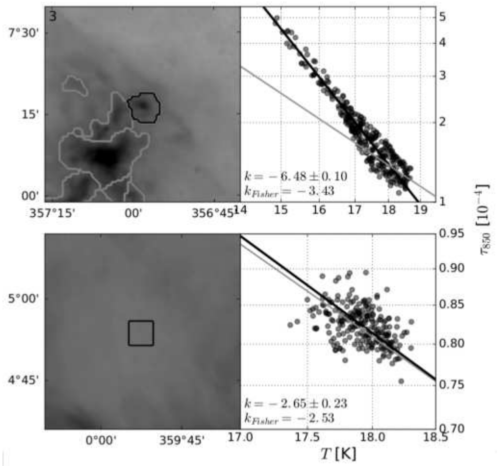

Fig. 2. Examples of τ-T relations for cores (*top*) and test areas (*bottom*). The left panels show the τ map with core and test area boundaries indicated by contours. In the right panels, the black line is a power-law fit to the data points and the grey line indicates the Fisher slope.

of molecular clouds to cool more efficiently than the outer layers, leading to an anticorrelation between τ and T (e.g., Evans et al. 2001).In most cores taken from the core sample by Rathborne et al. (2009), a clear anticorrelation is observed (see Fig. 2, top). However, due to a degeneracy between τ and T introduced by the data reduction, an anticorrelation is observed even in regions that appear to be devoid of dense material (test areas, see Fig. 2, bottom). We resolve this complication by estimating the slope caused by the degeneracy using the Fisher information matrix and comparing it to the observed slope. This method is capable of correctly identifying 96% of cores as containing dense structures and all test areas as diffuse regions.

3. Conclusions

We use column-density and effective-dust-temperature maps of the Pipe Nebula to show that the τ-T relation is an indicator for dense structures if systematic effects are taken into account. Since this relation is a result of shielding from the interstellar radiation field, the current study represents a first step towards a physically motivated definition of a dense core.

Acknowledgements. This research made use of Astropy (Astropy Collaboration et al. 2013) and Matplotlib (Hunter 2007).

References

Alves, J. et al. 2008, The Pipe Nebula: A Young Molecular Cloud Complex, ed. B. Reipurth, p. 415

André, P. et al. 2010, A&A, 518, L102

Astropy Collaboration et al. 2013, A&A, 558, A33

Evans, N. J. et al. 2001, ApJ, 557, 193

Forbrich , J. et al. 2009, ApJ, 704, 292

Hunter 2007, Comput. Sci. Eng., 9, 90

Kleinmann, S. G. et al. 1994, Ap&SS, 217, 11

Lombardi, M. 2009, A&A, 493, 735

Pineda, J. E. et al. 2009, ApJ, 699, L134

Planck Collaboration et al. 2014, A&A, 571, A11

Rathborne, J. M. et al. 2009, ApJ, 699, 742

Williams, J .P. et al. 1994, ApJ, 428, 693

Zari, E. et al. 2016, A&A, 587, A106