# ANR Chaire d'Excellence Project

at the

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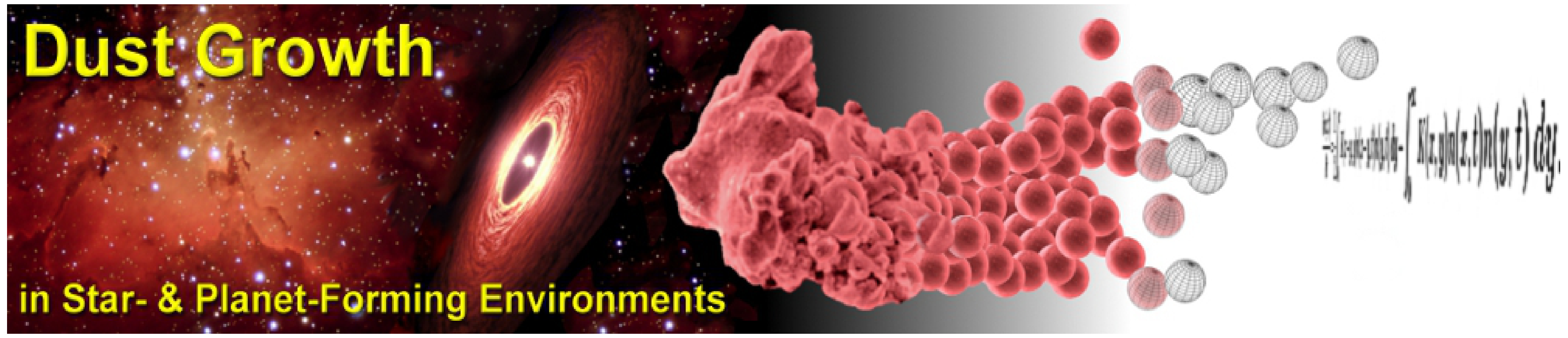
AGENCE NATIONALE DE LA RECHERCHE ANR cnrs IPAG

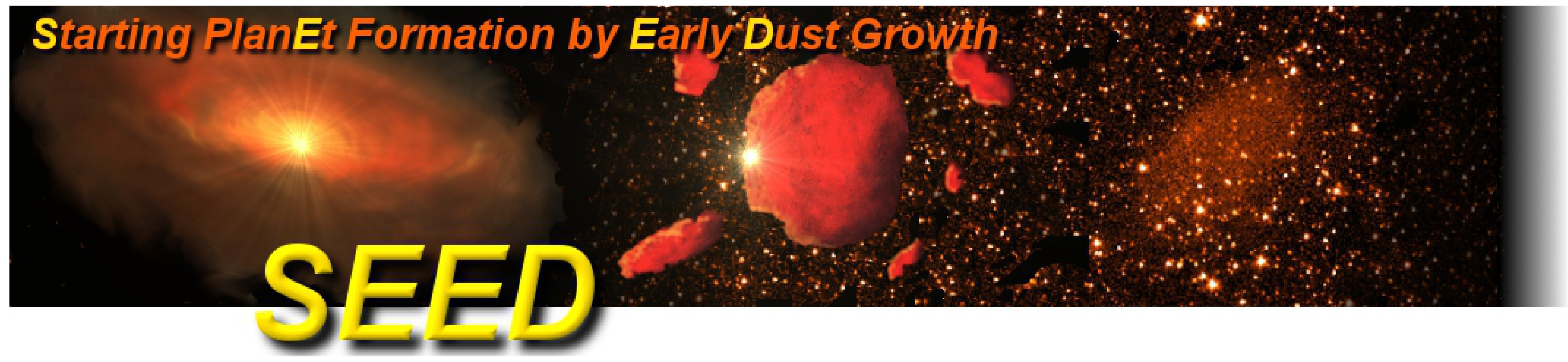
# Goal of the project

## "**S**tarting Plan**E**t Formation by **E**arly **D**ust Growth"

The scientific goal of the project is to explore the growth of dust grains in molecular cloud cores before and while they collapse to form stars and later planets, in this way determining the seed population of grains for the planet formation process.

Detailed results will be presented by the SEED team at the conference
***DG13 Dust Growth in Star & Planet Forming Environments***
at the Max-Planck-Institut for Astronomie Heidelberg
in the week after PPVI www.mpia.de/DG13

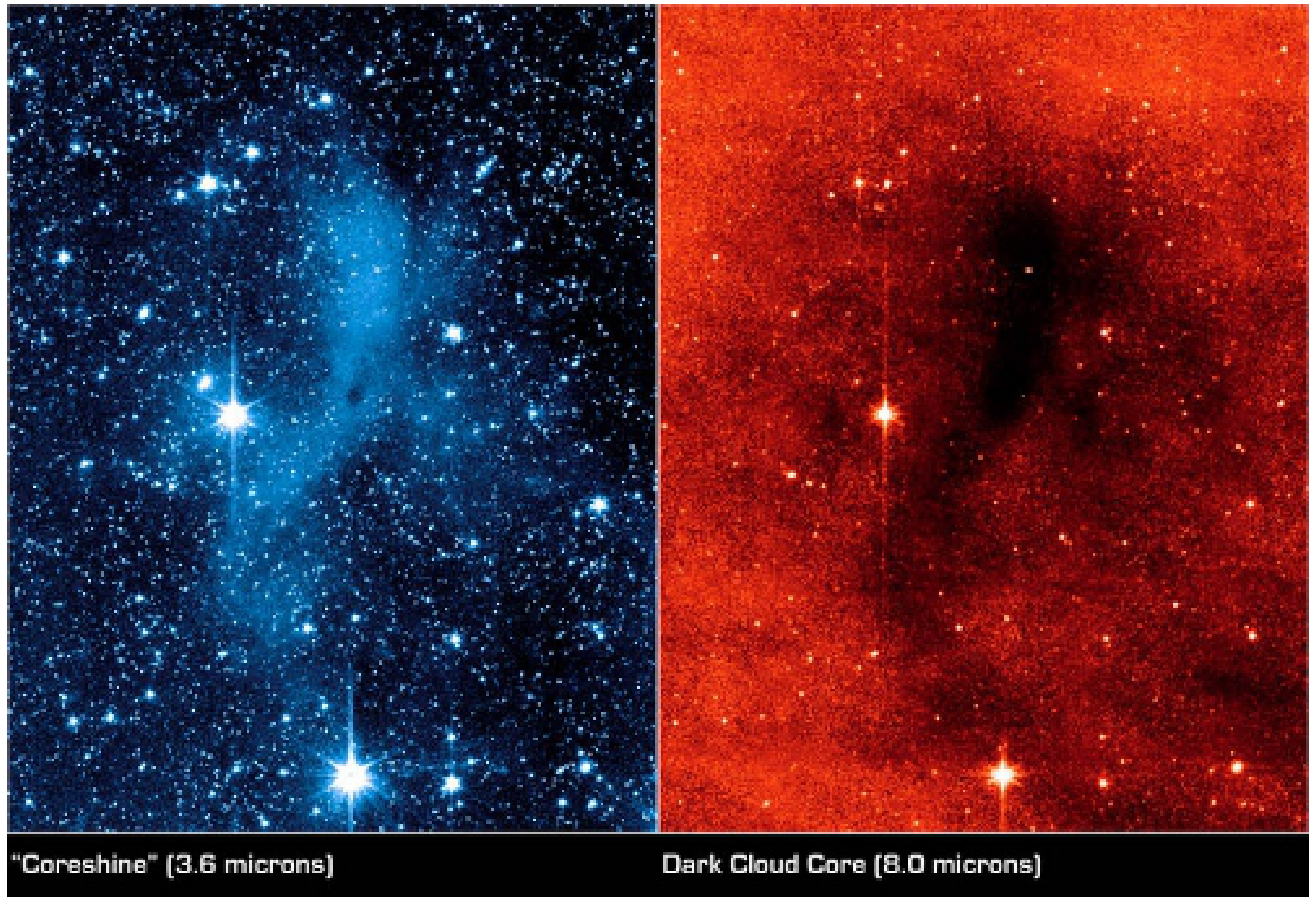




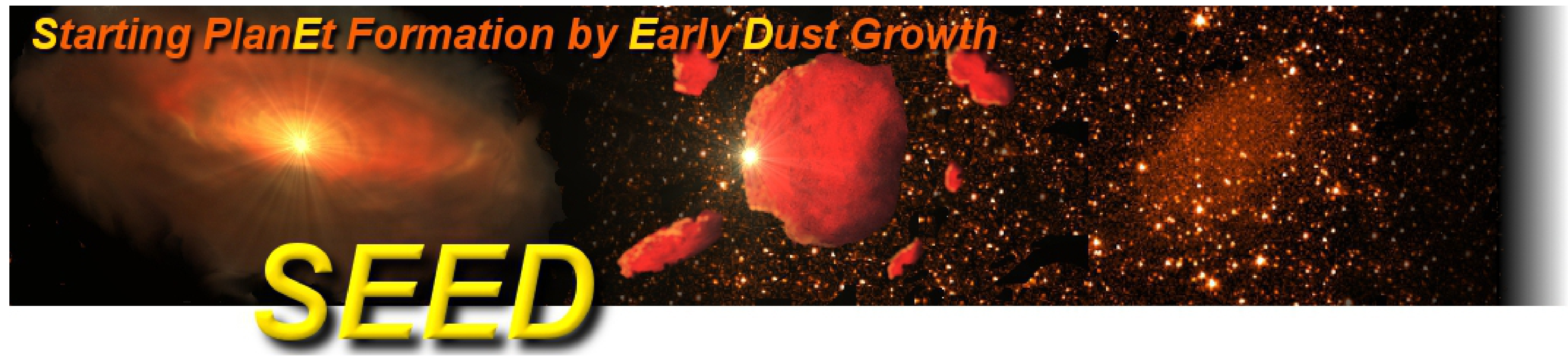
# Introduction

A team including the project leader has published papers in the journals *Science* and *Astronomy and Astrophysics* about a newly detected phenomenon called **coreshine** which is thought to be mid-infrared light scattered by big dust grains in the inner parts of molecular clouds. It indicates that dust grains as building blocks for later formed planets can already grow in molecular cloud cores even before the star formation process has started. The project SEED focusses on the exploration of the dust growth process outside the circumstellar accretion disk surrounding and feeding the young stellar object in the formation process, continuously providing a seed population of grown grains for further processing within the accretion disk.

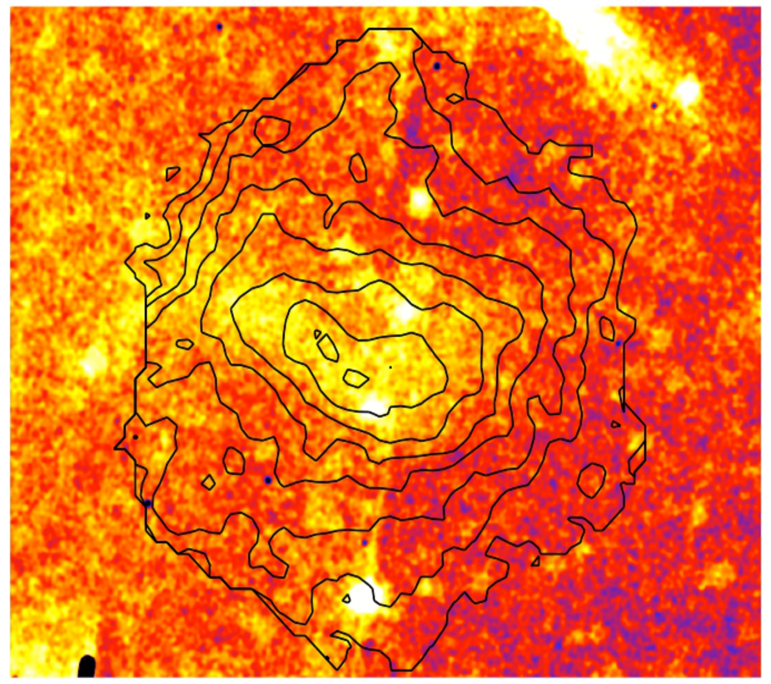
It was expected that grain growth can occur in the pre-stellar core phase already, but a direct way to measure the grain size was lacking. Hence, most calculations of the growth in the accretion disk started with a uniform size distribution of small grains as they can be detected in the low-density interstellar medium. The project makes use of 3D radiative transfer in a large parameter space. which is needed since the cores and disks are illuminated by a highly anisotropic interstellar radiation field.



The core L183 seen in coreshine and extinction (Steinacker et al. 2010).



# Results



*IRAC1 (color) and mm (contour) data of L1506C*

## Modeling of the core L1506C:
## Evidence for a primitive big-grain component or indication for a turbulent core history?

(Steinacker, Pagani, Ormel, Andersen, Bacmann, submitted)

The coreshine flux of L1506C is determined from IRAC Spitzer images at 3.6 µm. We perform grain growth calculations to estimate the grain size distribution in model cores similar in gas density, radius, and turbulent velocity to L1506C. Scattered light intensities at 3.6 µm are calculated for a variety of MRN and grain growth distributions using the DIRBE 3.5 µm all-sky map as external interstellar radiation field, and are compared to the observed coreshine surface brightness.

For a core with the overall physical properties of L1506C, no detectable coreshine is predicted with a size distribution following the shape and size limits of an MRN distribution. Extending the distribution to grain radii of about 1 µm allows to reproduce the observed surface brightness level in scattered light. Assuming the properties of L1506C to be preserved, models for the growth of grains in cores do not yield sufficient scattered light to account for the coreshine within the lifetime of the Taurus complex. Only increasing the core density and the turbulence amplifies the scattered light intensity to a level consistent with the observed coreshine brightness.

**Conclusions.**
The coreshine observed from L1506C requires the presence of grains with sizes exceeding the common MRN distribution.The grains could be part of primitive omni-present large grain population becoming visible in the densest part of the ISM, or could grow under the turbulent dense conditions of the evolving core. In the later case, L1506C must have passed through a period of larger density and stronger turbulence. This would be consistent with the surprisingly strong depletion usually attributed to high column densities, and with the large-scale outward motion of the core envelope observed today.

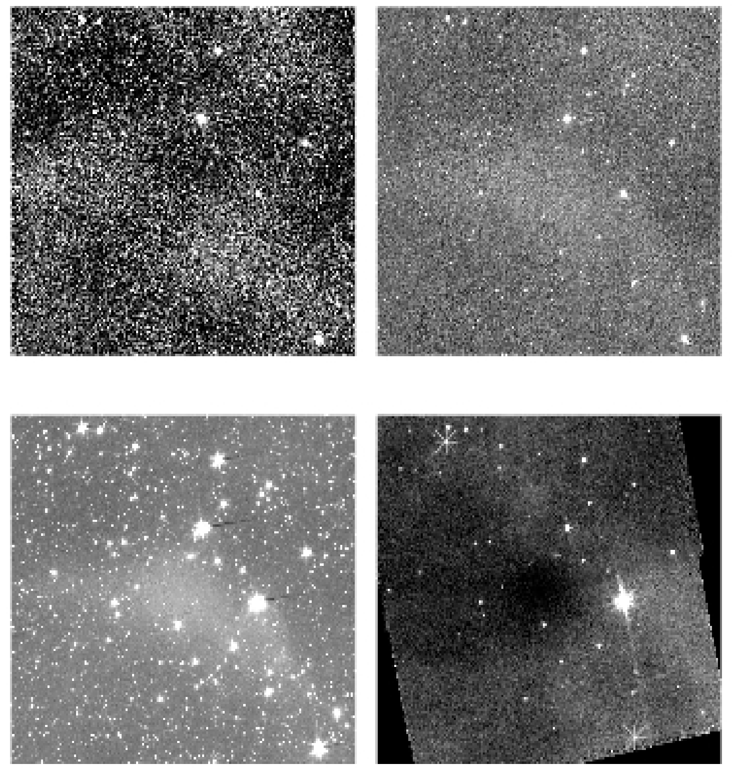


**Fig. 1.** Top from left to right: The *J*, *Ks*, *I1*, and *I4* images of L260. The centre of the core is clearly seen in the *I4* image. Note the strong absorption pattern in the *J* band compared to the *Ks* and *I1*. Marked in *I4* with two asterisks is the extent of the cuts shown in Fig 2. North is up, east to the left. The field of view of each image is $10'.8 \times 9'.8$.

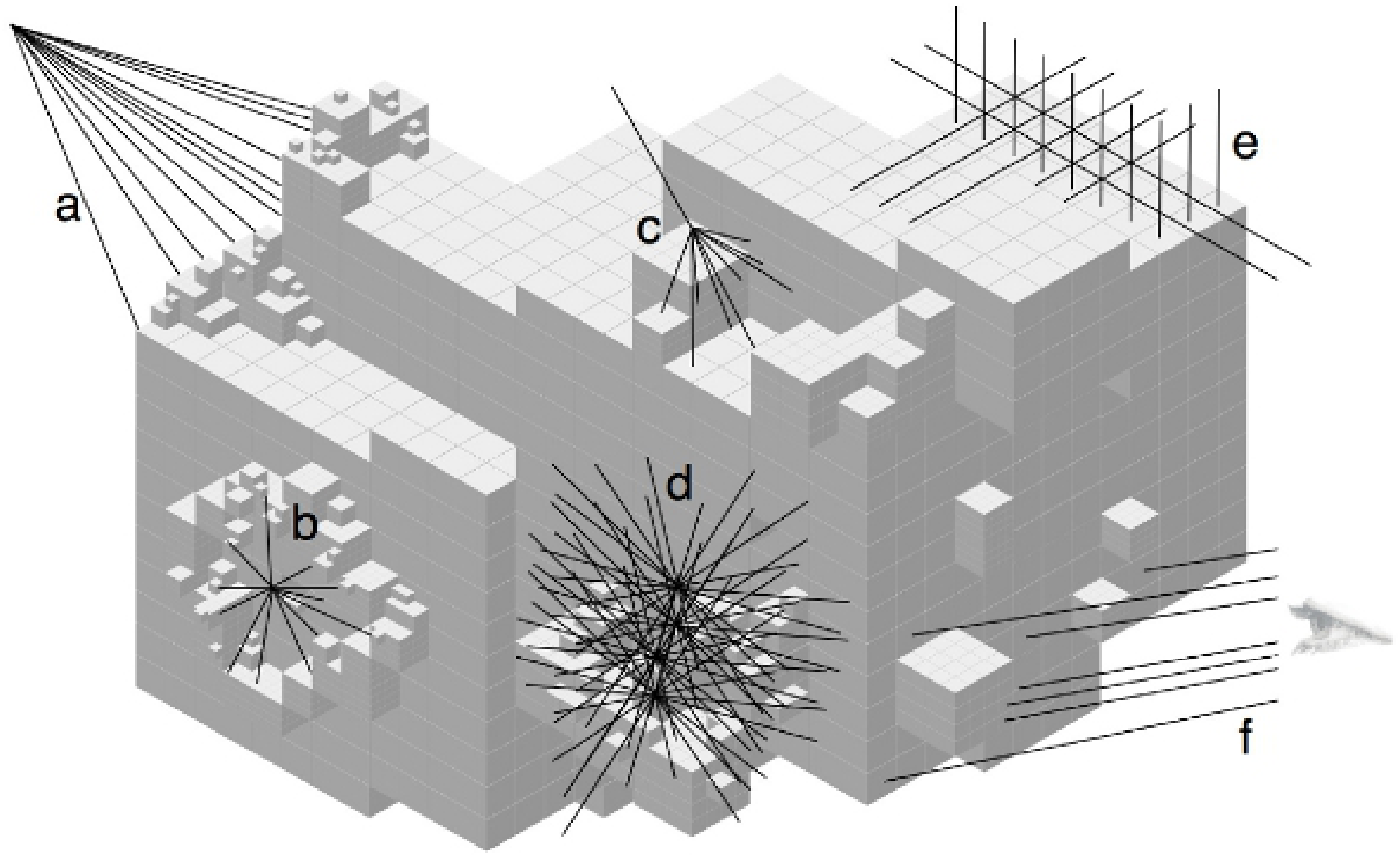
## Modeling the core L260:
## Constraining the dust grain size distribution through grainshine

(Andersen, Steinacker, Thi, Pagani, Bacmann, submitted)

We combine Spitzer IRAC and ground-based near-infrared observations to characterize the cloudshine and coreshine that appear in the core L260. Using a spatially simple one dimensional model core, we perform radiative transfer calculations to study the impact of various dust size distributions on the intensity profiles across the core.
The observed scattered light patterns in the Ks and 3.6 µm bands are found to be similar. By comparison with the radiative transfer models a comparison of the two profiles places constraints on the relative abundance of small and large (more than 0.25 µm) dust grains. The scattered light profiles are found to be inconsistent with an interstellar silicate grain distribution extending to 0.25 µm and large grains are needed to reach the observed fluxes and the flux ratios.

**Conclusions.**
In addition to observing coreshine in the Spitzer IRAC channels, the combination with ground-based near-infrared observations are suited to constrain the properties of large grains in cores.

# Results



## General overview on three-dimensional radiative transfer that includes cosmic dust

***Annual Reviews of Astronomy and Astrophysics:***

### *3D Dust Radiative Transfer*

(Steinacker, Baes, Gordon, arXiv: 1303.4998)

Cosmic dust is present in many astrophysical objects, and recent observations across the electromagnetic spectrum show that the dust distribution is often strongly three-dimensional (3D). Dust grains are effective in absorbing and scattering ultraviolet (UV)/optical radiation, and they re-emit the absorbed energy at infrared wavelengths. Understanding the intrinsic properties of these objects, including the dust itself, therefore requires 3D dust radiative transfer (RT) calculations.

Unfortunately, the 3D dust RT problem is nonlocal and nonlinear, which makes it one of the hardest challenges in computational astrophysics. Nevertheless, significant progress has been made in the past decade, with an increasing number of codes capable of dealing with the complete 3D dust RT problem. We discuss the complexity of this problem, the two most successful solution techniques [ray-tracing (RayT) and Monte Carlo (MC)], and the state of the art in modeling observational data using 3D dust RT codes. We end with an outlook on the bright future of this field.

Literature:

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