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Imaging the inner regions of debris disks with near-infrared interferometry

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Abstract

Most debris disks resolved so far show extended structures located at tens to hundreds AU from the host star, and are more analogous to our solar system's dusty Kuiper belt than to the ~AU-scale zodiacal disk inside our solar system's asteroid belt. Over the last few years however, a few hot debris disks have been detected around a handful of main sequence stars thanks to the advance of infrared interferometry. The grain populations derived from these observations are quite intriguing, as they point towards very high dust replenishment rates, high cometary activity or major collisional events. In this talk, we review the ongoing efforts to detect bright exozodiacal disks with precision near-infrared interferometry in both hemispheres with CHARA/FLUOR and VLTI/PIONIER. We discuss preliminary statistical trends on the occurrence of bright exozodi around nearby main sequence stars and show how this information could be used to constrain the global architecture and evolution of debris disks.

1. Introduction

First discovered by the InfraRed Astronomical Satellite, the presence of debris disks around other main sequence stars is now widely attested. At the sensitivity level of the Spitzer telescope (2 orders of magnitude above the luminosity of our Kuiper Belt), about 30% of A-type stars and 15% of solar-type stars (FGK) show evidence for far-infrared excesses on top of the stellar flux due to the thermal radiation of cold dust grains, arranged in "debris disks" [6]. Some of these disks have been resolved by visible or sub-millimeter imaging, generally showing a lack of dust in their inner parts. This inner void may be the result of dynamical interactions with unseen planets, but nonetheless, the presence of small amounts of dust in inner planetary systems is expected, due to asteroidal collisions and comet evaporation. Whether hot (~1000 K) or warm (~300 K) dust is actually present in observable quantities in these systems has been an important question for several years. However, neither aperture photometry nor single-pupil infrared imaging have been able to answer that question, due to their lack either of accuracy (>1%) or of angular resolution (hot dust is within 100 mas from its parent star). Recently, infrared interferometry has provided the first unambiguous resolved detection of hot dust around main sequence stars [1], showing an unexpectedly dense population of (sub) micrometric dust grains close to their sublimation temperature (see Figure 1). This discovery raises challenging questions on the origin and physical properties of such dust grains, which should theoretically be expelled from the inner part of the disk within a few years due to radiation pressure, or destroyed by mutual collisions. Furthermore, because future missions for spectroscopic characterization of exo-Earths could be severely affected by exozodiacal light, the systems with the strongest dust emission need to be identified and characterized.

2. The ongoing survey

Following the pioneering (and recently confirmed [4]) detection of exozodiacal dust around Vega in 2005 [1], a survey of nearby main-sequence stars has been initiated at the CHARA array with the FLUOR beam combiner. The survey includes a magnitude-limited sample (K<4) of 60 stars, among which 35 are known to have cold dust. The first results have been published [2, 3, 5] and show the presence of a resolved near-infrared emission in the first AU around four more targets (namely τ Ceti, ζ Aql, β Leo, ζ Lep). About 40 targets have been observed today and the preliminary results already indicate some interesting statisti-

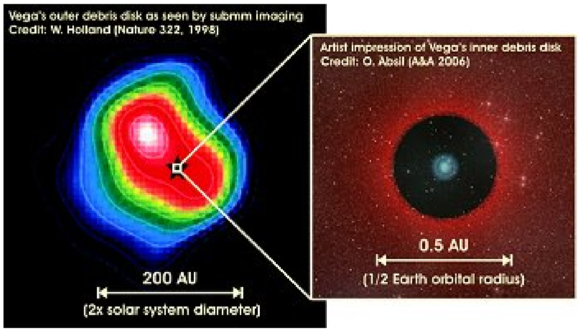

Figure 1: Artist impression of Vega exozodiacal dust (right panel) concentrated close to the dust sublimation radius (a few ∼0.1 AU, depending on grain size). The sub-millimeter image (left panel) emanates from a dusty analog to our Kuiper belt, sculpted by a hidden planet, and that may be the mass reservoir for the observed exozodiacal dust.

cal properties (see Figure 2):

- **Frequency versus spectral type.** Early type stars are more likely to present an infrared excess with 43±13% for A-type stars, 27±13% for F-type stars and 7±7% for G- and K-type stars.
- **Frequency versus presence of cold dust.** No significant correlation is presently found in the sample of observations. An infrared excess has been detected around 27±9% of stars with cold dust and 24±10% with no cold dust.

This survey is now complemented by observations in the Southern hemisphere with the PIONIER instrument at the VLTI. We plan to extend the survey to a sample of at least 200 targets. We will present the first results and prospects of this ongoing project.

3. Summary and Conclusions

Infrared stellar interferometry at the CHARA array is currently providing statistical results about the occurrence of exozodiacal dust disks around nearby main-sequence stars. Although in some cases the presence of a binary companion could not be ruled out (e.g. ζ Aql), 10 target stars (out of 40 observed so far) present a resolved near-infrared excess which is believed to emanate from hot dust grains located within the first AU of the system. The detected disks are much hotter and massive than the zodiacal cloud which raises several questions about the origin of the dust and the possible replenishment mechanisms. Current scenarios suggest that the detected populations are most likely produced by isolated catastrophic events (e.g., major asteroid collision, break-up of a massive comet), or by major dynamical perturbations such as the “falling evaporating bodies” phenomenon in the β Pic inner disk or the Late Heavy Bombardment that happened early in the history of our own planetary system.

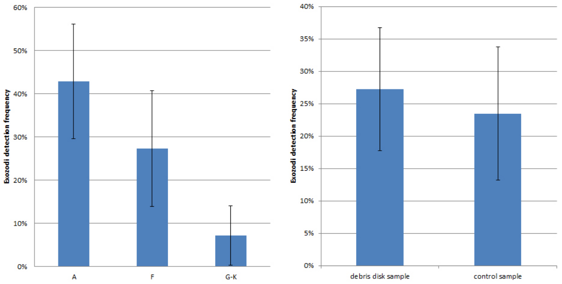

Figure 2: Preliminary results of our survey given as the occurence of exozodiacal disks with respect to the spectral types (left panel) and the presence or not of cold dust (right panel).

Acknowledgements

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