Unraveling the mystery of exozodiacal dust

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Our EXOZODI project is funded by the French National Research Agency (ANR)

Overview

Exozodiacal dust clouds are thought to be the extrasolar analogs of the Solar System's zodiacal dust. Studying these systems provides insights in the architecture of the innermost regions of planetary systems, including the habitable zone. Furthermore, the mere presence of the dust may result in major obstacles for direct imaging of earth-like planets. Our EXOZODI project aims to detect and study exozodiacal dust and to explain its origin. We are carrying out the first large, near-infrared interferometric survey in the northern (*CHARA*/FLUOR) and southern (*VLTI*/PIONIER) hemisphere. Preliminary results suggest a detection rate of up to 30% around A to K type stars and interesting trends with spectral type and age. In addition to the statistical analysis of our survey results, detailed modeling studies of single systems, modeling of possible dust creation mechanisms and the development of next-generation modeling tools dedicated to address the mystery of exozodiacal dust are main tasks of our project.

Questions?

Get in touch!

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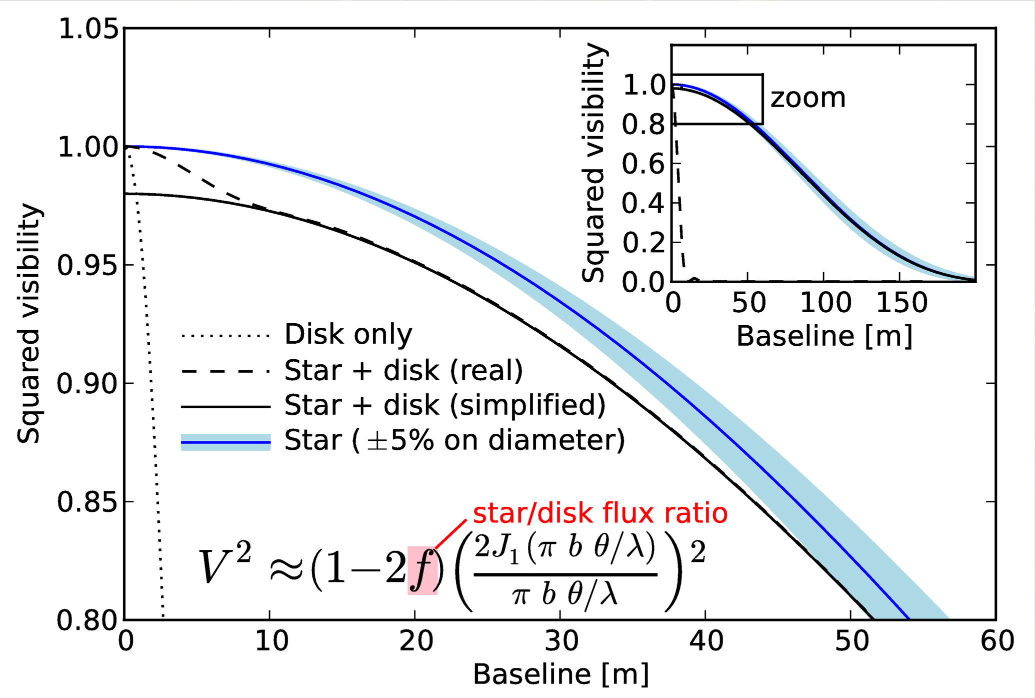
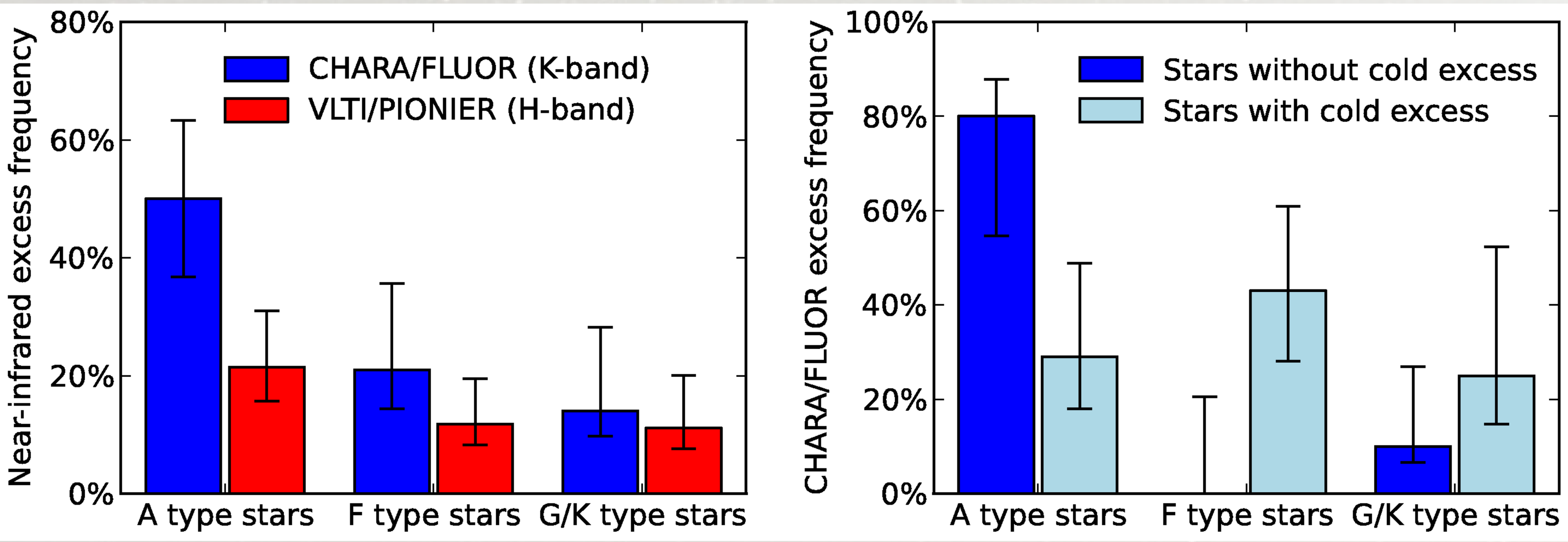
How to detect an exozodi?



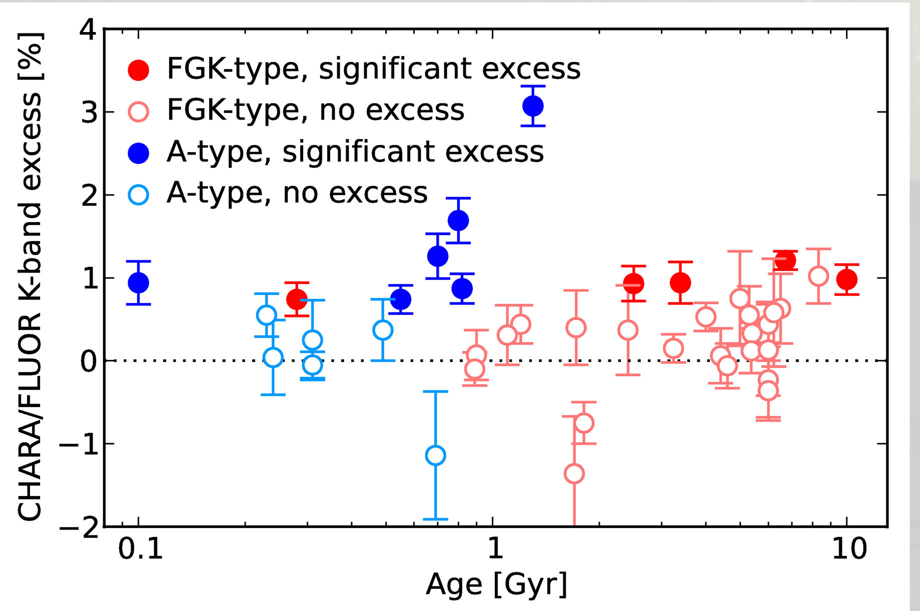
The thermal emission from hot exozodiacal dust (typically several hundred Kelvin up to the sublimation temperature) result in a near-infrared excess above the stellar flux (typically 1% for known systems). This accuracy is not reachable by simple photometry. It is necessary to spatially disentangle the dust and stellar emission. As the emission extends up to only a few hundred milli-arcseconds for nearby stars, this is only reachable by interferometry. At short baselines (~ 10 to 40 m), considering fully extended (incoherent) dust emission around a nearly unresolved star, the emission results in a visibility drop equal to twice the disk/star flux ratio [1].

An all-sky, near-IR survey for exozodiacal dust

We are carrying out the first large, near-infrared interferometric survey for exozodiacal dust. We are using the *CHARA*/FLUOR instrument in K band in the northern hemisphere and our *VLTI* visitor instrument PIONIER in H band in the southern hemisphere. A total of ~ 200 stars will finally be surveyed. Observing strategy and target selection are designed for combining the data to a large, statistical, and unbiased sample. A first sample of targets observed with CHARA consisting of 42 stars ($K < 4$) has just been accepted for publication [2]. The PIONIER sample (89 stars with $H < 5$) has been observed and the data are under analysis [3]. Detection statistics are shown below (preliminary for the PIONIER sample). Differences are most probably due to differences in sensitivity and lower excess in H band.

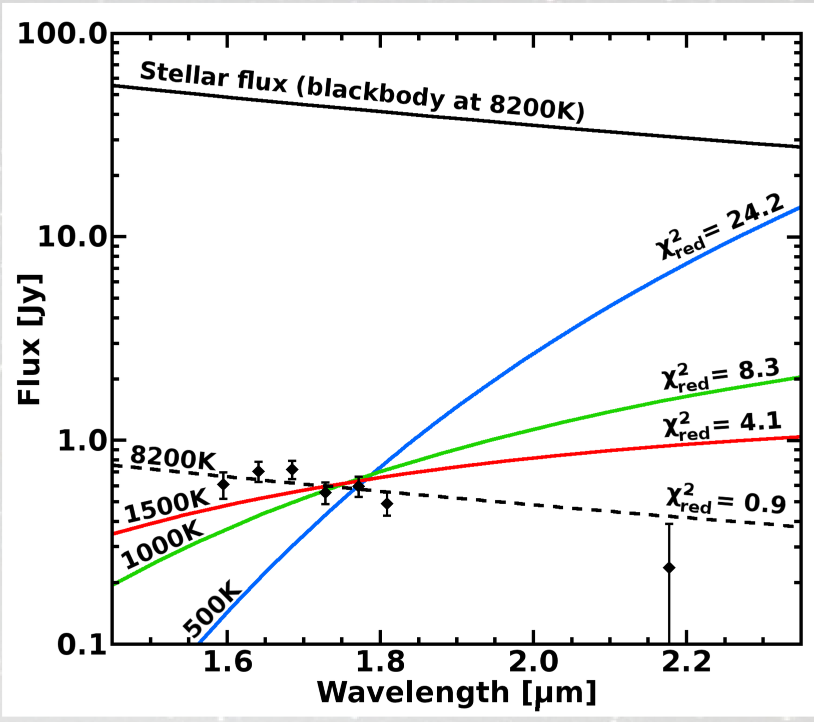


Our magnitude limited sample allows for statistical investigation of correlations of the detection rate and excess levels with other parameters such as the stellar age, spectral type, or presence of cold dust that could serve as a reservoir replenishing the dust.



The most intriguing results so far are the fact that not only stars with an outer reservoir harbor exozodiacal dust and that there is no significant correlation of the excess levels with the age of the star [2, 3]. This would be expected in analogy to the well known trend in normal debris disks if the dust was produced in a steady state collisional process of larger bodies over the whole age of the system locally or in an outer debris disk serving as a reservoir.

Detailed modeling of single systems

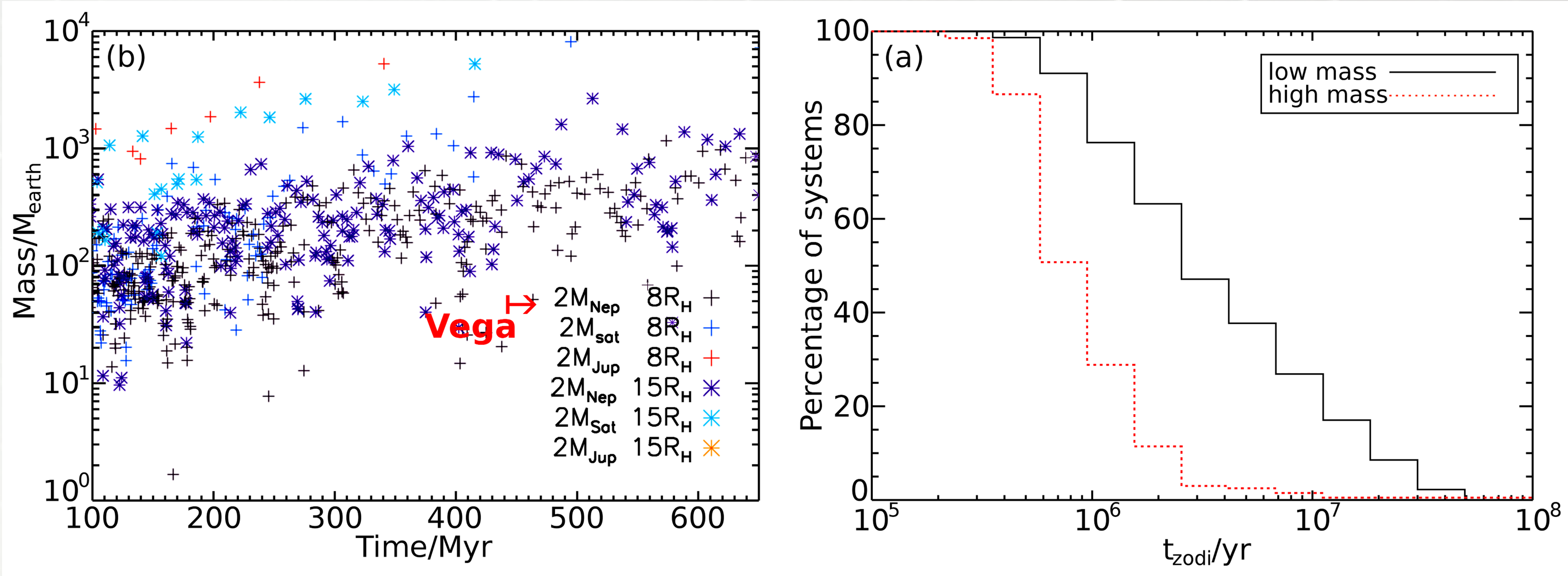


In addition to the statistical investigation of our survey sample, we study in detail systems that are of particular interest. This figure shows the spectral shape of the exozodiacal dust emission around β Pictoris [4]. The emission is very hot (~ sublimation) and includes a significant fraction of scattered stellar light in addition to thermal emission because of the edge-on orientation of the disk (cold dust on the line of sight). Other objects studied in detail are Vega [5, 6] and Fomalhaut [7].

Theoretical investigation

Explaining the high levels of dust observed is difficult, as it has a short lifetime (collisions, radiative forces). One origin could be in an outer planetary system. However, numerical simulations show that the *scattering inwards from an outer planetesimal belt by a chain of planets* is not sufficiently efficient to retain the high levels of dust observed after millions of years of evolution (*left* on the example of Vega, [8]).

Alternatively, we might be observing the *aftermath of a dynamical instability*, similar to the Solar System's LHB. Such events produce high levels of dust, but for a short period, making it highly unlikely that we detect > 0.06% of such systems (*right*, [9]).



Still, the interaction of an outer debris disk with planets in the system is promising to explain hot excess in most systems. To study such interactions, we are developing the new tools DyCoSS [10, 11] and LIDT-DD [12]. The latter is – for the first time – accurately simulating the collisional evolution and interaction of the dust with planets simultaneously and in a fully consistent way.

Future observational perspectives

The results from our survey as well as the state-of-the-art instruments and observing strategies used allow for important and promising observational studies. Using *VLTI*/PIONIER and in the near future *VLTI*/GRAVITY and *VLTI*/MATISSE, our team is currently working on the following topics:

- Multi-wavelength observations constraining temperatures of known exozodis
- Time variability of known exozodis on time scales of years
- Detailed studies of the hot dust in prominent debris disks
- The connection between warm mid-IR and hot near-IR excess

References: [1] Di Folco et al. 2007; [2] Absil et al. 2013; [3] Ertel et al., in prep.; [4] Defrère et al., 2012; [5] Absil et al., 2006; [6] Defrère et al., 2011; [7] Lebreton et al., 2013; [8] Bonsor et al., 2012; [9] Bonsor et al., 2013; [10] Thébault 2012; [11] Thébault et al., 2012; [12] Kral et al., submitted