Mid-infrared imaging of exo-Earths: impact of exozodiacal disk structures

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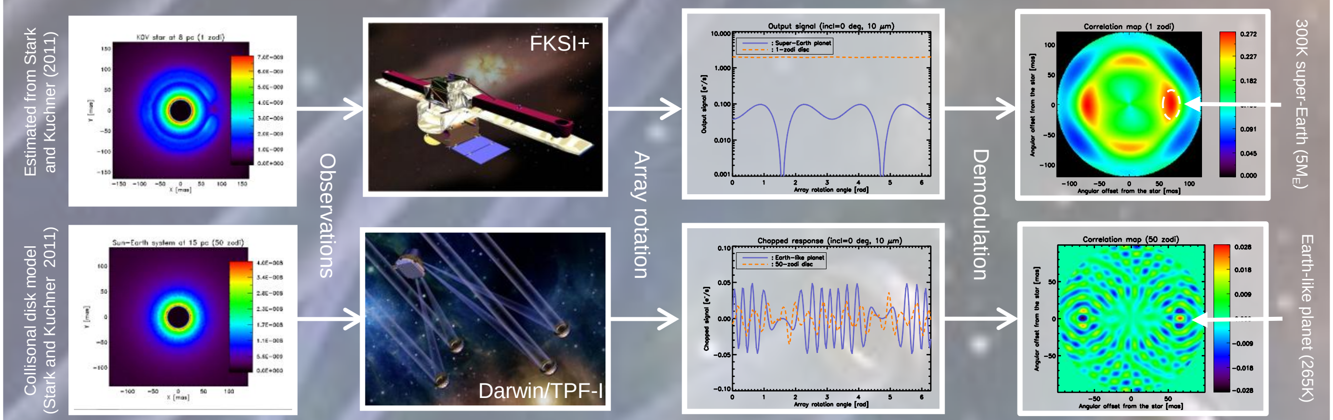
Abstract

The characterization of Earth-like extrasolar planets in the mid-infrared is a significant observational challenge that could be tackled by future space-based interferometers. The presence of large amounts of exozodiacal dust around nearby main sequence stars represents however a potential hurdle to obtain mid-infrared spectra of Earth-like planets. Whereas the disk brightness only affects the integration time, the emission of dust structures mixes with the planet signal at the output of the interferometer and could jeopardize the spectroscopic analysis of an Earth-like planet. Fortunately, the high angular resolution provided by space-based interferometry is sufficient to spatially distinguish most of the extended exozodi emission from the planetary signal and only the dust located near the planet significantly contributes to the noise level. Considering modeled resonant structures created by Earth-like planets, we address in this talk the role of exozodiacal dust in two different cases: the characterization of Super-Earth planets with single space-based Bracewell interferometers (e.g., the FKSI mission) and the characterization of Earth-like planets with 4-telescope space-based nulling interferometers (e.g., the TPF-I and Darwin projects). In each case, we derive constraints on the disk parameters that can be tolerated without jeopardizing the detection of Earth-like planets.

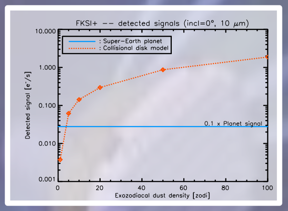
Instrument specifications

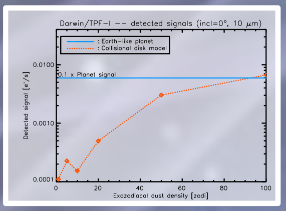
	FKSI +	DARWIN/TPF-I
Configuration	Bracewell	Emma X-array (1:6)
Aperture diam.	2 x 1 m	4 x 2 m
Baseline	20 m	5 x 30 m to 67 x 400 m
Wavelength	5 – 15 µm	6 – 20 µm
Main science goal	Super-Earth planets around nearby K and M stars (<10pc)	Earth-like planets around F, G, K, and M stars (< 30 pc)

Impact of disk structures on planet detection at 10-µm



Constraints on dust density





- **FKSI+**
  - Super-Earth @ 300K (10-σ, K0V at 8pc) : 4 zodis
  - Number of false positives at 5-σ : 0
- **Darwin/TPF-I**
  - Earth-like @ 265K (10-σ, G2V at 15pc) : 90 zodis
  - Number of false positives at 5-σ : 0

Summary and conclusion

Using the new collisional disk model developed by Stark and Kuchner (2011), we assess the impact of resonant dust structures in circumstellar disks on the detection at 10-µm of embedded terrestrial planets. Compared to our previous study that did not take into account grain-grain collisions (Defrère et al. 2010), the constraints on the dust density are relaxed and an exozodiacal disk **90 times denser that the solar zodiacal cloud** can be tolerated in order to ensure the 10-σ detection of an Earth-like planet orbiting in the habitable zone of a Sun located at 15 pc with a four-telescope mid-IR nulling interferometer (e.g., Darwin/TPF-I). With a more compact array, it is more difficult to distinguish the planet from disk structures due to the lower angular resolution. For instance, the tolerable dust density goes down to about 5 times the solar zodiacal density to detect at the 10-σ level a super-Earth (5 M_E) orbiting in the habitable zone of a K0V star located at 8 pc with a two-telescope nulling interferometer (e.g., an upgraded FKSI).

References

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