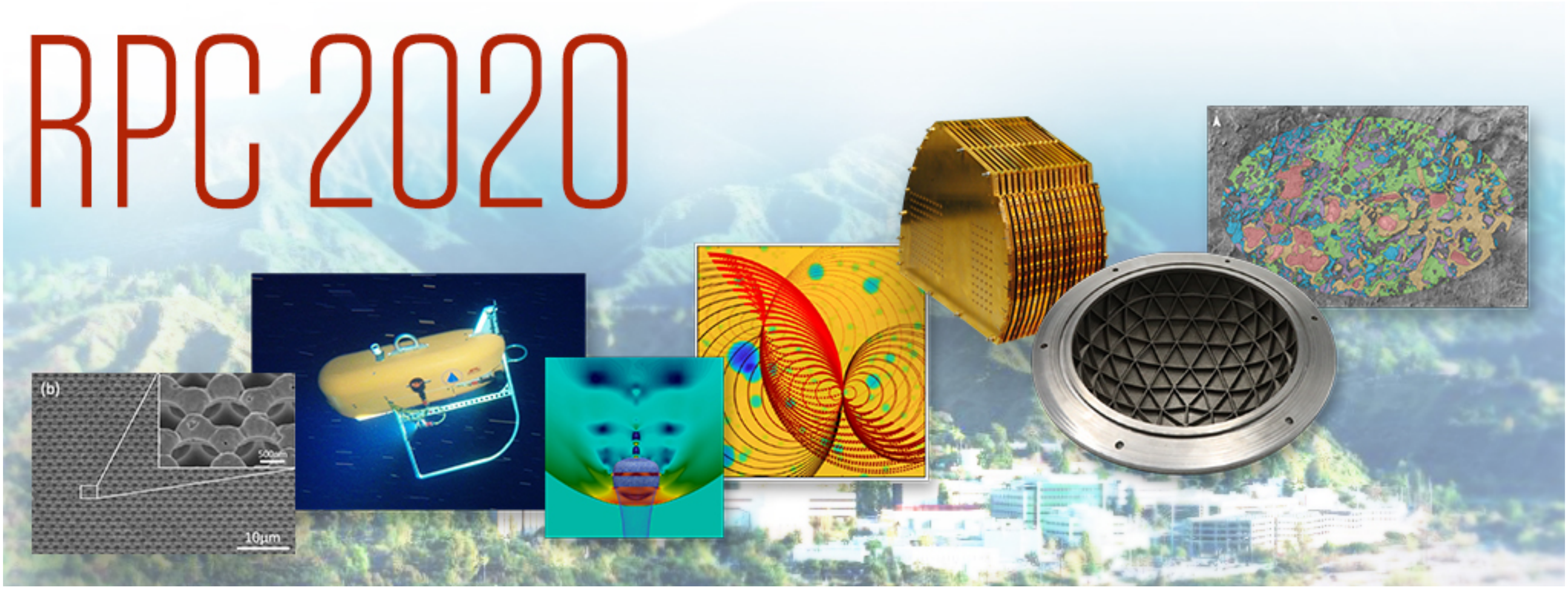

Virtual Research Presentation Conference

Debris Disk Composition: Probing Terrestrial Planet Formation

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Program: Strategic Initiative—Exoplanet Science Initiative

Assigned Presentation # RPC-026

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Tutorial Introduction

Abstract

Sub-blowout AstroSil grains ($a_{min} < a_{BOS}$) have been identified in the terrestrial-planet environments around 46 of 49 two-belt debris disk systems around A- and Solar-type stars. These debris disks have low-resolution 5-35 microns *Spitzer*/IRS spectroscopic detections from dust in an inner/warm asteroidal belt, and photometric measurements from an outer/cold Kuiper-like belt that is also spatially resolved with *Herschel*/PACS at 70 and/or 100 microns. The resolved outer/cold dust locations and the shape of the SED help constrain the outer/cold grain size distribution and composition (as icy) for each debris system. Thus, by adopting a weighted stacking technique on the IRS spectra, and by subtracting the flux contributions of 1) the star using a synthetic stellar NextGen model, 2) the outer/cold, and 3) the inner/warm dust components of each star+disk system, we readily recognize the presence of a population of sub-blowout inner/warm grains in the composite spectra, that is well modeled (ChiSqr ~ 1) using AstroSil emissivities (rocky material). Our result points at evidence of recent catastrophic events in the terrestrial-planet zones around these mature stars (median age ~100 Myr), reminiscent of the solar system's late heavy bombardment.

Problem Description

a) OBJECTIVE: The objective of this project was to explore the terrestrial-planet zone composition of dust grains in two-belt debris disks where the existence of a Kuiper-like belt has been confirmed and spatially resolved. By applying and further developing existing algorithms to probe the Spitzer/IRS 5-35 micron spectroscopic data on 49 debris disk system with spatially resolved Herschel/PACS detections, we explored the properties on the warm inner/dust grains and the relationship between the warm and cold dust. Our scientific goal is to 1) advance our understanding of the architecture and evolution of debris system—environments where planets are interacting and forming, while focusing on the exploration of the terrestrial-planet zones.

b) RELEVANCE: Our proposed effort addresses the primary goals of the NASA Exoplanet Exploration Program, “to discover and characterize planetary systems and Earth-like planets around nearby stars.” Assessing the distribution and impact of exozodiacal dust in the context of exoplanets is an essential element in planning any future exoplanet mission, in particular one that will aim at habitable planets and finding evidence of life. We set out to characterize the circumstellar environment where terrestrial planets form. The work described here provides a set of well-characterized targets and an expanded modeling capability in preparation for follow-up observations with JWST and WFIRST.

Methodology

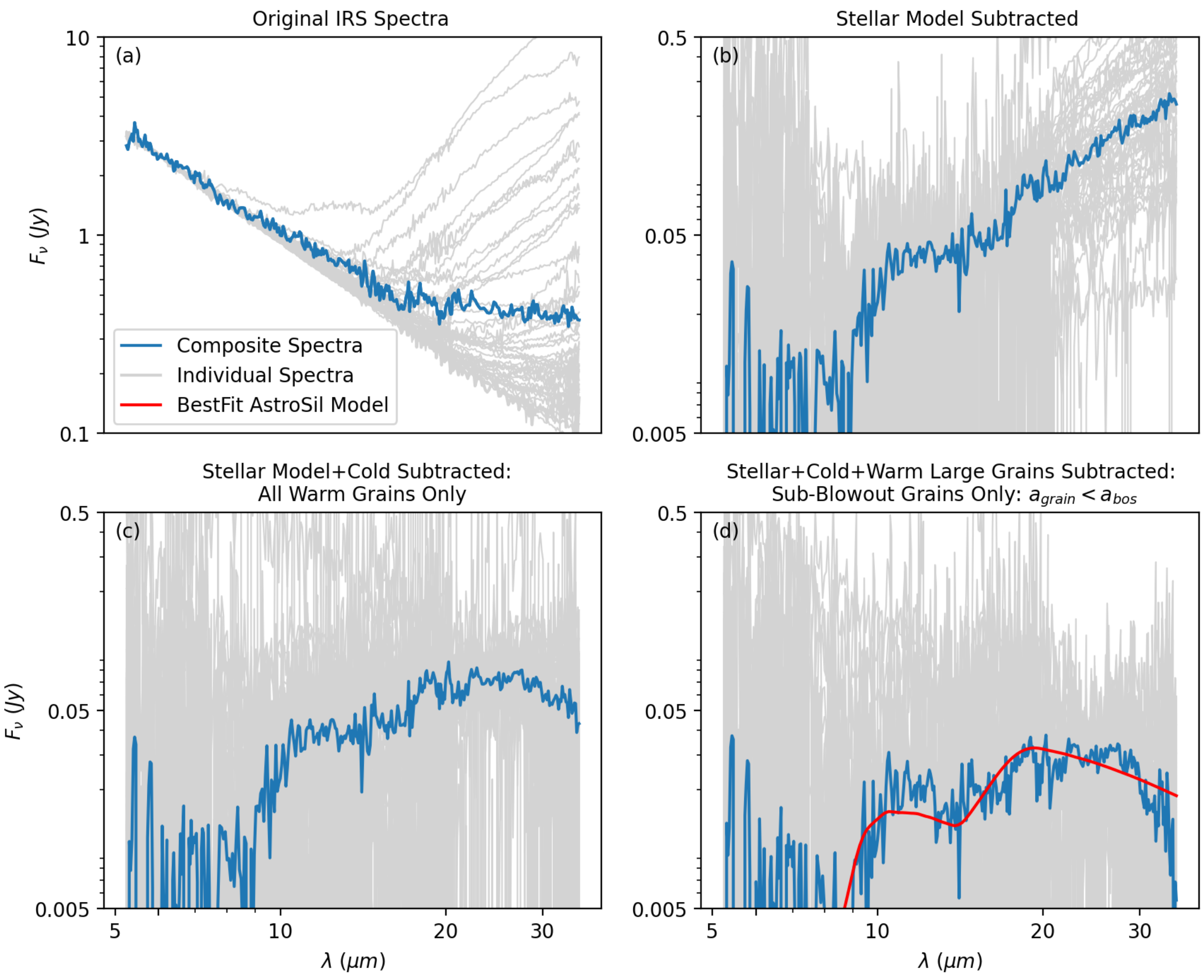
This project consisted of two tasks chosen to exploit and expand on our ability to model in detail individual debris systems, and to analyze data from a large set of stars. We augmented our existing SED analysis tools in two ways: 1) to include a module to identify spectral features (including organic molecules that may be present between 5 and 35 microns, and 2) to adopt a weighted stacking technique of the spectroscopic data, to enhance faint features that may be common among these systems.

a) We developed detailed models for SED analysis of *Spitzer*+*Herschel* photometry and spectra of debris disks with a range of particle sizes and compositions, including ice/rock mixtures. Unambiguous modeling, however, requires resolved images, without which there is a degeneracy between grain size and orbital location. Our SED modeling includes *Herschel* photometric and spatial information to help constrain the best-fit model

b) In addition, by adopting a weighted stacking technique on the Spitzer/IRS spectra, and by subtracting the flux contributions of 1) the star using a synthetic stellar NextGen model, 2) the outer/cold, and 3) the inner/warm dust components of each star+disk system (Figure 1), we readily recognize the presence of a population of sub-blowout inner/warm grains in the composite spectra (Figure 2), that is well modeled using AstroSil emissivities (rocky material).

Results

- The resolved outer/cold dust locations and the shape of the SED help constrain the outer/cold grain size distribution and composition (as icy) for each system despite the absence of narrow spectral features for ice.
- The figure shows the composite spectrum for each thermal profile (blue), plotted over a fan of the 49 individual profiles (gray).
- AstroSil is readily identified by its ~10 and ~20 micron spectral features.

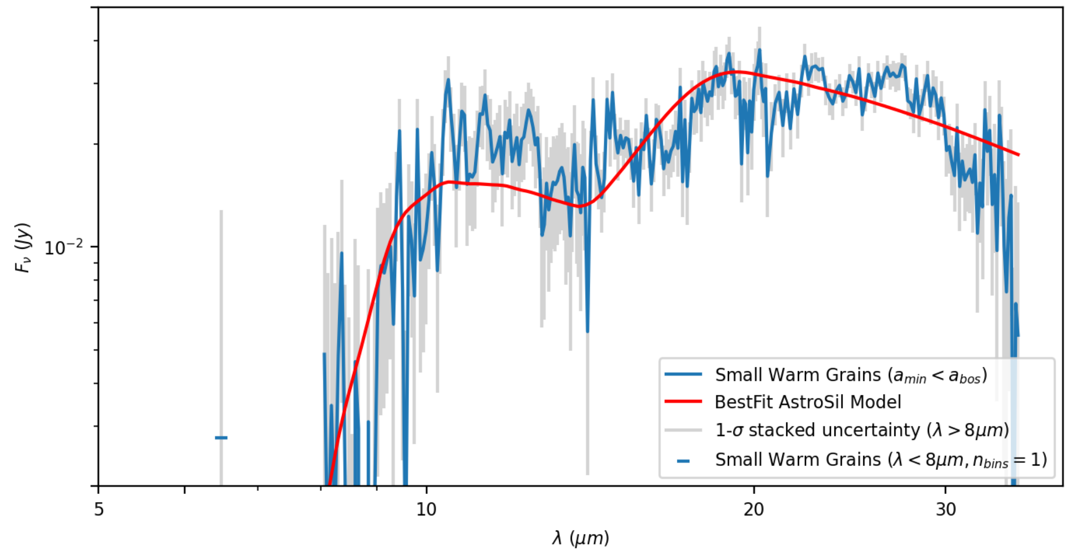


Results

- Small ($a_{min} < a_{bos}$) warm AstroSil grains are present in the composite spectrum (blue). 1-sigma stacked uncertainties shown in gray.

➔ Overall, the combined *Spitzer*/*Herschel* observations, were used to establish the presence of sub-blow out rocky (AstroSil) grains, in the terrestrial-planet environments around 46 of 49 two-belt debris disk systems around A- and Solar-type stars

➔ Our result points at evidence of recent catastrophic events in the terrestrial-planet zones around these mature stars (median age ~100 Myr), reminiscent of the solar system's late heavy bombardment



- Knowing of the characteristics of circumstellar dust around nearby stars has given JPL observers a competitive advantage for follow-up observations with *Palomar*, *Keck*, *HST*, and *LBTI, Spitzer*, *Herschel*, and *WISE* detections.
- Going forward, a well-characterized sample of debris disks will be useful for future missions by 1) placing spatially unresolved warm dust detections into context with surrounding cold dust, and 2) improving our understanding of dust transport into the habitable zone, a major design constraint for future terrestrial imaging mission

Publications and References

PUBLICATIONS

Farisa, Morales, “ASTROSIL DETECTED FROM THE TERRESTRIAL PLANET ENVIRONMENTS OF TWO- BELT DEBRIS DISKS,” *ApJ,* in prep for submission in 2020.

REFERENCES

Farisa, Morales, “HERSCHEL-RESOLVED OUTER BELTS OF TWO-BELT DEBRIS DISKS—EVIDENCE OF ICY GRAINS,” *ApJ,* 831:97, 2016 November 1, 29pp.