Sequencing Debris Disks Spectra: Relationships between Disks and their Host Stars

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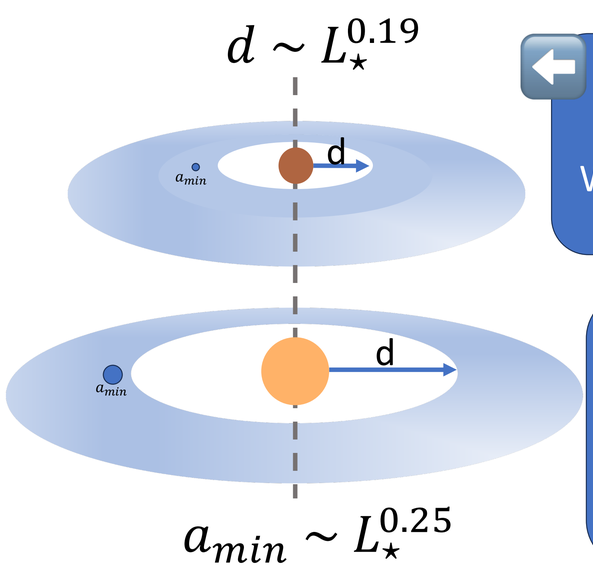
ABSTRACT

Planetary systems‘ formation and evolutionary history are imprinted in dust grain composition and properties in debris disks. Since Spitzer has played a definitive role in characterizing debris disk dust composition, we delve into the most comprehensive debris disk spectra catalog to investigate (1) whether debris disks are classified into two compositionally different types and (2) the relationship between disk composition and their host star properties. Our findings reveal a continuous range of disk mineralogy, ranging from the archetypal “silicate-dominated” and “silica-dominated” systems to those displaying a mixed ratio of dust compositions. We discover that disk mineralogy has no significant correlation with age of the systems. This result implies that large collisions events can happen at any time during the age of planetary system and produces dust that potentially dominate the mineralogy of the disk. Furthermore, contrary to the positive correlation between stellar luminosity and distance to inner edge of parent planetesimals from ALMA observations, we find no correlation between the micron-sized dust properties with stellar luminosity in the MIR wavelengths. The lack of correlation implies that micron-sized dust production mechanism operates on a much shorter timescales than their removal mechanism.

SCIENCE QUESTIONS



Background: Minimum grain sizes (a_min) and distance to inner edge of disk is correlated with host star luminosity (Mittal+15, Matra+18).

What about dust composition? Is dust composition host star luminosity correlated in debris disks?

Background: Previous works have shown 2 distinct groups compositions -- silica and silicates in debris disk (Morlok+14). The presence of silica indicates hypervelocity collisional events such as the Earth-moon forming giant impact (Lisse+07, Lisse+12). Such terrestrial planets formation activity are hypothesized to happened around ~30-100Myr in our solar system.

Is the disk composition correlated with the system age?

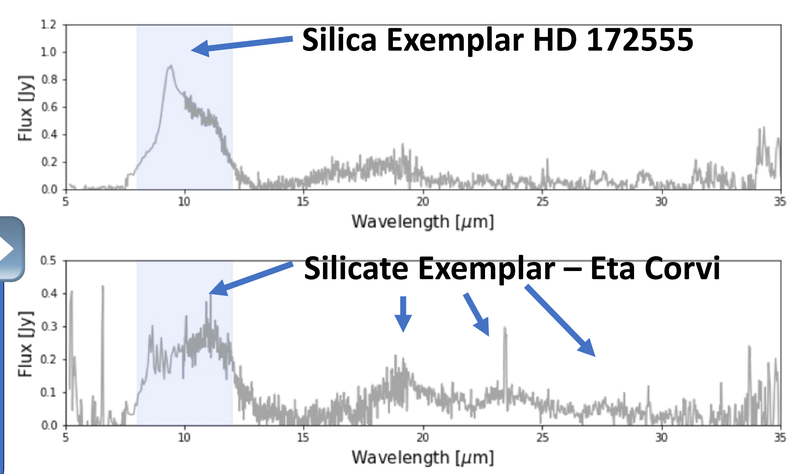


Figure 1.Two Exemplar debris disks showcasing silica and silicate compositions.

METHOD

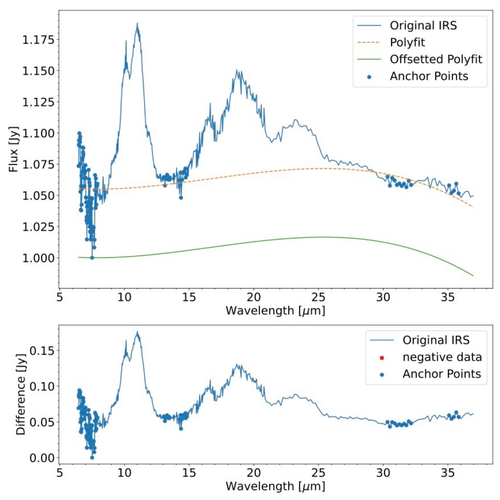


Figure 2. An Example of input IRS spectra and its continuum fitting and subtraction.

Data In

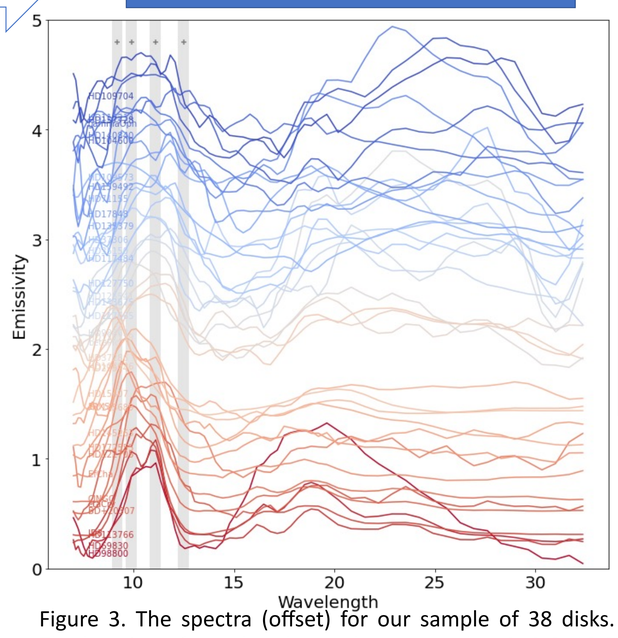
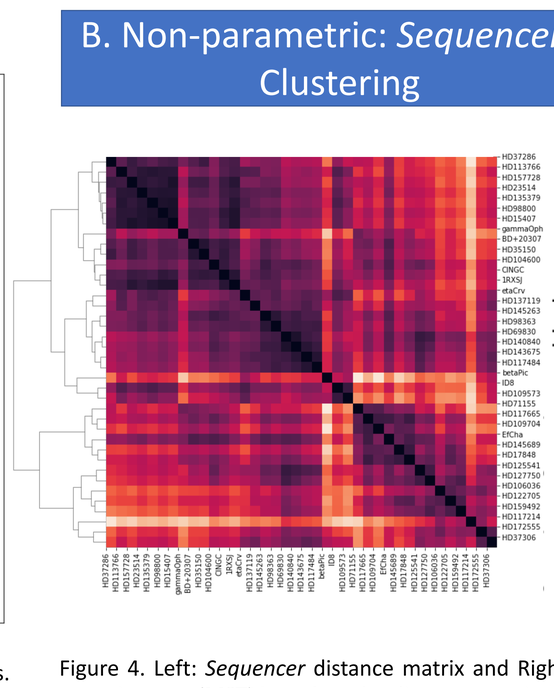


Figure 3. The spectra (offset) for our sample of 38 disks. The location of gray bands are the centered at 9, 9.6, 10.8 and 11.4 μm and their integrated line flux are used to calculate band ratio for Fig 6 and 7.



Model Out

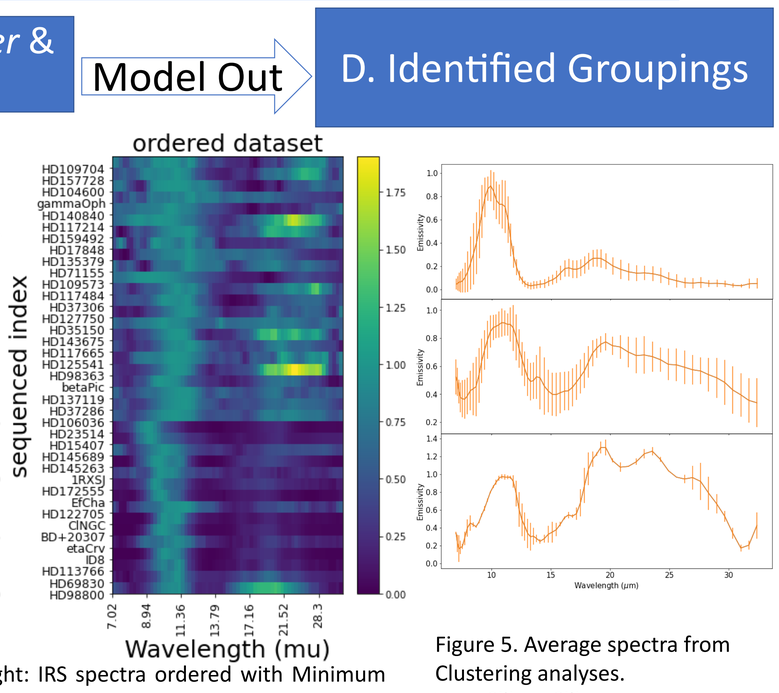


Figure 4. Left: *Sequencer* distance matrix and Right: IRS spectra ordered with Minimum spanning tree (MST) based on the distance matrix.

Figure 5. Average spectra from Clustering analyses. Top: Silica +Silicate, Middle: Amorphous Silicates Bottom: Crystalline silicates.

RESULTS

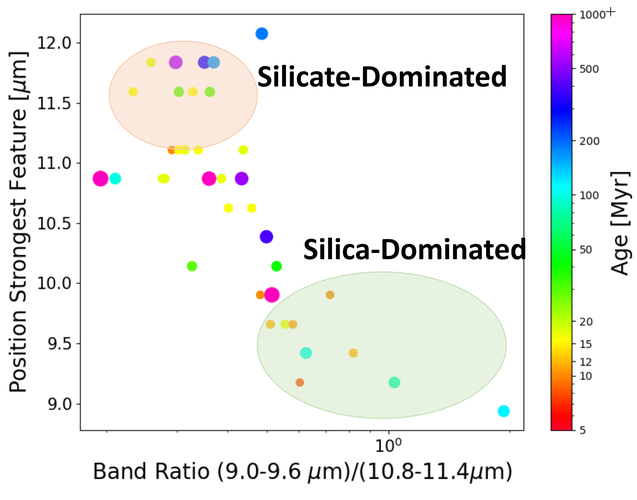


Figure 6. 10-μm Band Ratio as function of Stellar Ages, showing disk mineralogy has no correlation with system age.

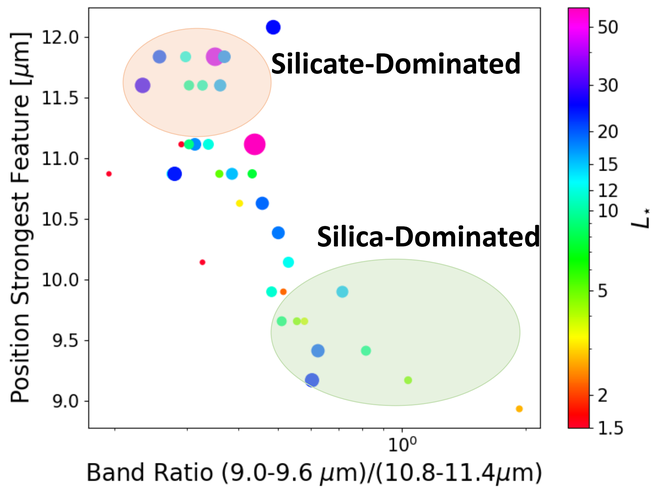


Figure 7. 10-μm Band Ratio as function of Stellar luminosity, showing disk mineralogy has no correlation with stellar luminosity.

CONCLUSIONS

1. We find no correlation between disk mineralogy with age or stellar luminosity for debris disks.
2. Our results indicate that planetesimal collisions are stochastic in nature and the dust produced from these stochastic events can dominate mineralogy.
3. We find A continuous range of disk mineralogy, ranging from the archetypal “silicate-dominated” and “silica-dominated” systems to those displaying a mixed ratio of dust compositions.