1. Science aim/goal:
Determine how and when dust in protoplanetary and debris disks is processed (e.g. by shocks, radial diffusion, and/or collisions) in the outer regions of planetary systems.

2. (i) Scientific Importance:
Silicates are widespread throughout our Solar System. They are the majority constituent of minor bodies (e.g. asteroids, comets, and Kuiper Belt Objects) and the crusts of terrestrial planets. Understanding the chemical and polymorph compositions, the dust temperatures, and crystalline fractions of silicates in protoplanetary and debris disks can provide insight into how material is processed in extrasolar planetary systems and whether the processes by which our Solar System formed are common or rare.

Spitzer IRS and *Herschel* PACS spectra of protoplanetary and debris disks have revealed thermal emission from amorphous and crystalline silicates, formed under a variety of pressures, temperatures, and cooling rates: enstatite (10.7 and 11.7 μm), forsterite (11.4 and 69 μm), and silicas, such as α-quartz, cristobalite, and tridymite (9, 12.6 and 21 μm). These observations suggest that dust at terrestrial temperatures may be processed by shocks and/or radial diffusion of material within protoplanetary disks (Sargent et al. 2009) and/or violent collisions within debris disks (Olofsson et al. 2012).

Relatively little is known about the detailed composition of cool dust in the midplane of protoplanetary disks or in the outer regions of debris disks. Detailed measurement and analysis of the mid- to far-infrared forsterite (33.8, 50, and 69.6 μm), enstatite (40.7, 43.2, and 65.7 μm) and silica (70 μm) features, including polymorph composition, grain temperature and Mg/(Mg+Fe) ratio, would help to elucidate the relative roles of shocks, radial diffusion and collisions during planetary system formation and evolution.

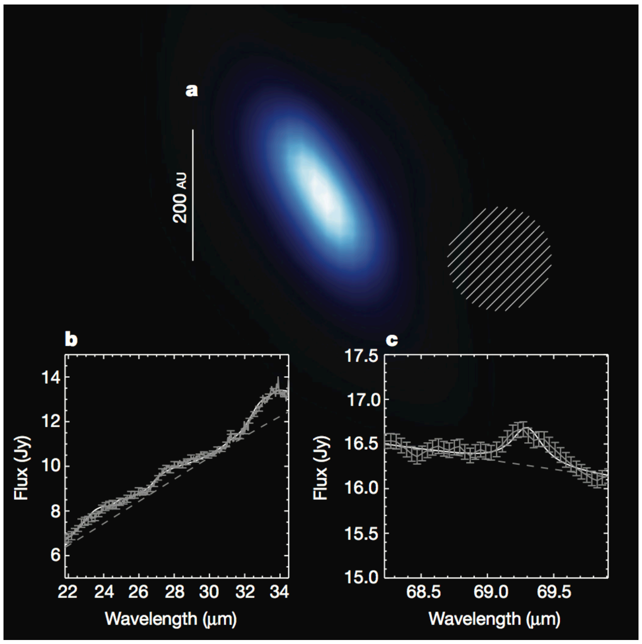
(ii) OST Observations Required:
To constrain the gross properties of cool silicates, high signal-to-noise (SNR~200), moderate resolution (R~500), mid- to far-infrared spectra are needed. *Herschel* PACS observations (R~1000) of the 69 μm β Pictoris forsterite feature measure a line:continuum ratio of ~3% and a FWHM ~ 0.3 μm (see Figure 1 from de Vries et al. 2011). Thus, a R~500 spectrum is expected to make 5 independent measurements across a typical forsterite feature, sufficient to measure accurately the peak position. A large number of protoplanetary and debris disks (~1000 targets) is needed to constrain not only the mean evolution of disks but also the variation.

(iii) Uniqueness to OST 5μm to 700 μm wavelength facility:
The 30 – 70 μm forsterite and enstatite features described here trace thermal emission from cool silicates at temperatures of 50-150K in direct emission. No other diagnostic provides constraints on silicate grain composition, crystallinity, temperature, and size.

(iv) Longevity/Durability:
Spitzer has already provided low-to-moderate resolution (R~60-600) 5-40 μm spectra for hundreds of nearby protoplanetary and debris disks. *JWST* MIRI MRS will provide

(R~3000) 5-30 μm spectra, enabling mapping of mid-infrared silicates and detailed characterization of warm silicates in more distant star forming regions. Since the far-infrared silicate emission feature positions are expected to change as a function of grain temperature and stoichiometry, joint analysis of mid- and far-infrared spectral features is needed to help break the degeneracy. Currently, SPICA-SAFARI is the only instrument planned that may address these science goals.

3. Figure:



Herschel PACS image (top), Spitzer IRS spectrum (bottom left), and Herschel PACS spectrum of the β Pic debris disk (from de Vries et al. 2011). β Pic is barely resolved with PACS with a beam FWHM ~ 8.2". The Spitzer IRS and Herschel PACS spectra detect crystalline olivine. A joint analysis of the Spitzer and Herschel spectra indicates that the best model contains crystalline olivine ($Mg_{2-2x}Fe_{2x}SiO_4$) with x = 0.01 ± 0.001 (1σ) and a temperature of 85 ± 6 K (1σ).

4. Table:

Medium Resolution Scanning Spectrometer (MRSS) modes	Check all that apply to your program
Pointed spectrum- 30-140 μm	X
Pointed spectrum- 140-660 μm	
Spectral Survey 30-660 μm R=500	
High-resolution FTS mode 30-660 μm, R~40,000	

Far-Infrared Imaging Polarimeter (FIP) Modes	Check all that apply to your program
Differential Polarimetry: 40 and 80 μm simultaneously	
Differential Polarimetry: 120 and 240 μm simultaneously	
Survey mapping: 40, 80, 120 and 240 μm simultaneously	
Pointed observations: 40, 80, 120 and 240 μm simultaneously	

High Resolution Spectrometer (HRS) Modes	Check all that apply to your program
Pointed spectrum, moderate resolution	
Small spectral map, moderate resolution	
Pointed spectrum high resolution	
Small spectral map, high resolution	

Heterodyne Instrument (HI or HERO) Modes	Check all that apply to your program
Stare: a) Pointed observations with dedicated off position	
b) Pointed observations with double beam switch	
c) Dual frequency (please specify, required vs faster)	
Raster	
Scanning: a) On the fly mapping with dedicated off Please indicate the approximate off position distance.	
b) On the fly with load chop	
Tracking moving objects, comets, planets, etc. Please specify which and/or required tracking speed	
Frequency survey	
Polarization measurements Please indicate required Stokes parameters and measurement accuracy (3sigma)	
Frequency switching (currently not designed for) Please indicate minimum frequency throw	

Mid-Infrared Imager Spectrometer and Coronagraph (MISC) Modes	Check all that apply to your program
MIR Imaging	
MIR Low Resolution Spectroscopy	
MIR Medium Resolution Spectroscopy	
MIR High Resolution Spectroscopy	
MIR Coronagraph Imaging	
MIR Coronagraph Spectroscopy	
MIR Transit Spectroscopy	

Note:
[1] MIR Imaging

Pointed observation (WFI-S; ON, WFI-L; ON). WFI-S and WFI-L share the same FOV by means of beam splitter and are operated simultaneously.

[2] MIR Low Resolution Spectroscopy (Long slit spectroscopy)

Pointed observation (WFI-S; ON, WFI-L; ON). WFI-S and WFI-L share the same FOV by means of beam splitter and are operated simultaneously.

[3] MIR Medium Resolution Spectroscopy (IFU spectroscopy)

Pointed observation (WFI-S; ON, WFI-L; ON, MRS-S; ON, MRS-M; ON, MRS-L; ON). MRS-S, MRS-M, and MRS-L share the same FOV by means of beam splitter and are operated simultaneously. WFI-S and WFI-L are operated in parallel to obtain the slit viewer image.

[4] MIR High Resolution Spectroscopy (Short slit spectroscopy)

Pointed observation (WFI-S; ON, WFI-L; ON, HRS-S; ON, HRS-L; ON). HRS-S and HRS-L share the same FOV by means of beam splitter and are operated simultaneously. WFI-S and WFI-L are operated in parallel to obtain the slit viewer image.

[5] MIR Coronagraph Imaging

Pointed observation (COR-S; ON, COR-L; ON, WFI-S; ON, WFI-L; ON). COR-S and COR-L share the same FOV by means of beam splitter and are operated simultaneously. WFI-S and WFI-L are operated in parallel to provide pointing knowledge

[6] MIR Coronagraph Spectroscopy

Pointed observation (COR-S; ON, COR-L; ON, WFI-S; ON, WFI-L; ON). COR-S and COR-L share the same FOV by means of beam splitter and are operated simultaneously. WFI-S and WFI-L may be operated in parallel to provide pointing knowledge

[7] MIR Transit Spectroscopy

Pointed observation (TRA-S; ON, TRA-M; ON, TRA-L; ON, WFI-S; ON, WFI-L; ON) COR-S, TRA-M and COR-L share the same FOV by means of beam splitter and are operated simultaneously. WFI-S and WFI-L may be operated in parallel to provide pointing knowledge

5. Descriptions of an observing plan:

We list ~1000 targets suitable for OST MRSS observations to constrain the properties of cool silicates (see companion text file). For protoplanetary disks, we selected ~800 stars that have been observed using Spitzer IRS in the nearest star forming regions (e.g. Taurus, Ophiuchus, Chamaeleon, Orion, NGC 1333) using primarily the n_{5-12} extinction free index to distinguish disks from photospheres and envelopes (McClure et al. 2010). For debris disks, we selected ~130 disks with strong to weak 10 μm silicate emission features and an additional ~80 disks with no warm terrestrial temperature debris but very strong far-infrared excess. Our targets have measured Spitzer MIPS 70 μm fluxes typically between a few mJy and several Jy. Assuming that MRSS will achieve SNR~200 on a 1.2 mJy source at 100 μm in one hour, we estimate that this program will require ~100 hours of on source exposure time.

6. Key references:

Henning (2010, ARAA, 48, 21), Sturm (2013, A&A, 553, 5), de Vries (2012, Nature, 490, 74)