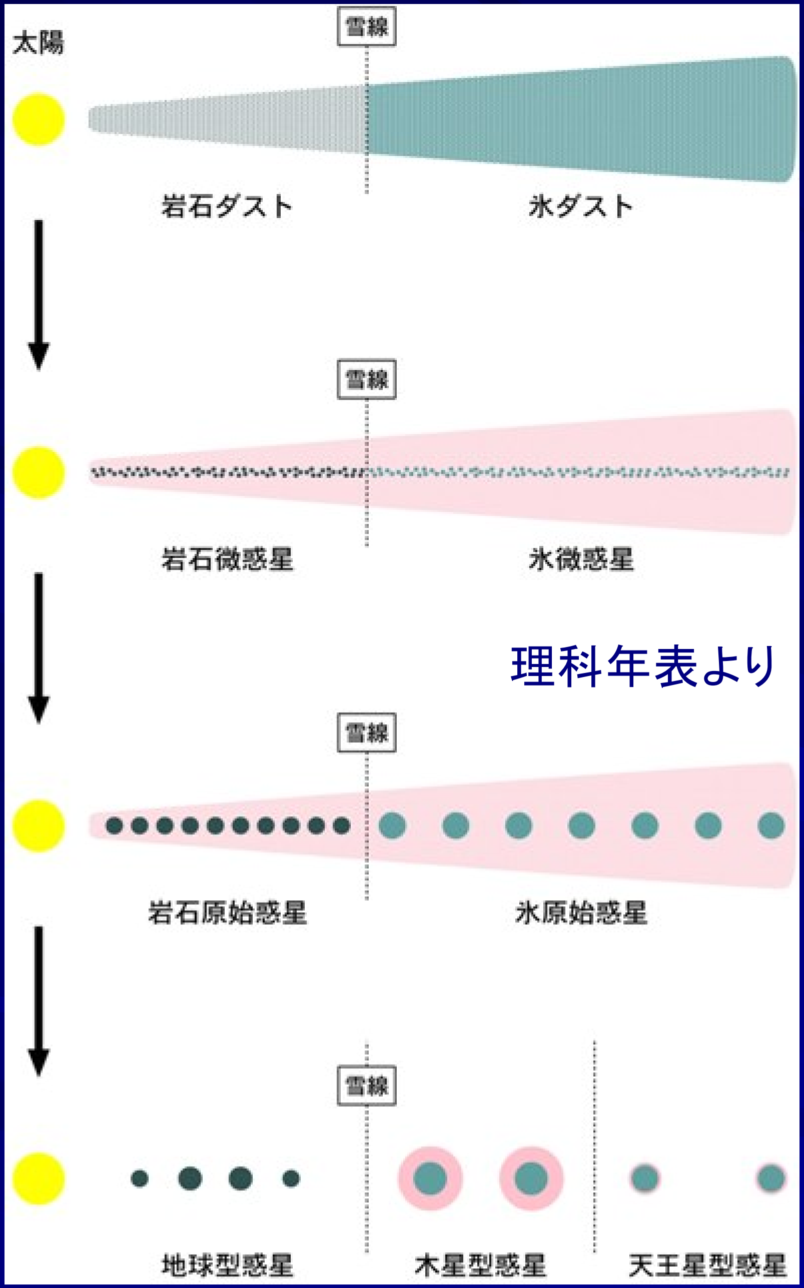
星周円盤のH_2O氷ダスト観測

本田充彦（神奈川大学）、
井上昭雄（大阪産業大学）、
岡明憲、中本泰史（東京工業大学）、
他多くの皆さま…



太陽系の雪線は2.7AUといわれている

Why H_2O ice ?

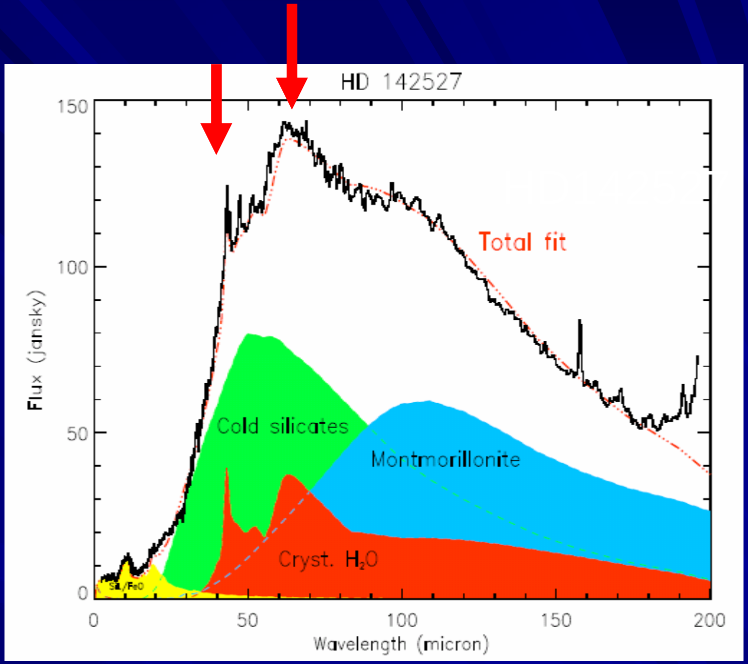
- major solid matter in disk
  - ice and silicate
  - H_2O is dominant in ice
- Role of H_2O ice grains in planet formation
  - enable formation of cores of gas giants (～$10M_E$)
  - First planetesimals / protoplanets formed at snow line ? (Lecar+2006)
- Link to origin of ocean on rocky planets

Issues that SPICA can shed light on

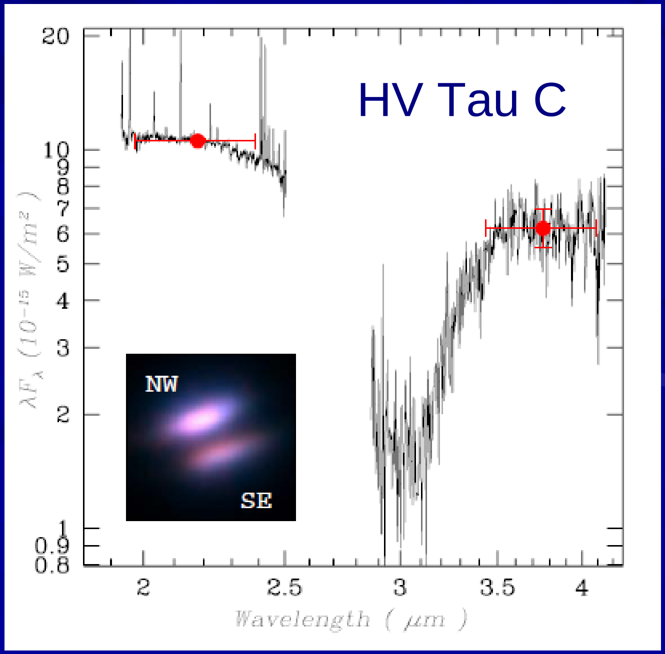
1. Can icy grains survive in debris disks?
   - Very short life time due to photodesorption by UV photons (e.g. Grigorieva et al. 2007)
2. Thermal history of icy material from molecular cloud to our solar system
   - Crystallinity of (water) ice especially in debris disks and solar system (comets and EKBOs)
3. Where is the snow line ?
   - Observationally, little is known
   - Is it consistent with the theoretical predictions?

H_2O ice IN disks

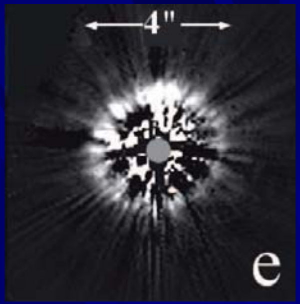
- Observations are limited
- Protoplanetary disks
  - 44, 62μm emission features
    (Lattice mode, Malfait et al. 1999)
    - HD142527＋a few source
  - 3.1μm absorption feature
    (OH stretching mode)
    - HKTauB, HVTauC
      (Terada+2007)
    - CRBR2422.8-3423
      (Pontoppidan+2005)
- Debris Disks
  - No direct detection except for Chen+08



(Malfait et al. 1999)

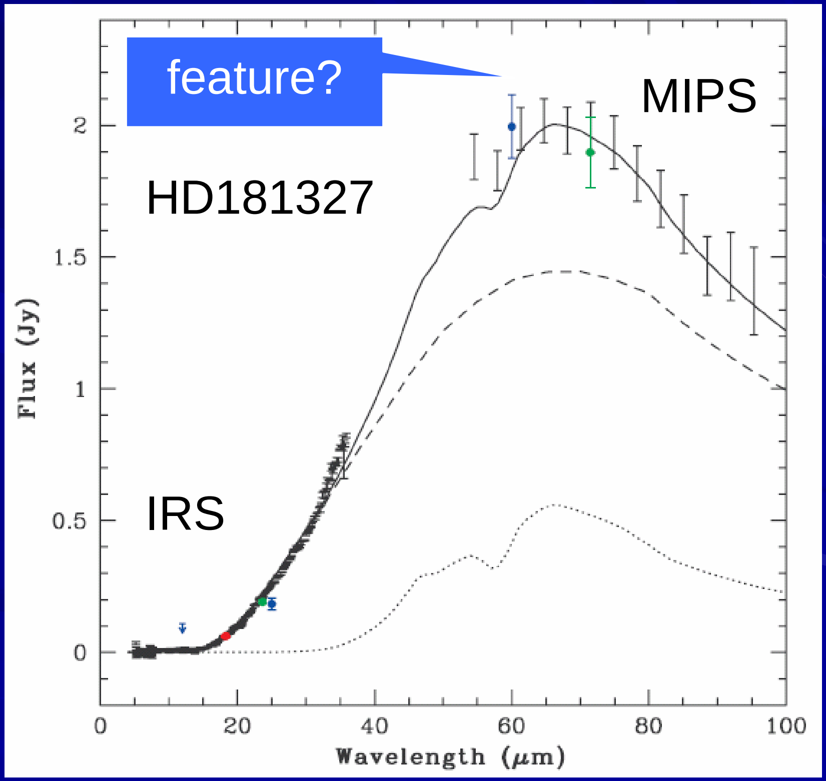


Schneider+06



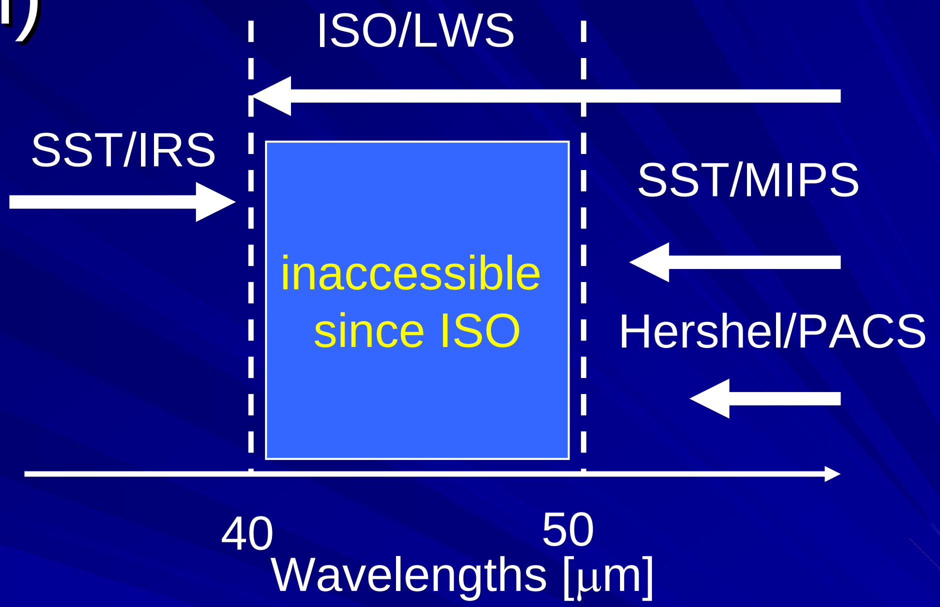
Ice in debris disk ?

- Possible 62μm feature to HD181327 (Chen+2008)
  - F5/F6V, 50.6pc, 12Myr (βPic group)
  - SST/IRS,MIPS spectra
- photodesorption lifetime
  - 1400 yr (1.5 μm H_2O ice)
  - Another evidence for grain replenishment
- 44μm feature is desired for robust detection



SPICA can access to 44μm feature

- ISO/LWS (40-200μm)
- Spitzer
  - IRS 5-40μm
  - MIPS 52-97μm
- Hershel
  - PACS 55-210μm



SPICA can observe 44μm feature since ISO !

Hershel/PACS can access 62μm feature, but this feature comes from only crystalline H_2O ice

Issues that SPICA can shed light on

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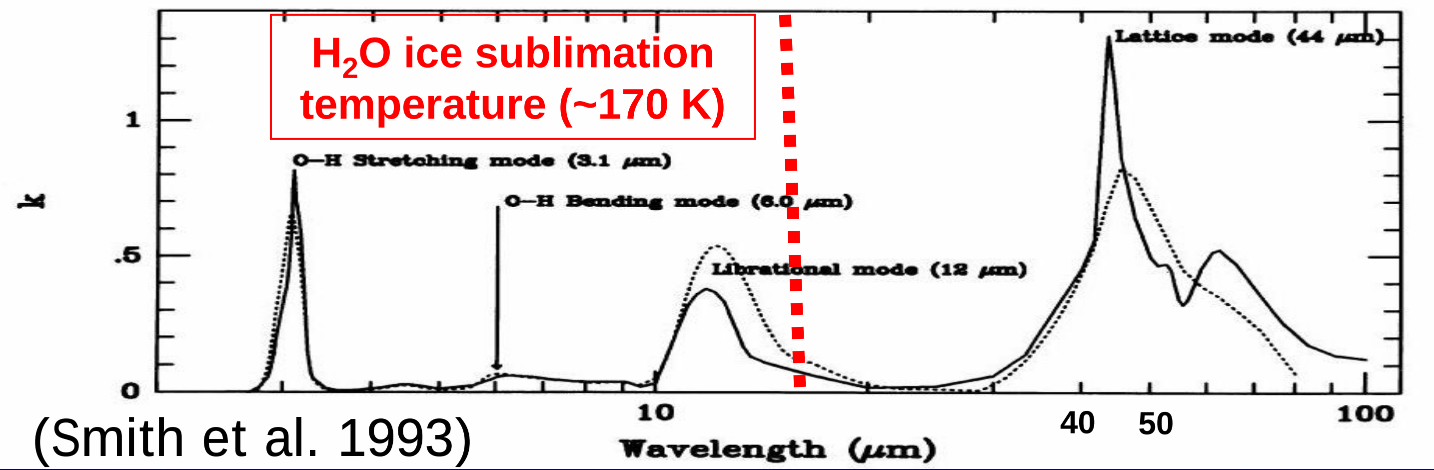
difficulties for detecting H_2O ices

- 3.1μm feature
  - Famous, but observable in absorption only !
  - light source is needed
  - Blending with other ices (e. g. NH3)
- 12μm feature
  - Blending with strong 10μm silicate feature
- 44, 62μm features
  - Limited obs. Opportunities
  - Absorption or **Emission !**

Ideal for unbiased uniform study

crystalline

amorphous



(Smith et al. 1993)

Current understanding of H_2O ice crystallinity evolution

- Silicate dust evolution has been well-established
- Icy dust crystallinity evolution is still unclear

	ISM mol. cloud	Protoplanetary disks	Debris disks	Solar sys. comets
Silicate T~1000K	A	A+C	A+C	A+C
H_2O ice T=110-140K	A	A?+C?	C???	C? A?

A: amorphous form, C: crystalline form

Comparison with model predictions

- Kouchi+94 discussed crystallinity evolution of H_2O ice from molecular cloud to solar system
- Need more sample to establish crystallinity evolution

	ISM mol. cloud	Protoplanetary disks	Debris disks	Solar sys. comets
Kouchi+94 prediction	A	C(+A)	C	C
H_2O ice T=110-140K	A	A?+C	C???	C? A?

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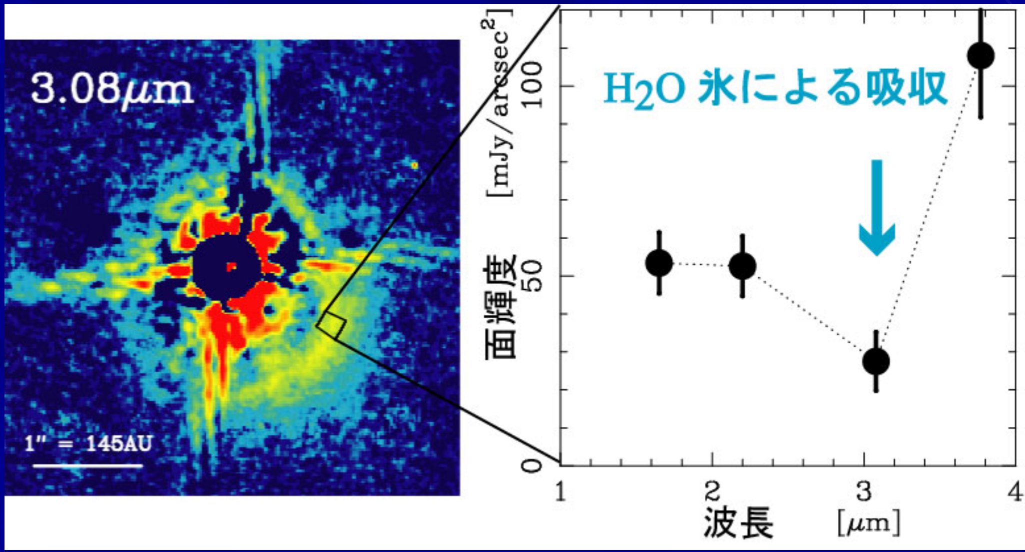
Spectroscopy of disk scattered light

- Detection of H_2O ice 3.1μm absorption by scattered light "spectroscopy" (Honda+09)
  - H_2O ice grains present at r>140AU
- There should be ice-free inner region
- Low resolution spectra will give us much more information

  on grain properties
- SCI should be

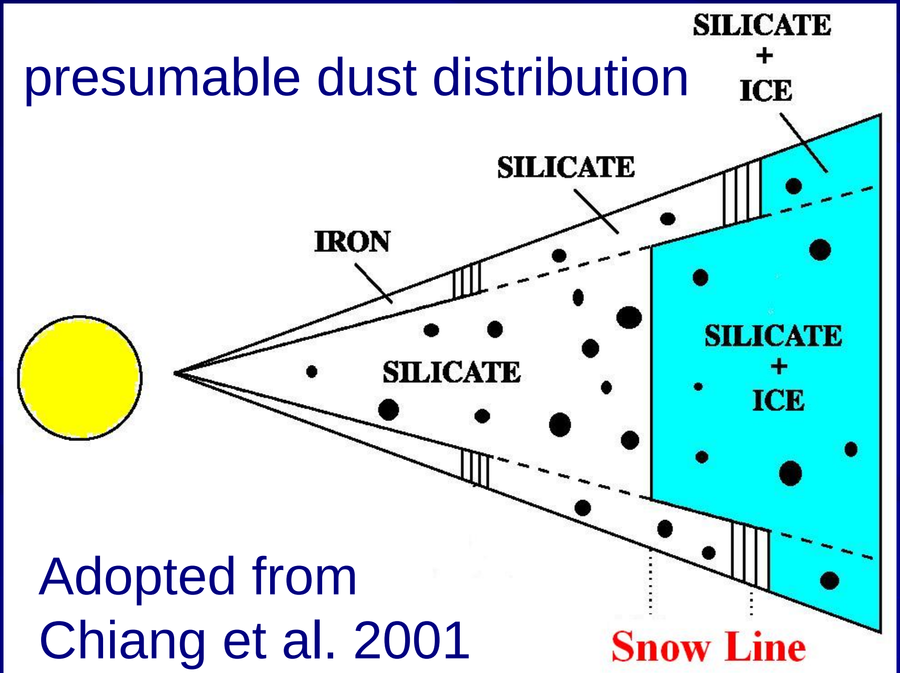
  a powerful tool !



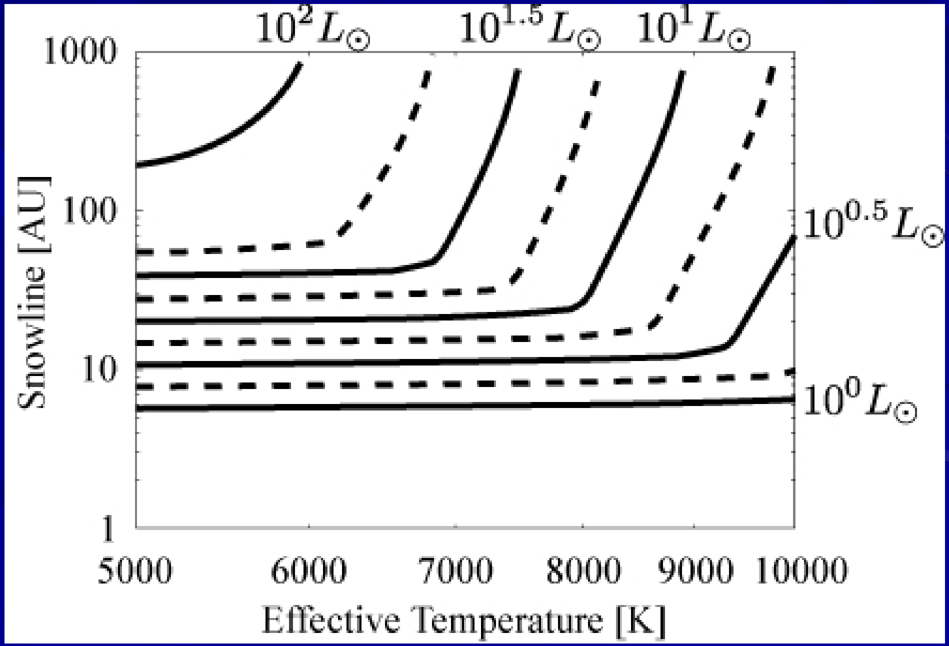
Expected radius of snow line

- Snow line
  - – mid-plane → a few ~ a few tens AU
  - – Surface → 10 ~ 100 AU

presumable dust distribution



Adopted from
Chiang et al. 2001



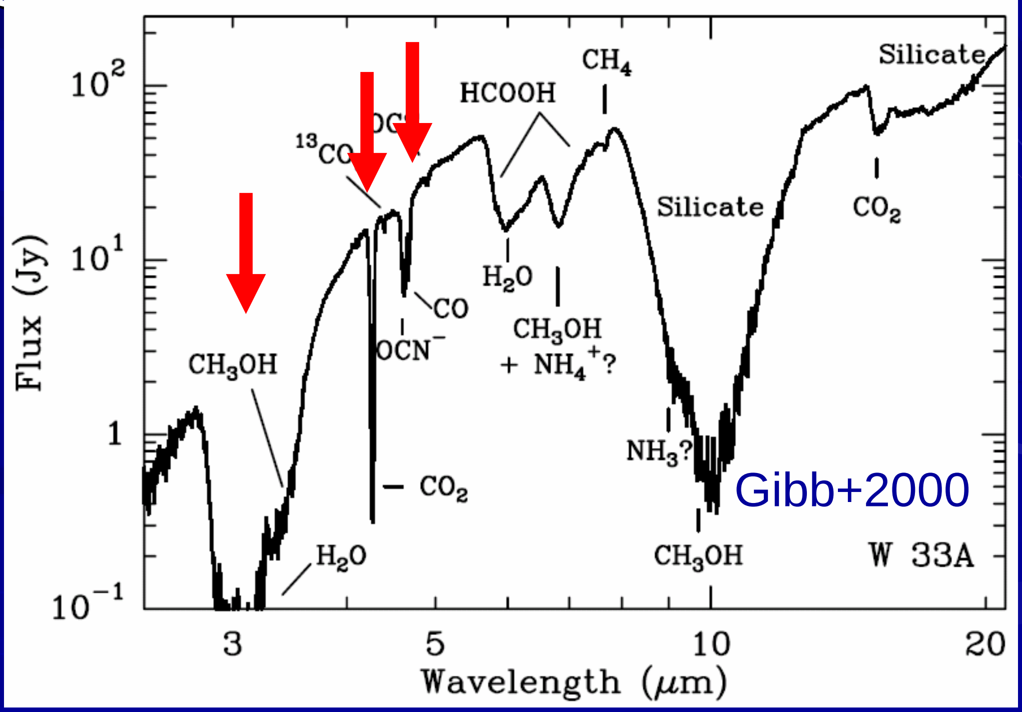
Surface snow line radius (Oka, A + in prep.)

Feasibility evaluation on snow line detection with SCI

- SCI IWA ~3.3 λ/D=0.68" @ 3.5μm
- Protoplanetary disks around Herbig Ae/Be stars
  - Typical distance to HAeBe is 100pc (or more)
    mid plane : 10AU → 0.1" surface : 50AU → 0.5"
  - Challenging observations…
- Nearby debris disks around Vega-like stars
  - βPic (20pc)
    90-100AU (Pantin+1997) → 4.5"-5.0"
  - OK !
  - but presence of icy grains is not confirmed
  - Spectroscopy is strongly desired !

SCI spectroscopy of disk scattered light is still important !

- Scattered light spectroscopy ~3μm<λ is very difficult for ground-based facility
  - Need for observations from space !
- Absorption features
  - H_2O ice @ 3.1μm
  - CO_2 ice @4.27μm
  - CO ice @4.67μm
  - etc ….
- CO_2 snow line
  - 70-300 AU



Summary

1. Can icy grains survive in debris disks?
   - SPICA FIR spectroscopy of emission from debris disk will provide conclusive answers (presence of 44 and 62μm features)
   - SCI spectroscopy of scattered light is also a powerful tool to investigate ice absorption
2. Thermal histroy of icy material from molecular cloud to our solar system
   - Systematic FIR spectroscopic study to investigate H_2O ice feature will establish the evolutional picture
3. Where is the snow line ?
   - Very challenging for protoplanetary disks
   - Feasible for debris disks, but presence of ice is not clear for the moment