星周円盤の氷ダスト観測

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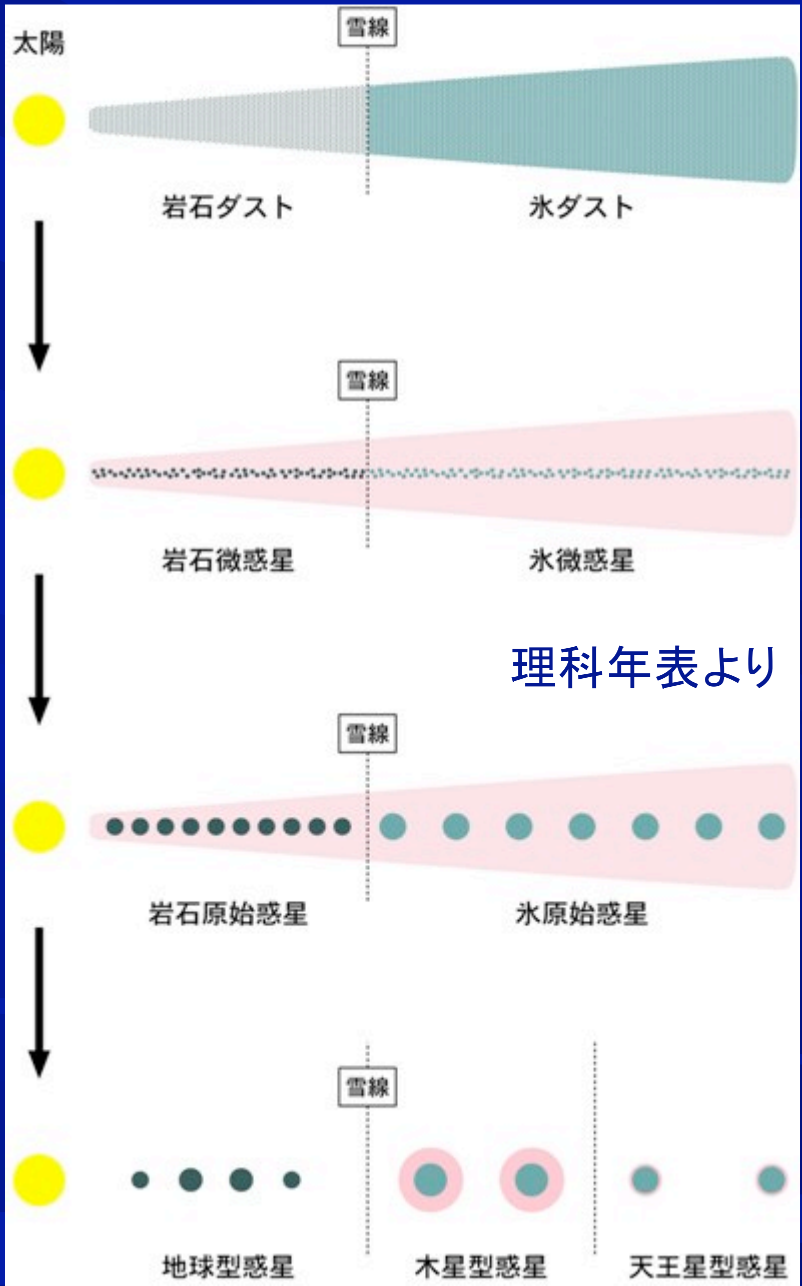
Why (H_2O) ice ?



太陽系の雪線は2.7AUといわれている

- 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)
- Ice distribution in the disk is important

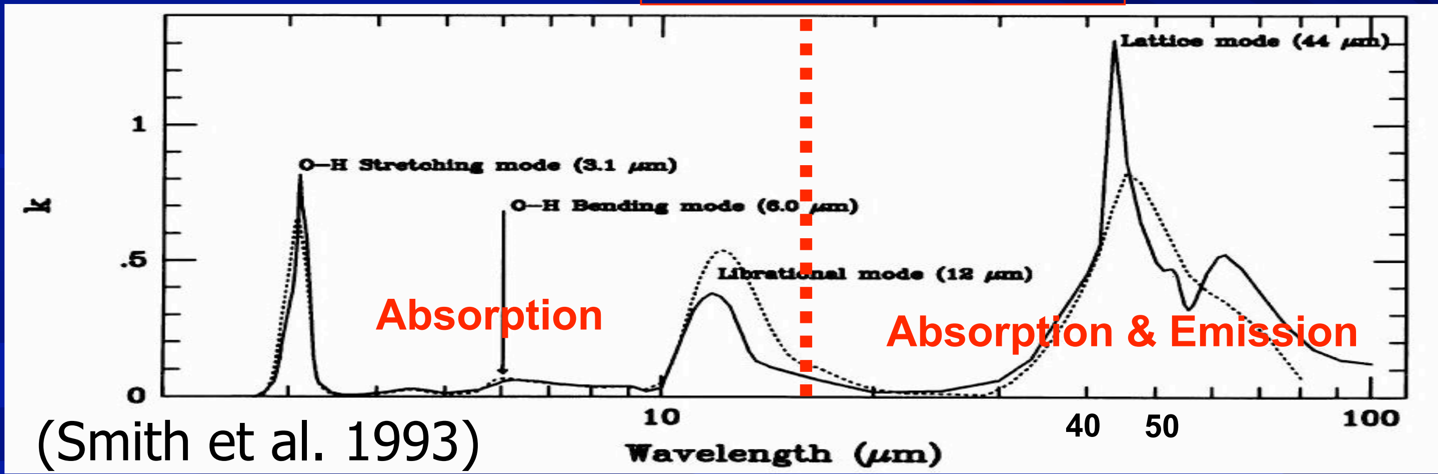
difficulties for detecting H_2O ices

- 3.1μm, 6.0μm
  - Famous, but observable in absorption only !
  - Background light source is needed
  - Blending with other ices (e. g. NH3, CH3OH…)
- 12μm
  - Blending with strong 10μm silicate feature
- 44, 62μm (crystalline), 46μm (amorphous)
  - Limited obs. Opportunities
  - Absorption or **Emission !**

H_2O ice sublimation temperature (~170 K)

——— crystalline

········· amorphous

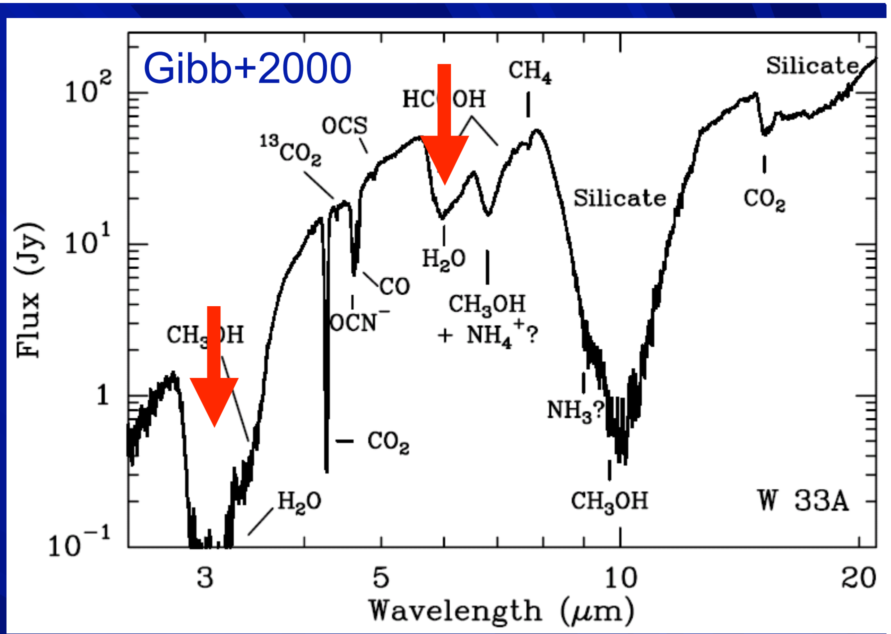


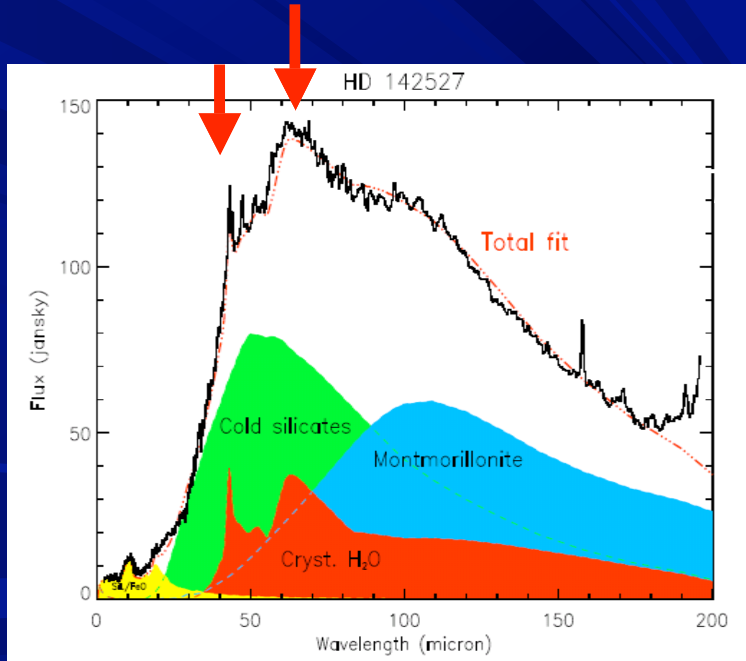
(Smith et al. 1993)

H_2O ice *IN disks*

- Limited Observations
  - ice in envelopes and molecular cloud is evident
- Protoplanetary disks
  - 44, 62μm emission features

    (Lattice mode, Malfait et al. 1999)
    - HD142527＋a few source
- Debris Disks
  - No clear detection (possible detection by Chen+08)

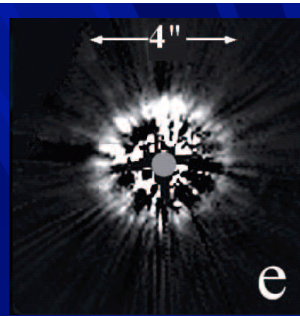




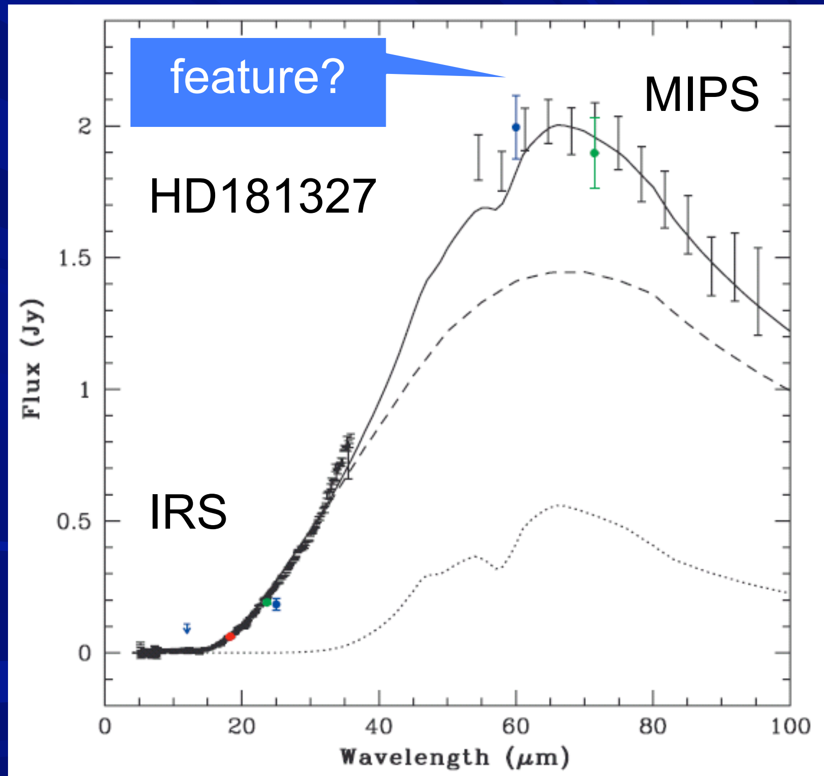
(Malfait et al. 1999)

Ice in debris disk ?

Schneider+06

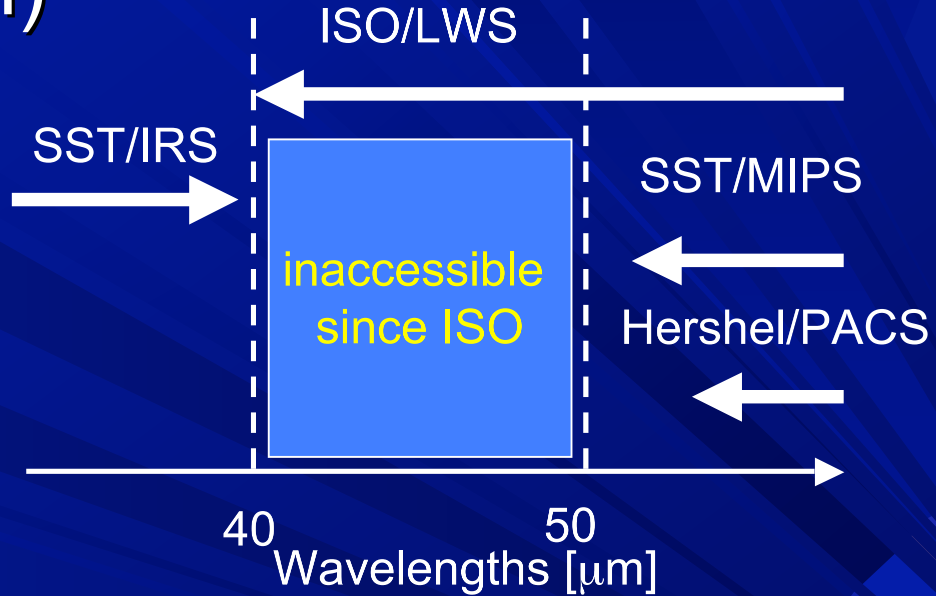


- Possible 62μm feature to HD181327 (Chen+2008)
  - F5/F6V, 50.6pc, 12Myr (βPic group)
  - SST/IRS,MIPS spectra
- photodesorption lifetime
  - 1400 yr (1.5 μm H_2O ice)
  - Another evidence for grain replenishment
- 44μm feature is desired for robust detection



SPICA can access to 44μm feature

- ISO/LWS (40-200μm)
- Spitzer
  - IRS 5-38μm
  - MIPS 52-97μm
- Hershel
  - PACS 55-210μm



SPICA/SAFARI can observe 44μm since ISO !

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

→ amorphous H_2O ice requires 46μm feature

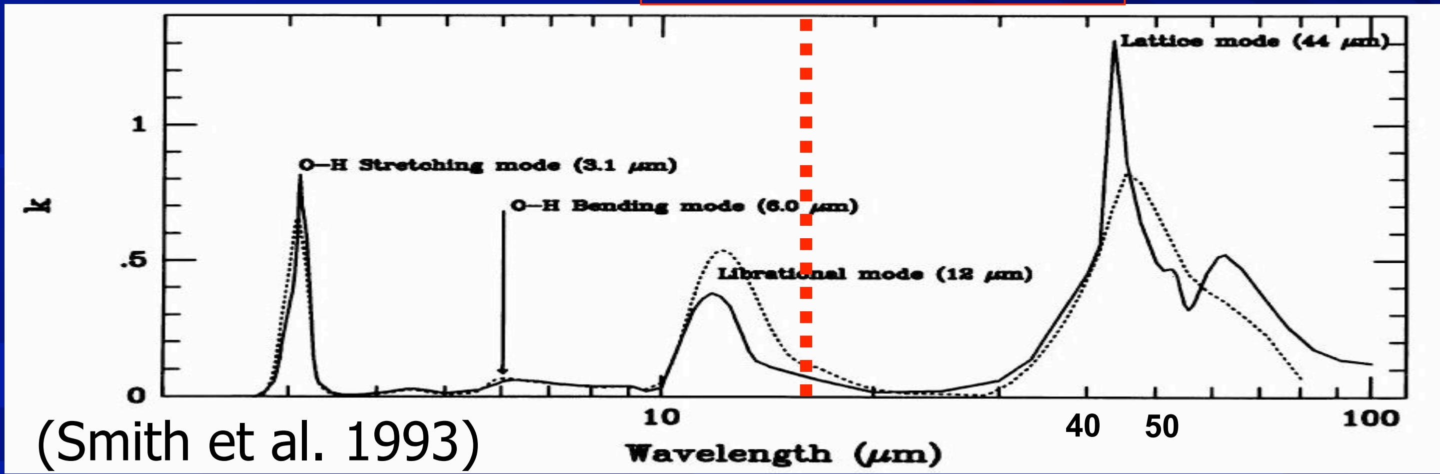
SAFARI spectroscopic survey of ice in protoplanetary/debris disks

- R~30 to distinguish crystalline / amorphous
  - 44, 62μm (crystalline)
  - 46μm (amorphous)
- SAFARI spectral resolution of R=2000 → OK

H_2O ice sublimation temperature (~170 K)

crystalline

amorphous



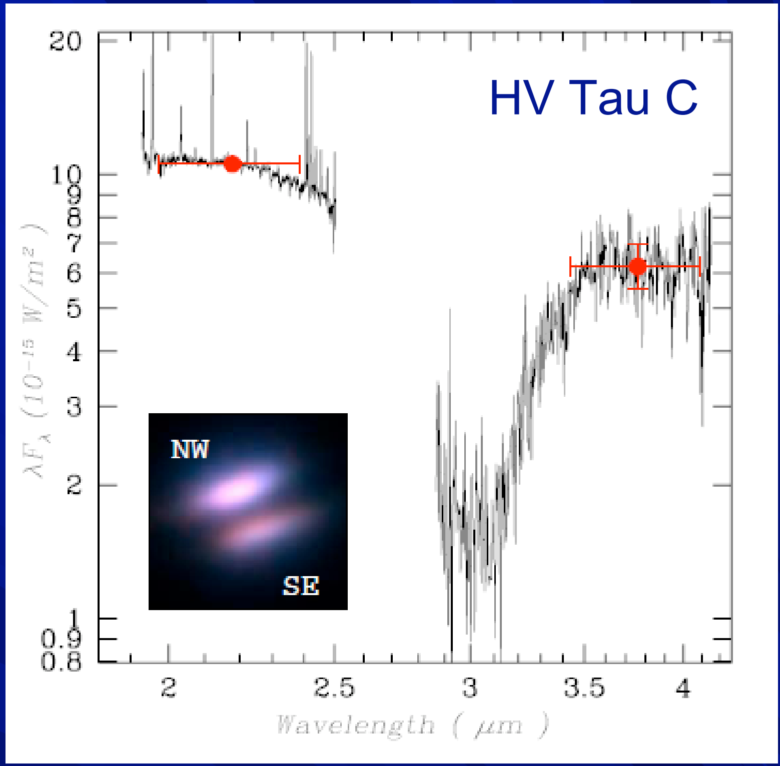
(Smith et al. 1993)

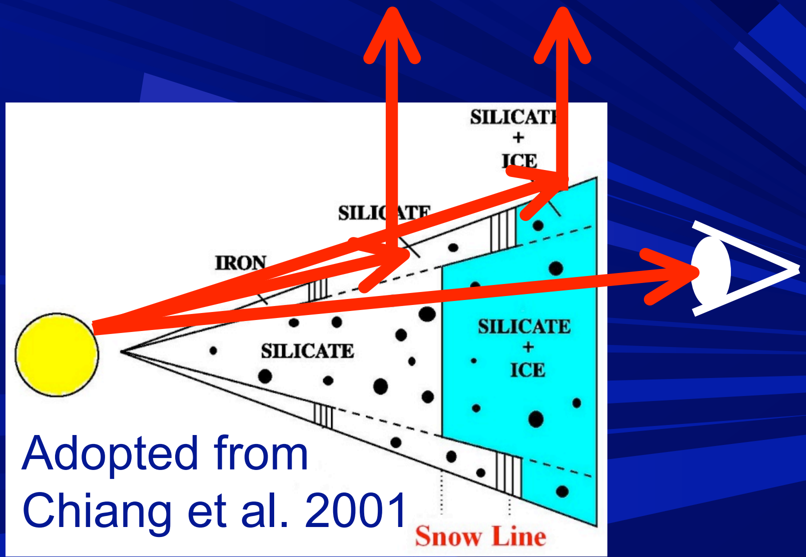
H_2O ice *IN disks*

- Protoplanetary disks
  - 3.1μm absorption feature towards edge-on disks

    (OH stretching mode)
    - HKTauB, HVTauC (Terada+2007)
    - CRBR2422.8-3423 (Pontoppidan+2005)
  - Radial location of ice in disk is unknown for edge-on disk
  - Scattered light observations from the face-on disk is necessary

    →coronagraphic multi-color imaging

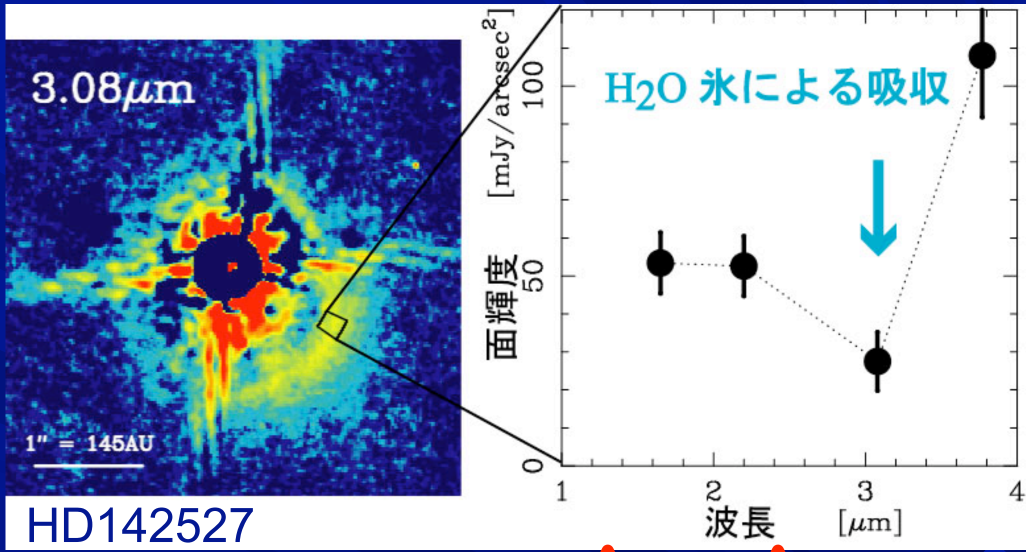


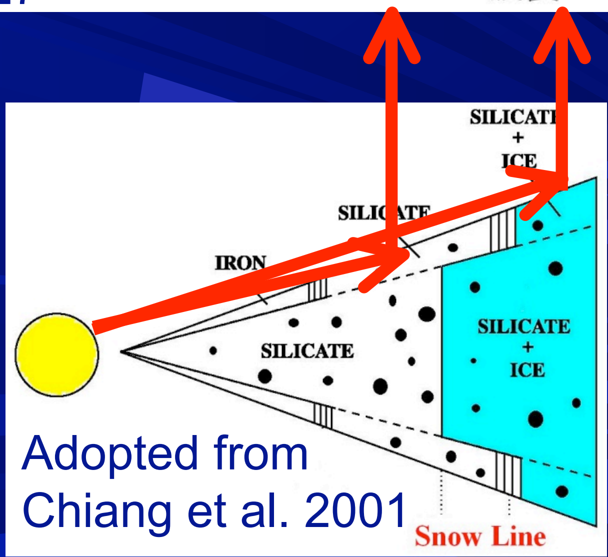


Adopted from Chiang et al. 2001

Coronagraphic multi-color imaging of scattered light from face-on disk

- H_2O ice 3.1μm absorption seen in disk scattered light "spectrum" (Honda+09)
  - H_2O ice grains present at r>140AU
- Real spectrum is desired
  - Detection of scattered light in L-band is difficult

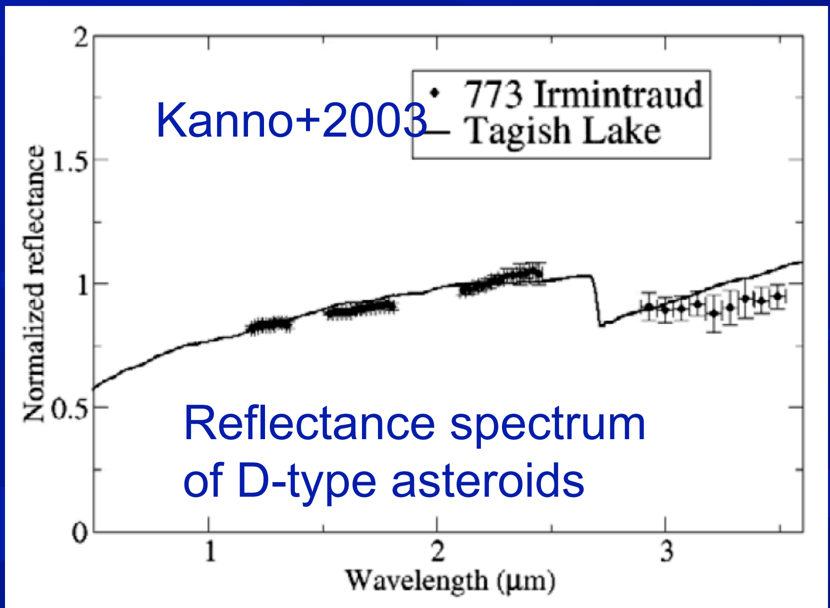


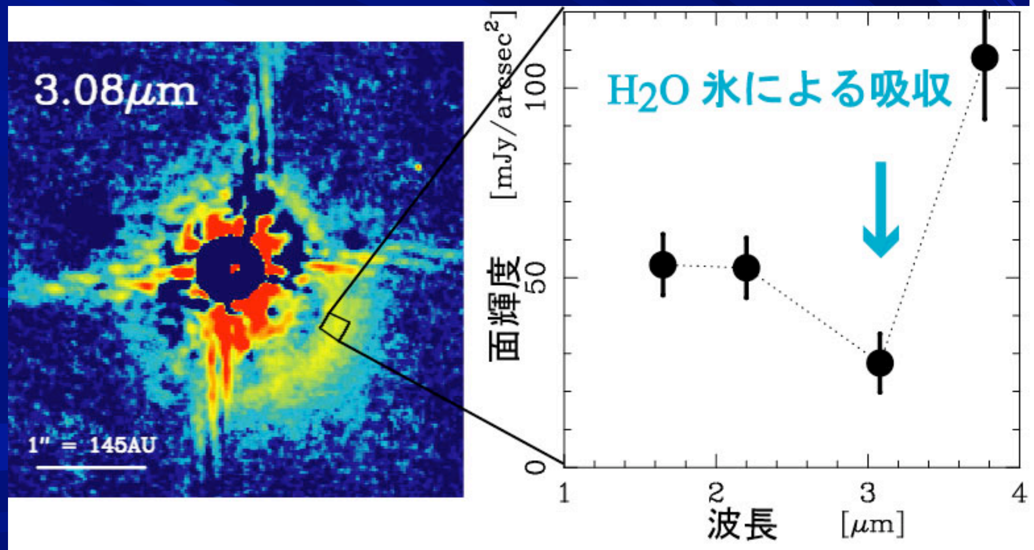


Adopted from Chiang et al. 2001

Importance of NIR coronagraphic spectroscopy from space

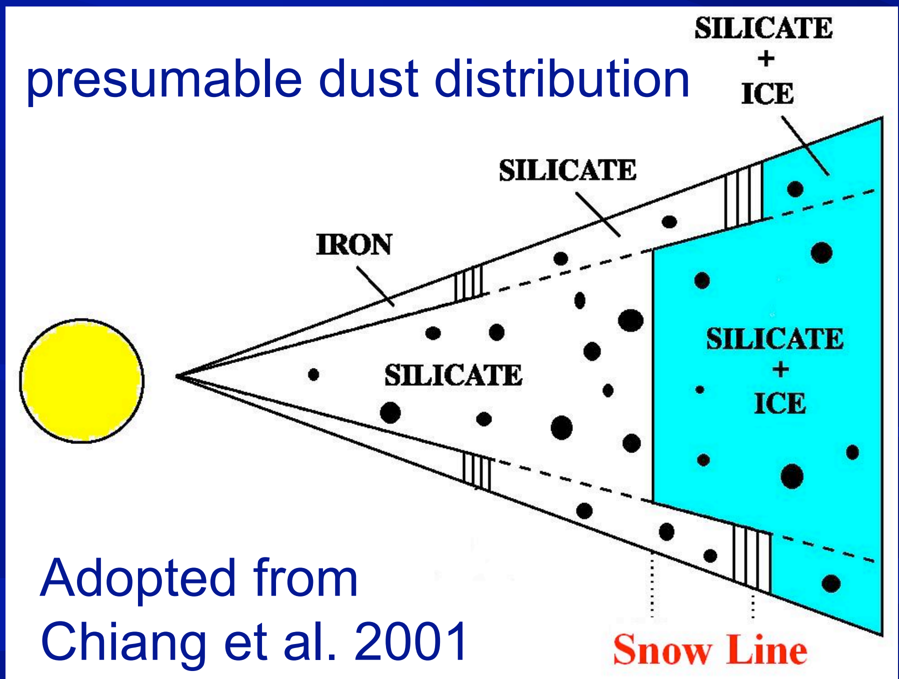
- Spectroscopy is necessary
  - water ice at 3.1μm
  - hydrated silicates at 2.7-2.9 μm
- SCI coronagraphic spectroscopy is useful !
  - Not available with JWST/NIRCam, FGS-TFI

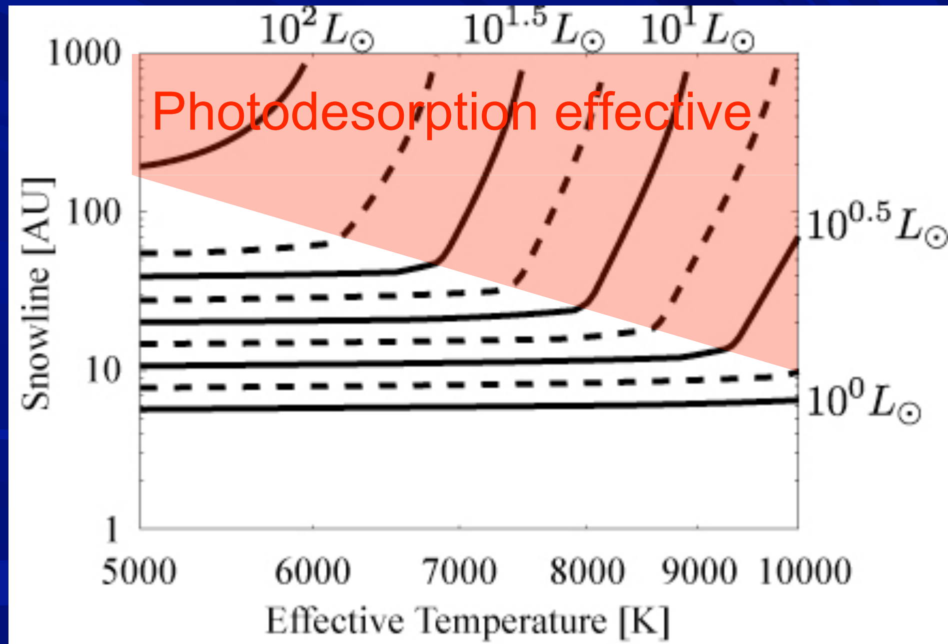




Expected position (radius) of surface snow line

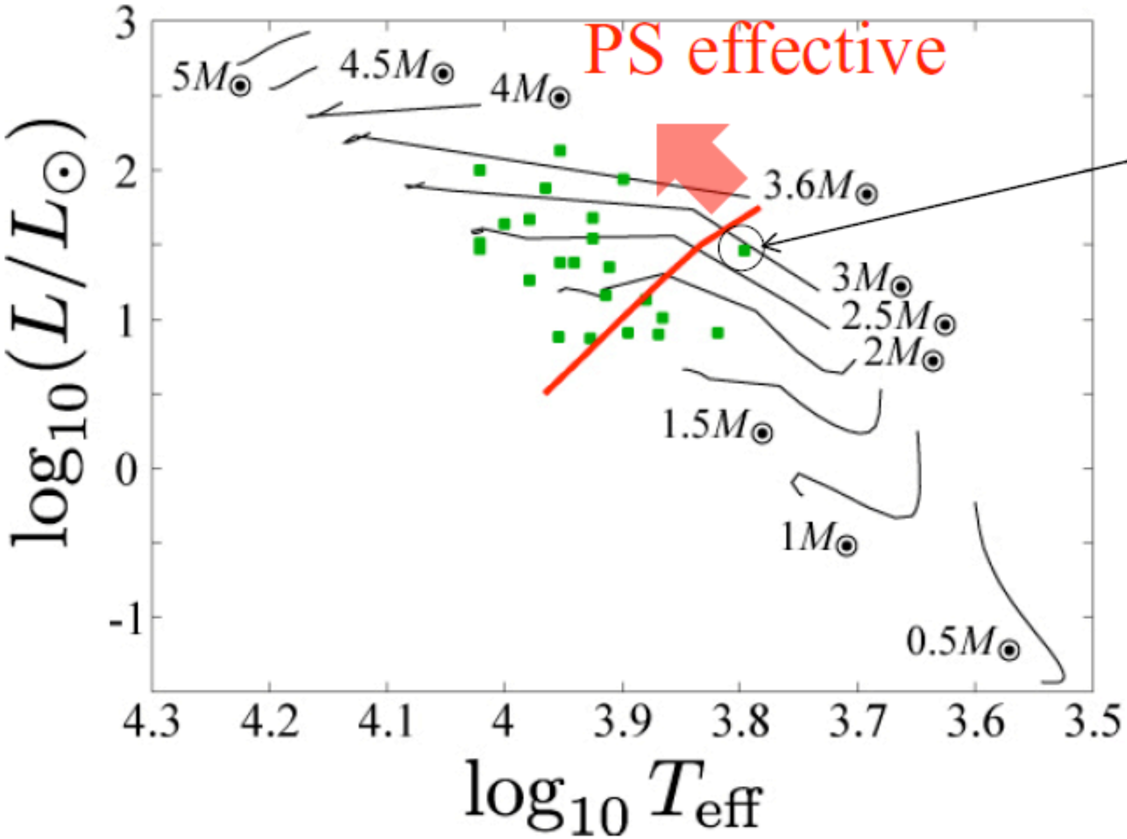
- Snow line depends on L_* and T_{eff}
  - mid-plane → a few ~ a few tens AU
  - Surface → 10 AU ~ ∞
    - No ice at the disk surface in some condition !





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

Photodesorption and water ice in the disk surface



Honda *et al.* (2009)
HD142527

■ Herbig Ae/Be stars (van Boekle *et al.* 2005)

― Evolutionary tracks (Solar abundance) : Yi *et al.* (2001)

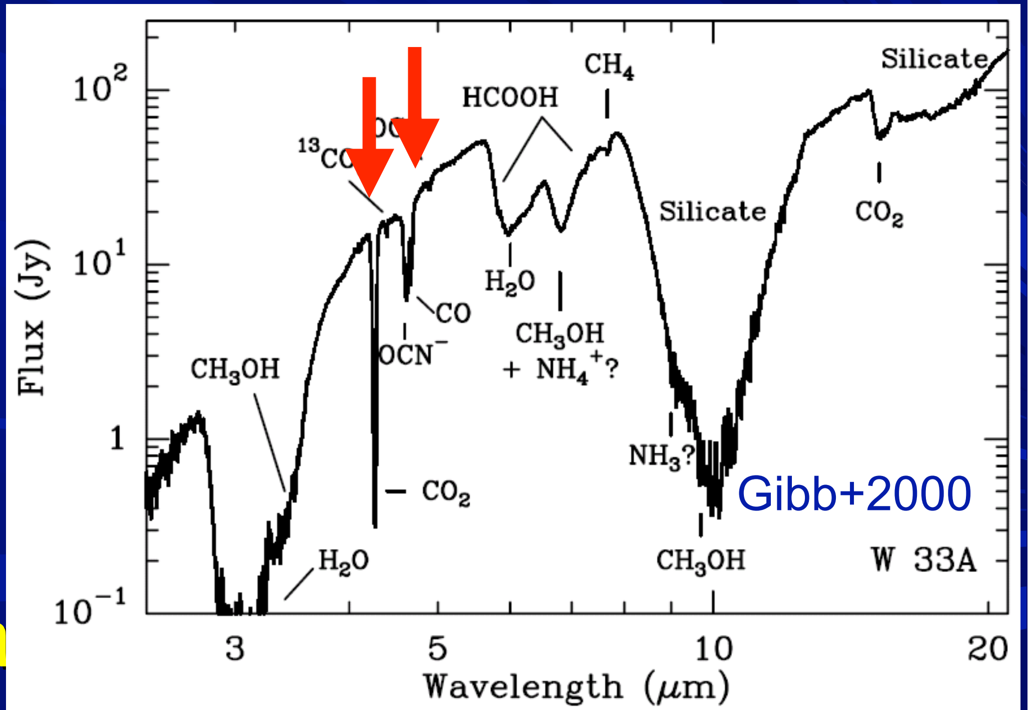
- Disks around relatively massive stars are affected by PS
  ➔ There would be no H2O ice above the disk surface

Feasibility evaluation on snow line detection with SCI

- SCI IWA (d=3.0m)
  - Mask1 : ~3.3 λ/D=0.79" @ 3.5μm
  - Mask2 : ~1.7 λ/D=0.41" @ 3.5μm
- Protoplanetary disks at 140pc
  - Mask 1: ~110 AU, Mask 2 : ~60AU
  - Snow line detection will be difficult, but effect of photodesorption can be checked
- Nearby debris disks around Vega-like stars
  - βPic (20pc)
    90-100AU (Pantin+1997) → 4.5"-5.0" (easy!)
  - (water) ice present ?
  - Spectroscopy is strongly desired

CO_2, CO ice in disks

- 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
- No CO ice @ surfa



Instrument requirements

- SAFARI spectroscopy of H_2O ice in disks (44μm feature)
  - R>30~100
  - Wavelength coverage : 35-70μm
- SCI coronagraphic spectroscopy of H_2O, CO_2, CO ice in disks
  - R=20,200 is OK
  - Wavelength coverage : 2.5 - 5μm
- Two independent observing methods allow us to make robust H_2O ice (non-)detection

Summary

- Can icy grains survive in debris disks?
  - SAFARI spectroscopy of emission from debris disk will provide conclusive answers (presence of 44/62μm features)
  - SCI coronagraphic spectroscopy of scattered light is also a powerful tool to investigate ice absorption
- Thermal histroy of icy material from molecular cloud to our solar system
  - FIR spectroscopic survey of disks will establish the evolutional picture of ice in disks
- Where is the snow line in disk?
  - SCI coronagraphic spectroscopy might be possible to detect snow lines of ices (H_2O, CO_2, CO,…) toward nearby debris disks