Warm Debris Disks Probed by AKARI Observations

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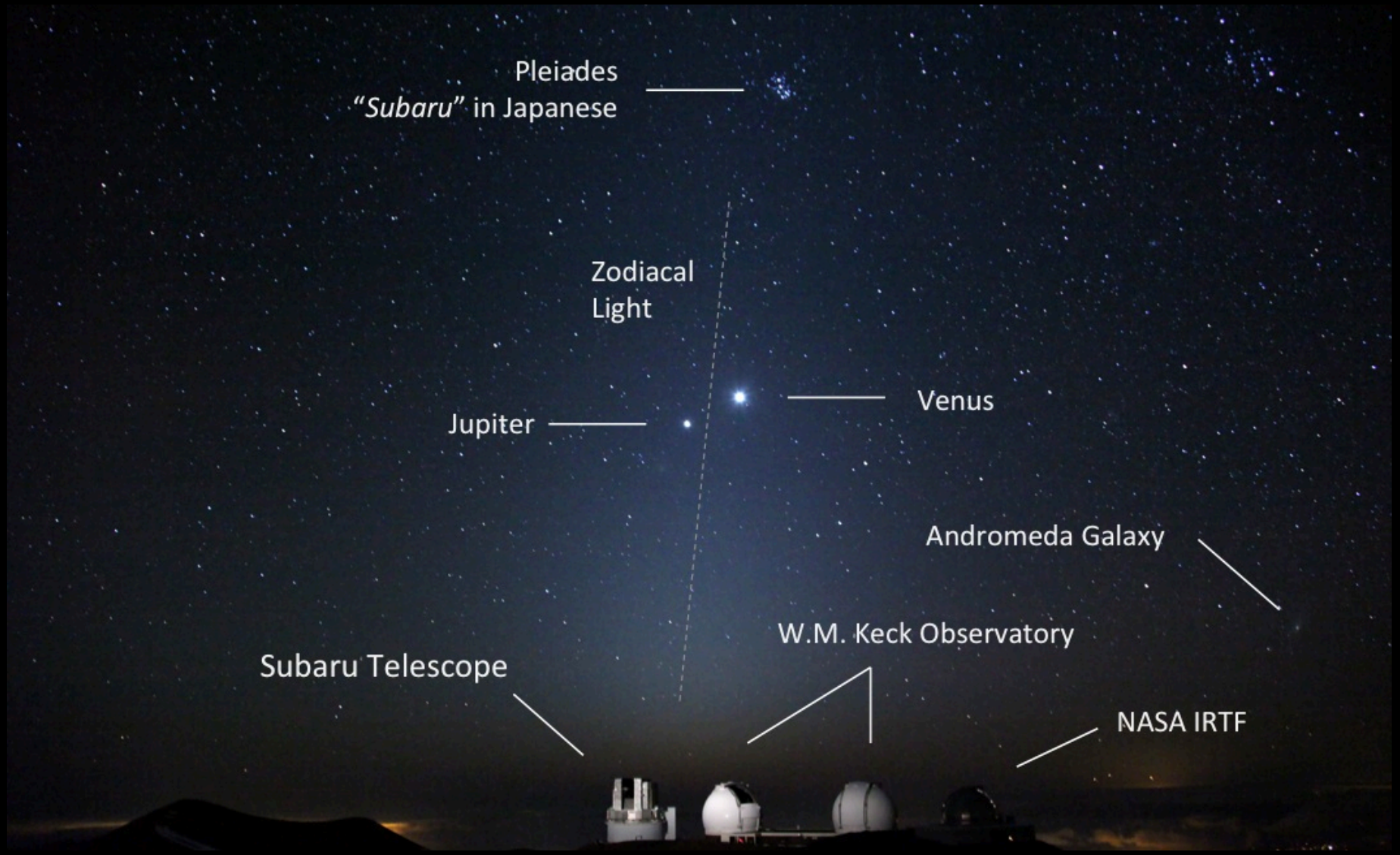
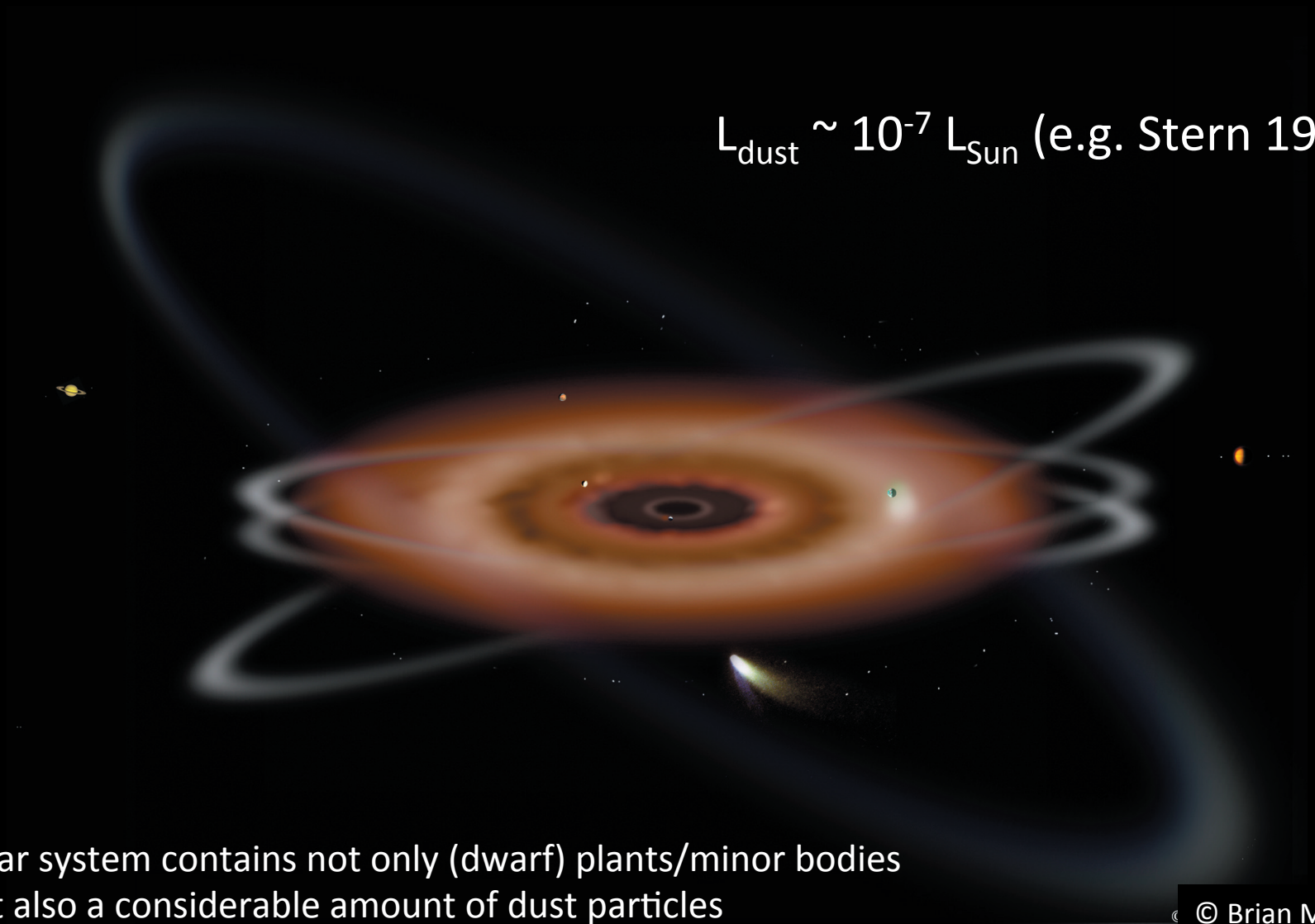
Zodiacal Light



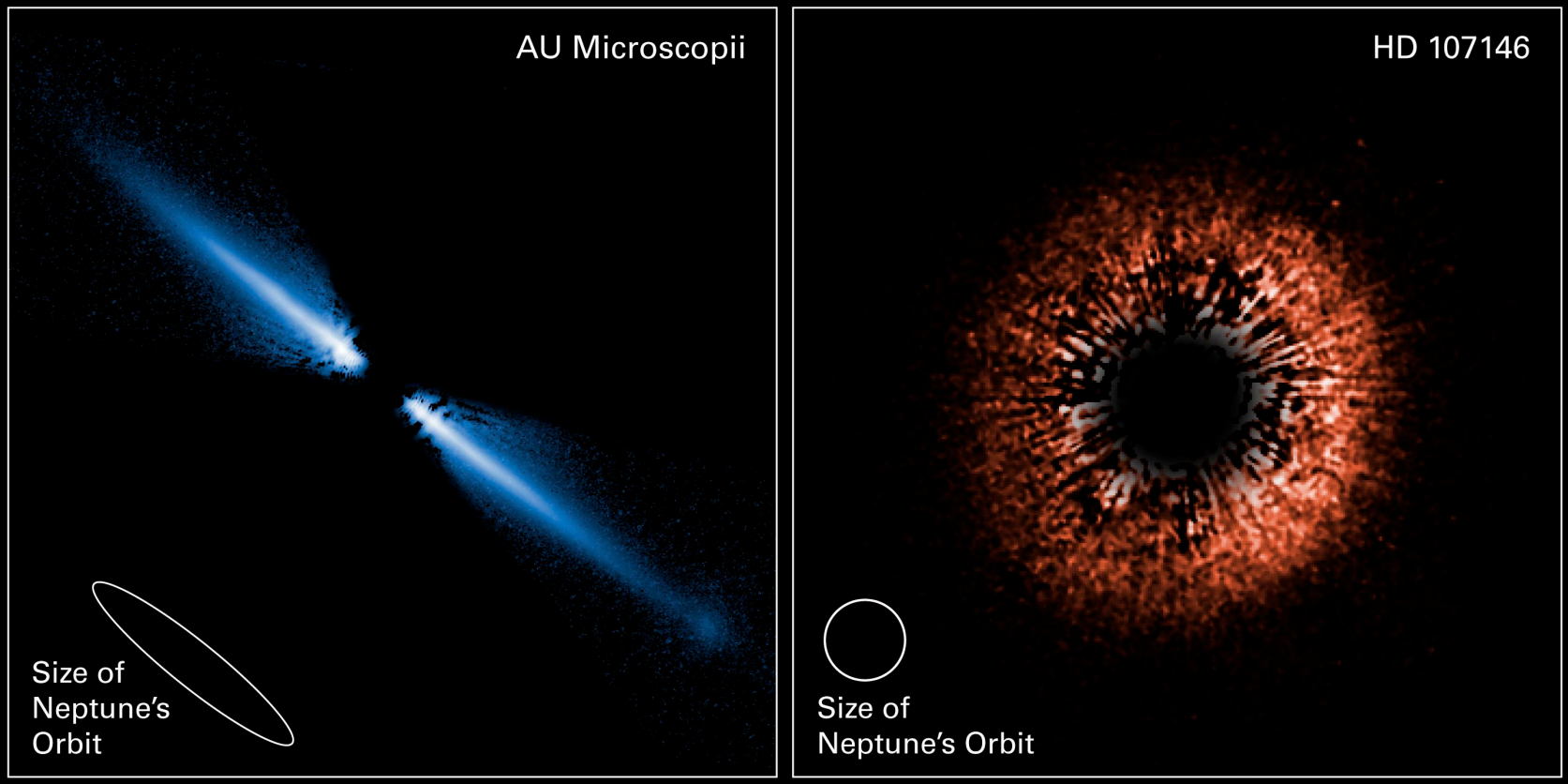
Dust in Solar System



$L_{dust} \sim 10^{-7} L_{Sun}$ (e.g. Stern 1996)

- Solar system contains not only (dwarf) plants/minor bodies
- But also a considerable amount of dust particles
- Coming from asteroids and comets

Extrasolar Zodiacal Light = Debris Disk



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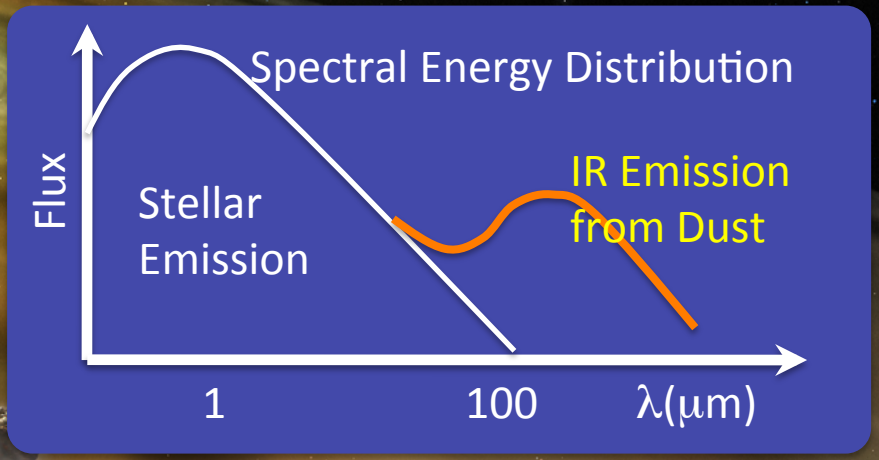
- <u>Debris Disk</u>
  - Some main-sequences (MS) stars also have "Zodiacal Light", or dusty disk
  - Called as "Debris Disk"

Extrasolar Zodiacal Light = Debris Disk

- Debris Disk
  - Seen as thermal emission from circumstellar dust heated by central star
  - Infrared (IR) excess over photospheric emission is an evidence

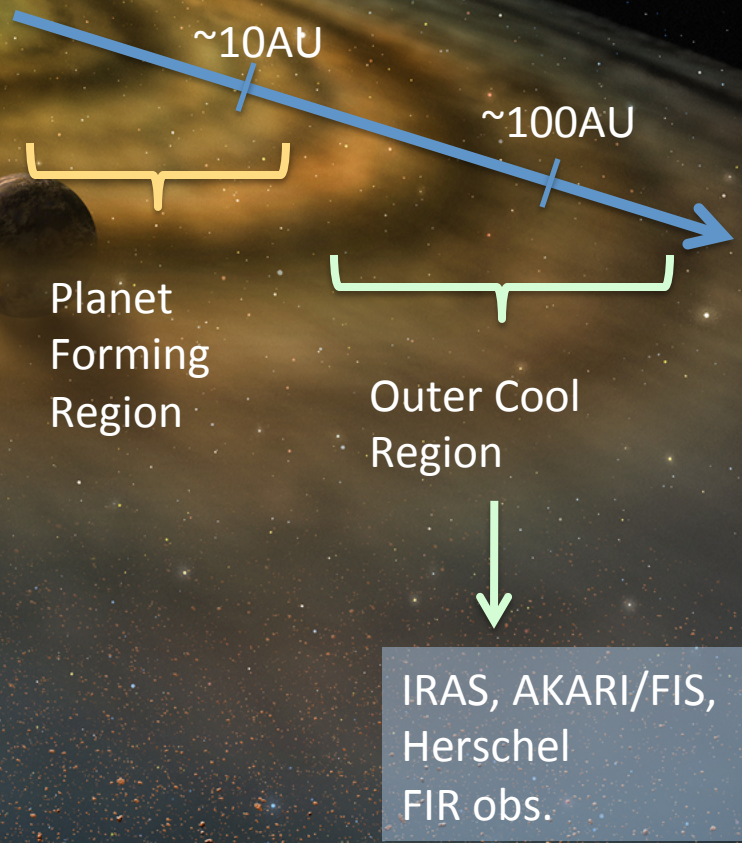


- IRAS
  - 1st sample – Vega with IR Excess at $\lambda > 25\mu m$ by IRAS (Aumann+ 1984)
  - >100 samples identified so far (e.g. Rhee+ 2007)

- Debris Disk and Planet Formation
  - Current Common view : Secondly generated from small bodies in MS phase
  - Debris disk can probe build-up processes of planets from planetesimals
  - Spatial distribution, size, composition of dust -> later stage of planet formation

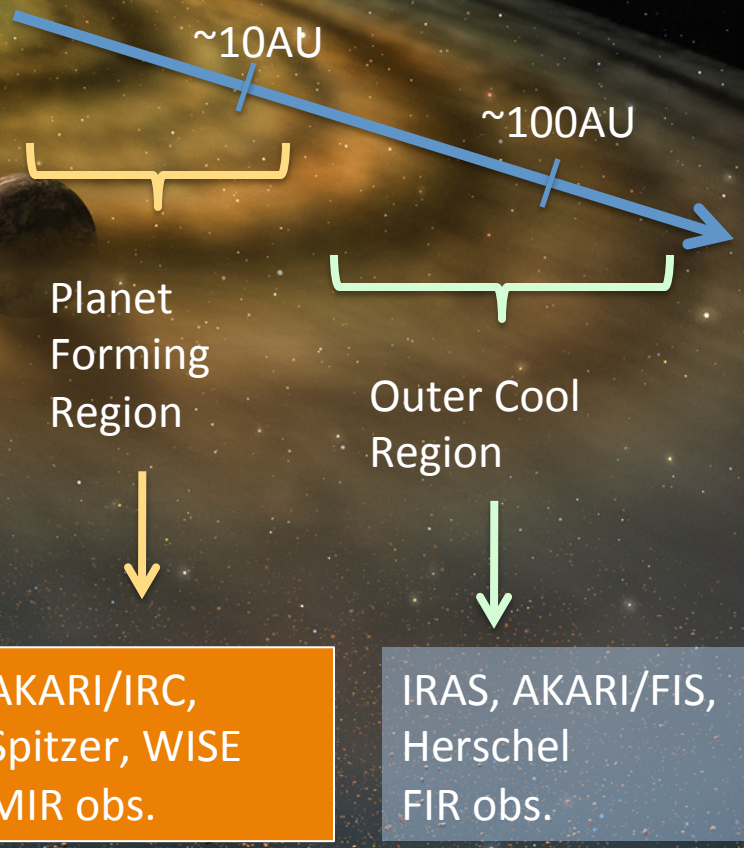
Warm Debris Disks

- Main stream after IRAS
  - Far-IR (FIR) observations trace low-temperature dust (~100K)
  - Outer region of debris disk (~100AU)
  - Analog of Kuiper-belt
- Debris dust with higher T
  - Located in the inner region (~1-10AU) (Asteroid analog)
  - Direct link to planet forming process
  - Mid-IR (MIR) observations of excess emission from warm dust

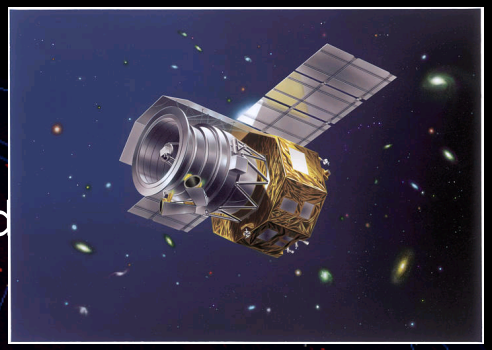


Strategy

- Problem (before several yrs ago)
  - Number of warm debris disk candidates was very limited
- AKARI, Spitzer
  - MIR observations with high sensitivity
  - Properties of the inner debris disk material
- Our Strategy
  - Increase the number of candidates by survey-type observations of large area
  - Detailed investigation of selected debris disk with follow-up observations



AKARI MIR All-Sky Survey



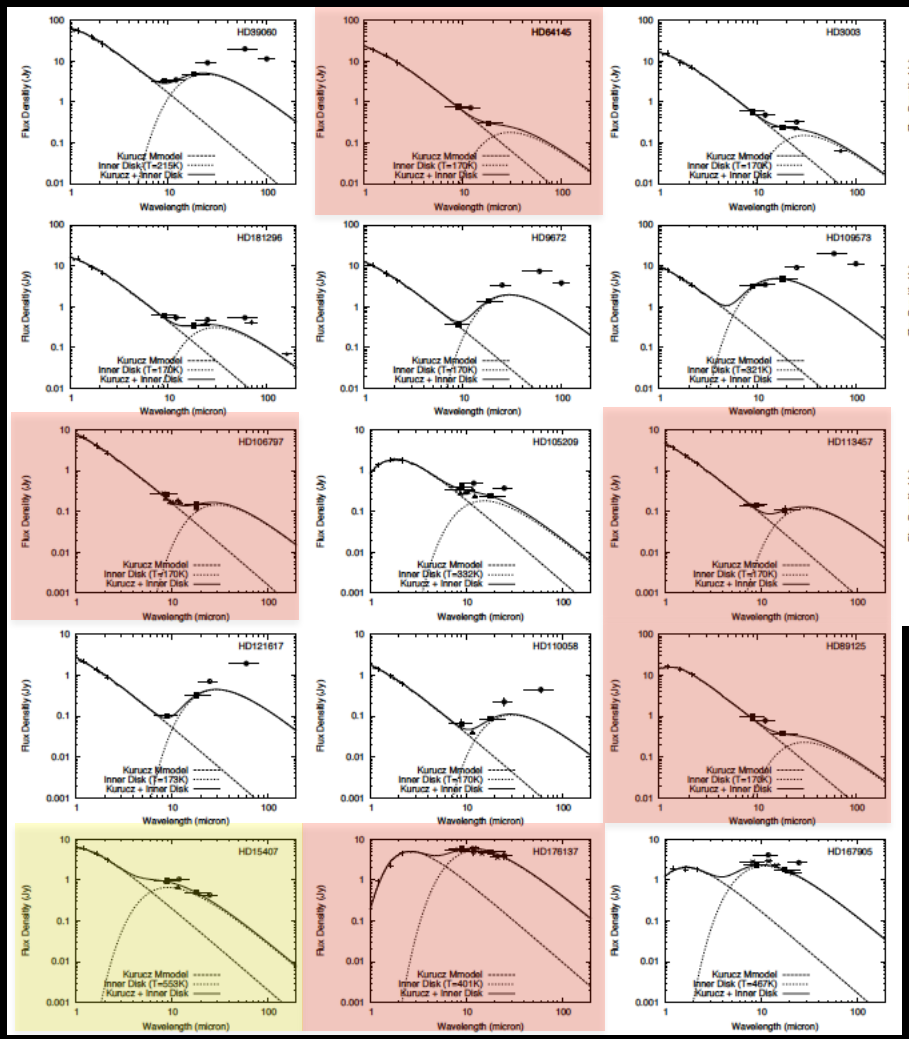
- AKARI : a Japanese IR satellite (surveyor)
  - All-sky survey in IR
  - MIR survey (9 and 18μm) with higher sensitivity and spatial resolution than IRAS
  - Point source catalog produced (Ishihara+ 2010)

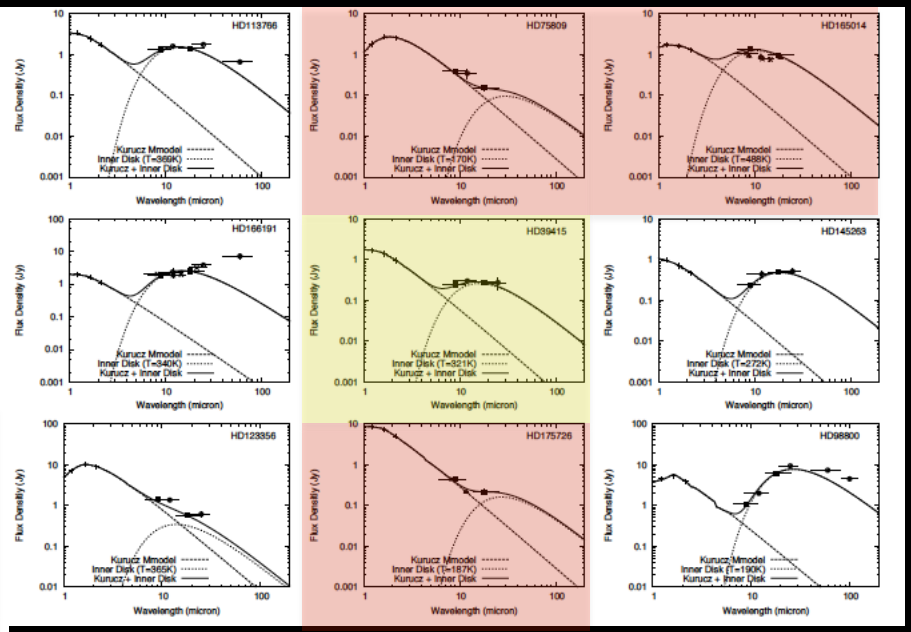
- Warm Debris Disk Survey with AKARI MIR Data
  - Fujiwara et al. 2013, A&A, 550, A45
- Method
  - Cross-correlating between AKARI, 2MASS, and Tycho-2 SpT catalog
  - Select MS stars with large 18 μm excess based on Ks-[18] color

Background : AKARI/IRC MIR All-Sky Survey
(Ishihara+ 2010, A&A)

AKARI-identified Debris Disks

- 24 candidates with 18μm excess identified out of 856 stars

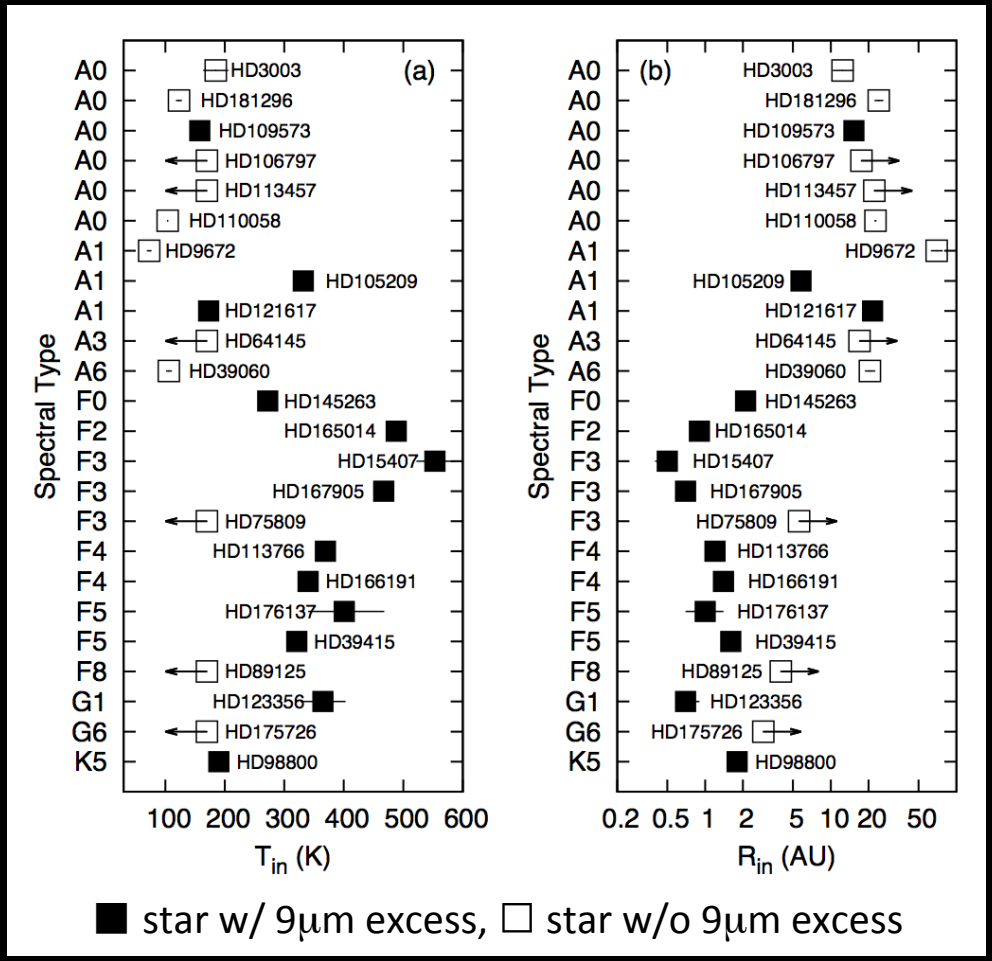




- Red: AKARI-discovered
- Yellow: 1st confirmation after IRAS (Oudmaijer+ 92)
- 13 stars also show 9μm excess
  - Presence of warmer dust

Debris Temperature & Radius

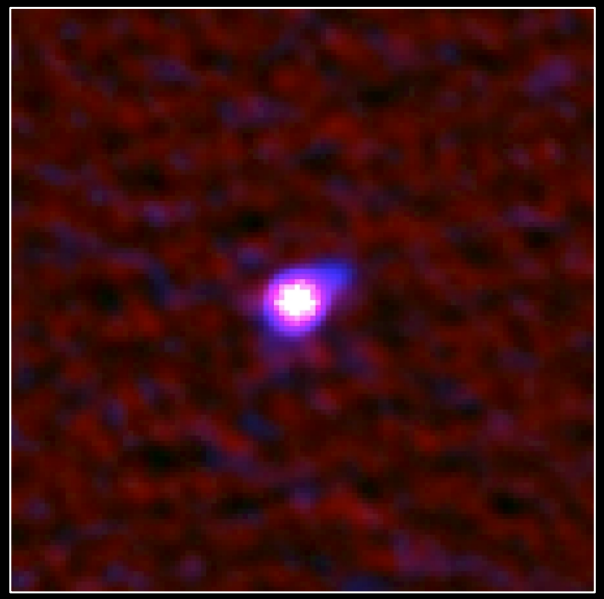
- Derived dust temperature and orbital radius of disk (inner rim)
  - Assume blackbody emission for IR excess

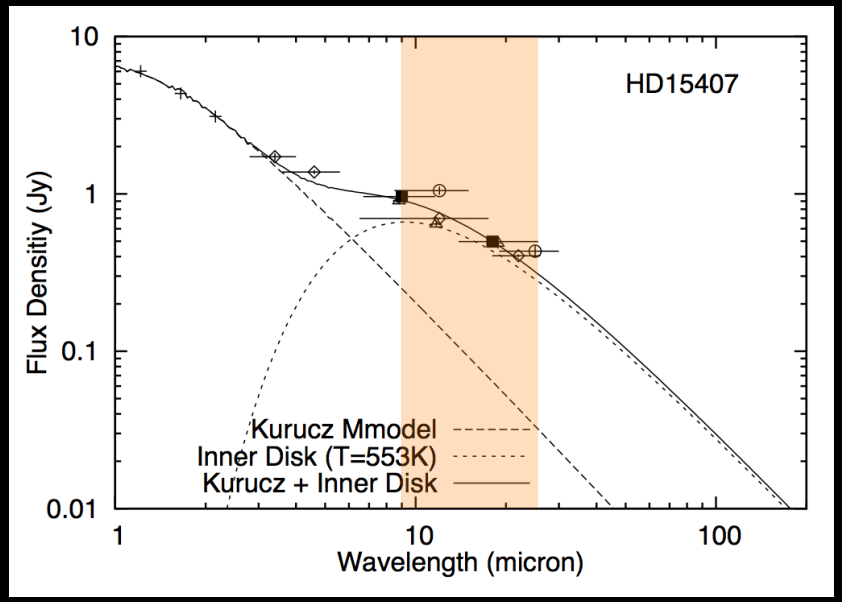


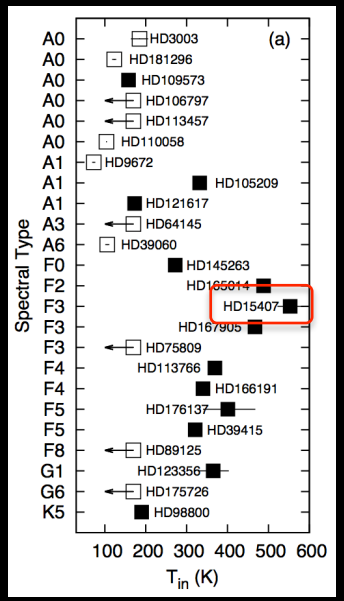
- Difference in the T between A and FGK stars
  - A stars: T_{dust} < 200K
    - Wien-side tail of relatively cool debris dust of large disk
  - FGK stars: T_{dust} = 300-500K
    - Presence of abundant warm dust in inner system
  - Radiation Pressure
    - μm-sized grains are blown out around A stars or earlier due to its larger radiation pressure

Extreme Debris Disk HD 15407A

- IRAS-discovered / AKARI-confirmed warm debris disk (F3V star at d=55pc)
- Extremely bright MIR excess at 9 and 18μm
  - A large amount of very warm (~500K) dust in the system
  - Disk luminosity -- x10^5 of solar system ZL

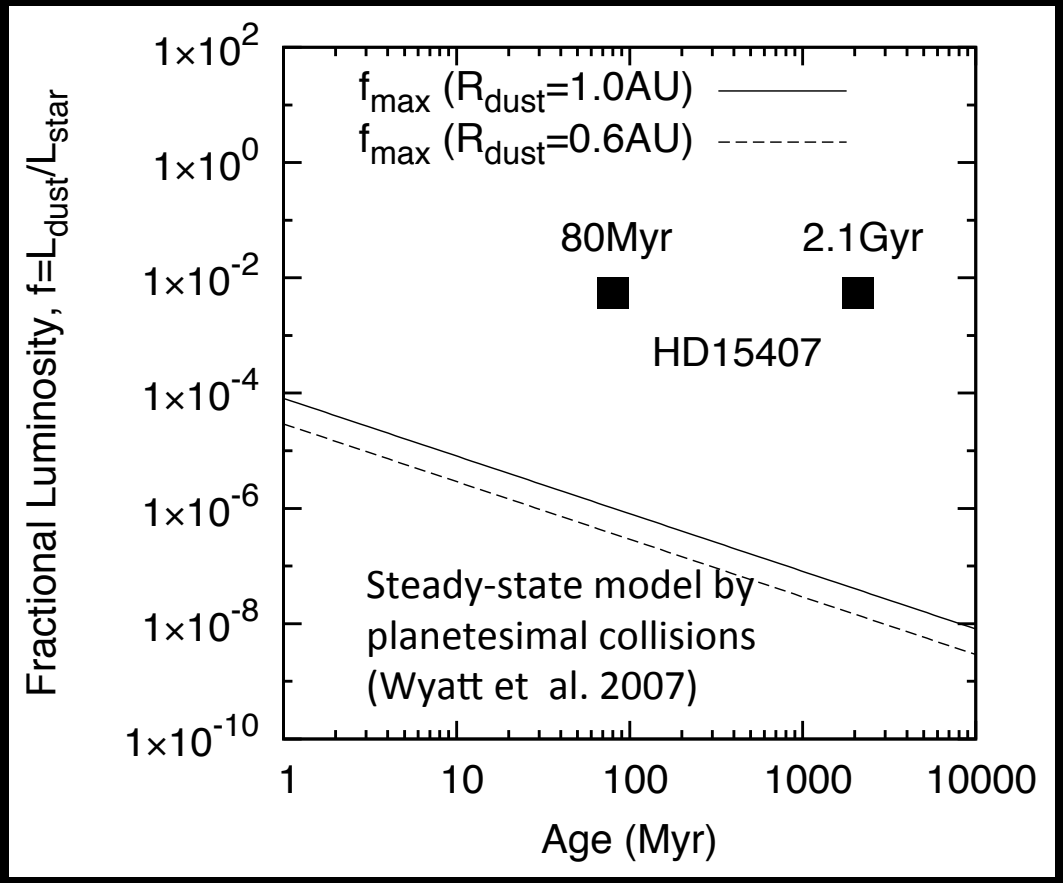






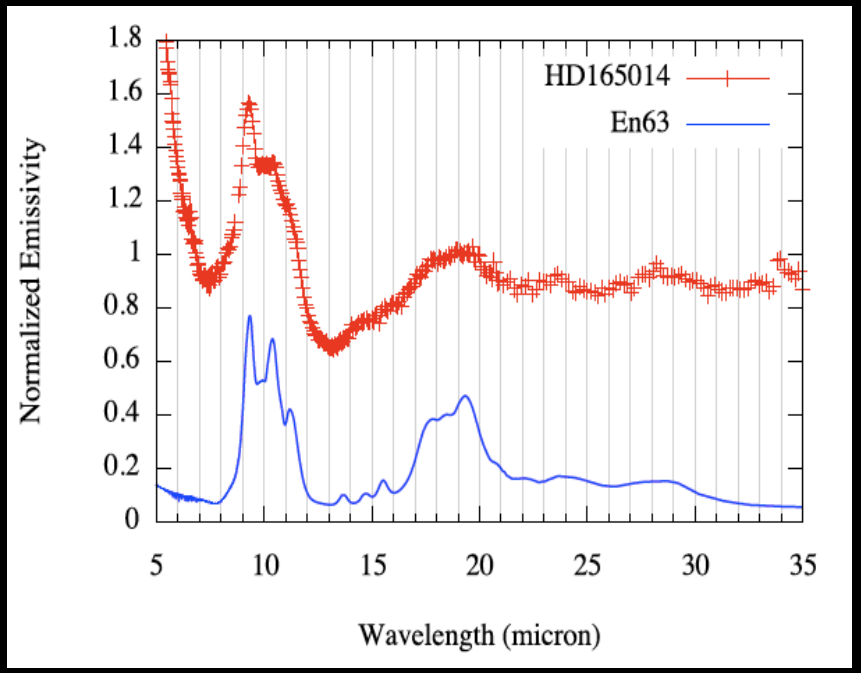
Fractional Luminosity of HD 15407A

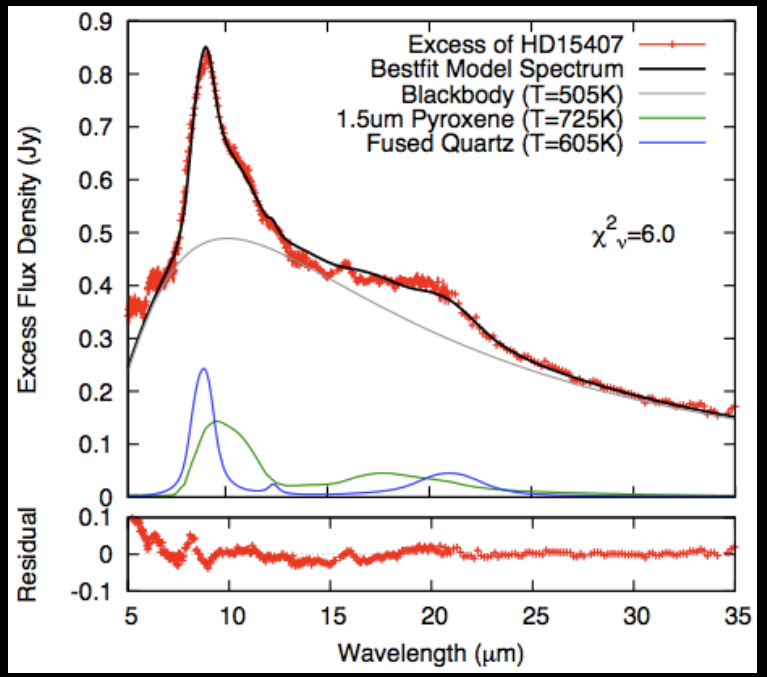
- Fractional luminosity
  - L_{dust}/L_{star}
  - An indicator of "dustiness"
- FL of HD 15407A ~ 0.005
  - Much larger than the steady-state evolution model of debris disk
- Originated in a transient dust production event such as giant impact?
  - Suggested for HD172555 by Lisse+2010, BD+20307 by Weinberger+2011



Target for Follow-up Observations

- MIR observations with Spitzer/IRS, Subaru, Gemini
  - HD 165014: Enstatite dust (Fujiwara+2010)
  - HD 15407A: Silica dust (Fujiwara+2012a,b)
  - HD 106797: Fe-rich silicate dust (Fujiwara+2009)
- Diversity of dust processing in debris disks
  - Clues for origin of debris dust





Summary

- 18μm survey of warm debris disks with AKARI
  - 24 warm debris disk candidates including 8 new candidate with bright MIR excess from all-sky survey data
  - Differences in dust temperature of warm debris disks between A and FGK stars
    - A stars: Large disks due to radiation pressure on small grains
    - FGK stars: Bright warm disk with small radii and without cool emission
  - Fractional luminosity much larger than steady-state model of debris disk (e.g. HD 15407A)
    - Transient dust production events?
  - Provided nice samples for follow-up observations

References

- Debris disk survey
  - Fujiwara et al. 2013, A&A, 550, A45 (AKARI)
- HD 15407A
  - Fujiwara et al. 2012, ApJ, 749, L29 (Spitzer)
  - Fujiwara et al. 2012, ApJ, 759, L18 (FIR)
- Others (dust mineralogy)
  - Fujiwara et al. 2010, ApJ, 714, L152 (ENSTATITE-RICH WARM DEBRIS DUST AROUND HD 165014)
  - Fujiwara et al. 2009, ApJ, 695, L88 (HOT DEBRIS DUST AROUND HD 106797)