Sensitivity of Upcoming Facilities to Debris Dust

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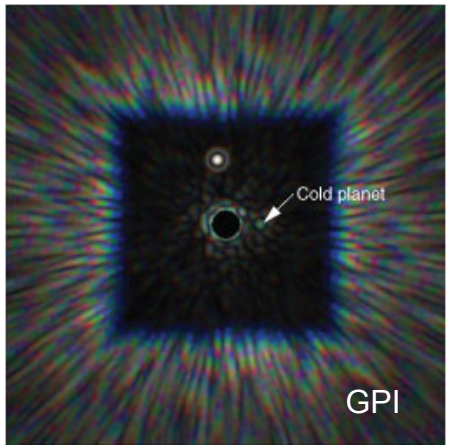
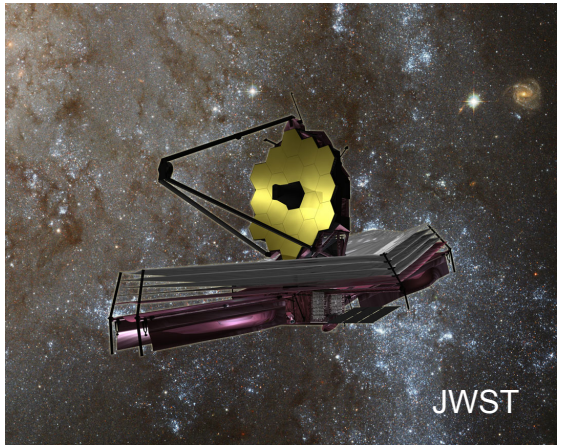
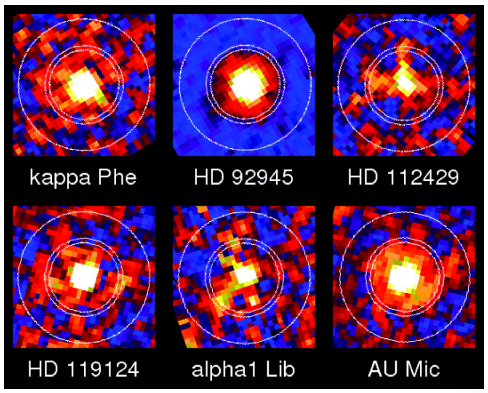


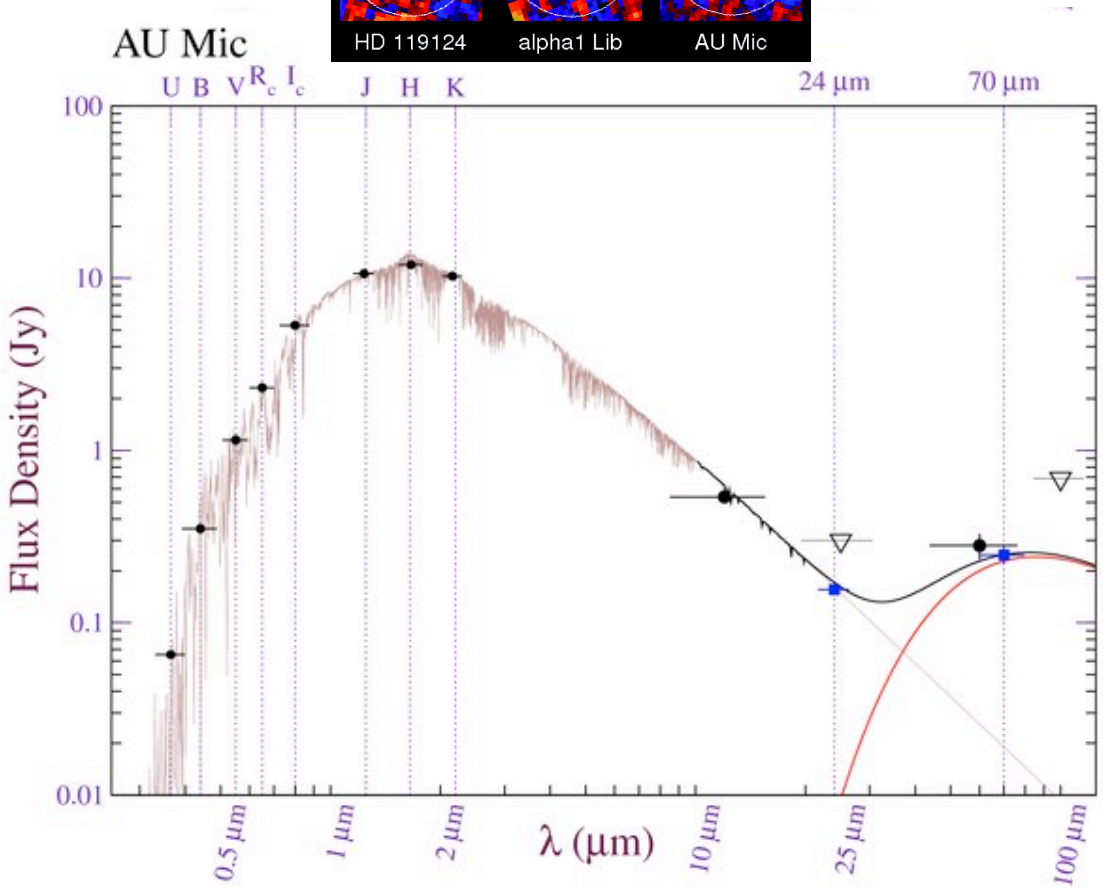


Past, Current, and Future Missions

- Infrared and Submillimeter Photometry
  - Past and Current: IRAS, Spitzer, Herschel
  - Future: WISE, JWST
- Nulling Interferometry
  - Past and Current: Keck Interferometer
  - Future: LBTI
- Coronagraphy
  - Past and Current: HST STIS, NICMOS, and ACS
  - Future: GPI, JWST MIRI, NIRCam, and TFI

Detecting Debris I. IR and Submm Photometry



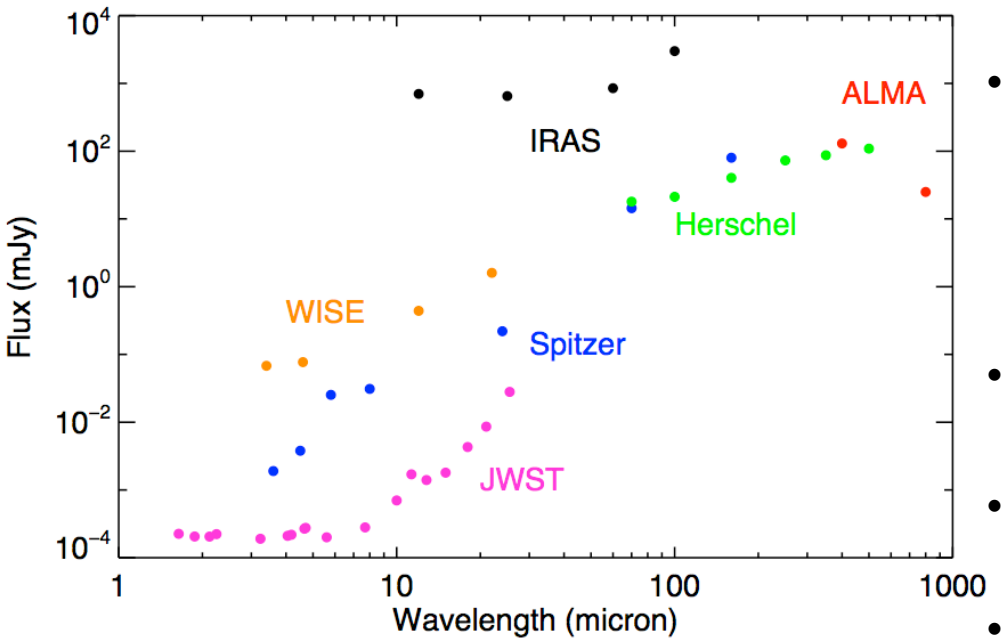


- Dust Thermal Emission
- Majority of systems (1000s) surveyed using this technique
- Measured Quantities: Flux (erg s^{-1} cm^{-2})
- Inferred Quantities: L_{dust}/L_{star} (proxy for dust mass) and T_{dust} (grain temperature)
- Detection depends on accurate (1) stellar photosphere model and (2) absolute calibration of data

Chen et al. (2005)
Plavchan et al. (2009)

Infrared and Submillimeter Missions

Sensitivities

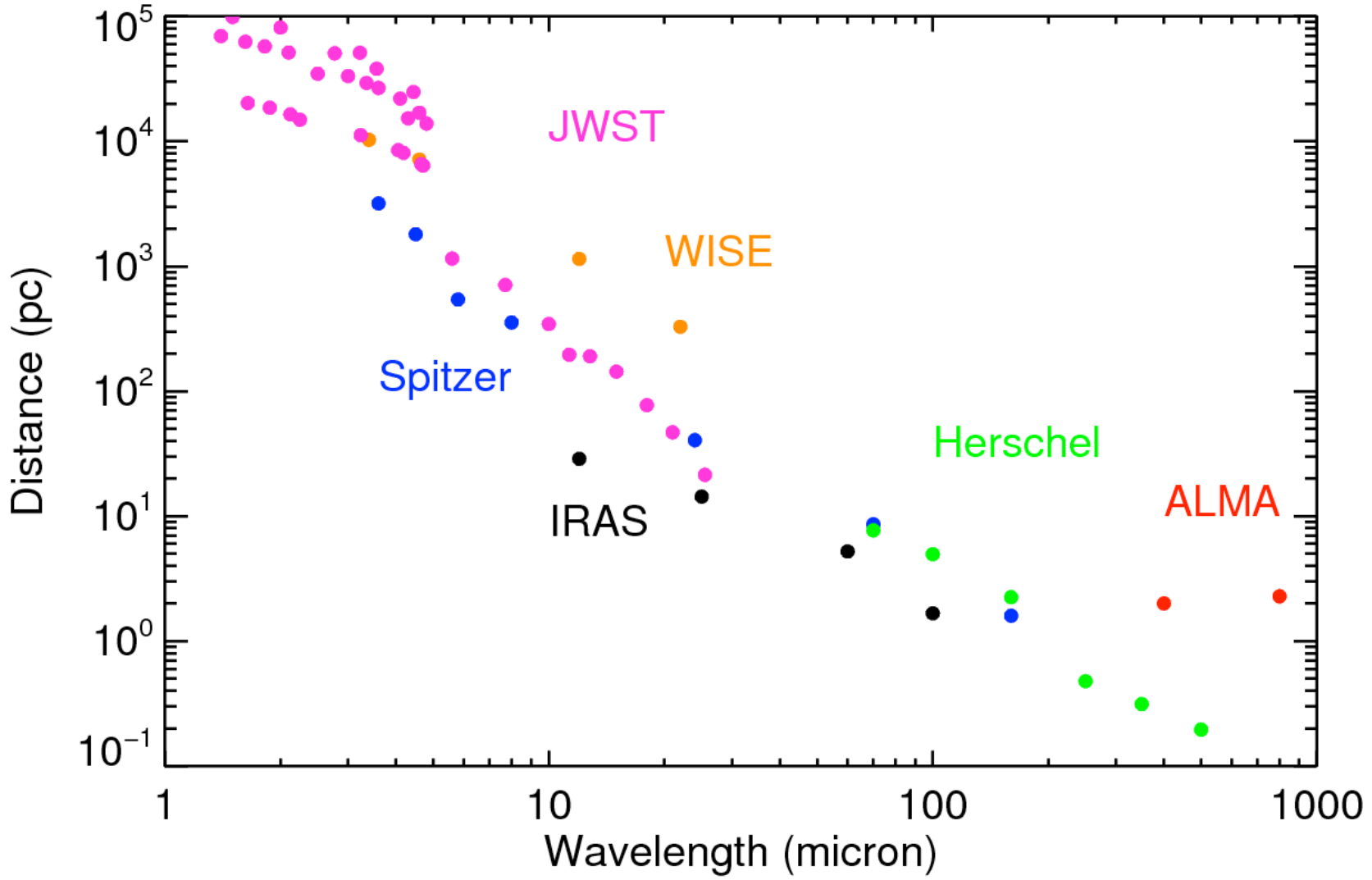


Herschel, JWST, and Spitzer sensitivities are 10σ in 10,000 sec

Calibration Uncertainties

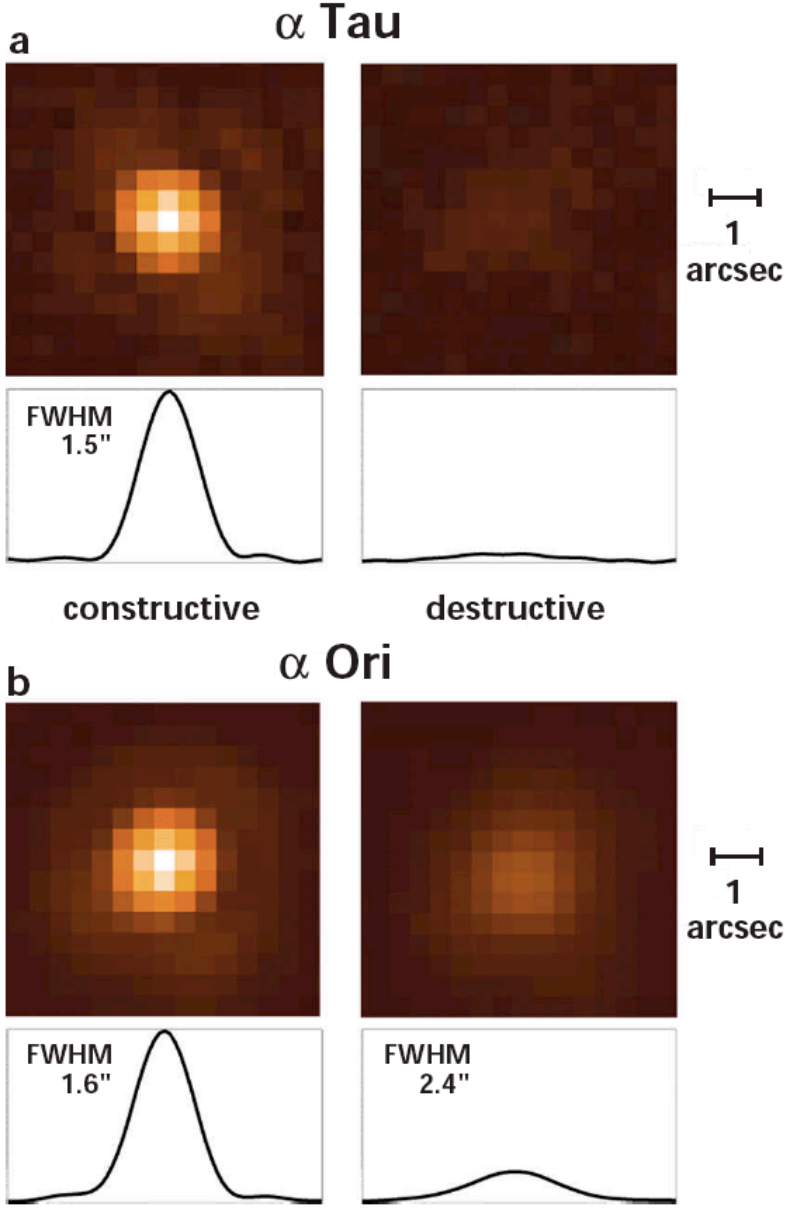
- Spitzer
  - IRAC: 3% at 3.6 μm, 4.5 μm, 5.8 μm, and 8.0 μm
  - MIPS: 4% at 24 μm, 7% at 70 μm, and 12% at 160 μm
- Herschel
  - PACS: 10-20% at 70-160 μm
- WISE
  - 10% at 3.4, 4.6, 12 and 22 μm
- JWST
  - NIRCam: 3% at 70-160 μm
  - MIRI: 2% at 5.6-25.5 μm

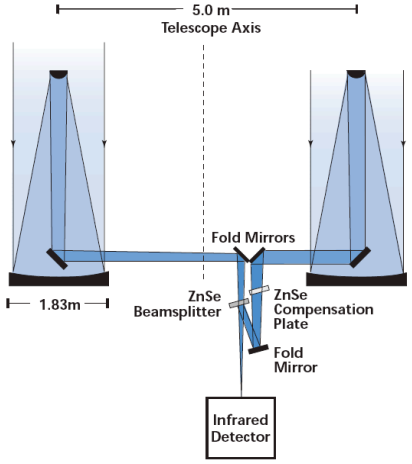
Probing Distant Solar Systems



- Distances calculated for a G2V star assuming published IRAS and WISE survey sensitivities and typical Spitzer (IRAC-30 sec; MIPS24-25 sec, MIPS70-625 sec, MIPS160-625 sec), Herschel (PACS and Spire - 625 sec) and JWST (NIRCam-30 sec, MIRI-25 sec) integration times

Detecting Debris II. Nulling Interferometry





- Dust Thermal Emission
- Few systems probed (~100)
- Measured Quantities: Source Null = $\Delta(I_{null}/I_o)$
- Inferred Quantities: L_{dust}/L_{star} assuming T_{dust}
- Potentially more sensitive technique that does not depend on stellar models or absolute calibration

Hinz et al. (1998)

Nulling Interferometers

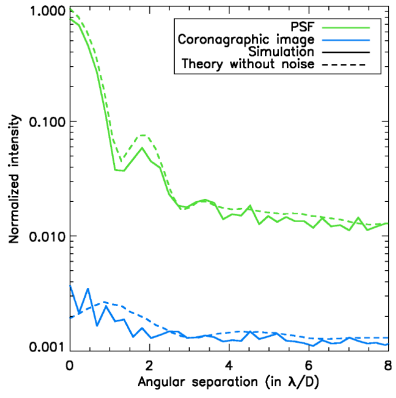
Keck Interferometer

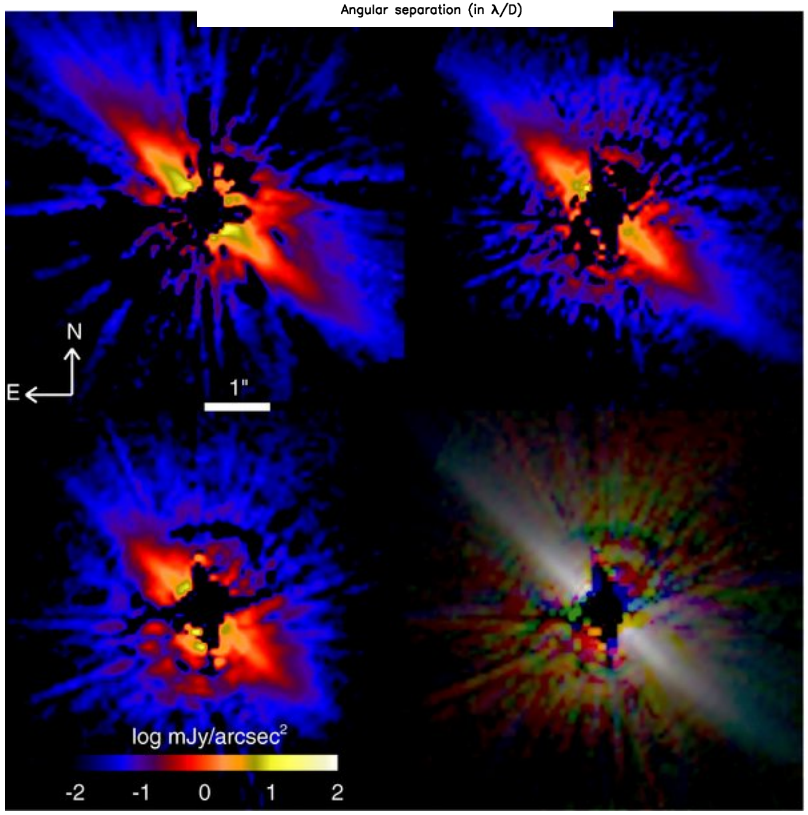
- Null Leakage Uncertainty
  - For bright sources (> 2.4F Jy), 0.25% at N-band
  - For faint sources (1.7-2.4F Jy), 0.5% at N-band
- Circumstellar Disk Detection with the Keck Nuller
  - P.I. W. Traub and M. Kuchner
  - 100 TPF Targets
- Nulling Key Science Team
  - P.I. E. Serabyn
  - 25 primarily FGK stars

LBTI

- Null Leakage Uncertainty
  - 0.01% at 11 μm
- Nulling InfraRed Survey of Extra-solar Systems for TPF (NIREST)
  - P.I. P. Hinz
  - 80 Targets

Detecting Debris III. Coronagraphy





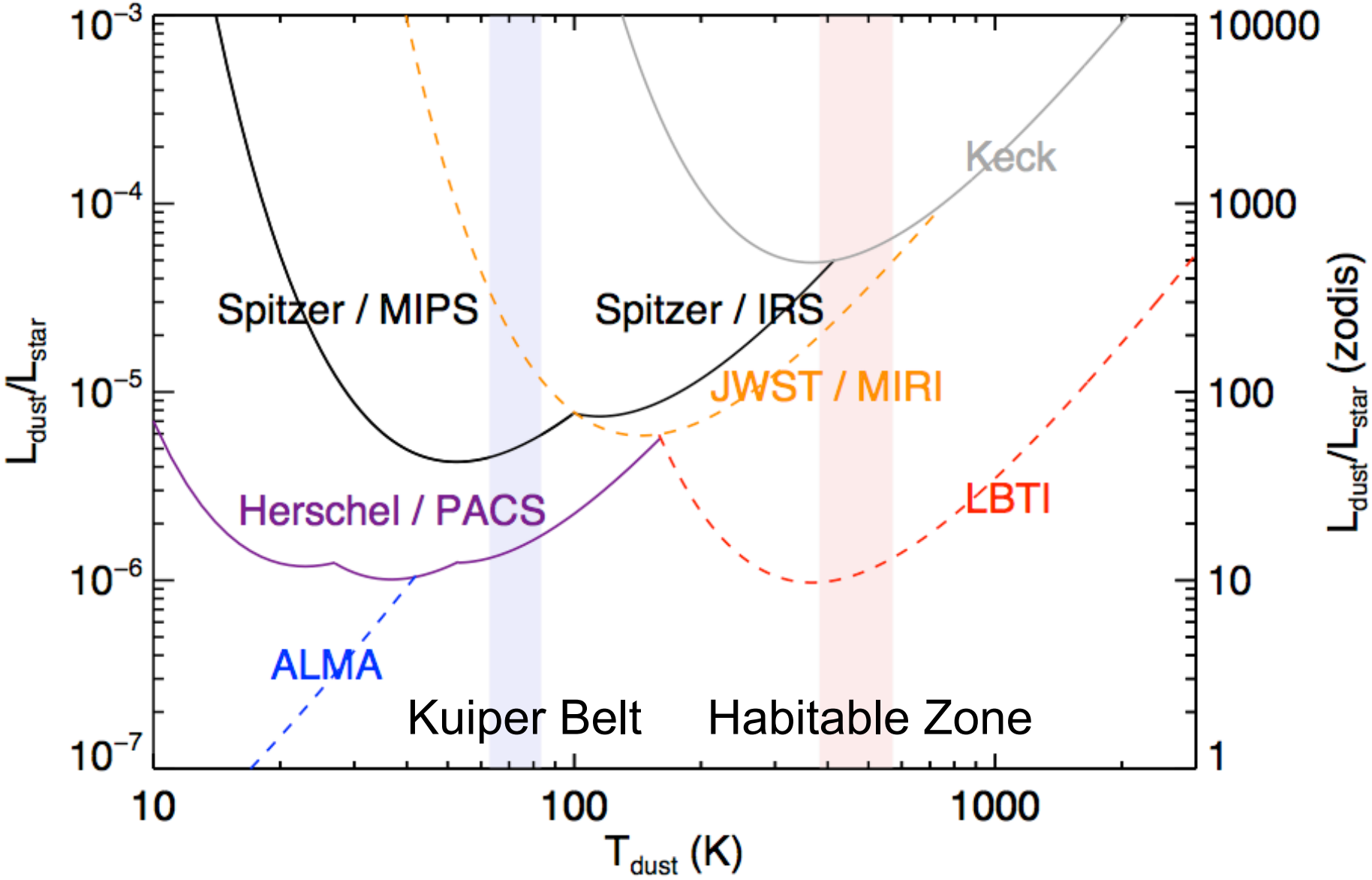
- Either Dust Thermal Emission or Scattered Light
- Few systems probed (100s) typically, as follow-up to resolve dust disk
- Measured Quantities: D (dust distance), Flux (surface brightness, erg s^{-1} cm^{-2} $arcsec^{-2}$)
- Inferred Quantities: albedo
- Potentially more sensitive technique that does not depend on stellar models or absolute calibration

Debes et al. (2009)

Coronagraph Performance

Instrument	Wavelength	Inner Working Angle	PSF Attenuation
HST ACS	BVI	1.8″	6-7x
HST STIS	BVI	0.3″	2-6x
HST NICMOS	0.95-2.4 μm	0.5″	2-3x
GPI	H	0.04″	10^6x
JWST NIRCam Radial Sombrero	2.1-4.3 μm	0.2″-0.41″	10^5x
JWST NIRCam Linear Sinc	2.1-4.6 μm	0.13″-0.29″	10^5x
JWST TFI	1.5-2.5 μm and 3.1-5.0 μm	2″	100x
JWST MIRI 4QPM	10.65 μm, 11.4μm, 15.5 μm	0.7″	400x
JWST MIRI Lyot	23 μm	2.2″	100x

Sensitivity vs. Debris Disk Properties



Conclusions

- The absolute calibration of IR and Submm missions limits our ability to detect zodiacal dust disks to better than 10x that observed in our Solar System
- Future IR and submm missions will search for dust in systems that are 10x further away
- Nulling interferometry and coronagraphy are expected to provide improved sensitivity to zodiacal dust (e.g. LBTI and GPI); however, these techniques will not be sensitive to 1 zodi and survey a relatively limited number of targets