

Imaging Gaps Created by Planets in Circumstellar Disks



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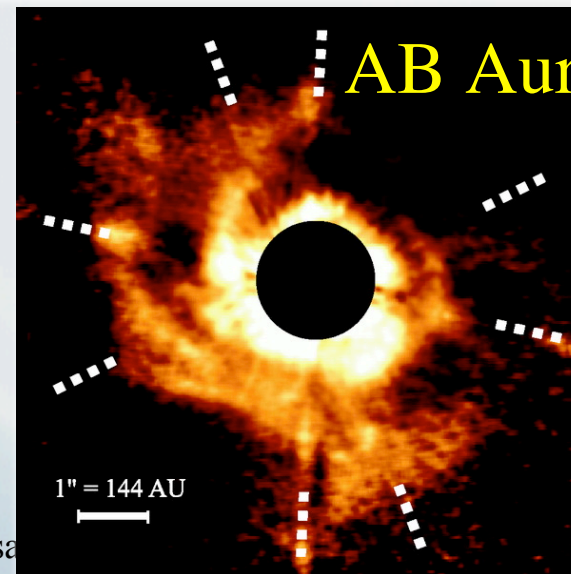
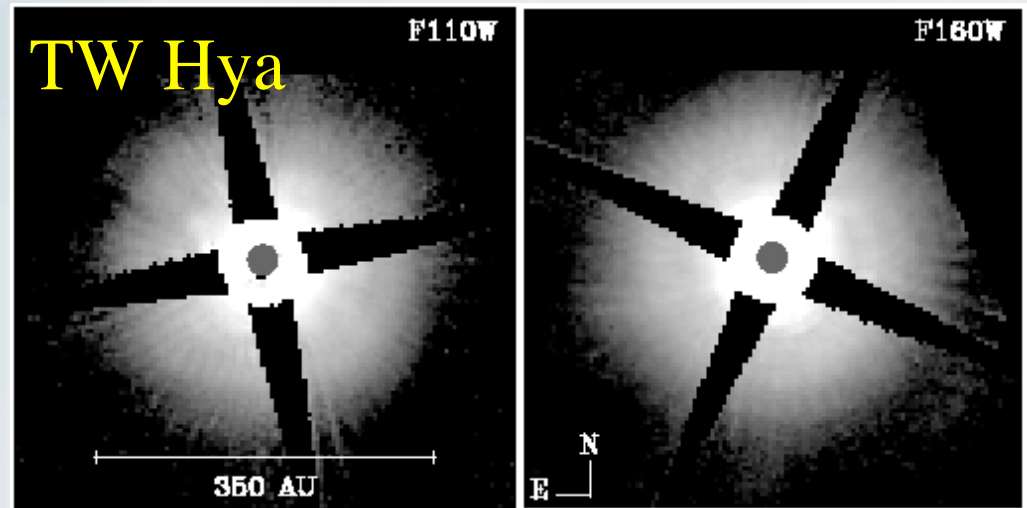


Collaborators

- Marc Kuchner (GSFC)
- Lee Mundy (UMD)
- John Debes (CIW/DTM)

Primordial Protoplanetary Disks

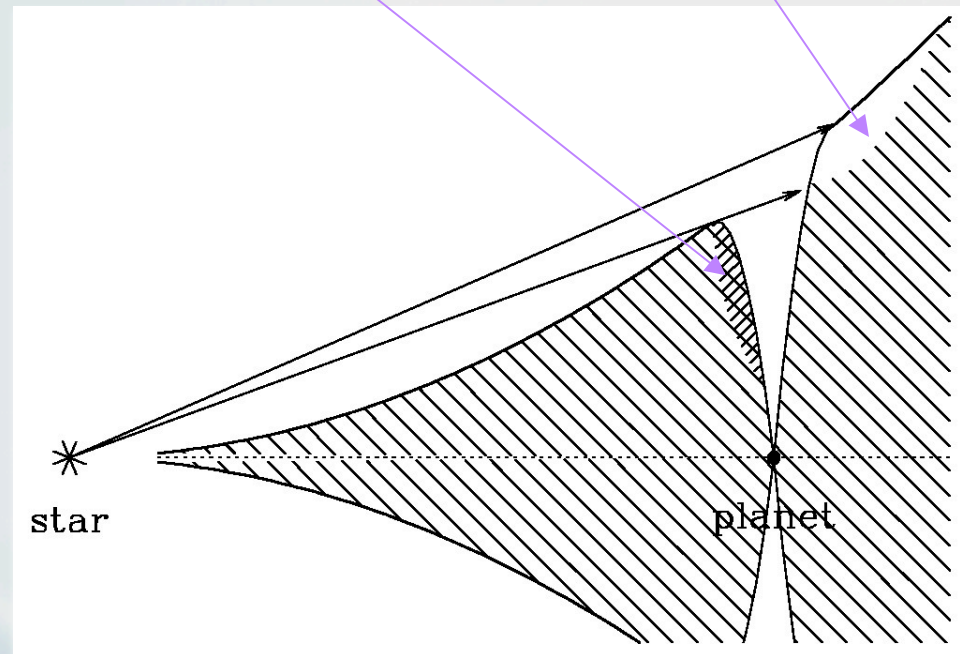
- T Tauri (F,G,K stars) or Herbig Ae/Be (A,B stars)
- Young (~ 1 Myr)
- Optically thick
- Gas-dominated
- Era of Giant Planet formation
- To predict observations, model **radiative transfer**



Planet Dimples

- Steady state
- Hydrostatic equilibrium
- Semi-analytic prescription for radiative heating
- T & ρ iteratively calculated for self-consistency

shadowing brightening



(Jang-Condell & Sasselov 2003, 2004;
Jang-Condell 2008)

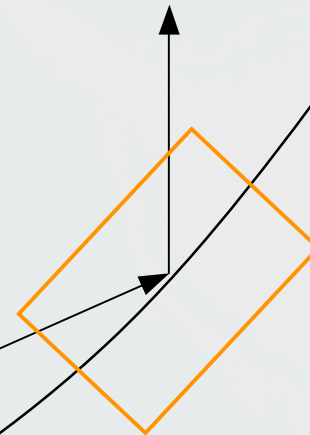


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Far IR Astronomy - Pasadena, CA

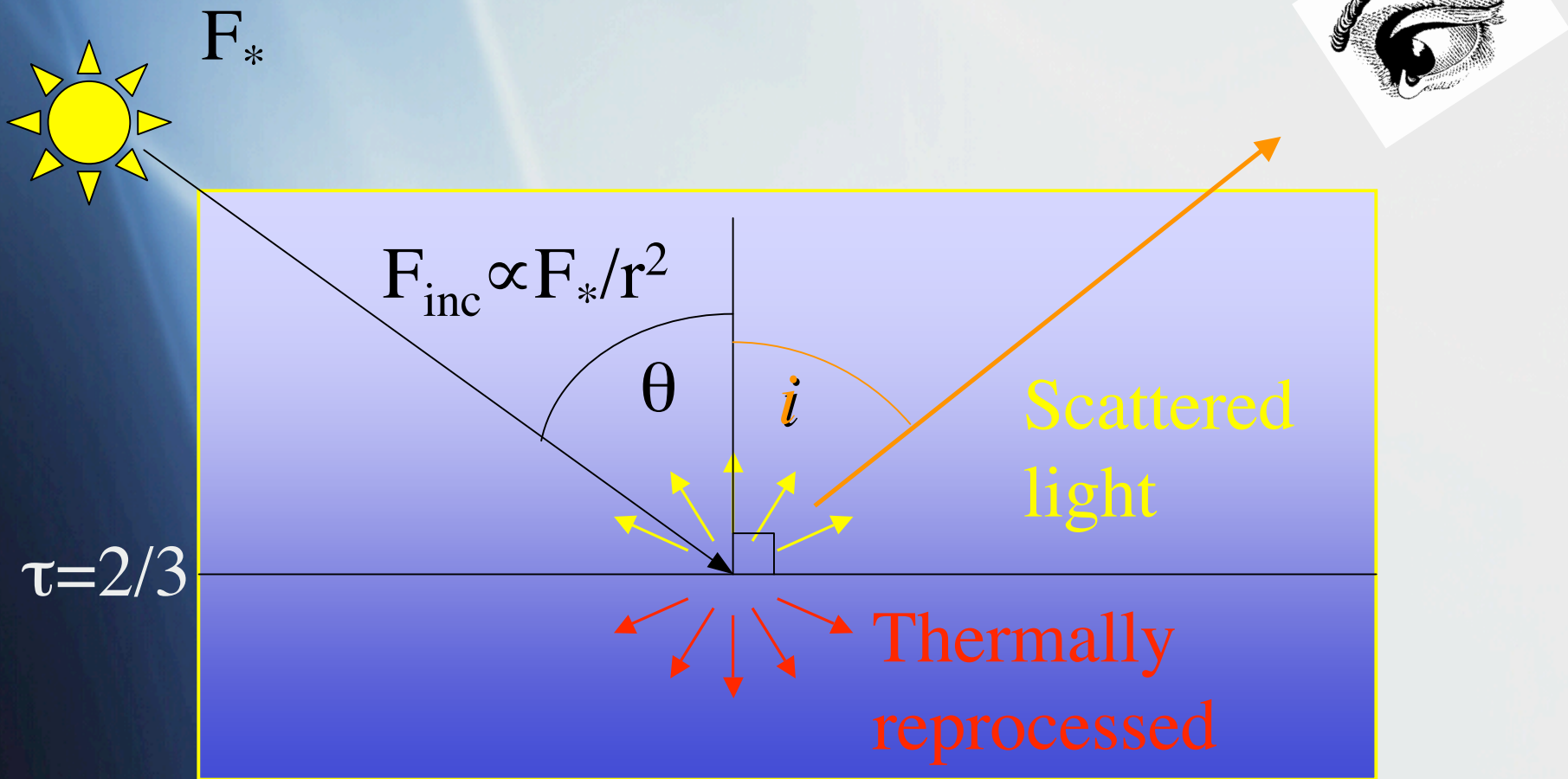
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To observer $\tau=2/3$



Flared disk

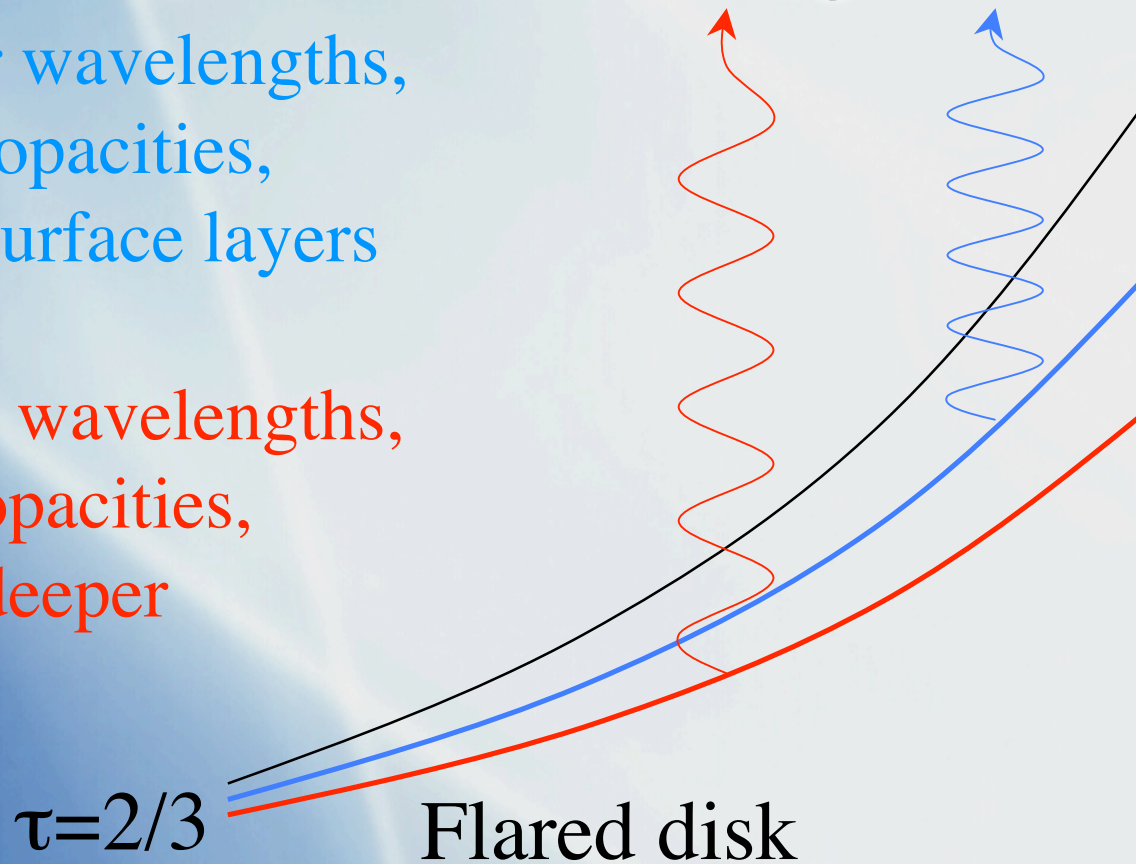
Simulated Images



Simulated Images

Shorter wavelengths,
higher opacities,
probe surface layers

Longer wavelengths,
lower opacities,
probe deeper

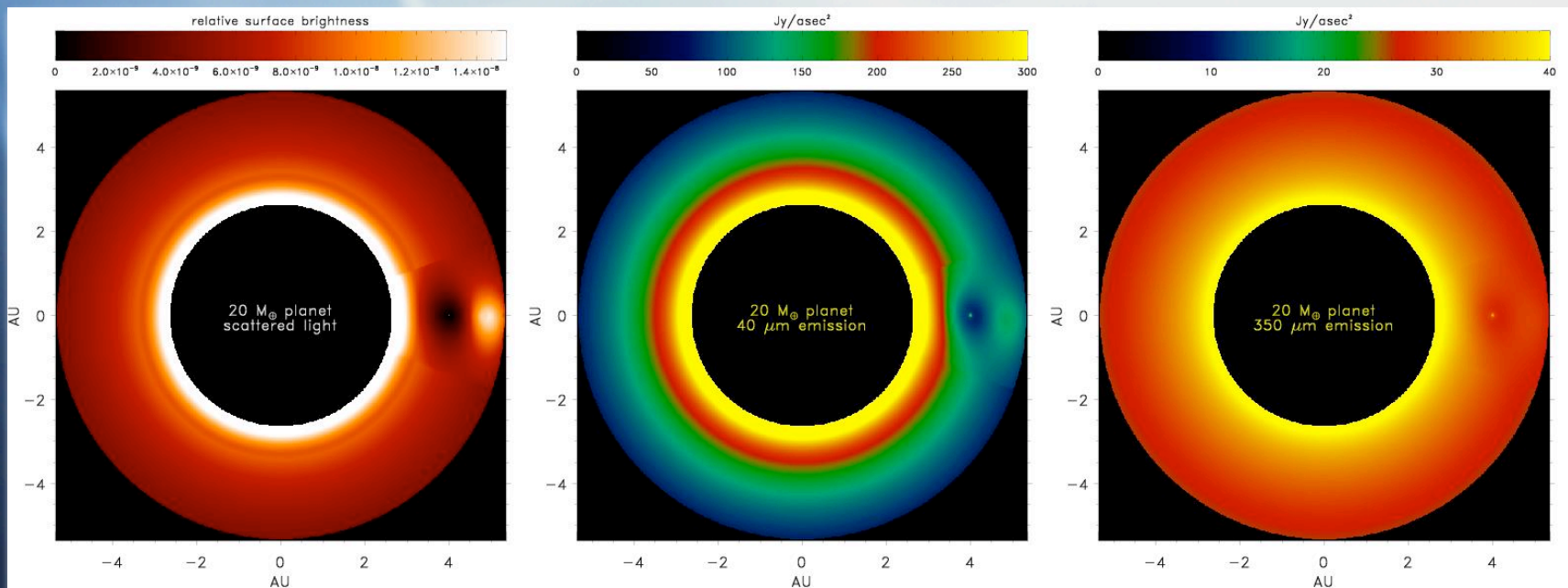


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20 M_{Earth} Core at 4 AU



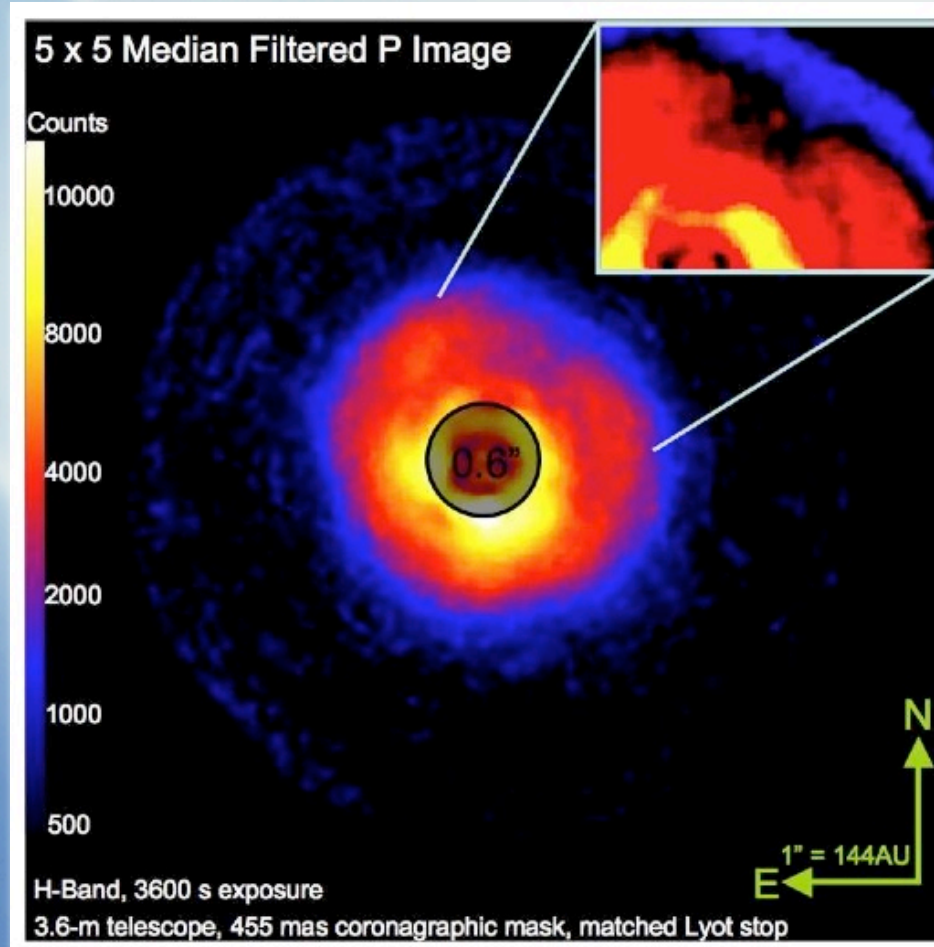
Scattered light

mid IR: 40 μm

0.35 mm

- Paired shadowing/brightening at surface (short λ)
- Effect diluted toward midplane (long λ)
- ~ 1 AU perturbation - 0.01'' resolution at 100 pc

AB Aur

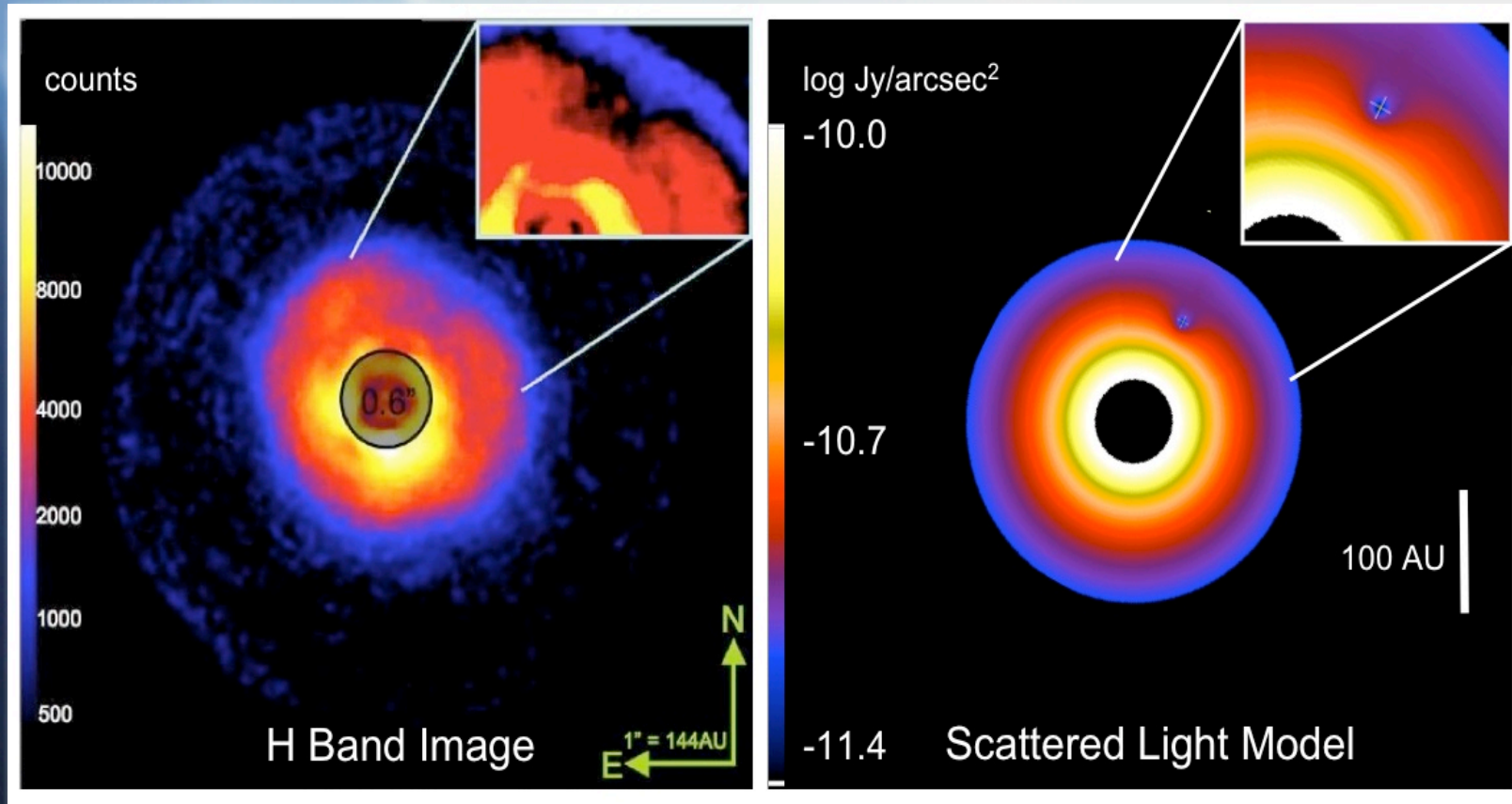


Oppenheimer,
et al., 2008

AB Aur

Oppenheimer, et al. 2008

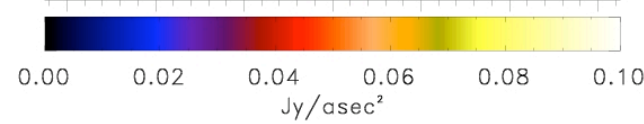
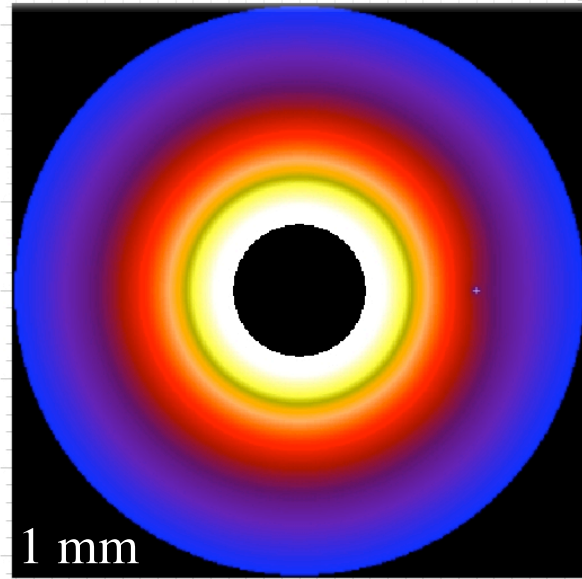
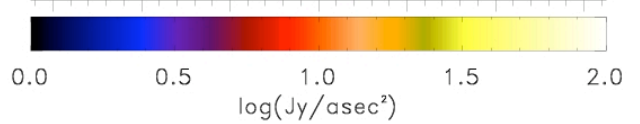
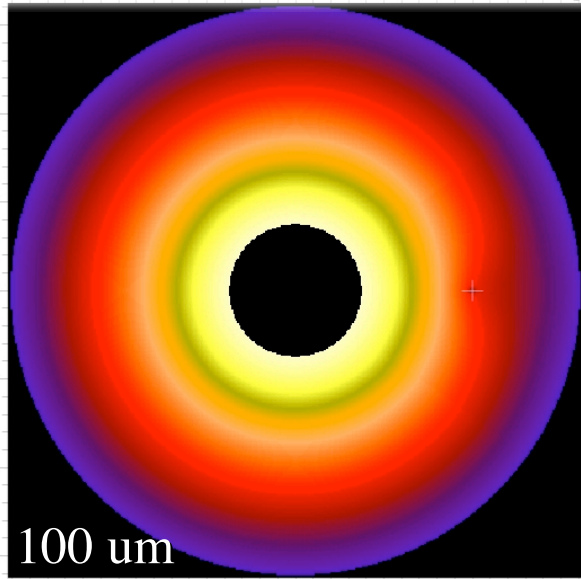
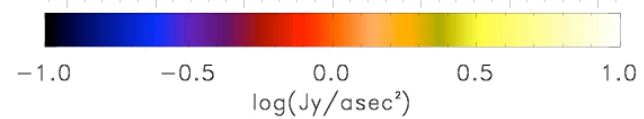
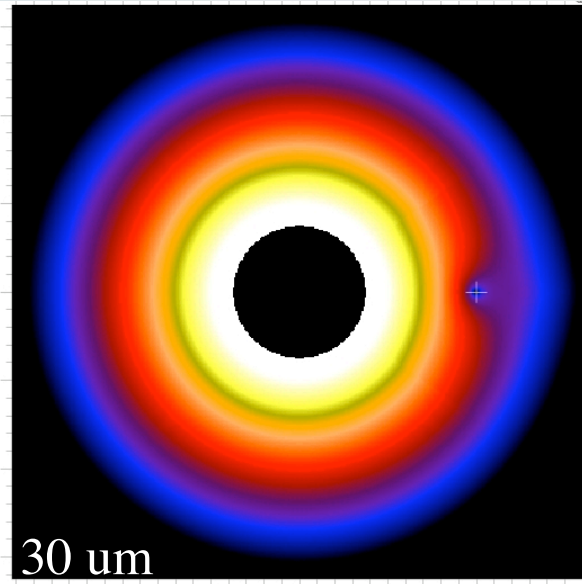
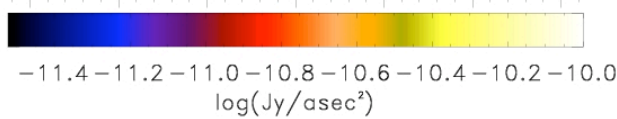
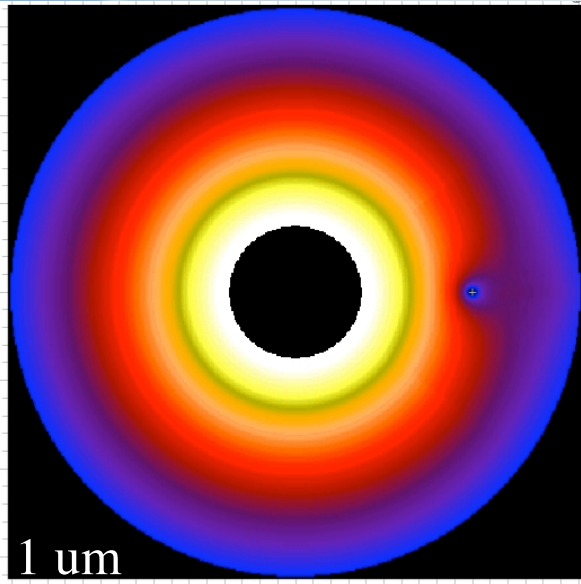
Jang-Condell & Kucher, in prep



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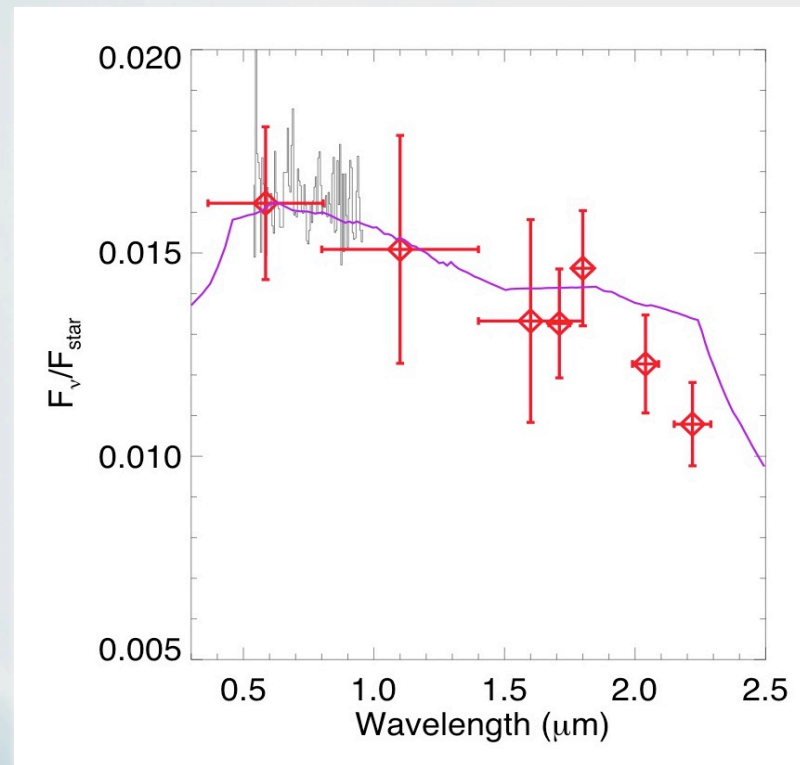
1 M_J @ 100 AU₁₀



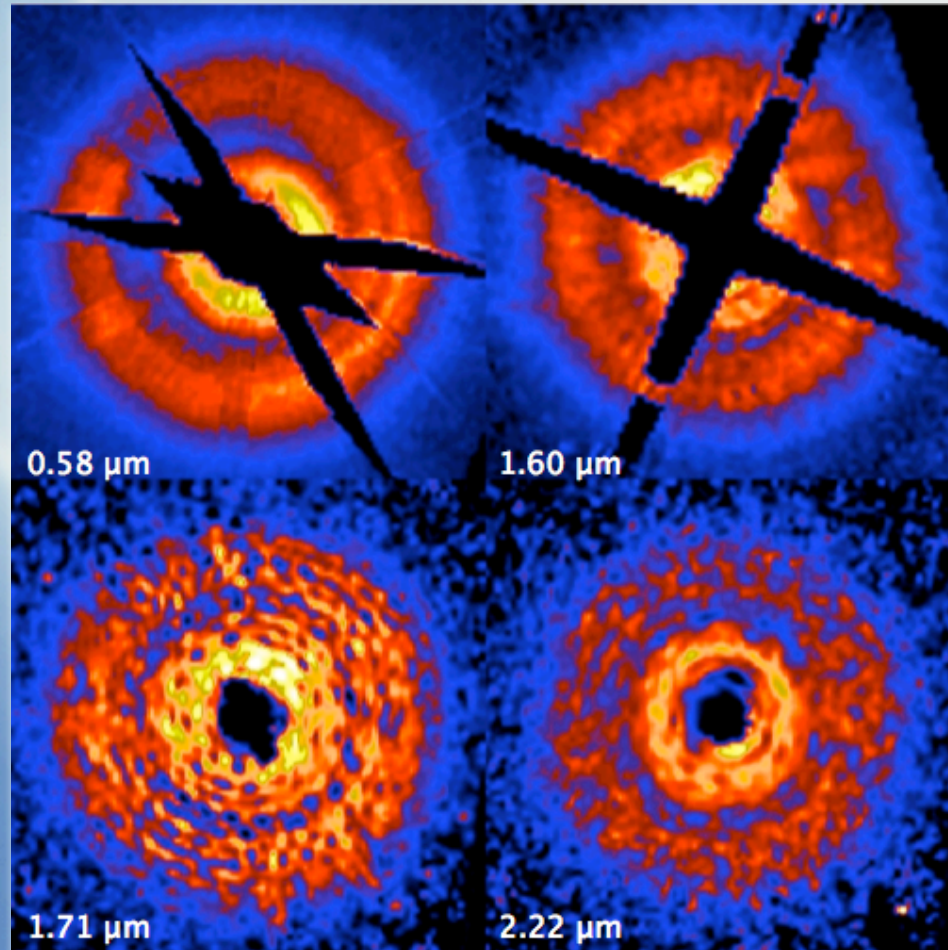
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TW Hya

- Debes, et al. (in prep)
- Hubble observations
 - STIS
 - NICMOS
- Dust opacities
 - Size distribution
 - Composition
- Create scattered light spectrum



TW Hya: A Gap?

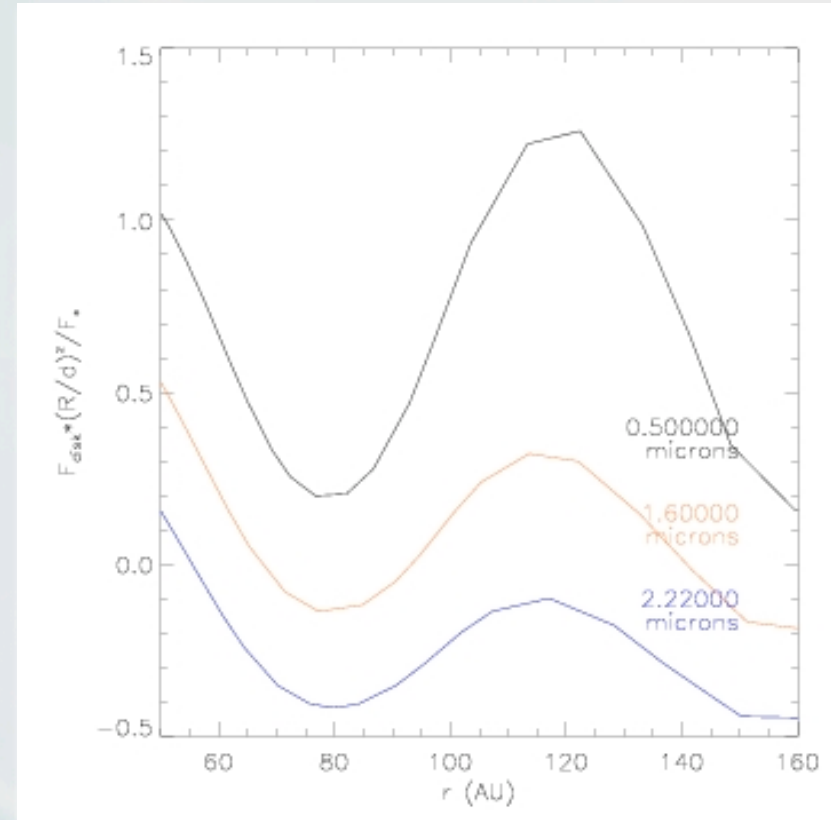
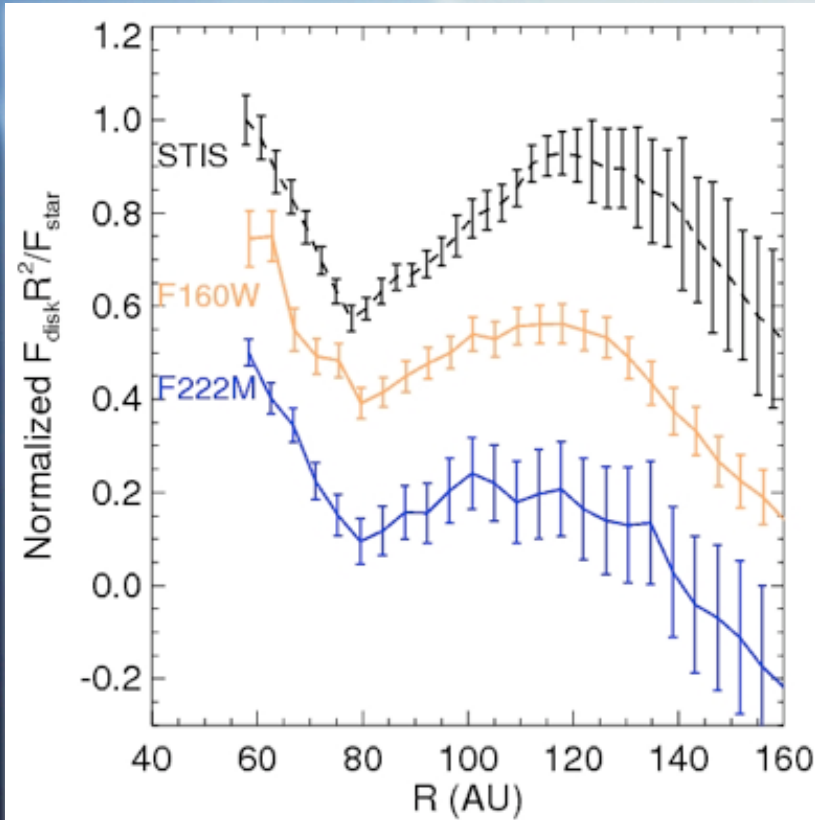


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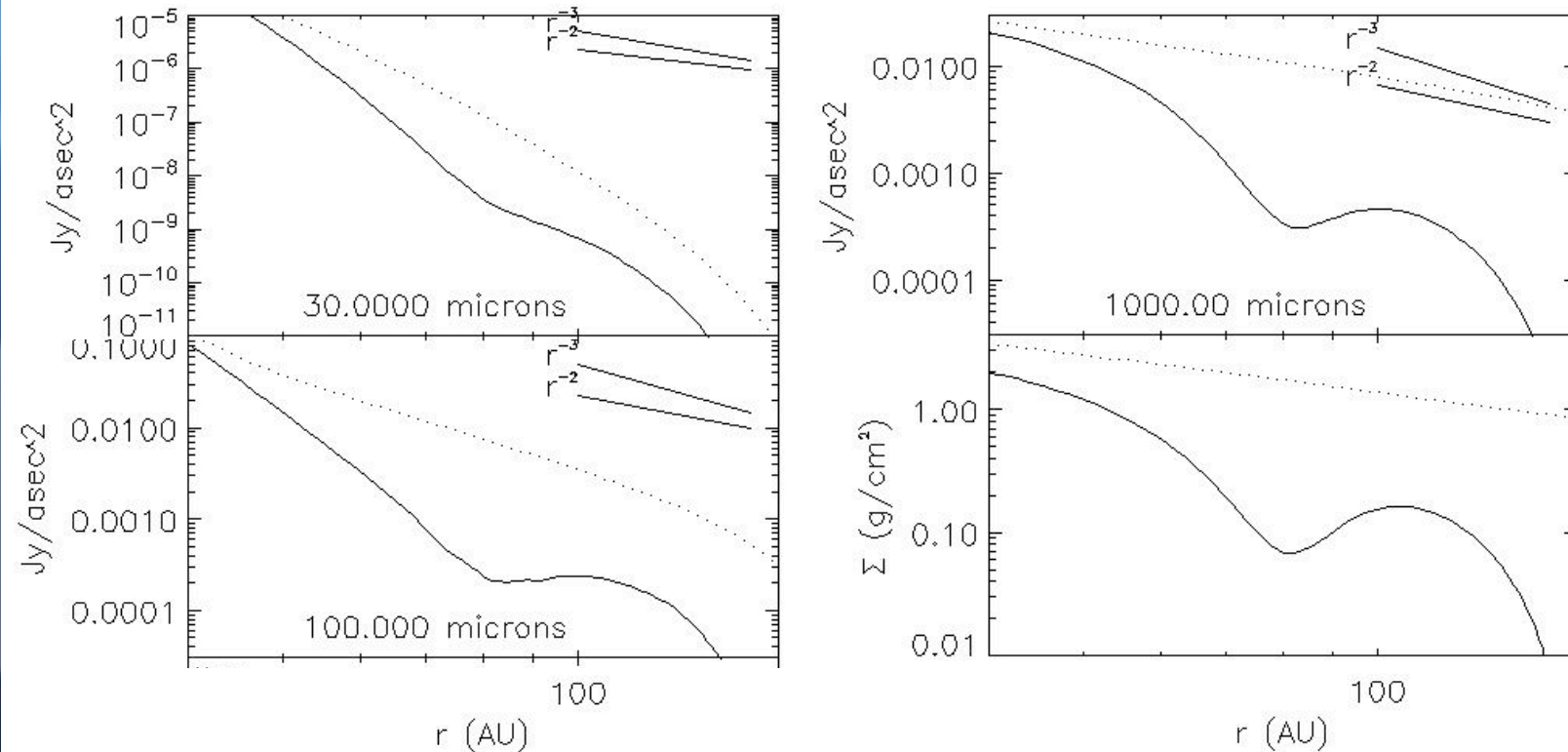
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Gap at 80 AU, 90% clearing Truncated at 160 AU



- Debes, Jang-Condell, et al., in prep

Thermal Emission



Caveat: grain properties may differ between surface and midplane

Summary

- Even relatively small planets embedded in protoplanetary disks can create observable signatures
- Different wavelengths probe different parts of disks
- Multi-wavelength observations are critical for identifying planet signatures
- High-resolution mid- to far-IR please! ($<0.1''$)
(SPIRIT, SPECS)