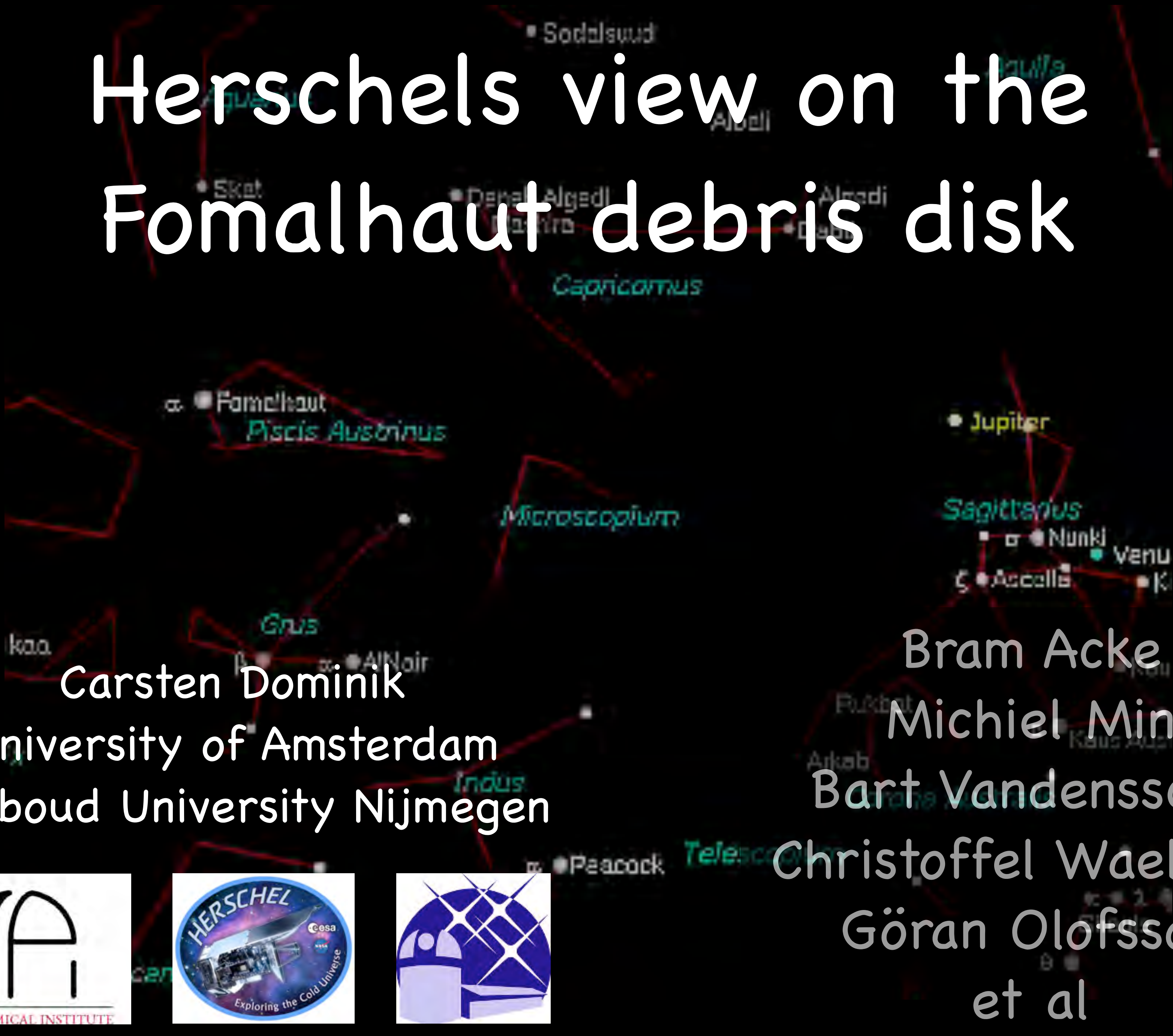
Herschels view on the Fomalhaut debris disk



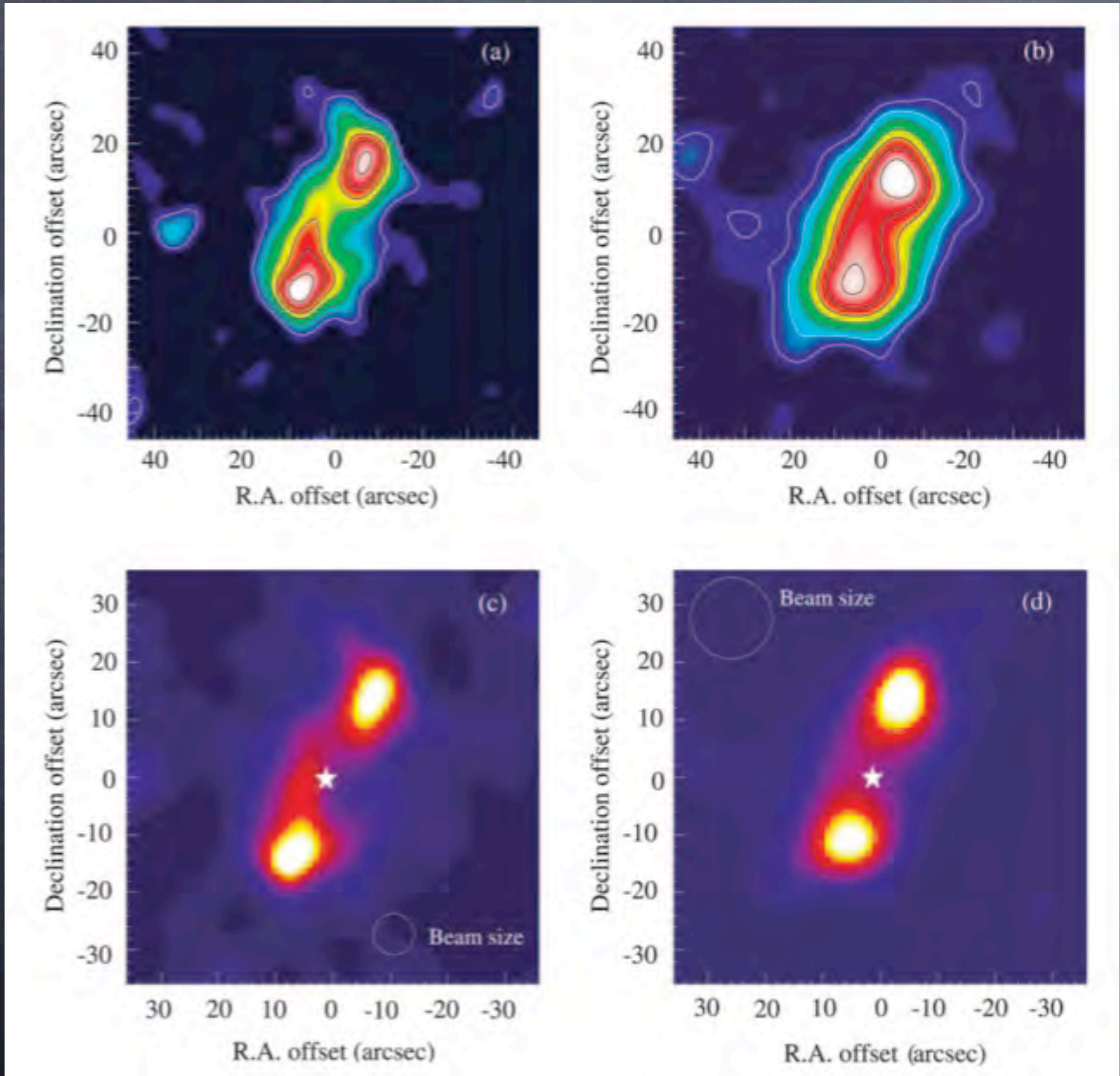
Carsten Dominik
University of Amsterdam
Radboud University Nijmegen

Bram Acke
Michiel Min
Bart Vandenssche
Christoffel Waelkens
Göran Olofsson
et al

Fomalhaut

- 2 $M_\odot$, A3V, 200 Myr, 7.7pc
- Disk discovered 1985 with IRAS, one of the "big four"
- One of the most important imaging targets

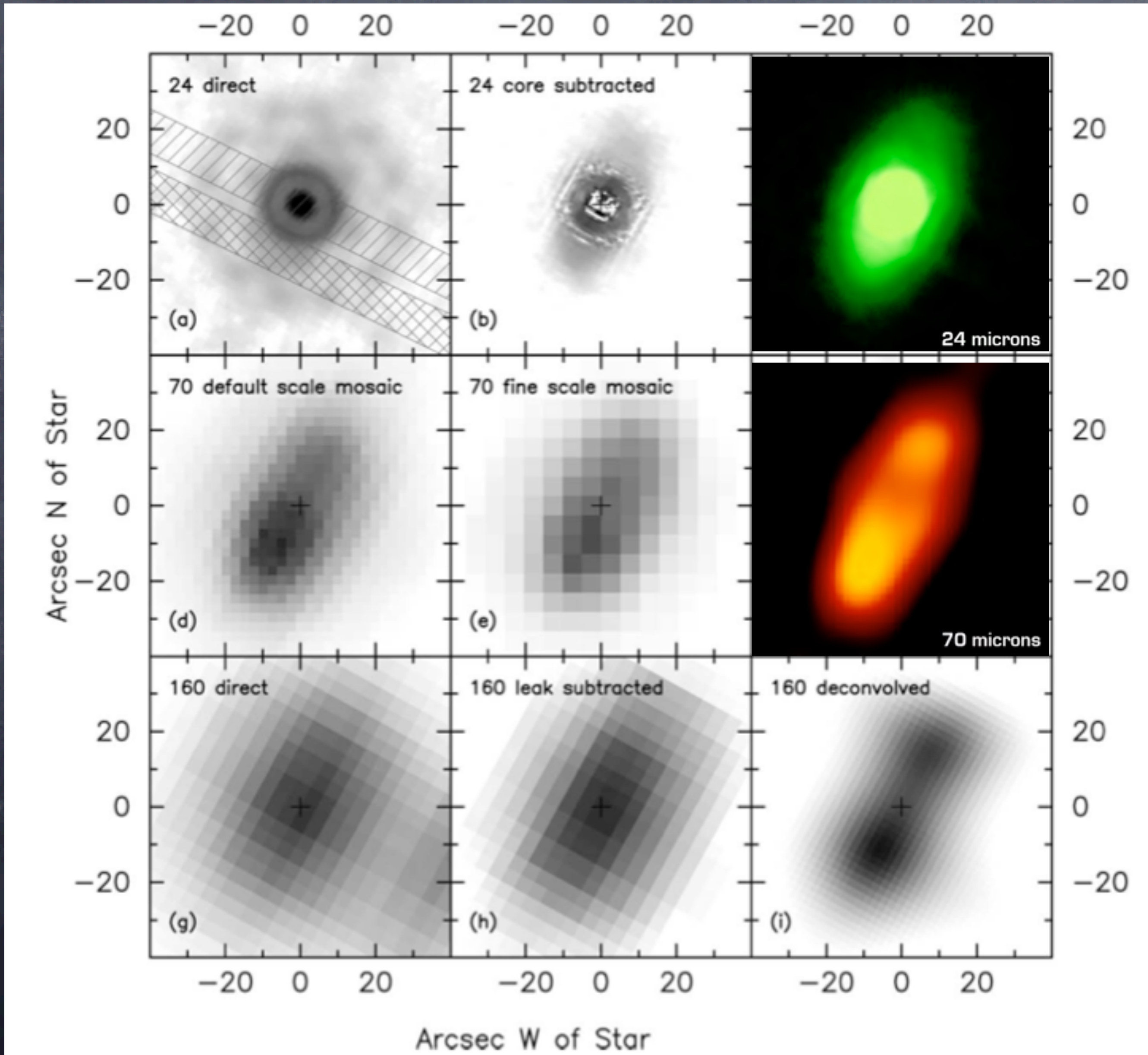
SCUBA @ 850μm



- edge-on doughnut
- diameter 315 AU
- cavity
- clumps due to large collisions?
  - probably not

Holland et al 1998
Holland et al 2002
Wyatt & Dent 2002

Spitzer @ 24,70,160μm

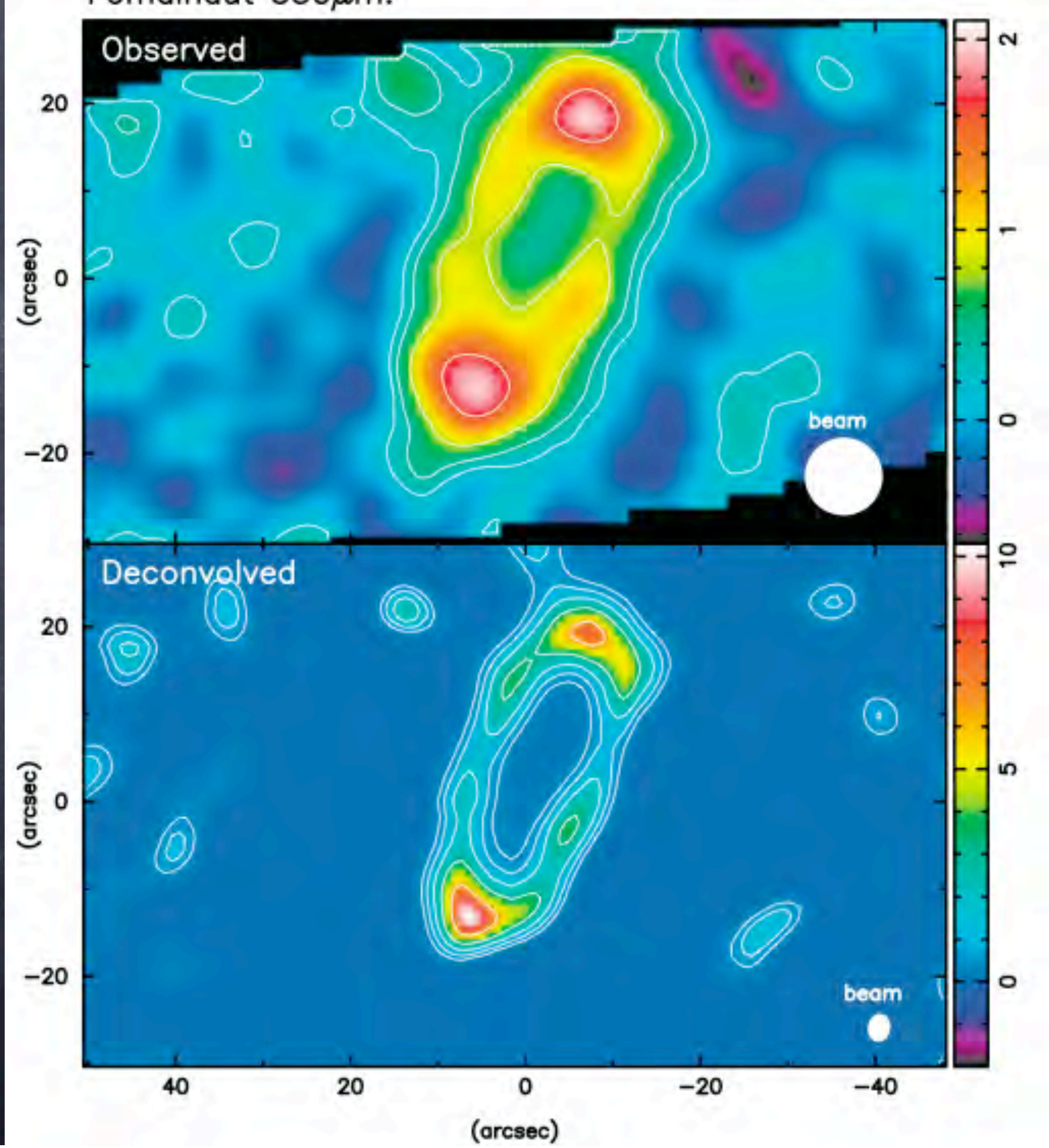


Inner hole partially filled

Asymmetry

Stapelfeldt et al 2004

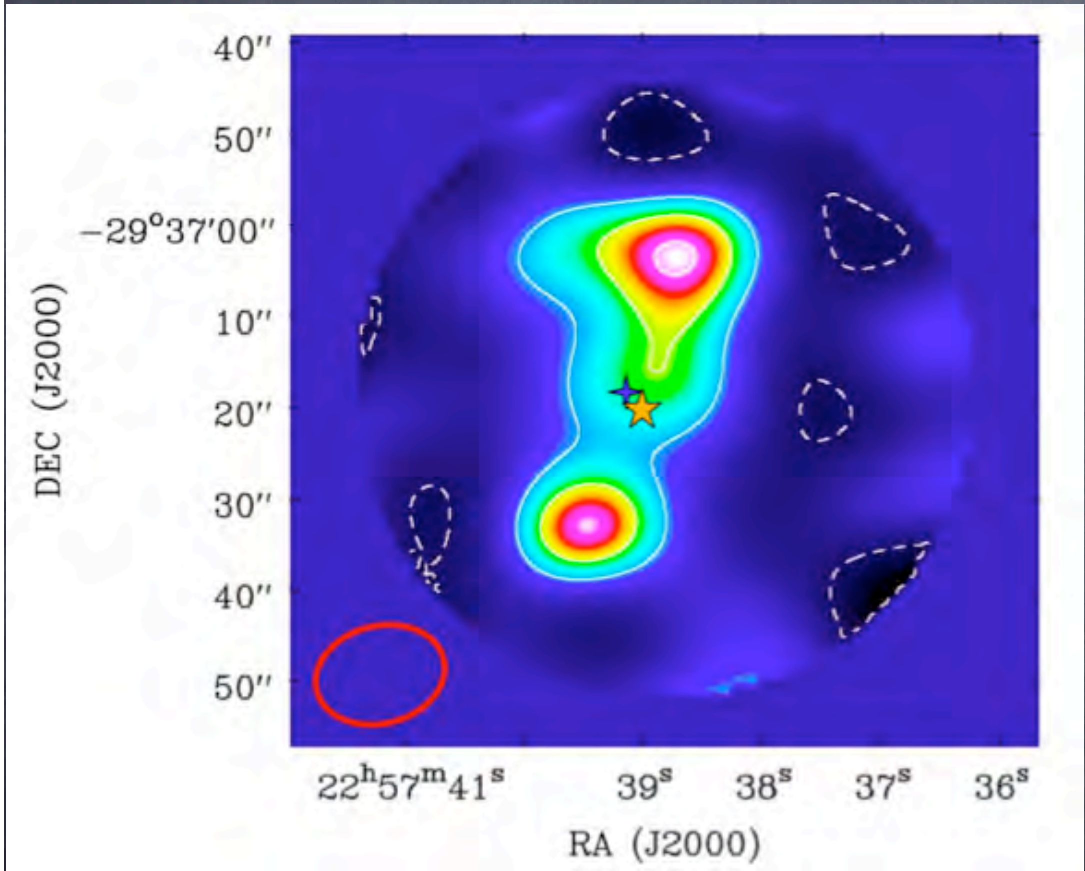
CSO/SHARK II @ 350μm

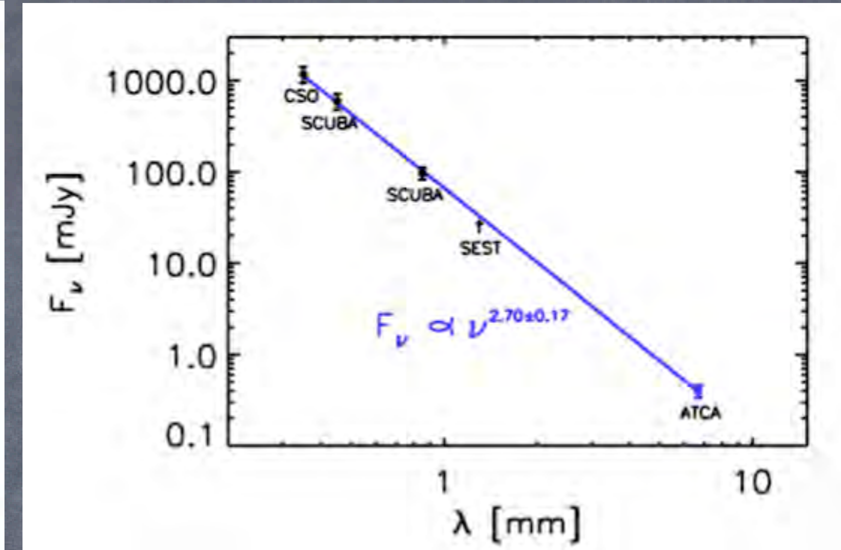


- i=70 degrees
- center displaced by 8 AU, planet with e=0.06?

Marsh et al 2005

ATCA @ 7mm



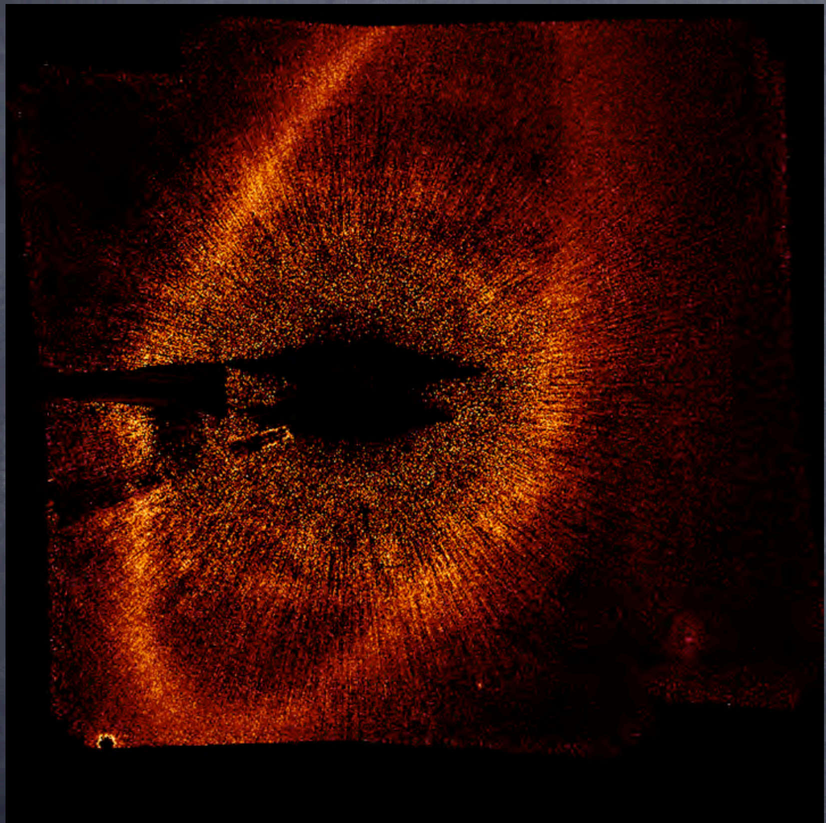


Size distribution

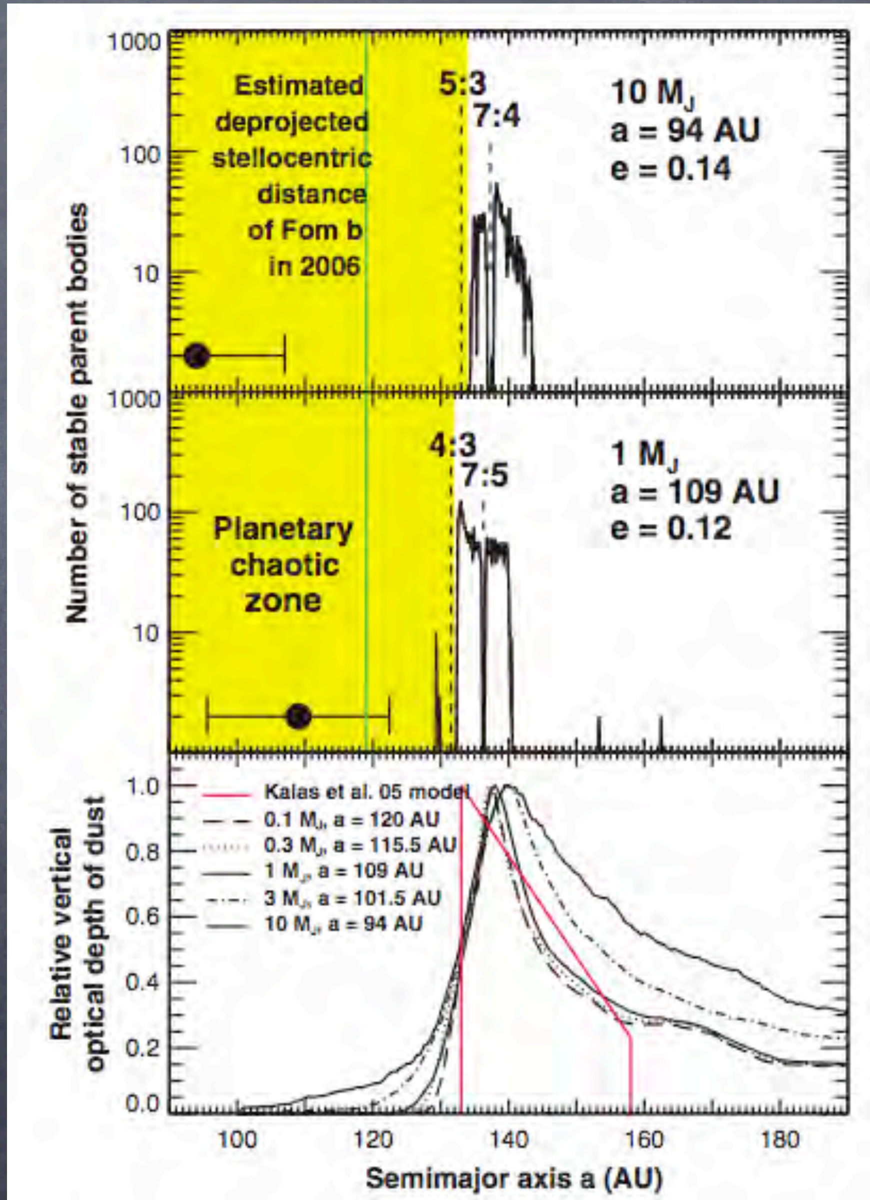
$f(a) \propto a^{-3.5}$

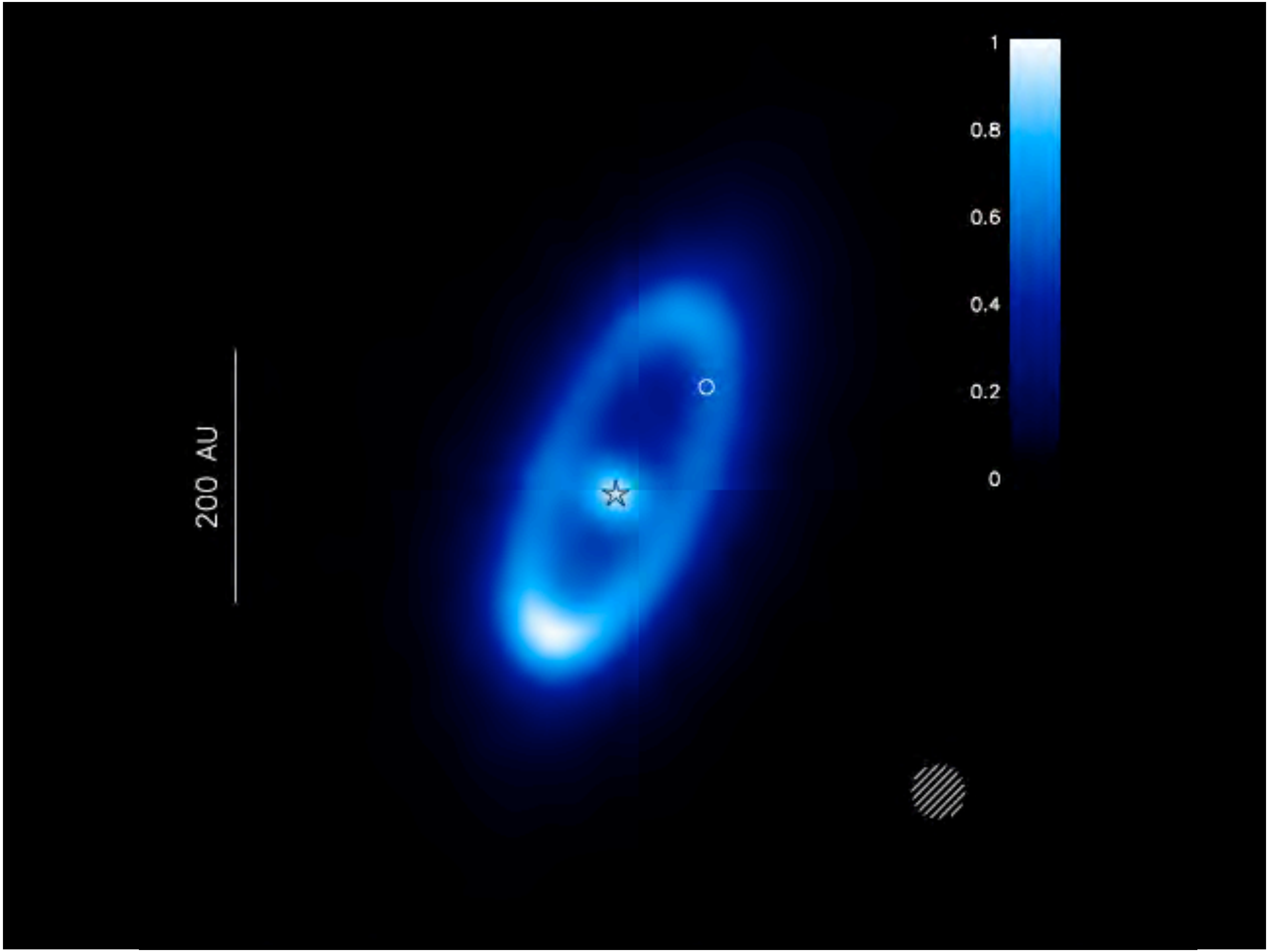
Ricci et al 2012

Prior Art: Hubble @ optical



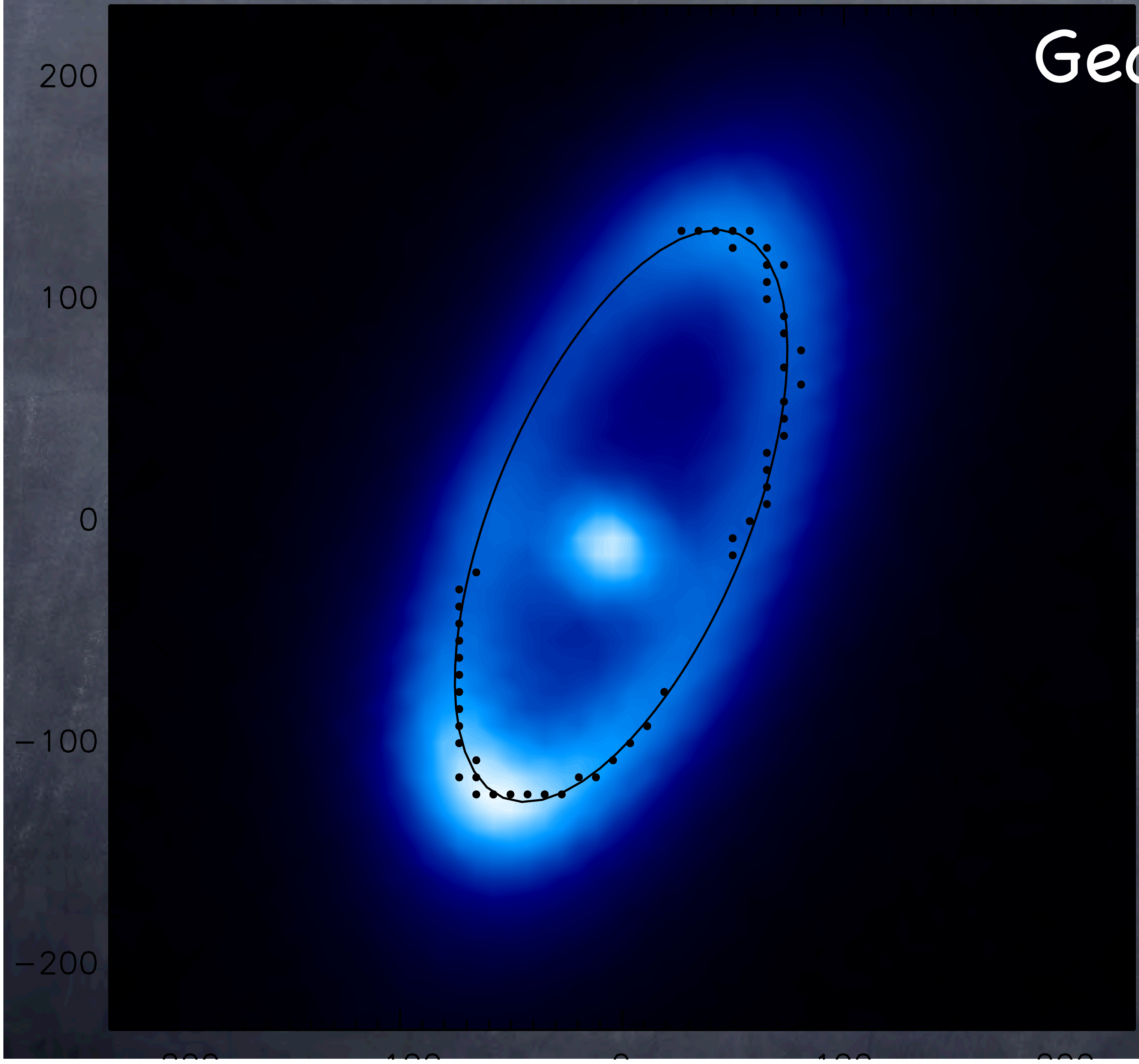
Kalas et al 2005, 2008
Chiang et al 2009



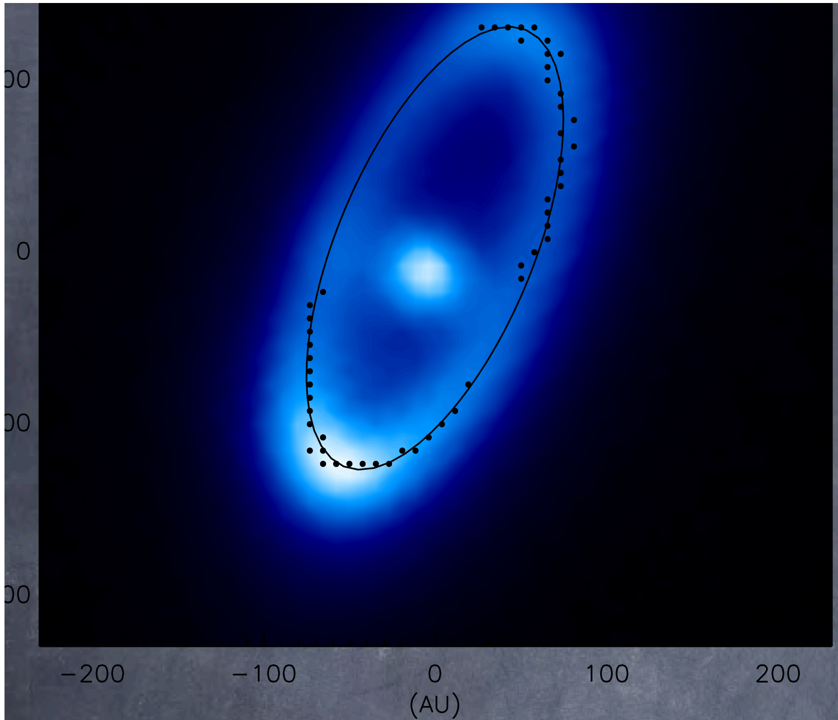


200 AU
1
0.8
0.6
0.4
0.2
0

Geometry

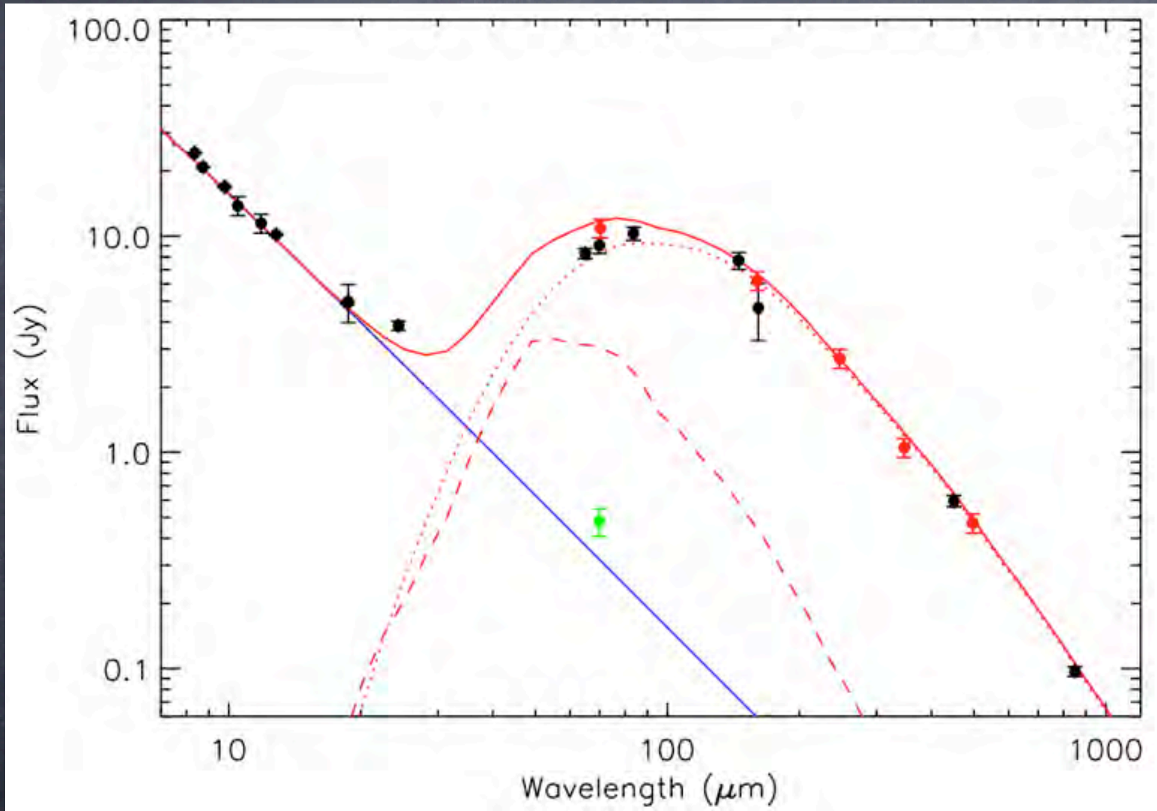


Geometry



	HST/optical	Herschel/70μm
a	141 ± 2	137 ± 0.9
e	0.11 ± 0.01	0.125 ± 0.006
i	65.6 ± 0.4	65.6 ± 0.5
Ω	156.0 ± 0.3	156.9 ± 0.5
ω	31 ± 6	1 ± 6
Offset	15 ± 1	17.2 ± 0.9

Photometry and SED



400 AU aperture, uncertainties 10%
10% calib. errors

Added values from SPITZER, stellar photometry, and SCUBA

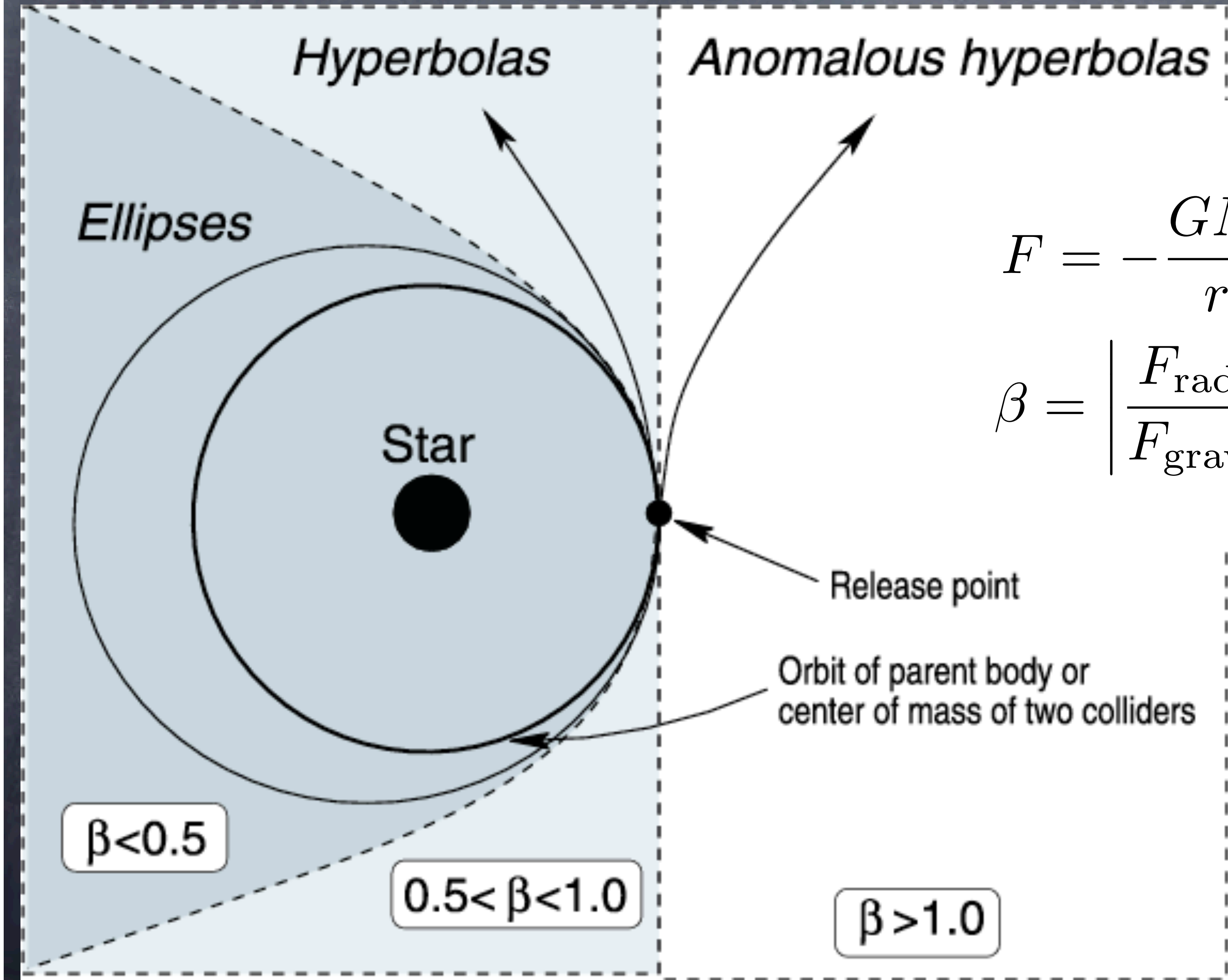
3 component model

1. Source ring of colliding planetesimals with equilibrium cascade and redistribution by radiative forces.

2. Central unresolved component

3. Powerlaw surface density to reproduce residual emission inside the source ring (PR grains?)

Semi-analytical model for the dust

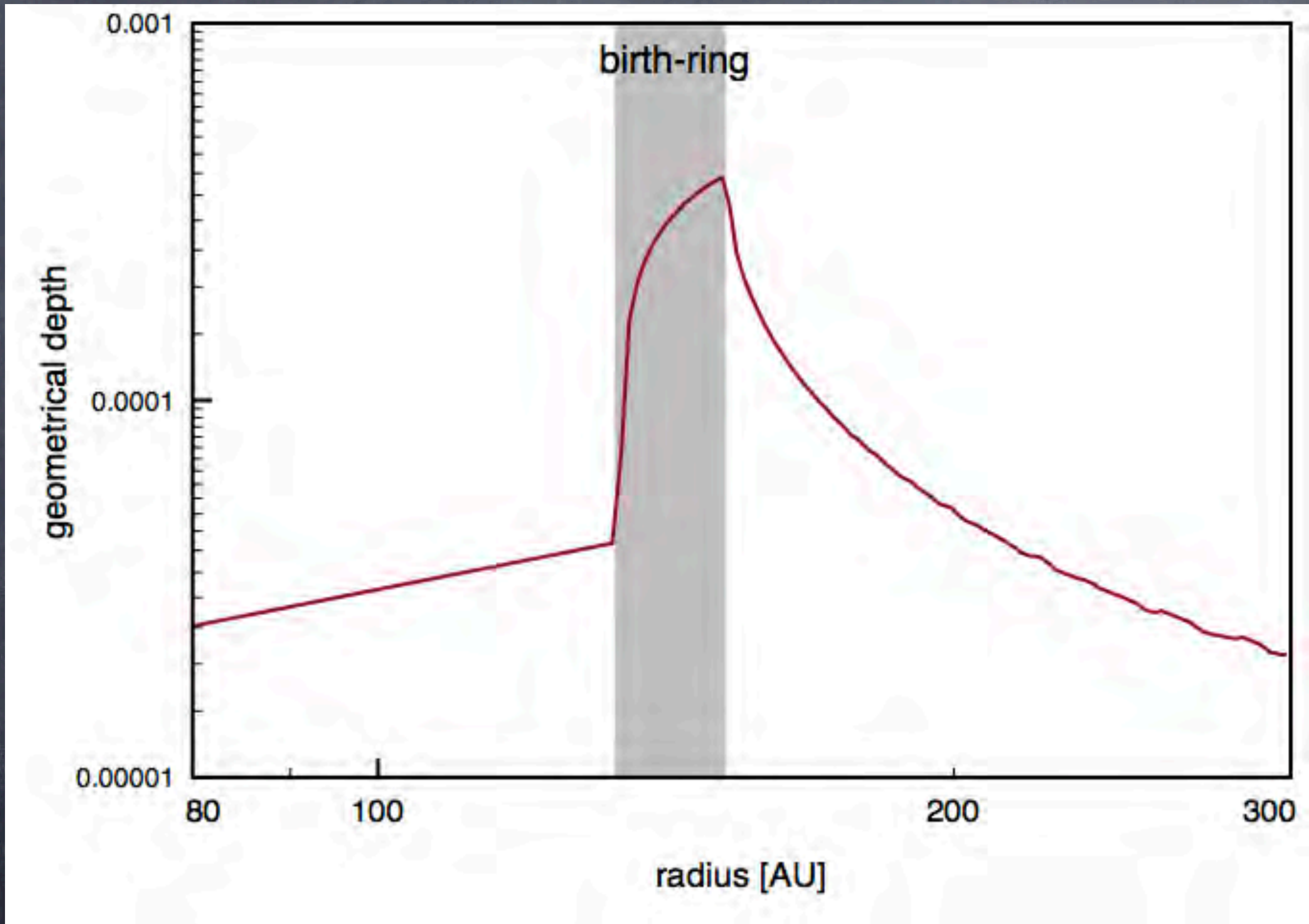


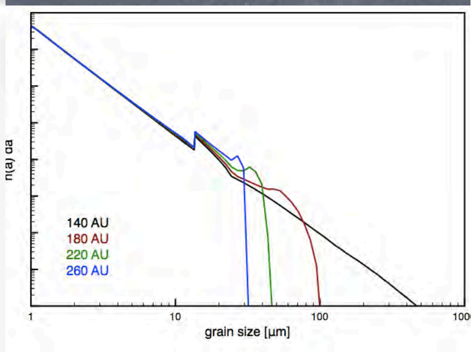
$$F = -\frac{GM_*}{r^2}(1-\beta)$$

$$\beta = \left|\frac{F_{\rm rad}}{F_{\rm grav}}\right| \propto \frac{\sigma}{m} \propto \frac{1}{s}$$

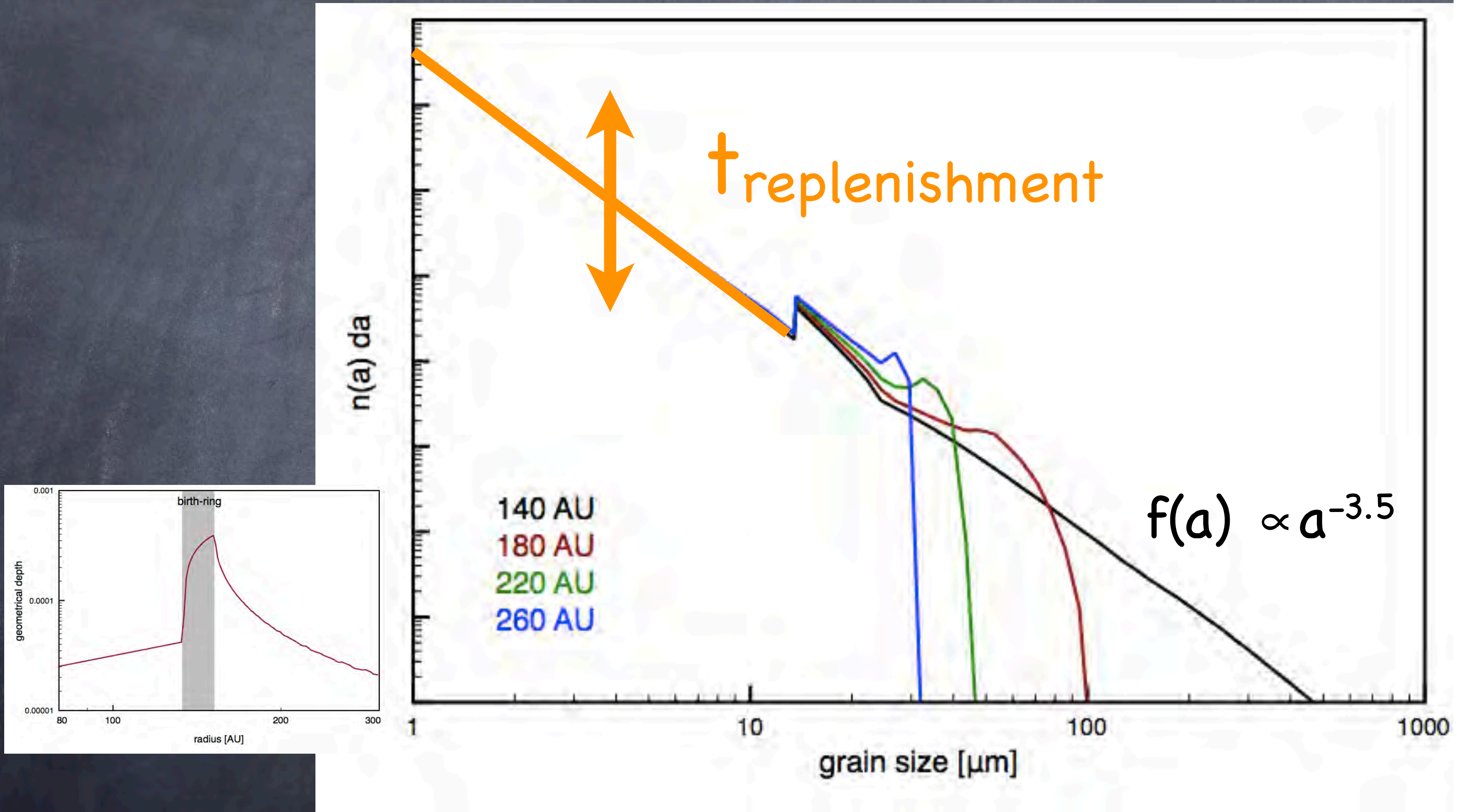
Fig. by M. Wyatt

Radial distribution of particles

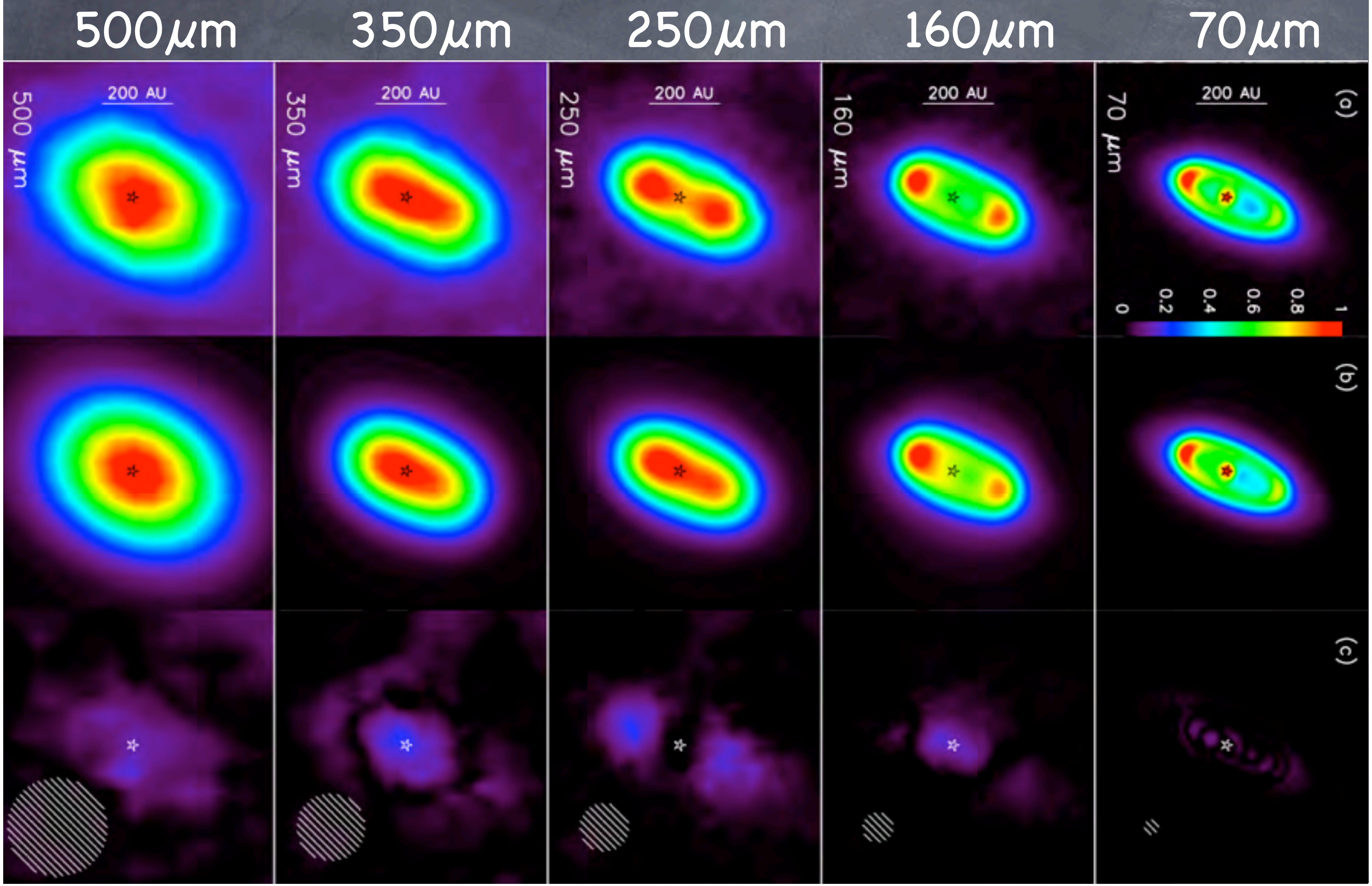




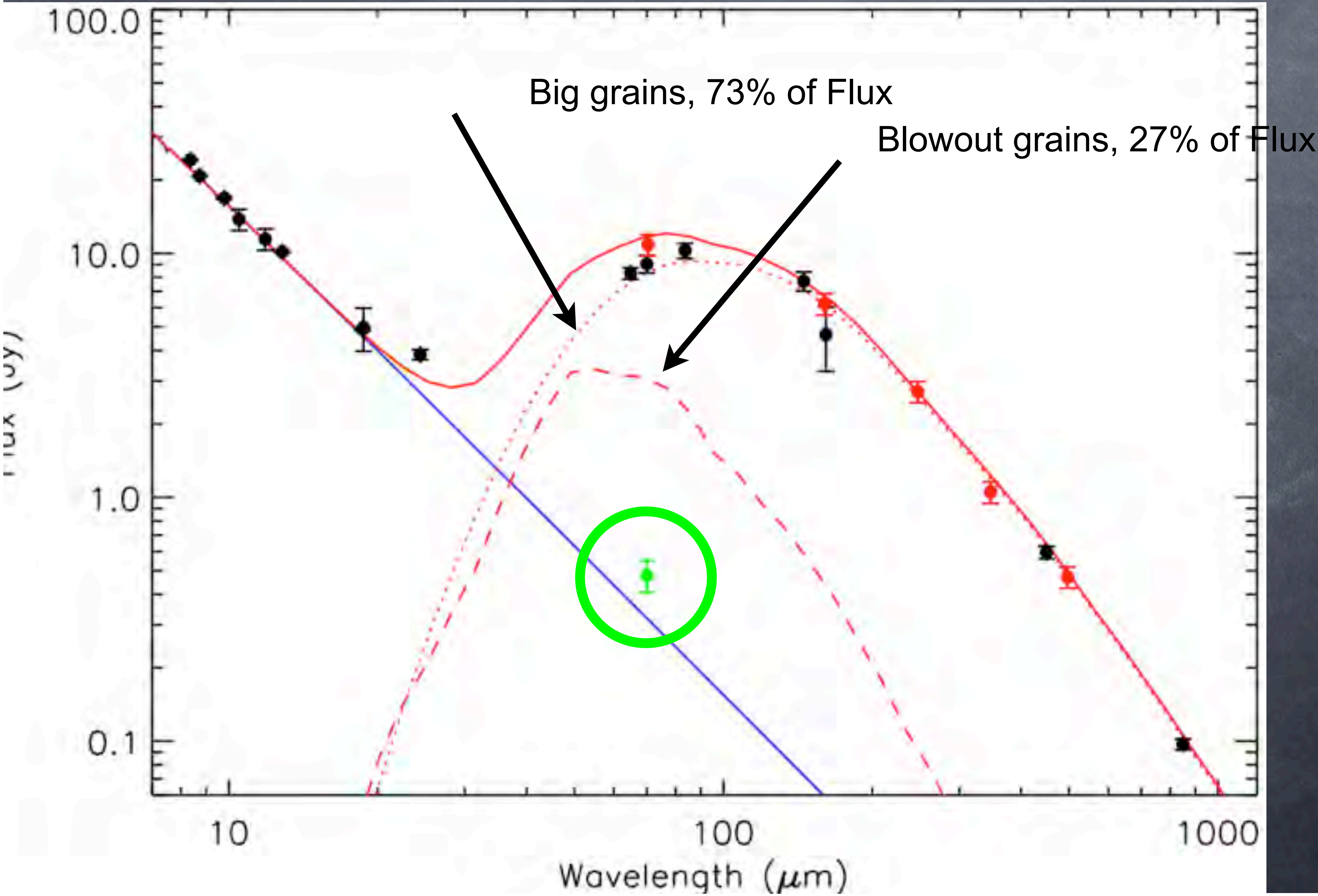
Radial distribution of particles



Model fits


500μm
350μm
250μm
160μm
70μm
200 AU
500 μm
350 μm
250 μm
160 μm
70 μm
(a)
(b)
(c)
0
0.2
0.4
0.6
0.8
1

Constructing the SED



Modeling results: Main Ring

- Source ring from 133 to 153 AU
- Contains 8×10^{25}g below 5000μm.
- Many grains below the blow-out size (13μm)needed to get the SED, the color, and the extend of the images correct
    - Replenishment time ~1700 yr
    - Mass in blowout grains $\sim 3 \cdot 10^{24}$ gram
    - Mass loss rate (= mass production rate): 2000 1km comets/day
- $\sim 10^{13}$ comets to sustain over 200Myr

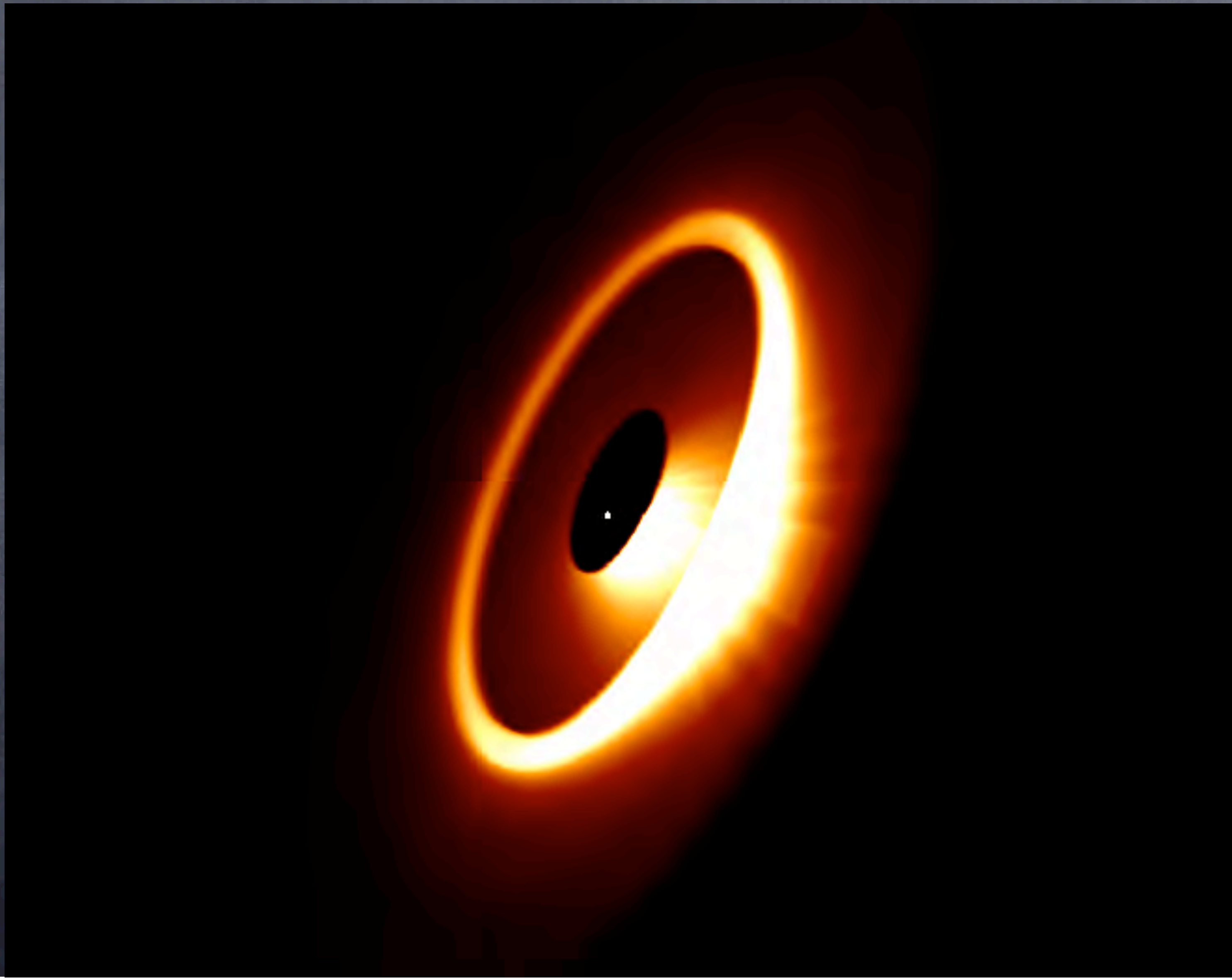
Modeling results: Inner disk and central point

- Inner disk
  - 8×10^{25}g in grains up to 5000 μm
  - Surface density increases linearly with r
  - 21-29% of flux in HERSCHEL images
- Central point
  - 50% of stellar flux at 70μm

Grain model

- Icy grains with 25% vacuum by volume
- Amount of dust in blowout grains is robust and nearly independent of the grain model (including pure silicate models)
  - Because heating and radiation pressure are both due to absorption properties.

Scattering constraints

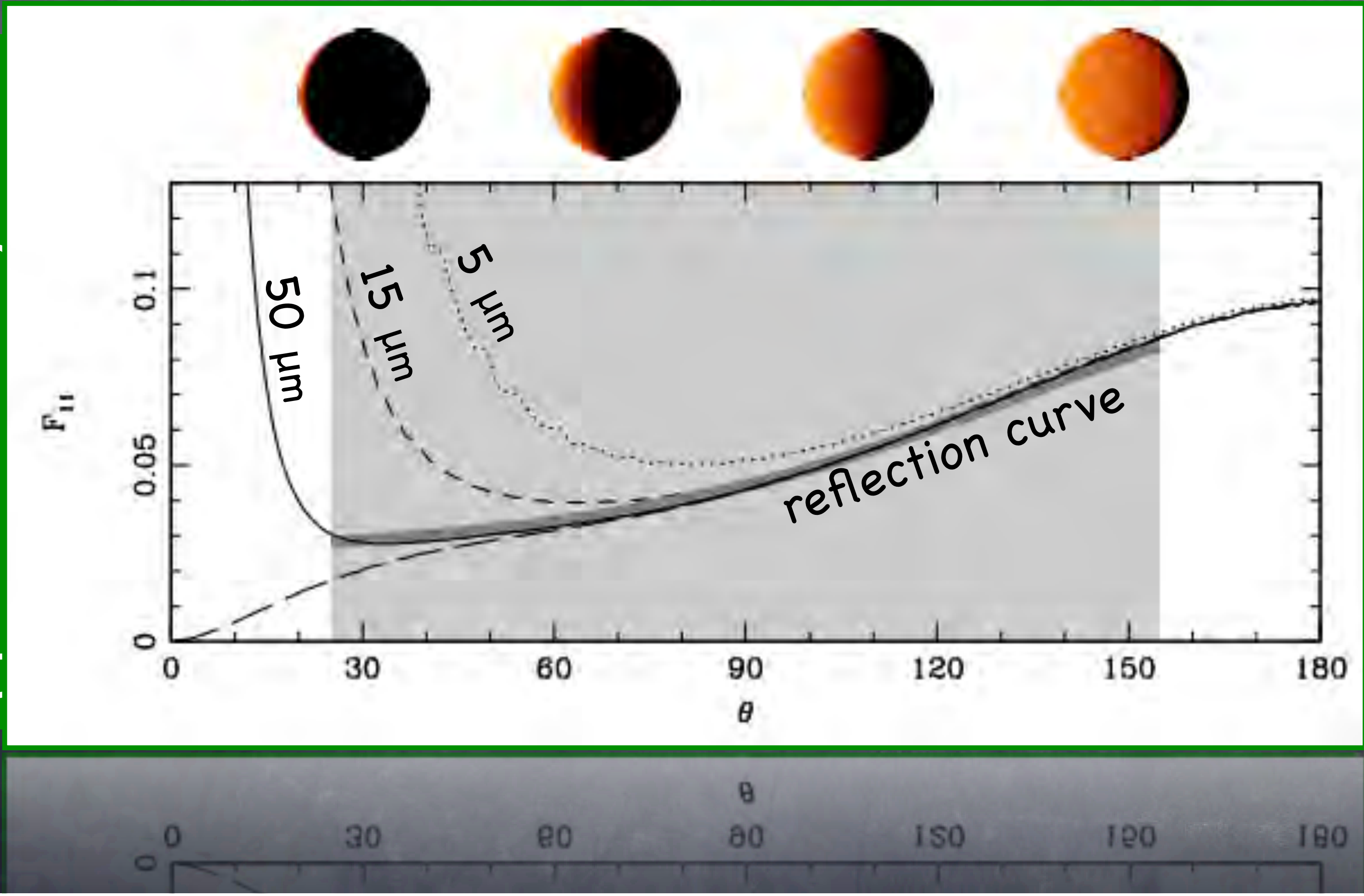


Scattering constraints

- Interaction of large grains with radiation has three components:
  - Absorption → 40-45%
  - Reflection → 5-10%
  - Diffraction → 50%

Scattering constraints

- Single scattering albedo very low (few %, Kalas et al. 2005)



Absor … ents:

Thank You!