Disk Imaging, Characterization, and Exploration (DICE) with HST/STIS Multi-Roll Coronagraphy: A Clearer Picture of The Moth's Anatomy

Dean C. Hines[1], Glenn Schneider[2], John Debes[1]
& the GO 12228 Team

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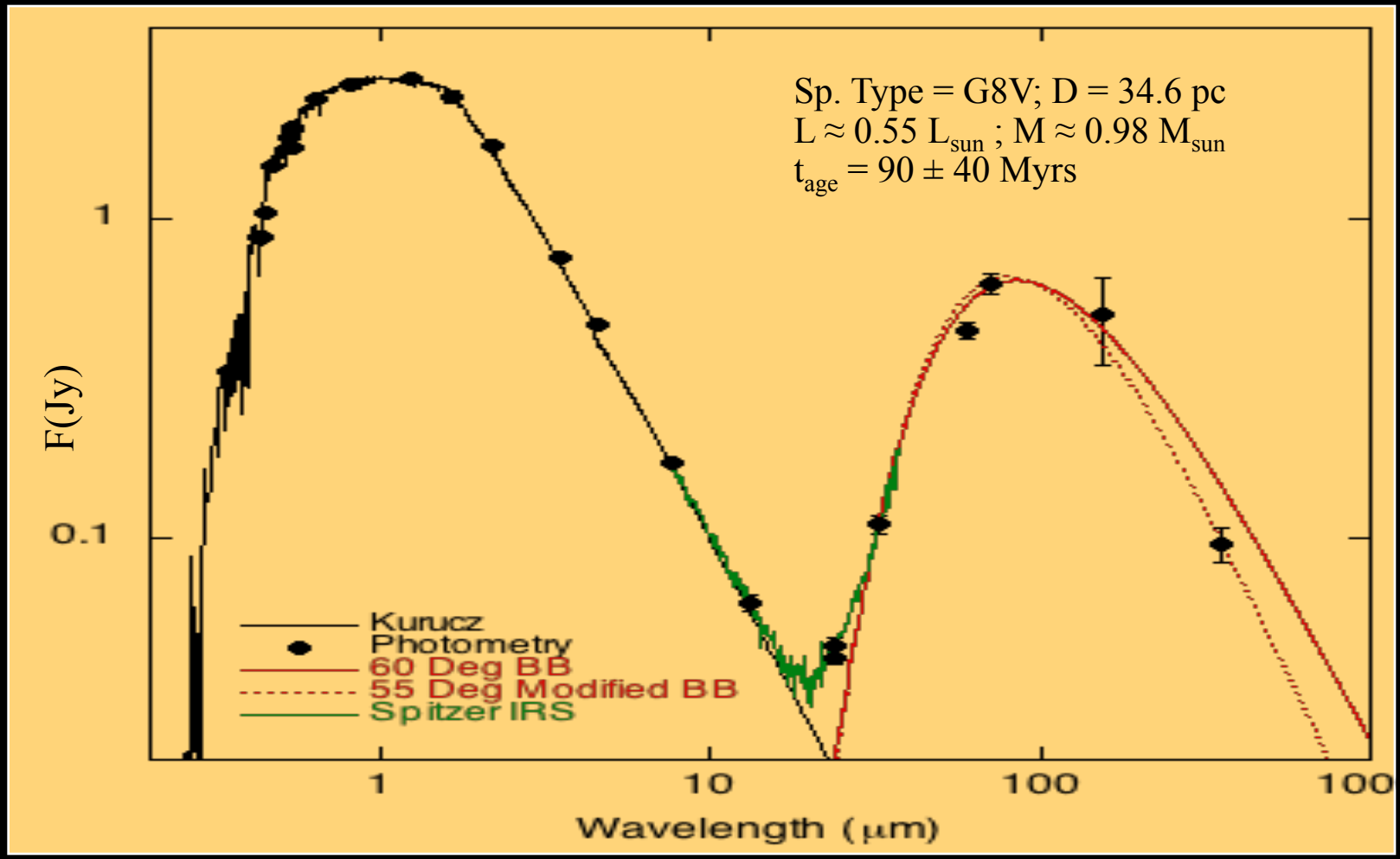
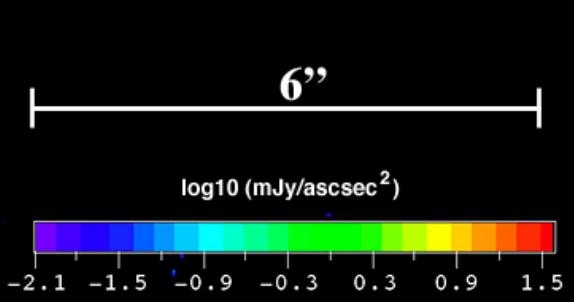
HD 61005

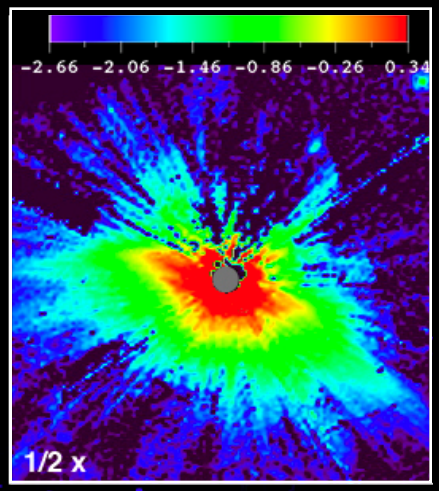


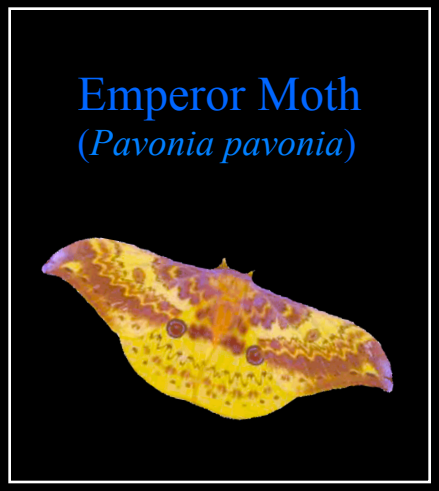
T_{BB}= 60 ± 10 K $r_{dust} \geq 15$ AU $L_{IR}/L_* = 2x10^{-3}$

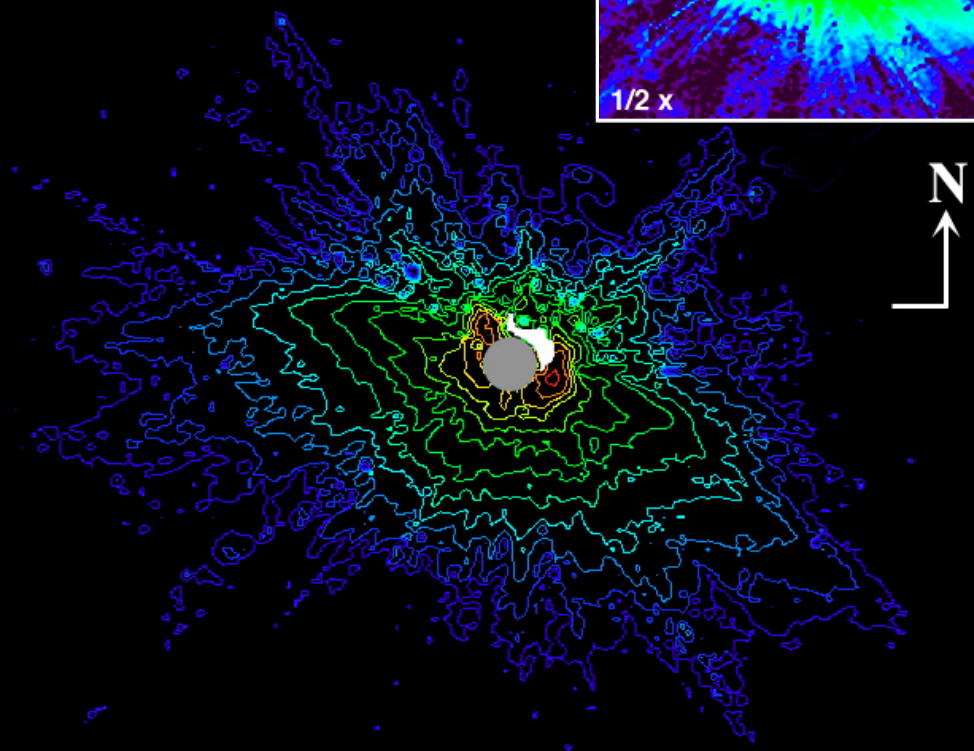
No obvious solid state dust features in spectrum

NICMOS Coronagraphic Image









Radial Extent ~ 240 AU

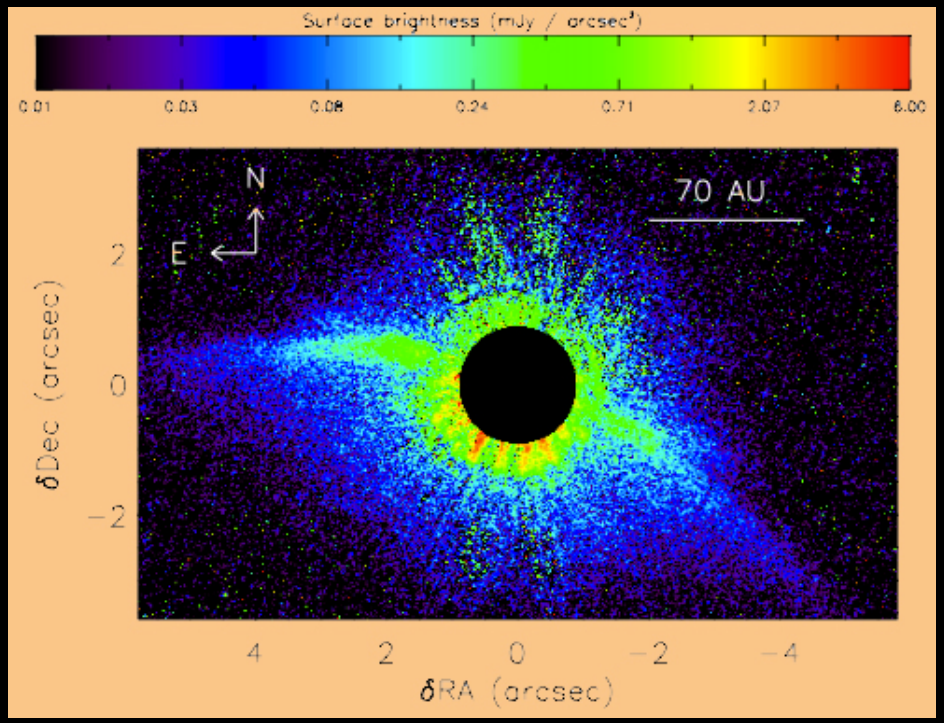
Flux Density (0.3" < r < 5")
= 18 mJy ± 3.3 mJy

f_{scat}/f_{*} (1.1μm) = 0.77% ± 0.17%

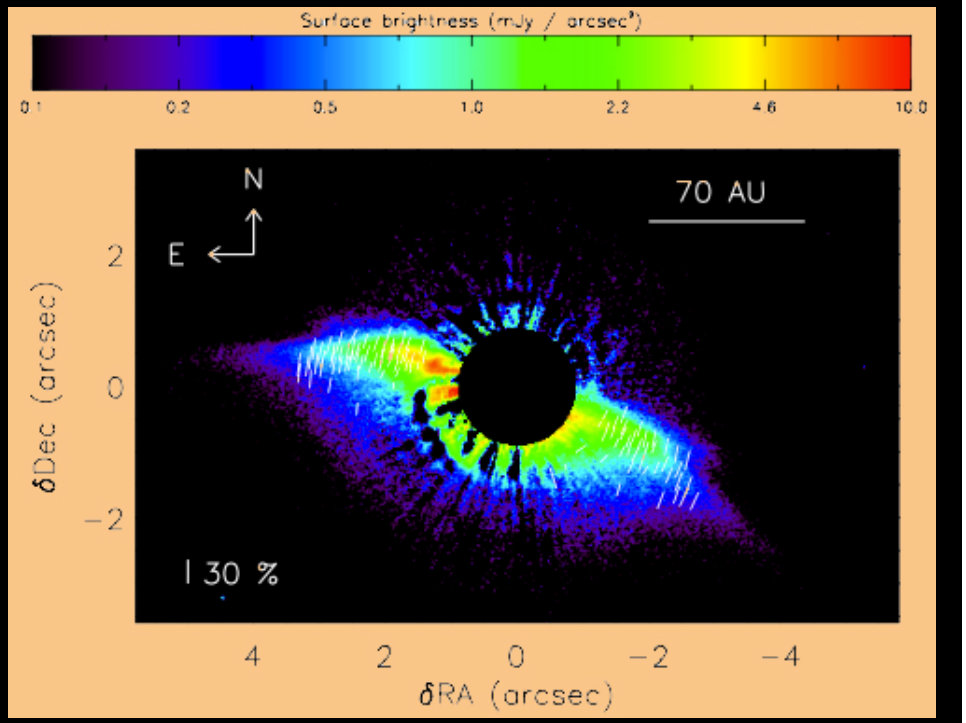
⇒ Small grains (a ~ 0.2μm)
$\leq a_{blowout} \approx$ 0.3μm

HST/ACS Imaging Polarimetry

Total Light

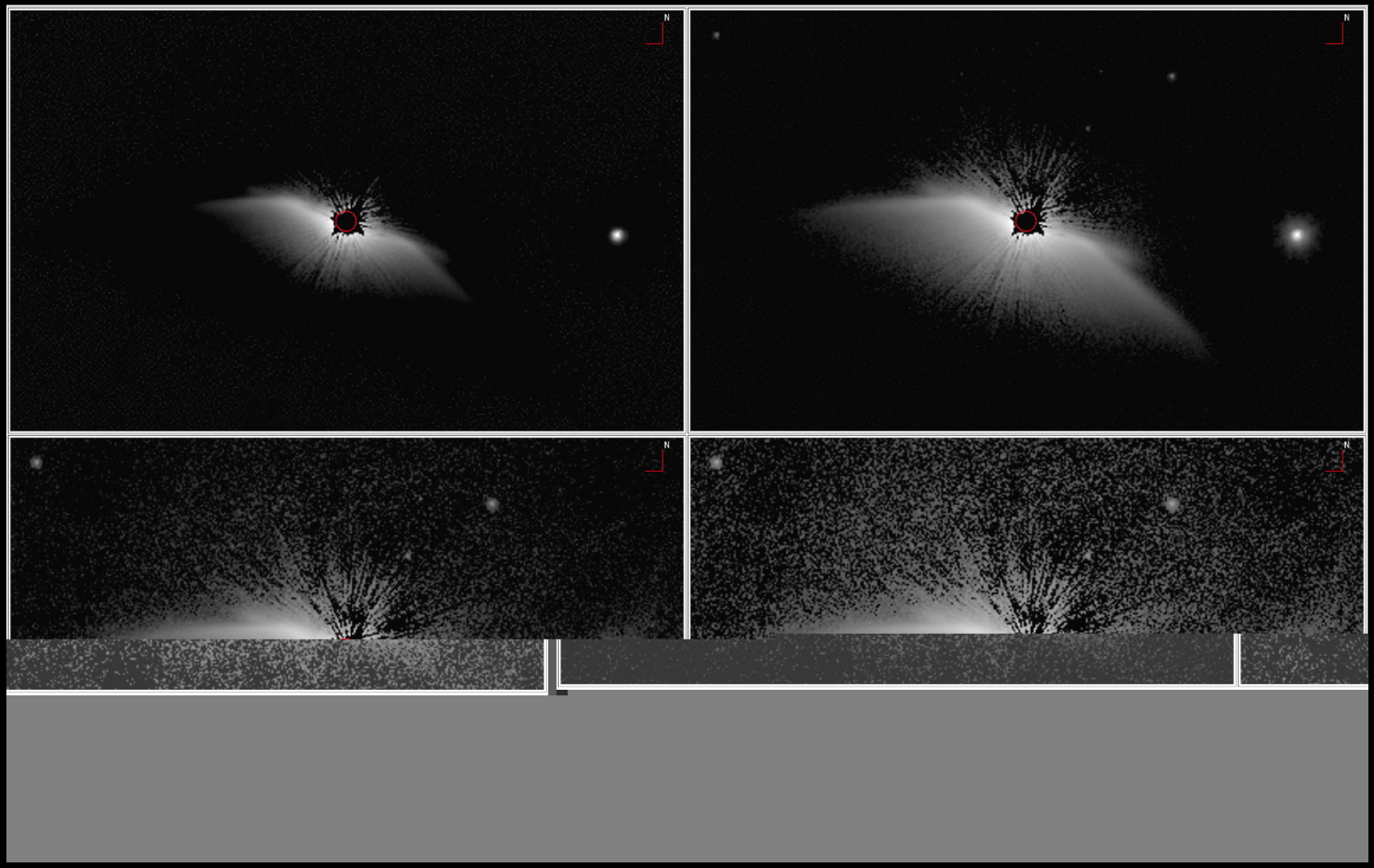


Polarized Light



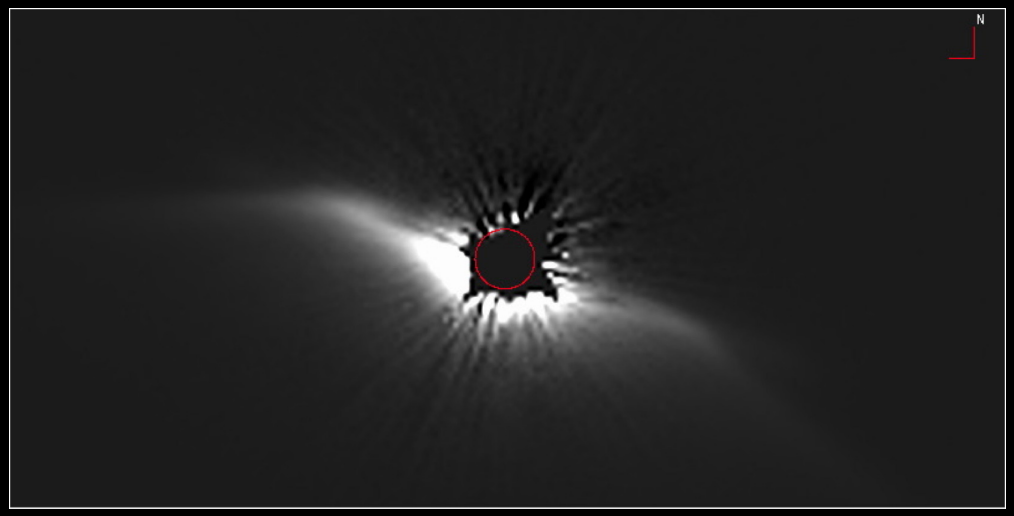
(GO/10847 [PI: Hines], Maness et al. 2009)

STIS Coronagraphic Images

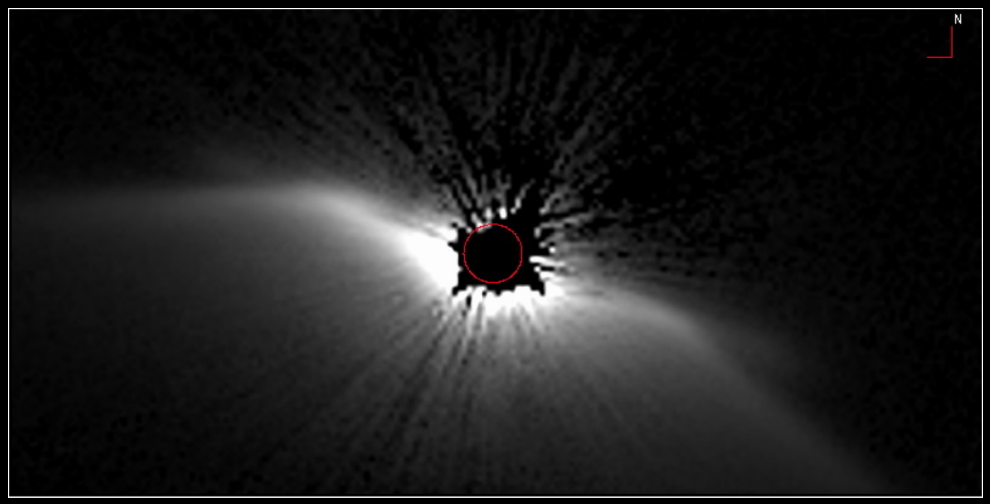


Views of the HD 61005 debris system @ x1, x10, x100, x1000 sensitivity depth.
1st similar depth as NICMOS discovery image but with STIS spatial resolution.

Nearly-Edge on Ring and Central Hole



$i \simeq 85°$
$r \simeq 63$ AU
$r_{in} \simeq 40$ AU



$f_{disk} = 4.46$ mJy
$f_{disk} : f_{star} = 0.245\%$

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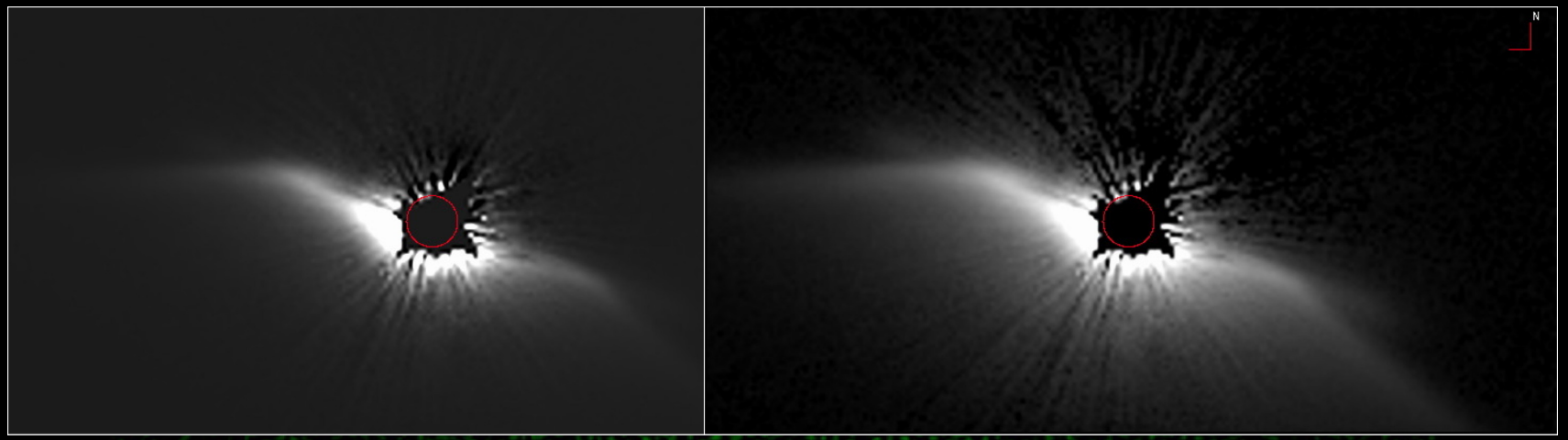
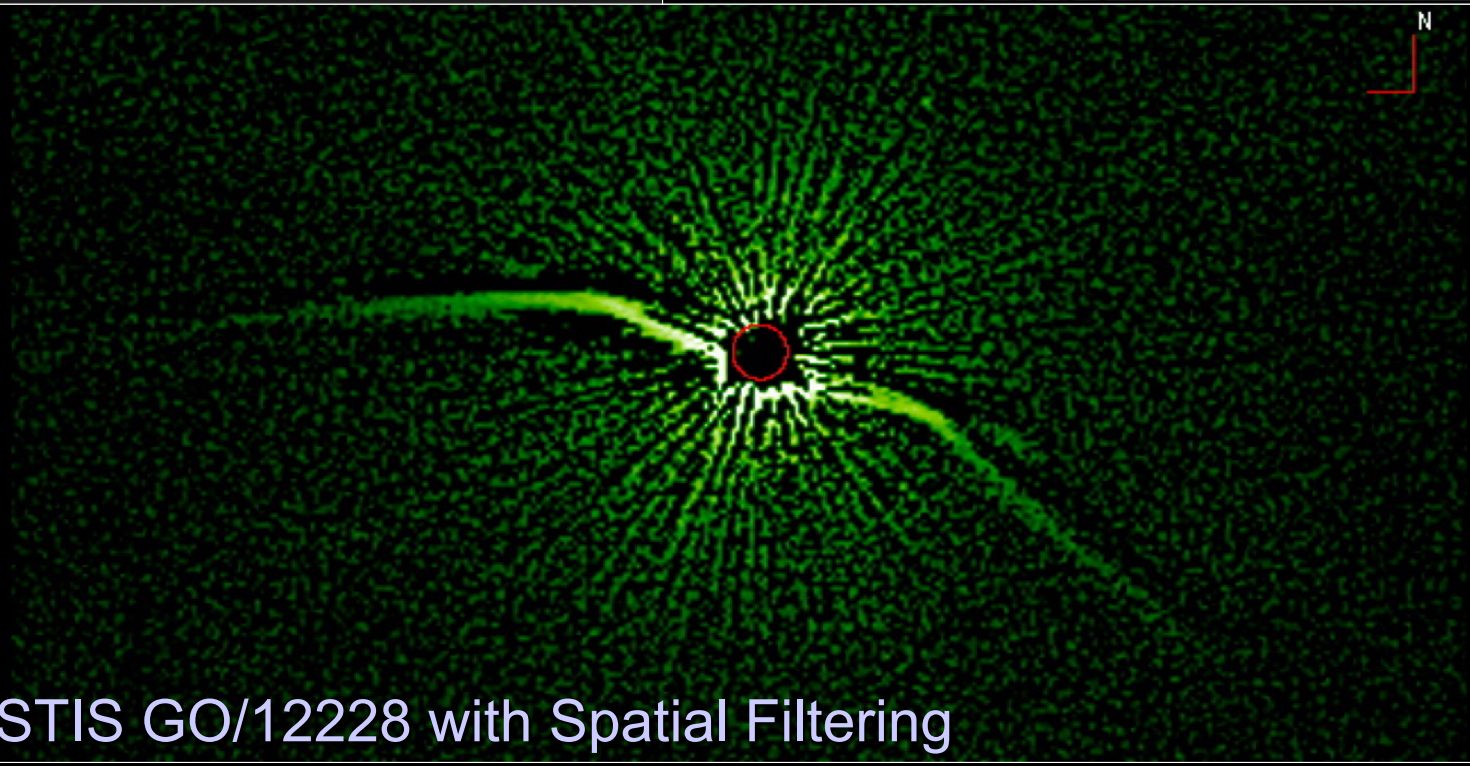
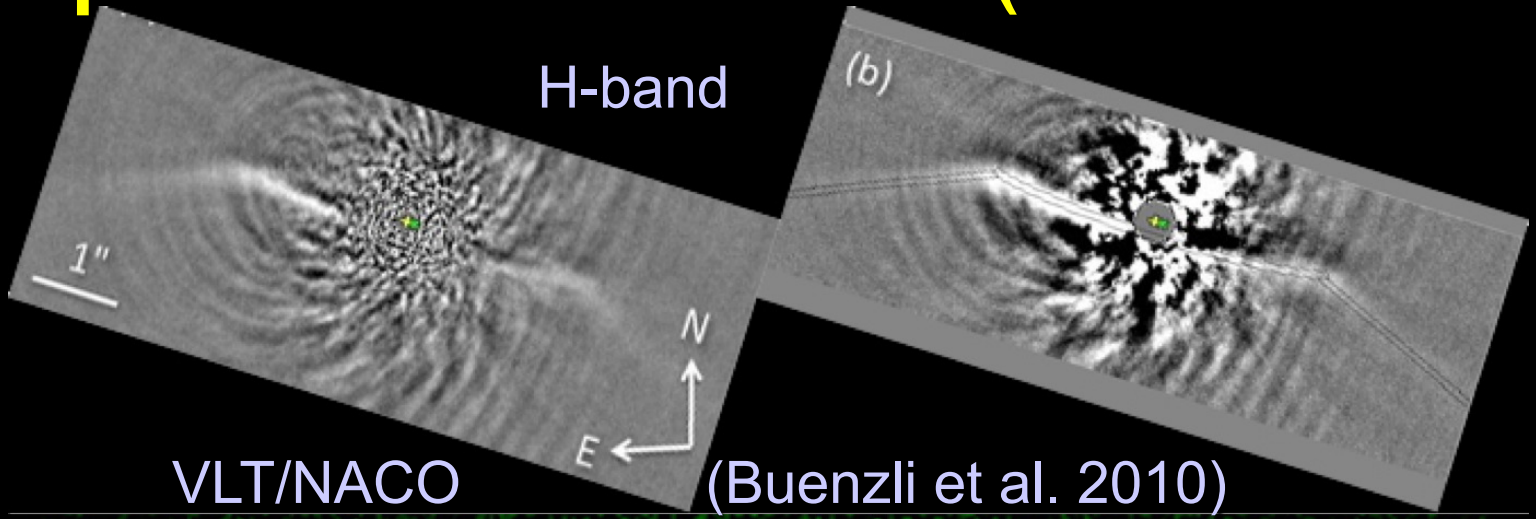


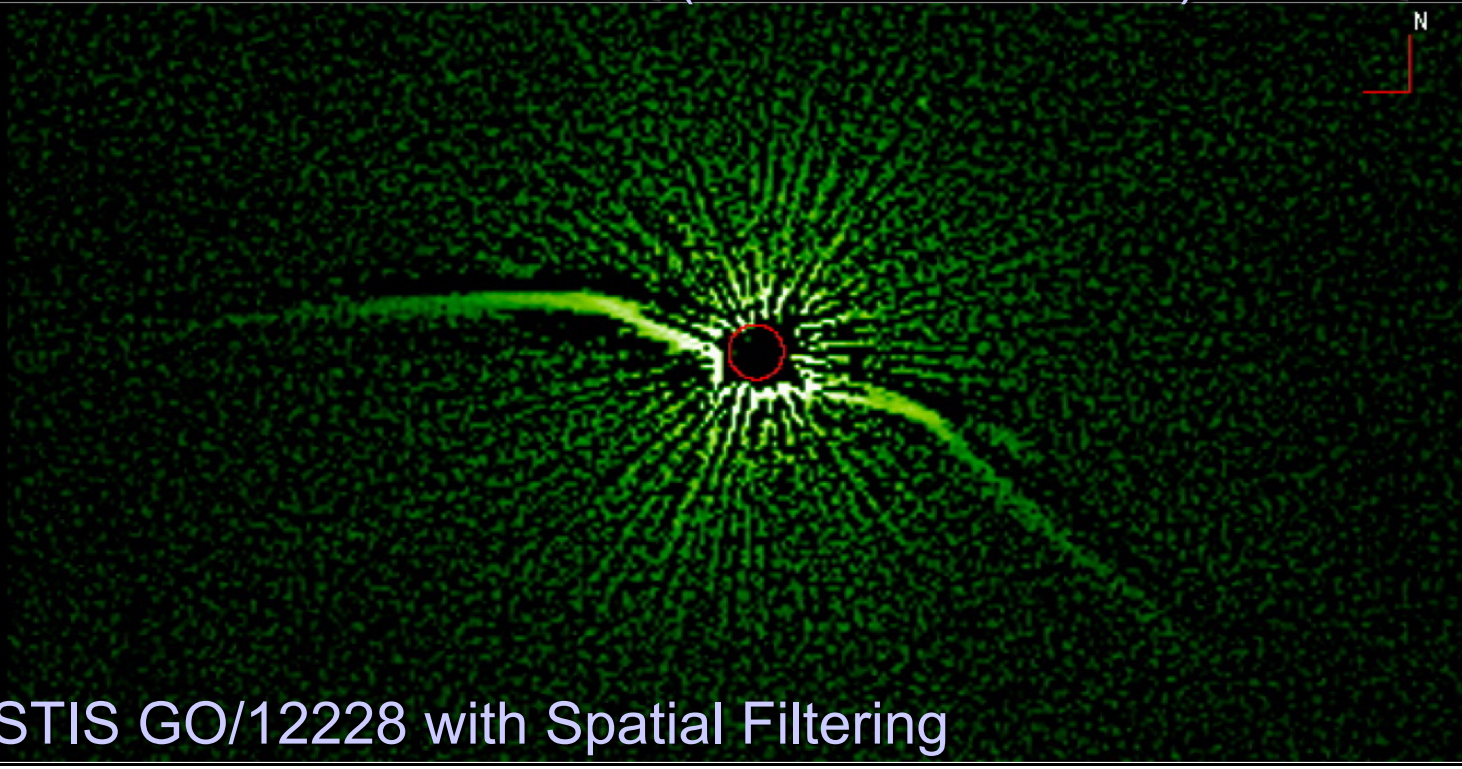


HST/STIS GO/12228 with Spatial Filtering

Comparison to ADI & LOCI (Ground-Based)



VLT/NACO (Buenzli et al. 2010)



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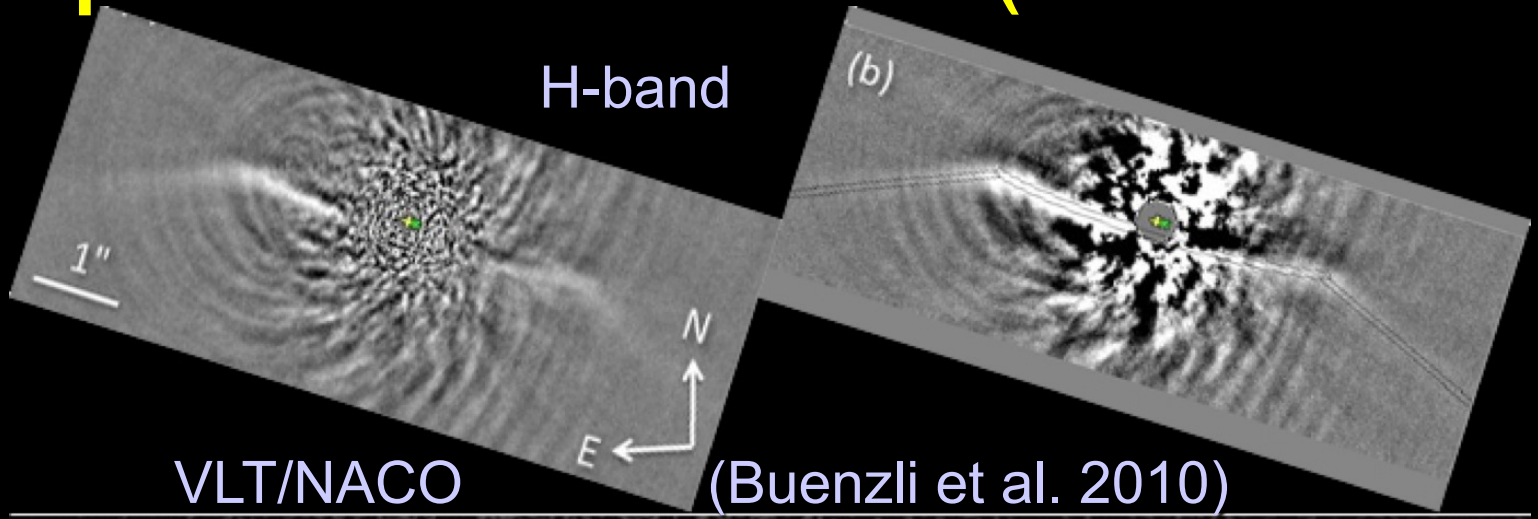

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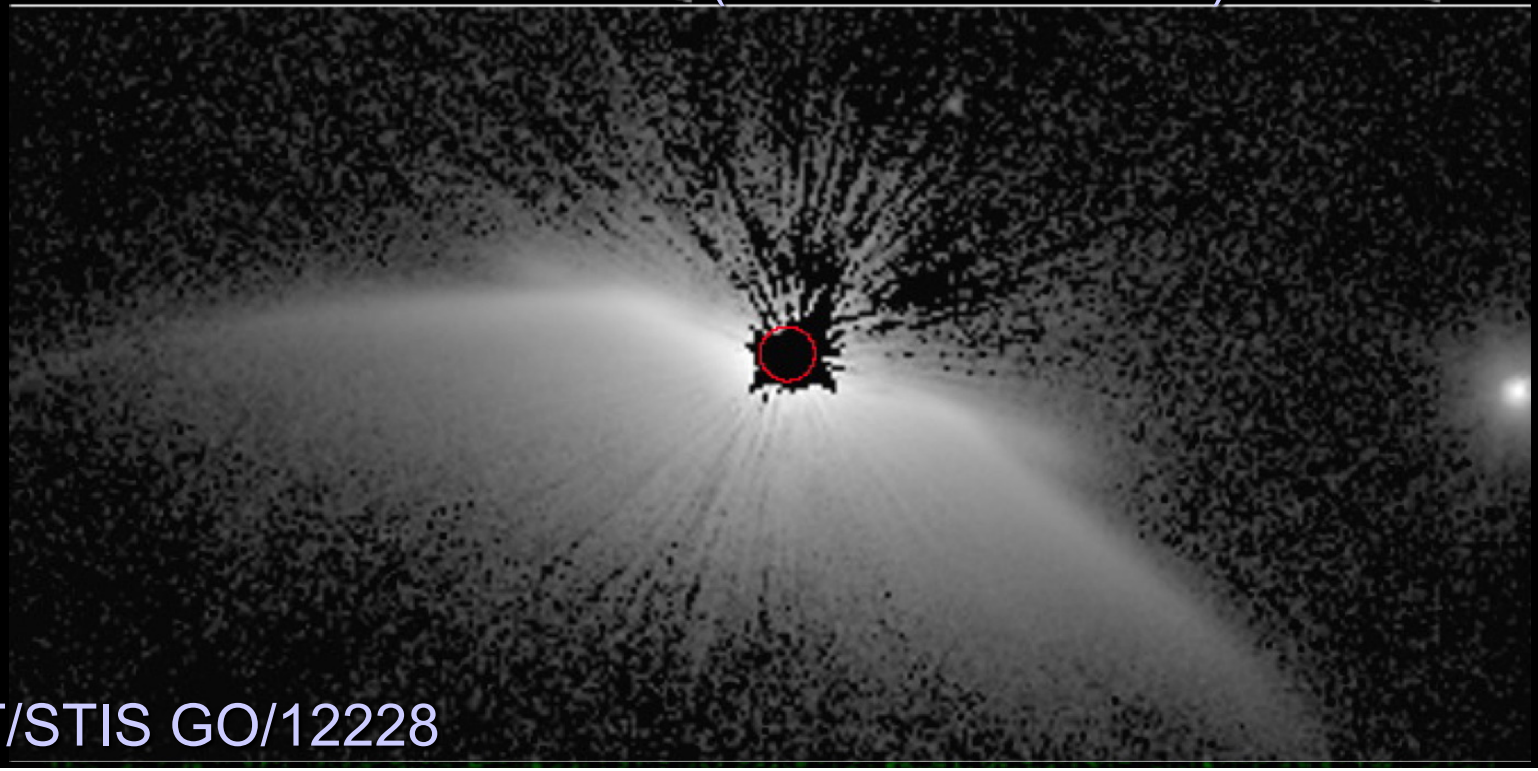
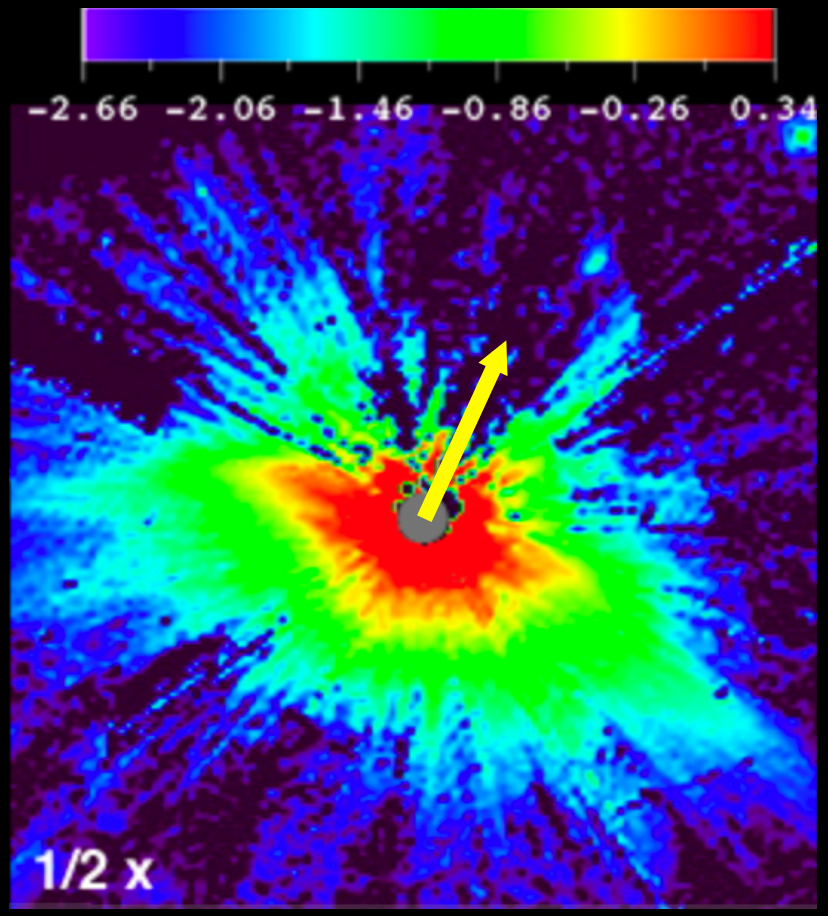


HST/STIS GO/12228

Interaction with ISM?

- *UVW* motion ≈12 km/s in "head" direction



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- Ram Pressure

$$\frac{z}{r} = f \sim 10^{-4} \left(\frac{n}{cm^3}\right) \left(\frac{r}{100AU}\right)^2 \left(\frac{1um}{a}\right) \left(\frac{v}{10km/s}\right)^2$$

  - $f \sim 0.3$ observed at r ~ 200 AU
  - If n = 100 cm^{-3}, $a \sim 0.1\mu$m, smaller than a_{blowout}

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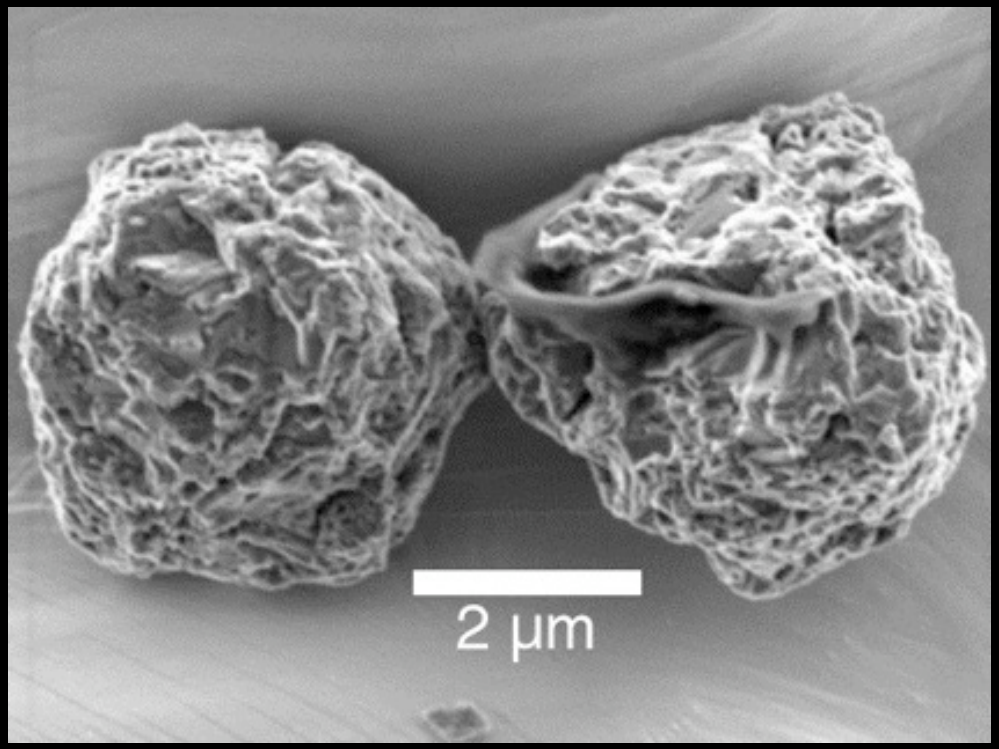
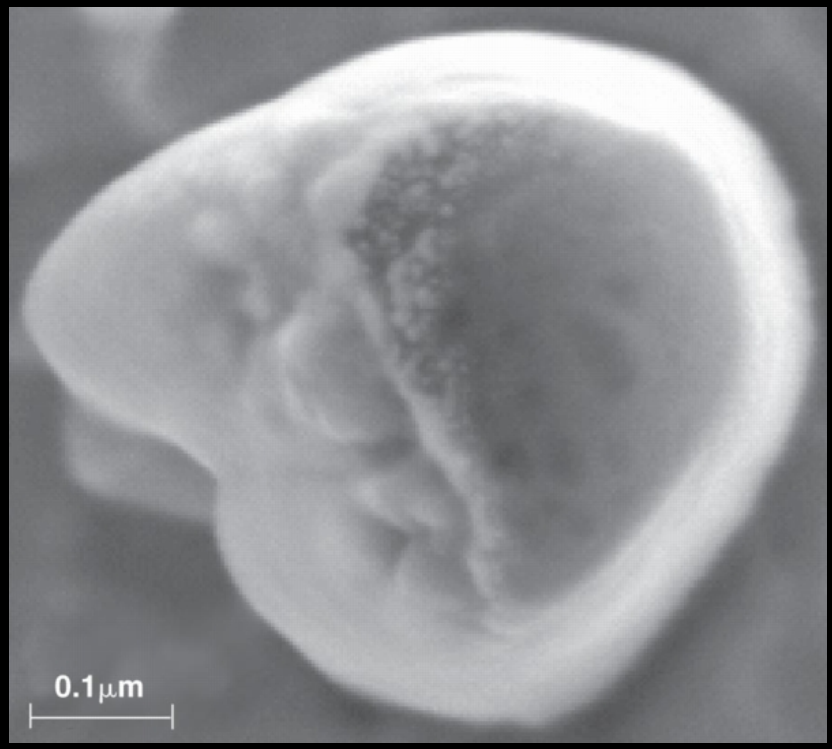
- BUT – gas density limits suggest $n < 100$ cm^{-3}
  - Maness et al. (2009) explore edge-on encounter?

A New Model

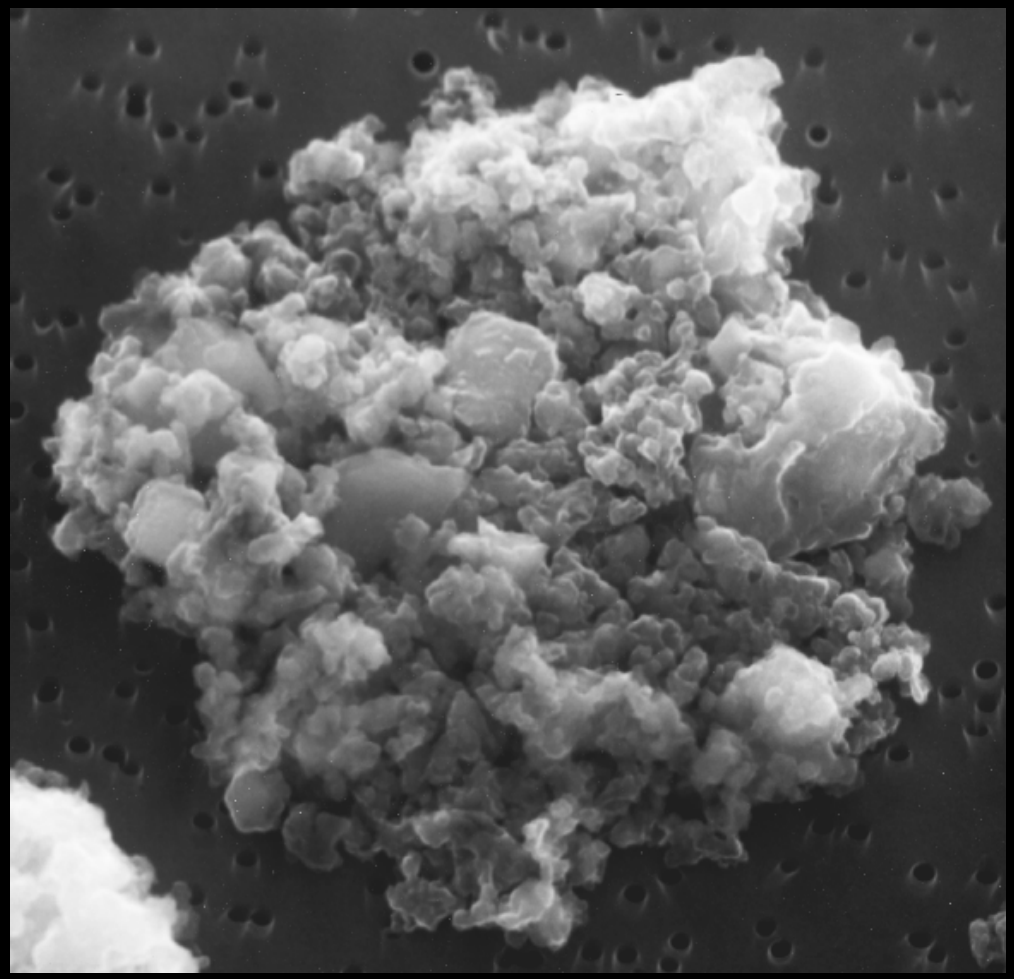
- Our new data strongly suggest a face-on encounter
- Material originates in ring and is blown out radiation pressure and ISM gas pressure
- How do we reconcile this with the limits on gas density from Maness et al. (2009)?
- Grain structure!

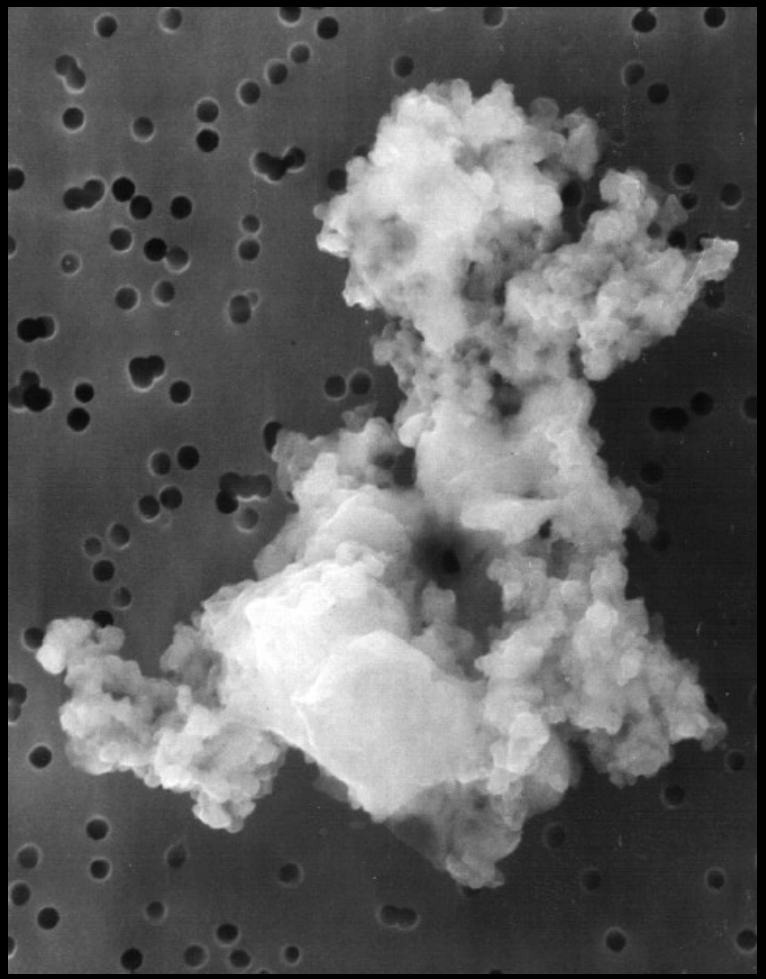
Hard and Regular?



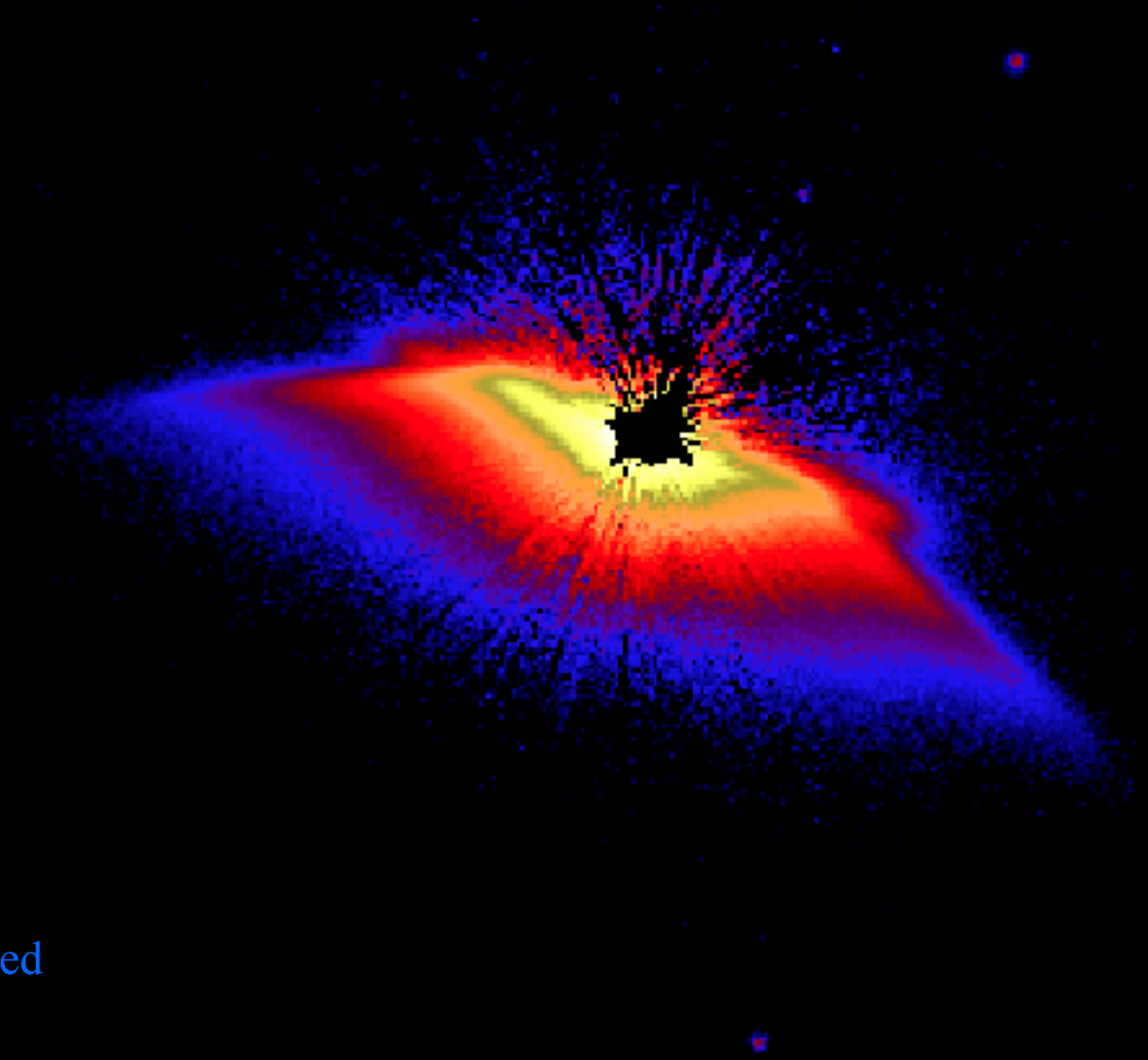


Fluffy and Irregular?





“Hard” *vs* “Fluffy” Dust Grains



Observed

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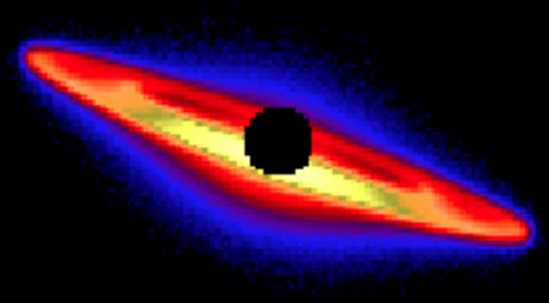

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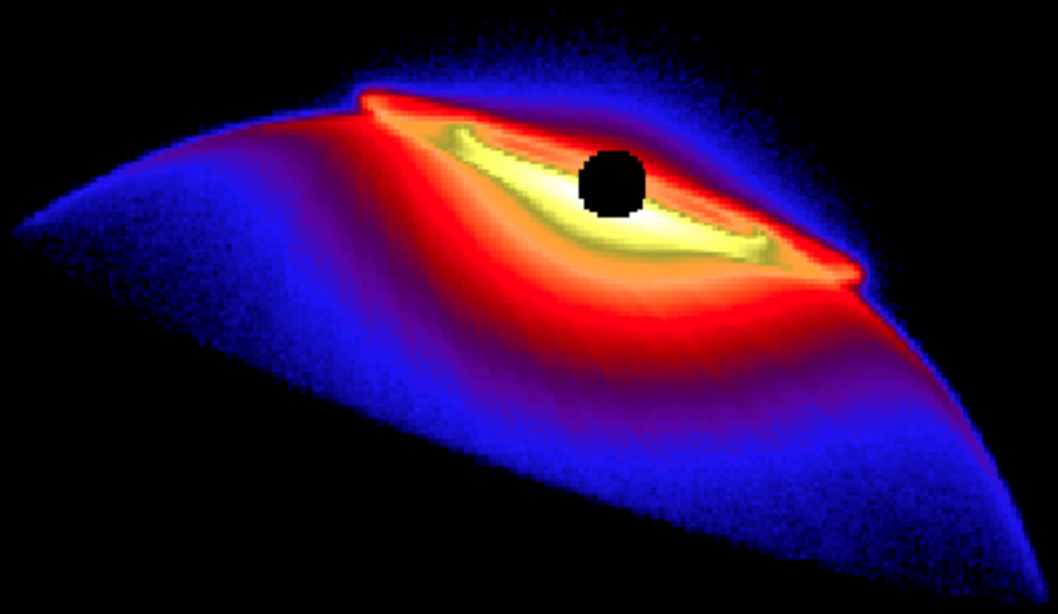

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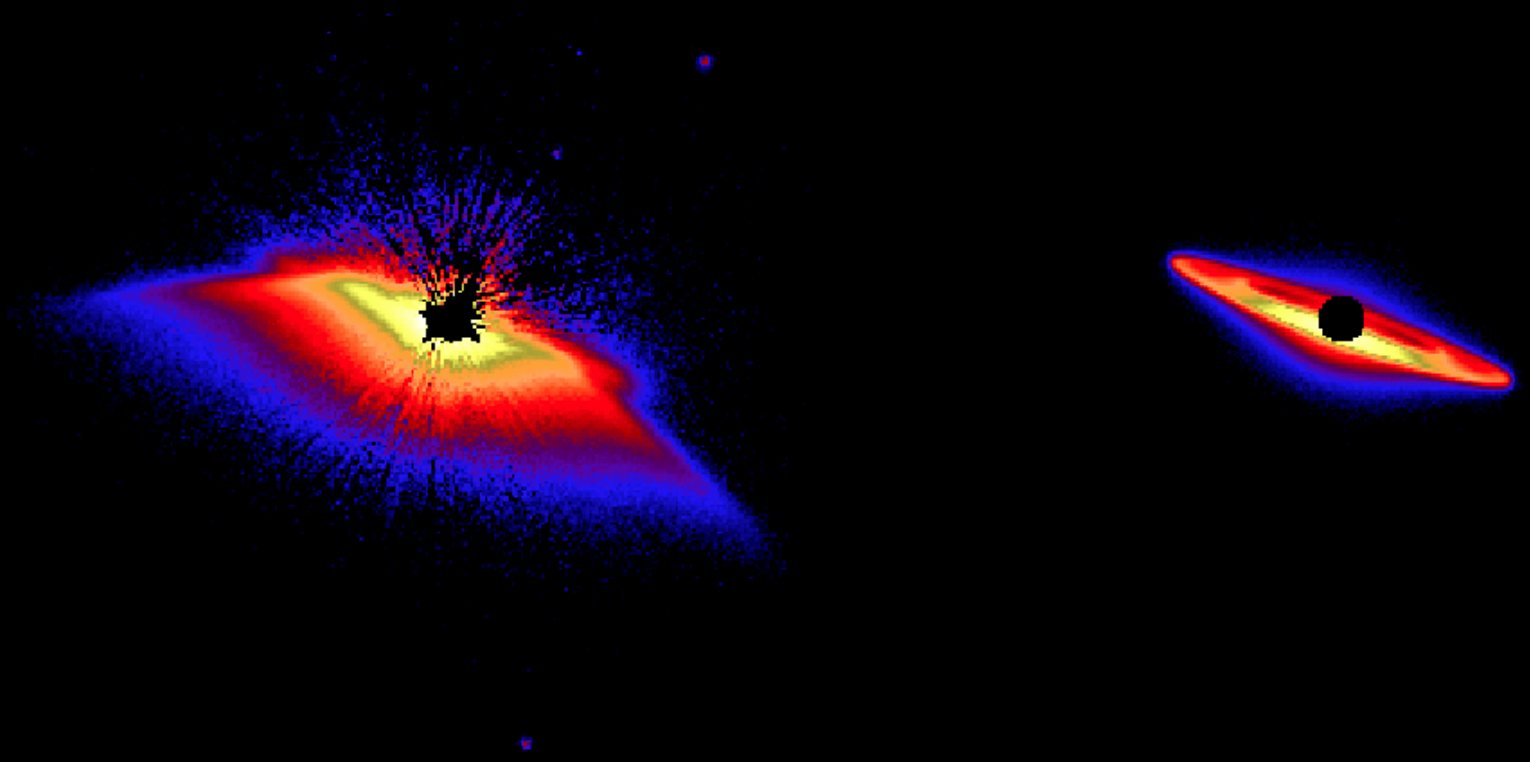

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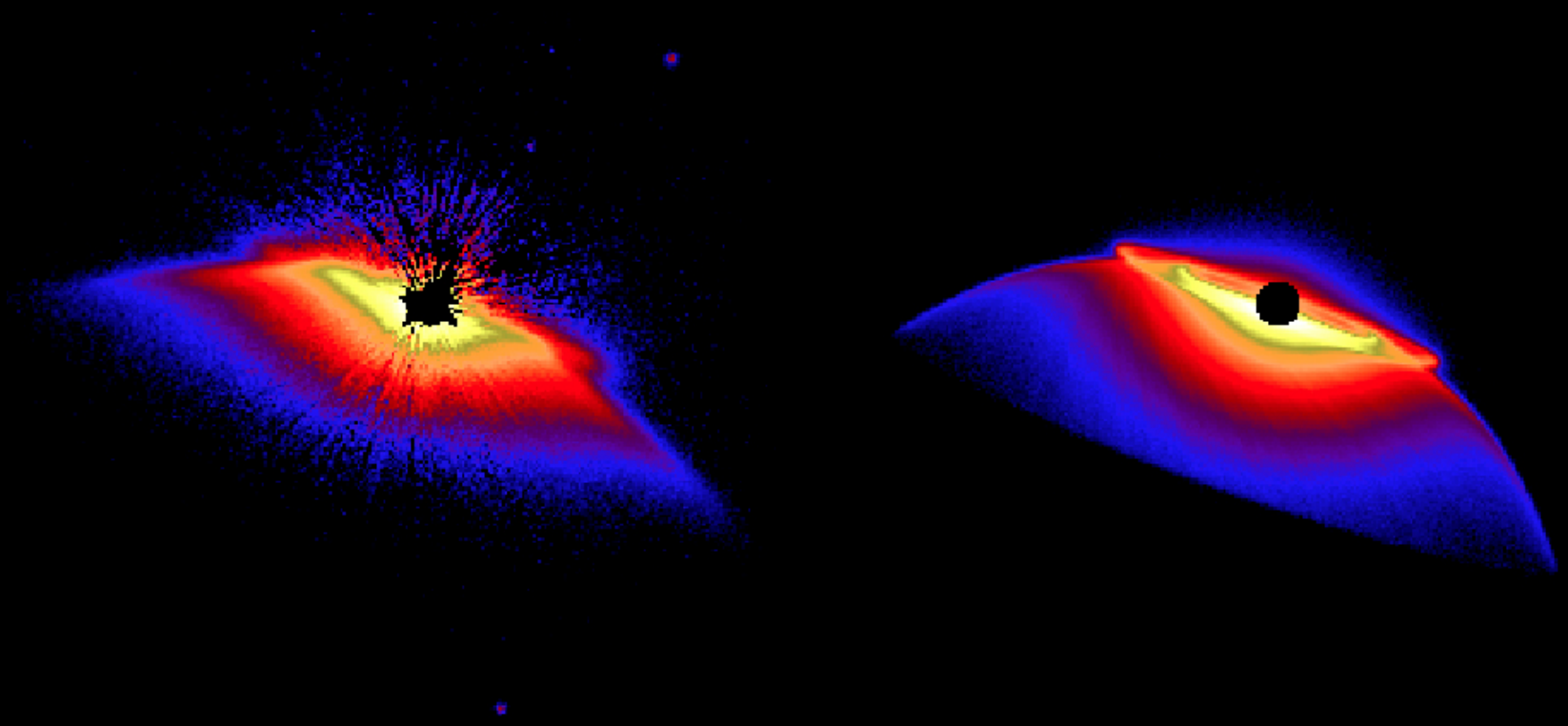

Observed

Fluffy Grains

HD 61005

- Evolutionary status of HD 61005
  - G8V @ 34.6 pc; t_{age} = 90 ± 40 Myrs; M ≈ 0.98 M_{sun}
- Infrared emission in excess of photosphere
  - T_{BB}= 60 ± 10 K, $r_{dust} \geq$ 13 AU, $L_{IR}/L_{*} = 2x10^{-3}$
  - No obvious signs of solid state dust features in spectrum
- NICMOS, ACS & STIS scattered light images
  - Asymmetric structure extending to ~ 240 AU
  - Nearly Edge-On Ring
- Interaction with the ISM
  - "Fluffy" dust grains originate in the ring; probably ground up by shepherding planet(s)
  - Grains blown out by radiation and gas pressure


Fin