The ELT Planets Case

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Outline

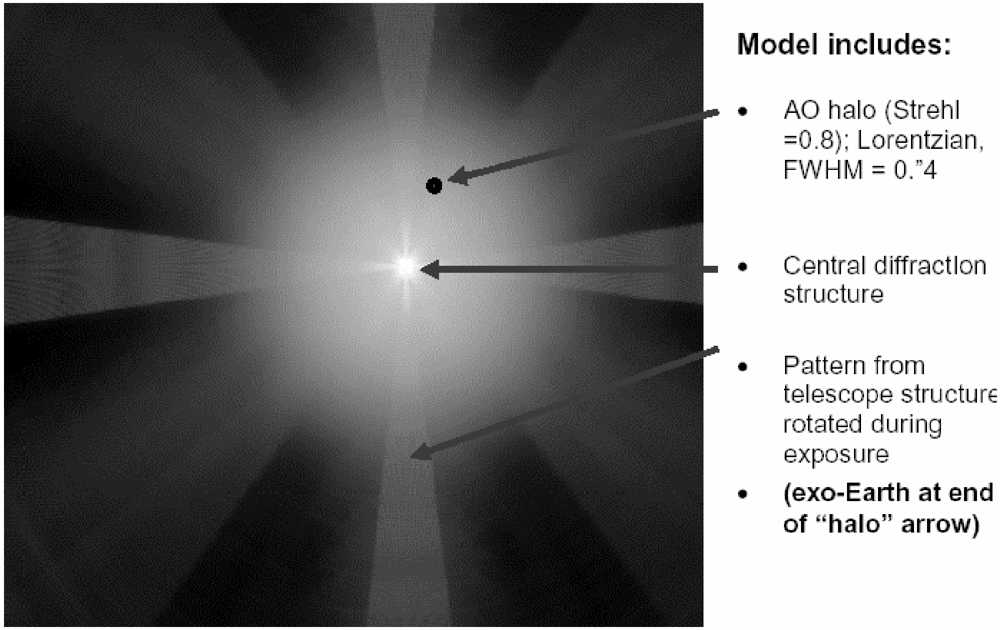
1. Detecting large numbers of planets, and characterising a significant number.
2. Elucidating how planets form.

How far away I. Resolution

- If simply use $1.22\lambda/D$ => 2.5mas at 1μm
- At 100pc 1AU = 10mas.
- Number of stars surveyable $\propto$ distance^3
- Distance you can reach $\propto$ resolution
- Resolution $\propto$ aperture
- Surveyable stars $\propto$ aperture^3

Why is this wrong?

- Its probably not very wrong, but…
- Reaching significantly above plane. (Might there be an ideal aperture?)
- Assuming ideal adaptive optics.
- (Piero Salinari)



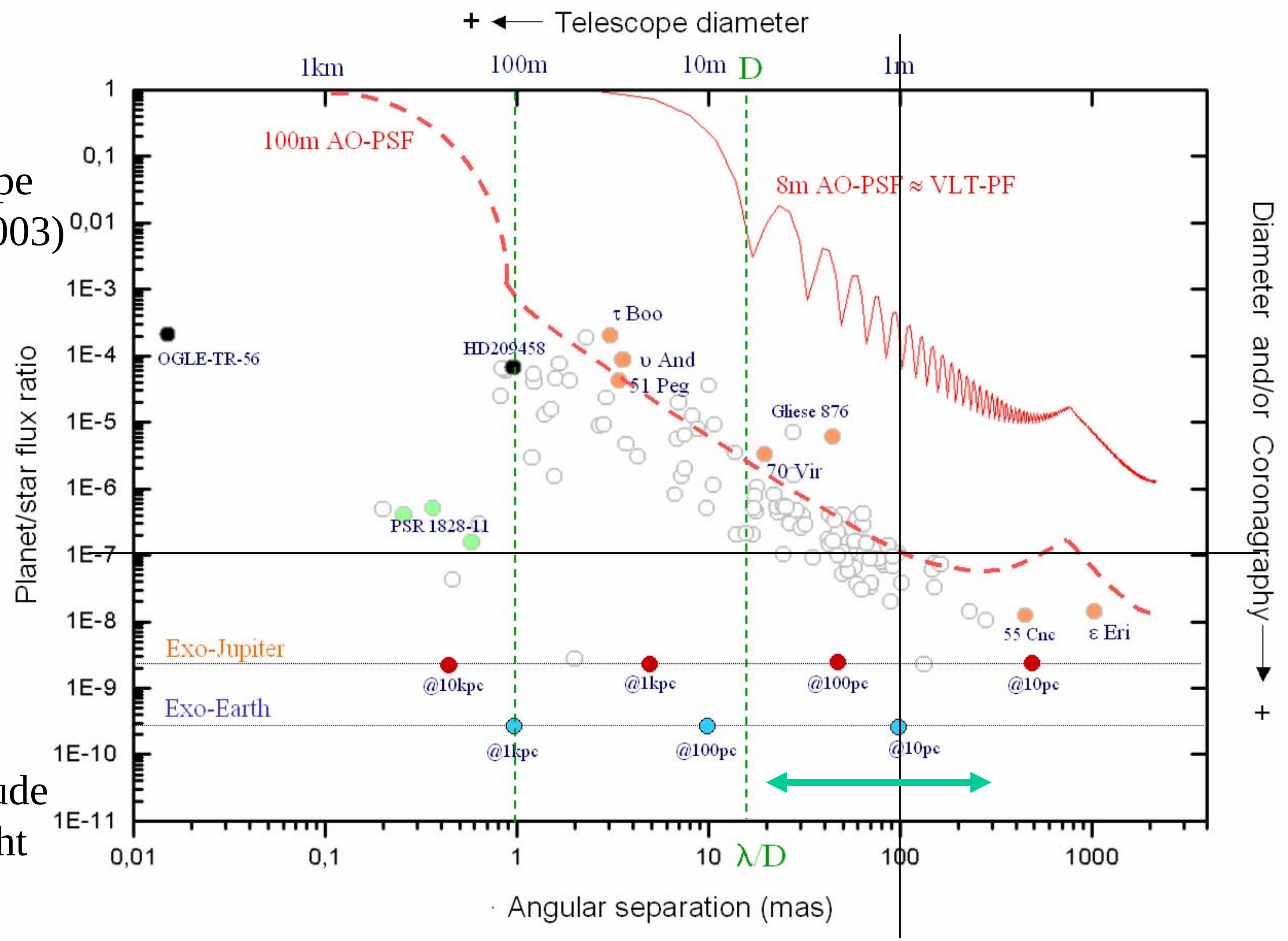
Result: V band AO PSF

Planet/star flux ratio and angular separation for known exoplanets compared with telescope PSF (Lardiere et Al. 2003)

A) even a 100 m telescope cannot resolve some of the known planets from their stars.

B) A one arcsec field radius includes most known planets

C) Exo-earths, at best distance, are about three orders of magnitude below the scattered light background



How far away? II. Counts

- Terrestrial planets 25 mags fainter than star (*i.e.* suppression of 10^{10}).
- Sun is about M_J=3 or J=8 at 100pc.
- Planet is J=33, or a day or two to signal-to-noise of 10.
- So, even in absence of scattered light running out of photons at 100pc.

How many Earth's do you want to detect?

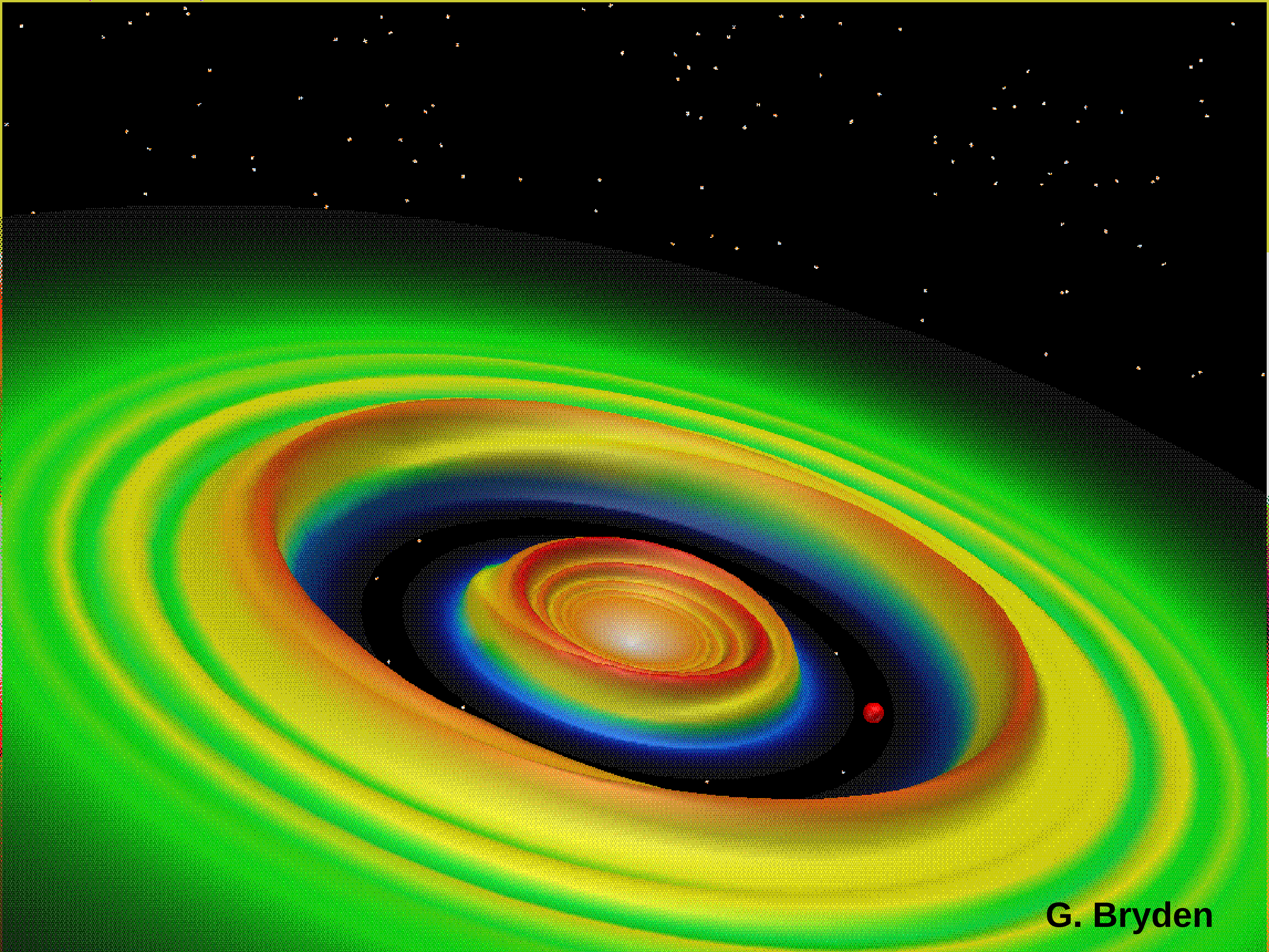
- Microlensing will probably discover a few Earth's before the ELT.
- What if 1% of solar type-stars have planets?
  - 5% chance 300 stars no detection.
  - Even with 1000 stars & 10 detections, limits poor.
- Need 25pc to get 360 F, G, K stars.

And when you’ve detected them…

- Find atmospheric composition, mainly through broad bands (O_2, O_3, H_2O, CO, CO_2, CH_4).
- Biomarker O_2 simultaneously with H_2O.
- Nominally hard due to Earth’s own similar bands, but, can correct this using the scattered starlight.
- Scattered light dominates uncertainties in S:N calculations, but ~weeks for spectra @10pc.

The Provocation

- Don’t want to detect planets, need to understand how you makethem.
- Is just detecting them stamp collecting?
  - No, but do need decent samples.
- Want to watch discs forming planets.


G. Bryden

Simulations. The Input Physics

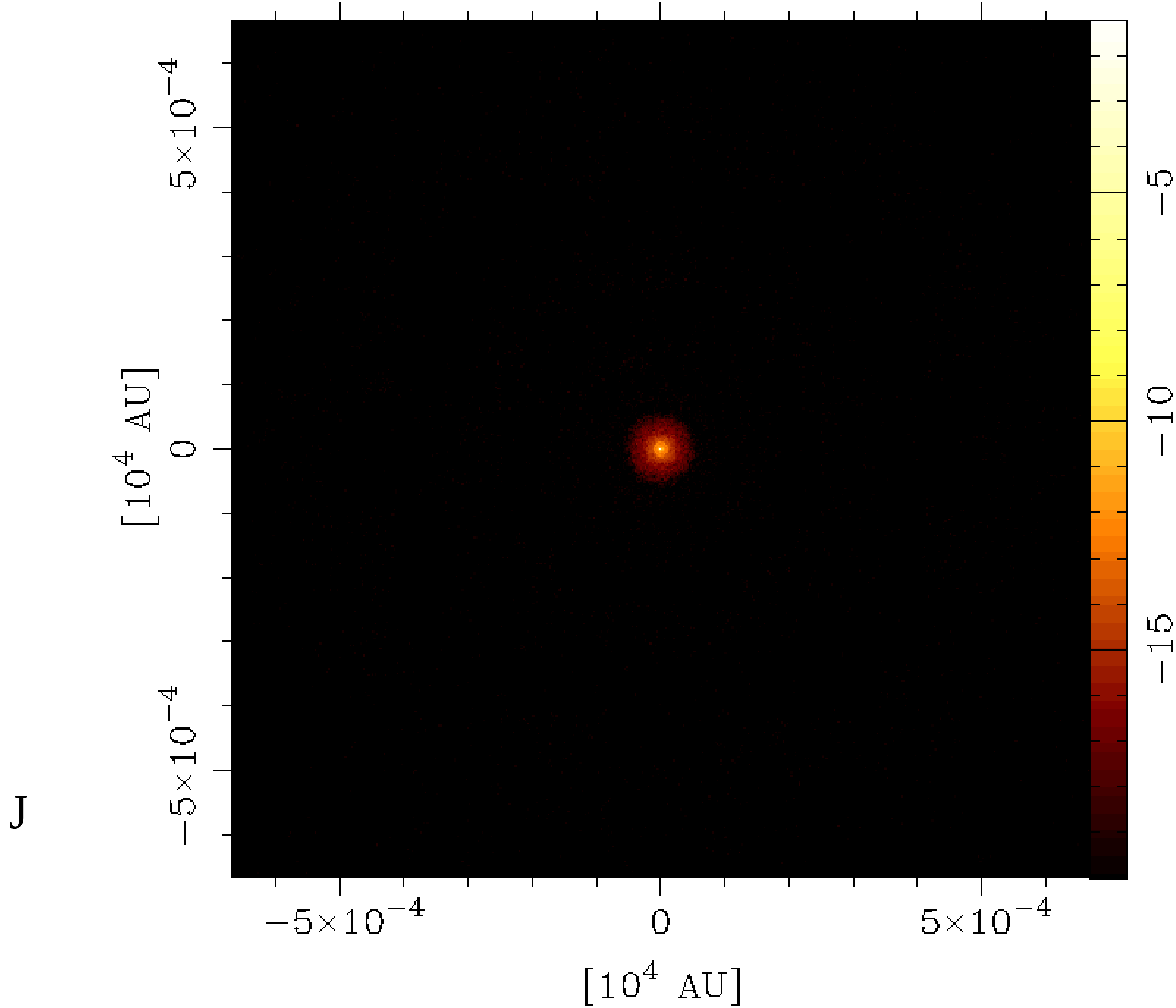
- Standard α-disc model.
- Passive – *i.e.* heated only by star.
- Basically seeing warm dust.
- Calculated by Ryuichi Kurosawa, with Tim Harries and Matthew Bate.

The Details

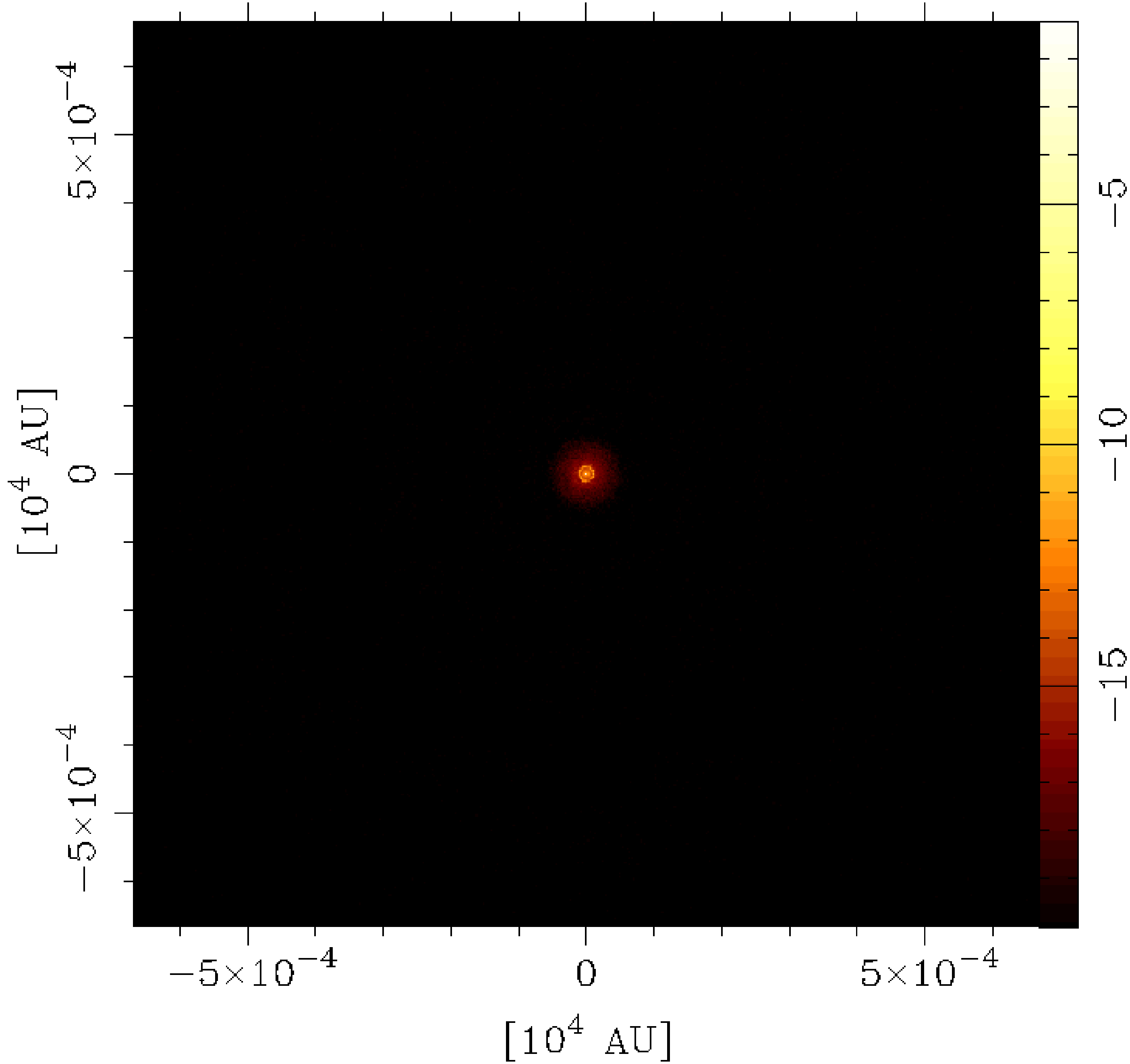
- The basic model used are.
  - $R_{disc(inner)} = 0.096$ AU
  - $R_{disc(outer)} = 10$ AU
  - $R_* = 1.71\ R_\odot = 1.7\text{x}10^{-3}$ AU
  - $L_* = 0.273\ L_\odot$
  - $T_* = 3200$K
  - $M_* = 0.16\ M_\odot$
  - $M_{disc} = 0.01M_*$
- $F_{disc}/F_* = 0.2$ for J band
- $F_{disc}/F_* = 0.1$ for K band

About the Images

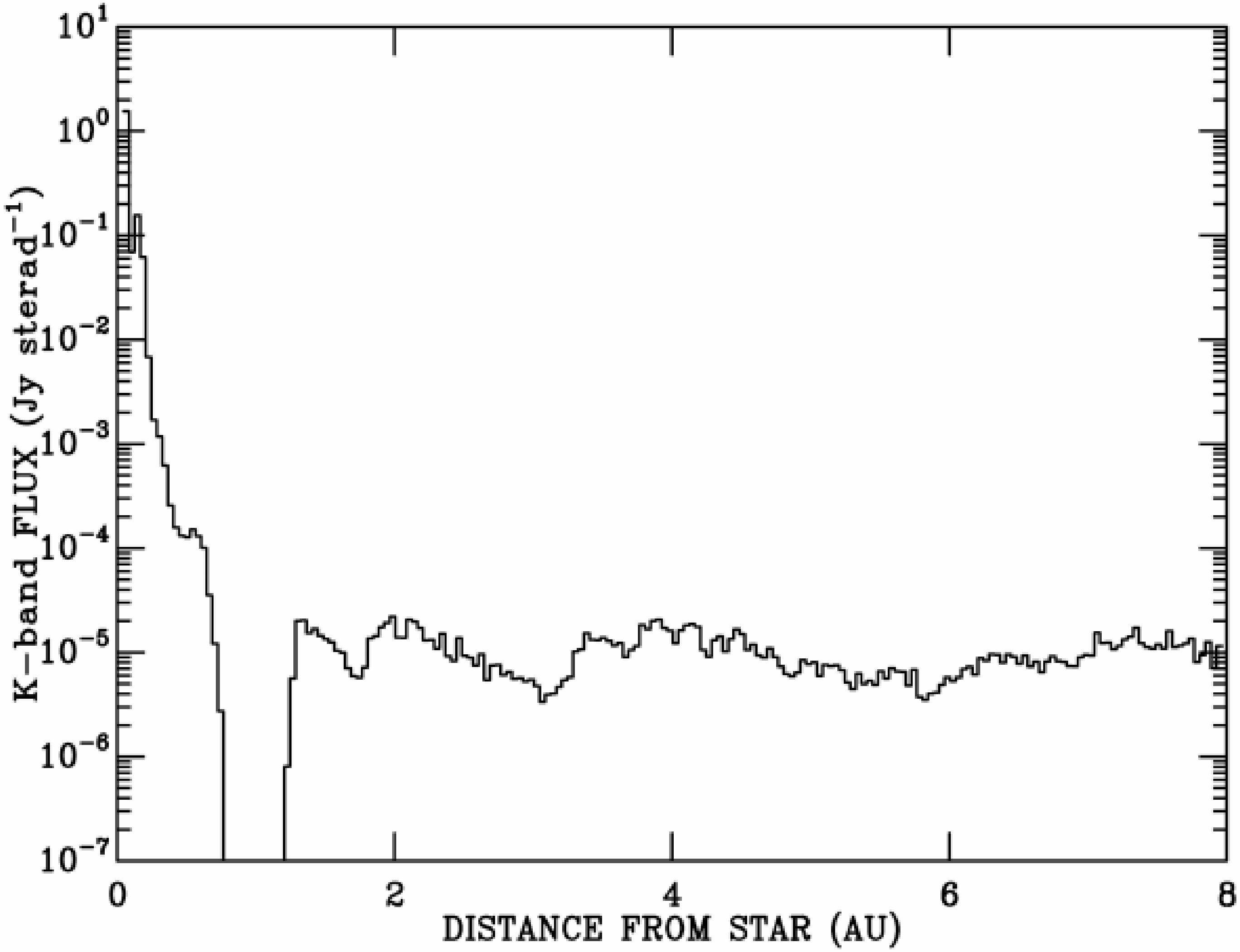
- Distance to the star = 100pc (Why?)
- Images are 513 by 513 pixels
- 1 pixel = 2.5×10^{-4} arcsec = 2.5×10^{-2} AU
- Diffraction limit of 100m telescope at 2.2 microns is about 5.5×10^{-3} arcsec.
- Images are about 20 resolution elements, or 12AU/side.



J
5×10^{-4}
0
-5×10^{-4}
$[10^4$ AU$]$
-5×10^{-4}
0
5×10^{-4}
$[10^4$ AU$]$
−5
−10
−15



K



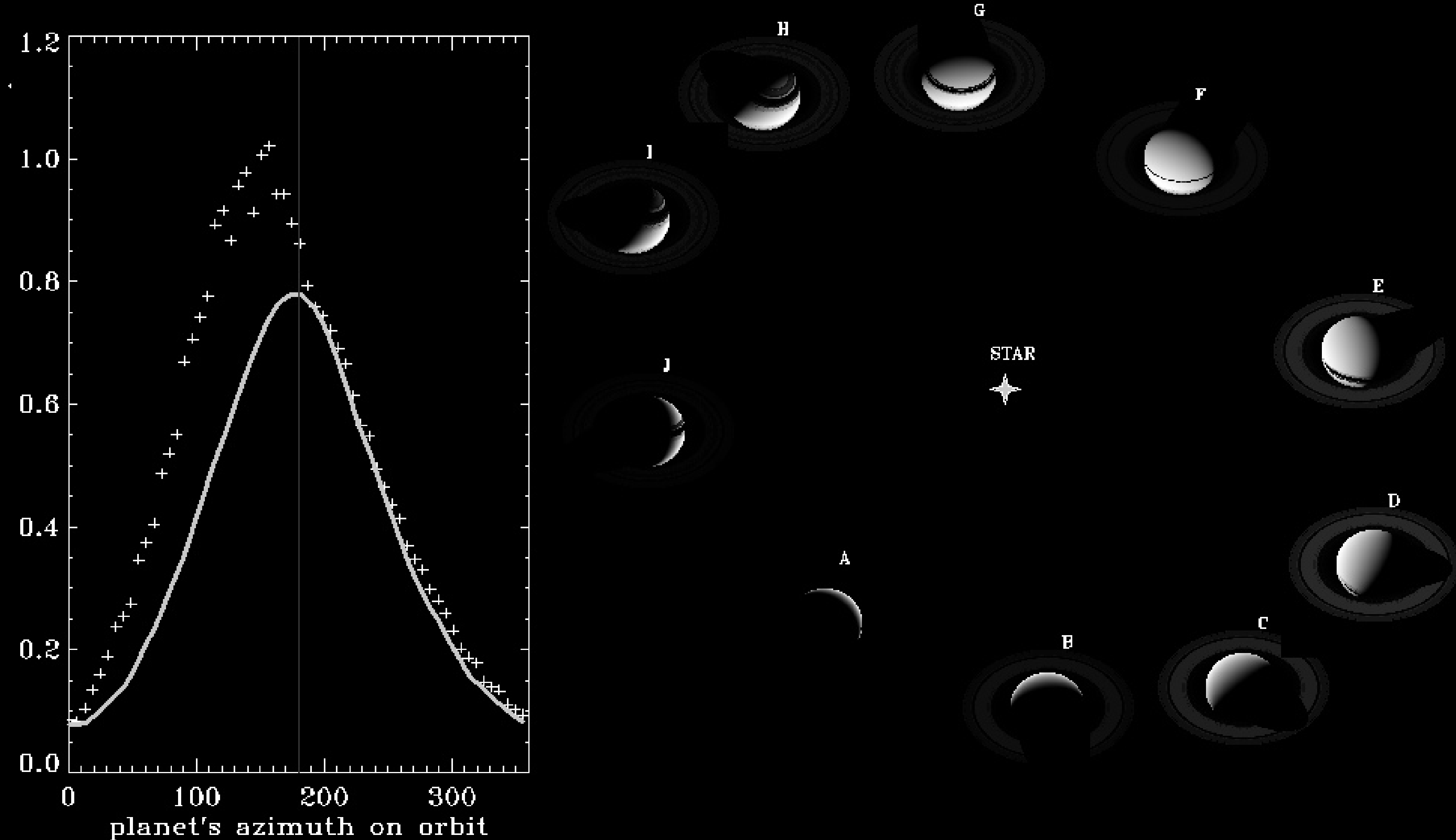
K–band FLUX (Jy sterad^{-1})
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
2
4
6
8
DISTANCE FROM STAR (AU)

Requirements for planet formation

- Complex images, need filled aperture.
- Resolution is
  - OK at places like ρ Oph (100pc),
  - Excellent for smaller, closer samples.
- Strehl
  - looks O.K., 10^5 not 10^{10}
  - but does need detailed calculation.

Some other cute things.

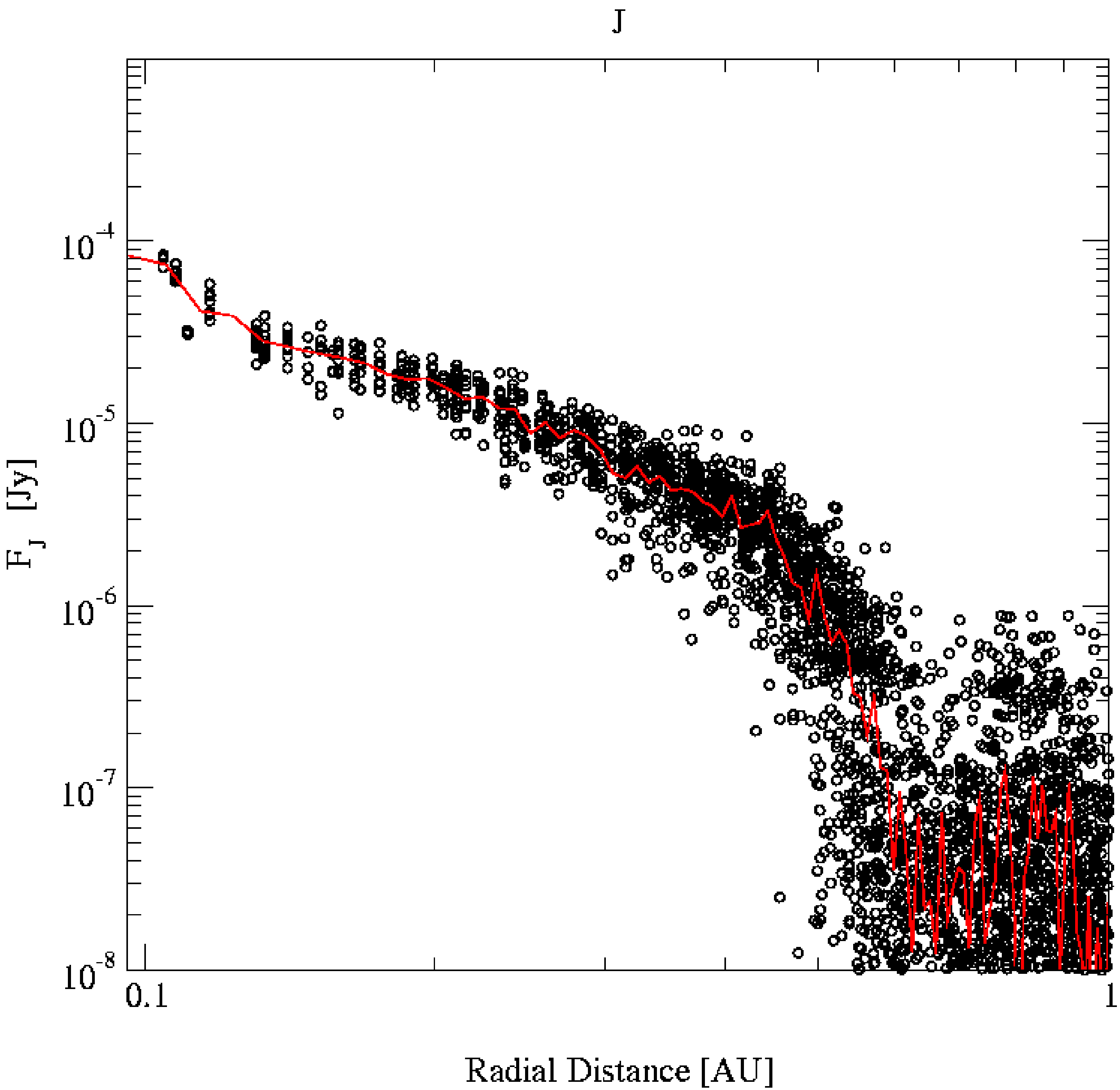
- Planetary rubble (size and extent).
- Planetary imaging (nearly S/C type resolution, but more frequent access and many un-imaged bodies).

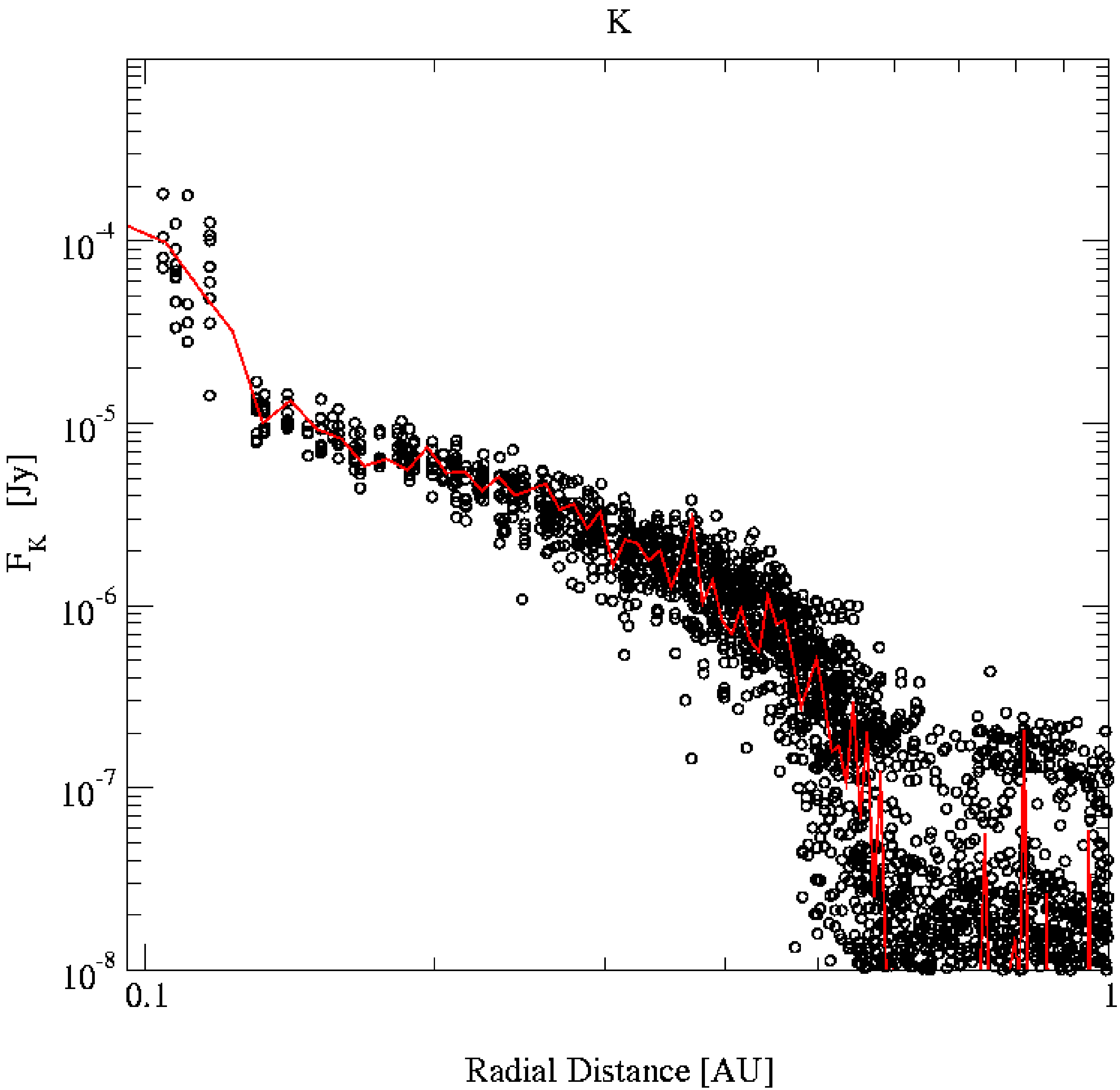


Credit: Dyudina et al, Australian National University.

Conclusions. The ELT's two tasks

1. Characterisation of planets (statistics and spectra). This drives aperture (for counts), but uncertainties for how aperture drives resolution are;
   - waveband (changes D by factor 4),
   - supression.
2. Understanding planet formation. Needs IR measurements of disc, which drives
   - resolution (3mas?), and hence baseline (100m)
   - but not (so) stringent on supression.


J
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
F_J [Jy]
0.1
1
Radial Distance [AU]


K
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
F_K [Jy]
0.1
1
Radial Distance [AU]