Summary of Exoplanet Parallel Sessions: Science with WFIRST

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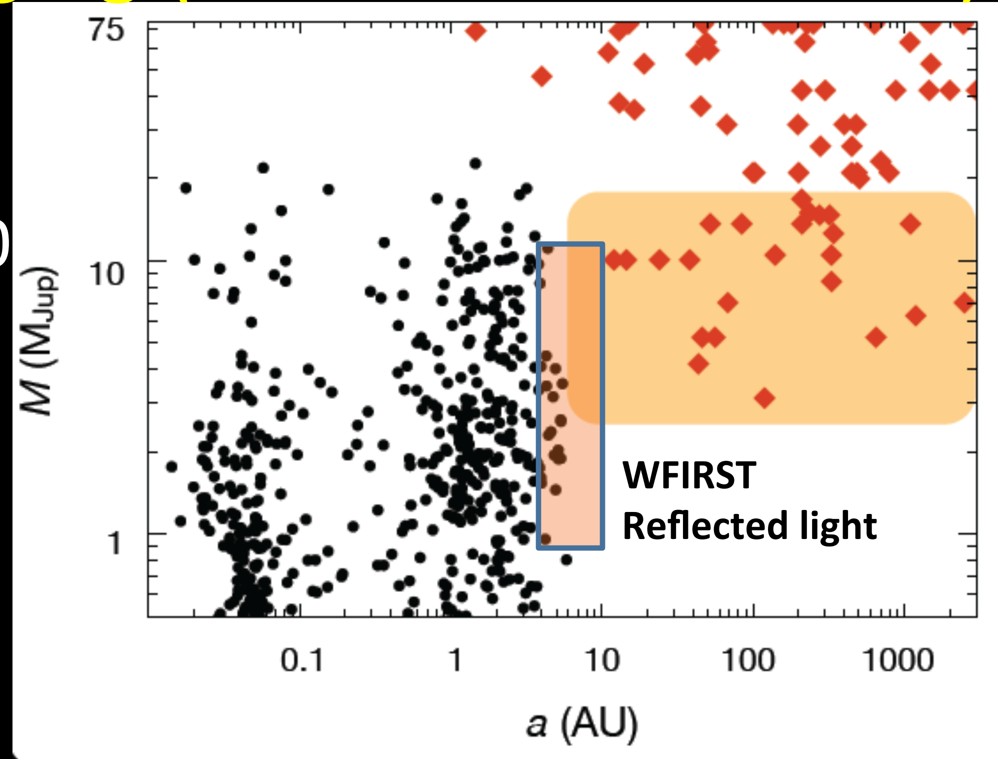
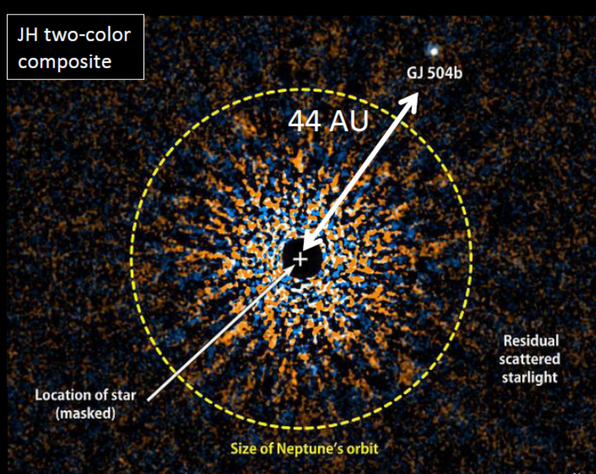
Topics of the Science Sessions

- Bowler Ground and Space-Based Imaging of Exoplanets Before WFIRST
- Tamura Exoplanet and Disk Imaging With Subaru
- Morley Reflected Light from Giant Exoplanets
- Roberge Scientific Opportunities with a Starshade Working With a 2.4 m Telescope at L2
- Ebbets Cosmic Origins Science enabled by WFIRST-AFTA coronagraph
- Gaudi Recent Microlensing Results from the Ground and from Space
- Levison The Formation of Planets from the Direct Accretion of Pebbles
- Calchi Novati Microlensing with Spitzer
- Penny The planets at the extremes of microlensing's sensitivity

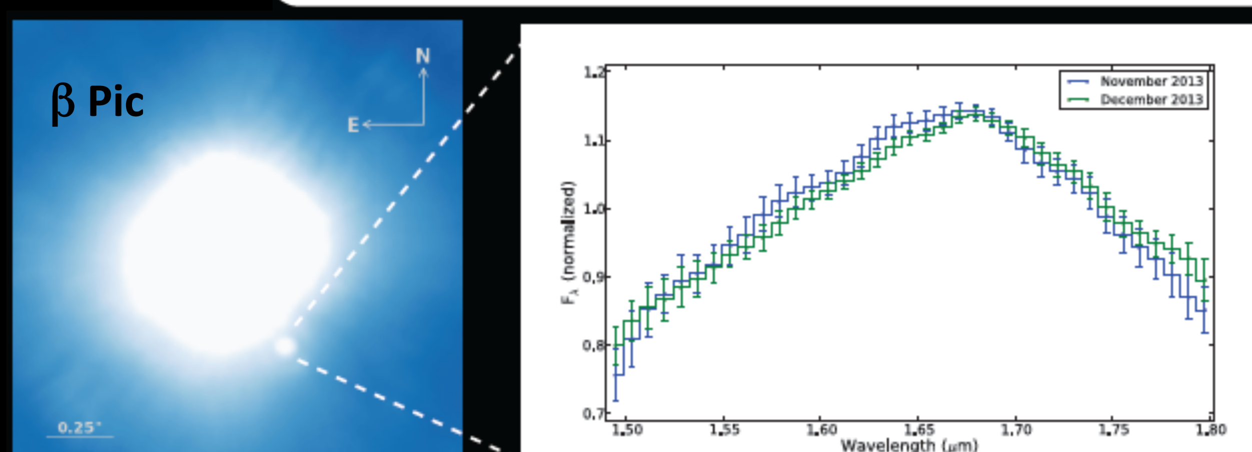
State of the Art in Imaging (Bowler and Tamura)

- Near-IR Imaging and Spectroscopy of Young Jupiters (2-10 Mjup;10-100 Myr) on distant orbits
- Probe formation mechanisms at large distances: disk instability, fragmentation, scattering



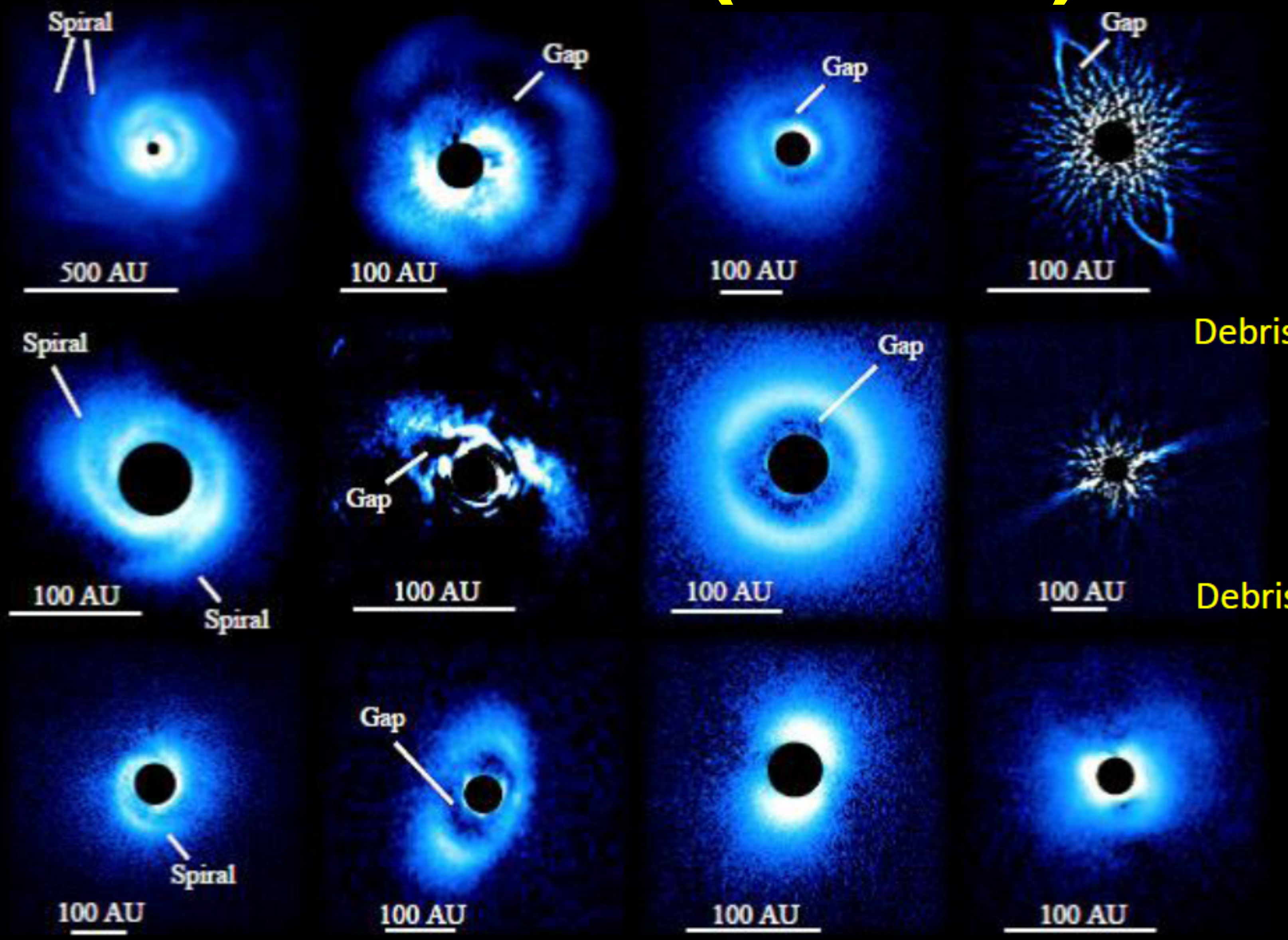


3-4 MJ orbiting 160 Myr G0 star



Chilcote et al. 2014

SEEDS have revealed gaps & rings of <100 AU scale in many disks (Tamura)



WFIRST and Albedo of Giant Planets (Morley)

- Critical parameters include equilibrium temperature (→cloud composition), metallicity
- R~ 70 for composition

HD 62509b (warm, alkali clouds)

HD 99492c (cold, ammonia clouds)

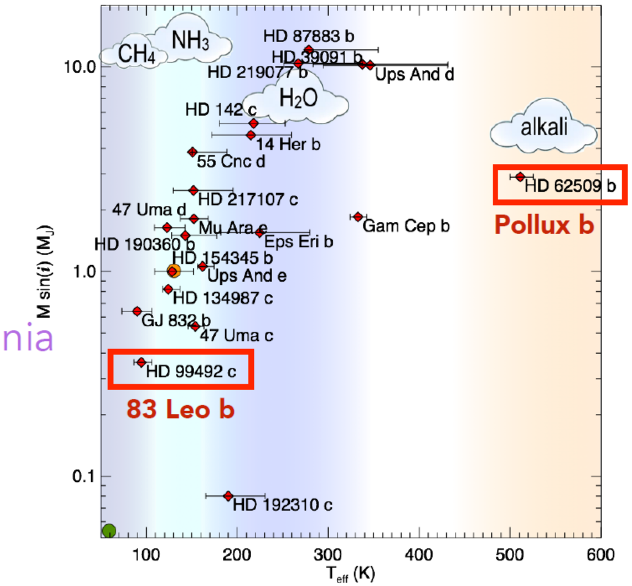
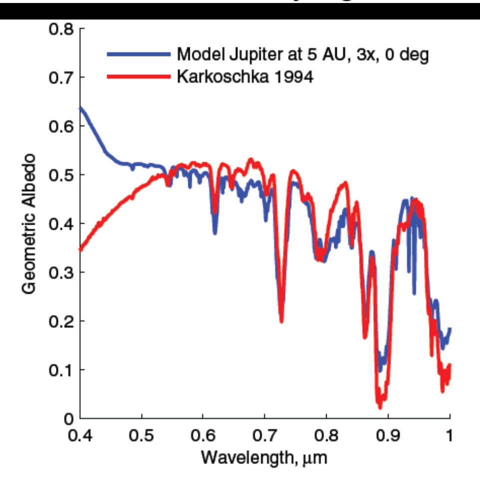


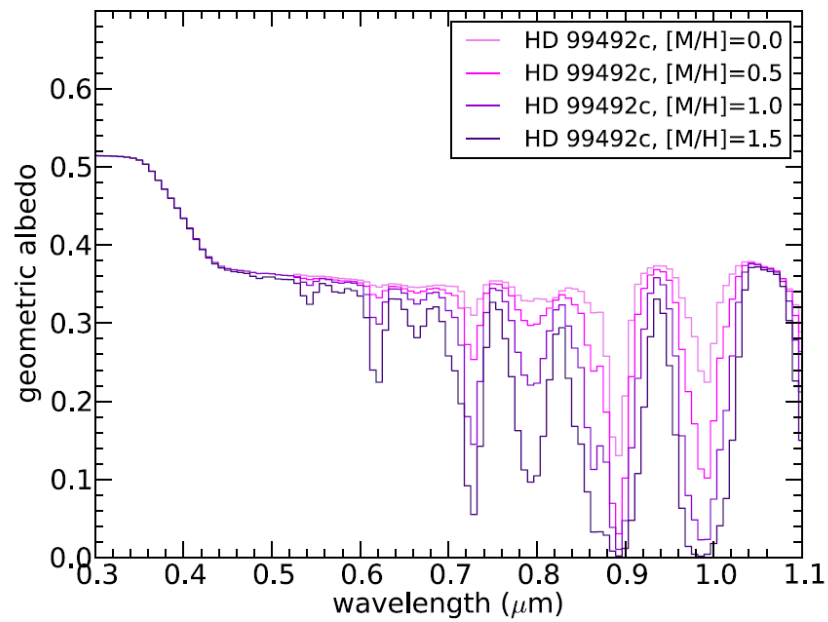
Figure from Nikole Lewis

1D radiative-convective equilibrium model: temperature, composition

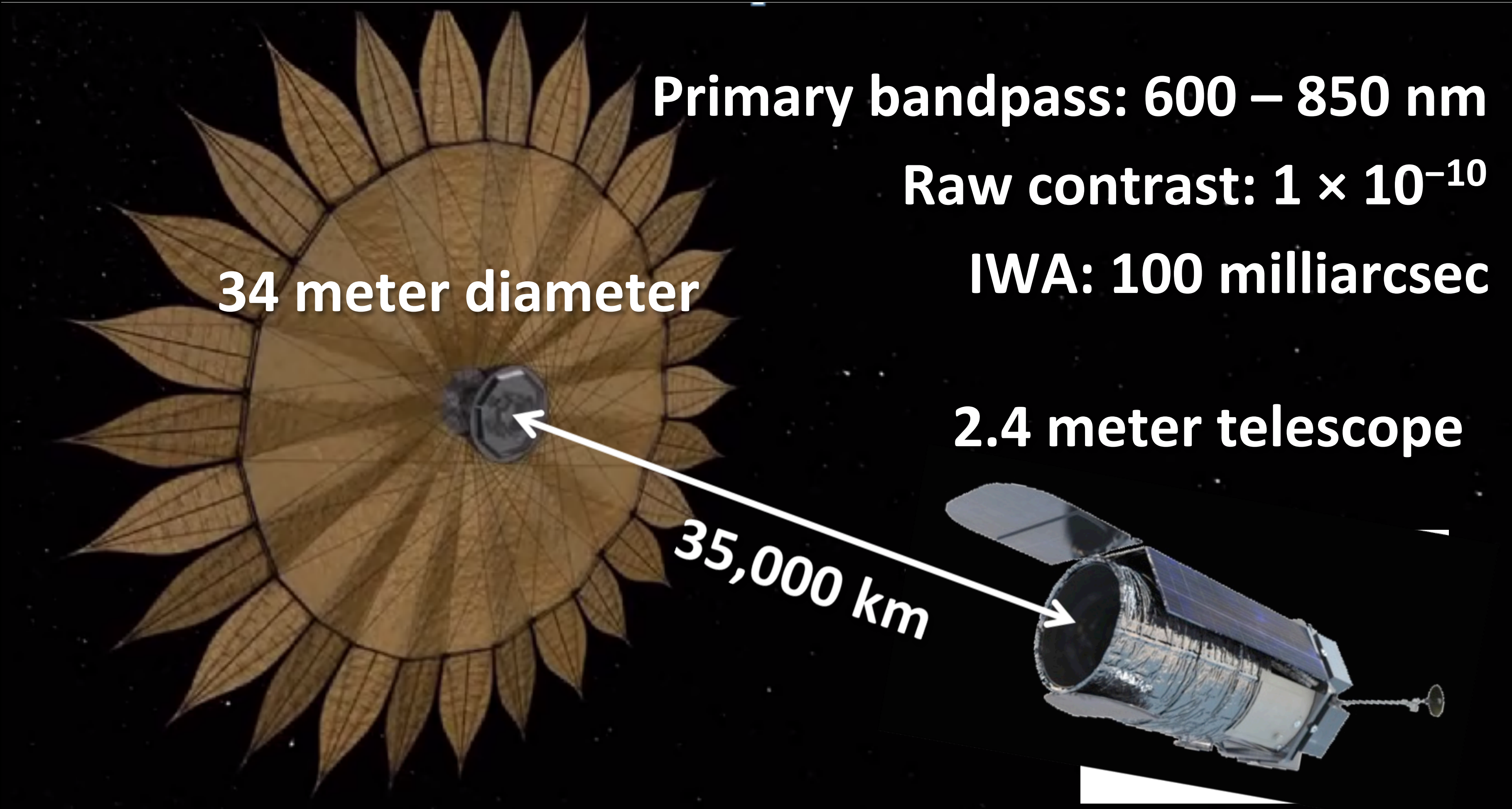
coupled cloud model: cloud tau, scattering, asymmetry

scattered radiation (Rayleigh, Raman, Mie)





Starshade for a 2.4 meter Telescope (Roberge)



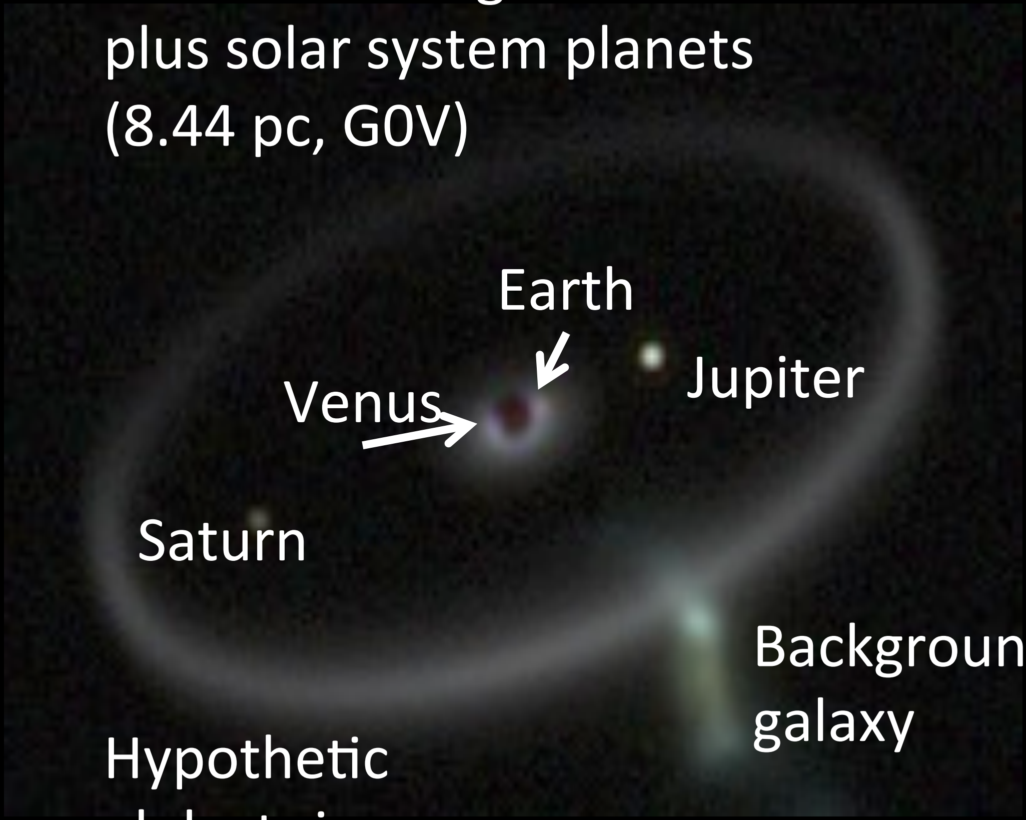
Assuming use of AFTA coronagraph (slight modifications)

Preliminary Starshade Performance

52 stars in 2 years

- 13 known exoplanets
- 19 HZ targets yields ~2 Earths/Super-Earth
- Detect sub-Neptunes to Jupiters around all HZ targets and 20 additional stars

Simulated image of Beta CVn plus solar system planets (8.44 pc, G0V)

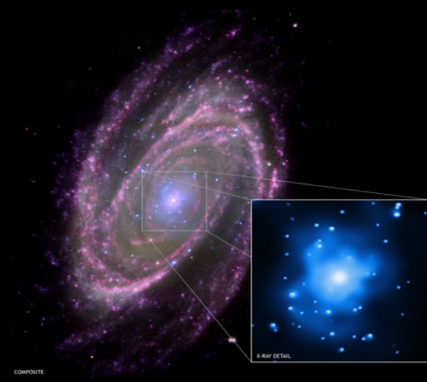


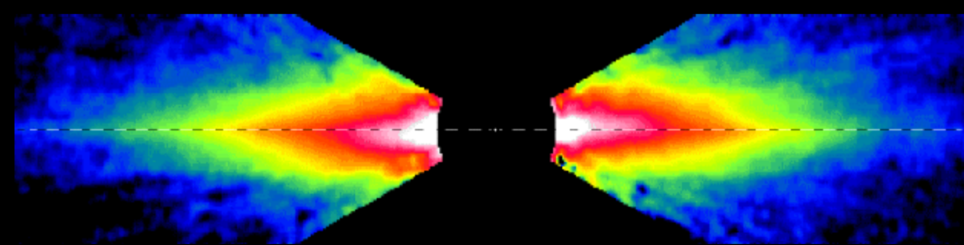
Hypothetical dust ring at 15 AU

Image credit: M. Kuchner

COR Coronagraphic Investigations (Ebbets)

- Quasars & AGN
  - Host galaxies
  - Central black holes
  - Accretion disks
  - Bulges, spiral arms etc.
  - Mergers
  - Jets
- Young stars
  - Accretion disks
  - Outflows, jets
  - Protoplanetary disks
- Evolved Stars
  - Debris disks
  - Ejecta, symmetries
  - LBVs - η Carinae
  - WR stars
  - Interactions with ISM

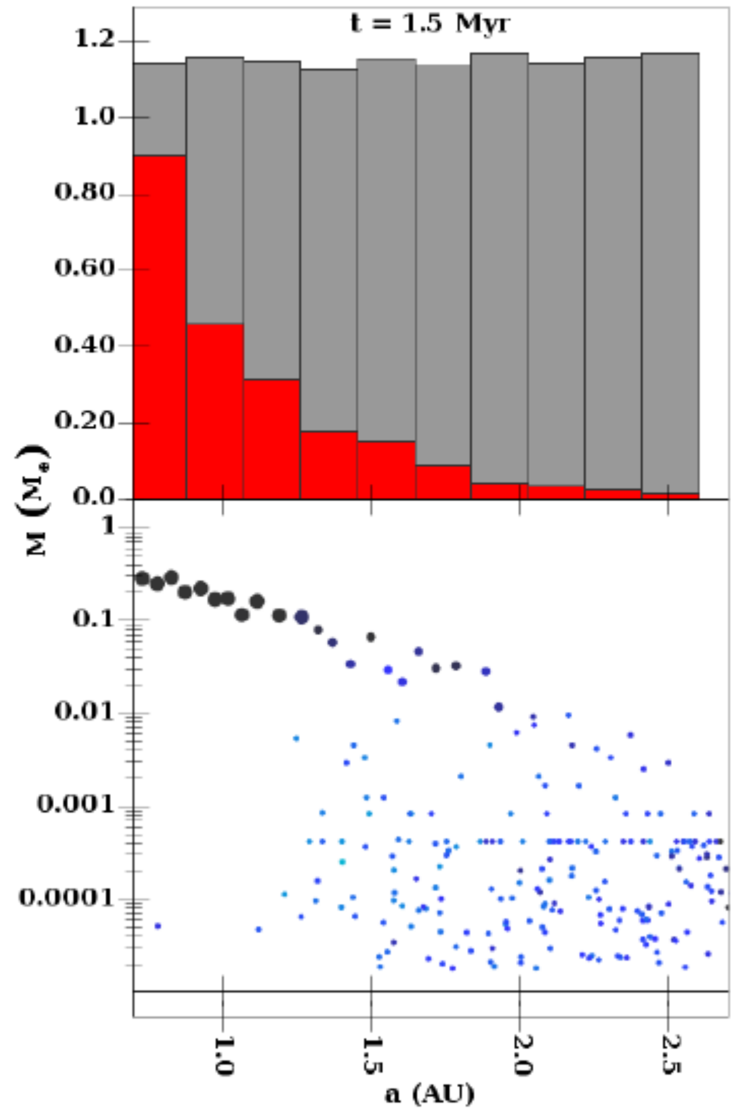




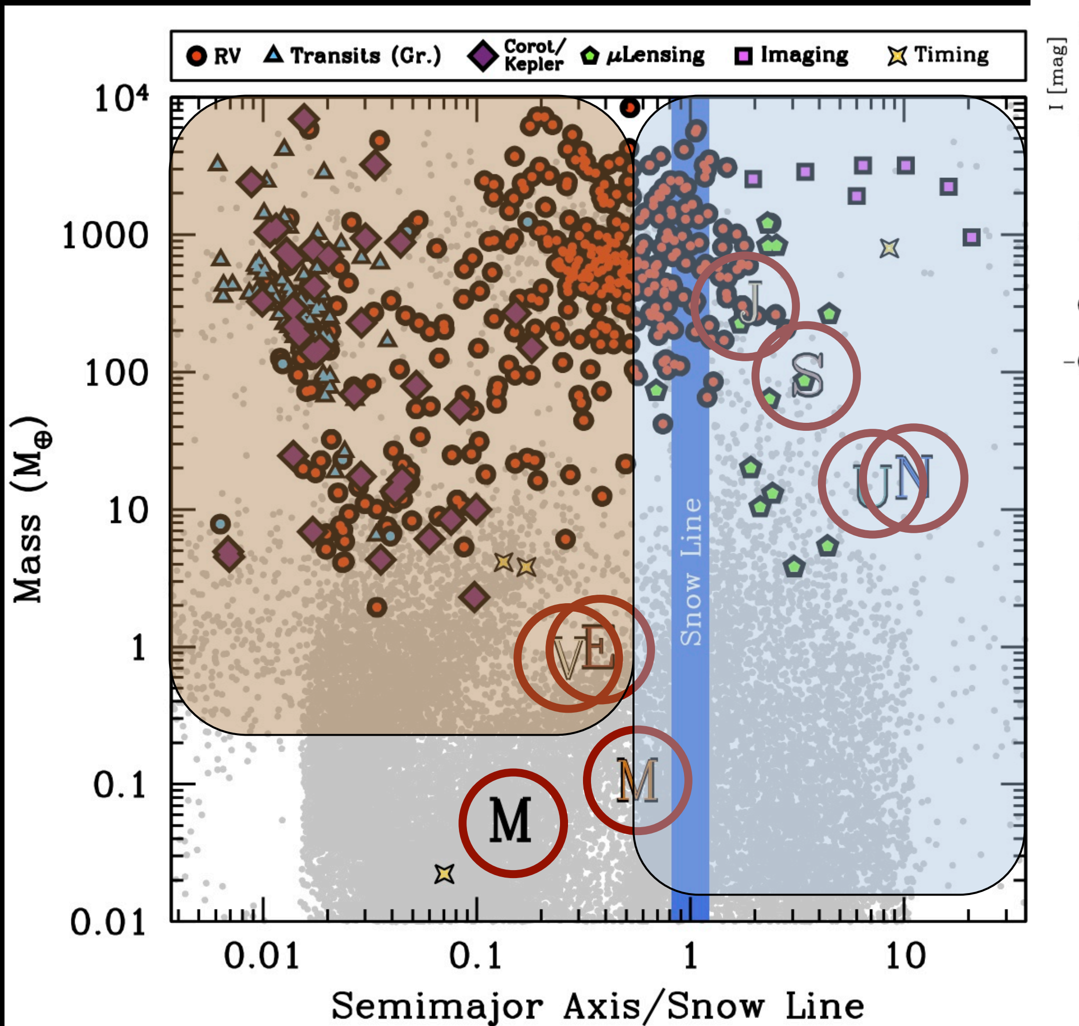
Slow Pebble Accretion and Terrestrial Planets

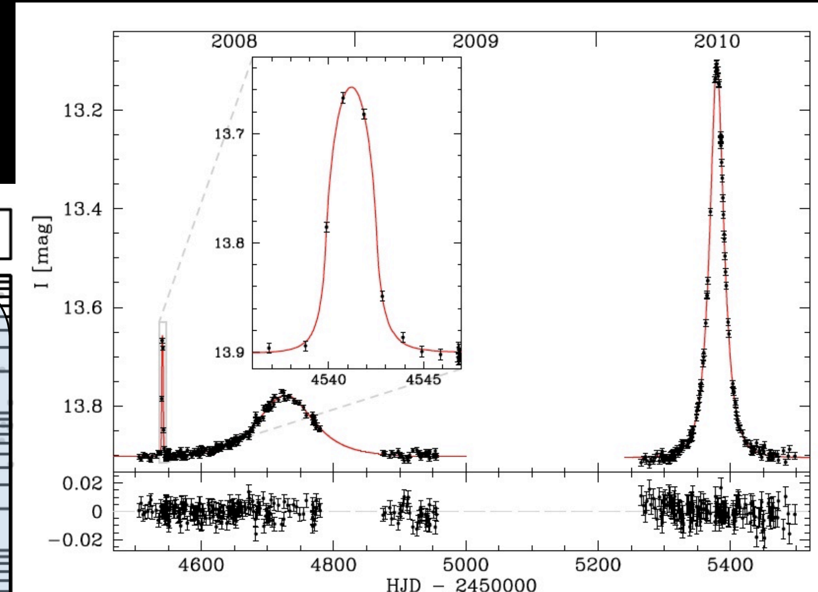
Let's look at what happens with slow pebble accretion:
We find that the terrestrial planets form in 2 stages.

- **Pebbles Stage:**
  - Little mass near 1.5 AU and almost none beyond 2 AU!
  - Closer to the Sun $\Rightarrow$ smaller objects can grow.
  - For this disk, Ceres-sized objects can only grow to $\sim$1.5 AU.
- **Bamm-Bamm Stage:**
  1. Eat all planetesimals w/ $a \lesssim 1$ AU.
  2. Settle into a system of $\sim$20 small planets.
  3. Suffer an instablity of 10s Myr $\Rightarrow$ giant impacts.
- So, we have a single physical process that can make:
  1) Earth and Venus.
  2) Low-mass Mars,
  3) Low-mass asteroid belt.

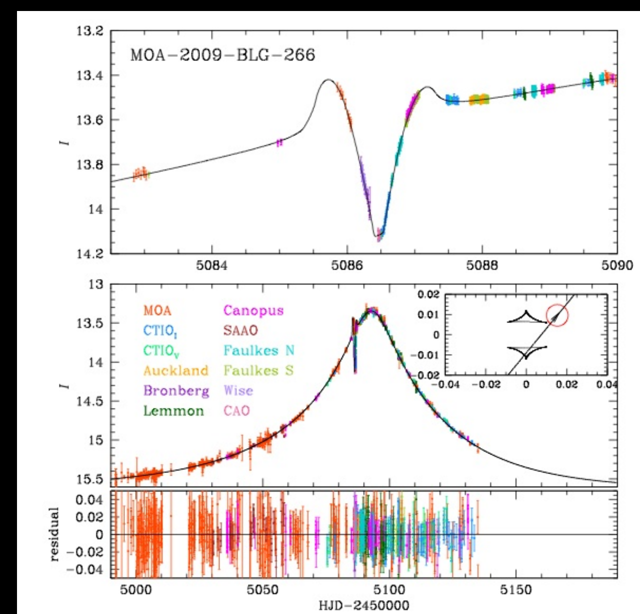


Demographics (Gaudi)





- ~4 M(uranus) @ ~18 AU
- 10 MEarth

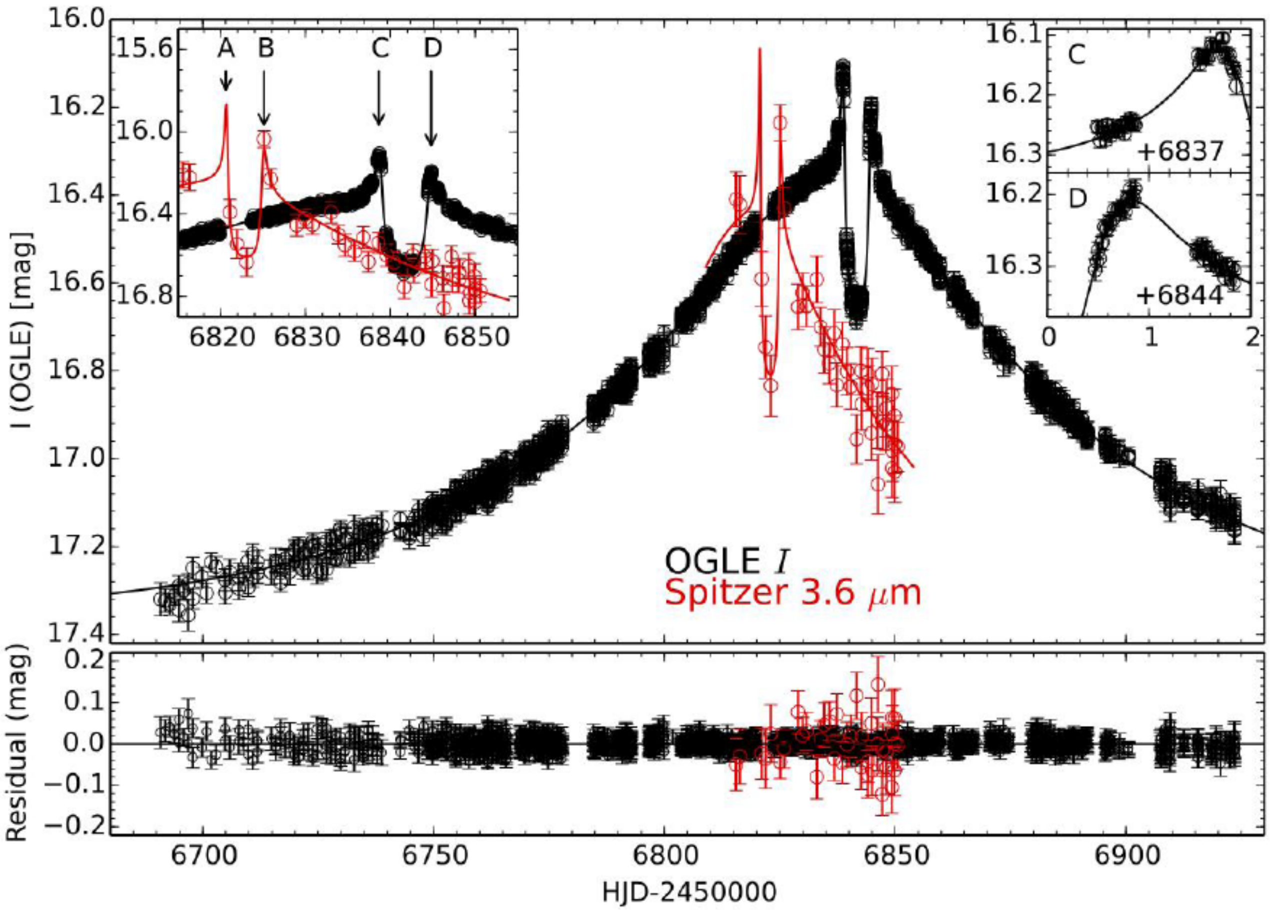


2.0±0.5 Planets/M Dwarf
0.17±0.08 Giant planets/M Dwarf

Spitzer as Microlens Parallax Satellite: Mass measurement for the OGLE-2014-BLG-0124L Planet and its Host Star

$\theta_E = 0.84 \pm 0.26$ mas (for $M < 1.2\,M_\odot$)

$\pi_E = 0.15$ (2.5%)



$M_{host} \sim 0.71\,M_\odot$

$M_{planet} \sim 0.51\,M_{jup}$

$D_l \sim 4.1$kpc

$a_\perp \sim 3.16$ AU

relative error $\sim 30\%$ from that on θ_E

Udalski, Yee, Gould et al (SCN) 2014, submitted

Detecting Moons w WFIRST (Penny)