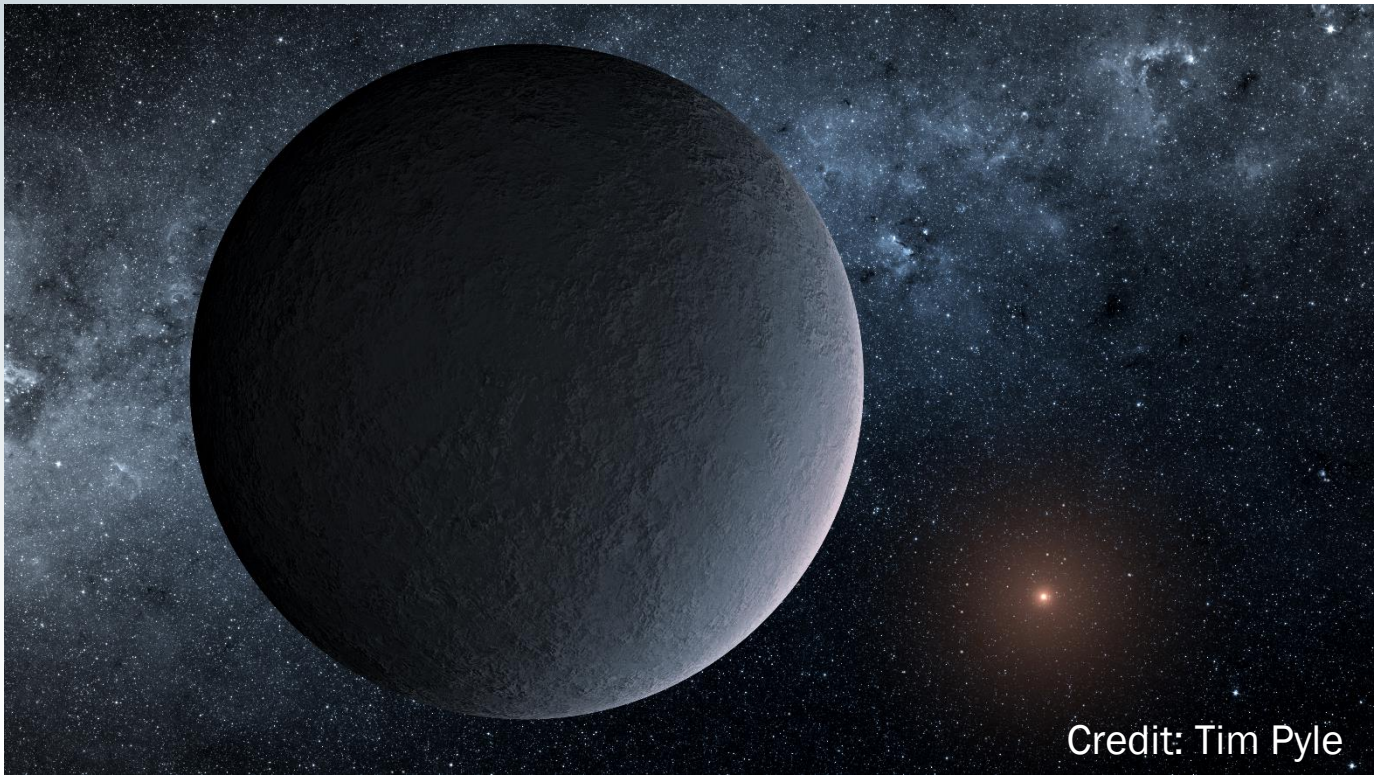
# An Earth-mass Planet in a 1-AU Orbit around an Ultracool Dwarf

Shvartzvald et al. 2017, ApJL, 840, L3

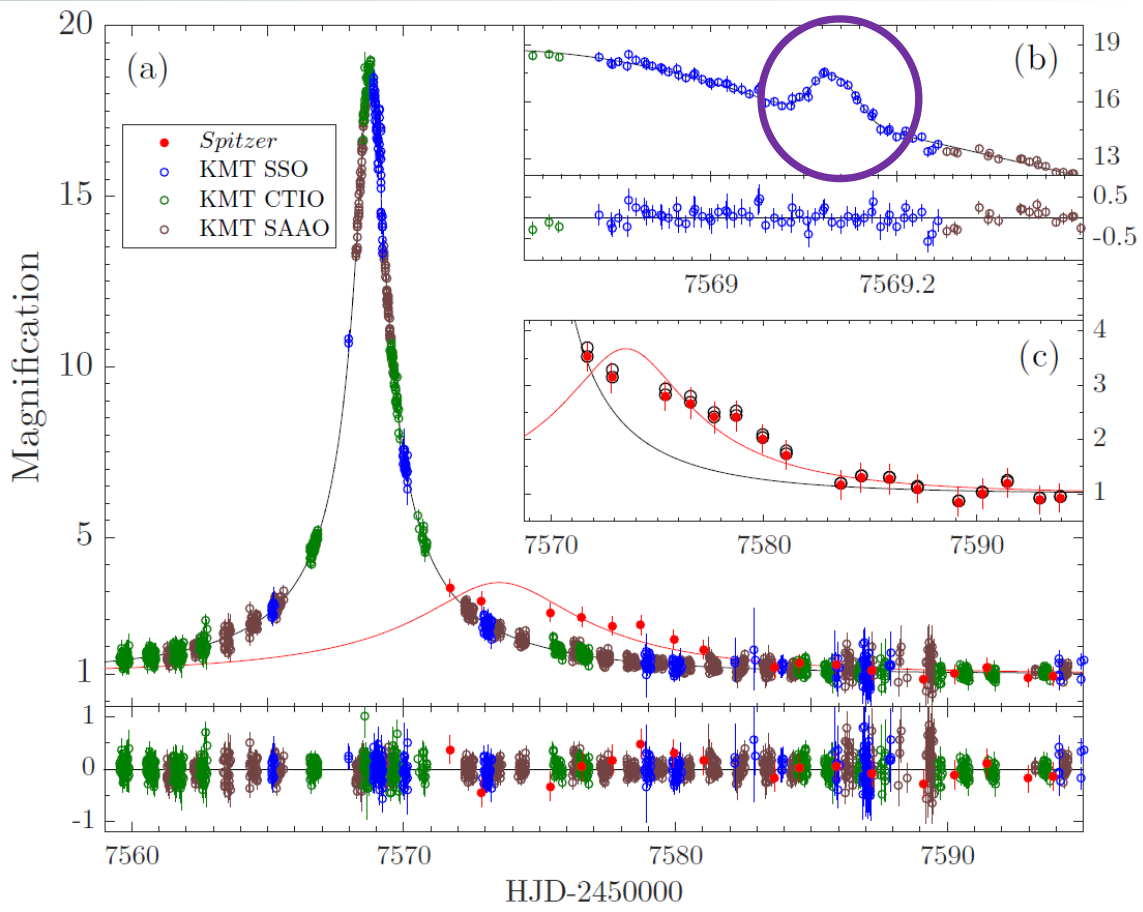



**Yossi Shvartzvald** NPP@JPL

*Spitzer* microlensing team: Andy Gould, Jennifer Yee, **Sebastiano Calchi Novati, Sean Carey, Calen Henderson,** Wei Zhu**, Chas Beichman, Geoff Bryden,** Scott Gaudi

# Lowest-mass microlensing planet

## OGLE-2016-BLG-1195Lb light curve




## Physical properties

| | |
|---|---|
| $M_1$ $[M_\odot]$ | $0.078^{+0.016}_{-0.012}$ |
| $M_2$ $[M_\oplus]$ | $1.43^{+0.45}_{-0.32}$ |
| $r_\perp$ [AU] | $1.16^{+0.16}_{-0.13}$ |
| $D_L$ [kpc] | $3.91^{+0.42}_{-0.46}$ |
| $\theta_E$ [mas] | $0.286^{+0.053}_{-0.038}$ |
| $\mu_{\rm hel}$ [mas/yr] | $8.7^{+1.6}_{-1.2}$ |

Shvartzvald+ (2017)

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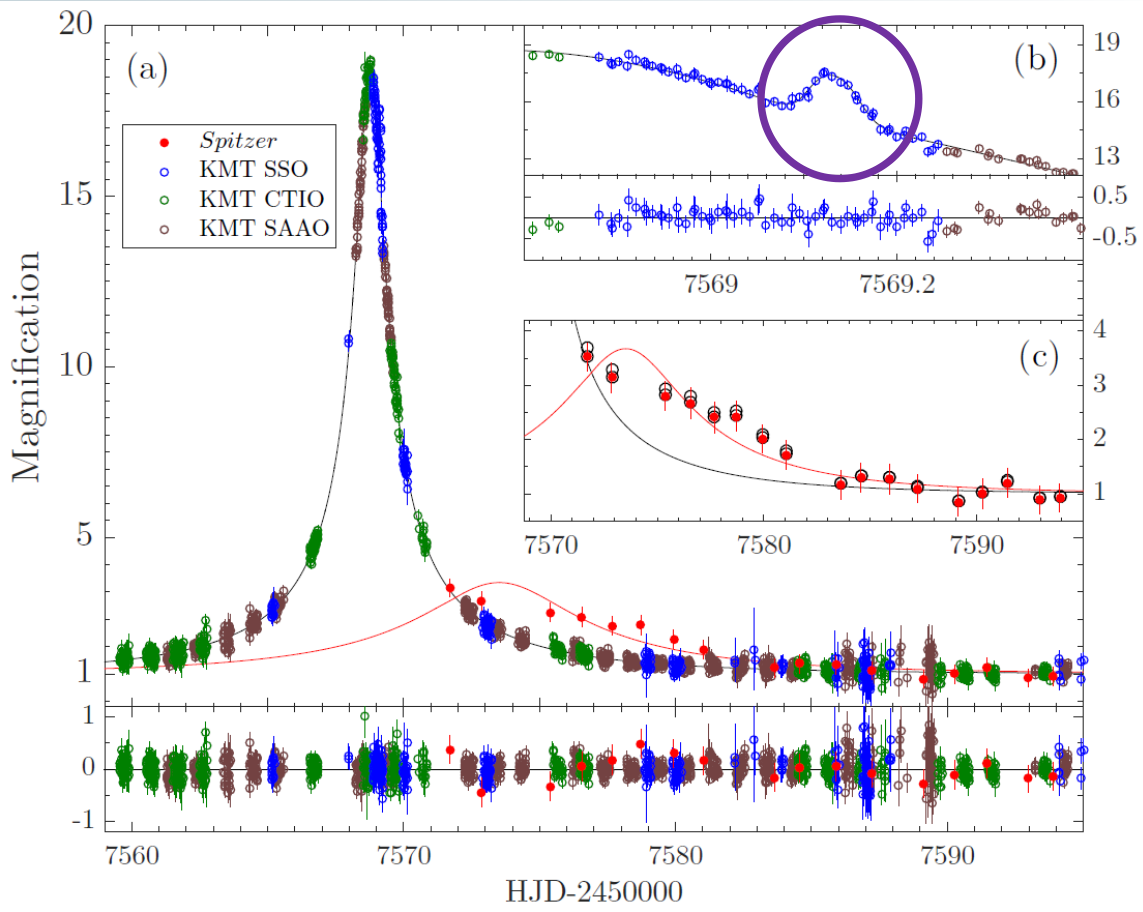



## Mass measurement

$$q = \frac{M_2}{M_1}$$

$$M = \frac{\theta_E}{\kappa \pi_E}$$

$\theta_E$ - Einstein radius

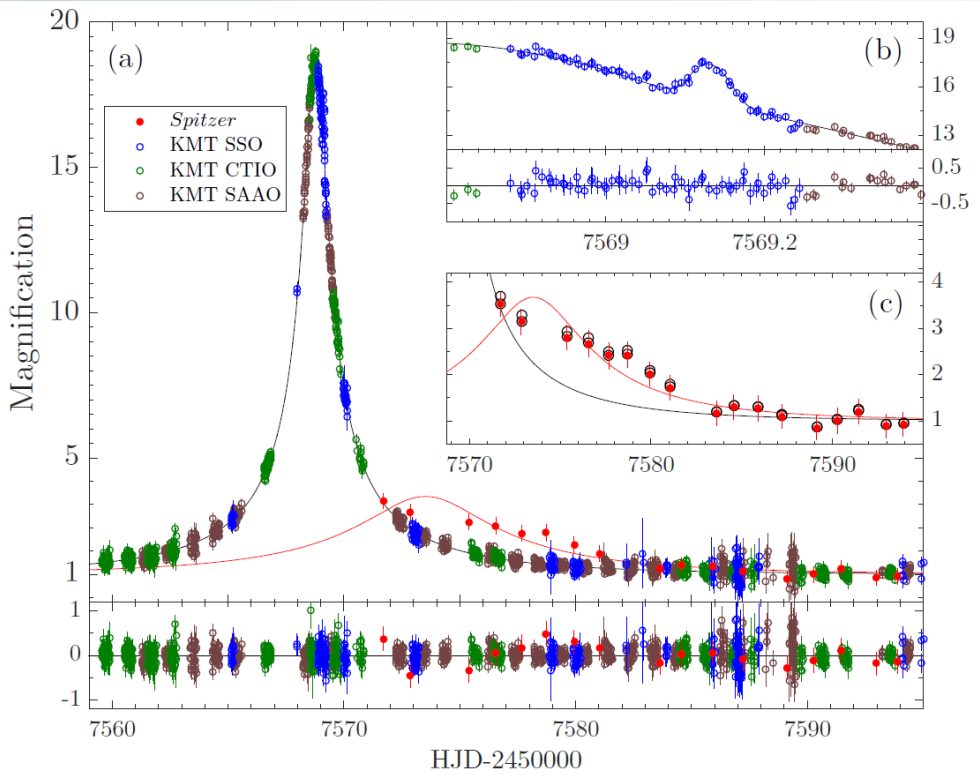
$\pi_E$ - Microlens parallax (*Spitzer*…)

$\kappa$ - constant

# Lowest-mass microlensing planet

Measure Einstein radius

OGLE-2016-BLG-1195Lb




$$\theta_E = \frac{\theta_s}{\rho}$$

Angular Source size

Finite source effect

Shvartzvald+ (2017)

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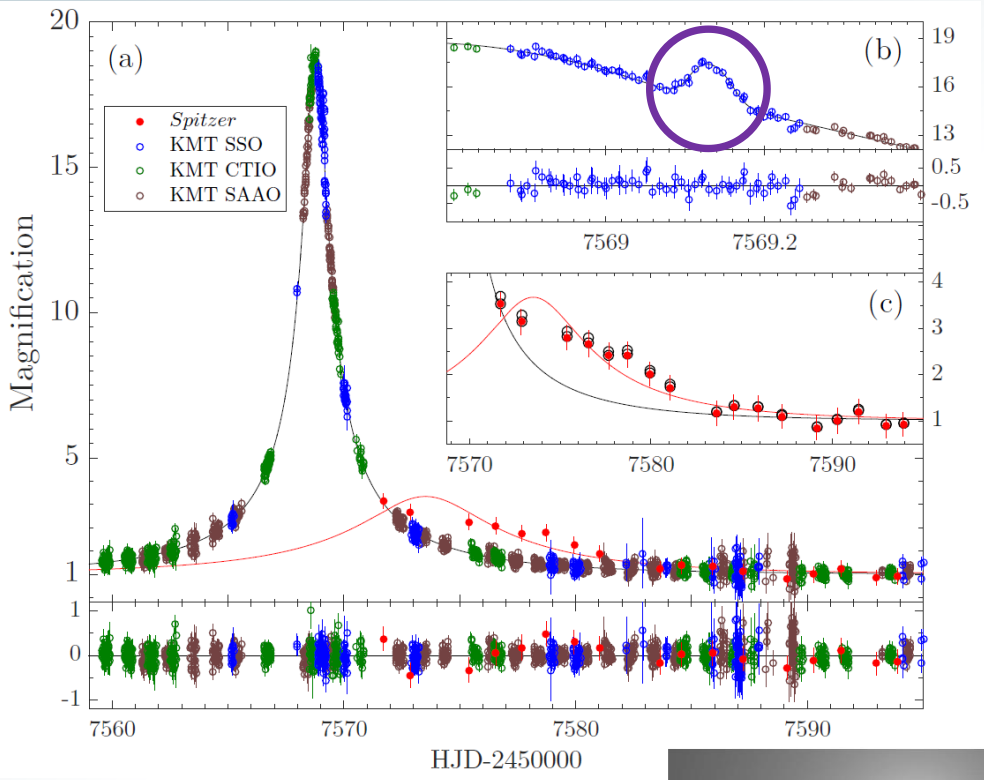


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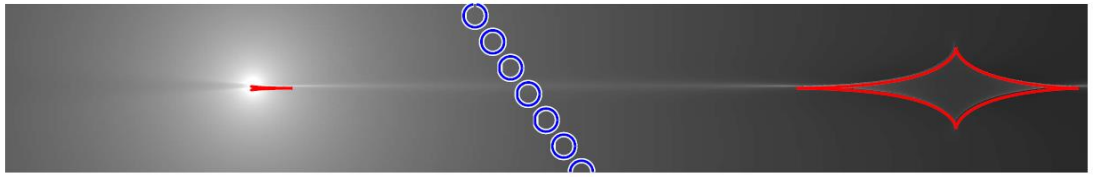

Shvartzvald+ (2017)

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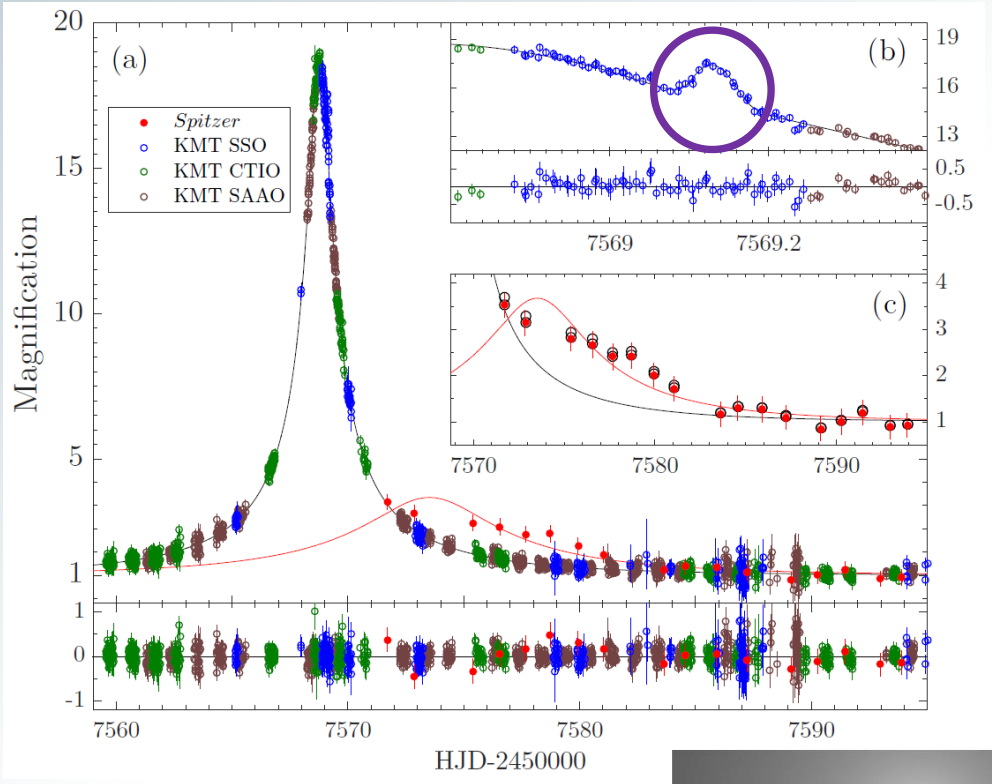


Shvartzvald+ (2017)

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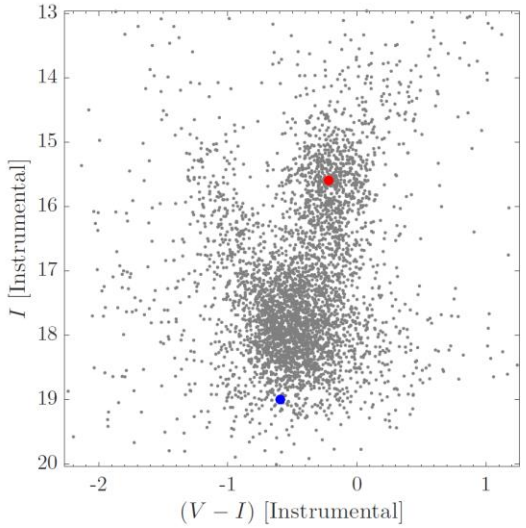


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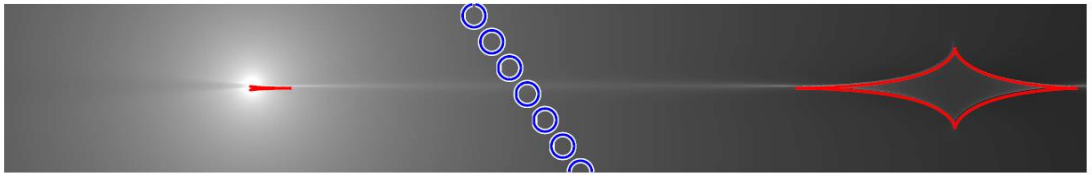

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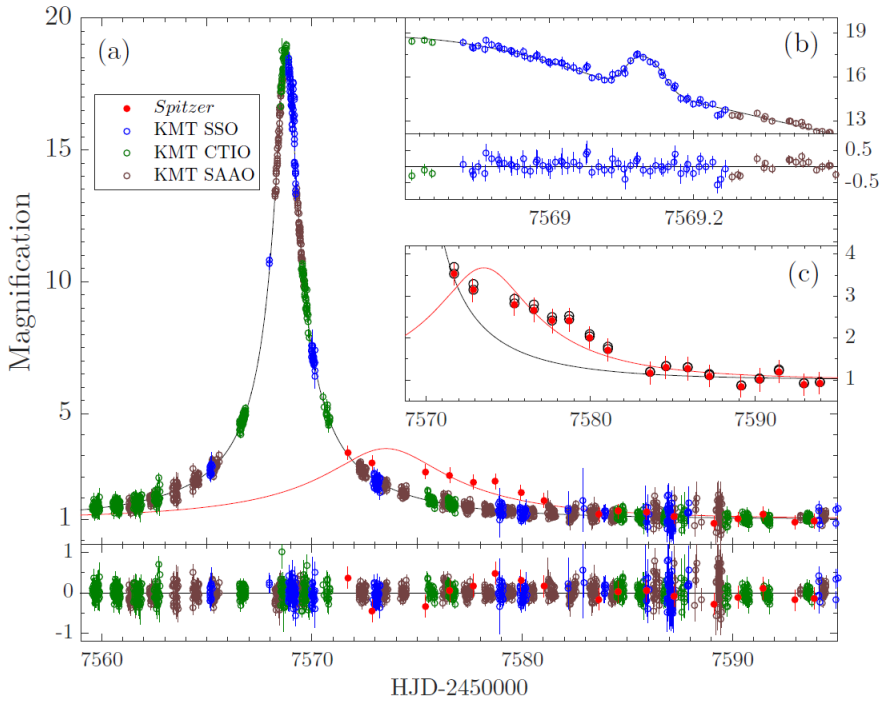
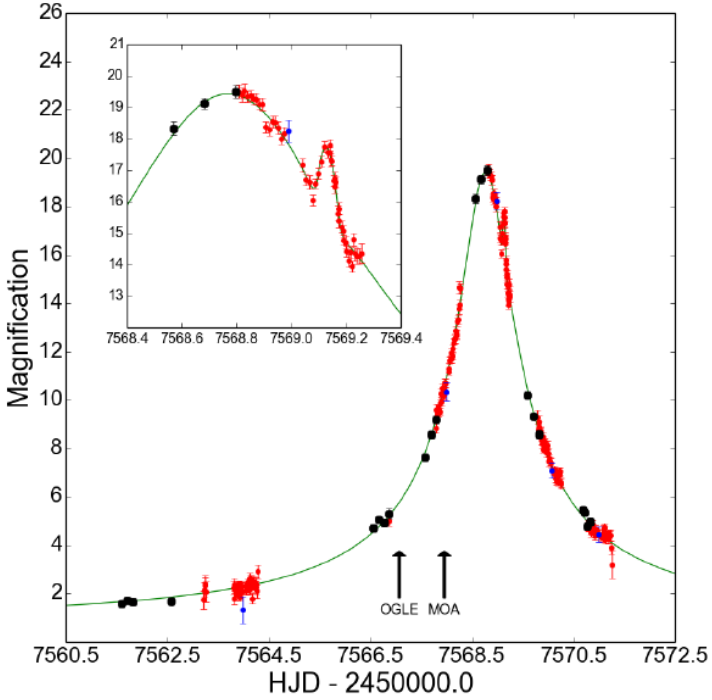
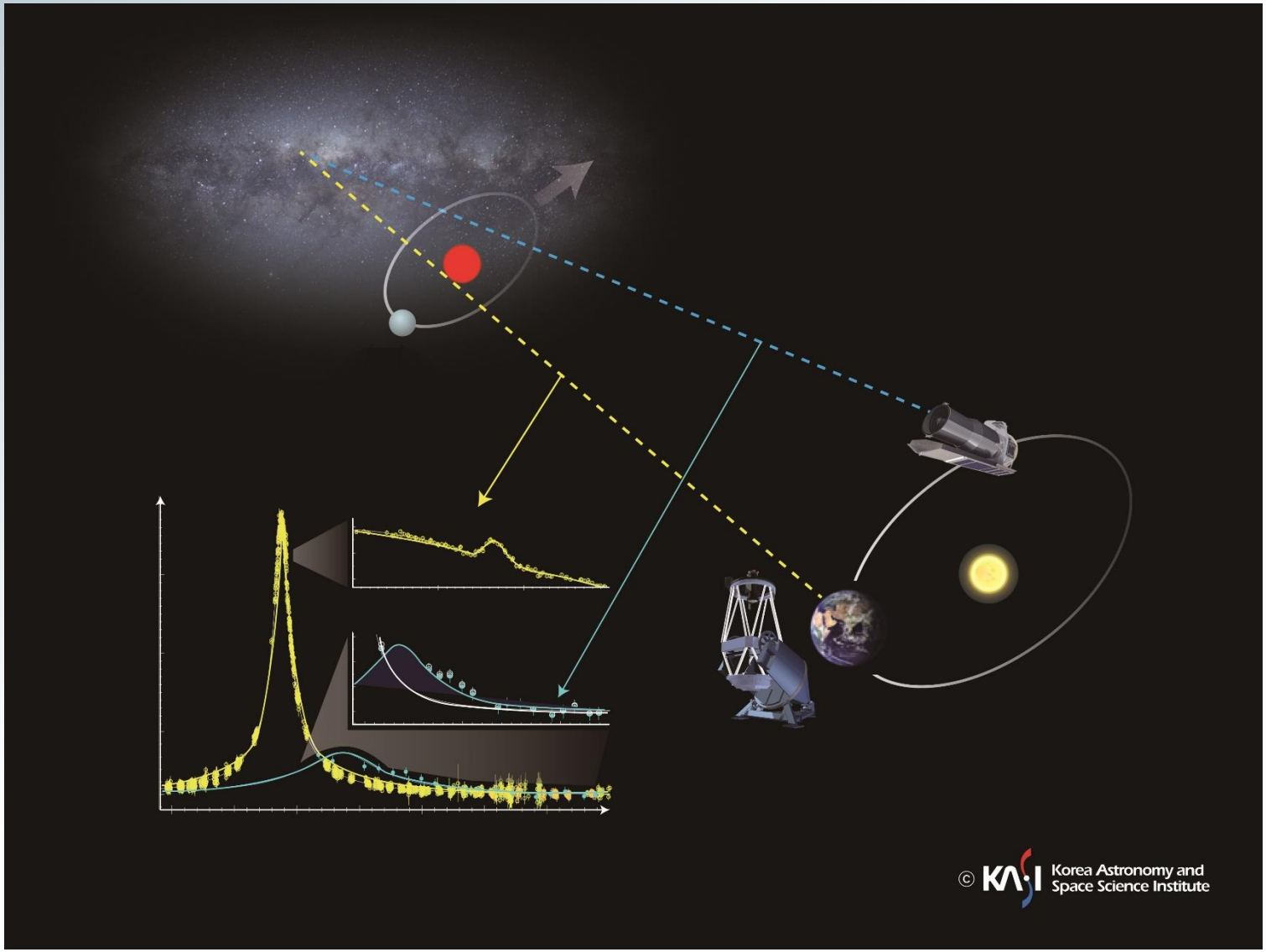



Shvartzvald+ (2017)




Bond+ (2017)

# *Spitzer* Satellite Microlensing Parallax



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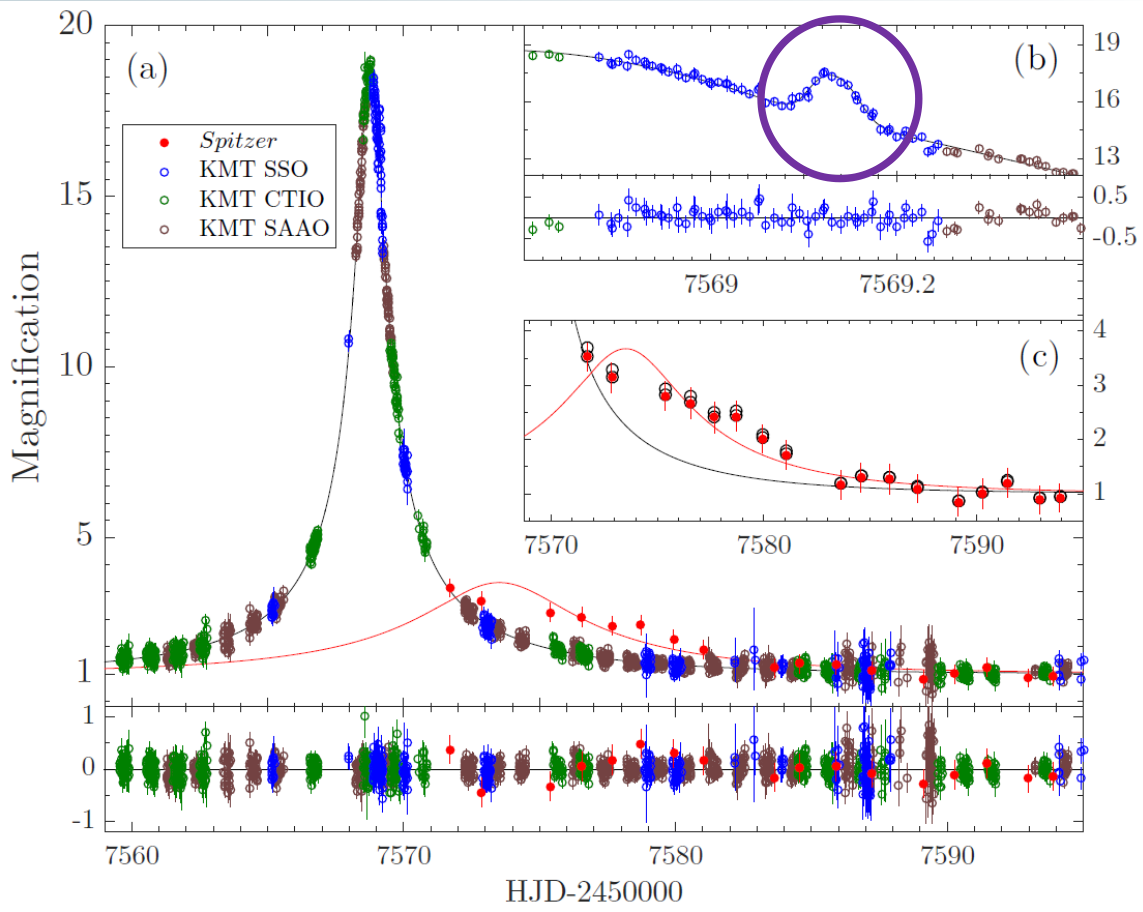


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# Planet formation around ultracool dwarfs

- Payne & Lodato (2007): Core accretion models around $0.05 M_{\odot}$ star
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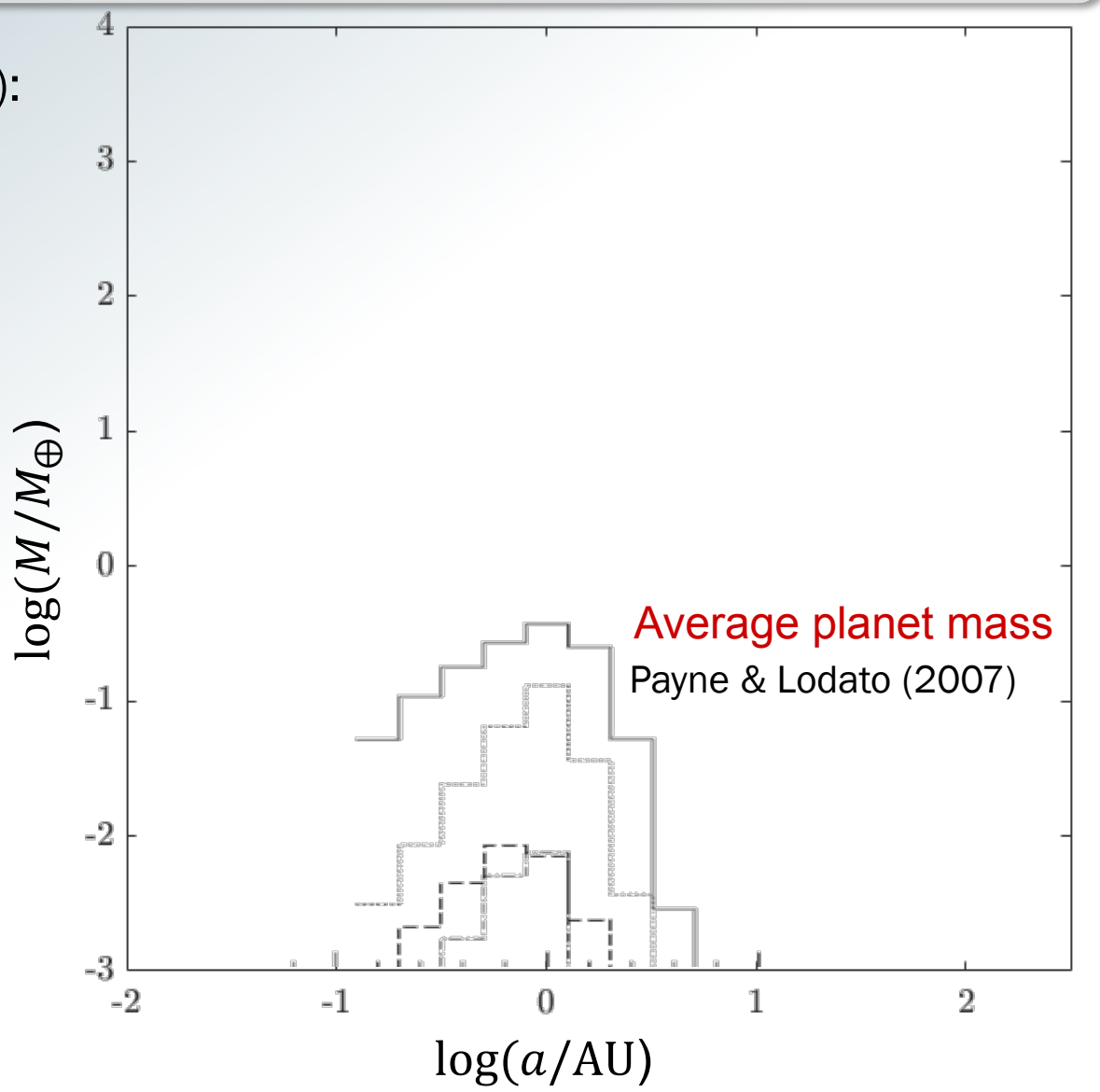

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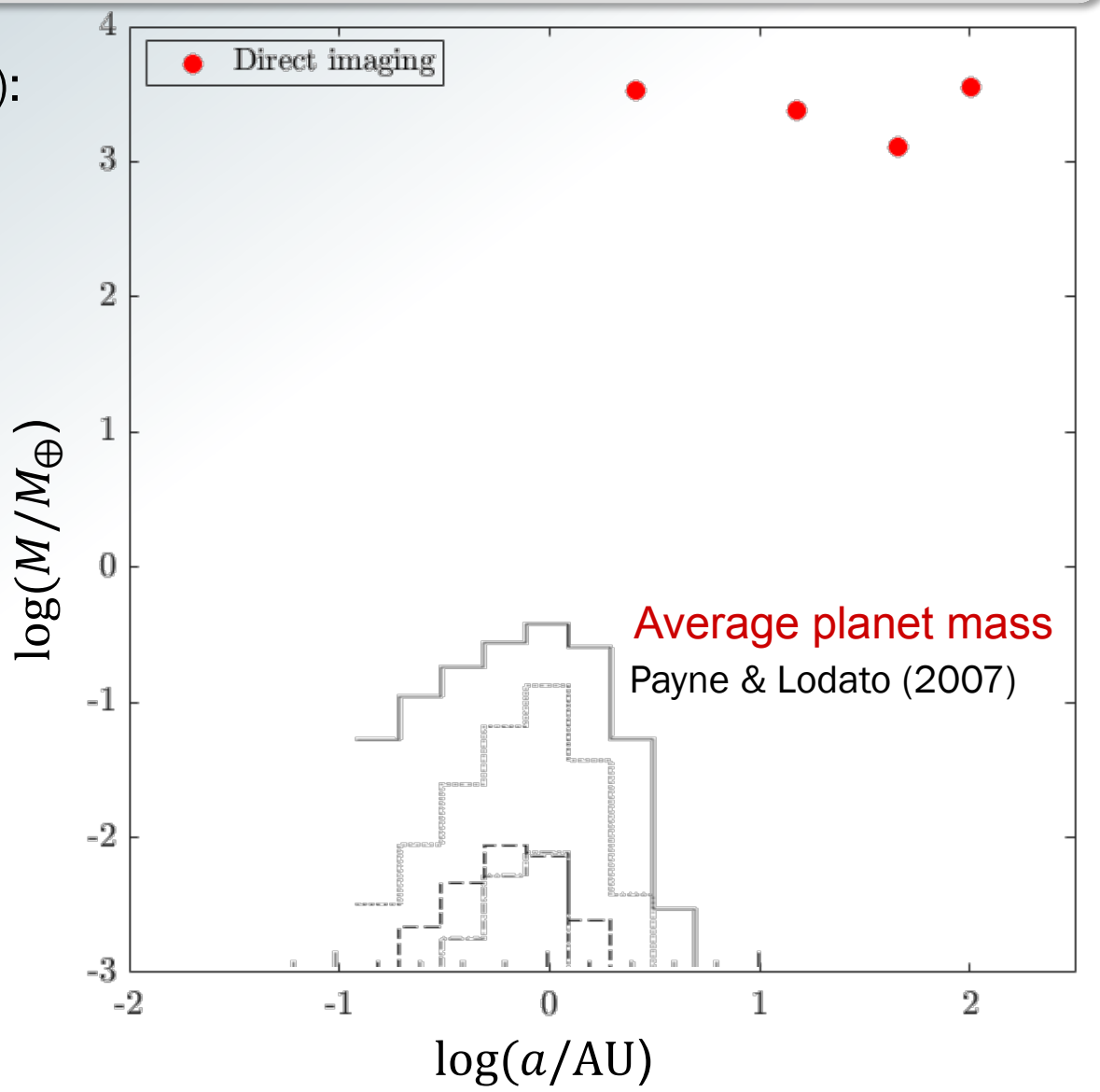

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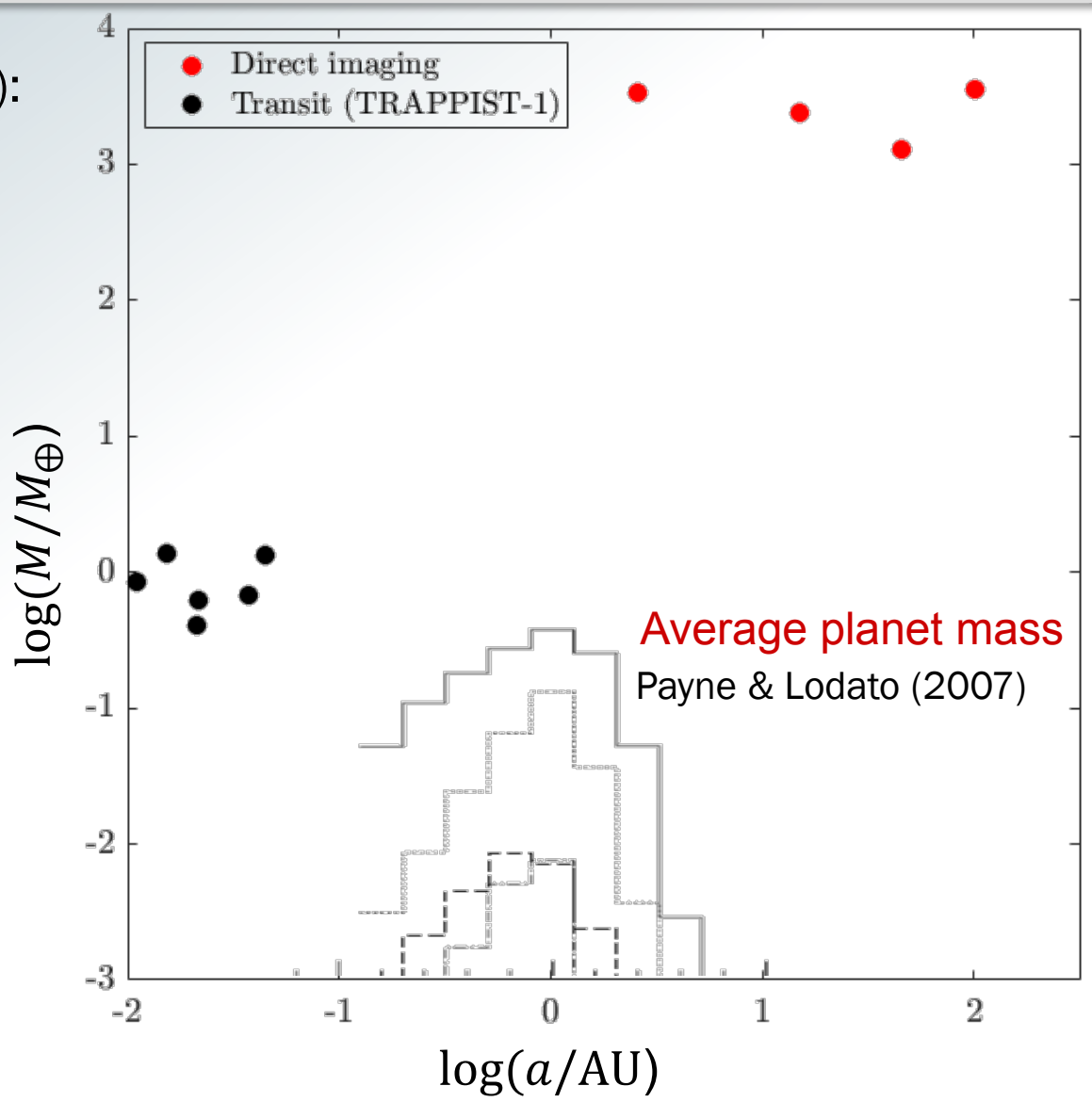

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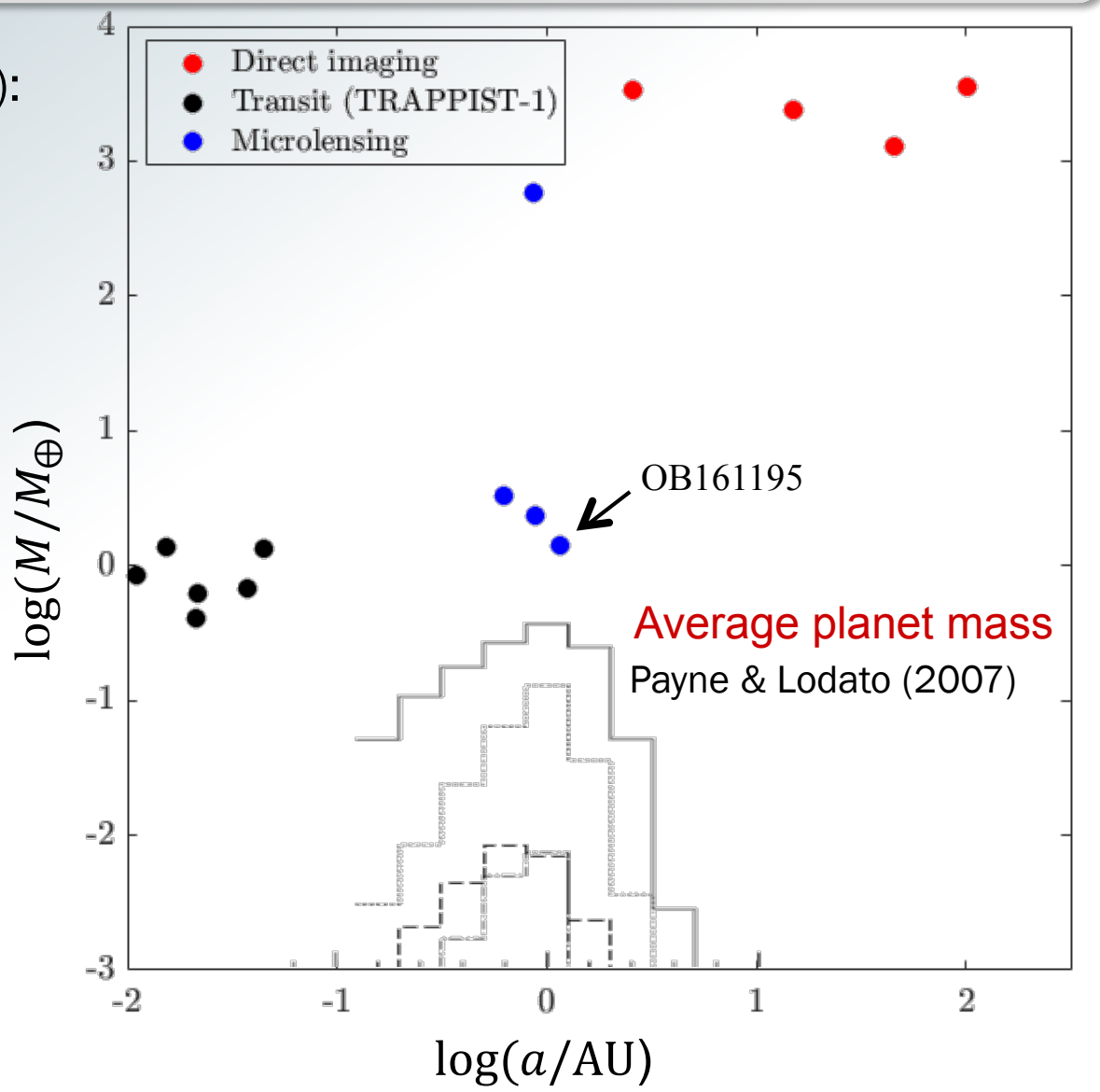

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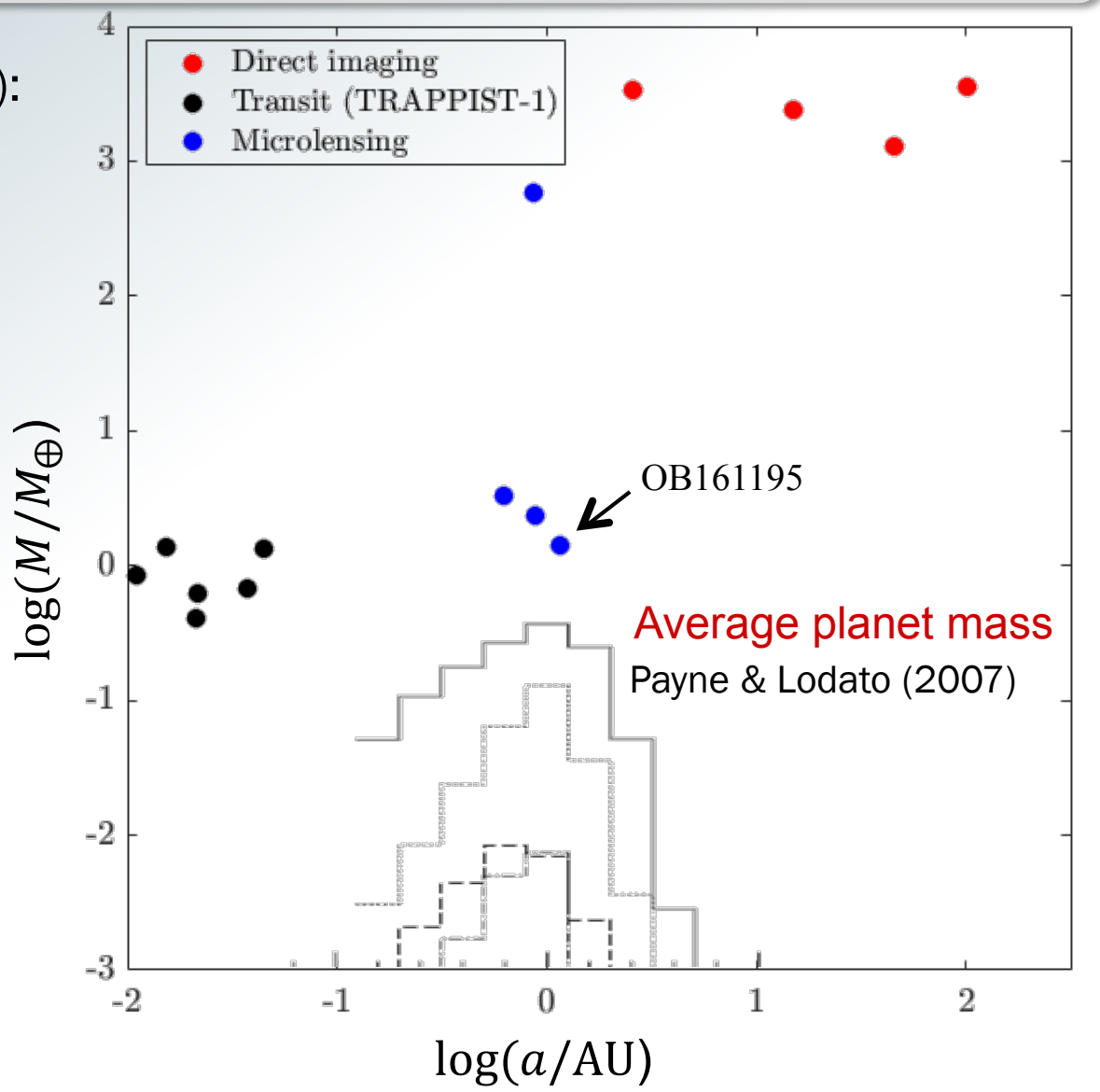

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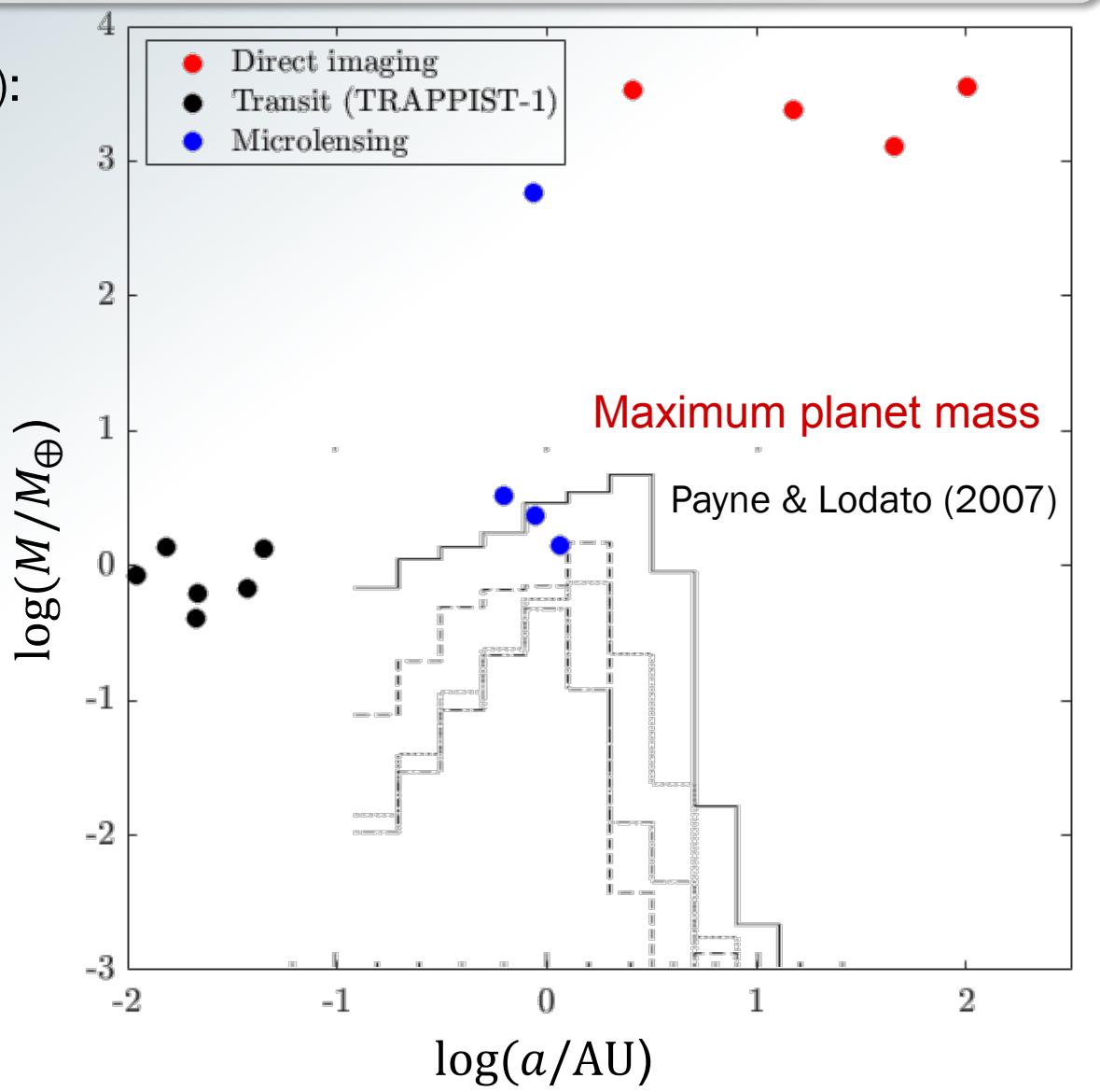

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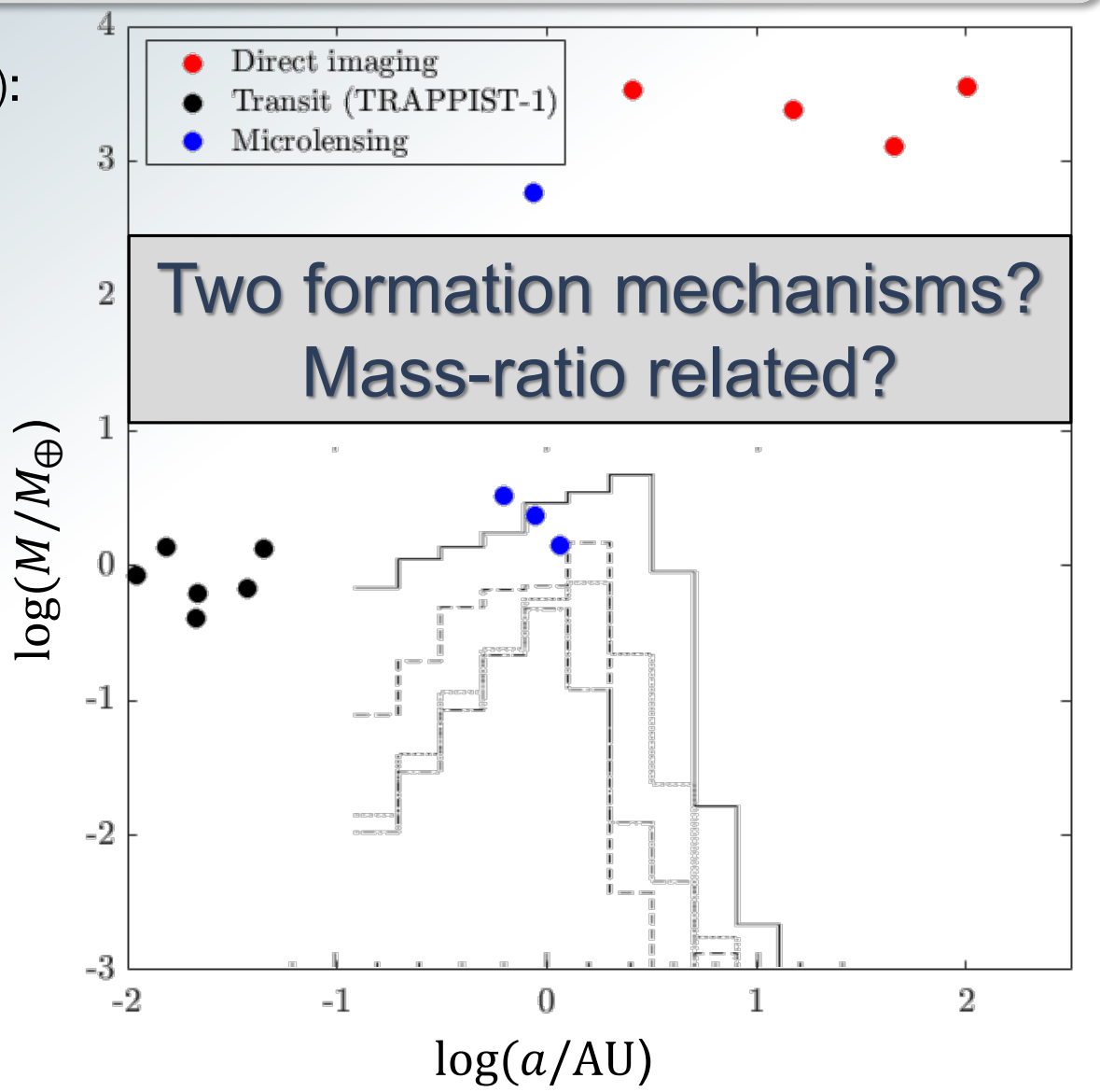
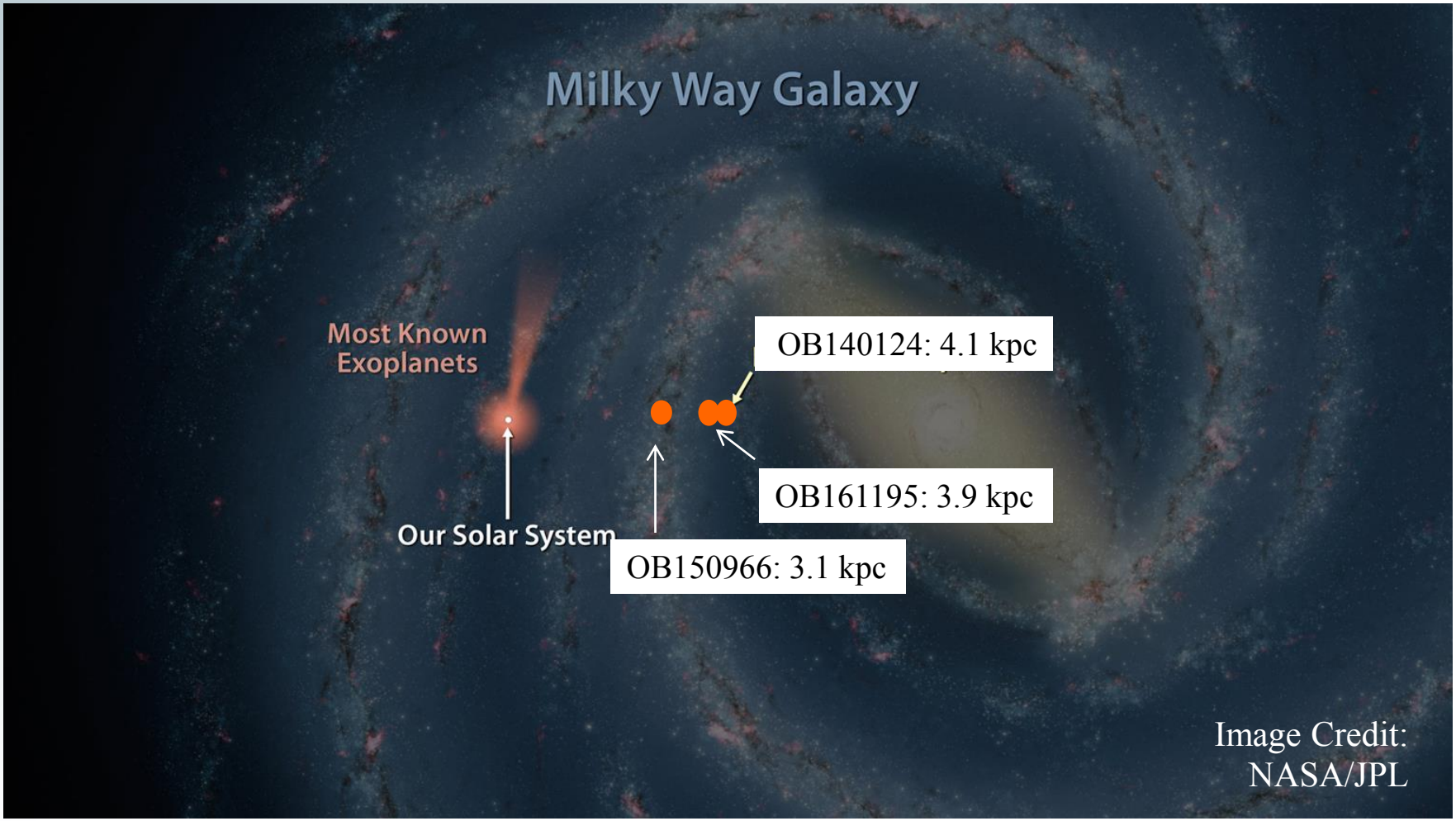
- But, observationally challenging…

- Two formation mechanism?
- Mass-ratio related?

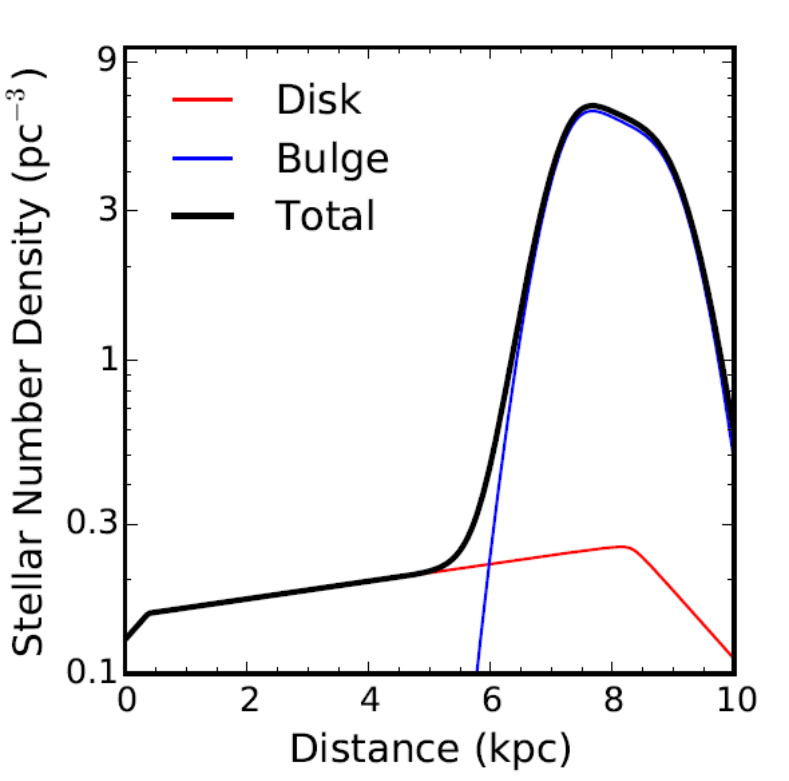


# Galactic Distribution of Exoplanets

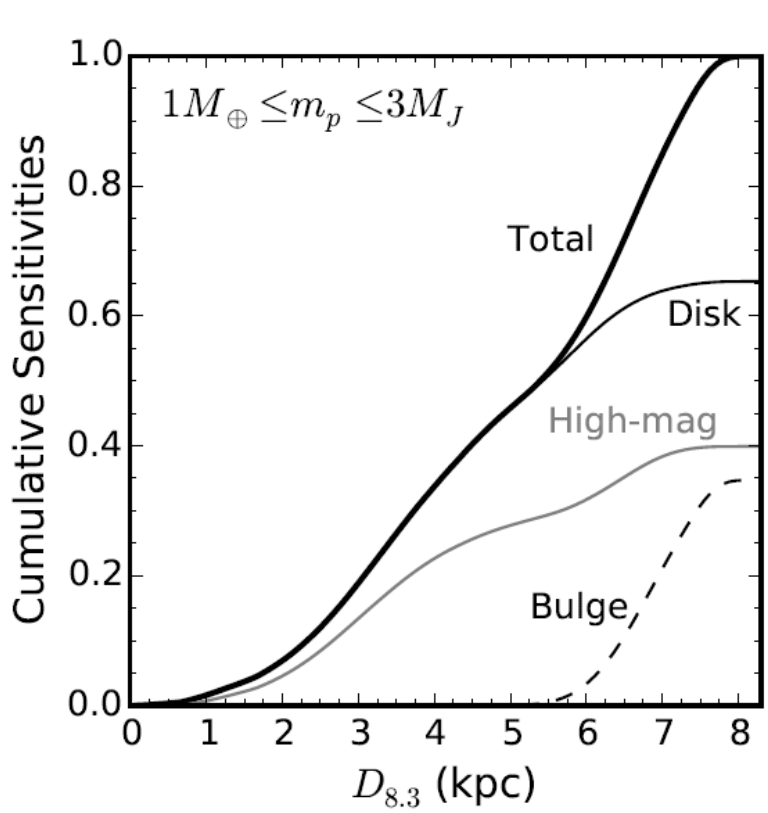


# Galactic Distribution of Exoplanets

Where does the bulge start?




Planet sensitivity




Zhu+ (2017)

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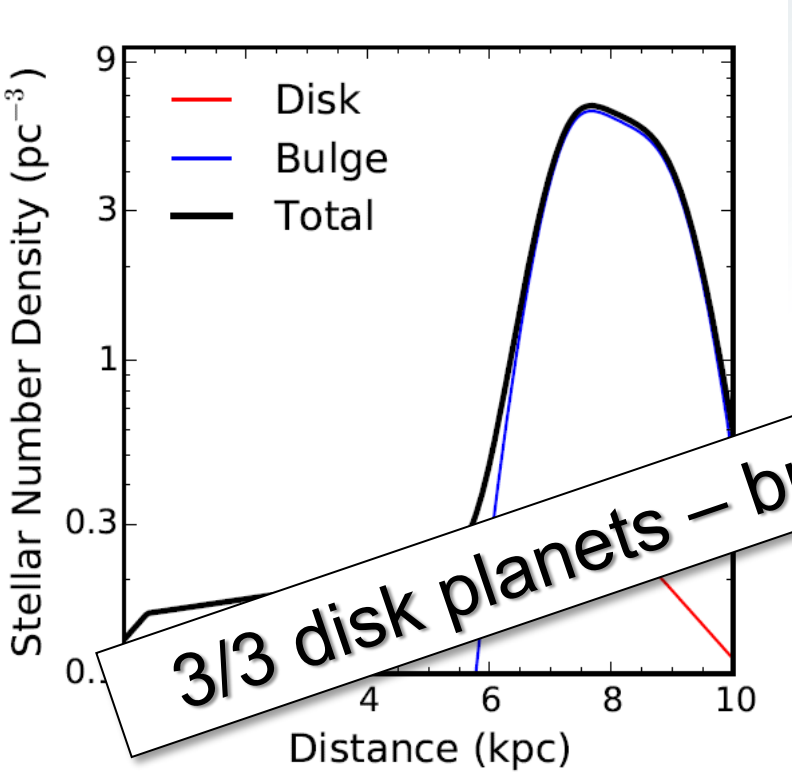


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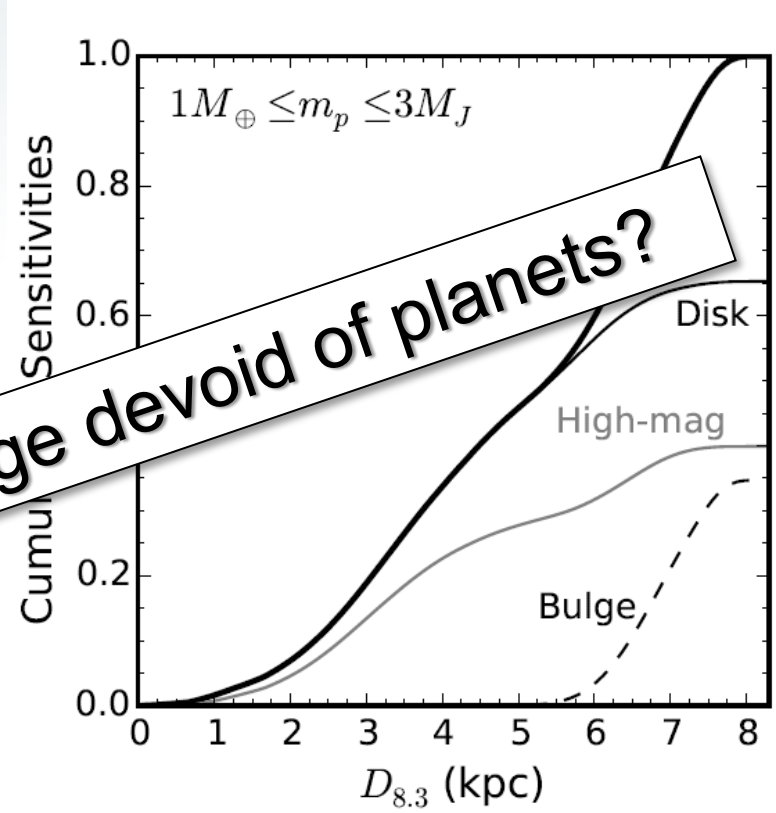



3/3 disk planets – bulge devoid of planets?

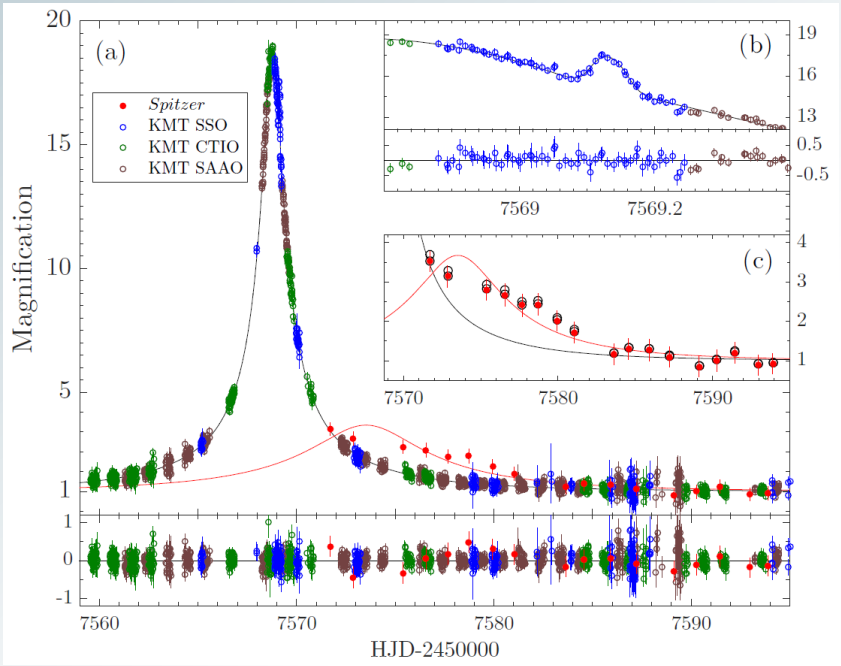
Zhu+ (2017)

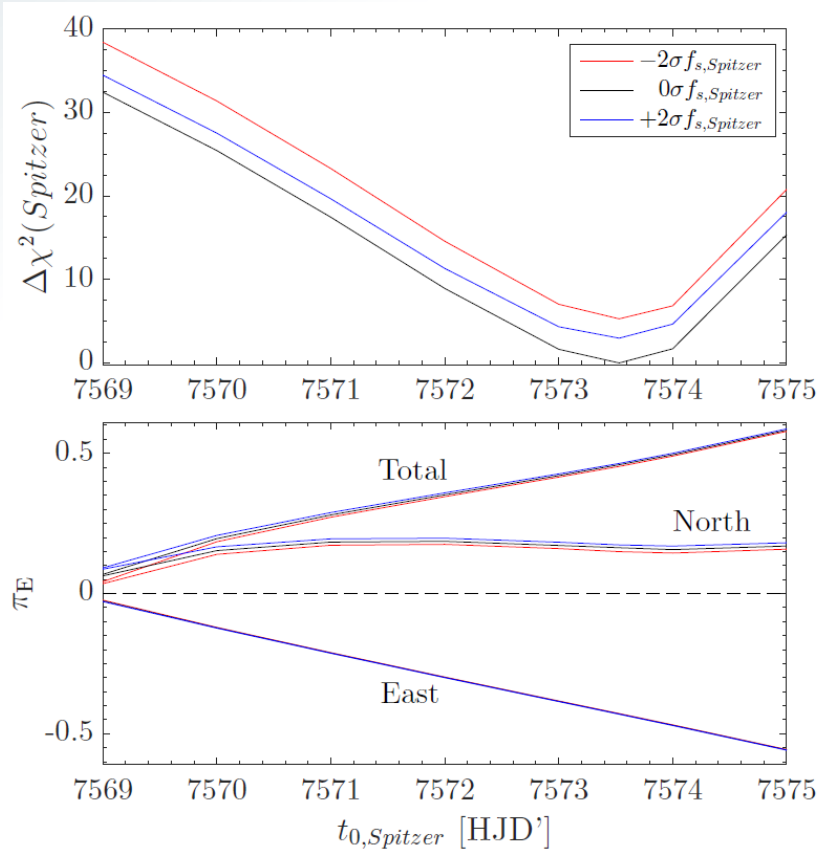
# Summary

OGLE-2016-BLG-1195Lb

- An Earth mass planet @ 1 AU around an ultracool dwarf
- Lowest-mass planet discovered by microlensing
  - *Spitzer* parallax measurement is the “gold mine”
- Planets around ultracool dwarfs
  - Excellent planet formation laboratory
  - Two formation mechanisms?
  - Microlensing is sensitive to all planets down to Earth mass
- Galactic distribution of planets
  - Is the Galactic bulge deficient of planets?
  - Need more data….stay tuned!!

# Well, since you asked...

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