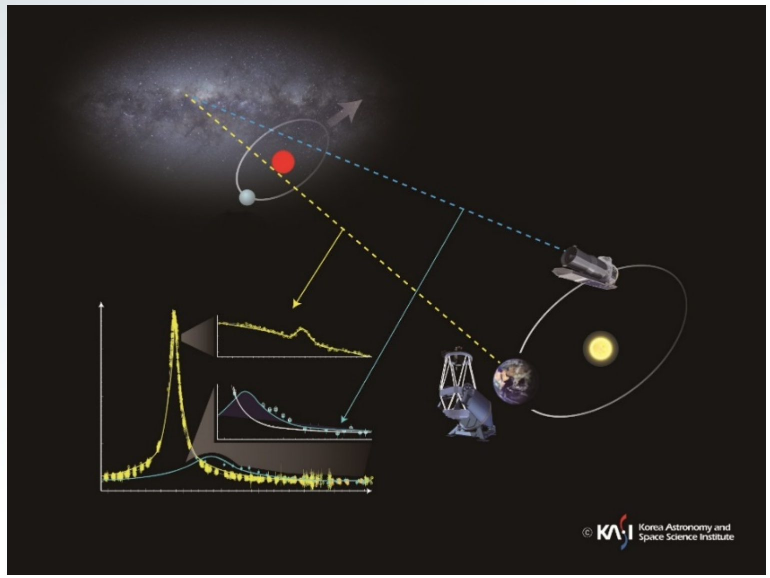
The Galactic Distribution of Planets from *Spitzer* Microlens Parallaxes



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Spitzer microlensing team:

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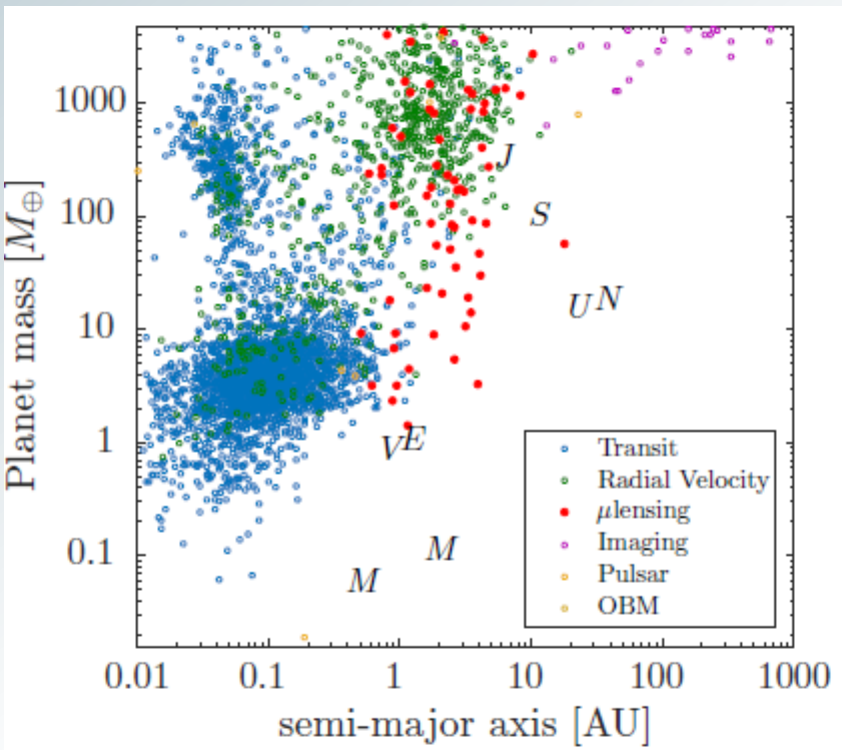
Planets: mass vs. separation

Microlensing probes planets at all masses, with separations of 1-10 AU



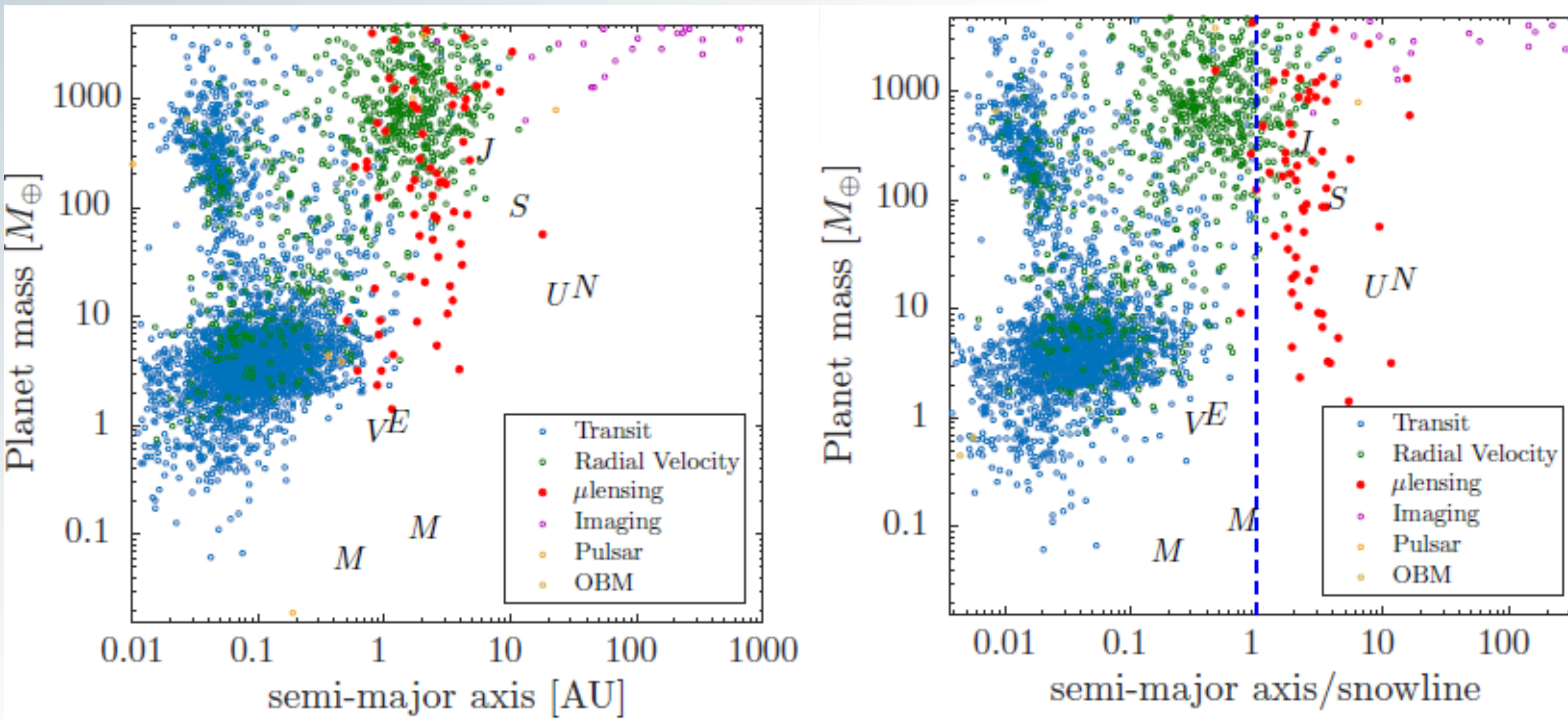
* data from: NASA Exoplanet Archive

* Assuming Solar-system planets density for transit planets w/o mass measurements

Planets: mass vs. separation

Microlensing probes planets at all masses, with separations of 1-10 AU

At and beyond the “snowline” of their host stars



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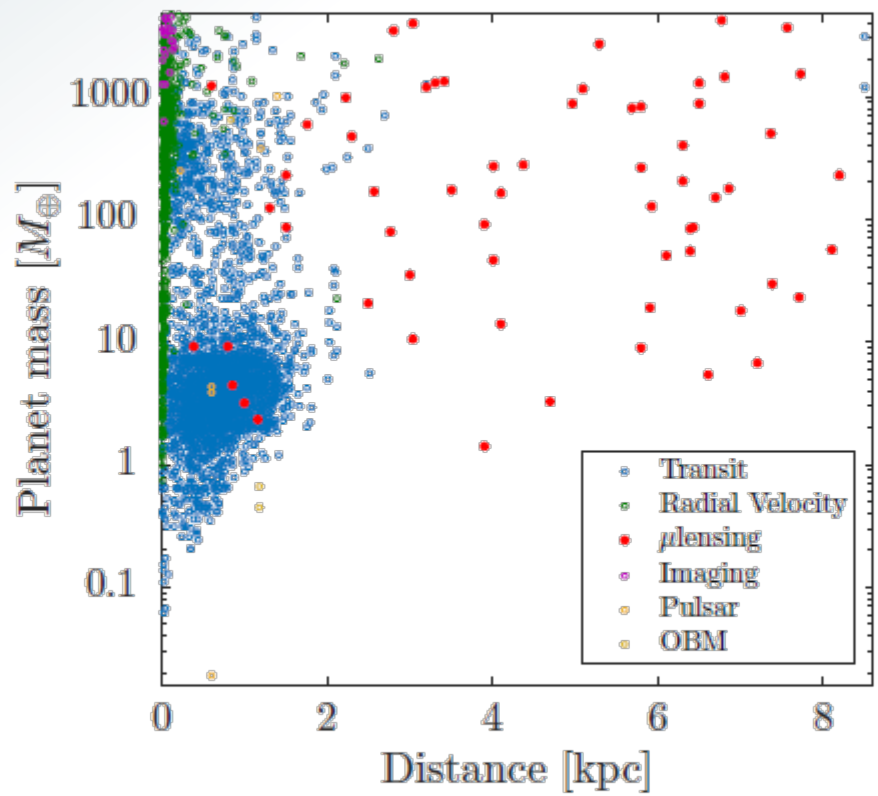
Planets: mass vs. Galactic distance

Microlensing is (currently) the only technique that probes planets throughout the Galaxy

Bulge vs. disk exoplanets frequency?

- Planet formation in different environments
- Impact of high radiation on protoplanetary disks
- Frequency vs. (average) age and metallicity
- …



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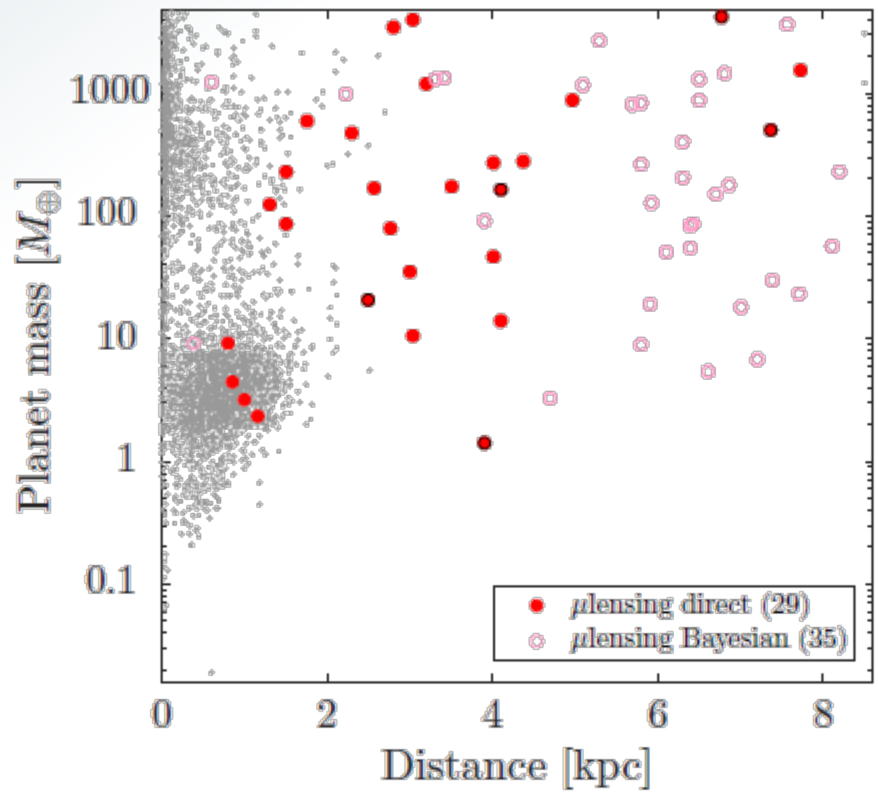
Planets: mass vs. Galactic distance

Microlensing is (currently) the only technique that probes planets throughout the Galaxy

But how well do we know the distances?

- Orbital parallax – only nearby systems
- Lens flux – difficult
- ***Satellite parallax !!!***



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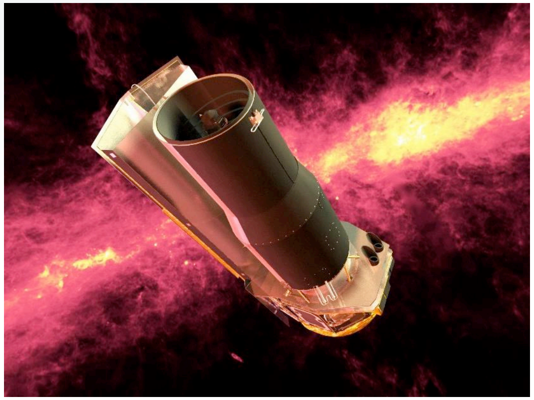
Space Microlensing Revolutionary

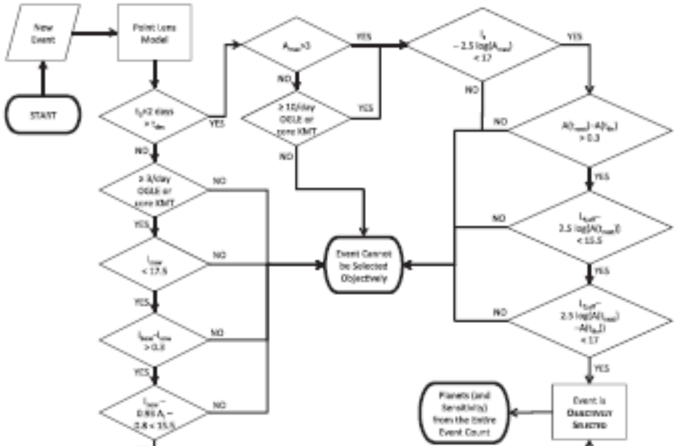
Spitzer microlensing campaigns

- ✓ 2014: 100 hr DDT program
- ✓ 2015: 832 hr
- ✓ 2016: 350 hr
- ✓ 2017: 350 hr
- ✓ 2018: 350 hr
- • 2019: 350 hr
- ○ 2020-?

~700 events



Objective event selection (Yee+15)



Microlensing Parallax

Satellite parallax

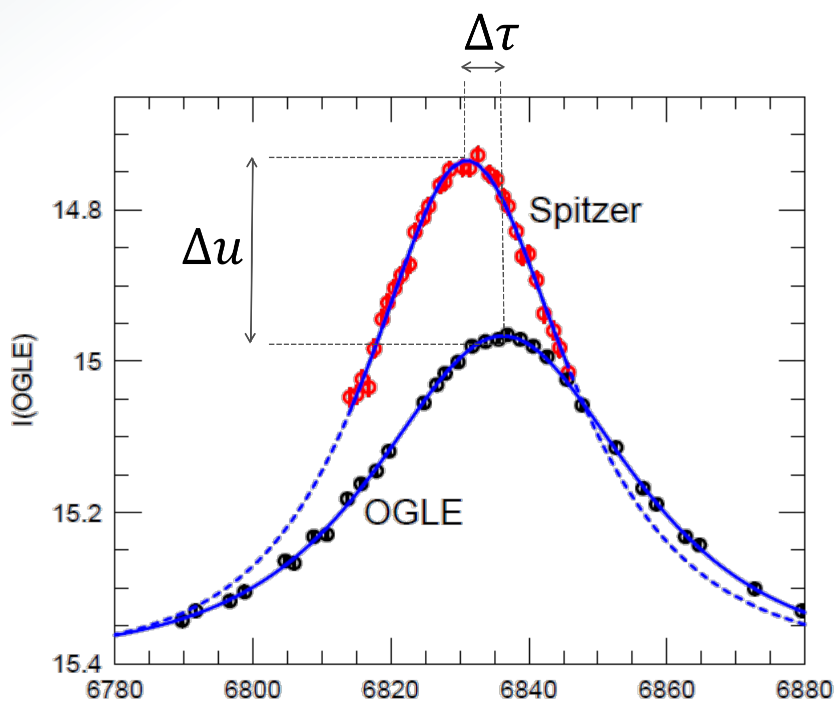
- Two (or more) observers
- Shift in time and peak of magnification
- Sensitive to all microlens parallaxes

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

$$D_L^{-1} = \frac{\theta_E \boldsymbol{\pi_E}}{\mathrm{AU}} + D_S^{-1}$$

$$\boldsymbol{\pi_E} = \frac{AU}{d_\perp}(\Delta\tau, \Delta u)$$

$d_\perp$ - Earth-satellite distance



Yee+ (2015)

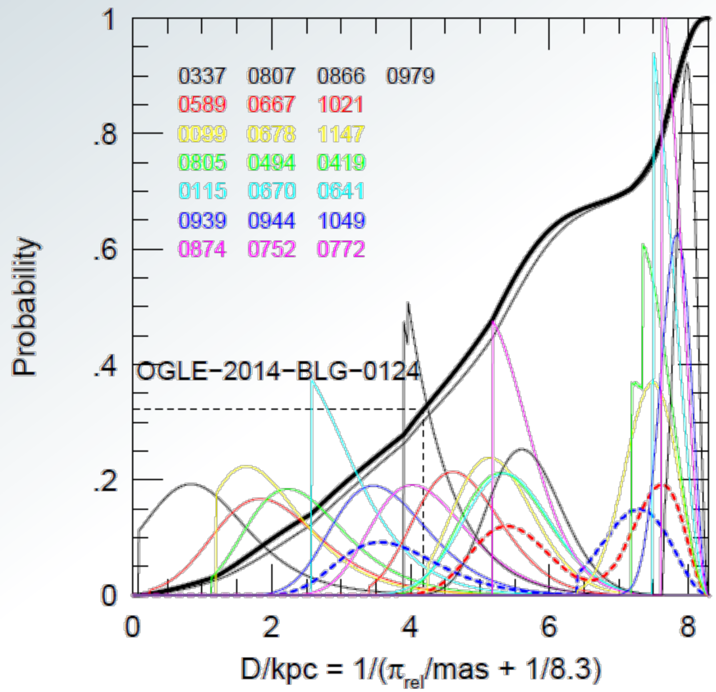
Galactic Distribution of Exoplanets

<u>Control sample</u>

- Single lens events as comparison
- Sensitive to all distances

Calchi Novati+ (2015)

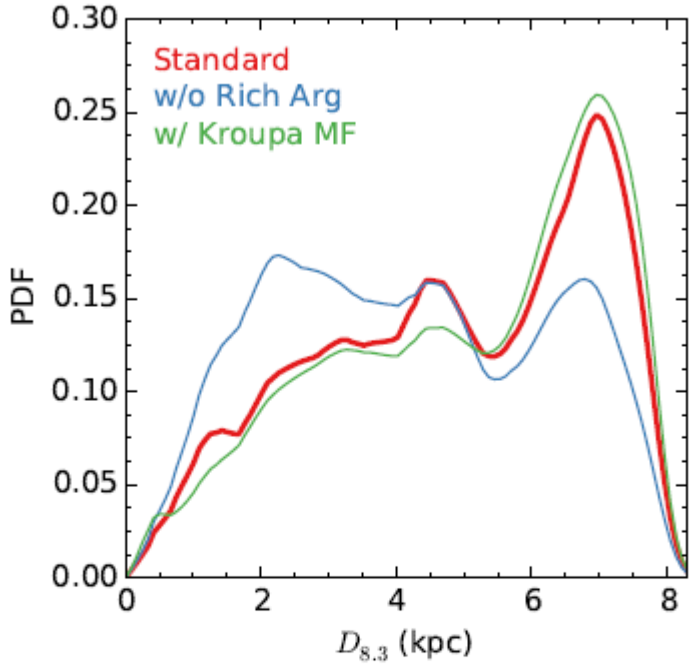
21 events



+

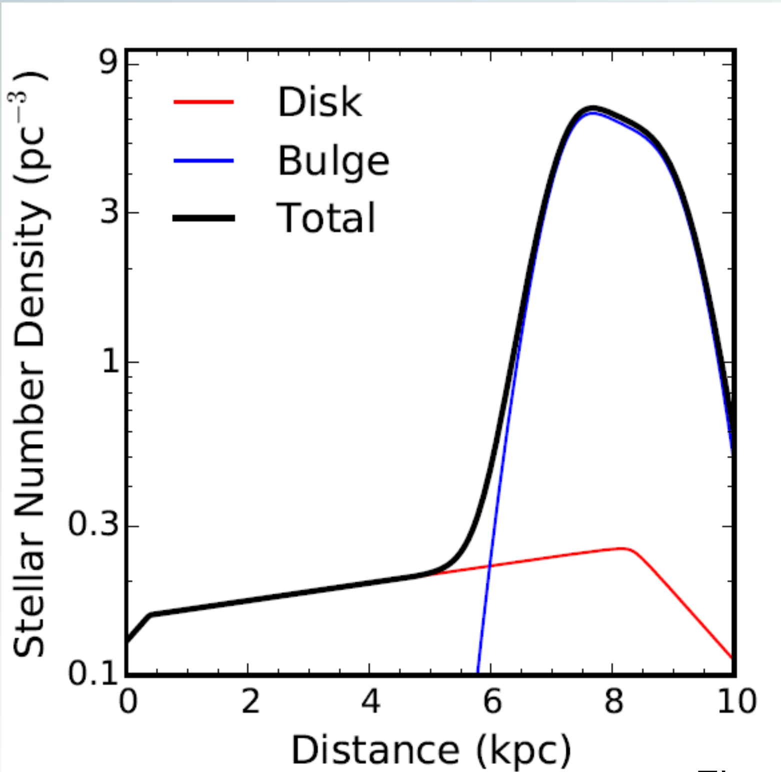
Zhu+ (2017)

41 events

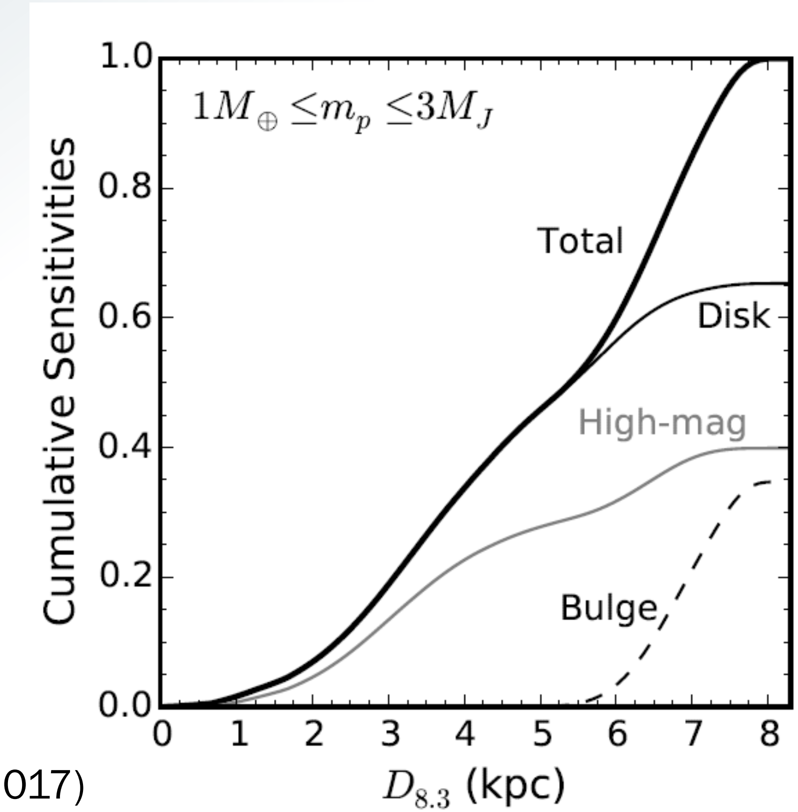


Galactic Distribution of Exoplanets

Where does the bulge start?



Planet sensitivity

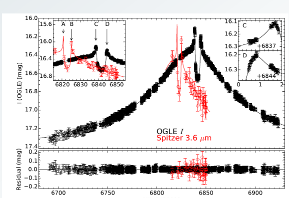


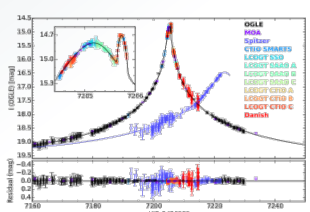
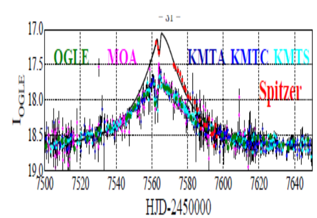
Zhu+ (2017)

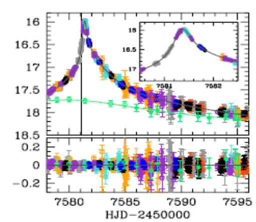
Disk planet sensitivity ≈ 2x Bulge planet sensitivity

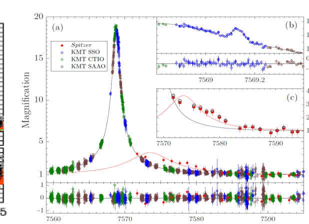
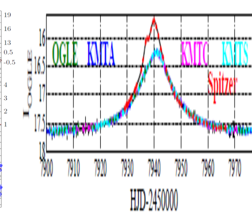
Galactic Distribution of Exoplanets

Planet	Mass	Distance	Reference
OGLE-2014-BLG-0124	$0.5\ M_J$	4.1 kpc	Udalski+ (2015)
OGLE-2015-BLG-0966	$21\ M_\oplus$	3.1 kpc	Street+ (2016)
OGLE-2016-BLG-1067	$0.4\ M_J$	3.7 kpc	Calchi Novati+ (2018a)
OGLE-2016-BLG-1190	$13\ M_J$	6.7 kpc	Ryu+ (2018)
OGLE-2016-BLG-1195	$1.4\ M_\oplus$	3.9 kpc	Shvartzvald+ (2017b)
OGLE-2017-BLG-1140	$1.6\ M_J$	7.3 kpc	Calchi Novati+ (2018b)



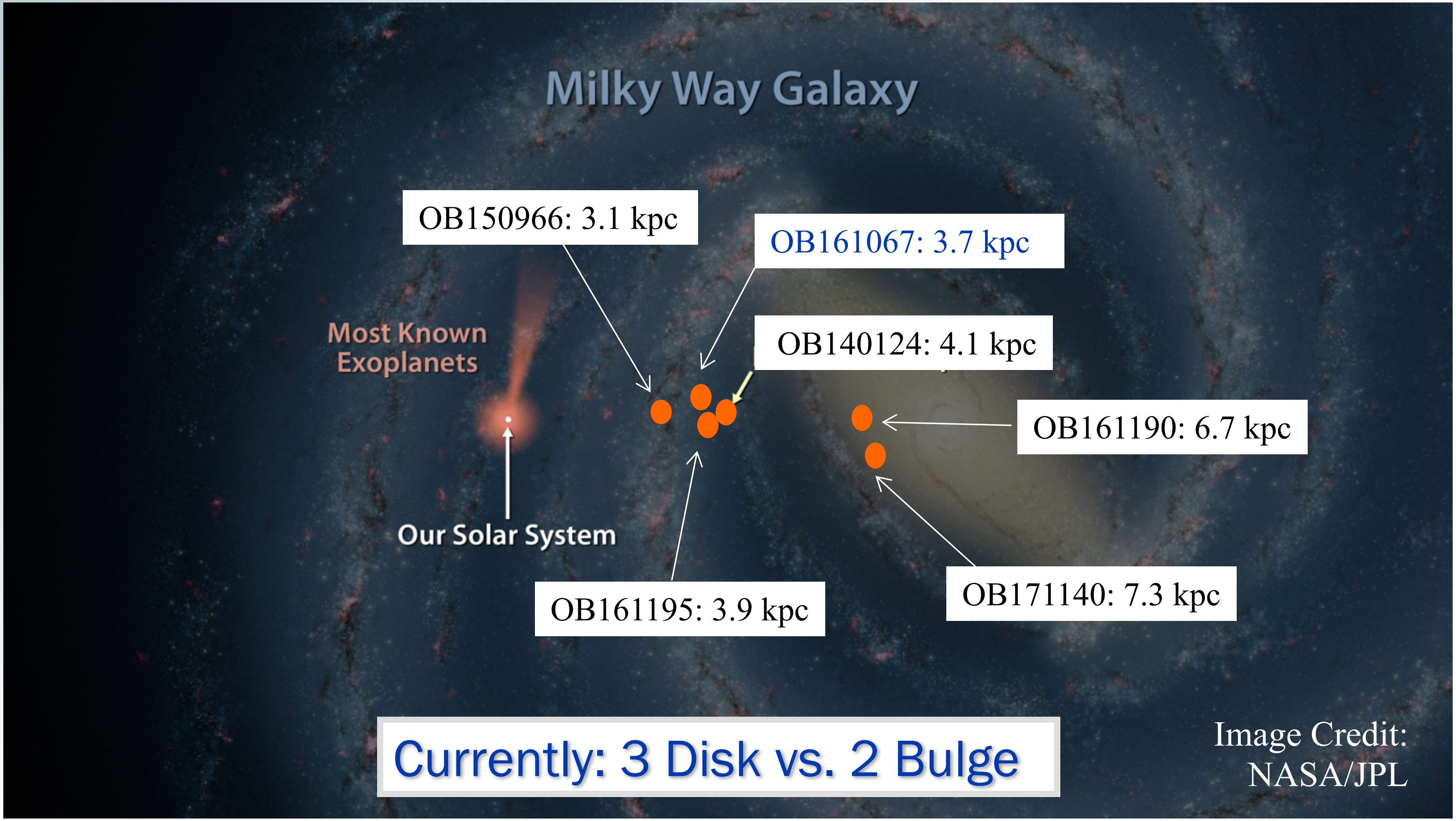





…and OB170406, OB180596, OB180799, OB180932

Galactic Distribution of Exoplanets



Stay tuned…!!!