Free-floating planets

Przemek Mróz

University of Warsaw

pmroz@astrouw.edu.pl

Free-floating planets (FFPs)

Free-floating planetary-mass objects can be formed:

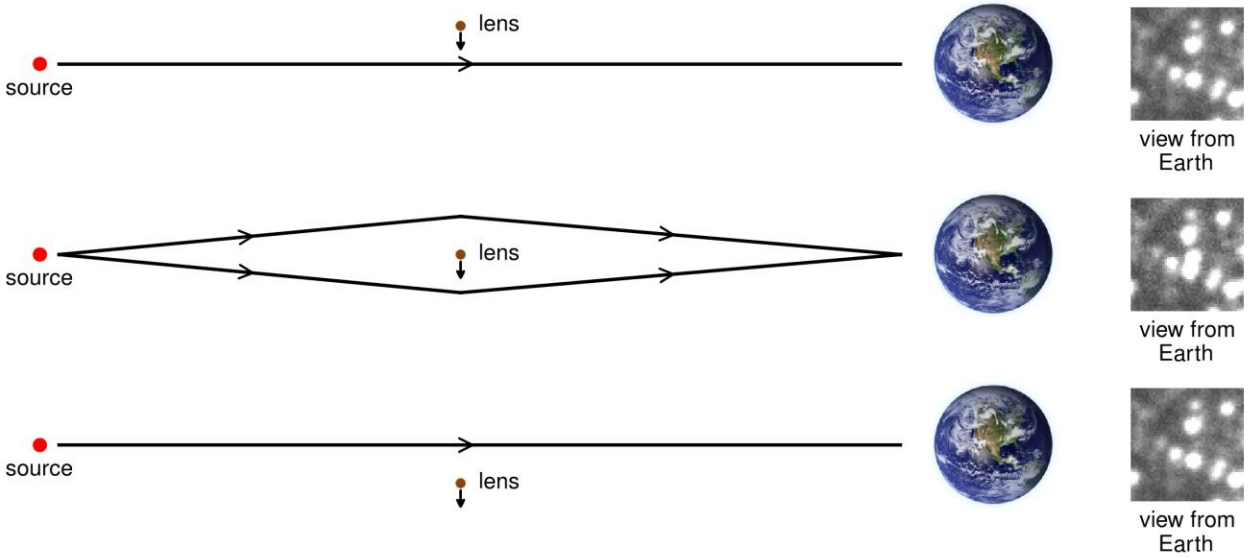
- through gravitational collapse, in a way similar to that in which stars form,
- around stars, in protoplanetary disks, ejected as a result of dynamical interactions with other planets, stars, etc.

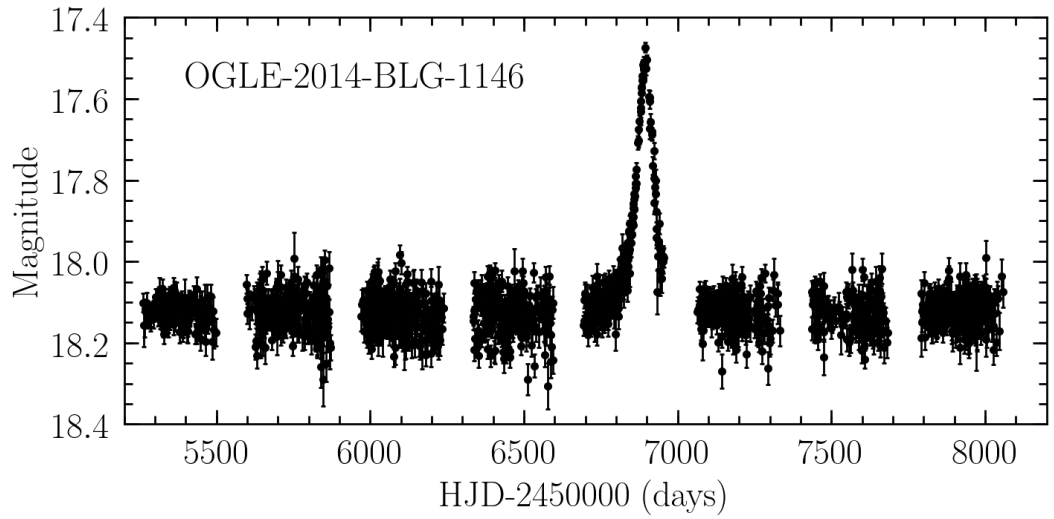
Properties of FFPs can give us better insights into early dynamical evolution of planetary systems

Caltech Magazine, Spring 2021

AND IT IS THOUGHT THAT SOMETIMES THE COLLISIONS IN YOUNG SOLAR SYSTEMS EJECT PLANETS INTO SPACE.

Gravitational microlensing





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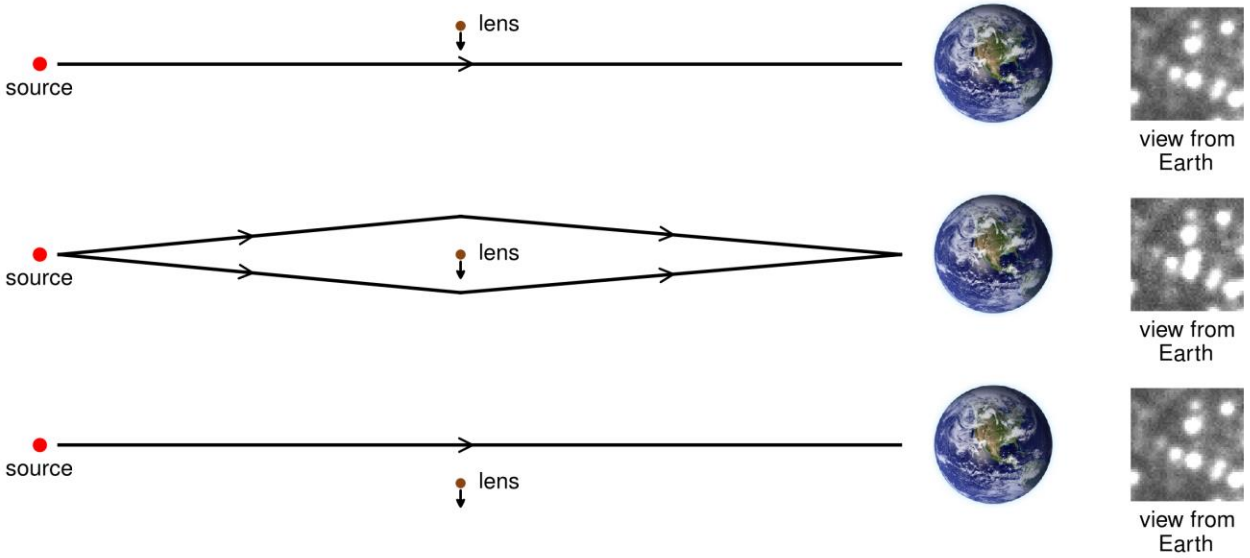
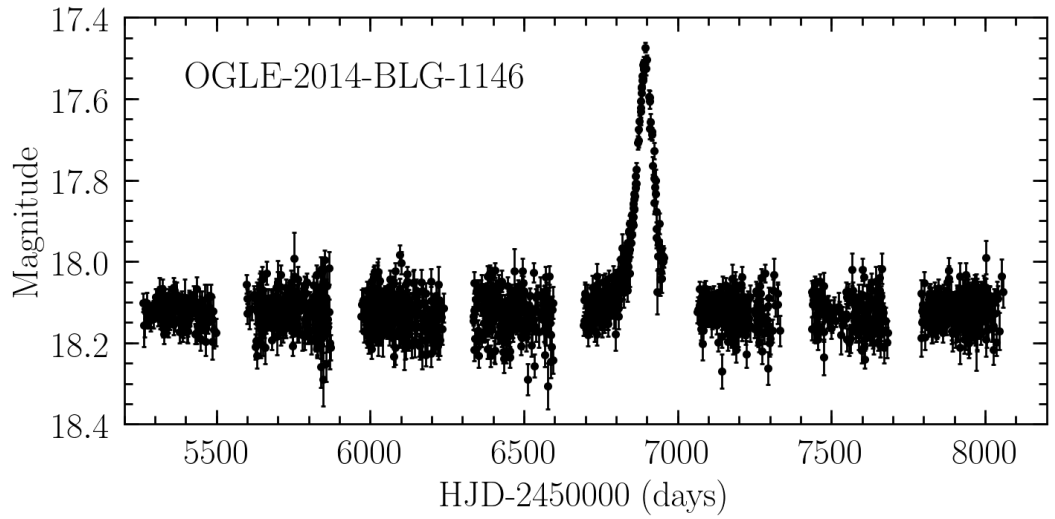




Microlensing event timescale

$$t_{\mathrm{E}} \propto \sqrt{M}$$

t_E ~ 20 d (stars)

t_E ~ 1 d (Jupiters)

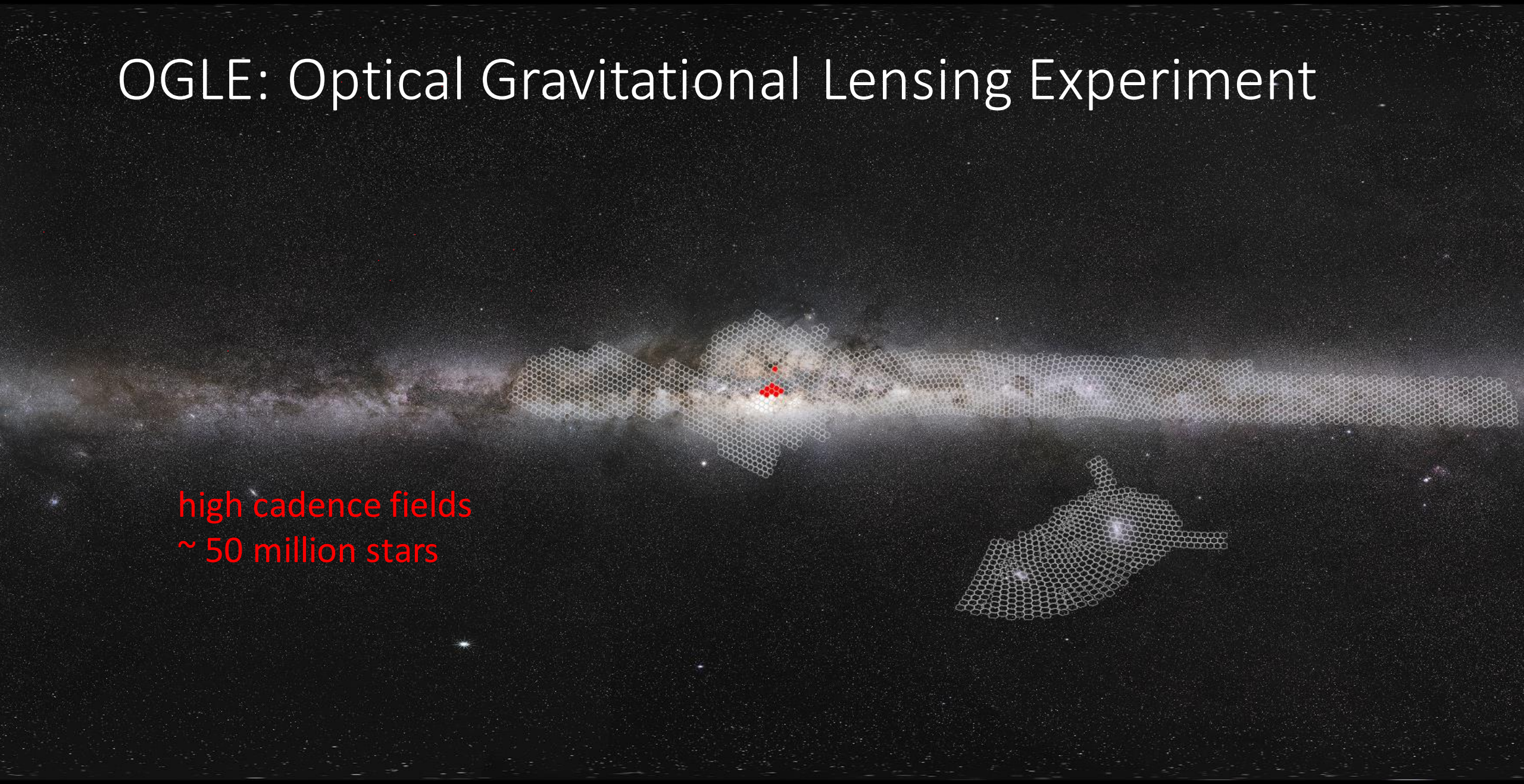
t_E ~ 0.1 d (Earths)

OGLE: Optical Gravitational Lensing Experiment

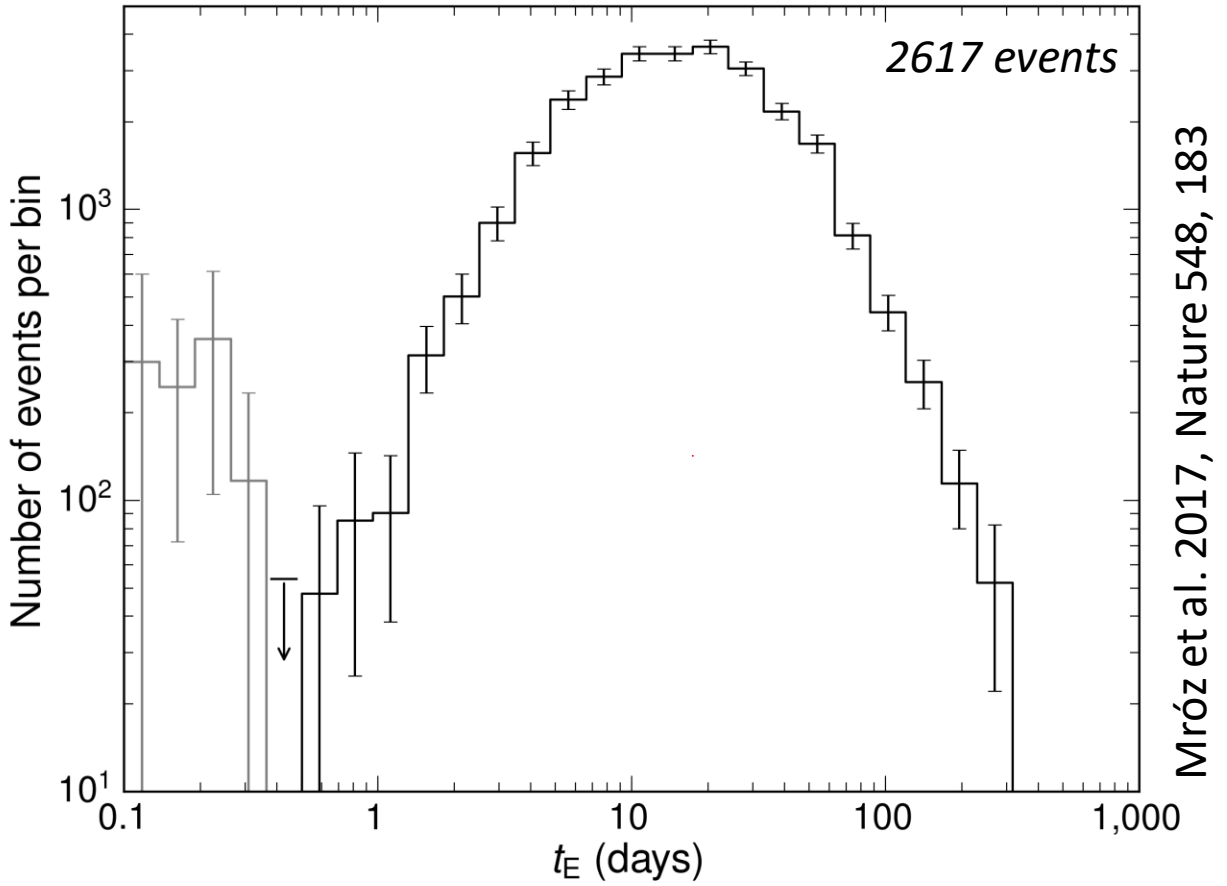
Warsaw 1.3-m
@ Las Campanas, Chile

- in operation since **1992**
- since 2010 as **OGLE-IV** (Udalski et al. 2015)
- over **20,000** microlensing detections
- over **100** exoplanets discovered

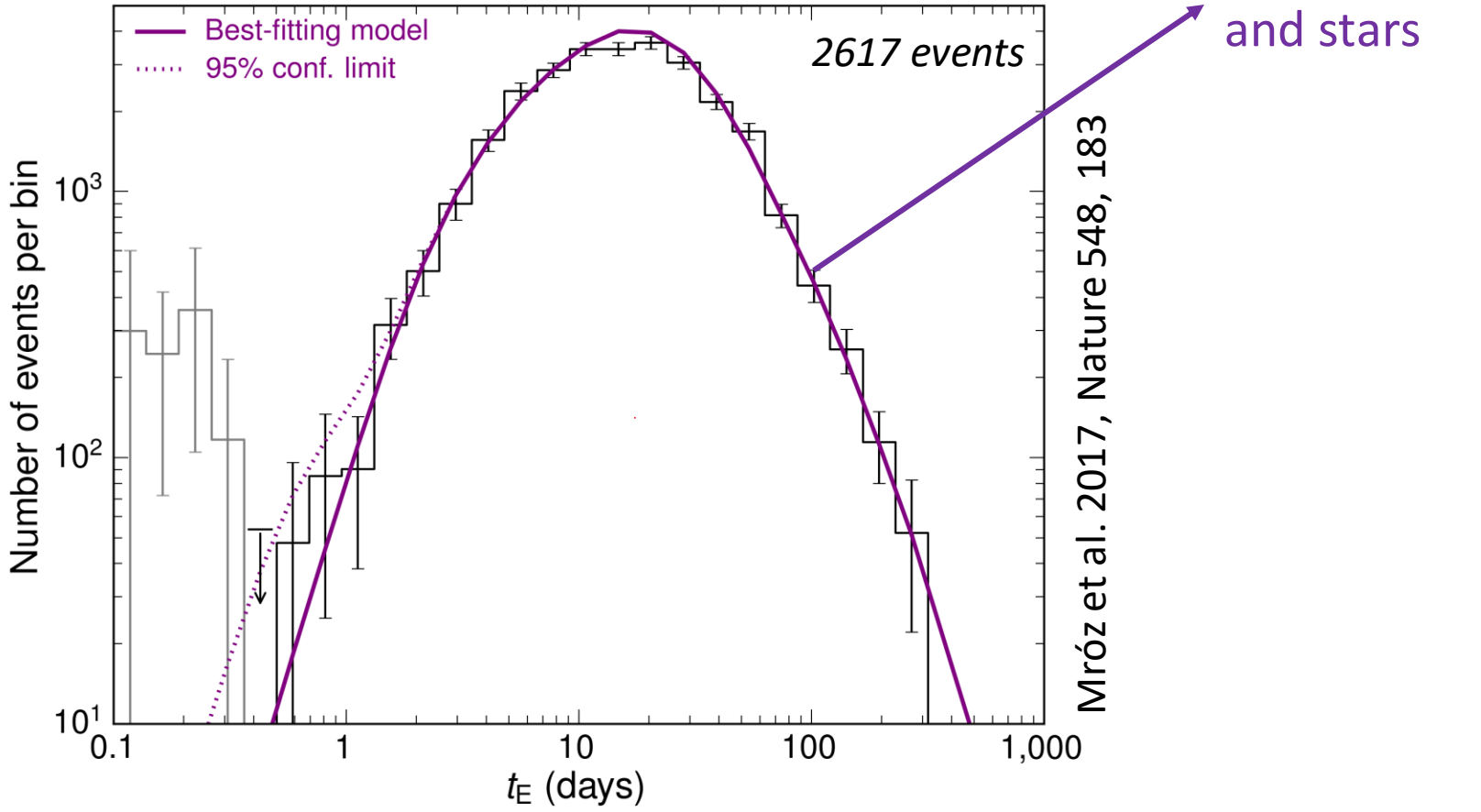
OGLE: Optical Gravitational Lensing Experiment



Event timescale distribution



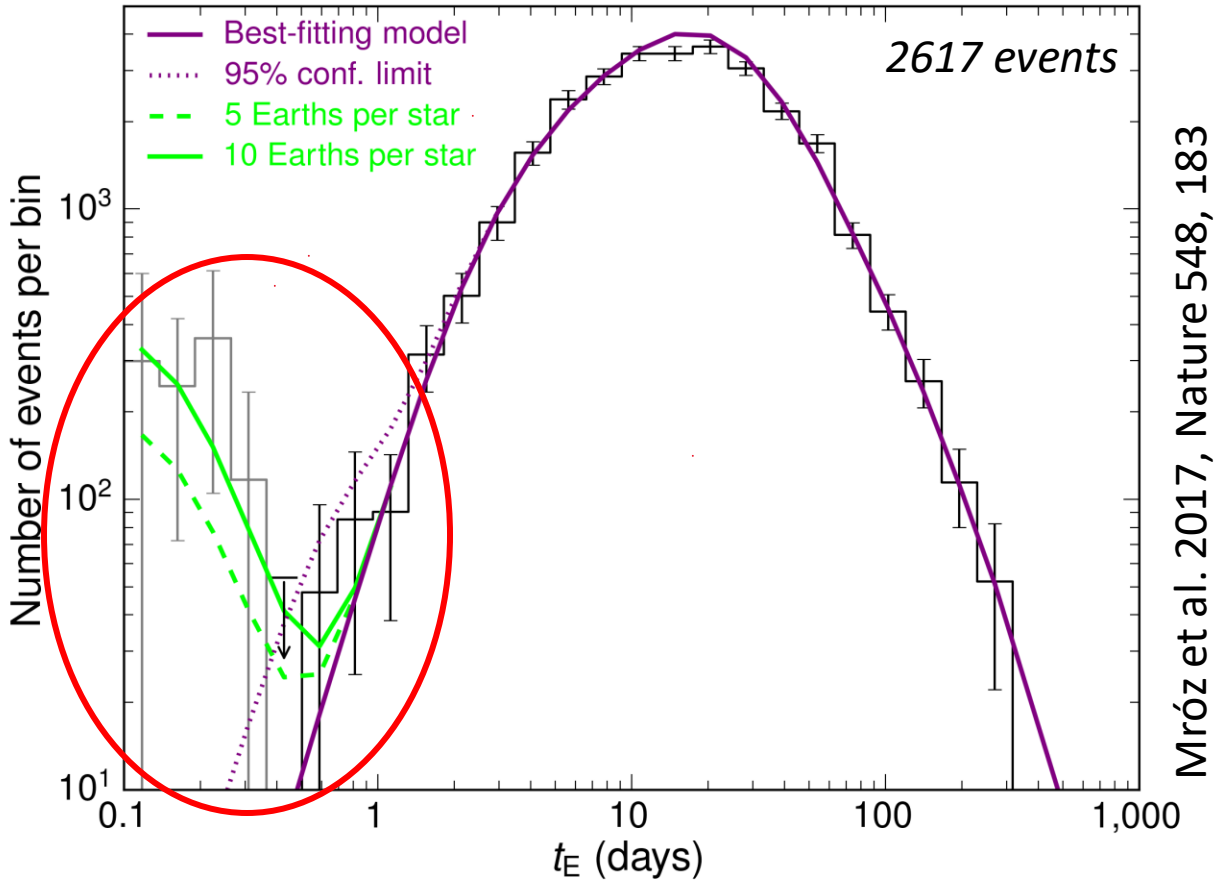
Jupiter-mass free-floating planets



brown dwarfs and stars

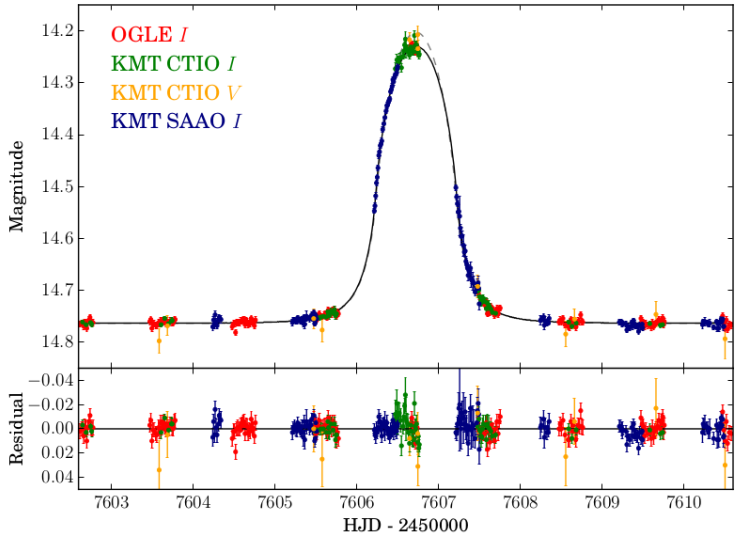
95% upper limit: less than 0.25 free-floating Jupiters per star

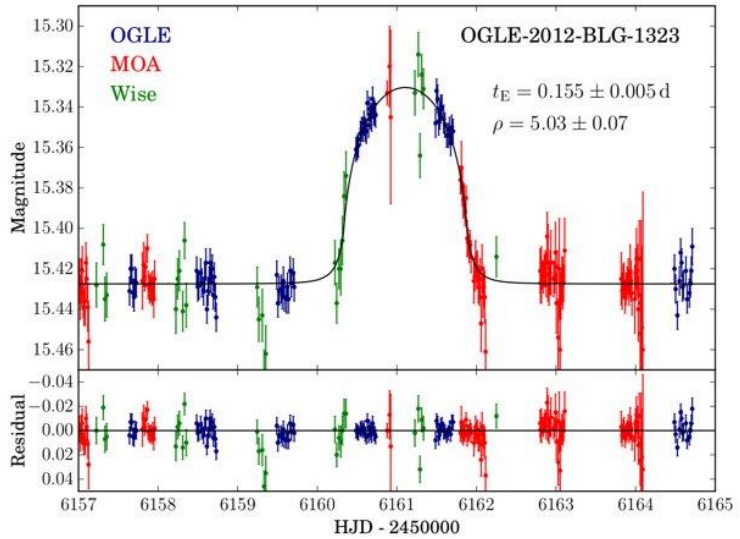
Earth/Neptune-mass free-floating planets



We detected a few extremely-short-timescale events: consistent with low-mass FFP being more common than stars.

Free-floating planet candidates

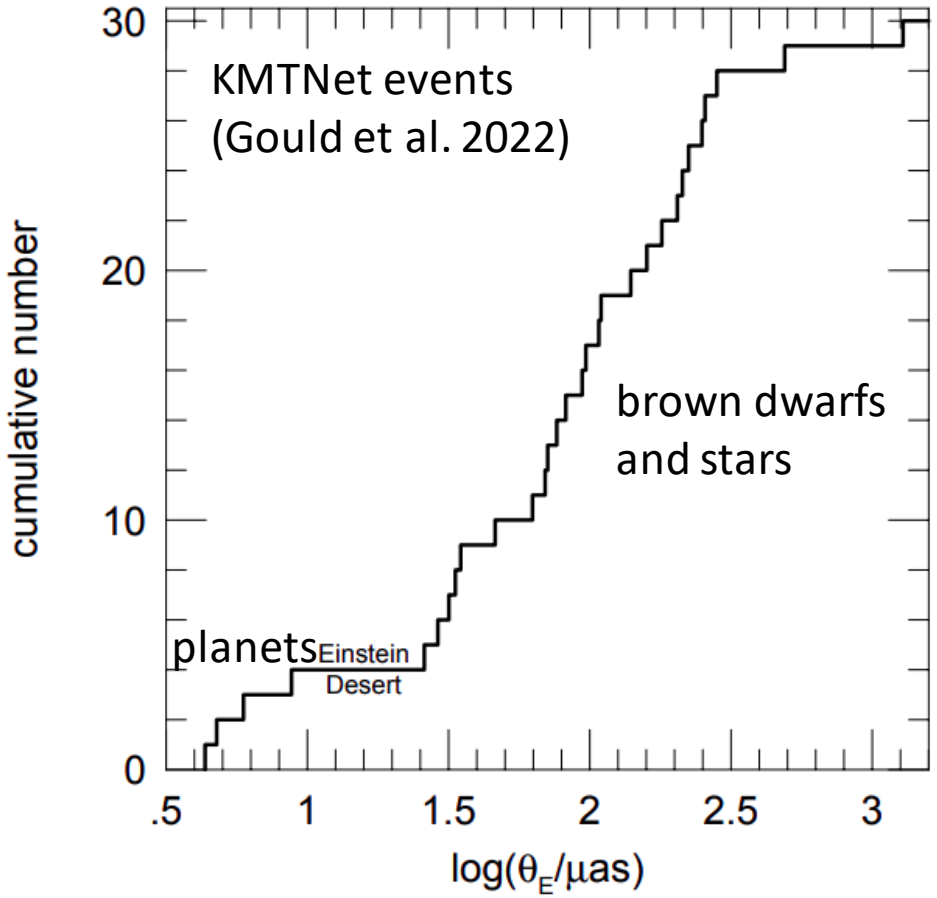


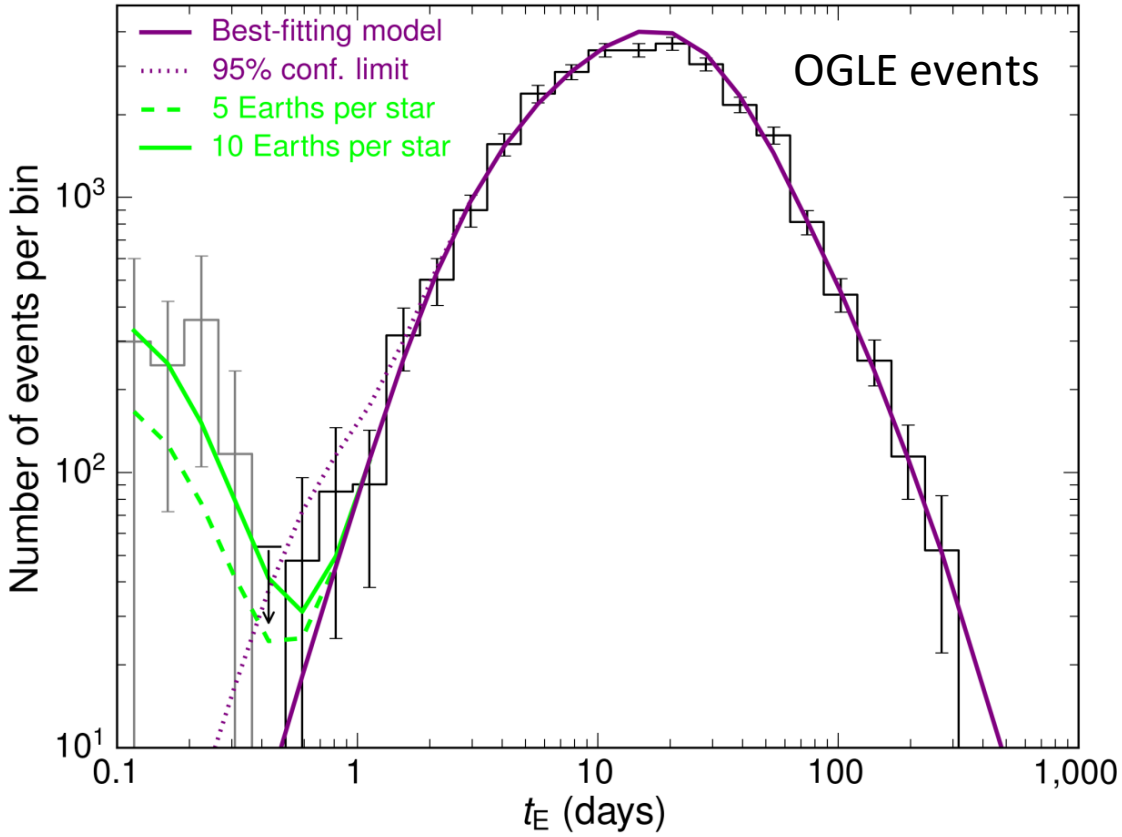


Event	t_E (days)	θ_E (μas)
OGLE-2016-BLG-1928	0.029 ± 0.003	0.842 ± 0.064
OGLE-2012-BLG-1323	0.155 ± 0.005	2.37 ± 0.10
OGLE-2016-BLG-1540	0.320 ± 0.003	9.2 ± 0.5
OGLE-2019-BLG-0551	0.376 ± 0.018	4.35 ± 0.34
KMT-2019-BLG-2073	0.272 ± 0.007	4.77 ± 0.19
KMT-2017-BLG-2820	0.273 ± 0.006	5.97 ± 0.37

Mróz et al. 2018, 2019, 2020, Kim et al. 2021, Ryu, Mróz et al. 2021

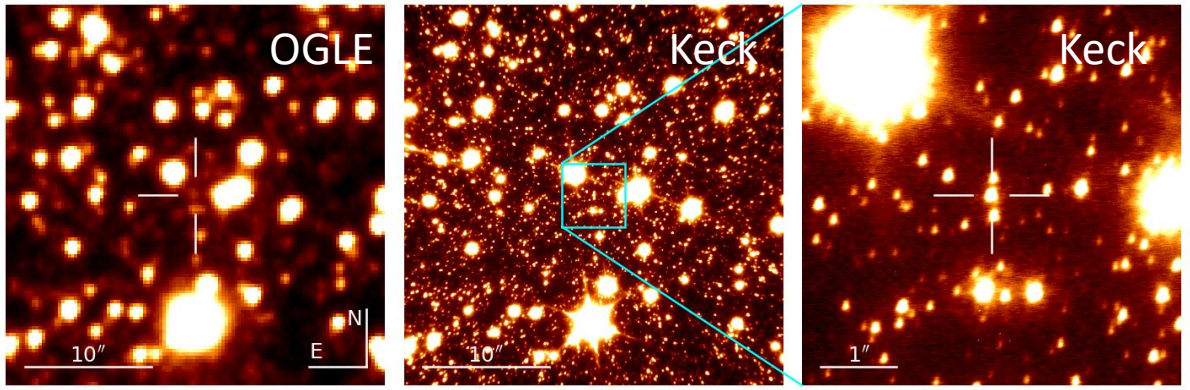
Einstein desert

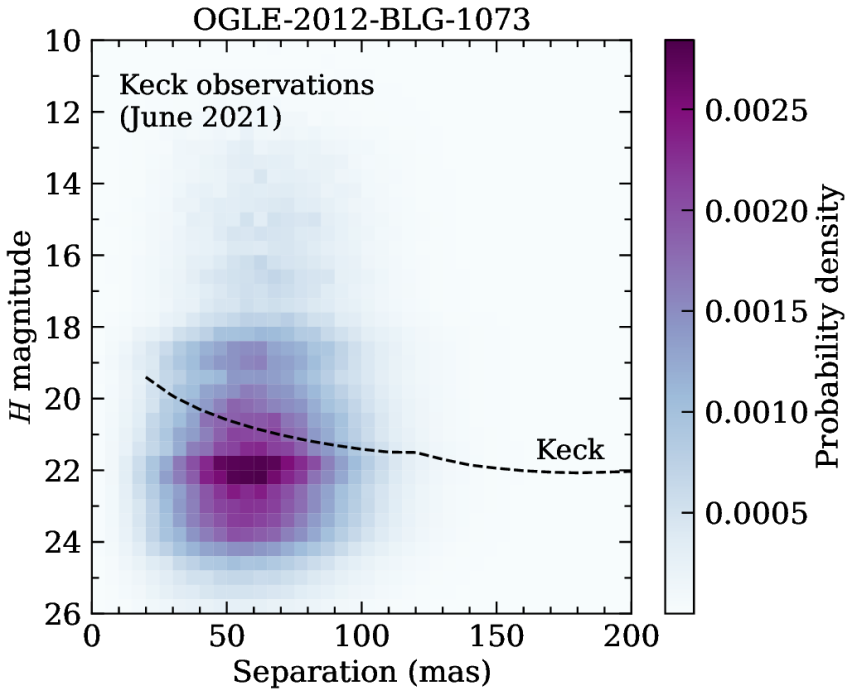




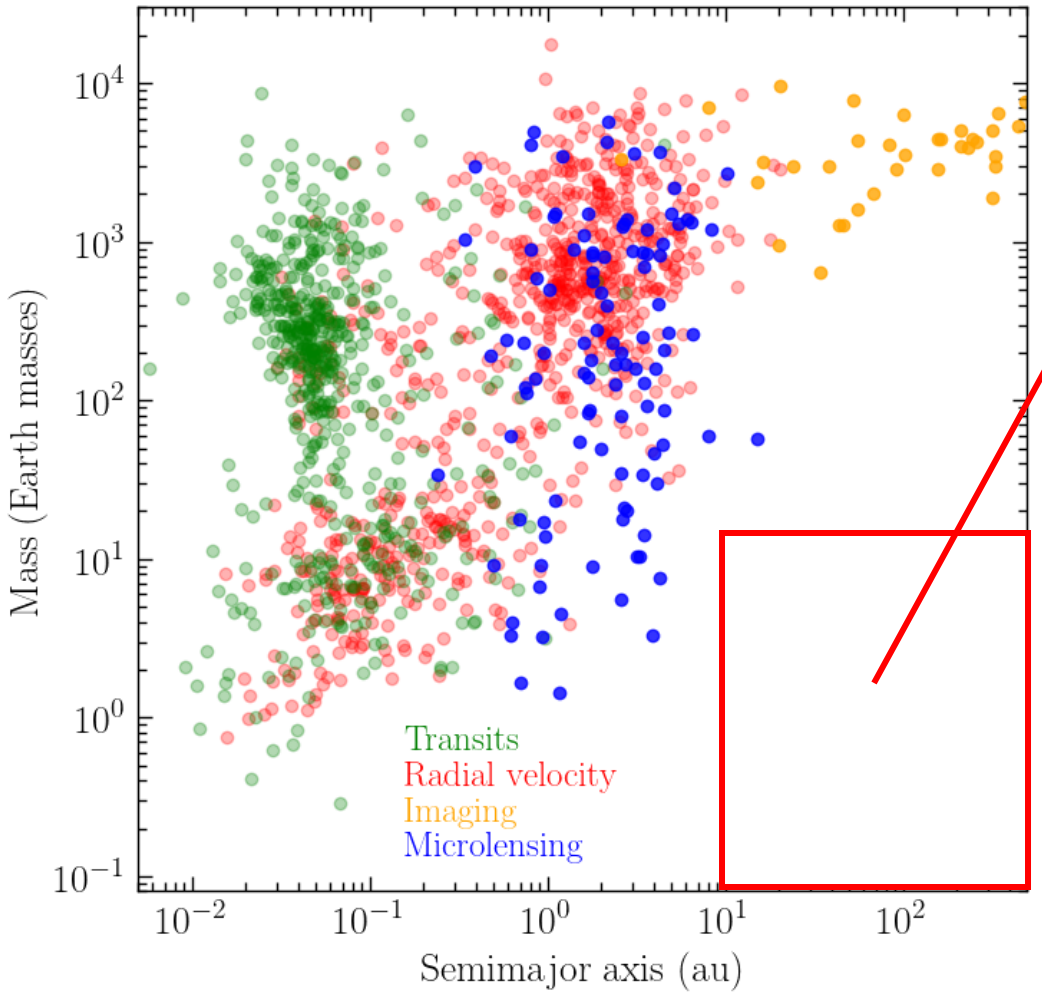
Free-floating or wide-orbit?

- microlensing data rule out putative stellar companions at < 10 au
- Keck adaptive-optics observations to search for putative host stars



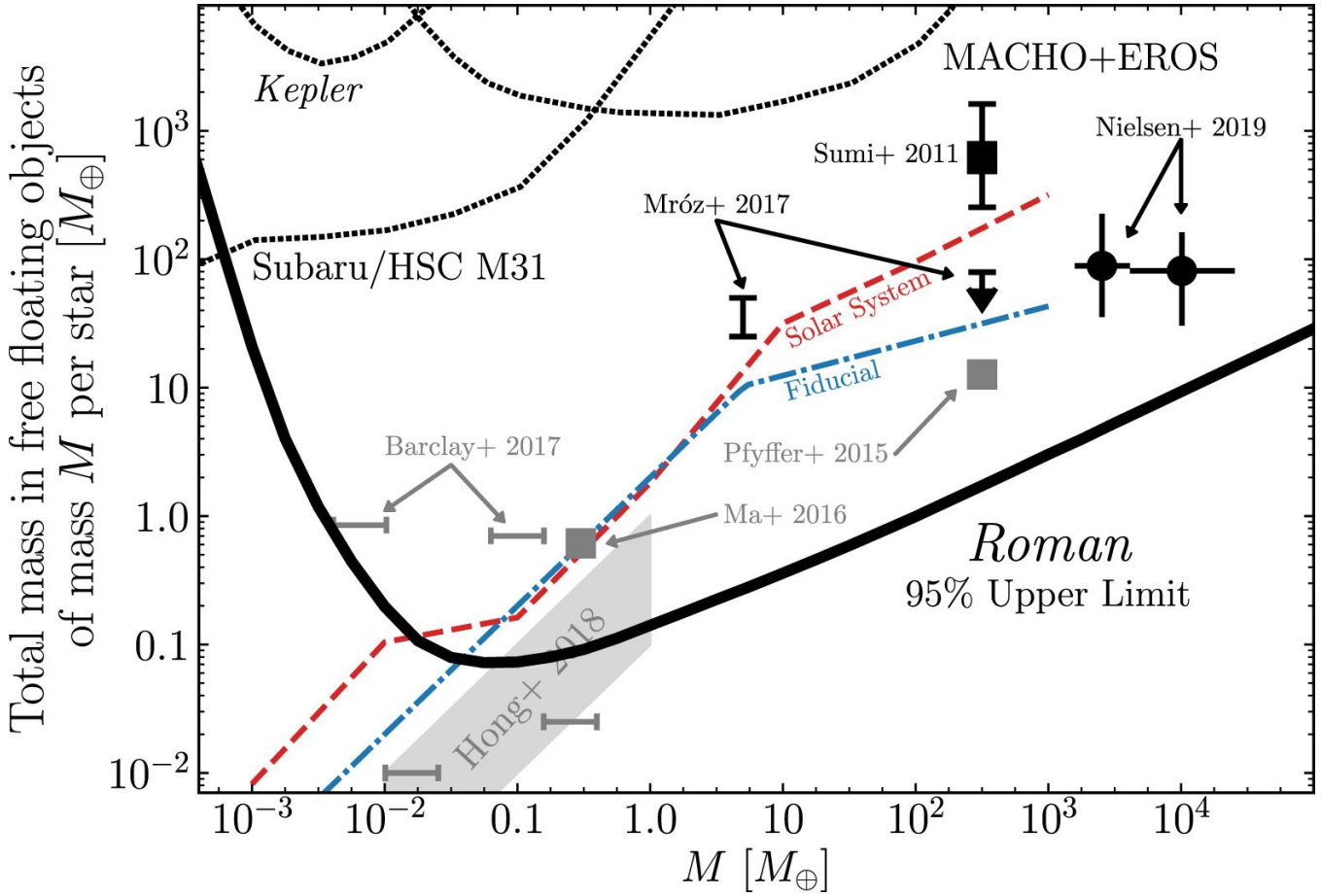


Wide-orbit planets are also cool!



We're probing an empty phase space of low-mass wide-separation planets

Roman telescope will be more sensitive to FFP



Johnson et al. 2020

Summary

- free-floating planets can be detected with gravitational microlensing
- less than 0.25 free-floating Jupiter-mass planets per star
- hints of a large population of Mars- to (super)Earth-mass free-floating / wide-orbit planets