Exoplanets from microlensing: First results and future prospects

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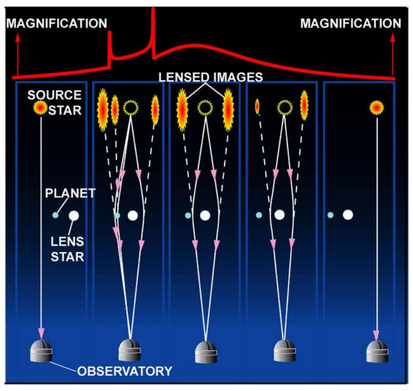
ABSTRACT. Amongst all techniques for detecting extra-solar planets, galactic microlensing is singled out by some unique characteristics, which allow to provide otherwise inaccessible information about their abundance and distribution of properties. The detection efficiency reaches a maximum for orbital separations of 1–10 AU, giving preference to system like our own. Planets with large orbital periods can be detected since the planetary-signal duration is mass-dependent instead, ranging from hours (earths) to days (jupiters). Being limited by the size of the observed stars whose light is gravitationally bent by the parent stars of the planets, microlensing is the only technique able to pick up a signal from a second Earth at the time being, albeit with a small probability. The parent stars are located in the Galactic disk ($\sim$ 1/3) or bulge ($\sim$ 2/3) at several kpc distance. By monitoring M31 rather than the Galactic bulge, it is even possible to obtain upper abundance limits on giant planets around M31 stars. Microlensing therefore provides a unique opportunity to gain observational evidence about planets surrounding stars in populations distinct from the one that comprises our neighbourhood, among which the distribution of stellar metallicity, being a critical parameter for planetary abundance, differs significantly. With the parent stars being selected according to their abundance and mass, but regardless of their luminosity, microlensing prefers M-dwarfs, which due to their faintness are not prominent targets in exoplanet searches relying on other detection techniques. In order to be able to properly characterize planetary deviations, the daily sampling by microlensing surveys such as OGLE or MOA is enhanced by follow-up telescope networks like PLANET, μFUN, or RoboNet, providing a dense (hourly) round-the-clock coverage. The recent years have seen the first detections of giant planets and the determination of significant upper abundance limits. If 10 % of the considered lens stars are surrounded by planets, powerful campaigns could detect a hundred giant planets, tens of neptunian planets and several terrestrial planets over the next five years.

Galactic microlensing



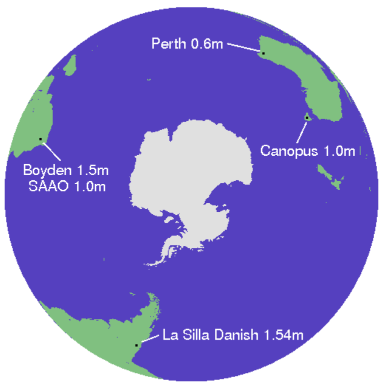
(courtesy of OGLE collaboration)

Bending of light received from stars in the Galactic Bulge or M31 due to the gravitational field of intervening stars (potentially surrounded by planets)

Daily sampling of the Galactic bulge by OGLE and MOA surveys yields 700-1000 microlensing alerts per year

PLANET telescope network

PLANET involves 32 collaborators affiliated with 18 institutions in 10 countries, led by
Jean-Philippe Beaulieu (Institut d'Astrophysique de Paris, Paris, France)
Martin Dominik (University of St Andrews, St Andrews, United Kingdom)



Nearly-continuous round-the-clock coverage of selected microlensing events with photometric precision of 1–2 %

Additional/former telescopes:

ESO La Silla Dutch 0.9m
ESO La Silla 2.2m
CTIO 0.9m
Yale-CTIO 1.0m
MSO 50″

Co-operation with RoboNet:

Liverpool 2.0m
Faulkes North 2.0m
Faulkes South 2.0m

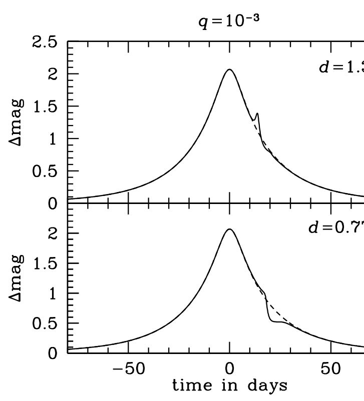
http://planet.iap.fr

Unique characteristics for planet detection

- parent stars are in the Galactic bulge or disk at several kpc distance, or in M31
- moderate orbital radii of 1–10 AU are preferred
- duration of planetary signal depends on mass rather than orbital period, ranging between hours (earths) and days (jupiters)
- signal limited by the size of the source stars, achievable photometry allows earths or even marses (space-based campaign) to be detected
- selection of parent stars (by chance) on basis of their abundance and mass, irrespective of their luminosity, makes M-dwarfs a preferred type

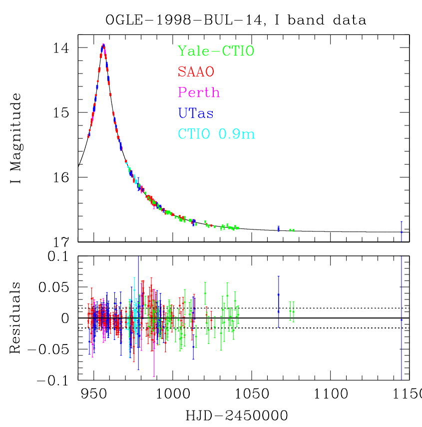
Photometric light curves

Expected planetary deviation

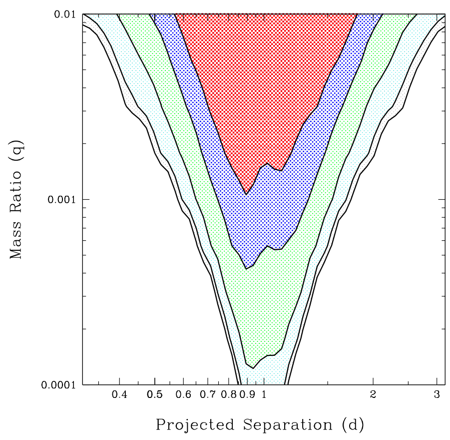


$t_E = 40$ d, $u_0 = 0.15$

Typical well-covered event



Limits on planetary abundance



Data basis: PLANET observations on 42 well-covered events between 1997 and 1999

Fractions $f(d, q)$ of lens stars having a companion with mass ratio q at the orbital radius parameter d that are excluded at 95 % confidence level. From inside to outside: $f = 3/4$, $2/3$, $1/2$, $1/3$, and $1/4$.

With M being the lens mass and D_L or D_S denoting lens or source distance, respectively, a characteristic scale is given by the *Einstein radius*

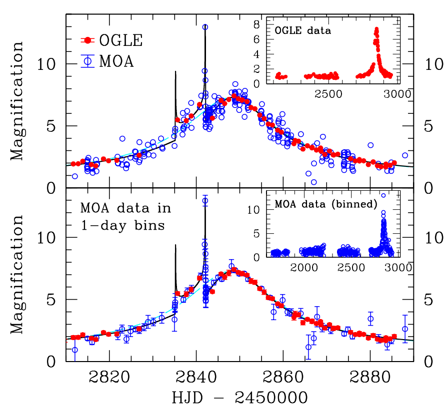
$$r_E = \sqrt{\frac{4GM}{c^2}\,\frac{D_L\,(D_S - D_L)}{D_S}}\,,$$

and d denotes the instantaneous orbital separation projected to a plane perpendicular to the line-of-sight at the distance of the parent (lens) star.

With $r_E \sim 2.5$ AU, more than $2/3$ of the lens stars (M-dwarfs) are *not* surrounded by jupiter-mass companions at orbital radii between 1.5 AU and 4 AU.

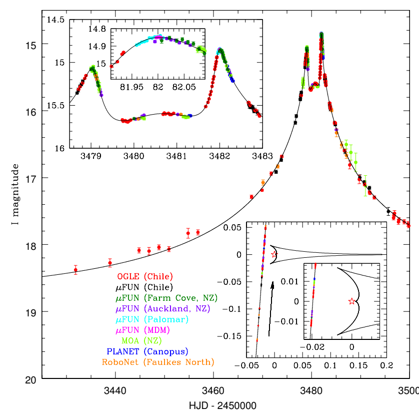
Detected planets

OGLE 2003-BLG-235 / MOA 2003-BLG-53



$m \sim 1.5\ M_{jup}$
$M \sim 0.36\ M_\odot$, $a \sim 3.8$ AU, $P \sim 12$ yr

OGLE 2005-BLG-071



$m \sim 2.7\ M_{jup}$, $M \sim 0.45\ M_\odot$
$a \sim 2.2$ AU, $P \sim 5$ yr *or* $a \sim 3.7$ AU, $P \sim 11$ yr

… more detections to follow …

Capabilities of microlensing searches

	Galactic bulge		M31
	ground	space	
number of source stars	$\sim 10^7$	$\sim 10^8$	$\sim 10^{10}$
resolution of source stars	resolved/crowded	well-resolved	unresolved
telescope time	dedicated	dedicated	0.5–2.5 h per night
field of view [sq deg]	0.004–0.03	2	0.01–1
number of fields monitored during night	~ 20	1	1–8
photometric accuracy	1 %	0.3 %	5–10 %
mean sampling interval	1.5–2.5 h	10–15 min	4–6 h
total event rate [yr^{-1}]	$\sim$ 300–600	~ 5000	$\sim$ 150–400
useful types of source stars	giants main-sequence stars	mainly main-sequence stars	giants
useful peak magnifications	$A_0 \gtrsim 2$	$A_0 \gtrsim 1.05$	$A_0 \gtrsim 10$
rate of useful events [yr^{-1}]	200–250	~ 5000	$\sim$ 35–100
planet detection efficiency	~ 25 % (jupiters) ~ 2 % (earths)	~ 25 % (jupiters) ~ 0.7 % (earths)	~ 35 % (jupiters) ~ 10 % (saturns)
planet probing rate [yr^{-1}]	50–60 jupiters 4–5 earths	1200 jupiters 30 earths	15–35 jupiters 4–10 saturns
upper limit on planetary abundance within 3 years	~ 2 % (jupiters) 20–25 % (earths)	0.1 % (jupiters) ~ 3 % (earths)	3–7 % (jupiters) 10–30 % (saturns)
location of parent stars	Galactic disk and bulge	Galactic disk and bulge	M31
extraction of planet parameters	fair (jupiters) difficult (earths)	good	difficult or even impossible
identification of parent stars	no	for ~ 33 % of the events	no
isolated and wide-orbit planets	no	yes	no

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