Planet frequency from microlensing observations

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Abstract. Galactic gravitational microlensing is a powerful tool to detect extrasolar planets at large orbital distances from their stars, from giant planets down to Earth-mass planets. More than 40 planets have been discovered so far, with 21 already published. Recent statistical results on the frequency of exoplanets based on several years of microlensing observations find that planets should be the rule rather than the exception, and confirm that super-Earth are much more frequent that giant planets in the Galaxy.

Detections

Galactic gravitational microlensing was proposed twenty years ago as a very promising method to detect extrasolar planets[1] located at great distances from Earth (1–10 kpc). In 2003, after a decade of monitoring marked by great technical improvements, the MOA and OGLE collaborations discovered the first microlensing exoplanets[2,3]. Since then, microlensing has contributed major exoplanet discoveries, such as the first cool super-Earth OGLE-BLG-2005-390Lb[4], a Jupiter-Saturn planetary system analog[5] or free-floating planets[6]. So far 21 planets have been published (Fig. 1), 20 more are now confirmed, and ongoing 2013 season has already revealed several new candidates.

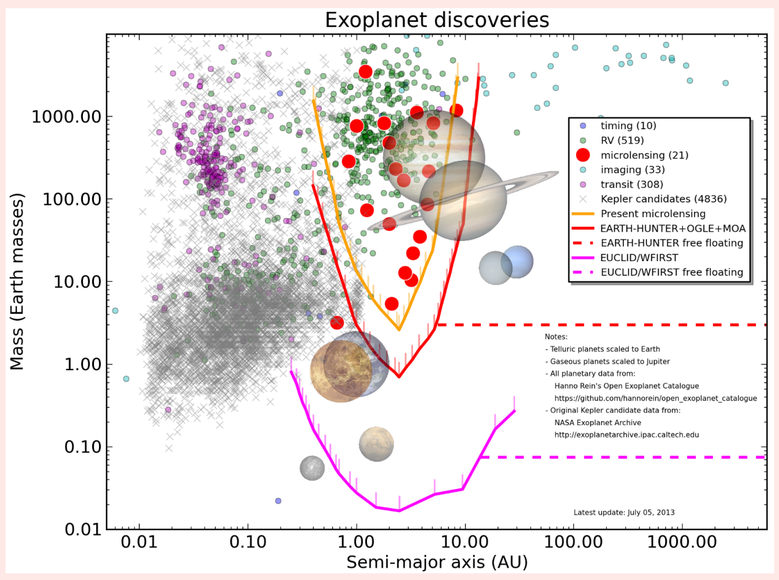

Fig. 1. Exoplanet discoveries, as a function of planetary mass and semi-major axis. Red dots mark microlensing planets, while solid lines encompass the core microlensing sensitivity using ground-based telescopes (red and orange) or a spacecraft (pink). The dashed lines indicate the typical minimum masses of free-floating planets detectable with microlensing (figure: courtesy J.-B. Marquette).

Statistics, PLANET data 2002-07

We have conducted a statistical analysis[6] that involves six years of microlensing observations gathered between 2002–07 by the PLANET and OGLE collaborations (Fig. 2). From these data combined with results from previous independent microlensing studies[8,9], we estimated the frequency of cool extrasolar planets with masses ranging from 5 Earths to 10 Jupiters and orbits between 0.5–10 AU. We found an average of 1.6 planet per star, which suggests that planets around Milky Way stars are the rule, rather than the exception.

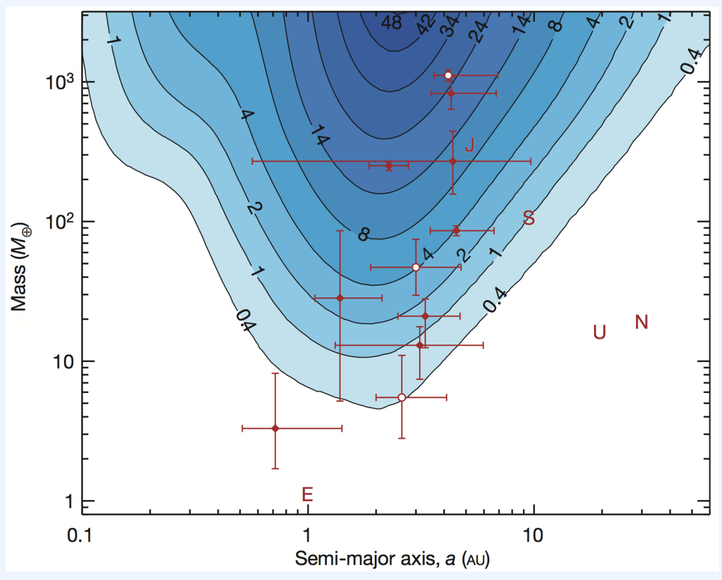

Fig. 2. Detection sensitivity diagram of PLANET 2002-07 data, as a function of planet mass and semi-major axis. Blue contours show the expected number of detections from the survey if all lens stars have exactly one planet with orbit size a and mass M. Red points with error bars mark all microlensing planet detections between 2002-07, while white dots further signal data consistent with PLANET detection efficiency (figure from Cassan et al., *Nature*, 2012).

Planet frequency

Microlensing surveys confirm that low-mass planets, such as super-Earth, are more frequently found around stars than giant planets. The mass function derived from microlensing data[6] predicts slightly more planets than other techniques, as seen in Fig. 3. These methods, however, probe a different range in host star masses and orbital separations, in particular, most microlensing planets are located beyond the snow line.

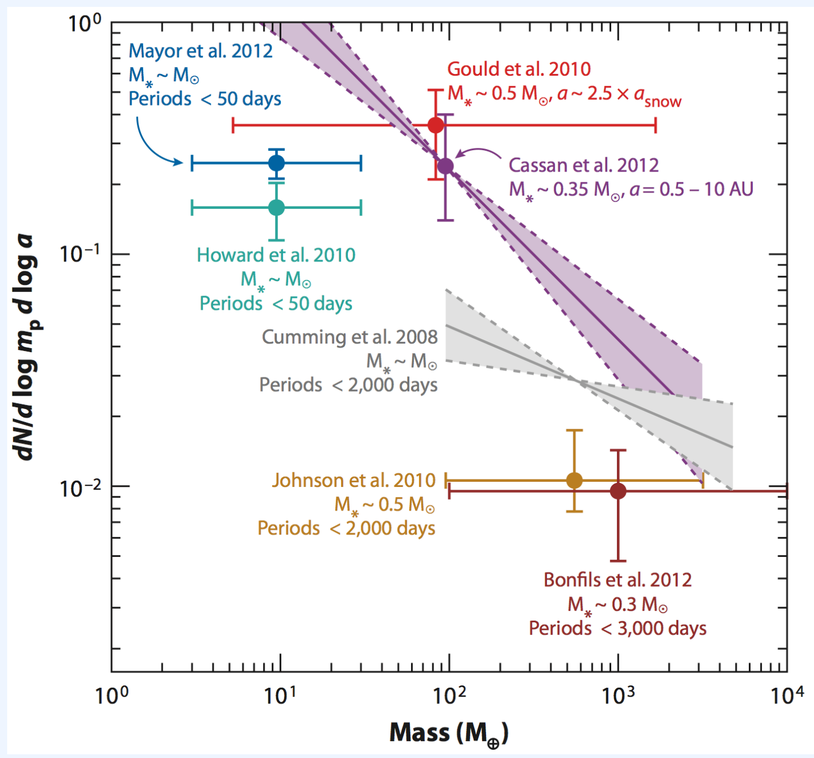

Fig. 3. Comparison of different planetary mass functions versus planetary mass, as derived from microlensing (violet, red) and Doppler (other colours) surveys. For each measurement, typical host star masses and orbit size ranges are indicated (figure from Gaudi, *Annu. Rev. Astron. Astrophys*, 2012).

The Future

New microlensing networks of ground-based, robotic telescopes with wide-field cameras are currently being deployed. While about 700 microlensing events were monitored in 2010, this number has now dramatically increased to more than 2000 alerts/year; current surveys already confirm a strong increase in the exoplanet discovery rate. Future satellite missions (possibly onboard Euclid or WFIRST) should detect a large number of planets and free-floating planets[10], and constrain the planetary mass functions down the mass of Mars.

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