Most known extrasolar planets (exoplanets) have been discovered using the radial velocity\textsuperscript{1,2} or transit\textsuperscript{3} methods. Both are biased towards planets that are relatively close to their parent stars, and studies find that around 17–30\% (refs 4, 5) of solar-like stars host a planet. Gravitational microlensing\textsuperscript{6–8}, on the other hand, probes planets that are further away from their stars. Recently, a population of planets that are unbound or very far from their stars was discovered by microlensing\textsuperscript{9}. These planets are at least as numerous as the stars in the Milky Way\textsuperscript{10}. Here we report a statistical analysis of microlensing data (gathered in 2002–07) that reveals the fraction of bound planets 0.5–10 AU (Sun–Earth distance) from their stars. We find that 17–29\% of stars host Jupiter-mass planets (0.3–10 MJ, where MJ = 318 M\textsubscript{\textregistered} and M\textsubscript{\textregistered} = Earth’s mass). Cool Neptunes (10–30 M\textsubscript{\textregistered}) and super-Earths (5–10 M\textsubscript{\textregistered}) are even more common: their respective abundances per star are 52 ±22\% and 62 ±35\%. We conclude that stars are orbited by planets as a rule, rather than the exception.

Gravitational microlensing is very rare: fewer than one star per million undergoes a microlensing effect at any time. Until now, the planet-search strategy\textsuperscript{7} has been mainly split into two levels. First, wide-field survey campaigns such as the Optical Gravitational Lensing Experiment (OGLE; ref. 11) and Microlensing Observations in Astrophysics (MOA; ref. 12) cover millions of stars every clear night to identify and alert the community to newly discovered stellar microlensing events as early as possible. Then, follow-up collaborations such as the Probing Lensing Anomalies Network (PLANET; ref. 13) and the Microlensing Follow-Up Network (μFUN; refs 14, 15) monitor selected candidates at a very high rate to search for very short-lived light curve anomalies, using global networks of telescopes.

To ease the detection-efficiency calculation, the observing strategy should remain homogeneous for the time span considered in the analysis. As detailed in the Supplementary Information, this condition is fulfilled for microlensing events identified by OGLE and followed up by PLANET in the six-year time span 2002–07. Although a number of microlensing planets were detected by the various collaborations between 2002 and 2007 (Fig. 1), only a subset of them are consistent with the PLANET 2002–07 strategy. This leaves us with three compatible detections: OGLE 2005-BLG-071Lb (refs 16, 17) a Jupiter-like planet of mass M = 3.8 M\textsubscript{\textregistered} and semi-major axis a ≈ 3.6 AU; OGLE 2007-BLG-349Lb (ref. 18), a Neptune-like planet (M ≈ 0.2 M\textsubscript{\textregistered}, a ≈ 3.8 AU); and the

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**Figure 1** | **Survey-sensitivity diagram.** Blue contours, expected number of detections from our survey if all lens stars have exactly one planet with orbit size a and mass M. Red points, all microlensing planet detections in the time span 2002–07, with error bars (s.d.) reported from the literature. White points, planets consistent with PLANET observing strategy. Red letters, planets of our Solar System, marked for comparison: E, Earth; J, Jupiter; S, Saturn; U, Uranus; N, Neptune. This diagram shows that the sensitivity of our survey extends roughly from 0.5 AU to 10 AU for planetary orbits, and from 5 M\textsubscript{\textregistered} to 10 M\textsubscript{\textregistered}. The majority of all detected planets have masses below that of Saturn, although the sensitivity of the survey is much lower for such planets than for more massive, Jupiter-like planets. Low-mass planets are thus found to be much more common than giant planets.

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Among the 98 events monitored, 43 met our quality-control criteria and semi-major axis microlensing events. It provided the number of planets that our survey obtained by summing the detection efficiencies over all individual order, \(f\), the mass-error bars reported in the literature) are plotted in Fig. 2c. The abilities of the mass for the three detections (computed according to \(f\)) do not explicitly depend on \(f\), where \(a\) are the parameters to be derived and \(d\) are the labelled contours show the corresponding expected number of detections. The figure shows that the core sensitivity covers the typical mass range of 0.14–1.0 \(M_\oplus\) (see Supplementary Fig. 3).

To derive the actual abundance of exoplanets from our survey, we proceeded as follows. Let the planetary mass function, \(f(\log a, \log M)\) = \(dN/(d\log a \times d\log M)\), where \(N\) is the average number of planets per star. We then integrate the product \(f(\log a, \log M) S(\log a, \log M)\) over \(\log a\) and \(\log M\). This gives \(E(f)\), the number of detections we can expect from our survey. For \(k\) (fractional) detections, the model then predicts a Poisson probability distribution \(P(k|E) = e^{-E}E^k/k!\). A Bayesian analysis assuming an uninformative uniform prior \(P(\log f) = 1\) finally yields the probability distribution \(P(\log f|k)\) that is used to constrain the planetary mass function.

Although our derived planet-detection sensitivity extends over almost three orders of magnitude of planet masses (roughly 5 \(M_\oplus\), to 10 \(M_\oplus\), it covers fewer than 1.5 orders of magnitude in orbit sizes (0.5–10 \(\text{AU}\)), thus providing little information about the dependence of \(f\) on \(a\). Within these limits, however, we find that the mass function is approximately consistent with a flat distribution in \(\log a\) (that is, \(f\) does not explicitly depend on \(a\)). The planet-detection sensitivity integrated over \(\log a\), or \(S(\log M)\), is displayed in Fig. 2b. The distribution probabilities of the mass for the three detections (computed according to the mass-error bars reported in the literature) are plotted in Fig. 2c (black curves), as their sum (red curve).

To study the dependence of \(f\) on mass, we assume that to the first order, \(f\) is well-approximated by a power-law model: \(f = f_0 (M/M_a)^\alpha\), where \(f_0\) (the normalization factor) and \(\alpha\) (the slope of the power-law) are the parameters to be derived and \(M_a\), a fiducial mass (in practice, the pivot point of the mass function). Previous works\(^{8,25–27}\) on planet frequency have demonstrated that a power law provides a fair description of the global behaviour of \(f\) with planetary mass. Apart from the constraint based on our PLANET data, we also made use in our analysis of the previous constraints obtained by microlensing; an estimate of the normalization\(^{19}\) \(f_0 (0.36 \pm 0.15)\) and an estimate of the slope\(^{25}\) \(\alpha (-0.68 \pm 0.2)\), displayed respectively as the blue point and the blue lines in Fig. 2. The new constraint presented here therefore relies on

![Figure 2](image)
giants\textsuperscript{21} found that fewer than 33\% of M dwarfs have a Jupiter-like planet between 1.5–4 AU, and even lower limits of 18\% have been reported\textsuperscript{29,30}. These limits are compatible with our measurement of 1.5\% for masses ranging from Saturn to 10 times Jupiter, in the same orbit range.

From our derived planetary mass function, we estimate that within 0.5–10 AU (that is, for a wider range of orbital separations than previous studies), on average 17\% of stars host a 'Jupiter' (0.3–10 M\textsubscript{J}) and 52\%\textsuperscript{22} of stars host Neptune-like planets (10–30 M\textsubscript{J}). Taking the full range of planets that our survey can detect (0.5–10 AU, 5 M\textsubscript{J} to 10 M\textsubscript{J}), we find that on average every star has 1.6\% of planets. This result is consistent with every star of the Milky Way hosting (on average) one planet or more in an orbital-distance range of 0.5–10 AU. Planets around stars in our Galaxy thus seem to be the rule rather than the exception.

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Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

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Author Contributions A.C. led the analysis and conducted the modelling and statistical analyses. A.Ca. and D.K. selected light curves from 2002–07 PLANET/OGLE microlensing seasons, analysed the data and wrote the Letter and Supplement. D.K. computed the magnification maps used for the detection-efficiency calculations. J.-P.B. and Ch.C. wrote the software for online data reduction at the telescopes. J.-P.B. led the PLANET collaboration, with M.D., J.G., J.M. and A.W.; P.F. and M.D.A. contributed to online and offline data reduction. M.D. contributed to the conversion efficiencies to physical parameter space and developed the PLANET real-time display system with A.W., M.D.A. and Ch.C.; K.Ho. and A.Ca. developed and tested the Bayesian formula for fitting the two-parameter power-law mass function. J.G. edited the manuscript, conducted the main data cleaning and managed telescope operations at Mount Canopus (1 m) in Hobart. J.W. wrote the original magnification maps software, discussed the main implications and edited the manuscript. J.M., A.W. and U.G.J., respectively managed telescope operations in South Africa (South African Astronomical Observatory 1 m), Australia (Perth 0.61 m) and La Silla (Dutch 0.94 m). A.U. led the OGLE campaign and provided the final OGLE photometry. D.P.B., V.B., S.B., J.A.R.C., A.C., K.H.C., S.D., D.D.P., I.D., P.F., K.H.L., N.K., S.K., J.-B.M., R.M., K.R.P., K.-S., C.V., D.W., B.W. and M.Z. were involved in the PLANET observing strategy and/or PLANET data acquisition, reduction, real-time analysis and/or commented on the manuscript. T.S. commented on the manuscript. M.K.S., M.K., R.P., I.S., K.J., G.P. and L.W. contributed to OGLE data.

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