## Faster and slower

For three of the four reactions studied, the directly measured rate constants differed by orders of magnitude from the indirect estimates that had been derived from ozonolysis experiments. The reactions with $SO_2$ and $NO_2$ were much faster than expected, and the reaction with NO was much slower—in fact, there was no measurable reaction with NO at all. "Really, it seems like we were surprised by almost every aspect of the results," remarks Taatjes.

Collaborators Carl Percival (University of Manchester) and Dudley Shallcross (University of Bristol) analyzed some of the atmospheric implications. Among the products of the $SO_2$ and $NO_2$ reactions are $SO_3$ and $NO_3$. A rapid reaction between $SO_3$ and $H_2O$ gives sulfuric acid, $H_2SO_4$, which contributes to atmospheric aerosol formation; $NO_3$ drives much of the chemistry of the atmosphere at night. Percival and Shallcross estimated that Criegee reactions could produce 40% as much $NO_3$, and more than 100% as much $SO_3$, as other known sources of those molecules.

They had to make some assumptions, though, since so far the Sandia team has studied only the smallest Criegee intermediate at only one temperature and pressure. Future experiments should clarify the picture.

**Johanna Miller**

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# Microlensing suggests that our galaxy has more planets than stars

**Gravitational bending of light reveals exoplanets with large orbital radii.**

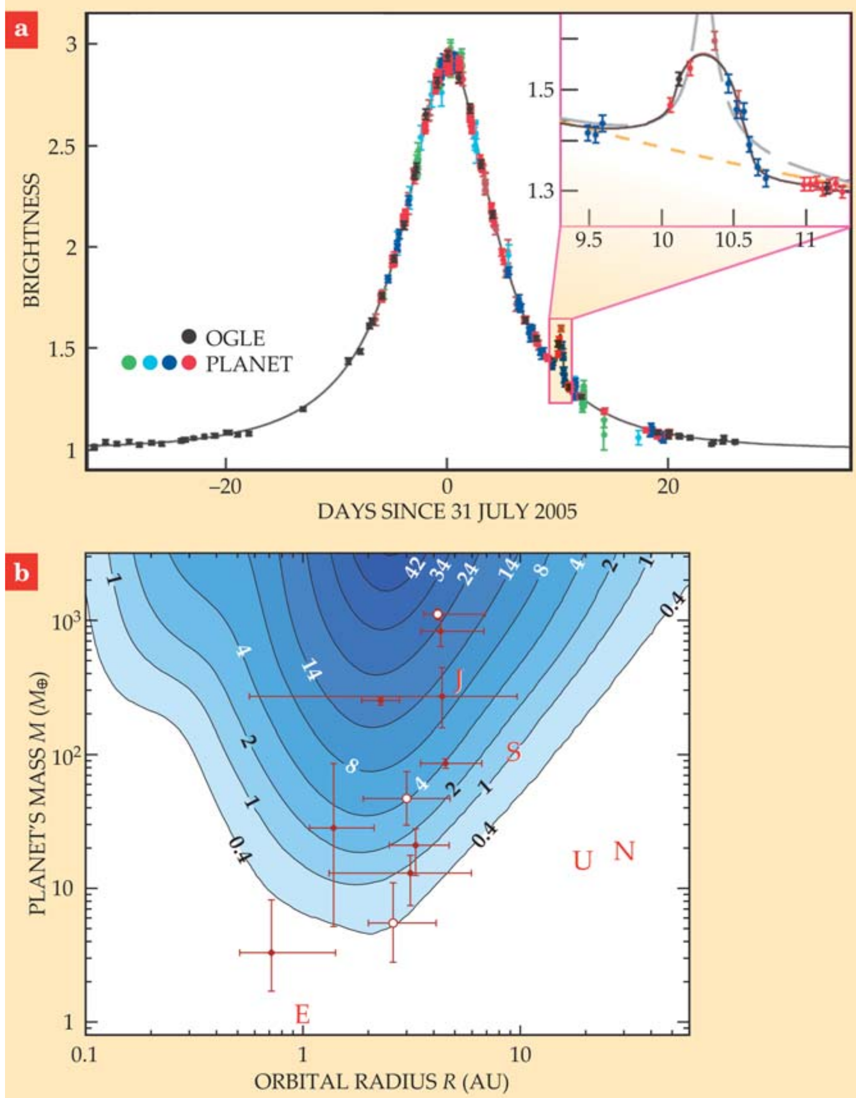
Most of the more than 600 exoplanets discovered to date have been found through Doppler evidence of periodic host-star motion or photometric evidence of transits across a star's face. Both methods are strongly biased in favor of planets with orbital radii much smaller than Earth's, which defines 1 astronomical unit (AU). Gravitational microlensing is an alternative technique that's most sensitive to planets a few AU from their stars. It favors very distant stars and it's relatively unbiased as to stellar mass. Though microlensing's discovery rate is still modest, it appeals to those who seek a representative galactic survey of planets with orbits like those of the solar system.

Gravitational bending of light is a central feature of general relativity. In a typical microlensing event, a foreground lensing star passing close by our line of sight to a background star produces milliarcsecond bending that focuses the background star so that it brightens over several weeks. Rarely, a planet several AU from the lensing star reveals itself by a short blip on the brightness curve as it too crosses the sight line (see the figure's panel a).

Because planetary blips typically last less than a day, finding and measuring them usually requires a two-tier strategy. First, a wide-field survey team, such as the OGLE collaboration based at the University of Warsaw, images the same star-crowded field night after night in search of the one in a million that's brightening. When the team finds one, it alerts one of several global networks of telescopes that then monitor the star round the clock for a telltale blip. If the blip is well measured, it yields the planet's mass $M$ and orbital radius $R$. Since that strategy was initiated in the late 1990s, many thousands of stellar microlensing events have yielded only about two dozen planet sightings.

Now the PLANET telescope network, led by Jean-Philippe Beaulieu (Paris Institute of Astrophysics), reports an analysis of six years of its search for planets.[1] Translating planet sightings into an estimate of the galactic abundance and mass distribution of planets requires a careful determination of detection efficiency as a function of $M$ and $R$. And that, in turn, requires adherence to a consistent, well-defined search protocol. So the PLANET analysis limits itself to the years 2002–07, after which innovations led to protocol modifications.

The only three planets discovered by PLANET during that period are plotted in panel b, together with eight discovered during the same period by other networks with protocols of their




**Microlensing planet search. (a)** The brightness curve of a distant lensed star discovered by the OGLE team and followed up by the PLANET network.[3] The best fit to the blip seen 10 days after maximum yields a 5.5 Earth-mass ($M_\oplus$) planet trailing the foreground lensing star at a distance of 2.6 astronomical units (AU). **(b)** That planet and the two others discovered by PLANET during 2002–07 are plotted (open points) together with eight planets discovered by other networks (solid points) in those years. PLANET's search-efficiency contours are labeled by the number of planets its survey would have found if every lensing star had precisely one planet, all with the same given mass and orbital radius. The capital letters indicate solar-system planets. (Adapted from ref. 1.)

own. The plot's contour lines indicate detection efficiencies calculated for PLANET's six-year survey. Heavier planets are easier to detect. The survey's mass-detection threshold was about 5 Earth masses ($M_\oplus$).

The PLANET team estimated the true galactic distribution of planet masses essentially by dividing its observed $M$ and $R$ distribution by the detection-efficiency function and then integrating over $R$. In seeking the best analytical fit for the galactic distribution, the team augmented its own meager harvest by taking account of fits by other networks to planets they found.[2]

Despite the increase of detection efficiency with increasing $M$, the density of points in panel b tends the other way. Thus the PLANET team concludes that over the $R$ range 0.5–10 AU, a region largely unexplored by Doppler and transit searches, the galactic planetary-mass distribution falls with increasing mass roughly like $M^{-0.7}$. In particular, $62 \pm 36\%$ of all stars harbor super-Earths (5–10 $M_⊕$); $52 \pm 25\%$ have Neptunian middleweights (10–30 $M_⊕$); and $17 \pm 7\%$ have Jovian planets heavier than 100 $M_⊕$.

On average, the team concludes, every star has 1.6 planets in the survey's $M$ and $R$ sensitivity range. "So in the Milky Way," says Arnaud Cassan, who led the analysis, "planets around stars seem to be the rule rather than the exception."

**Bertram Schwarzschild**

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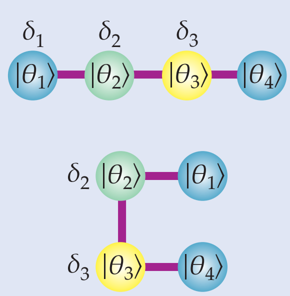
# A blind quantum computer makes its laboratory debut

**Quantum computing promises great efficiency advantages over classical computing. Quantum communication promises tamper-proof security. Combine them, and you get blind quantum computing.**

Described by Vlatko Vedral of the University of Oxford as "possibly the most exciting idea in quantum computing in the last 10 years," blind quantum computing would enable a client, who herself has no quantum computing capability, to run an algorithm on a remote server without revealing anything about her input, computation, or output. Now, Philip Walther (University of Vienna) and colleagues have demonstrated a small-scale version of a blind quantum computer.[1]

The experiment used a protocol[2] presented in 2009 by Anne Broadbent (University of Waterloo, Canada), Joseph Fitzsimons (then also at Waterloo, now at the National University of Singapore), and Elham Kashefi (University of Edinburgh). Broadbent and collaborators based their scheme on a so-called one-way quantum computer: Rather than manipulating a system of qubits and then reading out the result, the computer starts with a highly entangled state, universal for all computations up to a certain size, and performs a series of single-qubit measurements. The results of those measurements can then be processed with a classical computer to give the computation output. To make the computation blind, Broadbent and company have the client prepare the qubits with phase angles $\theta_i$ that only she knows and have her instruct the computer to measure them at angles $\delta_i$. The computer entangles the qubits in a specified way, measures them, and transmits the results back to the client. Without knowing the angles $\theta_i$, neither the computer nor an eavesdropper can deduce the underlying computation from the angles $\delta_i$ and the measurement results.

In contrast to previously proposed schemes for blind quantum computation, Broadbent and company's protocol doesn't require the client to do anything that's not well within the bounds




**A one-qubit gate** (top) and a two-qubit gate (bottom) implemented on a four-qubit blind quantum computer. The qubits are prepared in initial states $|\theta_i\rangle$, pairwise entangled as shown by the purple lines, and measured at angles $\delta_i$ in order from left to right (not necessarily numerical order). The rightmost qubits in each gate are the gate's output; they could become another gate's input in a larger computation. When $\theta_2$ and $\theta_3$ are kept secret, the computation is blind: Neither the computer nor an eavesdropper can deduce the underlying computation. (Adapted from ref. 1.)