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"Distant Planet Found by Gravitational Microlensing"

The most distant giant planet to orbit an ordinary star in the Milky Way has been discovered by an international team of astronomers. This is the first unequivocal planet discovery to be made by the gravitational microlensing technique, which has the potential to extend our knowledge of extra-solar planets to lower mass planets like Neptune and Earth. Microlensing can also detect planets in the central region of our Galaxy. This discovery is reported in a paper by jointly authored by the MOA and OGLE collaborations, to appear in the May 10 issue of The Astrophysical Journal Letters.

Gravitational microlensing makes use of a distant source star to probe the gravitational field of a foreground star and/or planet. The gravitational field of the foreground system can be probed because light rays are bent by gravity, as was first demonstrated in Sir Arthur Eddington's 1919 Solar Eclipse expedition that provided the first experimental verification of Einstein's Theory of General Relativity. Microlensing was first proposed as a method for detecting extra-solar planets by Bohdan Paczynski of Princeton University and his student, Shude Mao, in 1991. This was two years before the first reported microlensing events due to stellar mass objects by three different groups, known as the OGLE, MACHO, and EROS collaborations. Now, just over a decade later, the first discovery of an extra-solar planet with the microlensing technique has been announced. Paczynski is "thrilled as a theoretician to see the prediction come true: the first definite detection of a planet through gravitational microlensing".

"The real strength of the microlensing technique is its ability to detect low mass planets", said Ian Bond of the MOA Collaboration. The MOA and OGLE groups expect that observations over the next few years lead to the discovery of Neptune-mass planets in Jupiter-like orbits around distant stars. The improved sensitivity required for such discoveries is being made possible by the new large field-of-view OGLE-III camera, the MOA-II 1.8m telescope which is now being built, and improved cooperation between the different groups that observe microlensing events. Earth-like planets are also detectable by microlensing under favorable conditions. But to do a systematic study of their abundance requires a space-based telescope, such as the proposed Microlensing Planet Finder (MPF). "MPF would have the sensitivity to detect planets like those in our own solar system with the exception of Mercury and Pluto," said David Bennett (Notre Dame), the leader of the MPF team. MPF could complete the census of Earth-like planets begun by Kepler, a NASA mission in development, which can find Earth-like planets at star-planet separations as large as the Earth-Sun distance.

This discovery was made possible only through the cooperation and sharing of data between the competing MOA and OGLE groups. While such cooperation among competitors is rare in many other fields, it is becoming the norm among groups that observe microlensing events. "Observations of microlensing events can be so time-critical that the science would really suffer if we don't make our data available as quickly as possible", said OGLE team-leader Andrzej Udalski of the Warsaw University Observatory. The OGLE team has been the leader in this cooperative mode of science, being the first to announce microlensing events and release their measurements while the events are in progress.

The gravitational microlensing technique is able to detect a planet through the effect of the planet's gravitational field on the light we see from a more distant background star. The simple effect of gravitational lensing of one star by another has now been detected more than thousand times. When two stars are nearly perfectly aligned as seen from Earth, the gravitational field of the foreground star acts as a lens to magnify the background star. The magnified image is very small, and can only be resolved with a telescope that produces images 1000 times sharper than the Hubble Space Telescope. Hence the term "microlensing". Even so, the effect can be observed by the increased brightness of the magnified star. It is only a temporary effect. The orbital motion of the stars in the Galaxy will occasionally bring pairs of stars into alignment as seen from Earth. Their continued motion will then bring them out of alignment again and the microlensing effect ceases.

Most of the one thousand microlensing events that have been observed have followed a brightening pattern or "light curve" characteristic of a lens composed of a single star. However, some have followed a very different light curve caused by a lens composed of a double star. The planetary microlensing event observed by the OGLE and MOA Collaborations resembles the single lens light curve for most of its four-month duration. But for a period of about a week, the gravitational field of the planet causes the light curve to resemble that of a double star lens.

The precise shape of the light curve reveals that the lighter mass of the double lens has only 0.4% of the mass of the heavier component, which implies that the lighter component must be a planet. Analysis of the light curve revealed that it was most likely a red dwarf star and a planet of about 1.5 times the mass of Jupiter at a separation of about 3 AU. (An Astronomical Unit, or AU, is the mean distance between the Earth and Sun.) It was located about 17,000 light years away toward the central part of the Galactic disk, in the constellation Sagittarius.

OGLE is a Polish/American OGLE project led by Udalski in Poland and Paczynski in the US. It has operated continuously since 1992 at the Las Campanas Observatory in Chile, which is operated by the Carnegie Institution of Washington. They currently run the largest microlensing survey in the world on the 1.3 meter Warsaw Telescope which enables them to observe more than 150 million stars in the Galactic center every night. The OGLE Project operation is funded by NASA and NSF grants in the United States, and the Polish State Committee for Scientific Research and Foundation for Polish Science grants.

The MOA Project is primarily a New Zealand/Japanese group led by Phil Yock in New Zealand and Yasushi Muraki in Japan with collaborators in the UK and US. It has a MOA member in Scotland, Ian Bond, who first noticed the planetary feature in the light curve of the present event and is the first author of the Astrophysical Journal Letters paper. A quick response from Nagoya University graduate student, Tomohiro Sekiguchi, who was on telescope duty at the time, enabled a critical feature of the light curve to be observed. The MOA Project is supported by the Marsden Fund in New Zealand, NASA and the NSF in the US, and the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan, and the Japan Society for the Promotion of Science (JSPS).

The gravitational microlensing technique is, in one sense, the easiest way to detect extrasolar planets because the signal of the planet can be quite large. For the present event, the maximum effect due to the planet was more than a factor of two increase in the apparent brightness of the background source star. In contrast, the radial velocity technique requires the detection of Doppler shifts of one part in ten million. Moreover, the critical data for the present event were obtained over a period of only a couple of months. By contrast, many years of data by the radial velocity technique would be required to detect a similar planet.

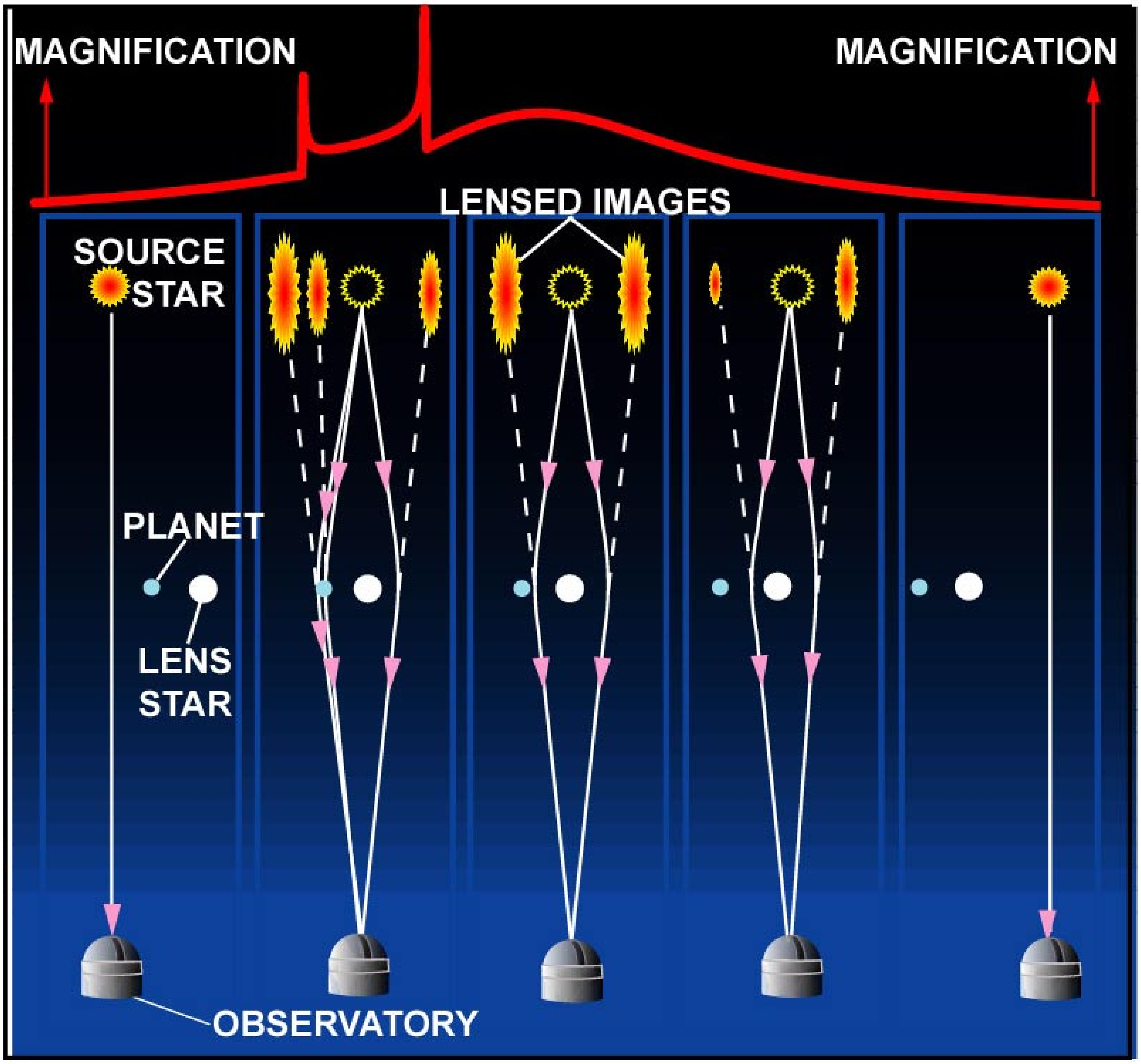

Figure 1: This Figure shows the geometry of a microlensing event in which the almost perfect alignment between a background source star, a lens star, and our observatory allow us to discover a planet that orbits the lens star. Each panel represents a different time in the history of the event, and time can be taken to run from either left to right or right to left depending on the motion of the lens and source stars. The left and right panels show the usual case in which the alignment is not good enough for the lens star or its planet to affect the light rays that we see. The third and fourth panels (from the left) show the case of lensing by a star: the light rays from the background source star are bent so that two distorted images of star are visible. These images cannot be resolved without a telescope with much sharper images than HST, but the overall magnification of the images is visible as an apparent brightening of the source star. The second panel shows the configuration for a planet detection. One of the light rays that is bent by the lens star's gravity comes close enough to the planet that it feels the gravity of the planet, too. This causes additional distortion of the images, and in some cases, additional images can be created which result in dramatic changes in brightness (the spikes seen in the magnification curve).

The difficulty with the gravitational microlensing technique is that the necessary alignment between pairs of stars is rare, so that many millions of stars must be monitored to detect planets. Recent developments in image analysis techniques have, however, made this task quite manageable.

The only other method that has been used to detect extrasolar planets orbiting ordinary stars (besides radial velocities and microlensing) is the transit technique which requires detection of a 1% variation in brightness. The first planet discovery by the transit method was initiated by photometry from the OGLE Collaboration, but follow-up spectroscopic observations were needed to prove that the transit was due to a planet.

The paper by the OGLE/MOA collaboration to be published in the Astrophysical Journal Letters is available at http://www.physics.auckland.ac.nz/moa/M53-O235.pdf, and additional information is available at http://www.nd.edu/~bennett/moa53-ogle235/ and http://ogle.astrouw.edu.pl/ogle3/blg235-53.html.

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