# Measuring the shape of distant stars using gravitational microlensing

May 31 2005


Fifty years after his death, Albert Einstein's work still provides new tools for understanding our universe. An international team of astronomers has now used a phenomenon first predicted by Einstein in 1936, called gravitational lensing, to determine the shape of stars. This phenomenon, due to the effect of gravity on light rays, led to the development of gravitational optics techniques, among them gravitational microlensing. It is the first time that this well-known technique has been used to determine the shape of a star.

*Image: The Galaxy Cluster Abell 2218 is so massive that it magnifies and distorts images of faraway galaxies that appear as "arcs" throughout the picture. Copyright NASA/HST.*

Most of the stars in the sky are point-like, making it very difficult to evaluate their shape. Recent progress in optical interferometry has made it possible to measure the shape of a few stars. In June 2003, for instance, the star Achernar (Alpha Eridani) was found to be the flattest star ever seen, using observations from the Very Large Telescope Interferometer. Until now, only a few measurements of stellar shape have been reported, partly due to the difficulty of carrying such measurements. It is important, however, to obtain further accurate determinations of stellar shape, as such measurements help to test theoretical stellar models.

For the first time, an international team of astronomers [1], led by N.J. Rattenbury (from Jodrell Bank Observatory, UK), applied gravitational lensing techniques to determine the shape of a star. These techniques rely on the gravitational bending of light rays. If light coming from a bright source passes close to a foreground massive object, the light rays will be bent, and the image of the bright source will be altered. If the foreground massive object (the â€œlensâ€?) is point-like and perfectly aligned with the Earth and the bright source, the altered image as seen from the Earth will be a ring shape, the so-called â€œEinstein ringâ€?. However, most real cases differ from this ideal situation, and the observed image is altered in a more complicated way. The image below shows an example of gravitational lensing by a massive galaxy cluster.

Gravitational microlensing, as used by Rattenbury and his colleagues, also relies on the deflection of light rays by gravity. Gravitational microlensing is the term used to describe gravitational lensing events where the lens is not massive enough to produce resolvable images of the background source. The effect can still be detected as the distorted images of the source are brighter than the unlensed source. The observable effect of gravitational microlensing is therefore a temporary apparent magnification of the background source. In some cases, the microlensing effect may increase the brightness of the background source by a factor of up to 1000. As already pointed out by Einstein, the alignments required for the microlensing effect to be observed are rare. Moreover, as all stars are in motion, the effect is transitory and non-repeating. Microlensing events occur over timescales from weeks to months, and require long-term surveys to be detected. Such survey programs have existed since the 1990s. Today, two survey teams are operating: a Japan/New Zealand collaboration known as MOA (Microlensing Observations in Astrophysics) and a Polish/Princeton collaboration known as OGLE (Optical Gravitational Lens Experiment). The MOA team observes from New Zealand and the OGLE team from Chile. They are supported by two follow-up networks, MicroFUN and PLANET/RoboNET, that operate about a dozen telescopes around the globe.

The microlensing technique has been applied to search for dark matter around our Milky Way and other galaxies. This technique has also been used to detect planets orbiting around other stars. For the first time, Rattenbury and his colleagues were able to determine the shape of a star using this technique. The microlensing event that was used was detected in July 2002 by the MOA group. The event is named MOA 2002-BLG-33 (hereafter MOA-33). Combining the observations of this event by five ground-based telescopes together with HST images, Rattenbury and his colleagues performed a new analysis of this event.

The lens of event MOA-33 was a binary star, and such binary lens systems produce microlensing lightcurves that can provide much information about both the source and lens systems. The particular geometry of the observer, lens and source systems during the MOA-33 microlensing event meant that the observed time-dependent magnification of the source star was very sensitive to the actual shape of the source itself. The shape of the source star in microlensing events is usually assumed to be spherical. Introducing parameters describing the shape of the source star into the analysis allowed the shape of the source star to be determined.

Rattenbury and his colleagues estimated the MOA-33 background star to be slightly elongated, with a ratio between the polar and equatorial radius of 1.02 -0.02/+0.04. However, given the uncertainties of the measurement, a circular shape of the star cannot be completely excluded. The figure below compares the shape of the MOA-33 background star with those recently measured for Altair and Achernar. While both Altair and Achernar are only a few parsecs from the Earth, the MOA-33 background star is a more distant star (about 5000 parsecs from the Earth). Indeed, interferometric techniques can only be applied to bright (thus nearby) stars. On the contrary, the microlensing technique makes it possible to determine the shape of much more distant stars. Indeed, there is currently no alternative technique to measure the shape of distant stars.

This technique, however, requires very specific (and rare) geometrical configurations. From statistical considerations, the team estimated that about 0.1% of all detected microlensing events will have the required configurations. About 1000 microlensing events are observed every year. They should become even more numerous in the near future. The MOA group is presently commissioning a new Japan-supplied 1.8m wide-field telescope that will detect events at an increased rate. Also, a US led group is considering plans for a space-based mission called Microlensing Planet Finder. This is being designed to provide a census of all types of planets within the Galaxy. As a by-product, it would also detect events like MOA-33 and provide information on the shapes of stars.

[1] The team is made of N.J. Rattenbury (UK), F. Abe (Japan), D.P. Bennett (USA), I.A. Bond (New Zealand), J.J. Calitz (South Africa), A. Claret (Spain), K.H. Cook (USA), Y. Furuta (Japan), A. Gal-Yam (USA), J-F. Glicenstein (France), J.B. Hearnshaw (New Zealand), P.H. Hauschildt (Germany), P.M. Kilmartin (New Zealand), Y. Kurata

(Japan), K. Masuda (Japan), D. Maoz (Israel), Y. Matsubara (Japan), P.J. Meintjes (South Africa), M. Moniez (France), Y. Muraki (Japan), S. Noda (Japan), E.O. Ofek (Israel), K. Okajima (Japan), L. Philpott (New Zealand), S.H. Rhie (USA), T. Sako (Japan), D.J. Sullivan (New Zealand), T. Sumi (USA), D.M. Terndrup (USA), P.J. Tristram (New Zealand), J. Wood (New Zealand), T. Yanagisawa (Japan), P.C.M. Yock (New Zealand).

---

*Determination of stellar shape in microlensing event MOA 2002-BLG-33*
by N.J. Rattenbury, F. Abe, D.P. Bennett, et al.
To be published in Astronomy & Astrophysics (DOI number: 10.1051/0004-6361:20052858)
Full article available in PDF format

Link: Jodrell Bank Observatory