Las Cumbres Observatory
Global Telescope Network

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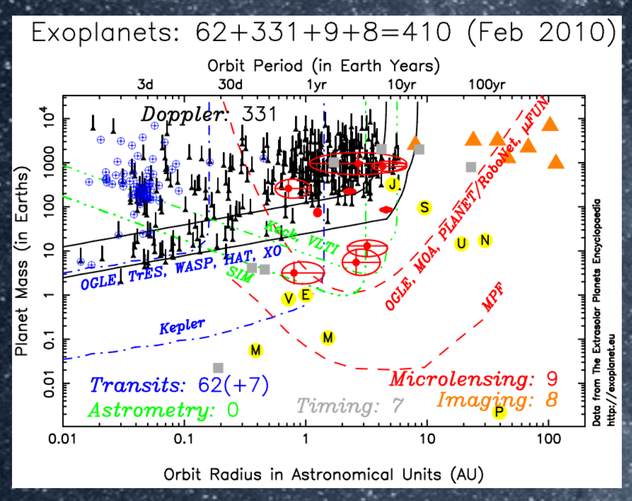
The RoboNet-II project

Observing microlensing events with the LCOGT network of telescopes

Microlensing searches for planets are sensitive to cold, small exoplanets at ~1–6AU from their host stars and therefore probe an important part of parameter space not readily accessible by other methods. We have developed an automated software system designed to make optimum use of the LCOGT network in conjunction with the Liverpool Telescope to monitor events carefully selected for their sensitivity to cool planets and provide intensive, quasi-continuous coverage of planetary anomalies. Results from the survey, complementing discoveries with other methods, will test planetary formation models and help form a complete census of exoplanets as a prelude to future searches for life.



Exoplanet discovery space. Microlensing is the fastest way to measure the mass function of cool planets down to the mass of the Earth

Event Priority Algorithm

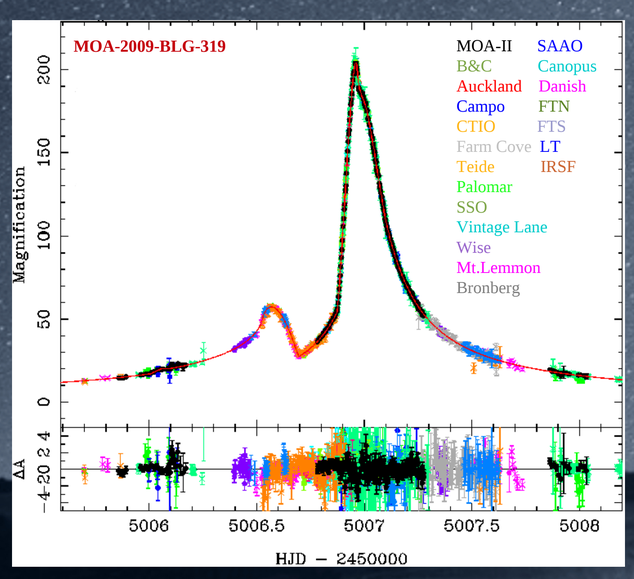
With more than 1000 microlensing events being alerted each year by the survey teams, it is important to identify early on which ones deserve follow-up observations. For this purpose, we make use of our prioritisation algorithm to select the set of events with the highest sensitivity to cool planets and request appropriate observations from the telescope network.

Incoming Microlensing data

All new microlensing data are copied over to the project computer where the quality of each image is checked and a log file of nightly observations is created and stored locally. Any images suffering from serious defects or where the sky background is too high are excluded from the analysis. The process is fully automated.

Microlensing Pipeline

The data processing pipeline runs in *Real Time* and operates on incoming new images of microlensing events. An optimal reference image is selected and new targets are automatically identified and processed.
The resulting lightcurves are promptly updated and the photometry is immediately available online.

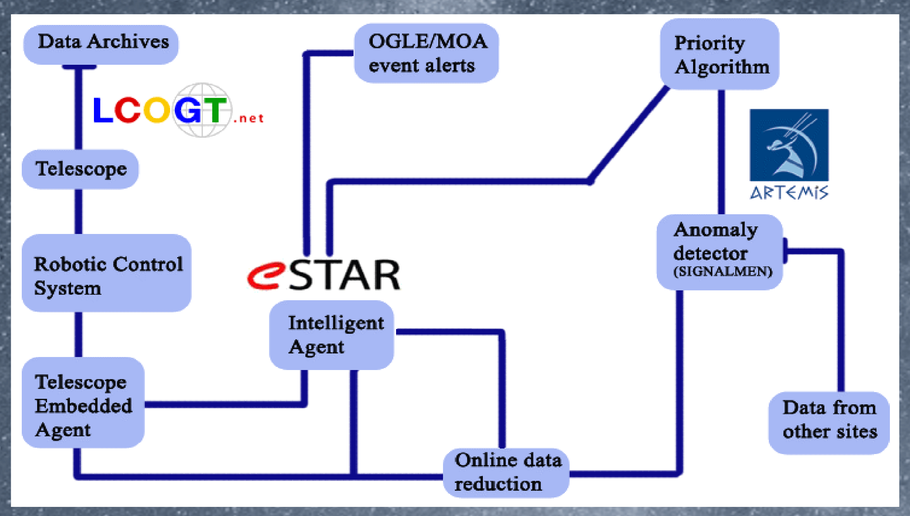


MOA-2009-BLG-319: Combined datasets from all observing sites and preliminary model by Noriyuki Miyake (Nagoya Univ.)

Robotic Telescope Network

RoboNet makes use of the 2.0m Faulkes North (Hawaii) and Faulkes South (Siding Spring) telescopes in conjunction with the Liverpool Telescope (La Palma) to look for planetary signatures in microlensing events.

By 2012, the complete LCOGT network is expected to comprise of 22x0.4m telescopes and 12x1.0m robotic telescopes, linked through the internet. As more robotic telescopes become available for microlensing follow-up, RoboNet will improve on the cool planet discovery rate.

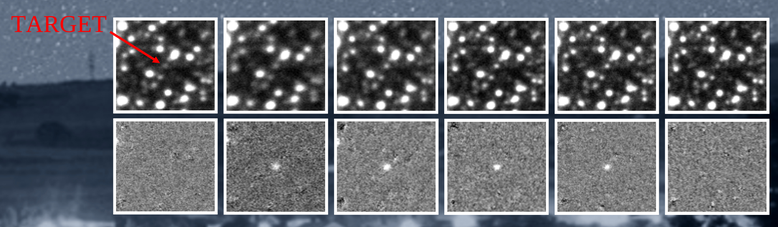


Flowchart of the robotic observing system for the RoboNet microlensing campaign

Difference Image Analysis

Incoming images are automatically sorted in appropriate event directories. Every new image is geometrically and photometrically aligned to a reference frame. The seeing of the reference is then degraded to match that of each individual image and the two are subsequently subtracted. Any regions in the resulting subtracted image that correspond to variable sources will leave a measurable residual.

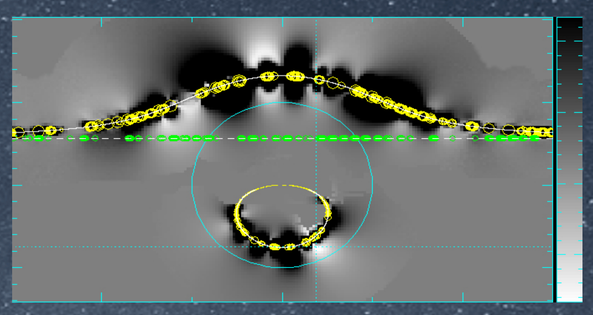
Unlike the standard *DIA* technique which involves modelling the kernel as a linear combination of Gaussian basis functions, we consider the kernel as a discrete pixel array and solve for the kernel pixel values directly. The pixel kernel model is sufficiently flexible to correct for image misalignments and distorted *PSF*s.



Detection Maps

We fit the lightcurves by a global χ^2 minimisation of a PSPL model. For each event, we calculate $\Delta\chi^2$ detection maps. These show the change in χ^2, relative to the no planet model, for a fit with a planet of mass ratio q at position x,y (measured in units of R_E).

White zones identify regions where the $\Delta\chi^2$ values are above the threshold of detection whereas black zones are the regions where the presence of the planet can be excluded given the data. The grey zones identify all the possible positions where the presence of the planet does not perturb the lightcurve i.e. $\Delta\chi^2=0$.

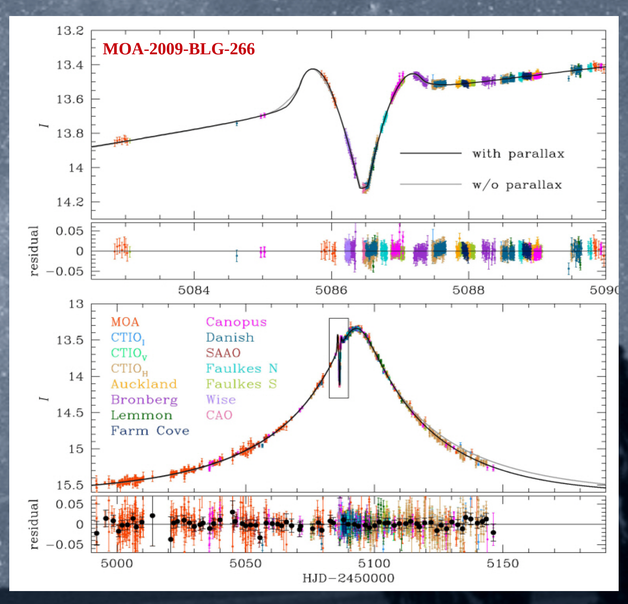


Recent Results

RoboNet has contributed to most of the microlensing planet detections to date. Ongoing analysis of the 2009 Galactic Bulge season holds evidence of the presence of at least **4 new planets**. We have obtained excellent datasets for two of these, **MOA-2009-BLG-319** and **MOA-2009-BLG-266,** and have good coverage of the remaining two.

Preliminary models of **MOA-2009-BLG-319** suggest the presence of a Jovian planet with planet/star mass ratio q~4×10^{-4}. On the other hand, the event **MOA-2009-BLG-266** (shown in the figure below) reveals a cool Neptune of mass ratio q~5×10^{-5} orbiting it's parent star at ~3.5-4.0AU.

Work on these events is ongoing.



MOA-2009-BLG-266: Combined datasets from all observing sites and preliminary model by Cheongho Han (Chungbuk Univ.)

Online Resources:

RoboNet : http://robonet.lcogt.net
ARTEMiS : http://www.artemis-uk.org
***e*STAR** : http://www.estar.org.uk
DanDIA : http://www.danidl.co.uk

Related Publications:

- A Metric and Optimisation Scheme for Microlens Planet Searches [Horne, Snodgrass, Tsapras, 2009,MNRAS,396,2087]
- A systematic fitting scheme for caustic-crossing microlensing events [Kains et al, 2009,MNRAS,395,787]
- RoboNet-II: Follow-up observations of microlensing events with a robotic network of telescopes [Tsapras et al, 2009,AN,330,4]
- A new algorithm for difference image analysis [Bramich, 2008,MNRAS,386L,77]
- ARTEMiS: A possible expert-system based cooperative effort to hunt for planets of Earth mass and below [Dominik et al, 2008,AN,329,248D]