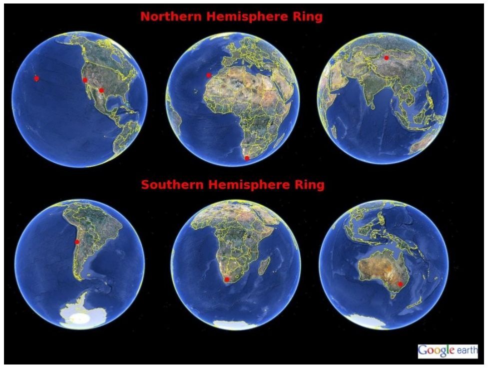
Characterizing Exoplanets via Transits and Microlensing with LCOGT

Missions.26

Rachel Street rstreet@lcogt.net

Tim Lister, Yiannis Tsapras, Avi Shporer, Federica Bianco, BJ Fulton LCOGT Keith Horne, Martin Dominik, Paul Browne, University of St. Andrews Colin Snodgrass, MPI for Solar System Research
Noé Kains, Dan Bramich, ESO Nicholas Law, University of Toronto Iain Steele, Liverpool John Moores

The Las Cumbres Observatory Global Telescope Network is in a period of major expansion. This year, we will begin to deploy 1m and 0.4m telescopes to 3 southern hemisphere sites: CTIO, SAAO and Siding Spring, Australia. These new facilities, like our two operational 2m, will be fully robotic. This will offer a unique and highly flexible tool for the characterization of exoplanets. The distributed-but-homogenous nature of the network allows us to observe targets intensively and easily combine datasets to achieve high precision over extended timescales. Here we present LCOGT programs designed to characterize exoplanets.



Network map of LCOGT facilities
Operational telescopes: 2m FTN (Hawai'i), 2m FTS (Siding Spring, Australia), 0.8m Byrne Observatory Sedgwick (California), plus test facilities in Santa Barbara, California)
Red dots indicate observing sites

Fully Robotic Telescopes with Homogenous Instrumentation

- Worldwide network → constant coverage
- All facilities will initially be equipped with imagers (spectrographs under development).
- All with standardized set of 18 filters spanning the NUV, optical and NIR (300 nm – 1050 nm).
- Dynamic, automated scheduling allows us to explore multiple science programs efficiently in parallel.
- Robotic and scriptable observation request & scheduling gives us a fast response to changes in target/program priorities.

Now being commissioned: **High Speed Cameras**

2010: Installation of first high-speed camera and successful test observations
2011: Installing upgraded high speed cameras and integrating with our robotic control system.
Andor iXon+ DU888, 1kx1k back-illuminated frame-transfer CCD
12.5 Mpix/s read out speed with variable gain.
FOV: 2.2x2.2 arcmin
Behind LCOGT-standard 18-position filter wheel

LCOGT Deployment Schedule 2010 - 2013

	2010	2011	2012	2013
Santa Barbara, CA	1m, 2x0.4m			
Byrne Observatory Sedgwick CA USA	0.8m			
Cerro Tololo Chile		1m, 2x0.4m		1m, 2x0.4m
Sutherland South Africa		1m, 2x0.4m		1m, 2x0.4m
Siding Spring Australia	2m	1m, 2x0.4m		1m, 2x0.4m
Tenerife Spain			1m, 2x0.4m	
McDonald TX USA			1m, 2x0.4m	
Haleakala HI USA	2m	0.4m		1m
Site, TBD Asia				

2014 onwards: complete 2nd-wave deployment

Eng. Test site
1st wave deploy
2nd wave deploy

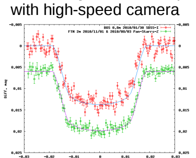
SUPA/University of St. Andrews have joined forces with LCOGT to fund up to as many as 3 additional 1m telescopes which will be operated as part of LCOGT's wider network. These telescopes will form part of our Southern ring and will be among the first telescopes online in 2011/2012. Primary science: microlensing follow-up.

Hot Planets: Transits and Low-Mass Binaries

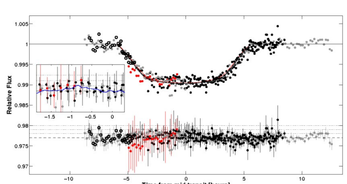
- Confirming and characterizing new survey discoveries including SuperWASP, PTF, Qatar Exoplanet Survey, HATNet, CoRoT, etc [e.g. WASP-16 Lister et al, WASP-24 Street et al.]

- Long term monitoring of targets of special interest:
- Searching for transit timing variations [Fulton, in prep.]
- Characterizing long period/rare transit event planets [e.g. HD 80606b, Hidas et al. 2010, Shporer et al. 2010]

- Soon: High time- and spacial-resolution imaging observations with high-speed camera



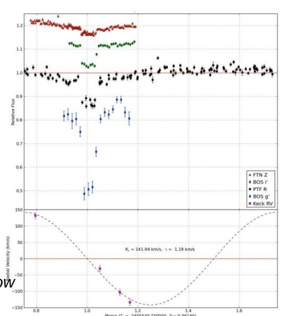
Transits of WASP-32b [Maxted et al. 2010], including data from FTN in Pan-Starrs-z from 2010/01/01 and 2010/08/03, binned to 120s and data from BOS in SDSS-I.



Two transits of HD 80606b, combining data from 9 observatories including FTN to cover the ~12hr-long events [Shporer, et al. 2010]. With a period of 111.4 d, such events are rare and require a network of facilities – but the data allow us to test models of the planetary mass/radius relation at cooler temperatures.

Palomar Transient Factory Search for Transiting Planets and Eclipsing Companions around 100,000 M-dwarfs

LCOGT is a member of PTF [Law et al. 2009] and is closely involved in following up a number of the transient phenomena it discovers. PTF/M-dwarfs [Law et al. 2011] is a planet transit survey of 100,000 M-dwarfs using the 8-sq.deg. widefield imaging capabilities of the PTF camera. The survey is sensitive to Jupiter-radius planets around all of the target stars, and has sufficient precision to reach Neptunes and super-Earths for brighter stars. The survey has been running since mid-2009 and has detected 41 new eclipsing M-dwarf binaries. LCOGT provides high cadence, high-precision, multi-color photometric follow-up of the best planetary and low-mas binary candidates, while Keck/HIRES radial velocities complete the measurements required to determine masses and radii.

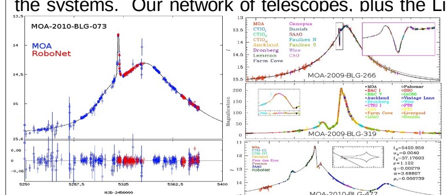


Example of follow-up data for one of our candidates, which is consistent with an M-dwarf/white dwarf binary with period 0.46145d and a time of ingress/egressof ~5.7min. Publication in preparation.

Cool Planets: Microlensing

ROBONET-II

Microlensing events can detect even terrestrial planets at wide separations from their stars, regimes which take years to probe with other techniques. Events typically last weeks to months with anomalous features betraying planetary companions lasting hours-days around the peak of the event, but densely-sampled lightcurves are critical to characterizing the systems. Our network of telescopes, plus the Liverpool Telescope, spread over a range of longitudes is an excellent tool to monitor high priority targets continuously, [eg MOA-2009-BLG-137 Ryu et al. 2010, OGLE-2008-BLG-290 Fouqué et al. 2010, OGLE-2007-BLG-368Lb Sumi et al. 2010] In the 2010 season, we supplied photometry of all events showing planetary anomalies, for which publications are in preparation.



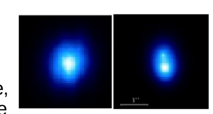
Selected events from 2010 exhibiting planetary anomalies. Models by Cheongho Han, Chungbuk National University and using his online plotting tool.

Understanding Microlensed Sources

Microlensing lightcurves require a highly non-linear model of 9+ parameters including limb-darkening coefficients for the source, so it is helpful to exploit any independent constraints which can be applied. For some events exhibiting finite source effects, a spectral type for the source star has been derived by comparing I,(V-I) photometry of the source with that of the Red Clump Giants [Bensby et al, 2010]. The Kepler Input Catalog team applied [Brown et al 2011] a different multi-band approach to spectral typing which allowed them to derive a complete set of parameters: Teff, log g, log Z, mass, radius, luminosity, reddening, extinction & distance. Taking advantage of LCOGT's large selection of filters our program in 2011 will apply both techniques to selected events, comparing their results and performance, and building a database of stars in the field for future reference.

High Speed Imaging/Photometry

Lucky imaging tests have achieved resolutions of ~0.6" from FTN. We will use this facility to achieve higher photometric precision in the crowded starfields of the Bulge, which will also help us to resolve blends of the target with its neighbors. Once these instruments are fully commissioned, their higher cadence (up to ~10Hz) will allow us to better characterize event lightcurves, particularly at times when they are changing most rapidly, e.g. during caustic crossings.



Test imaging of a close binary from FTN with and without lucky imaging.

Combined SDSS-r exposures are 13.5s each, taken at 10Hz with 1% selection used for Lucky Imaging.

References:
Hidas, M et al. 2010, MNRAS, 406, 1146. **Lister, TA** et al. 2009, ApJ, 703, 752 Bensby T et al. 2010, arXiv0911.5076 Law, N et al, 2009, PASP, 121, 1395 **Shporer, A** et al, 2010, ApJ, 722, 880 Fouqué, P et al. 2010, A&A, 518,51
Maxted, PFL et al. 2010, PASP, 122, 1465. **Street, RA** et al. 2010, ApJ, 720, 337 **Brown, T** et al. 2011, arXiv1102.0342 Law, N et al, 2011, arXiv1101.0630 Ryu Y-H et al. 2010, ApJ, 723, 81 Sumi, T et al, 2010, ApJ, 710, 1641