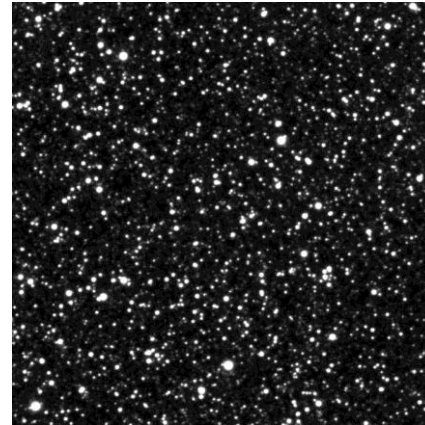


The 2010 RoboNet season



What is LCOGT

(Las Cumbres Observatory Global Telescope)

Privately funded organization

- registered charity
- ~40 people
- main offices in Santa Barbara, CA
- operational offices in Liverpool, UK



Dedicated to time-domain astronomy

- members of Pan-STARRS, LSST, PTF
- staff involved with SN Legacy Survey, Kepler, SuperWASP, RoboNet
- collaborations strongly encouraged

What is LCOGT

(Las Cumbres Observatory Global Telescope)

Building world-wide network of telescopes

- fully robotic, controlled by scheduling algorithms
- identical design, instrumentation
- will be available to astronomical community & schools
- all software developed & mechanical designs open-source



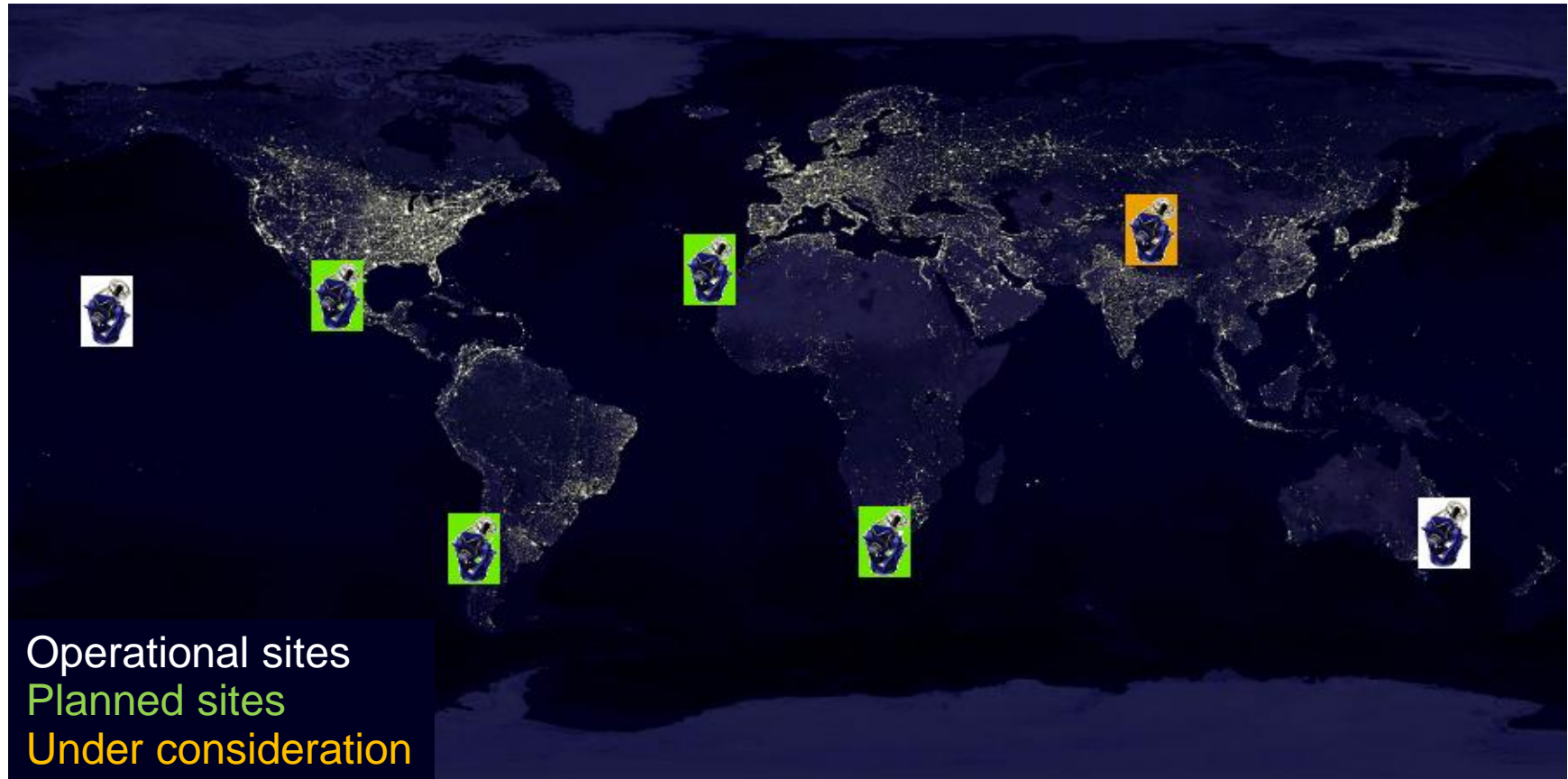
Astronomy Staff

- 2 staff astronomers
- 8 post-docs
- 2 PhD students



Complete network

<http://lcogt.net/>



- 2x2m, ~12x1m, ~22x0.4m
- SUPA-II grant from St Andrews → +3x1m telescopes
- 22x1m mirrors ordered

Status of new telescopes

Working 1m prototype in SBA

- still testing fully robotic controls

CTIO:

- initial site work for foundations finished
- awaiting 1.0m domes and Aqawans
- soon to follow → 1.0m and 2x0.4m
- ready March 2011

SAAO:

- foundations ready
- deployment of 1m and 2x0.4m after CTIO
- expected ~Q3 2011



The RoboNet project



Yiannis Tsapras
Rachel Street



Keith Horne
Martin Dominik
Paul Browne



Colin Snodgrass
Dan Bramich



Iain Steele

The RoboNet project



Yiannis Tsapras
Rachel Street



Keith Horne
Martin Dominik
Paul Browne



Colin Snodgrass
Dan Bramich



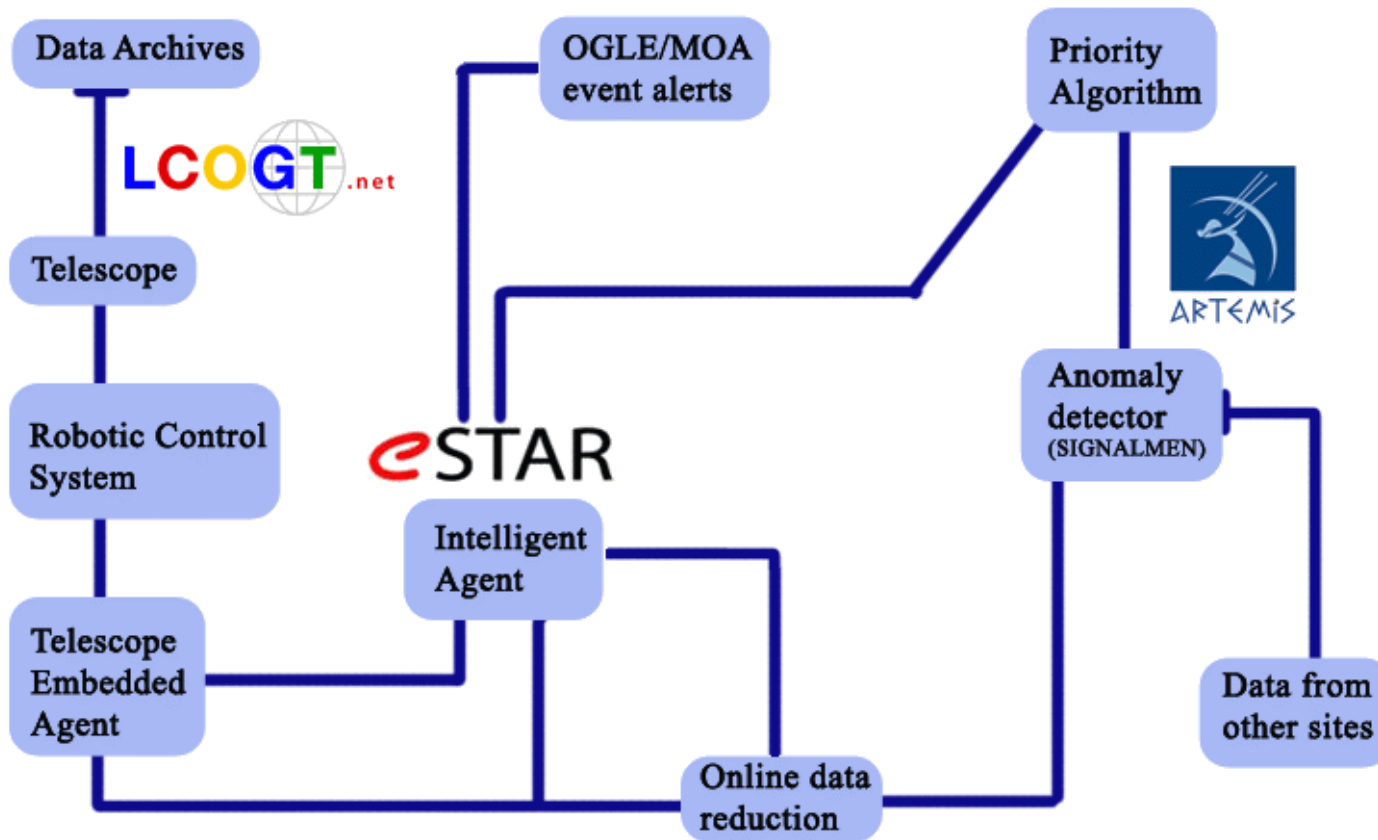
Iain Steele

- using LCOGT telescopes together with Liverpool Telescope (currently FTN, FTS, LT)
- follow-up on microlensing alerts by OGLE/MOA
- operate robotically with real-time automatic target selection
- occasional use of ToOs

Performing the observations

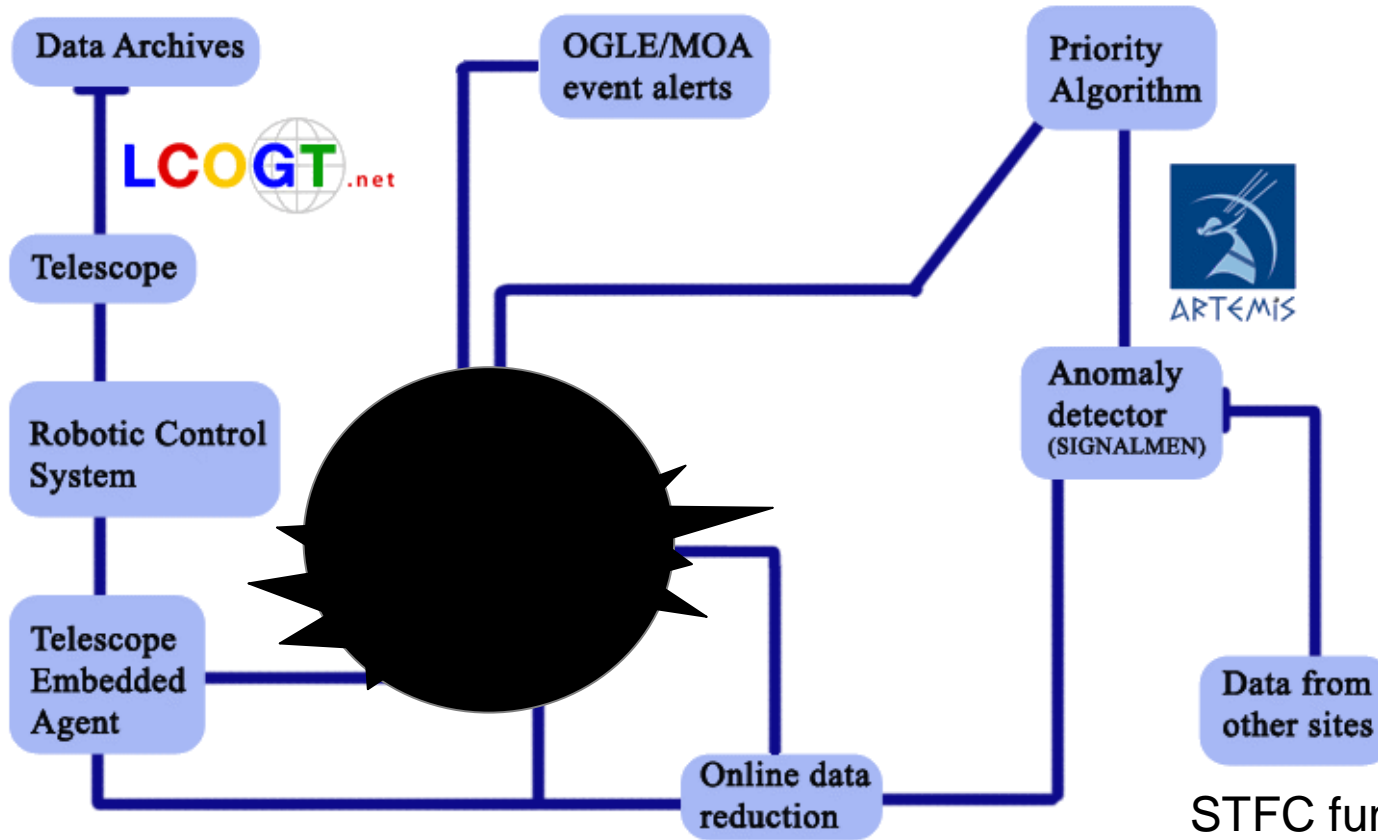
- new microlensing events picked up from internet alerts
- targets selected through **prioritization algorithm** and submitted to network
 - calculates optimal required sampling for each event
 - maximize planet detection probability
 - requires complete **LCOGT** network for optimal performance
 - Adaptive Scheduling - priorities reassessed every few minutes

eSTAR



- RoboNet was depending on eSTAR system
- collecting and distributing observation requests to network
- dealt with translating observing request → telescope babble

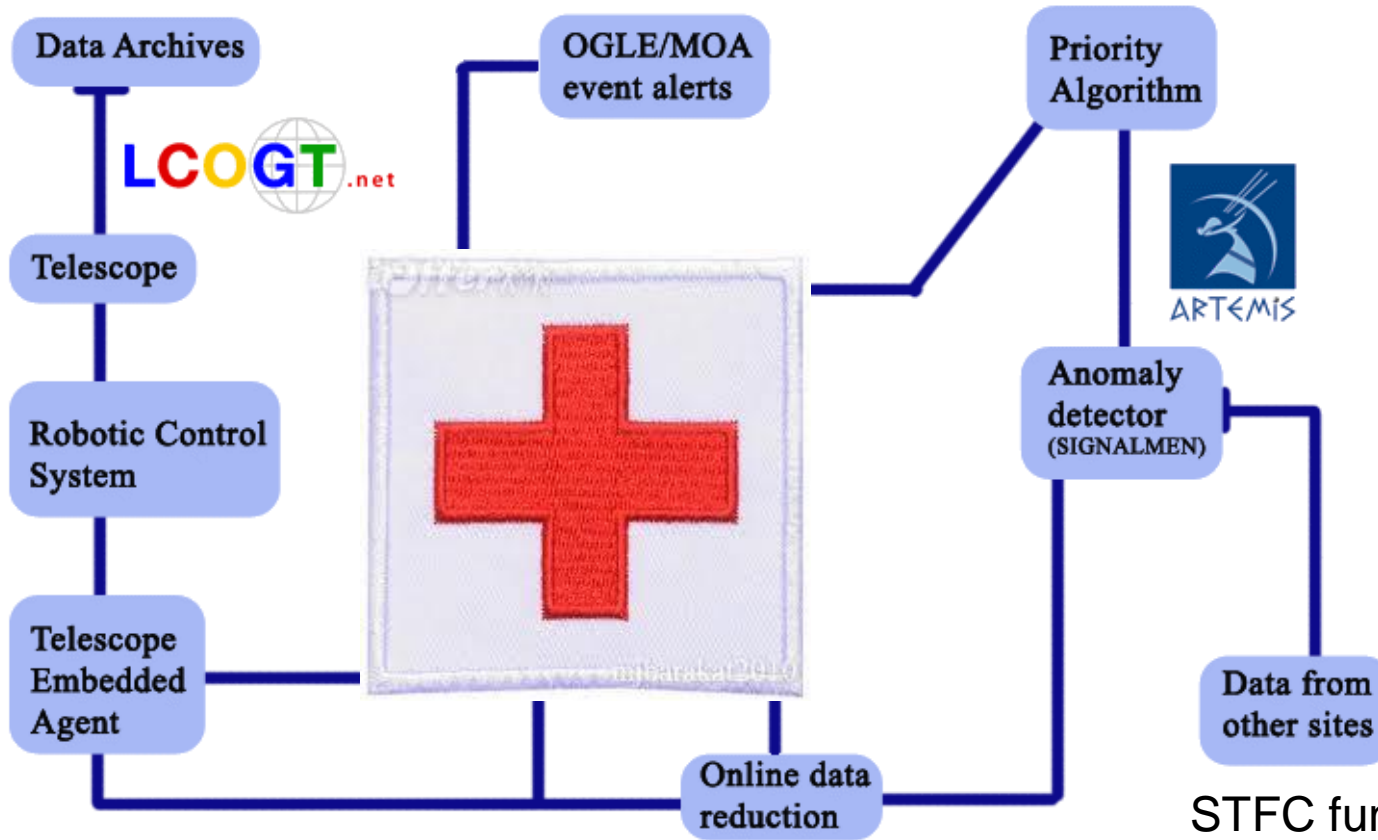
eSTAR



STFC funding cuts in UK



eSTAR



STFC funding cuts in UK



Queue observations online

| Event Information | | |
|---|--|--|
| R.A. : <input type="text"/> <small>Format: hh:mm:ss.s</small> | Dec. : <input type="text"/> <small>Format: ±dd:mm:ss.s</small> | Name : MOA-2010-BLG-481 <small>Event name:(e.g. MOA-2010-BLG-123)</small> |
| Observing Constraints | | |
| Type : Flexible observation ▾ <small>Type of observation requested</small> | Exposure Time: <input type="text"/> <small>Exposure time (secs) (Exposure Time Calculator)</small> | Exposure Count: <input type="text"/> <small>Exposures to obtain in the group</small> |
| Telescope: FTN ▾ <small>Telescope requested</small> | Instrument: EM01(FTN) ▾ <small>Instrument requested</small> | Filter : SDSS-I ▾ <small>Filter requested</small> |
| Simulate: False ▾ <small>Select simulation mode or add to the observation queue</small> | Priority: Normal ▾ <small>Select required priority</small> | TTL: 1 <small>Time to Live (Lifetime of group in fractional days)</small> |
| | | <input type="button" value="Submit Event"/> <input type="button" value="Reset Input Fields"/> |

Edit active groups

| ObsGrpID | Telescope | Instrument | Filter | sourceID |
|--|-----------|------------|--------|-------------------|
| <input type="checkbox"/> RBN20100930T18.00105199 | FTN | EM01 | SDSS-I | MOA-2010-BLG-0364 |
| <input type="checkbox"/> RBN20100930T18.00105207 | FTN | EM01 | SDSS-I | MOA-2010-BLG-0117 |
| <input type="checkbox"/> RBN20100930T18.00105211 | FTN | EM01 | SDSS-I | MOA-2010-BLG-0587 |
| <input type="checkbox"/> RBN20100930T18.00105215 | FTN | EM01 | SDSS-I | MOA-2010-BLG-0583 |
| <input type="checkbox"/> RBN20100930T21.00126058 | FTS | EM03 | SDSS-I | MOA-2010-BLG-0364 |
| <input type="checkbox"/> RBN20100930T21.00126067 | FTS | EM03 | SDSS-I | MOA-2010-BLG-0117 |
| <input type="checkbox"/> RBN20100930T21.00126071 | FTS | EM03 | SDSS-I | MOA-2010-BLG-0587 |
| <input type="checkbox"/> RBN20100930T21.00126074 | FTS | EM03 | SDSS-I | MOA-2010-BLG-0583 |



(Un)Check All

Submit Request

Simulate: True ▾

Active status page

Current List of Active Observation Requests from RoboNet

Guidelines:

Click [here](#) for information about this log.

Click [here](#) to see the ObsControl system log.

Last updated: 2010-09-30T23:00:03

Observations queued at LT - currently in nighttime

| GrpID | Target | RA(J2000) | Dec(J2000) | Filter | ExpTime | ExpCommit | ExpTaken | Priority | TS_Submit | TS_Expire | ReqOrigin | RCS_Report |
|-------------------------|------------------|-------------|-------------|--------|---------|-----------|----------|----------|---------------------|---------------------|------------|------------|
| RBN20100930722.83443448 | MO42101-B1G-0583 | 18:06:15.10 | -27:10:48.4 | J | 175 | 1 | 0 | normal | 2010-09-30T22:50:03 | 2010-10-01T00:02:03 | nlrcontrol | add_OK |
| RBN20100930722.83443433 | MO42101-B1G-0354 | 17:57:05.33 | -34:27:05.0 | J | 3 | 1 | 0 | normal | 2010-09-30T22:50:03 | 2010-10-01T00:02:03 | nlrcontrol | add_OK |
| RBN20100930722.83443441 | MO42101-B1G-0117 | 18:07:49.66 | -25:20:40.6 | J | 48 | 1 | 0 | normal | 2010-09-30T22:50:03 | 2010-10-01T00:02:03 | nlrcontrol | add_OK |
| RBN20100930722.83443445 | MO42101-B1G-0587 | 18:05:48.48 | -27:13:26.2 | J | 100 | 1 | 0 | normal | 2010-09-30T22:50:03 | 2010-10-01T00:02:03 | nlrcontrol | add_OK |

Observations queued at FTS - currently in daytime

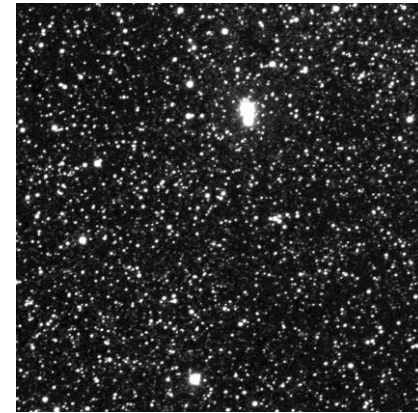
| GrpID | Target | RA(J2000) | Dec(J2000) | Filter | ExpTime | ExpCommit | ExpTaken | Priority | TS_Submit | TS_Expire | ReqOrigin | RCS_Report |
|-------------------------|------------------|-------------|-------------|--------|---------|-----------|----------|----------|---------------------|---------------------|------------|------------|
| RBN20100930721.00126074 | MO42101-B1G-0583 | 18:06:15.10 | -27:10:48.4 | SDSS-I | 168 | 1 | 0 | normal | 2010-09-30T21:00:04 | 2010-10-01T11:00:04 | nlrcontrol | add_OK |
| RBN20100930721.00126058 | MO42101-B1G-0354 | 17:57:05.33 | -34:27:05.0 | SDSS-I | 4 | 1 | 0 | normal | 2010-09-30T21:00:04 | 2010-10-01T11:00:04 | nlrcontrol | add_OK |
| RBN20100930721.00126071 | MO42101-B1G-0587 | 18:05:48.48 | -27:13:26.2 | SDSS-I | 56 | 1 | 0 | normal | 2010-09-30T21:00:04 | 2010-10-01T11:00:04 | nlrcontrol | add_OK |
| RBN20100930721.00126067 | MO42101-B1G-0117 | 18:07:49.66 | -25:20:40.6 | SDSS-I | 48 | 1 | 0 | normal | 2010-09-30T21:00:04 | 2010-10-01T11:00:04 | nlrcontrol | add_OK |

Observations queued at FTN - currently in daytime

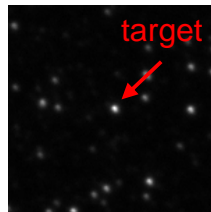
| GrpID | Target | RA(J2000) | Dec(J2000) | Filter | ExpTime | ExpCommit | ExpTaken | Priority | TS_Submit | TS_Expire | ReqOrigin | RCS_Report |
|-------------------------|------------------|-------------|-------------|--------|---------|-----------|----------|----------|---------------------|---------------------|------------|------------|
| RBN20100930718.00105215 | MO42101-B1G-0583 | 18:06:15.10 | -27:10:48.4 | SDSS-I | 170 | 1 | 0 | normal | 2010-09-30T18:00:03 | 2010-10-01T18:00:03 | nlrcontrol | add_OK |
| RBN20100930718.00105198 | MO42101-B1G-0354 | 17:57:05.33 | -34:27:05.0 | SDSS-I | 5 | 1 | 0 | normal | 2010-09-30T18:00:03 | 2010-10-01T18:00:03 | nlrcontrol | add_OK |
| RBN20100930718.00105211 | MO42101-B1G-0587 | 18:05:48.48 | -27:13:26.2 | SDSS-I | 94 | 1 | 0 | normal | 2010-09-30T18:00:03 | 2010-10-01T18:00:03 | nlrcontrol | add_OK |
| RBN20100930718.00105207 | MO42101-B1G-0117 | 18:07:49.66 | -25:20:40.6 | SDSS-I | 50 | 1 | 0 | normal | 2010-09-30T18:00:03 | 2010-10-01T18:00:03 | nlrcontrol | add_OK |

Data Reduction Pipeline

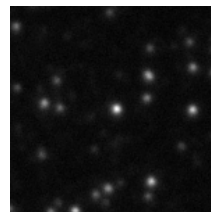
- intercepts incoming images from telescopes
- performs initial quality assessment
- initiates **Difference Image Analysis** Pipeline
 - creates template reference image
 - automatic target identification
 - geometric and photometric alignment of all images to reference
 - matches the seeing between reference and each image
 - subtracts each scaled image from reference
 - variable stars leave a positive or negative residual
 - fits PSF to target position
 - updates photometry & webpages, distributes lightcurves



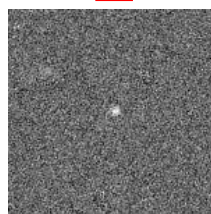
Reference



-



=



Difference

DIA results online

RoboNet-II - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://robonet.lcogt.net/cgi-bin/event_image_details.cgi?event=MOA-2010-BLG-0073&telescop Google

Microlensing event: MOA-2010-BLG-0073

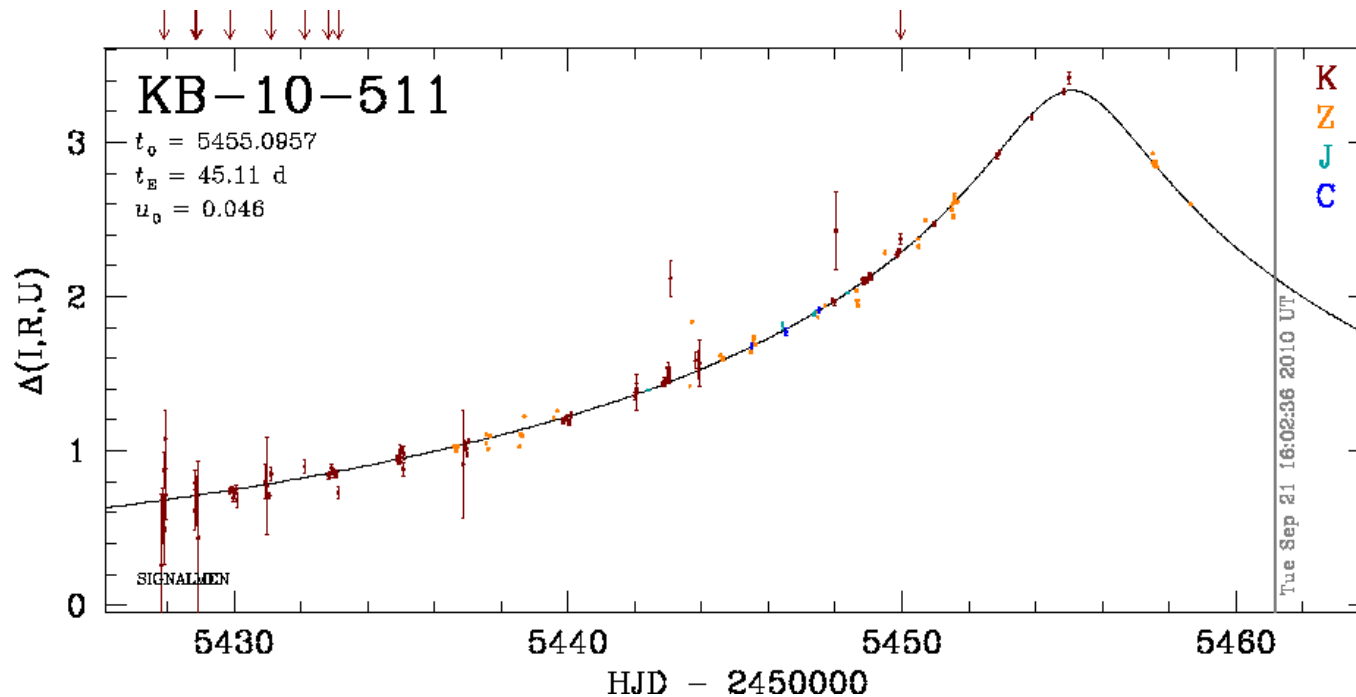
RoboNet-II data:
[MOA-2010-BLG-0073_FTN_SDSS-I.vot](#)
[MOA-2010-BLG-0073_FTN_SDSS-I.t](#)

| Telescope | HJD 245+(d) | Image Name | Image | Diff. Image | χ^2/N_{pix} | FWHM(pix) | Sky(ADU) | Phot. Scale | Airmass | Filter | Exp. time(s) |
|-----------|----------------|--------------------------|-------|-------------|-------------------------|-----------|----------|----------------|---------|--------|-----------------|
| FTN | 5321.944 | 1_e_20100504_059_001_1_9 | | | 1.197 | 4.037 | 159.291 | 0.768 | 2.446 | SDSS-I | 18.0 |
| FTN | 5321.945 | 1_e_20100504_059_003_1_9 | | | 1.146 | 4.927 | 159.131 | 0.768 | 2.423 | SDSS-I | 18.0 |
| FTN | 5321.945 | 1_e_20100504_059_004_1_9 | | | 1.062 | 4.781 | 160.772 | 0.764 | 2.411 | SDSS-I | 18.0 |
| FTN | 5321.946 | 1_e_20100504_059_005_1_9 | | | 1.09 | 5.142 | 160.8 | 0.767 | 2.4 | SDSS-I | 18.0 |
| FTN | 5321.946 | 1_e_20100504_059_006_1_9 | | | 1.064 | 5.719 | 160.587 | 0.763 | 2.388 | SDSS-I | 18.0 |

Anomaly detection



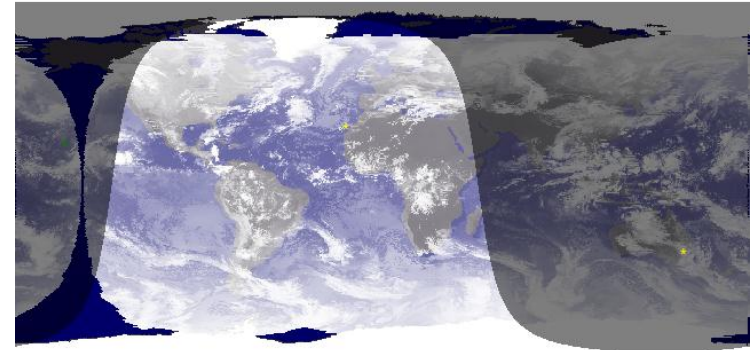
- uses **ARTEMIS** system hosted in St Andrews
- receives new data by *rsync* from RoboNet-II cluster
- data from other telescopes also included, if available
- identifies new points that are deviating
- action requests: *check*, *anomaly*, *ordinary*
- no manual intervention needed
- can trigger automatic overrides to confirm/deny anomalies



robonet.lcogt.net

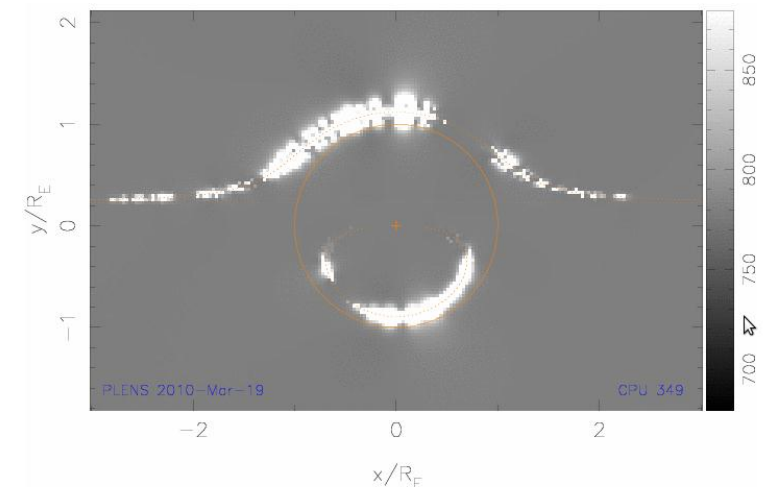
- can submit manual requests for observations & ToOs
- online logs of observations (active and expired)
- displays real-time status of system
- allows interactive inspection of pipeline results
- hosts event prioritization pages
 - displays relative priorities
 - event parameters & reduction information
 - single-lens lightcurve fits
 - detection maps

RoboNet-II Status at UT: 2010-10-13 14:36:26.820313.



| | Status: | Data Flow: | Data Flow: | Links: |
|-------------|-----------------|----------------|--------------|--------------------|
| PLOP: | Autodownload | datacatcher | Get LT data | Observing Calendar |
| | Plens Control | reception | ObsControl | LCOGT Quicklook |
| | Data Subscriber | pipemonitor | dicontrol | LT Quicklook |
| Pipeline: | ARTEMIS comms | schools page | MOA updates | Live Status LCOGT |
| | rundandia | R D subscriber | eventmonitor | Live Status LT |
| Telescopes: | FTN | update | | Plens Fit Status |
| | FTS | | | School pages |
| | LT | | | Post report |

Green = Status OK/OPEN, Orange = Status OFF/CLOSED, Red = stale process,
Purple = Running but Lock file present, Grey = Status Unknown

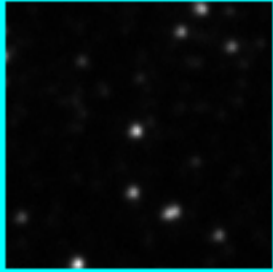


Event pages

Number of frames per filter and telescope

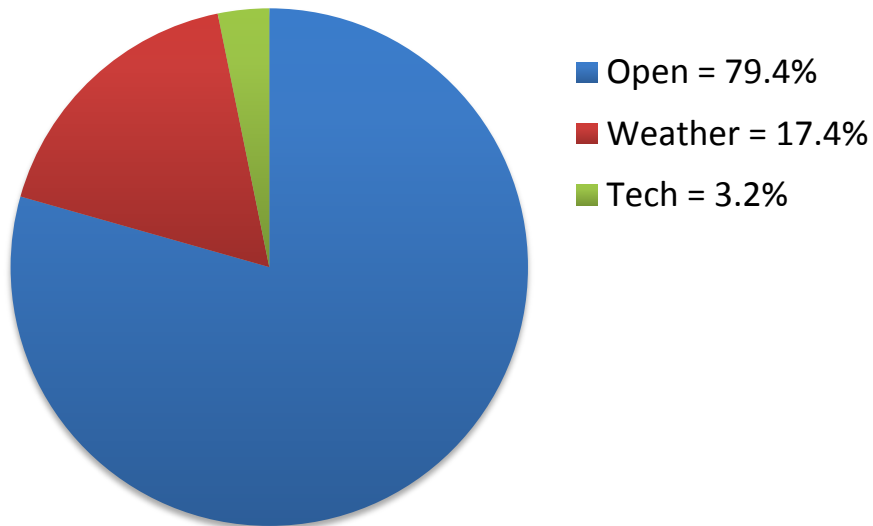
| Tel | Filter | N preproc | N register | N diff | Red Status | View: |
|-----|--------|-----------|------------|--------|------------|----------------------------|
| FTN | SDSS-I | 172 | 167 | 167 | halted | FTN stamps |
| FTS | SDSS-I | 135 | 135 | 135 | halted | FTS stamps |
| LT | SDSS-I | 178 | 170 | 170 | halted | LT stamps |

Finderchart and reference frames

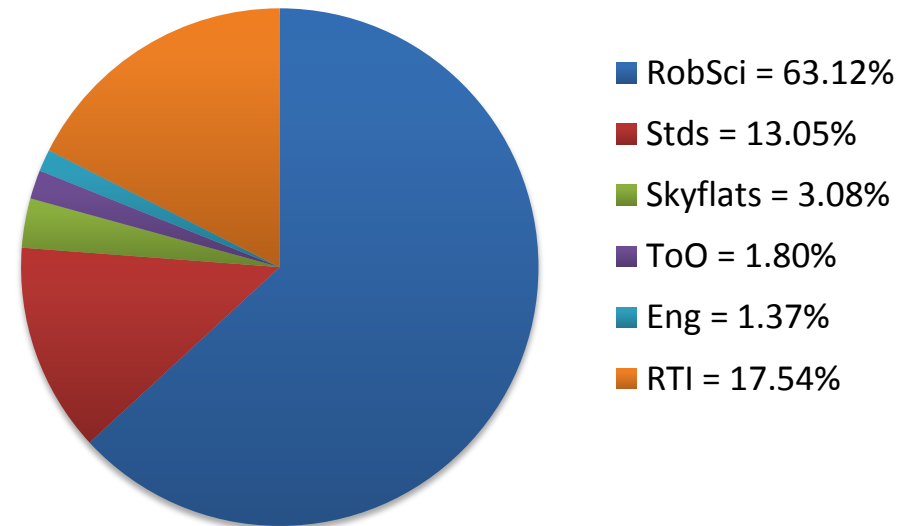
| | | |
|-----|---|-------------|
| FTN | SDSS-I | Finderchart |
| |  Edit Red.Config Reset Reduction Start Reduction Remove Reduction Lock | |

FTN: 2010 at a glance

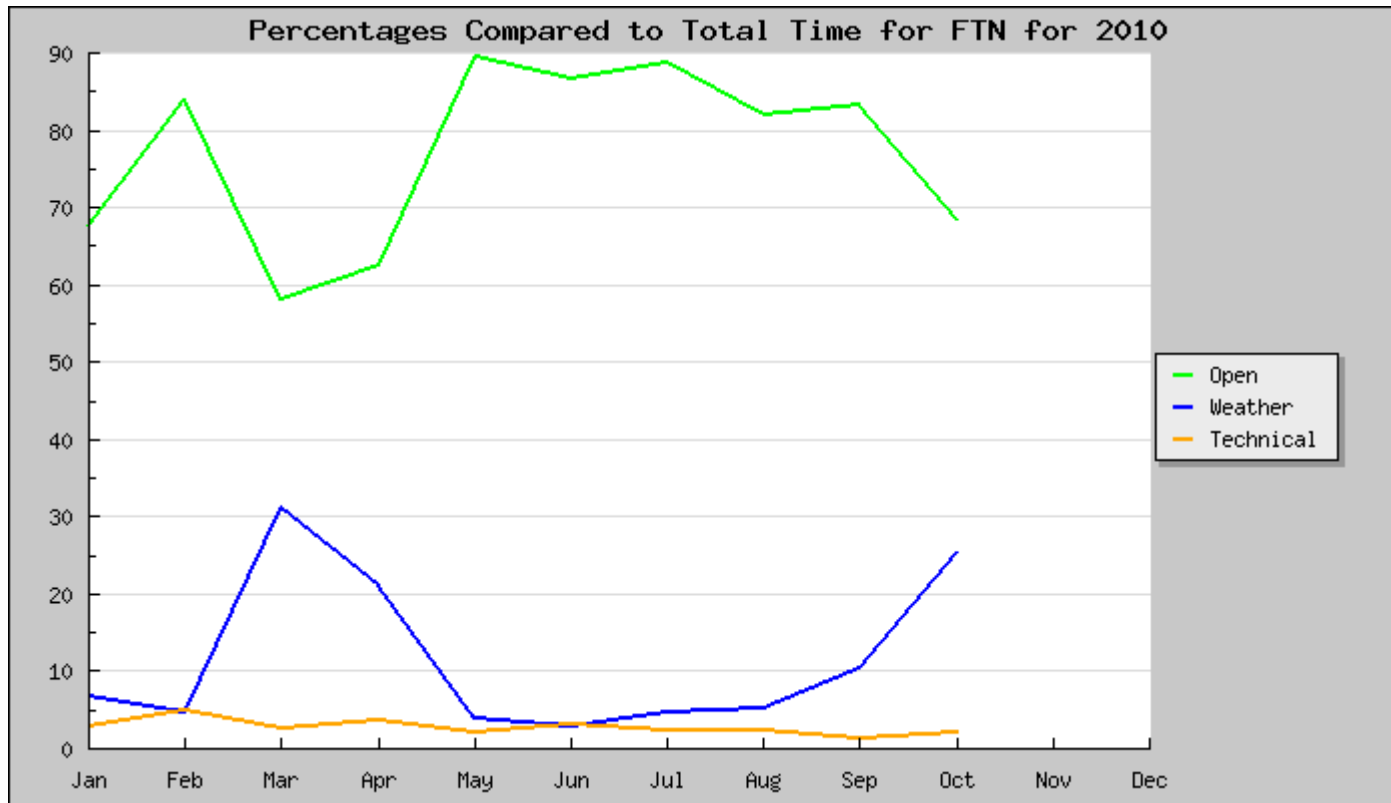
FTN 2010 at a glance



FTN 2010 CCD open shutter times

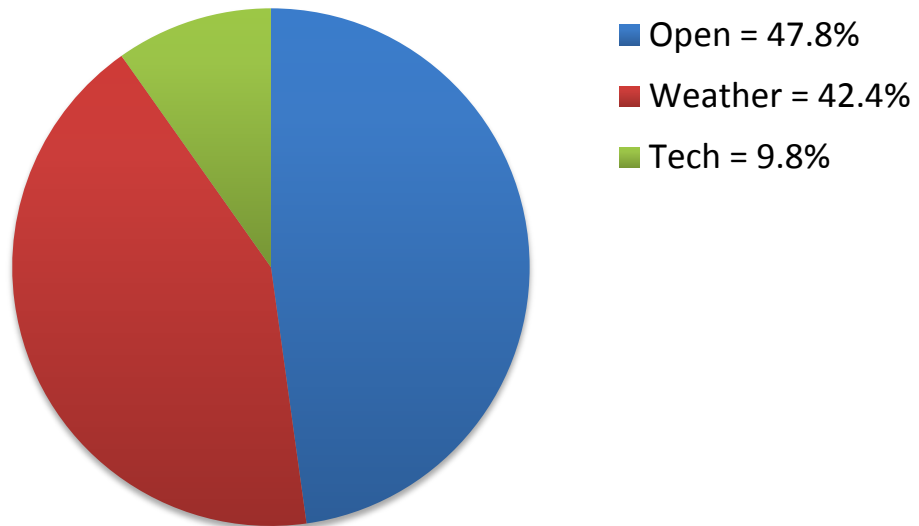


Weather conditions (Hawaii)

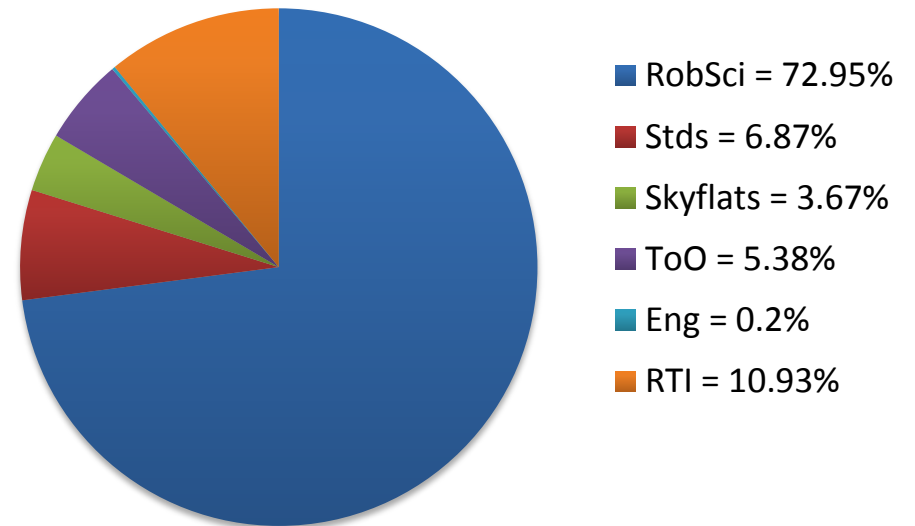


FTS: 2010 at a glance

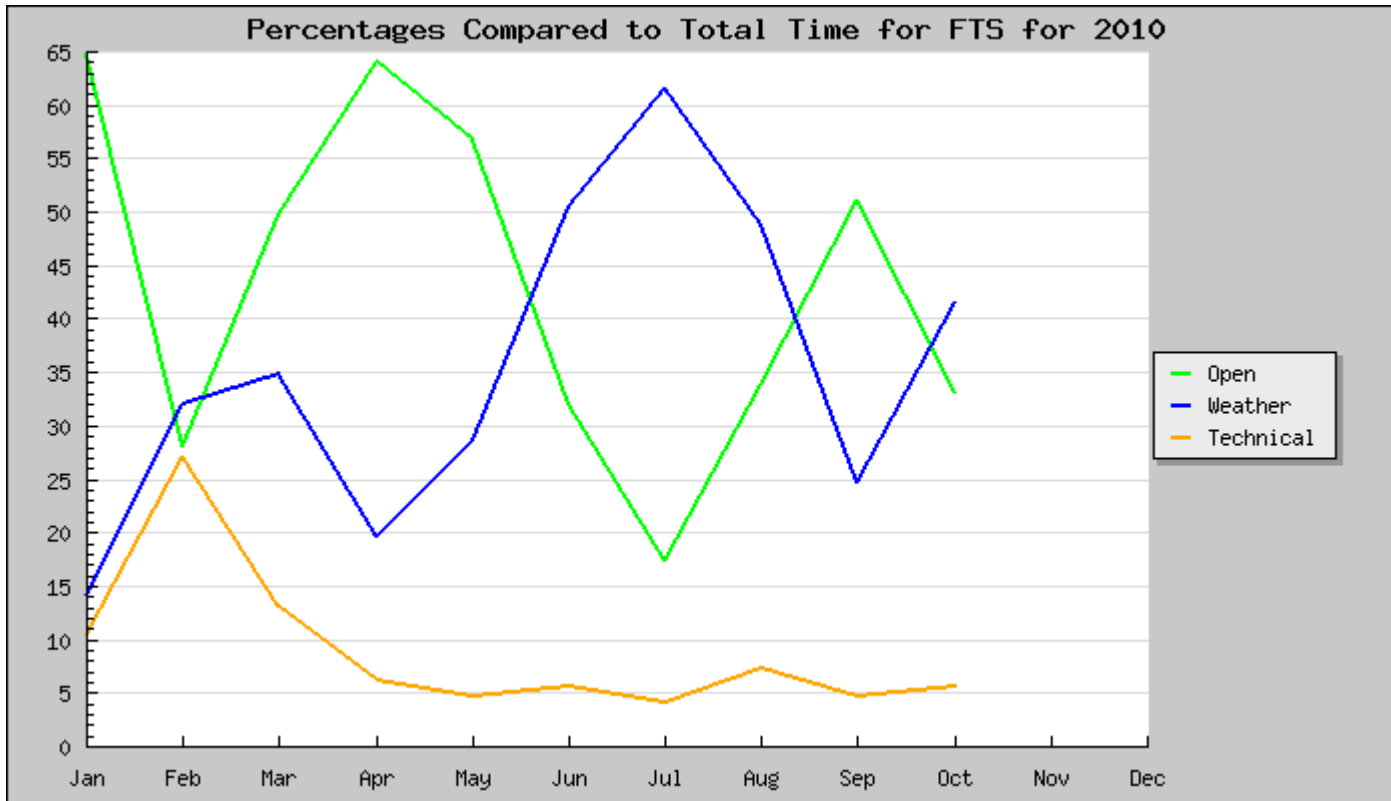
FTS 2010 at a glance



FTS 2010 CCD open shutter times

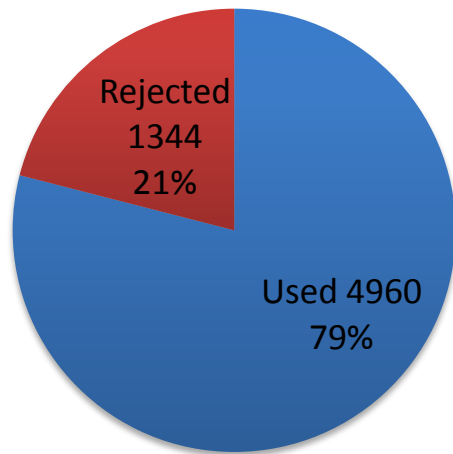


Observing conditions (Siding Spring)

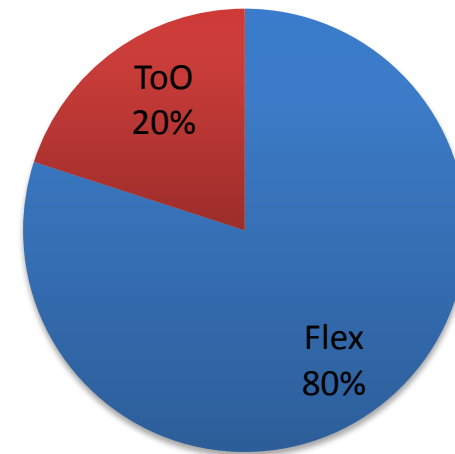


2010 Observation summary

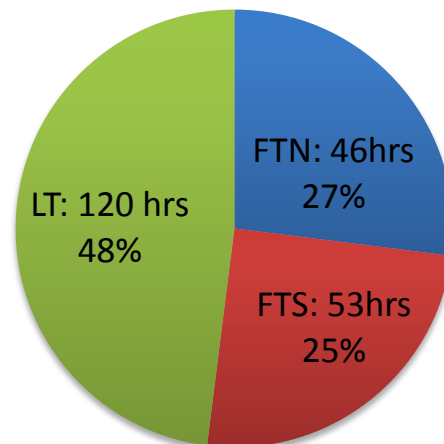
Total Nr of Images rejected



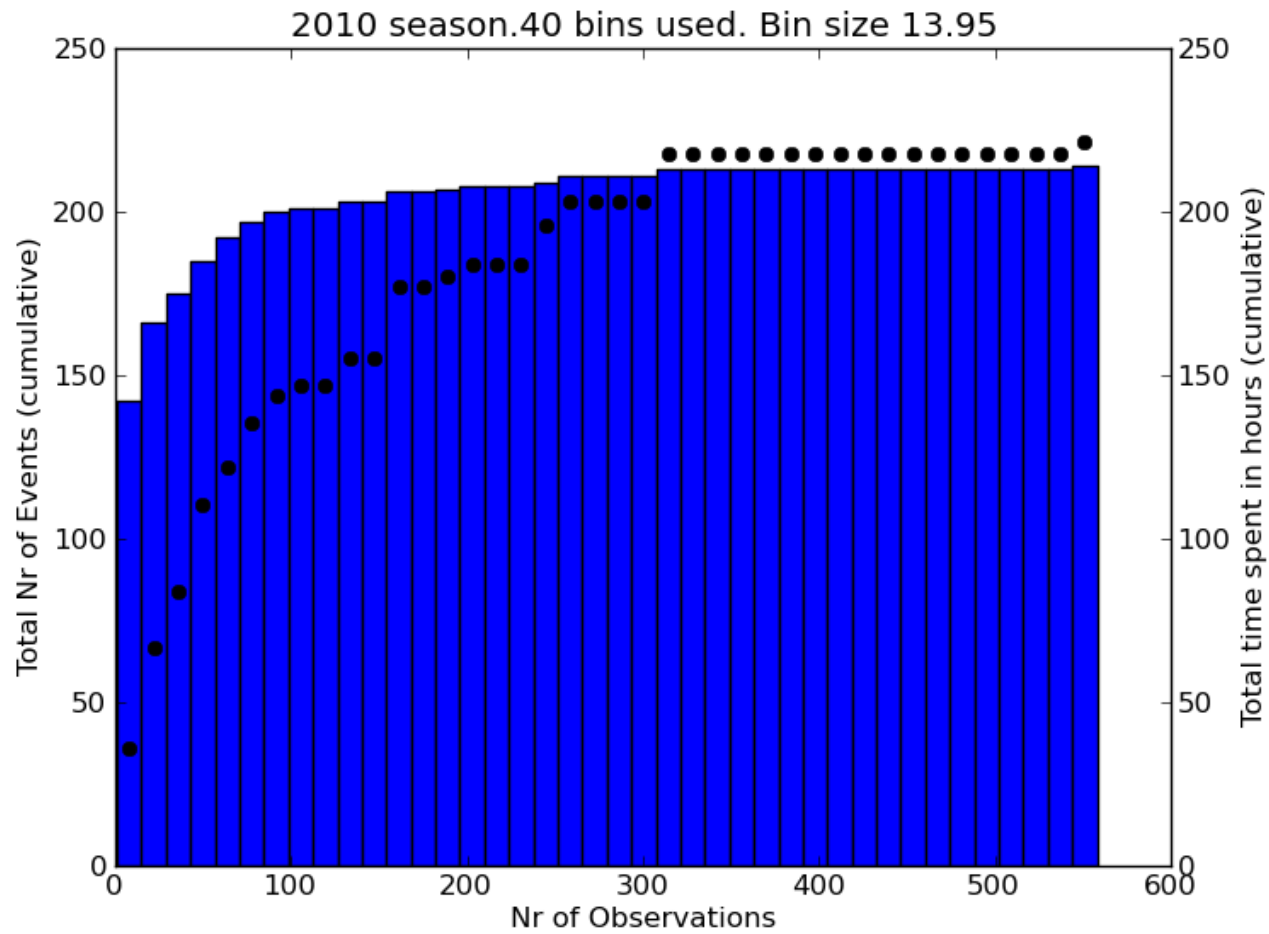
ToO vs. Flexible time used



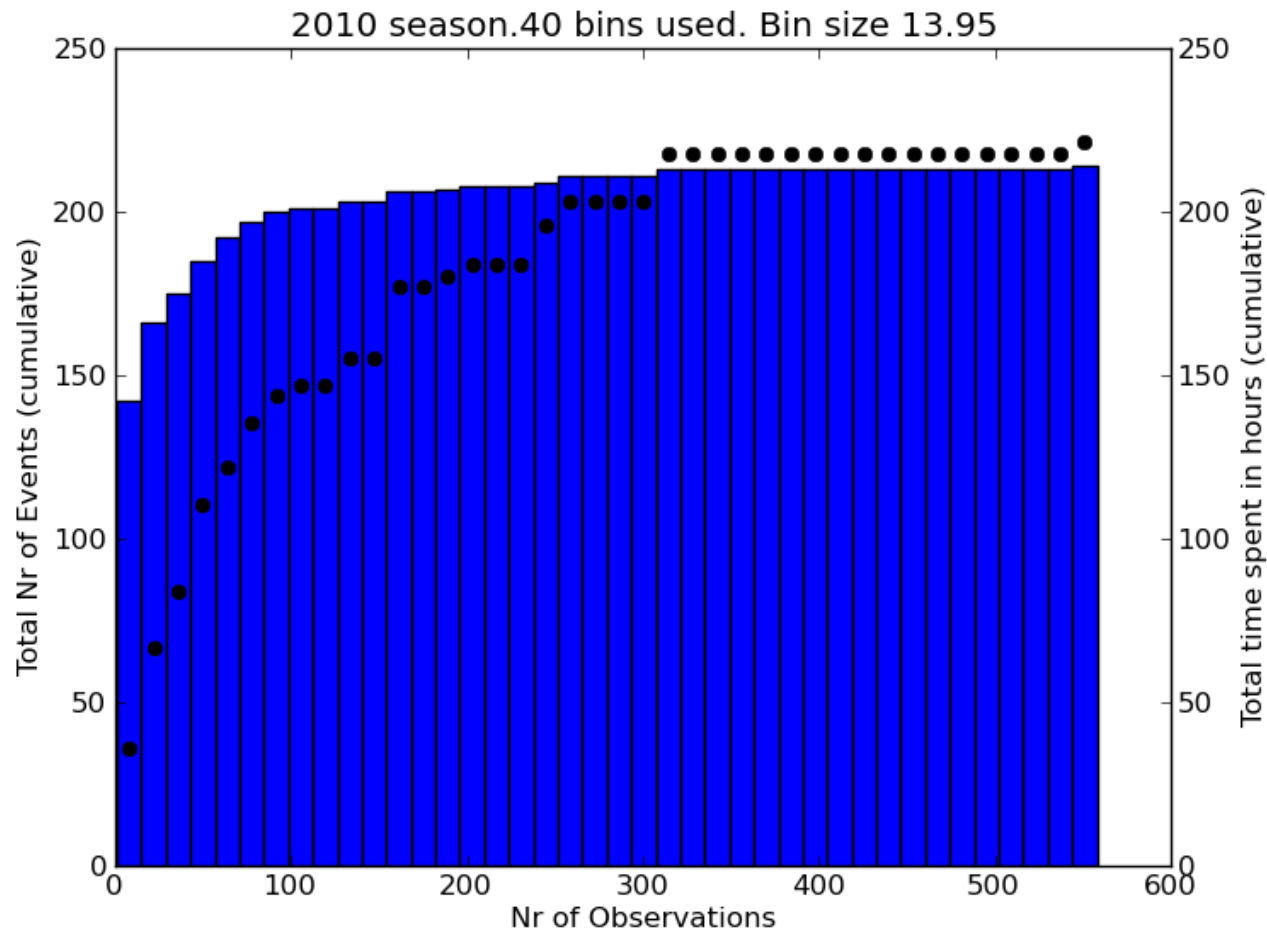
Fraction of Images per Telescope



Events followed

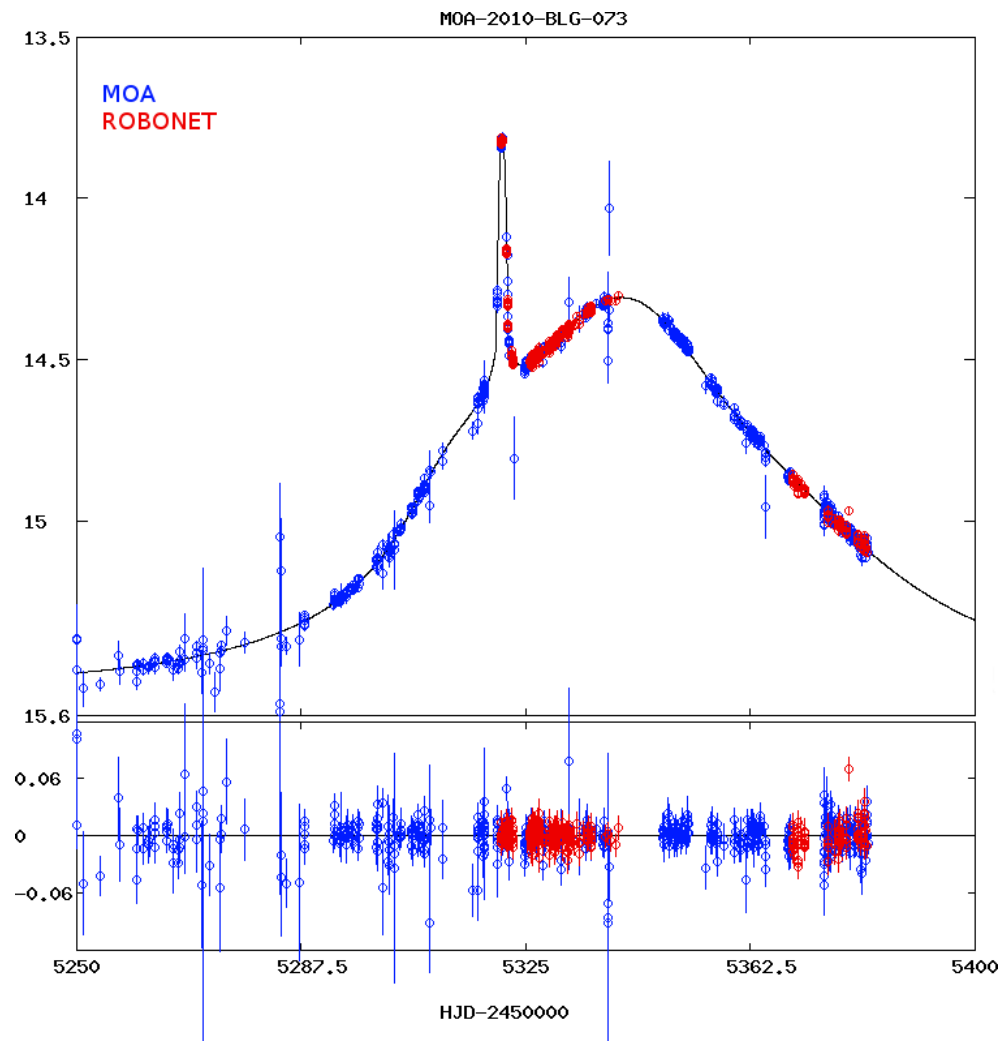
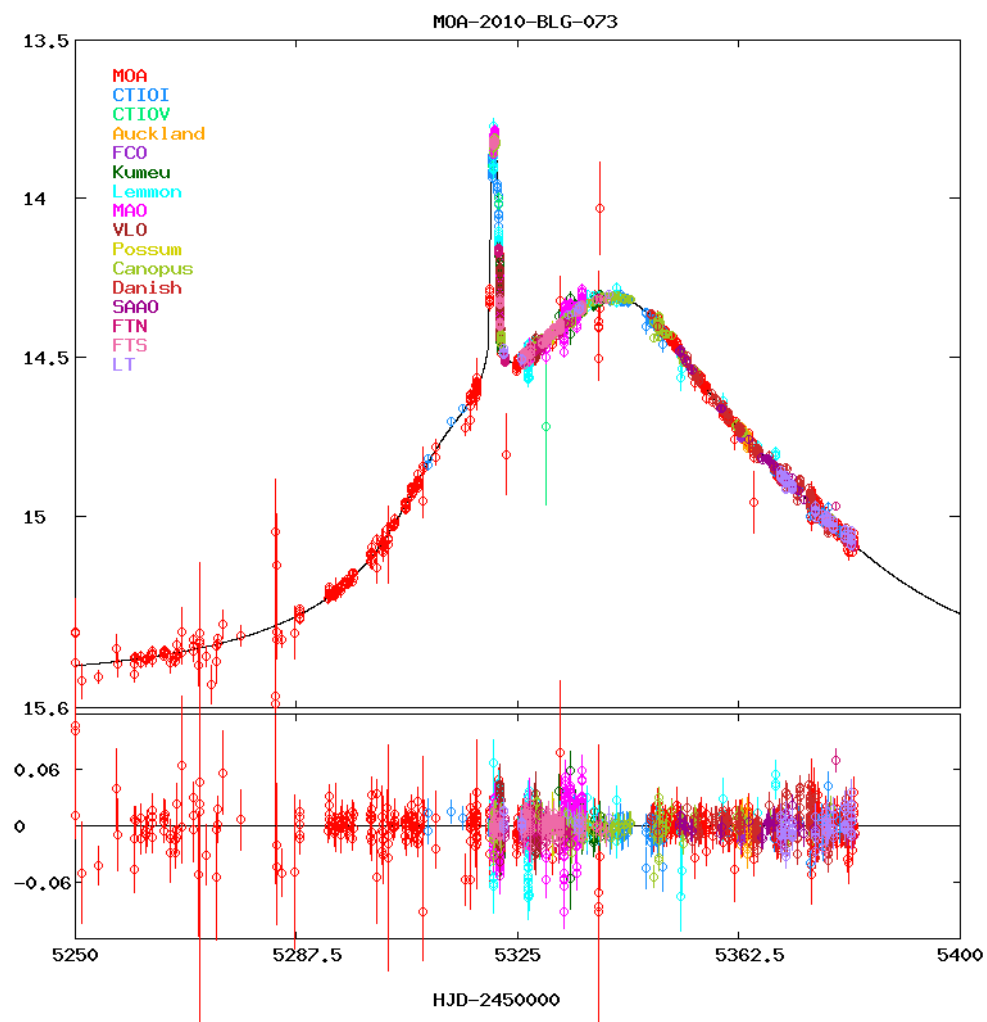


Events followed

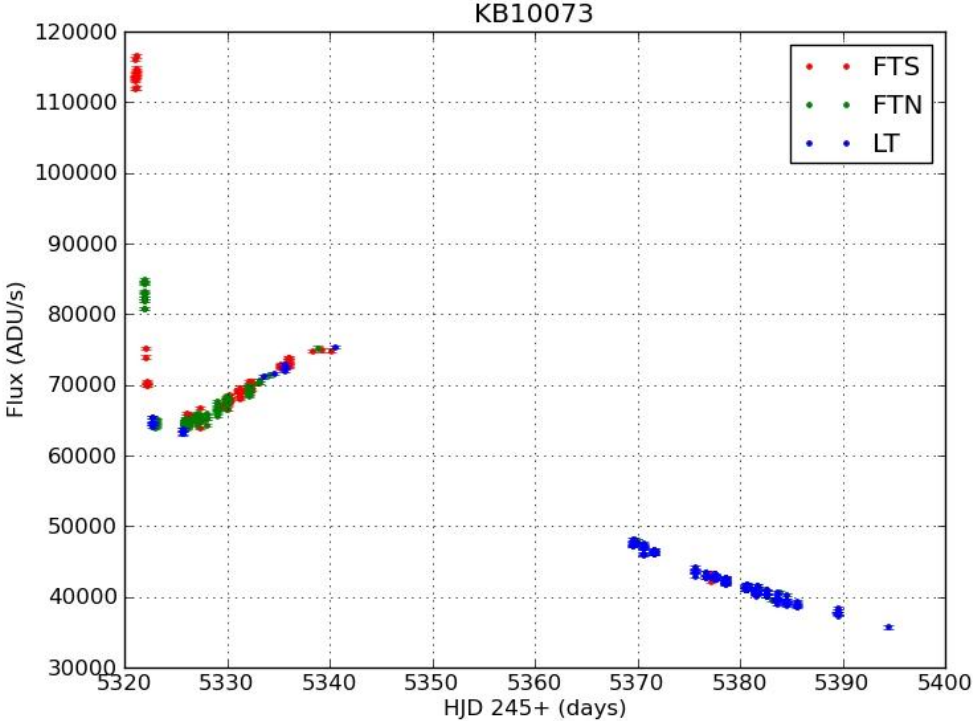
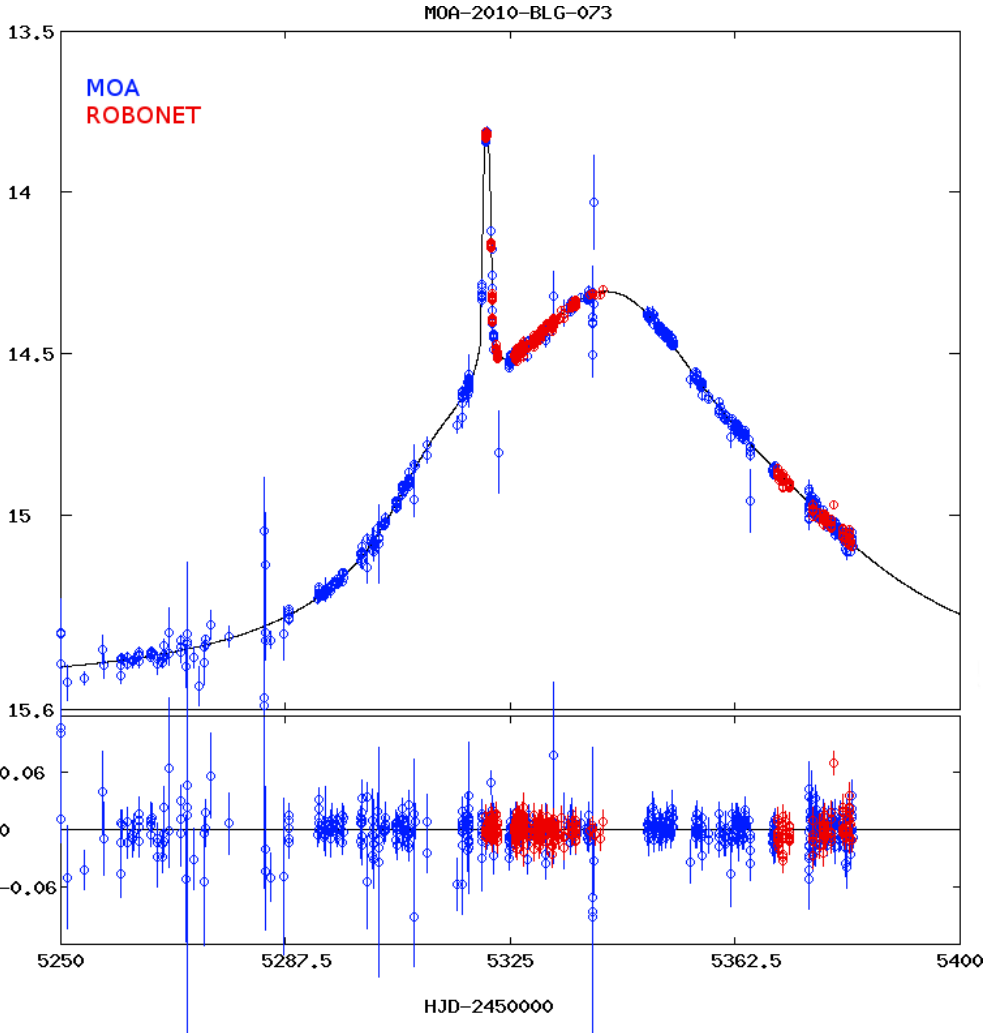


- Observed ~200 events
- Used ~220 hours
- 140 events:
 - <13 observations
 - used 16% of time
- 13 events (inc. planet cand.):
 - >100 observations
 - used 36% of time
- 48% of total time went to remaining events

MOA-2010-073

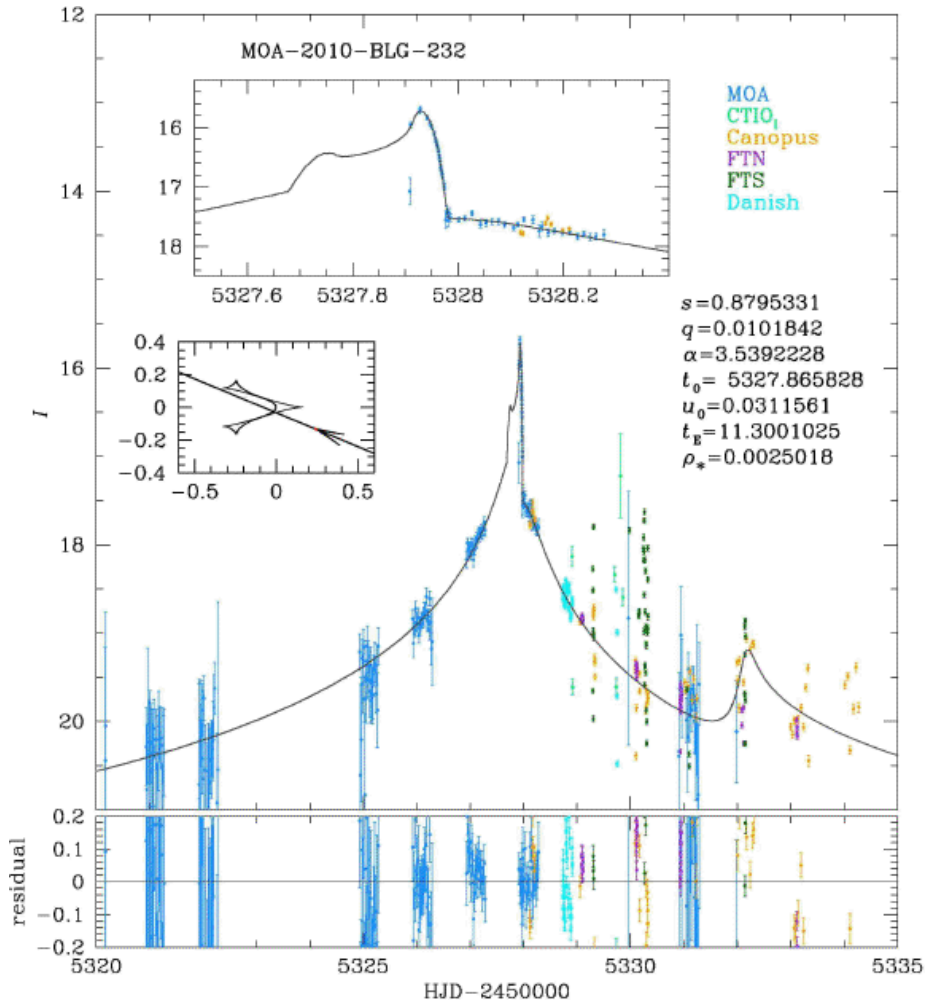


MOA-2010-073



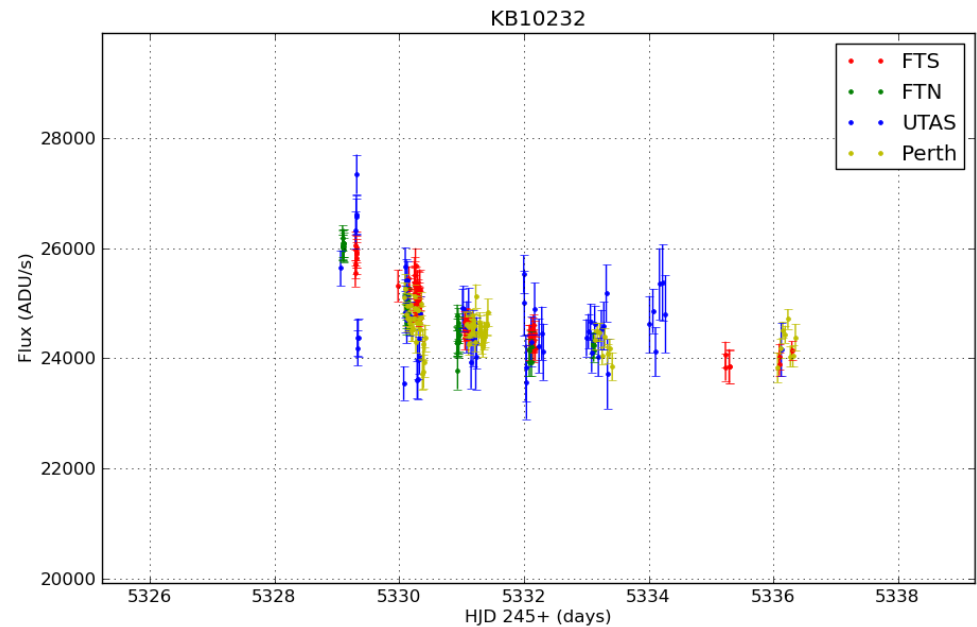
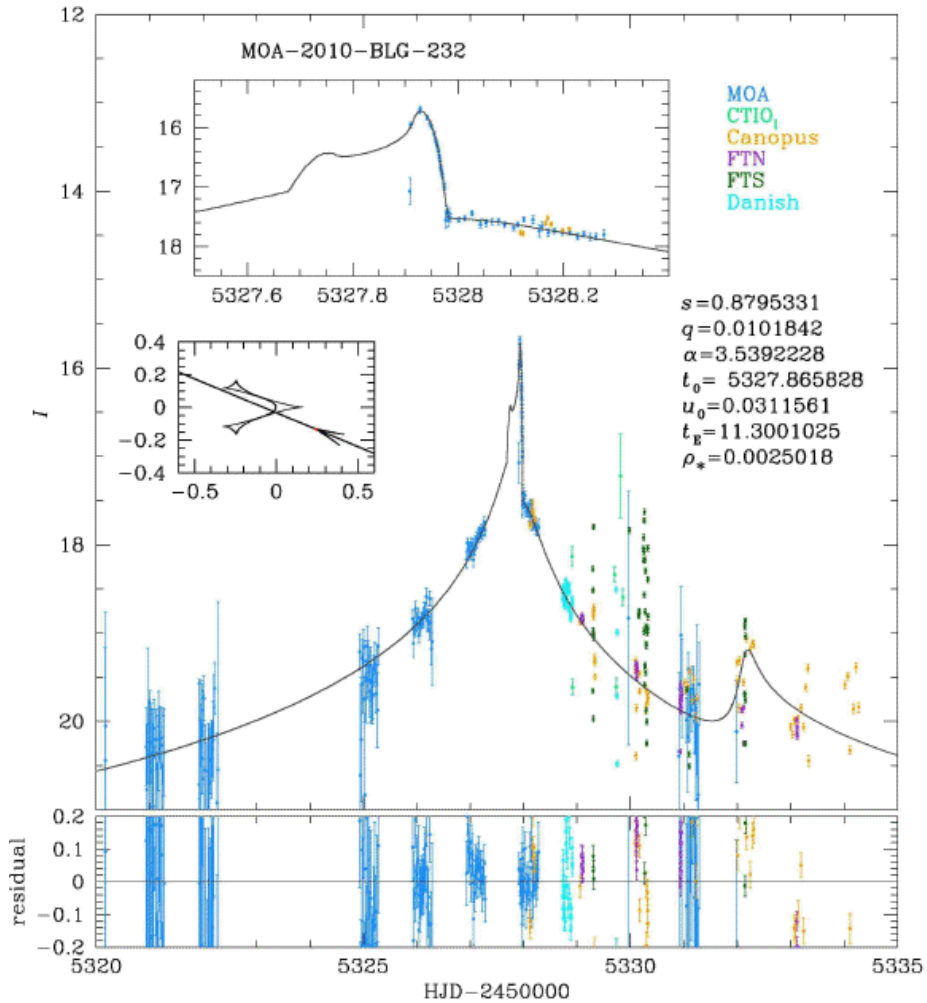
MOA-2010-232

- one of faintest microlensing events
- target invisible on raw images, barely visible even on subtracted frames
- re-reduction requested 22/06/2010
- no evidence for second peak

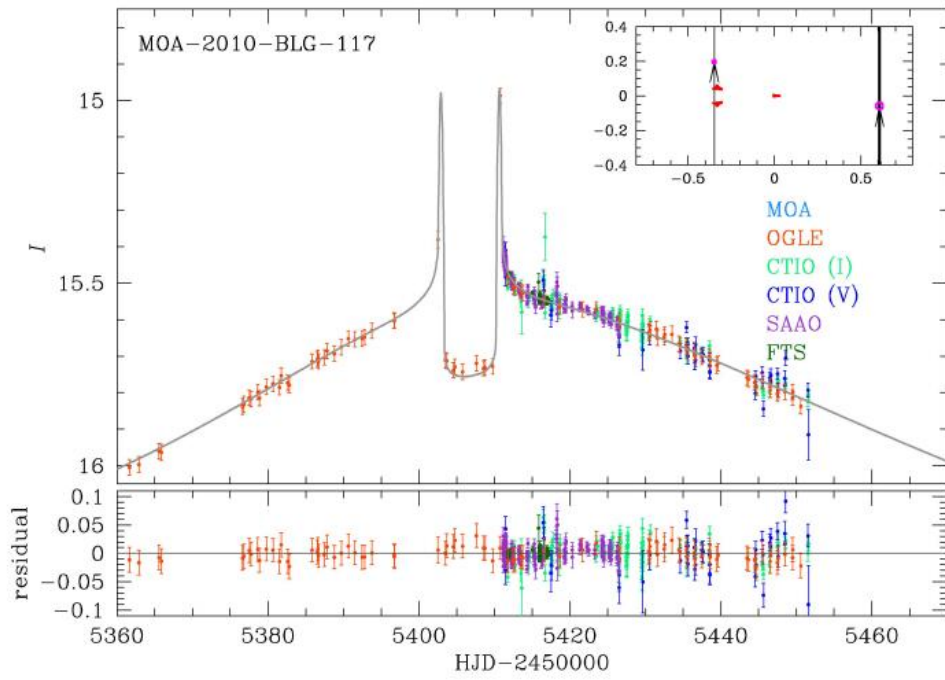
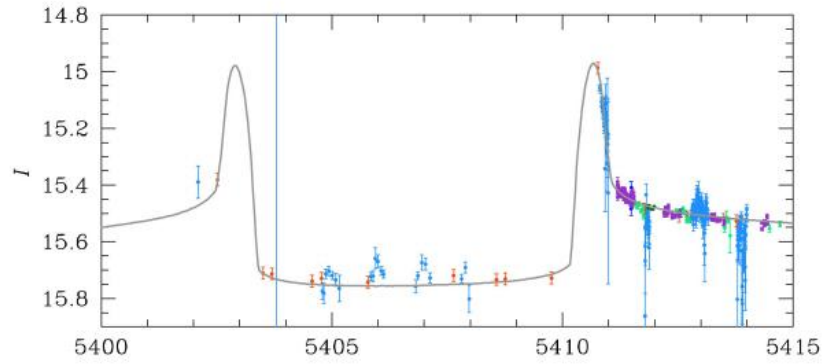


MOA-2010-232

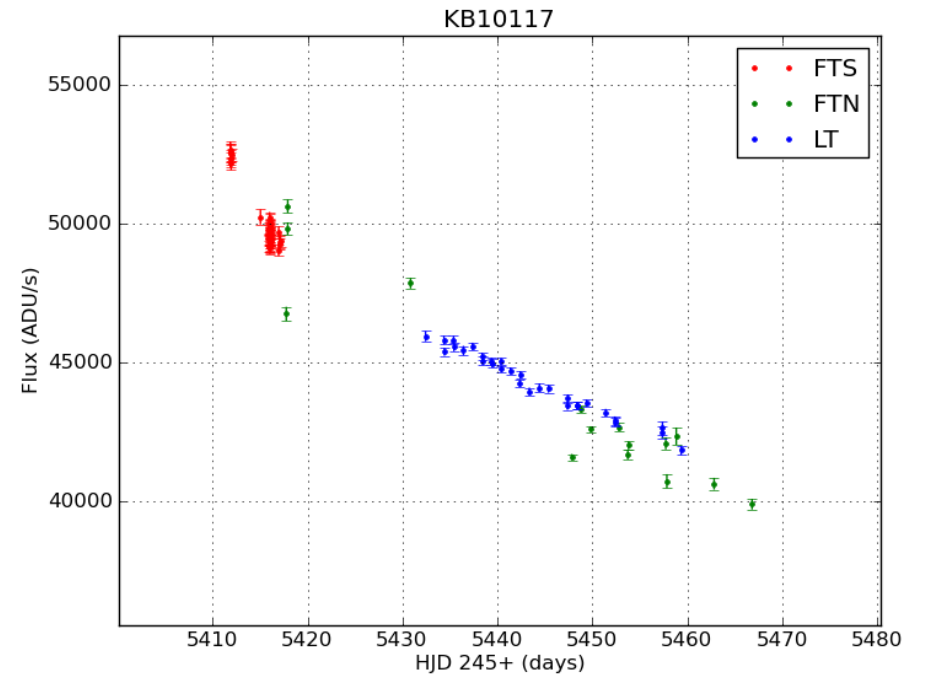
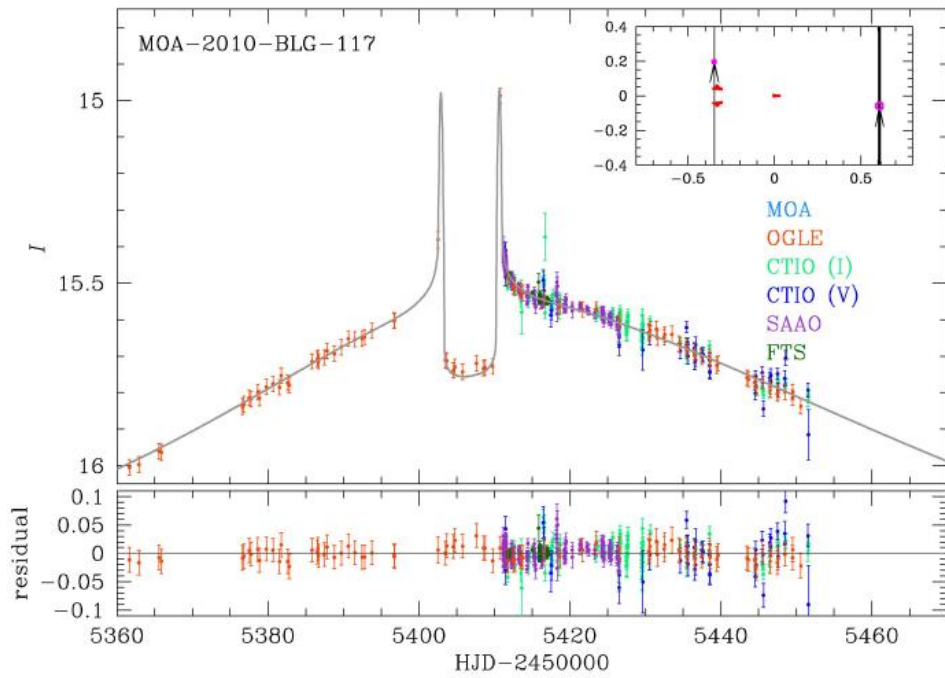
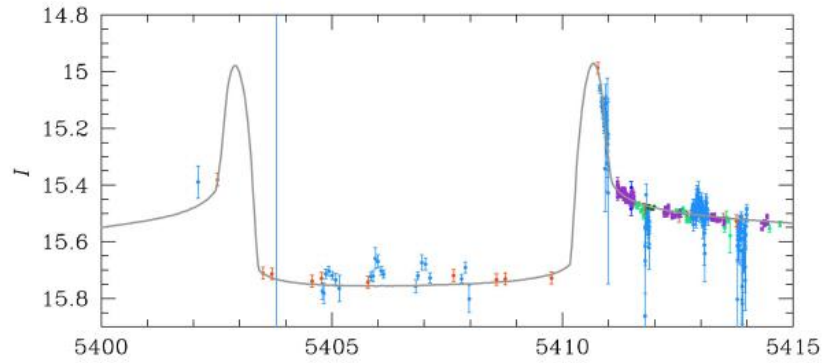
- one of faintest microlensing events
- target invisible on raw images, barely visible even on subtracted frames
- re-reduction requested 22/06/2010
- no evidence for second peak



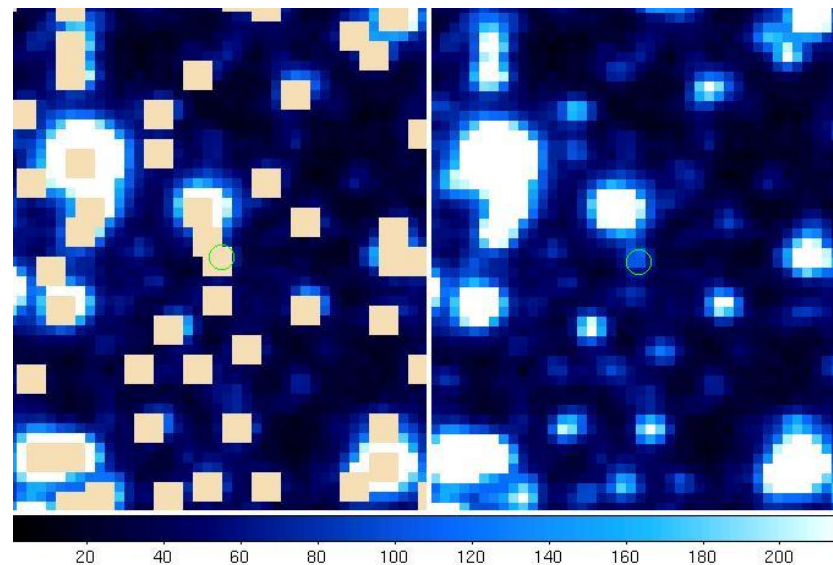
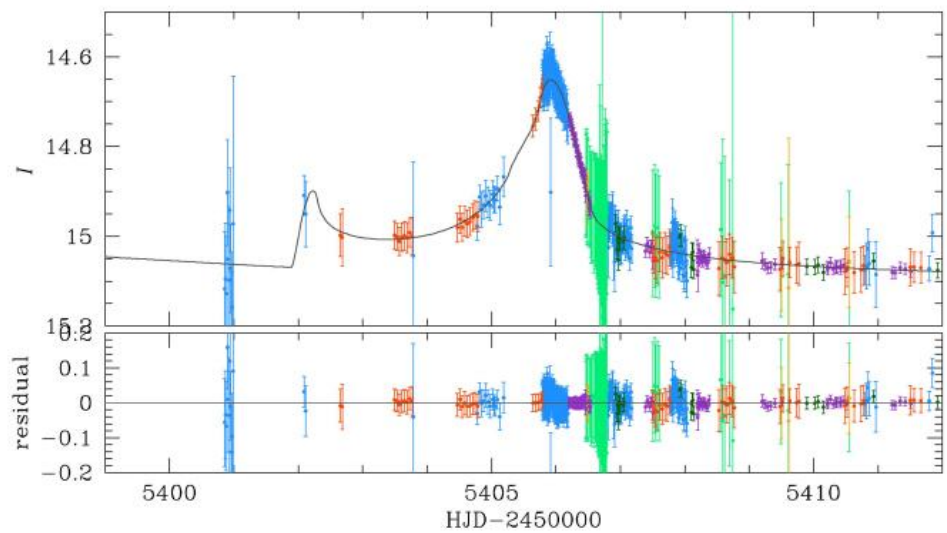
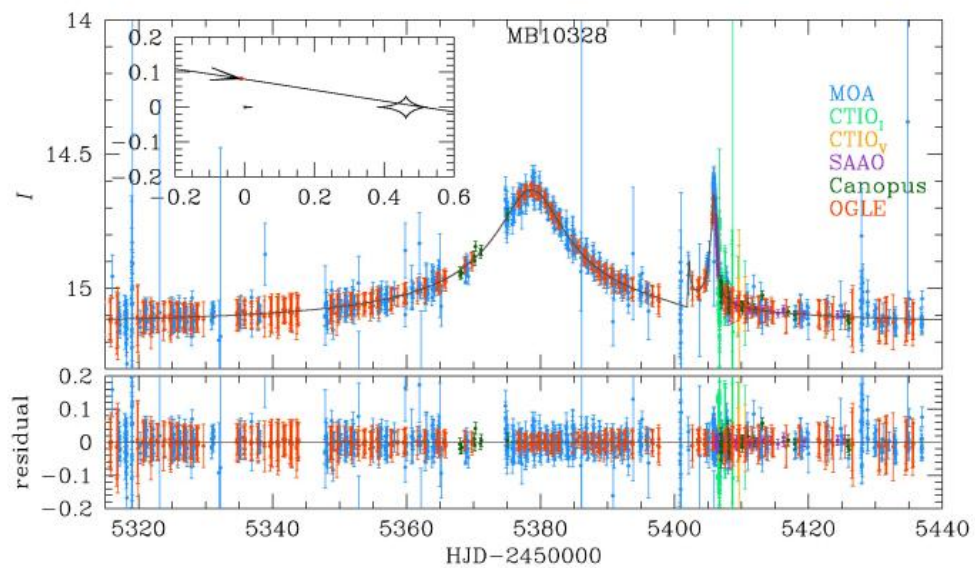
MOA-2010-117



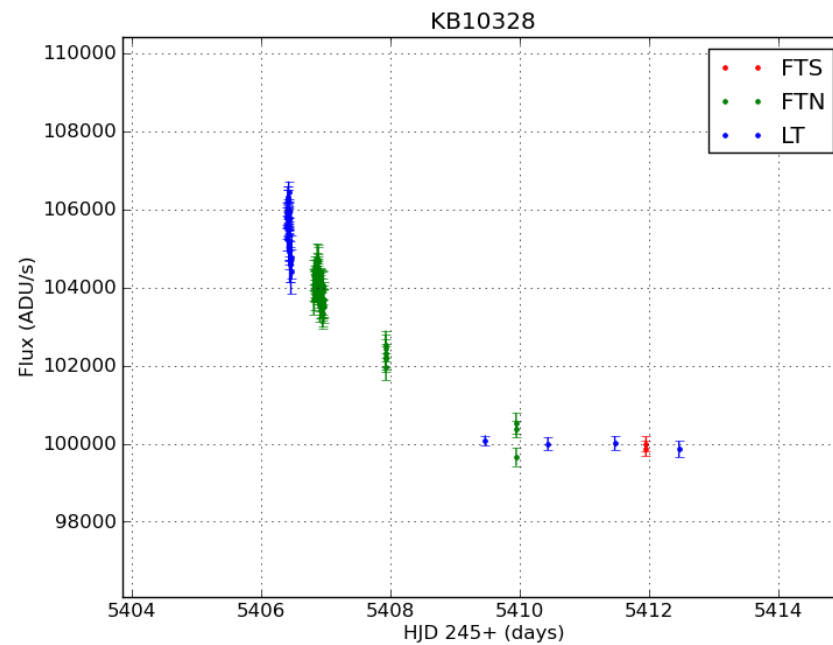
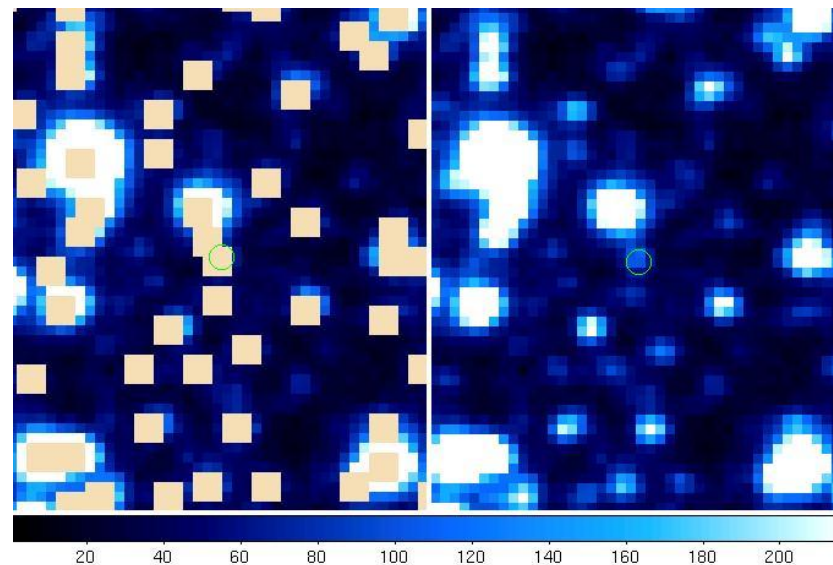
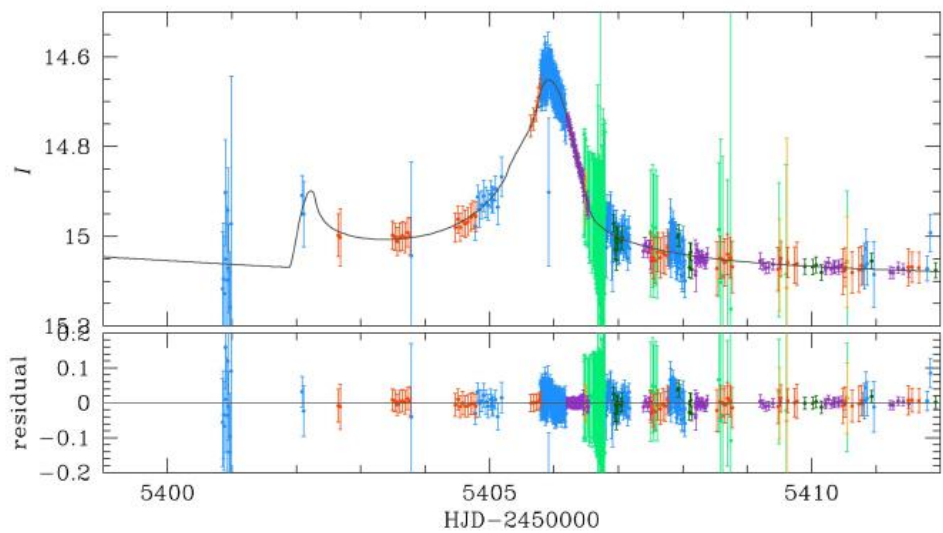
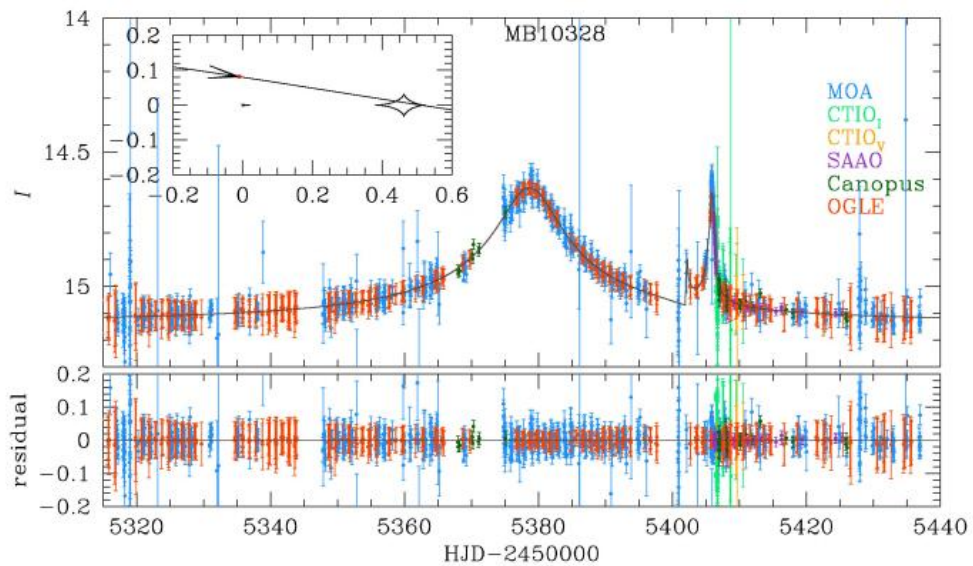
MOA-2010-117



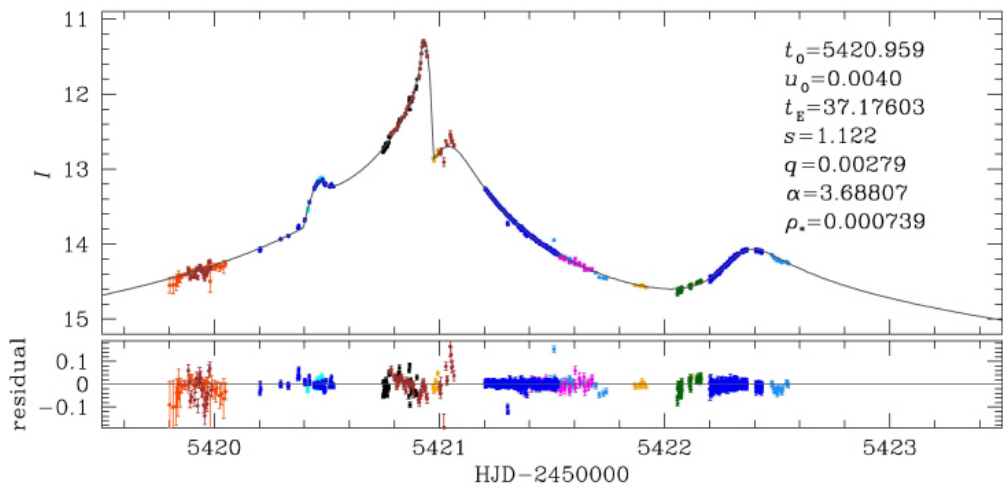
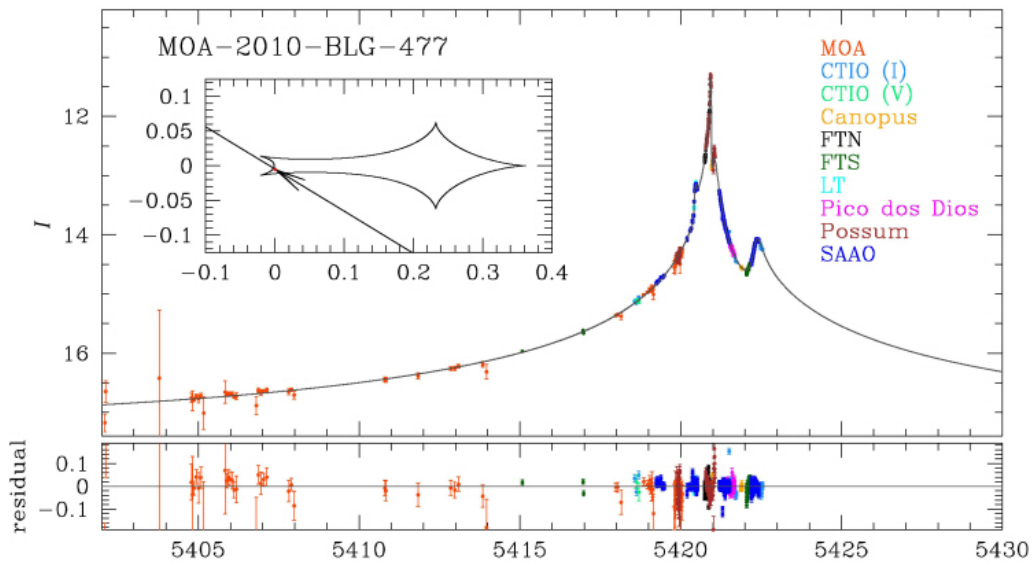
MOA-2010-328



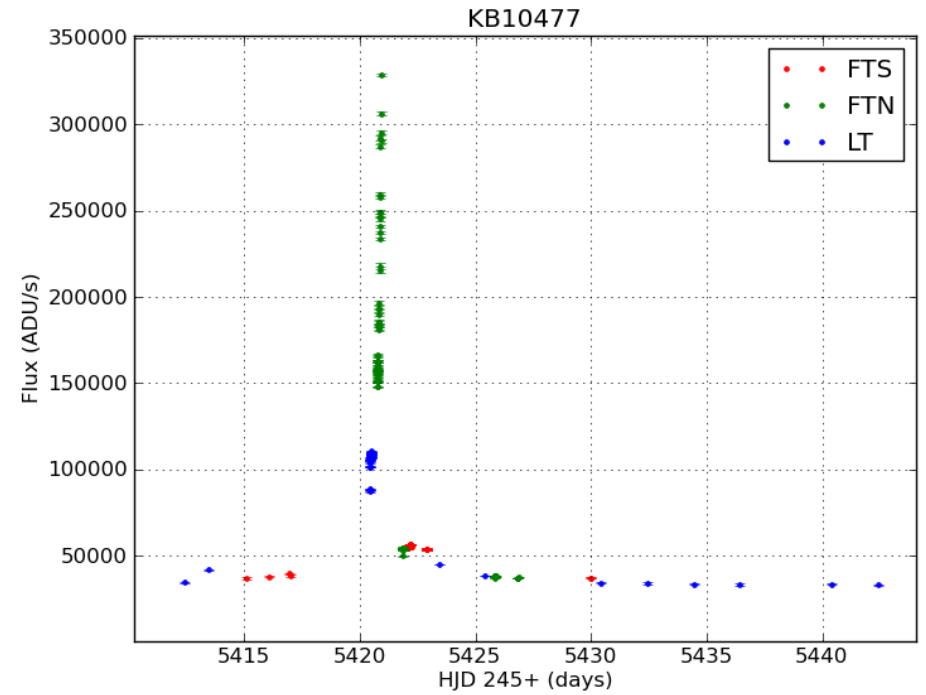
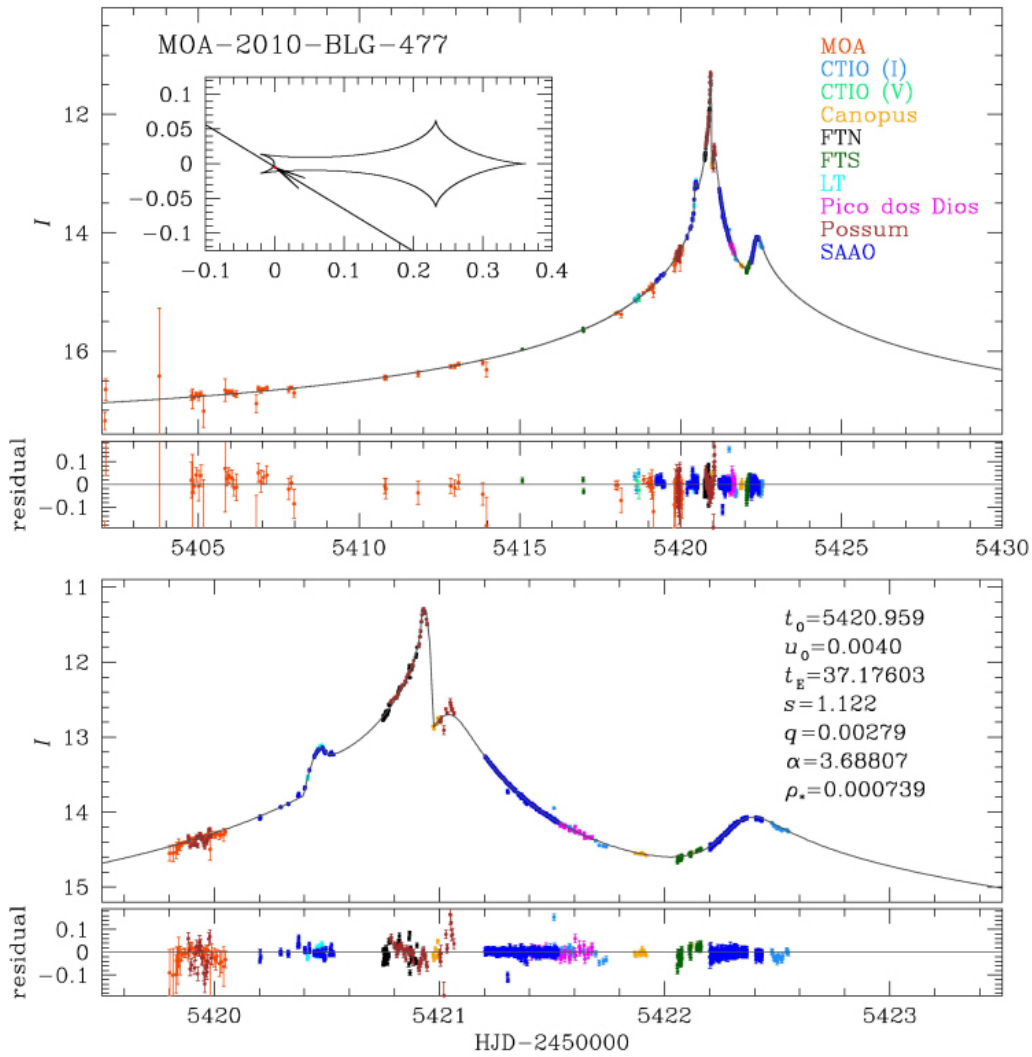
MOA-2010-328



MOA-2010-477

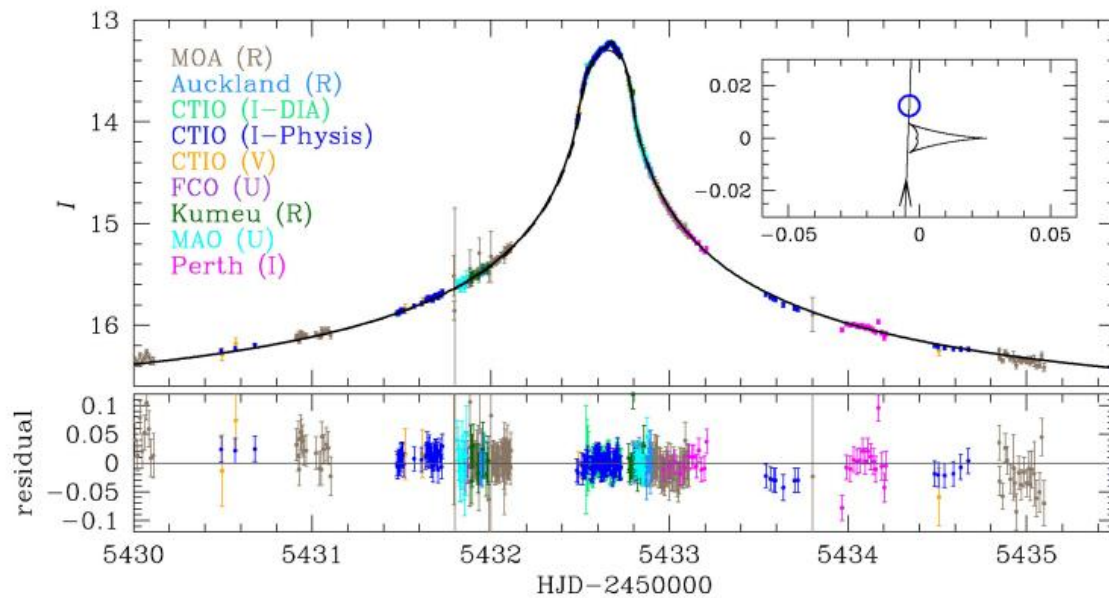
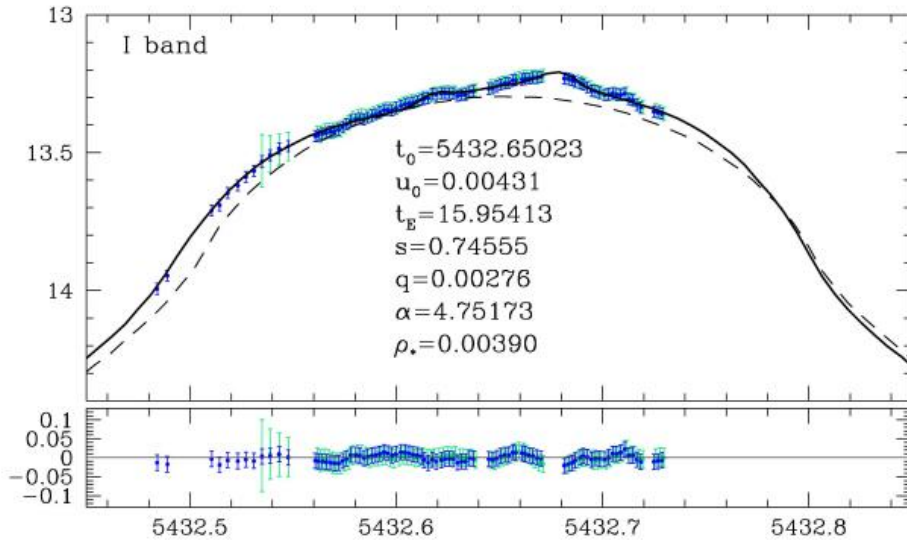


MOA-2010-477



MOA-2010-523

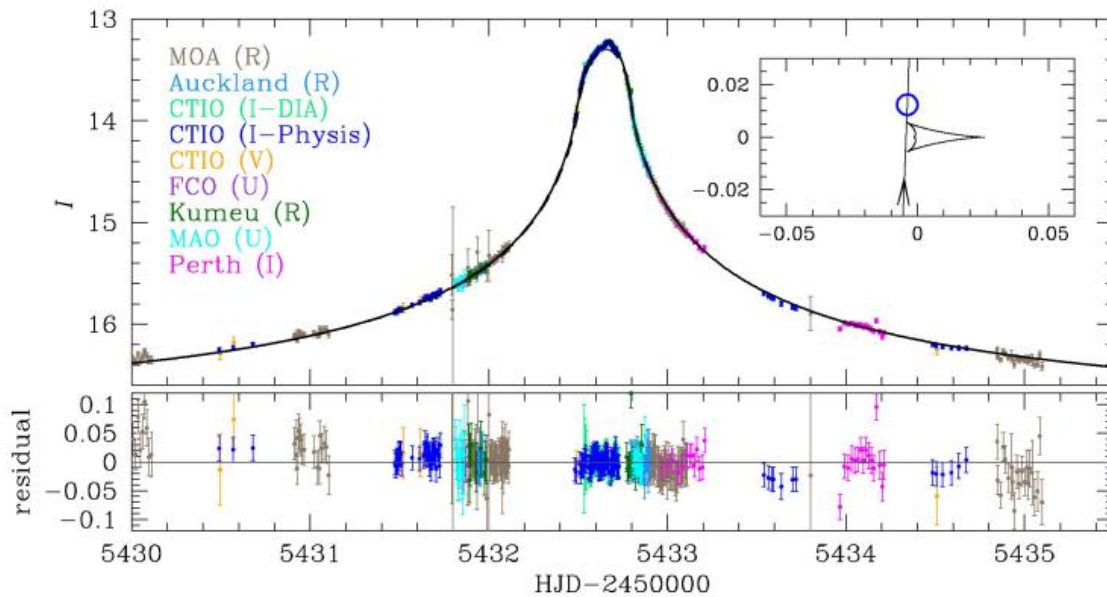
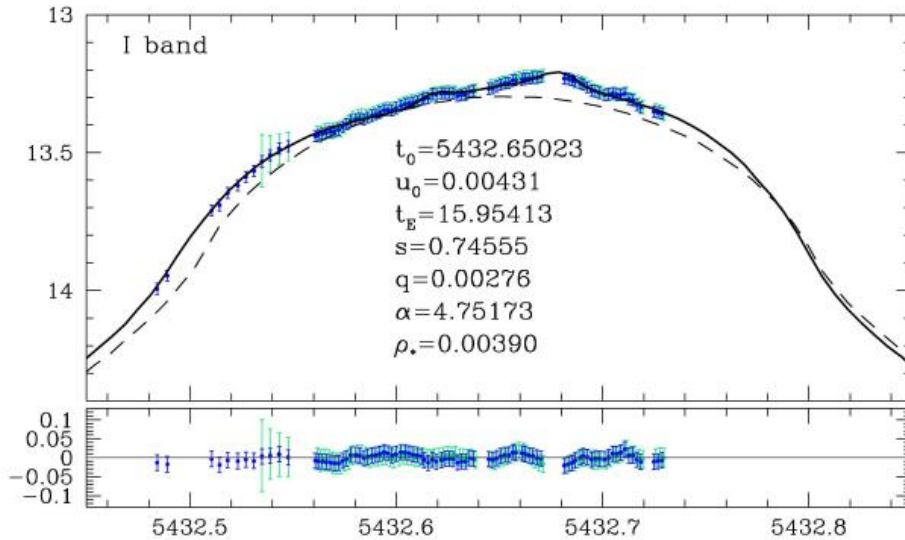
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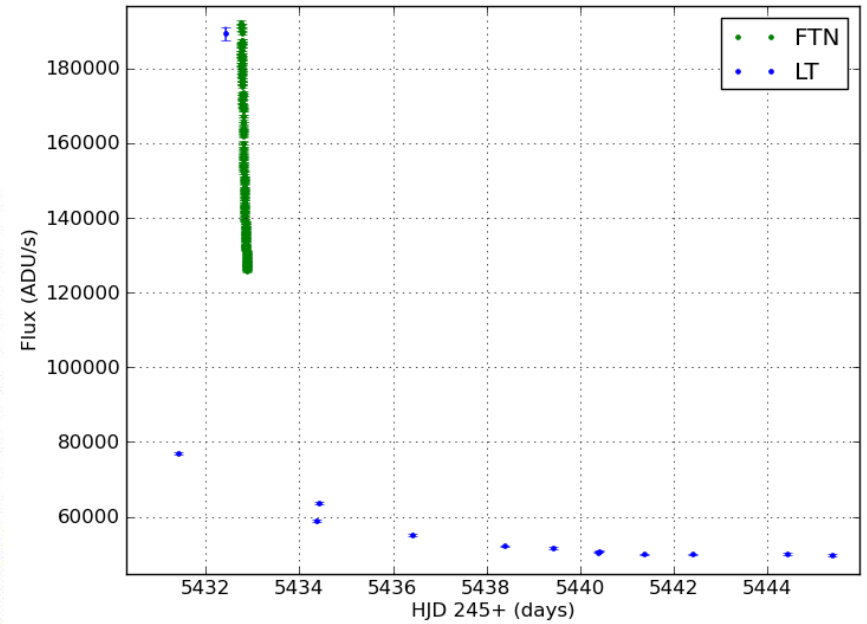
MOA-2010-523



MOA-2010-BLG-523



KB10523



Current status

- currently 3 robotic telescopes
- expand system to use new LCOGT telescopes
- collaboration with other microlensing teams (RoboNet leading analysis of 073)
- use new SPECTRAL camera in 2011
- to draw conclusions about planet populations must understand selection bias of surveys
 - move towards a fully automated observing strategy.
 - simulate full network performance

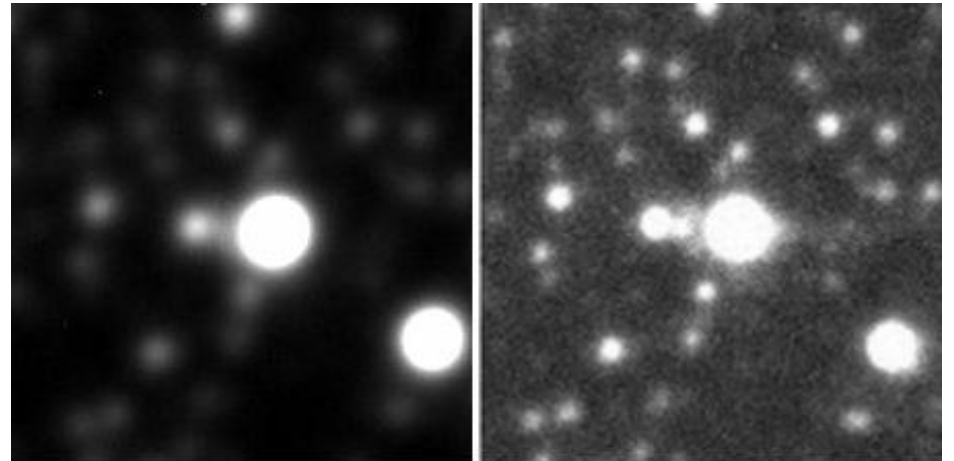
Future plans

Lucky Imaging

- can deliver near diffraction limited images
- takes images fast enough to “freeze-out” motion of atmospheric turbulence

Polarization signals

- polarization should be detectable when extended sources are being microlensed
- if detected, can constrain lensing geometry and break parameter degeneracies
- submitted a proposal to look for polarization in 2011



Thank you for your attention

- References:

- RoboNet → Tsapras et al (2009, AN, 330, 4)
- Target prioritisation → Horne, Snodgrass, Tsapras (2009, MNRAS, 396, 4, 2087)
- Difference imaging → Bramich (2008, MNRAS, 386, 77)
- Anomaly detection → Dominik et al (2008, AN, 329, 248)



Yiannis Tsapras
Rachel Street



Keith Horne
Martin Dominik
Paul Browne



Colin Snodgrass
Dan Bramich



Iain Steele