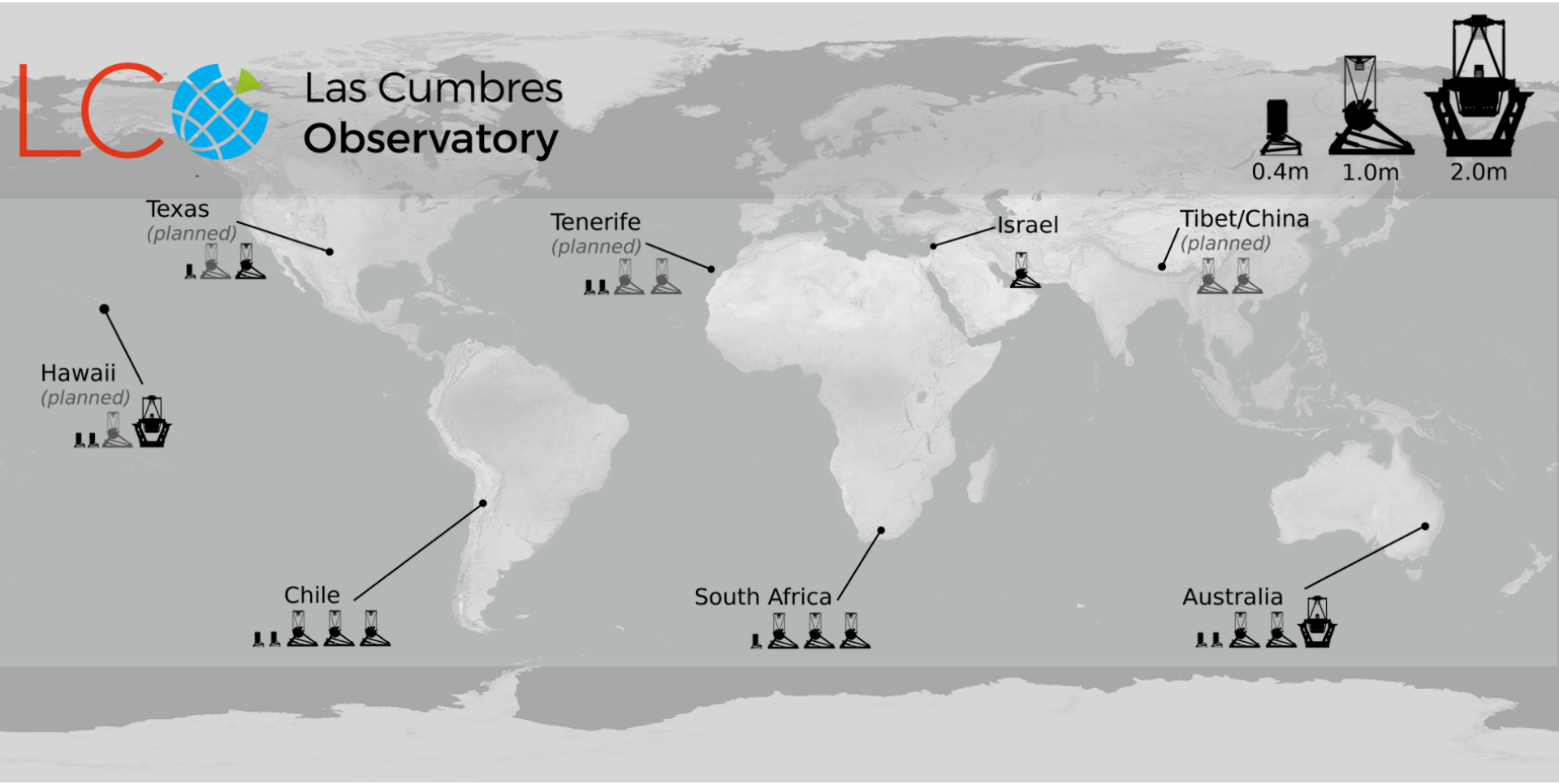
Robotic astronomy with the Las Cumbres Observatory

Large surveys with small telescopes: Past, Present, and Future (Astroplate III), Bamberg

Yiannis Tsapras

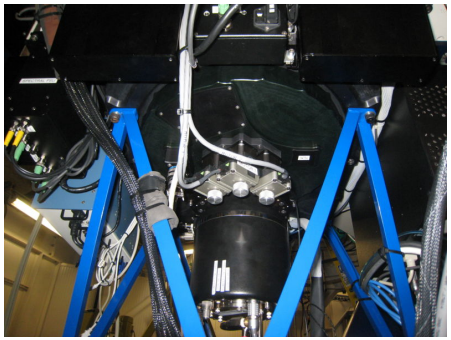
Astronomisches Rechen-Institut
Zentrum für Astronomie der Universität Heidelberg



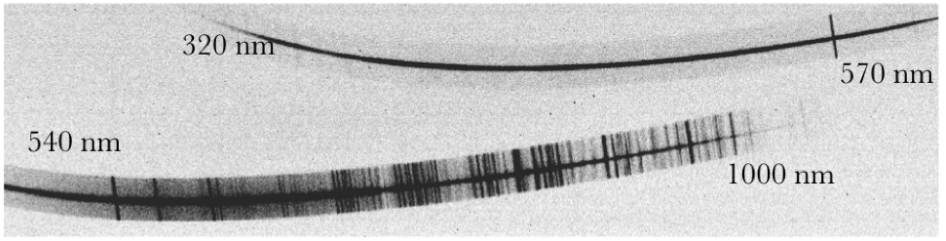
Las Cumbres Observatory (LCO) is a global network of astronomical observatories run by a private non-profit operating foundation

https://lco.global/

2m Telescopes: Instruments



Spectral (FTS)

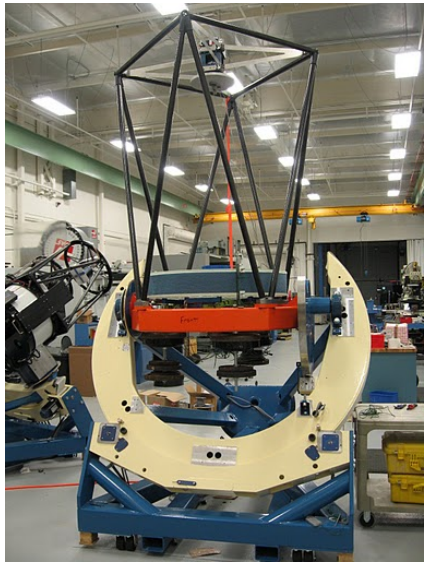


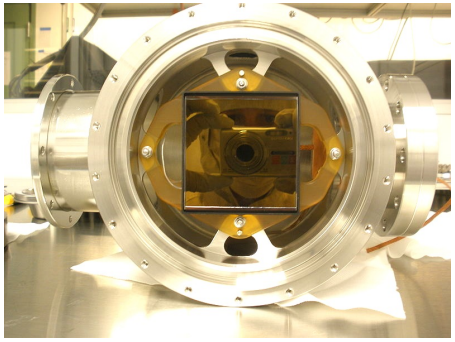
FLOYDS spectrum of SN2012cg

Instrument	Camera	Detector and Format	Plate Scale
Spectral	Spectral Inst. 600	FI CCD486 BI 4096 x 4096 x 15 µm	0.152″/pix 10.5′ FOV
FLOYDS LR Spect.	Andor Newton 940	e2v CCD 512 x 2048 x 13.5 µm	single slit λ 320-1000 nm

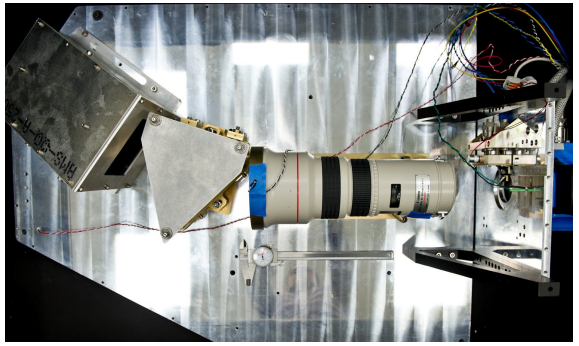
- Standard filters: Johnson-Cousins/Bessell UBVRI, SDSS/PanSTARRS u'g'r'i'z'sYw
- Narrowband filters: Hα, Hβ, OIII, D51, Astrodon-UV, and Skymapper v

1m Telescopes: Instruments





SiNiSTRO prototype



NRES prototype

Instrument	Camera	Detector and Format	Plate Scale
SiNiSTRO	LCO SiNiSTRO Camera	FI CCD486 BI 4096 x 4096 x 15 µm	0.389″/pix 26.6′ FOV
NRES	…	…	R~53000 λ 380-860nm

- Standard filters: Johnson-Cousins UBVRI, SDSS u'g'r'I', Pan-STARRs zs,ys

0.4m Telescopes: Instruments

Luca-R

SBIG

Instrument	Camera	Detector and Format	Plate Scale
p4 PSC	SBIG STX-6303E	Kodak KAF-6303E 3072 x 2048 x 9 µm	0.570″/pix 19.8x29.7′ FOV
p4 FastIm	Andor Luca R	Texas Inst. TC285 1004 x 1002 x 8 µm	0.258″/pix 8.6′ FOV

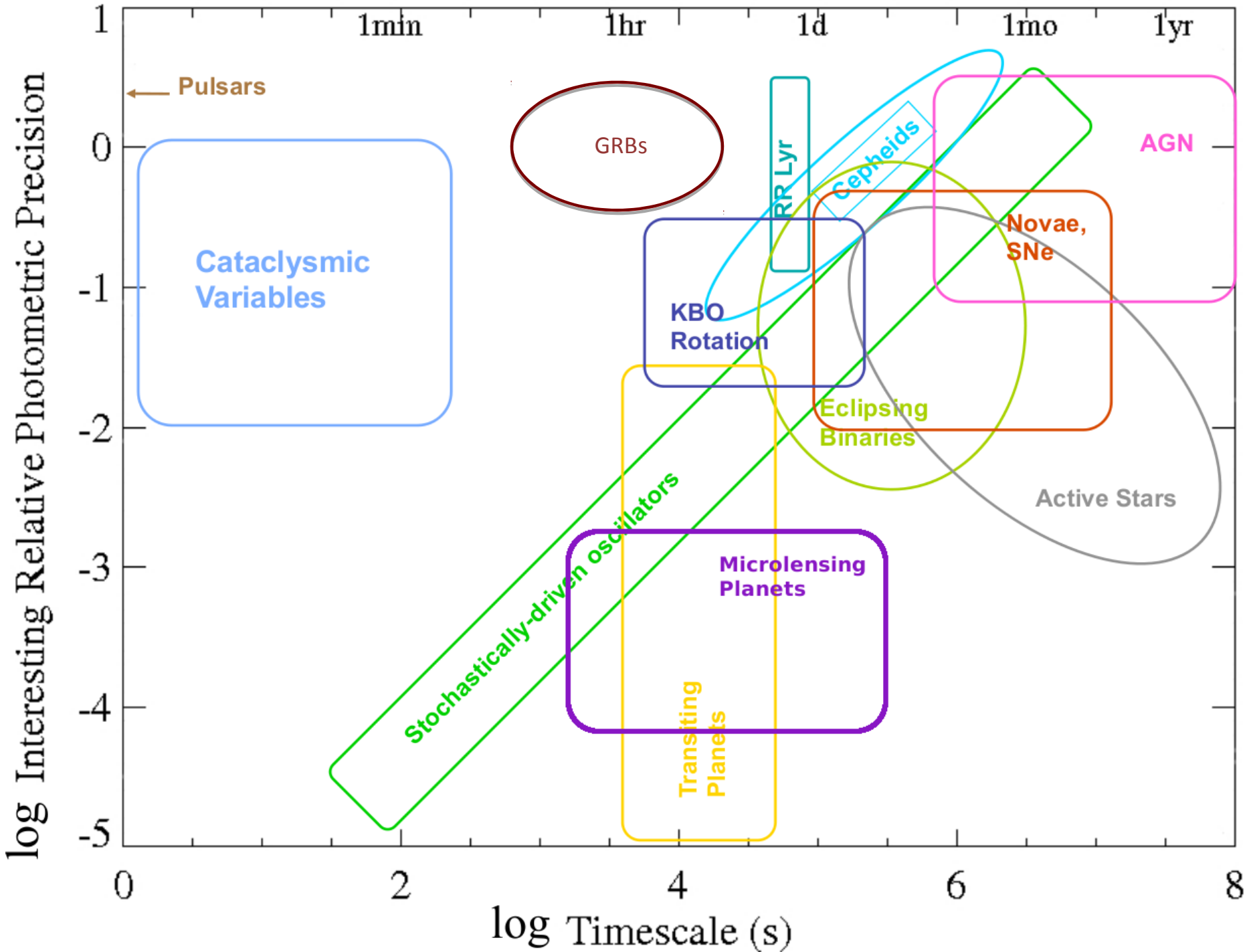
- Standard filters: Johnson-Cousins VB, SDSS u'g'r'i'z', Pan-STARRS w

Observing @LCO

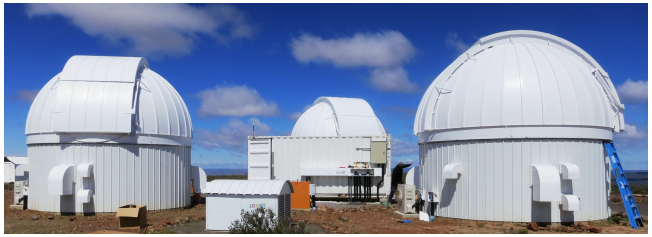
- ✓ Identical telescopes and instruments
- ✓ Common reduction processes
- ✓ Homogeneous photometric system
- ✓ Continuous observations in perpetual night
- ✓ Multiple telescopes per site
- ✓ Possible simultaneous spectroscopy & photometry

Focus on time-domain

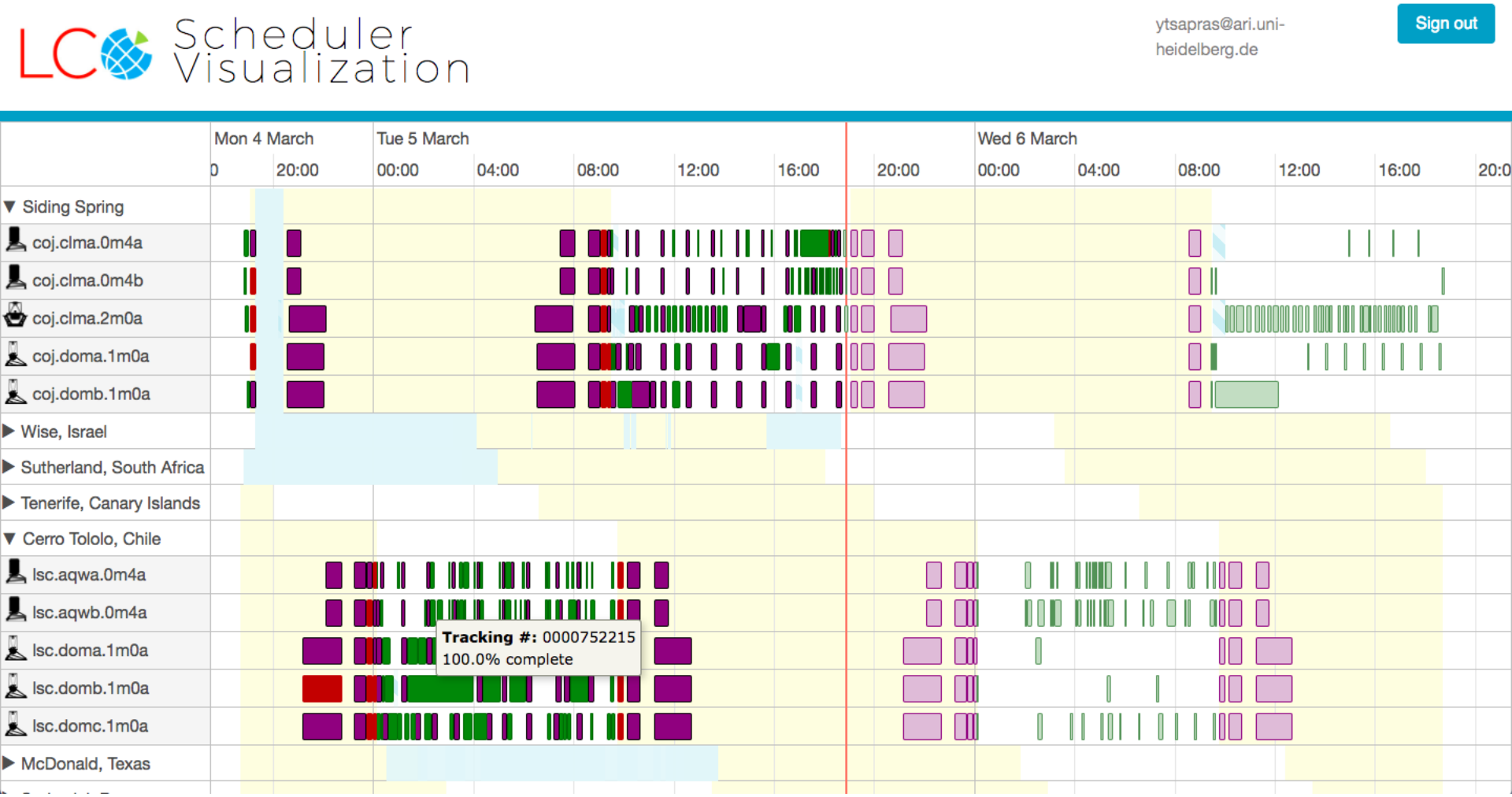
- Telescopes make observing decisions based on predefined conditions
- Science targets often unknown when proposals are submitted
- Observations controlled by a central scheduler
- Data products typically available within 10 min after shutter close
- Rapid-response mode available


1min
1hr
1d
1mo
1yr
Pulsars
GRBs
RR Lyr
Cepheids
AGN
Cataclysmic Variables
KBO Rotation
Novae, SNe
Eclipsing Binaries
Active Stars
Stochastically-driven oscillators
Microlensing Planets
Transiting Planets
log Interesting Relative Photometric Precision
log Timescale (s)
1
0
-1
-2
-3
-4
-5
0
2
4
6
8

Scheduling the network



- Scheduler selects the site/telescope best suited to perform an observation every ~5 min
- Software agents can mine data online
  - can assess scientific interest
  - select targets automatically
  - negotiate observing requests with network
  - provide rapid response to critical events (*e.g. SN, GRBs, μL*)
- Seamless 24/7 automated observations


LCO Scheduler Visualization
ytsapras@ari.uni-heidelberg.de
Sign out
Mon 4 March
Tue 5 March
Wed 6 March
0
20:00
00:00
04:00
08:00
12:00
16:00
20:00
00:00
04:00
08:00
12:00
16:00
20:0
Siding Spring
coj.clma.0m4a
coj.clma.0m4b
coj.clma.2m0a
coj.doma.1m0a
coj.domb.1m0a
Wise, Israel
Sutherland, South Africa
Tenerife, Canary Islands
Cerro Tololo, Chile
lsc.aqwa.0m4a
lsc.aqwb.0m4a
lsc.doma.1m0a
lsc.domb.1m0a
lsc.domc.1m0a
McDonald, Texas
Tracking #: 0000752215
100.0% complete

Education

- Education has been one of the core themes of LCO since its early days
- During the period 1 June 2016 - 1 June 2017 1.500 individual education partner accounts observed a total of 75.000 images using LCO
  - Many of these individual user accounts are teachers leading classes
- LCO launched Global Sky Partners in 2017 to inspire students around the world to engage in astronomy and science: 1.000 hours of telescope time is given to educational organizations
- For more information visit

  https://lco.global/education/partners/

  https://lco.global/news/call-for-education-partners-2019/

Getting observing time

- LCO Science Collaboration
  - Call for proposals & TAC process

    https://lco.global/observatory/proposal/process/
- Joining the LCO Science Collaboration
  - Requires “significant investment in the network”:
    - Contributing funds for further network development
    - 5-year membership: funds for 5000 hours of observing time on the network for 5 years
- Purchase time directly from LCO
  - Limited time per year available
  - For information visit

    https://lco.global/sales/networktime/

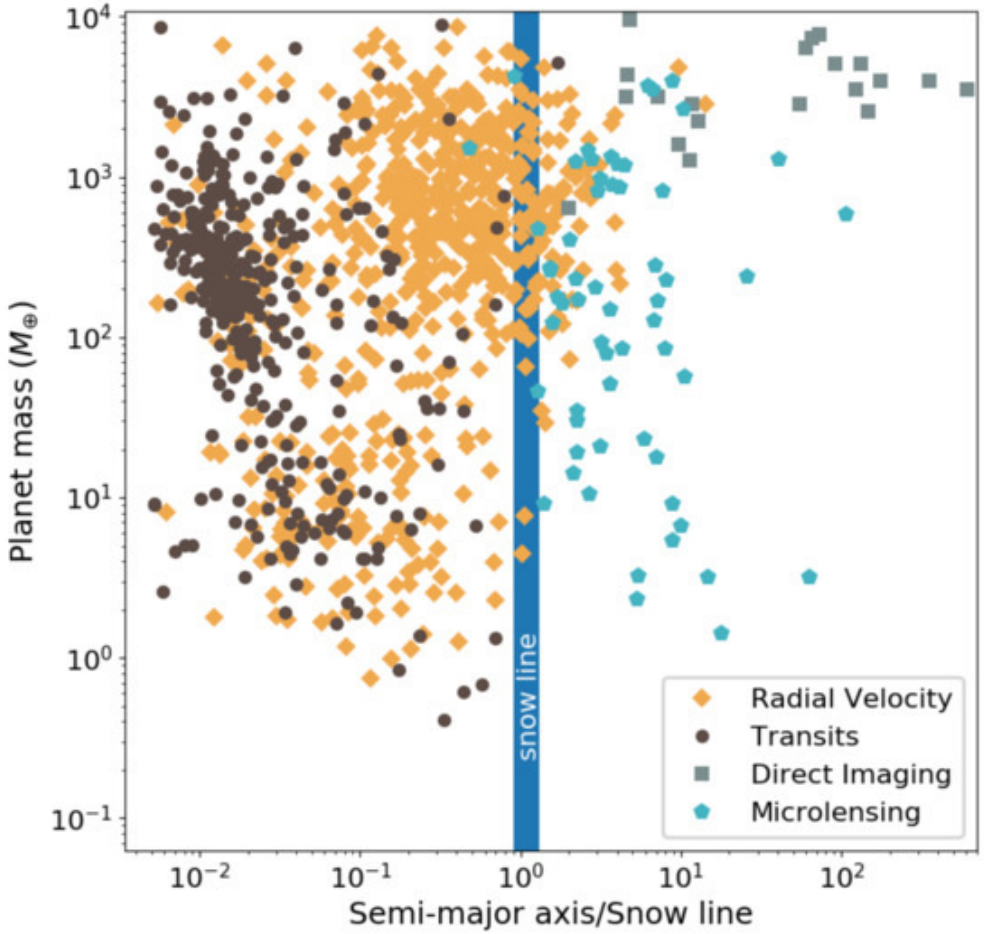
ONGOING LCO KEY PROJECTS	PI (Affil.)
Echo Mapping of AGN Accretion Flows	K. Horne (St. Andrews)
The Next Generation Sample of Supernovae	D.A. Howell (LCO)
Exploring Cool Planets Beyond the Snowline	R. Street (LCO)
Ultra Deep Imaging of NGC0493	M. Cebrian (IAC)
The Global Supernova Project	D.A. Howell (LCO)
Using NRES to Validate and Characterize Exoplanets Found by TESS and other Surveys	T. Brown (LCO)
Transiting Exoplanet Science with LCO	A. Shporer (MIT)
ROME/REA - a three-color window to planets beyond the snow-line	Y. Tsapras (Heidelberg)
High-Cadence Monitoring of the Sun's Coolest Neighbors	P. Robertson (PSU)
LCO/Swift/multi-mission intensive accretion disk reverberation mapping of AGN	R. Edelson (Maryland)
Discovery of and Follow-up of Optical Counterparts to Gravitational-Wave Events	I. Arcavi (Tel Aviv)

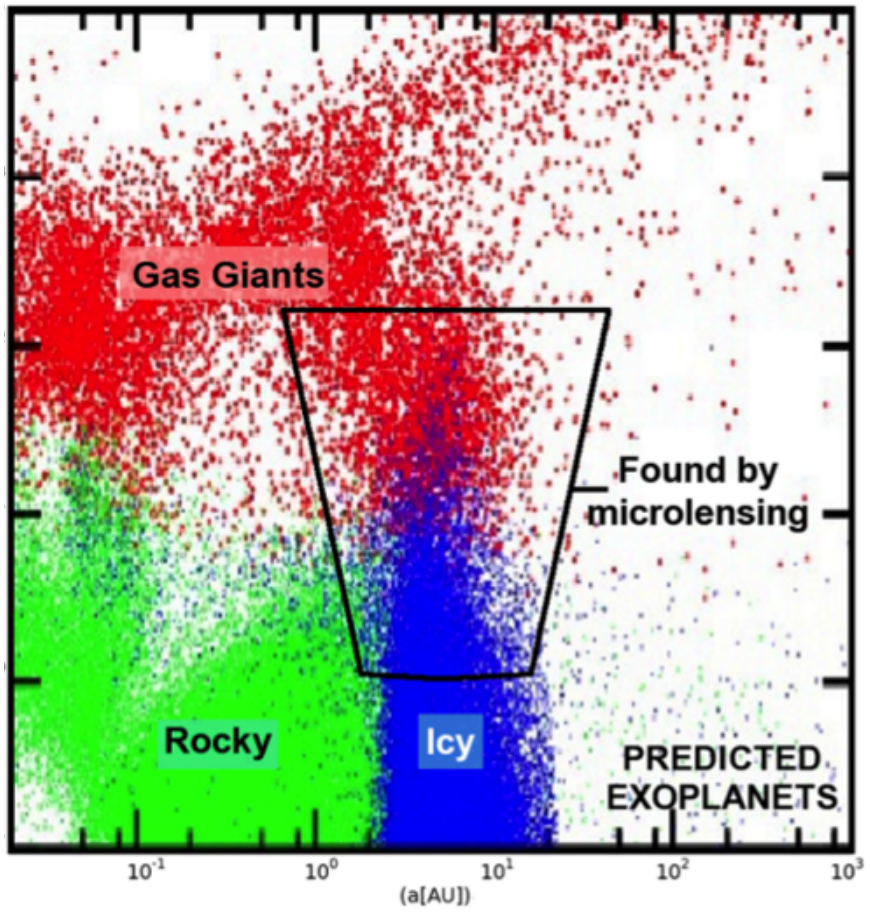
ROME/REA: planets beyond the snow-line

- Theory predicts a high abundance of exoplanets between 1 to 10 AU
- Discovering them is critical in comprehe the process of planet formation
- *Microlensing* is the fastest and most cost effective method to find them

Exoplanet Diversity
DFG SPP-1992

Planets beyond the snow-line

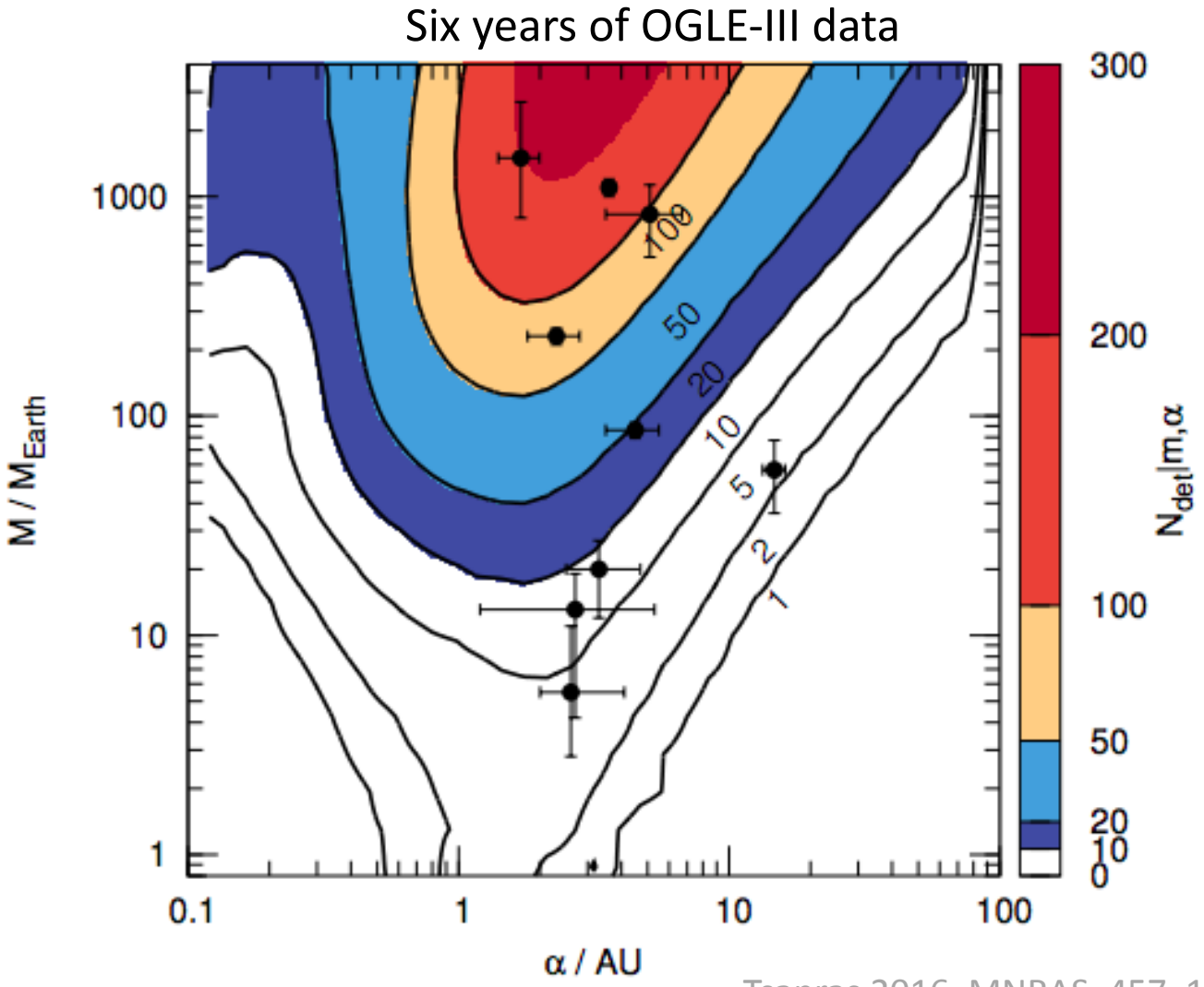




Tsapras 2018, Geosciences, 8(10), 365

Ida, Lin & Nagawawa, 2013, ApJ, 775:42

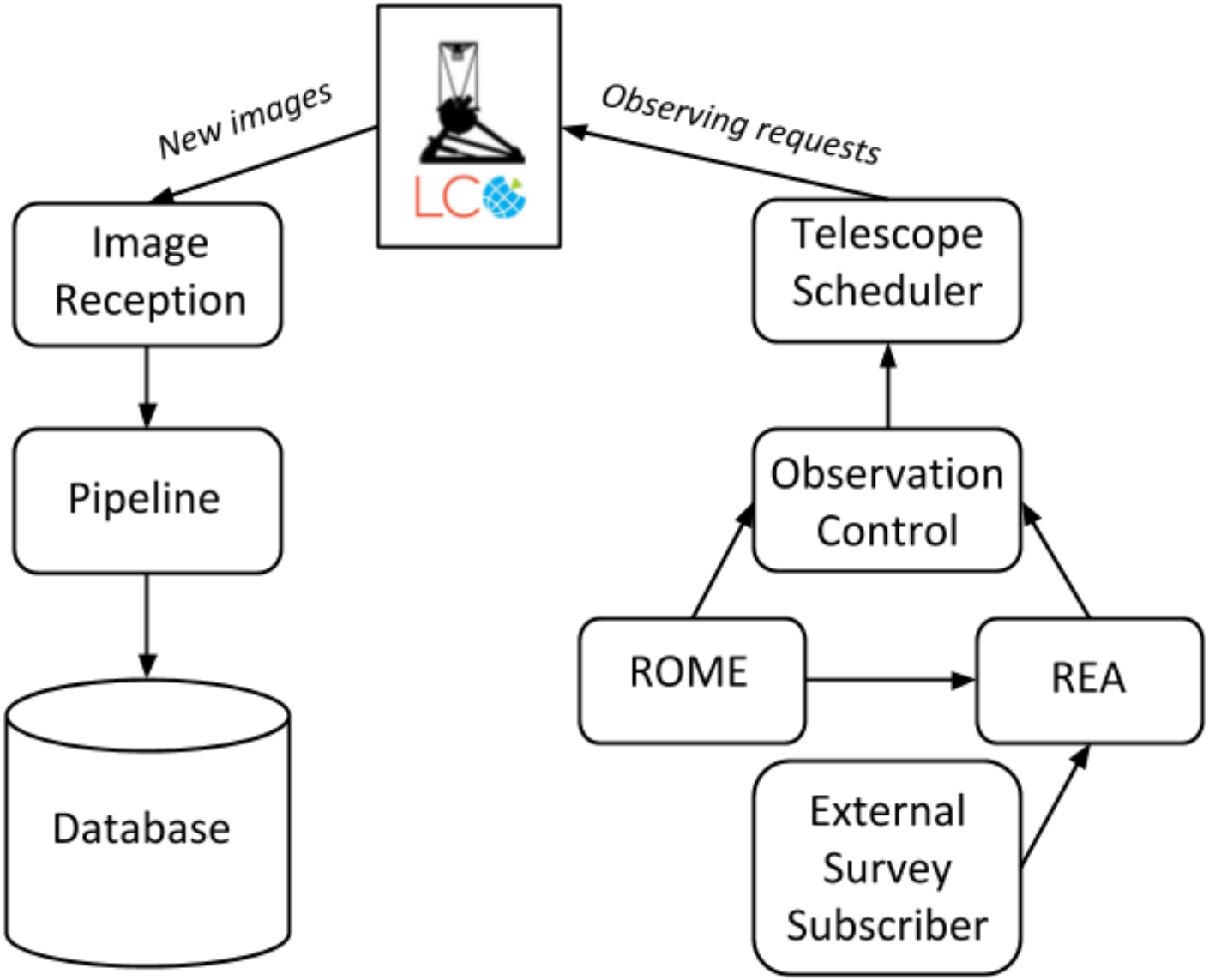
Microlensing sensitivity



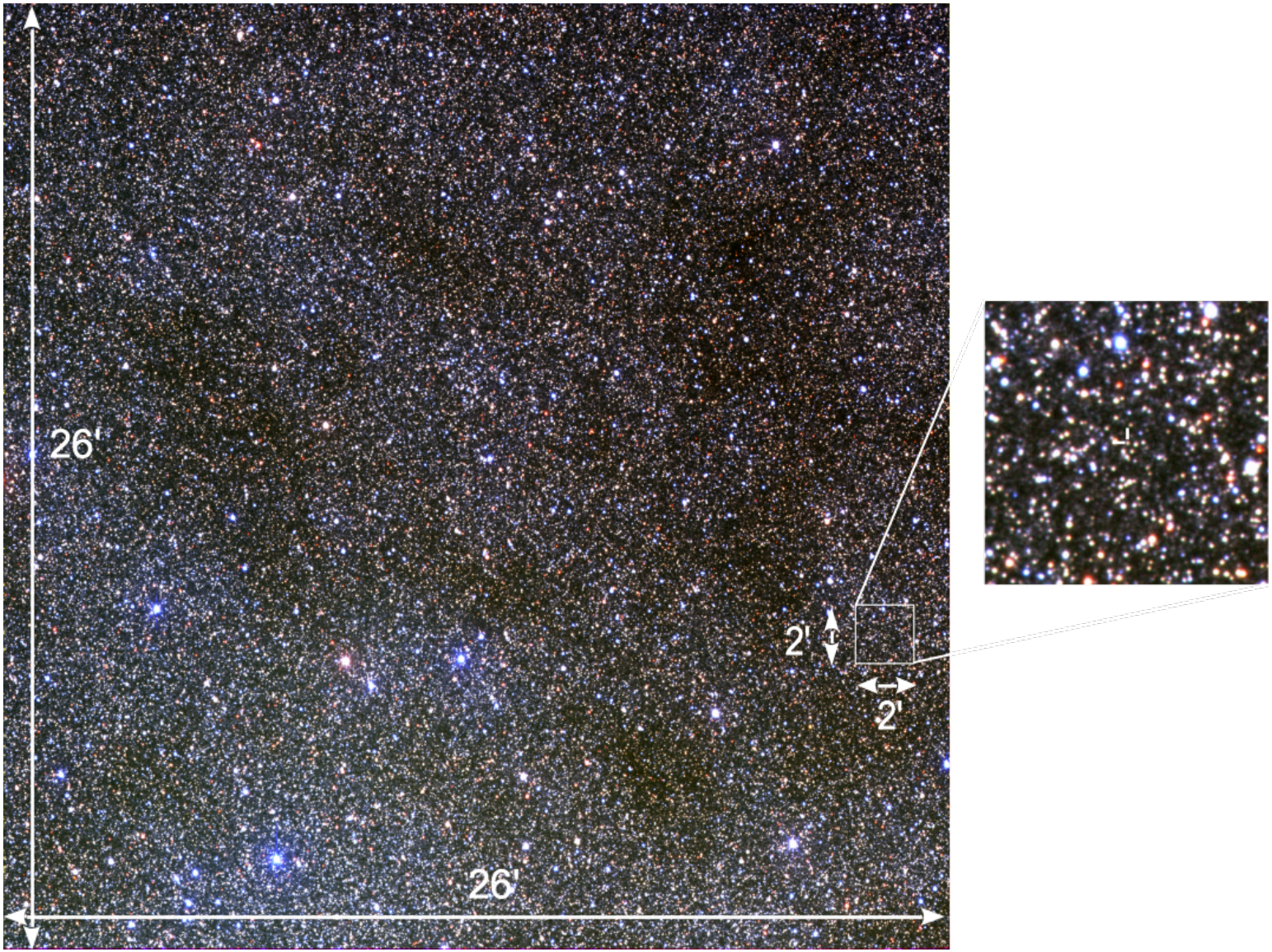
Tsapras 2016, MNRAS, 457, 1320

Strategy

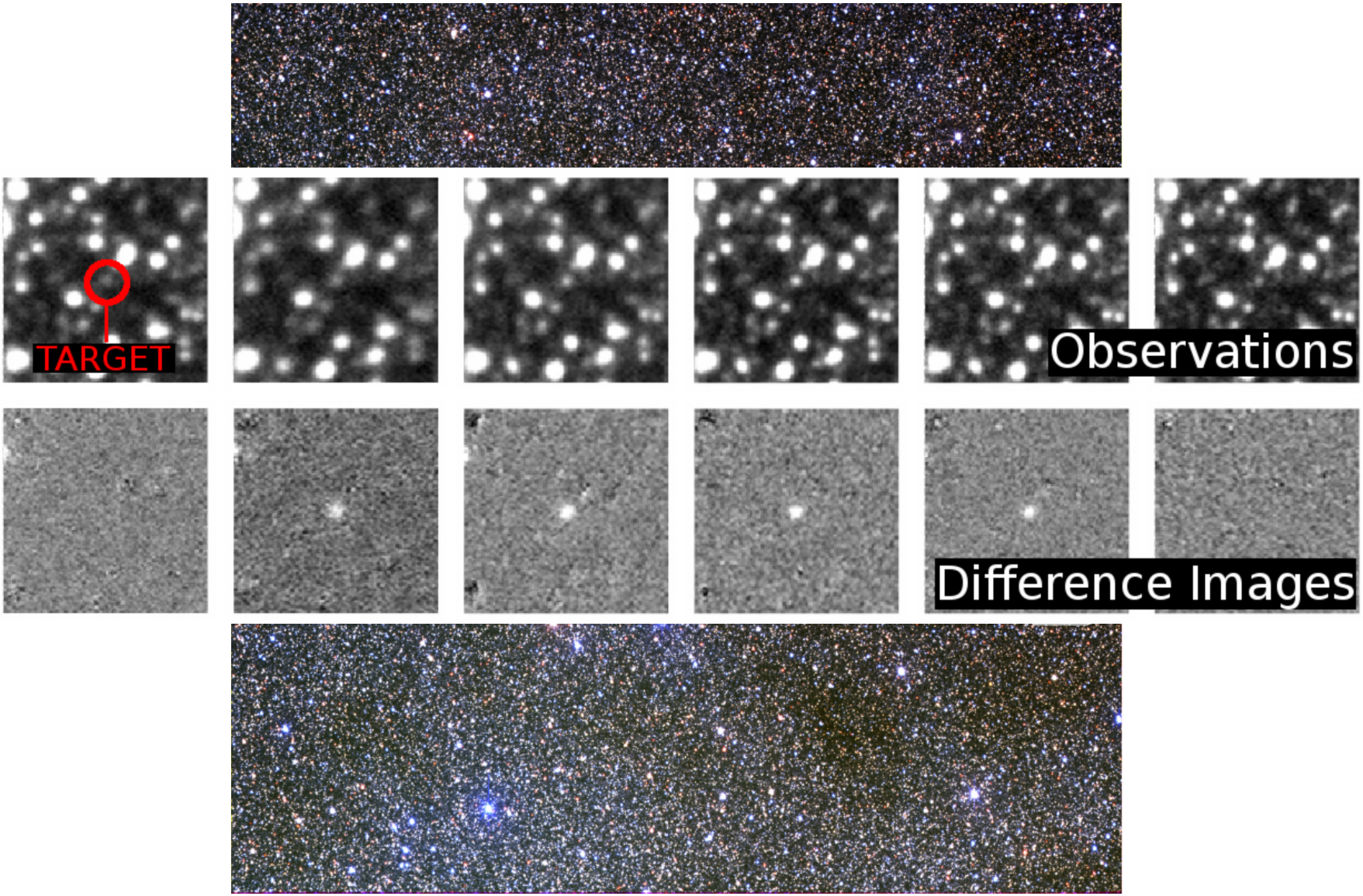
- **20 target fields: ~4 sq. deg.** close to the GC
- Observations performed **in 3 bands** (SDSS-g',r',i') – aiming to characterize source stars
- 24/7 coverage from using southern LCO sites
- **ROME**: regular observations **every 7 hrs**
- **REA**: reactive observations of highly-magnified targets **every 60 min**


New images
Observing requests
LCO
Image Reception
Pipeline
Database
Telescope Scheduler
Observation Control
ROME
REA
External Survey Subscriber

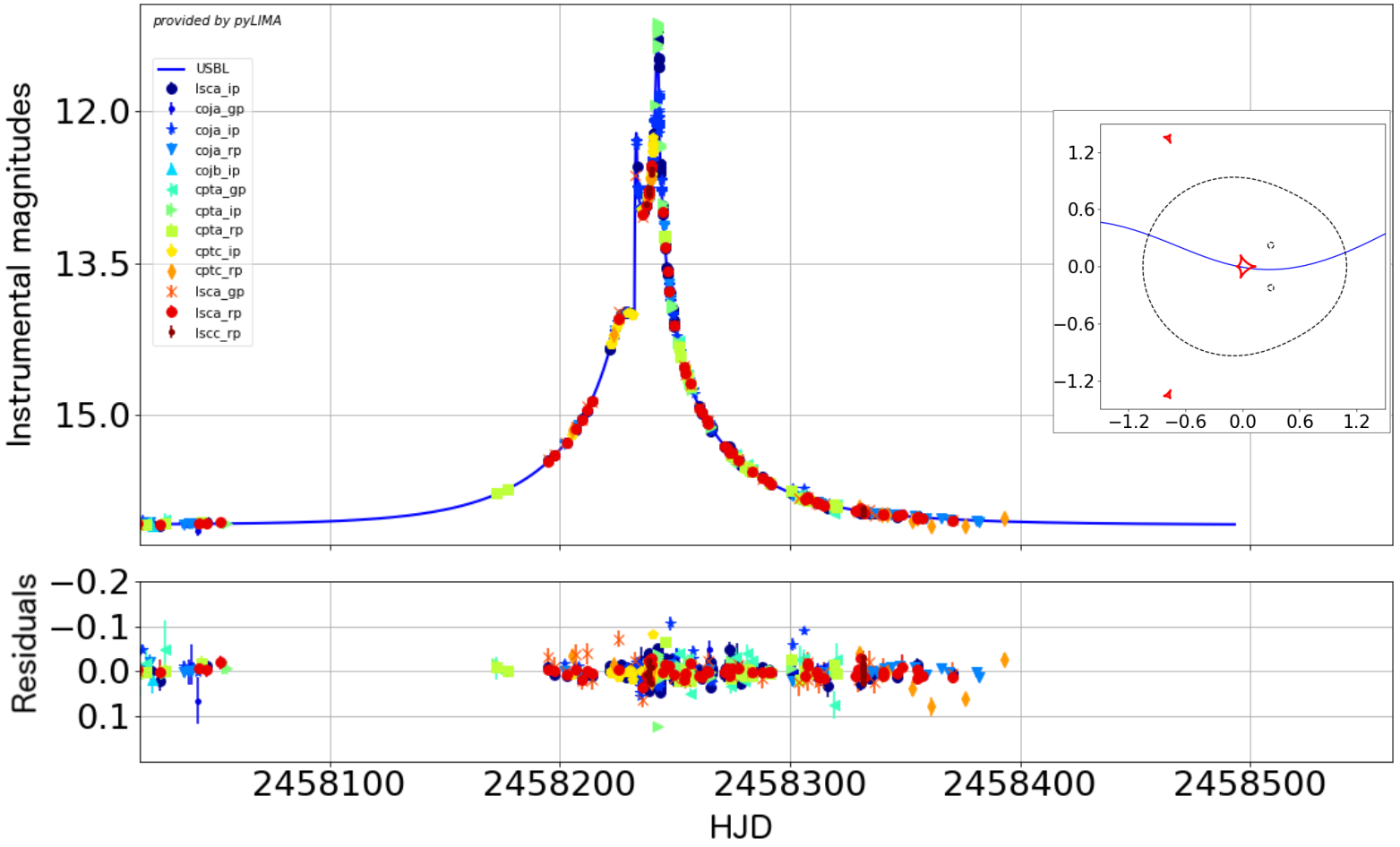
Single ROME field view



Difference Imaging



OGLE-2018-BLG-0022

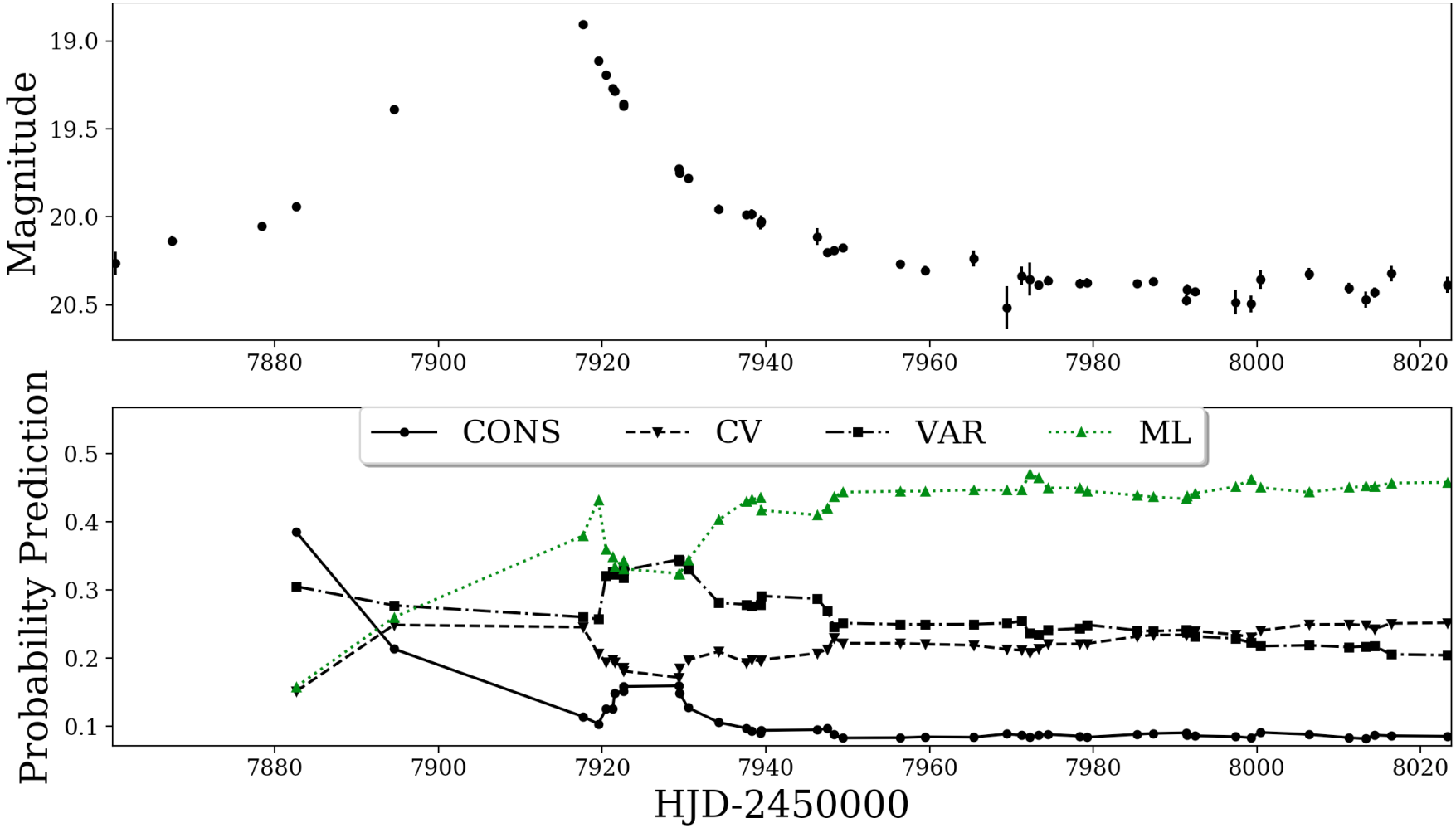


Modeled wih pyLIMA (https://github.com/ebachelet/pyLIMA.git)

(Street al. submitted)

Machine learning event identifier

OGLE-2017-BLG-0406 (LCO-SAAO I'-band light curve)



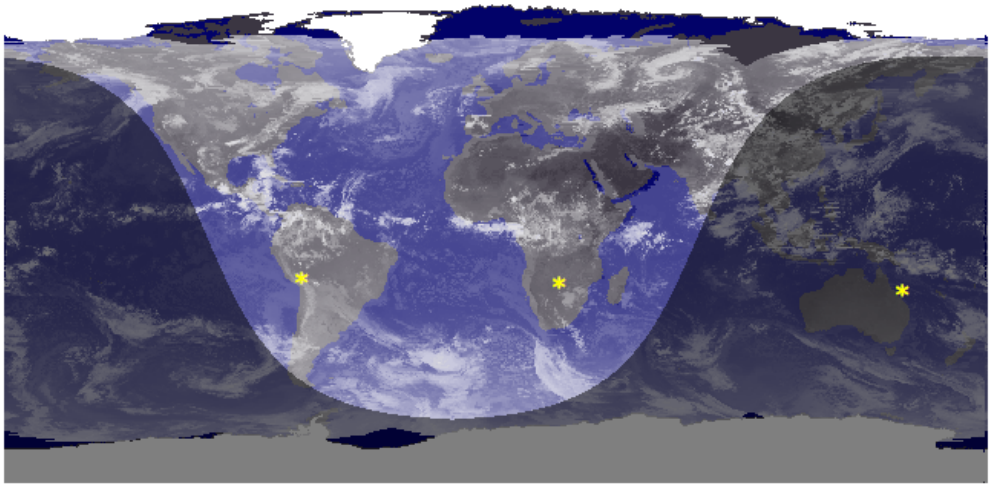
Work by Etienne Bachelet and Daniel Godines Alcantara (paper submitted)

Communication: Database front end

ROME/REA Database View

WELCOME, **YIANNIS**. VIEW DB / HOME / CHANGE PWD / LOG OUT

ROME/REA Key Project Status: June 19, 2017, 1:03 p.m. UT [HJD: 2457924.04439]



List all events | Observations in last 24 hours | Obs. Requests in last 24 hours

Process	Last updated	Description
1.artemis_subscriber	2017-06-19T13:00:03	Status OK
2.obs_control_rome	2017-05-31T14:10:19	Status OK
3.obs_control_rea	2017-06-19T12:10:03	Status OK
4.run_rea_tap	2017-06-19T13:00:02	Status OK (ARTEMiS mode)
5.reception	2017-05-31T14:10:19	Status OK

Target Prioritization

ROME/REA Database View

WELCOME, **YIANNIS.** VIEW DB / HOME / CHANGE PWD / LOG OUT

Current Time: June 19, 2017, 1:11 p.m. UT [HJD: 2457924.04975]

Target Priority: LCO 1m network

Event	RA	DEC	Texp [s]	Priority	Tsamp [h]	Imag	Ω_S	Ω_S@peak	Visibility [h]
OGLE-2017-BLG-0926 MOA-2017-BLG-0313	17:51:21.61	-30:05:44.70	246	L	1.00	16.80	0.15	0.27	23.40
OGLE-2017-BLG-0924 MOA-2017-BLG-0304	17:53:19.30	-30:12:38.60	52	L	1.00	15.33	0.06	0.06	23.40

Rejected events (> available observing time) LCOGT 1m network

Event	RA	DEC	Texp [s]	Priority	Tsamp [h]	Imag	Ω_S	Ω_S@peak	Visibility [h]

Observing requests

ROME/REA Database View

WELCOME, **YIANNIS.** VIEW DB / HOME / CHANGE PWD / LOG OUT

Observation Requests in database in the last 24 hours

Field Name:	Sampling(min):	Exp.time(sec):	Submitted @:	Expires @:	Status:	Req. Type:	Site:	Instr:	Filter:	GRP ID:	TRK ID:	REQ ID:	N exp:
ROME-FIELD-01	60.00	267	2017-06-19T07:20:04	2017-06-20T07:20:04	AC	M		fl03	SDSS-i	REALO20170619T7.16780285	448701	9999999999	1
ROME-FIELD-01	60.00	267	2017-06-19T07:20:05	2017-06-20T07:20:05	AC	M		fl06	SDSS-i	REALO20170619T7.16817156	448702	9999999999	1
ROME-FIELD-01	60.00	267	2017-06-19T07:20:06	2017-06-20T07:20:06	AC	M		fl11	SDSS-i	REALO20170619T7.16840209	448703	9999999999	1
ROME-FIELD-05	60.00	87	2017-06-19T11:20:03	2017-06-20T11:20:03	AC	M		fl03	SDSS-i	REALO20170619T11.1676696	448729	9999999999	1
ROME-FIELD-05	60.00	87	2017-06-19T11:20:04	2017-06-20T11:20:04	AC	M		fl06	SDSS-i	REALO20170619T11.16794957	448730	9999999999	1
ROME-FIELD-05	60.00	87	2017-06-19T11:20:05	2017-06-20T11:20:05	AC	M		fl11	SDSS-i	REALO20170619T11.16818838	448731	9999999999	1

Event details

ROME/REA Database View

WELCOME, **YIANNIS**. VIEW DB / HOME / CHANGE PWD / LOG OUT

Current Time: June 19, 2017, 1:10 p.m. [HJD: 2457924.04863]

ID
875

Download lightcurves

Status
active

Field
ROME-FIELD-07

Event name: OGLE-2017-BLG-0470

RA: 17:54:18.21

Dec: -28:30:40.90

Last observation: 2017-06-18 05:32:33.216
[HJD: 2457922.73094000] from OGLE 1.3m

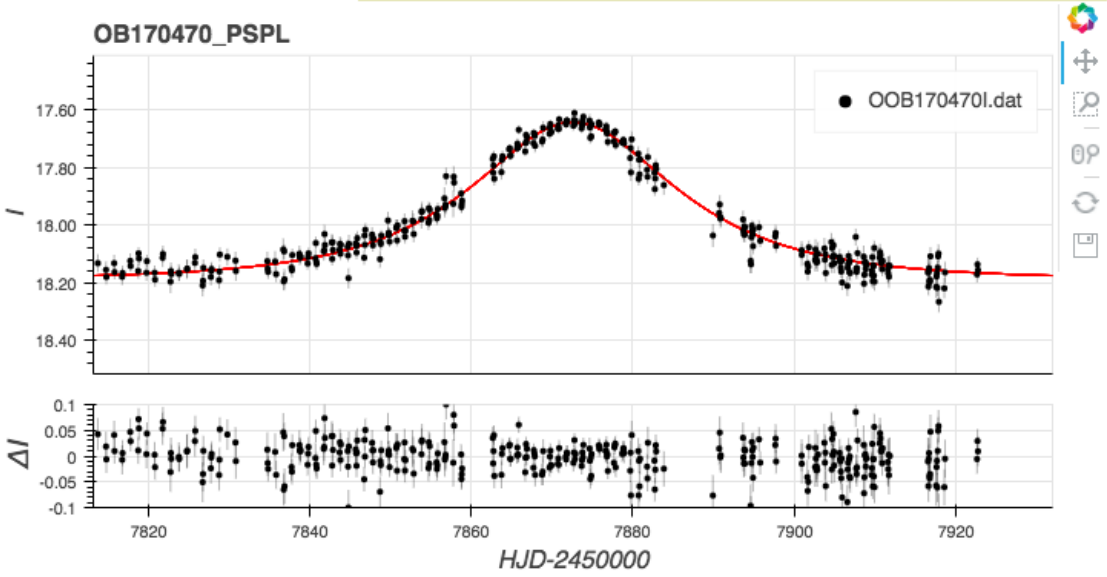
Event parameters:

Last update:
May 17, 2017, 4:20 p.m.
[HJD: 2457891.18124]

t_0: 2457872.6046±None

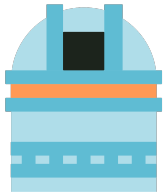
t_E: 19.7846±None

u_0: 0.6341±None



Observing details for this event

TOM toolkit



- Target and Observation Manager software
- Open-source software to display and interact with own data through a browser or GUI
  - Submit requests for observations to networked telescopes
  - harvest alerts and data products
  - visualize data
  - fully programmable and customizable (Astropy-style)
- For information visit

  https://lco.global/tomtoolkit/

What next?

Preparing for the  era

- Optical time-domain astronomy is about to experience a revolution in data rates and transient alerts
- Machine learning methods will need to sift through the data to eliminate false positives and provide classification
- Follow-up facilities will depend on efficient harvesting of alert streams and target selection algorithms to provide high-cadence observations

Thank you for your attention