Planning hybrid follow-up strategies

for turning microlenses into cold worlds

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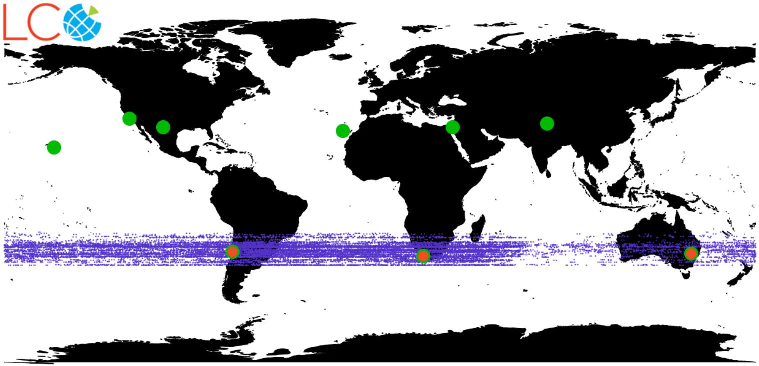
LCO global network

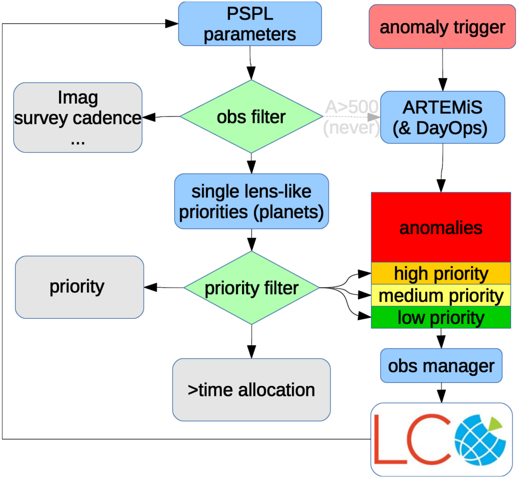


- Key project "Exploring Cool Planets Beyond the Snowline" [1]
- Regular operations: 2014-2016, pilot phase 2013

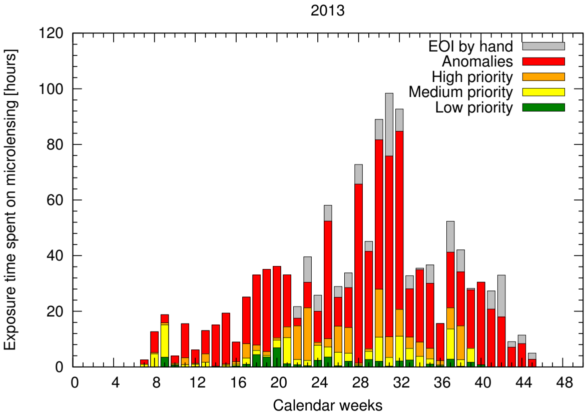
[1] PI: R. Street

Underlying philosophy

- Easy operations first
- Analytic expressions
- Interpolants where appropriate
- Keep results in memory

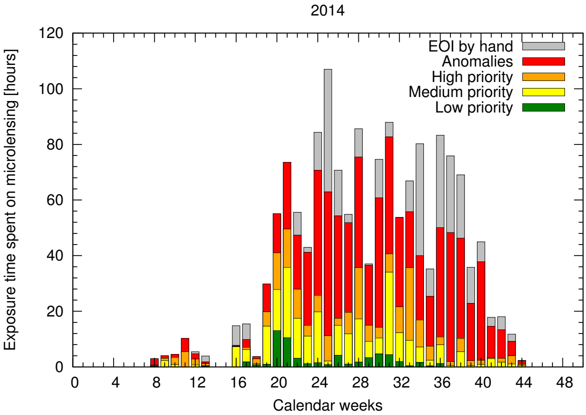


TAP in action - pilot phase



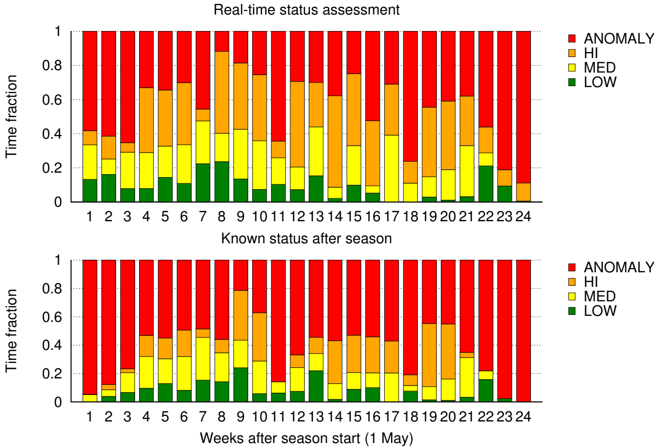
- Pilot phase (observation manager scheduled events)
- EOI: evens of interest (external requests)

TAP in action - regular operations



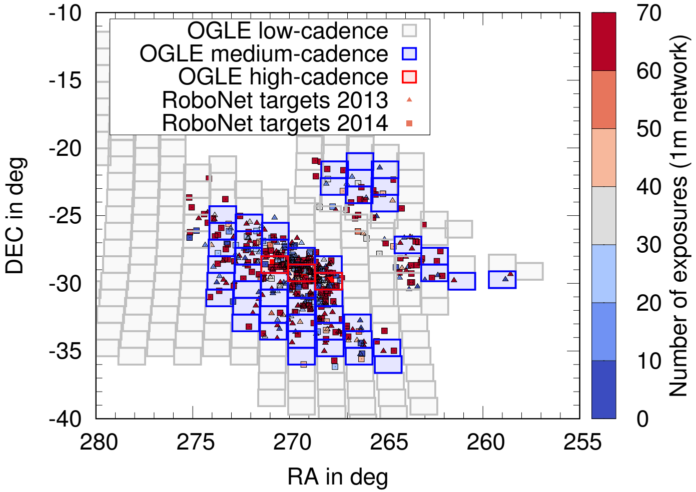
- LCO scheduler active since May 1st
- Anomalies: daily operations interaction (cadence, exptime)

Real-time and post-season status (2013)



- $\sim 10\,\%$ of all regular events turn out to be anomalous (mostly in high-cadence fields)

Requested targets and achieved cadence



- Precedence was given to low-cadence observations

What limits our ability to characterise planets?

Planet mass estimates

$$M_{\mathrm{p}} = \frac{\mu t_{\mathrm{E}}}{\kappa \pi_{\mathrm{E}}} \frac{q}{1+q}; \kappa \approx 8.14 \frac{\mathrm{mas}}{M_{\odot}}$$

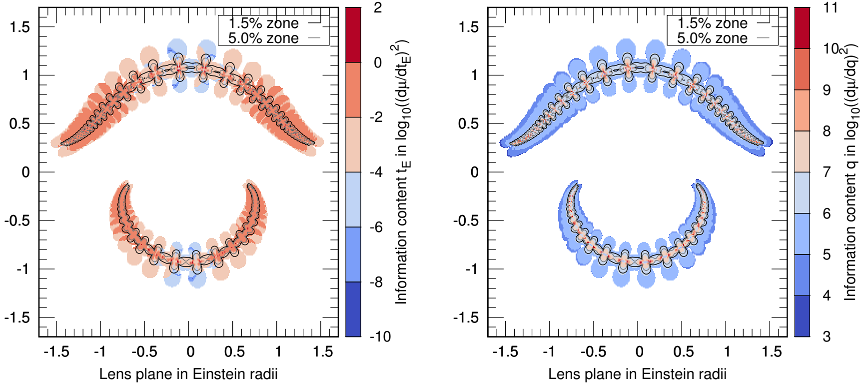
Planet mass uncertainties

$$\sigma_{M_{\mathrm{p}}} = \frac{\mu q t_{\mathrm{E}}}{\kappa \pi_{\mathrm{E}} (1+q)} \left(\frac{\sigma_{\pi_{\mathrm{E}}}^2}{\pi_{\mathrm{E}}^2} + \frac{\sigma_{\mu}^2}{\mu^2} + \frac{\sigma_q^2}{q^2 (1+q)} + \frac{\sigma_{t_{\mathrm{E}}}^2}{t_{\mathrm{E}}^2} \right)^{1/2}$$

$\Rightarrow$ The term with maximum relative uncertainty limits us.

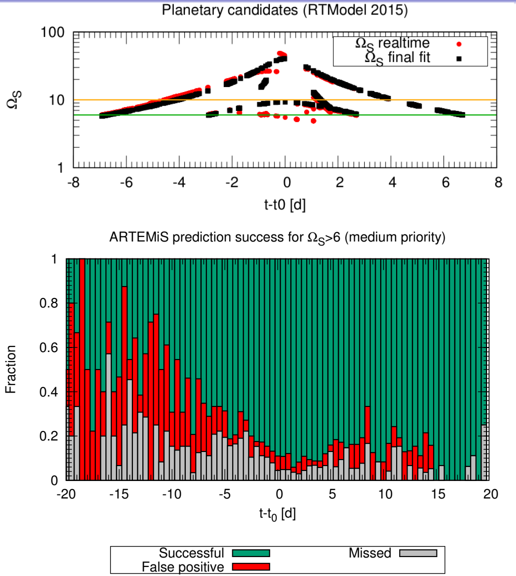
Detection zones contribute to characterisation

Information content for t_{E} and mass ratio q in a $u_0 = 0.15$ event



- Planet perturbation coincides with sensitivity in q
- Rule of thumb: 10-15 points sufficient for characterization

False-positives and priority function

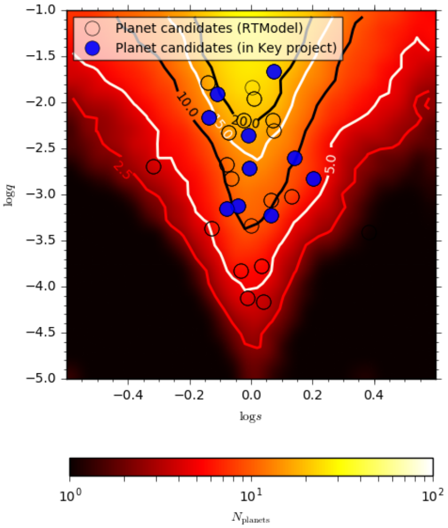


- Priority Ω_S: Planet probability per invested time
- Thresholds based on full-season simulation[a]
- Fractions of over- and underrated events
- How early can we obtain a reasonable estimate?

[a]Dominik et al. 2010

RoboNet sensitivity 2013 & 2014

- Non-anomalous events: 181
- Peak sensitivity 20%
- 1/2 candidates from anomaly monitoring
- >1 planet per year
- Candidates from RTModel (Bozza 2010)

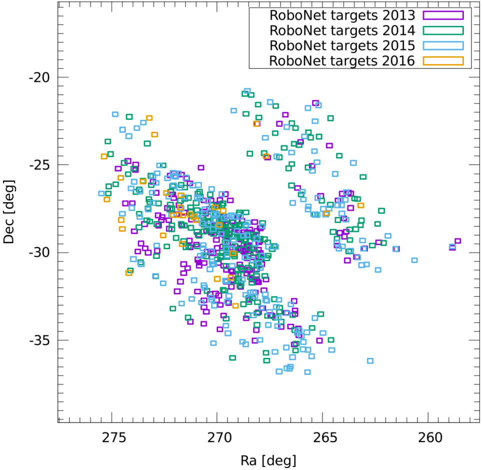


Remarks on the sensitivity estimates

- Mass function: requires number of detections, campaign sensitivity & corresponding uncertainties
- Even for $\log q$: Galactic model and t_{E} rejection of brown dwarfs and free-floating planets
- "Single star mass(-ratio) function": Detected binaries 2-3 % (Tsapras et al. 2016), actually 20-30 %
- Blending: correlated with t_{E}, thus relevant for mass function estimates

For an independent study: baseline

- Event centered follow-up does not guarantee baseline coverage
- > 700 events $(15' \times 15')$ in 4 years
- Data-mining opportunity for the future



Camera footprint

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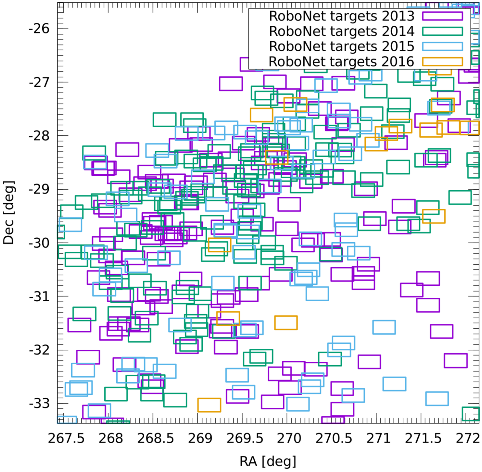

Camera footprint

Conclusions

- Hybrid strategies increase the chance to cover planetary events (5 planet candidates per year for LCO Key project)
- Human-interaction was limited to anomalies and their cadence
- Initial two-years were optimized for targets within the OGLE footprint
- Insights from 2015: more sensitivity has not lead to more detections

Thank you to all teams supporting our efforts!