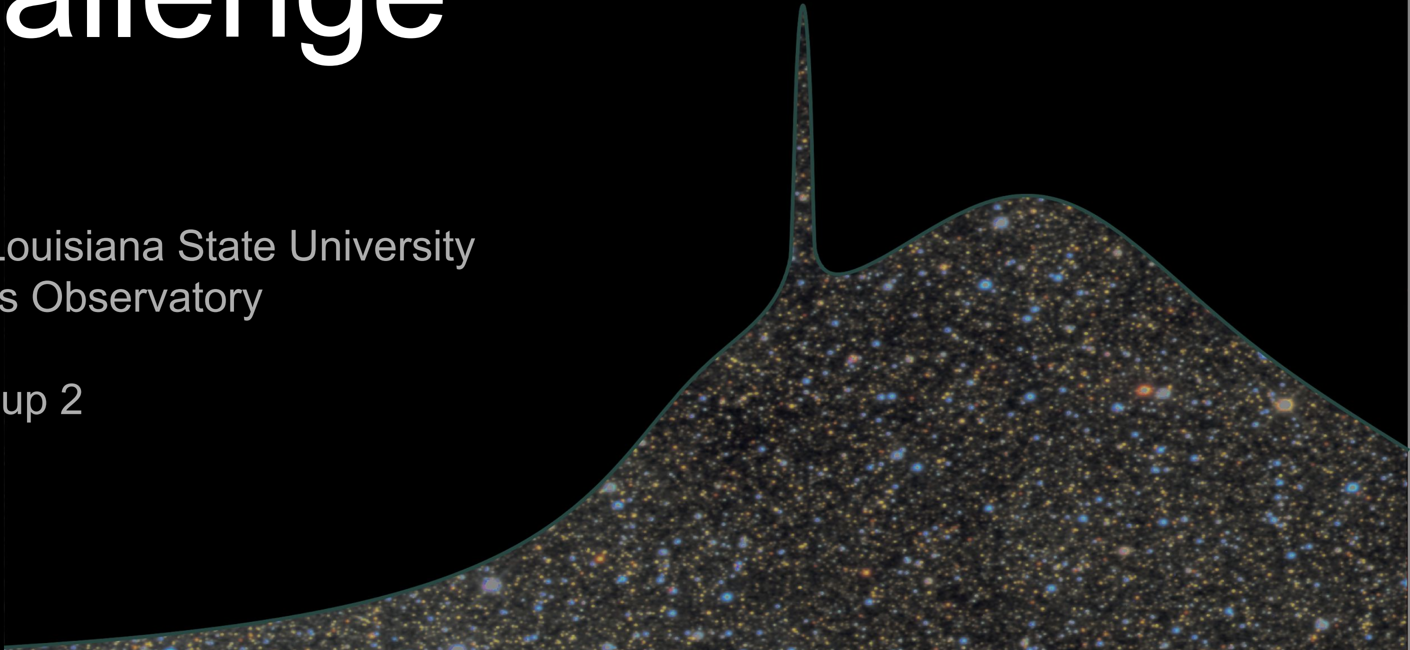
Microlensing Data Challenge

Presenter: M. Penny, Louisiana State University
R. Street, Las Cumbres Observatory
J. Yee, R. Poleski
WFIRST MicroSIT Group 2

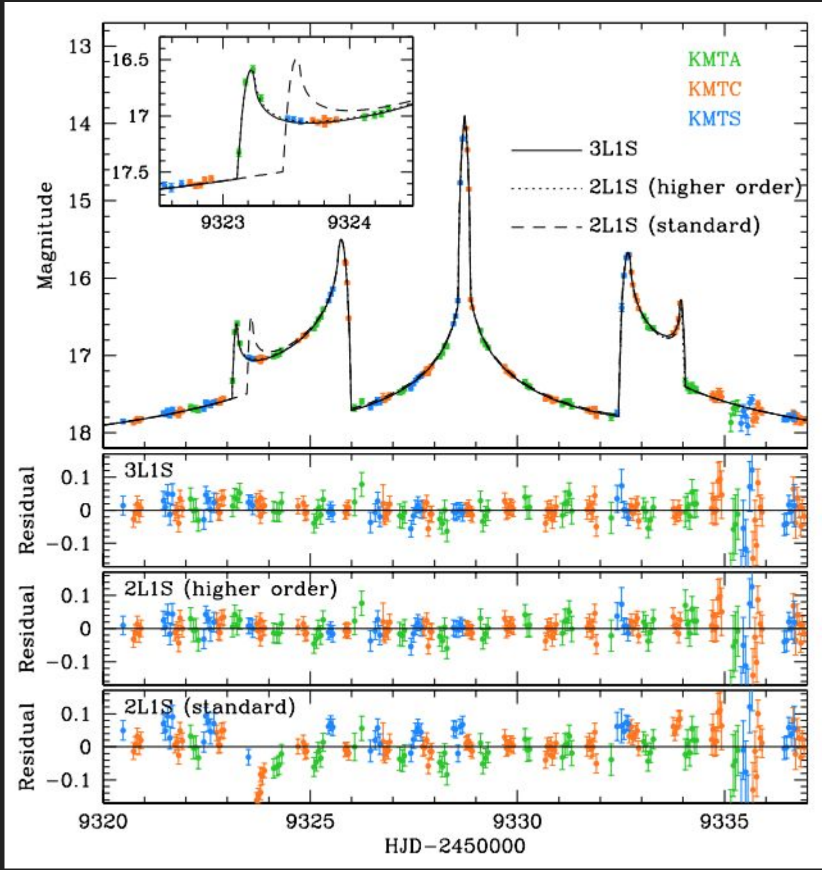


Motivation

- To stimulate research effort into outstanding modeling issues

E.g.

- Triple lens systems
- Automated event classification
- Variable source microlensing

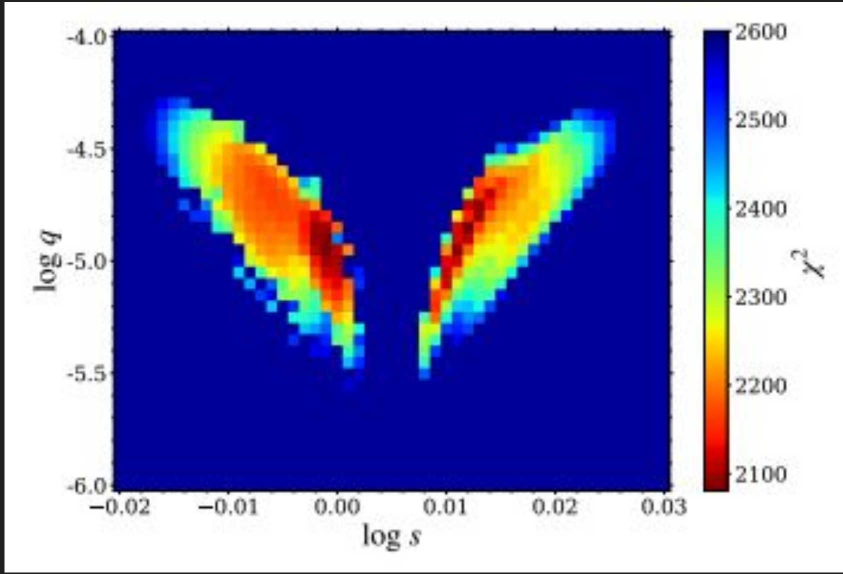


Han et al, 2021, KMT-2021-BLG-0322

Motivation

- Improve efficiency of computationally-intensive modeling process

- Thorough but efficient searching of parameter space
- Distinguishing binary and triple lenses



Yee et al. 2021: Grid search for best fitting models over binary lens mass ratio and separation for OGLE-2019-BLG-0960

Motivation

- Increase the number of people trained to analyze microlensing events

Bring in expertise in mathematics, statistics, informatics

Motivation

Data Challenges have been successful in stimulating engagement and innovation in other fields including exoplanets

Radial velocity fitting challenge

Dumusque, X. et al. (2016), A&A, 593, 5

Dumusque, X. et al. (2017), A&A, 598, 133

Transit detection

CoRoT analyses challenge

Exoplanet atmosphere spectral analysis

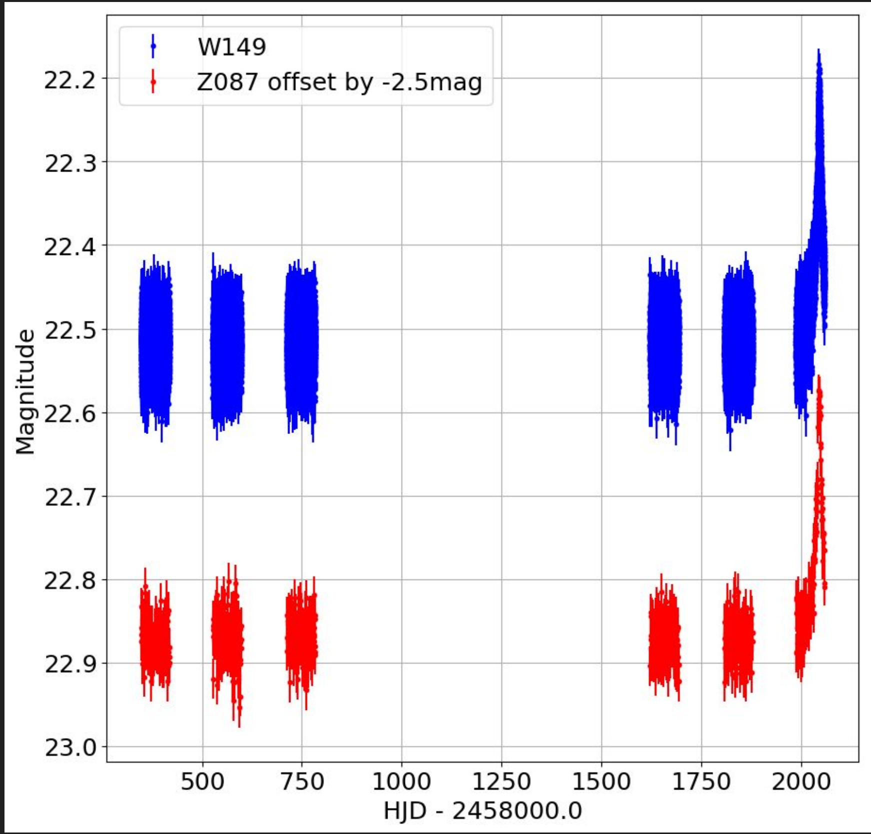
Hildebrant, S et al.

Simulated Dataset

Simulations by M. Penny

293 WFIRST lightcurves in two filters (Z087 and W149)

Roman lightcurves = Cadence, length and noise mimicking the nominal multi-year mission length and cadence of the Bulge survey, two filters



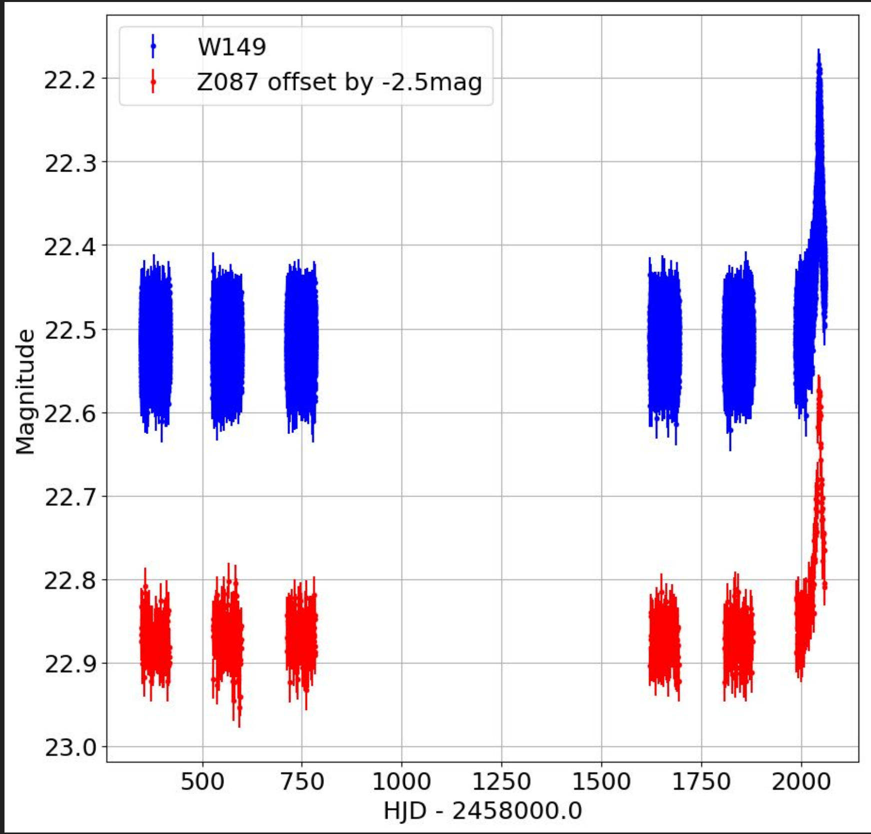
Simulated Dataset

Simulations by M. Penny

293 WFIRST lightcurves in two filters (Z087 and W149)

293 WFIRST lightcurves in two filters (Z087 and W149)

- 74 Single lenses (including FFP candidates)
- 83 Binary star lenses
- 43 Planetary binary lenses
- 93 Cataclysmic variables
- 0 Non-variables



Logistics

M.Penny alone had access to the simulated event parameters

R.Street handled all data challenge logistics, website, review panel

Jan 2018: Annual Microlensing Conference, Auckland, NZ

- Public release of data + description of evaluation criteria

Oct 2018: Entry submission deadline

Challenge Entries

http://microlensing-source.org/data-challenge

Github organization: https://github.com/microlensing-data-challenge

Microlensing Source

Overview Learning Glossary Resources Interactive Opportunities Software Data Challenge

Microlensing Data Challenge

The analysis and modeling of microlensing events has always been a computationally-intensive and time-consuming task, requiring a powerful computer cluster as well as well sampled lightcurves. While the number of interesting events with adequate data remained fairly low, it has been practical to perform a careful interactive analysis of each one, often with the aid of a powerful computer cluster. Even so, a number of challenges remain, particularly concerning the analysis of triple lenses.

This is expected to change with next-generation surveys, especially with the launch of WFIRST. This mission is expected to detect thousands of microlensing events, including hundreds of planetary events. Clearly, our analysis techniques need an upgrade to fully exploit this dataset, and we encourage people from outside the current microlensing community to bring in diverse expertize.

Entry Data Products

- Summary table of fitted event parameters with uncertainties
- Technical specifications of the computing resources used
- Description of software used including the language(s), libraries or package dependencies.
- Time taken to model each event
- Plots of the lightcurves with the fitted models overlaid and residuals.
- Plots of the lens plane geometry, caustic structures and source trajectory.

Evaluating the Results

All entries were anonymized

4-person evaluation panel + non-voting chair (RAS):

Rachel Akeson, IPAC
Scott Gaudi, Ohio State
Hyungsuk Tak, Harvard
Eamonn Kerins, Manchester

Rachel, Matthew and panel members not permitted to participate in teams

Programmatic evaluation for classification data

Comparison of fitted parameters for Team1

The table below compares the parameters obtained during the fitting process (black) with the true parameters used to simulate the datasets (grey, italics)

If a team provided several alternative models for a single dataset, these are represented by multiple entries with the same ModelID

'None' entries represent values missing from the team's table entry data.

Back to entry summary

ModelID	Class	t0	tE	u0	rho	piE	fs_W	fb_W	fs_Z	fb_Z	s
ulwdc1_002	PSPL *Binary_star*	2459650.03355 ± 0.2432288499 *2459648.31840479*	55.2527260873 ± 8.4917345258 *36.8514*	0.7818939997 ± 0.1701036718 *2.16671*	None ± None *0.00104122*	None ± None *0.0729903*	59.2011595983 ± 23.7946204763 *0.413613*	1437.78721782 ± 23.776920539 *2.852503507111193*	45.529139359 ± 18.3081887461 *0.557115*	810.515447624 ± 18.29614764 *1.558477832946977*	None ± Non *0.325677*
ulwdc1_004	USBL *Binary_planet*	2460024.22001 ± 0.0820564796 *2460024.31690896*	10.5138334848 ± 0.3966804041 *6.6877*	0.7376195568 ± 0.049117409 *-1.52343*	0.0293813664 ± 0.0061434232 *0.00120717*	None ± None *0.171343*	47.4894608478 ± 5.2688112877 *0.607462*	304.554801836 ± 5.2679127284 *1.2773515524873547*	15.9822566229 ± 1.7903792031 *0.744427*	79.7004473245 ± 1.7911315991 *0.8446015179946584*	1.843624606 ± 0.032415774 *2.48124*
ulwdc1_005	PSPL *PSPL*	2459816.21546 ± 0.0016982558 *2459816.21264422*	1.7893880493 ± 0.0968700982 *1.85542*	0.074382326 ± 0.0051480273 *-0.0712711*	None ± None *0.00280589*	None ± None *0.321621*	12.1824876967 ± 0.8667417313 *0.0206938*	551.305006801 ± 0.8649149434 *1188.2484362550706*	4.3035231358 ± 0.3155290846 *0.0242225*	158.888516415 ± 0.3169077042 *866.6305304269218*	None ± Non *None*
ulwdc1_006	USBL *Binary_star*	2459651.85513 ± 0.00014 *2459651.8548187*	5.7205166855 ± 0.1265098915 *5.31401*	0.0052095829 ± 0.000121 *-0.00588459*	0.000314 ± 0.00045 *0.000772343*	None ± None *0.0902075*	4.5936183648 ± 0.1093460461 *0.0684179*	69.3814569304 ± 0.1078596445 *106.46494240328049*	0.707314727 ± 0.0180179795 *0.102309*	6.7651987964 ± 0.0191512543 *47.72488953238265*	0.101764207 ± 0.002037278 *0.113947*
ulwdc1_008	USBL *Binary_planet*	2458728.97888 ± 0.0782798178 *2458729.060358196*	24.6969140599 ± 0.012271923 *26.2846*	0.9553988635 ± 0.0062206637 *0.891991*	0.0060379147 ± 0.005790243 *0.000547291*	None ± None *0.0852794*	269.887440907 ± 3.2659930145 *0.117726*	1722.52821132 ± 3.2748087289 *37.82059169457552*	130.963101858 ± 1.8441740261 *0.123387*	798.231271522 ± 1.8660343201 *34.64534799491492*	1.964981072 ± 0.005348349 *1.92159*
ulwdc1_009	USBL *Binary_star*	2460010.3793 ± 0.0111140771 *2459971.19486356*	68.5770508011 ± 1.0854118002 *74.0461*	0.1339243004 ± 0.0036791371 *-0.455631*	0.0002158844 ± 19562.5973645534 *0.00113586*	0.294186215297 ± 0.0413956007609 *0.0837776*	315.271470443 ± 8.5666518598 *0.306943*	900.743222029 ± 8.5658655513 *4.127217676764982*	163.280300414 ± 4.4375477854 *0.280945*	524.529954616 ± 4.4383429874 *5.0269384536568955*	0.356605725 ± 0.002179945 *4.65476*
ulwdc1_012	USBL *Binary_planet*	2458598.60756 ± 0.00207 [illegible]	16.1039968738 ± 0.0218605962 [illegible]	0.0475759283 ± 7.59e-05 [illegible]	0.00166 ± 0.000588 [illegible]	None ± None *0.0714066*	570.95653707 ± 1.3587459961 [illegible]	620.137900987 ± 1.3535267983 [illegible]	336.753036923 ± 0.840082427 [illegible]	308.858865384 ± 0.8431768844 [illegible]	1.035444269 ± 0.001636715

Programmatic evaluation for classification data

Comparison of simulated/true parameters highlights weaknesses (some known) in modeling process, e.g. tendency for u_0(fitted) > u_0(true)

Comparison of fitted parameters for Team1

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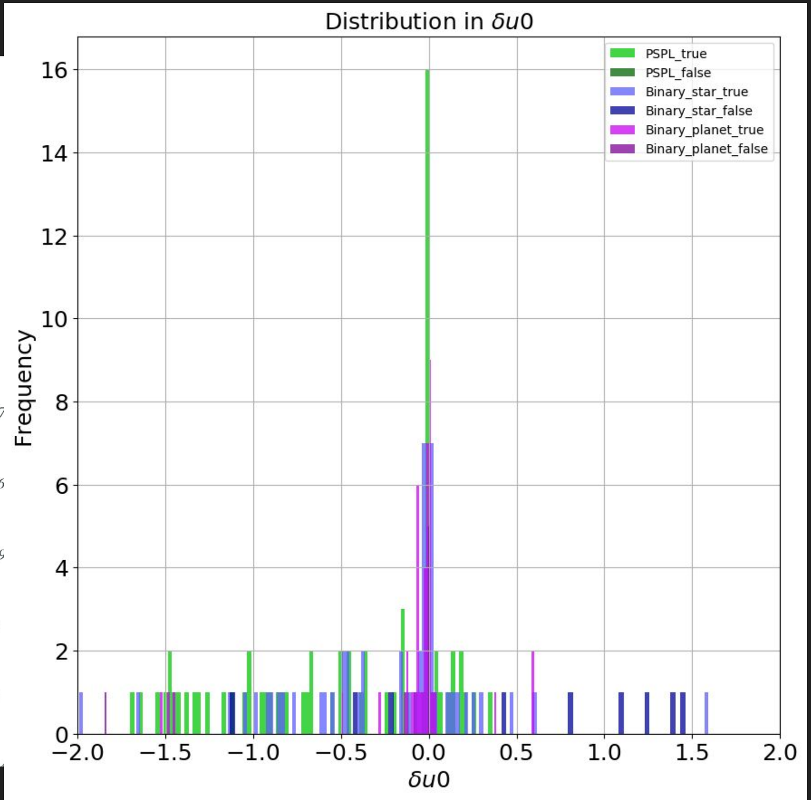
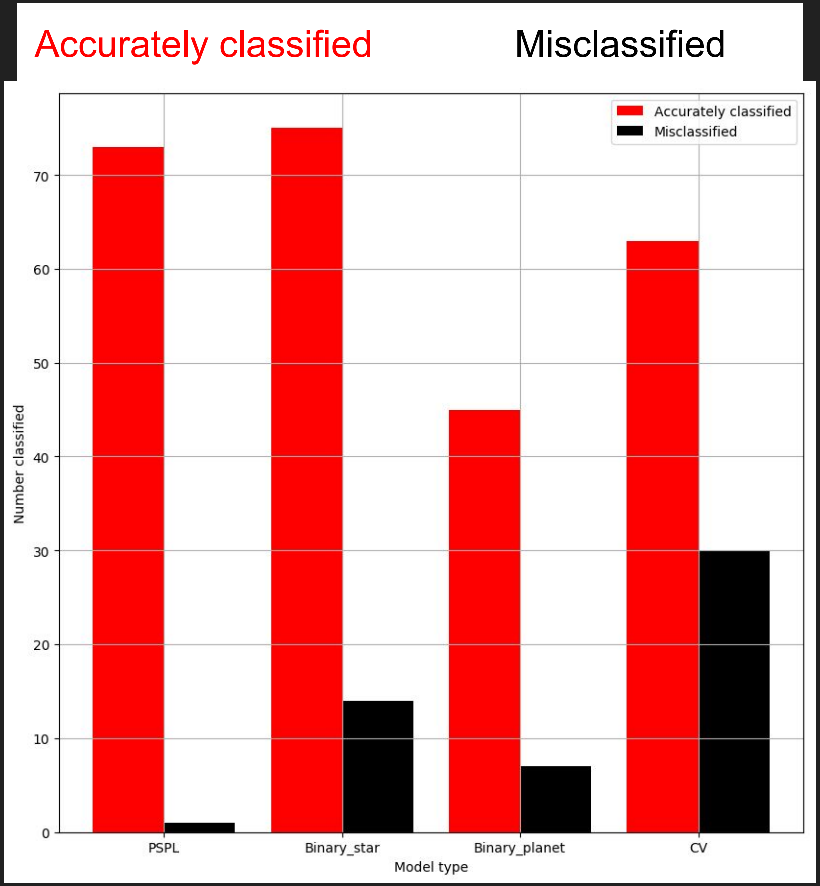
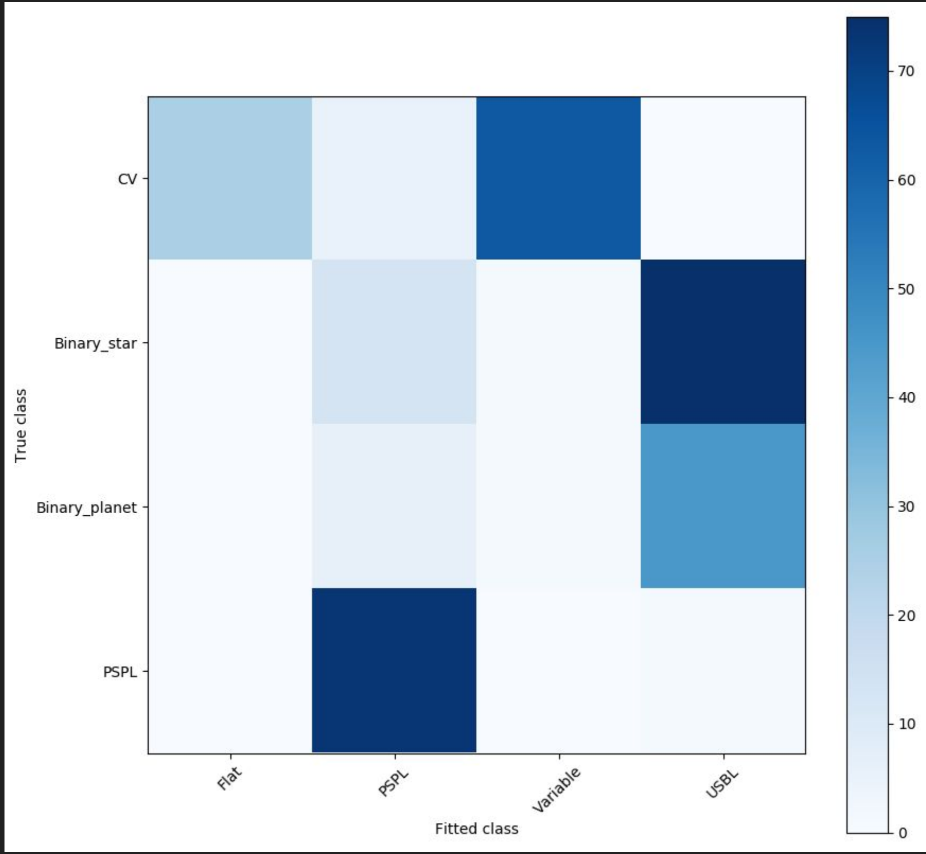


Programmatic evaluation for classification data





Evaluating the entries

Panel members awarded grades out of 5 in each category

- Accuracy of fitted model parameters
- Software/modeling process efficiency/scalability
- Innovations in approach
- Broadening the field

Each team received written feedback regarding the panel's conclusions
Some important but hard-to-evaluate criteria
True benchmarking not implemented for logistical reasons
Panel relied on documentation to evaluate process and innovative aspects

Evaluation supplemented by questionnaire to all teams, requesting specific information regarding e.g. computing resources used

Team credits

Team 1	Contact: Etienne Bachelet	Markus Hundertmark Daniel Godines Charlotte Fling
Team 2	Contact: Etienne Bachelet	
Team 3	Vandylions Contact: Geoffrey Bryden	Savannah Jacklin Rob Siverd Keivan Stassun Ryan Oelkers
Team 4	Contact: Clément Ranc	Arnaud Cassan Richard K. Barry Esther Euteneuer Stela Ishitani Silva Yiannis Tsapras

Results

Accuracy in fitted parameters

	Combined scores	Rank
Team 1	16.17	1
Team 2	14.5	2
Team 3	7.83	4
Team 4	11.0	3

Std.dev 3.72

Overall, when events were properly classified, model parameters could be accurately derived, noting known weaknesses.
Future work to investigate “un-modelable” events
Classification problem non-trivial, particularly for subtle anomalies

Results Software/modeling process efficiency

	Combined scores	Rank
Team 1	13.5	1
Team 2	11.5	2
Team 3	9.5	4
Team 4	11.0	3

Std.dev 1.65

All teams used publicly available software
New approaches to classification/detection in development, but early stage
Effective progress on question of scalability, but room for improvement
At least two teams required laptops/workstations rather than cluster computers

Results Innovation

	Combined scores	Rank
Team 1	14.5	3
Team 2	15.0	2
Team 3	8.0	4
Team 4	17.0	1

Std.dev 3.90

Significant effort invested into development of modern, open-source software
Some welcome attempts made to trial non-standard techniques
Evaluation dependent on documentation provided

Results

Broadening the field

	Combined scores	Rank
Team 1	12.0	3
Team 2	4.5	4
Team 3	14.5	1
Team 4	13.0	2

Std.dev 4.45

All but one of the teams included students and/or researchers whose previous work is primarily outside microlensing
All teams included established microlensers
More work to do to bring in "fully" new teams

Lessons learned

While the processing of large datasets will be a concern for Roman, meaningful comparison between teams is difficult without formal benchmarking

- Requires standardized computing facilities
- Could be done with a cloud-based server and virtual environments but some cost associated with this.
- Best achieved in a hackathon-style targeted “mini-challenge” workshop

Lessons learned

Attracting researchers from outside astronomy/exoplanets was difficult, despite publicizing the challenge on a number of astro-statistics forums

- Recent LSST data challenge used Kaggle platform attracted 1094 teams, most non-astro
- Drawbacks:
  - cost – prizes expected, typically $15K - $100K
  - high overhead to prepare challenge dataset to meet platform requirements, avoid “leakage”
- Kaggle is really designed for supervised classification challenges

More Challenges?

Ideas discussed:

- More lightcurve analysis challenge(s)
  - Add triple lenses (multiple planets, circumbinaries, distant companions), binary sources
- Image-based photometry and astrometry challenge(s)
- Specific aims or broad scope?