



MOON  
AND  
YOU

# Public Microlensing Analysis Tools and Survey Data

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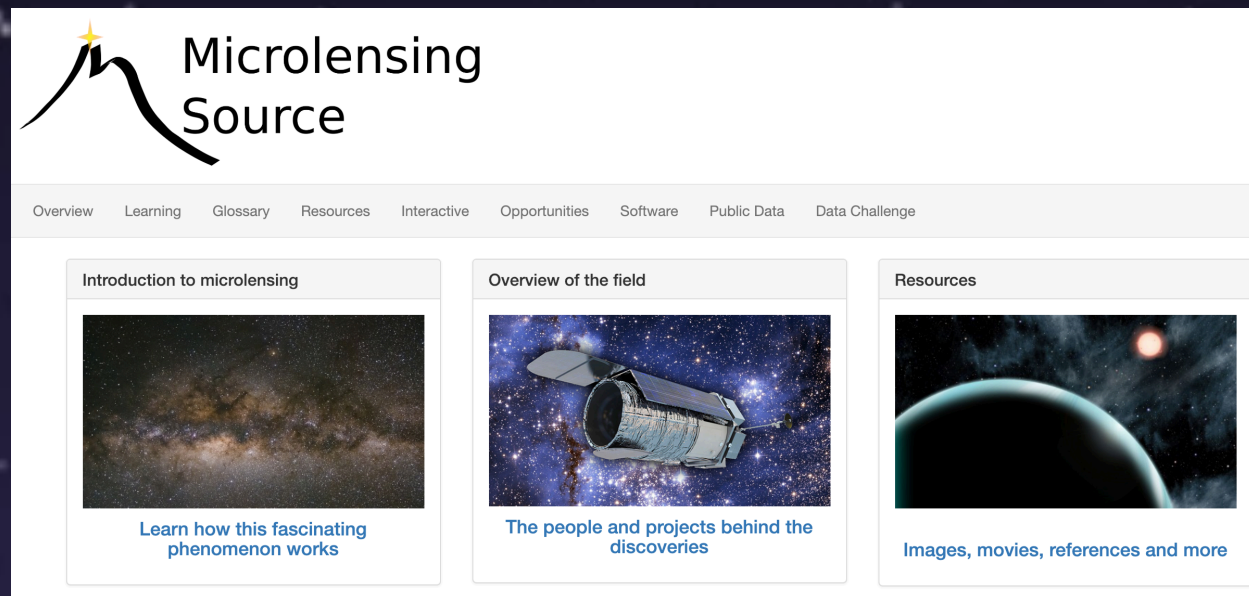
# Four Parts

1. Data
2. Analysis Tools (Code)
3. Data Challenge
4. What you can do



# Microlensing in the Era of *WFIRST*

- *WFIRST* will spend 1/3 of its time on a near-infrared (NIR) microlensing survey
  - Microlensing observations focus on the central Galactic bulge
- [Microlensing-source.org](http://Microlensing-source.org)



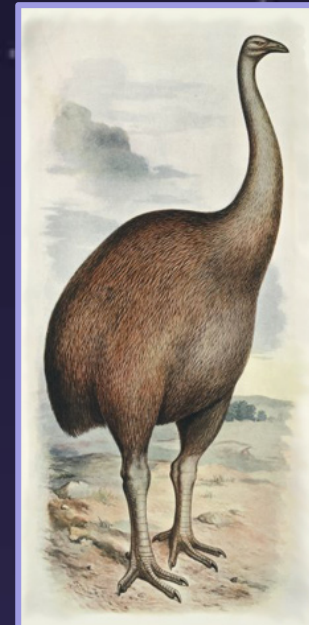
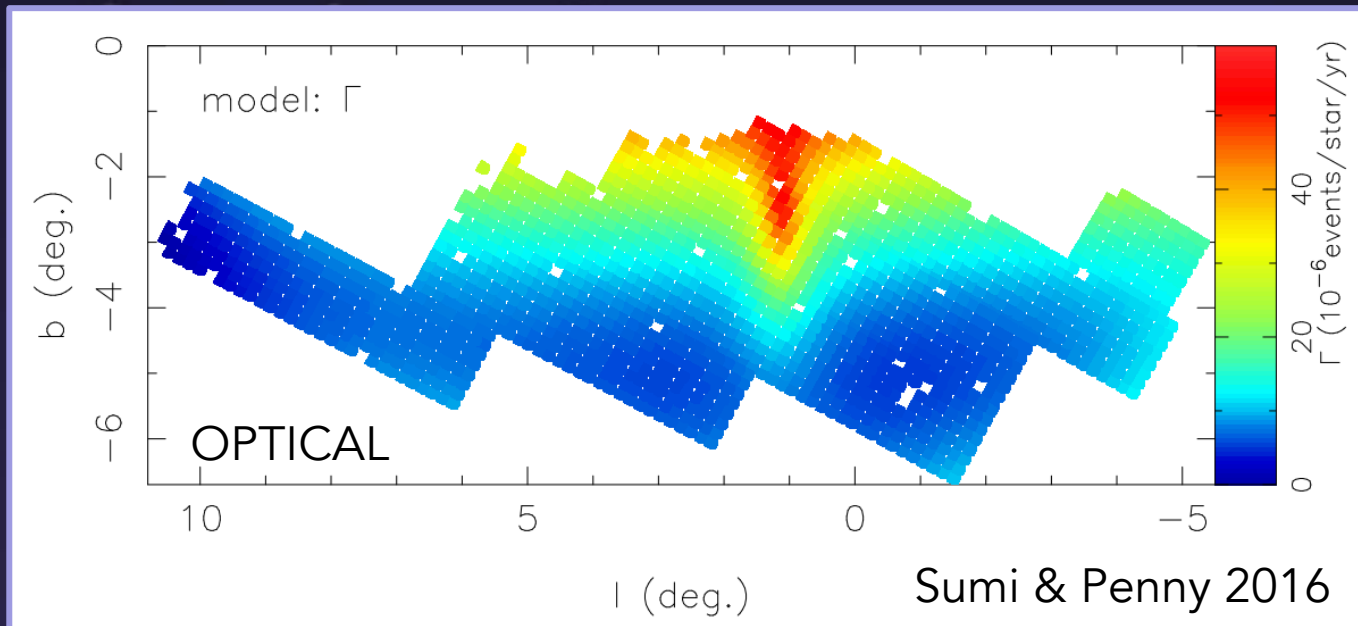
Microlensing-source.org is your one-stop shop for all things microlensing

# THE DATA



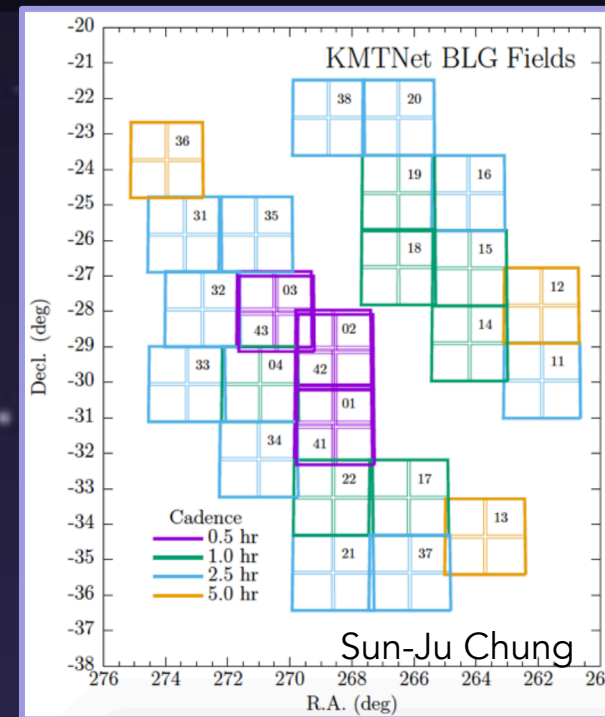
# Microlensing Observation in Astrophysics (MOA)

- Dedicated high-cadence microlensing survey
  - Upcoming data release of 9 years baseline data (2006—2014)
- Good longitudinal coverage in conjunction with OGLE
  - High quality data compared to many alert light curves



# Korea Microlensing Telescope Network (KMTNet)

- Wide field photometric survey observing central Galactic bulge
- 2015 and *K2C9* data are currently public, rest to follow
- Dedicated and continuous monitoring of the center of the Galaxy helps us understand event rate, types of planets, etc.

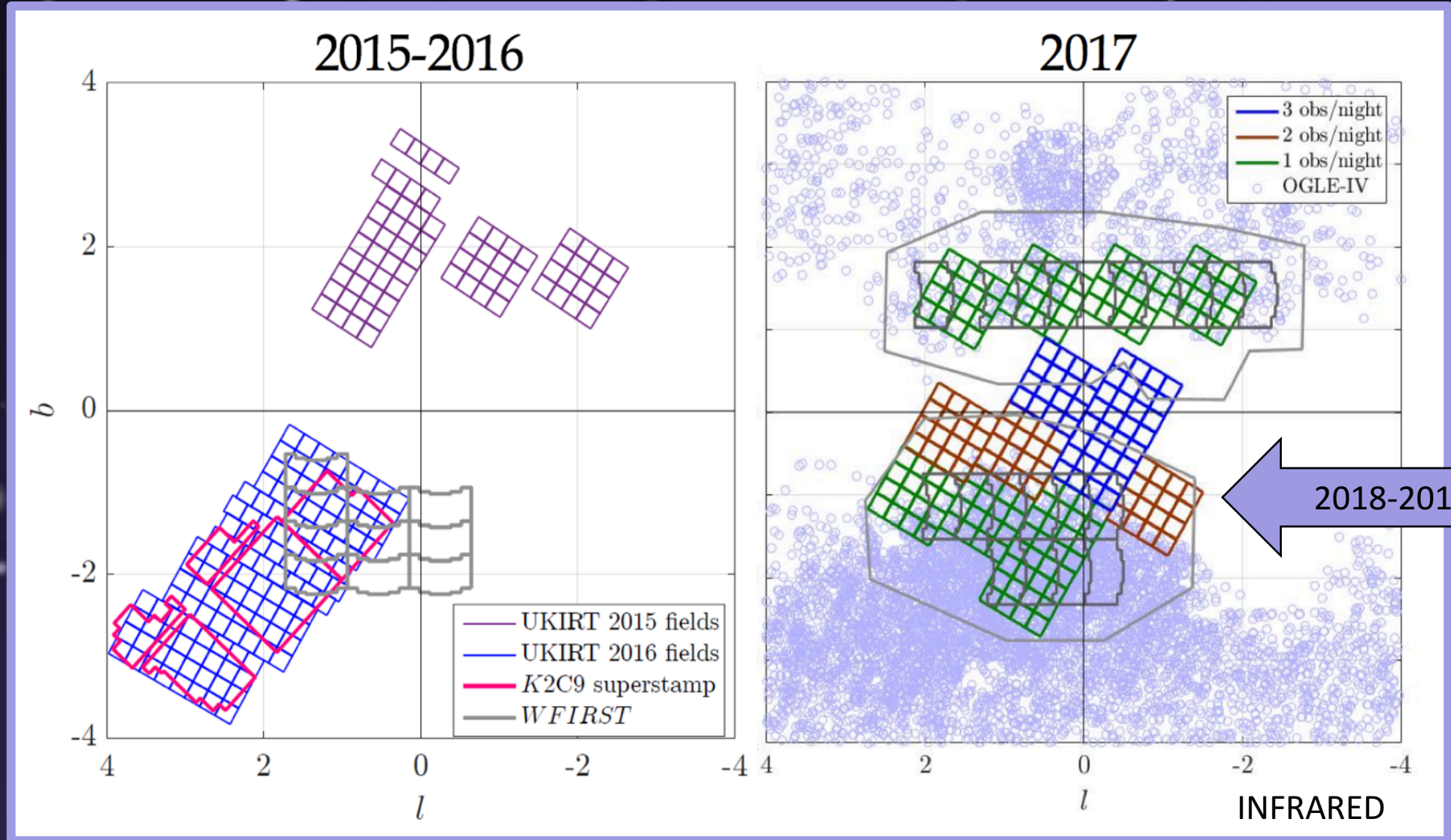


# The United Kingdom Infrared Telescope (UKIRT)



- 3.8m Telescope on Mauna Kea in Hawai'i
- Survey Area: 10.5 deg<sup>2</sup>
- Duration: 2015—2019
- Cadence: 1—3 epochs/night
- Filters: *H* and *K*
- Overlap with OGLE IV Microlensing survey

# UKIRT Field Map





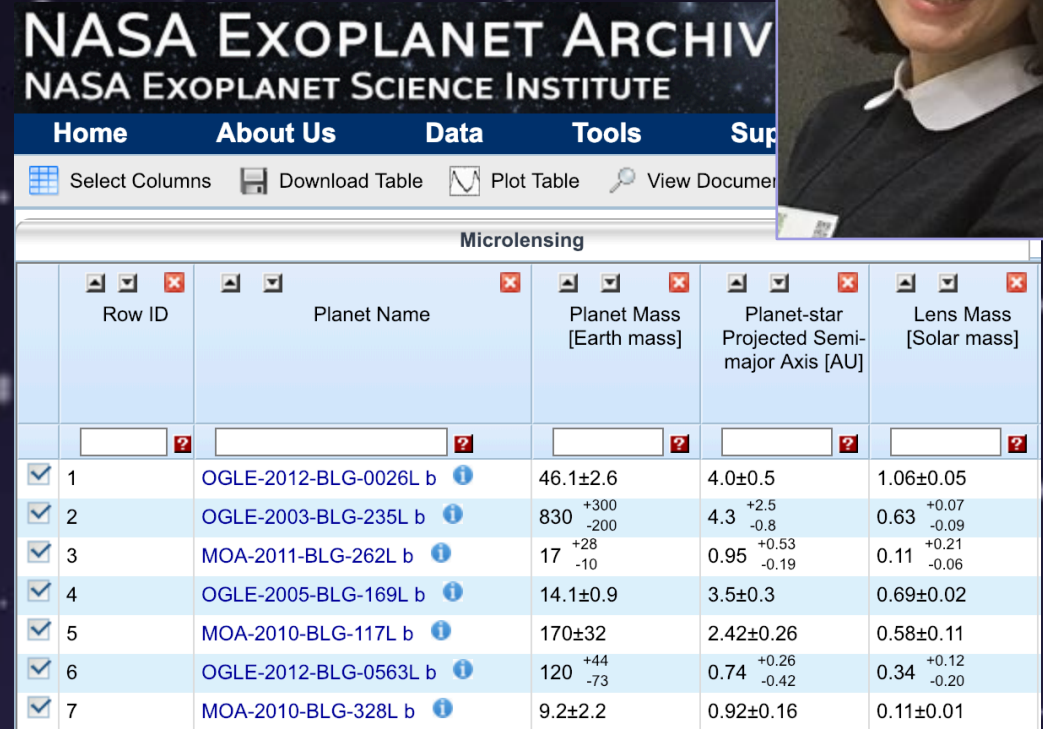
# UKIRT Microlensing Survey

- Use mock microlensing injections to determine NIR detection efficiency and event rate at Galactic center ([Jacklin et al. 2019](#) *in prep*)
- Data are made publically available within six months of end of the observing period on the NASA Exoplanet Archive
  - 2018 data available by the end of the month

Precursor microlensing observations for *WFIRST* are available for YOU to play with today

# NASA Exoplanet Archive

- Construction of first publically available comprehensive database of microlensing model parameters
  - Project conducted by Caltech SURF student Naylynn Tañón
  - Includes all statistically indistinguishable degenerate model solutions



The screenshot shows the NASA Exoplanet Archive website interface. At the top, there is a navigation bar with links for Home, About Us, Data, Tools, and Support. Below the navigation bar, there are several utility buttons: Select Columns, Download Table, Plot Table, and View Document. The main content area is titled "Microlensing" and displays a table with the following columns: Row ID, Planet Name, Planet Mass [Earth mass], Planet-star Projected Semi-major Axis [AU], and Lens Mass [Solar mass]. The table contains seven rows of data, each with a checkbox in the first column and an information icon in the Planet Name column.

Row ID	Planet Name	Planet Mass [Earth mass]	Planet-star Projected Semi-major Axis [AU]	Lens Mass [Solar mass]
<input checked="" type="checkbox"/>	OGLE-2012-BLG-0026L b	46.1±2.6	4.0±0.5	1.06±0.05
<input checked="" type="checkbox"/>	OGLE-2003-BLG-235L b	830 <sup>+300</sup> <sub>-200</sub>	4.3 <sup>+2.5</sup> <sub>-0.8</sub>	0.63 <sup>+0.07</sup> <sub>-0.09</sub>
<input checked="" type="checkbox"/>	MOA-2011-BLG-262L b	17 <sup>+28</sup> <sub>-10</sub>	0.95 <sup>+0.53</sup> <sub>-0.19</sub>	0.11 <sup>+0.21</sup> <sub>-0.06</sub>
<input checked="" type="checkbox"/>	OGLE-2005-BLG-169L b	14.1±0.9	3.5±0.3	0.69±0.02
<input checked="" type="checkbox"/>	MOA-2010-BLG-117L b	170±32	2.42±0.26	0.58±0.11
<input checked="" type="checkbox"/>	OGLE-2012-BLG-0563L b	120 <sup>+44</sup> <sub>-73</sub>	0.74 <sup>+0.26</sup> <sub>-0.42</sub>	0.34 <sup>+0.12</sup> <sub>-0.20</sub>
<input checked="" type="checkbox"/>	MOA-2010-BLG-328L b	9.2±2.2	0.92±0.16	0.11±0.01



The Exoplanet Archive is the center of the public microlensing data universe

# THE CODES



# PyLIMA



- <https://github.com/ebachelet/pyLIMA>
- Flexible, python-based, continuously adapted
- PSPL with options of higher-order effects
  - More flexibility coming soon
- Tested and well-received at 2017 Sagan Summer Workshop

Etienne Bachelet, Valerio Bozza, and Rachel Street

# MulensModel

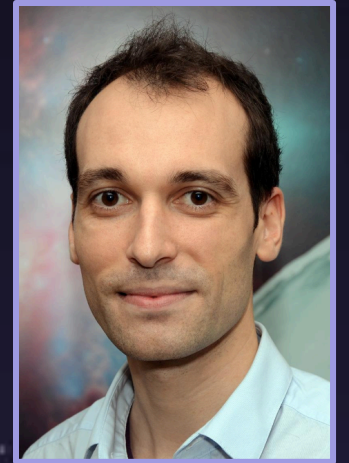


- <https://github.com/rpoleski/MulensModel>
- Model magnification curves
- Goodness-of-fit statistics for microlensing events
  - single and binary lenses
- Higher-order effects
  - Extended sources with limb-darkening, annual microlensing parallax, and satellite microlensing parallax

Radek Poleski and Jennifer Yee

# MuLAn and VBBinaryLens

- MuLAn
  - <https://github.com/muLAn-project/muLAn>
  - Another excellent fitting software for a variety of microlensing events
  - Clement Ranc and Arnaud Cassan
- VBBinaryLens
  - [MNRAS 479 \(2018\) 5157](#) and [MNRAS 408 \(2010\) 2188](#)
  - What's under the hood of a lot of these light curve fitting routines
  - Valerio Bozza

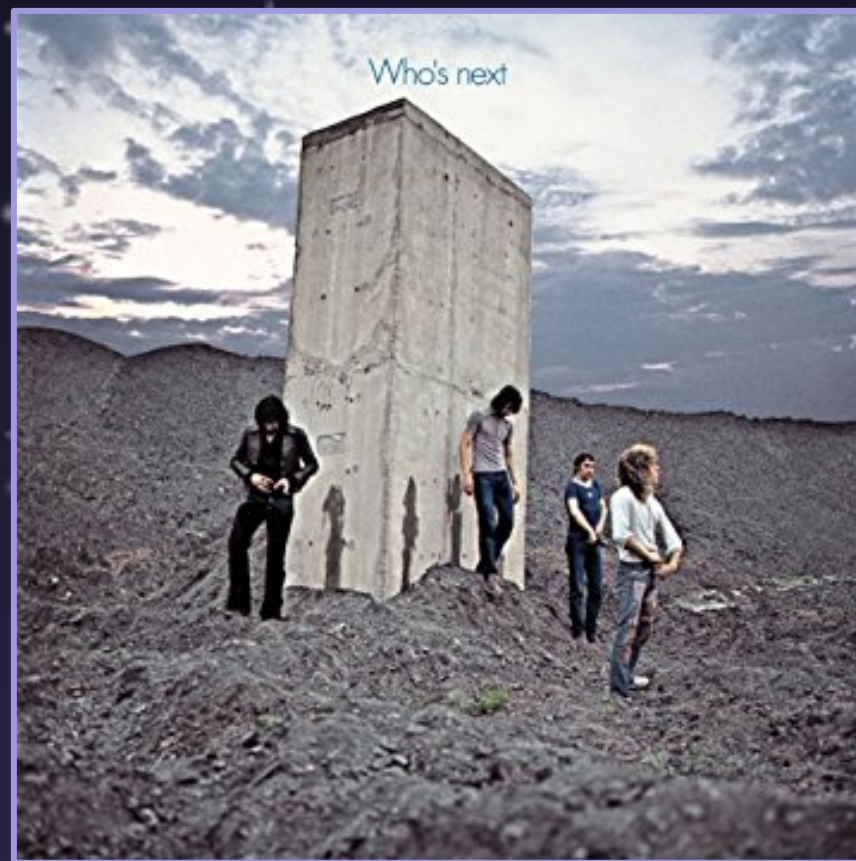


# Microlensing Data Challenge

- 290 Simulated *WFIRST* light curves with variety of anomalies
  - GOALS:
    1. Distinguish single lens, binary lens, and planetary events from other variables
    2. Model the parameters of microlensing events
- Participants encouraged to use publically available codes while adding their own twist
  - i.e., faster and better classification and fits

Results presented at upcoming Microlensing 23 meeting, tune in then for updates or join in the next challenge

# WHAT'S NEXT

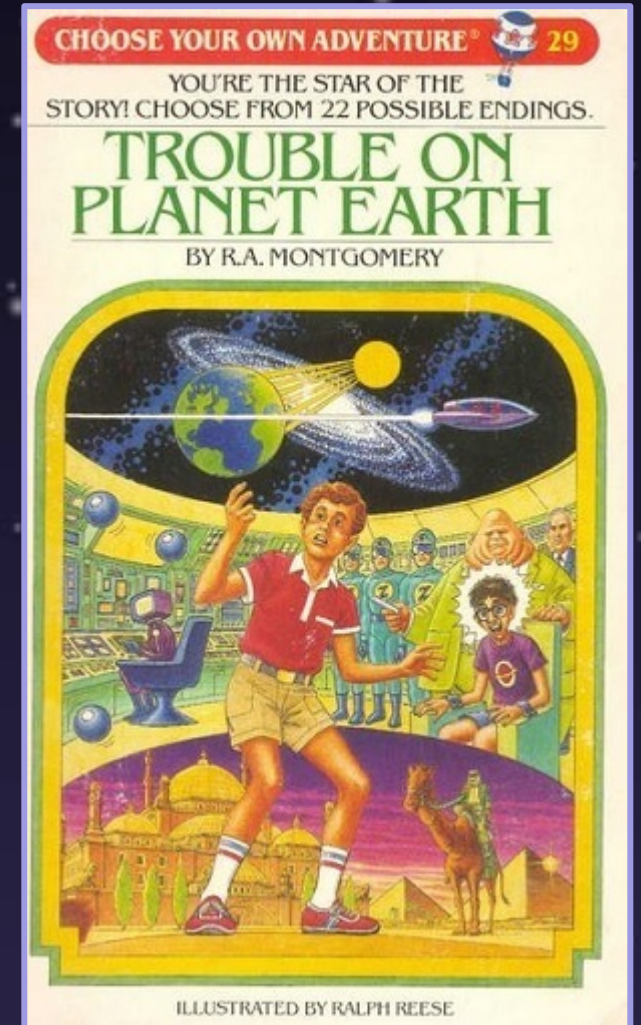




# What YOU can do today...

- Join the microlensing community
  - Looking to expand person power
- Potential for auxiliary science
  - Transients, single black hole mass function, choose your own adventure
- Synergies between facilities
  - E.g., *WFIRST* and LSST

With all of these tools, you can choose your own (science) adventure



# ...in anticipation of tomorrow!

