Systematic Planetary Anomaly Search for the 2016 KMTNet archive

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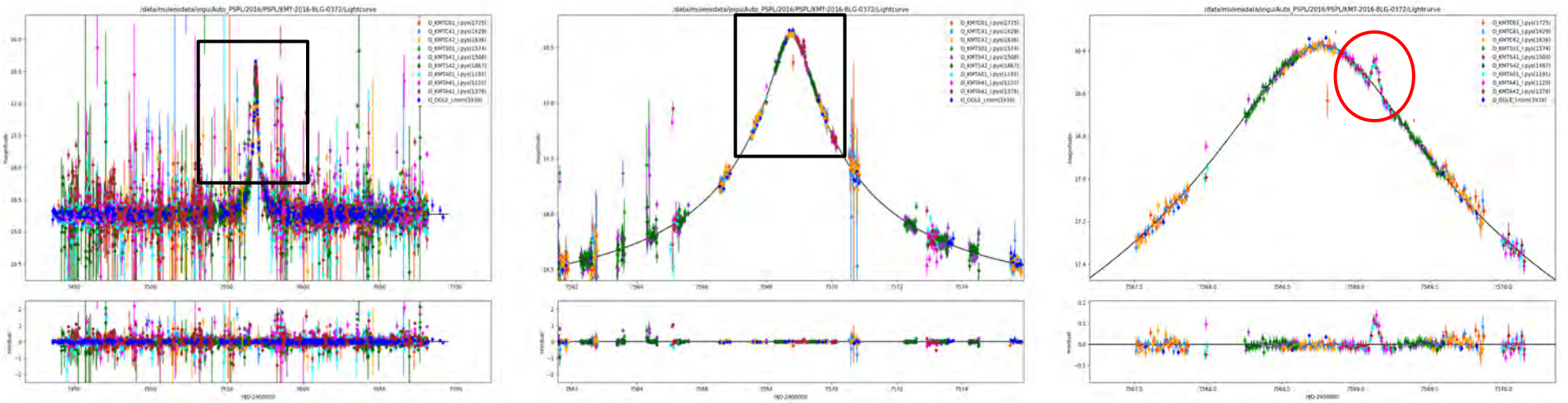
Goal of systematic search series

- Systematically search ALL anomalous events
  - using the KMTNet archive from 2016 to 2021+

- To build **complete microlensing planet sample**

- Ultimately, based on the complete sample
  - Build / validate **planet mass-ratio function**
  - Build / validate **planet sensitivity**

Methods to identify anomaly



- Conventional method – “by-eye”
  - Human dependence → May exists hidden planets
- AnomalyFinder (AF): Zang et al. (2021, 2022)
  - Systematic search
  - Semi-machine-based method

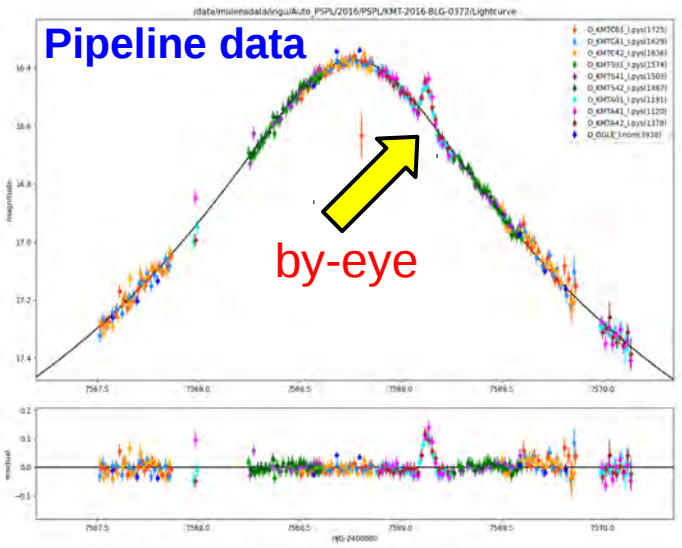
AF search for 2016 KMTNet archive

Total events in **2016**	**2588**		
	High-cadence fields	Low-cadence fields	
Anomalous events	106	113	
Recovered publications	10 (+4)	8	**Criteria**
Binary events	79	83	**q > 0.06**
Planet-like events	13	22	
Planet candidates	**1**	**7**	
New planets	**5**	**4**	**q < 0.03**
log(q) < 10^{-5} Planets	**+1**	**+1**	

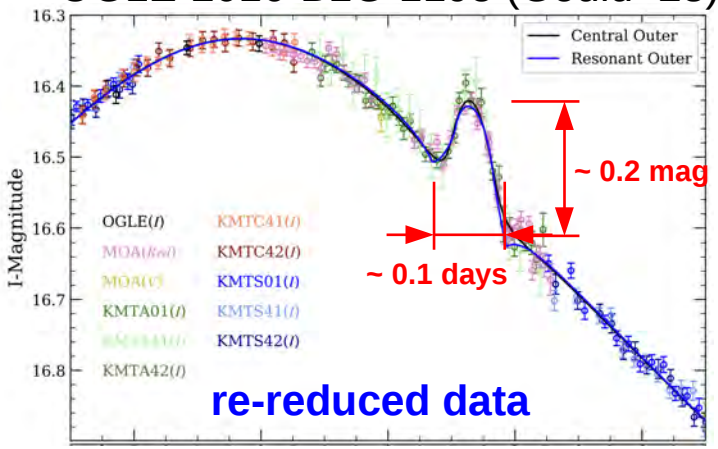
Resolving degeneracy: Planet / Binary ($\Delta\chi^2 > 10$), 2L1S/1L2S ($\Delta\chi^2 > 15$)

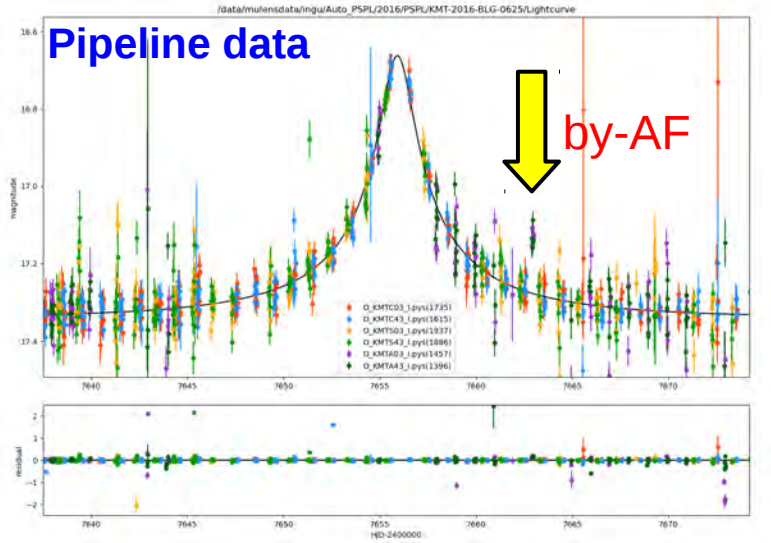
Why the anomaly couldn't be identified by eye?

- Example: bump-shaped anomaly

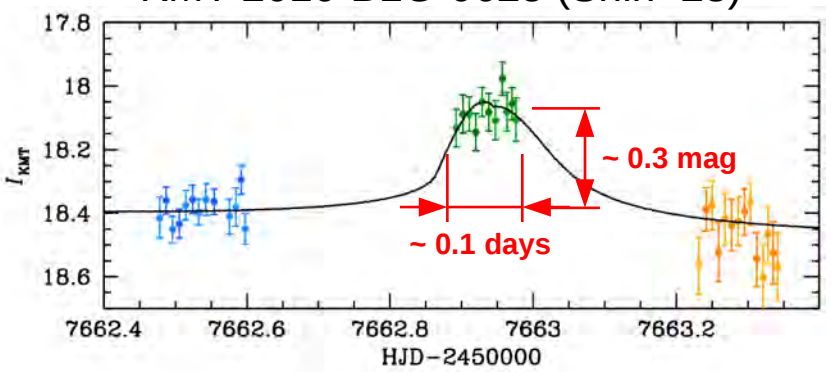


OGLE-2016-BLG-1195 (Gould+23)



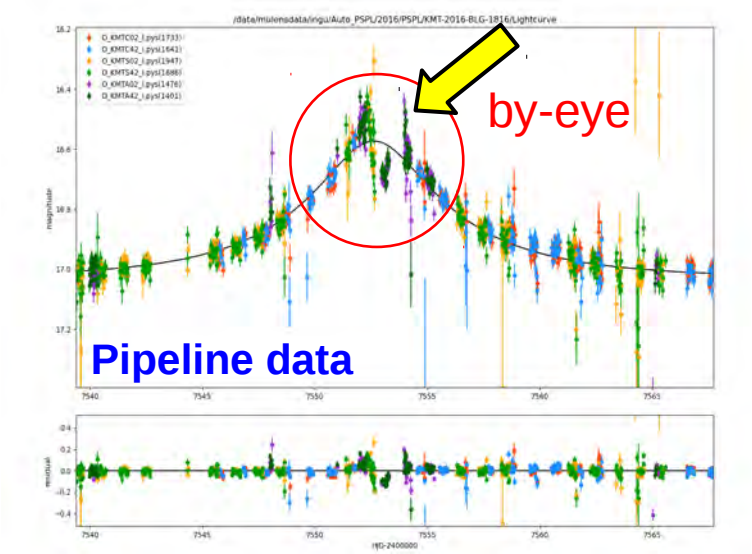


KMT-2016-BLG-0625 (Shin+23)

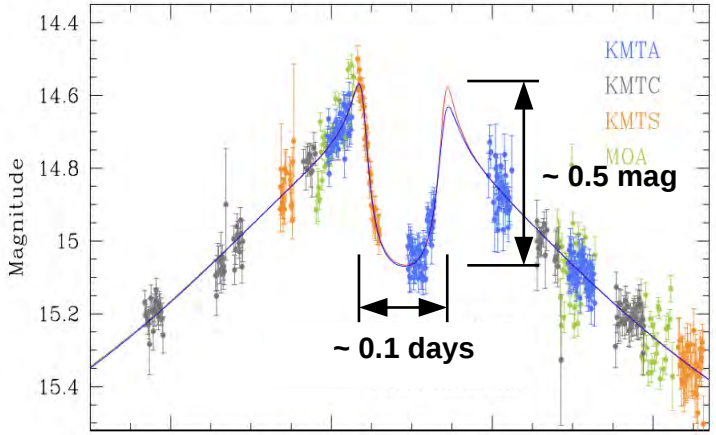


Why the anomaly couldn't be identified by eye?

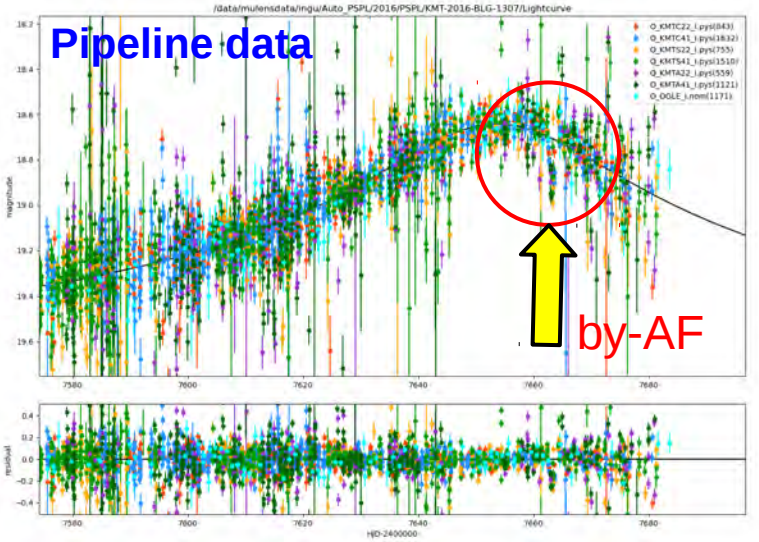
- Example: dip-shaped anomaly



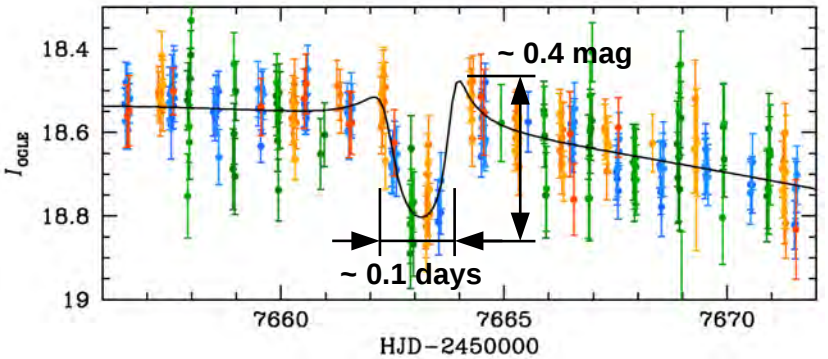
MOA-2016-BLG-319 (Han+18)



re-reduced data



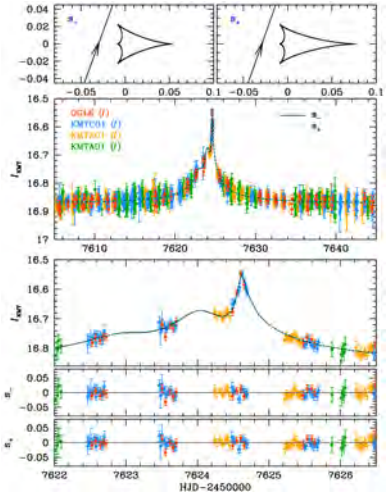
OGLE-2016-BLG-1850 (Shin+23)



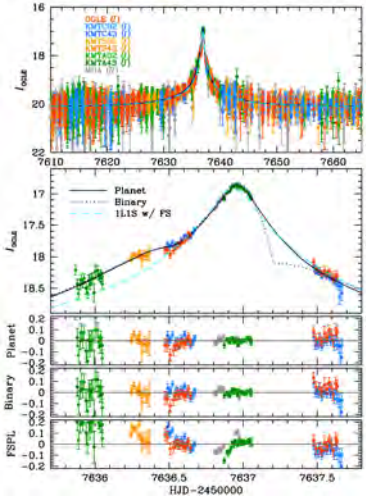
re-reduced data

Light Curves of 2016 New Planets

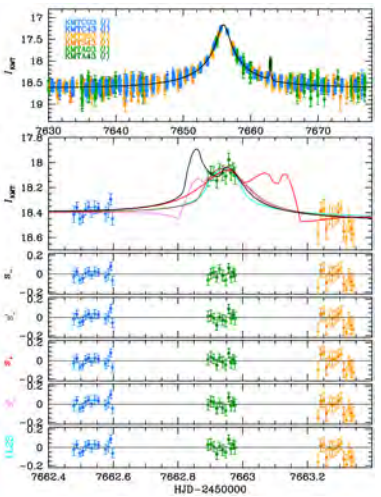
OGLE-2016-BLG-1635



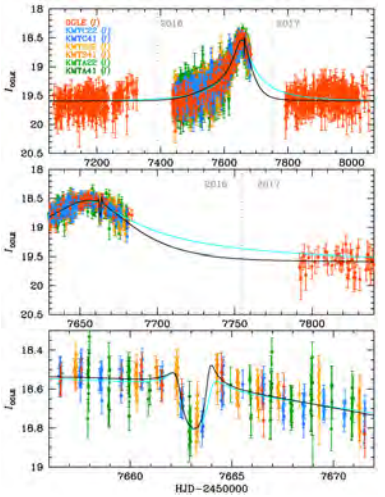
MOA-2016-BLG-532



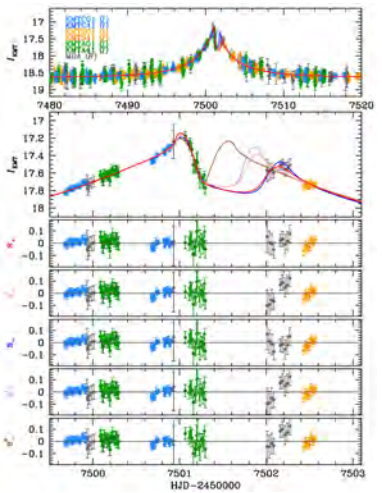
KMT-2016-BLG-0625



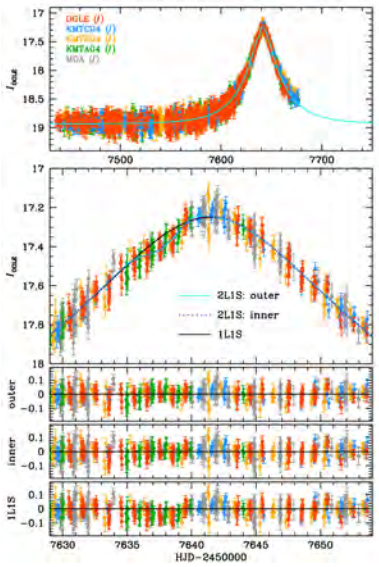
OGLE-2016-BLG-1850



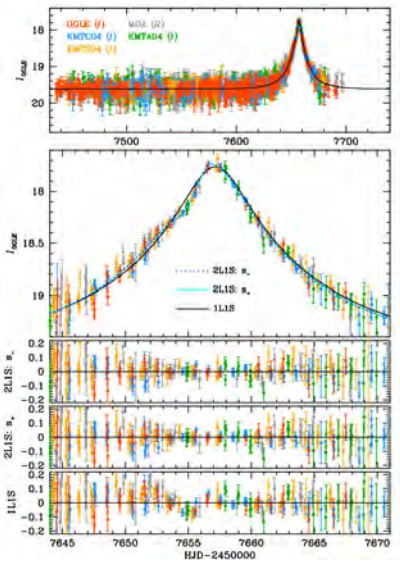
KMT-2016-BLG-1751



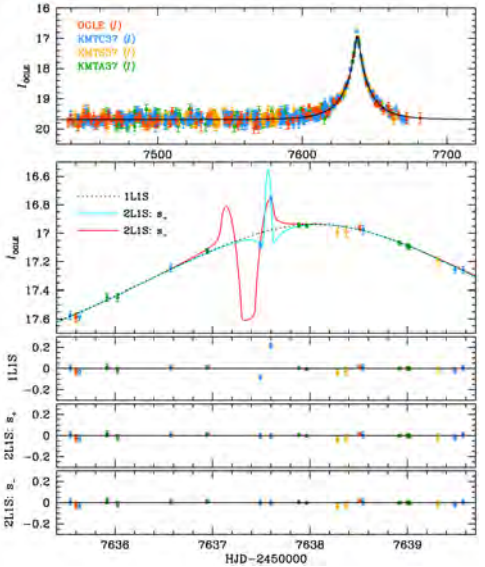
OGLE-2016-BLG-1598



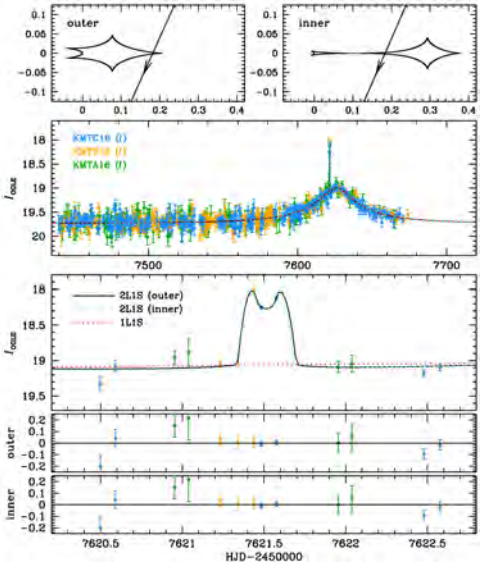
OGLE-2016-BLG-1800



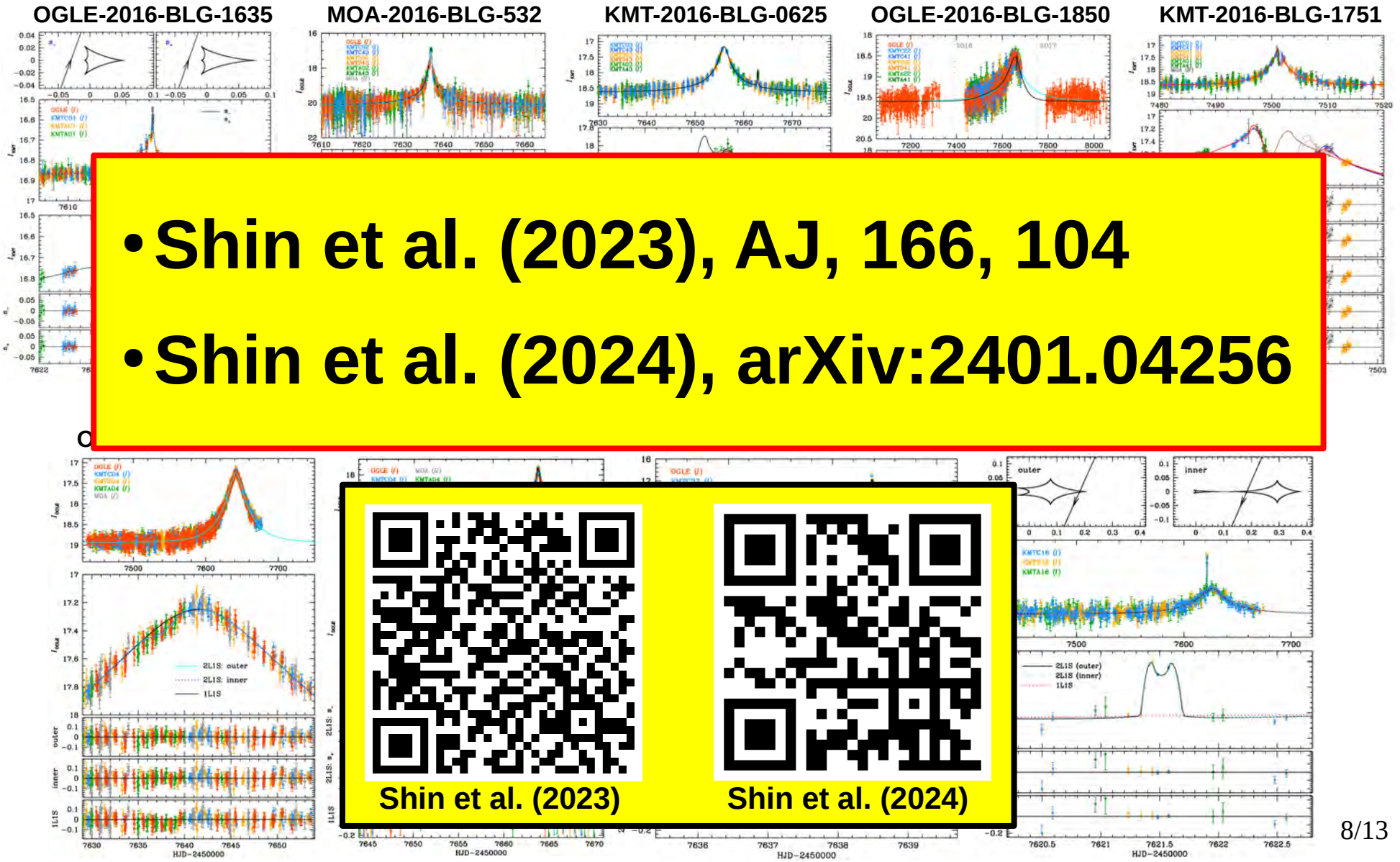
MOA-2016-BLG-526



KMT-2016-BLG-2321



Light Curves of 2016 New Planets



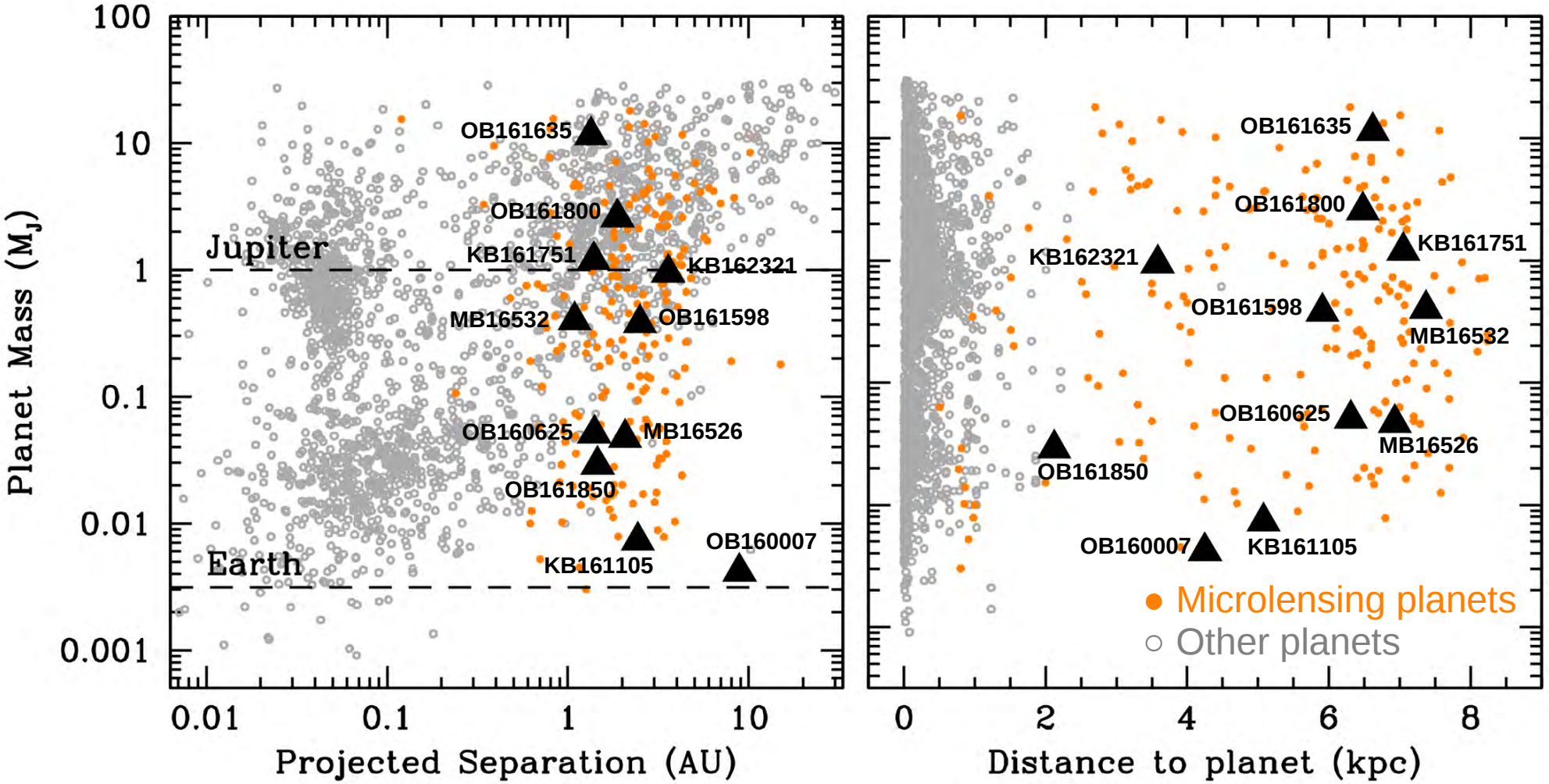
- **Shin et al. (2023), AJ, 166, 104**
- **Shin et al. (2024), arXiv:2401.04256**

Shin et al. (2023)

Shin et al. (2024)

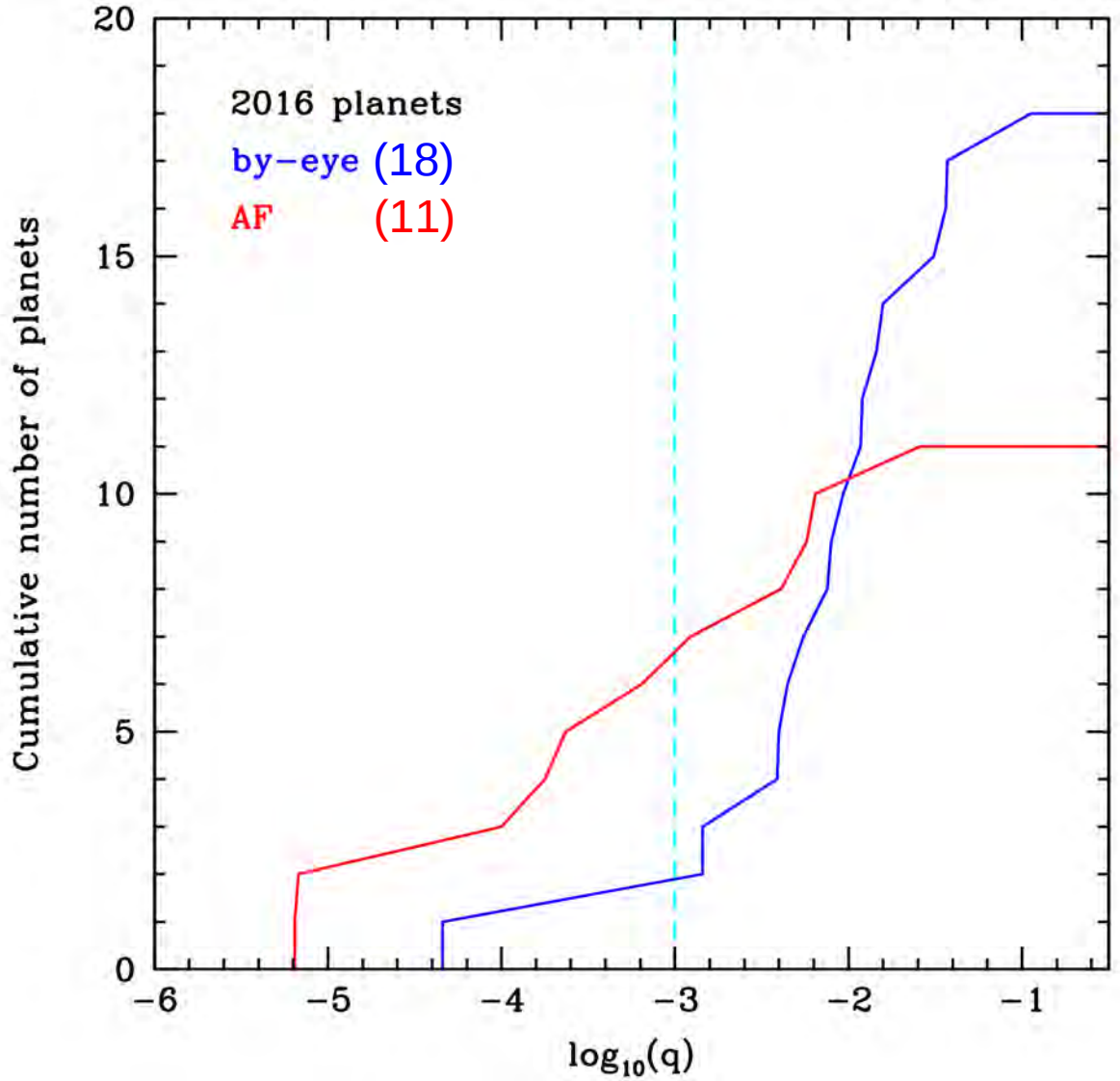
Properties of New 2016 Planets

New planets are mostly giant planets orbiting M-dwarf hosts



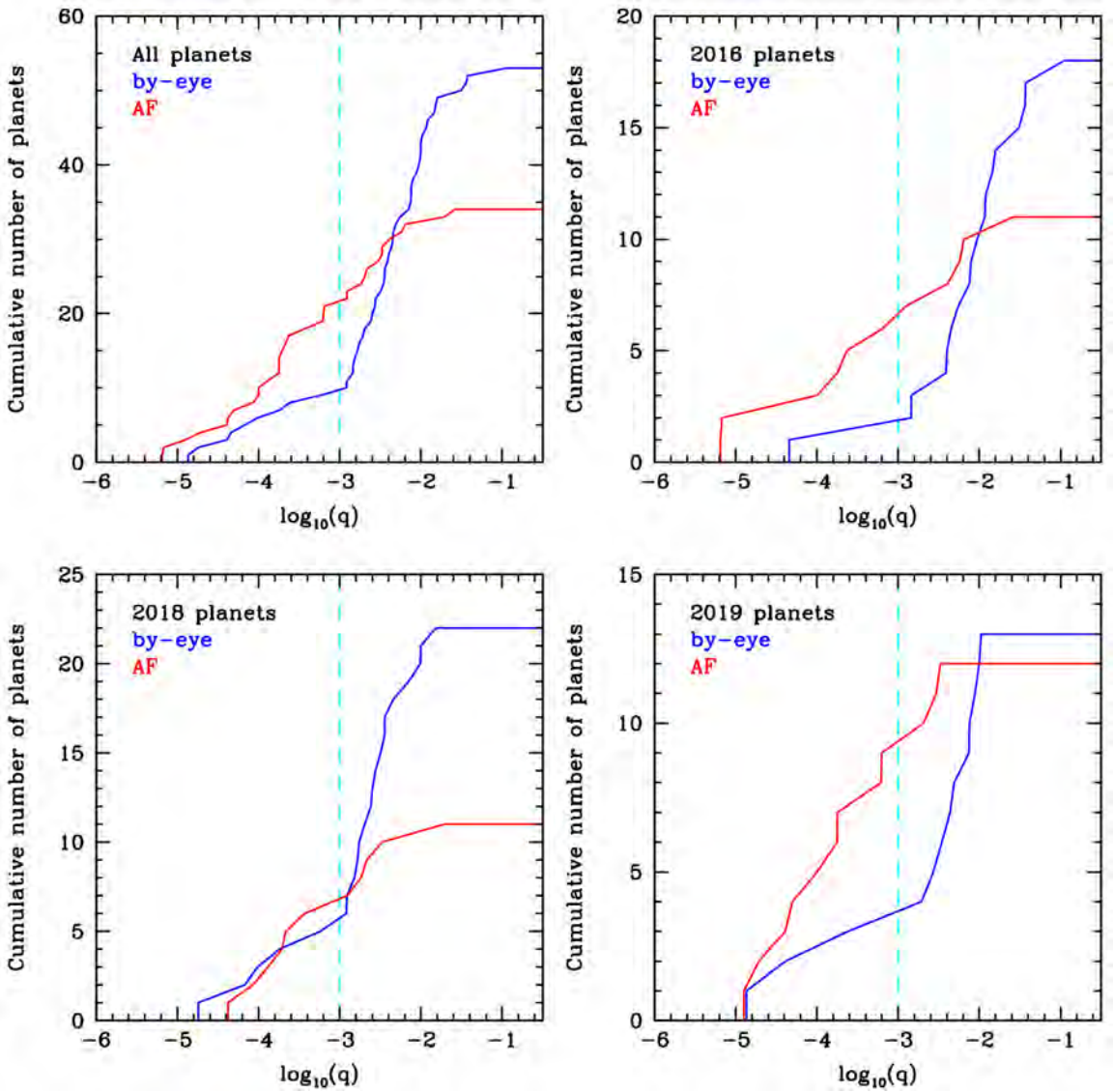
Data from the NASA Exoplanet Archive (https://exoplanetarchive.ipac.caltech.edu/)

Impact of systematic search



Contributes **~ 38%** of total planet detections observed in 2016

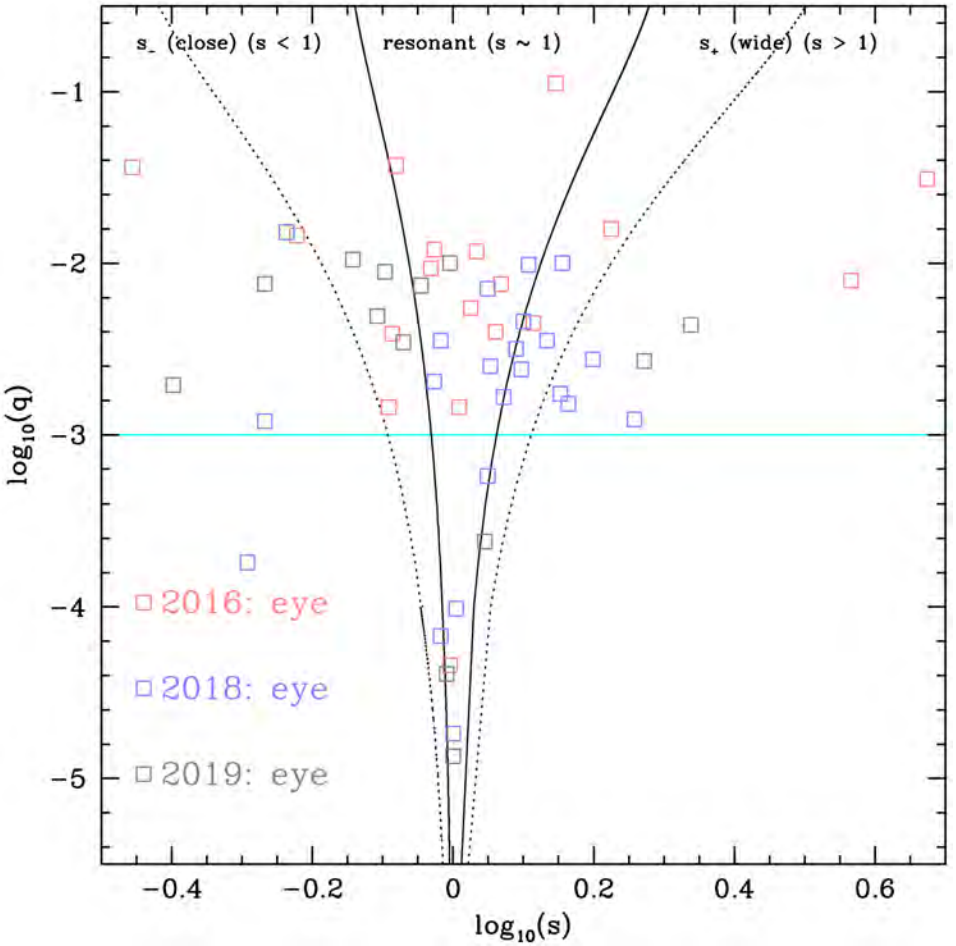
Impact of systematic search

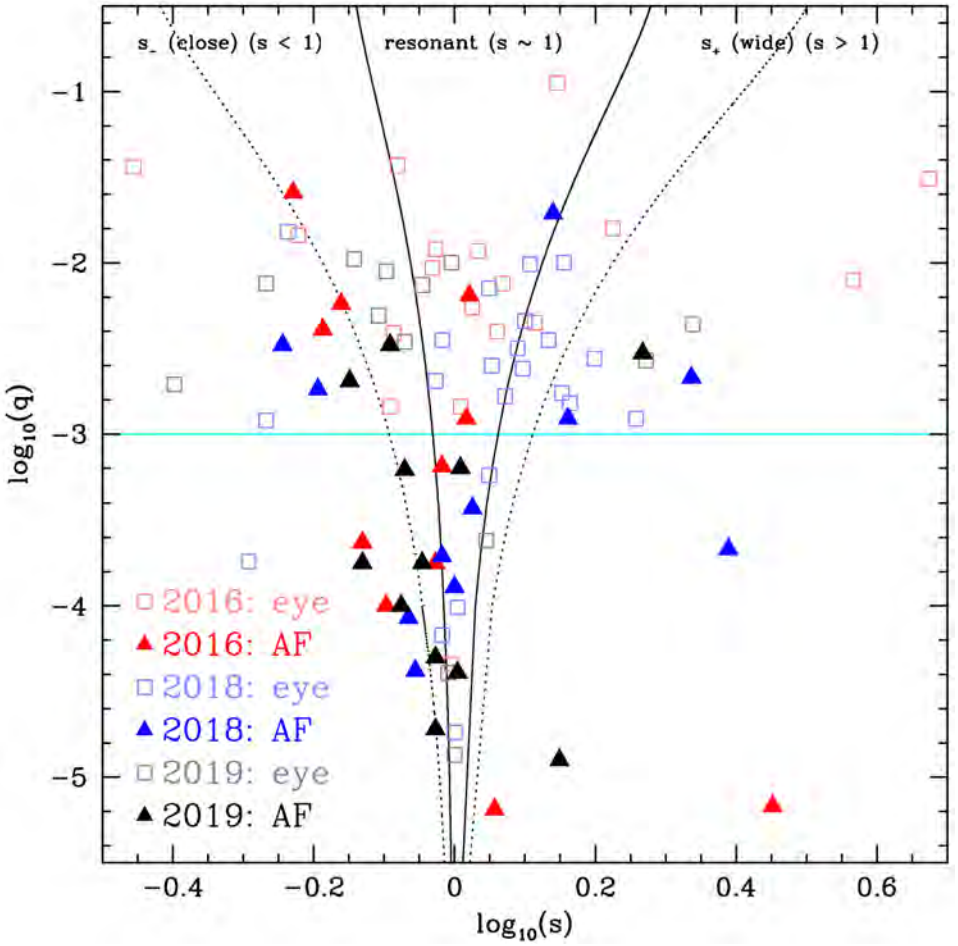


# of planets	by-AF	by-eye
2016	11	18
2018	11	22
2019	12	13
total	**34**	53

Contributes ~ 40% of total planet detections in 2016, 2018, & 2019

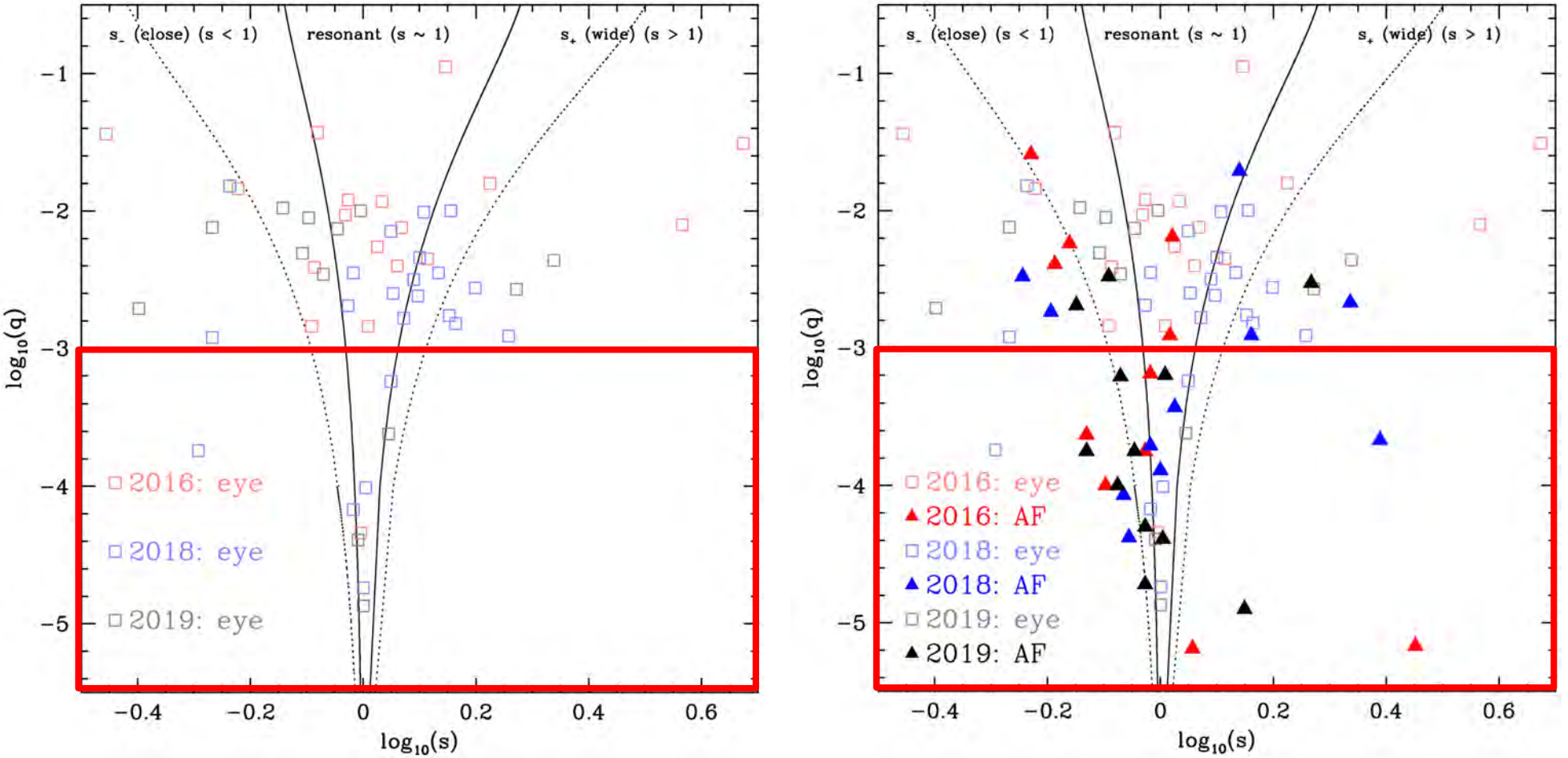
Impact of systematic search





Relatively less planet detections below $\log_{10}(q) = -3.0$

Impact of systematic search



Contributes ~ 70% of planet detections below $\log_{10}(q) = -3.0$

Optional: AnomalyFinder 2.0

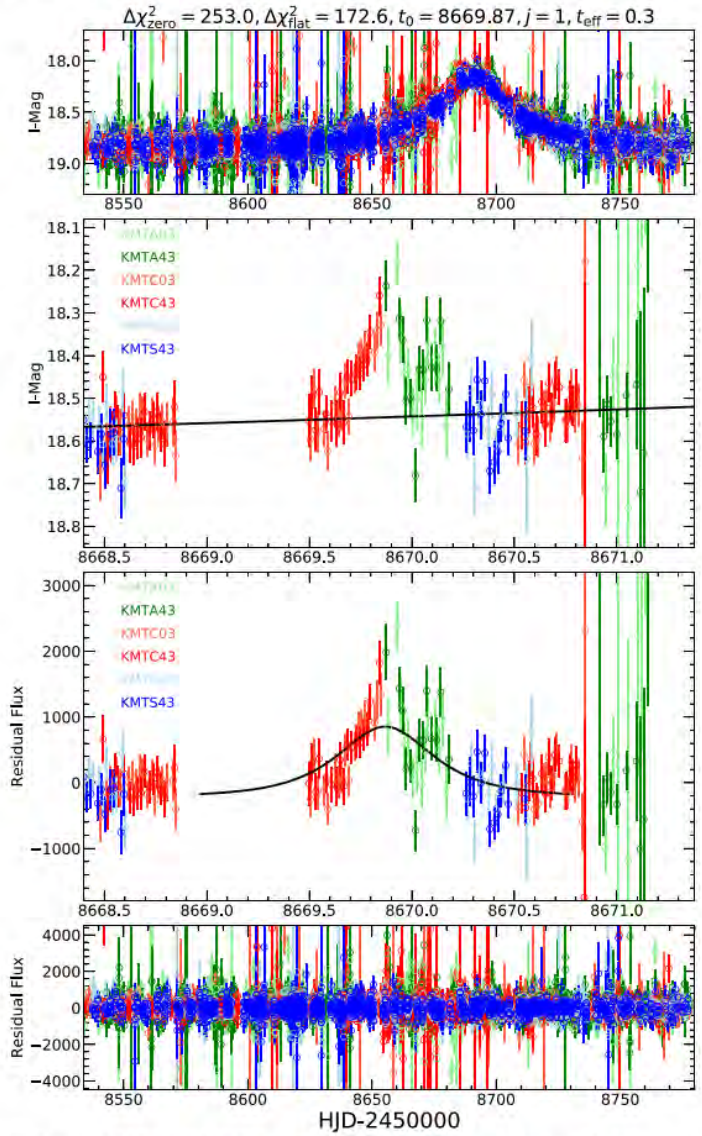


Figure 2. Example of a candidate signal of OGLE-2019-BLG-1053 (ultimately judged to be real) as shown to the operator. The first and fourth panels show the whole season of data and their residuals to the PSPL model, respectively. The second and third panels show a zoomed-in view ($t_0 \pm 5\ t_{eff}$) of the candidate signal. The circles with different colors are the observed data points for different data sets. The black line in the second panel represents the best-fit PSPL model, and the black line in the third panel represents the best-fit grid search model for $t_0 \pm 3\ t_{eff}$. Five parameters are shown above the first panel: $\Delta\chi^2_{zero}$, $\Delta\chi^2_{flat}$, t_0, j, and t_{eff}.

- Describing AnomalyFinder
  – Zang et al, (2021), AJ, 162, 163
- Optimized algorithm and criteria
  – Zang et al. (2022), MNRAS, 510, 1778
- Brief of the algorithm

  (1) fit LC using 1L1S model with different flux setting (χ^2_{zero} and χ^2_{flat})

  (2) fit residuals of the intervals (χ^2_{signal})

  (3) compute $\Delta\chi^2_{zero} = \chi^2_{zero} - \chi^2_{signal}$
  compute $\Delta\chi^2_{flat} = \chi^2_{flat} - \chi^2_{signal}$

  (4) find anomaly using optimized criteria:
  $\Delta\chi^2_{zero} > 200$,
  $\Delta\chi^2_{zero} > 120$ & $\Delta\chi^2_{flat} > 60$

  (5) review these anomaly candidates