Detection Efficiencies of Low-magnification Events in MOA-II Data

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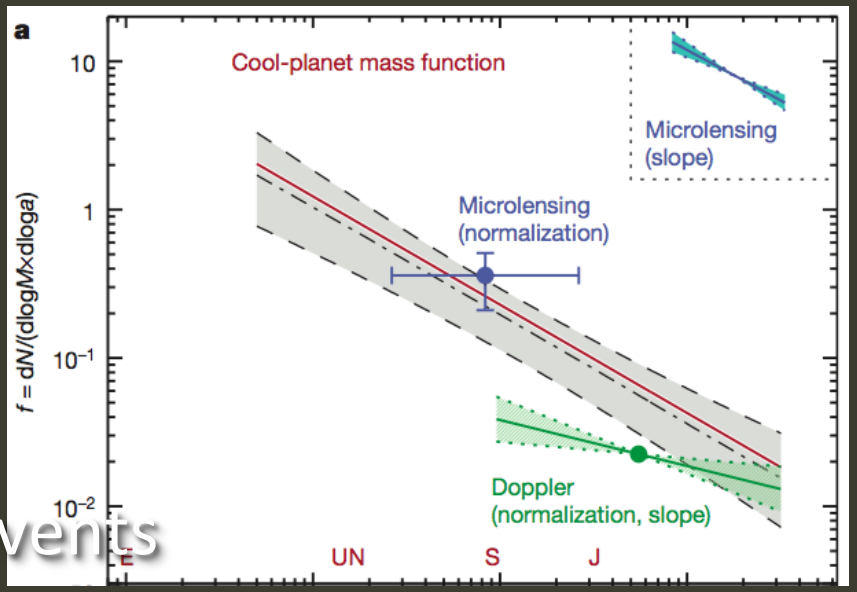
Statistical analysis



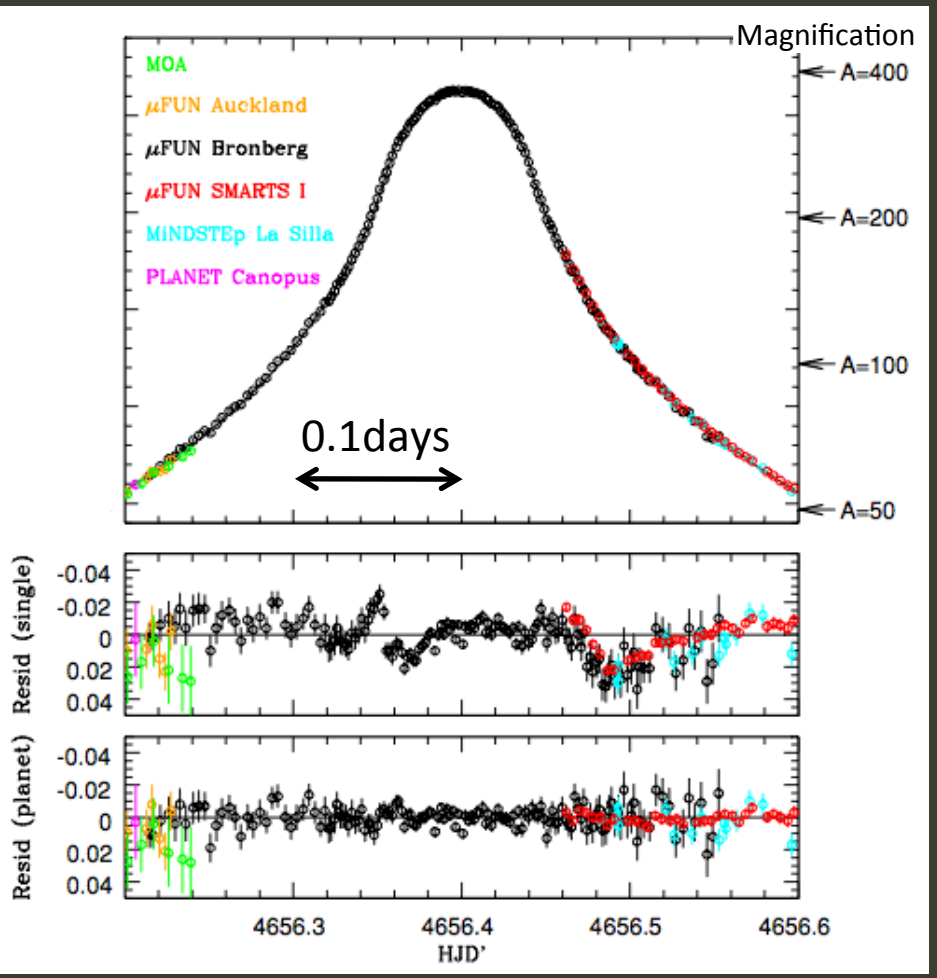
Cassan et al. 2012

- Sumi et al. 2010
  - 10 planets, $\propto q^{-0.68}$
- Gould et al. 2010
  - 6 planets in 13 high-mag events
  - 0.36 @ $q \sim 5\times10^{-4}$
- Cassan et al. 2012
  - 2002 – 2007 data
  - 3 additional planets combined with the above.

GOAL : derive planet abundance including low-mag planetary event found by MOA-II

High-mag VS Low-mag

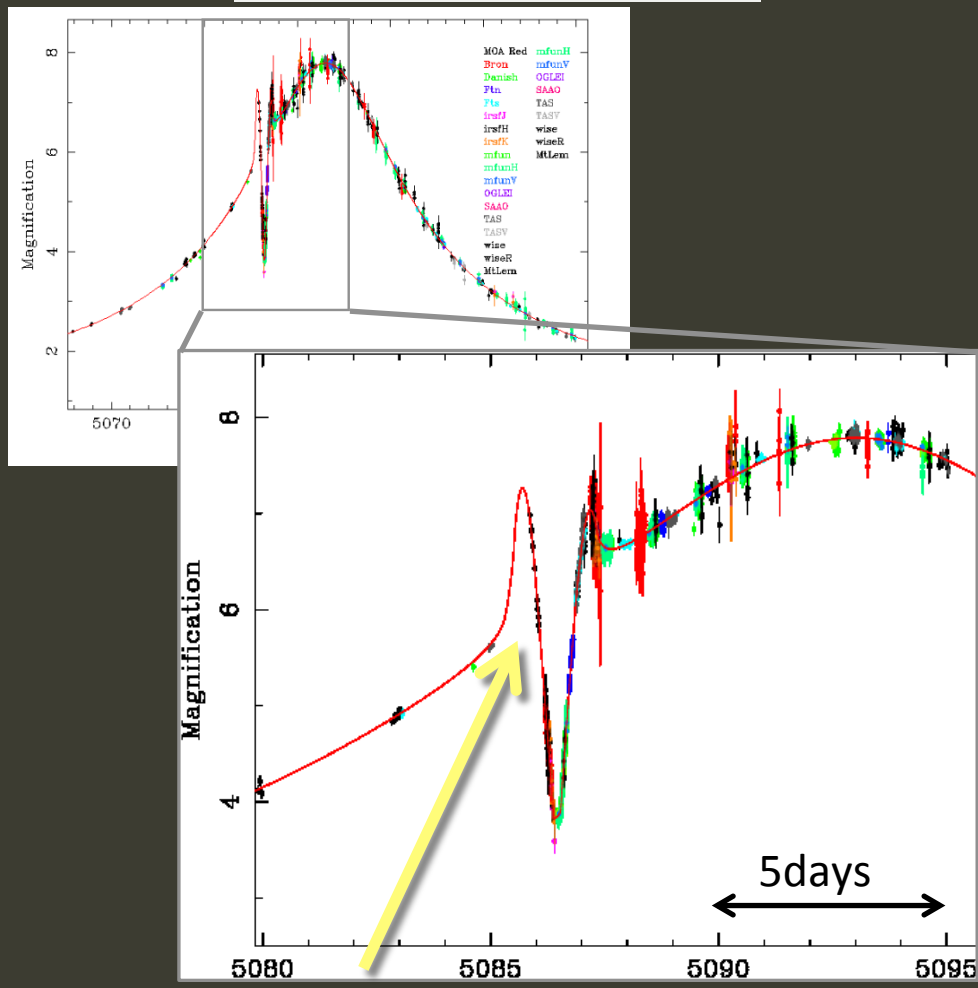
High-magnification



CONSTANT observation frequency

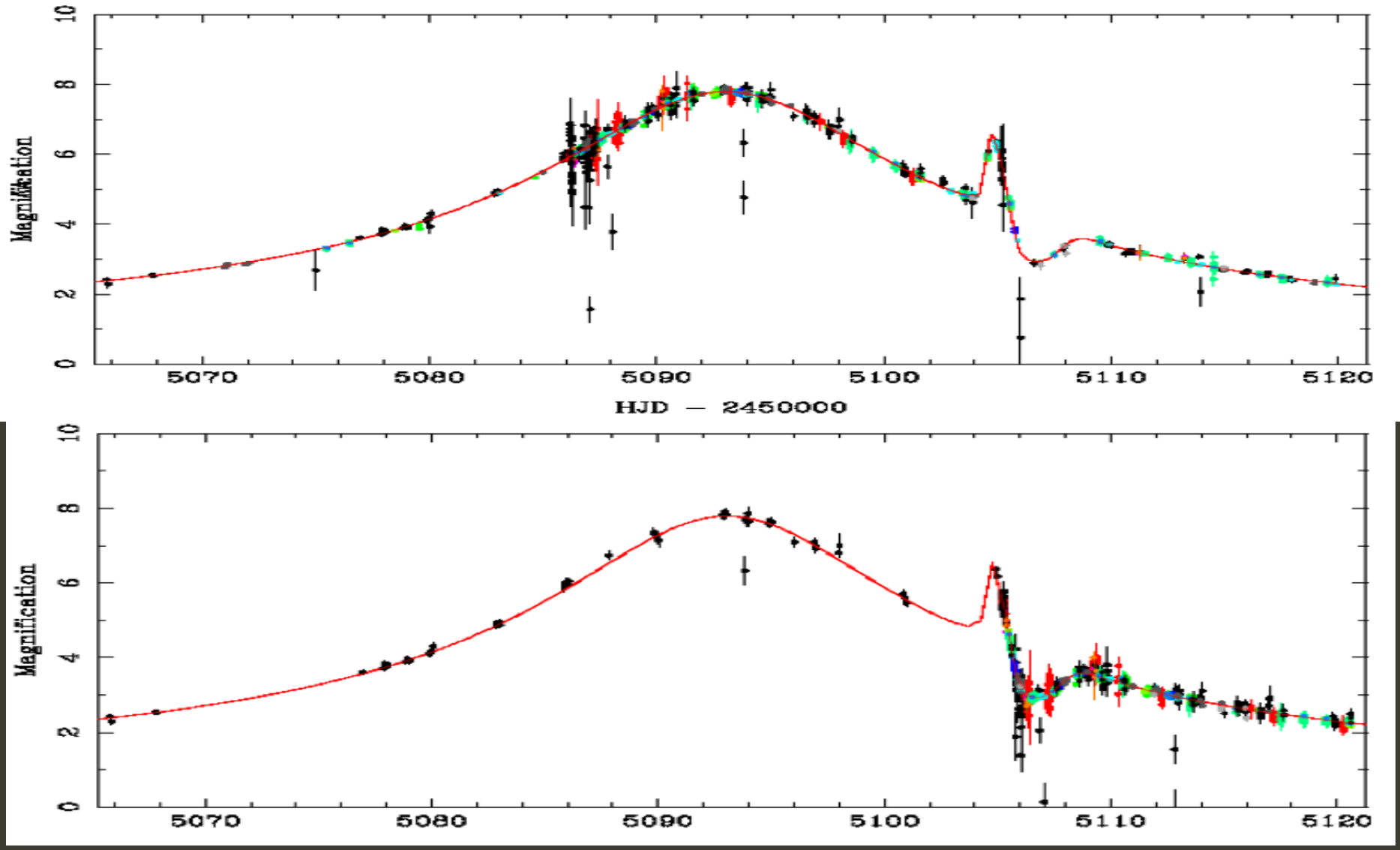
Janczak et al. 2010

Low-magnification



Observation frequency was CHANGED due to the anomaly

Artificial lightcurve of Low-mag event (MB09266)



Observation frequency should change if different anomalies occurred.

Method of calculating D.E in Low-mag events

1. Generate artificial lightcurve (s, q, α) Gaudi & Sackett 2002
   - ➢ Simulate survey observations by MOA-II
   - ➢ Detect an anomaly in real-time

$$S_3 = \left| \sum_{i=n-2}^{n} \frac{F_i - F_{data,i}}{\sigma} \right| > S_{3\_thr}$$

$$S_{3\_thr} = 9$$

   - ➢ Simulate follow-up observations if anomalous

2. Detect a planet

$$\Delta\chi^2 = \chi^2_{Single} - \chi^2_{Binary}$$

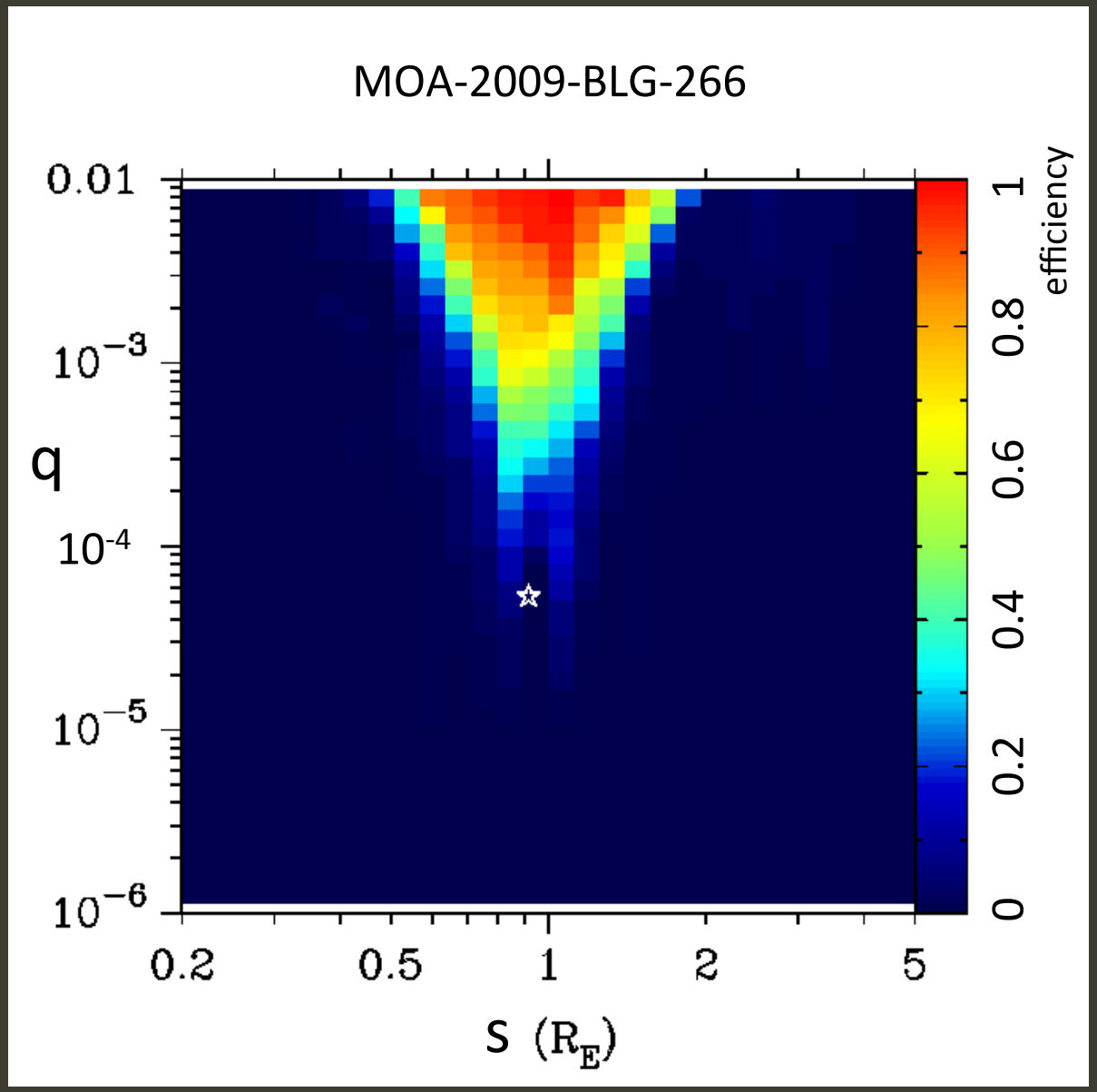
$$\Delta\chi^2 \geq \chi^2_{thr} = 500$$

Gould et al. 2010

3. Repeat 1, 2 for the α(0<α<2π), then

$$\varepsilon(q,d) = N_{DETECTION} / N_{ALL}$$

Detection efficiencies to ANOMALIES



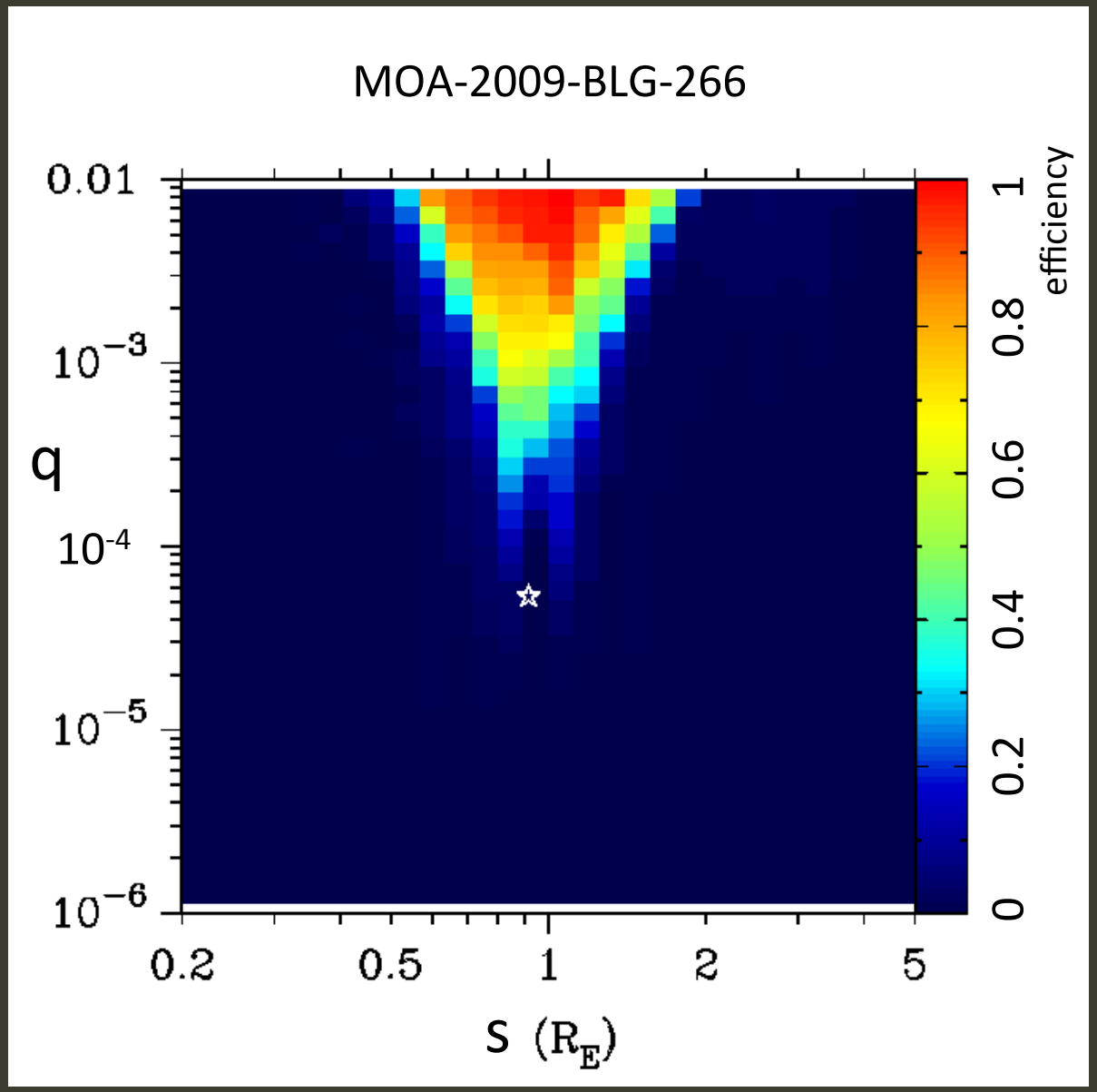
$$S_3 = \left| \sum_{i=n-2}^{n} \frac{F_i - F_{data,i}}{\sigma} \right| > S_{3\_thr}$$

$$S_{3\_thr} = 9$$

MOA-2009-BLG-266Lb
s : 0.92
q : 5.3 e-5

12 +/- 3.7 %

Detection efficiencies to PLANETS



$$\Delta\chi^2 = \chi^2_{Single} - \chi^2_{Binary}$$
$$\Delta\chi^2 \geq \chi^2_{thr} = 500$$

MOA-2009-BLG-266Lb
s : 0.92
q : 5.3 e-5

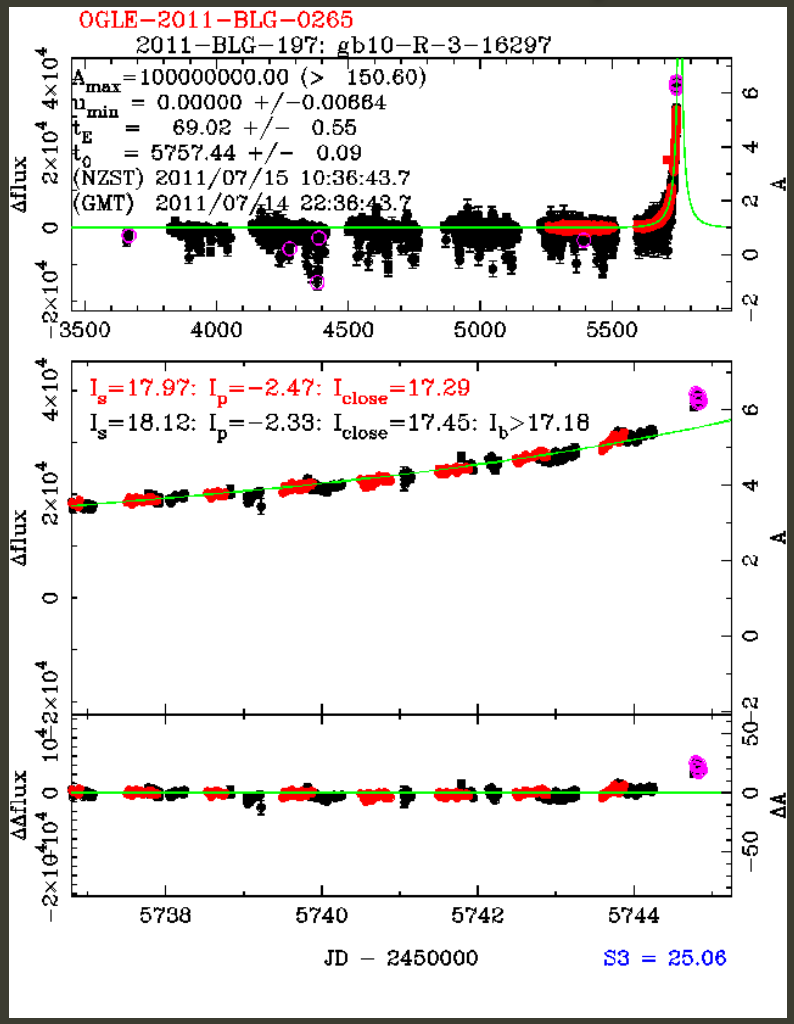
10 +/- 3.3 %

REAL anomaly detection

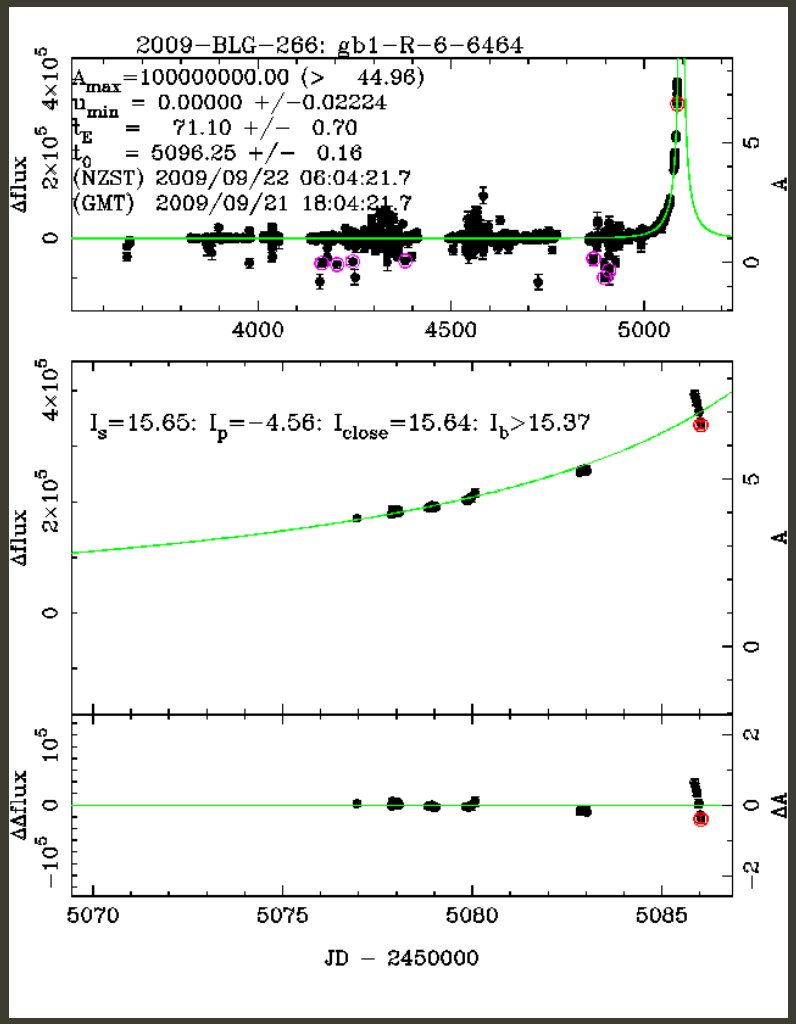
$$S_3 = \left| \sum_{i=n-2}^{n} \frac{F_i - F_{data,i}}{\sigma} \right| > S_{3\_thr}$$

$$S_{3\_thr} = 9$$

OB20110265 : easy

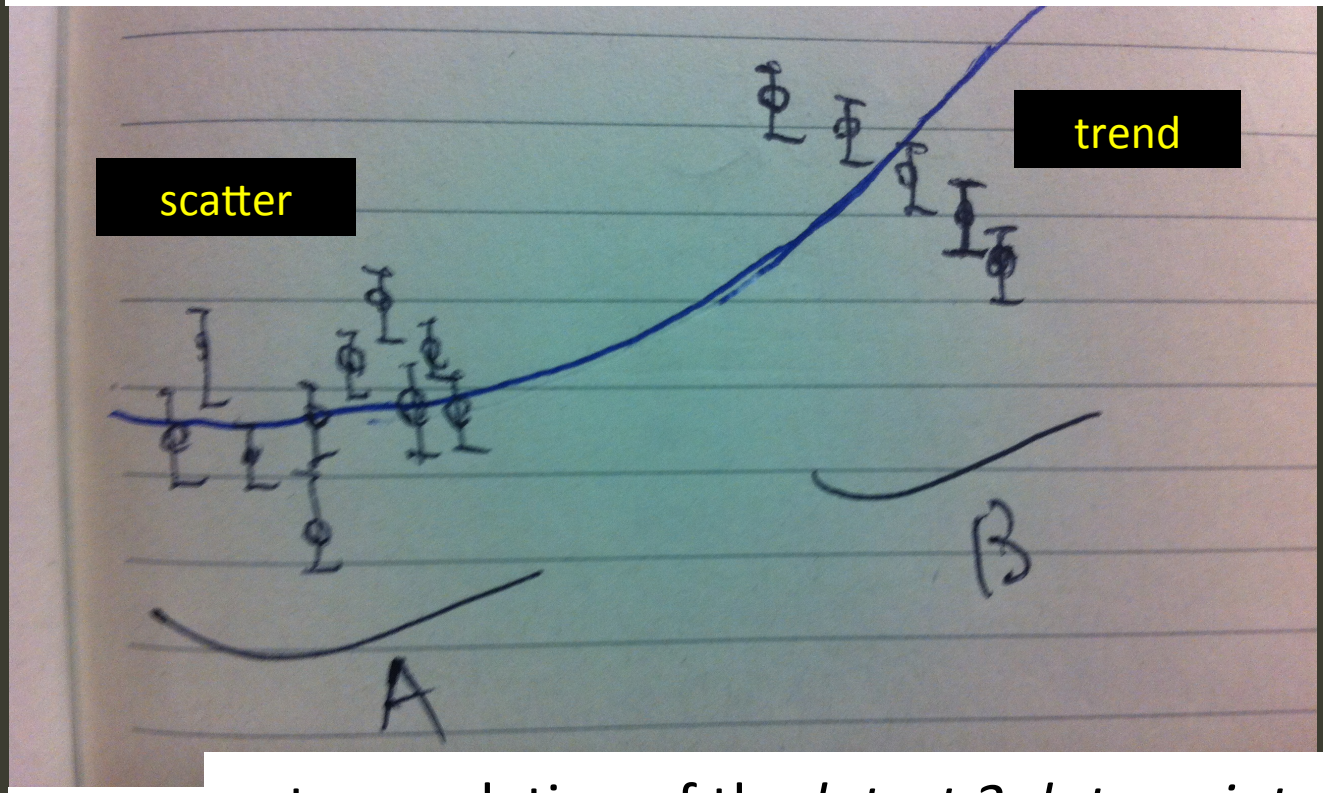


MB2009266 : hard



Criteria to detect anomalies in real-time

$$autocorrelation = \left| \sum_{i-j=k}^{n} \frac{\Delta F_i \times \Delta F_j}{\sigma_{Fi} \times \sigma_{Fj}} \right|$$



$$a_3 = \frac{\text{autocorrelation of the } \textit{latest 3 data points}}{\text{autocorrelation of the } \textit{whole data points}}$$

Criteria to detect anomalies in real-time

- S_3

$$S_{3\_CRI} > 9$$

AND

autocorrelation

$$a_{3\_CRI} > 30$$

OR

- S_1

$$S_{1\_CRI} > 15$$

This criteria will be used in real observation in 2012 season.

Event selection

- Full sample : 2007-2011 MOA-II data, 2620 events
- Sub-sample must Include the planetary events.
  - OB07368(MB07308), MB09266, MB09387, MB10117, MB10328, MB11028, OB110265(MB11197),
  - MB09319
  - ~~MB11262~~
- The selection must not depend on planet itself.
- High S/N deviation from the baseline during the event.

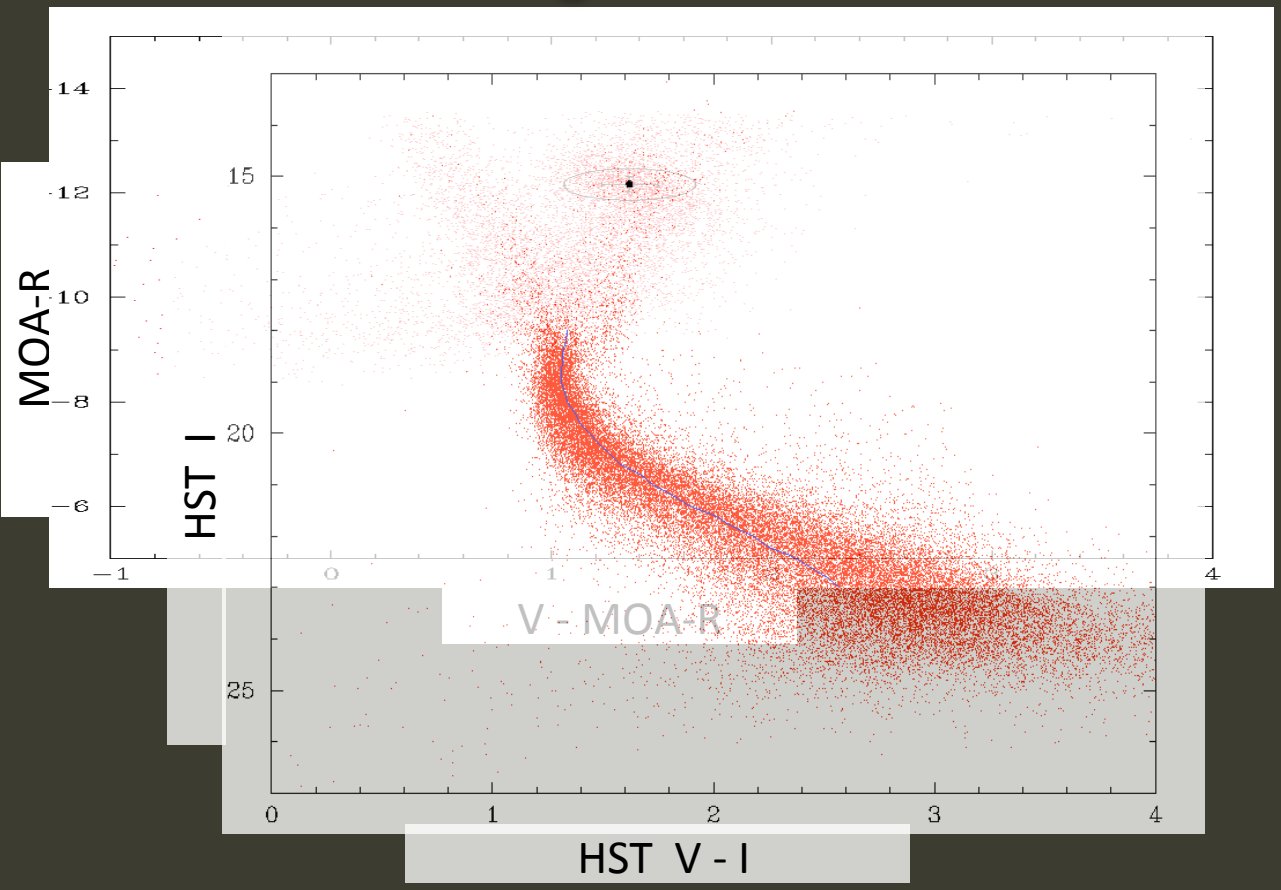
preliminary

- 74 single lens events + 5 planetary events

(MB09266, MB10117, MB10328, MB11028, OB110265)

Finite source effect

- Need to estimate the source star radius.
- No color information during the event.
- Use source magnitude and CMD from HST Holtzman et al. 1998

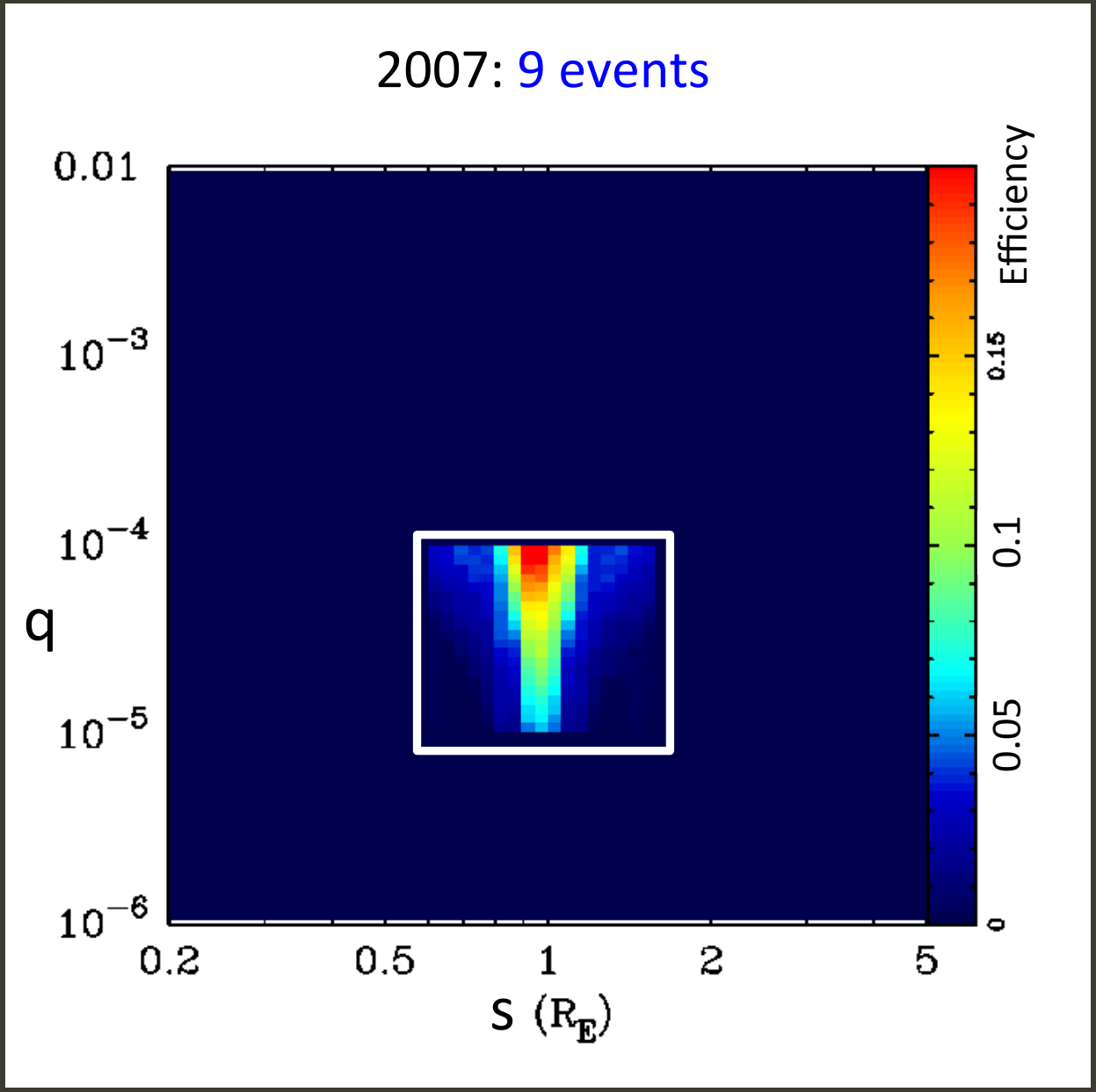


$$\rho = \frac{\theta_*}{\theta_E} = \frac{\theta_*}{t_E \times \mu}$$

μ = <12.5> km s^{-1} kpc^{-1}
$\sim$3 mas yr^{-1}

Gaudi et al. 2002,
Kervella et al. 2008,
Bennett et al. 2008

Detection efficiencies to ANOMALY



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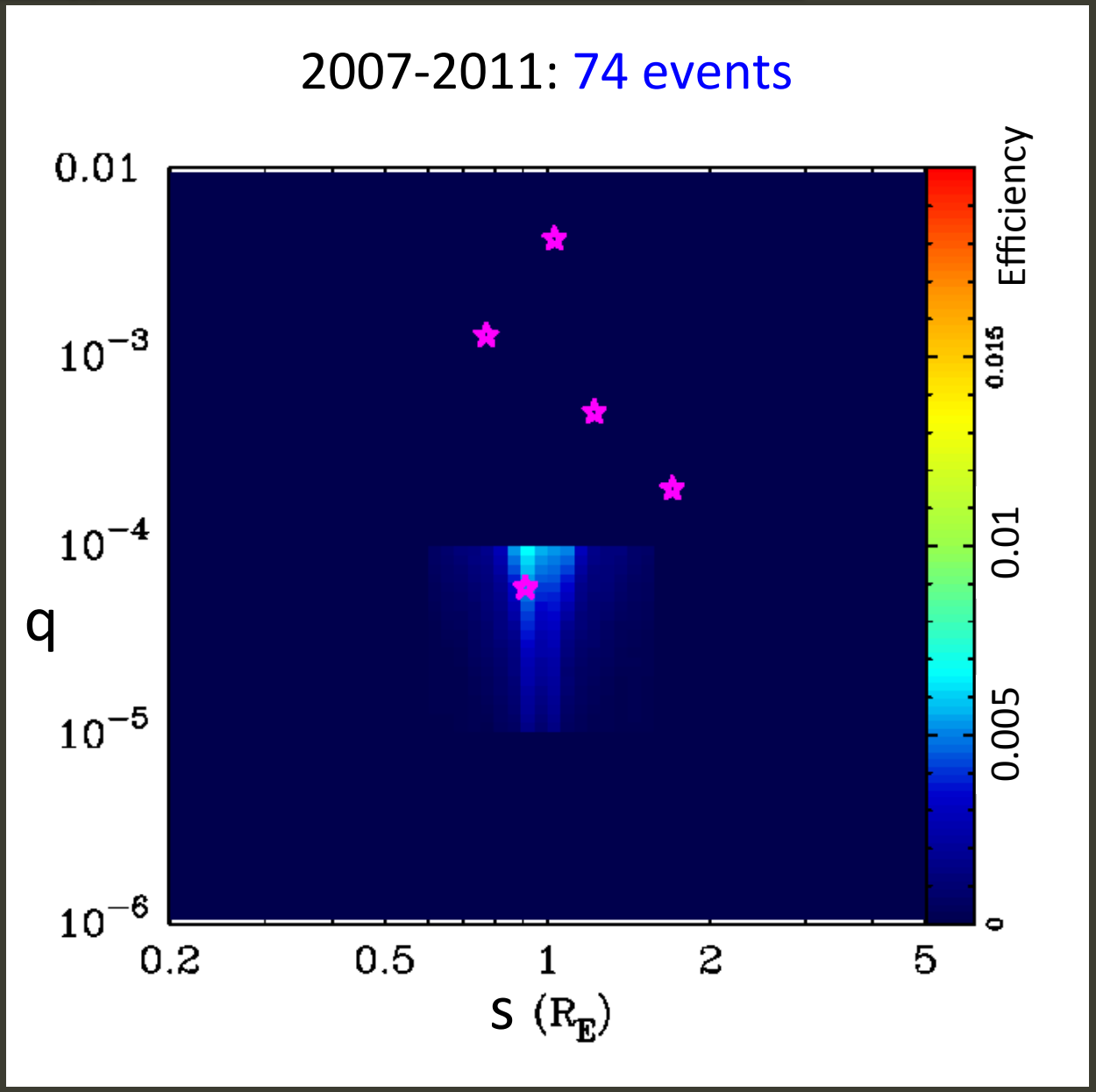
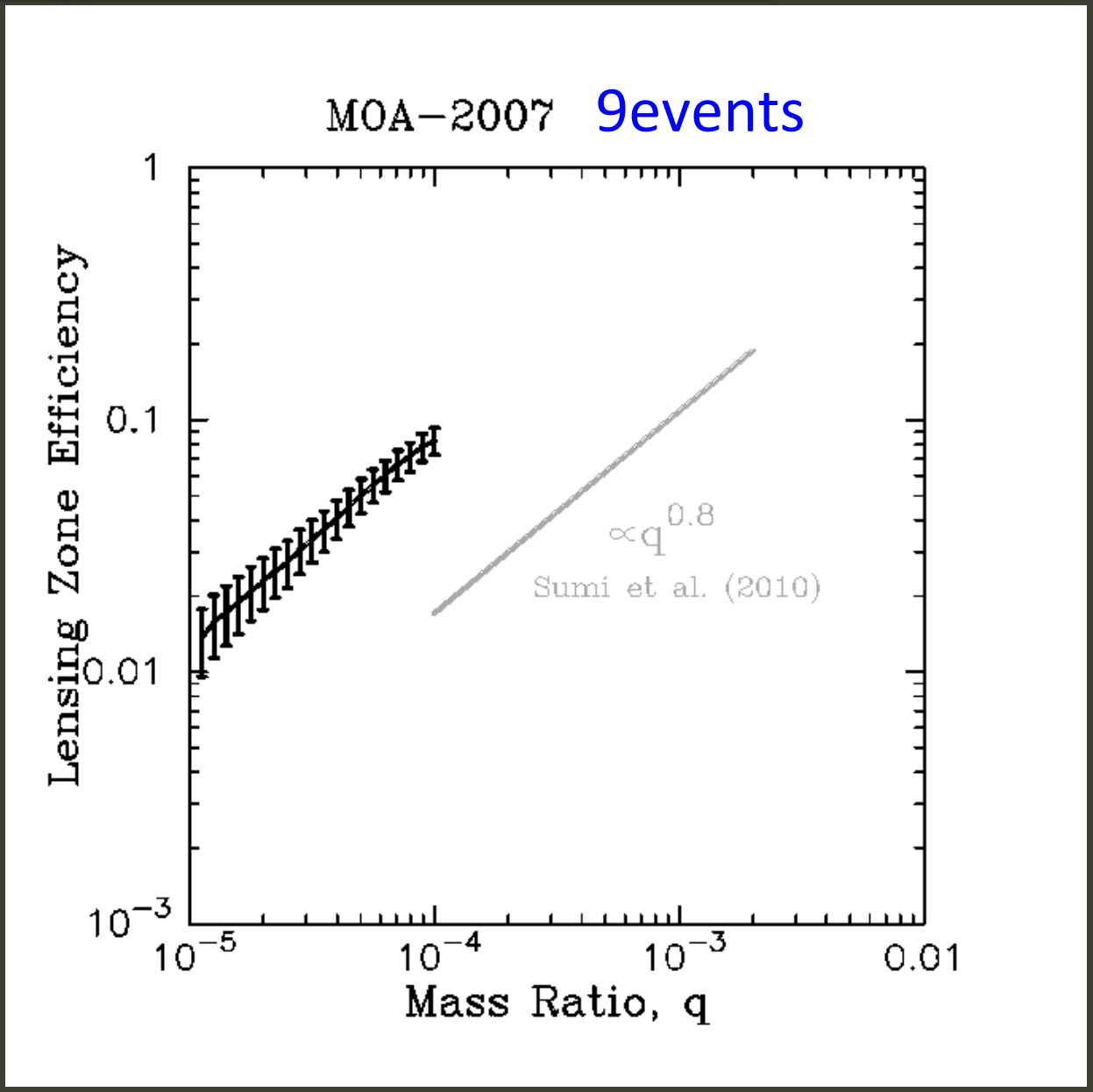
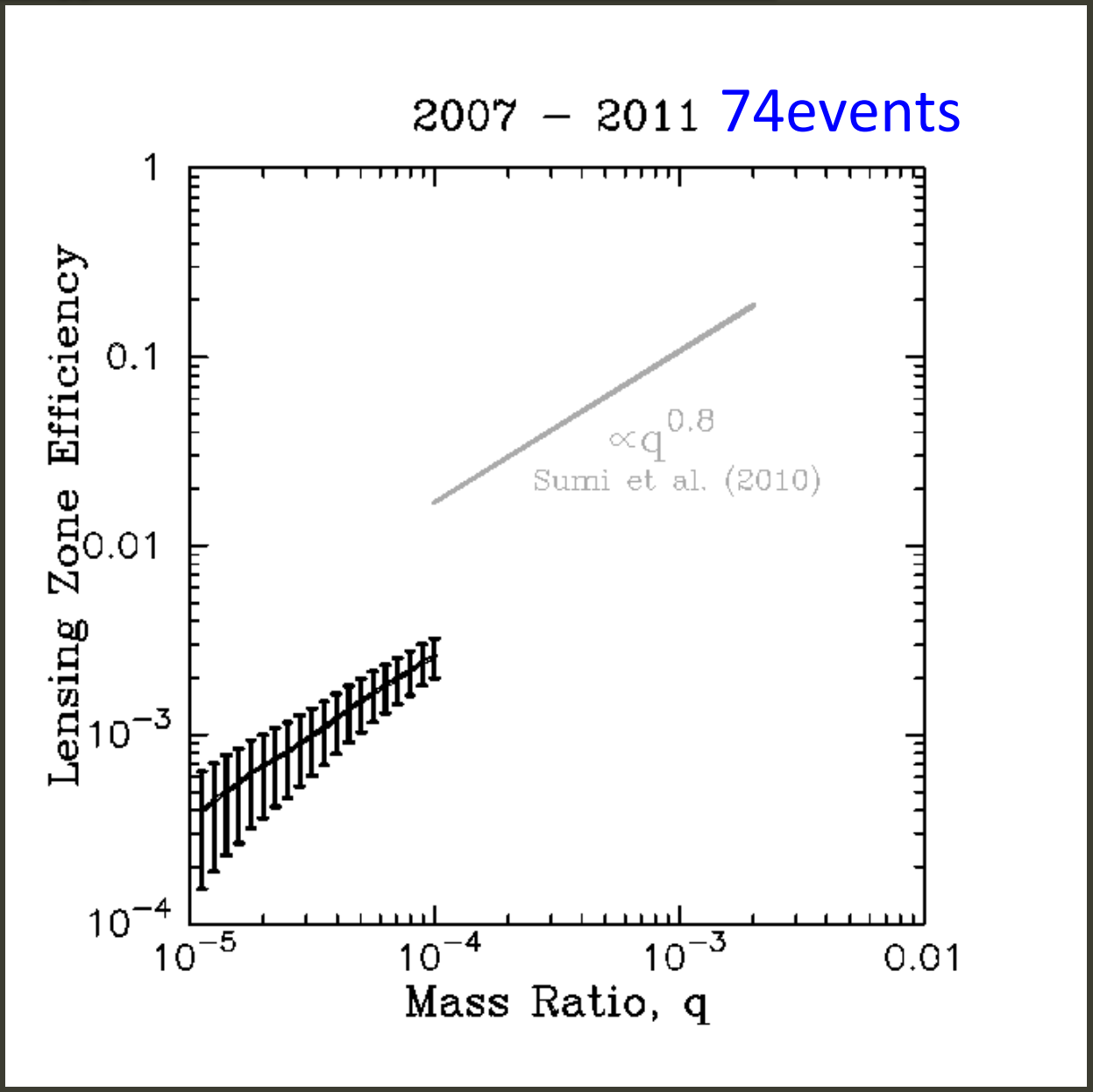


Detection efficiencies to ANOMALY



Detection efficiencies to ANOMALY



Summary & Future work

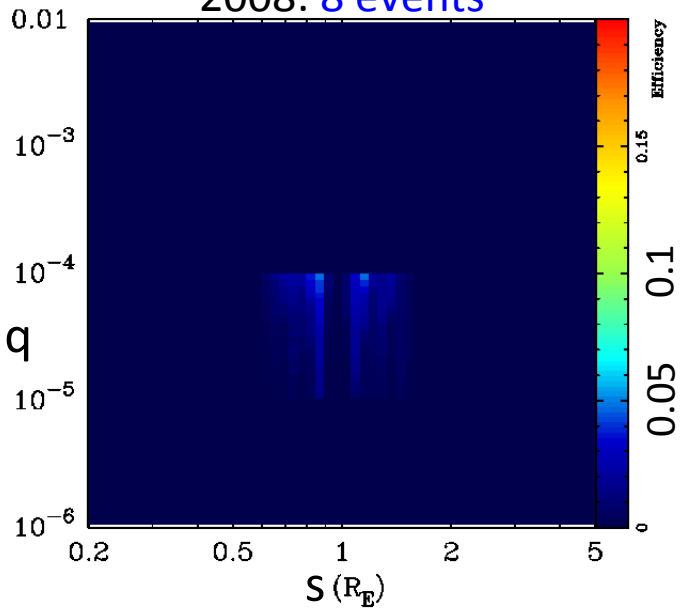
- Set the criteria to detect an anomaly in real-time.
  - Combination of several criteria
  - Able to detect the planetary anomalies in 07' – 11' MOA-II data
- Calculated the detection efficiencies to ANOMALY within the limited region using preliminary sub-sample.
  - The slope is consistent with the previous work.

With whole sample,

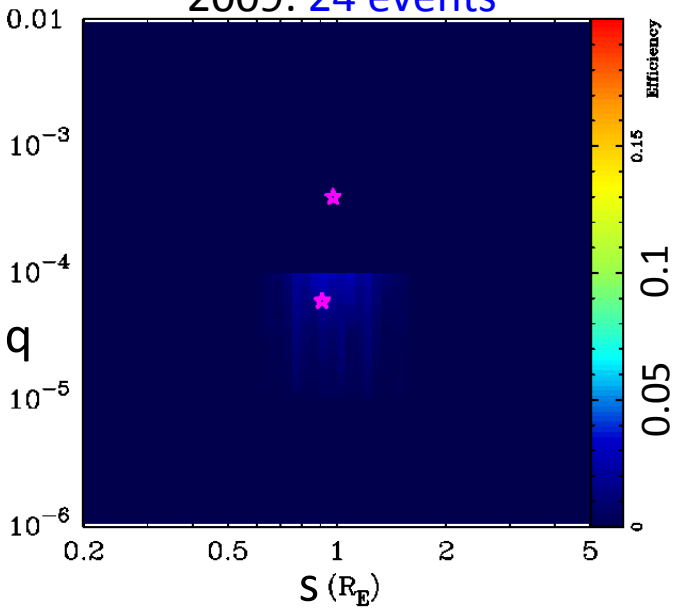
- Calculate the other (s, q) region.
- Simulate follow-up observations.
- Estimate the planet abundance.
- **# of planets included statistics will be double.**


Thank you

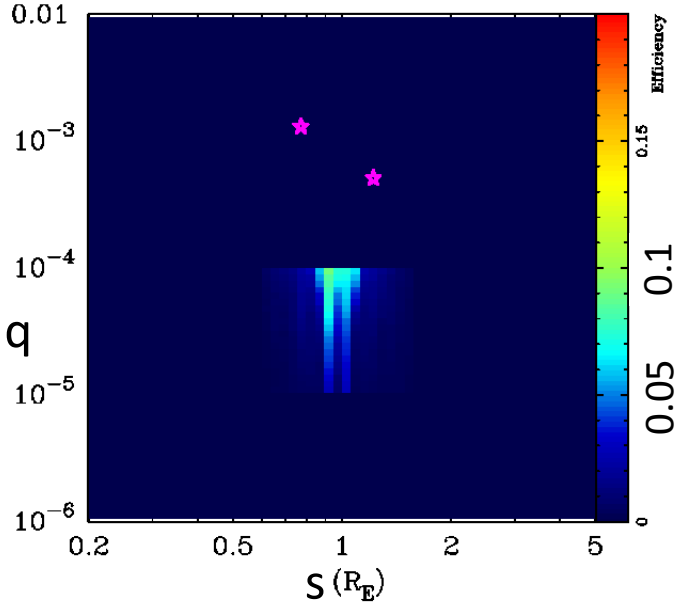
2008: 8 events



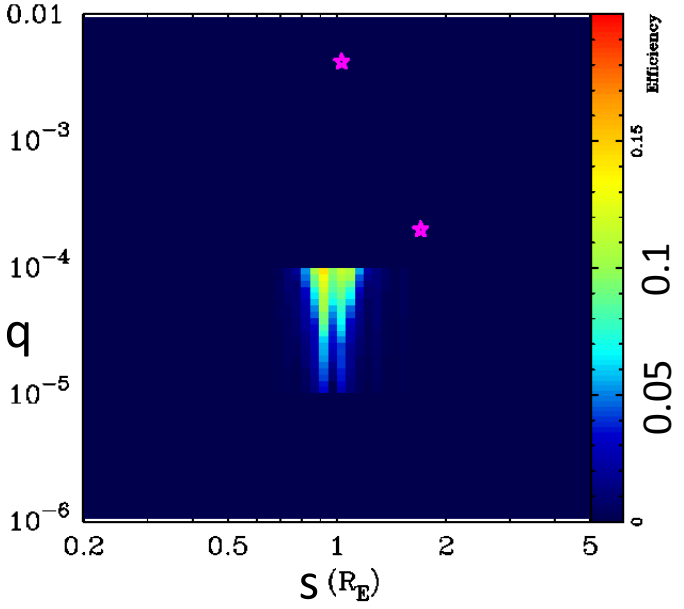
2009: 24 events



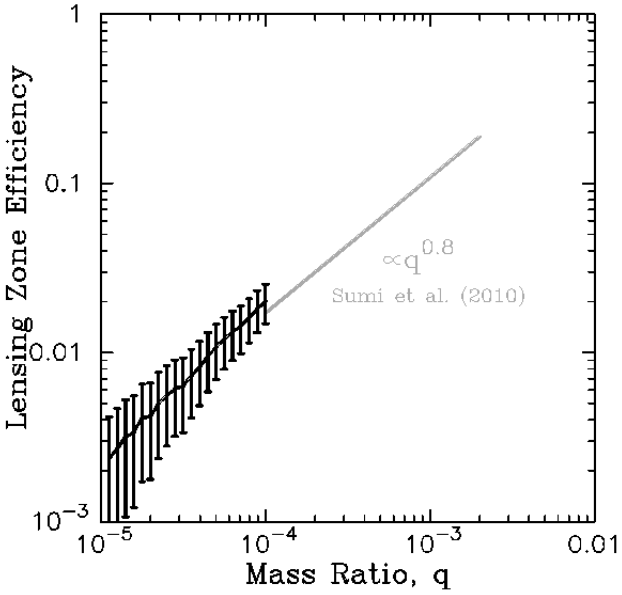
2010: 23 events



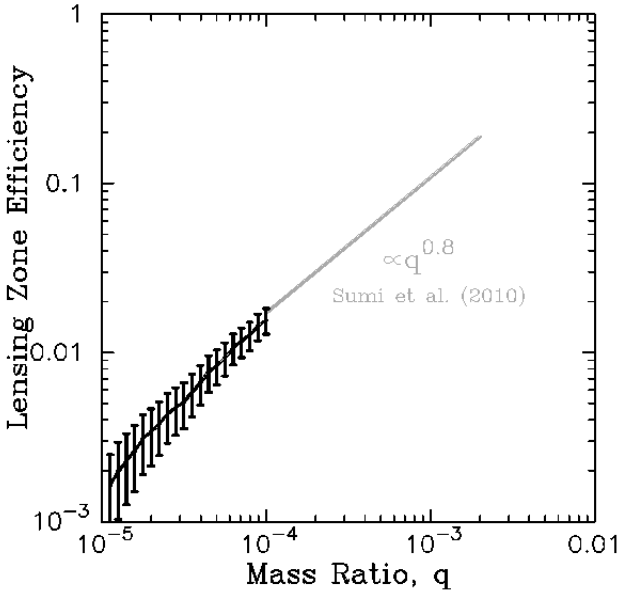
2011: 10 events



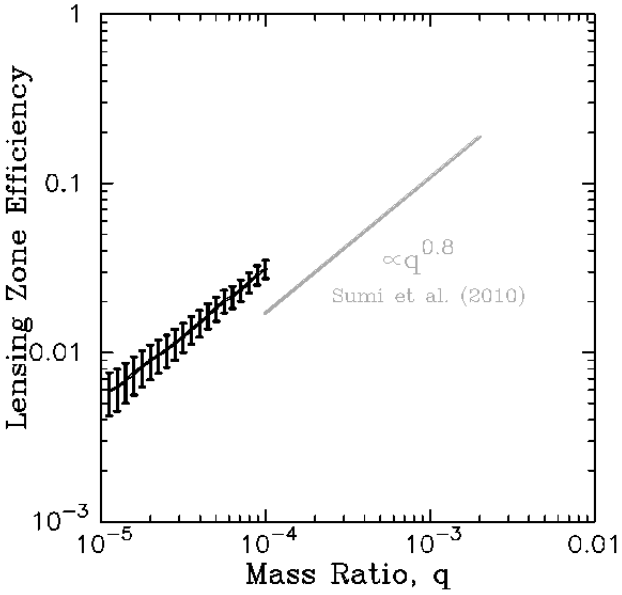
MOA−2008 8events



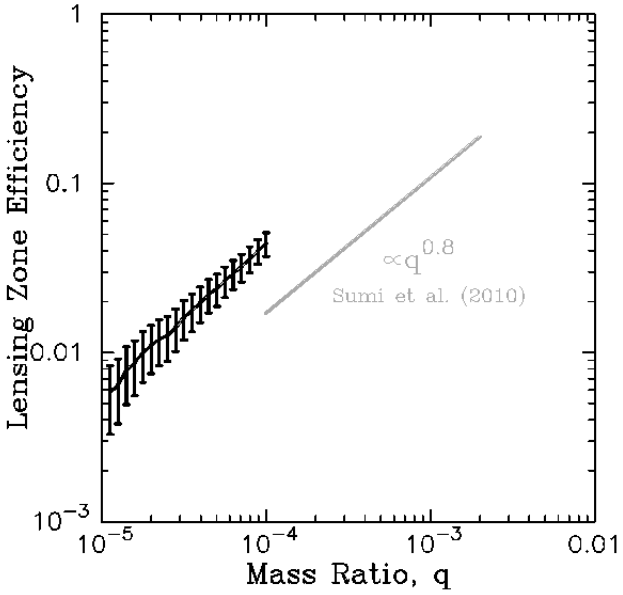
MOA−2009 24events



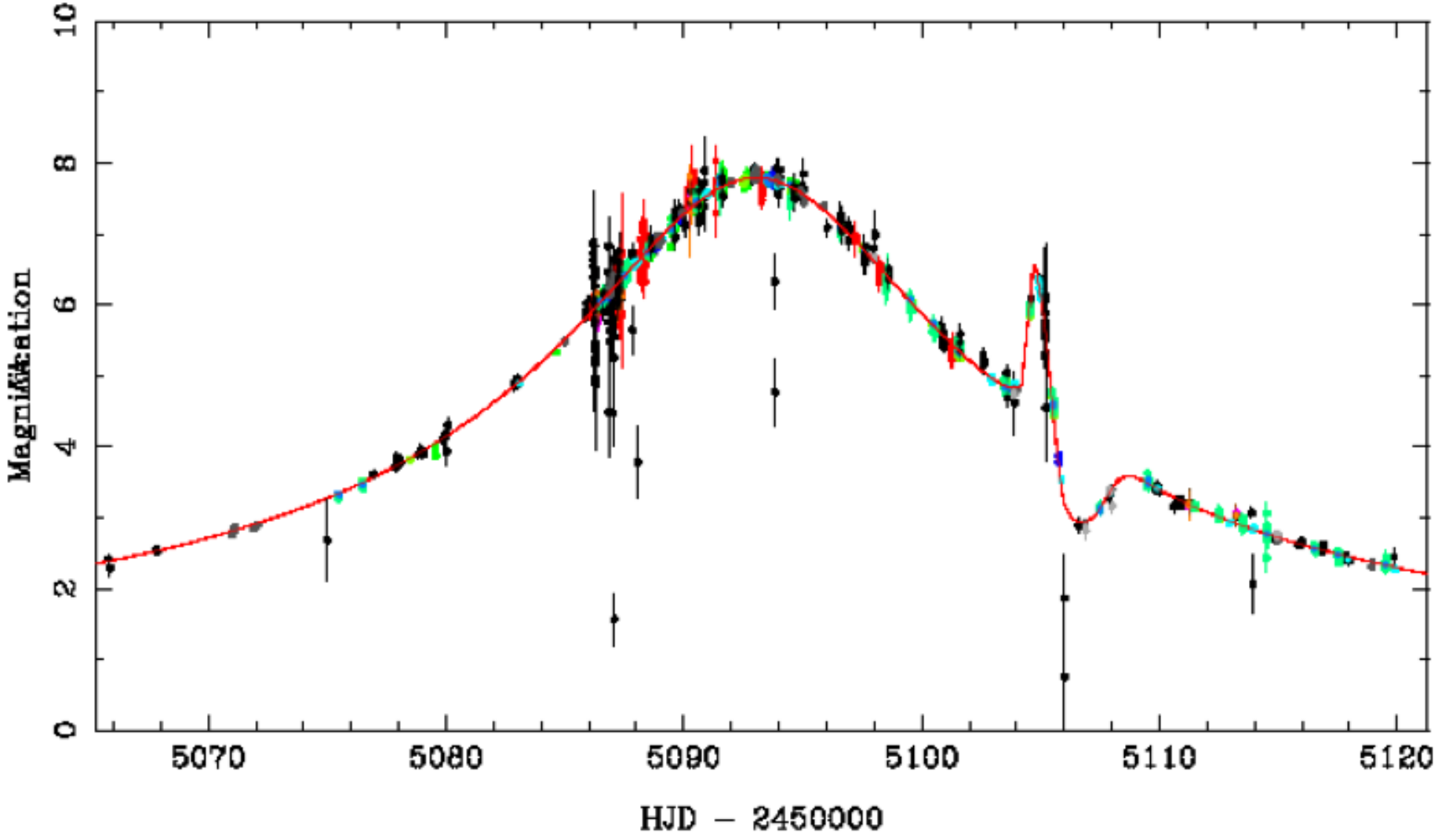
MOA−2010 23events



MOA−2011 10events

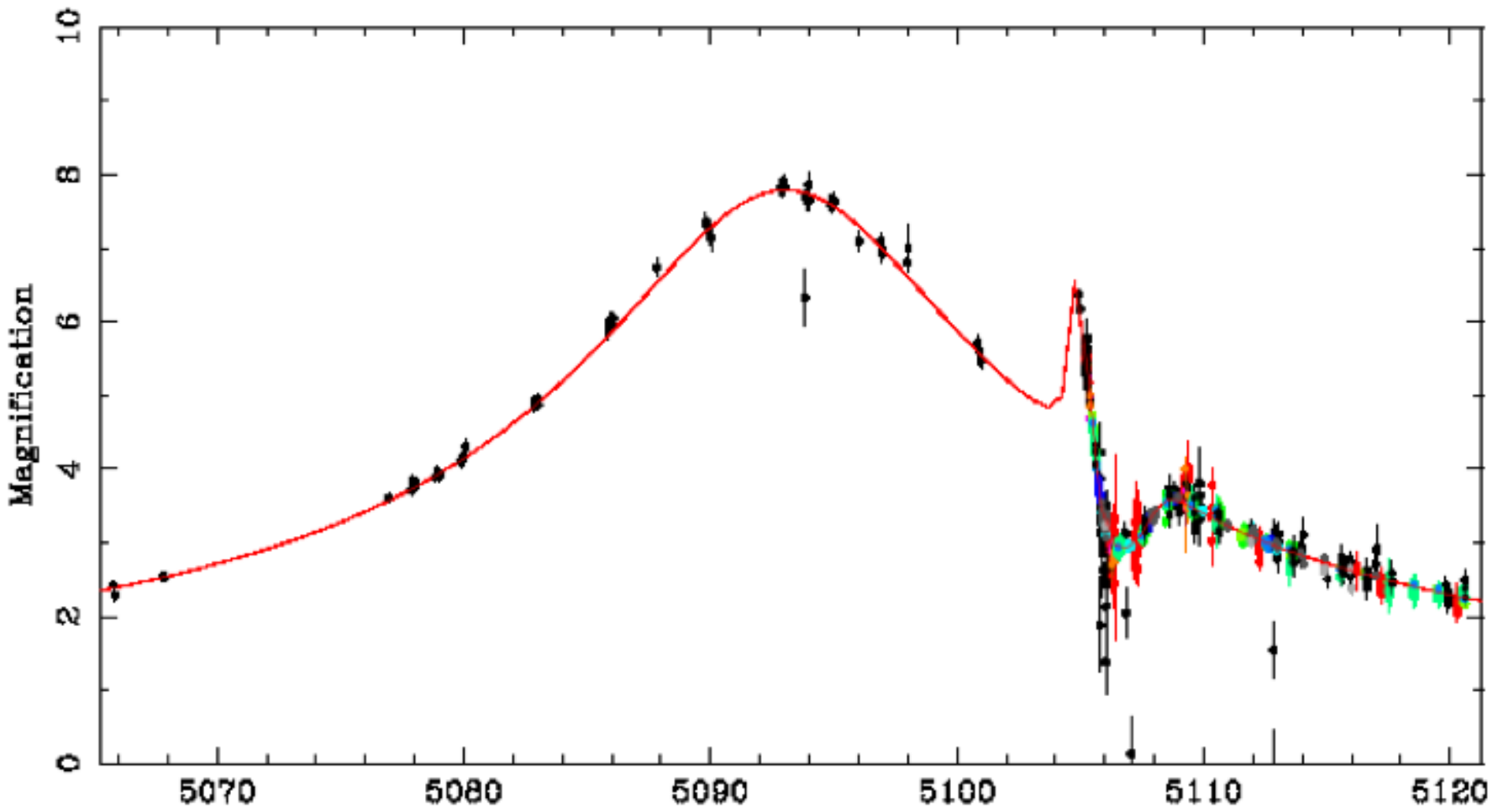


Artificial lightcurve of Low-mag event (MB09266)



惑星のパラメータが違えば、観測頻度も違うはず。

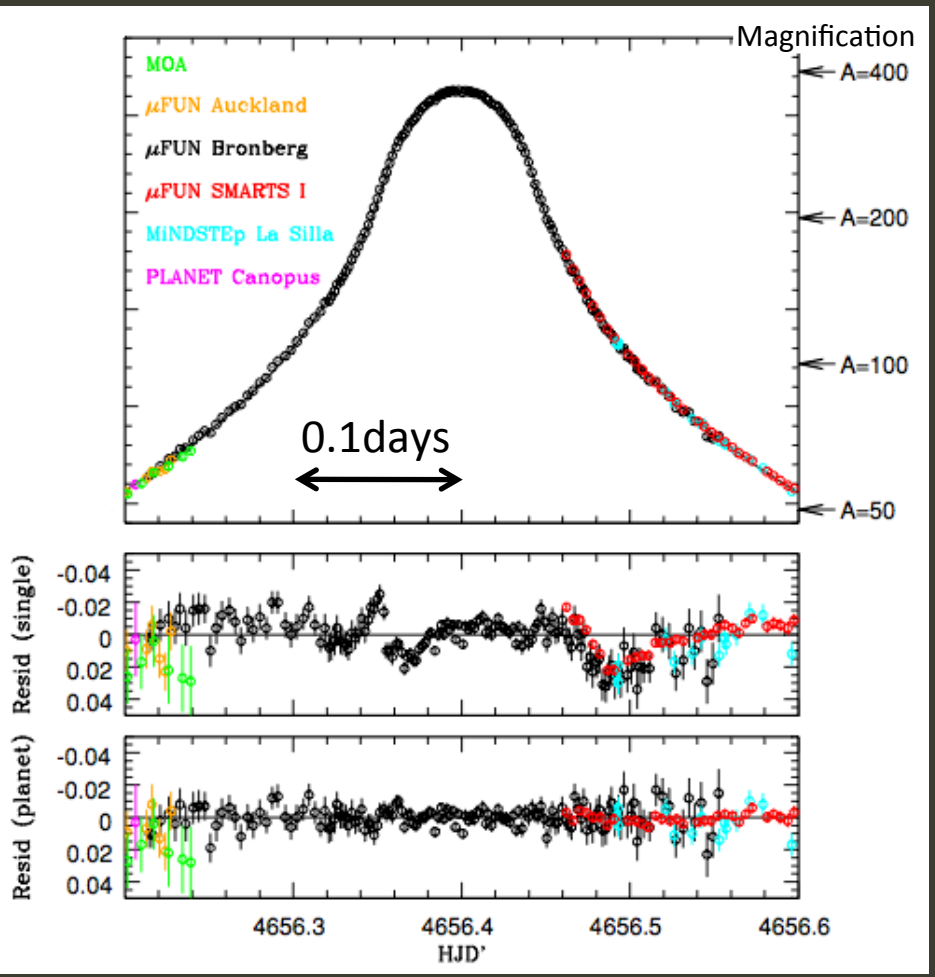
Artificial lightcurve of Low-mag event (MB09266)



こういう観測頻度になるはず。

High-mag VS Low-mag

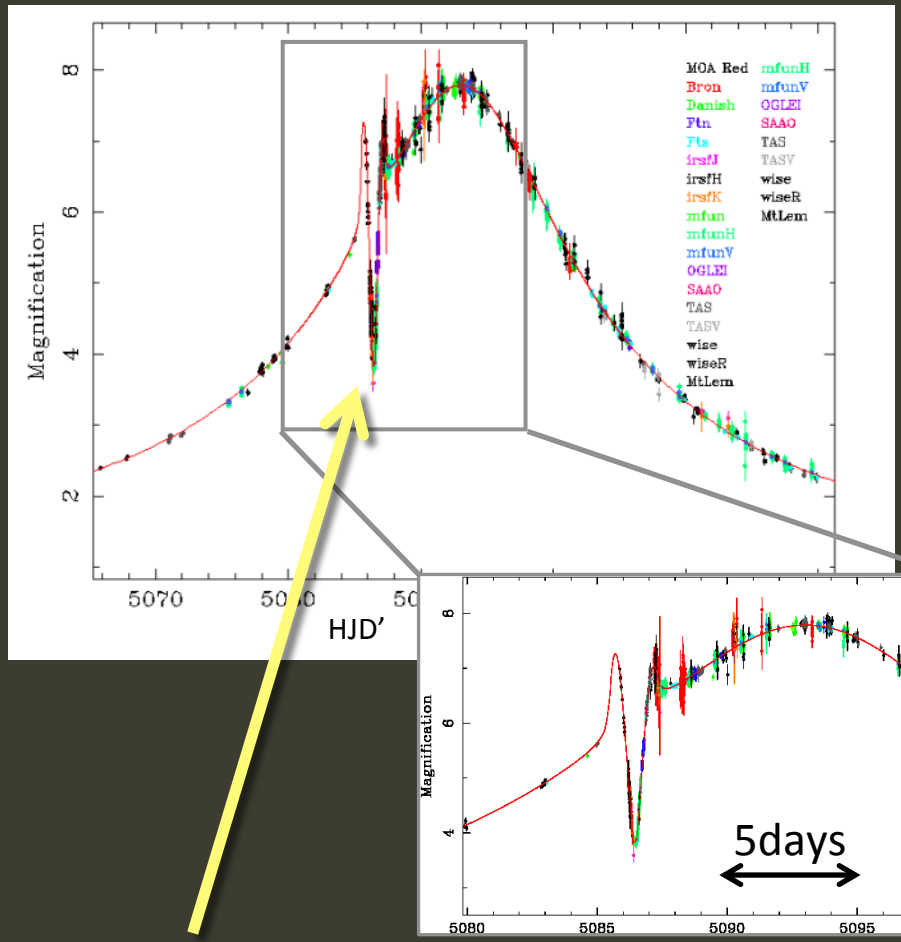
High-magnification



CONSTANT observation frequency

Janczak et al. 2010

Low-magnification



Observation frequency was increased due to the anomaly