Photometry for K2 Campaign 9

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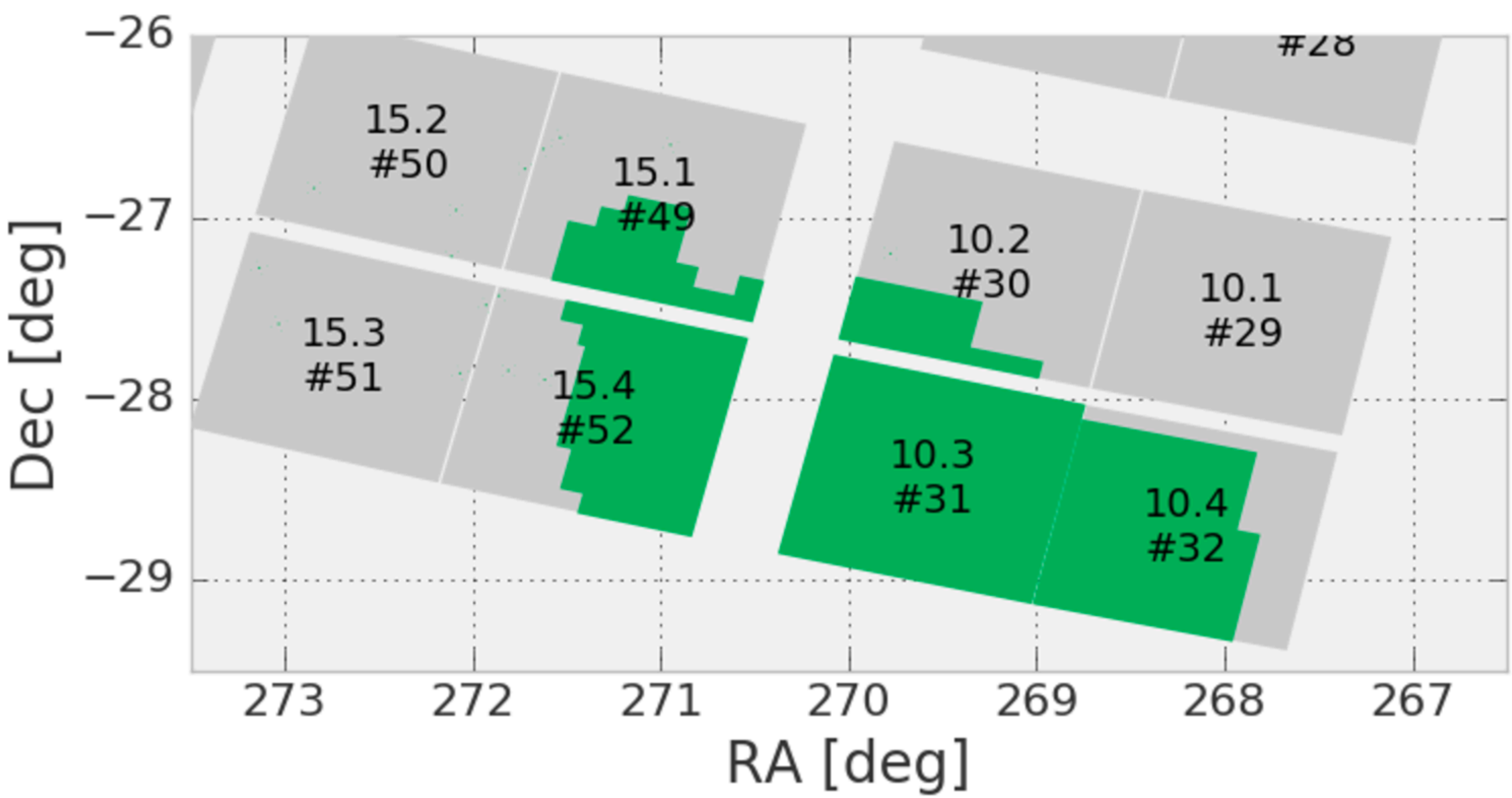
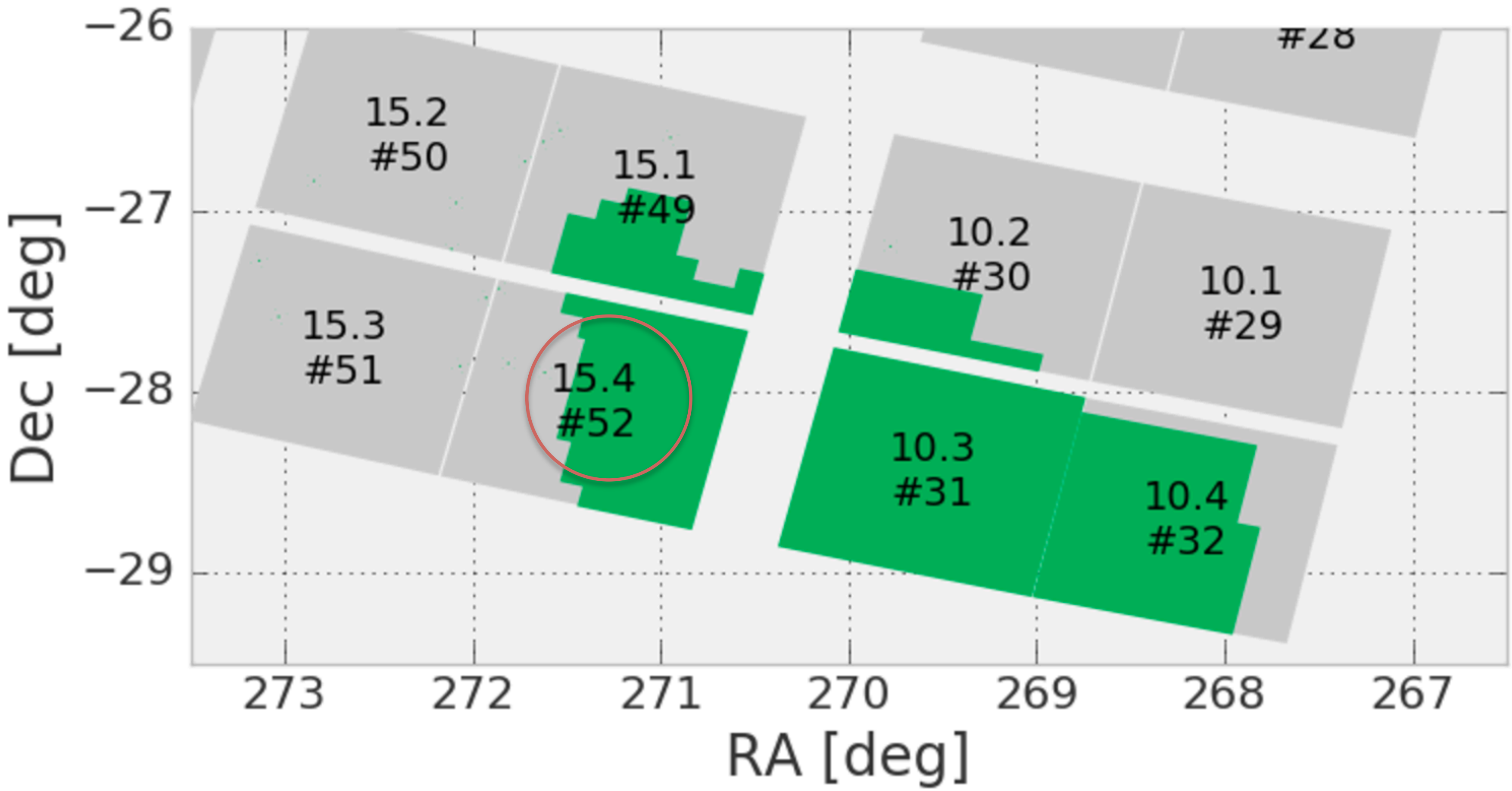
Outline

- Preliminary K2 Campaign 9 photometry result
- K2 photometry methods
  - Sparse Field (K2C1)
  - Super Stamps (K2C0)

K2C9 super stamps





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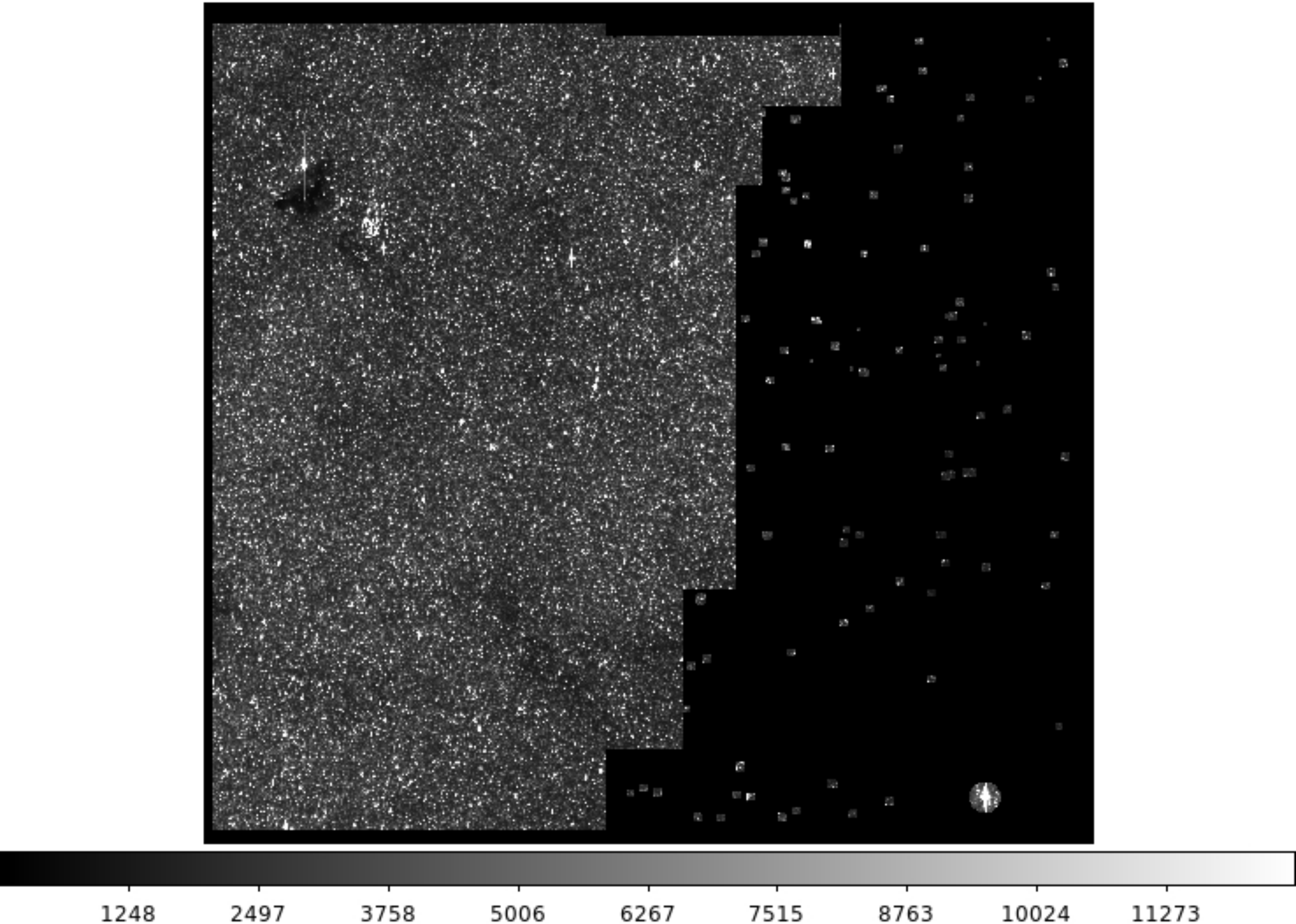
1248
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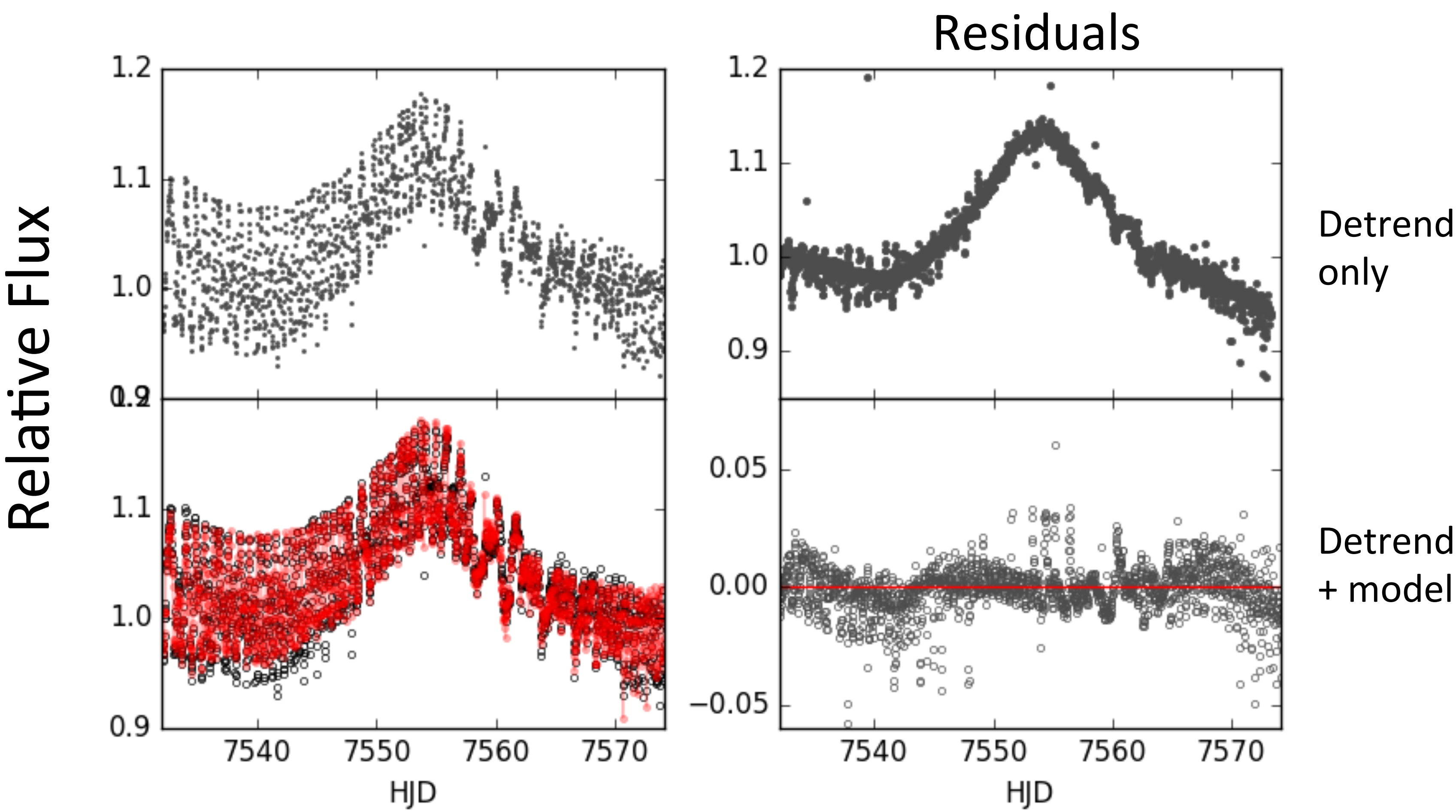
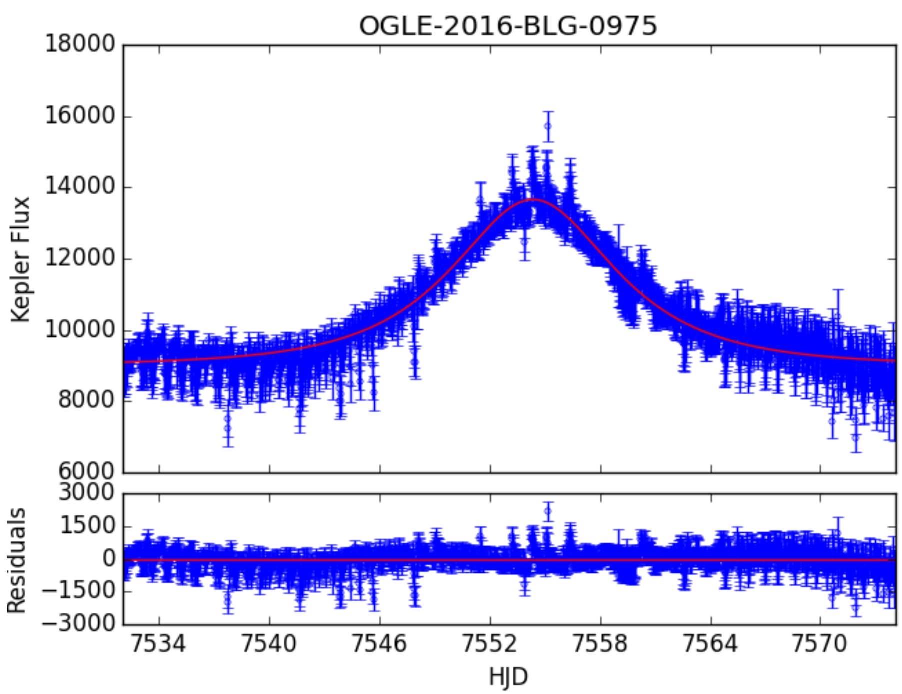
OGLE-2016-BLG-0975: Bright Event

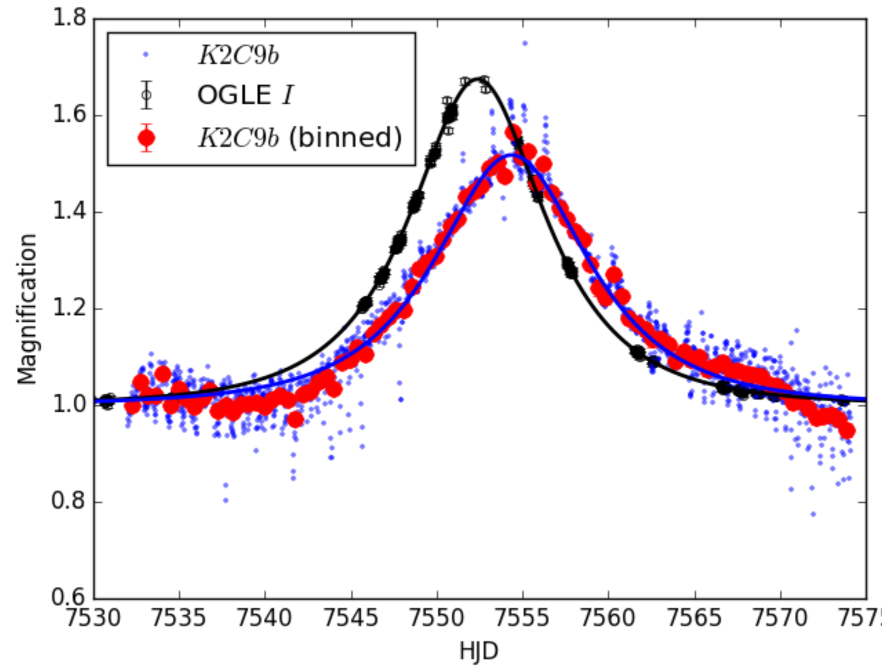
$_{\lambda}I_{base}$=14.4, t_E=6 days



OGLE-2016-BLG-0975: Bright Event

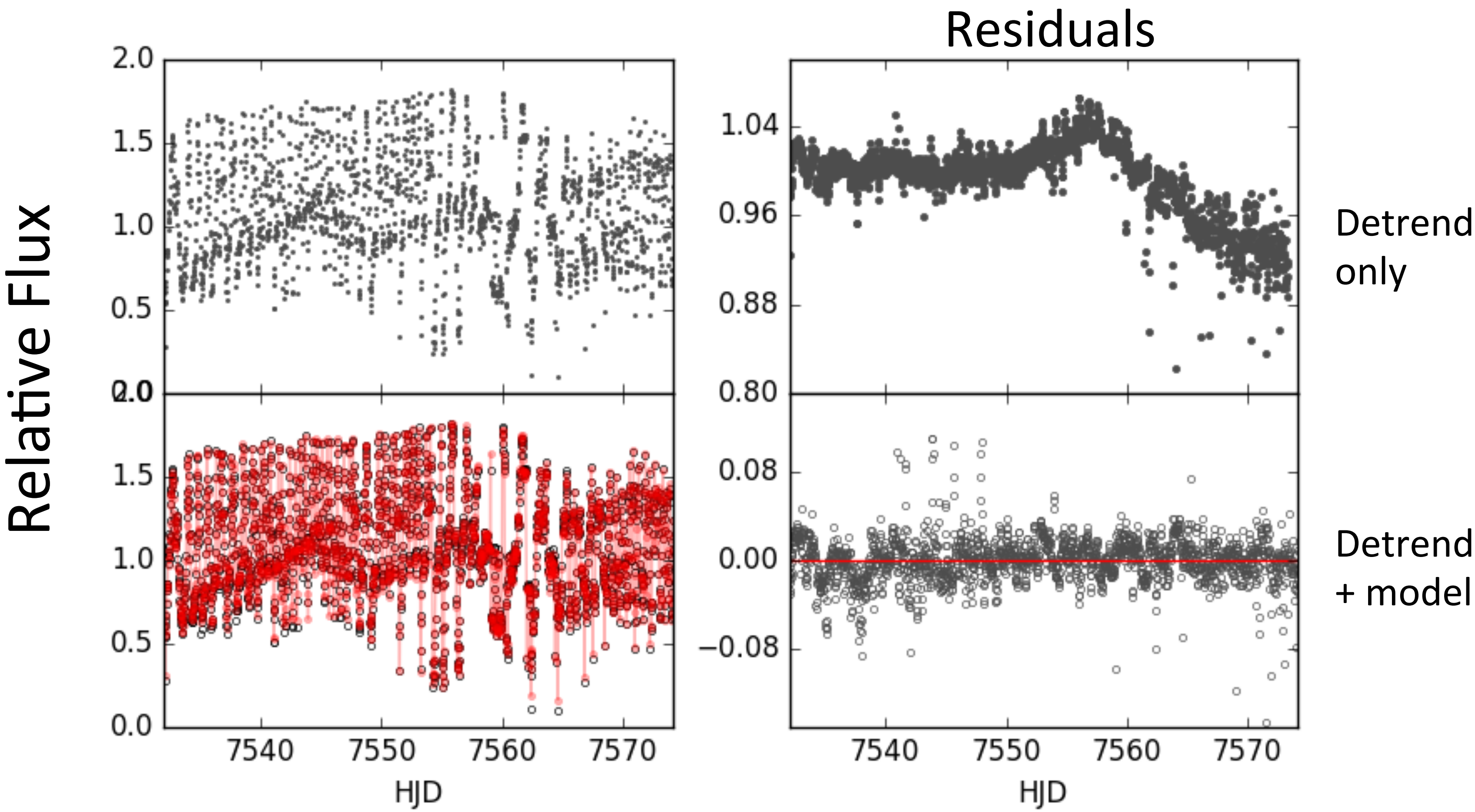
- I_{base}=14.4, t_E=6 days
- Kepler baseline flux~13,000 (Kp=14.7 mag) vs. Blending flux~40,000 (Kp=13.5 mag)
- Parallax (one out of four solutions):
- $\pi_{E,N}$=0.330+-0.021, $\pi_{E,E}$=-0.518+-0.012, Kp_base=14.68+-0.04





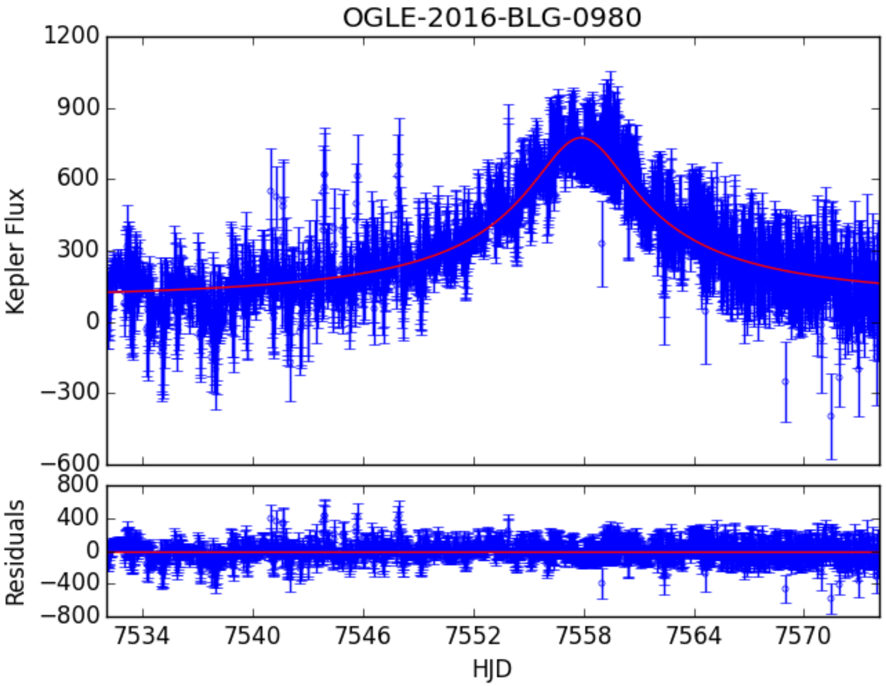
OGLE-2016-BLG-0980: Typical Event

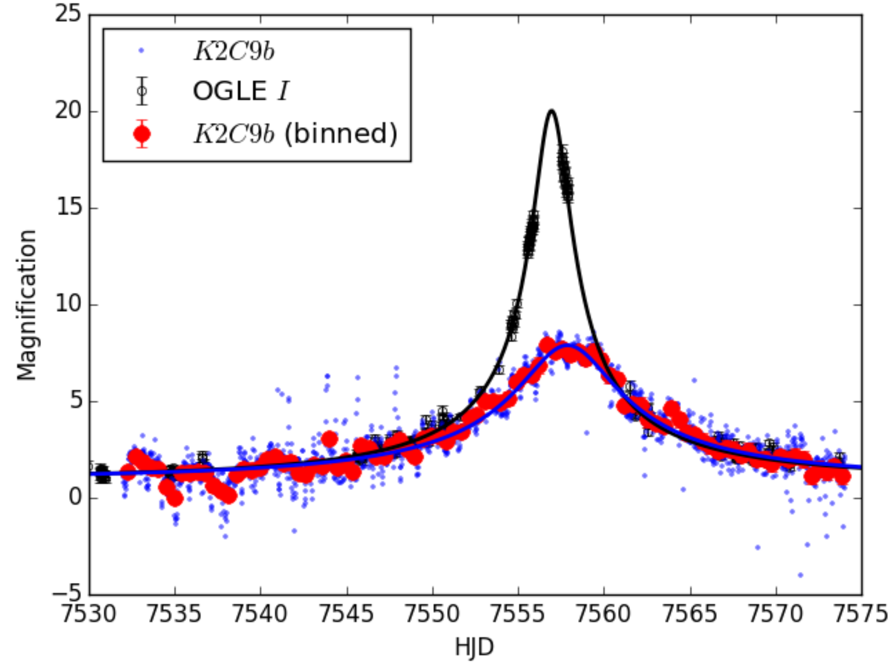
$_{\lambda}I_{base}$=19.5, t_E=27 days



OGLE-2016-BLG-0980: Typical Event

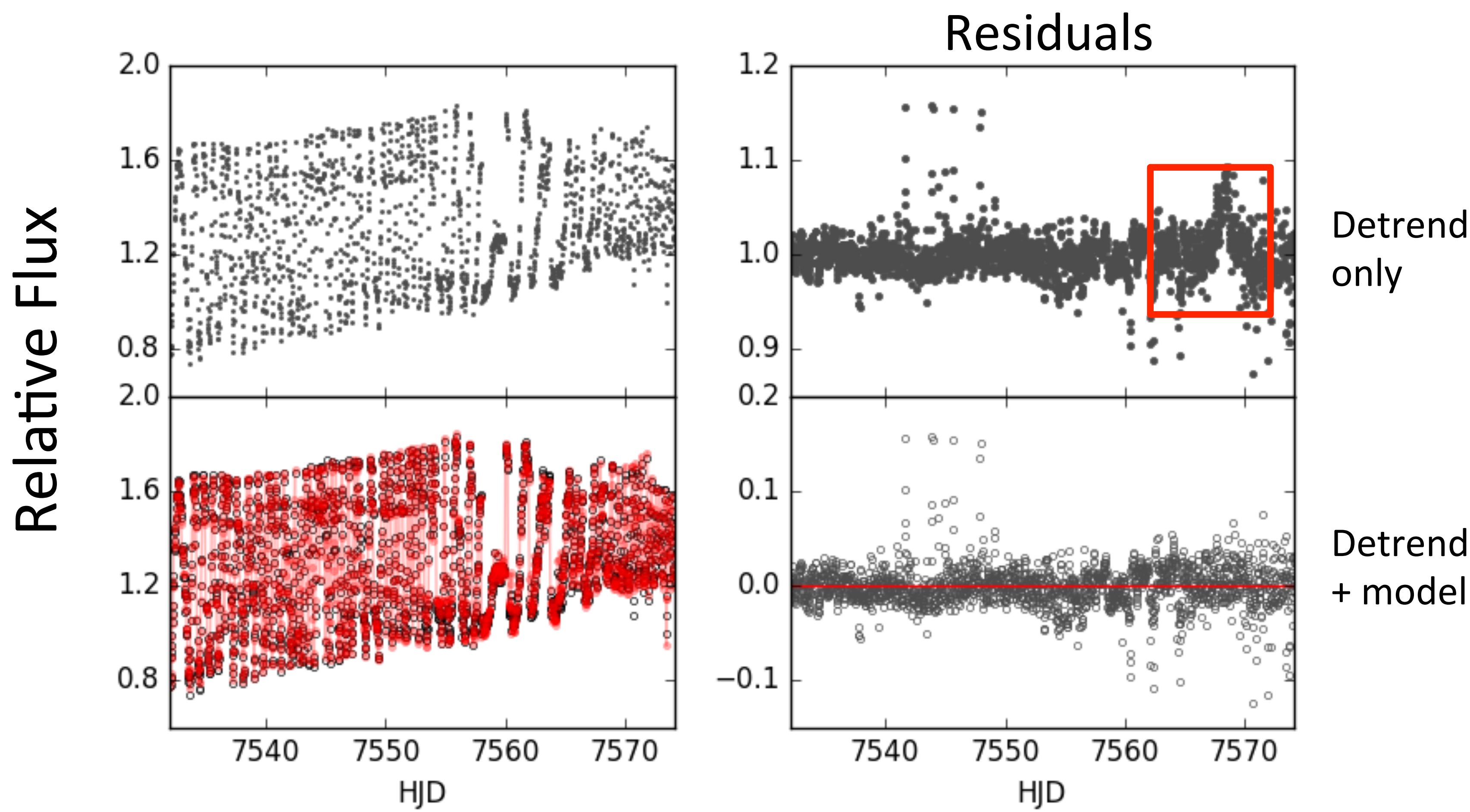
- I_base=19.5, t_E=27 days
- Kepler baseline flux=100 (Kp=20 mag) vs. Blending flux=5000 (Kp=15.7 mag)
- Parallax: $\pi_{E,N}$=0.105+-0.007, $\pi_{E,E}$=-0.062+-0.006, Kp_base=19.99+-0.08





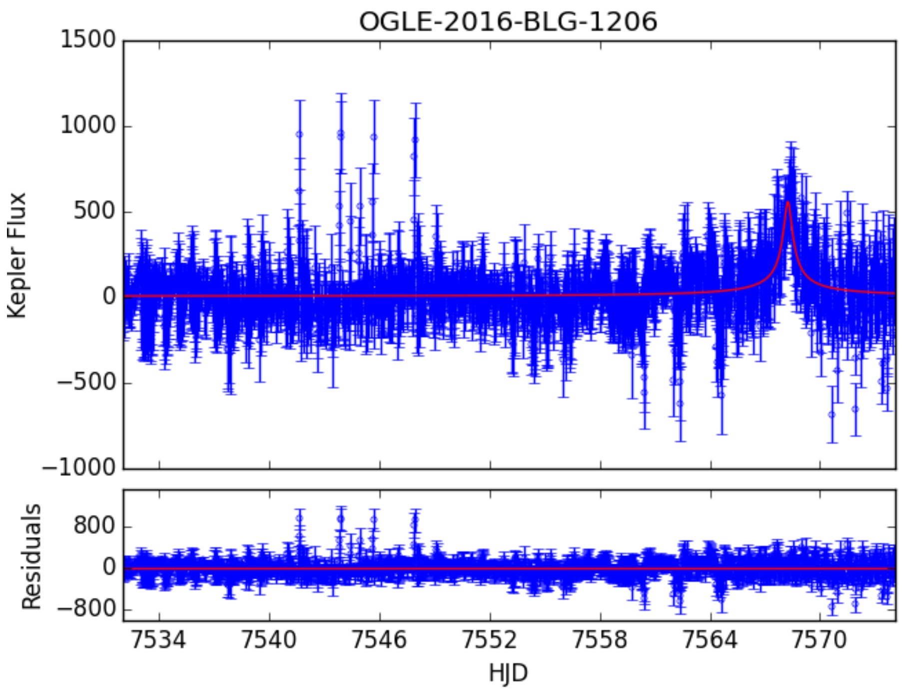
OGLE-2016-BLG-1206: Faint Event

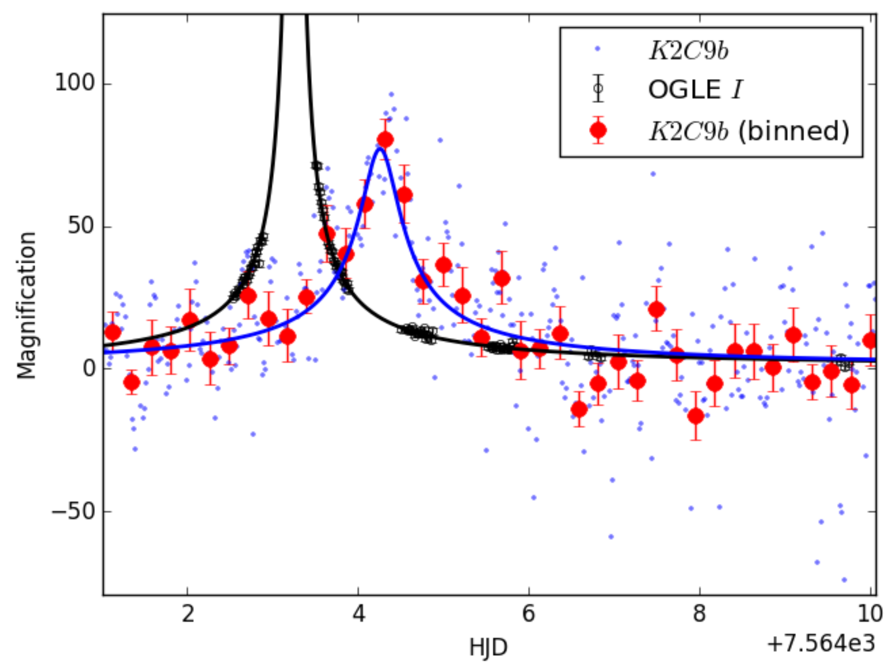
$_{\lambda}I_{base}$=21.4, t_E=17 days

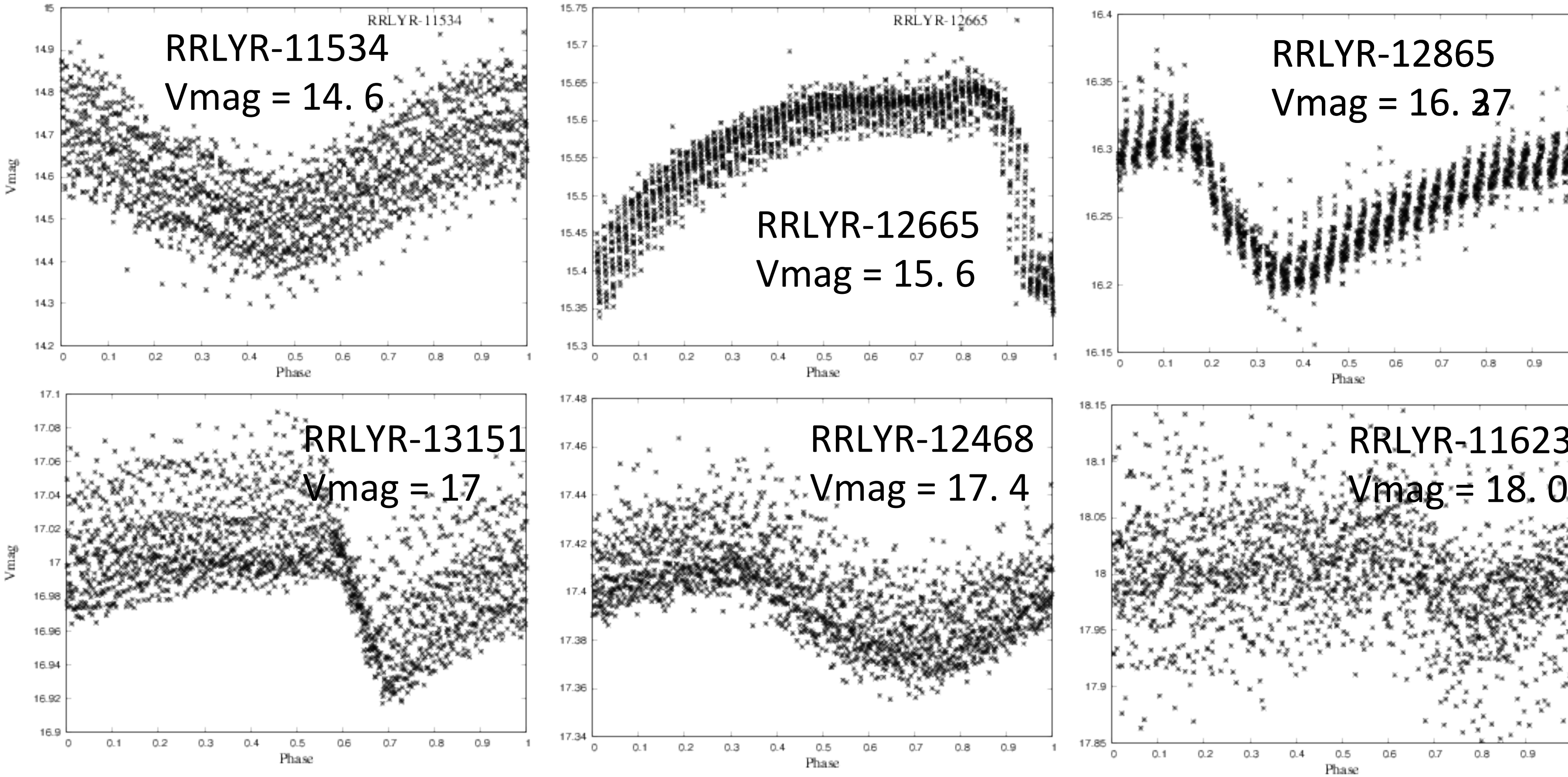


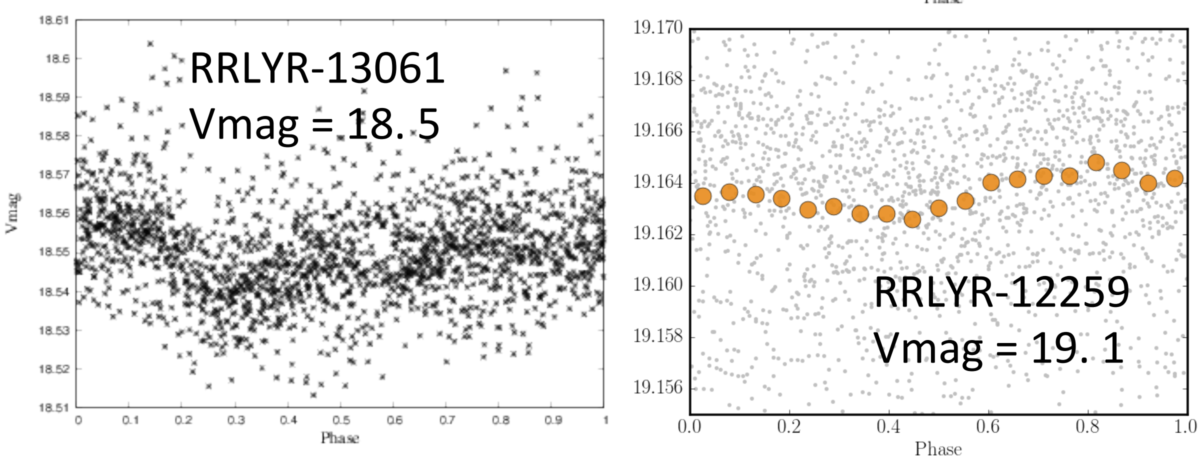
OGLE-2016-BLG-1206: Faint Event

- I_{base}=21.4, t_E=17 days
- **Kepler baseline flux~8 (Kp=22.8 mag) vs. Blending flux=8000 (Kp=15.2 mag)**
- Parallax: $\pi_{E,N}$=0.016+-0.004, $\pi_{E,E}$=-0.074+-0.007, Kp_base=22.8+-0.2

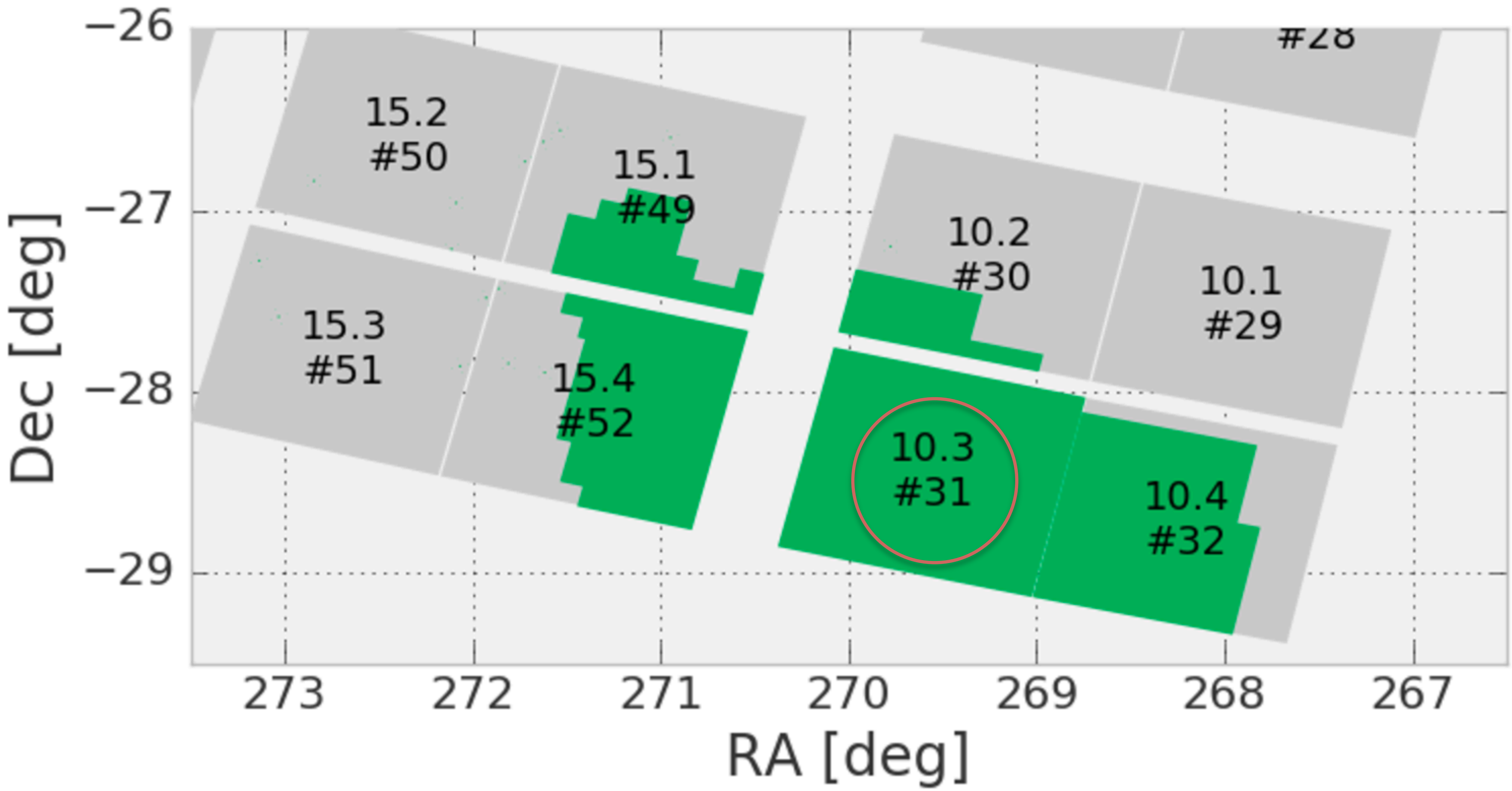








Example known
RR-LYRAE
In K2C9b



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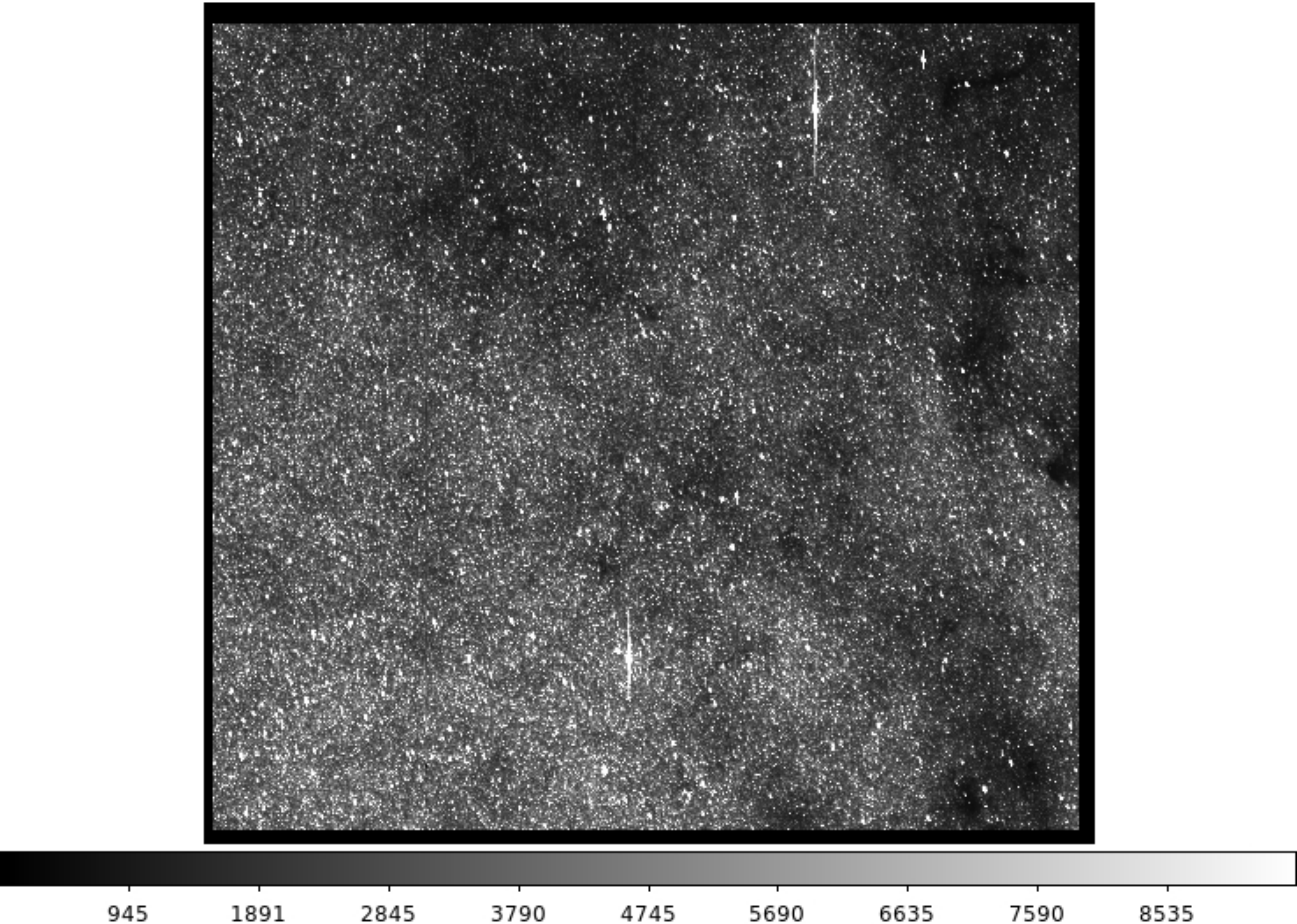
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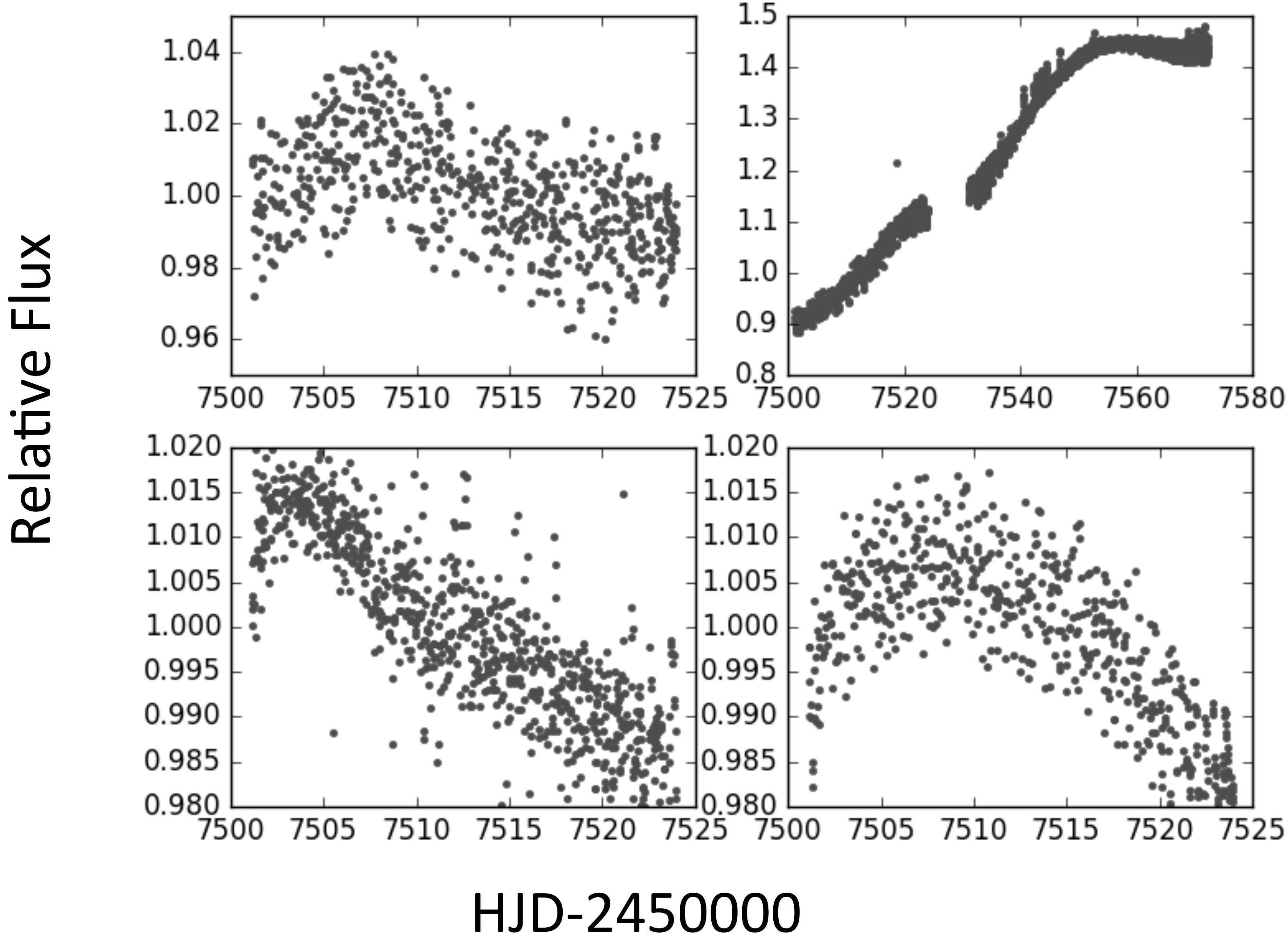

Relative Flux
HJD-2450000
1.04
1.02
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0.98
0.96
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7505
7510
7515
7520
7525
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
7500
7520
7540
7560
7580
1.020
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
7500
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1.020
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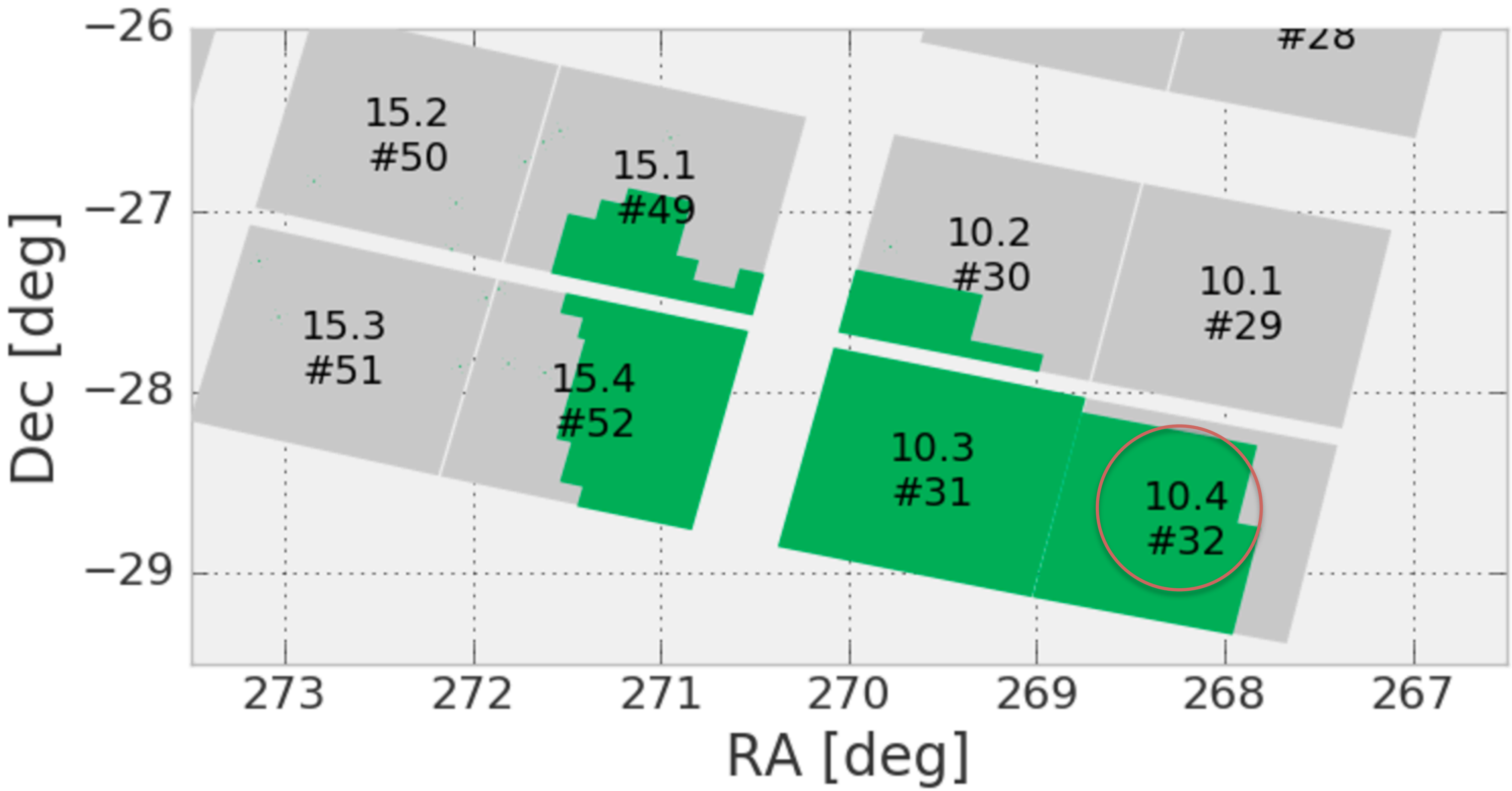

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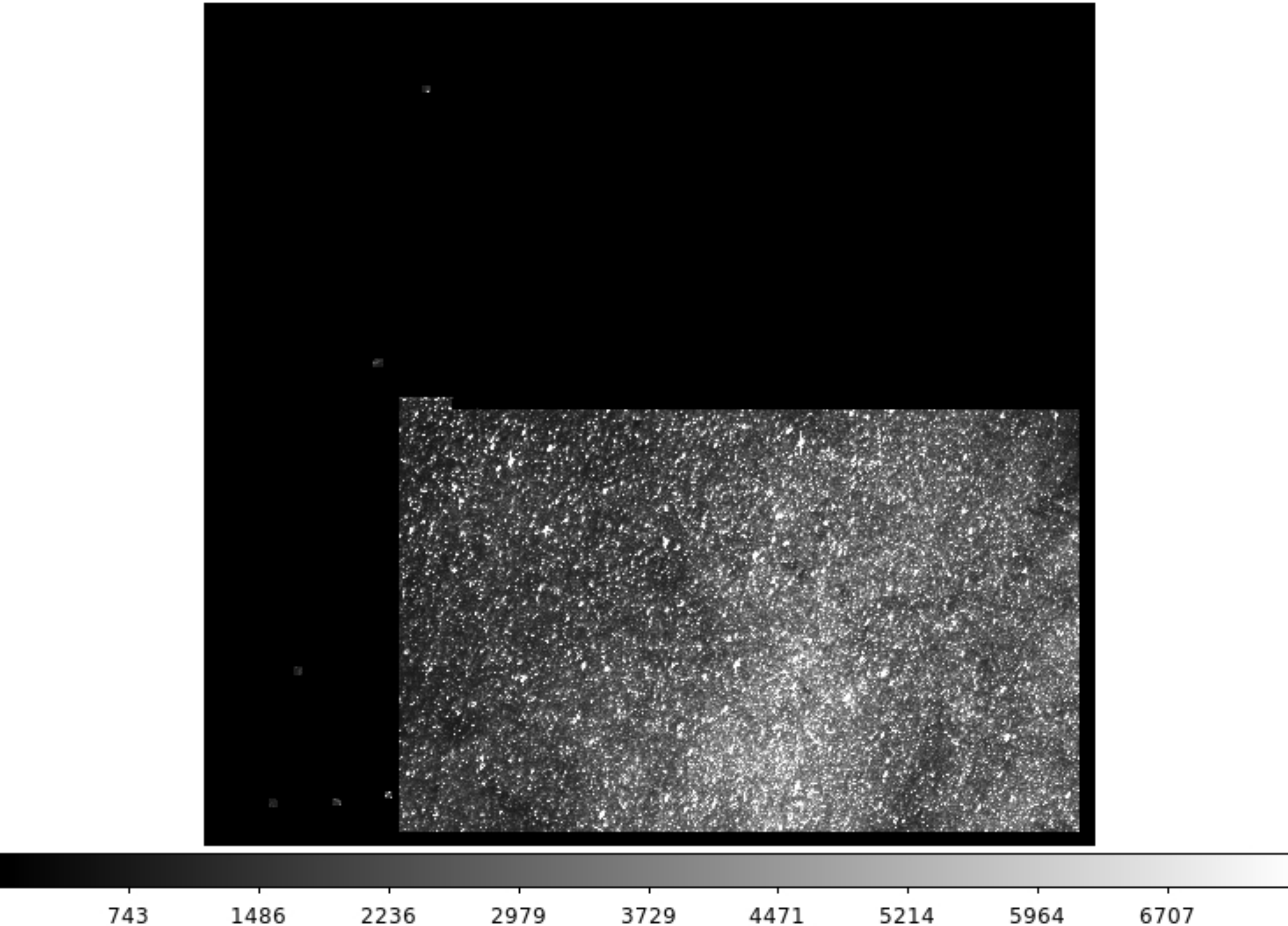
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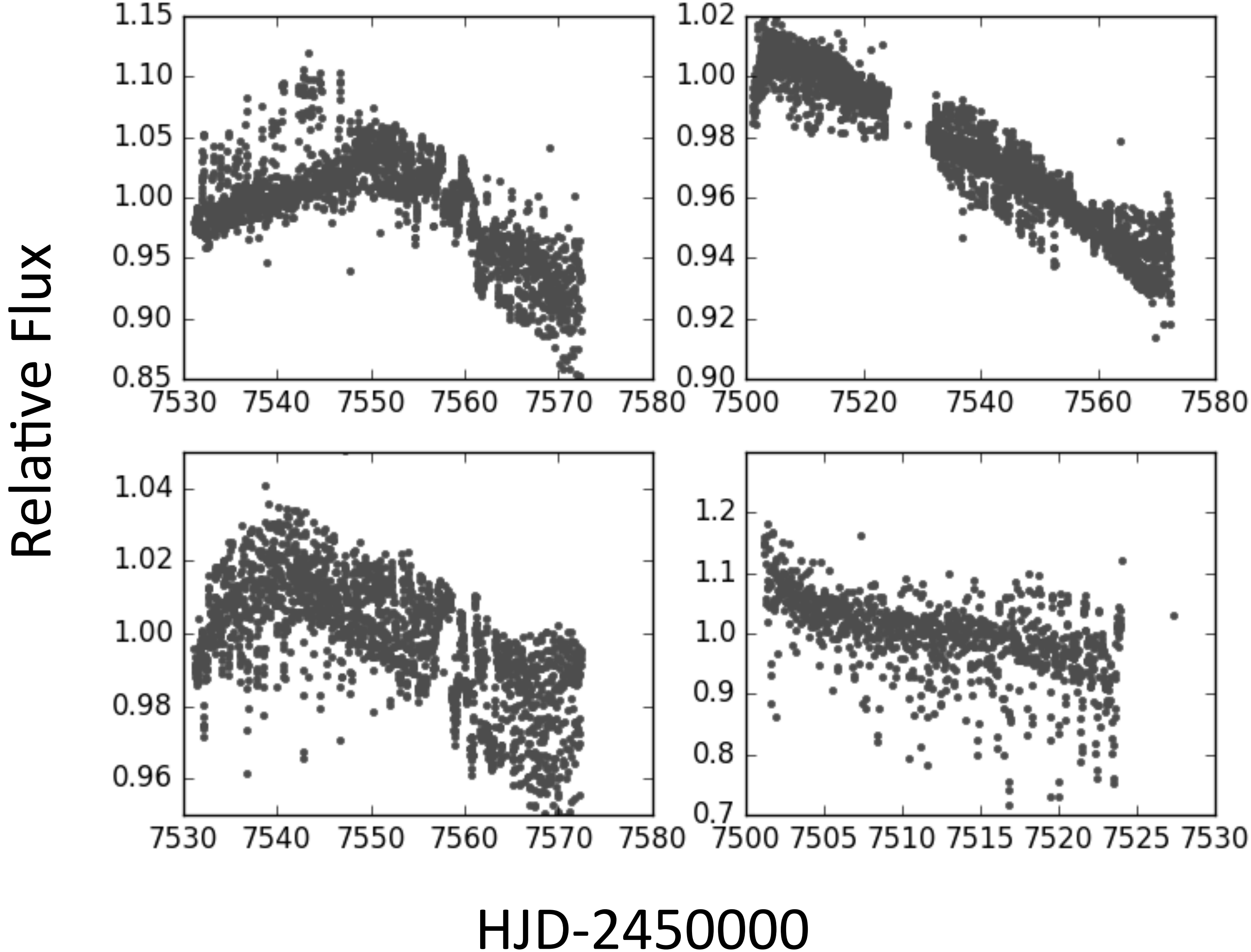
Relative Flux
HJD-2450000
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Various Efforts to Reduce K2 photometry

- Vanderburg & Johnson 2014

https://www.cfa.harvard.edu/~avanderb/k2.html

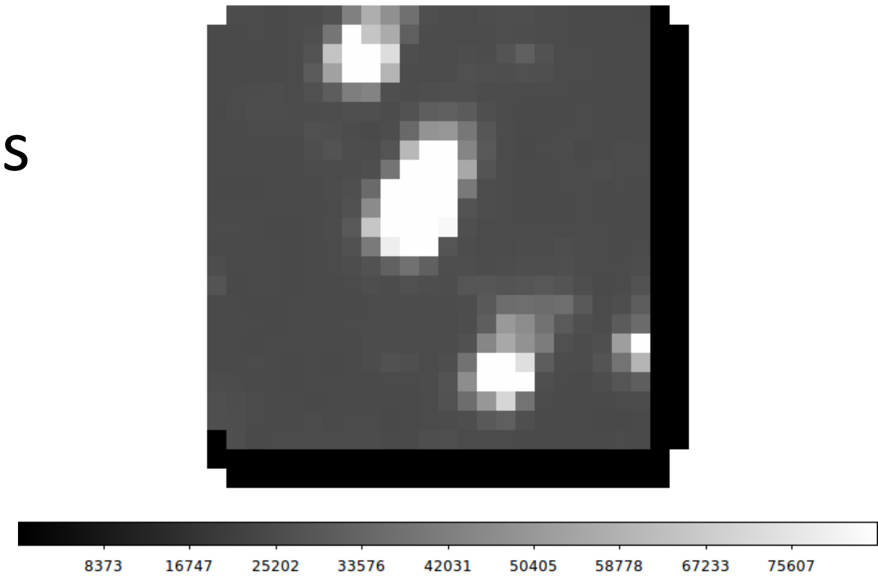
- Aigrain et al 2015 (engineering data)
- Foreman-Mackey et al 2015
- Lund et al 2015
- **Huang et al 2015 (campaign 1)**

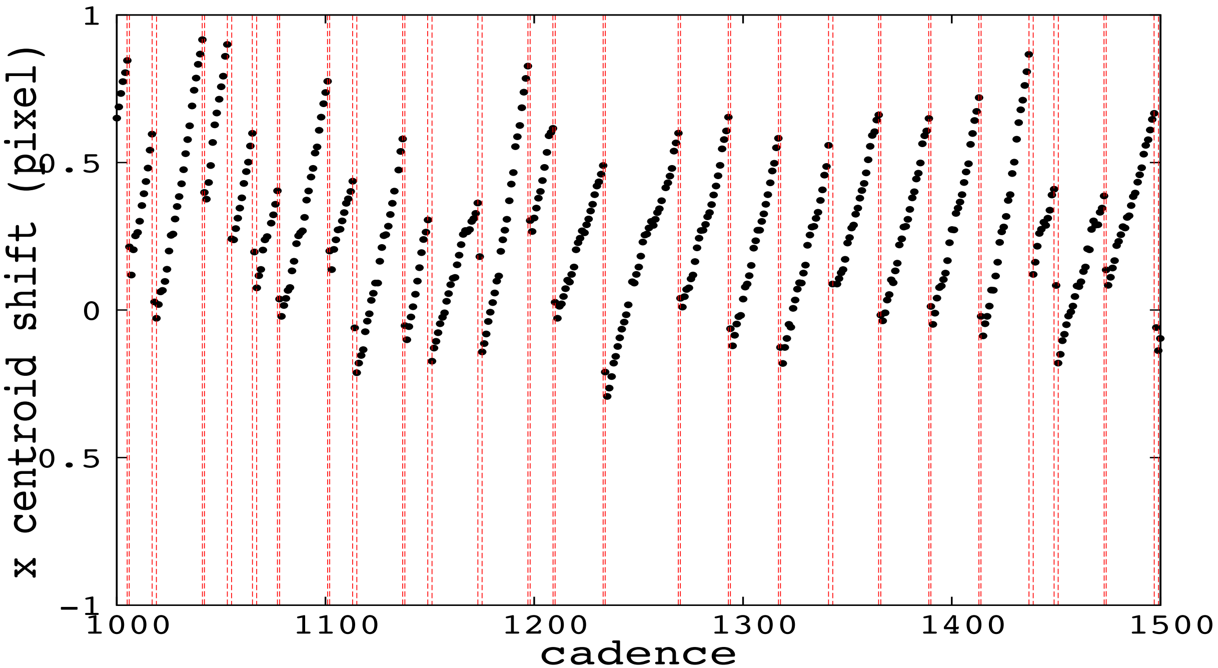
http://k2.hatsurveys.org

- Pope et al 2015
- **Sores-Furtado et al (2017) (campaign 0)**
- And many many more …

Two reaction wheel era Kepler suffers from severe pointing drifts

Stacked K2 frames within 1 day



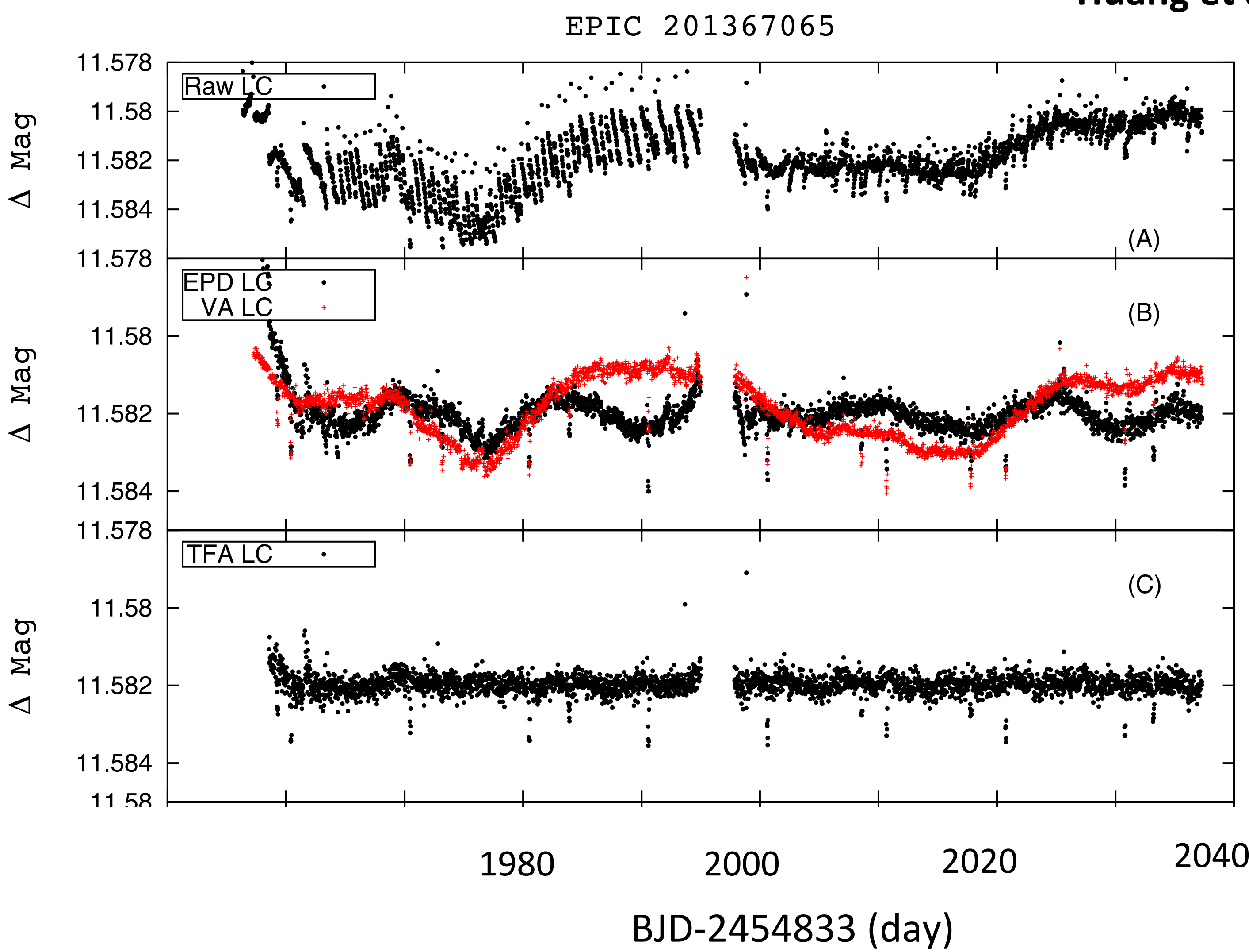


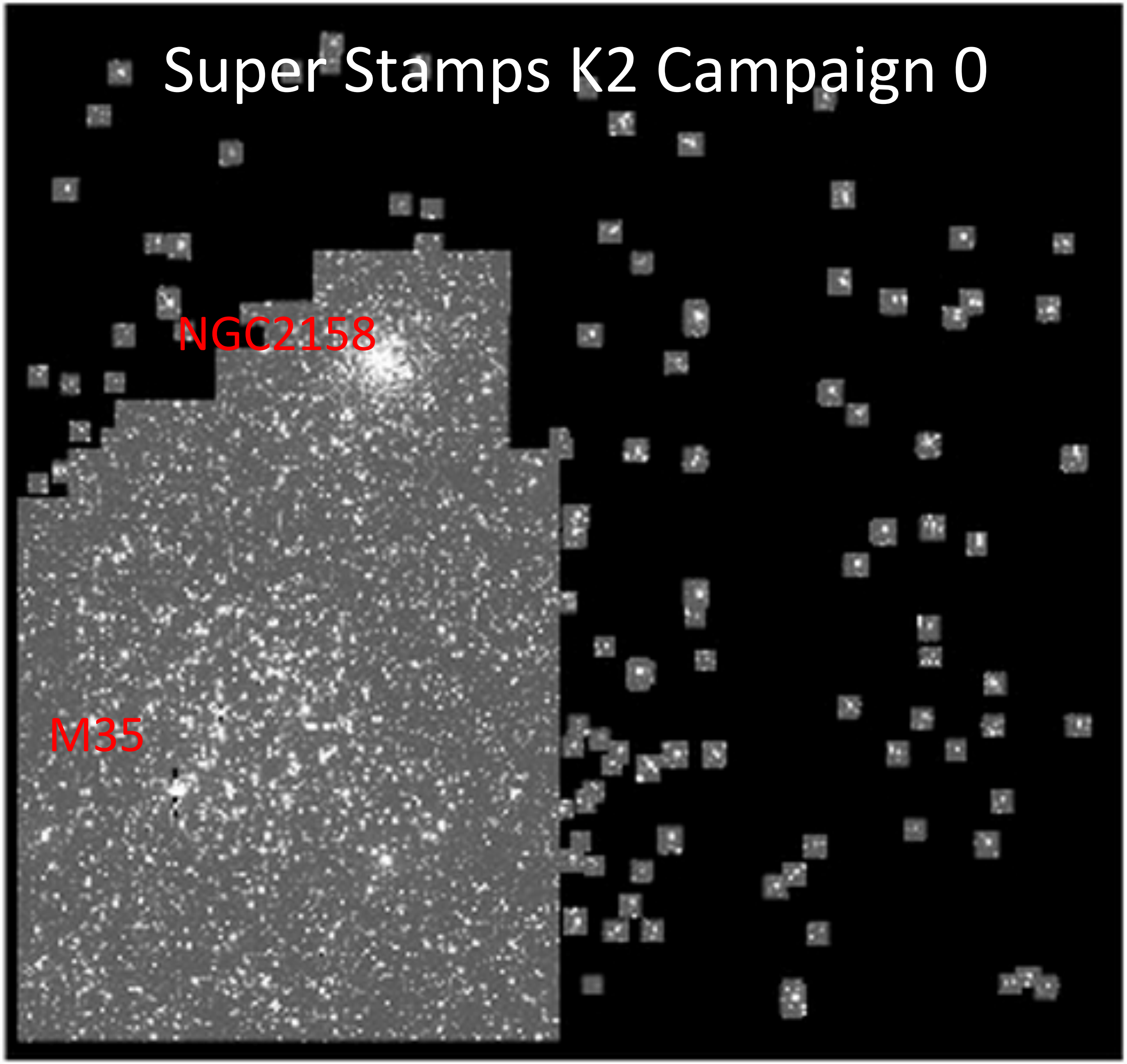
Our Solution

- Use accurate astrometry to constrain the motion;

- Use the refined drifts to correct the photometry.

Huang et al 2015 (campaign 1)

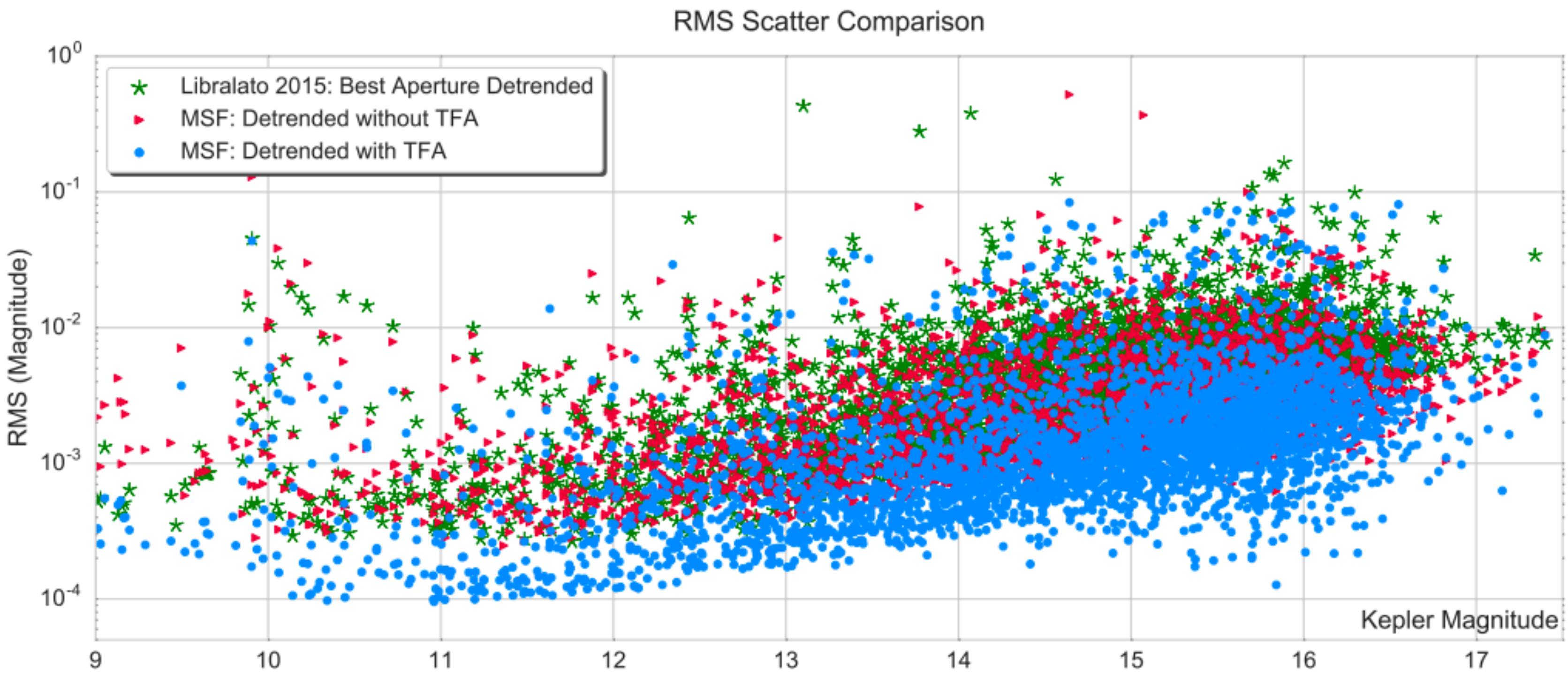




Sores-Furtado et al (2017)

Image subtraction reduction

Make use of FITSH developed by A. Pal (See Pal et al (2009)),
Based on algorithm described in Alard & Lupton (1998) and Alard (2000)



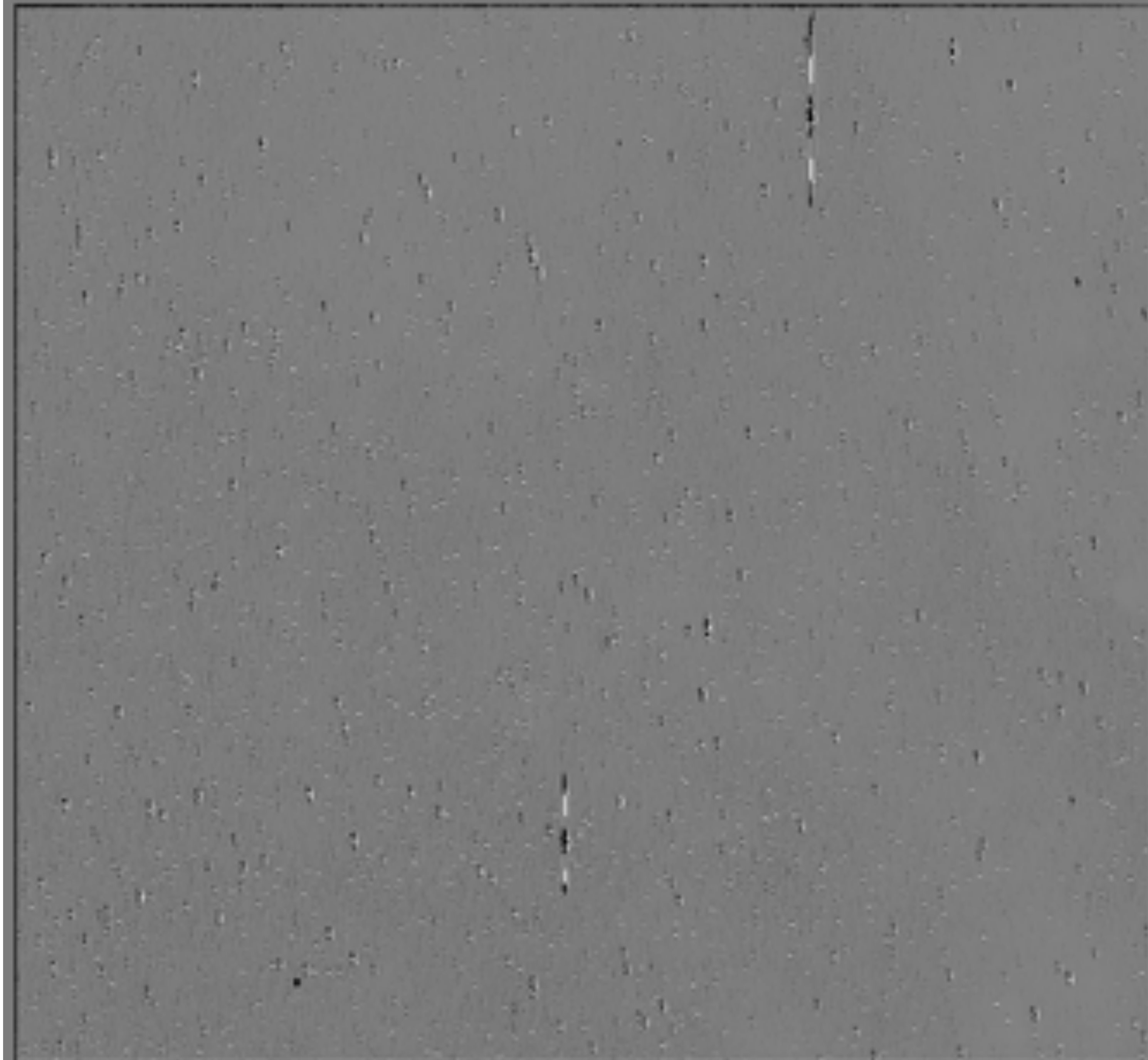
Sores-Furtado et al (2017)

K2C9 Data Products

- Raw Light curves (40 different appertures) for all the stars in UCAC4 + additional OGLE targets on super stamps.
- Difference Images at each cadence.

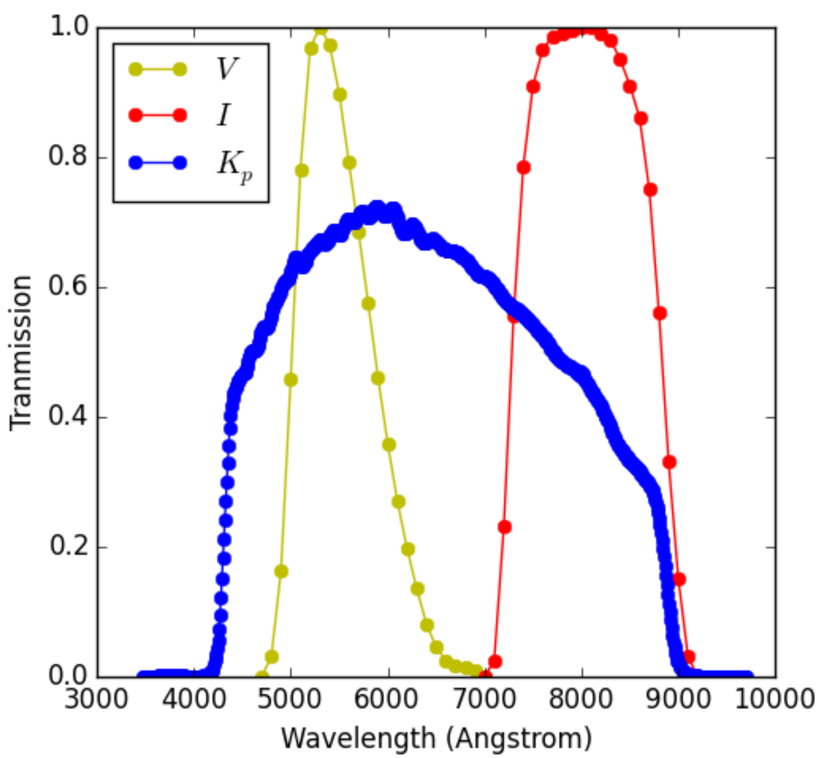
Ongoing/Future work

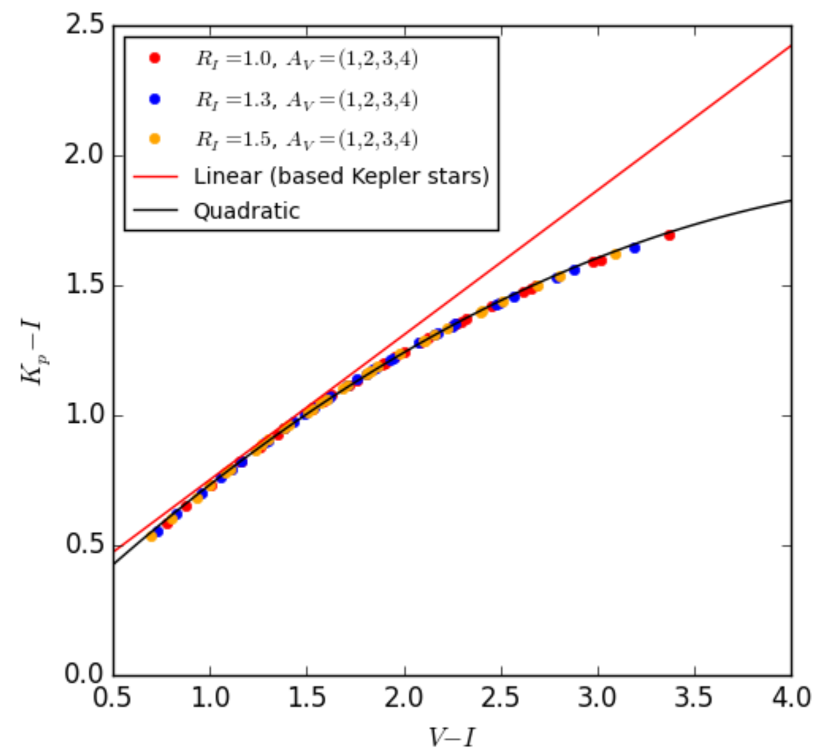
- Finish the last super Stamp channel
- Optimize difference imaging kernel
- Determine optimized aperture for each targets.
- Apply simultaneous TFA with modeling fitting.
- Late targets reduction



Constraining Flux in Kepler Band

- Important for 1) partial event; 2) extremely faint event; 3) break 4-fold degeneracy
- Kp-I vs. V-I relation independent of extinction
  - Kp-I = -0.072(V-I)^2+0.72(V-I)+0.080

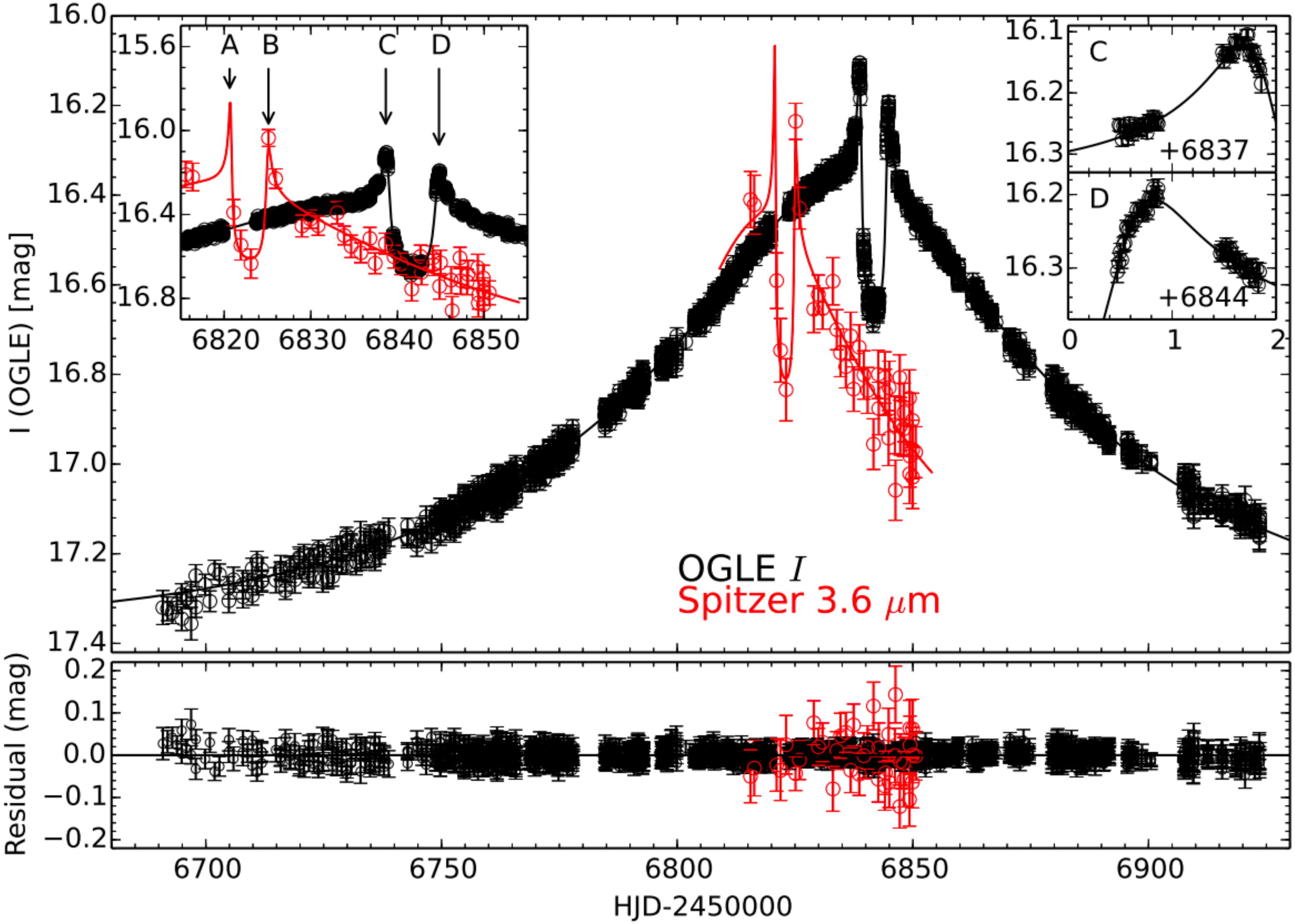




Why Satellite Observations Important?

- Simultaneous ground-based and space-based observations measure microlensing parallax.
  - Can show light curve of planet ob140124 (Udalski et al. 2015) if needed.
- Microlensing parallax is crucial to constrain the mass and distance of lens object/system.
  - To measure mass, one needs two out of the three: microlens parallax, lens flux, angular Einstein radius (via finite source effect).
  - See Figure 1 of Yee (2015, ApJL, 814,11) for an illustration.
- With parallax alone, mass & distance can be constrained statistically with ~25% uncertainty → statistical studies of stellar mass function & Galactic structures.

Why is Satellite Observations Important



Udalski et al 2014

K2C9 is Unique

- K2C9 is a blind survey
  - Continuous observation from Kepler for ~ 40 days (K2C9b)
  - Good for detecting short time scale (t_E~2days) events and cover caustic-crossing events.
  - Constraining FFP population (up limit) & isolated brown dwarfs.

Henderson et al (2016)

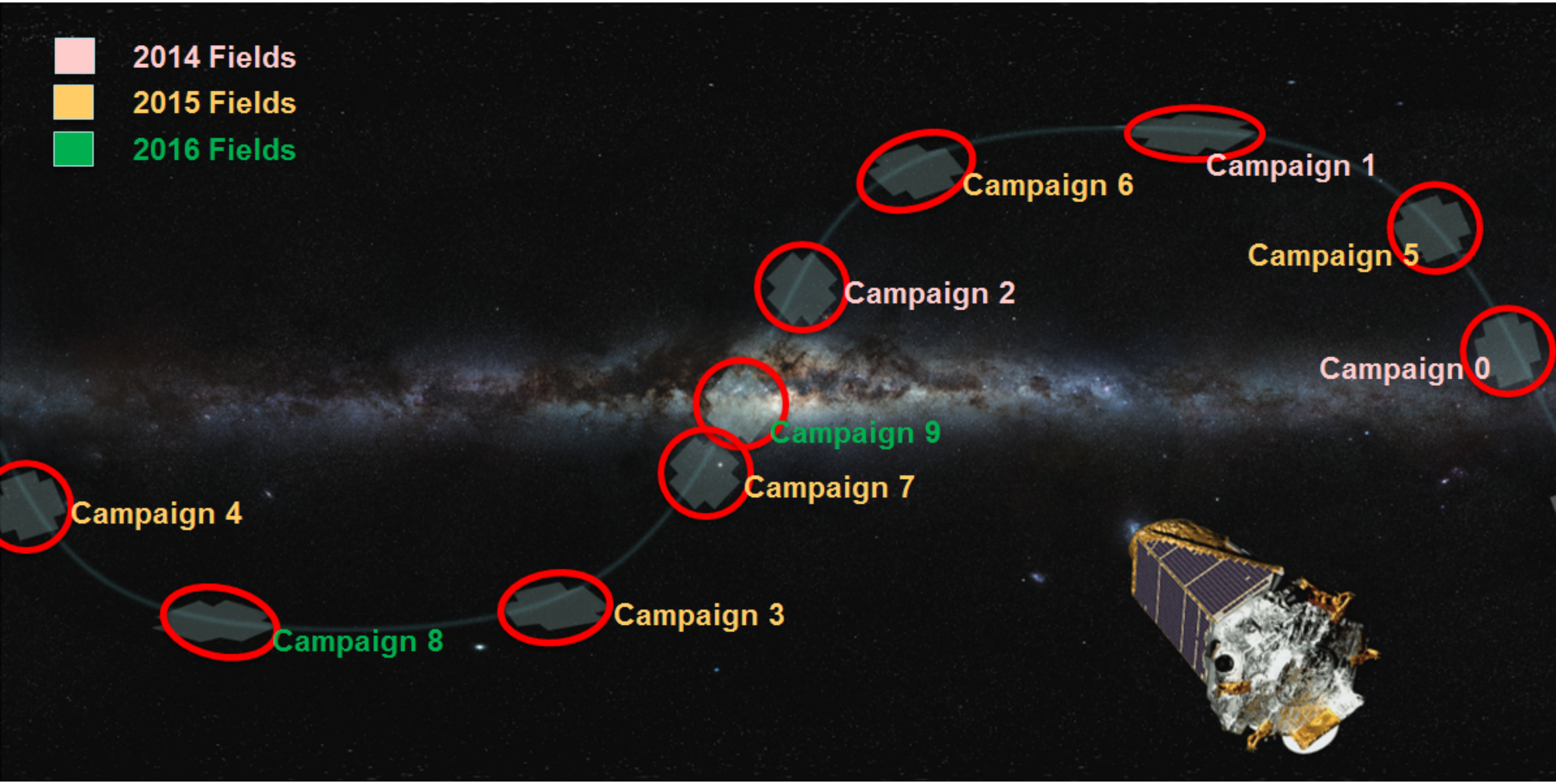
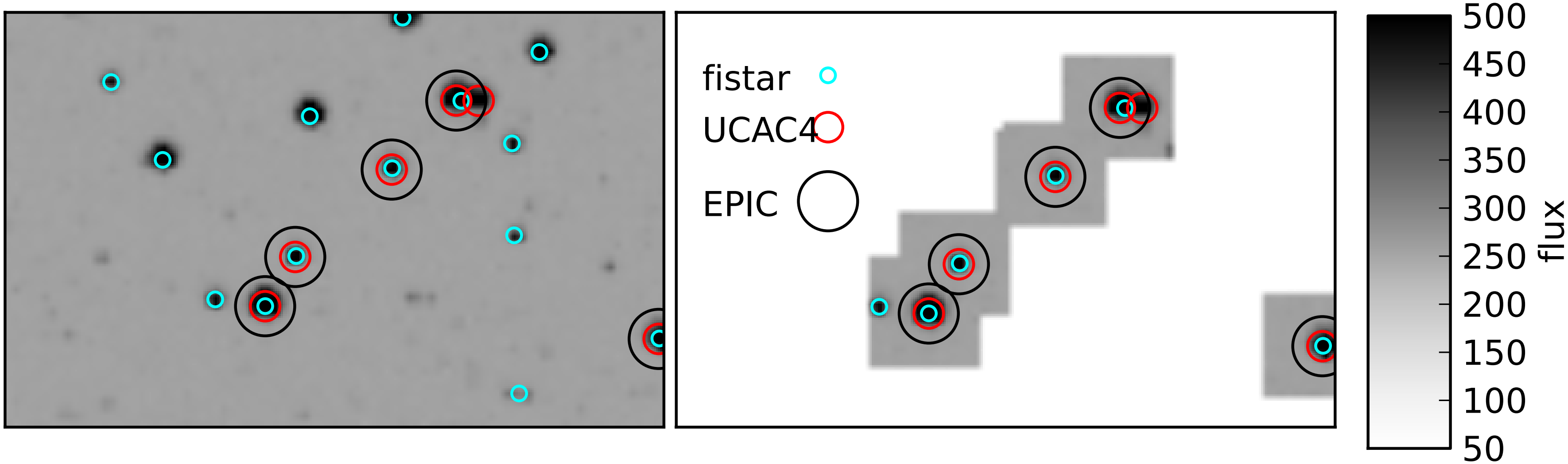


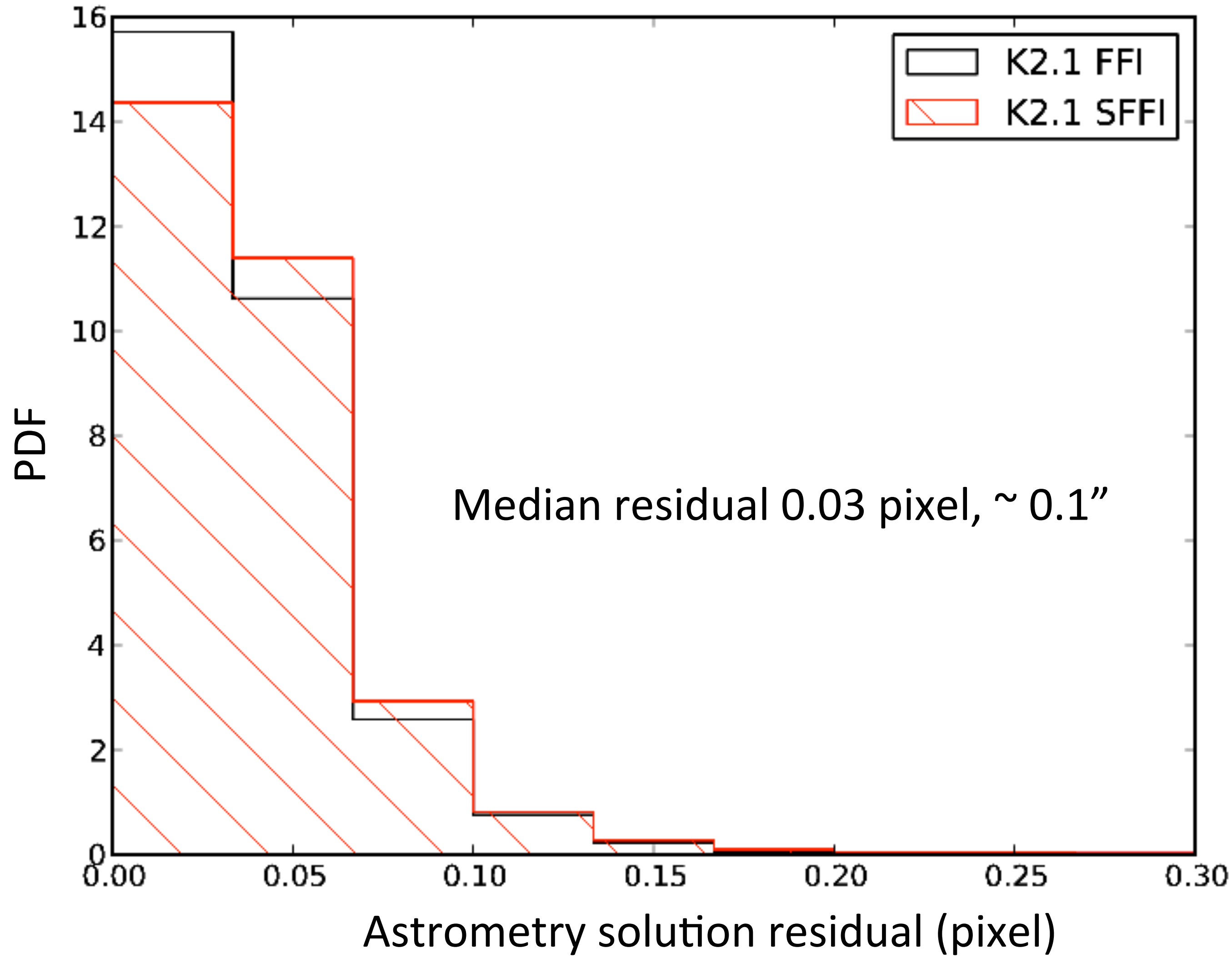
Image from: http://www.physics.usyd.edu.au/k2gap/

K2C1 Sparse field reduction



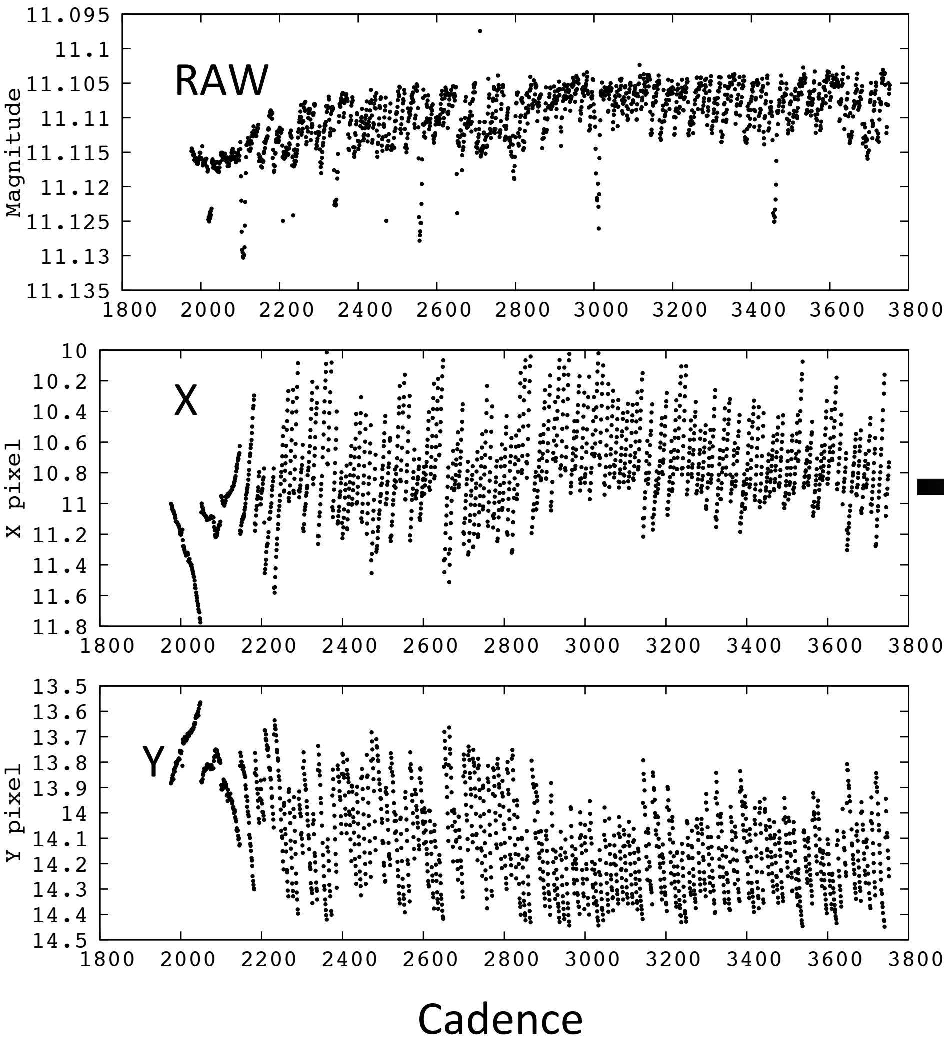
Huang et al 2015 (campaign 1)

Astrometry on K2 Campaign 1

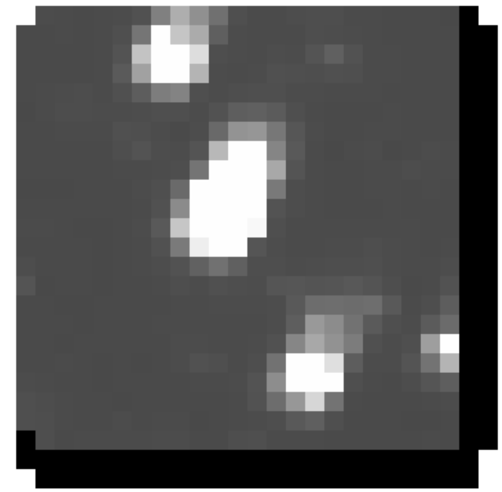


Huang et al 2015

Two reaction wheel era Kepler suffers from severe pointing drifts



Stacked K2 frames within 1 day



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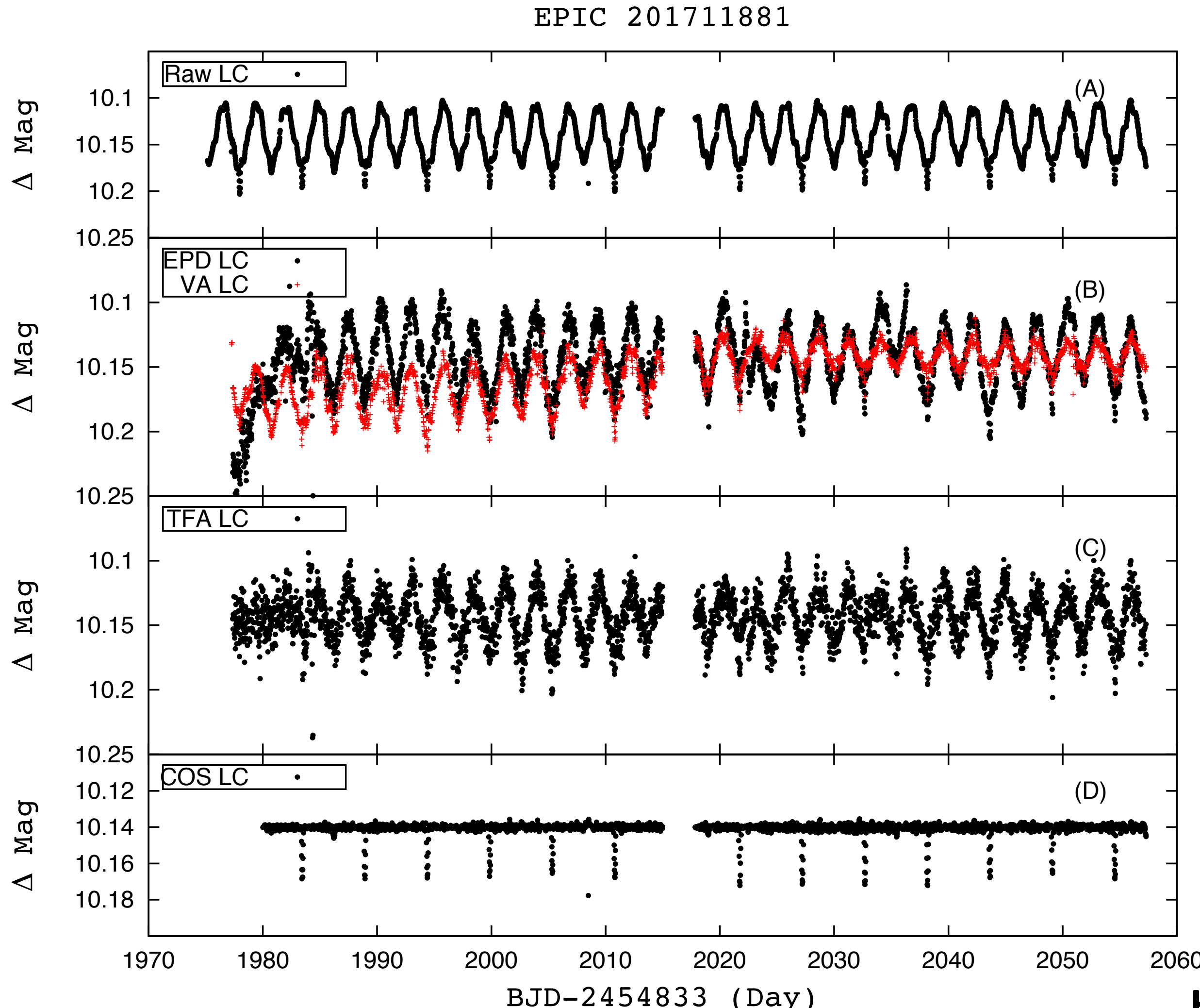
- Use the refined drifts to correct the photometry.

Our method keep the amplitude of variable stars



Huang et al 2015