Exoplanet Transits from Solar System Spacecraft & EPOCh Transit results

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Exoplanet Science Measurements from Solar System Probes

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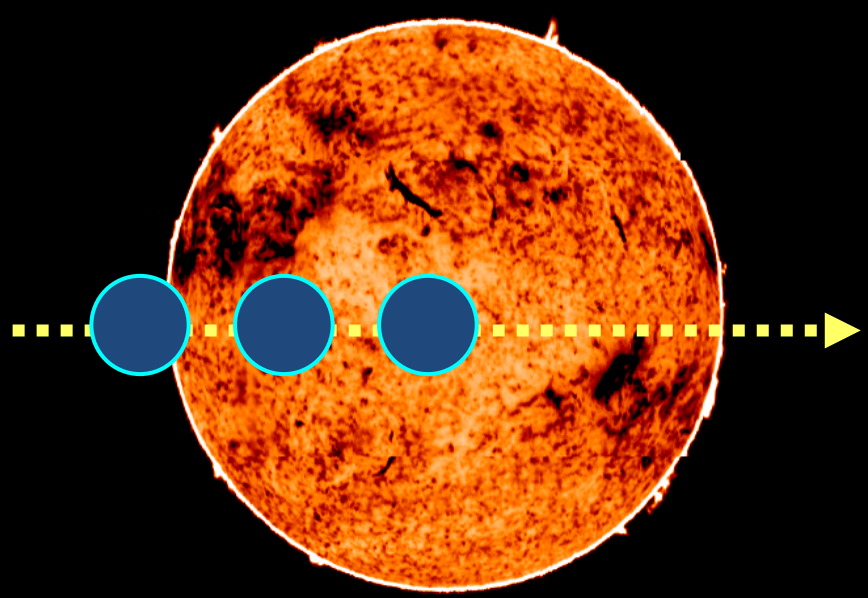
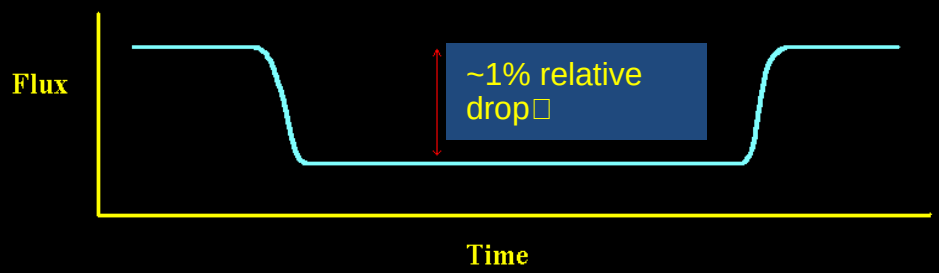
Transiting Planets





Bulk properties
- radius
- density

Atmospheric properties
- transmission
- emission

Informative but elusive…
- high precision
- high phase coverage
- high cadence

= space…!

Spacecraft Requirements*

TRANSIT DISCOVERY

- At least 1% photometric precision
- Stable over timescales of days/weeks
- Either wide field of view (> 1 degree square) to survey lots of stars (Kepler/CoRoT) or…
- Narrow field of view to target a specific set of stars (Mearth) although wide enough for nearby stars of comparable brightness
- Significant dedicated instrument time and…
- High data downlink capacity

TRANSIT CHARACTERIZATION

- ~0.1% photometric precision
- Stable over timescales of hours
- Multiple filters an advantage
- Narrow field of view sufficient, although wide enough for nearby stars of comparable brightness
- Less dedicated instrument time but…
- Strict time constraints

***Gas Giants**

The NASA *EPOXI* Mission



Michael A'Hearn - EPOXI PI, Tilak Hewagama, Jessica Sunshine, Dennis Wellnitz (U. Maryland)

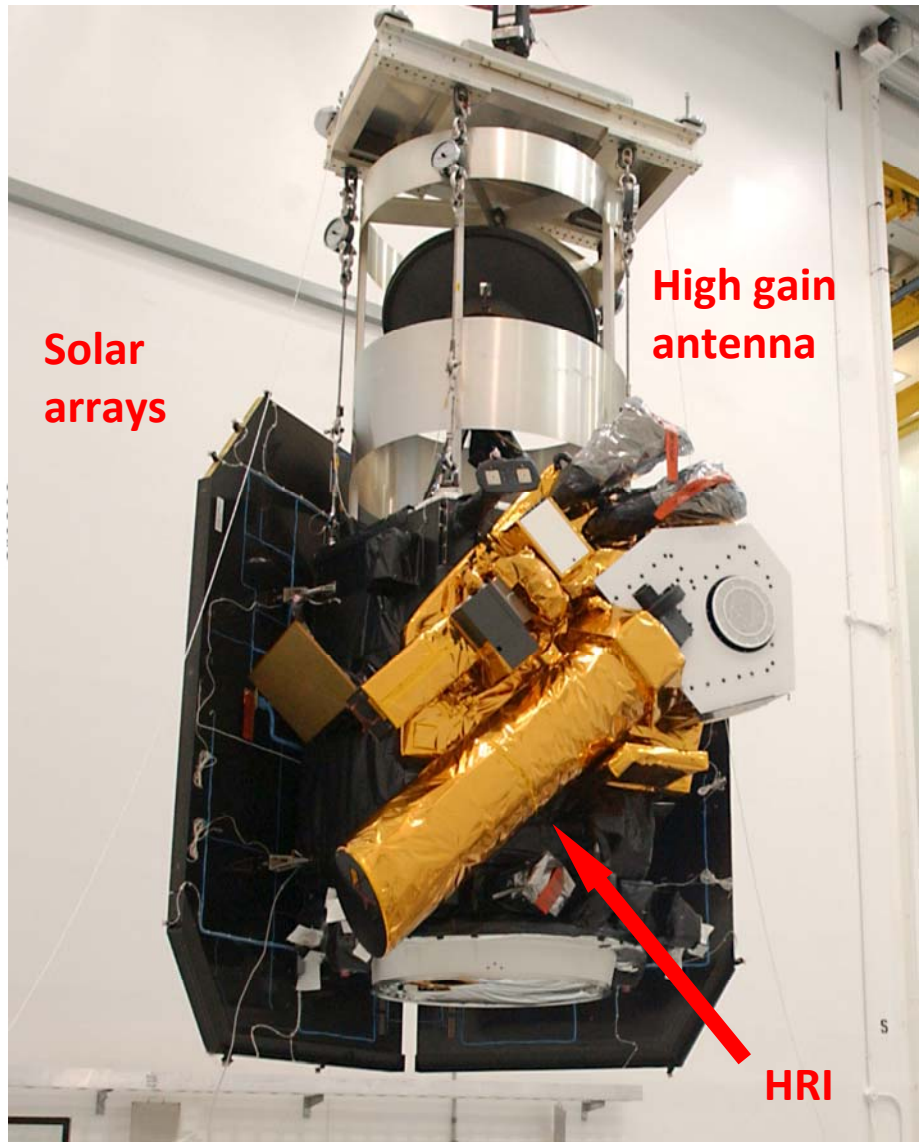
Drake Deming - EPOXI Deputy PI, Richard Barry, Marc Kuchner, Tim Livengood, Jeffrey Pedelty, Al Schultz (GSFC)

David Charbonneau, Matt Holman, Jessie Christiansen, David Weldrake, Sarah Ballard (CfA)

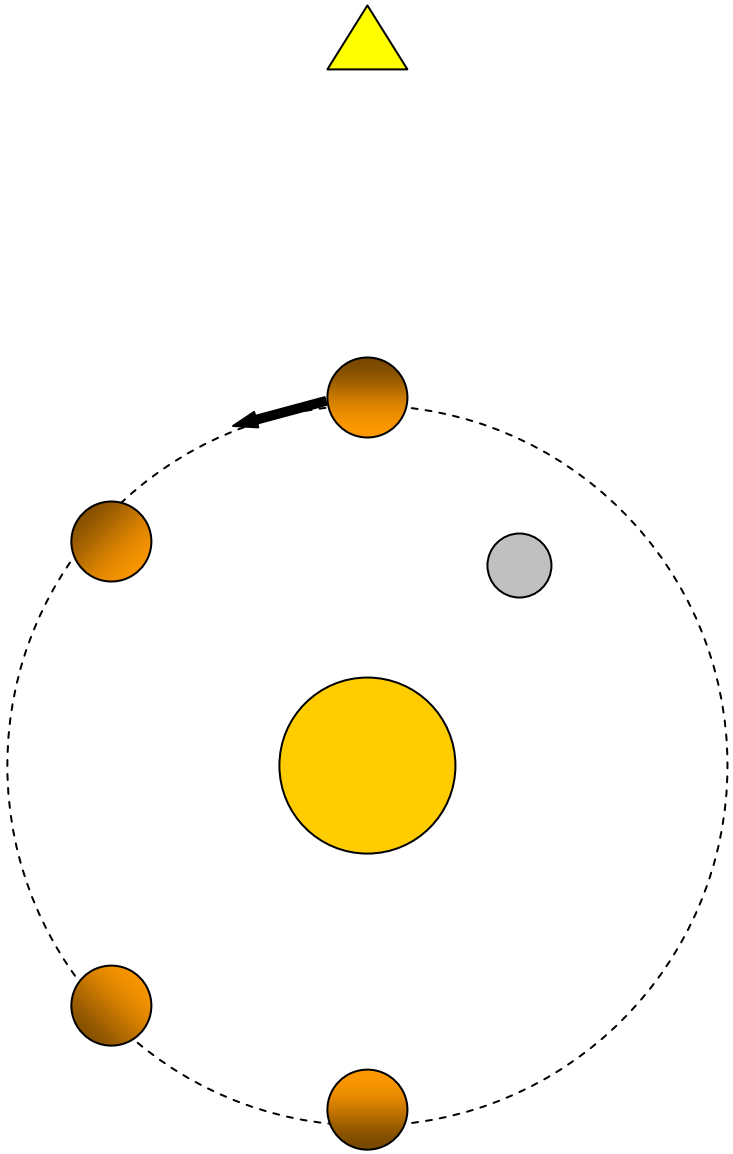
Don Hampton (U. Alaska), Carey Lisse (JHU), Sara Seager (MIT), Joseph Veverka (Cornell)

High-res vis instrument

- 30-cm aperture, clear filter (350-950nm)
- 1k x 1k CCD, 0.4”/pixel, FOV 51” in 128x128 sub-array
- 230MB of onboard memory ~ 7000 images
- Defocus (FWHM~10 pixels) an advantage for high precision photometry!

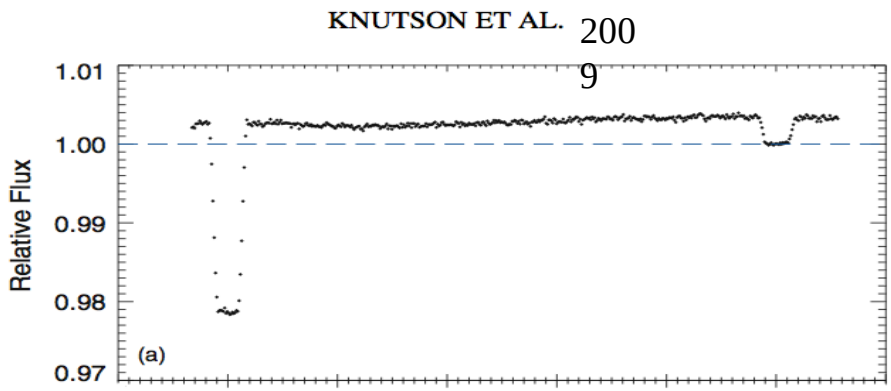


EPOCh Science goals



Obtaining ultraprecise, high phase coverage time series photometry for characterization of a small set of known transiting planets

- Additional transiting planets
- Transit timing variations
- Reflected light at secondary eclipse

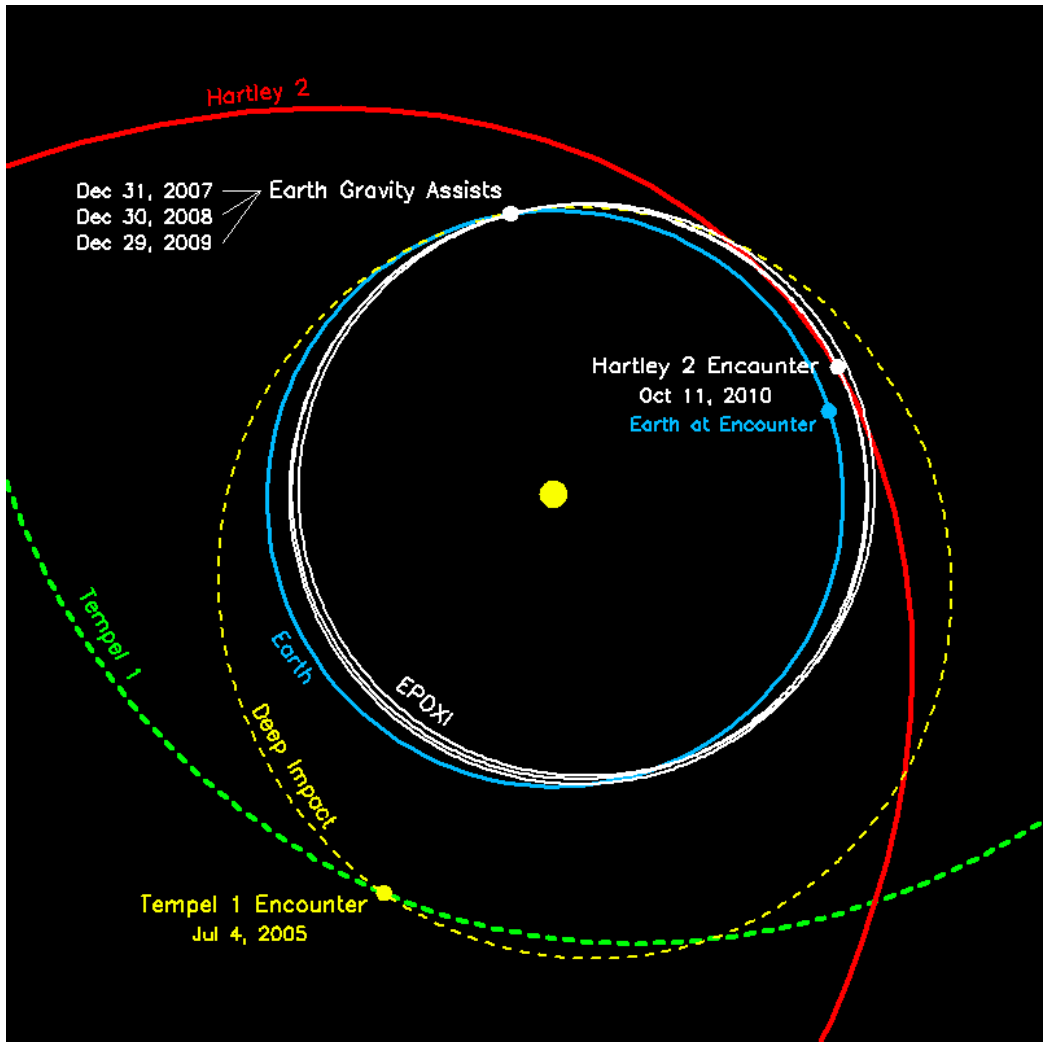


Mission overview

Jul 2005: Deep Impact Comet Tempel I encounter

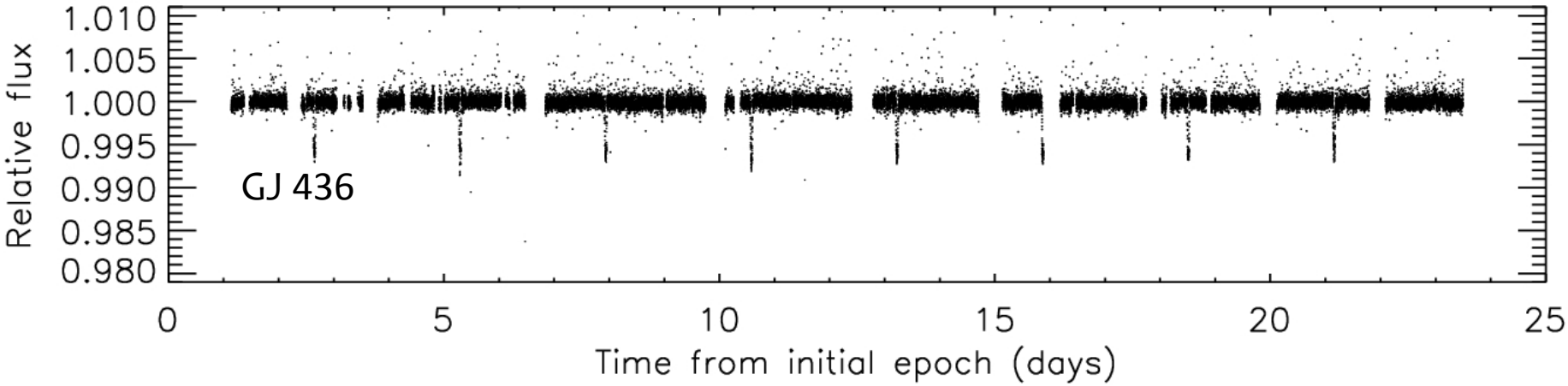
Jan - Aug 2008: EPOCh observations

Dec 2010: DIXI Comet Hartley 2 encounter



(stable heliocentric orbit)

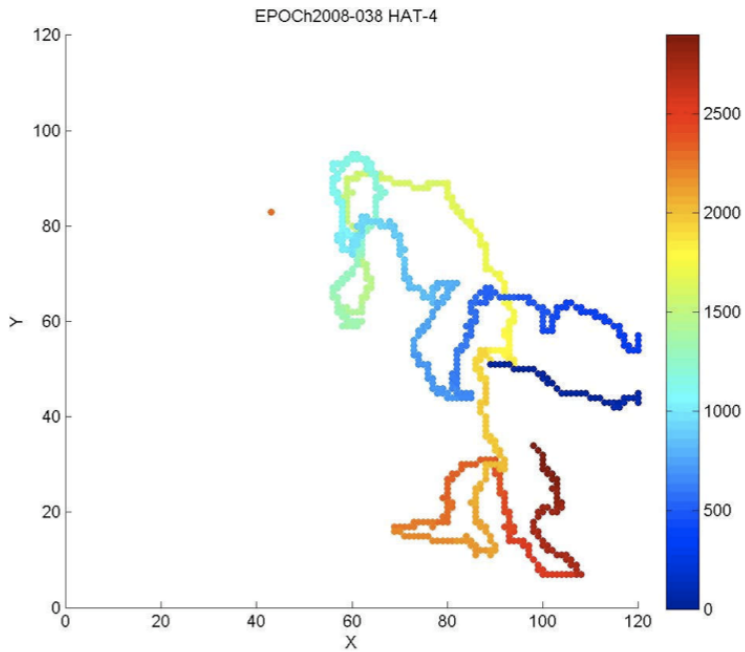
Photometry



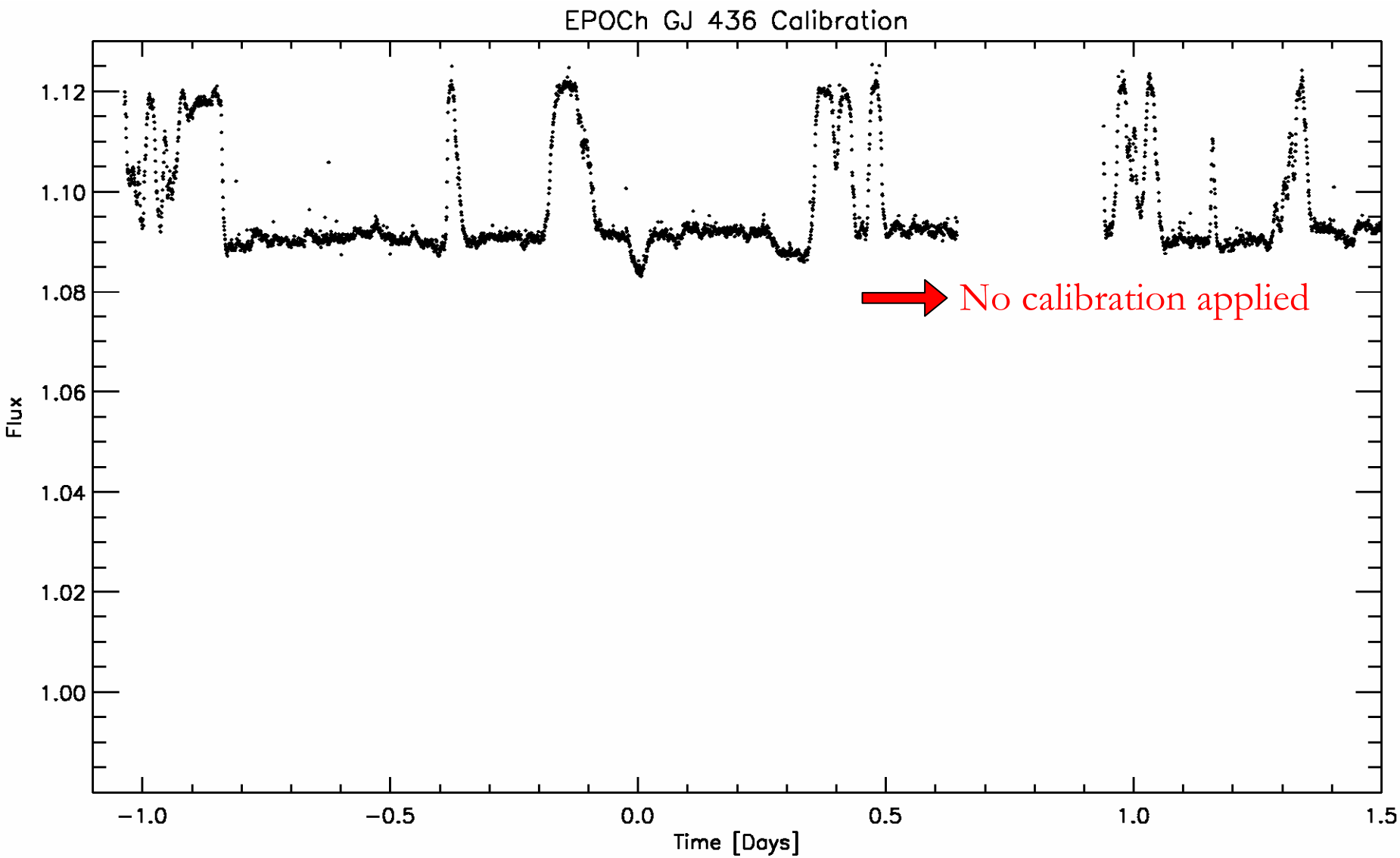
- Calibrated images via Cornell/UMD

- Major systematic: pointing jitter!

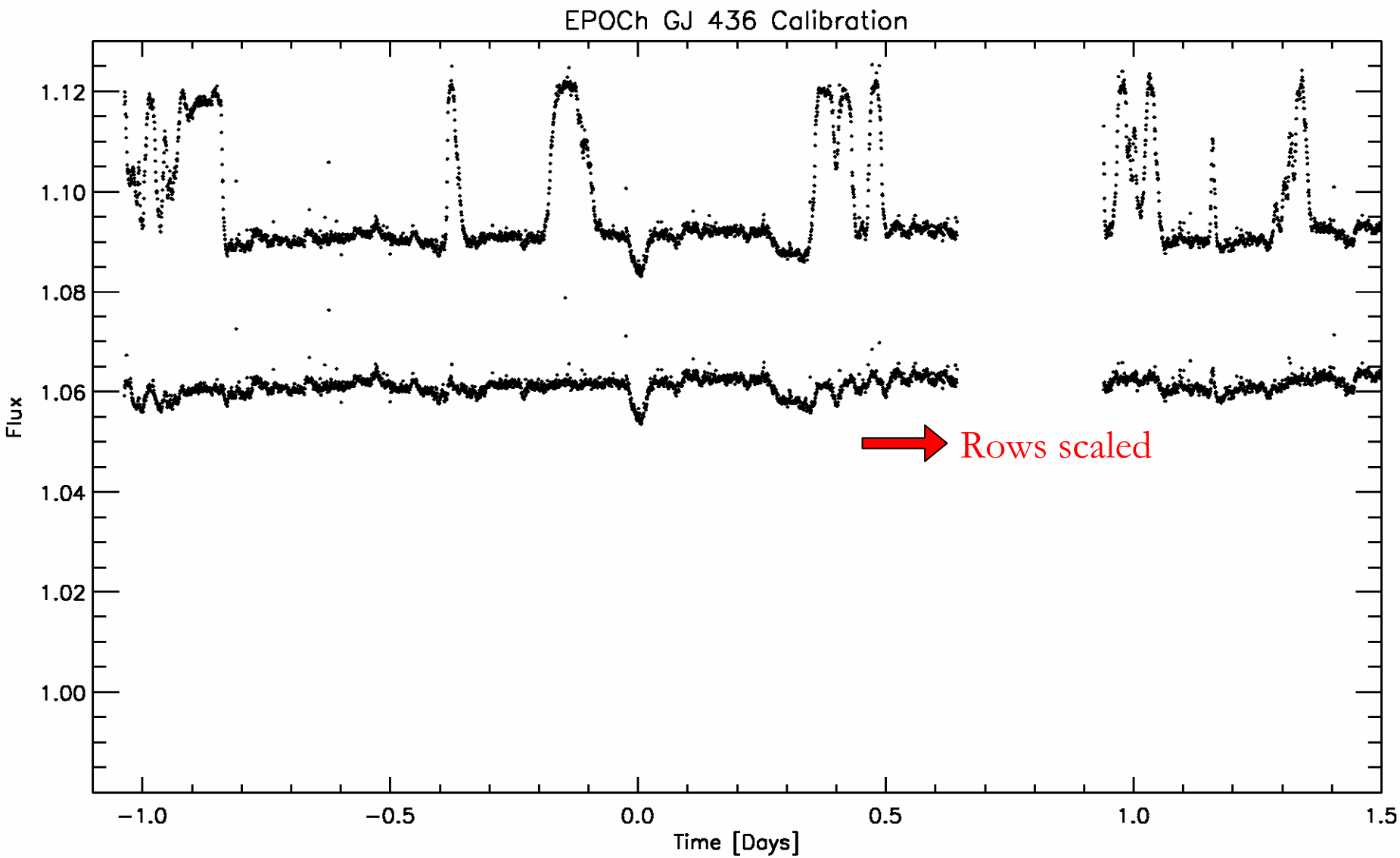
- Current photometric noise in 50-s integration
  = 1.5-1.9 times the Poisson noise limit



EPOCh Calibration



EPOCh Calibration



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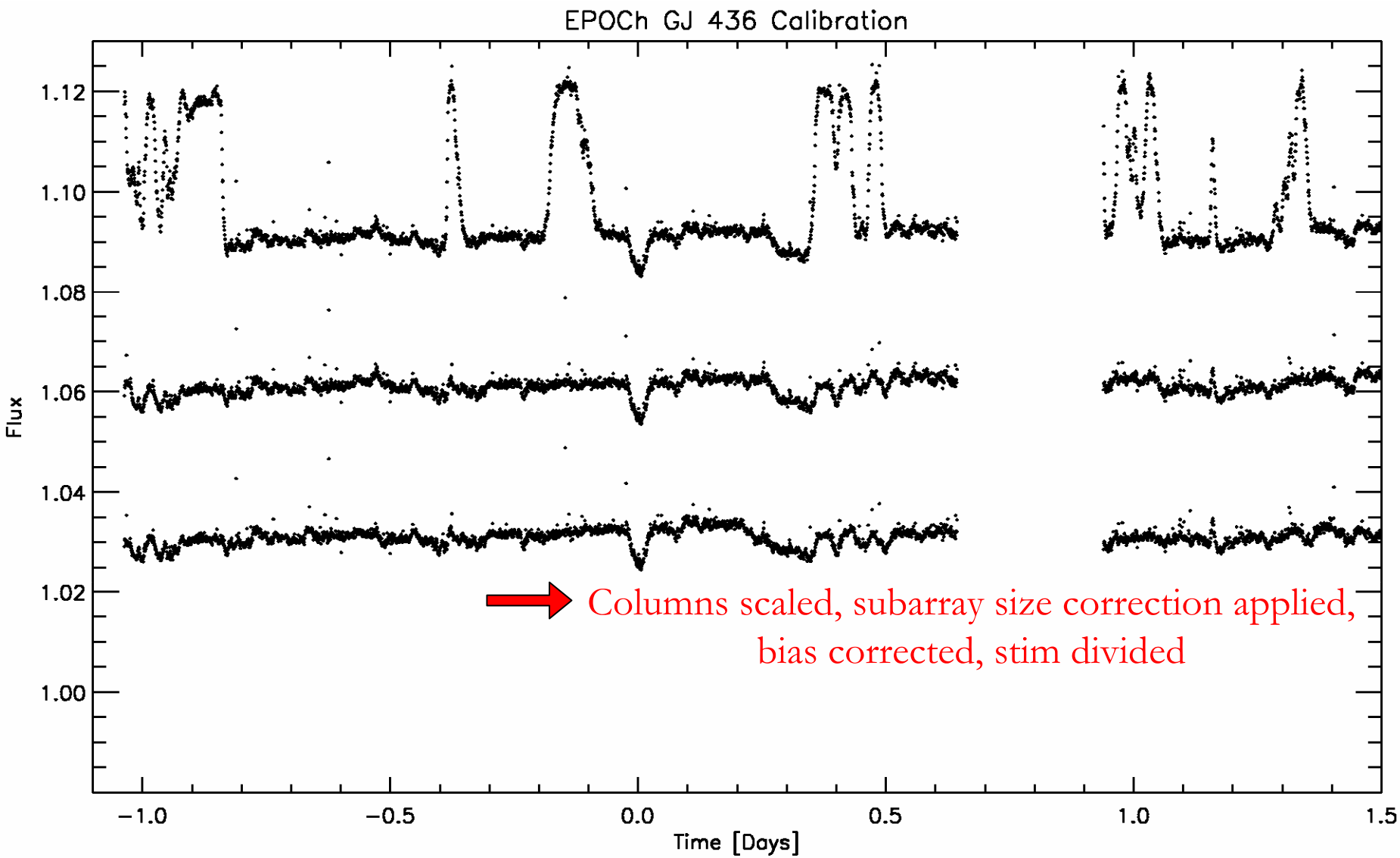

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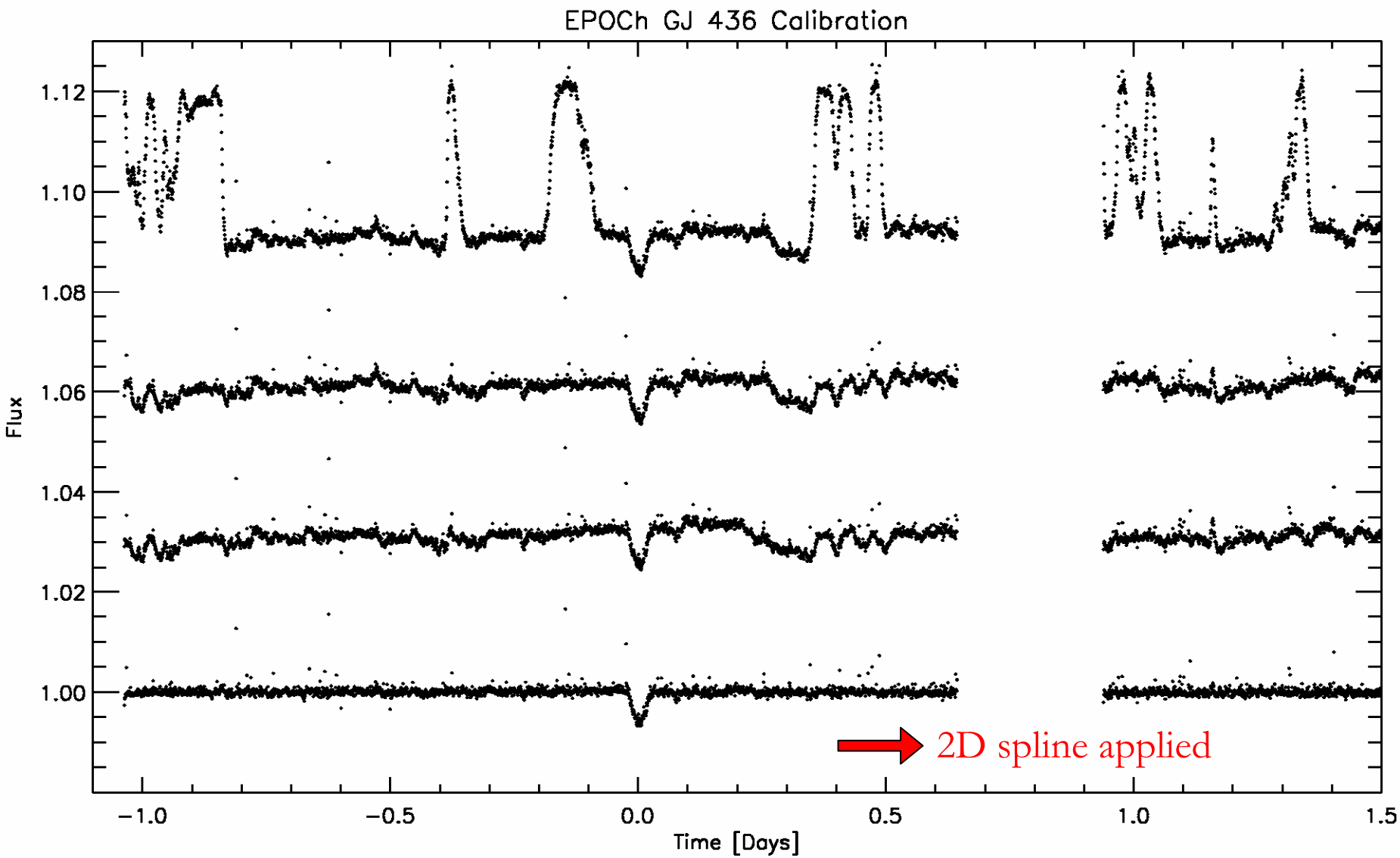
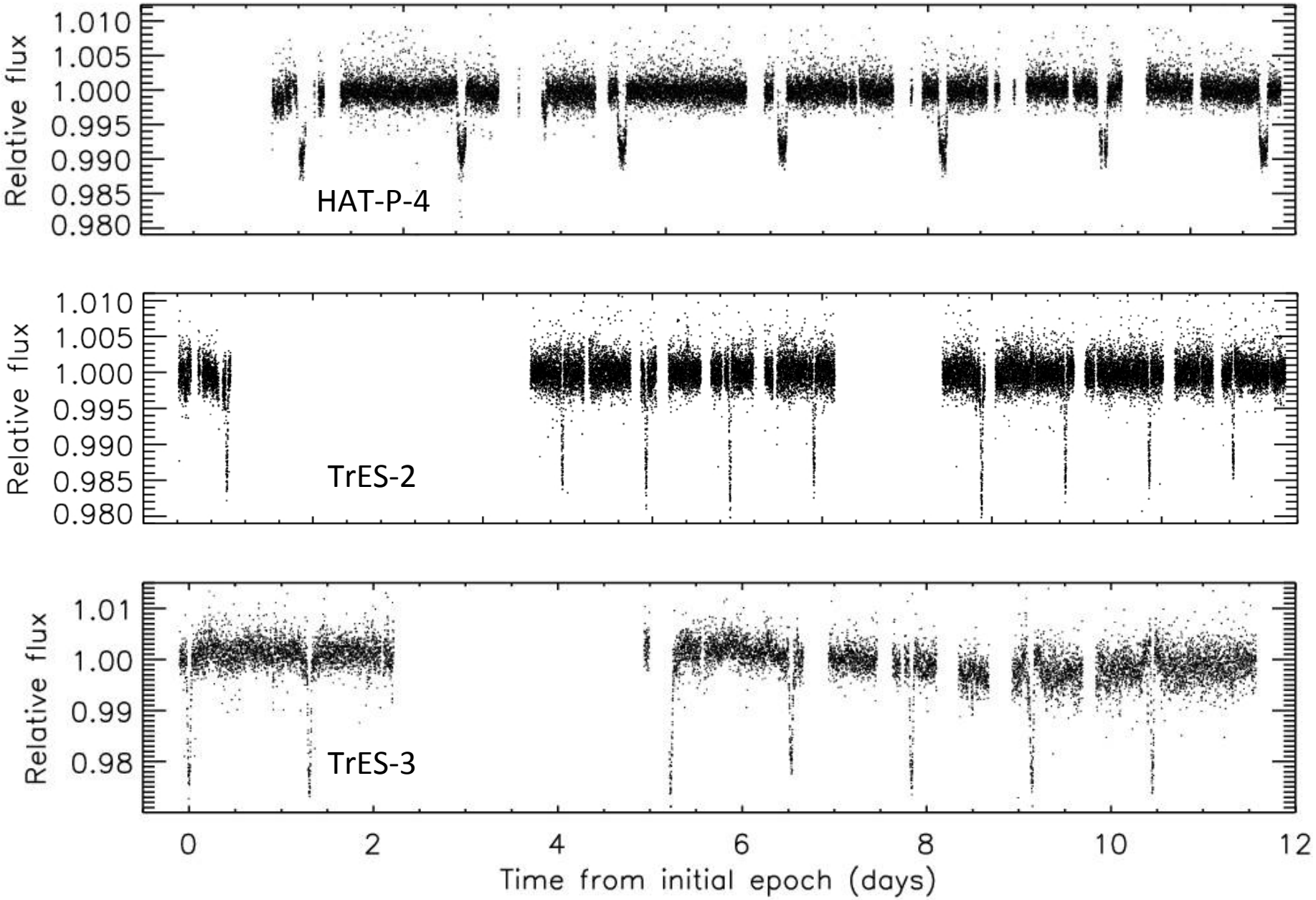


Photometry


Relative flux
1.010
1.005
1.000
0.995
0.990
0.985
0.980
HAT-P-4
Relative flux
1.010
1.005
1.000
0.995
0.990
0.985
0.980
TrES-2
Relative flux
1.01
1.00
0.99
0.98
TrES-3
0
2
4
6
8
10
12
Time from initial epoch (days)

EPOXI Family Portrait

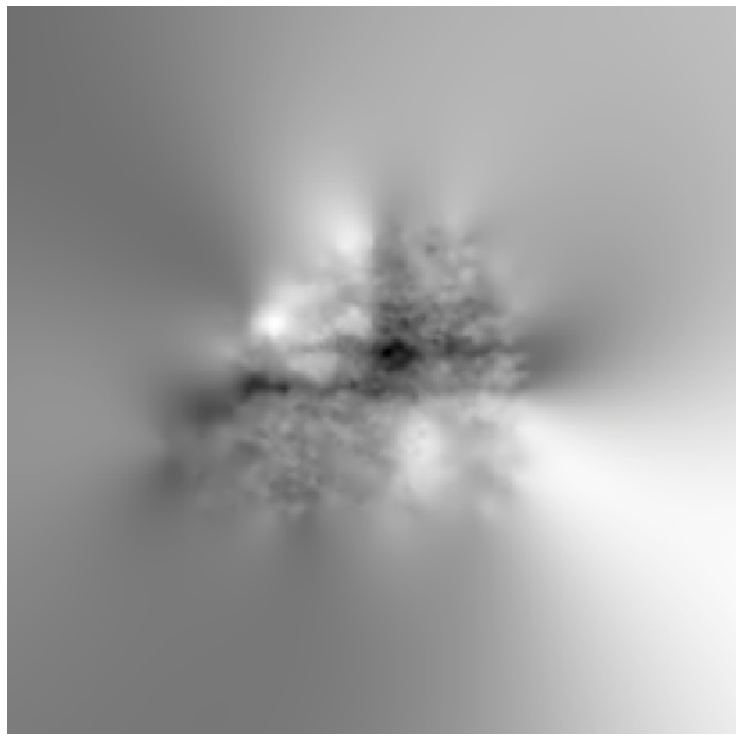
Plots withheld pending publication.

EPOXI Major Results

- GJ 436 (Ballard et al, in press)
  - Refined system parameters
  - New set of transit times
  - Ruled out additional transiting planets with 95% confidence interior to GJ 436b (>1.25Rearth) and to periods up to 8.5 days (>2.0Rearth)
- HAT-P-7 (Christiansen et al, 2010)
  - Refined system parameters
  - New set of transit times
  - 'Confirmed' the Kepler secondary eclipse depth measurement in the optical
- HAT-P-4, TrES-3, TrES-2, WASP-3 (Christiansen et al, submitted)
  - Refined system parameters, new sets of transit times

Lessons Learned…

- Stability, stability, stability
  - Repeatability
  - ‘World’s most expensive thermometer’
  - Prefer the star to stay in the field of view
- Calibration!
  - Pre-launch can be insufficient
- Photons, photons, photons
  - Obvious but critical when shoe-horning instruments/projects into transit work
- Fast response required
  - Time is (lots of) money



Conclusions

- It is possible to re-purpose a solar system probe to measure transits of extrasolar planets
- It may however require considerable finessing of the system and data analysis
- With time and effort you can access a parameter space that is unavailable from the ground