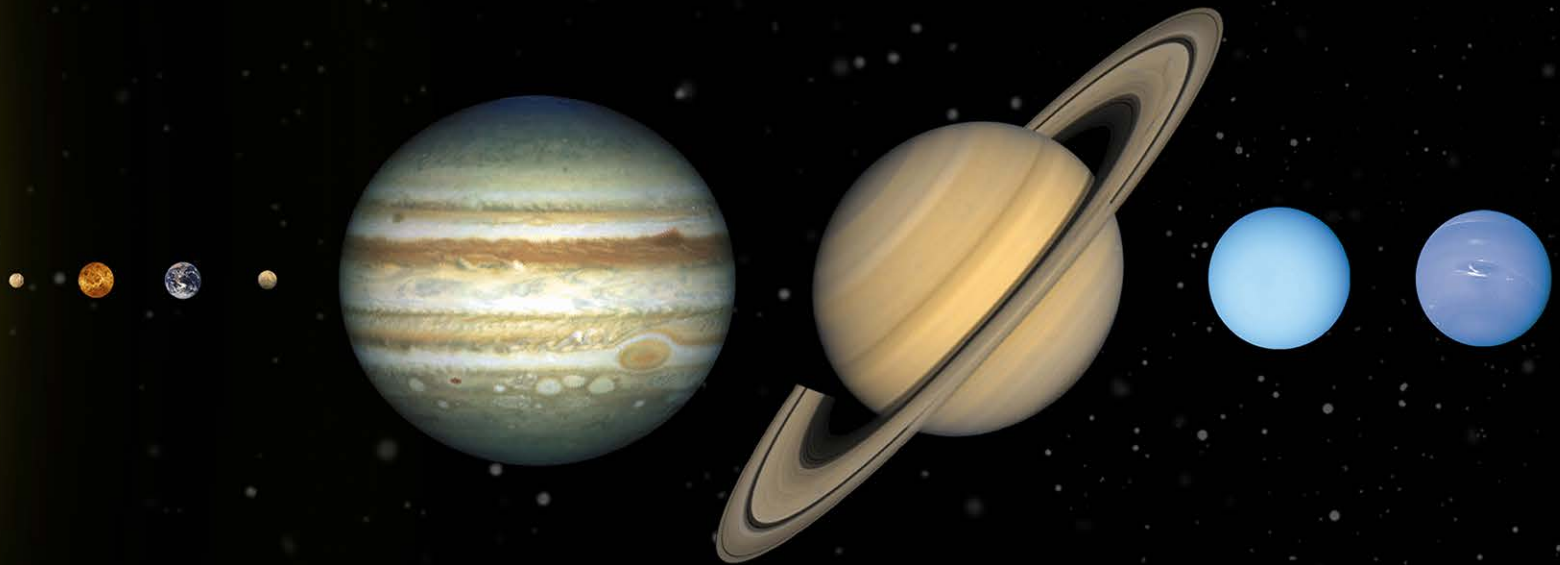


From Pixels to Planets

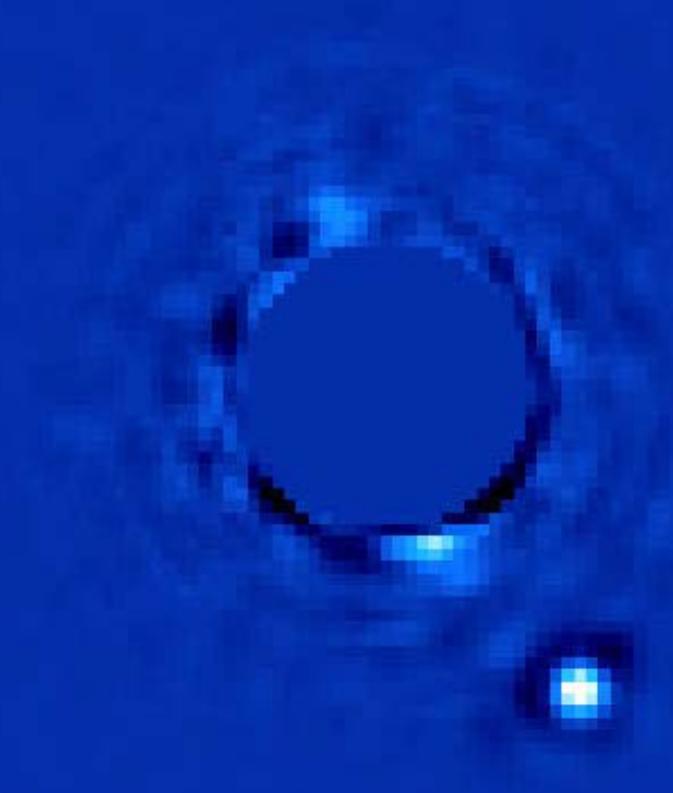
Lee Brownston, SGT, Inc.

Jon M. Jenkins, NASA

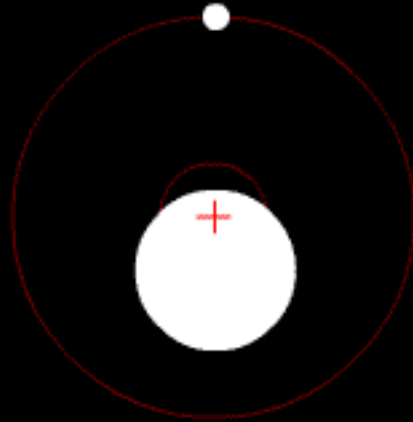
The Known Planets in 1994



Direct Imaging: Beta Pictoris b

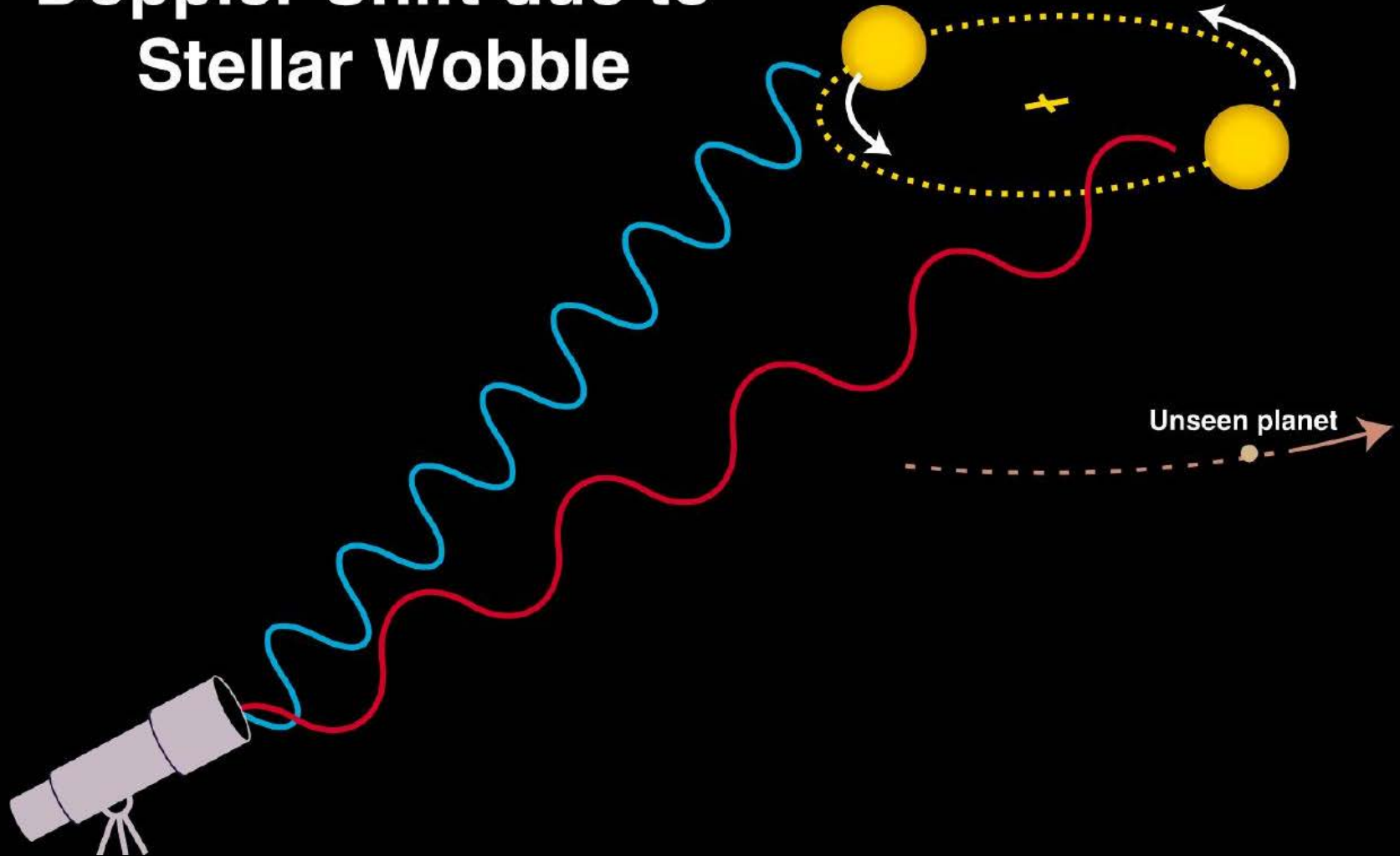


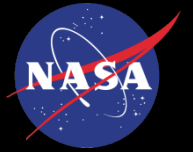
Planetary System Center of Mass



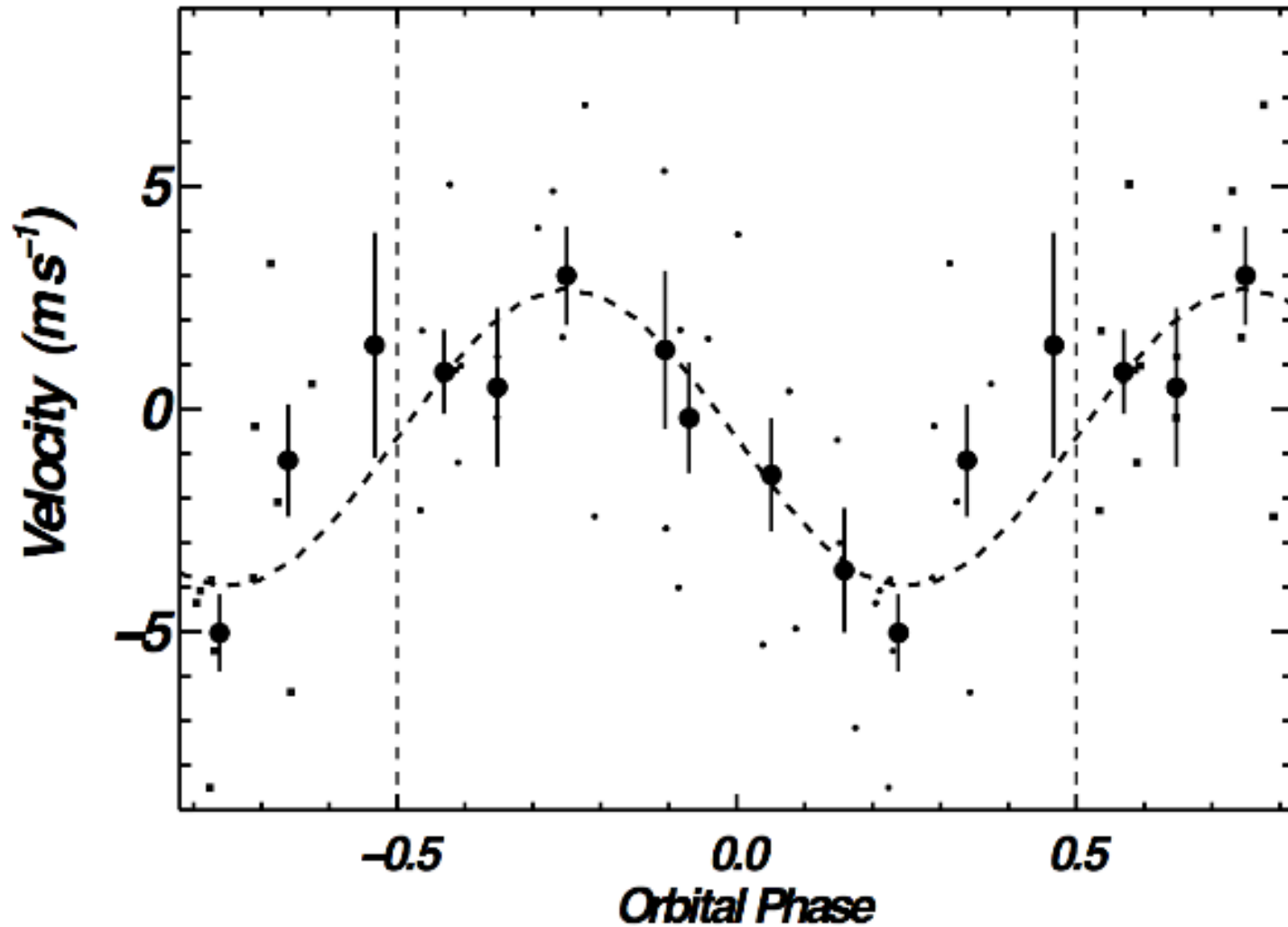
Radial Velocity

**Doppler Shift due to
Stellar Wobble**



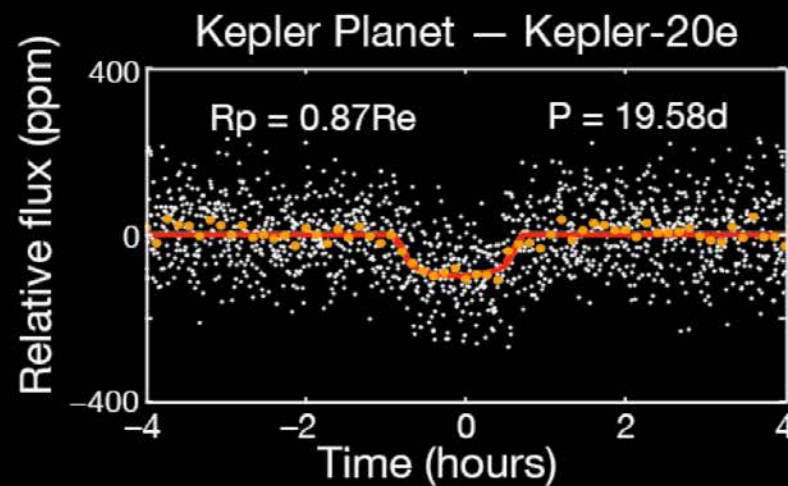
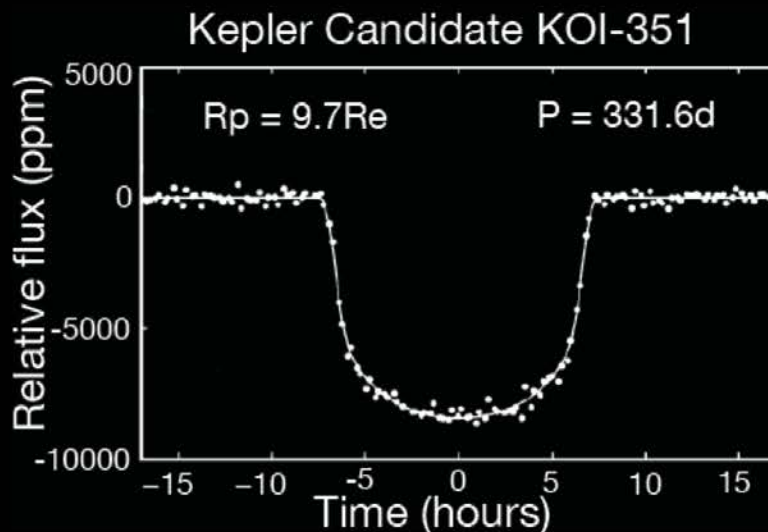
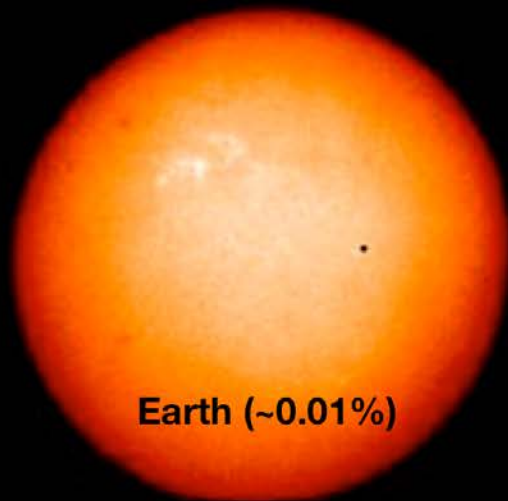
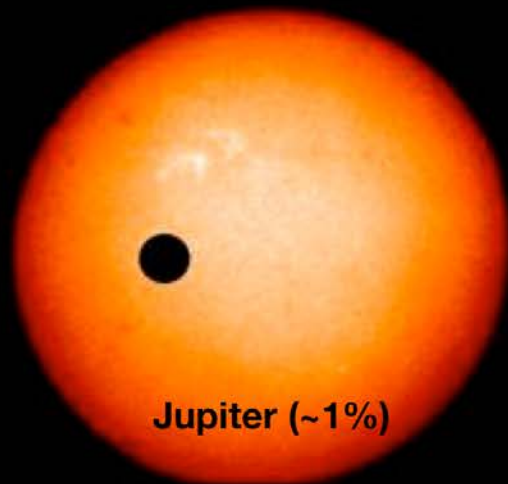


Doppler Measurements

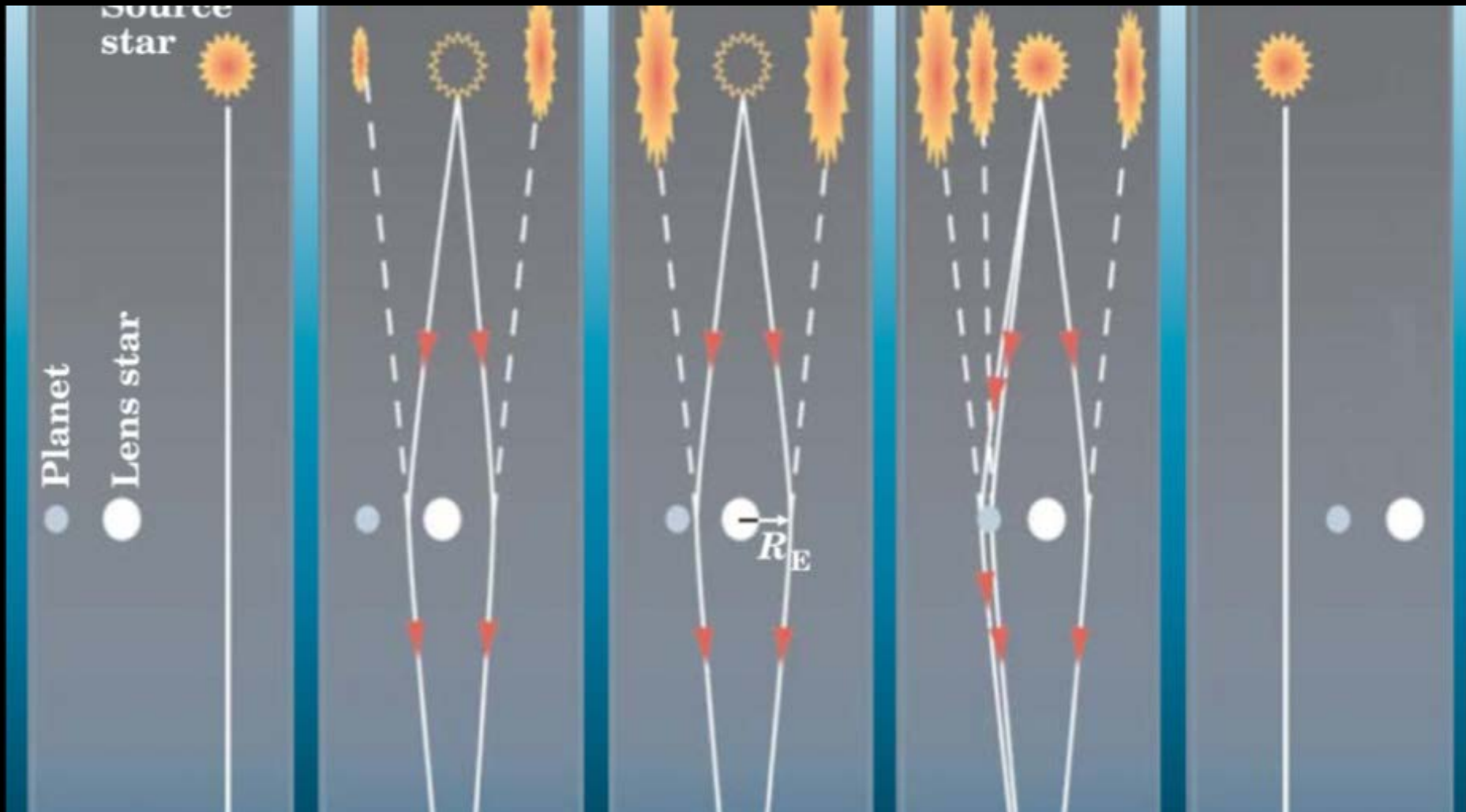




Earth-size Planets: Detection Method

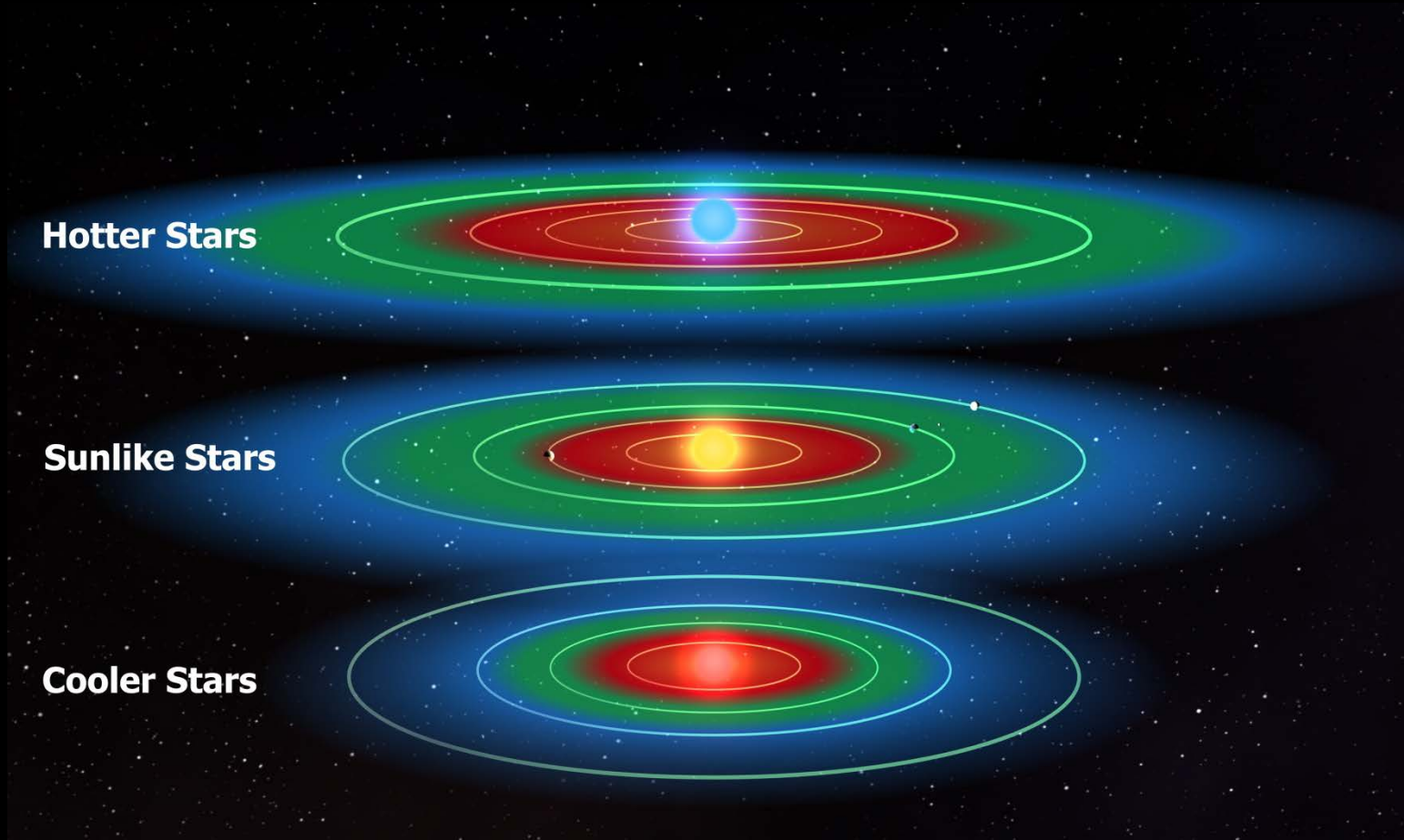


Gravitational Microlensing



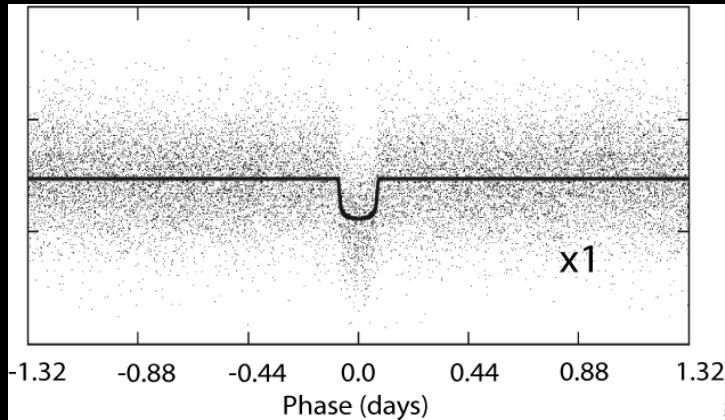


The Habitable Zone

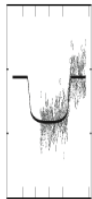




HAT-P-7b Ground vs. Space

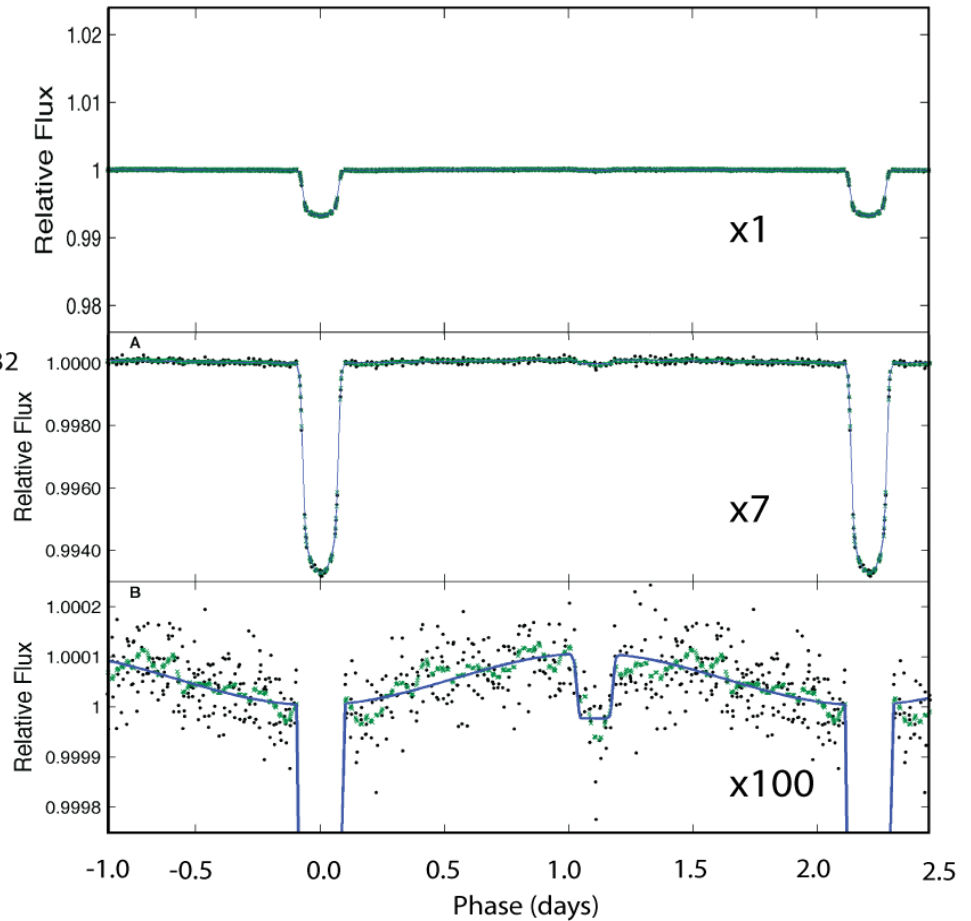


16,620 HATNet data points (57.7 days of data)



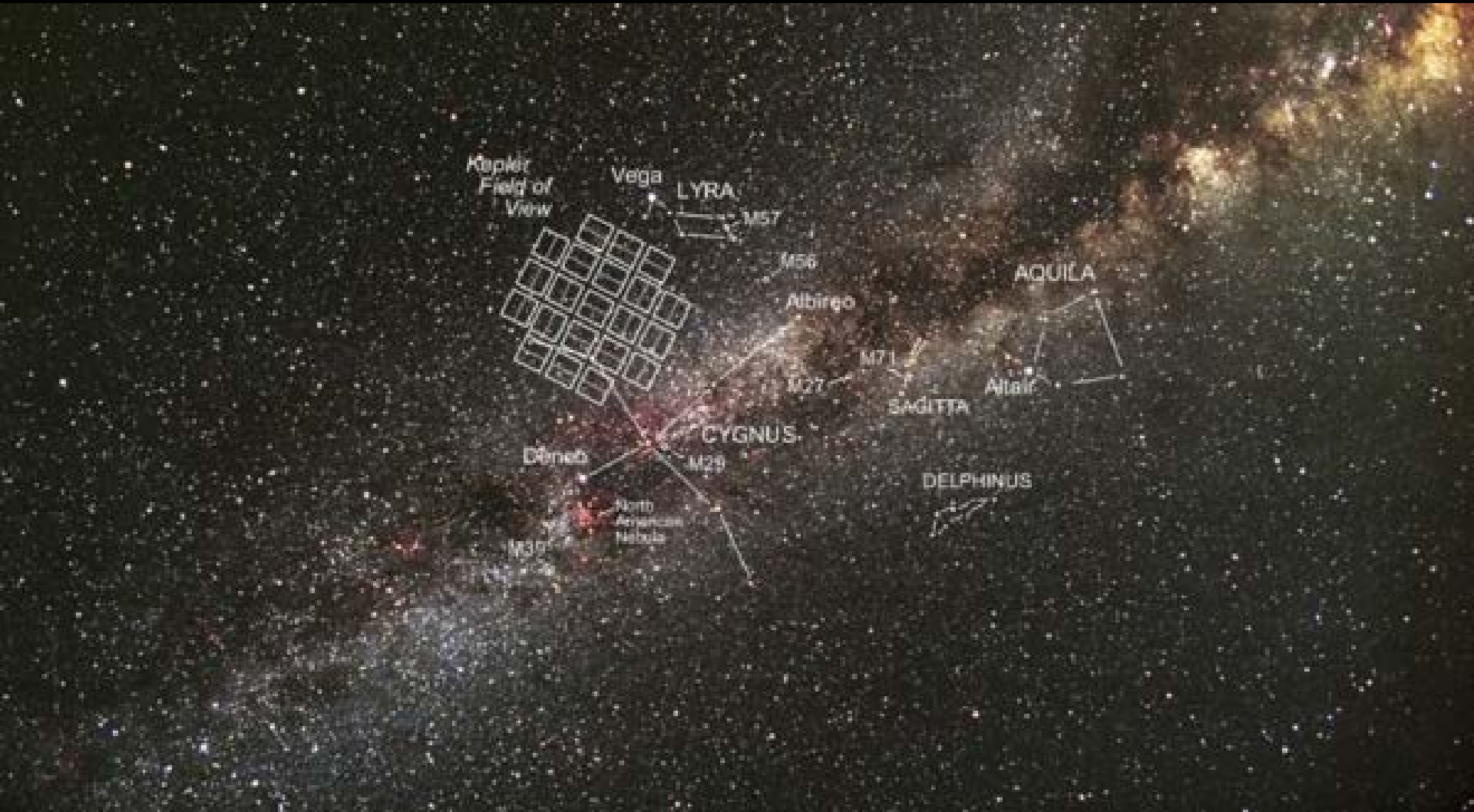
Single night at 1.2 m FLWO with Kepler Cam

HAT-P-7b data from the ground
A. Pal et al., 2008

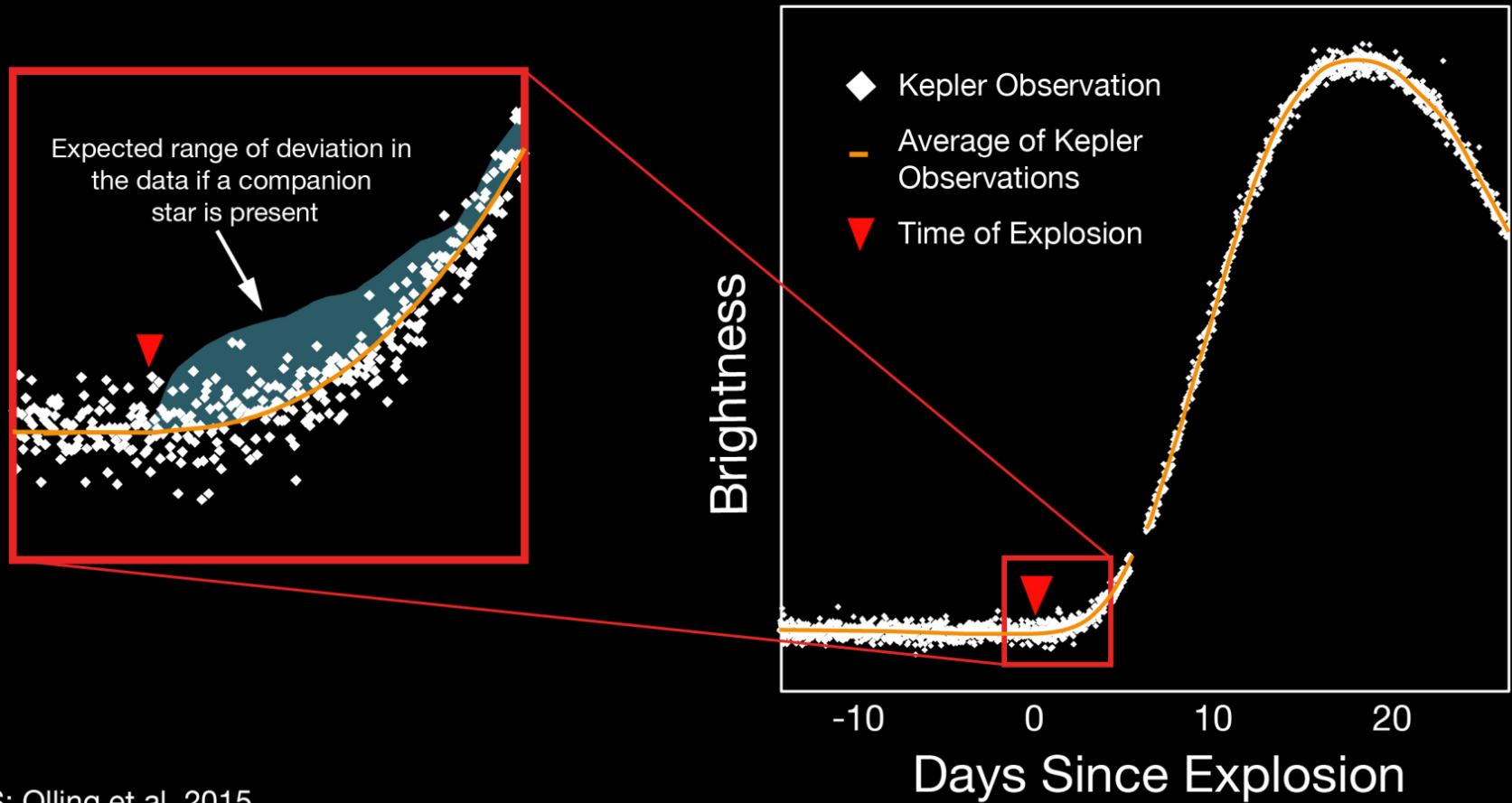


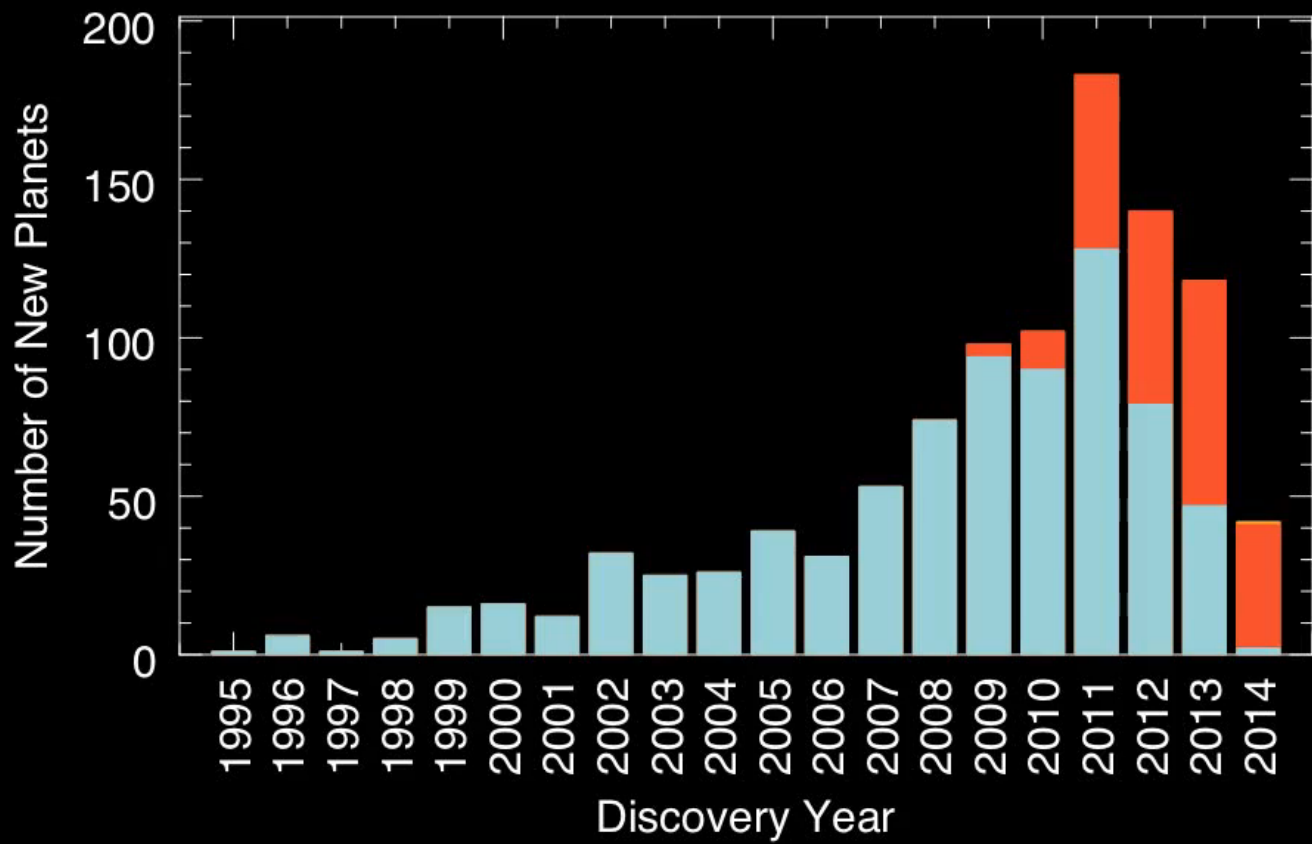
Kepler Commissioning data (10 days)
W. Borucki et al., 2009

Kepler's Field of View



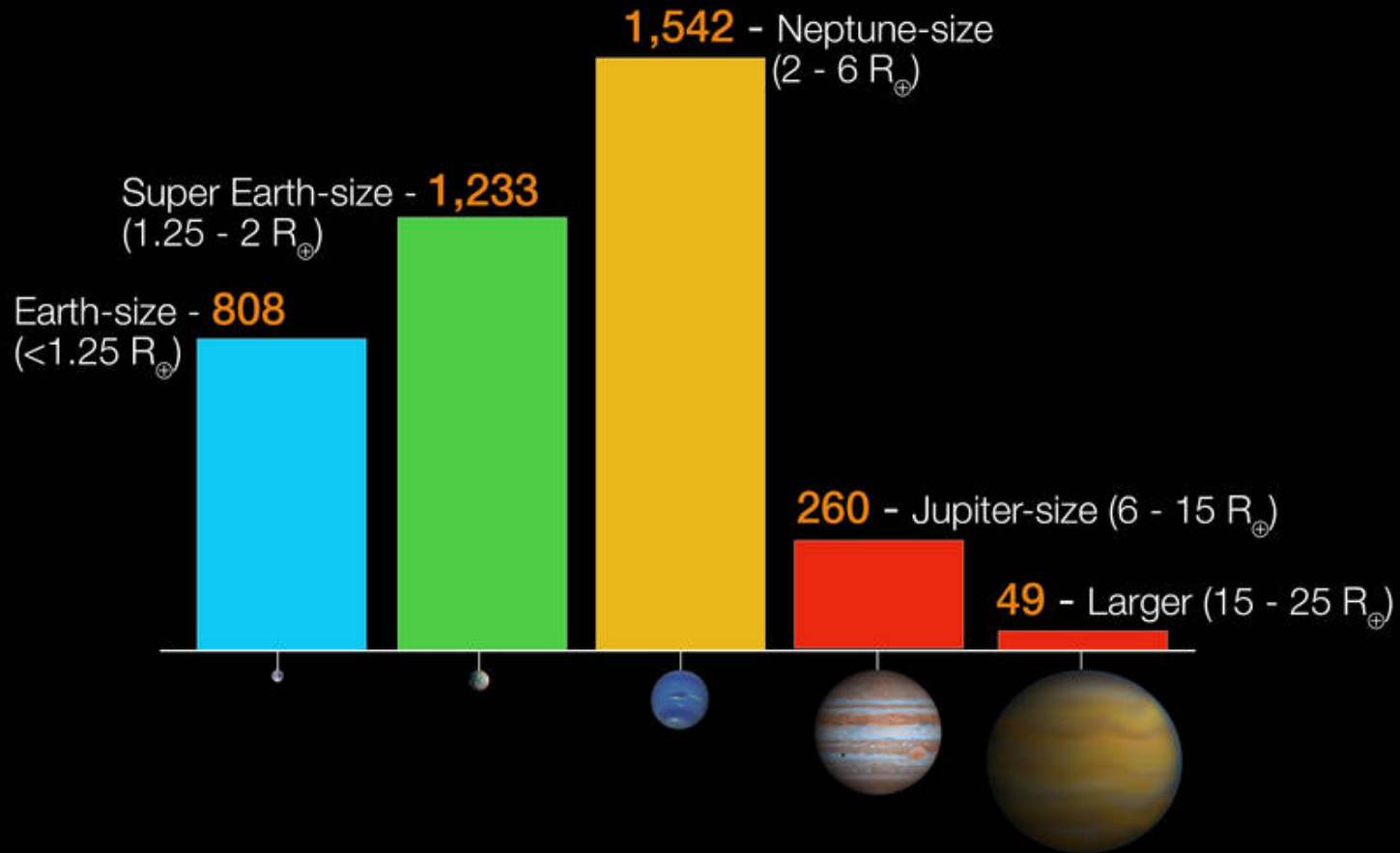
Kepler Observations of Supernova KSN 2011b





Sizes of Kepler Planet Candidates

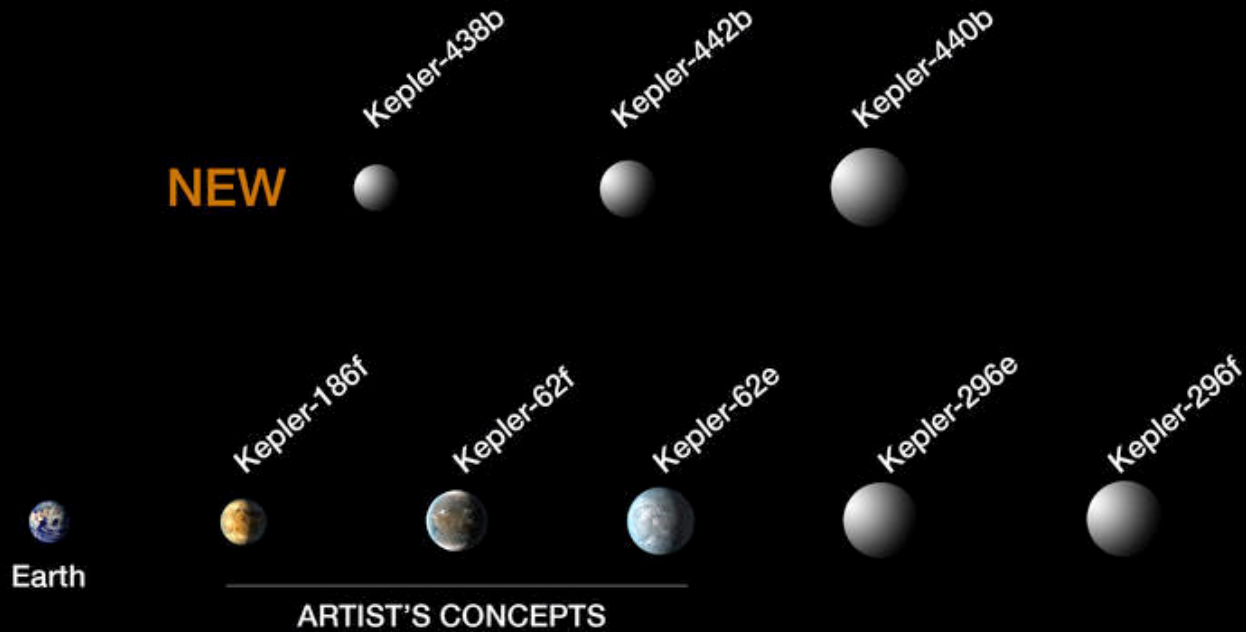
Totals as of January 6, 2015



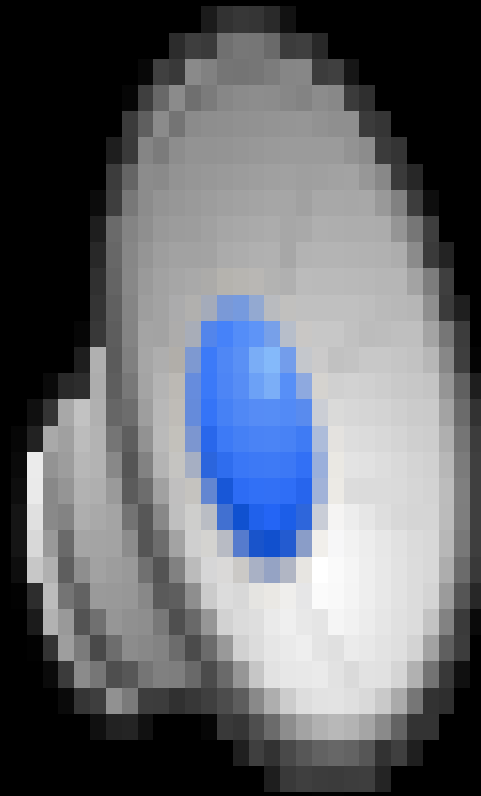
NASA Kepler's Hall of Fame:

Small Habitable Zone Planets

As of January 2015

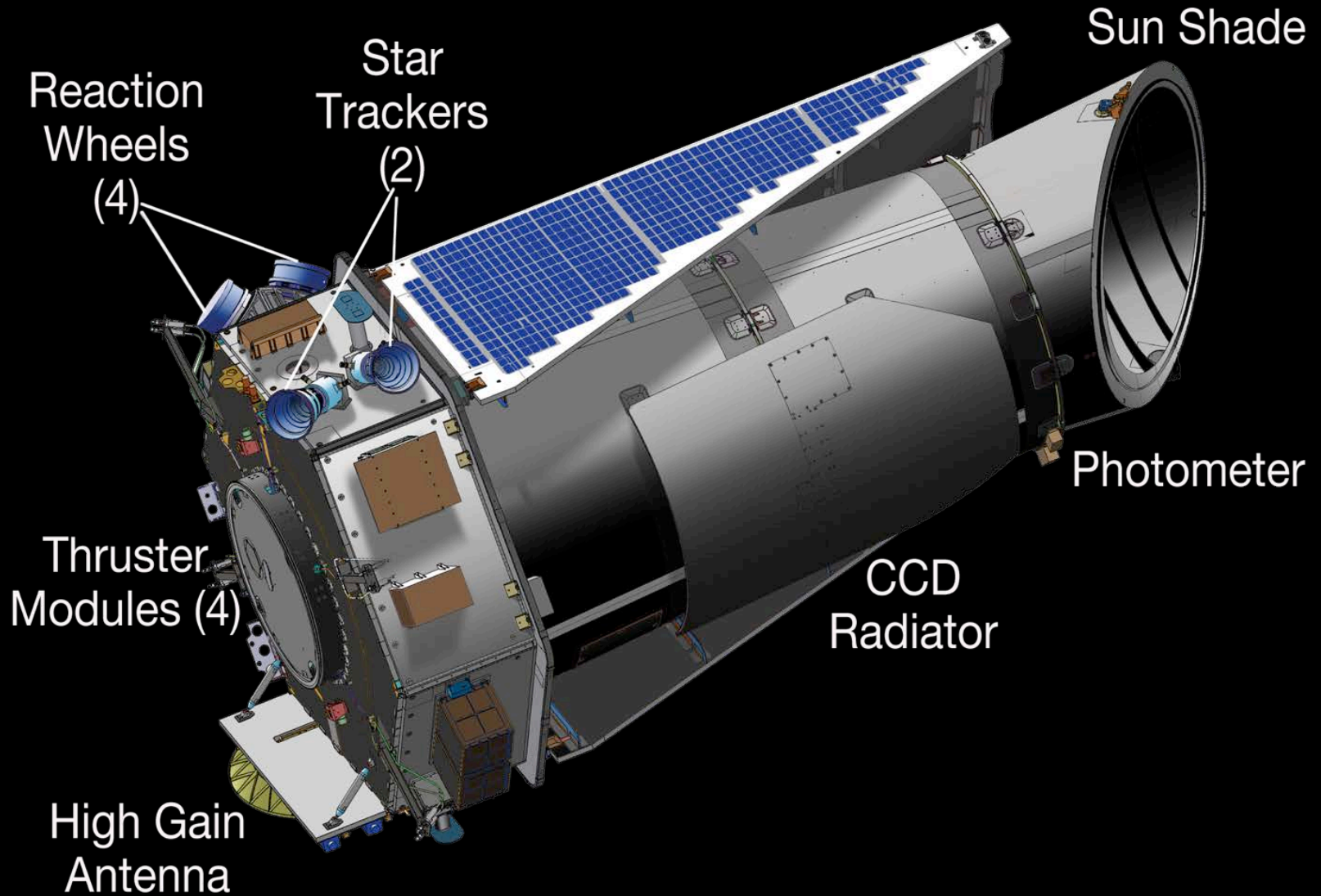


5253 Planet Transits in a Typical Week



- <http://i.imgur.com/28LQQo2.gifv>

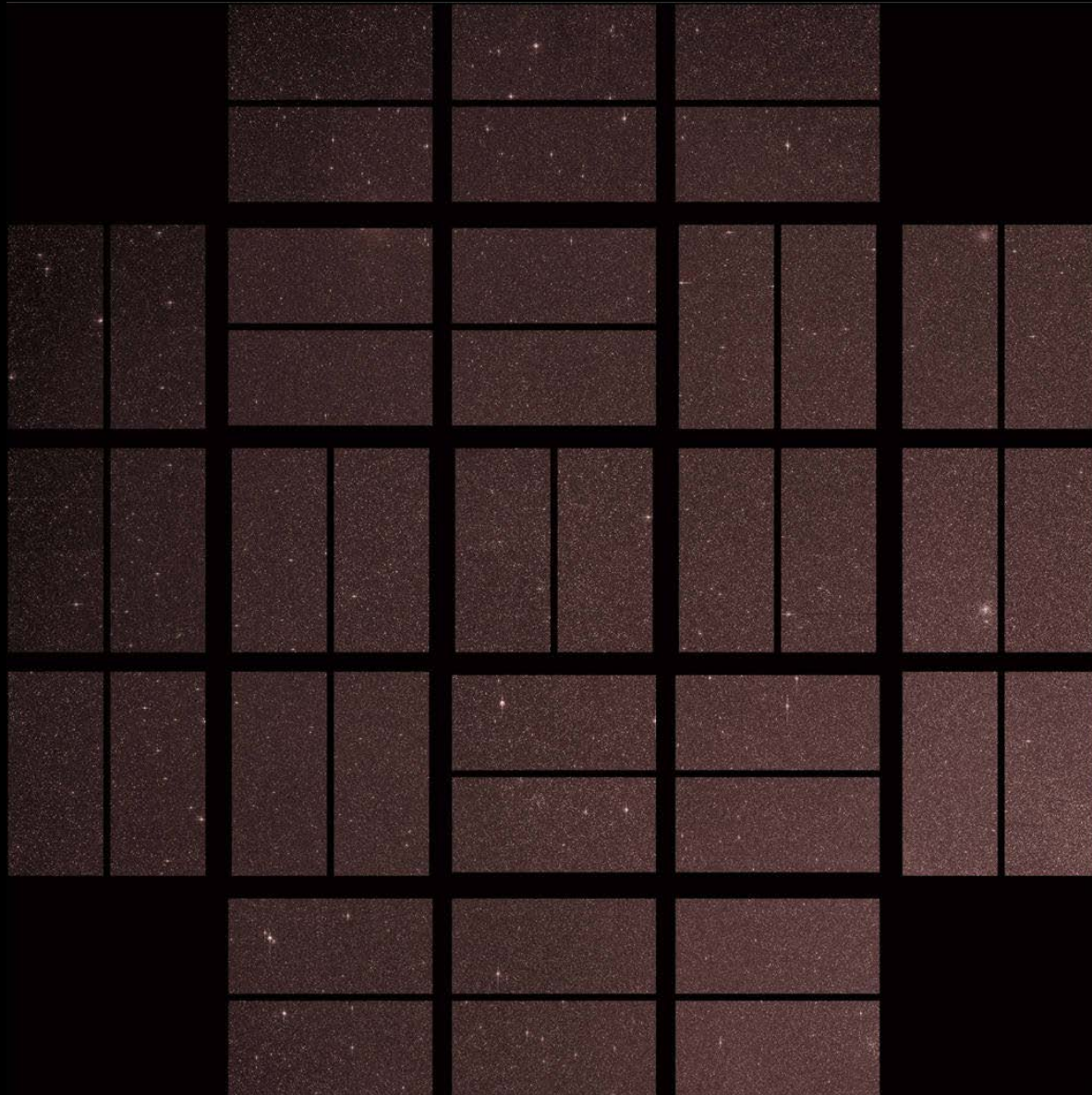
The Spacecraft



The Focal Plane

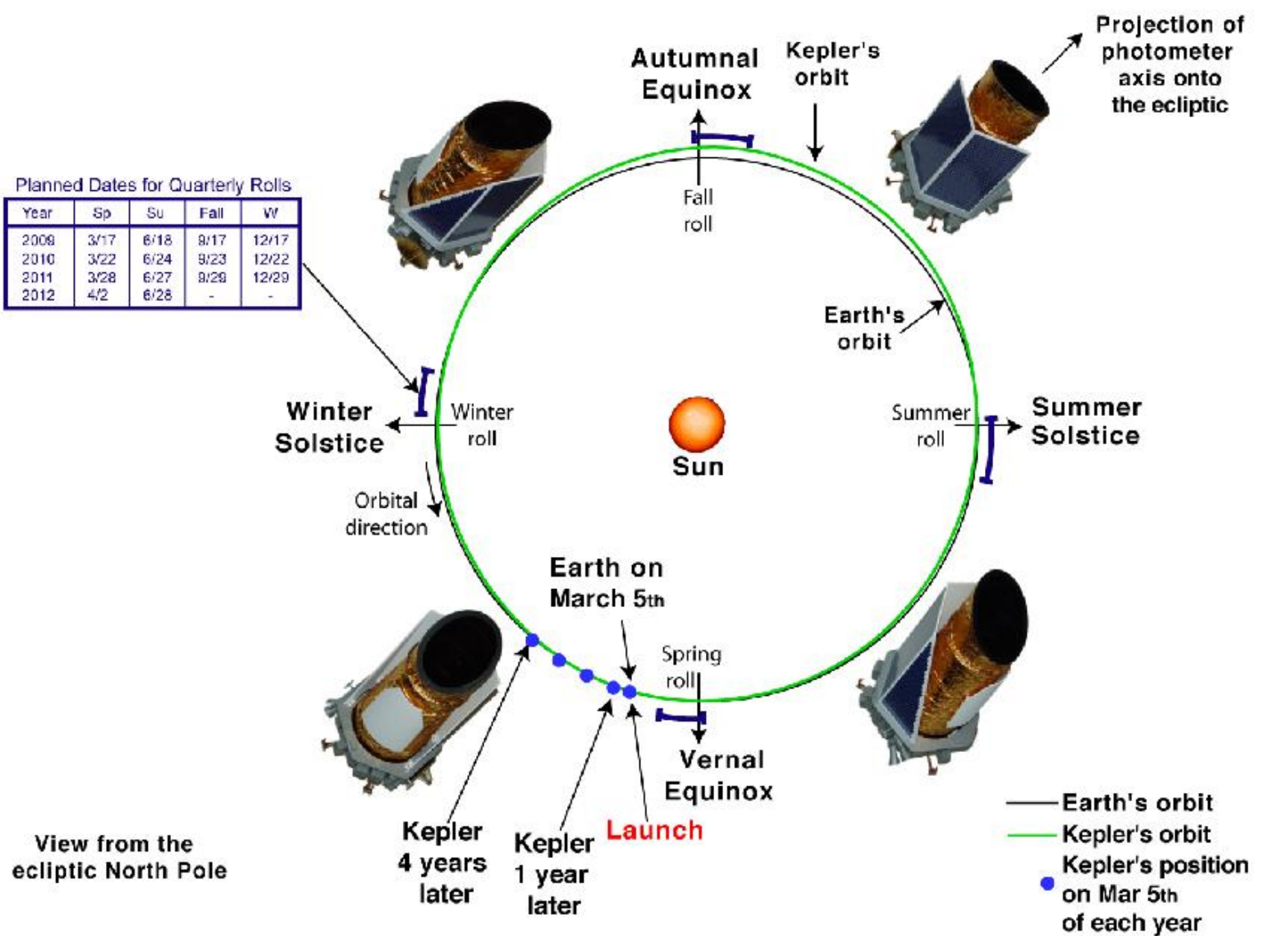


Full Frame Image



Planned Dates for Quarterly Rolls

Year	Sp	Su	Fall	W
2009	3/17	6/18	9/17	12/17
2010	3/22	6/24	9/23	12/22
2011	3/28	6/27	9/29	12/29
2012	4/2	6/28	-	-



View from the ecliptic North Pole

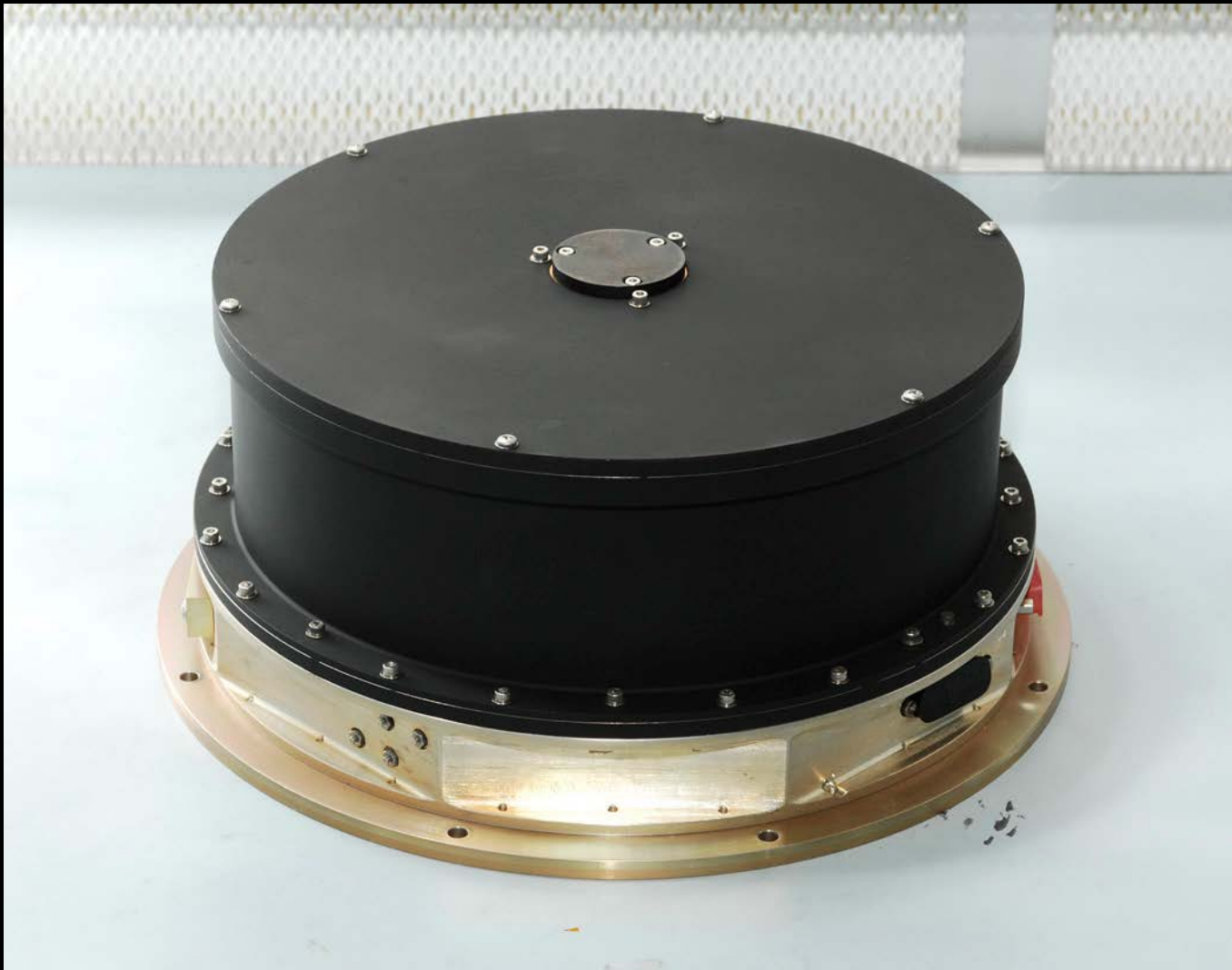
- Earth's orbit
- Kepler's orbit
- Kepler's position on Mar 5th of each year



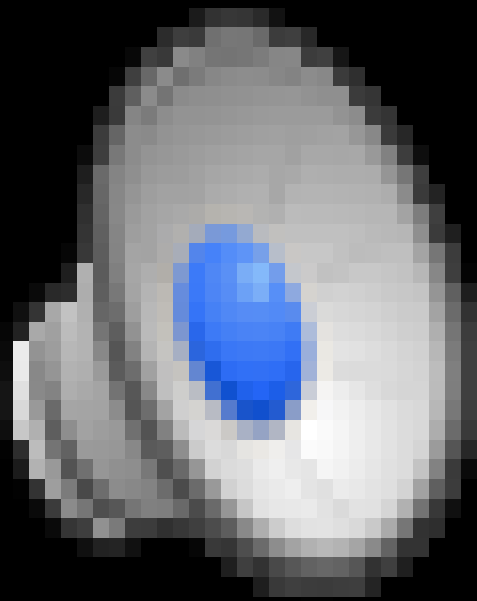
March 6, 2009



Reaction Wheel

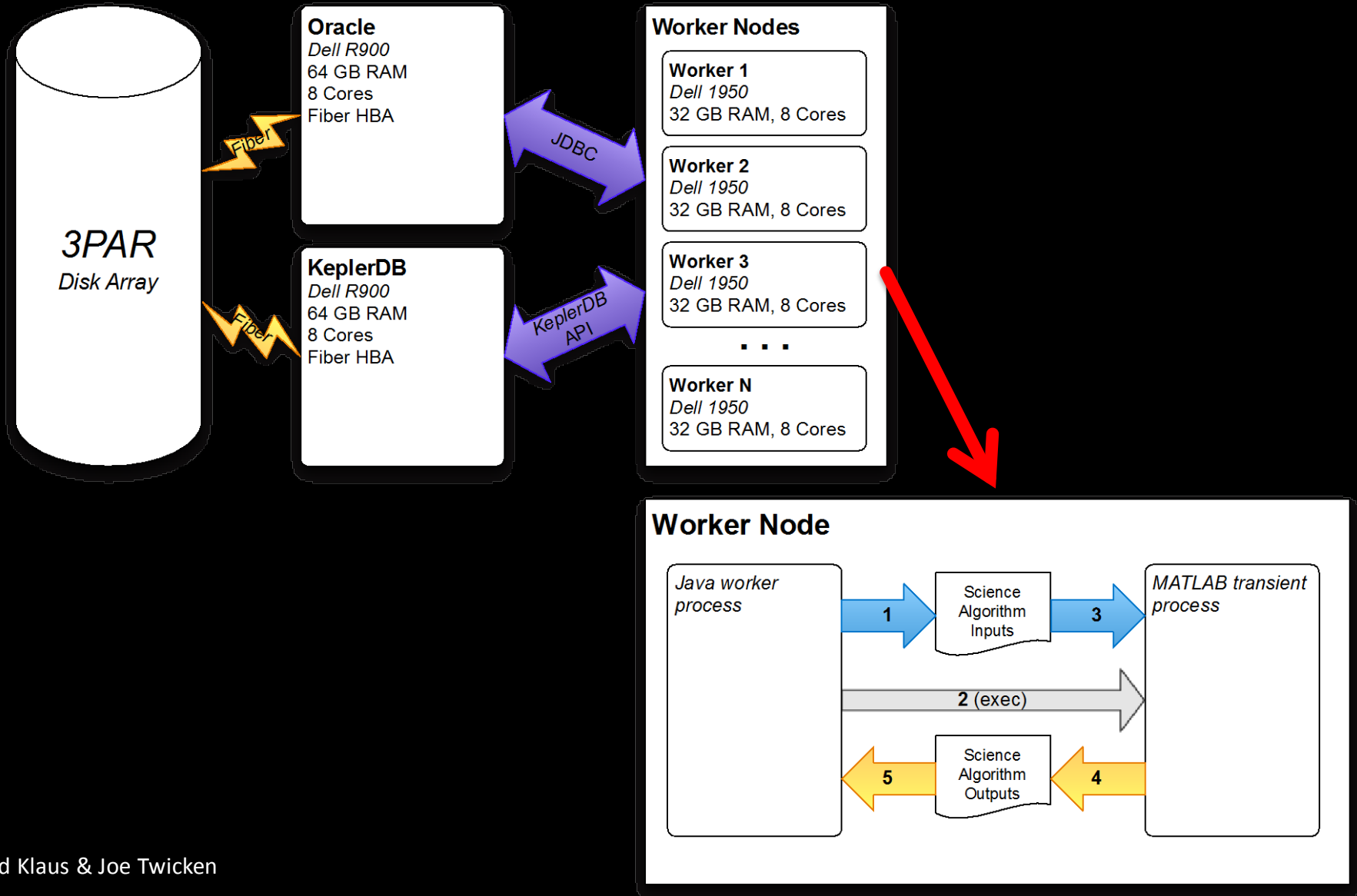


K2 Captures Neptune and Moons

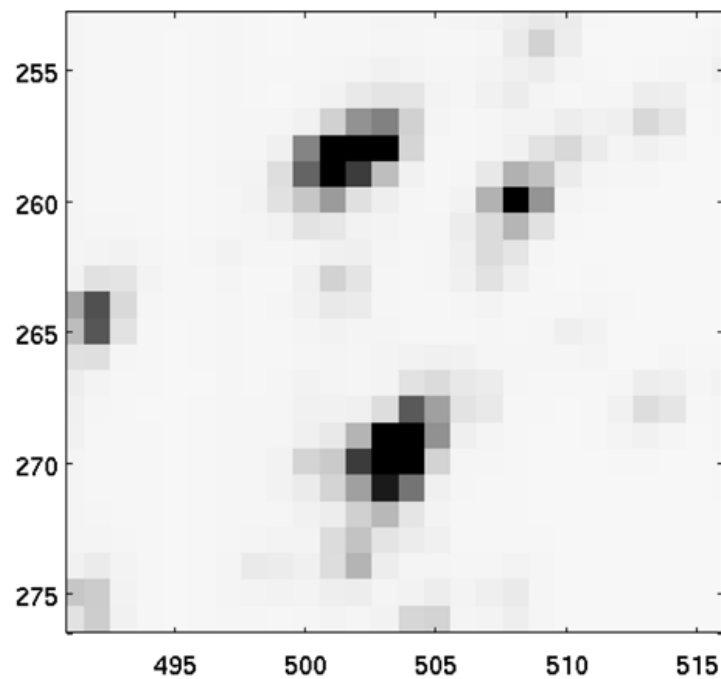
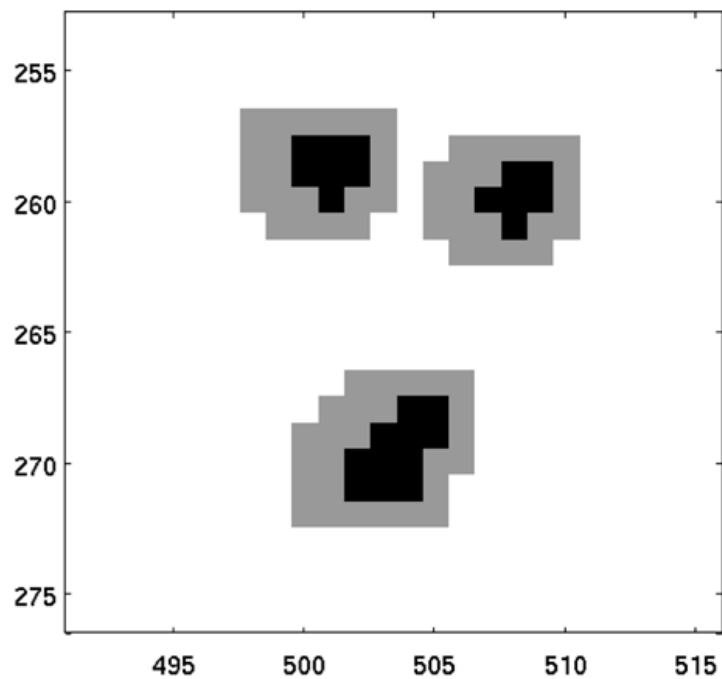


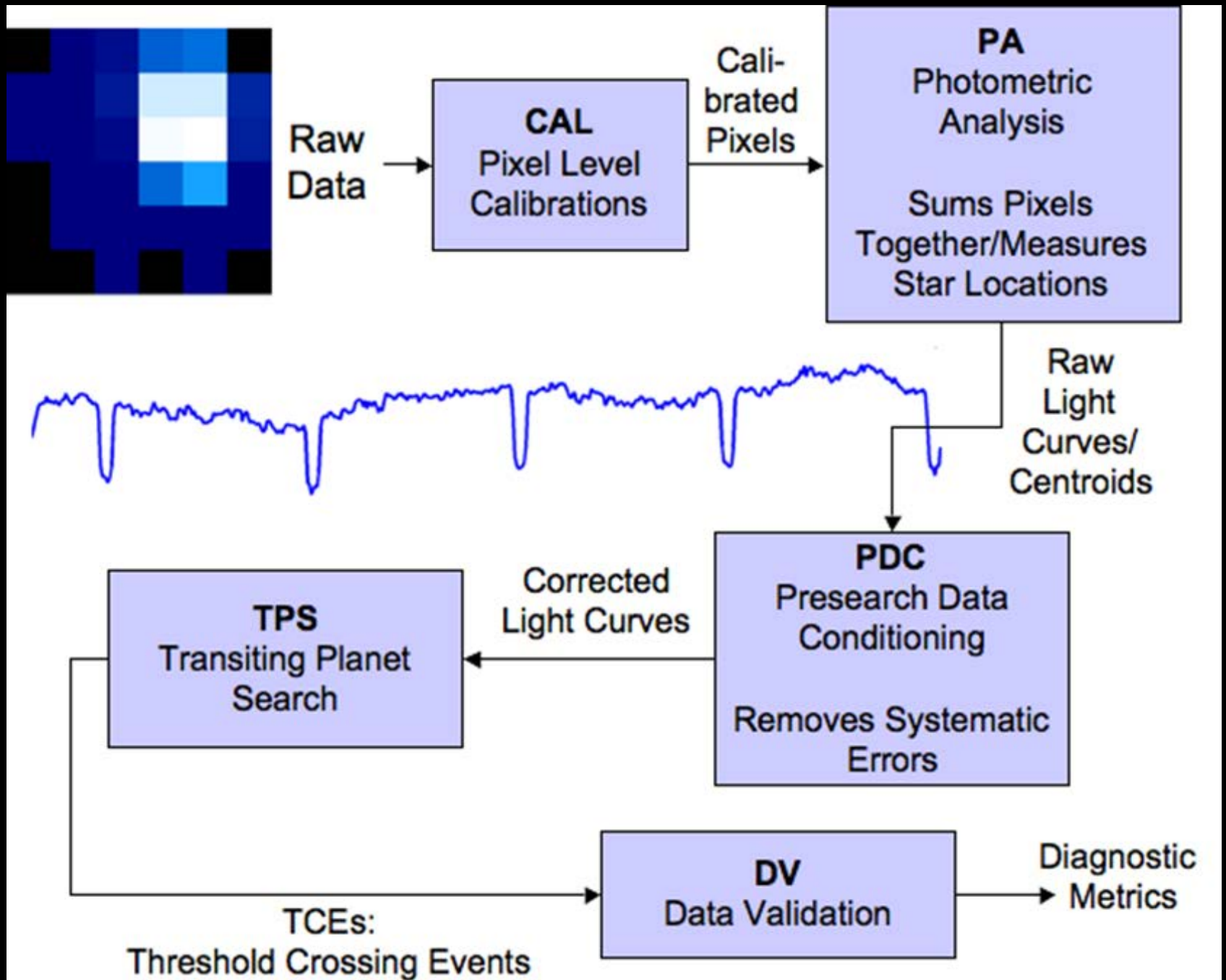
- [https://youtu.be/Tw-q3uM 5 0](https://youtu.be/Tw-q3uM50)

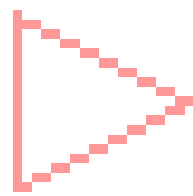
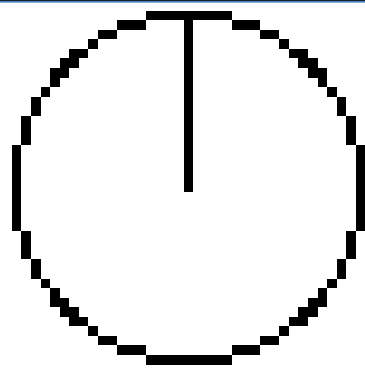
Baseline Architecture



Target and Aperture Definition

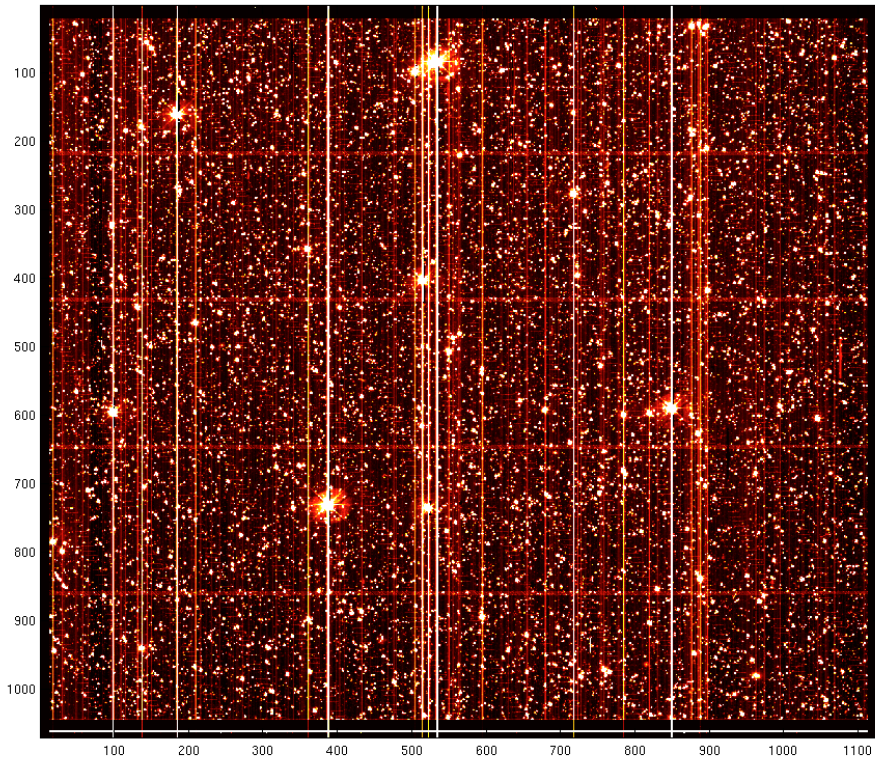




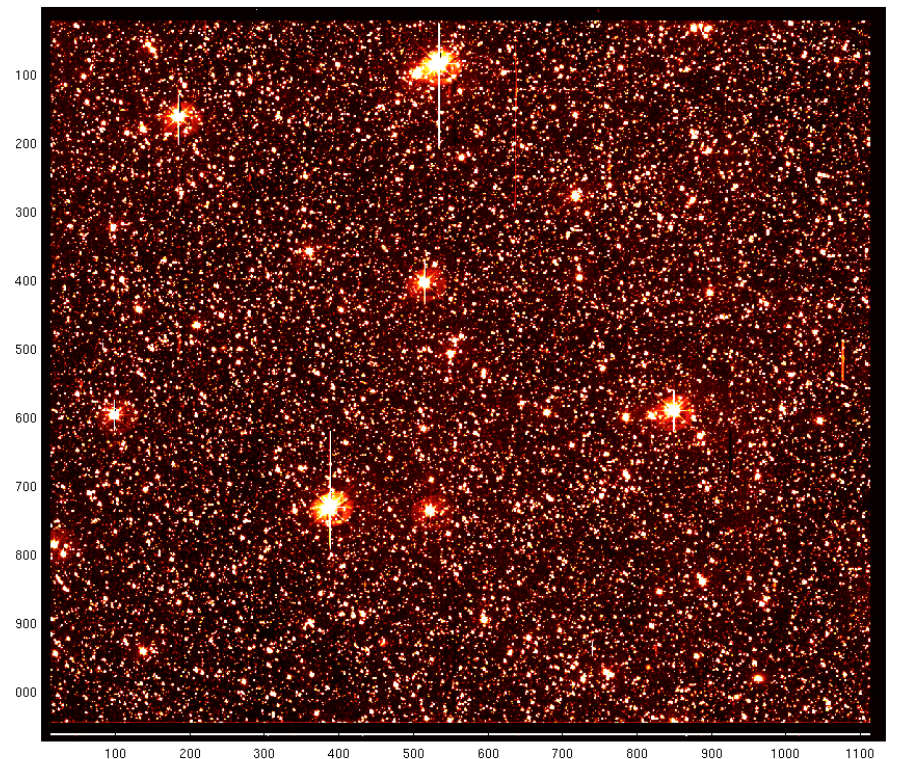


Expose

CAL: Pixel Level Calibrations

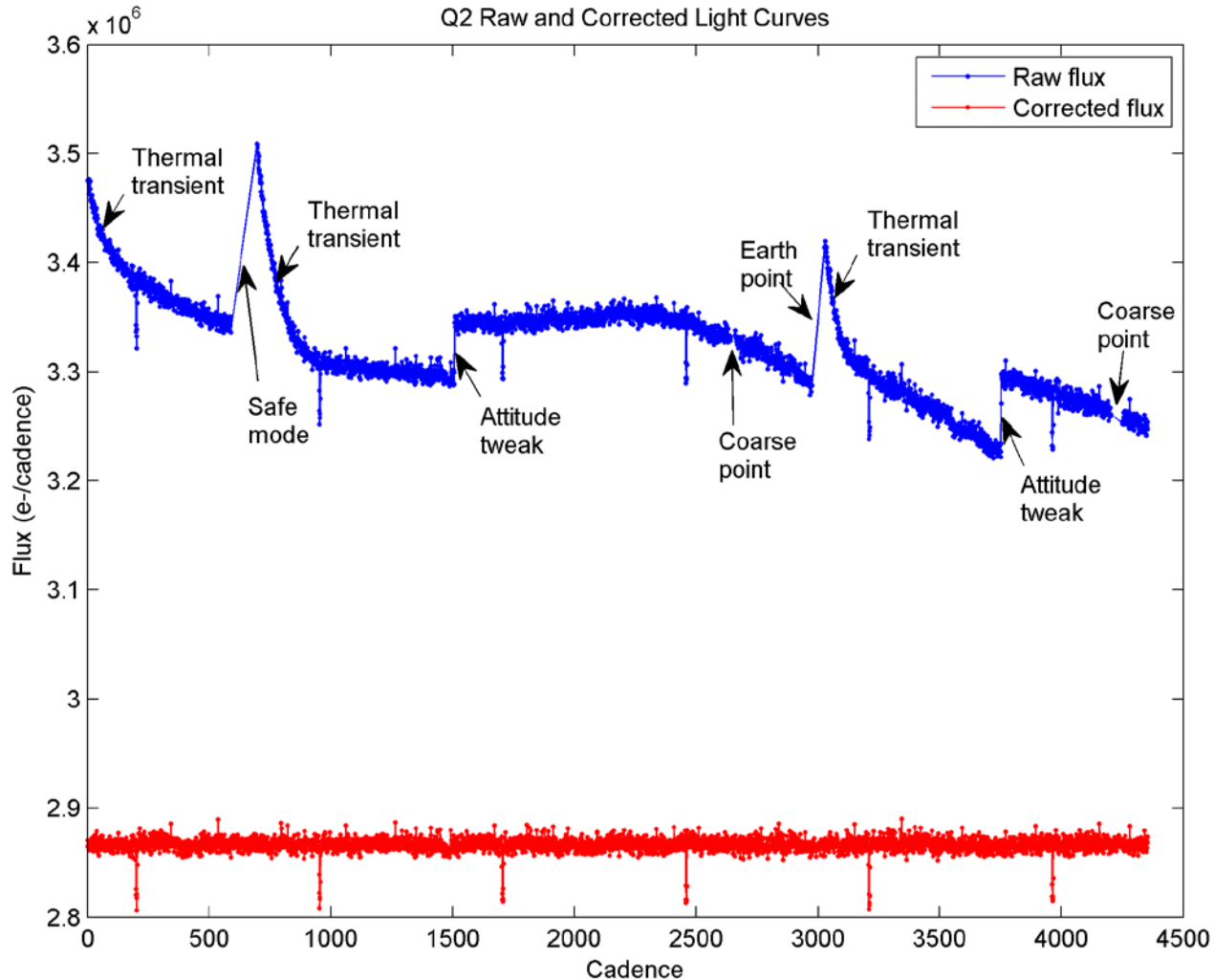


Raw FFI

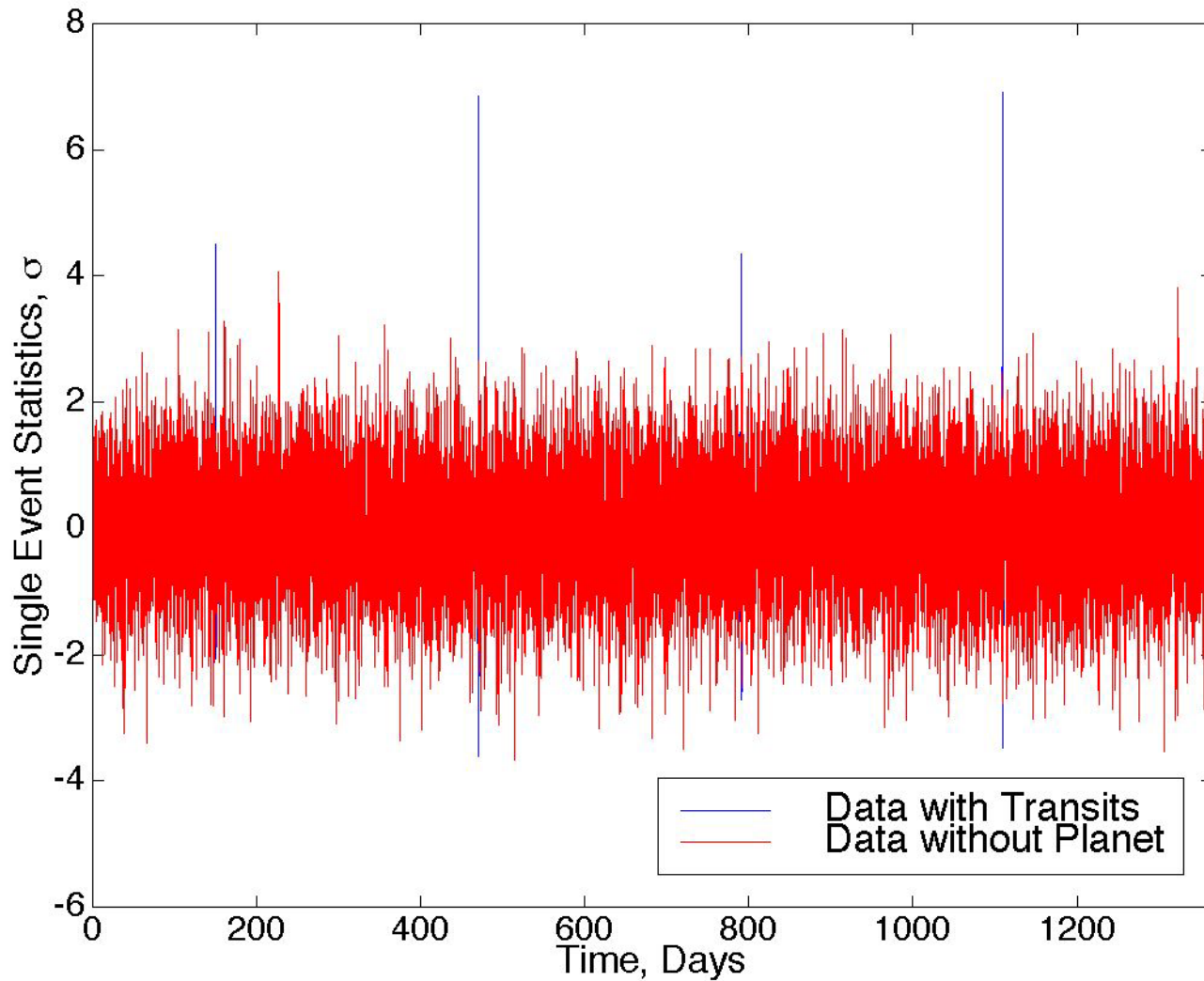


Calibrated FFI

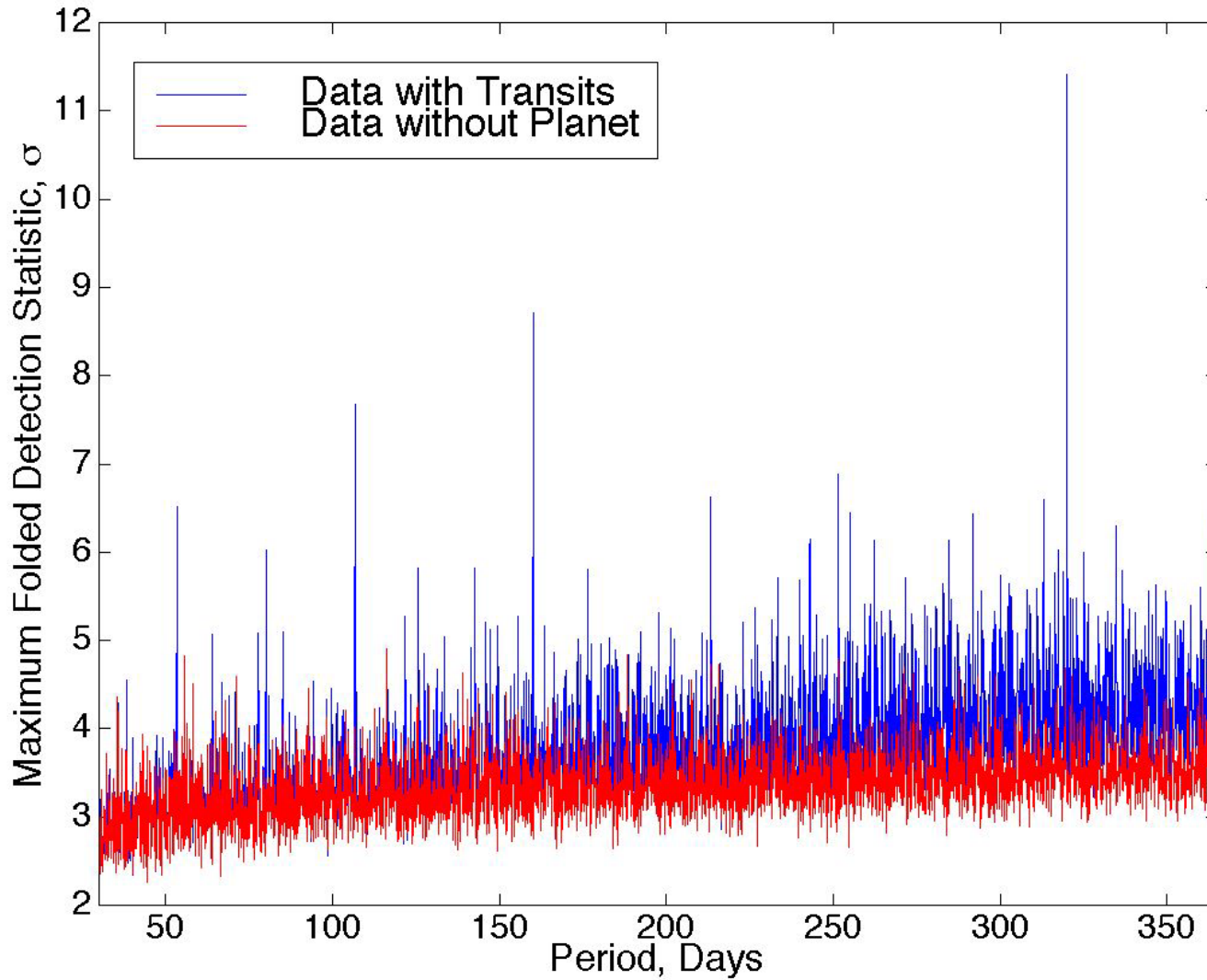
Light Curves Also Need 'Calibration'



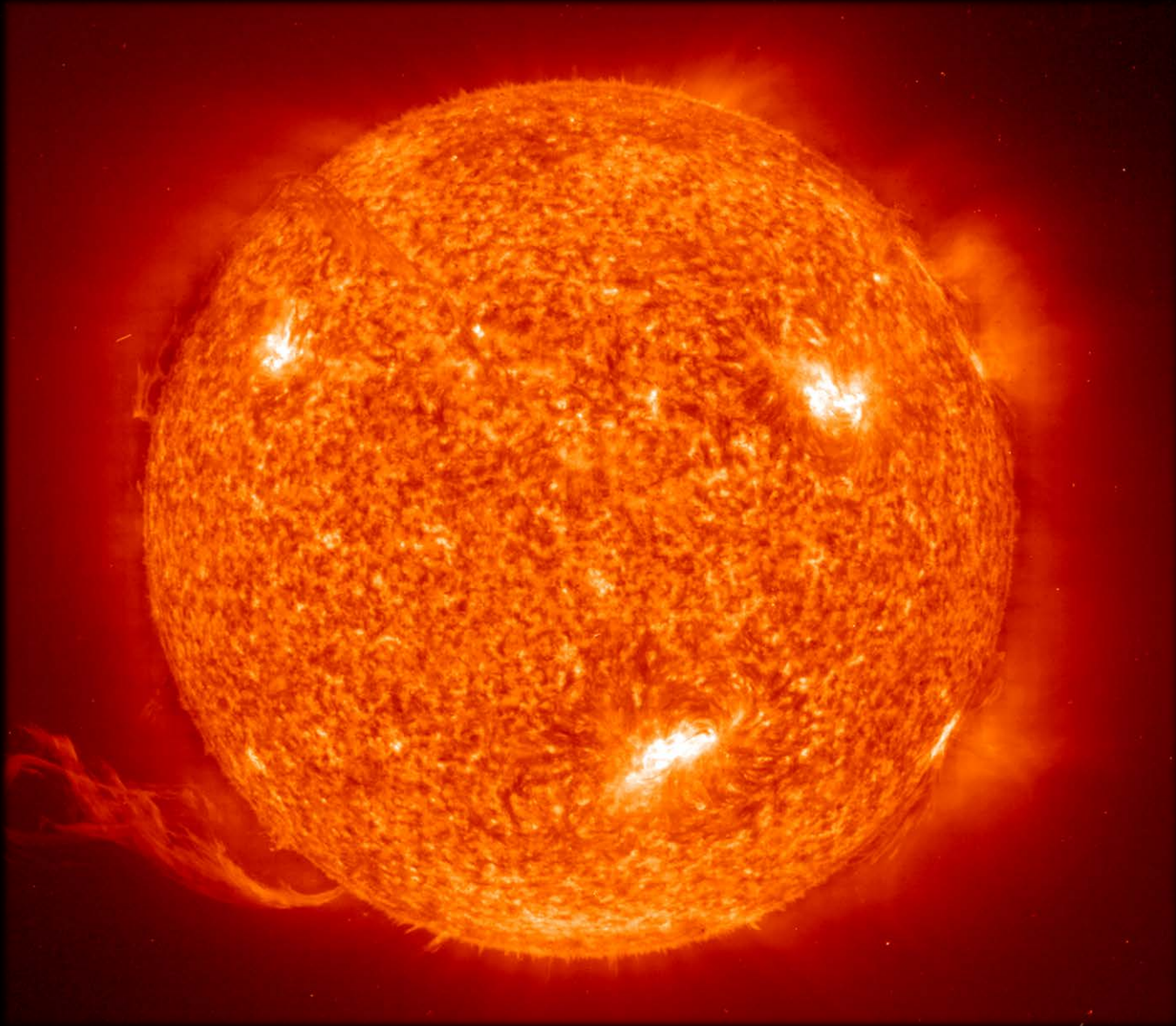
Single Transit Statistics



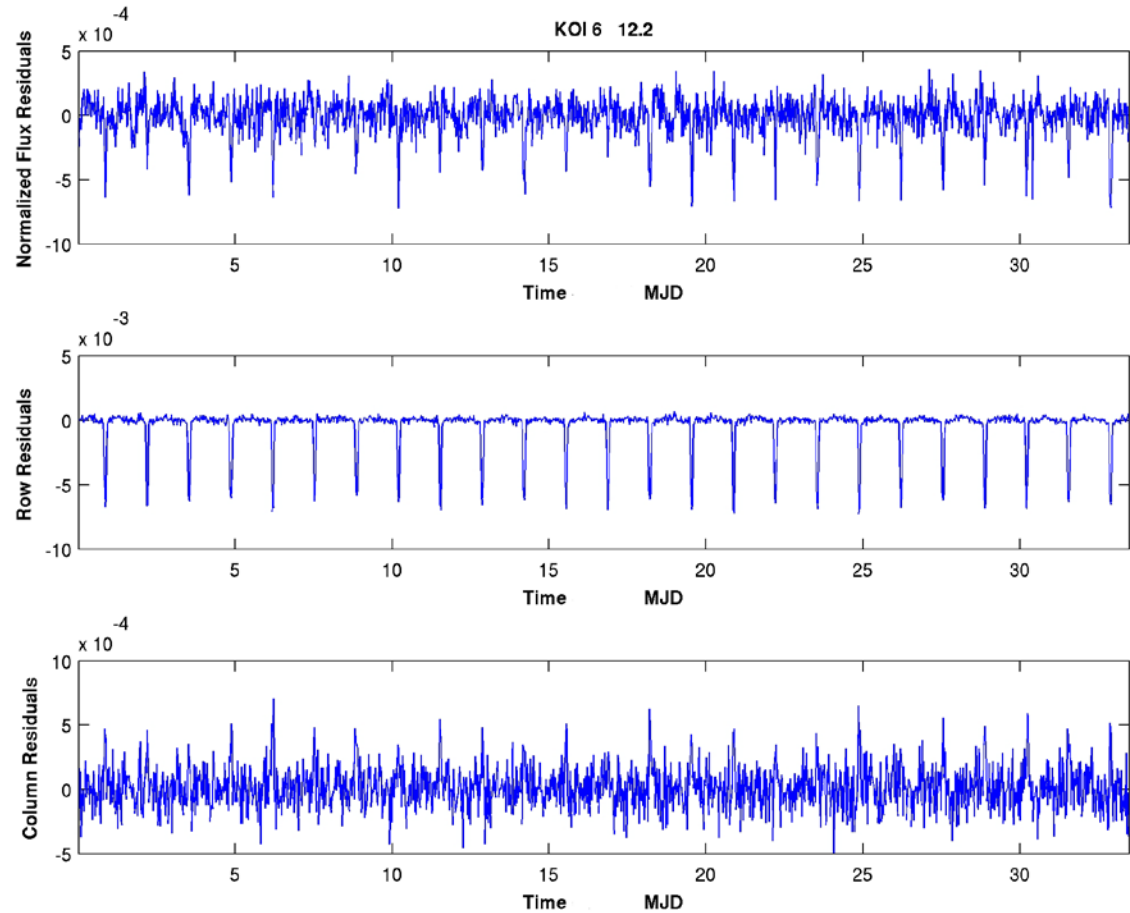
Folded Transit Statistics



Limb Darkening



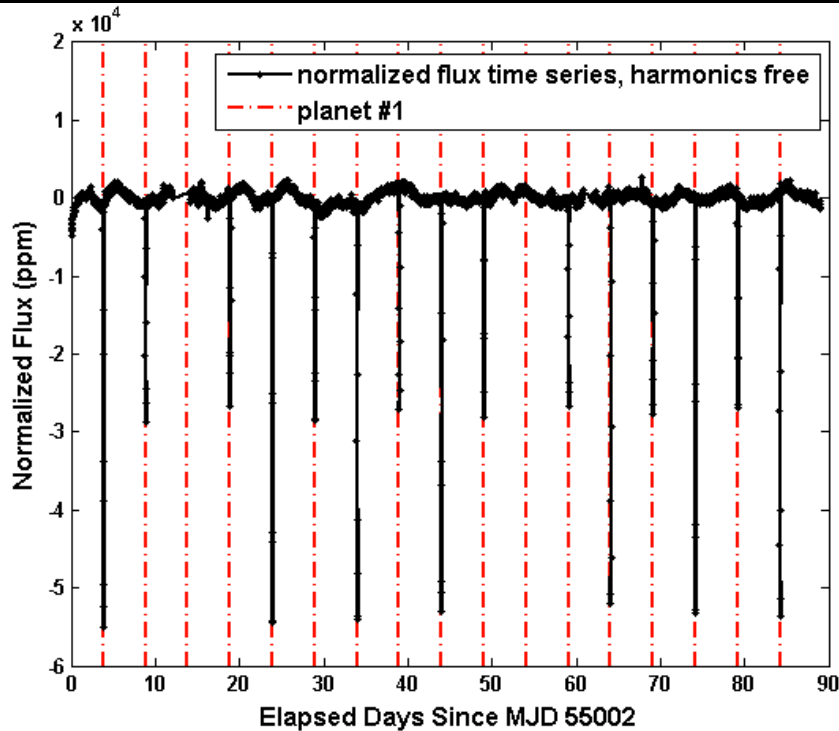
Centroid Timeseries



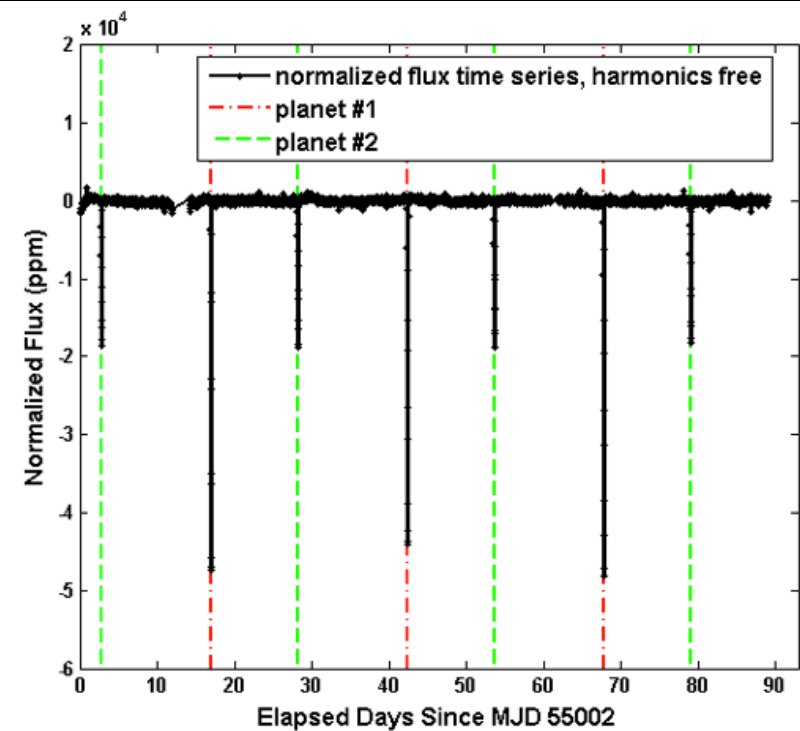
Row centroid shows large shifts correlated with flux

Eclipsing Binary Discrimination Test Example

Flight data, 1 TCE



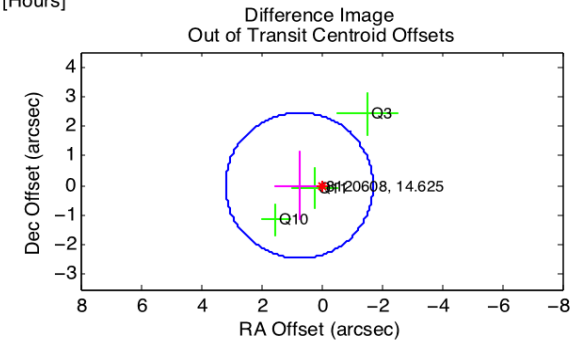
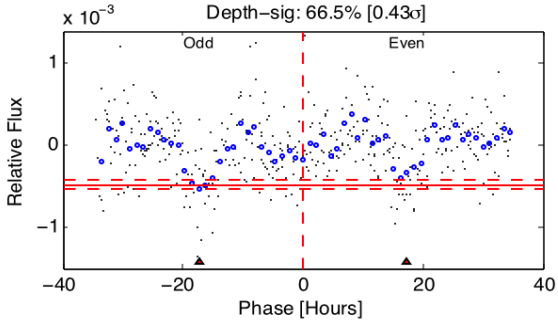
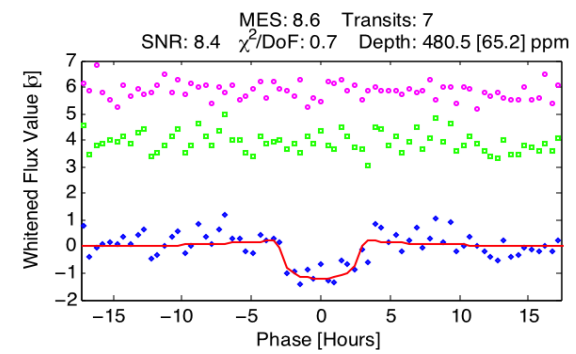
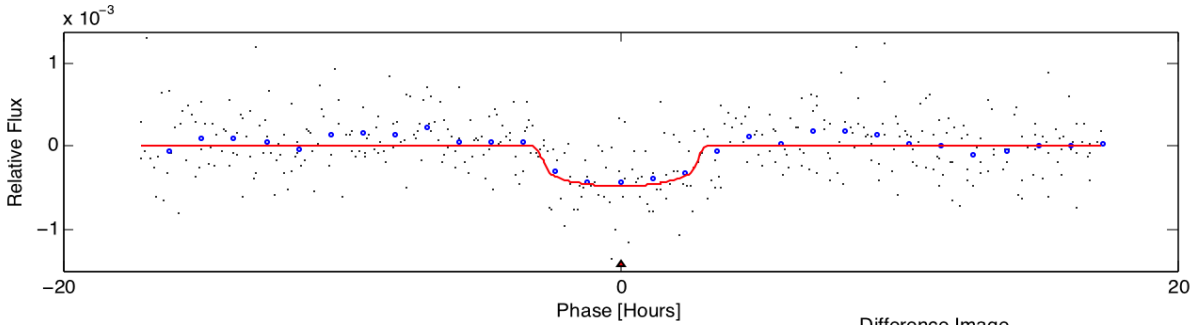
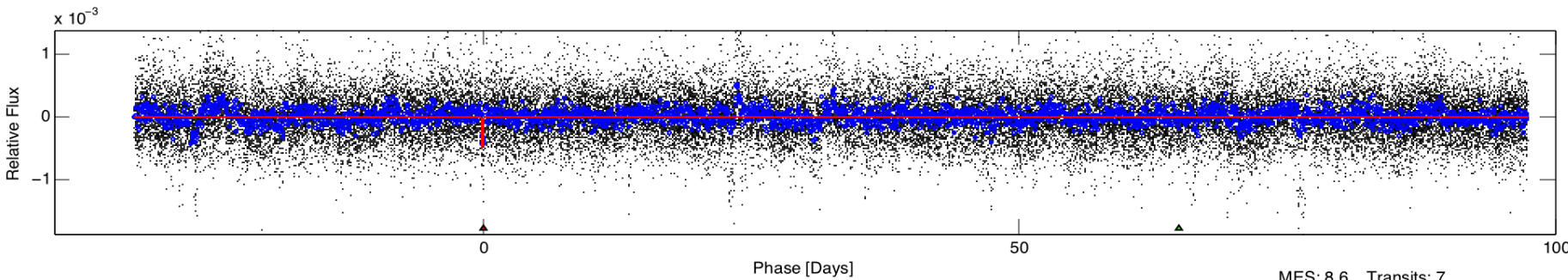
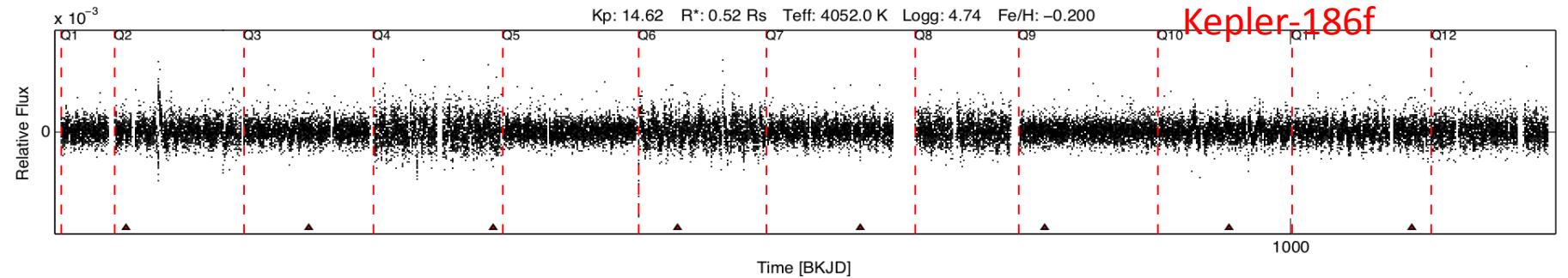
Flight data, 2 TCEs



- Odd depths \neq even depths
- Unlikely a planet

- $P_1 = P_2$
- Unlikely a planet

Kepler-186f



DV Fit Results:

- Period = 129.94545 [0.00238] d
- Epoch = 176.8272 [0.0115] BKJD
- Rp/R* = 0.0200 [0.0271]
- a/R* = 165.05 [882.88]
- b = 0.34 [13.80]
- Teq = 202 K
- Rp = 1.14 Re
- a = 0.4104 AU

DV Diagnostic Results:

- Epoch-sig: 78.0% [0.28 σ]
- ShortPeriod-sig: 100.0% [0.00 σ]
- LongPeriod-sig: N/A
- Centroid-sig: 4.6% [1.99 σ]
- Bootstrap-pfa: N/A
- OotOffset-rm: 0.735 arcsec [0.90 σ]
- KicOffset-rm: 0.869 arcsec [1.17 σ]
- OotOffset-bf: N/A
- KicOffset-bf: N/A

SOC Clusters



The Pleiades Supercomputer



For More Information

- <http://kepler.nasa.gov>
- <http://www.nasa.gov/kepler/>
- <http://planetquest.jpl.nasa.gov/kepler/>
- <http://exoplanetarchive.ipac.caltech.edu>
- <https://archive.stsci.edu/kepler/>
- <http://exoplanets.org>
- <http://en.wikipedia.org/wiki/Exoplanet>