Exoplanets in the Habitable Zone

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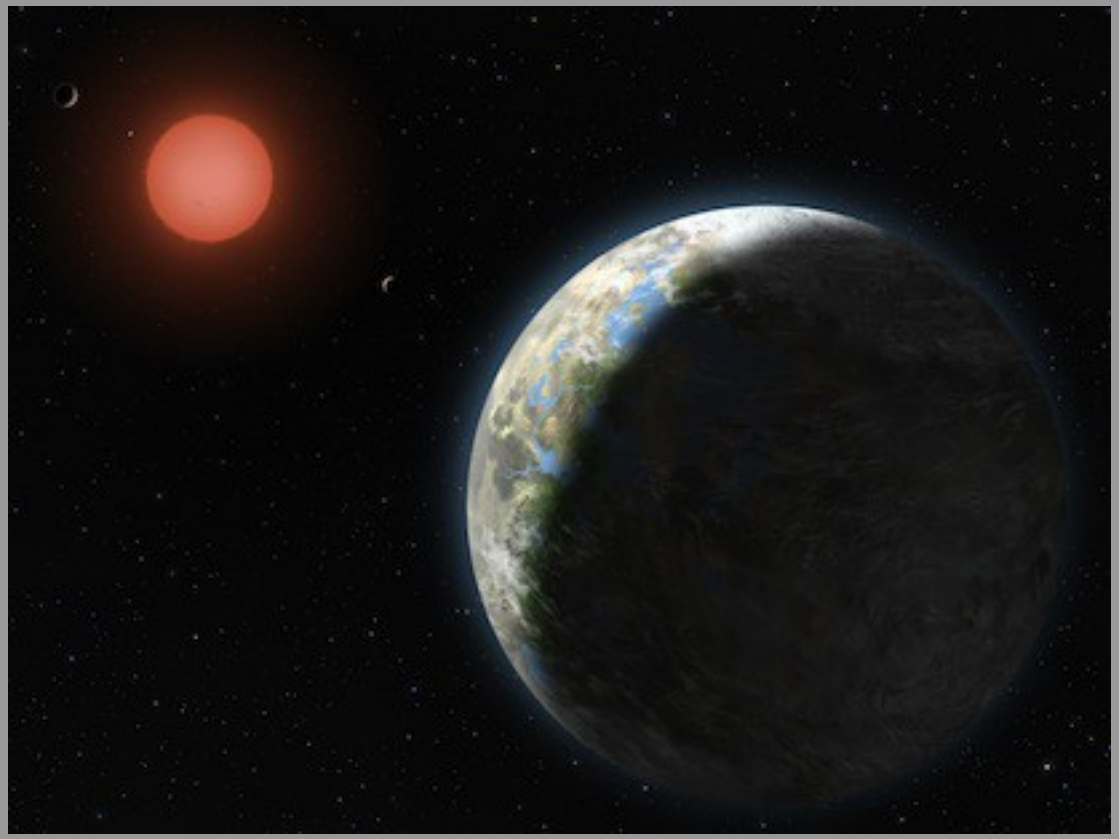
May 15, 2012

Astro Obs Final Presentation

Outline

- Hunting for exoplanets
- The Kepler mission
- Making measurements
- Examine the data

Planets, Planets Everywhere!



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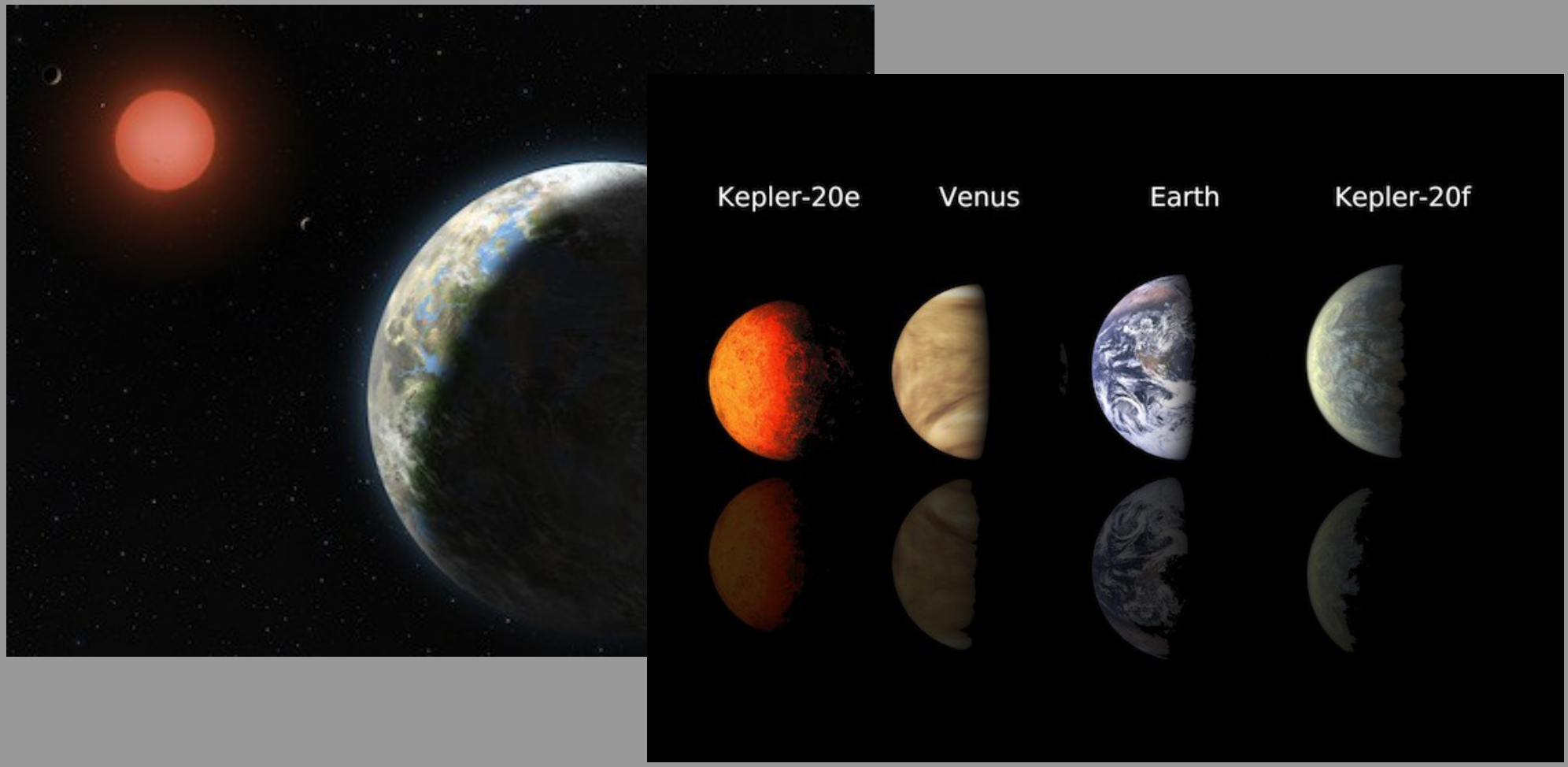

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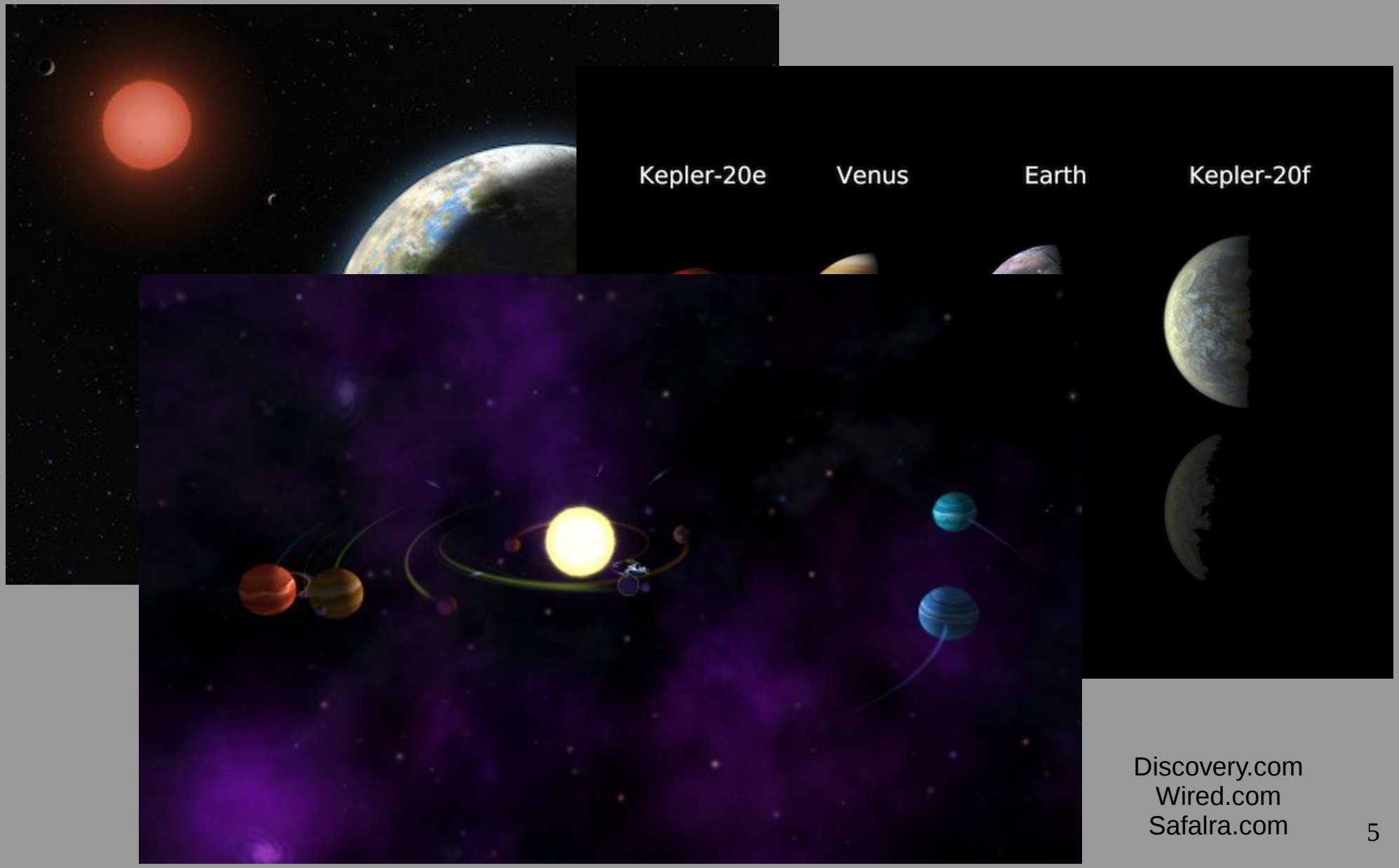
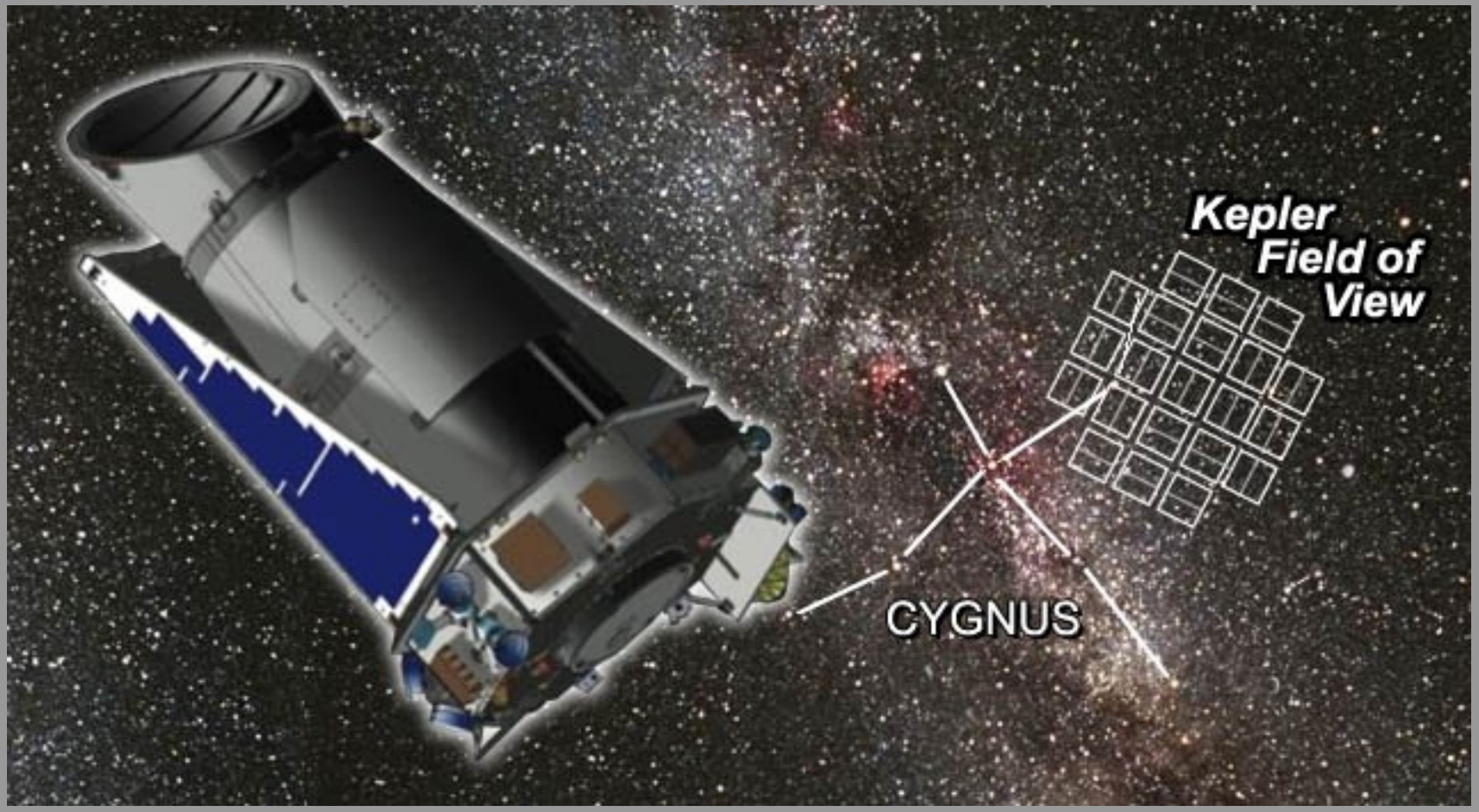


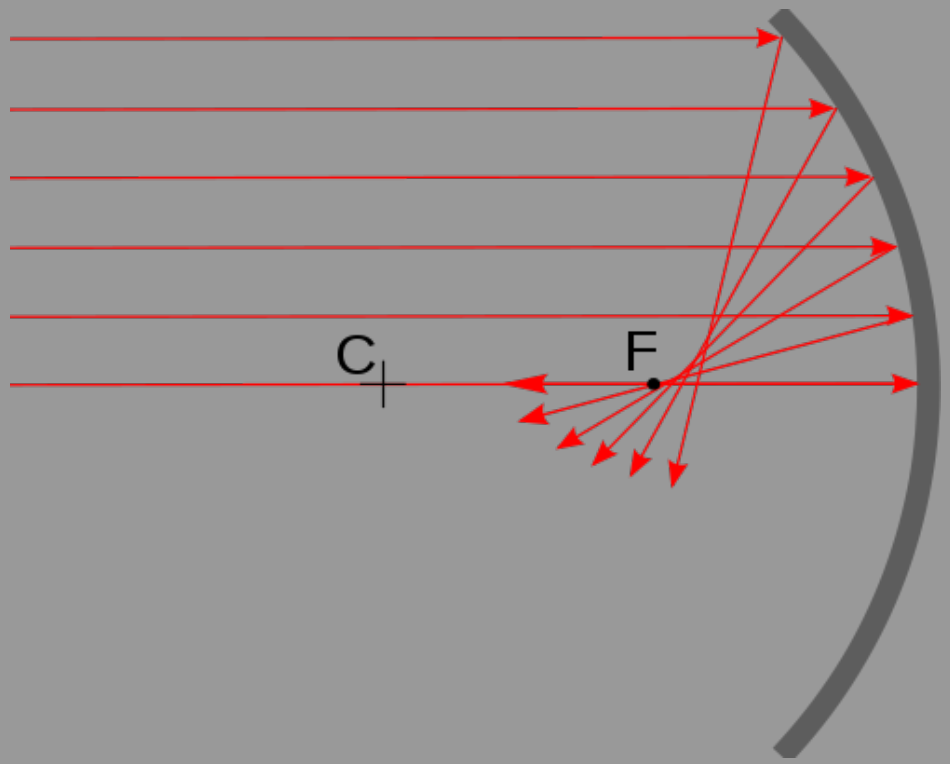
Discovery.com
Wired.com
Safalra.com

The Kepler Mission



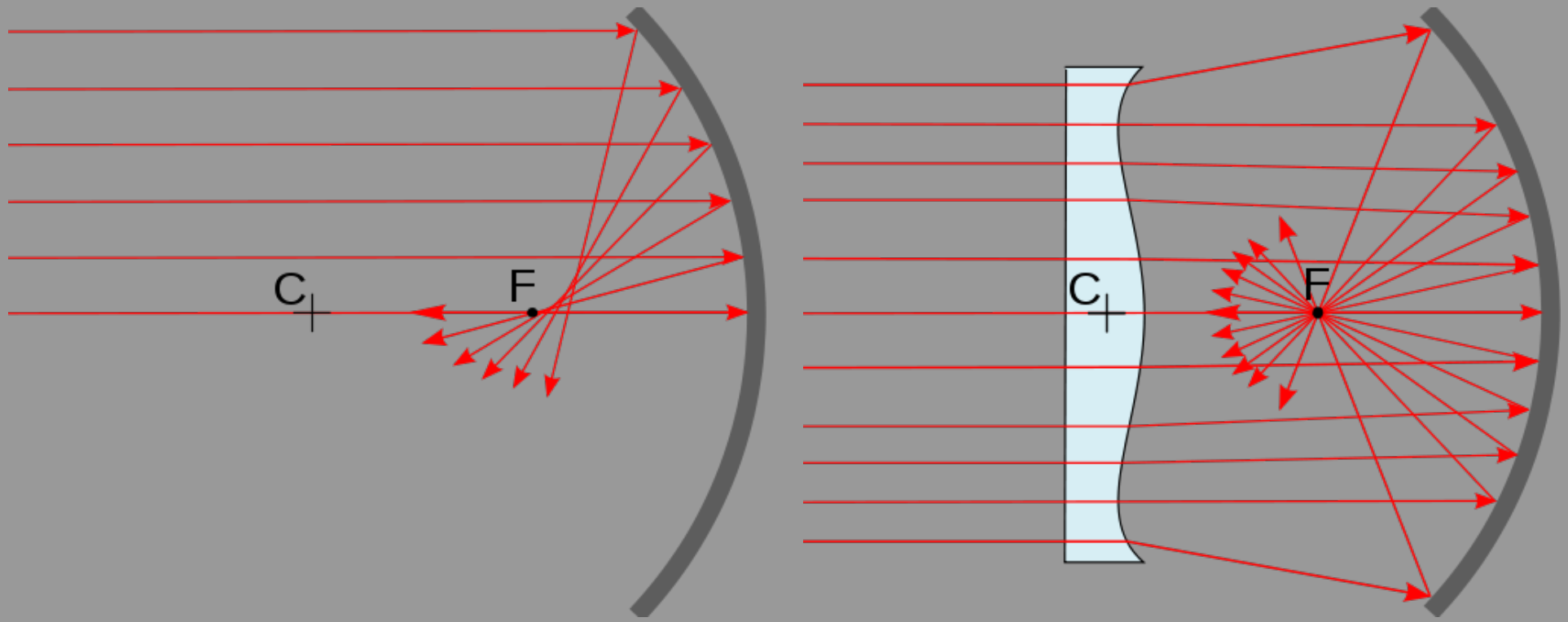
Universetoday.com

Schmidt Correction



http://en.wikipedia.org/wiki/Schmidt_corrector_plate

Schmidt Correction



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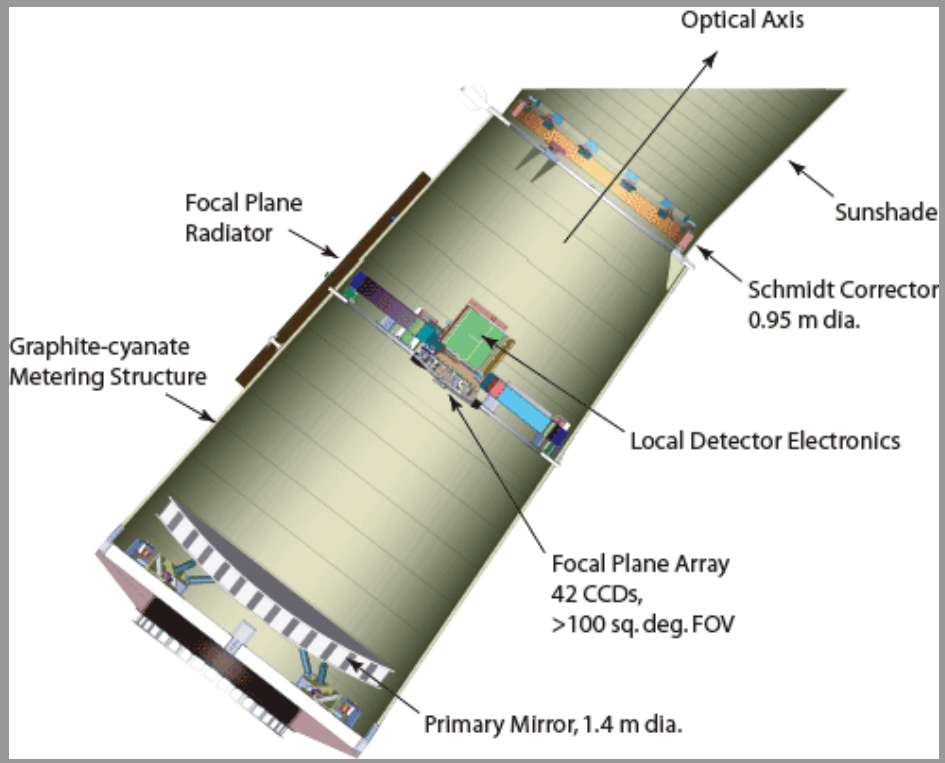
Kepler Curved CCD Array

- 42 CCDs
- 50x25 mm
- 2200x1024 pixels
- ~95 megapixels
- Pixel size 27 μm
- Thinned, backside illuminated
- T = -93 C
- ~60 e^-/s shot noise
- $m_V \leq 14$

Putting it Together

- 105 deg^2 field of view
- Data for ~100k stars recorded continuously and simultaneously
- Stored on board; transmitted to Earth about once per month

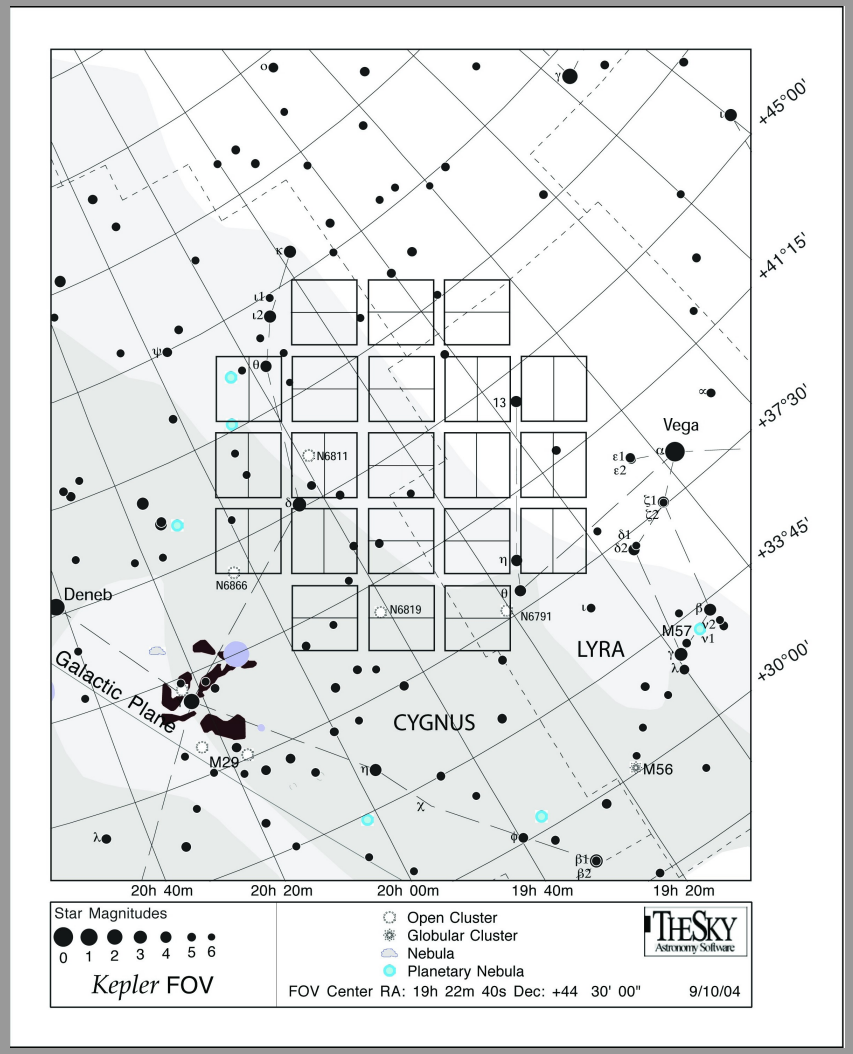


Detection Sensitivity

- Detect Earth-sized planet
- Host star m_V = 12 G2V
- 6.5 hours of integration
- 4σ ~ 0.99994 CI
- P(Transit along LOS) = $R_* / (2\,a)$
- For Earth-Sun system, P ≈ 0.5%

Mission So Far

- Launched March 7, 2009 for ≥ 7.5 year mission
- Operates in heliocentric orbit
- 2326 candidates, to date
- Median detectable stellar variability is 29 ppm



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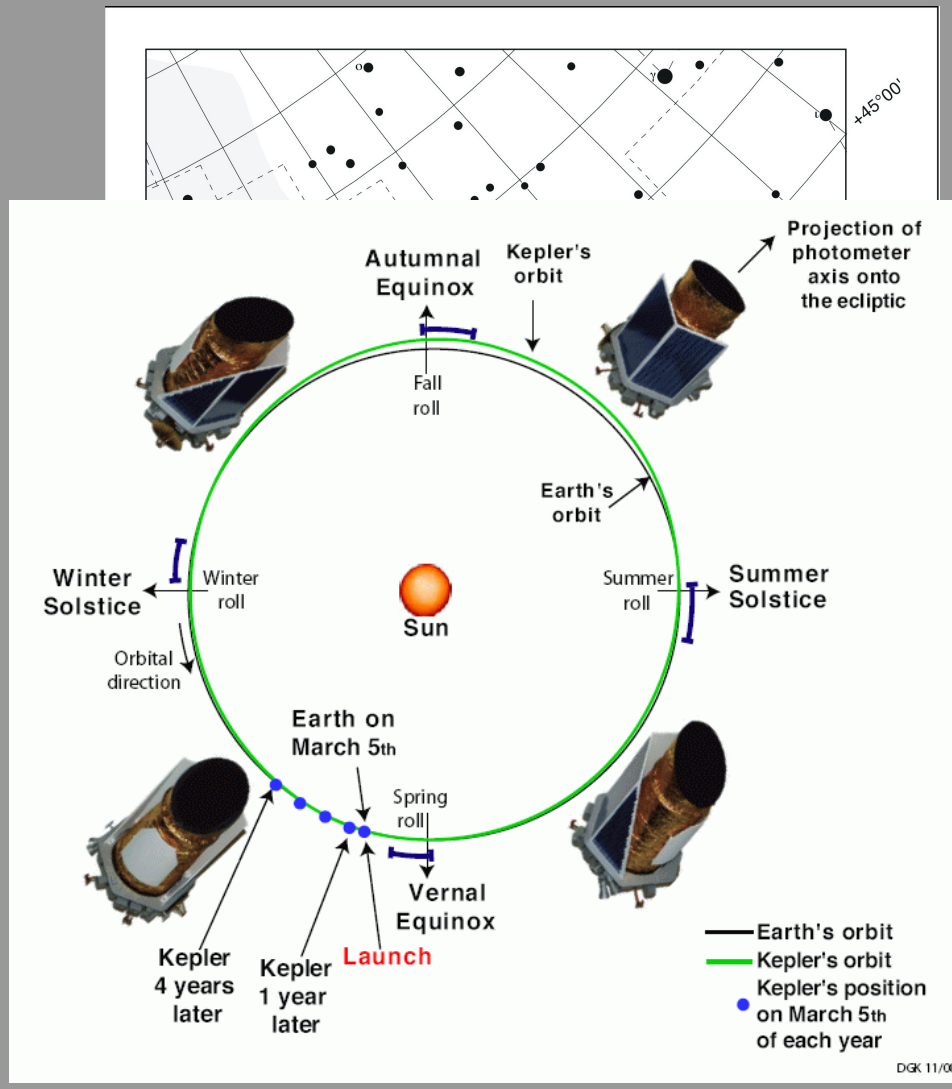

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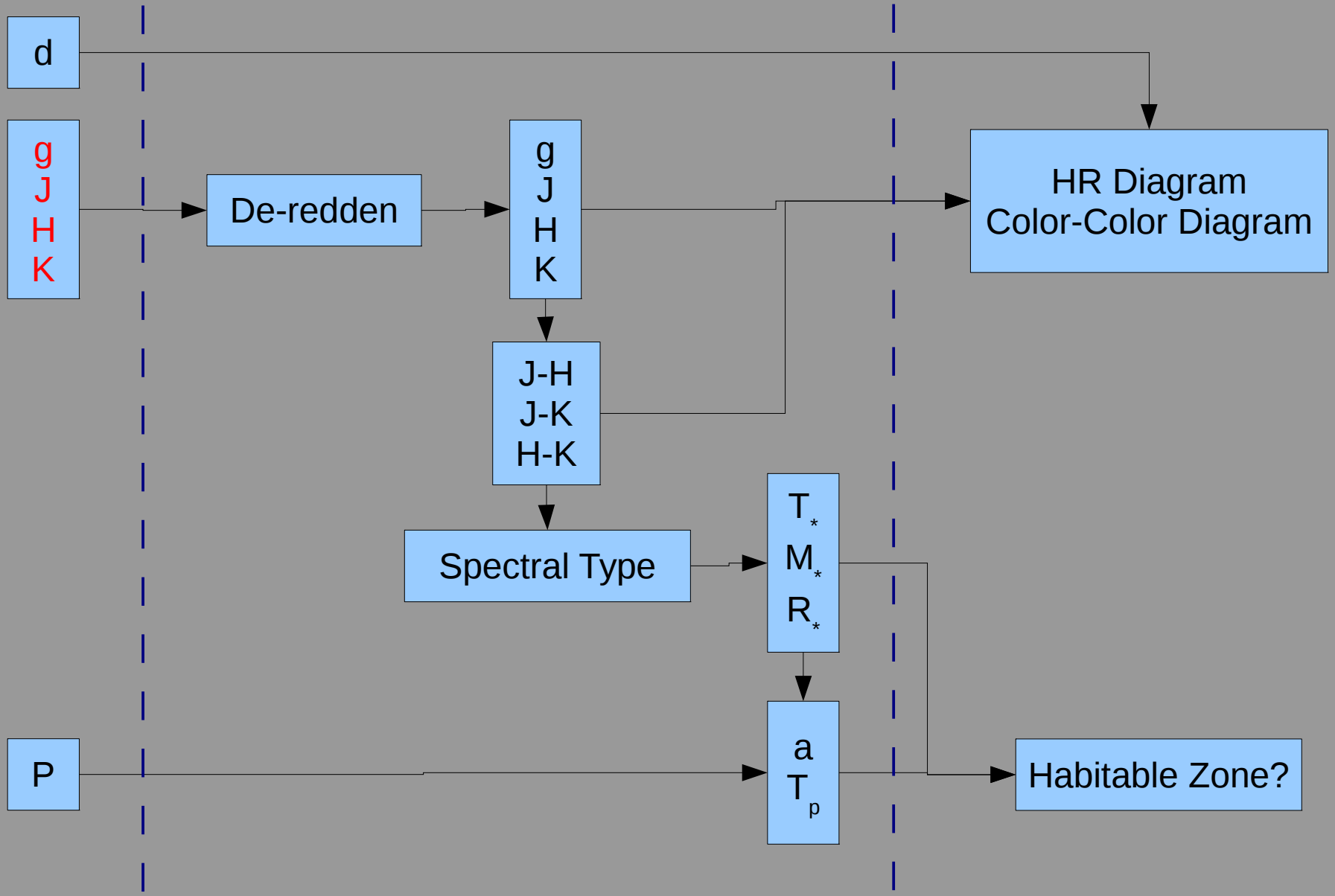
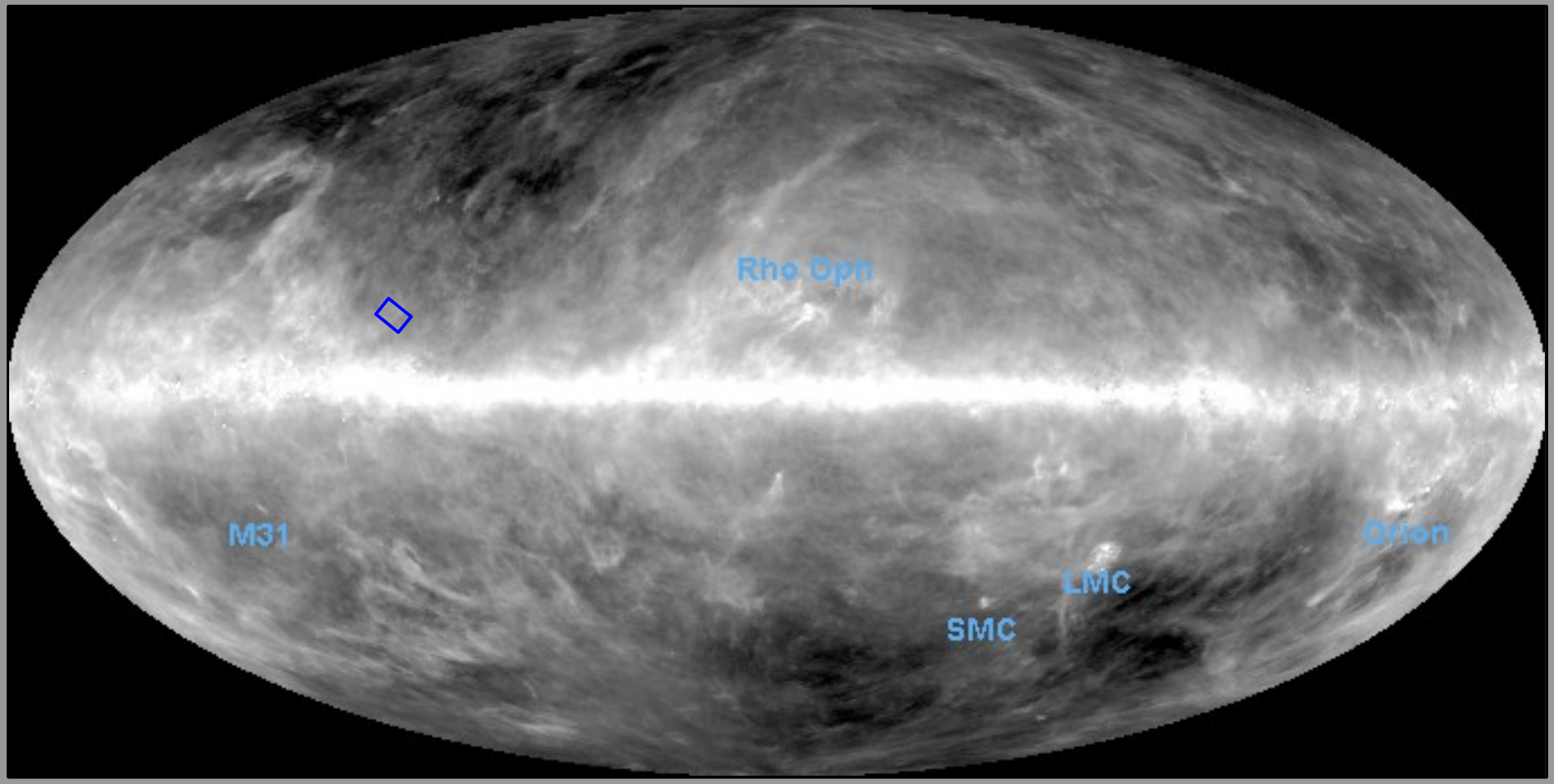
Measurement Outline

- MAST Kepler Data Archive
  - List of planet candidates
  - 2MASS ID and g, J, H, K mags, orbital period, comparison planet temperatures
- 2MASS GATOR
  - Parallax
- NASA/IPAC Infrared Science Archive
  - Extinction data
- Straižys and Allen & Cox
  - De-reddened Colors → Spectral type → Stellar properties

Analysis Flow



Dust Map



http://irsa.ipac.caltech.edu/applications/DUST/

Orbit Semi-major Axis

- Kepler's law
- Stellar mass M_*
- Orbital period P

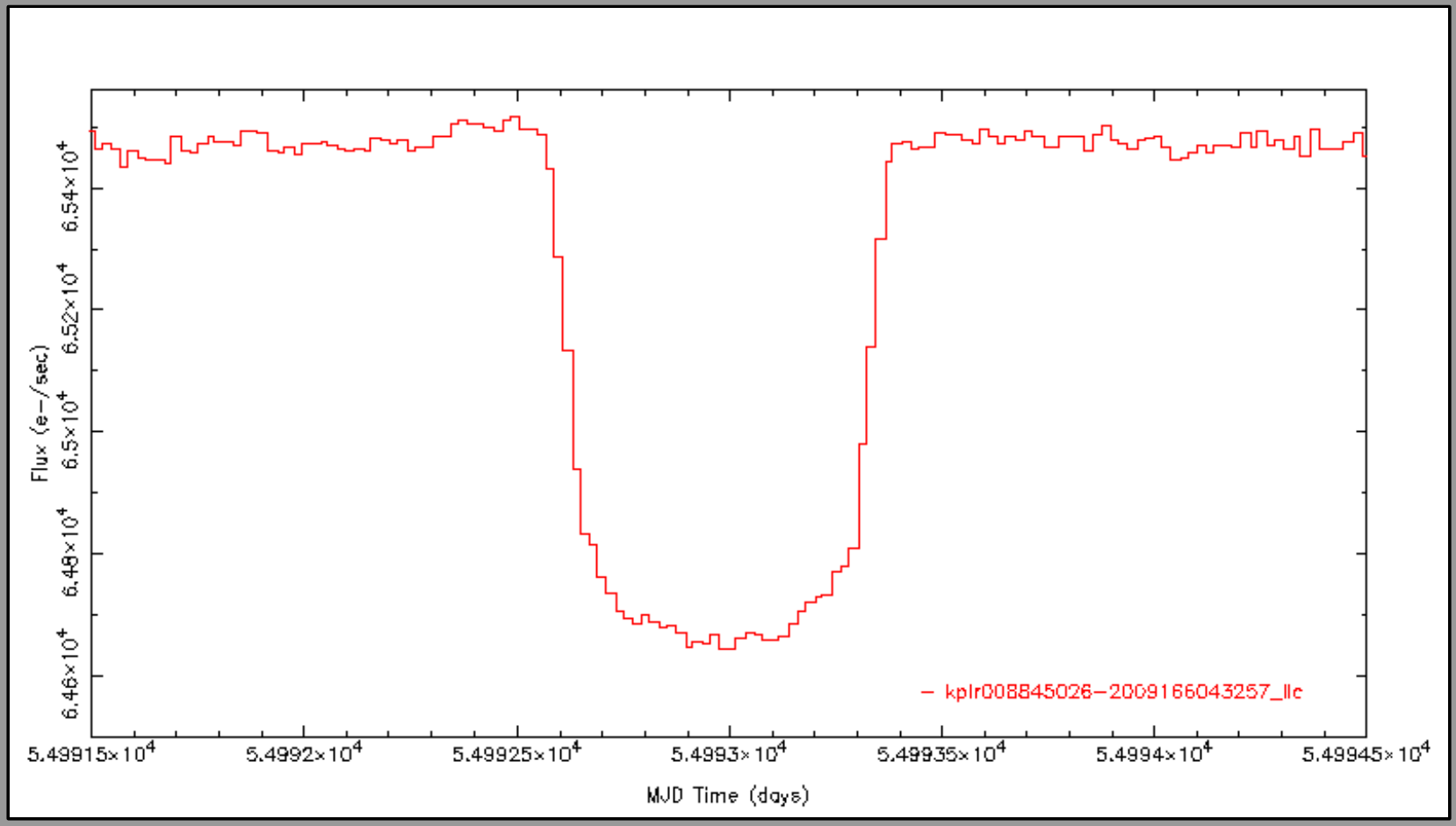
$$a = \left(\frac{GM_*}{4\pi^2} P^2 \right)^{1/3}$$

Planet Temperature

- Gray body approximation
- Star temperature T_*
- Star radius R_*
- Orbit semi-major axis a
- Albedo of planet A_B~0.3

$$T_p = T_* \left(\frac{R_*}{2a} \right)^{1/2} (1 - A_B)^{1/4}$$

Example Light Curve

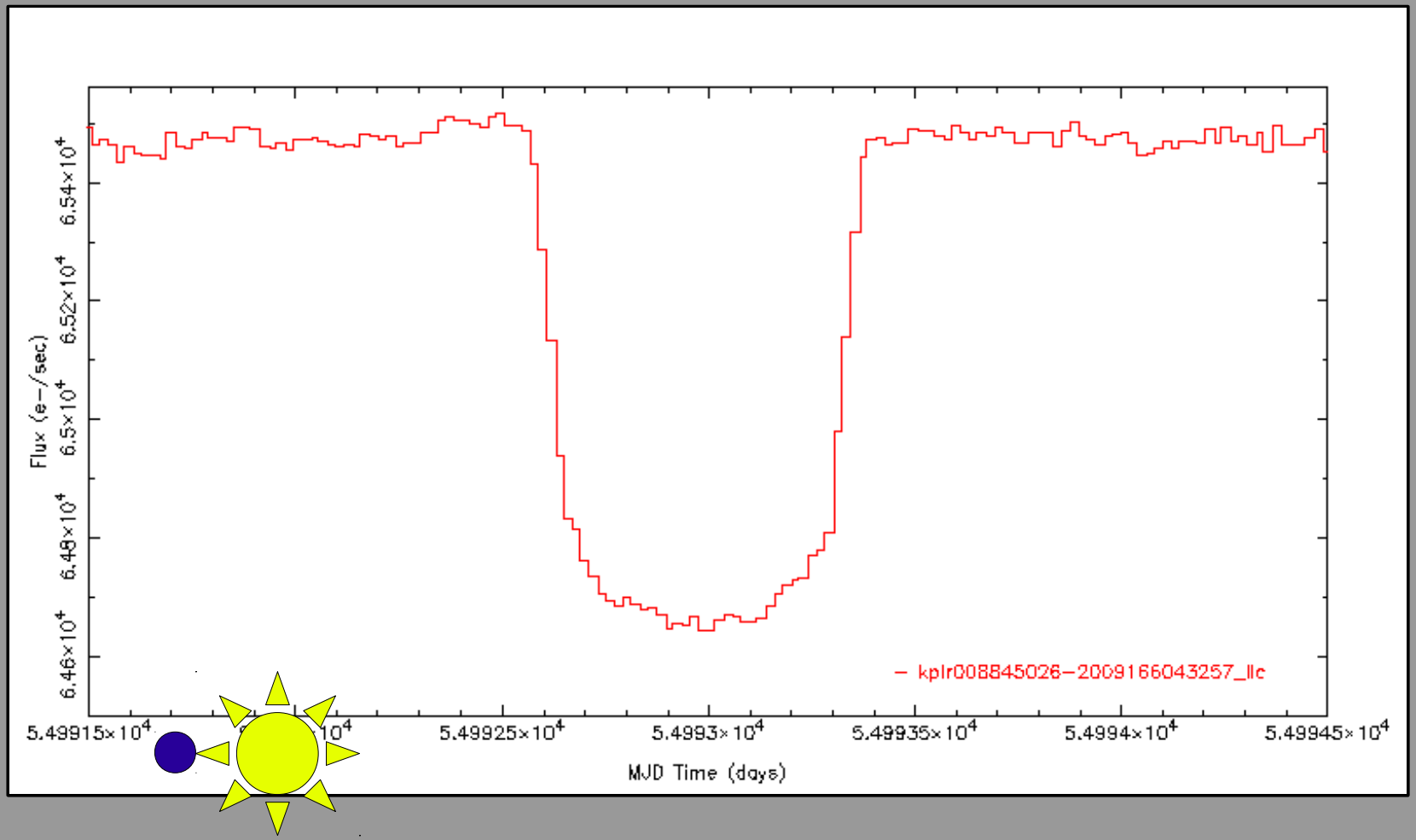


KID 8845026

T_p = 654 K

Make orbital period measurements

Example Light Curve



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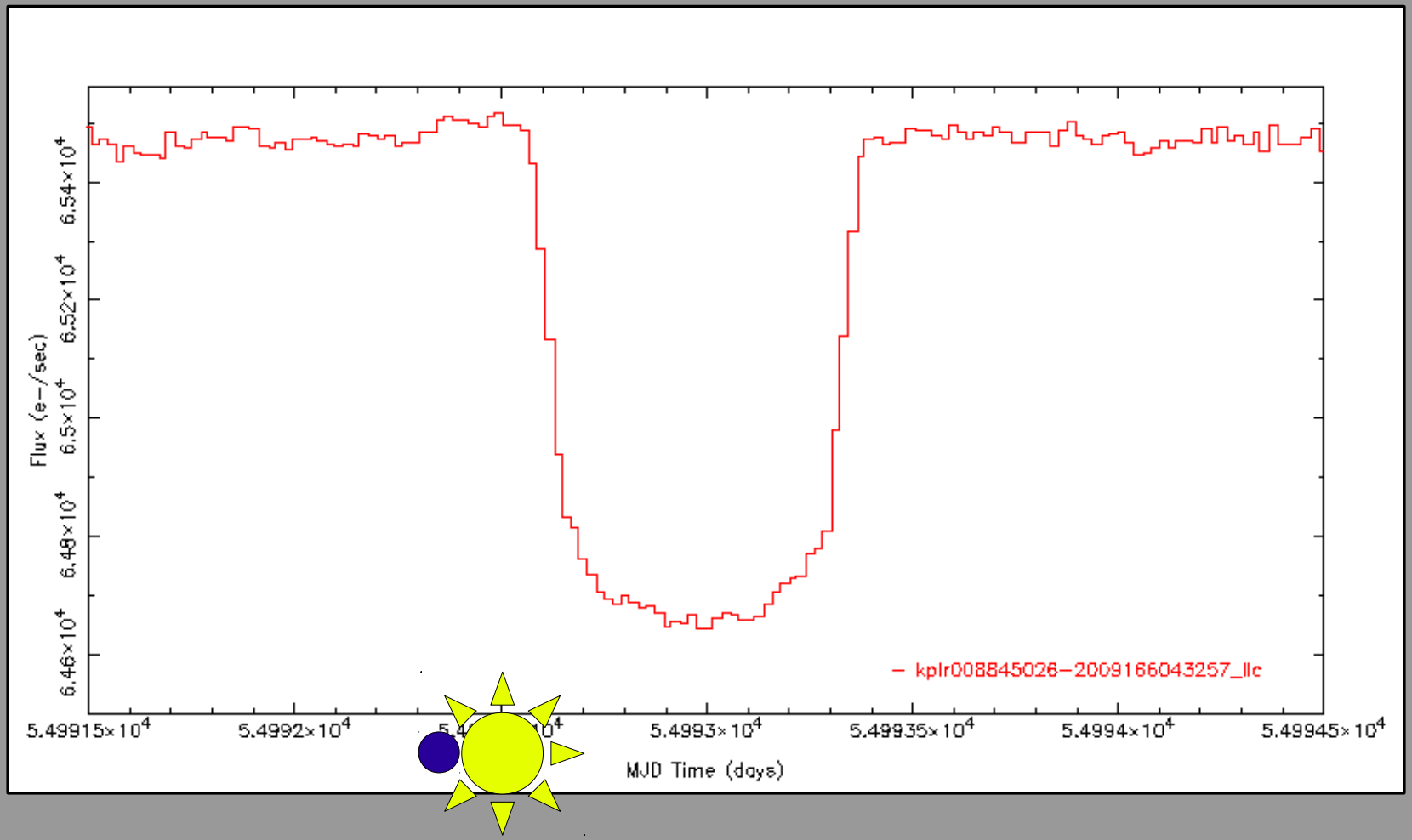

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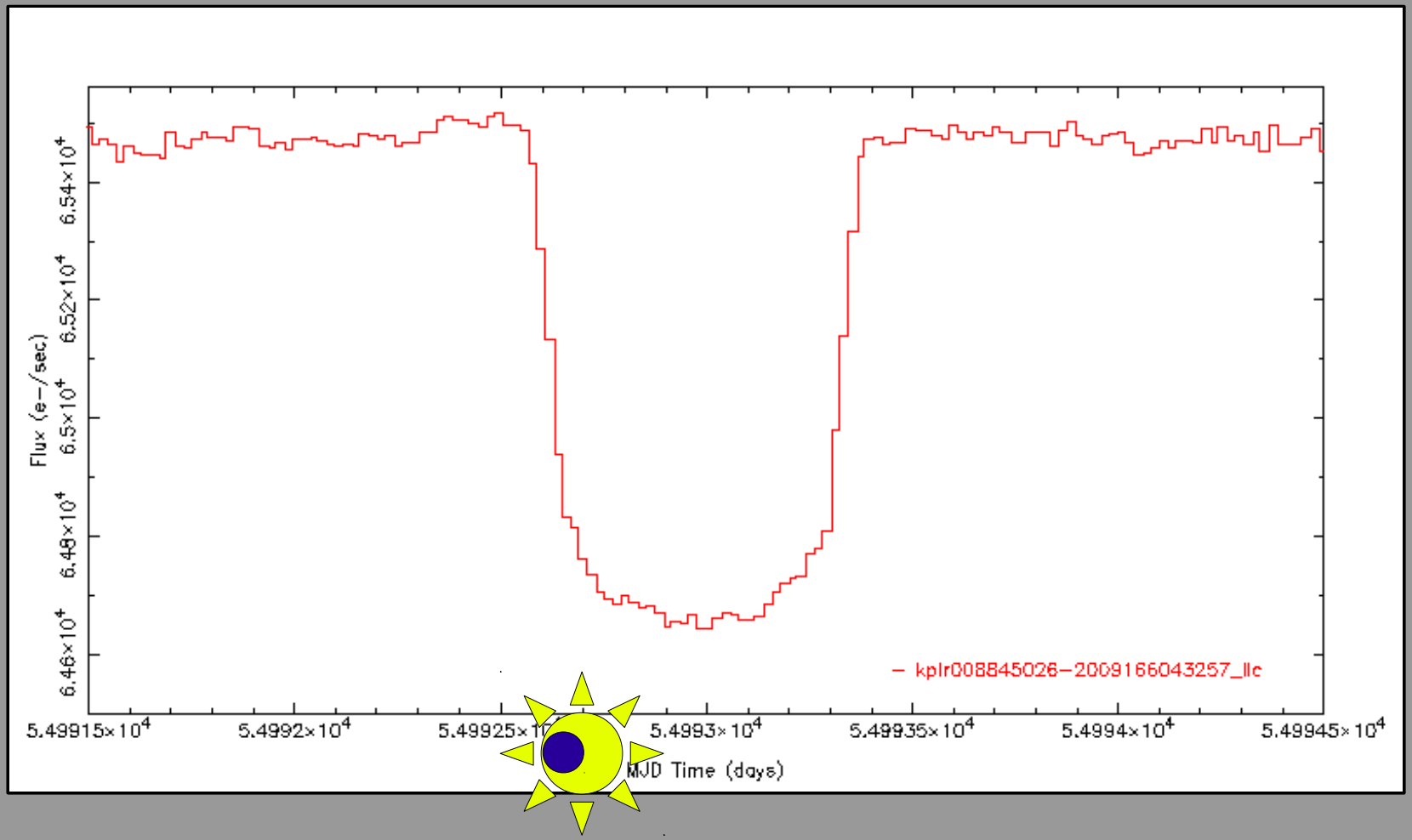

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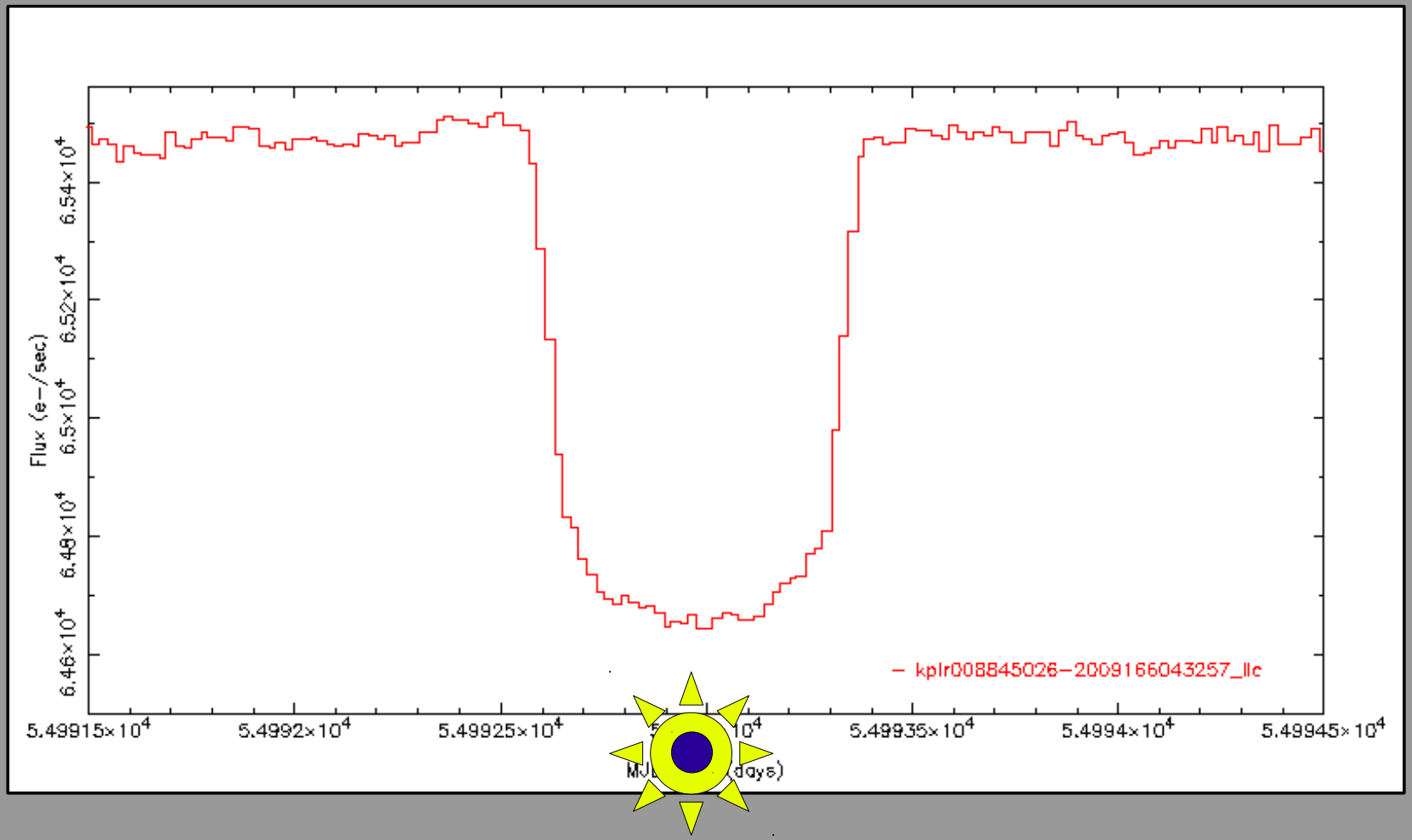

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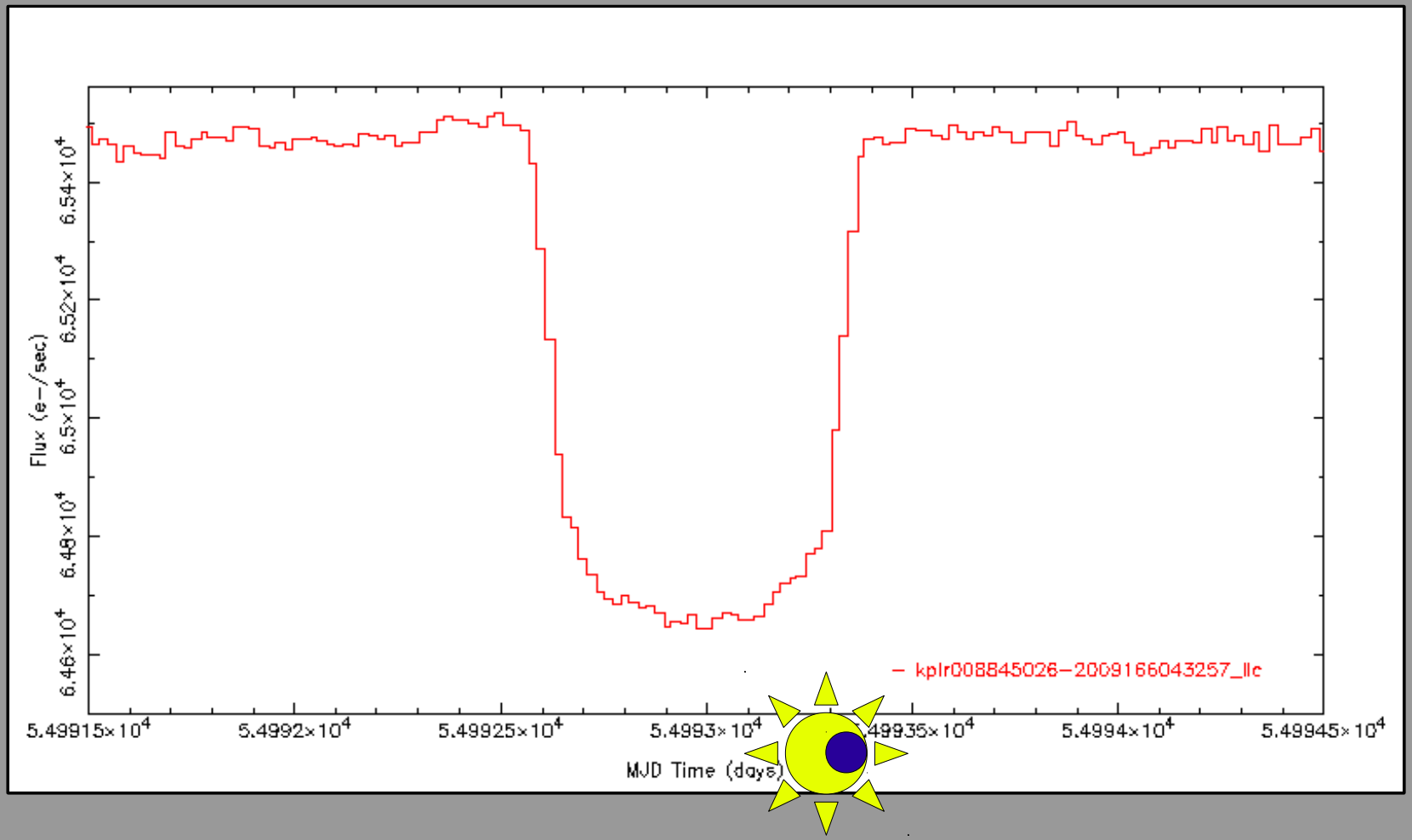

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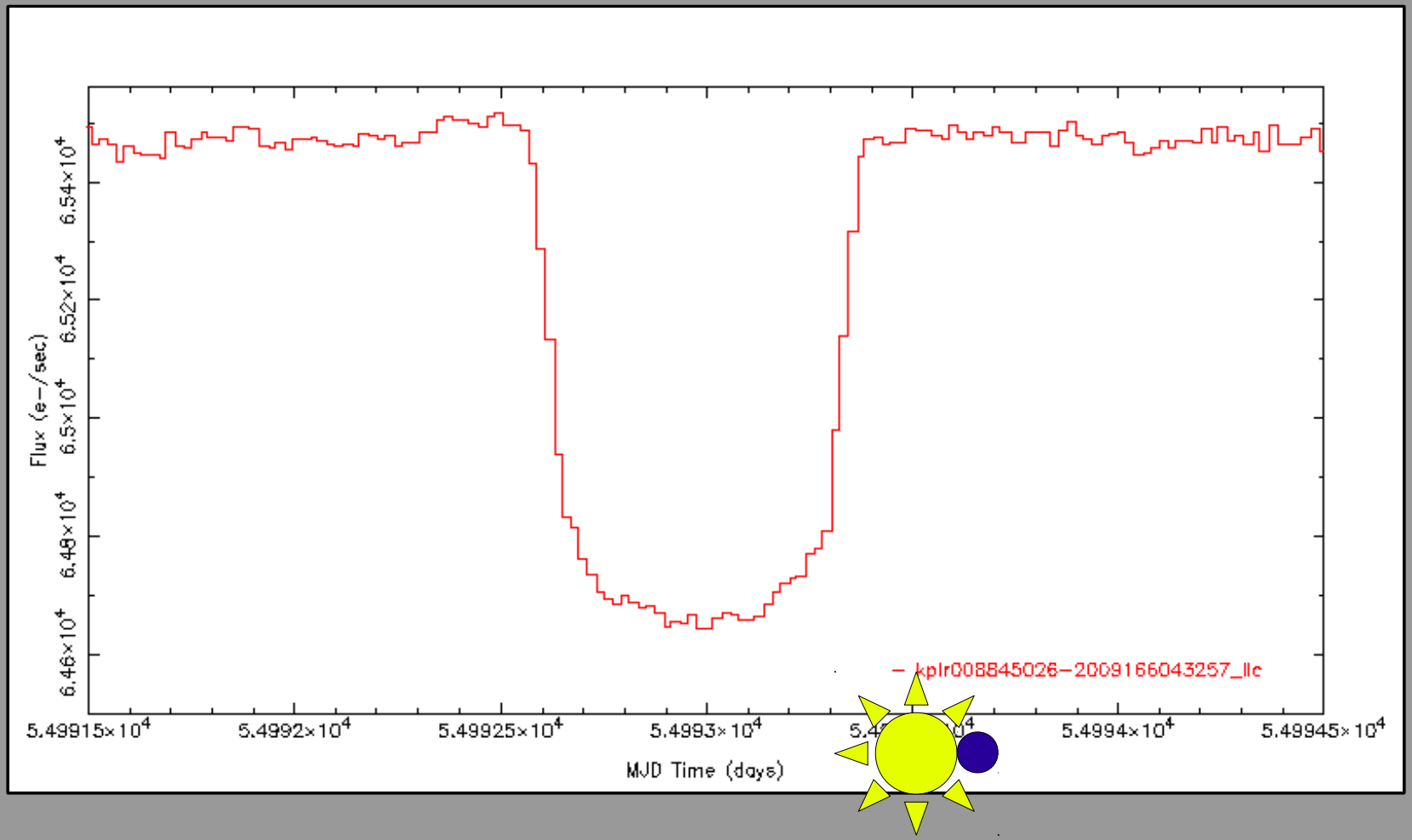

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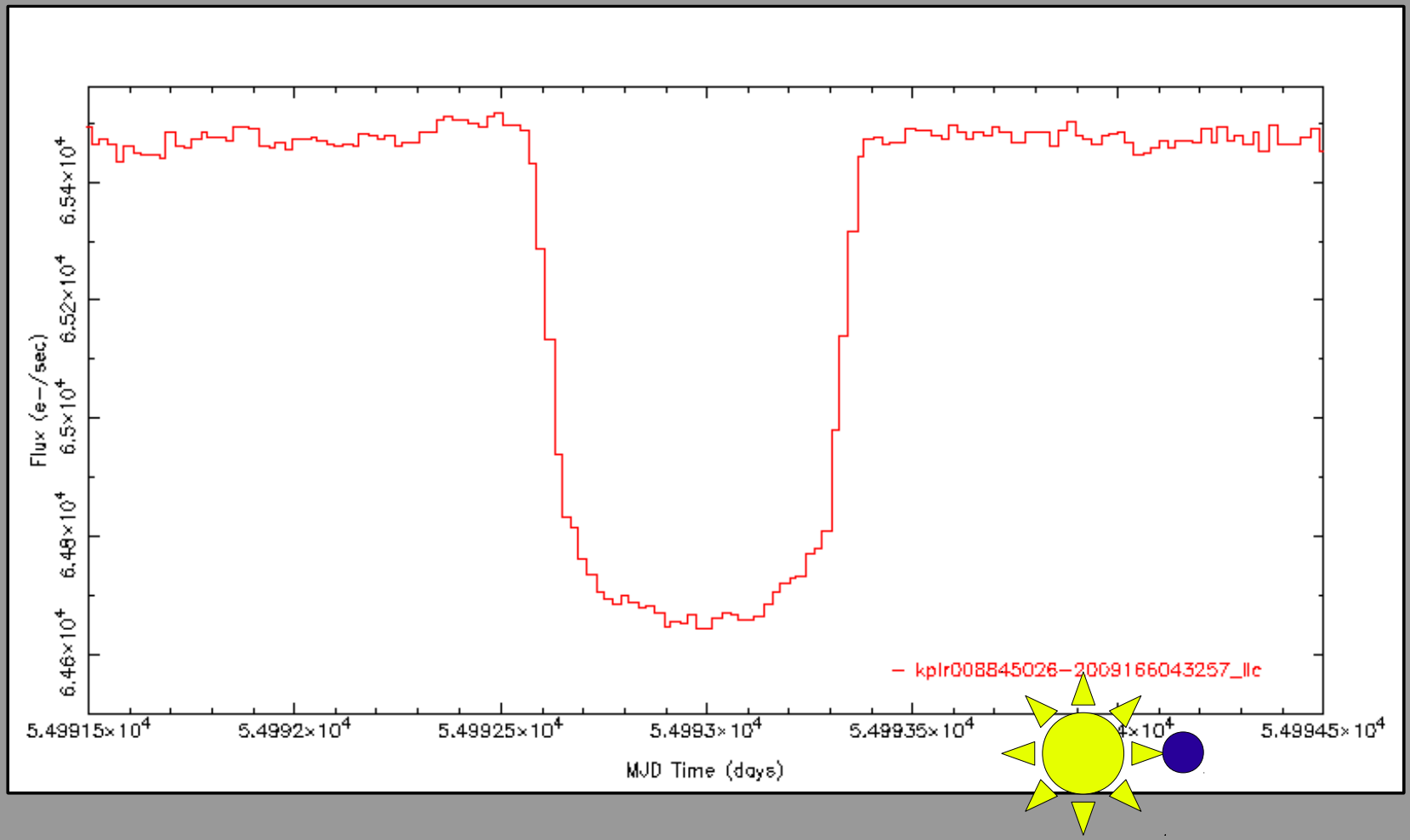

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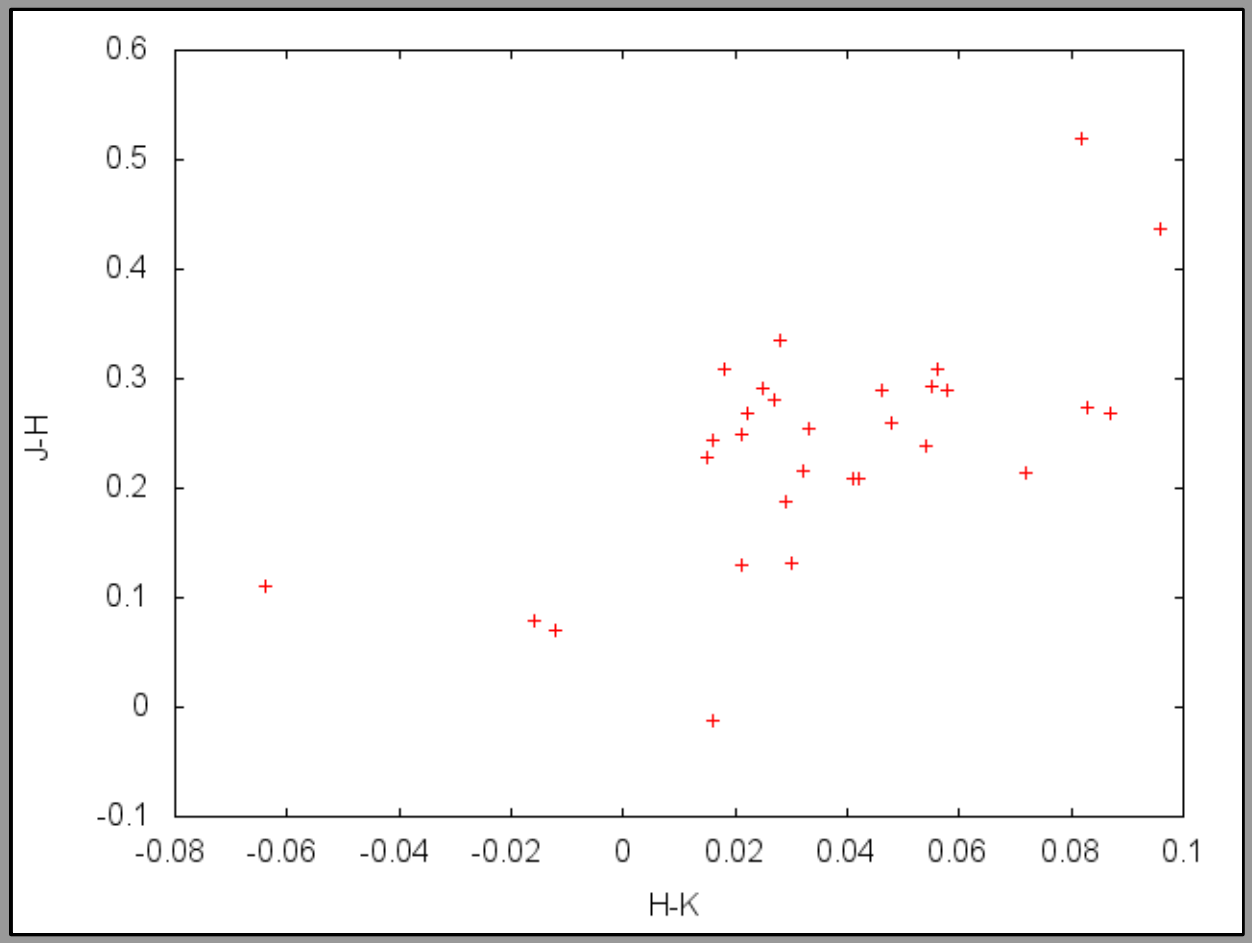
Color-color Diagram



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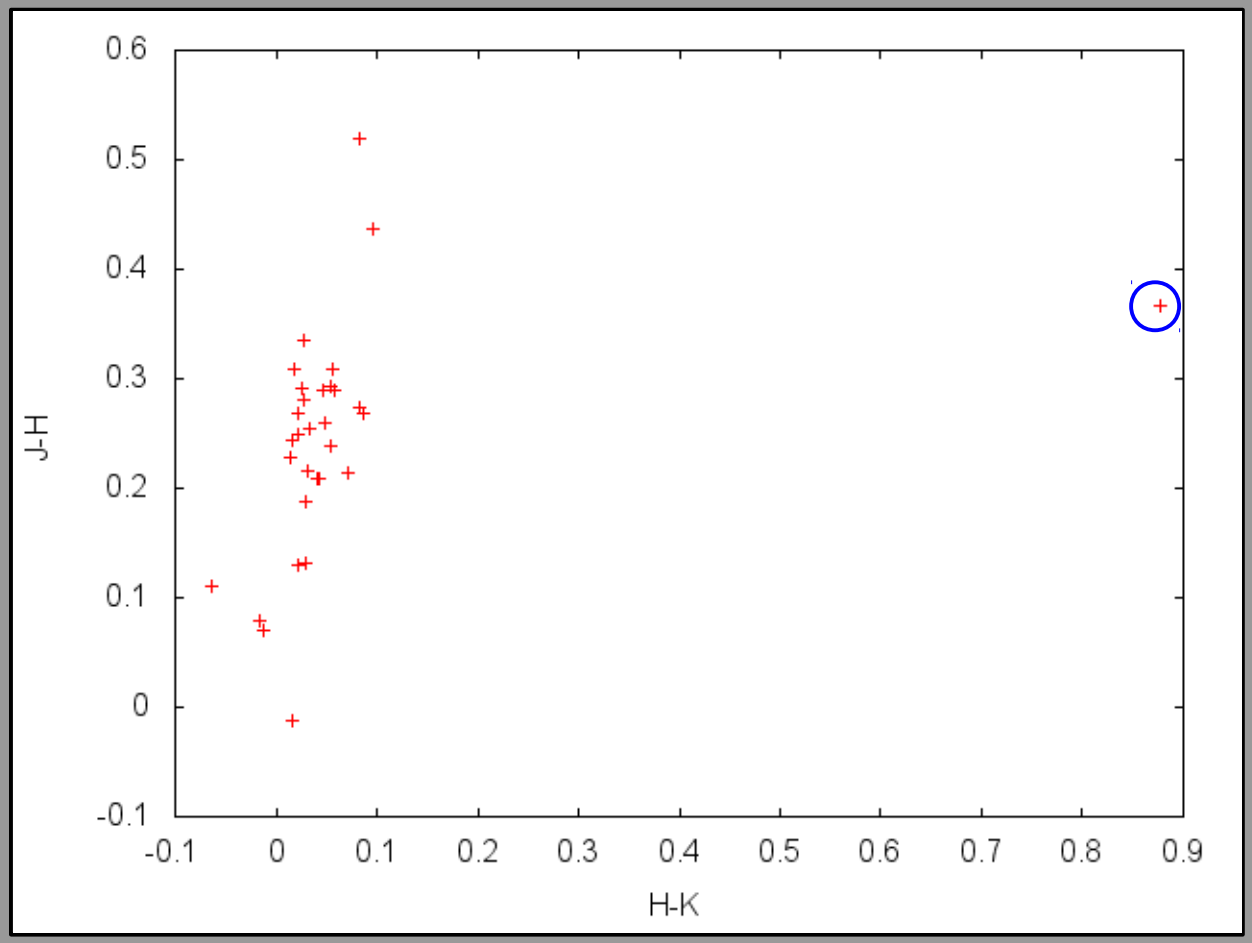
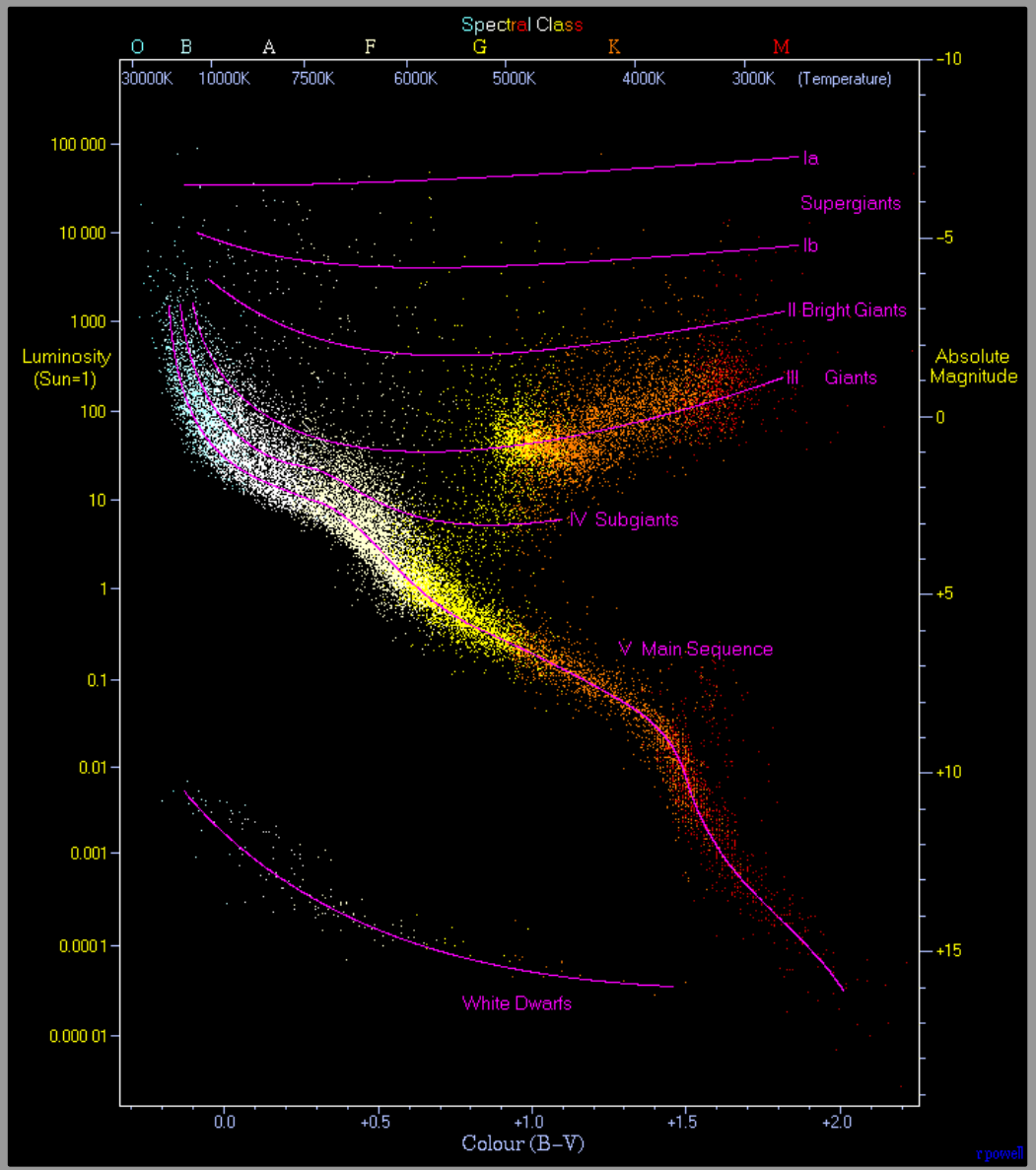
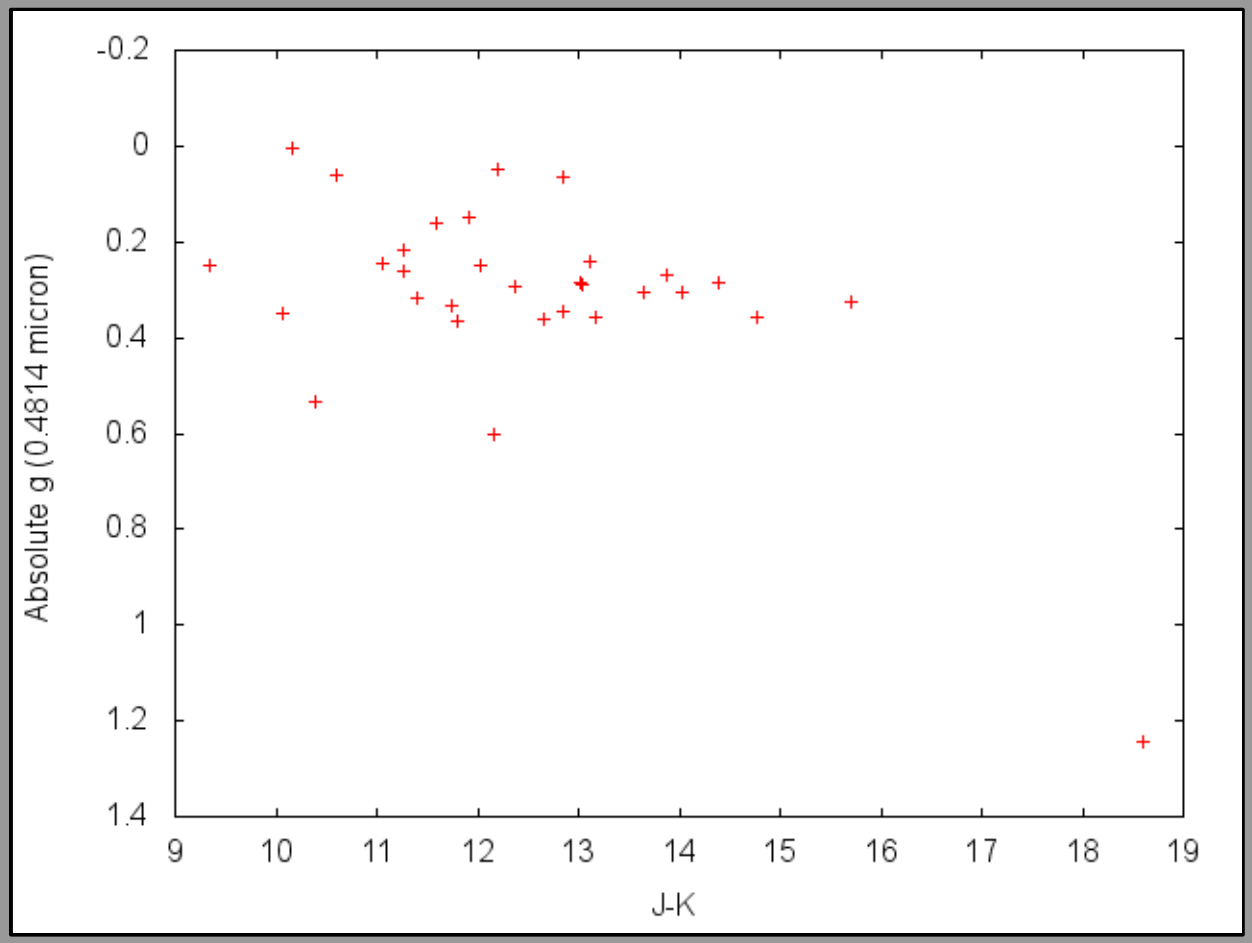


HR Diagram



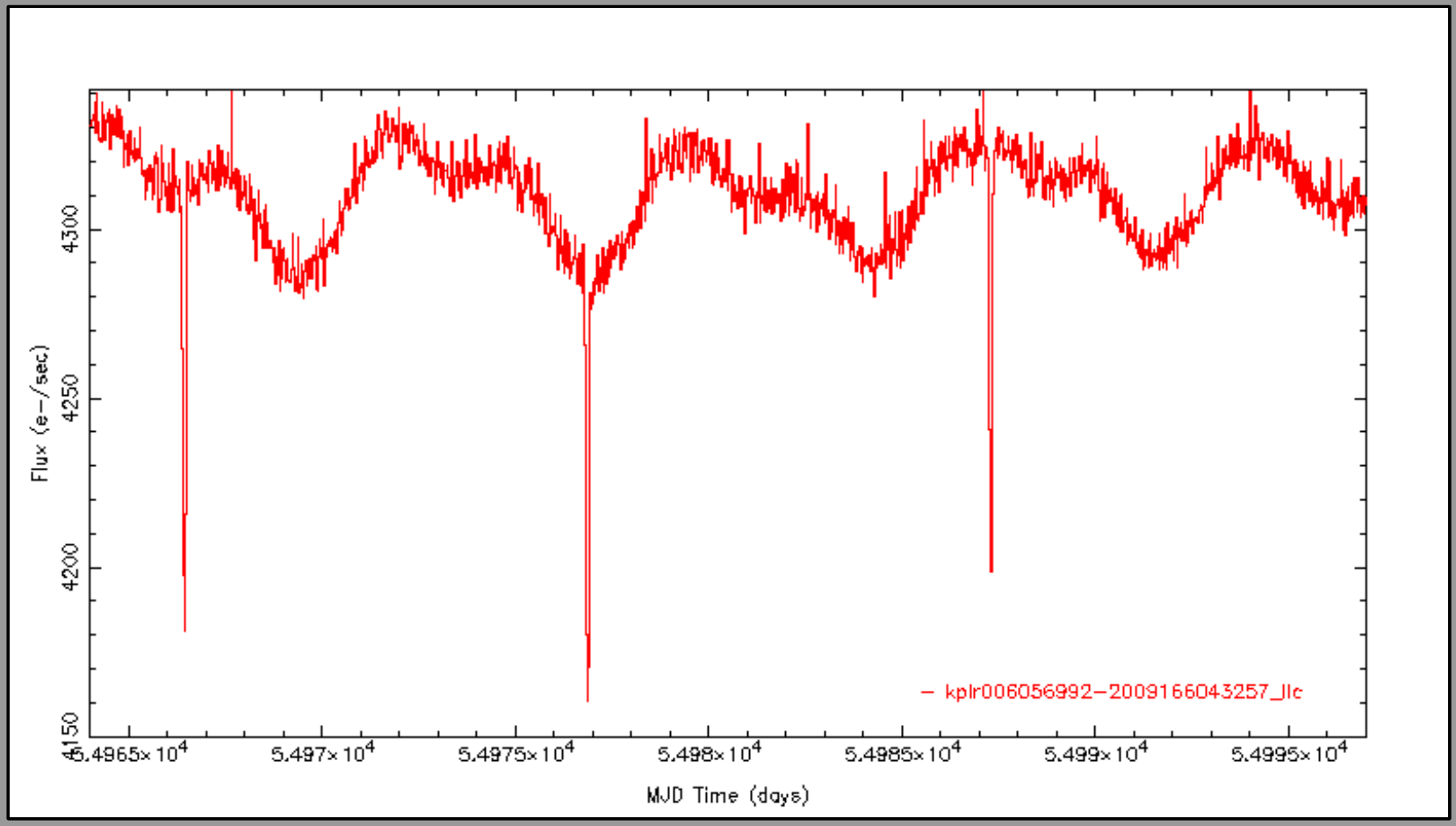
http://en.wikipedia.org/wiki/Hertzsprung%E2%80%93Russell_diagram

HR Diagram



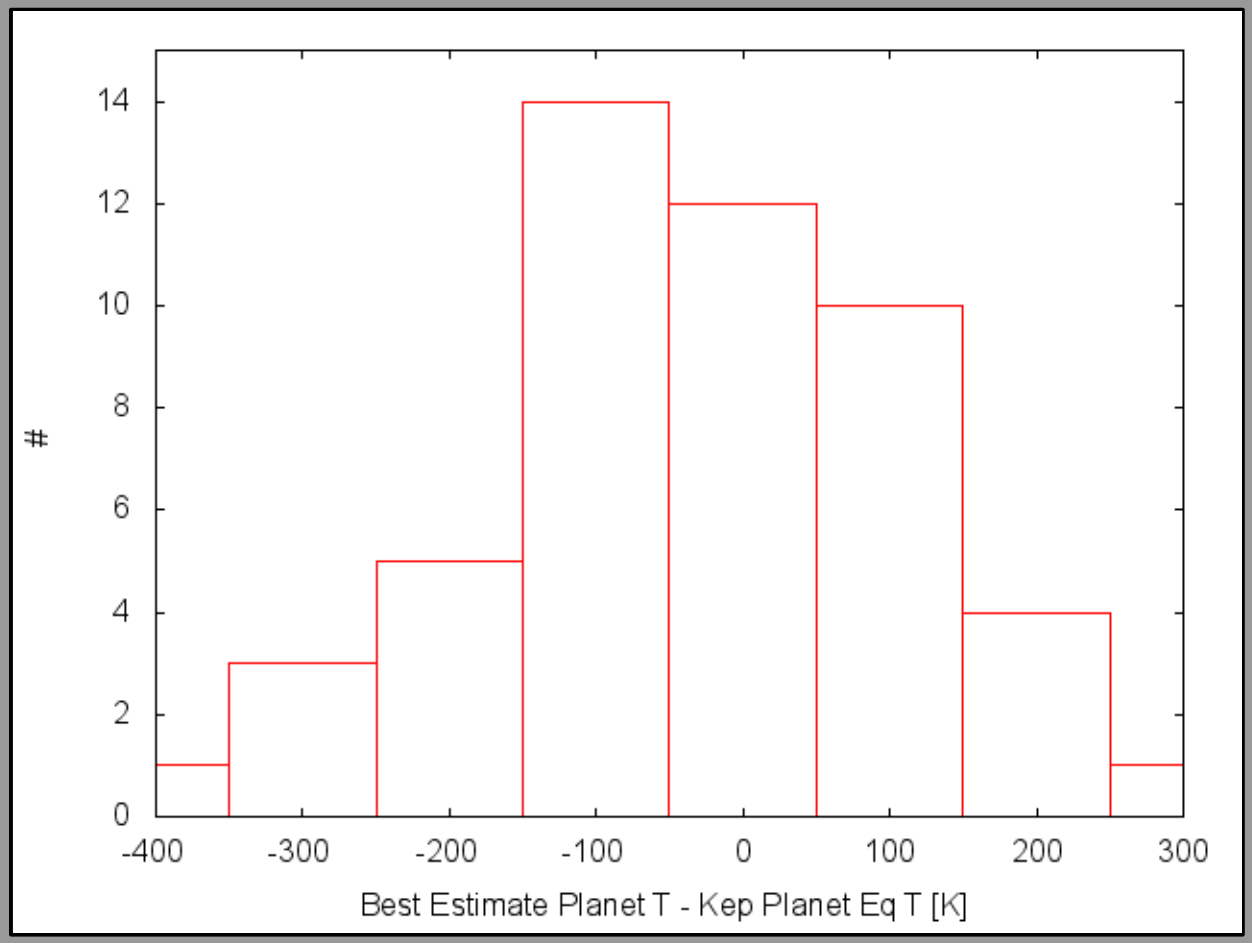
Just a red dwarf?

Outlier Light Curve



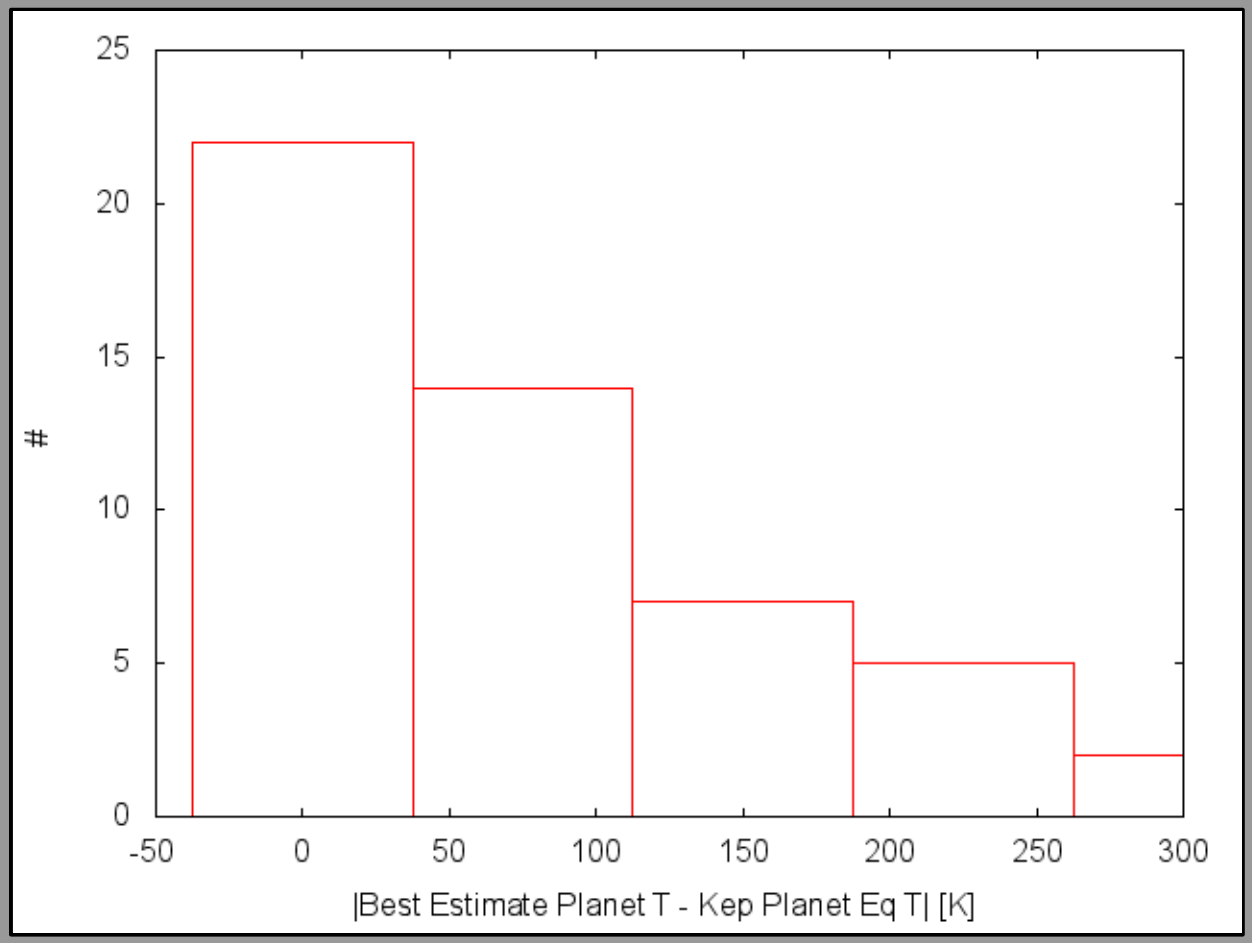
KID 6056992
T_p = 272 K
d = 26 pc
a = 0.05 AU

Temperature Estimate Comparison



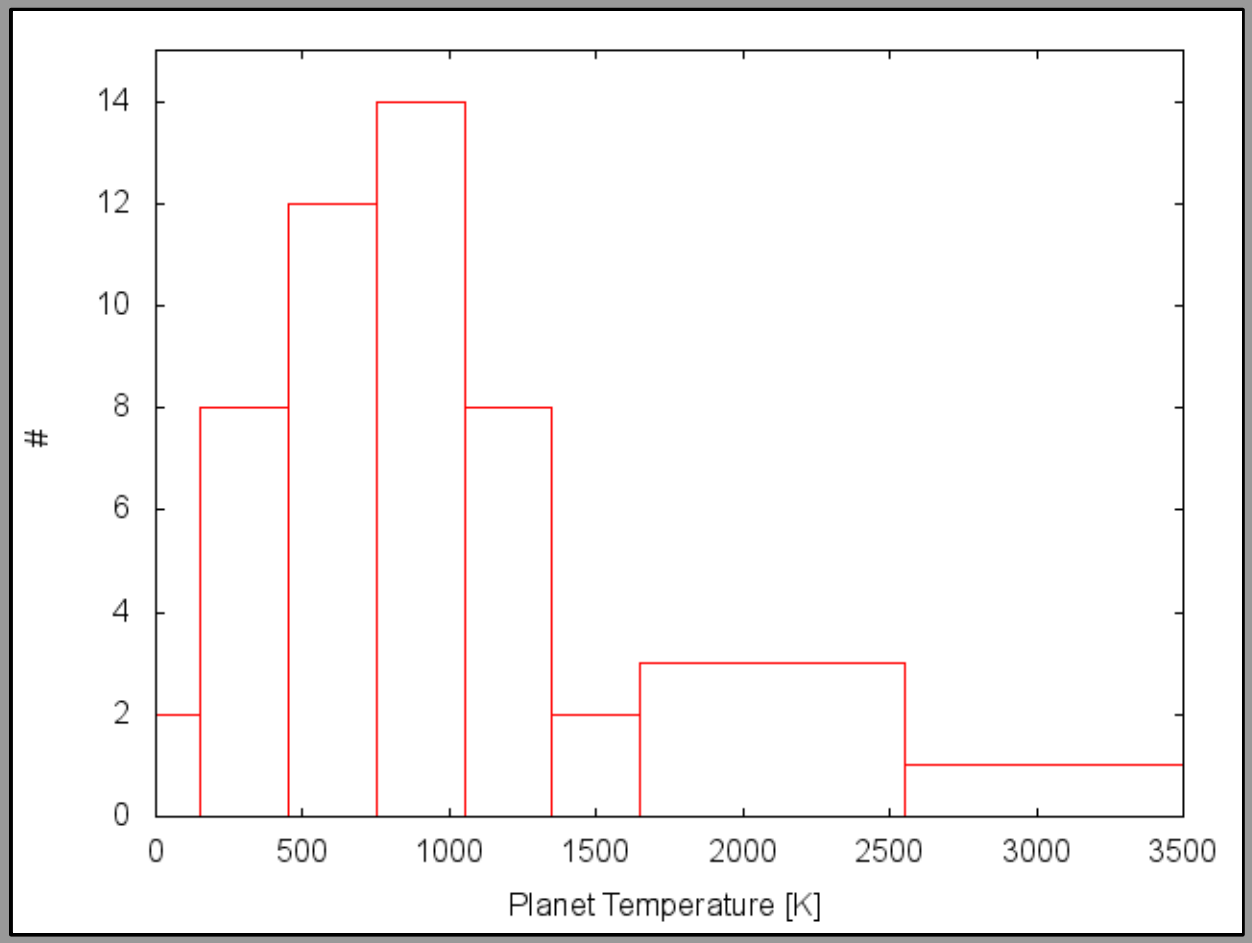
$$\sigma \approx 141 \text{ K}$$

Temperature Estimate Comparison cont.



$$|\Delta T| \approx 100 \text{ K}$$

Planet Temperature Distribution



$$f_{\rm HZ} = \frac{N(200 \lesssim T_p \lesssim 500)}{N_p} \approx 0.2 \pm 0.07$$

Summary

- Planets appear to be quite common
- Kepler is a powerful tool for identifying planets
- Fraction of planets existing in habitable zone is non-negligible

References

- Batalha et. al. (2012) “Planetary Candidates Observed by *Kepler* III: Analysis of the First 16 Months of Data”
- Straižys (1992) “Multicolor Stellar Photometry”
- Allen & Cox (2000) “Allen's Astrophysical Quantities”
- Gautier & Gilliland (2005) “Expected effects of hot CCD pixels on detection of transits of extra-solar planets with the *Kepler Mission*”
- NASA/IPAC Infrared Science Archive
- 2MASS GATOR
- MAST Kepler Data Archive