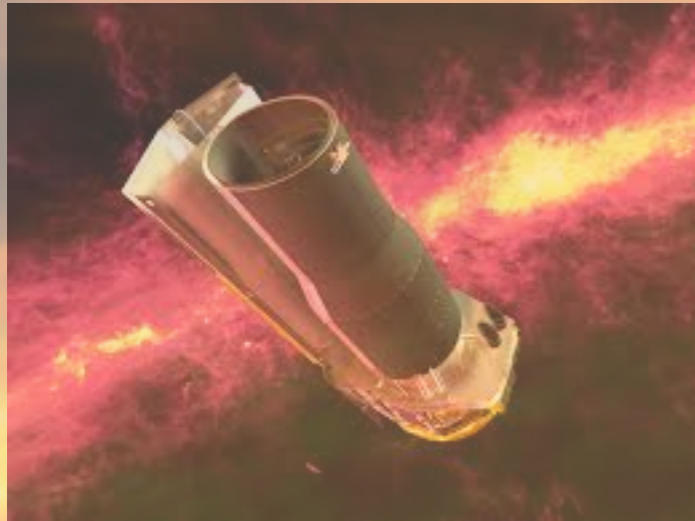


# Notes on a Multi-Transit Spitzer Campaign for HD 97658b



**Diana Dragomir**

UCSB/Las Cumbres Observatory Global Telescope ( [LCOGT.net](http://LCOGT.net) )

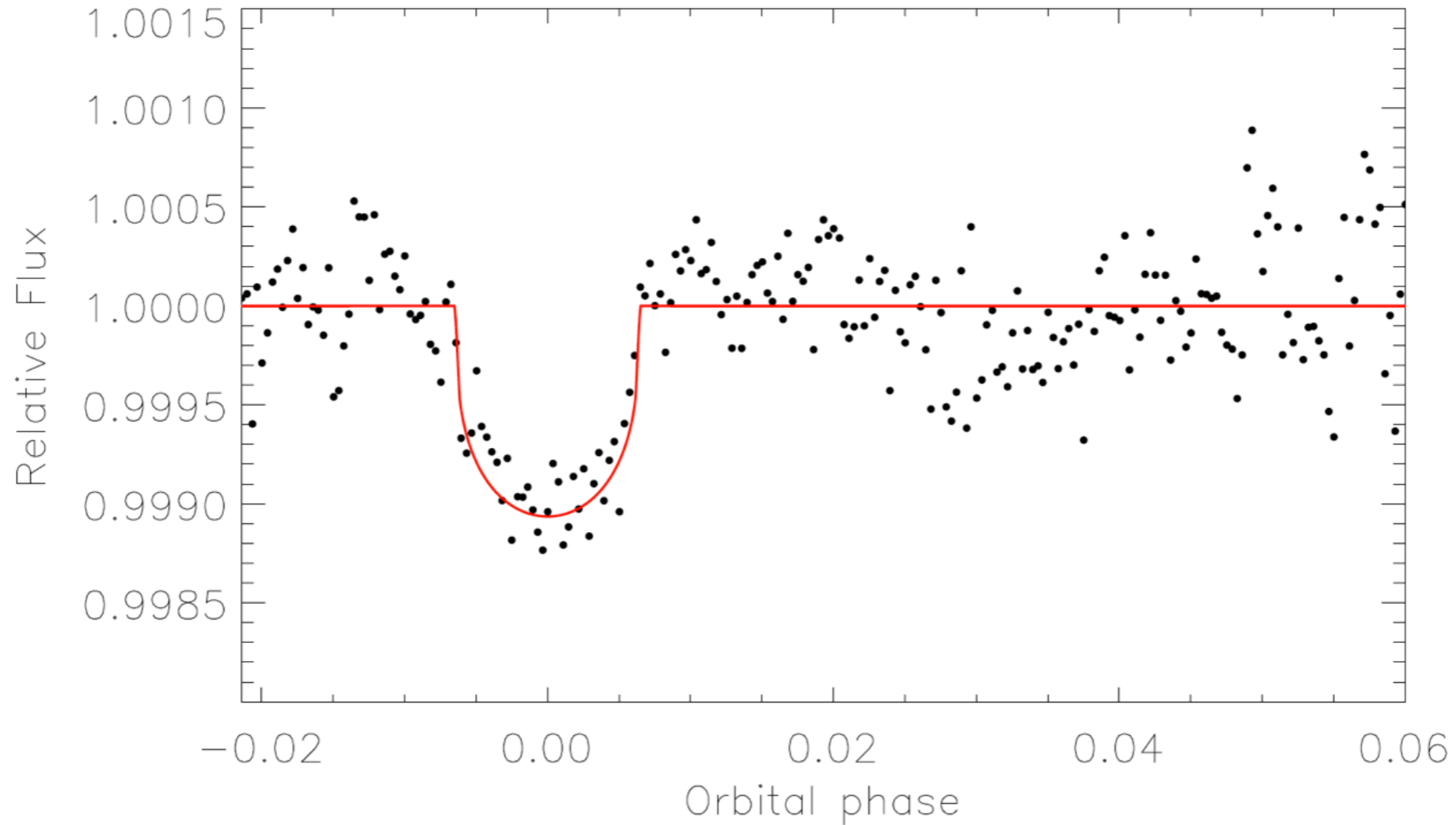
--> University of Chicago

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*IRAC 2nd Workshop on High Precision Time Series Photometry*

*Honolulu, August 7, 2015*

# HD 97658b



Dragomir et al. (2013)

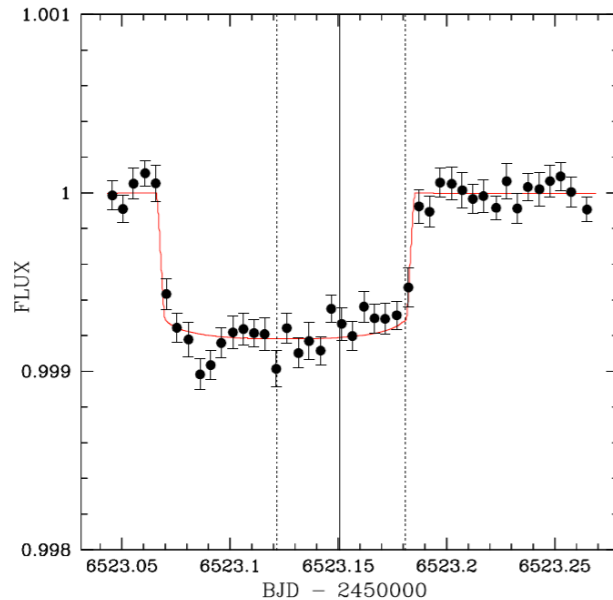
**Phased MOST light curve**

planetary radius =  $2.34 \pm 0.16 R_{\text{Earth}}$   
planetary mass =  $7.86 \pm 0.73 M_{\text{Earth}}$   
planetary mean density =  $3.4 \pm 0.7 \text{ g/cm}^3$

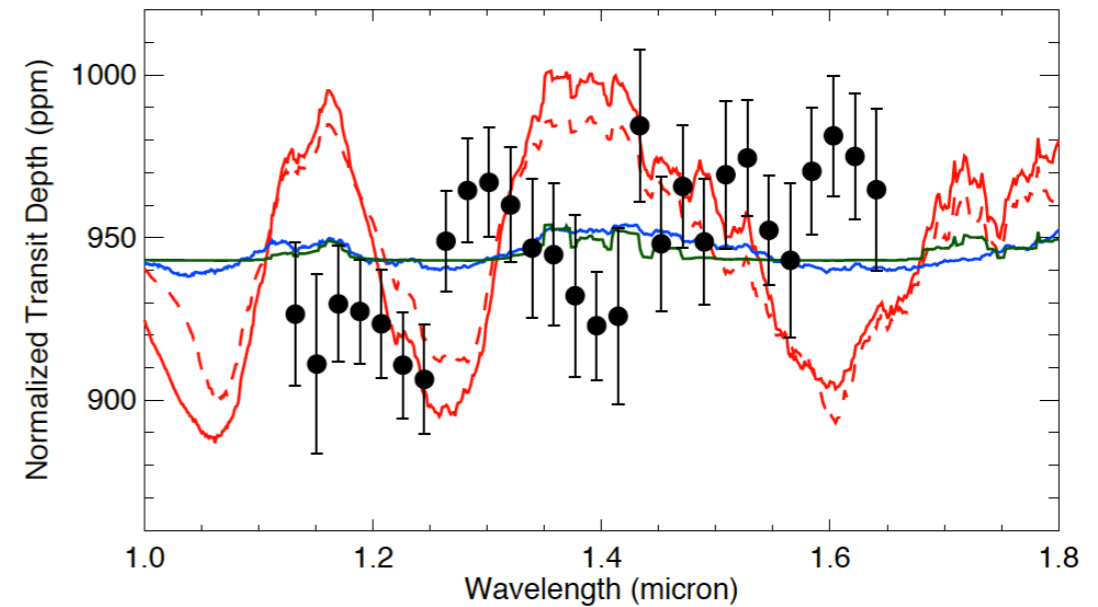
stellar radius =  $0.703 \pm 0.035 R_{\text{Sun}}$   
stellar mass =  $0.747 \pm 0.030 M_{\text{Sun}}$

period =  $9.4894 \pm 0.0002 \text{ days}$   
orbital inclination =  $89.45 \pm 0.4 \text{ deg}$

# HD 97658b: Transmission Spectroscopy

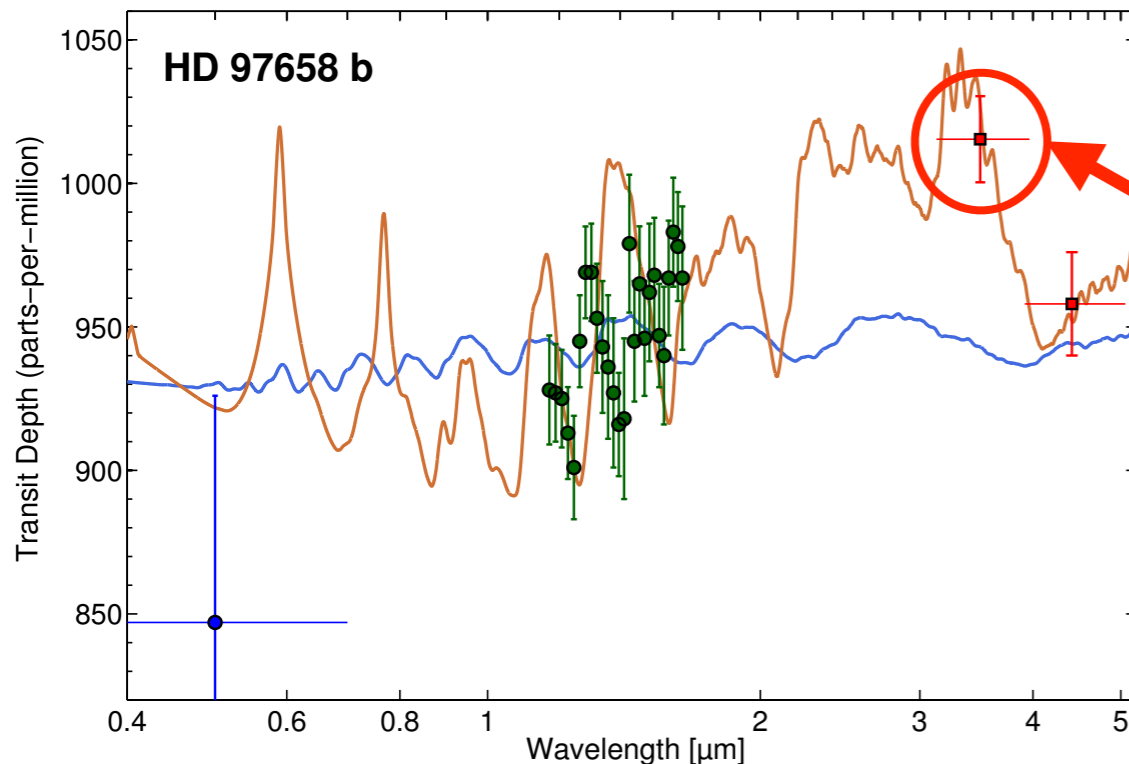


Van Grootel et al. (2014)



(Knutson et al. (2014))

## Spitzer 4.5 $\mu\text{m}$ transit of HD 97658b



The HD 97658b WFC3 transmission spectrum is inconsistent with the solar cloud-free model at the  $17\sigma$  level.

Six *Spitzer* transits at 3.6  $\mu\text{m}$ , currently being analysed (PI: D. Dragomir)

**Expect < 42 ppm per-transit uncertainties**

# **HD 97658b: Spitzer 3.6 $\mu\text{m}$ Transit Observations**

**(PID 10105)**

**Visit 1: July 26, 2014**

**Visit 2: Aug. 14, 2014**

**Visit 3: Aug. 23, 2014**

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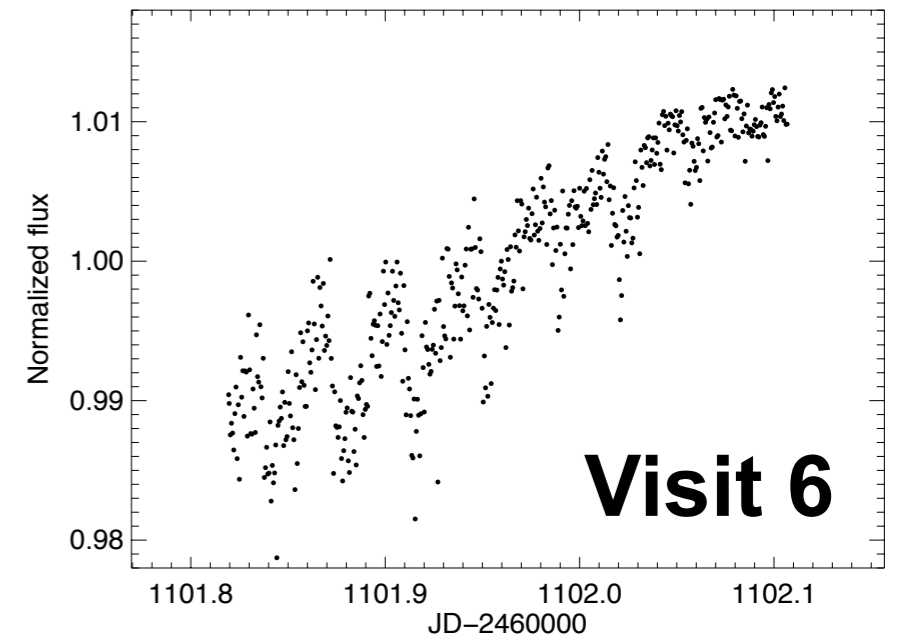
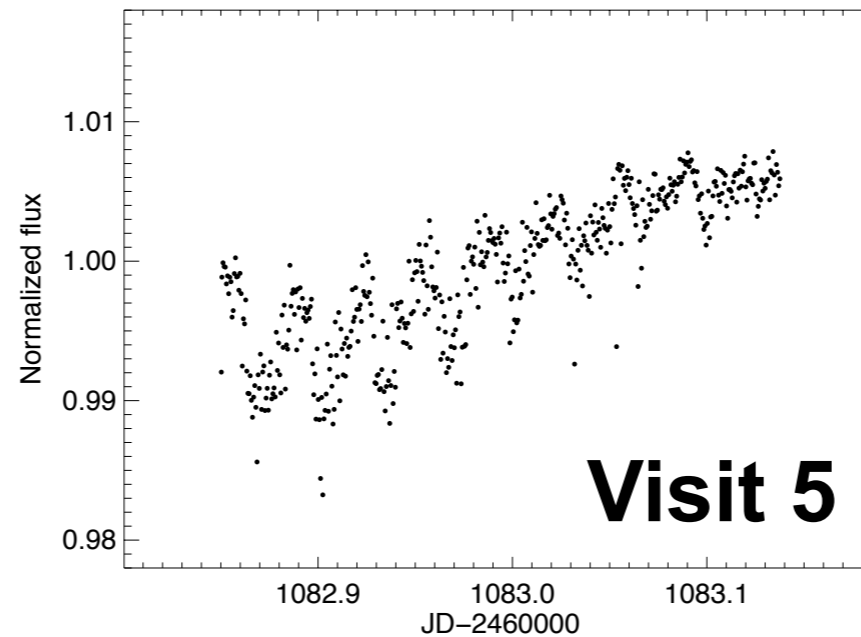
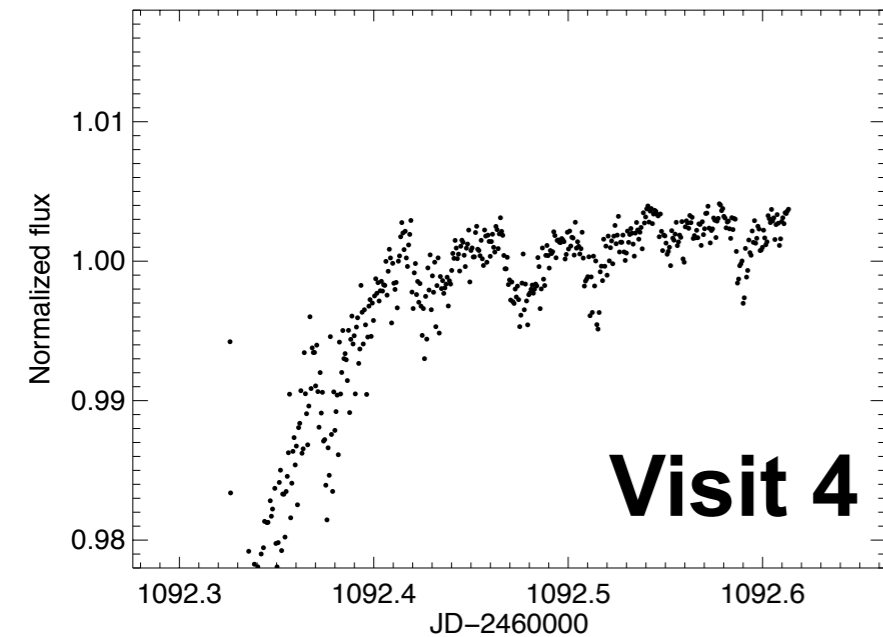
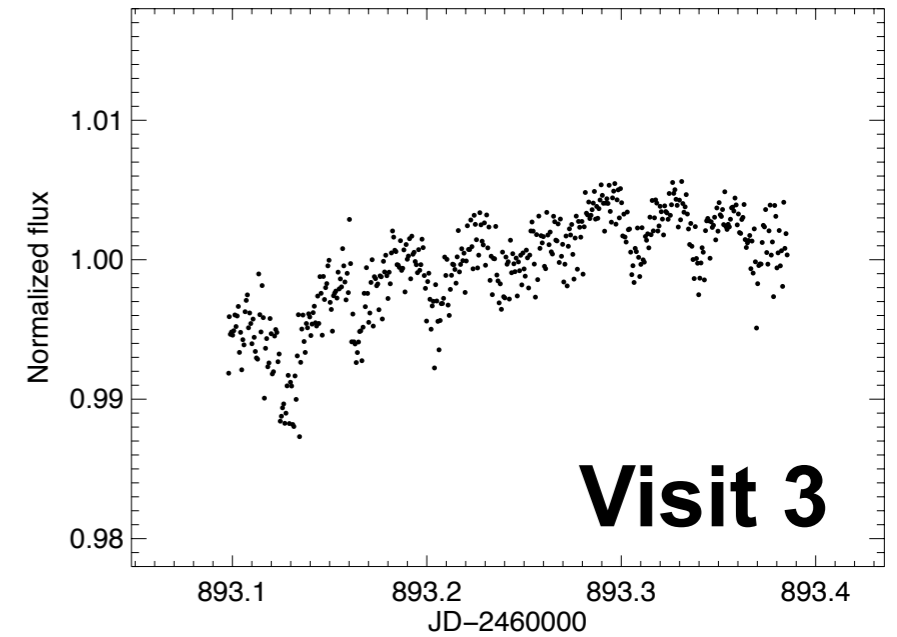
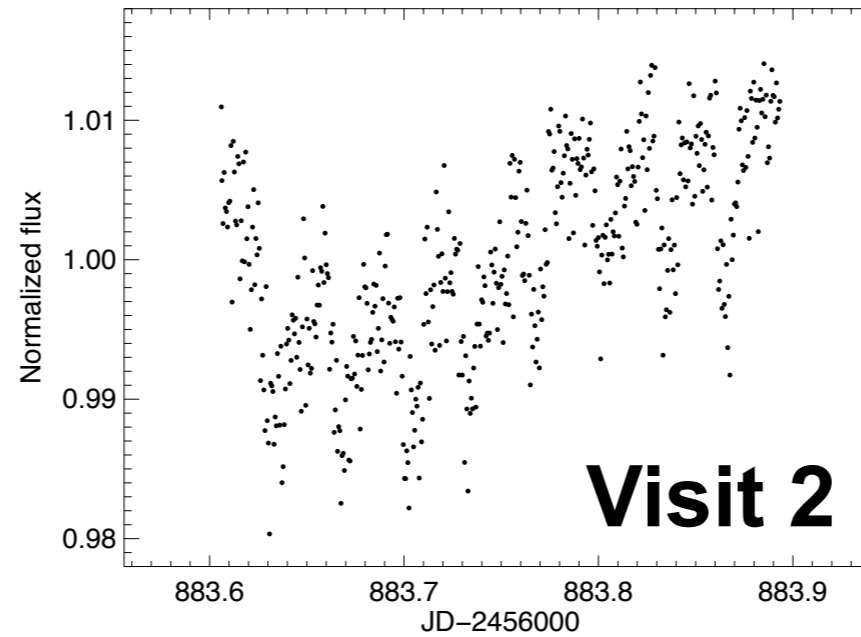
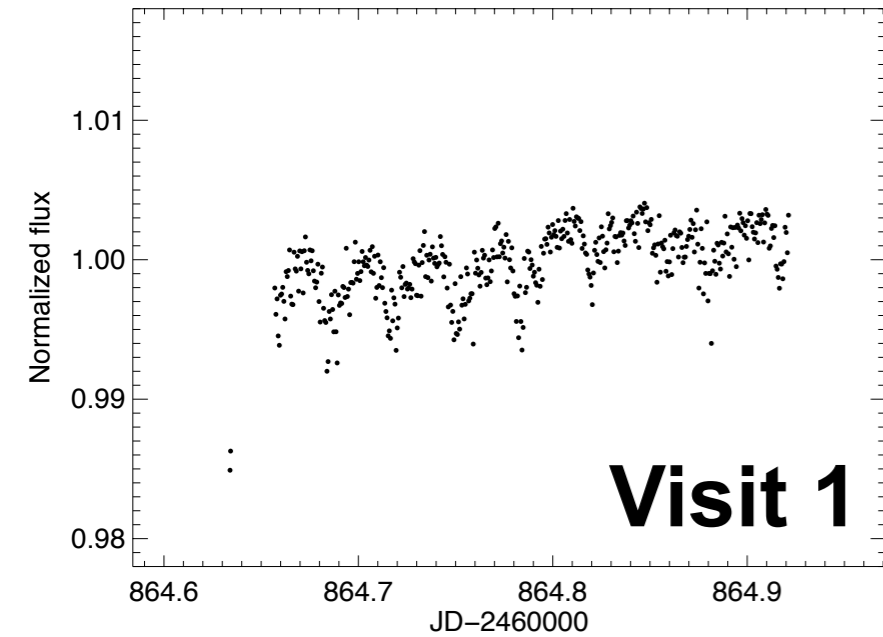
**Visit 4: Mar. 1, 2015**

**Visit 5: Mar. 10, 2015**

**Visit 6: Mar. 20, 2015**

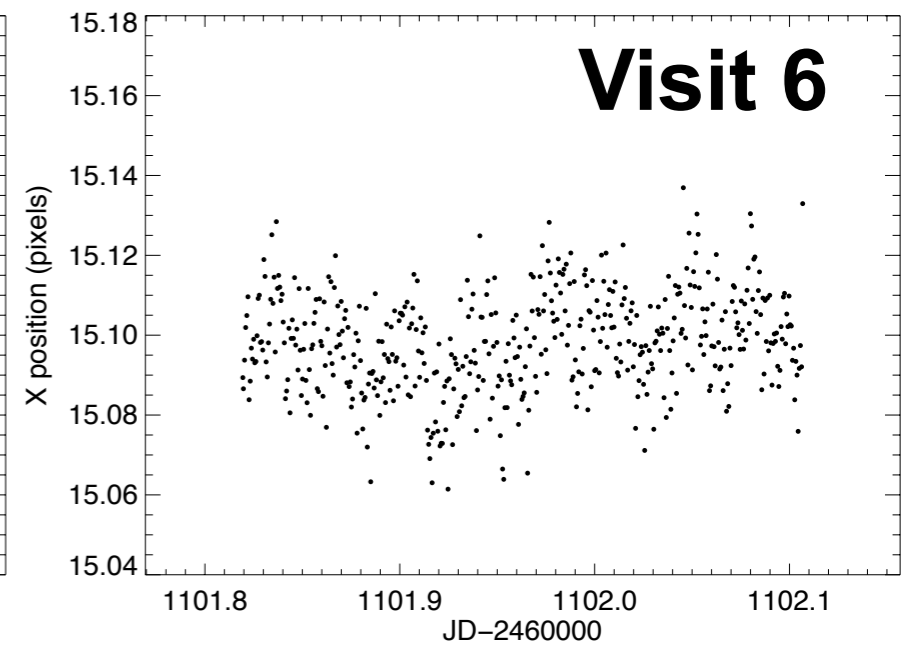
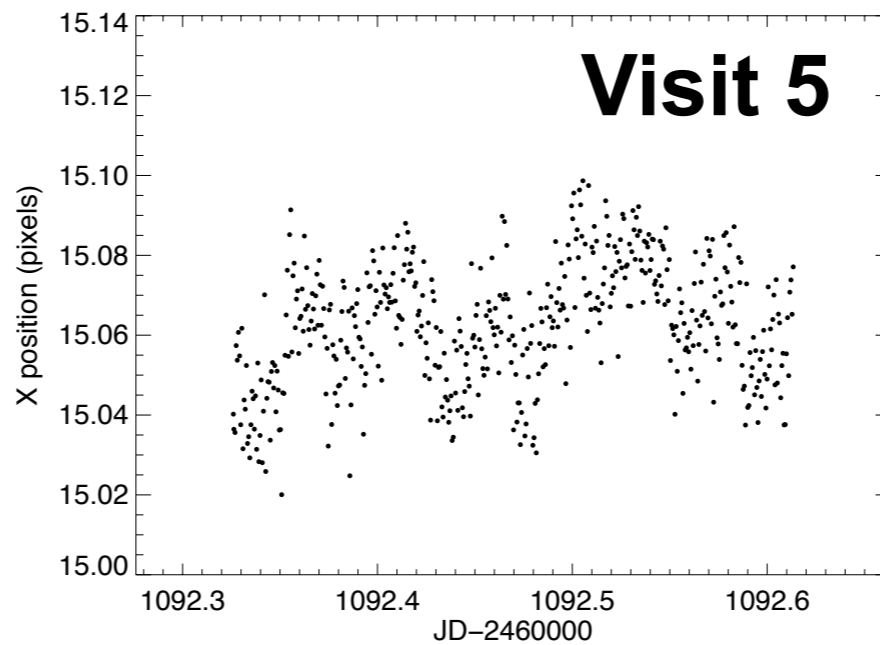
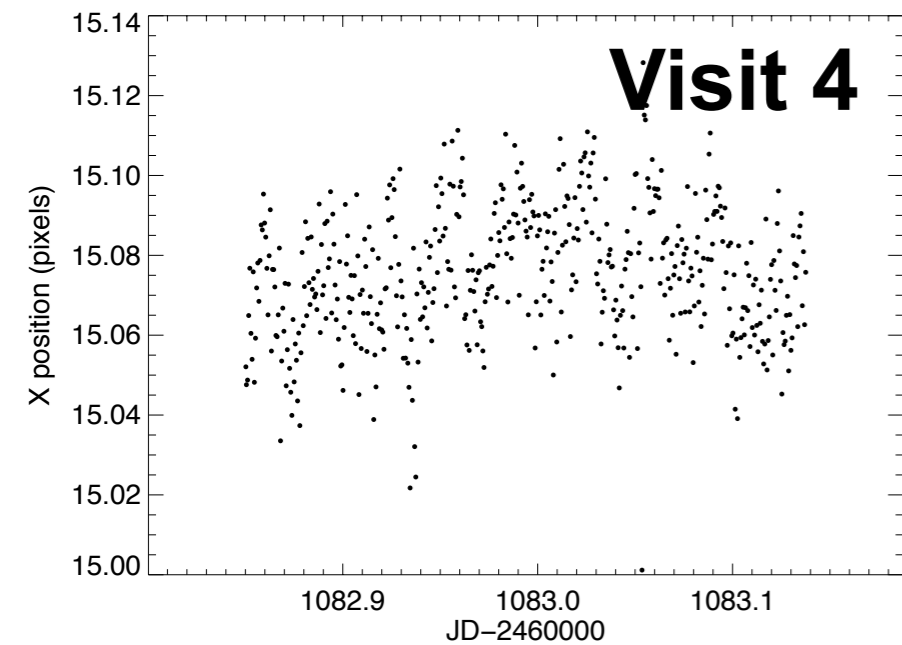
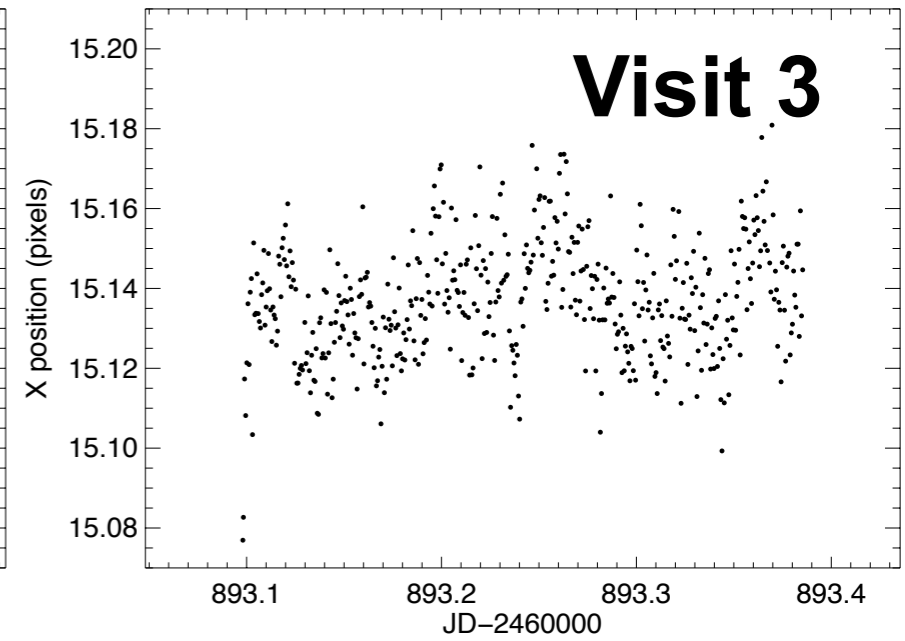
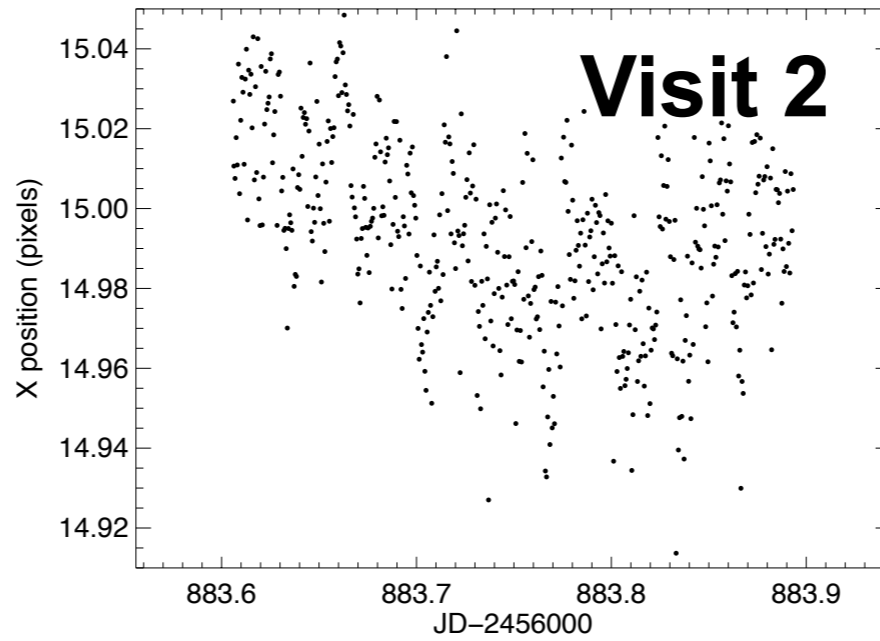
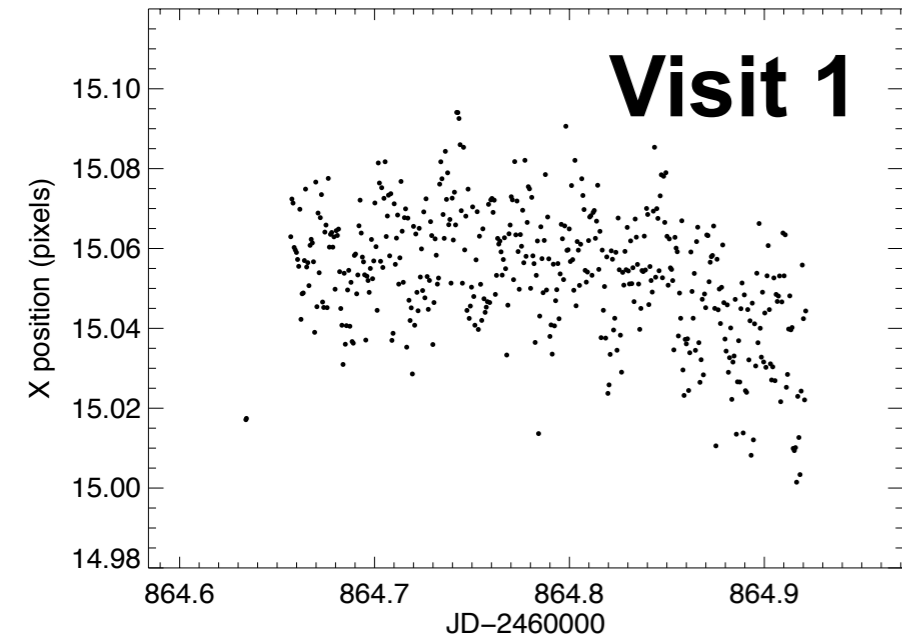
**All observations done in Peak-up mode**

# Raw light curves



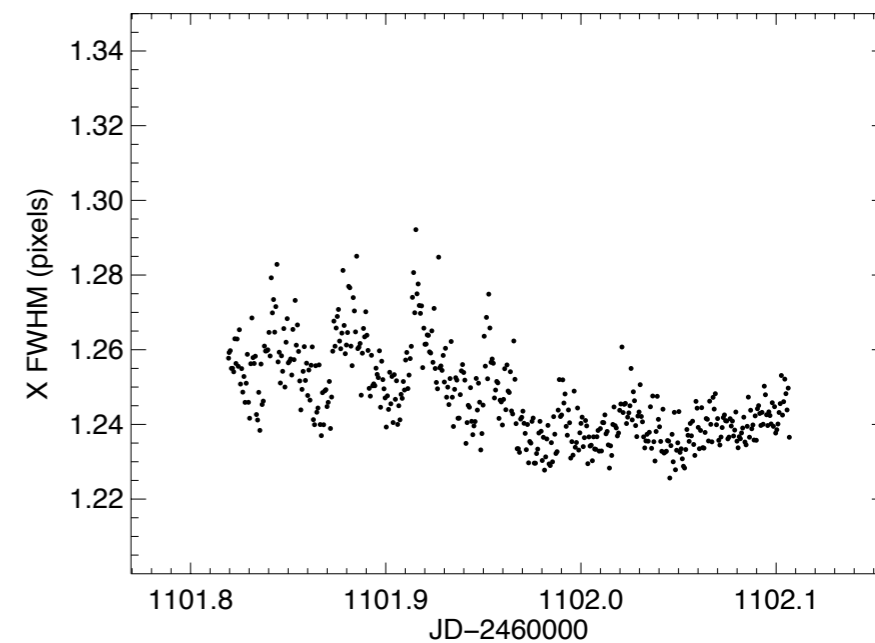
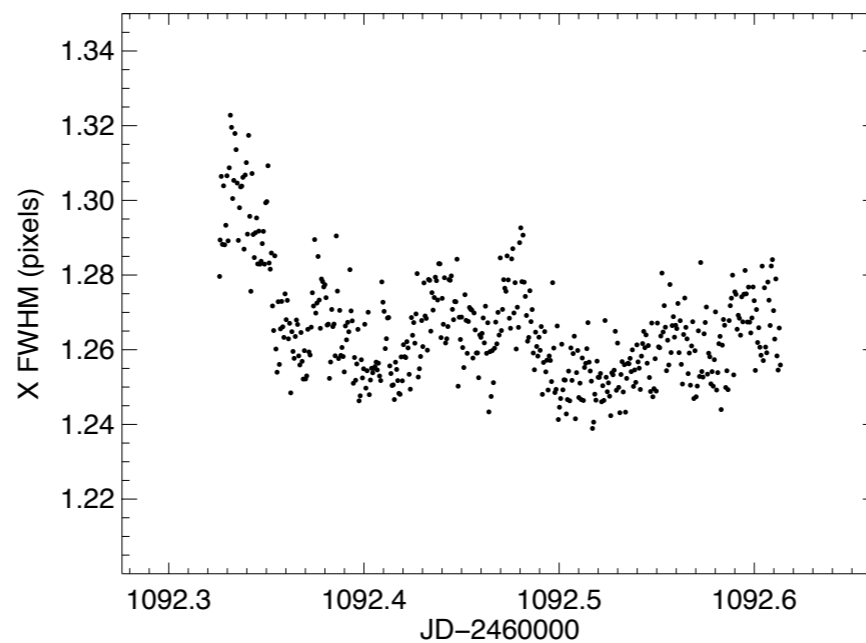
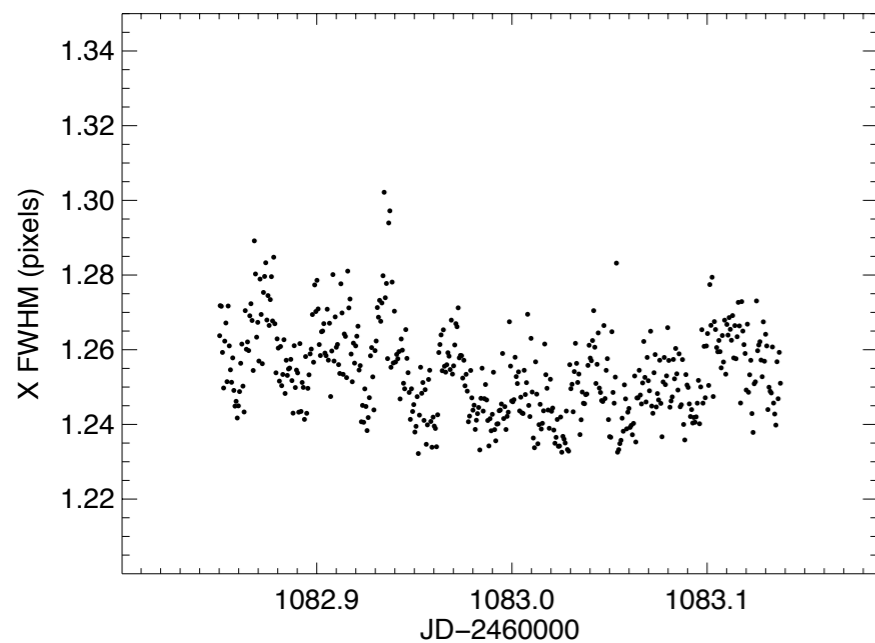
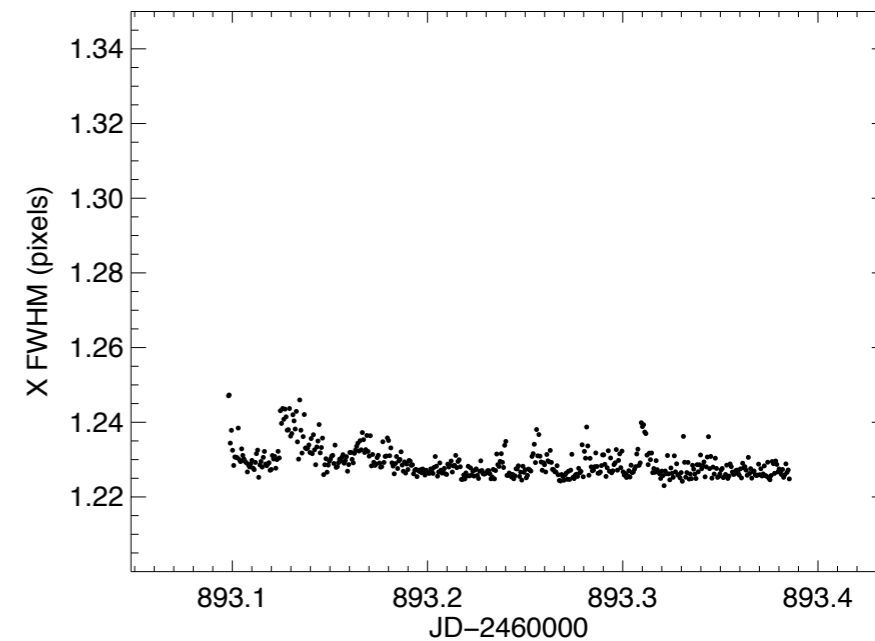
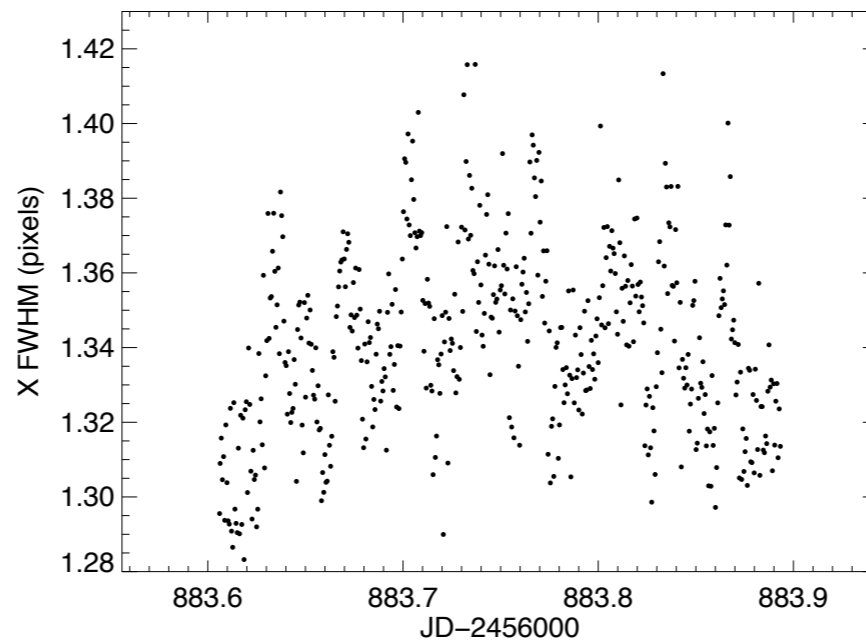
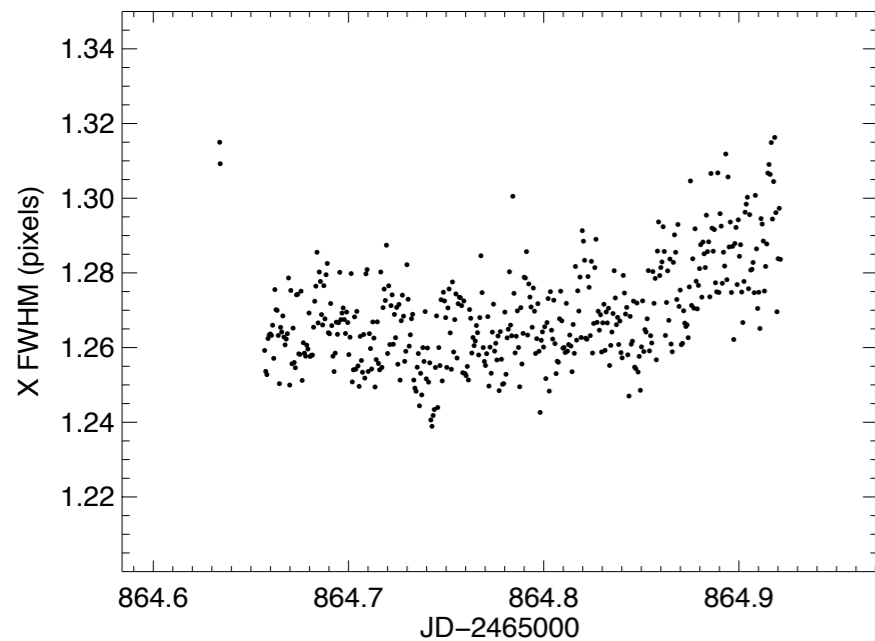
**Aperture: 3.5 pixels**

# X Position



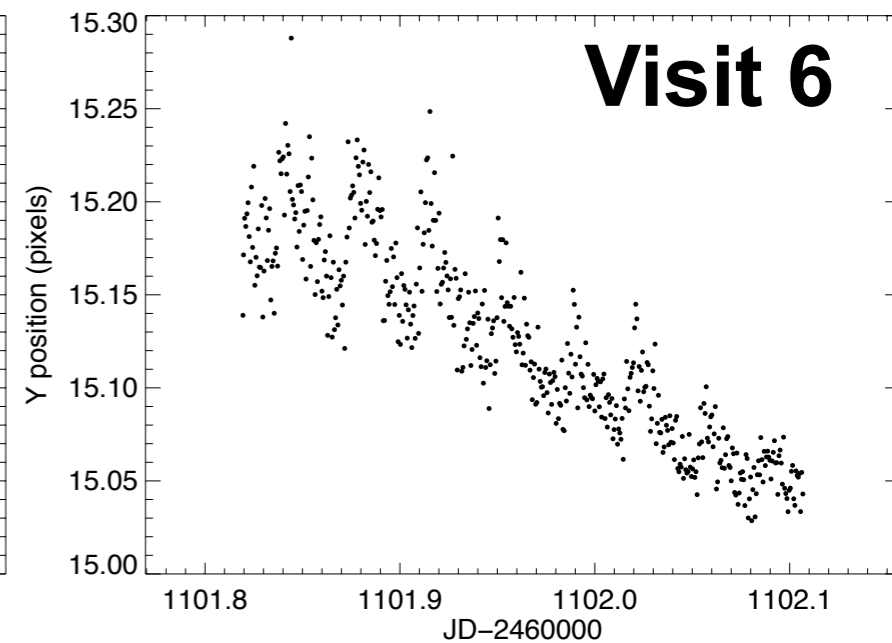
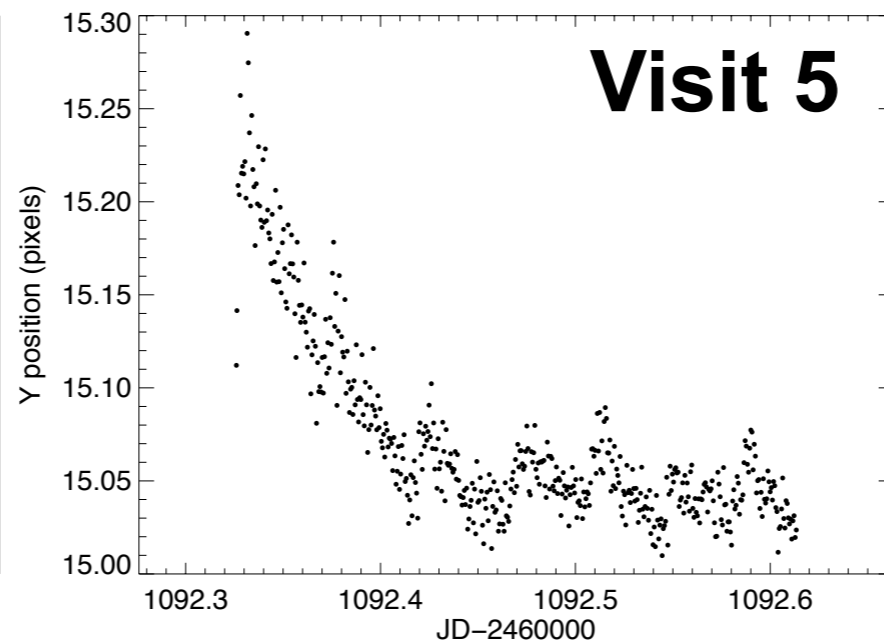
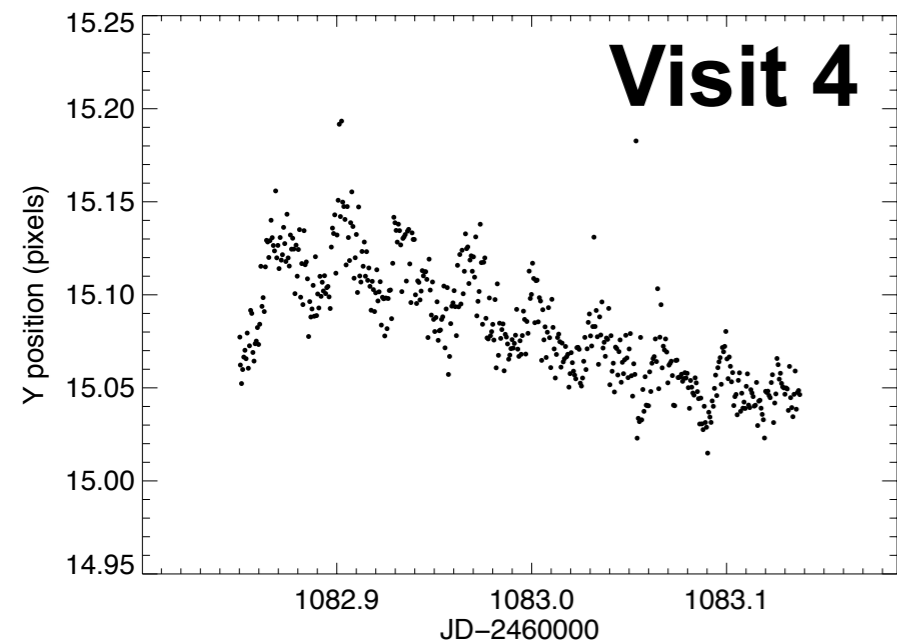
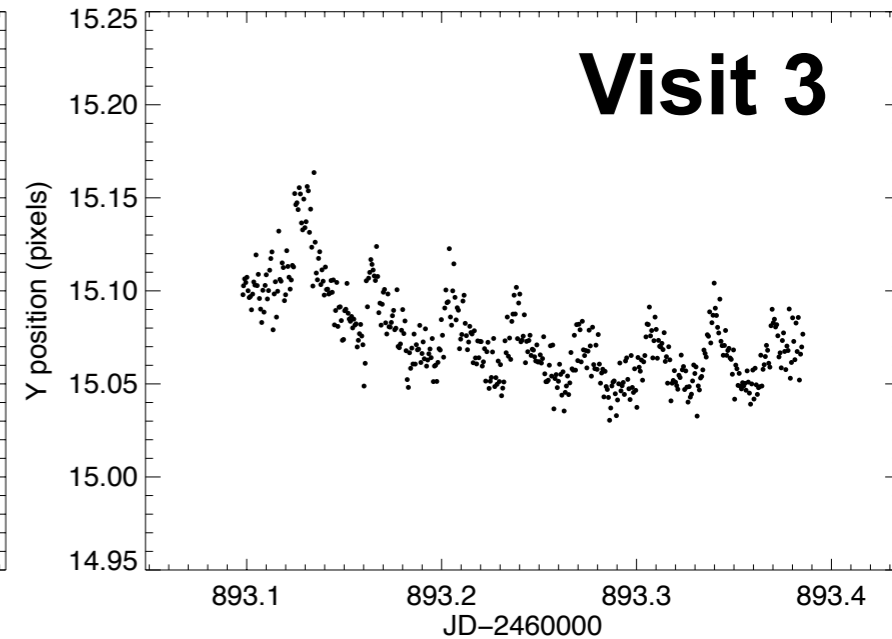
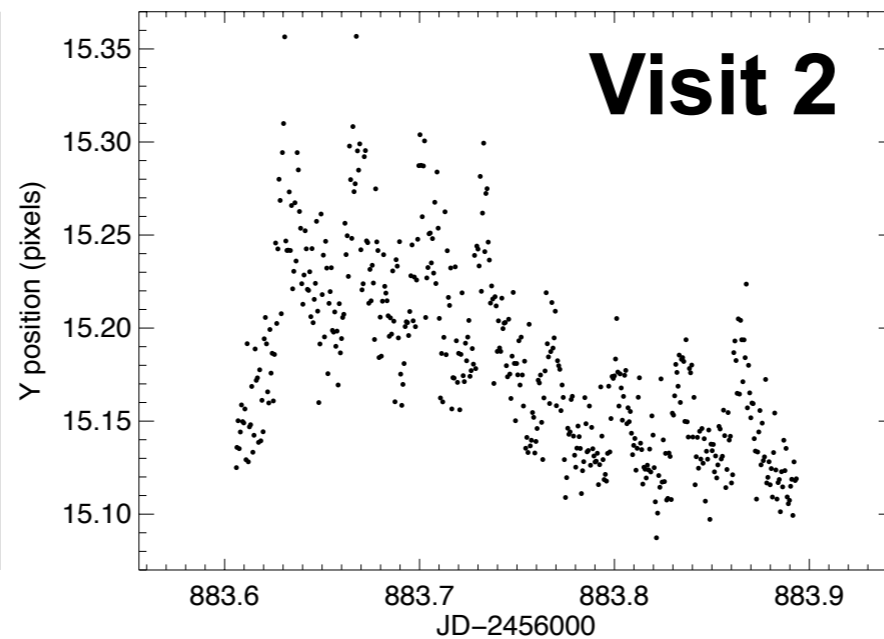
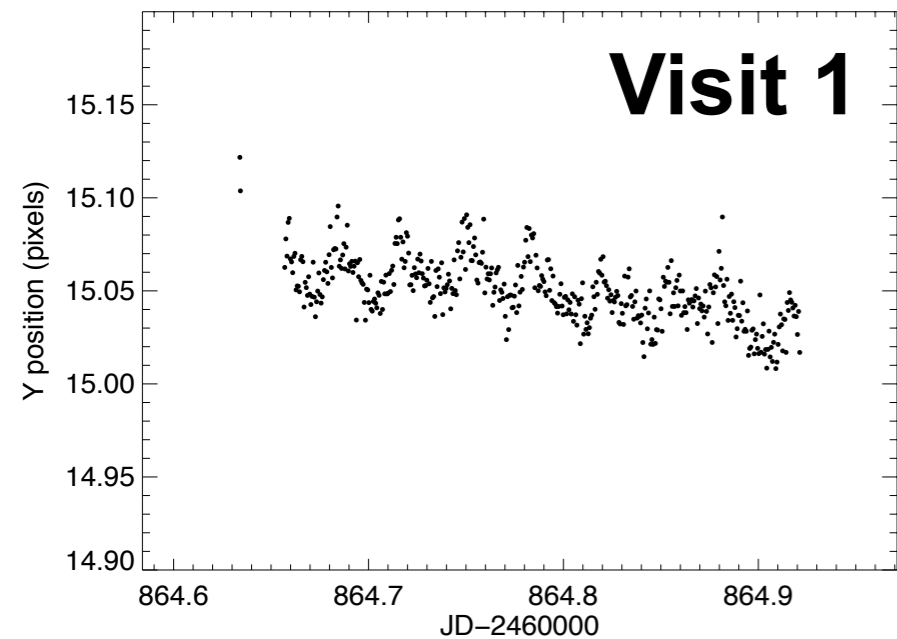
**Aperture: 3.5 pixels**

# X FWHM



**Aperture: 3.5 pixels**

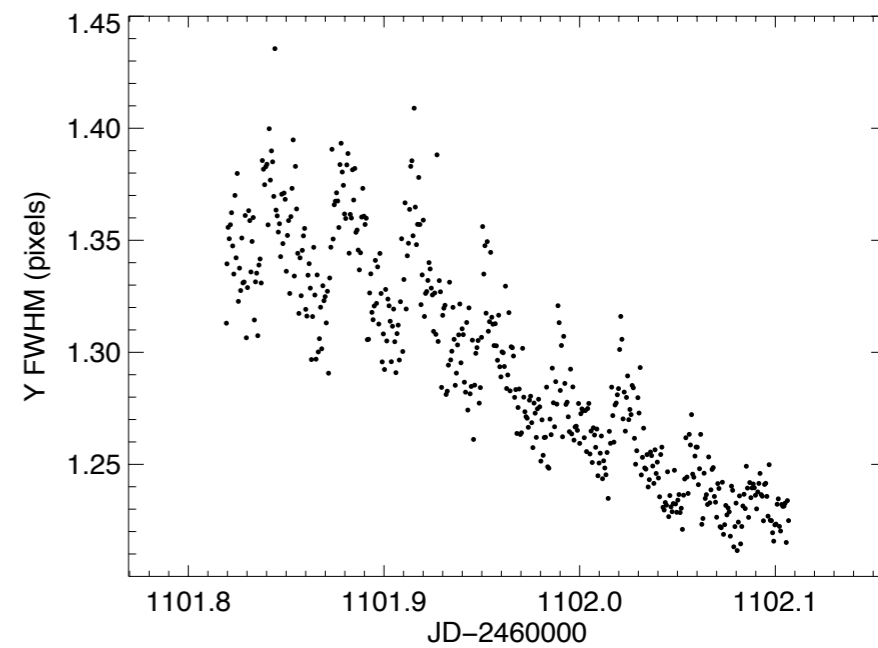
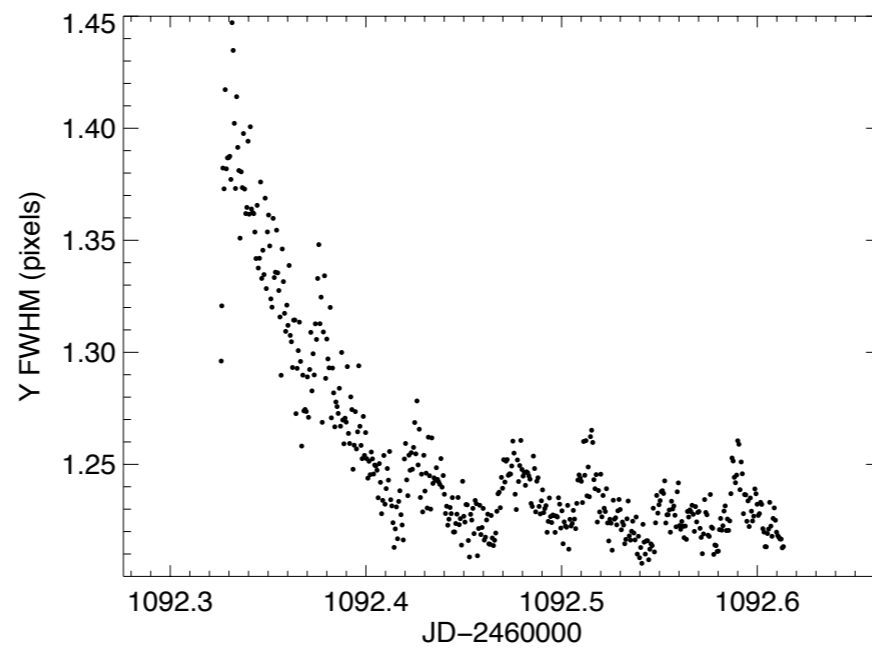
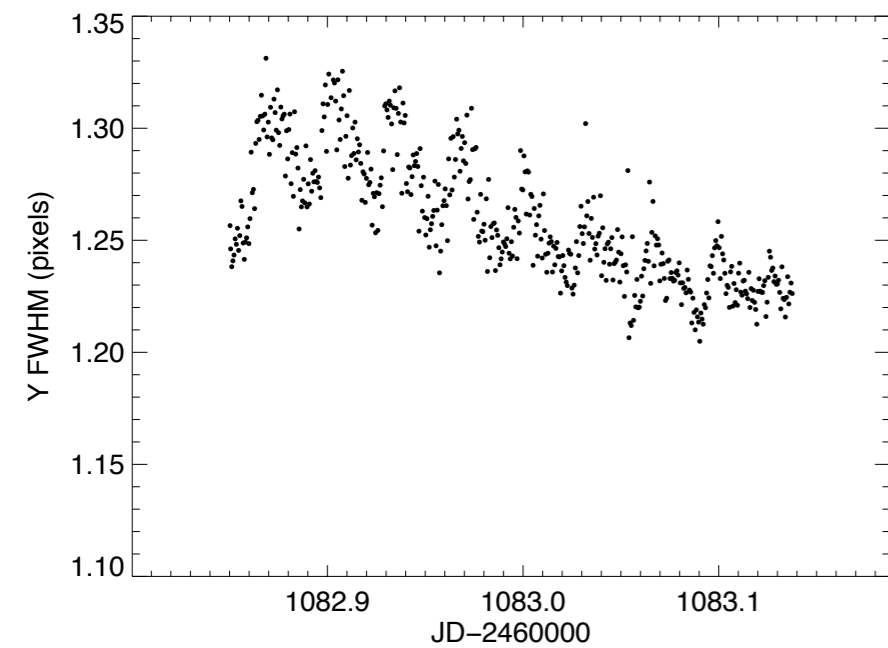
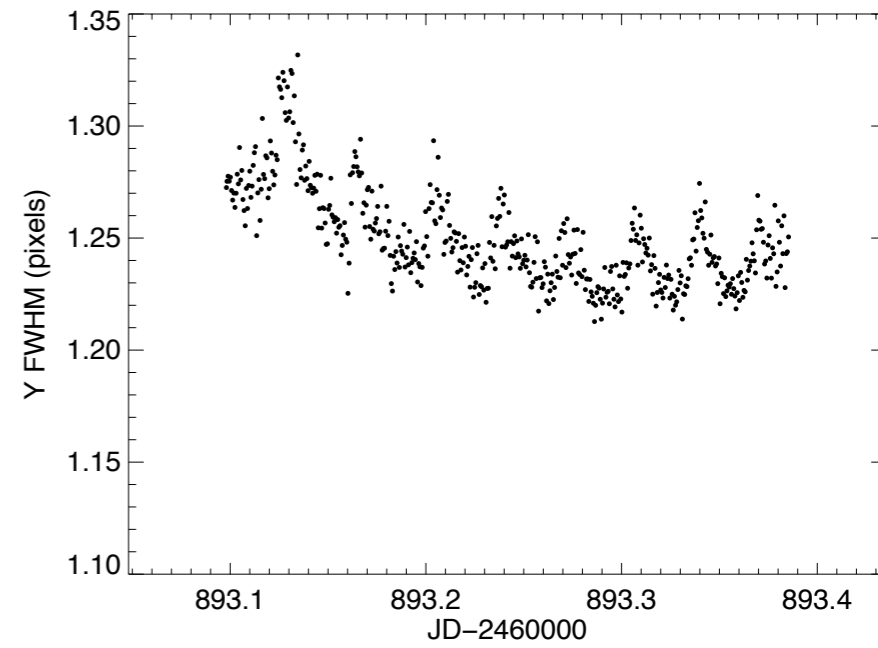
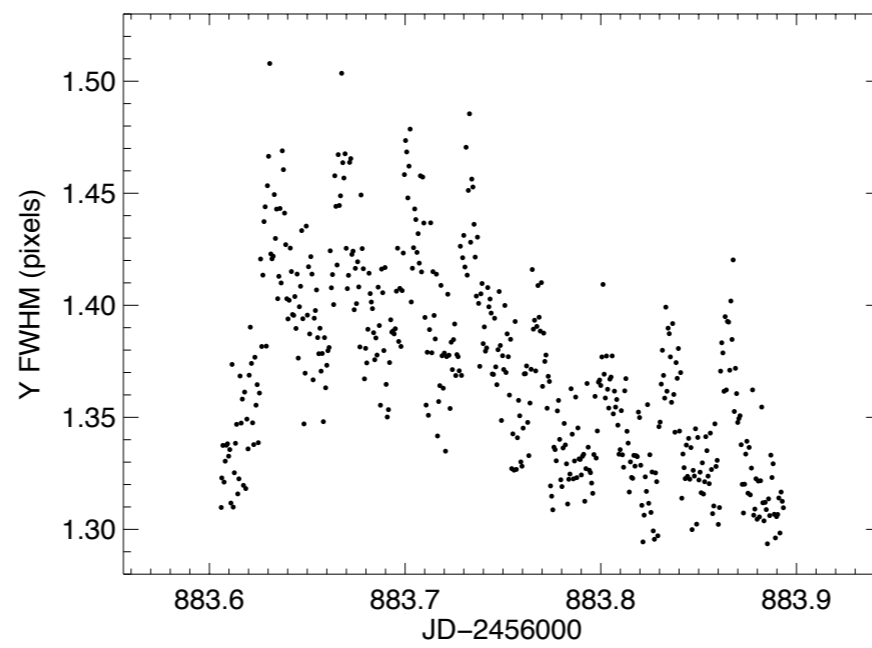
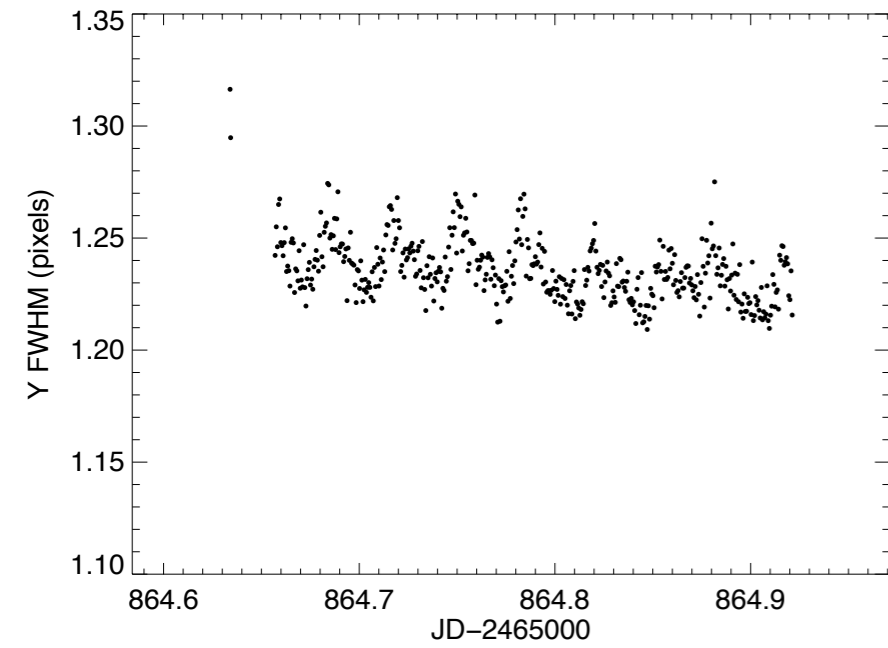
# Y Position



**Aperture: 3.5 pixels**

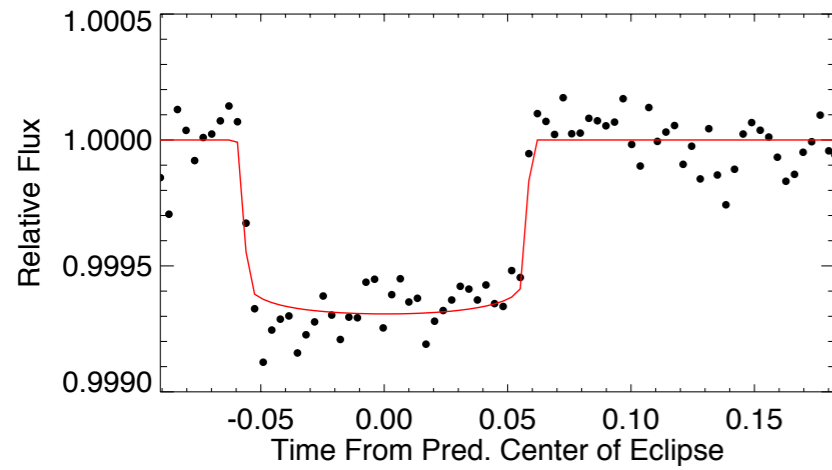


# Y FWHM

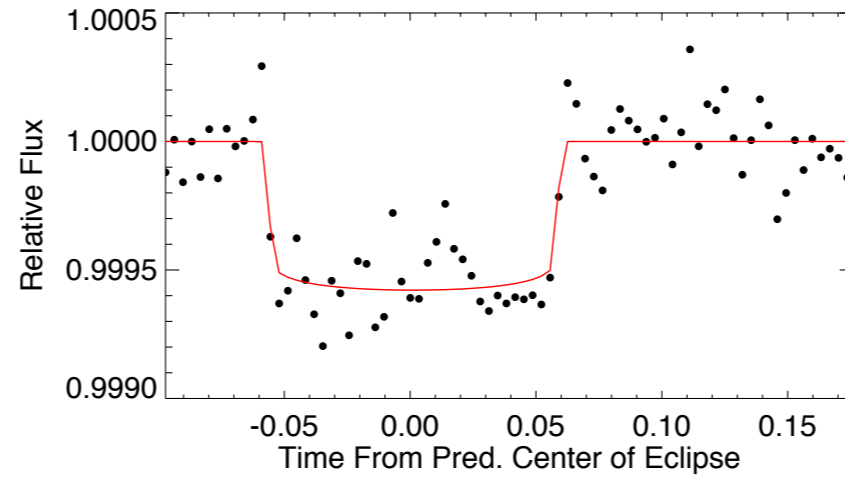


**Aperture: 3.5 pixels**

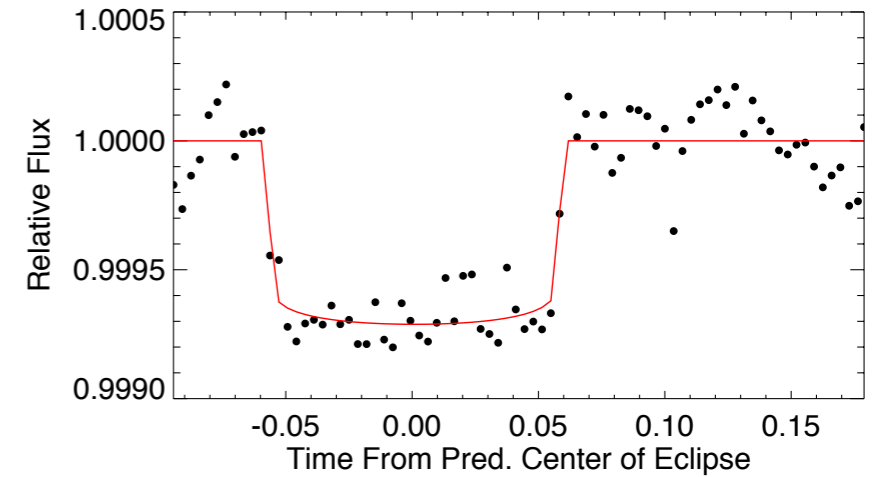
# Light curves detrended with Pixel Level Decorrelation (Deming et al. 2015)



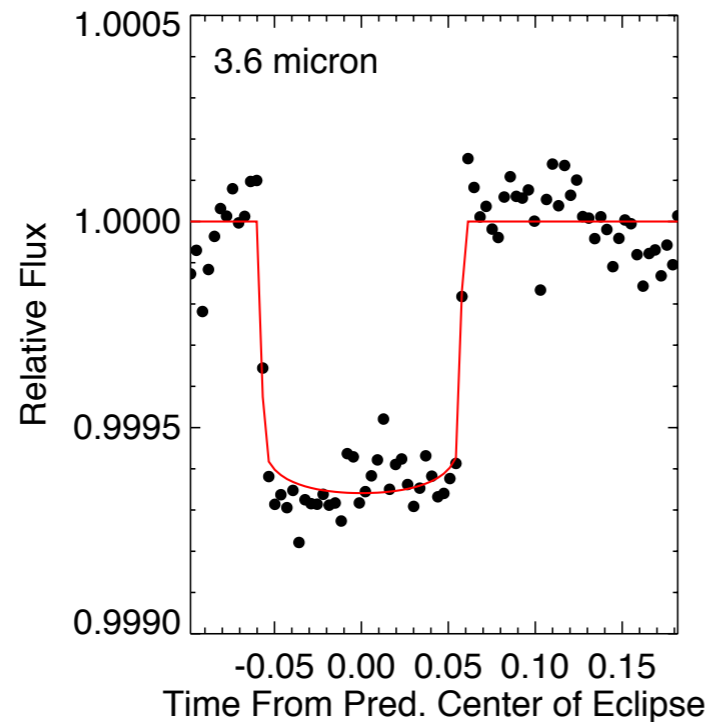
**Visit 1**



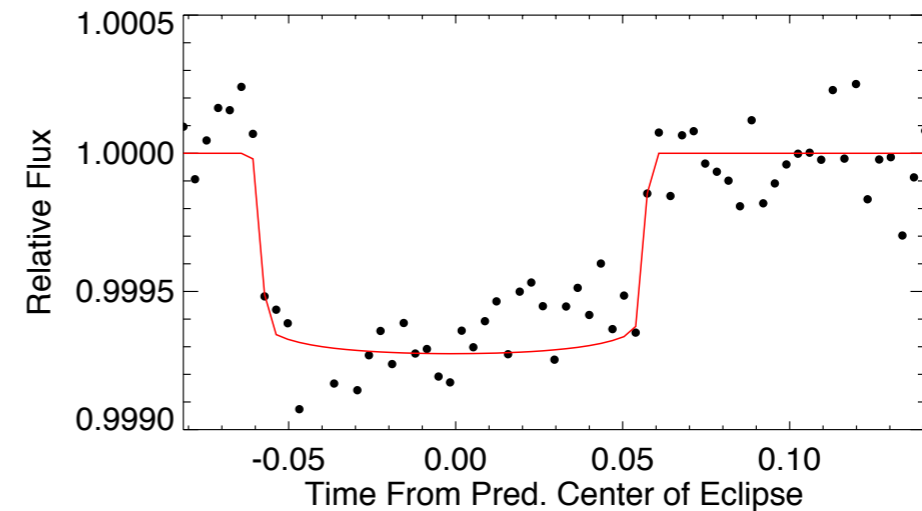
**Visit 2**



**Visit 3**



**the three visits phased**



**4.5  $\mu\text{m}$  visit  
(PID 90072, Aug. 18, 2013)**

# Transit Depths (PLD)

Visit 1:  $(R_p/R_s)^2 = 0.000650 \pm 0.000038$

Visit 2:  $(R_p/R_s)^2 = 0.000543 \pm 0.000042$

Visit 3:  $(R_p/R_s)^2 = 0.000671 \pm 0.000037$

Visit 4: TBD

Transit depths from visits 1 and 3 are in agreement.

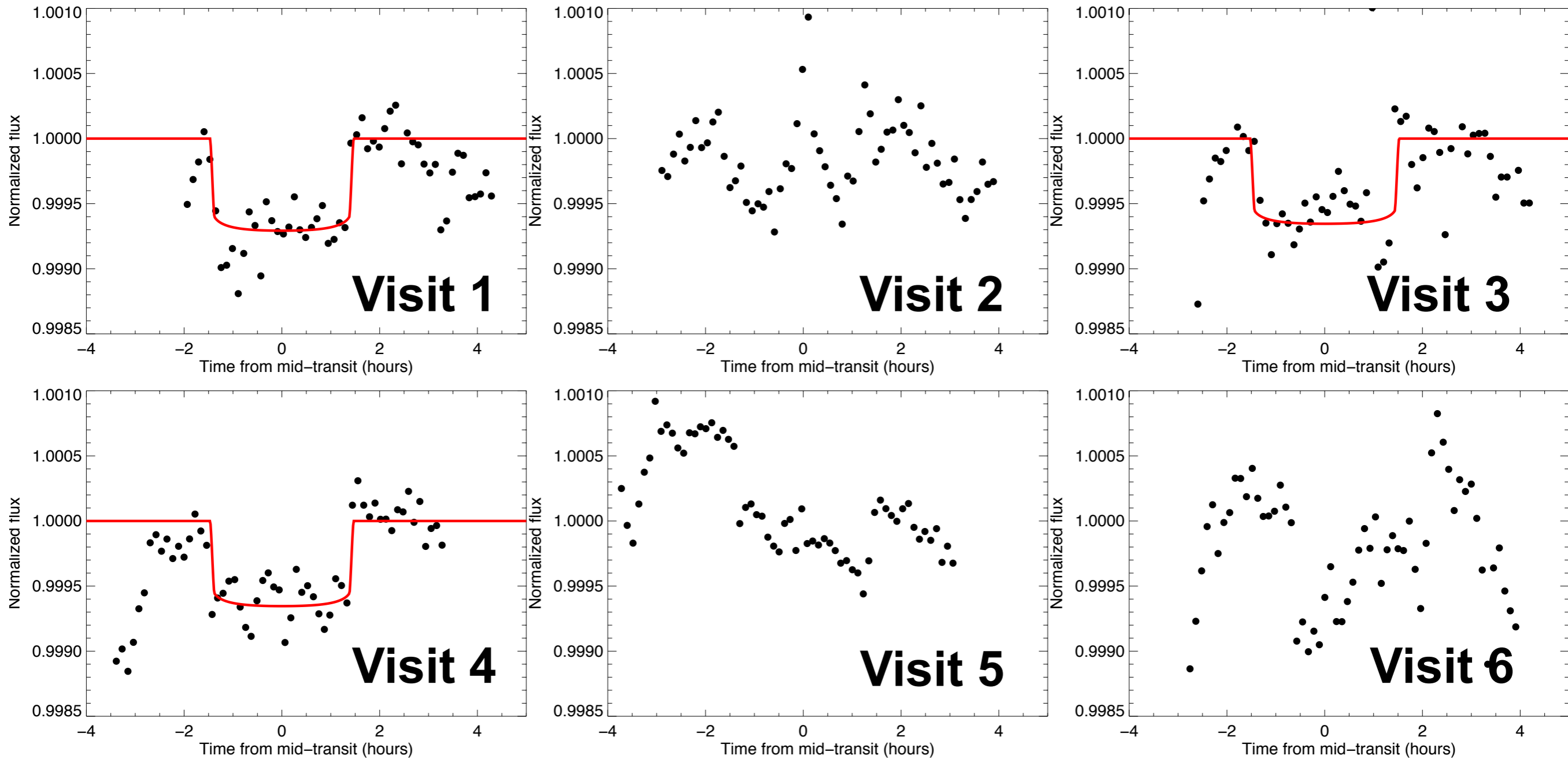
Visit 5: TBD

Transit depth from visit 2 is off by  $\sim 2 \sigma$ .

Visit 6: TBD

4.5  $\mu\text{m}$  Visit:  $0.000689 \pm 0.000042$

# Light Curves De-trended with Polynomial Fits (using EXOFAST; Eastman et al. 2013)



De-trended from  $t$ ,  $t^2$ ,  $x$ ,  $x^2$ ,  $y$ ,  $y^2$

# Transit Depths (EXOFAST)

Visit 1:  $(R_p/R_s)^2 = 0.000676 \pm 0.000030$

Visit 2: TBD

Visit 3:  $(R_p/R_s)^2 = 0.000645 \pm 0.000042$

Visit 4:  $(R_p/R_s)^2 = 0.000666 \pm 0.000032$

Visit 5: TBD

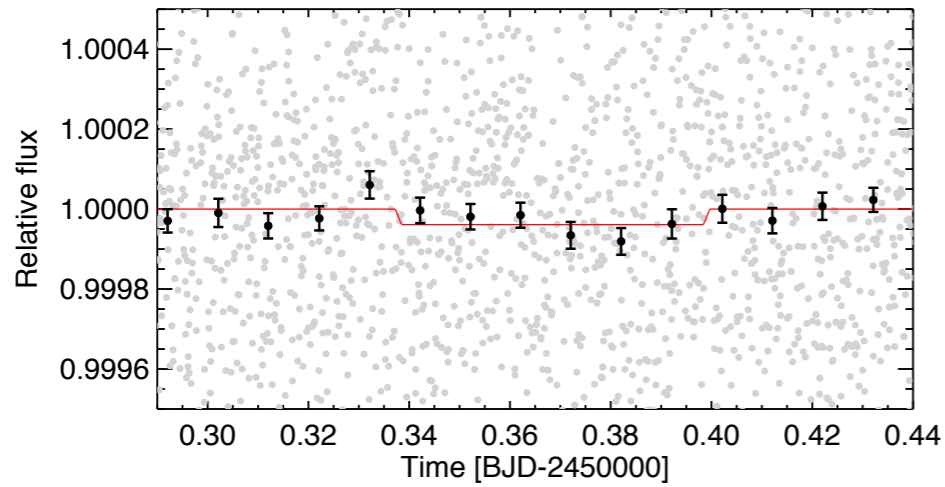
Visit 6: TBD

Transit depths from visits 1, 3  
and 4 are in agreement.

4.5  $\mu$ m Visit:  $0.000828 \pm 0.000032$

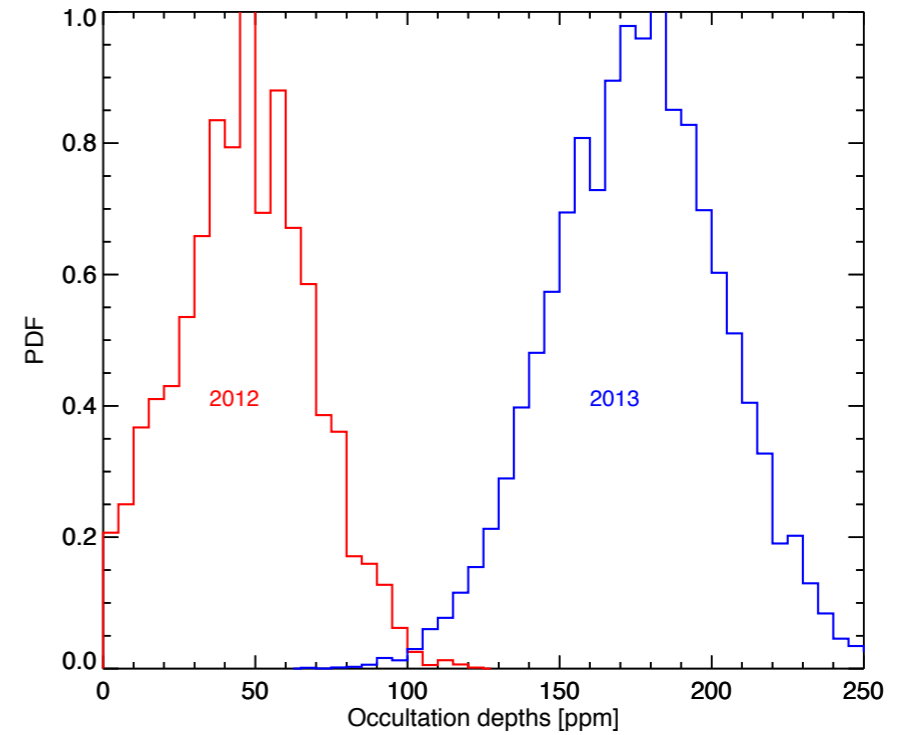
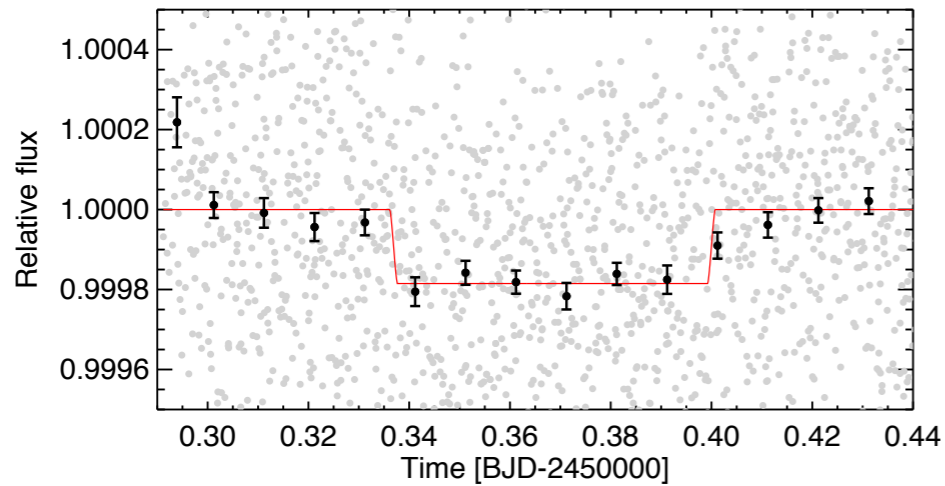
# Comparison with Demory et al. (2015)

**2012**



## 55 Cnc 4.5 $\mu\text{m}$ secondary eclipses

**2013**



**Difference in eclipse depths: 130 ppm**

**Comparable to difference we see between PLD light curves of visit 2 vs. visits 1/3**