

# Multichannel Spitzer Observations of HD 149026b

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# Secondary Eclipses

**Assume blackbody (Planck) emission:**

$$I(\lambda) = \frac{2hc}{\lambda^3} \frac{1}{(\exp(hc/\lambda kT) - 1)}$$

**Contrast ratio, emitted light:**

$$C_{p,\star}(\lambda) = \frac{r_p^2 I_p}{r_\star^2 I_\star} = \left(\frac{r_p}{r_\star}\right)^2 \frac{\exp(hc/\lambda kT_\star) - 1}{\exp(hc/\lambda kT_p) - 1}$$

**Equilibrium temperature:**

$$E_{\text{out}} = E_{\text{in}}$$

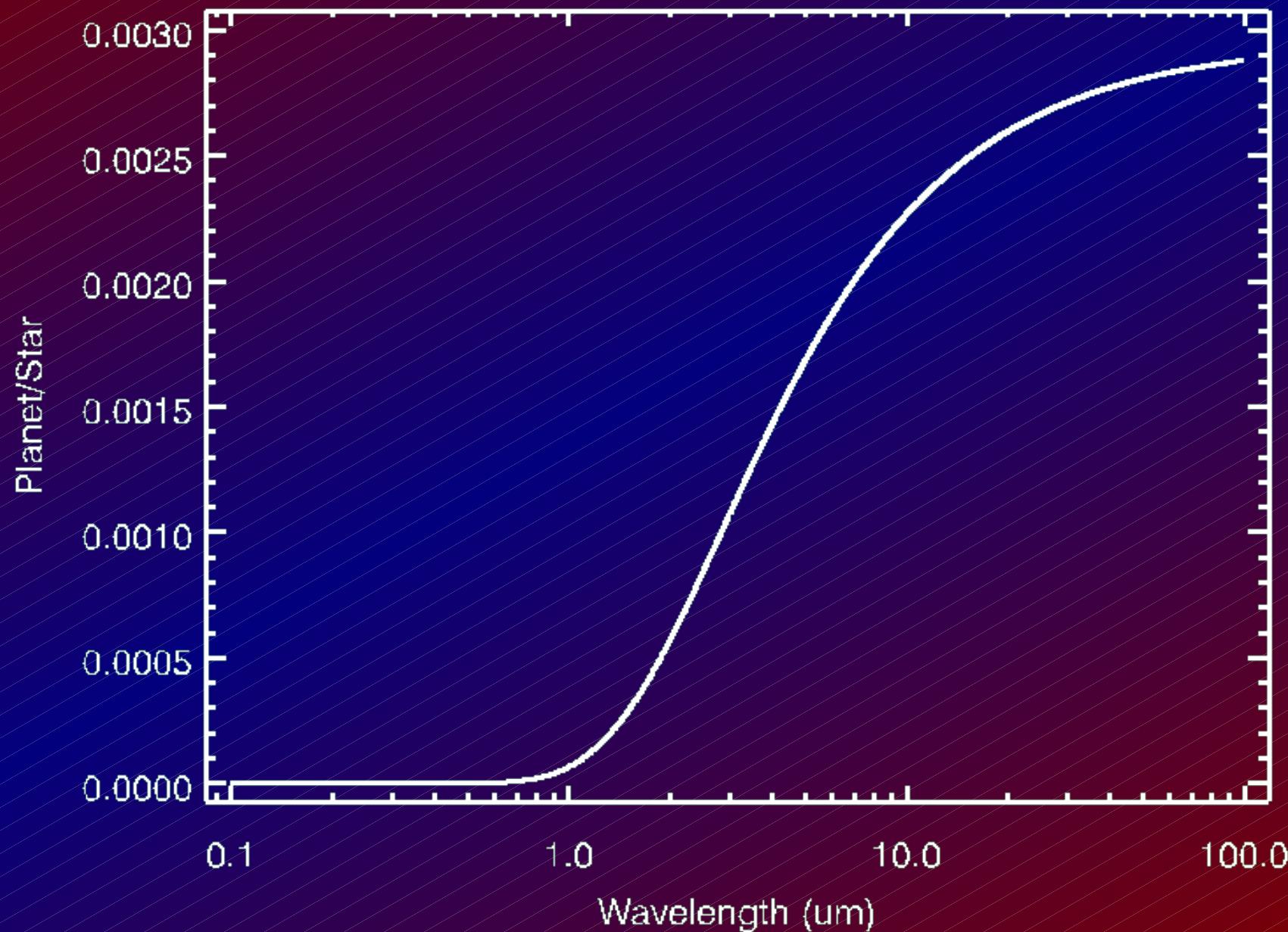
$$L_p = L_\star \left( \frac{\pi r_p^2}{4\pi a^2} \right) (1 - A)$$

$$L = 4\pi r^2 \sigma T^4$$

$$T_{p,\text{eq}} = \left( \frac{1-A}{4} \right)^{1/4} \left( \frac{r_\star}{a} \right)^{1/2} T_\star$$

# Secondary Eclipses

Thermal Emission Contrast



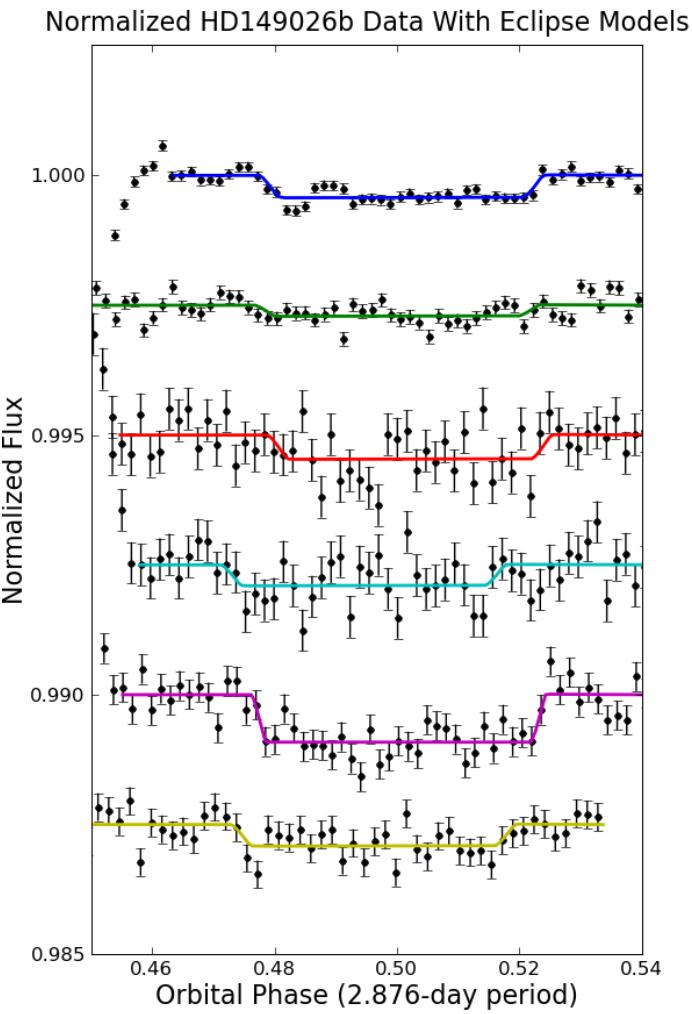
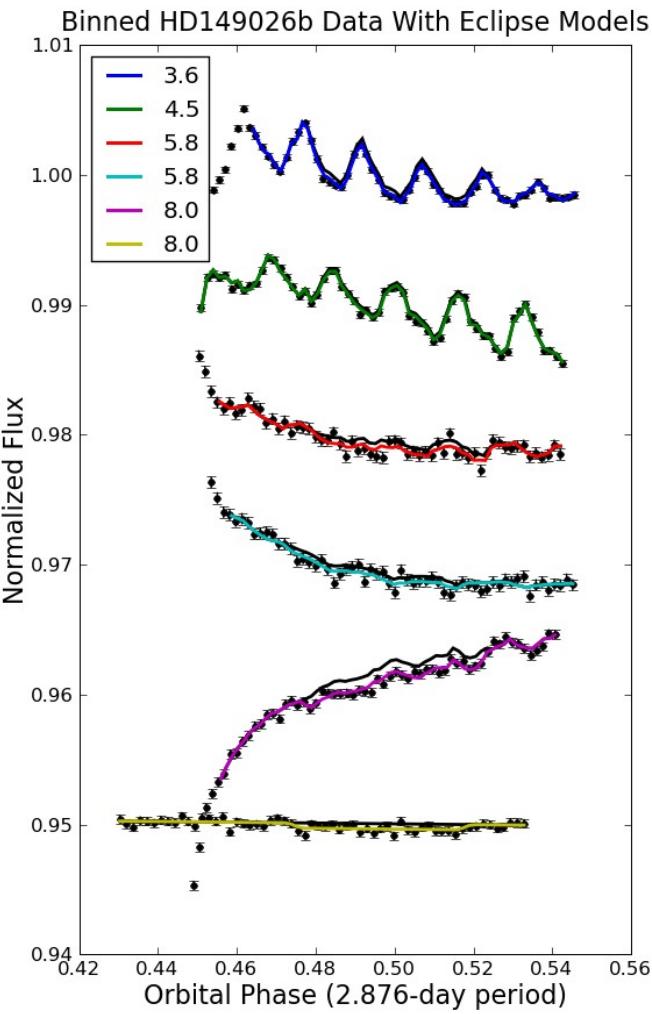
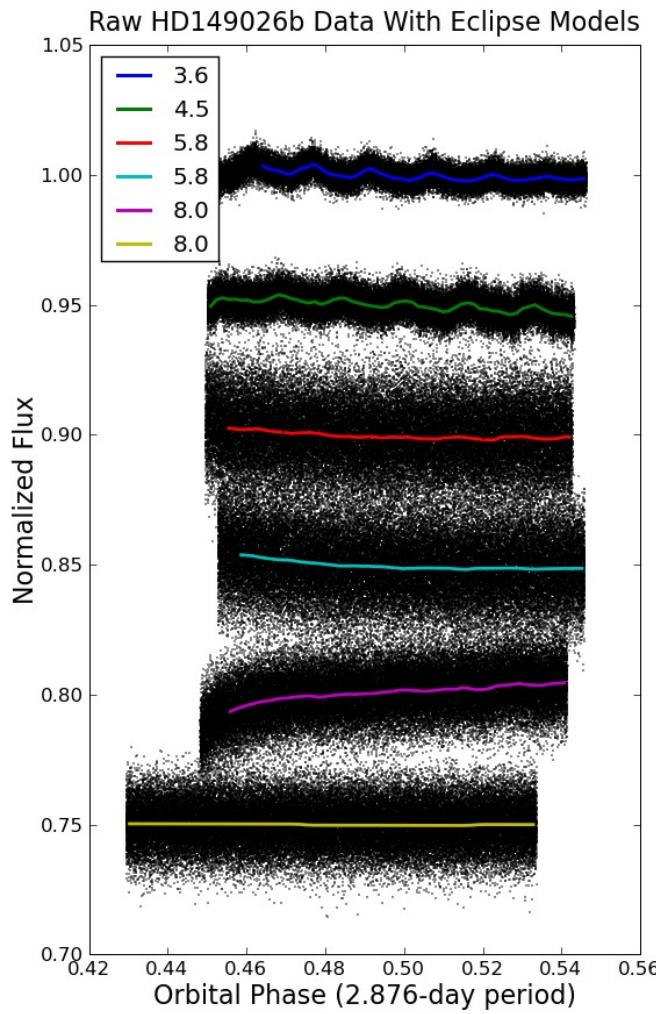
# HD 149026b

- 3rd-smallest transiting exoplanet, Saturn-sized
- Large, bright, metal-rich star
- $\sim 80 M_E$  heavy elements (more than all SS)
- $T_{\text{eq}} = 1740 \text{ K}$  ( $A_B = 0$ , uniform redist.)
- Bright star + small planet = weak eclipse

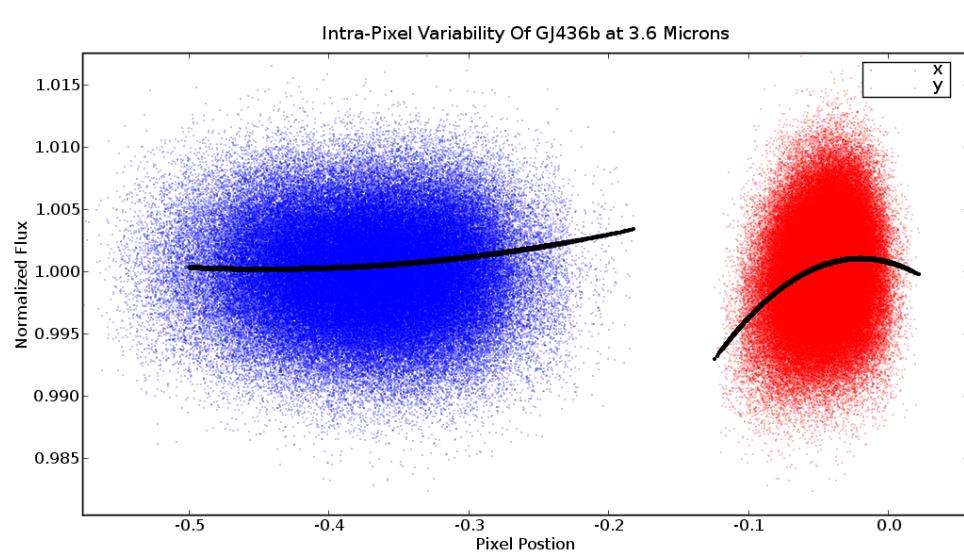
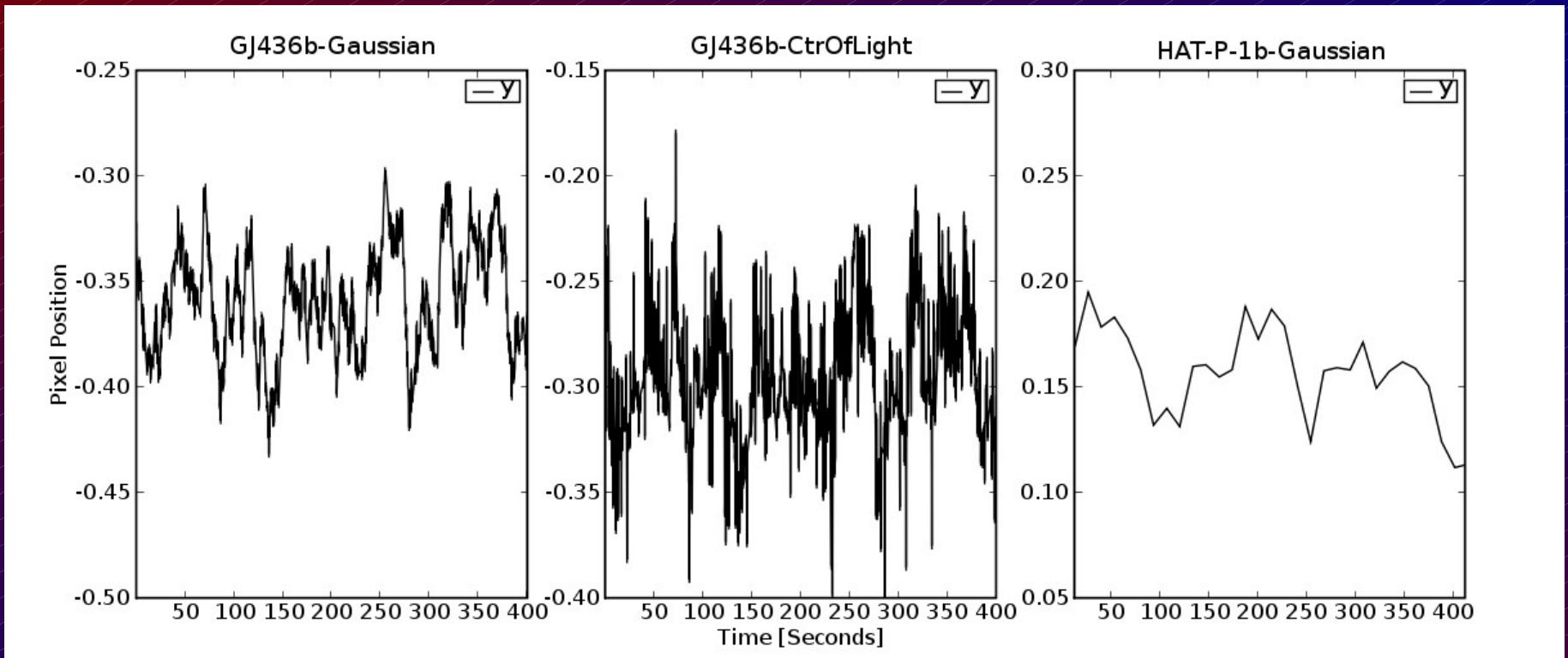
# Observations, Preslts

$\lambda$ $\mu\text{m}$	#	Date	Preslts
3.6	1	2008-03-10	
4.5	1	2008-05-09	
5.8	1	2007-08-13	
	2	2008-06-16	
8.0	1	2005-08-24	Harrington DDT, 0.08%, Knutson: 0.04%
	2	2008-04-11	
	3	2008-05-12	Knutson phase curve, 0.04%
16.0	1		(still working...)
	2		(still working...)

# Raw, Binned, Normalized



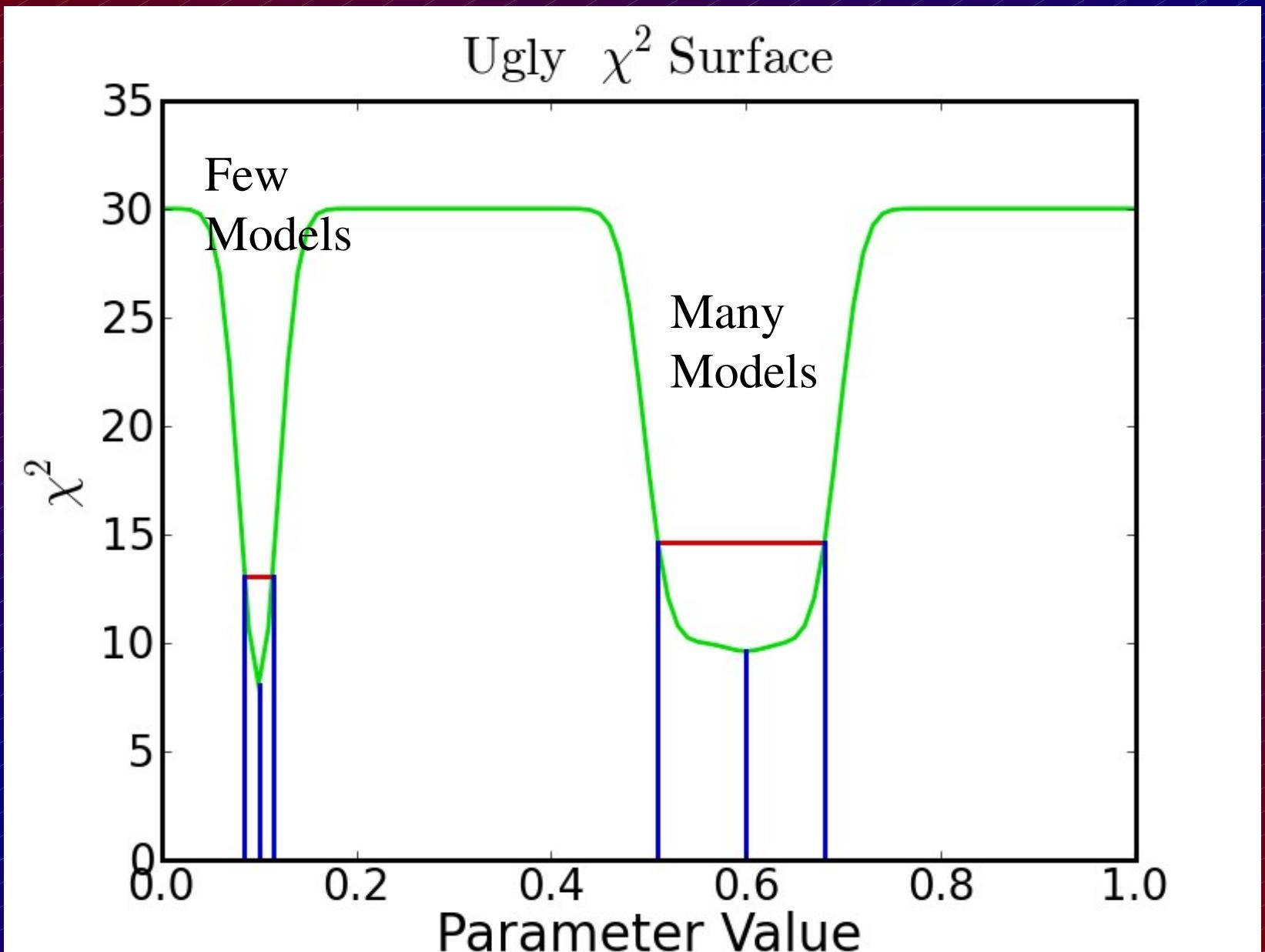
# Pixel-Phase Effect

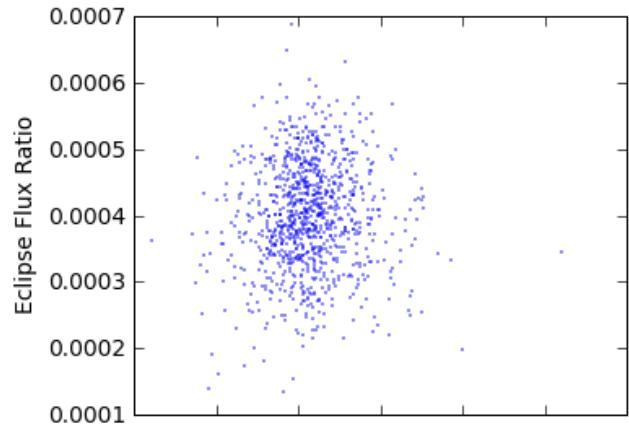


# Eclipse Fits

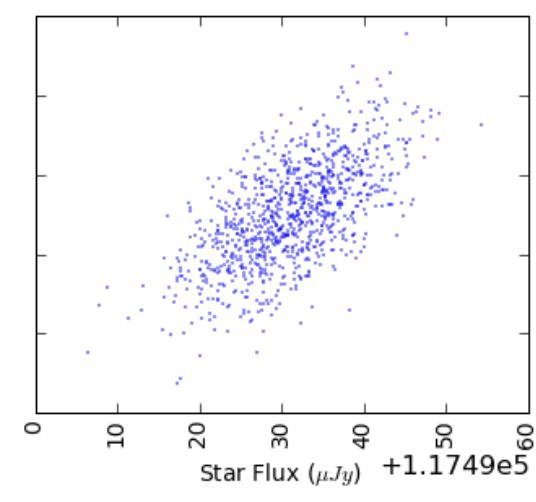
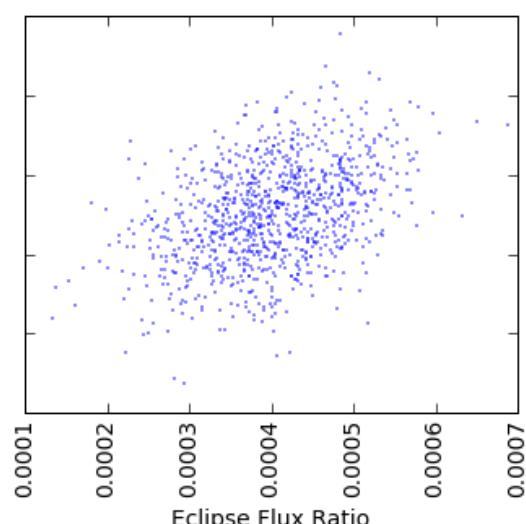
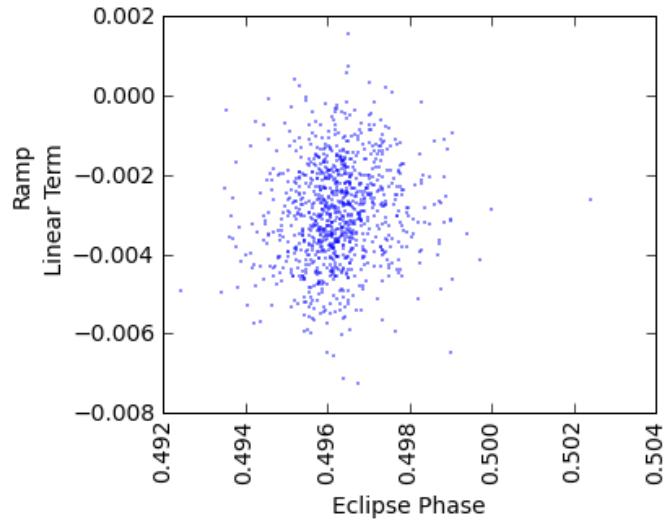
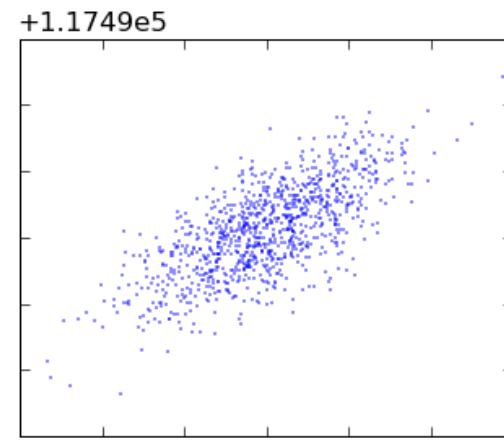
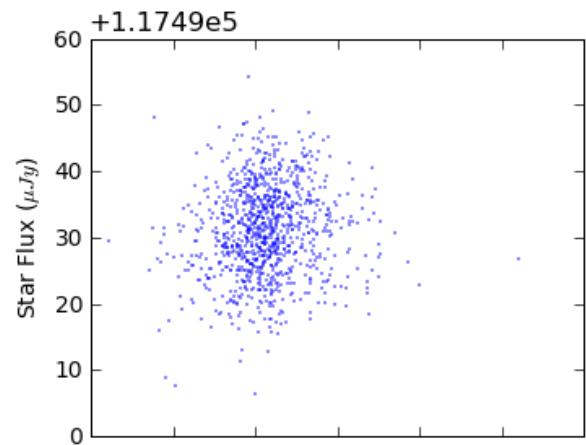
$\lambda$ $\mu\text{m}$	#	Run	BIC	Depth	Unc. %	$T_b$ K	Unc. K
3.6	1	m1fecip	700611	0.042	0.003	2069	59
4.5	1	m1fecip	774797	0.020	0.004	1405	100
5.8	1	m1feqip	801434	0.057	0.013	2049	239
		m1feqip4	801362	0.040	0.014	1622	302
		m1feqip4	801329	0.046	0.016	1773	305
	2	m1feqip	800857	0.039	0.014	1546	293
8.0	2	m1re	687023	0.136	0.008	3136	148
		m1reqip	686980	0.127	0.009	3059	151
		m1ll	687024	0.097	0.009	2456	154
		m1llqip	686979	0.091	0.009	2317	158
3	m1ln		829513	0.041	0.008	1433	163
							+

# Which to Pick?

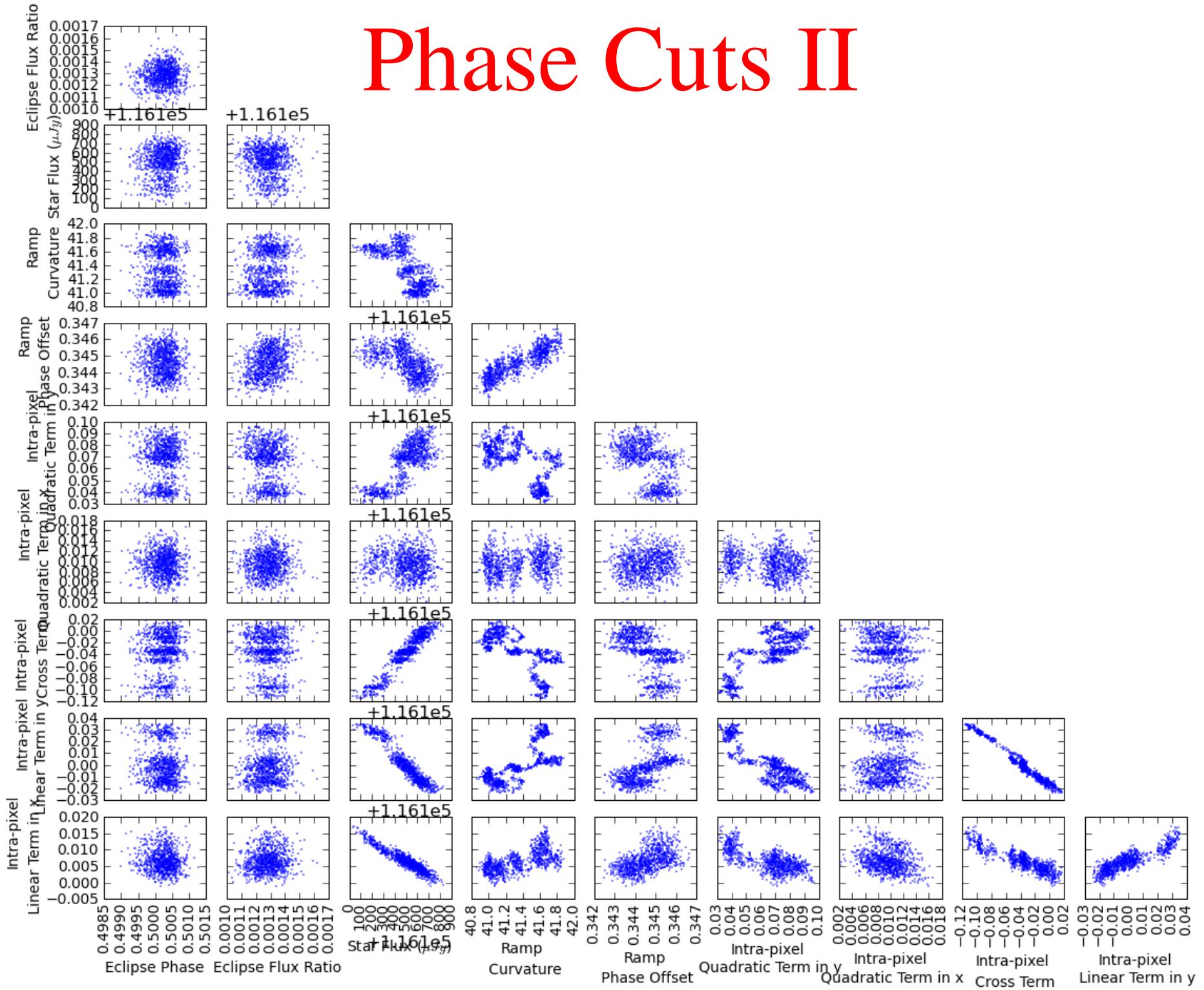




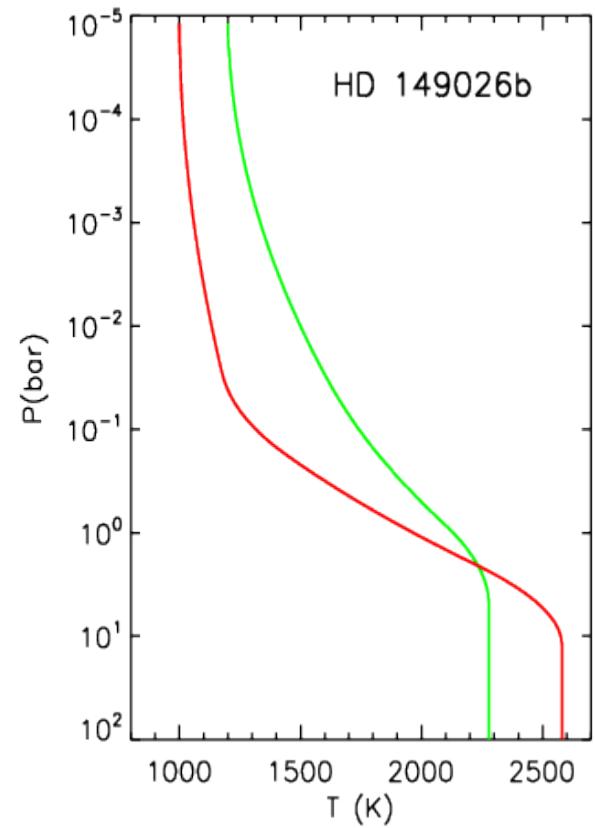
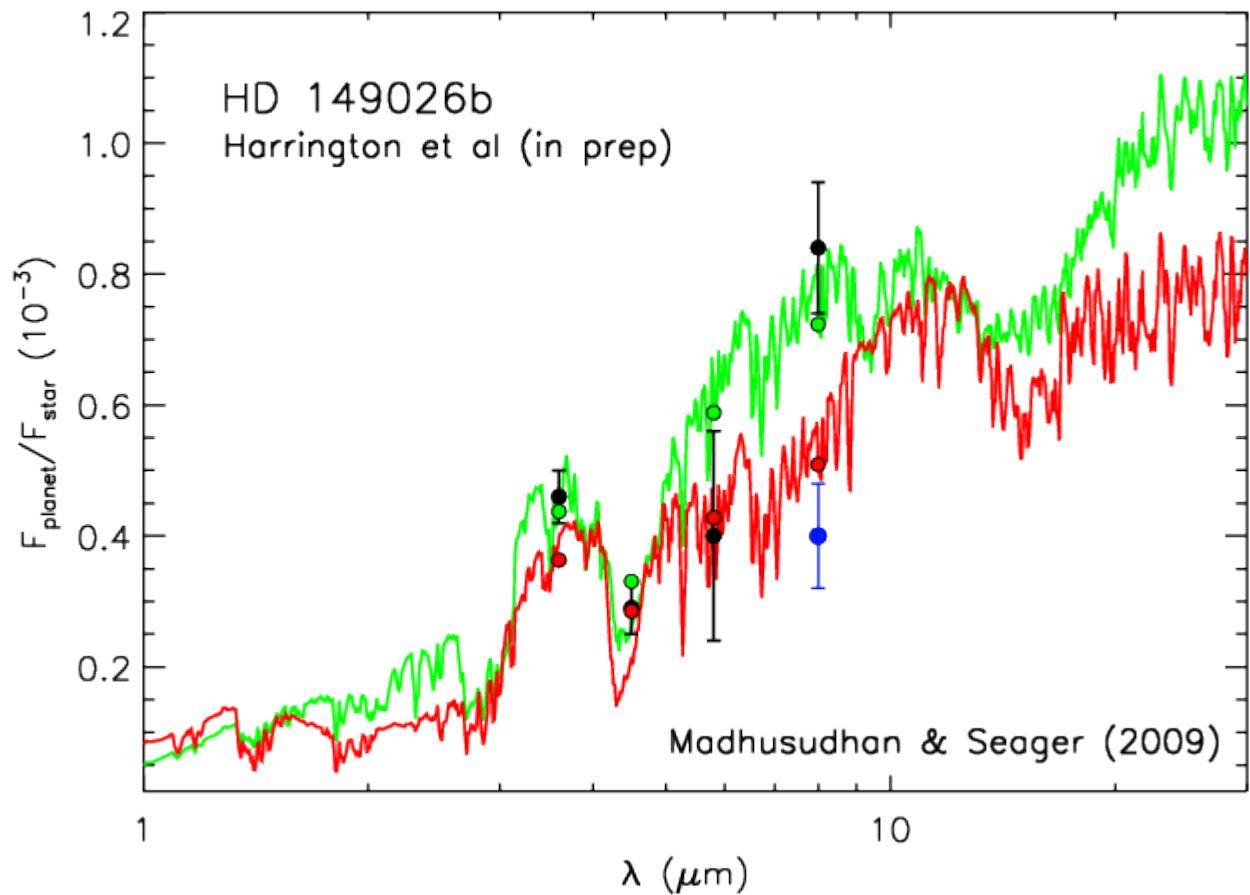
# Phase Cuts



# Phase Cuts II



# Atmosphere



Look Ma, no inversion (yet)!

# Conclusions

- Variability? But, very messy  $\chi^2$  surface
- Lessons: Insist on phase cuts, histograms
- Don't date the first minimum  $\chi^2$  you meet!
- The idea that you can always calibrate after the fact is questionable
- Better instruments at this aperture could do this for many planets
- Modestly larger apertures viable for balloons, space

# UCF Winter School 2010: Exoplanets for Planetary Scientists

- Sessions: Introductory review + invited oral + poster
- 6-8 January (Wed-Fri), UCF in Orlando
- Collier-Cameron, Deming, Gaidos, Malhotra, Showman
- Abstracts: still accepting...
- <http://planets.ucf.edu/winterschool2010>