

# Measuring Eclipsing Binary Star Parameters with the Kepler Data

“The Julian Dates \_\_\_\_...”

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# The project

- Install SW: BinaryMaker
- Select targets from Prsa et al. 2010

1. [arXiv:1006.2815](https://arxiv.org/abs/1006.2815) [pdf, ps, other]

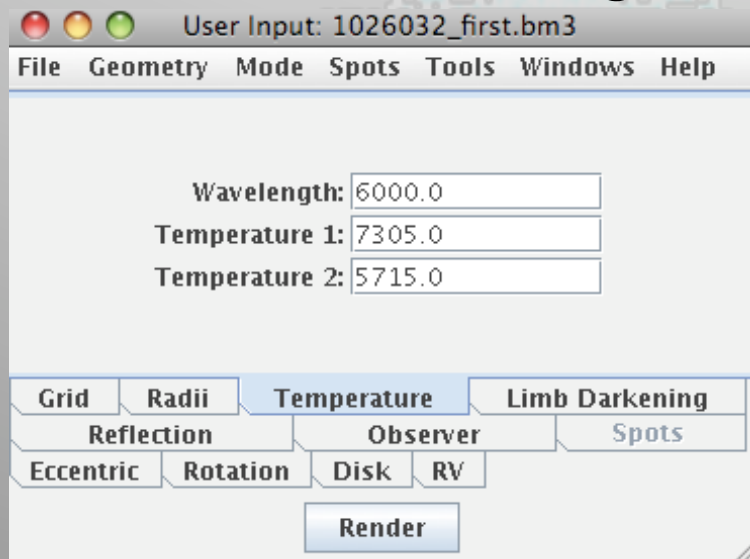
**Kepler Eclipsing Binary Stars. I. Catalog and Principal Characterization of 1832 Eclipsing Binaries in the First Data Release**

Andrej Prsa, Natalie M. Batalha, Robert W. Slawson, Laurance R. Doyle, William F. Welsh, Jerome A. Orosz, Sara Seager, Michael Rucker, Kimberly Mjaseth, Scott G. Engle, Kyle Conroy, Jon M. Jenkins, Douglas A. Caldwell, David G. Koch, William J. Borucki

- Periodogram analysis and light-curve folding on <http://nsted.ipac.caltech.edu/>
- Try to reproduce light curve with BinaryMaker
- Conclude

# BinaryMaker

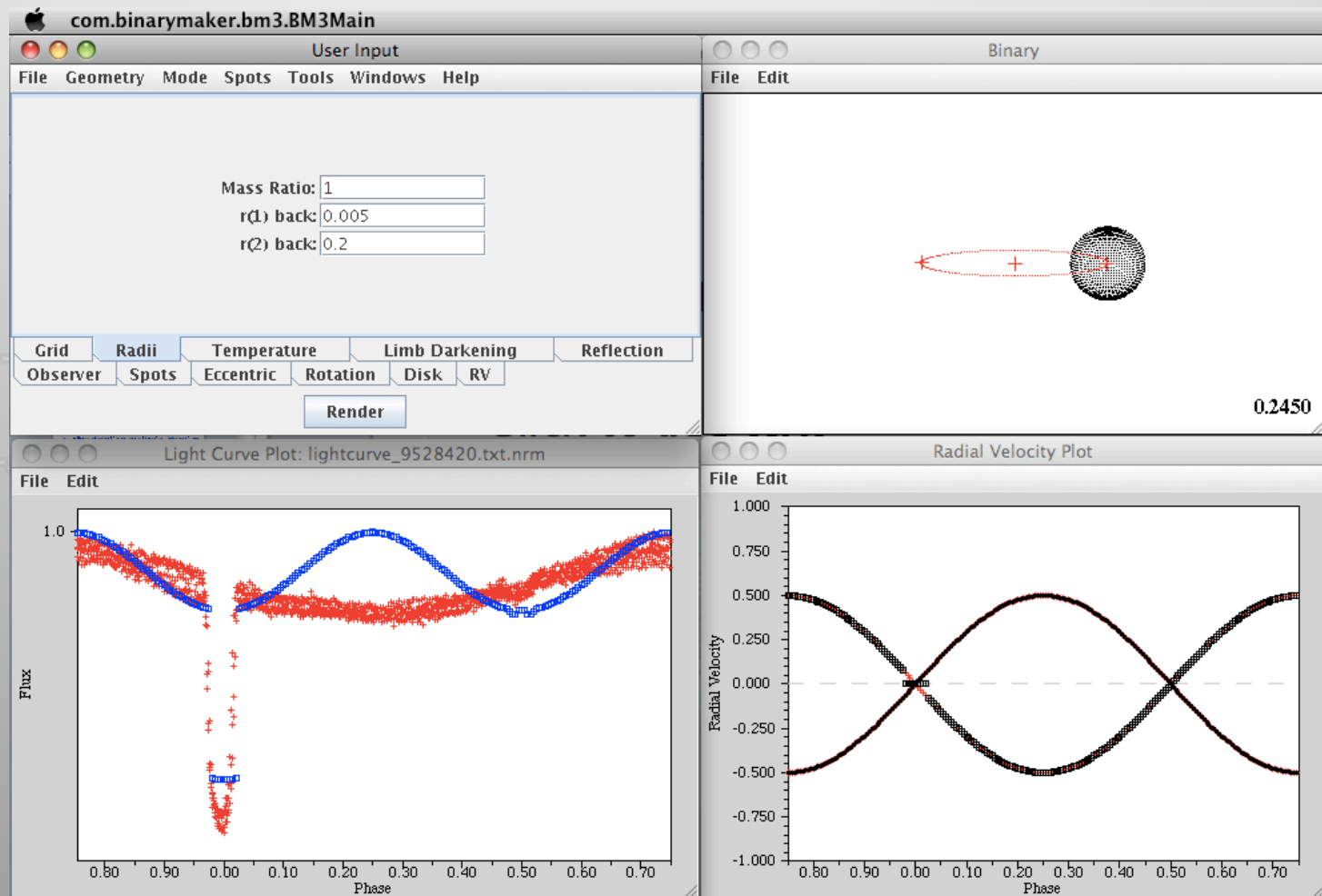
- Input: phase-folded light-curve (P)
- 52 parameters to model the binary q, R, T, e....
- GUI – interface
- Visual  $\chi^2$  - fitting



```
mass ratio input = 1.000000
Omega 1 = 28.075092
Omega inner = 3.929700
C 1 = 28.325092
C inner = 4.179700
Fillout 1 = -0.852438
Lagrangian L1 = 0.477293
AG = r1(back) = 0.037000
BG = r1(side) = 0.036997
CG = r1(pole) = 0.036995
DG = r1(point) = 0.037000
Surface area 1 = 0.017205
Volume 1 = 0.000211
Mean radius 1 = 0.036997
Mean radius 1 (vol) = 0.036908
Eccentricity = 0.04300
Phase of periastron = 0.76200
Angular Rotation F1 = 1.0909
Normalization Phase = 0.25000
inclination = 86.690
temperature 1 = 7305.00
luminosity 1 = 0.7183
gravity coefficient 1 = 0.000
limb darkening 1 = 0.000
reflection 1 = 0.000
Third light = 0.0000

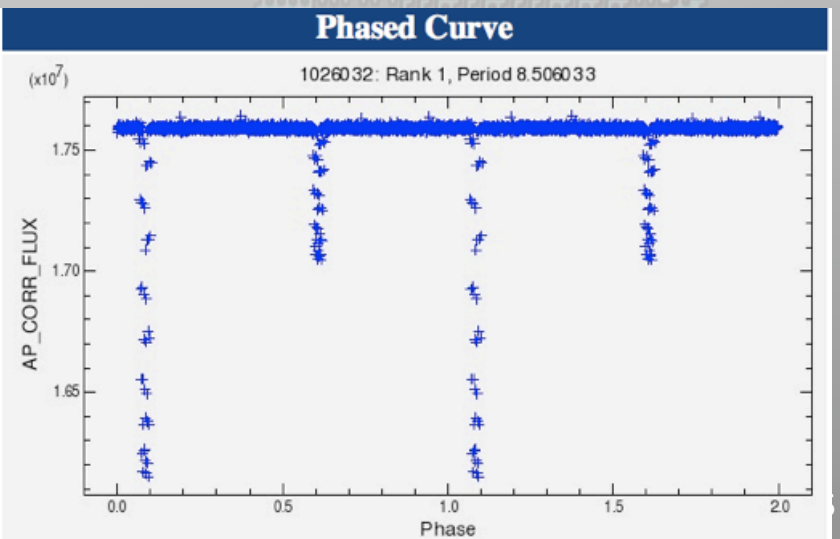
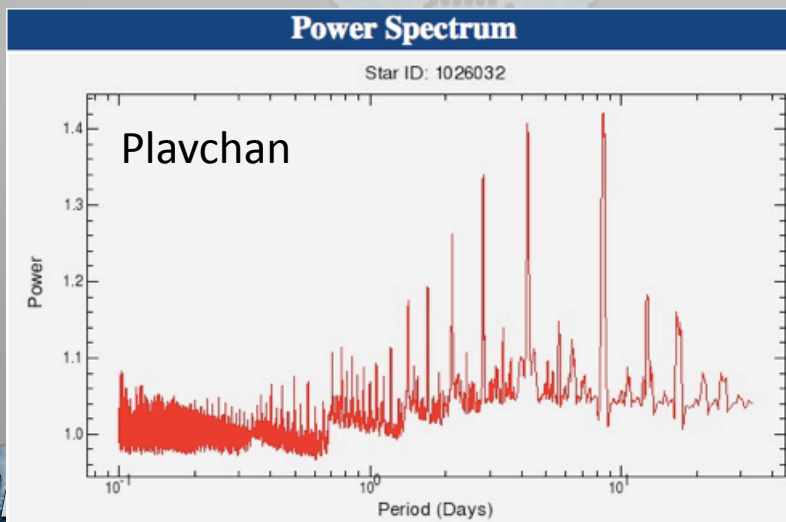
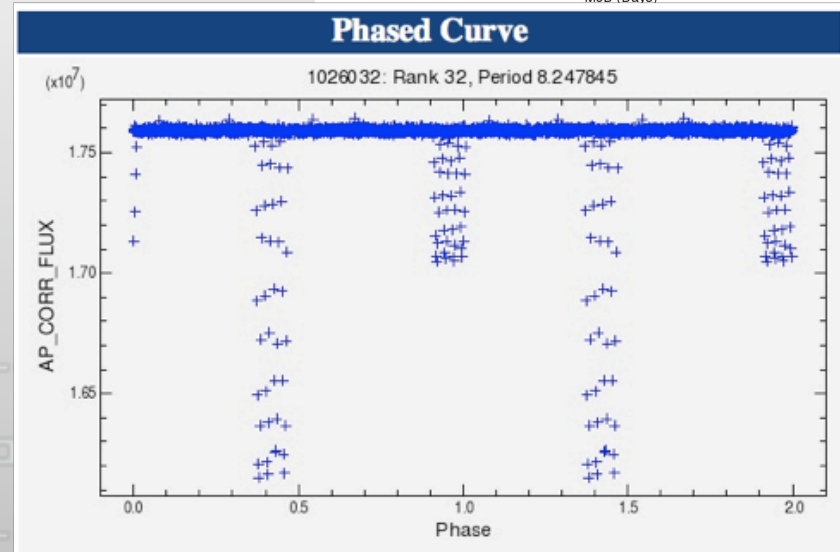
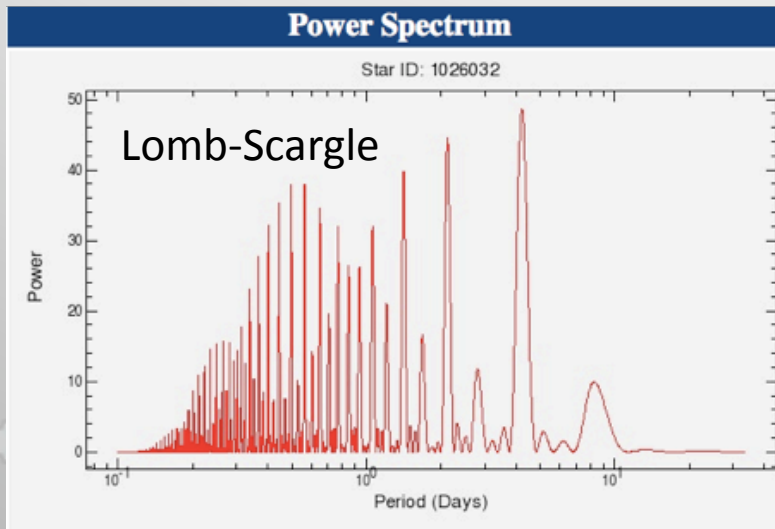
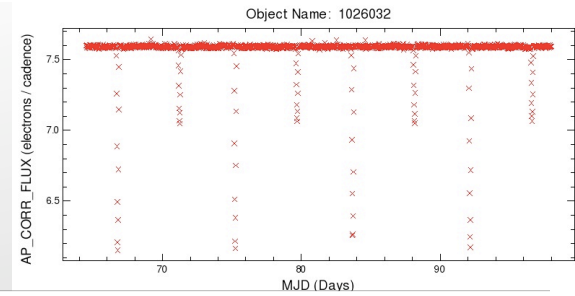
mass ratio < 1 = 1.000000
Omega 2 = 28.075092
Omega outer = 3.123753
C 2 = 28.325092
C outer = 3.373753
Fillout 2 = -0.852438
Lagrangian L2 = 1.698406
AS = r2(back) = 0.037000
BS = r2(side) = 0.036997
CS = r2(pole) = 0.036995
DS = r2(point) = 0.037000
Surface area 2 = 0.017205
Volume 2 = 0.000211
Mean radius 2 = 0.036997
Mean radius 2 (vol) = 0.036908
Longitude of Periastron = 0.0000
Phase of conjunction = -0.00168
Angular Rotation F2 = 1.0909
Normalization Factor = 0.99700
wavelength = 6000.00
temperature 2 = 5715.00
luminosity 2 = 0.2817
gravity coefficient 2 = 0.000
limb darkening 2 = 0.000
reflection 2 = 0.000
Period = 0.00000000
```

# BinaryMaker screenshot

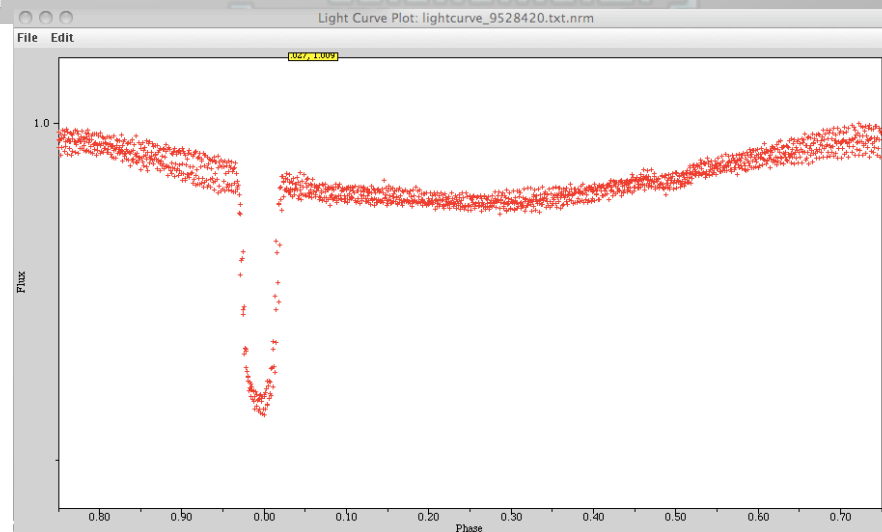
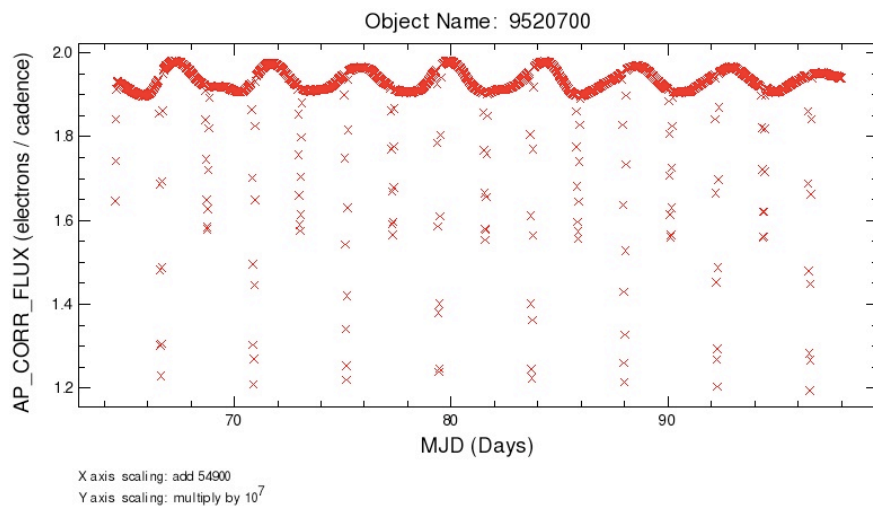
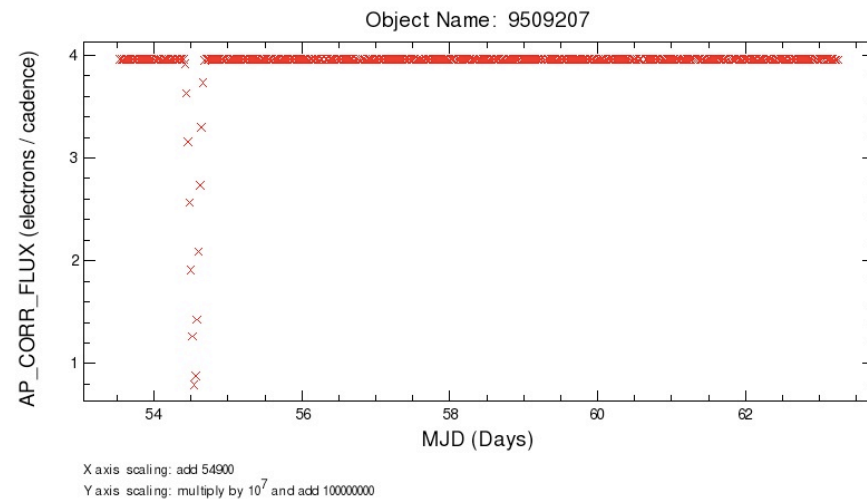
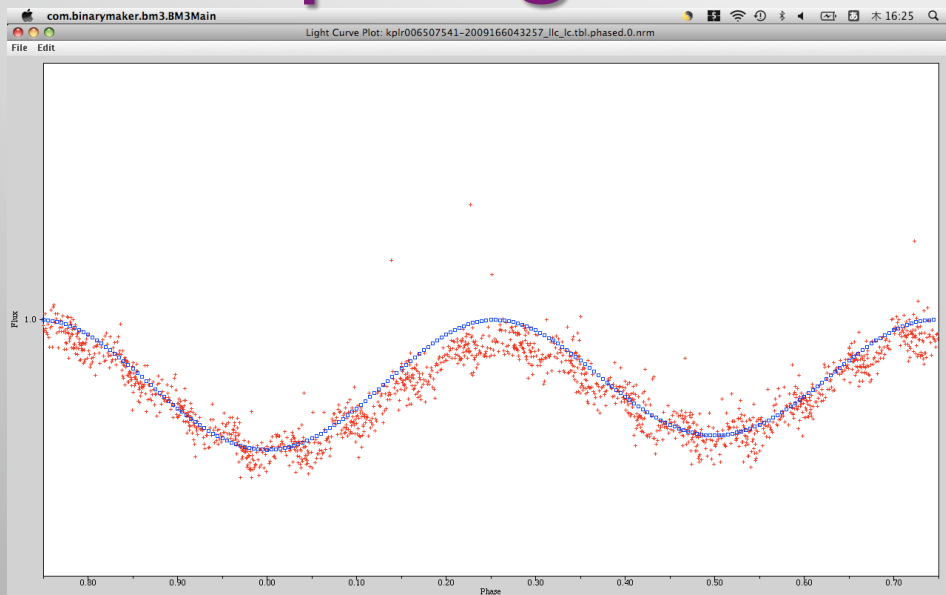




# Periodogram analysis



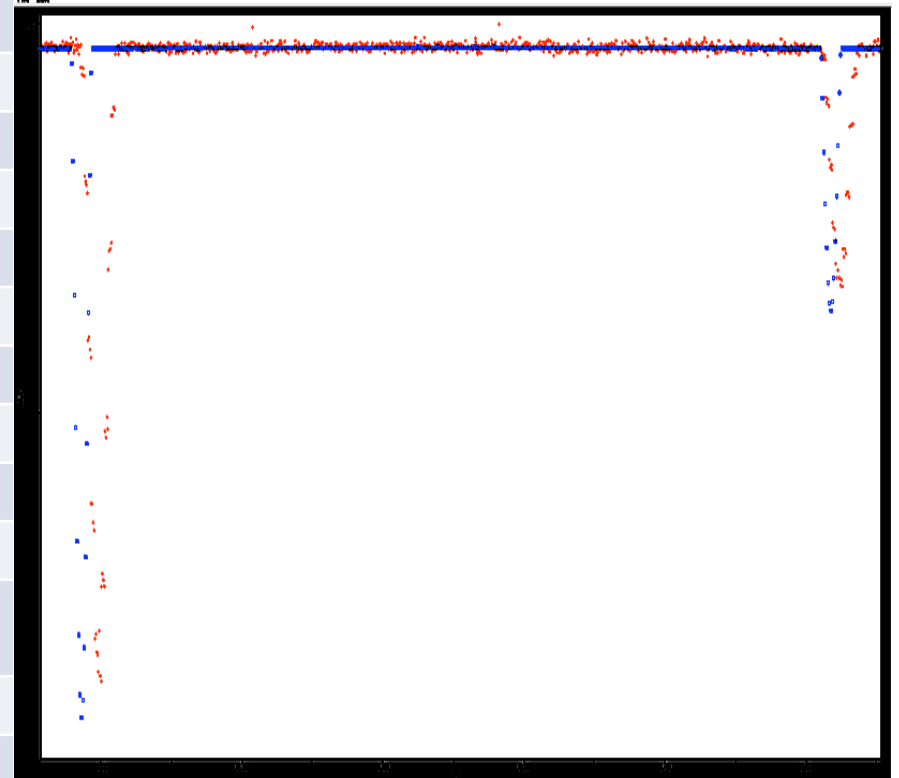
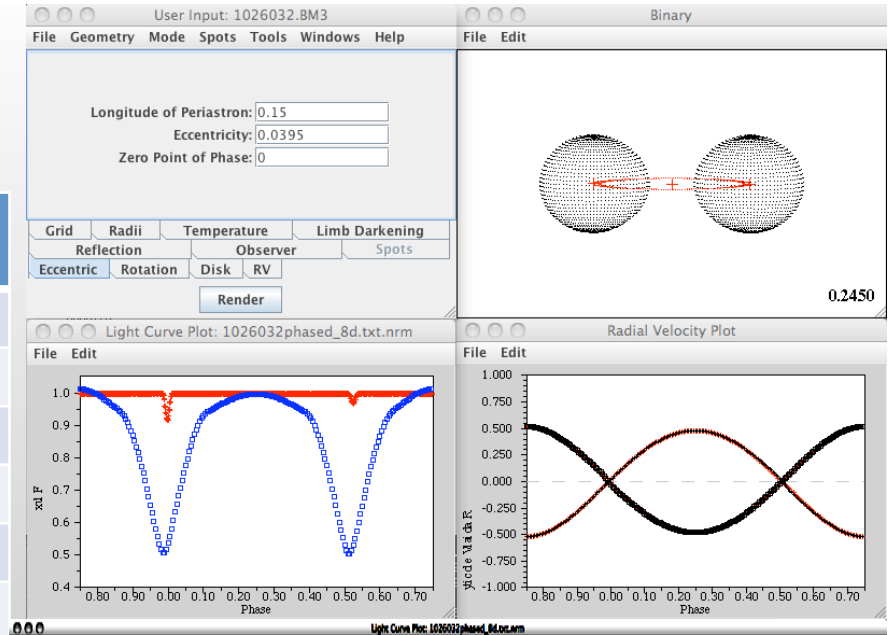
# Sample light-curves



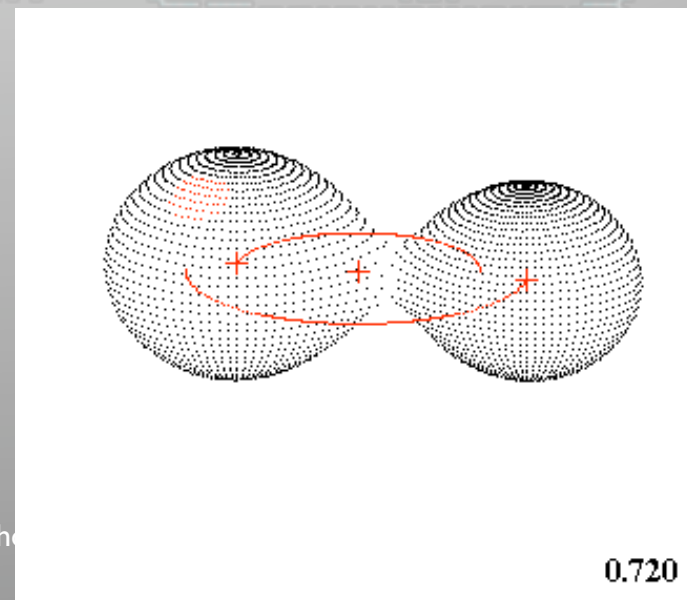
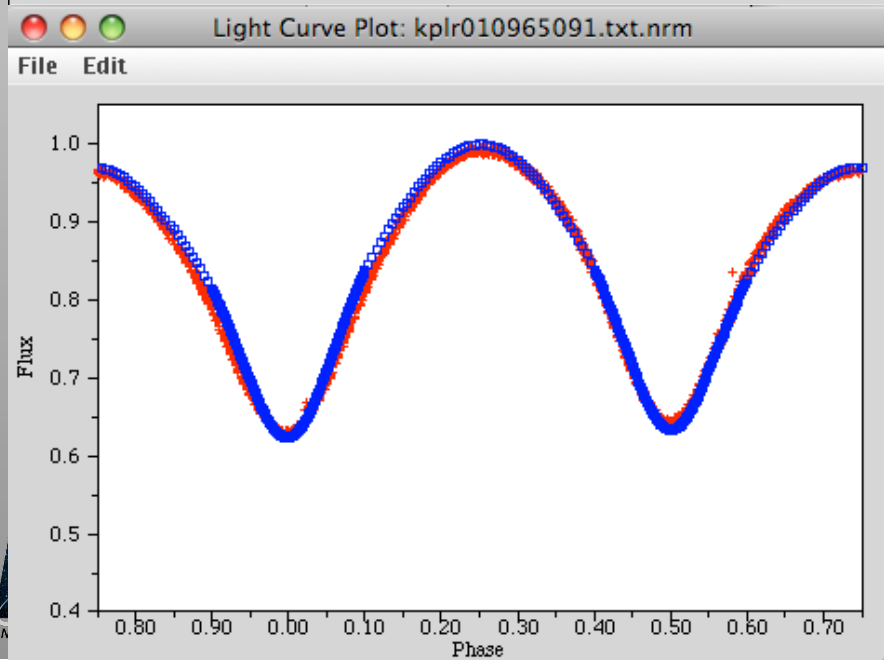
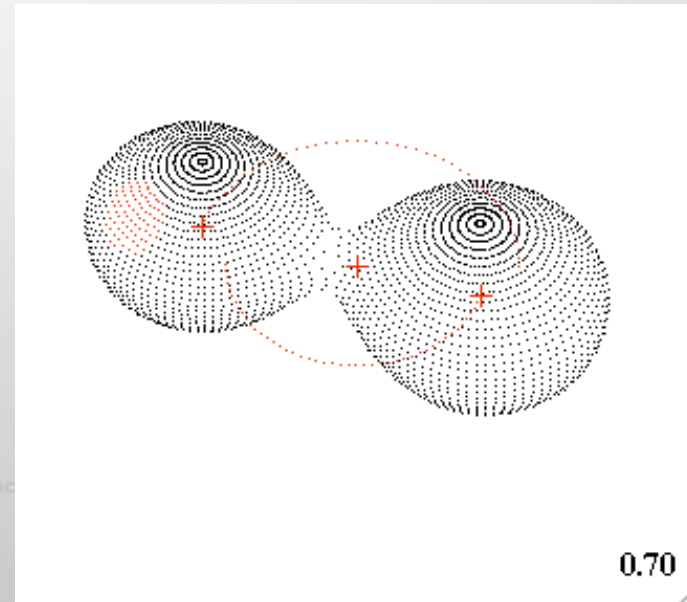
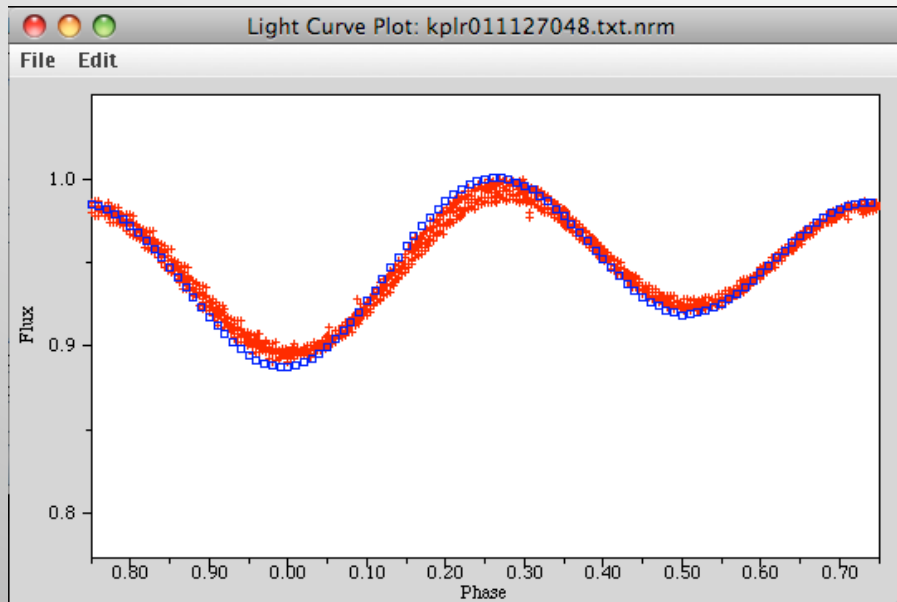
# Kepler target 1026032

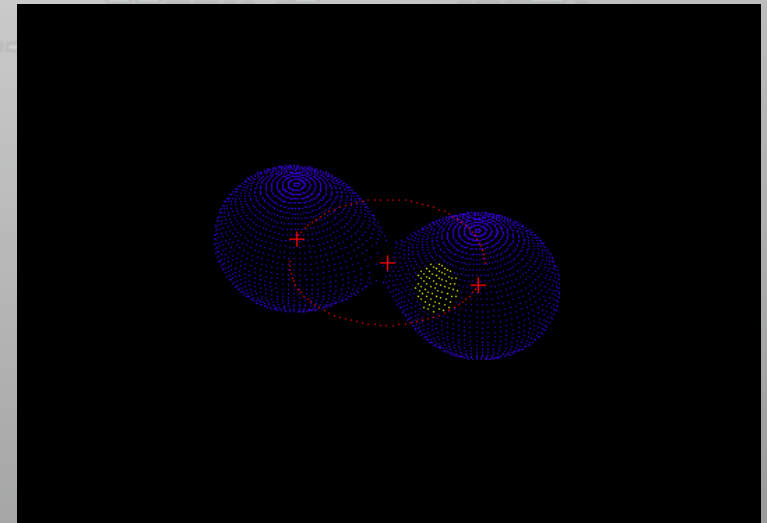
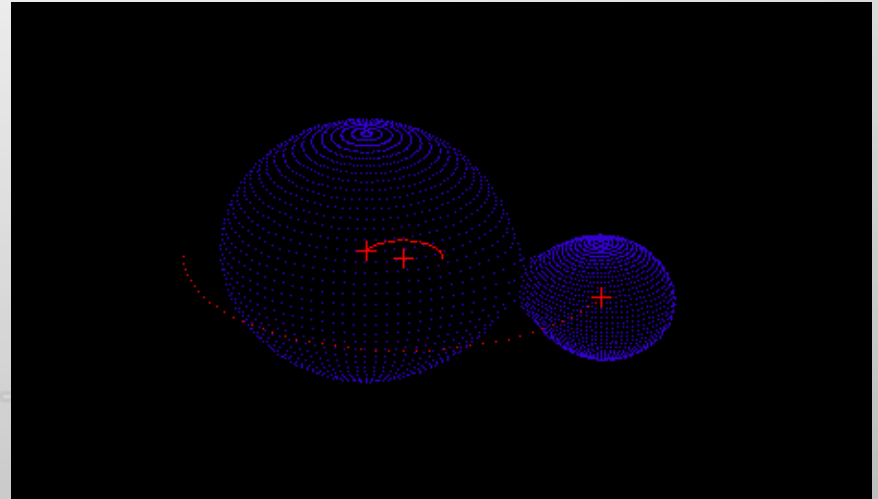
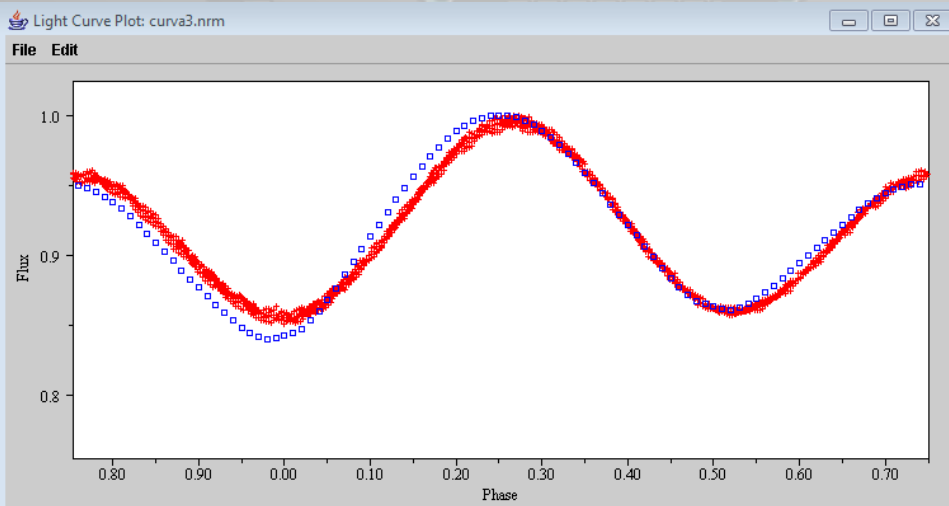
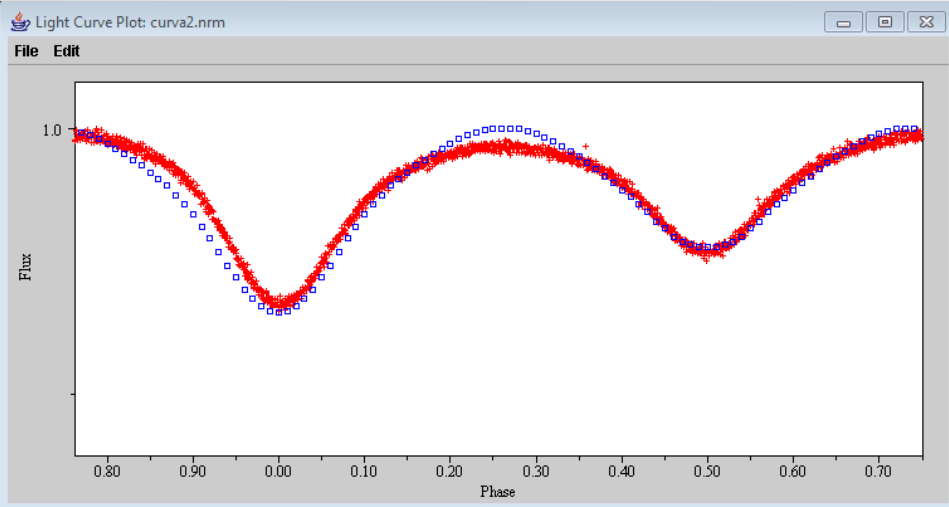
Period: 8.466032 days

Parameters	J1	J2	N	K	avg.	% stddev.
Mass ratio Q	1.0	1.0	1.0	0.9	0.975	5
r1	0.052	0.037	0.1	4	1.05	188
r2	0.052	0.037	0.1	4	1.05	188
T1	5715	7305	5715	5000	5934	16
T2	4600	5715	4500	9000	5954	35
T1/T2	1.24	1.28	1.27	0.56	1.09	32
Grav. Dark. G1	1.0	0.0	0.0	1.0	0.5	115
G2	1.0	0.0	0.0	1.0	0.5	115
Limb Dark. X1	0.73	0.0	0.0	0.71	0.36	115
X2	0.73	0.0	0.0	0.71	0.36	115
Reflection 1	0.0	0.0	0.5	1.0	0.38	126
Reflection 2	0.0	0.0	0.5	1.0	0.38	126
L3	0.0	0.0	0.0	0.0	0.0	0
Inclination	85.5	86.69	81	90	85.798	4
Norm. Phase	0.25	0.25	0.25	0.25	0.25	0
Norm. Factor	0.997	0.997	0.995	0.997	0.9965	0.1
Long. Periastron	0.0	0.0	0.0	0.6	0.15	0.3 f
Eccentricity	0.035	0.043	0.05	0.03	0.0395	22
Quality Factor	0.9	0.9	0.6	0.8		

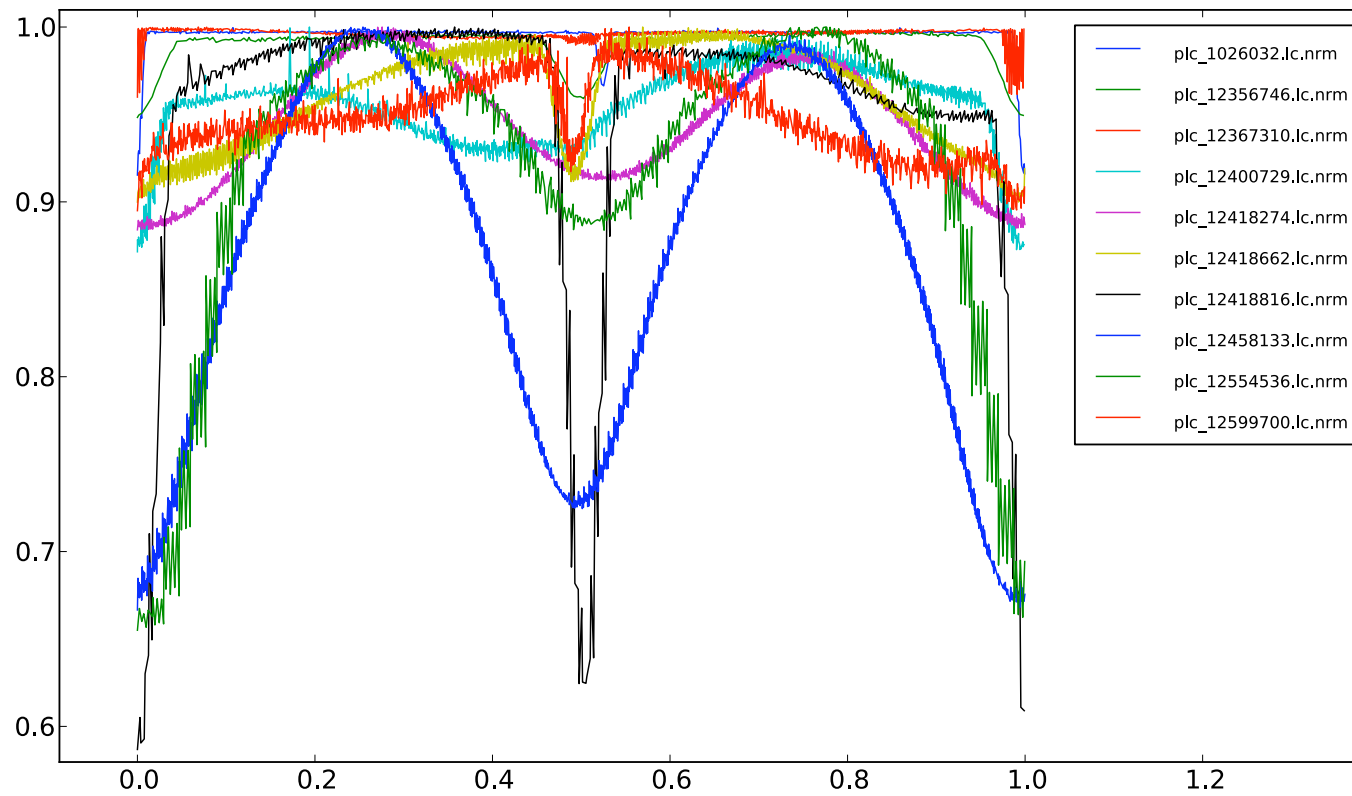


# Good fits





# Jon's curves





# Periods:

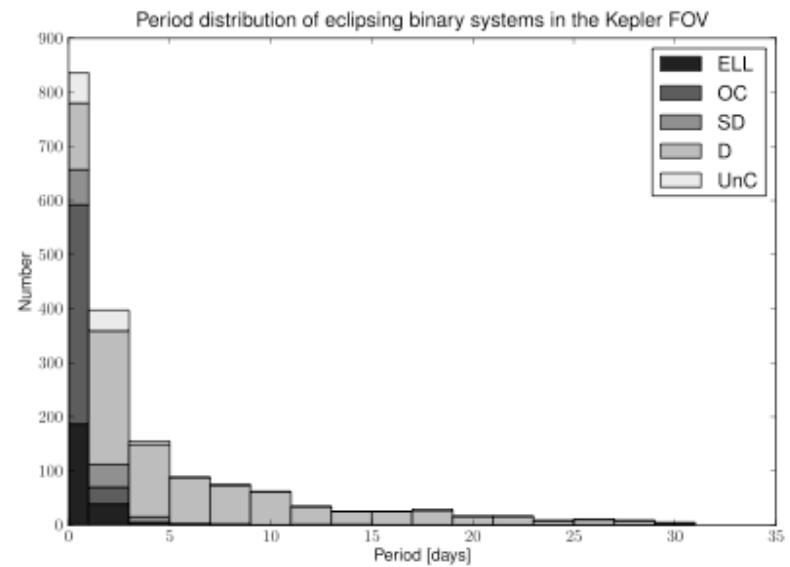
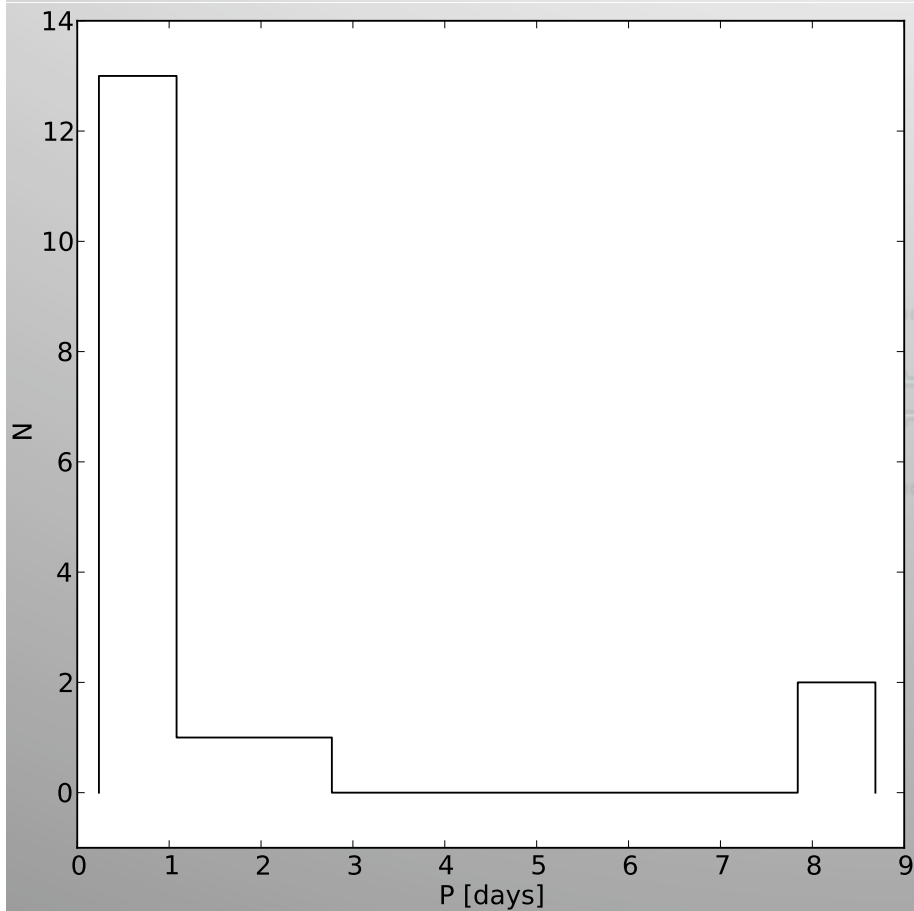
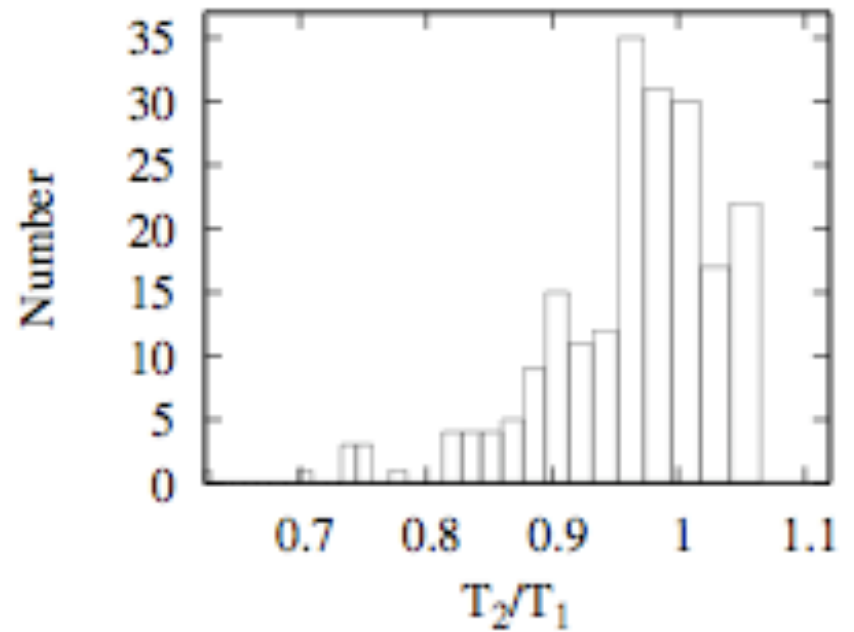
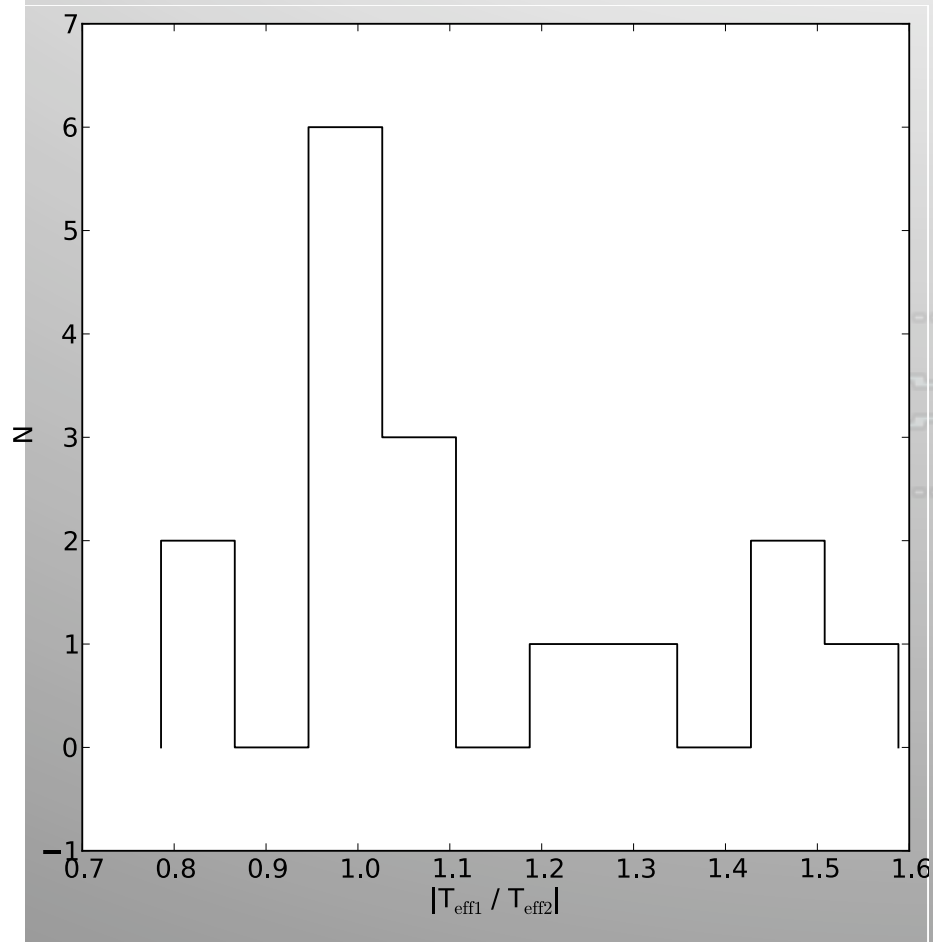
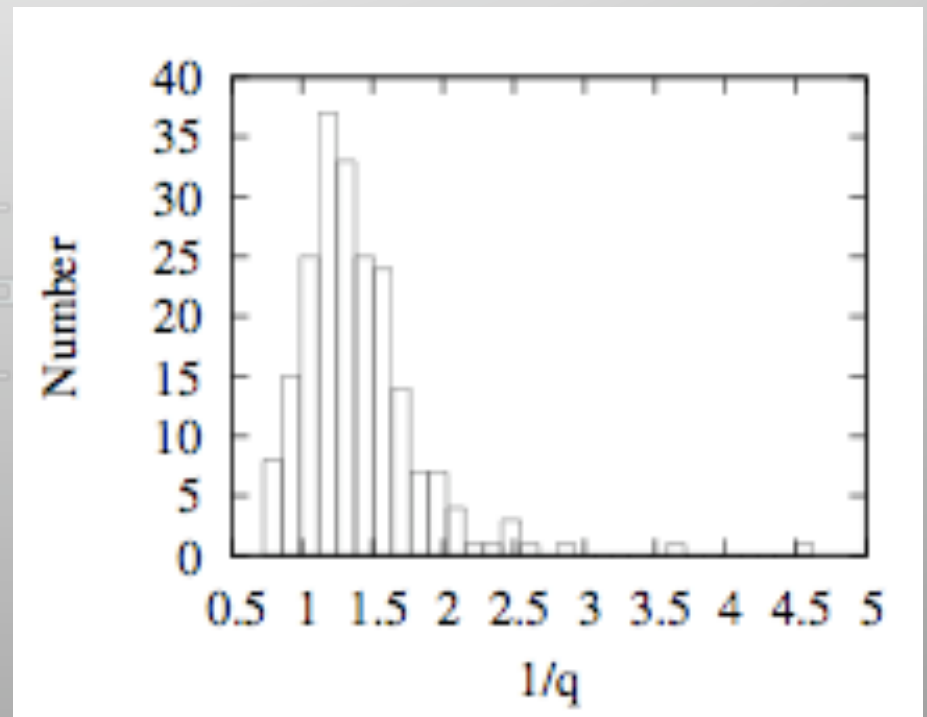
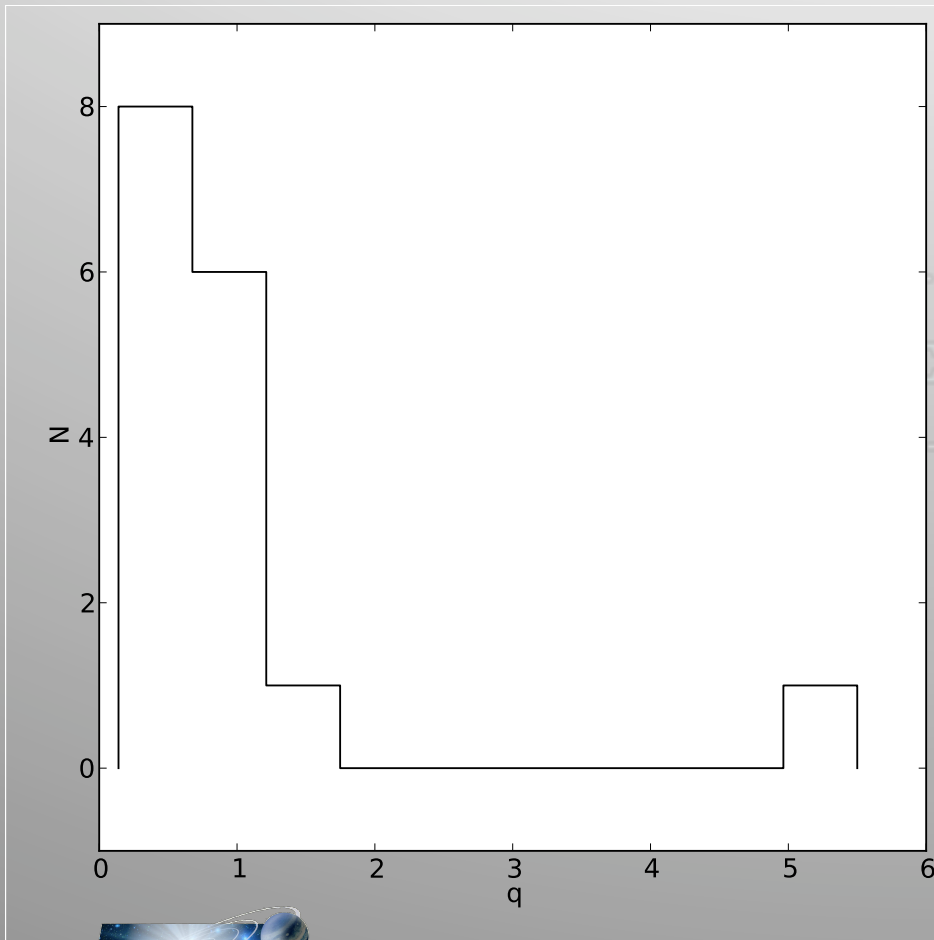


Fig. 11.— The distribution of periods for all the stars identified as eclipsing binaries in the *Kepler* Q1 data set. The baseline was 34 days (44 with Q0). Systems have been classified as ellipsoidal ('ELL'), over-contact ('OC'), semi-detached ('SD'), detached ('D'), and unclassified ('UnC').

# Temperature ratio

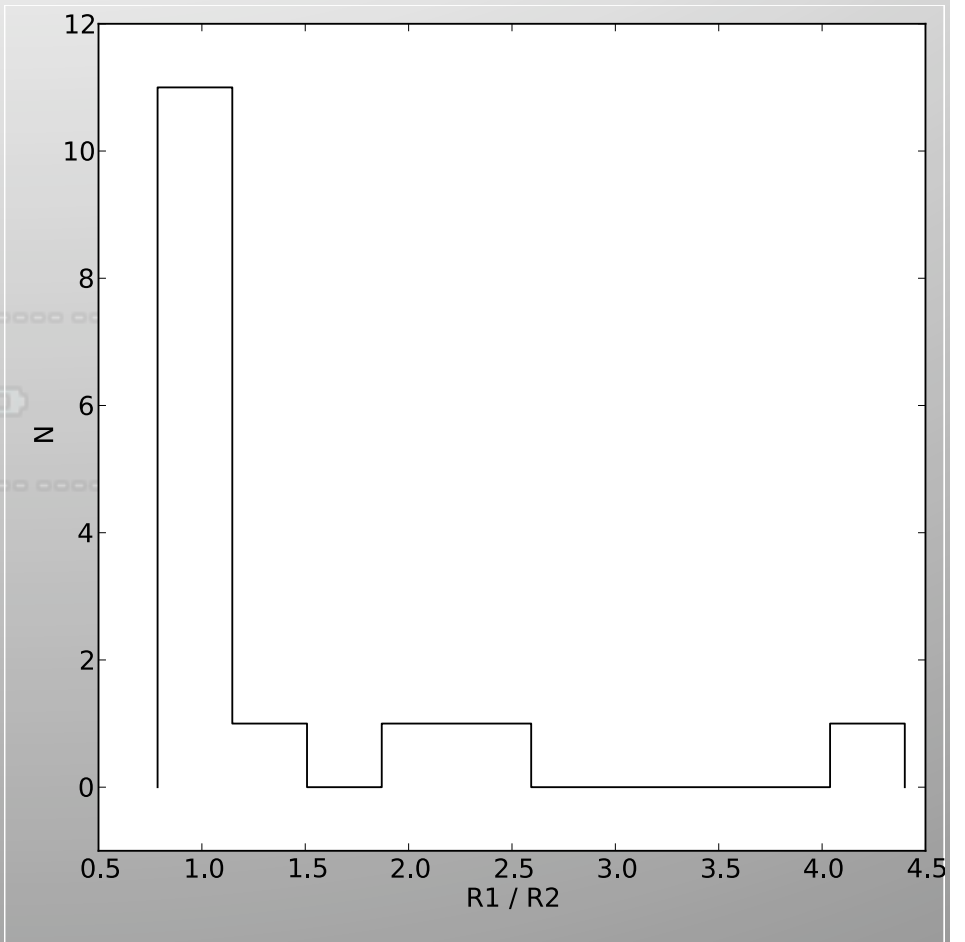
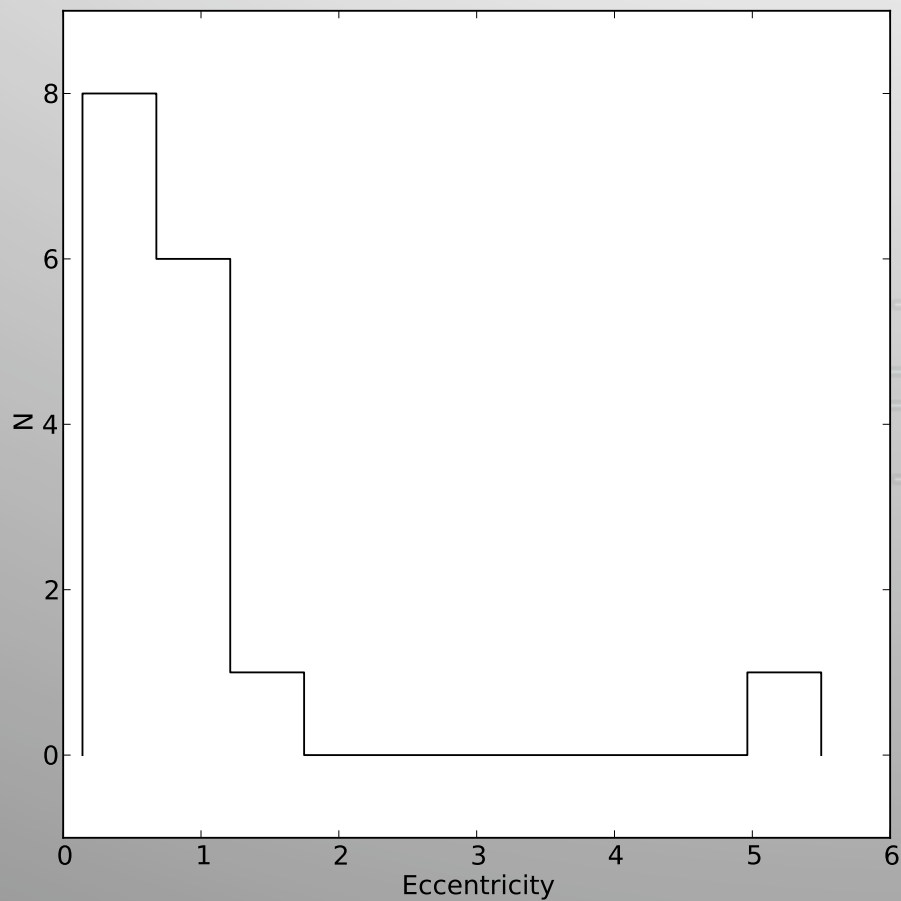


# Mass ratio



# Eccentricity

# Radius ratio



# Conclusions

- Binaries are not as simple as we thought
- Good fit requires complementary information due to degeneracies
- Mind the periodogram algorithm
- Visual fitting is hard, slow, and student-dependent
- Most of the (randomly-chosen) systems are contact-binaries

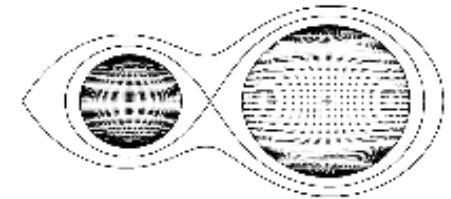


Figure 6. Both stars have fillouts equal to  $-0.10$  (detached system)

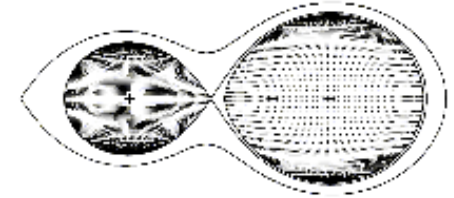


Figure 7. The smaller star has a fillout of  $0.0$ , the larger star a fillout of  $-0.02$  (a typical near-contact system)

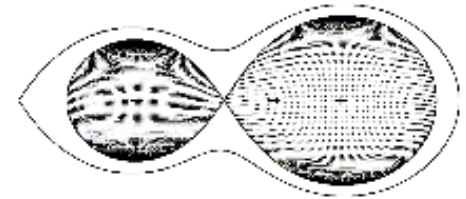


Figure 8. Fillout factor =  $0.0$  (definition of a contact system)

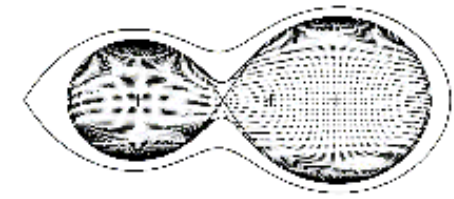


Figure 9. Fillout factor =  $0.15$  (typical overcontact system)

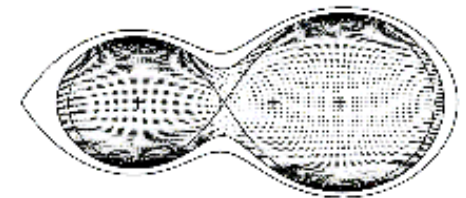


Figure 10. Fillout factor =  $0.50$

**User Input**

File Geometry Mode Spots Tools Windows Help

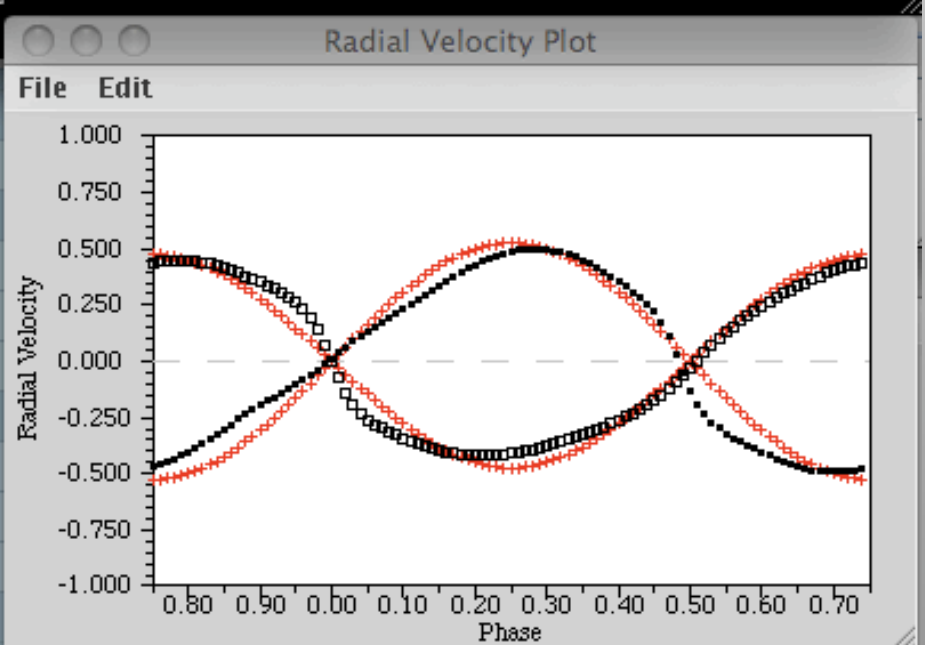
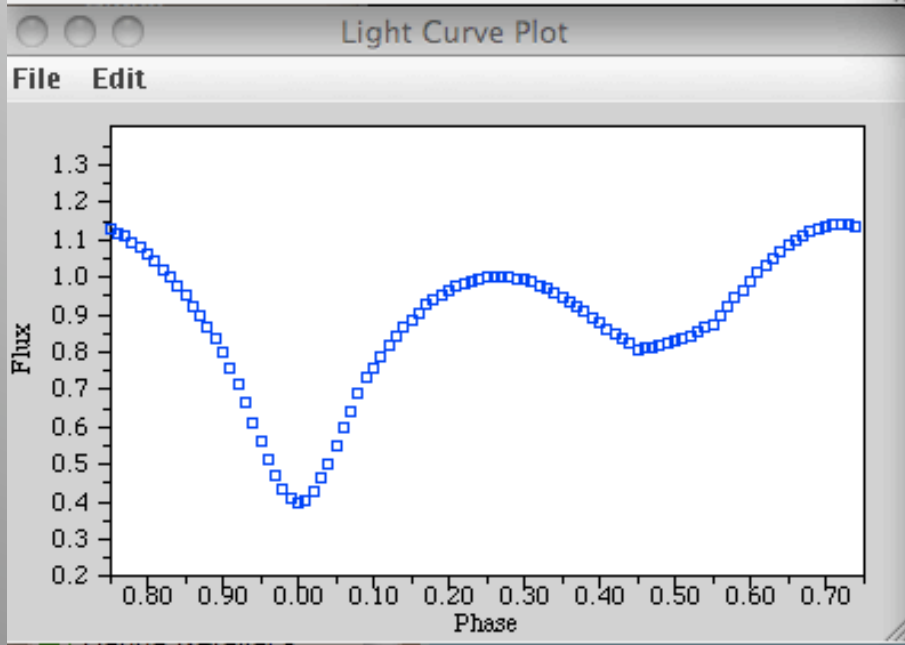
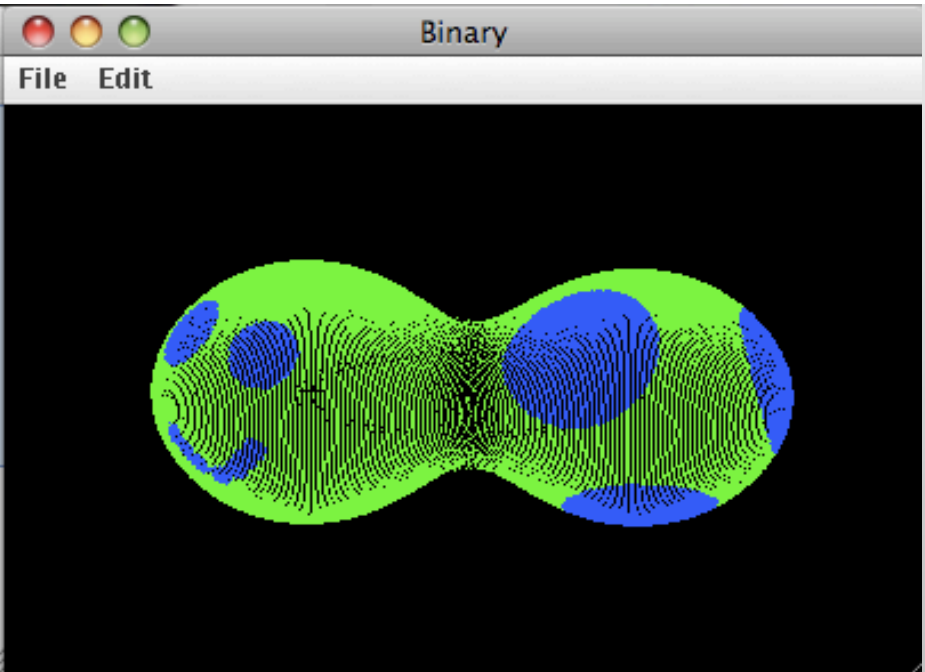
Wavelength:

Temperature 1:

Temperature 2:

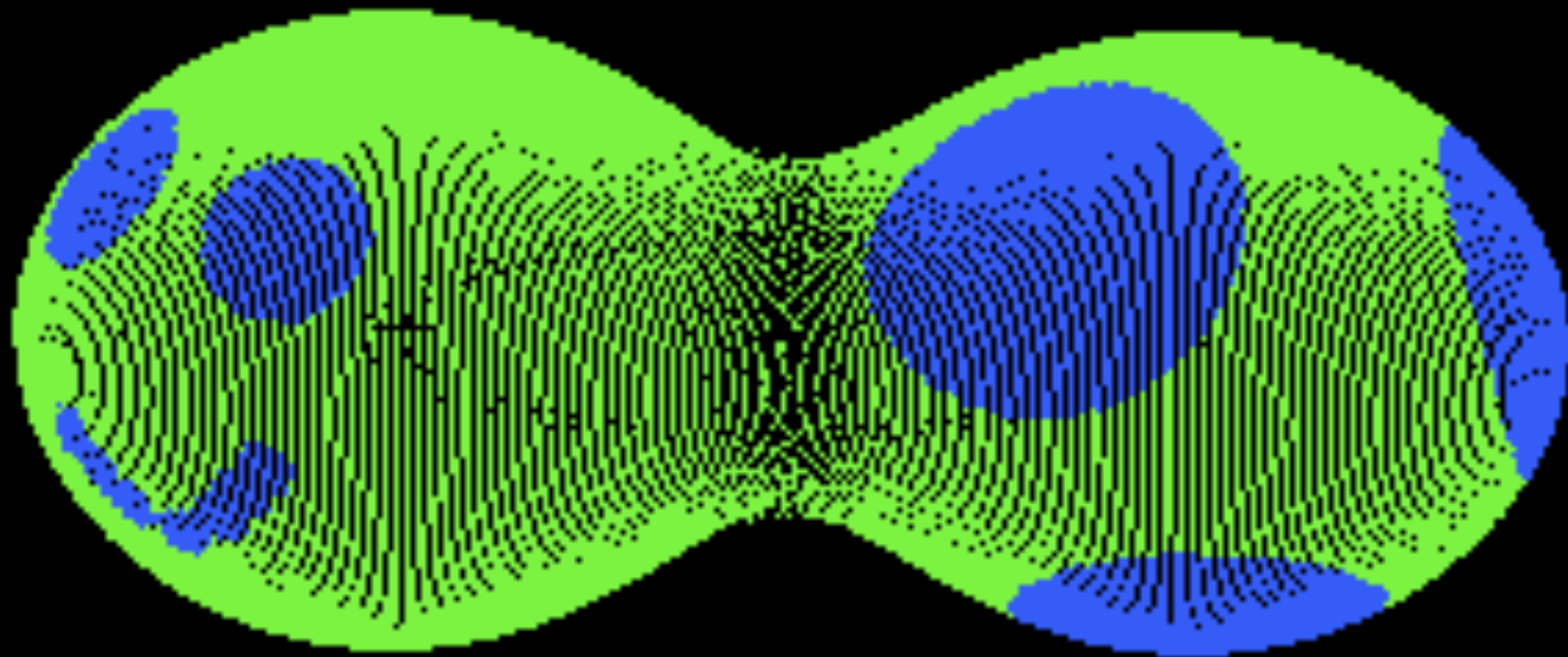
Grid	Radii	Temperature	Limb Darkening
Reflection		Observer	
Eccentric	Rotation	Disk	RV

**Render**





THE



END