

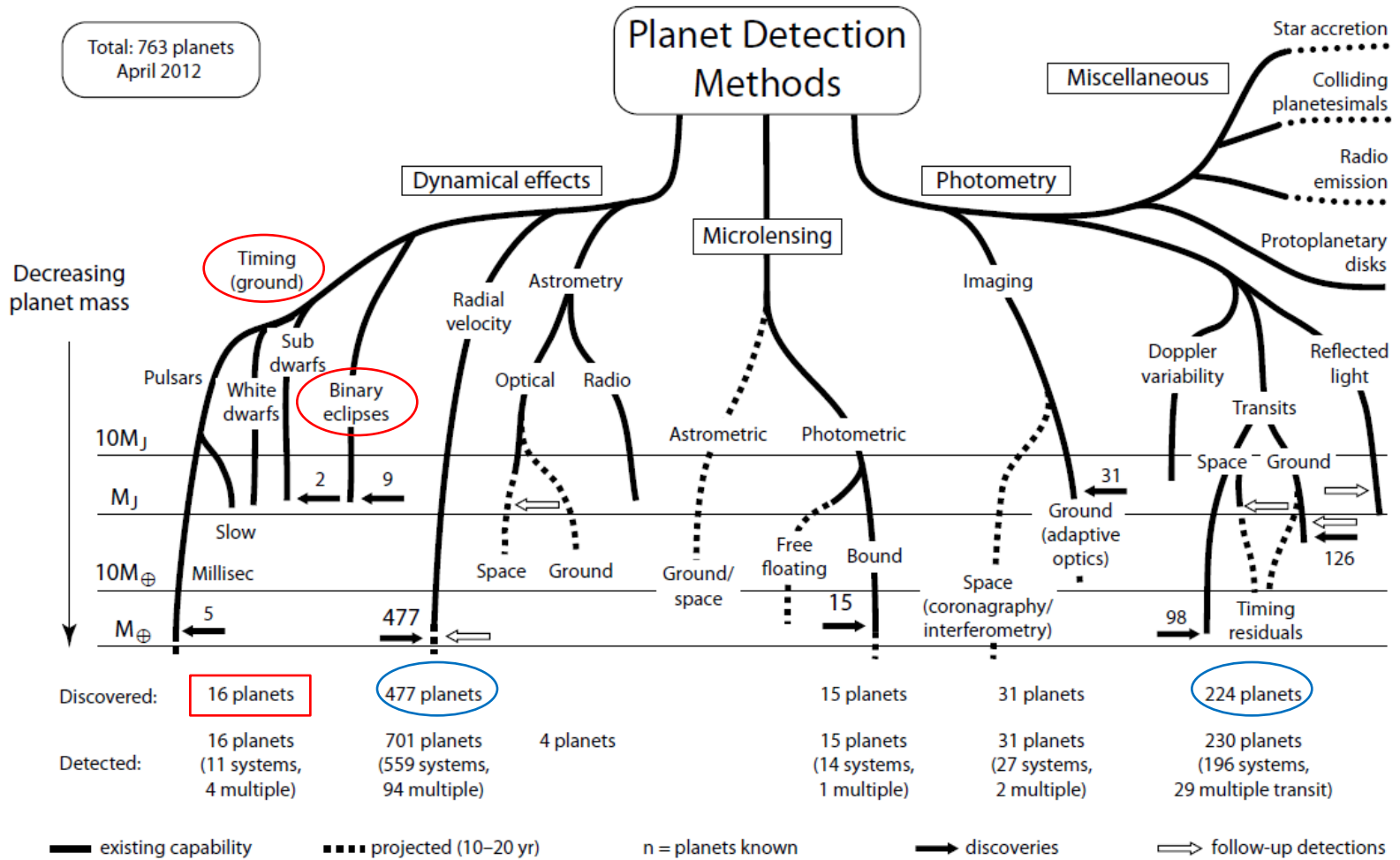
# Substellar Companions to Post Common Envelope Eclipsing Binaries

Stefan Dreizler, Klaus Beuermann, Frederic Hessman, Tim-Oliver Husser  
Institut für Astrophysik, Georg August Universität Göttingen



# Detection Methods

Substellar Companions to Post Common  
 Envelope EBs, SALT Science Symposium  
 6.11.2012



Perryman - diagram

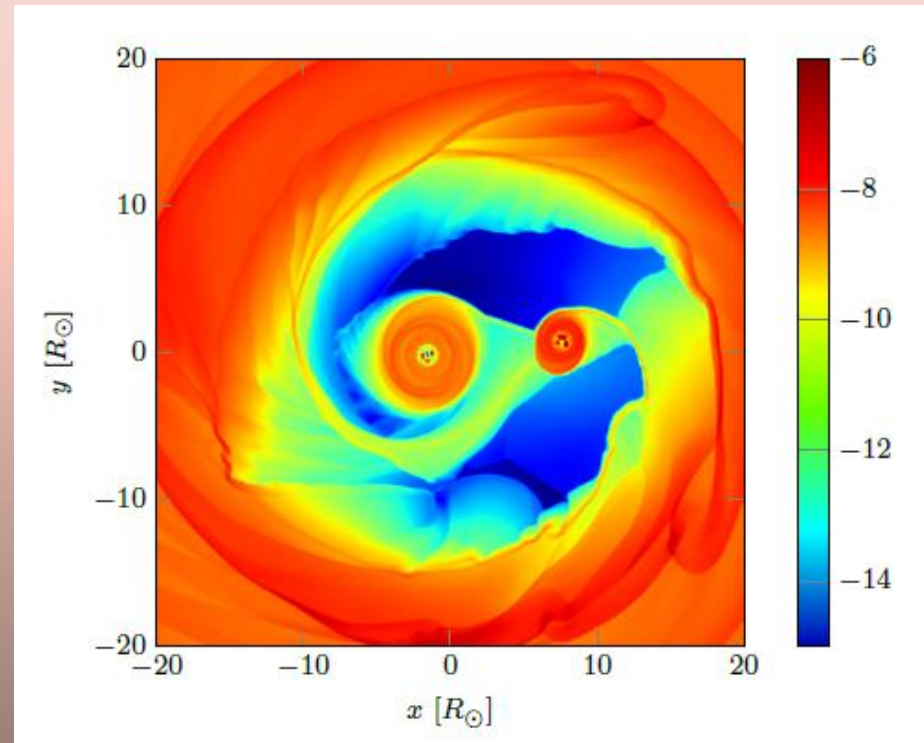
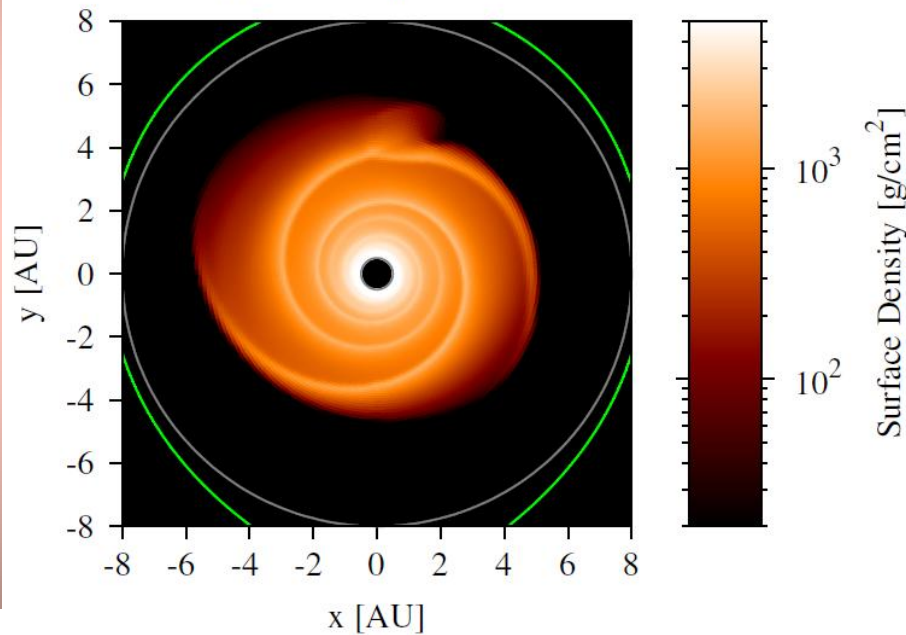


# Existence of planets in binary systems

- Dynamical stable orbits exist
- Formation via a protoplanetary disk seems possible

t Common  
Symposium

$\varphi_{\text{bin}} = 1.5\pi, r_{\text{bin}} = 17.0 \text{ AU}$



Müller & Kley 2011

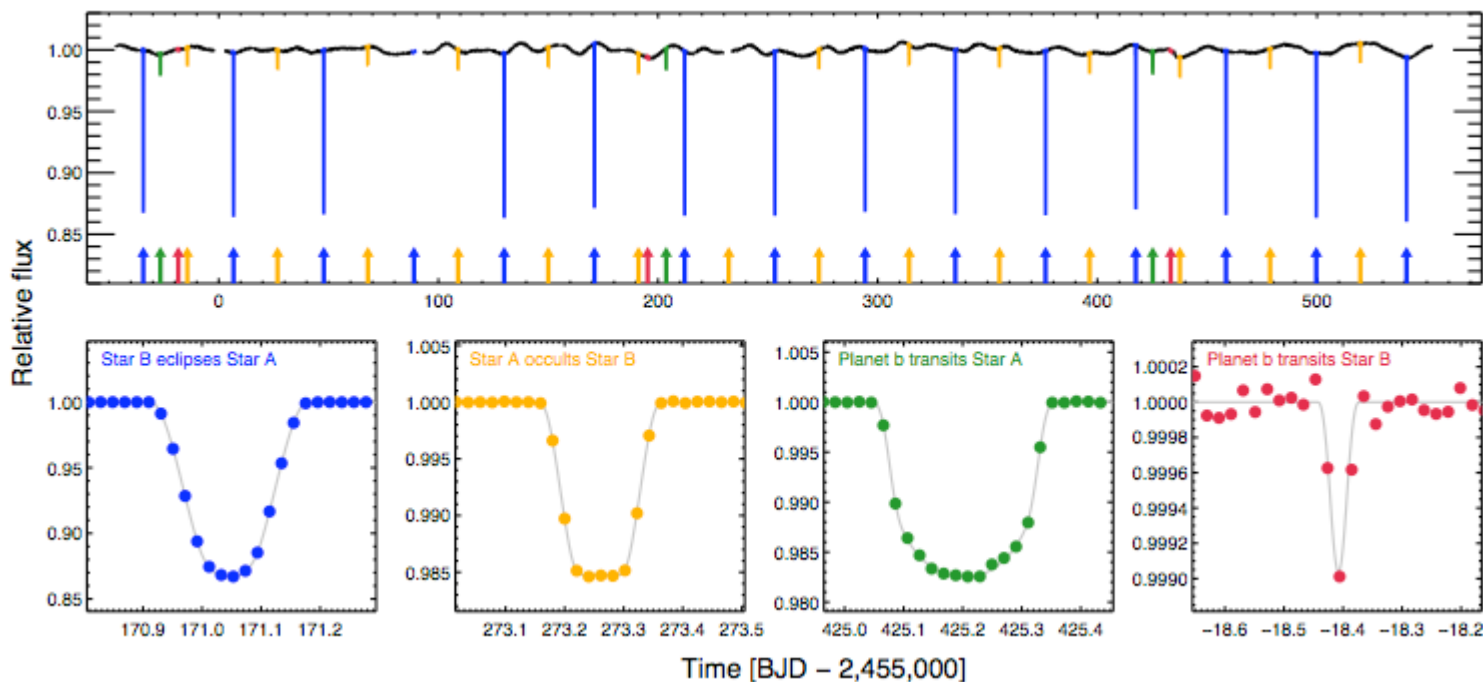
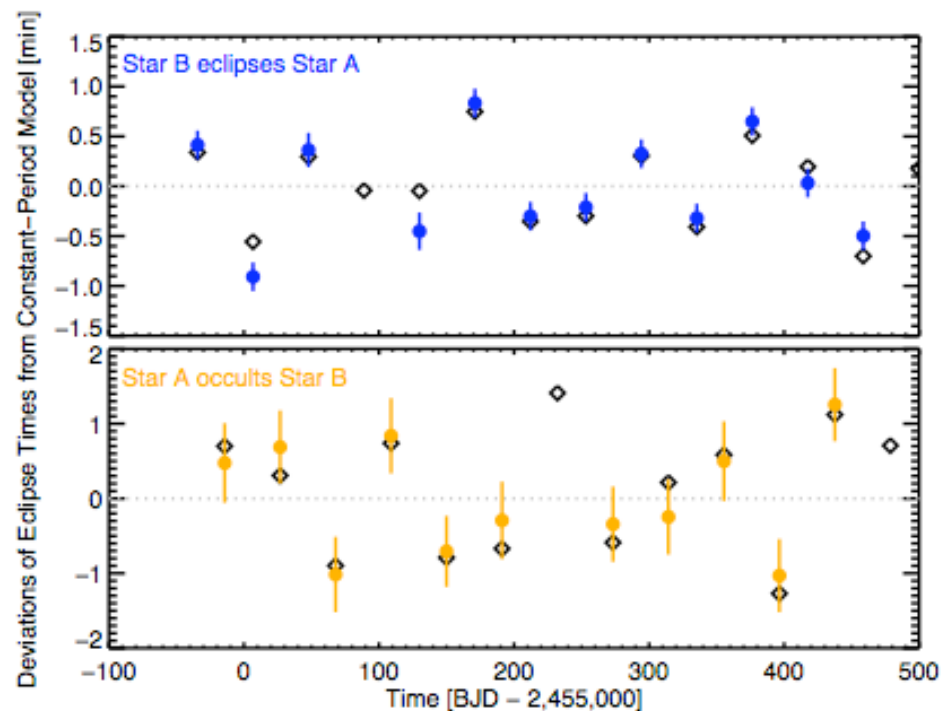
De val-Borro 2011





is to Post Common  
Science Symposium

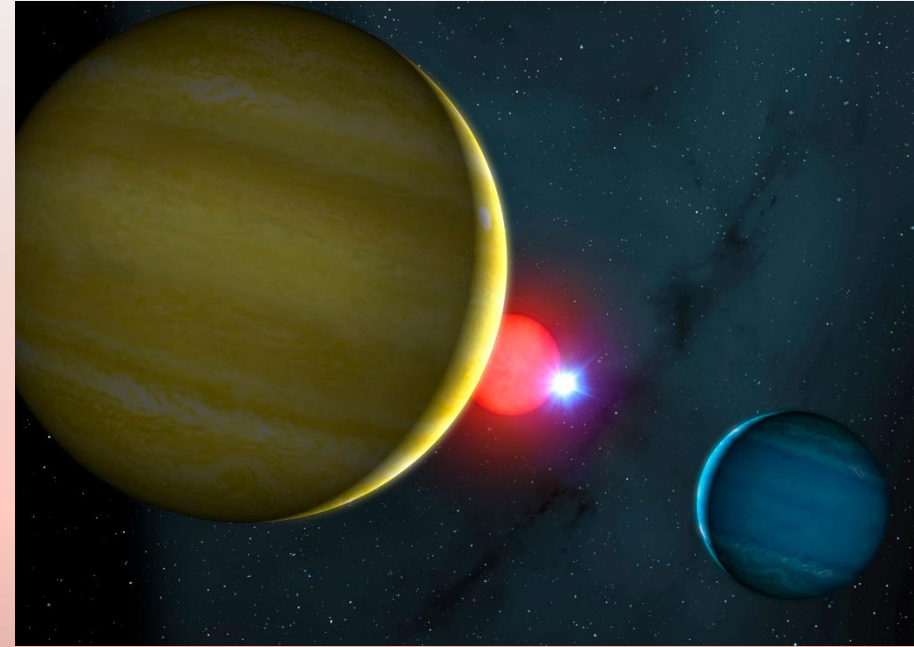
# Kepler 16 – transiting planet in an eclipsing binary



Doyle et  
al. 2011,  
Science  
333, 1602

# Exoplanets around compact binary stars

- Frequent eclipses
- Use eclipses as timing signal
- Long base line
- Interpretation
  - **Real** period variation: magnetic braking, gravitational waves, tidal interaction, Applegate's mechanism, apsidal motion
  - **Apparent** period variation: third body, eclipse profile variation



# NN Ser

Parsons et al. 2010a

$$a = 0.934 R_{\odot}$$

$$M_{\text{WD}} = 0.535 M_{\odot}$$

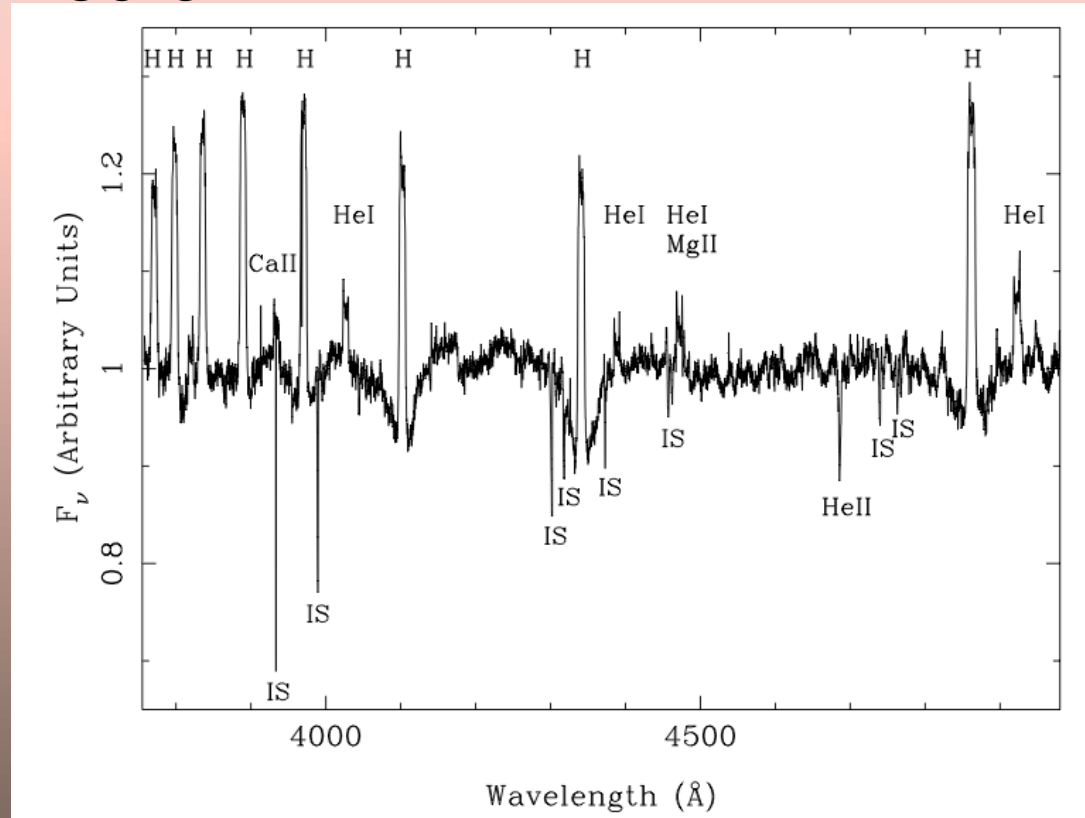
$$M_{\text{sec}} = 0.111 M_{\odot}$$

$$i = 89.6^{\circ}$$

$$T_{\text{WD}} = 57,000 \text{ K}$$

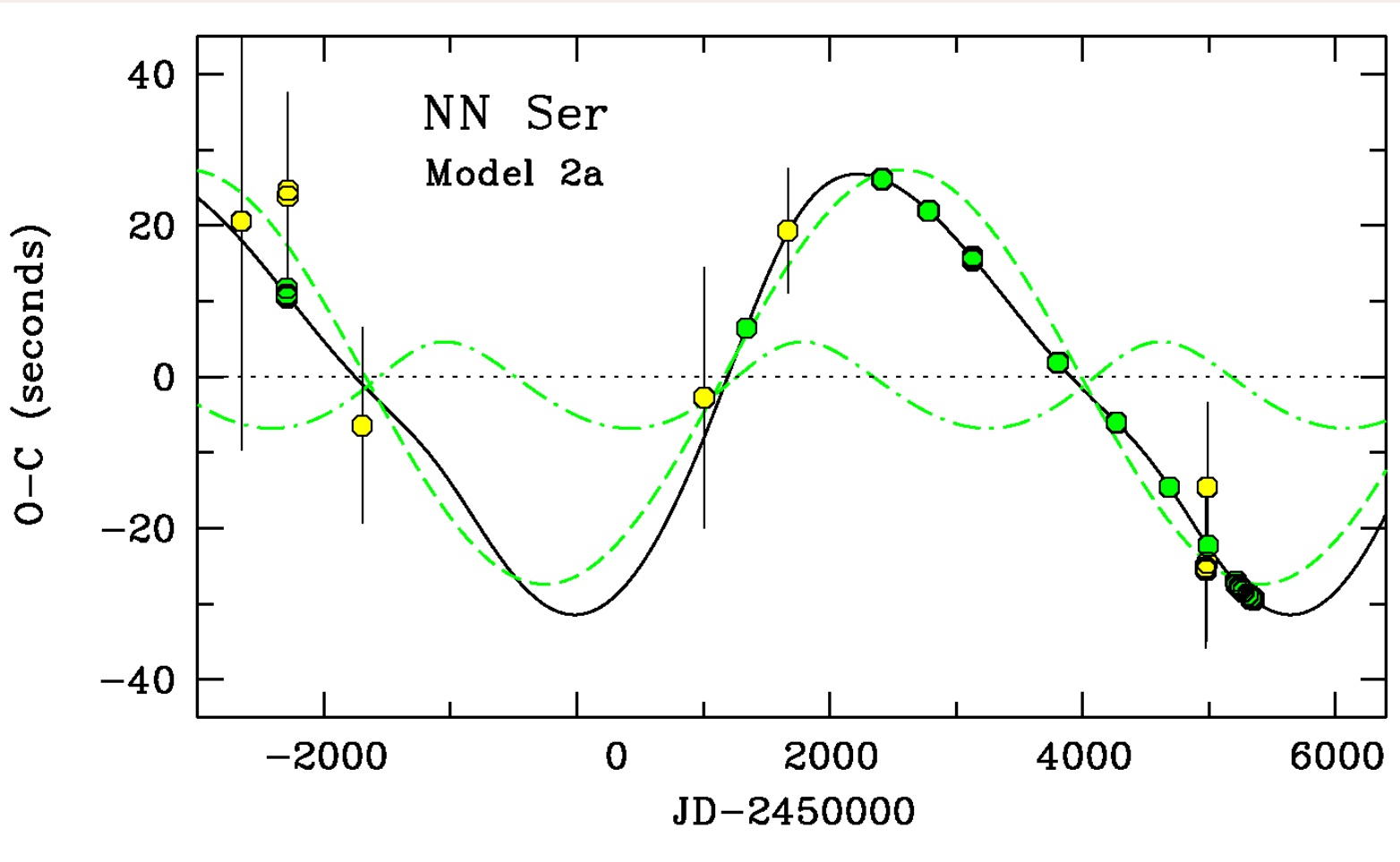
$$D = 512 \text{ pc}$$

$$\text{Age of WD} \sim 10^6 \text{ yr}$$



# NN Ser Model #2 : 2 Bodies

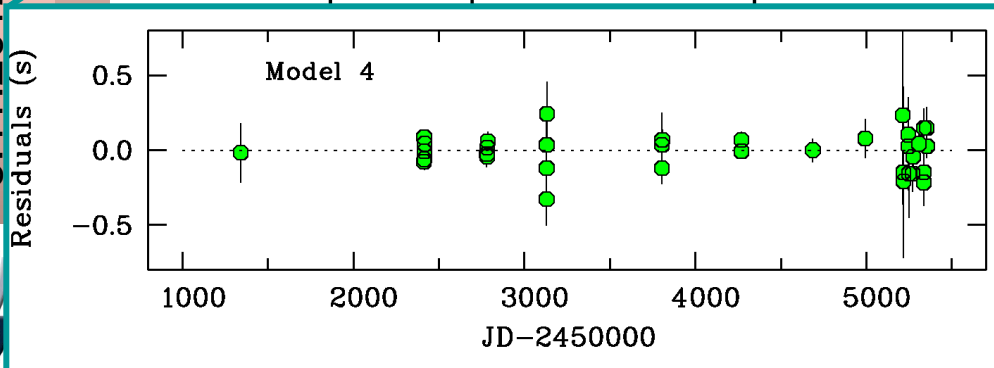
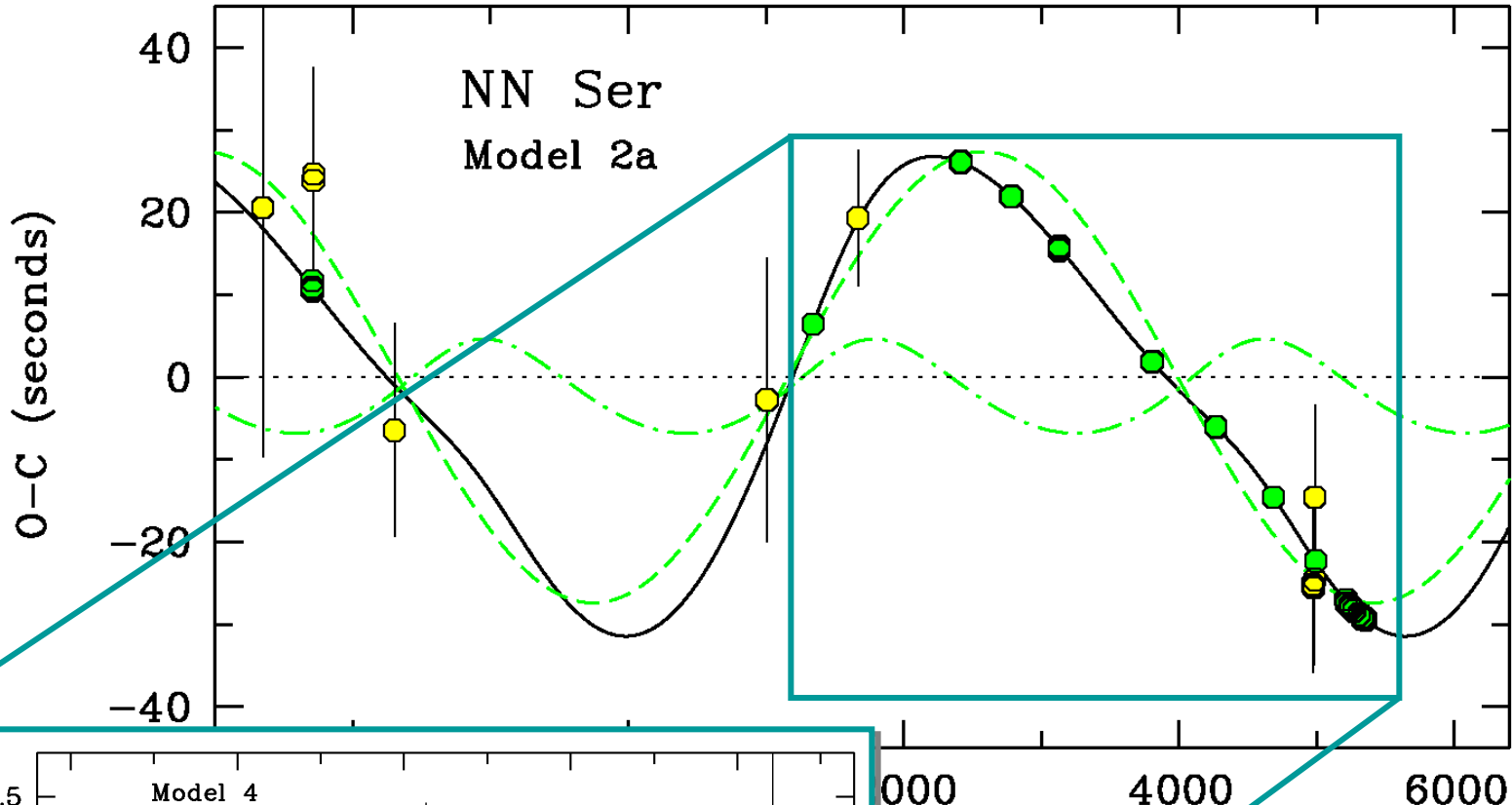
Substellar Companions to Post Common  
Envelope EBs, SALT Science Symposium  
6.11.2012



# NN Ser Model #2 : 2 Bodies

Substellar Companions to Post Common  
Envelope EBs, SALT Science Symposium

6.11.2012





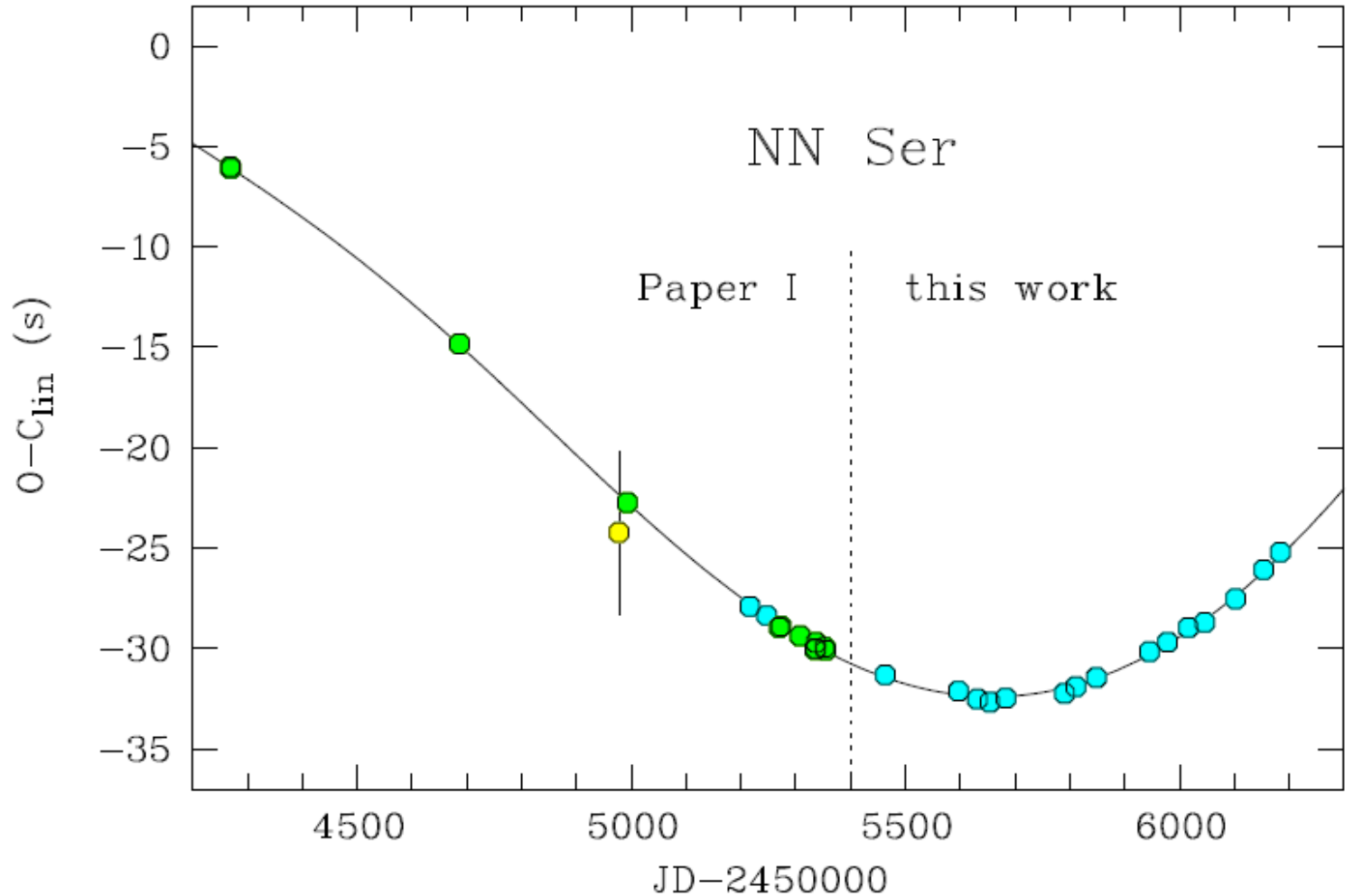
# The 2+2-Body Solutions

- Binary
  - $\dot{P} < -10^{-13}$  (GR angular momentum loss OK)
- Two stable 2+2 solutions (grid search)
  - $P_b:P_c$   $\approx 2:1$   $\approx 5:2$  ( $\pm 15\%$ )
  - Reduced  $\chi^2$  0.90 0.91
- NN Ser b
  - $e_b \equiv 0$   $\equiv 0$
  - $P_b$  [years]  $15.50 \pm 0.45$   $16.73 \pm 0.26$
  - $a_b$  [A.U.]  $5.38 \pm 0.20$   $5.65 \pm 0.06$
  - $M_b \sin i$  [ $M_{\text{Jupiter}}$ ]  $6.89 \pm 0.54$   $5.93 \pm 0.40$
- NN Ser c
  - $e_c$   $0.20 \pm 0.02$   $0.22 \pm 0.02$
  - $P_c$  [years]  $7.75 \pm 0.35$   $6.69 \pm 0.40$
  - $a_c$  [A.U.]  $3.39 \pm 0.10$   $3.07 \pm 0.13$
  - $M_c \sin i$  [ $M_{\text{Jupiter}}$ ]  $2.24 \pm 0.38$   $1.61 \pm 0.27$



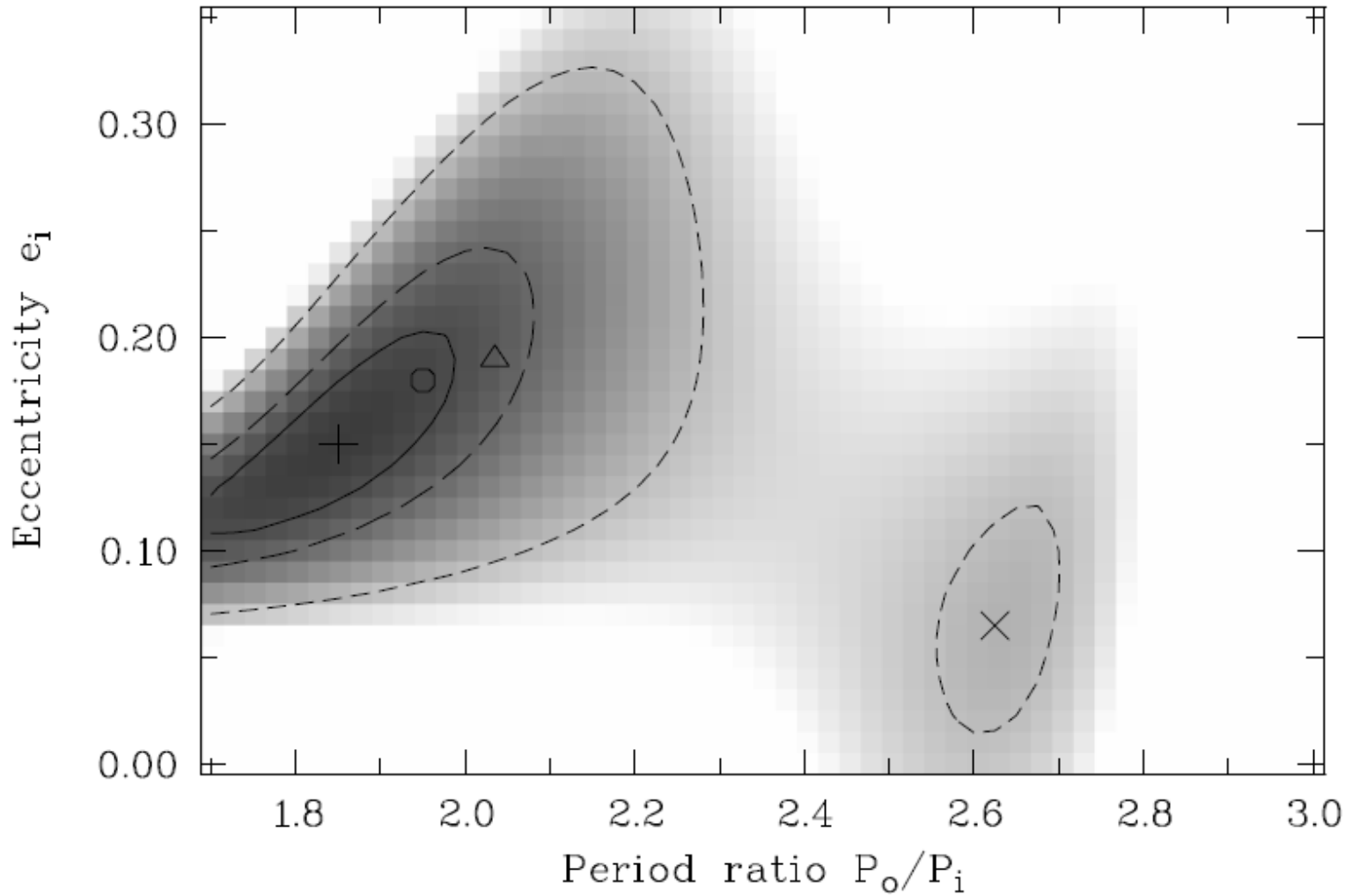
# New Results NN Ser

Substellar Companions to Post Common  
Envelope EBs, SALT Science Symposium  
6.11.2012



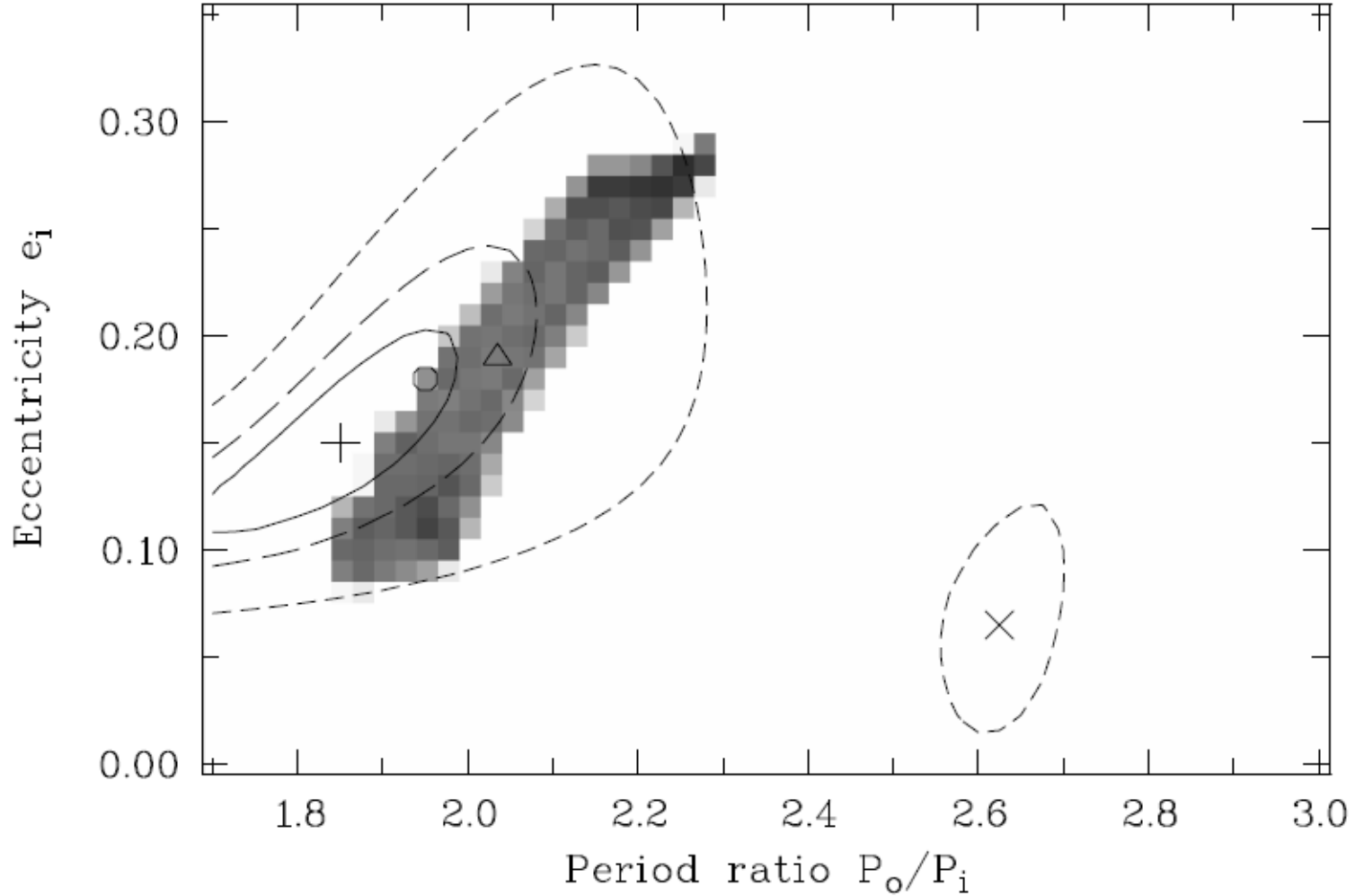
# New Results NN Ser

Substellar Companions to Post Common  
Envelope EBs, SALT Science Symposium  
6.11.2012



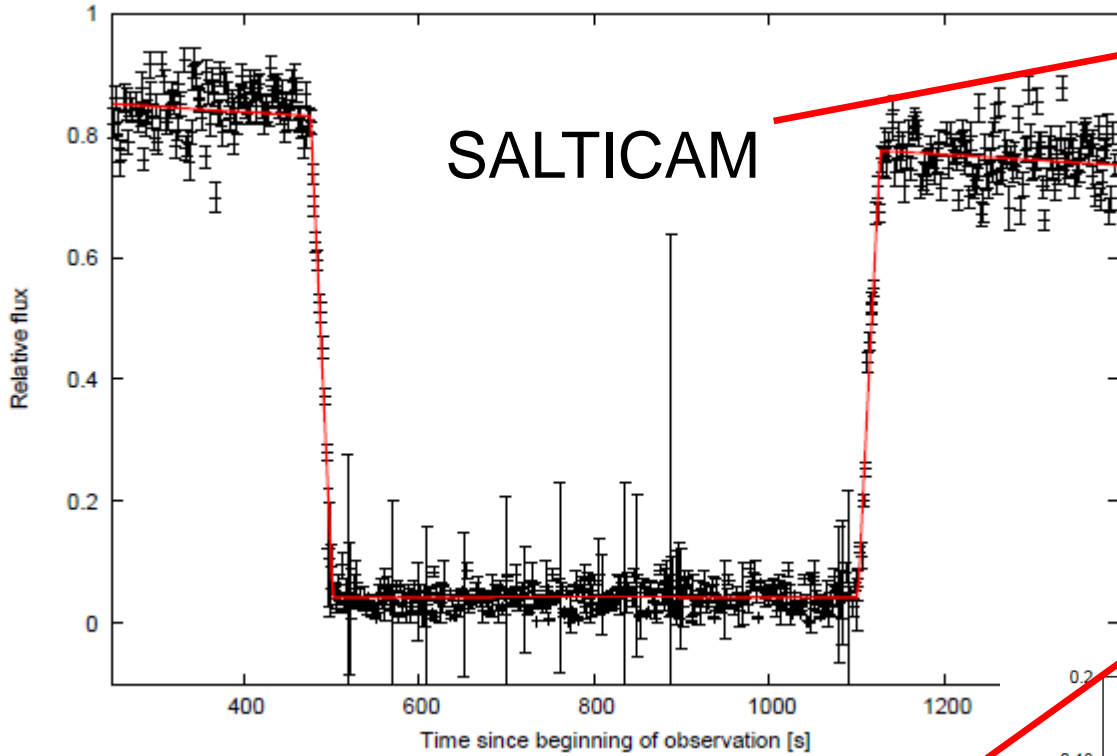
# New Results NN Ser

Substellar Companions to Post Common  
Envelope EBs, SALT Science Symposium  
6.11.2012



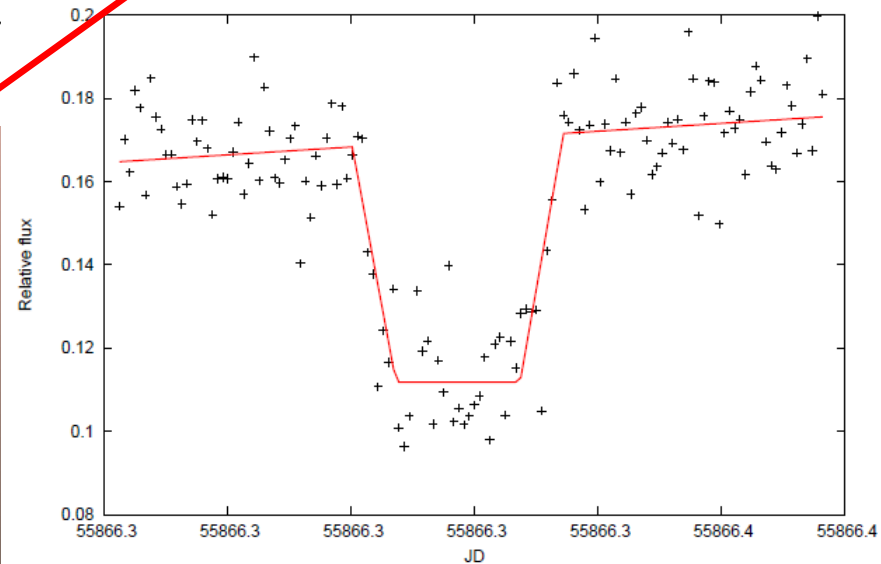
# SALT Contribution

SDSS0303 2011-10-23



MONET/S

SDSS0303 2011-10-27 Monet/S



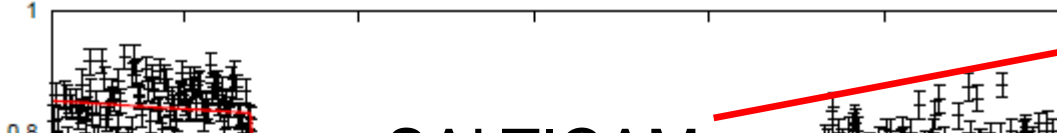
Substellar  
Envelope  
6.11.2012



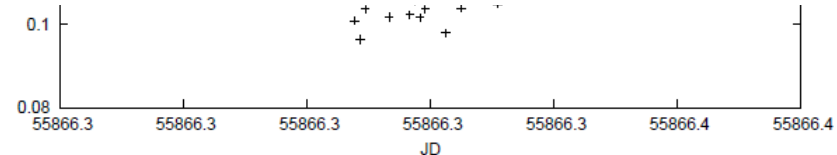
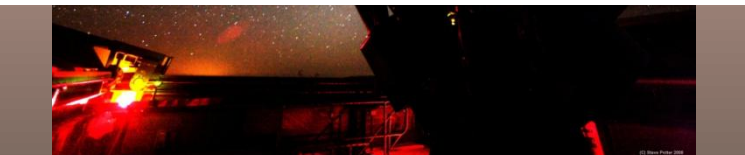
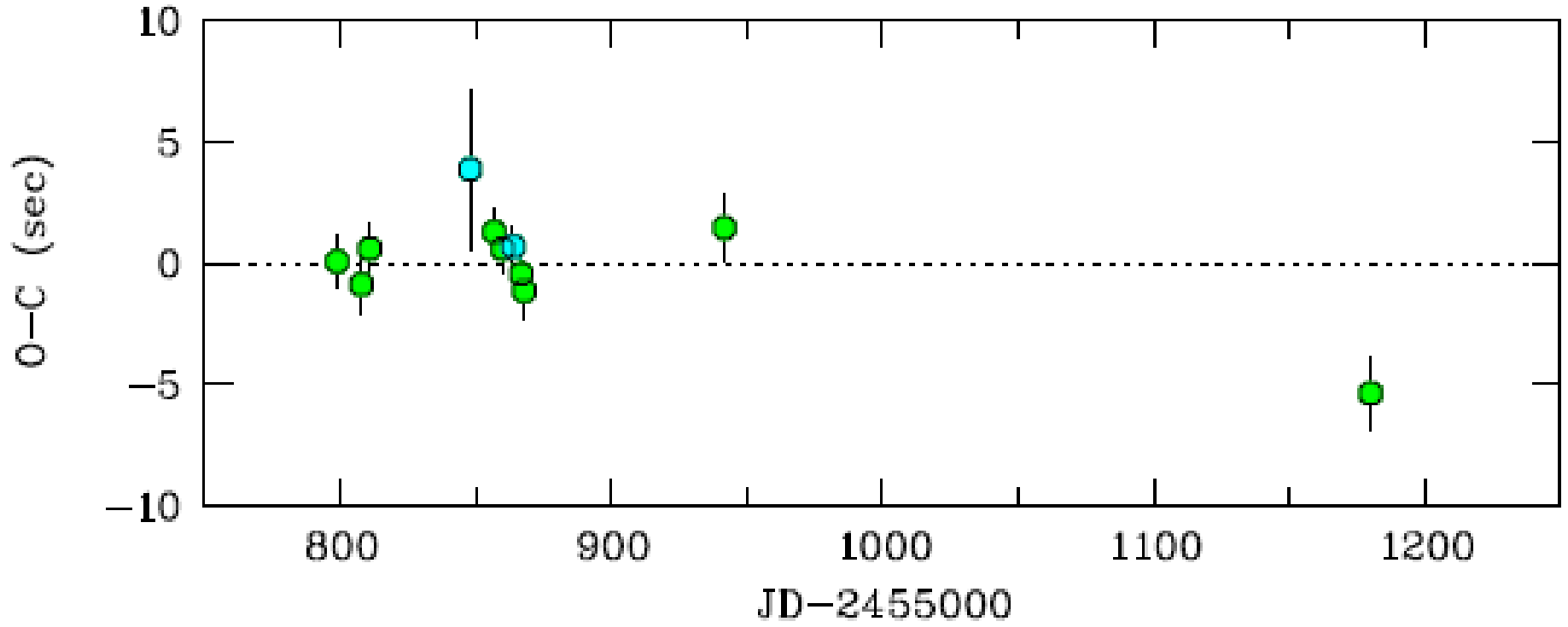
# SALT Contribution



SDSS0303 2011-10-23

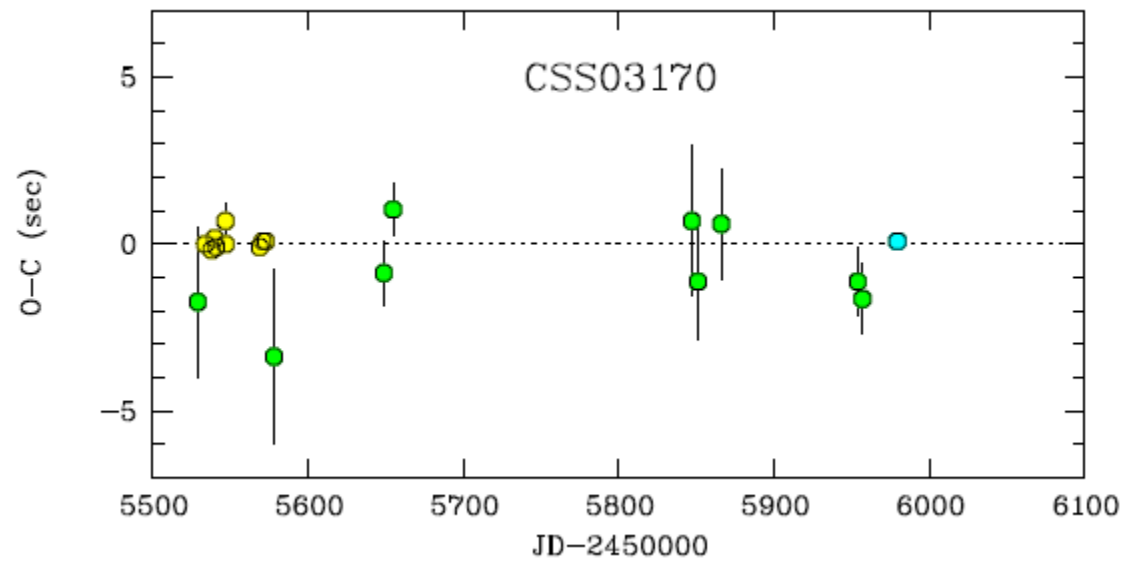
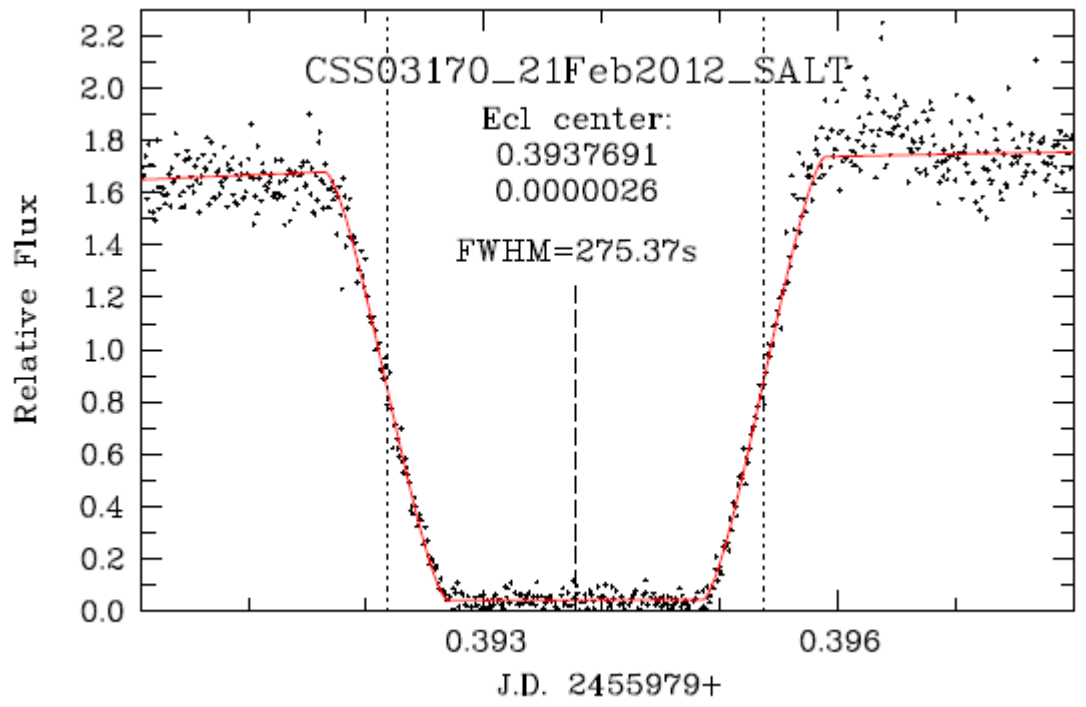


SDSSJ0303+00





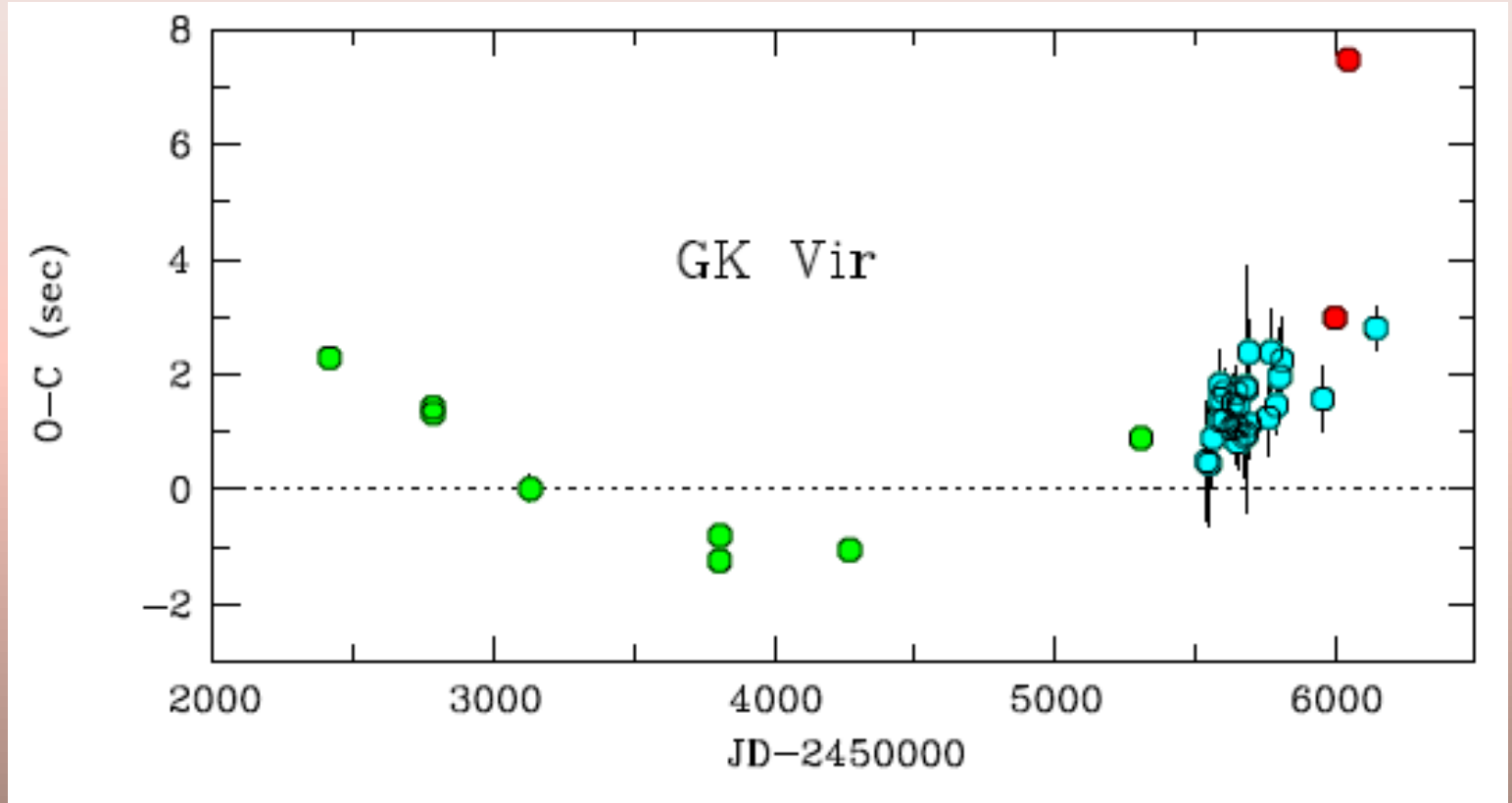
# CSS03170





Substellar Companions to Post Common  
Envelope EBs, SALT Science Symposium  
6.11.2012

# GK Vir





# Conclusion

- Superb timing precision will fix parameters of more substellar/planetary companions
- Superb timing precision will set tight non-detection limits
- Constraints for planet formation and evolution in binaries
- Difficulties encountered
  - Timing offset due to slot mode (solved)
  - Distribution of time on 9 categories makes phase II a tedious job