PROMPT:
An effective tool for studies of pulsating stars

Brad N. Barlow
Graduate Student
Department of Physics & Astronomy
University of North Carolina - Chapel Hill

THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

Bart Dunlap, Chris Clemens
SKYNET Team: D. Reichart, A. LaCluyze, J. Haislip,
K. Ivarsen, M. Nysewander

Fortnightly Fluctuations in the O-C Diagram of CS 1246

Brad N. Barlow
Graduate Student
Department of Physics & Astronomy
University of North Carolina - Chapel Hill

THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

Bart Dunlap, Chris Clemens
SKYNET Team: D. Reichart, A. LaCluyze, J. Haislip,
K. Ivarsen, M. Nysewander

The Tools at UNC-Chapel Hill

SOAR Telescope

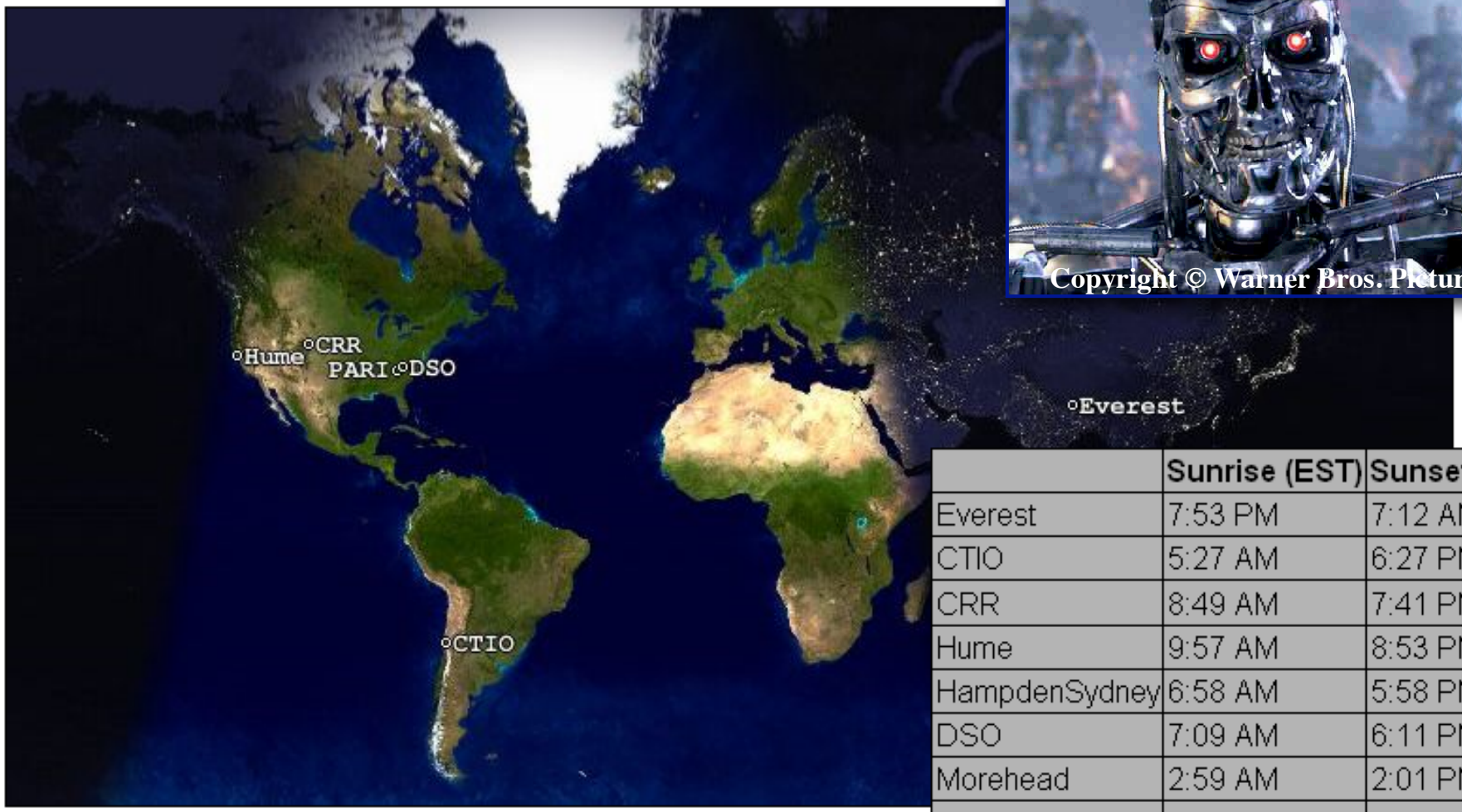
- 4.1-m aperture
- Cerro Pachon, Chile

PROMPT (part of SKYNET)

- array of 5 robotic telescopes
- 0.4-m apertures
- Cerro Tololo, Chile
- 100% automated

SKYNET

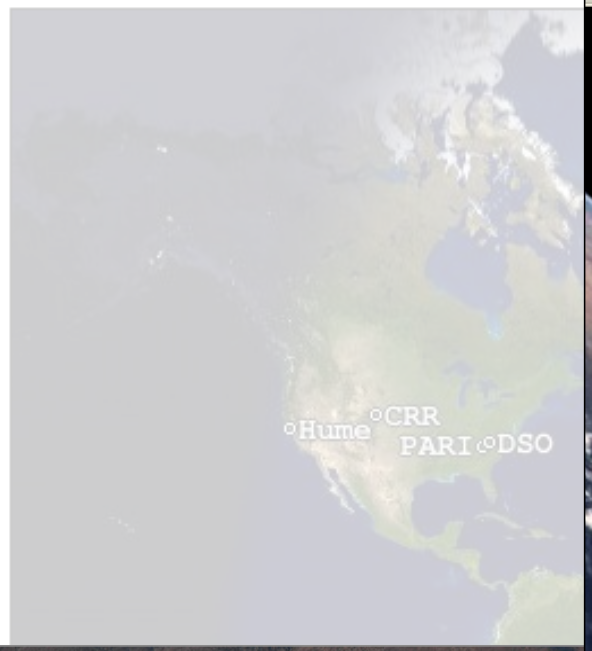
Skynet sunlight map

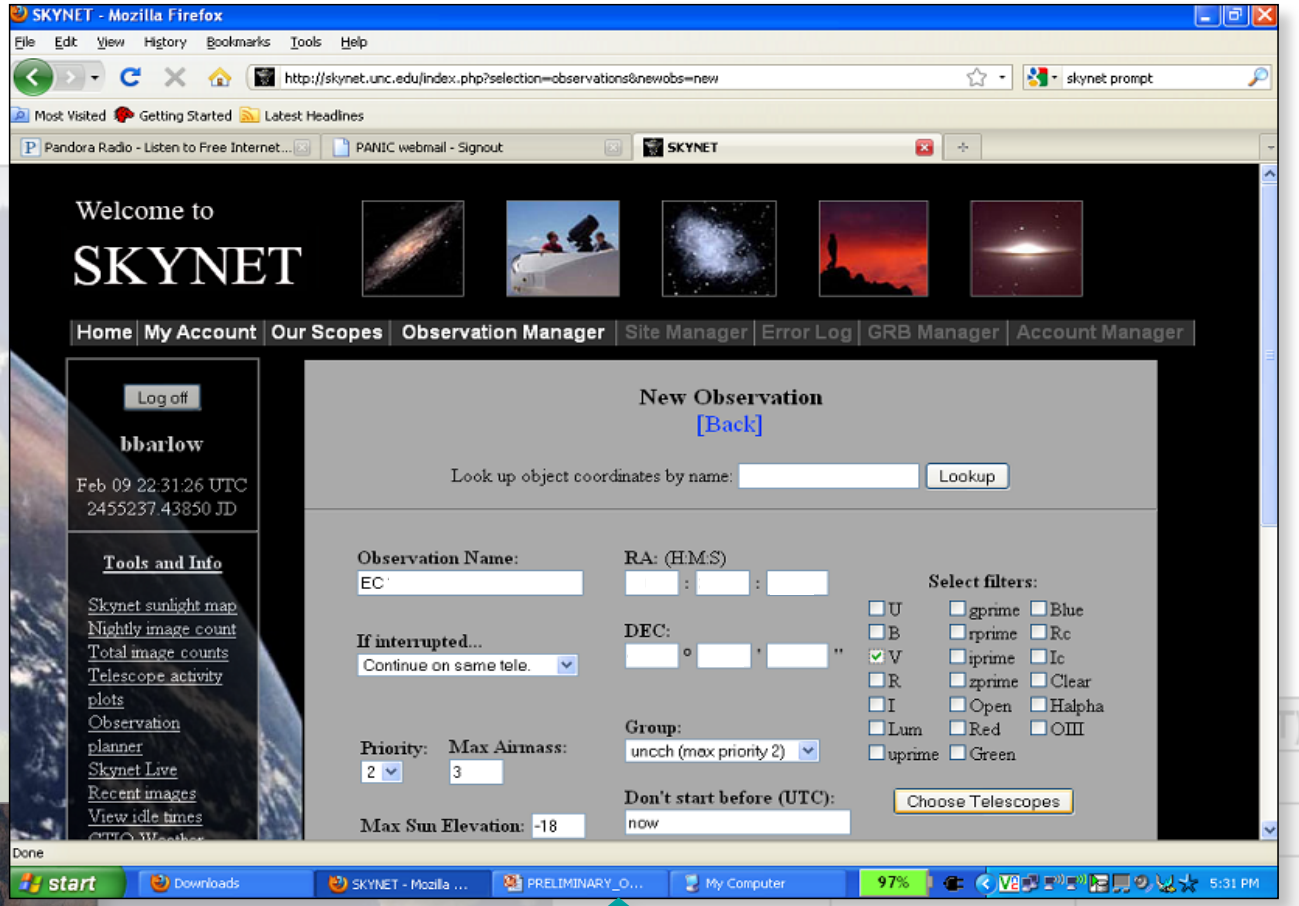


	Sunrise (EST)	Sunset (EST)
Everest	7:53 PM	7:12 AM
CTIO	5:27 AM	6:27 PM
CRR	8:49 AM	7:41 PM
Hume	9:57 AM	8:53 PM
HampdenSydney	6:58 AM	5:58 PM
DSO	7:09 AM	6:11 PM
Morehead	2:59 AM	2:01 PM
Dolomiti	1:14 AM	11:48 AM
PARI	7:14 AM	6:18 PM
Yerkes	7:57 PM	6:43 AM

SKYNET

Skynet sunlight map



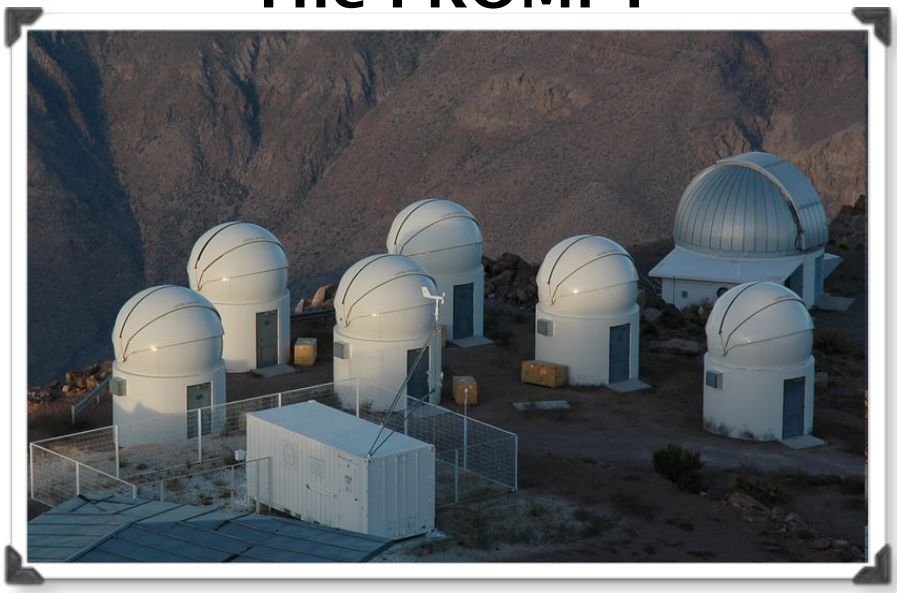


Terminators

	9:57 AM	8:53 PM
denSydney	6:58 AM	5:58 PM
	7:09 AM	6:11 PM
Morehead	2:59 AM	2:01 PM
Dolomiti	1:14 AM	11:48 AM
PARI	7:14 AM	6:18 PM
Yerkes	7:57 PM	6:43 AM

PROMPT as a Tool for Studying Pulsators

The PROMPT



Advantages

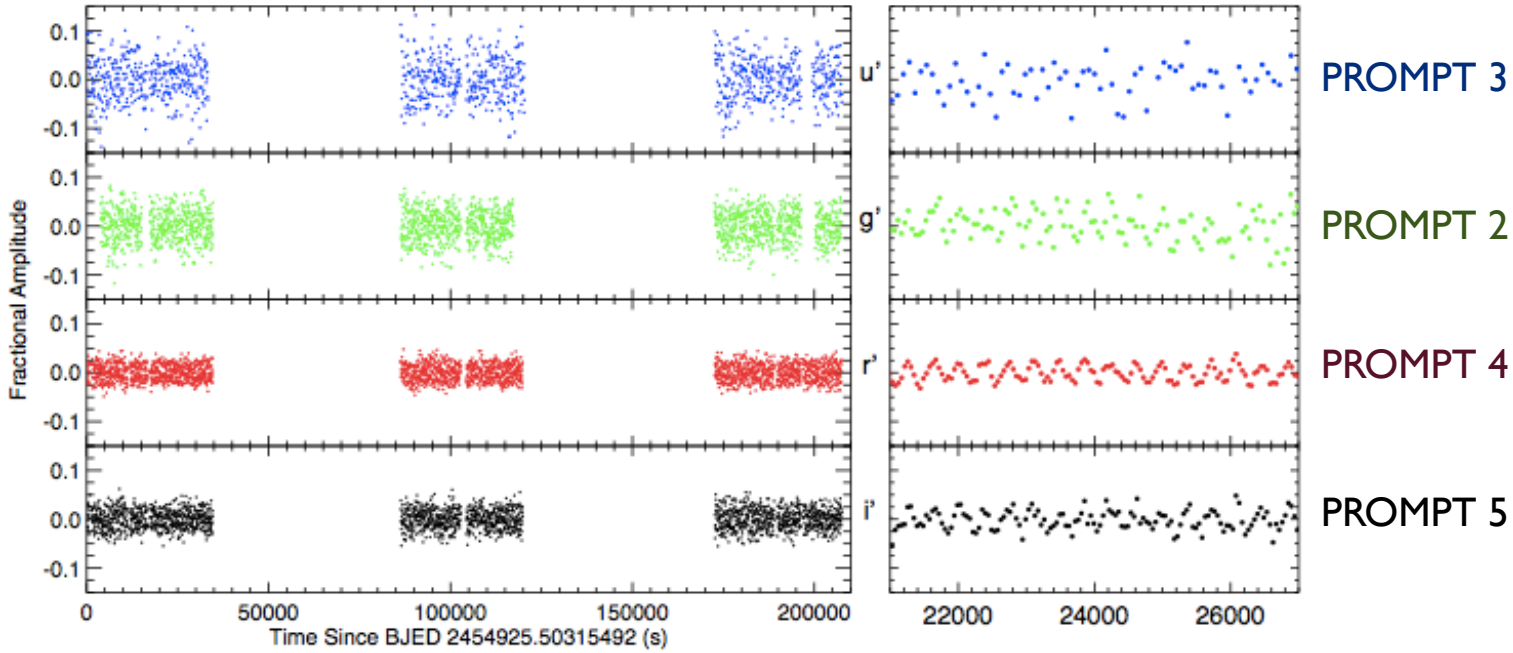
- great observing site
- 10' x 10' F.O.V.
- multi-color photometry easy
- lots of time available to us

Disadvantages

- small apertures

PROMPT as a Tool for Studying Pulsators

Simultaneous, multi-color photometry of CS 1246



Advantages

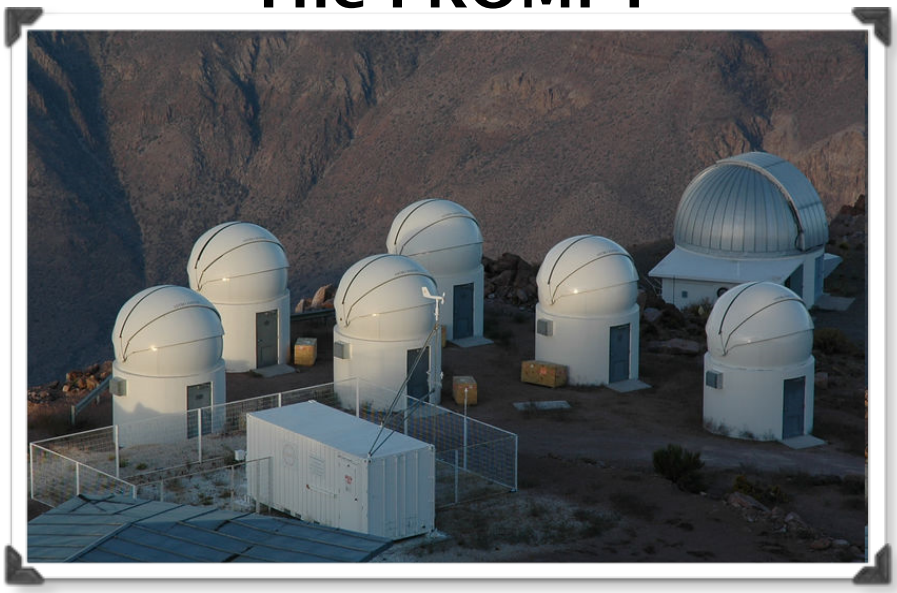
- great observing site
- 10' x 10' F.O.V.
- multi-color photometry easy
- lots of time available to us

Disadvantages

- small apertures

PROMPT as a Tool for Studying Pulsators

The PROMPT



Advantages

- great observing site
- 10' x 10' F.O.V.
- multi-color photometry easy
- lots of time available to us

Disadvantages

- small apertures

O-C Diagram Basics

- 'O-C' = 'observed - calculated'

- used to measure small differences in arrival times of photons

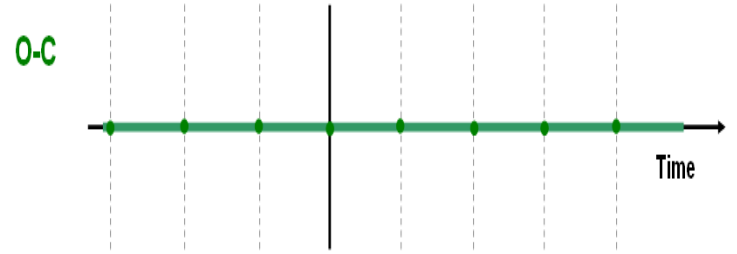
- same timing method used to find planets around pulsars

$$C = T_o + P_o E$$

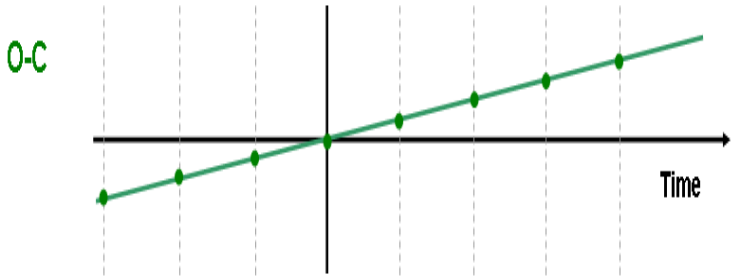
T_o - time at cycle E=0
P_o - period at T_o
E - cycle #

O taken from data

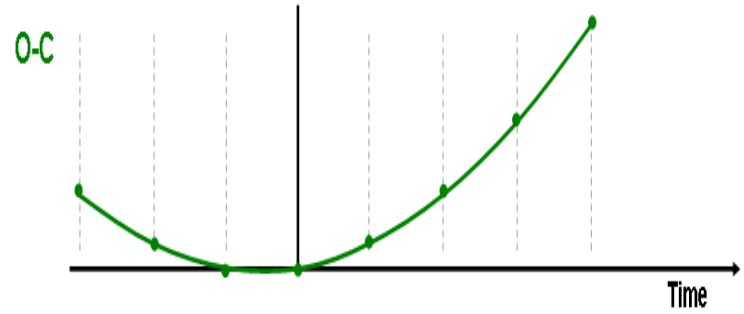
1. **Period correct and constant**



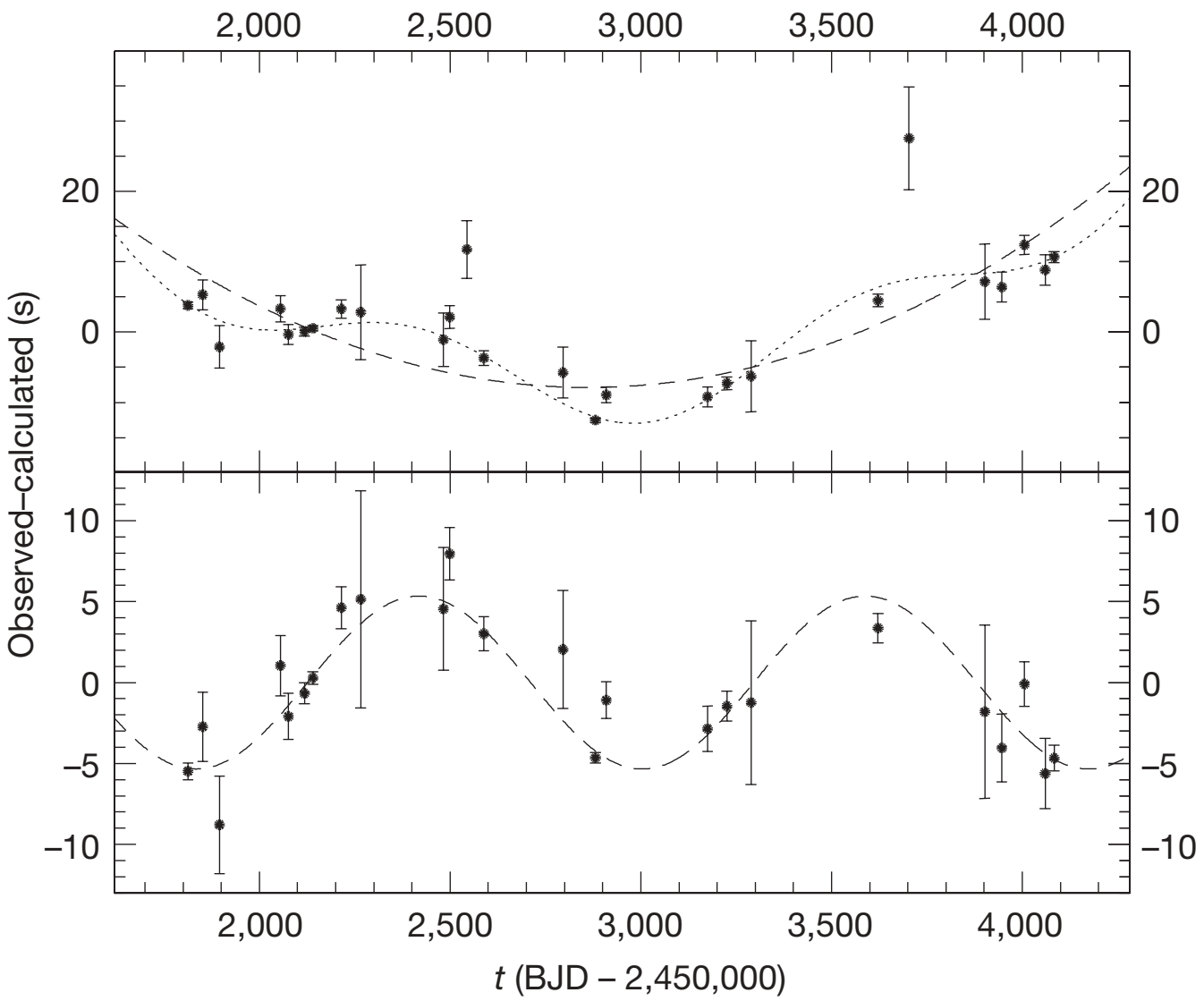
2. **Period wrong but constant**



3. **Period increasing**

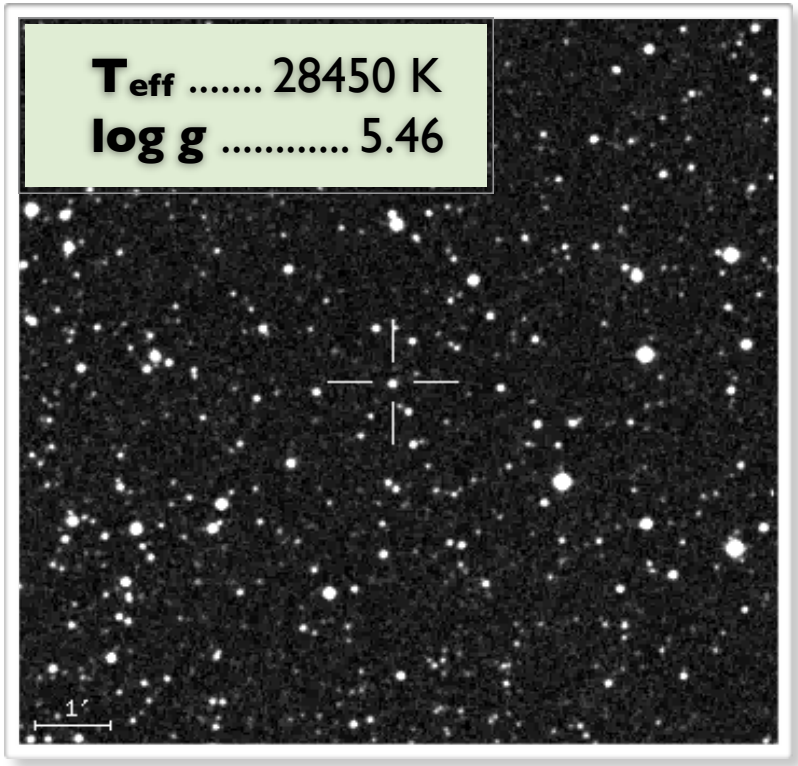


Example O-C Diagram: V391 Pegasi

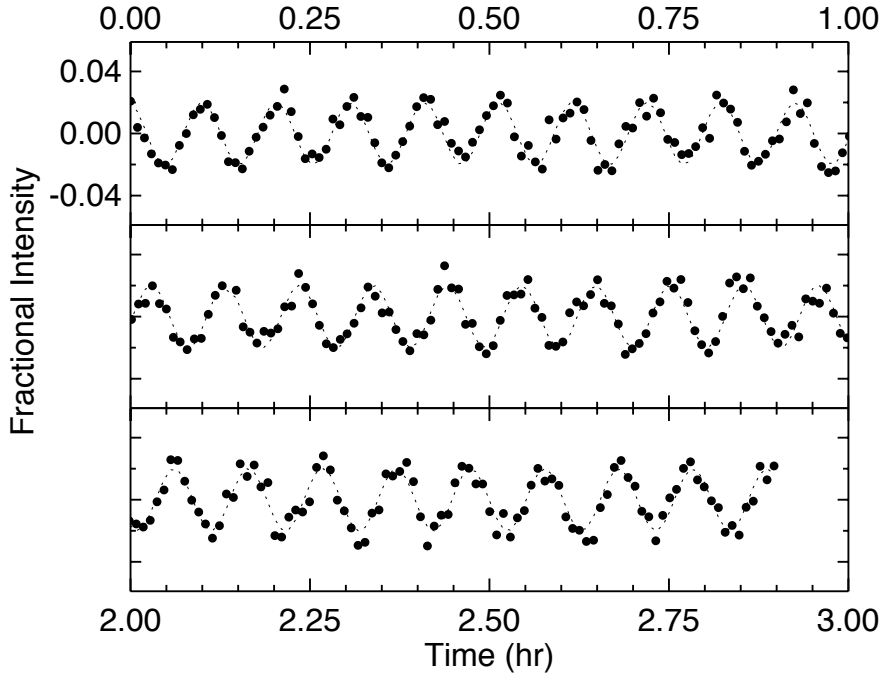


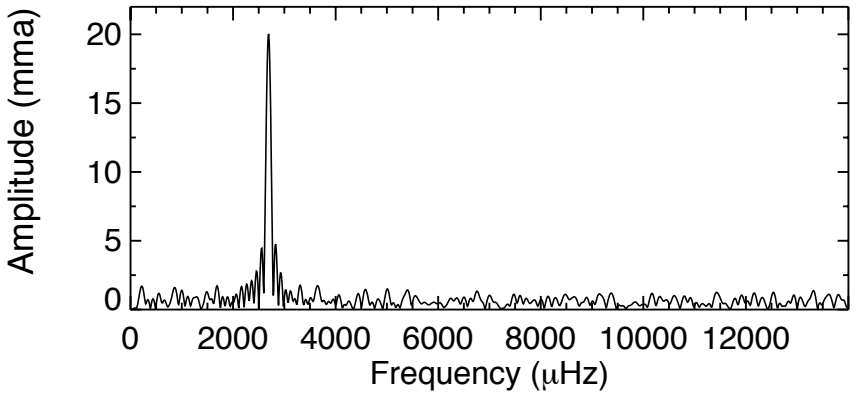
Silvotti et al. (2007)

CS 1246 - a rapidly-pulsating sdB (sdBV$_r$) star



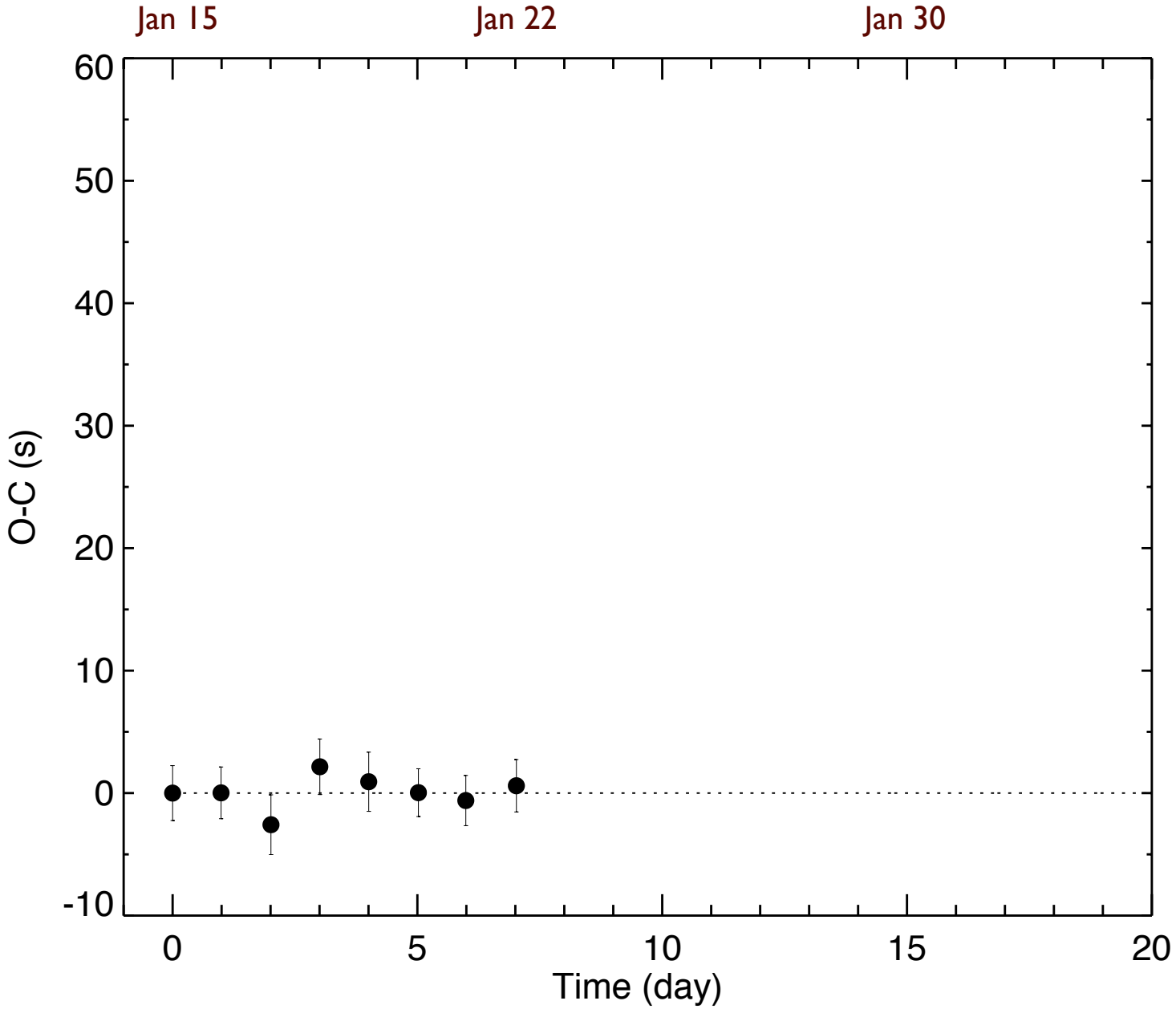
Period ..... 371 seconds
Frequency ..... 2690 uHz
Amplitude 2%
Spherical degree .... l=0 ?



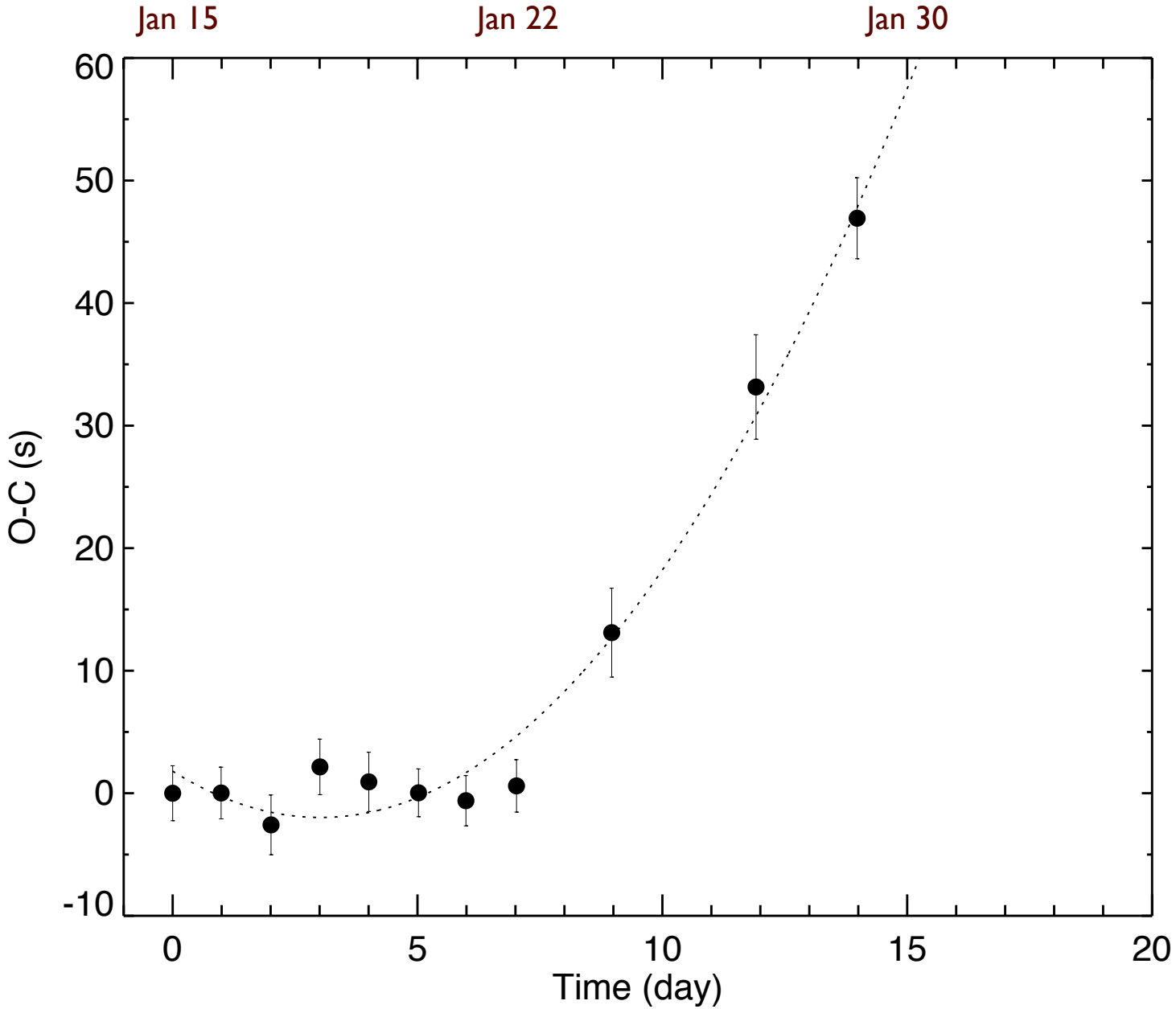


Barlow et al. (2010)

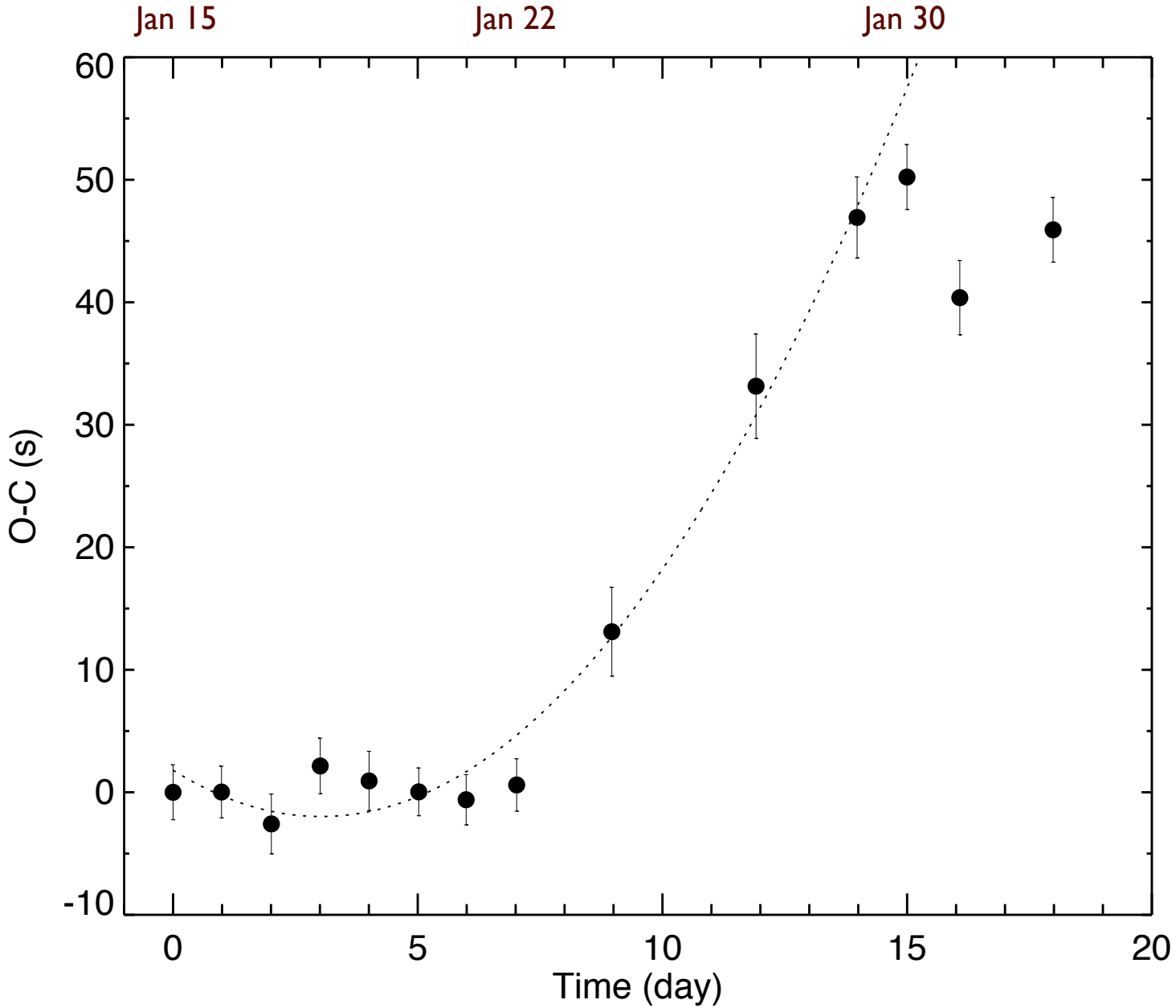
The O-C Diagram of CS 1246: Week 1



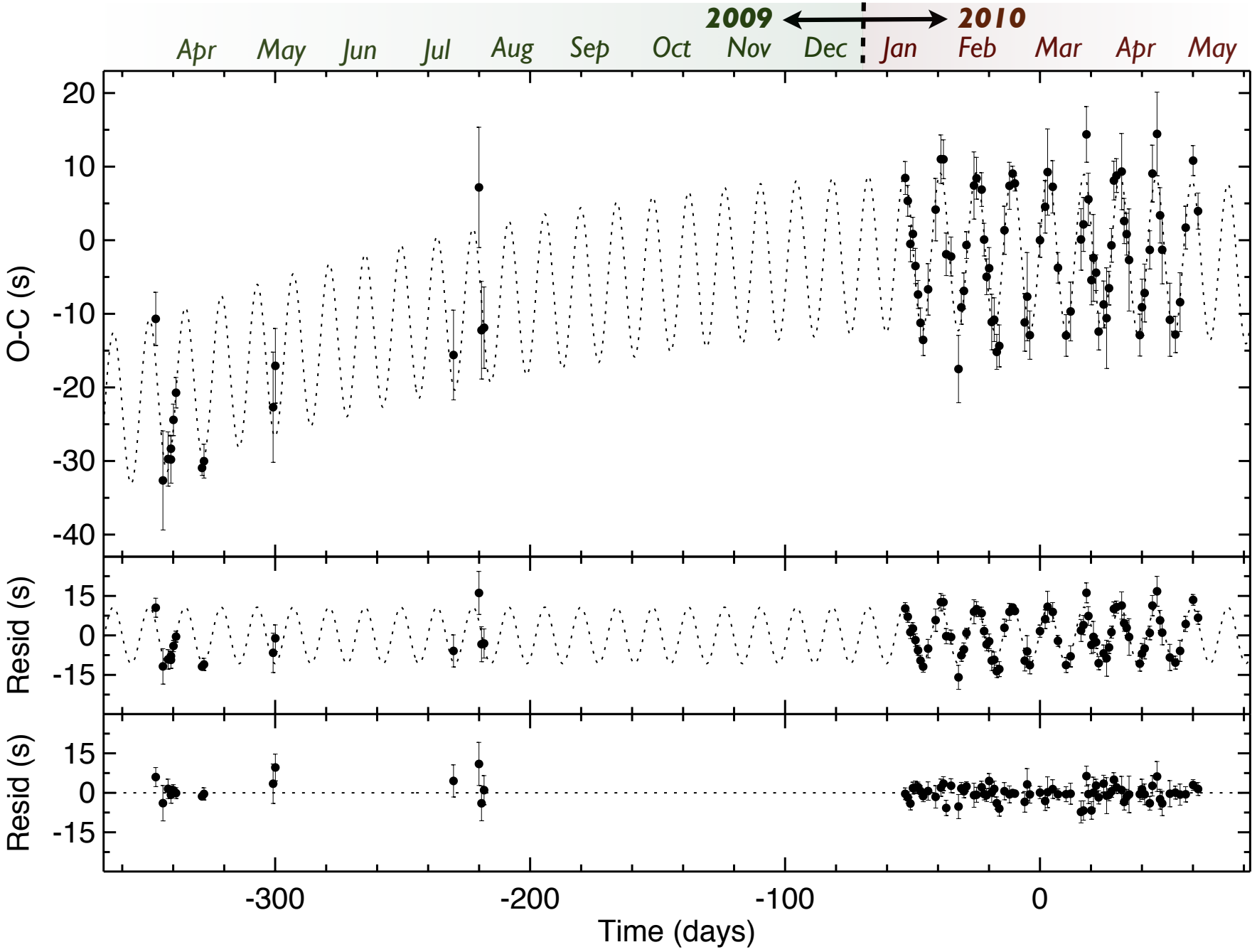
The O-C Diagram of CS 1246: Week 2



The O-C Diagram of CS 1246: Week 2+

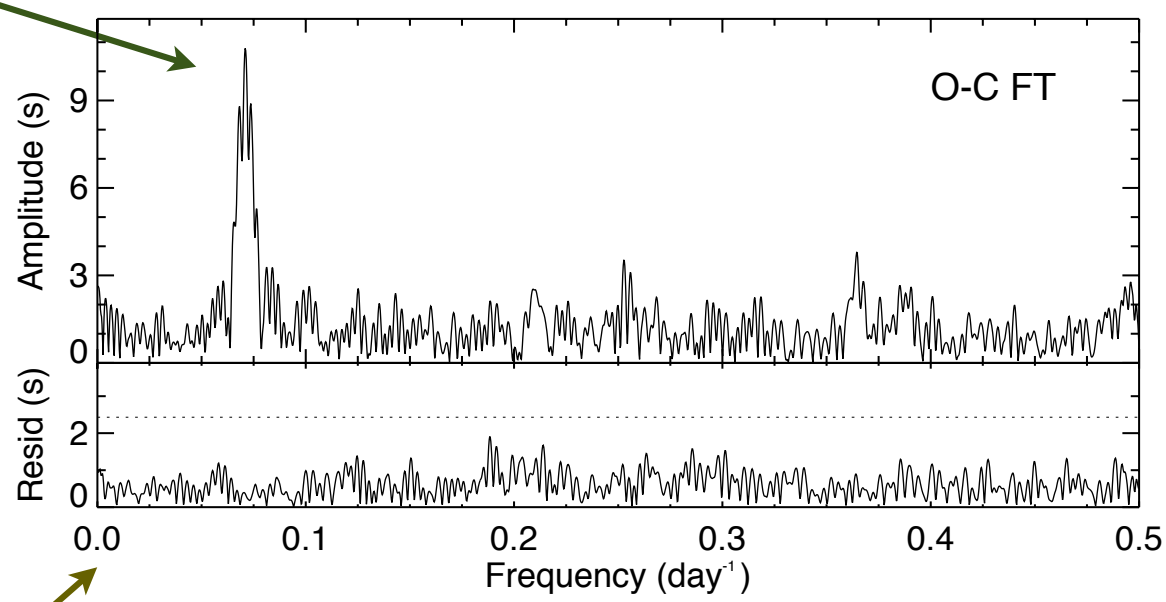


The O-C Diagram of CS 1246



Fourier Transform of the O-C Diagram

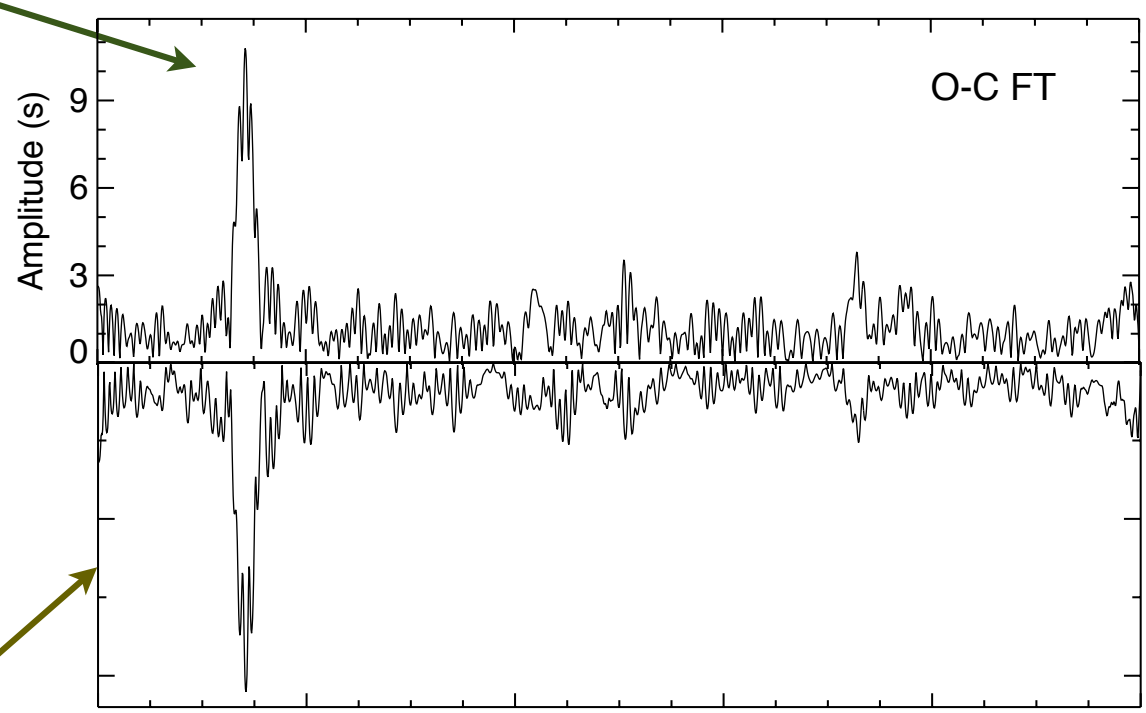
Period ..... 14.1 days
Amplitude ..... 10.7 s



Mean Noise Level:
0.75 s

Fourier Transform of the O-C Diagram

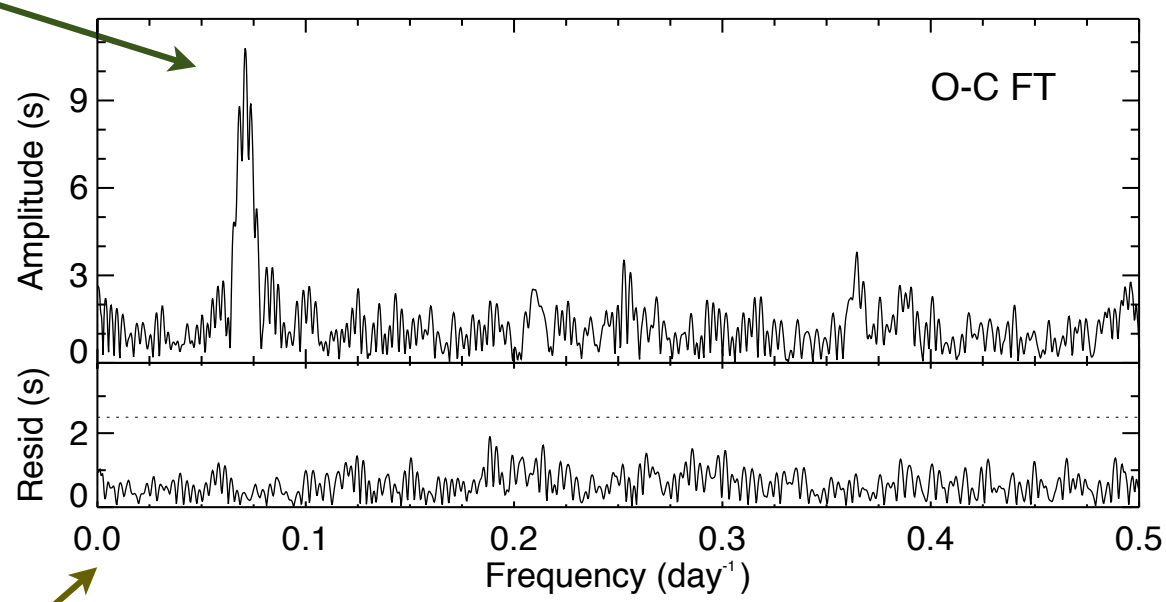
Period ..... 14.1 days
Amplitude ..... 10.7 s



Mean Noise Level:
0.75 s

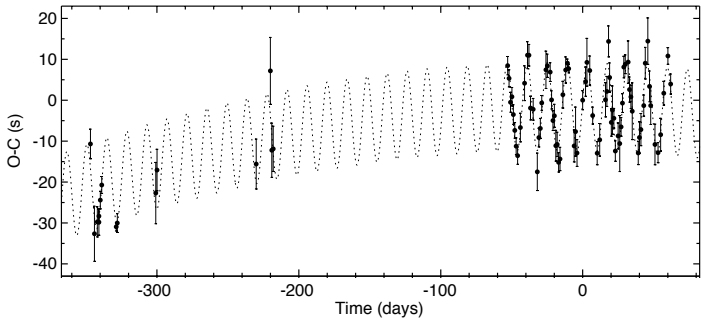
Fourier Transform of the O-C Diagram

Period ..... 14.1 days
Amplitude ..... 10.7 s



Mean Noise Level:
0.75 s

Fitting the O-C Values



$$O - C = \Delta T + \Delta P E + \frac{1}{2} P \dot{P} E^2 + A \sin\left(\frac{2\pi E}{\Pi} + \phi\right)$$

Pulsation

Period (P)..... 371.691692 s
P-dot ($\dot{P}$)..... 1.8 x 10^{-11}

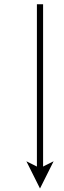
Phase Oscillation

Period (Π)..... 14.105 days
Amplitude (A)..... 10.7 s

(Upper) Limit on P-dot

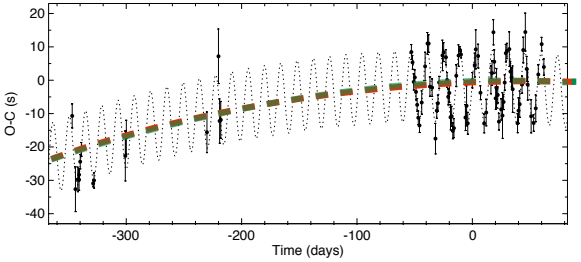
$$\dot{P} = -(1.8 \pm 0.3) \times 10^{-11}$$

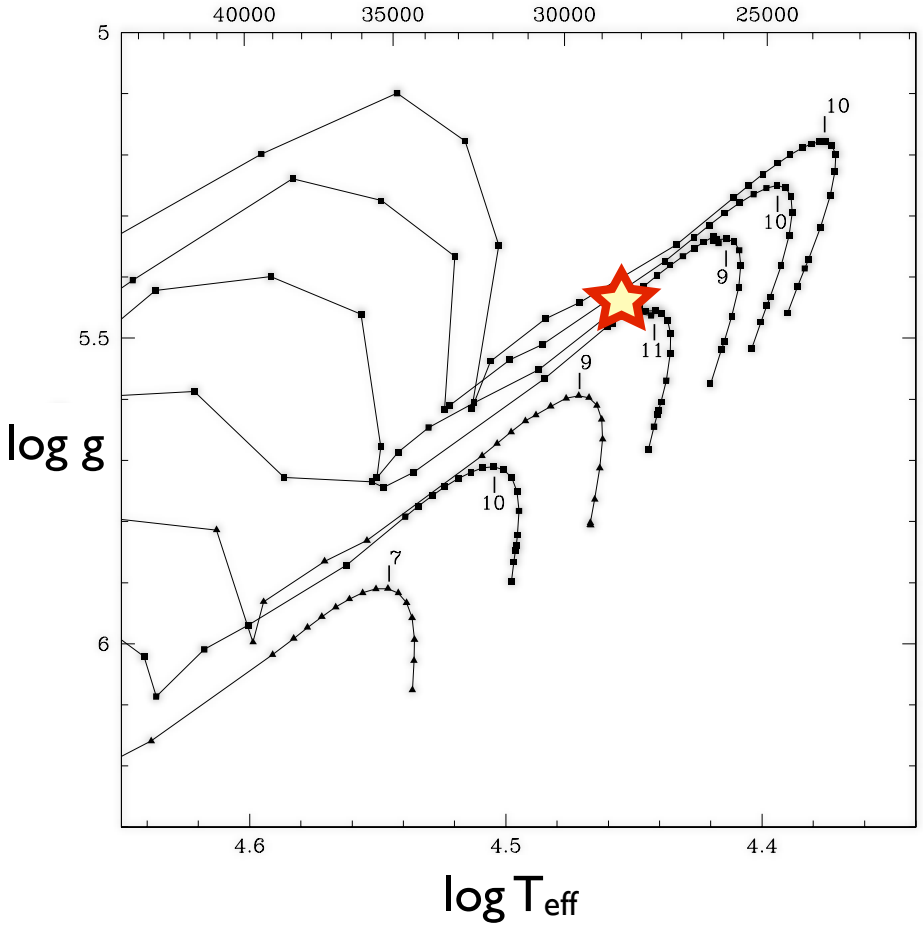
(1 second in 1768 years)



CS 1246 is contracting

Helium in core almost depleted



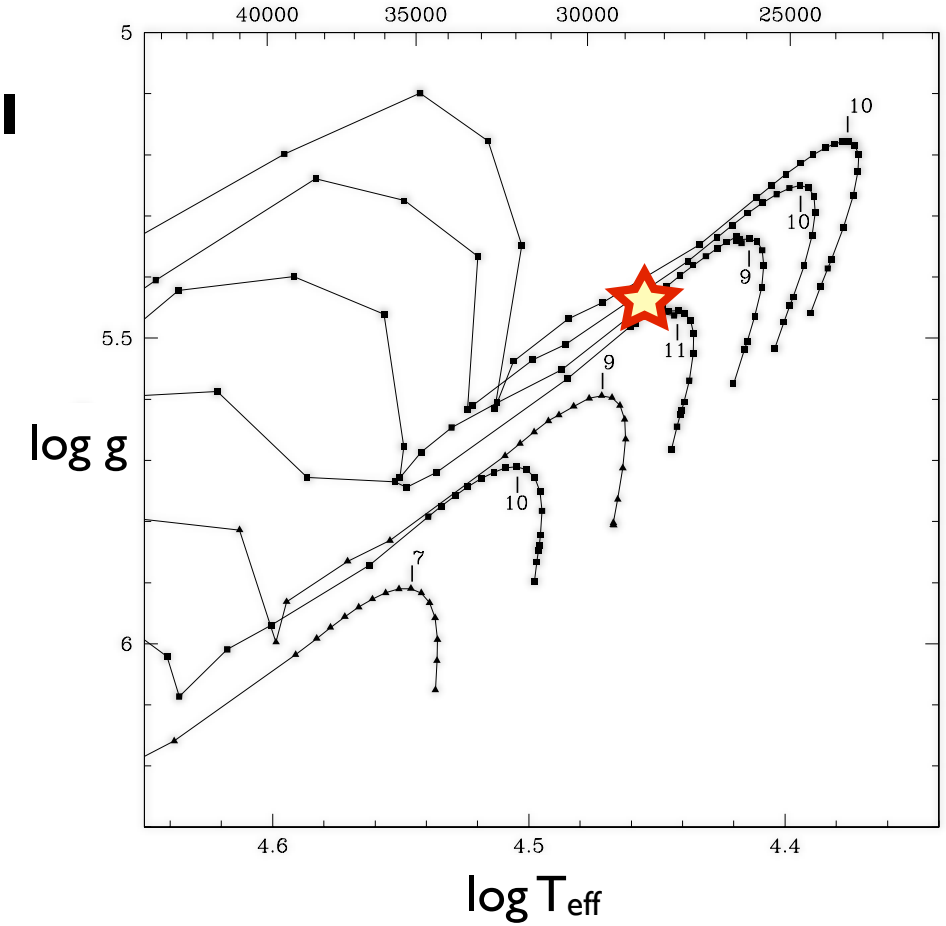


Charpinet et al. (2002)

(Upper) Limit on P-dot

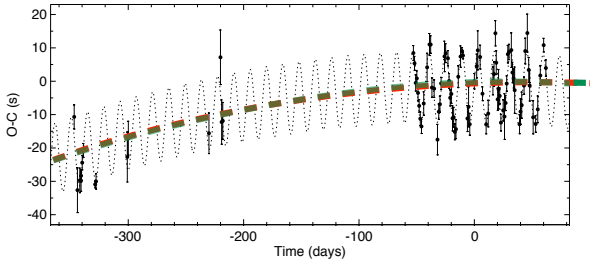
$$\dot{P} = -(1.8 \pm 0.3) \times 10^{-11}$$

(1 second in 1768 years)



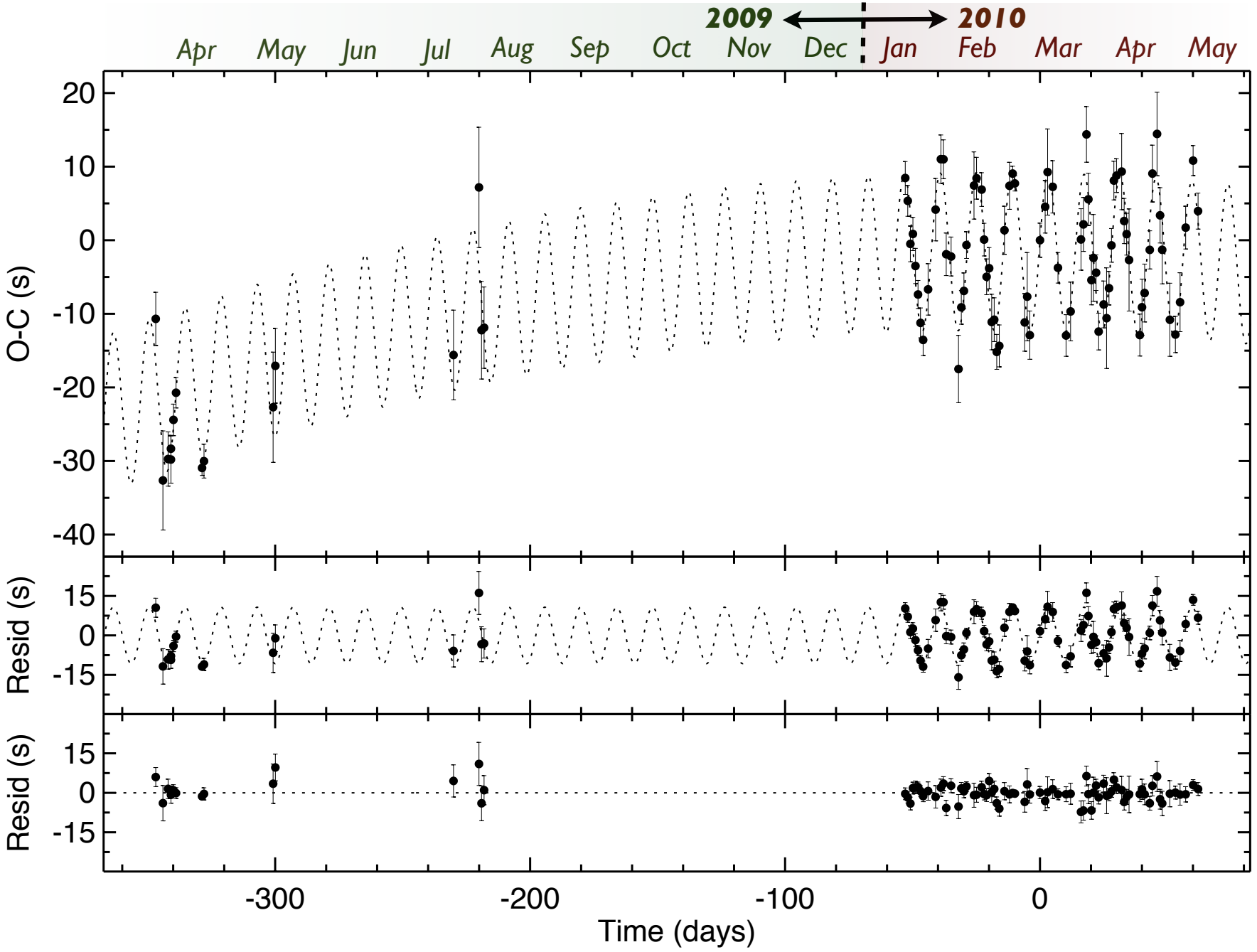
CS 1246 is contracting

Helium in core almost depleted



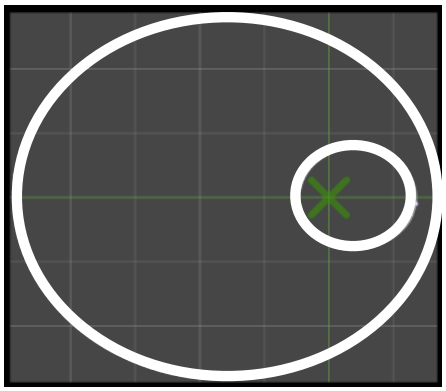
Charpinet et al. (2002)

The O-C Diagram of CS 1246

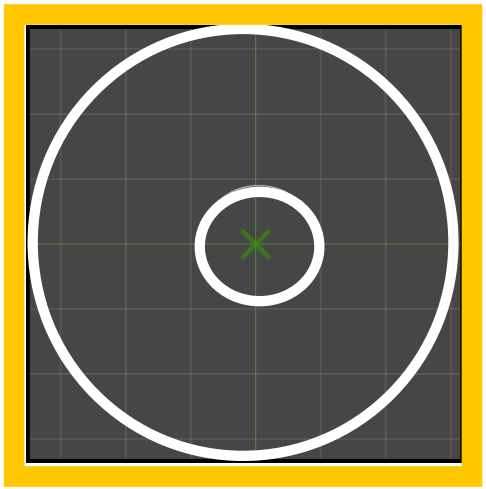


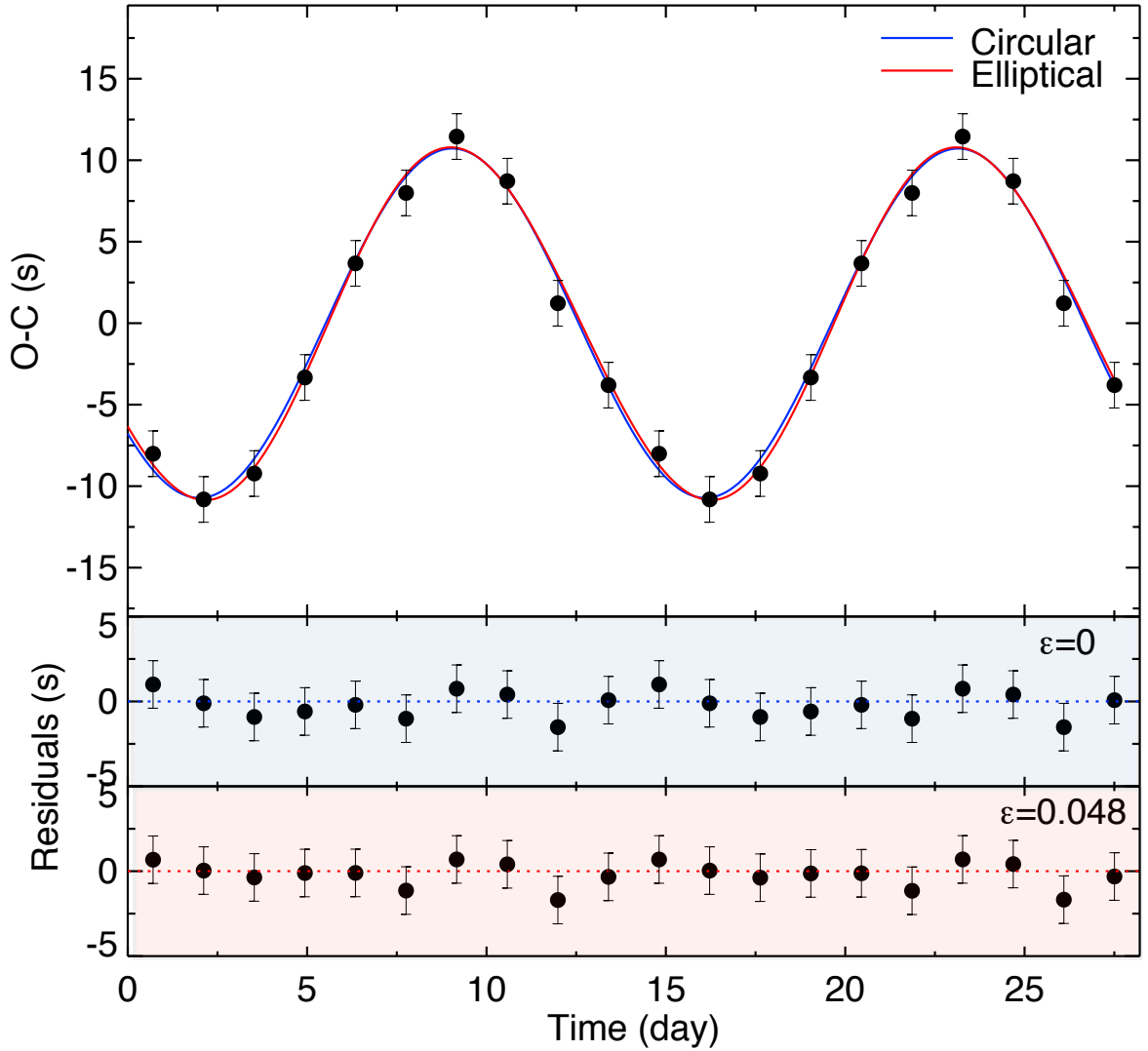
The phase-folded O-C diagram

highly-elliptical?



or not?





Note: data plotted twice for visualization purposes

System Parameters

Param	Value	Error	Units	Comment
Π	14.105	$\pm$ 0.011	days	orbital period
K	16.6	$\pm$ 0.6	km s^{-1}	RV semi-amplitude[a]
f	0.0066	$\pm$ 0.0007	$M_\odot$	mass function
ϵ	0.045	$\pm$ 0.019		orbital eccentricity
ϕ	185	$\pm$ 20	degrees	orbital periastron angle
a	0.0910	$\pm$ 0.0003	AU	separation distance[b]
	0.0963	$\pm$ 0.0003	AU	separation distance[c]
$m \sin i$	0.115	$\pm$ 0.005	$M_\odot$	minimum companion mass[bd]
	0.129	$\pm$ 0.005	$M_\odot$	minimum companion mass[cd]

[a] circular orbit approximation
[b] assuming an sdB mass of 0.39 $M_\odot$
[c] assuming the canonical sdB mass of 0.47 $M_\odot$
[d] assumes no error bar on the sdB mass

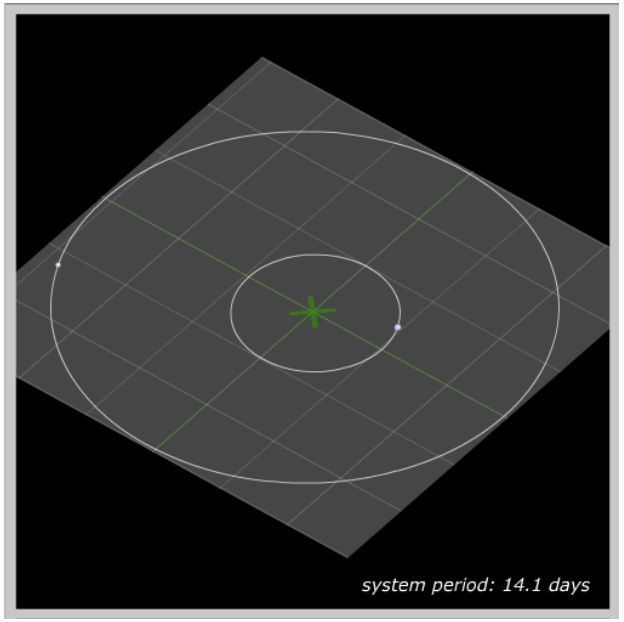
What is the companion?

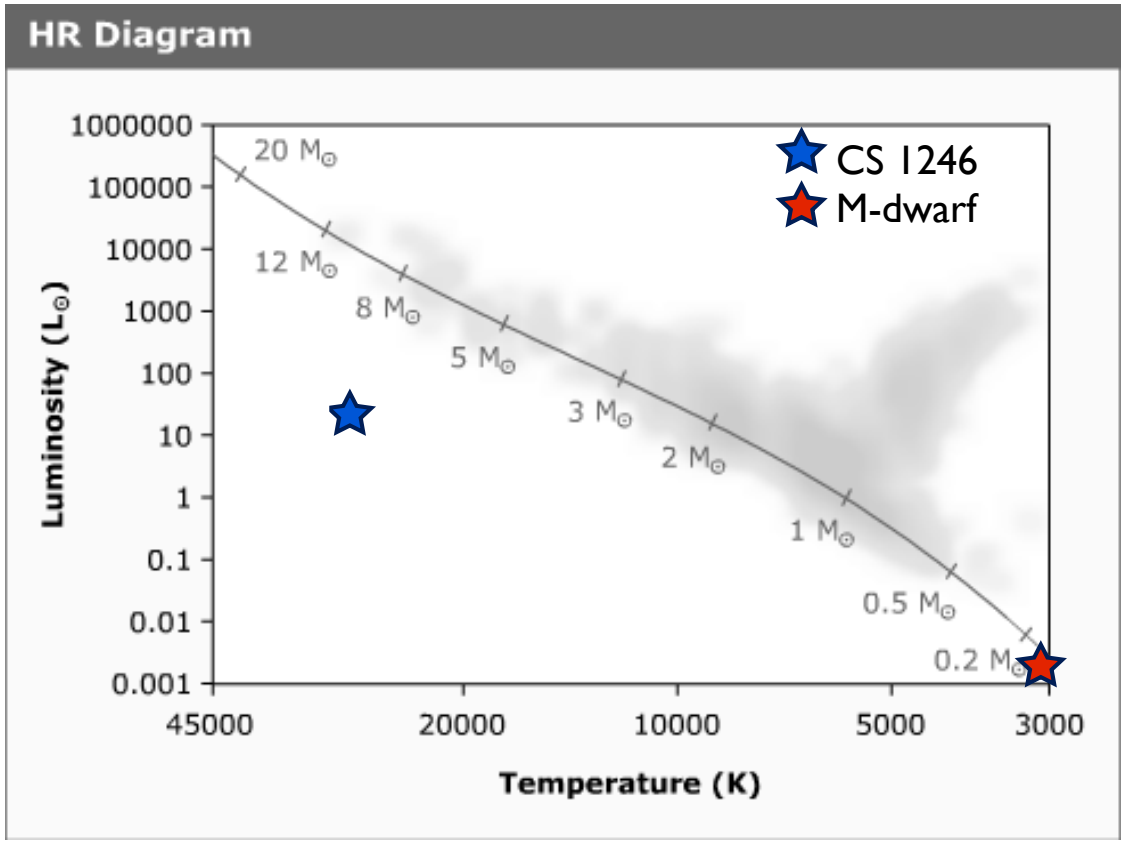
- *m sin i* = 0.12 M_{sun}

- 95% probability m < 0.45 M_{sun}

- no optical signature of companion

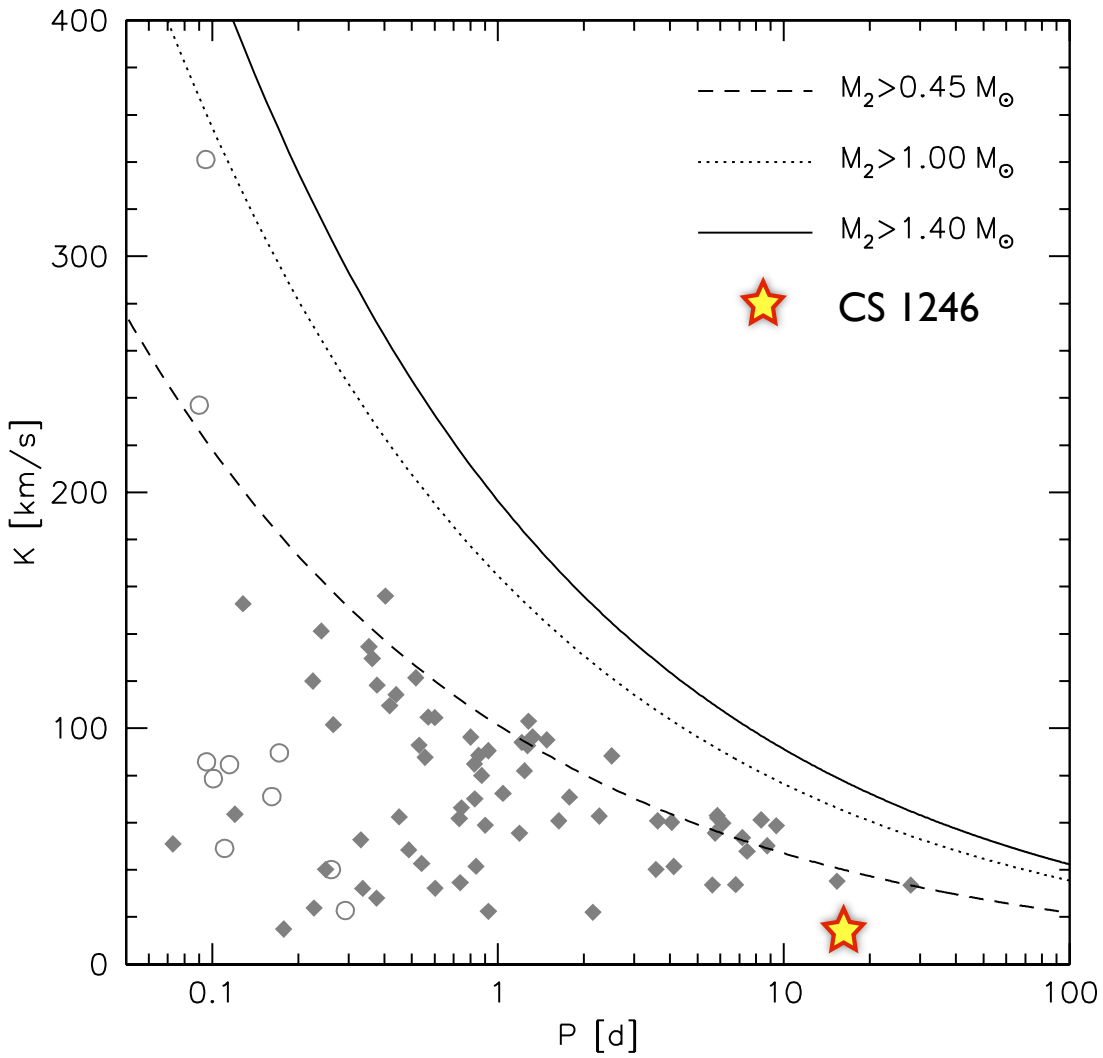
Scale System Model





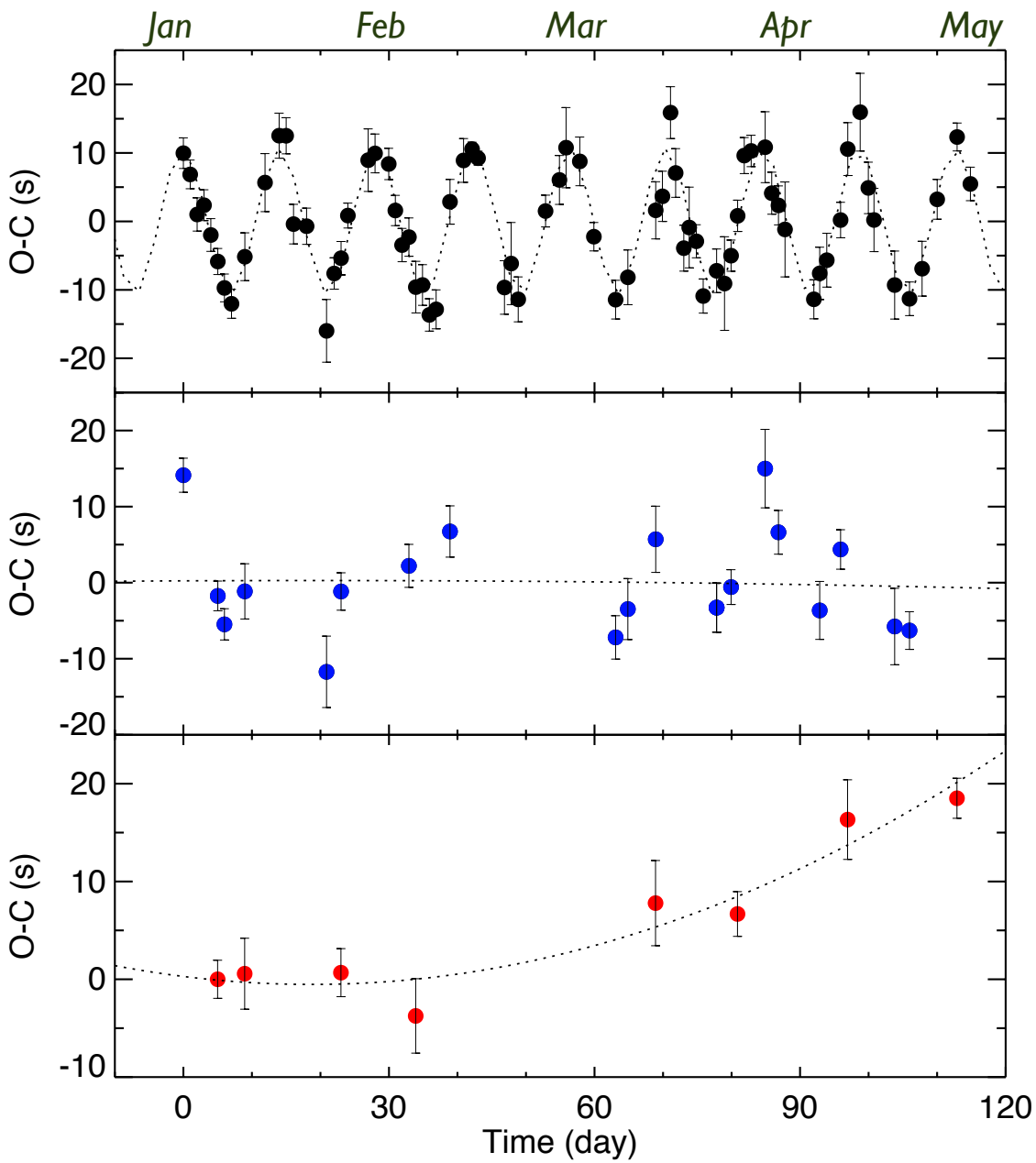
M-dwarf
or
white dwarf?

Known RV semi-amplitudes of sdB binary systems



Geier et al. (submitted)

Potential Sampling Effects



All light curves from 2010

19 randomly-selected light curves

8 light curves, chosen specifically to mimic P-dot

Summary & Future Work

- used O-C diagram to measure:
  - orbital reflex motion
  - P-dot

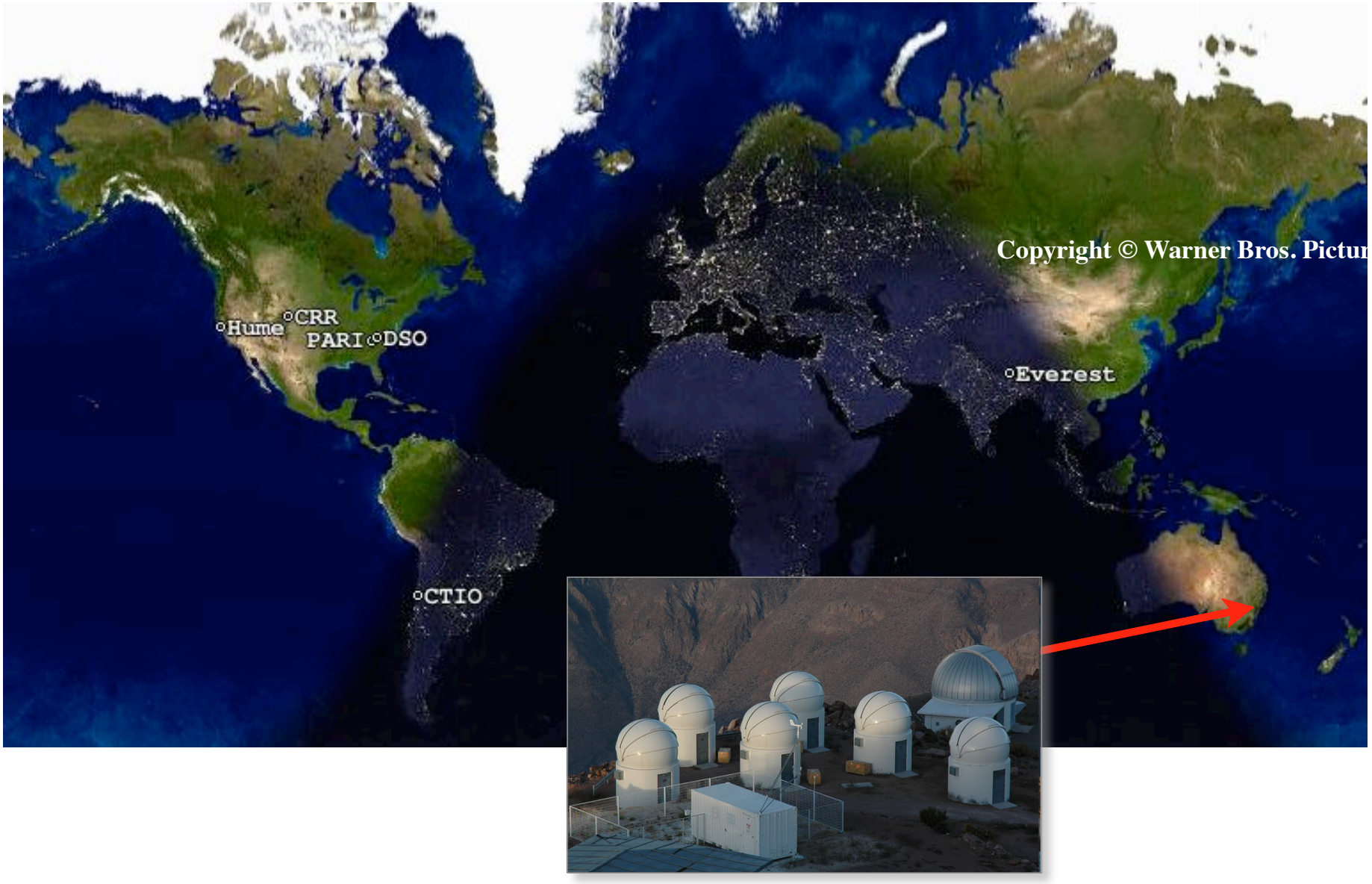
- P-dot implies CS 1246 near core He-exhaustion

- phase oscillation implies unseen companion
  -M-dwarf or white dwarf

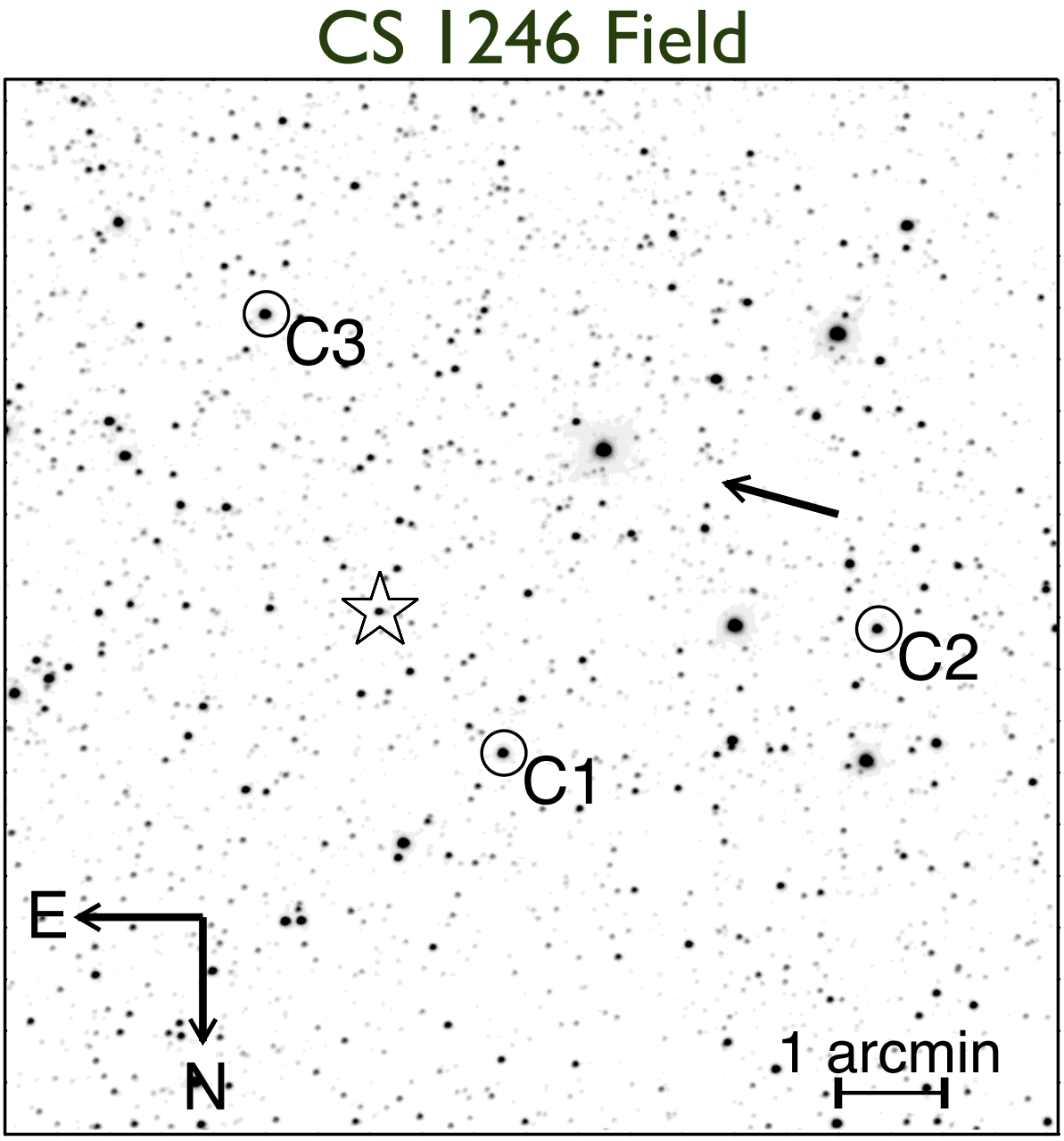
- continue collecting O-C data

- obtain RV measurements, compare to O-C results

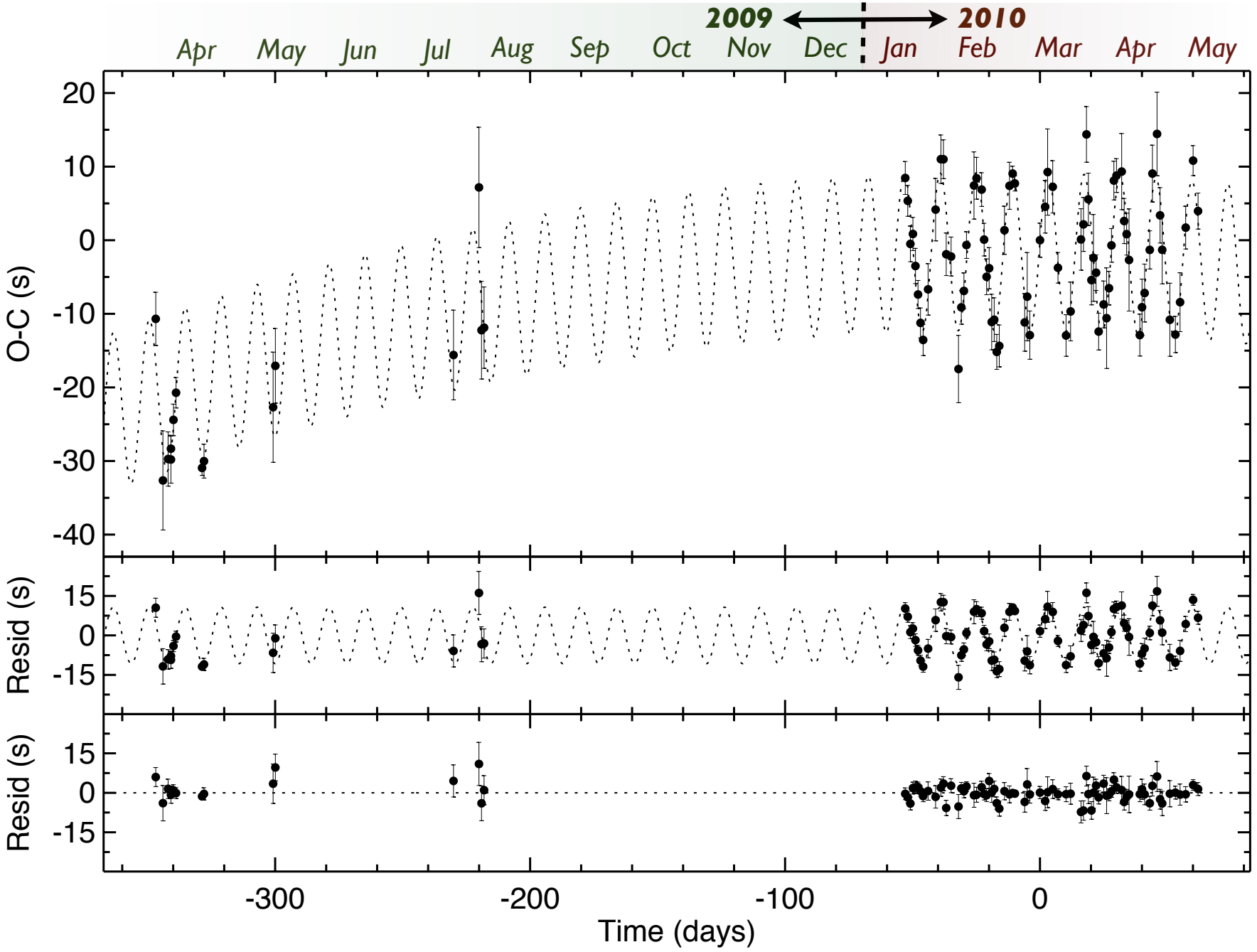
Expansion of SKYNET



One man's trash...



The O-C Diagram of CS 1246



Fortnightly Fluctuations in the O-C Diagram of CS 1246

Brad N. Barlow
Graduate Student
Department of Physics & Astronomy
University of North Carolina - Chapel Hill

THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

Bart Dunlap, Chris Clemens
SKYNET Team: D. Reichart, A. LaCluyze, J. Haislip,
K. Ivarsen, M. Nysewander