The O-C Diagram of EC20058-5234: Detection of Neutrino Emission?

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O-C Background...

The flux variations from a pulsation with frequency f are given by a simple sinusoid...

$$\delta F = A \sin(2\pi f(t - \tau))$$

A time varying frequency can be written in terms of the “semi-instantaneous” phase...

$$f(t) = f_0(1 - \frac{d\tau}{dt})$$

We can simply measure the phase of pulsation of several data sets (using a fixed frequency and with respect to a fixed t=0) to measure a changing frequency or phase. This is known as the O-C or “Observed-Calculated” method.

O-C Background...

If we assume that the frequency is changing very slowly:

$$f(t) \approx f_0 + \dot{f}t$$

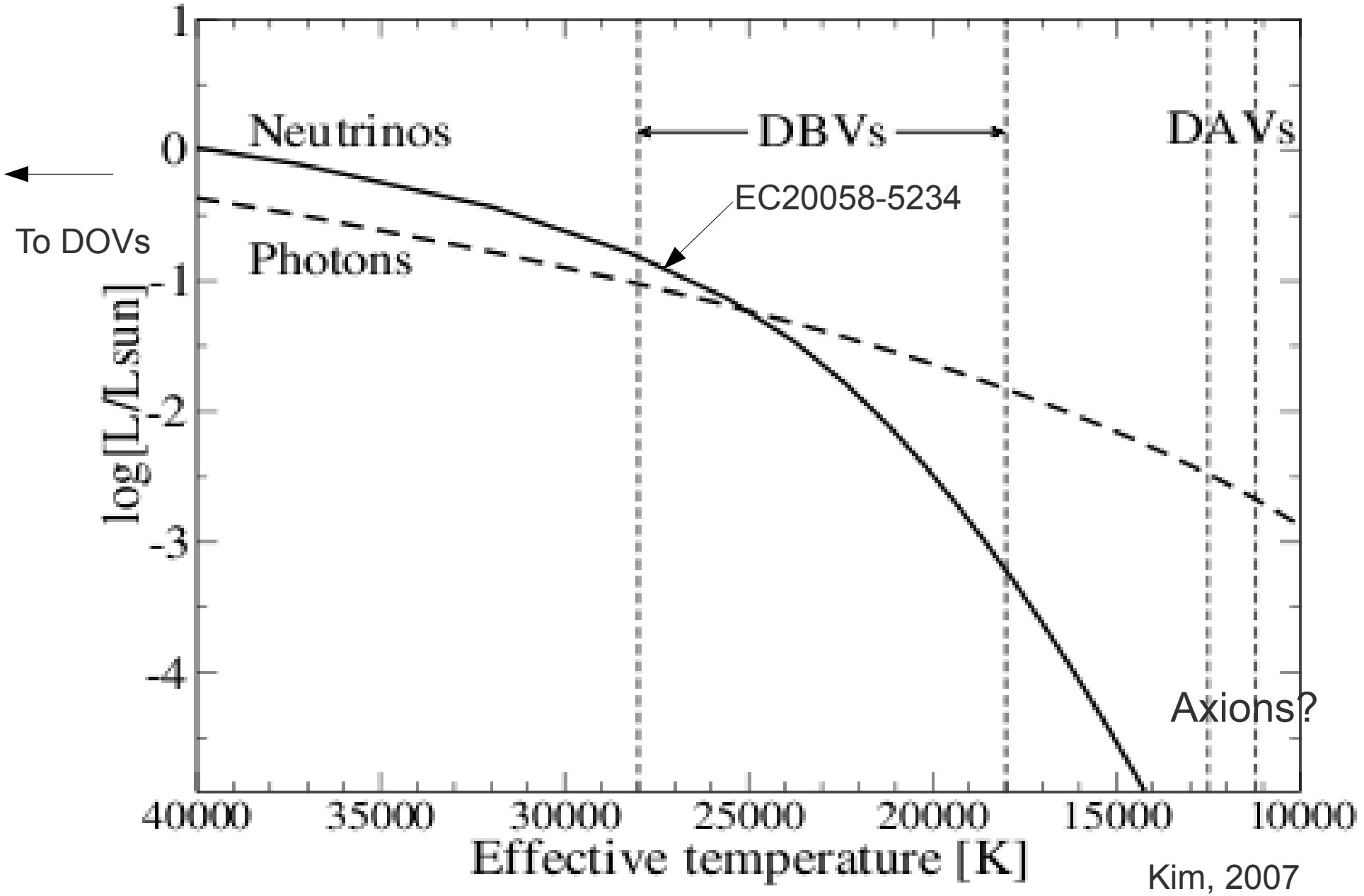
The time zero phase of pulsation would vary as:

$$\tau(t) = \tau(0) - \frac{\dot{f}}{2f_0}t^2$$

Or equivalently...

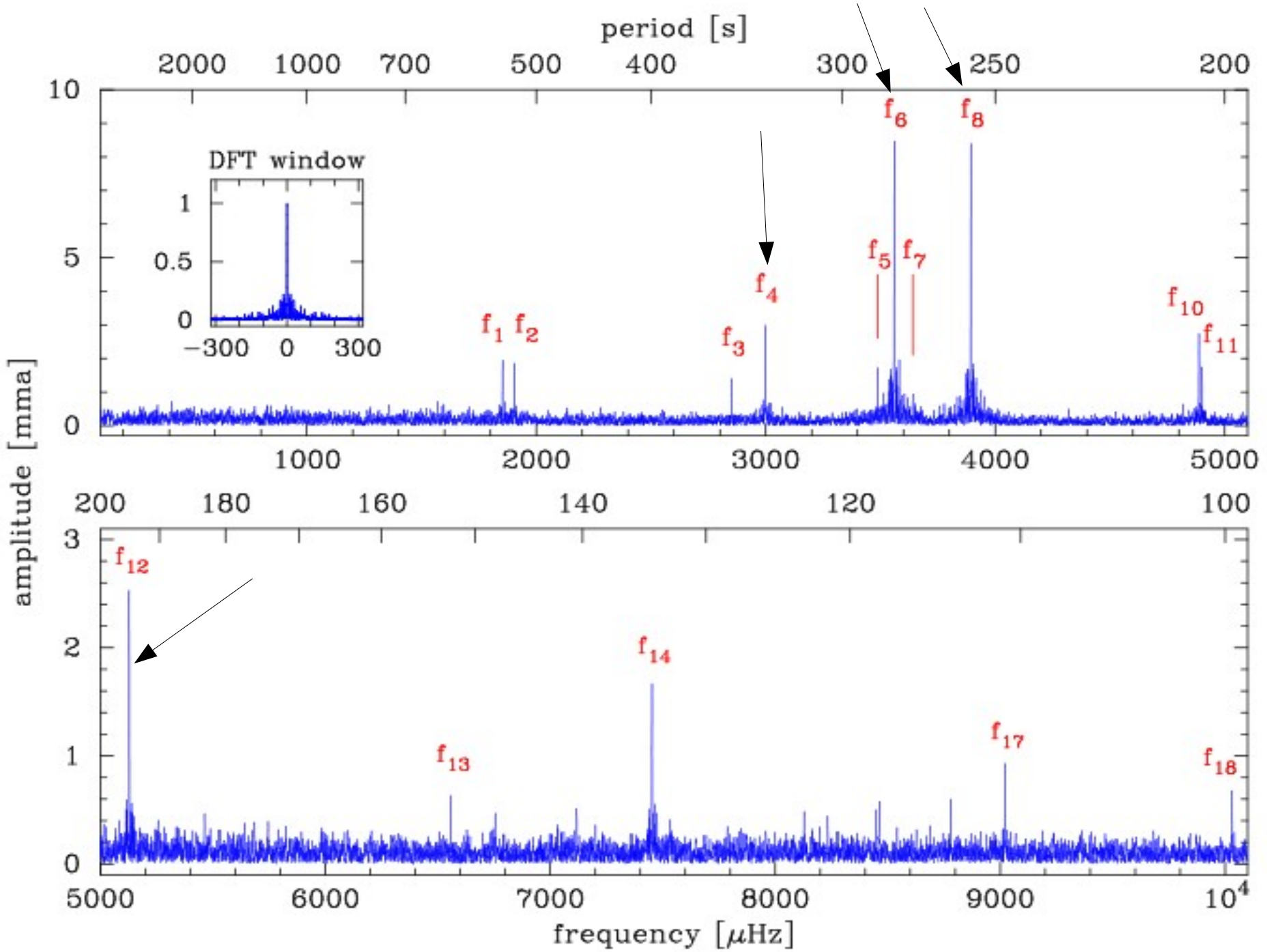
$$\tau(t) = \tau(0) + \frac{\dot{P}}{2P}t^2$$

Goldilocks and the Three Bears

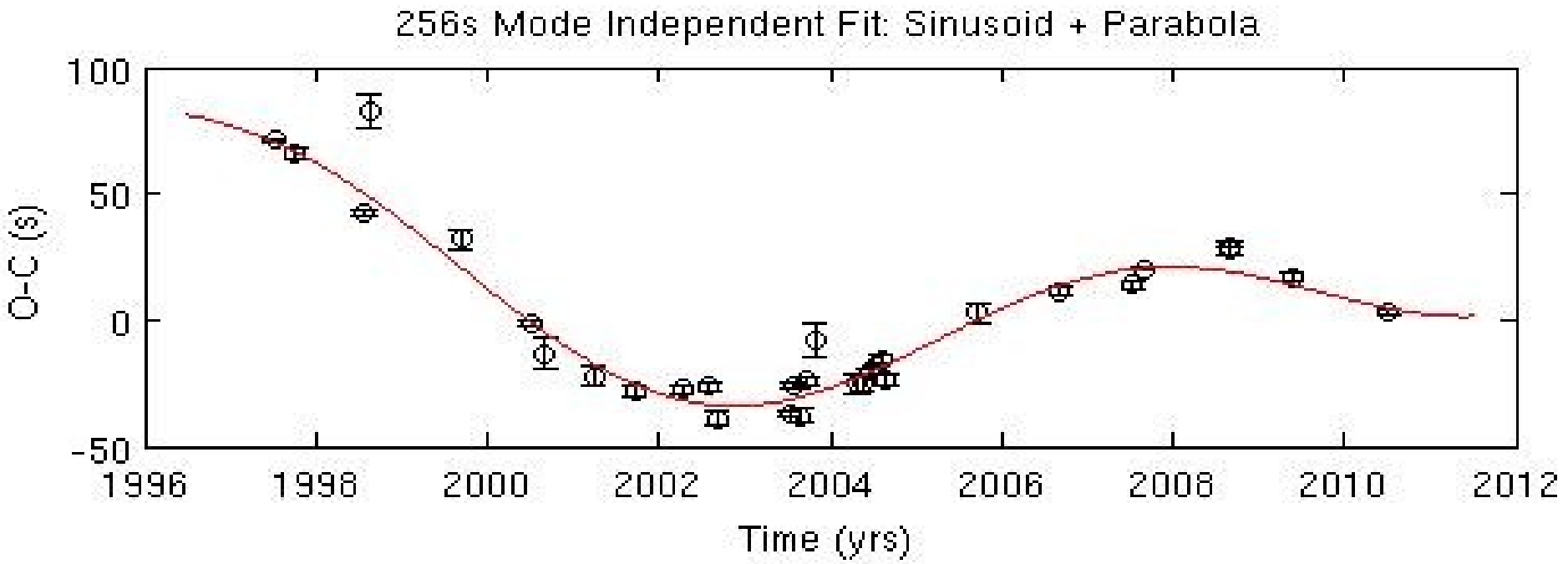


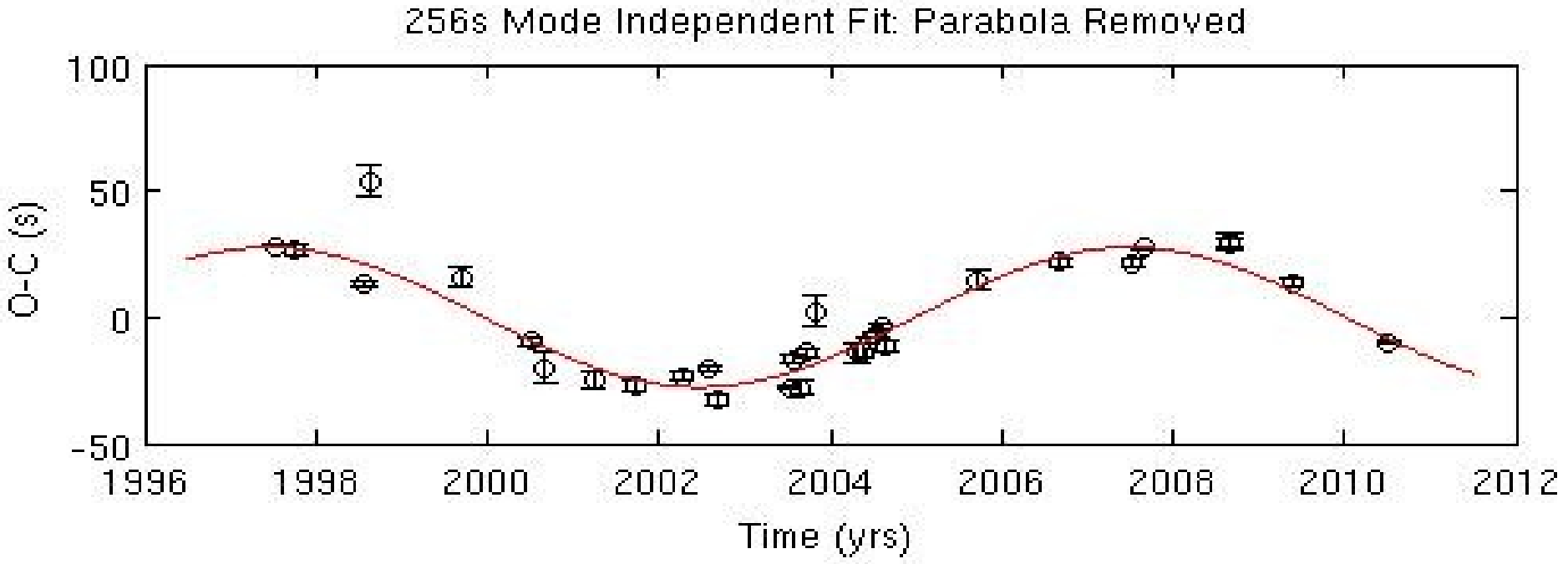
Kim, 2007

DFT of EC20058-5234 XCOV15 (Sullivan et. al. 2008)

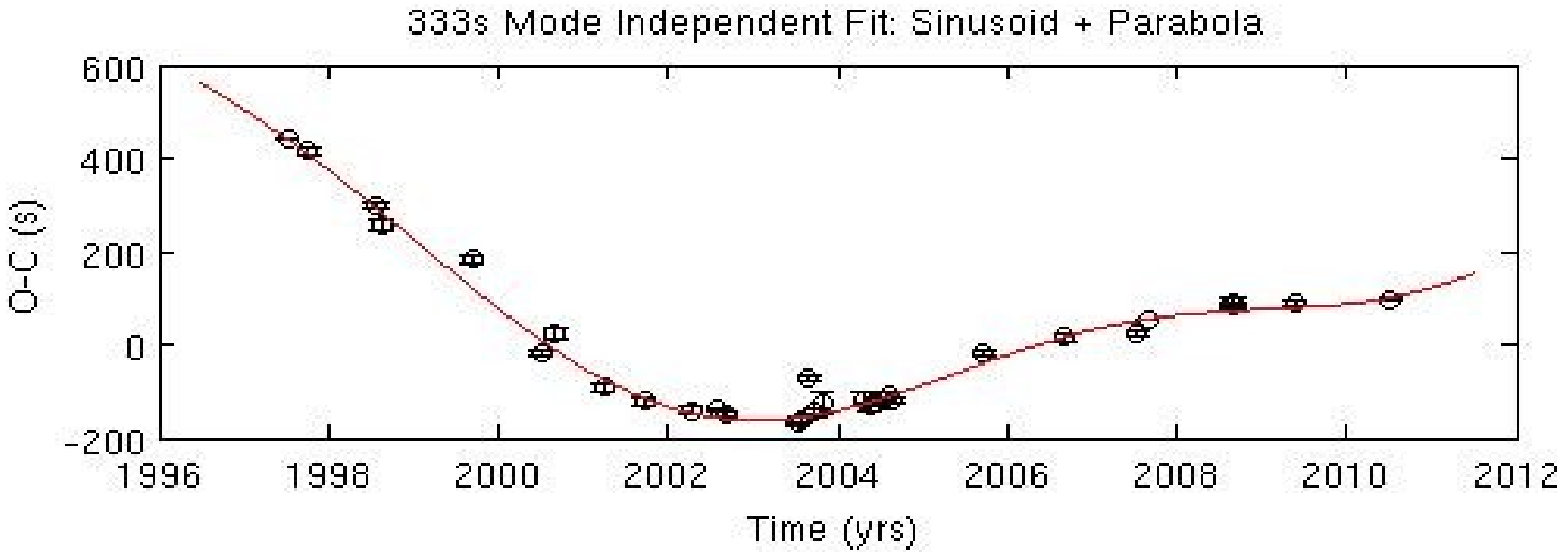


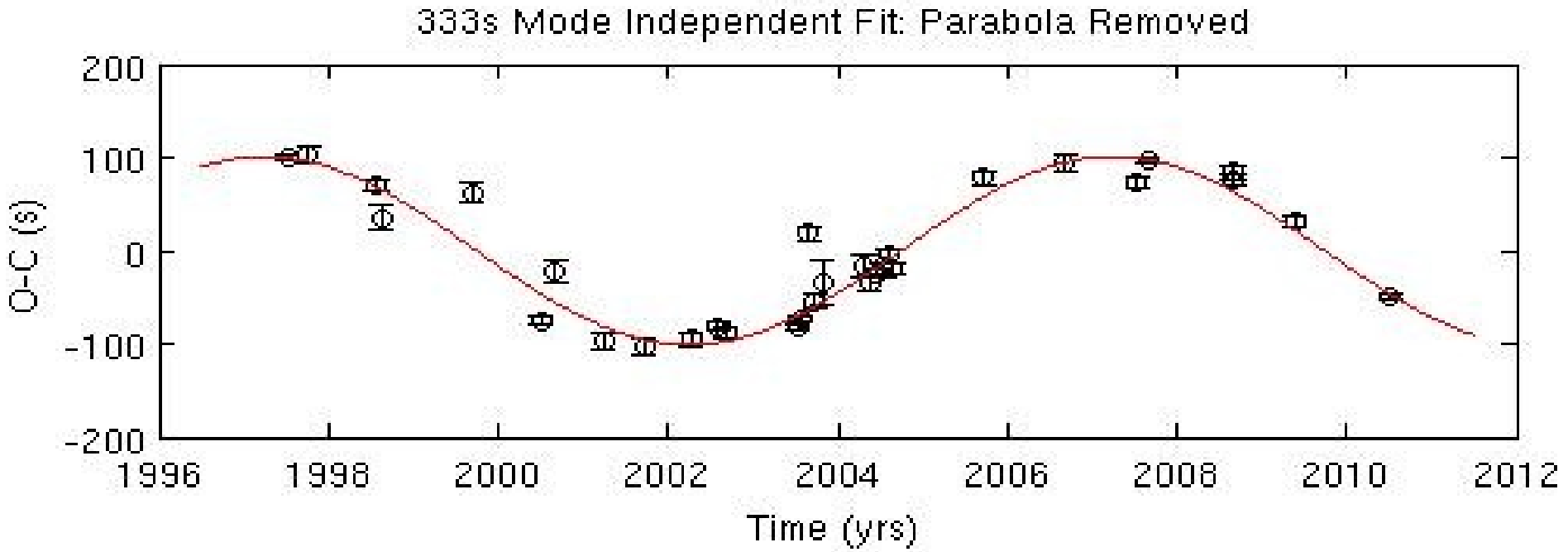
A = 27.6s, P = 10.05yrs, Phi = -.83, Pdot = 4.8E-13, Reduced Chi^2 ~ 10



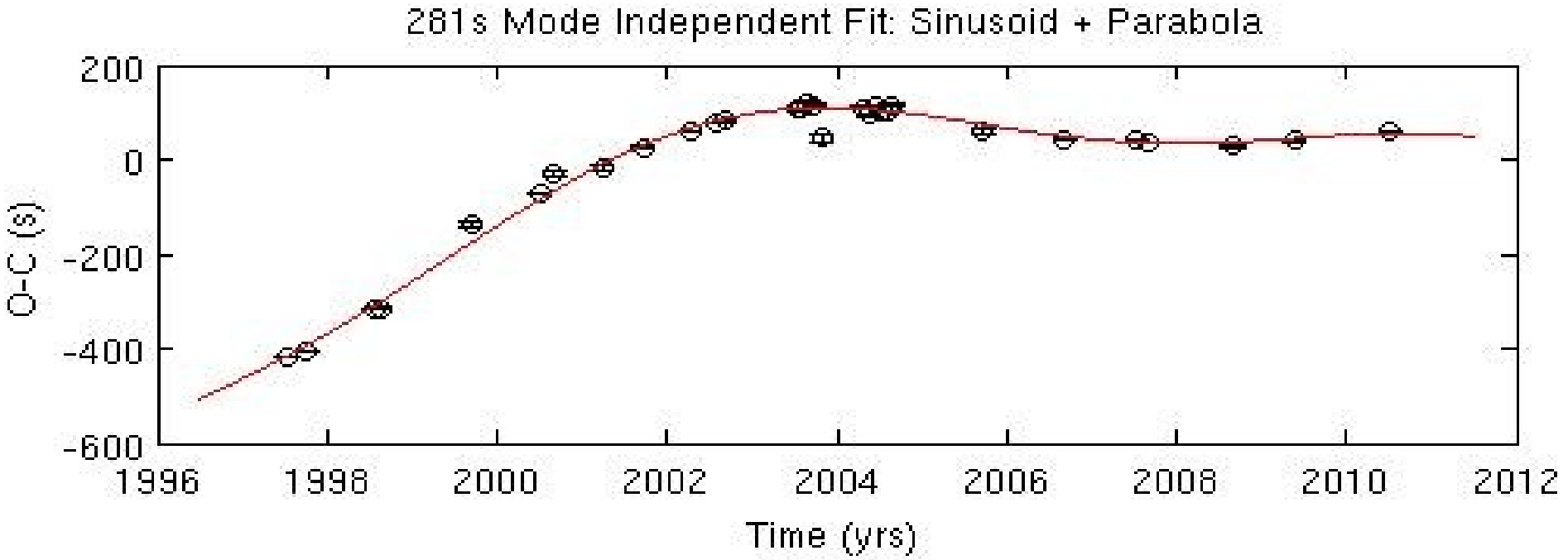


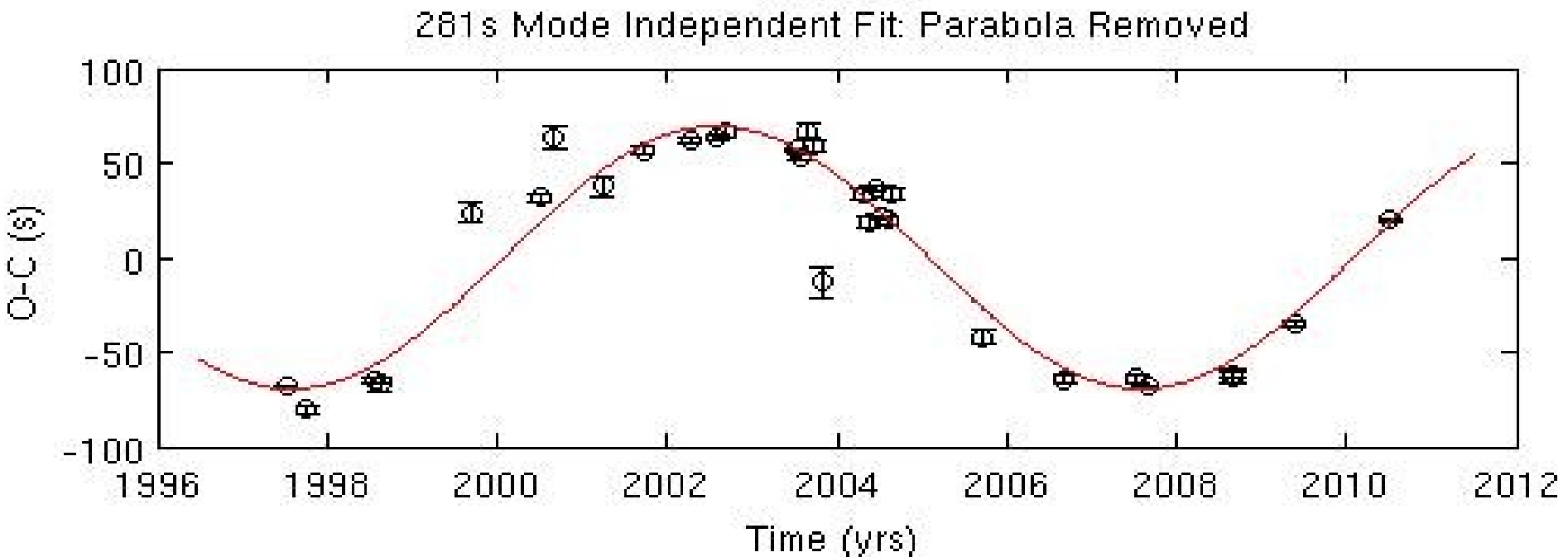
A = 101.0s, P = 10.00yrs, Phi = -.68, Pdot = 5.4E-12, Reduced Chi^2 ~ 10



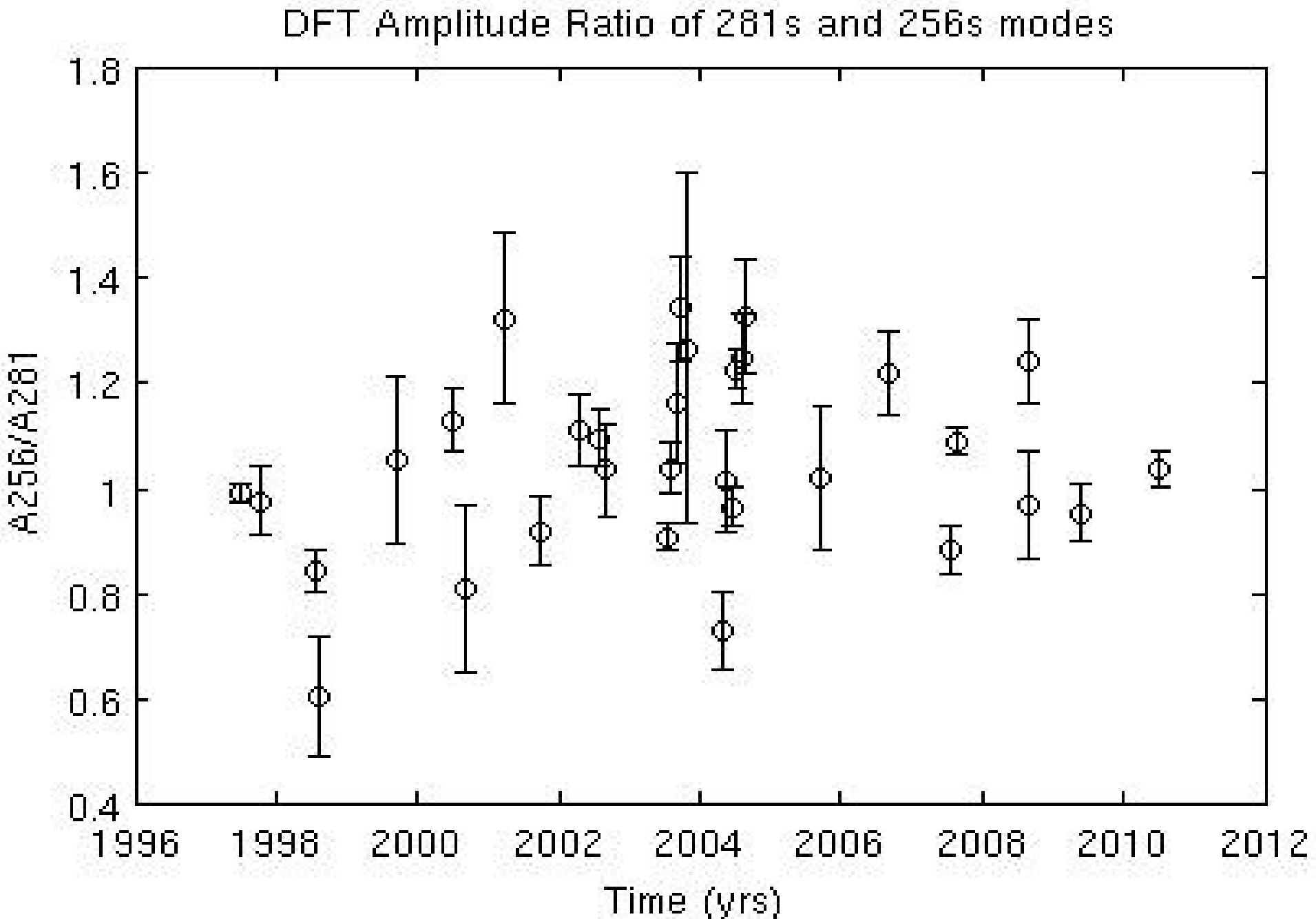


A = 69.3s, P = 10.06yrs, Phi = -.88+pi, Pdot = -2.9E-12, Reduced Chi^2 ~ 21

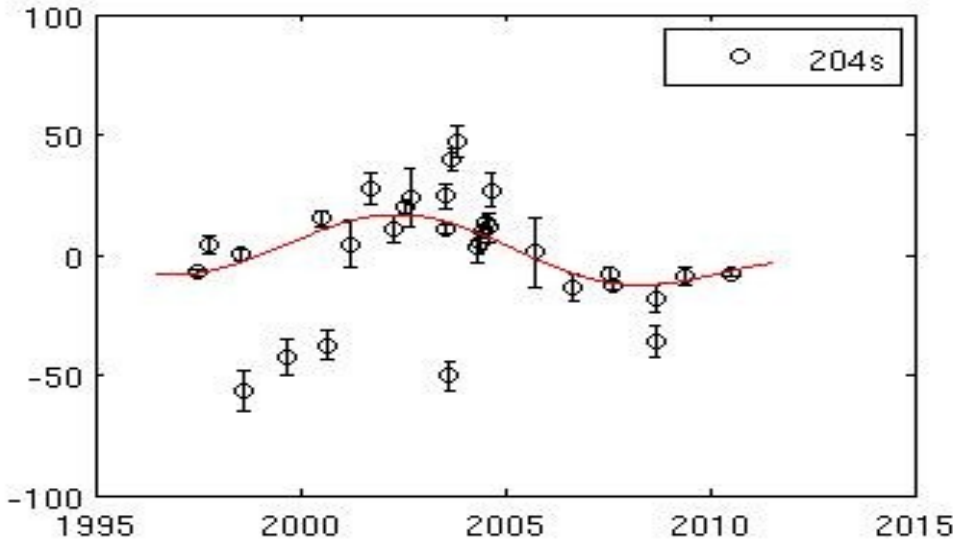


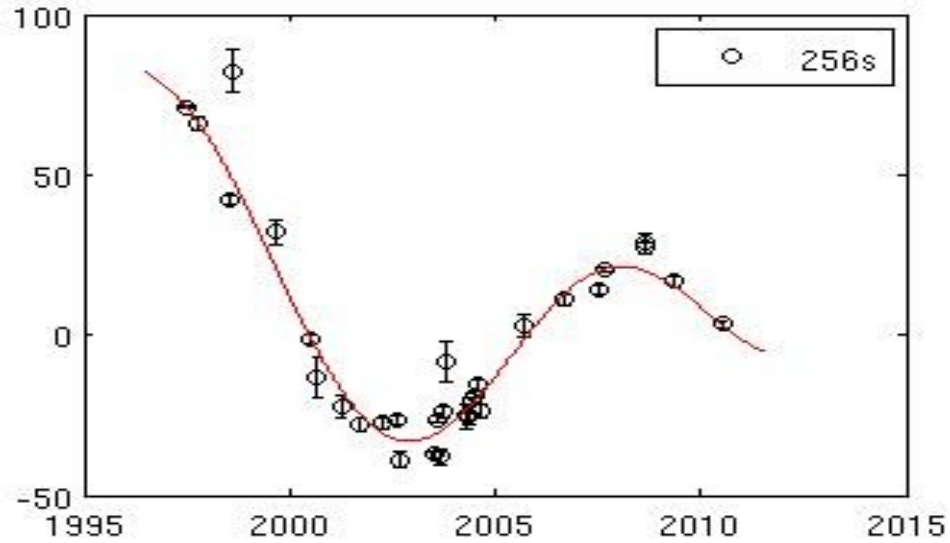


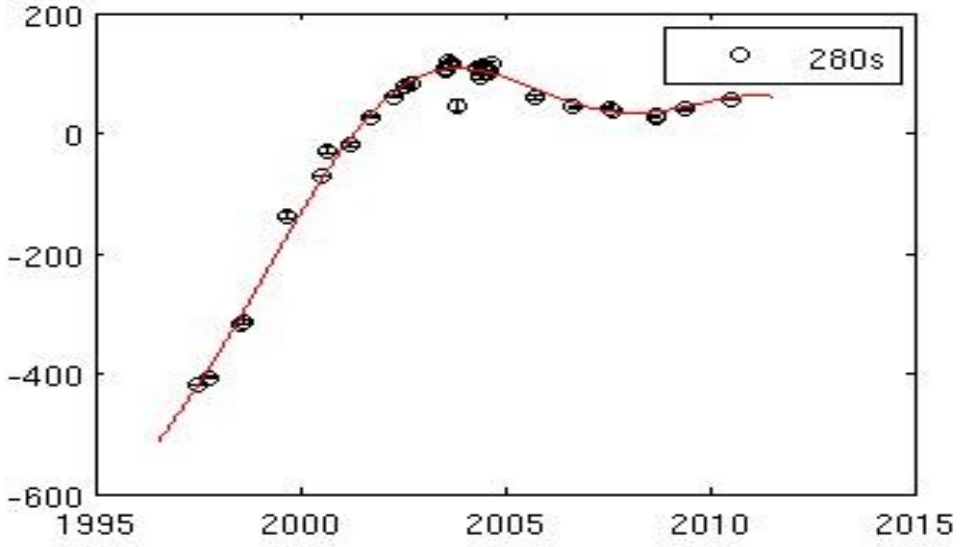
What about beating? Hidden modes?

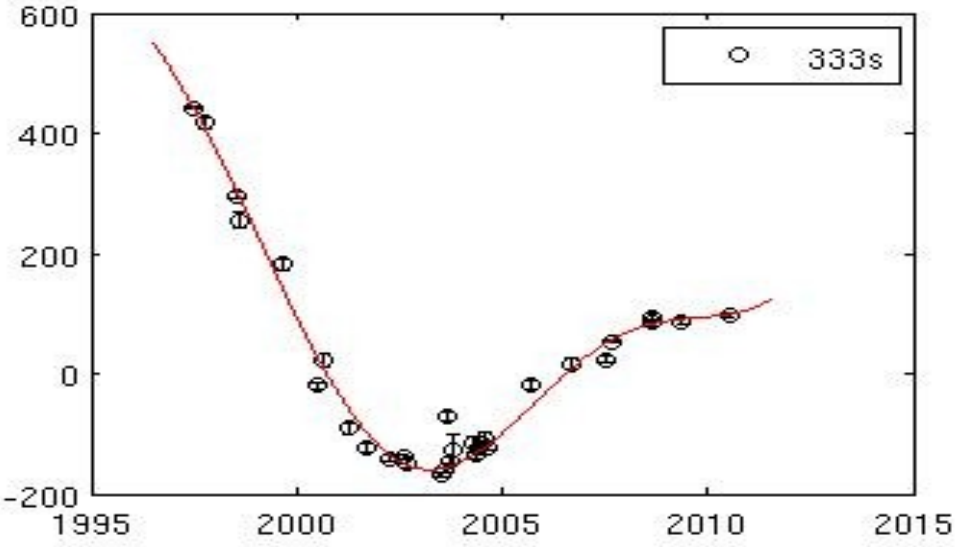


Simultaneous 4 Mode O-C Fit: Period and phase of oscillation shared.

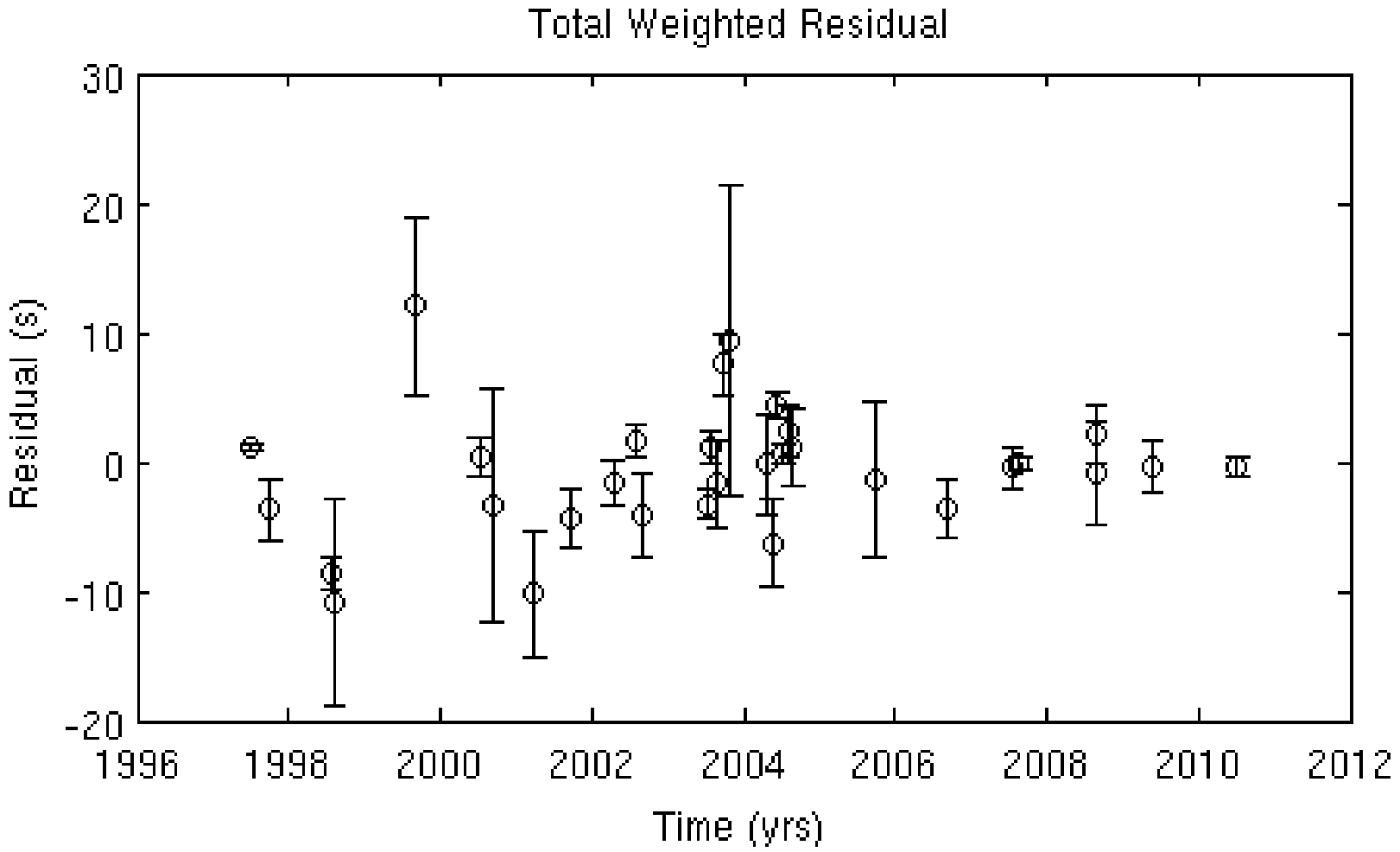








Residuals of 4 mode fit



Two Groups of Modes

Group One
- Negative dP/dt
- Relative Phase = 0

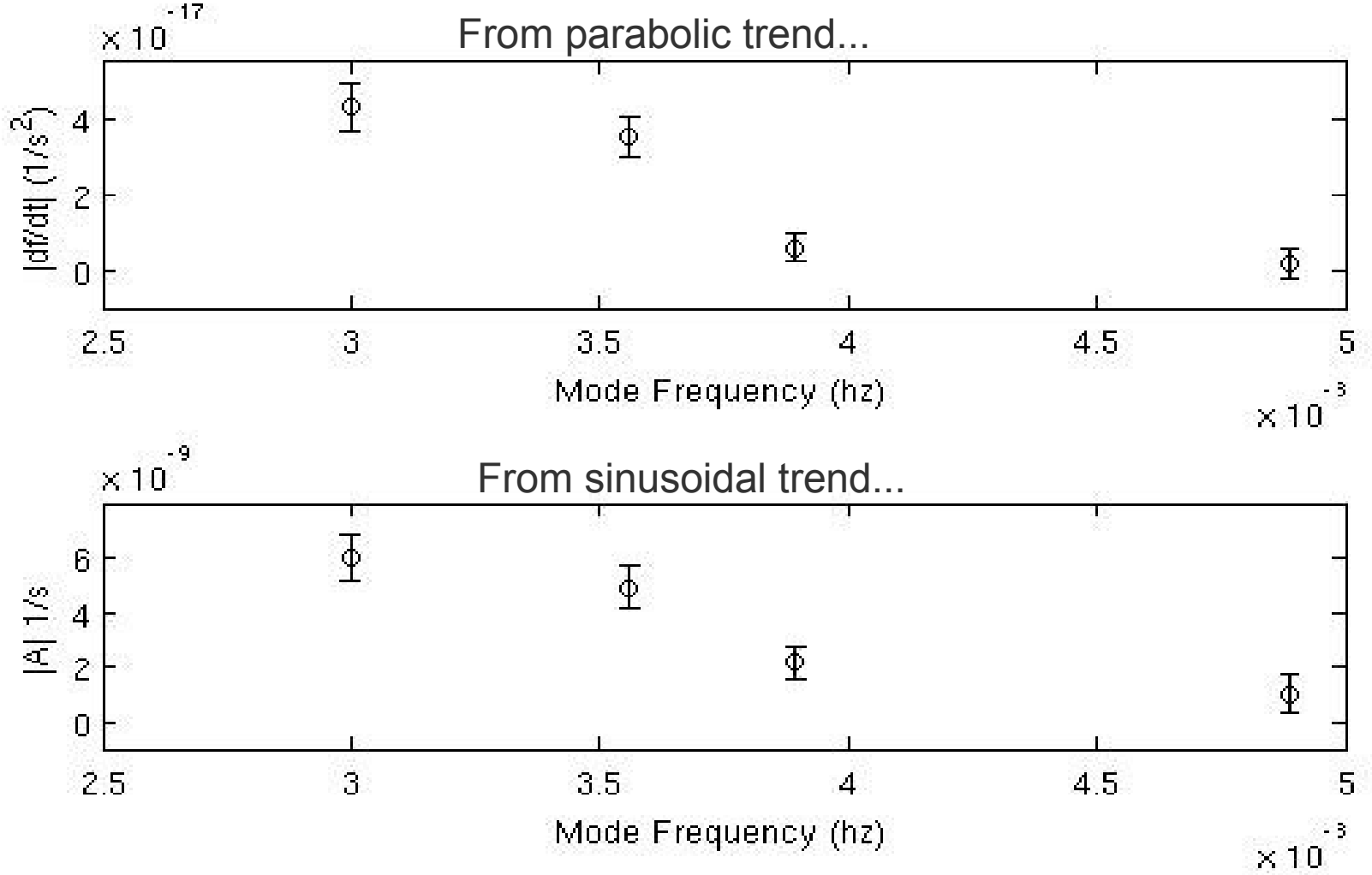
→ **204s and 281s**

Group Two
- Positive dP/dt
- Relative Phase = π

→ **256s and 333s**

Most simple explanation...
- One group is m=+1 and the other m=-1
- The variations are due to rotational effects
- A global change in rotation would affect all modes identically (for equal l), not the case in the data

Magnitude of the variations as a function of frequency...



Observation: The variations are correlated in frequency, and increase with period (or k)

Conclusion: The physical processes governing these changes appear to be affecting the same region near/at the surface of the star.

The observed rate of frequency/period change should be equal to the evolutionary (cooling) rate + the other contribution

$$\dot{f}_{obs} = \dot{f}_{cooling} + \dot{f}_{other}$$

The observed amplitude of the sinusoidal variations is all from the unexplained or “other” contribution

$$A_{obs} = A_{other}$$

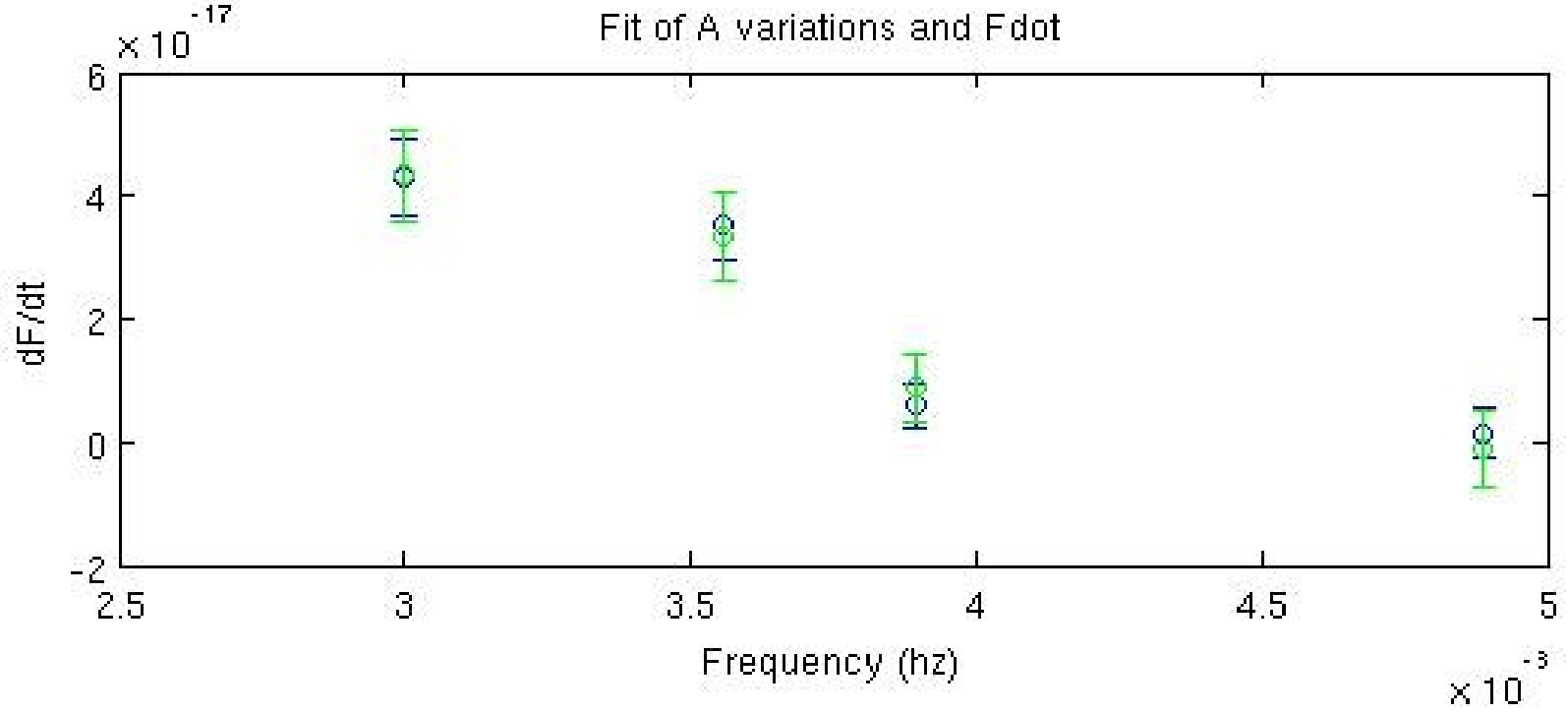
The amplitude variations appear to be affecting the star in the same region as the other frequency variations. The variations are directly proportional to each other, or...

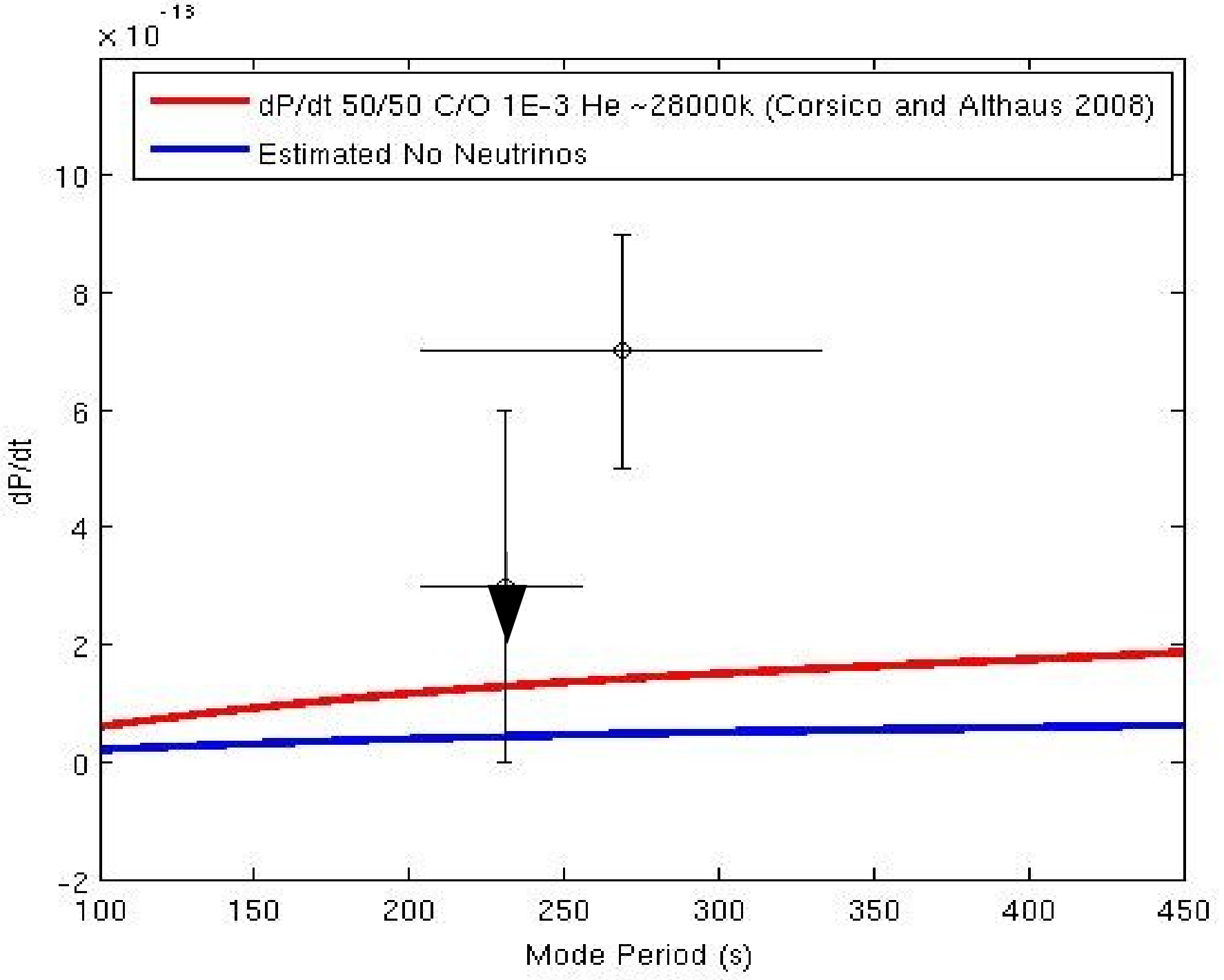
$$a \times A_{other} = \dot{f}_{other} = a \times A_{obs}$$

Putting this together we find...

$$\dot{f}_{obs} = a \times A_{obs} + \dot{f}_{cooling}$$

We can fit the observed frequency and amplitude variations to measure the evolutionary rate of period change...




x 10^-13
dP/dt 50/50 C/O 1E-3 He ~28000k (Corsico and Althaus 2006)
Estimated No Neutrinos
dP/dt
10
8
6
4
2
0
-2
100
150
200
250
300
350
400
450
Mode Period (s)

To Do List

- Improve the asteroseismology model for EC20058-5234

- Find relationship between frequency changes and rotation in the star
- Examine the assumption that the physical process causing the sinusoid and parabolic trends are affecting the same region in the star
- C/O ratio, He mass, temperature important for model dP/dt

-More Observation/Analysis

- Continue to observe the target, improve precision
- Explore using combination and harmonics to improve precision
- Other modes?
- Investigate more reliable mode amplitude calculations

- Theory: Explore models to explain O-C variations

- Pulsations carrying angular momentum? Spin up/down? Companion?
- Magnetic field precession? Magnetic pole flipping (not in weak field limit)?


Das ist Alles!