The DBV White Dwarf EC 20058−5234 the continuing story

Denis J Sullivan
Victoria University of Wellington, NZ

August 20, 2010

A brief history of EC 20058–5234

- 1994 Discovered and identified as a DBV white dwarf as part of Edinburgh-Cape survey of blue objects (Koen et al. 1995).

A brief history of EC 20058–5234

- 1994 Discovered and identified as a DBV white dwarf as part of Edinburgh-Cape survey of blue objects (Koen et al. 1995).
- 1997 Whole Earth Telescope (WET) run (Sullivan et al. 2008)

A brief history of EC 20058–5234

- 1994 Discovered and identified as a DBV white dwarf as part of Edinburgh-Cape survey of blue objects (Koen et al. 1995).
- 1997 Whole Earth Telescope (WET) run (Sullivan et al. 2008)
- 1997+ Single site observations (Mt John NZ)

A brief history of EC 20058–5234

- 1994 Discovered and identified as a DBV white dwarf as part of Edinburgh-Cape survey of blue objects (Koen et al. 1995).
- 1997 Whole Earth Telescope (WET) run (Sullivan et al. 2008)
- 1997+ Single site observations (Mt John NZ)
- 2003 Magellan 6.5 m ($\times 0.67!$) photometry (2 nights)

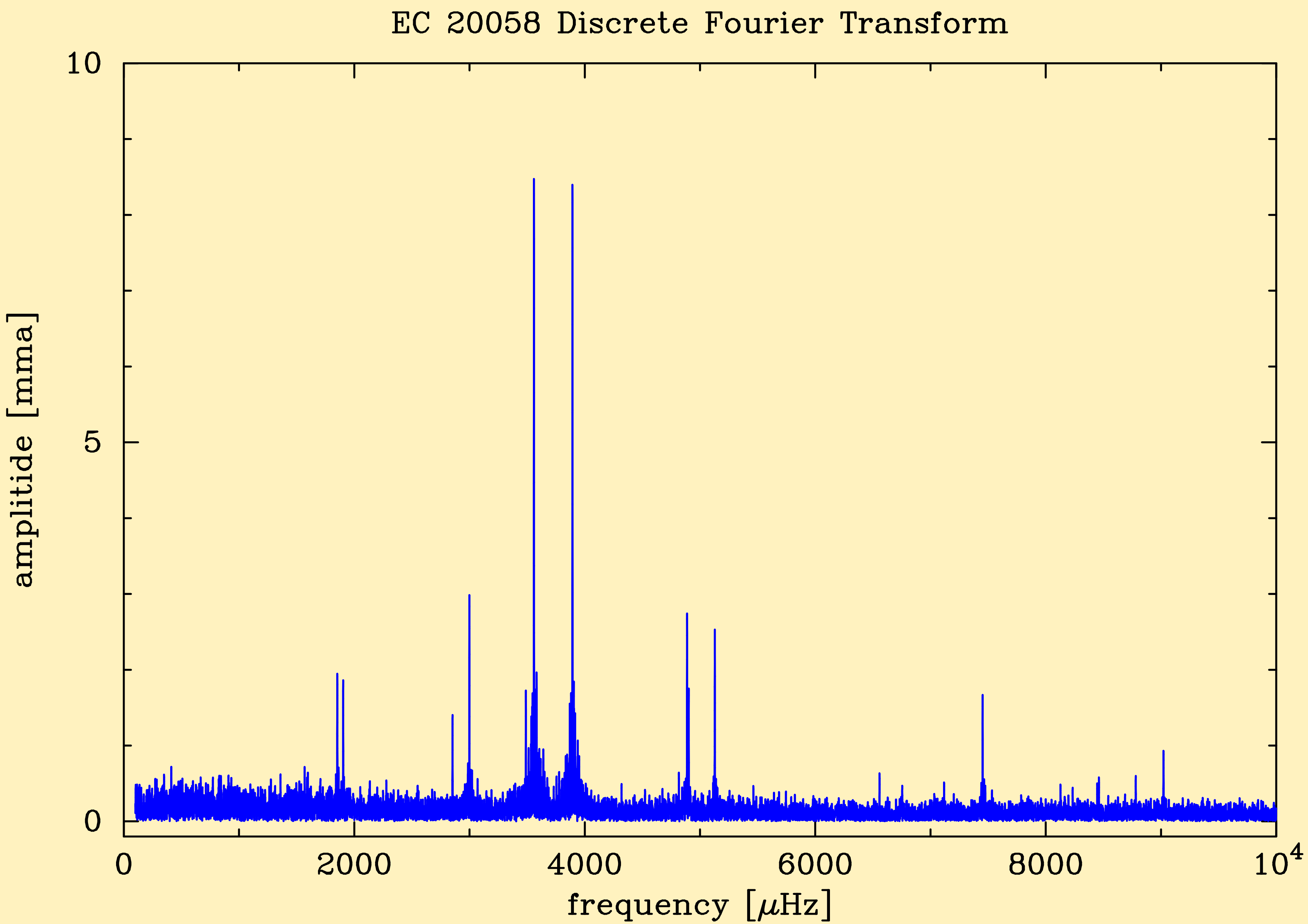
A brief history of EC 20058–5234

- 1994 Discovered and identified as a DBV white dwarf as part of Edinburgh-Cape survey of blue objects (Koen et al. 1995).
- 1997 Whole Earth Telescope (WET) run (Sullivan et al. 2008)
- 1997+ Single site observations (Mt John NZ)
- 2003 Magellan 6.5 m ($\times 0.67!$) photometry (2 nights)
- 2004 Magellan 6.5 m time-resolved spectroscopy (3 nights)

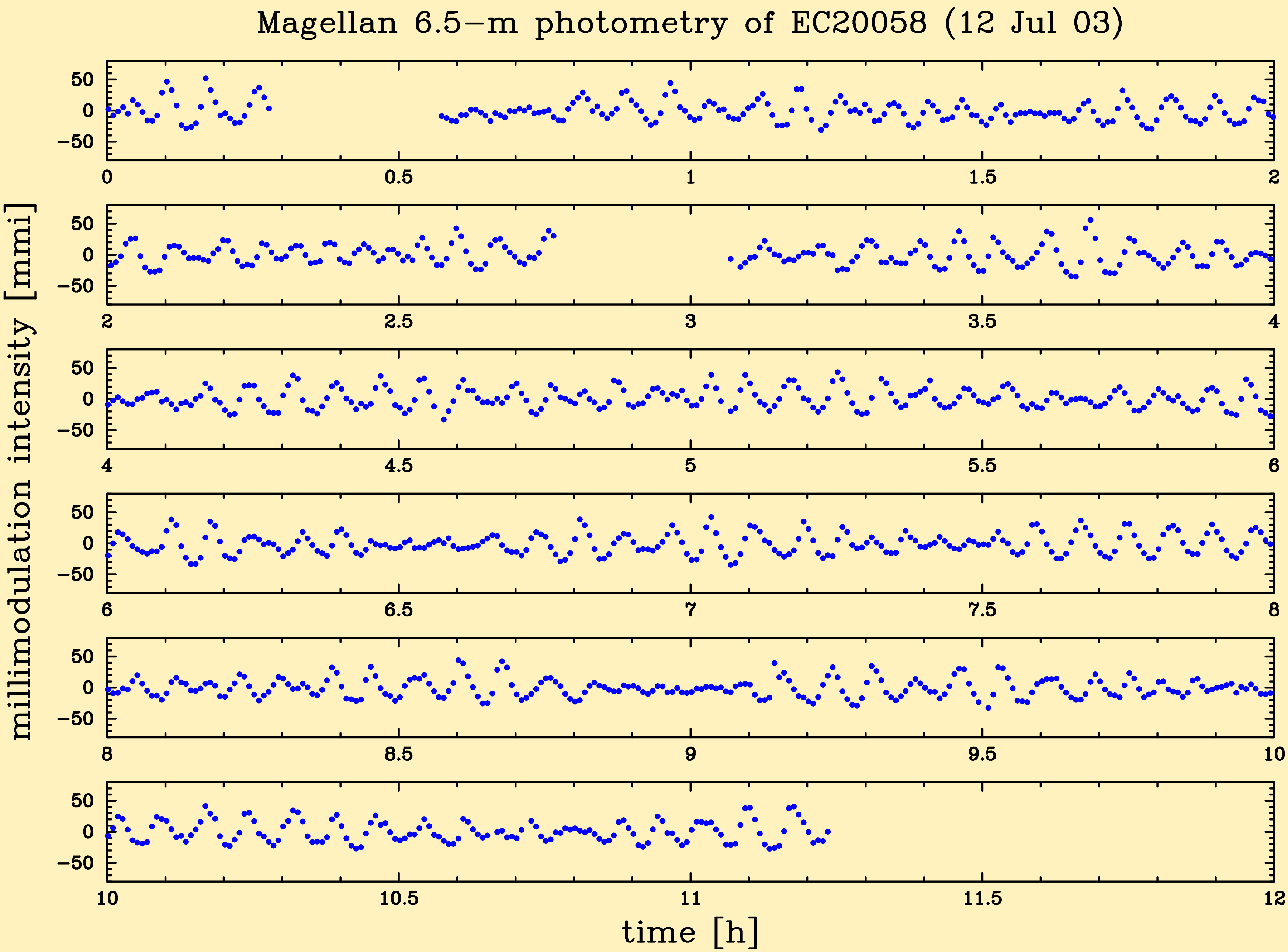
A brief history of EC 20058–5234

- 1994 Discovered and identified as a DBV white dwarf as part of Edinburgh-Cape survey of blue objects (Koen et al. 1995).
- 1997 Whole Earth Telescope (WET) run (Sullivan et al. 2008)
- 1997+ Single site observations (Mt John NZ)
- 2003 Magellan 6.5 m ($\times 0.67!$) photometry (2 nights)
- 2004 Magellan 6.5 m time-resolved spectroscopy (3 nights)
- 2006+ Seasonal observations from Chile (Delassio & Provencal)

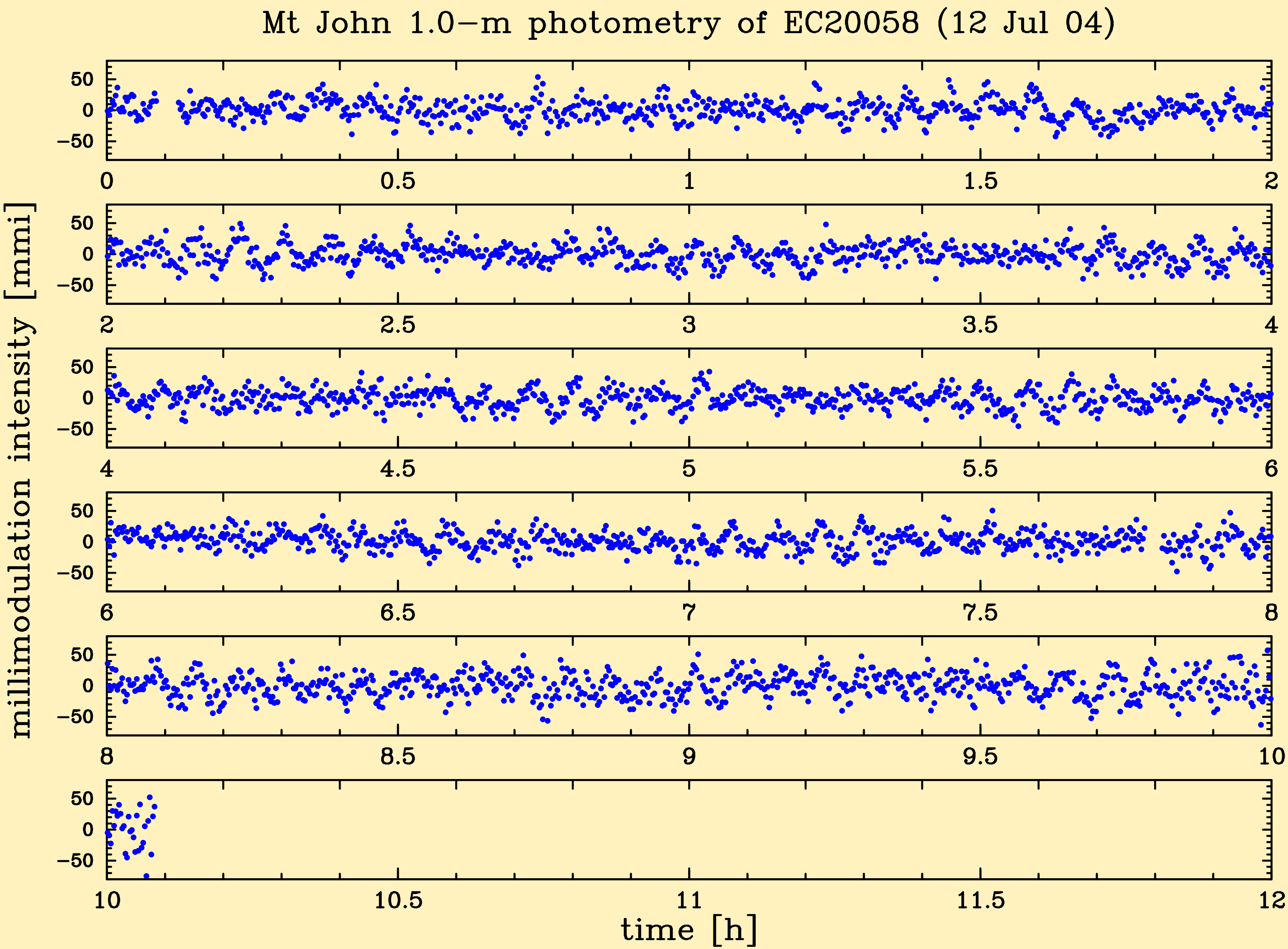
WET xcov15 DFT EC 20058



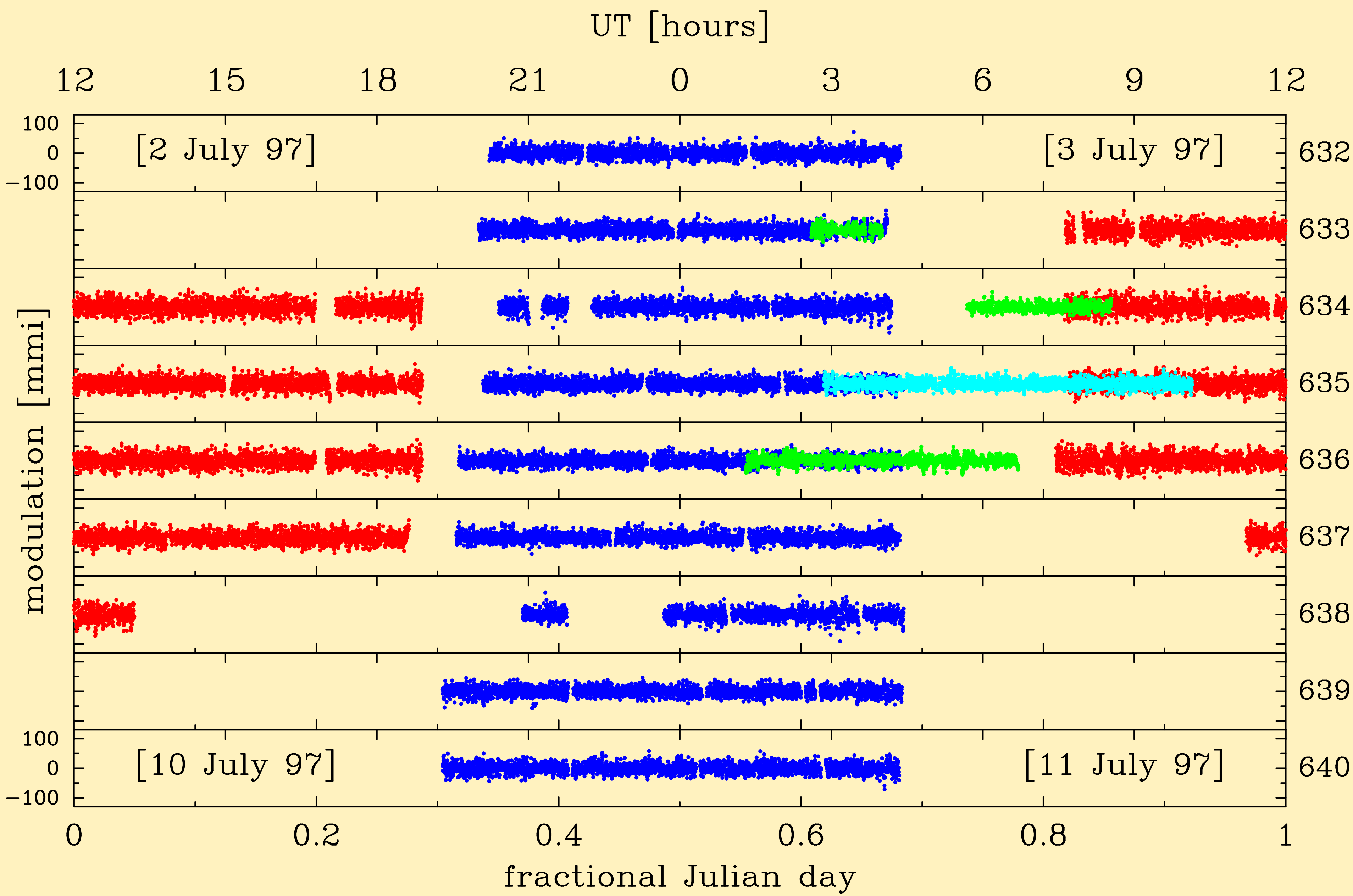
Magellan 6.5 m light curve



Mt John 1.0 m light curve

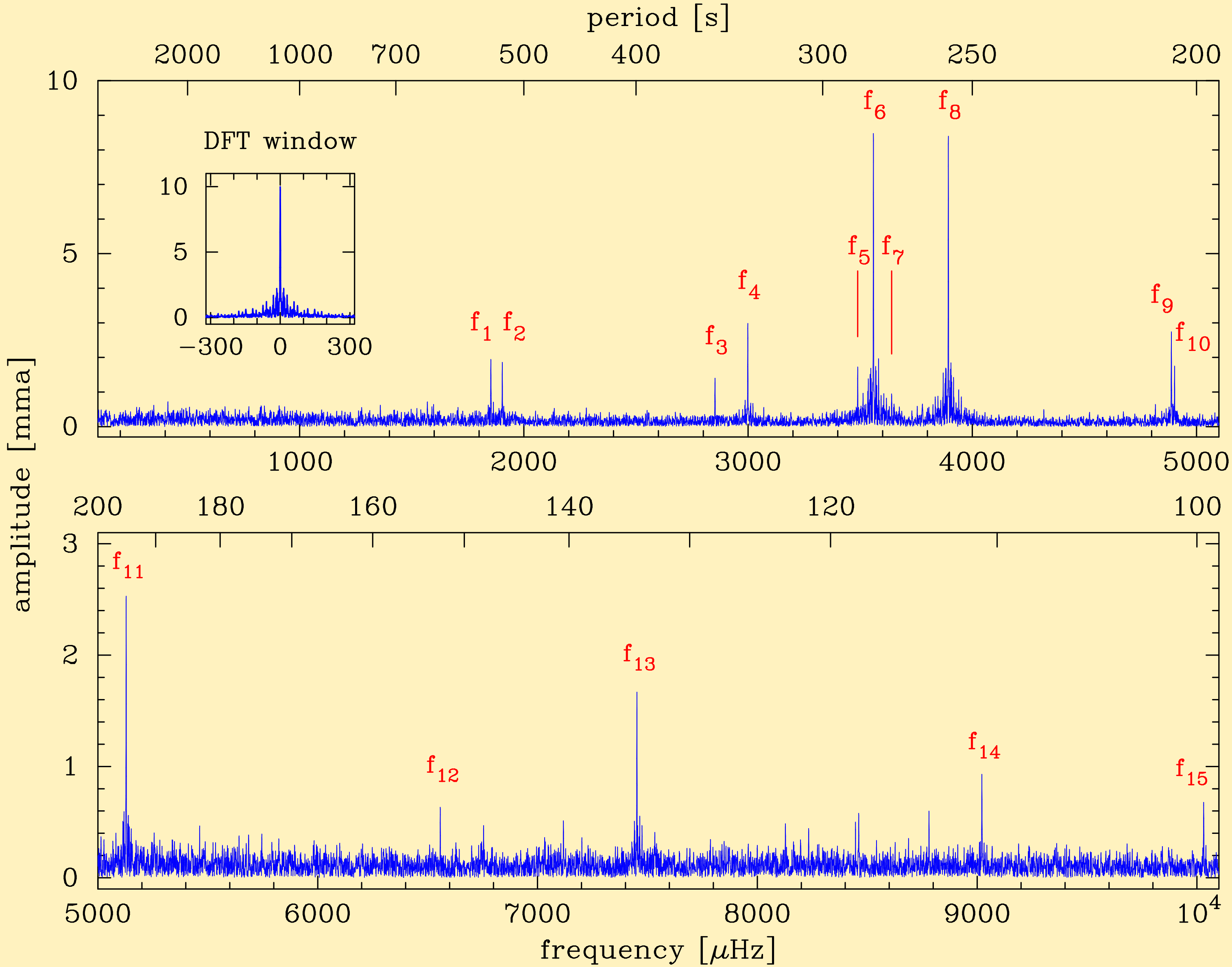


WET photometry xcov15 light curves

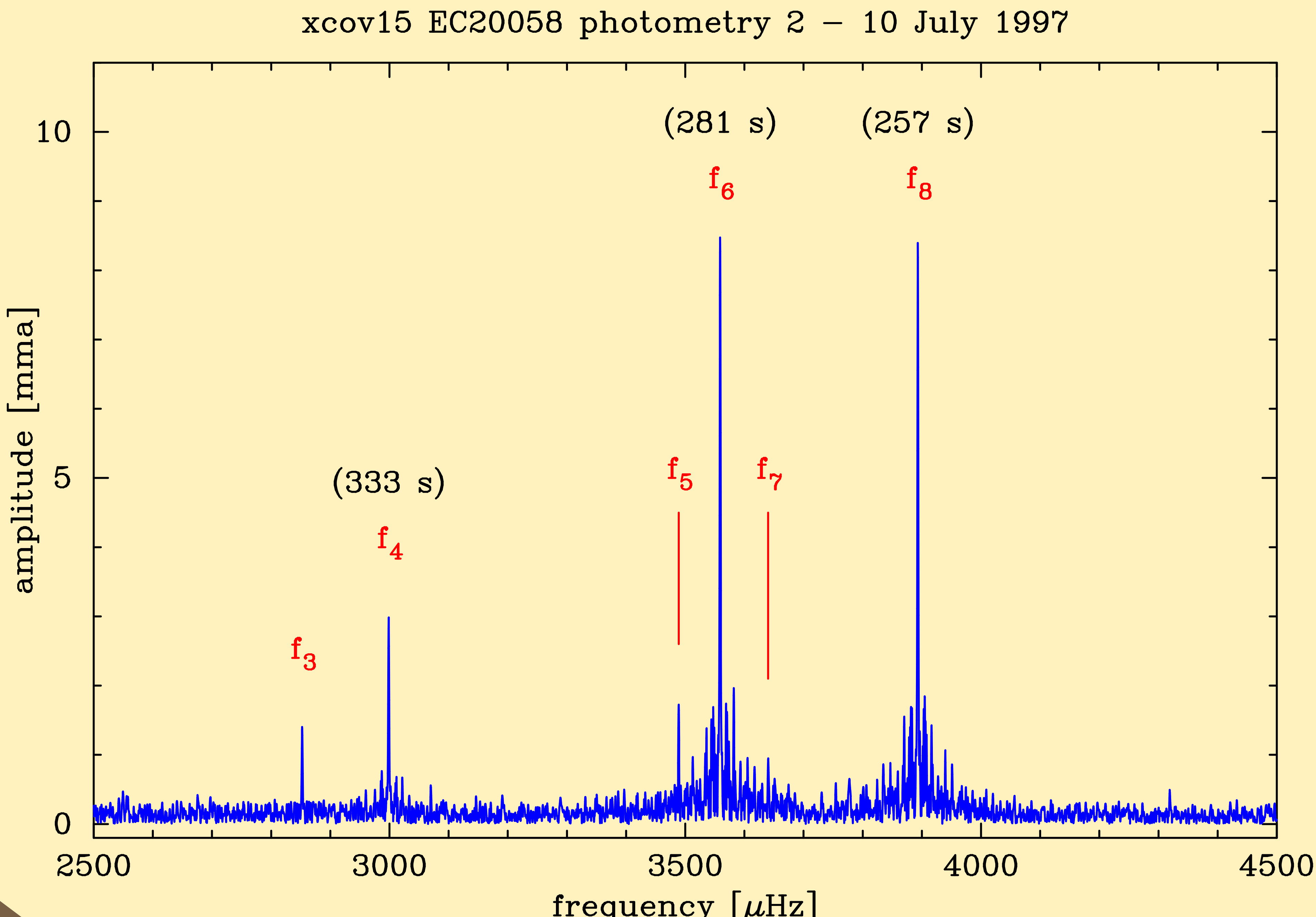


Asteroseismology of EC 20058

See Sullivan et al. MNRAS 387, 137 (2008)



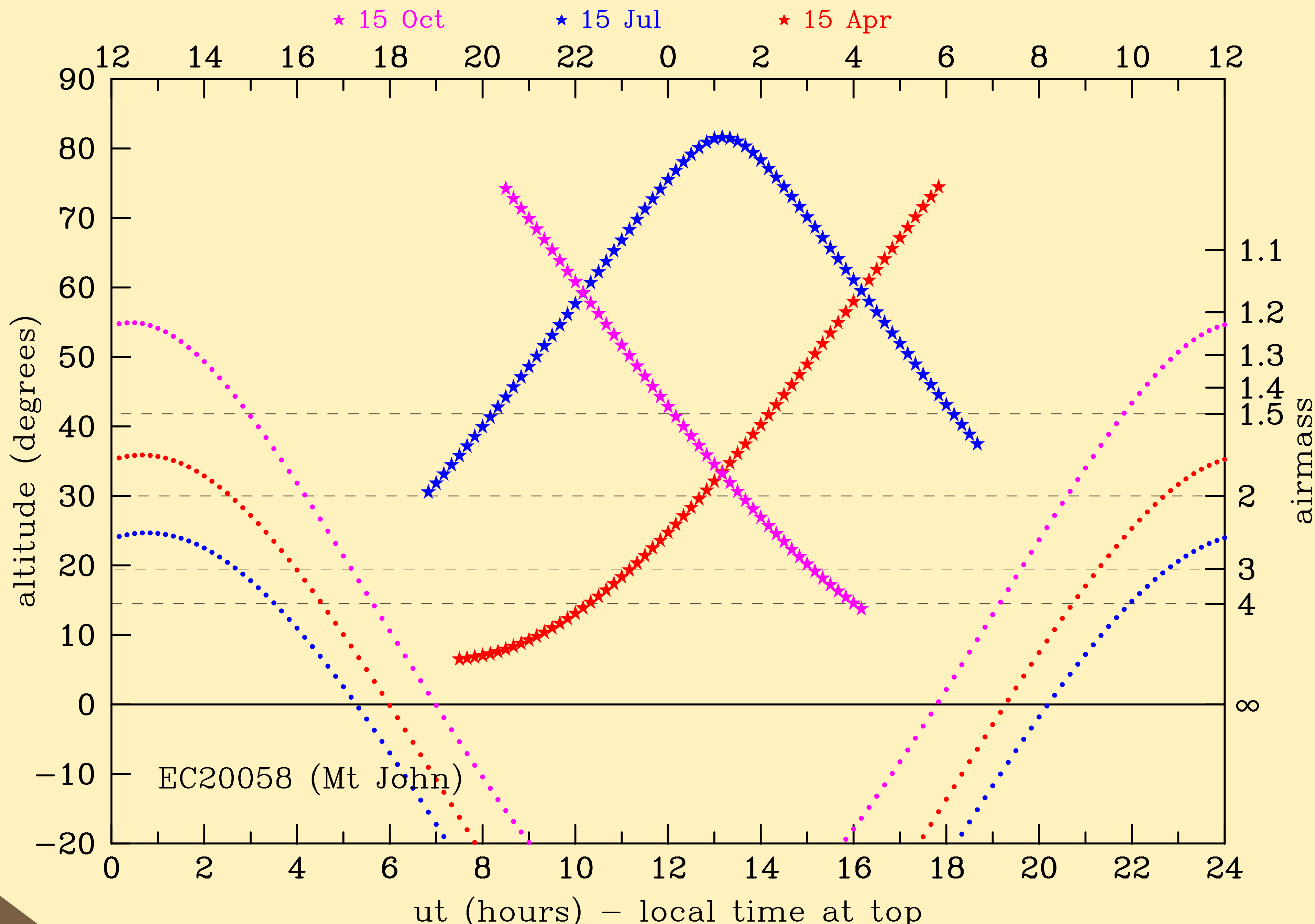
EC 20058 dominant periodicities and P_{dot}



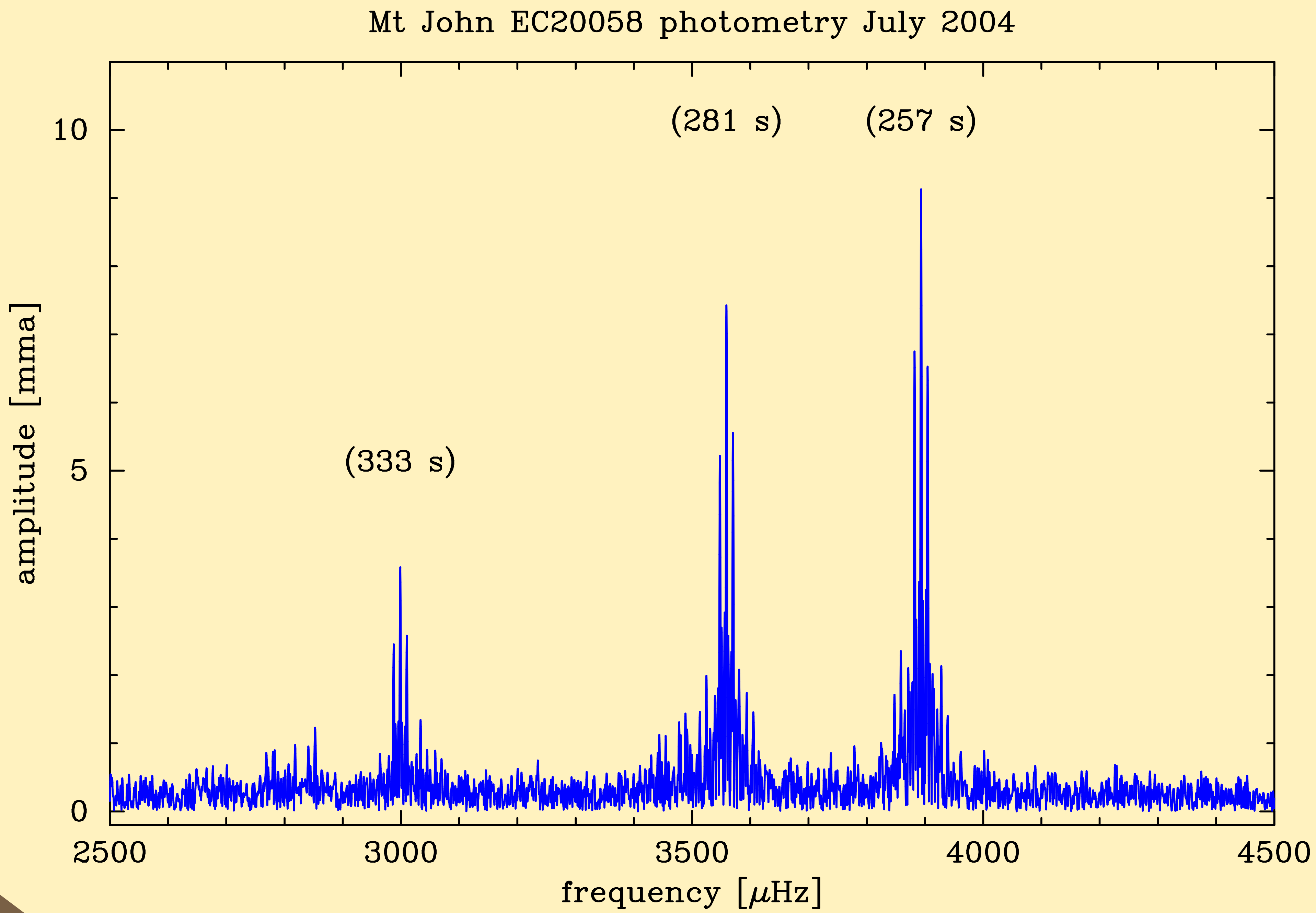
Mt John 1.0 m telescope (NZ)

Mt John 1.0 m telescope + 3ch photometer

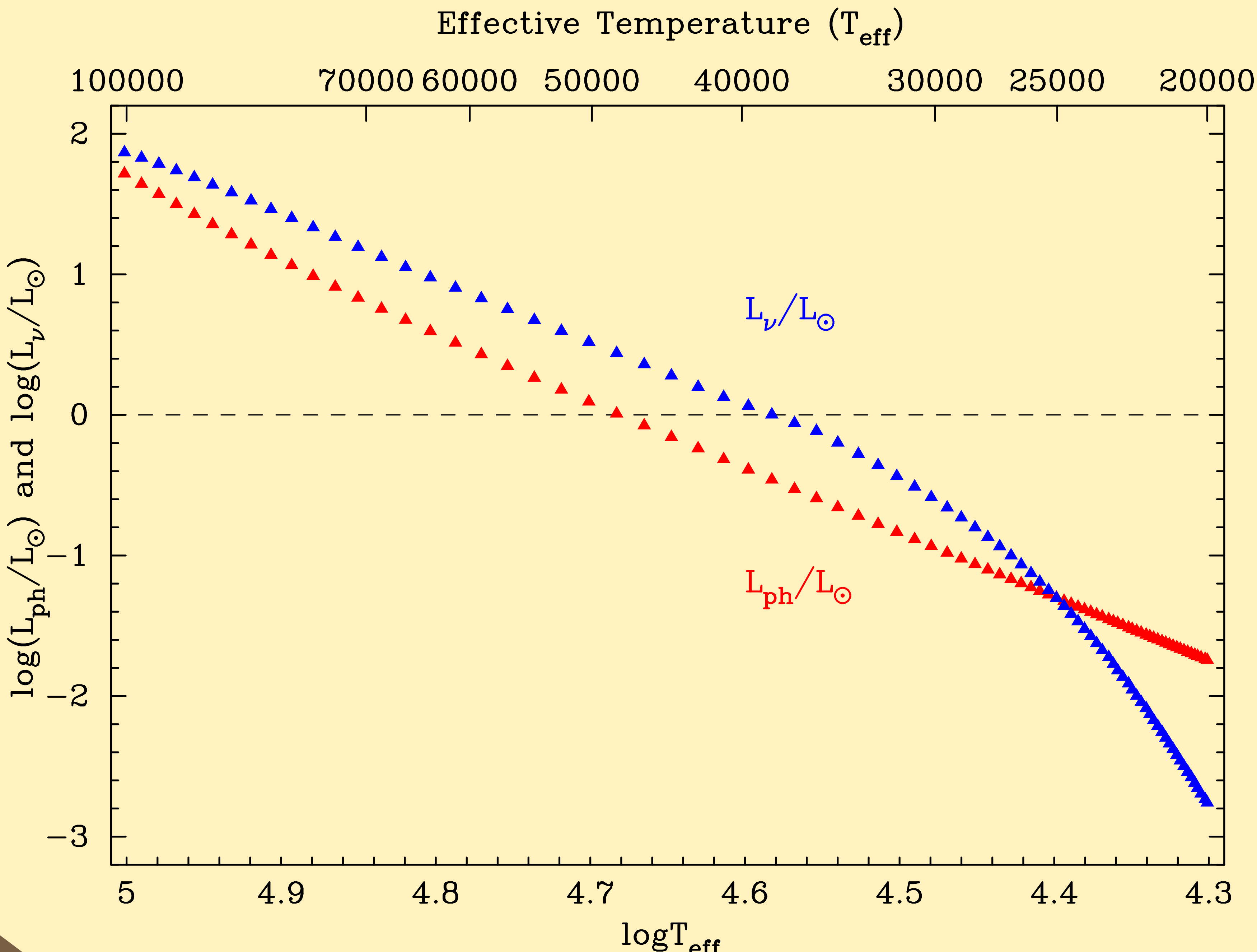
EC 20058 observing season at Mt John



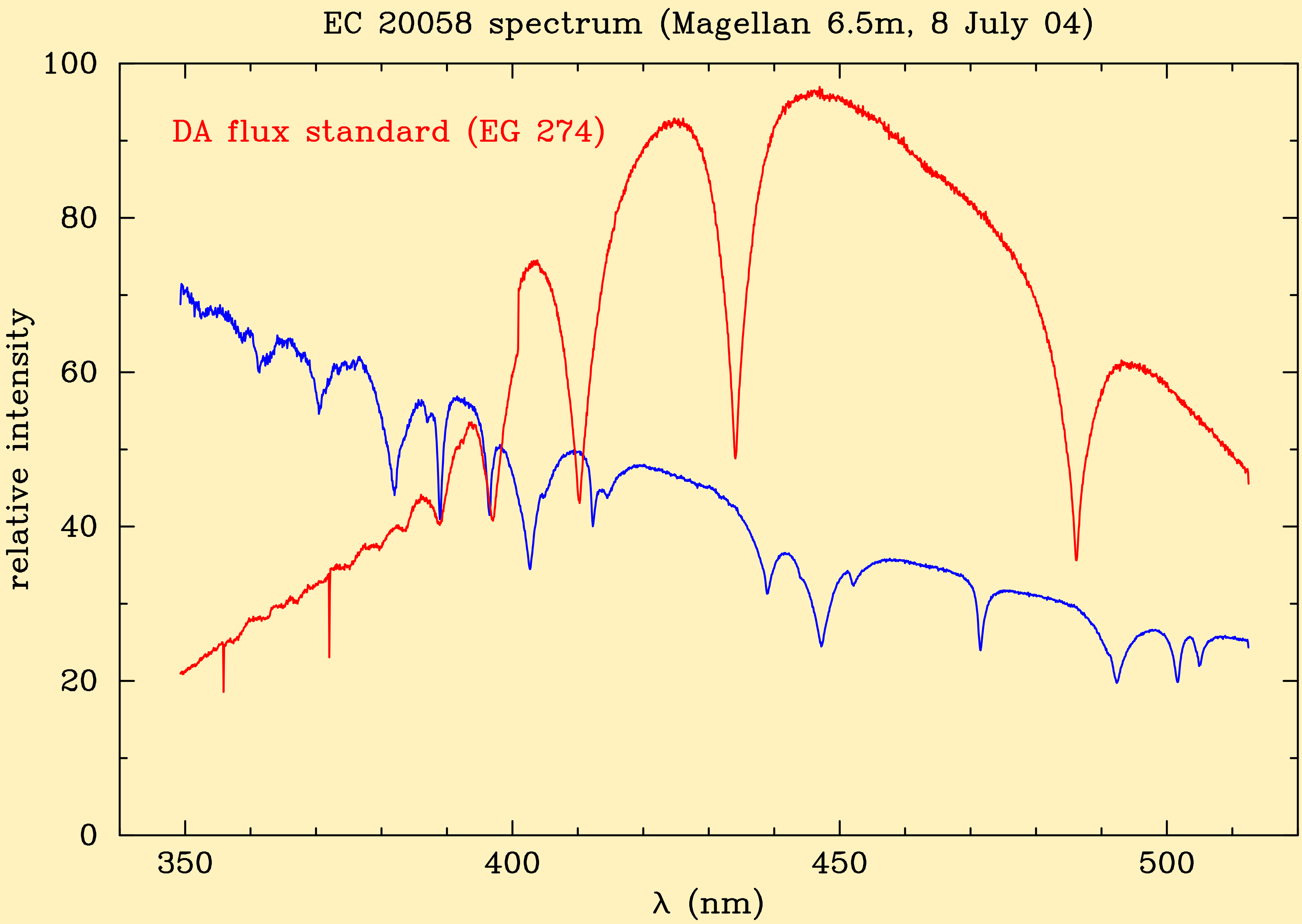
EC 20058 dominant periodicities



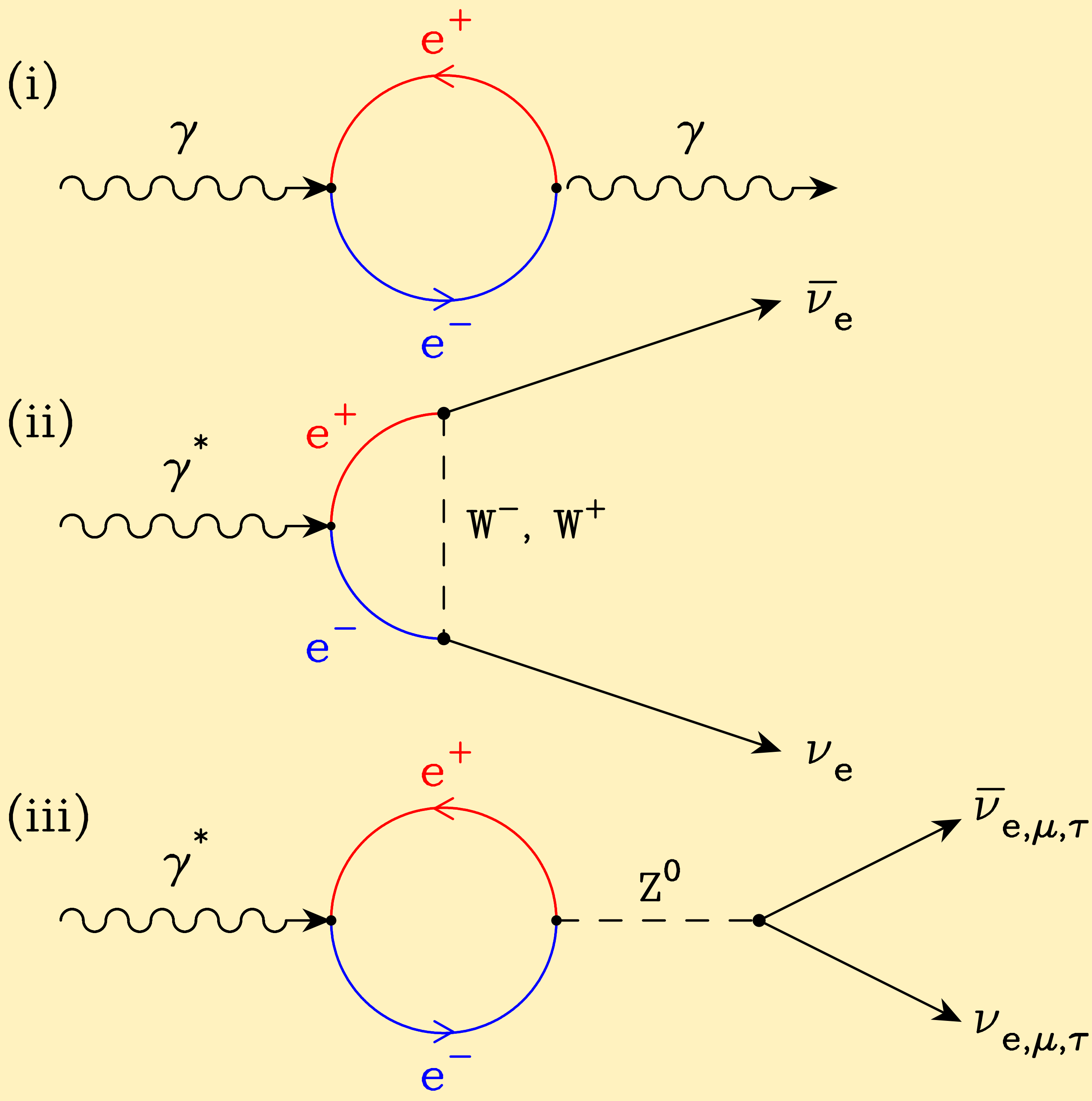
White cooling: photons vs neutrinos



EC 20058 (He atmos) and flux standard (H atmos)



Plasmon Neutrino Processes – Feynman diagrams



Neutrino physics in hot WD plasmas

1. Basically, neutrinos produced by $e^- e^+$ annihilation.
2. Numerous virtual $e^- e^+$ pairs produced in WD cores (Quantum Electrodynamics – QED).
3. Essentially *all* these virtual pairs recombine back into a photon as dictated by the energy-time uncertainty principle.
4. But every now and then (1 in 10^{19}!), electroweak theory predicts the transformation of a virtual $e^- e^+$ pair into a neutrino pair via a charged $W^{\pm}$ boson exchange (electron neutrinos) or neutral Z^0 boson creation and subsequent annihilation (neutrinos of any flavour).
5. Real final state energetic neutrinos can be produced if both energy and momentum conservation are satisfied.
6. Energy conservation is satisfied for the low energy photons (eg, $\sim$1 keV) due to the small mass of neutrinos (used to be zero!)
7. Momentum conservation requires another "particle" in the initial state $\longrightarrow$ among several mechanisms plasmons dominate.

White dwarf cooling and P_{dot}

1. The decreasing temperature of a white dwarf affects the periods of the pulsation modes.

White dwarf cooling and $\mathbf{P}_{\mathrm{dot}}$

1. The decreasing temperature of a white dwarf affects the periods of the pulsation modes.
2. Measurable in principle . . . . . . in human lifetimes!.

Theoretical evolutionary white dwarf $\dot{\mathrm{P}}$ values

$$\frac{\dot{P}}{P} = a\frac{\dot{R}}{R} - b\frac{\dot{T}}{T}$$

Type	$\dot{\mathrm{P}}$	Comment
DOV	$\sim 10^{-11}$ s s^{-1}	If $\dot{T}$ dominates, but $\dot{R}$ important
DBV	$\sim 10^{-13}$ s s^{-1}	$\dot{R}$ unimportant
DAV	$\sim 10^{-15}$ s s^{-1}	$\dot{R}$ unimportant

Actual measured pulsating white dwarf $\dot{P}$ values

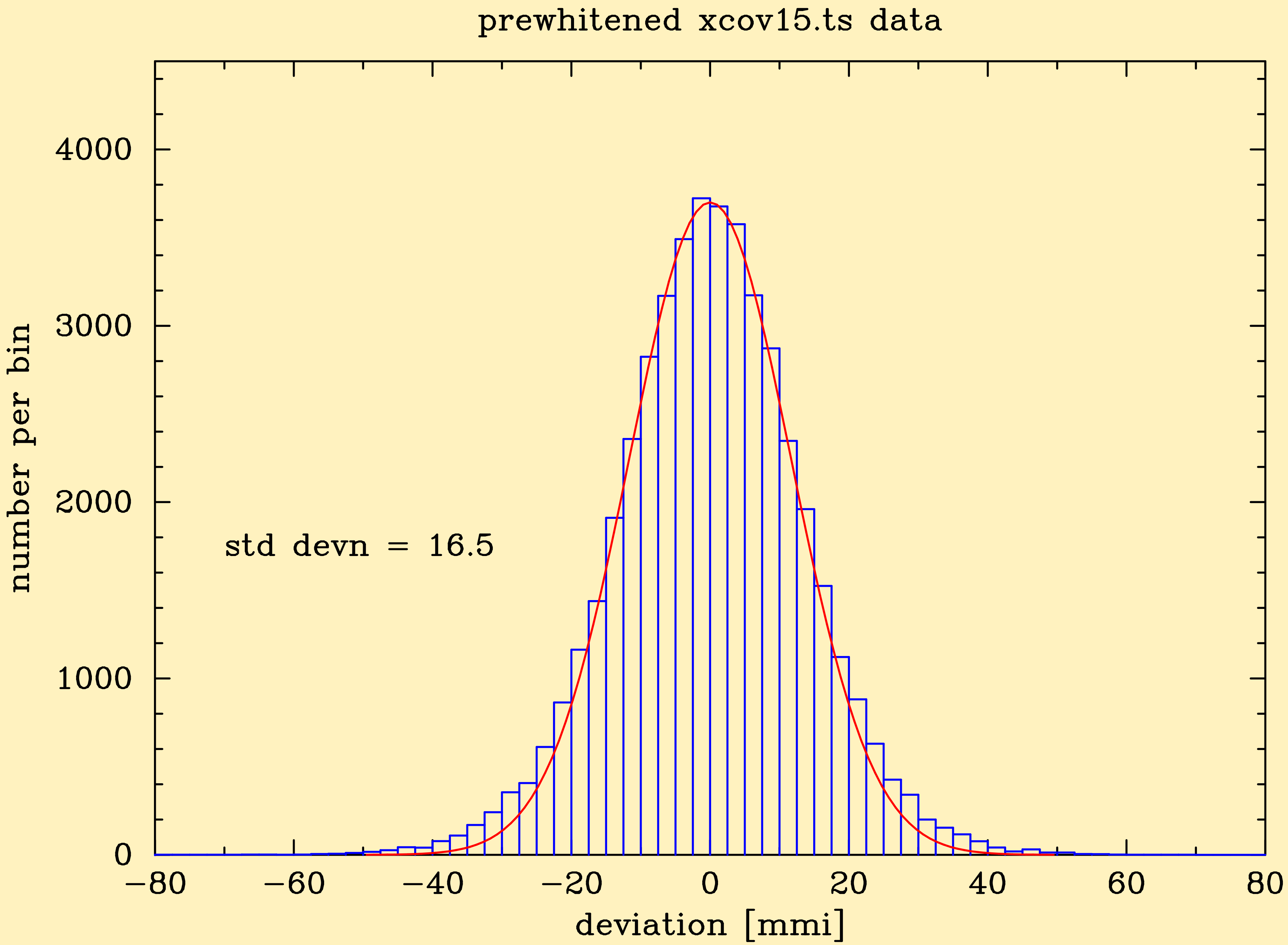
Object	Type	Mode	$\dot{P}$	Reference
PG 1159	DOV	516 s	$-1.21 \pm 0.06 \times 10^{-11}$	Winget et al. (1985)
			$-2.49 \pm 0.06 \times 10^{-11}$	Winget et al. (1991)
			$+13.0 \pm 2.60 \times 10^{-11}$	Costa et al. (1999)
		539 s	$-0.34 \pm 0.02 \times 10^{-11}$	Costa & Kepler (2008)
		...	... various ...	Costa & Kepler (2008)
G 117–B15A	DAV	215 s	$+3.6 \pm 0.80 \times 10^{-15}$	Kepler et al. (2005)
ZZ Ceti	DAV	213 s	$\leq 5.5 \pm 1.90 \times 10^{-15}$	Mukadam et al. (2003)

Determining realistic uncertainties via MC methods

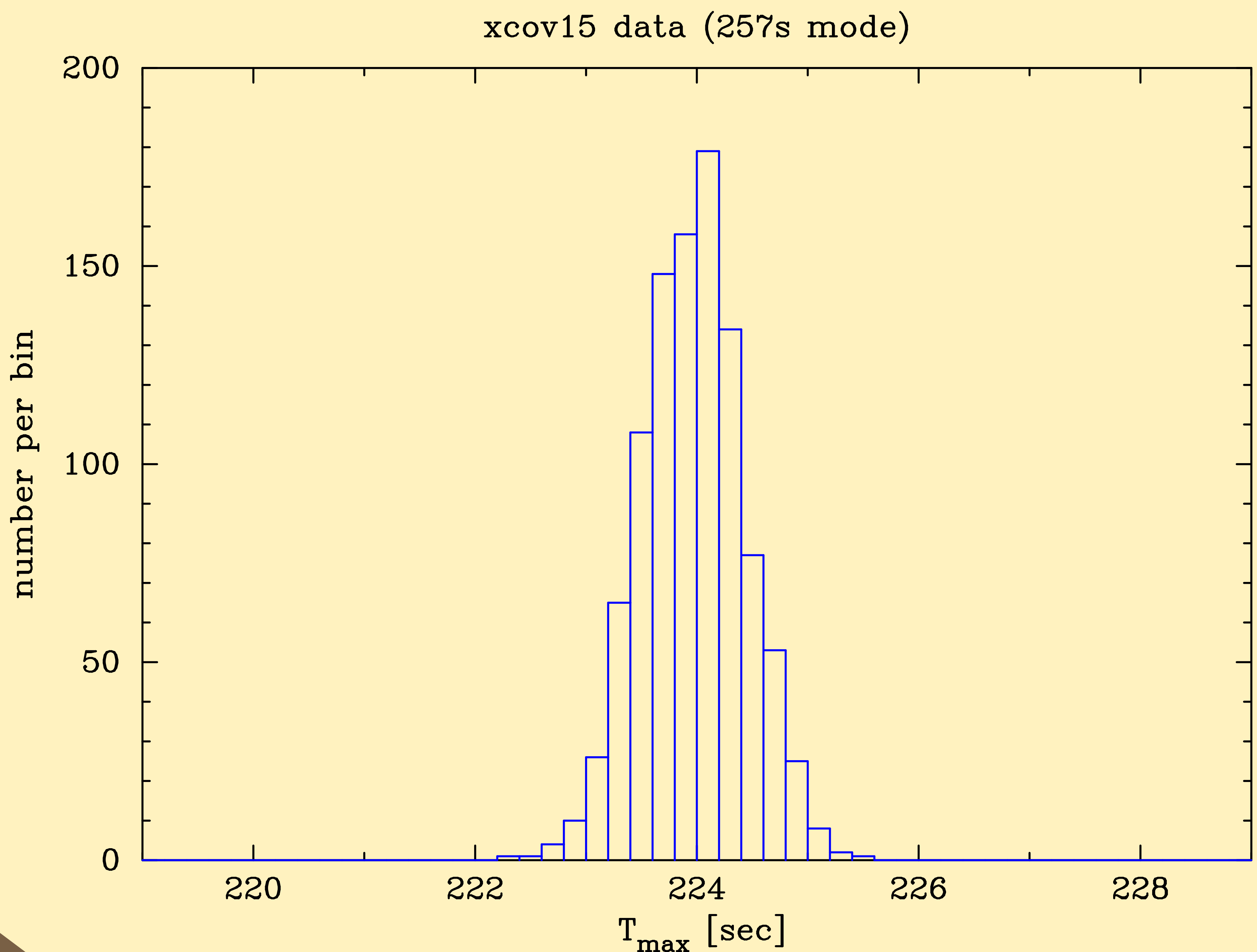
To properly implement the O-C period change method we require realistic assessments of the specific mode phases (time of maxima: t_{max}) for each light curve:

1. Prewhiten light curve using a multiple frequency linear least squares (LLSQ) fit with all known frequencies.
2. Examine ensemble of light curve deviations to determine statistical noise model $\longrightarrow$ gaussian model with given σ.
3. Create model noiseless light curve using LLSQ fit parameters.
4. Create synthetic noisy light curve by adding random gaussian noise from model $(0,\sigma)$ to noiseless model light curve.
5. Perform multiple frequency LLSQ fit on synthetic light curve and extract parameters (eg t_{max}) of interest.
6. Repeat 4 and 5 as many times as desired (eg 1000).

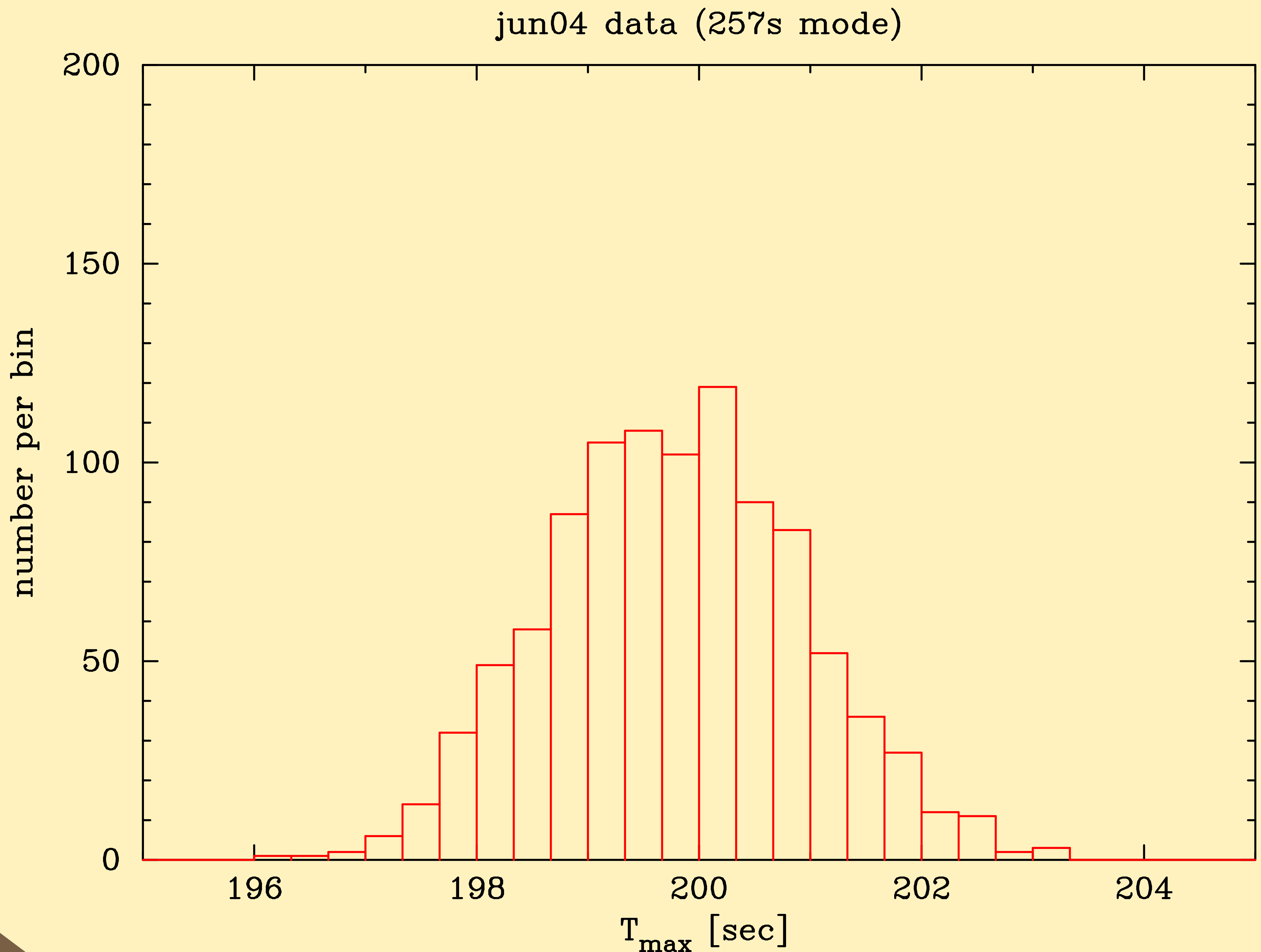
Light curve statistics – WET run



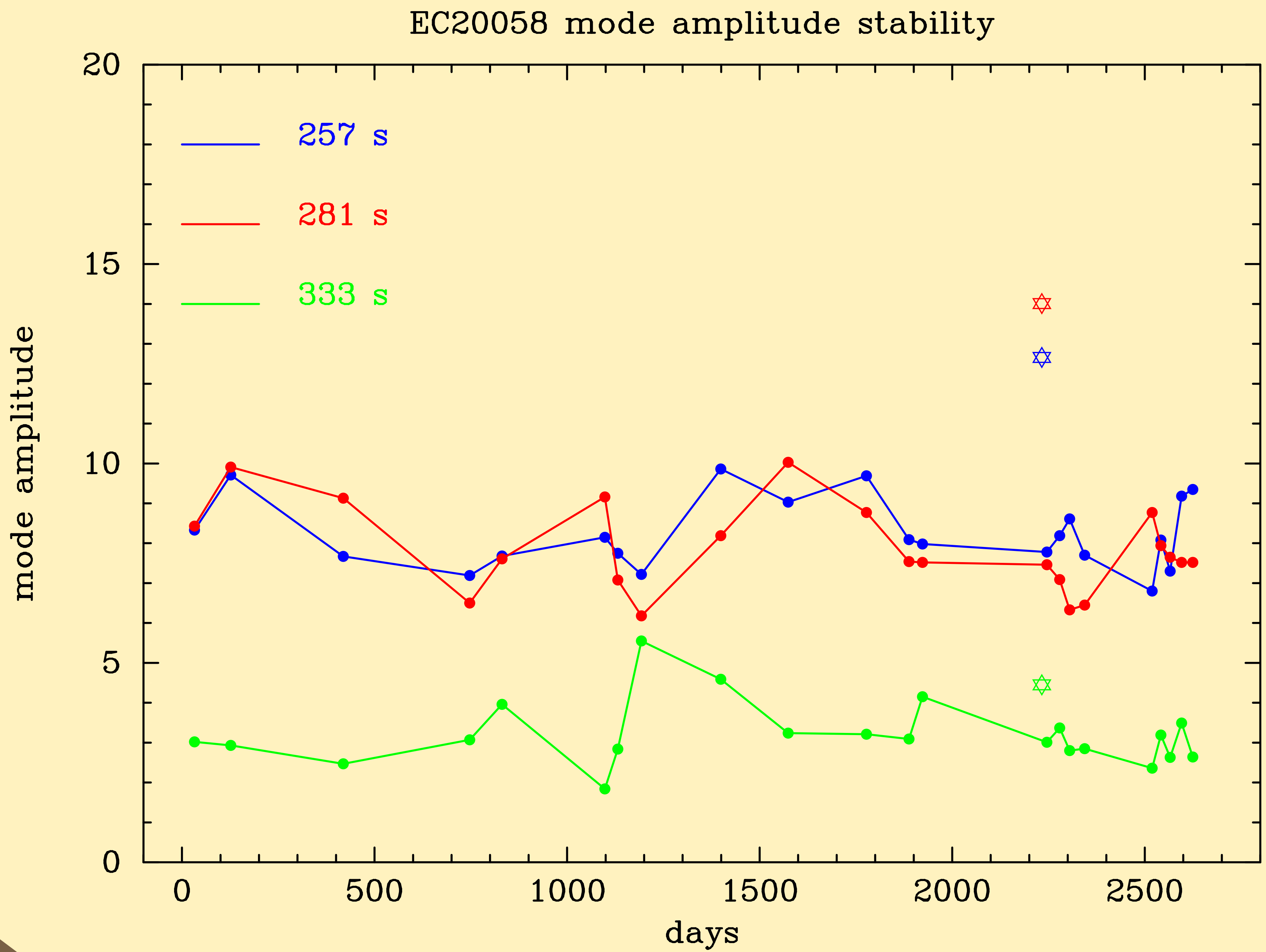
Mode timing uncertainties



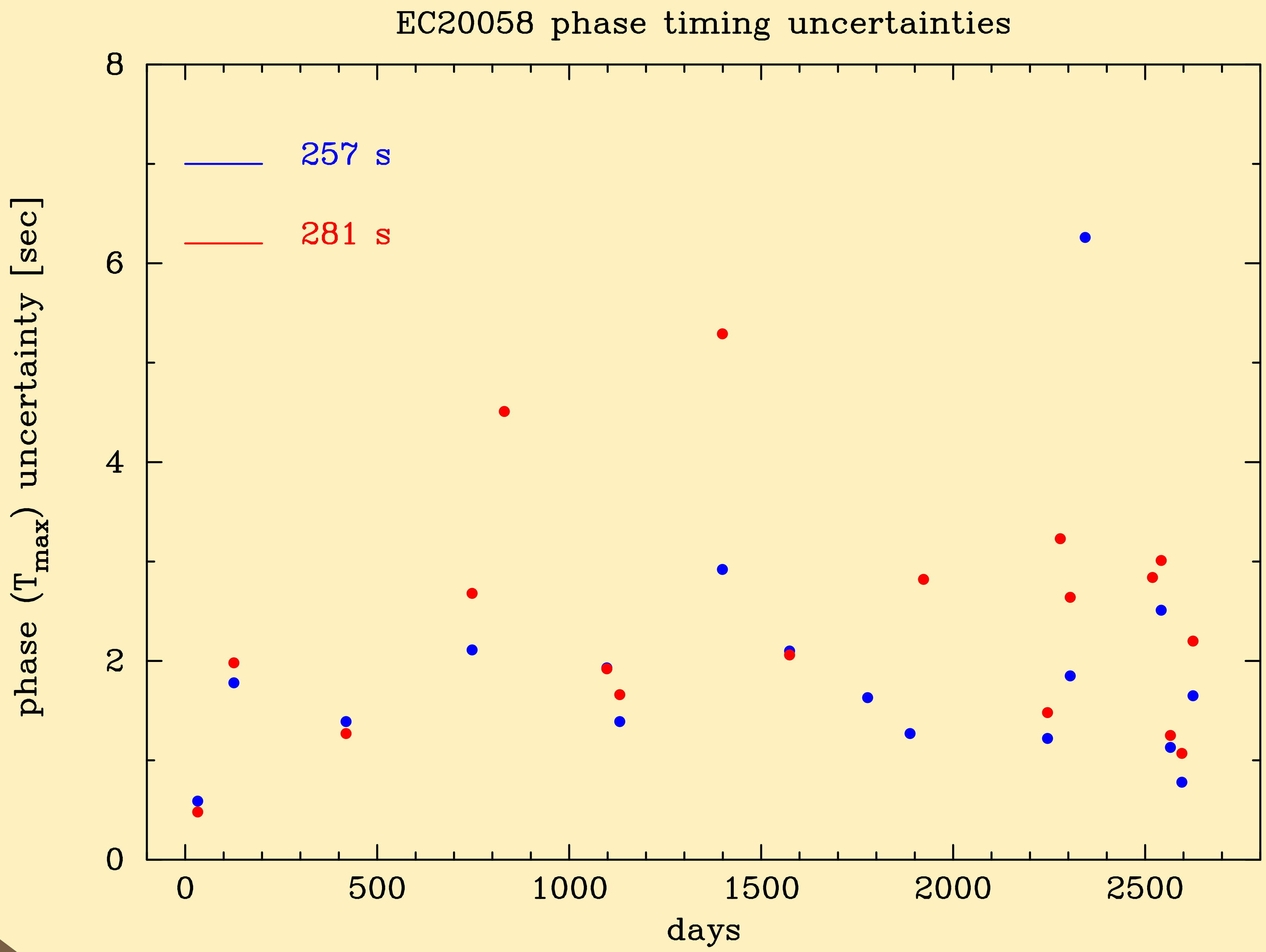
Mode timing uncertainties



Mode amplitude stability



Mode timing uncertainties



Data set phase uncertainties

Data Set	Site	σ_t [mmi]	σ_{257} [s]	σ_{281} [s]	σ_{333} [s]
xcov15	WET	13.4	0.59	0.48	1.56
jul03_mag	Magellan	5.9	0.56	0.57	-
jul04	Mt John	15.9	0.78	1.07	2.6
jun04	Mt John	17.1	1.13	1.25	16.3
jul03	Mt John	15.9	1.22	1.48	4.28
aug02	Mt John	20.5	1.27	1.45	1.48
...	Mt John	...	...	...	...
jun00	Mt John	16.8	1.93	1.92	18.7
...	Mt John	...	...	...	...
aug03	SSO	39.8	7.90	32.3	11.4
...	Mt John	...	...	...	...

The end

continued . . .