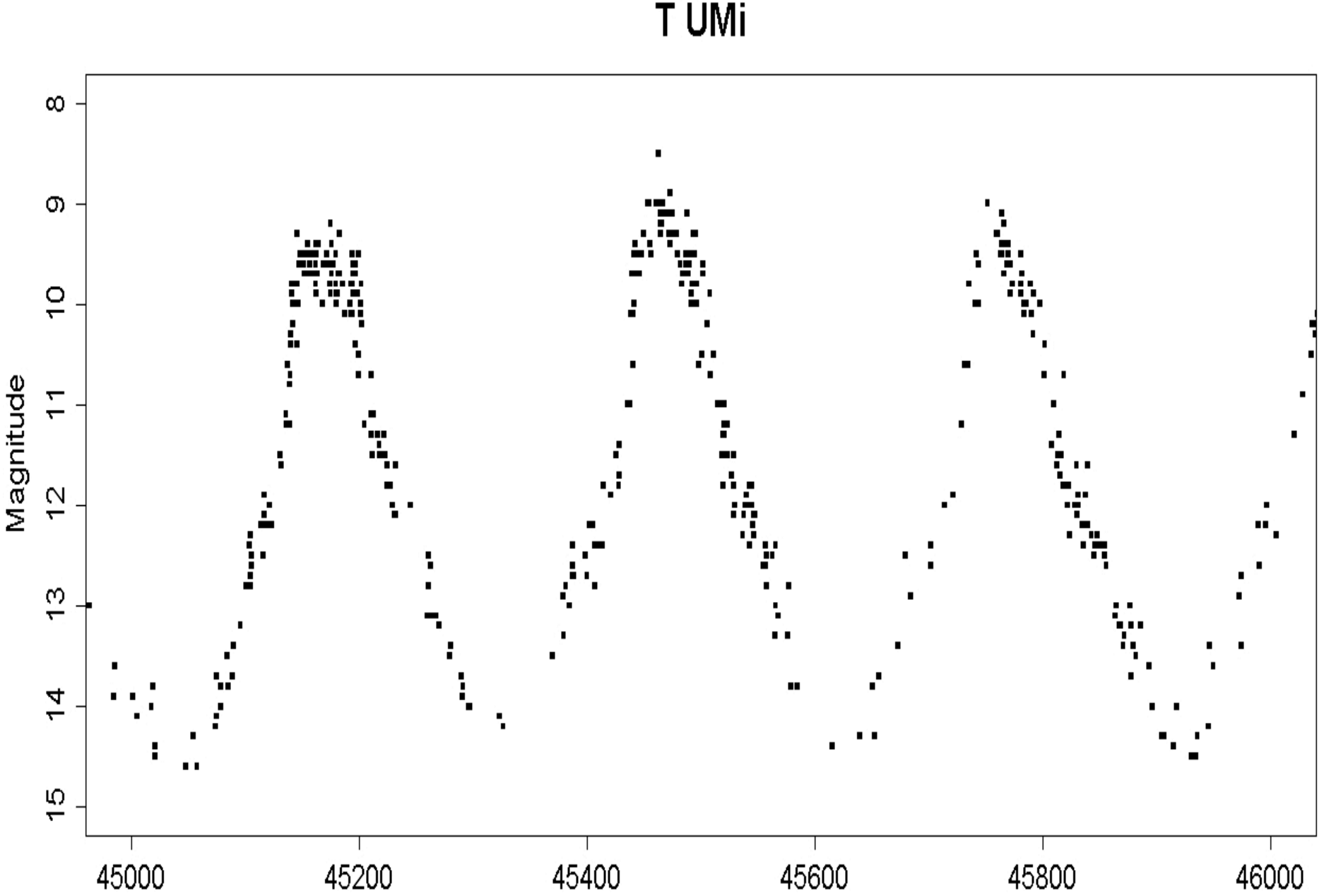
T UMi

From Mira to ???

T UMi

- One of the first stars Janet asked me to study in detail
- Is a Mira-type variable
- Uh ... WAS a Mira-type variable

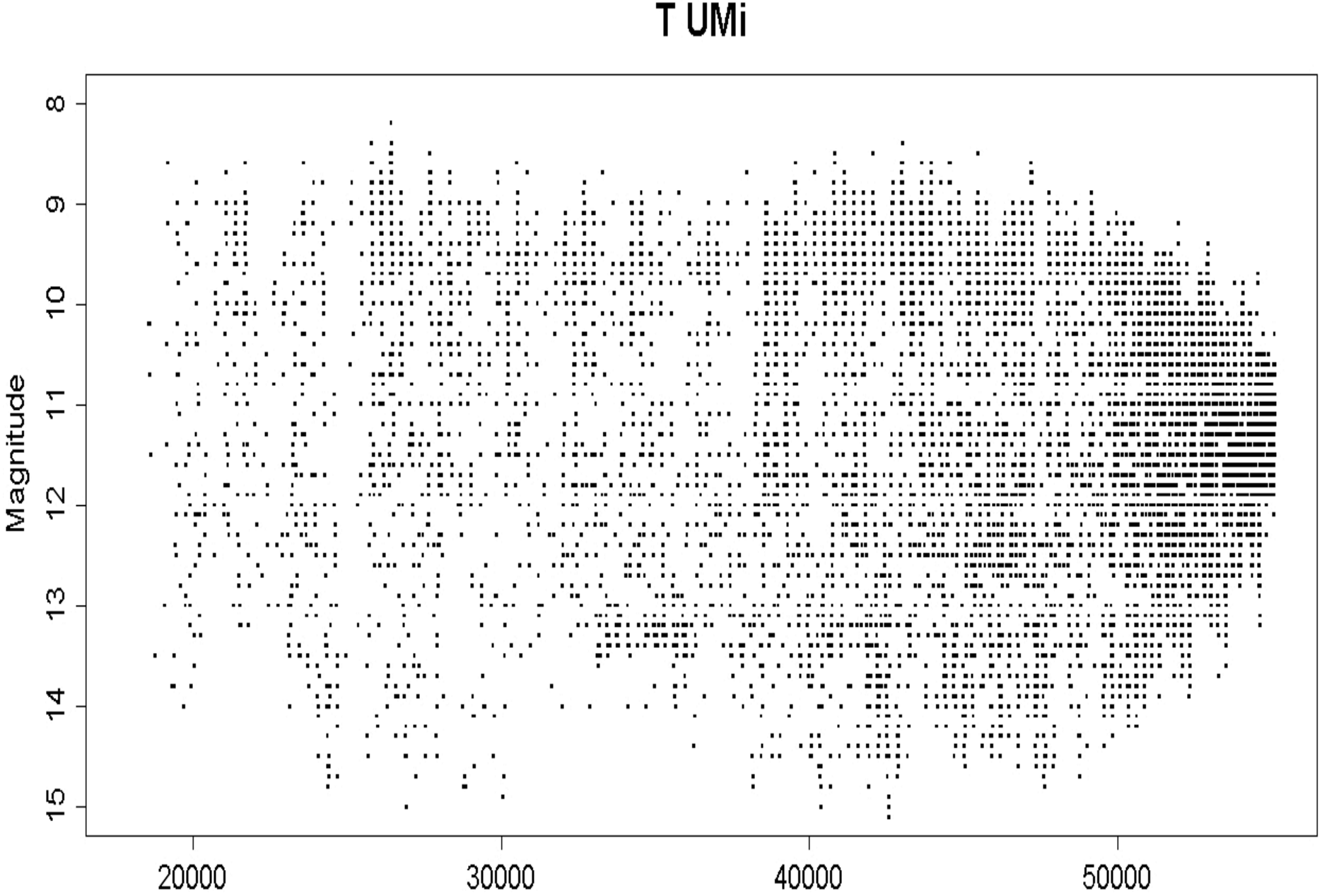

T UMi
Magnitude
8
9
10
11
12
13
14
15
45000
45200
45400
45600
45800
46000

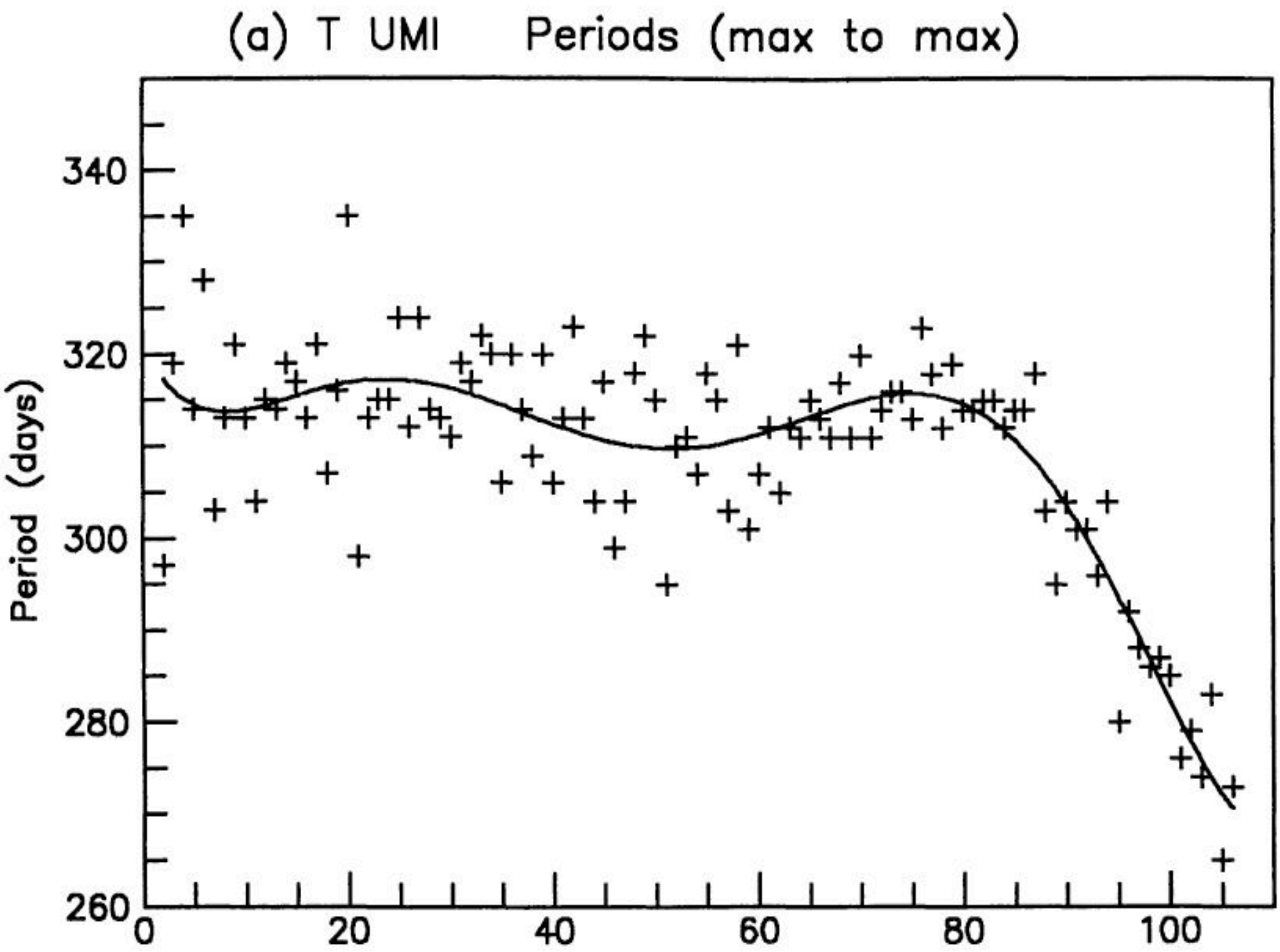
Predicting LPVs

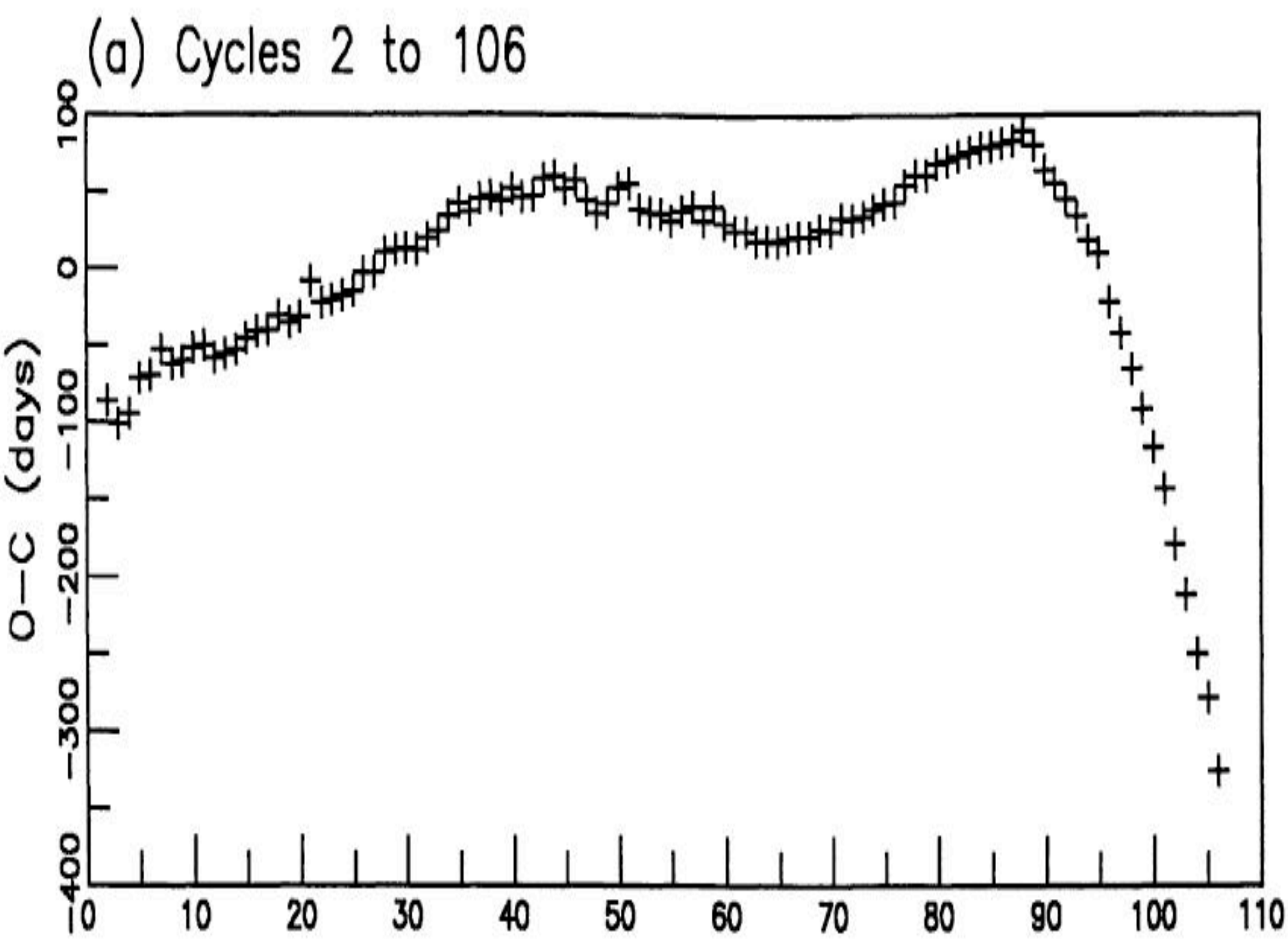
- Compare mean light curve (= expected behavior) to recent light curve
- Predict upcoming times max/min
- Also: comparing expected to recent behavior – detects changes
- Showed that T UMi period was decreasing

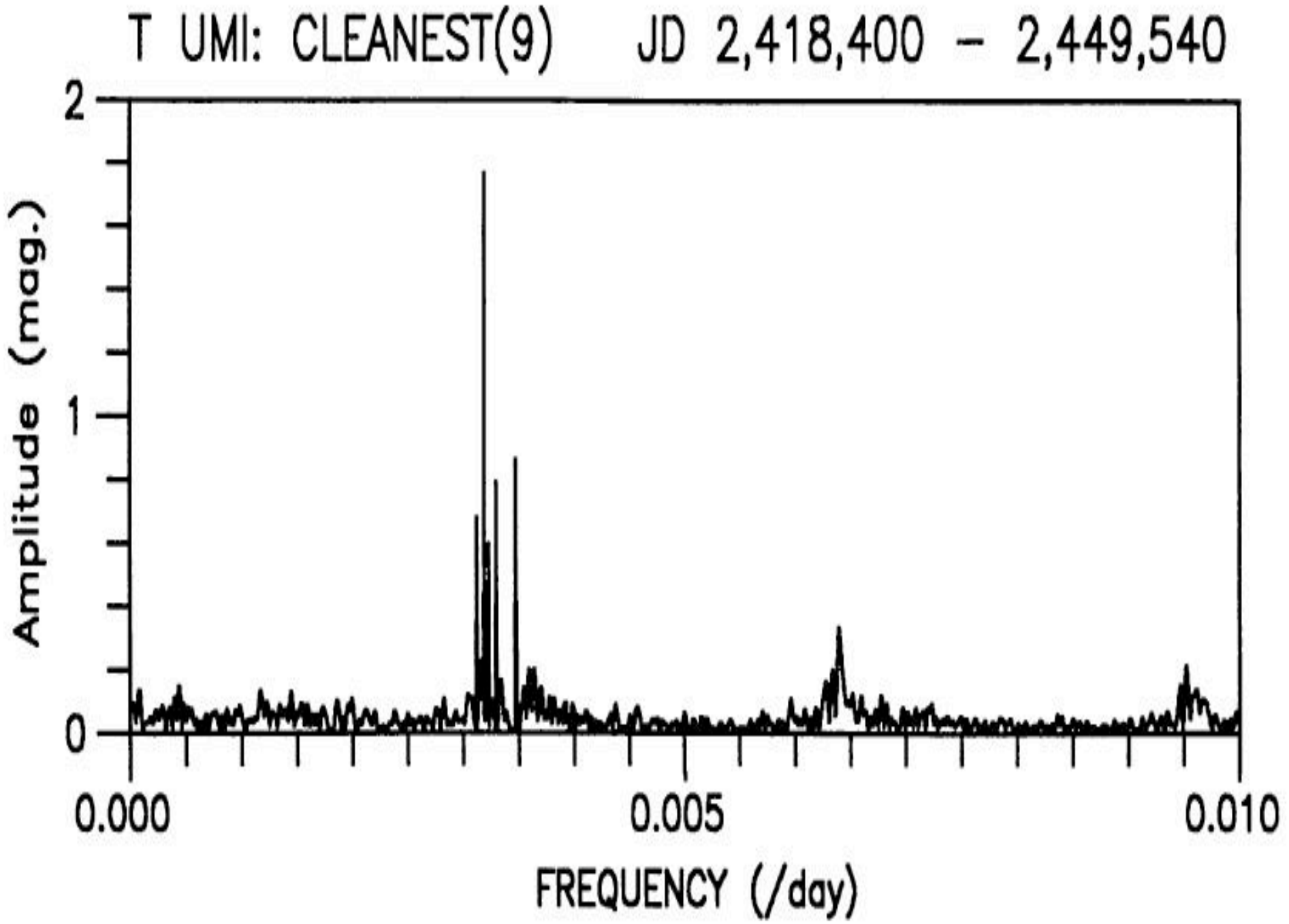
Pulsation Changes

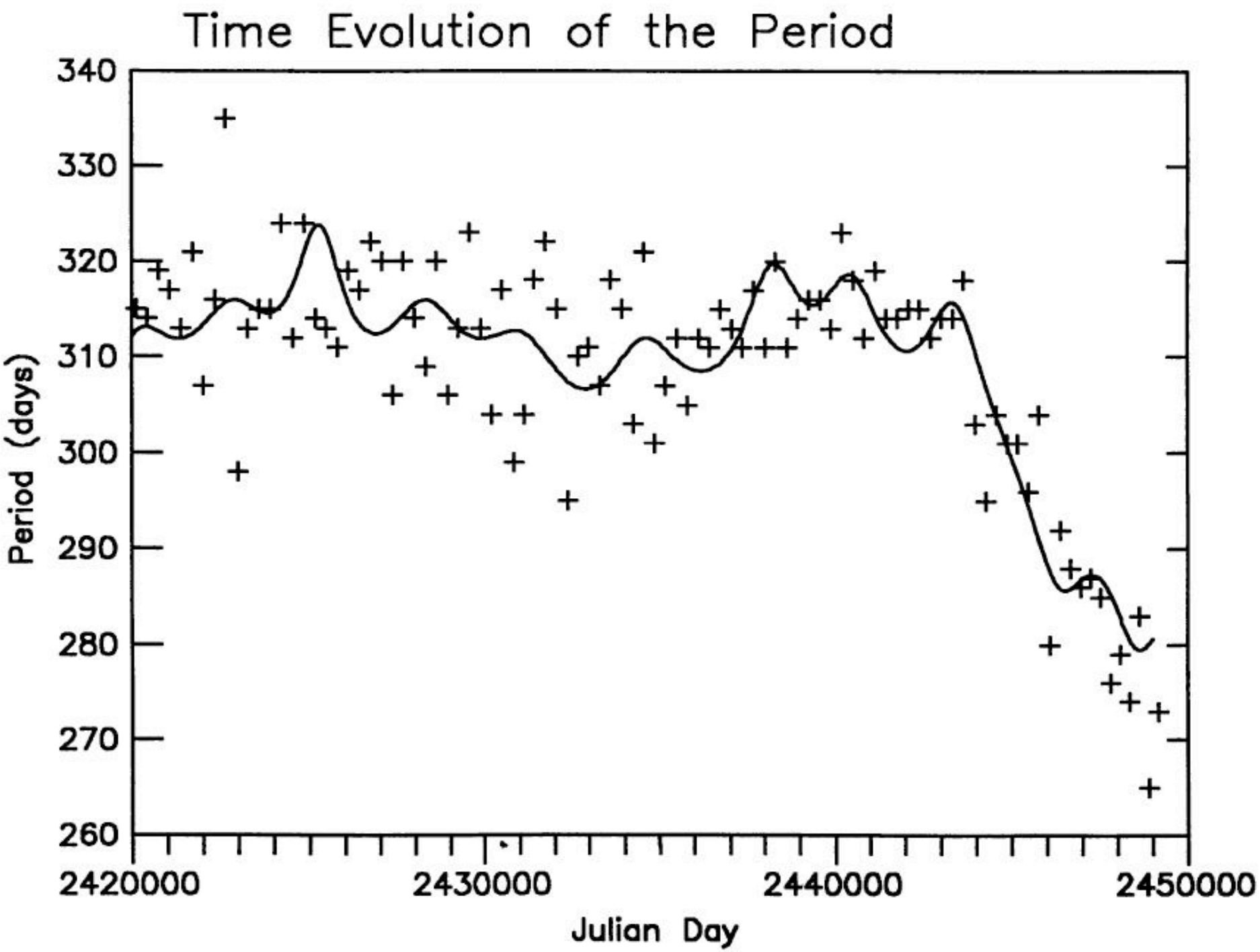
- Period started decreasing ~ 1970
- By 1980 period decrease was clear
- Amplitude started decreasing ~ 1995
- By 1998 amplitude decrease was clear

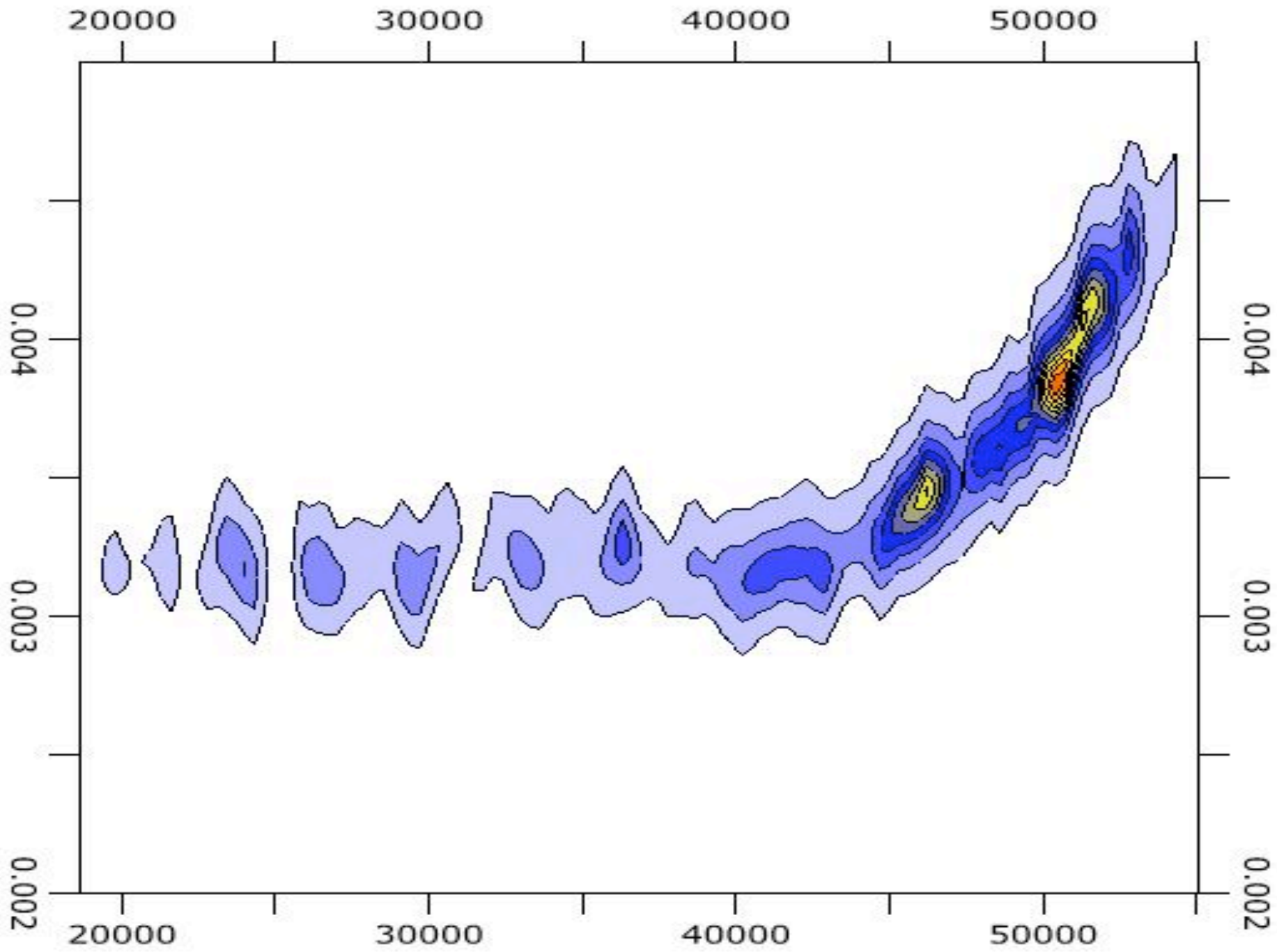

T UMi
Magnitude
8
9
10
11
12
13
14
15
20000
30000
40000
50000

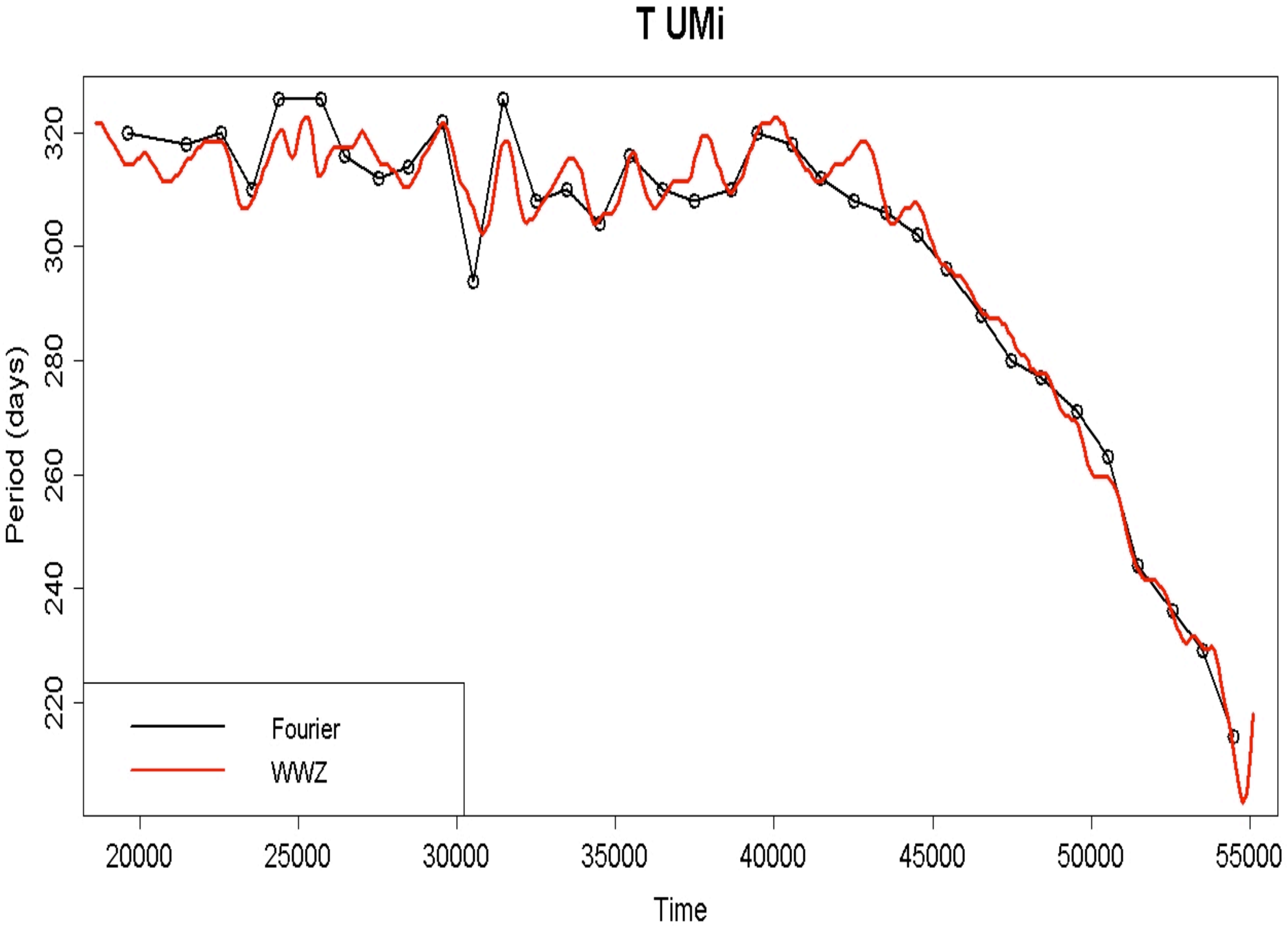

(a) T UMI Periods (max to max)
Period (days)
340
320
300
280
260
0
20
40
60
80
100

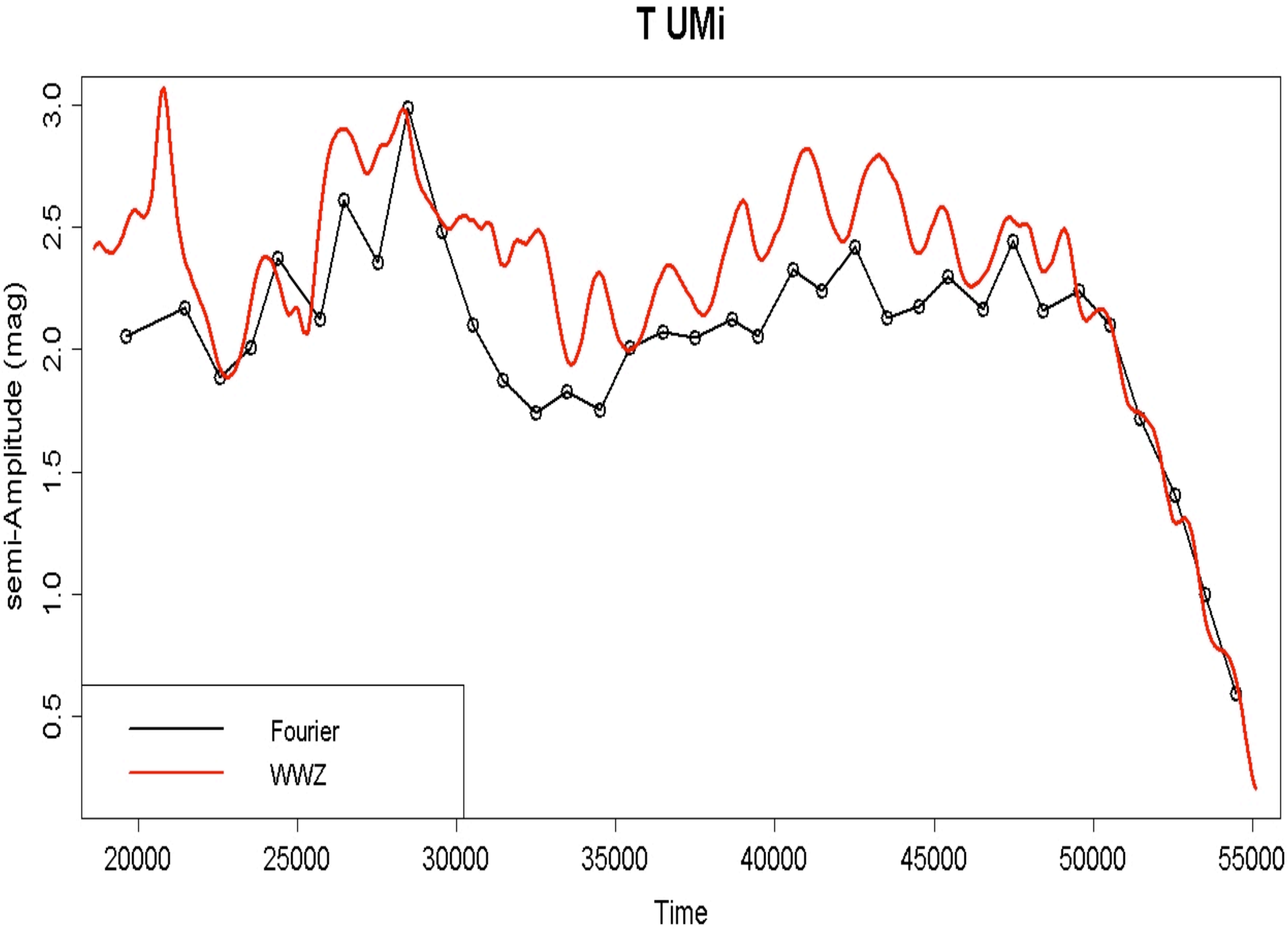

(a) Cycles 2 to 106
O—C (days)
100
0
−100
−200
−300
−400
0
10
20
30
40
50
60
70
80
90
100
110


T UMI: CLEANEST(9) JD 2,418,400 - 2,449,540
Amplitude (mag.)
2
1
0
0.000
0.005
0.010
FREQUENCY (/day)


Time Evolution of the Period
340
330
320
310
300
290
280
270
260
Period (days)
2420000
2430000
2440000
2450000
Julian Day


20000
30000
40000
50000
0.004
0.003
0.002


T UMi
Period (days)
220
240
260
280
300
320
20000
25000
30000
35000
40000
45000
50000
55000
Time
Fourier
WWZ


T UMi
semi-Amplitude (mag)
0.5
1.0
1.5
2.0
2.5
3.0
Fourier
WWZ
20000
25000
30000
35000
40000
45000
50000
55000
Time

Helium Shell Flash?

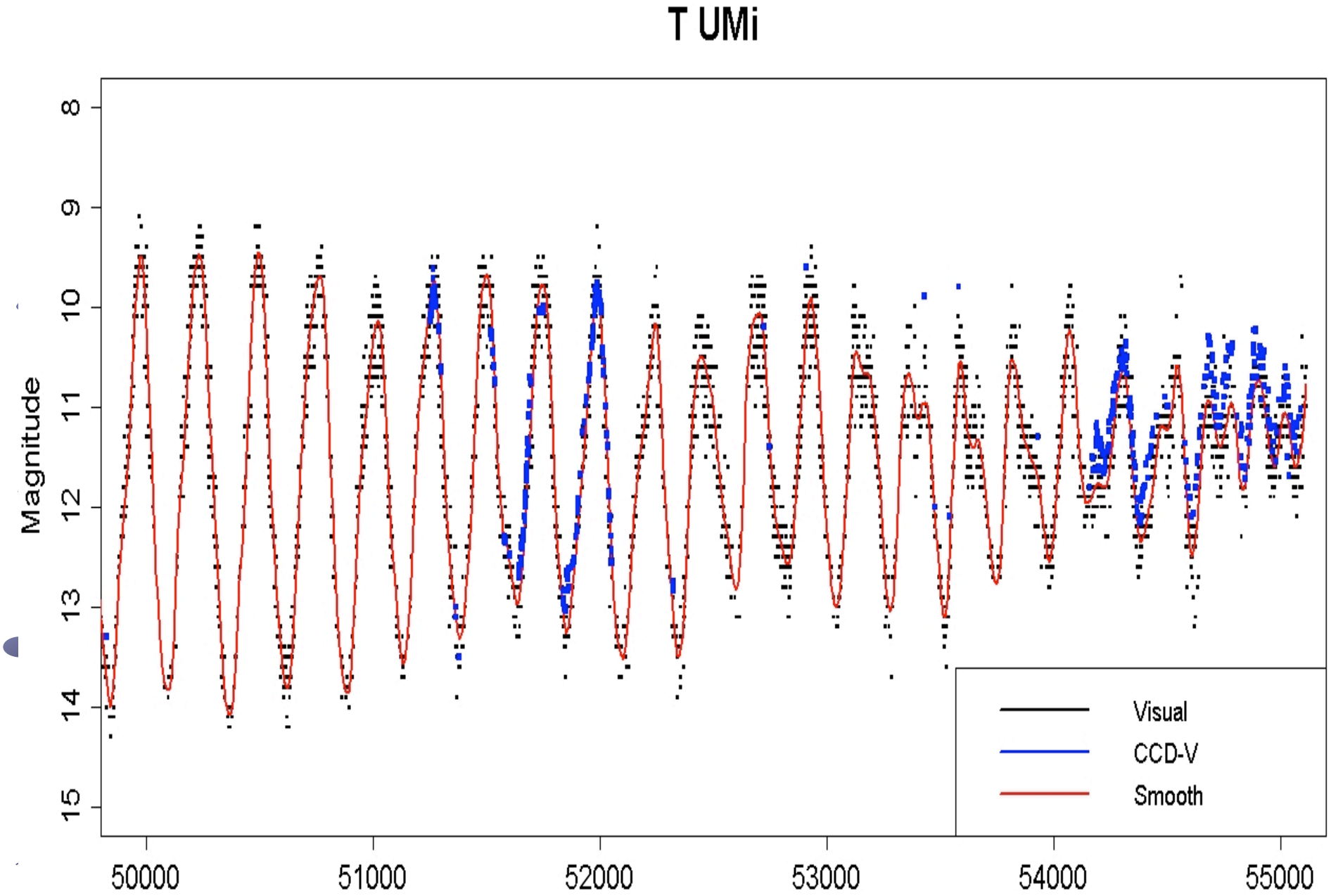
- The core is depleted, surrounded by a He shell, surrounded by a H-burning shell
- As temperature rises, it ignites furious burning in the He shell
- That causes the H shell to expand and cool
- Can also lead to greater mass loss

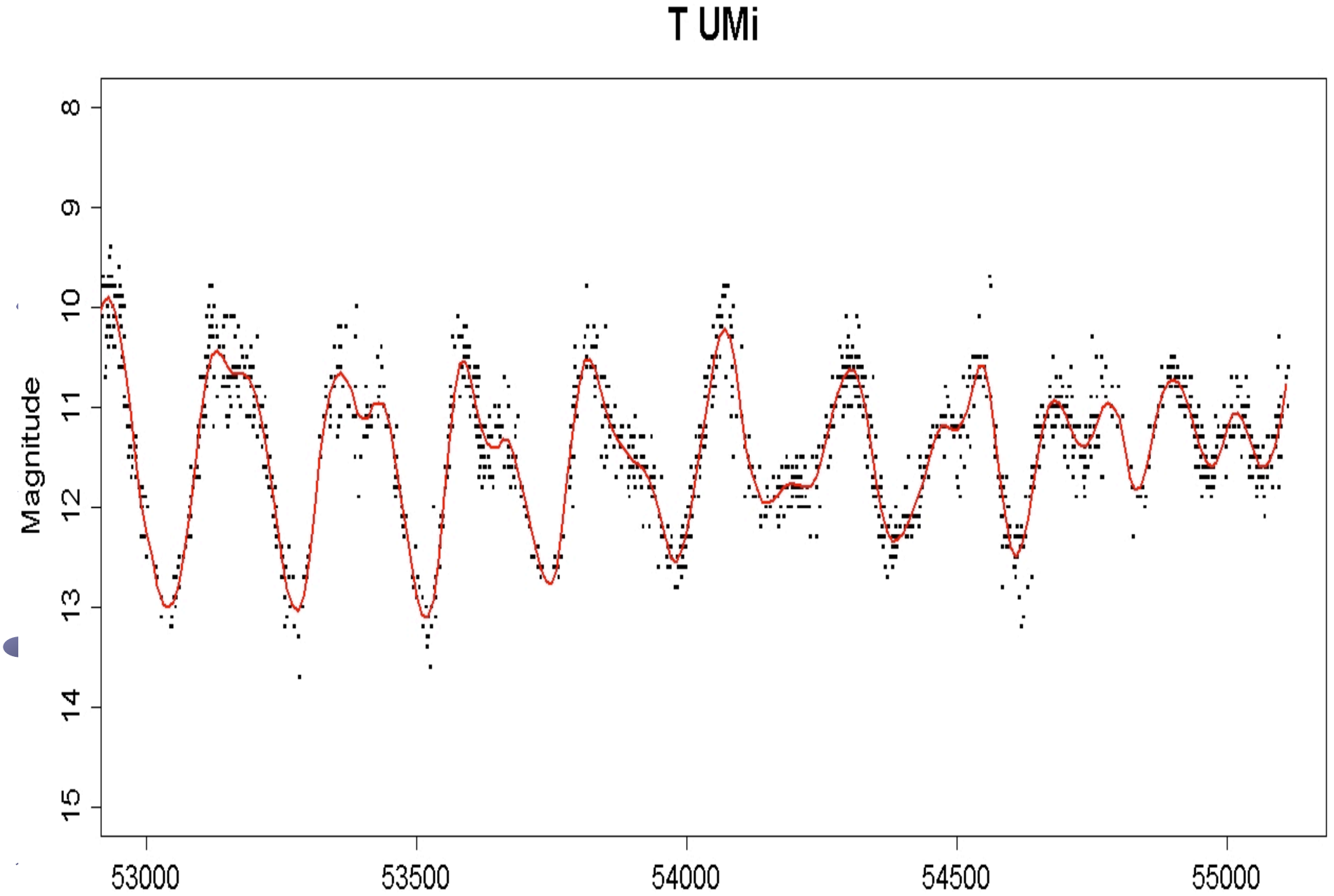
Szatmary et al. 2003 A&A 398, 277-282

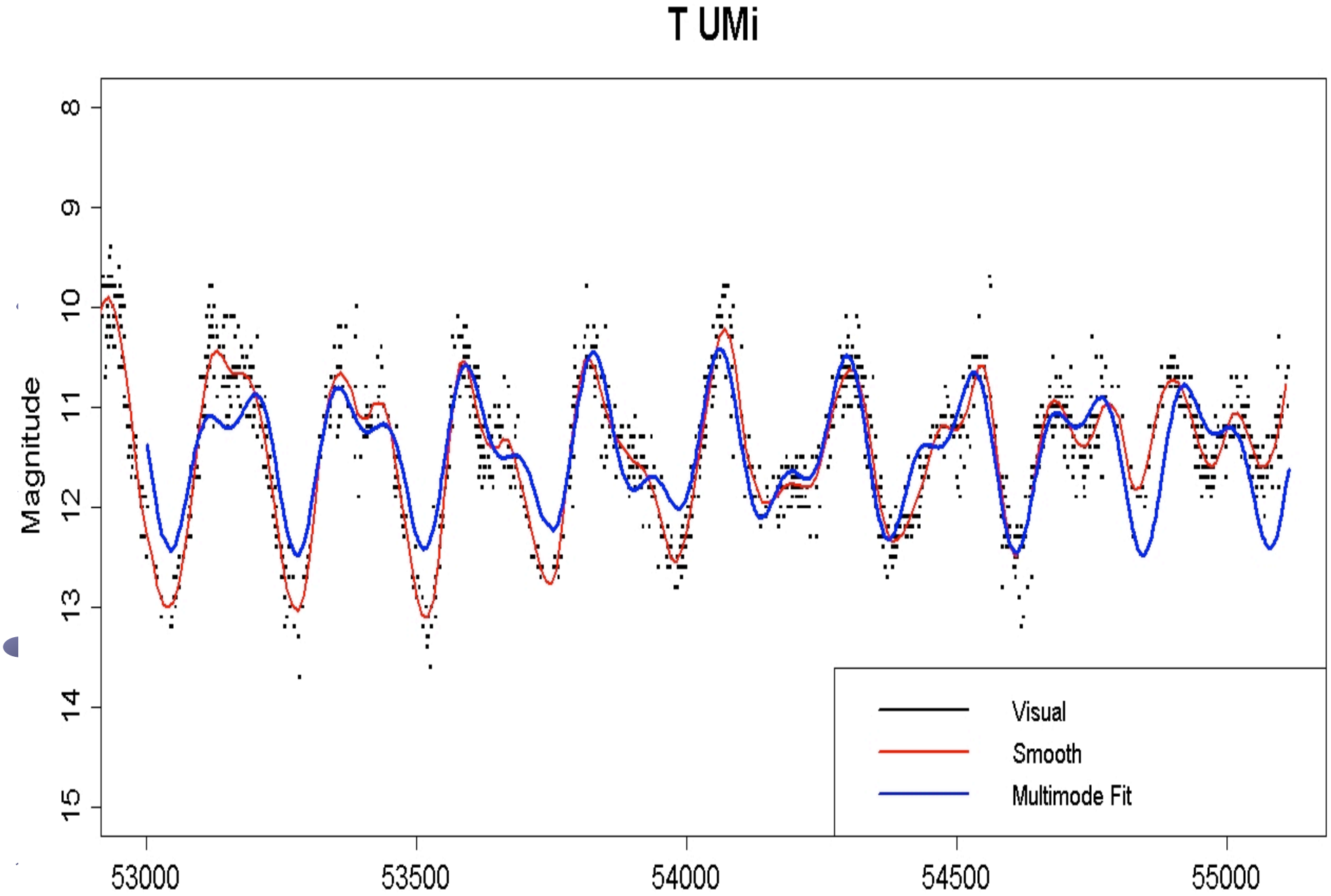
- Either mode change or He-shell flash is acting in T UMi
- Visual data are crucial for prompt detection of period stabilization or even period increase. The latter would be the final argument confirming the concept of the He-shell flash. However, if the period will turn to a constant value and remains there for a considerable time then the whole theory should be revised. In that case T UMi shall shed new light on a peculiar mode switching phenomenon not well understood.

Mode Switching?

- I don't think so (at least not at first)
- In other stars, one mode turns on, another off – but not a steady change of period
- Doesn't seem possible, either physically or mathematically!
- BUT – most recent behavior may show mode switching (activation of a secondary period)


T UMi
Magnitude
8
9
10
11
12
13
14
15
50000
51000
52000
53000
54000
55000
Visual
CCD-V
Smooth


T UMi
Magnitude
8
9
10
11
12
13
14
15
53000
53500
54000
54500
55000

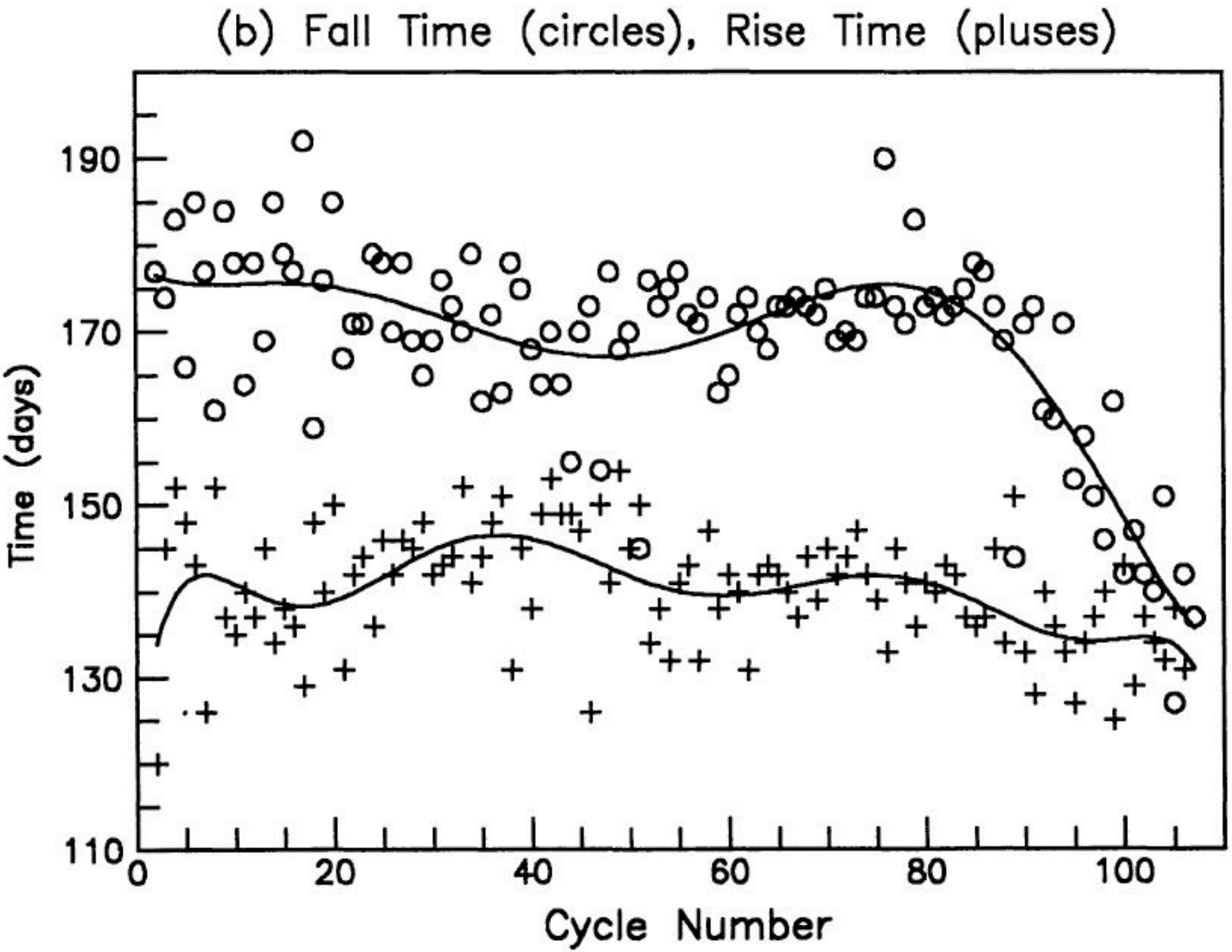

T UMi
Magnitude
8
9
10
11
12
13
14
15
53000
53500
54000
54500
55000
Visual
Smooth
Multimode Fit

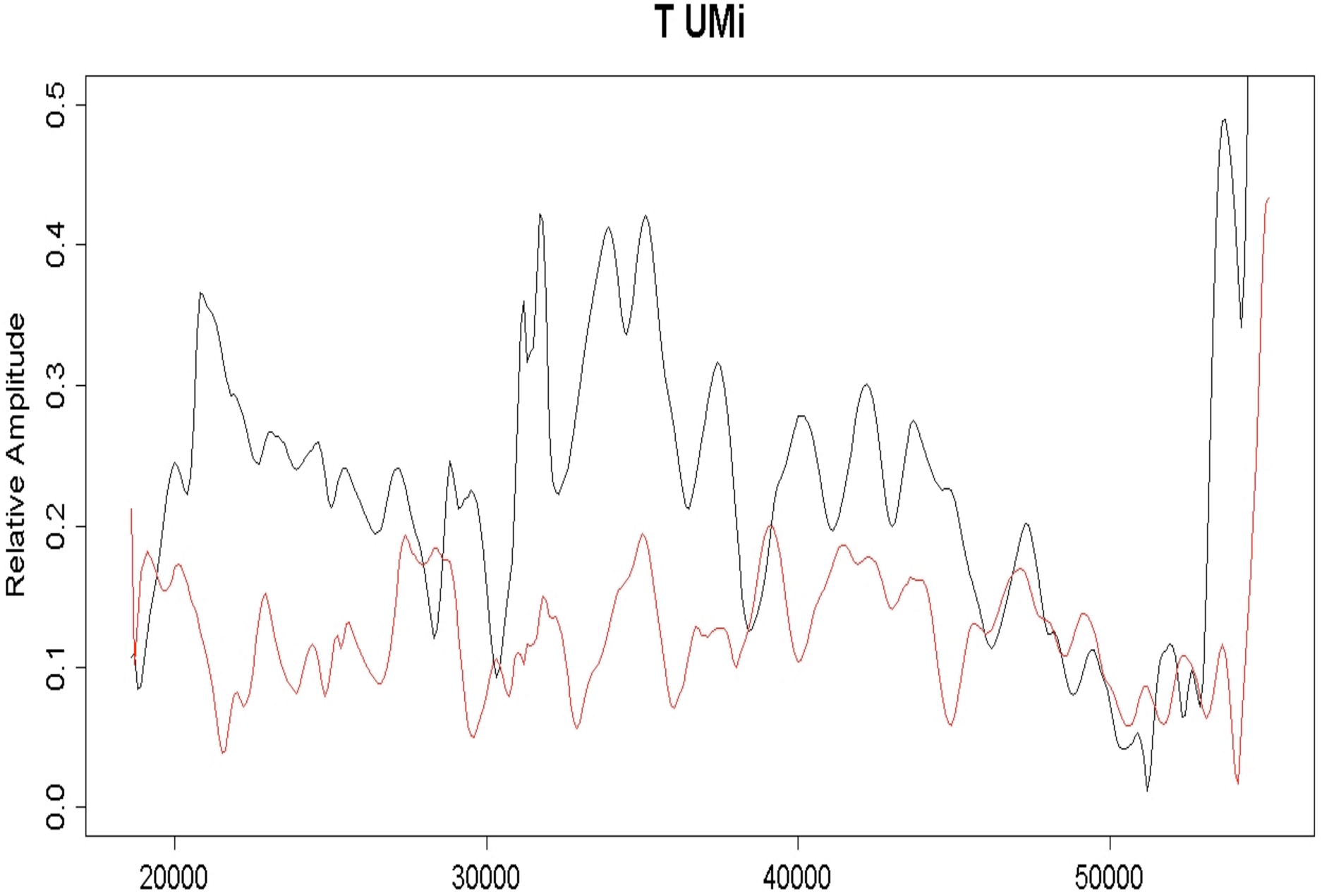
Most recent behavior

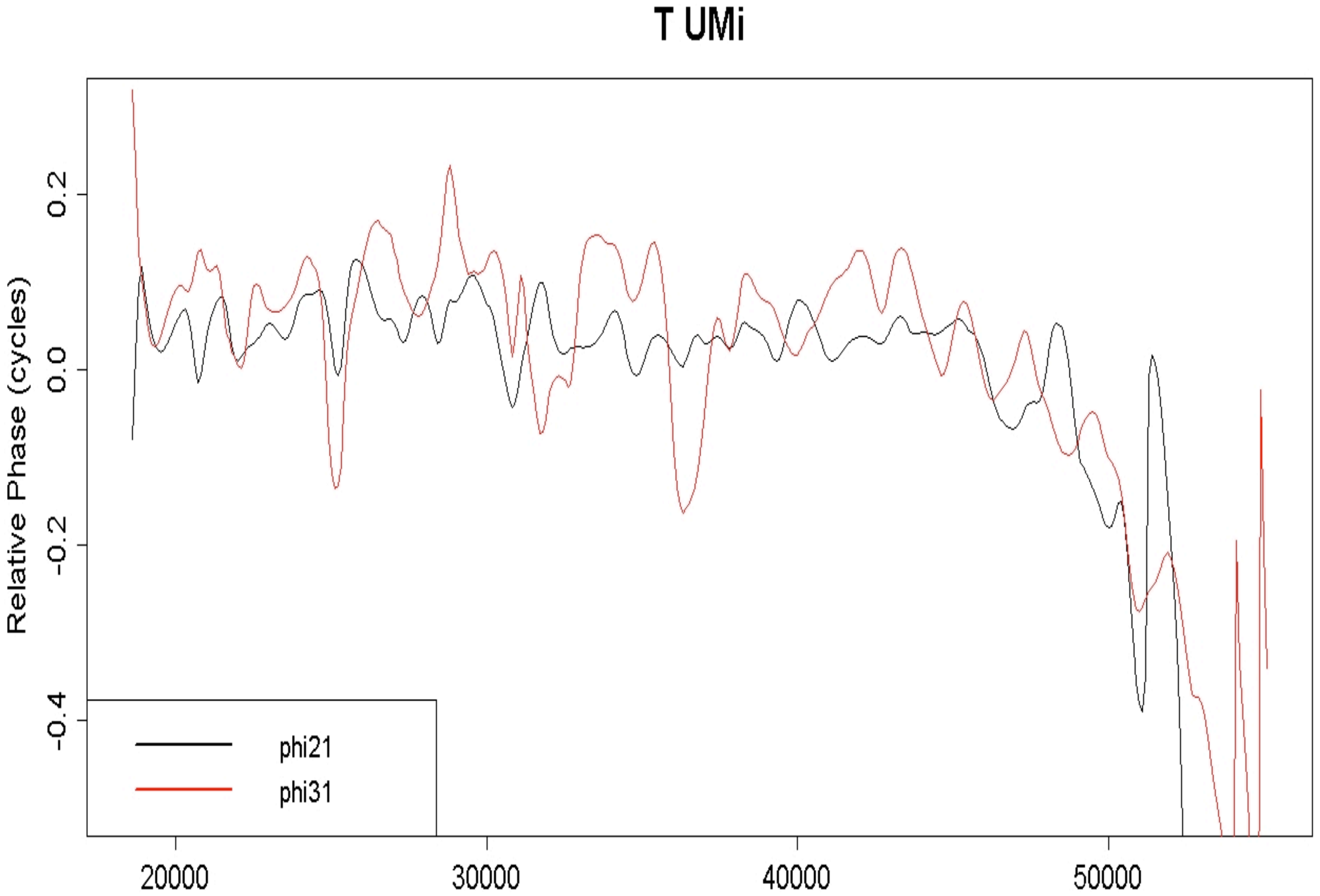
- Amplitude is well below the Mira limit
- Shows ***multi-mode*** pulsation
- Two periods, $P_1/P_2 \sim 1.8$
- Just like a ***SR*** variable
- Is T Umi now a SR variable?
- It sure looks like one

Shape Shift

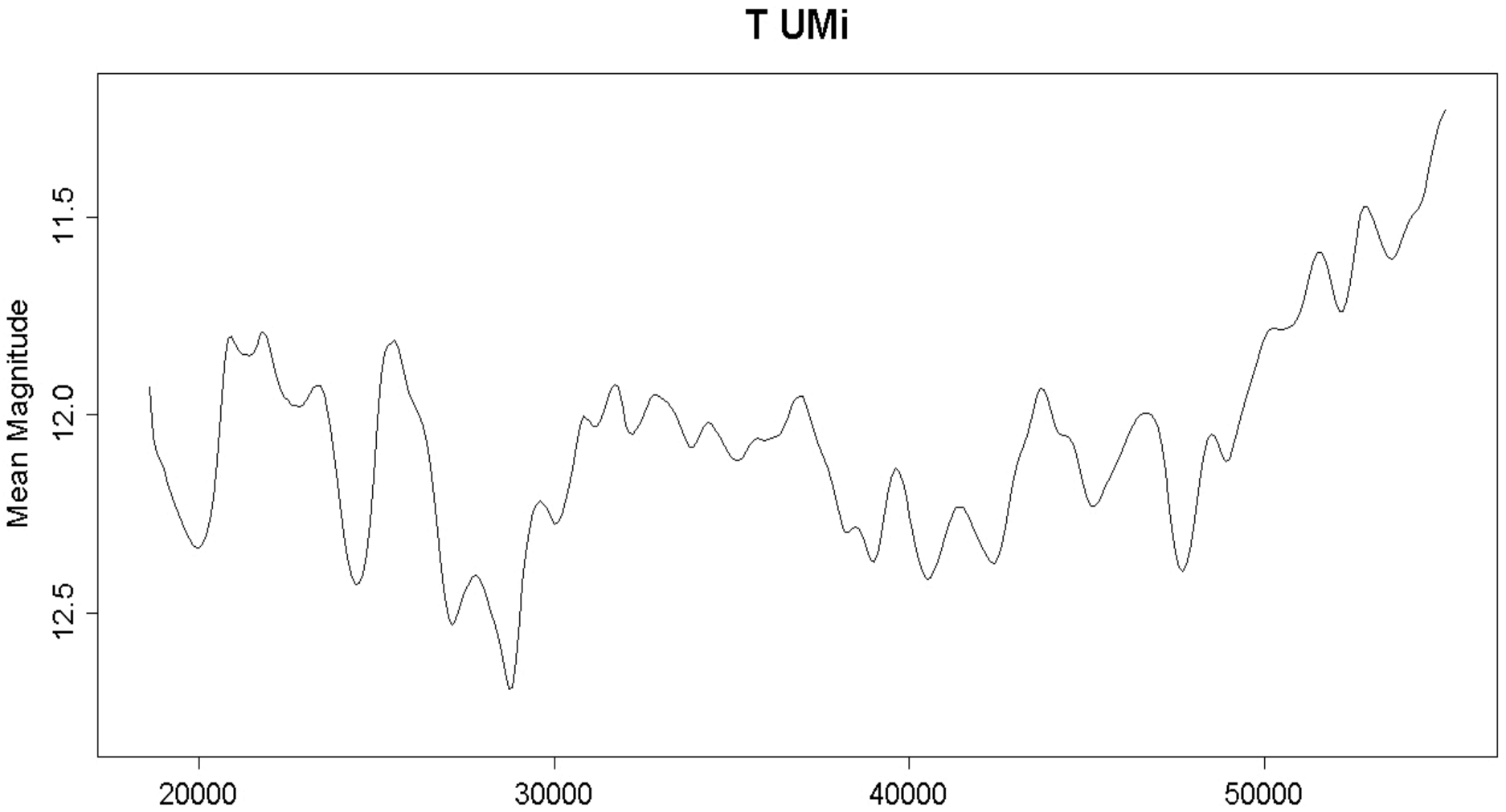
- Light curve ***shape*** has changed
- WAS: rapid rise, slower fall
- IS: about equal rise/fall times
- Also shows in a “Fourier Decomposition”
  - Relative amplitudes change
  - Relative phases change


(b) Fall Time (circles), Rise Time (pluses)
190
170
150
130
110
Time (days)
0
20
40
60
80
100
Cycle Number

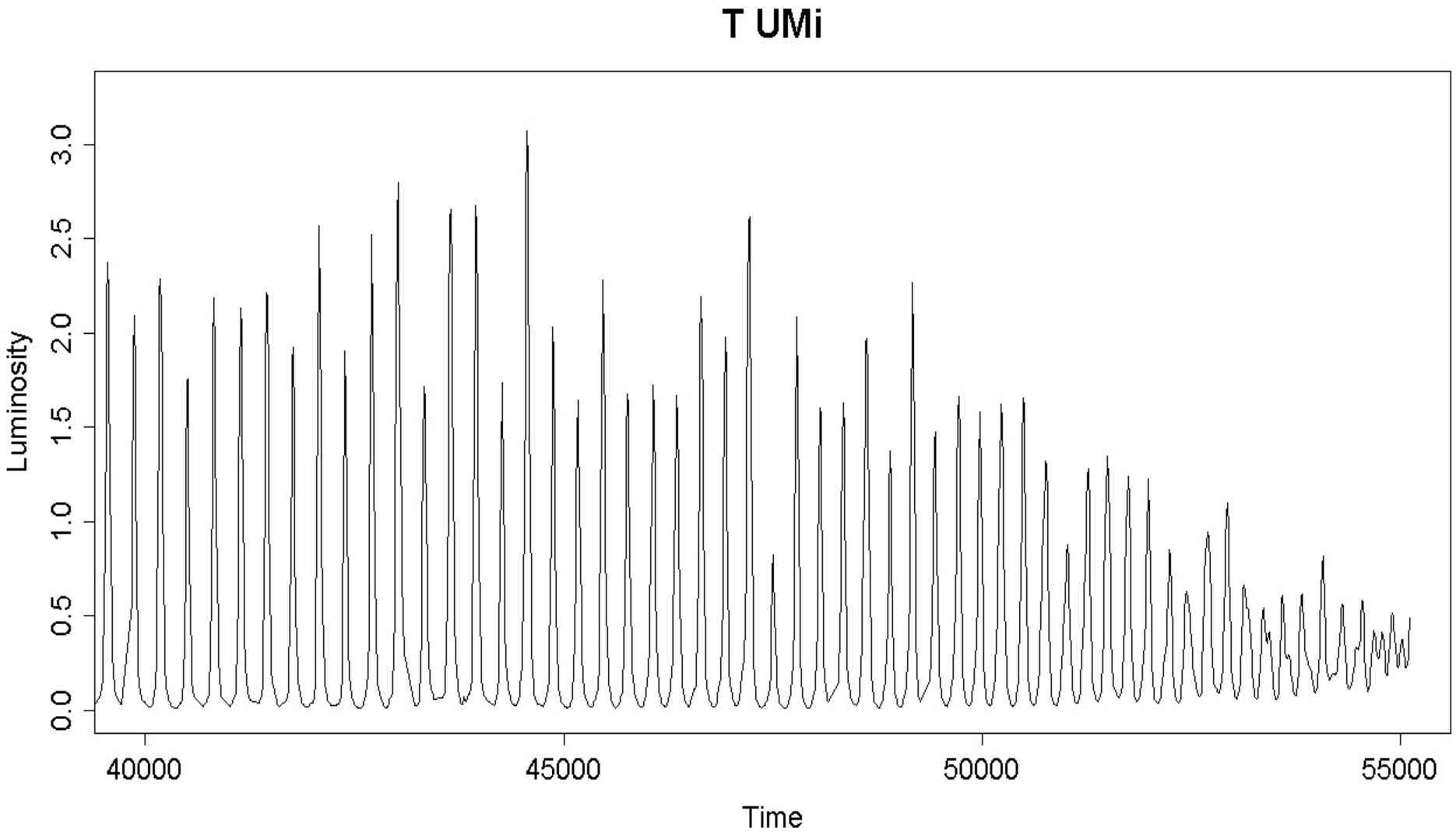

T UMi
Relative Amplitude
0.0
0.1
0.2
0.3
0.4
0.5
20000
30000
40000
50000


T UMi
Relative Phase (cycles)
0.2
0.0
-0.2
-0.4
20000
30000
40000
50000
phi21
phi31

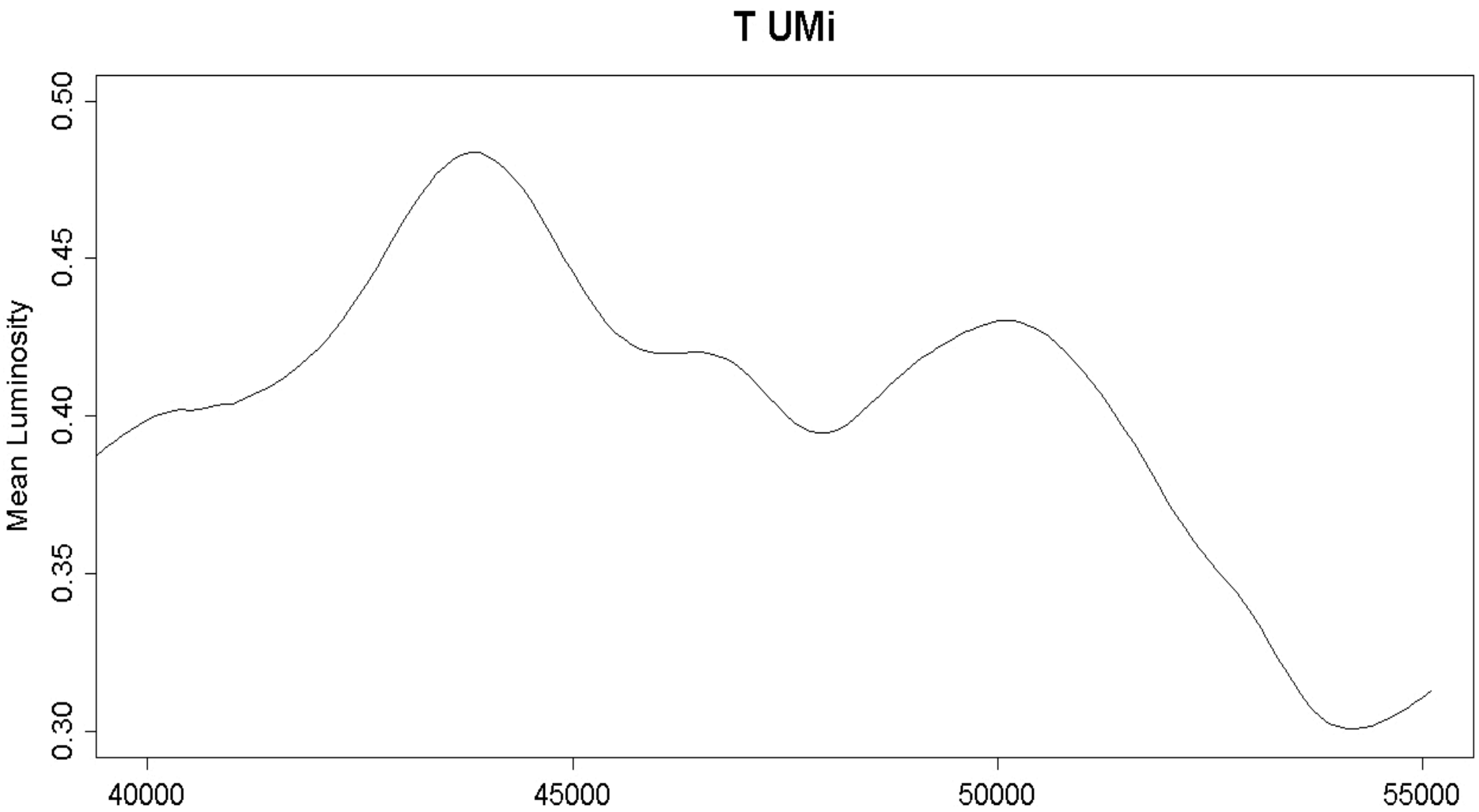
Mean MAGNITUDE increasing



But ...


T UMi
Luminosity
0.0
0.5
1.0
1.5
2.0
2.5
3.0
40000
45000
50000
55000
Time

mean LUMINOSITY decreasing



Mode Switching?

- Yes … **but**
- NOT the smooth change of period from one mode to another
- Instead, a smooth period decrease ***of the main mode***
- Followed by activation of a 2nd mode
- and de-activation of the main mode?

Keep Watching T UMi !!!

- Very important for stellar evolution of AGB stars
- Is it He shell flash or mode switching or ... Something else?
- Has it changed from Mira to SR right before our eyes?
- Professional observing campaigns don't match amateur visual observers
- http://www.aavso.org/