T Tauri Research at VBO

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T Tauri Stars

- T Tauri stars were identified as a separate class of objects because of their light variability by Alfred Joy.
- It was largely due to the work of Herbig they were recognized as pre-main sequence stars.
- The late type T Tauri stars have masses about 1M and ages about a few million years and display a wide variety of phenomena.
- In the setallar evolutionary sequence they represent an important phase that lies between the low luminosity sources, which are deeply embedded in dust and solar type stars.

- T Tauri stars are broadly classified into Weak emission T Tauri stars (WTTS) and Classical T Tauri stars (CTTS).
- The WTTS include mostly weak emission pre-main sequence stars of spectral type later than K0 and Hα EEW < 10 Å.
- CTTS are classified as PMS with spectral type later than K0 and Hα EEW > 10 Å.
- T Tauri stars show drastic light variations on time-scales of hours to months and also UV flaring.

Activity Signatures

- Photometric light variability
- Hα and other chromospheric line emissions
- UV excess and continuum
- Infrared emissions and excess
- Polarimetric variability
- X-ray emission
- + …

Hα Emissions

- The most classical method of identifying active stars surrounded by disks has been from Hα emission.
- It is believed that large emission equivalent widths reflect emission arising in magnetospheric columns which transort material from the inner region of a circumstellar accretion disk to the stellar surface.
- The emission line profiles exhibit large line widths indicative of large-scale gas flows, and often show inverse P Cygni features clearly tracing infall.
- Models with infalling gas via magnetospheric accretion have successfully reproduced these characteristics, such as blueshifted emission peaks, blueward asymmetries as well as total line fluxes.
- Weaker emission is believed to arise in active stellar chromosphere.

Program stars

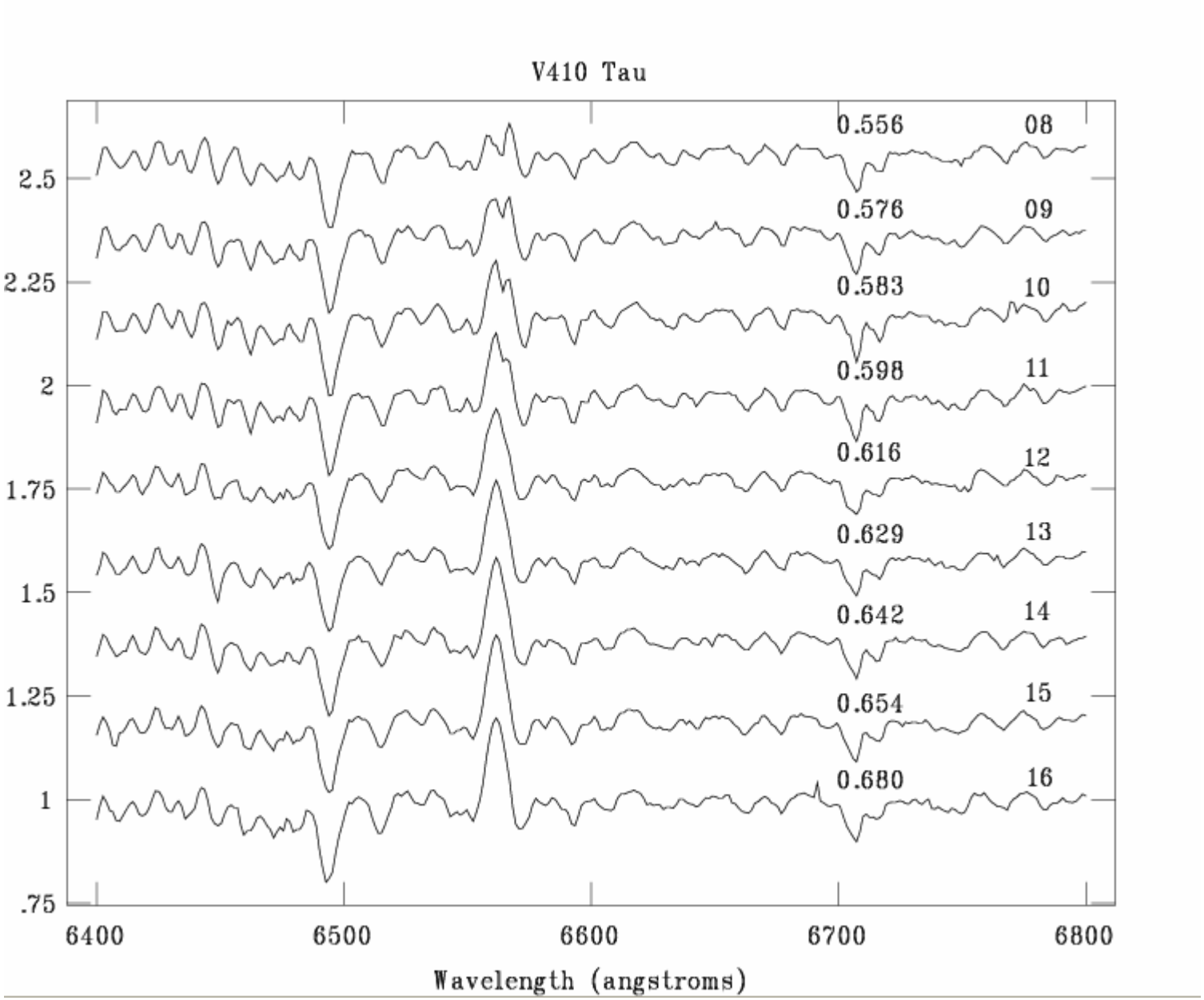
- WTTS → V410 Tau and HD 288313
- CTTS → V4046 Sgr and TW Hya

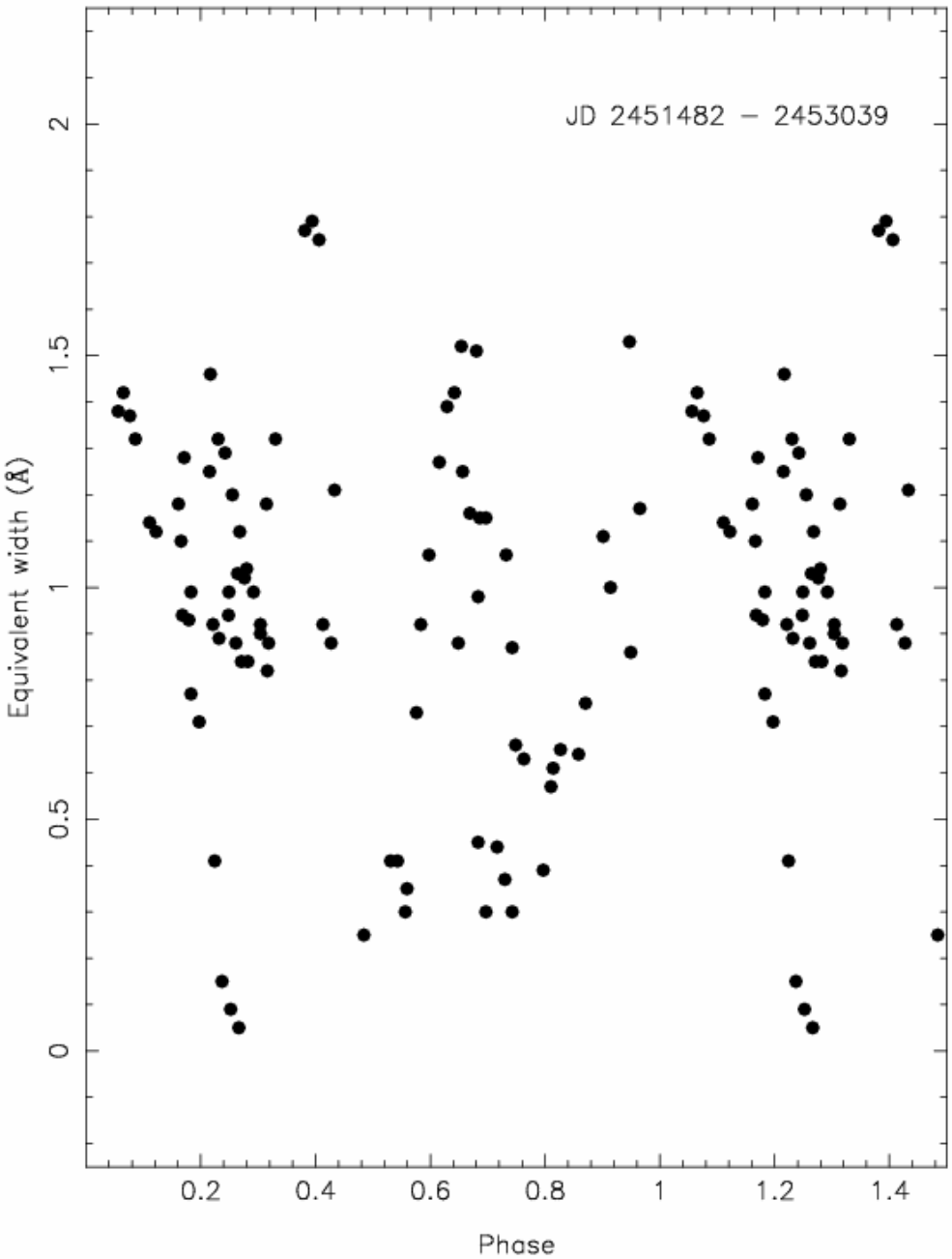
Observational setup

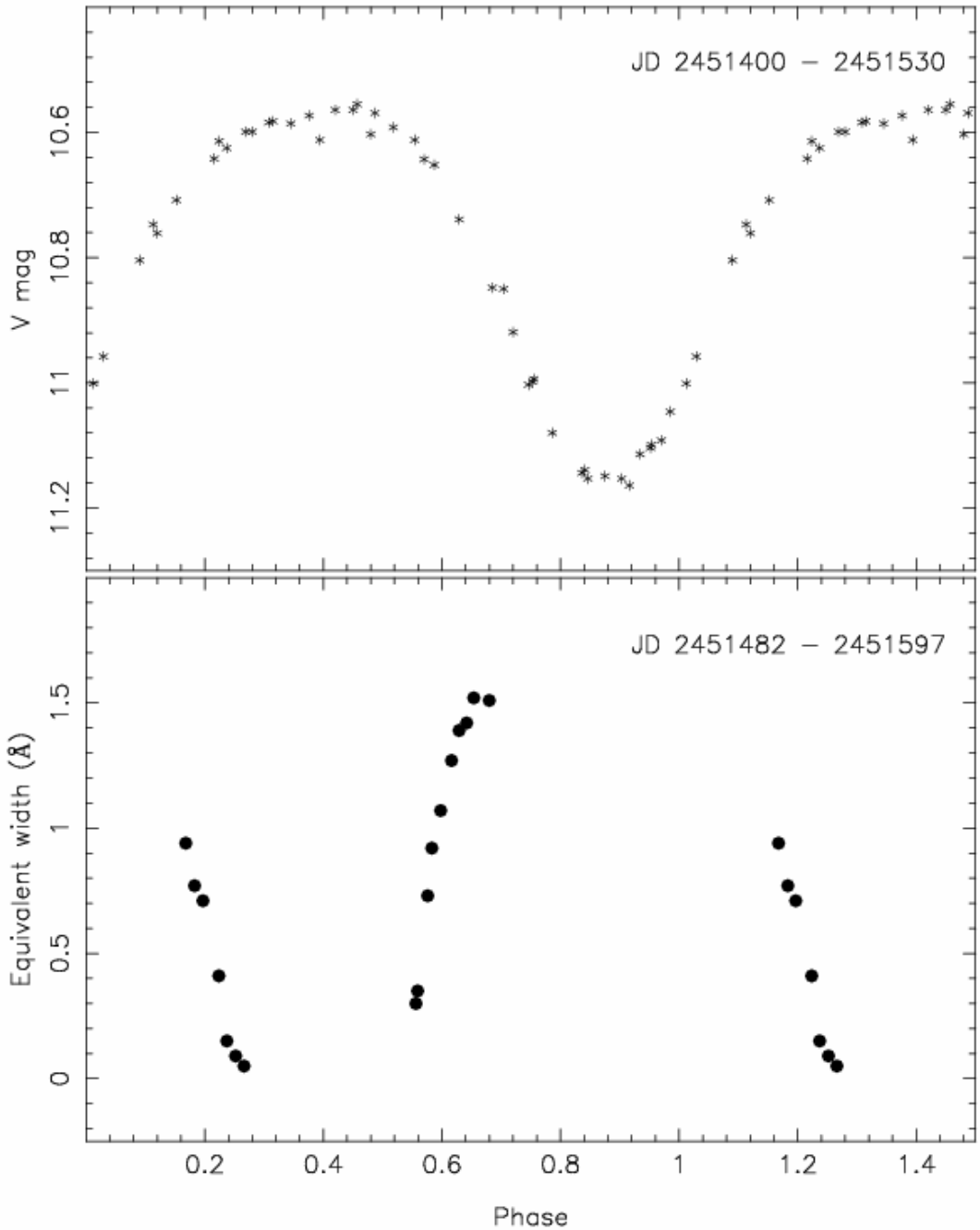
- OMR spectrograph attached to the VBT.
- The setup using 1200 lines grating gives a resolution of 1.3 Å/ pixel.
- Exposure time was adjusted for a S/N of the order of 80-100.
- The stars were observed during several seasons between 2000 and 2006.

V410 Tau

- Period – 1.872 days
- Simultaneous photometry, spectroscopy, and polarimetry were done at Kavalur during 1993 season.
- Hα observations were obtained during 1999/2000, 2002/2003, 2003/2004 and 2006 seasons.
- Hα EW varies from absorption (~ 0.16 Å) to emission (~ 3.0 Å).
- The chromospheric active regions are short-lived compared to the photospheric spots.


V410 Tau
0.556
08
0.576
09
0.583
10
0.598
11
0.616
12
0.629
13
0.642
14
0.654
15
0.680
16
2.5
2.25
2
1.75
1.5
1.25
1
.75
6400
6500
6600
6700
6800
Wavelength (angstroms)


JD 2451482 – 2453039
Equivalent width (Å)
Phase
0
0.5
1
1.5
2
0.2
0.4
0.6
0.8
1
1.2
1.4


JD 2451400 – 2451530
V mag
10.6
10.8
11
11.2
JD 2451482 – 2451597
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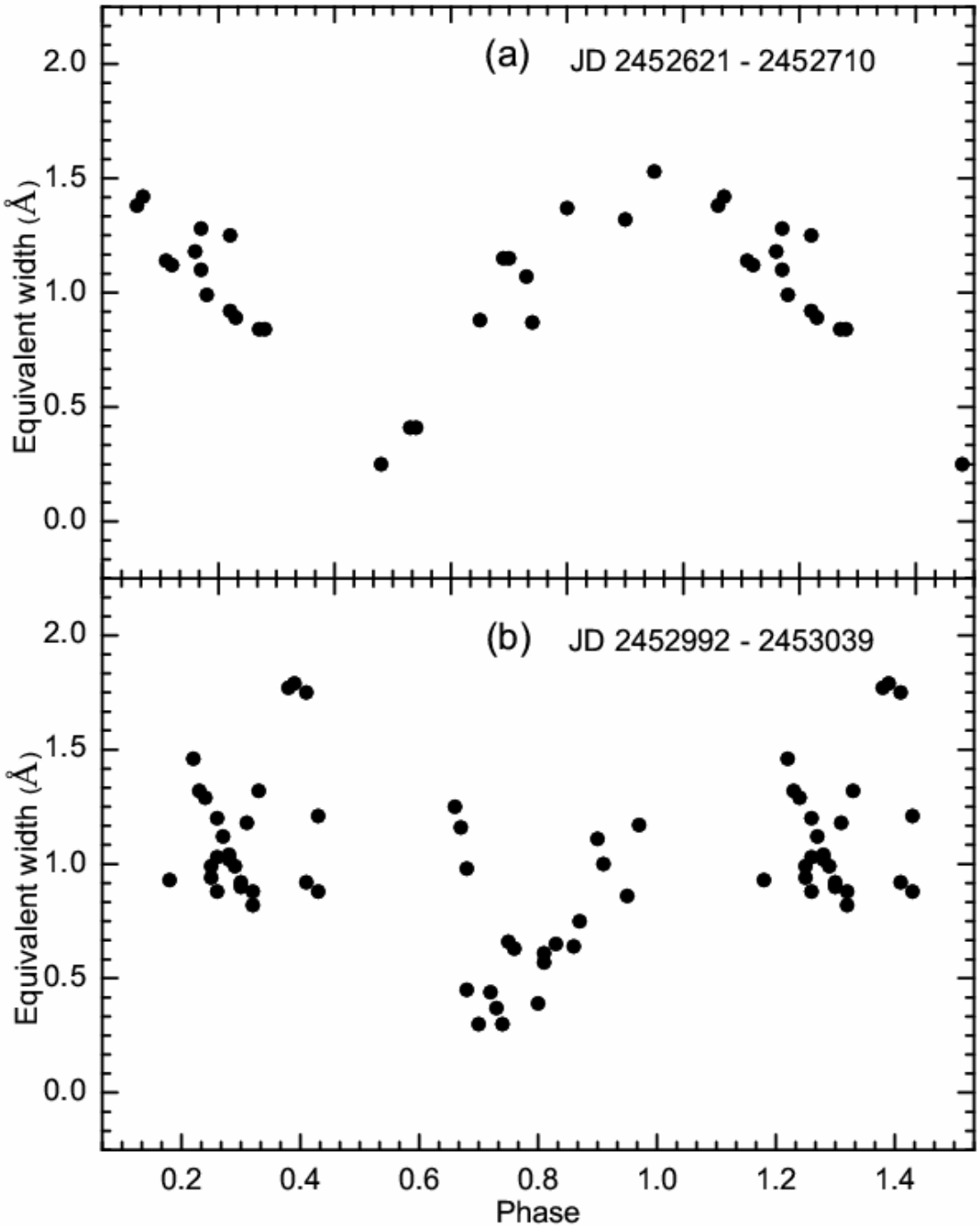
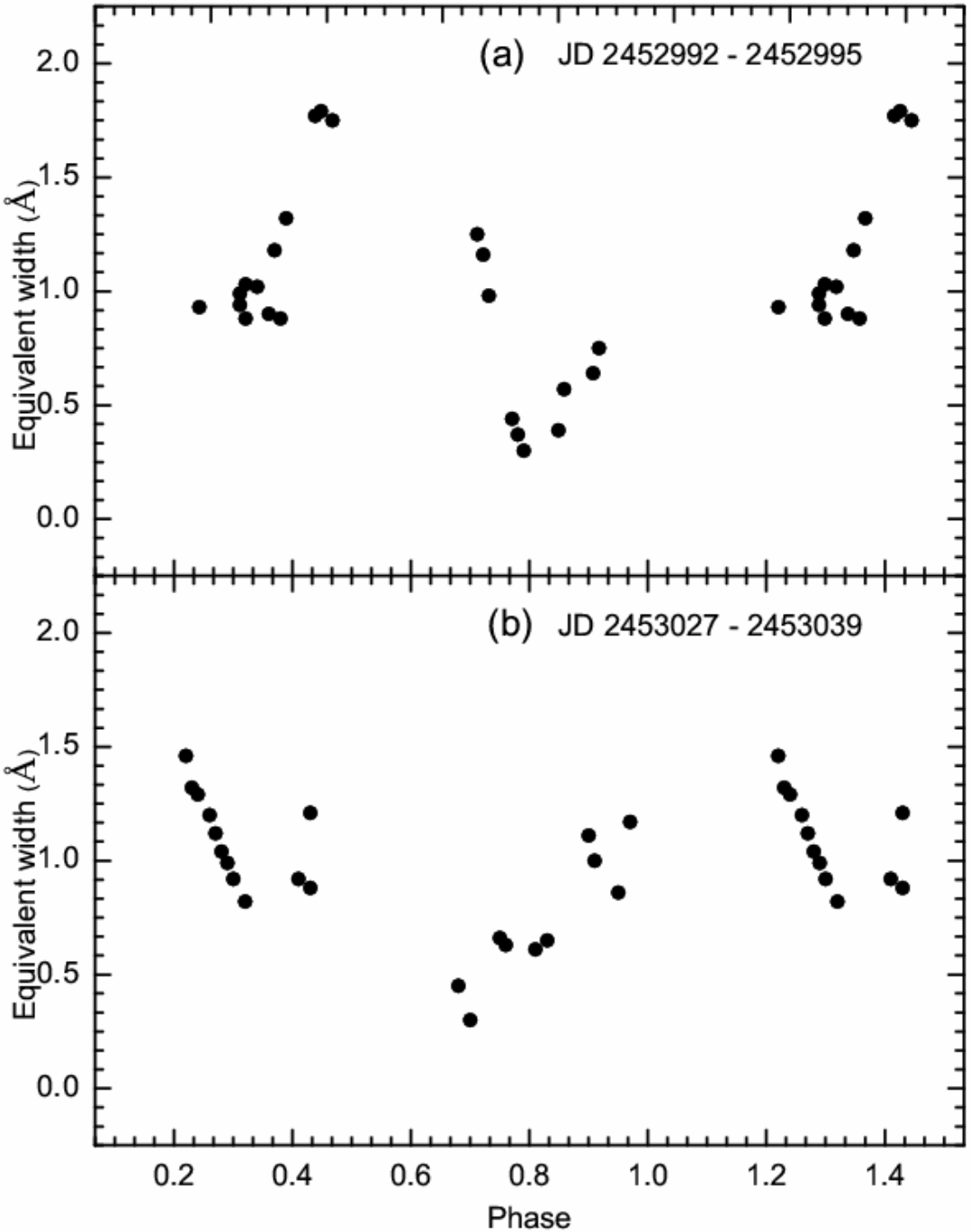
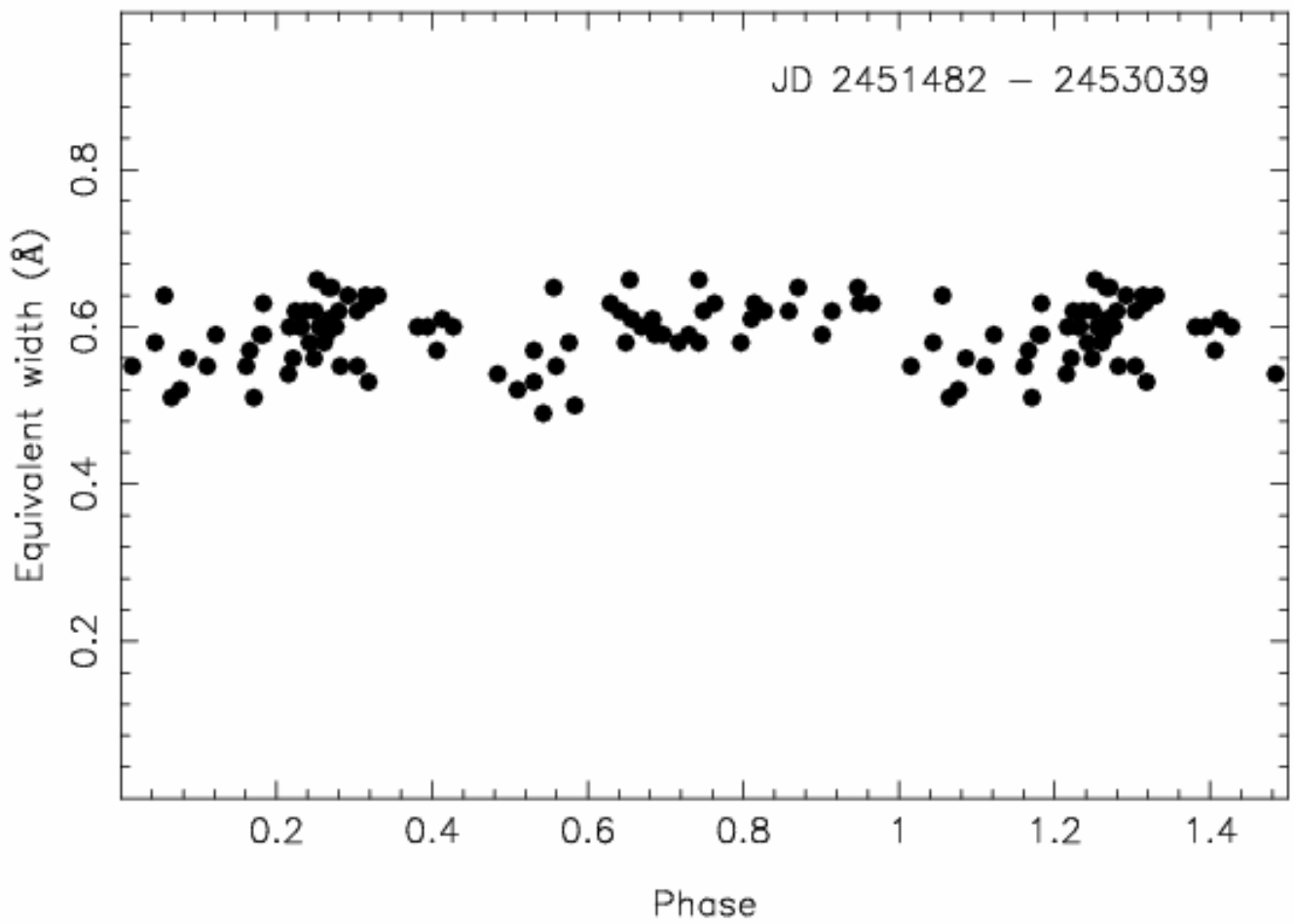
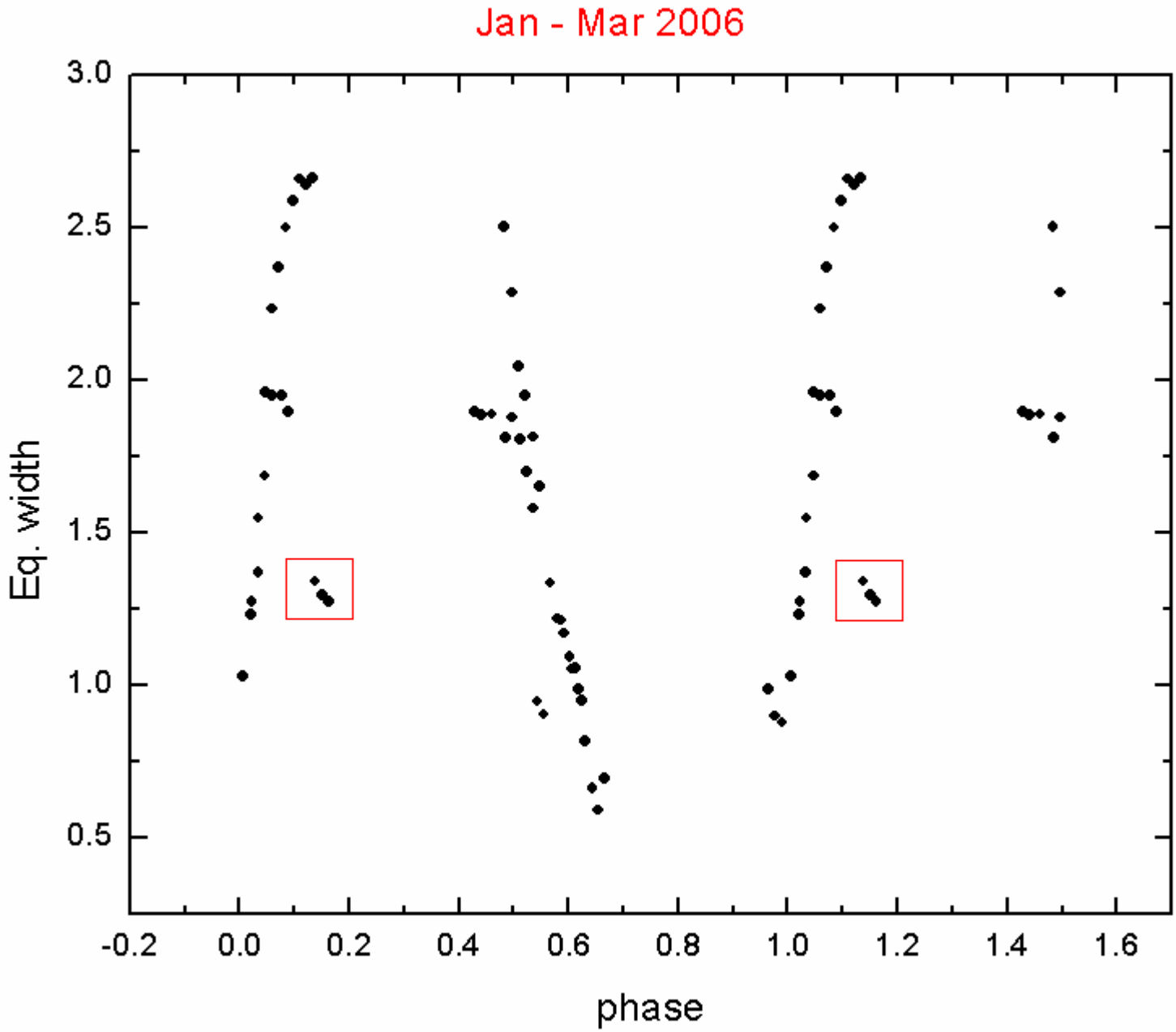
1
1.5
0.2
0.4
0.6
0.8
1
1.2
1.4
Phase


(a)
JD 2452621 - 2452710
(b)
JD 2452992 - 2453039
Equivalent width (Å)
Equivalent width (Å)
Phase
0.0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

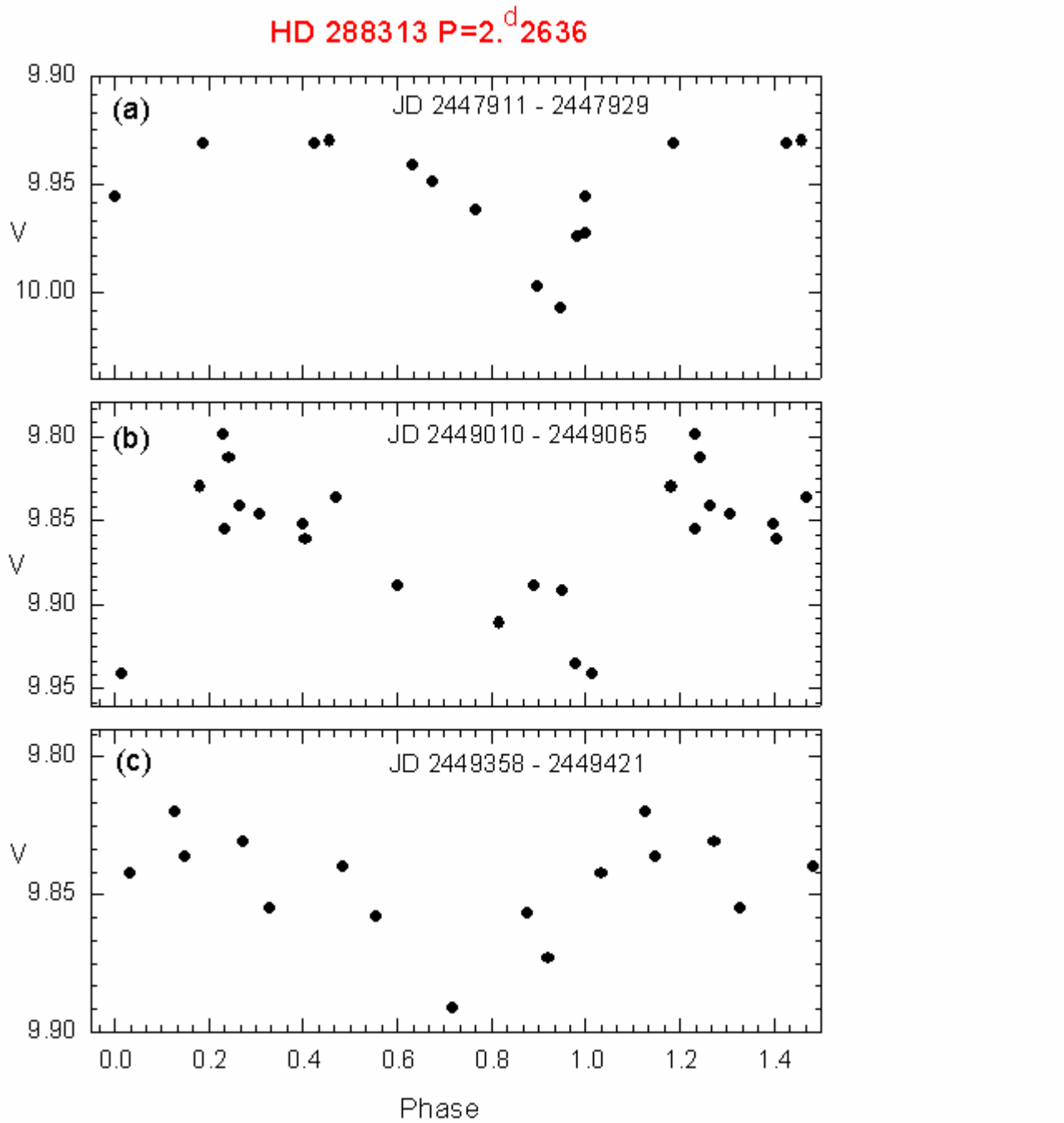

(a) JD 2452992 - 2452995
(b) JD 2453027 - 2453039
Equivalent width (Å)
Equivalent width (Å)
Phase
0.0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

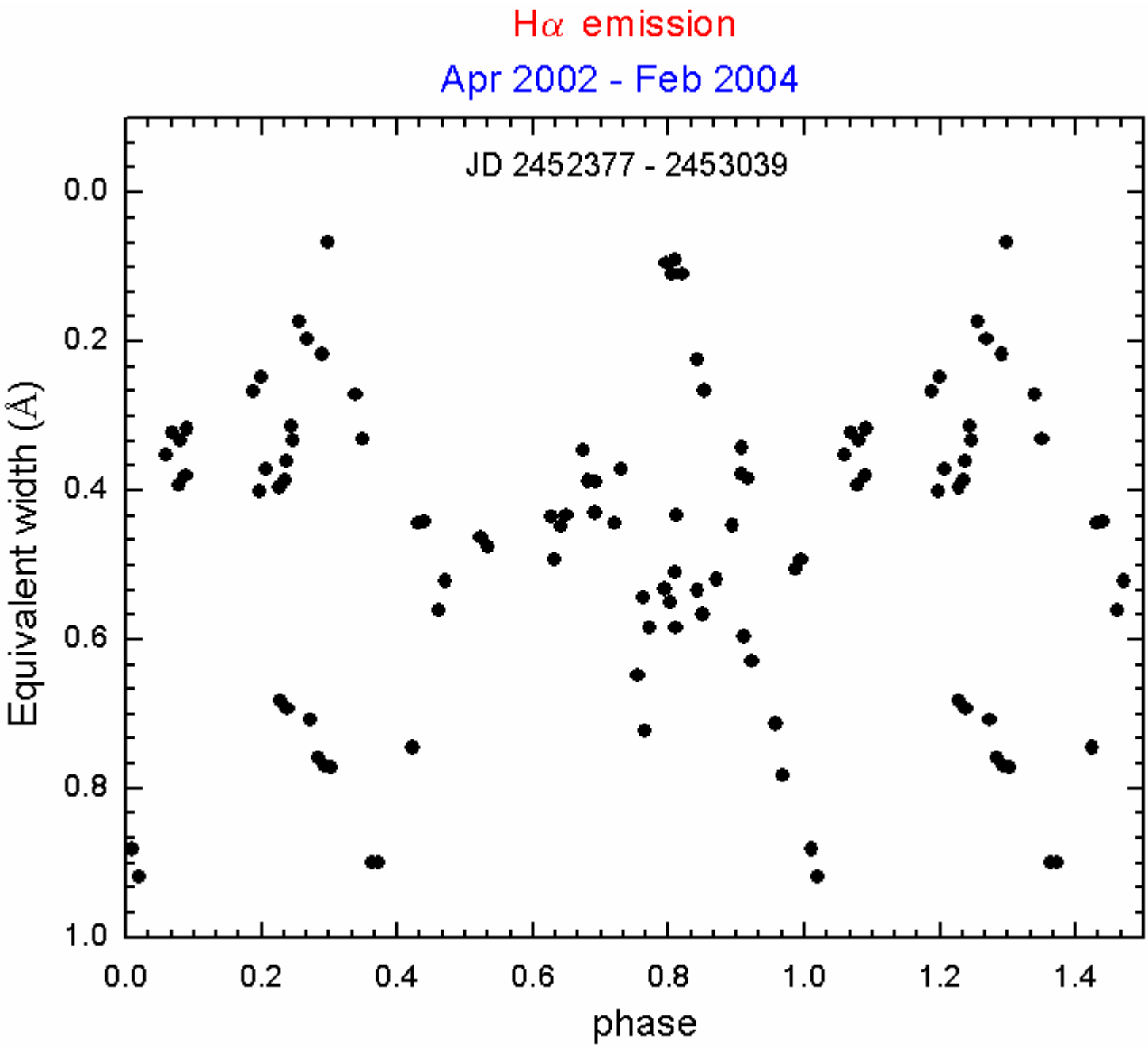

JD 2451482 – 2453039
Equivalent width (Å)
0.2
0.4
0.6
0.8
0.2
0.4
0.6
0.8
1
1.2
1.4
Phase

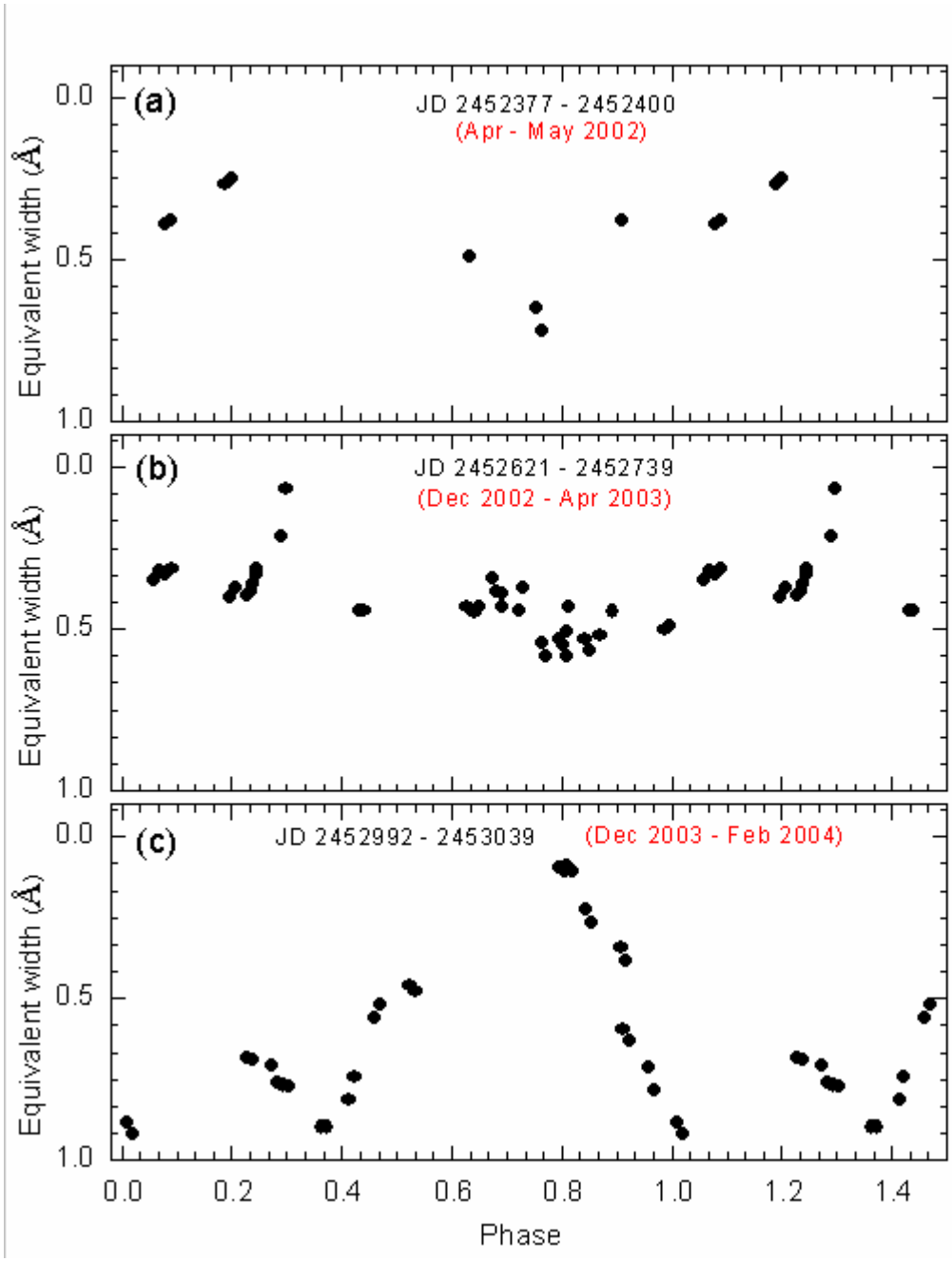

Jan - Mar 2006
3.0
2.5
2.0
1.5
1.0
0.5
Eq. width
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
phase

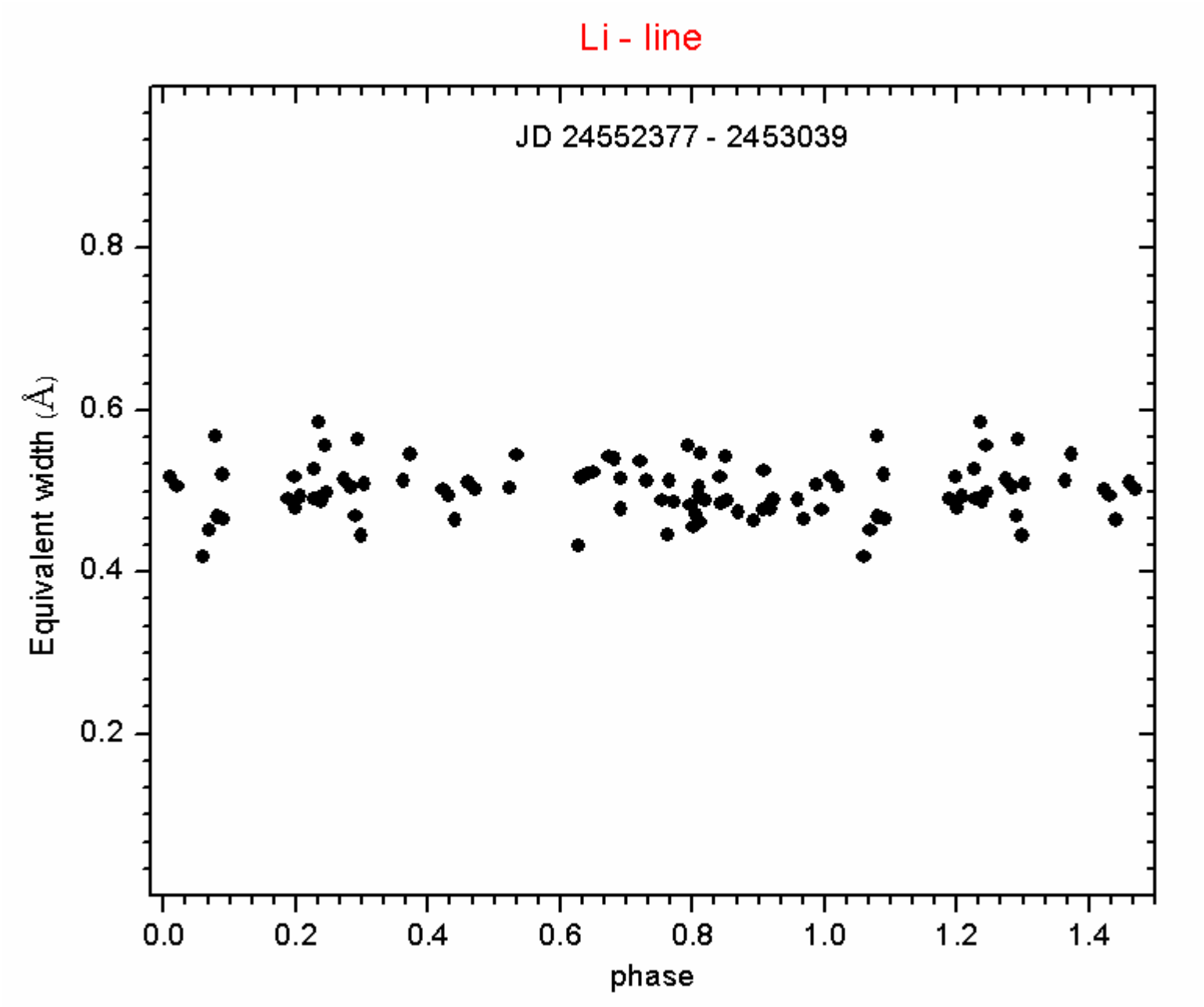
HD 288313

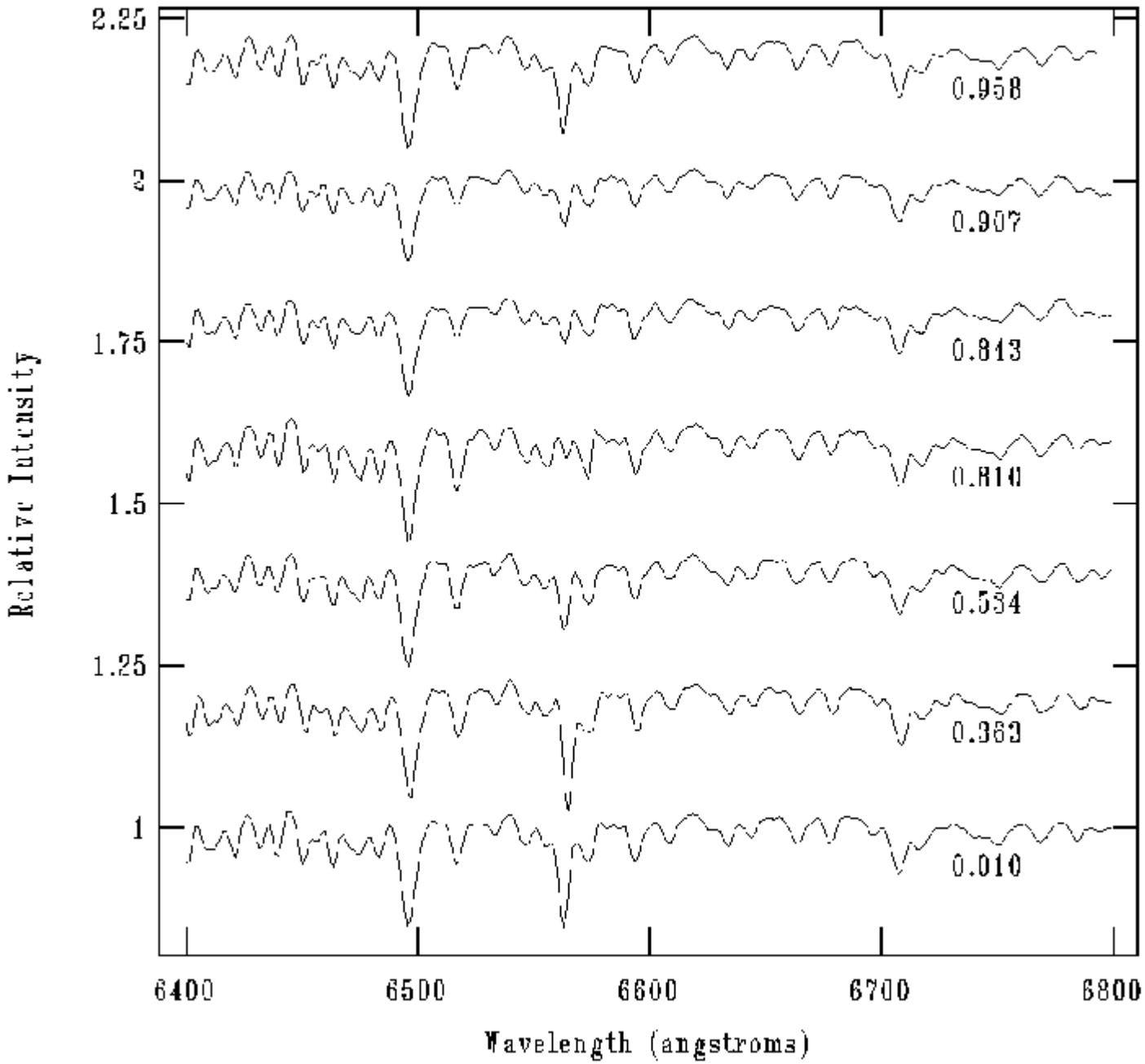
- Period – 2.2636 days
- Light variations and periodicity detected from our observations.
- Hα observations were obtained during 2002, 2002/2003 and 2003/2004 seasons.
- Hα line varies from shallow absorption to filled-in emission.


HD 288313 P=2.d2636
(a)
JD 2447911 - 2447929
(b)
JD 2449010 - 2449065
(c)
JD 2449358 - 2449421
V
9.90
9.95
10.00
9.80
9.85
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Phase


Hα emission
Apr 2002 - Feb 2004
JD 2452377 - 2453039
Equivalent width (Å)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
phase

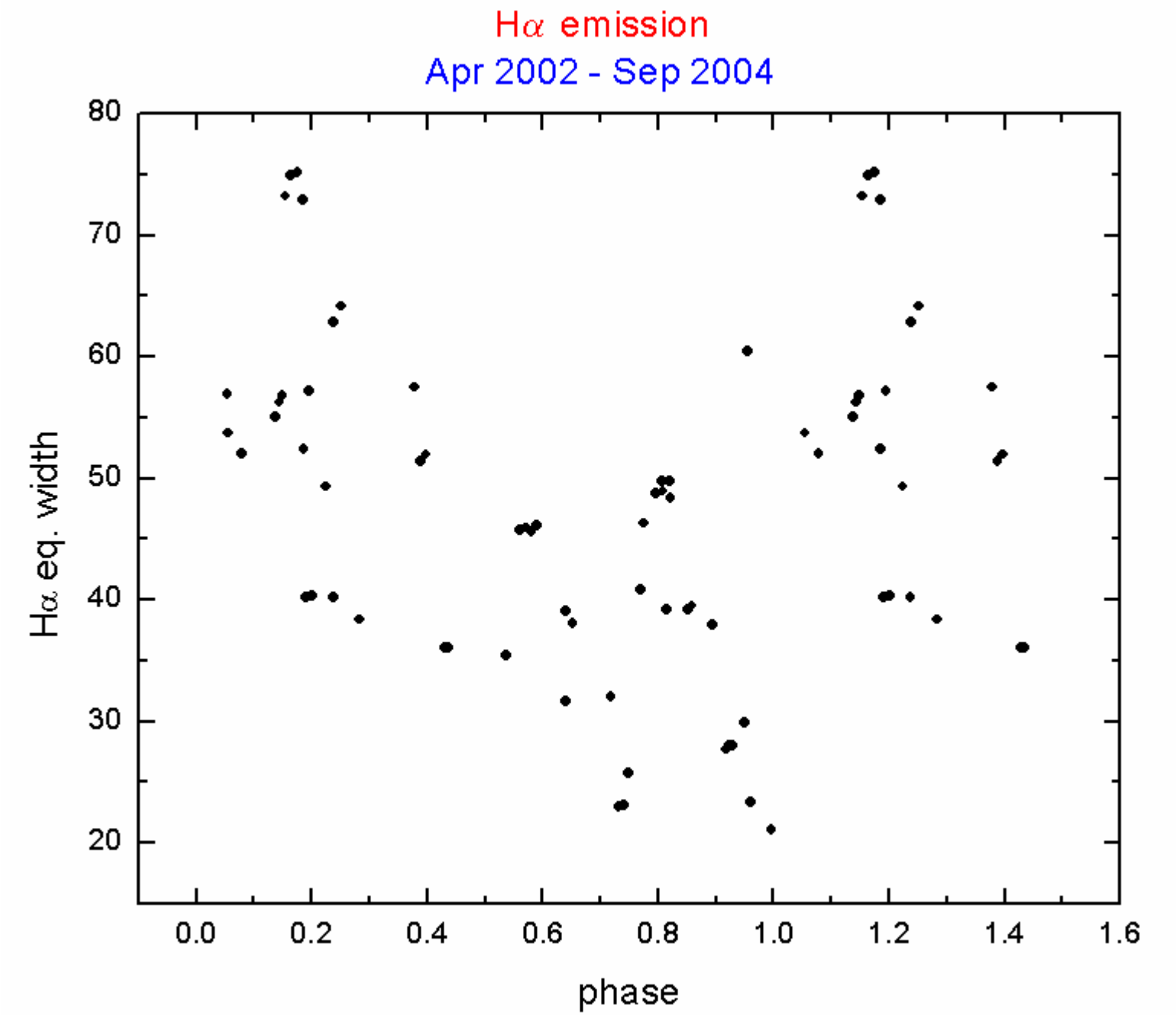

(a)
JD 2452377 - 2452400
(Apr - May 2002)
(b)
JD 2452621 - 2452739
(Dec 2002 - Apr 2003)
(c)
JD 2452992 - 2453039
(Dec 2003 - Feb 2004)
Equivalent width (Å)
0.0
0.5
1.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Phase

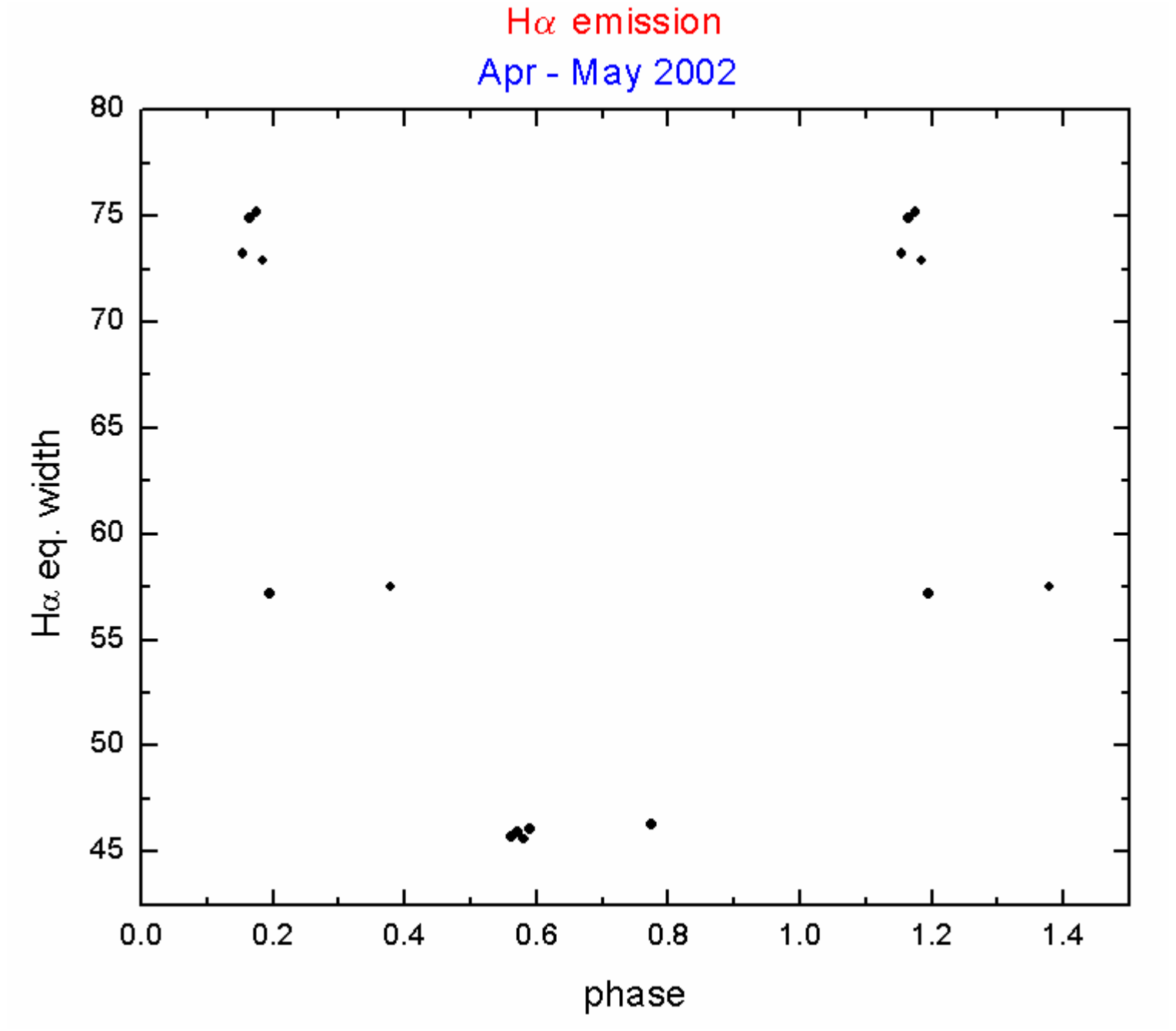

Li - line
JD 24552377 - 2453039
Equivalent width (Å)
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
phase

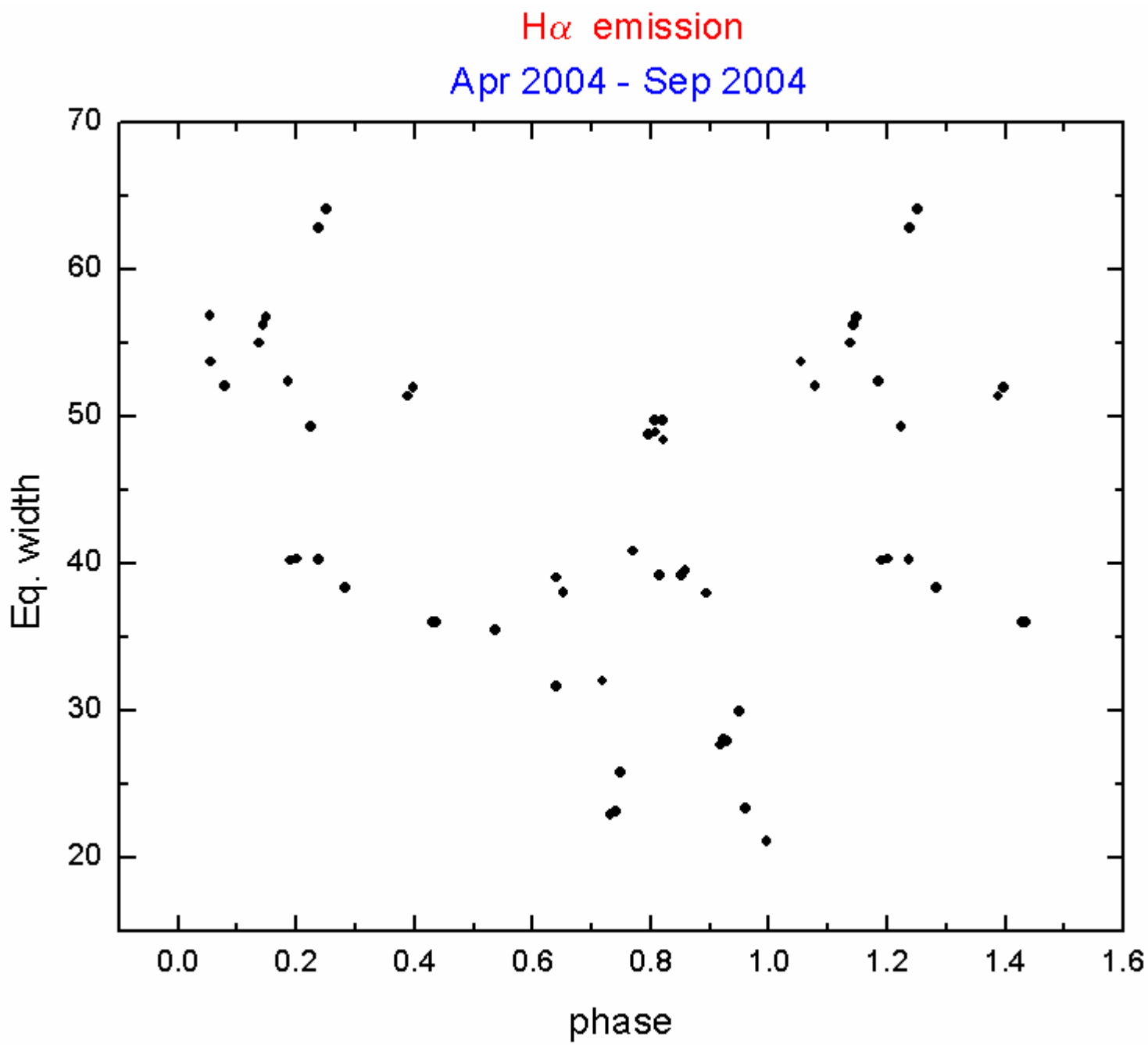

2.25
2
1.75
1.5
1.25
1
0.958
0.907
0.813
0.810
0.534
0.363
0.010
6400
6500
6600
6700
6800
Relative Intensity
Wavelength (angstroms)

V4046 Sgr

- Spectroscopic binary with an orbital period 2.4213 days.
- The analysis of our earlier photometric observations show periodic light variation with a period of 2.4457 days.
- Not associated with any star-forming region.
- Hα observations were obtained over 2002 and 2004 seasons.
- Hα EEW varies between 20 Å and 80 Å

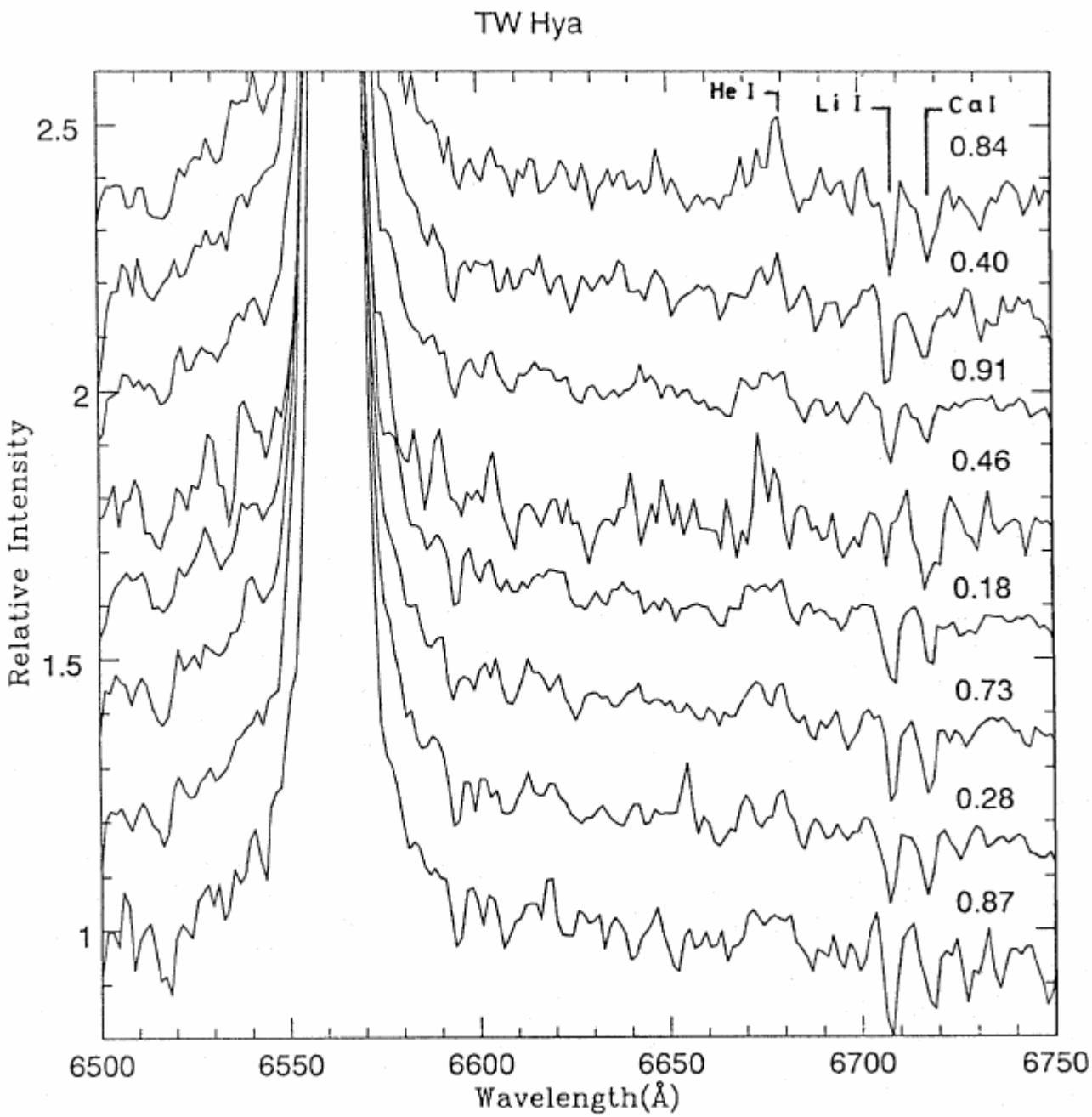

Hα emission
Apr 2002 - Sep 2004
Hα eq. width
80
70
60
50
40
30
20
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
phase

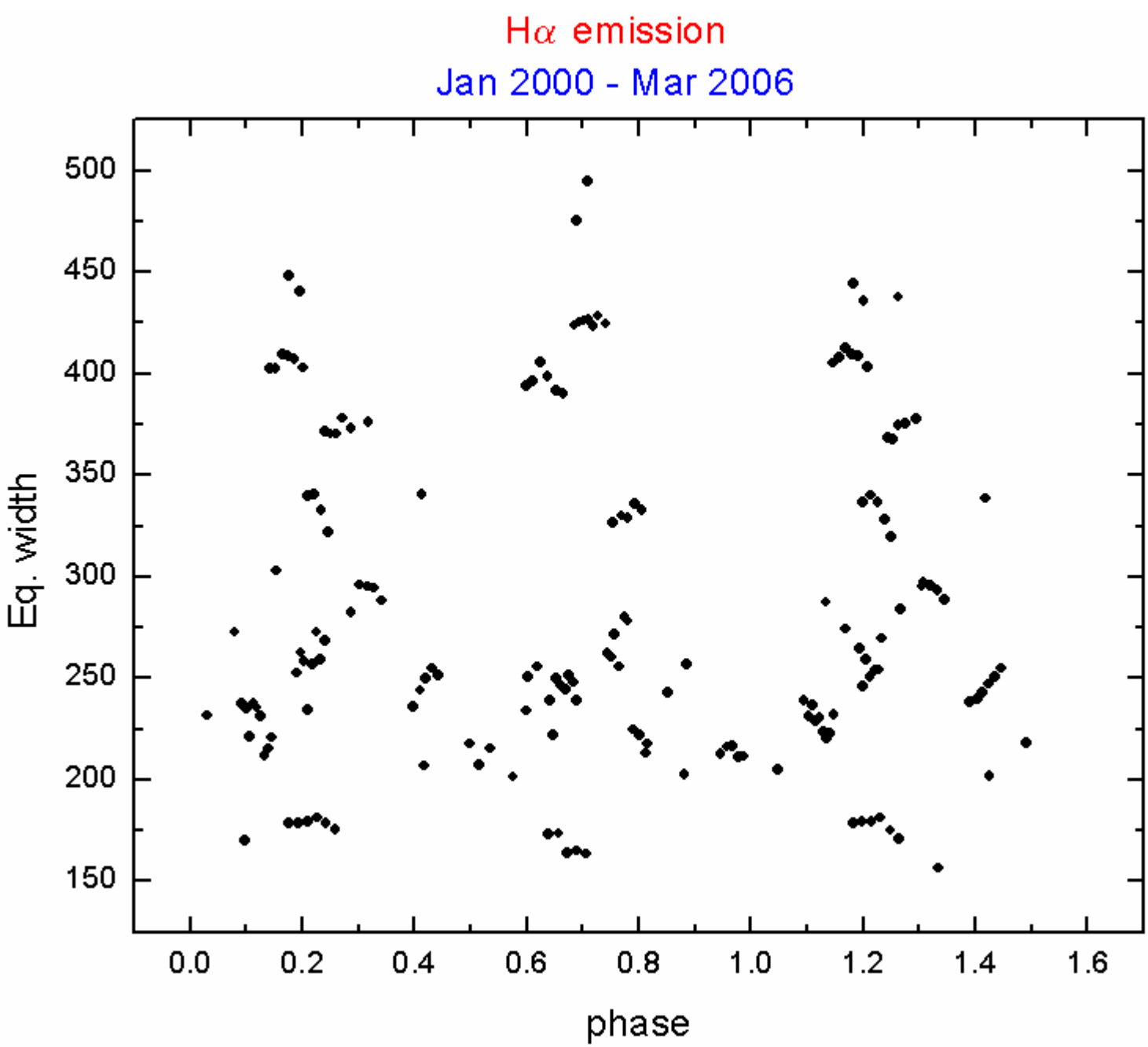

Hα emission
Apr - May 2002
Hα eq. width
phase
80
75
70
65
60
55
50
45
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

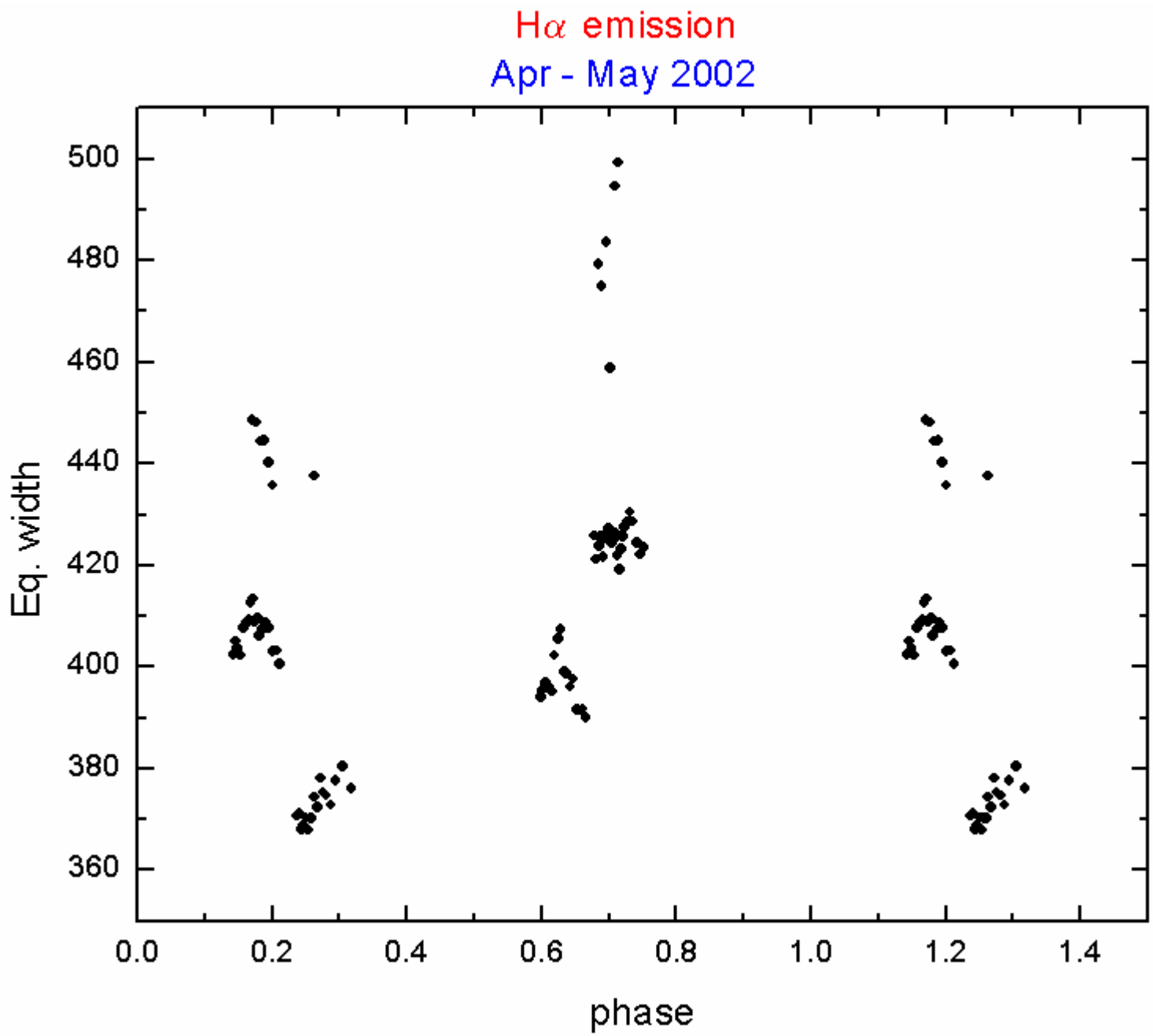

Hα emission
Apr 2004 - Sep 2004
Eq. width
phase
70
60
50
40
30
20
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

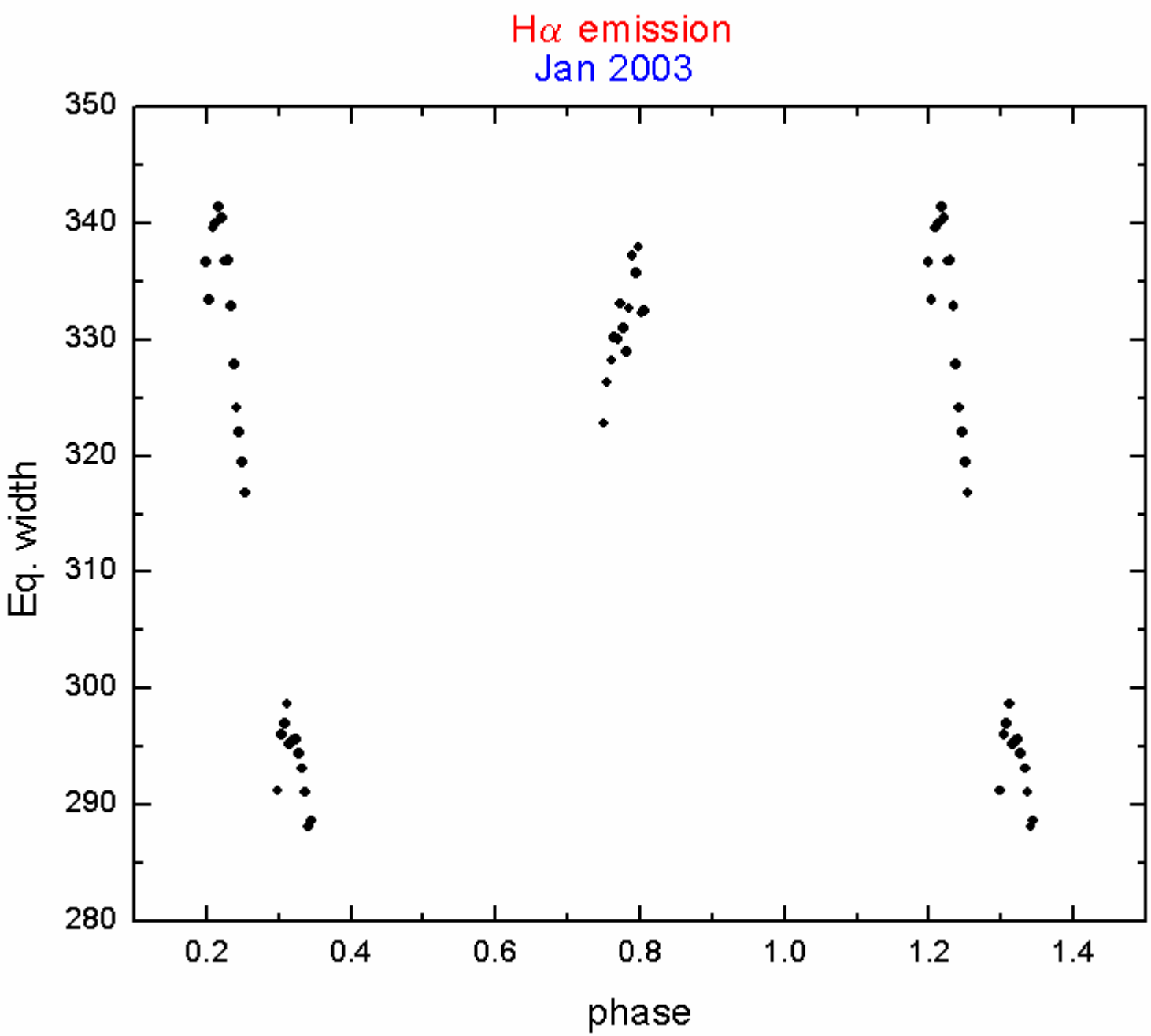
TW Hya

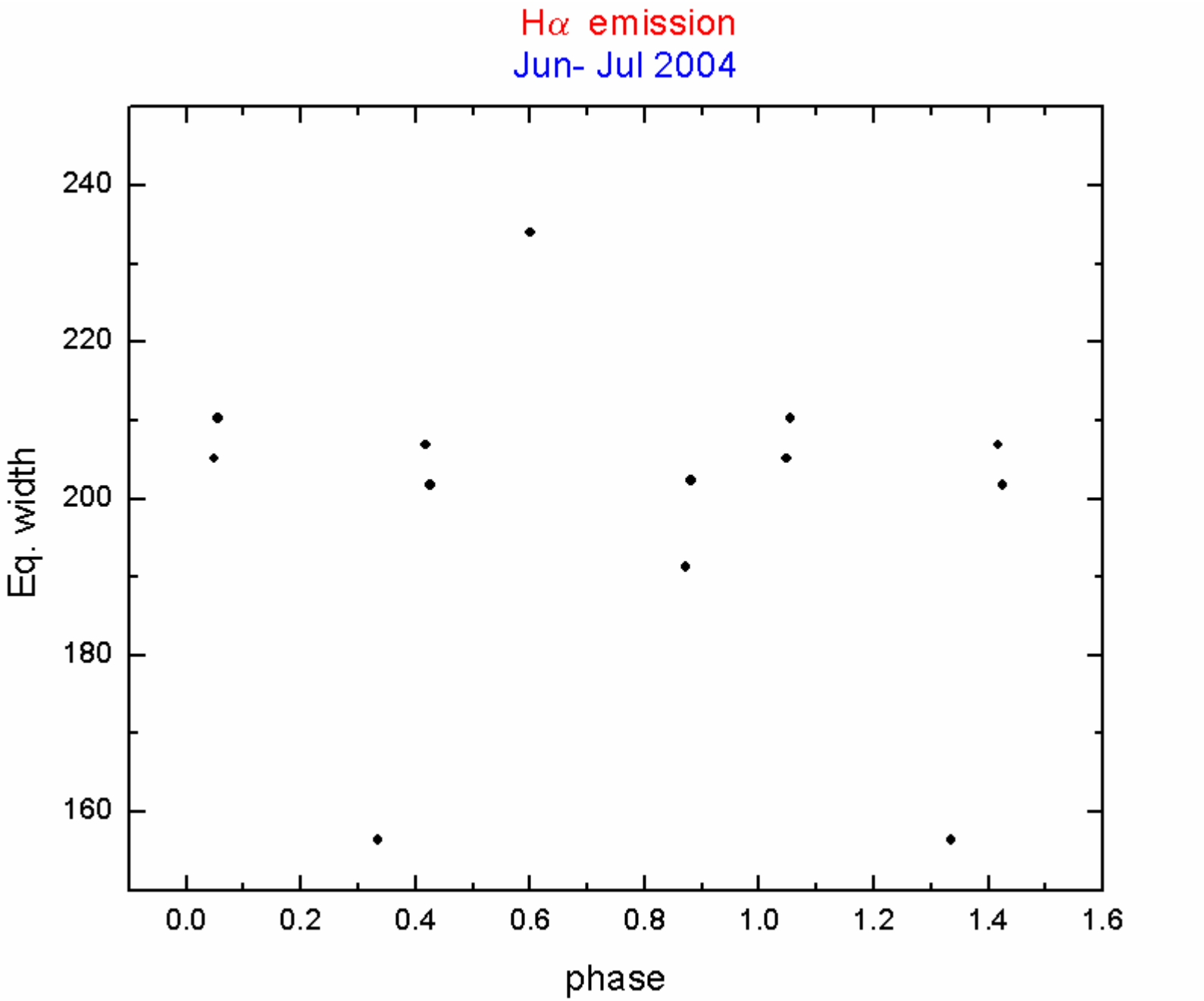
- Very active CTTS.
- Derived the rotation period (P = 2.196 days)
- The Hα observations were obtained over 2000, 2002, 2003, 2004 and 2006 seasons.
- The Hα line strength varies from 150 Å to 500 Å.
- Muzerolle used radiative transfer models of magnetospheric accretion. The model reproduces the observed flux and the accretion shock has a filling factor of 0.3 % of the stellar surface. This small value of filling factor is consistent with our hot spot models of photospheric light vaiability.

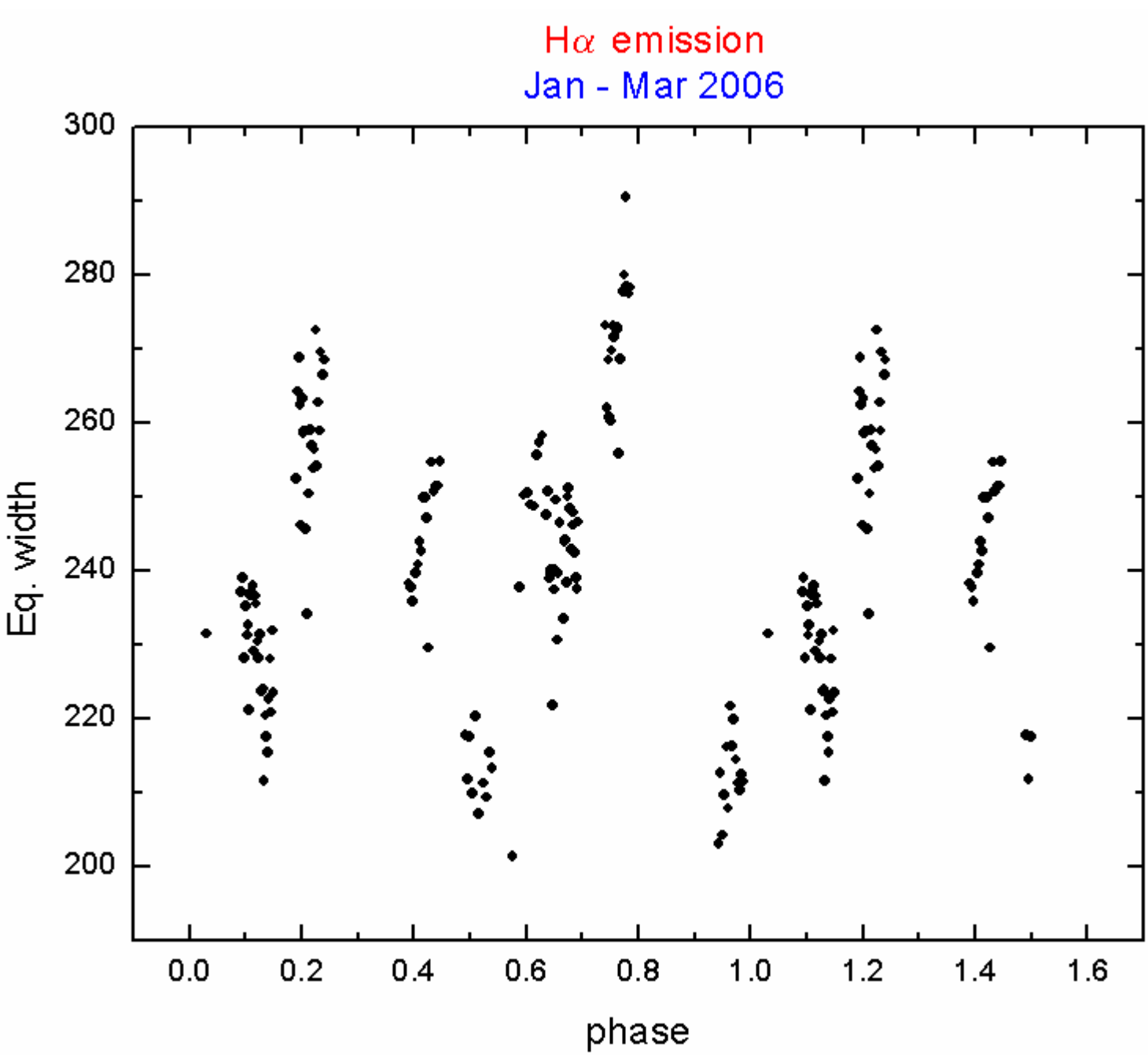

TW Hya
He I
Li I
Ca I
0.84
0.40
0.91
0.46
0.18
0.73
0.28
0.87
Relative Intensity
2.5
2
1.5
1
6500
6550
6600
6650
6700
6750
Wavelength(Å)


Hα emission
Jan 2000 - Mar 2006
Eq. width
500
450
400
350
300
250
200
150
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
phase


Hα emission
Apr - May 2002
Eq. width
500
480
460
440
420
400
380
360
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
phase


Hα emission
Jan 2003
Eq. width
phase
350
340
330
320
310
300
290
280
0.2
0.4
0.6
0.8
1.0
1.2
1.4


Hα emission
Jun- Jul 2004
Eq. width
240
220
200
180
160
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
phase


Hα emission
Jan - Mar 2006
Eq. width
phase
300
280
260
240
220
200
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6