Composite-Spectrum Binaries

The Good, the Bad and the Ugly

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Definition: Detached binary

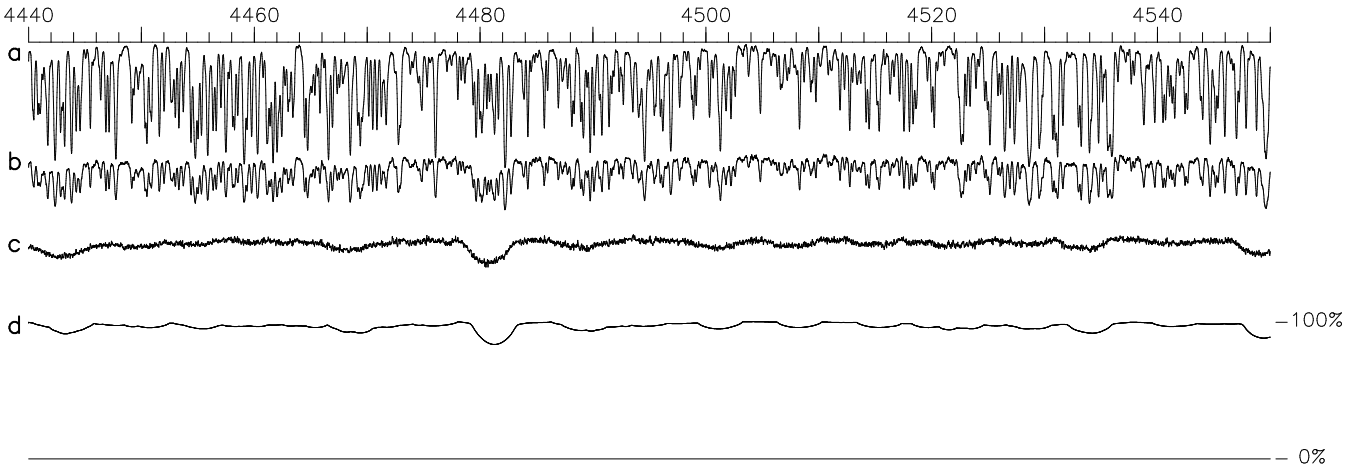
Red Giant: G-K-(M) + Hot Dwarf (B-A)

Sample of 45 Composite-Spectrum Binaries

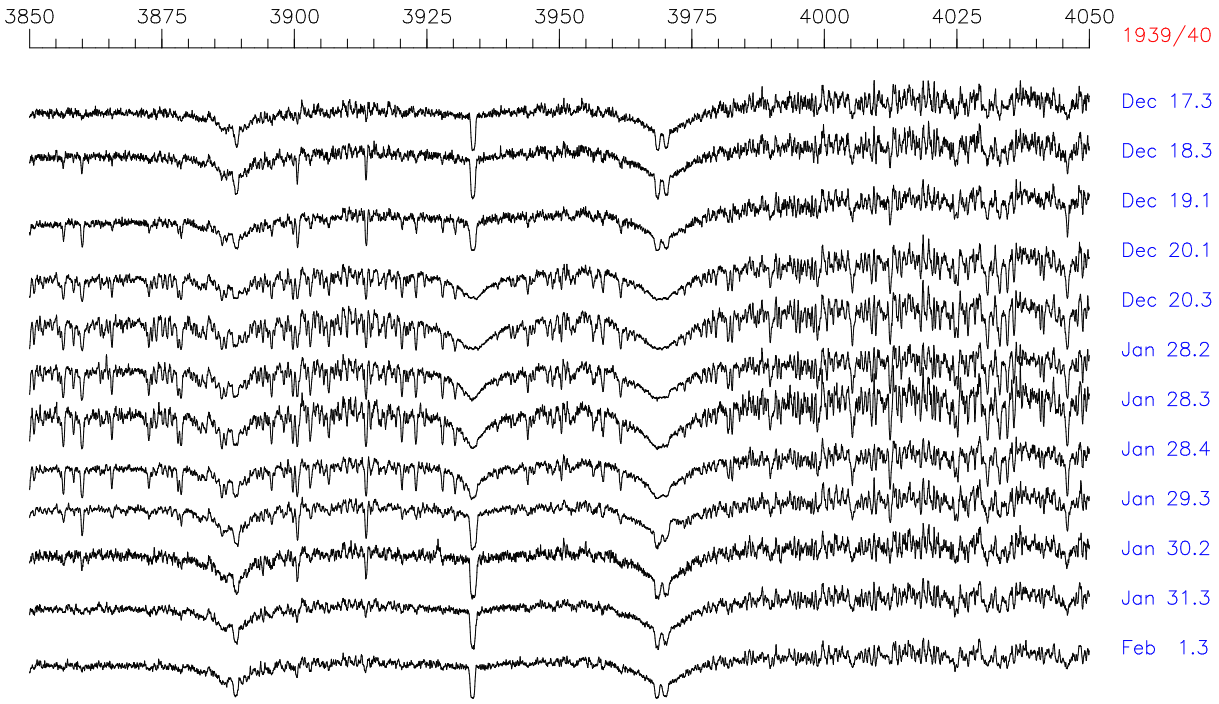
	Cool Primary (evolved)	Hot Secondary (much less evolved)
1. Range of spectral types	**G0 - M2**	**B5 – F2**
2. Am stars	**1 (o Leo)**	**9 (20 %)**

3. Triple systems	**6, maybe 7 (14 %)**
4. Eclipsing systems	**9 (20 %)**
5. Astrometric orbits	**12 (27 %)**
6. Range of periods	**14 days – 65 years** **< 120 days: 11 (24 %)** **0.3 – 3 years: 12 (27 %)** **> 3 years: 22 (49 %)**

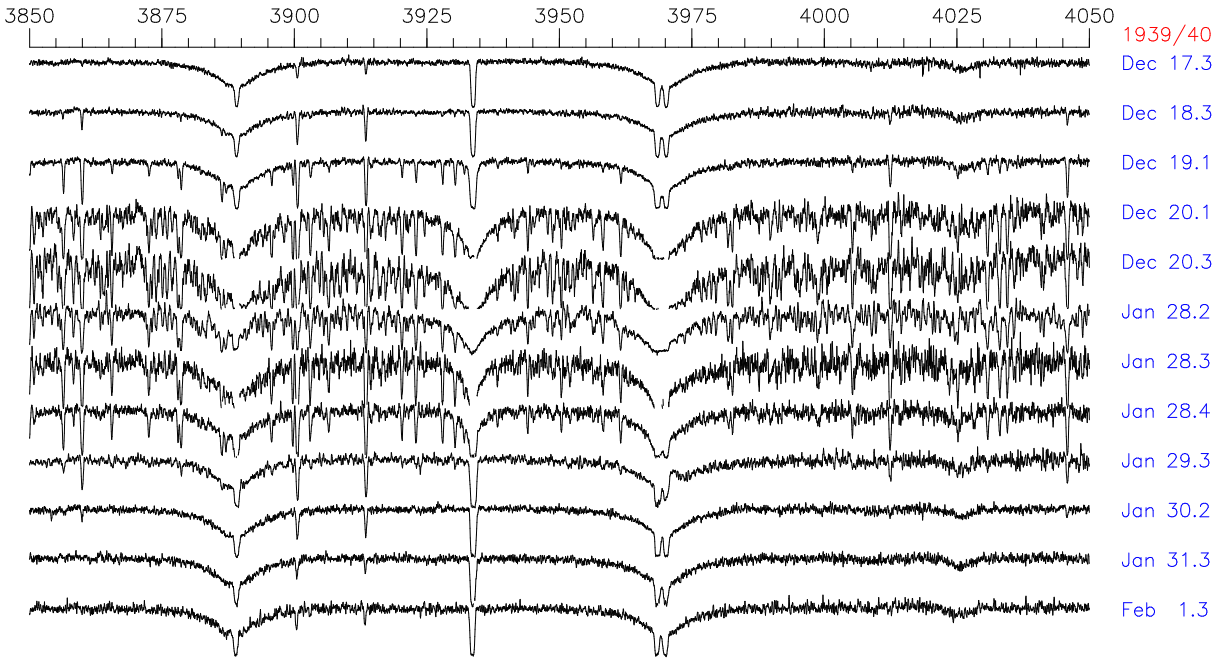
THE GOOD . . .

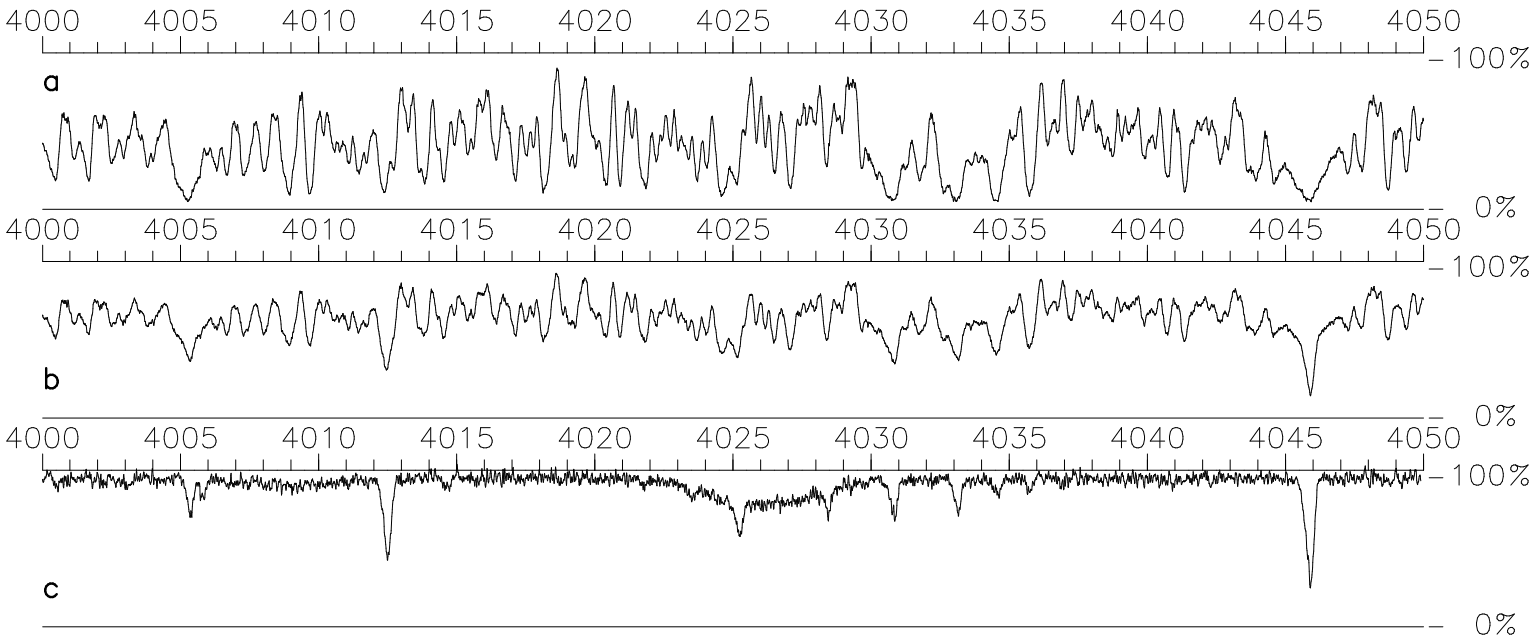


Separating the components of the composite-spectrum binary 45 Cnc. An appropriate G-giant spectrum – see panel (a) – is subtracted from the observed composite spectrum in panel (b), leaving the spectrum of the secondary star, 45 Cnc B – see panel (c) – as a residue. Panel (d) contains a synthetic spectrum which is a close match to that of 45 Cnc B.

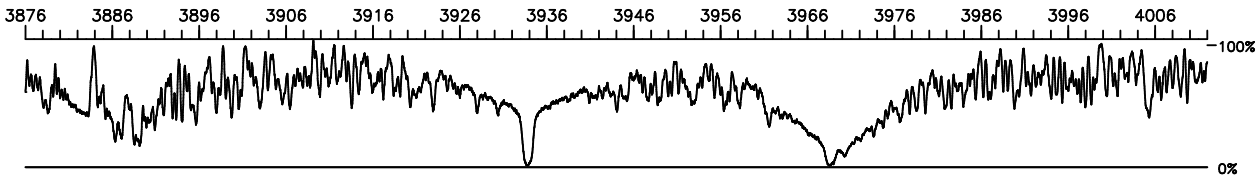


Spectra of ζ Aur passing through eclipse, showing changing chromospheric absorption both before and after totality. The strengths of those lines are strongly phase-dependent, and vary noticeably within 1 day. Upper: Observed composite spectra. Lower: After the giant's spectrum has been subtracted, leaving the spectrum of the mid-B dwarf, plus chromospheric absorption. Quantitative measurements are now possible.

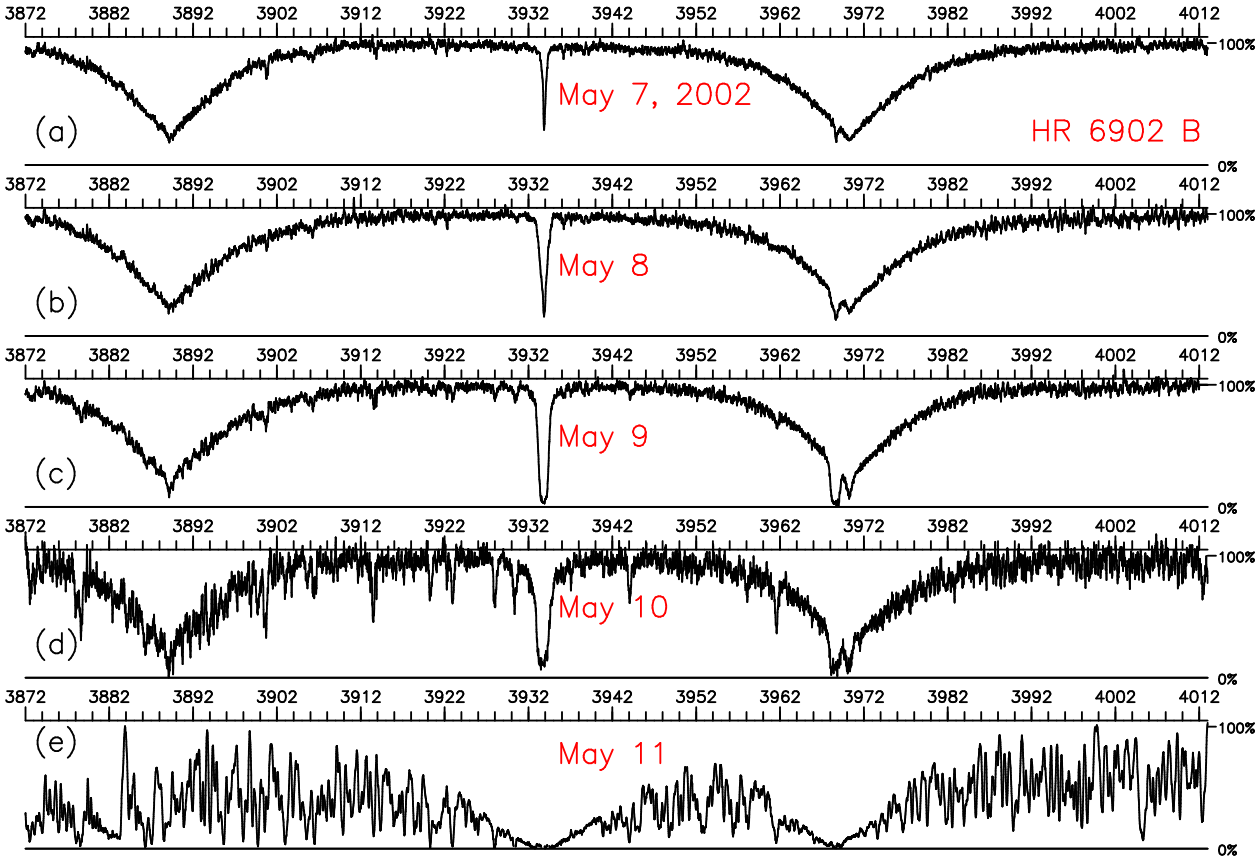


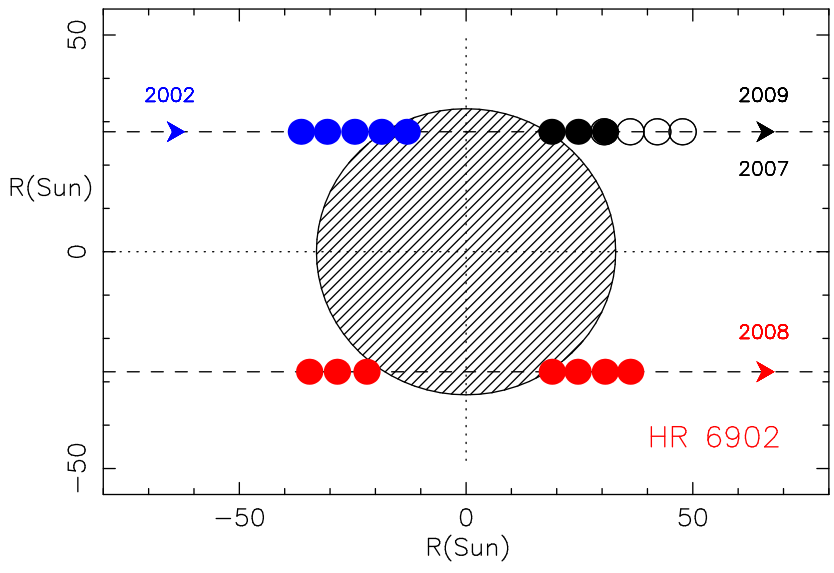


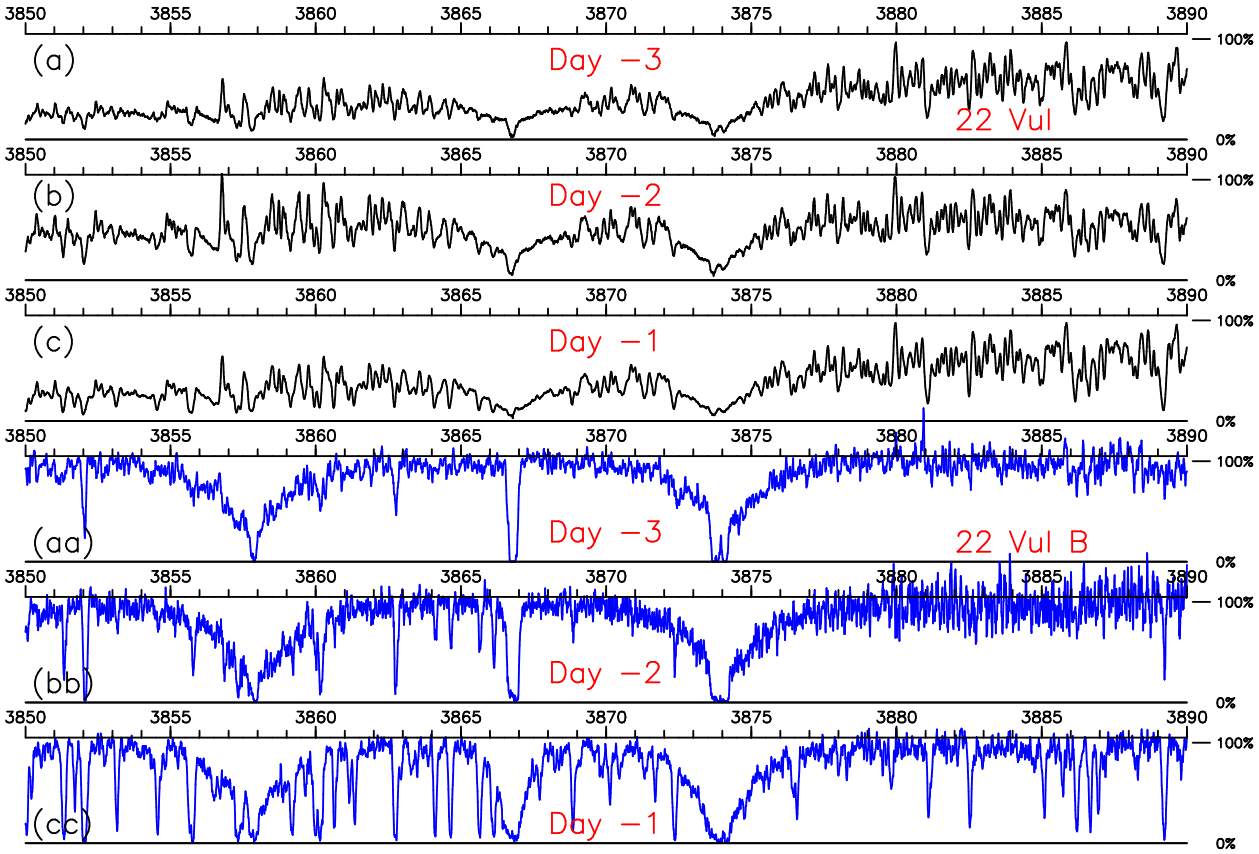
Uncovering exquisite detail in a chromospheric-eclipse spectrum of ζ Aur.
(a): (the giant spectrum alone, observed during total eclipse)
(b): Giant's spectrum (observed during totality)
(c): spectrum of the B star (note the broad line of He I at $\lambda\,4026\,\text{Å}$) with numerous sharp lines of chromospheric absorption superimposed.



HR 6902. Above: ingress in 2009, before removing the giant's spectrum. Below: Nightly changes seen against the B-star spectrum, after subtracting that of the G8 IIb primary.

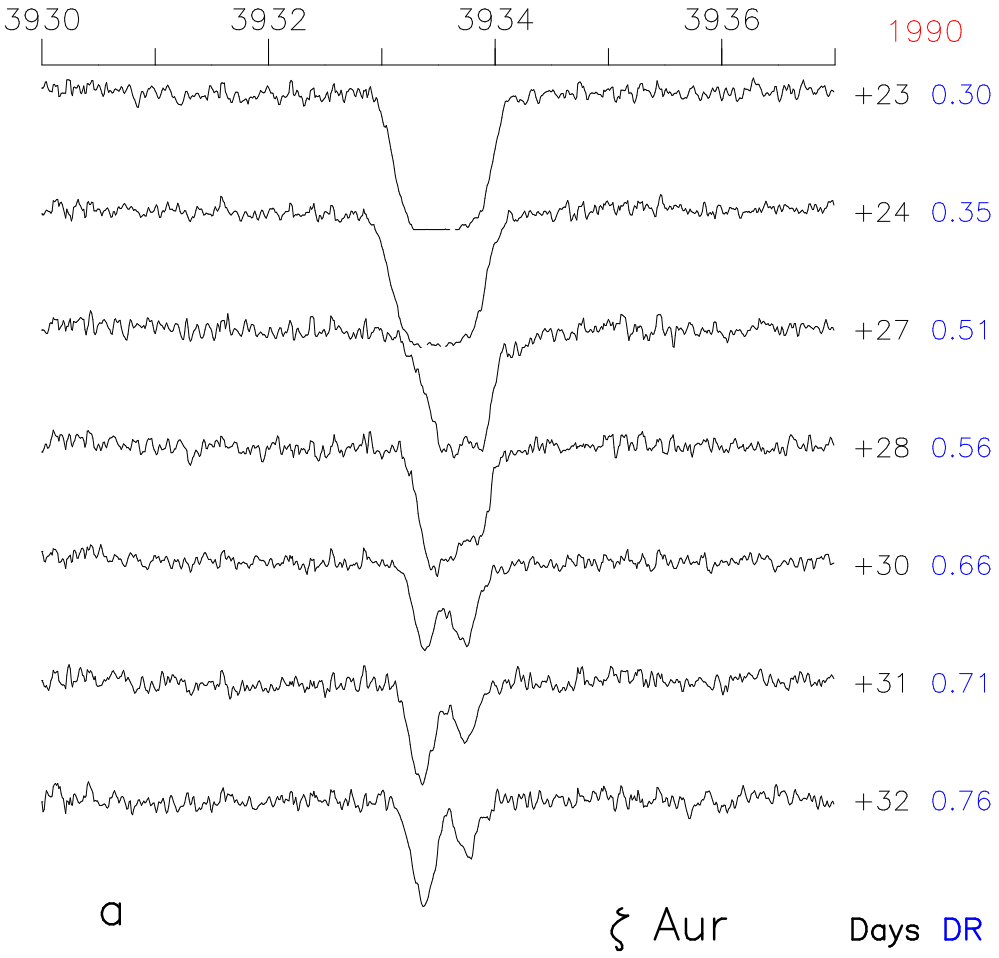


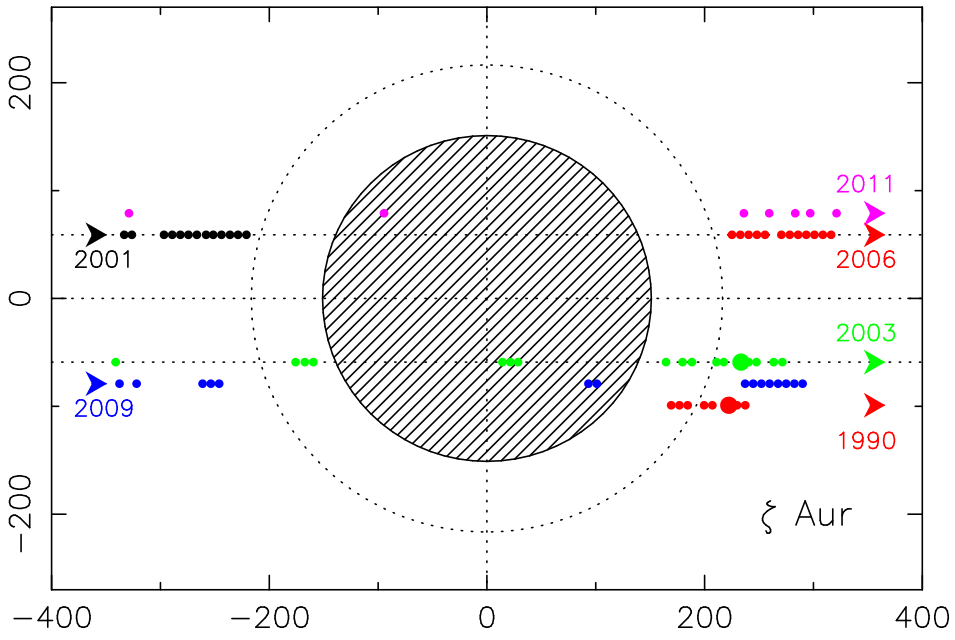


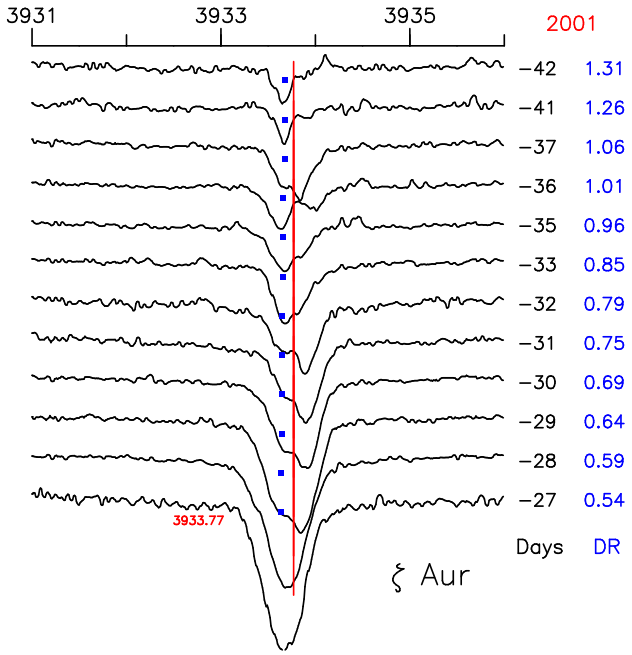


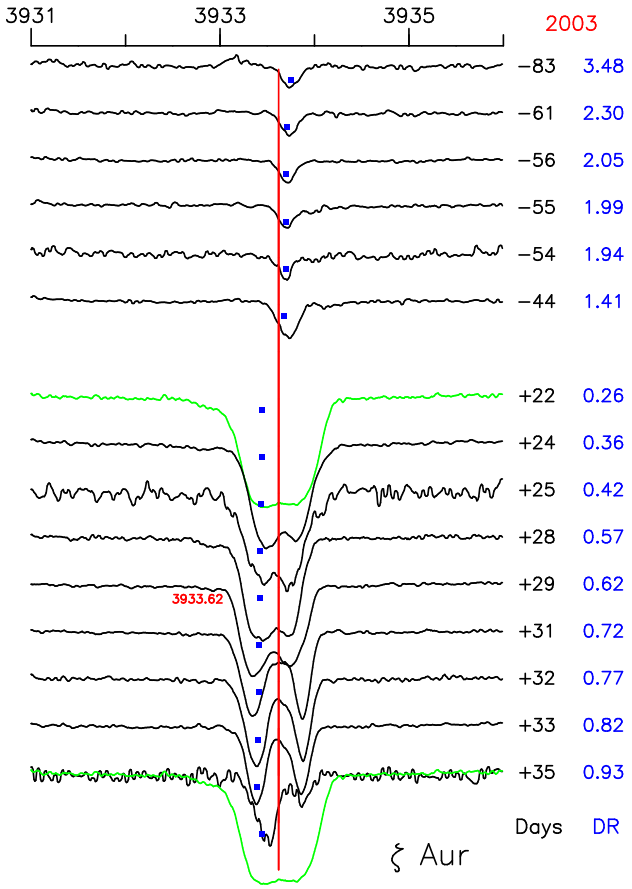
Top three: Ingress into total eclipse of 22 Vul (G8Ib + B9 V).
Lower three, in blue : Same spectra, but after subtraction

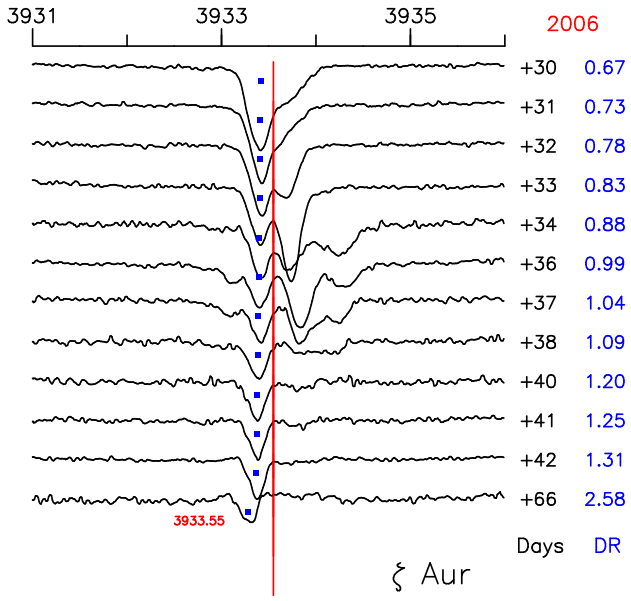
THE CURIOUS . . .

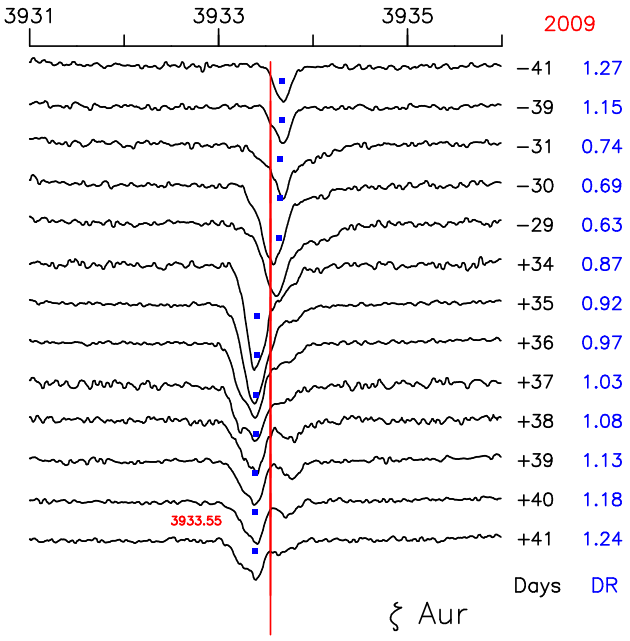

3930
3932
3934
3936
1990
+23 0.30
+24 0.35
+27 0.51
+28 0.56
+30 0.66
+31 0.71
+32 0.76
a
ζ Aur
Days DR

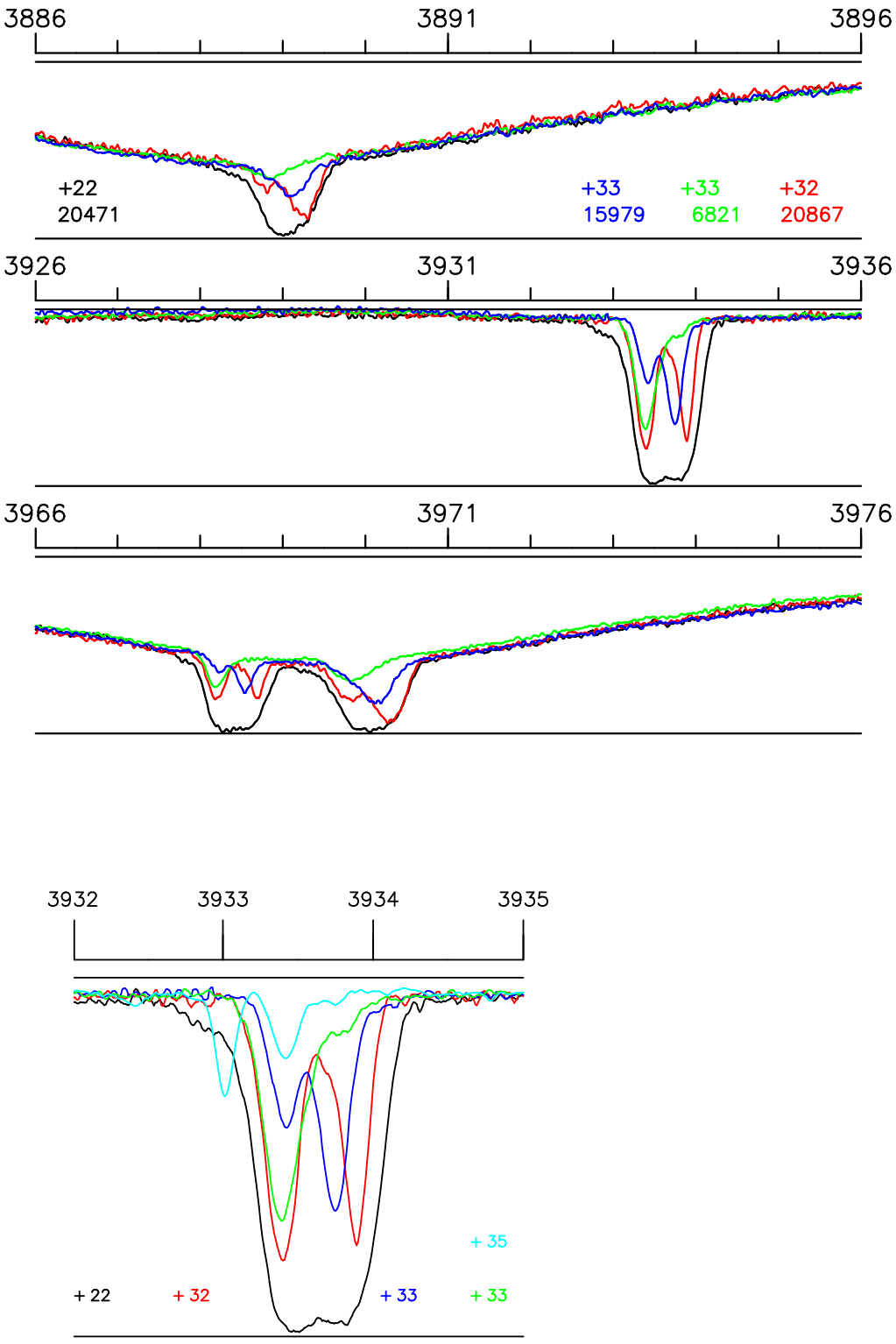

200
0
−200
−400
−200
0
200
400
2001
2011
2006
2003
2009
1990
ζ Aur


3931
3933
3935
2001
−42 1.31
−41 1.26
−37 1.06
−36 1.01
−35 0.96
−33 0.85
−32 0.79
−31 0.75
−30 0.69
−29 0.64
−28 0.59
−27 0.54
3933.77
Days DR
ζ Aur

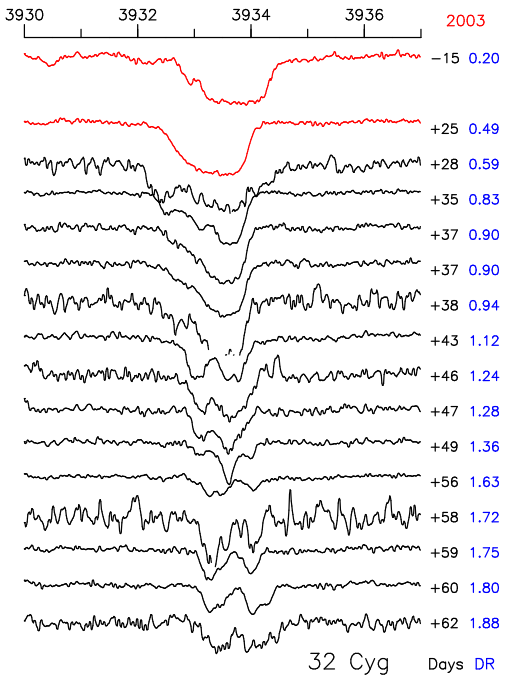

3931
3933
3935
2003
−83 3.48
−61 2.30
−56 2.05
−55 1.99
−54 1.94
−44 1.41
+22 0.26
+24 0.36
+25 0.42
+28 0.57
+29 0.62
3933.62
+31 0.72
+32 0.77
+33 0.82
+35 0.93
Days DR
ζ Aur

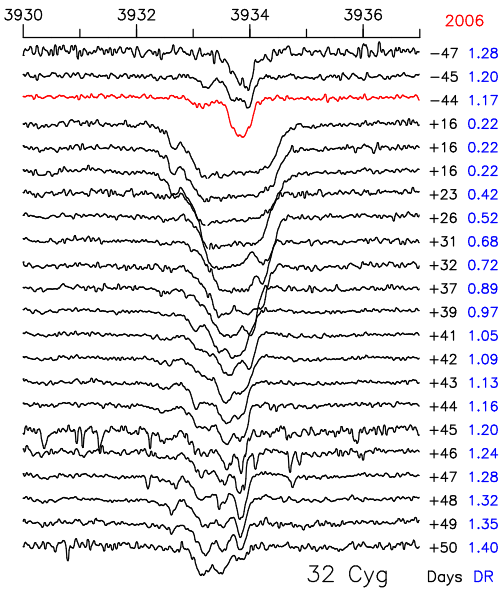

3931
3933
3935
2006
+30 0.67
+31 0.73
+32 0.78
+33 0.83
+34 0.88
+36 0.99
+37 1.04
+38 1.09
+40 1.20
+41 1.25
+42 1.31
+66 2.58
3933.55
Days DR
ζ Aur

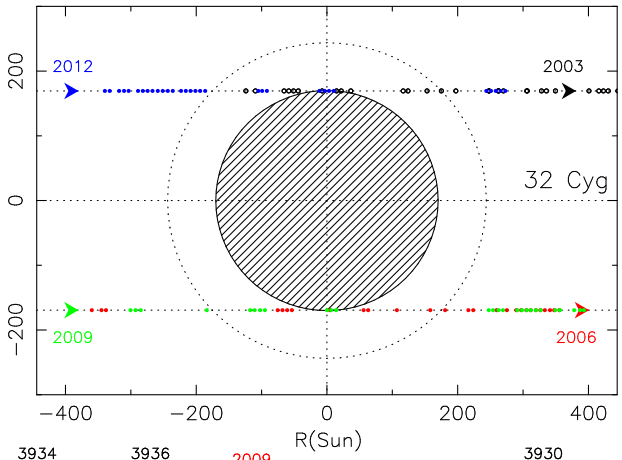

3931
3933
3935
2009
−41 1.27
−39 1.15
−31 0.74
−30 0.69
−29 0.63
+34 0.87
+35 0.92
+36 0.97
+37 1.03
+38 1.08
+39 1.13
+40 1.18
3933.55
+41 1.24
Days DR
ζ Aur

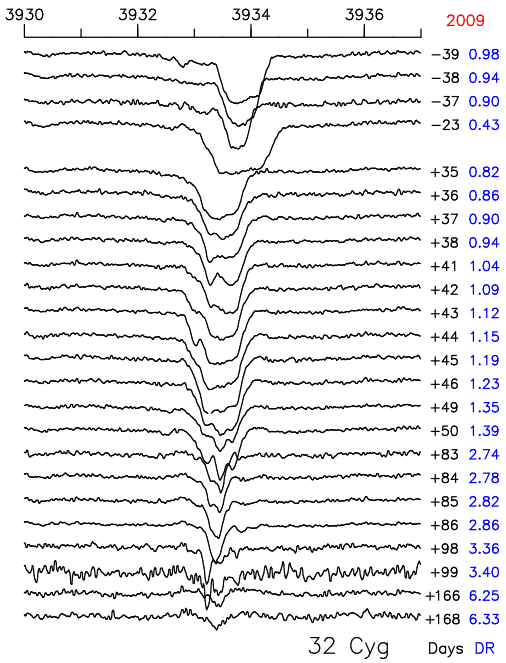


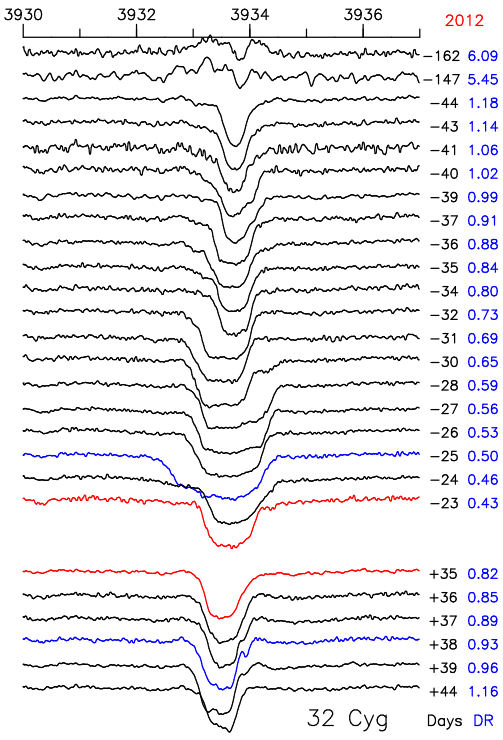
Chromospheric line-profiles in different eclipses of ζ Aur. Red: 2003, blue: 2006, green: 2009, light blue: 2014. Black: 2003, at an earlier phase (deeper in the chromosphere).

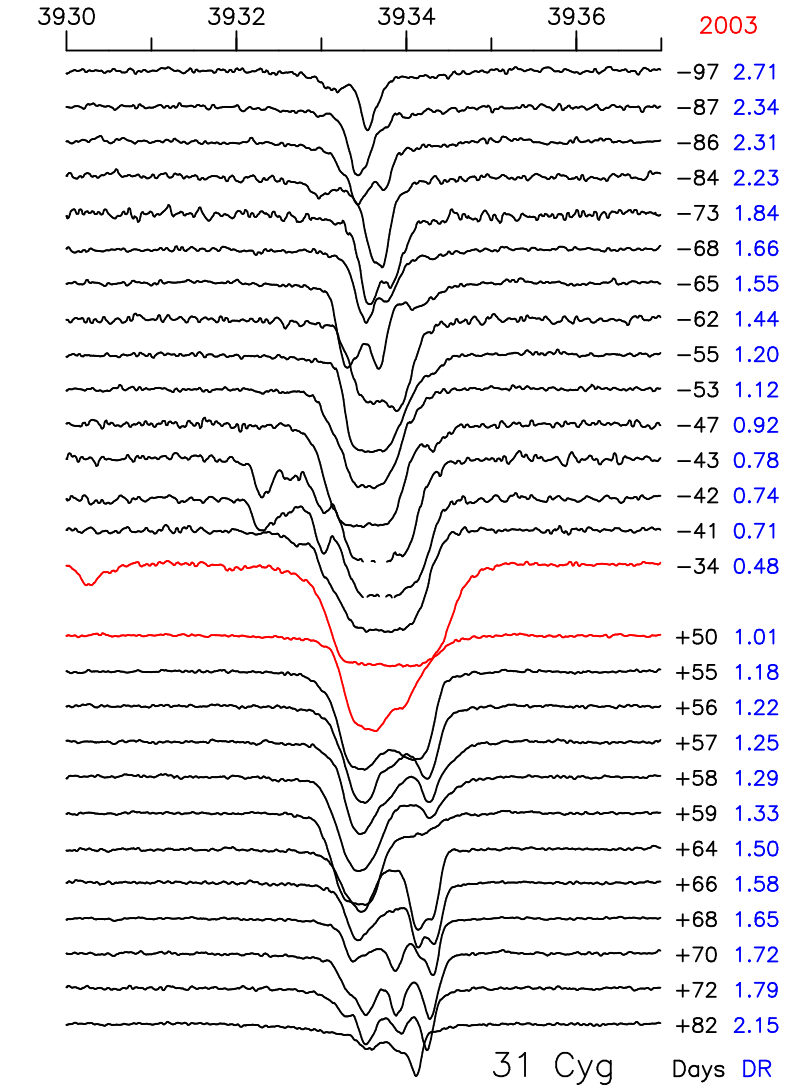

3930
3932
3934
3936
2003
−15 0.20
+25 0.49
+28 0.59
+35 0.83
+37 0.90
+37 0.90
+38 0.94
+43 1.12
+46 1.24
+47 1.28
+49 1.36
+56 1.63
+58 1.72
+59 1.75
+60 1.80
+62 1.88
32 Cyg
Days DR

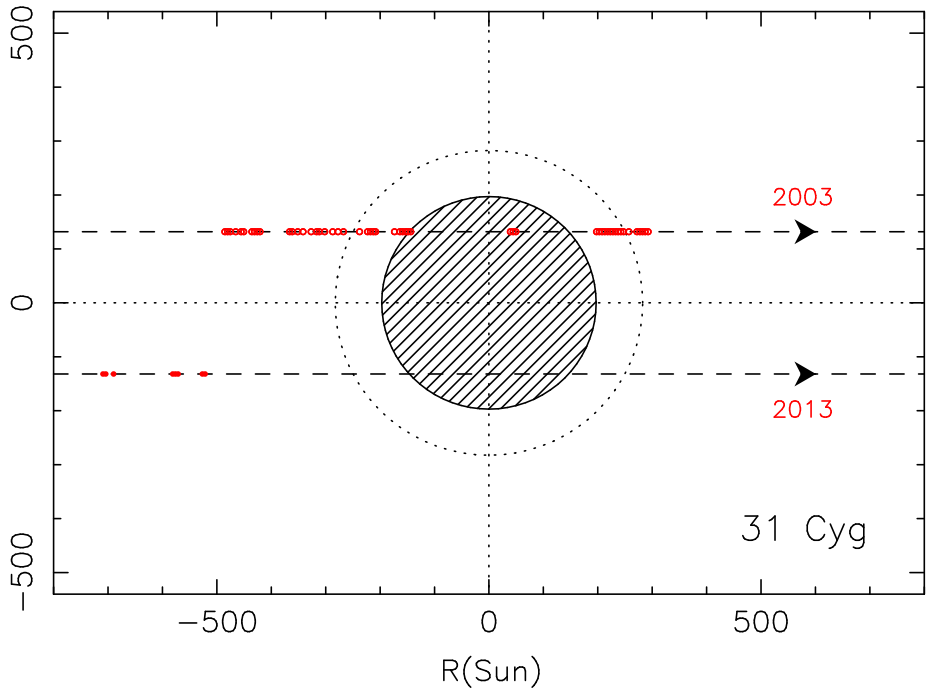

3930
3932
3934
3936
2006
−47 1.28
−45 1.20
−44 1.17
+16 0.22
+16 0.22
+16 0.22
+23 0.42
+26 0.52
+31 0.68
+32 0.72
+37 0.89
+39 0.97
+41 1.05
+42 1.09
+43 1.13
+44 1.16
+45 1.20
+46 1.24
+47 1.28
+48 1.32
+49 1.35
+50 1.40
32 Cyg
Days DR

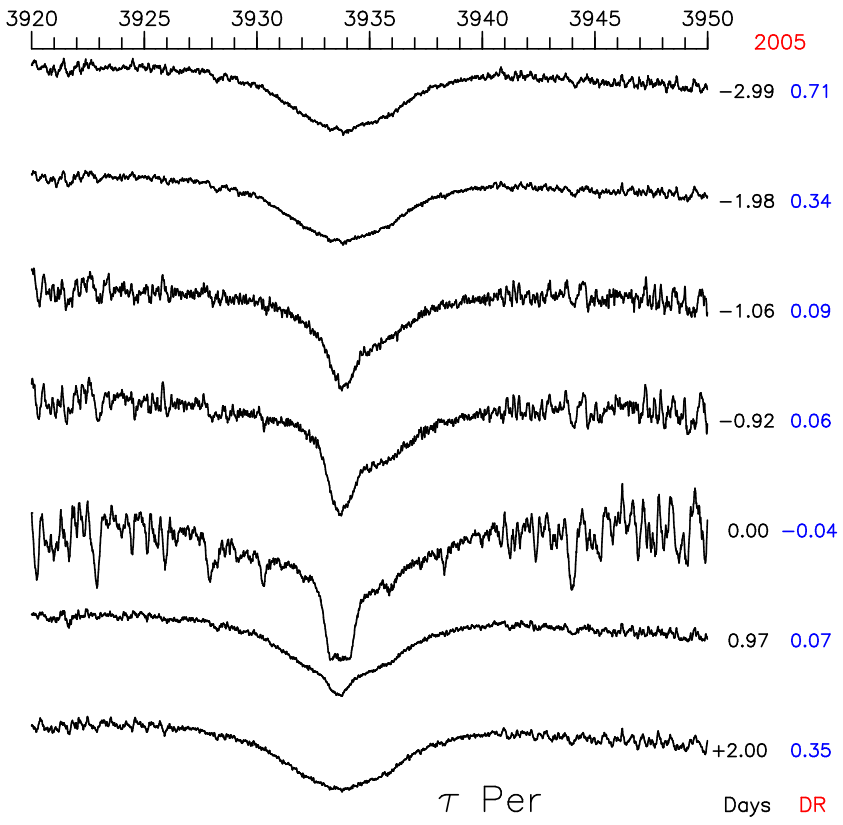

2012
2003
32 Cyg
2009
2006
200
0
−200
−400
−200
0
200
400
R(Sun)


3930
3932
3934
3936
2009
−39 0.98
−38 0.94
−37 0.90
−23 0.43
+35 0.82
+36 0.86
+37 0.90
+38 0.94
+41 1.04
+42 1.09
+43 1.12
+44 1.15
+45 1.19
+46 1.23
+49 1.35
+50 1.39
+83 2.74
+84 2.78
+85 2.82
+86 2.86
+98 3.36
+99 3.40
+166 6.25
+168 6.33
32 Cyg
Days DR

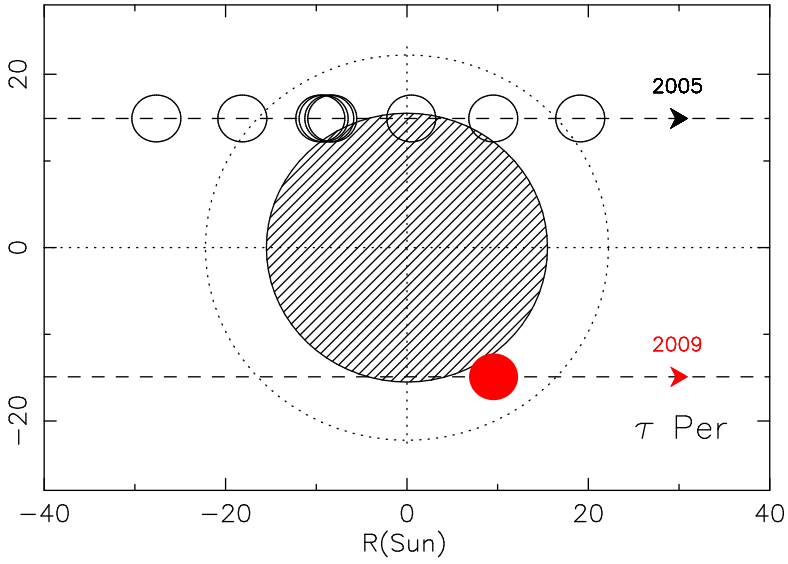

3930
3932
3934
3936
2012
−162 6.09
−147 5.45
−44 1.18
−43 1.14
−41 1.06
−40 1.02
−39 0.99
−37 0.91
−36 0.88
−35 0.84
−34 0.80
−32 0.73
−31 0.69
−30 0.65
−28 0.59
−27 0.56
−26 0.53
−25 0.50
−24 0.46
−23 0.43
+35 0.82
+36 0.85
+37 0.89
+38 0.93
+39 0.96
+44 1.16
32 Cyg
Days DR

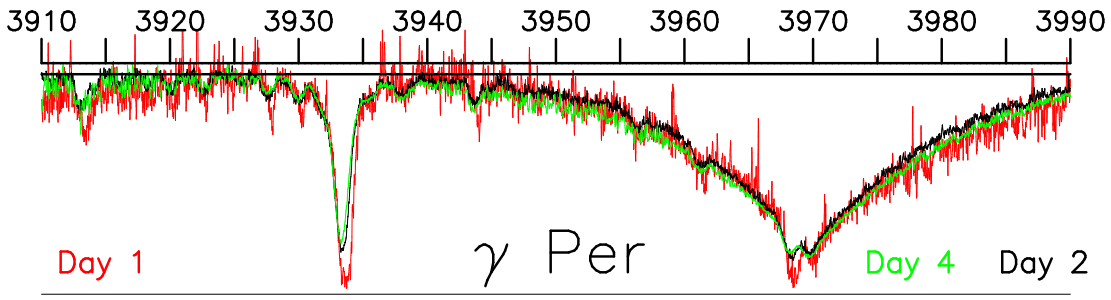

3930
3932
3934
3936
2003
−97 2.71
−87 2.34
−86 2.31
−84 2.23
−73 1.84
−68 1.66
−65 1.55
−62 1.44
−55 1.20
−53 1.12
−47 0.92
−43 0.78
−42 0.74
−41 0.71
−34 0.48
+50 1.01
+55 1.18
+56 1.22
+57 1.25
+58 1.29
+59 1.33
+64 1.50
+66 1.58
+68 1.65
+70 1.72
+72 1.79
+82 2.15
31 Cyg
Days DR

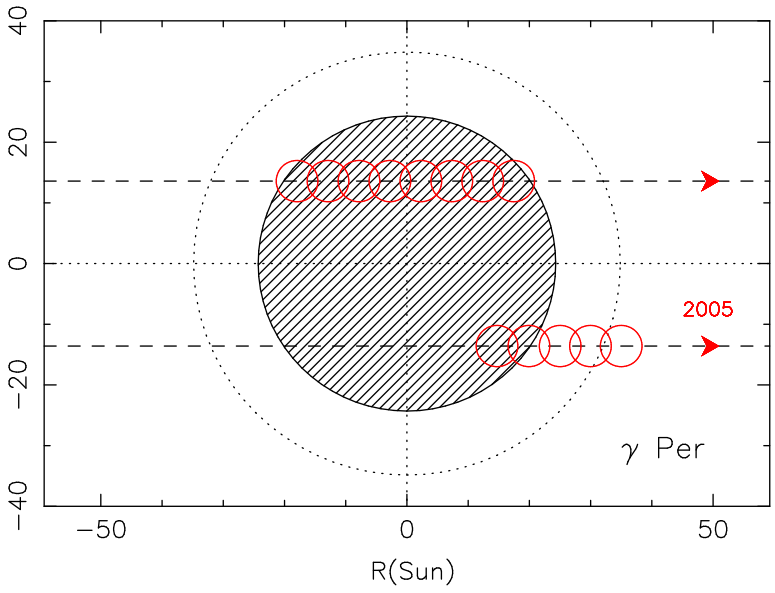

500
0
−500
−500
0
500
R(Sun)
2003
2013
31 Cyg



A brief partial eclipse of τ Per

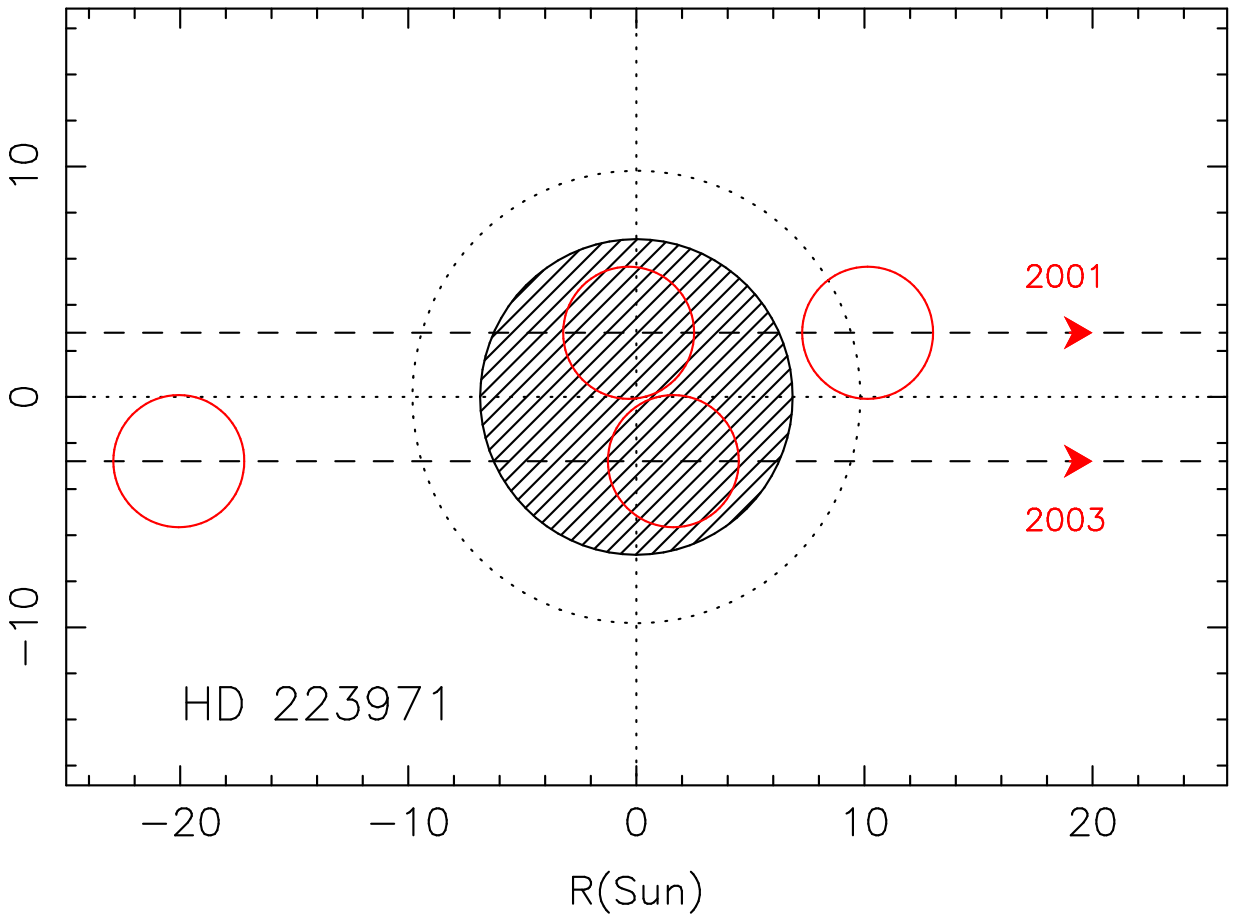


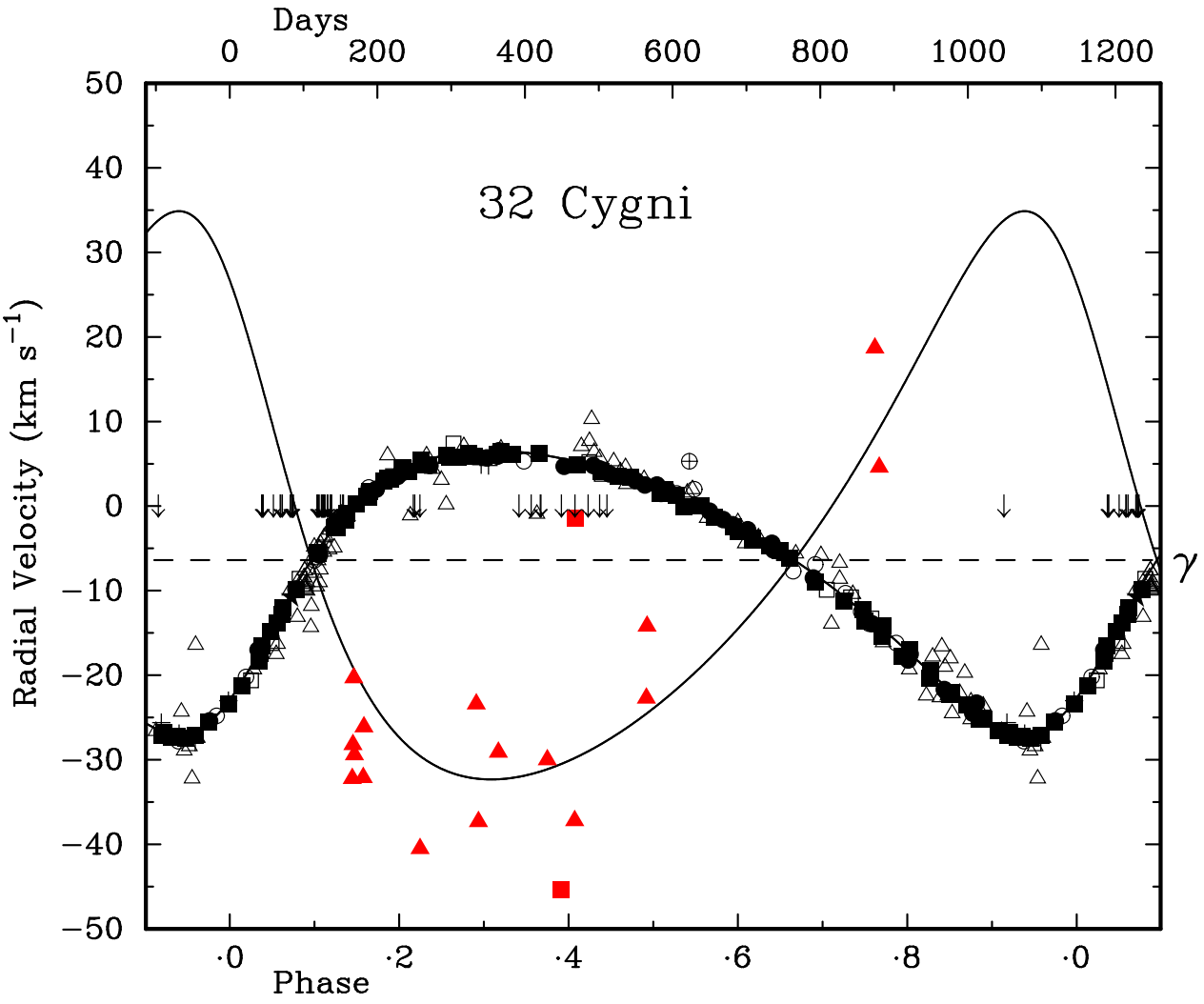


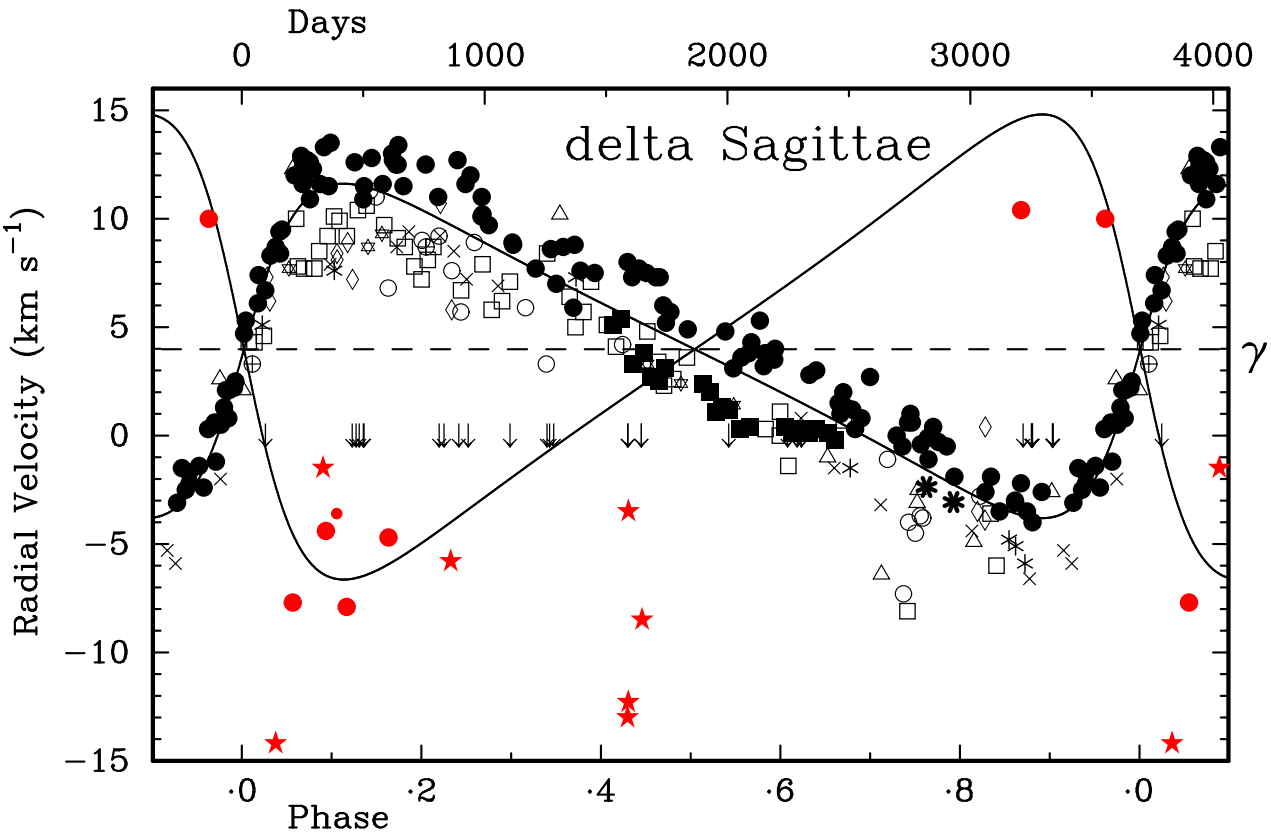


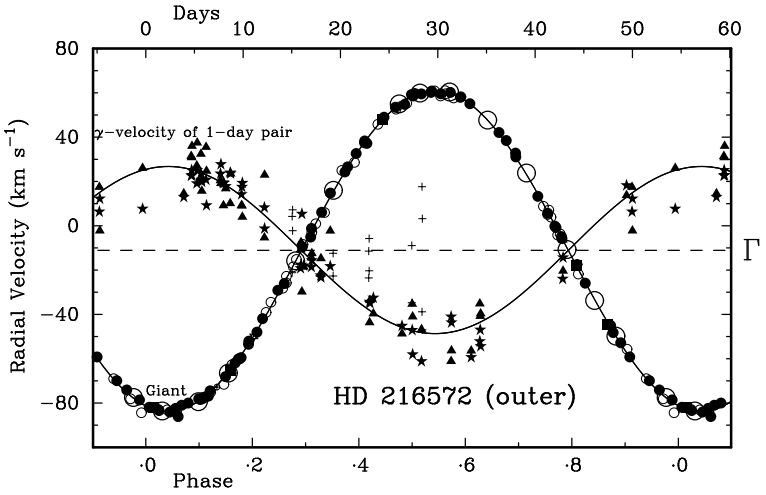
γ Per eclipses for 8 days, but its chromosphere is either extremely thin or is too hot to be detected in Ca^{+}

THE BAD . . .




Days
0
200
400
600
800
1000
1200
32 Cygni
Radial Velocity (km s^{-1})
50
40
30
20
10
0
−10
−20
−30
−40
−50
γ
·0
·2
·4
·6
·8
·0
Phase


Days
0
1000
2000
3000
4000
delta Sagittae
15
10
5
0
−5
−10
−15
Radial Velocity (km s^{-1})
γ
·0
·2
·4
·6
·8
·0
Phase



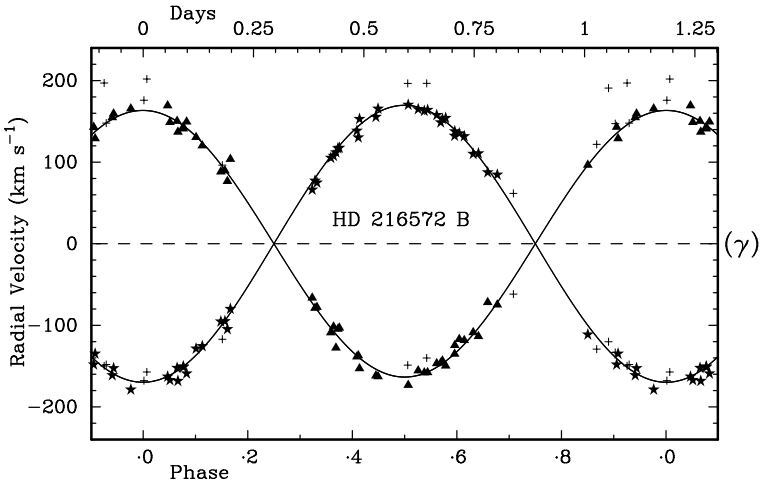
OUTER ORBIT :

$m_1 \sin^3 i = 2.625\ M_\odot$

$m_2 \sin^3 i = 5.003\ M_\odot$

We find i_o is near 81°

HD 216572

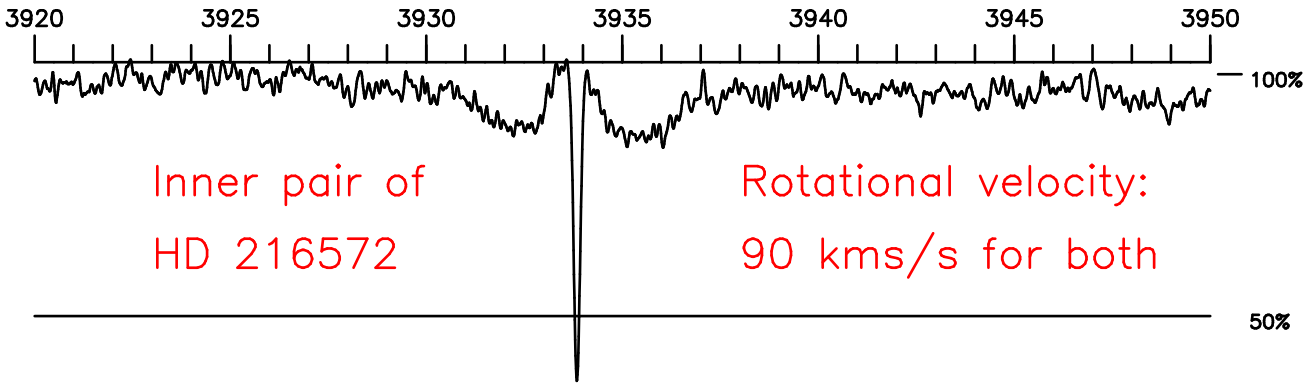


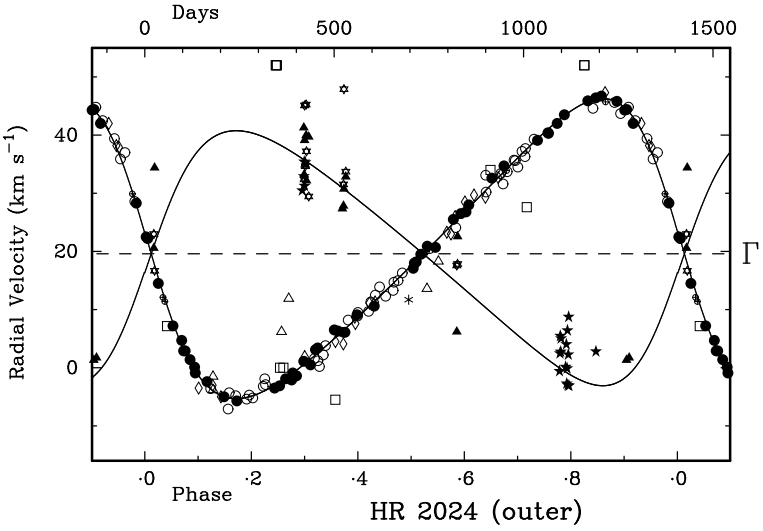
INNER ORBIT :

$m_1 \sin^3 i = 2.319\ M_\odot$
$m_2 \sin^3 i = 2.232\ M_\odot$

$m_1 + m_2 = 4.55\ M_\odot$

We know $i_i = 75°$





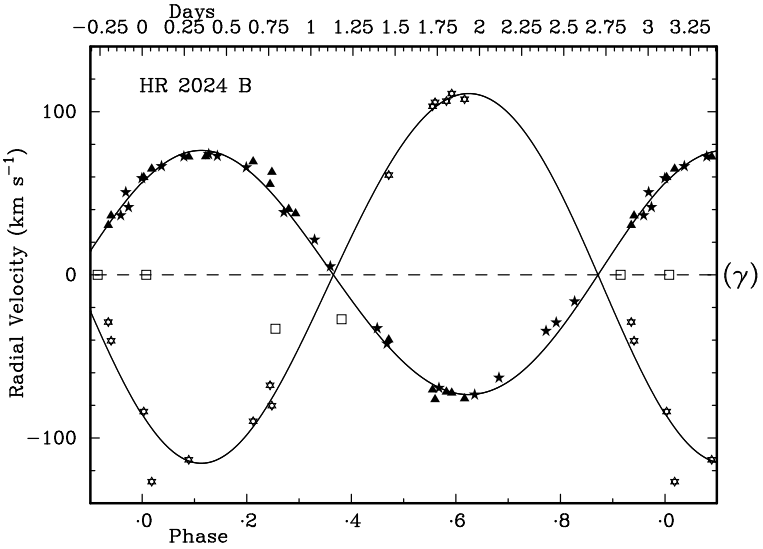
OUTER ORBIT :

$m_1 \sin^3 i = 6.245\ M_\odot$

$m_2 \sin^3 i = 7.374\ M_\odot$

Suppose $i_o = 85^o$

HR 2024

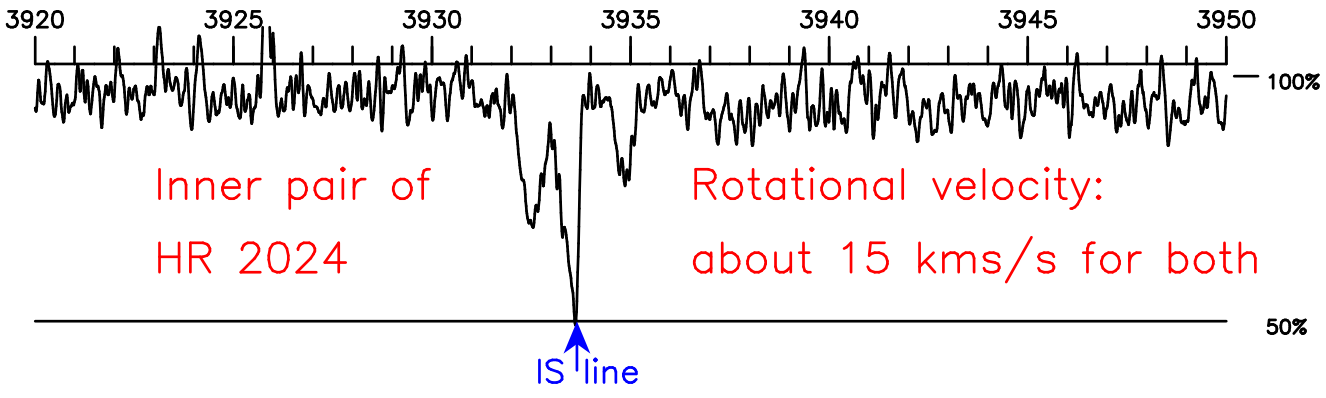


INNER ORBIT :

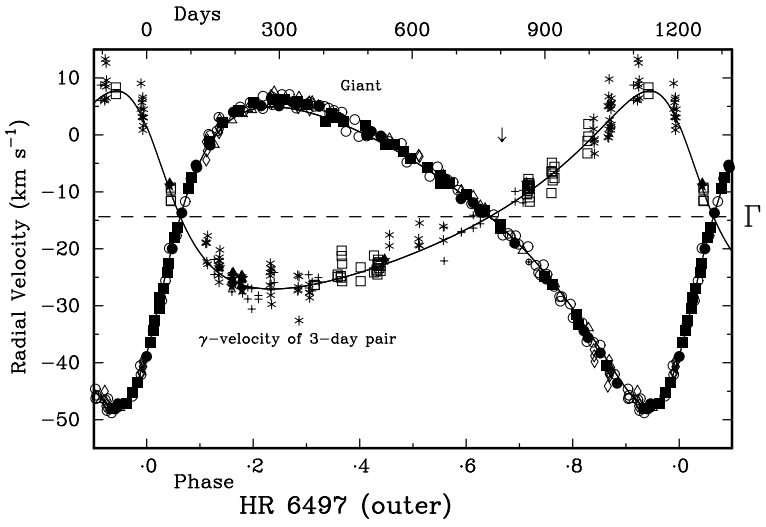
$m_1 \sin^3 i = 1.292\ M_\odot$
$m_2 \sin^3 i = 0.853\ M_\odot$

$m_1 + m_2 = 2.145\ M_\odot$

Then $i_i = 41^o$



and THE UGLY . . .



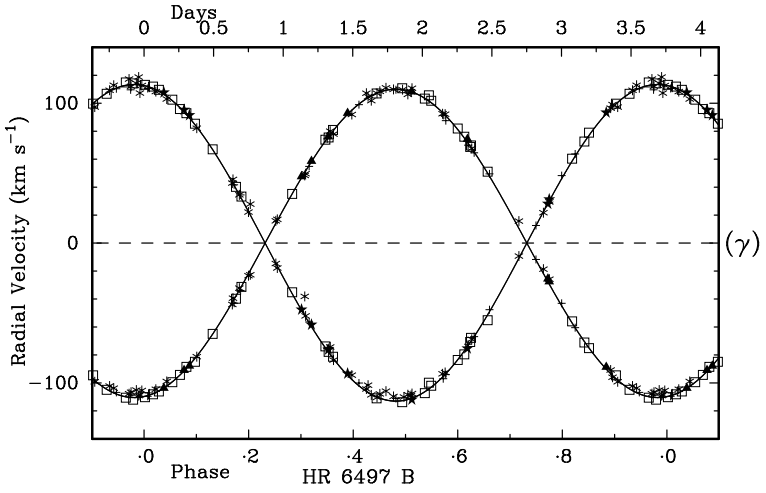
OUTER ORBIT :

$m_1 \sin^3 i = 3.06\ M_\odot$

$m_2 \sin^3 i = 4.97\ M_\odot$

We find $i_o = 80^o$

HR 6497

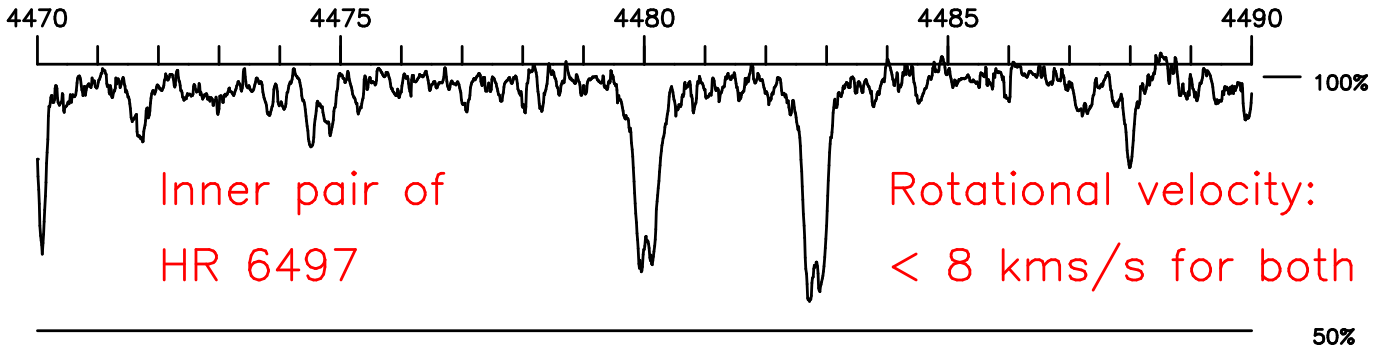


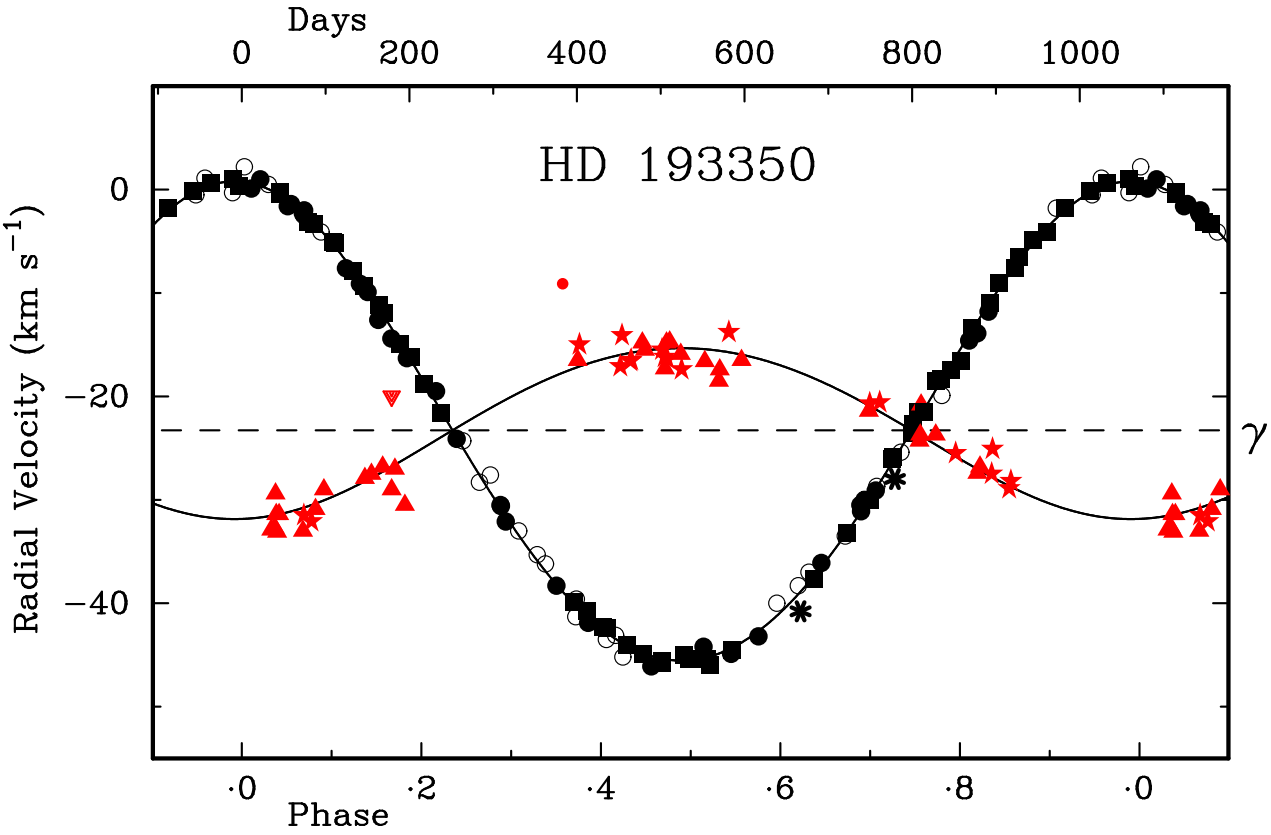
INNER ORBIT :

$m_1 \sin^3 i = 2.21\ M_\odot$
$m_2 \sin^3 i = 2.15\ M_\odot$

$m_1 + m_2 = 4.36\ M_\odot$

We find $i_i = 72^o$




Days
0
200
400
600
800
1000
HD 193350
0
−20
−40
Radial Velocity (km s^{-1})
γ
·0
·2
·4
·6
·8
·0
Phase