Simultaneous spectroscopic and photometric coverage of 2007 outburst of V455 And = HS2331+3905

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AN OBJECT THAT HAS IT ALL

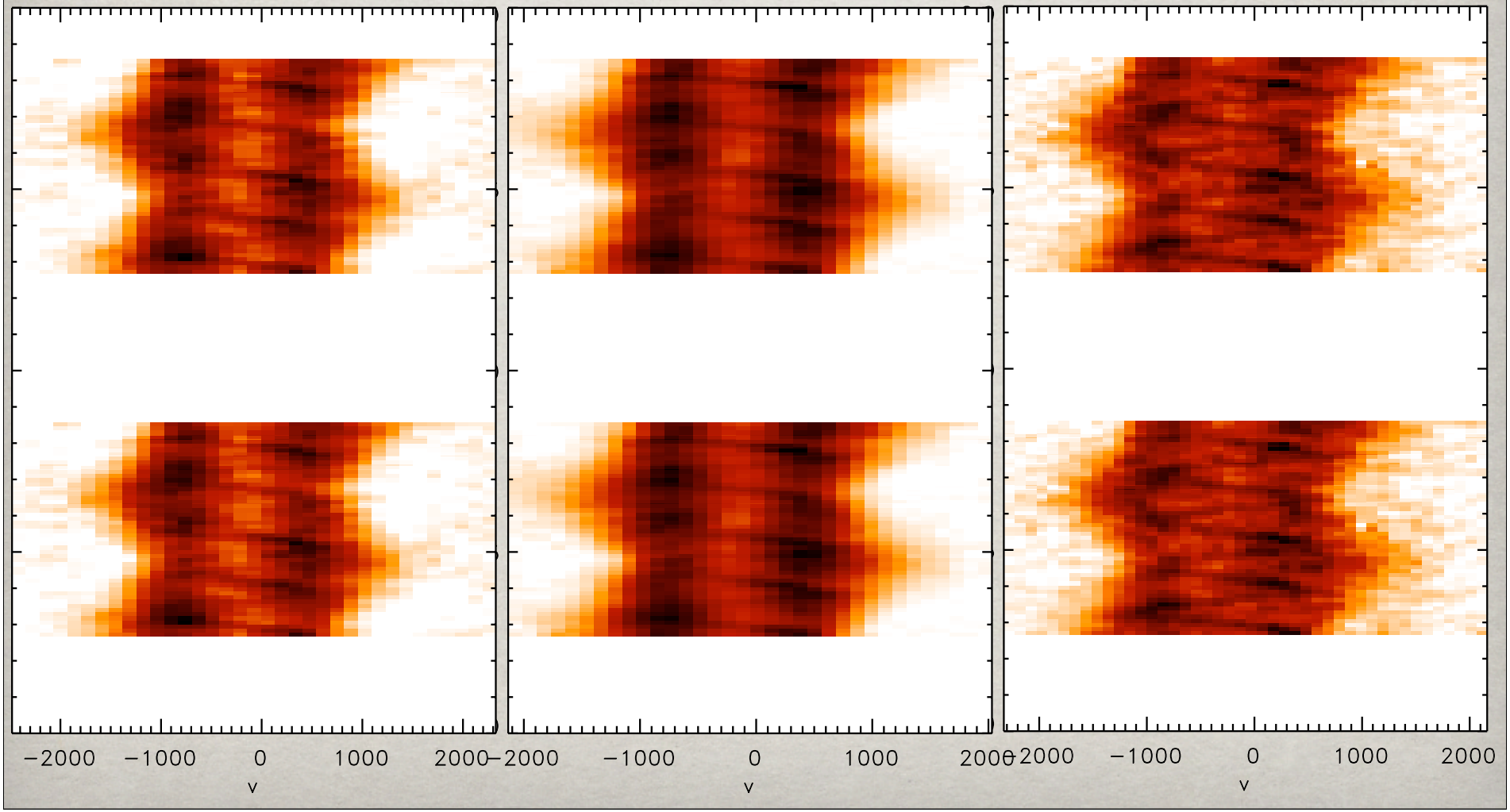
- Orbital Period: 81.08 min
- Permanent superhumps: 83.38 min (2.8% +P_{orb})
- Spin period of WD: 1.12 min
- Non-radial WD pulsations: ~ 5-6 min.
- A large-amplitude quasi-sinusoidal radial velocity modulation of the Balmer and Helium lines with a period ~3.5 h.
- Super-outburst.

Observations.

- 4.2m William Herschel Telescope. ISIS is a high-efficiency, double-armed, medium-resolution spectrograph (1.4 A).
- 2.12m San Pedro Martir. B&Ch, medium-resolution spectrograph (FWHM 1.95 - 3.2 A resolution).
- 2.12m San Pedro Martir. Echelle, high-resolution spectrograph (0.4 A).

August 12, 2007; JD 2454324

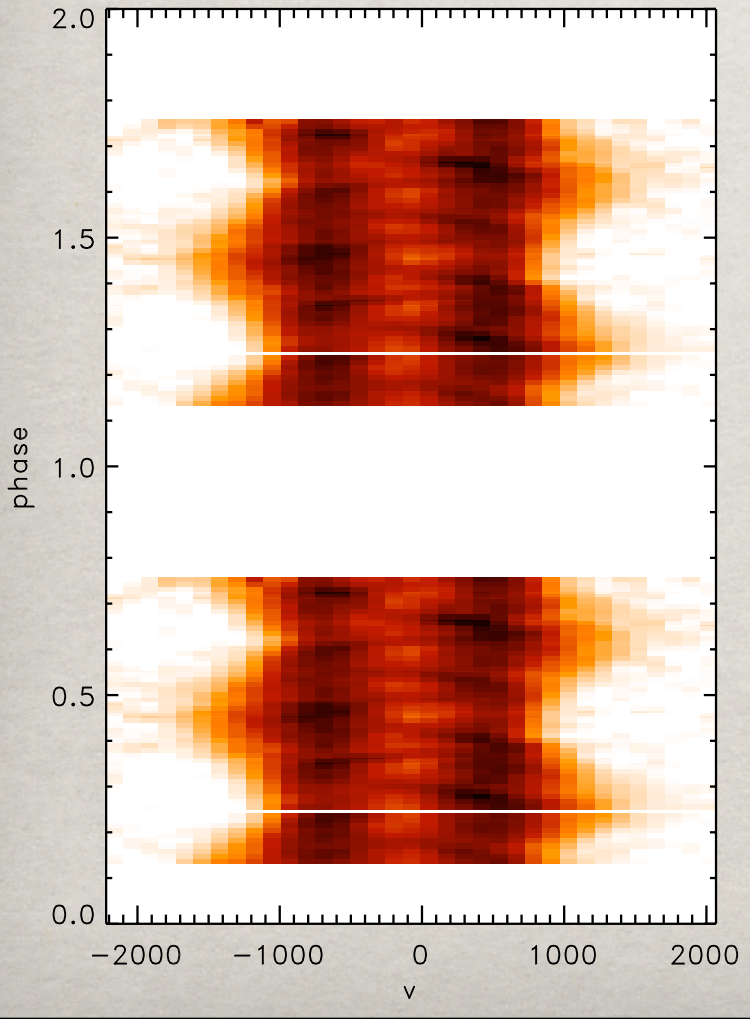
- The system is in quiescence, displaying its spectacular double period in trailed spectra.

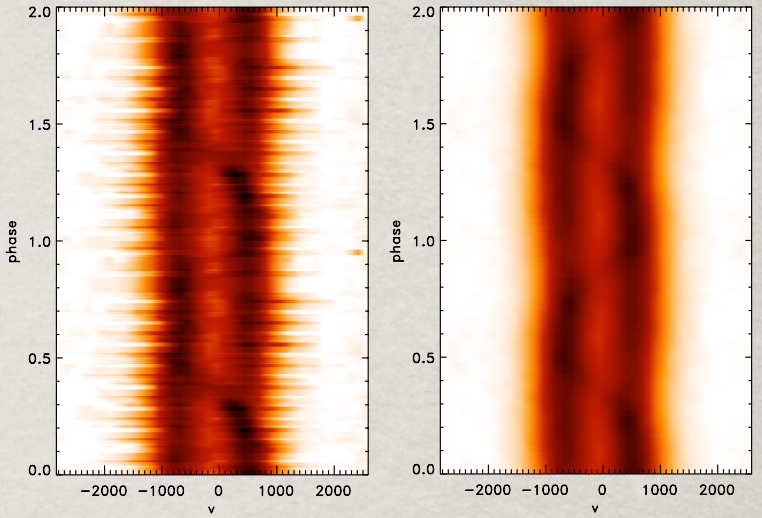


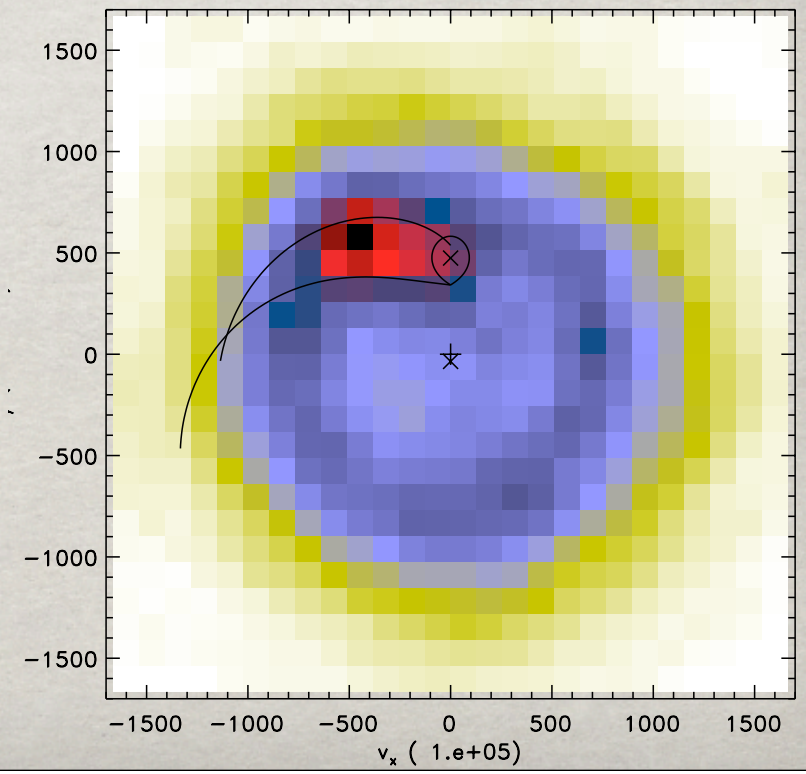
August 30, 2007; JD 2454342

- Six nights before the outburst, similar picture

Hβ

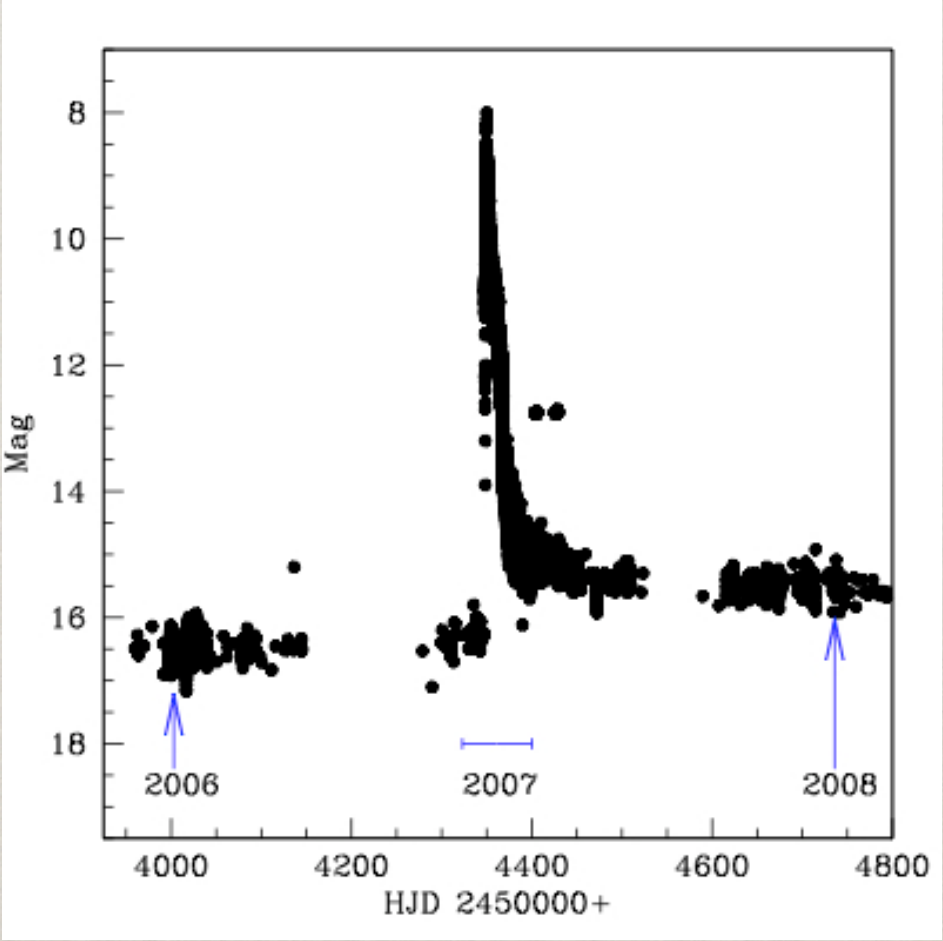






V455 And, the Outburst

- This is probably the best spectroscopic coverage of the WZ Sge type superoutburst, or even any DN outburst. Particularly, the onset of the outburst is the most difficult to catch.



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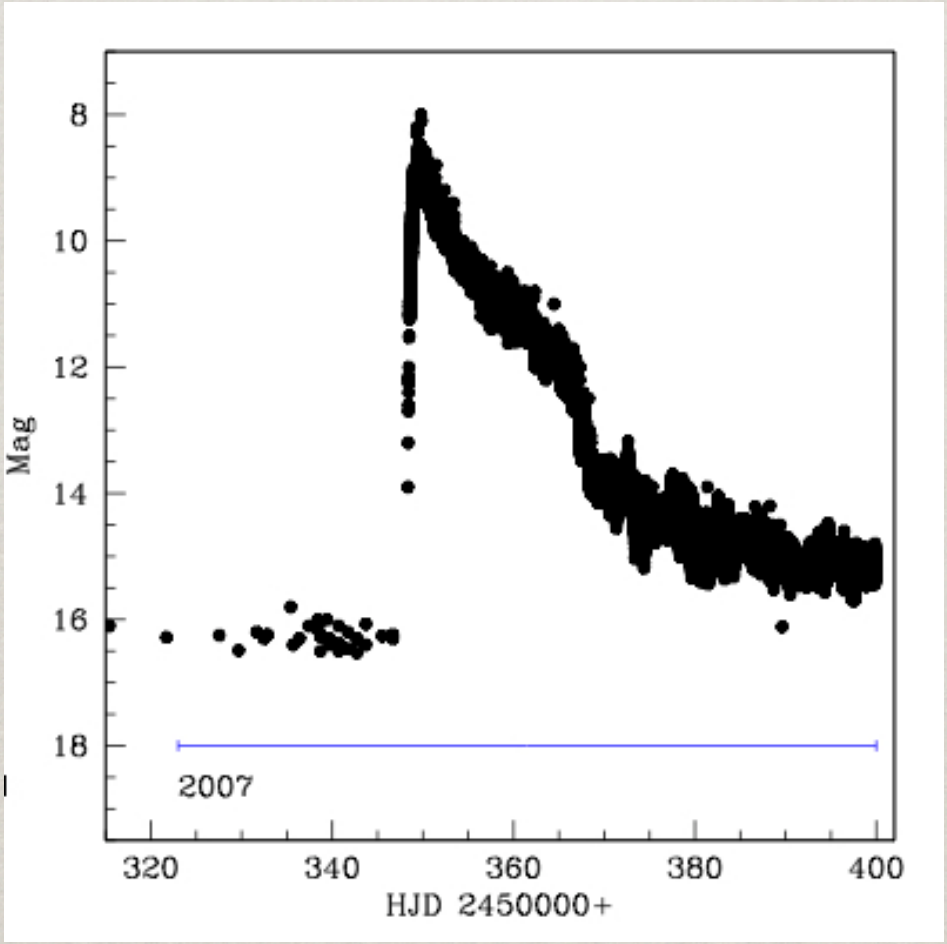
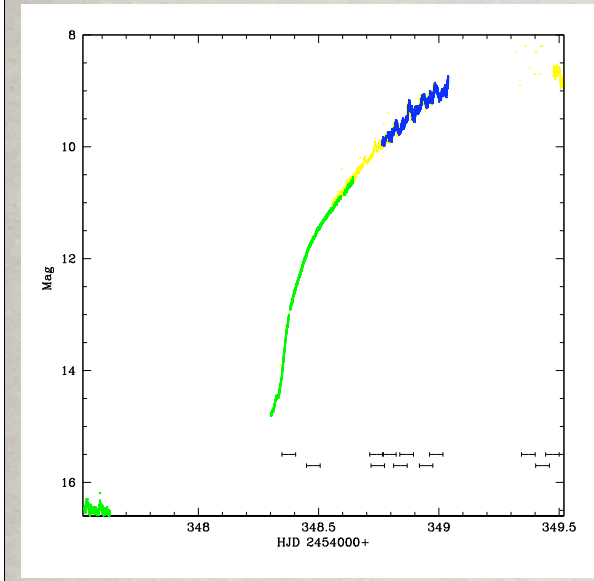




- spectral observations started when the system has brightened only 1.5 mag (out of 8 mag super outburst)

- it is widely believed that DNe outbursts are both due to a thermal/viscous instability of the accretion disc triggered when hydrogen becomes partially ionized (Osaki 1996; Lasota 2001). In this picture, the accretion disc performs a limit cycle between a cold, quiescent state of low accretion rate and a hot, viscous state of high accretion rate corresponding to the outburst.

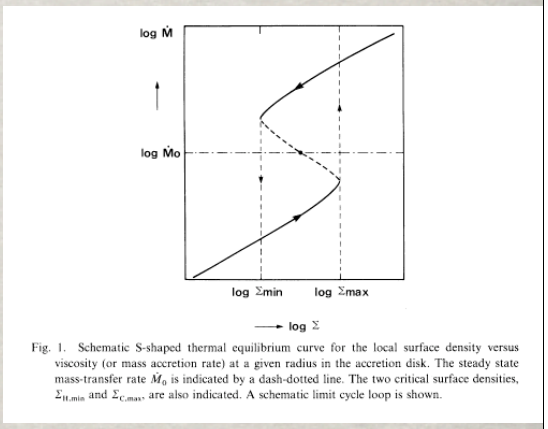


Fig. 1. Schematic S-shaped thermal equilibrium curve for the local surface density versus viscosity (or mass accretion rate) at a given radius in the accretion disk. The steady state mass-transfer rate $\dot{M}_0$ is indicated by a dash-dotted line. The two critical surface densities, $\Sigma_{H,min}$ and $\Sigma_{C,max}$, are also indicated. A schematic limit cycle loop is shown.

- it is also believed that there are two types of outbursts (Smak 1984). The systems with high $\partial m/\partial t$ undergo outside-in kind of outburst, while in low MTR accretion disks the thermal instability first sets in at the inner-most region and propagates to the out.

- In order to explain super outbursts, Osaki (1989) combined thermal instability and tidal instability models (Paczinski 1977, Whitehurst 1988) to allow the disk growth beyond critical radius throughout normal outbursts.

- However WZ Sge objects does not have series of normal outbursts in between super-outburst and the later recurrence time is extremely long.

- Such long occurrence times were obtained by lowering the viscosity of the accretion disk from usual $\alpha_{cold} \sim 0.03$ to $\alpha_{cold} \sim 0.001$ (Smak 1993, Osaki 1994, Howell et al 1995). The low viscosity also helped to simulate light curve of WZ Sge type super-outburst closely resembling to the one we observed in V455 And.

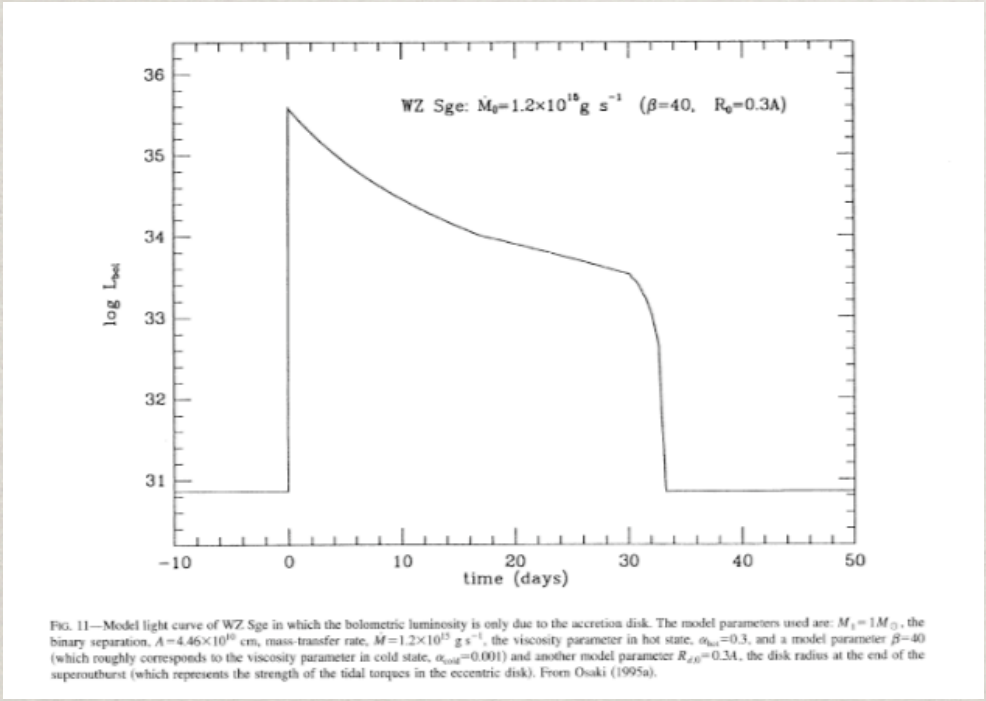
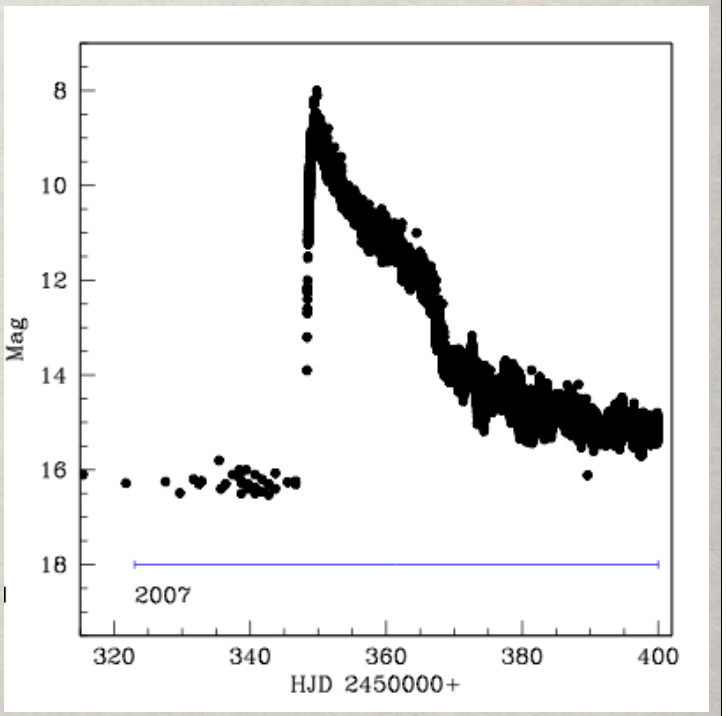
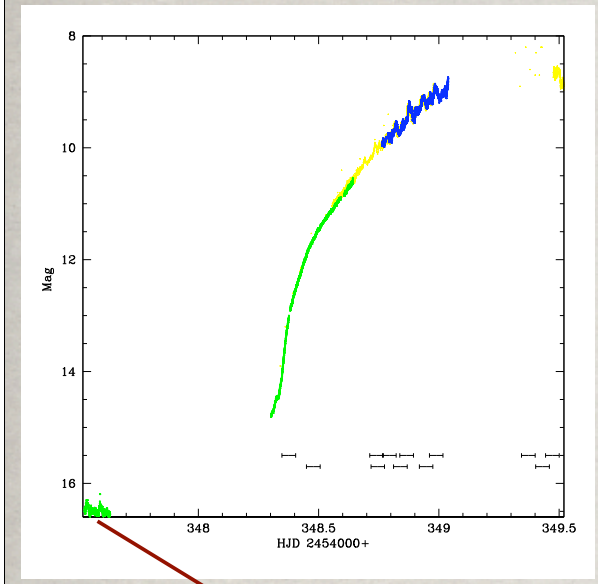
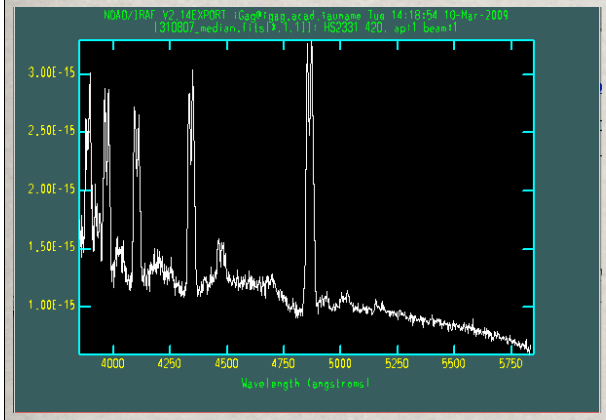


FIG. 11—Model light curve of WZ Sge in which the bolometric luminosity is only due to the accretion disk. The model parameters used are: $M_1 = 1M_\odot$, the binary separation, $A = 4.46 \times 10^{10}$ cm, mass-transfer rate, $M = 1.2 \times 10^{15}$ g s^{-1}, the viscosity parameter in hot state, $\alpha_{hot} = 0.3$, and a model parameter $\beta = 40$ (which roughly corresponds to the viscosity parameter in cold state, $\alpha_{cold} = 0.001$) and another model parameter $R_{fo} = 0.3A$, the disk radius at the end of the superoutburst (which represents the strength of the tidal torques in the eccentric disk). From Osaki (1995a).



Pre-outburst: JD 2454342





THE START: JD 2454348

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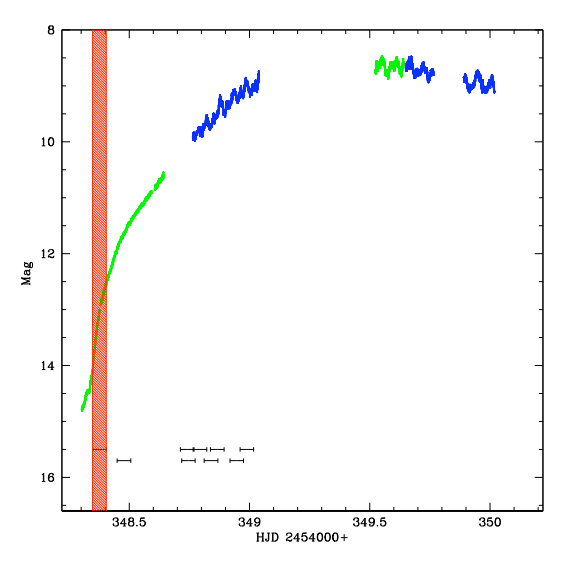

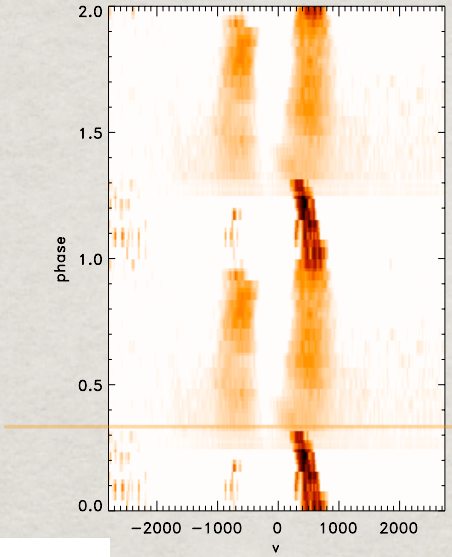

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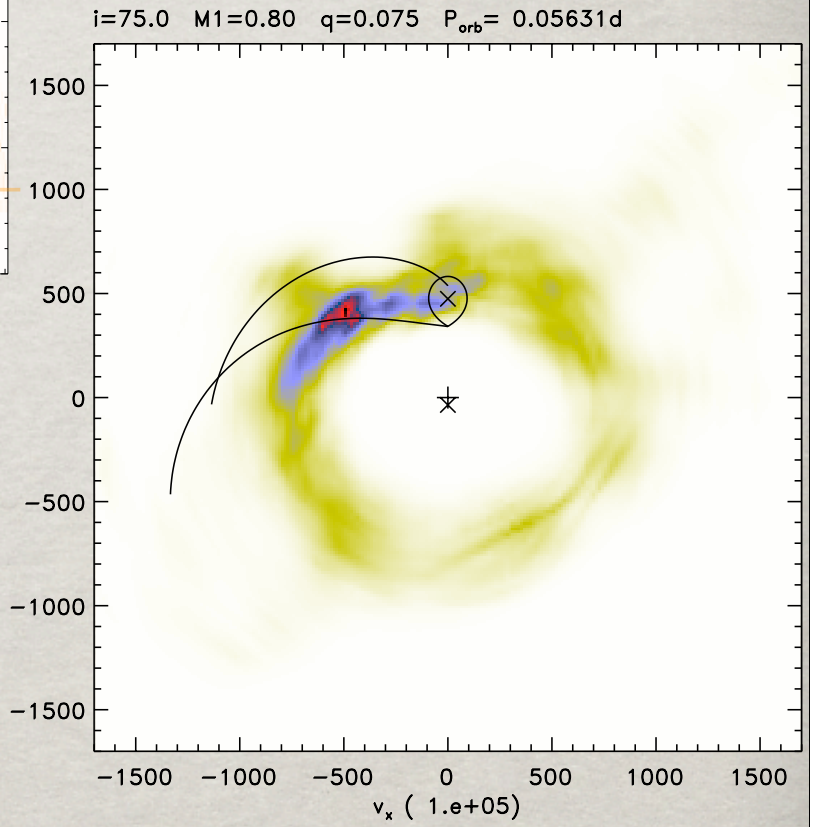

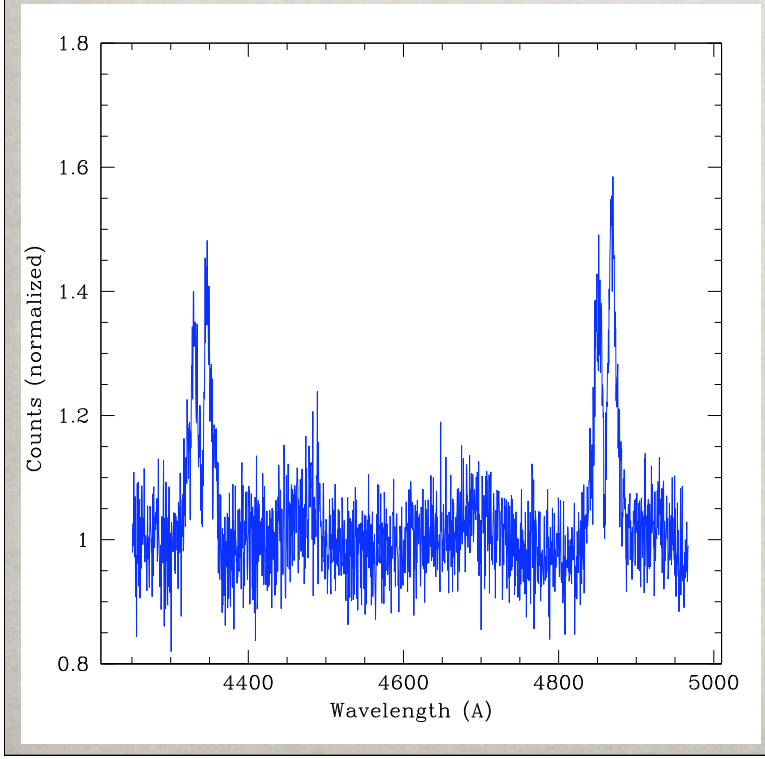

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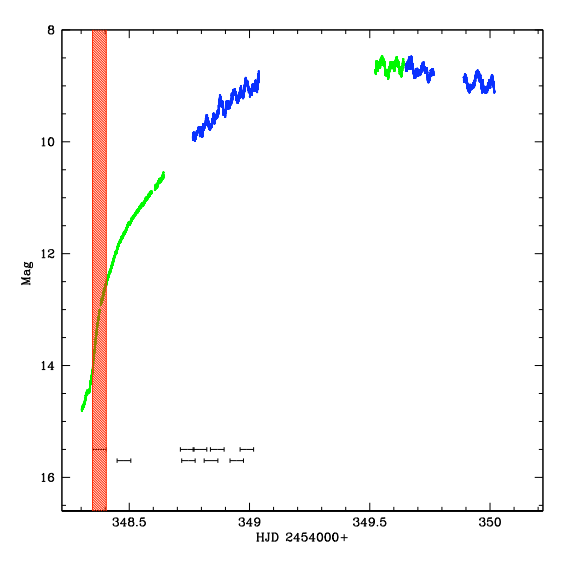

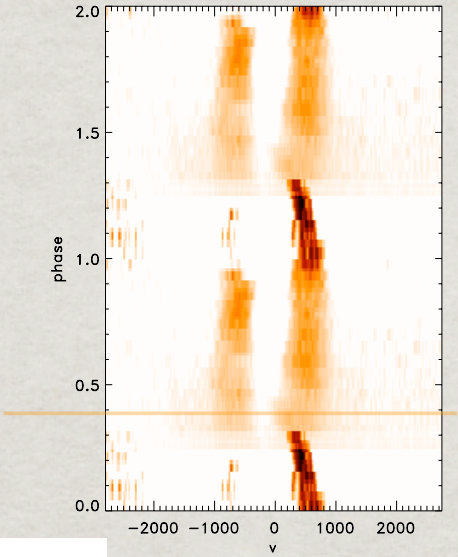

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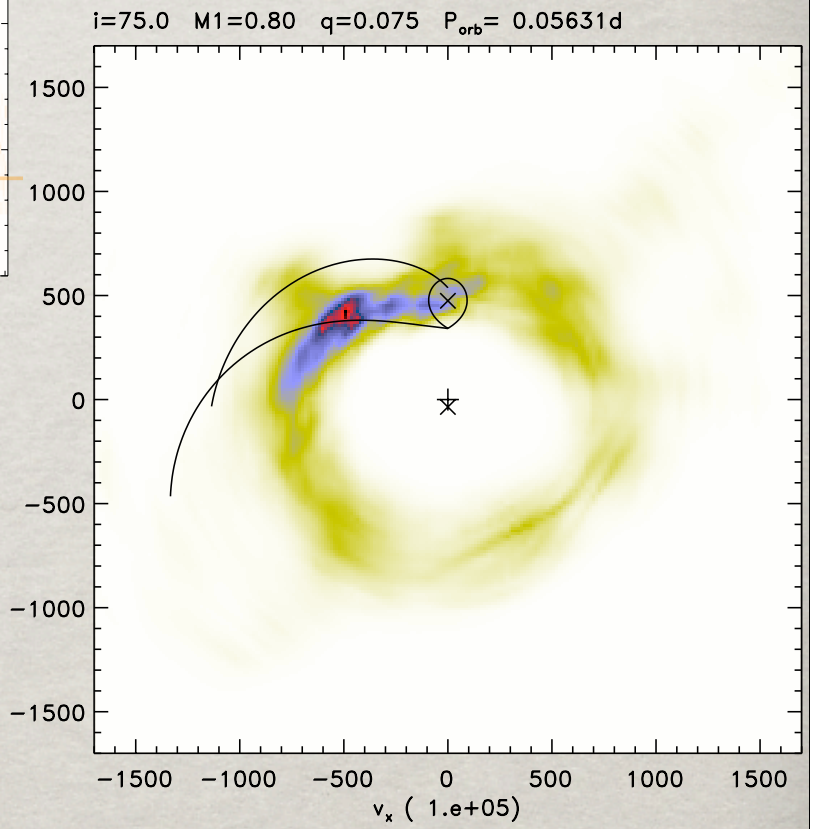

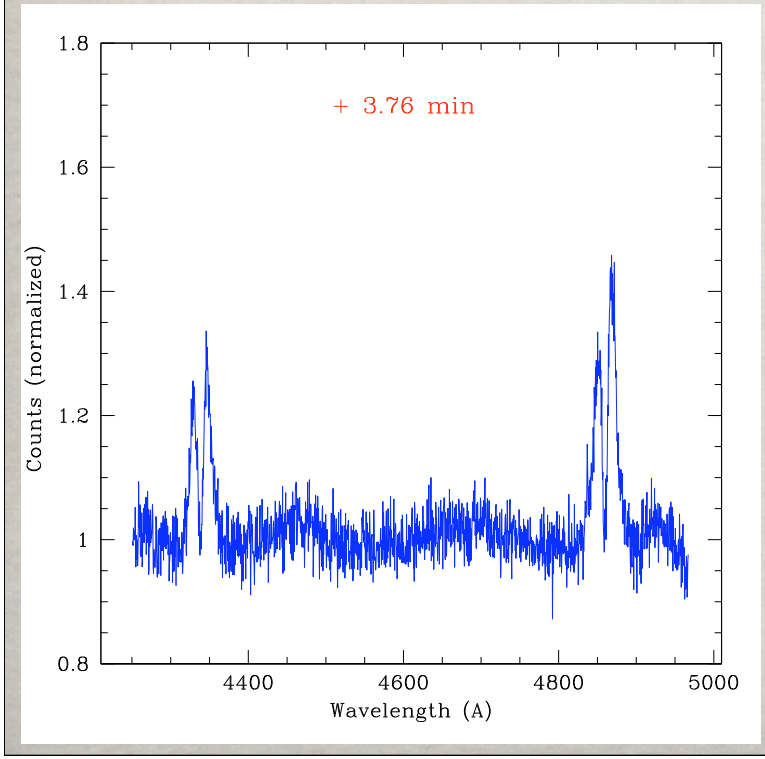

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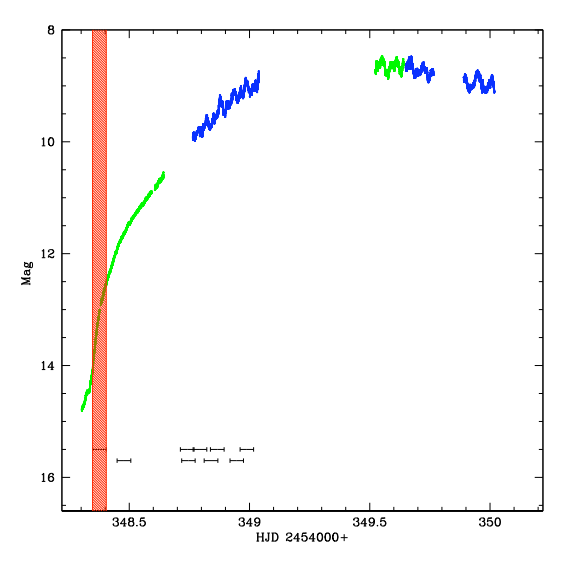

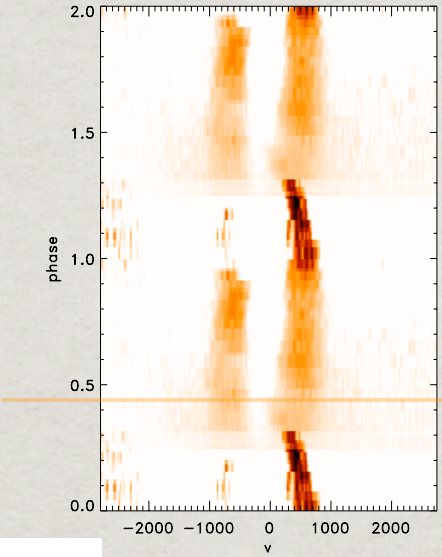

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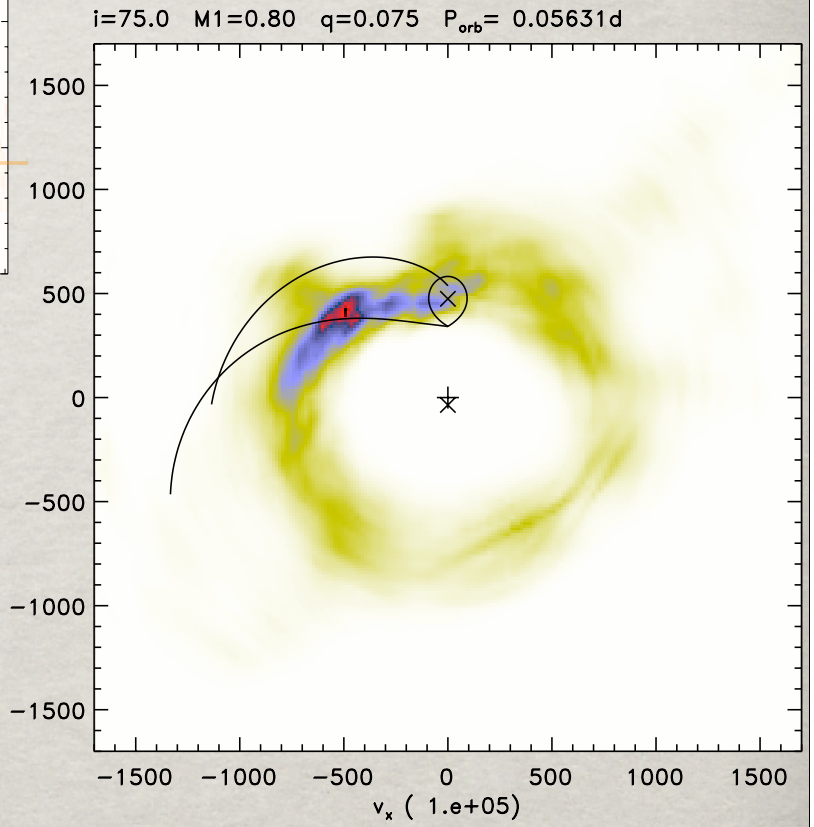

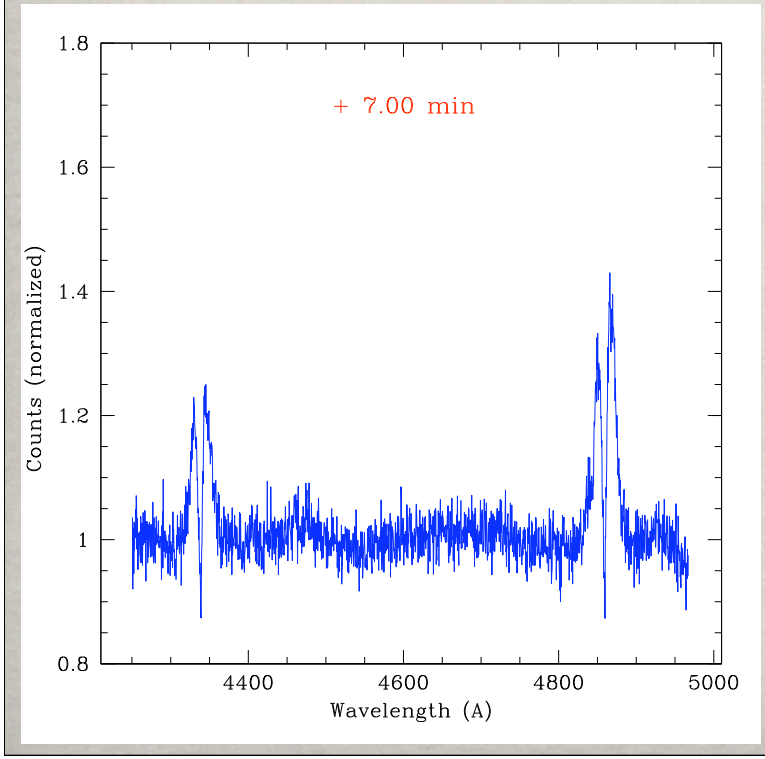

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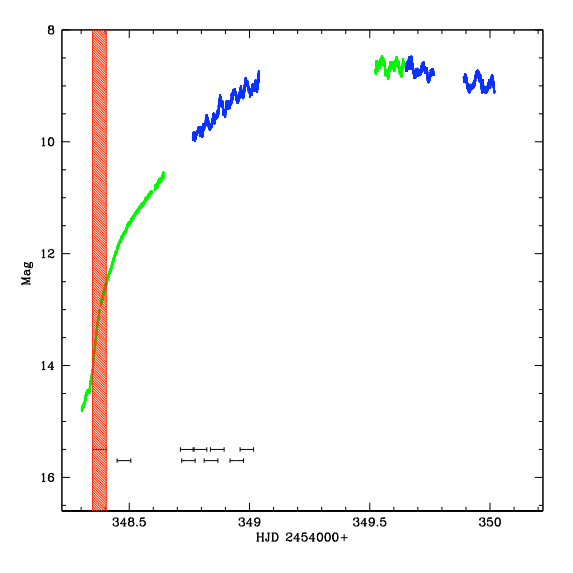

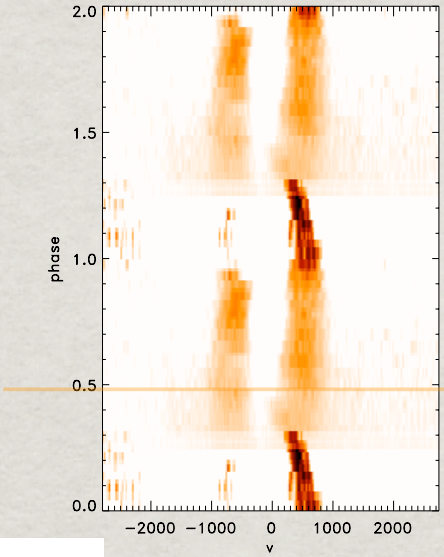

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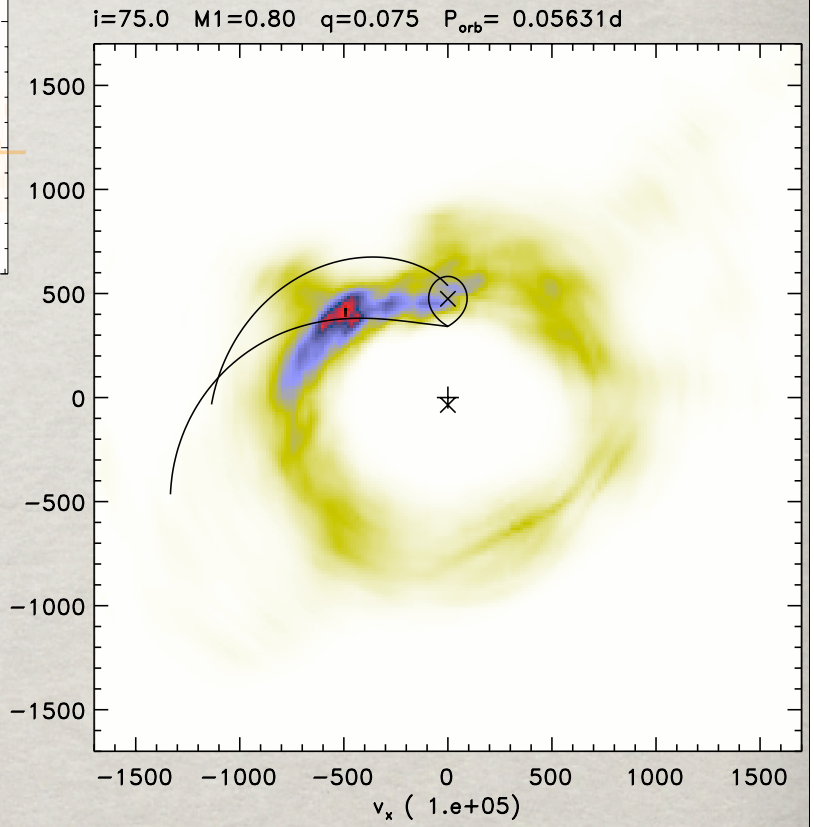

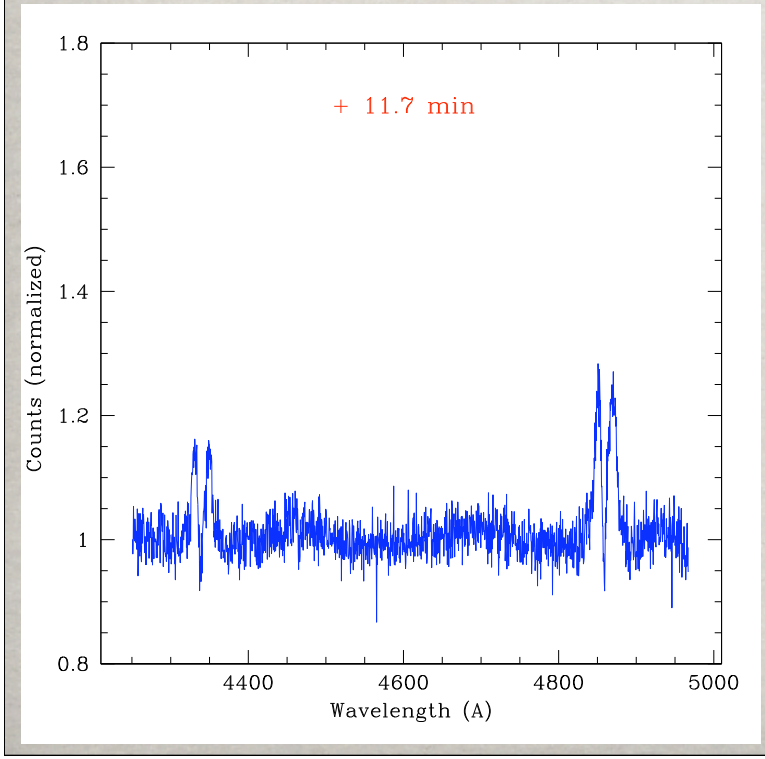

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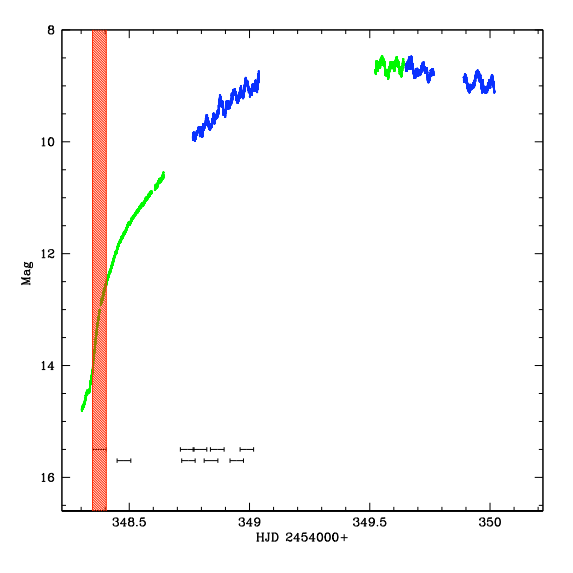

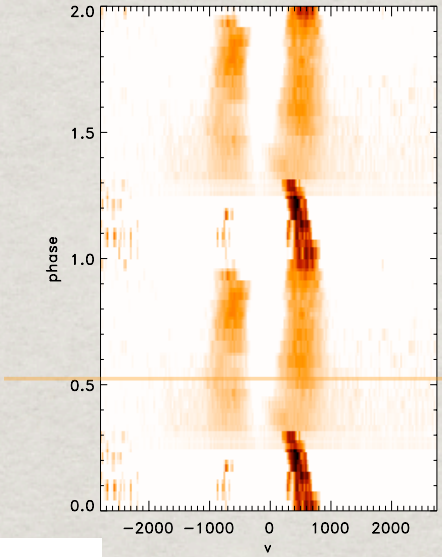

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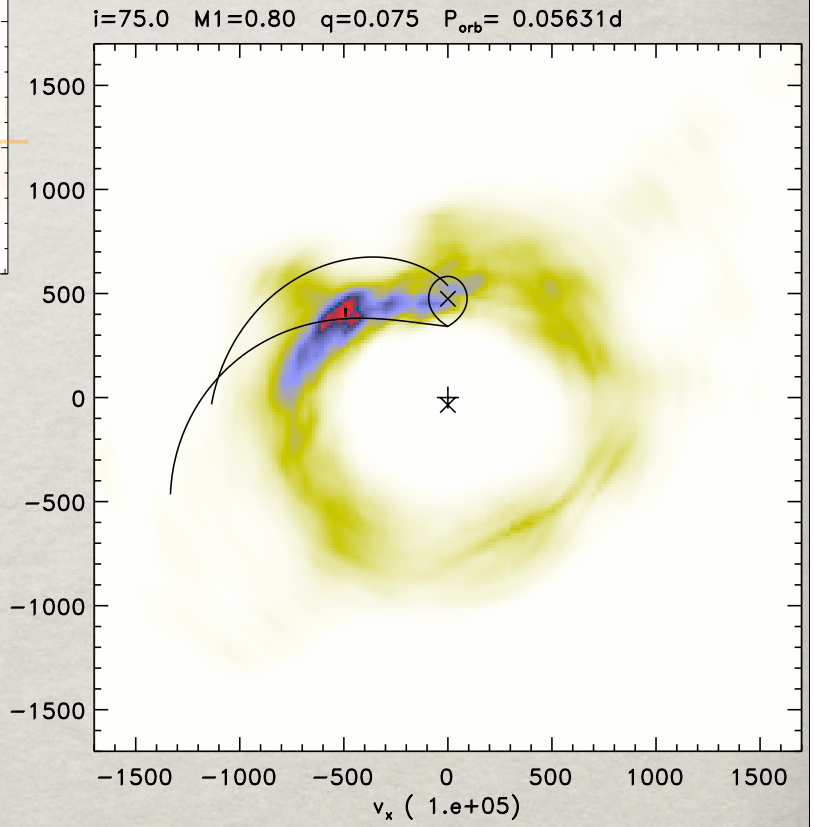

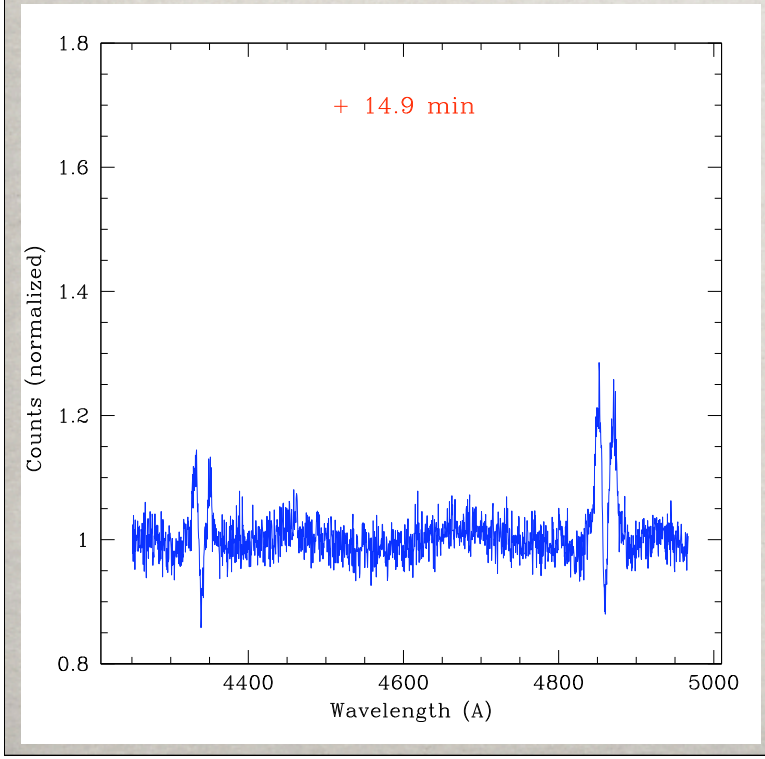

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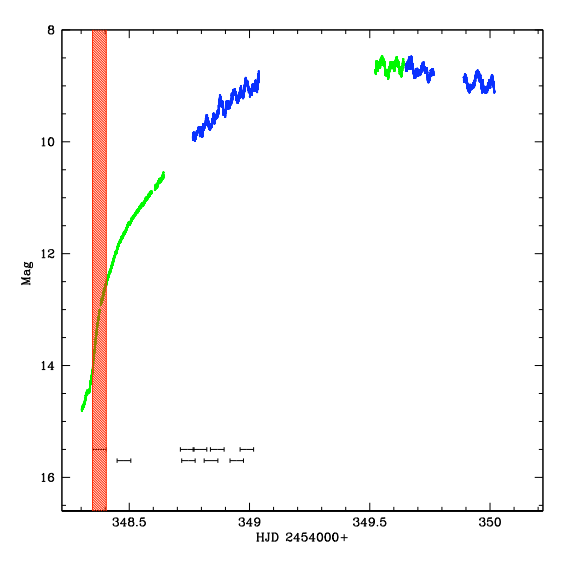

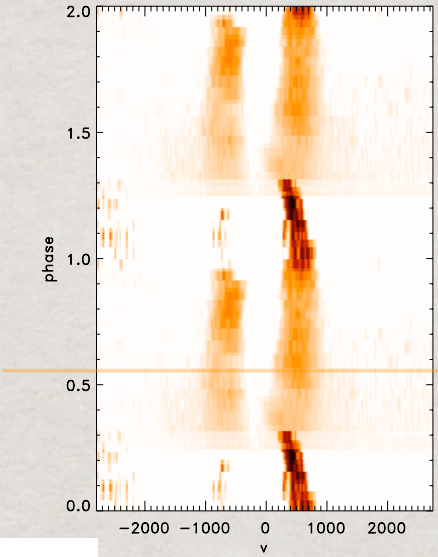

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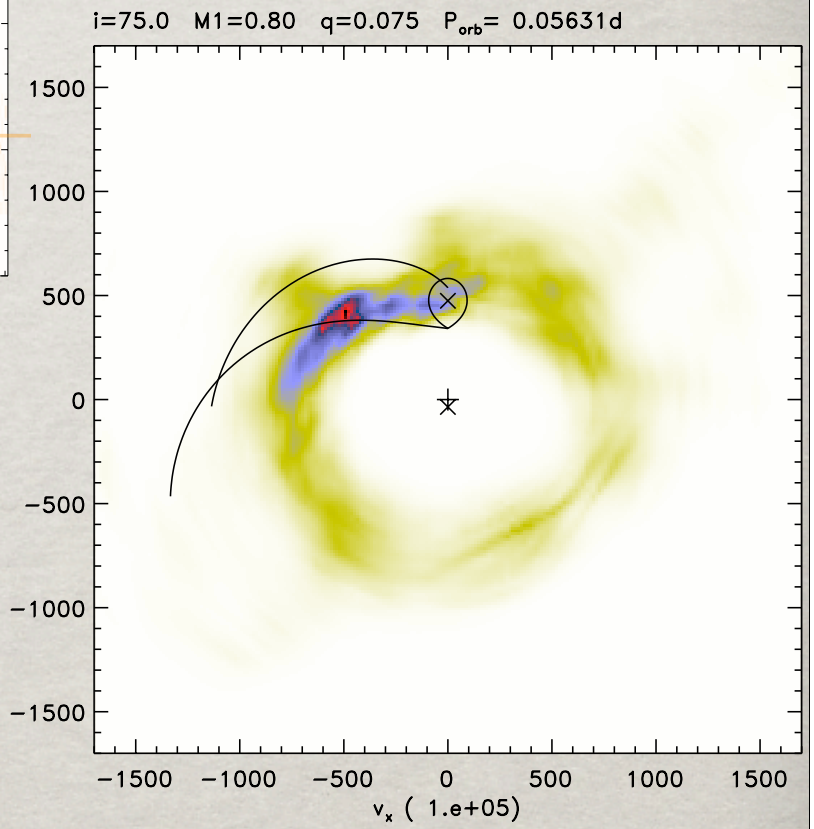

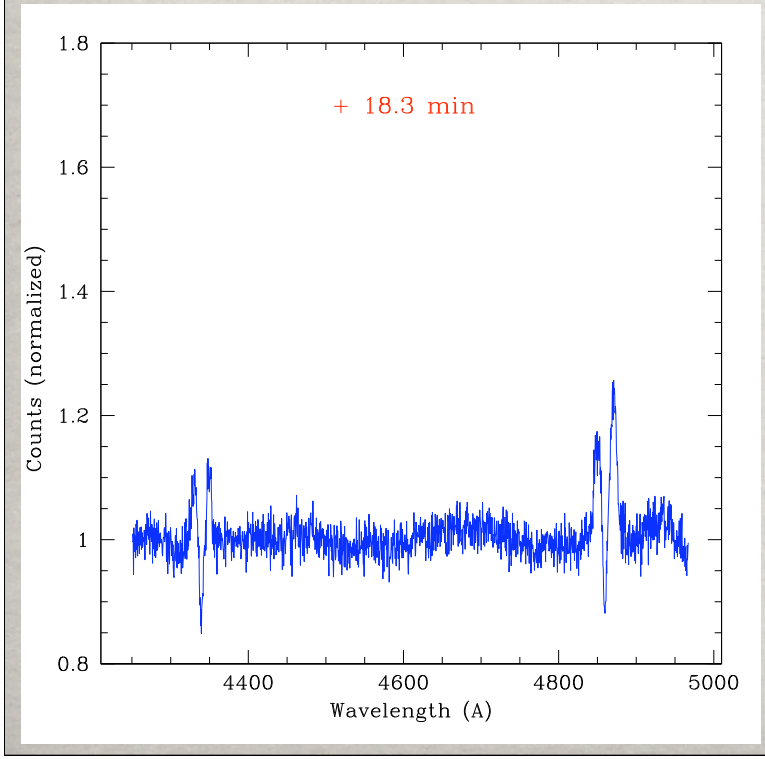

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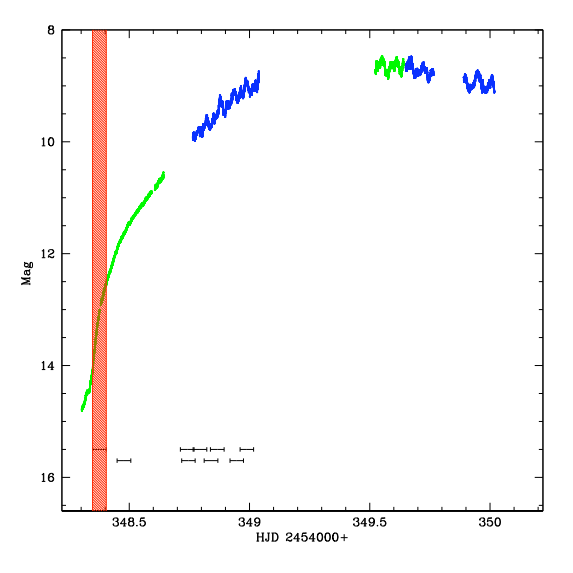

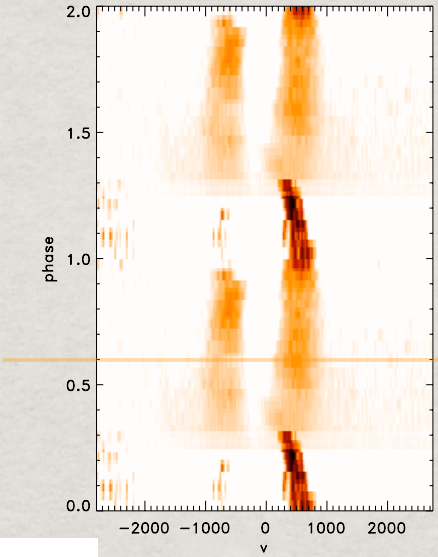

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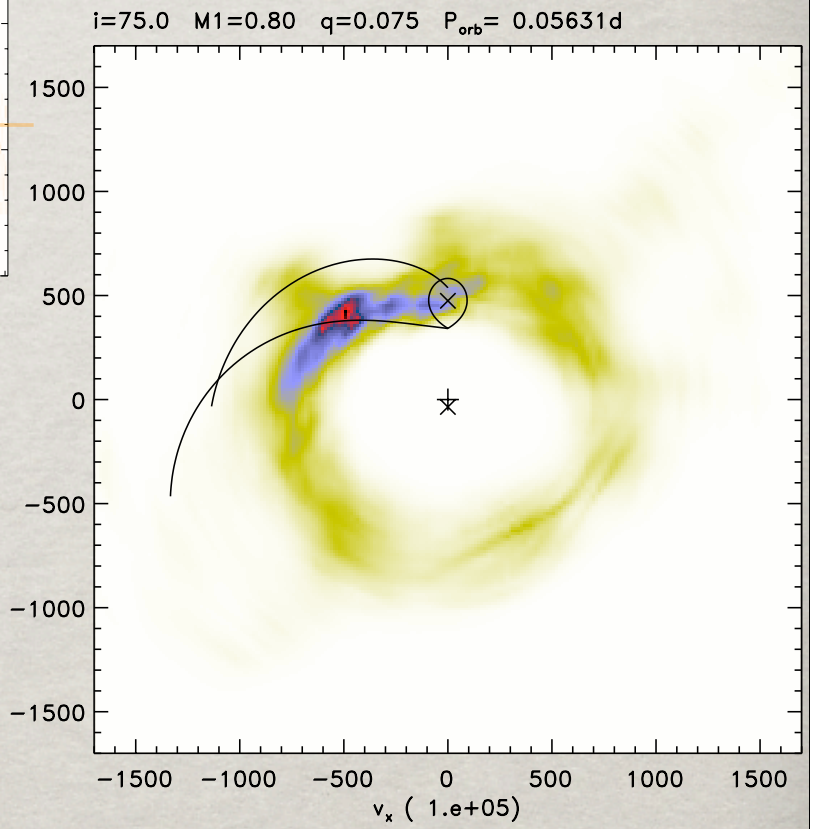

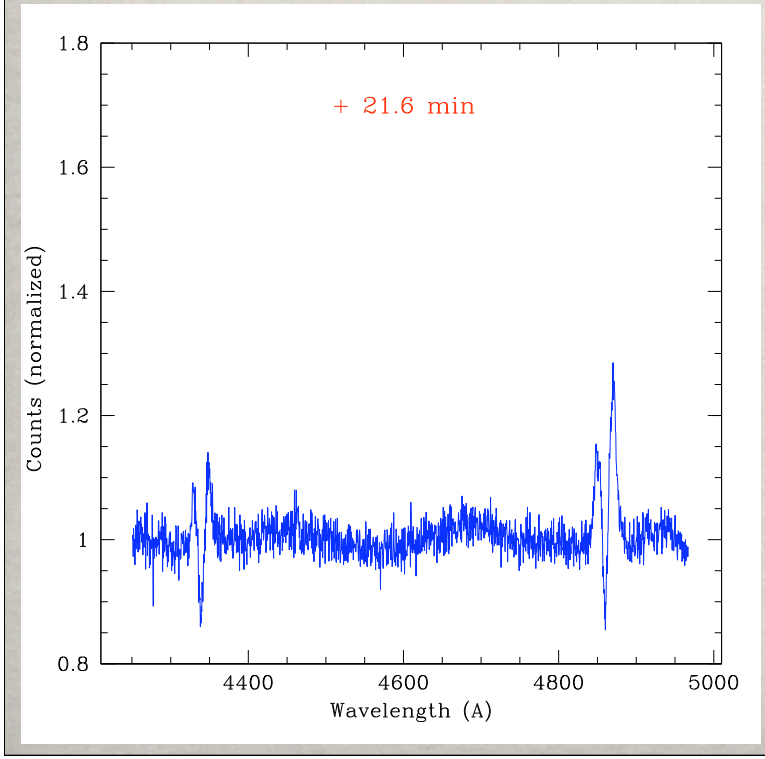

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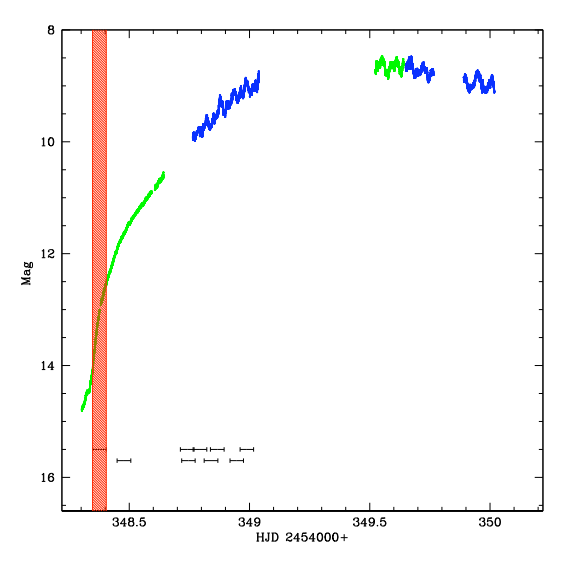

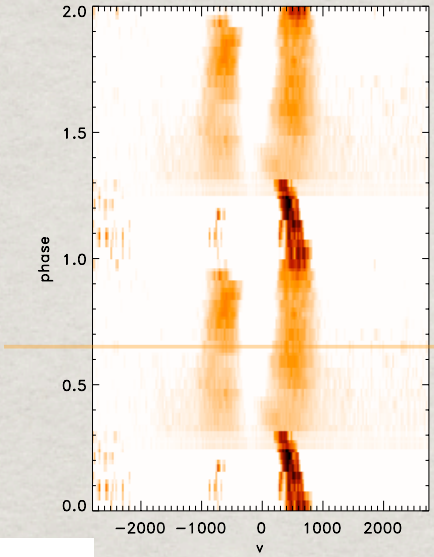

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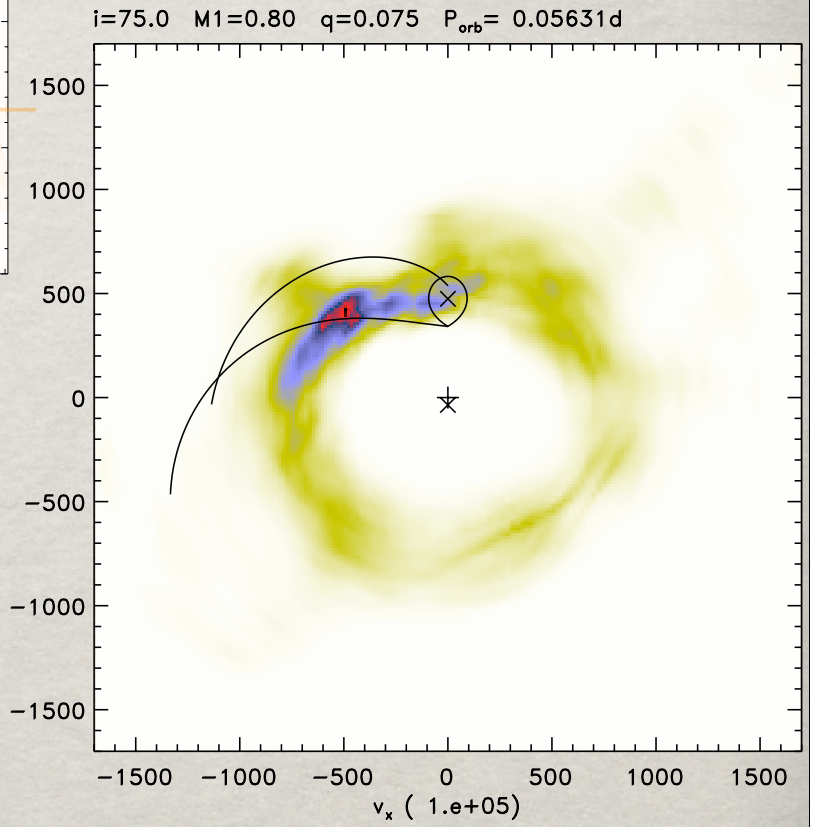

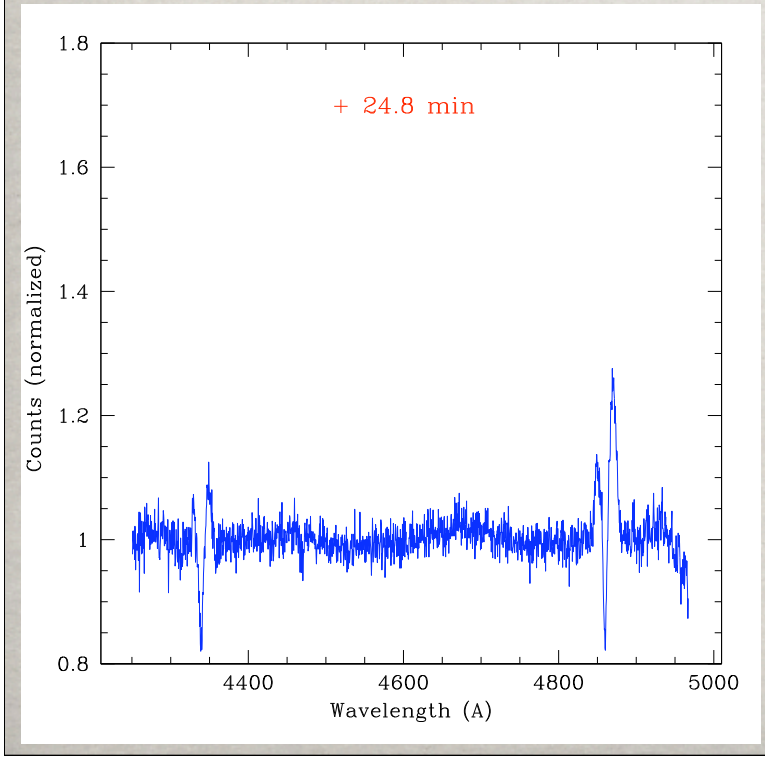

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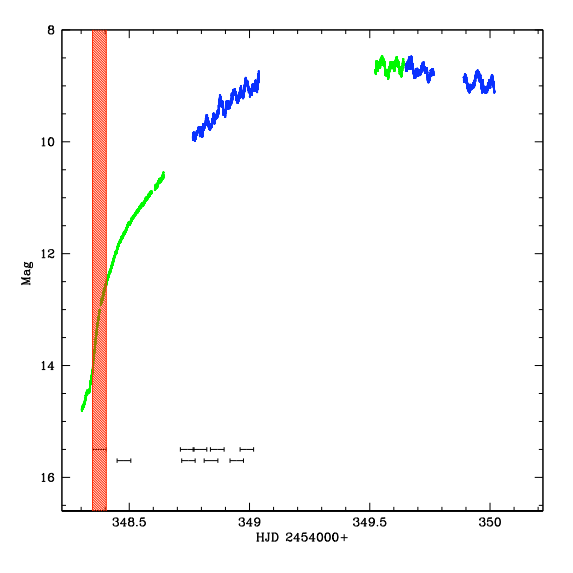

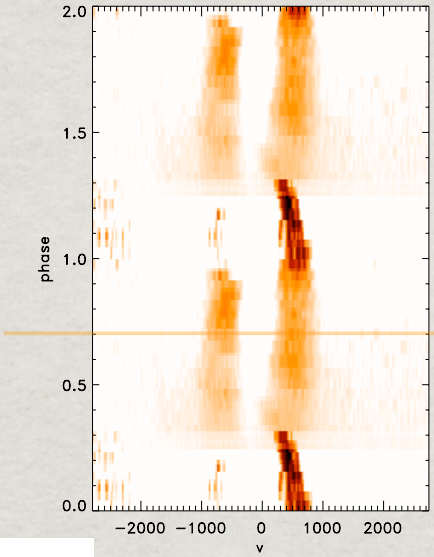

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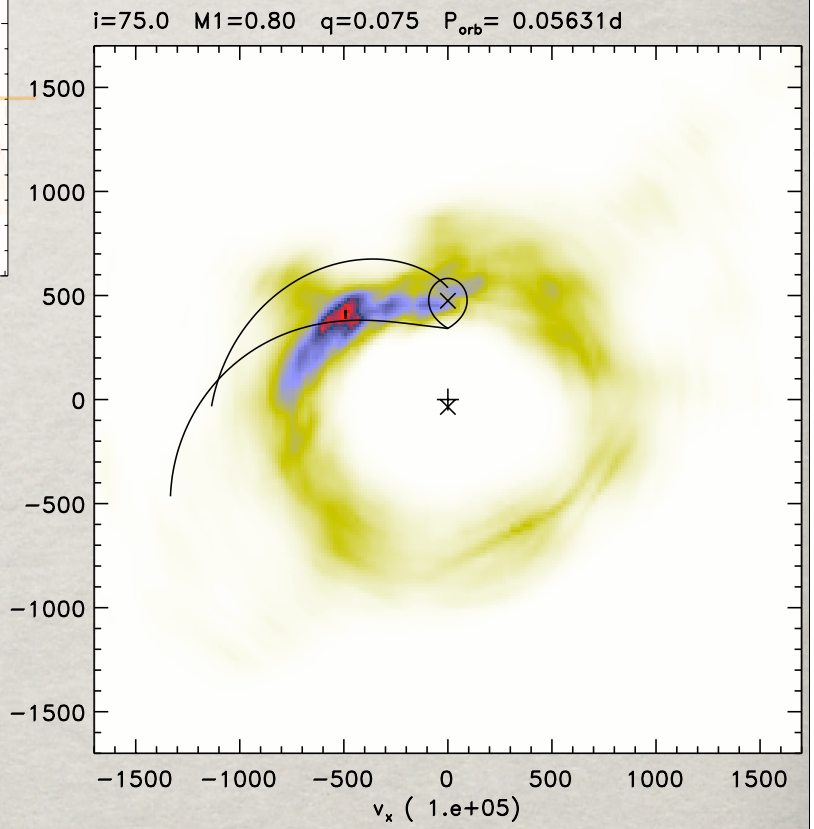

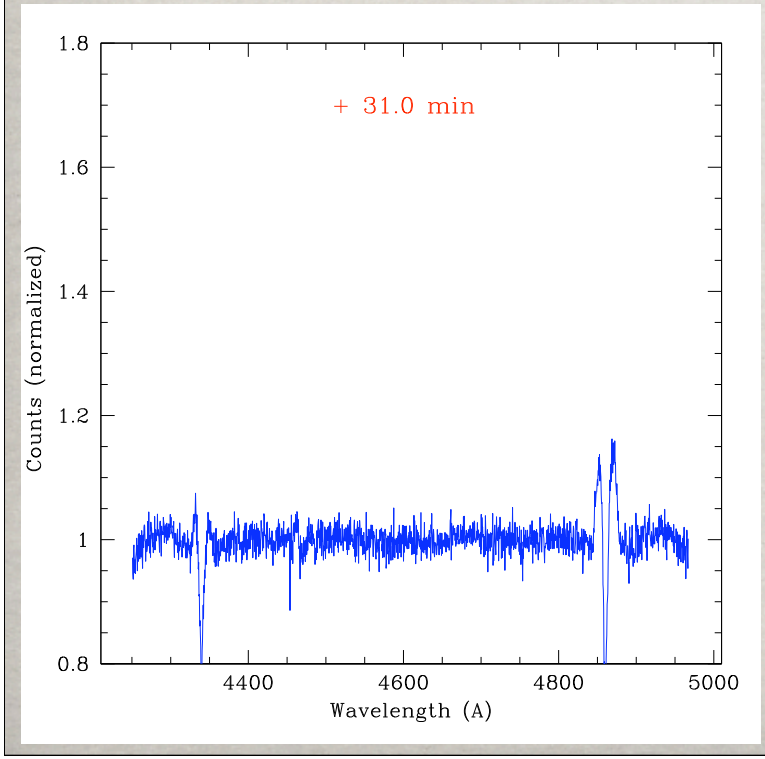

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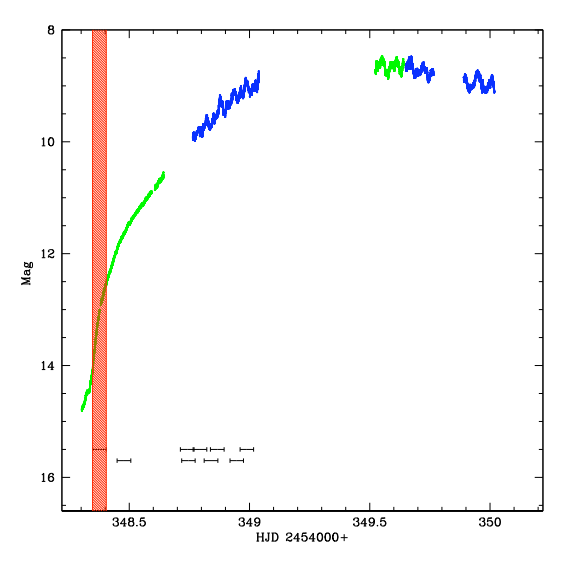
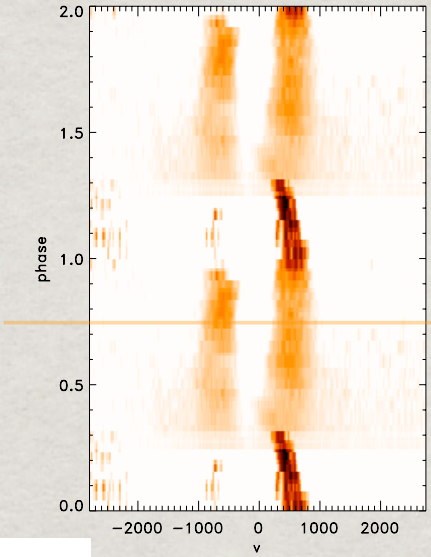
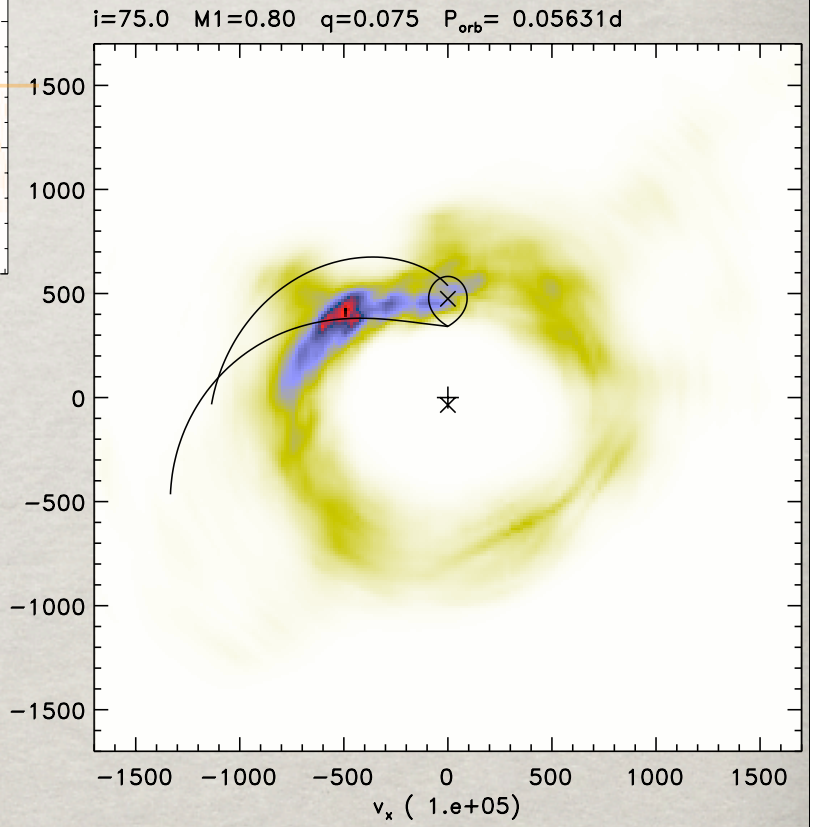
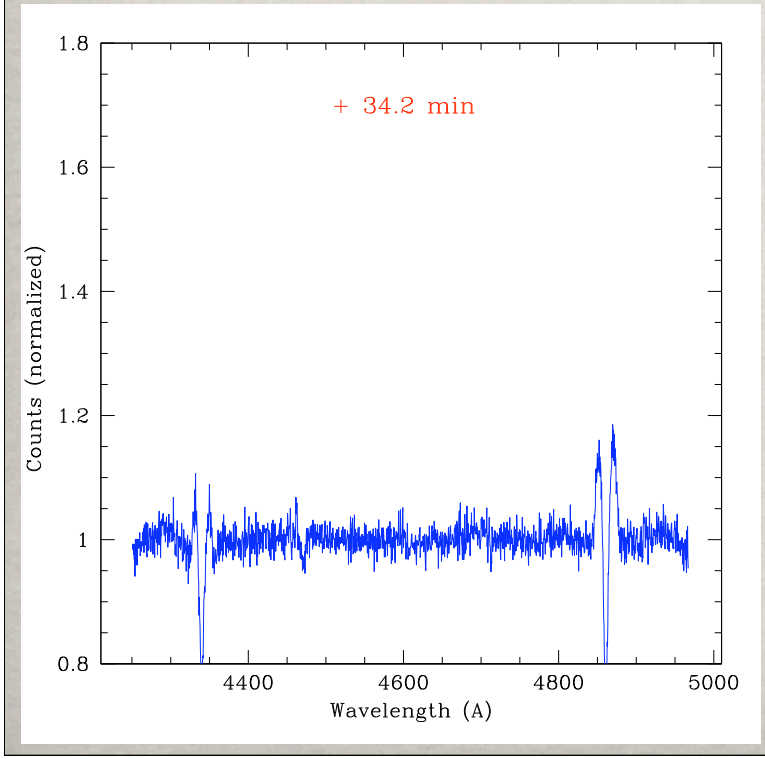




Hβ emission component





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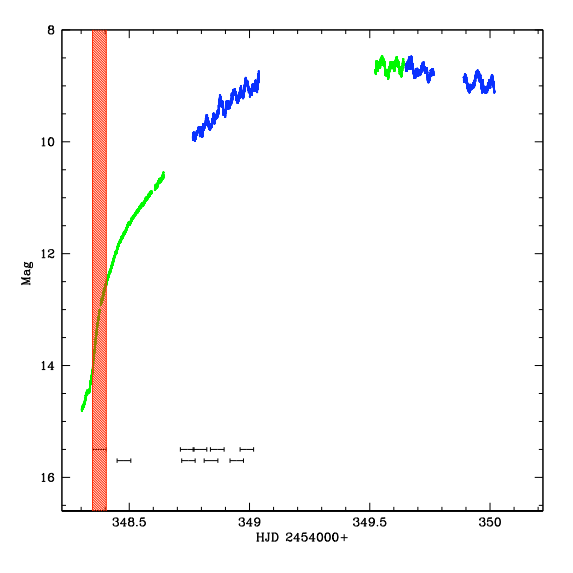

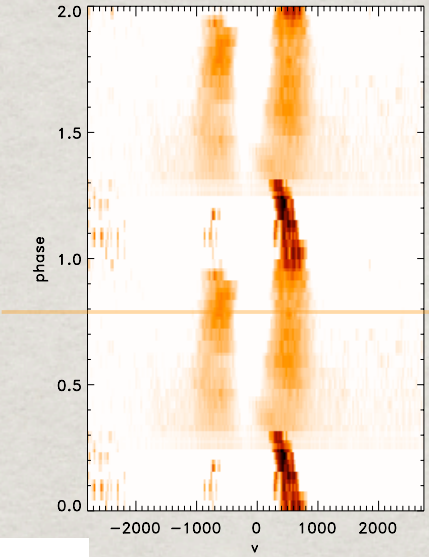

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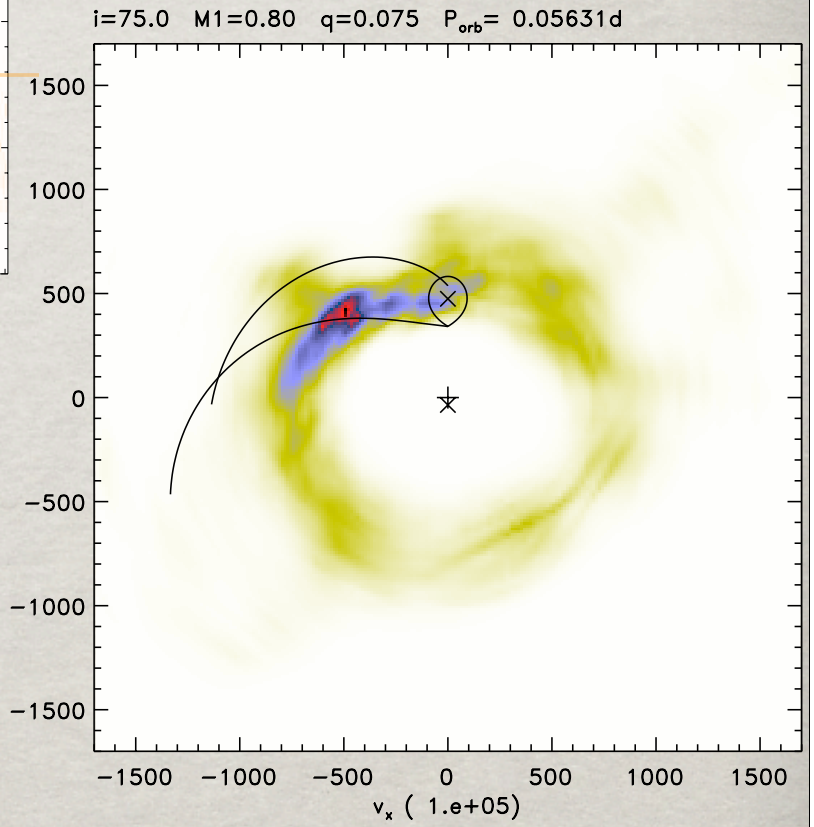

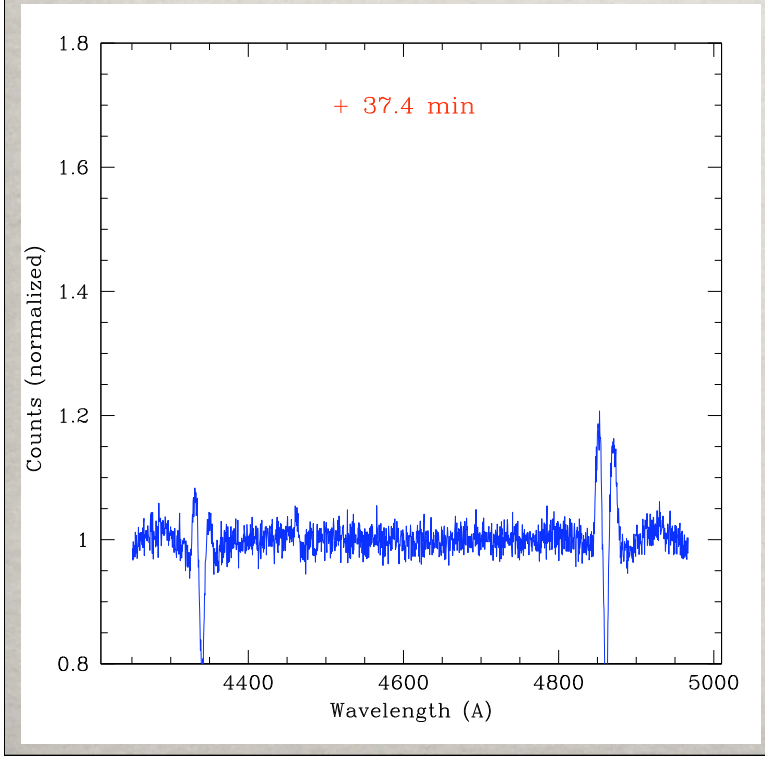

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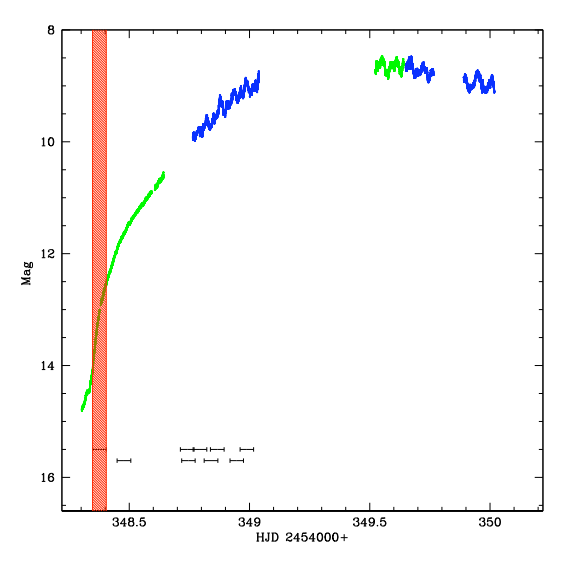

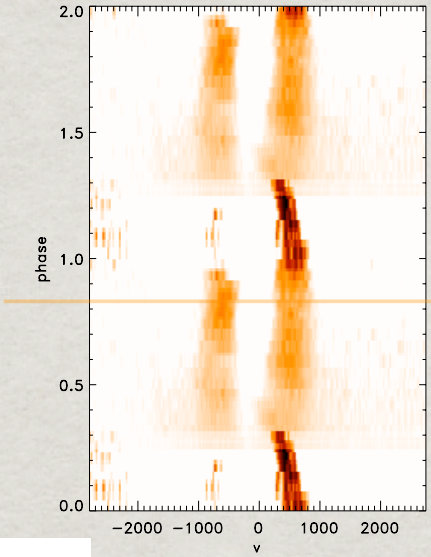

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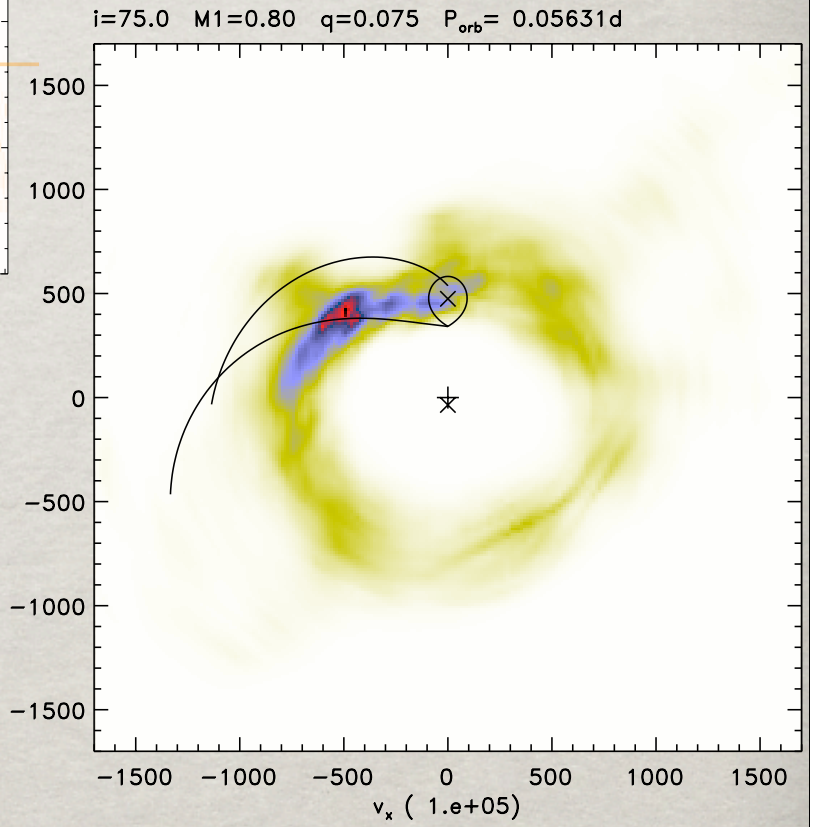

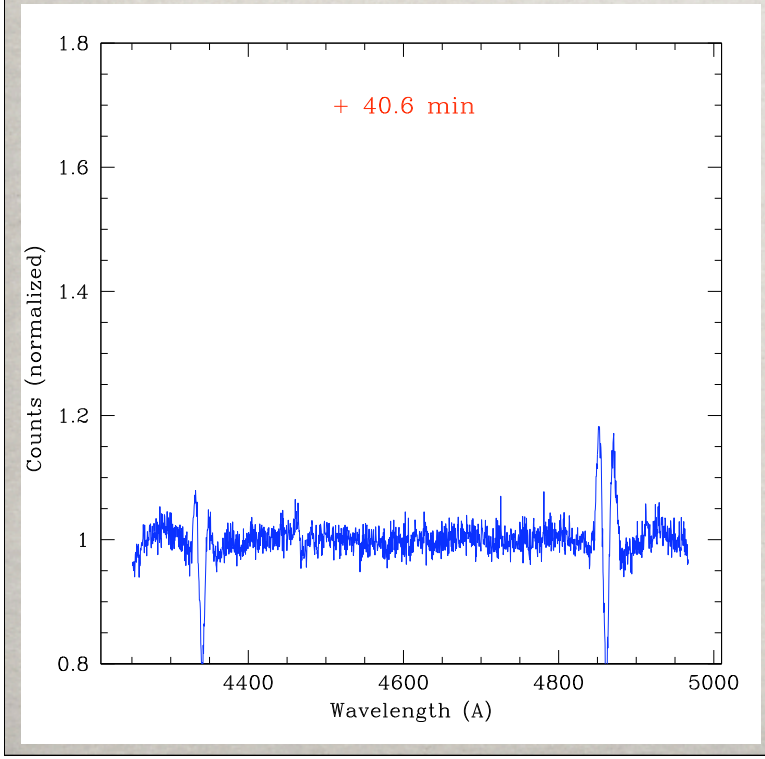

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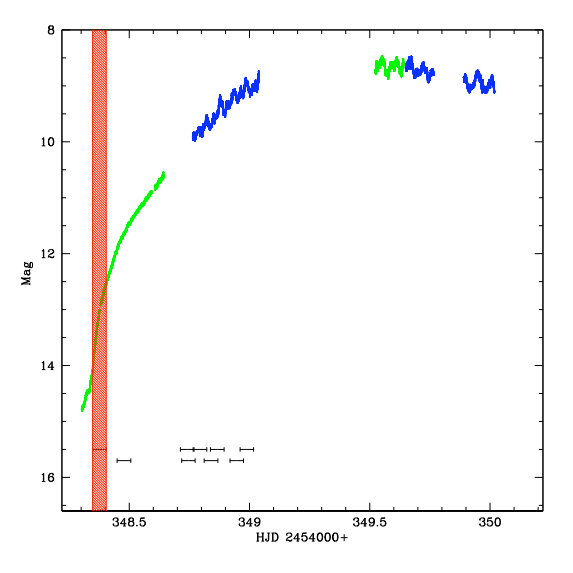

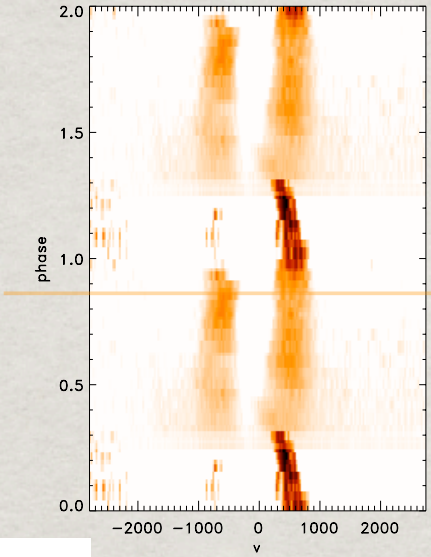

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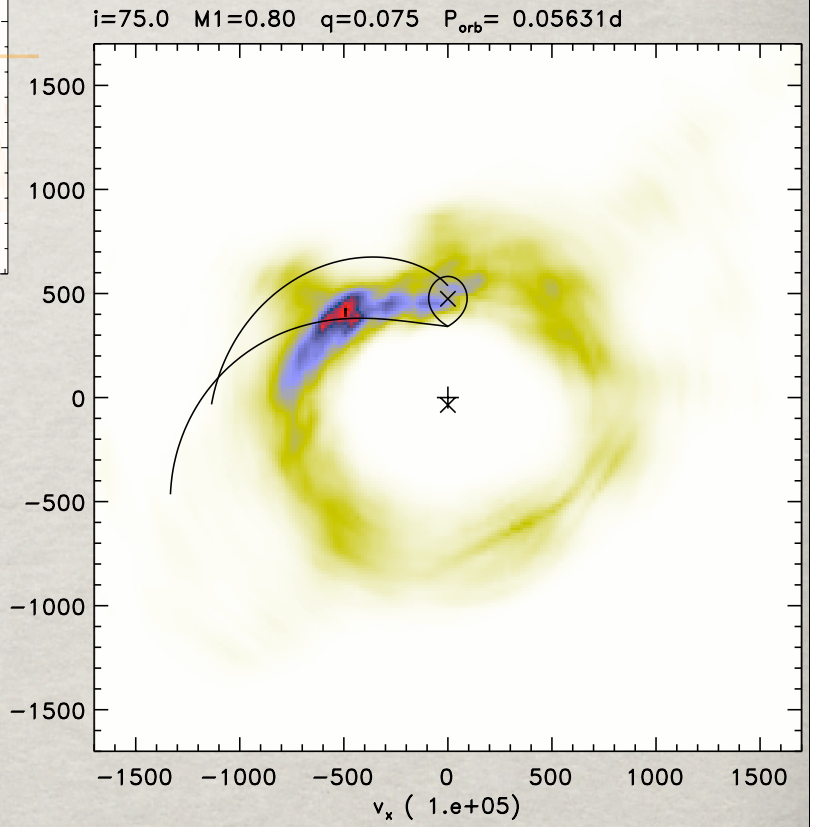

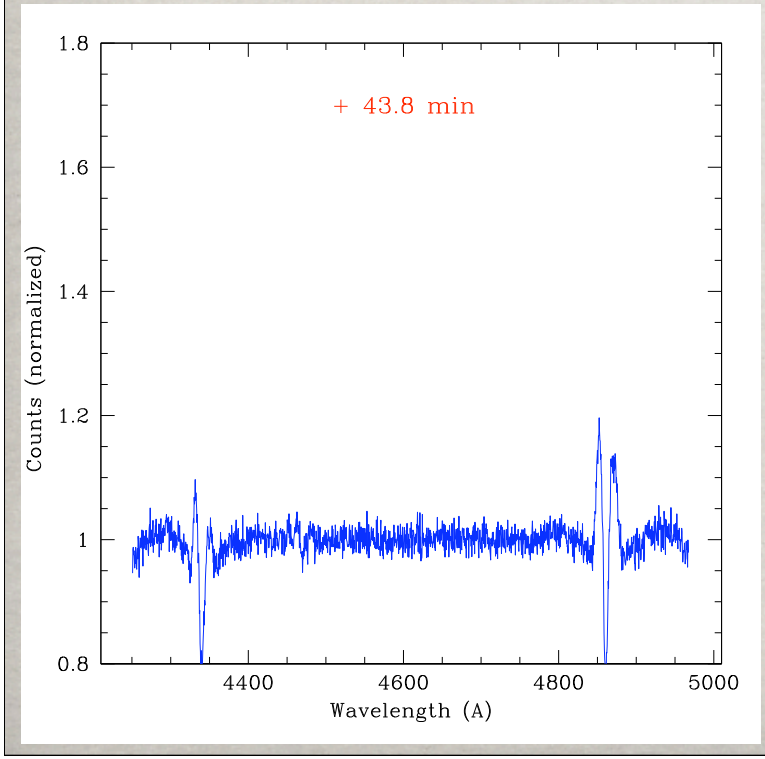

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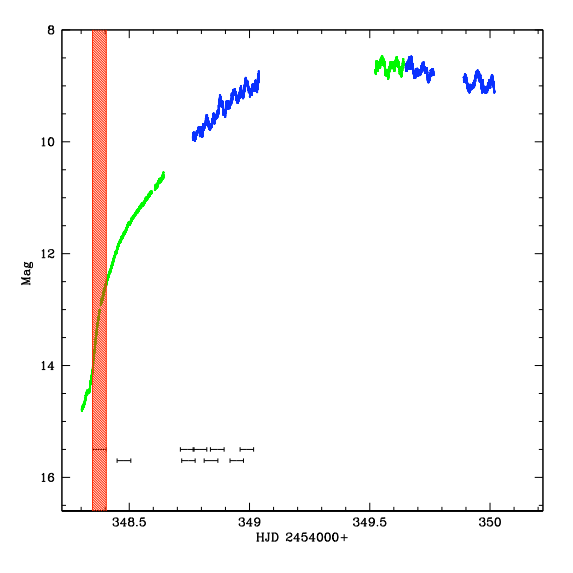

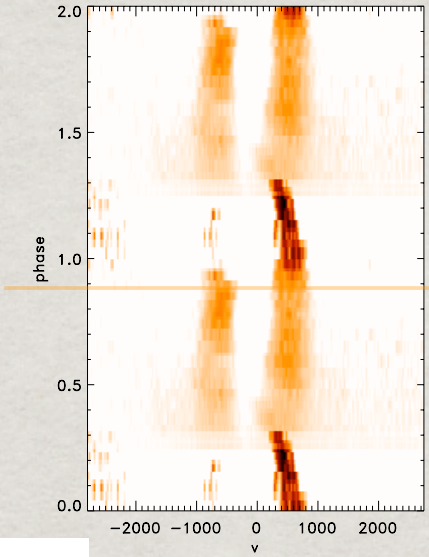

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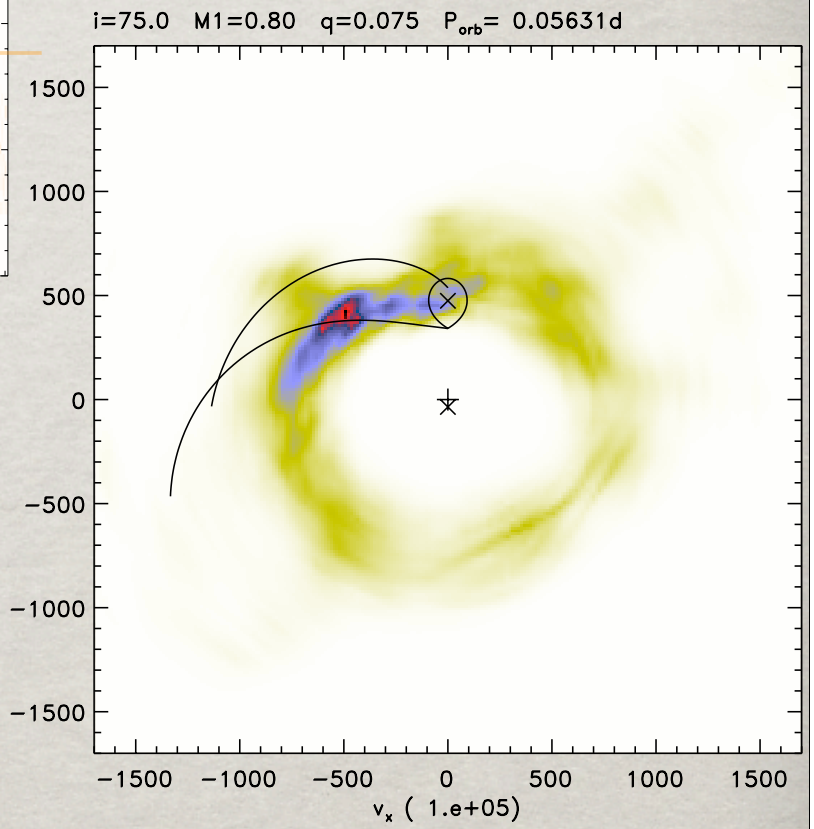

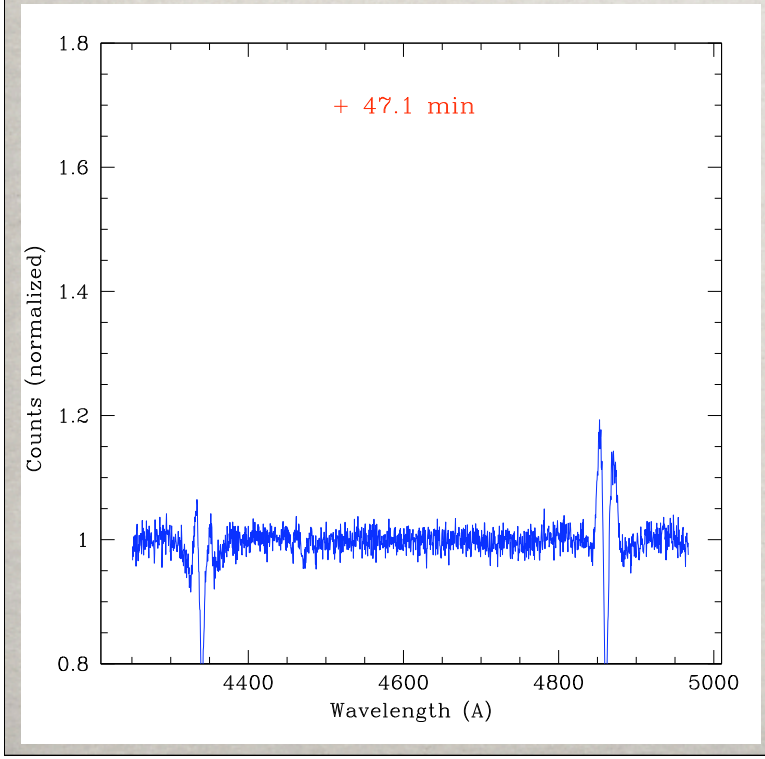

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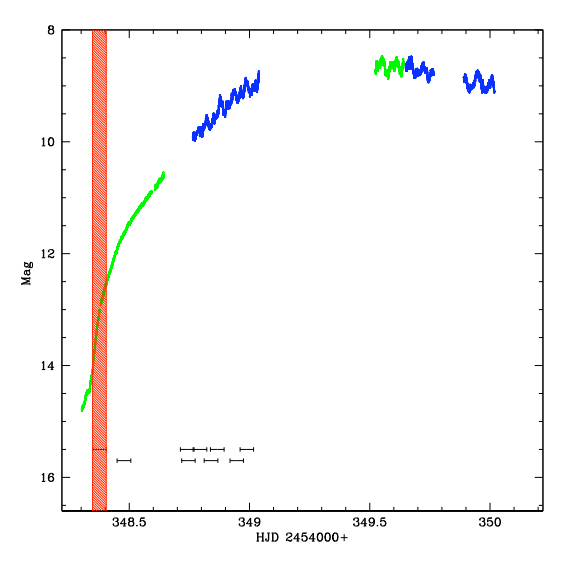

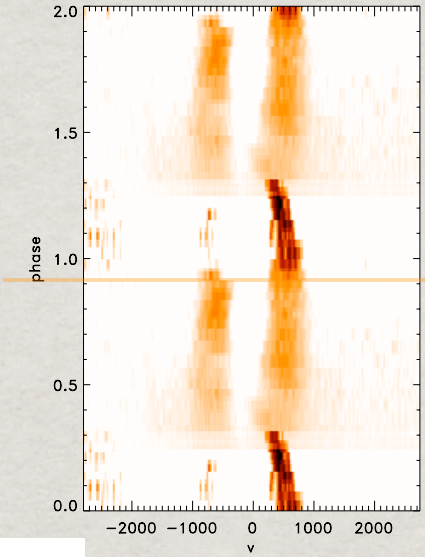

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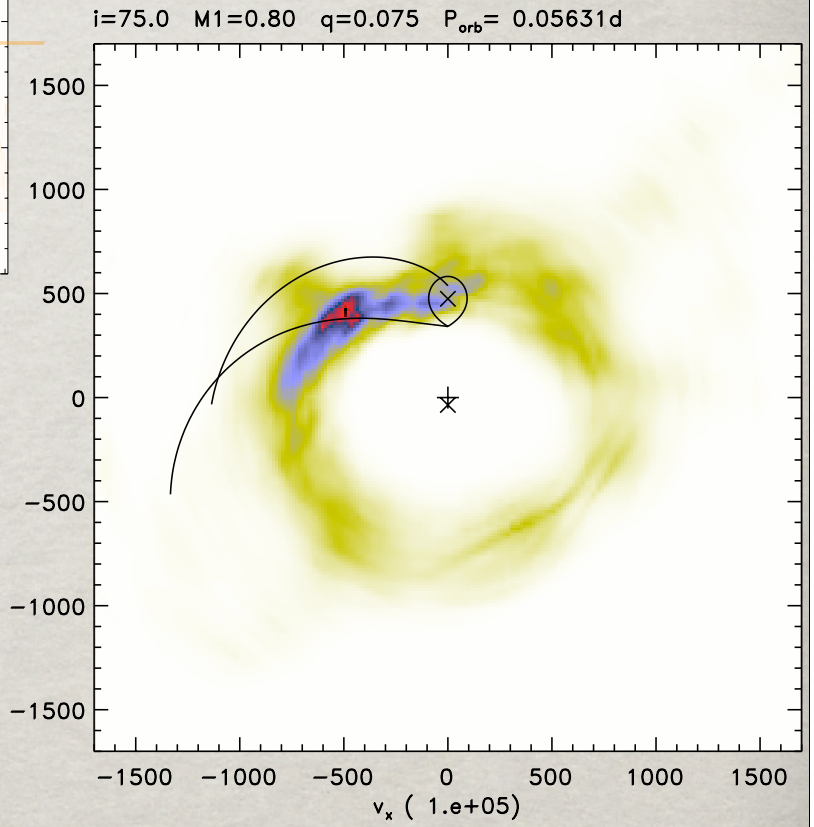

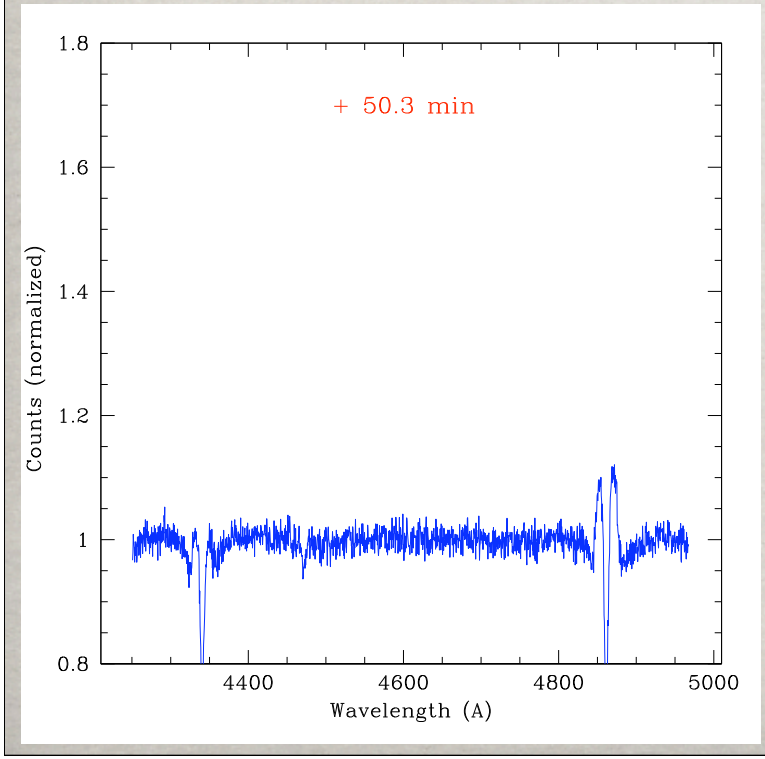

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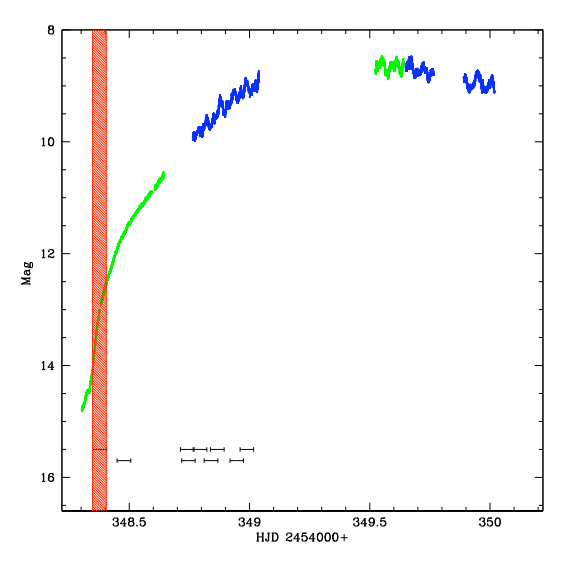

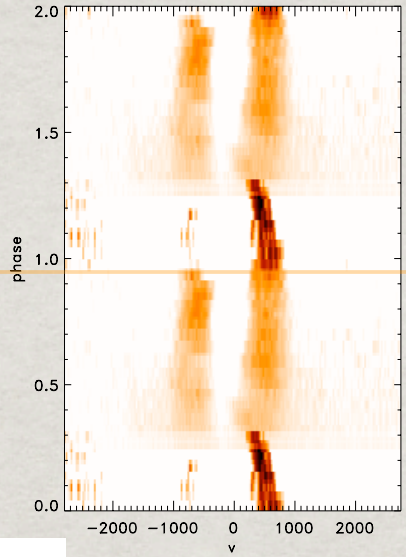

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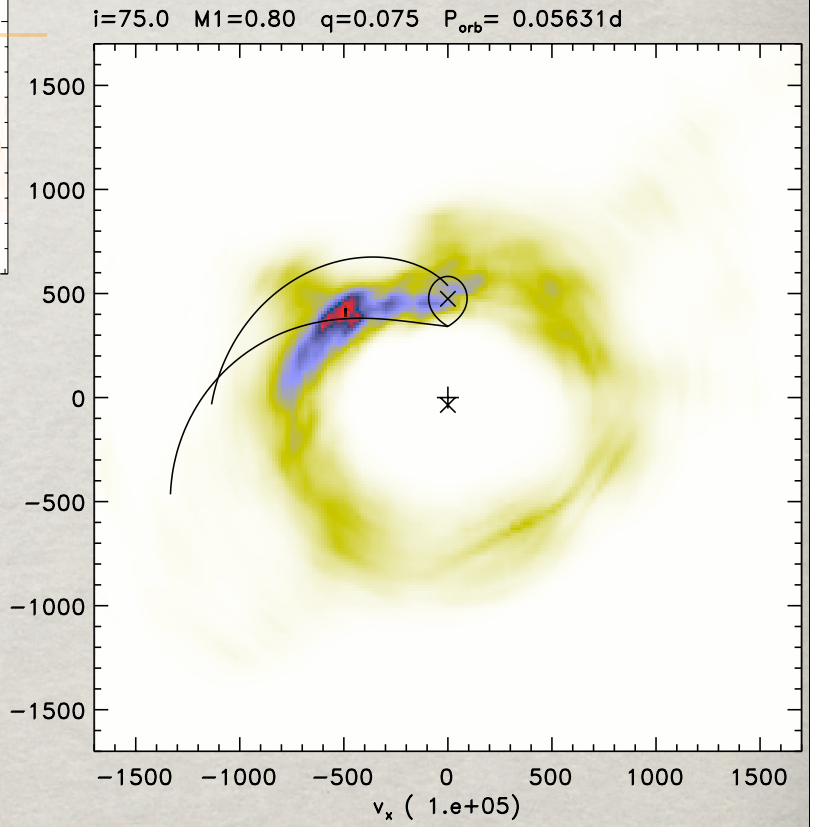

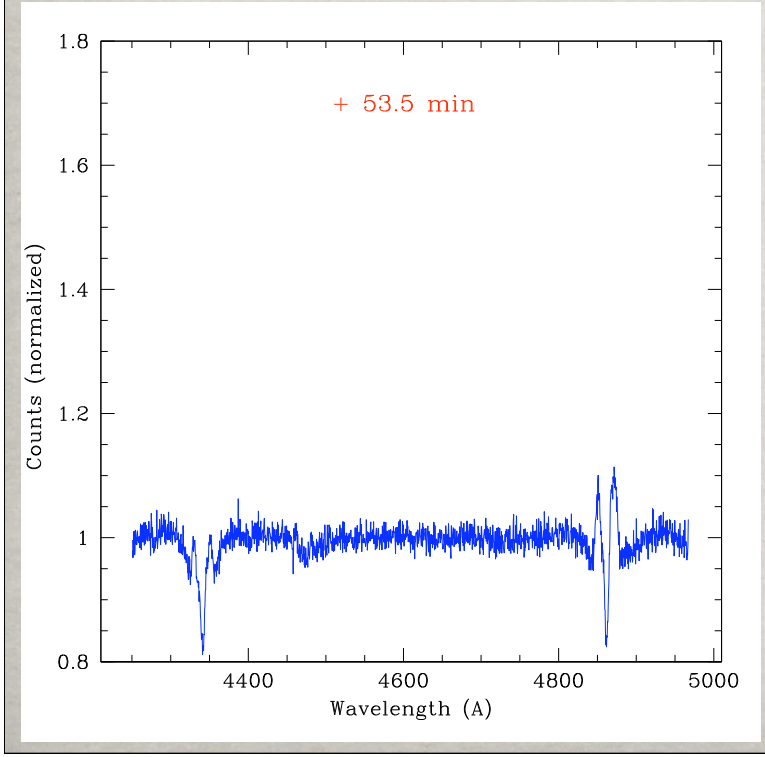

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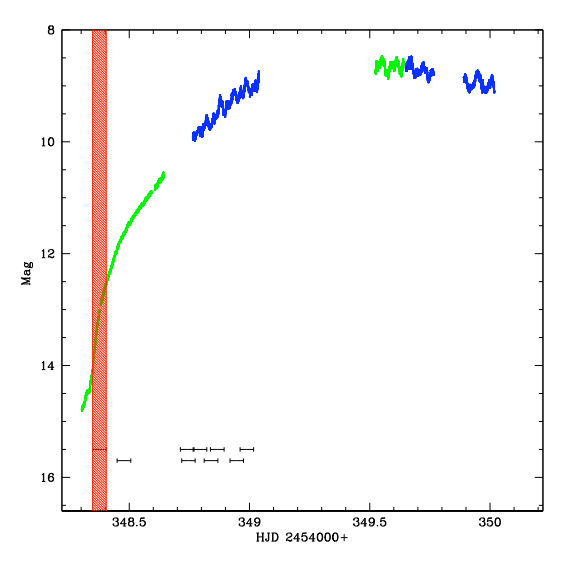

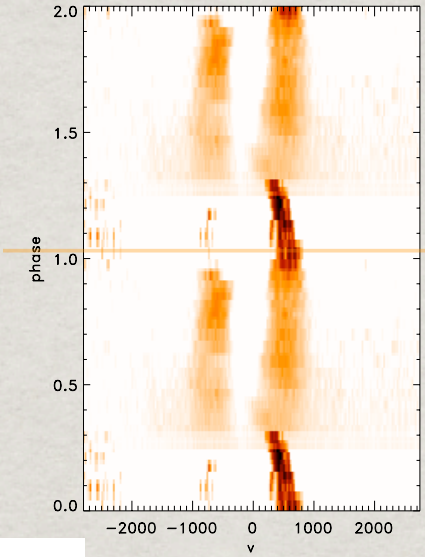

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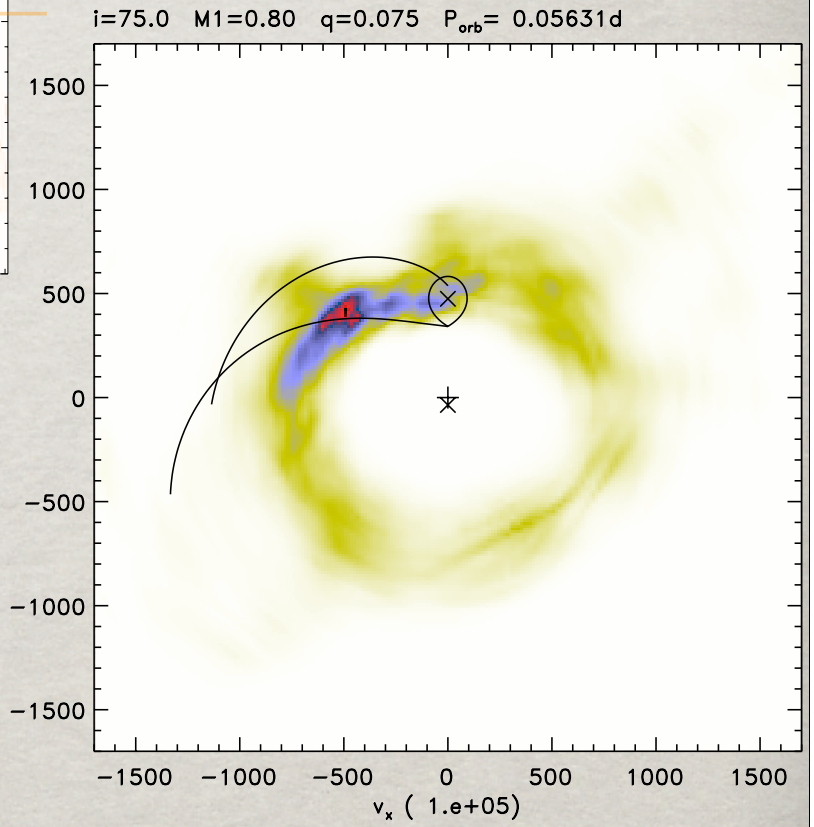

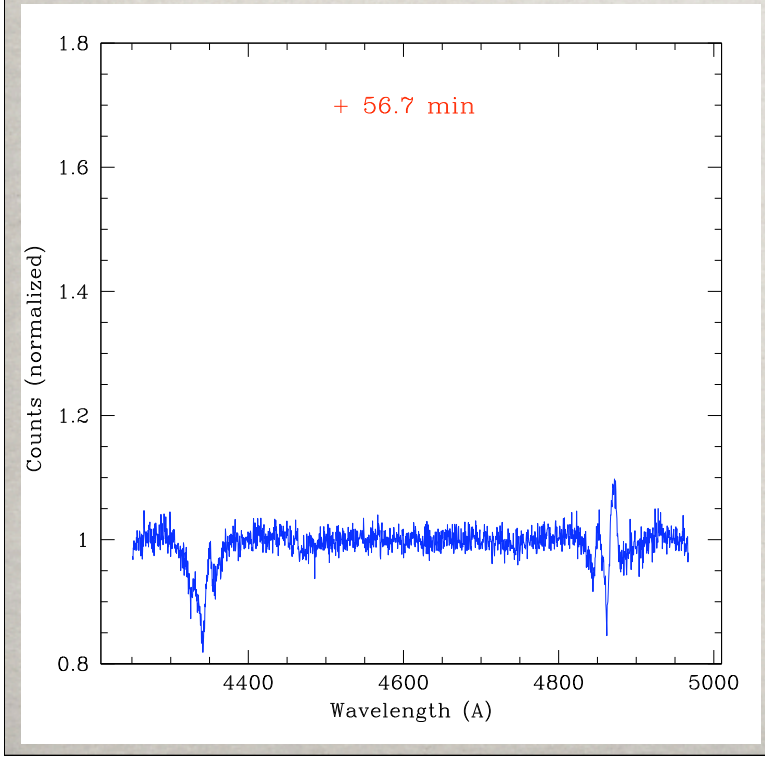

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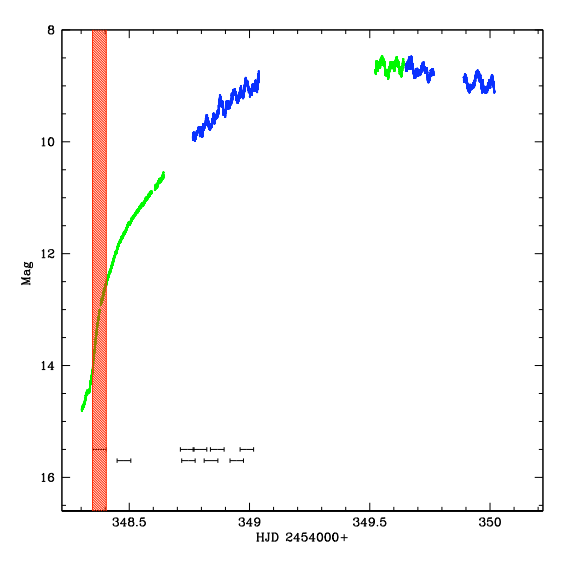

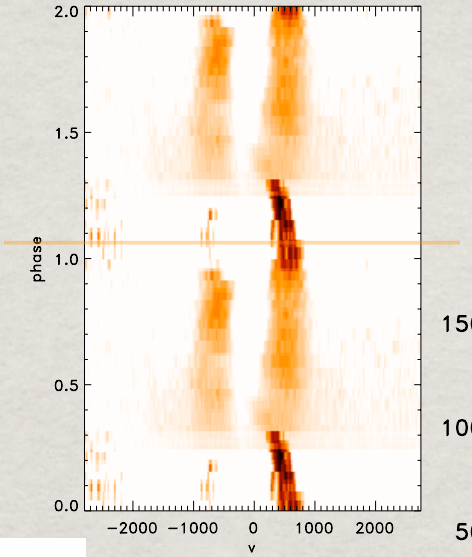

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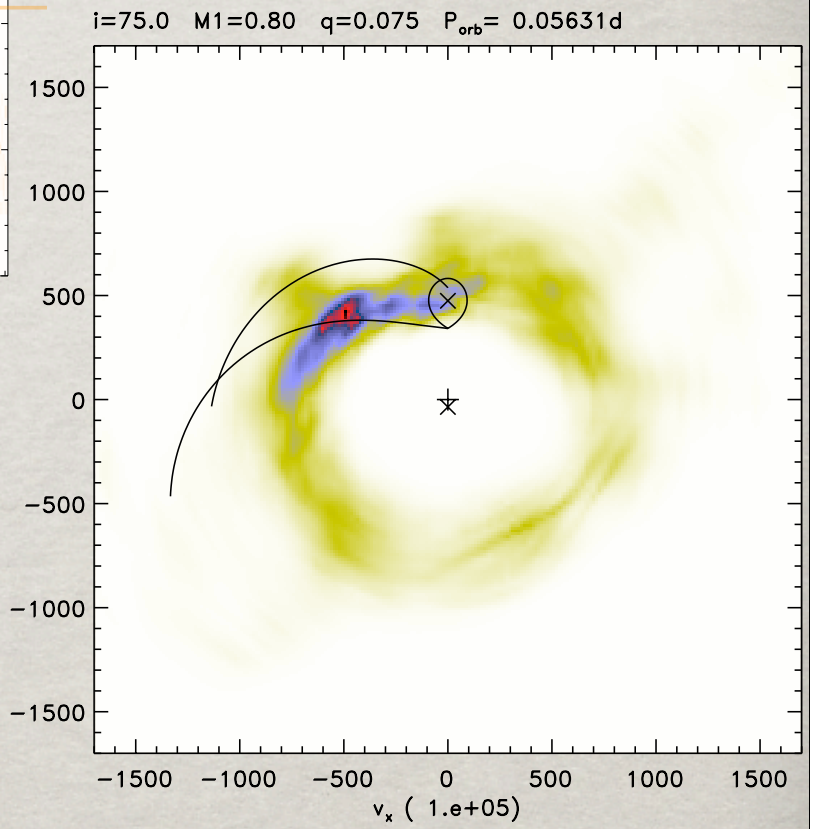

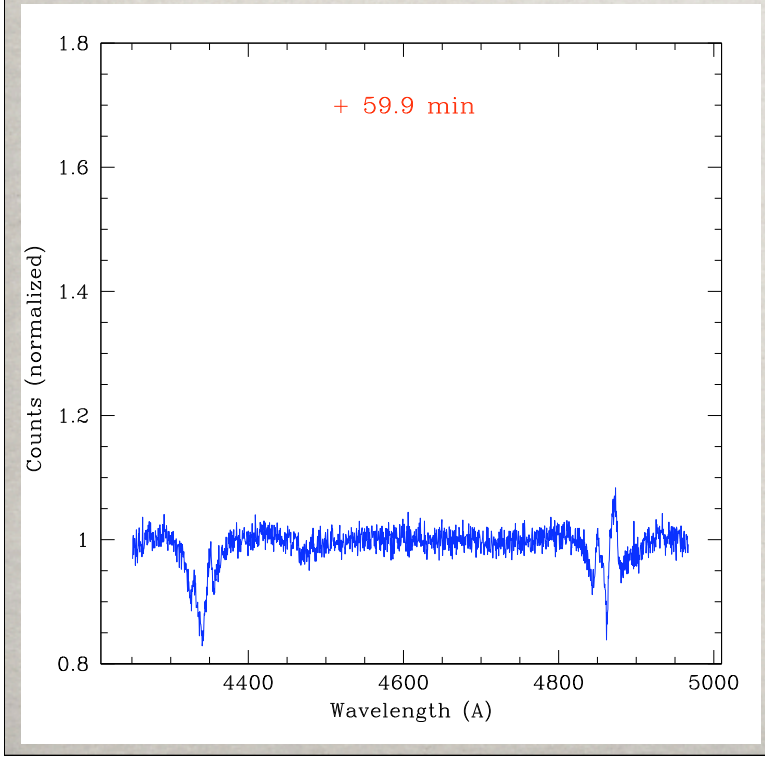

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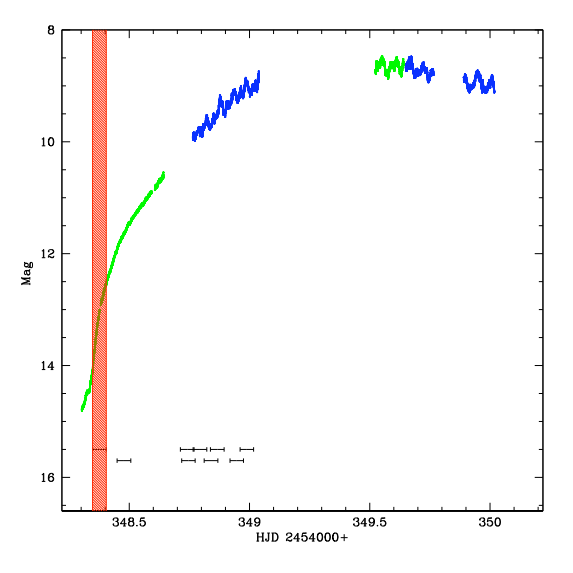

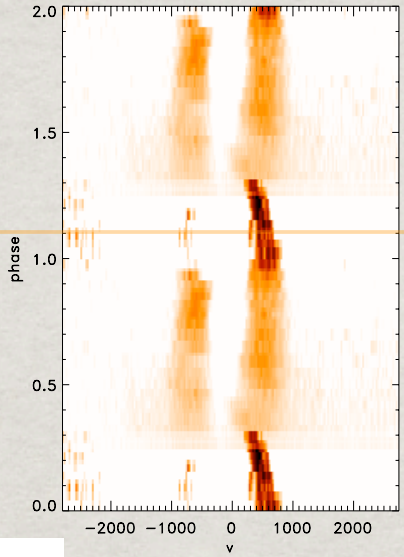

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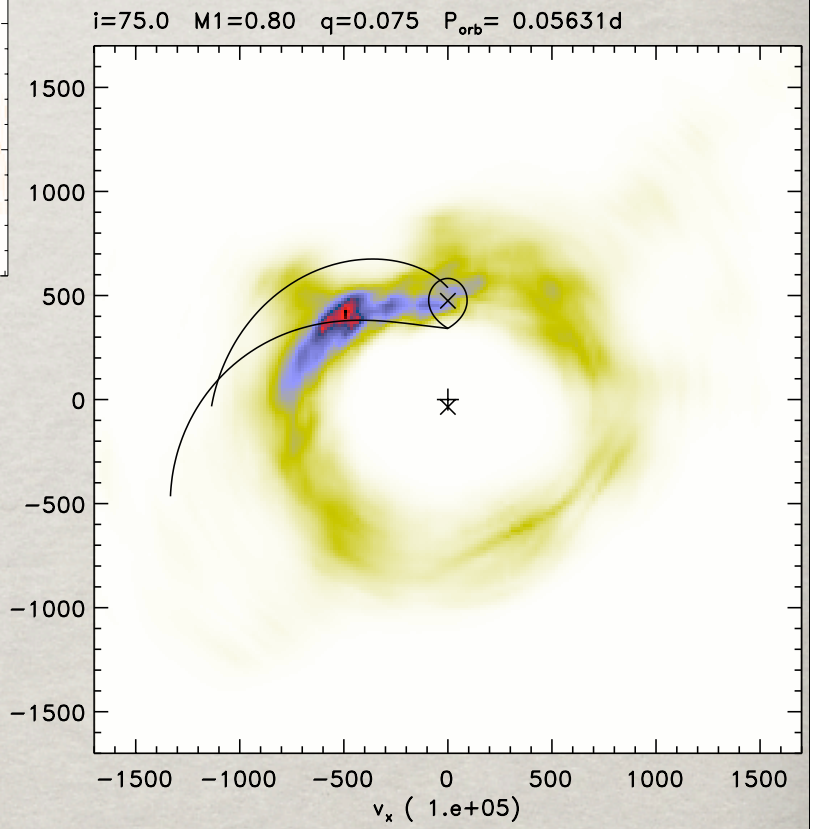

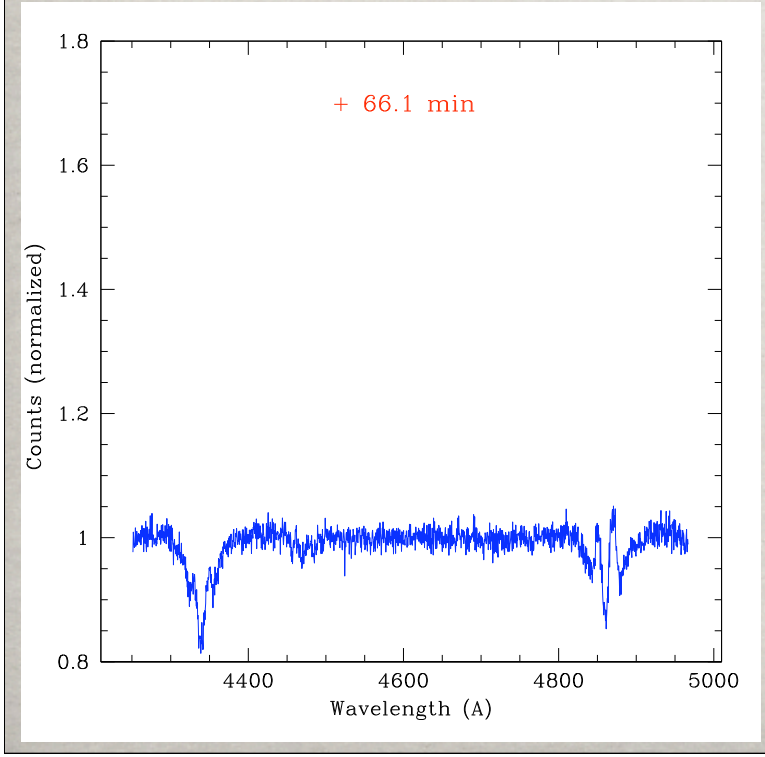

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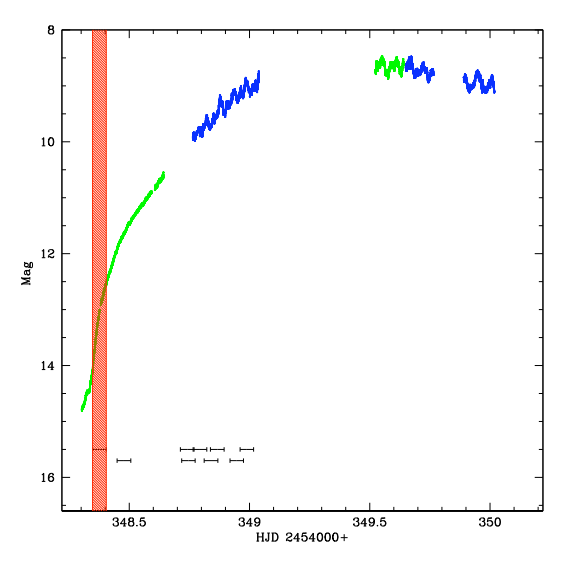

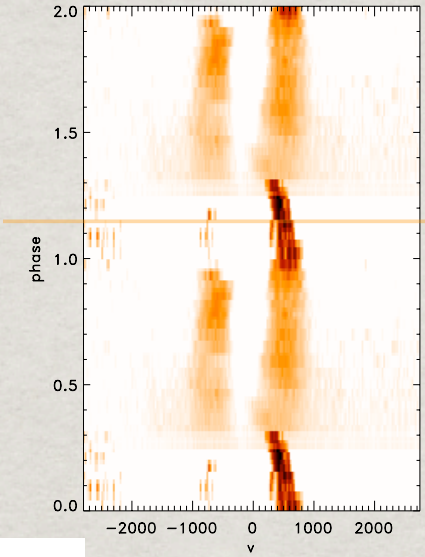

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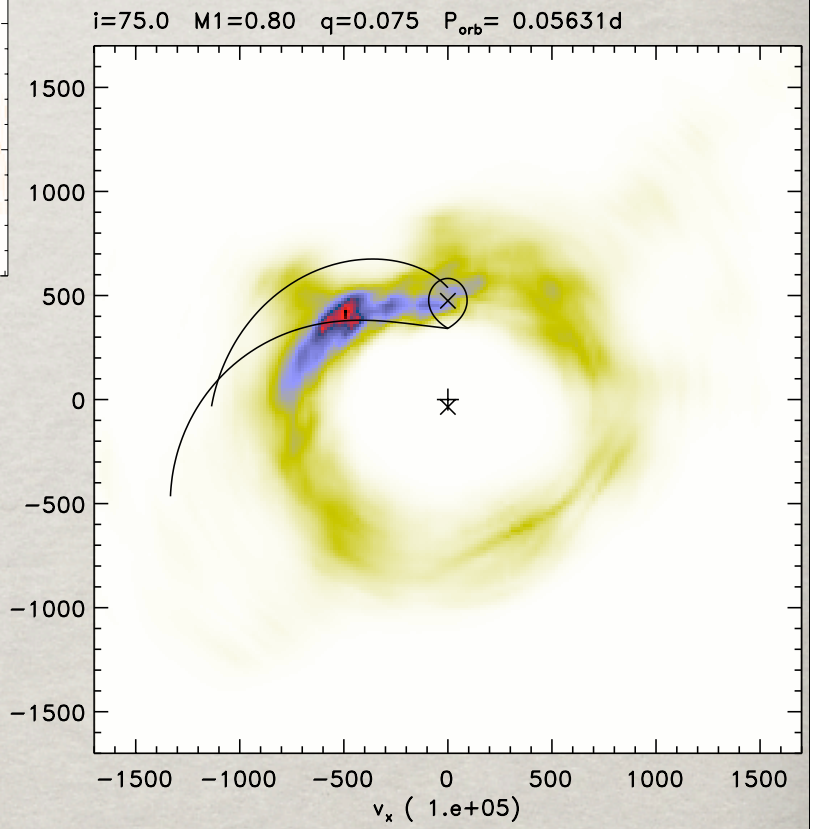

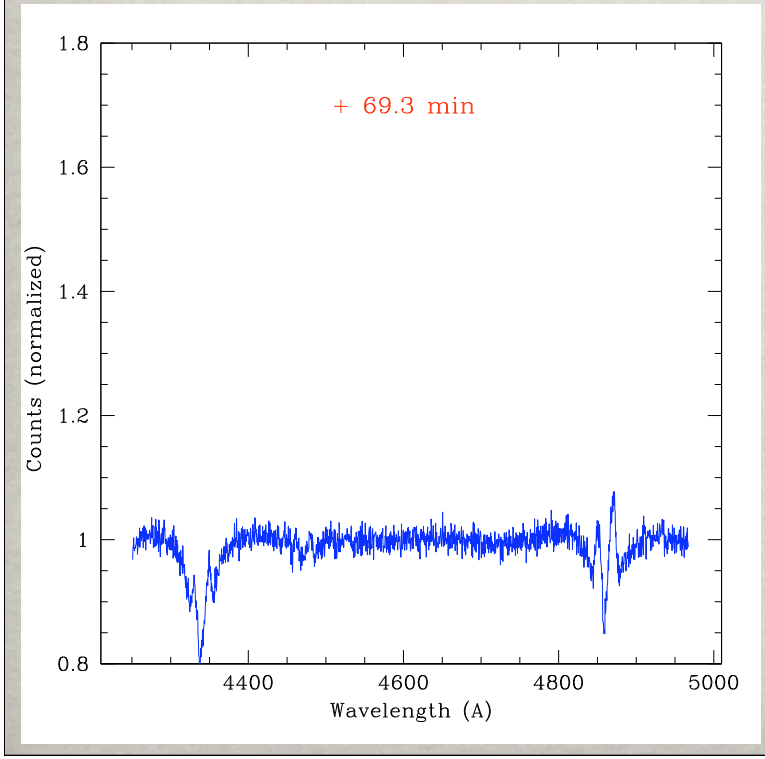

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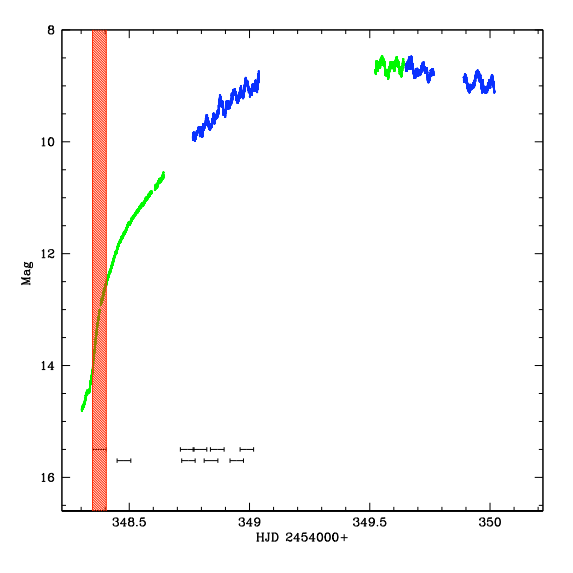

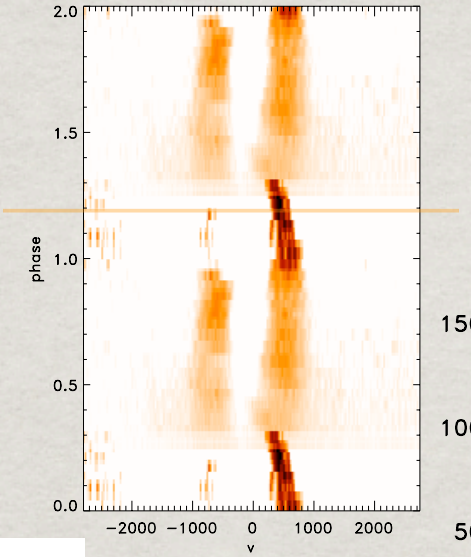

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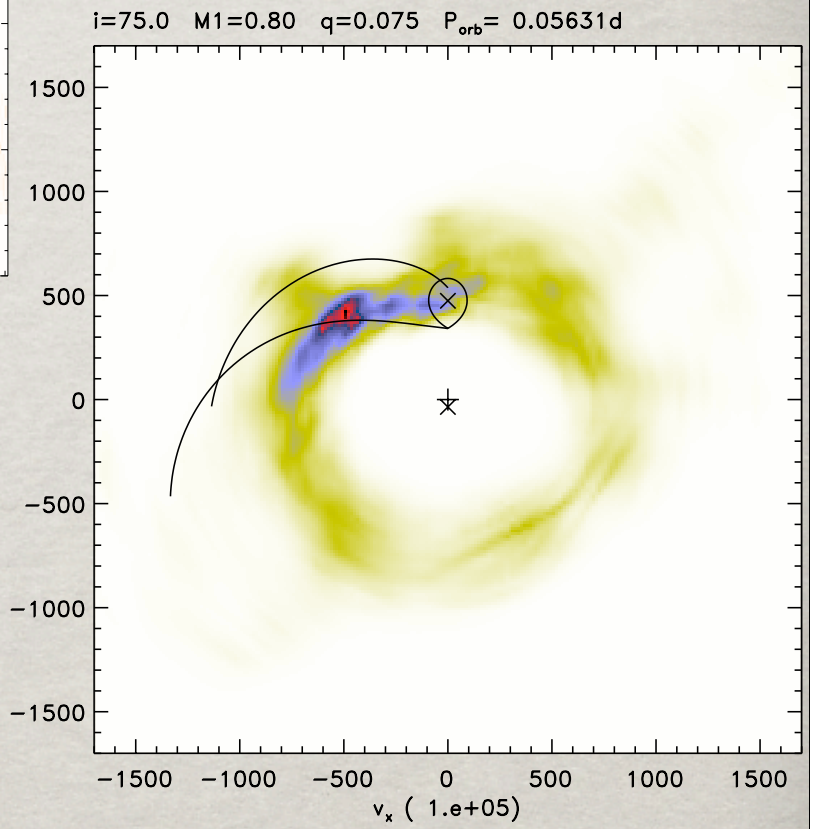

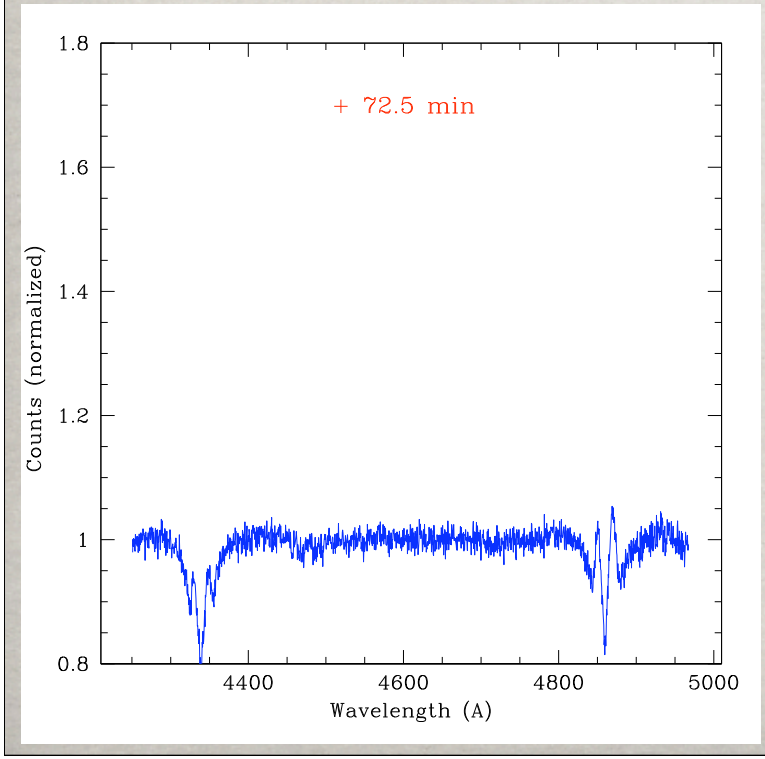

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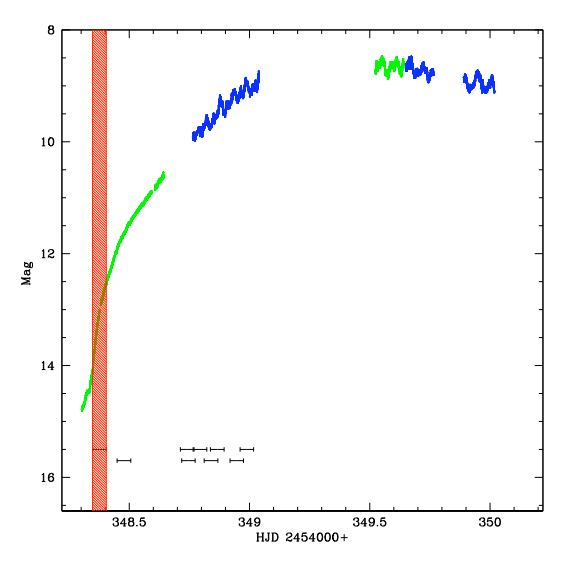

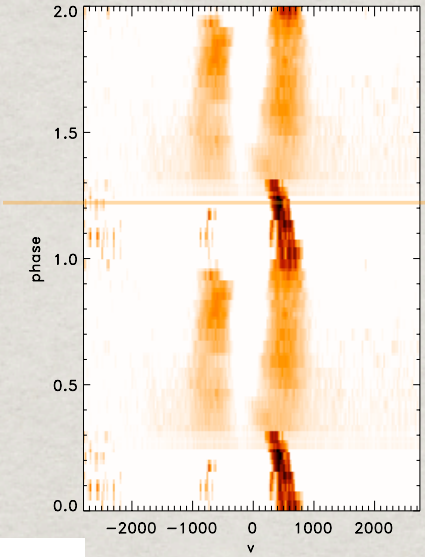

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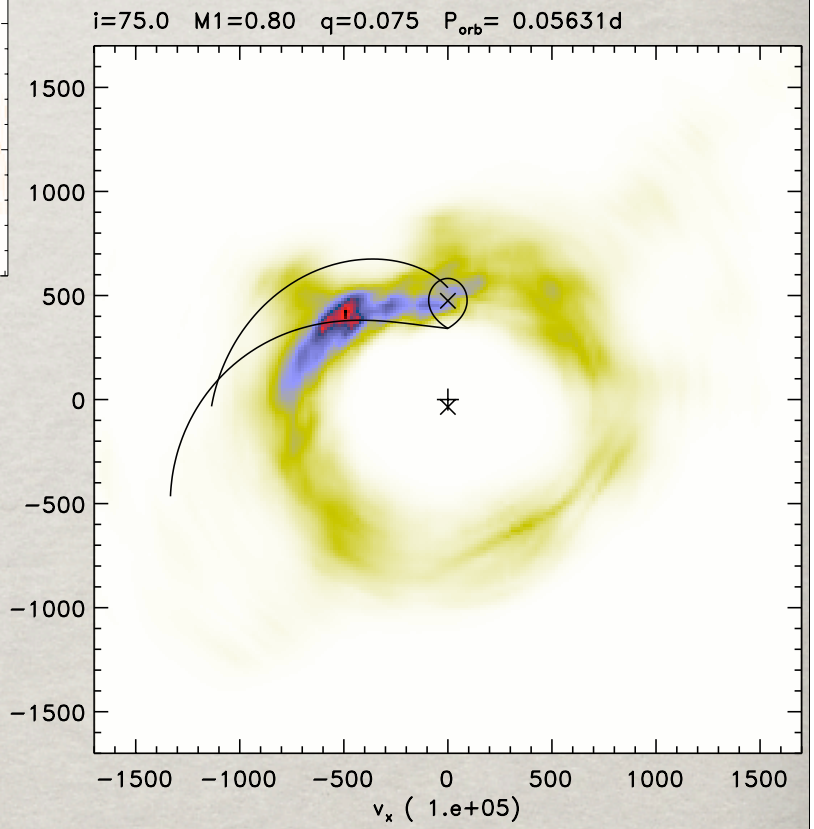

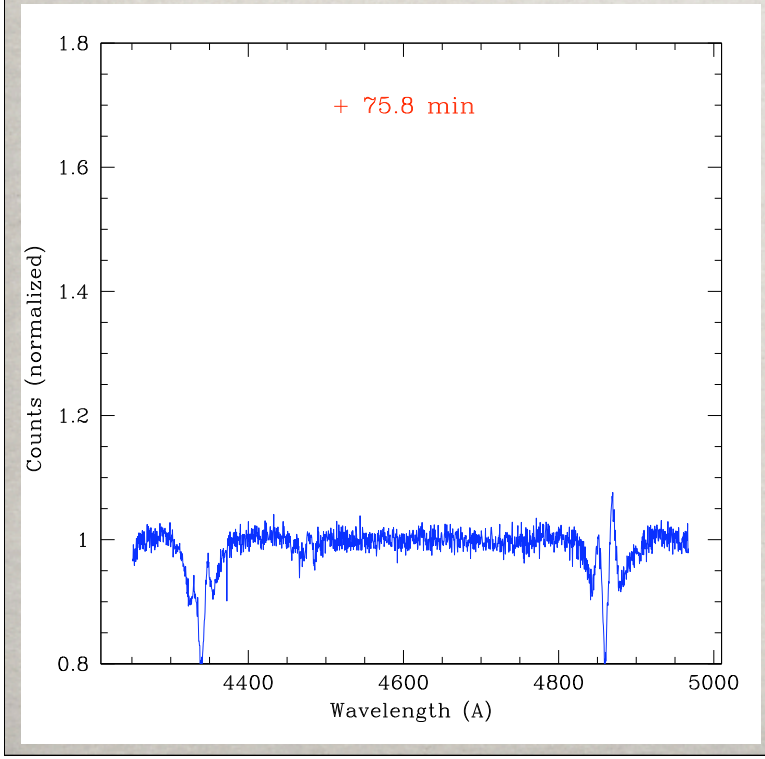

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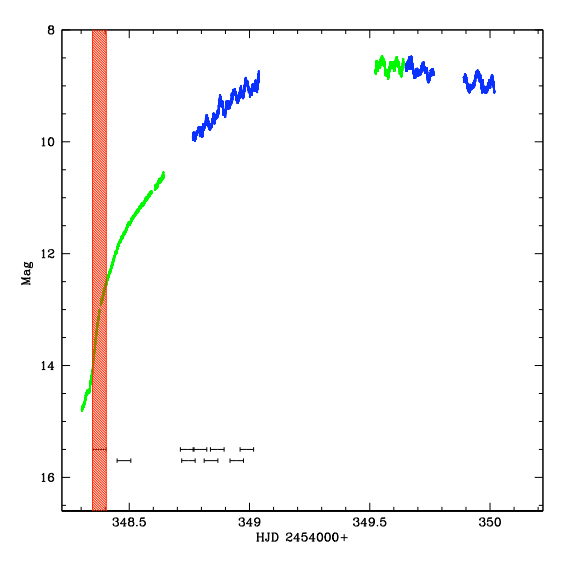

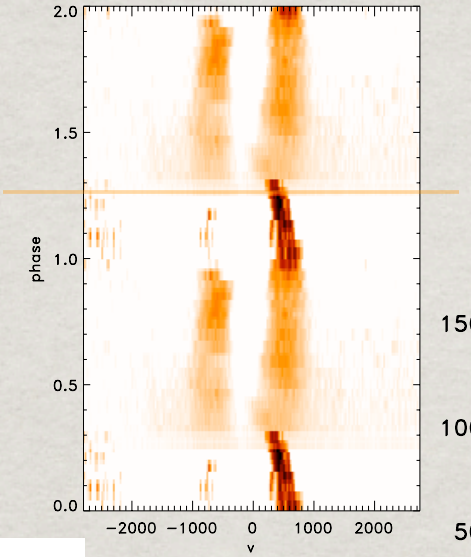

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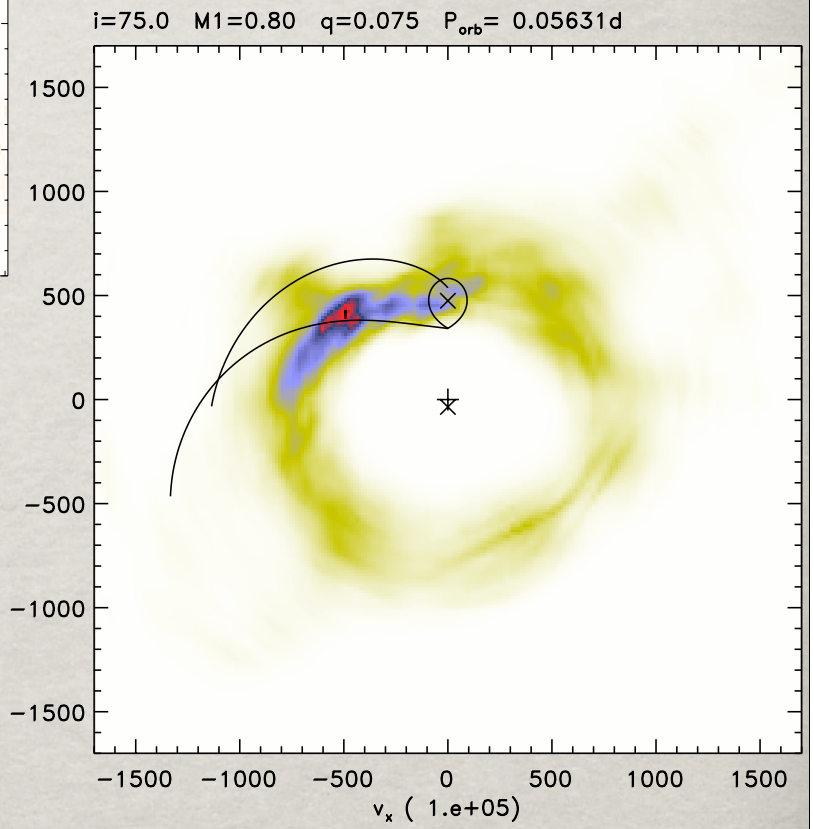

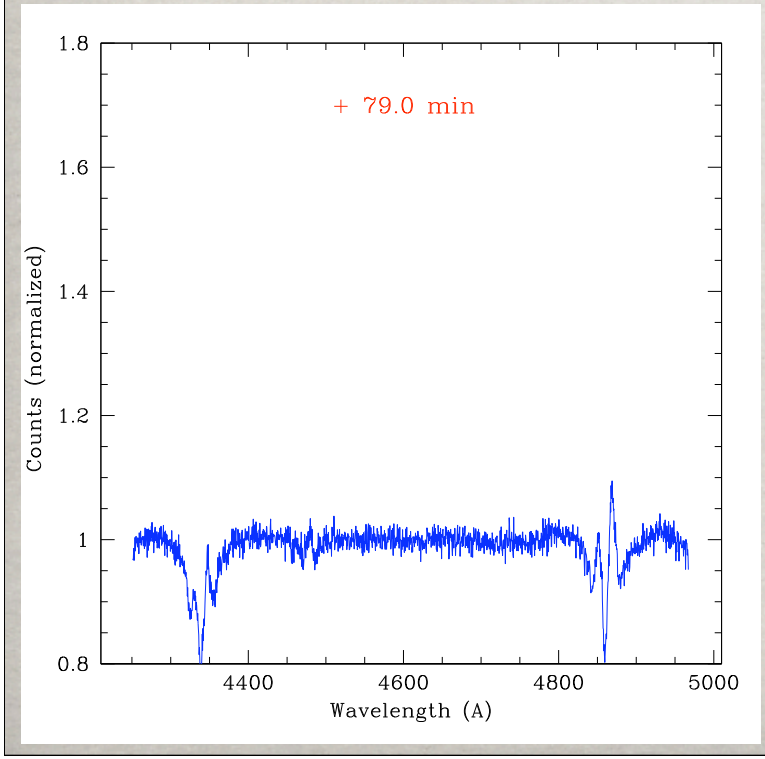

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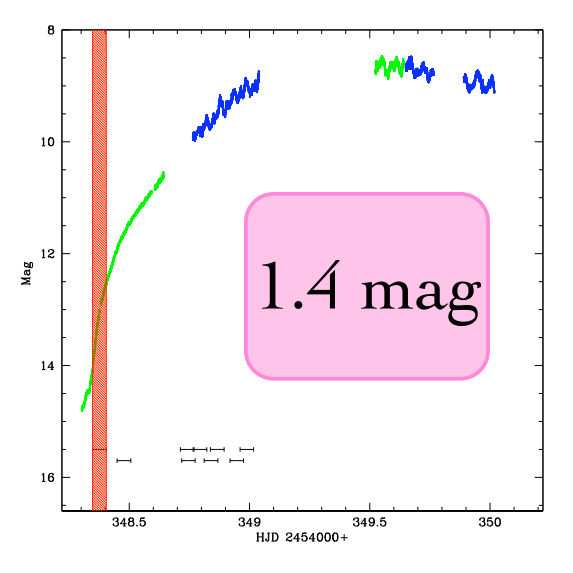

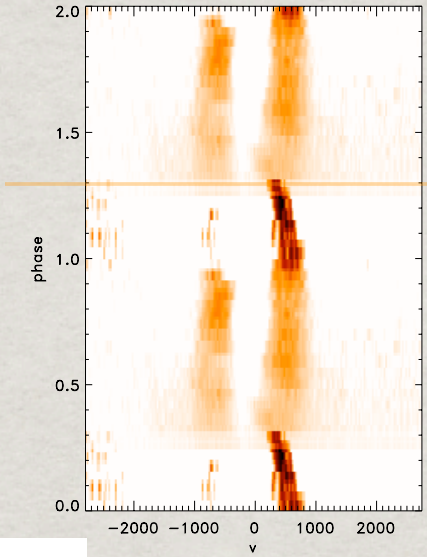

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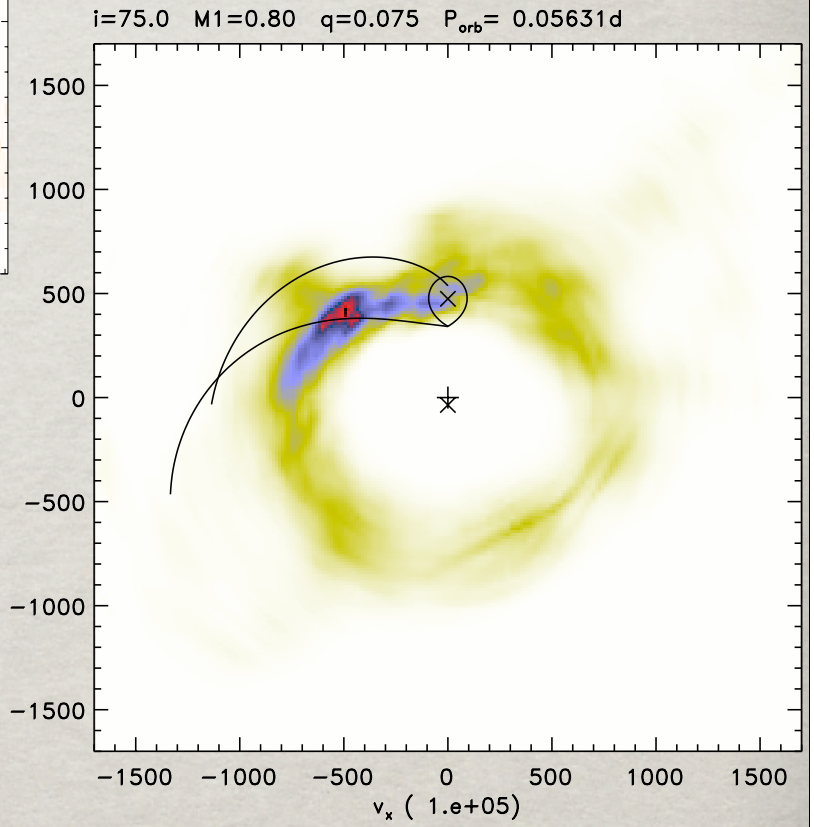

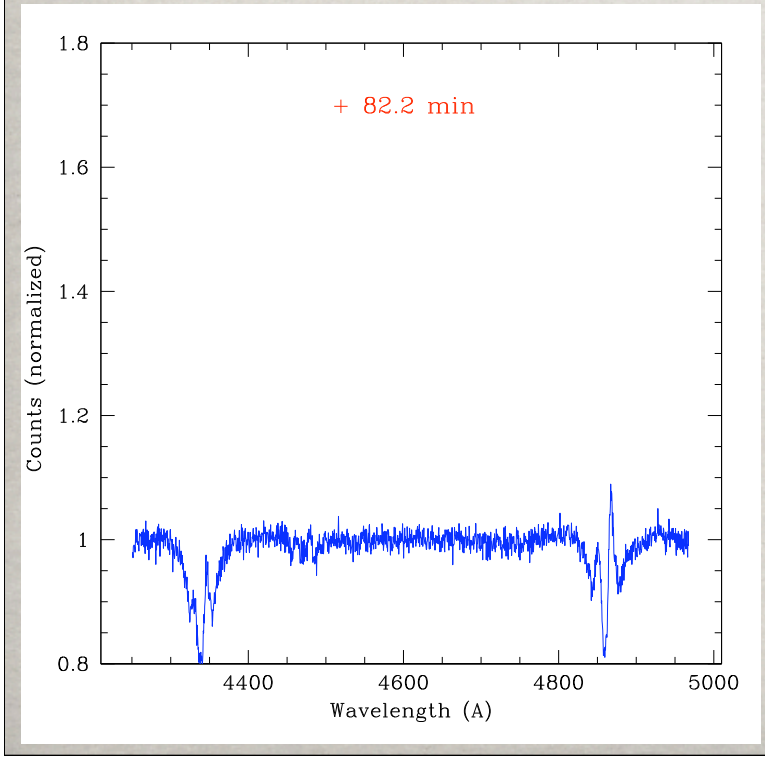

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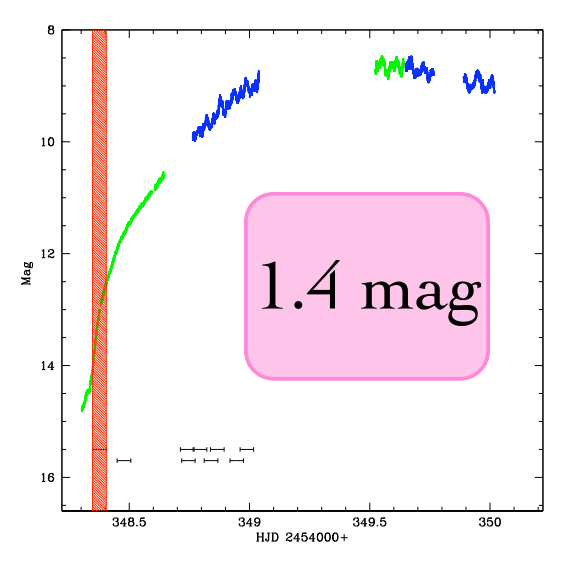

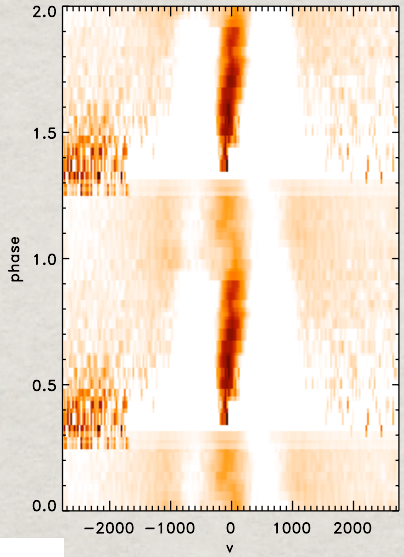

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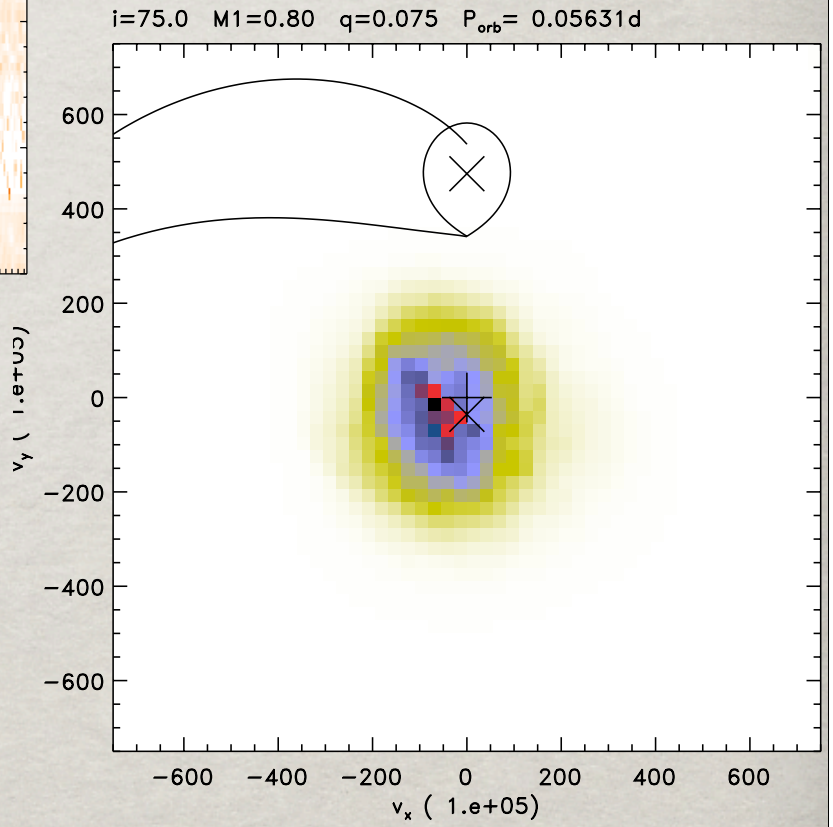

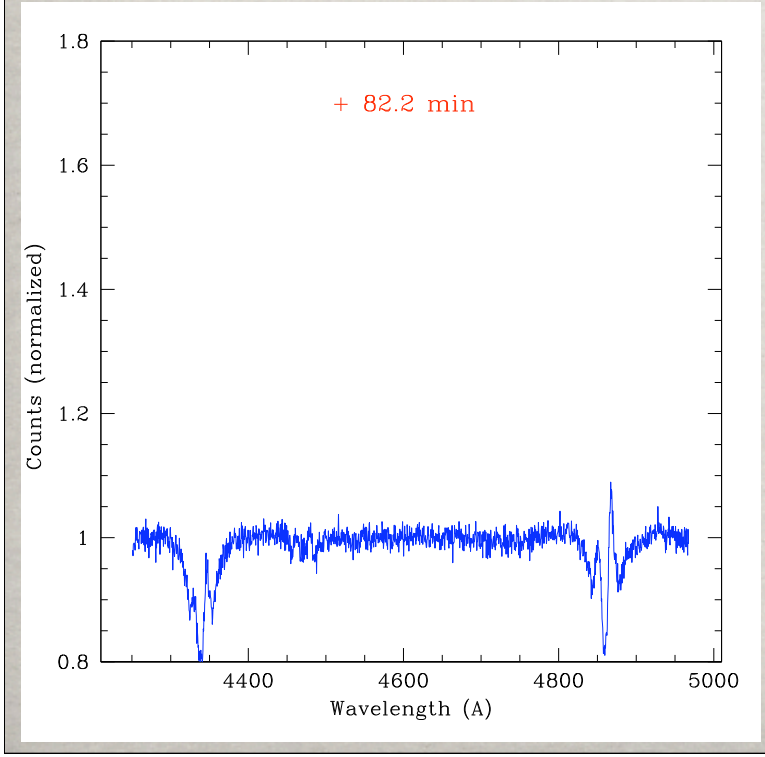

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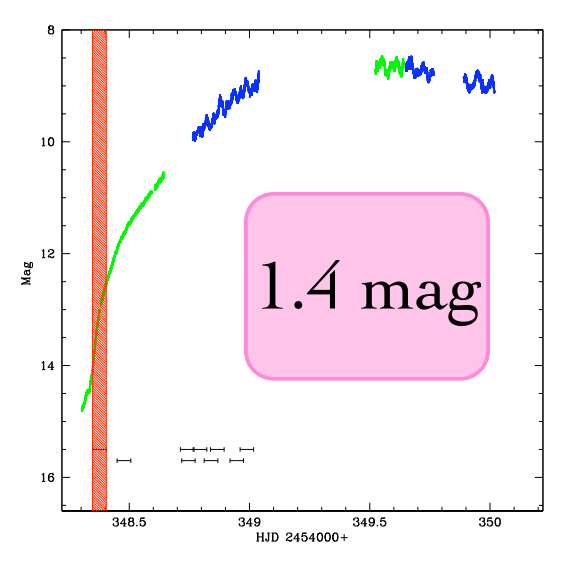
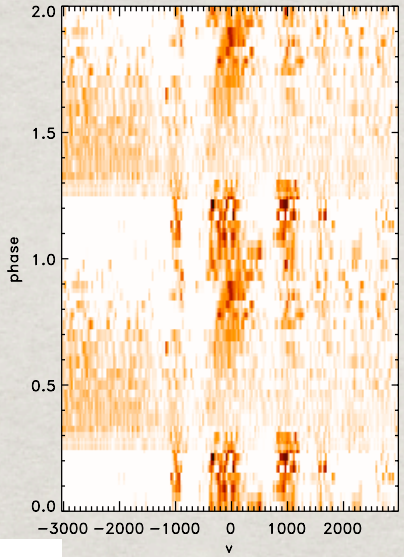
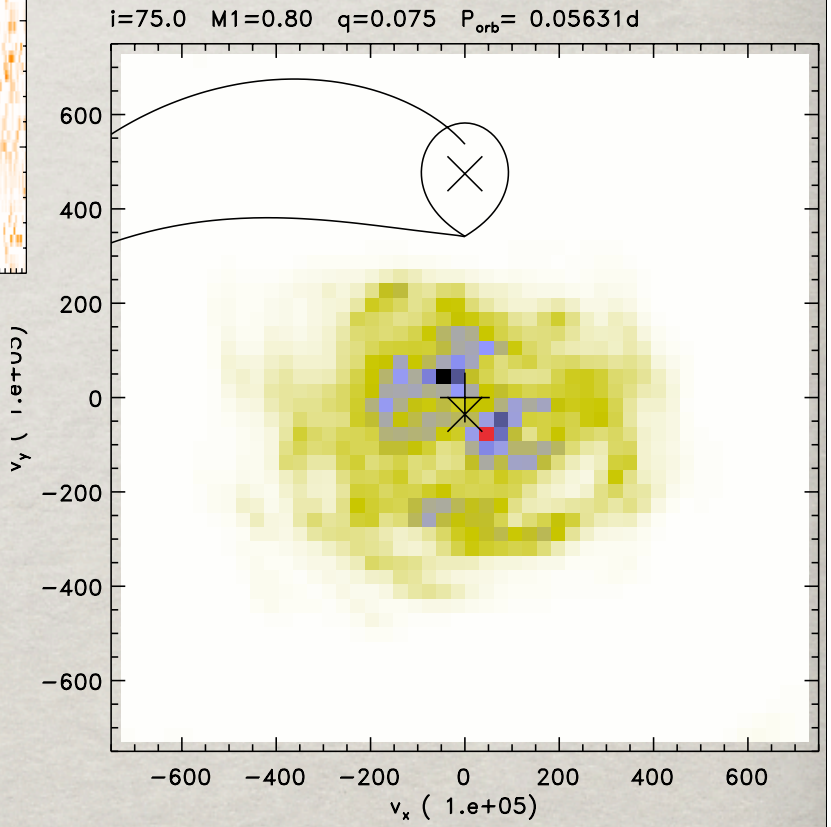
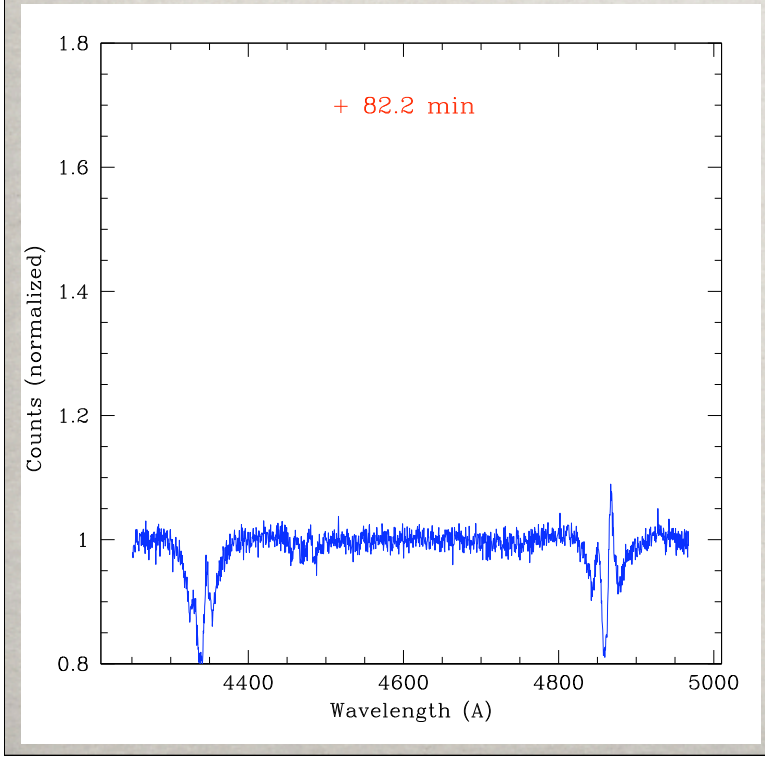




He I absorption component





THE START: JD 2454348

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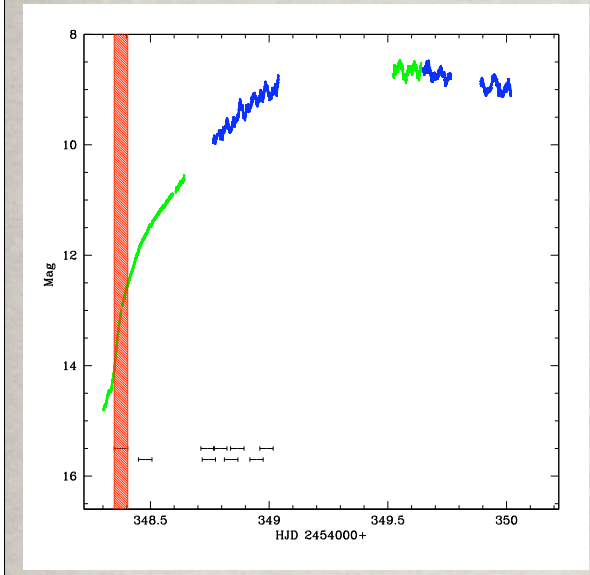
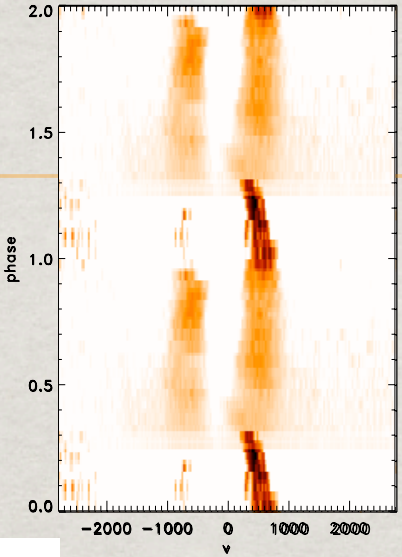
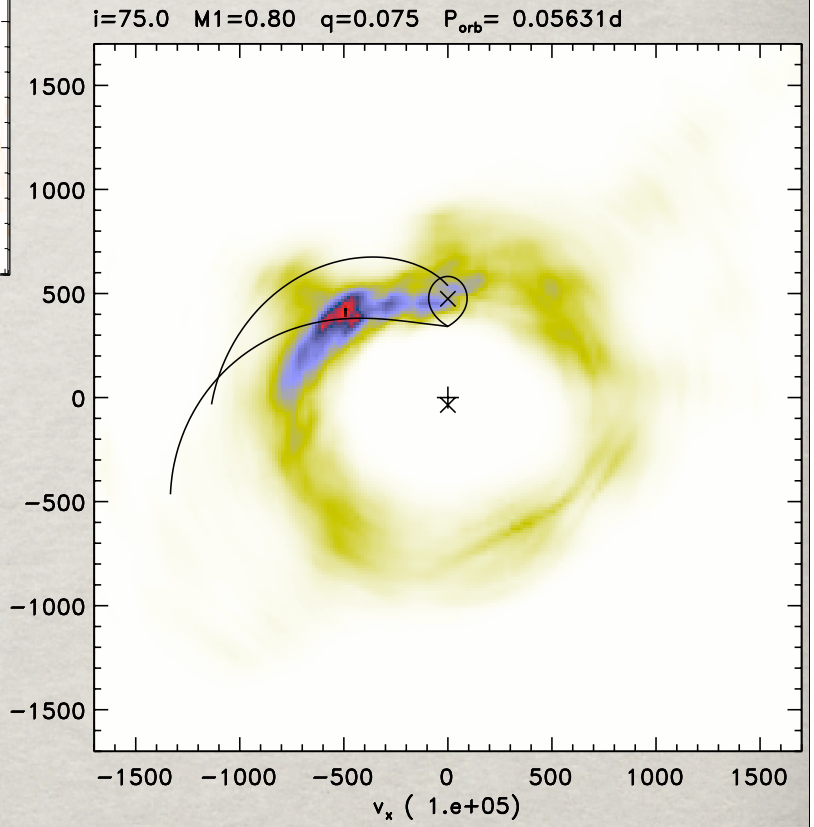
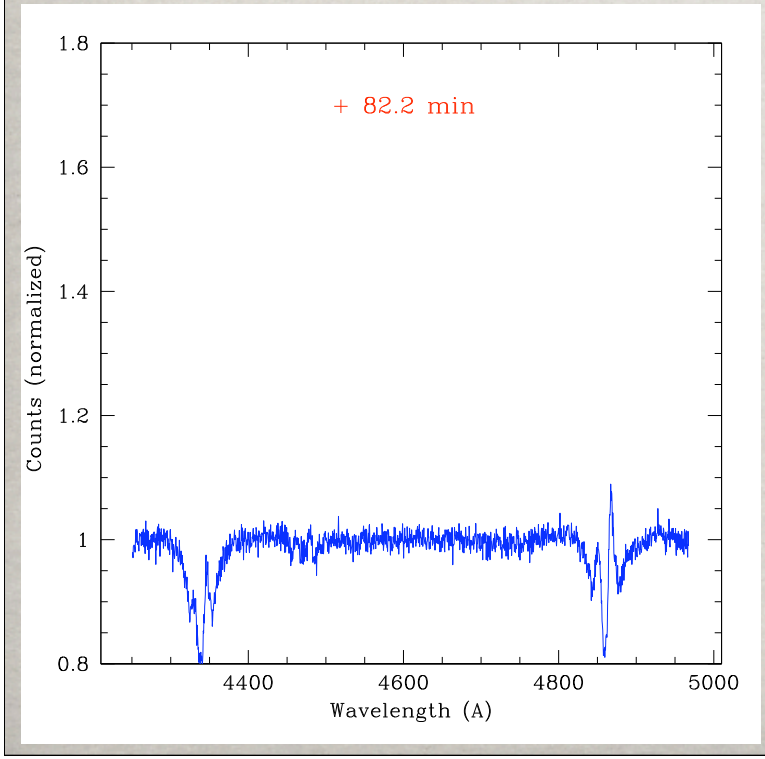




Hβ emission component





THE START: JD 2454348

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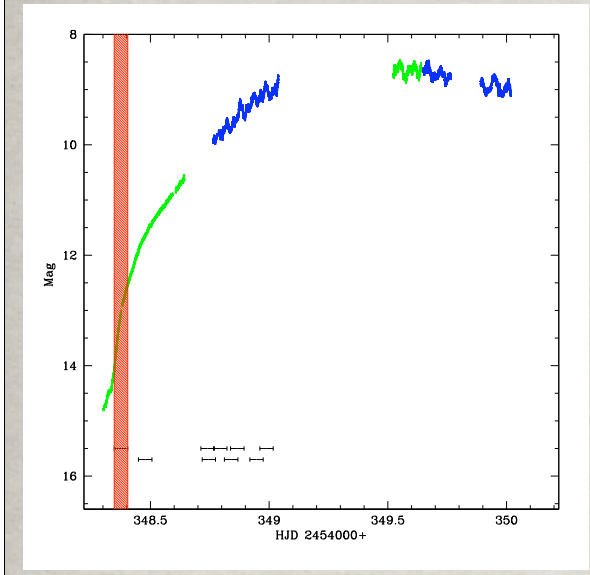
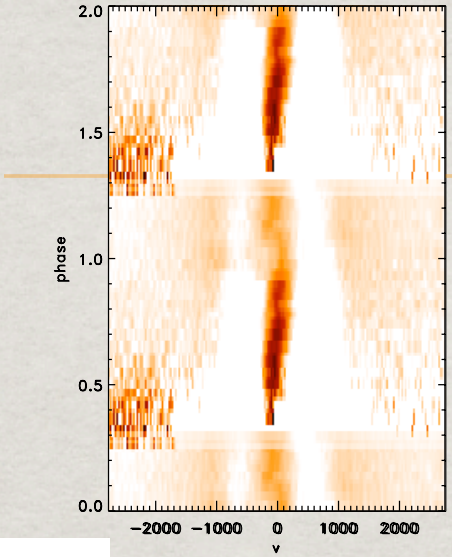
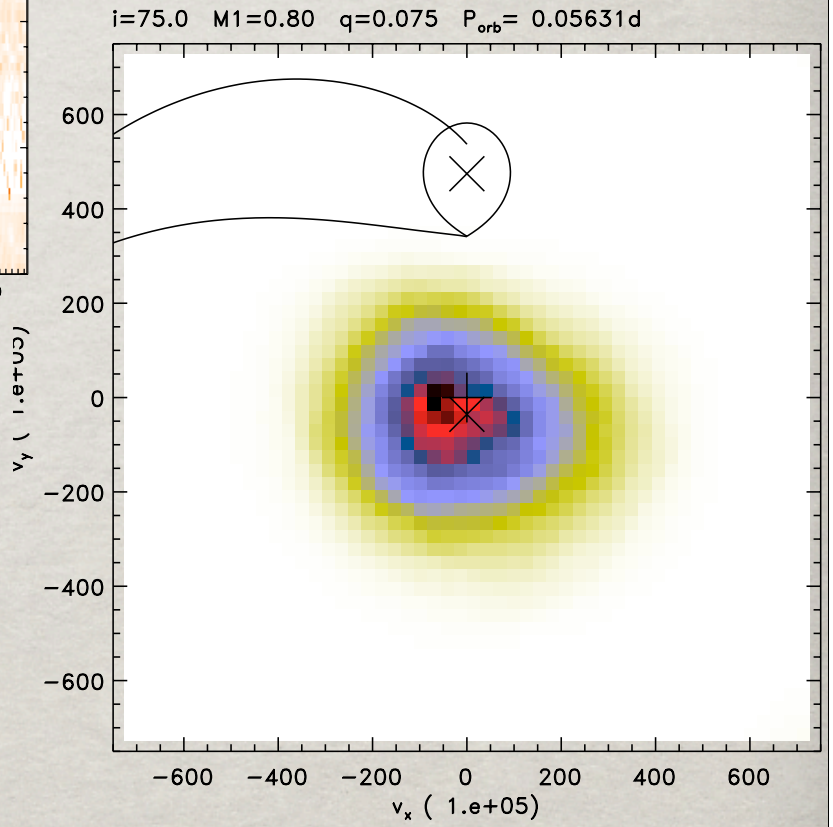
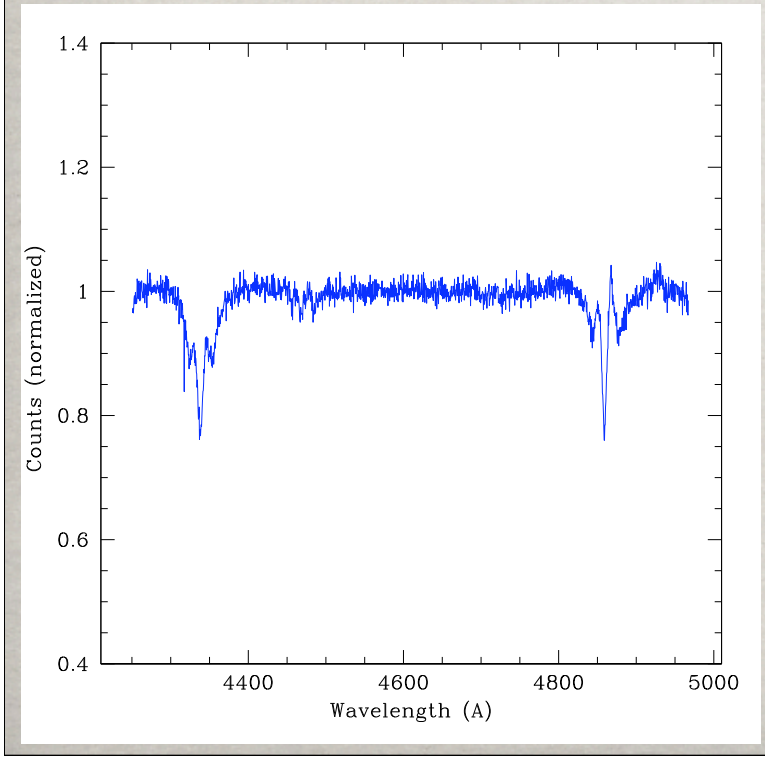




Hβ absorption component





THE START: JD 2454348

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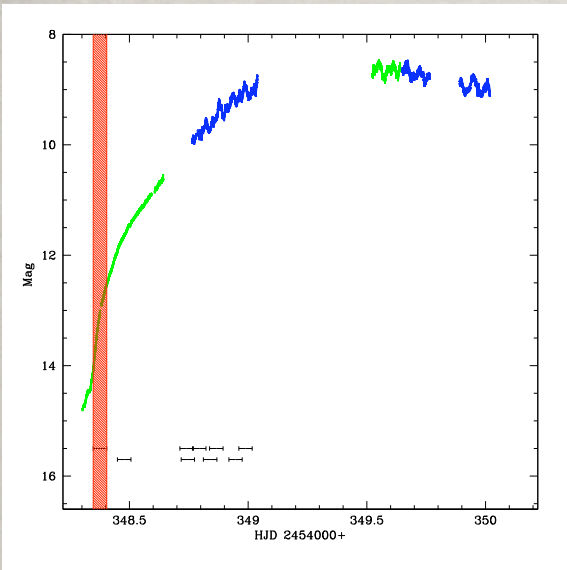
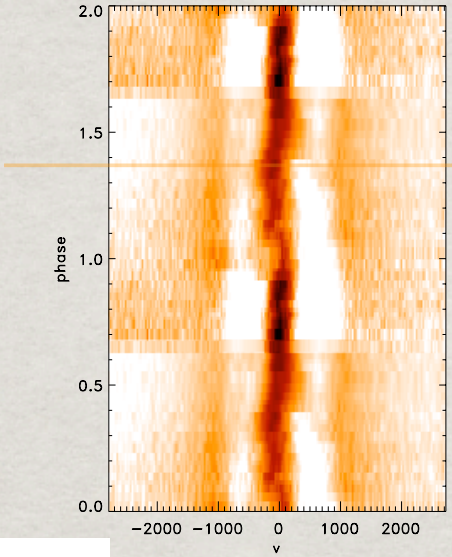
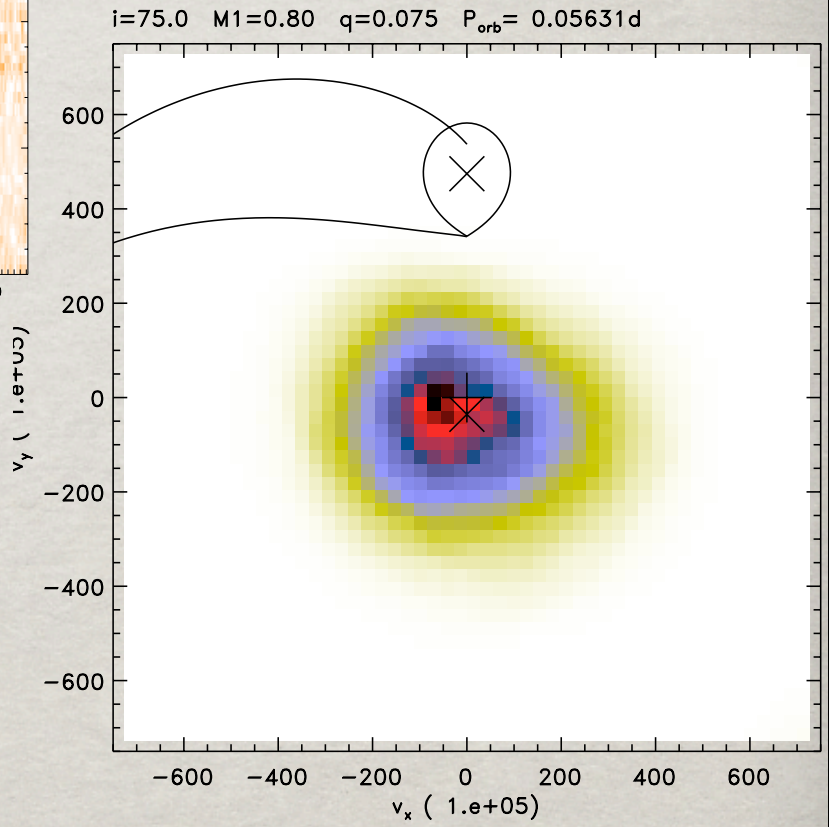
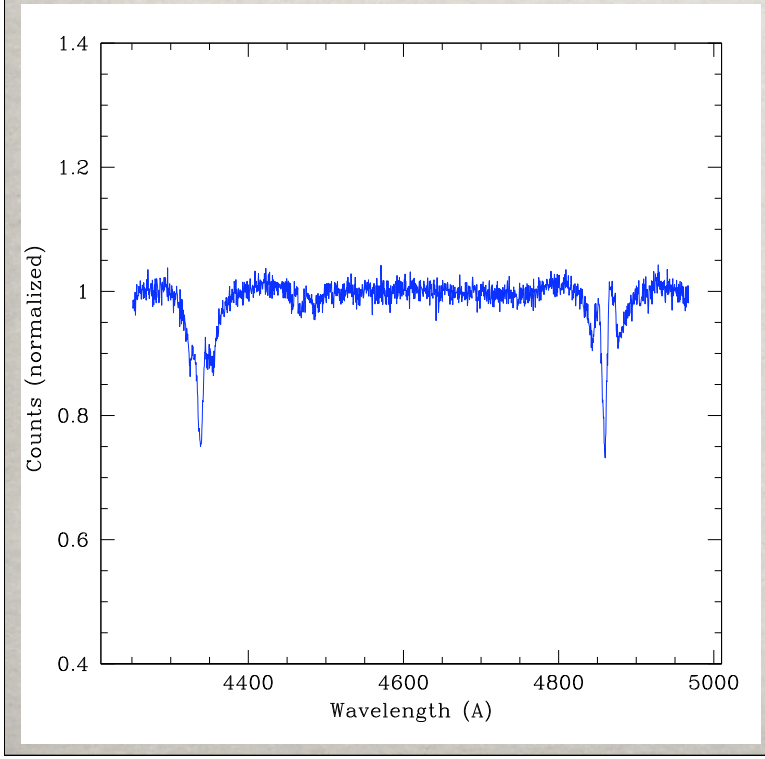




Hβ absorption component





THE START: JD 2454348

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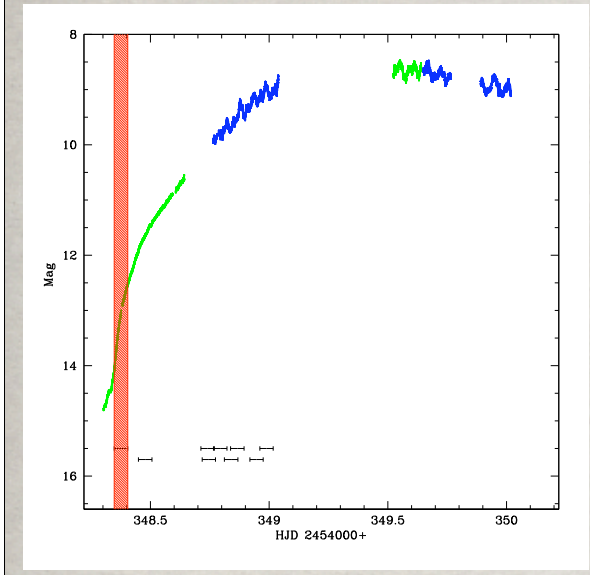
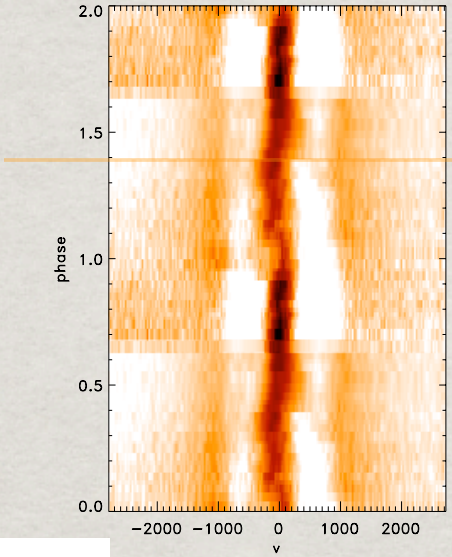
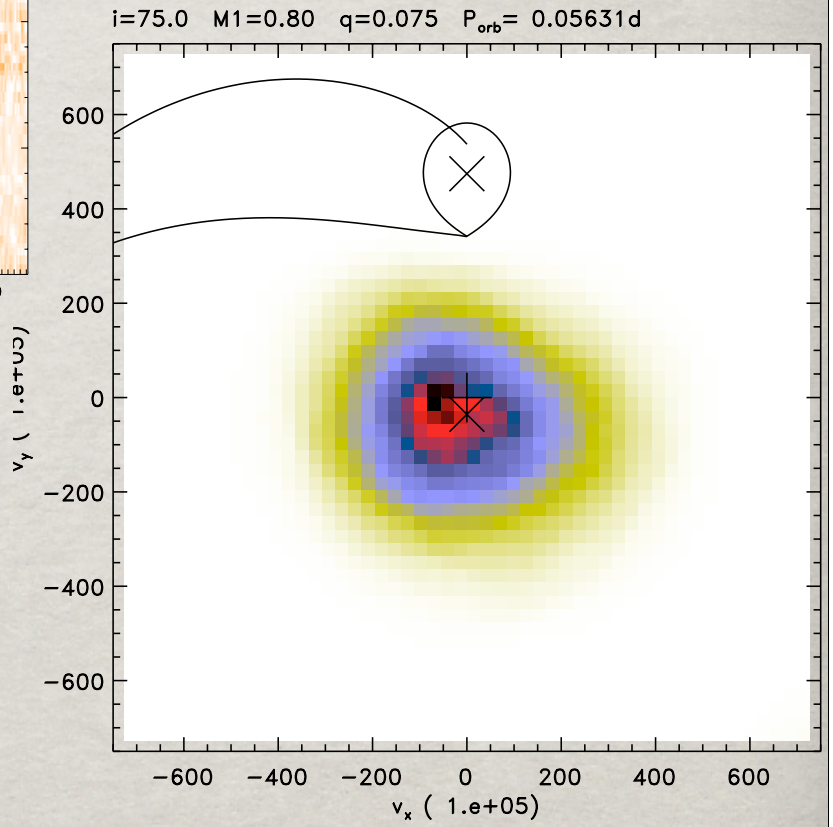
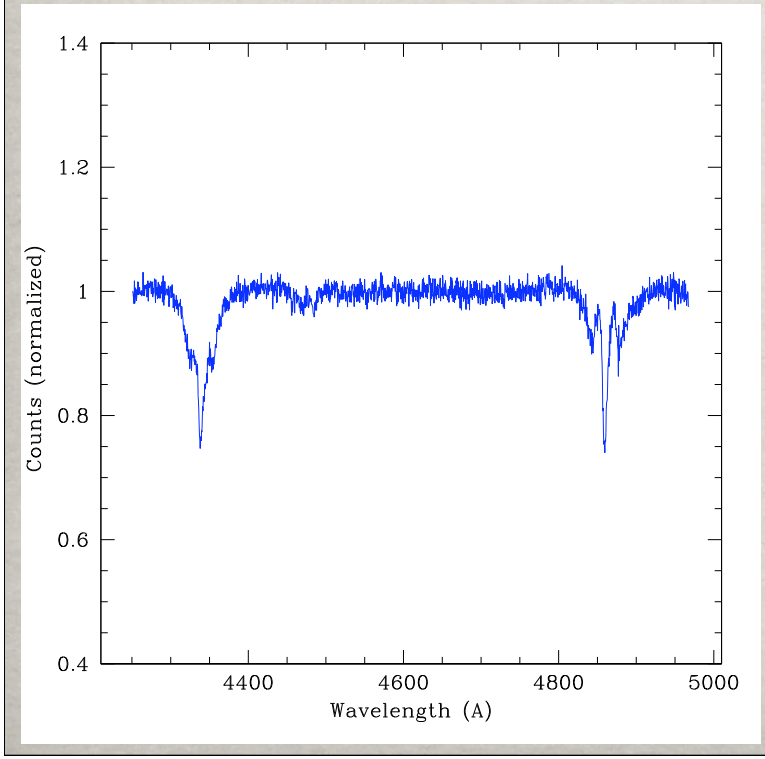




Hβ absorption component





THE START: JD 2454348

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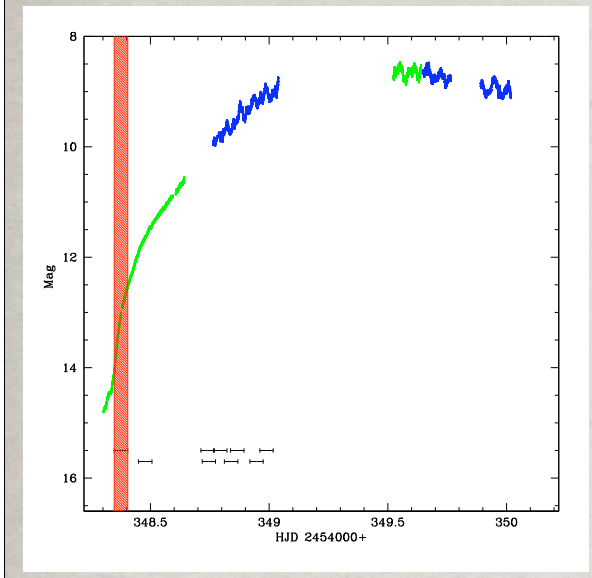
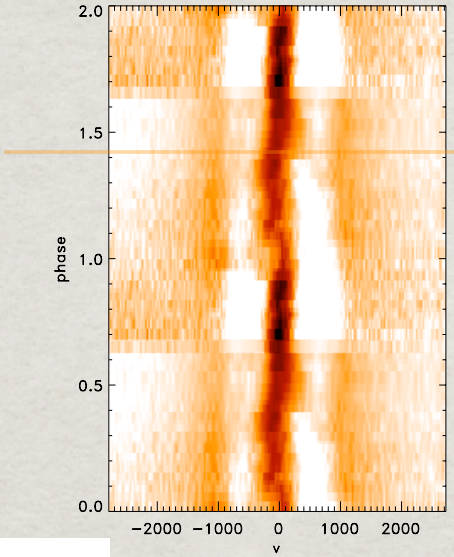
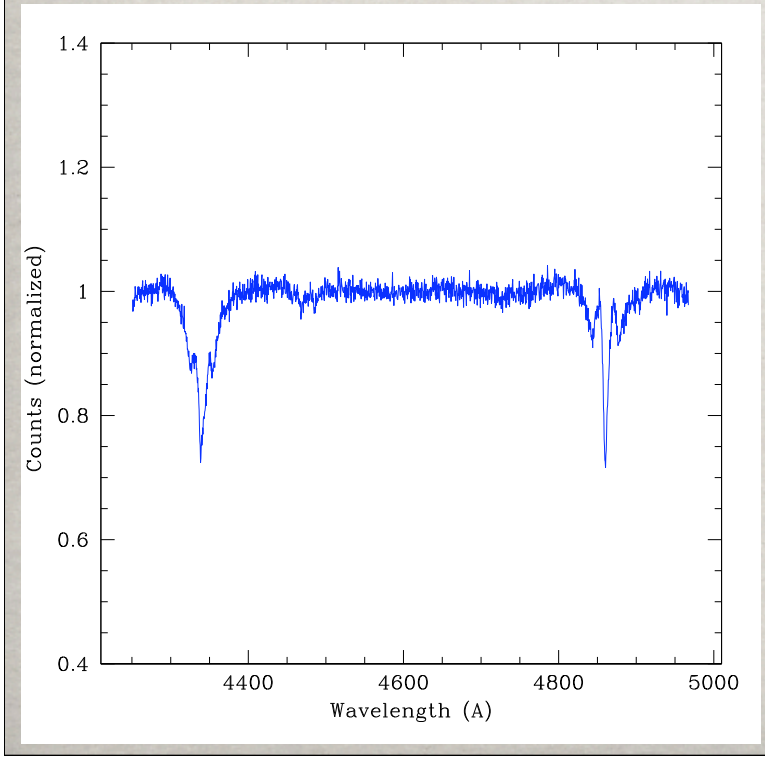
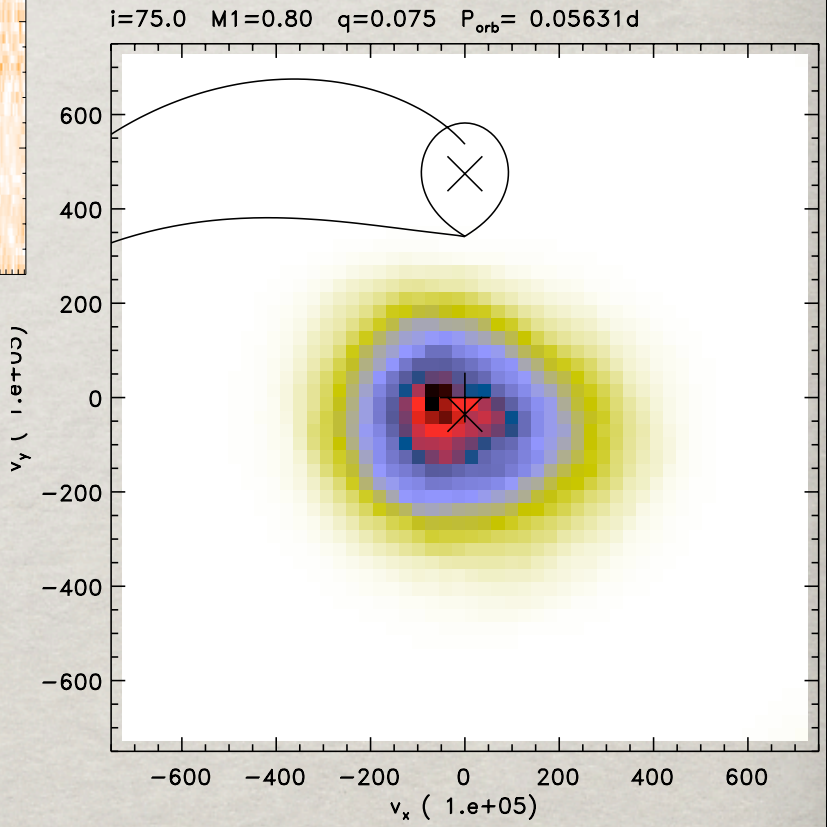
Hβ absorption component









THE START: JD 2454348

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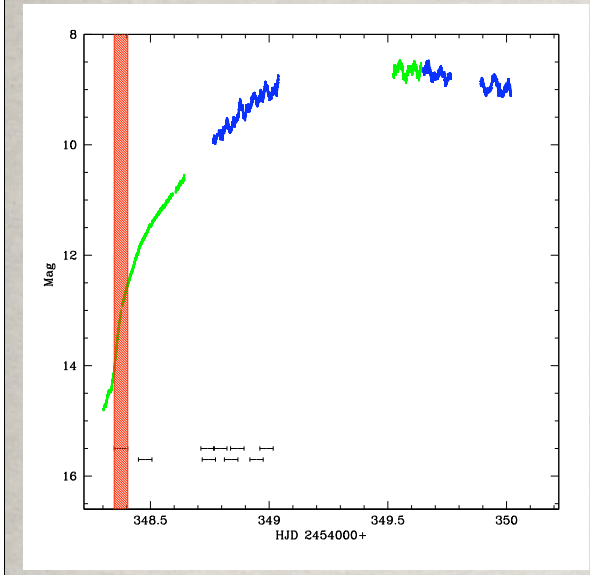
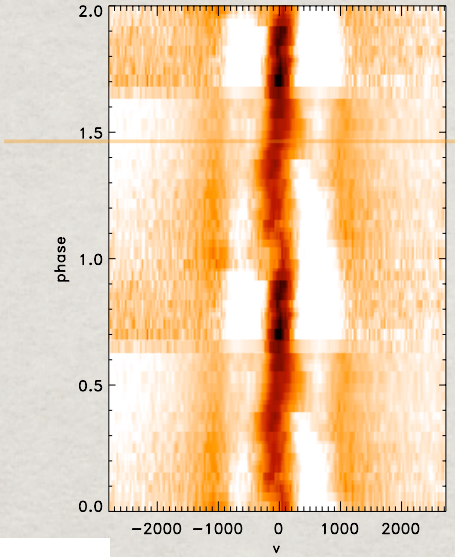
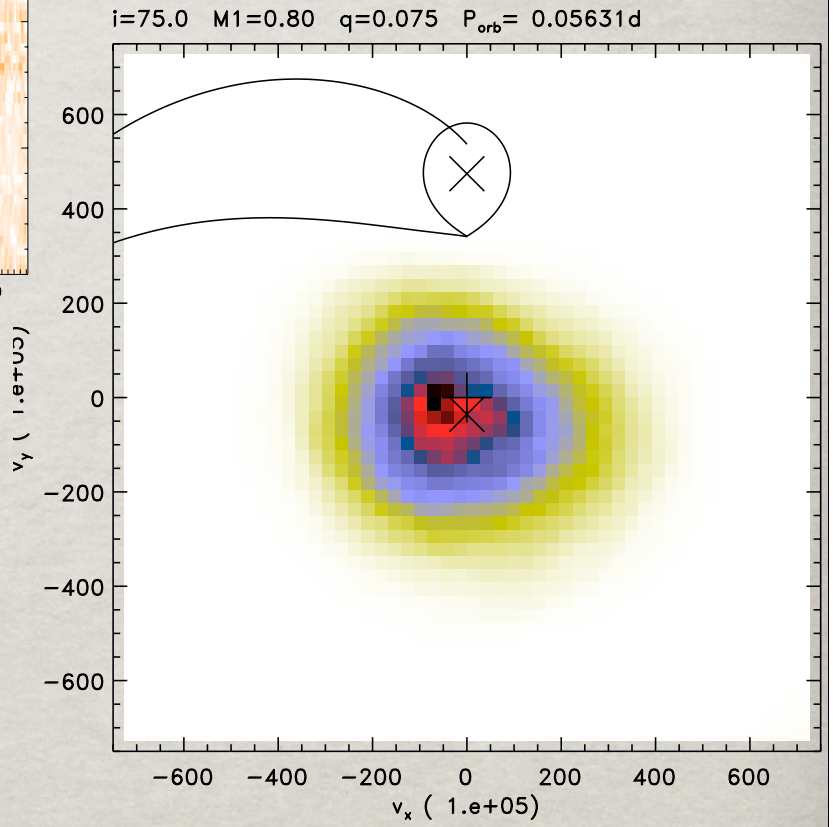
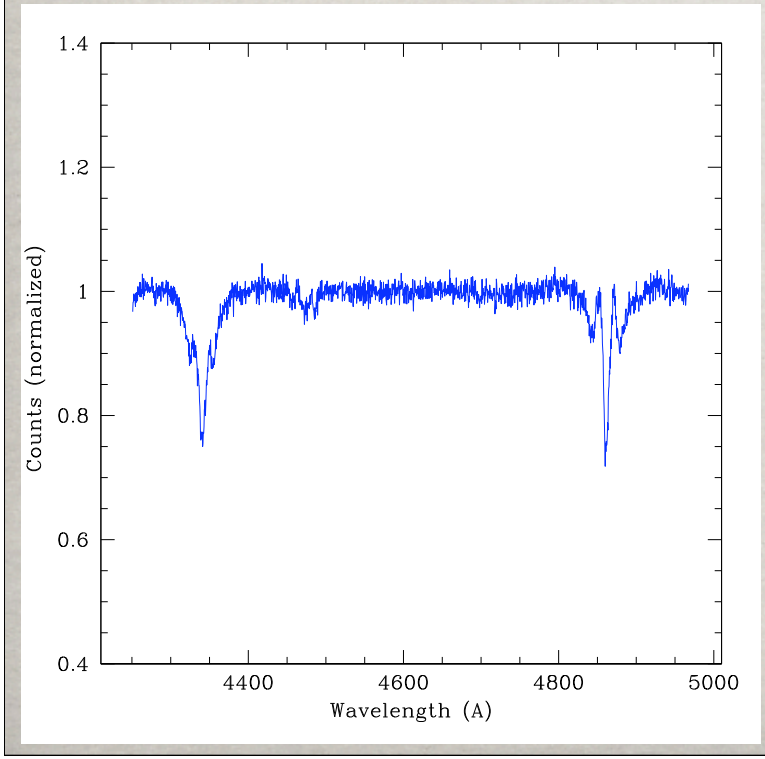




Hβ absorption component





THE START: JD 2454348

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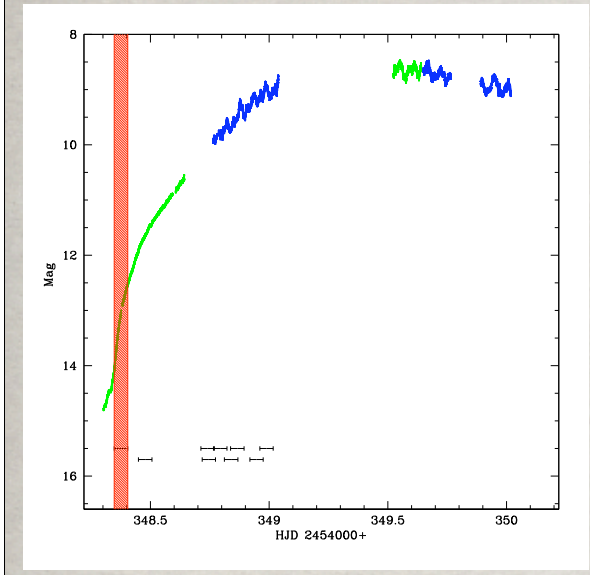
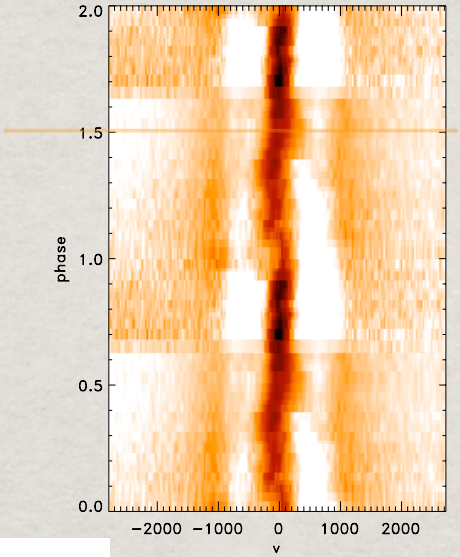
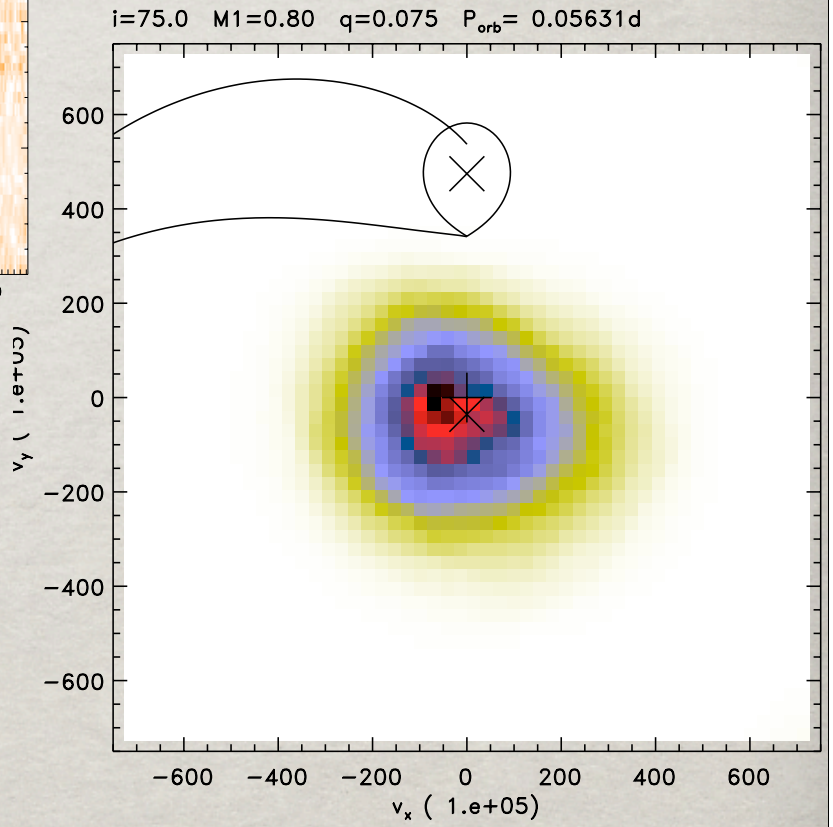
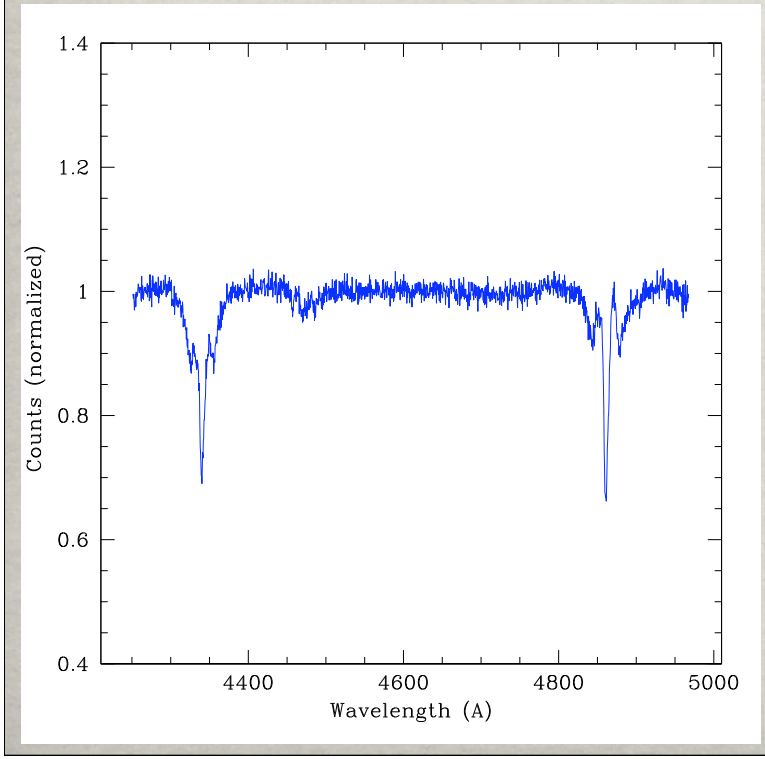




Hβ absorption component





THE START: JD 2454348

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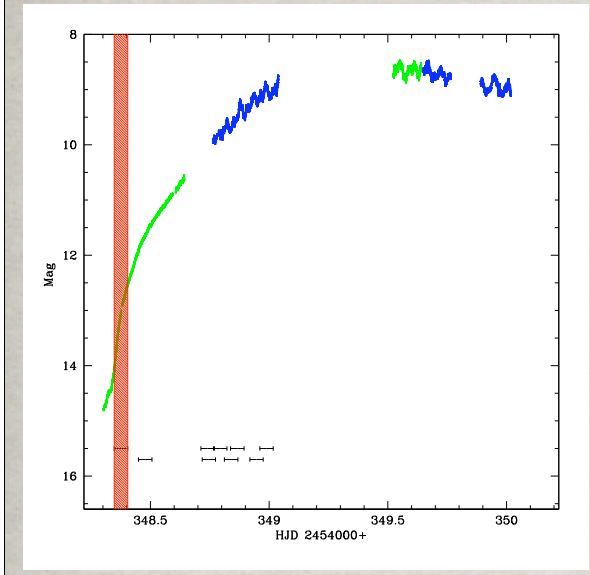
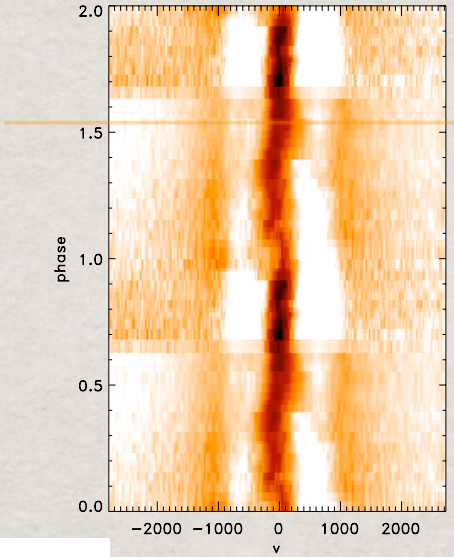
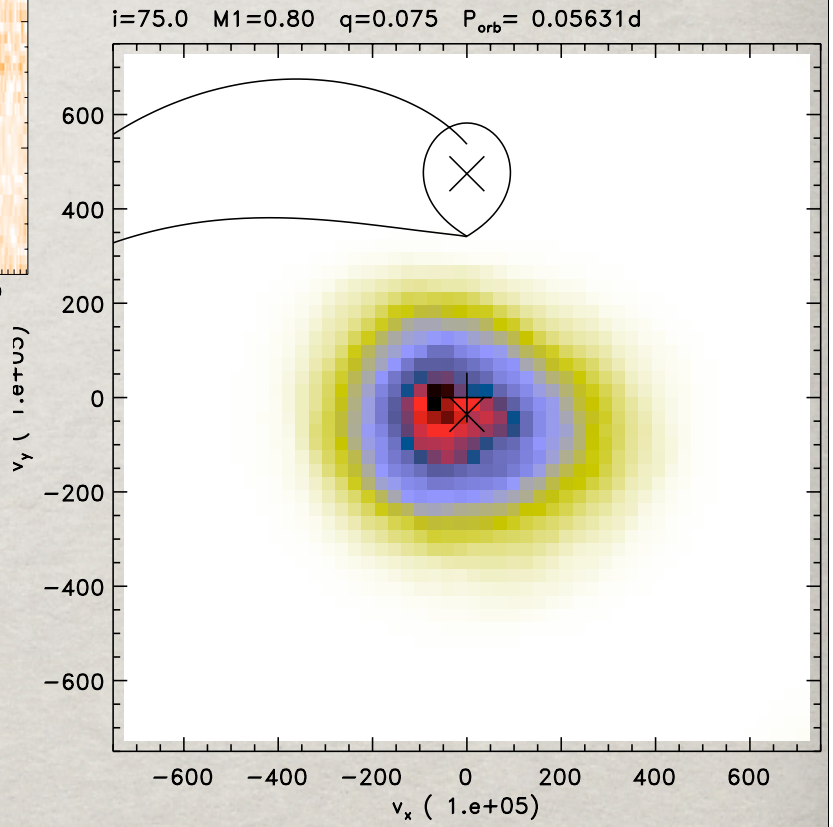
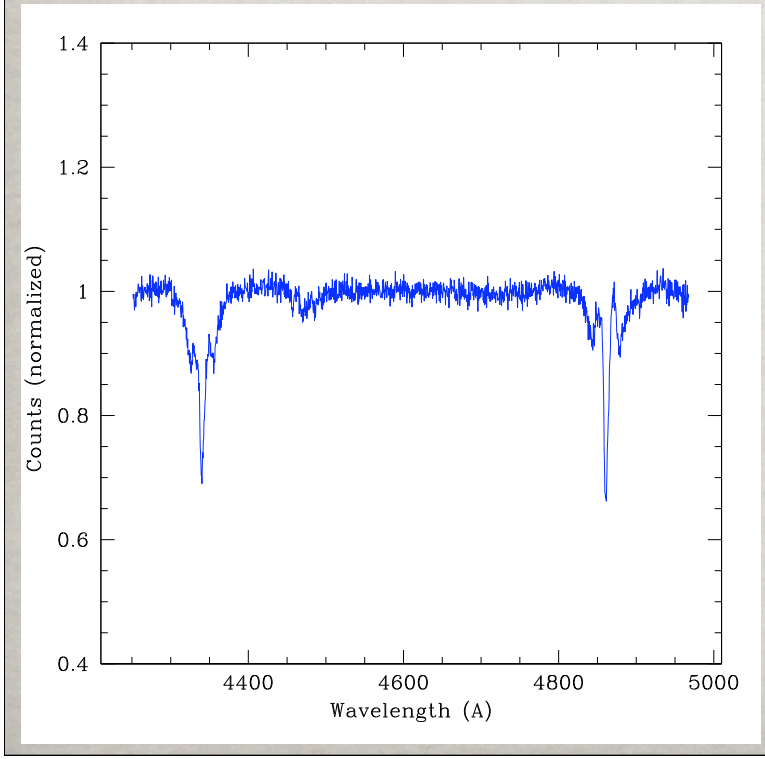




Hβ absorption component





THE START: JD 2454348

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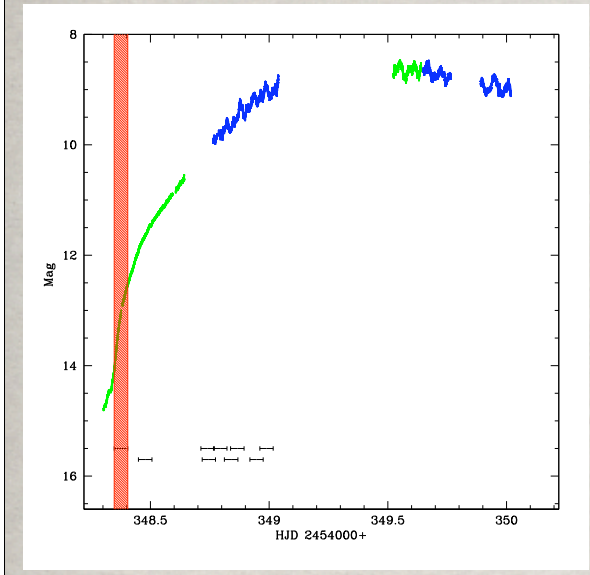
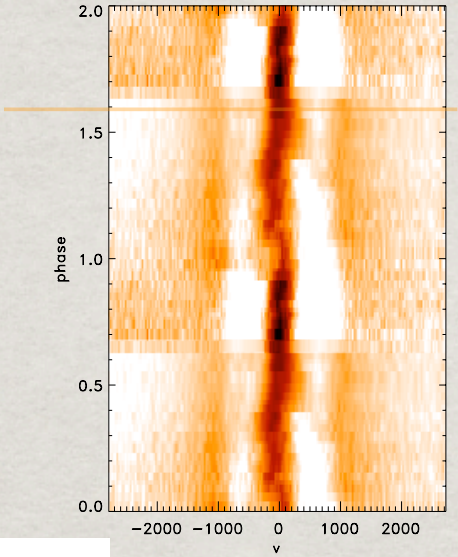
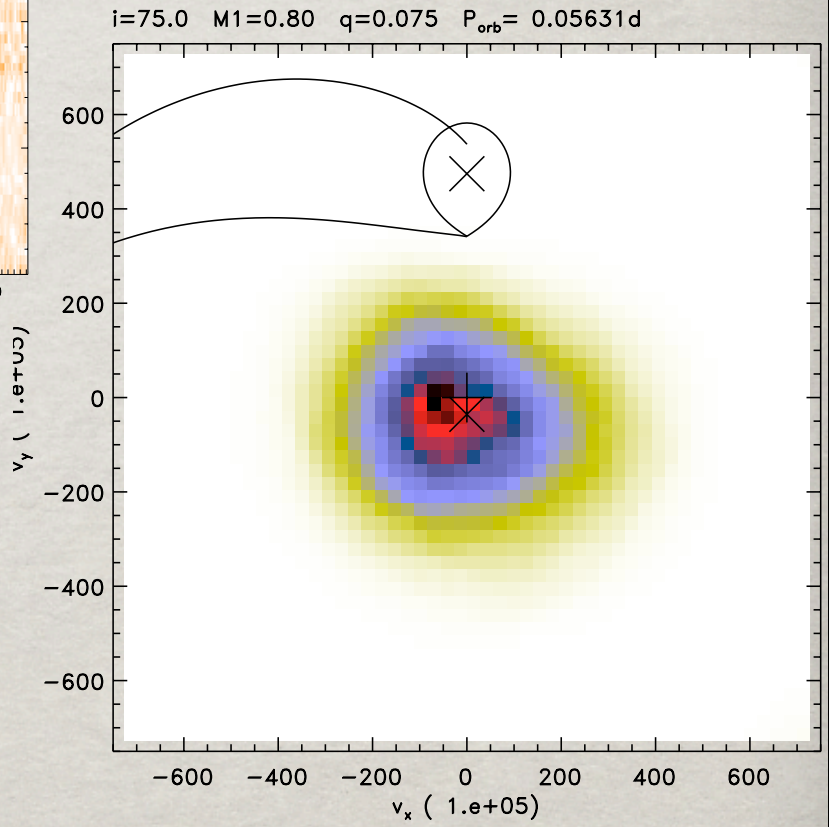
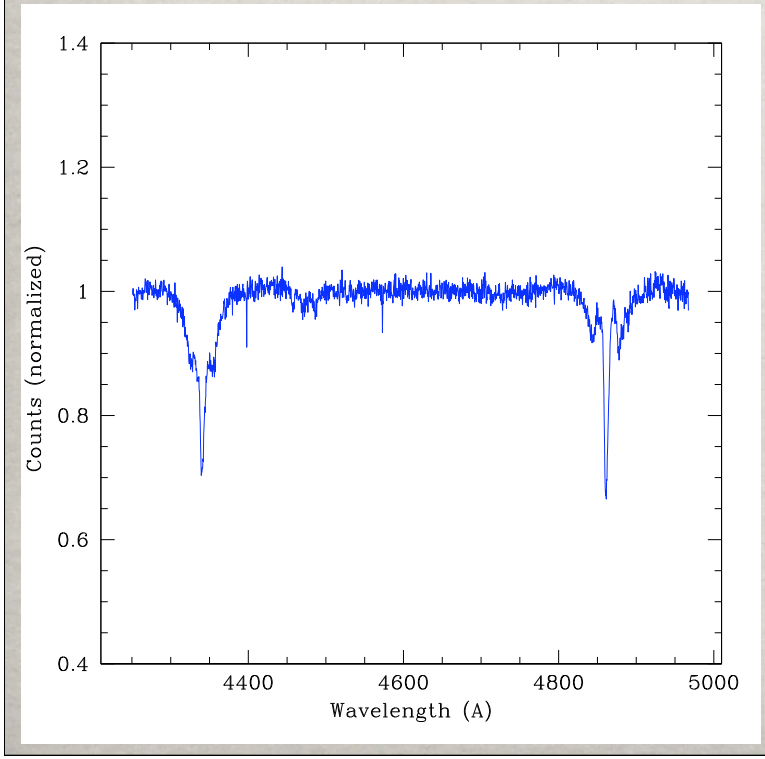




Hβ absorption component





THE START: JD 2454348

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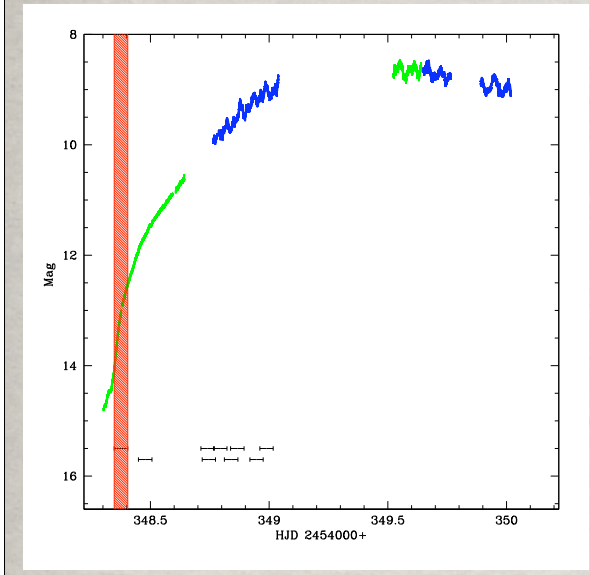
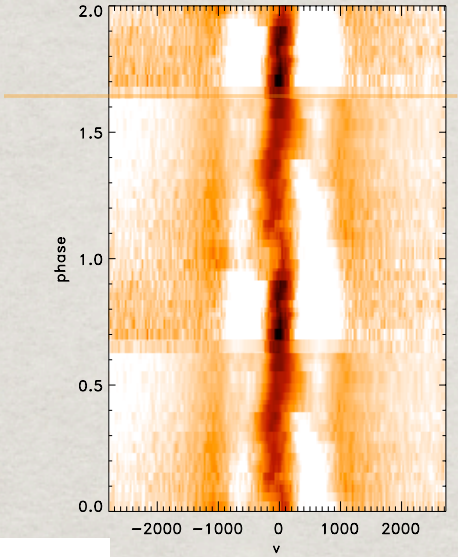
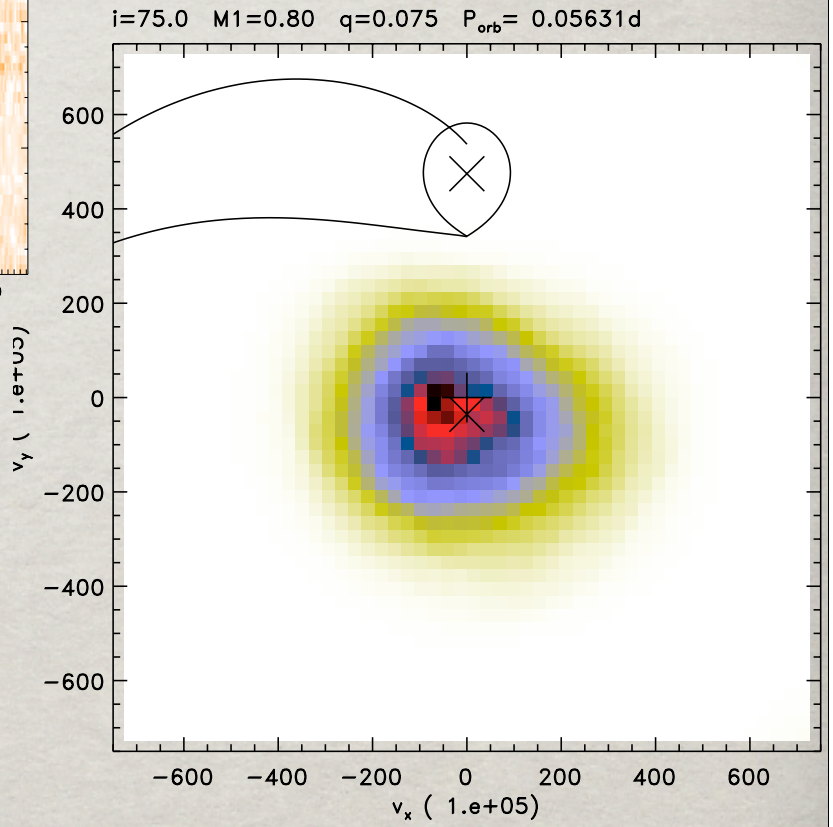
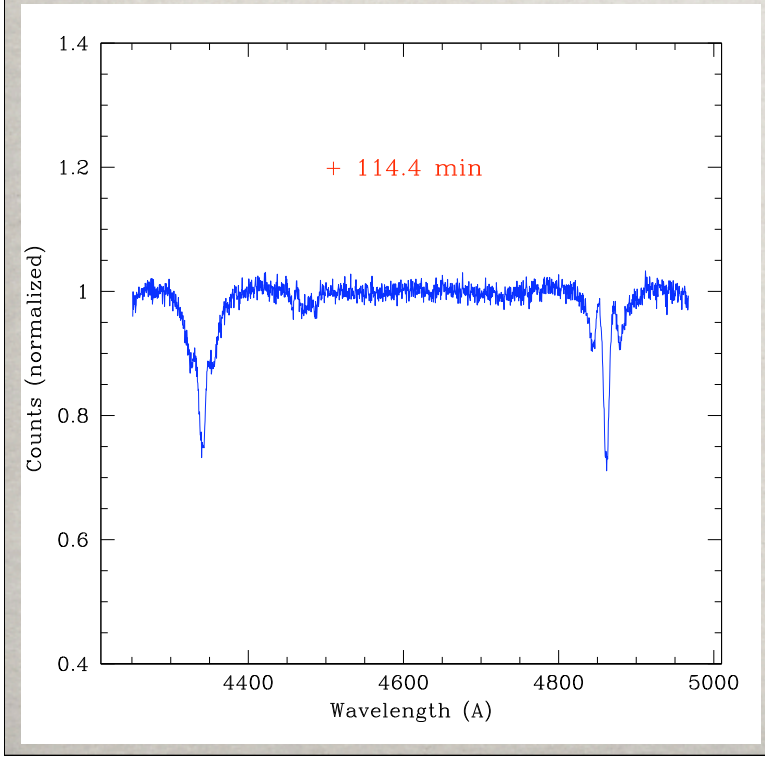




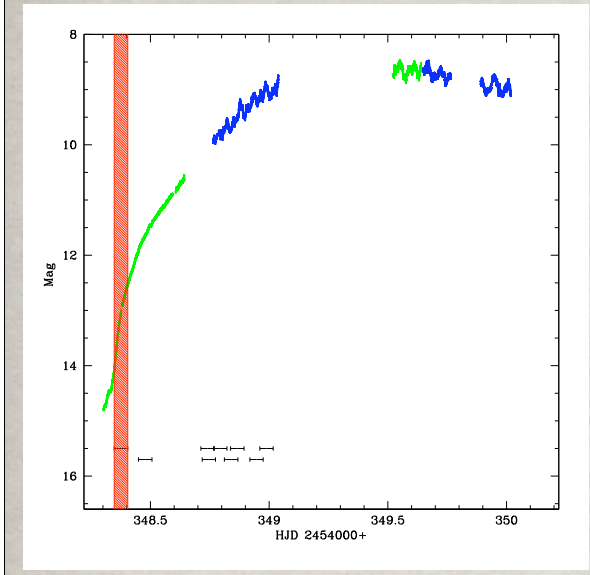
Hβ absorption component

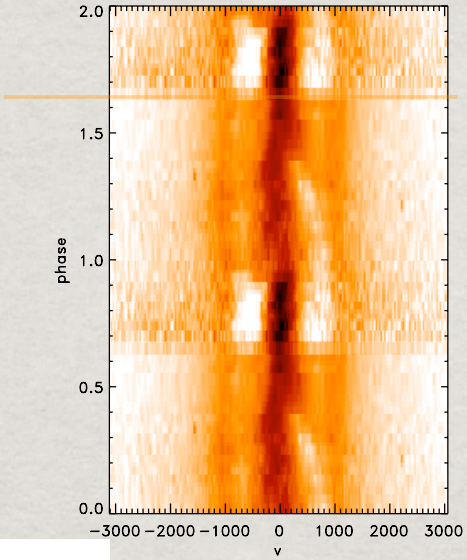




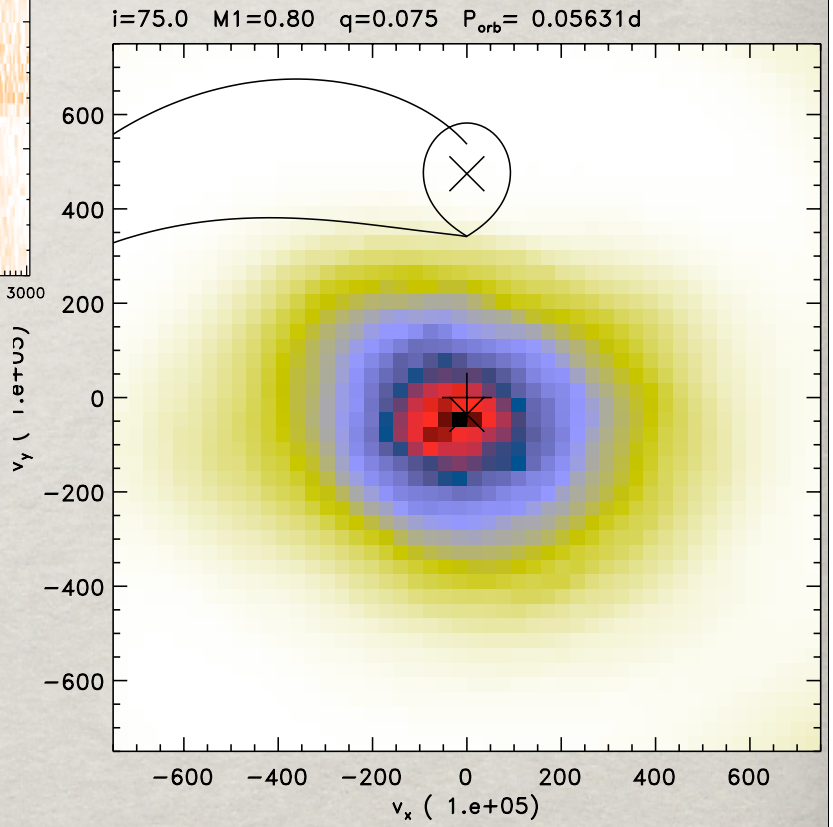
THE START: JD 2454348

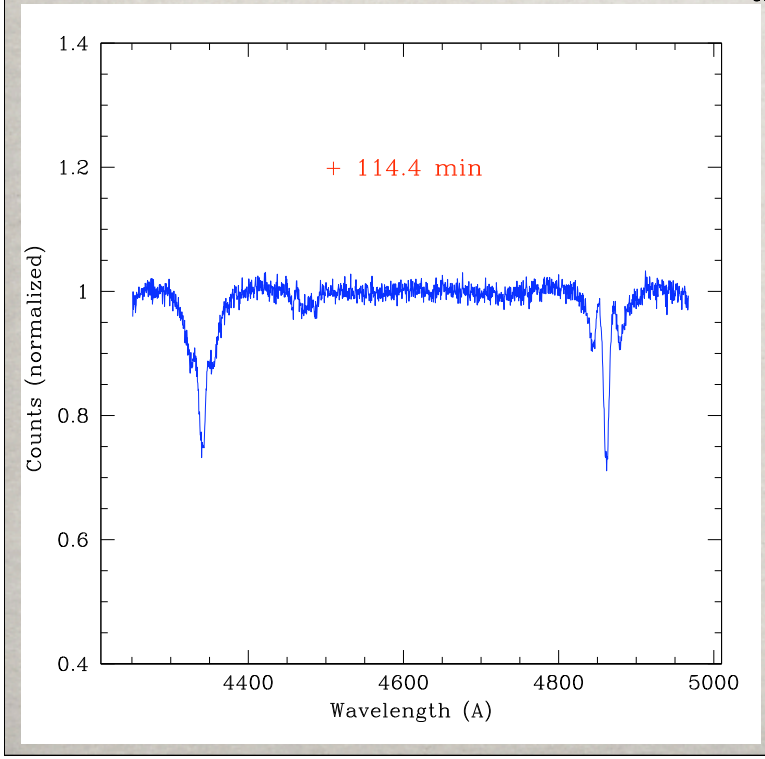
348.369854
348.427796





Hγ absorption component





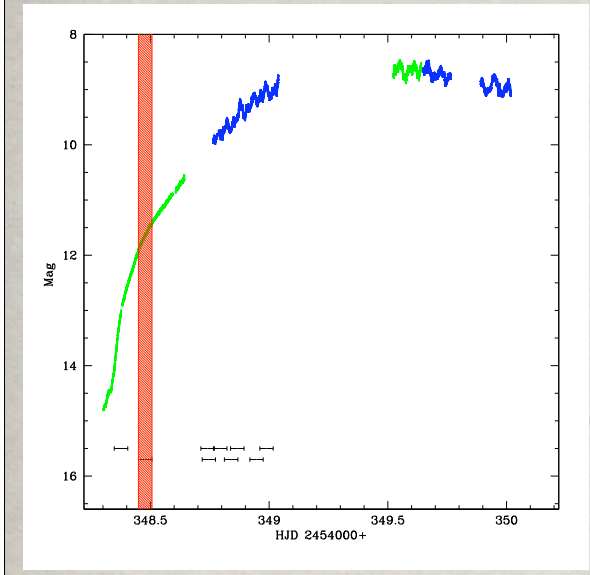
Boris having a break

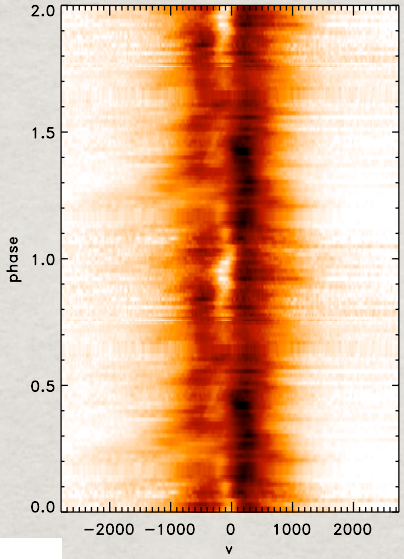
348.592906
348.713490

- 2.9 hours is a lot of time for a coffee.

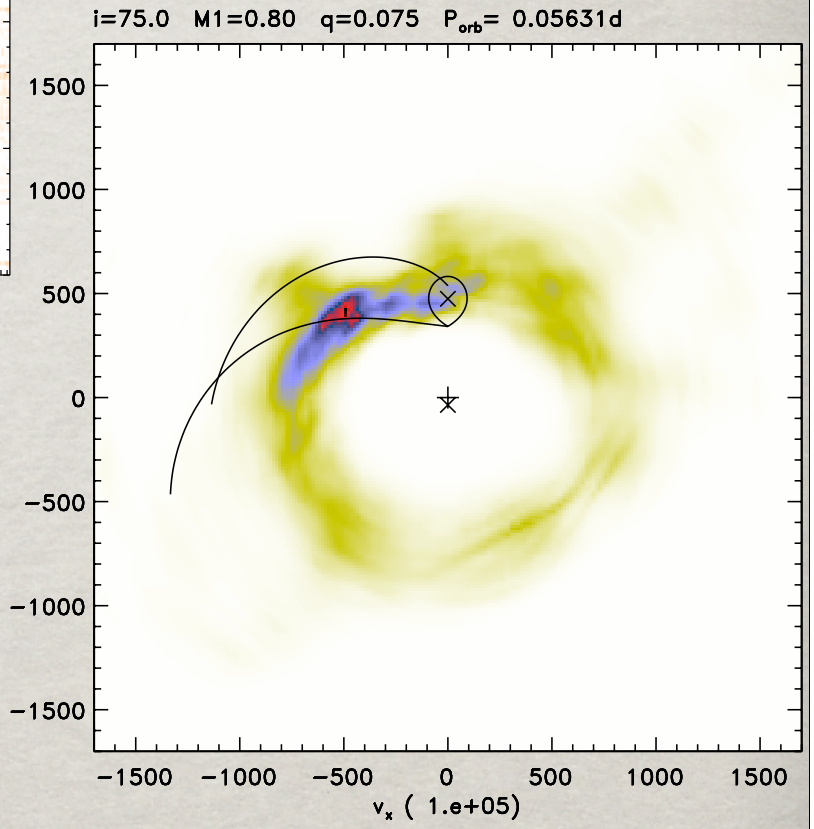
THE START: JD 2454348

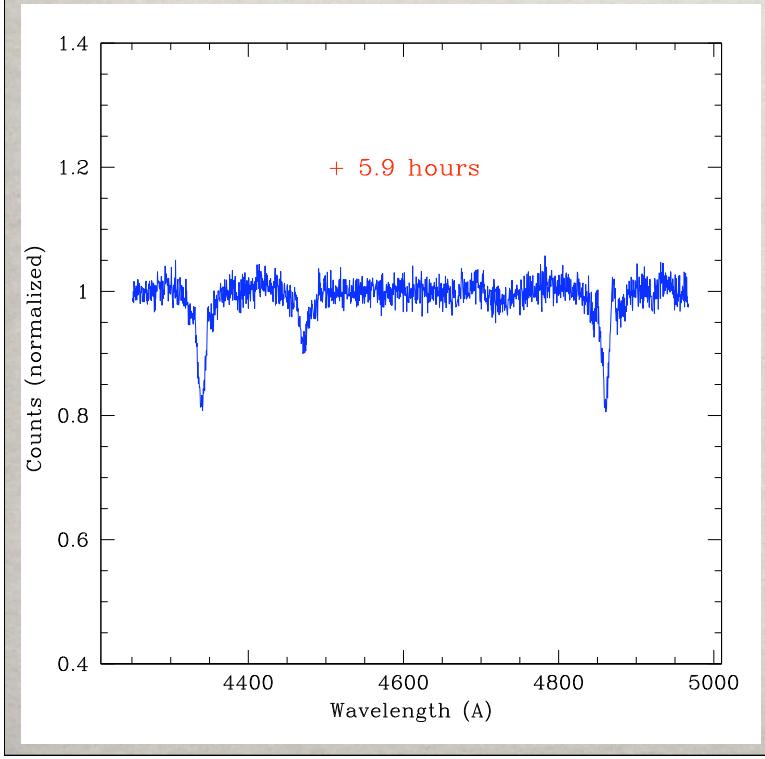
348.713490
348.770054





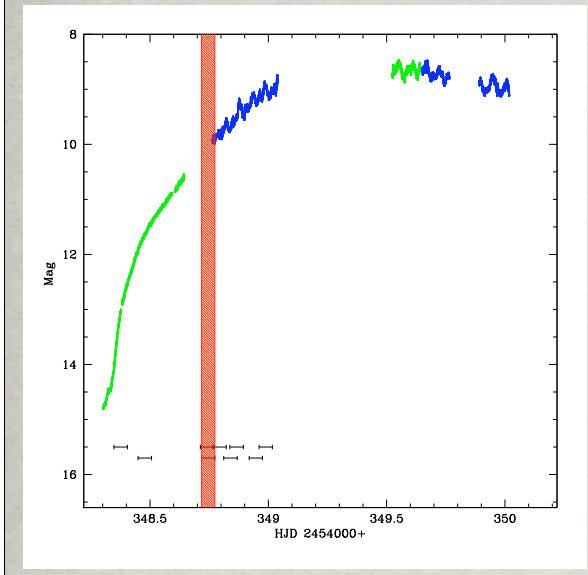
Hβ emission component

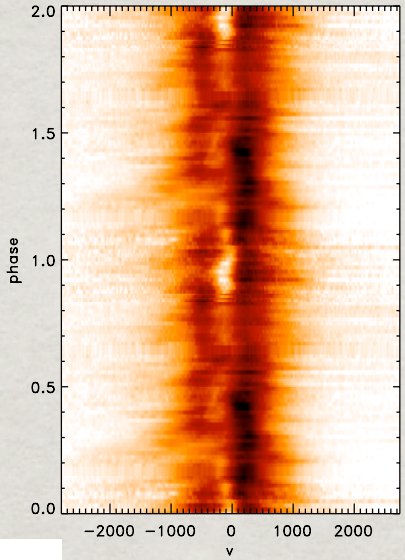




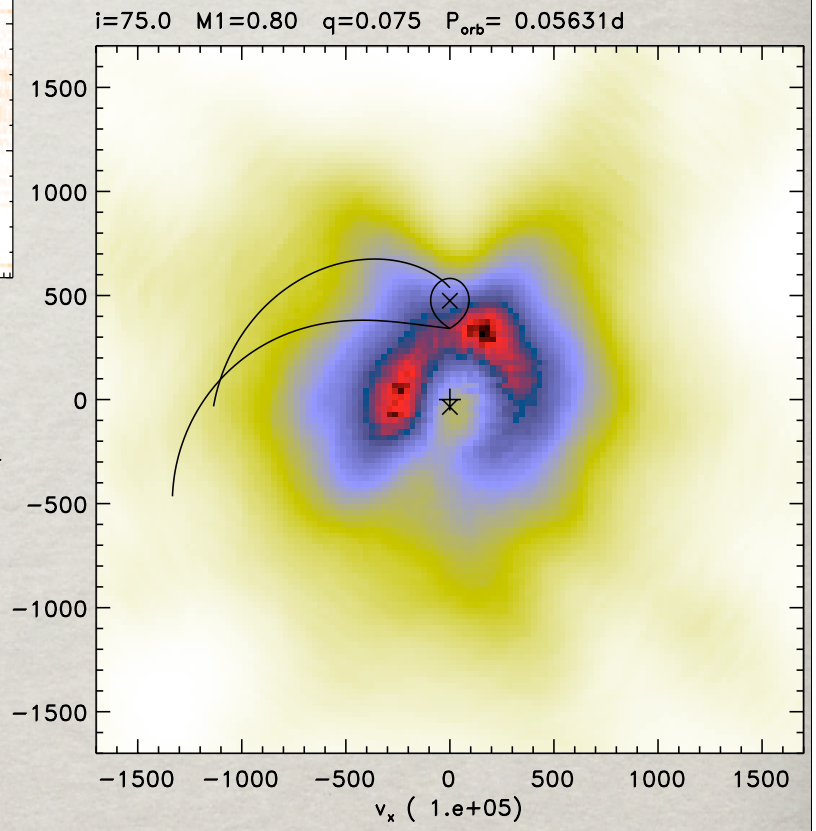
THE START: JD 2454348

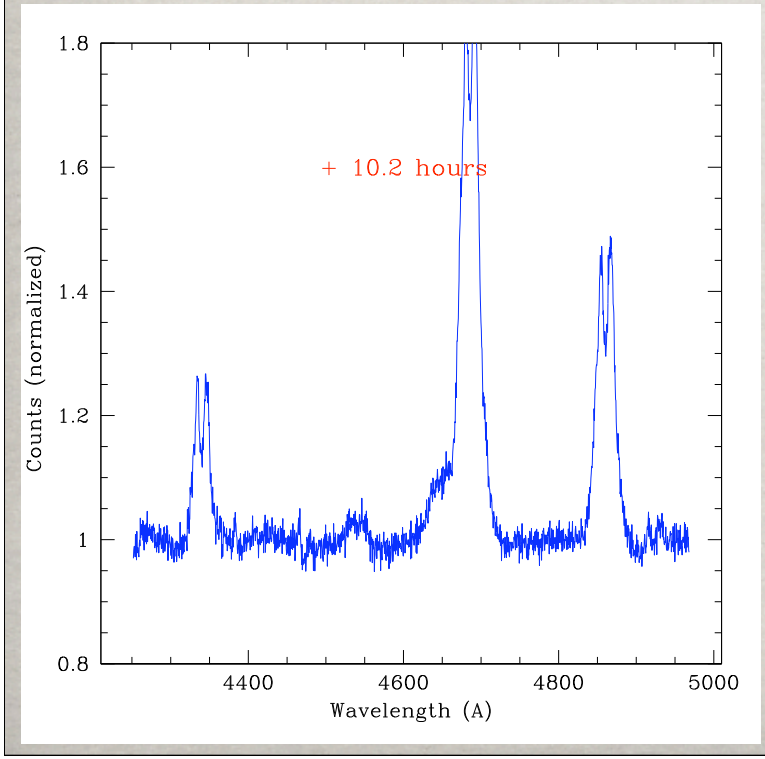
348.772543
348.775078





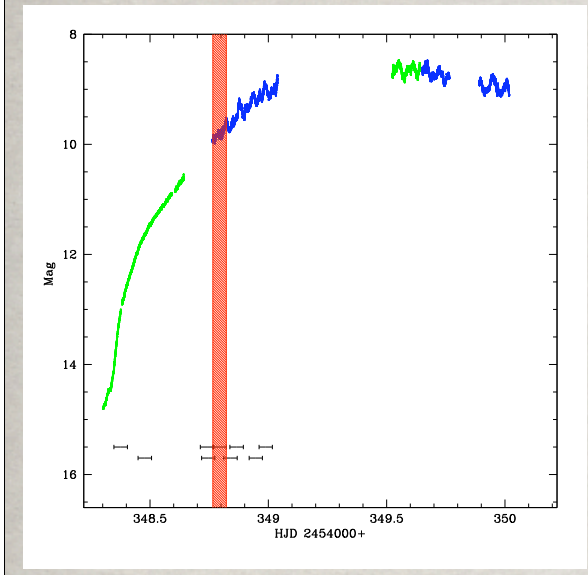
Hβ emission component

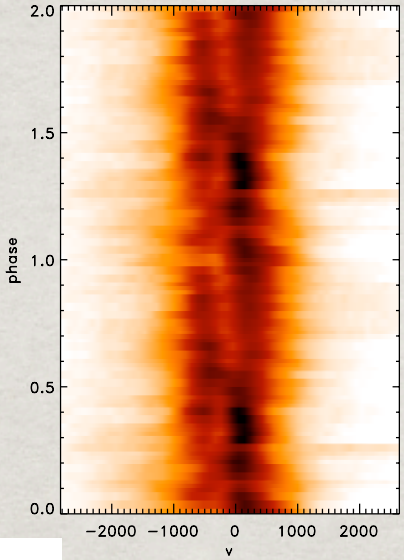




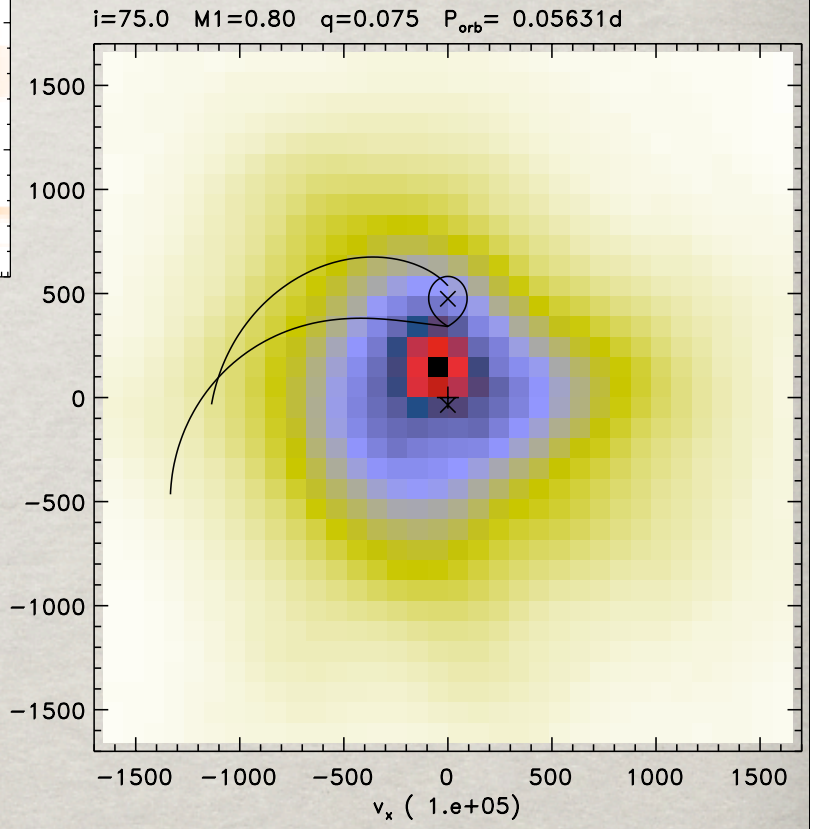
THE START: JD 2454348

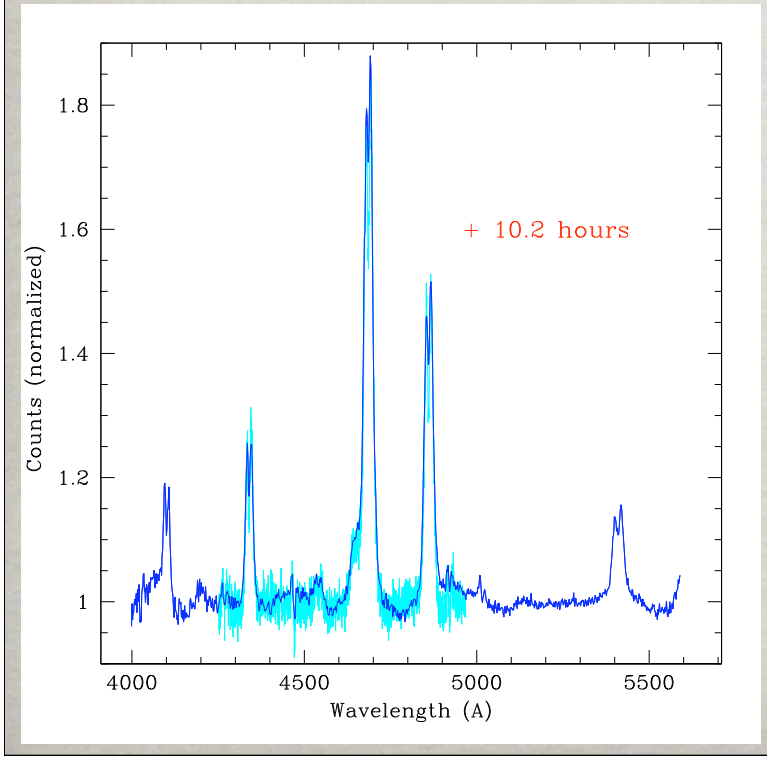
348.76622
348.82311





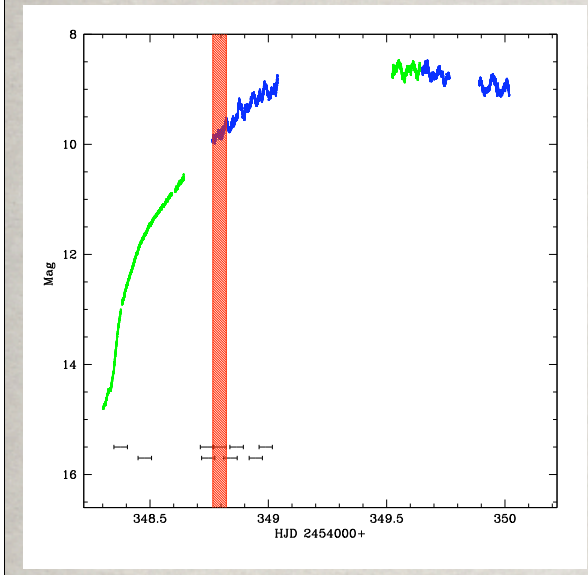
Hβ emission component

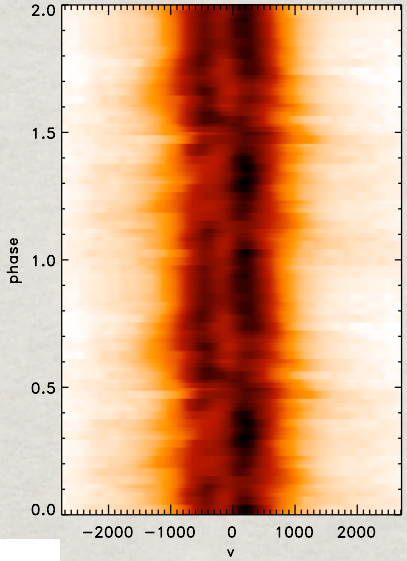




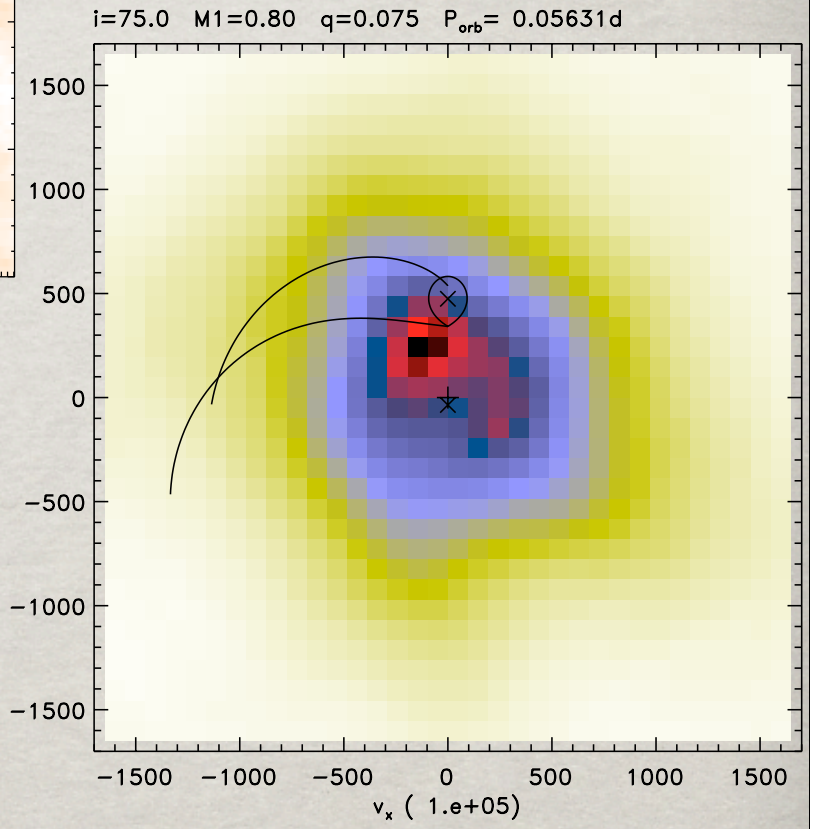
THE START: JD 2454348

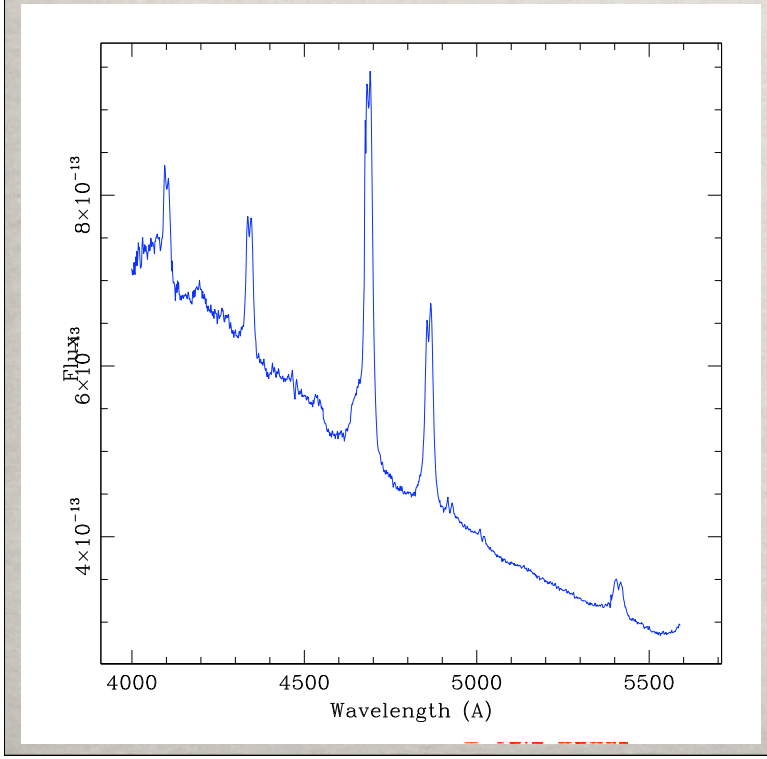
348.81207
348.86918





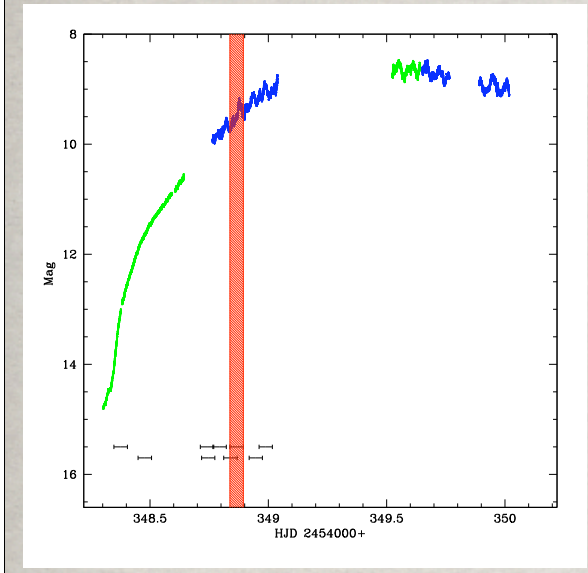
Hβ emission component

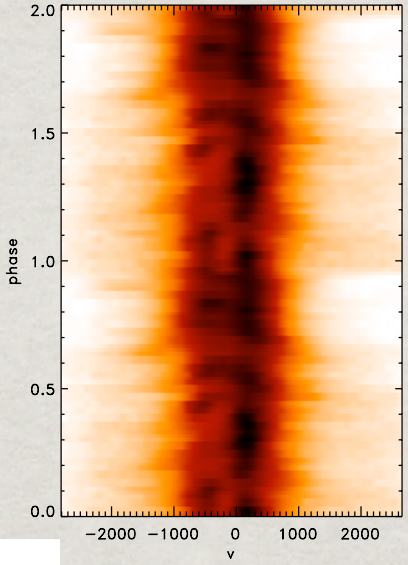




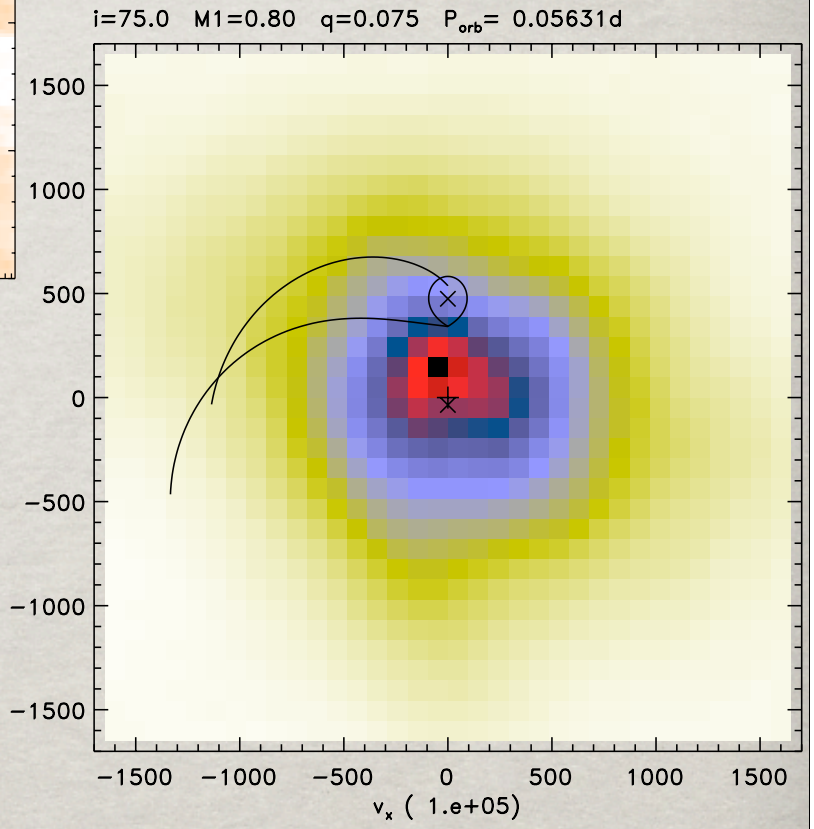
THE START: JD 2454348

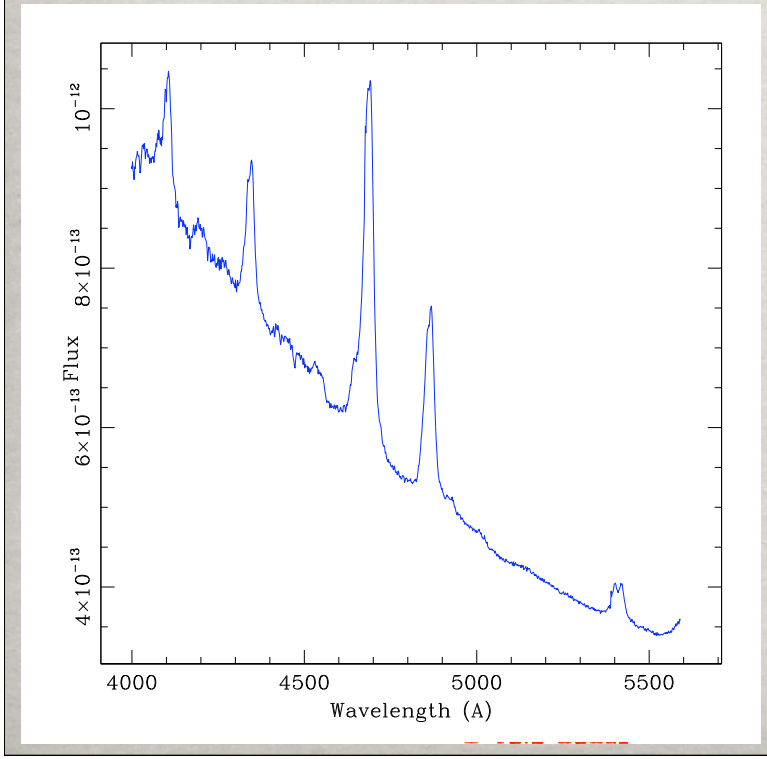
348.83762
348.89443





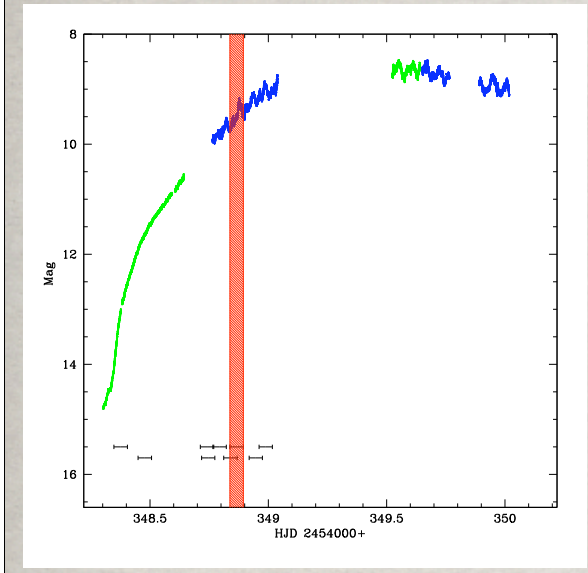
Hβ emission component

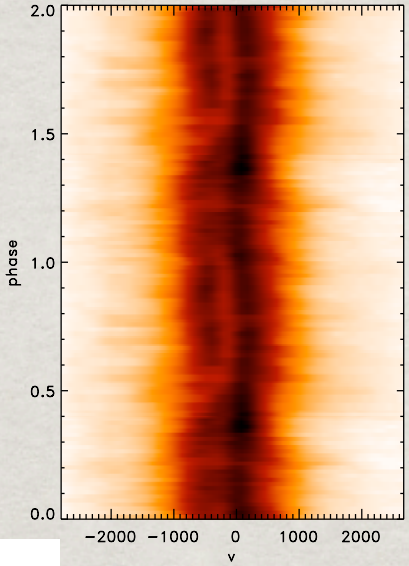




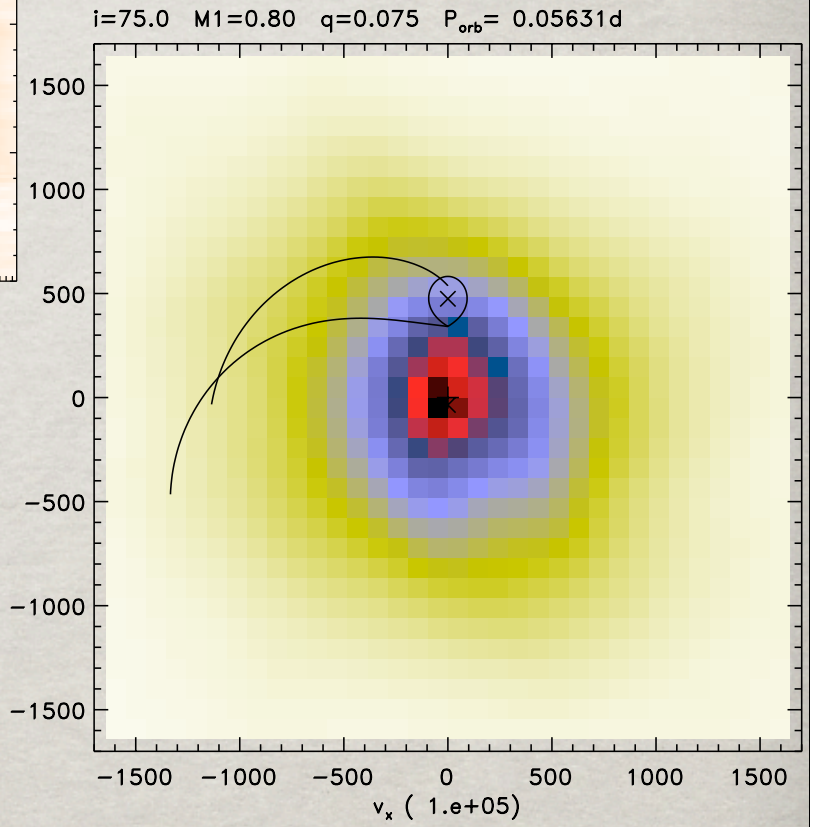
THE START: JD 2454348

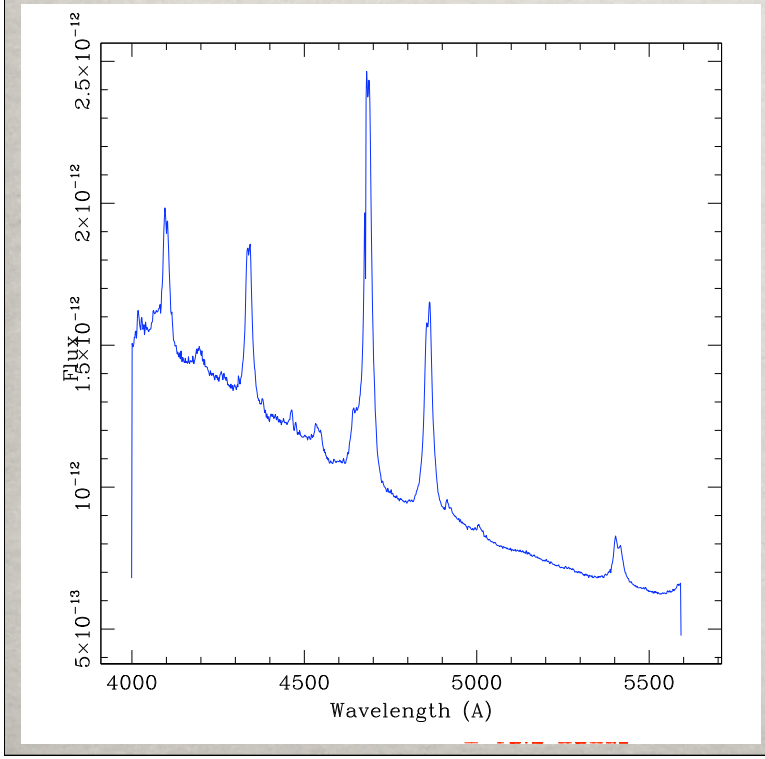
348.91911
348.97507





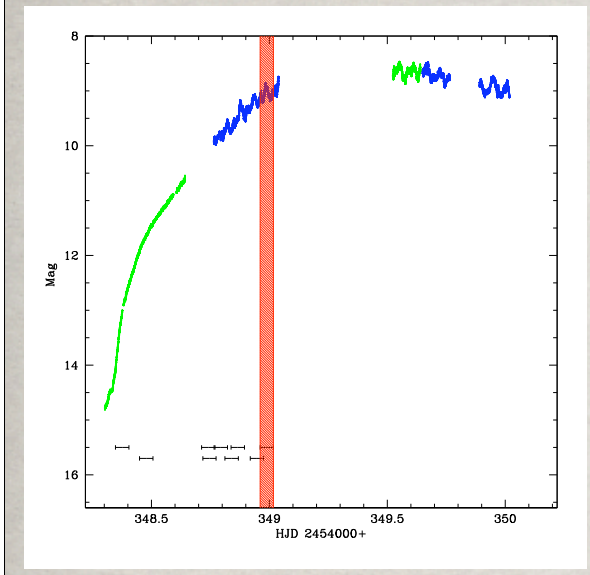
Hβ emission component

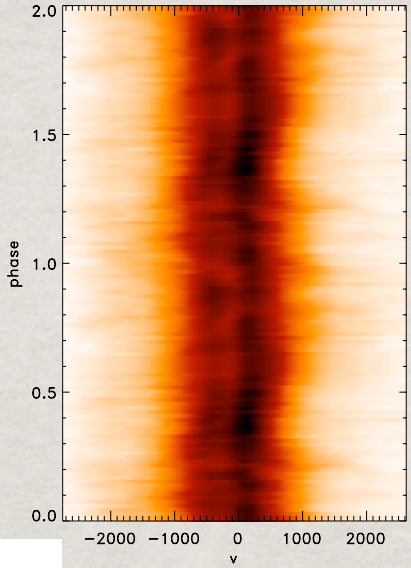




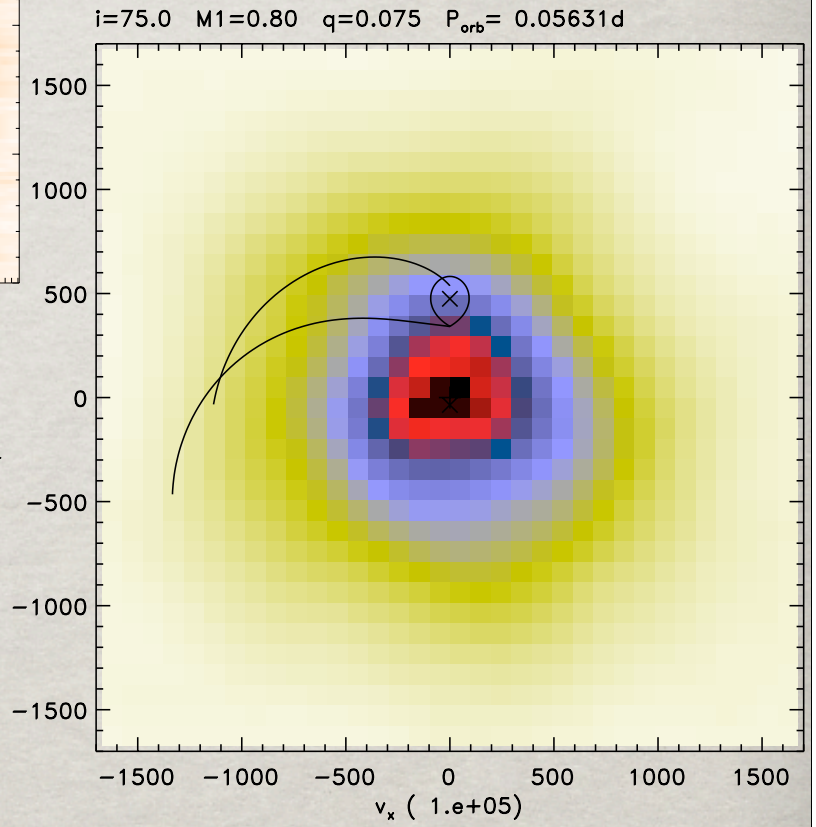
THE START: JD 2454348

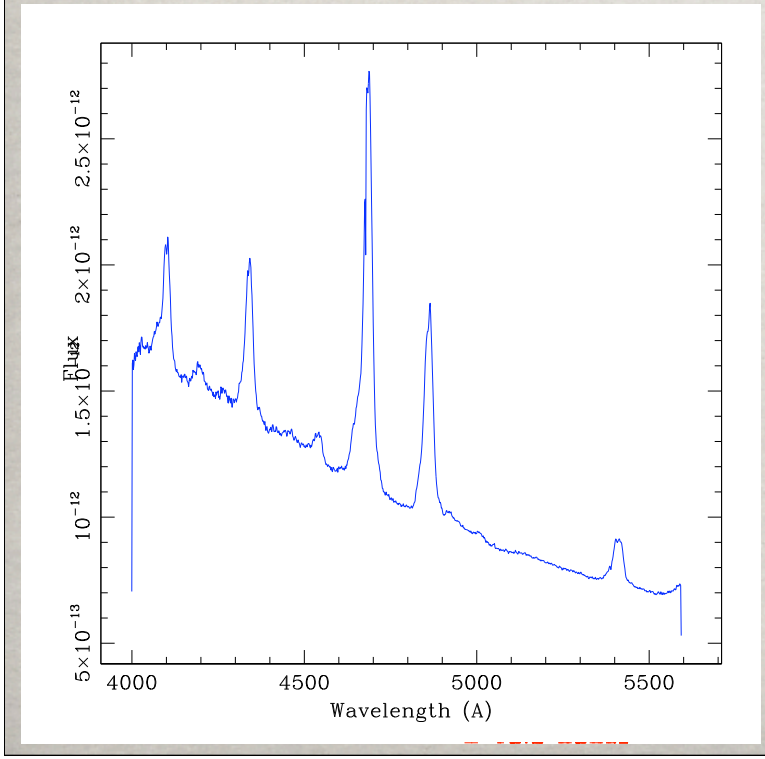
348.96181
349.01816





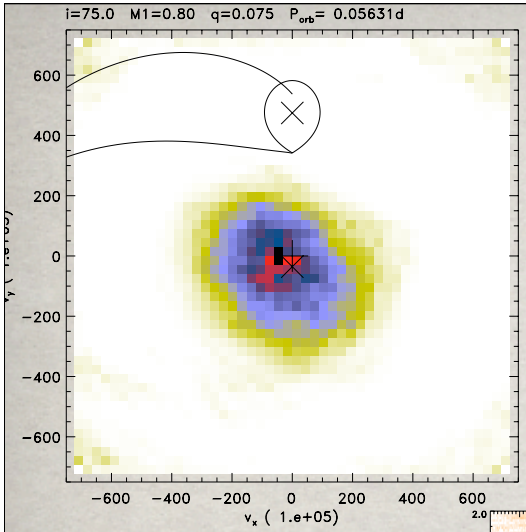
Hβ emission component

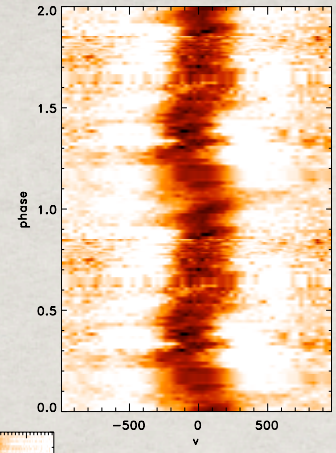




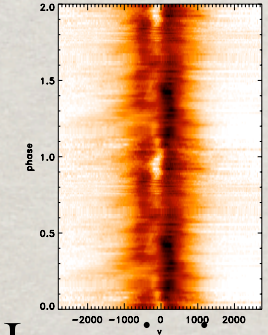
THE START: JD 2454348

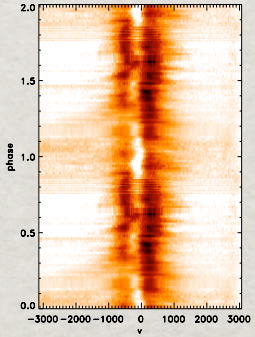
348.713490
348.770054

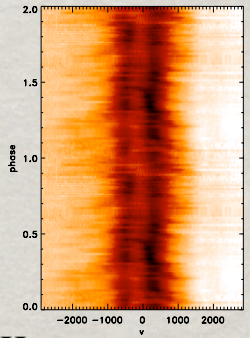




He I absorption



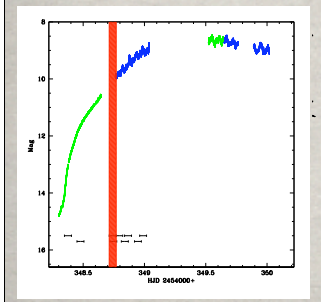


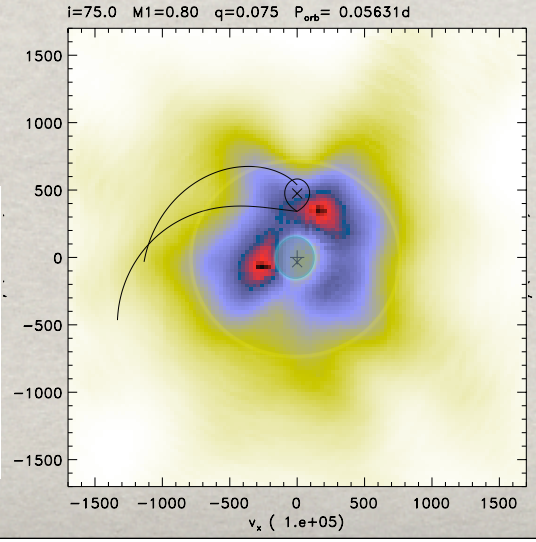


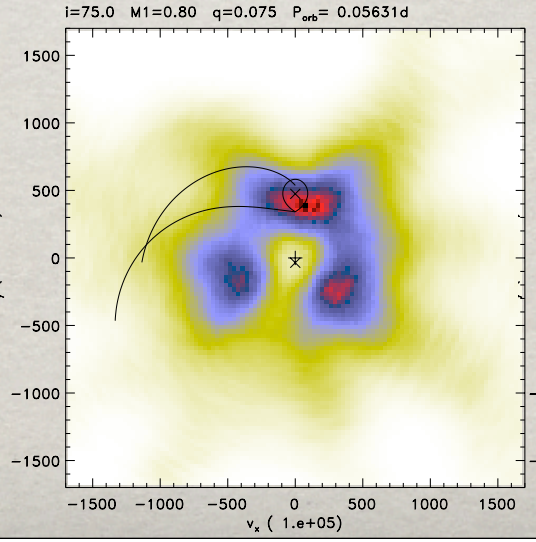
Hβ emission

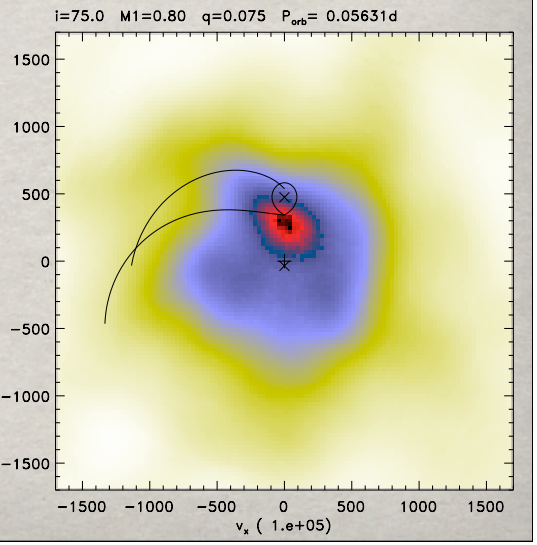
Hγ

He II



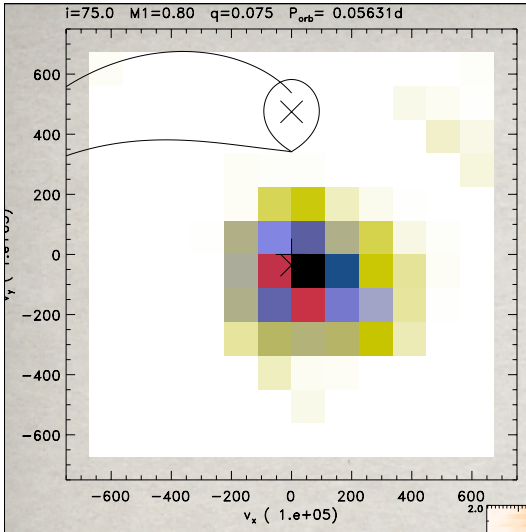


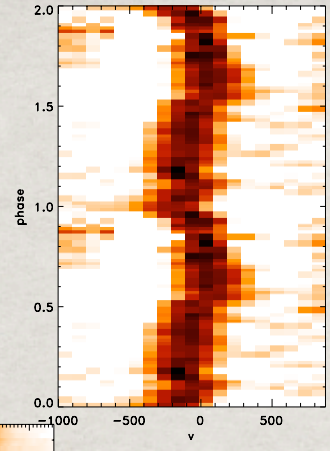




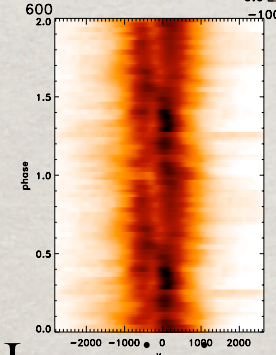
THE START: JD 2454348

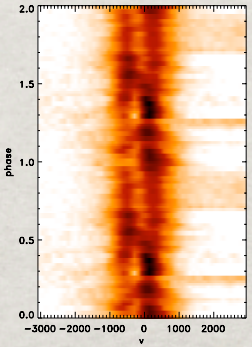
348.76622
348.82311

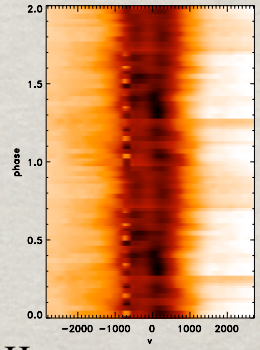




He I absorption



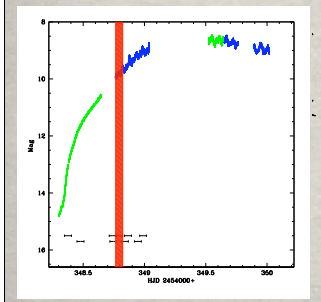


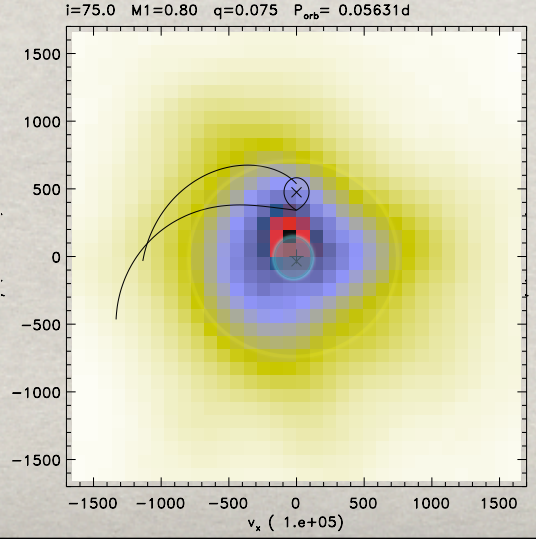


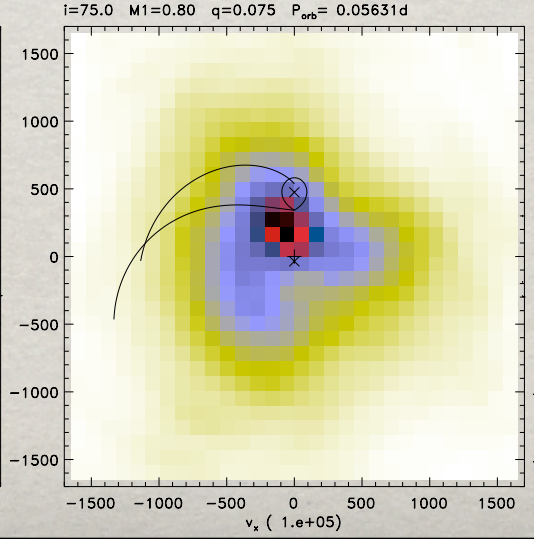
Hβ emission

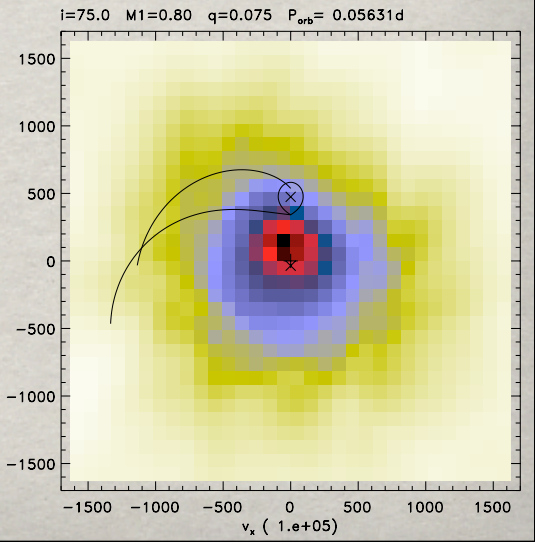
Hγ

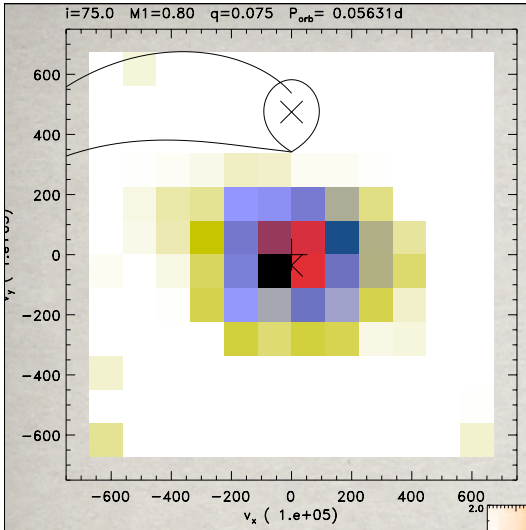
He II





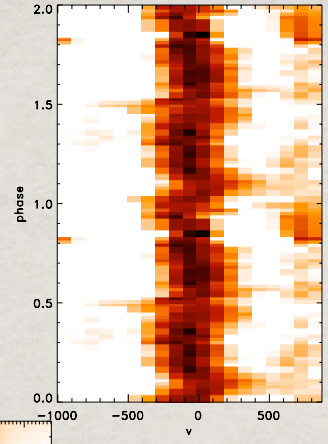




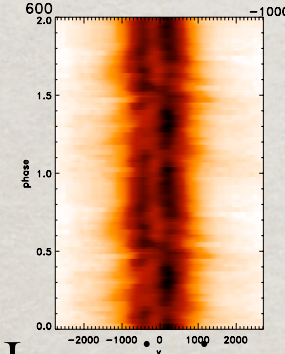


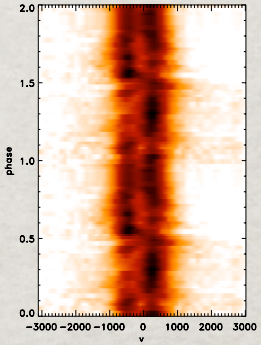
THE START: JD 2454348

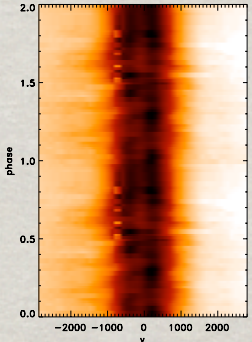
348.81207
348.86918



He I absorption



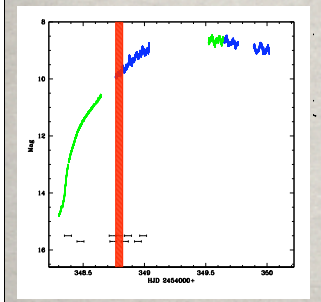


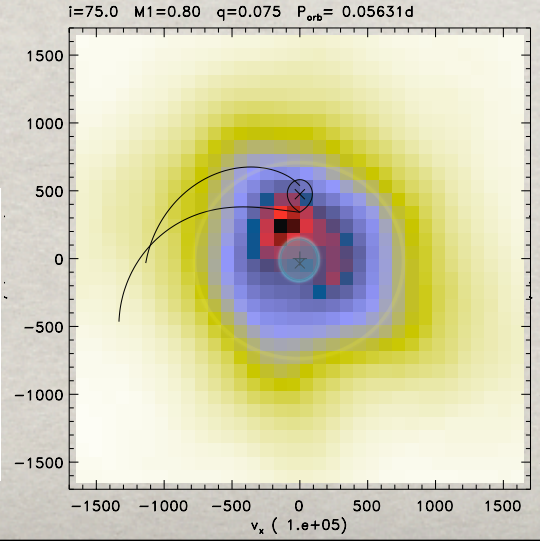


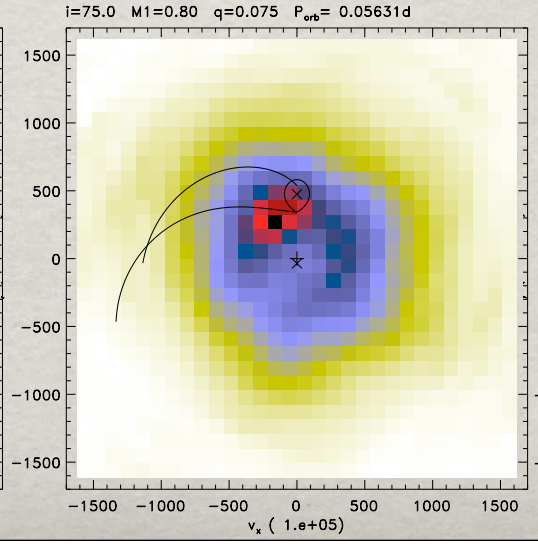
Hβ emission

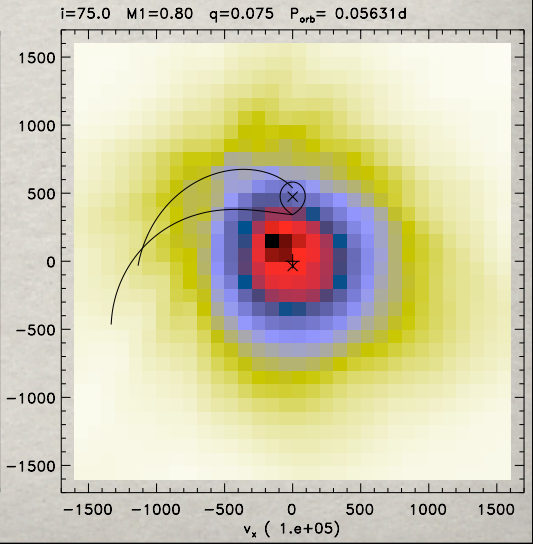
Hγ

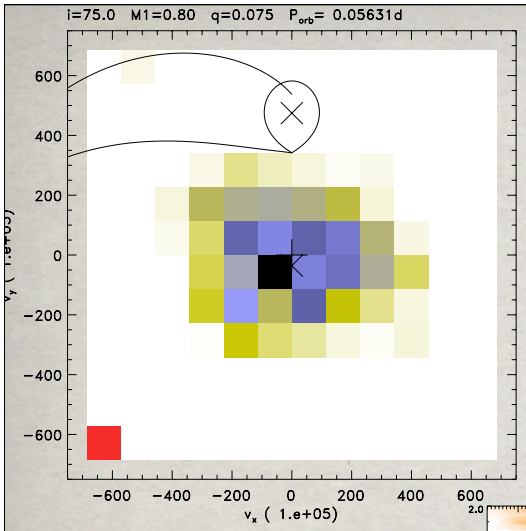
He II





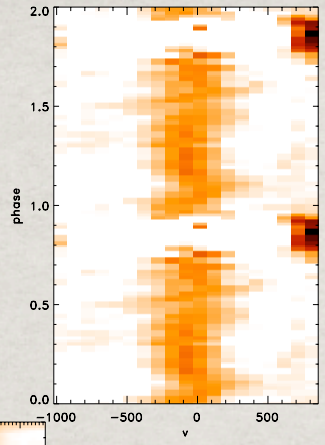


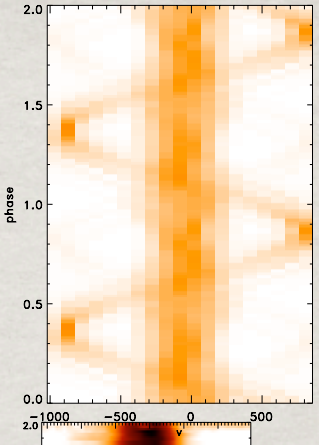


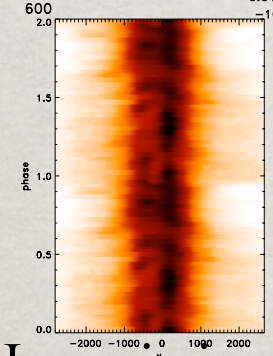


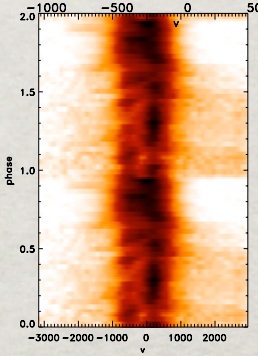
THE START: JD 2454348

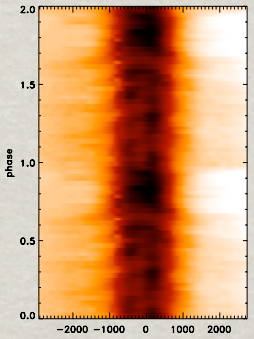
348.83762
348.89443







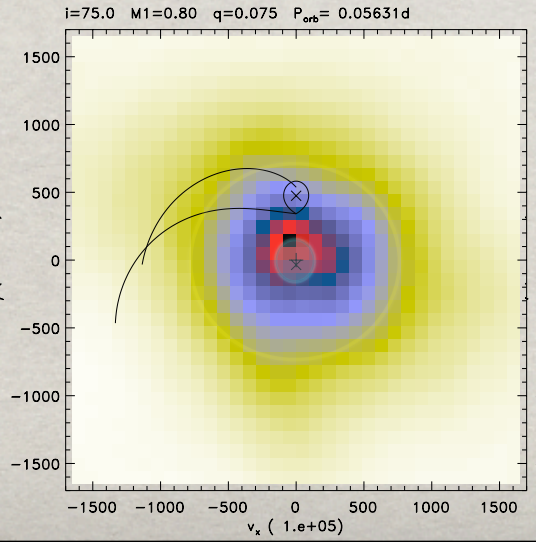


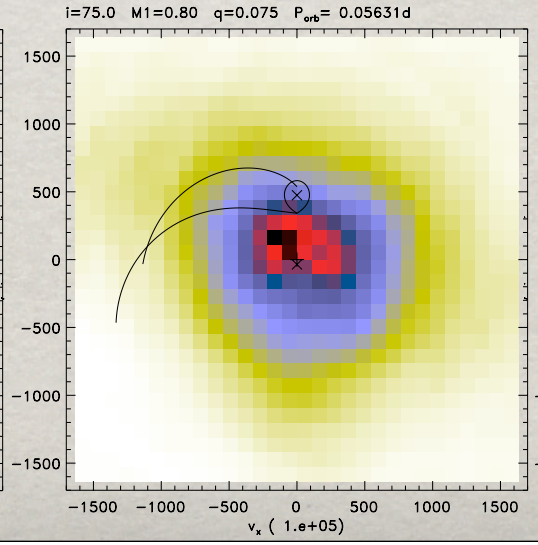


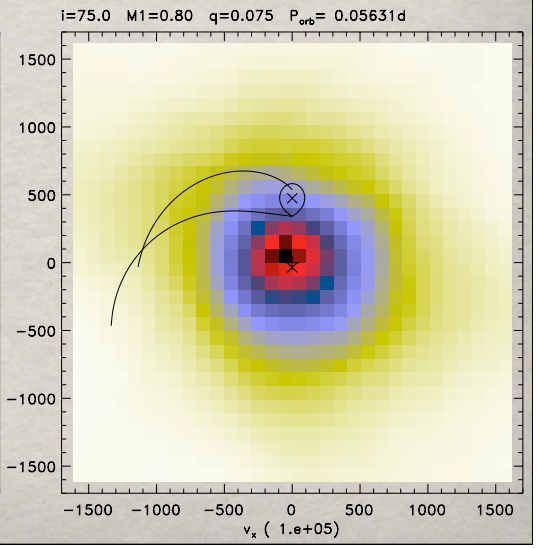
Hβ emission

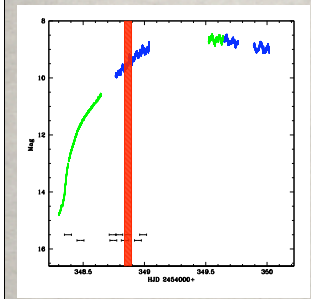
Hγ

He II



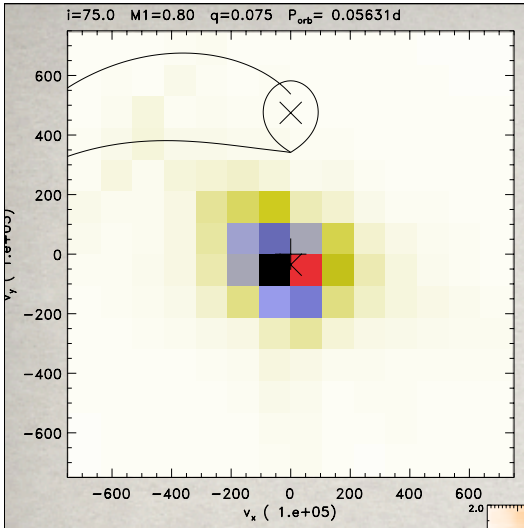


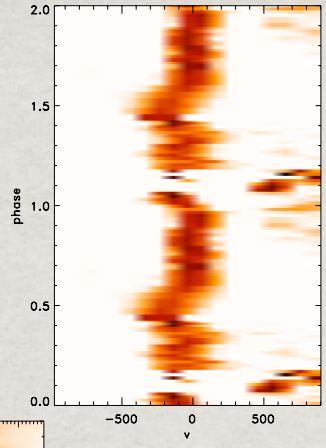




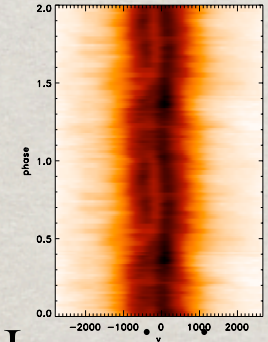
THE START: JD 2454348

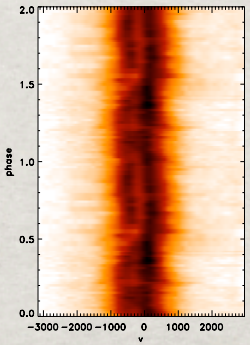
348.91911
348.97507

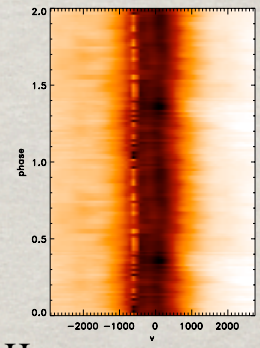




He I absorption



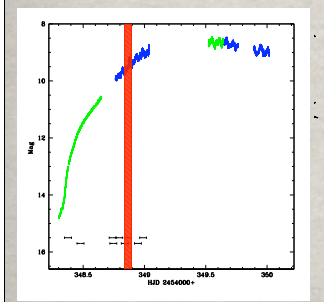


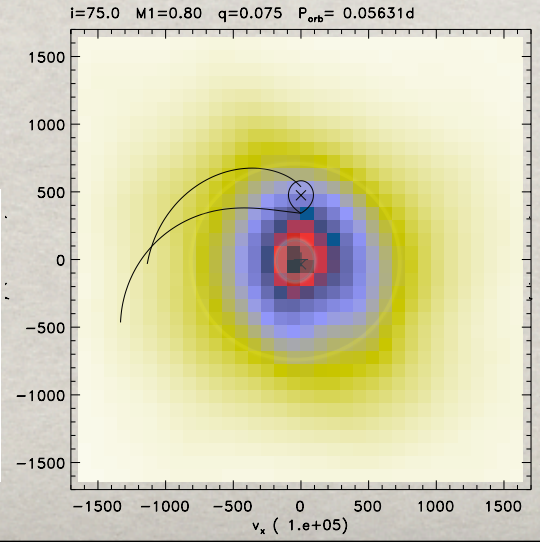


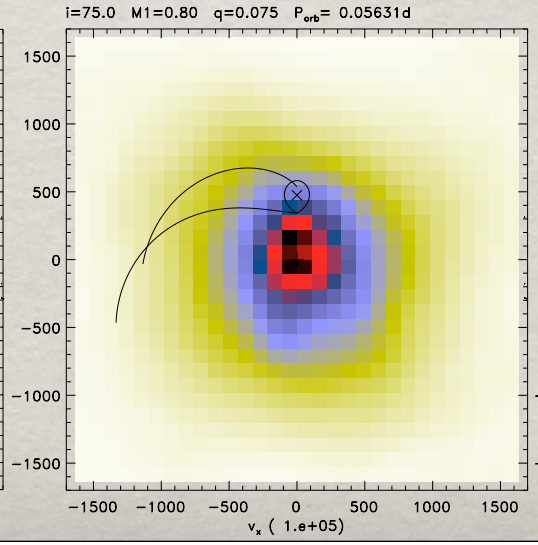
Hβ emission

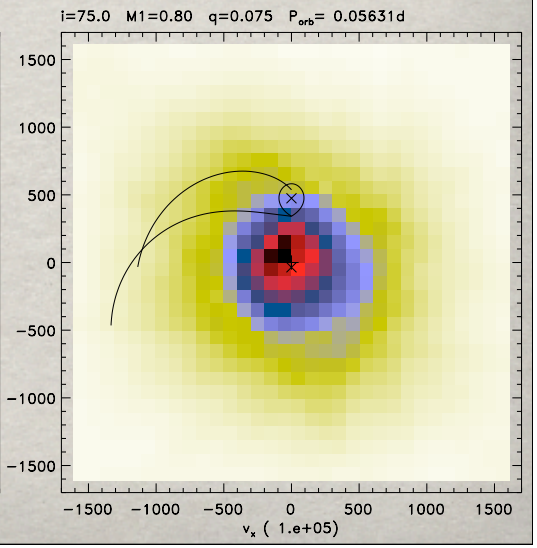
Hγ

He II



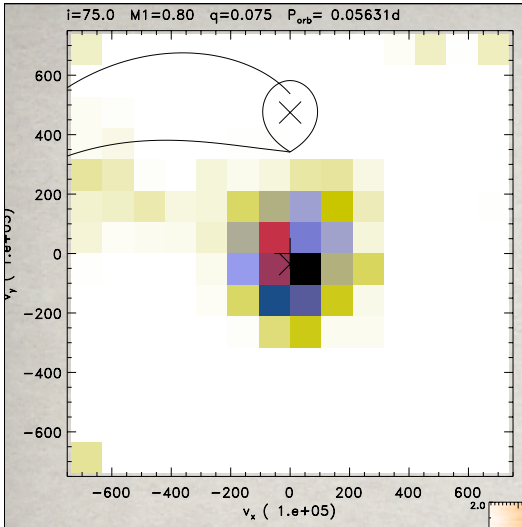


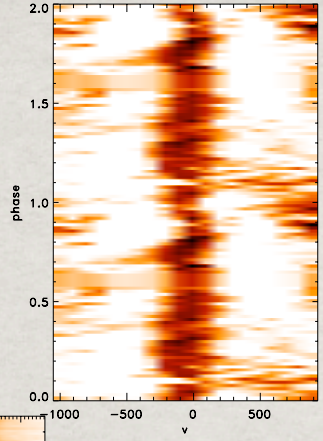




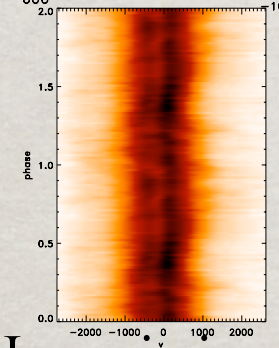
THE START: JD 2454348

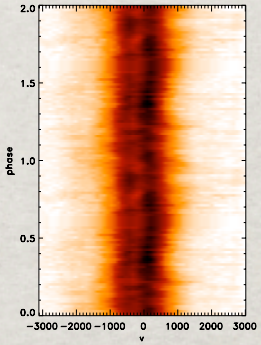
348.96181
349.01816

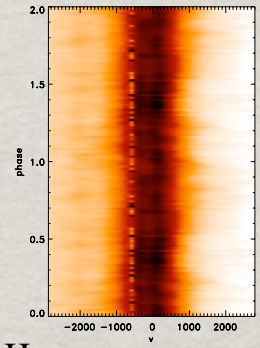




He I absorption



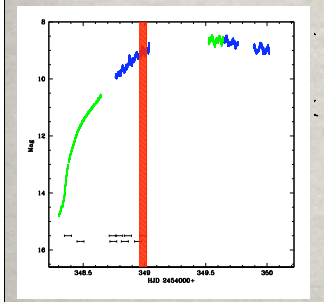


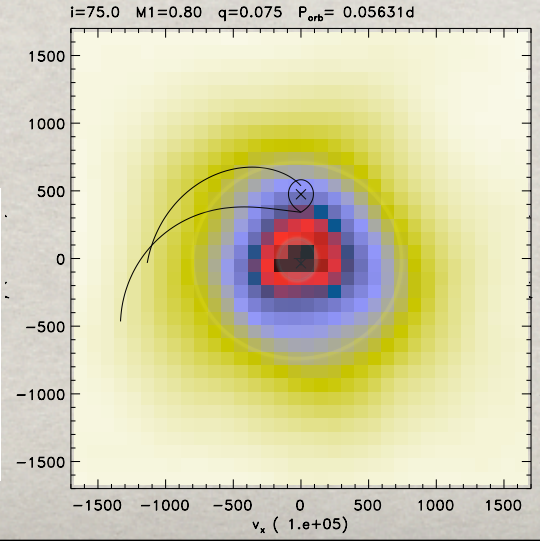


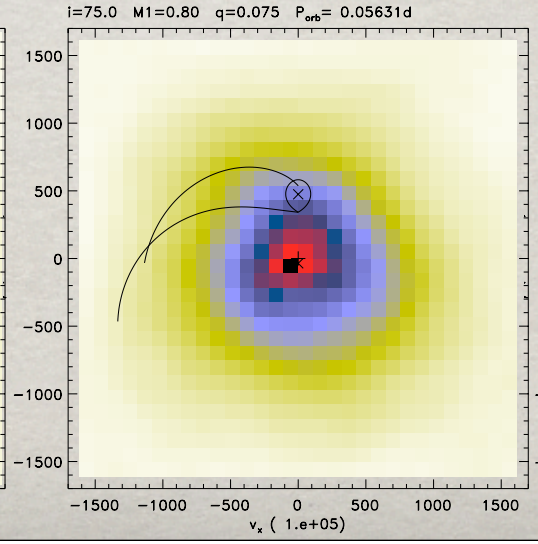
Hβ emission

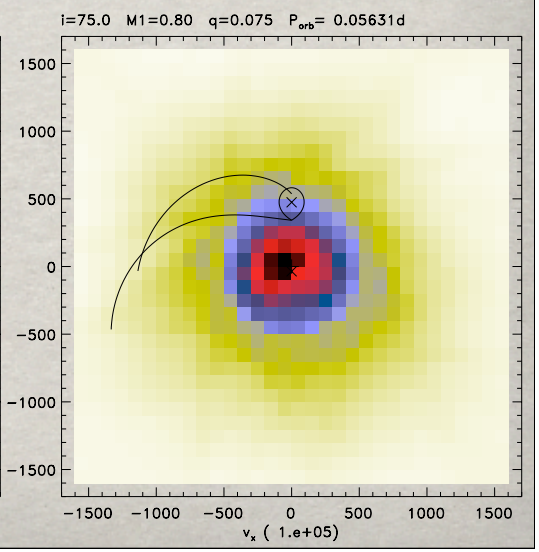
Hγ

He II



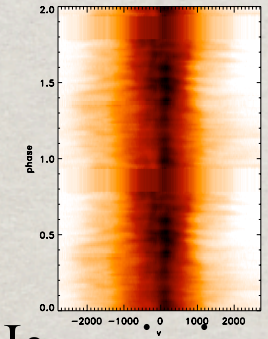


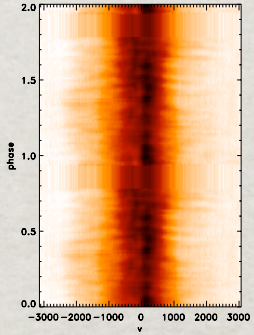


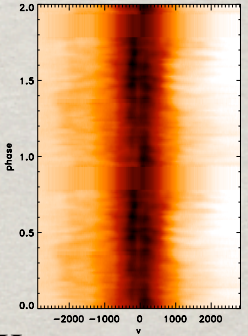


THE MAXIMUM: JD 2454349

349.342212
349.389846



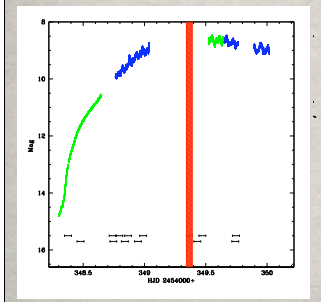


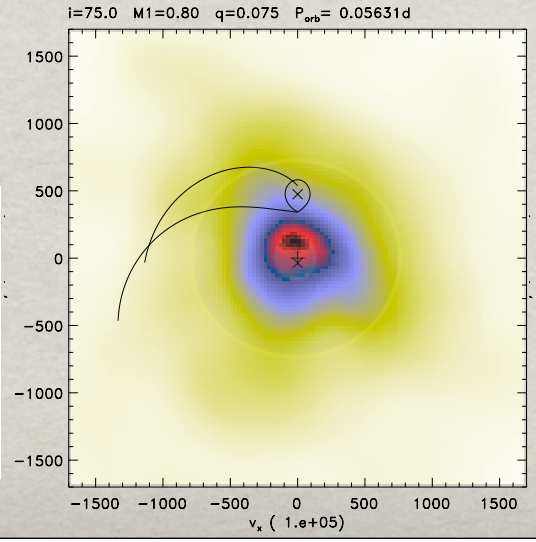


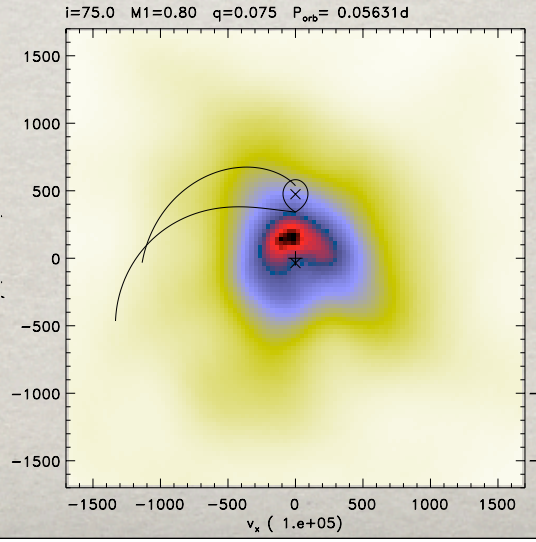
Hβ emission

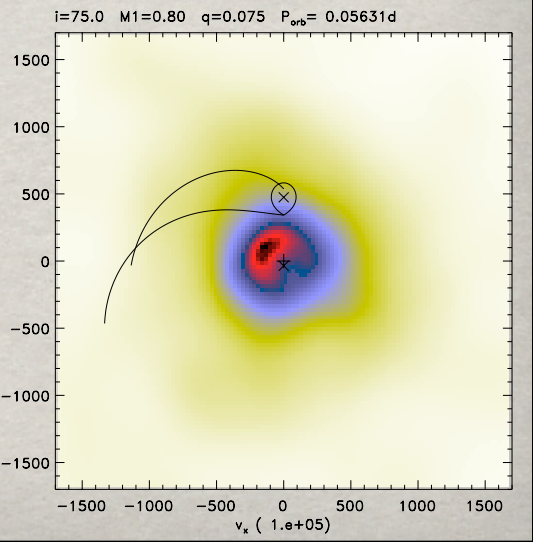
Hγ

He II



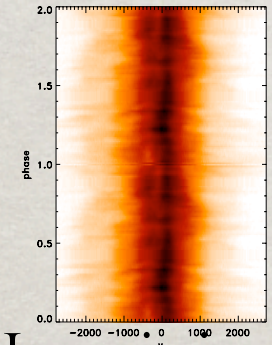


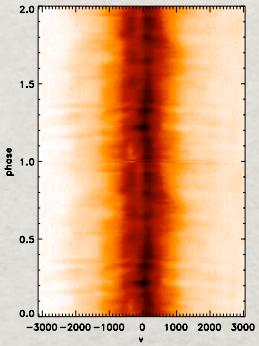


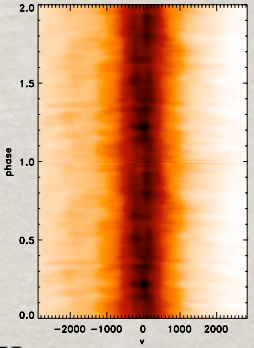


THE MAXIMUM: JD 2454349

349.402798
349.459317



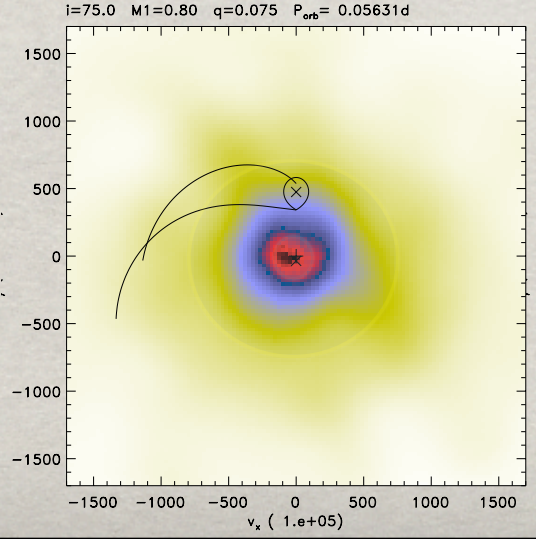


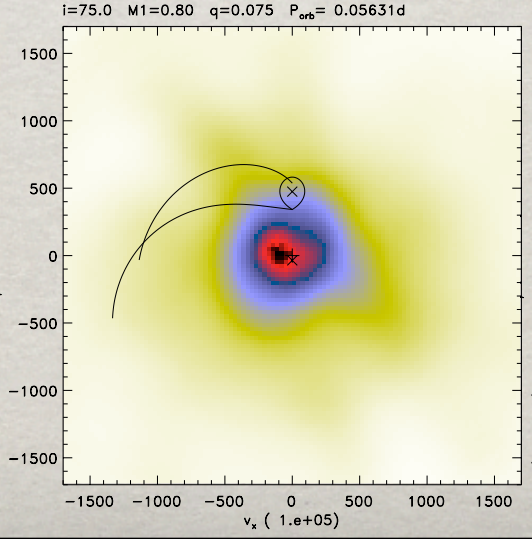


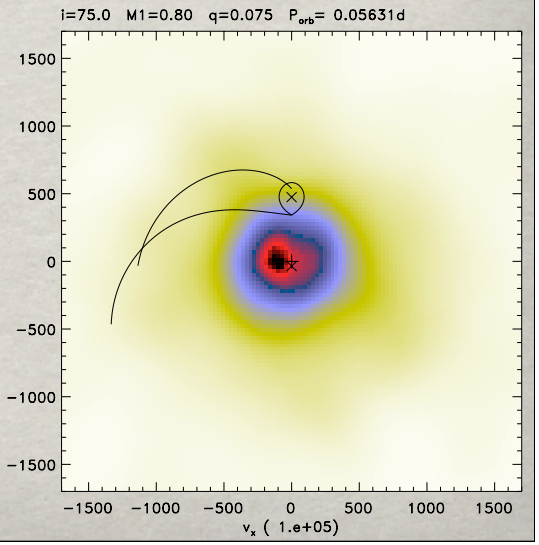
Hβ emission

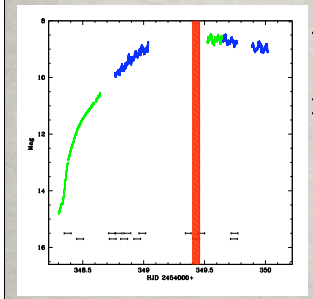
Hγ

He II



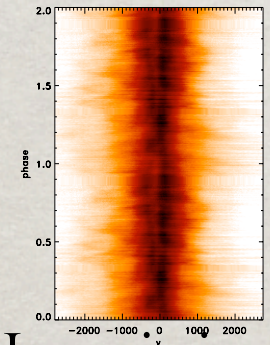


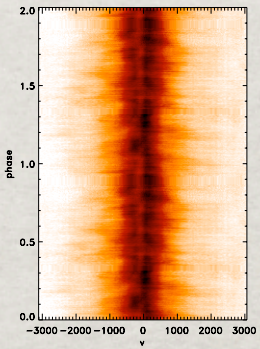


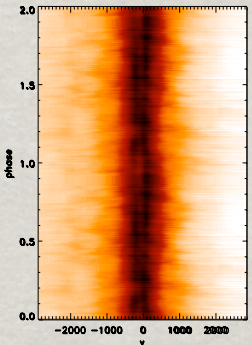


THE MAXIMUM: JD 2454349

349.444397
349.500892



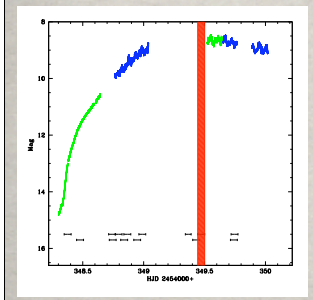


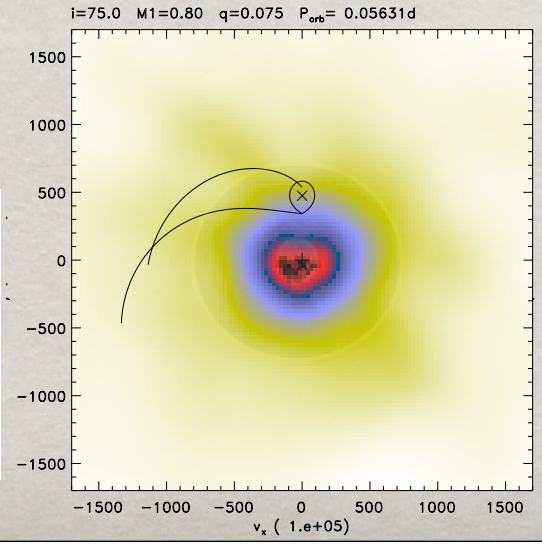


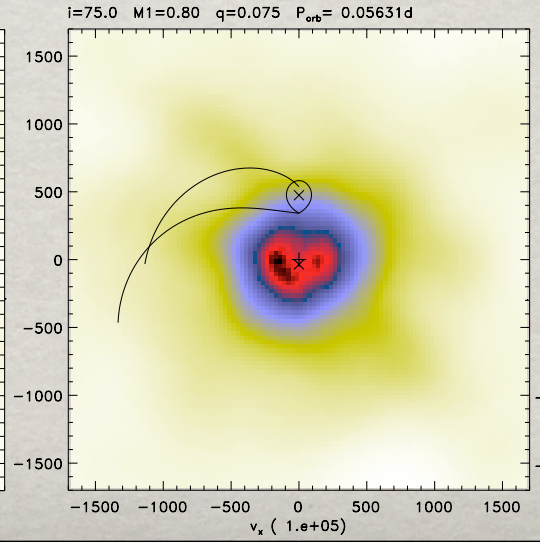
Hβ emission

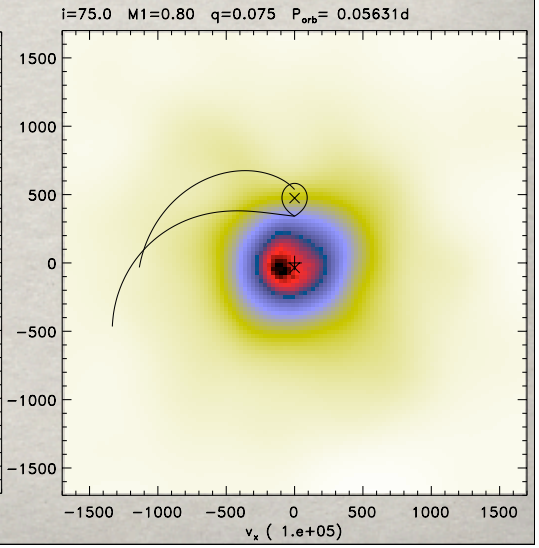
Hγ

He II



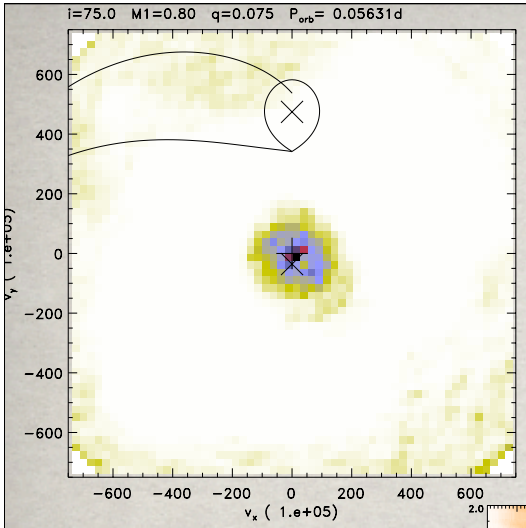


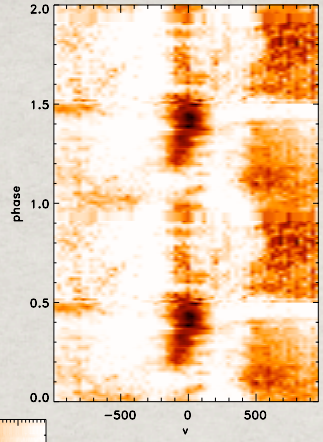




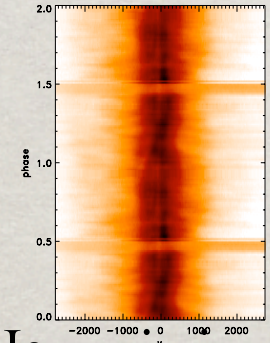
THE MAXIMUM: JD 2454349

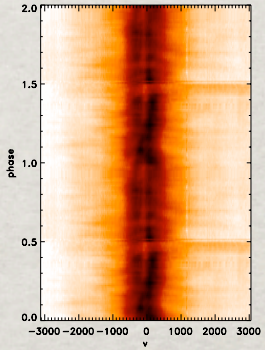
349.712555
349.767962

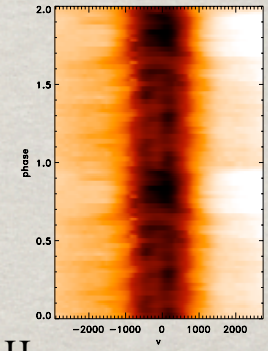




He I absorption



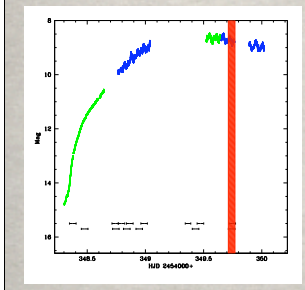


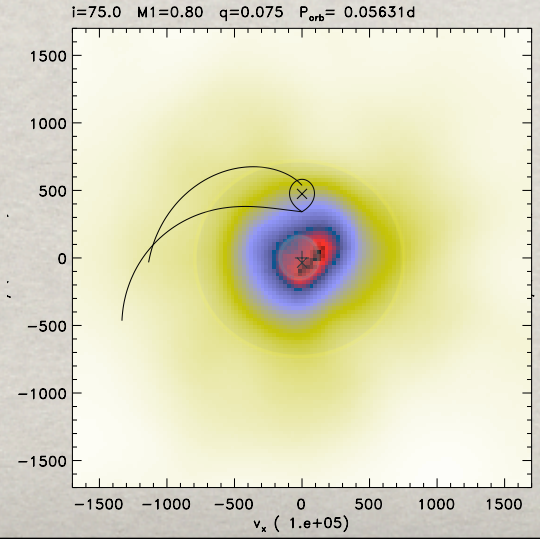


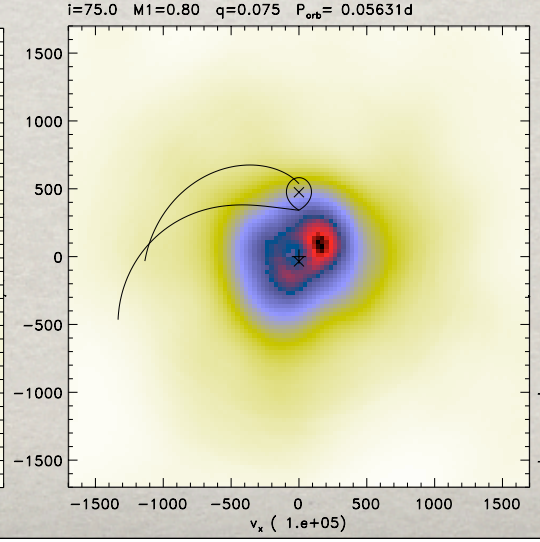
Hβ emission

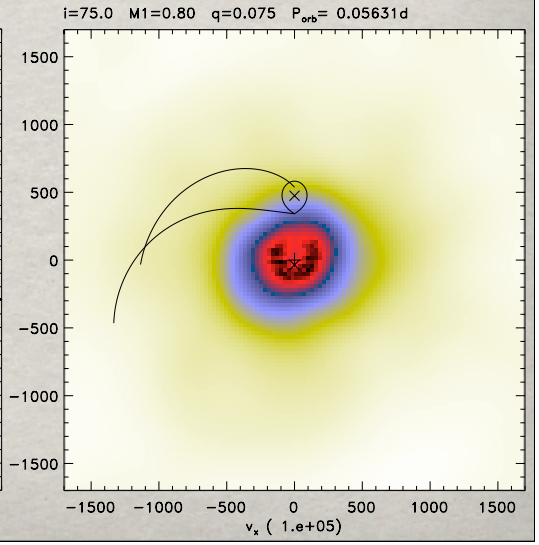
Hγ

He II



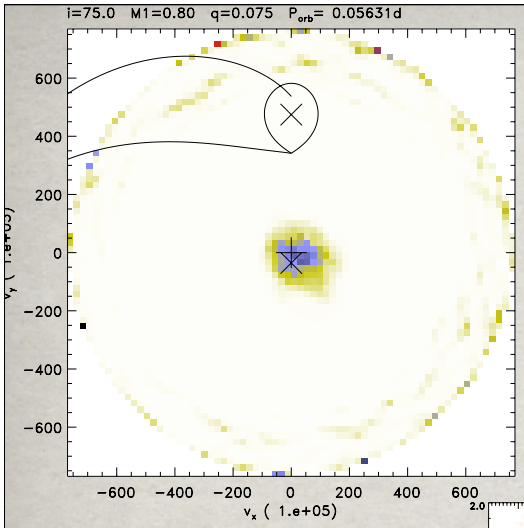


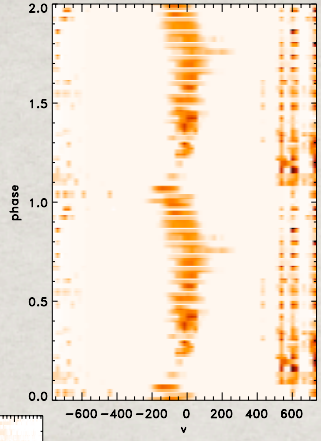




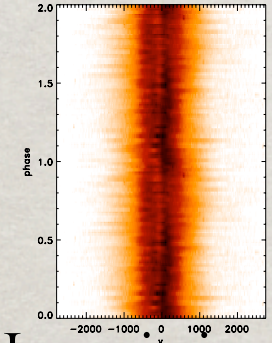
THE MAXIMUM: JD 2454349

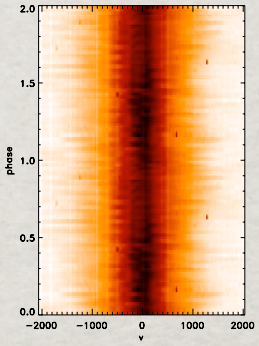
349.70184
349.97472

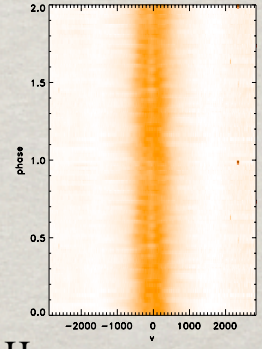




He I absorption



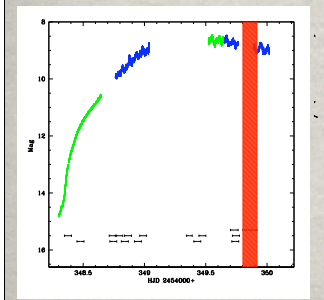


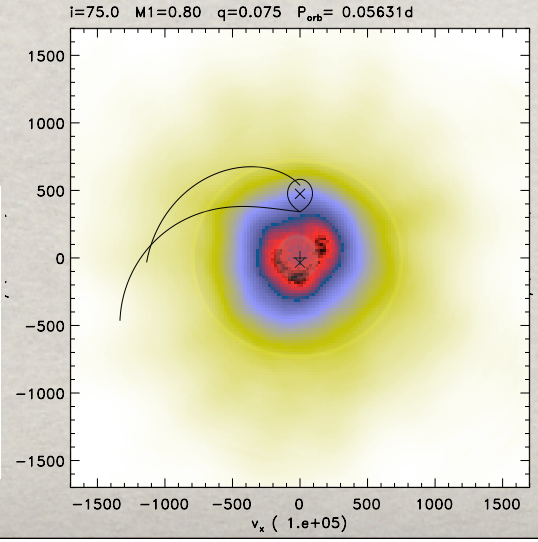


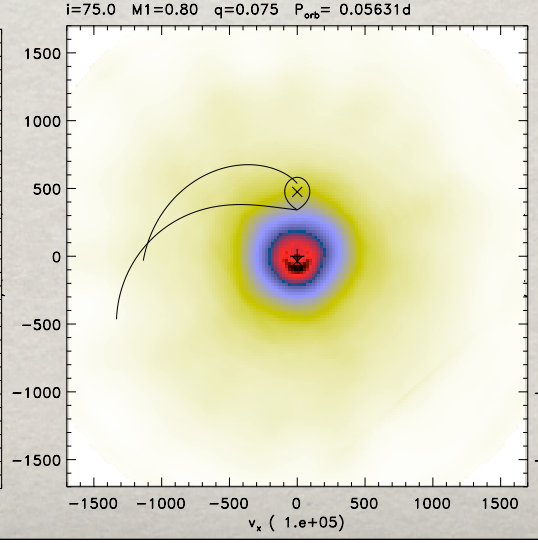
Hβ emission

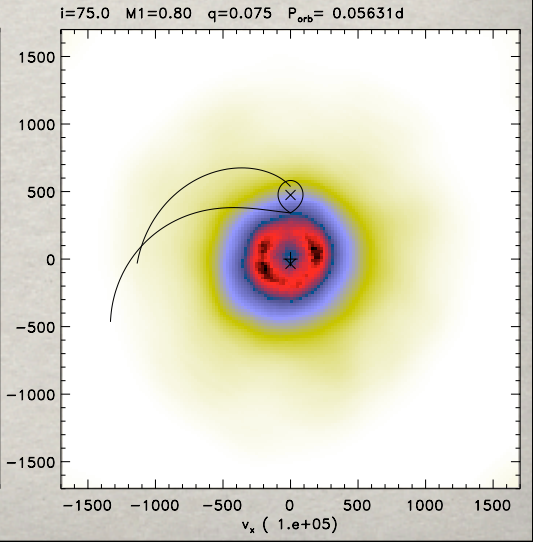
Hα

He II

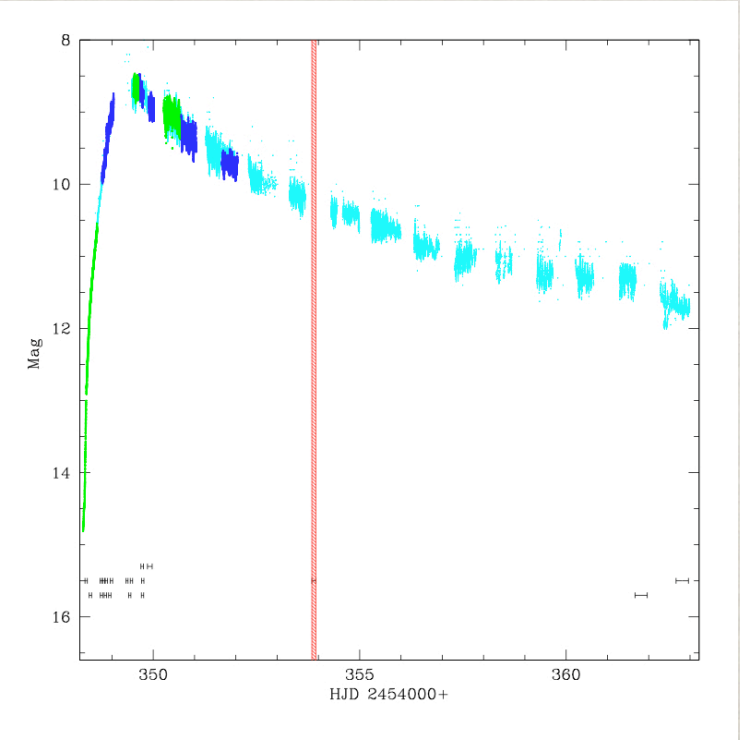


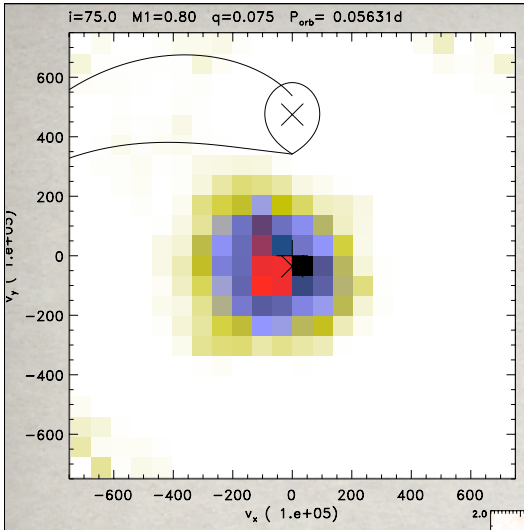






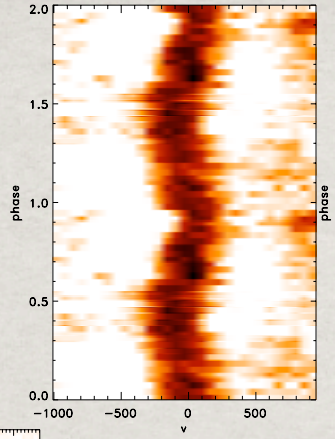
THE EARLY DECLINE: JD 2454353

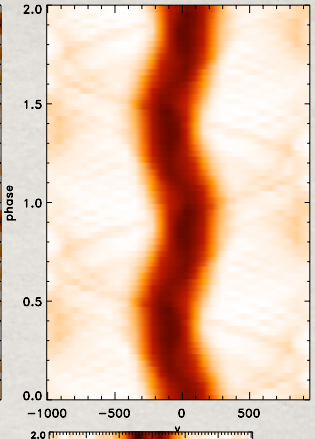


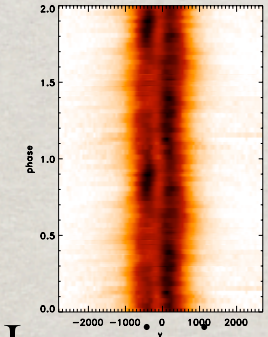


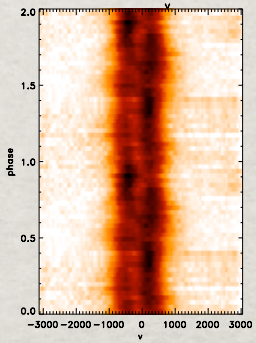
THE MAXIMUM: JD 2454353

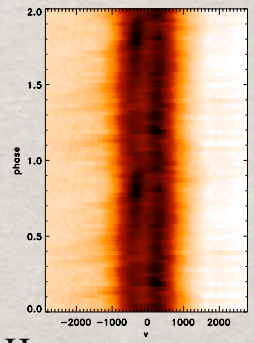
353.86505
353.93774







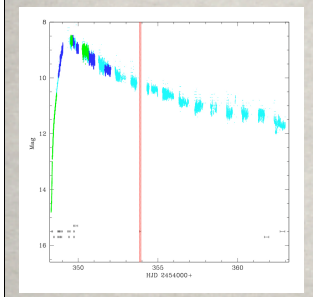


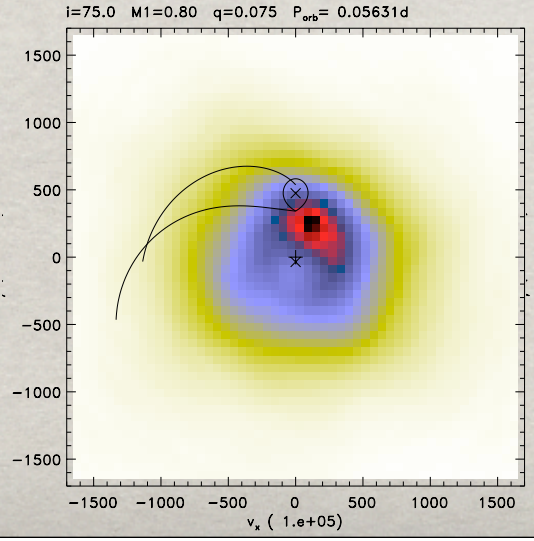


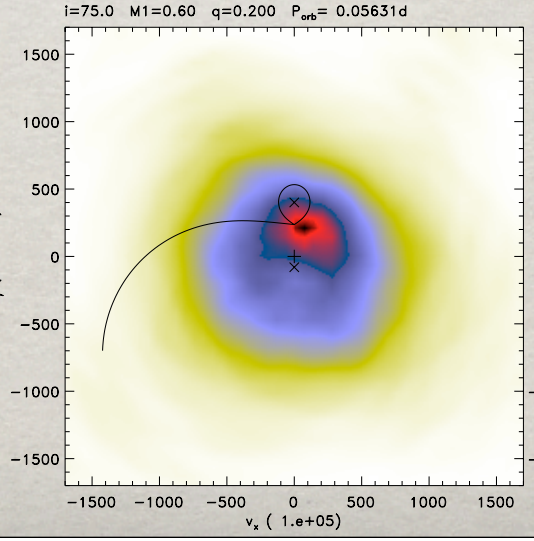
Hβ emission

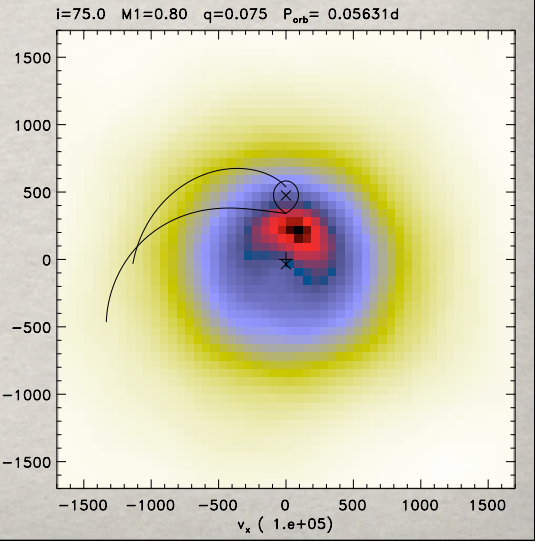
Hγ

He II

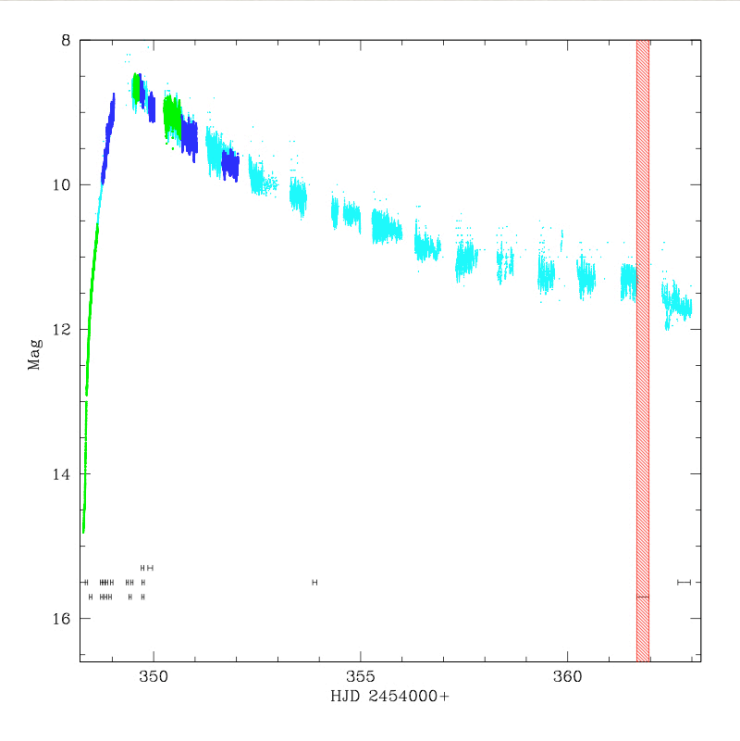






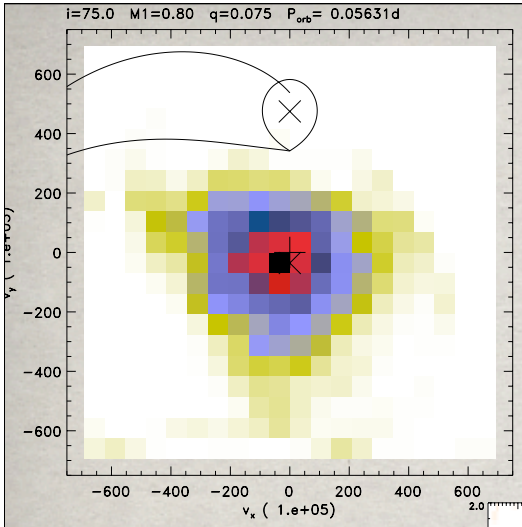


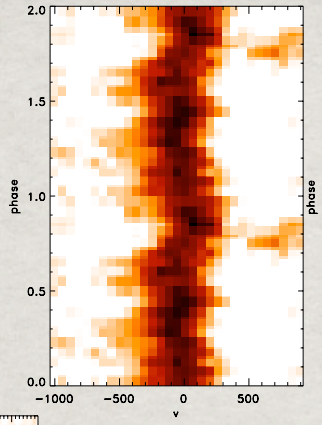
THE LATE DECLINE: JD 2454361-62

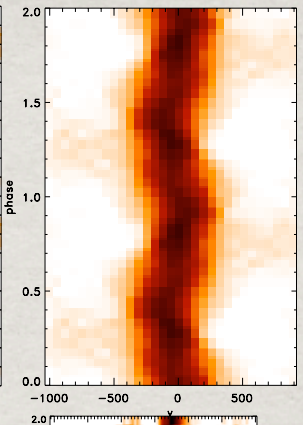


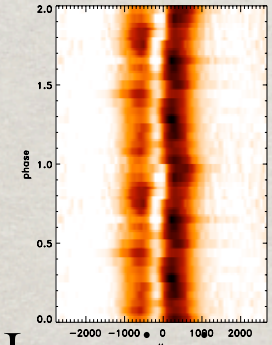
THE LATE DECLINE: JD 2454361-62

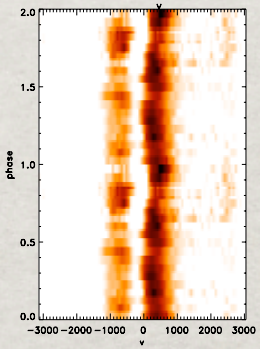
361.66784
361.72600

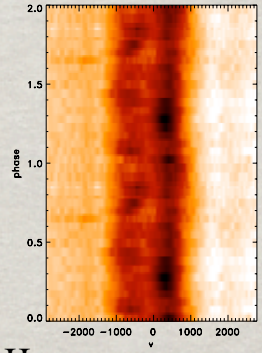








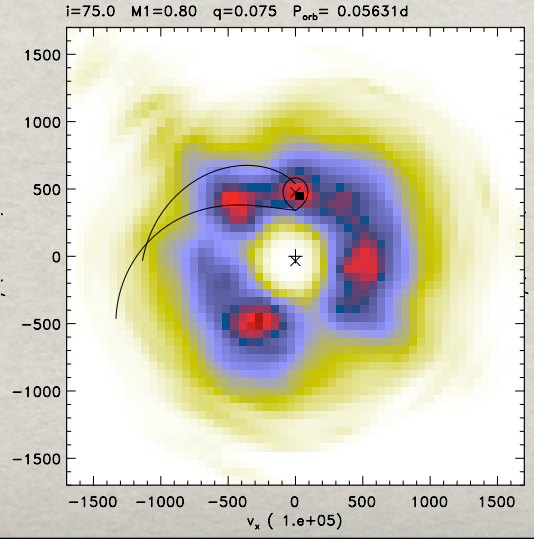


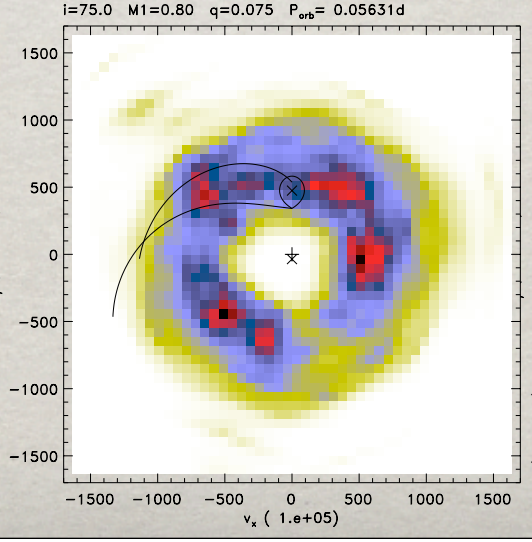


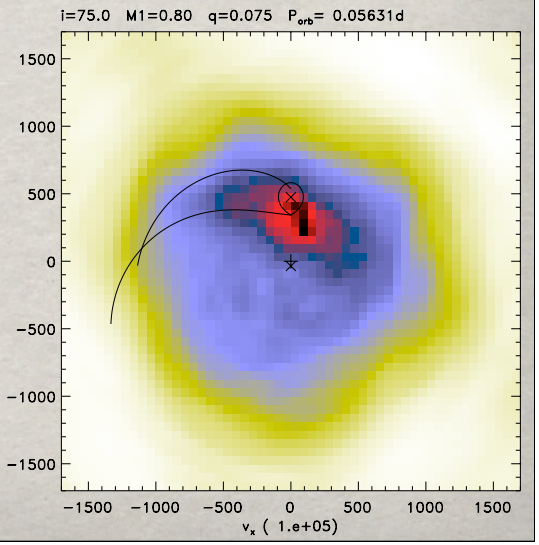
Hβ emission

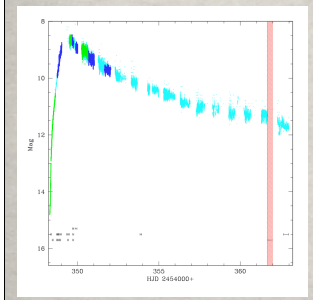
Hγ

He II



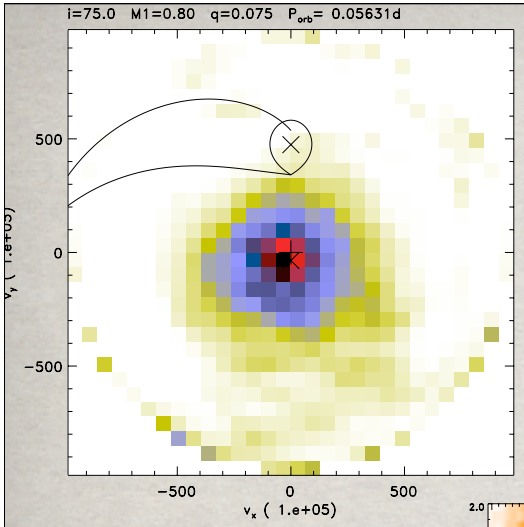


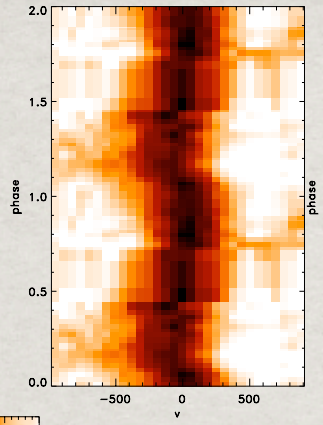


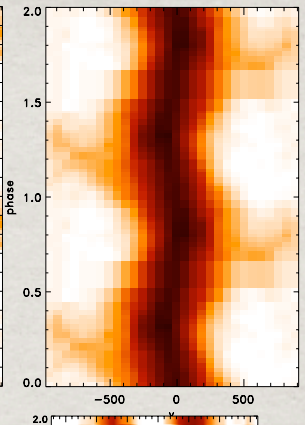


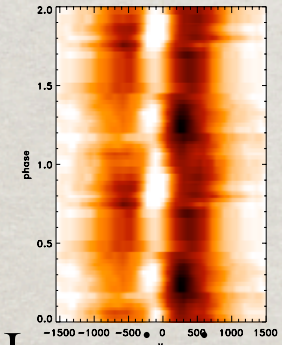
THE LATE DECLINE: JD 2454361-62

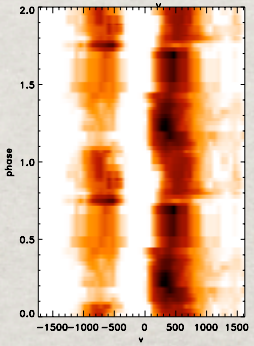
361.72600
361.78471





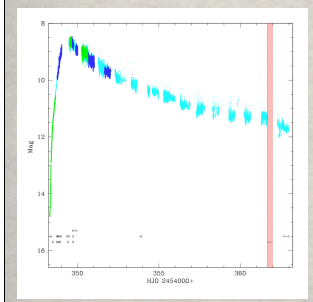


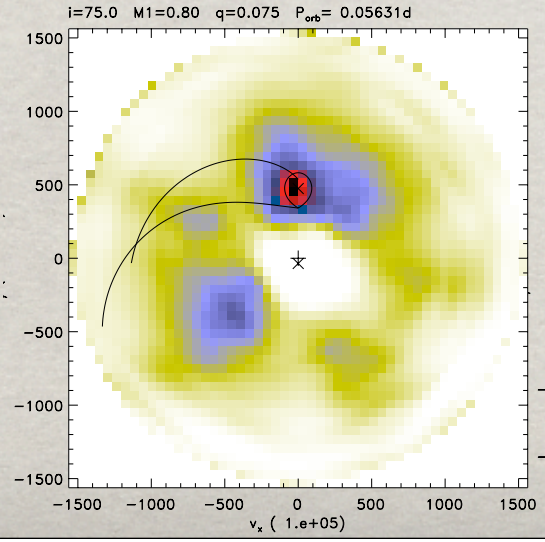


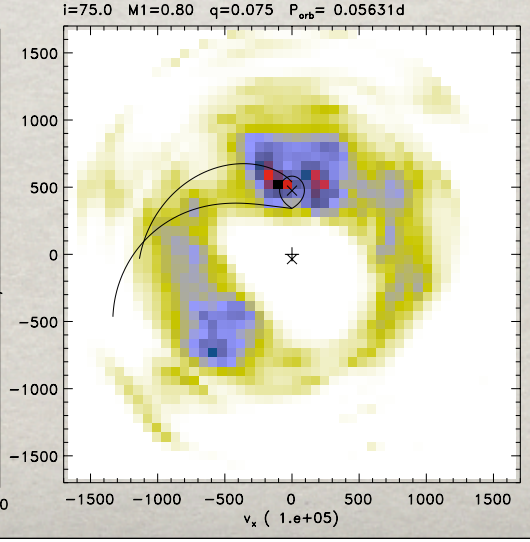


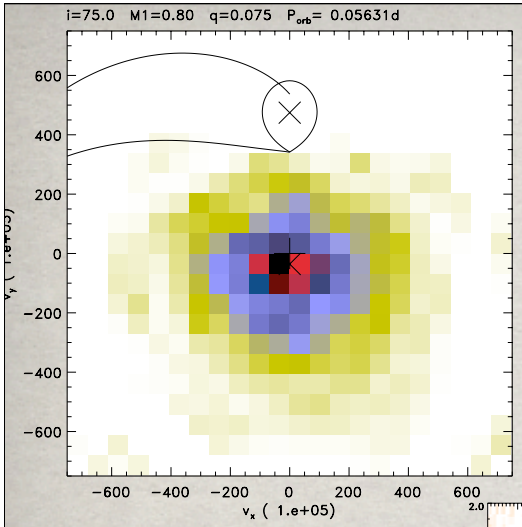
Hβ emission

Hγ



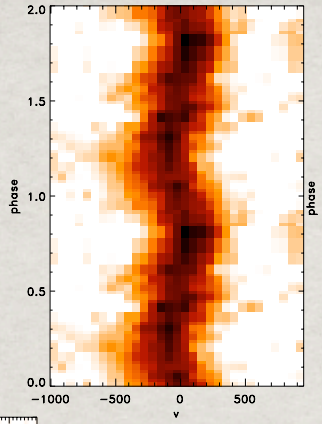


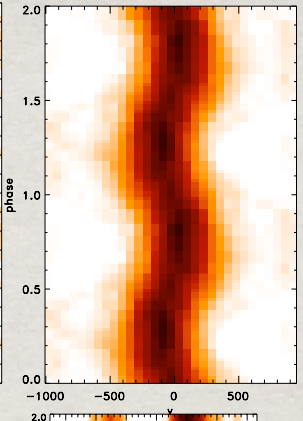


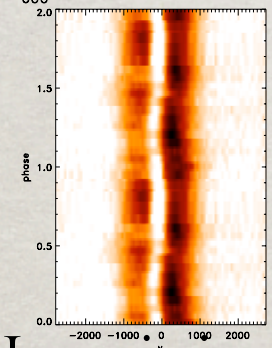


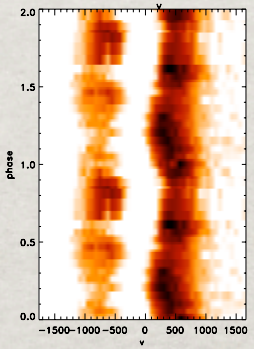
THE LATE DECLINE: JD 2454361-62

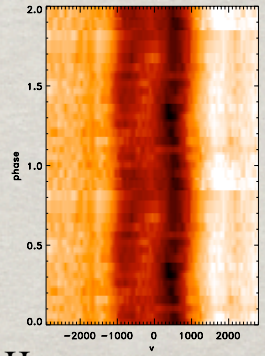
361.78471
361.84242







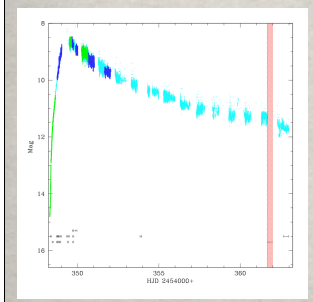


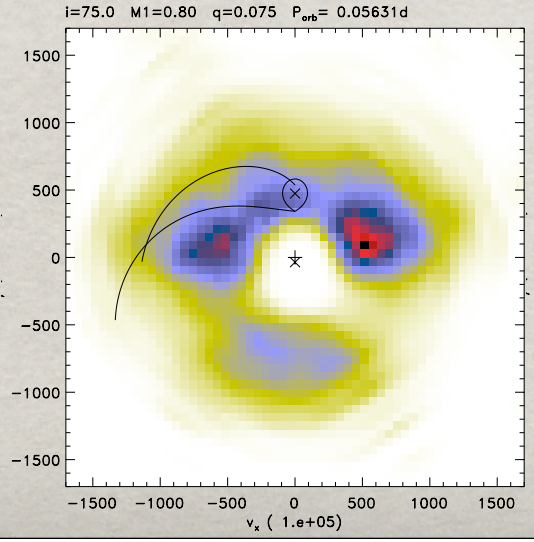


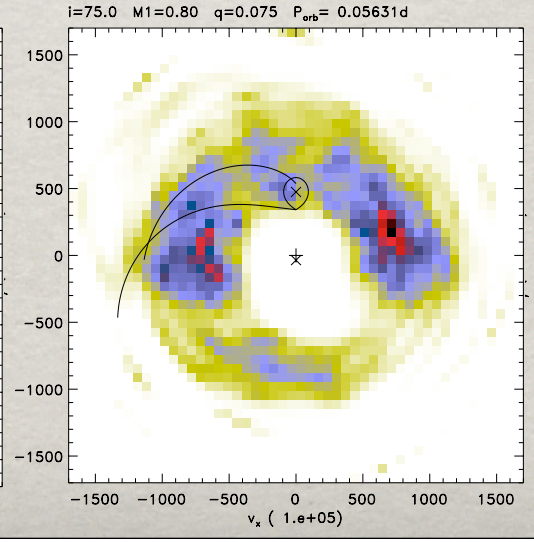
Hβ emission

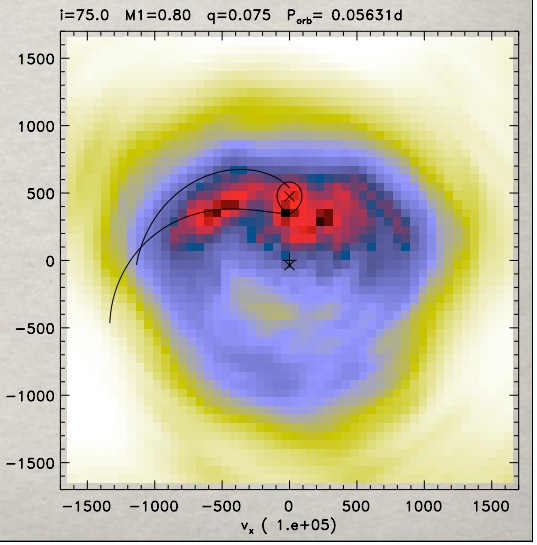
Hγ

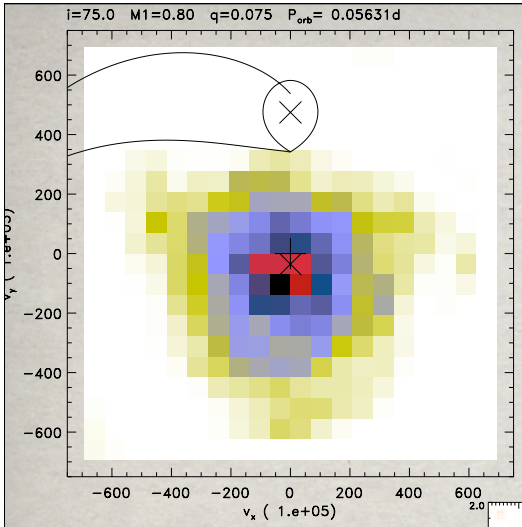
He II





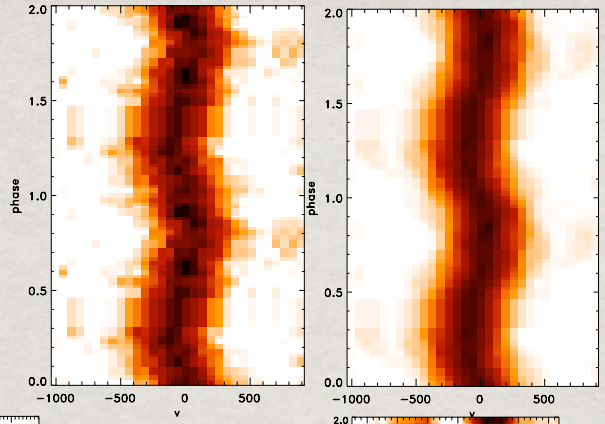


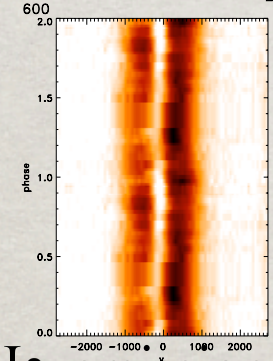


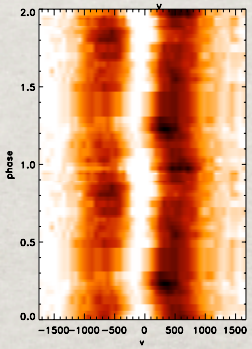


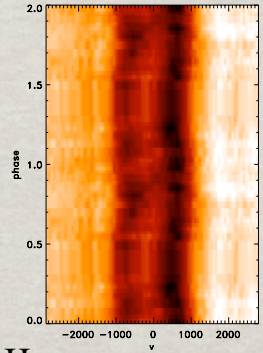
THE LATE DECLINE: JD 2454361-62

361.84242
361.90040





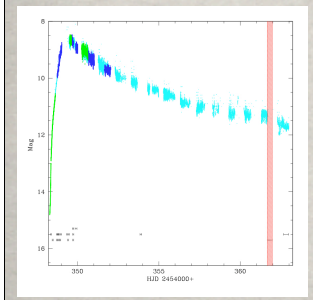


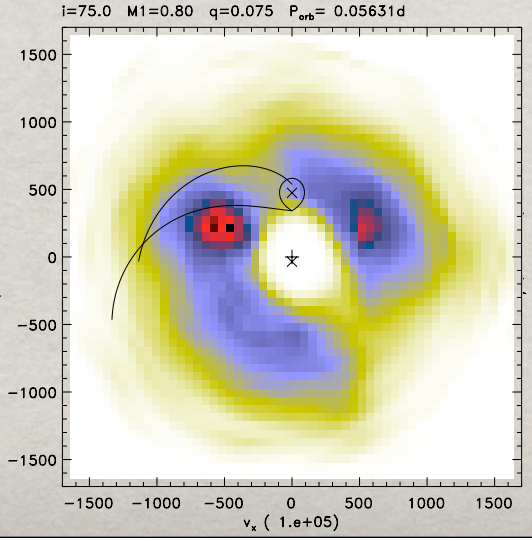


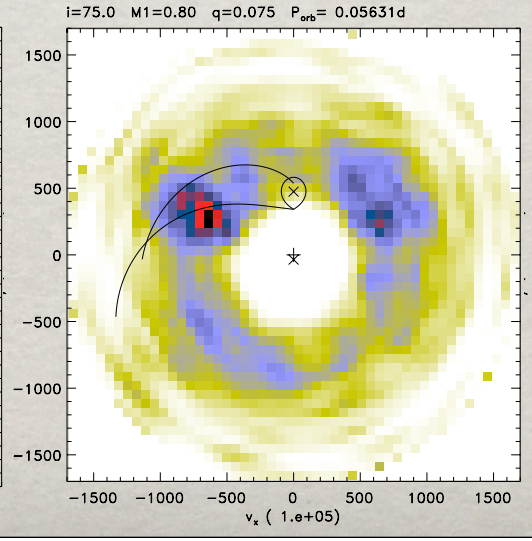
Hβ emission

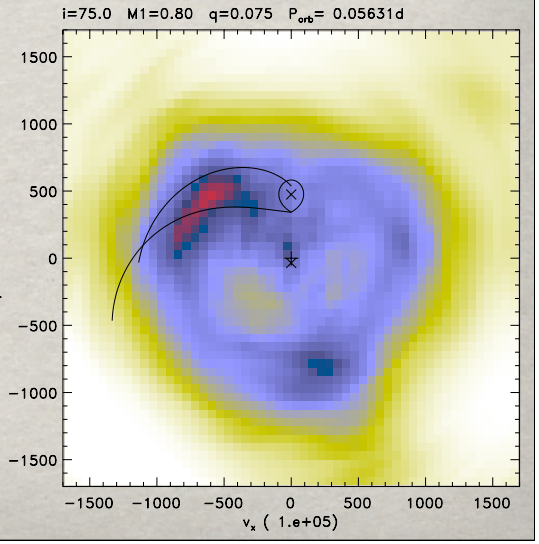
Hγ

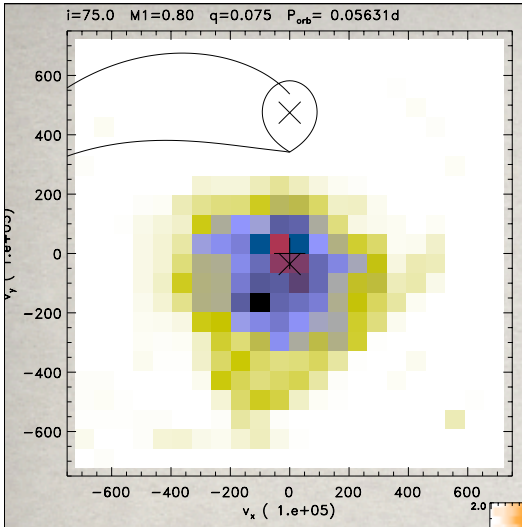
He II





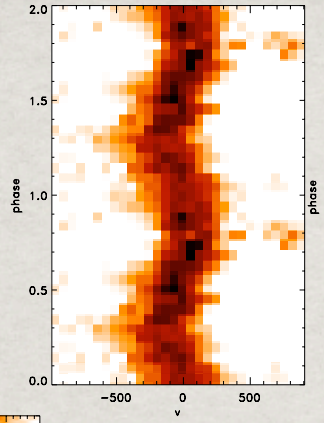


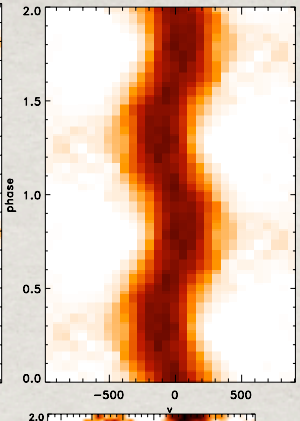


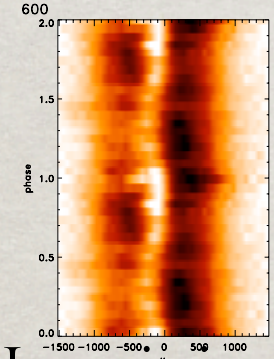


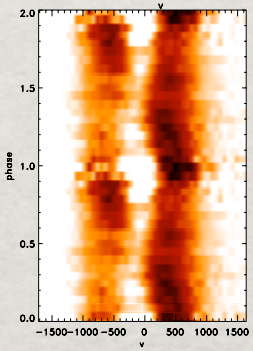
THE LATE DECLINE: JD 2454361-62

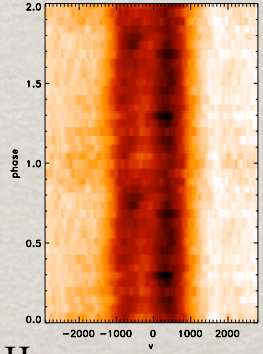
361.90817
361.96457







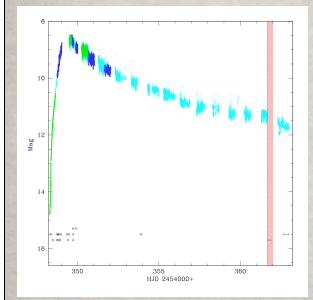


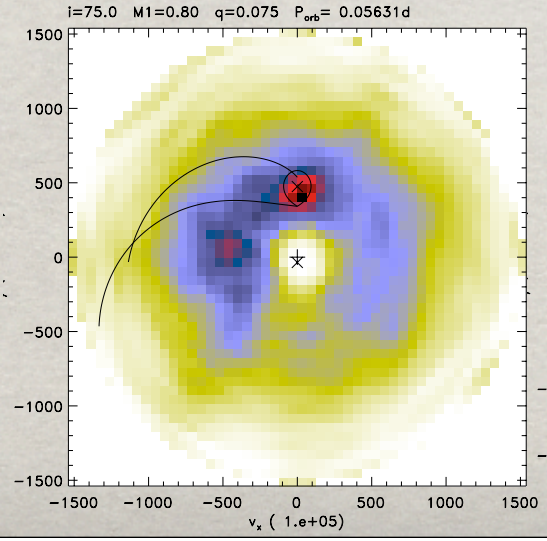


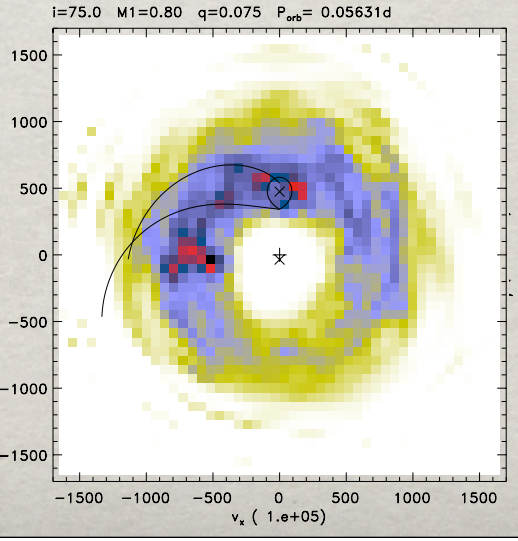
Hβ emission

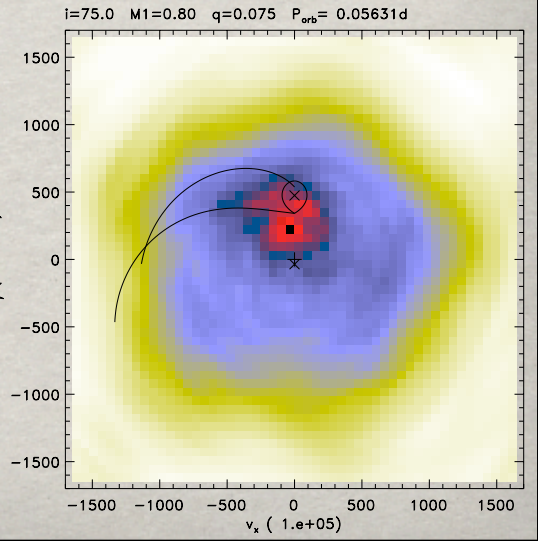
Hγ

He II



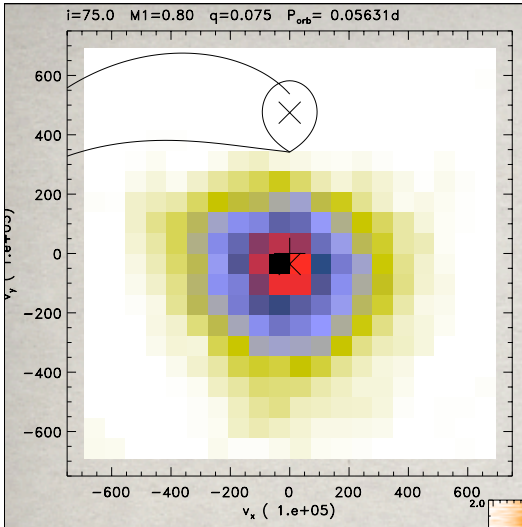


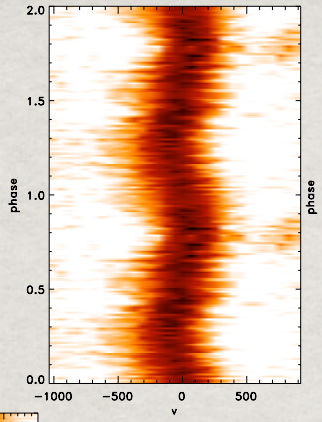


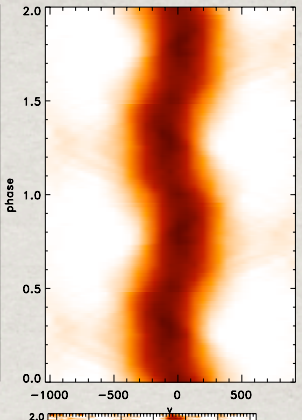


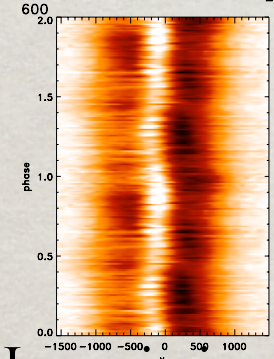
THE LATE DECLINE: JD 2454361-62

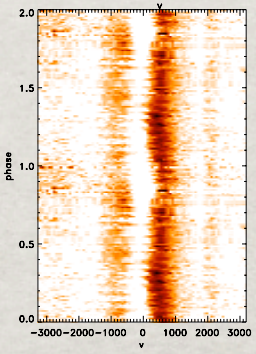
361.66784
361.96457

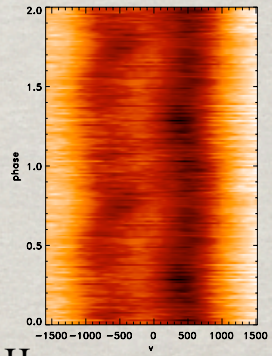








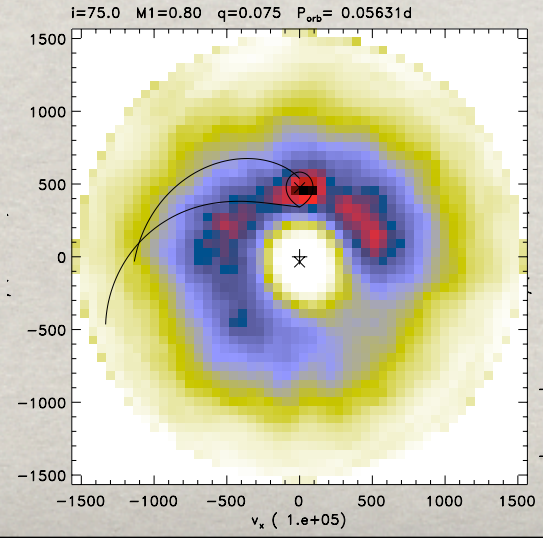


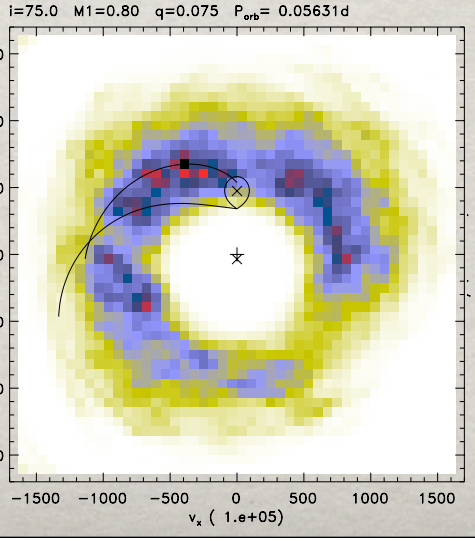


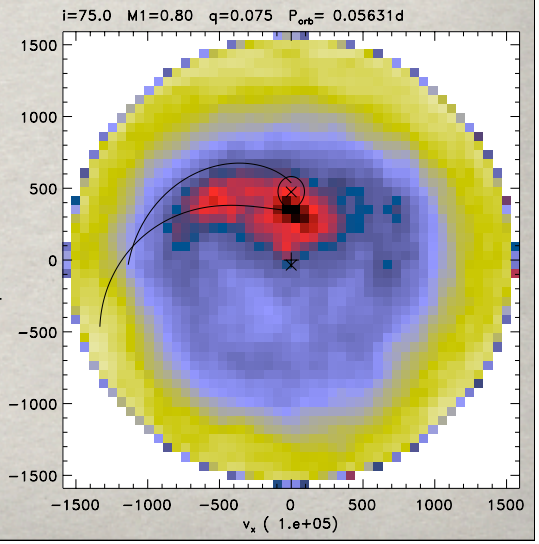
Hβ emission

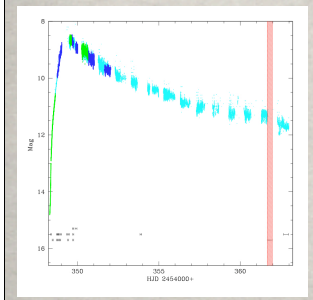
Hγ

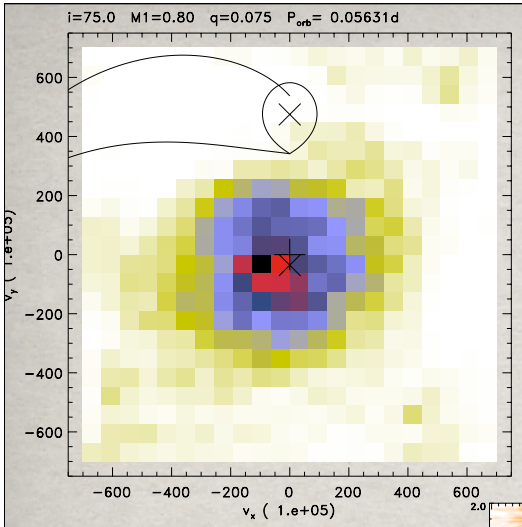
He II





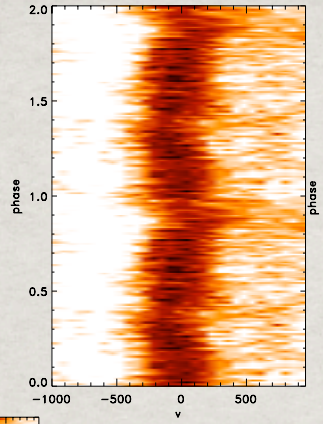


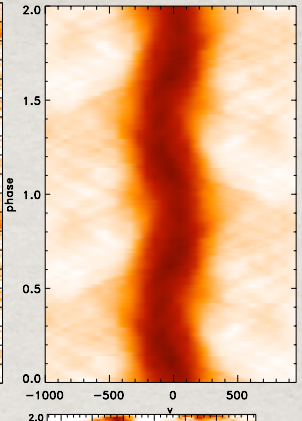


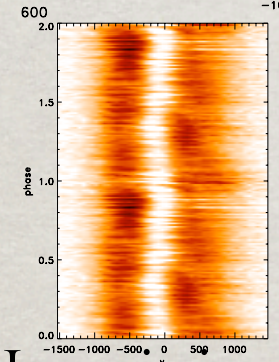


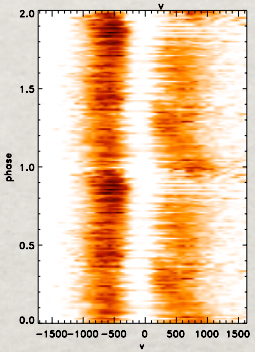
THE LATE DECLINE: JD 2454361-62

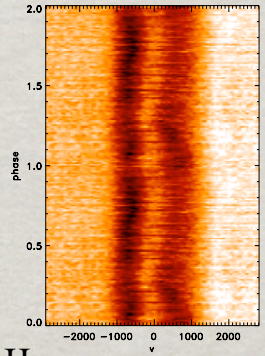
362.66231
362.71723







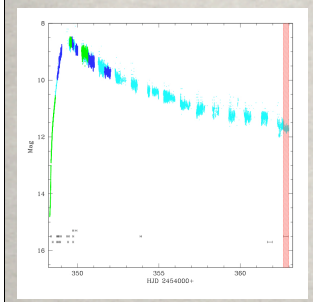


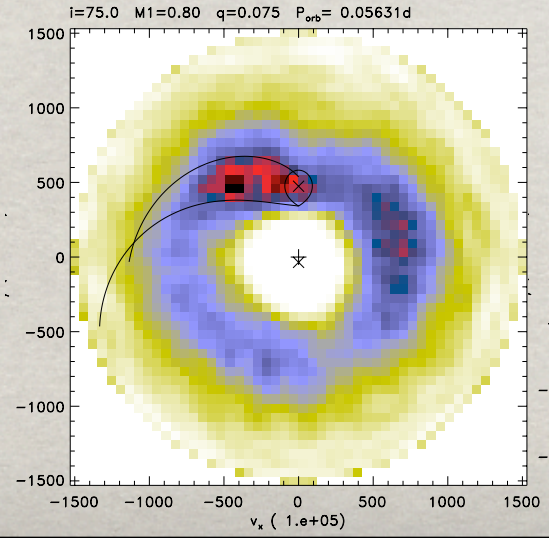


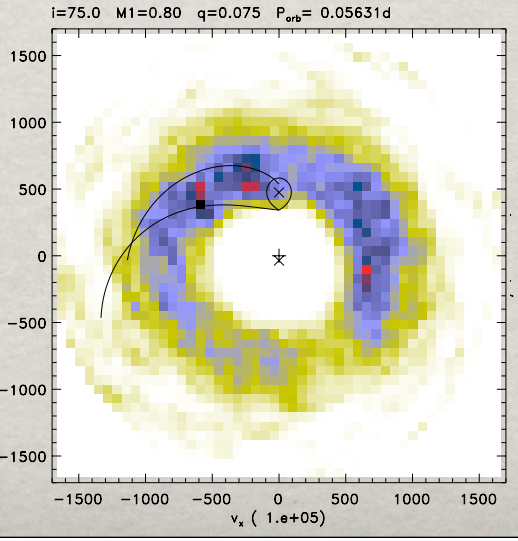
Hβ emission

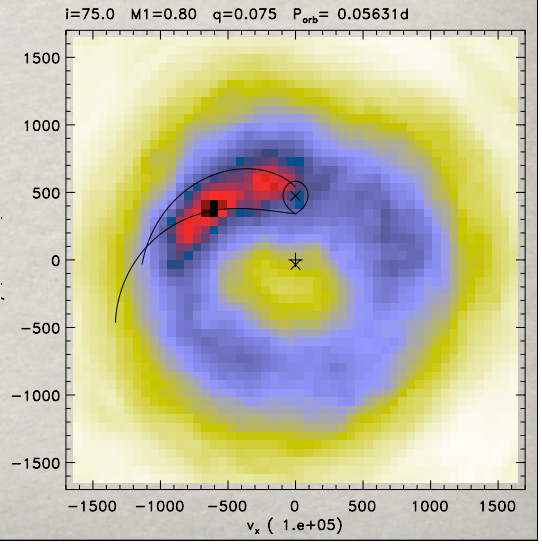
Hγ

He II

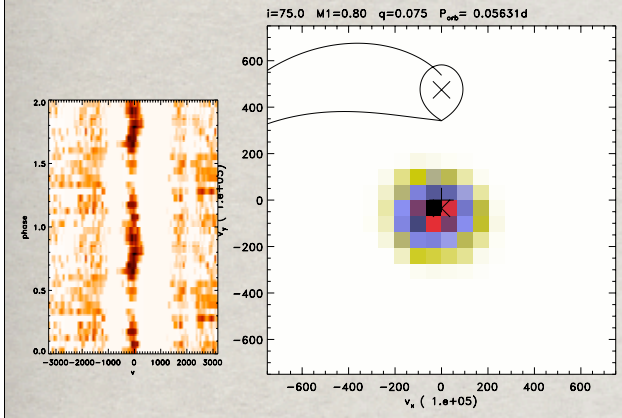




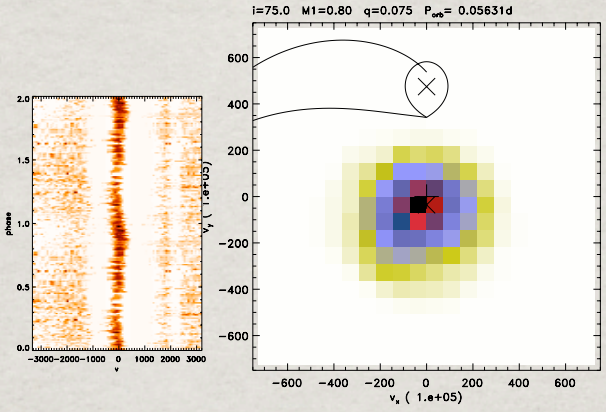




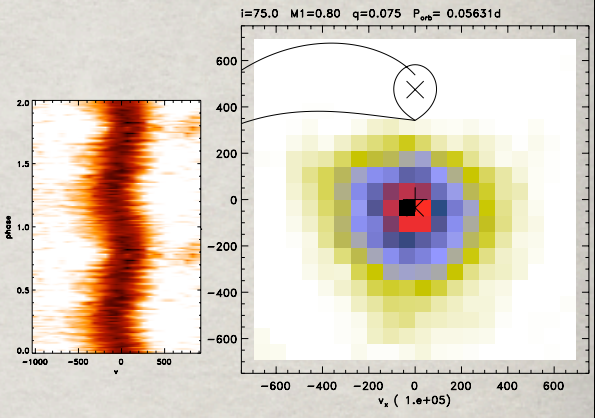
THE LATE DECLINE: JD 2454361-62



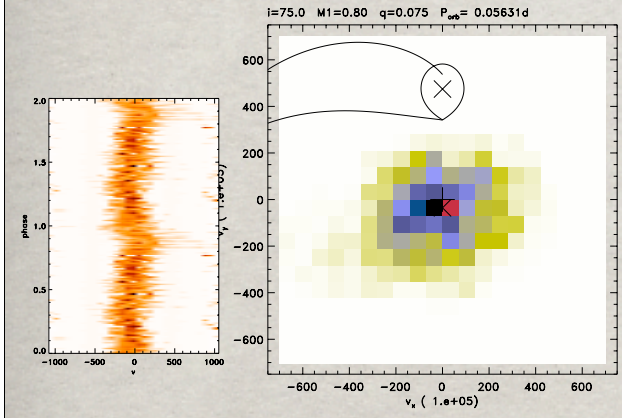
absorption component Hδ

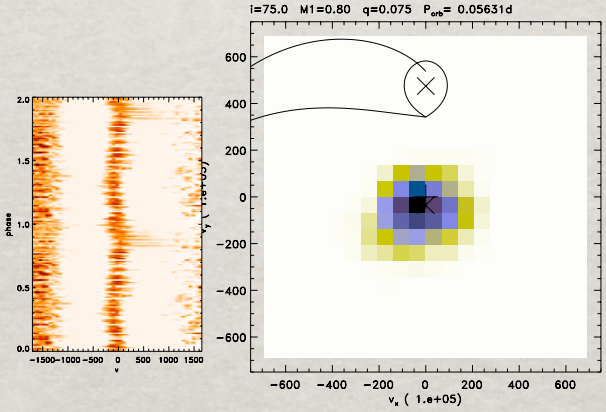


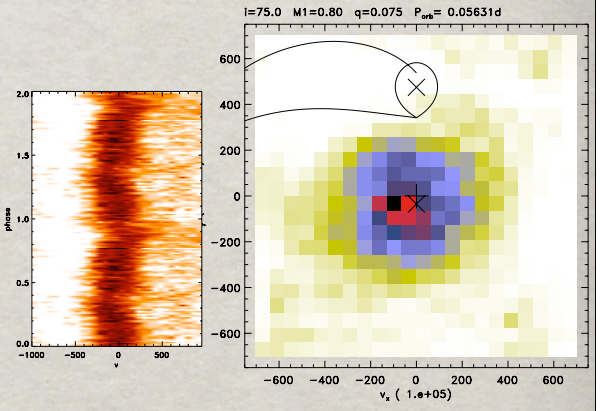
Hγ

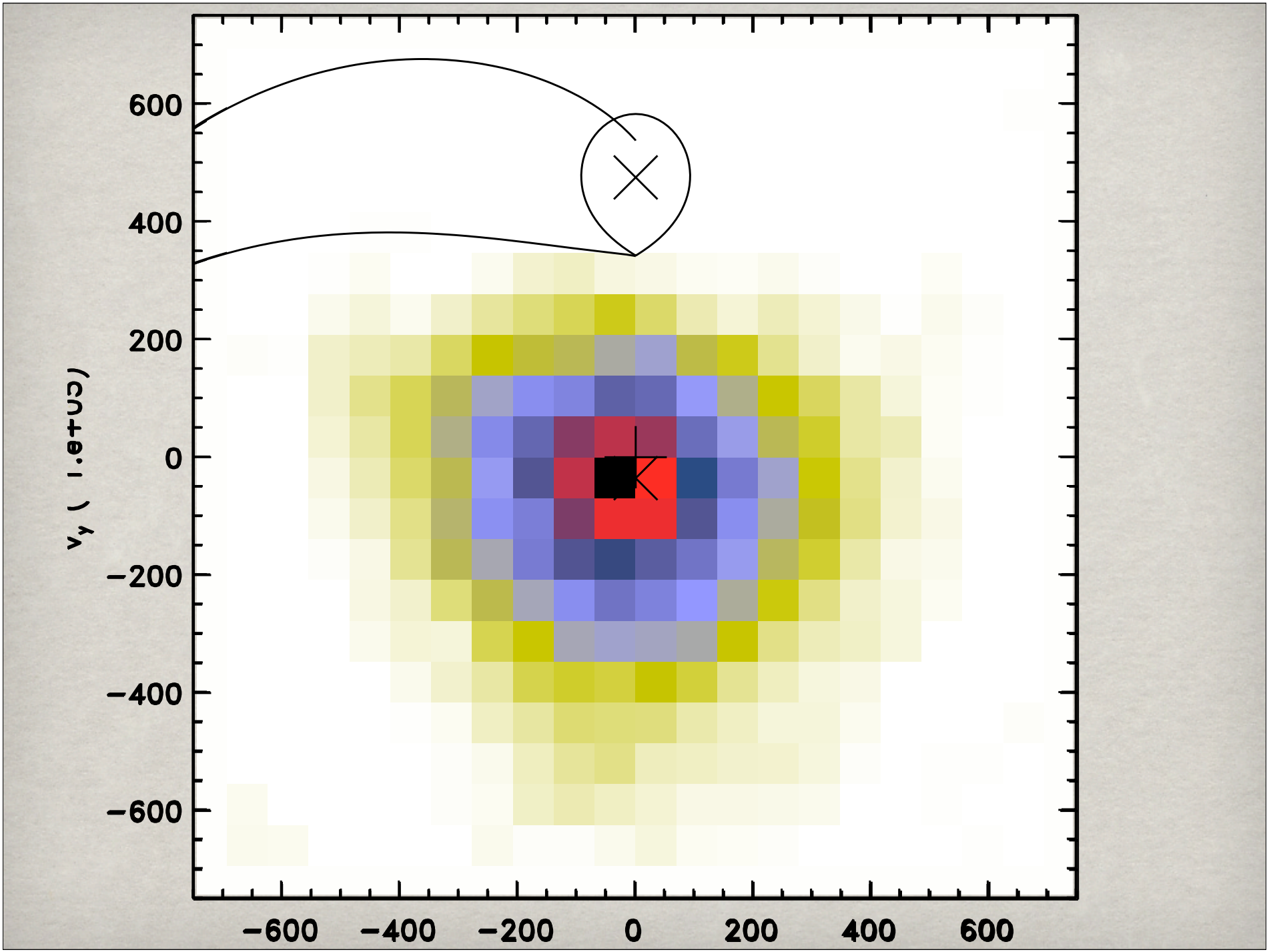


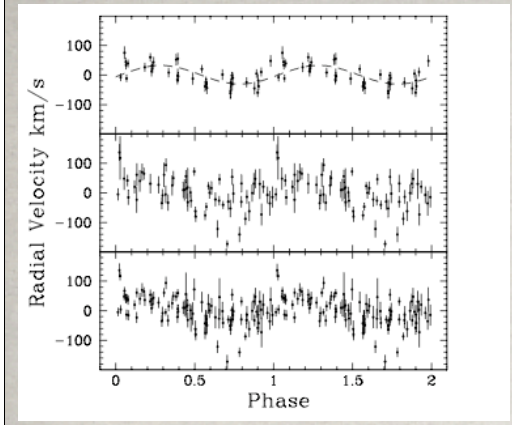
He I



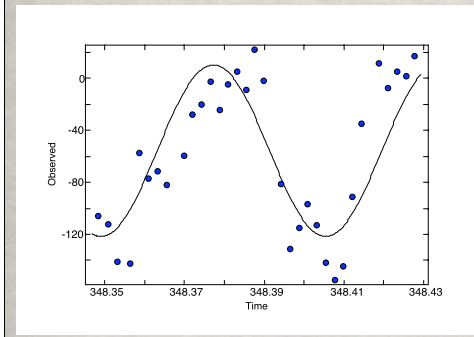





600
400
200
0
−200
−400
−600
−600
−400
−200
0
200
400
600

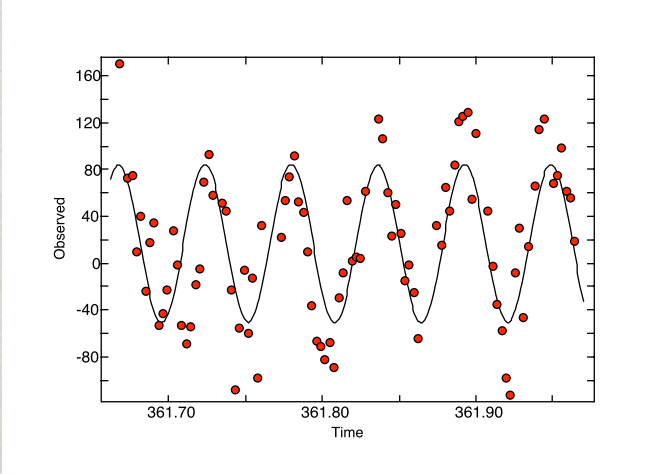


- Araujo-Betancor et al (2005) deduced K1=32 km/sec



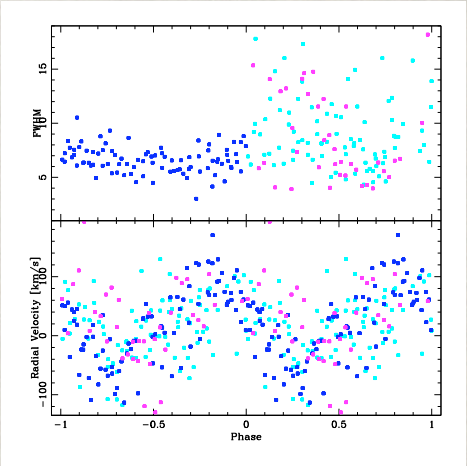
Fre = 17.7590842; K1 = 66.0

Residuals: 31.2882026



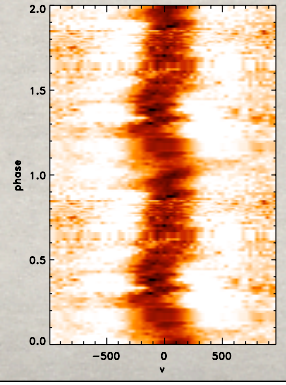
K1 = 67.4

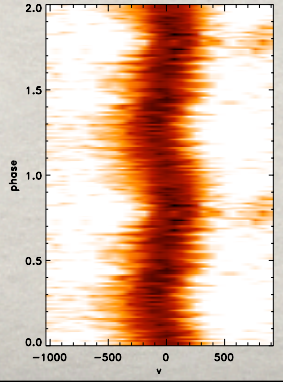
Residuals: 40.5

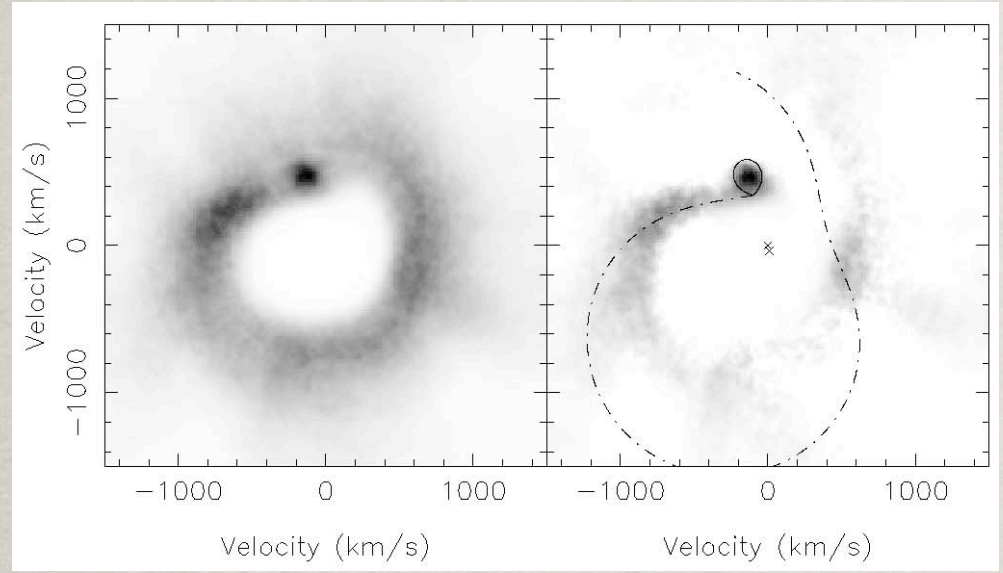


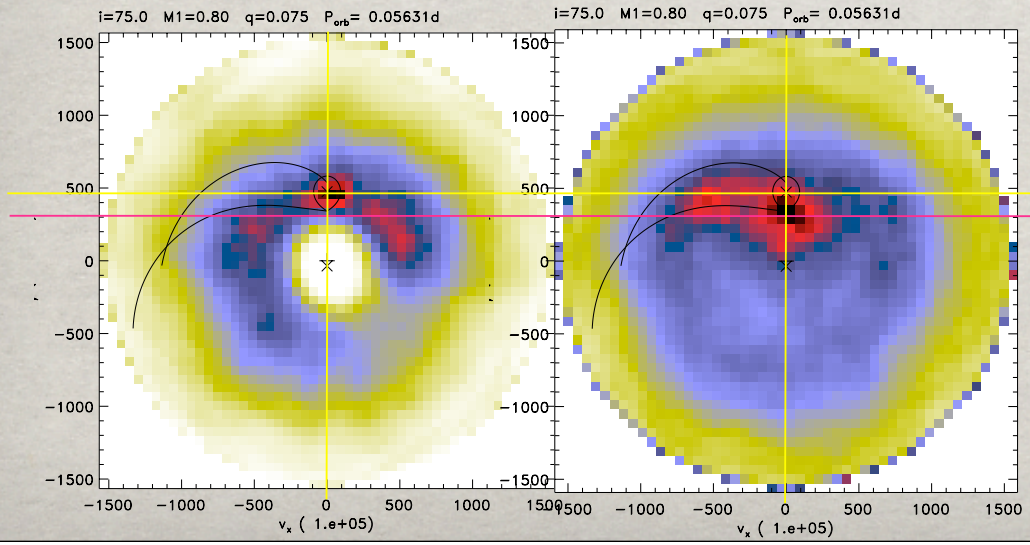
K1 = 48.3

Residuals: 54.1



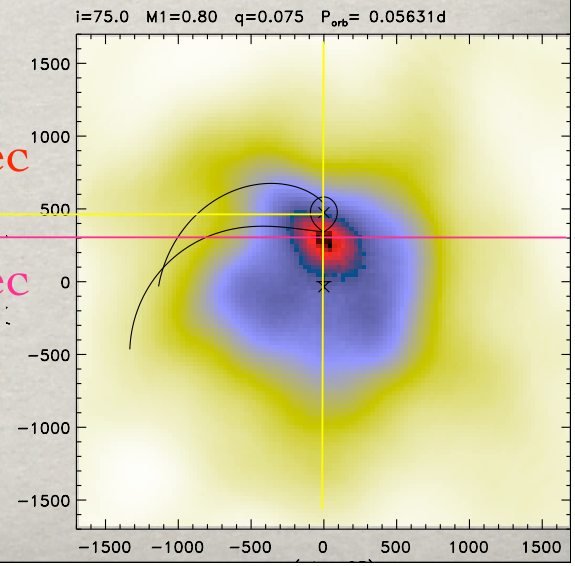


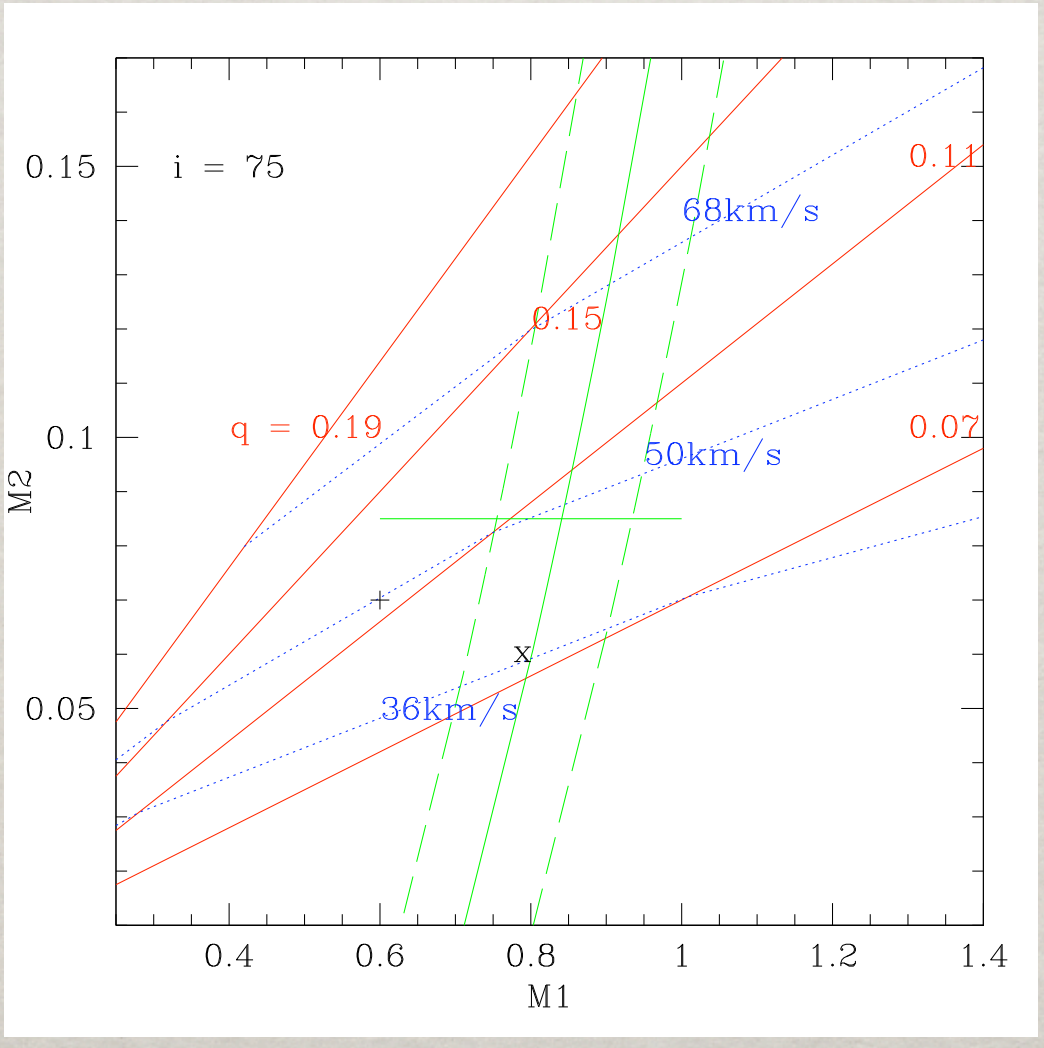




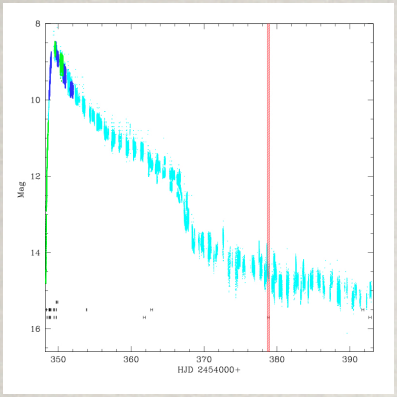
475 km/sec

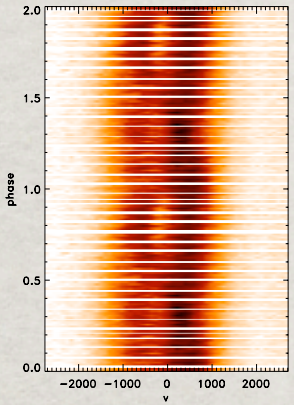
300 km/sec

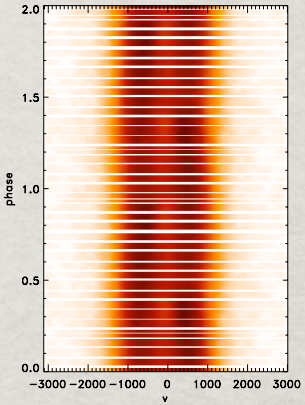



i = 75
0.15
0.1
0.05
M2
0.4
0.6
0.8
1
1.2
1.4
M1
q = 0.19
0.15
0.11
0.07
68km/s
50km/s
36km/s
+
x

THE LATE LATE DECLINE: JD 2454378

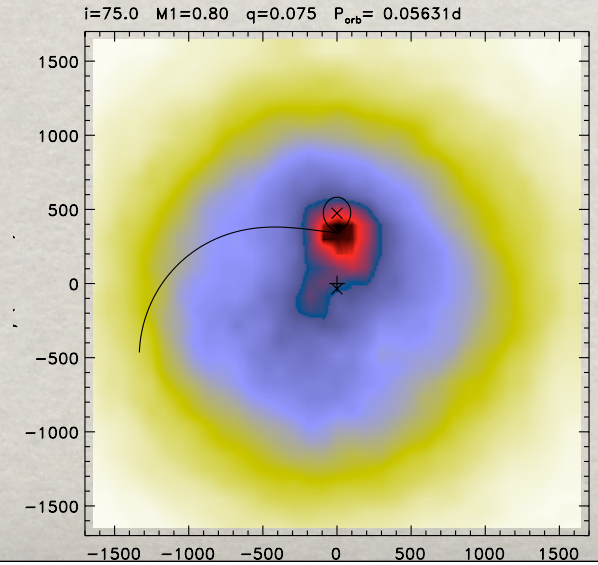


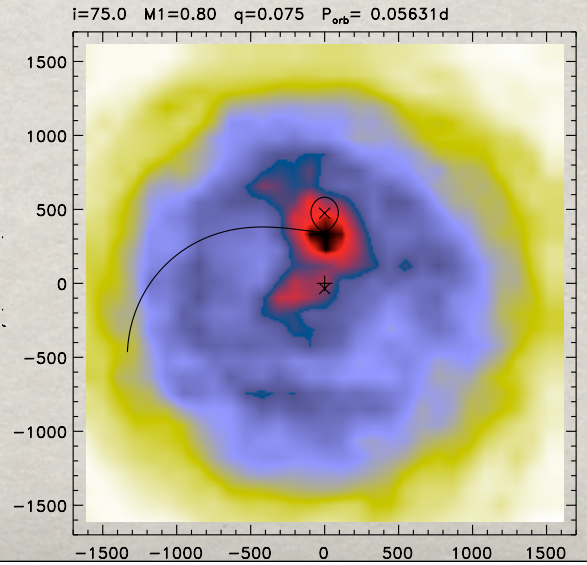




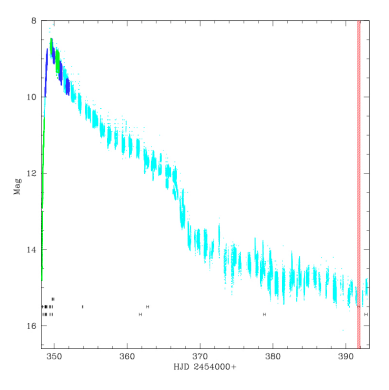
Hβ emission

Hγ



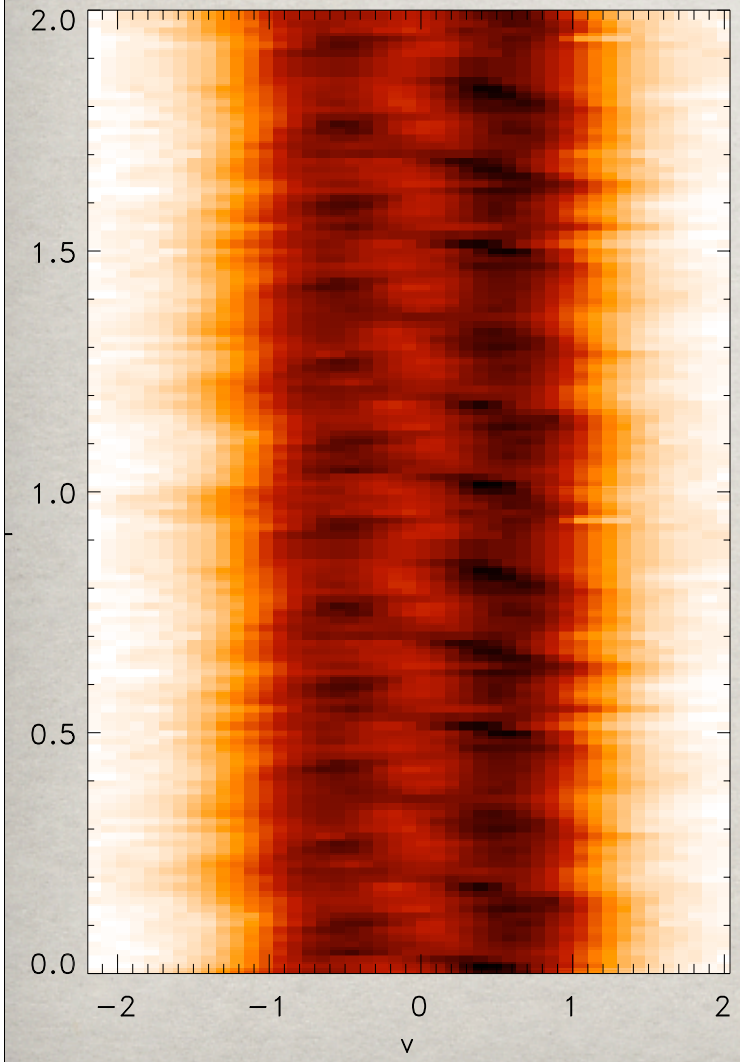


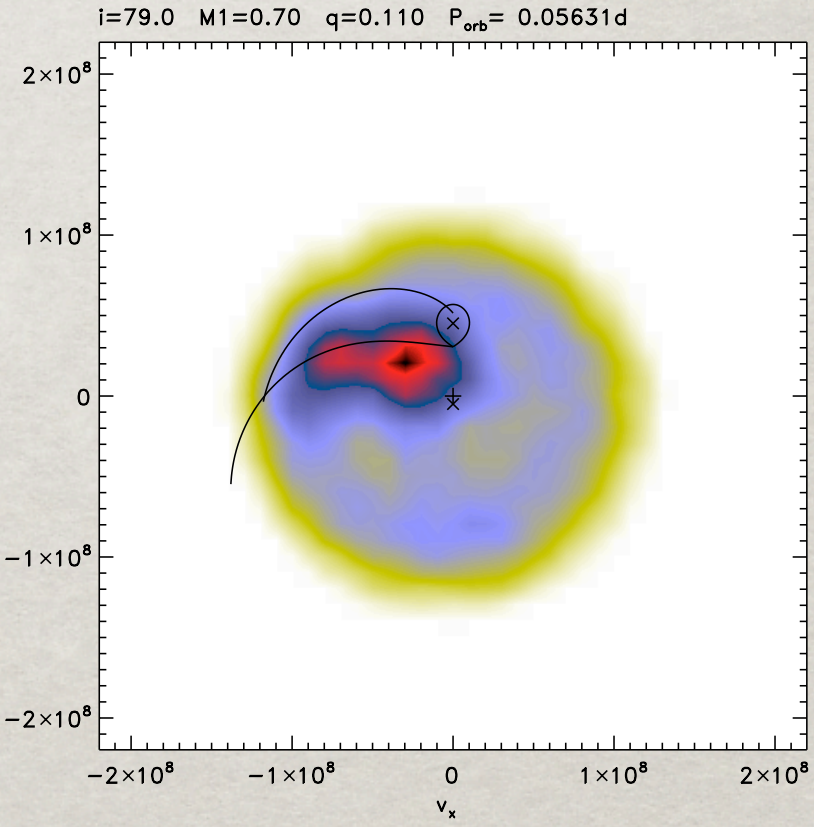
THE END: JD 2454391-92



ONE YEAR LATER: 2454737

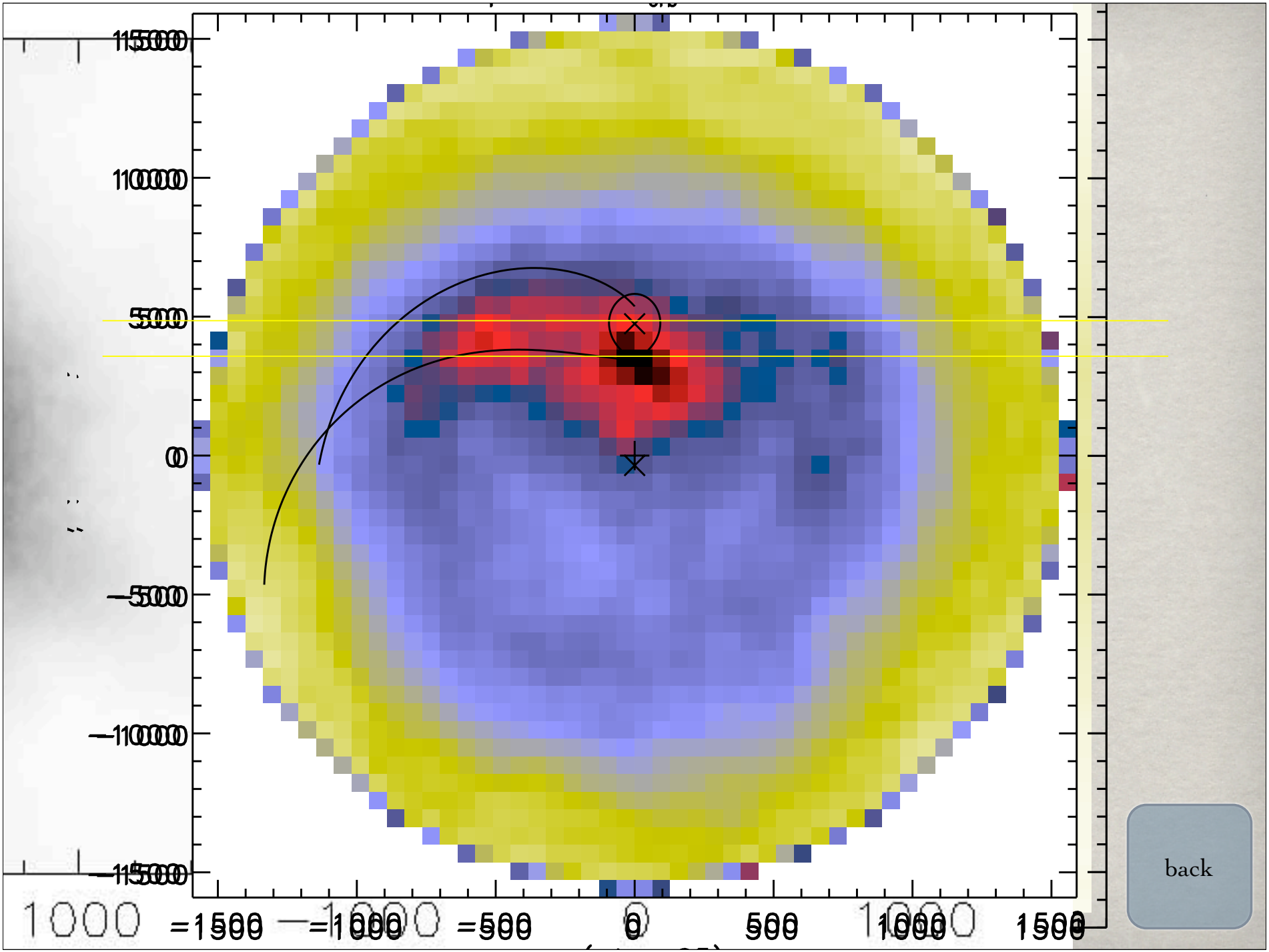
- No sign of a long spectroscopic period in the trailed spectra





Conclusions

- The amplitude and shape of the outburst enlist V455 And to WZ Sge family of short period CVs.
- The estimate of masses places V455 And rather below the min period turnaround, than above (M_1 ~ 0.8+/-0.08 M , M_2 ~ 0.085+/- 0.02)
- Analysis of spectroscopy should be complemented with photometry to understand better the processes going on in the accretion disk.
- We tentatively see a "pulsation" of the accretion disk, i.e. contraction and expansion of emission zone of the disk during decline.
- The 2nd long spectroscopic period in the wings of emission lines of V455 And has disappeared and did not come back yet, one year after the outburst.


back