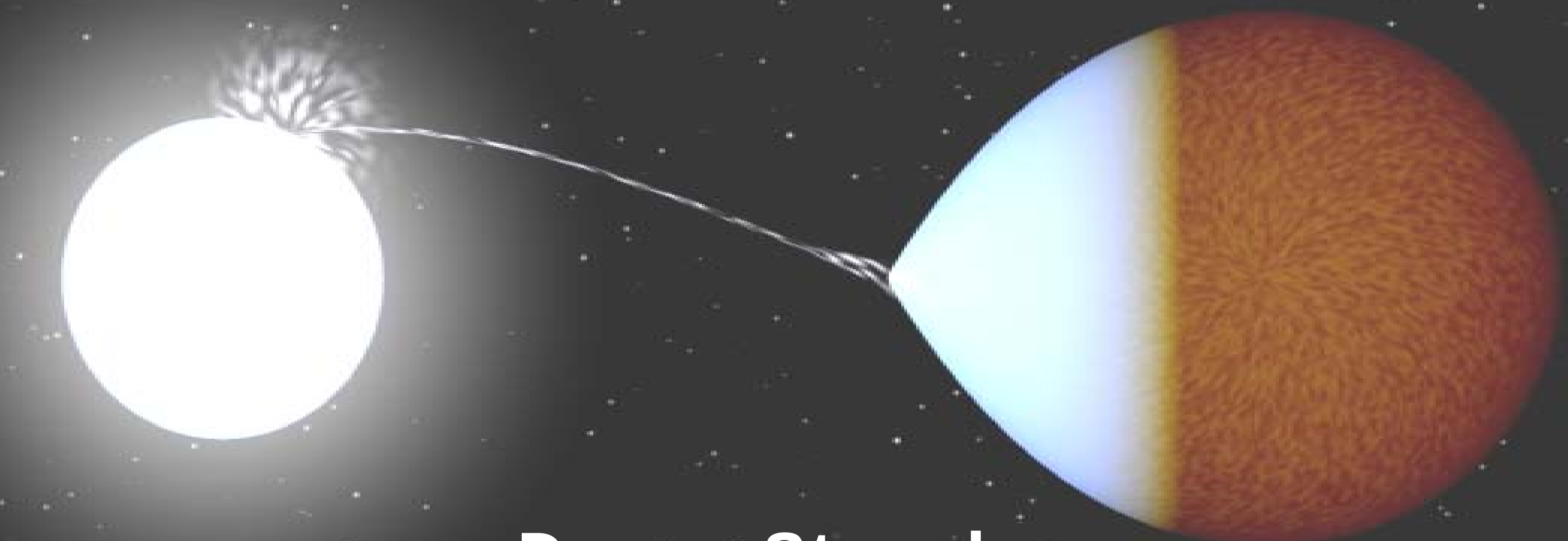
Binsim courtesy R.Hynes

Spikes and mass ratios : emission line diagnostics in AM CVns

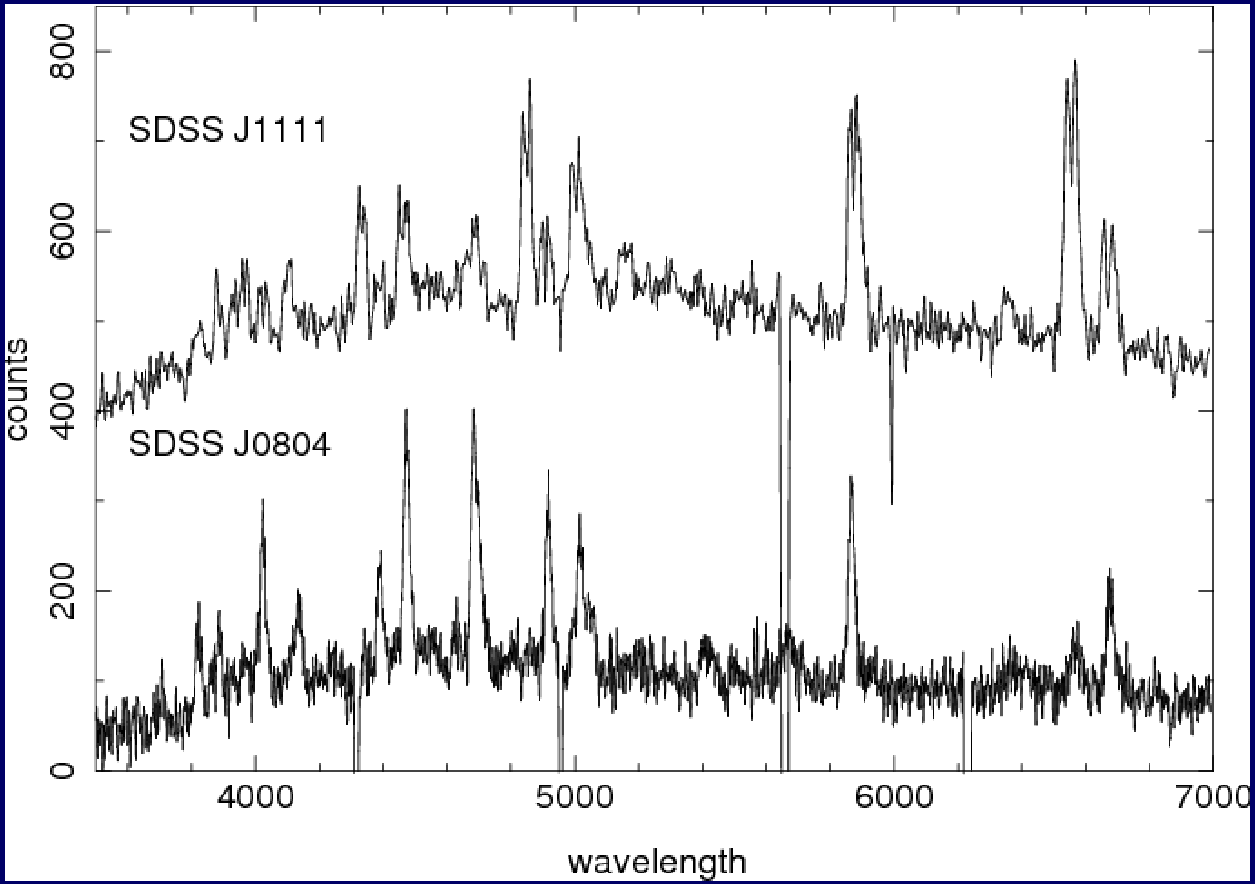


Danny Steeghs

University of Warwick

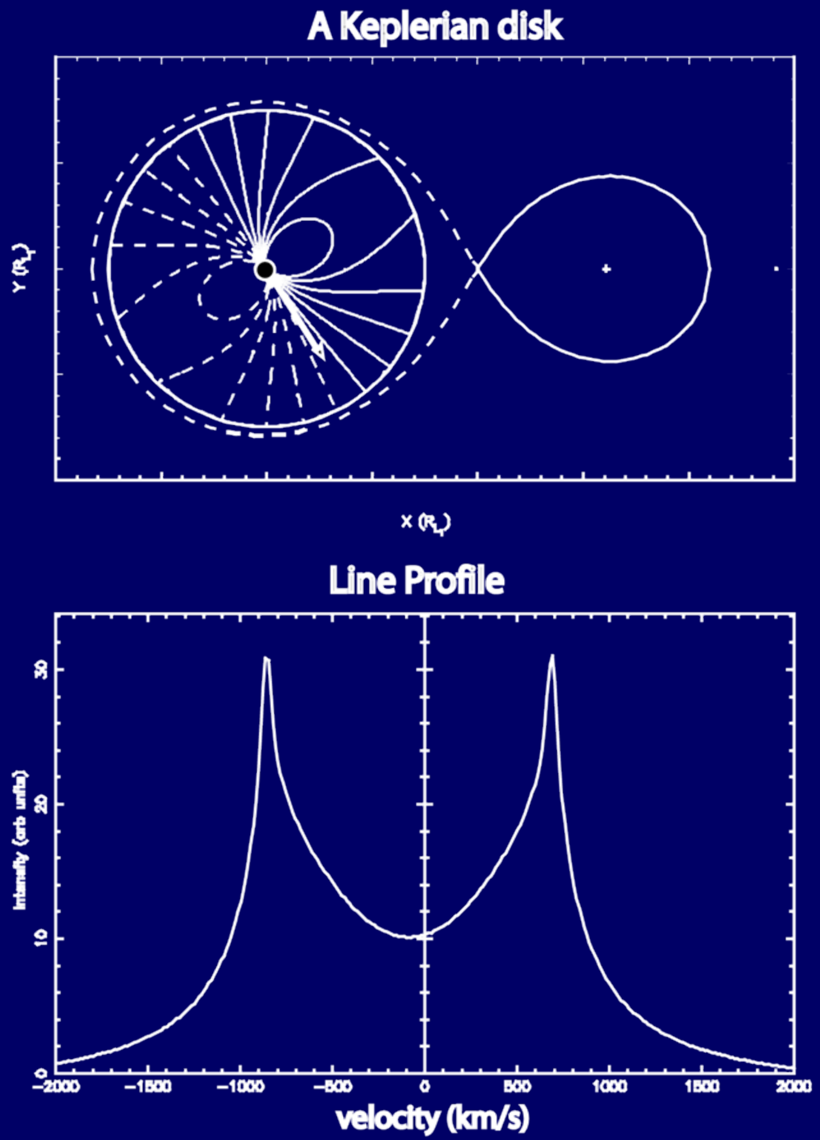
G.Roelofs, G.Nelemans, T.Marsh, P.Groot et al.

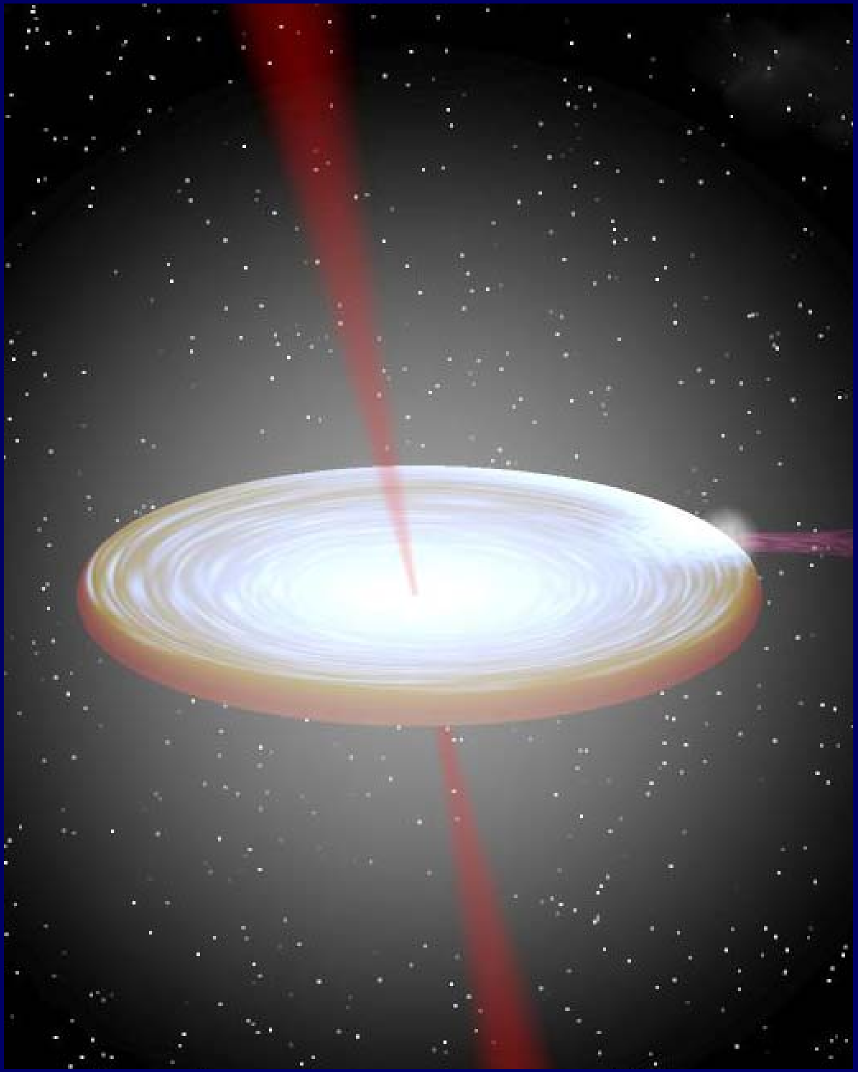
Emission line spectra



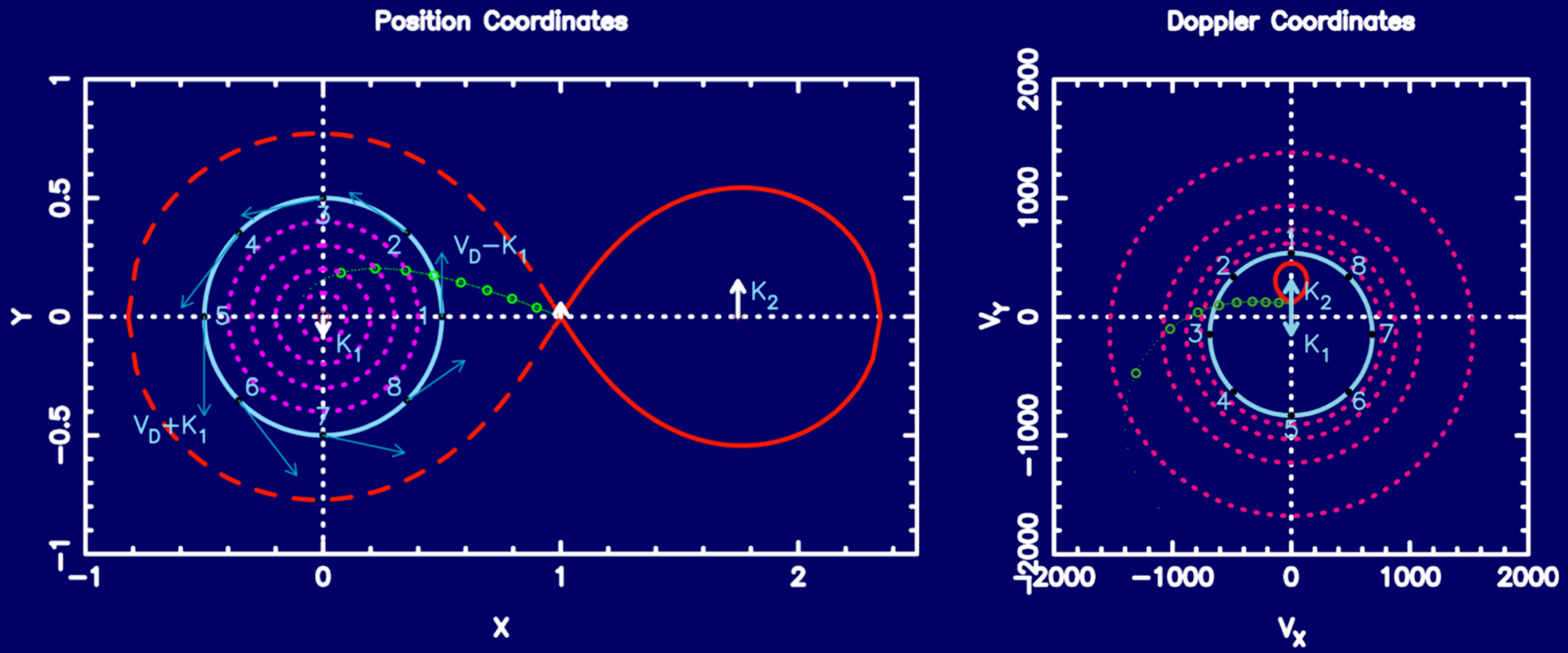
- facilitate their discovery/identification (see P.Groot)
- sample the abundances of the donor star
- provide a detailed dynamical probe of the emission line regions

Emission lines from a disk





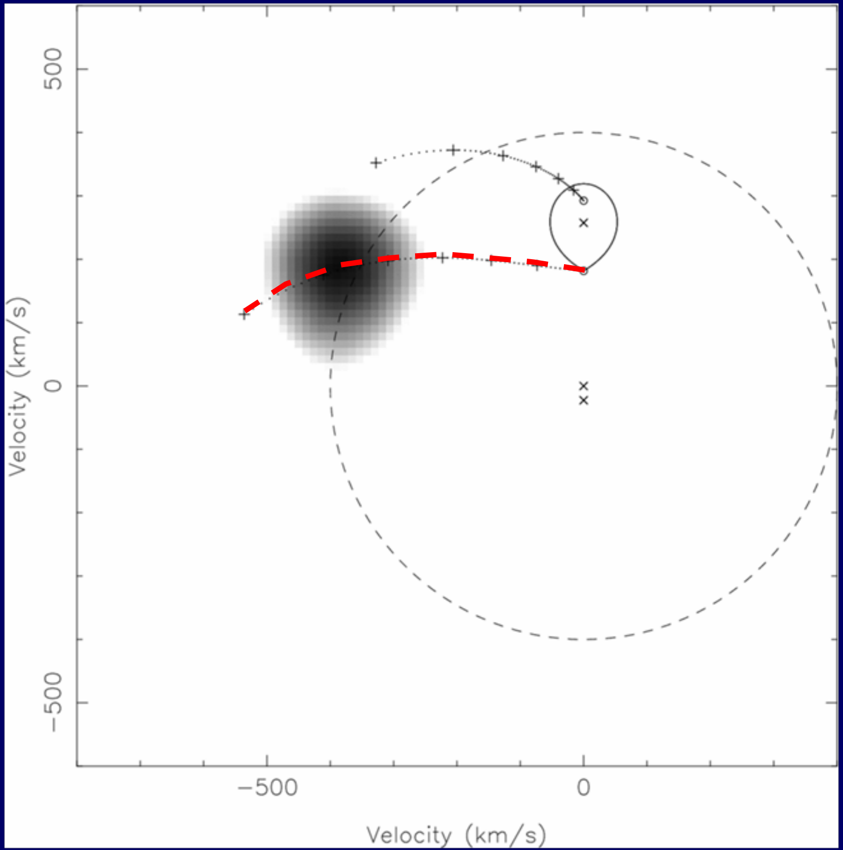
Key locations



- Donor star with velocity K2
- Accretor with velocity K1
- (Ballistic) accretion stream
- Accretion disk
- Stream-disk interaction
- Stream-accretor interaction (direct impact)

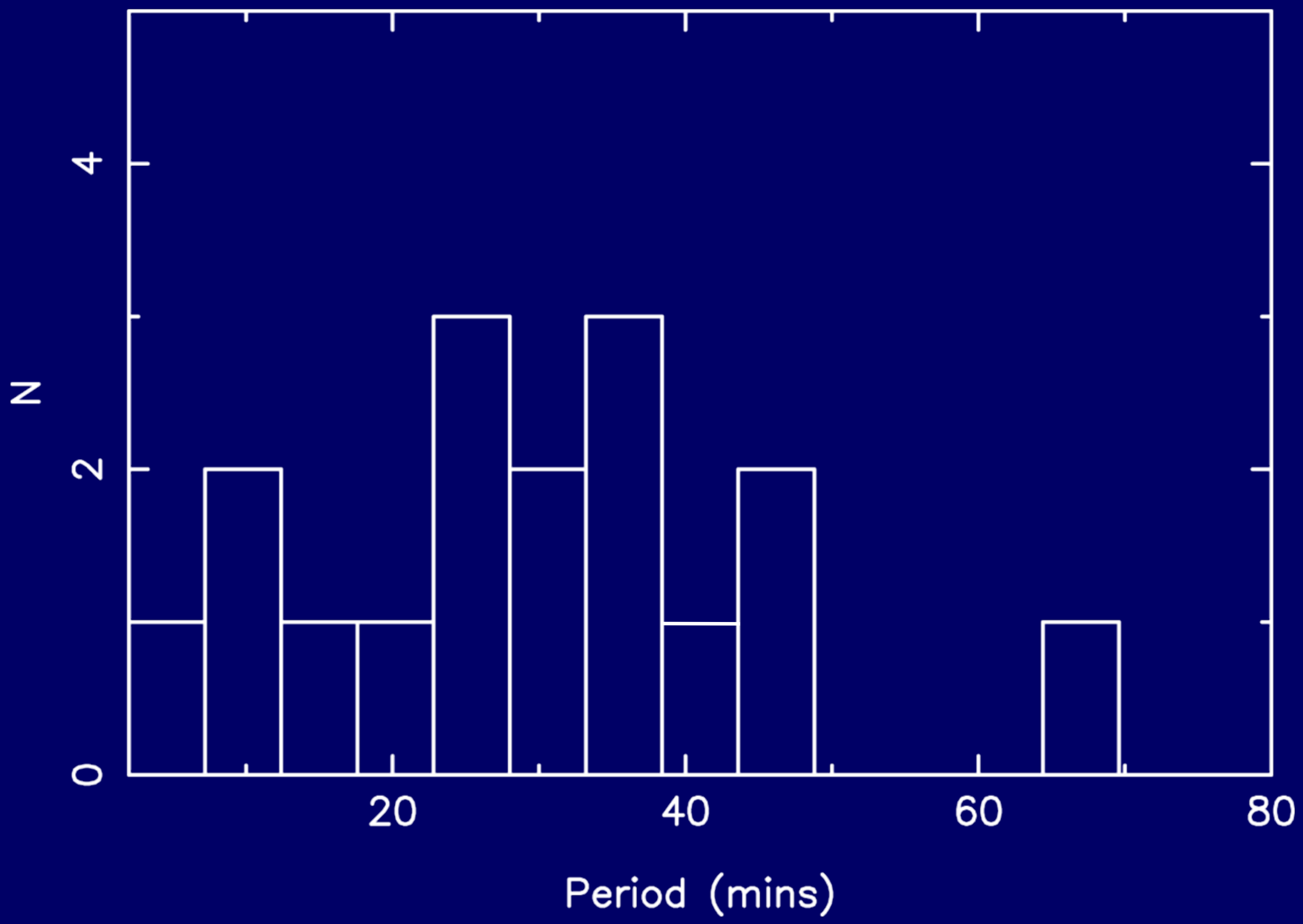
Spectroscopic periods

- Complex photometric behaviour of AM CVn stars makes a solid identification of the binary period difficult
- The stream-disk impact localisation provides a common beacon in the binary frame
- Kicked off by fast spectroscopy of AM CVn itself



Accretion disc + bright spot emission (Nelemans, Steeghs & Groot 2001)

Period distribution of current AM CVn systems



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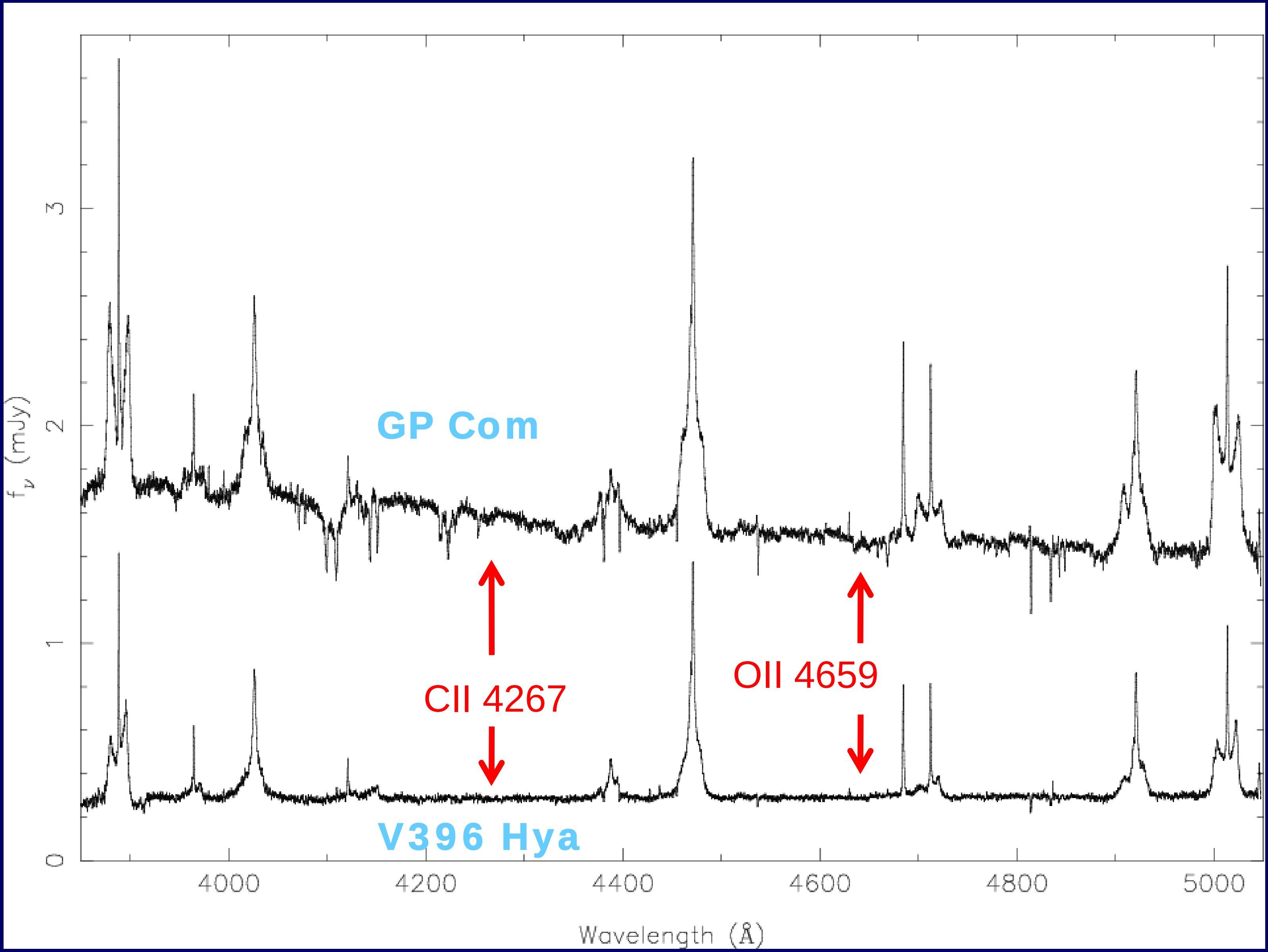
The (almost) twins GP Com & V396 Hya



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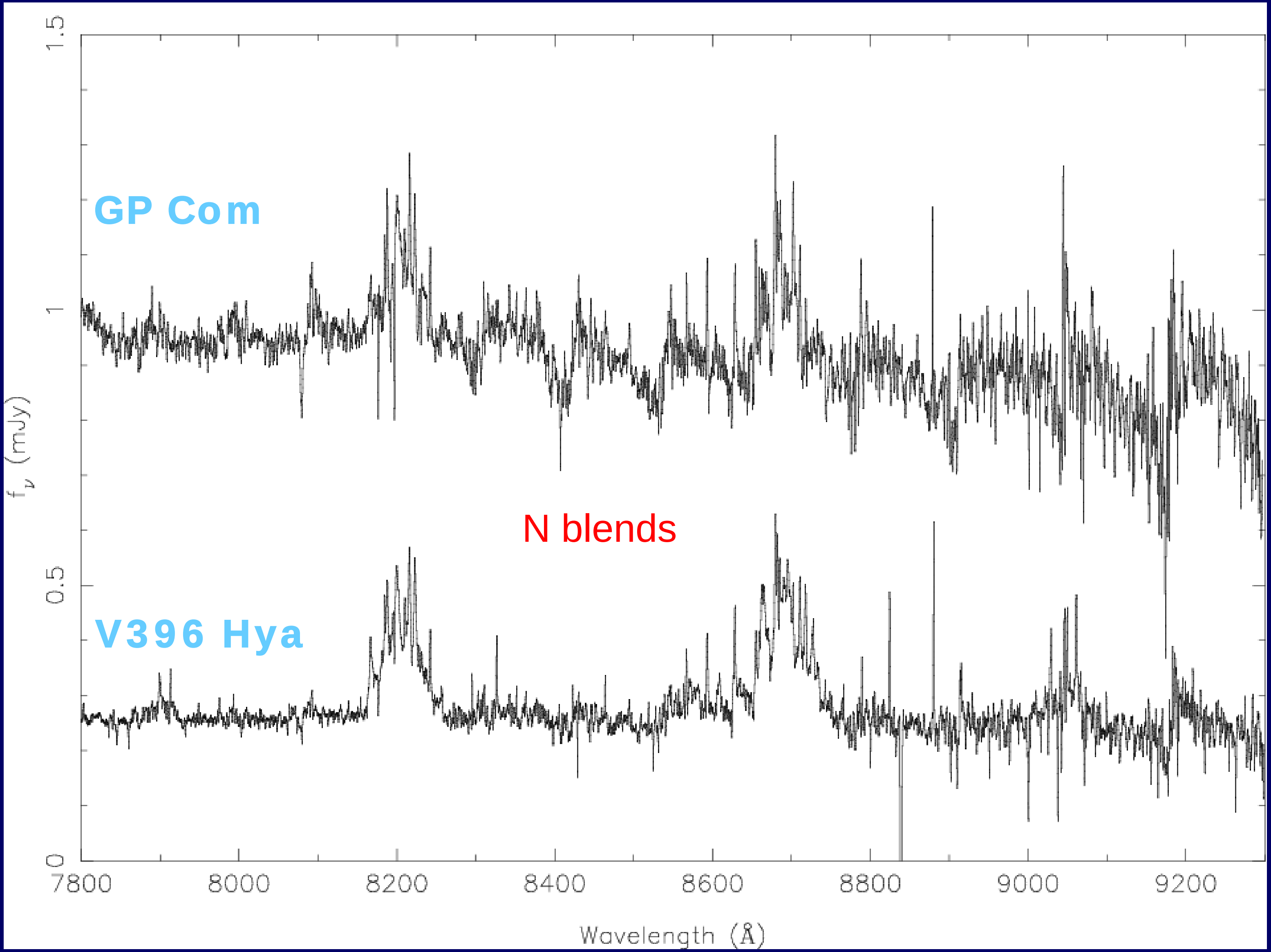
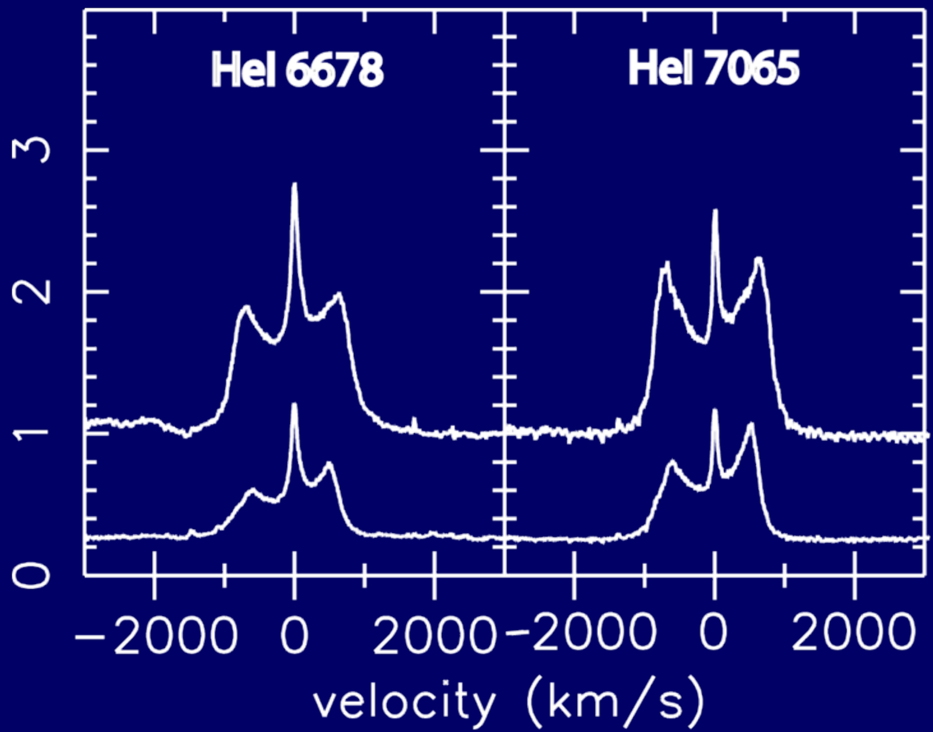
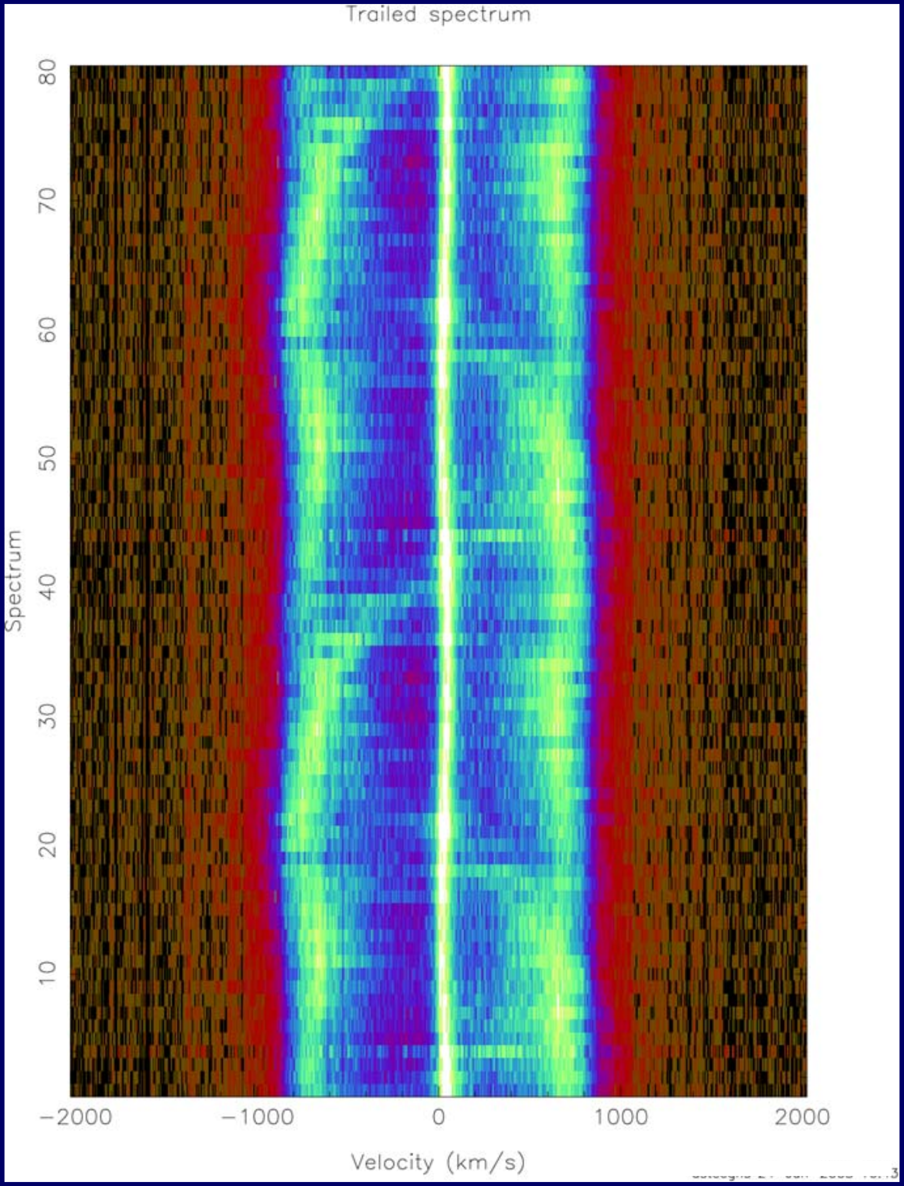
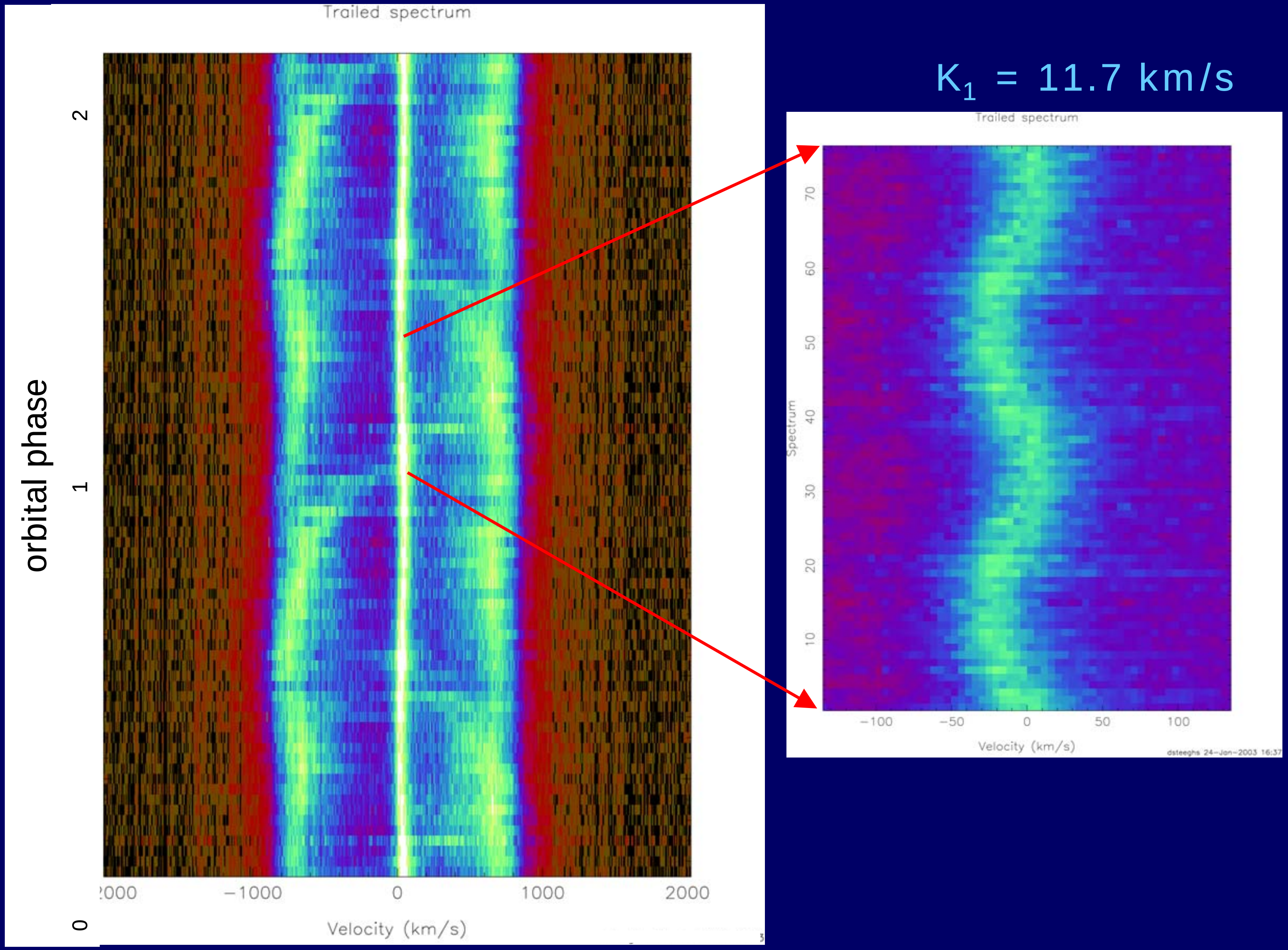


GP Com & V396 Hya





Central spike from the accreting WD



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Emission spikes from the white dwarf

• Spikes all move in phase and with the same amplitude

=> near WD   (Marsh 1999)

• However, spike mean velocity changes significantly from line to line (~ 0-50 km/s)

• Some lines show double spikes, each moving together

• Both GP Com and V396 Hya show the same pattern, other AM CVn systems show spikes as well (Roelofs et al.)

• Spikes are narrow, though non-Gaussian

• Stark effect in high-density line formation region?

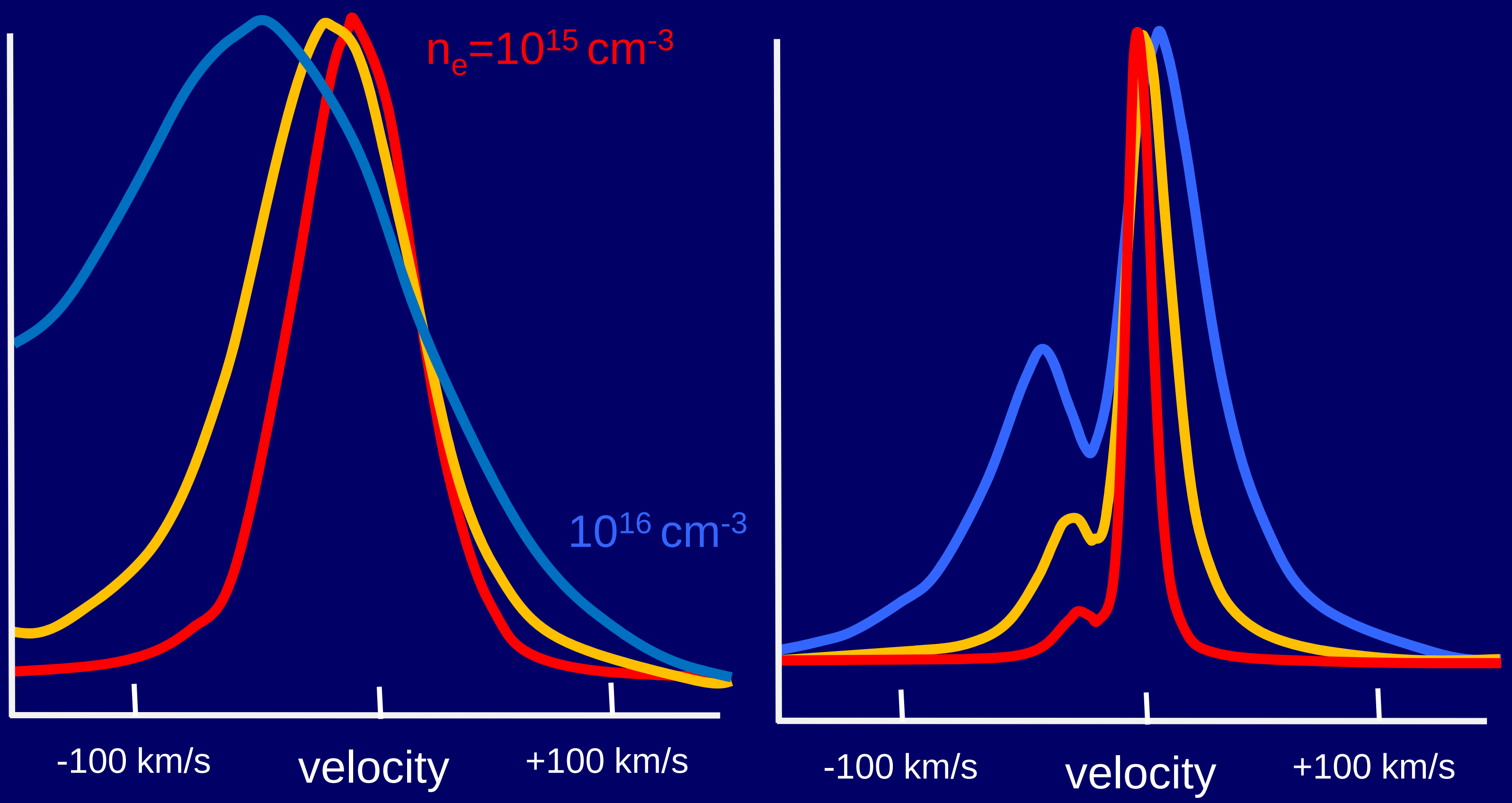
(Morales-Rueda et al. 2003)

TABLE 3
VELOCITY OF THE CENTRAL SPIKE

	GP Com		CE 315	
wavelength	γ	K_1	γ	K_1
HeI 3888.643	-4.7 ± 0.2	12.7 ± 0.3	-9.9 ± 0.3	6.1 ± 0.4
3964.730	-4.1 ± 1.1	13.0 ± 1.6	-2.5 ± 1.2	5.8 ± 1.6
4387.929	14.5 ± 2.3	11.5 ± 3.2	20.1 ± 3.4	8.6 ± 4.2
4471.502	42.4 ± 0.5	11.1 ± 0.7	39.4 ± 0.6	5.4 ± 0.9
4685.710	17.4 ± 0.3	11.7 ± 0.5	16.1 ± 0.5	5.2 ± 0.6
4713.170	32.6 ± 0.3	11.1 ± 0.5	27.3 ± 0.5	4.3 ± 0.6
4921.930	52.6 ± 1.0	12.3 ± 1.6	47.8 ± 0.8	5.8 ± 1.1
5015.678	6.4 ± 0.3	12.3 ± 0.4	7.5 ± 0.4	6.0 ± 0.5
5875.661	0.4 ± 0.3	11.3 ± 0.3	2.5 ± 0.3	5.1 ± 0.5
6678.152	18.2 ± 0.2	11.6 ± 0.2	11.2 ± 0.3	6.8 ± 0.3
7065.251	23.2 ± 0.2	13.3 ± 0.3	16.0 ± 0.3	6.2 ± 0.4
7281.351	17.2 ± 0.2	8.0 ± 0.4	16.3 ± 0.4	4.1 ± 0.5
weighted mean		11.7 ± 0.3		5.8 ± 0.5

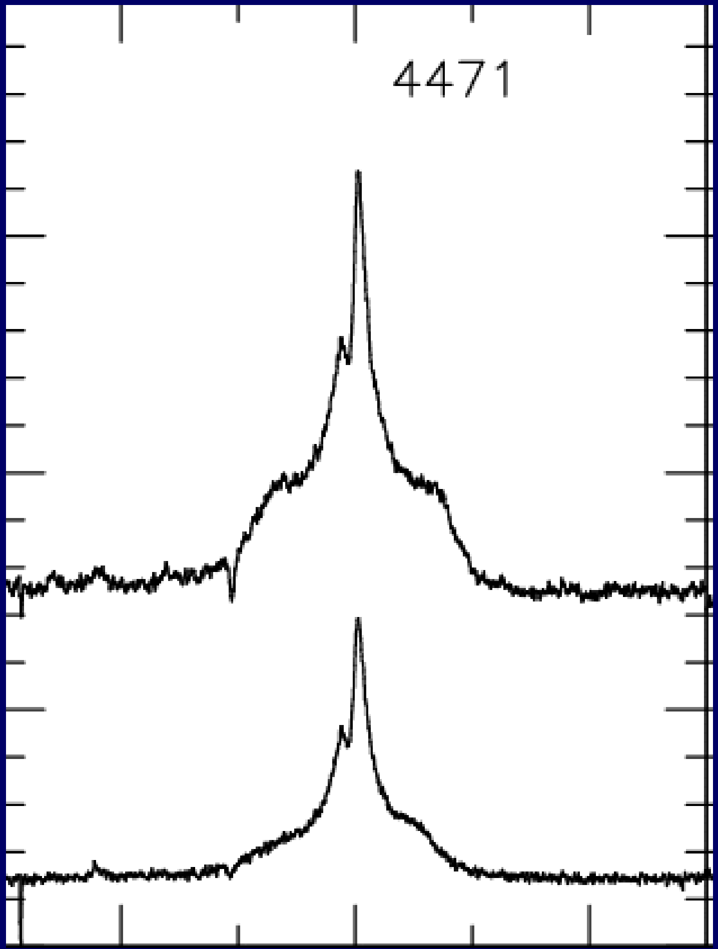
appears not to be consistent with DB/EHe models for Stark-shift and split (Beauchamp et al. 1997)

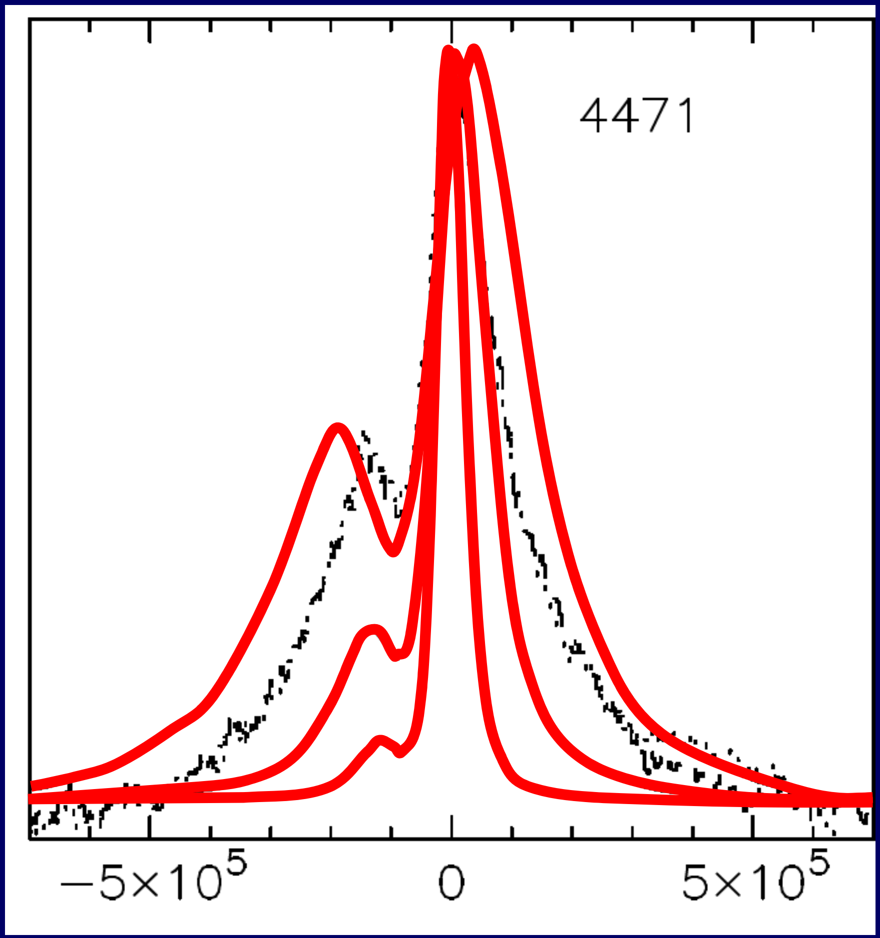
Beauchamp et al. (1997) Stark profiles



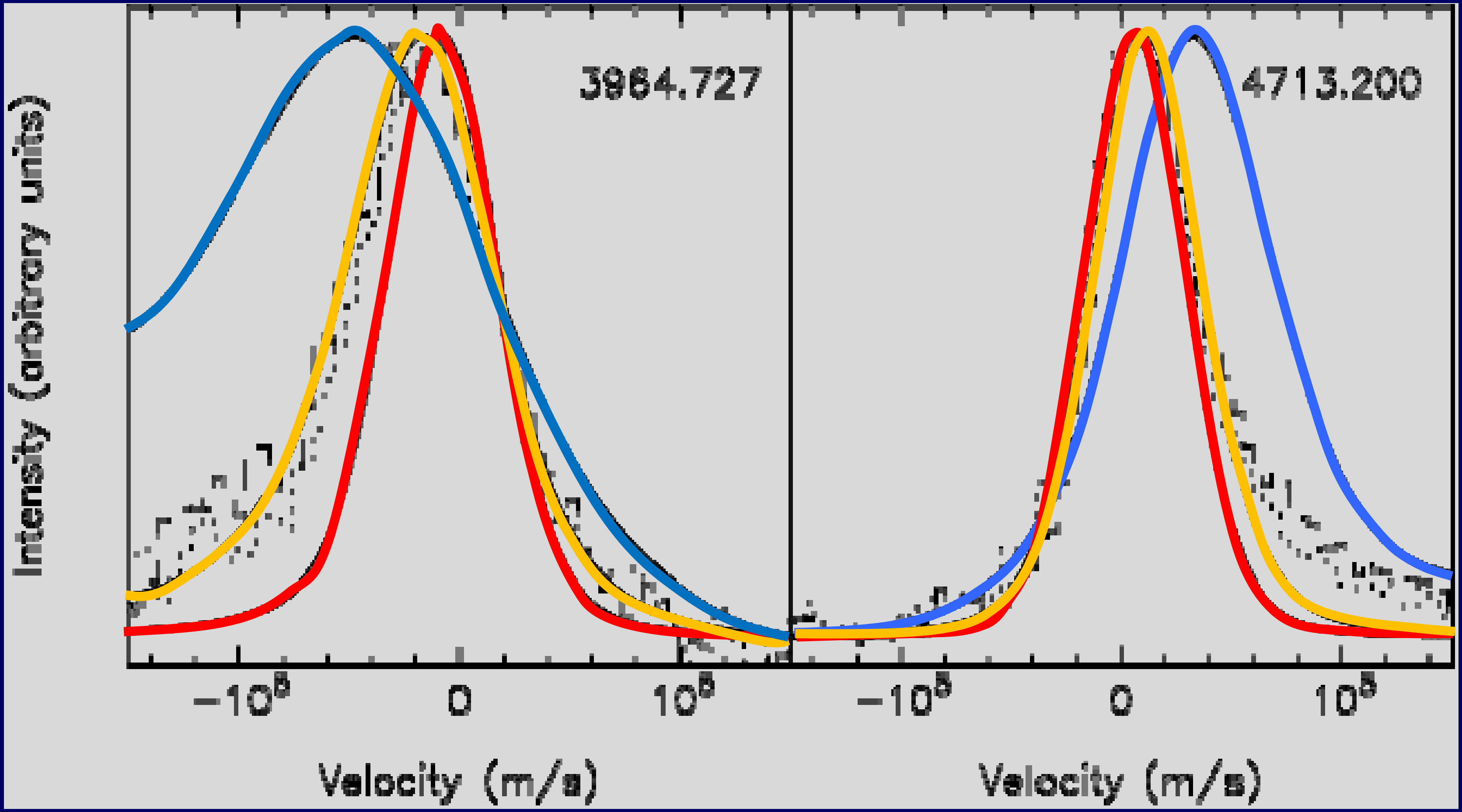
Both velocity of peak and overall profile shape depends on n_e

Observed split spike profiles





Spike velocity shifts

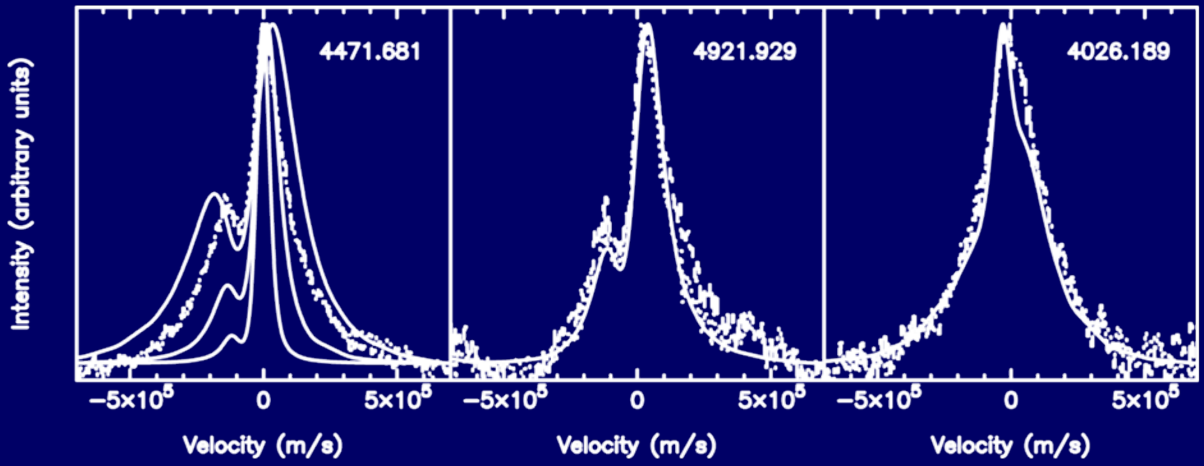


Decent match to the family of spike profiles (both shift and shape) for $n_e = 3\ 10^{15}\ cm^{-3}$

Spikes at the accreting WD

- Single density Stark profiles describe the spike properties in both GP Com and V396 Hya

- Kinematics and density conditions of the spike match an emission line region tied to the accreting white dwarf



- Provide us with the orbital velocity K1, the absolute binary phase and the (Stark corrected) systemic velocity

- Unknown binary space velocity prevents us from converting the overall velocity offset (+16-17 km/s) into a gravitational red-shift

Rotation

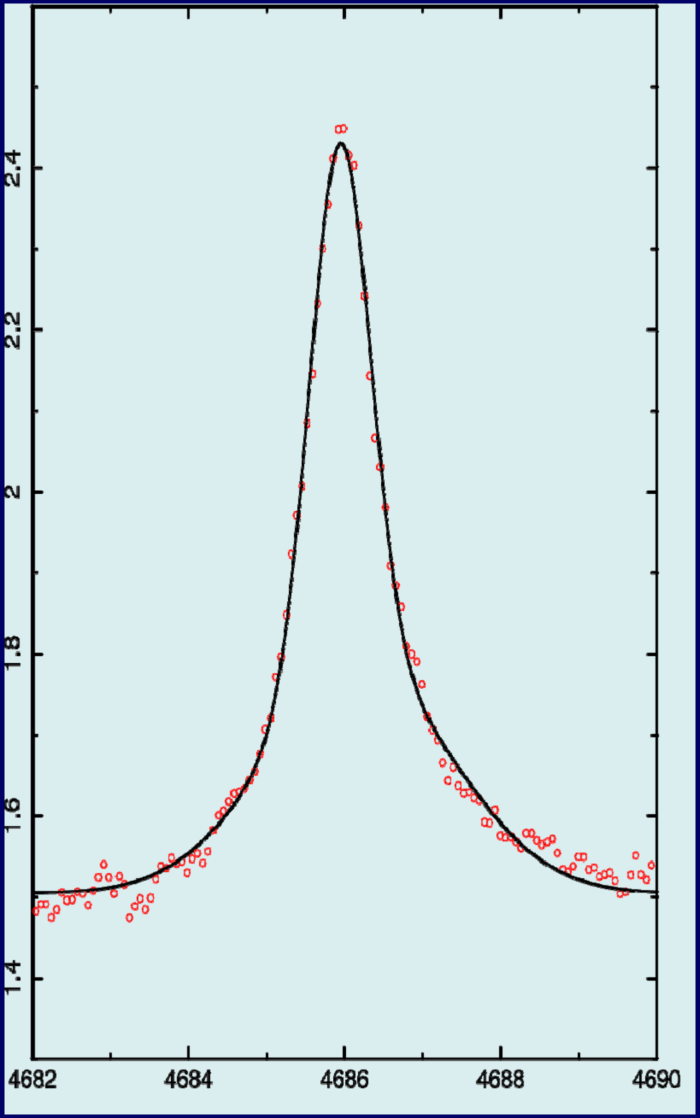
- Spikes are relatively narrow, and shapes are dominated by the Stark broadening profile

- Need very little rotational broadening !

- From HeII 4686 :

  vsini = 60 – 85 km/s

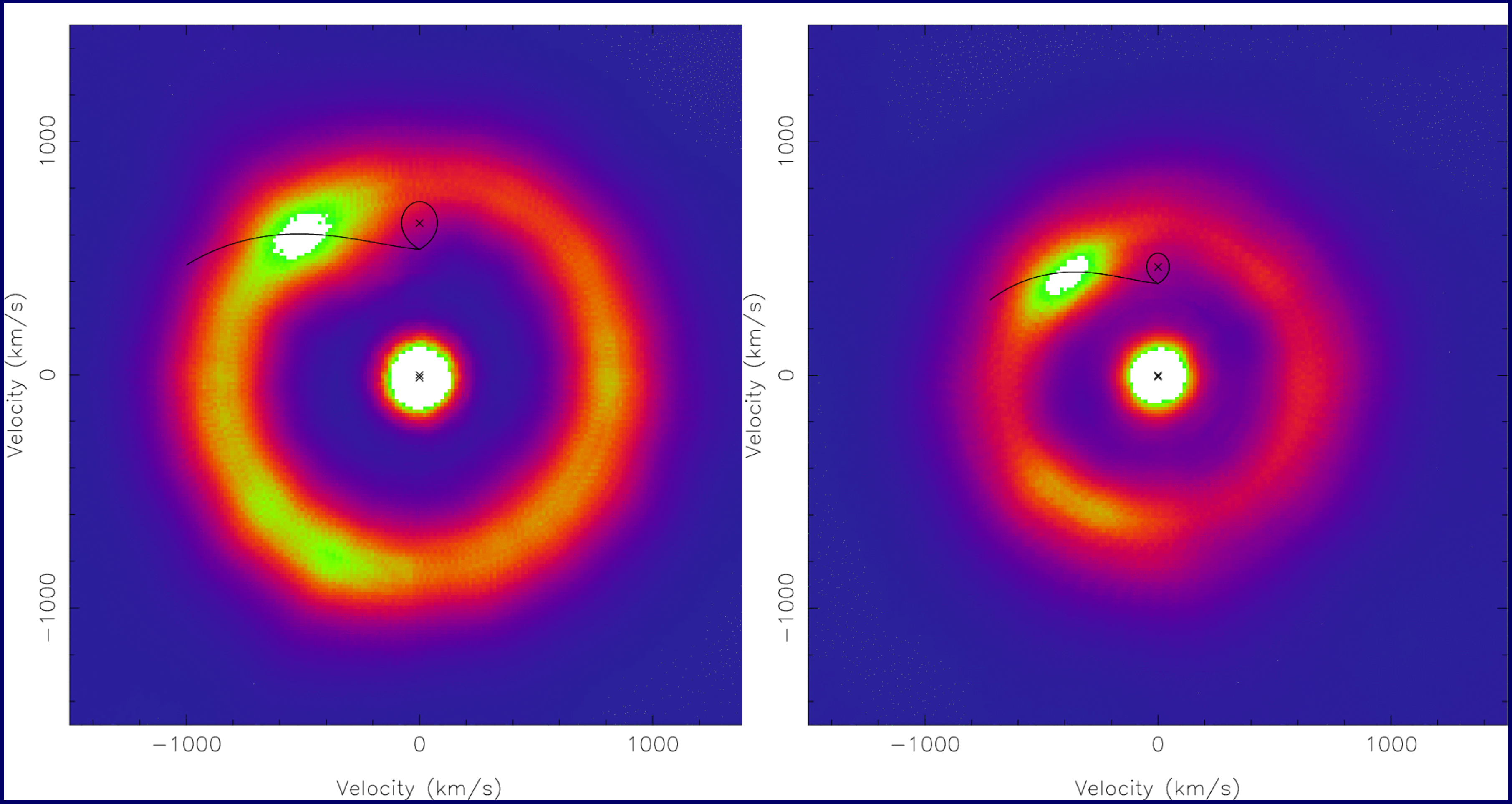
- White dwarfs appear to be rotating slowly, unless the spike photosphere does not co-rotate with the white dwarf



Doppler maps

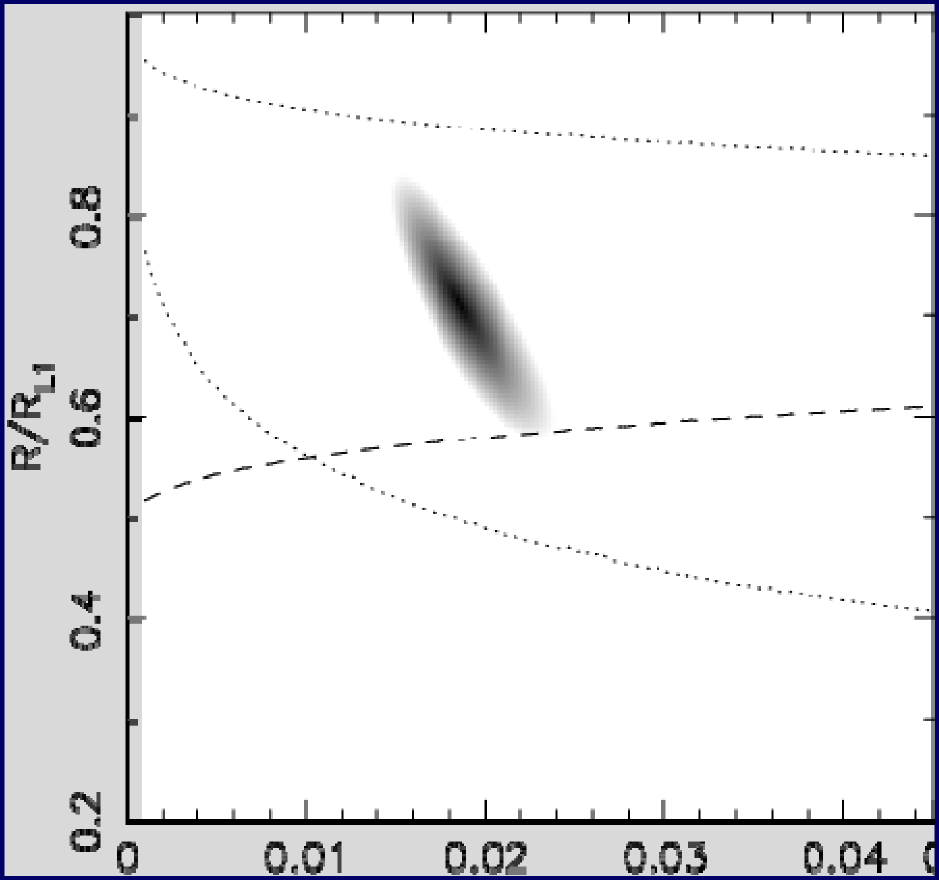
GP Com HeI 3888

V396 HeI 5015



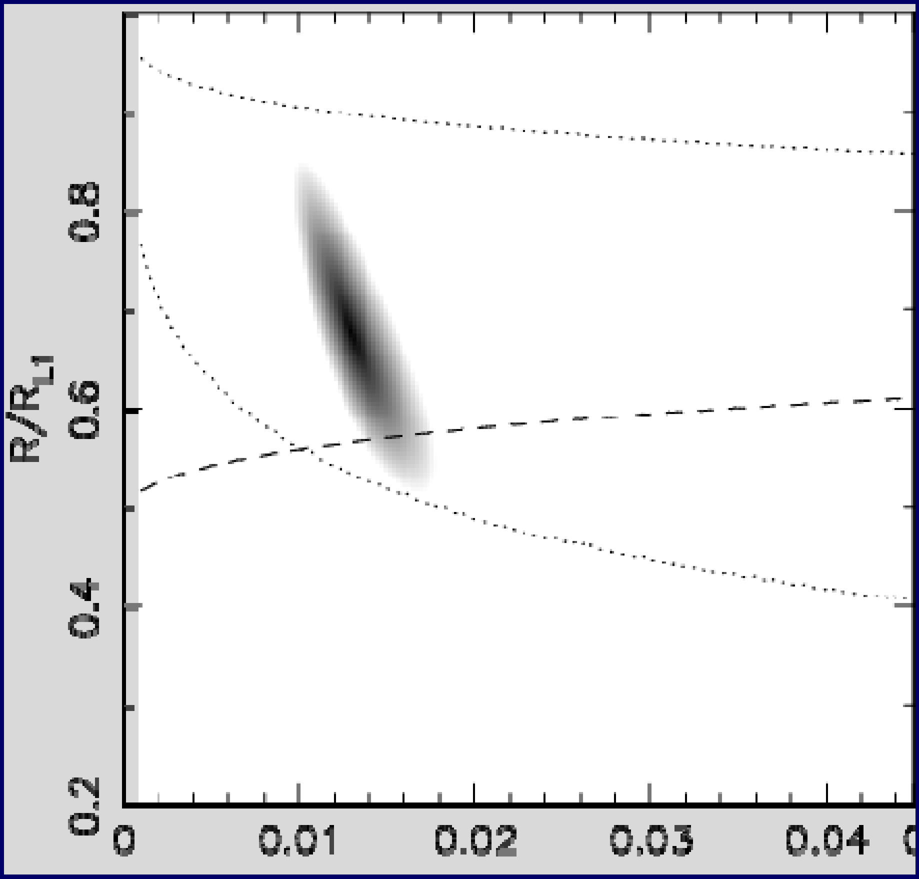
Mass ratio from disk-stream impact : ballistic

GP Com



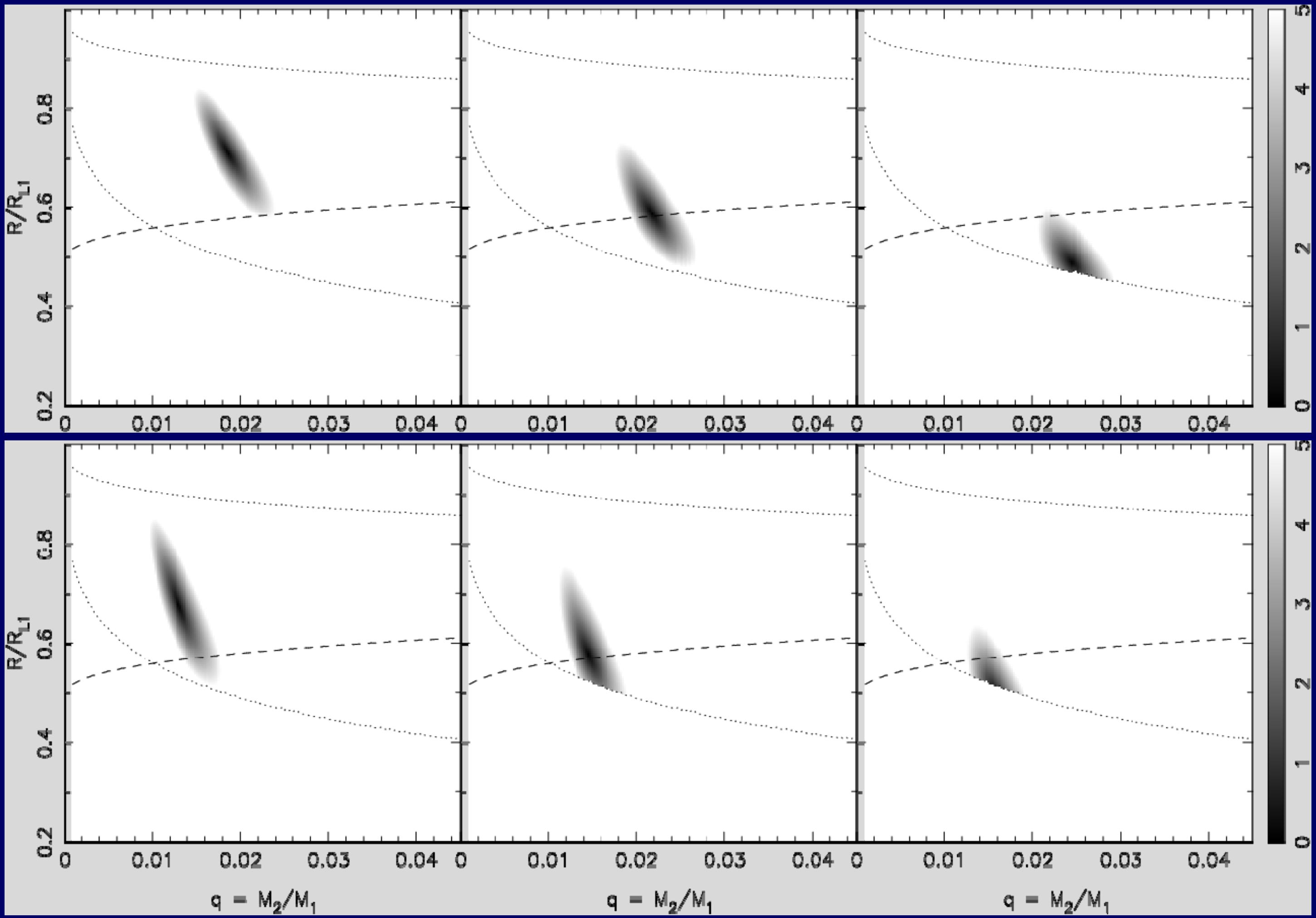
q

V396 Hya



q

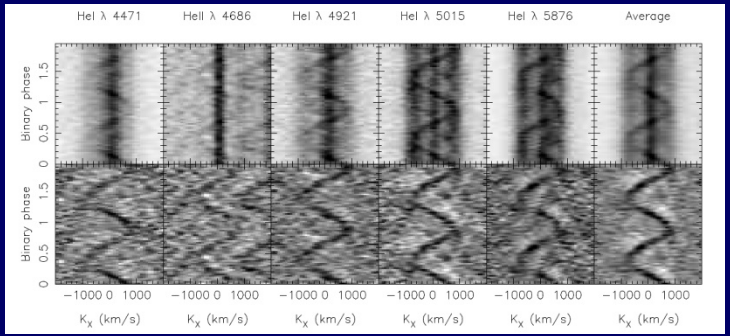
Mass ratio from disk-stream impact : disk velocities

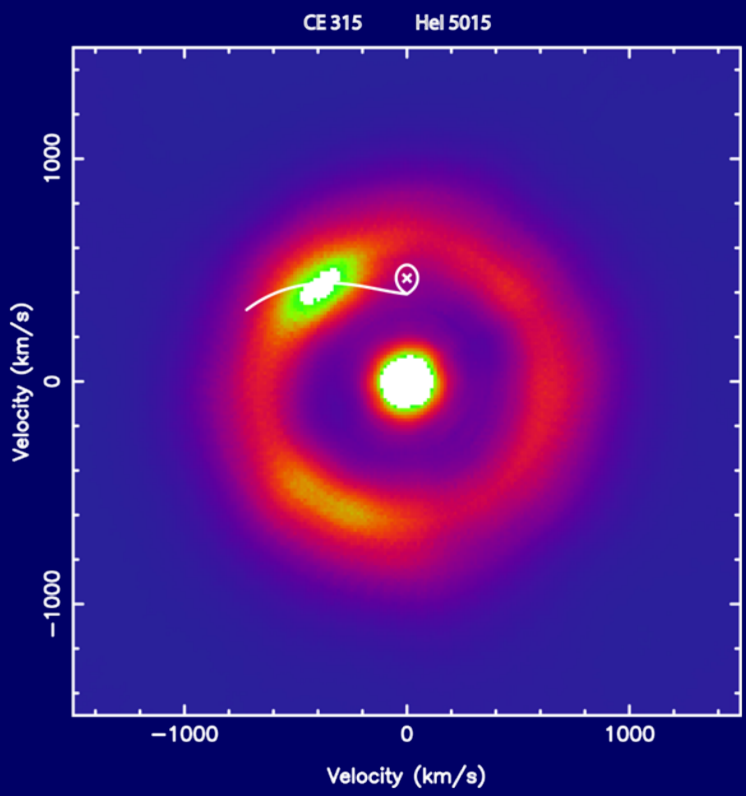


ballistic mix disk velocities

Mass ratios from spike + impact spot

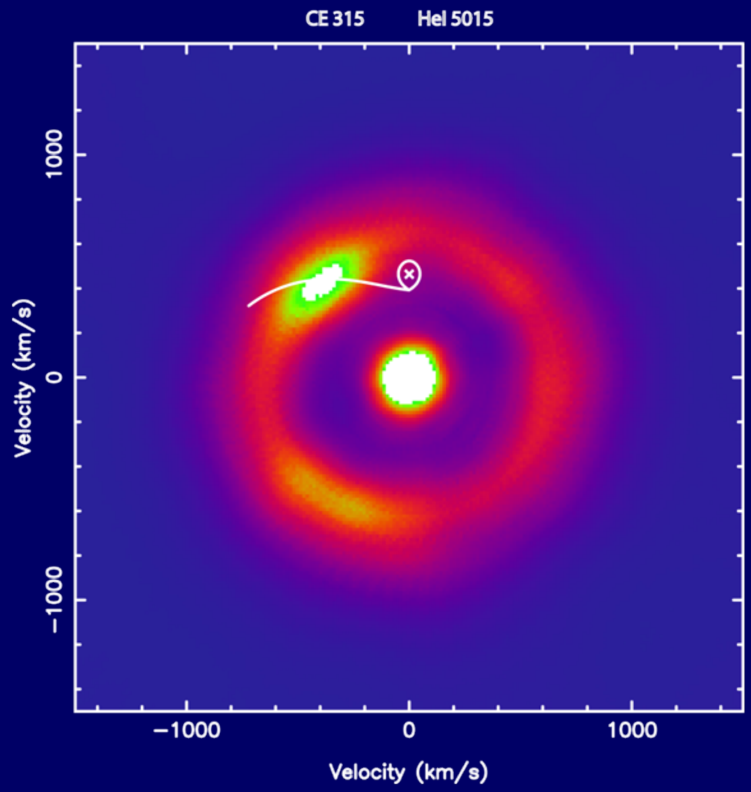
- GP Com
  q = 0.019 ± 0.002
- V396 Hya
  q = 0.013 ± 0.002
- SDSS J1240 (Roelofs et al. 2005)
  q = 0.039 ± 0.010
- AM CVn (Roelofs et al. 2006)
  q = 0.18 ± 0.01
- (SDSS J1552)



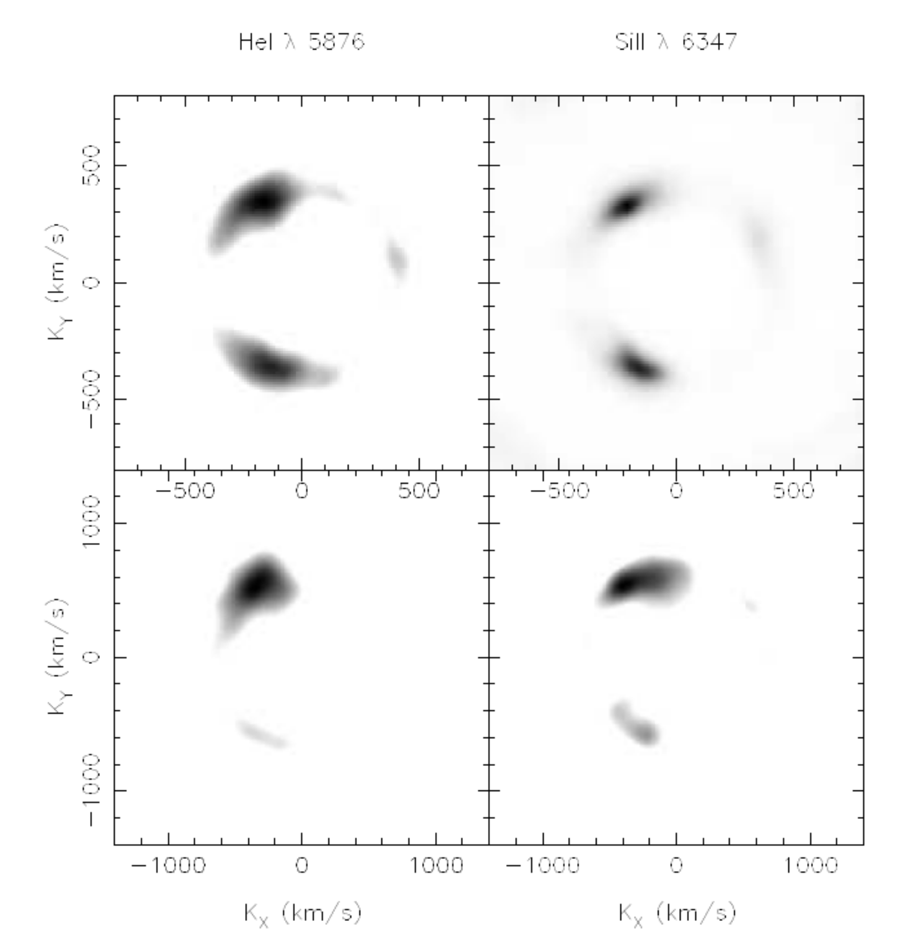


Double hot-spots ; stream overflow ?

V396 Hya



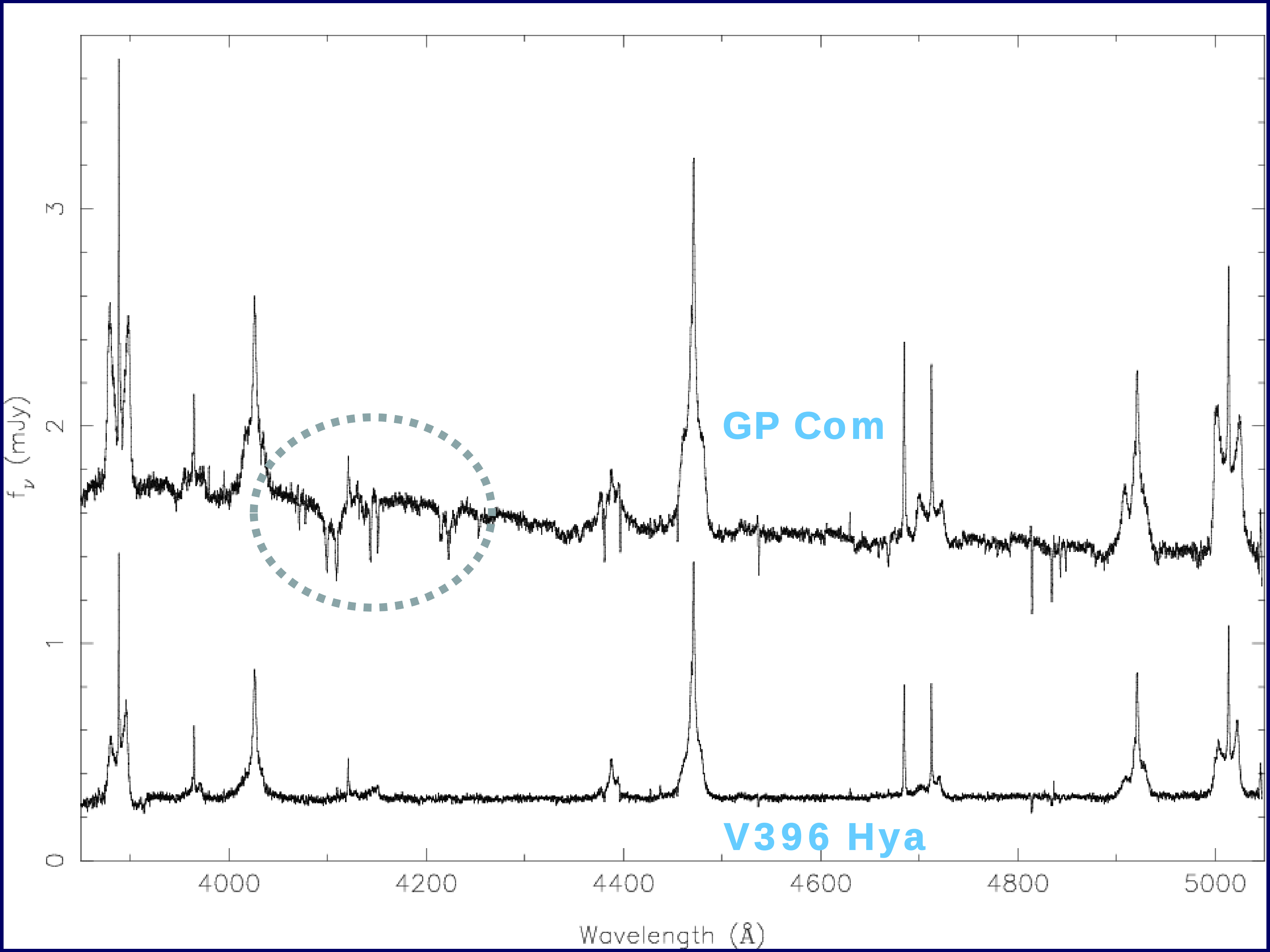
SDSS J1240 + sn2003aw



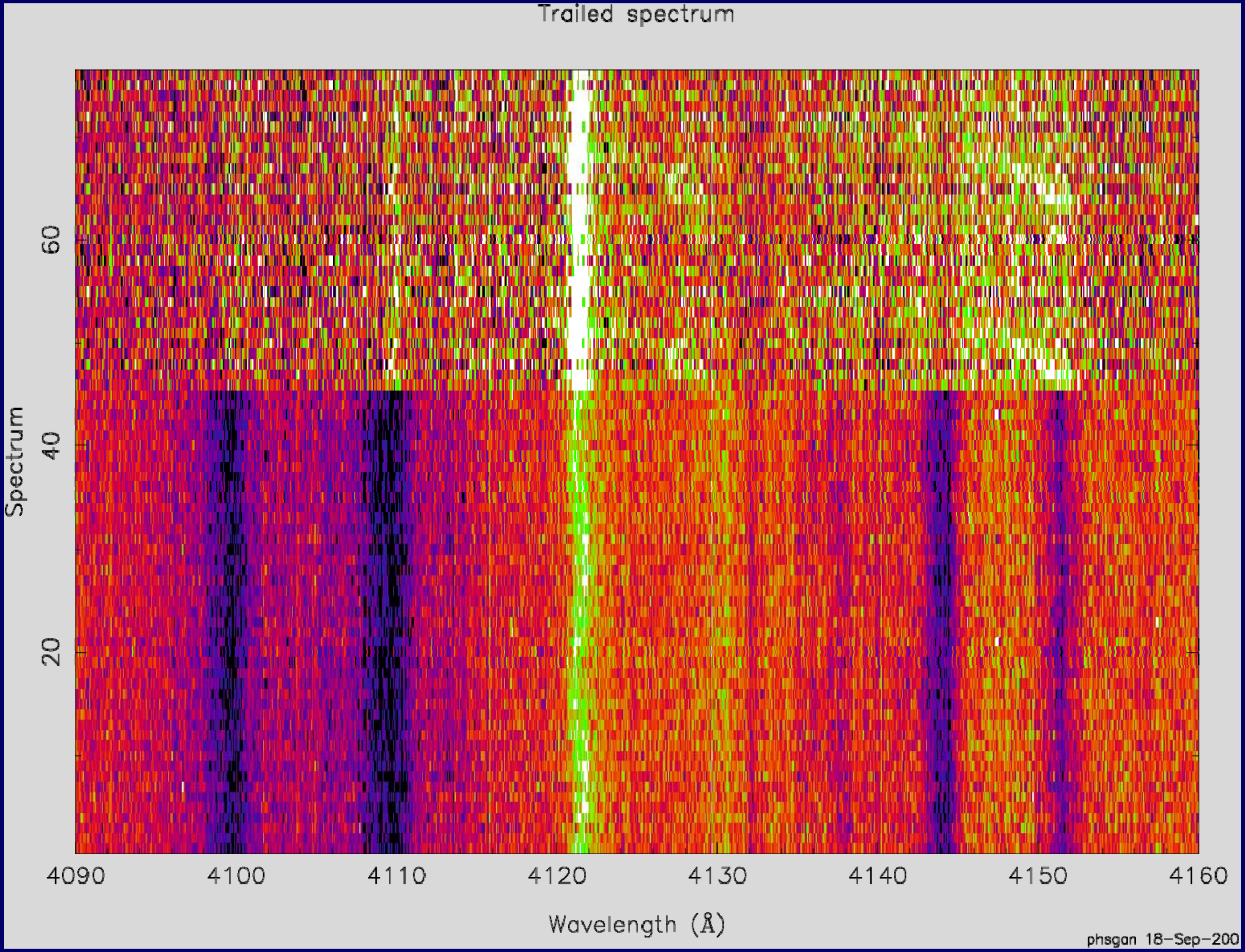
not sensitive to q ?

Roelofs et al. 2005

The (almost) twins GP Com & V396 Hya



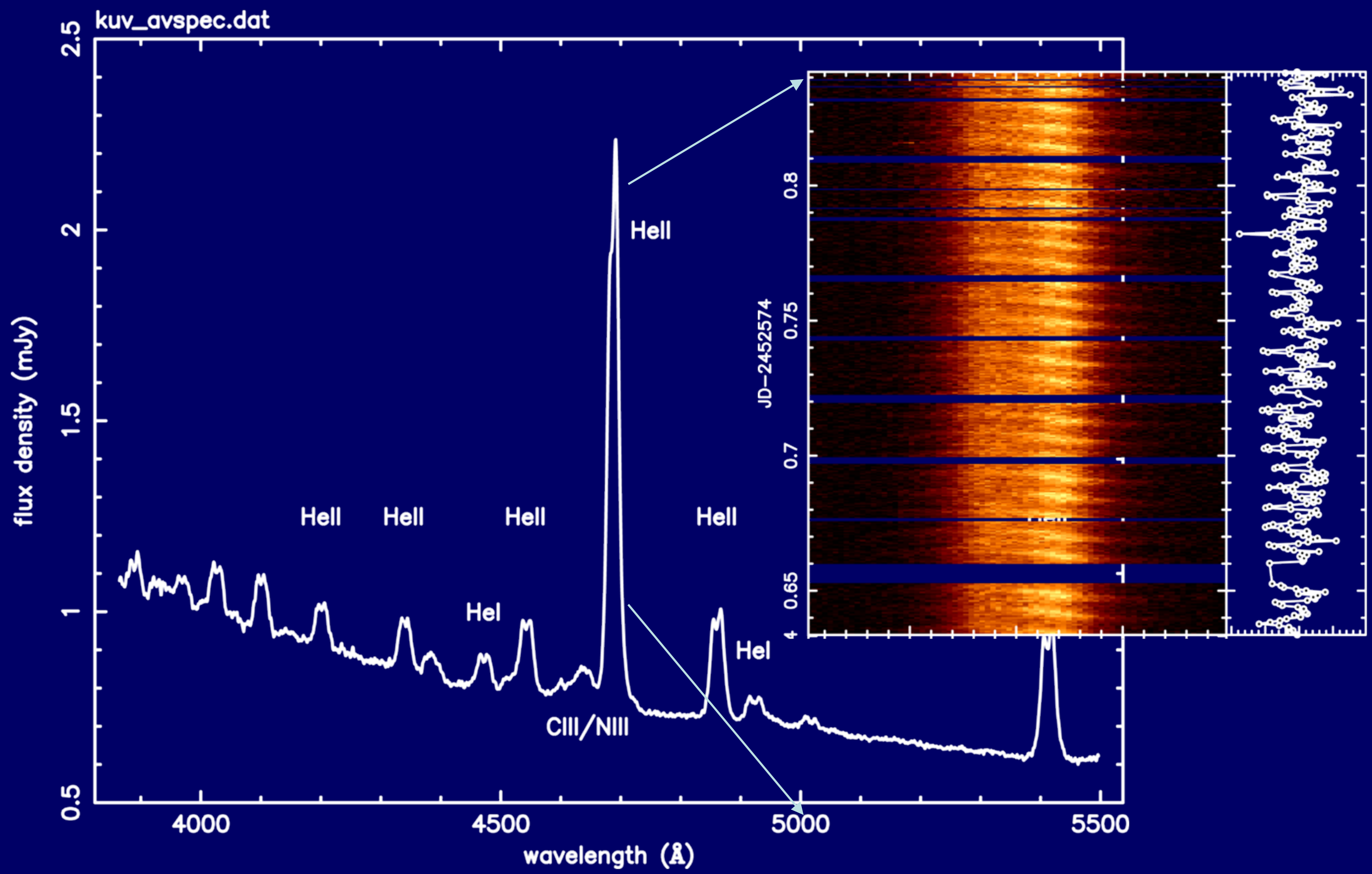
Non-moving absorption lines ; circum-binary ?



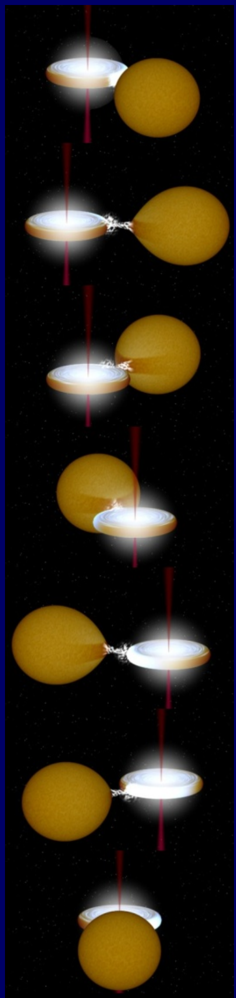
V396 Hya

GP Com

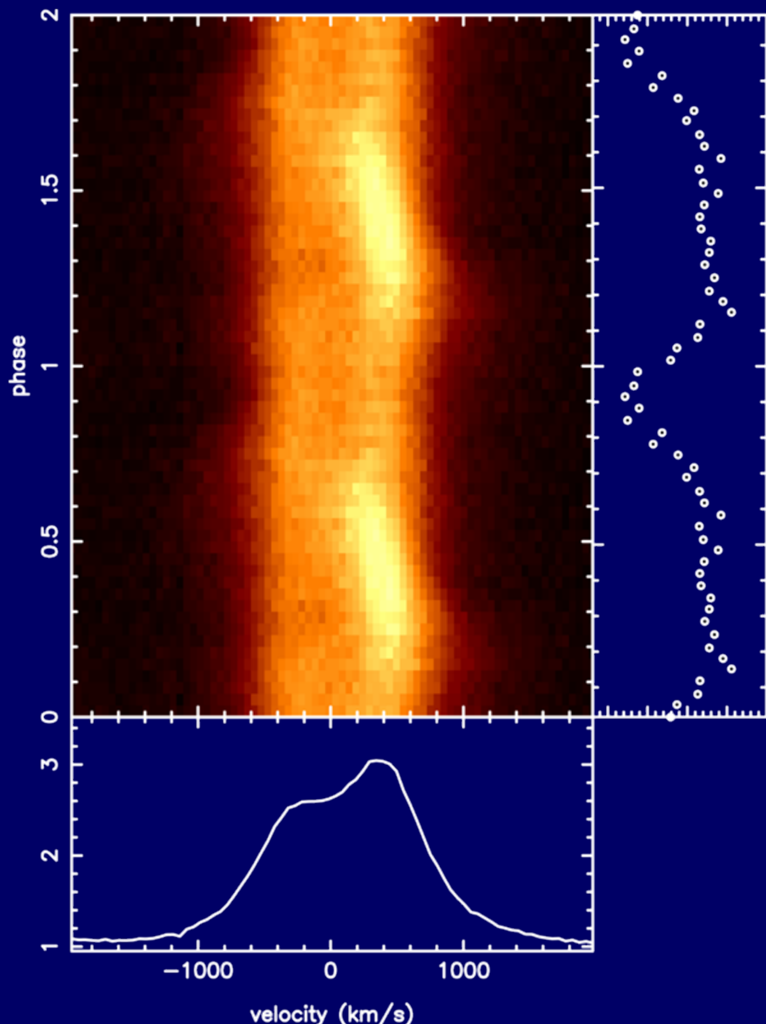
ES Ceti with Magellan



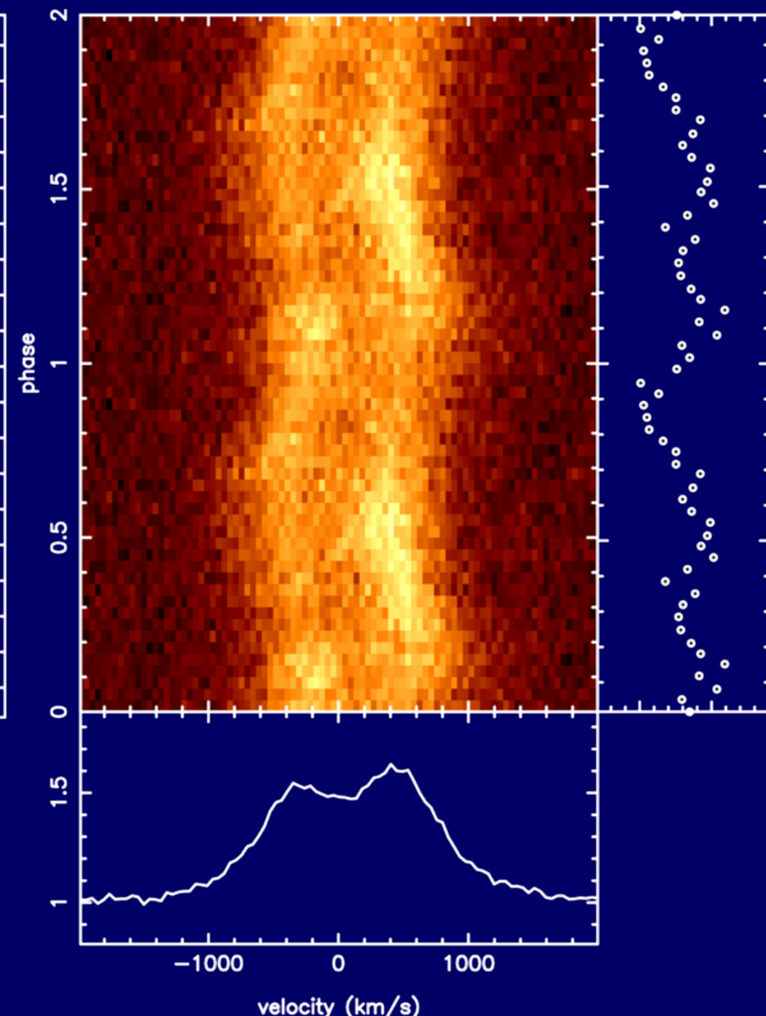
ES Cet at 10.3 mins



HeII 4686



HeII 5411



No measurable polarisation (<0.1%) argues against a magnetically channeled flow

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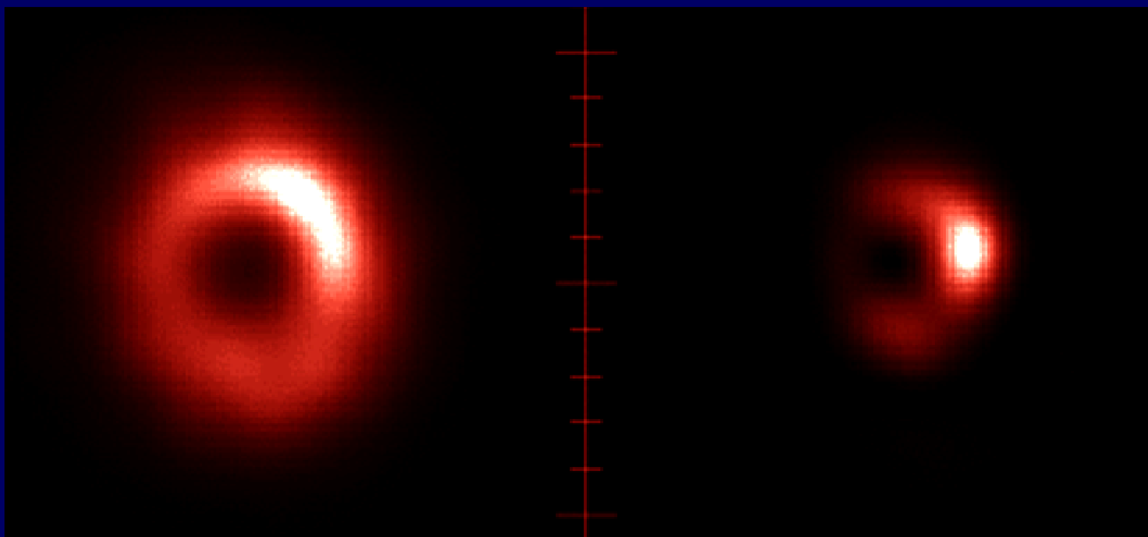
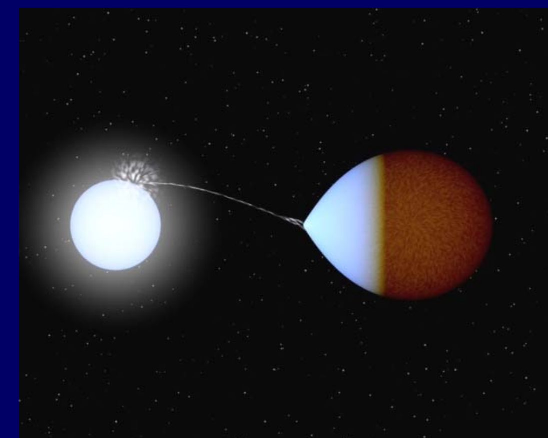
The accretion geometry

constant variable





A disk is present, though containing a strong asymmetry, most likely the stream-disk interaction

No classic direct-impact, but how far does the stream penetrate?

Strong orbital modulations in the UV (HST/XMM)

Conclusions and outlook

- Jan-Erik's Question : What do AM CVns look like?

  emission lines can tell us what the accretion flow looks like

- Disk-stream hot spots are beacons for reliable orbital periods through fast spectroscopy

- Disk dynamics ; precession , direct-impact, double spots

- Spikes from the accretor
  - Kinematics of the white dwarf (K1), Stark effect
  - Spike + hot-spot provides a mass ratio
  - Slow rotation ?

- No sign of the donor stars so far
- Abundances could use some effort
- Comparison with atmosphere & SPH codes