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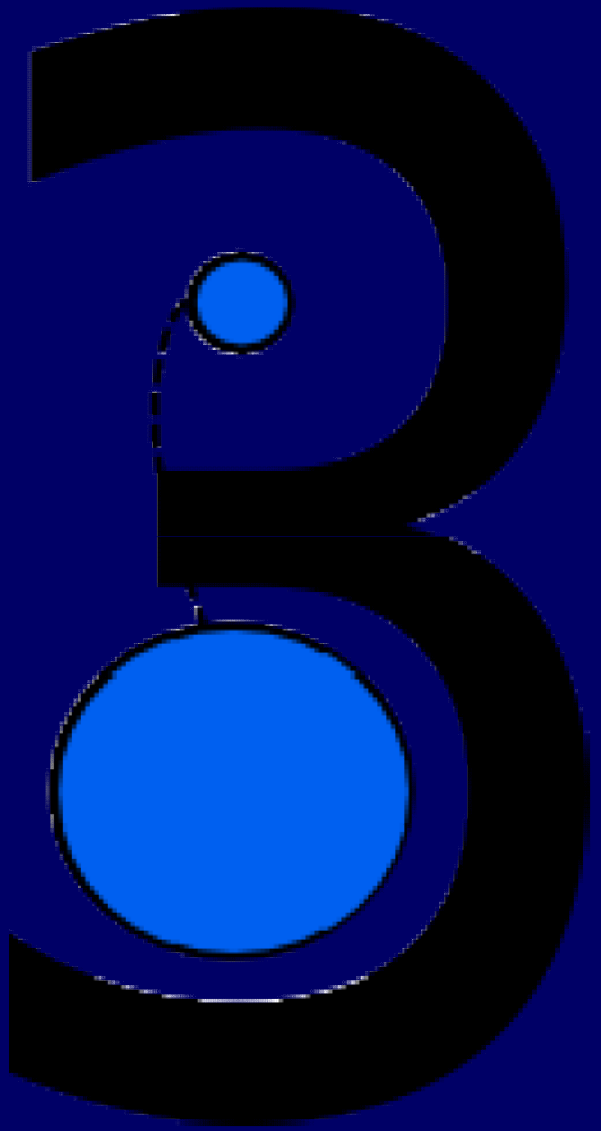
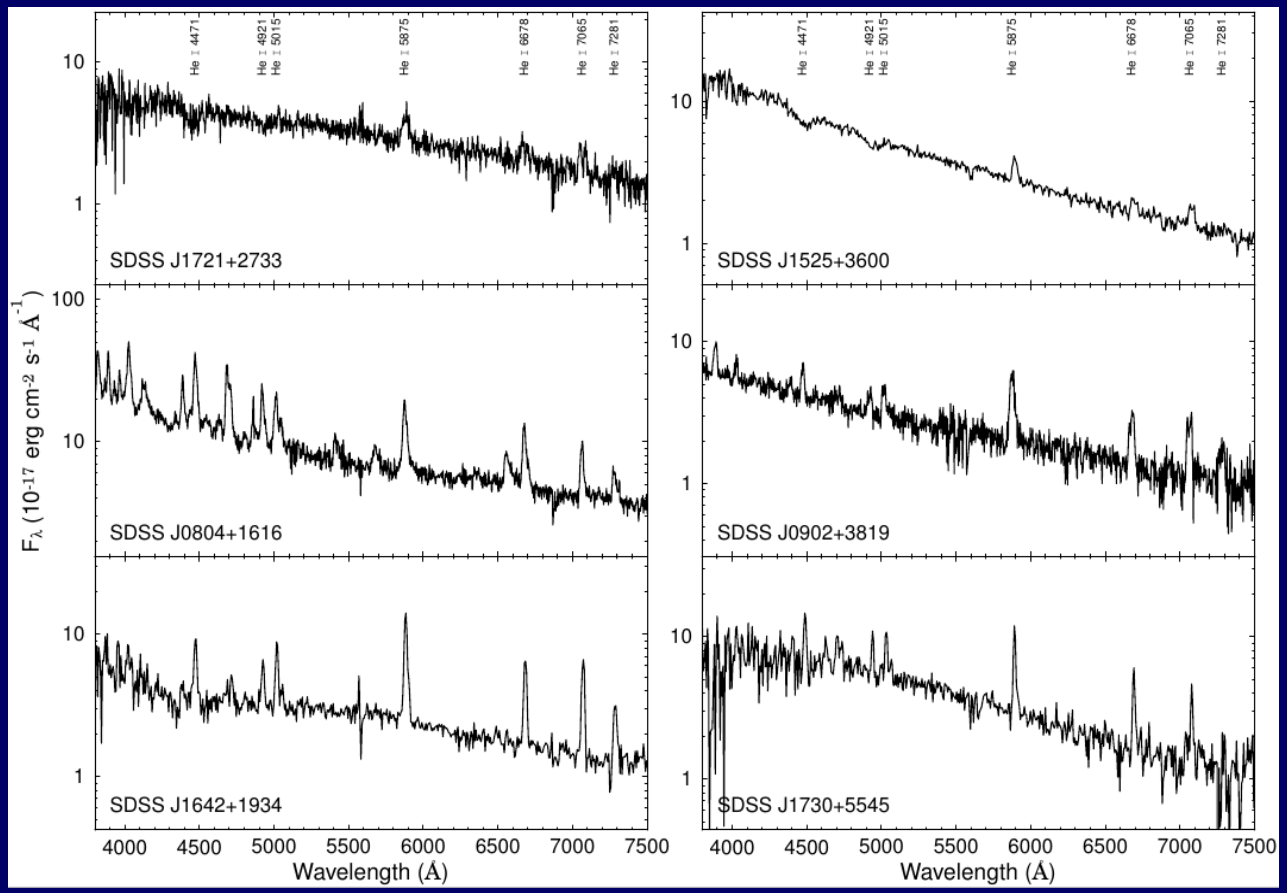
Spectroscopic diagnostics & MOA2010BLG-087

Danny Steeghs
University of Warwick

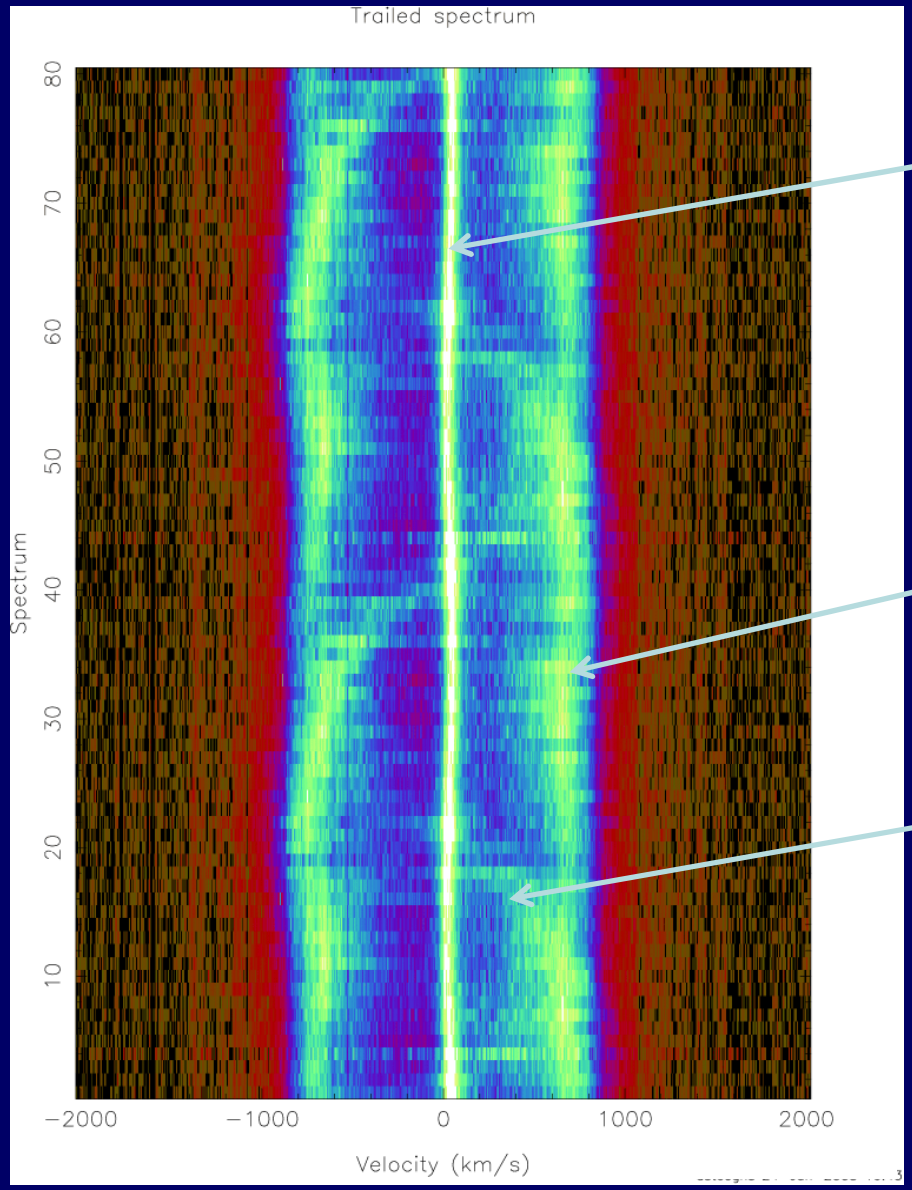


Spectroscopy of AM CVn stars



- emission lines key for discovery (e.g. SDSS sample)
- time-series spectroscopy favoured method for orbital periods
- accretion flow dynamics
- component masses
- abundances ; formation channels

Common components in the emission lines



accretor

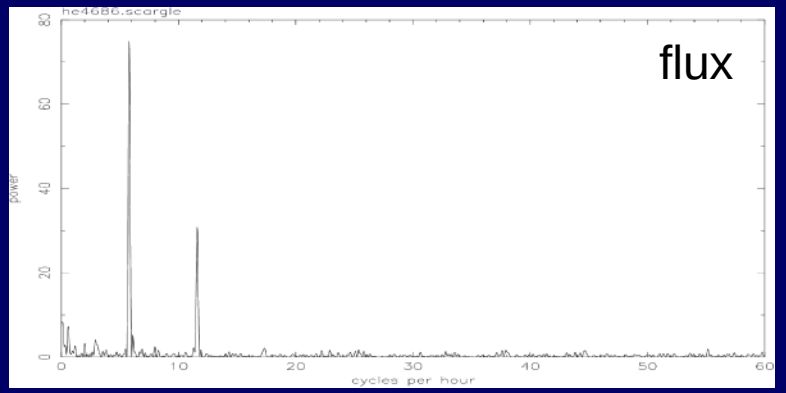
accretion disk

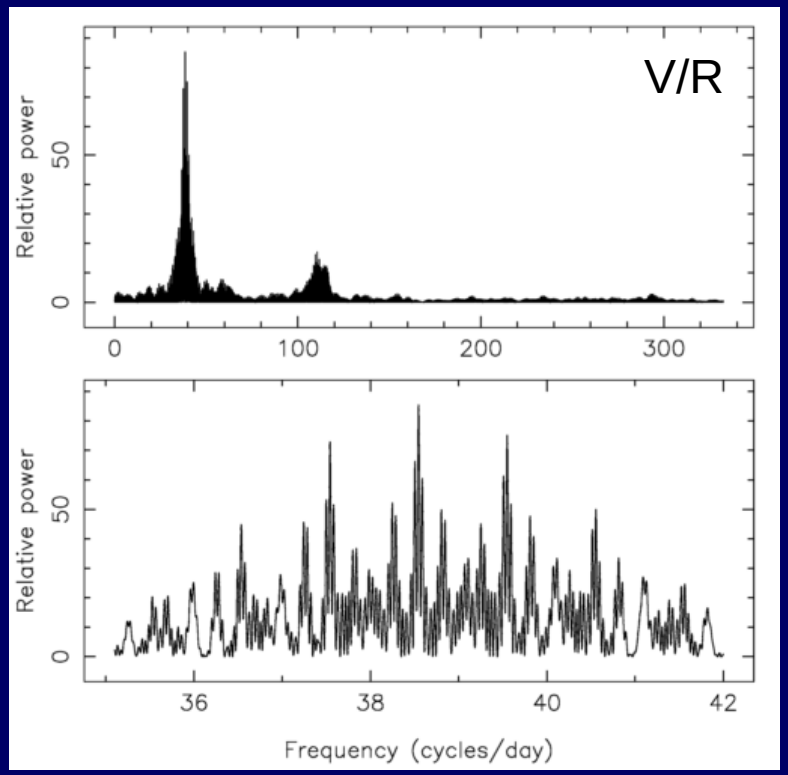
bright spot

Velocity modulations key for orbital periods

Bright-spot S-waves have proven to be present in almost all AM CVn systems, forming the basis of most orbital periods, particularly at longer periods

Period precision in principle a matter of time baseline just like in conventional radial velocity period searches (with the advantage of short cycle times)

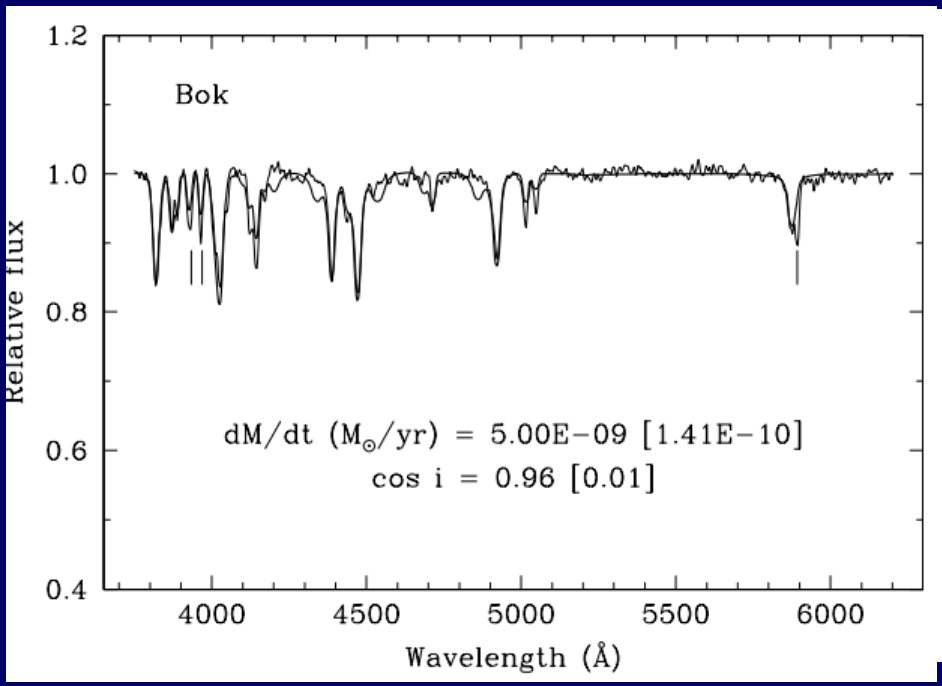


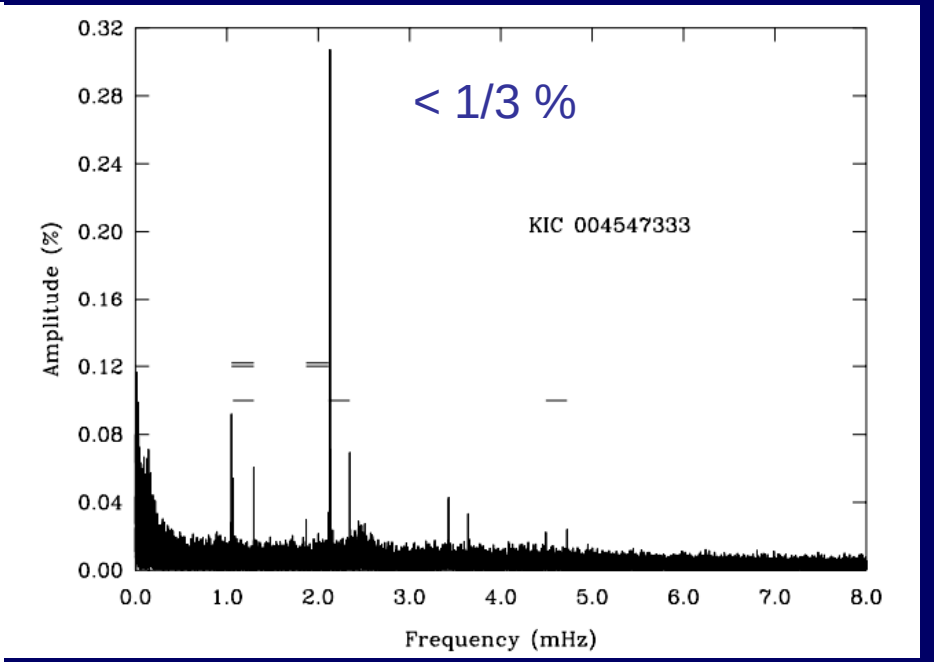


periodograms of emission line flux and velocity variations

But …

High-state systems very challenging ; spectral variability is weak, but also photometric variability is complex and can be weak

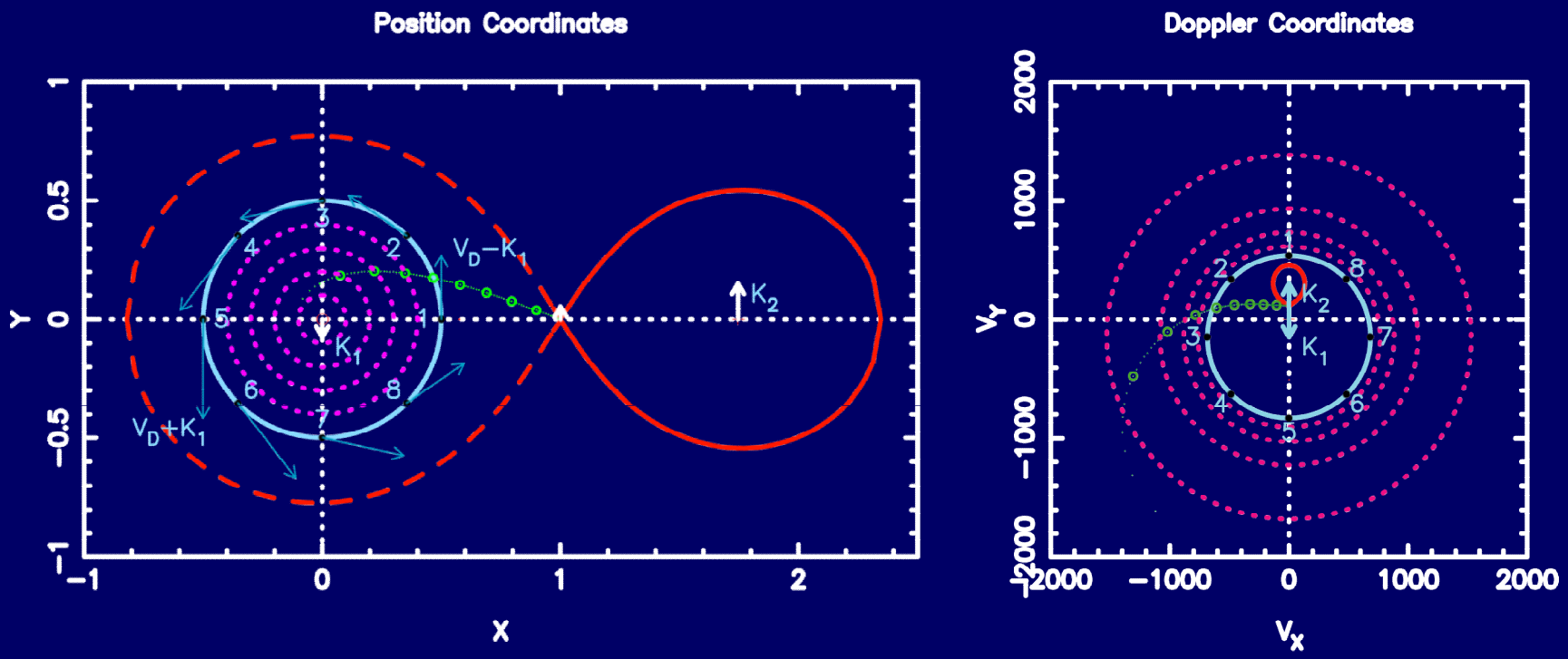




Kepler AM CVn (Fontaine et al 2011)

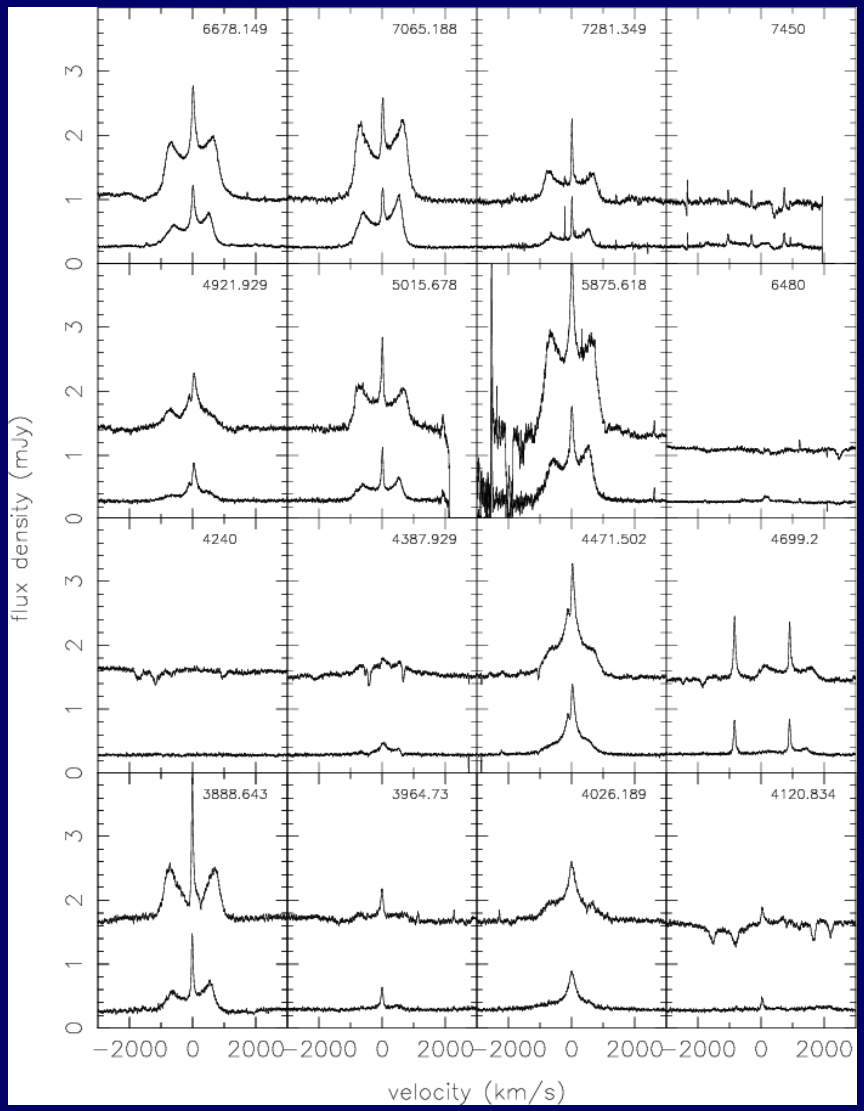
[see also Kupfer's talk]

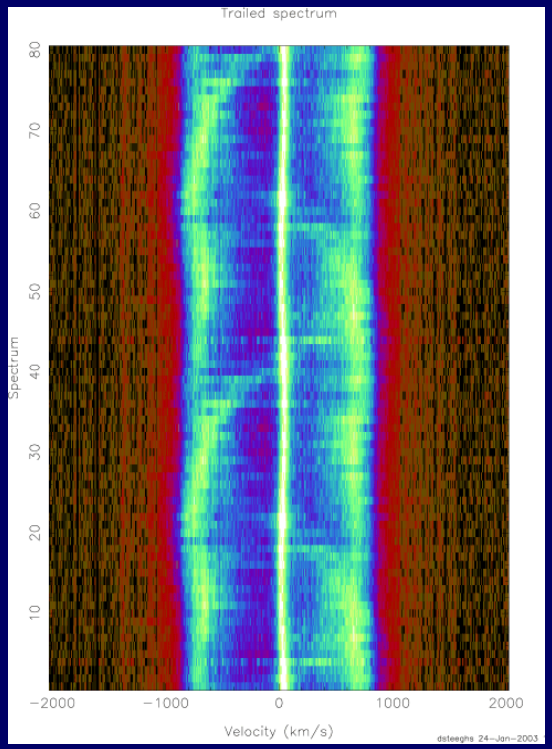
Key locations and Doppler maps

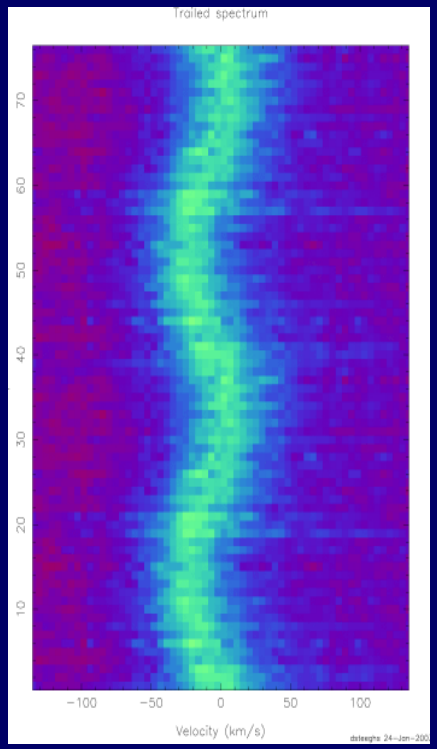


- Donor star (can measure/constrain K_2 and absolute phase)
- Accretor (gives us K_1 and phase)
- Accretion stream (sensitive to mass ratio $q=M_2/M_1$)
- Accretion disk (radial emissivity profile / asymmetries)
- Stream-disk interaction (bright spot(s) sensitive to q)
- Stream-accretor interaction (direct impact)

Common traits ; central spikes







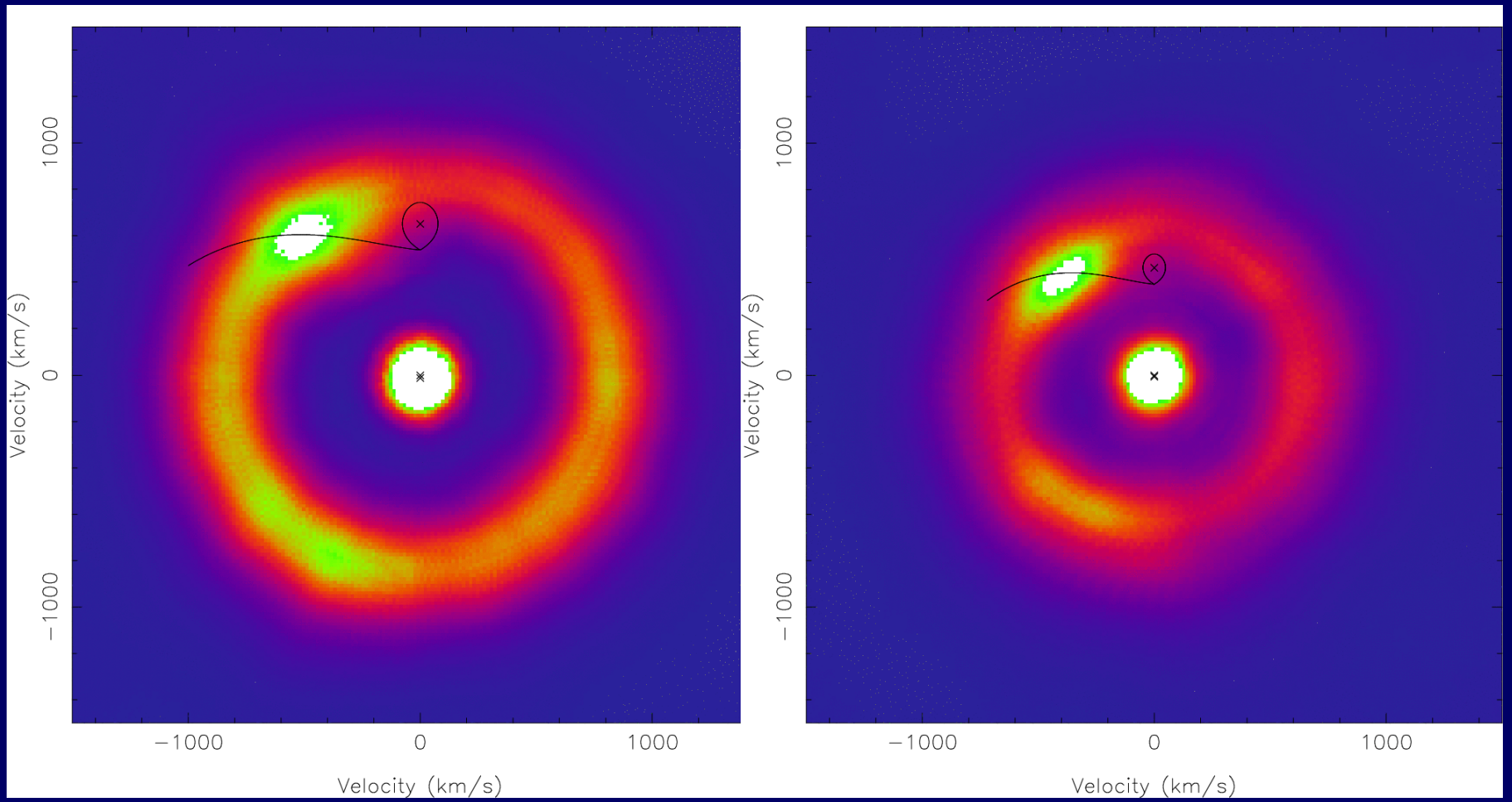
- Spikes are narrow (60-90 km/s)
- Move in phase with white dwarf (K~12 km/s)
- Exhibit Stark components indicative of high n_e (3 10^{15} cm^{-3})
- Could deliver redshift-based mass if we know systemic component

GP Com / V396 Hya

Doppler maps

GP Com HeI 3888

V396 HeI 5015

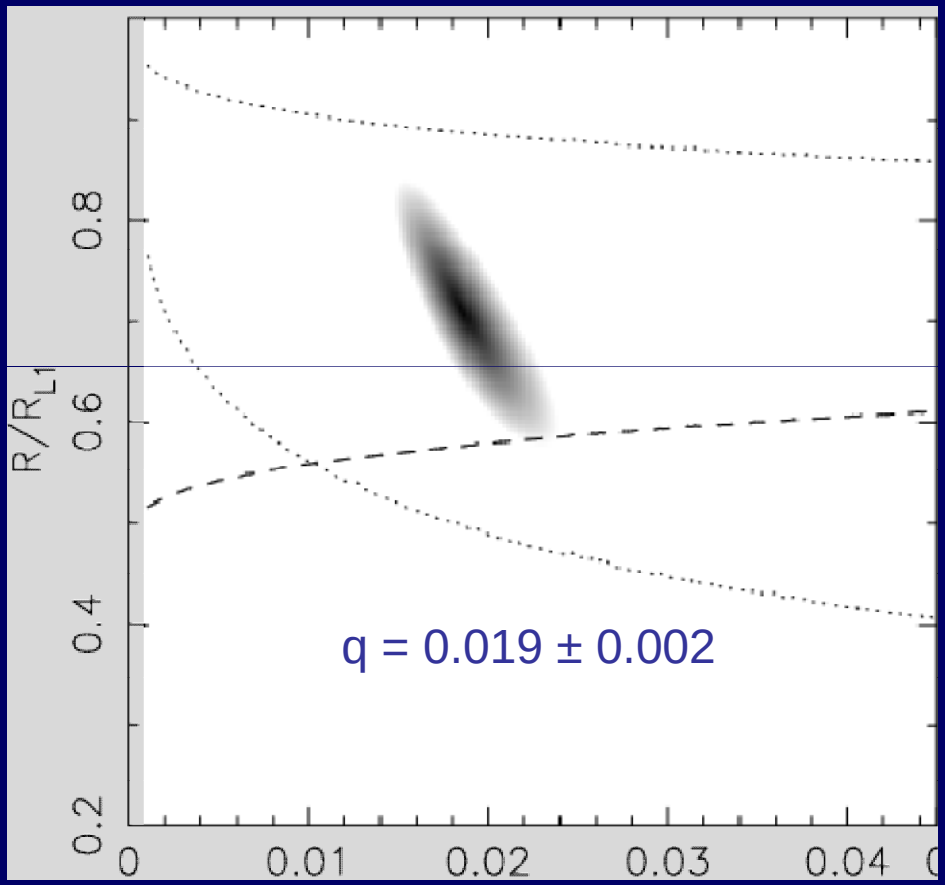


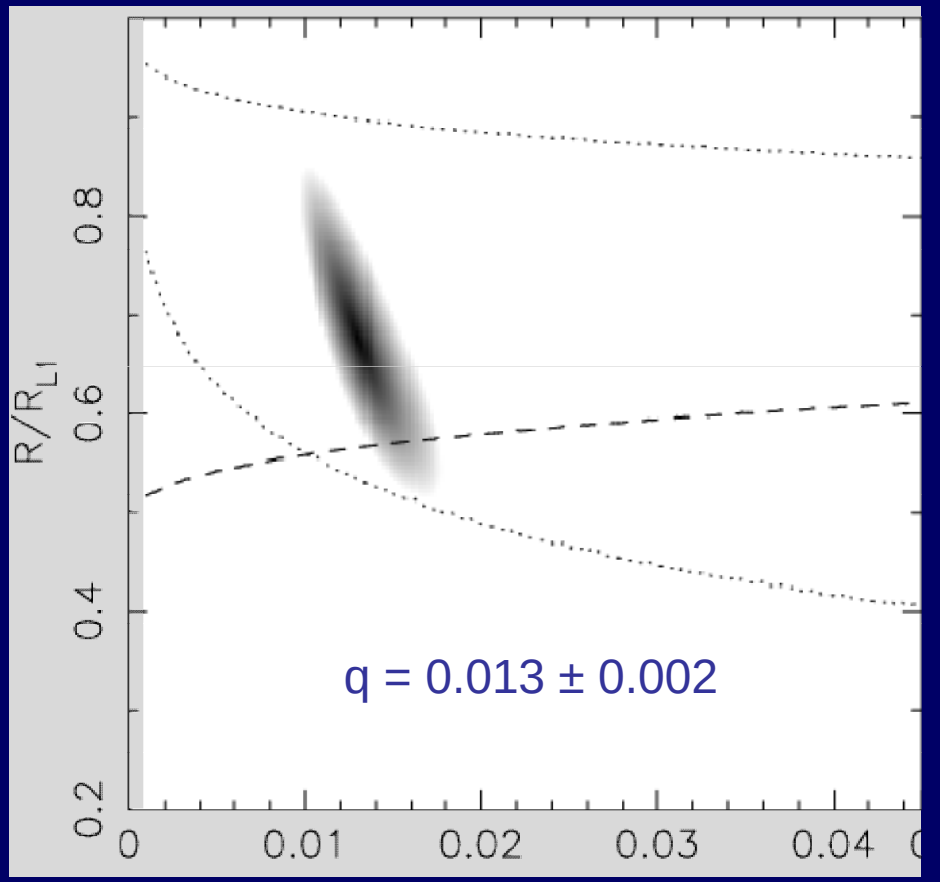
Steeghs et al. (2018)

Mass ratios from disk-stream impact

GP Com

V396 Hya





q=M2/M1

q

[this needs an absolute phase via spike]

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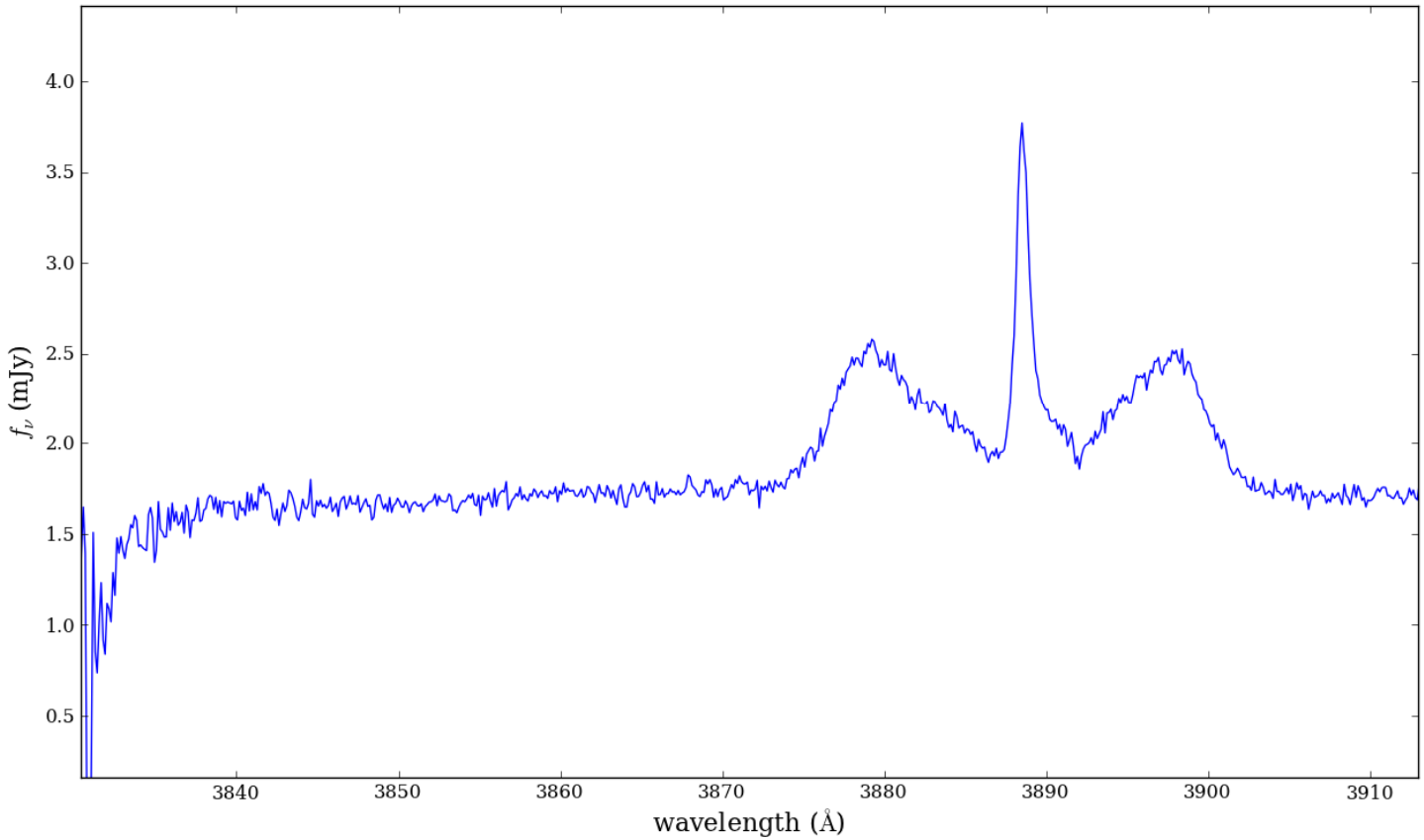
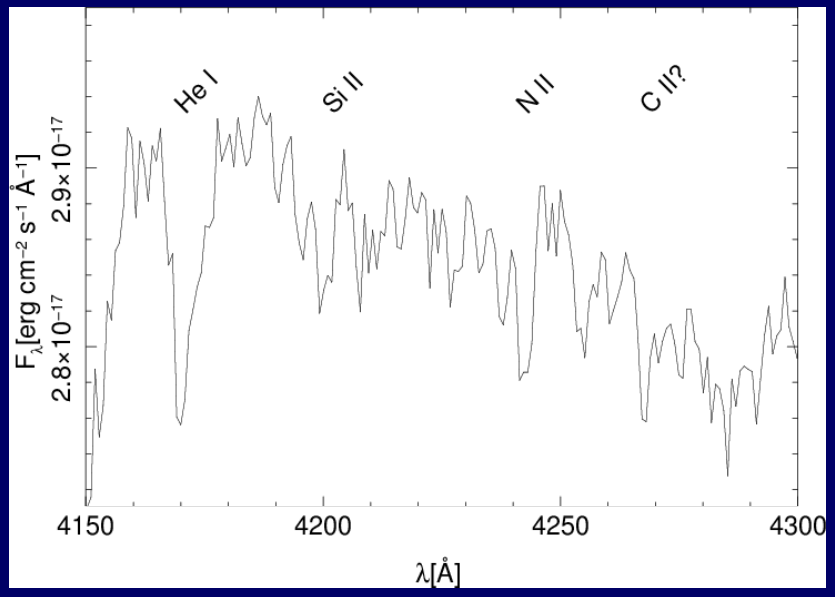
Mg/Ca anomaly in GP Com?

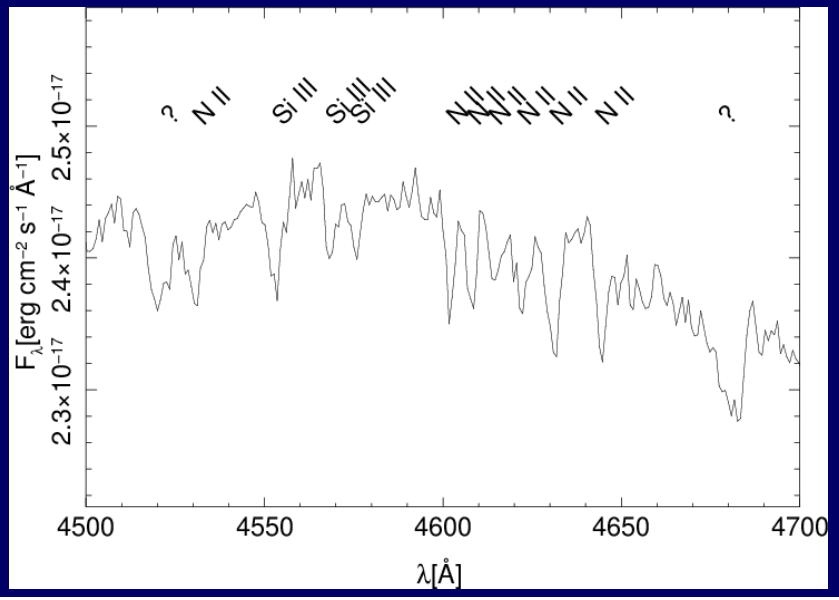


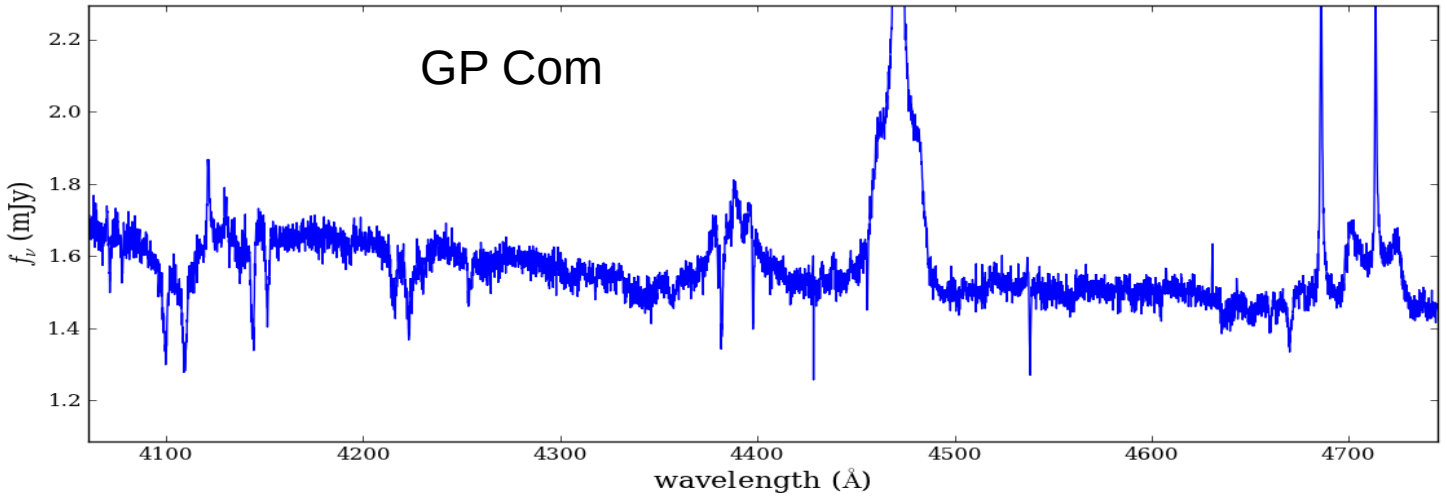
Just outside CCD coverage….

Absorption lines

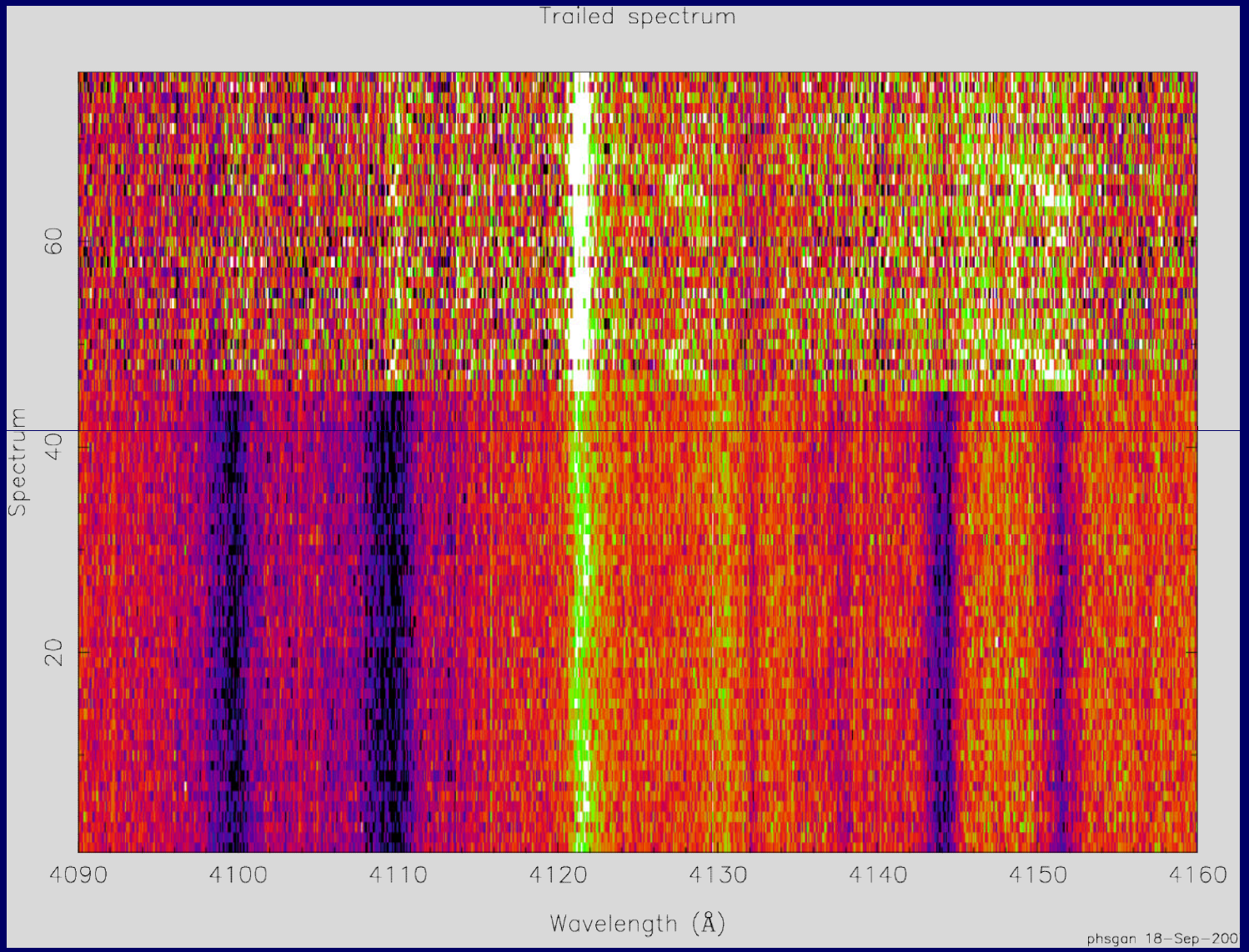
SDSSJ1908+3940 (Kupfer)







Absorption lines ; resolved and do not move



V396 Hya

GP Com

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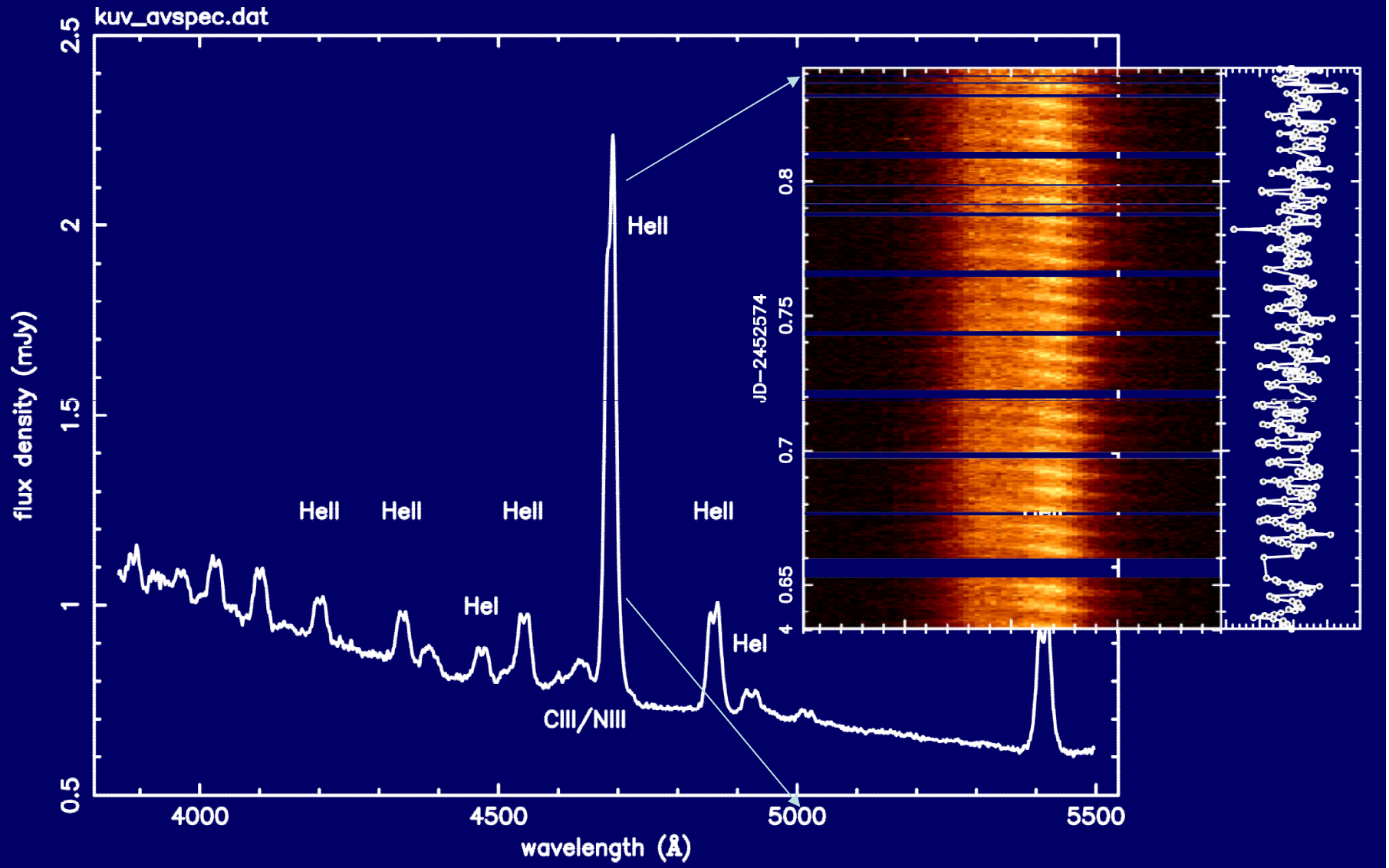
ES Cet



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ES Cet – orbit to orbit variability

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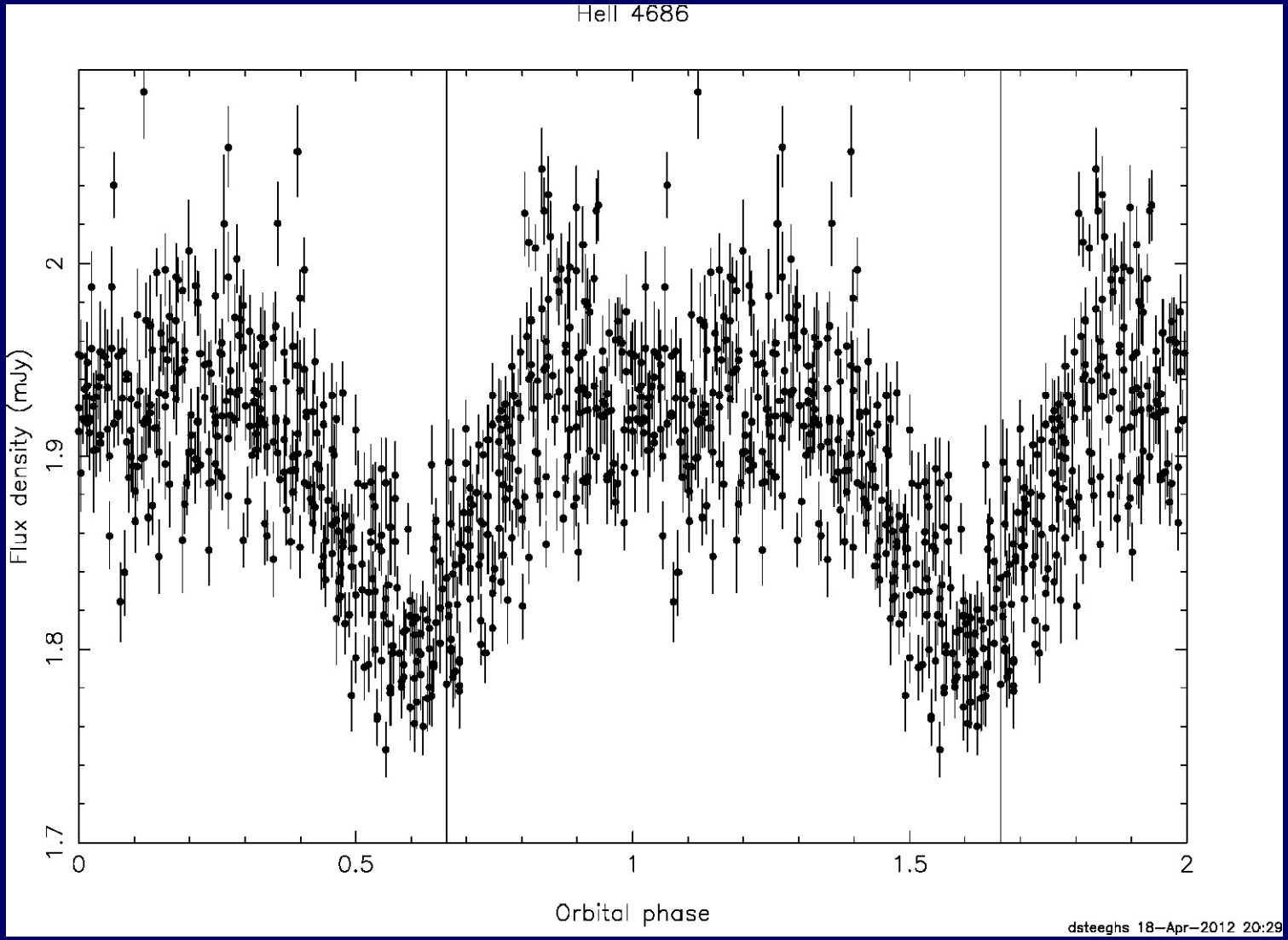
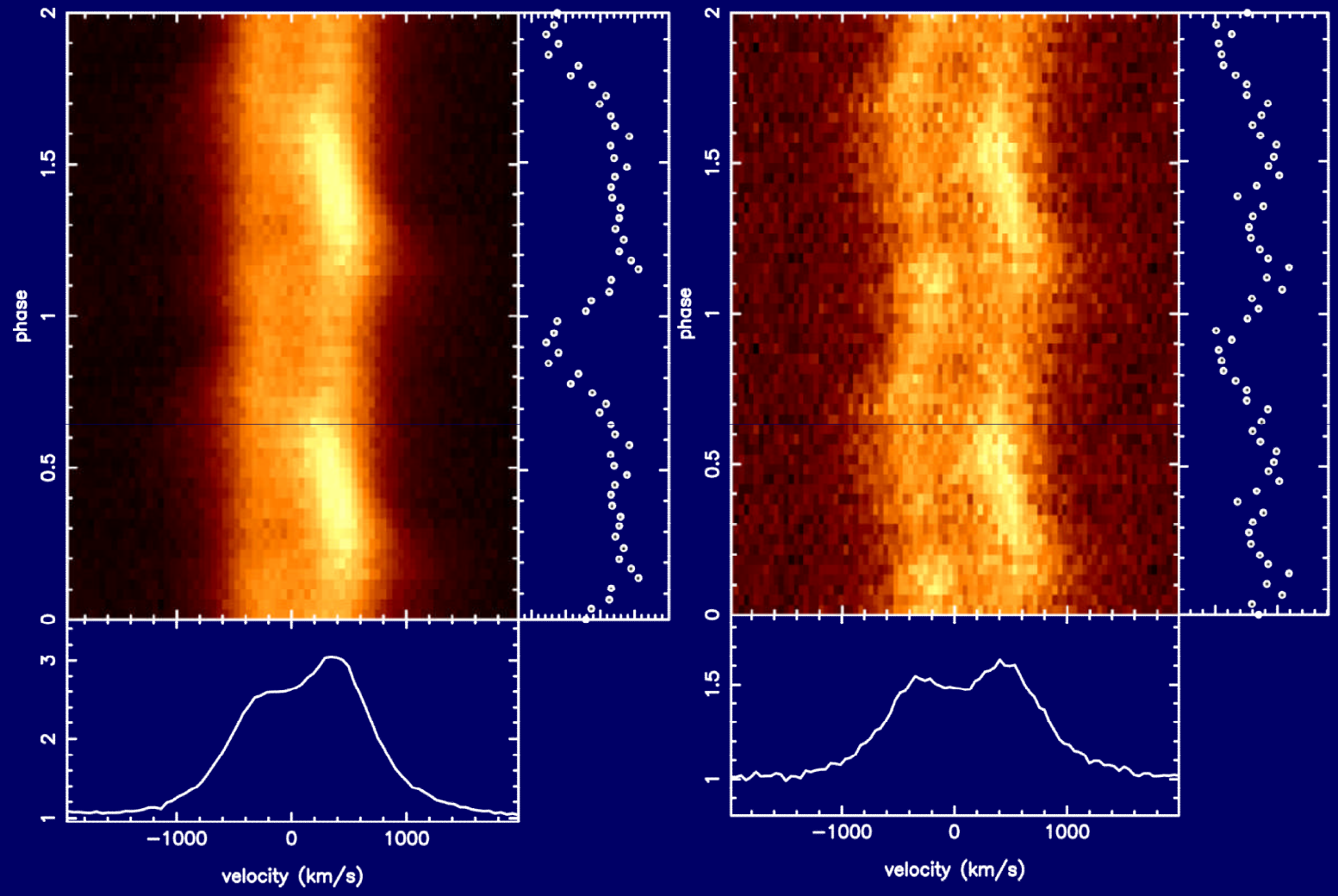
He II 4686



ES Cet : phase-binned

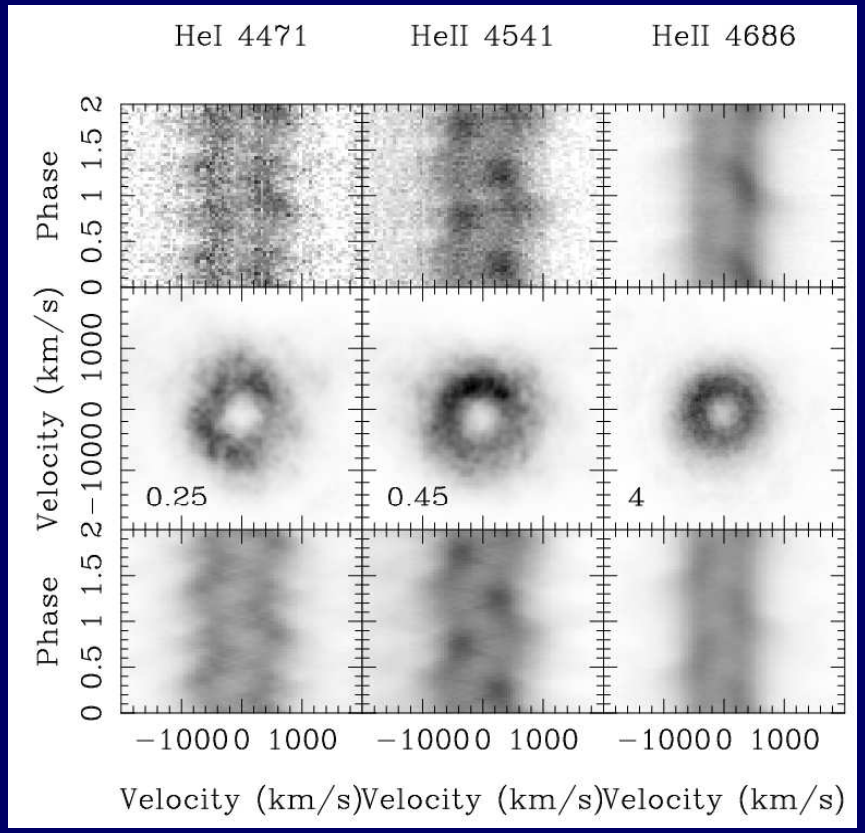
HeII 4686

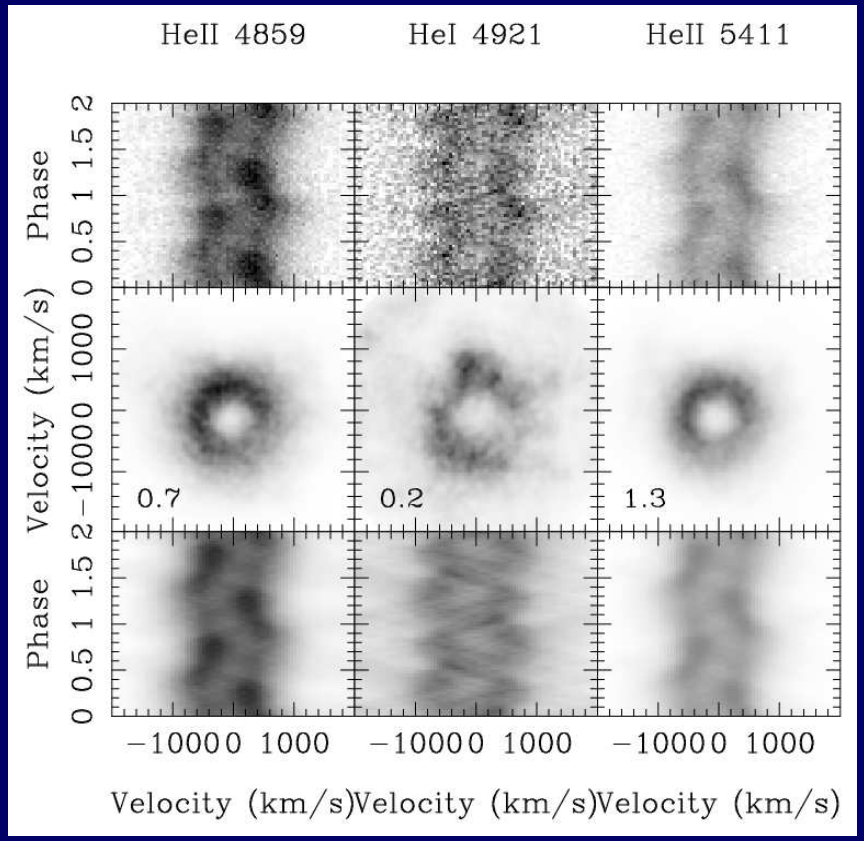
HeII 5411



double peaks (disk/belt) and disc asymmetries

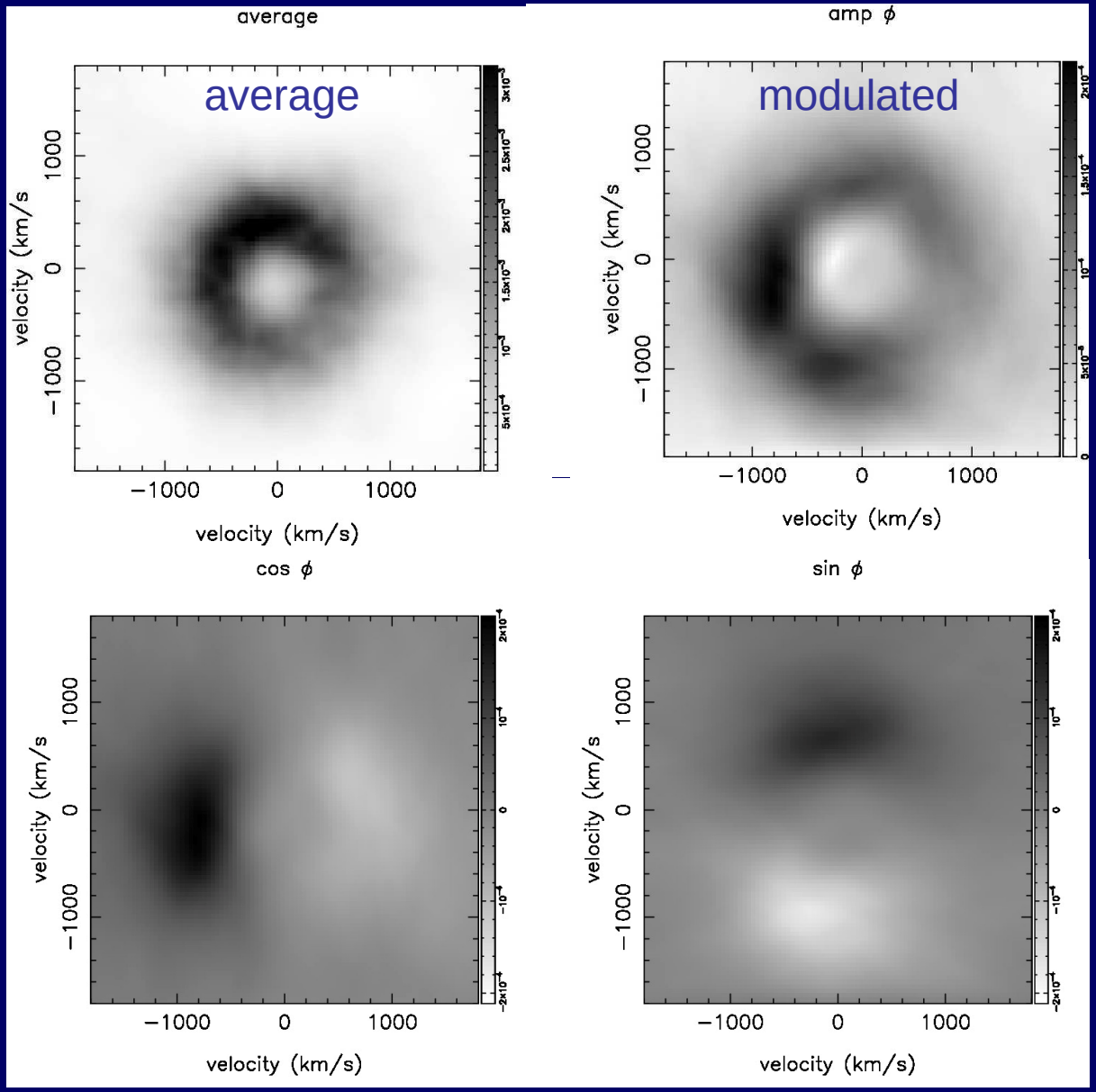
ES Cet maps



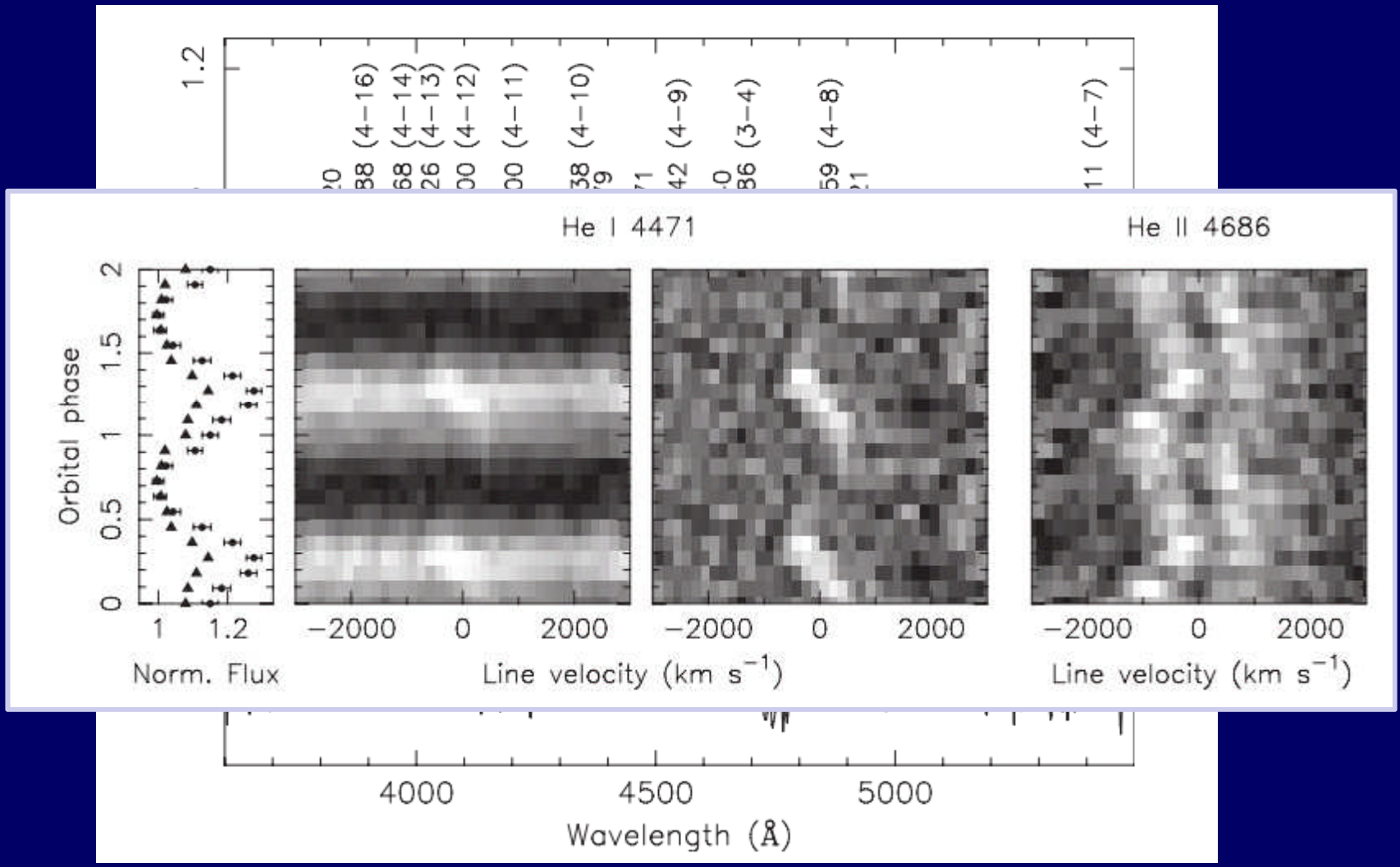


rather disk-like, no traditional stream/hot spot signature?

Allowing modulated component



HM Cnc



Roelofs et al. (2010)

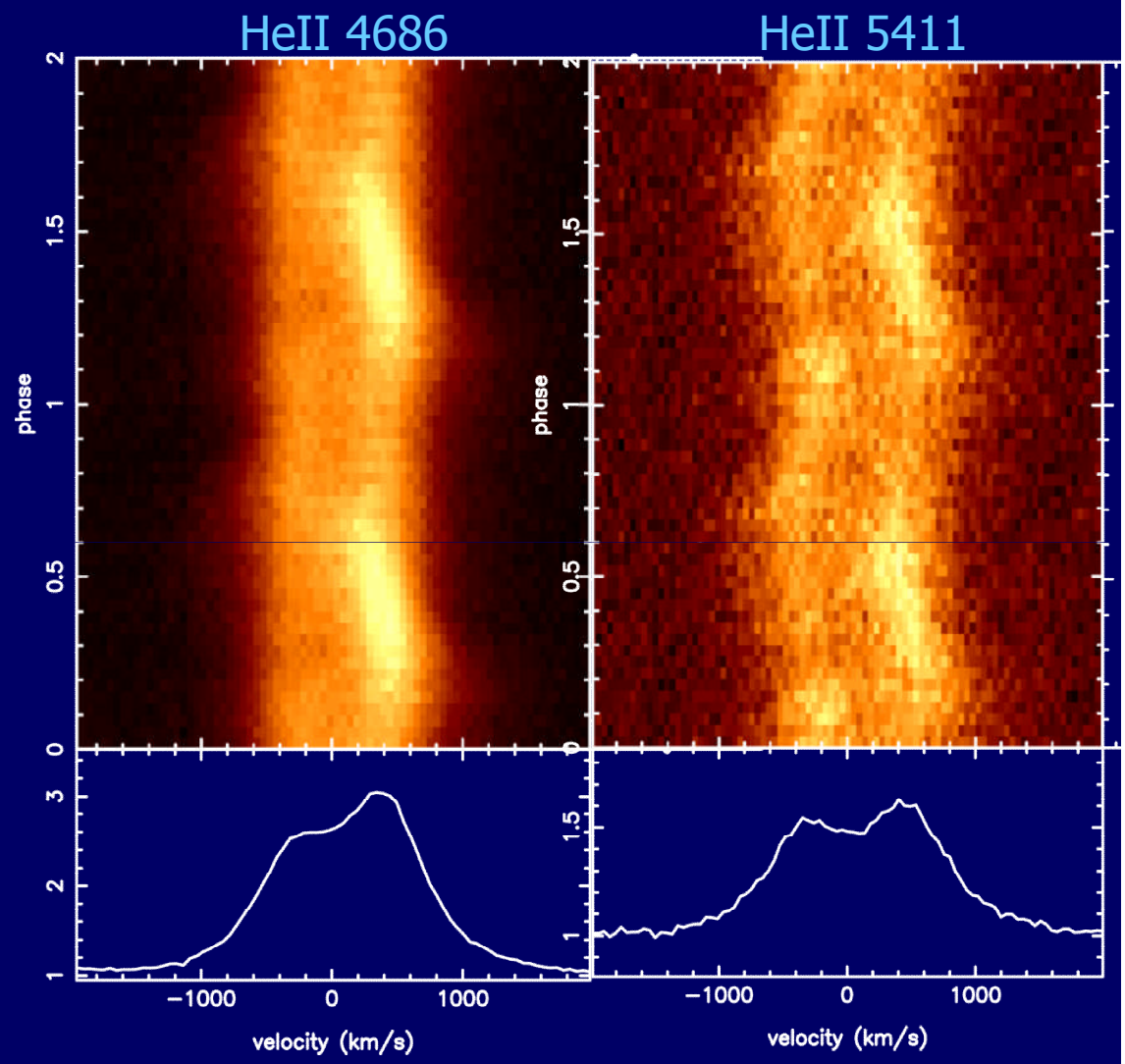
Component masses / direct impact ?

ES Cet/ HM Cnc:

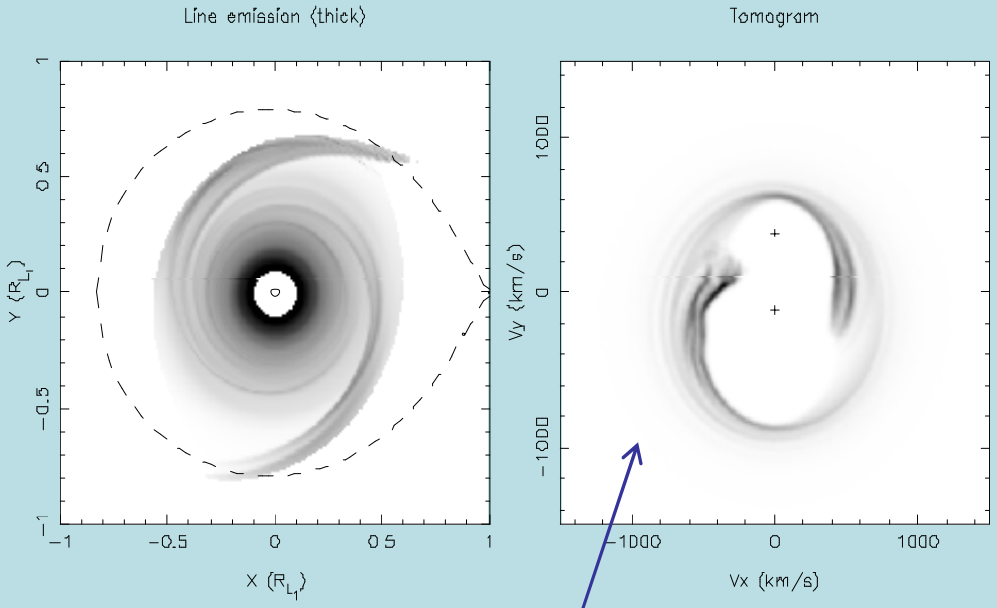
Peculiar emission line dynamics makes inferring mass constraints from accretion dynamics less straightforward

Can we model this?

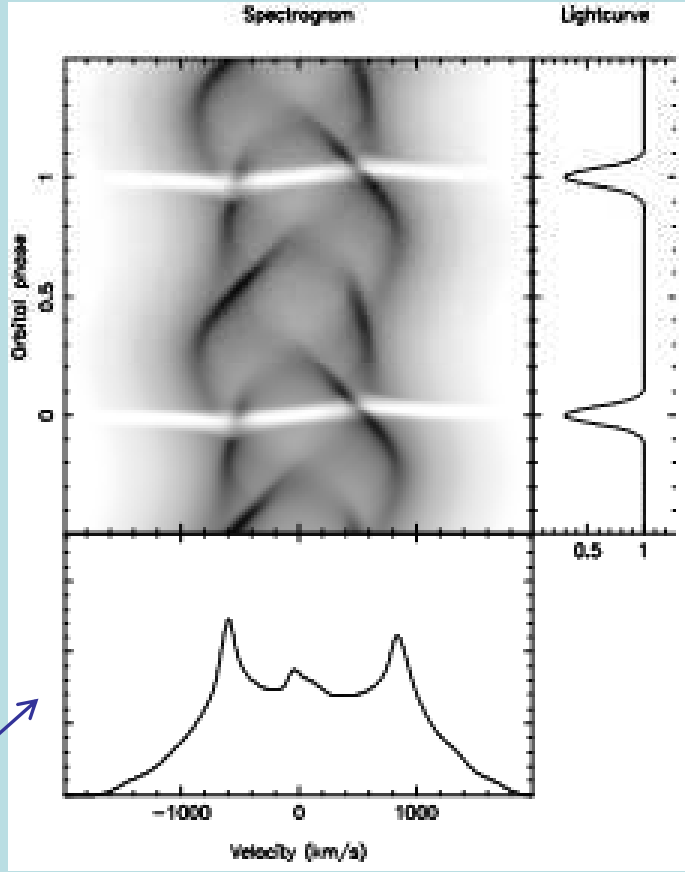
Does this suggest direct-impact site is not a significant contributor?



Models in velocity/data space



Model mapped to v-space



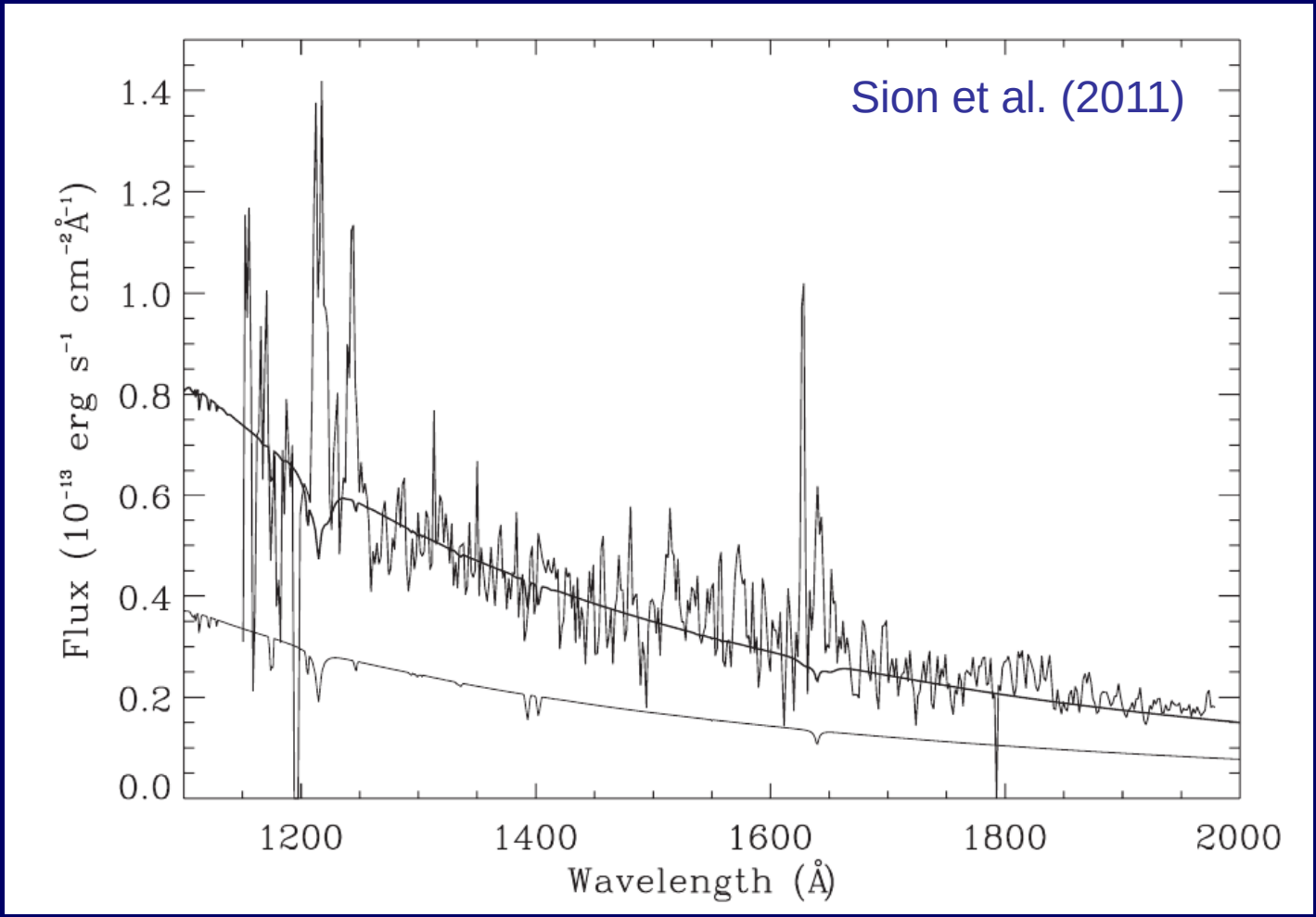
Model converted into data space

Multi-line modeling

Multi-line Doppler maps can in principle isolate regions within the accretion flow, avoiding some of the complications of needing to fit the whole line profiles at once?

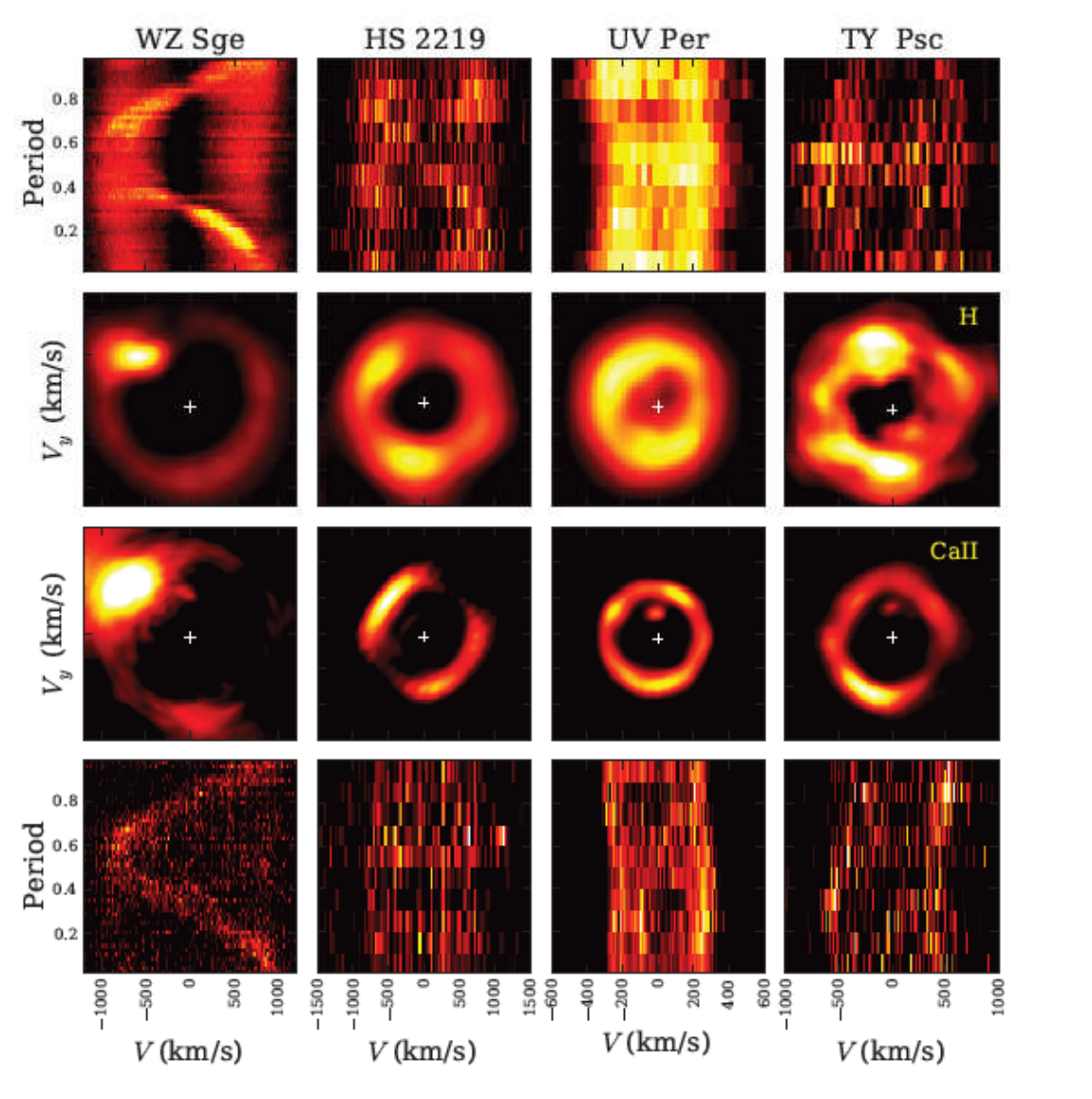
false-colour ratio map of GP Com

The accretor ; UV spectroscopy



Accretor a strong/dominant contributor but need reliable WD + disk models and good UV spectra

Mass donors



So far little sign of irradiated donors in AM CVn Doppler maps

Ca II triplet reveals feeble mass donor star in evolved CVs

Should/can we probe other lines?

L. van Spaandonk's PhD thesis

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Challenges / opportunities

- Double bright-spots
- Disk/belt stream modelling in short period systems
- High-state systems
- Exploit (multi)line diagnostics ; abundances
- Metal lines
- Are the spikes dynamically reliable to provide K_WD and vsini?
- Non-orbital variability
- Donor stars
- UV spectroscopy (vsini from photospheric lines)
- Fainter samples; tensioning accuracy against pushing for larger samples
- Spectroscopy versus photometry

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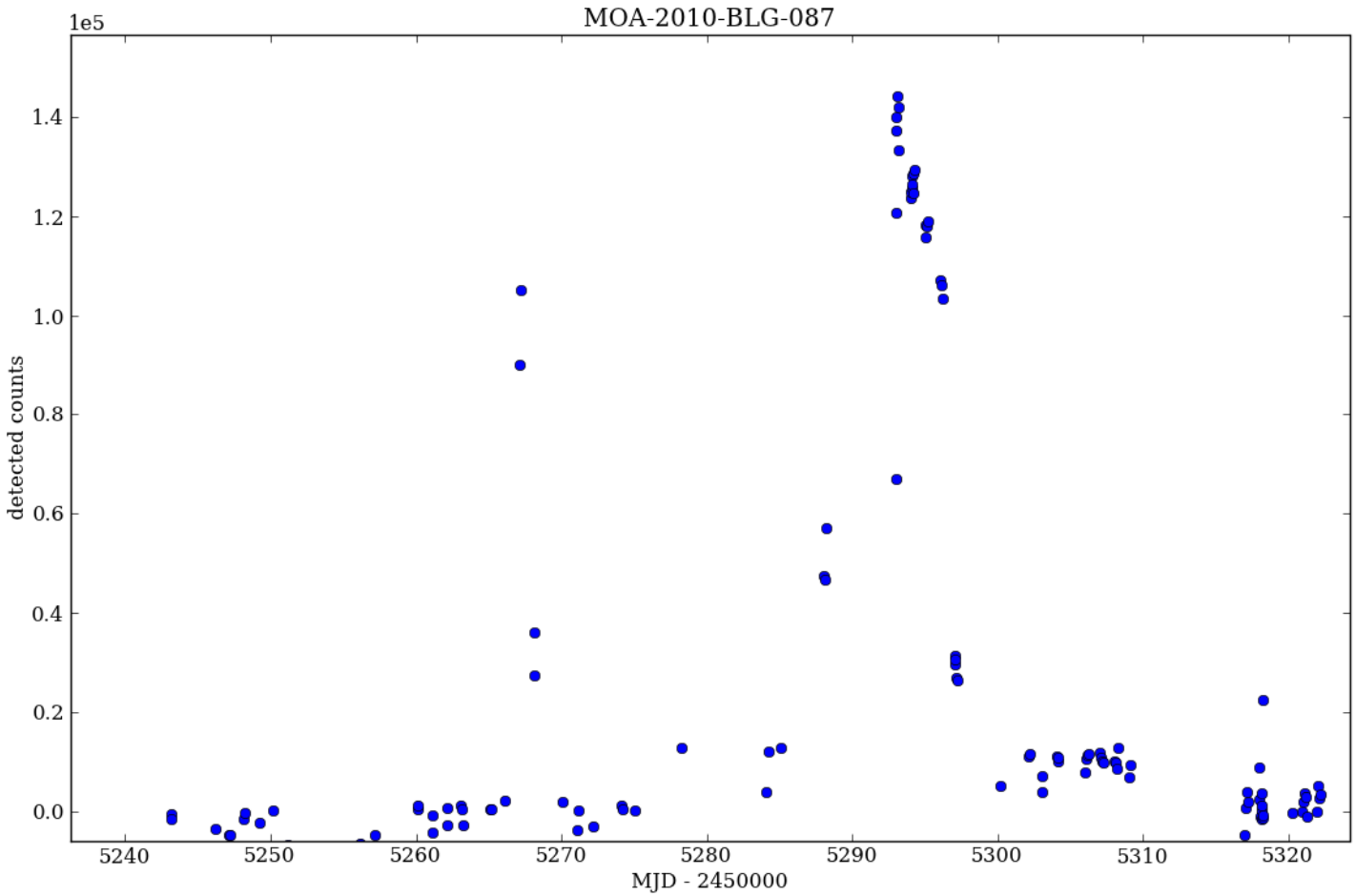
March 2010: microlens alert in galactic bulge



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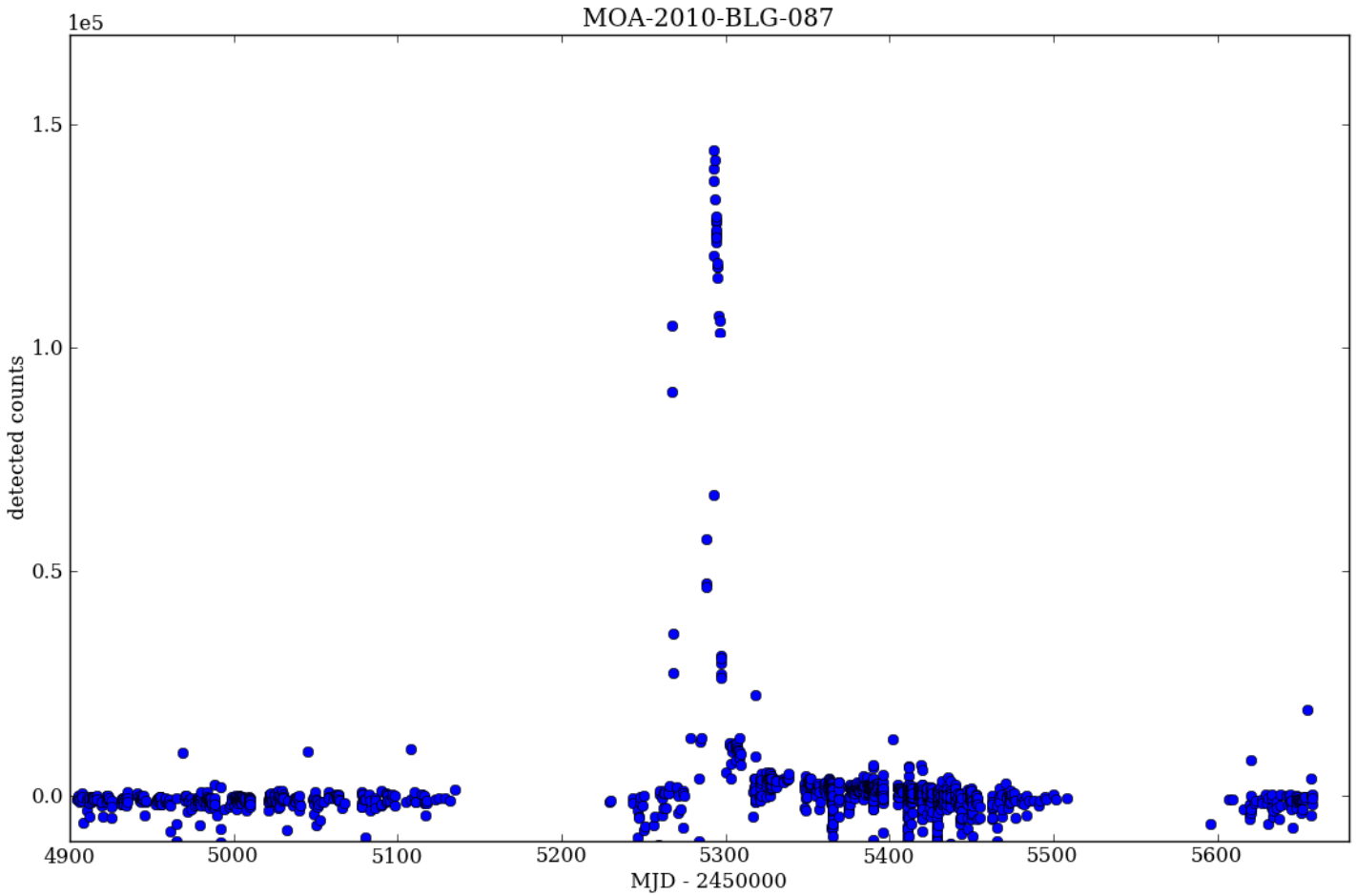
long term light-curve



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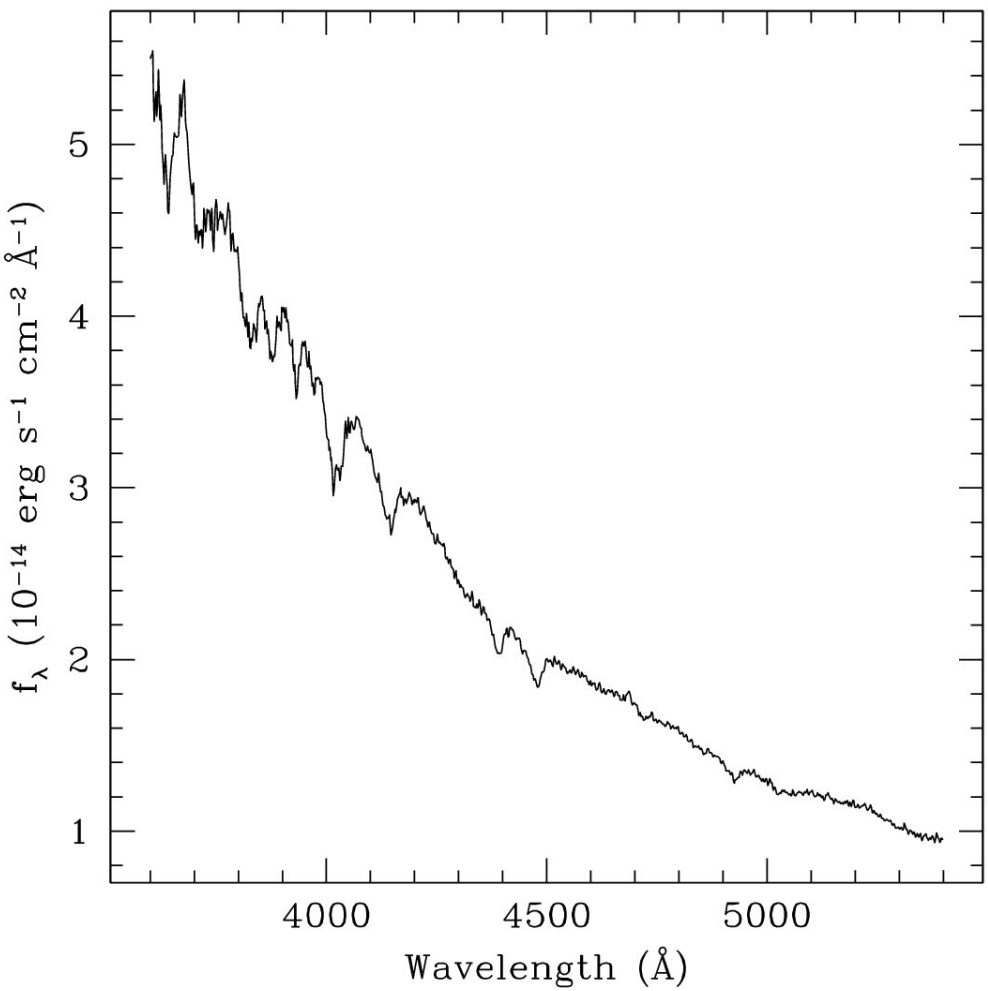
Outburst spectrum : its an AM CVn



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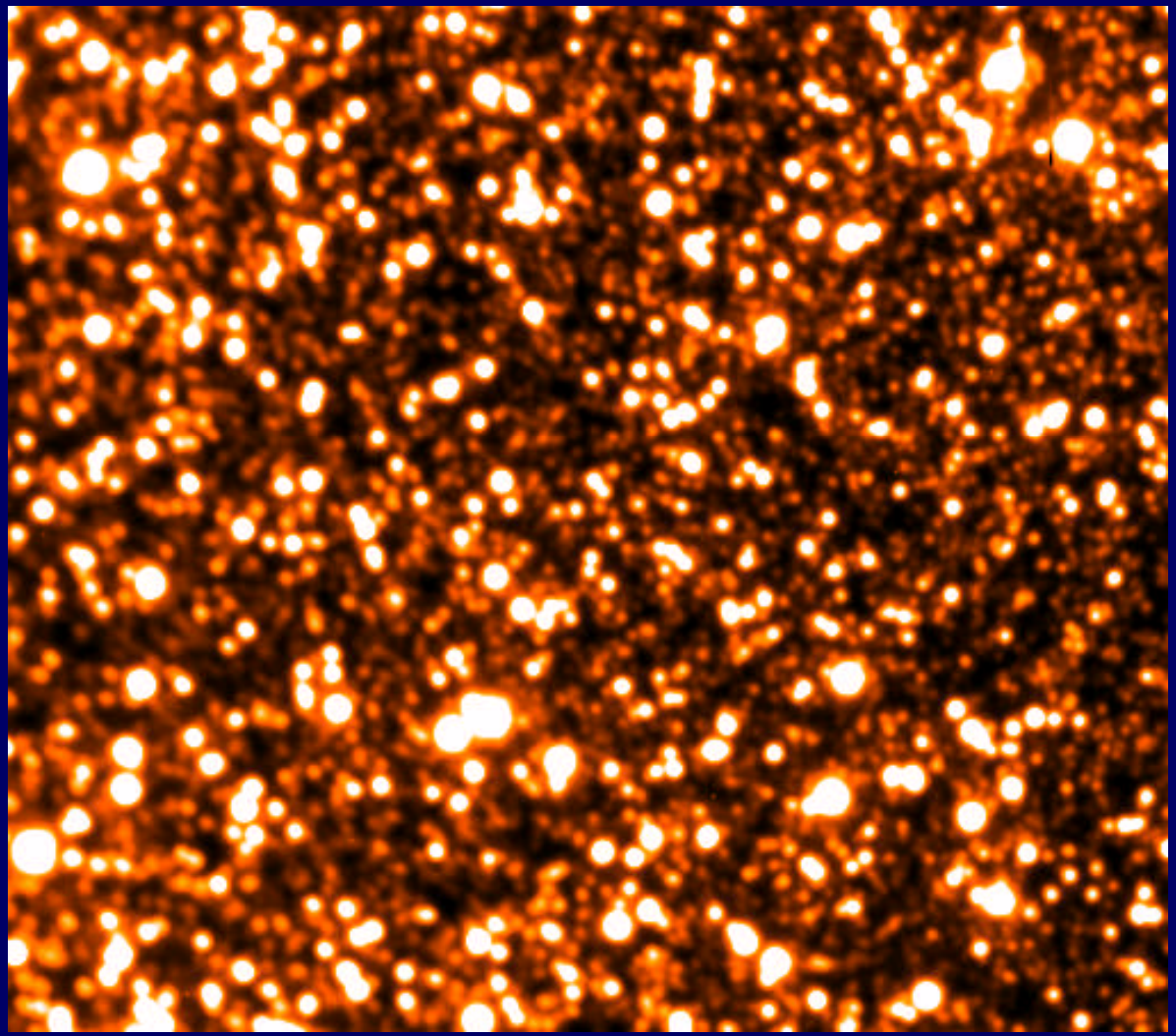
Quiescent counterpart : challenging bulge environment



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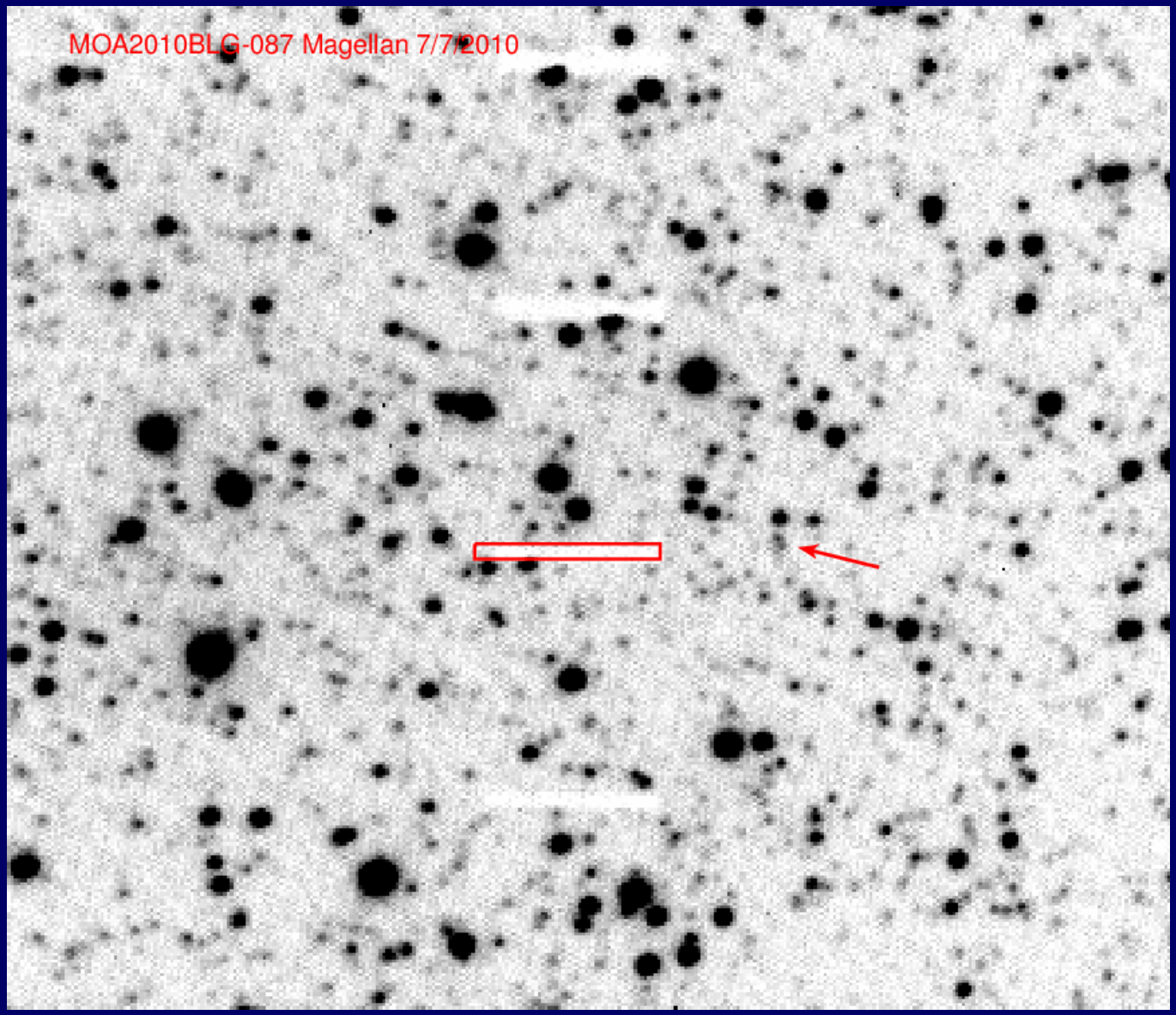

g~20 quiescent counterpart but field stars within 2”

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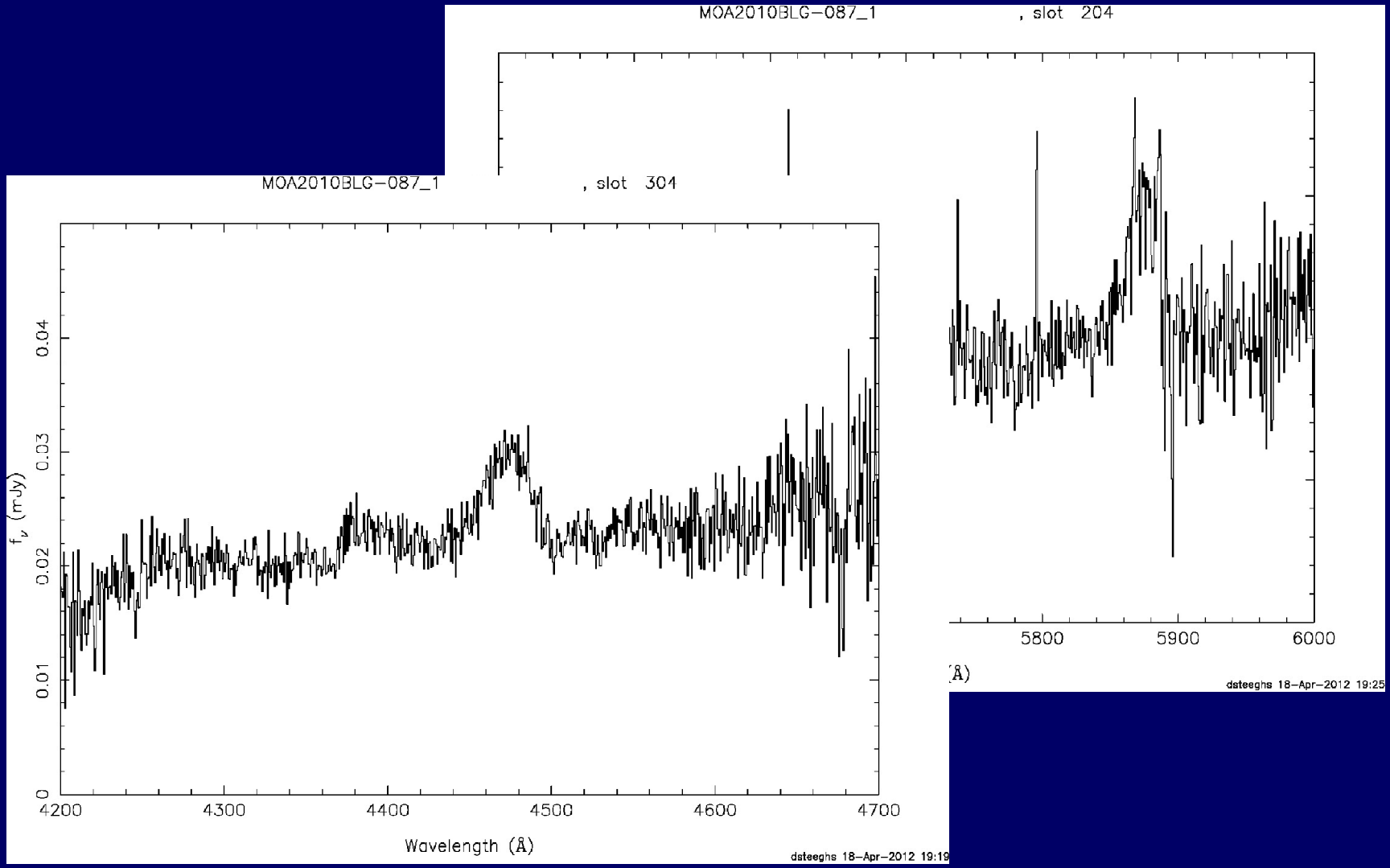
Magellan MAGE spectrum (2x1800s)



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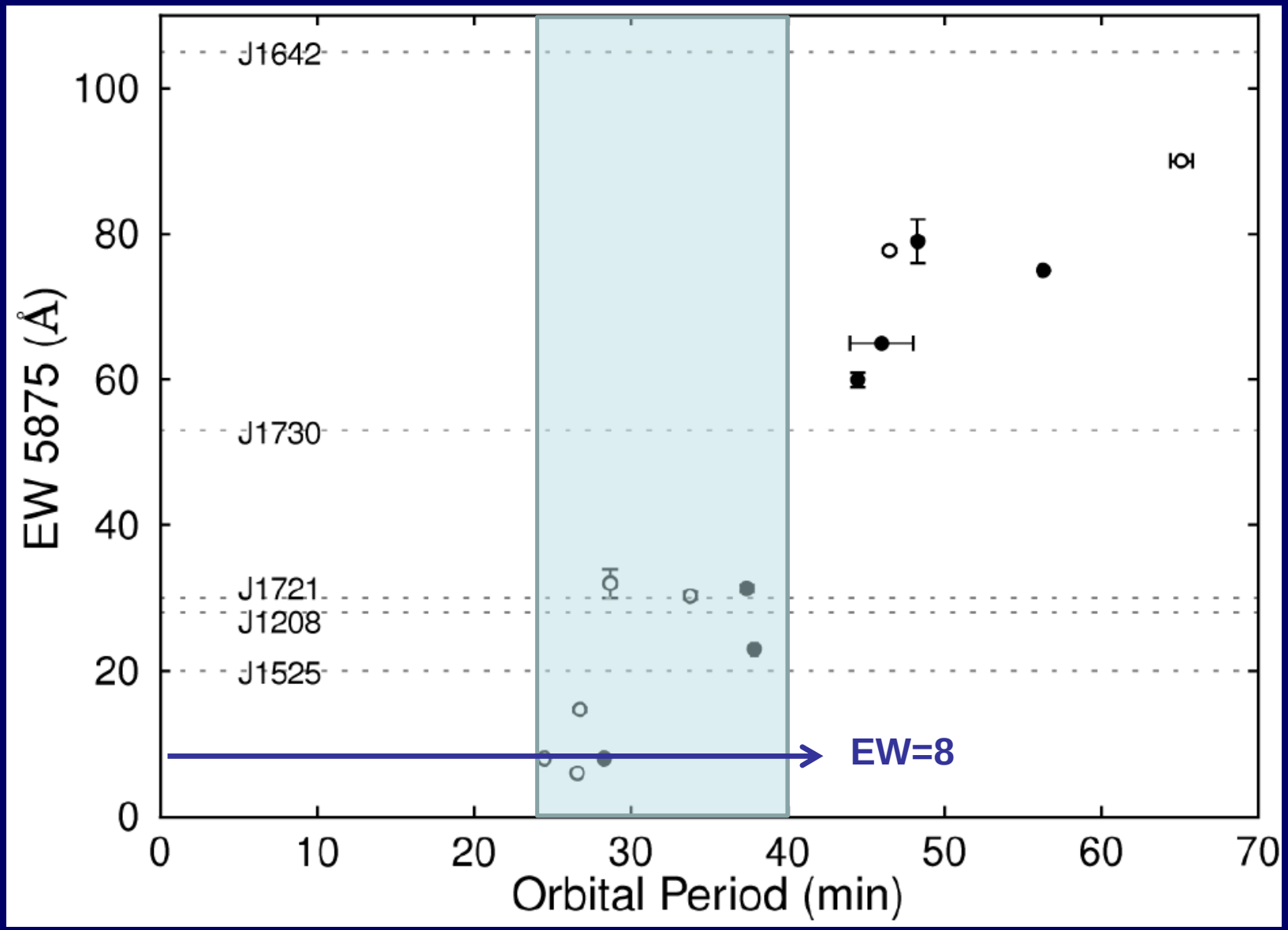

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Conclusions

- Time-series spectroscopy offers accurate periods even at low S/N
- Spikes offer a key proxy, but some questions remain
- Spike+bright spot can deliver accurate mass ratio
- 2nd order complexities need to be modeled/understood
- Do we understand the 'direct impact' line dynamics?
- Can we bring the modelling to a level that we can exploit the detailed kinematics (and line intensities) offered in the brighter systems