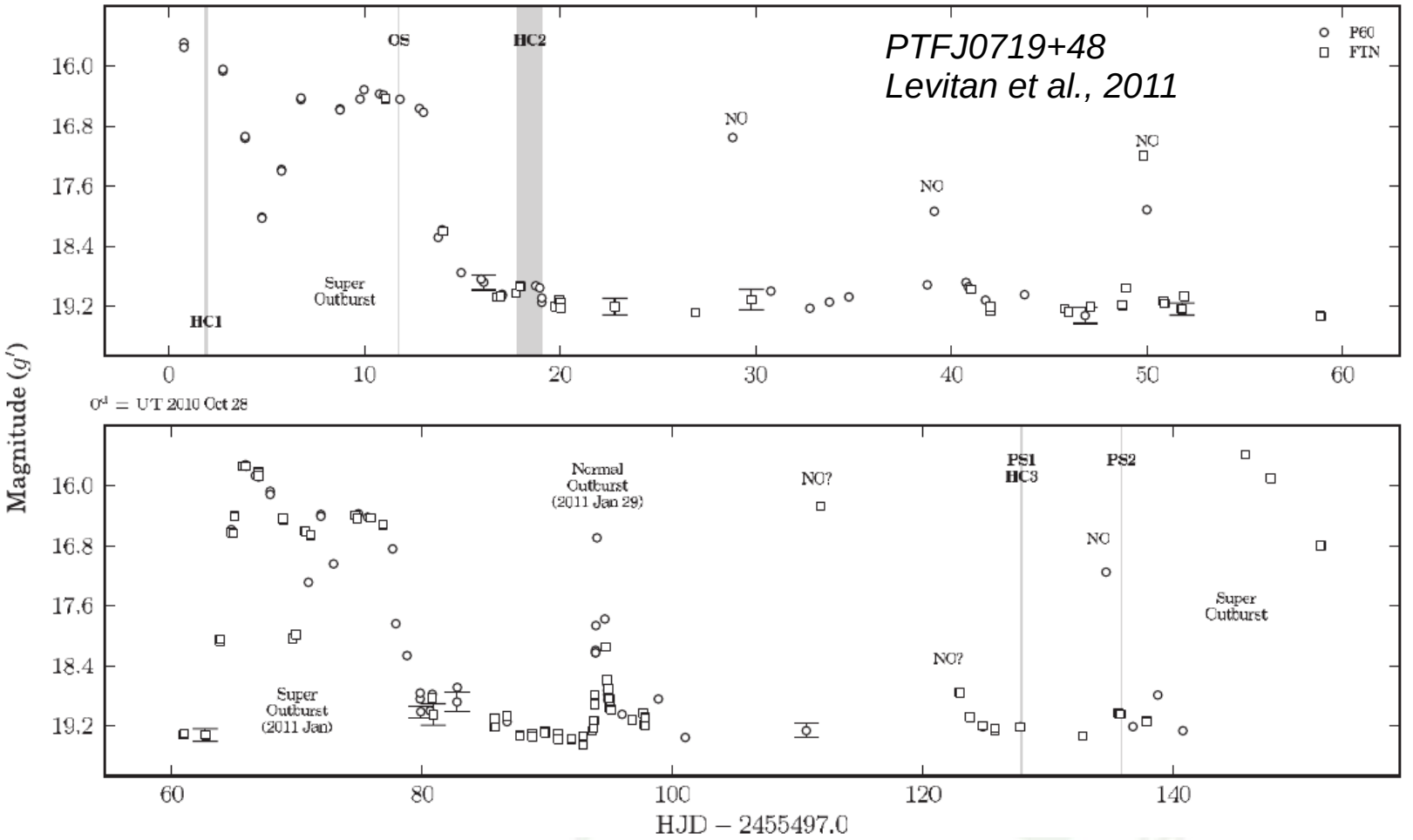
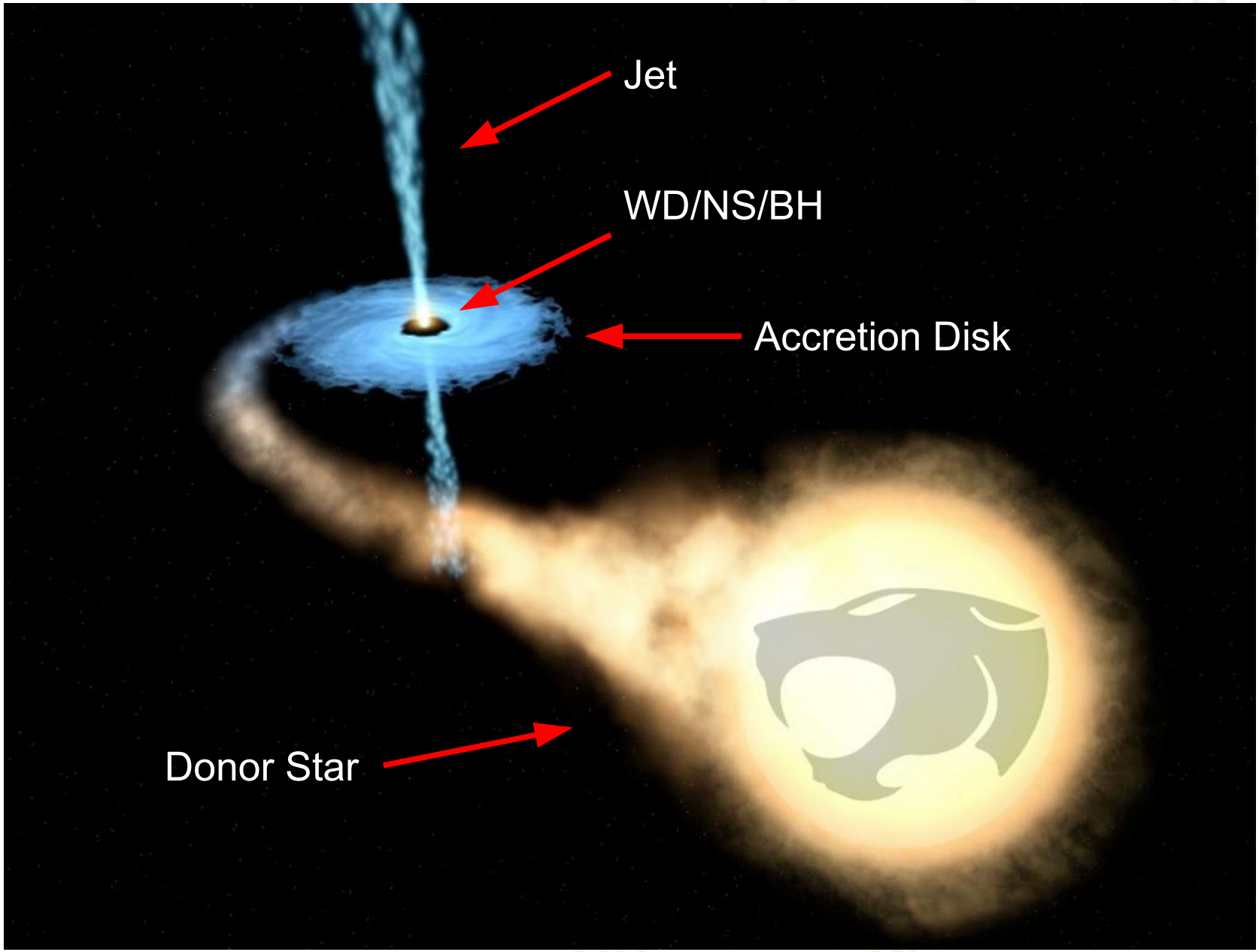
Accretion disks in (ultra)compact binaries

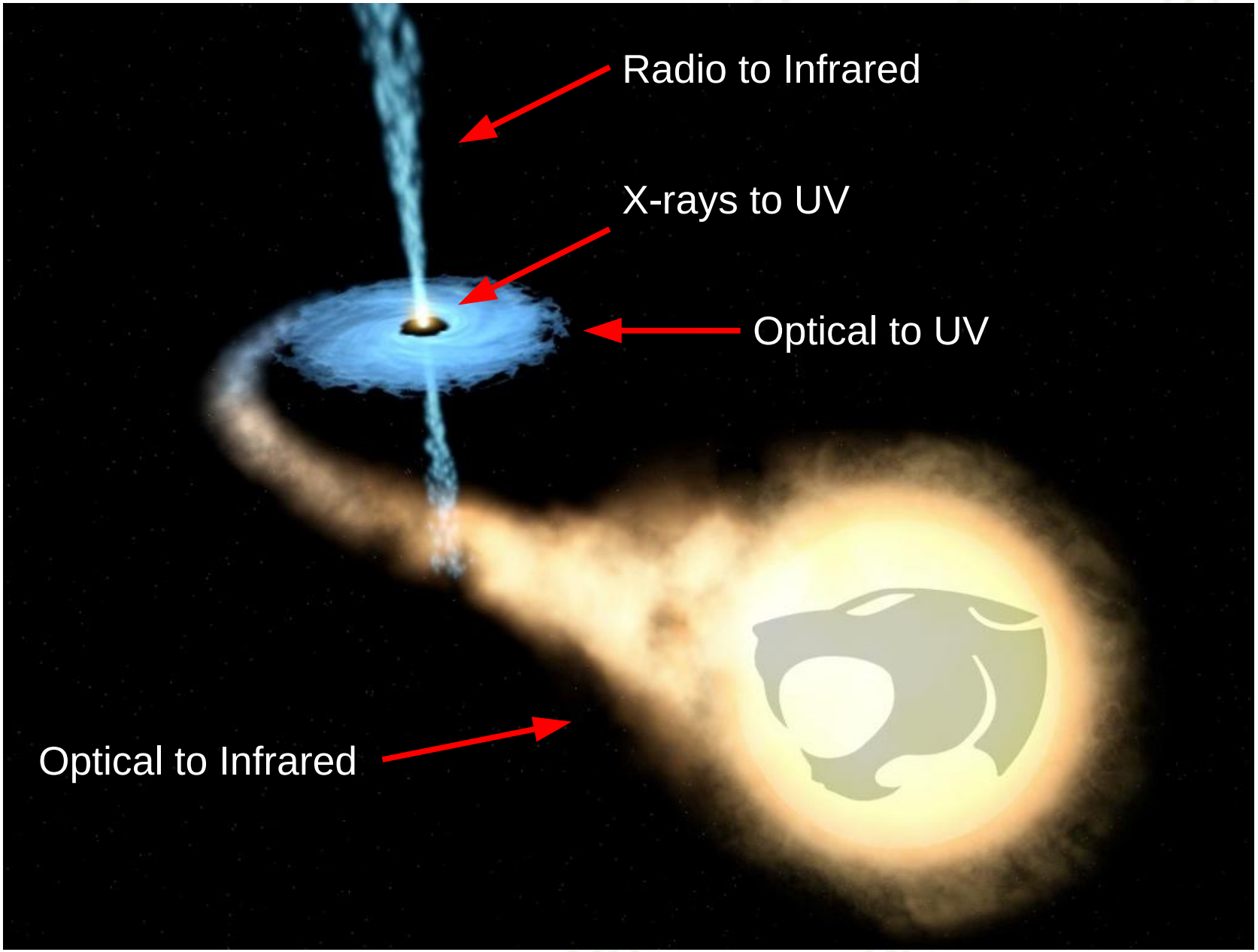


Paul Groot,
Thomas Kupfer, David Levitan, Roque Ruiz-Carmona, Deanne Coppejans
Tom Prince, Gijs Nelemans, Patrick Woudt, Danny Steeghs, Tom Marsh, Elmar Körding, Shri Kulkarni, Christian Knigge, Gavin Ramsay

Accreting Compact Binaries

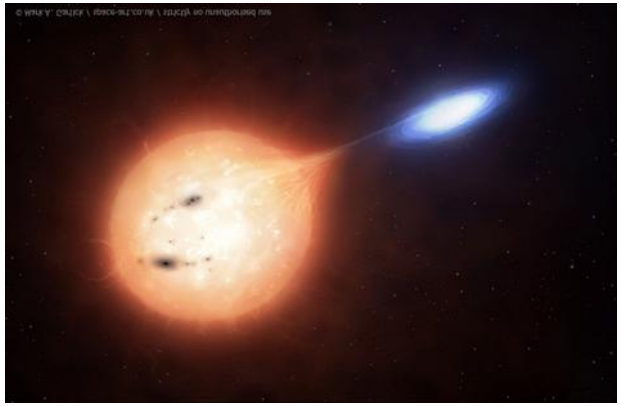


Multiwavelength Science



Two Classes

Cataclysmic Variables



- Accretor: White Dwarf
- Donor: Low-mass star (H-fusing)
- Solar composition material

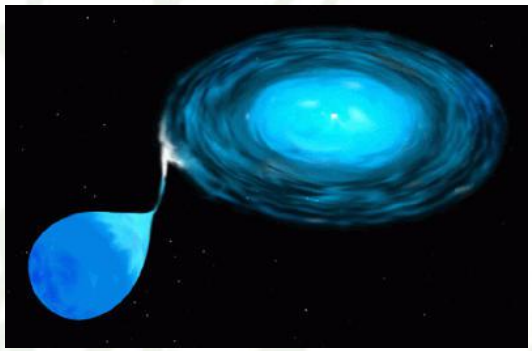
- $10^{-8} < \dot{M} < 10^{-10}\, M_{sun}/yr$

- 75 min < P_{orb} < 12 hrs
- $R_{disc} \sim R_{sun}$, $R_{disc} \leq$ 100-200 R_{WD}
- 3000 K < T_{disc} < few x 10^4 K

- Thousands of systems known
- Show dwarf novae outbursts

Review: Knigge et al., 2011

AM CVn stars



- Accretor: White Dwarf
- Donor: White Dwarf/ semi-deg. He star
- Hydrogen deficient: helium-dominated discs

- $10^{-8} < \dot{M} < 10^{-13}\, M_{sun}/yr$

- 5.4 min < P_{orb} < 65 min
- $R_{disc} \leq R_{sun}$, $R_{disc} \leq 50\, R_{WD}$
- 10000 K < T_{disc} < few x 10^4 K

- Only 51 systems known
- Show dwarf novae outbursts

Review: Solheim et al., 2010; Nelemans et al., 2005

Accretion disc issues

1) Stability in high-mass transfer rate (AM CVn) systems

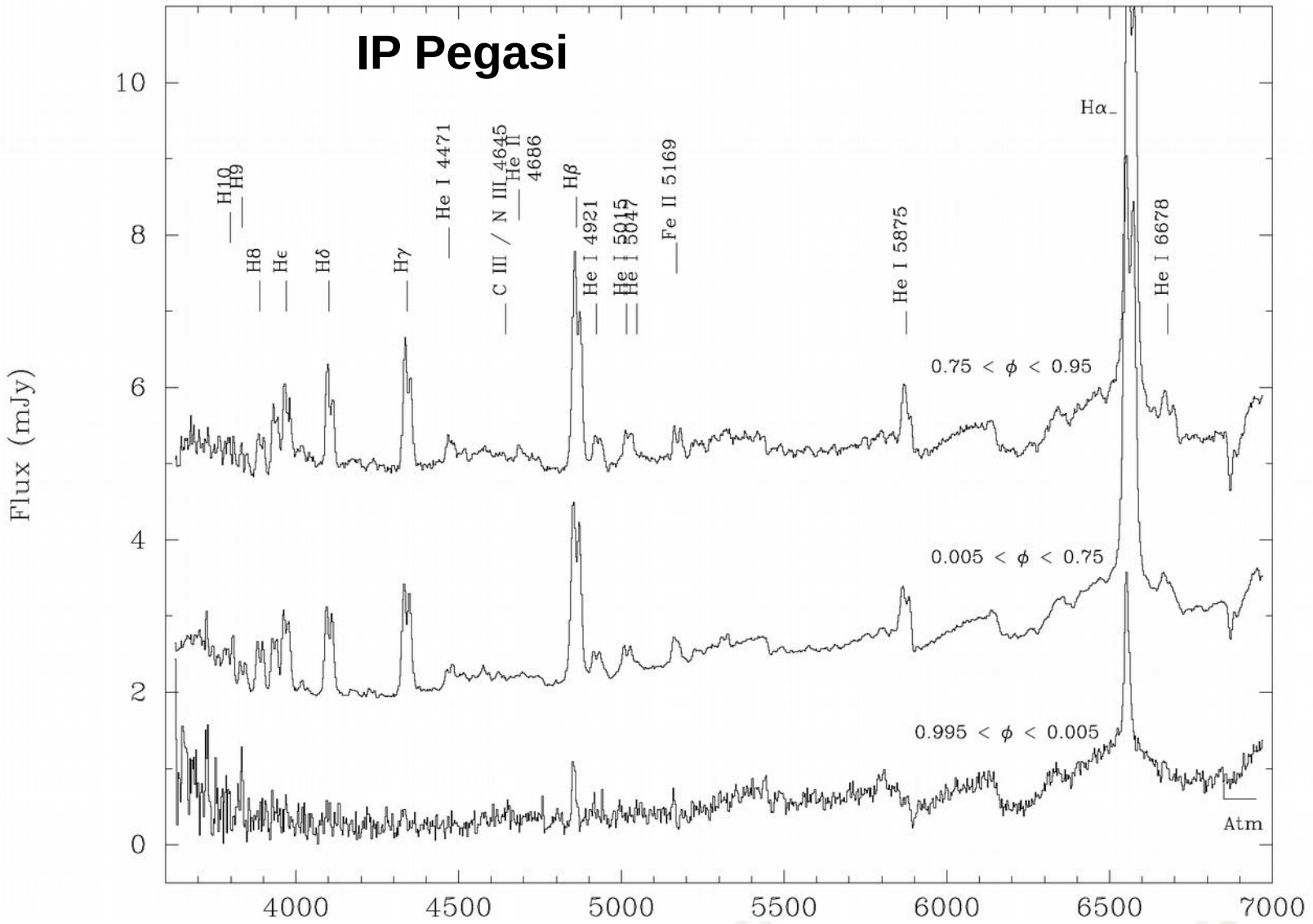
2) Dwarf novae outbursts in AM CVn stars

3) Accretion in long-period AM CVn stars, disc structures

4) Spiral density waves in outbursting CVs

5) Radio emission from Cataclysmic Variables: Jets?

Spectra



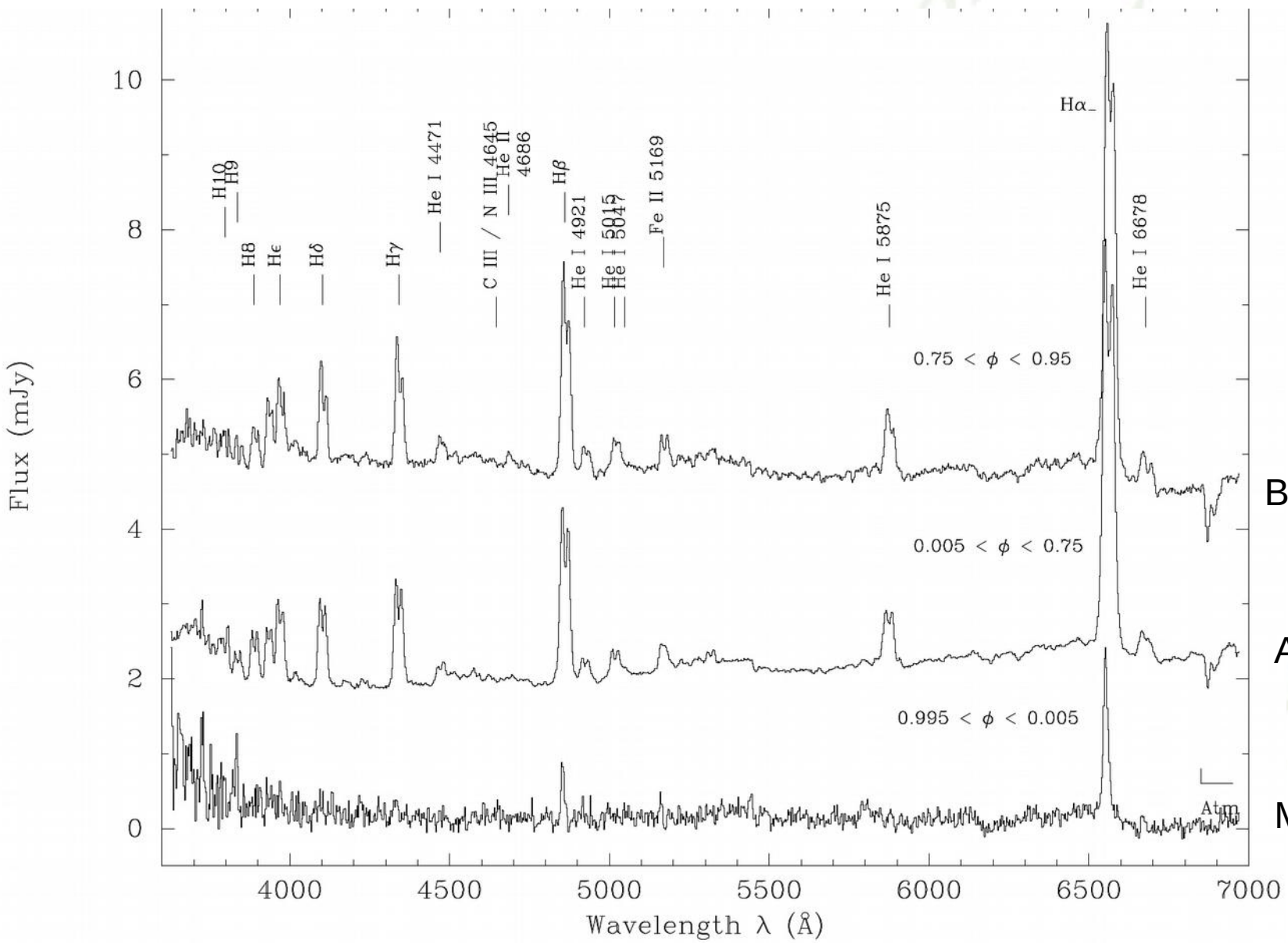
Bright spot phase

Average spectrum

Mid-eclipse

Disk continuum, disk emission, secondary star

Spectra



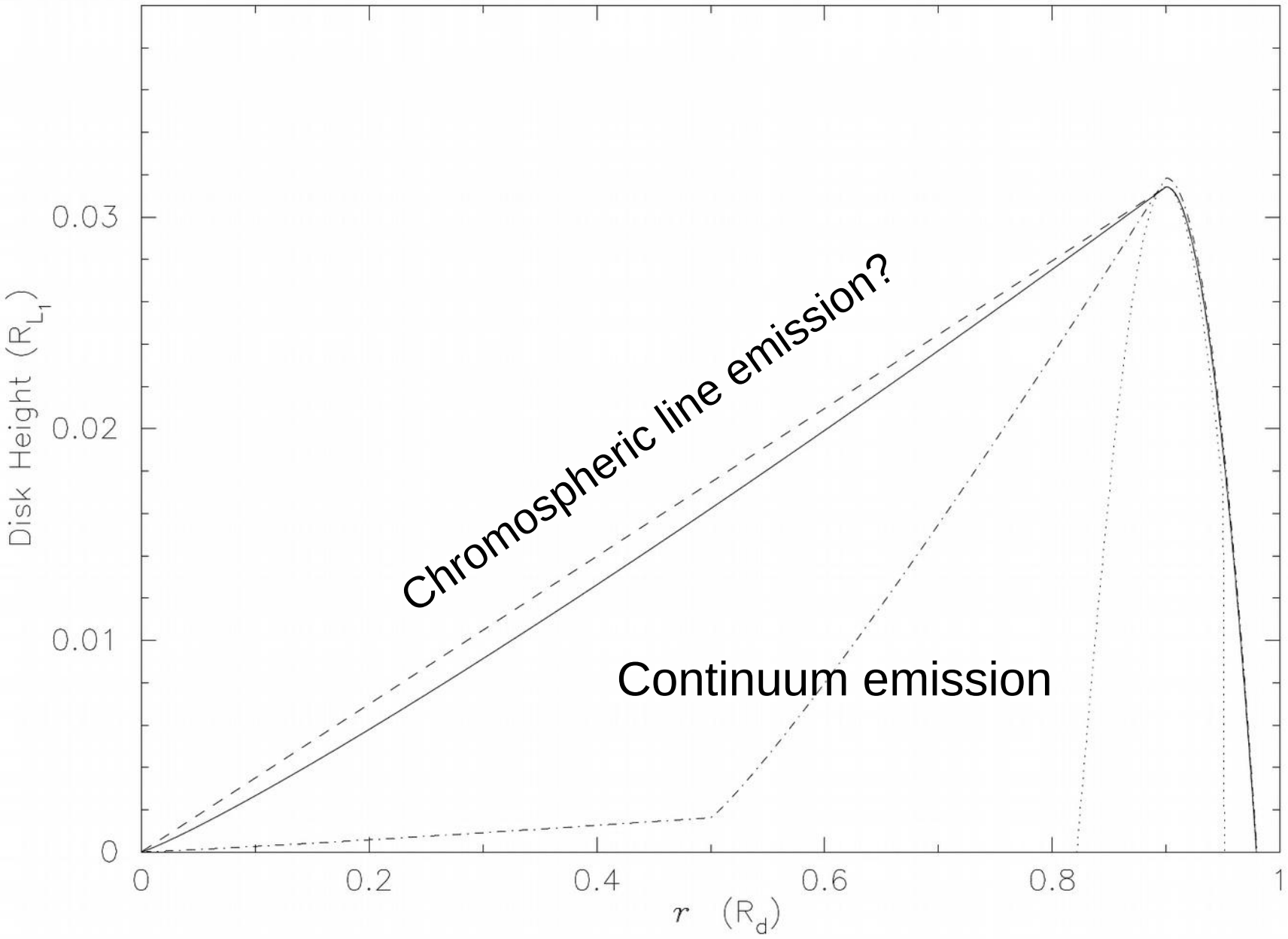
Bright spot phase

Average spectrum

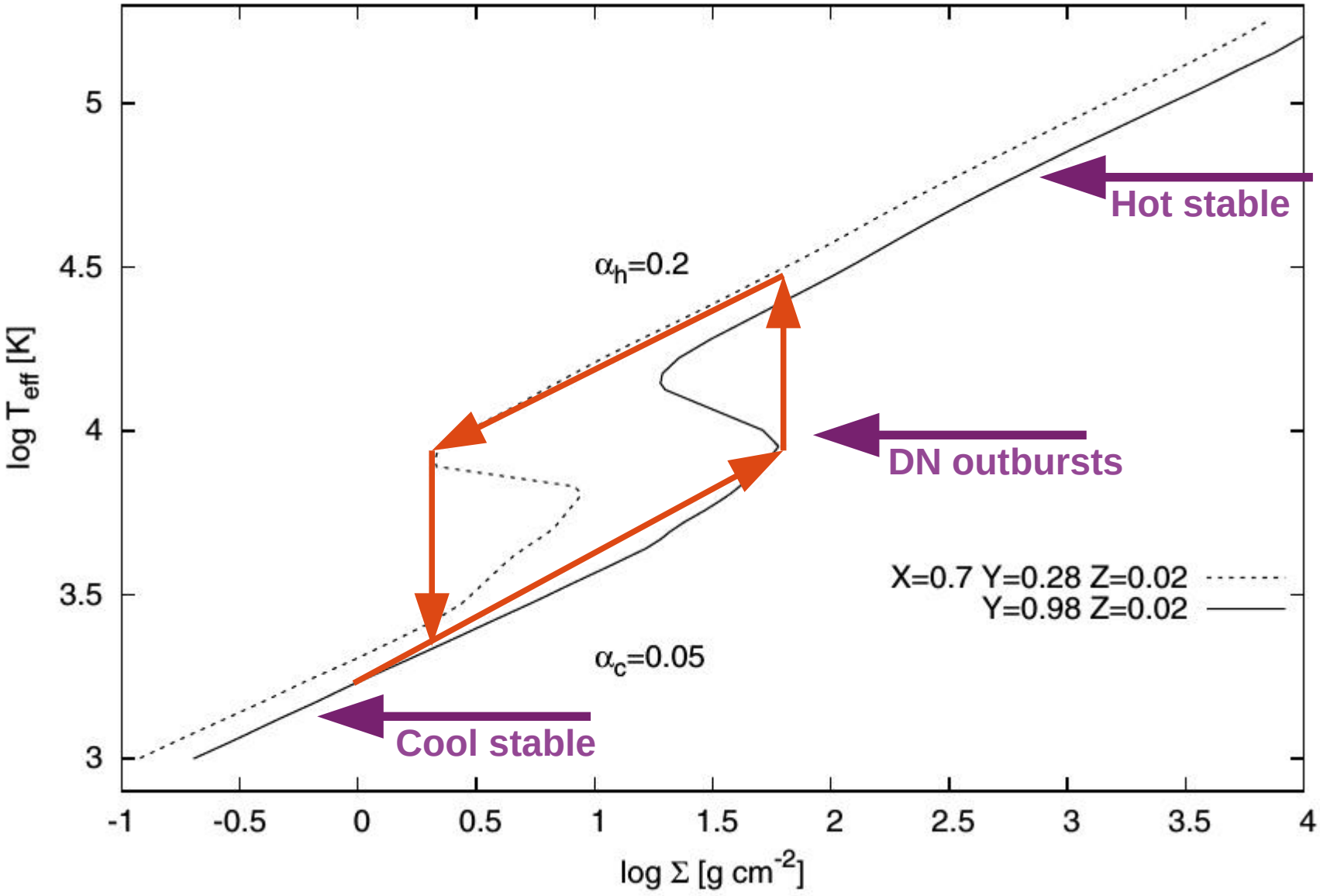
Mid-eclipse

Disk continuum, disk emission: we don't understand the emission lines...

Spectra: chromosphere



Stability of disks



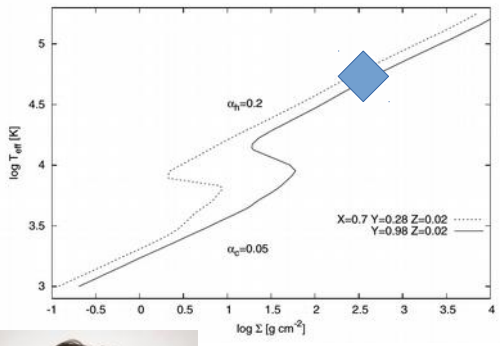
Kotko, Lasota, Hameury, 2012

Short period AM CVn system

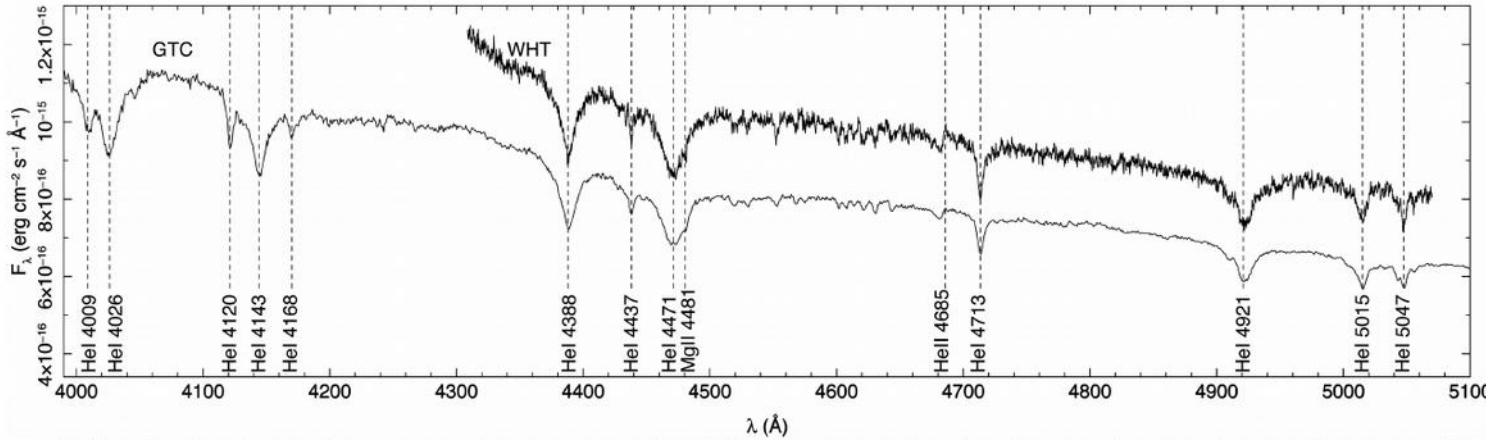
SDSS1908+3904
P_{orb} = 18.1 minutes
I ~ 15 degrees
(almost face-on)
High mass transfer rate:
hot-stable disc

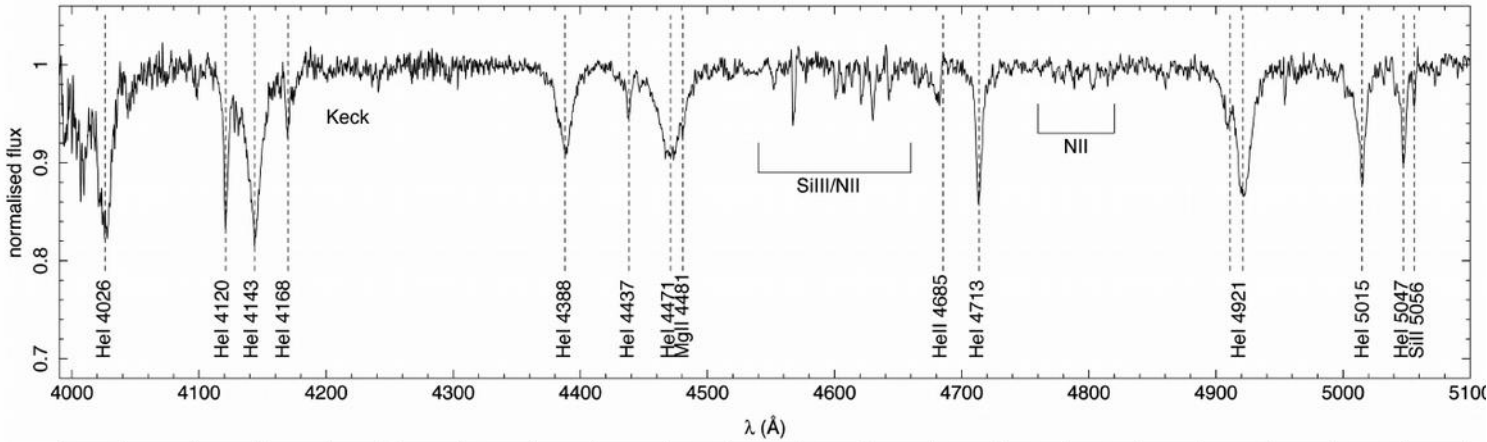
Four years of
high cadence
Kepler data... :

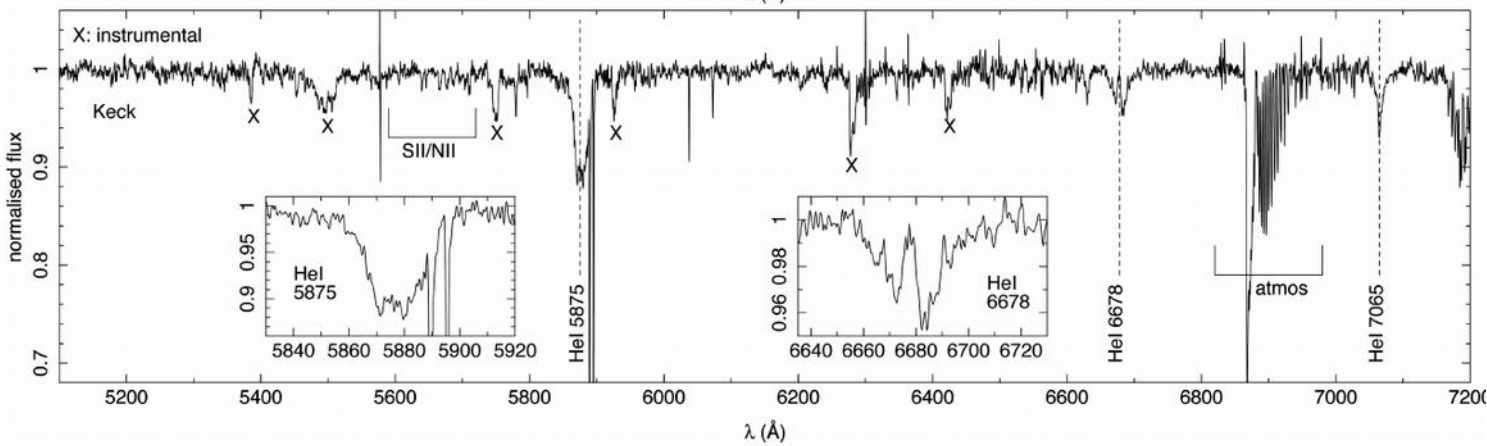
1.3 million data points



Kupfer et al., 2015







Short period AM CVn system

Four years of high cadence Kepler data... :
1.3 million data points

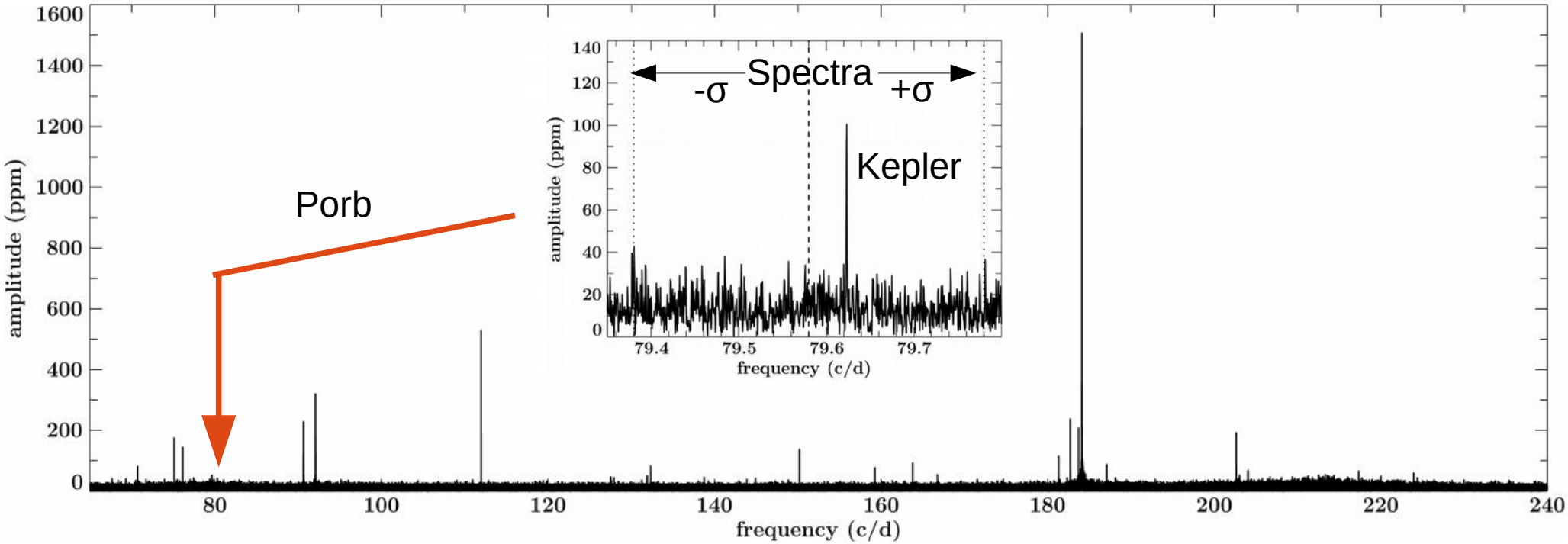
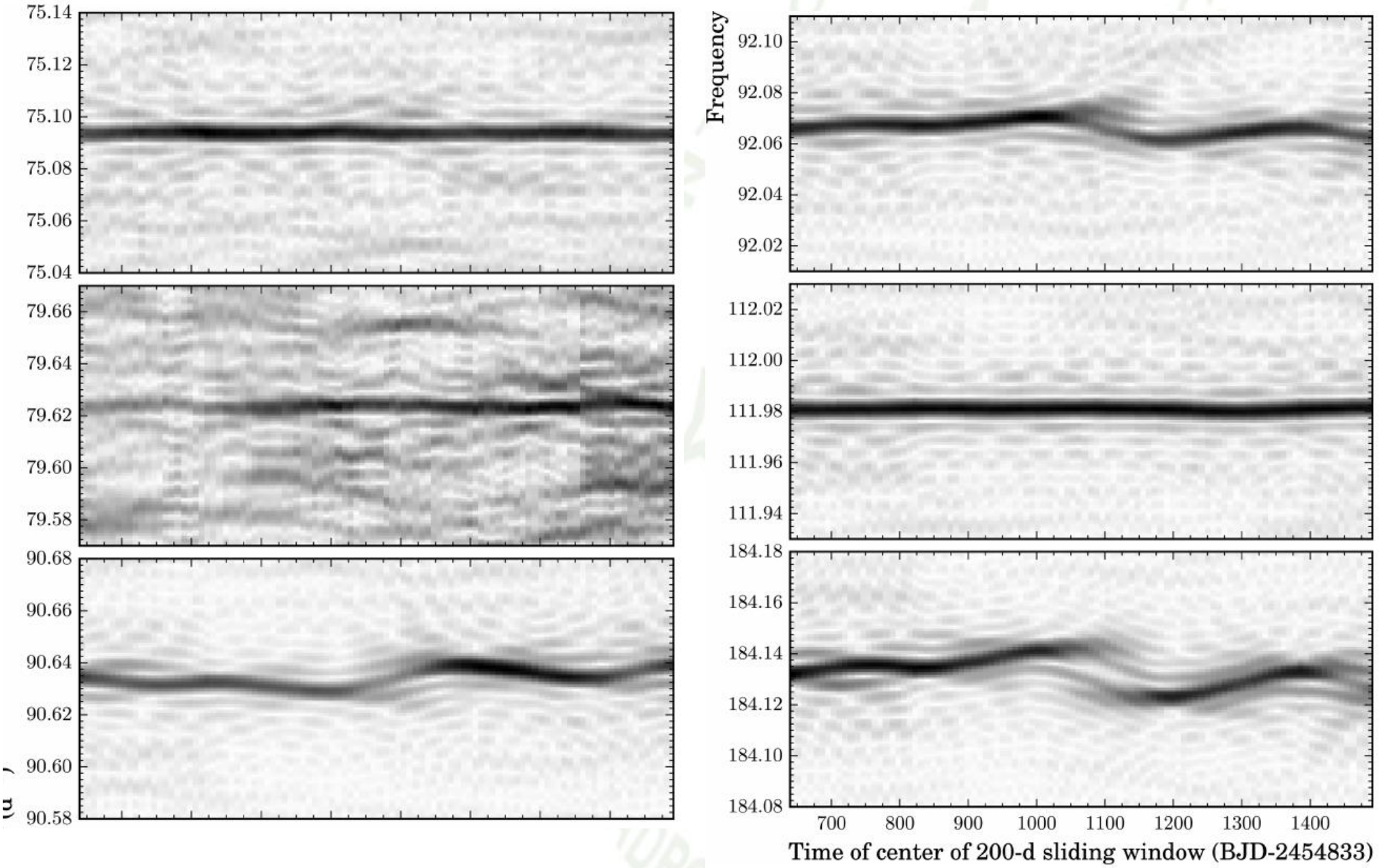


Figure 5. Fourier transform of the light curve obtained with *Kepler* of SDSS J1908.

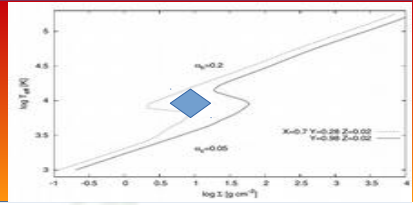
Kupfer et al., 2015

Dynamic Fourier Spectra



Kupfer et al., 2015

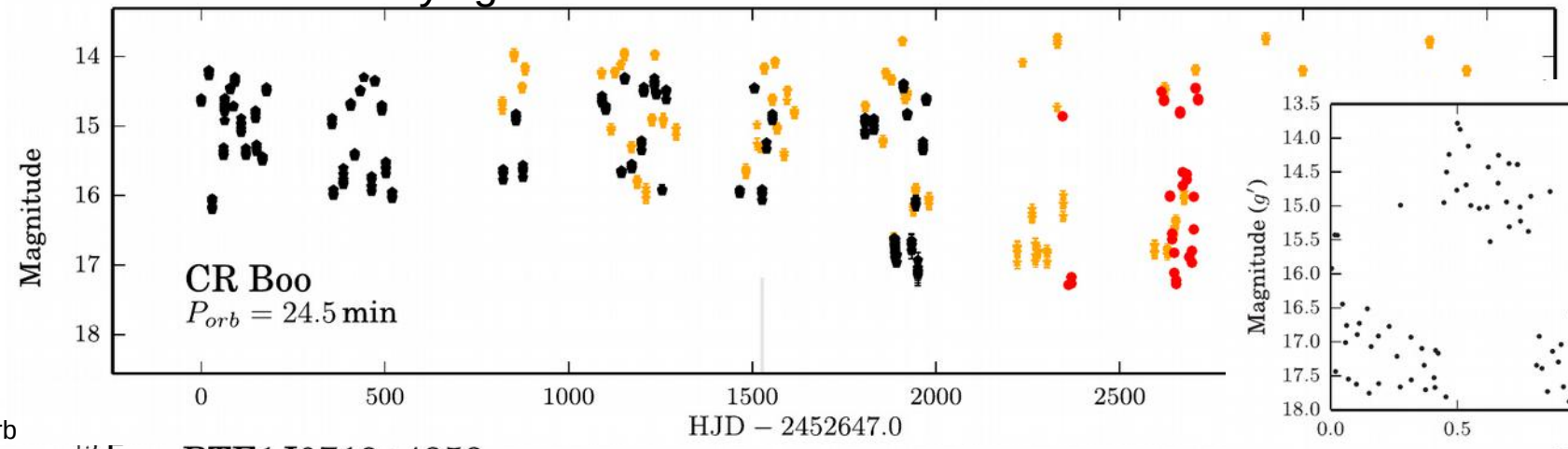
Outbursting AM CVn stars

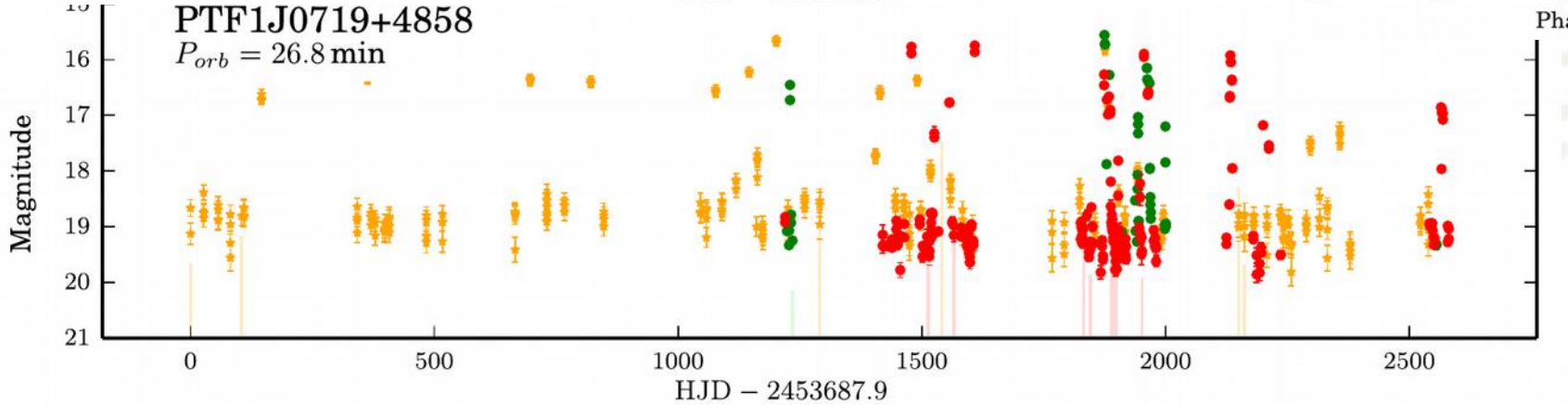


Palomar Transient Factory light curves: recurrence time dwarf nova outbursts in AM CVn systems

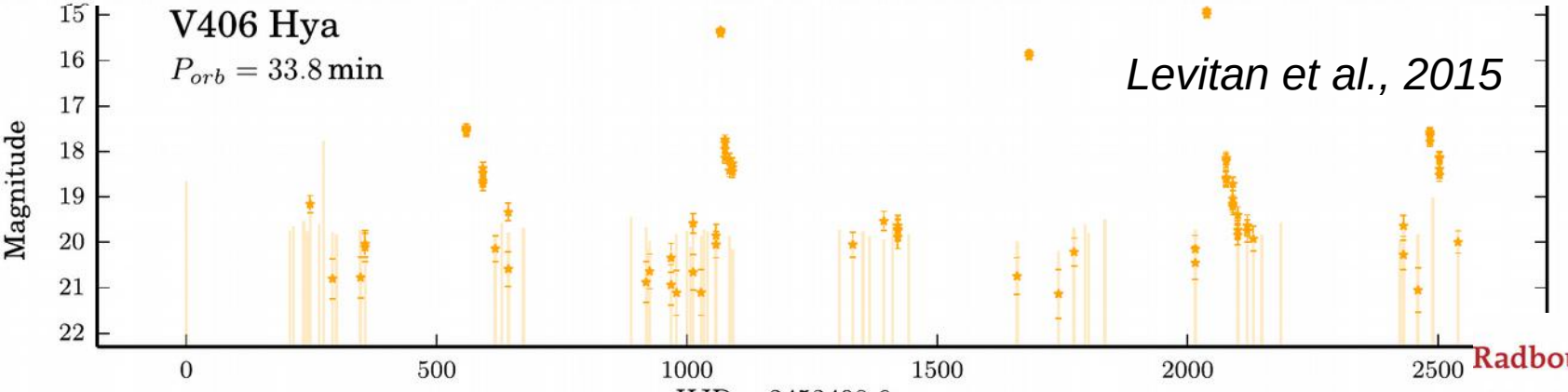
P_{SOB}=46d

P_{orb}





$\dot{M}$



Levitan et al., 2015

Radboud University

Outbursting A

Palomar Transient Factory light curves: recurrence time dwarf nova outbursts in AM CVn systems

Levitan et al., 2015

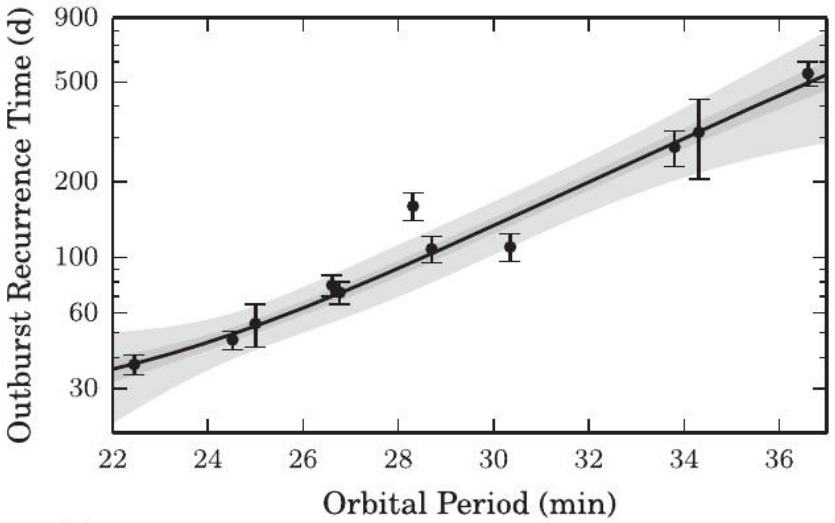
Relation between P_{orb} and $\tau_{recurrence}$:

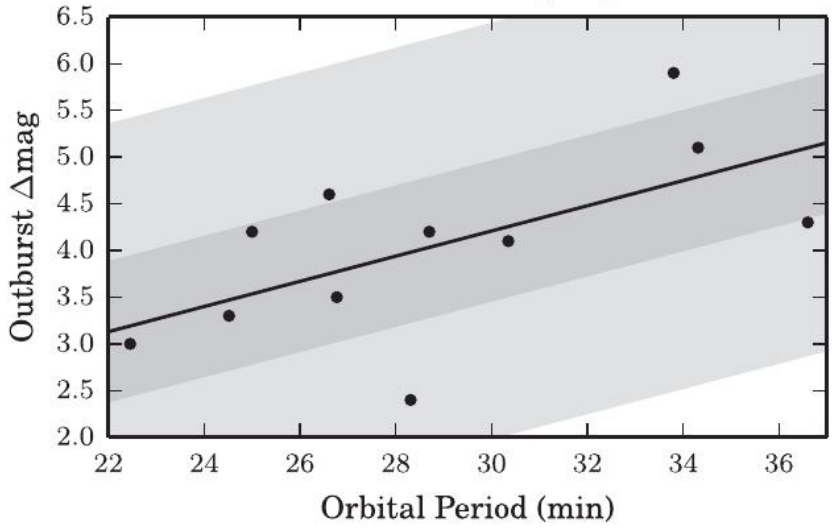
$$t_{\rm recur} = 1.46\ {\rm days}\left(\frac{P_{\rm orb}}{1000\ {\rm s}}\right)^{7.35} + 24.7\ {\rm days}.$$

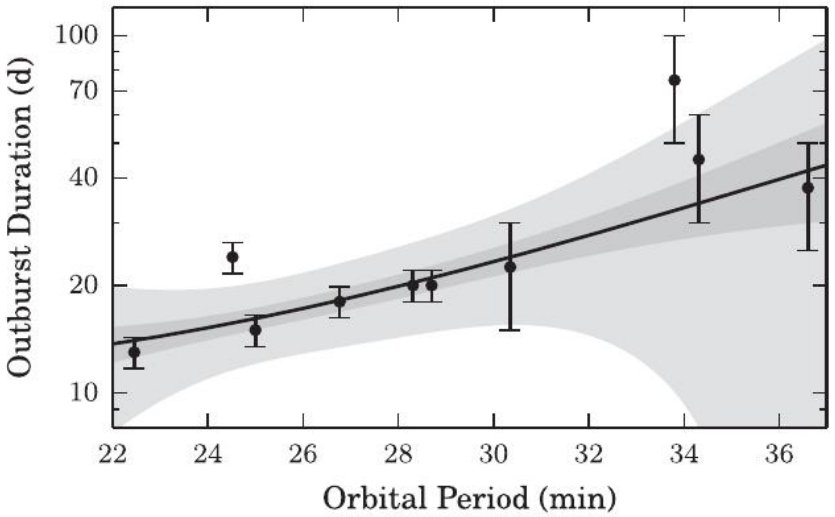
reflects evolution through gravitational wave emission

$$= (4.92\ {\rm days})\left(\frac{P_{\rm orb}}{1000\ {\rm s}}\right)^{7.51}$$

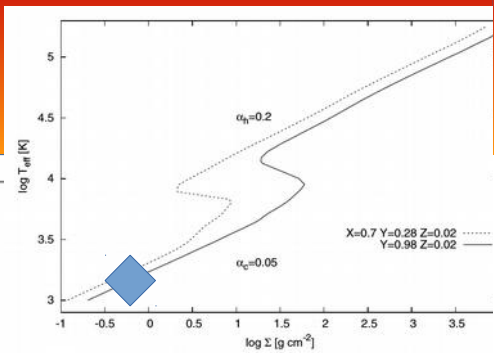
Cannizo & Nelemans (2015), using Kotko et al. (2012)

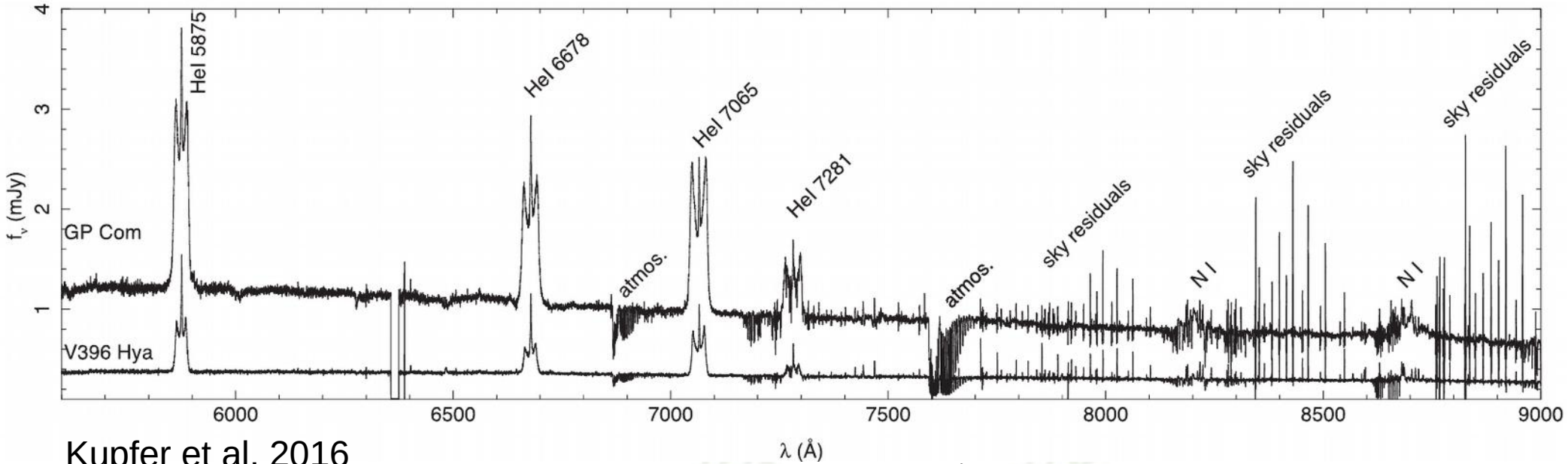






Cool Stable AM CVn discs

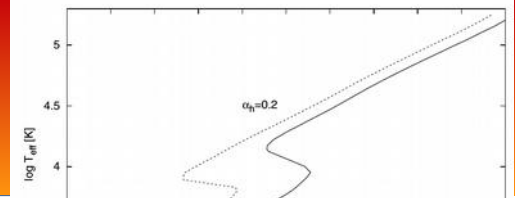


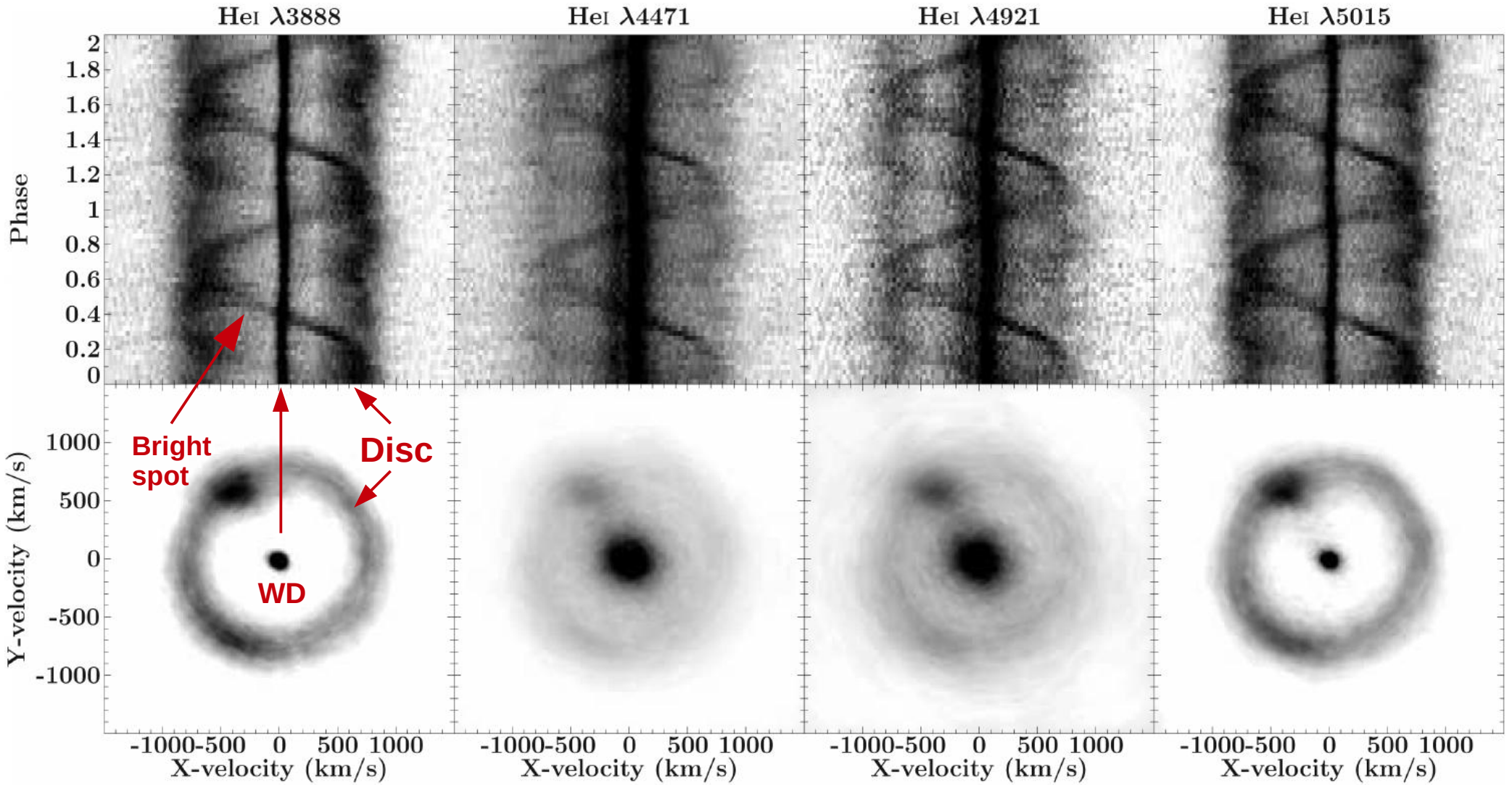


Kupfer et al, 2016

GP Com (P_{orb} = 46 min); V396 Hya (P_{orb} = 65 min). $\dot{M} \sim 10^{-12} M_{sun}/yr$

Doppler tomography

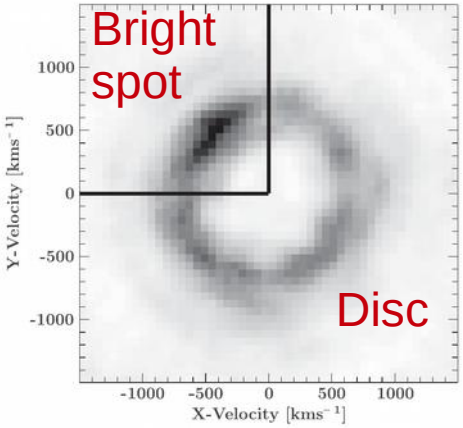


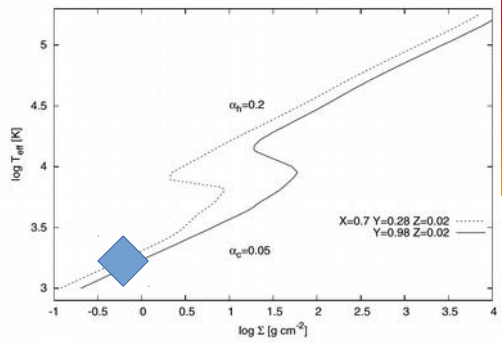


Clear inner and outer disc velocities from the emission profiles

Kupfer et al, 2016

Doppler tomography

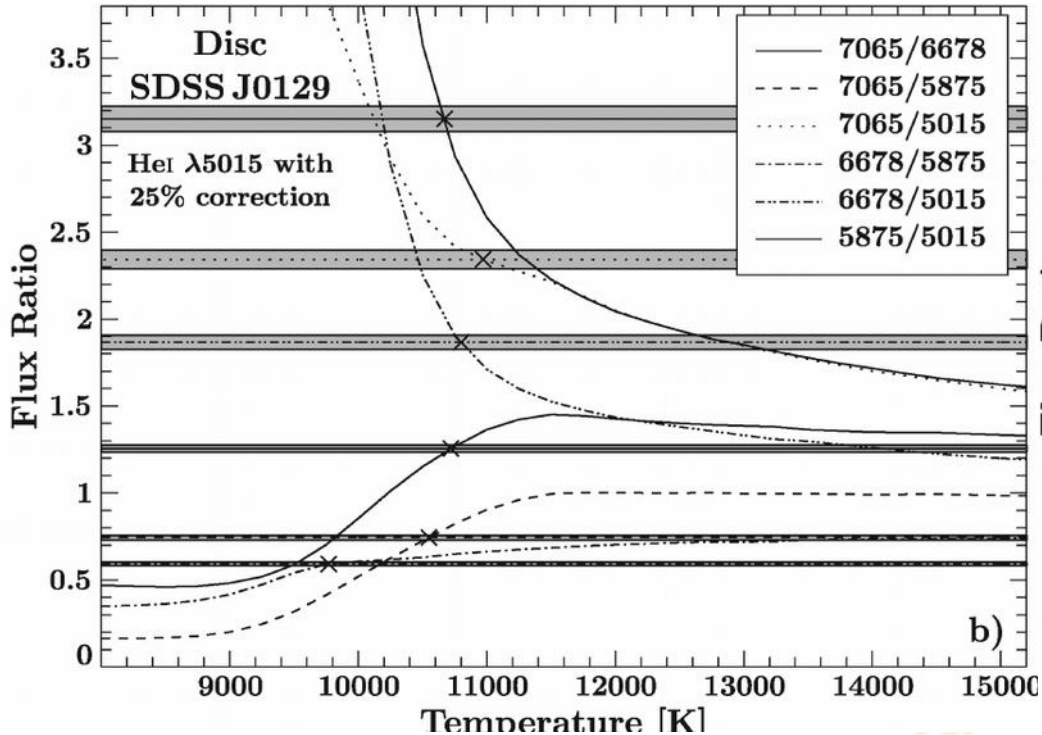


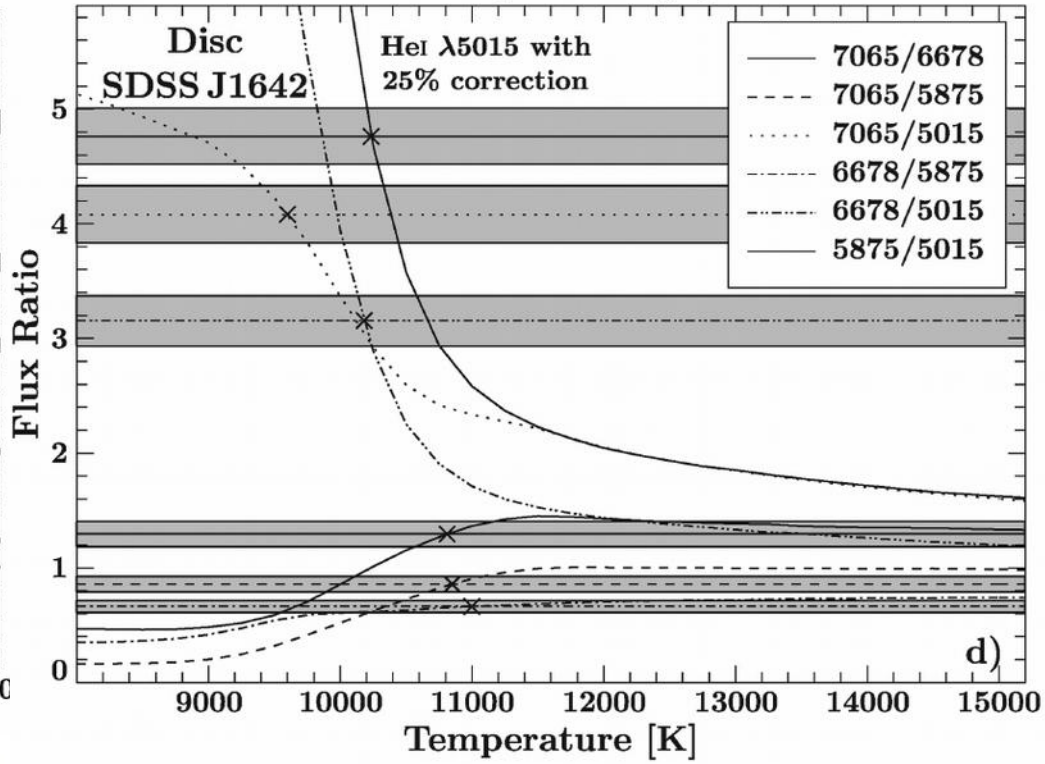


Modelling line ratios with an isothermal slab model

(Marsh, Horne & Rosen, 1991)

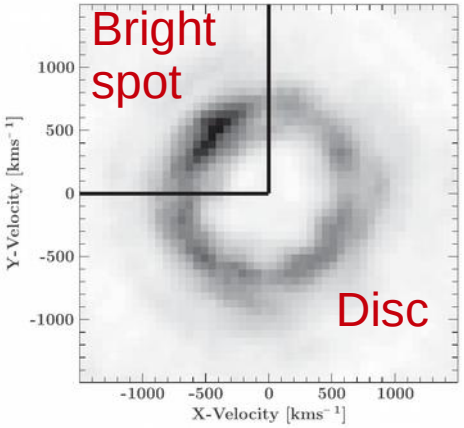
Discs are 11000 – 12000 K

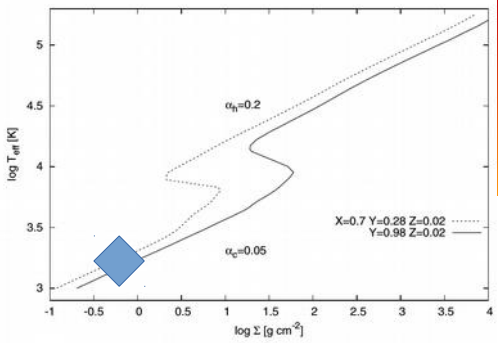




Kupfer et al, 2013

Doppler tomography

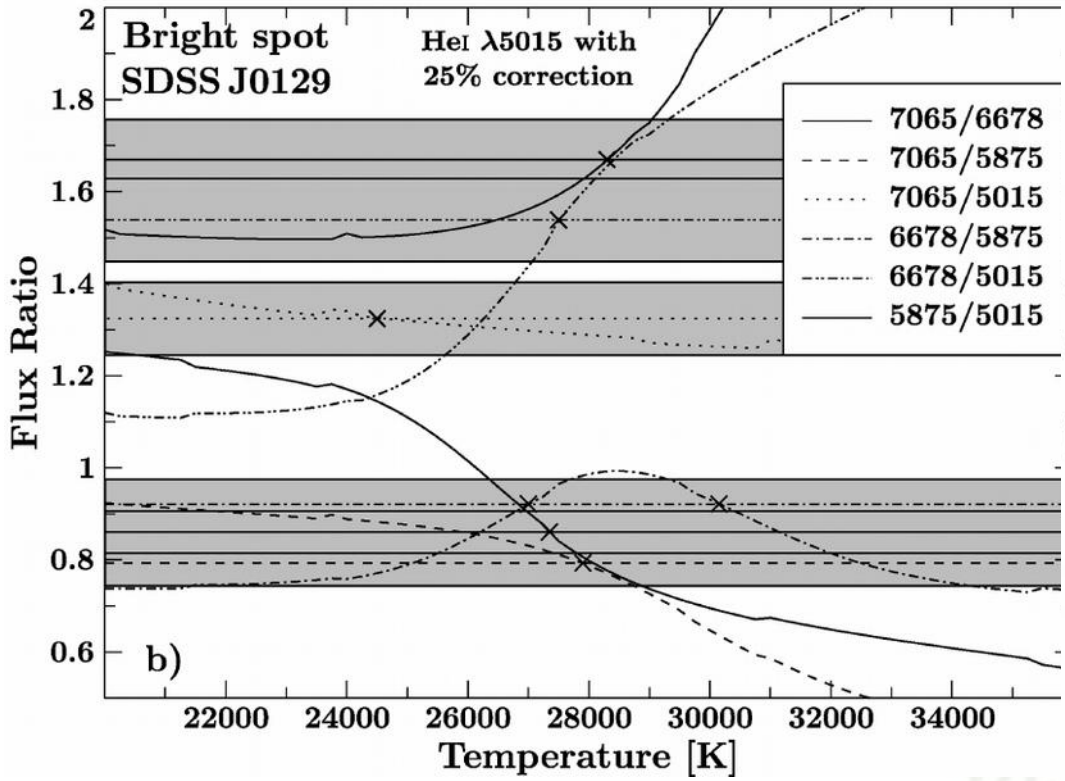


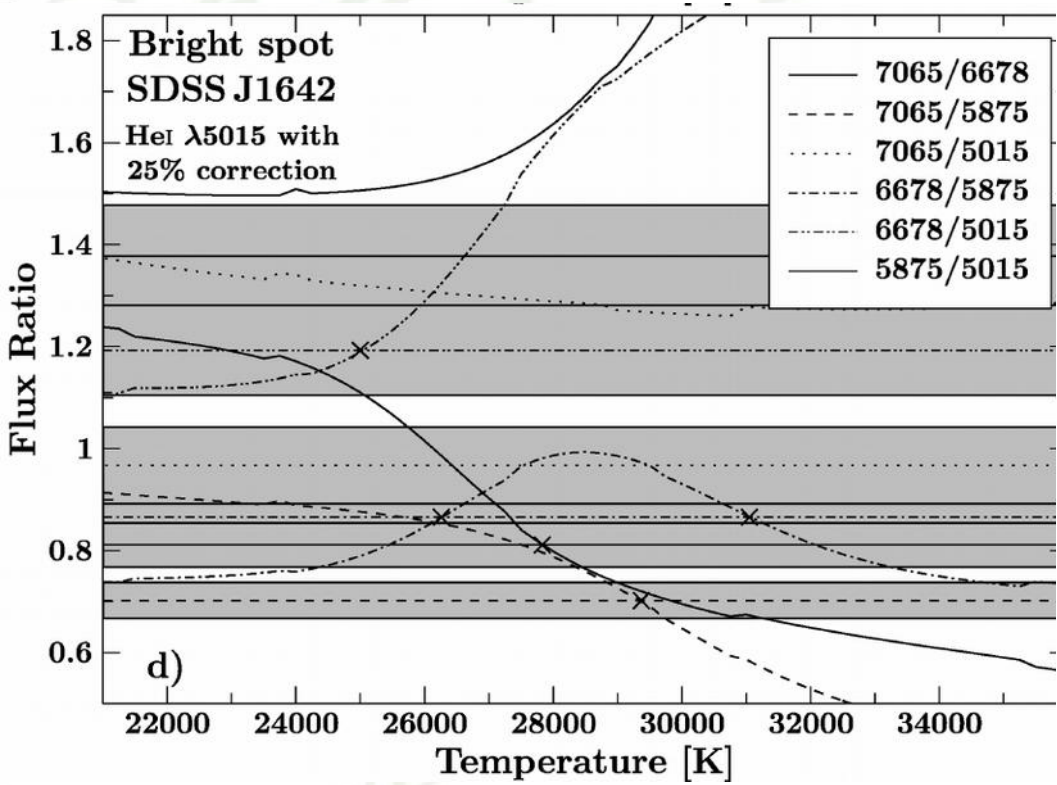


Modelling line ratios with an isothermal slab model

(Marsh, Horne & Rosen, 1991)

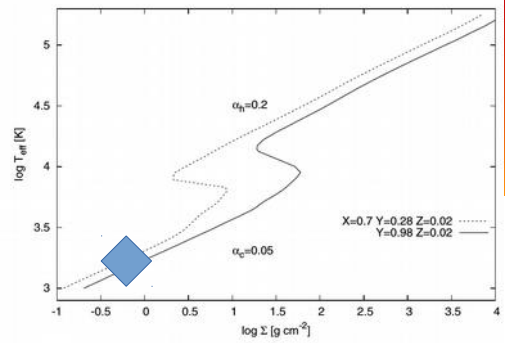
Not a good model for bright spots

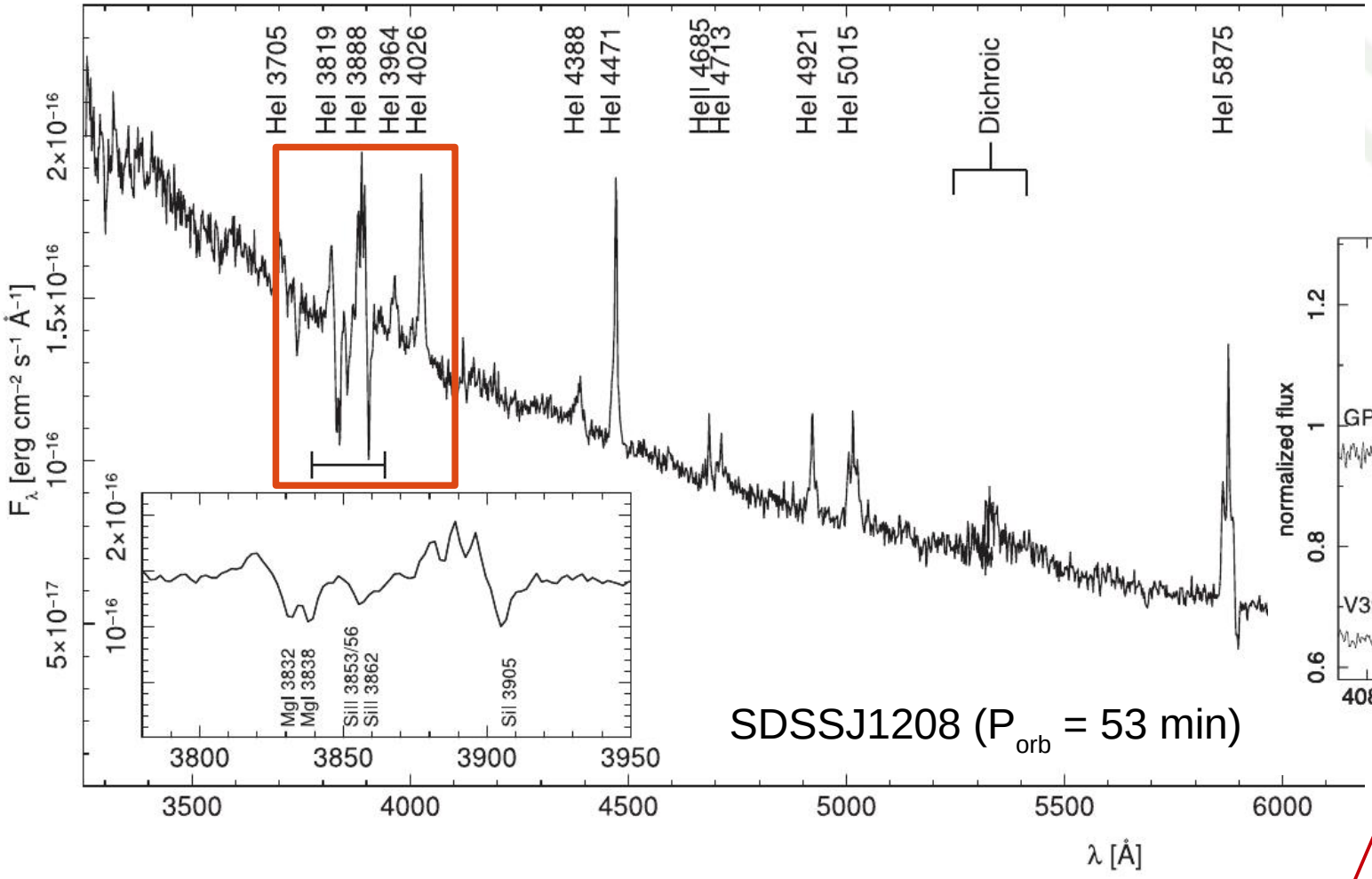


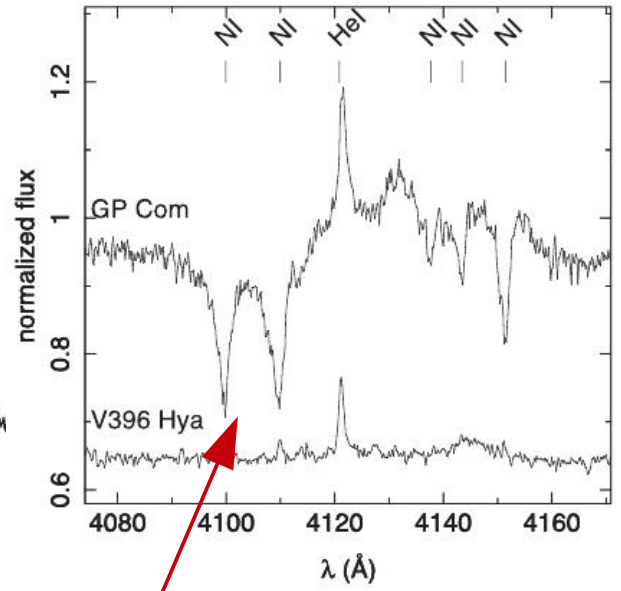


Kupfer et al, 2013

Ongoing accretion? Yes



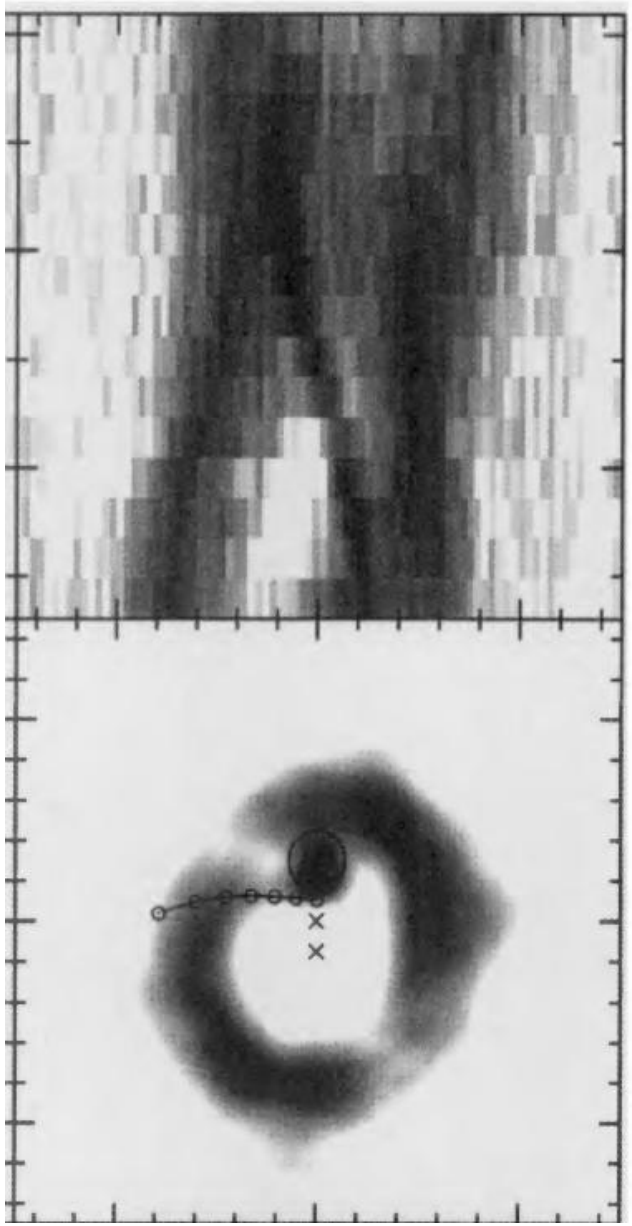


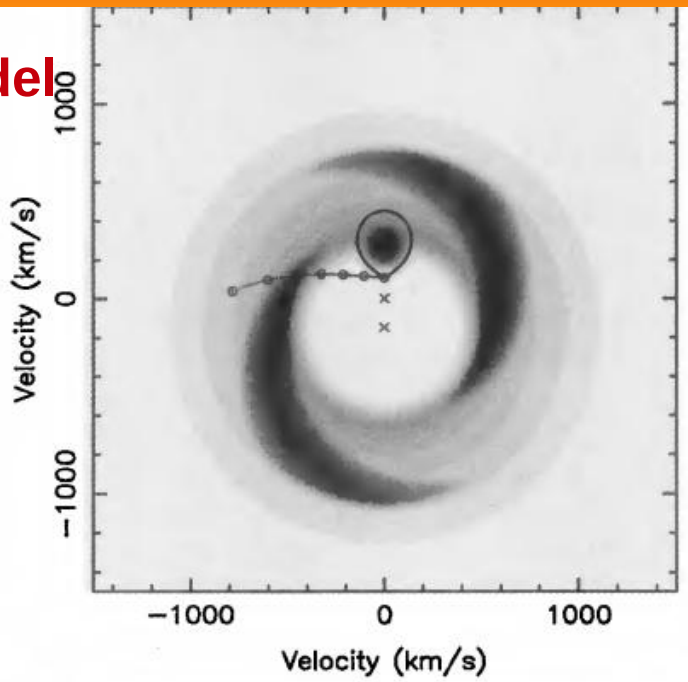


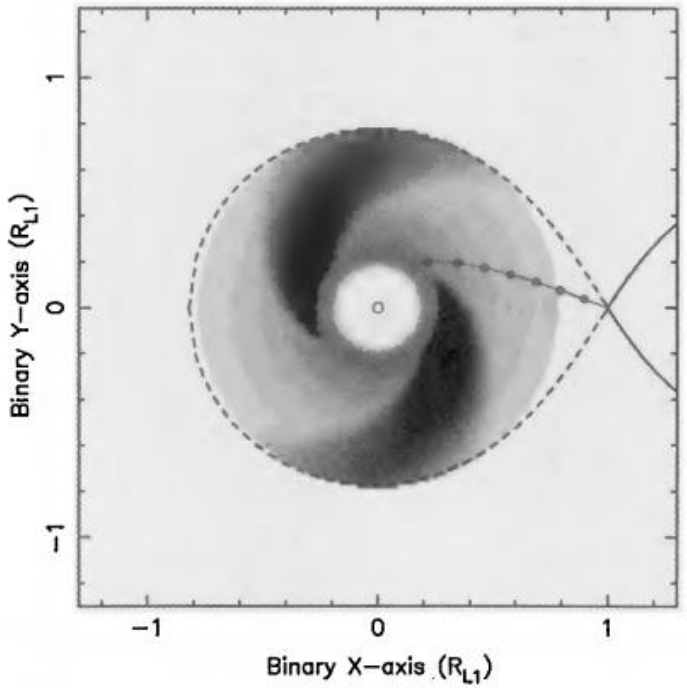
Accretor photospheric absorption lines of Mg and Si ; or Nitrogen
Settling time << evolutionary time i.e. accretion must be ongoing

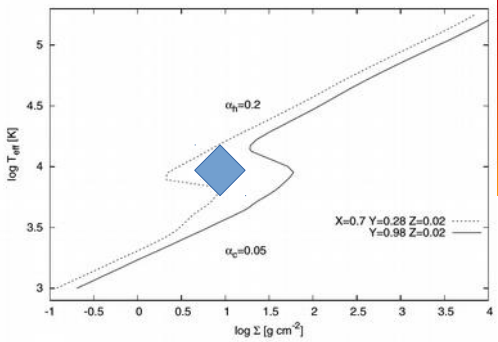
Kupfer et al, 2013

CV outbursts, Spiral Arms









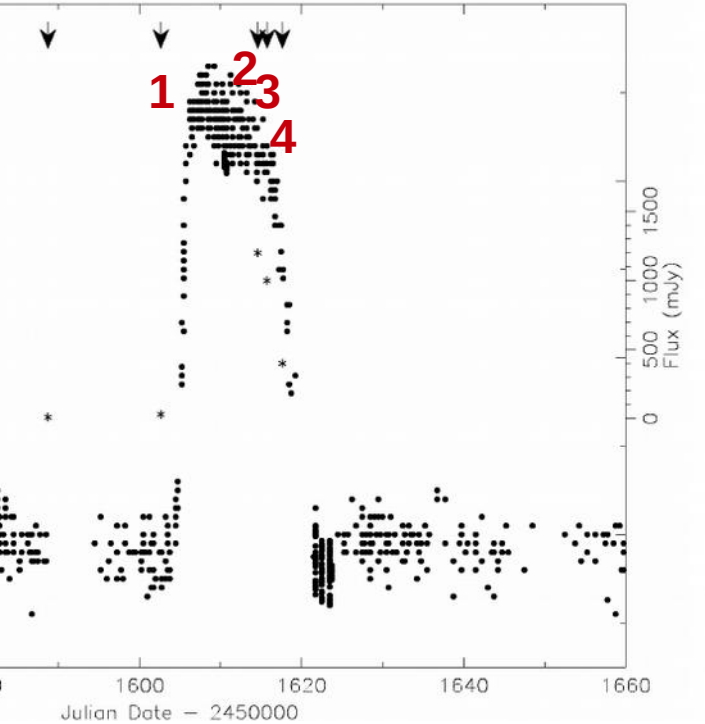
Very open, m=2 spiral wave during outburst

Problem: Very low Mach Number required

Too hot for comfort

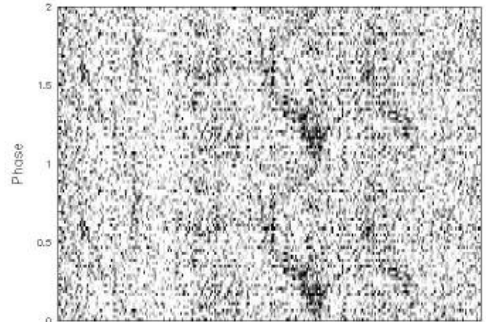
Steeghs et al. 1997

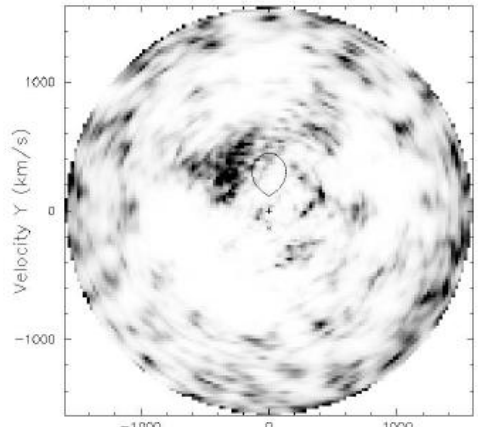
CV outbursts, Spiral Arms



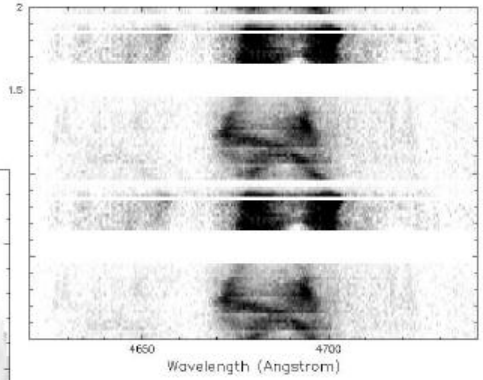
U Gem
Groot 2001

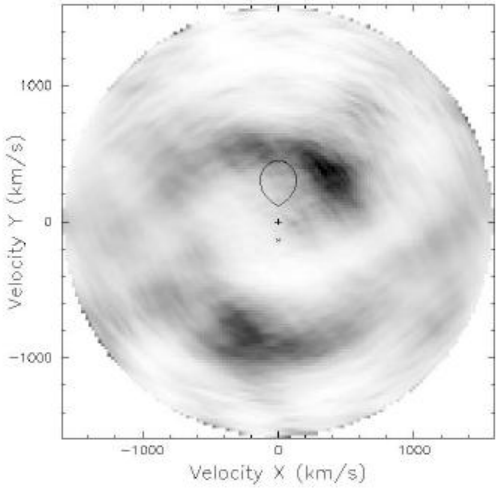
1 Before



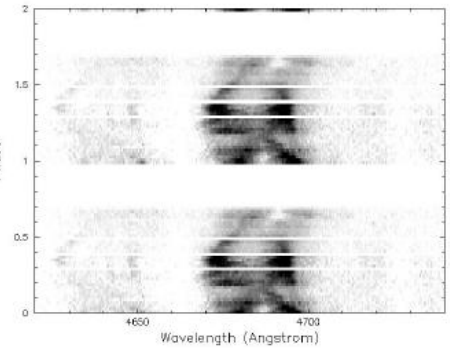


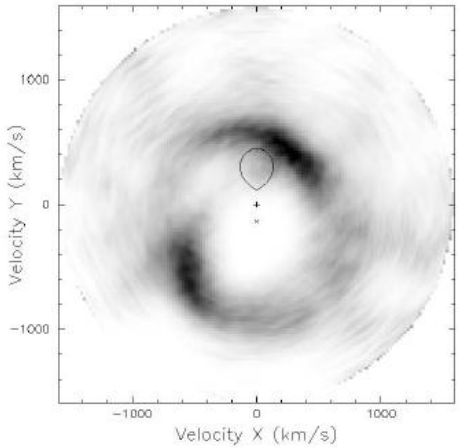
3 At maximum



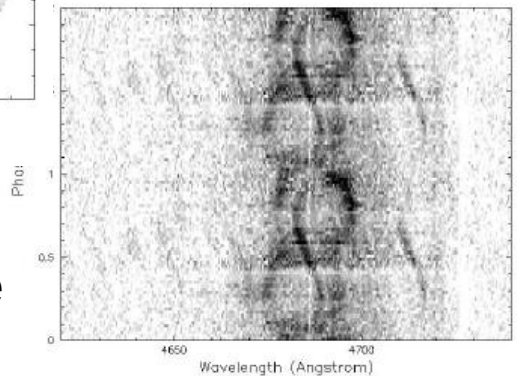


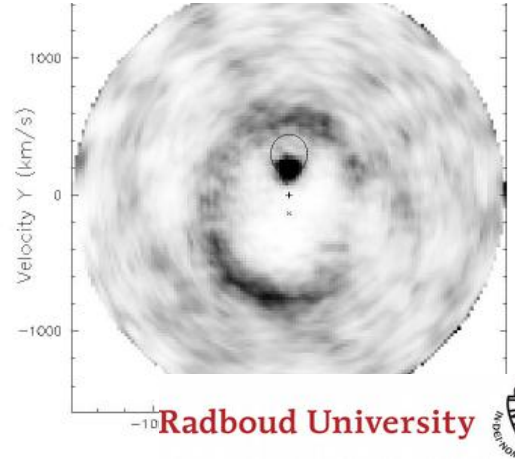
2 At maximum





4 During decline

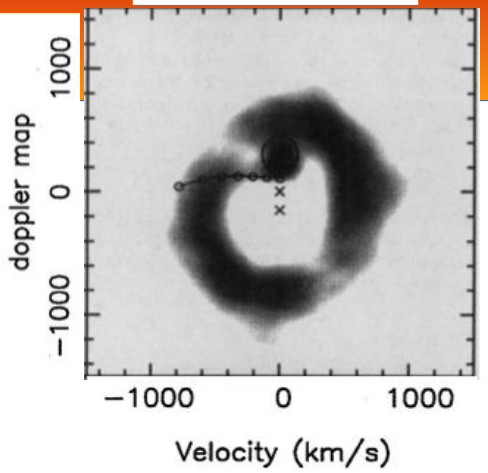




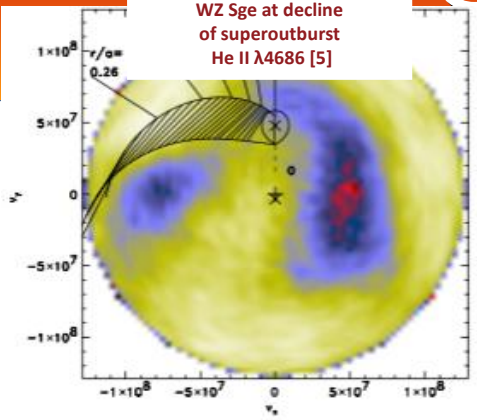
No spirals just before outburst
Little evolution during outburst/decline

Old and

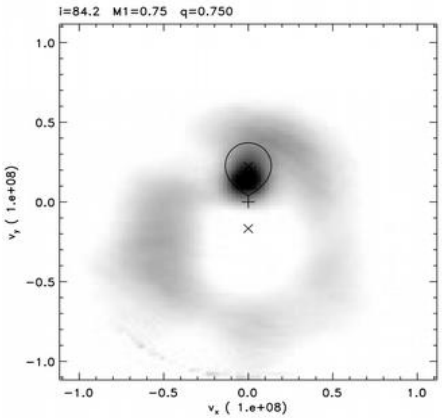
IP Peg at peak
He I λ6678 [1]



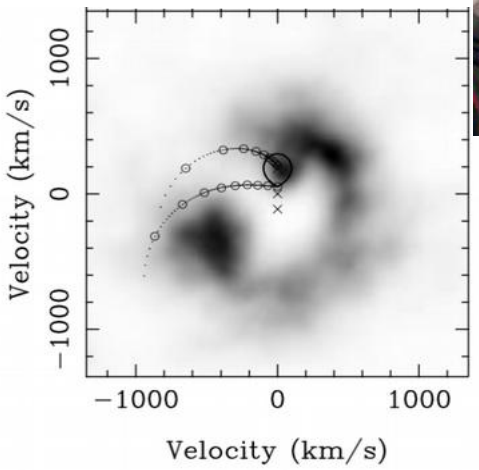
WZ Sge at decline
of superoutburst
He II λ4686 [5]



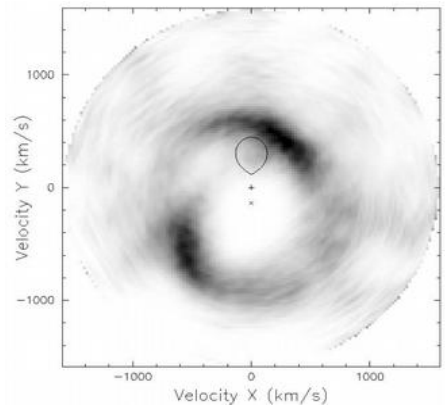
See poster outside!!



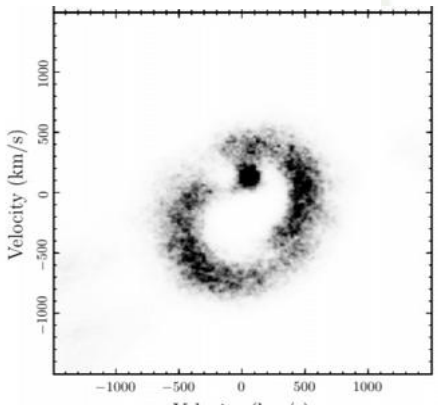
V347 Pup He II λ4686 [6]



U Gem at peak
He II λ4686 [3]

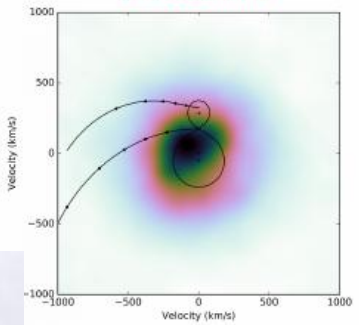


DQ Her in quiescence
He I λ6678 [7]

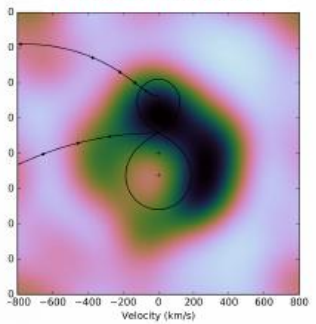


Spirals are rare...

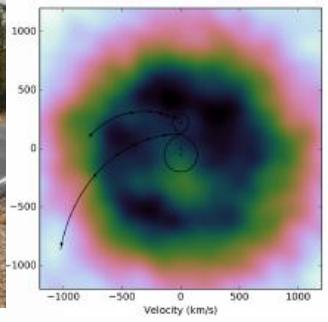
PTFS1118m Hα



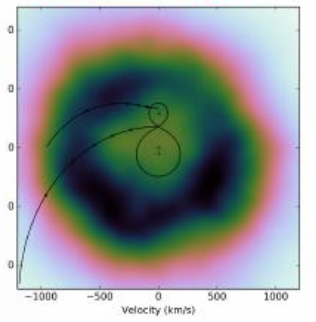
PTFS1122s He I λ7075



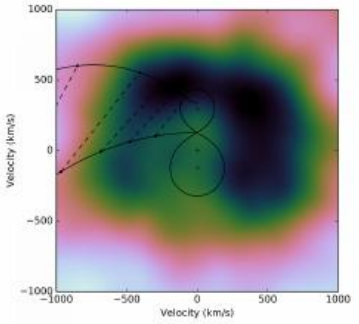
PTFS1115aa He I λ5876



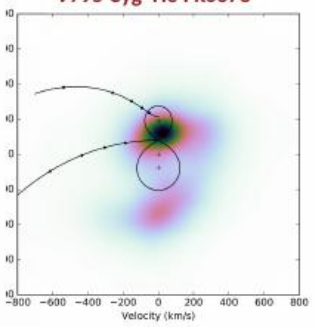
PTFS1117an He I λ5015



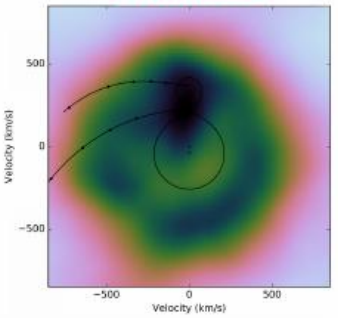
PTFS1200o He I λ6678



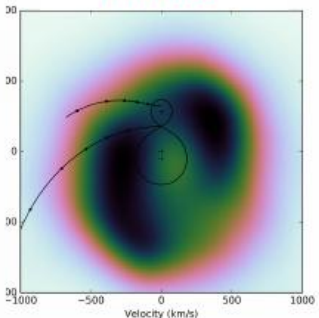
V795 Cyg He I λ6678



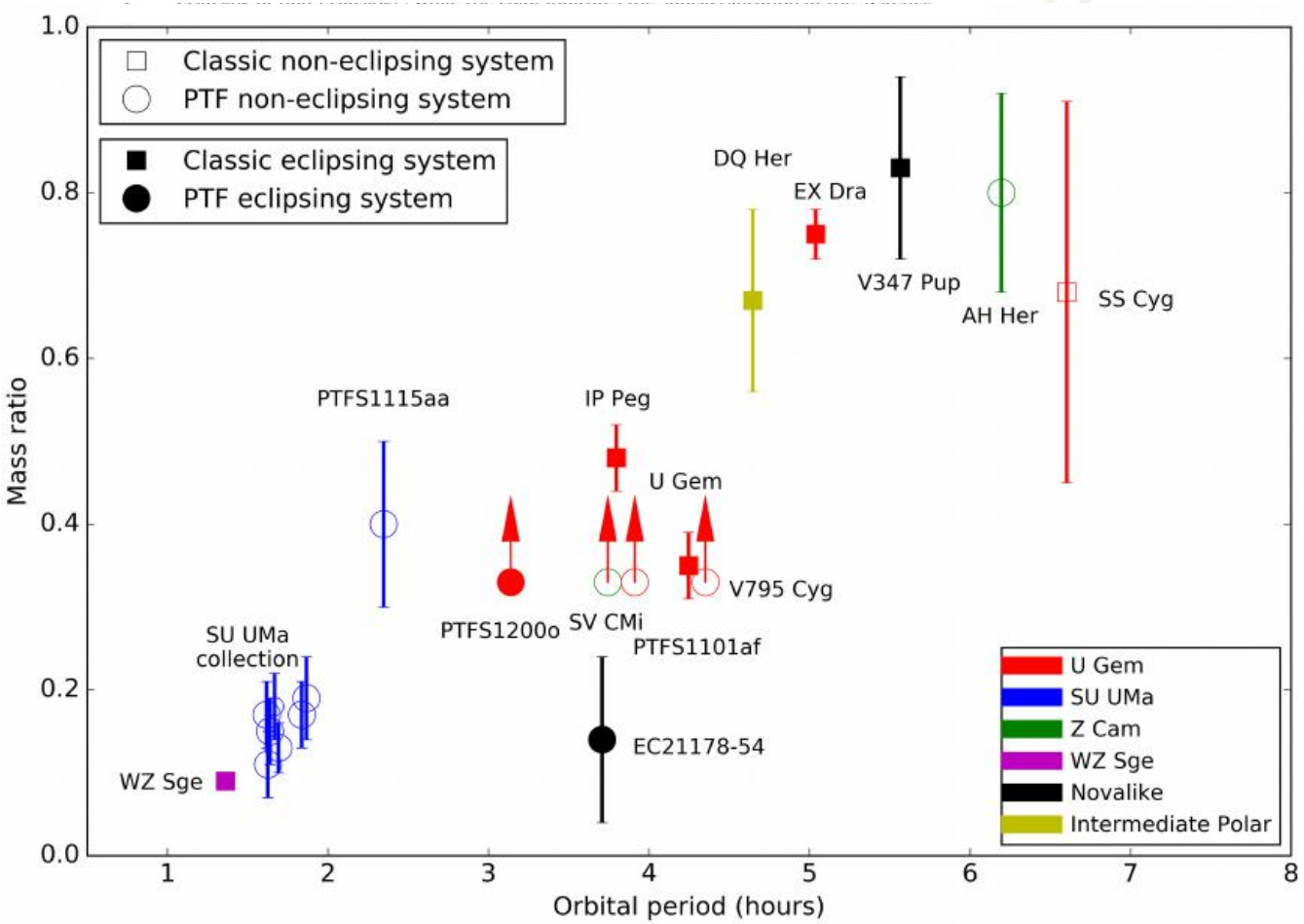
PTFS1215t Hα



EC211178-54
He II λ4686



Old and New sample

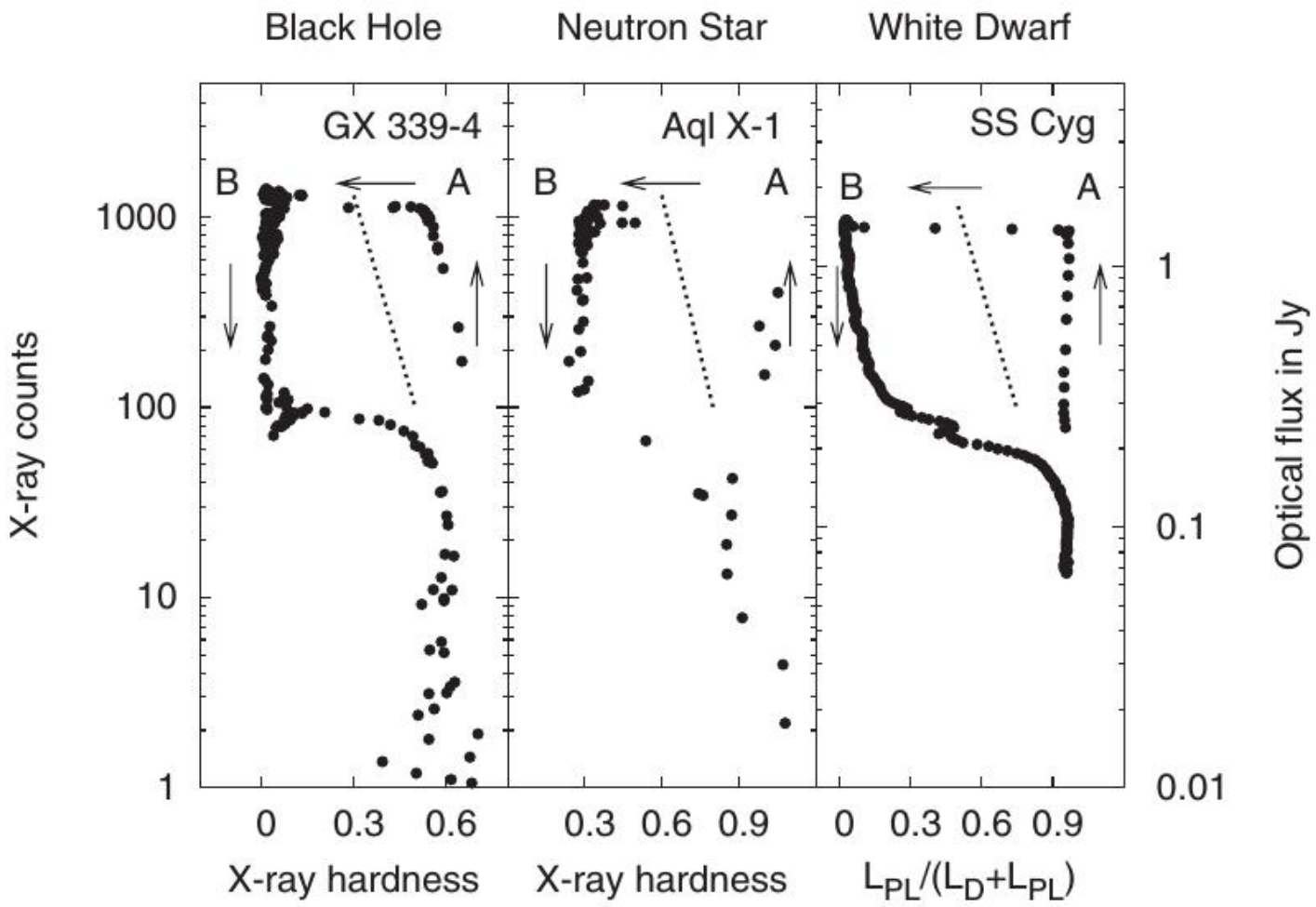


Ruiz-Carmona et al., in prep.

What governs appearance of the spirals?

Inclination?	✘	Mass ratio?	✘
Type?	✘	Primary mass?	~
Period?	✘	HeII emission?	~

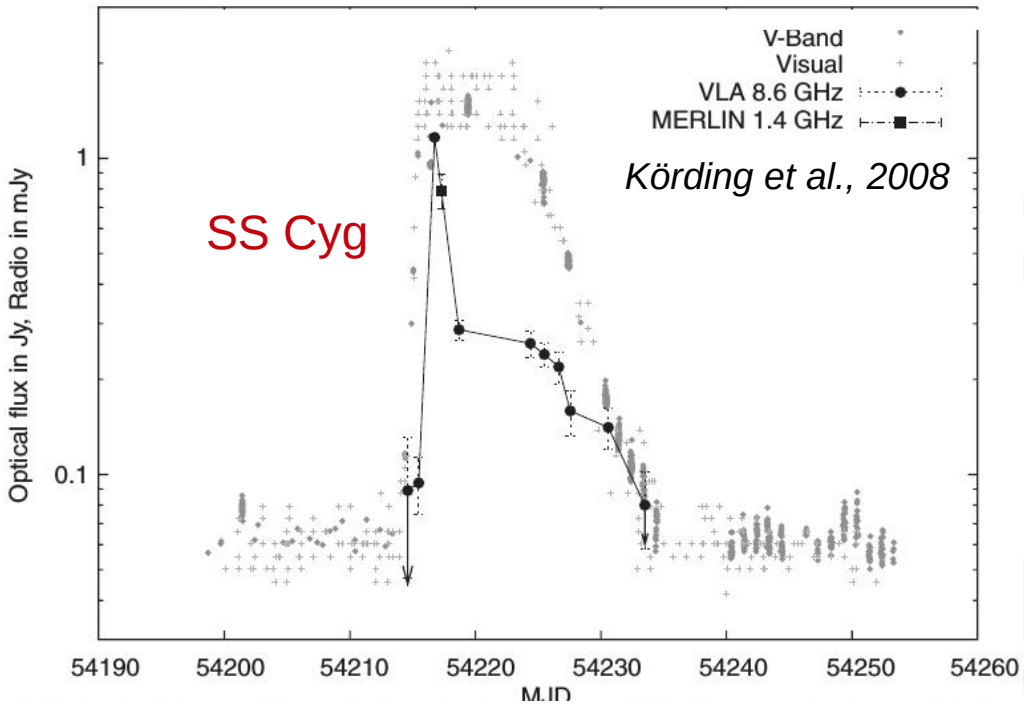
Outflows/Jets during DN outburst

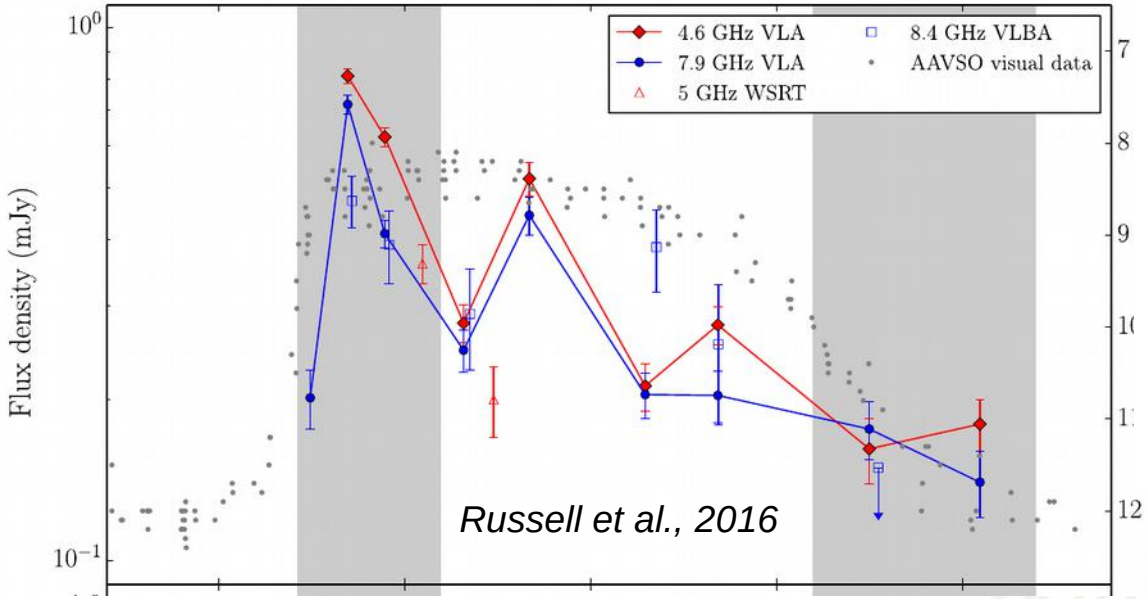


Evolution of outbursts in Black Hole, Neutron Star and White Dwarf systems is globally ***the same*** ***(Körding et al., 2008)***

→ Should lead to (radio) jet launcing from inner disk at start outburst

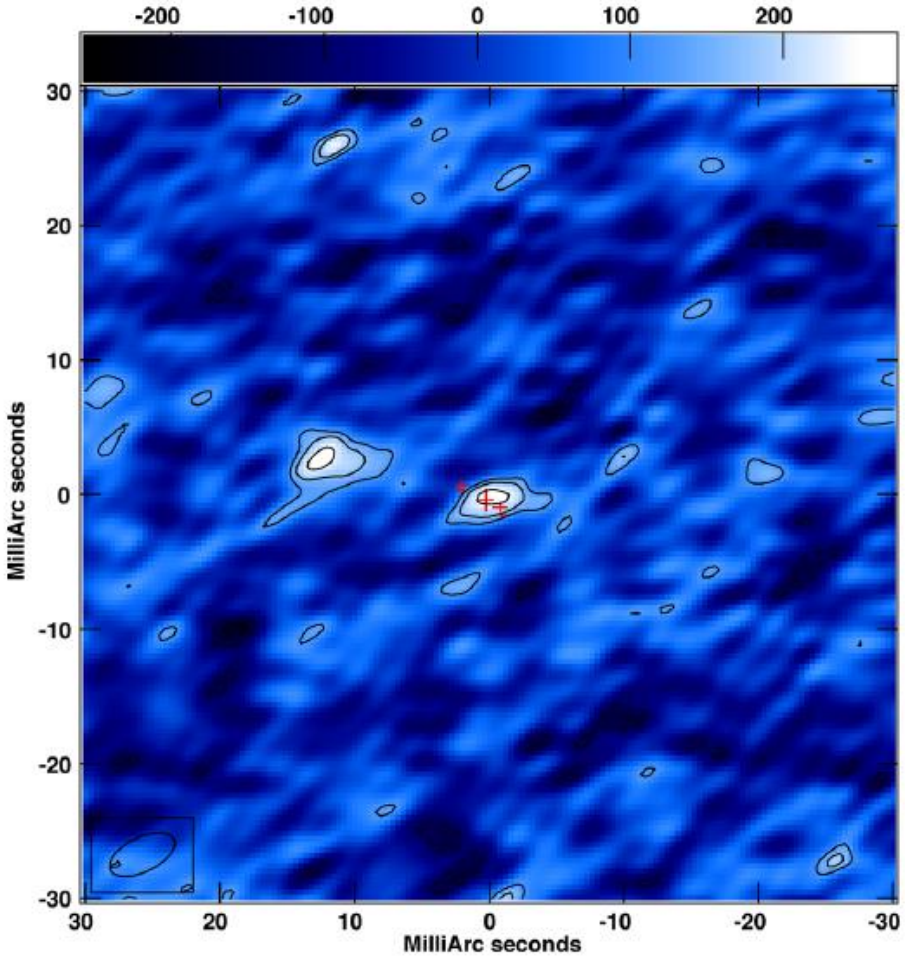
Outflows/Jets during DN outburst





SS Cygni certainly does it:

Reproducible emission: yes
Jet: maybe

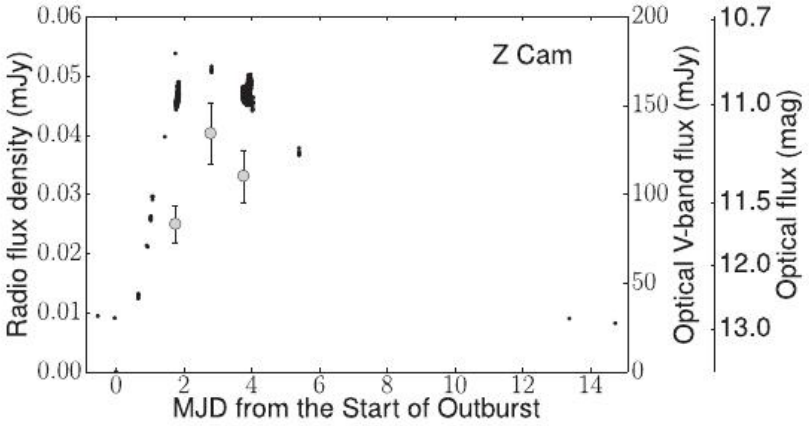


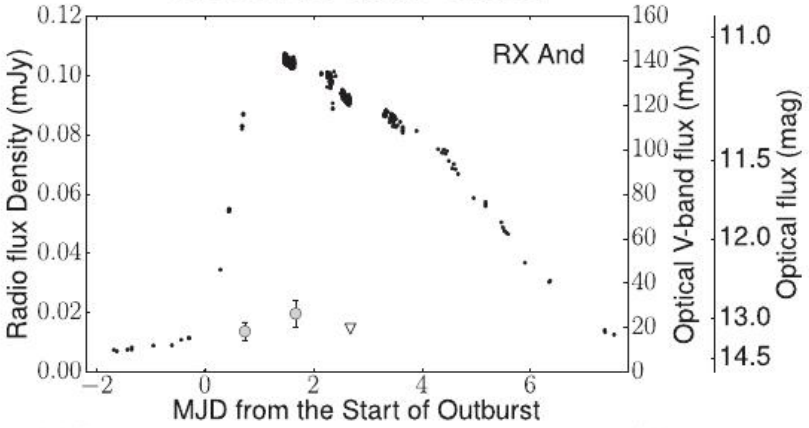
Russell et al., 2016

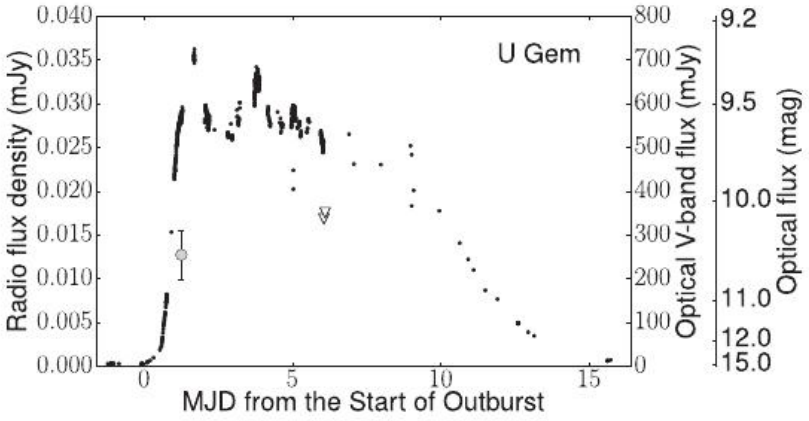
Oddball or ***common***?

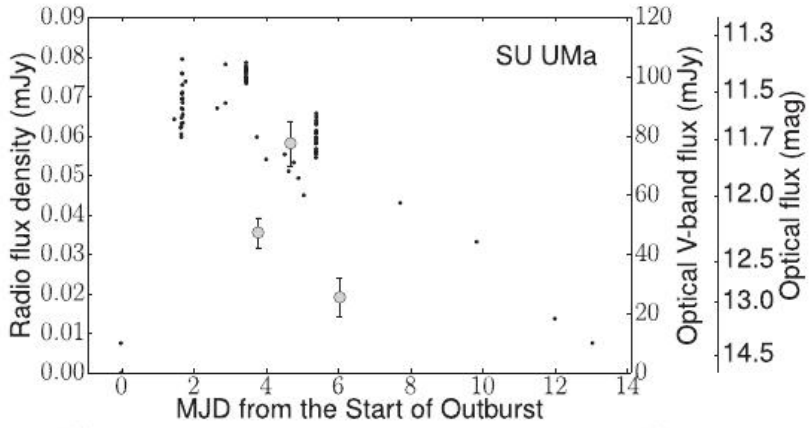
Radio emission in dwarf novae during outburst:
5 out of 5 detected with VLA

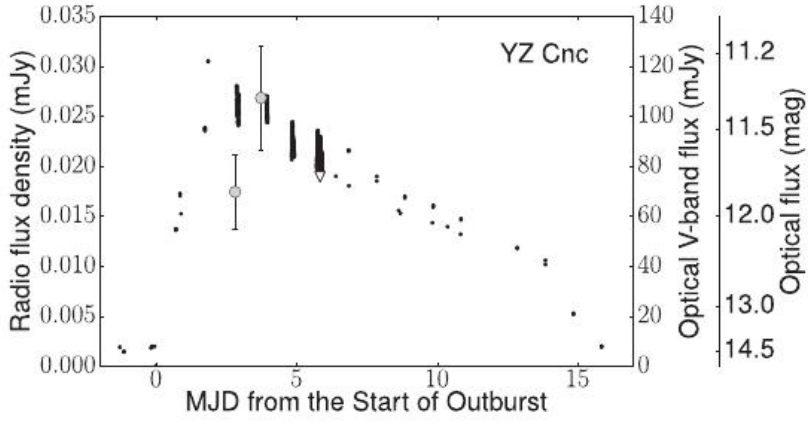
Deanne Coppejans et al. 2016









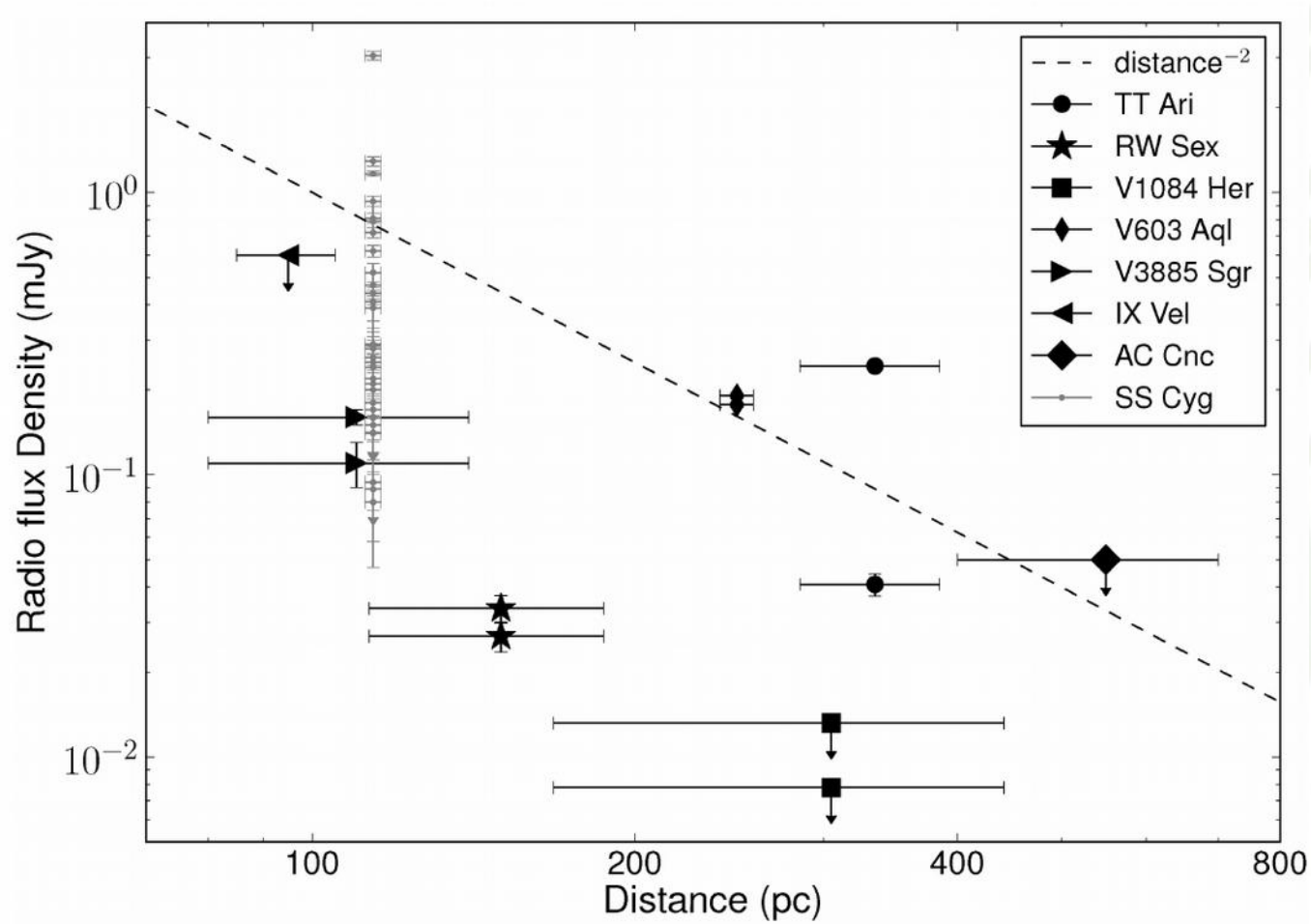


Oddball or ***common***?

Novalike CV are ***also*** significant emitters!
4 out of 5 detected with VLA

Deanne Coppejans et al., 2015

Spectral indices are all over the place. No clear picture yet.



MeerKAT & MeerLICHT

Situation soon to change: MeerKAT Radio array coming online
MeerLICHT optical telescope to be twinned to MeerKAT. Both operational in 2017

MeerKAT: 64 dishes , now 24+ operational
MeerLICHT: 65cm wide-field (2.7 sqd) telescope at 0.56”/pix

BlackGEM

Synoptic Survey Array at ESO La Silla
Phase 1: 3 telescopes, start 2018
Phase 2: 15 telescopes, start 2020(?)

Radboud Universiteit

Phase 1:
- 3 wide field telescopes
- 8 square degrees total
- 65cm diameter each
- g=23 in 5 minutes
- ESO La Silla
- Seeing limited (<1")
- *u,g,q,r,i,z* filter set
  ("PTF South" / "Proto-LSST")

Phase 2:
- Expansion to 15 telescopes
- 40 square degrees
  ("ZTF South")

Science:
- ***GW counterparts***
- Southern Sloan
- Fast Transients & Variables
- Nearby Universe Survey