UV Observations of Cataclysmic Variables and their role in multiband studies

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&

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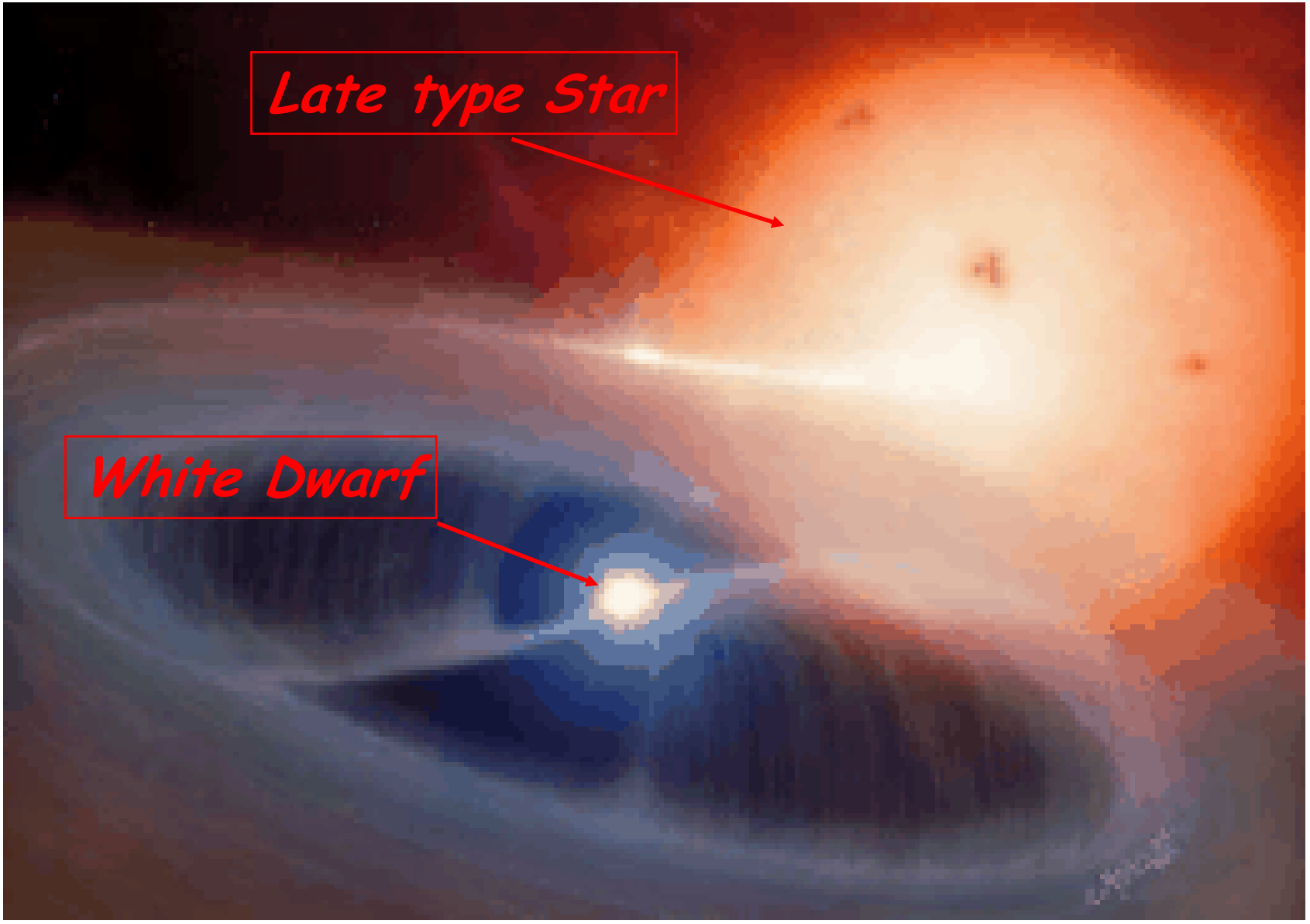
Outline

Hot topics:

- CV Evolution
- Magnetism in White Dwarfs
- Accretion and outflows
- Stellar Properties
- WD Pulsators in CVs

- CVs in clusters
- Contribution to galactic X-ray population


Late type Star
White Dwarf

Questions on CV Evolution

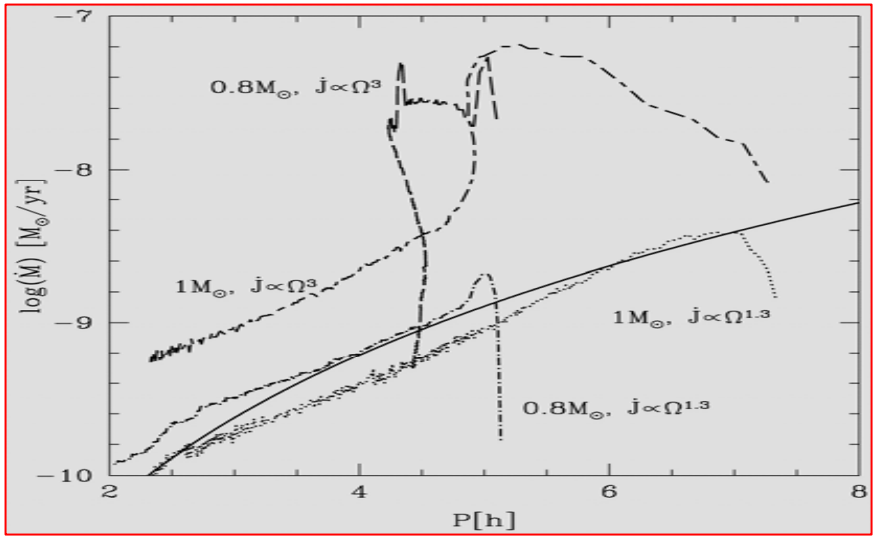
- **Angular Momentum Loss mechanisms?**

Standard Theory: - Magnetic Braking (Porb>3hr)

- Gravitational Radiation (Porb<2hr)

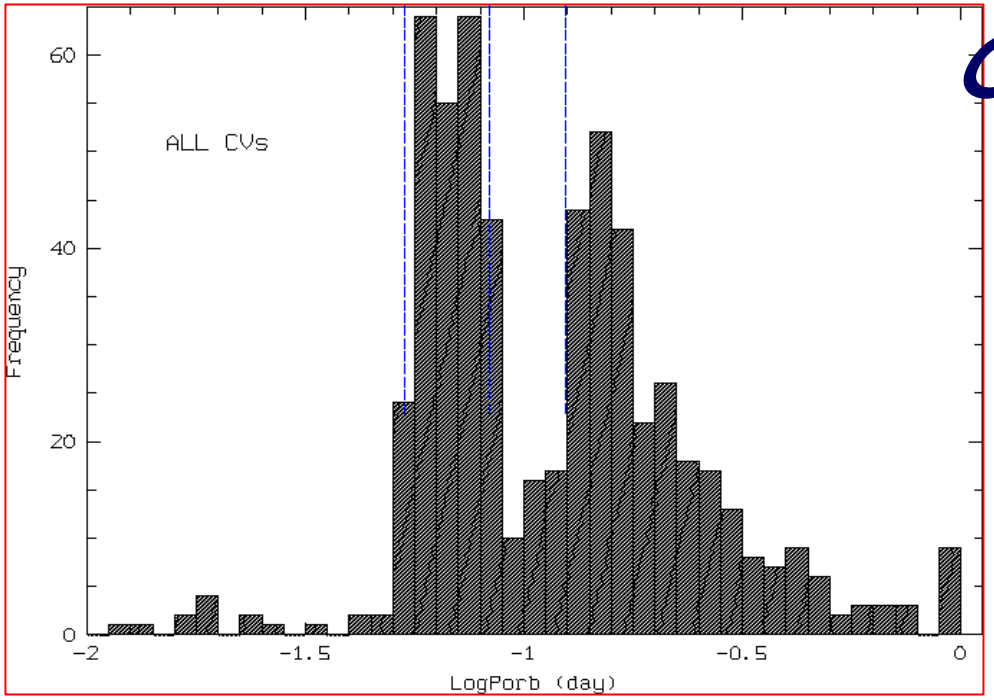
Rappaport et al. 1983; Patterson 1984; Kolb 1993; Sills et al. 2000;Ivanova&Taam, 2003

AML drives evolution



From Ivanova &Taam, 2003

Observed Orbital Period Distribution



OK 2-3hr GAP

BUT

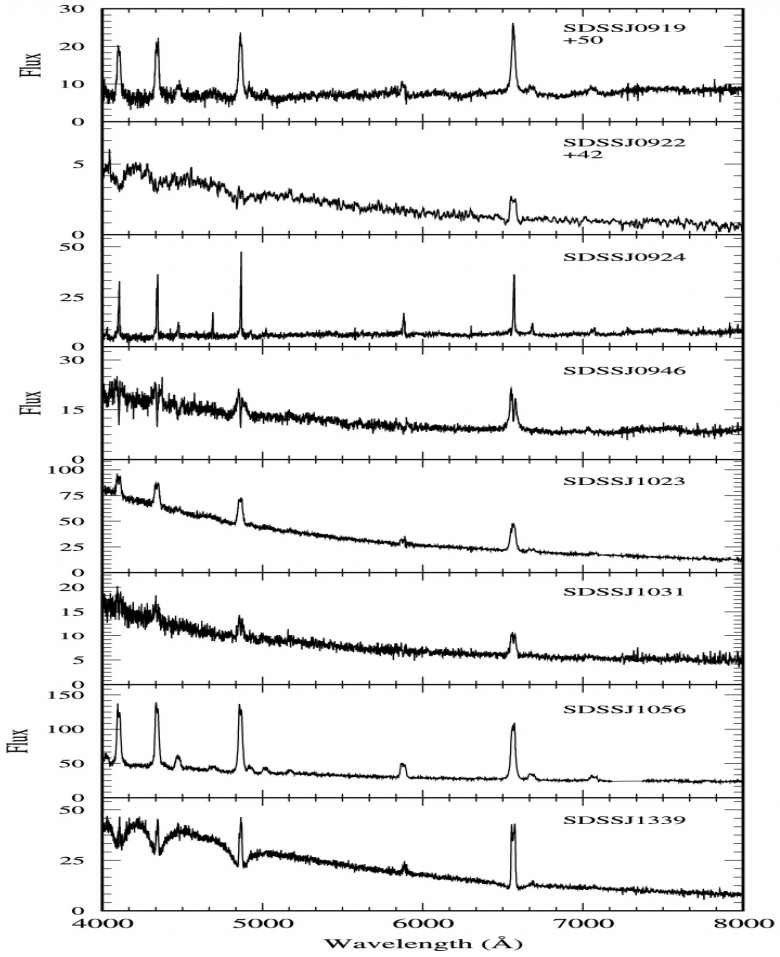
→ 99% present day CVs should be @ Porb<2hr!

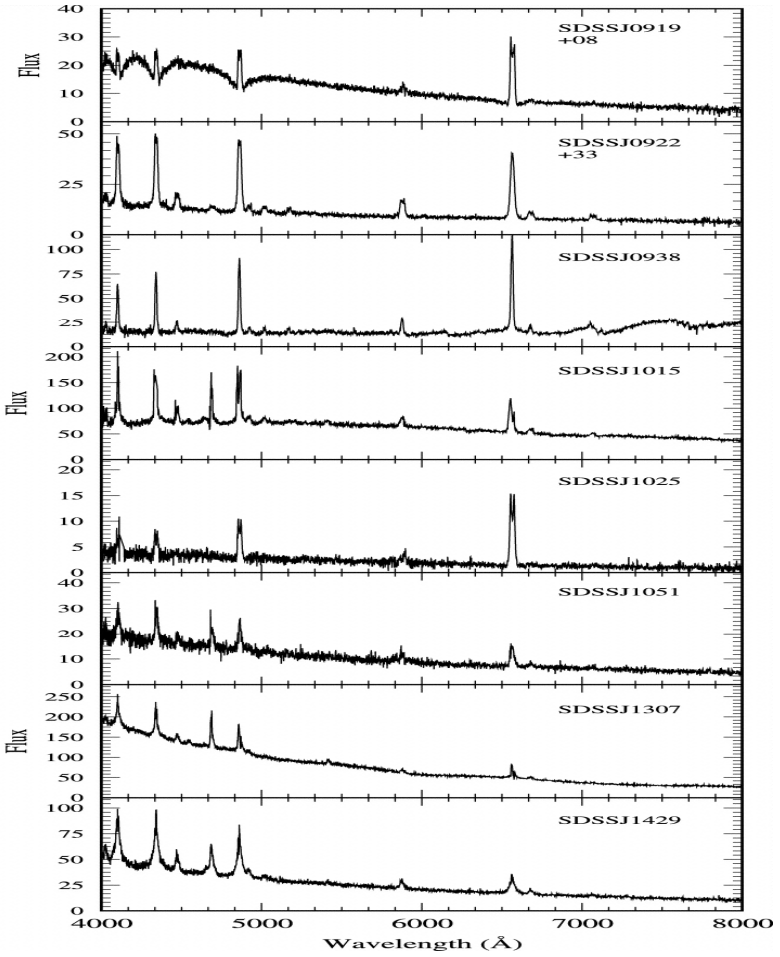
→ P_{min}(obs)≠ 80min > P_{min}(th)≠65min

SELECTION EFFECTS

Search for the missing population in:

- **Optical Deep Surveys (Sloan: Szkody et al. 2001,2002,..2006)**



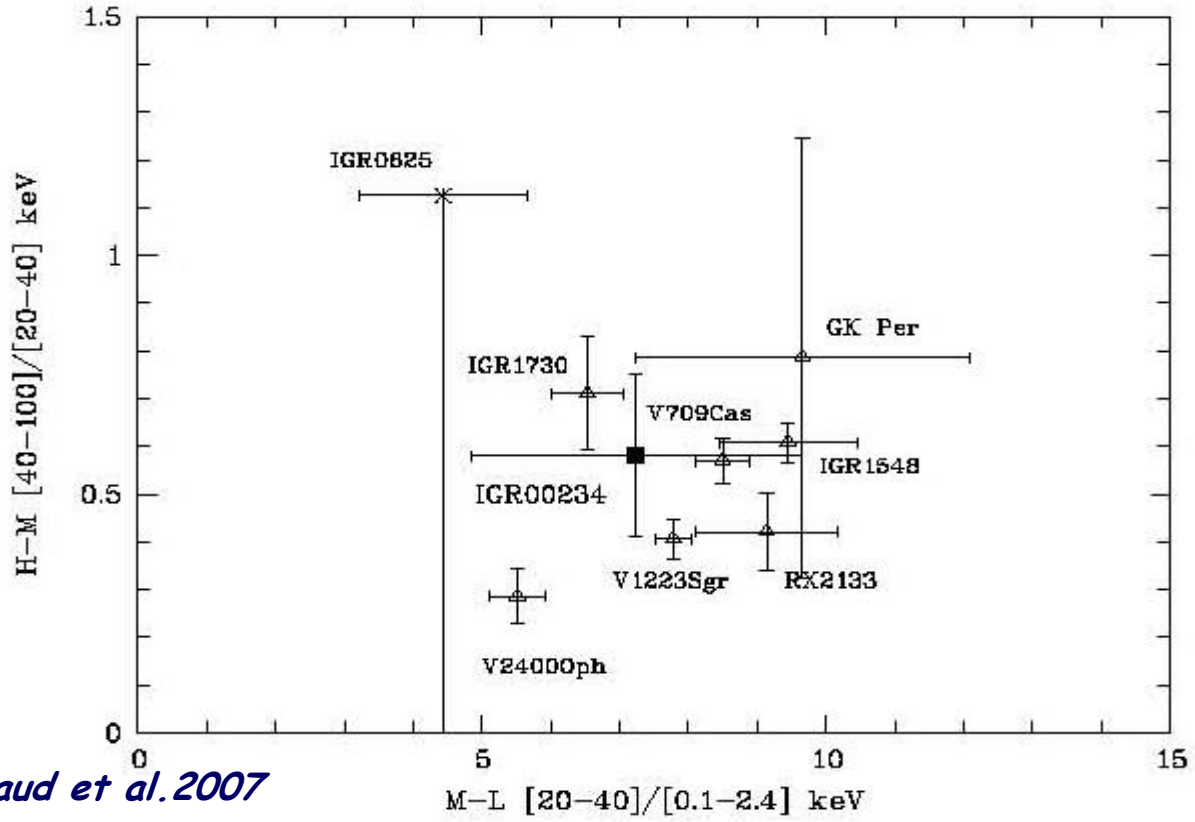


Search for the missing population in:

- **X-Ray Surveys:**

  ROSAT - Soft Sources *(Voges et al. 1999)*

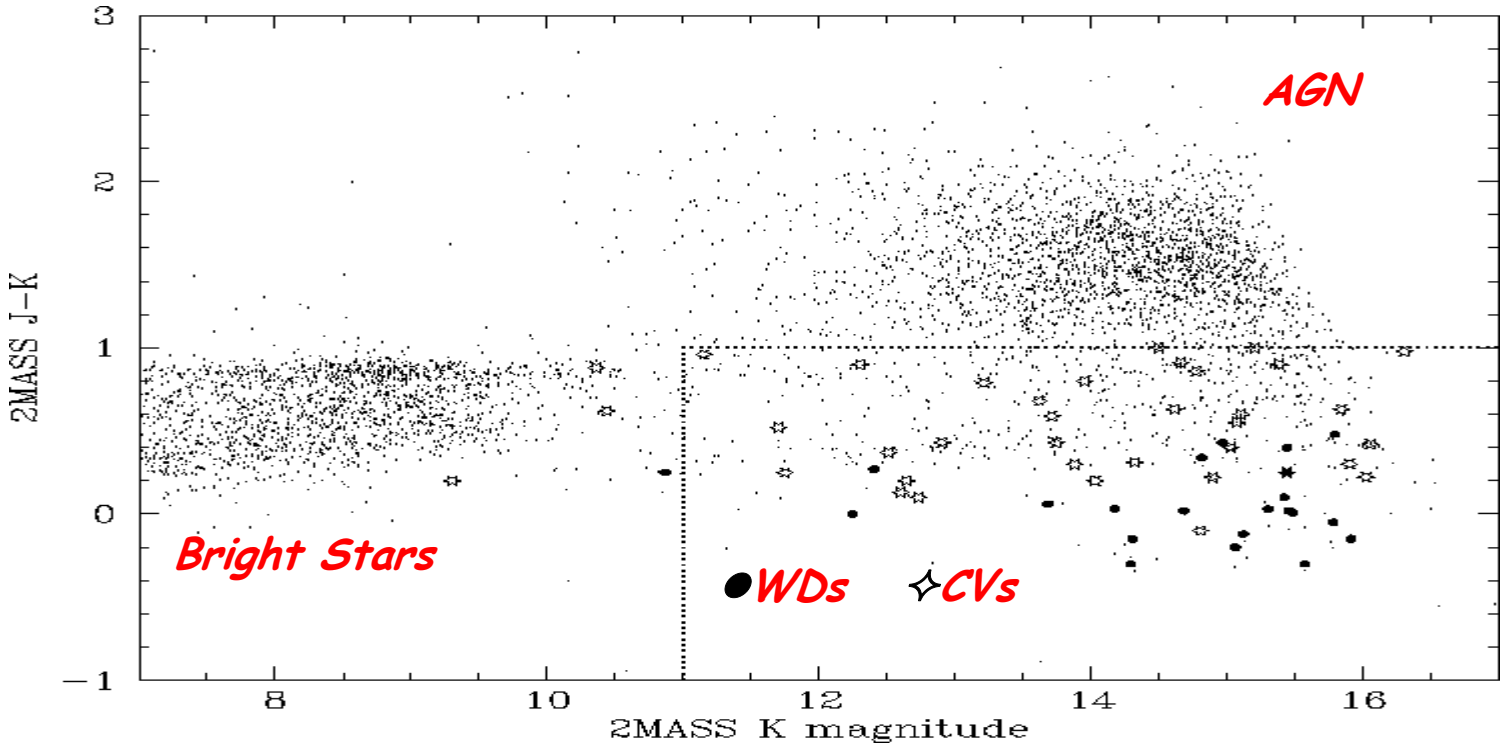
  Integral, Swift - Hard Sources *(e.g. Bird et al. 2006)*



From Bonnet-Bidaud et al.2007

Search for the CV population in:

- IR Surveys (2MASS vs ROSAT Gaensicke et al. 2005)



Understanding CV Evolution

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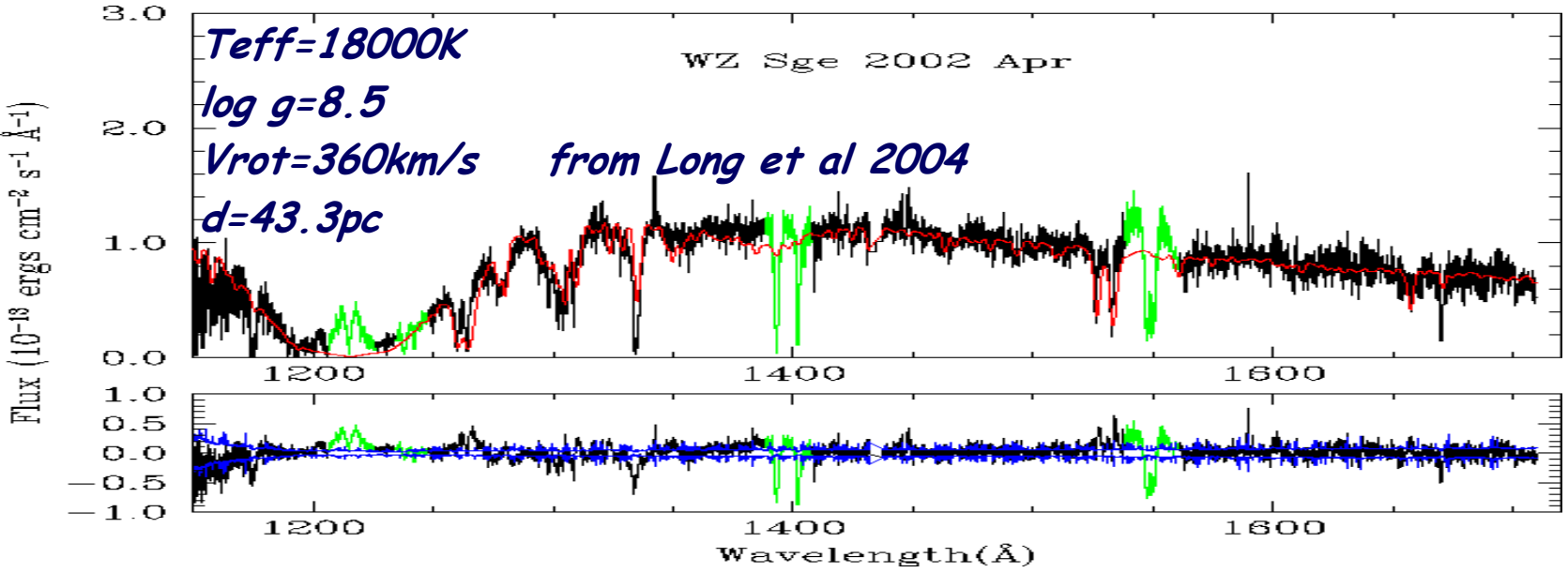
Binary components properties

Study of WD properties difficult in the optical

but

easier in the UV!

Teff, log g, Vrot, Abundances from WD model fits



But not always easy….

Modelling of Accretion Discs to be included:

Optically thick discs (TLUSDISK -Hubeny & Lanz 1995) + WD:

V436 Cen

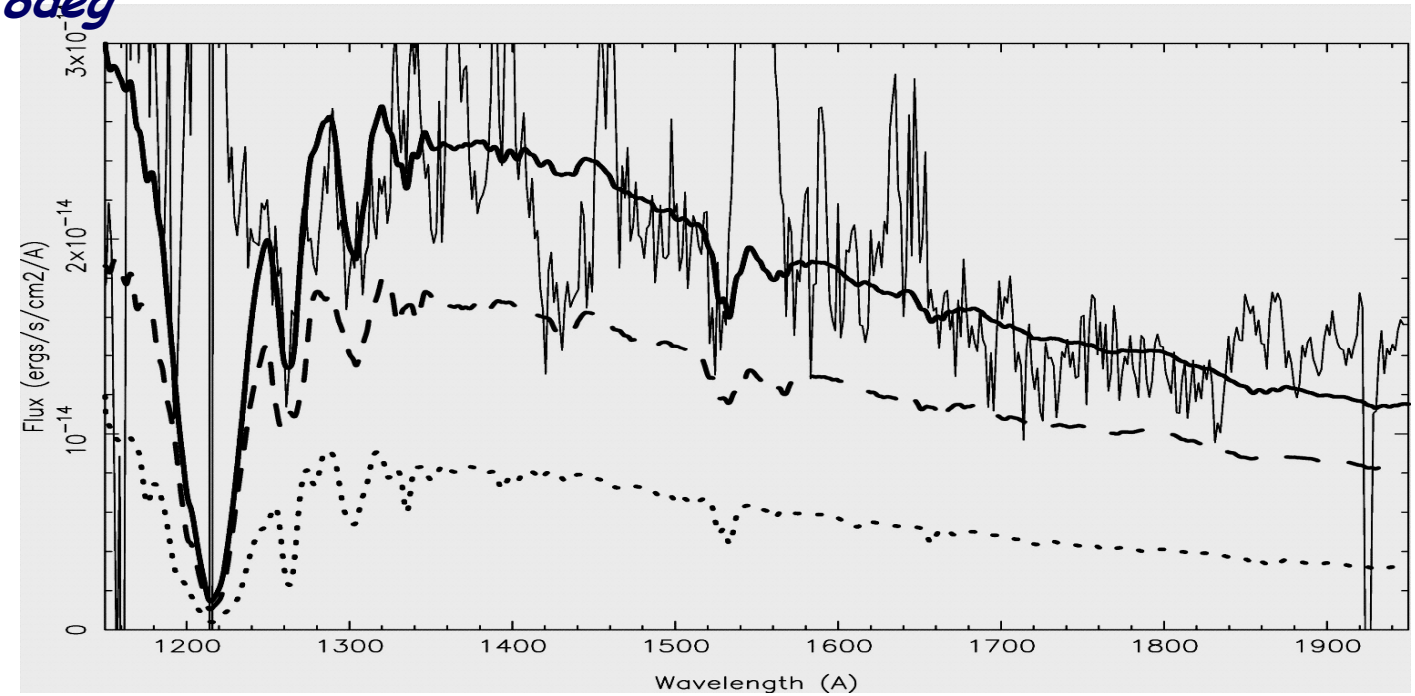
Teff=24000K

log g=8.3

Mdot=8E-11 Msun/yr

i=18deg

from IUE Urban & Sion 2006

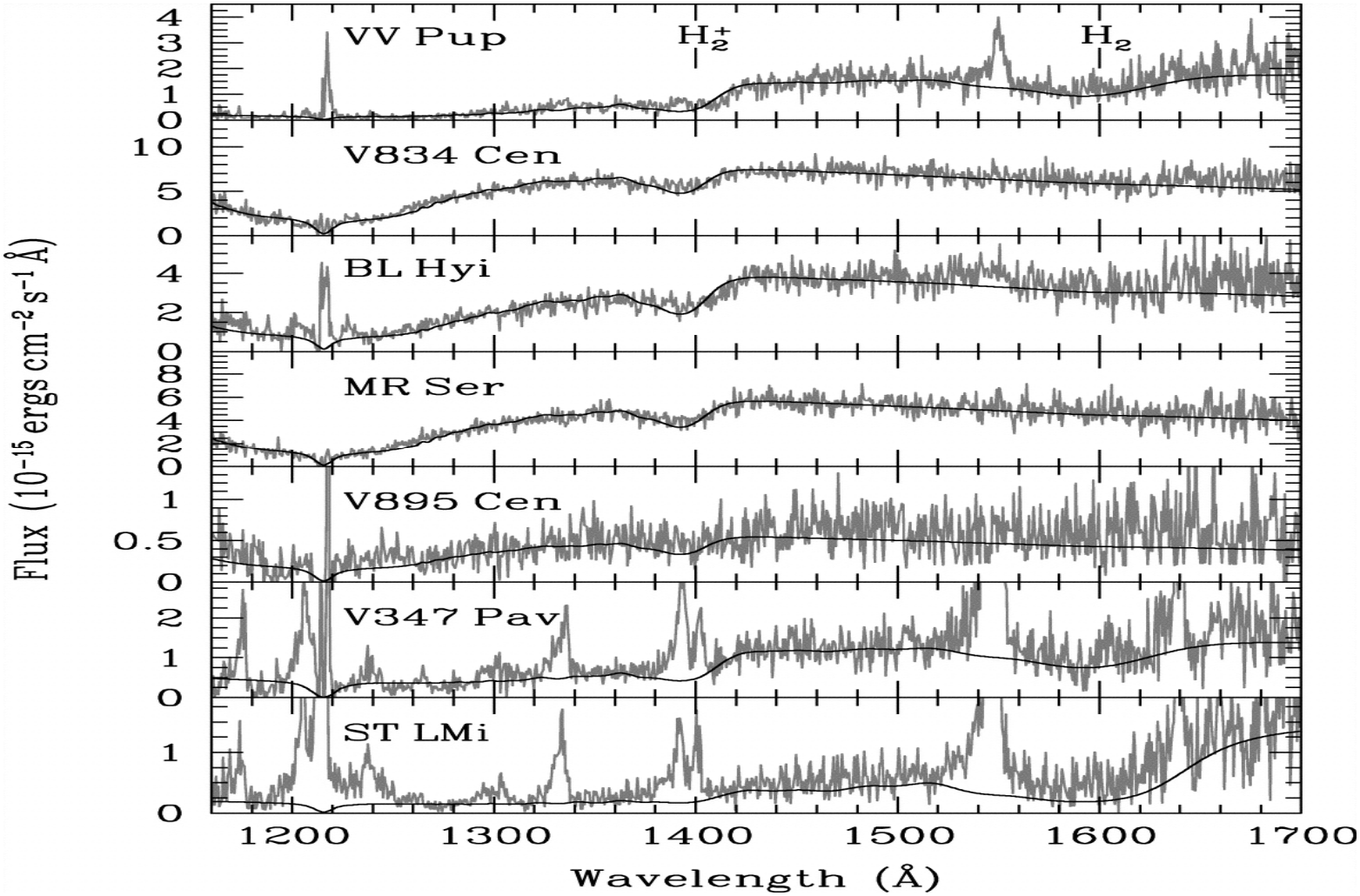


….& in Magnetic CVs….

but

No WD Signatures in high state

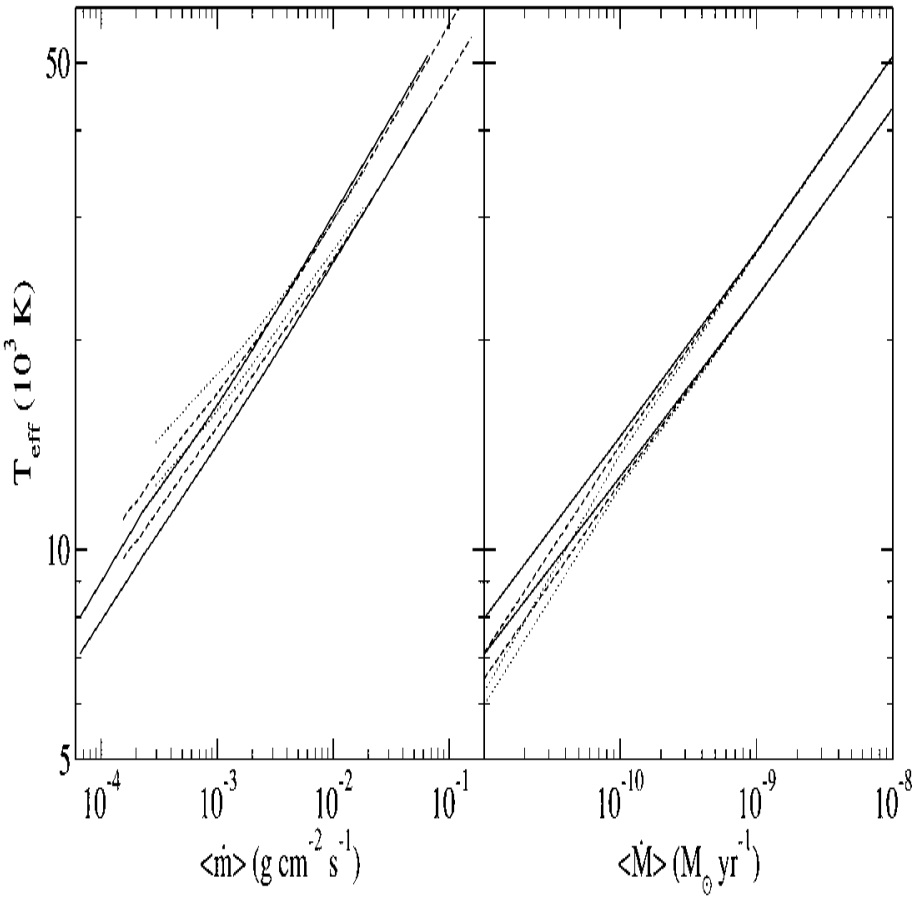
in low state models require 2 WD components

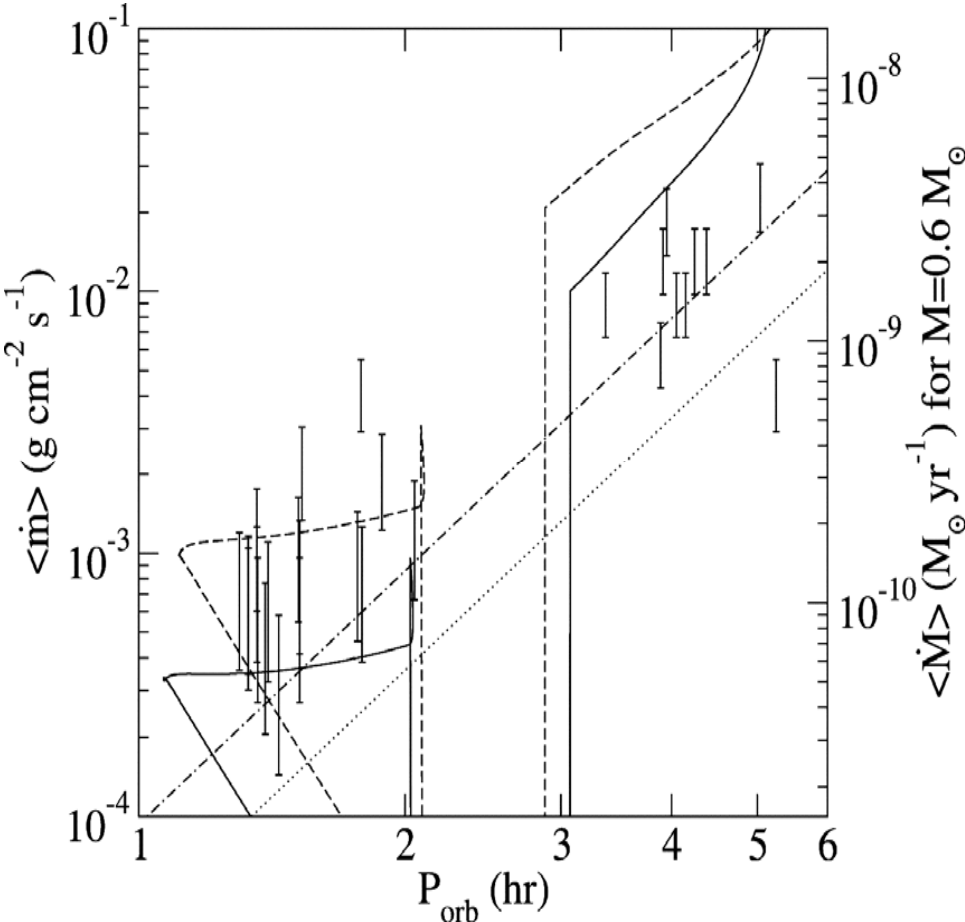


From Araujo-Betancor et al. 2005

WDs Probe Accretion history

- WD Teff can be used to test predictions
- Mass Accretion rate decreases by 10 below Gap

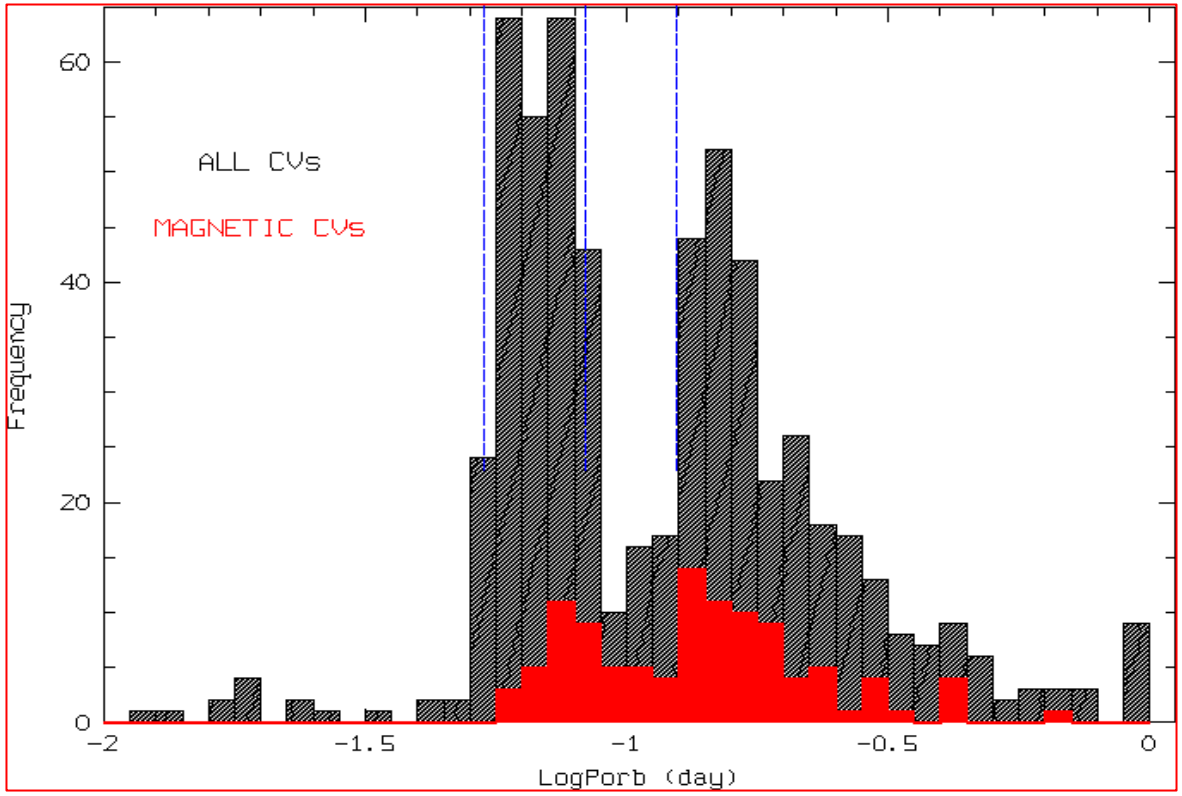




From Townsley & Bildstein 2003 using Teff from Winter & Sion 2003

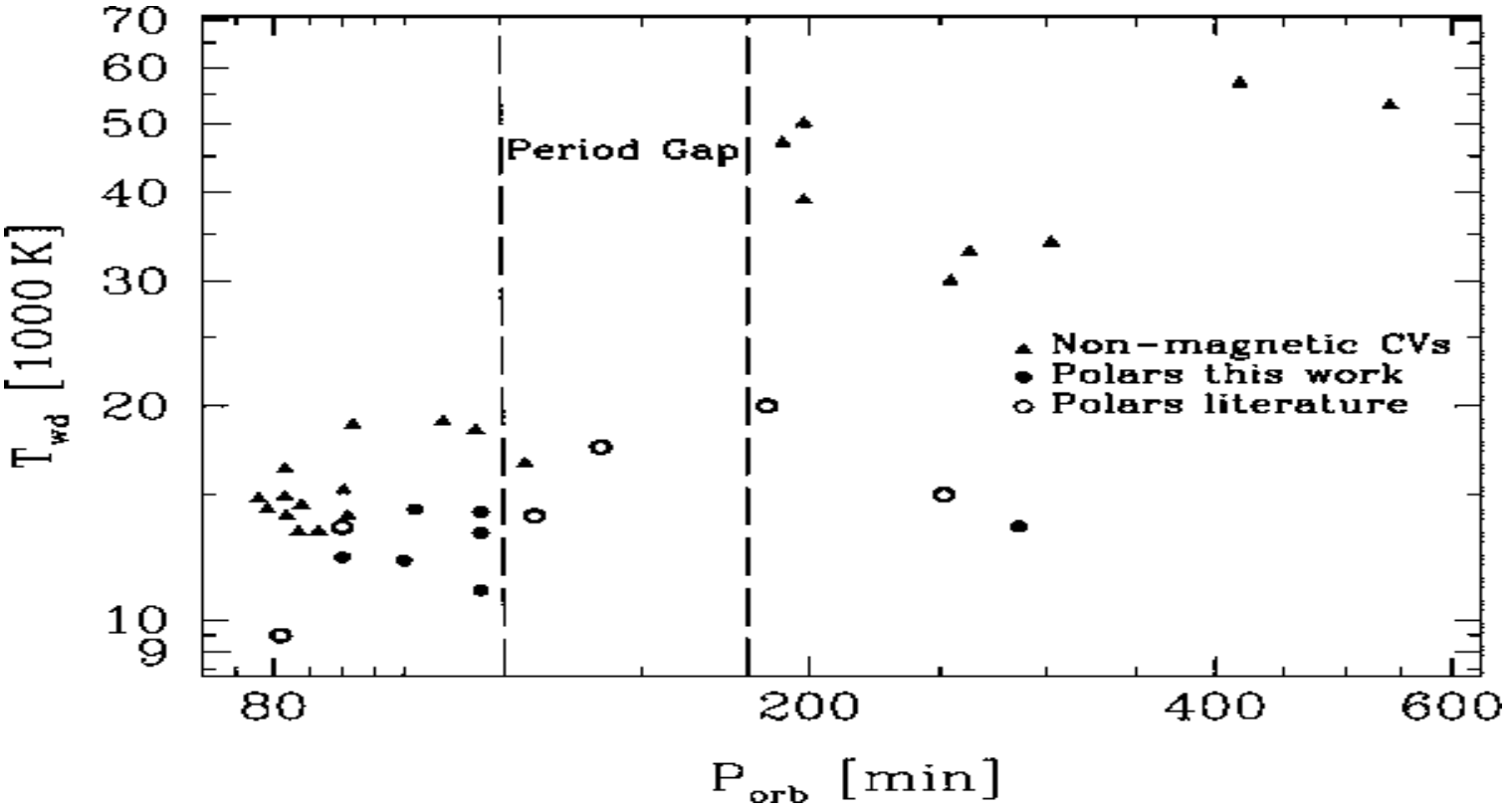
Evolution:influence of magnetic fields

MCVs≠25% of all CVs against MWDs≠10% of all WDs



Why MCVs overabundant?

- *Selection effects: MCVs bright sources in X-ray surveys*
- *Reduced Magnetic Braking (Lee & Wickramasinghe 1998)*



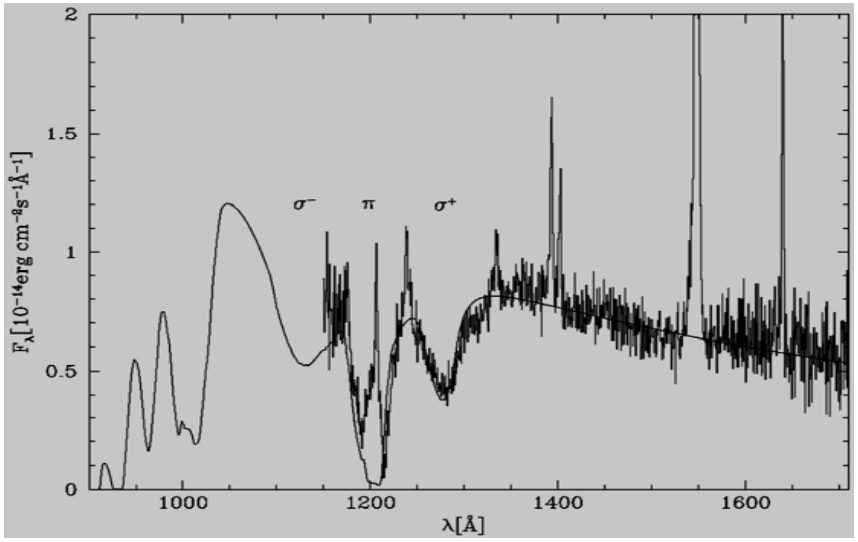
Lower accretion rates in MCVs (From HST/STIS Araujo-Betancor et al.2005)

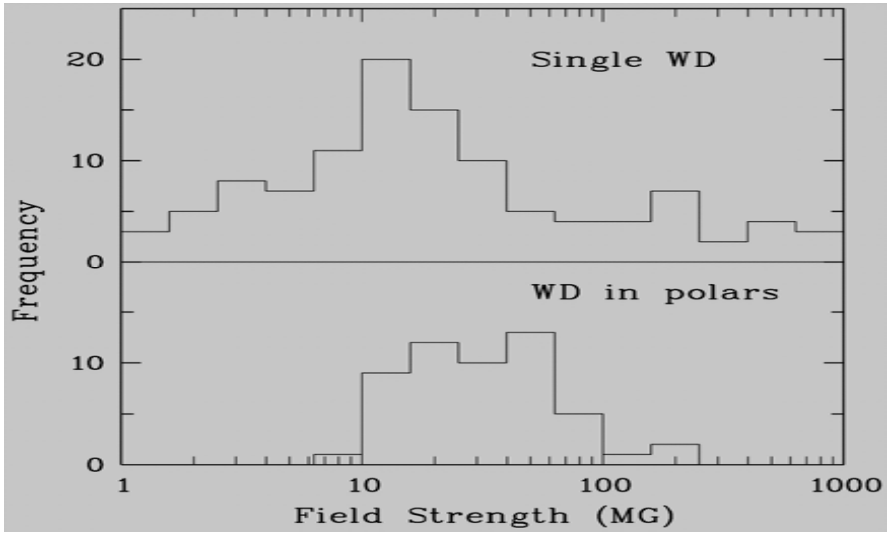
-> Longer evolutionary timescales

->Overabundance of MCVs

Magnetic fields in CVs

- High field CVs emit cyclotron radiation in optical/nIR
- In low states Zeeman components might be detected
- High (B>100MG) can be detected in the UV!



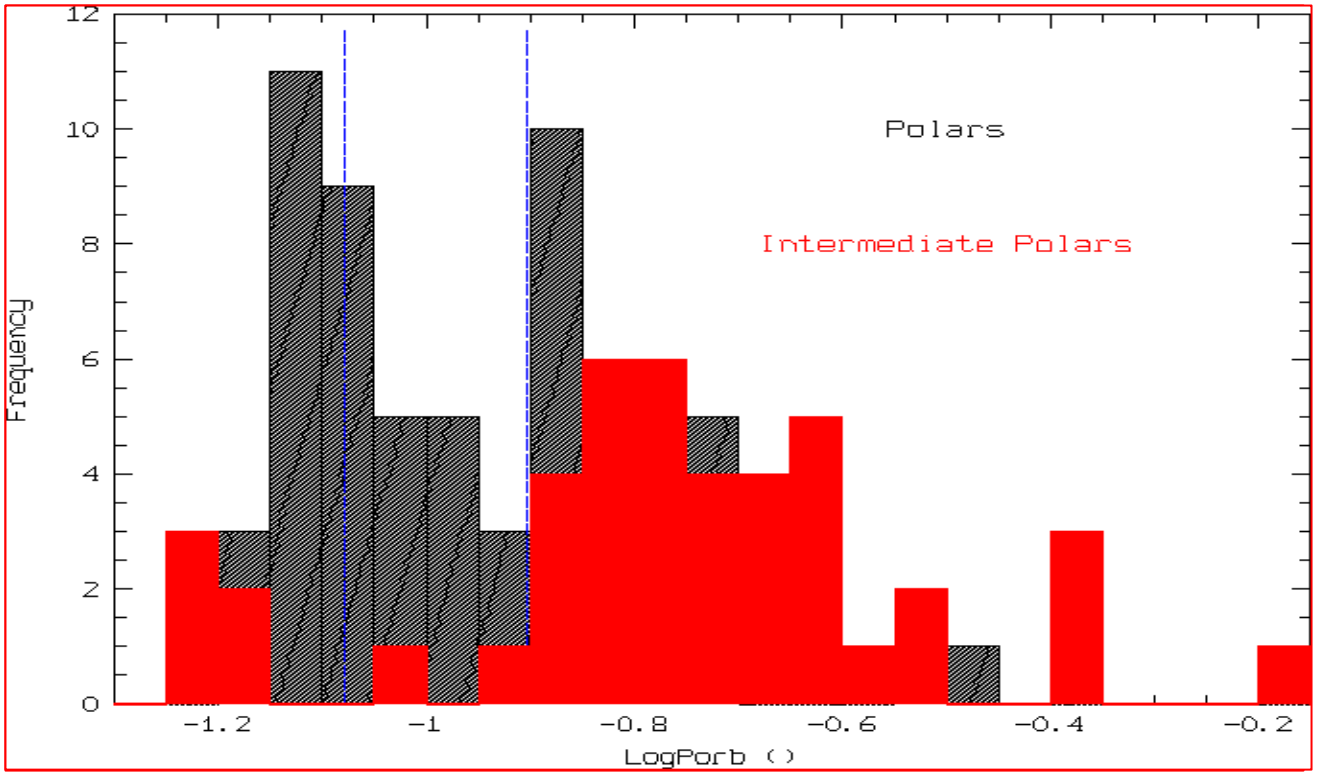


TwdC⋆20000K Log g=8.0 Bwd✡144MG From HST/STIS Gaensicke et al. 2004

- Only 3 high B (>100MG) CVs found so far
- Still lot of work to be done in UV!

Two MCV Groups

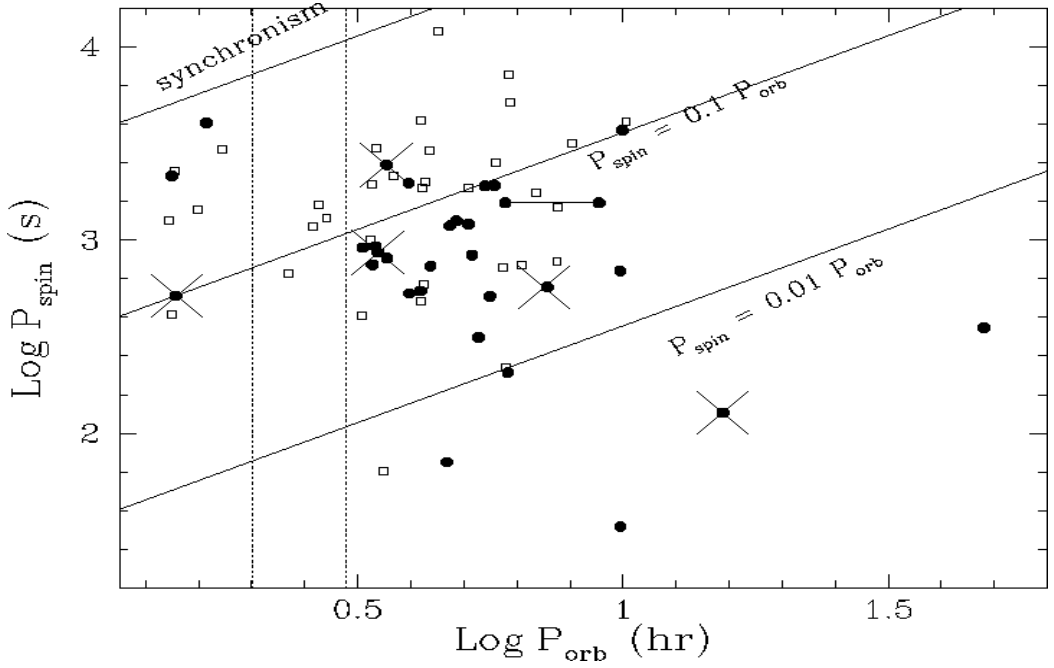
- *Polars: high field CV (B>10MG)*
- *Intermediate Polars (IPs): Low field (B<10MG) or progenitors?*



Do IPs evolve towards synchronism?

Current census of mCVs: Polars(63%) -IPs (37%)
Clustering around Pspin/Porb=0.10
Selection effects: Soft X-ray Surveys, long Porb?
Wide range of asynchronisms including new candidates
- IPs increased ✠50% in the last 4 yrs! More to come with Integral, Swift surveys

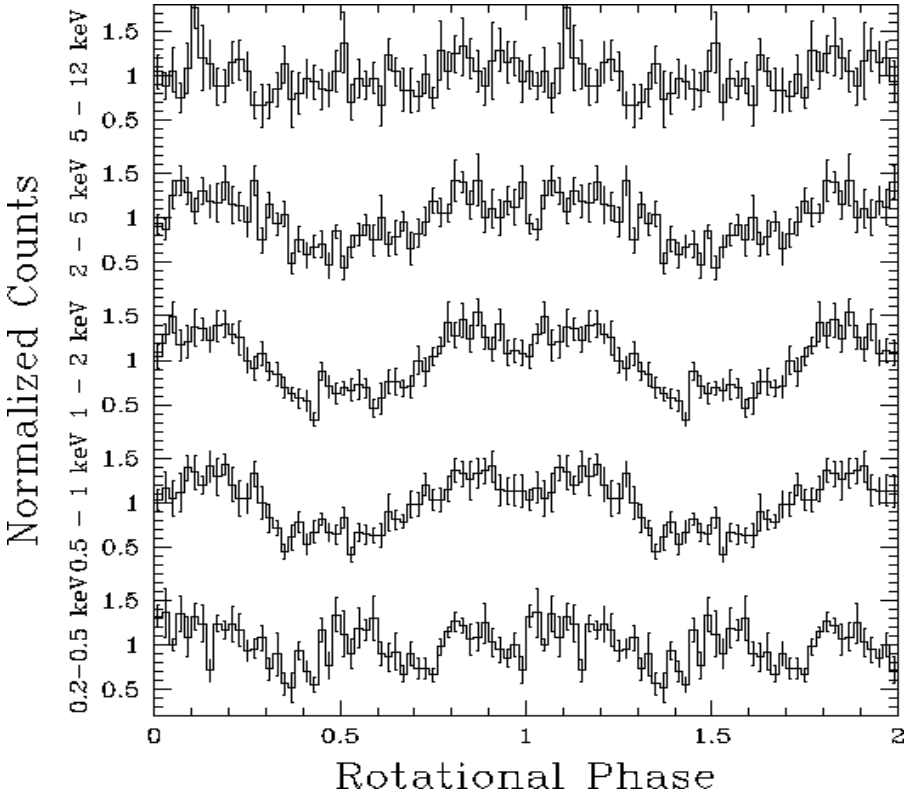
Evolutionary link still unclear!

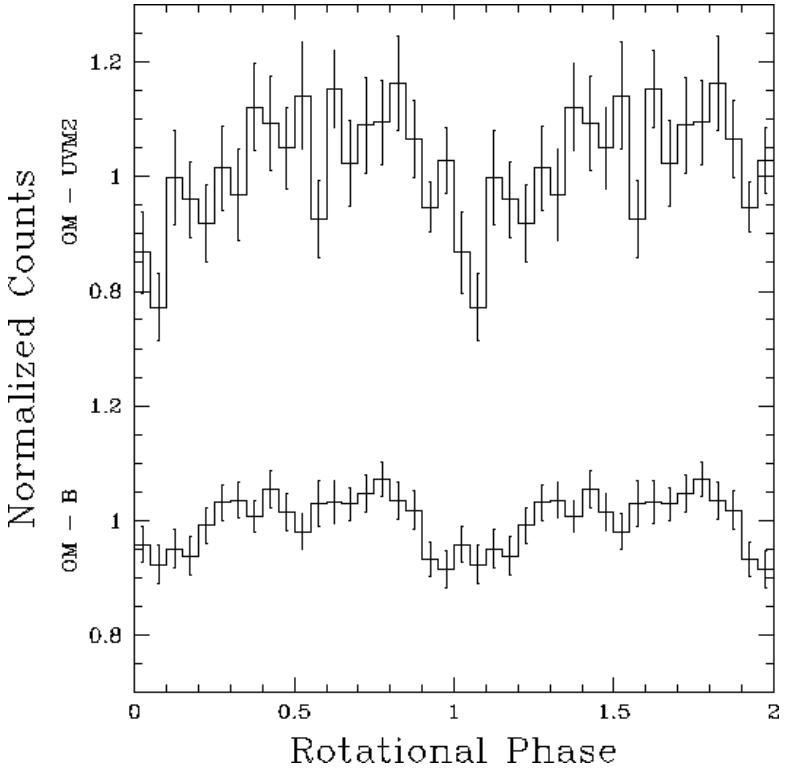


- Confirmed
- Candidates
- de Martino 2007

Magnetic Accretion in CVs

Energy dependent structured pulsations provide constraints on primary and reprocessed radiation



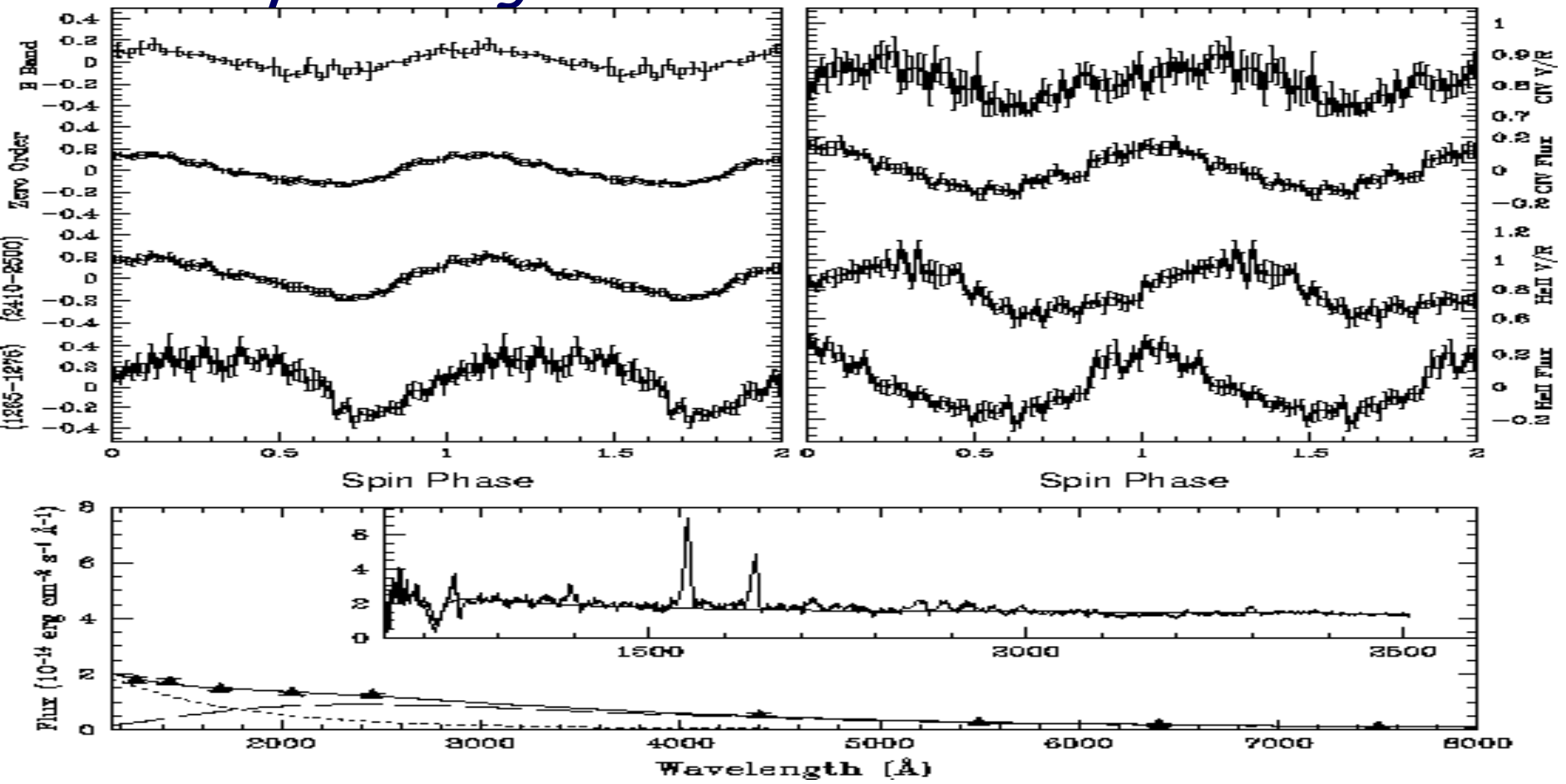


XMM-Newton simultaneous X-Ray and UV-Optical light curves show reprocessing at WD surface in some systems (de Martino et al. 2006)

UV Pulses trace X-ray reprocessing

UV-Optical Light Curves

Line flux and V/R curves



Pulse spectrum is multi-component: multi-temperature accretion flow

From HST/FOS de Martino et al. 1999

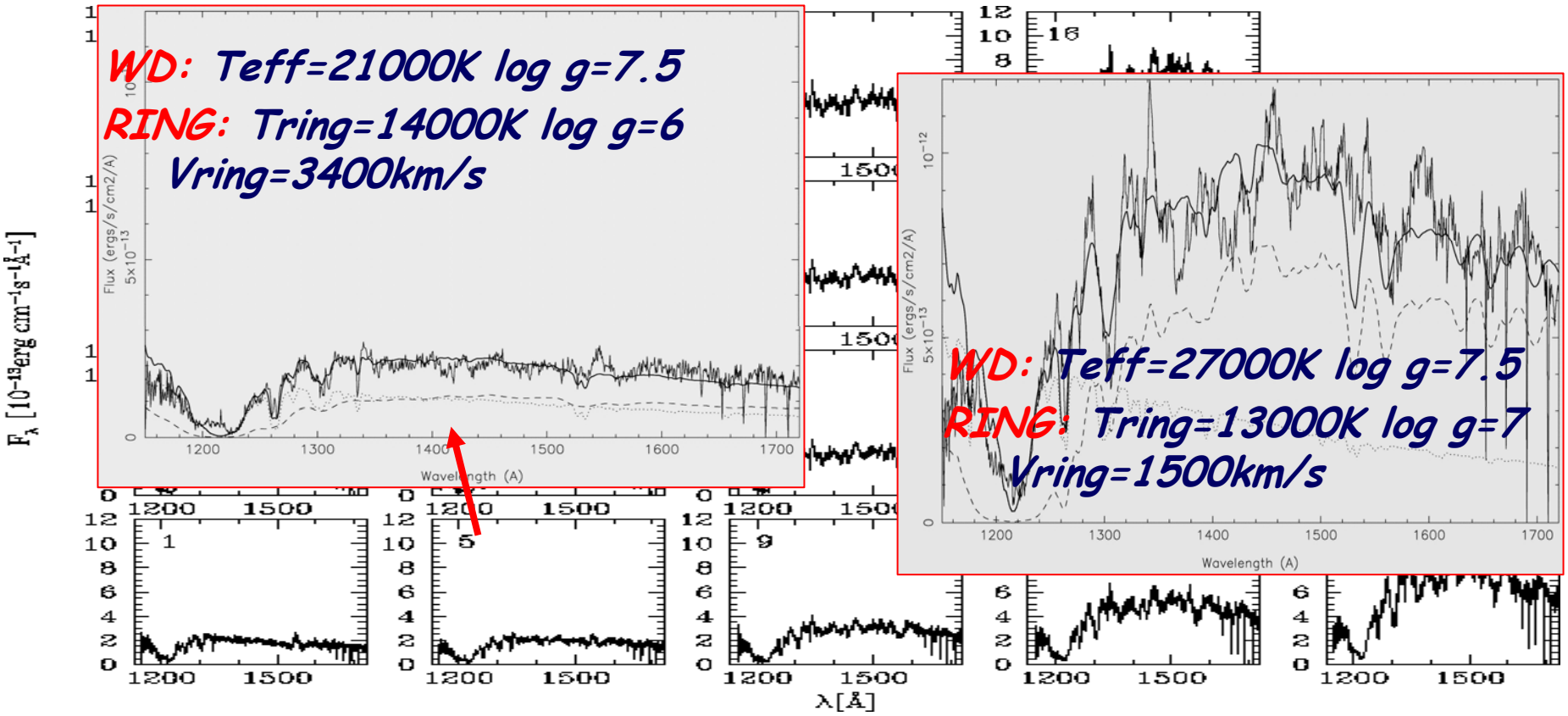
Accretion discs

- Transfer of angular momentum driven by viscosity
- How energy is dissipated in the disc remains unclear
- Luminosity and radial Temperature distribution are independent of viscosity in stead-state discs
- In quiescence viscosity is low and viscous time is long -> accumulation of mass in outer parts of disc until viscosity increases by 100times -> Dwarf Nova Outbursts
- Vertical temperature structure depends on viscosity.

UV to diagnose discs

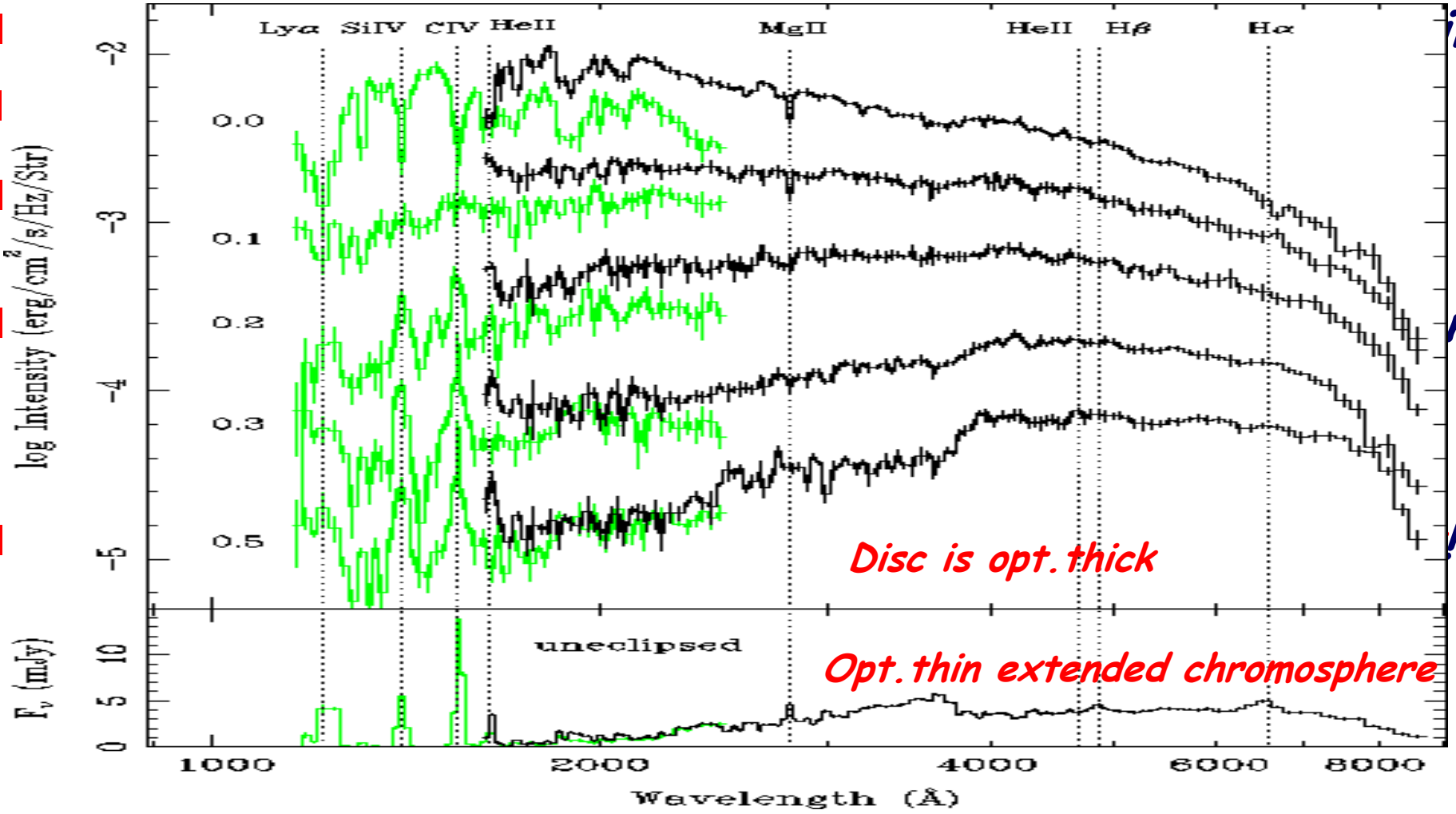
Dwarf Nova Outbursts in the UV

- Early evolution of outburst: FUV flux increase less rapidly than nUV (UV Delay) -> propagation of heating fronts



HST/STIS follows VW Hyi outburst for 2.5hrs from Sion etal. 2004

Quiescent discs

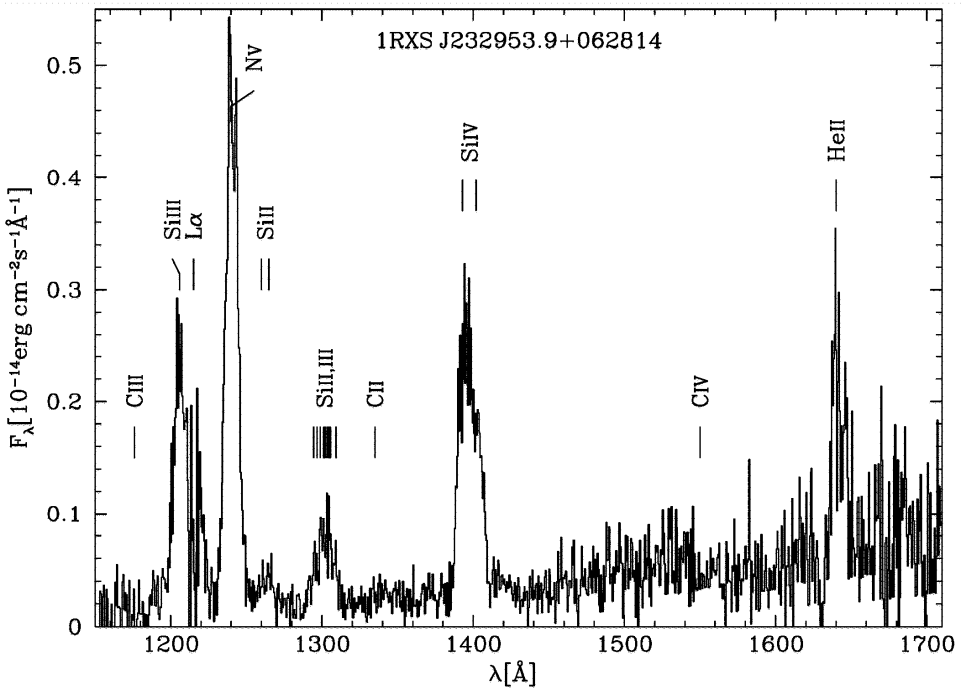


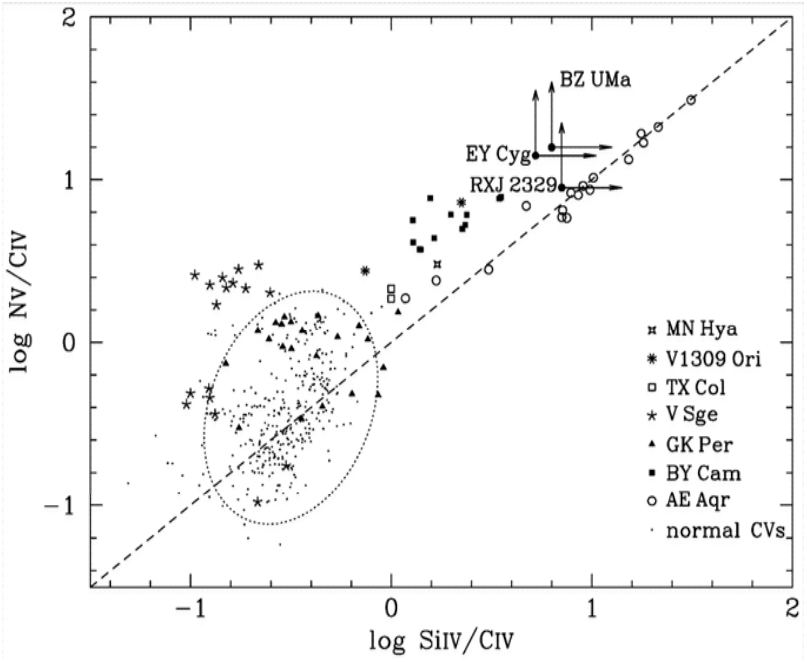
- *Spectra change during eclipse -> radial distances of disc*

From HST/FOS + OPTICAL UX Uma Baptista et al. 1998

"Normal" CVs hiding their true face in the UV

- IUE discovered a few systems with "normal" optical spectra but with anomalous NV/CIV>>1
- HST/STIS further increased the number to 11

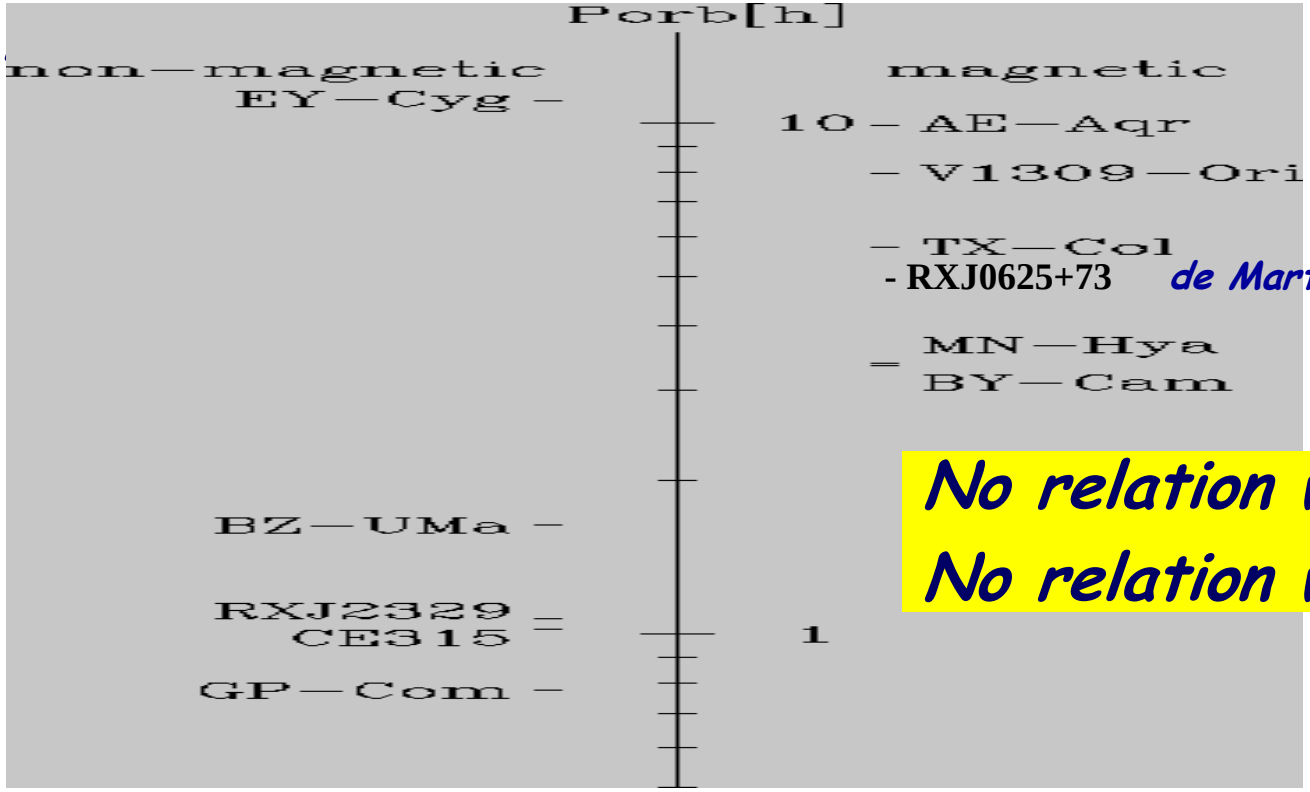




From HST STIS

Gaensicke et al. 2003;

Also in the Far UV.....



de Martino et al. 2007

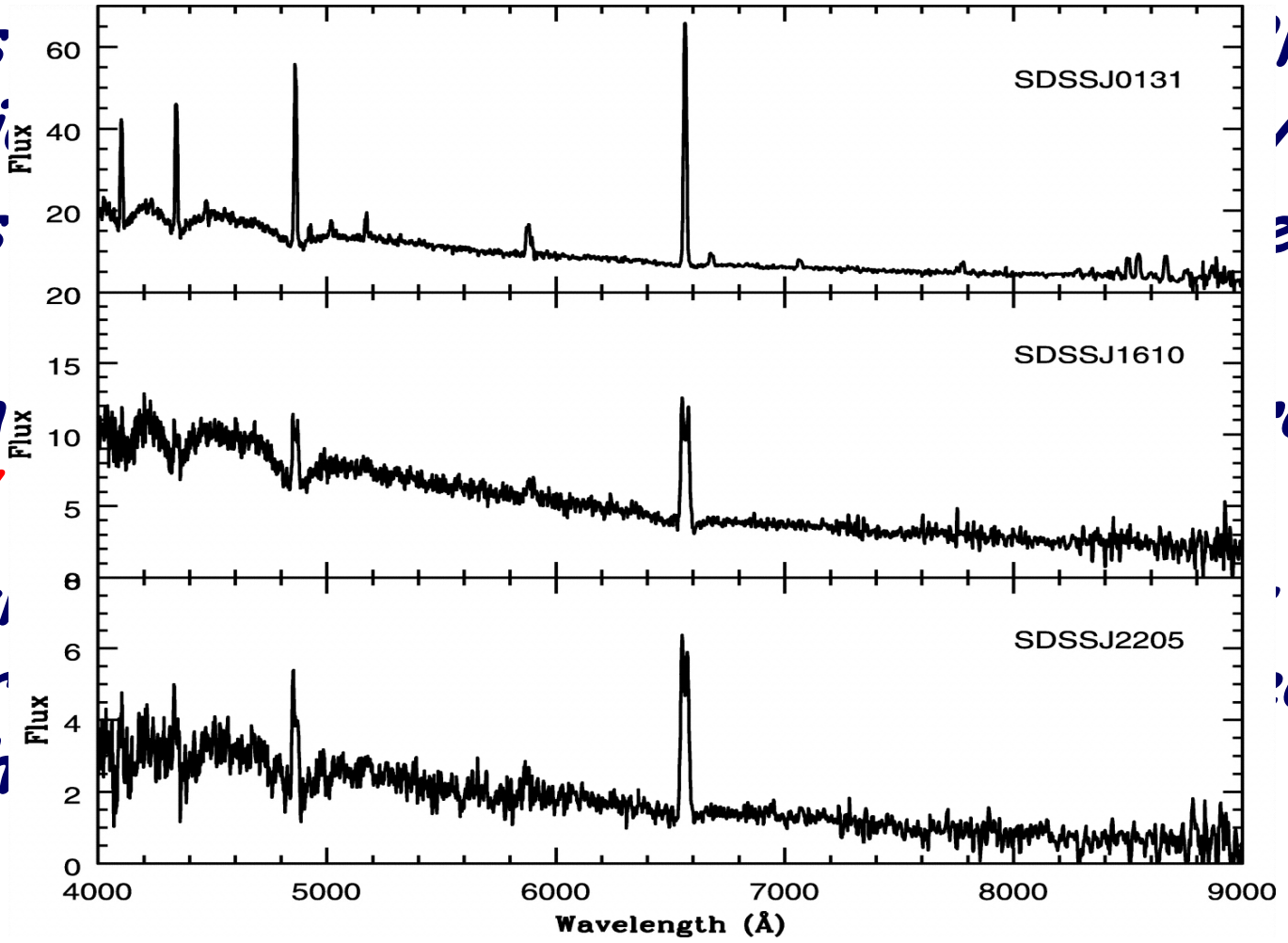
No relation with Porb

No relation with B

- Signature of CNO processed core of evolved secondary suggests TTSMT evolution similarly to Super Soft X-ray Sources but failed to grow in mass (failed SNIa?)
- Evolutionary TTSMT (Shencker et al. 2003) model predicts 1/3 of CVs have started from companions with M>Mwd

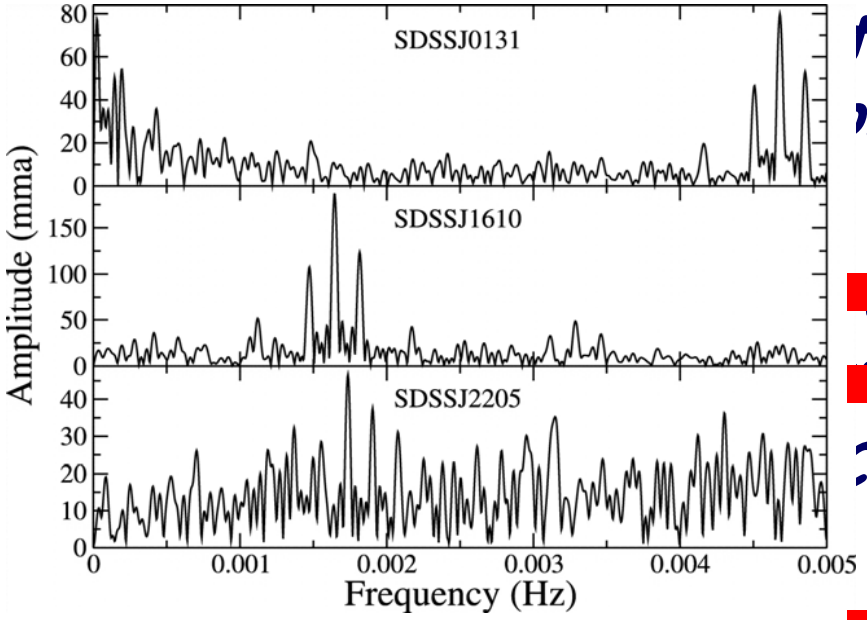
A future for Asteroseismology of WD in CVs?

- Mos… …hr Peri… …r)
- Mos… …ed by the …
- Non… …ed in GW …
- Sea… … just star… …d) with …



Szkody et al. 2007

Are Pulsating WDs in CVs similar to single pulsators?



From HST/ACS Szkody et al. 2007

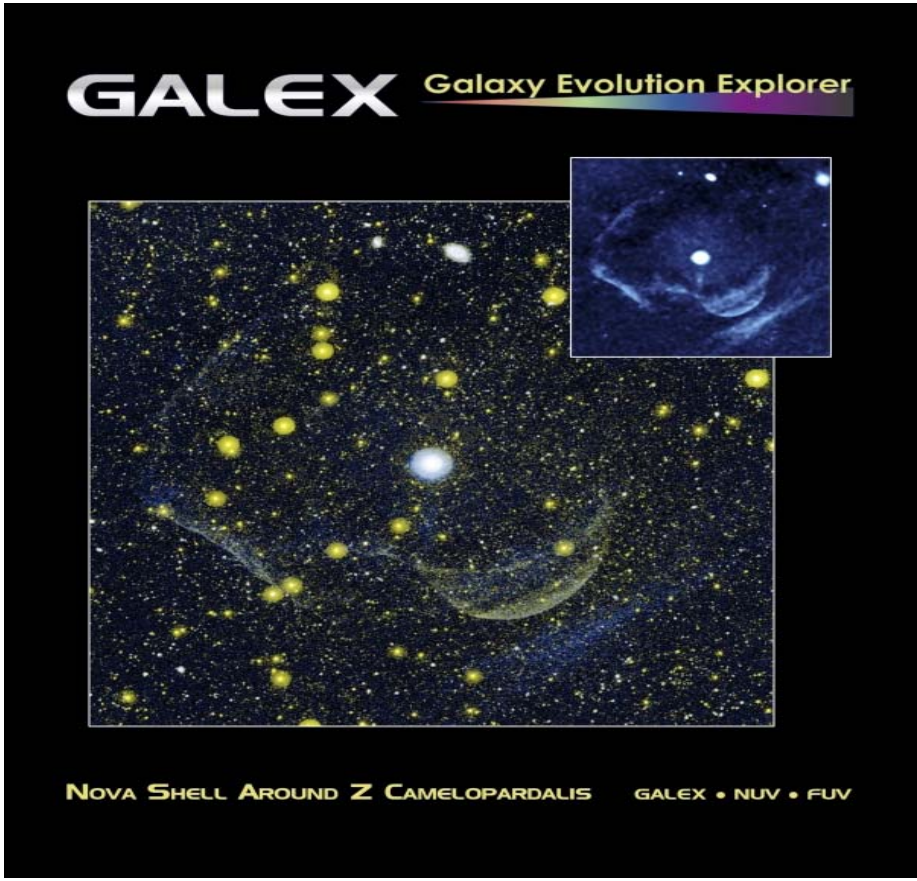
to 10 systems with periods of
plitude of tens mmag .

to infer WD properties

- HST available for 4 CVs
- WD hotter (14000 -16000K) than single ZZ Cet stars (✠11000-12000K)
- One system with Twd=12000K
- If confirmed with new systems, the instability strip for WD CVs is hotter.
- Accreting WDs do not have pure H atmosphere. Effects to be taken into account

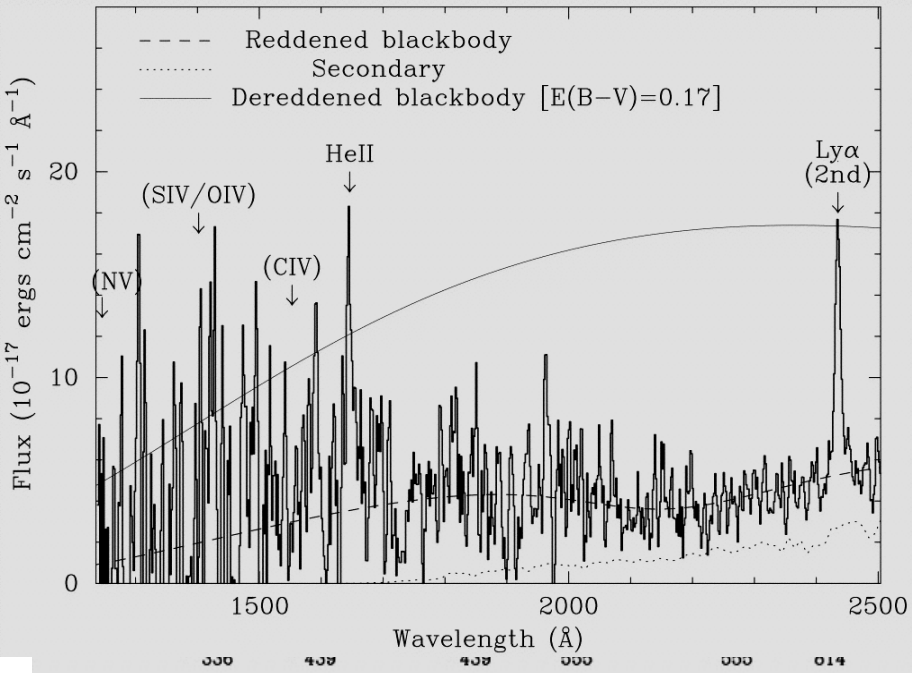
NOVA SHELLS around Dwarf Novae

- CVs are predicted to undergo (cyclic) Nova outbursts (hybernation theory - Shara et al. 1986)
- Recent Galex observations give first evidence of Nova event in a Dwarf Nova (Z Cam) (Shara et al. 2007)
- Shell is more extended (r✠15'✠0.7pc) than in Classical Novae -> an ancient event (2400yrs)
- Mass (10^{-3}-10^{-4}Msun)✠CN not compatible with DN winds or PN.



Compact Binaries in Globular clusters

- Globular Clusters are the most efficient site for compact binary production
- GCs are rich in X-ray sources still to be identified (LMXRB, CVs, AM CVn systems and Millisecond Pulsars)
- HST Optical-nUV CMD diagrams show blue objects (Cool et al. 1998; Ferraro et al. 2000, Knigge et al. 2002)



- Follow-up spectroscopic HST/STIS observations suggest a magnetic CV

NGC 6397

Nonvariable UV stars

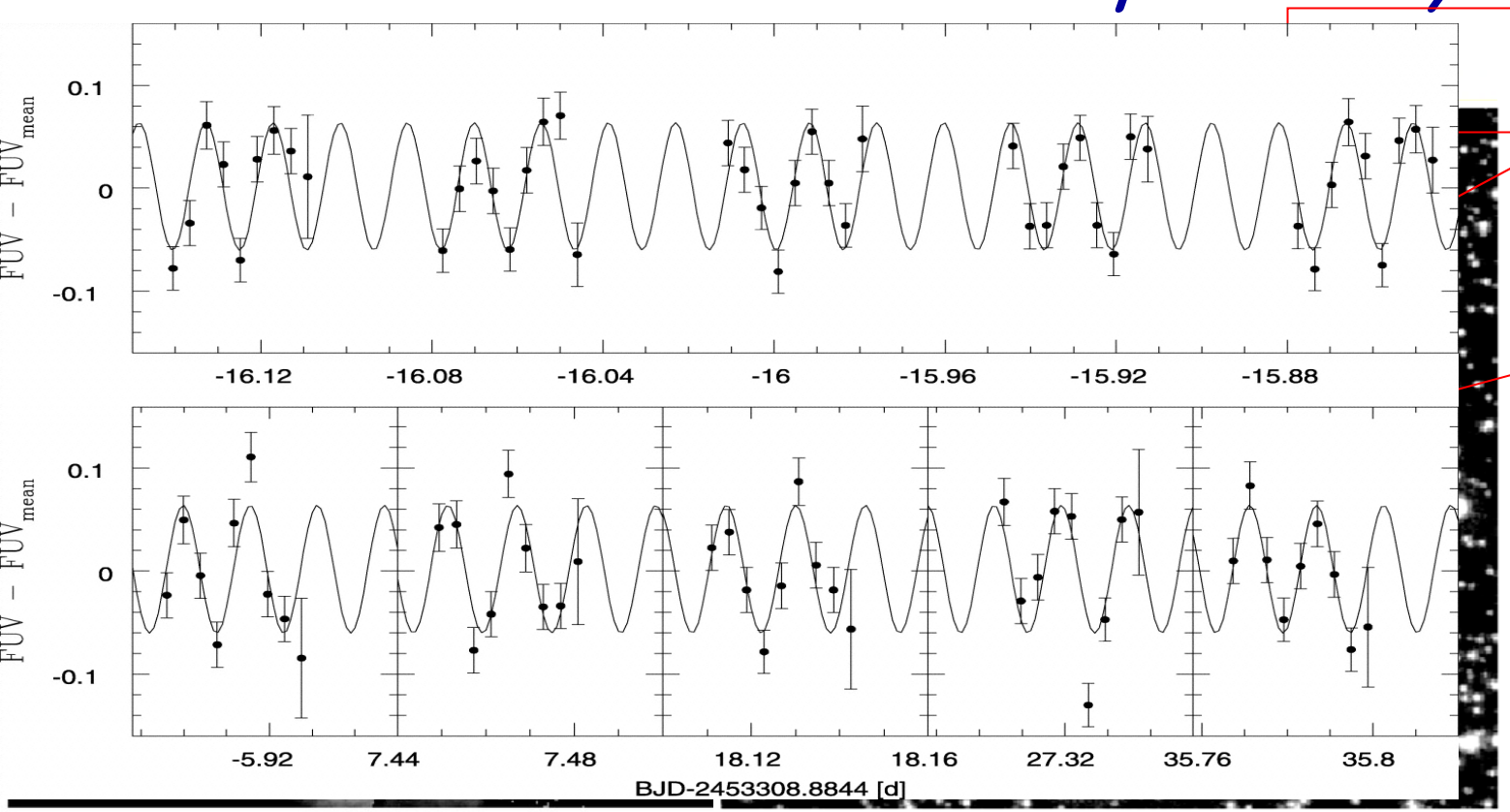
CVs

From HST/STIS Edmonds et al 1999

from Cool et al. 1998

UV to identify GC Compact binaries

- Crowding severely affects optical and nUV images
- FUV is best suited to isolate Compact Binary candidates



ULC
Porb=22min

HST/ACS NGC 7078 (1600Angs) and nUV(1300Angs)
Core of NGC 7078 FUV (1600Angs) and nUV(1300Angs)
from Dieball et al. 2005 et al. 2002

SUMMARY

- *CVs are most numerous among Interacting Binaries*
- *CVs are key objects to study Binary Evolution and Accretion Processes including magnetic effects*
- *UV range plays a key role in the context of multi-band studies*
- *UV is the only range to answer specific questions on evolution and accretion*
- *UV studies require secure future beyond Galex, FUSE and HST….*

THANK YOU!