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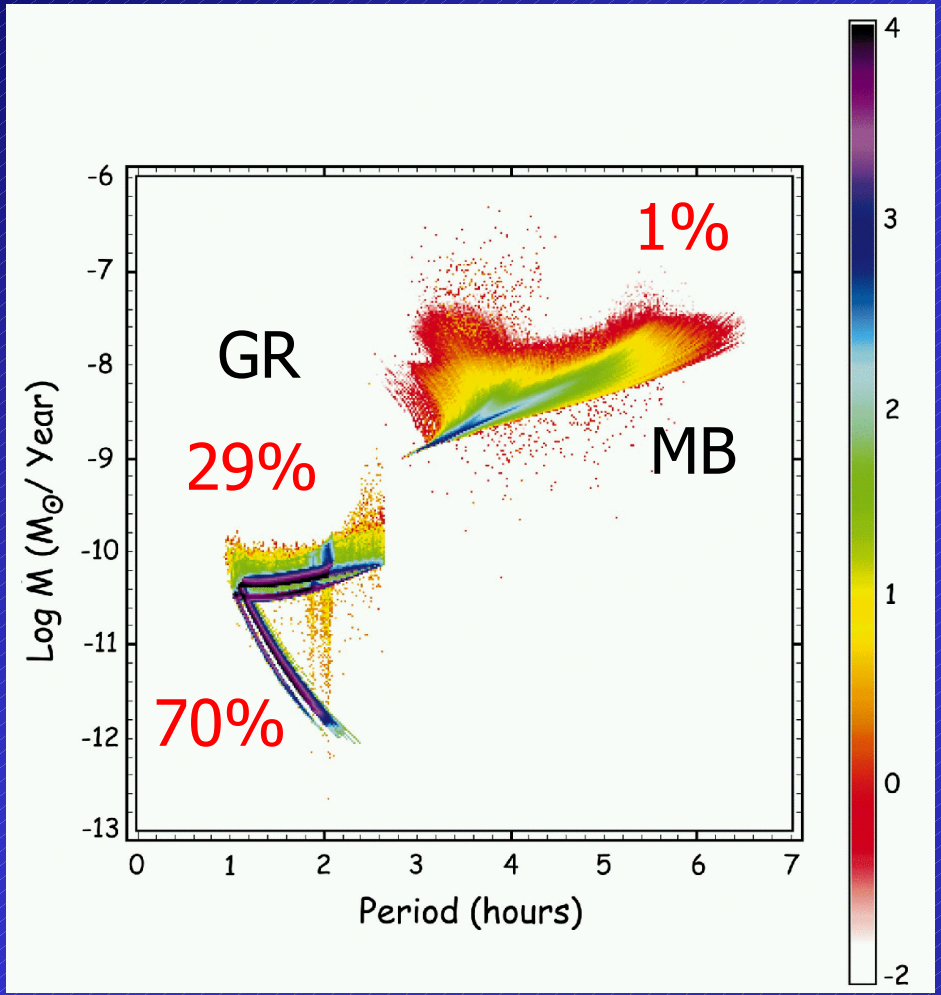
Observational constraints on the evolution of white dwarf binaries

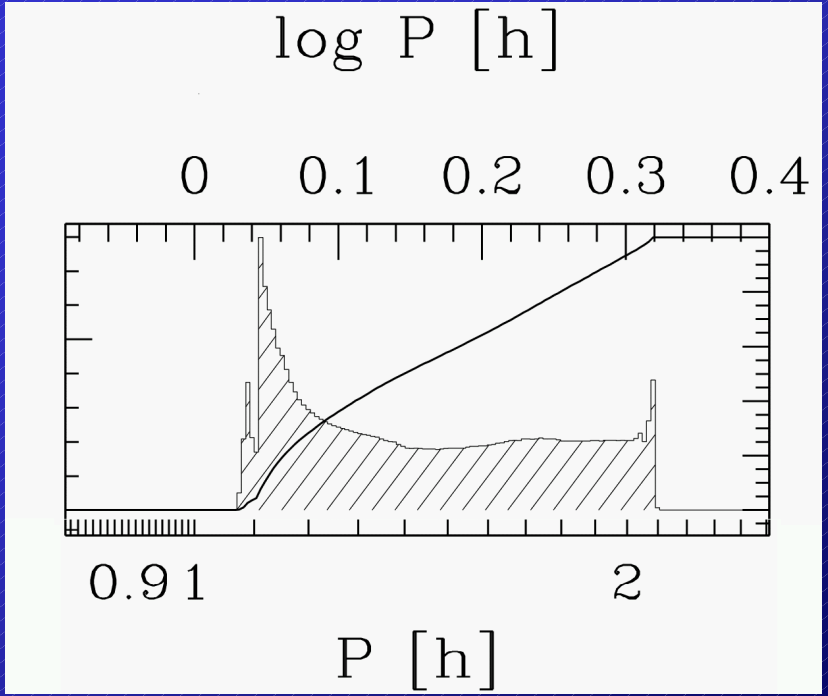
1) Population studies of CVs
2) The beauty of detached WD/MS binaries
3) Failed SNIa

KITP – 19 March 2007

CV evolution in a nutshell

- Angular momentum loss MB/GR
- MB disrupted at P=3h
- At Pmin: donor ⇒ BD
- Spike at Pmin
- Most systems post-bounce

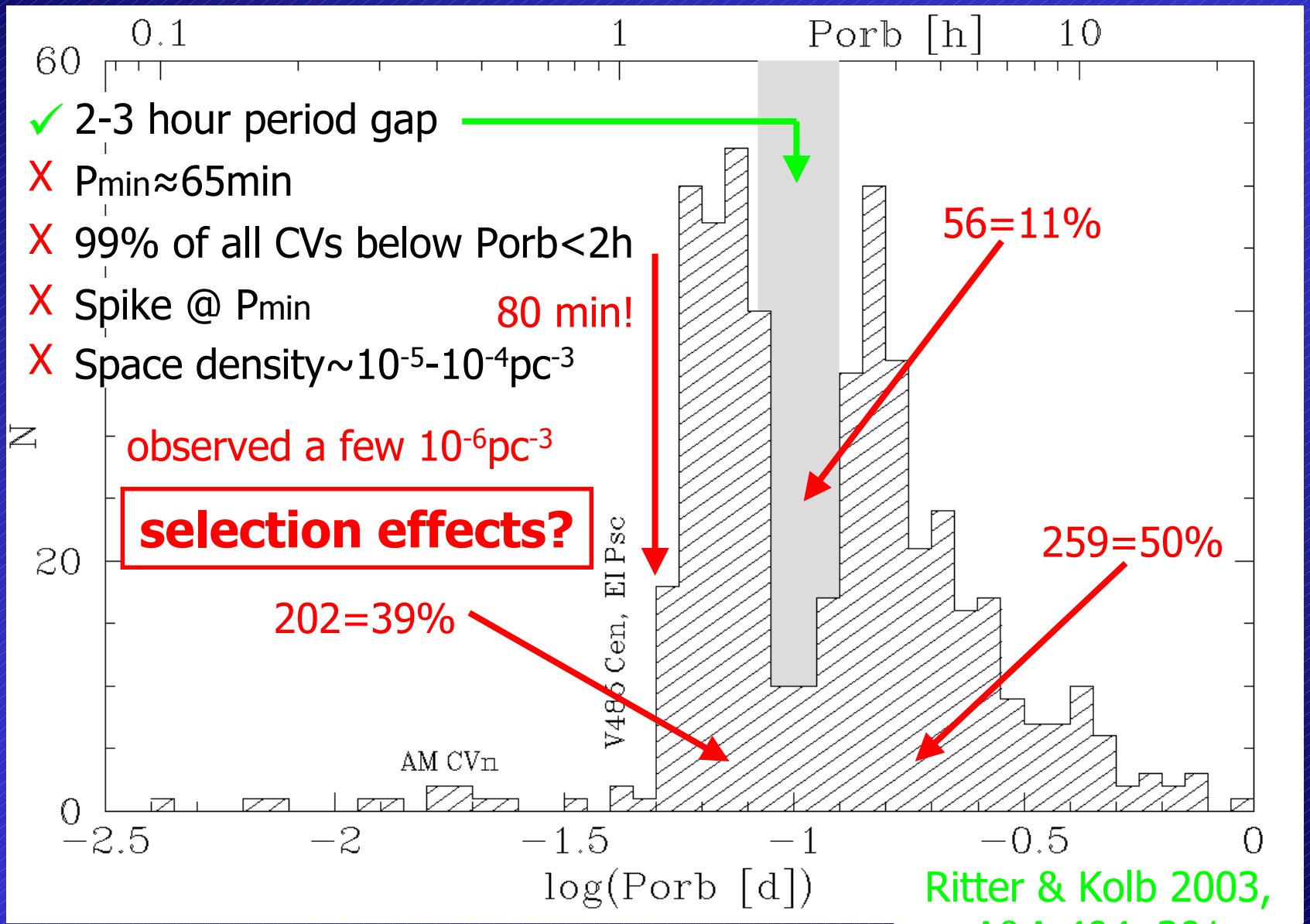




Howell et al. 2001, ApJ 550, 897

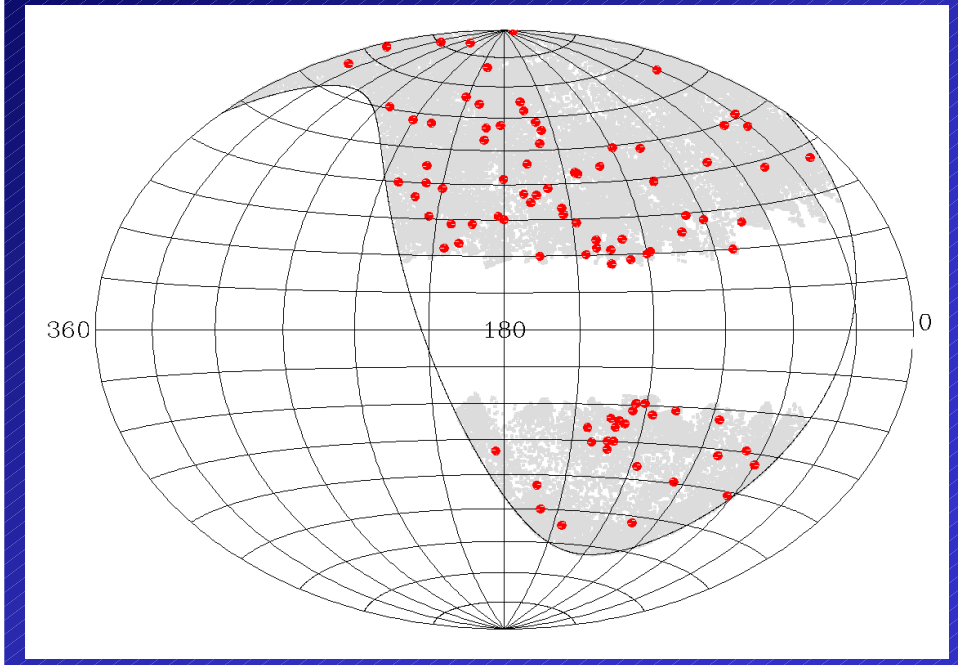
Kolb & Baraffe 1999, MNRAS 309, 1034

CV evolution: theory & observations



Ritter & Kolb 2003, A&A 404, 301

CVs from the Hamburg Quasar Survey



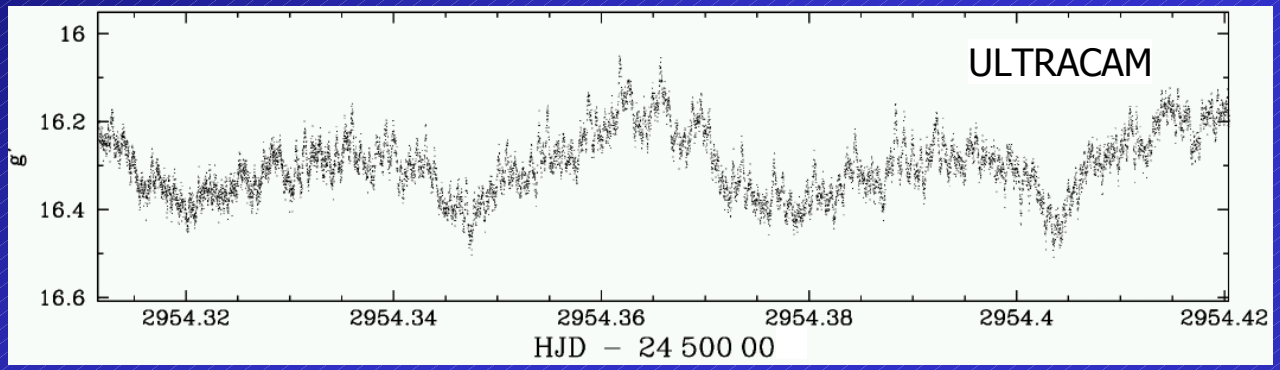
- photographic Schmidt prism survey
- Northern sky, high galactic latitude
- $13 \lesssim B \lesssim 18.5$
- 11000 square degrees, 50000 spectra

- 96 CVs, of which 53 new

HS2331+3905: brightest WD pulsator in a CV

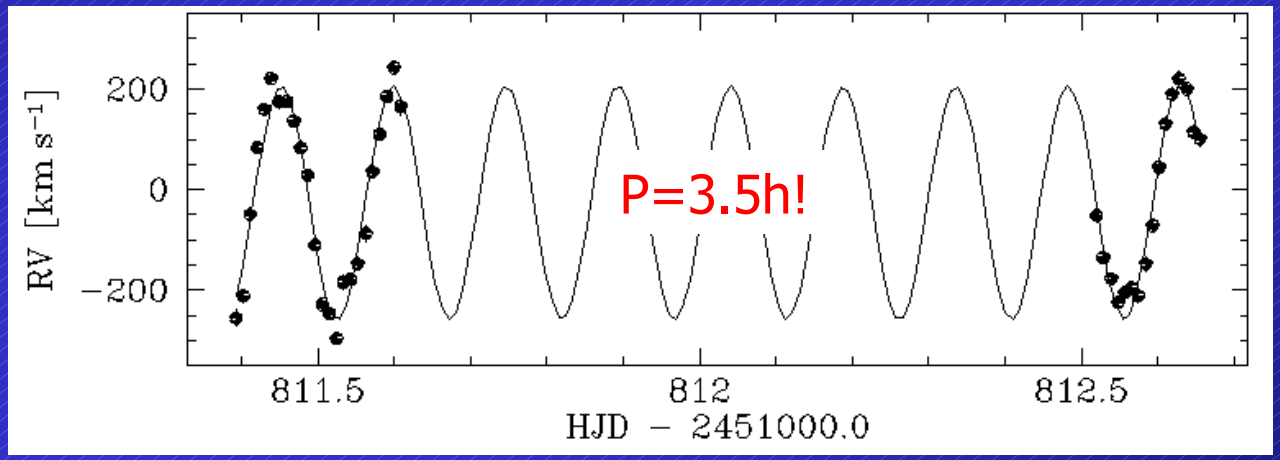
- P_{orb}=81min (eclipsing)
- T_{wd}=10500K
- no outbursts
- probable brown dwarf donor

} low mass transfer rate, probably very old



The brightest CV white dwarf pulsator

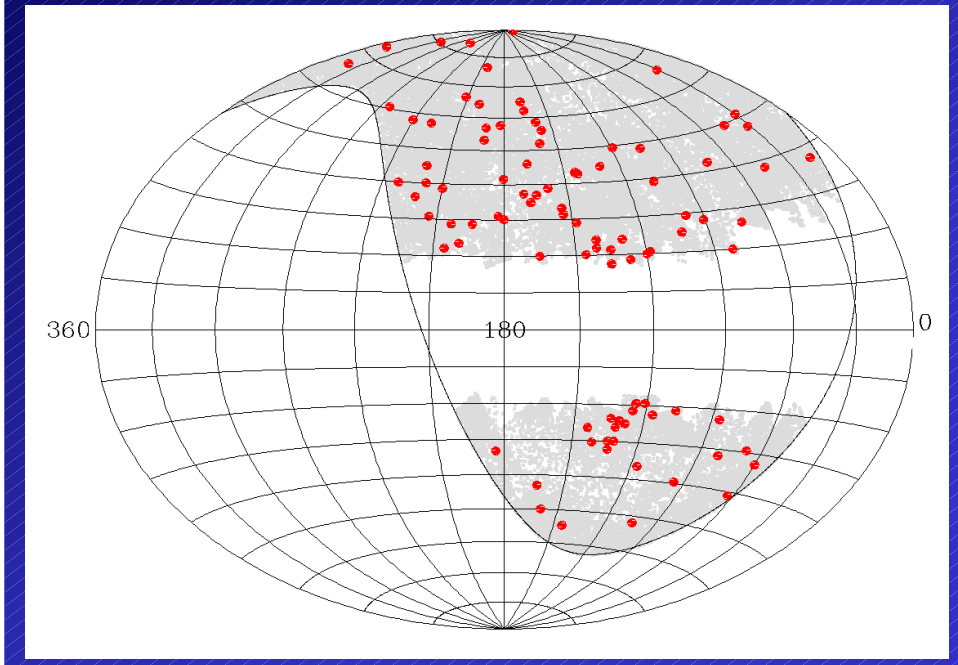
→ asteroseismology

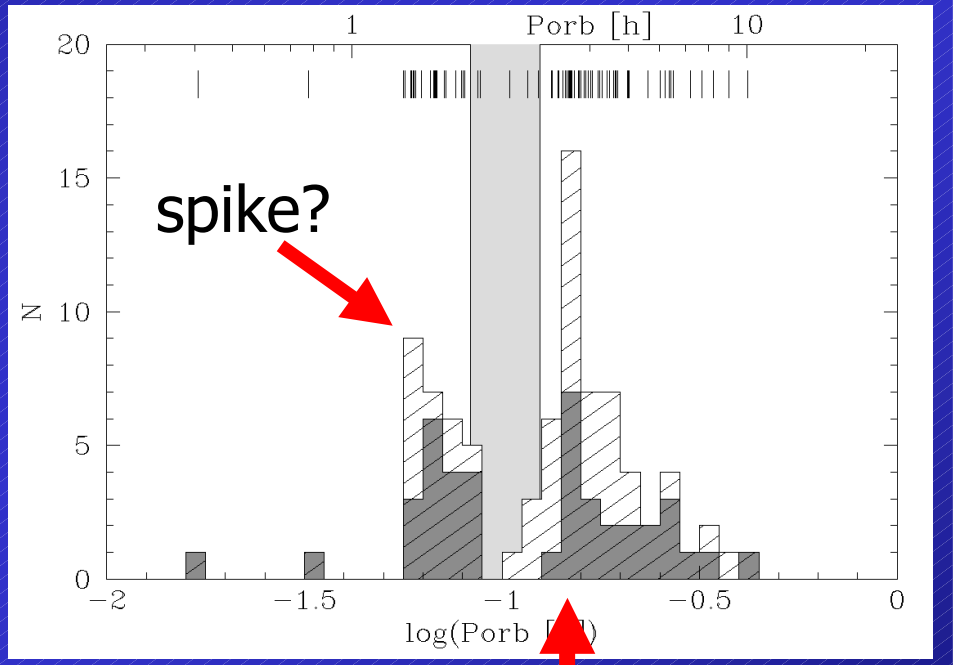


A warped precessing disc?

(Araujo-Betancor et al. 2005, A&A 430, 629)

CVs from the Hamburg Quasar Survey



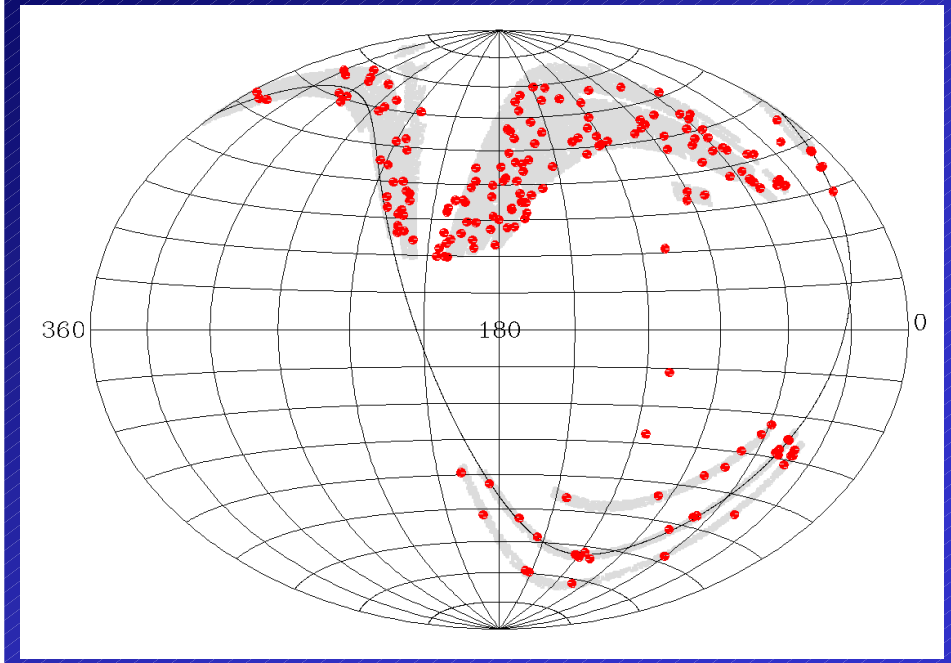


- 96 CVs, of which 53 new
- 86 periods determined

... 24 HQS CVs with P_{orb}=3-4h ...

(Gänsicke, Rodríguez-Gil, Aungwerojwit, Araujo-Betancor, Hagen, Engels, Harlaftis, Kitsionas, Fried, Barwig, ...)

CVs from the Sloan Digital Sky Survey

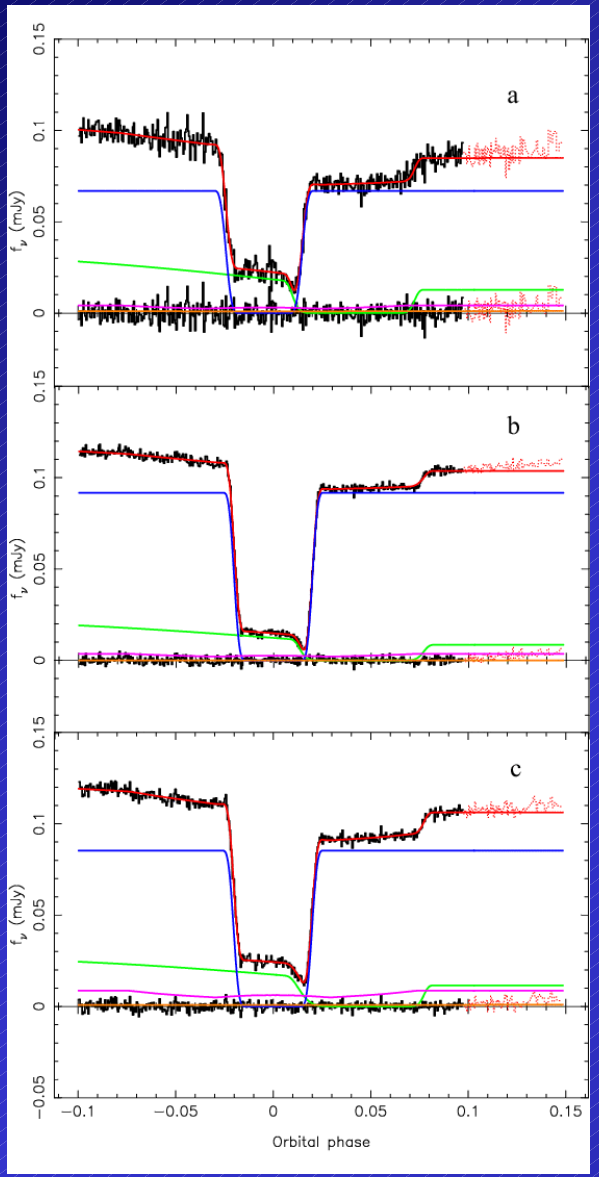


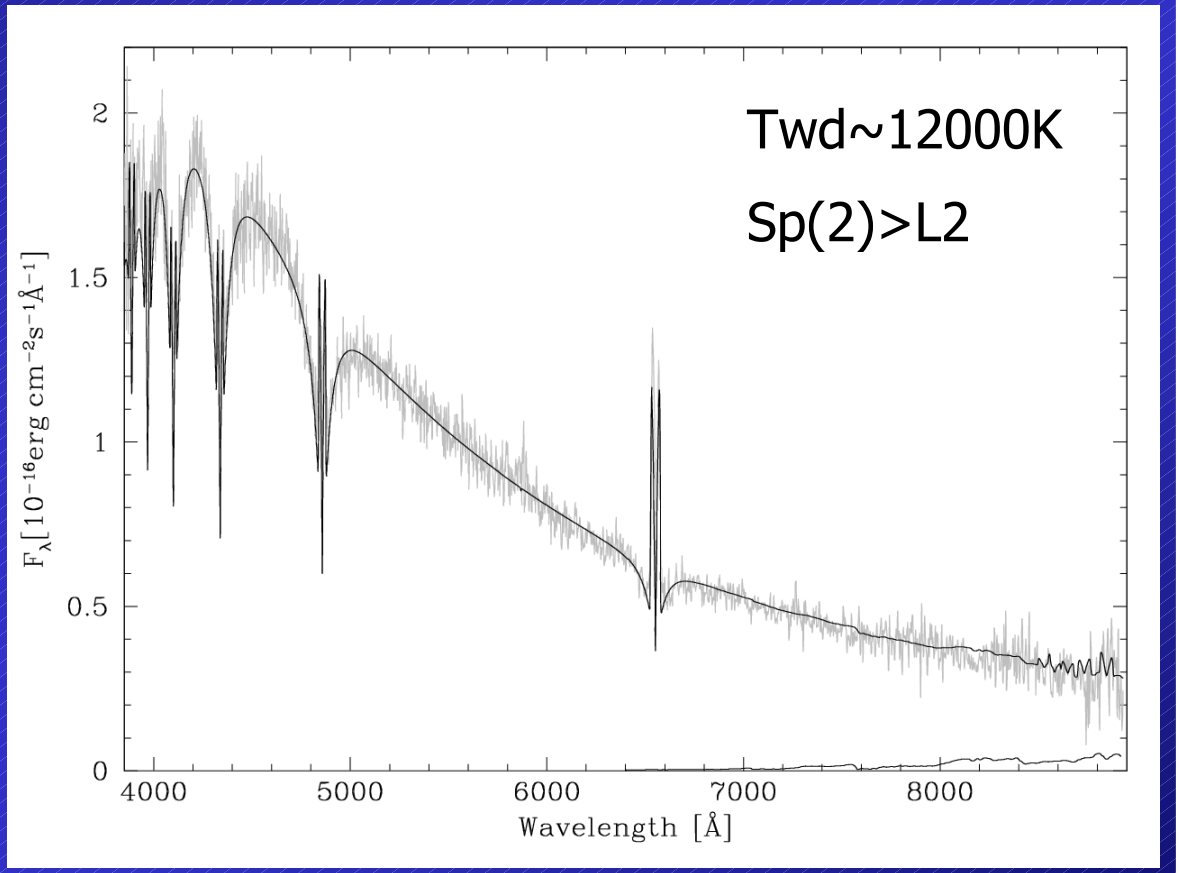
- *u,g,r,i,z* imaging & multifibre spectroscopy
- Northern sky, high galactic latitude
- $15 \lesssim g \lesssim 21$
- DR5: 5740 square degrees, 1048960 spectra

- 191 CVs, of which 153 new

Szkody et al. 2002, 2003, 2004, 2005, 2006 AJ 131, 973

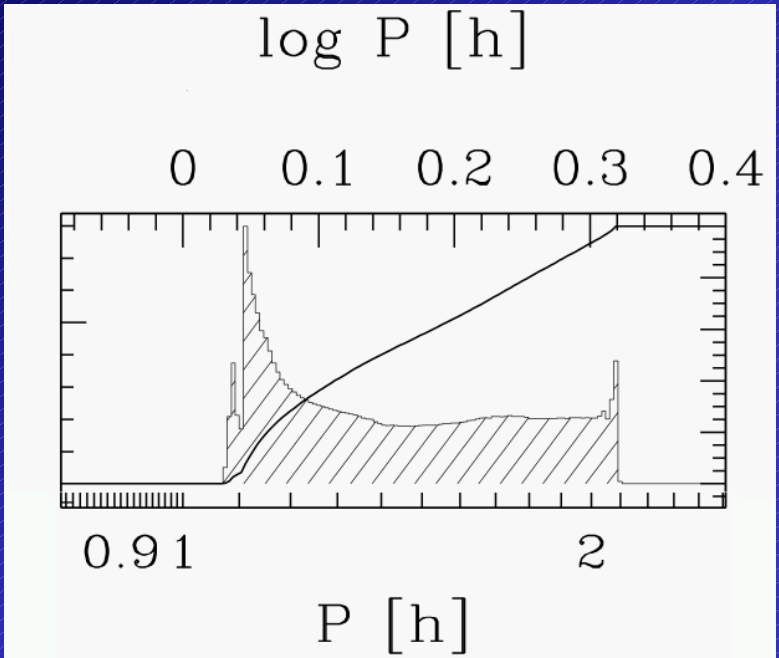
SDSS1035+0551: The first confirmed BD donor

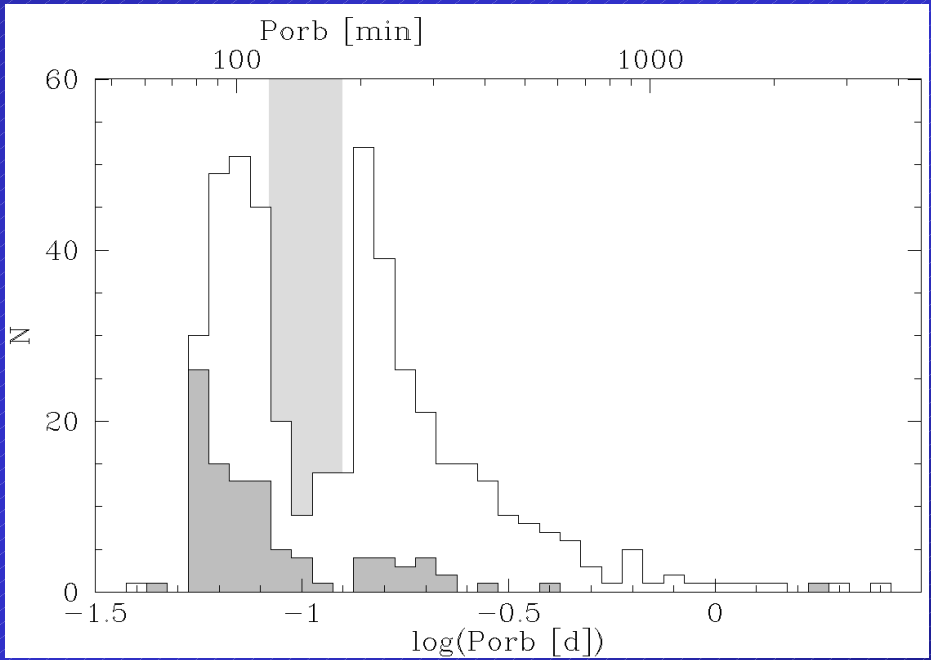




VLT spectroscopy: eclipsing, P=82min
(Southworth et al. 2006, MNRAS 373, 687)
ULTRACAM photometry: M2=0.052±0.002
(Littlefair et al. 2006, Science 314, 1578)

The period minimum spike: finally found





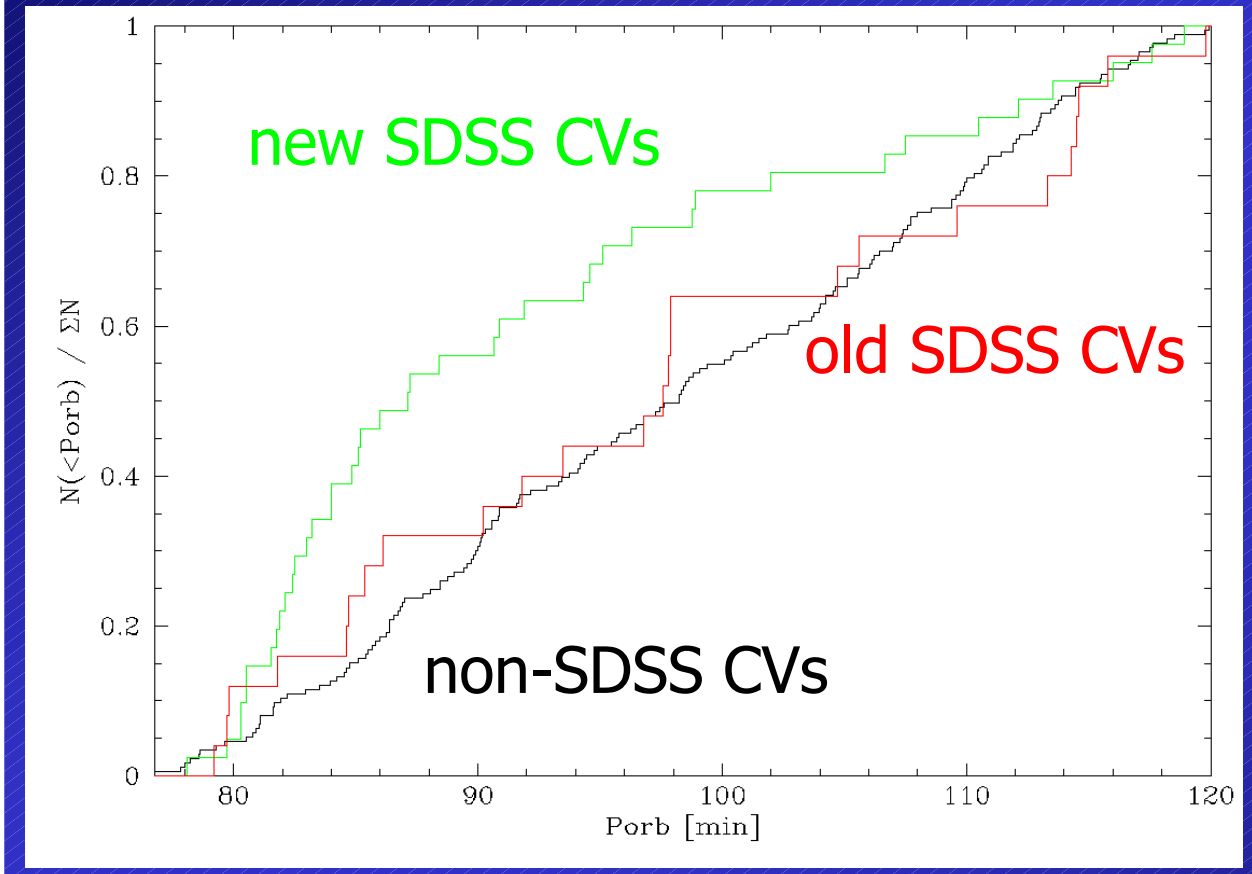
ITP time 2004/5 for SDSS CV follow-up: 70 nights WHT, TNG, INT, NOT & LT (PI Gänsicke)

90 accurate periods determined

(Gänsicke, Dillon, Rodriguez-Gil et al. ; Szkody, Schmidt, Homer et al. ; Thorstensen, Woudt & Warner, Tovmassian; …)

SDSS CVs differ from previous samples

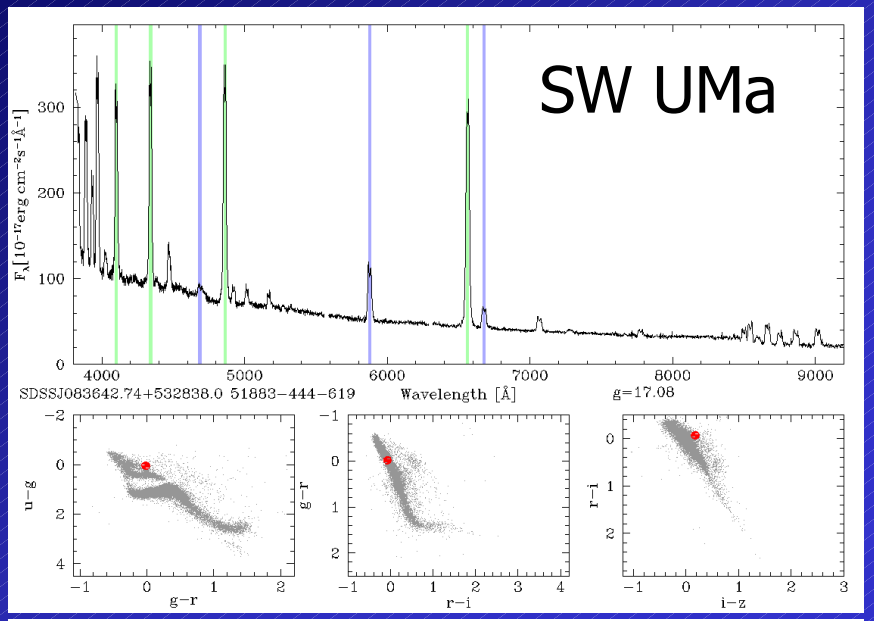
two-sided Kolmogorov-Smirnov test

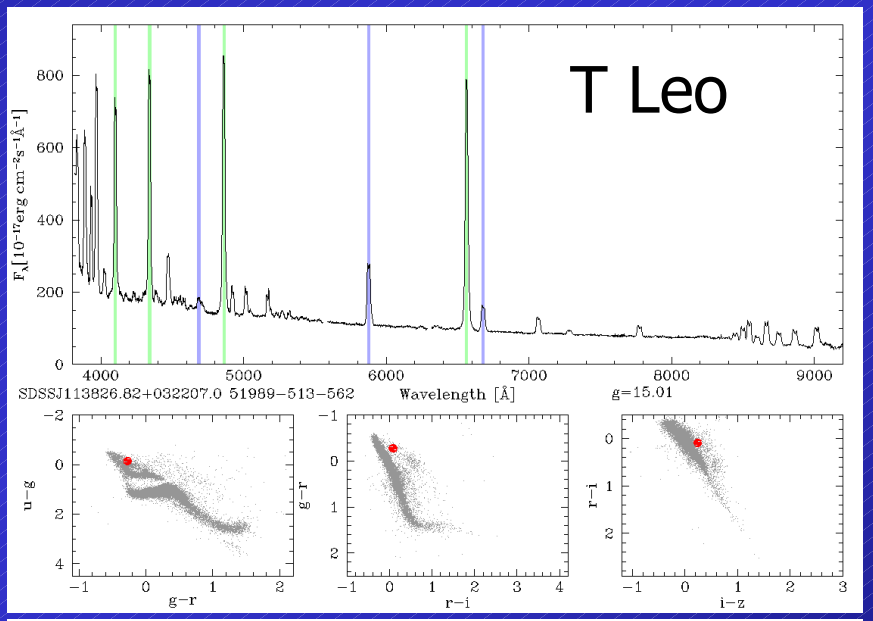


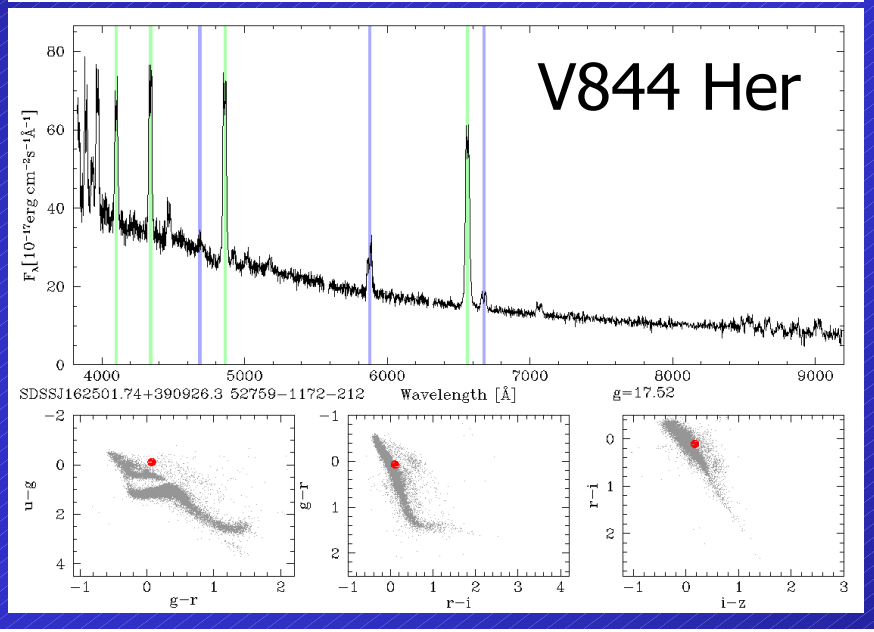
- old vs non: 73%
- SDSS vs non: 0.7%
- new vs non: 0.2%

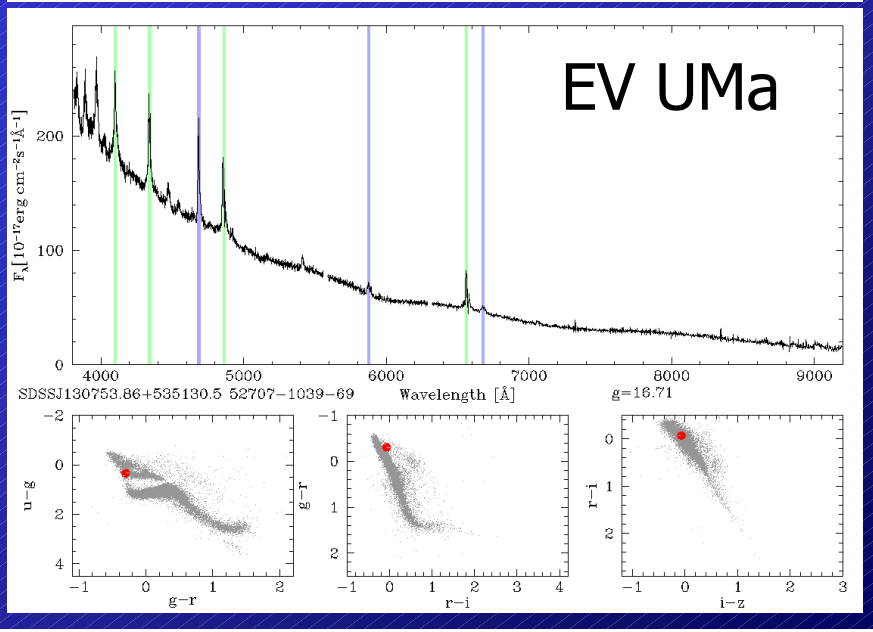
Gänsicke et al. 2007, MNRAS, in prep

Old SDSS CVs with 80min<Porb<86min

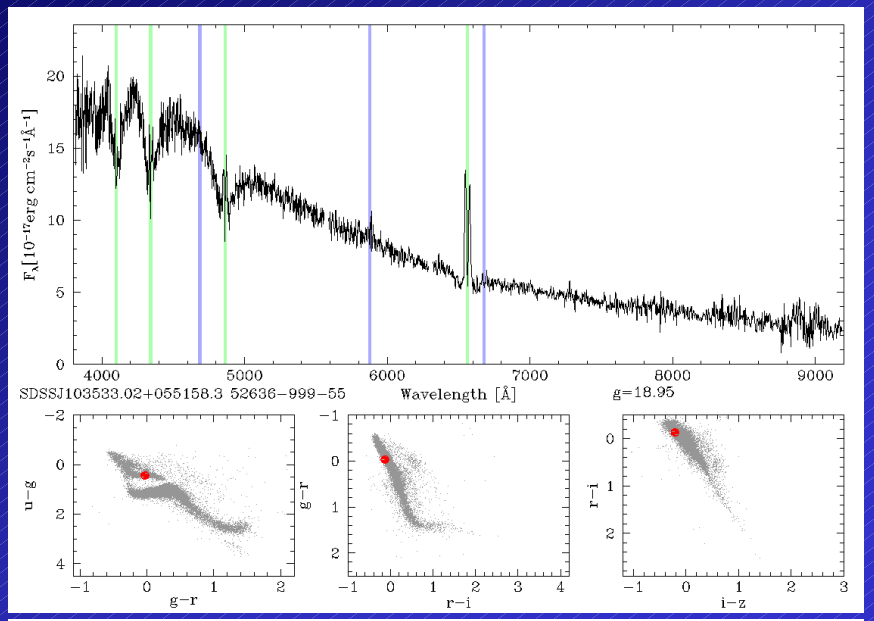


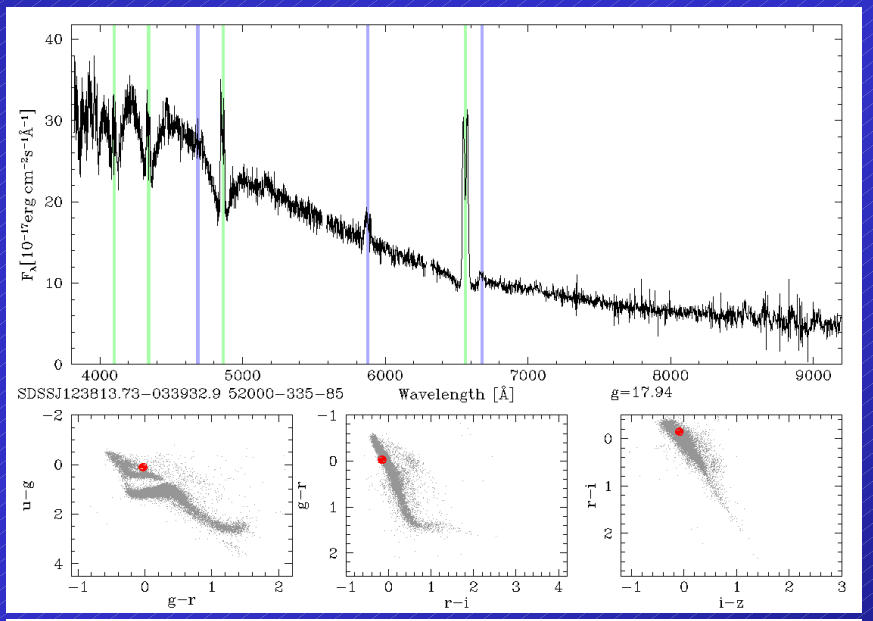


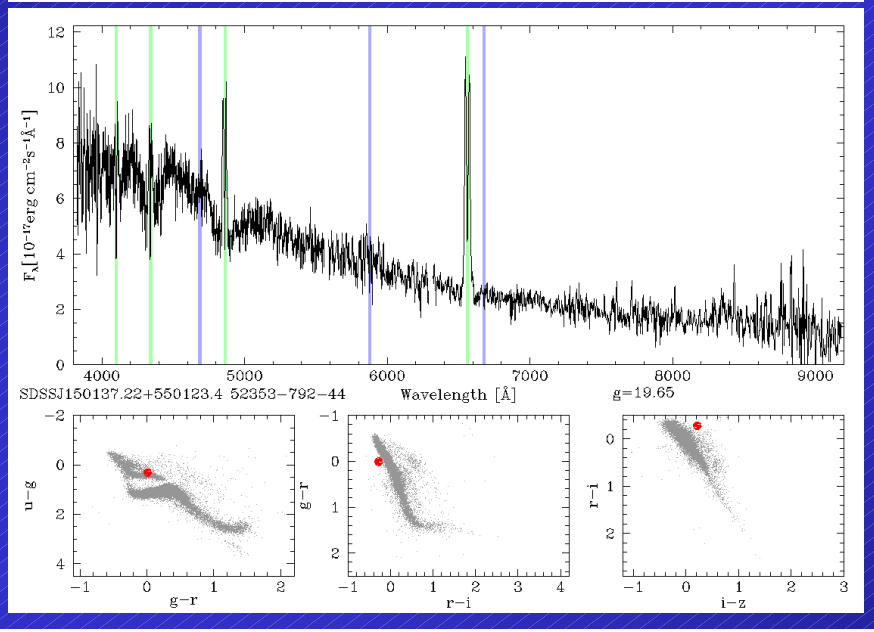


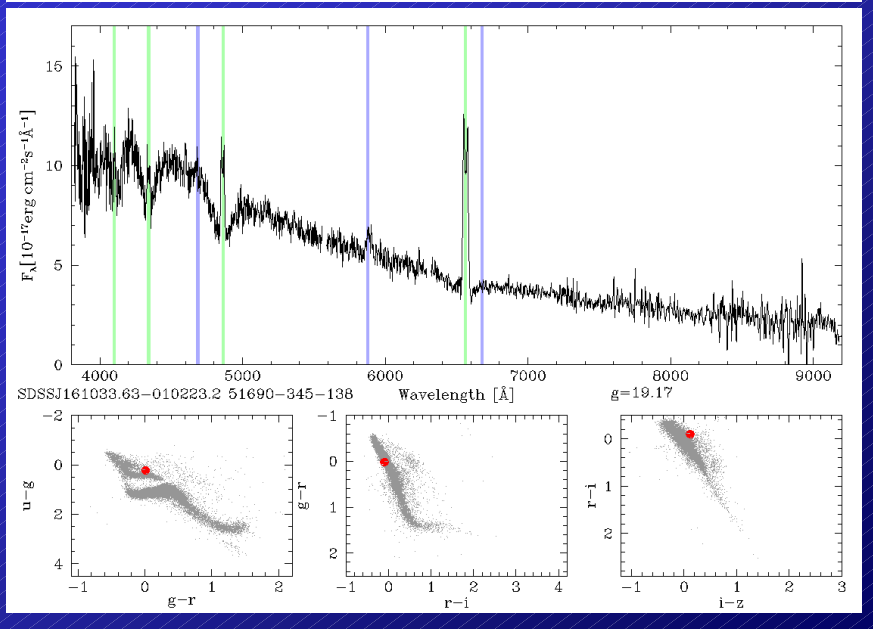


New SDSS CVs with 80min<Porb<86min

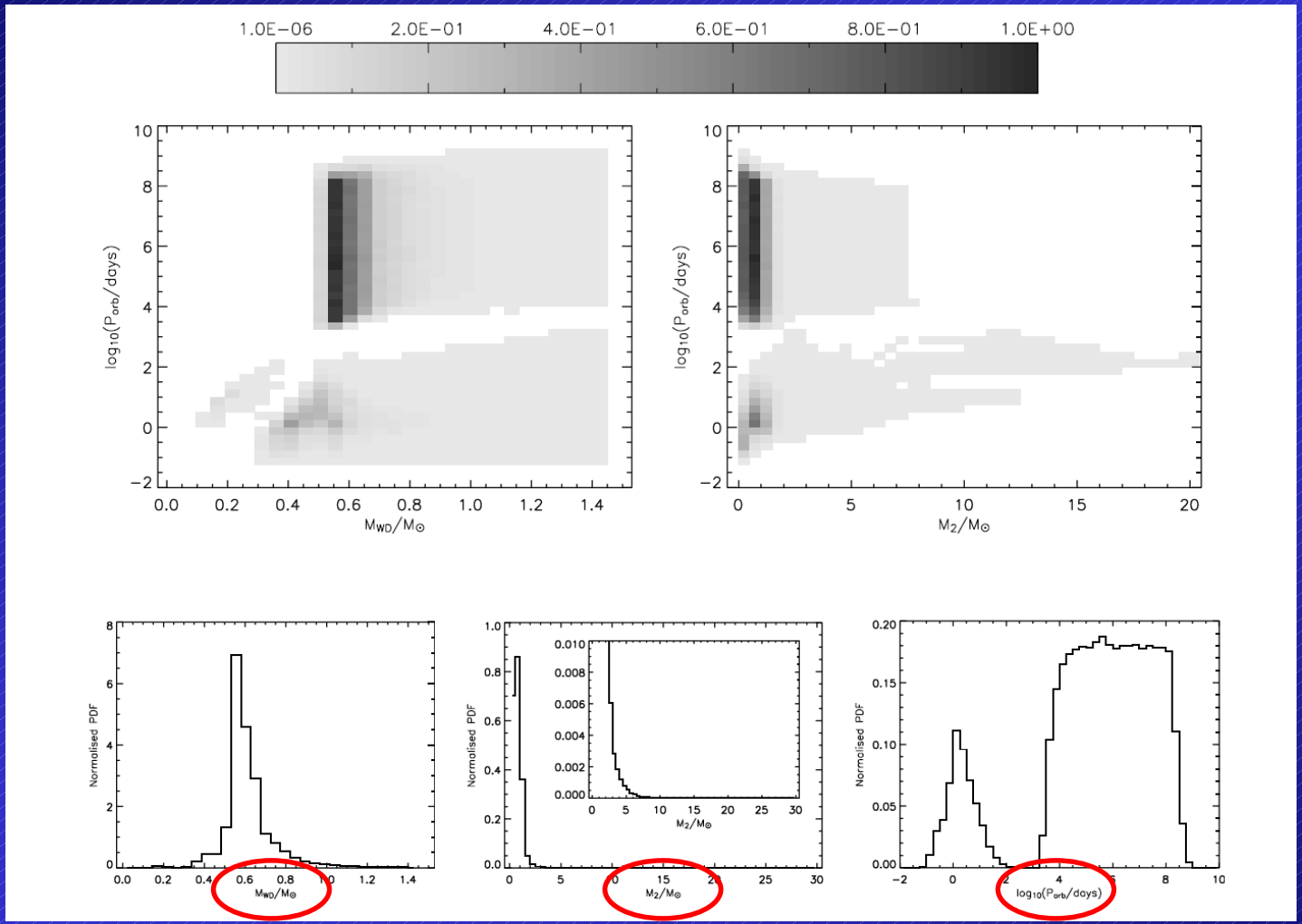








Population models of WD/MS binaries



Willems & Kolb 2004, A&A 419, 1057; de Kool 1993, A&A 267, 397; Nelemans & Tout 2005, MNRAS 356, 753; Politano & Weiler 2006, ApJL 641, 137

Post-common envelope binaries (PCEBs)

Well-suited for the study of CE & angular momentum loss:

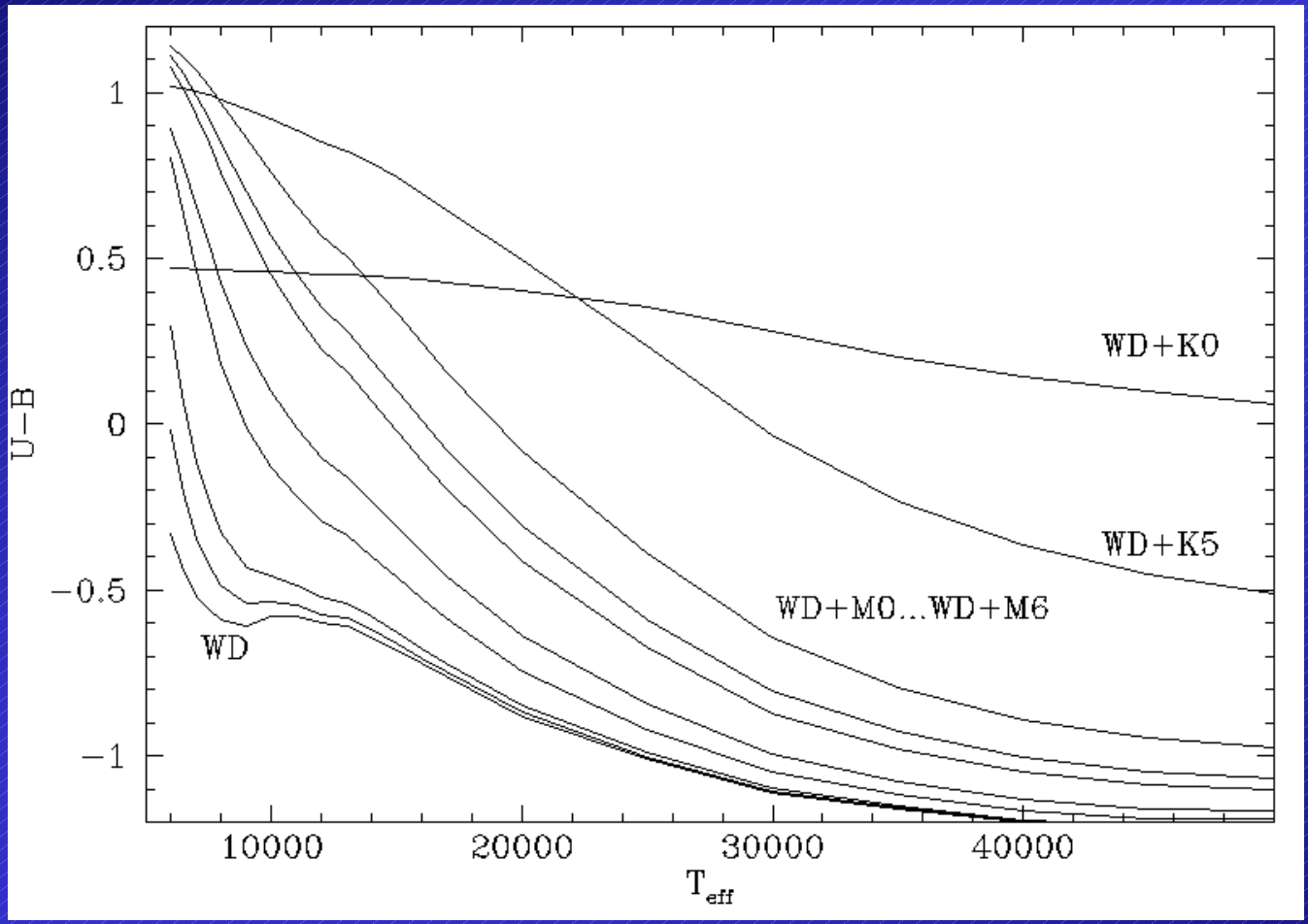
- No mass transfer / mass loss
- Precise determination of $M_{1,2}$ and $R_{1,2}$ possible
- Age can be derived from WD temperature

But: (Schreiber & Gänsicke 2003, A&A 406, 305)

- Only ~40 PCEBs with measured parameters known !!

- ***Extremely biased sample:***
  hot white dwarfs = young systems ($t<10^8$yr)
  low mass companions = will start mass transfer at $P_{orb}<4$h

Selection effects in the known PCEB population



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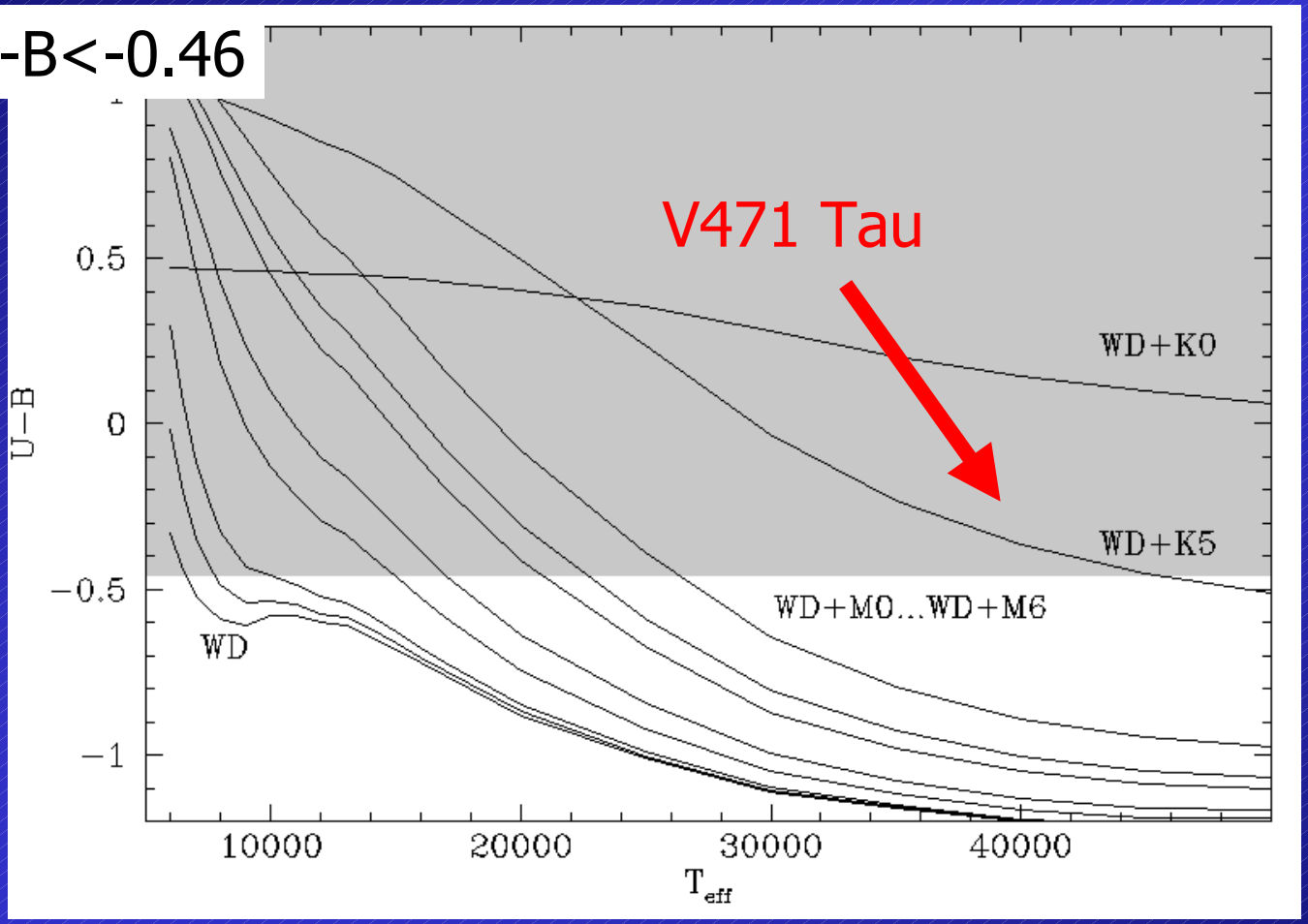
Selection effects in the known PCEB population

PG: U-B<-0.46



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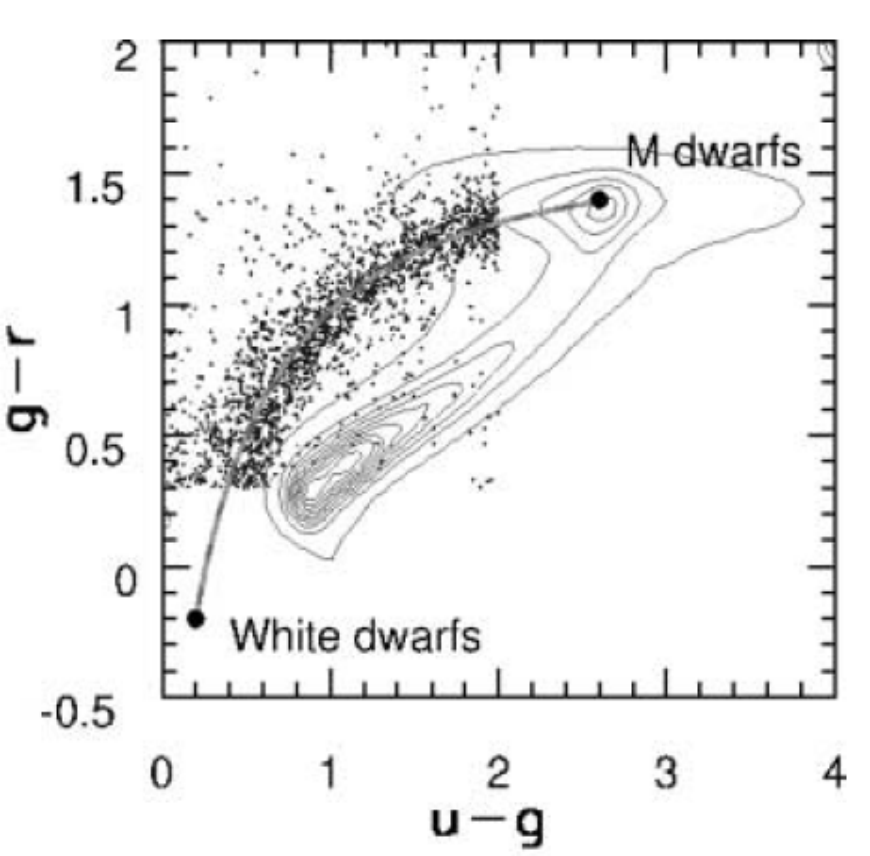
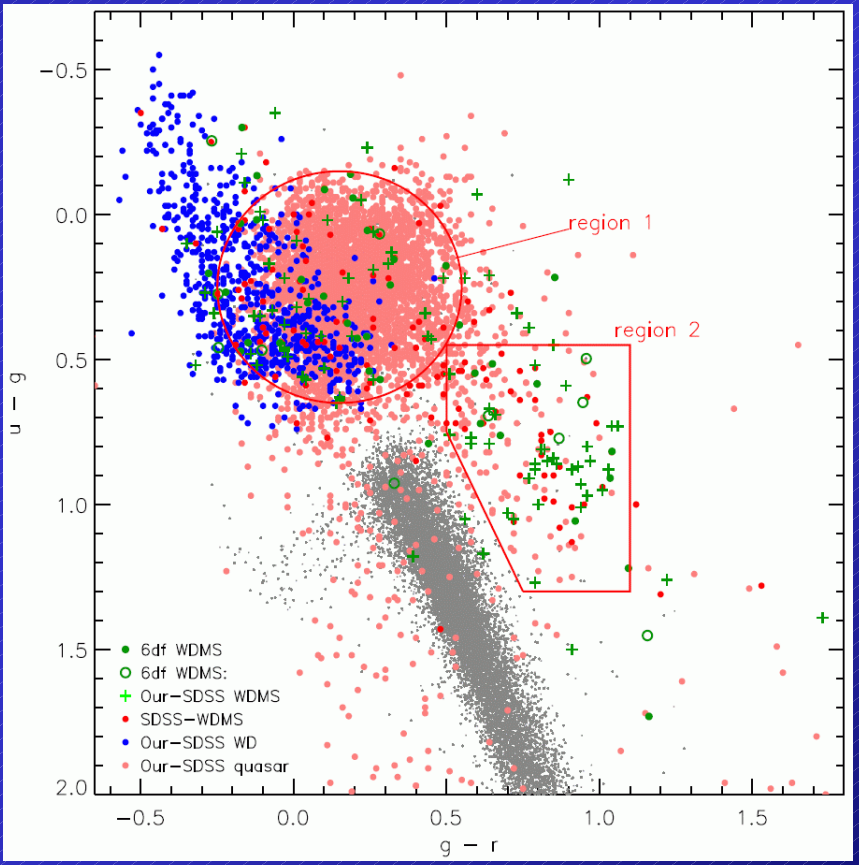
WD/MS selection easy in SDSS

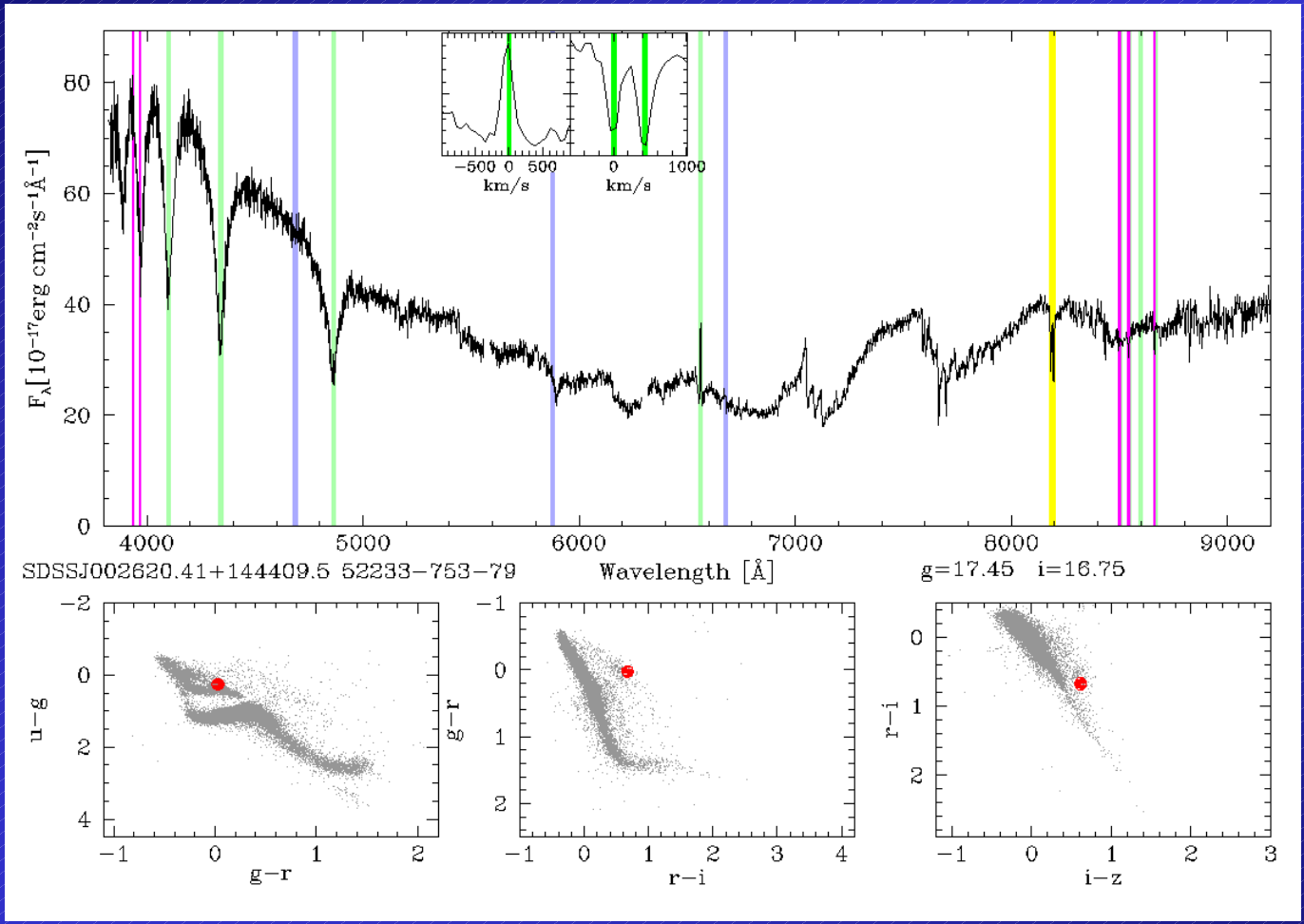




Smolcic et al., 2004,
ApJL 615, 141

Southworth et al 2007,
MNRAS submitted

>1000 WD/MS binaries in SDSS DR5



Raymond et al. 2003, AJ 125, 2621; Silvestri et al. 2005, AJ 131, 1674; Southworth et al. 2007, MNRAS submitted; Schreiber SEGUE project, astro-ph/0611461

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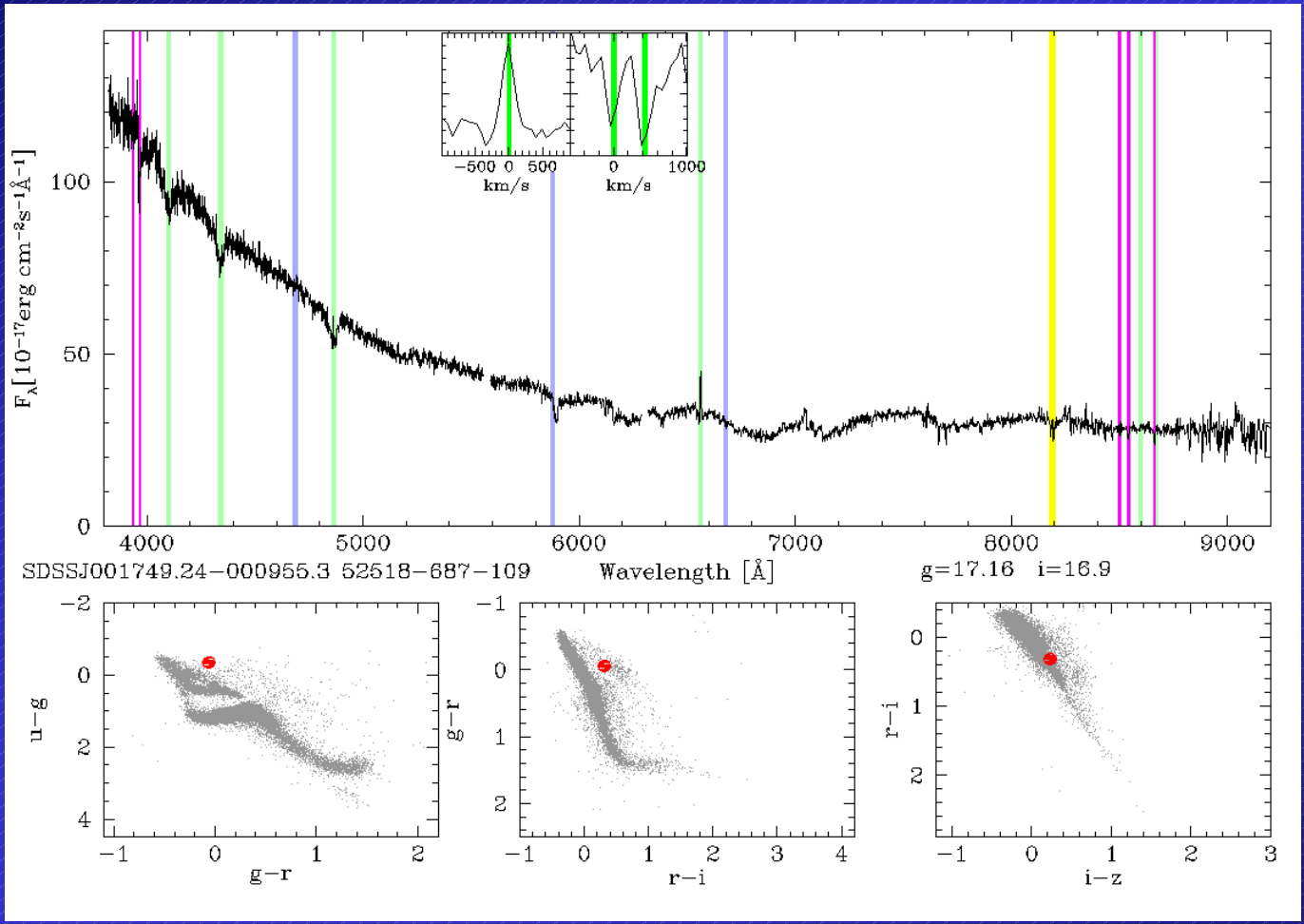

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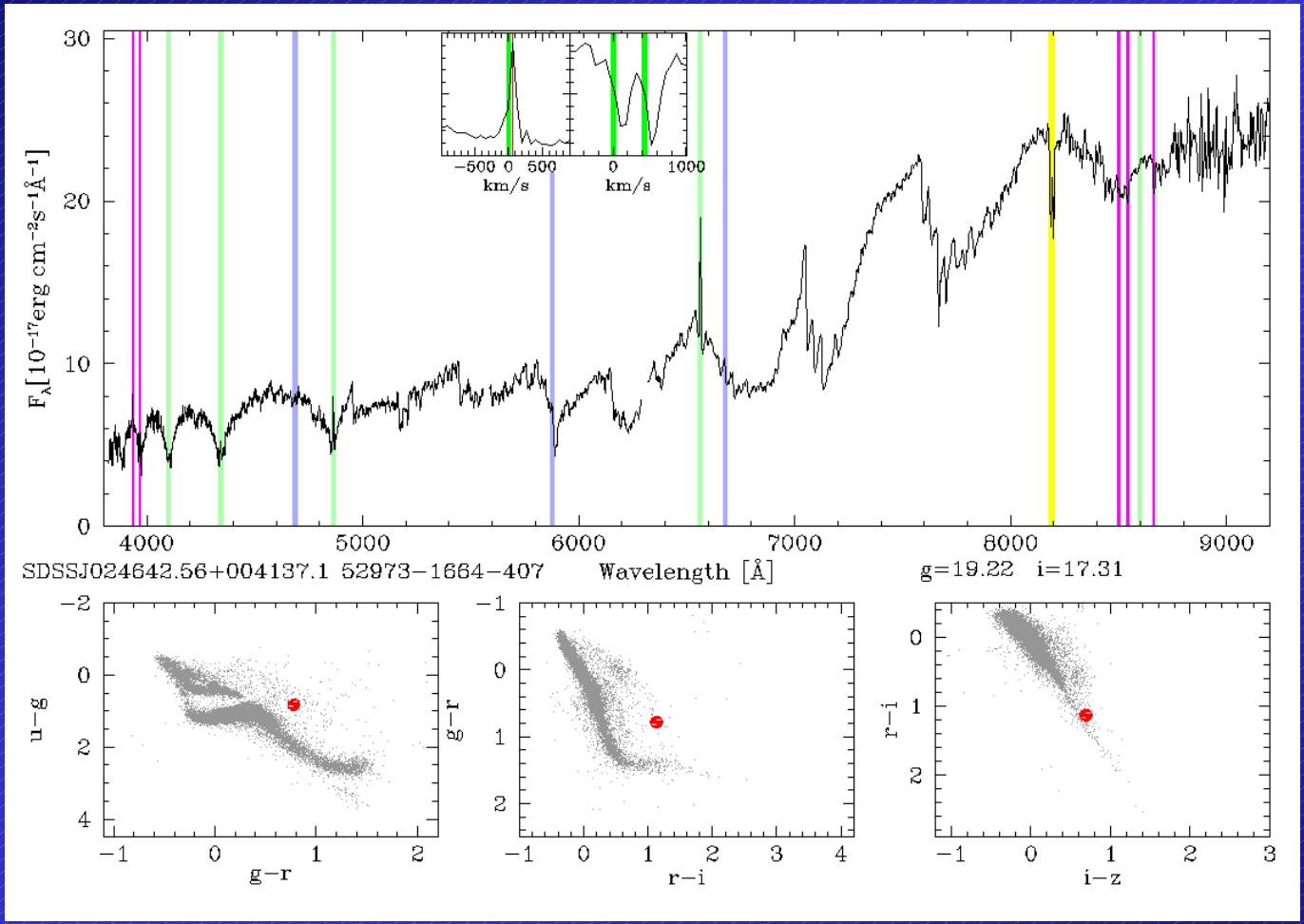

Raymond et al. 2003, AJ 125, 2621; Silvestri et al. 2005, AJ 131, 1674; Southworth et al. 2007, MNRAS submitted; Schreiber SEGUE project, astro-ph/0611461

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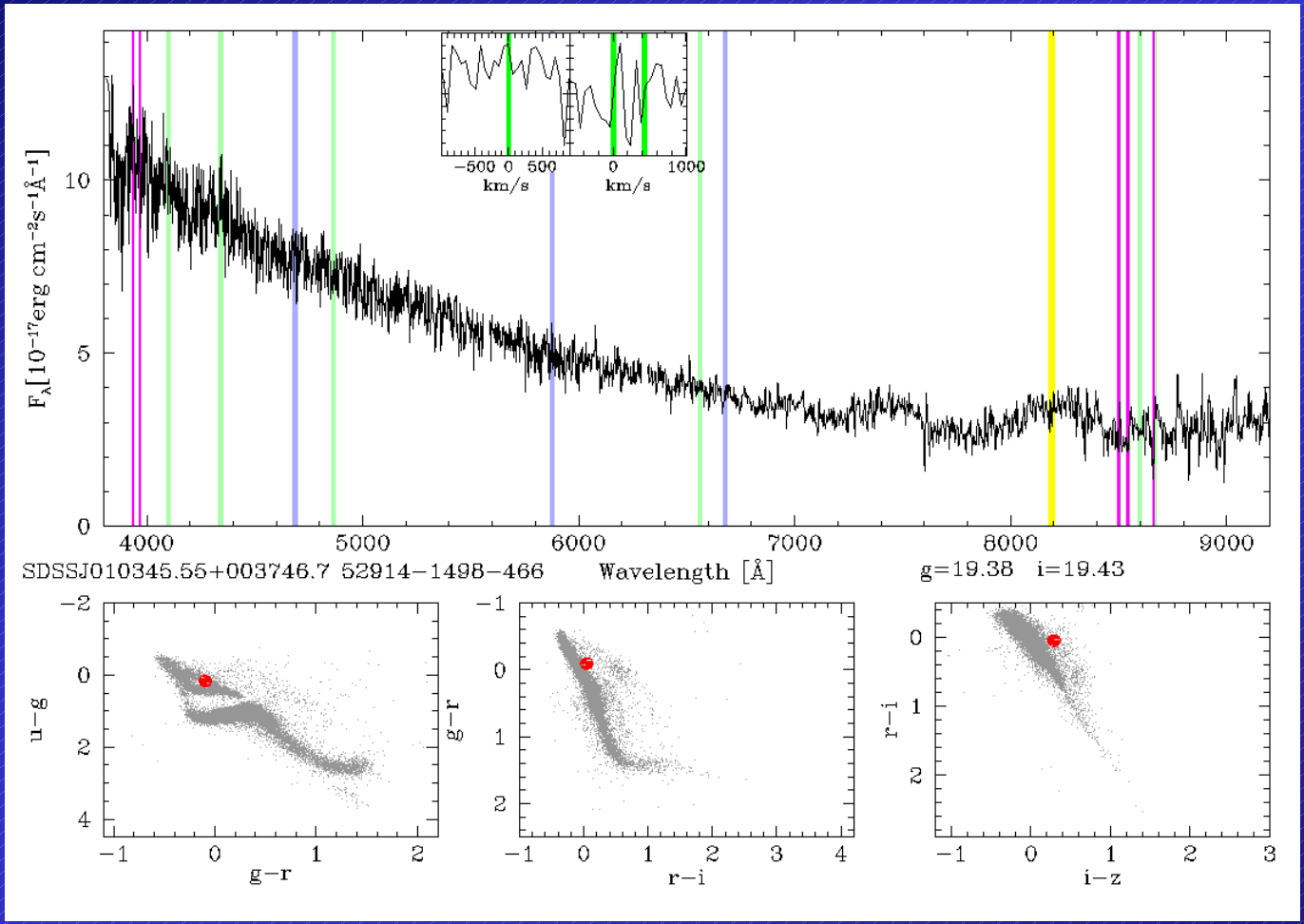

Raymond et al. 2003, AJ 125, 2621; Silvestri et al. 2005, AJ 131, 1674; Southworth et al. 2007, MNRAS submitted; Schreiber SEGUE project, astro-ph/0611461

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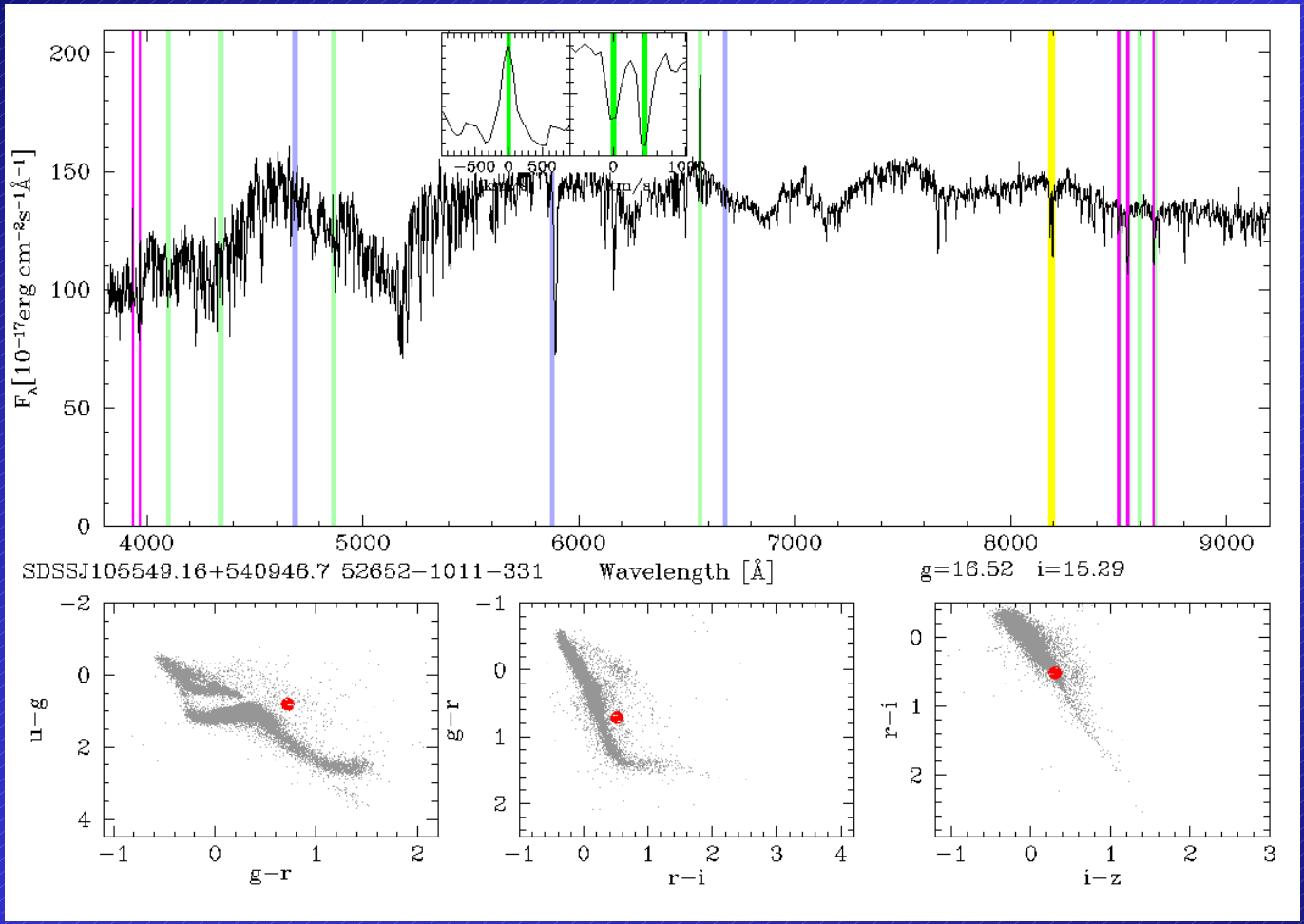
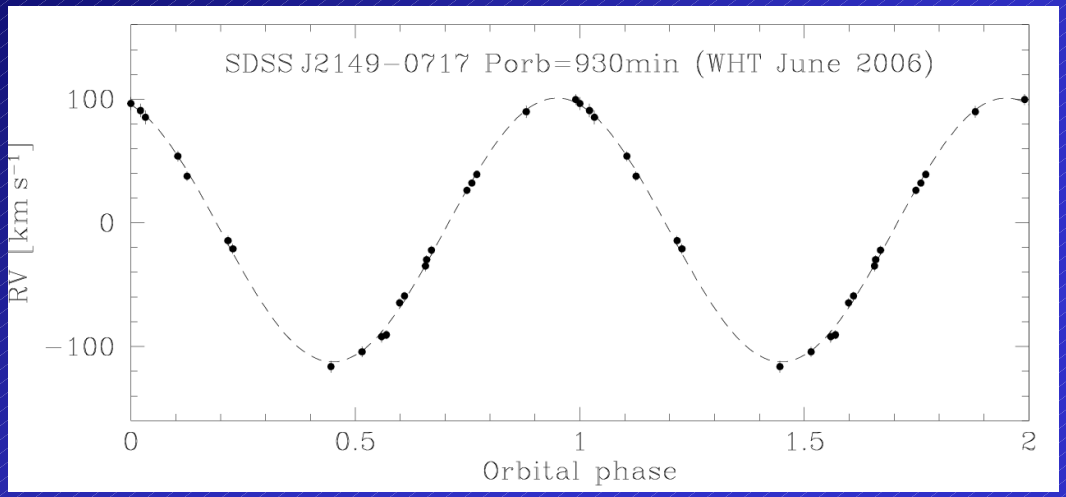


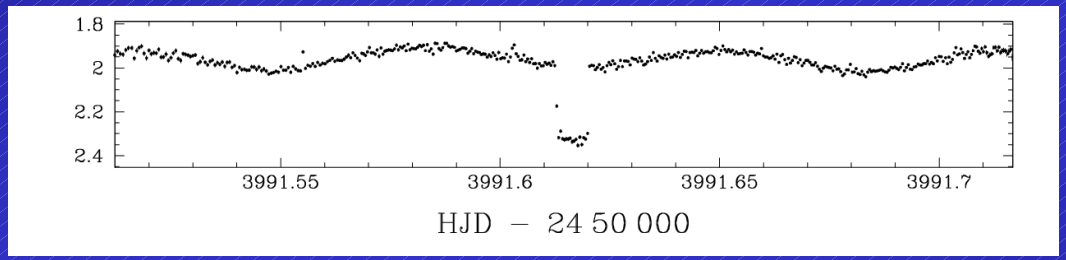
Raymond et al. 2003, AJ 125, 2621; Silvestri et al. 2005, AJ 131, 1674; Southworth et al. 2007, MNRAS submitted; Schreiber SEGUE project, astro-ph/0611461

Mission: measure PCEB parameter

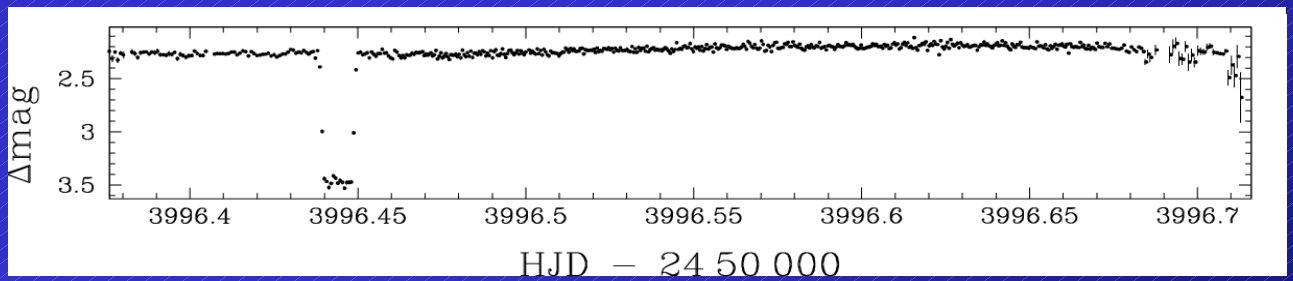
… 12n WHT, 60h VLT, 4n Magellan, 4n NTT …



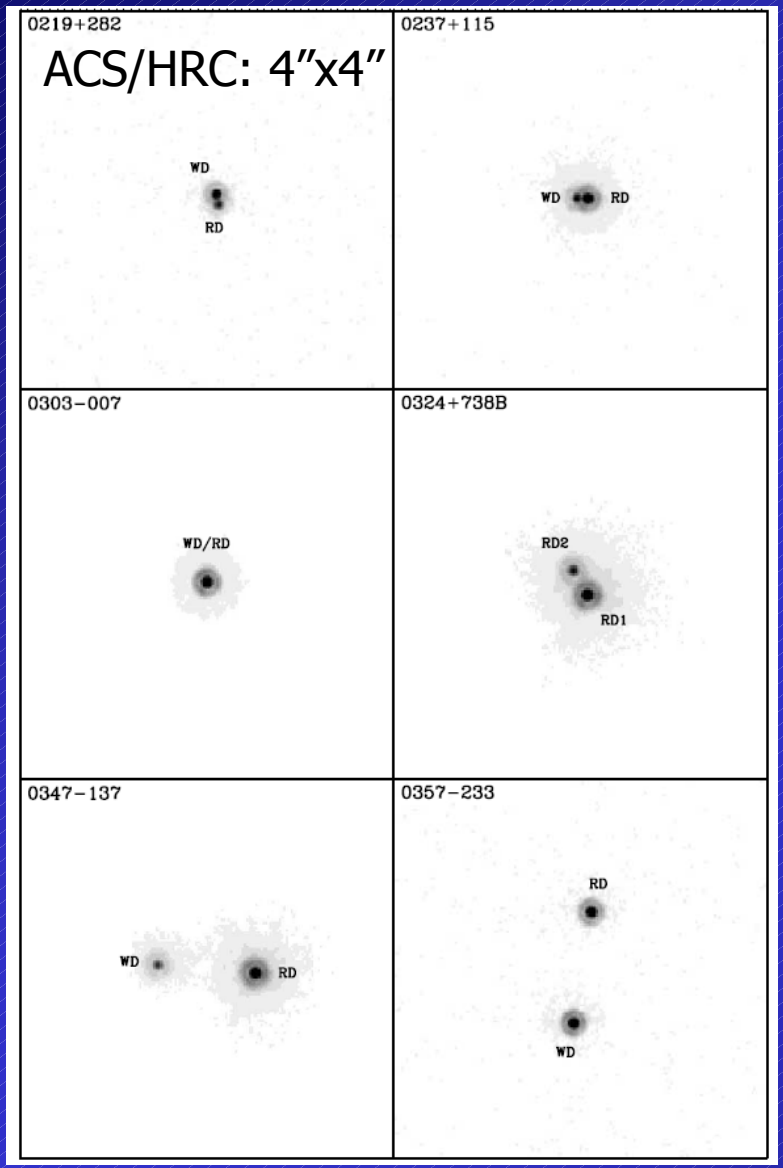
4 new eclipsing WD/MS
⇒ accurate masses & radii

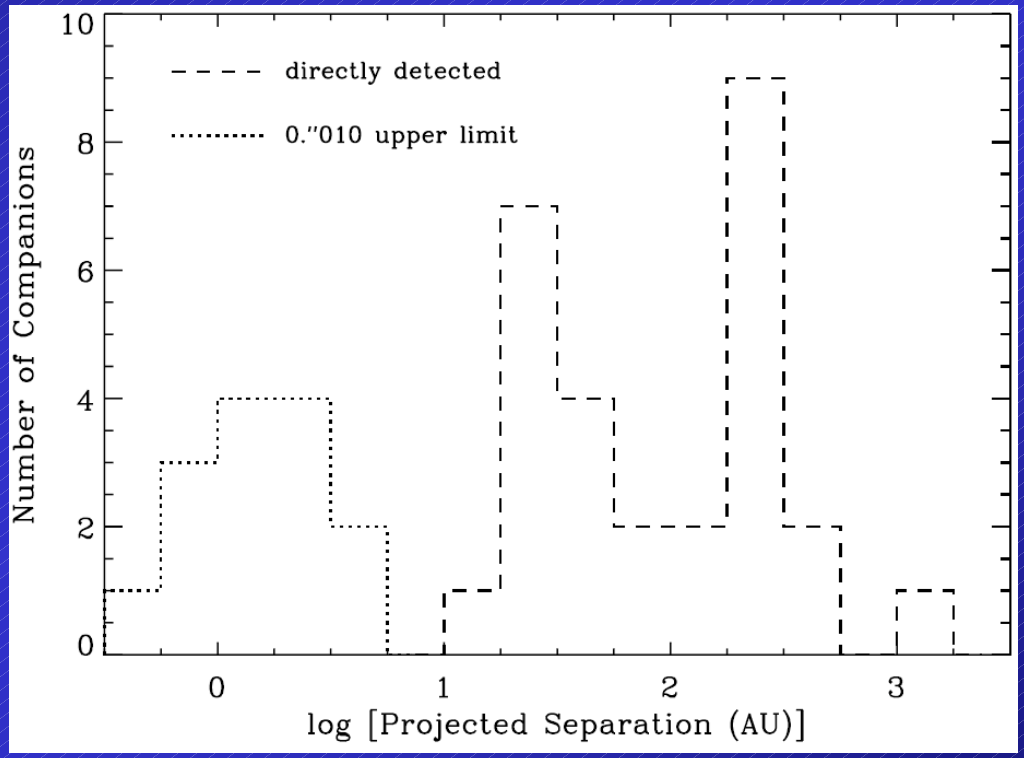


SDSS PCEBs will provide quantitative test/input for CE theory within a next few years



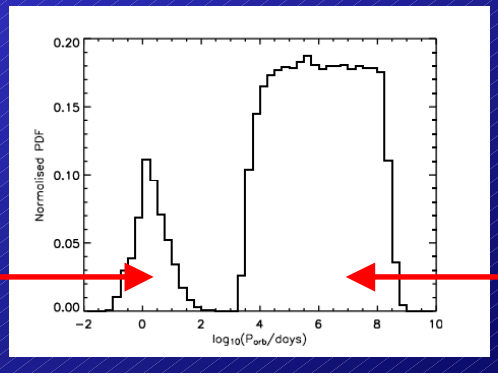
Joining in from the long-period side





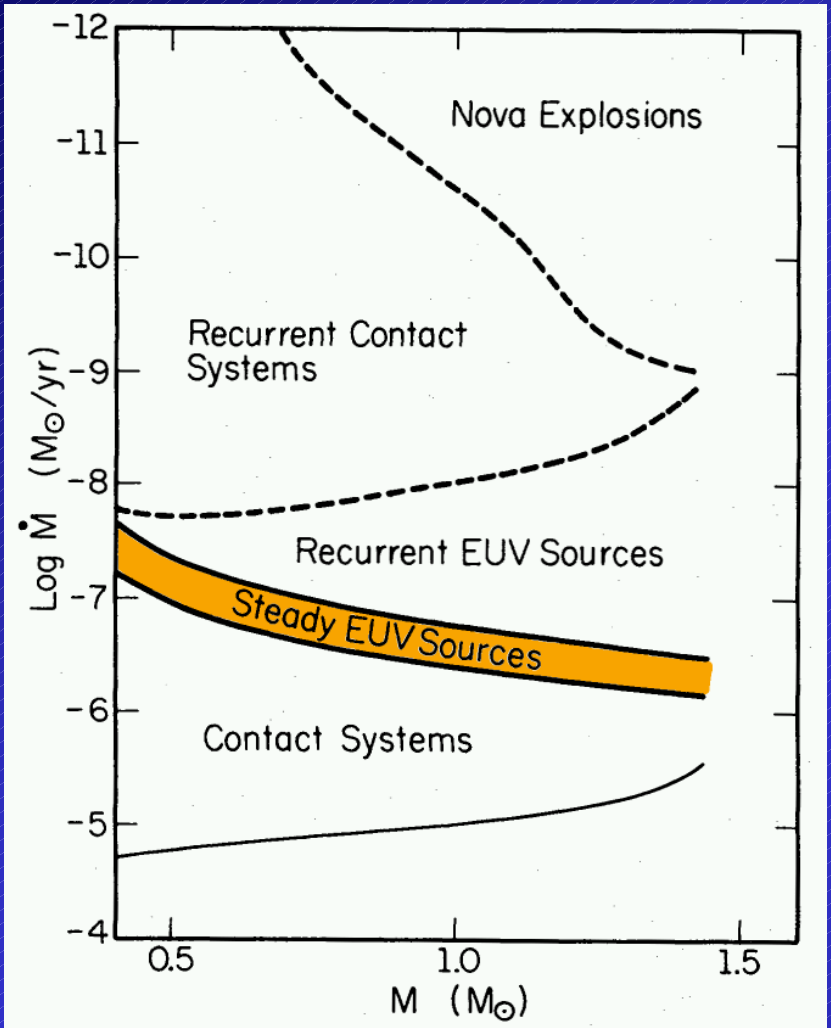
Farihi et al. 2006, ApJ 652, 636

phot.
spect.



imaging

Stable shell burning on white dwarfs



Fujimoto 1982, ApJ 257, 767

Iben 1982, ApJ 259, 244

Shara et al. 1977, A&A 61, 363

"Non-ejecting novae as EUV sources"

Long et al. 1981, ApJ 248, 925

CAL83 & 87

van den Heuvel 1992, A&A 262, 97

CAL83 & 87 are shell-burning WDs

Yungelson & Livio 1998, ApJ 497, 168;

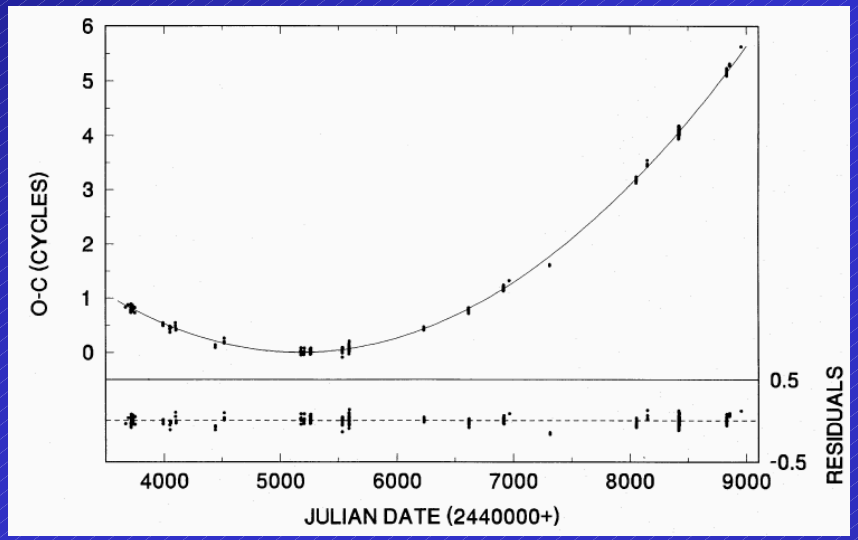
Starrfield et al. 2004, ApJL 612,53

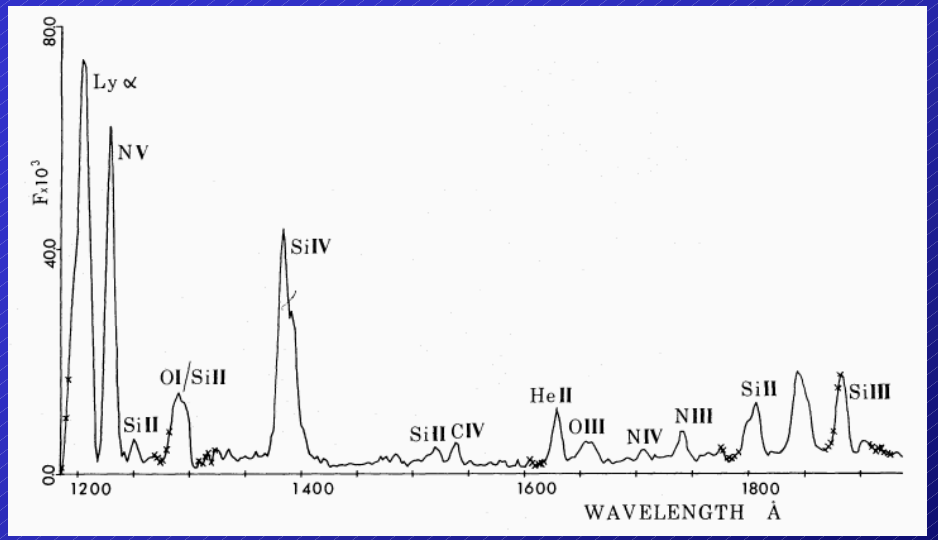
SNIa progenitors

Supersoft X-ray binaries (SSXB) – short-lived, rare, almost nothing known about their stellar components

AE Aquarii as an odd CV

- Rapidly rotating WD: Pspin=33s (Patterson 1979, ApJ 234, 978)
- Spin-down time scale ~10^7yr (de Jager et al. 1994, MNRAS 267, 577)





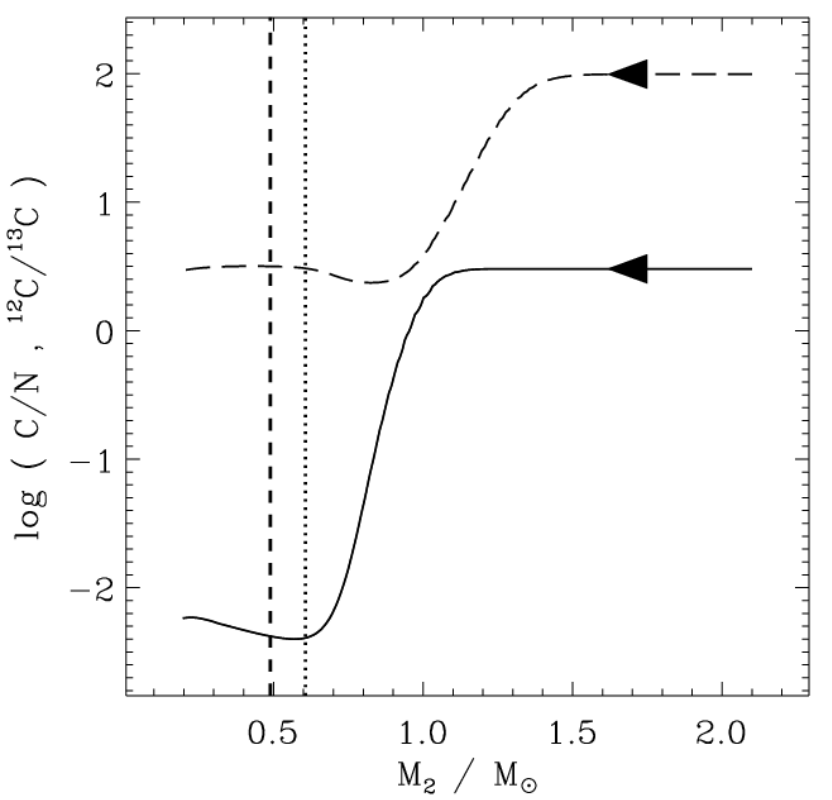
- Strong N/C abundance anomaly (Jameson et al. 1980, MNRAS 191, 559)

AE Aquarii as a post-SSXB

Initial binary: $M_{wd}=0.6M_{\odot}$ & $M_2=1.6M_{\odot}$

→ thermal time scale mass transfer

→ spin-up of the WD



- The present-day donor is the exposed core of the previously much more massive secondary star

- Simple population model: ~1/3 of all CVs could be post-SSXBs

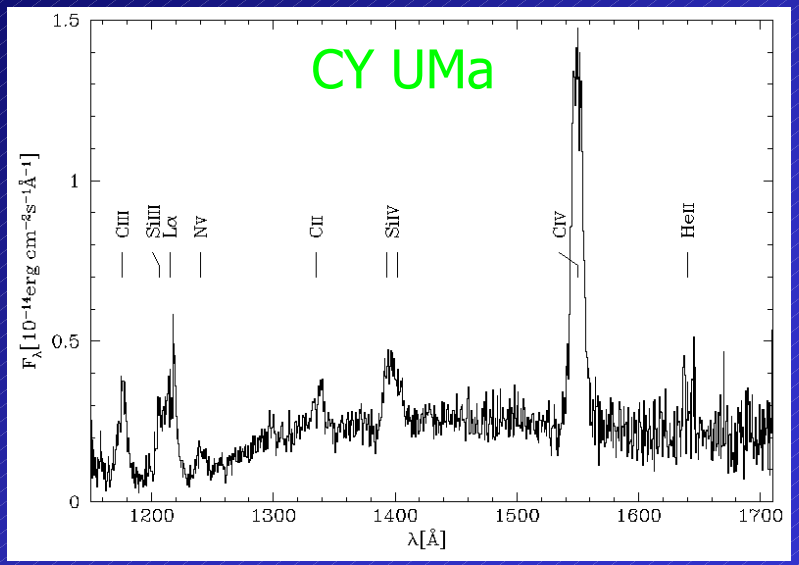
Schenker et al. 2002, MNRAS 337, 1105
Podsiadlowski et al. 2003, MNRAS 340, 1214

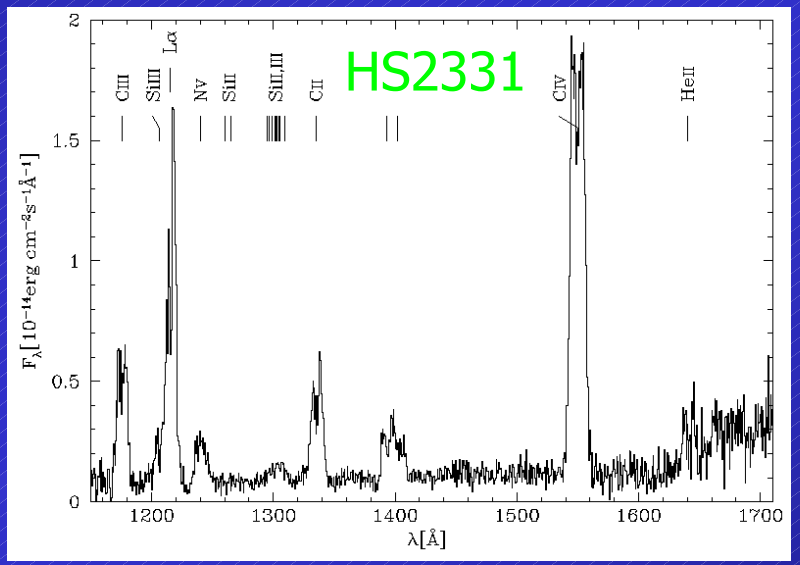
HST Cycle 11, 12 & 13 snapshot survey of CVs

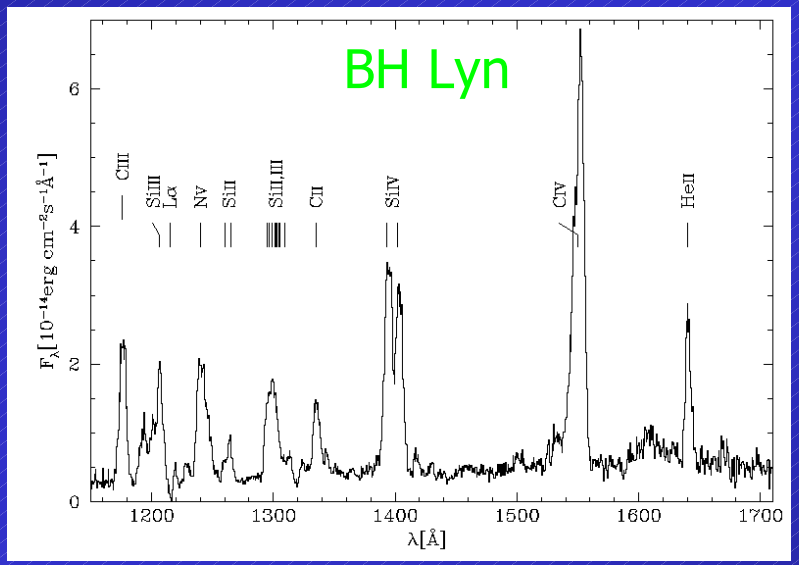
- Cycle 11: 149 orbits allocated, 51 observed
- Cycle 12: 70 orbits allocated, 18 observed
- Cycle 13: 70 orbits allocated, 0 observed (STIS ✝ 3/8/04)

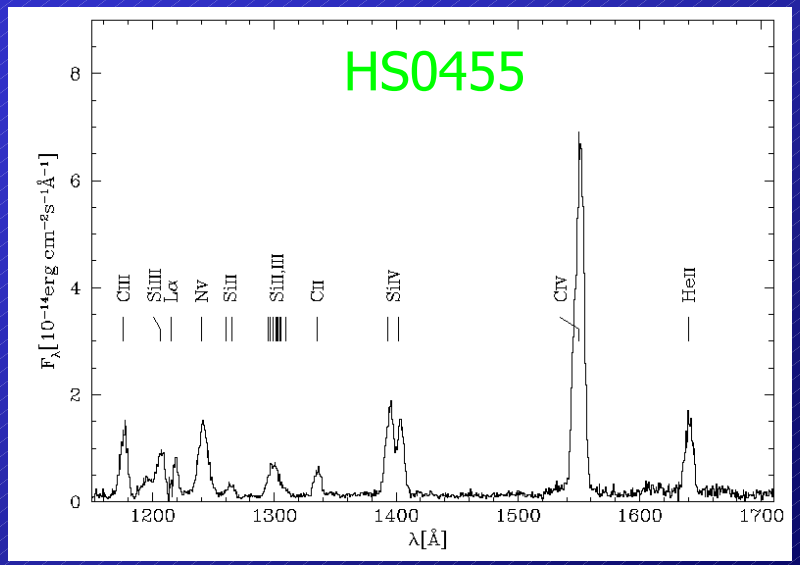
- Magnitude limited V~17.5
- Exposure times: 600s-900s
- STIS/G140L: 1150-1710Å, R~1000

HST CV survey: normal CVs

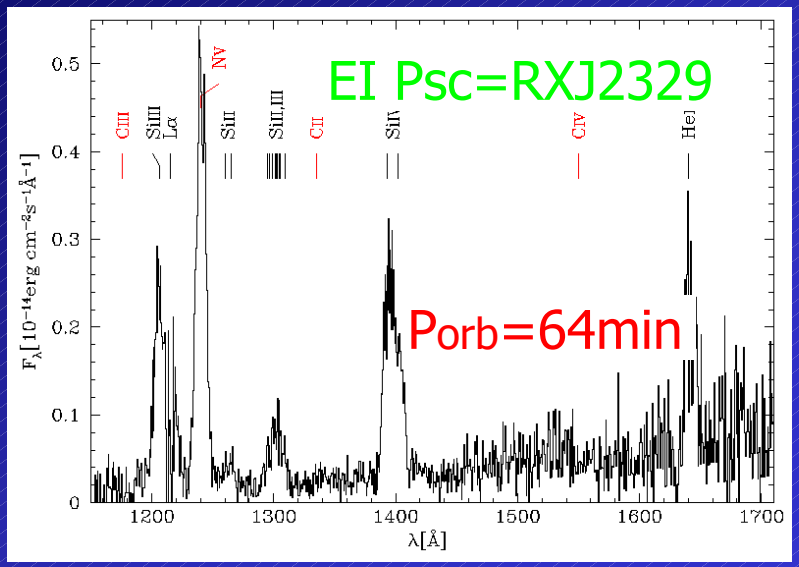


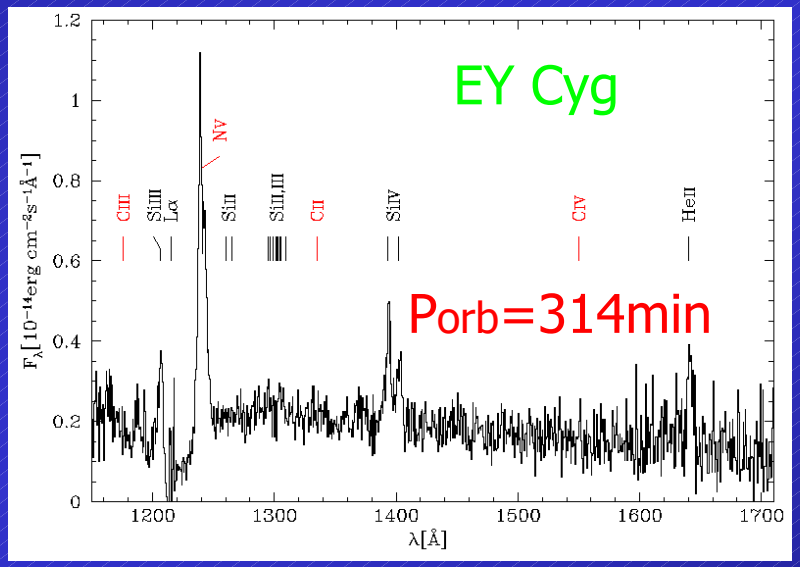


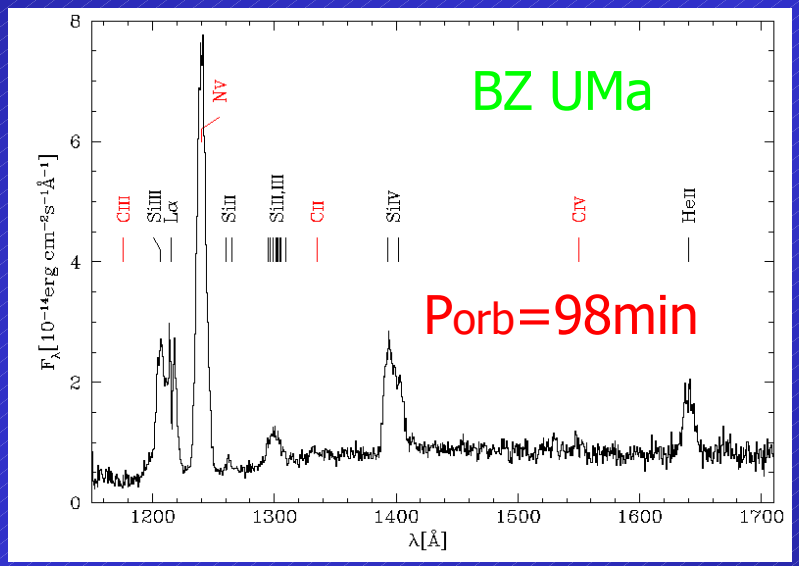


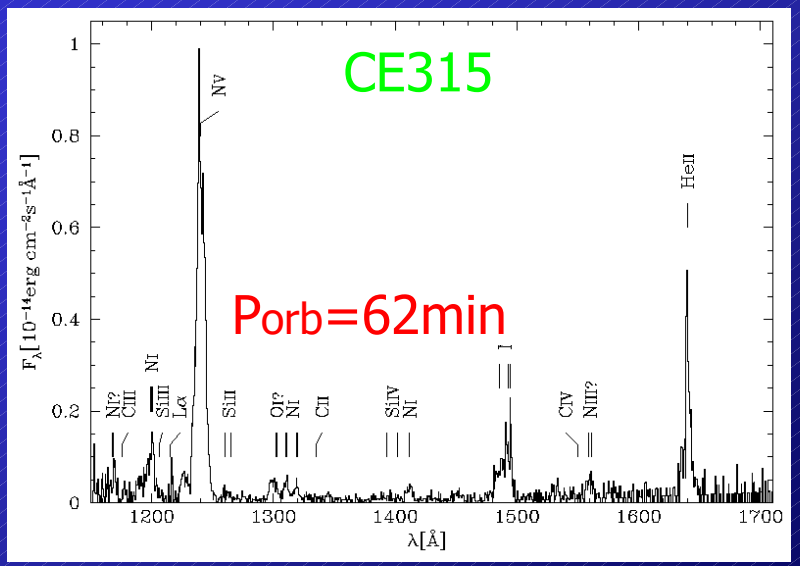


HST CV survey: anomalous CVs



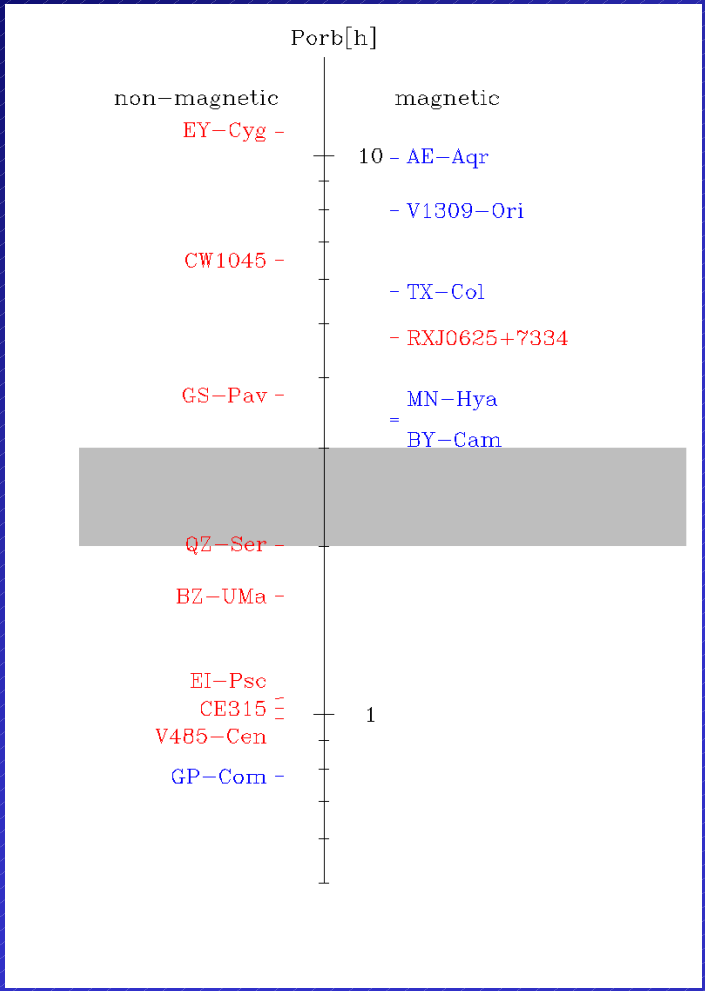


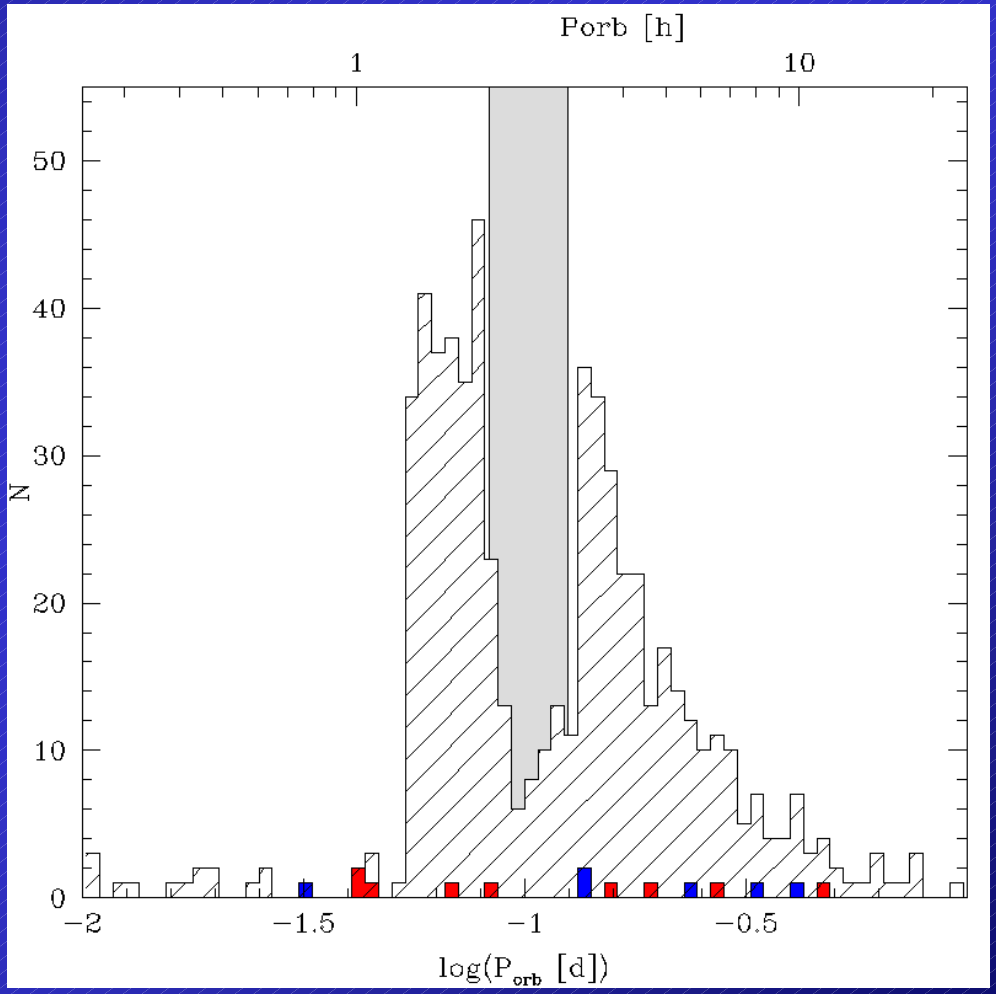




(Gänsicke et al. 2003, ApJ 594, 443)

Period distribution of failed SNIa





HST snapshot survey: ~13% with N/C overabundance, no preference in Porb

Summary

- SDSS going deeper than any survey before confirms two major predictions of CV evolution theory: BD donors, and an accumulation of systems at Pmin. However, total number of CVs still short of the predictions, and Pmin=80min

- SDSS has the potential of providing 100s of PCEBs with accurate binary parameters, should all strong constraints on CE models

- Post-SSXBs, or failed SNIa are abundant, relatively easy to study, and should teach us a lot about genuine SNIa progenitors. Need an UV spectrograph to identify them!