K-band Observations of Sub-Gap Cataclysmic Variables

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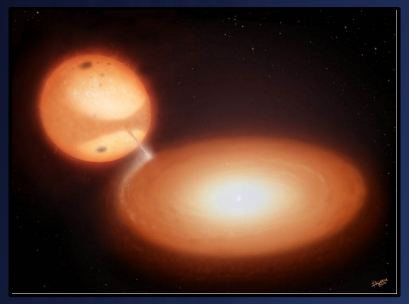
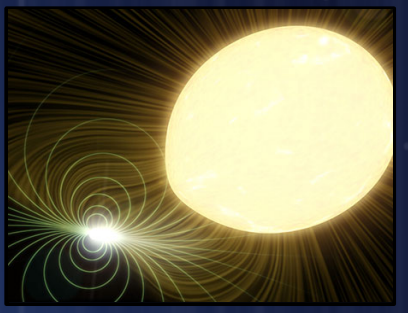
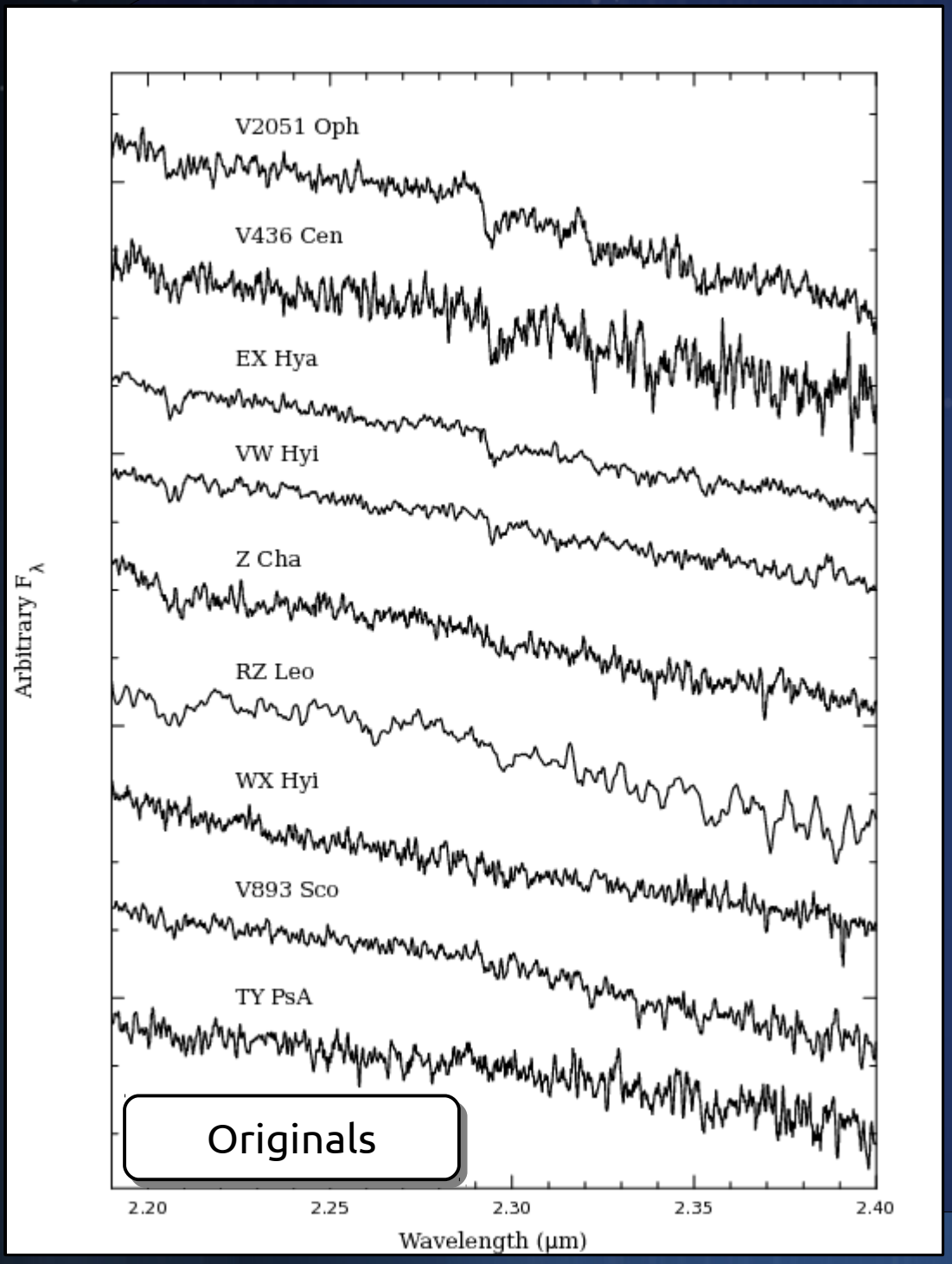
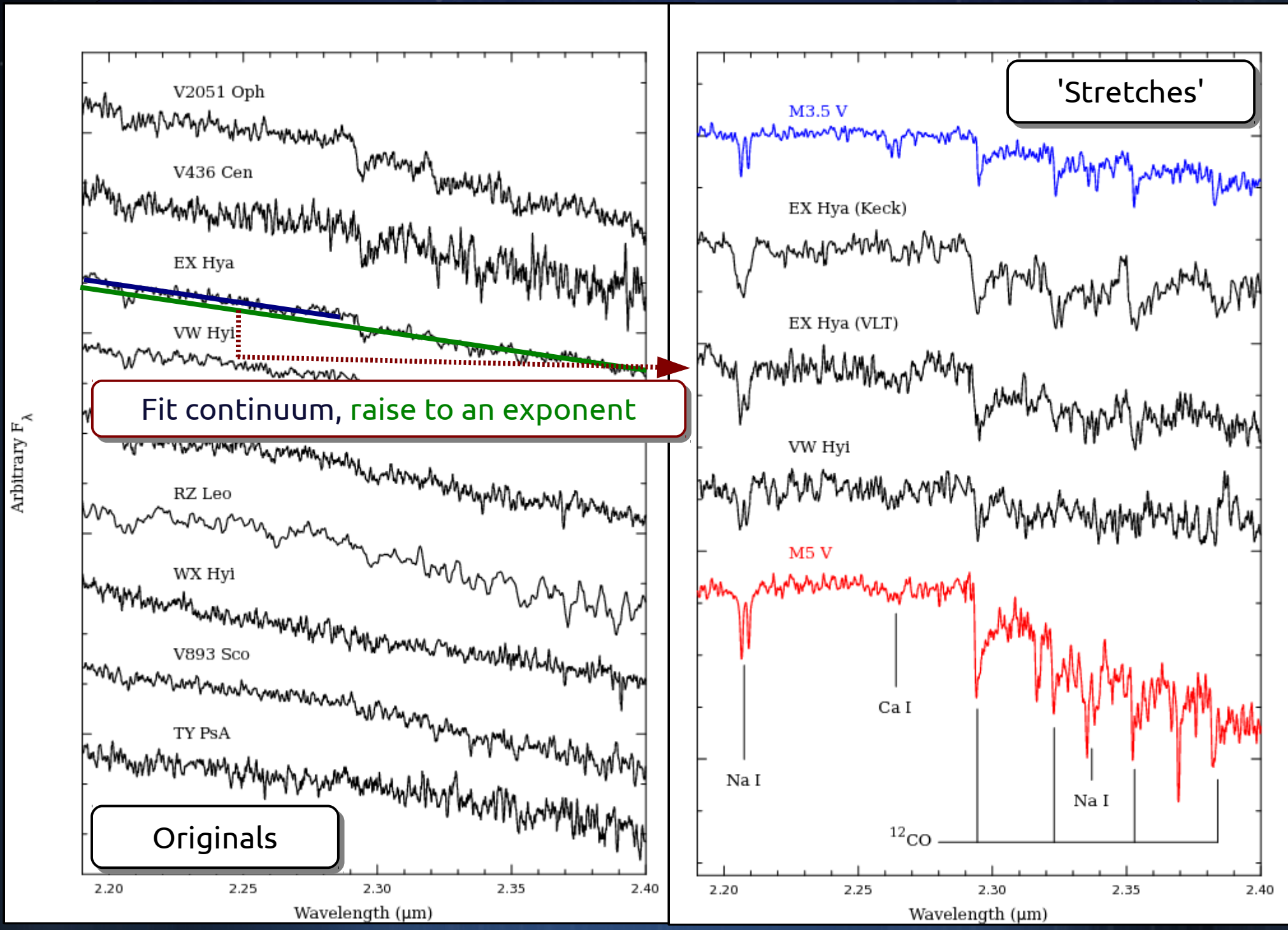


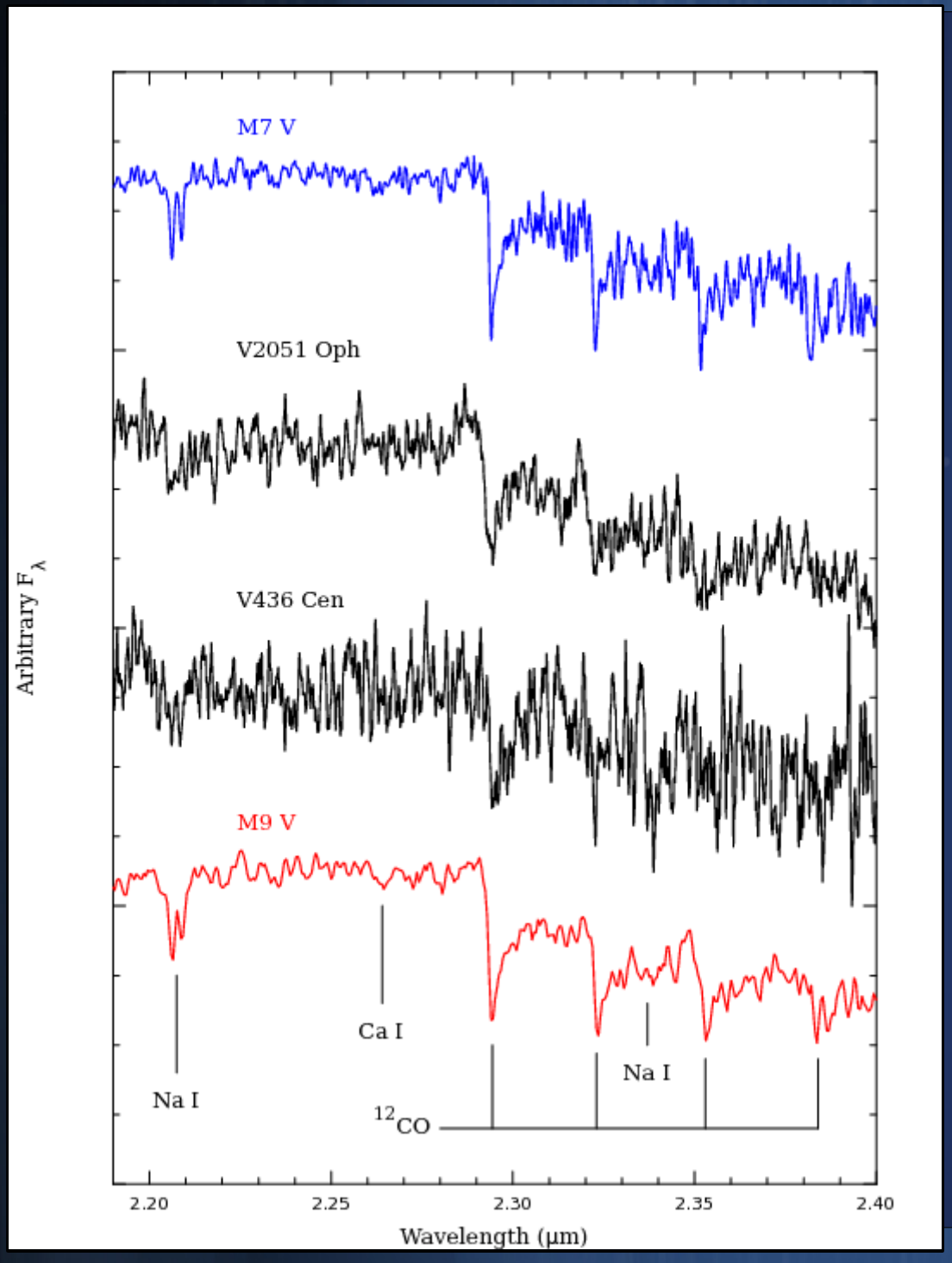
Motivation

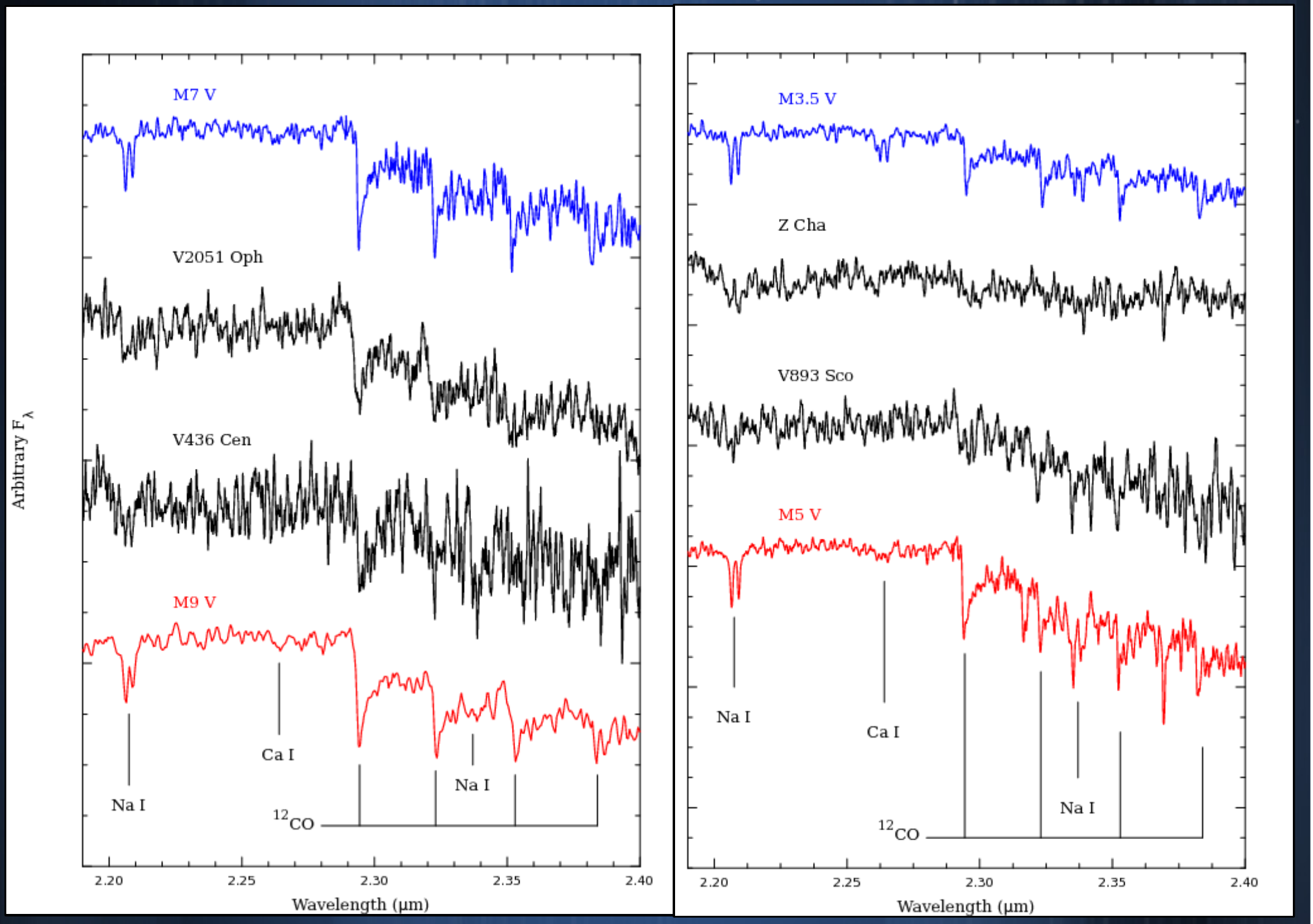


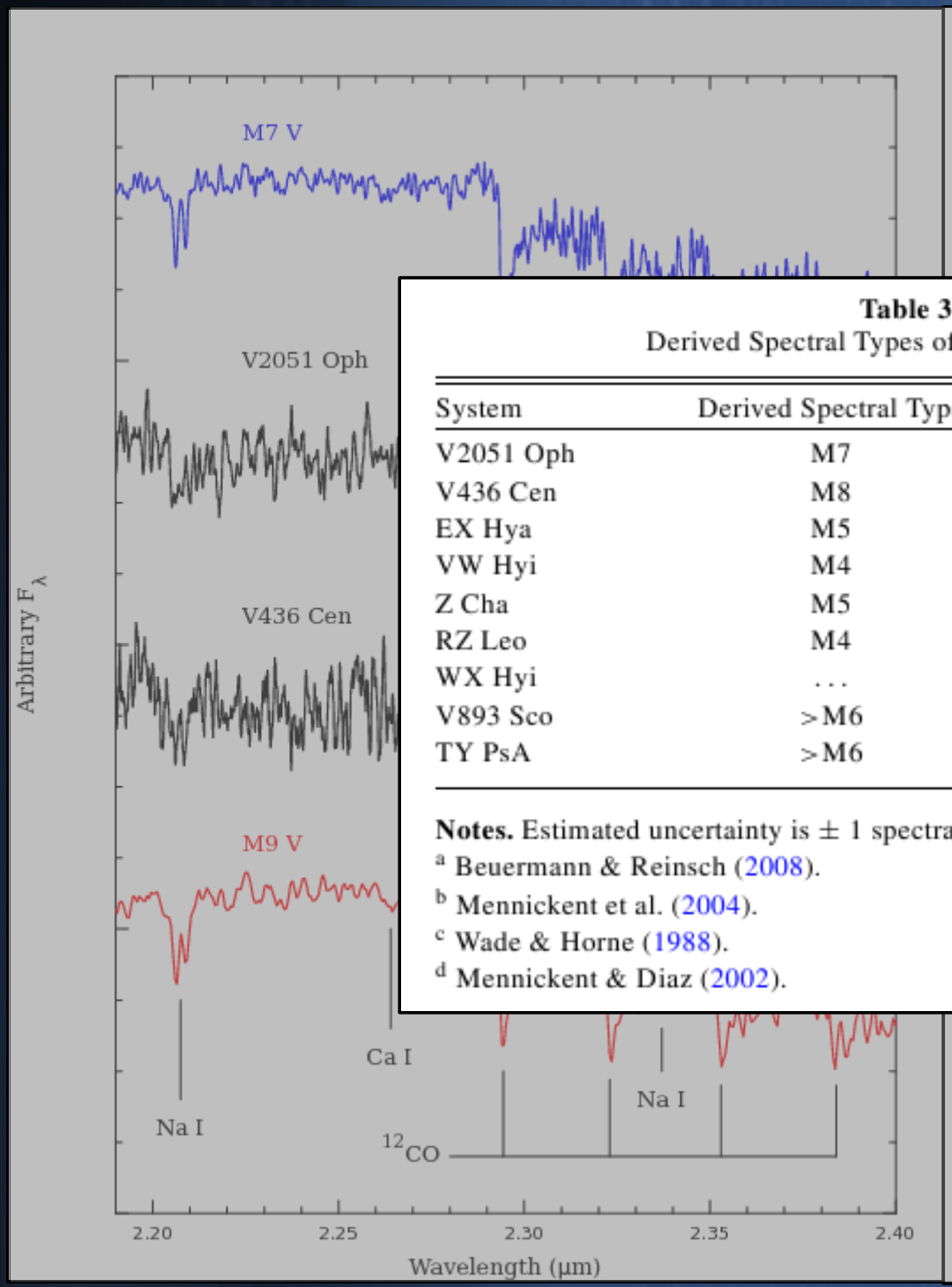
- CV's in 6 words or less:
  - White dwarf, low-mass dwarf, accretion, boom
- Explanation for 2-3 hr period gap rough
- NIR spectra examine secondary directly
  - NIR → UV connection? CVs with UV CNO anomaly tend to show weak CO bands...
    - Need more observations! Have any to share? ☺
  - 61 systems with NIR spectra
    - 19 Pre-CVs, 31 Non-Mag., 11 Mag./IP


V2051 Oph
V436 Cen
EX Hya
VW Hyi
Z Cha
RZ Leo
WX Hyi
V893 Sco
TY PsA
Originals
Arbitrary F_λ
2.20
2.25
2.30
2.35
2.40
Wavelength (μm)


V2051 Oph
V436 Cen
EX Hya
VW Hyi
RZ Leo
WX Hyi
V893 Sco
TY PsA
Arbitrary F_λ
Fit continuum, raise to an exponent
Originals
2.20
2.25
2.30
2.35
2.40
Wavelength (μm)
'Stretches'
M3.5 V
EX Hya (Keck)
EX Hya (VLT)
VW Hyi
M5 V
Na I
Ca I
Na I
^{12}CO
2.20
2.25
2.30
2.35
2.40
Wavelength (μm)


M7 V
V2051 Oph
V436 Cen
M9 V
Na I
Ca I
Na I
^{12}CO
Arbitrary F_λ
2.20
2.25
2.30
2.35
2.40
Wavelength (μm)


M7 V
V2051 Oph
V436 Cen
M9 V
Na I
Ca I
Na I
12CO
Arbitrary Fλ
2.20
2.25
2.30
2.35
2.40
Wavelength (μm)
M3.5 V
Z Cha
V893 Sco
M5 V
Na I
Ca I
Na I
12CO
2.20
2.25
2.30
2.35
2.40
Wavelength (μm)



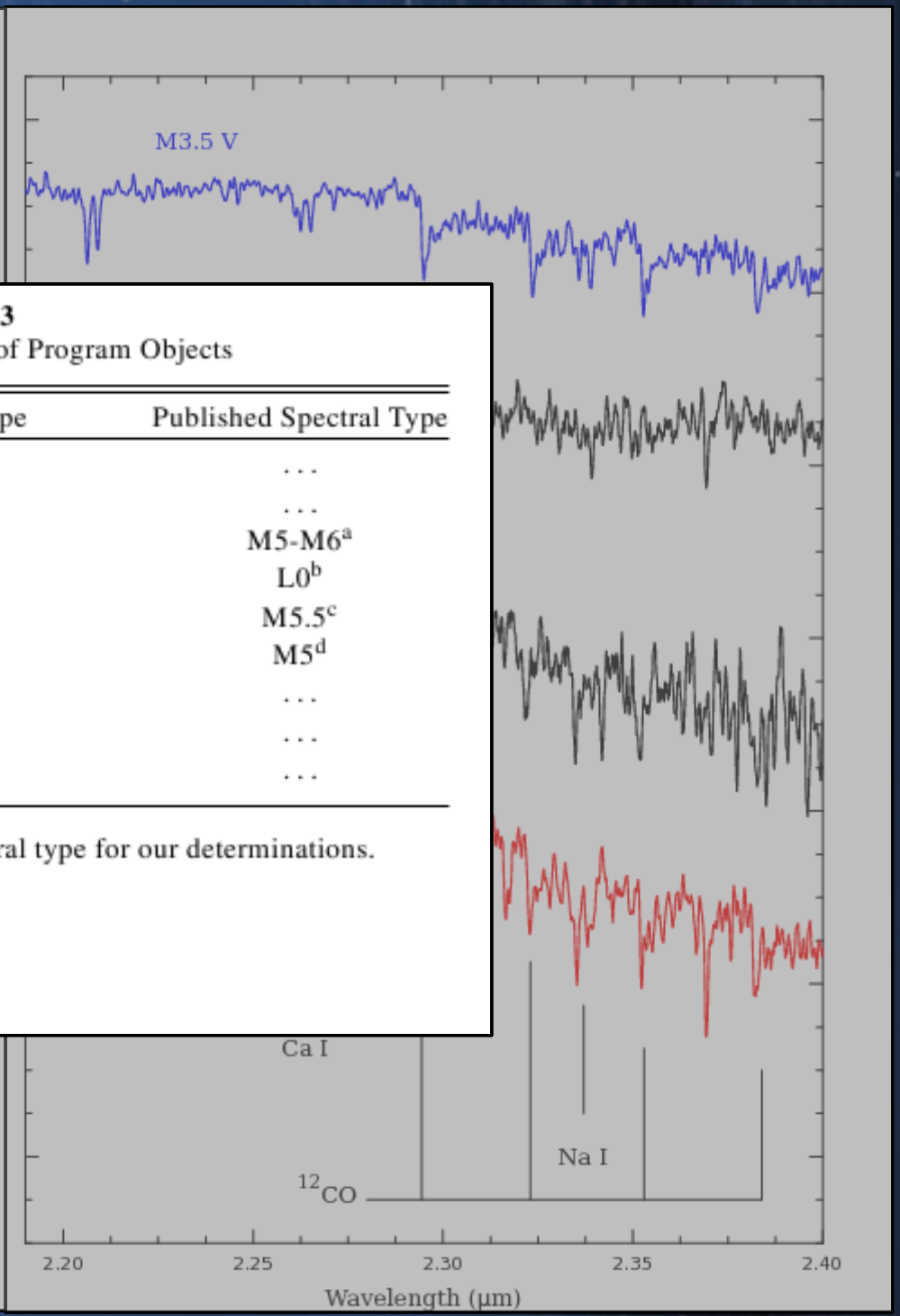


Table 3
Derived Spectral Types of Program Objects

System	Derived Spectral Type	Published Spectral Type
V2051 Oph	M7	...
V436 Cen	M8	...
EX Hya	M5	M5-M6[a]
VW Hyi	M4	L0[b]
Z Cha	M5	M5.5[c]
RZ Leo	M4	M5[d]
WX Hyi	...	...
V893 Sco	>M6	...
TY PsA	>M6	...

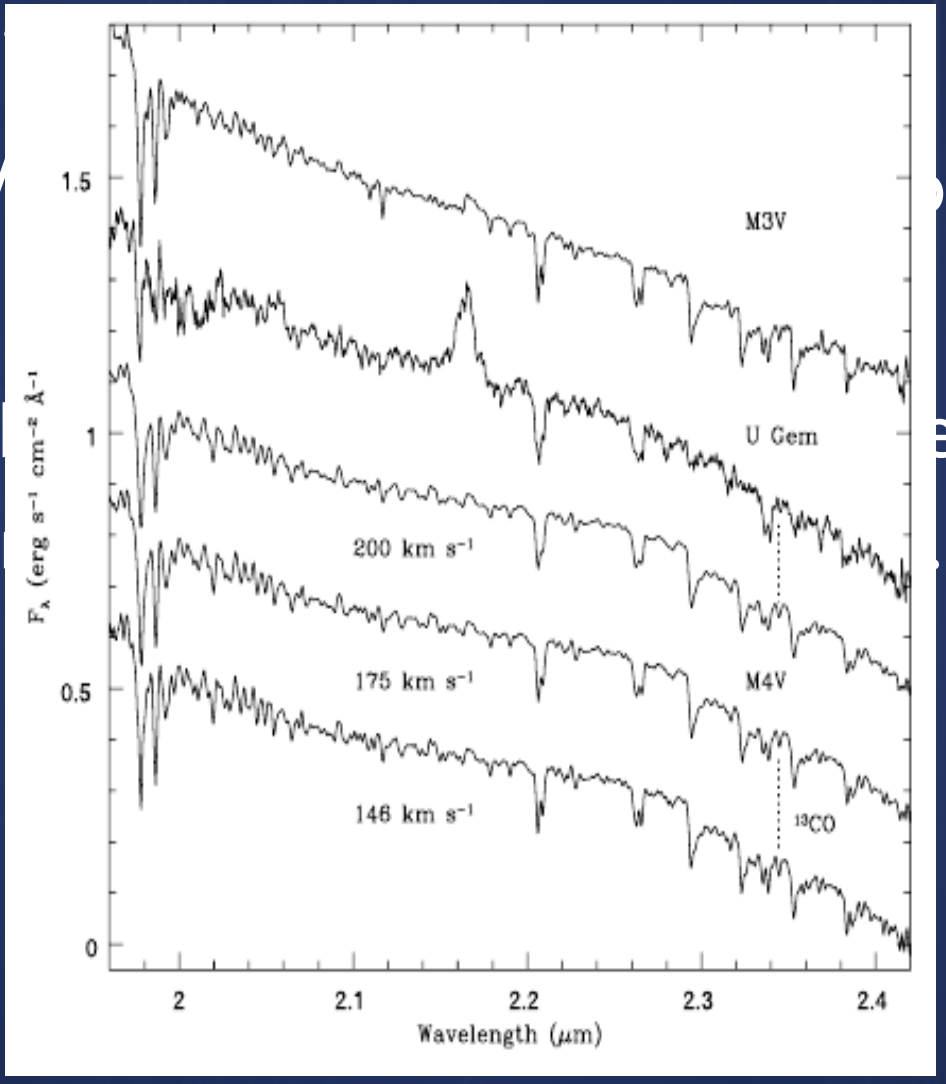
Notes. Estimated uncertainty is ± 1 spectral type for our determinations.
[a] Beuermann & Reinsch (2008).
[b] Mennickent et al. (2004).
[c] Wade & Horne (1988).
[d] Mennickent & Diaz (2002).

Thesis Work

- Short period systems normal
  - Pre-CV/Magnetic systems appear normal too
- Long period systems strange
  - 13/19 show weak/absent CO features (~70%)
  - Some enhanced ^{13}CO (Harrison et al. 2005)
- Synthetic spectra to play with
  - Weak CO → low C abundance?
  - PHOENIX & MOOG modeling

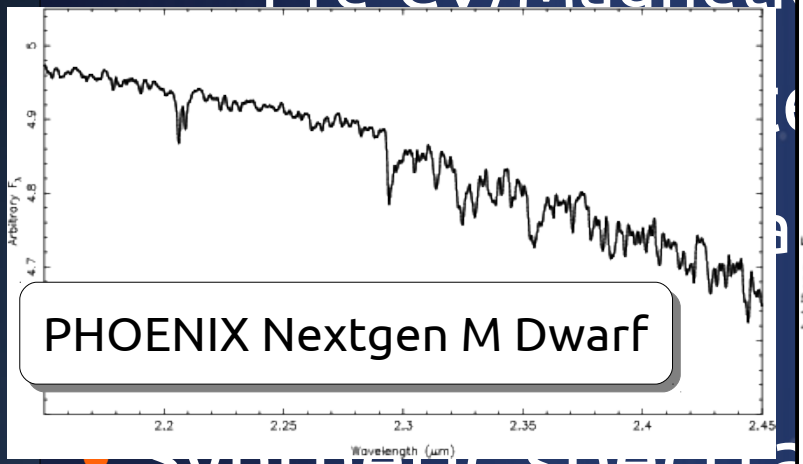
Thesis Work

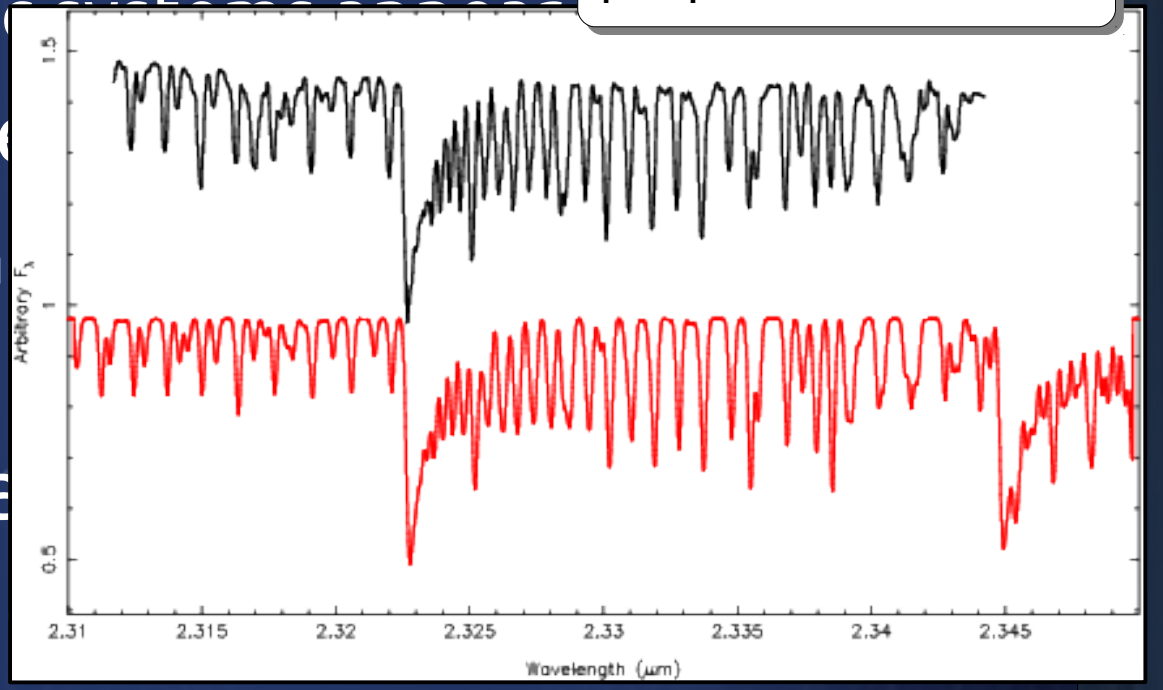
- Short per
  - Pre-CV/ rmal too
- Long peri
  - 13/19 s es (~70%)
  - Some e 2005)
- Synthetic
  - Weak C
  - PHOEN



Thesis Work

- Short period systems normal
  - Pre-CV/Magneti
- Synthetic spectra
  - Weak CO → low
  - PHOENIX & MOOG modeling





Thanks!

Our paper is available! ApJ soon and arXiv now: **arXiv:1012.1368**

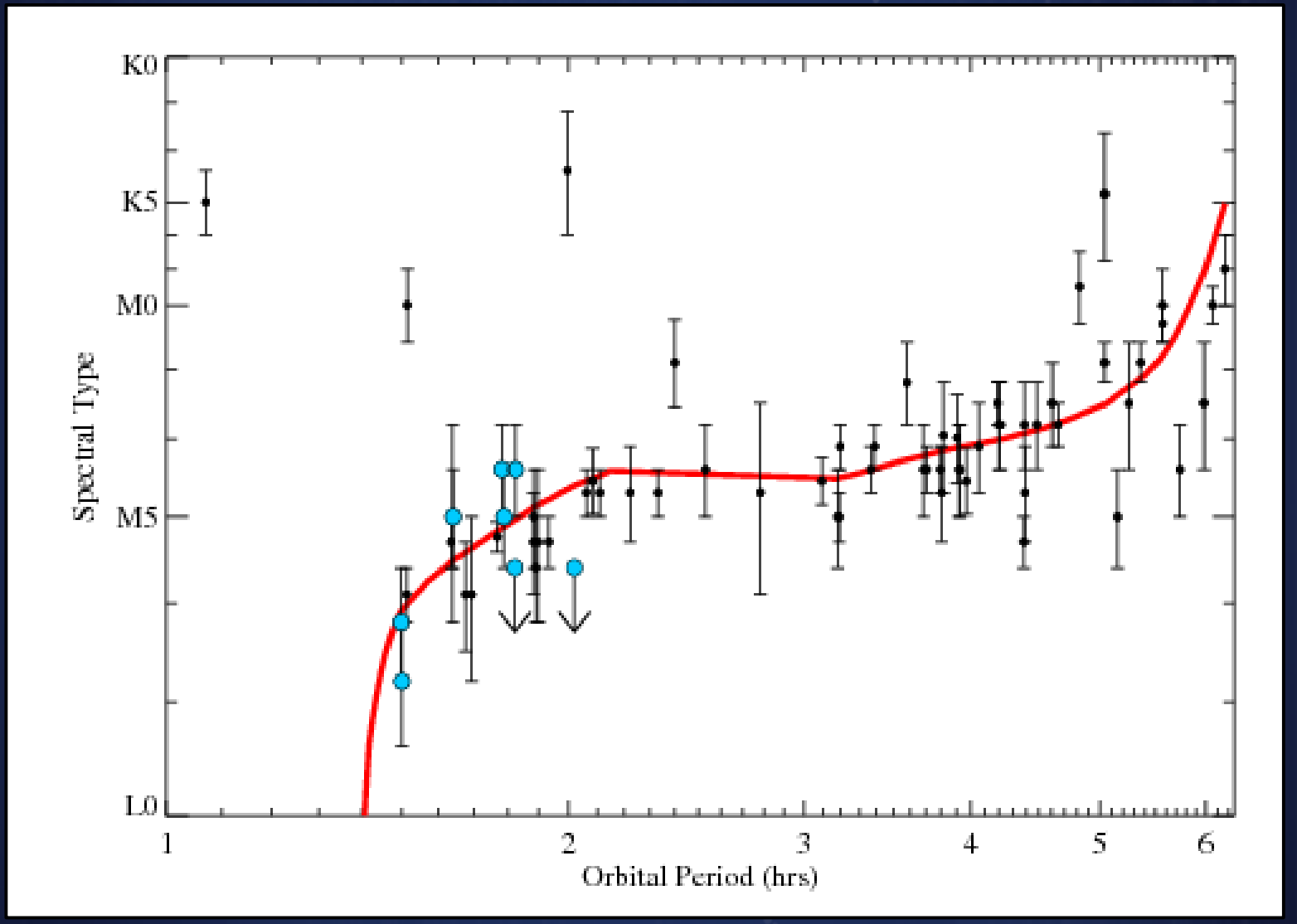
Special thanks to K. Cunha, V. Smith, and E. Sion for all their helpful discussions!

R.T. Hamilton, T.E. Harrison, C. Tappert, S.B. Howell

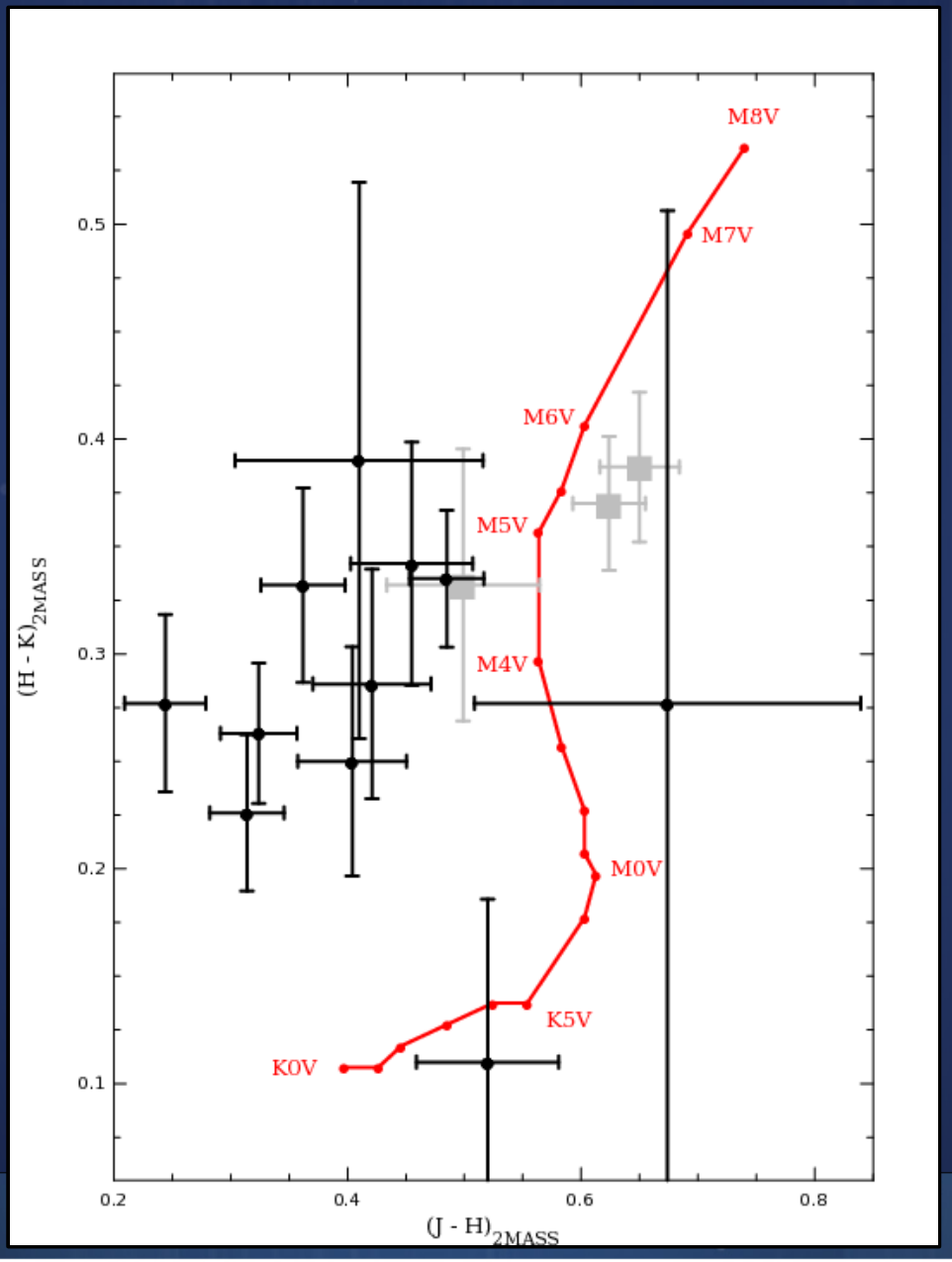
http://astronomy.nmsu.edu/rthamilt/conferences

Extra Slides

Knigge Comparison



Comparison Colors



Big List (PreCV, NonMag)

Table 4
CO Absorption Strength Across all CV Subtypes

Star	Subtype	P_{orb} (hr)	CO Ab.[a]	Ref[b]
Pre-CV Systems				
P83l-57	Pre-CV	...	Y	11
HS1136	Pre-CV	20.1	ND	8
RE 1016-053	Pre-CV	18.9	Y	11
UZ Sex	Pre-CV	14.3	Y	11
EC 12477-1738	Pre-CV	13.7:	Y	11
V471 Tau	Pre-CV	12.5	Y	8
EC 13349-3237	Pre-CV	11.4:	Y	11
EC 14329-1625	Pre-CV	8.4:	Y	11
BPM 6502	Pre-CV	8.08	Y	11
RR Cae	Pre-CV	7.29	Y	11
CC Cet	Pre-CV	6.82	Y	11
SDSS0743	Pre-CV	4.6	Y	8
BPM 71214	Pre-CV	4.33	Y	11
BPM 71213	Pre-CV	4.33	Y	8
EC 13471-1258	Pre-CV	3.62	Y	11
LTT 560	Pre-CV	3.54	Y	11
SDSS0757	Pre-CV	3.5	Y	8
NN Ser	Pre-CV	3.12	Y	11
SDSS0830	Pre-CV	2.9	Y	8
Non-magnetic Systems				
EY Cyg	DN UG	11.0	W[c]	9
BT Mon	NL SW	7.99	ND	8
SY Cnc	DN ZC	9.12	ND*	5
RU Peg	DN UG	8.99	W	5
CH UMa	DN UG	8.23	W	5
MU Cen	DN UG	8.21	W	5
AC Cnc	NL SW	7.21	Y ?	5
EM Cyg	DN ZC	6.98	W**	5
V426 Oph	DN ZC	6.85	Y	5
SS Cyg	DN UG	6.60	W	5
AH Her	DN ZC	6.20	W	5
BV Pup	DN UG	6.35	ND	5
EX Dra	DN UG	5.04	Y	4
TW Vir	DN UG	4.38	N	4
SS Aur	DN UG	4.38	Y	8
U Gem	DN UG	4.25	W[d]	4
UU Aql	NL SW	3.92	N	4
IP Peg	DN UG	3.80	Y	4
RR Pic	NL Nb SW	3.48	W	4
TY PsA	DN SU	2.02	ND	10
RZ Leo	DN SU	1.82	Y	8
V893 Sco	DN SU	1.82	?	10
WX Hyi	DN SU	1.80	ND	10
Z Cha	DN SU	1.79	W	10
VW Hyi	DN SU	1.78	Y	10
VY Aqr	DN SU WZ	1.51	N	1
V436 Cen	DN SU	1.50	Y	10
V2051 Oph	DN SU	1.50	Y	10
WZ Sge	DN SU WZ	1.35	E	6
GW Lib	DN SU WZ ZZ	1.33	?	8
EI Psc	DN SU	1.07	N[e]	1

Big List (Magnetics)

Magnetic Systems				
GK Per	DN Na IP	47.9	W	3
AE Aqr	NL DQ	9.86	W[f]	7
V1309 Ori	NL AM	7.98	W[g]	8
MQ Dra	NL AM LA	4.39	Y	3
SDSS0837	NL AM LA	3.18	Y	8
AM Her	NL AM	3.09	Y	4
AR UMa	NL AM	1.93	Y	3
ST LMi	NL AM	1.91	Y	3,8
MR Ser	NL AM	1.89	Y	4
VV Pup	NL AM	1.67	Y	2,3
EX Hya	NL IP	1.64	Y	10

Notes. Only objects with NIR observations in the K band with $R \gtrsim 1500$ are included. A colon next to the orbital period indicates an uncertain result.

[a] Y = appears normal for spectral type; W = appears weaker than normal for spectral type; N = not present, but should have been for spectral type; ND = not detectable; ? = too low S/N; and E = emission.

[b] (1) Harrison et al. 2009; (2) Howell et al. 2006; (3) Harrison et al. 2005b; (4) Harrison et al. 2005a; (5) Harrison et al. 2004b; (6) Howell et al. 2004; (7) Harrison et al. 2007; (8) Howell et al. 2010; (9) T. E. Harrison (2010, private communication); (10) this Work; (11) Tappert et al. 2007.

[c] Sion et al. (2004); Gänsicke et al. (2003).

[d] Long & Gilliland (1999).

[e] Gänsicke et al. (2003).

[f] Jameson et al. (1980).

[g] Szkody & Silber (1996); Schmidt & Stockman (2001).

* Very early spectral type, G1.5V so CO bands are not prominent.

** Third light contamination in the system, see North et al. (2000).