The Time Domain Spectroscopic Survey: Stellar Variables

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SDSS-IV Meeting, 2019

Ensenada, Mexico

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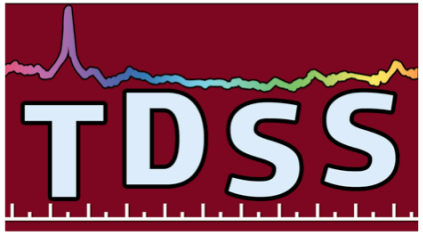
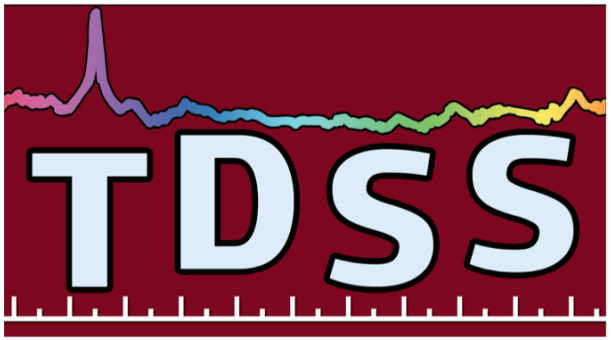


SDSS-IV TIME DOMAIN SPECTROSCOPIC SURVEY



- Adds dedicated spectra to era of time domain imaging.
- First large-scale, *inclusive* spectroscopic survey of variable sources
  - No color selection
  - Generic variability, i.e., no requirement for periodicity, flares, etc.
- Extending Survey Science to the Time Domain/Spectroscopy through:
  - ***Systematic discovery*** of celestial variables
  - ***Population studies*** of variable stars and quasars
  - ***Exploring the unknown:*** rare objects

Overview:

Three principal components of TDSS, piggy-back on

Main survey

eBOSS ELG plates

- TDSS main (90%) survey: SES=single-epoch spectroscopy BOSS classification/characterization spectra of imaging variables from Pan-STARRS 1, 3π imaging survey (PS1); ~10^5 fibers in SDSS-IV (10/deg^2)
- TDSS (10%) FES=few-epoch spectroscopy of potential spectral variables of interest (e.g., known from SDSS I-IV spectra) ~$10^{3\text{-}4}$ fibers in SDSS-IV
- TDSS RQS=repeat quasar spectroscopy of SDSS I-IV quasars; ~10^4 fibers in SDSS-IV

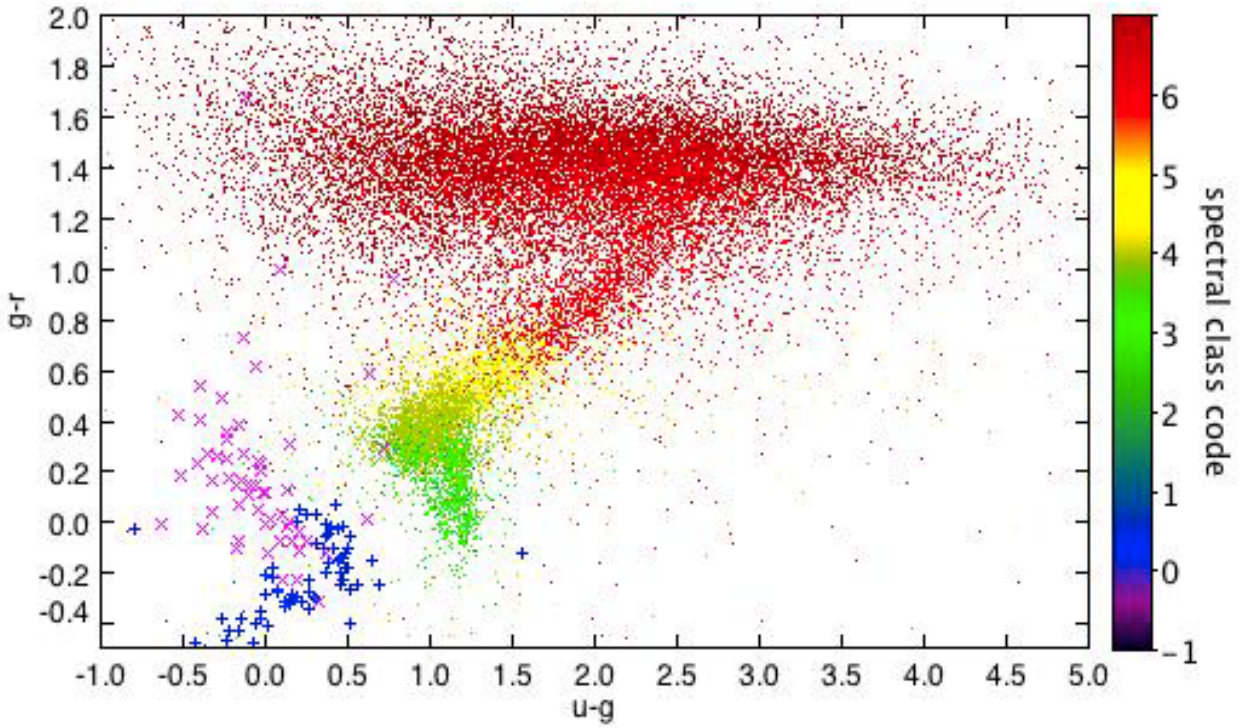
10% of TDSS fibers for special FES programs:

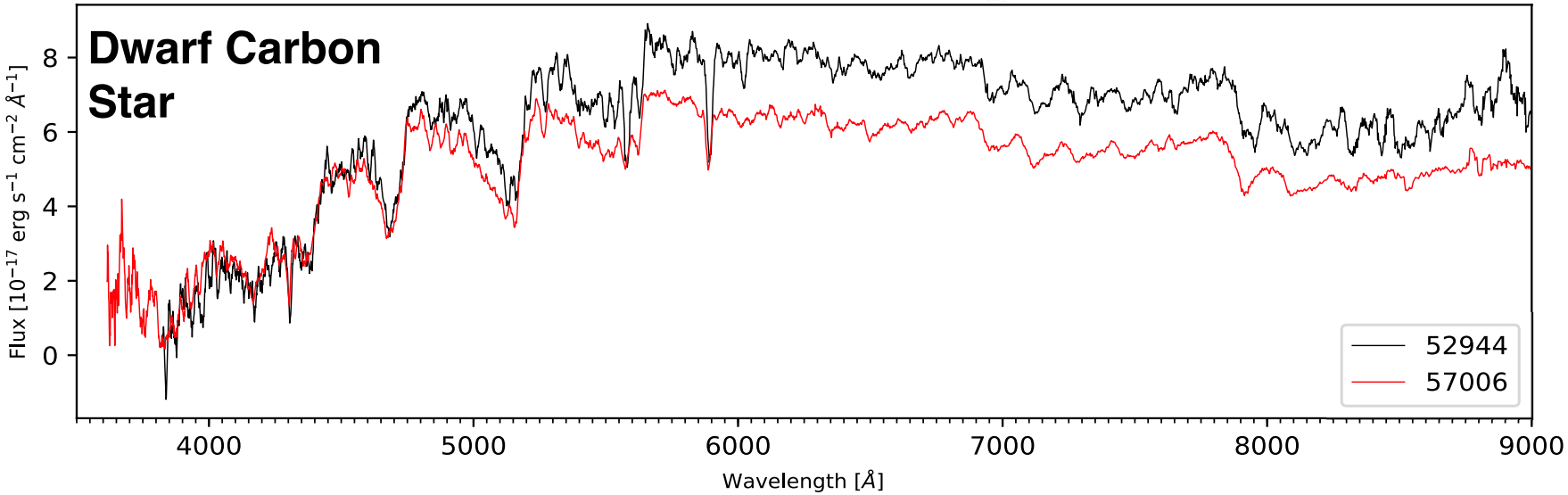
Target Type	Number	Observed (March '19)
Total (~1 deg^{-2})	**9143**	**6261**
WD/dM Binaries	1036	**214**
Dwarf Carbon Stars	830	**370**
Ultracool Dwarfs	402	**556**
Hypervariable Stars ($\gtrsim$0.3m)	1150	**727**
BAL Quasars	2900	**1926**
High S/N Quasars	1100	**593**
Double Peaked Emitters	900	**576**
QSO MGII Line Shifts	70	**62**
Hypervariable Quasars	1555	**1237**

(Target Selection Details in MacLeod et al. 2018)

TDSS/SES update (through DR14)

STAR subclasses (pipe) range from O/B, through A/F (green), to K/M (orange/red). Flaring M stars dominate, but thousands are in A/F-star regime that includes pulsating RR Lyrae. >710 have cataloged periodic light curves, e.g., also includes eclipsers. Large symbols highlight ~60 each CVs (purple x's) & variable WDs (blue +'s).

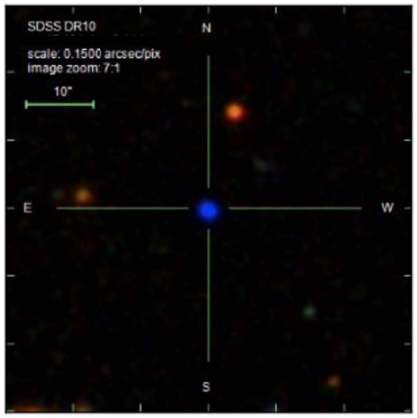


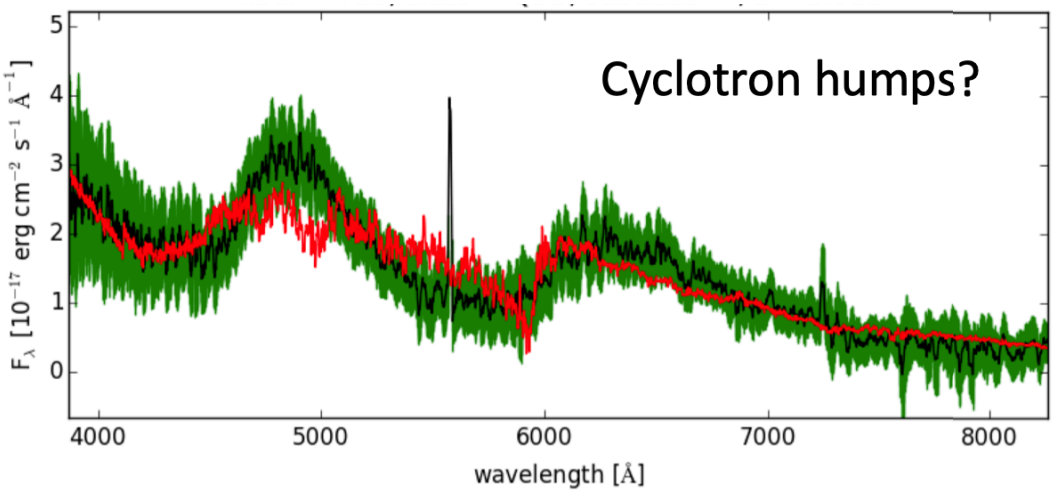


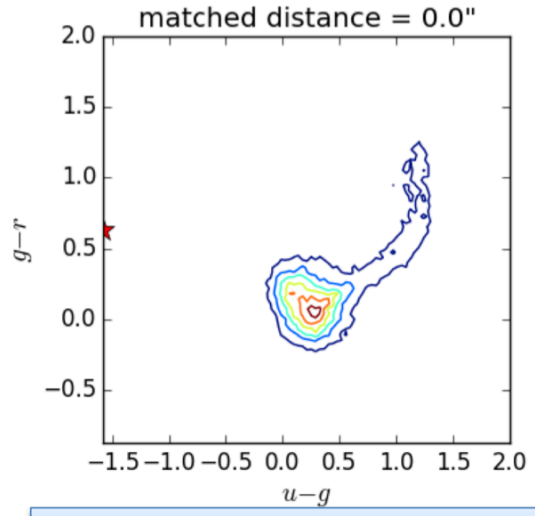
TDSS Stellar Science Opportunities

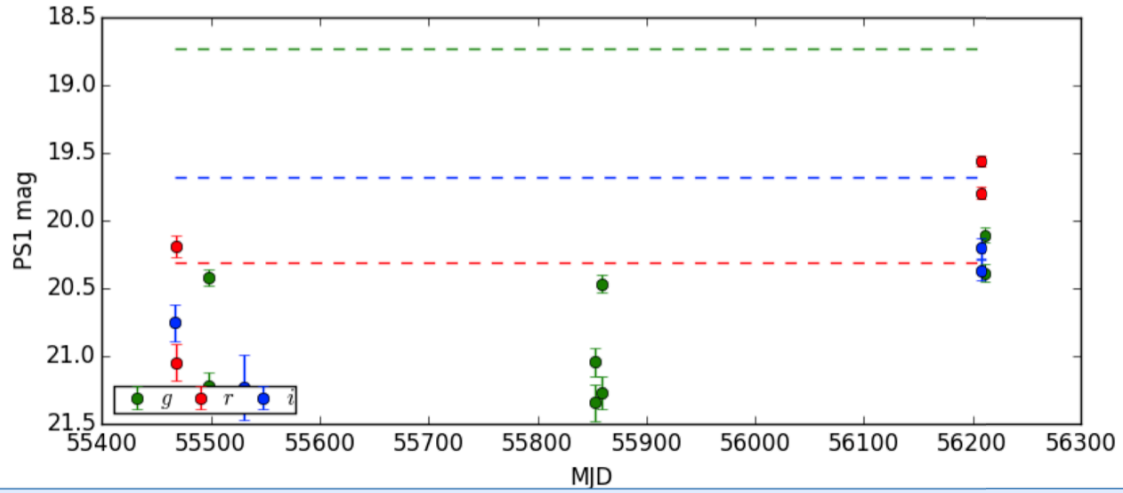
- Expect ~25,000 stellar variables in TDSS
  (pulsating, eclipsing, accreting, active)
  - ~ 4,000 off the main sequence
  - ~ 1,000 RR Lyr
  - ~ Handful of
    - WDs
    - CVs
    - Carbon stars
- ~10% of variables are periodic (logProb < -10)

TDSS Stellar Exotica: LARP?



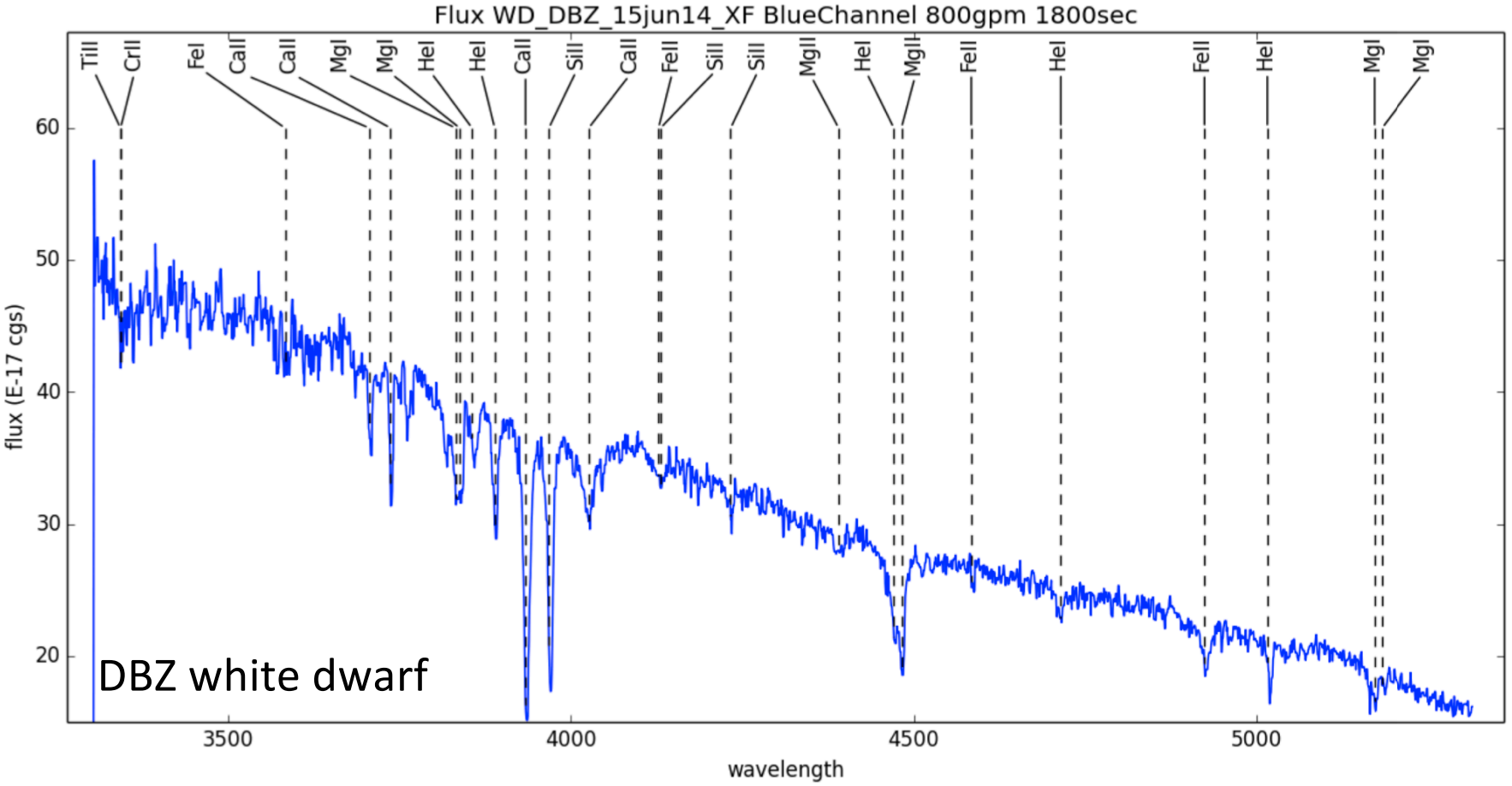






Low accretion rate polar? Highly variable. GALEX detected.

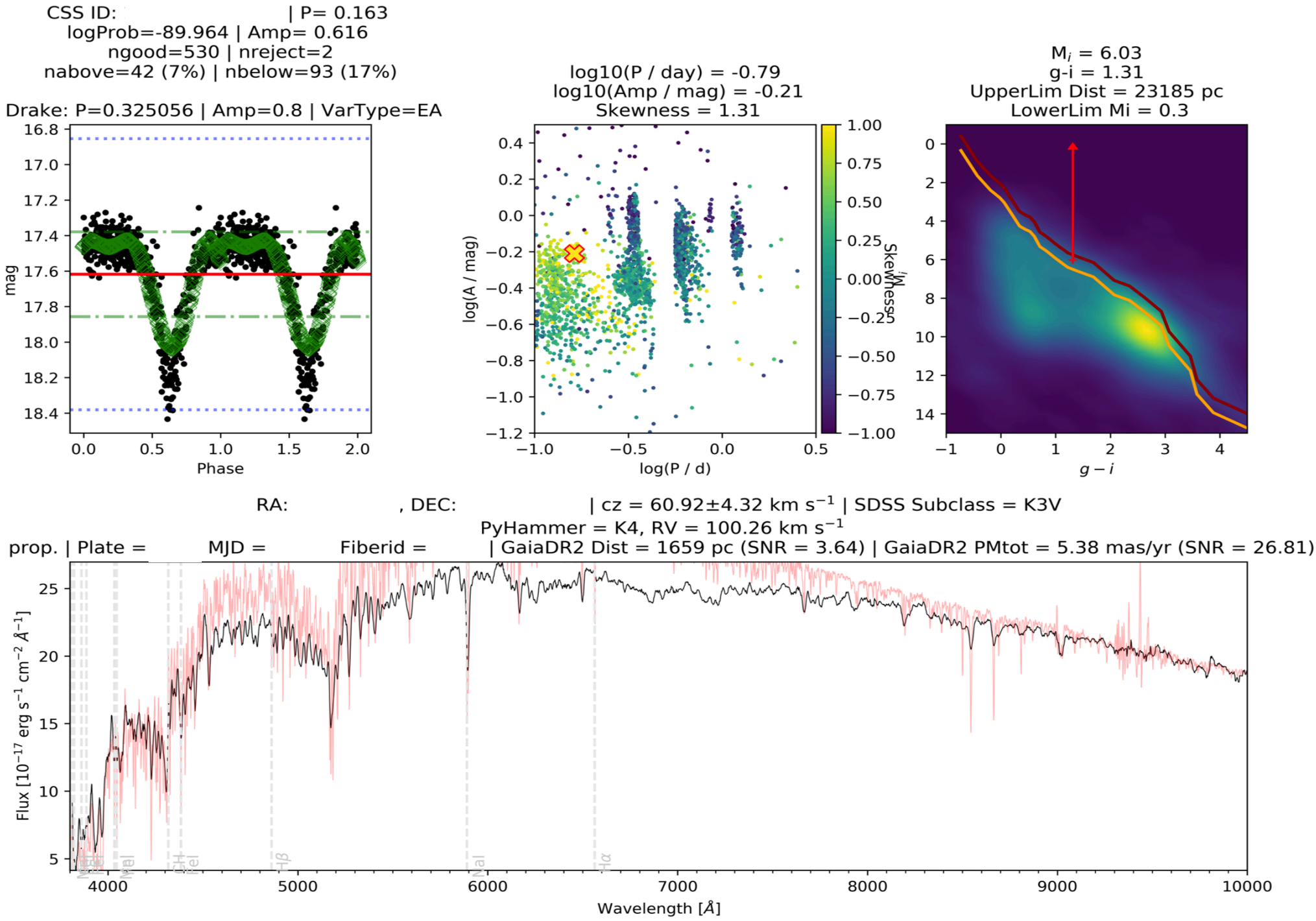
TDSS Stellar Exotica: DBZ WDs

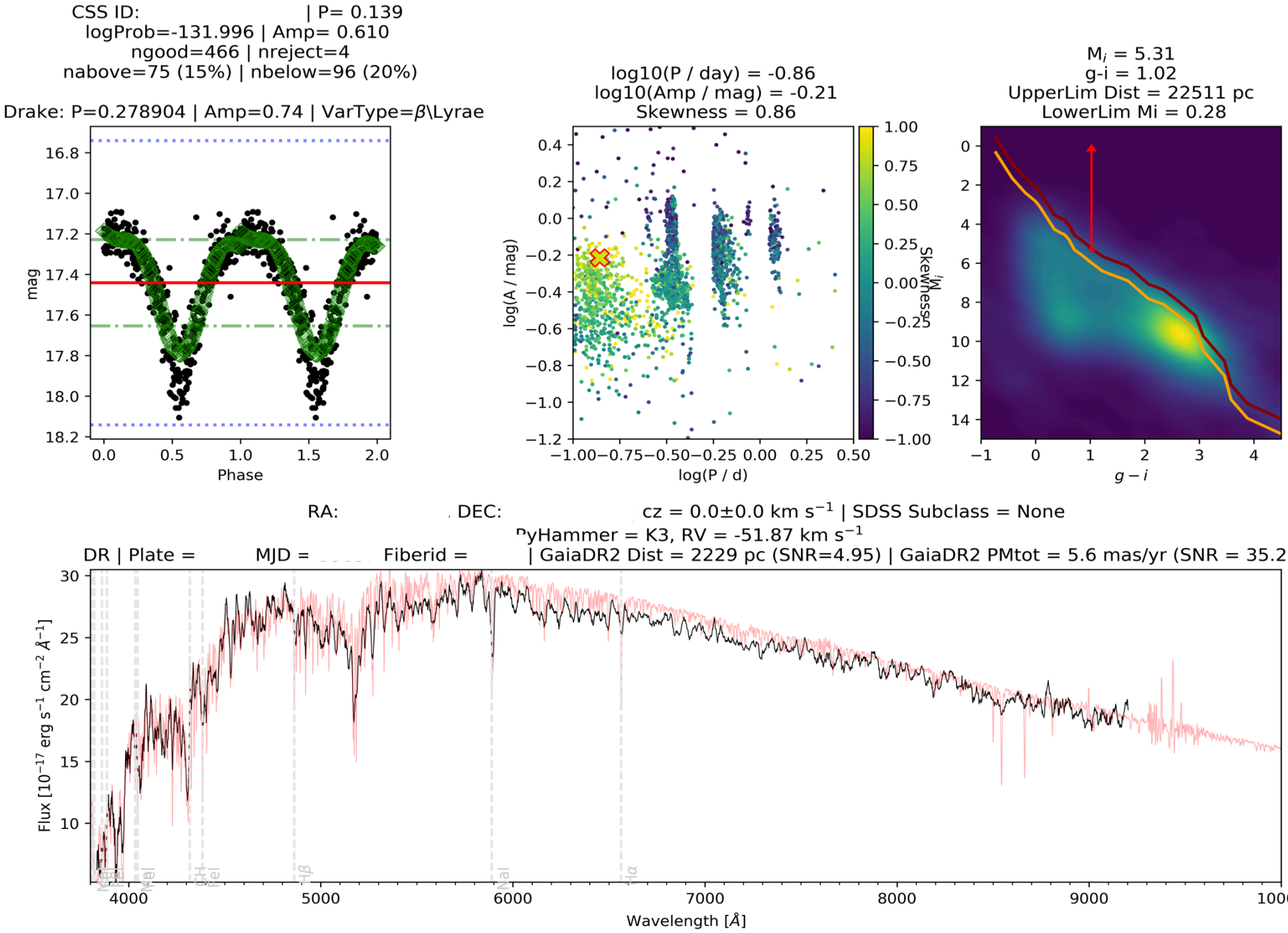


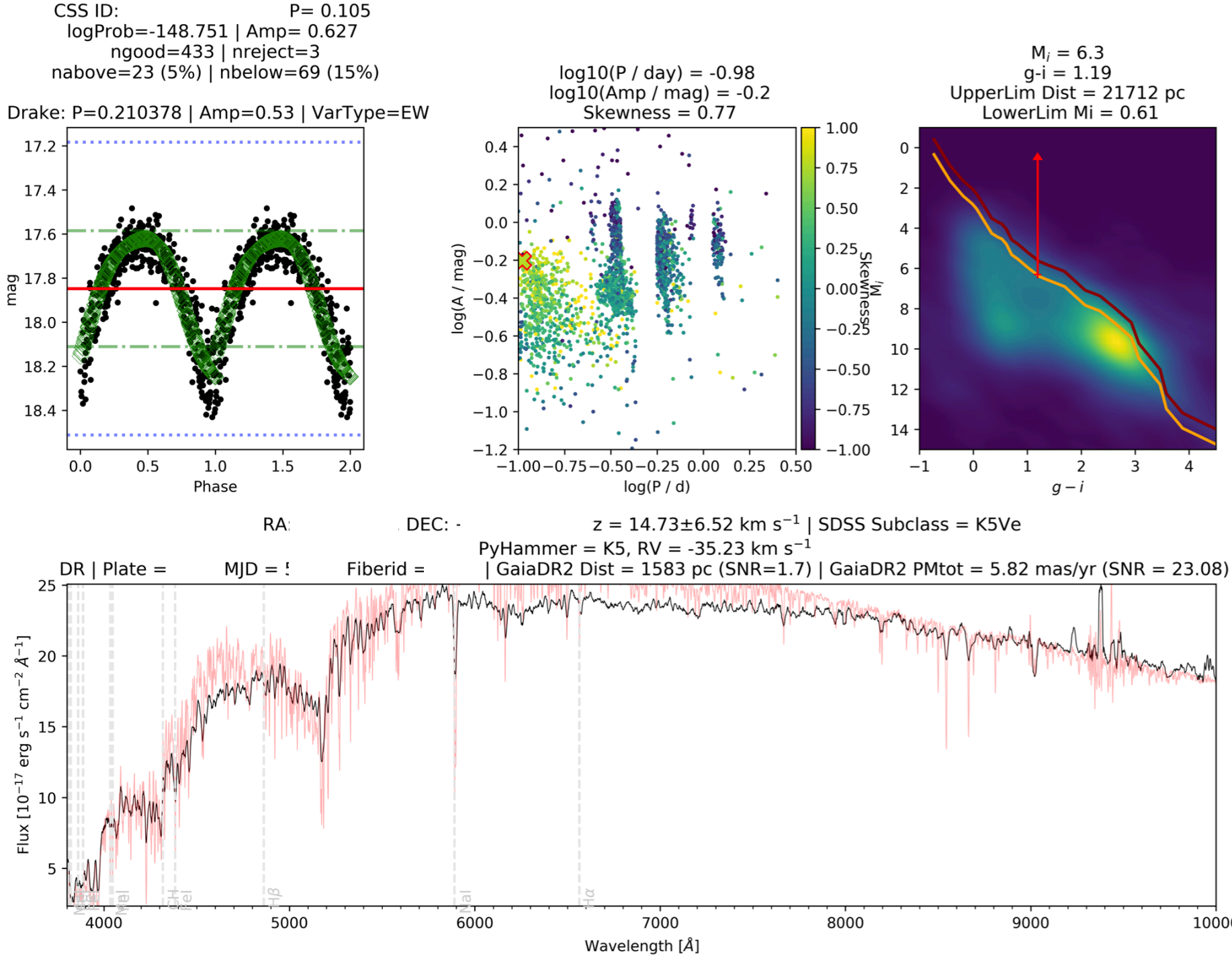
6.5m MMT followup spectrum. Analysis pending via EC Dufour.

Expected Periodic Stellar Variable Types to r < 18.5 *(Drake et al.* 2014, ApJ, 213, 1)

Type		Percent	Description
Eclipsing:			
	EW	50.5	contact eclipsing binary
	EA	7.6	detached (Algol) eclipsing binary
	betaLyrae	0.5	semi-detached eclipsing binary
RR Lyr:			
	RRab	27.3	RR Lyrae (fundamental mode pulsators)
	RRc	8.9	RR Lyrae (multi-period pulsators)
	RRd	0.8	RR Lyrae (both)
	Blazkho	0.4	RR Lyrae (quasi-periodic)
CEPHEID:			
	ACEP	0.1	anomalous Cepheid
	Cep-II	0.2	type II Cepheid
	HADS	0.4	high amplitude delta Scuti
MISC:			
	RSCVn	2.5	spotted rotator
	LPV	0.8	Mira or semi-regular AGB variables


CSS ID: | P= 0.163
logProb=-89.964 | Amp= 0.616
ngood=530 | nreject=2
nabove=42 (7%) | nbelow=93 (17%)
Drake: P=0.325056 | Amp=0.8 | VarType=EA
mag
Phase
log10(P / day) = -0.79
log10(Amp / mag) = -0.21
Skewness = 1.31
log(A / mag)
log(P / d)
Skewness
M_i = 6.03
g-i = 1.31
UpperLim Dist = 23185 pc
LowerLim Mi = 0.3
$g - i$
RA: , DEC: | cz = 60.92±4.32 km s^{-1} | SDSS Subclass = K3V
PyHammer = K4, RV = 100.26 km s^{-1}
prop. | Plate = MJD = Fiberid = | GaiaDR2 Dist = 1659 pc (SNR = 3.64) | GaiaDR2 PMtot = 5.38 mas/yr (SNR = 26.81)
Flux [10^{-17} erg s^{-1} cm^{-2} Å^{-1}]
Wavelength [Å]
MgI
NaI
CH
FeI
Hβ
NaI
Hα


CSS ID: | P= 0.139
logProb=-131.996 | Amp= 0.610
ngood=466 | nreject=4
nabove=75 (15%) | nbelow=96 (20%)
Drake: P=0.278904 | Amp=0.74 | VarType=β\Lyrae
mag
Phase
log10(P / day) = -0.86
log10(Amp / mag) = -0.21
Skewness = 0.86
log(A / mag)
log(P / d)
Skewness
M_i = 5.31
g-i = 1.02
UpperLim Dist = 22511 pc
LowerLim Mi = 0.28
g − i
RA: DEC: cz = 0.0±0.0 km s^-1 | SDSS Subclass = None
PyHammer = K3, RV = -51.87 km s^-1
DR | Plate = MJD = Fiberid = | GaiaDR2 Dist = 2229 pc (SNR=4.95) | GaiaDR2 PMtot = 5.6 mas/yr (SNR = 35.2)
Flux [10^-17 erg s^-1 cm^-2 Å^-1]
Wavelength [Å]


CSS ID: P= 0.105
logProb=-148.751 | Amp= 0.627
ngood=433 | nreject=3
nabove=23 (5%) | nbelow=69 (15%)
Drake: P=0.210378 | Amp=0.53 | VarType=EW
mag
Phase
log10(P / day) = -0.98
log10(Amp / mag) = -0.2
Skewness = 0.77
log(A / mag)
log(P / d)
Skewness
M_i = 6.3
g-i = 1.19
UpperLim Dist = 21712 pc
LowerLim Mi = 0.61
M_i
$g - i$
RA: DEC: -
z = 14.73±6.52 km s^{-1} | SDSS Subclass = K5Ve
PyHammer = K5, RV = -35.23 km s^{-1}
DR | Plate = MJD = Fiberid = | GaiaDR2 Dist = 1583 pc (SNR=1.7) | GaiaDR2 PMtot = 5.82 mas/yr (SNR = 23.08)
Flux [10^{-17} erg s^{-1} cm^{-2} Å^{-1}]
Wavelength [Å]
MgI
CaH
FeI
Hβ
NaI
Hα

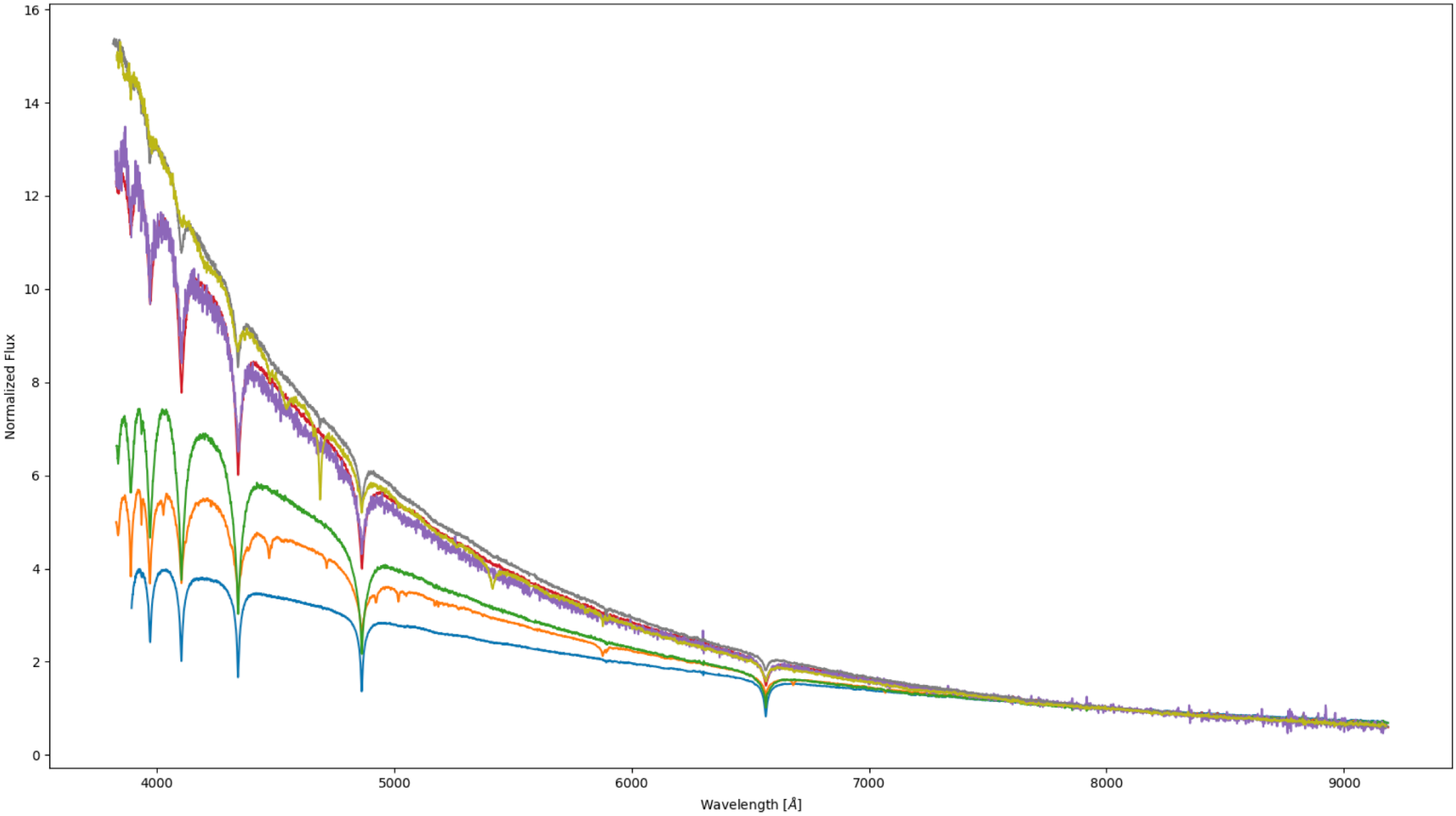
TDSS Stellar Science Opportunities

- 1000 RR Lyr w/RVs and metallicity estimates, could help identify streams
- Flare stars
- Active WD+dM systems
  - Follow FES dC paper and get separations
  - new post-CE?
  - Statistically examine the activity variation of close pairs as a function of spectral type, measure the white dwarf cooling age, and (possibly the) metallicity of the system
- **identify SB2s within the sample**

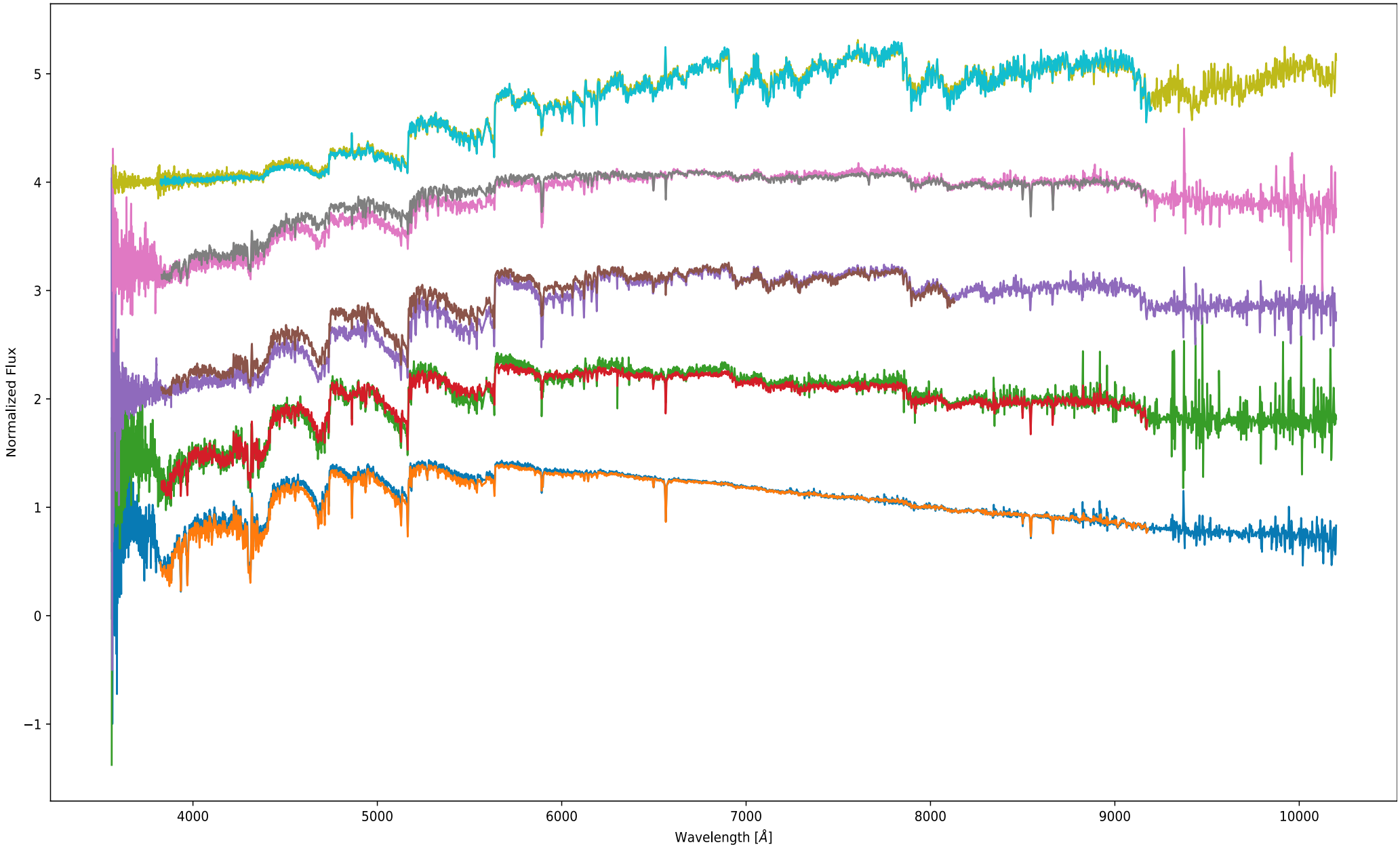
PyHammer & Extension

- PyHammer (Kesseli et al. (2017), https://github.com/BU-hammerTeam/PyHammer)
- Add additional C and WD templates (from TDSS)
- Developing tool to identify SB2s within the sample
  - Stellar templates from: A (Pickles+1998)
    FGKM (MaStar, Yan+2018)
    WD (Levenhagen+2017)

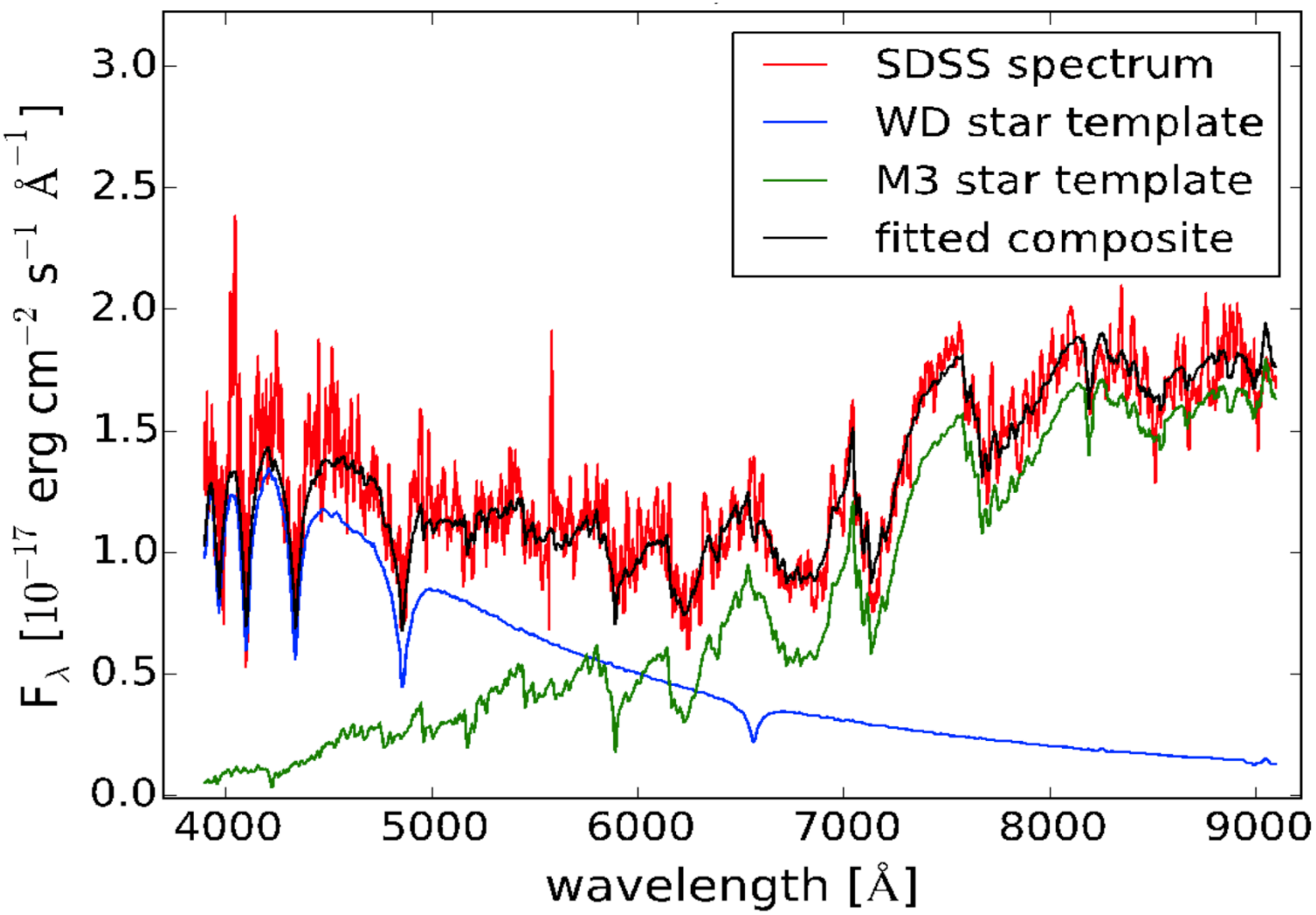
TDSS PyHammer WDs



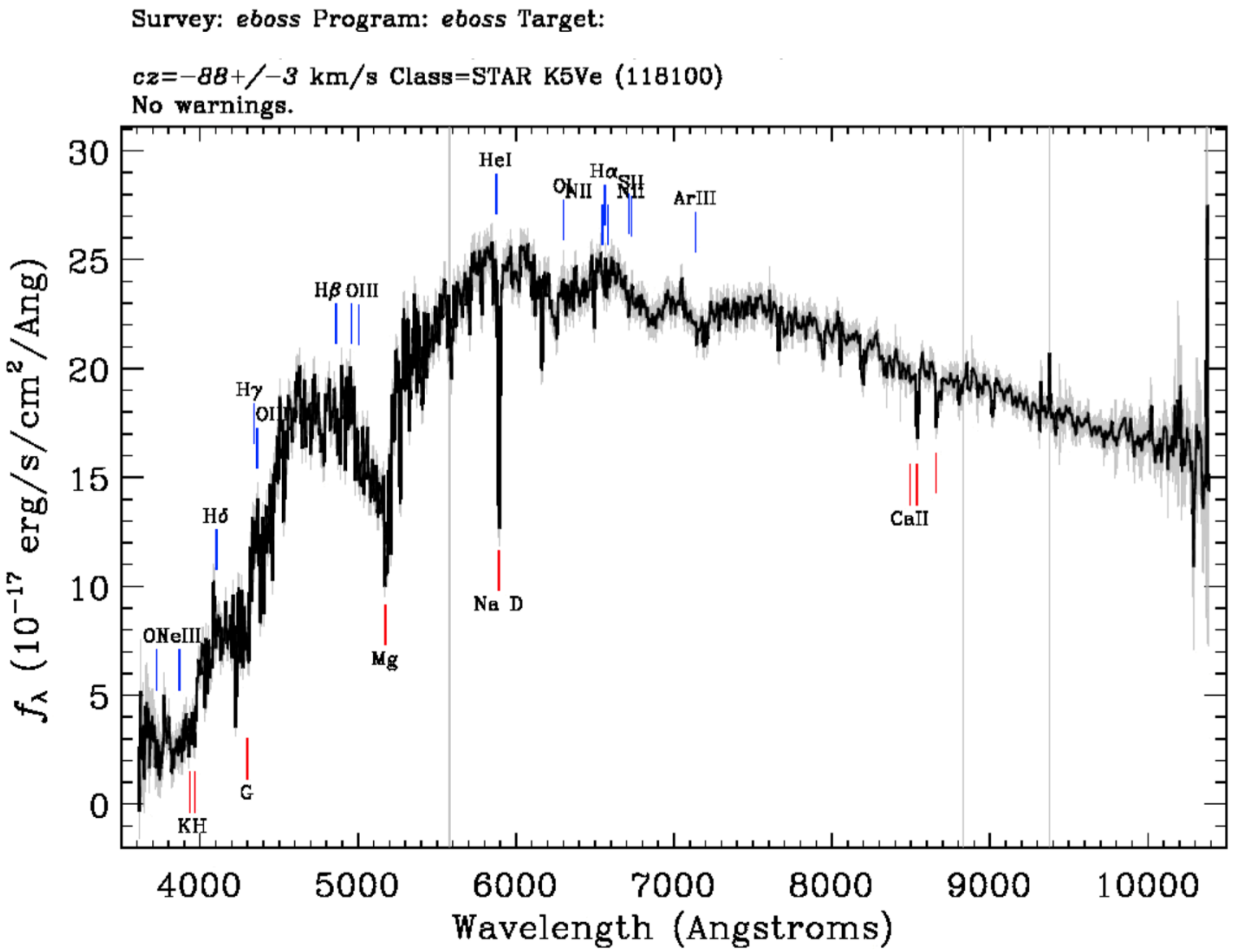
TDSS PyHammer Carbon Stars



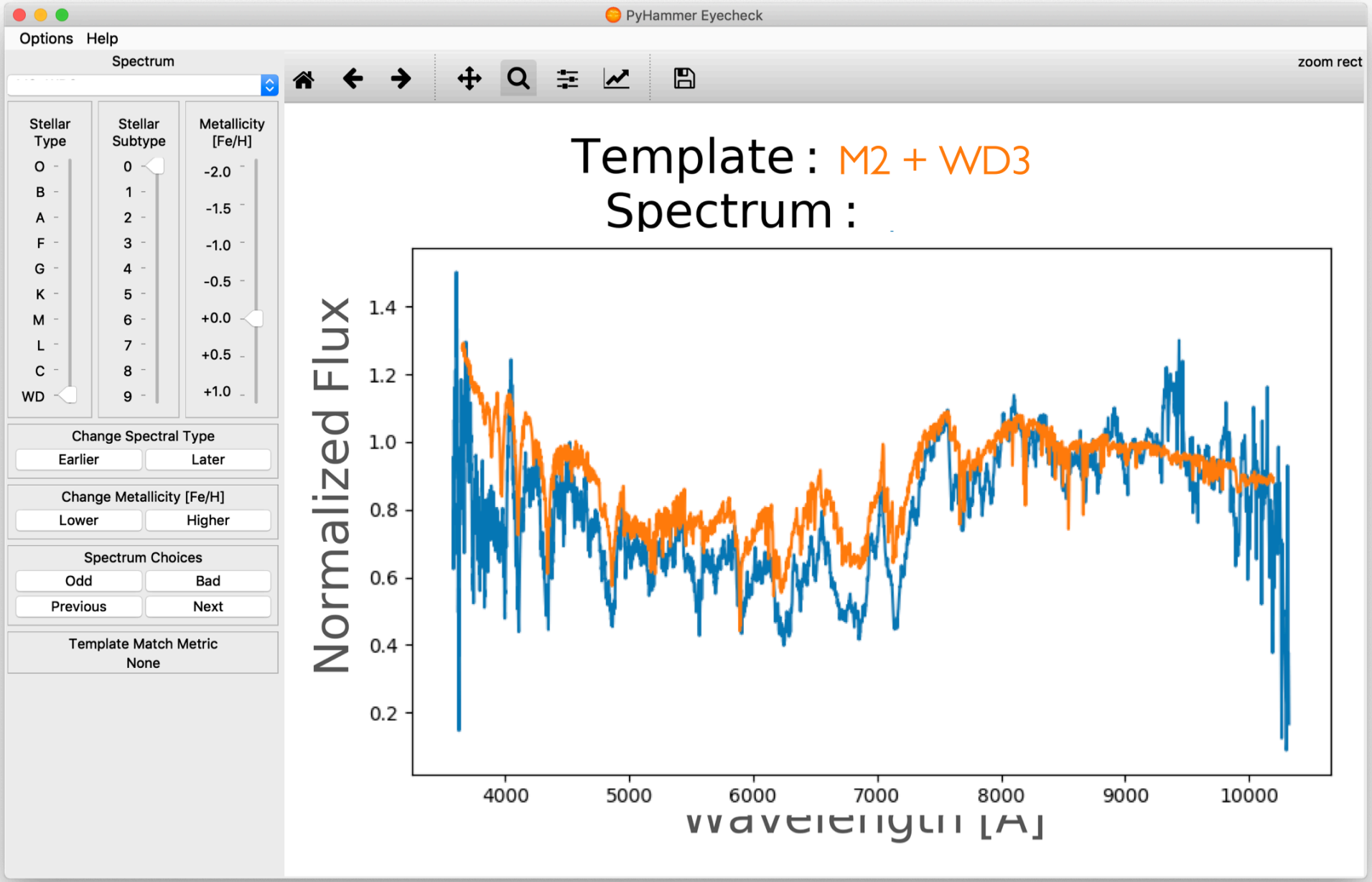
Composite-spectrum Binaries (a.k.a. SB2) Can sometimes be obvious!



More Typical Composite-Spectrum Binaries



PyHammer SB2 Extension

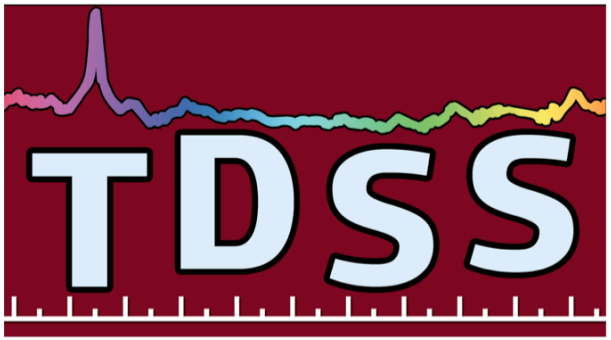


TDSS WIKI

https://trac.sdss.org/wiki/TDSS

- Telecon number/minutes
- Documents and brief primer
- Instructions/software info for VIP (Ruan et al.)
- spAllTDSS file (an spAll file for TDSS targets, with SDSS-IV spectro pipeline parameters): spAllTDSS-v5_10_10-01Jul2018_v0.txt
- PS1/SDSS-IV data-sharing file

TEAM



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