SALT observations of symbiotic stars and related objects

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National Research Foundation

South African Astronomical Observatory

SALT programs (not all)

RSA/POL: With Joanna Mikołajewska (CAMK, Warszawa)

Proposal	**Title**	**2013 status**
2012-1-RSA-009	A robust search for close binary central stars of planetary nebulae	2 papers published
2012-2-RSA-002	A deep survey for accretion-enriched companions in close binary central stars of planetary nebulae	1 paper submitted
2012-2-RSA_POL-001	A deeper look at an enlarged sample of Magellanic symbiotic stars	several in prep
2013-1-RSA_POL-001	In search of missing Galactic symbiotic stars	1 paper submitted
2013-1-POL_RSA-001	A deeper look at SMC symbiotic stars	several in prep

What are symbiotic stars?

#SymbioticStars are something like this: ↴

losing mass to companion.

- "Cool", red giant
- quite bright

- RED GIANT

- compact (ie. dense $\frac{\text{Sun mass}}{\text{Earth mass}}$)
- ~~hot~~ very hot
- ~~not~~ (very) bright.
- companion.
- WHITE DWARF

-@fikiswa ☺

Galactic symbiotic population

- Concentrated towards Galactic Bulge
- Estimated size varies dramatically
  - $3x10^3$ (Allen 1984)
  - $3x10^4$ (Kenyon+1993)
  - $3\text{-}4x10^5$ (Munari & Renzini 1992; Magrini+ 2003)
- Observed <300 (Belcznyski+ 2000)
  - 14 published from INT Photometric Halpha Survey (Corradi 2012) + 5 in prep (Corradi, priv. comm)
  - No concerted effort in Southern Galactic Plane...

Symbiotic stars towards the Galactic bulge

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ROYAL ASTRONOMICAL SOCIETY

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Symbiotic stars and other Hα emission-line stars towards the Galactic bulge*

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ABSTRACT

Symbiotic stars are interacting binaries with the longest orbital periods, and their multicomponent structure makes them rich astrophysical laboratories. The accretion of a high-mass-loss-rate red giant wind on to a white dwarf (WD) makes them promising Type Ia supernova (SN Ia) progenitors. Systematic surveys for new Galactic symbiotic stars are critical to identify new promising SN Ia progenitors (e.g. RS Oph) and to better estimate the total population size to compare against SN Ia rates. Central to the latter objective is building a complete census of symbiotic stars towards the Galactic bulge. Here we report on the results of a systematic survey of Hα emission-line stars covering 35 deg^2. It is distinguished by the combination of deep optical spectroscopy and long-term light curves that improve the certainty of our classifications. A total of 20 bona fide symbiotic stars are found (13 S-types, 6 D-types and 1 D′-type), 35 per cent of which show the symbiotic specific Raman-scattered O VI emission bands, as well as 15 possible symbiotic stars that require further study (six S-types and nine D-types). Light curves show a diverse range of variability including stellar pulsations (semi-regular and Mira), orbital variations and slow changes due to dust. Orbital periods are determined for five S-types and Mira pulsation periods for three D-types. The most significant D-type found is H1-45 and its carbon Mira with a pulsation period of 408.6 d, corresponding to an estimated period–luminosity relation distance of ~6.2 ± 1.4 kpc and $M_K = -8.06 \pm 0.12$ mag. If H1-45 belongs to the Galactic bulge, then it would be the first bona fide luminous carbon star to be identified in the Galactic bulge population. The lack of luminous carbon stars in the bulge is a longstanding unsolved problem. A possible explanation for H1-45 may be that the carbon enhancement was accreted from the progenitor of the WD companion. A wide variety of unusual emission-line stars were also identified. These include central stars of planetary nebulae (PNe) [one (WC10-11) Wolf–Rayet and five with high-density cores], two novae, two WN6 Wolf–Rayet stars, two possible Be stars, a B[e] star with a bipolar outflow, an ultracompact H II region and a dMe flare star. Dust obscuration events were found in two central stars of PNe, increasing the known cases to five, as well as one WN6 star. There is considerable scope to uncover several more symbiotic stars towards the bulge, many of which are currently misclassified as PNe, provided that deep spectroscopy is combined with optical and near-infrared light curves.

Key words: surveys – binaries: symbiotic – stars: carbon – stars: emission-line, Be – planetary nebulae: general – Galaxy: bulge.

* Based on observations made with the Anglo-Australian Telescope (AAT) at Siding Spring Observatory, the 1.3 m Warsaw Telescope at Las Campanas Observatory of the Carnegie Institution for Science, Chile, the Very Large Telescope (VLT) at Paranal Observatory under programme 079.D-0764(A),

Miszalski, Mikołajewska & Udalski 2013, MNRAS, 432, 3186 [MMU13]

3.5 years in the making

20 new symbiotic stars

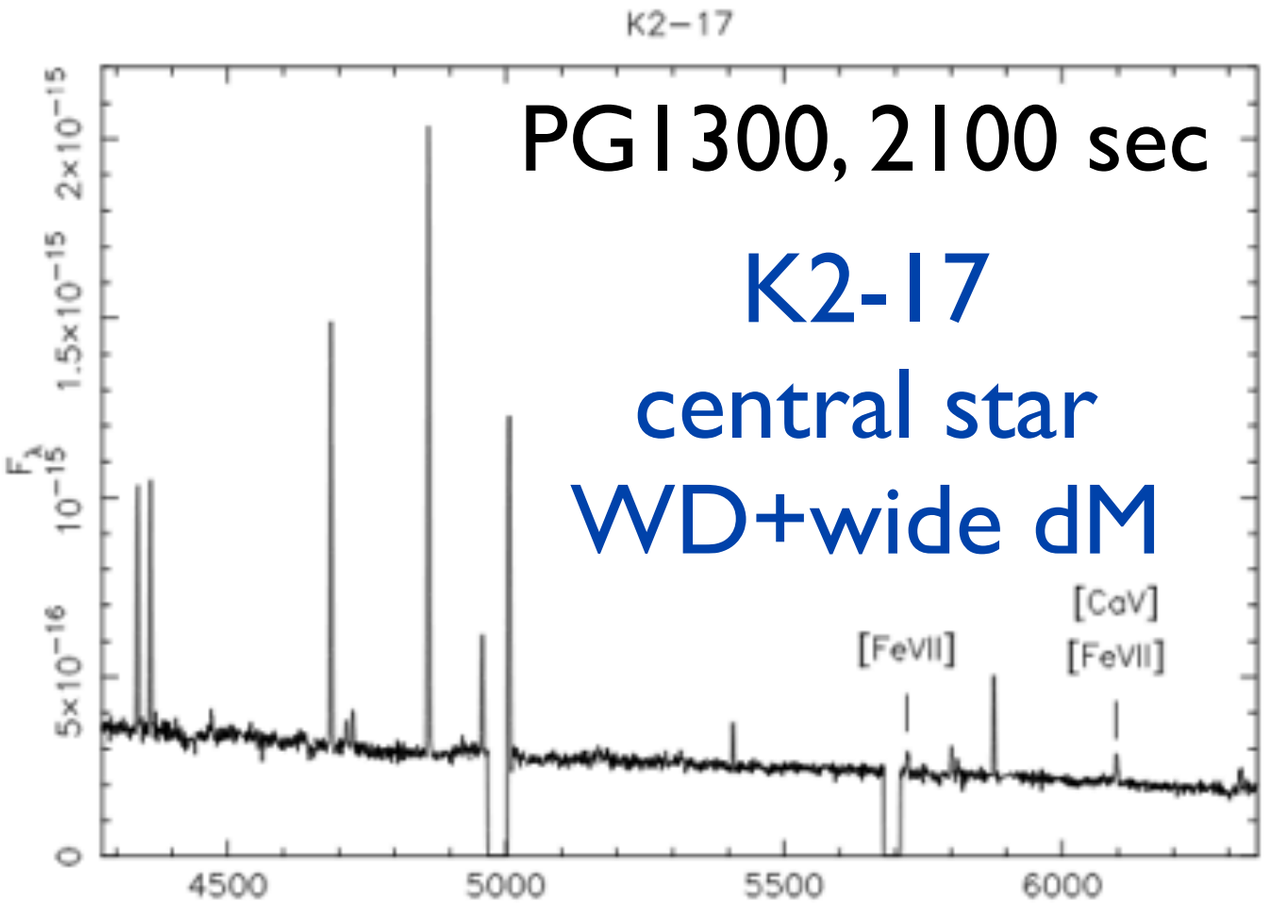
AAT 2dF/AAOmega spectra

+2012-1-RSA-009 SALT spectra

high density symbiotic-like => but no red giant

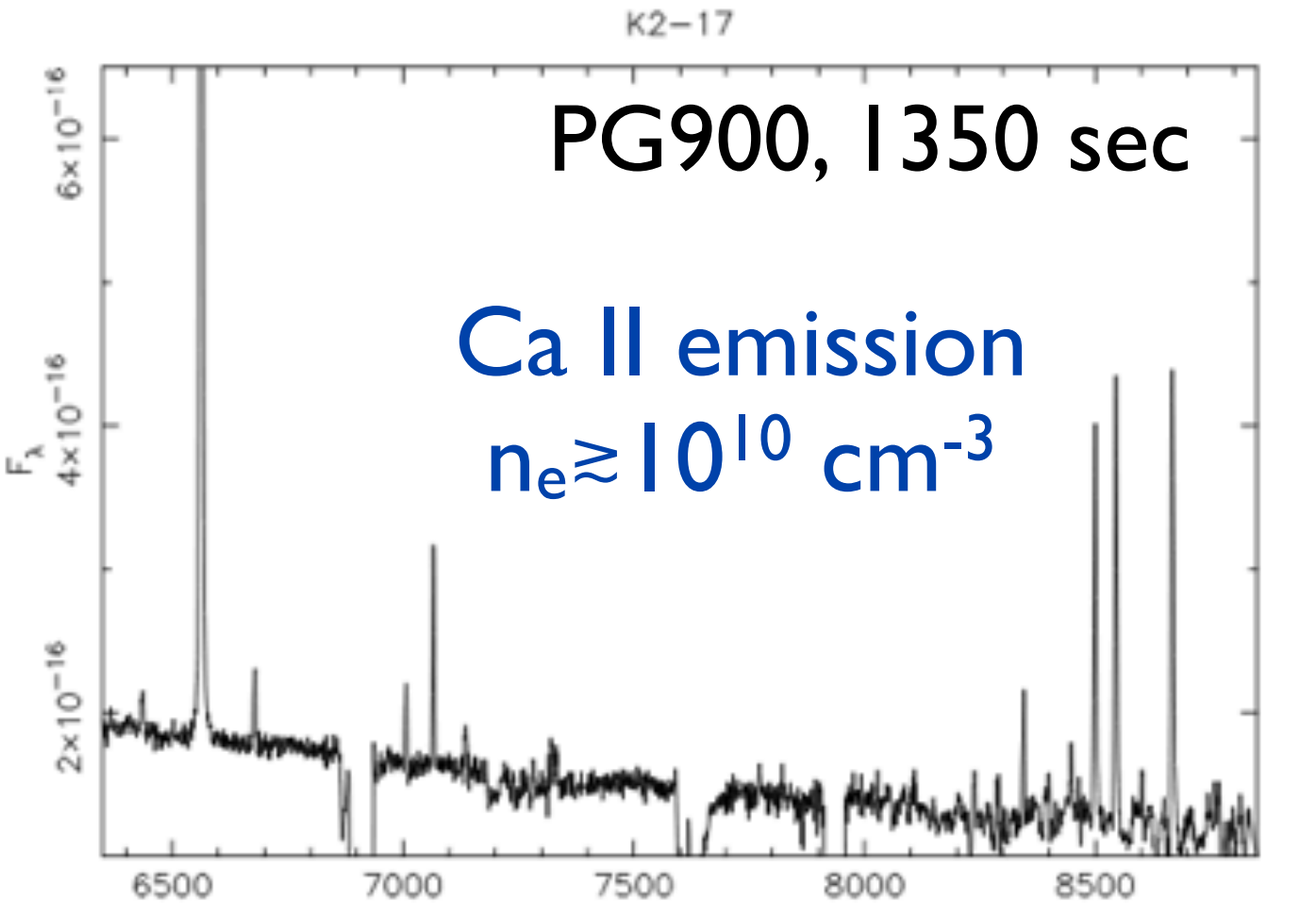
PG1300, 2100 sec

K2-17
central star
WD+wide dM



PG900, 1350 sec

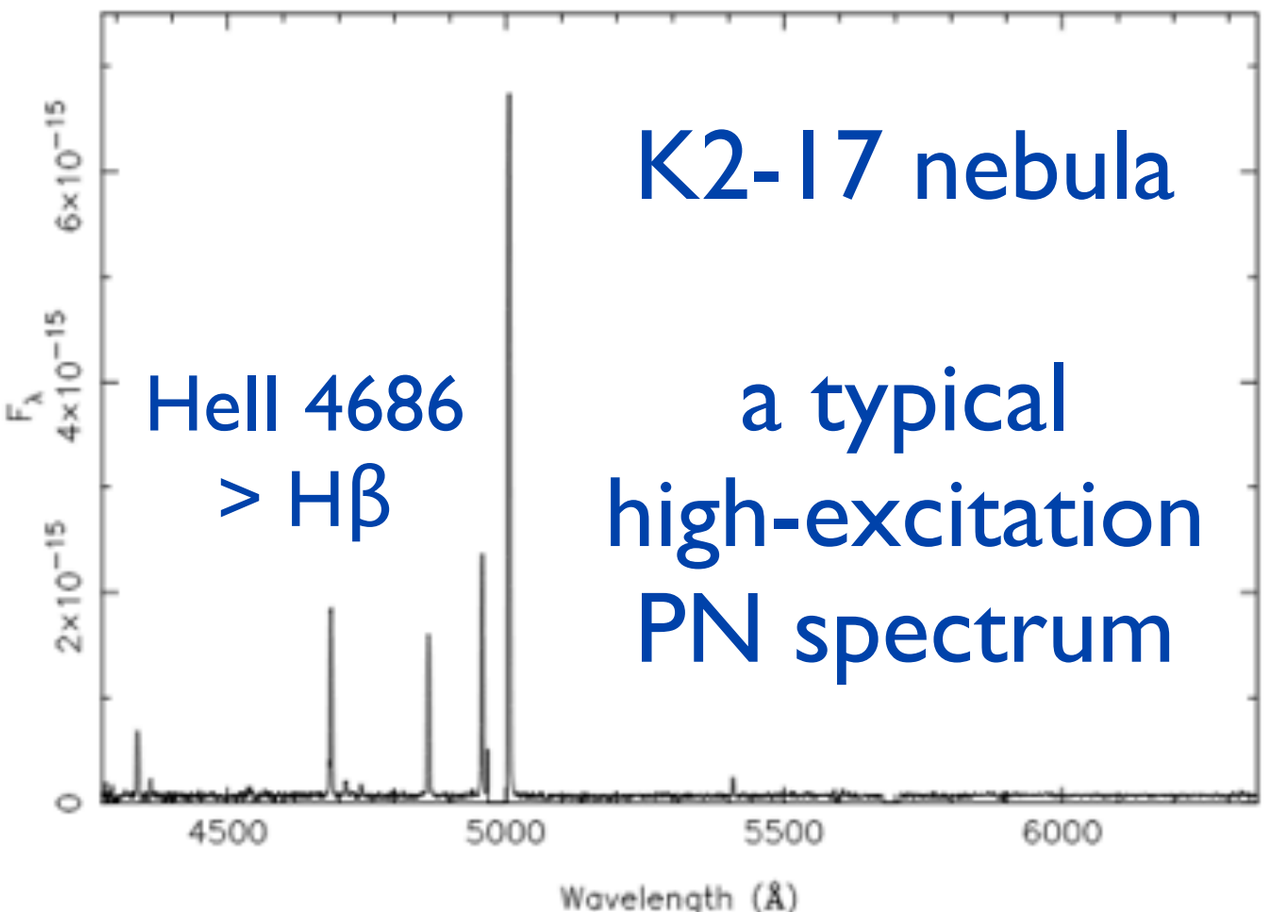
Ca II emission
$n_e \gtrsim 10^{10}$ cm^{-3}

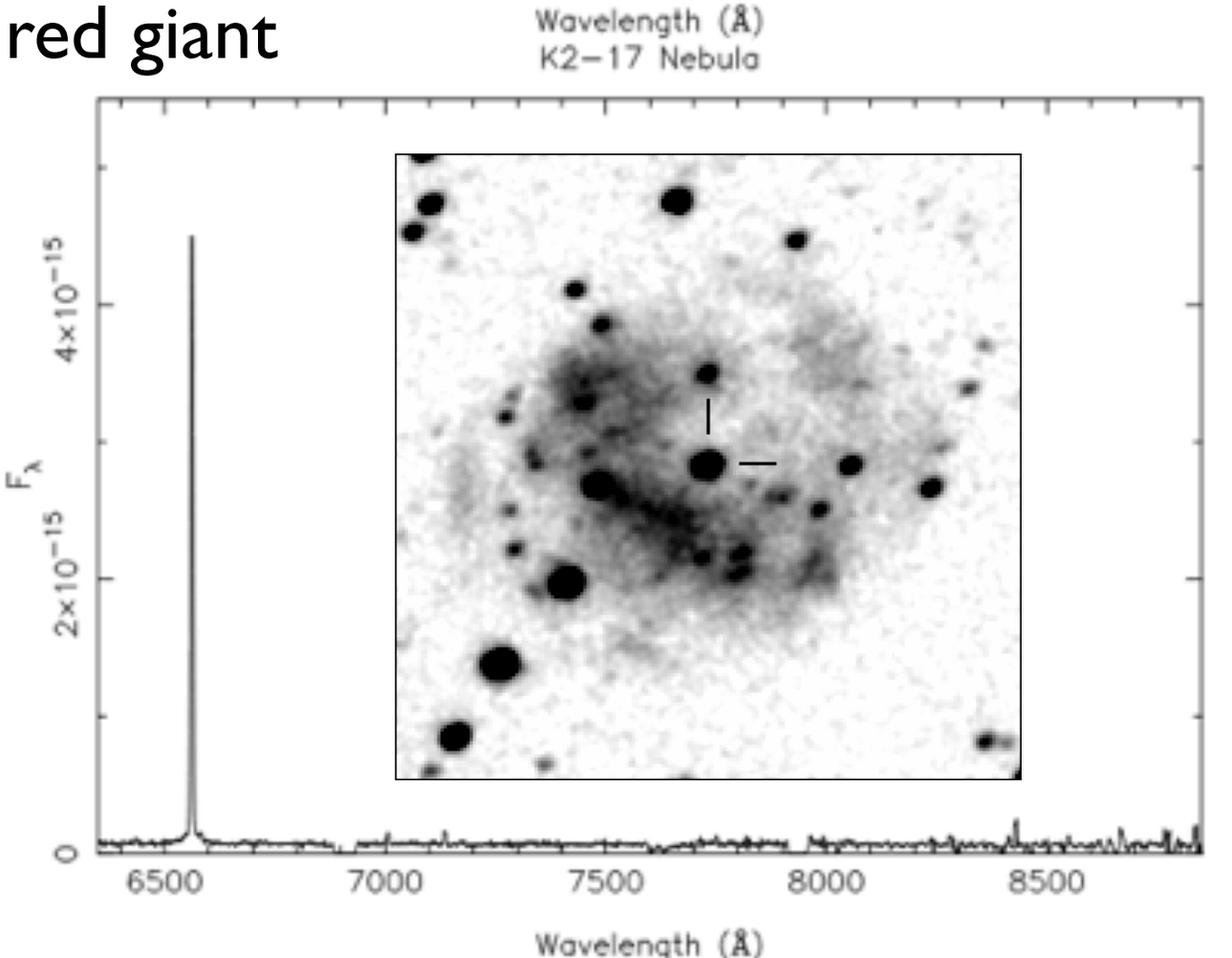


K2-17 nebula

HeII 4686
> Hβ

a typical
high-excitation
PN spectrum

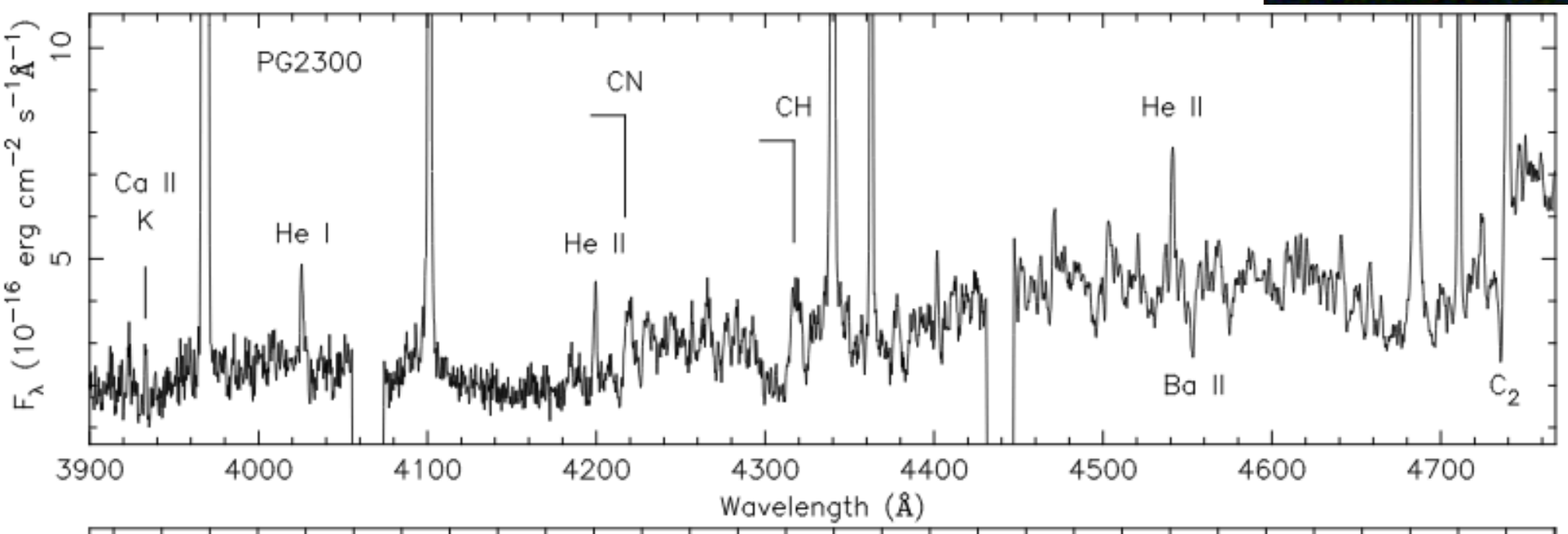


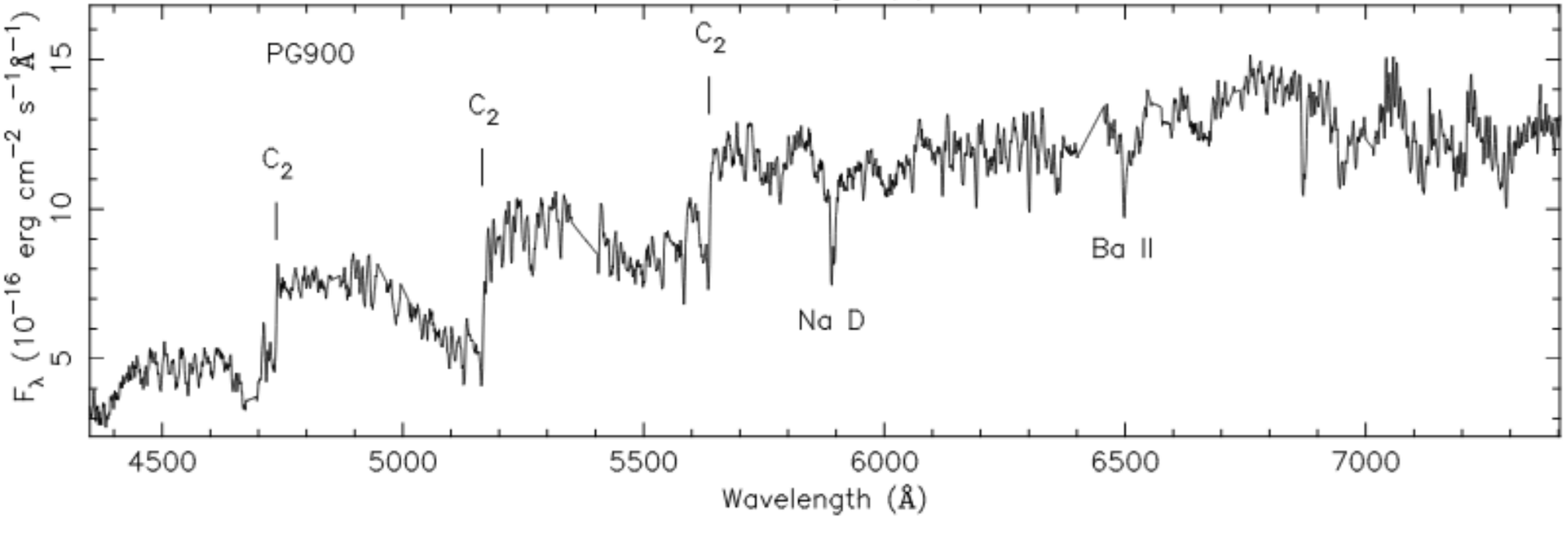


Hen2-39 barium CSPN

Miszalski, Boffin, Jones, Karakas, Köppen, Tyndall, Mohamed, Rodriguez-Gil & Santander-Garcia

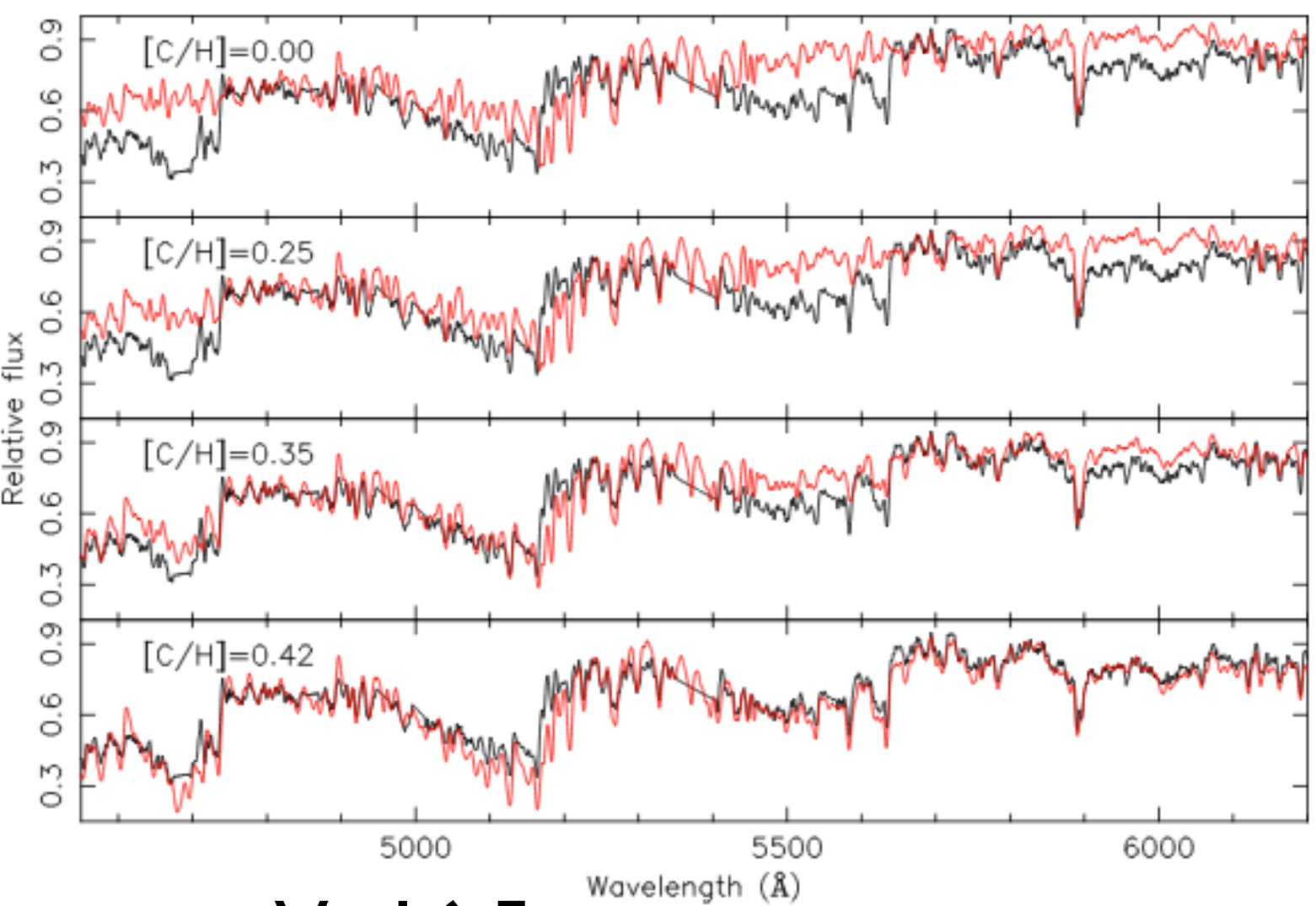
2013, MNRAS, in press





Only 4th known example of barium star + PN
=> very rare

SALT spectra from
2011-3-RSA-029
2012-1-RSA-009



Initial abundance estimates

[C/H]=0.42±0.02 dex

Type = C-R3 $C_2$4

Teff=4250±150 K

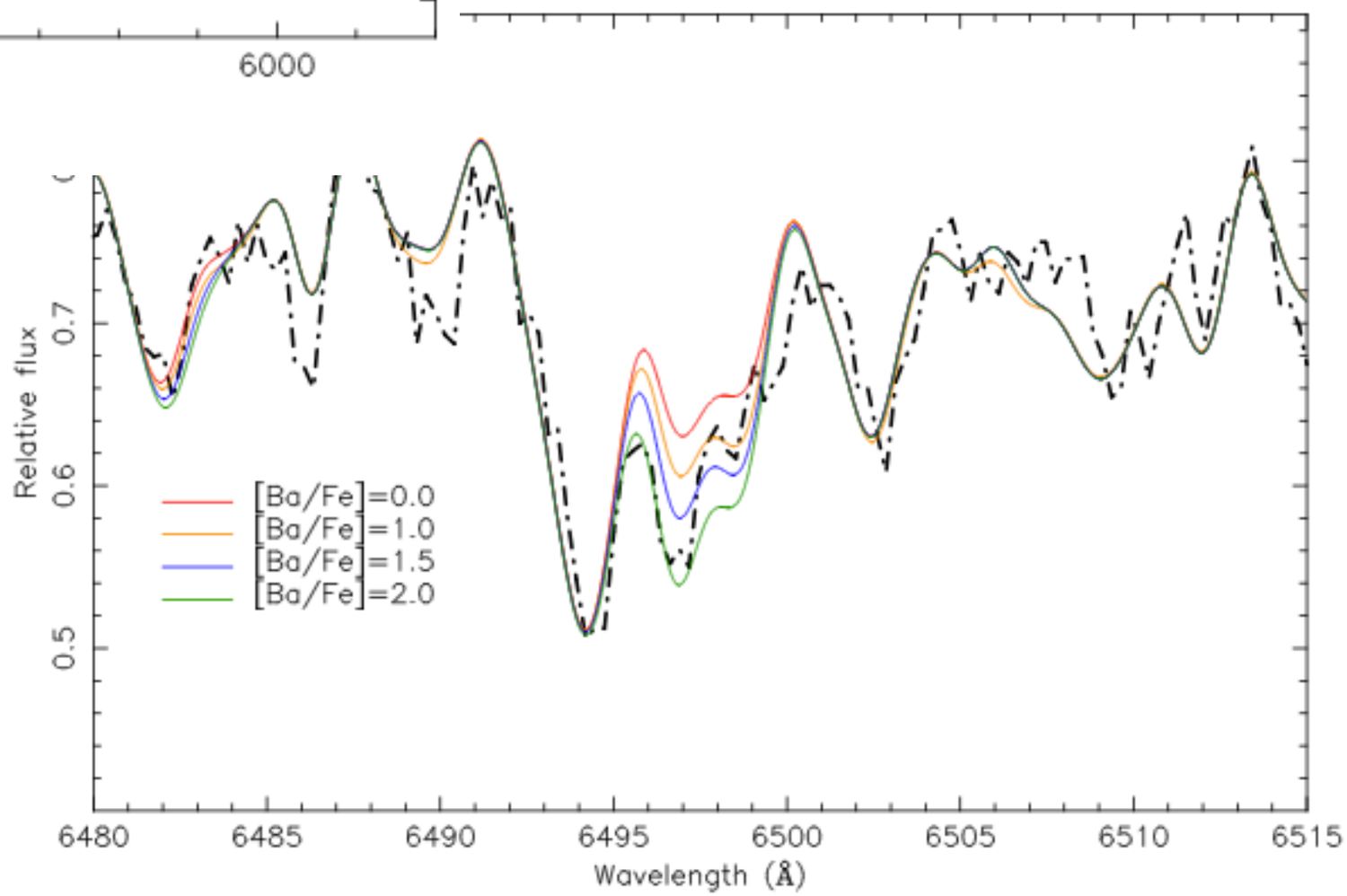
[Ba/Fe]=1.50±0.25 dex

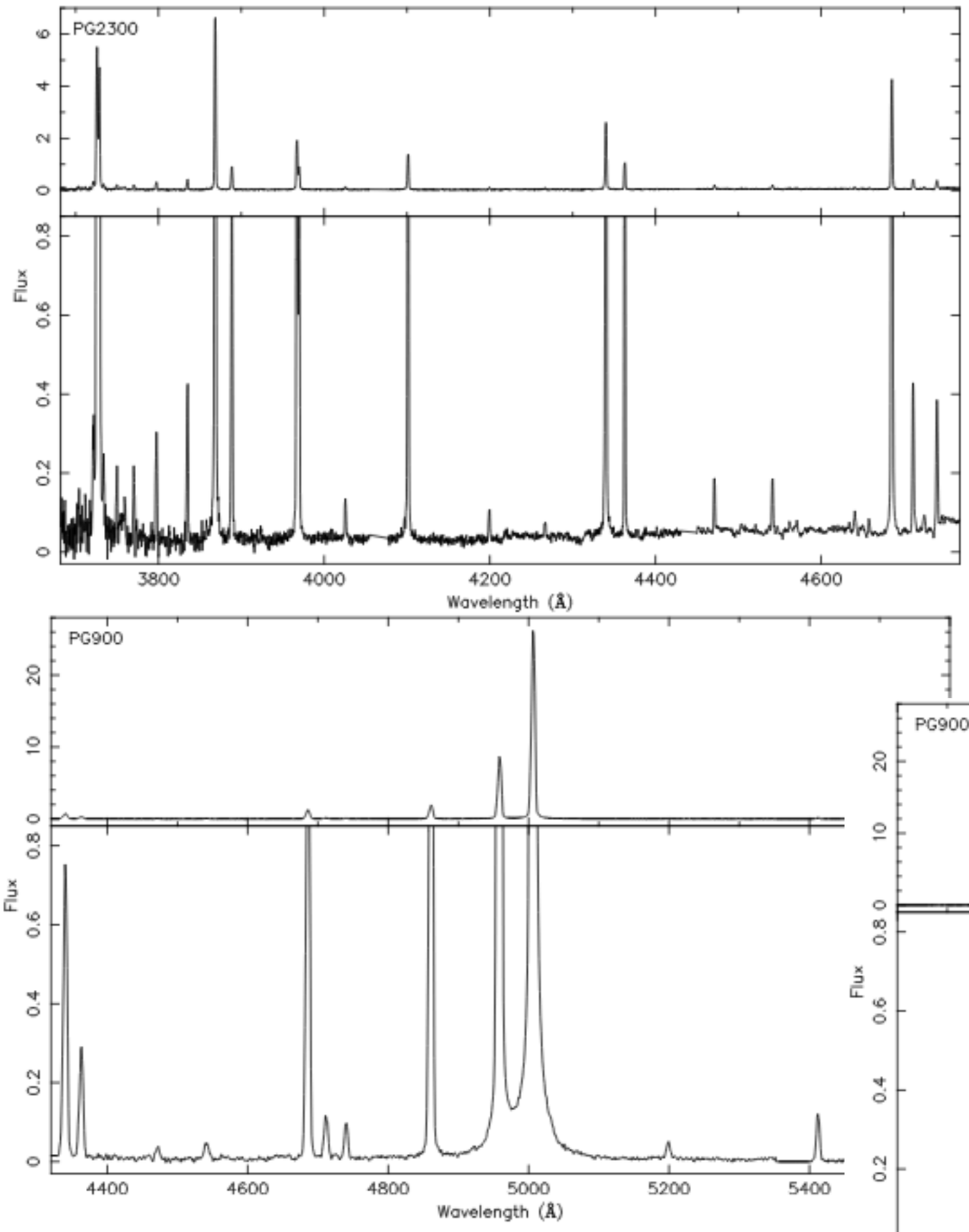
V=16.5 mag

HRS commissioning proposal for detailed abundance study

MR mode

(s-process elements and more)

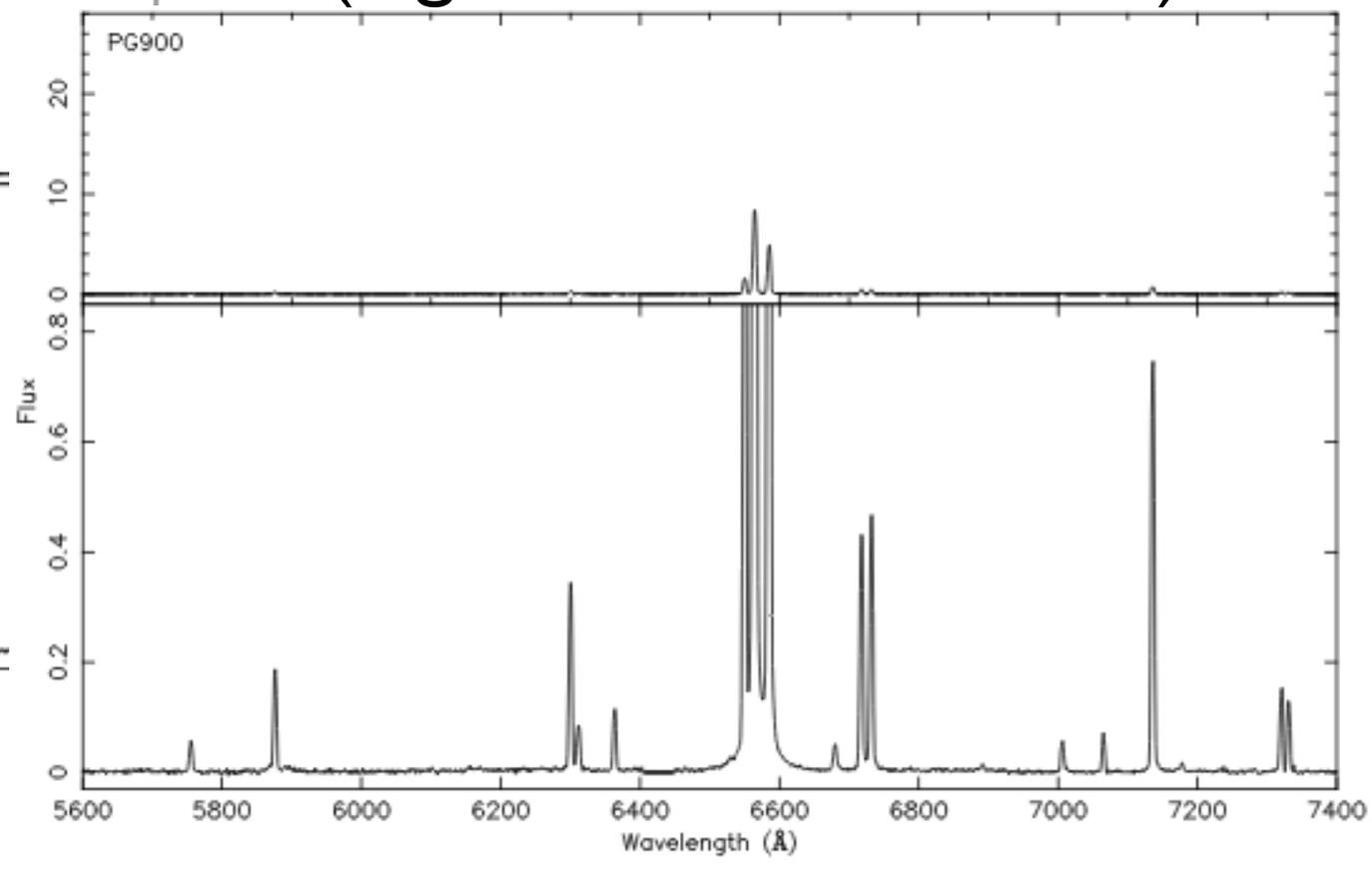




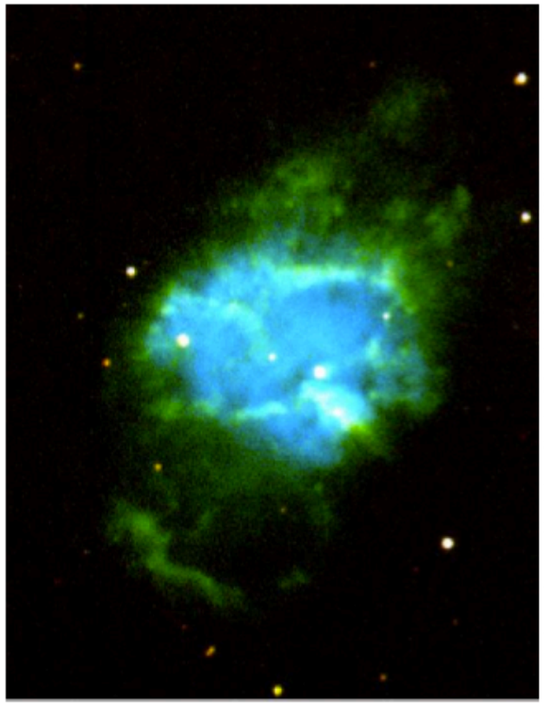
Nebular chemical abundances

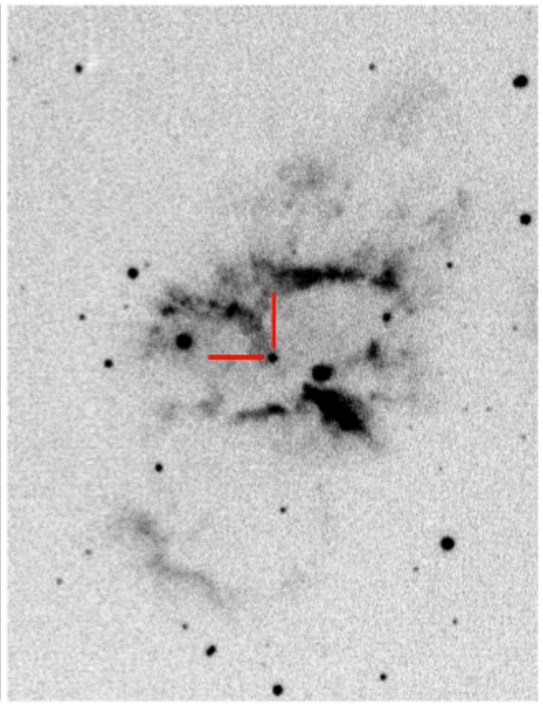
Not enhanced in He and N => lower mass progenitor

supports - He,N seem anticorrelated with s-process (e.g. Karakas et al. 2009)



Hen2-11

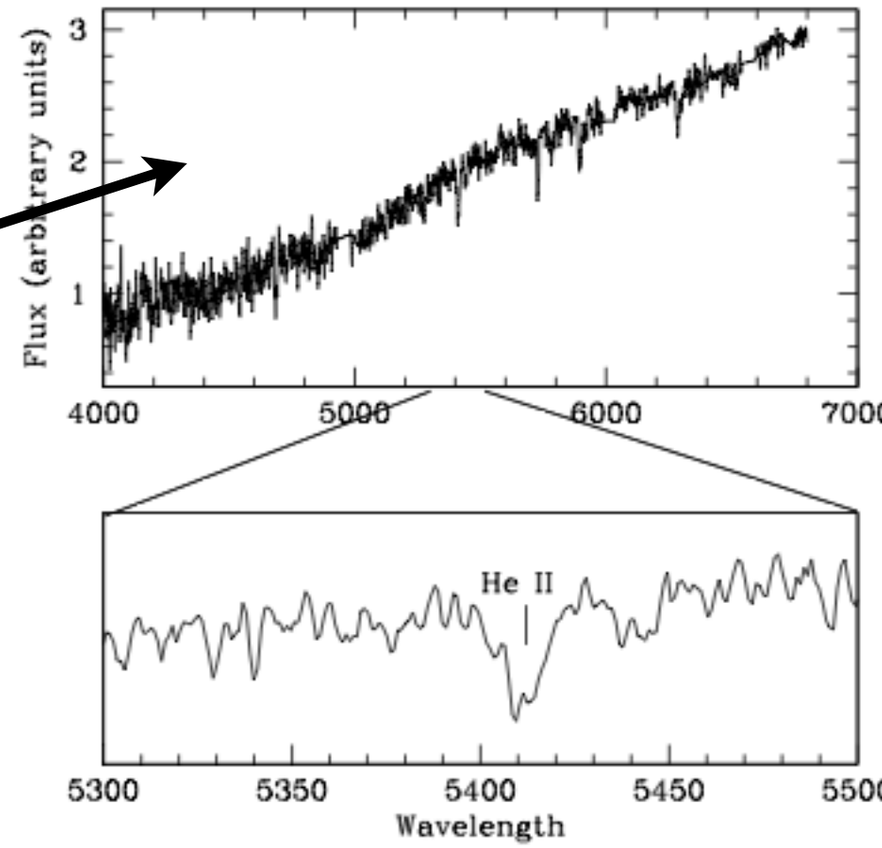


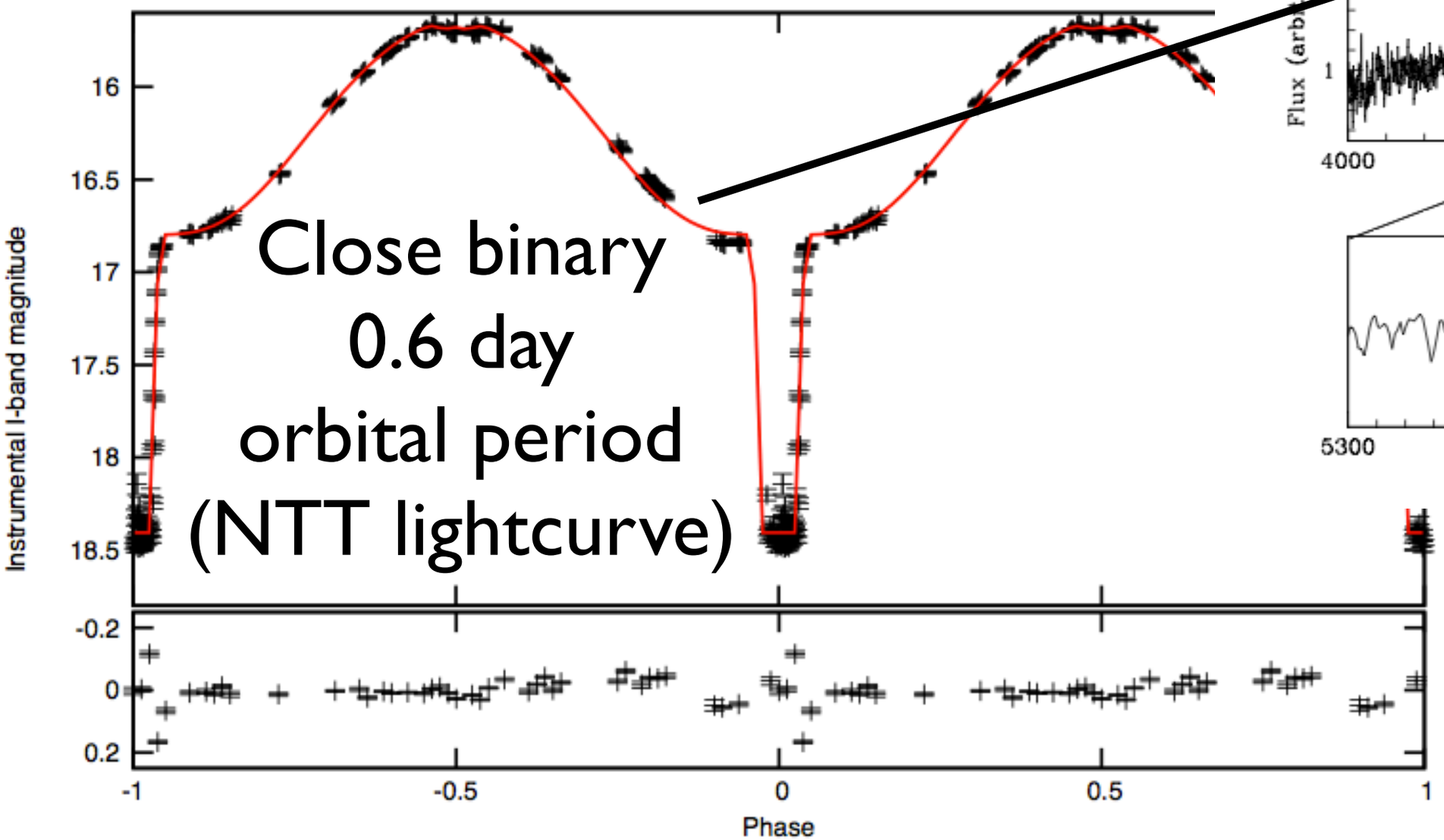


A&A paper submitted: 4 Oct

Jones, Boffin, Miszalski et al.

2012-2-RSA-002 spectrum near lightcurve min





Close binary
0.6 day
orbital period
(NTT lightcurve)

SALT RSS
spectrum
V=18-18.5 ma

2013-1-RSA_POL-001

An ongoing, systematic survey for new symbiotic stars with SALT

2013-1-RSA_POL-001

Submitted to MNRAS, 4 Nov

arXiv:1311.0797v1 [astro-ph.SR] 4 Nov 2013

Identification of new Galactic symbiotic stars with SALT. I. Initial discoveries and other emission line objects*

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Accepted . Received ; in original form

arXiv:1311.0797

spectra of 32 objects

ABSTRACT

We introduce the first results from an ongoing, systematic survey for new symbiotic stars in the southern Galactic plane selected from the AAO/UKST SuperCOSMOS Hα Survey (SHS). The survey aims to identify and characterise the fainter population of symbiotic stars underrepresented in extant catalogues. Less than 300 symbiotic stars are known, in stark contrast to population estimates of 10^{3-5} symbiotic stars. The accreting white dwarf (WD) in symbiotic stars, fuelled by their red giant donors with high mass loss rate winds, make them promising candidates for type Ia supernovae. Several candidates were observed spectroscopically with the Southern African Large Telescope (SALT). A total of 12 bona-fide and 2 possible symbiotic stars were identified. The most remarkable example is a carbon-rich symbiotic star that displays coronal [Fe X] emission, suggesting it may be a supersoft X-ray source with a massive WD, however strong interstellar absorption may severely hinder any supersoft X-ray detection. This is the fifth carbon-rich Galactic symbiotic star found and raises the interesting possibility that carbon-rich giants have a higher rate of occurrence in fainter populations of symbiotic stars. Several other emission line objects with near-infrared colours similar to symbiotic stars were also discovered, including 6 B[e] stars, 4 PNe, 2 possible Be stars, one [WC9] Wolf-Rayet (WR) central star of a PN and one WC9 WR star. Revealing D-type symbiotic stars remains difficult, with only one new D-type found in contrast to 6 B[e] stars that were promising D-type candidates. These discoveries will help shape and refine the candidate selection criteria that we expect will uncover several more symbiotic stars as the survey progresses.

Key words: surveys - binaries: symbiotic - planetary nebulae: general - stars: carbon - stars: emission-line, Be - stars: Wolf-Rayet

2013-1-RSA_POL-001

Submitted to MNRAS, 4 Nov

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8 ACKNOWLEDGEMENTS

All of the observations reported in this paper were obtained with the Southern African Large Telescope (SALT) and we would like to thank the Polish SALT time allocation committee for their generous award of SALT time. JM is supported

2013-1-RSA_POL-001

12 new symbiotic stars + 2 possible, over 6 months
c.f. IPHAS: 14 new symbiotics over, 2008-2011

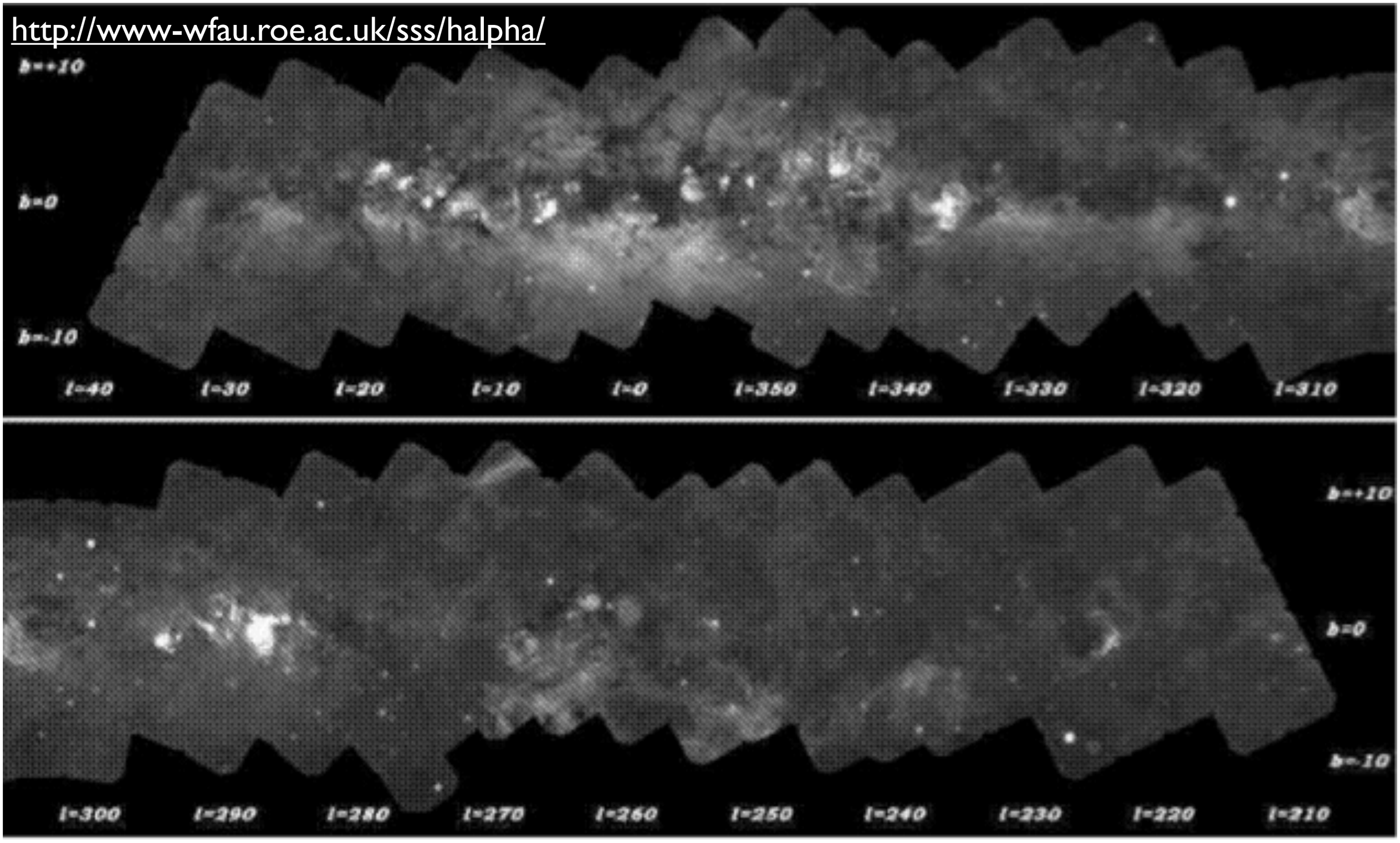
Table 2. Basic properties of the new and possible symbiotic stars.

2MASS ID	ℓ (°)	b (°)	IR type	Spectral type	J	$J-H$	$H-K_s$	Hα	H$\alpha-SR$	$SR-I$
14031865−5809349	312.3148	3.3967	S	M4	10.42	1.10	0.38	12.10	−1.60	1.44
15431767−5857221	323.5413	−3.1423	S	M2.5	11.22	1.09	0.41	12.43	−1.40	0.34
16003761−4835228	332.0679	3.2823	S	C-N5 $C_2$4.5	10.80	1.33	0.58	13.22	−1.75	1.89
16422739−4133105	342.2640	3.0318	D	-	10.33	1.37	1.30	10.71	−3.30	−1.21
16503229−4742288	338.5095	−2.0533	D?	-	13.99	2.44	2.07	14.54	−2.78	−0.73
17050868−4849122	339.1468	−4.6492	S	M4	10.04	1.09	0.38	11.81	−2.07	2.28
17334728−2719266	359.9791	3.0663	S	M2	9.32	1.41	0.65	11.23	−1.79	−0.58
17391715−3546593	353.4730	−2.4679	S	M1.5	9.81	1.37	0.81	12.93	−2.60	0.86
17422035−2401162	3.8062	3.1975	S	M2:	10.20	1.21	0.56	12.70	−1.98	1.05
17460199−3303085	356.5301	−2.2173	S?	K5-M0	9.86	1.16	0.53	9.50	−2.34	0.81
17463311−2419558	4.0423	2.2155	S	M4:	9.86	1.35	0.60	11.46	−2.28	−0.86
18131474−1007218	19.5540	3.7375	S	M0	10.94	1.30	0.46	13.75	−1.51	1.16
18272892−1555547	16.0601	−2.0558	S	M1	9.16	1.36	0.62	11.14	−2.95	3.67
18300636−1940315	13.0226	−4.3378	S	M3.5	11.07	1.11	0.41	12.56	−2.21	1.23

Motivation

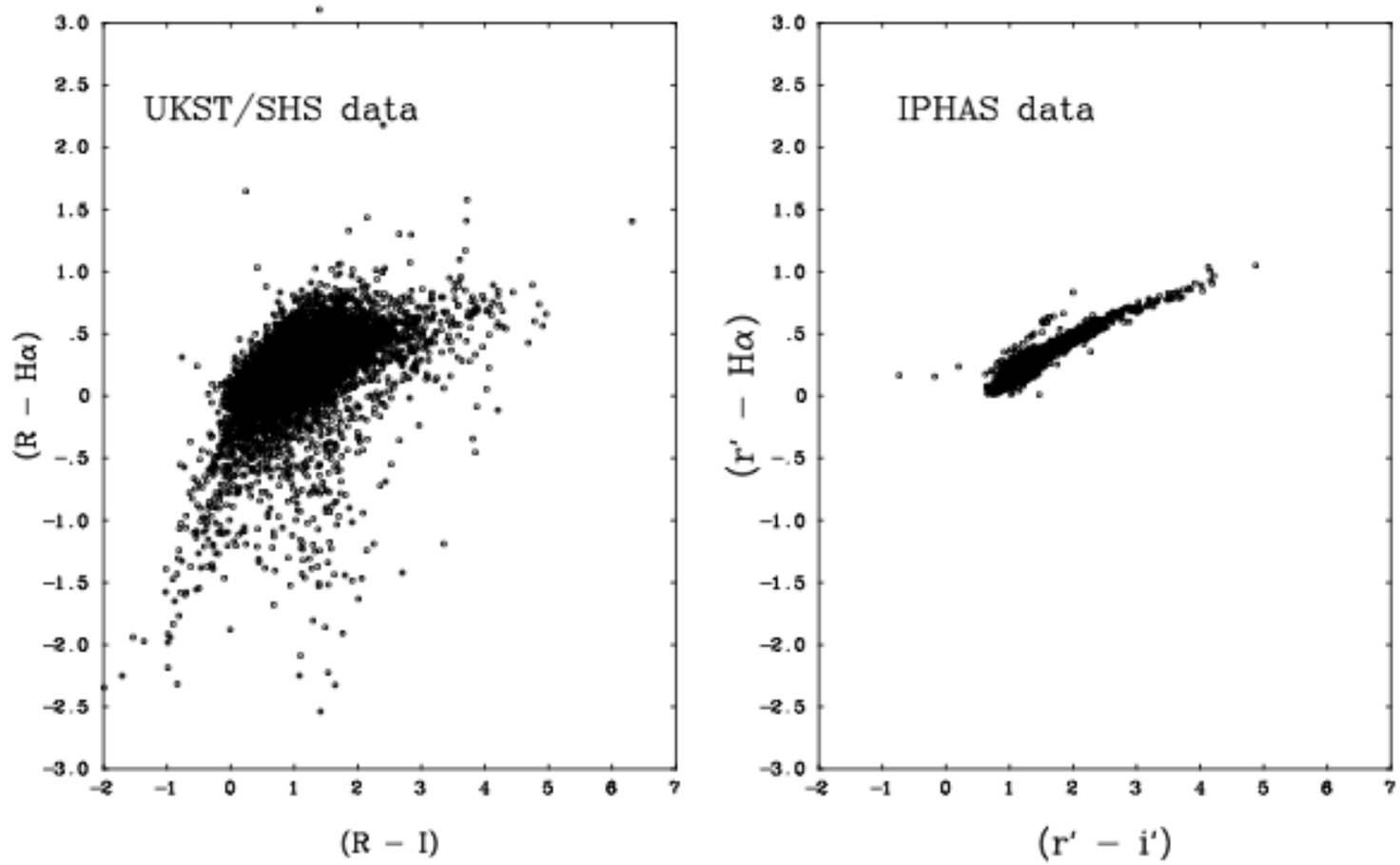
- Corradi+ - Northern Galactic Plane [IPHAS]
- No equivalent search in south [VPHAS+ is coming]
- BUT we can use the digitised photographic plates of SuperCOSMOS Halpha Survey (SHS)
- Miszalski+2008 used SHS to select a few hundred compact PNe via catalogue photometry colour-cuts
- Find more symbiotic stars in regions of interest
  - Lightcurve coverage: OGLE I-band + VVV Ks
- Rare objects: carbon-rich symbiotics, supersoft sources, symbiotic novae => connection with Type Ia supernovae

SuperCOSMOS Halpha Survey (SHS, Parker+ 2005)



4000 deg^2, |b|<10 deg, digitised photographic Schmidt survey

SHS and IPHAS colour-colour planes



It is still possible to select Ha emitters from SHS...

Figure 2: Point-source SHS colours obtained from the existing UKST photographic Hα survey of a ~ 0.25 sq.deg. patch of sky in Aquila are compared with the analogous colours obtained for approximately the same field, obtained as part of the IPHAS survey. Only stars in the magnitude range $13 < R < 19$ are plotted. Note the much tighter definition of the IPHAS stellar locus, revealing 3 convincing blue Hα-excess objects (candidate interacting binaries, in this example).

(VPHAS+ science case, Drew et al.)

MASH-II PNe
(Miszalski+ 2008)

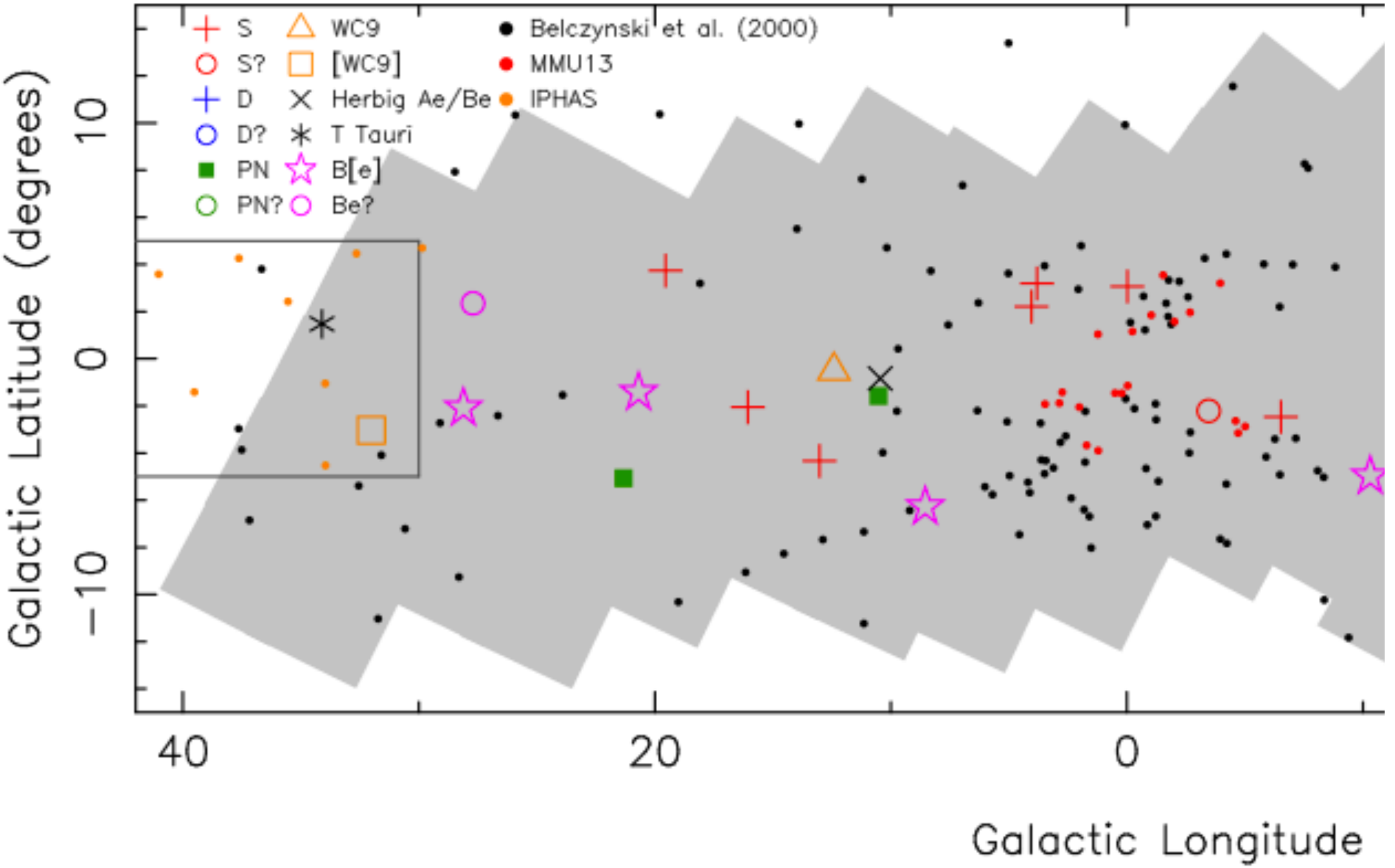
SHS search for symbiotics

- Miszalski+ 2008 - noticed Ha emitters + red giant colours, but selected against these (focus was on PNe)
- Miszalski & Mikołajewska - systematic search for Ha emitters in RA=14-19h (HA <= 15 mag)
- Use colours of MMU13 symbiotics to define colour-colour cuts in SHS (Ha, SR and I)
- Cross match results with 2MASS + select best candidates (relatively loose selection criteria)
- A few hundred candidates

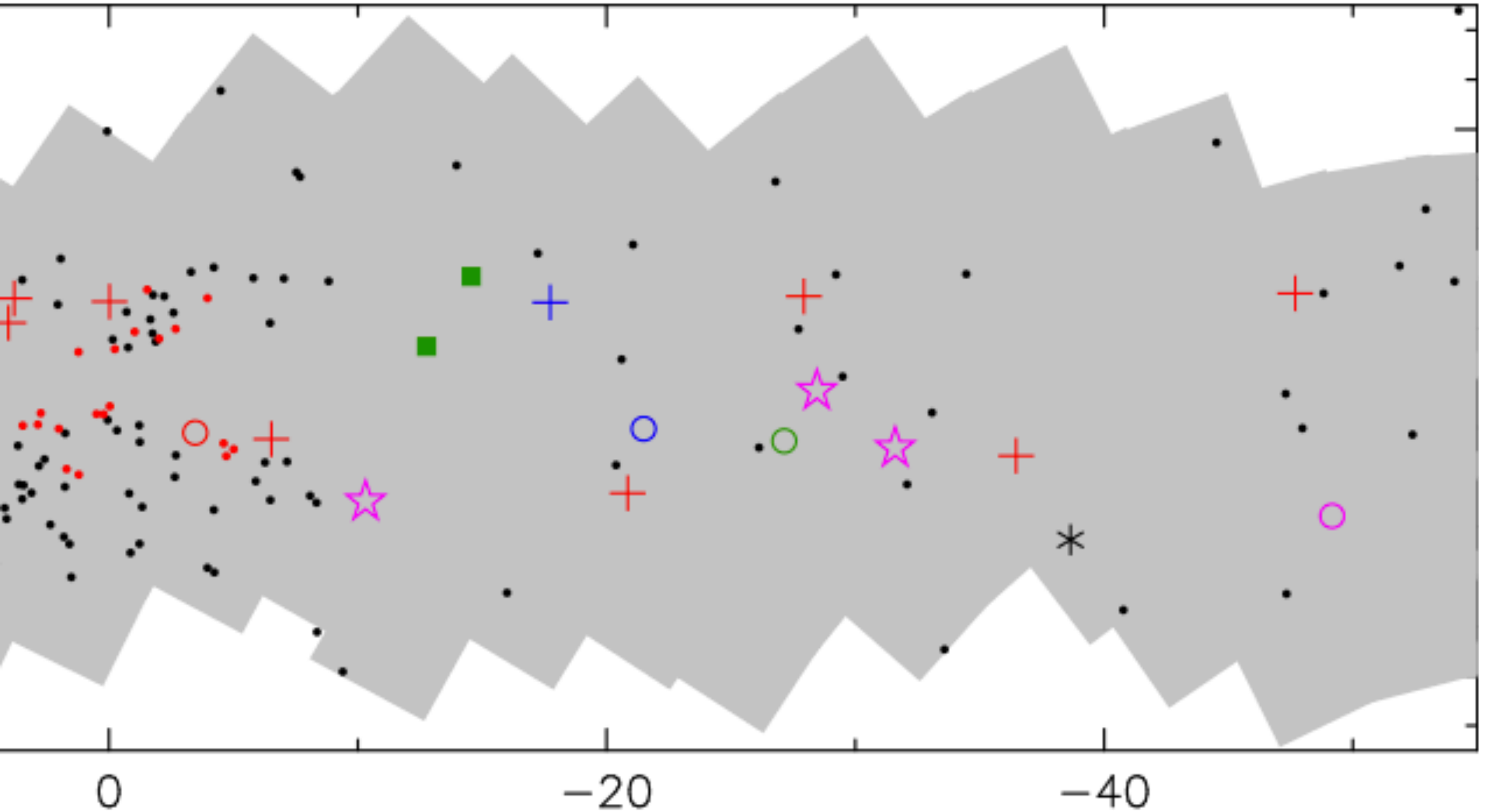
SALT spectroscopic followup

- Max 3.0” seeing program (Poland+RSA)
- Use Robert Stobie Spectrograph (RSS) PG900 VPH grating, 4340-7400 A @ 6A resolution
- Typical exptimes: 1x60s, 1x1200-1800s
- 12 new symbiotic stars + 2 possible
- 18 other interesting objects
- 2013-2 semester: followup of search in RA=6-13 h

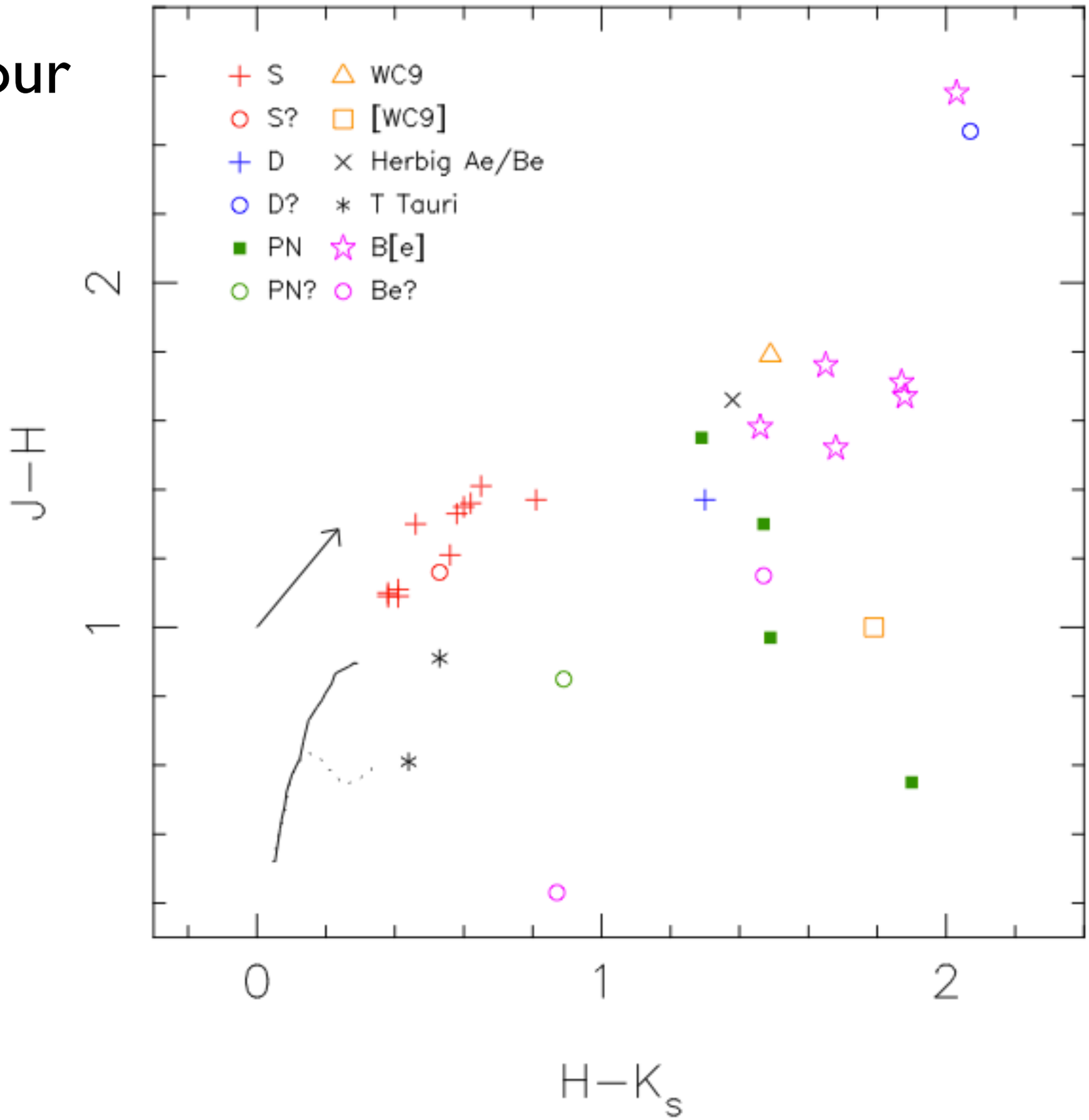
Galactic distribution



Galactic distribution

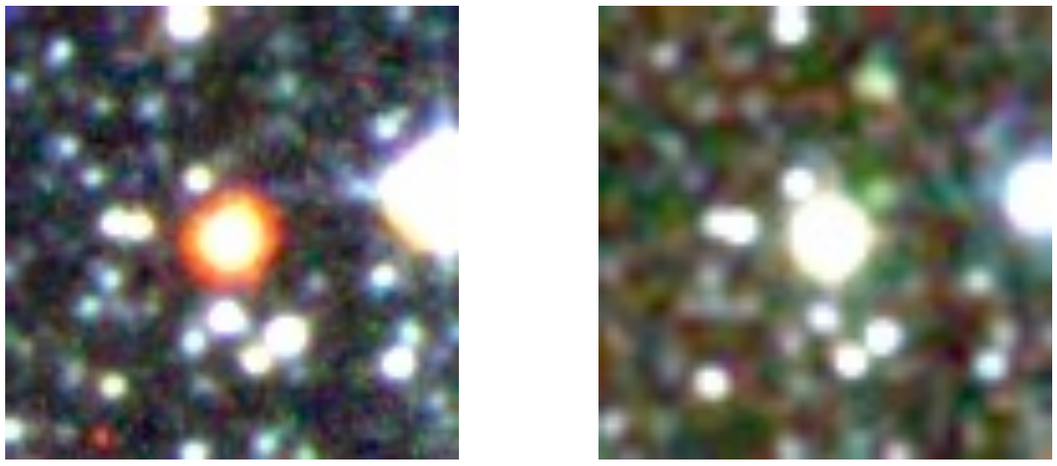


2MASS colour-colour plane

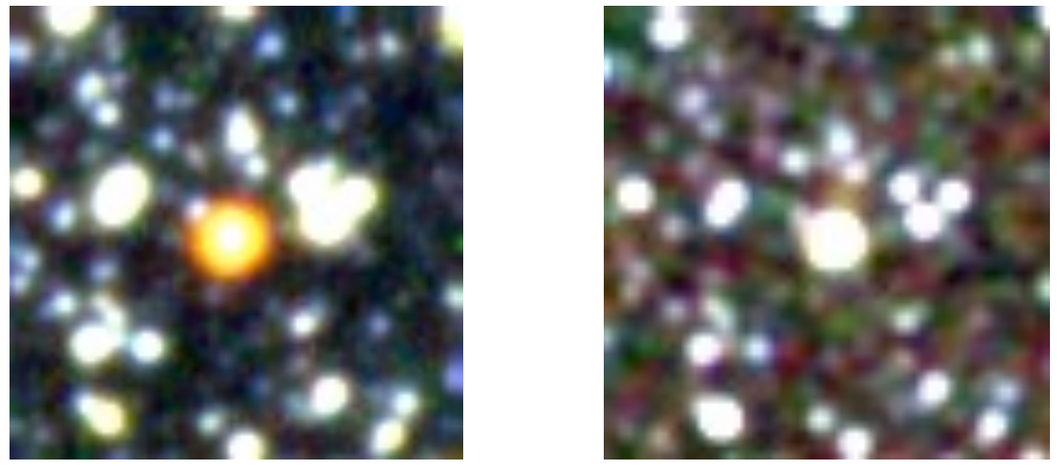


New symbiotic stars

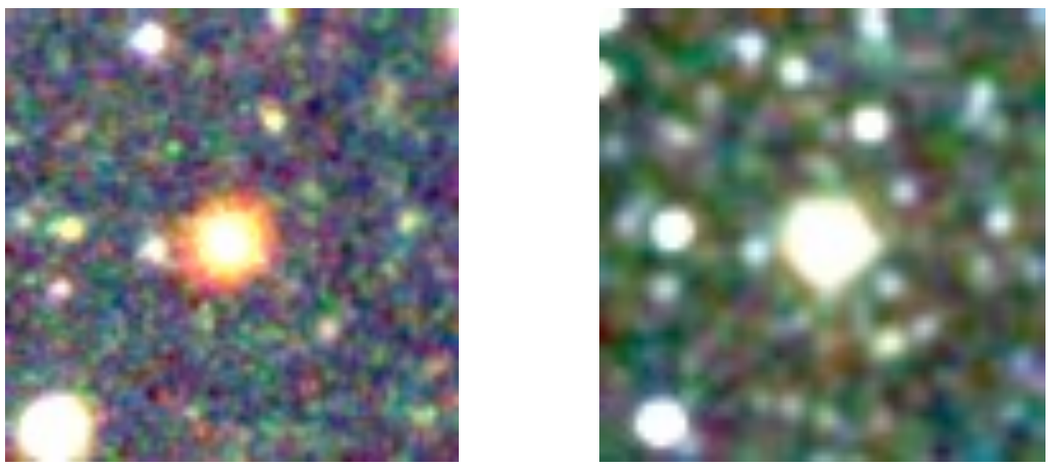
14031865-5809349



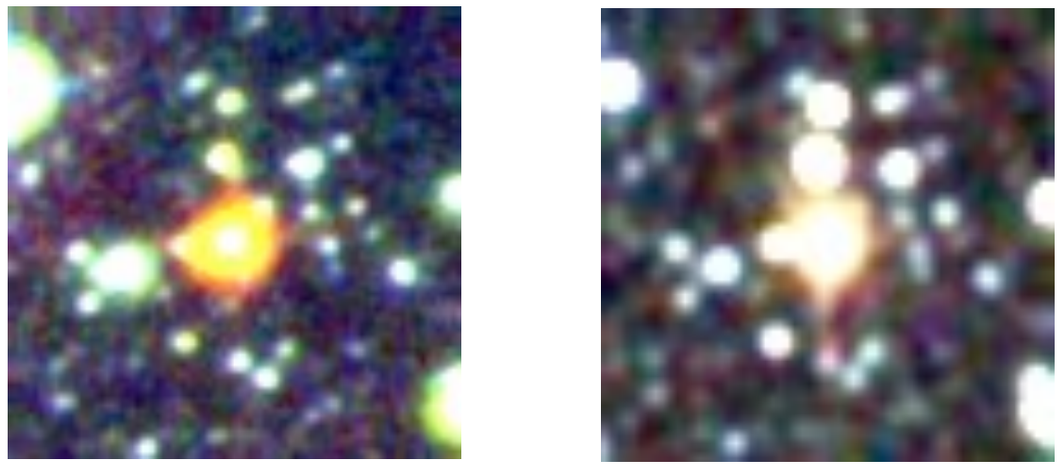
15431767-5857221



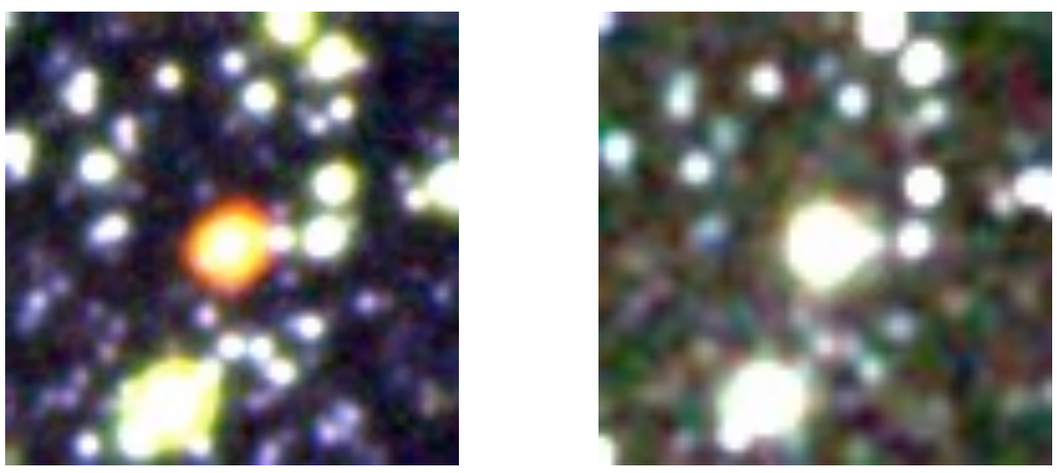
16003761-4835228



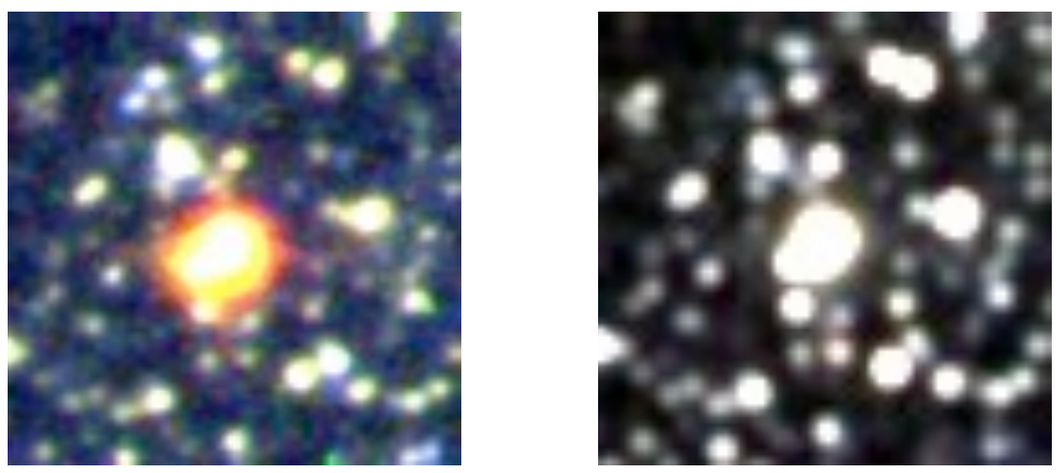
16422739-4133105



17050868-4849122

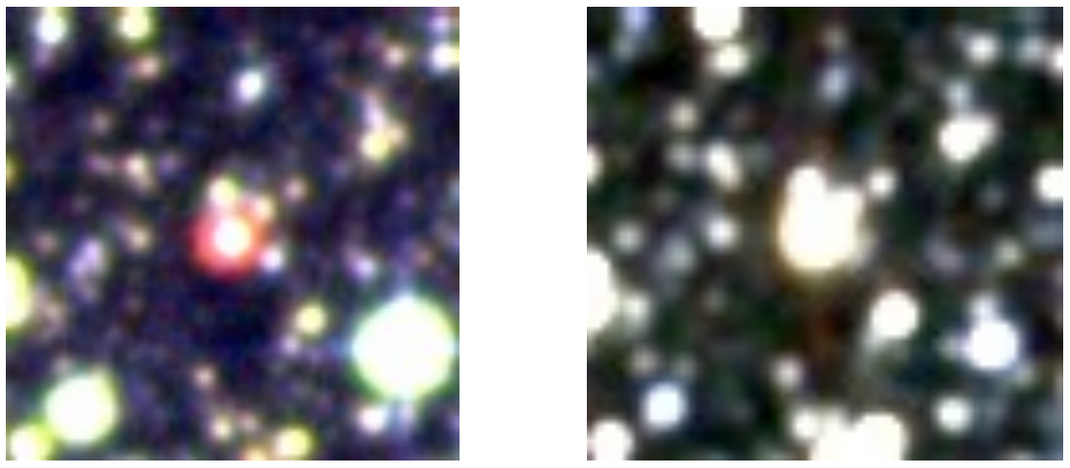


17334728-2719266

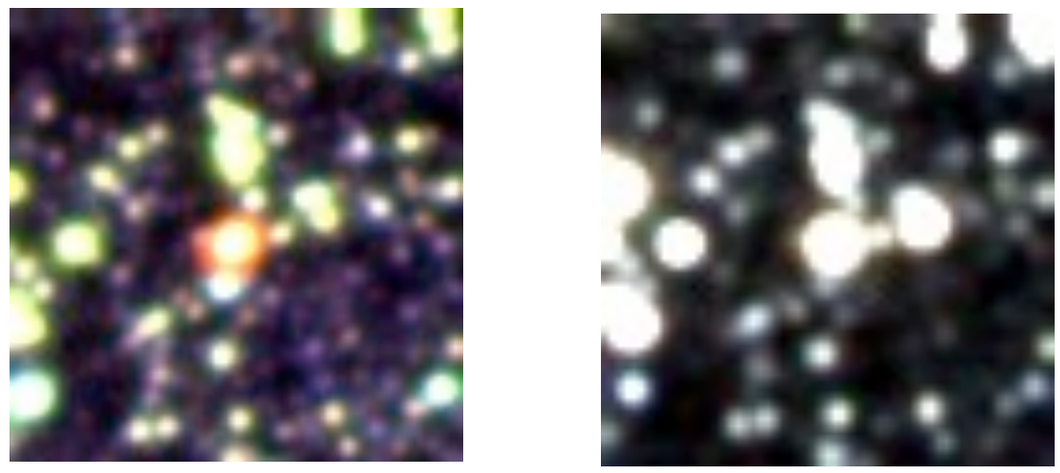


New symbiotic stars

17391715-3546593



17422035-2401162



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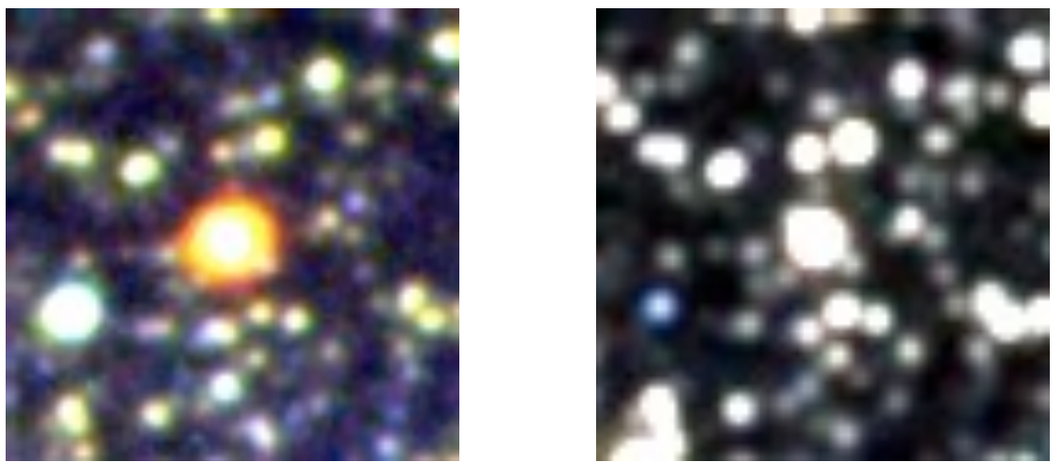
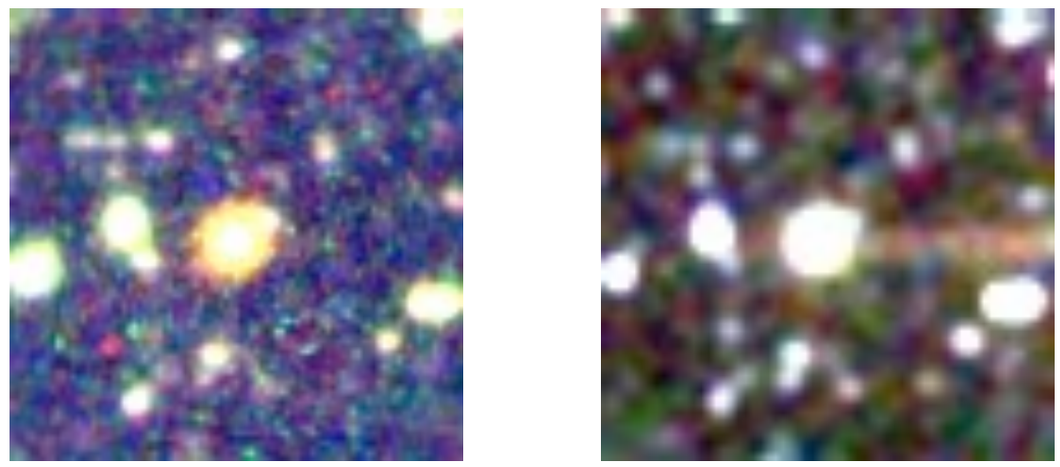


18131474-1007218



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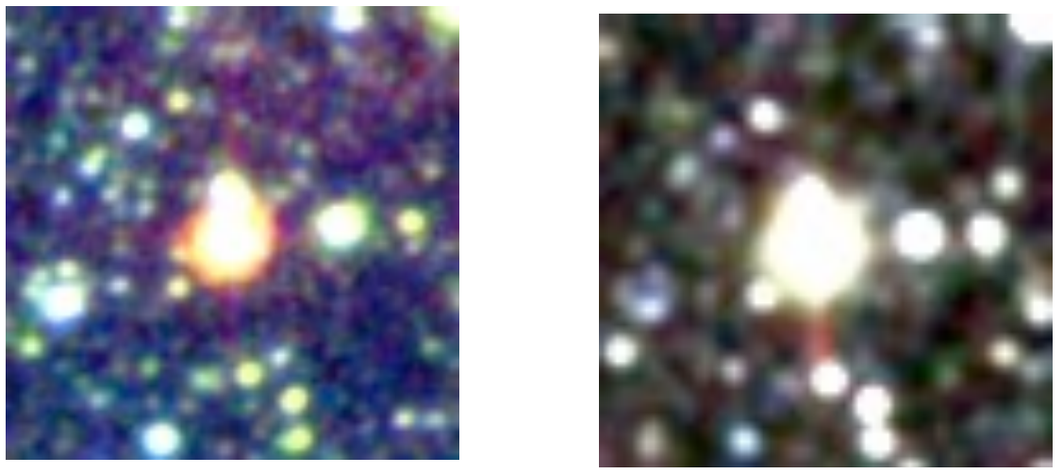
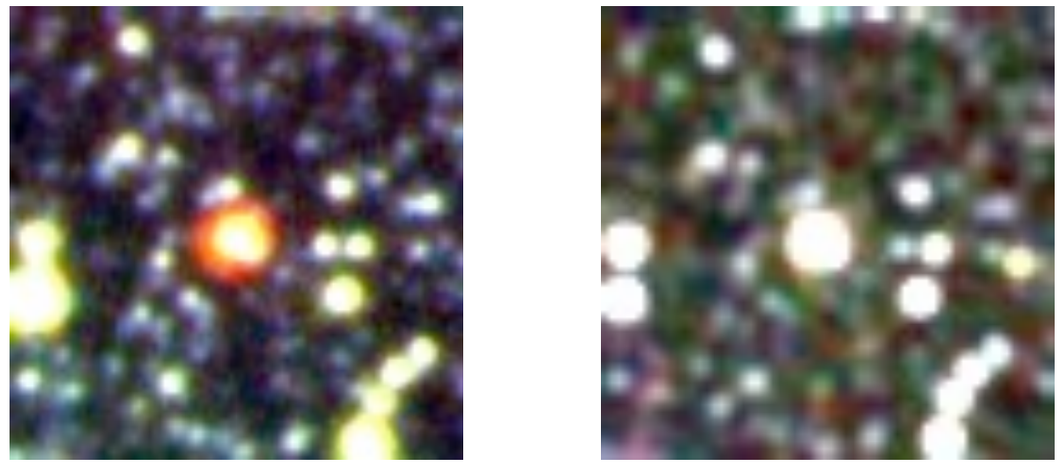


18300636-1940315



14031865−5809349

Rectified Flux

Wavelength (Å)

15431767−5857221

[Fe VII]

[Ca V]

[Fe VII]

O VI

Rectified Flux

Wavelength (Å)

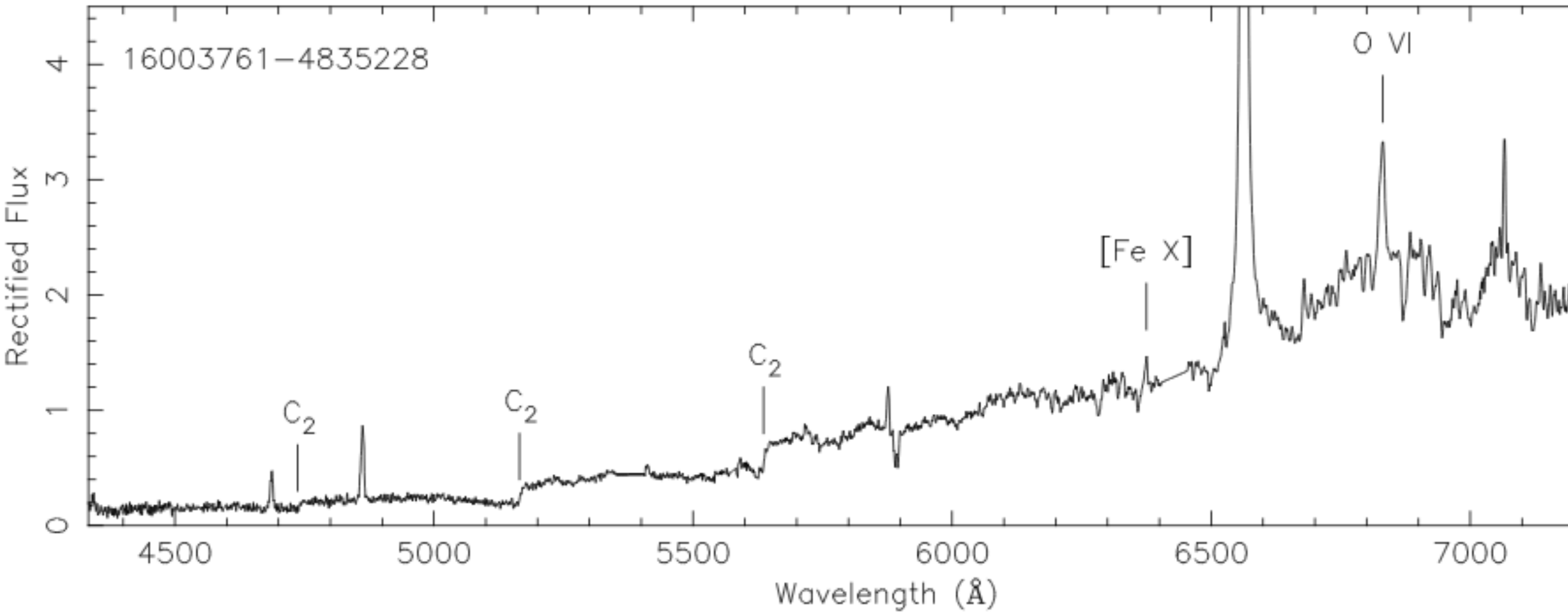
1600-4835

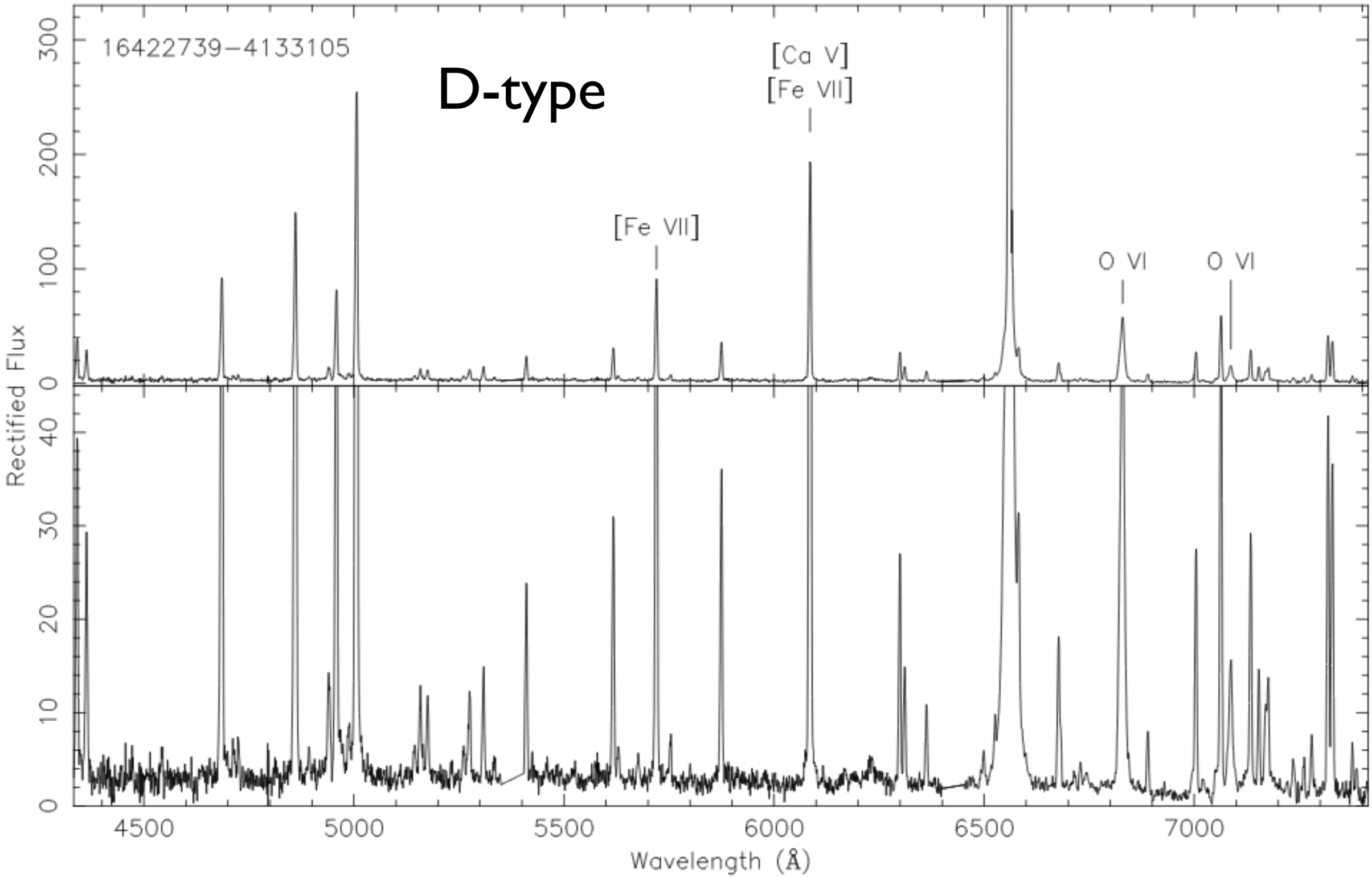
carbon-rich!

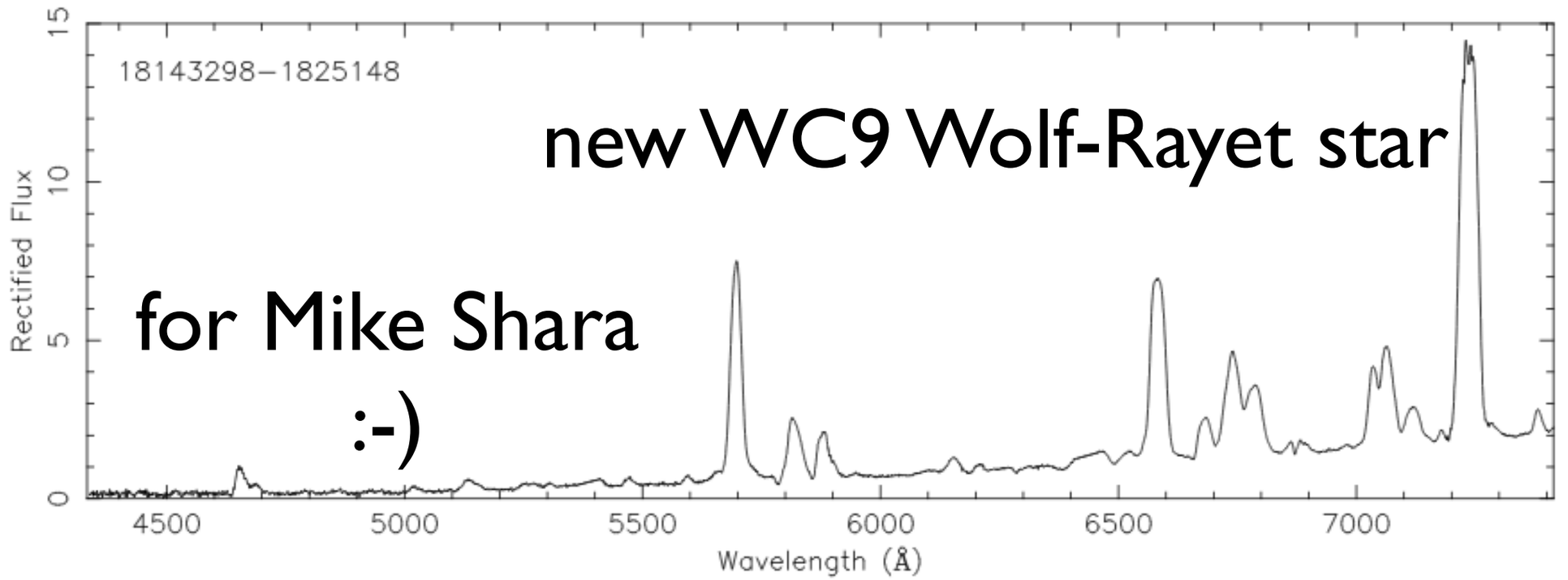
fifth C-rich Galactic symbiotic

[Fe X] 6375 emission

potential supersoft X-ray source!



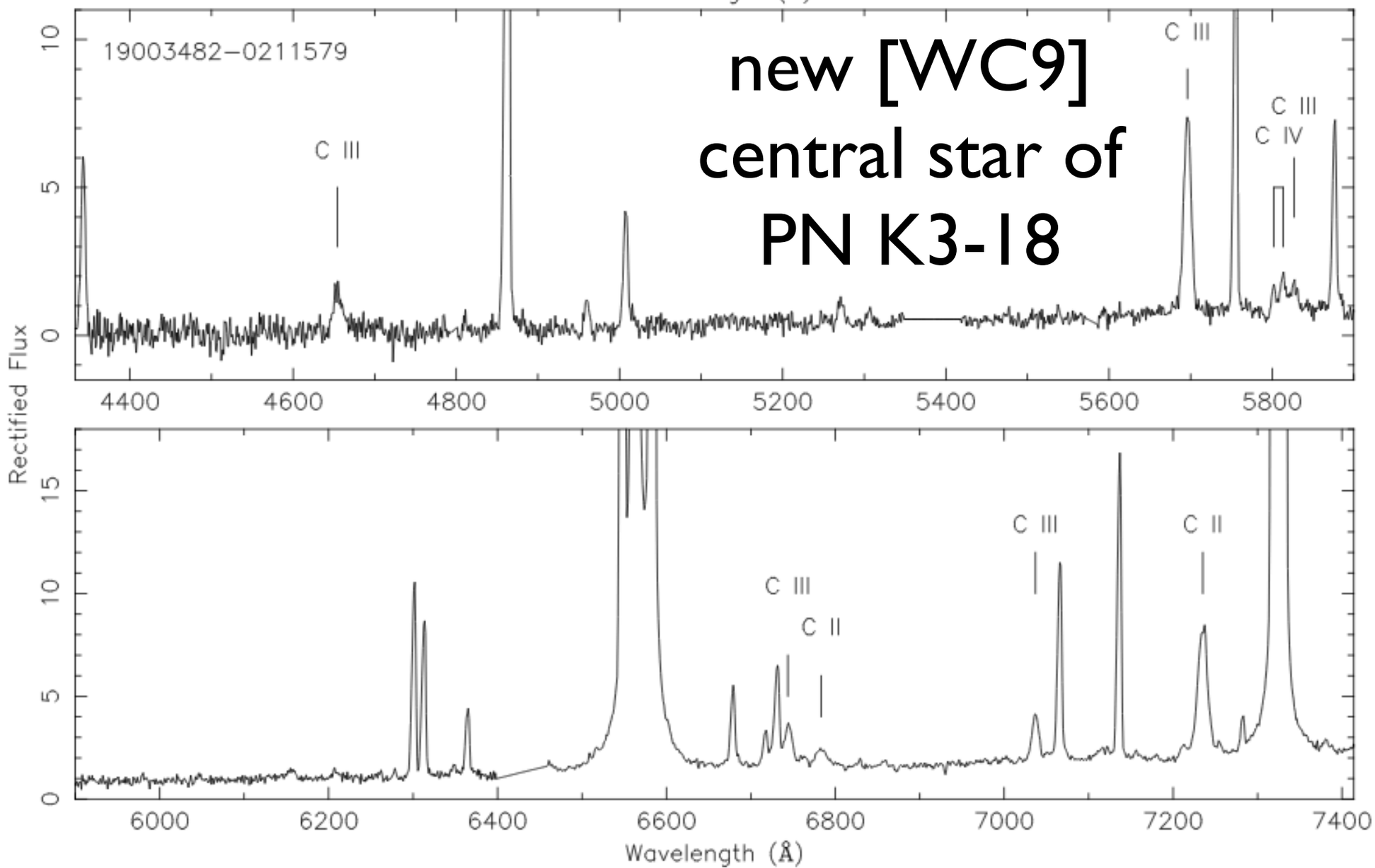

16422739−4133105
D-type
[Ca V]
[Fe VII]
[Fe VII]
O VI
O VI
Rectified Flux
0
10
20
30
40
100
200
300
4500
5000
5500
6000
6500
7000
Wavelength (Å)



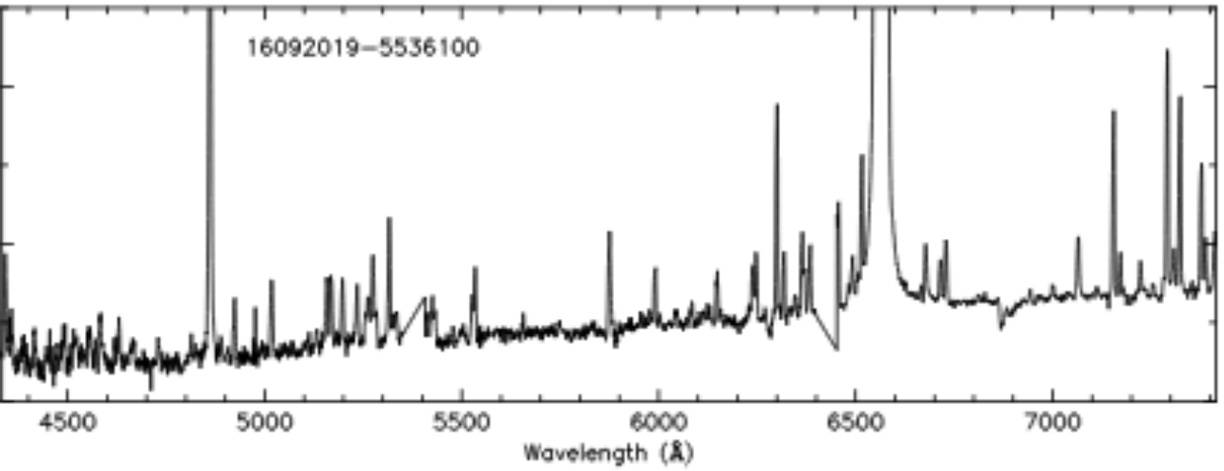
new WC9 Wolf-Rayet star

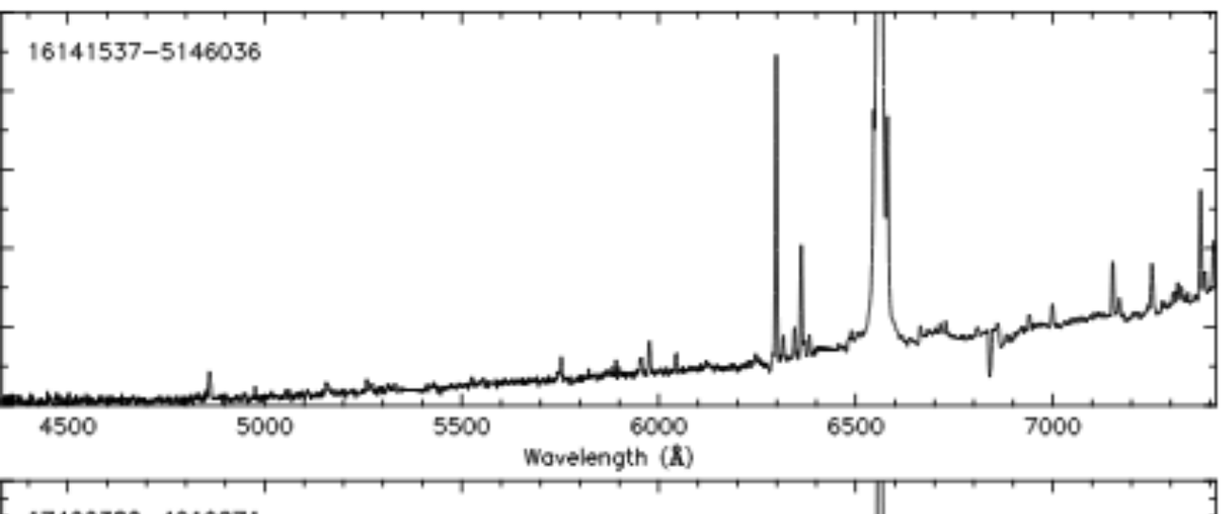
for Mike Shara

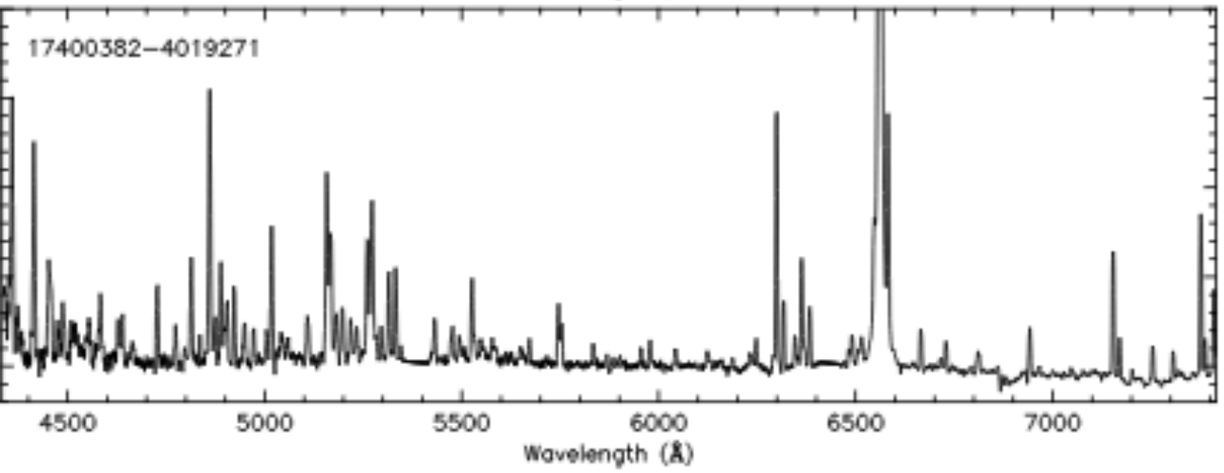
:-)

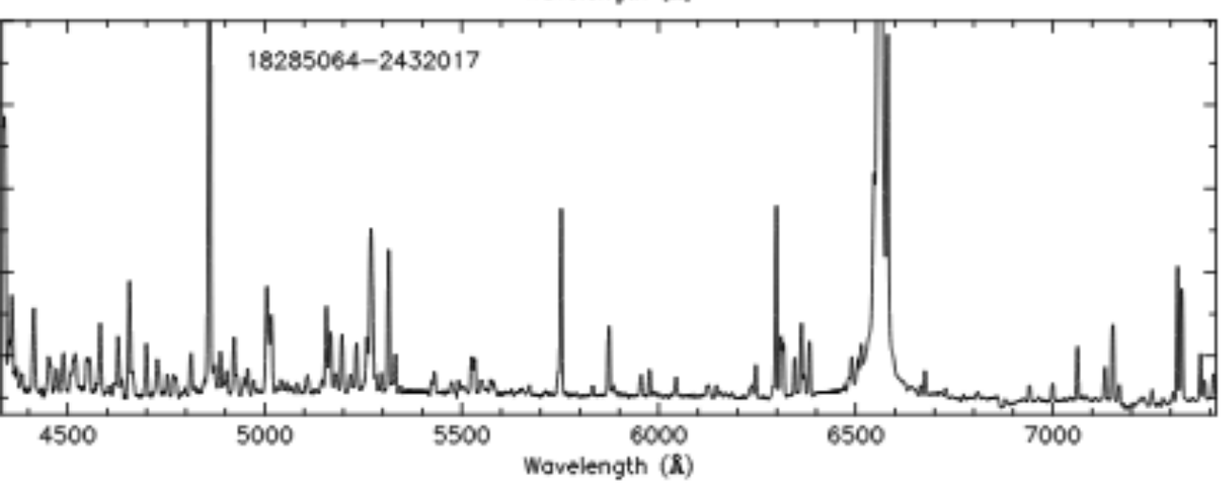


new [WC9]
central star of
PN K3-18



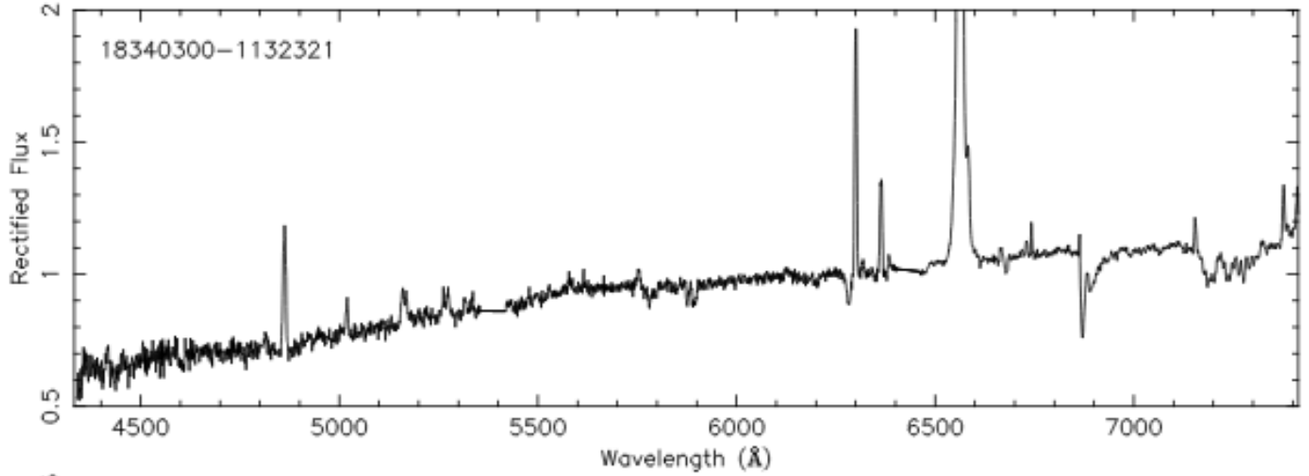


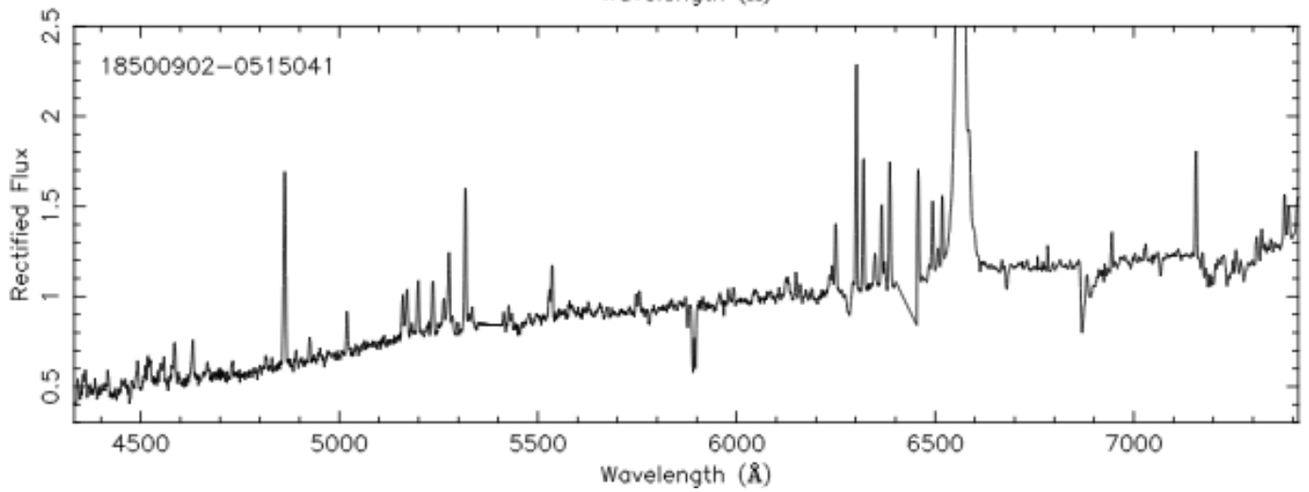




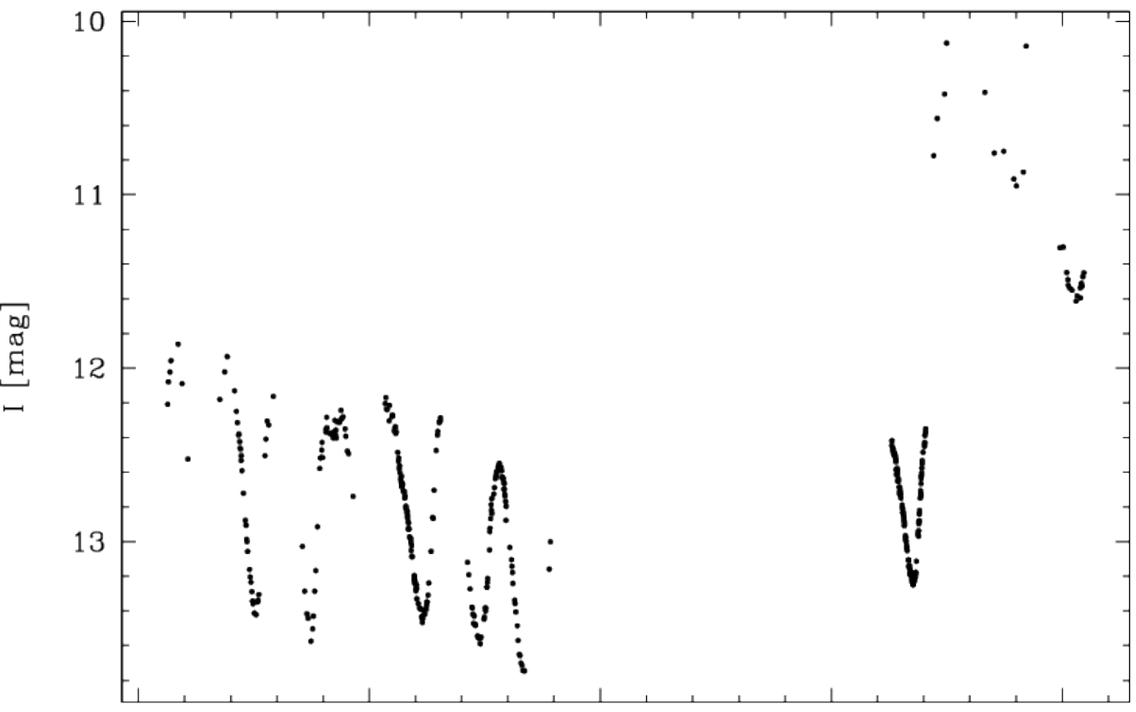
6 new B[e] stars

Were good
D-type candidates
:-(

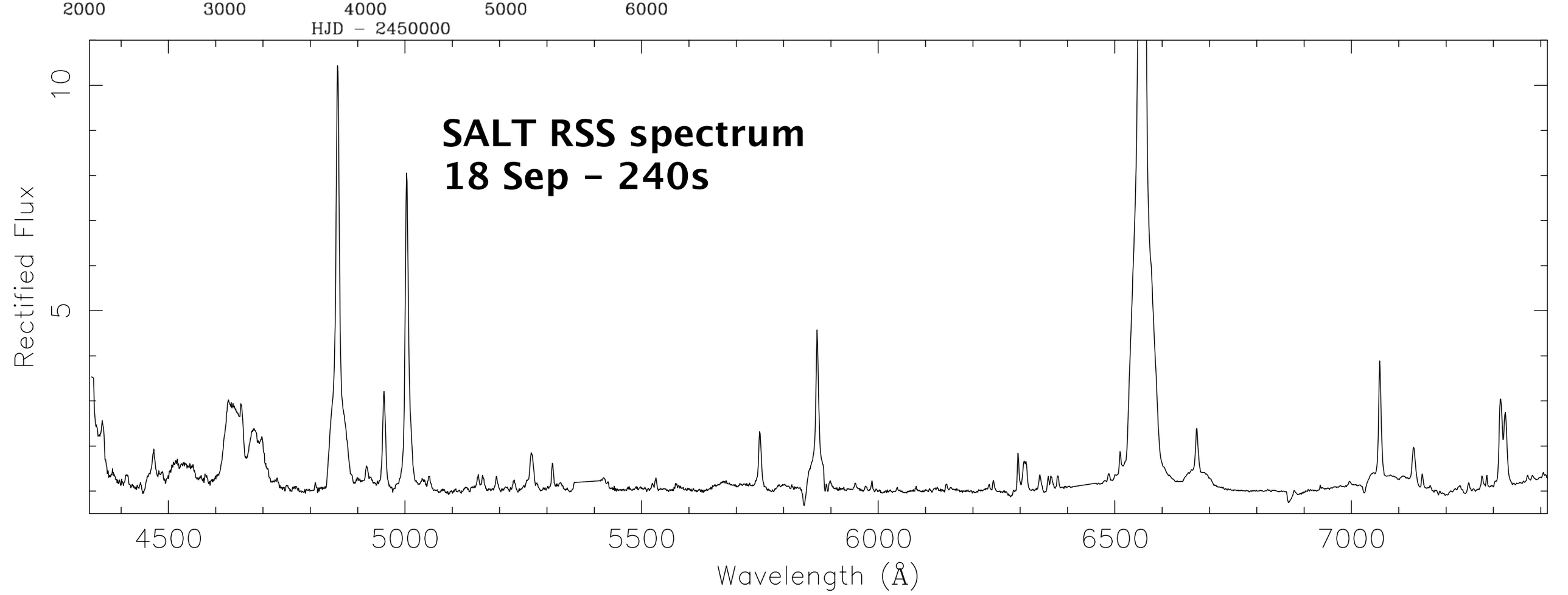




A SALTy symbiotic nova (Mira)



Only 10 symbiotic nova knwon thus far +
4 symbiotic recurrent novae (Mikołajewska 2010)
Observed a new symbiotic nova in 2013-1-RSA_POL-001
Mira companion: distance from L-P relation (Whitelock et al.)



Magellanic Clouds

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A deeper look at an enlarged sample LMC symbiotic stars

2012-2-RSA_POL-001

- Known and candidate LMC symbiotic stars and difficult to classify PNe; Several papers are expected
- Data reduced and analysis/write up ongoing

A deeper look at SMC symbiotic stars

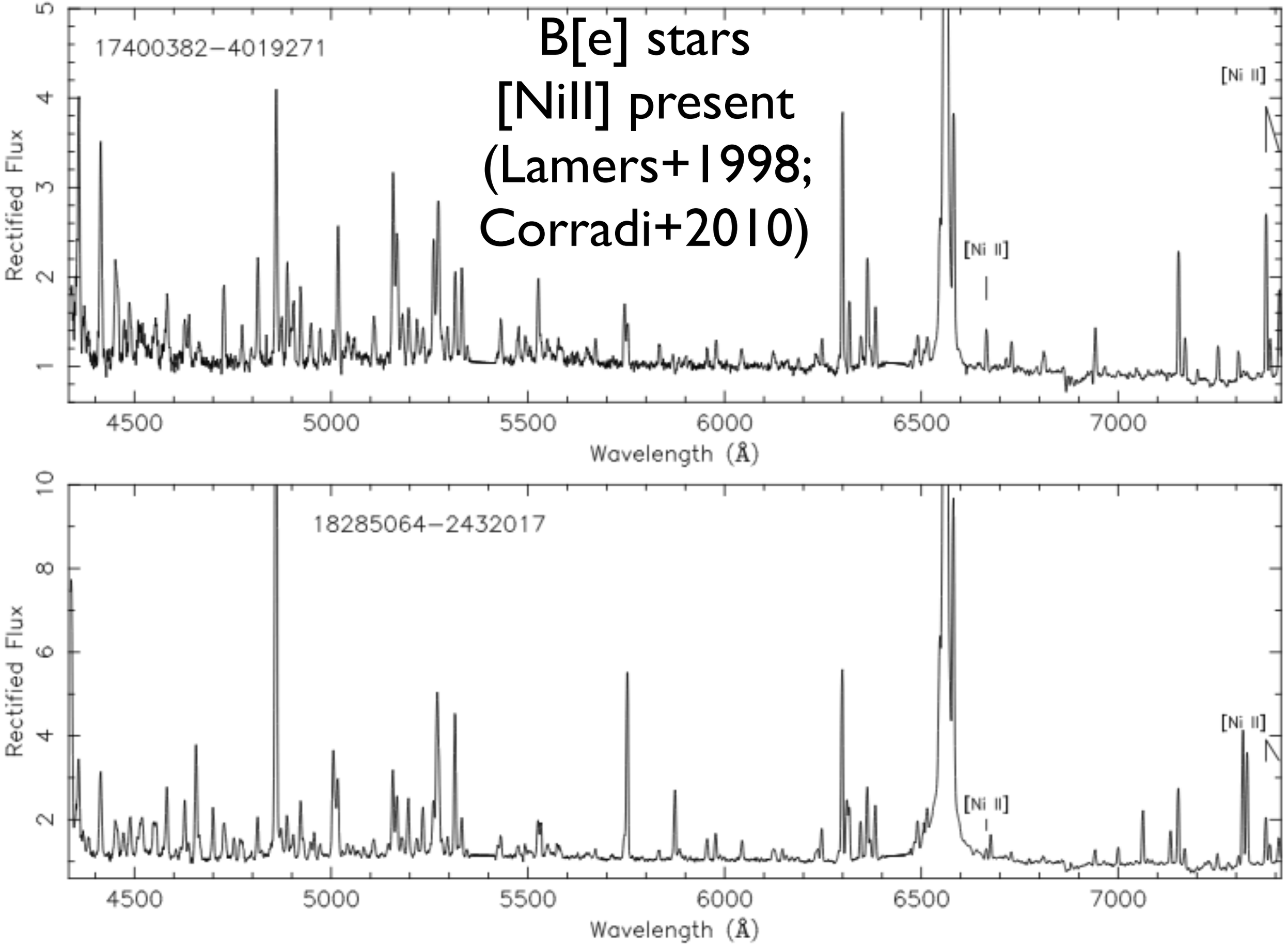
2013-1-POL_RSA-001

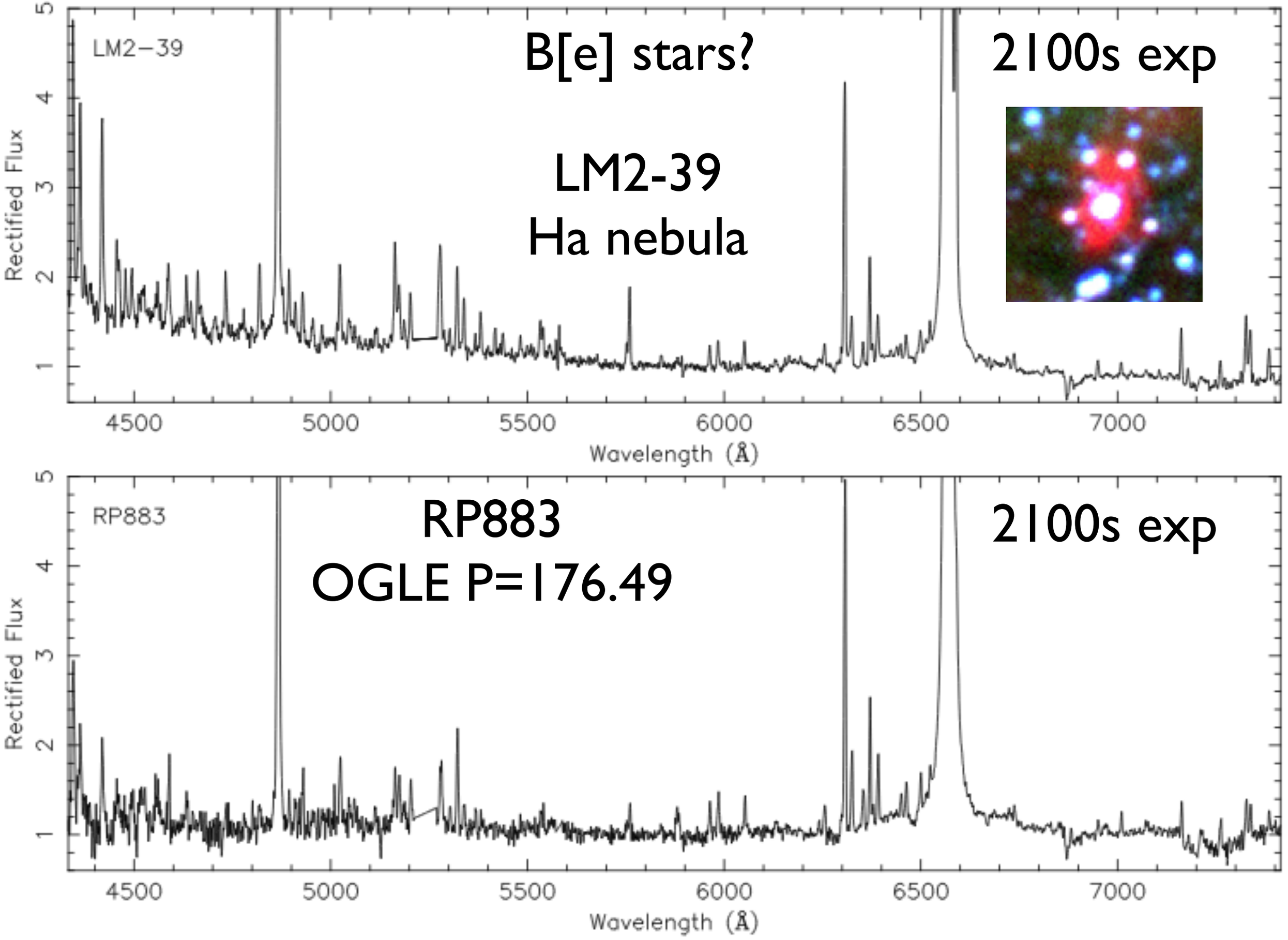
- Several known and candidate SMC symbiotic stars
- Some data reduced and analysis/write up has started
- Letter drafted and other papers to come

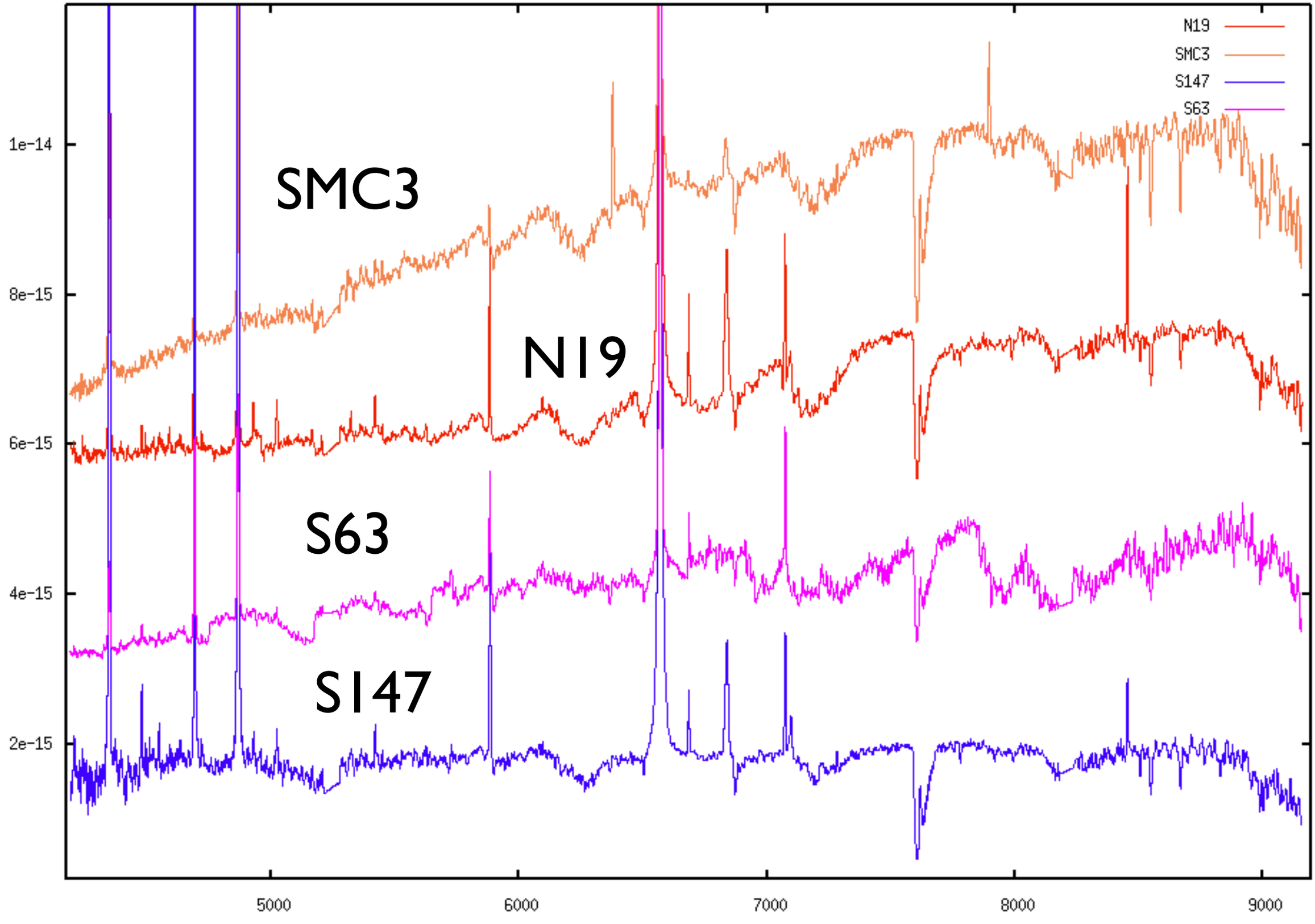
VISTA Magellanic Cloud Survey (Cioni+2011)

- Deep Y, J and Ks sub-arcsec multi-epoch atlas of LMC, SMC, Bridge and Stream
- Only 8 LMC and 7 SMC symbiotics known
  - **Key populations** - known distance, low reddening, carbon-types common, amongst hottest and brightest WDs, 2 supersoft sources
- Can leverage Hα emission line object catalogues to find new symbiotics (Planetary Nebulae, others) as done routinely in Milky Way (Miszalski et al. 2011)

B[e] stars
[NiII] present
(Lamers+1998; Corradi+2010)




LM2−39
B[e] stars?
LM2-39
Ha nebula
2100s exp
Rectified Flux
Wavelength (Å)
RP883
RP883
OGLE P=176.49
2100s exp
Rectified Flux
Wavelength (Å)

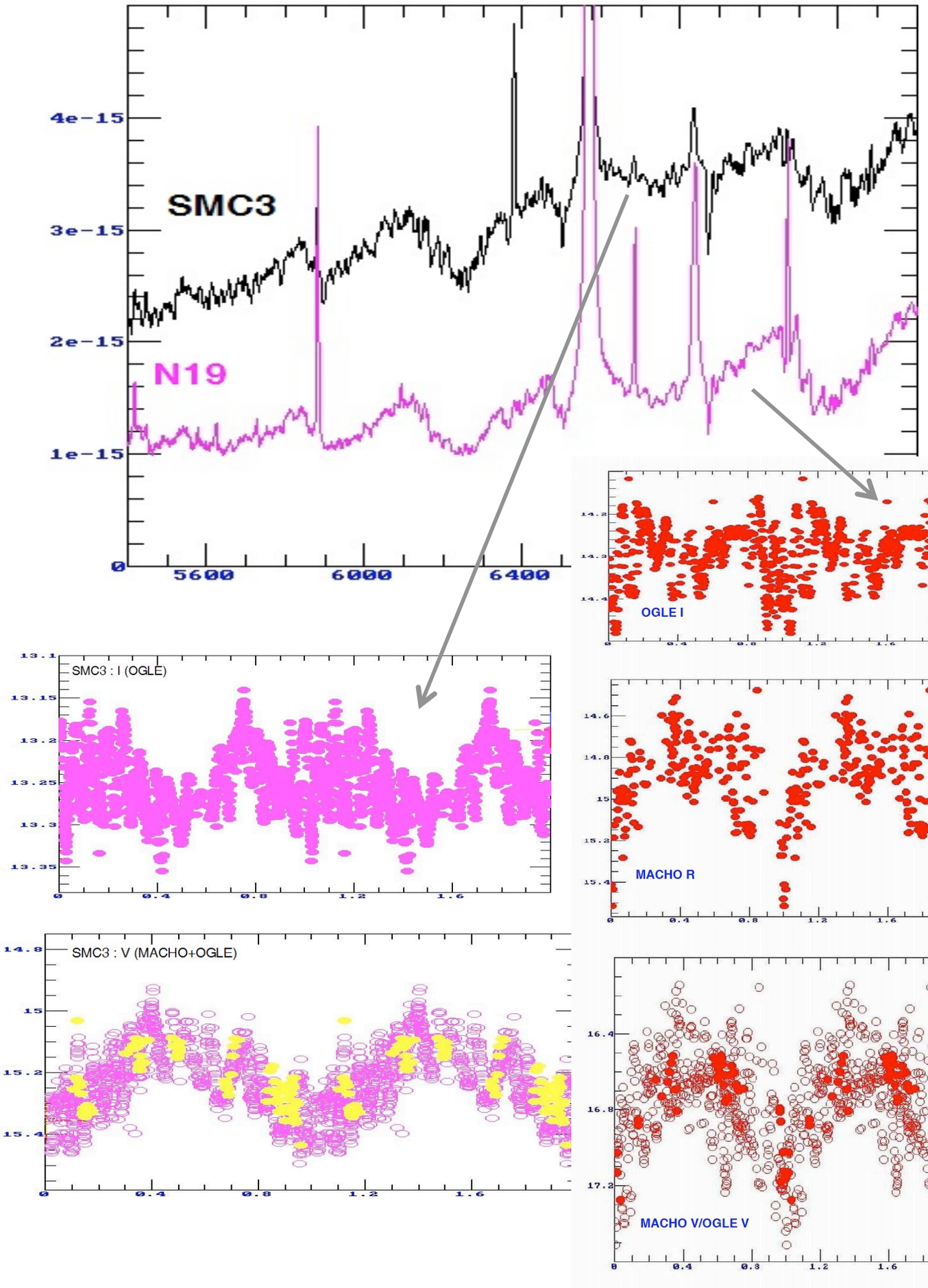

N19
SMC3
S147
S63
SMC3
N19
S63
S147
1e-14
8e-15
6e-15
4e-15
2e-15
5000
6000
7000
8000
9000

SMC 3 & N19

2 papers in preparation

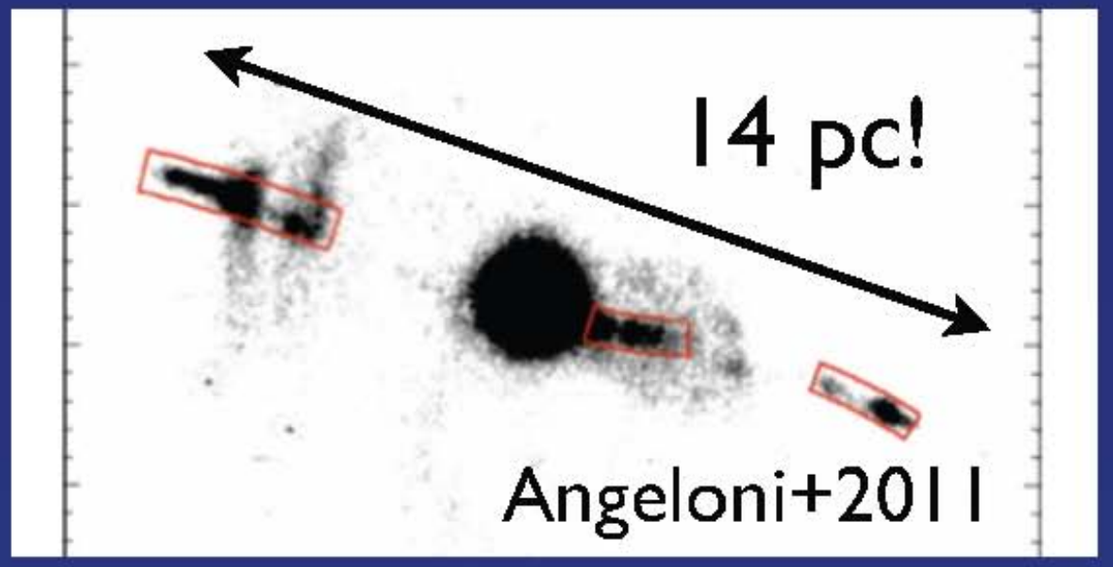
- Known orbital periods:
- N19: 946 d (Mikolajewska 2004)
- SMC3: 1643 d (e.g. Kato, Hachisu & Mikolajewska 2013)
- Both ellipsoidal variables: giants (almost?) fill RL
- Emission line fluxes vary with Porb
- Evidence for s-process elements: ZrO, strong BaII..
- Additional SMC3 SALT spectra: Orio (UW) and possibly(?) Odendaal (RSA)

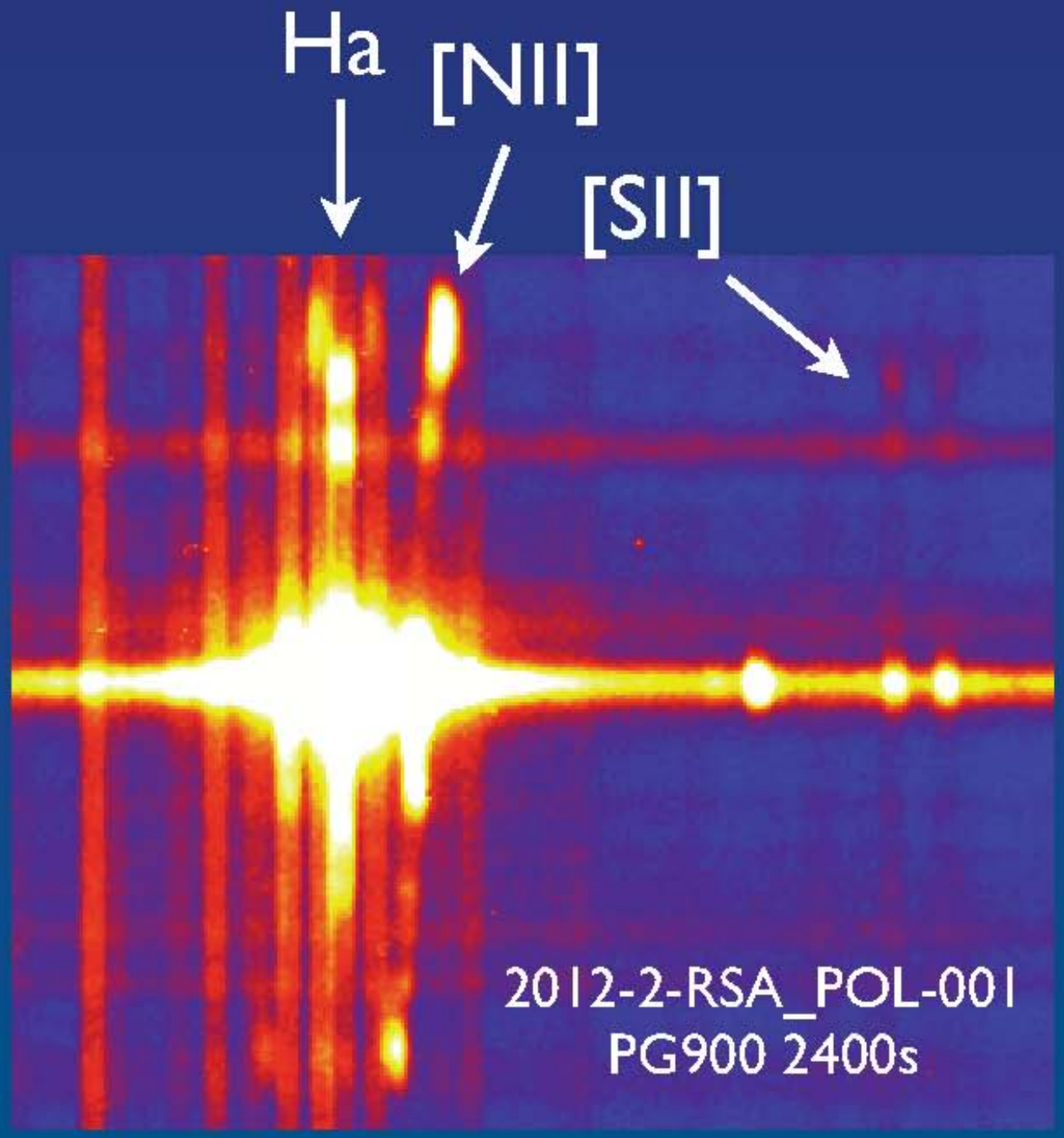
2012-2-RSA_POL-001
2013-1-POL_RSA-001



Sanduleak's star

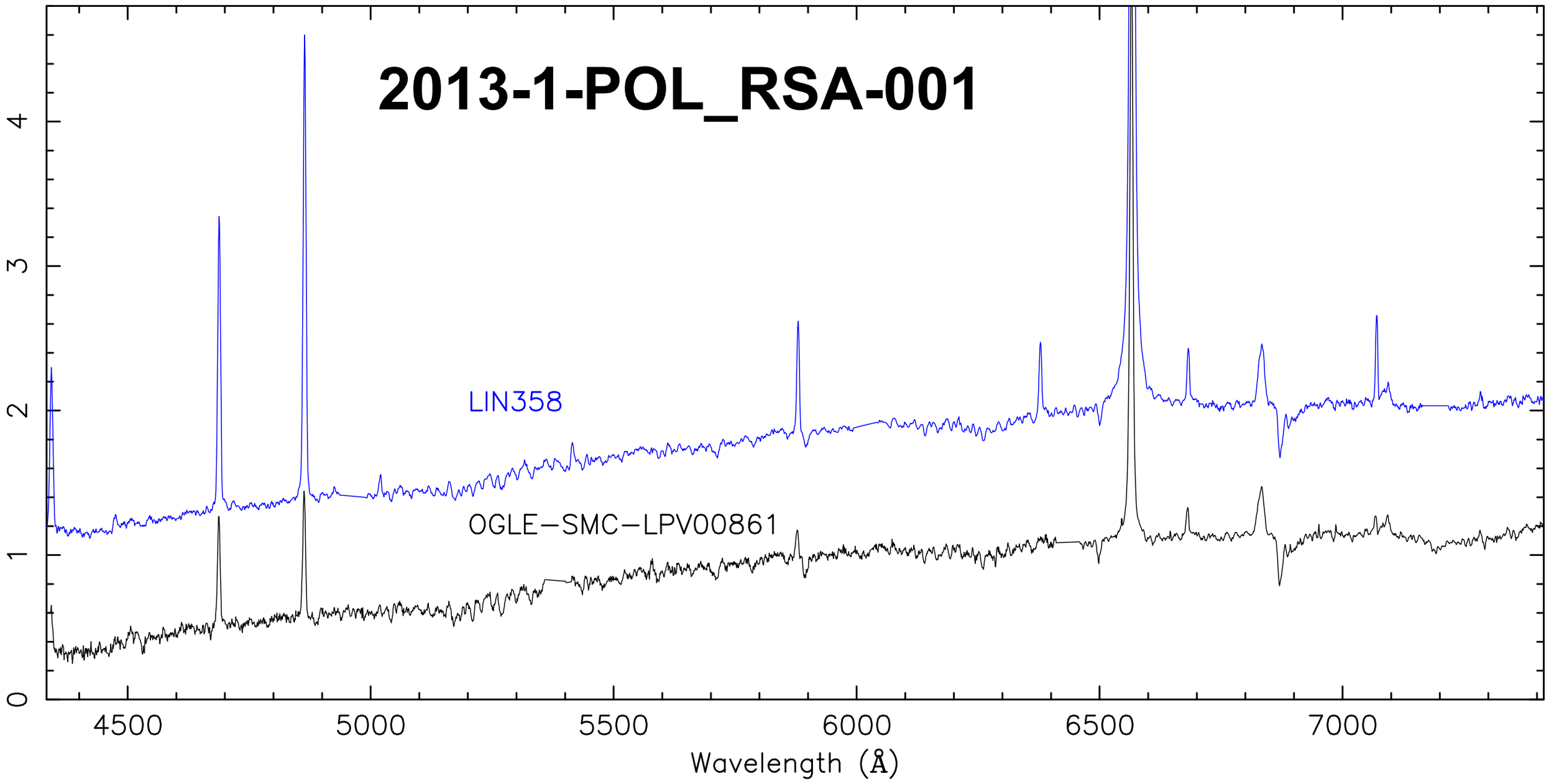
- LMC D-type symbiotic with huge jet (Angeloni+ 2011)
- 40 min PG900 RSS spectrum taken
- Deeper than 20 min 300 line grating Magellan 6.5 m spectrum
- New detection of [SII], [OIII], [NI] in jet
- Constrain jet properties





OGLE-SMC-LPV00861 (LIN9) – the first proven Z And outburst in a Magellanic symbiotic star

MNRAS letter drafted (Miszalski, Mikołajewska & Udalski)



OGLE III-IV lightcurve

OGLE I−band

OGLE V−band

Z And-type outburst

$L_{hot,out} \sim L_{hot,quiet} \sim$ 1000-3000 Lsun

unstable disc-accretion onto hydrogen-shell burning white dwarf

SALT spectrum taken during late decline or quiescence

OGLE magnitude

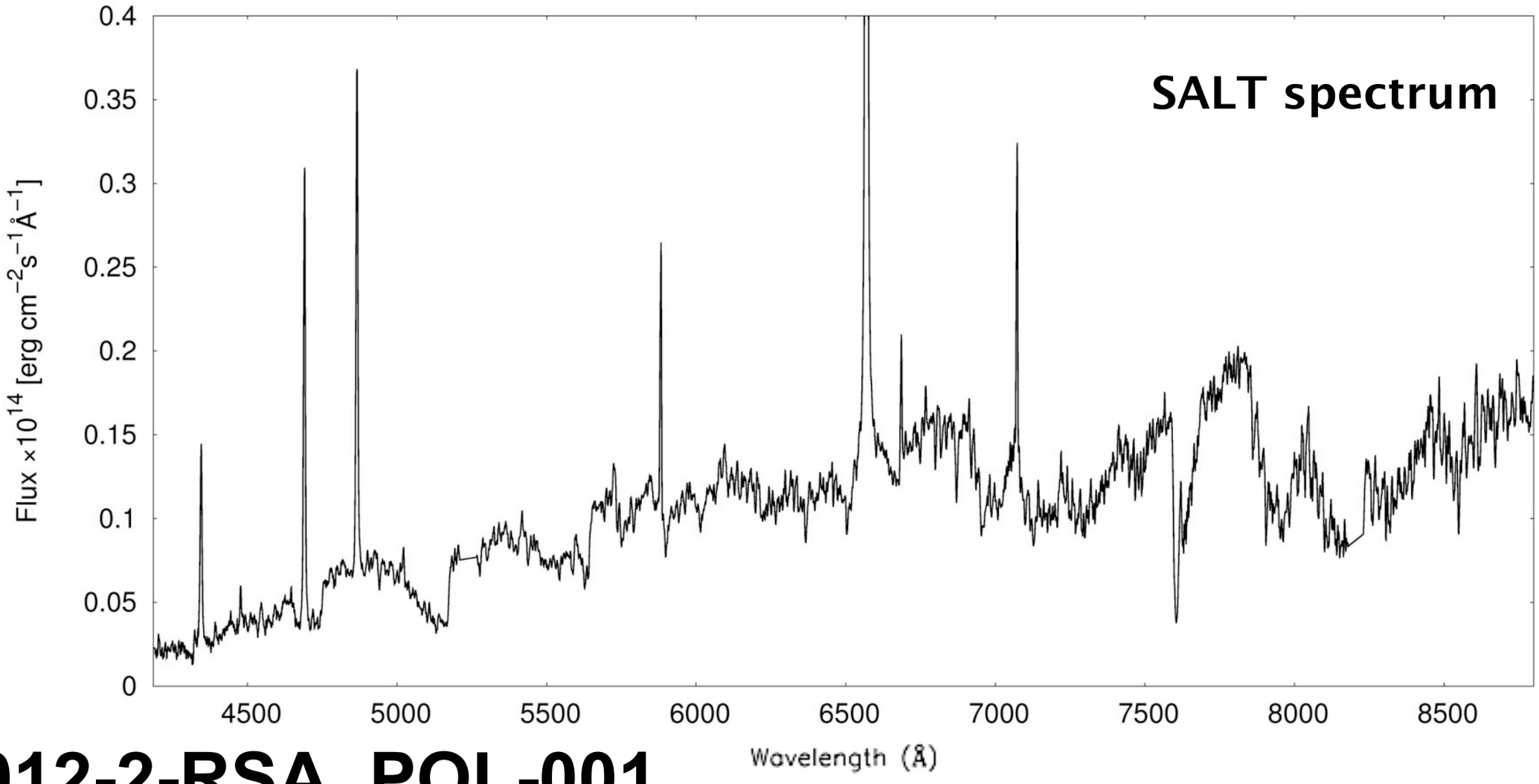
14
14.5
15
15.5
16

3000
4000
5000
6000

HJD−2450000

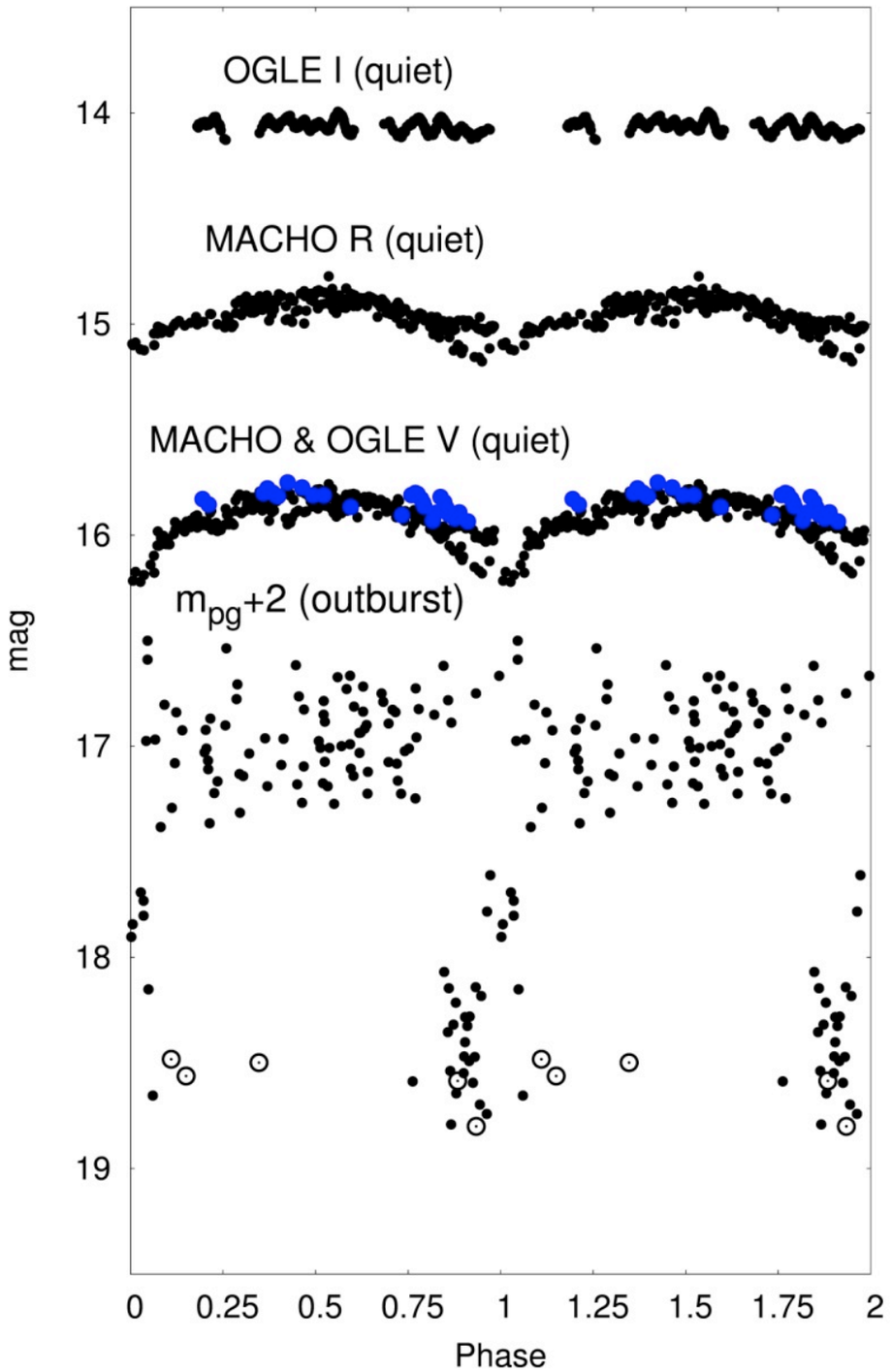
LMC S63: a historical reappraisal of a Z And-type symbiotic star

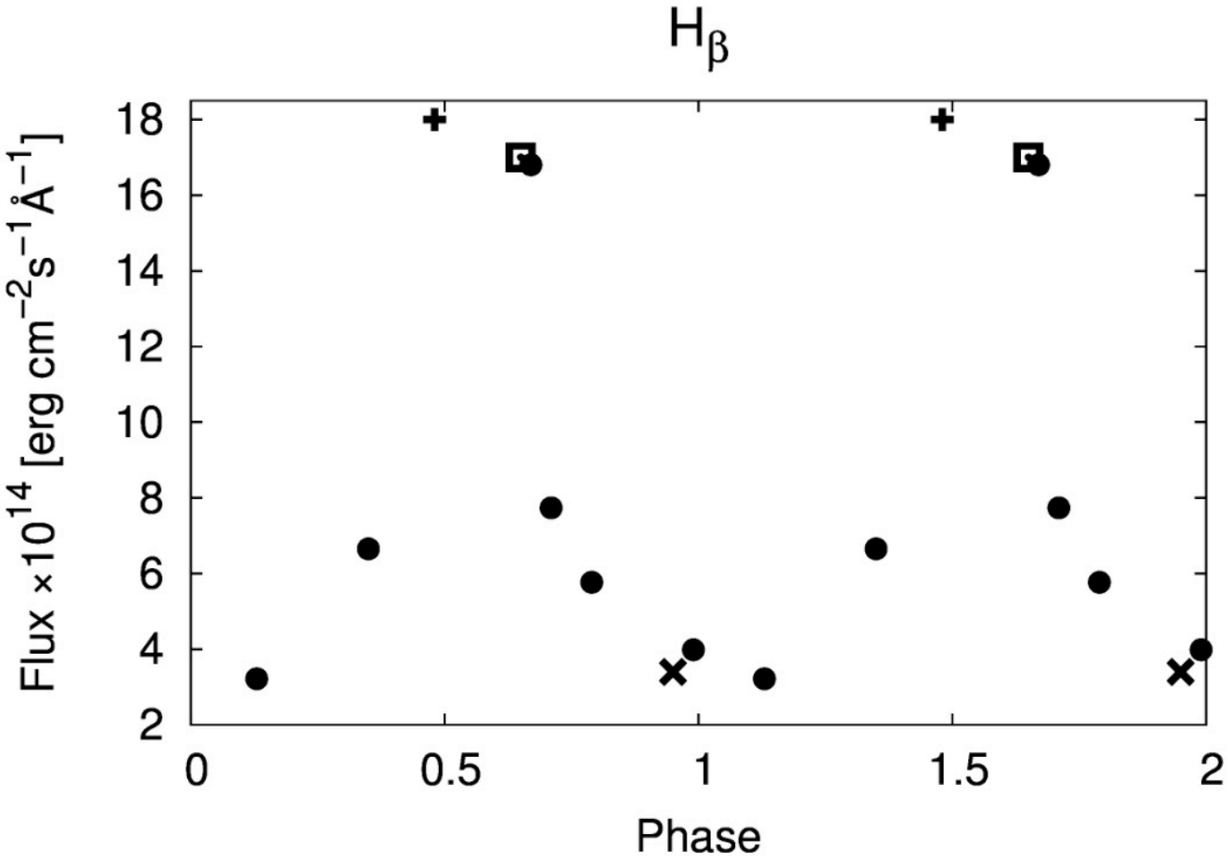
paper Ilkiewicz (Polish MSc student), Mikołajewska, Miszalski + to be submitted in 1-2 months



2012-2-RSA_POL-001

LMC S63





Refined ephemeris:
MJD,eclipse=(49861+/-14)+(1042.5+/-1.5) E
The old one P~1060 d (Mikolajewska 2004)
P~1020d due to R CrB-type phenomena
Gaposhkin (1970)

Thank You