Eruptive stars spectroscopy
Cataclysmics, Symbiotics, Novae, Supernovae

ARAS Eruptive Stars
Information letter n° 3 - 30-03-2014

News

Nova in Scorpius

Discovered by Koichi Nishiyama, Kurume,Japan and Fujio Kabashima, Miyaki,Japan 2014 Mar. 26.84867 UT (mag = 10.1)
http://www.cbat.eps.harvard.edu/unconf/followups/J17154683-3128303.html

Observed in X rays by SWIFT, consistent with an expending shell in a nova
http://www.astronomerstelegram.org/?read=6015

Confirmed as a nova, with a spectrum type He near maximum light, showing broad balmer and He lines by K. Ayani and S. Maeno, Bisei Astronomical Observatory (BAO), Ibara Okayama, Japan - 2014 03 27.8
http://www.bao.city.ibara.okayama.jp/astro/2014/nova/TCP_J17154683-3128303_Mar27.png

Coordinates (2000.0)	
R.A.	**20 54 23.75**
Dec.	**+60 17 06.9**

Contents

Aknowledgements : V band light curves from AAVSO photometric data base

ARAS Spectroscopy

ARAS Web page
http://www.astrosurf.com/aras/

ARAS Forum
http://www.spectro-aras.com/forum/

ARAS list
https://groups.yahoo.com/neo/groups/spectro-l/info

ARAS preliminary data base
http://www.astrosurf.com/aras/Aras_DataBase/DataBase.htm

ARAS BeAM
http://arasbeam.free.fr/?lang=en

Submit your spectra

Please :
- respect the procedure
- check your spectra BEFORE sending them

Resolution should be at least R = 500
For new transcients, supernovae and poorly observed objects, SA spectra at R = 100 are welcomed

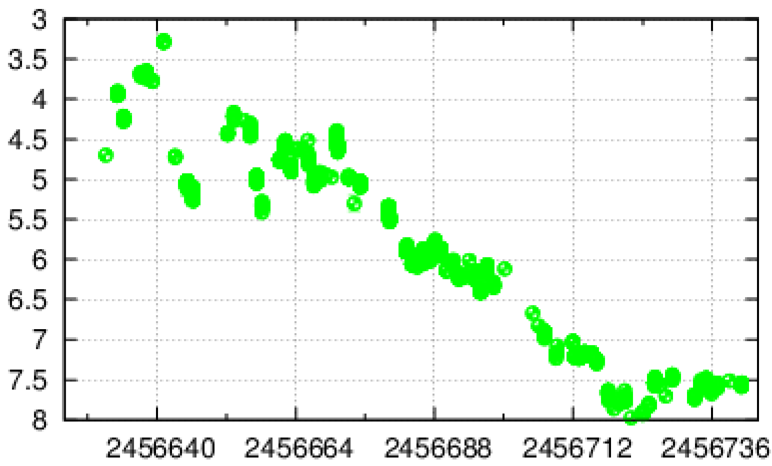
1/ reduce your data into BeSS file format
2/ name your file with: _novadel2013_yyyymmdd_hhh_Observer
novadel2013: name of the nova, fixed for this object
yyyy: year
mm: month
dd: day
hhh: fraction of the day, beginning of the observation
Observer: your pseudo/name
Exemple: _chcyg_20130802_886_toto.fit

3/ send you spectra to
Novae Symbiotics : François Teyssier
Supernovae : Christian Buil
to be included in the ARAS database

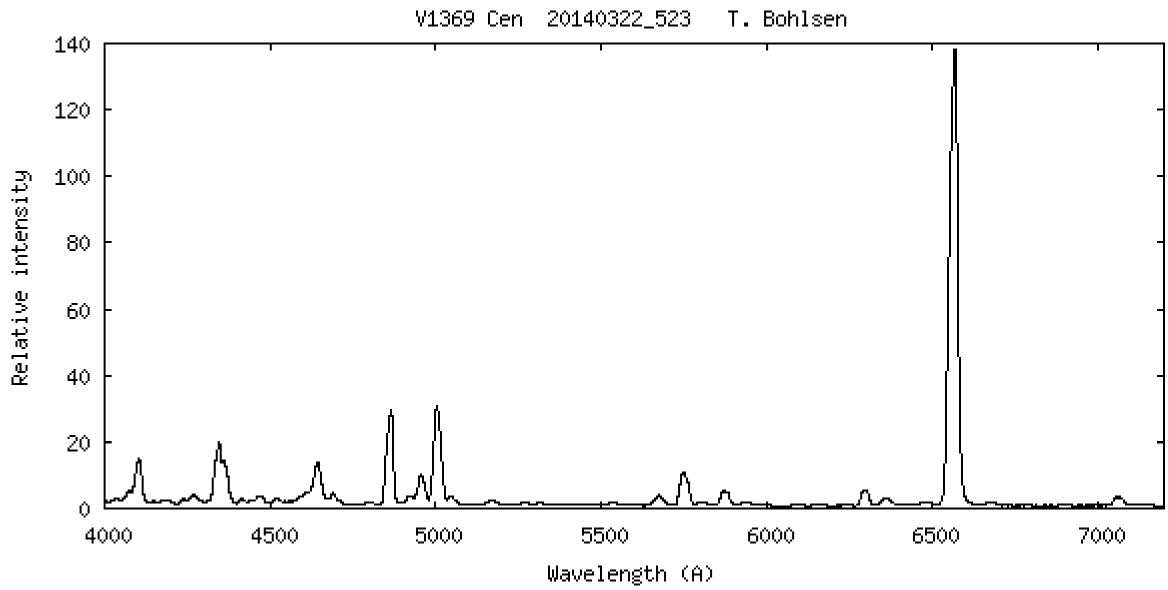
NOVAE

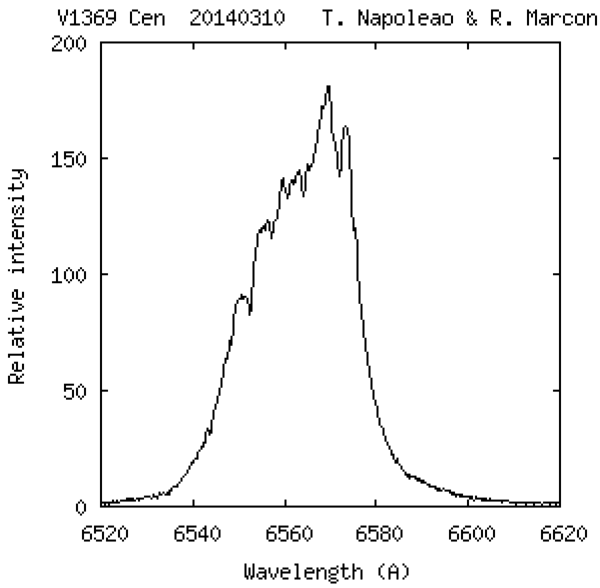
Nova Cen 2013 = V1369 Cen

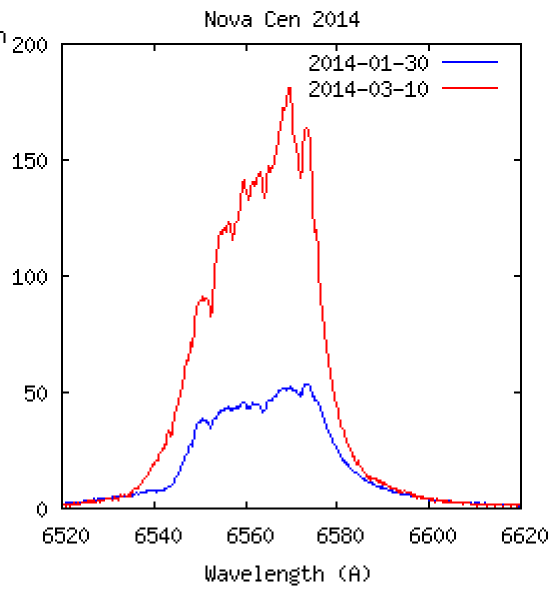
Luminosity
Mag V = 7.5 (24-03-2014)
Rebrighning a mag 7.5 after a minimum at 8.0 (05-03-2014) and now plateau phase about 4 mag under maximum



Observing
New spectra from Terry Bohlsen
(17, 18, 22/03)and Ha profile by Tasso Napoleo







Observers
Terry Bohlsen
Malcom Locke
Jonathan Powles
Ken Harrison
Julian West
Tasso Napoleao
Rogerio Marcon

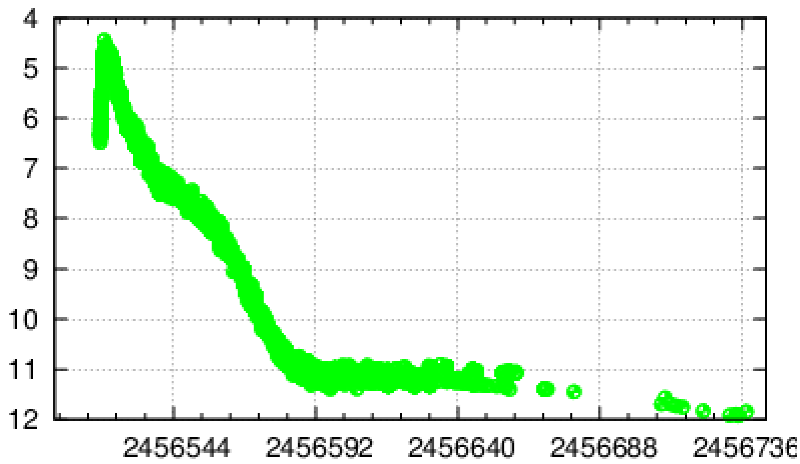
ARAS DATA BASE : 96 spectra
http://www.astrosurf.com/aras/Aras_DataBase/Novae/Nova-Cen-2013.htm

N O V A E

Nova Del 2013 = V339 Del

Luminosity
Mag V = 11.85 (20-03-2014)

Observing :
Spectra required
One spectrum a week required



Observers (2014)
C. Buil
F. Teyssier

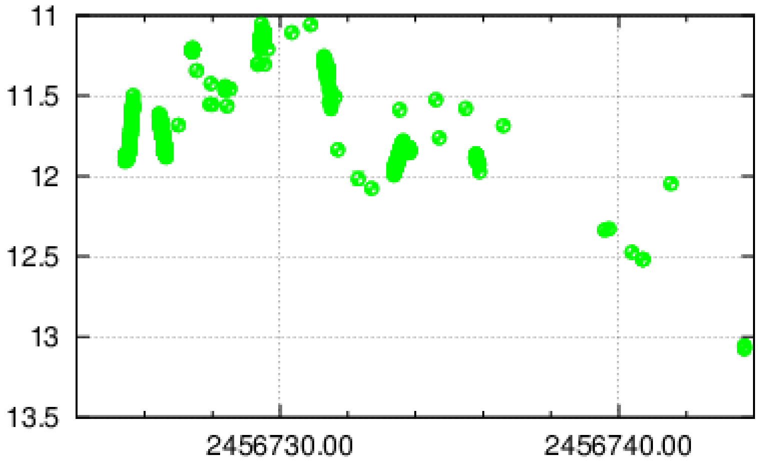
ARAS DATA BASE | 5 spectra| http://www.astrosurf.com/aras/Aras_DataBase/Novae/Nova-Del-2013_2.htm
ARAS Web Page for Nova Del 2013 : http://www.astrosurf.com/aras/novae/Nova2013Del.html

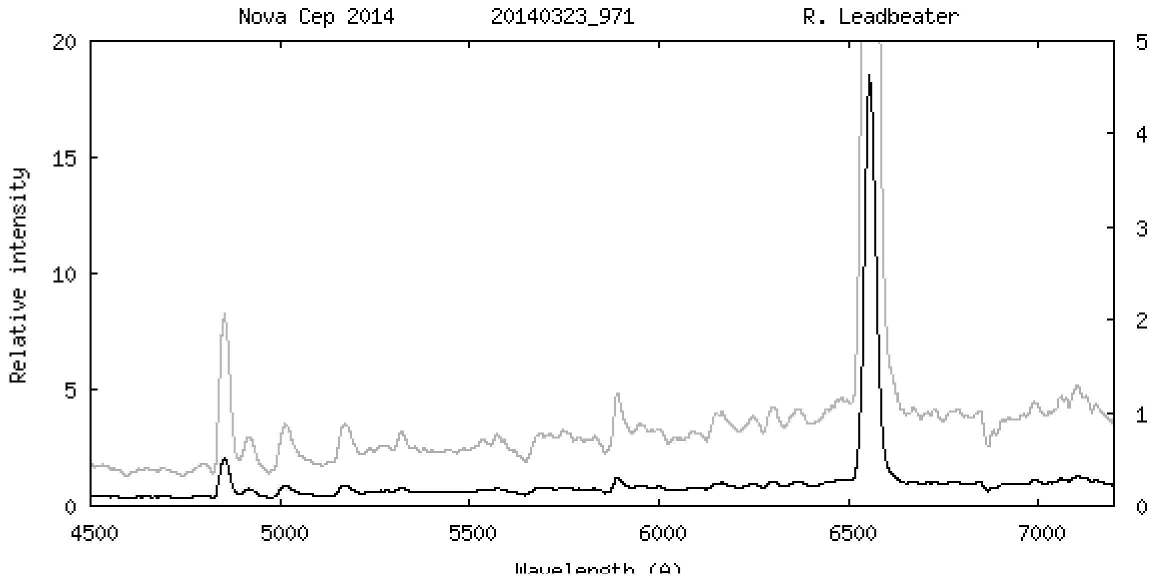
NOVAE

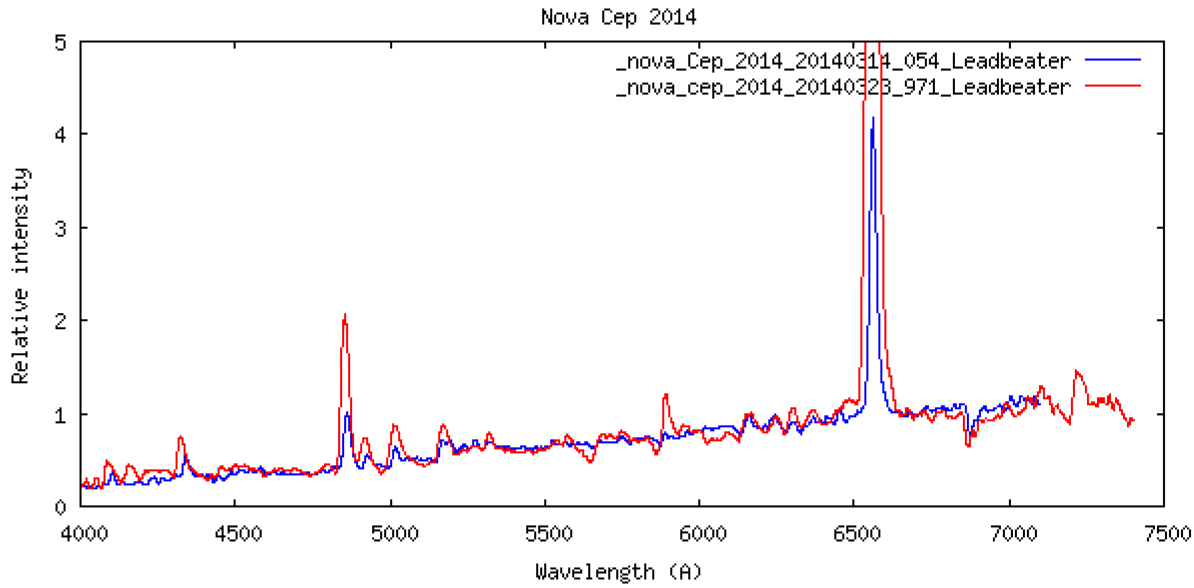
Nova Cep 2014 = TCP J20542386+6017077

Coordinates (2000.0)	
R.A.	**20 54 23.75**
Dec.	**+60 17 06.9**

Luminosity
Mag V ~ 13 (28-03-2014)
T2 ~ 24 days







Comparison of 14 and 23th, march spectra
The continuum reamains red, slope unchanged. Increasing intensities of the emission lines relative to continuum. Note [OI] 6300, 6363 and Na I D lines

Observers
C. Buil
R. Leadbeater

ARAS DATA BASE | 5 spectra| http://www.astrosurf.com/aras/Aras_DataBase/Novae/Nova-Cep-2014.htm

It's been a long silence, for which I apologize to all -- this has been a pretty intense period for us all with too many novae at once (if that's possible). So let me update the situation and explain some of what is now happening.

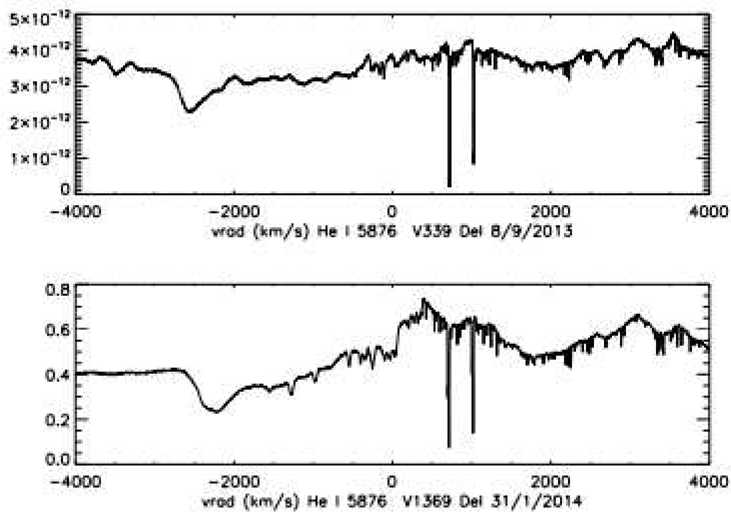
V745 Sco

As discussed earlier, the recurrent nova V745 Sco was a shortlived event although it continues to be observable in XRs with {\it Swift}. The low level emission is only at energies about several keV, indicating that the shock is still with us but that the optical emission is well below the level of the red giant spectrum and unobservable. During the first roughly two weeks of the outburst the high ionization lines never developed broad wings, although they showed some acceleration (especially [Fe X] 6374 Å). There are still spectra coming from CHIRON (Fred Walter's observations) but the NOT specta show that the highest ionization never displayed the V407 Cyg sequence of post-shock broadening. In other words, the ejecta in this symbiotic-like recurrent nova seem to have undergone breakout quite quickly relative to the more extended traverse of the companion's wind in V407 Cyg. The V745 Sco event resembles RS Oph, except for the quicker soft XR turnoff (which might be a signal of a more massive WD, we don't know), where the system and wind are more compact that the very extended environment of V407 Cyg. In th next set of notes I'll try to go into more detail about this subclass. For now, one comment. In these novae we see what is likely a fast forward of the symbiotic nova vent. Whether explosive (like these) or impulsive (as in Z And or AG Dra or CH Cyg) the ejecta from the WD environment is structured by its passage through the wind and only the relative total energy seems to make a difference in the phenomenology. In the symbiotics there isn't enough kinetic energy,. or perhaps simply a lower shock velocity, to produce detectable γ-ray emission (for V745 Sco and RS Oph this was about 4000-5000 $km.s^{-1}$, for the symbotics with bipolar ejections this is a factor of 4-5 lower). Otherwise much of the behavior is the same, especially the high ionization lines.

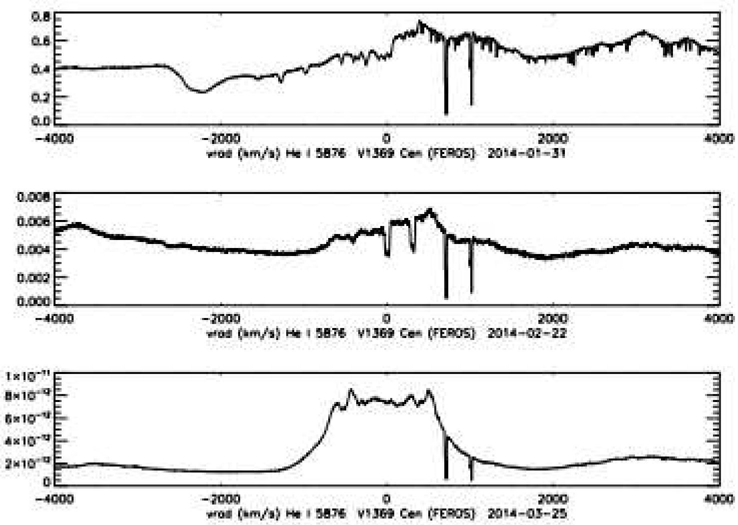
V339 Del

The nova re-emerged from solar obscuration more than one month ago and immediately posed a puzzle: the soft X-ray source that has dominated the previous months before the end of the year 2013 was gone. In early Jan., the He I spectrum was well developed with the lines extending to about -1500 $km.s^{-1}$ (spectra from Martin Dubs) with similar profiles to the Balmer series (nearly flat-topped and symmetric). This is in striking contrast to the forbidden transitions, especially [N II] 5755 Å and the [O III] lines (4363, 4959, 5007 Å) that are more intense in the approaching side of the line (-1500 to -500 $km.s^{-1}$. The forbidden lines, those of the higher ionization species tan H I, are also broader. But this was stil when the X-rays were being strongly emitted. The current energy distribution is mainly detected, however weakly, above about 1 keV. To explain what this means, consider the post-explosion sate of the WD. There remains a thin shell, below the photosphere (buried within the envelope) that continues to burn until the accreted hydrogen has exhausted. The mixing continues but rather weakly, porting matter from the WD envelope and providing catalysts for the CNO cycle. The presence of a source, illuminating the envelope in XRs, at a temperature of several 10^5 K implies to important characteristics of the WD: it's massive and has a relatively long thermal timescale, and there remains a portion of the accreted layer that both screens the burning zone from view and responds structurally to the shell source. This thin layer, whose properties have been a bone of contention for a decade, must be H-rich and the only source for that matter is the accreted -- but not completely expelled -- stuff from the companion. But whether this is purely relic from the pre-explosion stage or is being supplied again by accretion disk deposition from the now regenerated flow from the red companion, is the main problem. How a burning zone would behave in the presence of a re-established accretion disk and its attendant boundary layer, where the inner disk joins onto the WD, is a fundamental unknown in the picture. In effect, what you are seeing now is another venture into new territory: many old novae are known and some have been followed into quiescence but here we have a range of bolometric (luminosity) and thermal probes in the combination of the UV and optical along with the XRs. The turn-off of the soft XRs, with the consequent cooing of the WD, depends on its mass and a rapid timescale is usually taken to mean that most of the accreted material is blown off in the ejecta and the remaining stuff is an excess, increasing the mass of the degenerate. Again, since there is a strict upper mass limit to a star with the pressure-density law (called the equation of state) of an electron degenerate gas, any increase in mass pushes the WD progressively closer to its stability limit and *it may* induce collapse to form a supernova and neutron star. The latter is possible because at nuclear densities (around 10^{14} $g.cm^{-3}$) the particle interactions produce a repulsive force when the nucleons -- protons and neutrons -- are very closely packed that makes a neutron star stiffer than an electron degenerate star. The maximum mass of the WD is about 1.4 M⊙ while that of a neutron star is close to 2 M⊙. This has been one of the reasons for the continued interest in the high energy and cosmology communities in novae: they are one of the inevitable avenues to SN Ia *if the mass keeps increasing despite induced explosions*. We simply don't know and, irrespective of the other beautiful ensemble of physical processes we see in these systems, their ultimate fate is still an open question. Having now the indication that their ejecta are neither densely filled nor spherical, the detailed dynamics of the explosion make a big difference in how much mass is actually processed and expelled and how much remains to continue burning. The length, then, of this *supersoft source* (SSS) stage becomes the one unambiguous measure of the amount of hydrogen remaining. You see that once the nuclear shell ignites, and rapidly turns turbulent (this is not a process that continues in the ejecta where all motions are frozen out by the supersonic expansion) the remaining hydrogen is completely redistributed by the random motions of the convection on timescales of a few kiloseconds, even longer than the nuclear decay time of the out-of-equilibrium abundances of the β-unstable nuclei (about a few hundred seconds).

With the cessation of the SSS, the ejecta once again recombine. But since they are differentially expanding and the density drops precipitously, as an inverse power of the time (as t^{-3} for ballistic motion) this recombination is throttled and the ionization freezes-out. This is the stage we're now in. From here on, the rate of change of the spectrum should be quite slow so cadences of a month or even longer will be quite enough and very useful. Since the ejecta are nearly optically thin throughout, and near the densities at which the forbidden lines become unique density tracers and the temperature slowly decreases, the geometry is completely revealed by the line profiles. I say *nearly* because the differences in the species' profiles, still evident from the Balmer to He I to forbidden line comparisons, suggests that there are still rather dense knots within the ejecta that dominate the H I line formation throughout.



He I 5876Å in V339 Del (top, NOT) and V1369 Cen (bottom, FEROS at almost the same time in their outburst. The start dates were 14/8/13 and 5/12/13, respectively. Both show the detached, shortlives He I absorption feature on all of the triplets (and also He I 6678Å , the one strong singlet).

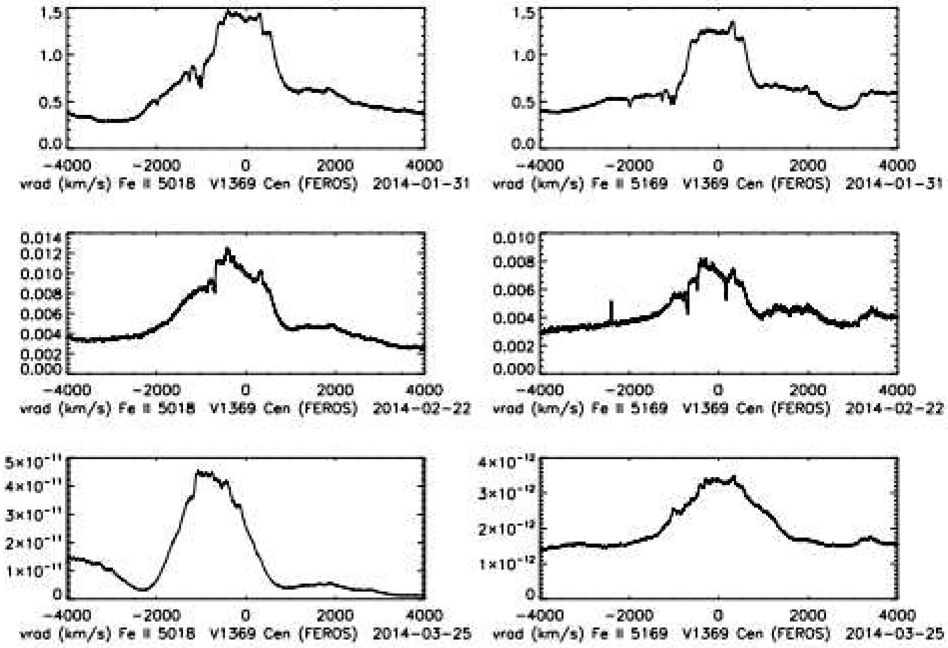


He I 5876Å and Na I 5889, 5895Å in V1369 Cen showing the three different forms of the profile (note, in the second spectrum, the strong absorption lines (detached) from the Na I D1,D2 lines in the ejecta. By now this should look familiar!

For you in the southern hemisphere, V1369 Cen has been a gift and your spectra have been the kind o coverage this needs. This nova, even brighter than V339 Del, has posed a serious problem for UV observations since it's still dangerously bright for the UV instruments (the MAMA detectors are very sensitive, like extremely delicate photomultipliers, and can actually be damaged in a way that reduces their lifetimes if overexposed). For now, the only information we have about what's happening at higher energies is from interpreting specific phenomena in the optical spectra. An example is this post-fireball He I spectral sequence. This is the same thing that T Pyx showed, and at later times was seen on the excited state lines of C III], N IV], and O V] in the UV shortward of 2400 Å . It's an effect of the overpopulation of the lower state of the transition, which in this case means the He I lines in the far UV are still very optically thick. This absorption stage lasts only for a short time, in the transition between the Na I and He I-dominated stages of the region around 5900 Å . The similarity of the Balmer lines, and the increase in the violet emission in all profiles, also indicates that we're now approaching the thinning out of the Fe curtain. But the XR emission is still very weak, so this is happening rather slowly and with halts in the light curve, as Francois' notes show. There is still Fe II 4923, 5169 emission but it appears that, like V339 Del, the 5018 line has been replaced by N II around 5003 Å . The [N II] 5755 and other forbidden lines have appeared so there is sone ionized, low density gas at large velocity, and the profiles are different than the permitted lines so we will have a density structure soon for the ejecta.

The Fe II lines, and other permitted transitions, remain very broad. So we still have a long ait to see how this nova will develop, but it resembles the V339 Del sequence almost exactly so as more of your spectra accumulate the differences -- and there certainly are many -- will become clearer. At this stage, the ejecta are obviously structures but this is mainly in a relatively high filling factor and, perhaps, a greater radial thickness (perhaps a $\Delta R/R$ of about 0.7. The importance of the detached feature on the He I lines is the information it provides about the maximum radial velocity of the ejecta, it confirms what comes from the Balmer lines and will be essential in interpreting the interferometry that may be obtained for this nova. You may recall that V339 Del was imaged with CHARA, a northern hemisphere optical interferometer, within the first week. V1369 Cen is certainly close, likely closer than V339 Del, and this may even be visible as a resolved ejecta with ALMA when it's optically thin in radio. Now it is still (I think) thick.

What to expect is that the same stages we watched with V339 Del should occur here. The recombination is now over, the ejecta are marginally thin (making the transition to the nebular stage) and the profiles of the forbidden lines are *almost* indicating a uniform electron density and temperature in the line forming region. I say almost because the [O III] lines (4363, 4959, 5007 Å) don't quite have the same profiles and there isn't enough resolved emission at the [N II] 6548, 6583 Å lines to yet compare with [N II] 5755 Å . The [O I] 5577 Å line is now gone and no very high ionization lines, e.g. [Fe VII], have yet appeared (consistent with the still low count rate from Swift).



Fe II 5018Å (left), 5169Å (right) for three dates for V1369 Cen. Compare the structure of the Fe II 5169Å line with the He I 5876Å profiles above.

More will be coming and, always, thanks so much!

One last comment, since Ken Harrison asked about this. The first paper summarizing the γ-ray characteristics of the classical novae with the {\it Fermi} Large Aperture Telescope (LAT) has been submitted to Science this week. We don't know its fate but it has, as co-authors- some of your companions in arms in the ARAS group. As we assemble the papers for these individual novae, and continue the legacy program, your contributions will be increasingly needed and noted. There will be a talk at the proposed special session on the nova outburst, proposed for the IAU General Assembly in Hawaii next year, and the NASA press office has been notified to contact members of the non-professional community for further information.

Steve's notes download

First part

http://www.astrosurf.com/aras/novae/Images_NovaDel2013/SteveNotes.pdf

Second part

http://www.astrosurf.com/aras/novae/Documents/NotesSteve_II.PDF

V339 Del

http://www.astrosurf.com/aras/novae/Nova2013Del.html

Selected list of bright symbiotics stars of interest

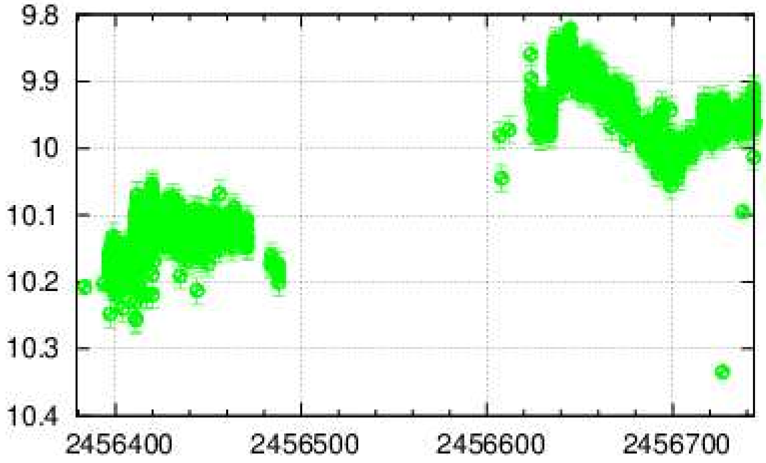
Target						Refrence Star					
#	Name	AD (2000)	DE (2000)	Mag V *	Interest	Name	AD (2000)	DE (2000)	Mag V	E(B-V)	Sp Type
1	AX Per	1 36 22.7	54 15 2.5	11.6	++	HD 6961	01 11 06.2	+ 55 08 59.6	4.33	0	A7V
2	UV Aur	5 21 48.8	32 30 43.1	10		HD 39357	05 53 19.6	+ 27 36 44.1	4.557		A0V
3	ZZ CMi	7 24 13.9	8 53 51.7	10.2		HD 61887	07 41 35.2	+ 03 37 29.2	5.955		A0V
4	BX Mon	7 25 24	-3 36 0	10.4	+	HD 55185	07 11 51.9	- 00 29 34.0	4.15		A2V
5	V694 Mon	7 25 51.2	-7 44 8	10.5	++	HD 55185	07 11 51.9	- 00 29 34.0	4.15		A2V
6	NQ Gem	7 31 54.5	24 30 12.5	8.2		HD 64145	07 53 29.8	+ 26 45 56.8	4.977		A3V
7	T CrB	15 59 30.1	25 55 12.6	10.4	++	HD 143894	16 02 17.7	+ 22 48 16.0	4.817	0	A3V
8	AG Dra	16 1 40.5	66 48 9.5	9.7	++	HD 145454	16 06 19.7	+ 67 48 36.5	5.439	0	A0Vn
9	RS Oph	17 50 13.2	-6 42 28.4	10.4	++	HD 164577	18 01 45.2	+ 01 18 18.3	4.439	0	A2Vn
10	YY Her	18 14 34.3	20 59 20	12.9	++	HD 166014	18 07 32.6	+ 28 45 45.0	3.837	0.02	B9.5V
11	V443 Her	18 22 8.4	23 27 20	11.3	++	HD 171623	18 35 12.6	+ 18 12 12.3	5.79	0	A0Vn
12	BF Cyg	19 23 53.4	29 40 25.1	10.8	++	HD 180317	19 15 17.4	+ 21 13 55.6	5.654	0	A4V
13	CH Cyg	19 24 33	50 14 29.1	7	+	HD 184006	19 29 42.4	+ 51 43 47.2	3.769	0	A5V
14	CI Cyg	19 50 11.8	35 41 3.2	10.5	++	HD 187235	19 47 27.8	+ 38 24 27.4	5.826	0.02	B8Vn
15	StHA 190	21 41 44.8	2 43 54.4	10.3	+	HD 207203	21 47 14.0	+ 02 41 10.0	5.631	0	A1V
16	AG Peg	21 51 1.9	12 37 29.4	8.6	++	HD 208565	21 56 56.4	+ 12 04 35.4	5.544	0	A2Vnn
18	Z And	23 33 39.5	48 49 5.4	9.65	++	HD 222439	23 40 24.5	+ 44 20 02.2	4.137	0	A0V
19	R Aqr	23 43 49.4	-15 17 4.2	9.9	++	HD 222847	23 44 12.1	- 18 16 37.0	5.235	0	B9V

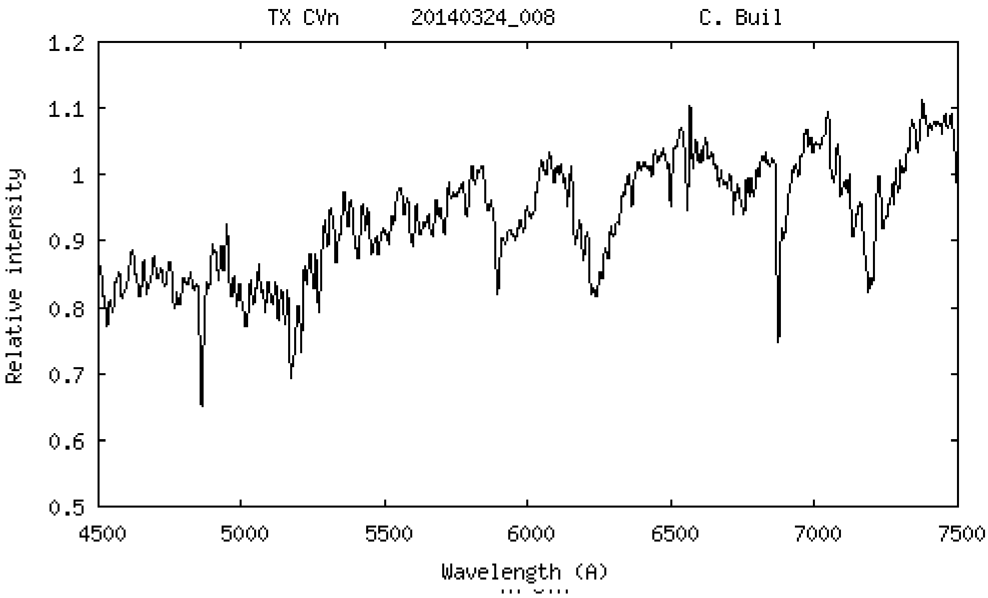
Mag V * : current value

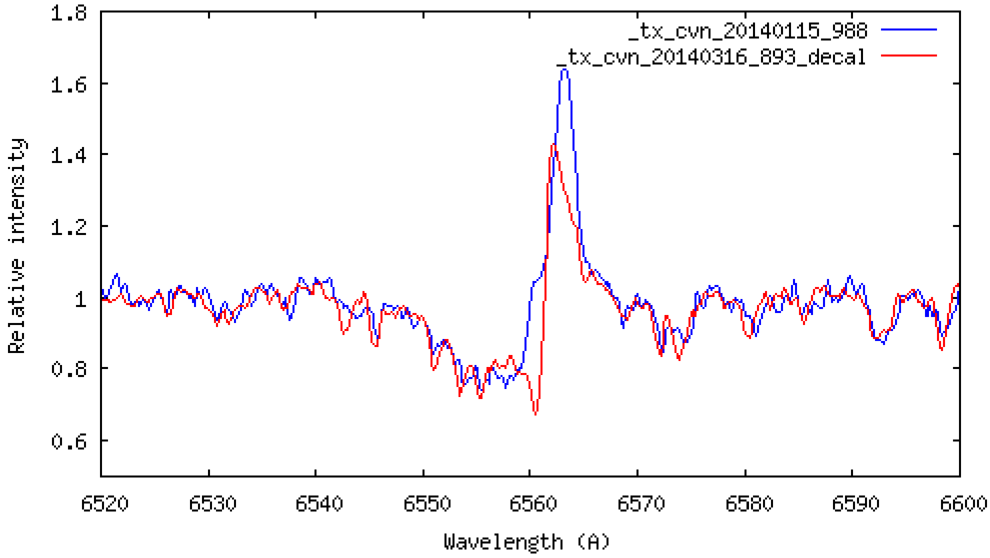
Symbiotics

TX CVn

New spectra from P. Berardi and C. Buil

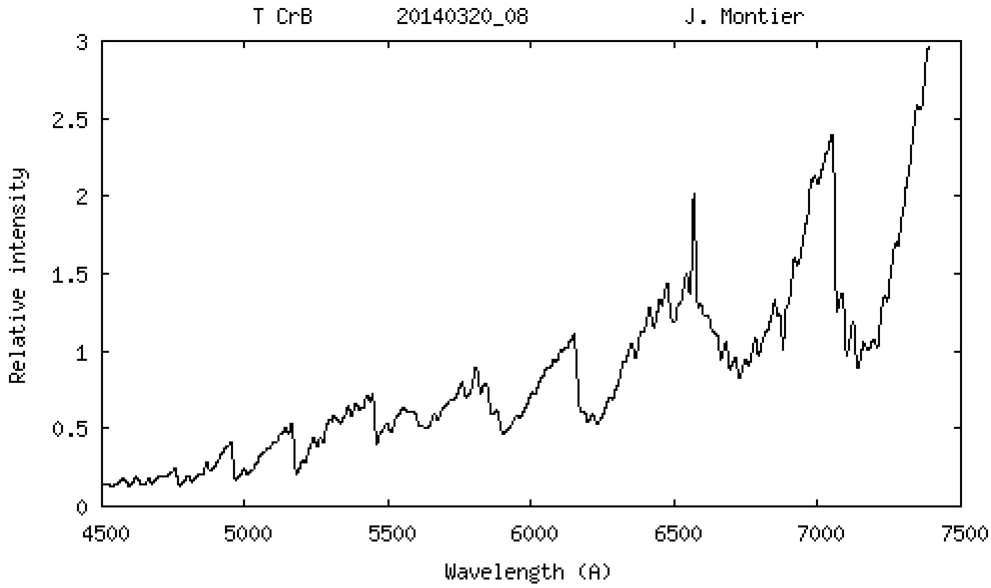


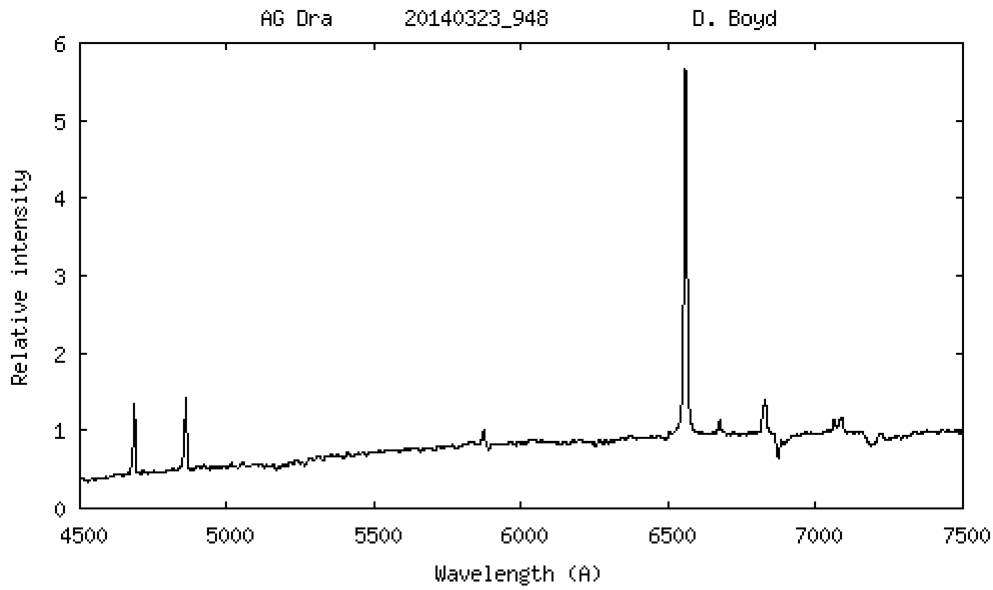




Comparison of H alpha profiles in medium resolution spectra by P. Berardi

T CrB, AG Dra recent spectra

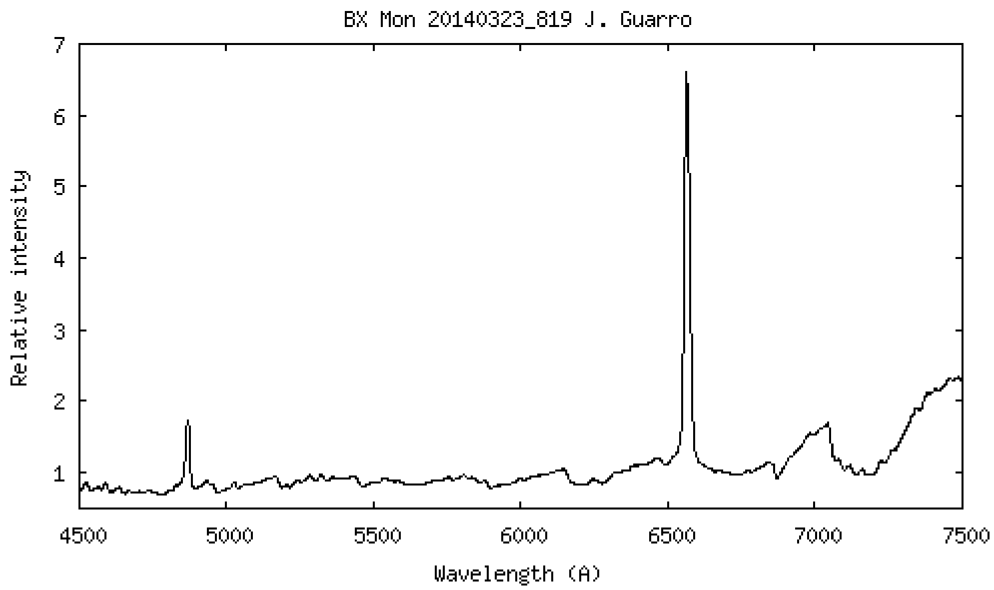


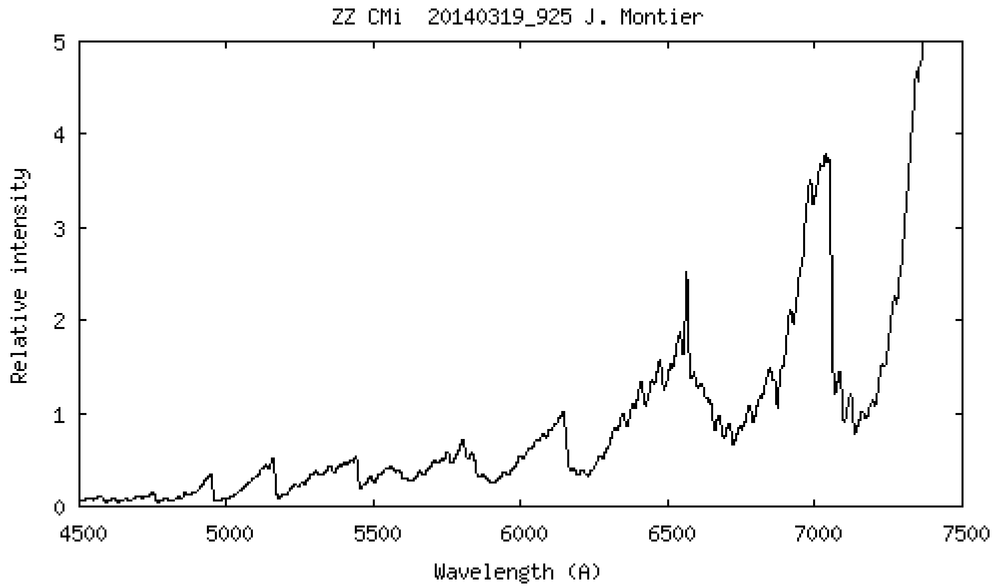


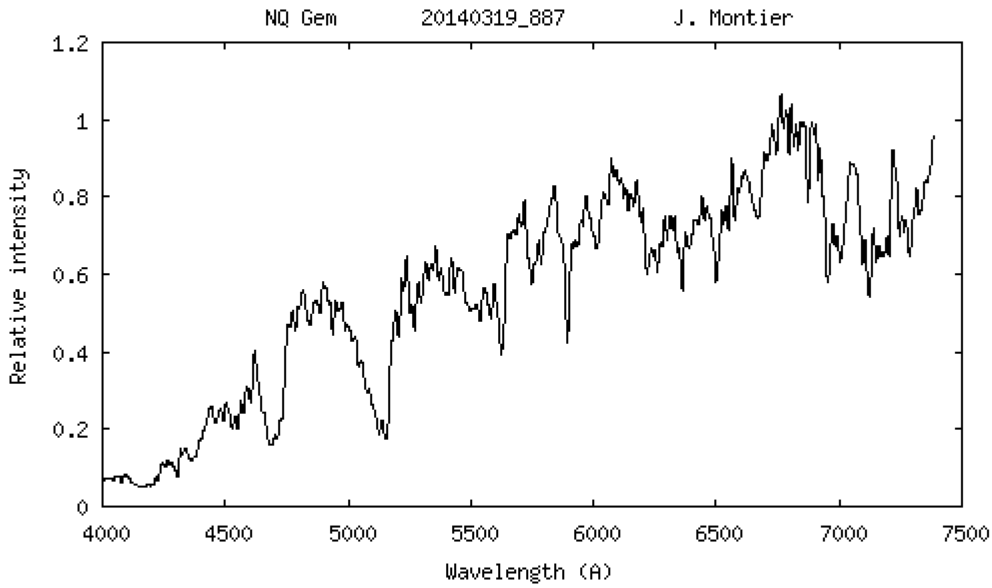
AG Dra is an S (stellar) type symbiotic binary containing a K giant as a cool component.
The giant in AG Dra is hotter than in most symbiotic binaries and possibly brighter than luminosity class III (Friedjung 1997; Zhu et al. 1999). There are contradictions in spectral classi?cation derived using di♂erent criteria, caused by metal underabundance. M¨urset & Schmid (1999) have adopted spectral class K2, while Zhu et al. (1999) restrict the possible range to K0–K3, luminosity class Ib or II. The range K4–K5 has been derived from the infrared colours (Kenyon 1988)
The surface temperature of the white dwarf companion has been estimated to be about 100 000 K (Friedjung 1997) or 120 000 K (Greiner et al. 1997; Schmid & Schild 1997). AG Dra is also classified as one of the few Galactic supersoft X-ray sources (Greiner et al. 1997 and references therein; Ogley et al. 2002)
AG Dra is one of the most active symbiotic stars. Its light curve shows many active phases separated by quiescent periods. The most prominent active phases consisting usually of several outbursts start at about 14–15 year intervals, e.g. In 1936, 1951, 1966, 1980, 1994. The mechanism of the outbursts is not yet clear...
In **Emission lines in the spectrum of the symbiotic star AG Draconis**
Leedjärv, L., Burmeister, M., Mikolajewski, M., Puss, A.; Annuk, K., Galan, C.
Astronomy and Astrophysics, v.415, p.273-282 (2004)
http://adsabs.harvard.edu/abs/2004A%26A...415..273L

See also :
The Long-Term Spectroscopic Misadventures of AG Dra with a Nod toward V407 Cyg: Degenerates Behaving Badly
Shore, S. N.; Genovali, K.; Wahlgren, G. M.
Baltic Astronomy, Vol. 21, p. 139-149

BX Mon, ZZ Cmi, NQ Gem recent spectra

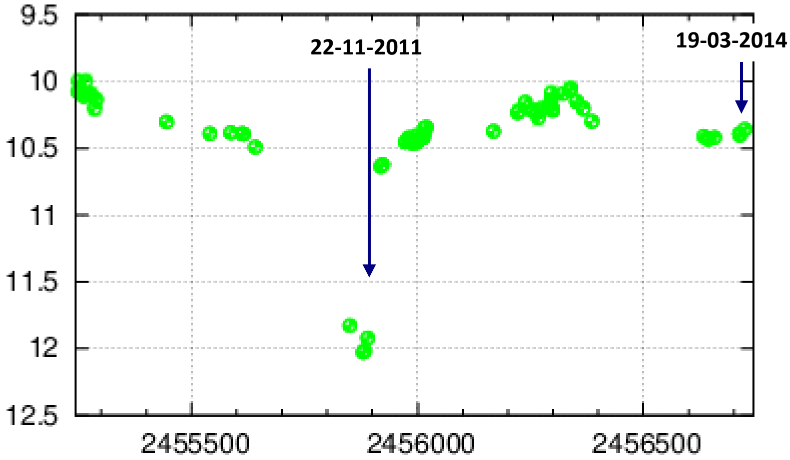






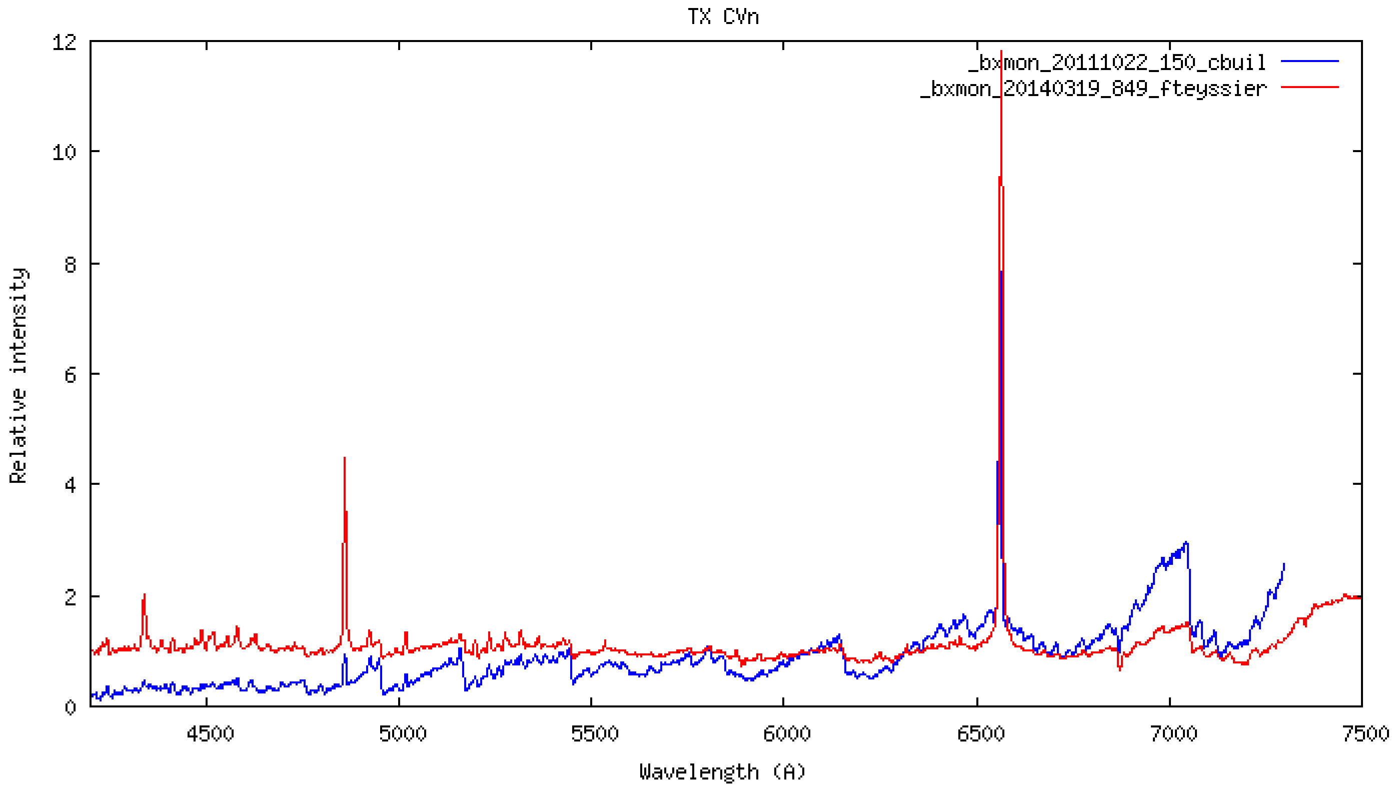
BX Mon

Comparison of BX Mon spectra in low state (22-11-2011) and high state (19-03-2014)



AAVSO light curve shows the short low state of BX Mon

BX Monocerotis is a S-type symbiotic star with a M5 III cool component (Murset & Schmid 1999). It is an eclipsing system with orbital parameters derived by various authors as: Porb = 1410 d (Dumm et al. 1998), 1259 d, (Fekel et al. 2000), 1290 d (Brandi et al. 2009) and 1256 d (Leibowitz & Formiggini 2011), and e = 0.49 (Dumm et al. 1998) and 0.44 (Fekel et al. 2000). Zamanov et al. (2007) and that the orbit is in a circularization process. The hot component has a mass of 0.6 M⊙ , a luminosity of 230 L⊙ and is most probably a shell flashed white dwarf.
G. C. Anupama & al., 2011
Baltic Astronomy, vol.21, 172–176, 2012



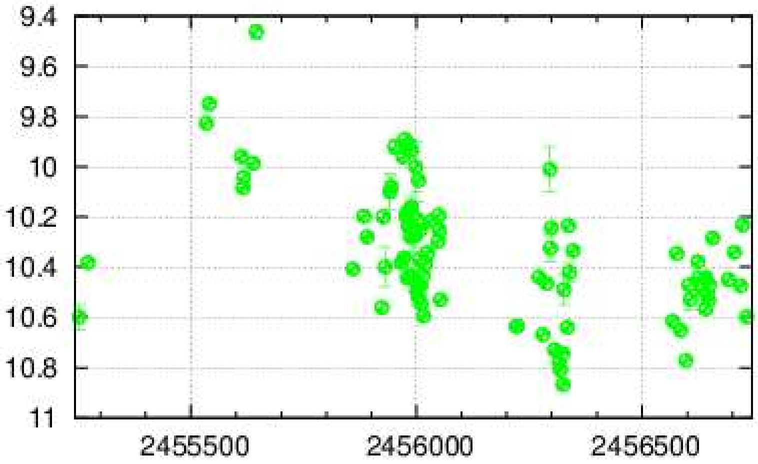
High resolution spectroscopy of symbiotic stars. IV. BX Monocerotis: orbital and stellar parameters
Dumm, T. & al., Astronomy and Astrophysics, v.336, p.637-647 (1998)

The symbiotic star BX Monocerotis
Viotti, R. & al., Astronomy and Astrophysics, vol. 159, no. 1-2, April 1986

BX MON as a long-period eclipsing binary system
Iijima, T., Astronomy and Astrophysics, vol. 153, no. 1, Dec. 1985, p. 35-43

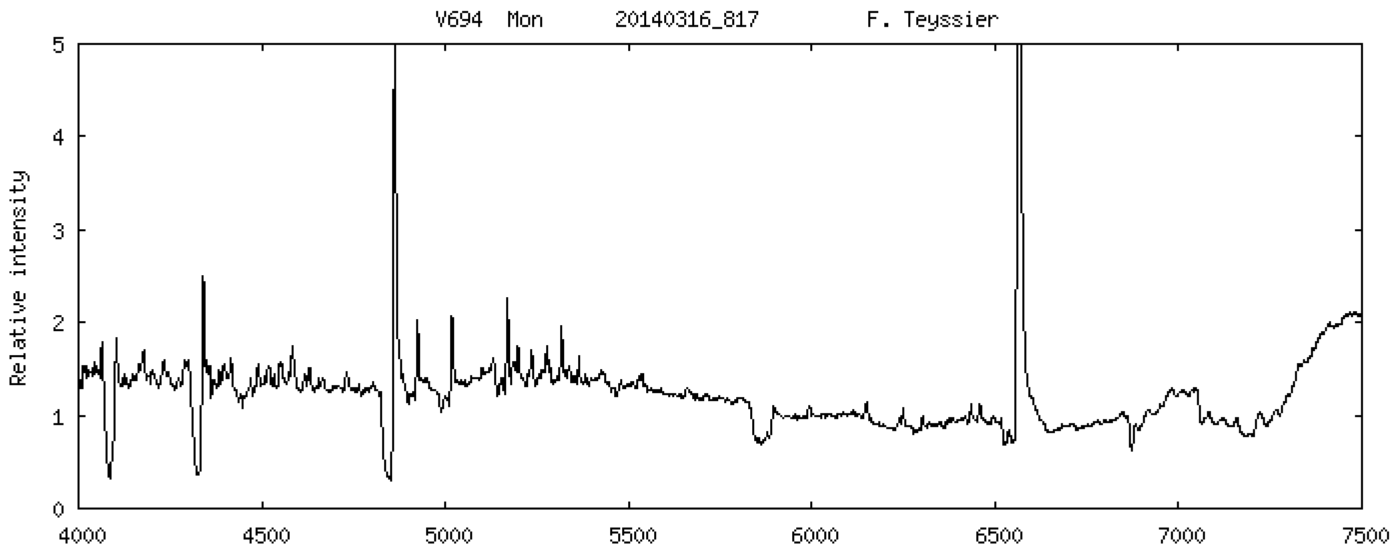
V694 Mon

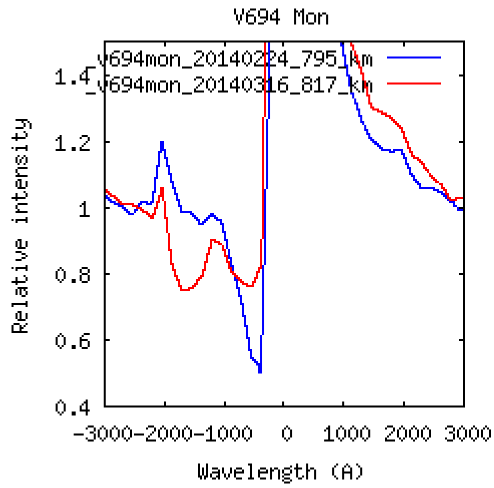
The peculiar object MWC 560 was discovered as an emission star by Merrill & Burwell (1943). It consists of a red giant and a white dwarf. Its orbital period, as estimated by Gromadzki et al. (2007), equals to Porb = 1931±162 days.
The spectrum of MWC 560 contains several emission lines of H I, Fe II, superimposed on the late-type continuum.
The most spectacular feature of the spectrum is the highly blue-shifted broad absorption components of the hydrogen lines.
During a stable state the absorption components show a maximum outflow speed of ~ 1580 – 2140 $km.s^{-1}$ and widths of 500 – 1400 $km.s^{-1}$
The first large outburst took place in 1989 – 1990, when the brightness of the object reached V =9.2 and the absorption components were shifted with up to – 6500 $km.s^{-1}$
Kondratyeva, L., Rspaev, F., IBVS 6032, 1, 2012

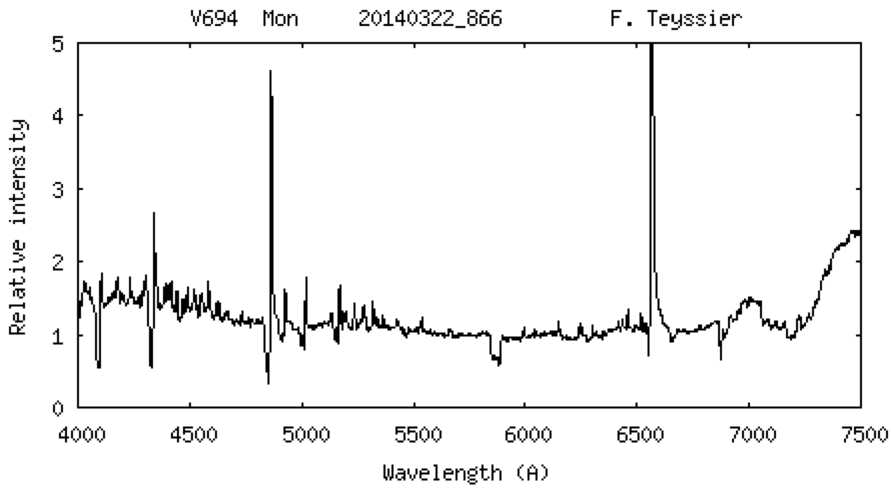


Faint activity in V694 Mon spectrum the 16-03-2014

The 16-03-2014, the absorption of H alpha (and Fe II 42 multiplet) shows a double peak. The outflow speed is about 2000 $km.s^{-1}$
In the spectra of march 22th and 24th the absorption component of Ha line turns up to its previous shape (1000 $km.s^{-1}$), but Fe II absorption remains double peaked

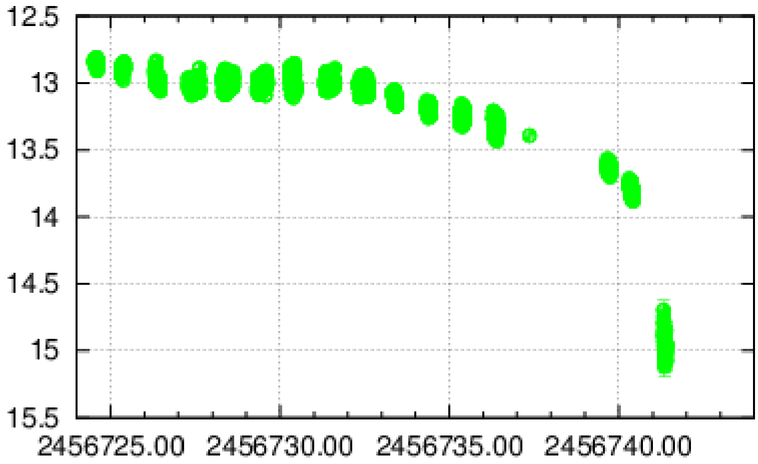


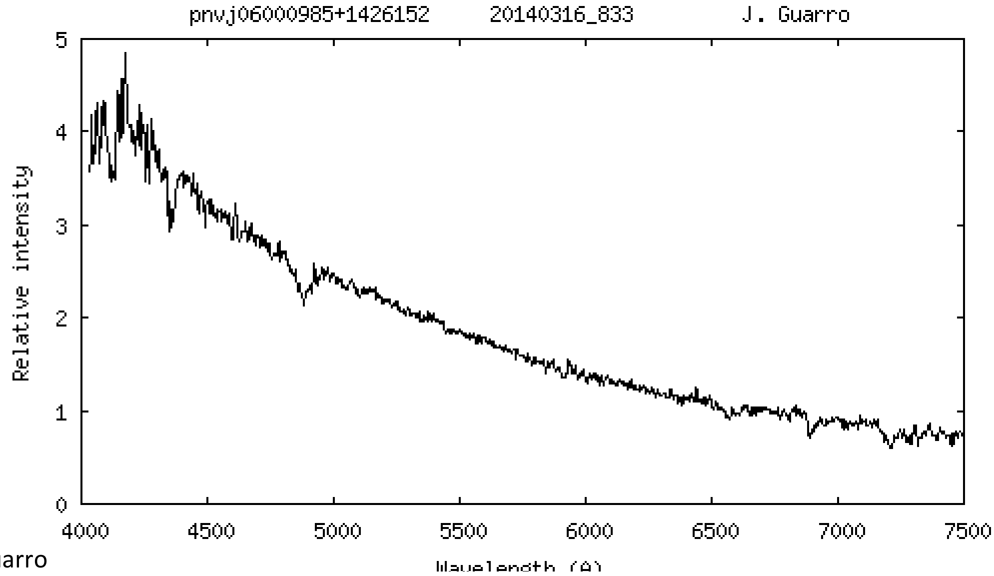




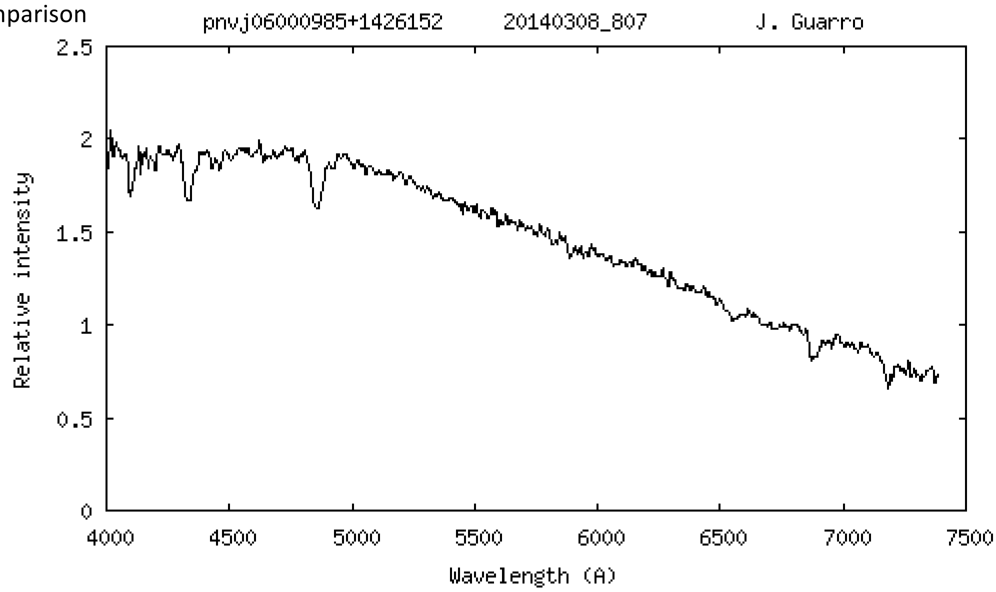
PNV J06000985+1426152

Superoutburst of a WZ Sge cataclysmic
PNV J06000985+1426152
http://www.cbat.eps.harvard.edu/unconf/followups/J06000985+1426152.html





PNV J06000985+1426152 by Joan Guarro
and spectrum of 08-03-2014 for comparison



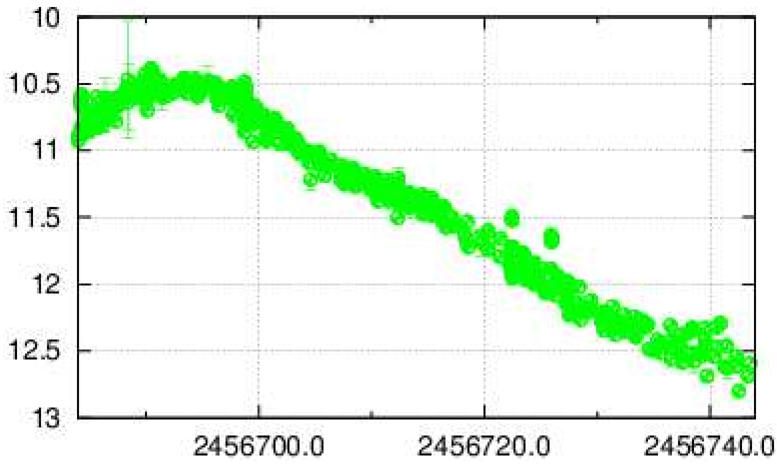
Supernova

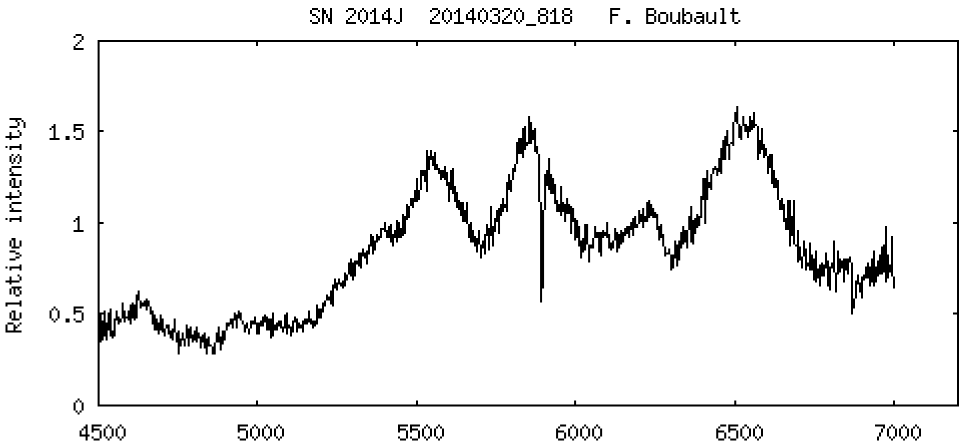
SN 2014J in M 82 Type Ia

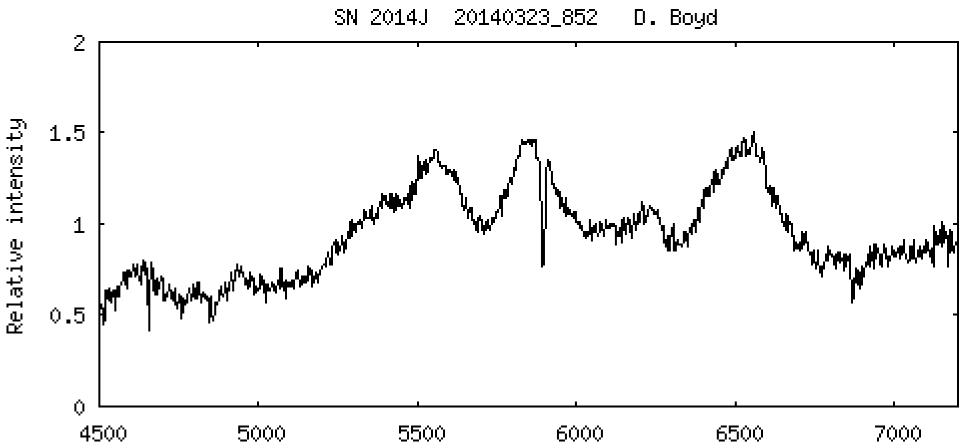
Luminosity
Mag V = 12.8 (28-03-2014)

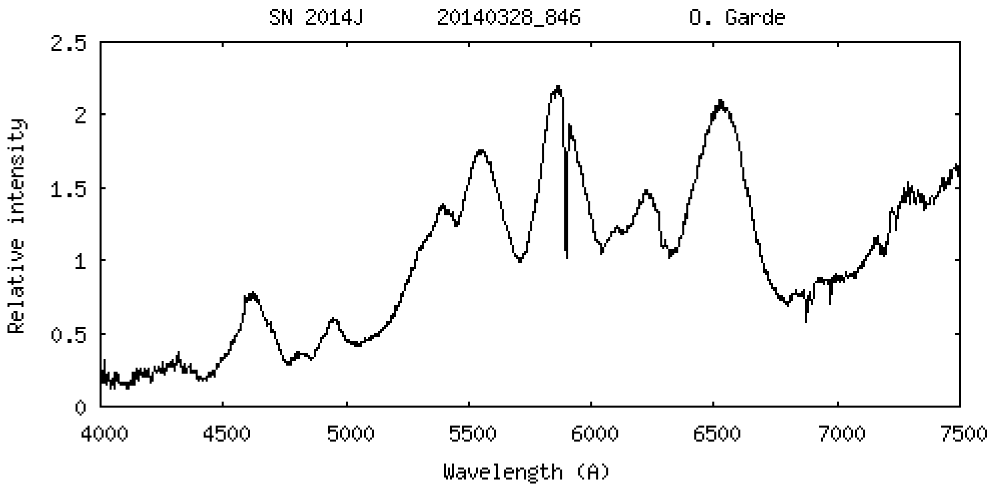
Observing

Ungoing campaign, more than 50 days after maximum luminosity
58 spectra in ARAS data base
New spectra from F. Boubault, D Boyd and C. Buil









ATEL #6018

Mid-IR Spectrum of Supernova SN 2014J in M82

http://www.astronomerstelegram.org/?read=6018

On behalf of the CanariCam Science Team, we report the measurement of the 8-13 micrometer spectrum of the Type Ia supernova 2014J using CanariCam at the 10.4-m Gran Telescopio CANARIAS (GTC). The total integration time was 2400 s (on-source, excluding overhead) starting at UT 2014 Mar 12.95.

The achieved spectral resolution is about 0.1 micrometer (3000 km/s). The high-quality spectrum shows what we interpret to be the [Ar III], [Co II]+[S IV], and [Co III] lines centered near 9.0, 10.5, and 11.9 micrometers,respectively. The peak flux density of the [Co III] line is about 60 mJy, with a FWHM about 0.5-0.6 micrometers (12000-13000 km/s)

Observers

- P. Berardi
- D. Boyd
- F. Boubault
- C. Buil
- P. Gerlach
- J. Guarro
- O. Garde
- A. Heidemann
- R. Leadbeater
- J. Montier

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Novae

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http://arxiv.org/pdf/1403.1579.pdf

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U. Munari, E. Mason, P. Valisa
http://arxiv.org/pdf/1403.3284.pdf

Study of three 2013 novae: V1830 Aql, V556 Ser and V809 Cep
U. Munari, P. Ochner, S. Dallaporta, P. Valisa, M. Graziani, G.L. Righetti, G. Cherini, F. Castellani, G. Cetrulo, A. Englaro
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Supernovae

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http://arxiv.org/pdf/1403.7089.pdf