

Novae

Analysis of the spectra

An example:

nova Per 2020 with strong oscillations at maximum luminosity

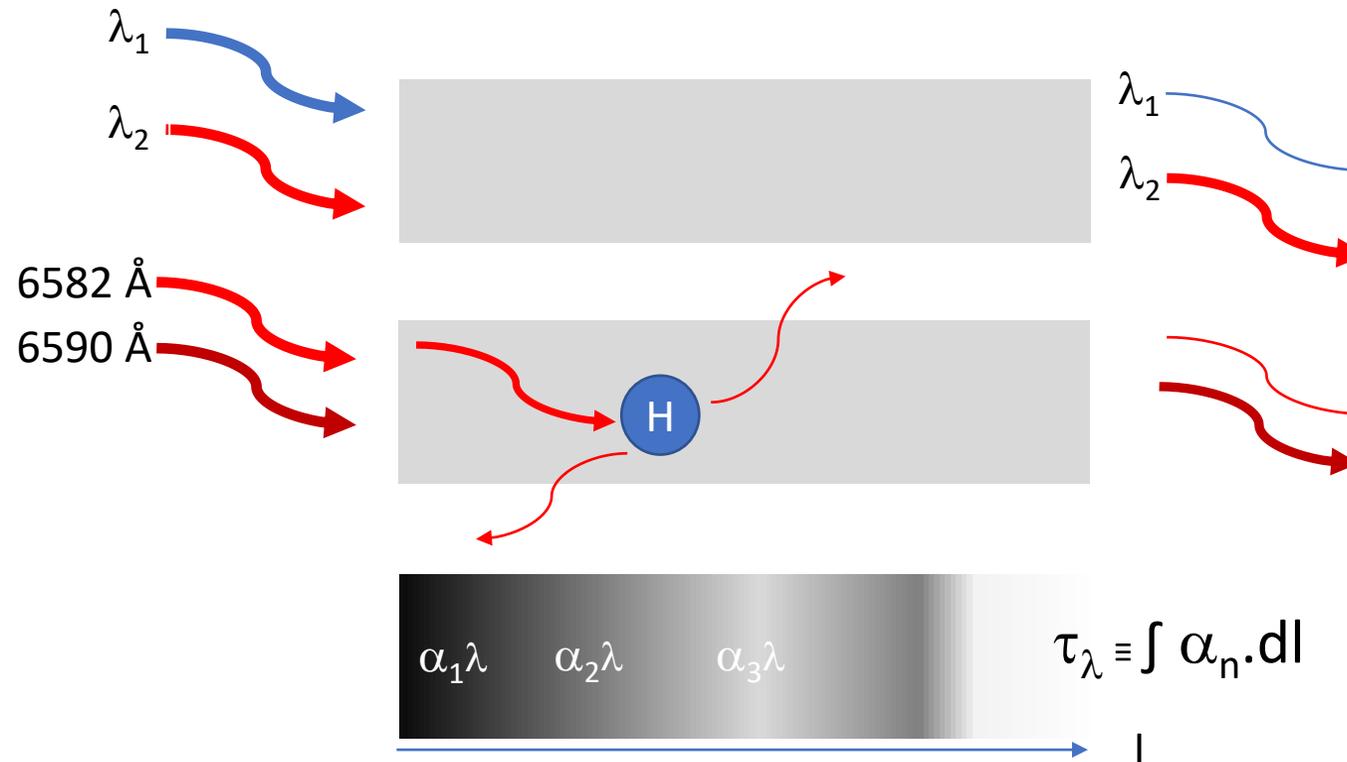
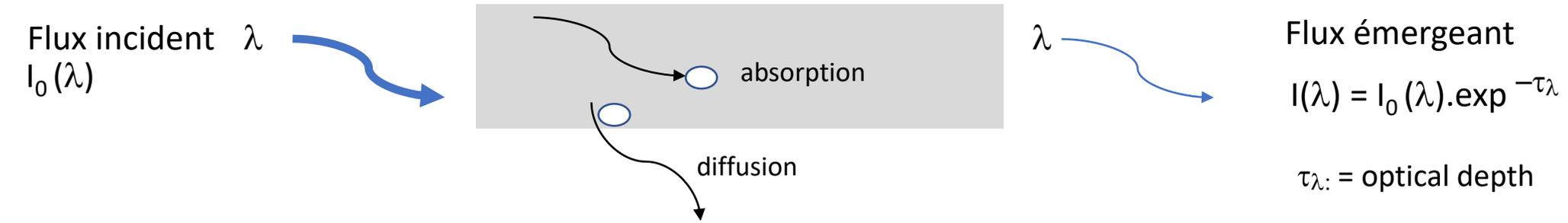
François Teyssier

ARAS group Eruptive stars
www.astronomie-amateur.fr

Shelyak Novae WorkShop
2020, January



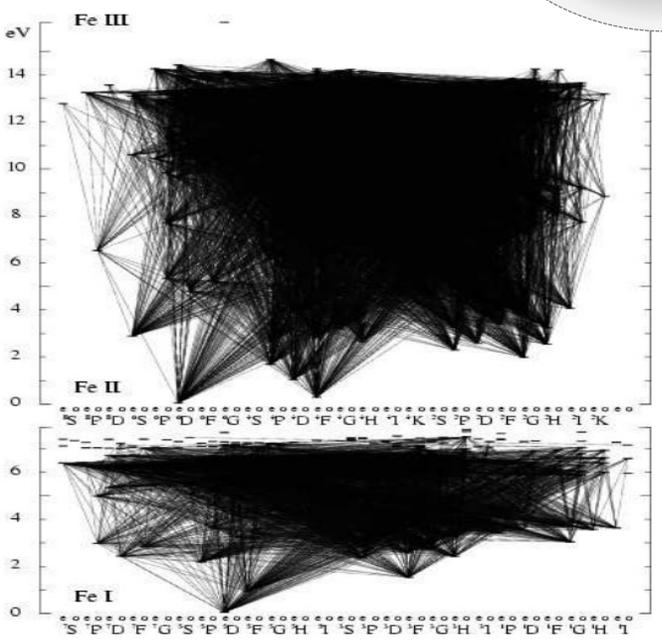
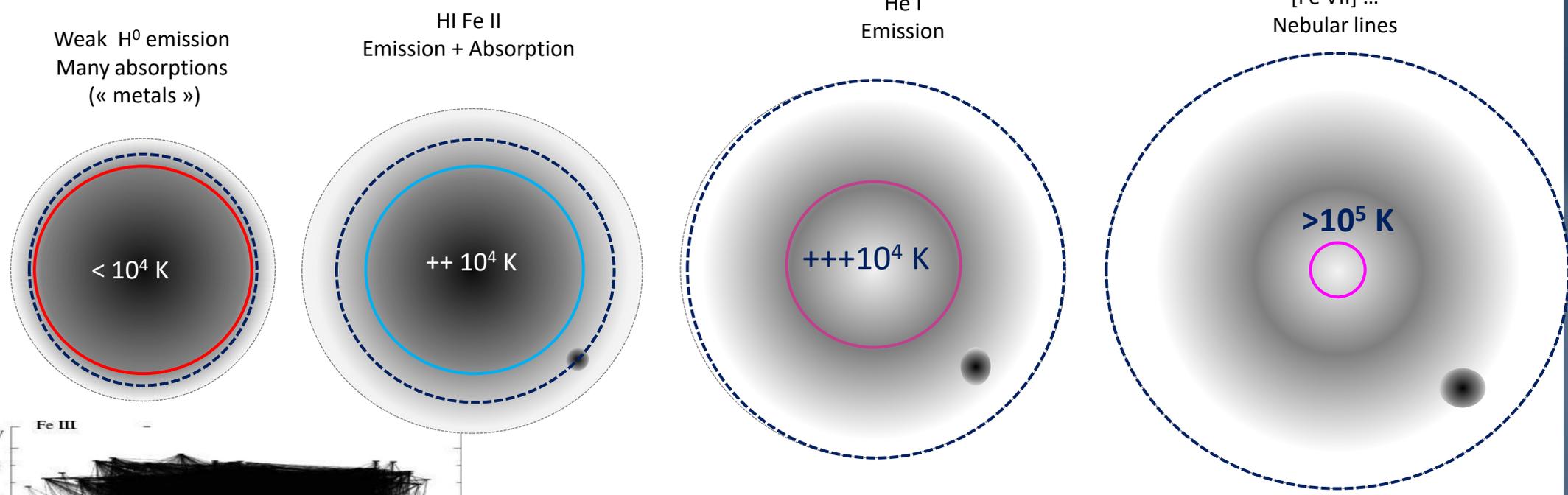
Opacity



$\tau \gg 1$

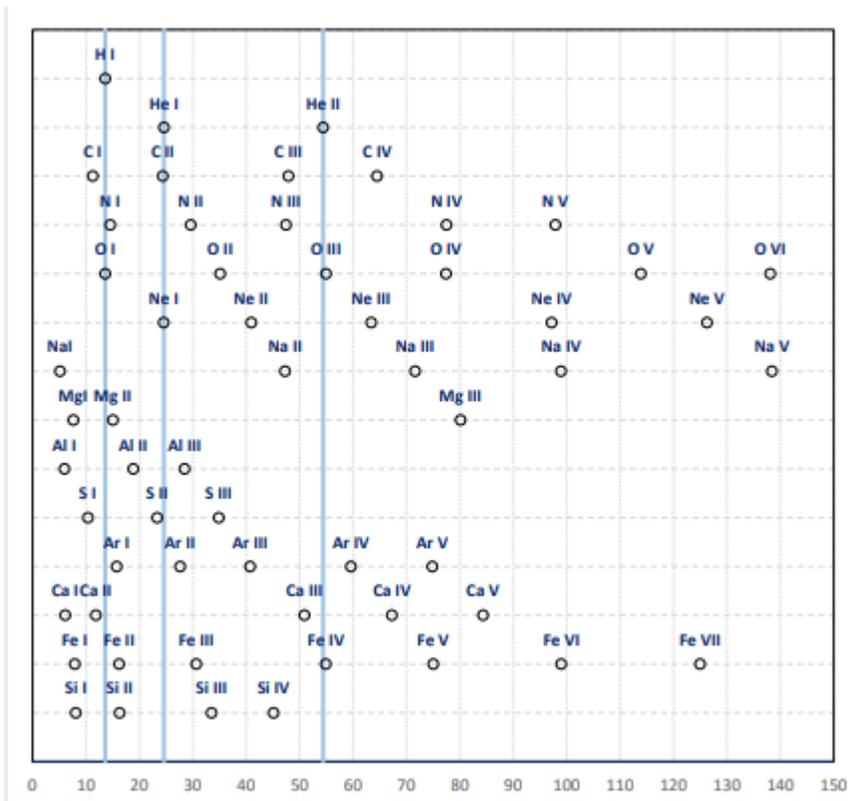
$\tau \ll 1$

Opacity



— « Photosphere » =pseudo-photosphere (τ_λ : factor 1 to 100)
 - - - Ionisation zone

Ionisation level



Ionization Energy (eV)

	0	+	2+	3+	4+	5+	6+
	I	II	III	IV	V	VI	VII
H	13.6						
He	24.6	54.4					
C	11.3	24.4	47.9	64.5			
N	14.5	29.6	47.4	77.5	97.9		
O	13.6	35.1	54.9	77.4	113.9	138.1	
Ne	24.6	41.0	63.4	97.2	126.2		
Na	5.1	47.3	71.6	98.9	138.4		
Mg	7.6	15.0	80.1				
Al	6.0	18.8	28.4				
S	10.4	23.3	34.9				
Ar	15.8	27.6	40.7	59.6	74.8		
Ca	6.1	11.9	50.9	67.3	84.3		
Fe	7.9	16.2	30.7	54.9	75.0	99.0	125.0
Si	8.1	16.3	33.5	45.1	166.8		

$$E = h \cdot \nu$$

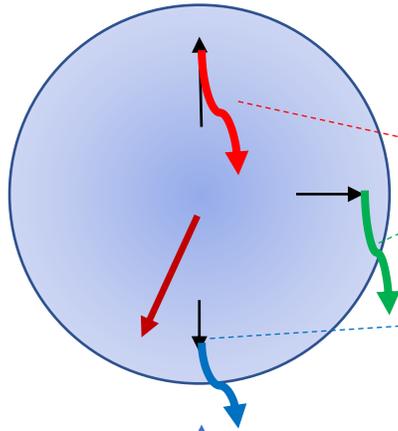
$$E \sim k \cdot T \quad (k = 8.62 \cdot 10^{-5} \text{ eV} \cdot \text{K}^{-1}, \text{ Boltzman's Constant})$$

$$T \text{ (K)} \sim 1000 * E.I. \text{ (eV)}$$

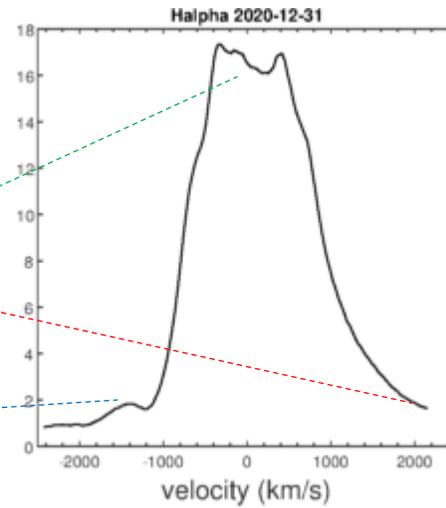
(Order of magnitude)

Line	T
Na I	7000
H I Fe O I	15000
He I	25000
He II O III	55000
Fe VII	125000

Radial Velocity



Note:
Field of the velocities
≠ Physical Field

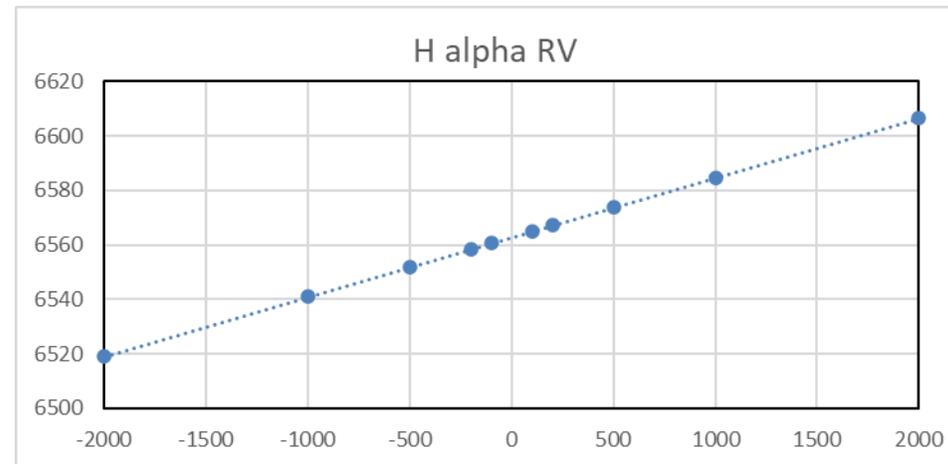


Nova Per 2020
Kevin

Doppler effect

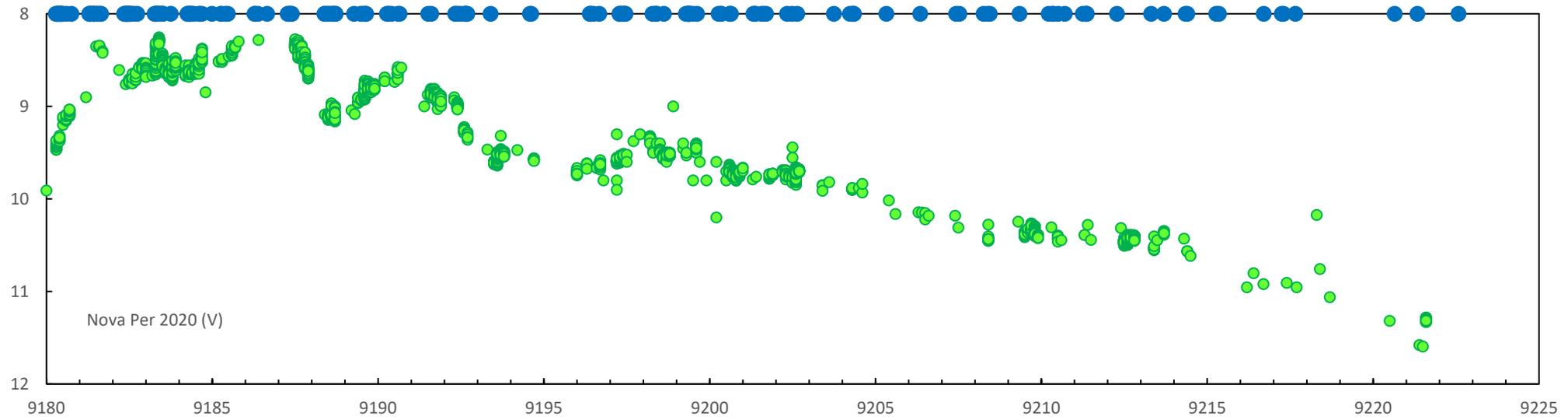
$$Vr = (\lambda - \lambda_0) / \lambda_0 \cdot c$$

$$\lambda = \lambda_0 \cdot (1 + c / Vr)$$



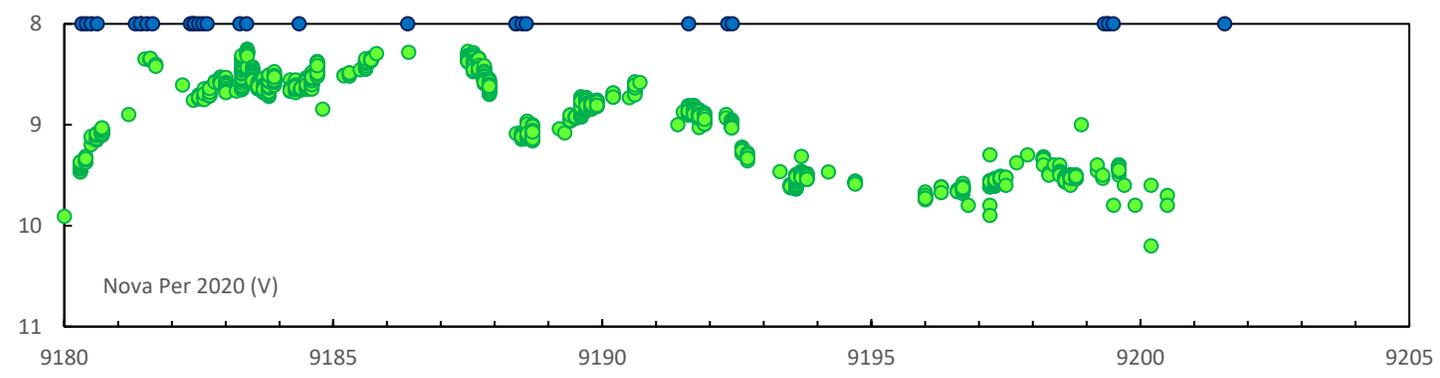
- Tuning the gratings angle
- Analysis of the lines profiles
- Photon H α produced by H⁰ shifted by Vr = -1000 km.s⁻¹
Wavelength = 6540 Å

196 spectra

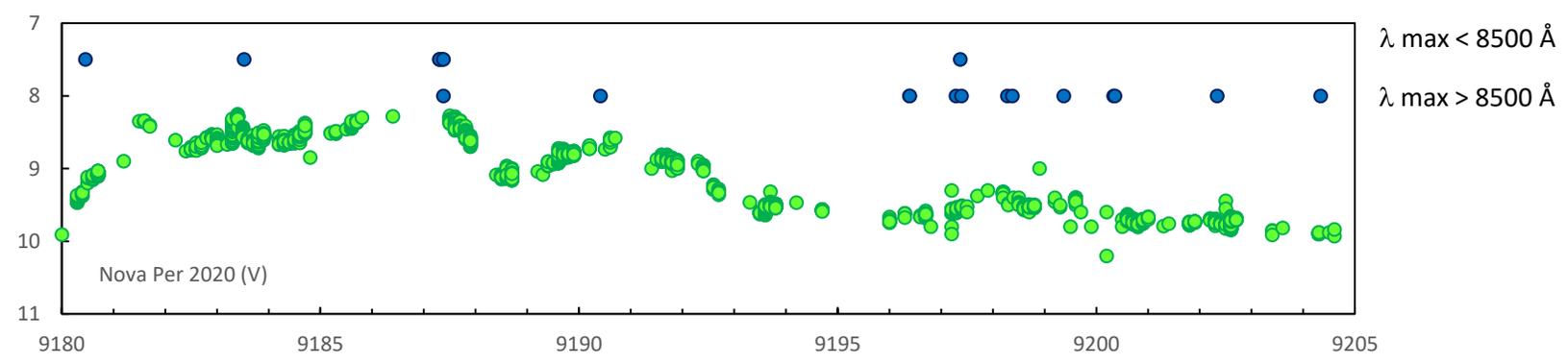


http://www.astrosurf.com/aras/Aras_DataBase/Novae/2020_NovaPer2020.htm

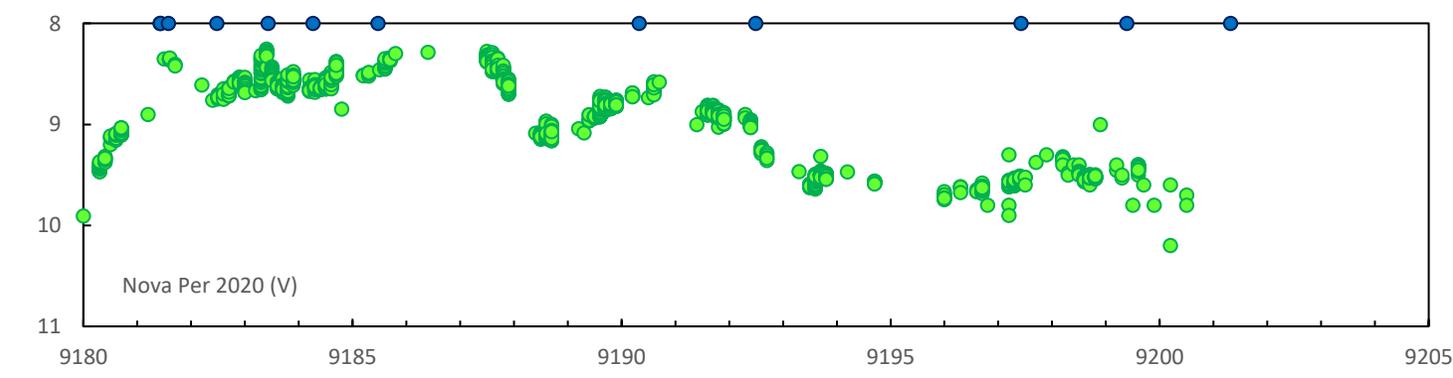
Echelle R = 10-14000



Near IR
R = 2000-3000

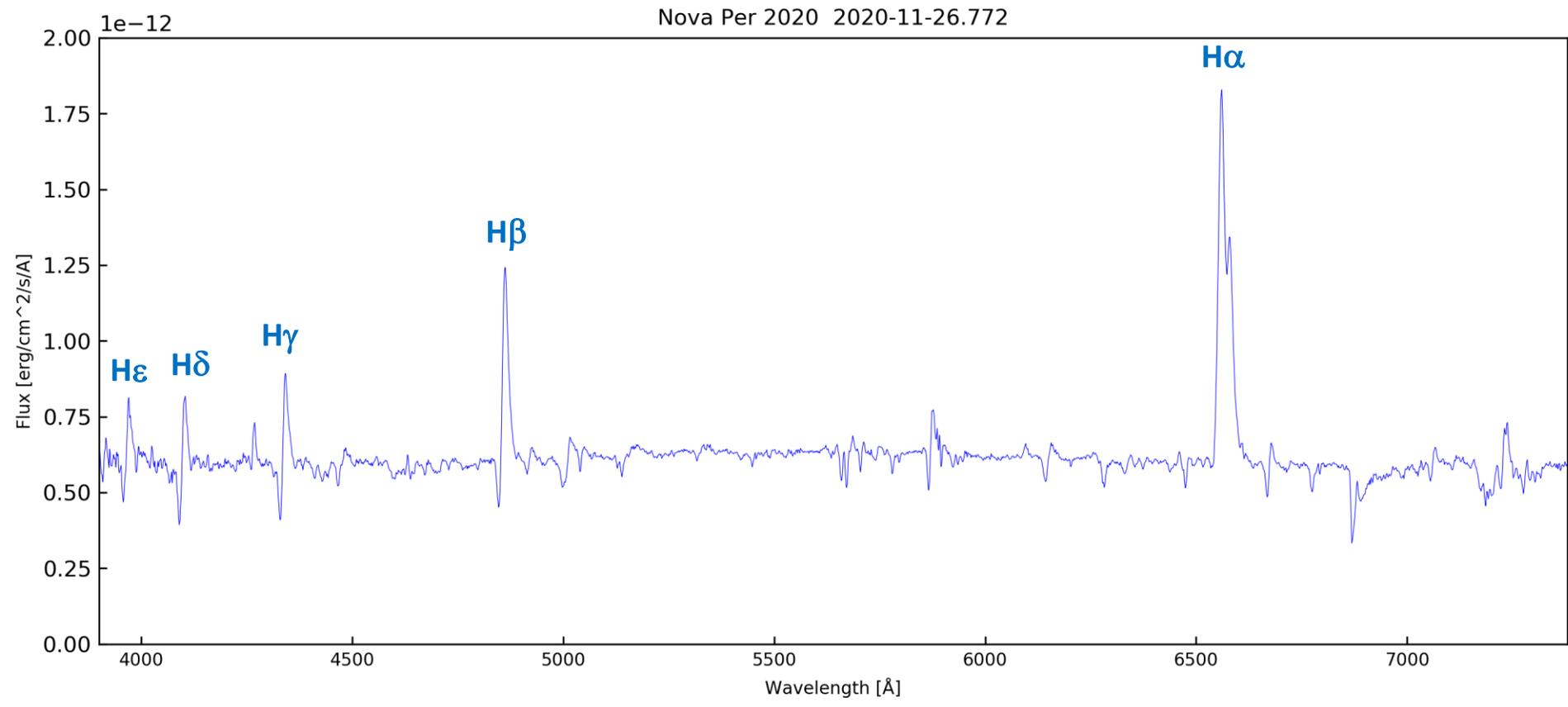
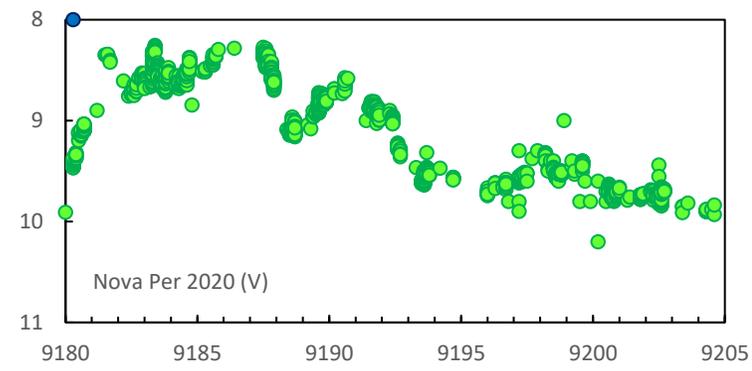


H alpha R = 15000



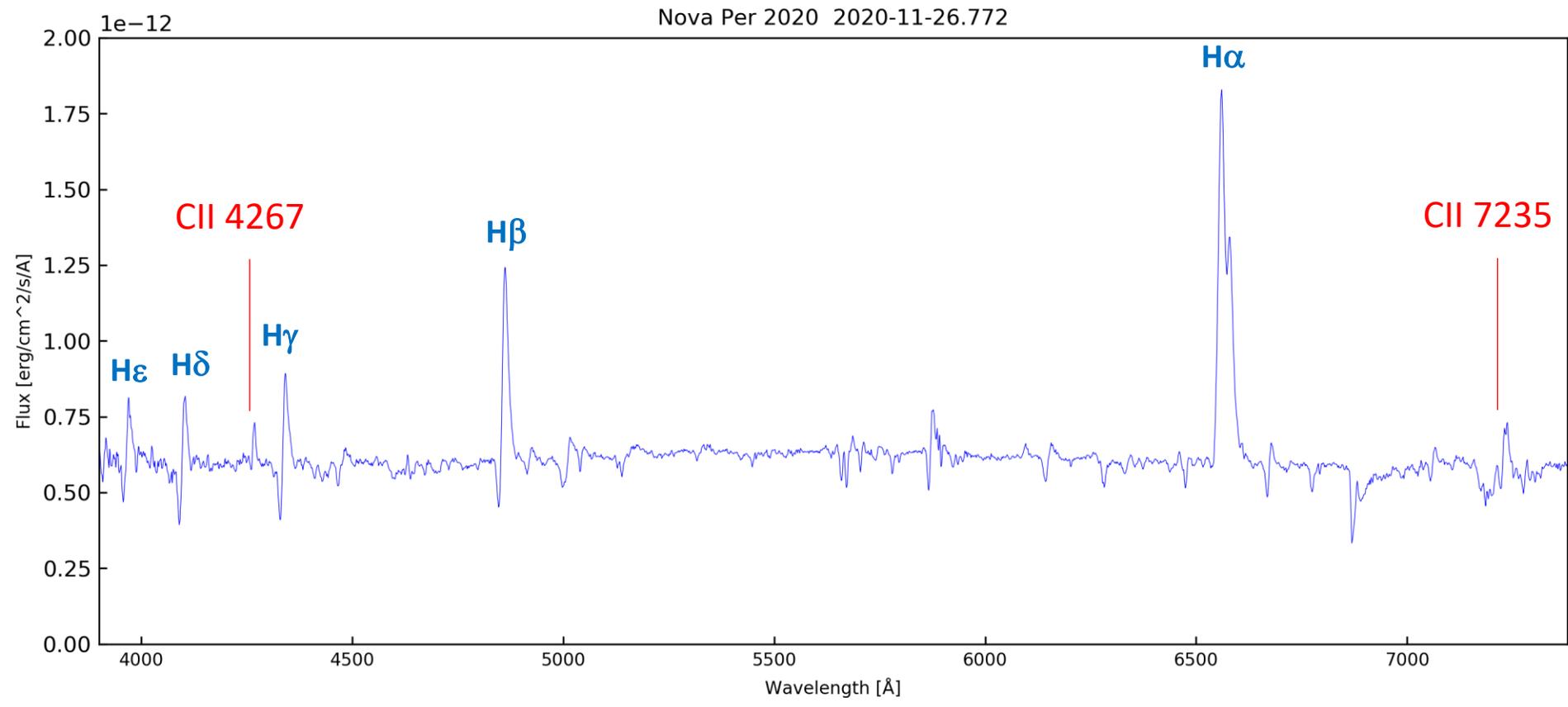
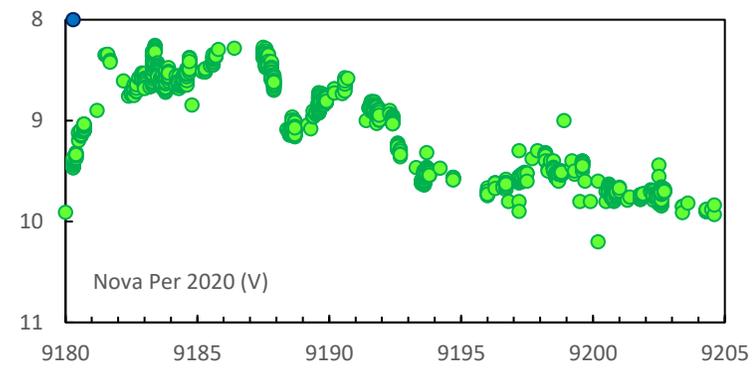
Nova Per 2020 During the Rise

David Boyd LISA (R = 1000) Flux calibrated spectrum (V =)



Nova Per 2020 During the Rise

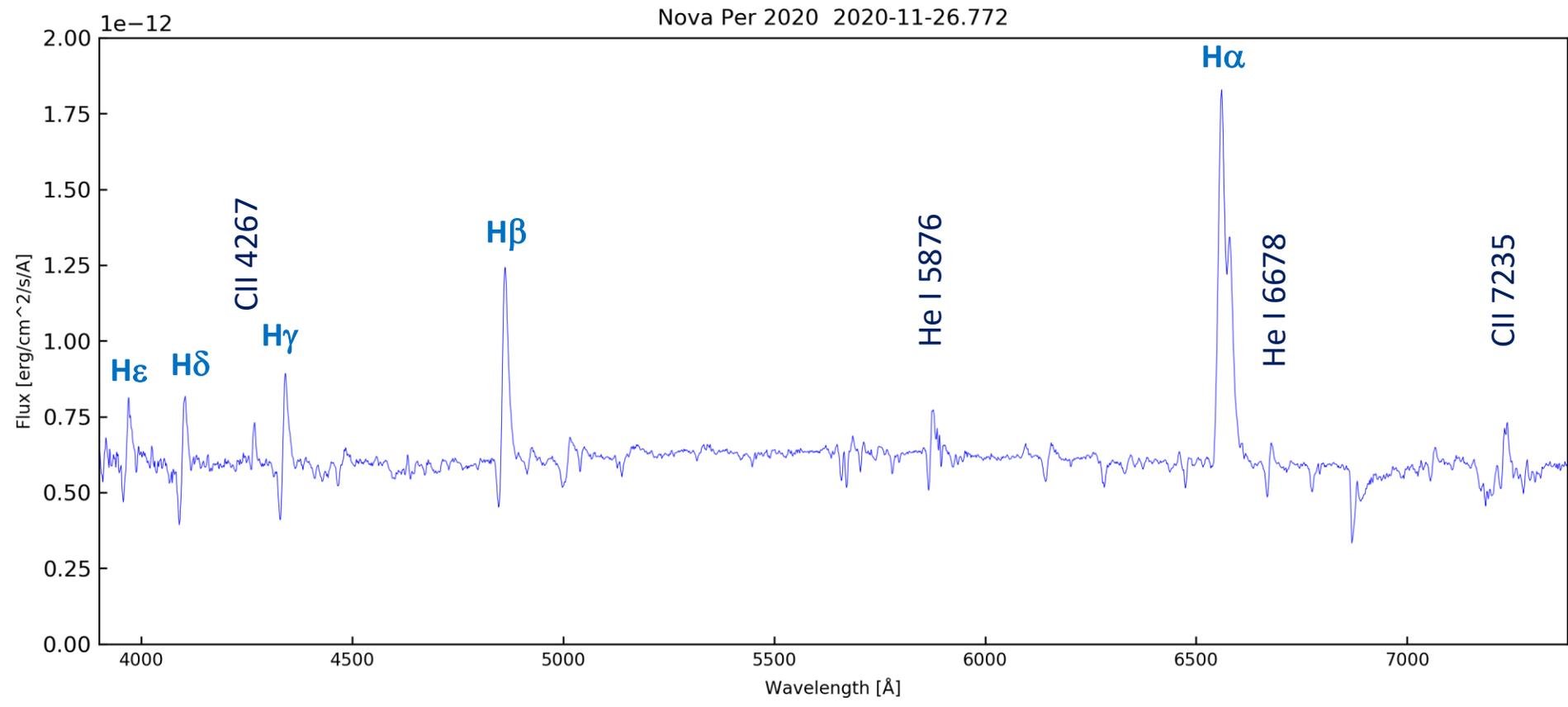
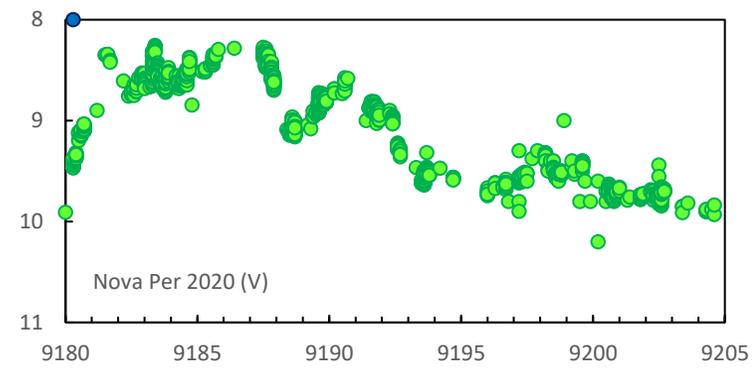
David Boyd LISA (R = 1000) Flux calibrated spectrum (V =)



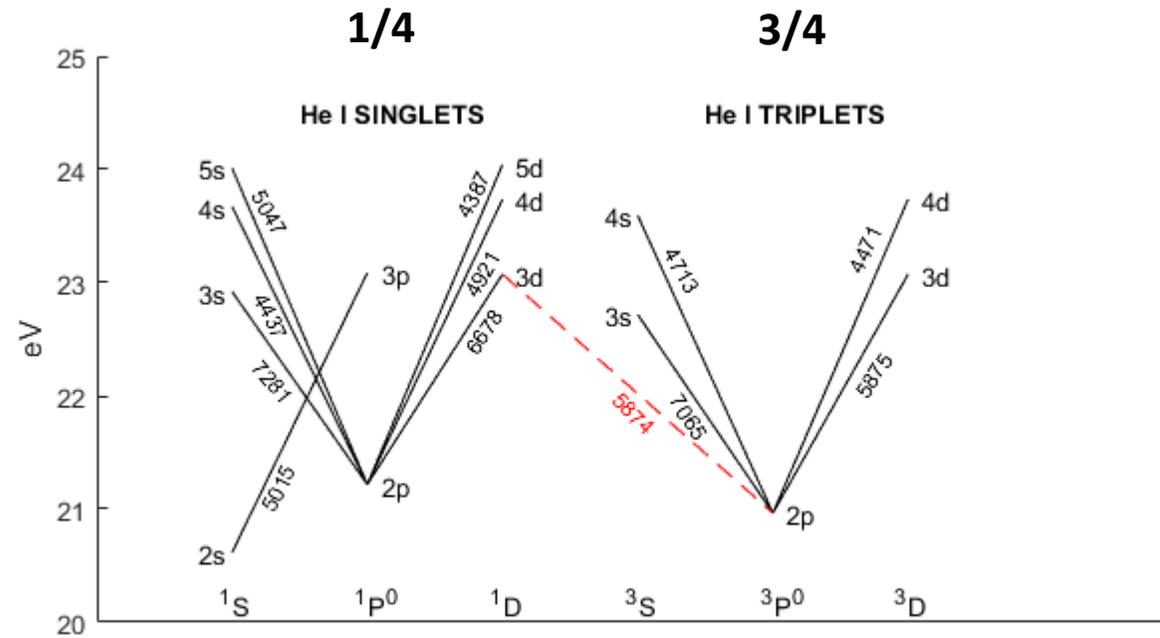
The identification of CII 7235 is confirmed by CII 4267 - F. Teyssier

Nova Per 2020 During the Rise

David Boyd LISA (R = 1000) Flux calibrated spectrum (V =)



The identification of CII 7235 is confirmed by CII 4267 - F. Teyssier



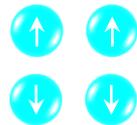
Main He I transitions in the visible range

Singlets

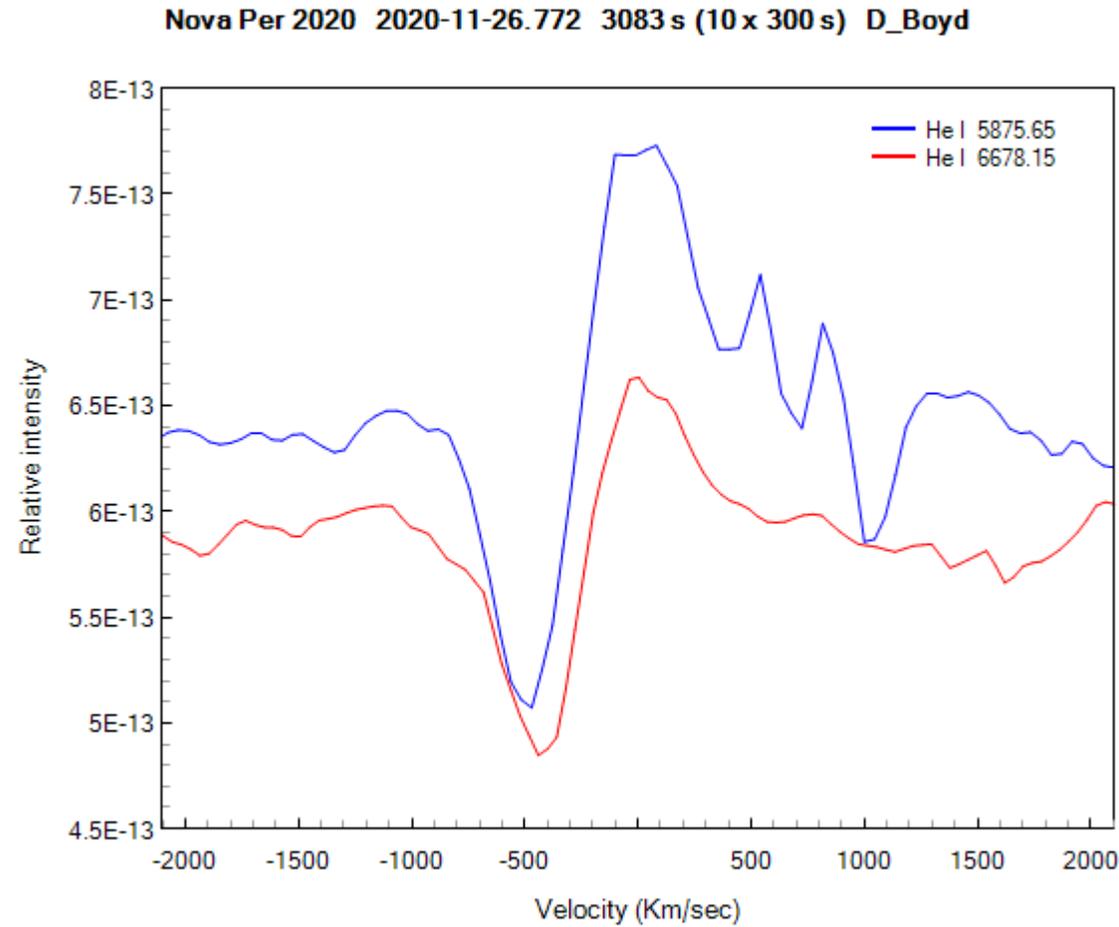


Transition	λ (Å)
4s \rightarrow 2p	4437
4d \rightarrow 2p	4921
3p \rightarrow 2s	5015
3d \rightarrow 2p	6678

Triplets



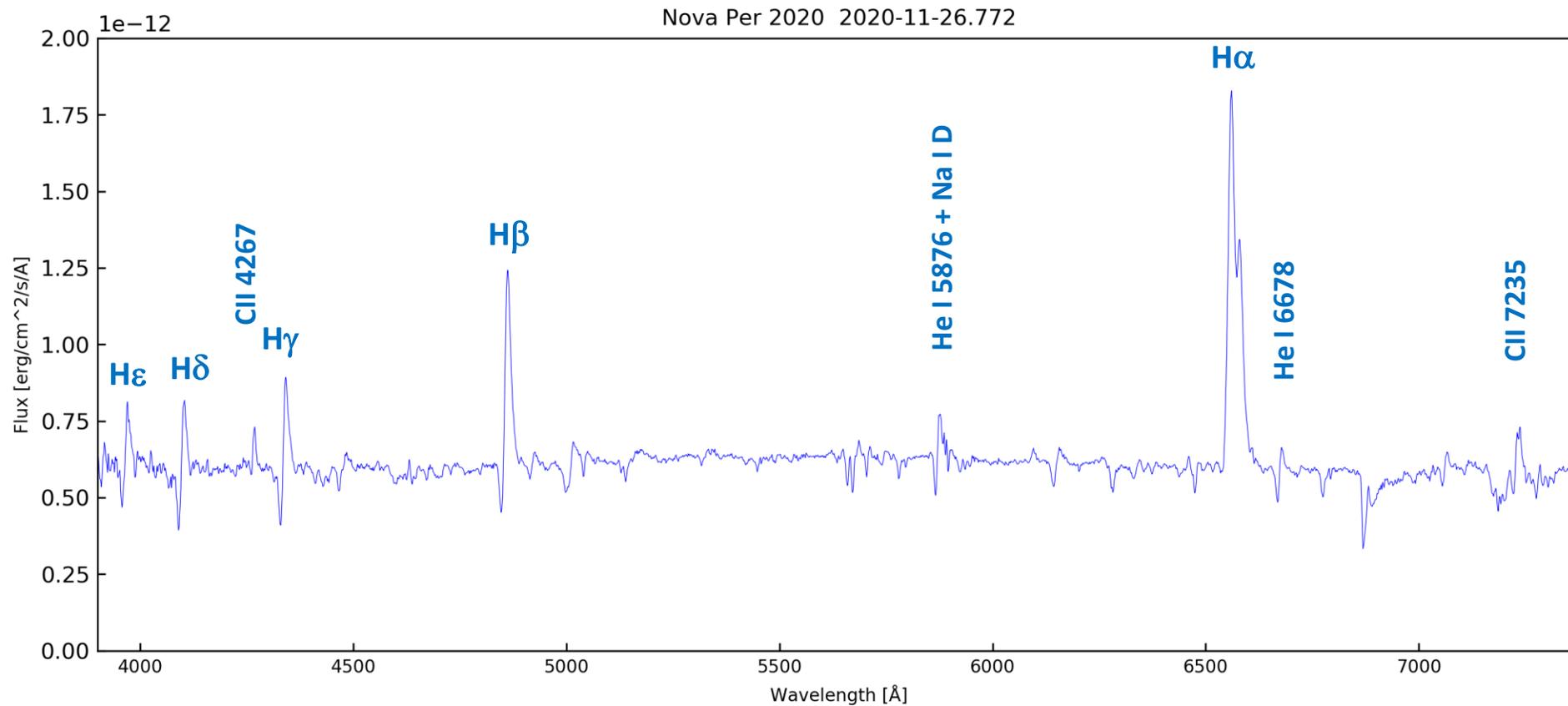
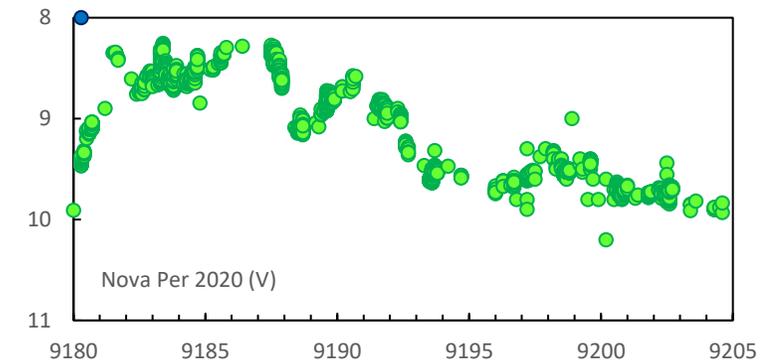
Transition	λ (Å)
4d \rightarrow 2p	4471
4s \rightarrow 2p	4713
3d \rightarrow 2p	5875
3s \rightarrow 2p	7065



The identification of He I 6678 (singlet) is confirmed by He I 5876 (triplet)
 Note the emissions of Na I D₂, D₁

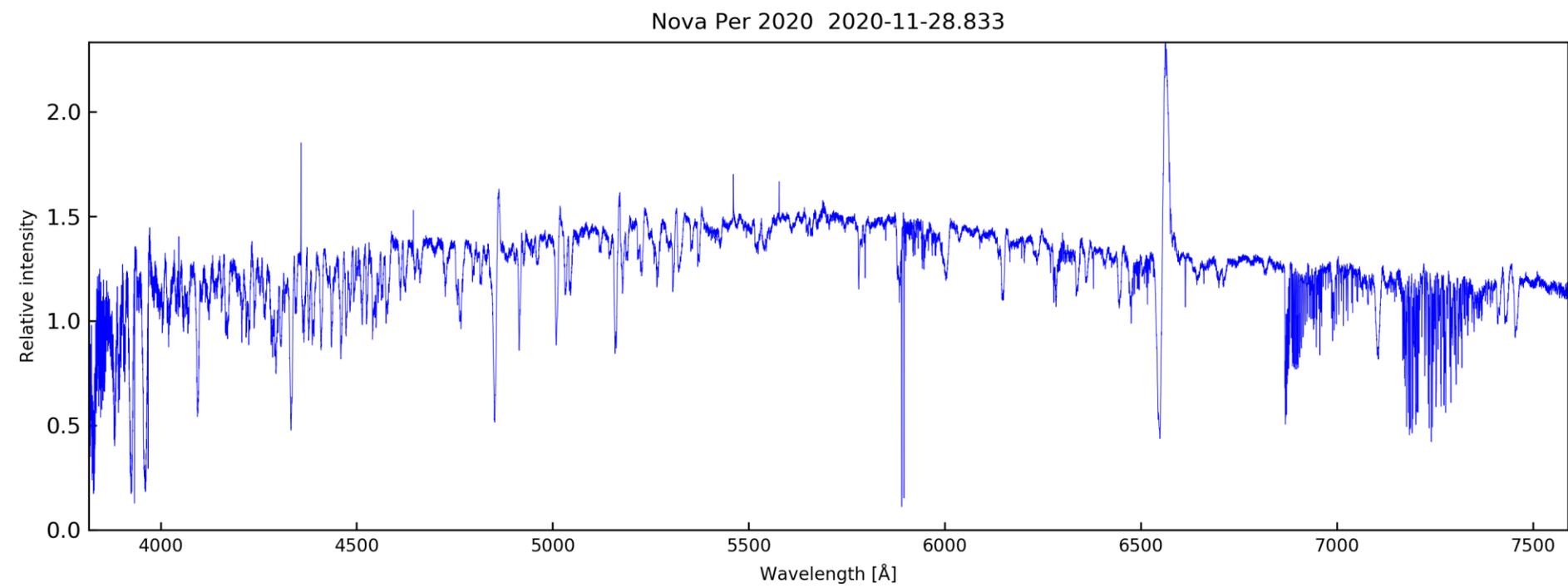
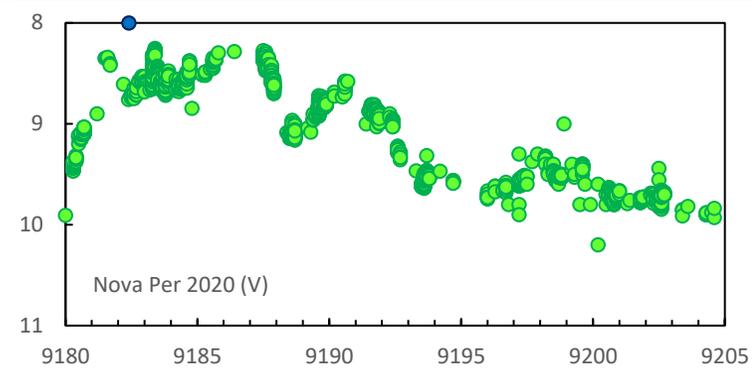
Nova Per 2020 Montée en luminosité (*Rise*)

David Boyd LISA (R = 1000) Flux calibrated spectrum (V =)



Nova Per 2020
Maximal Luminosity

Christian Buil eShel2 (R = 11000)

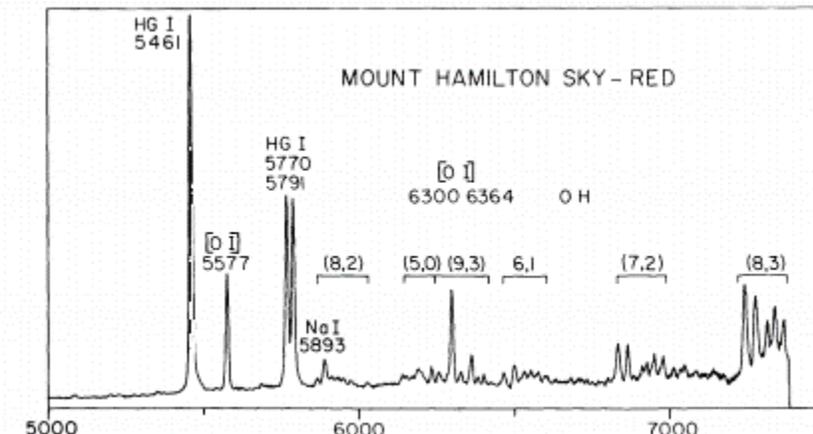
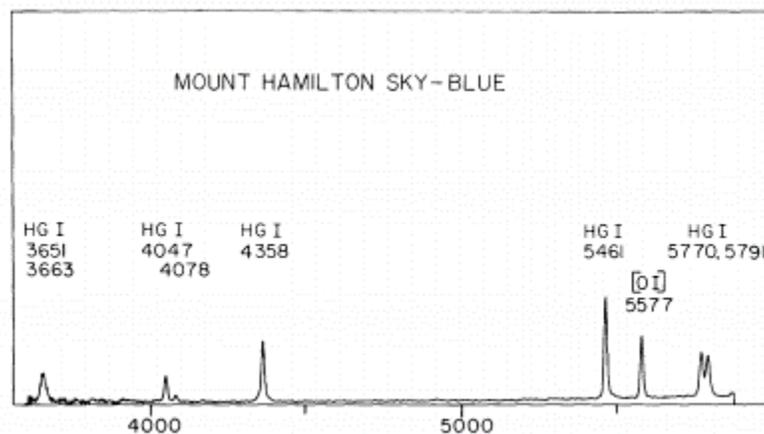


Flat continuum – very strong absorptions of Na I D
P Cygni profiles Balmer lines, Fe II (42)
Very narrow emissions

Nova Per 2020 Maximal Luminosity

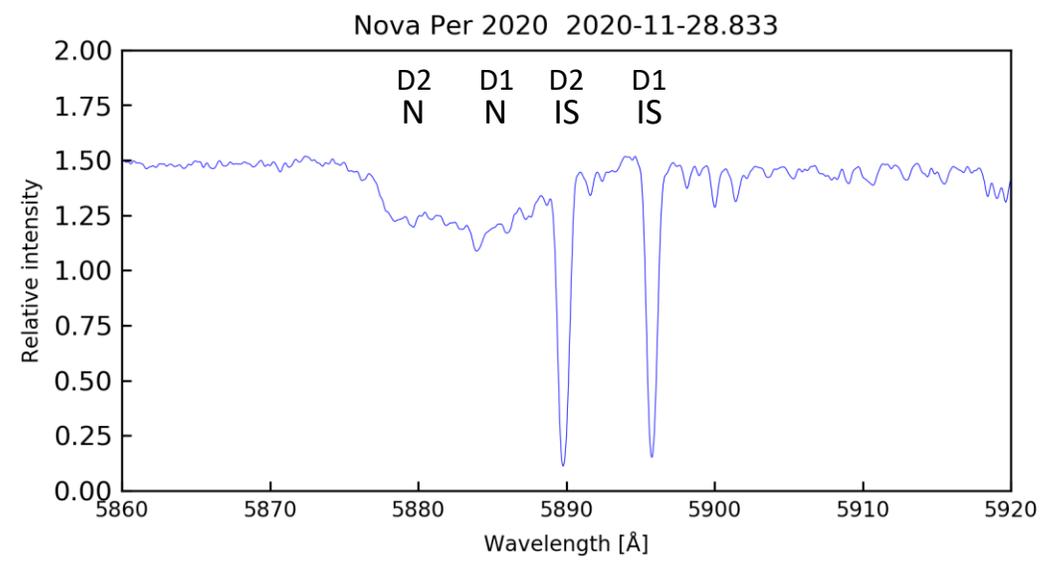
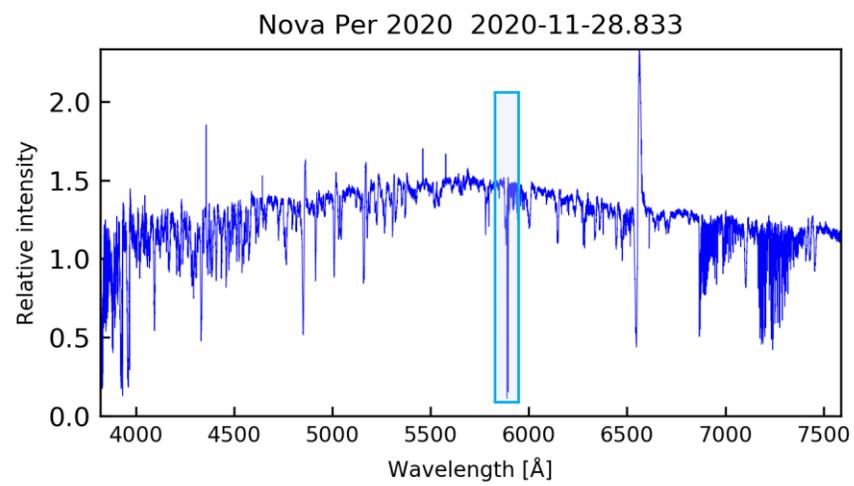
« Cleaning the spectrum »

Line	Sources
Hg I 3650	Hg lighting
Hg I 3663	Hg lighting
Hg I 4047	Hg lighting
Hg I 4078	Hg lighting
Hg I 4358	Hg lighting
Na I 4665, 4669	HPS
Na I 4748, 4752	HPS
Na I 4978, 4983	HPS
Na I 5149, 5153	HPS
Hg I 5461	Hg lighting
Na I 5683, 5688	HPS, LPS
Hg I 5770	Hg lighting
Hg I 5791	Hg lighting
Na I 5890, 5896	HPS, LPS, airglow
Na I 5700 - 6100	HPS
Na I 6154, 6161	HPS, LPS
K I 7665	HPS, LPS
K I 7699	HPS, LPS
Na I 8183	HPS, LPS
Na I 8195	HPS, LPS



Buil your own light pollution map

Nova Per 2020 Maximum Luminosity

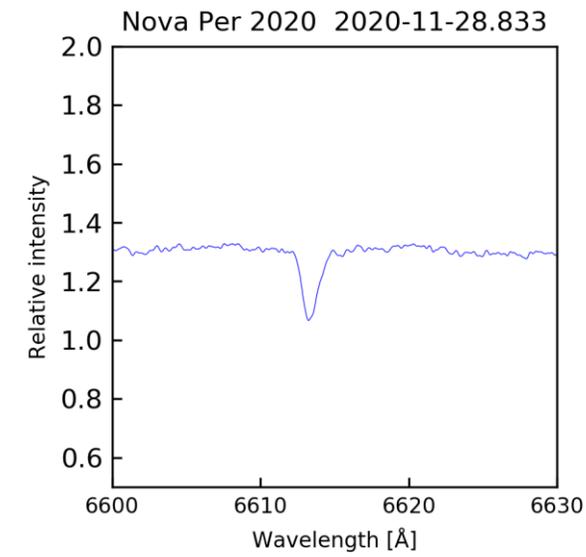


E_{B-V}	Equiv. width (Å)		E_{B-V}	Equiv. width (Å)	
	Na I D1	K I 7699		Na I D1	K I 7699
0.00	0.00	0.00	0.70	0.63	0.180
0.05	0.16	0.018	0.80	0.65	0.204
0.10	0.27	0.027	0.90	0.66	0.227
0.15	0.35	0.045	1.00	0.67	0.250
0.20	0.41	0.054	1.10	0.69	0.272
0.25	0.46	0.072	1.20	0.70	0.294
0.30	0.49	0.080	1.30	0.71	0.315
0.40	0.54	0.106	1.40	0.71	0.336
0.50	0.59	0.131	1.50	0.72	0.357
0.60	0.61	0.156	1.60	0.73	0.377

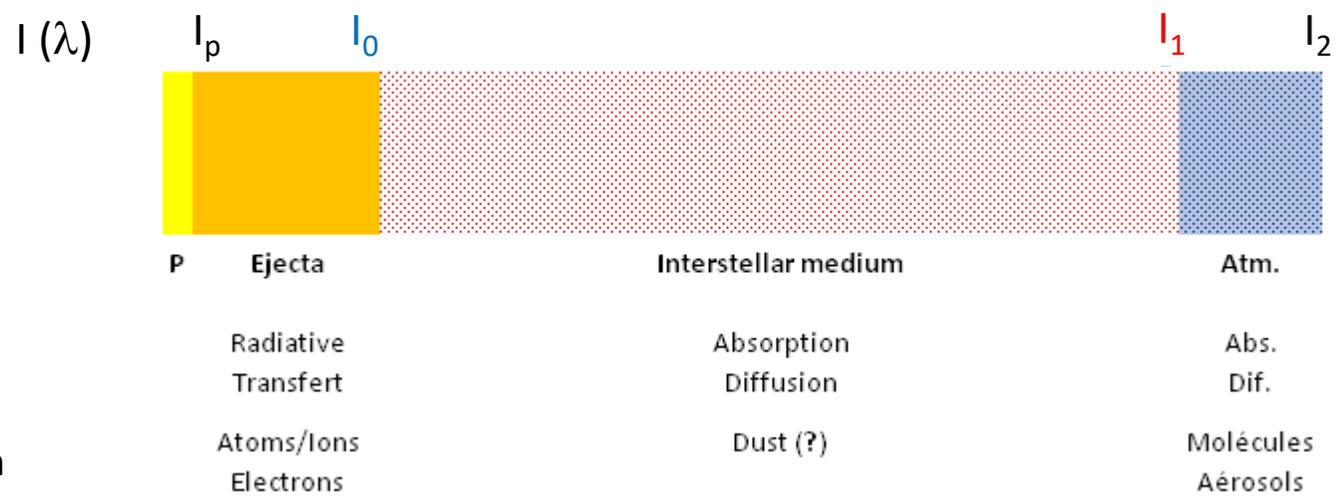
This sort of behaviour of W vs. E_{B-V} is well represented by the solid lines in Fig. 4, which are empirical fits to the data of the stars presenting a single component profile for the interstellar lines. The values of the coefficients α and β for the Na D1 and K I (7699 Å) lines from fit to our data are:

$$\begin{aligned} \text{Na D1: } & \alpha = 0.354 \pm 0.01 \text{ \AA} & \beta &= 11.0 \pm 1.0 \\ \text{K I: } & \alpha\beta = 0.277 \pm 0.01 \text{ \AA} & \beta &= 0.3 \pm 0.2 \end{aligned} \quad (3)$$

Munari & al.,
 E_{B-V} as a function of
EW Na I D
et K I 7699Å

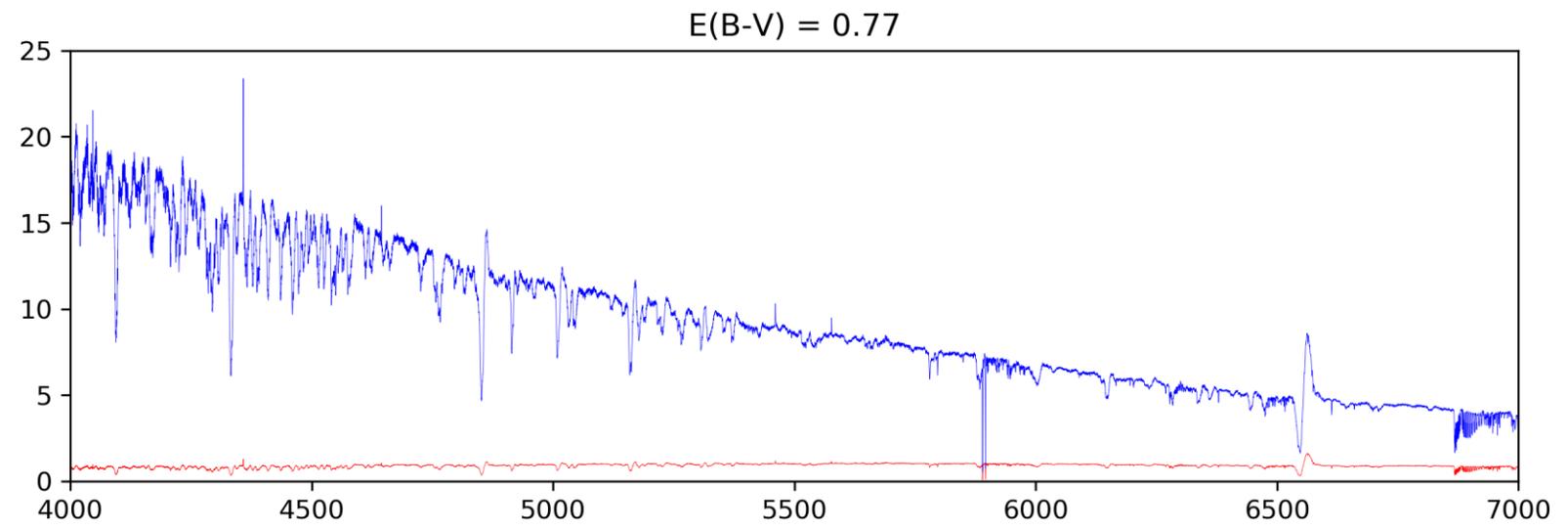


Nova Per 2020



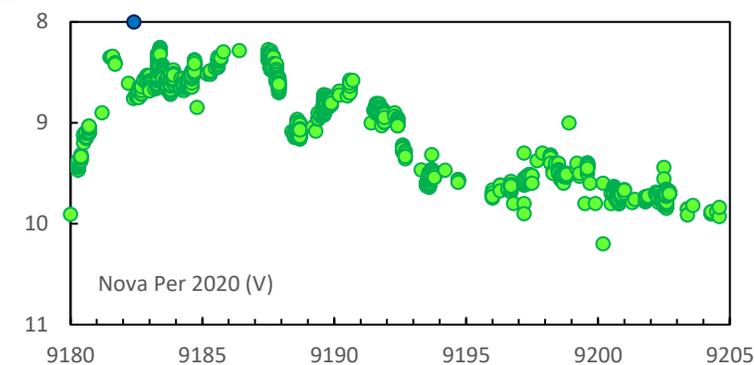
Derredening the spectrum (Python, AstroPy)

$E_{B-V} = 0.77$



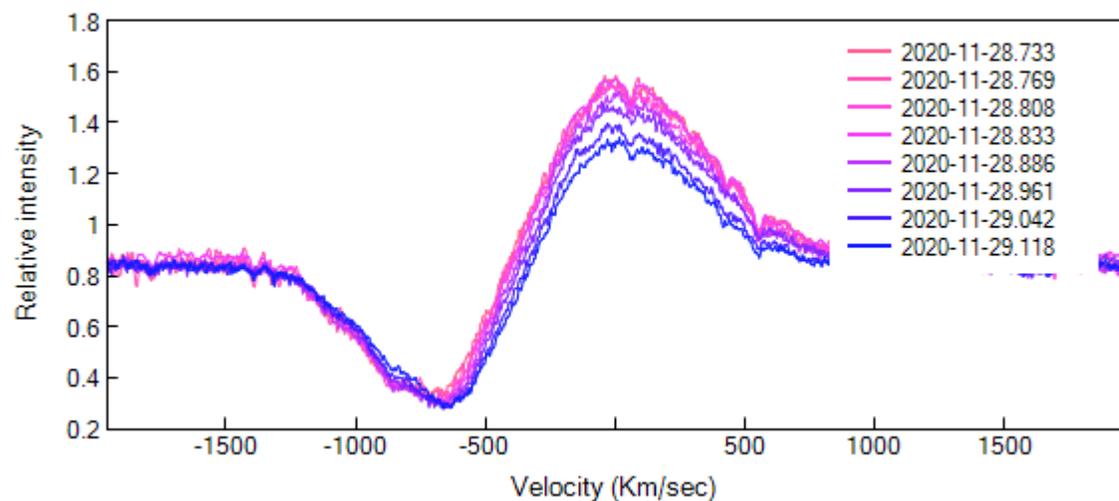
Red: the observed spectrum after atmospheric/instrumental correction = $I_1(\lambda)$
Blue: the derredened spectrum as it emerges from the ejecta = $I_0(\lambda)$

Nova Per 2020 Maximum

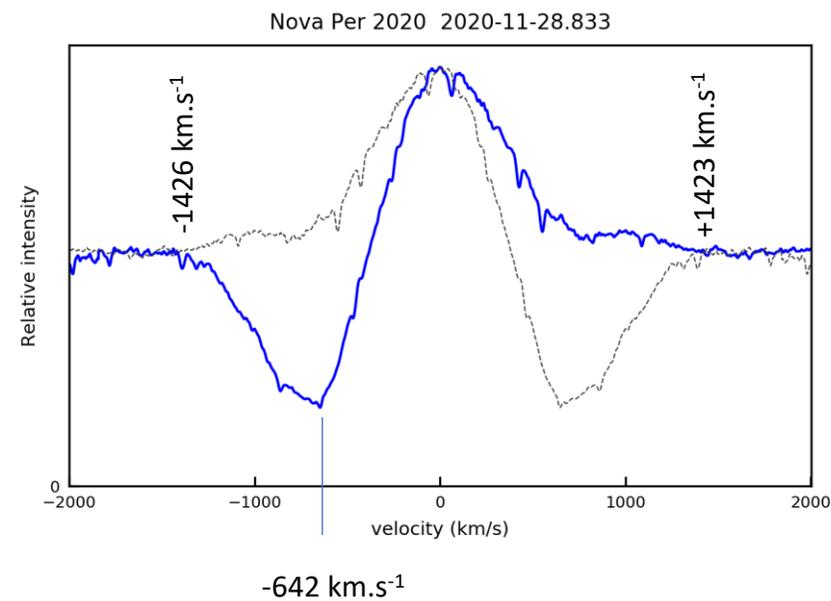


Nightly Variation of H alpha

Halpna 6562.801 - Nova Per 2020

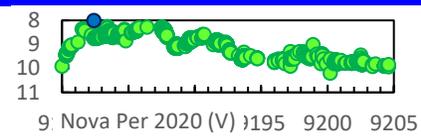


Profile + reversed profile

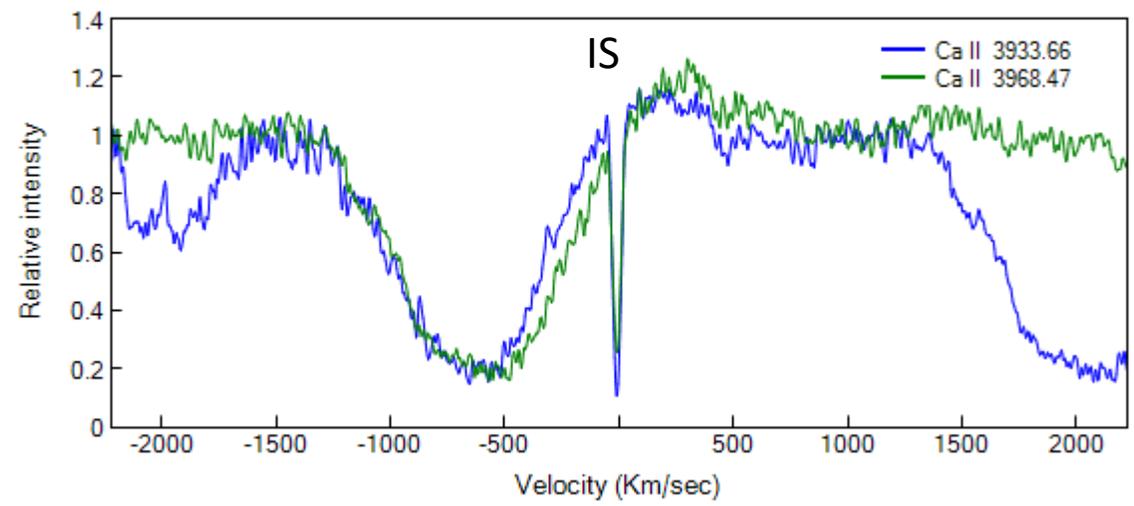


S. Charbonnel (6), C. Buil (1), F. Teyssier (1) Echelle R = 11000

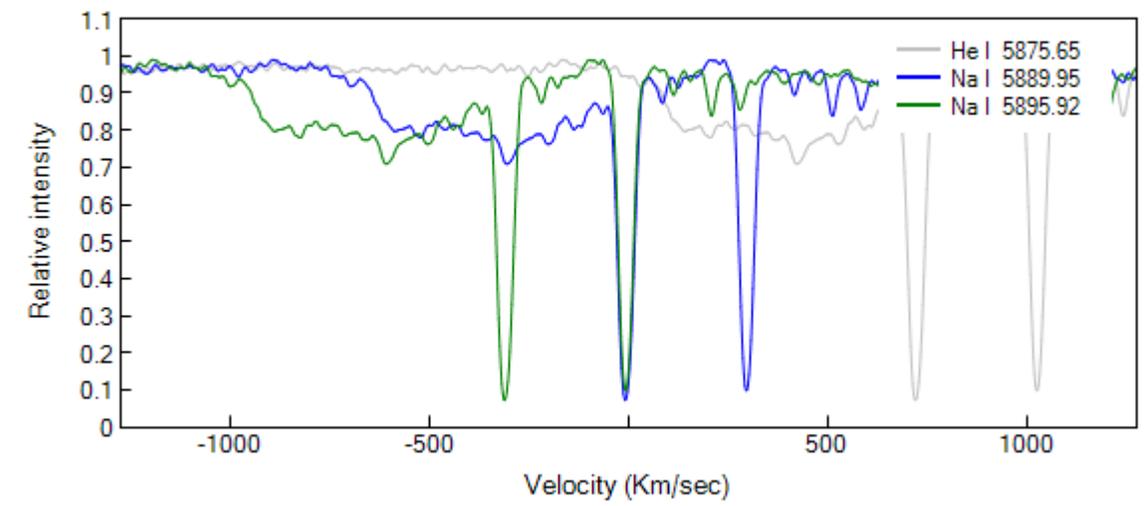
Nova Per 2020 Maximum



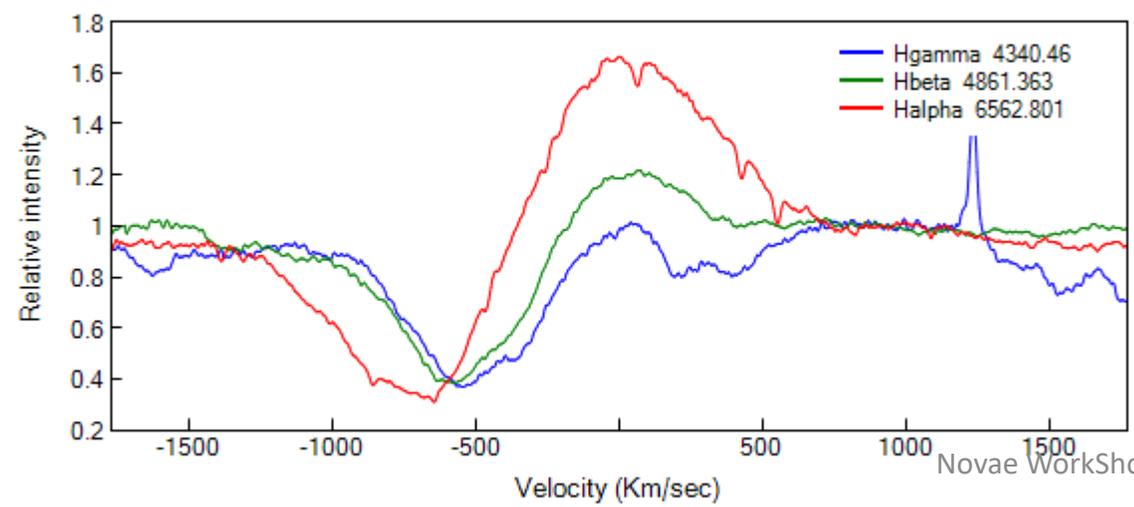
Nova Per 2020 2020-11-28.833 12122 s (10 x 1200 s) cbuil



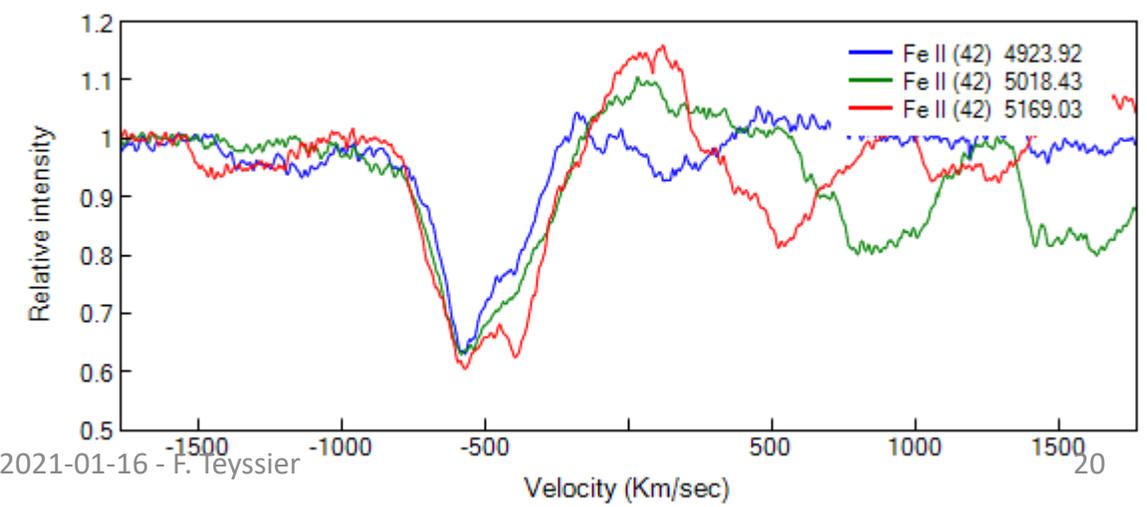
Nova Per 2020 2020-11-28.833 12122 s (10 x 1200 s) cbuil



Nova Per 2020 2020-11-28.833 12122 s (10 x 1200 s) cbuil

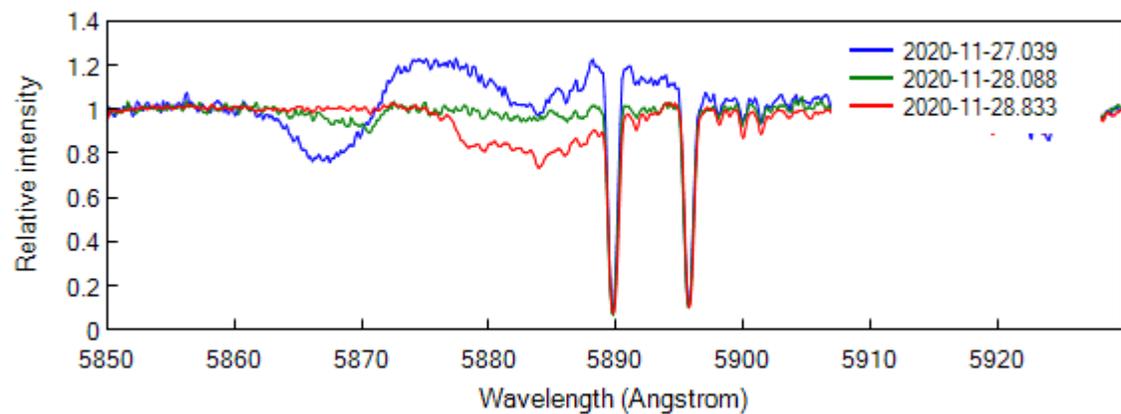


Nova Per 2020 2020-11-28.833 12122 s (10 x 1200 s) cbuil

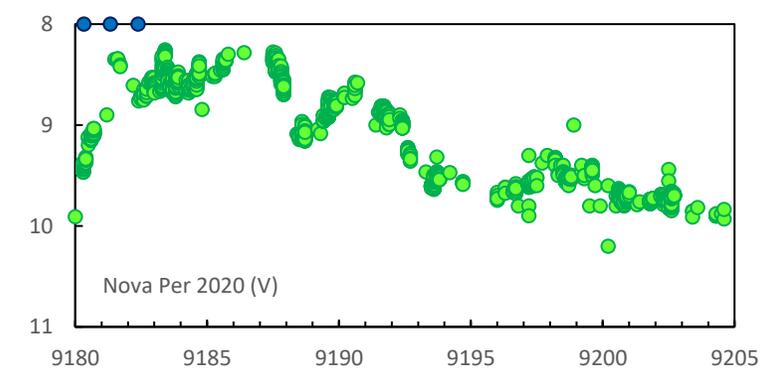
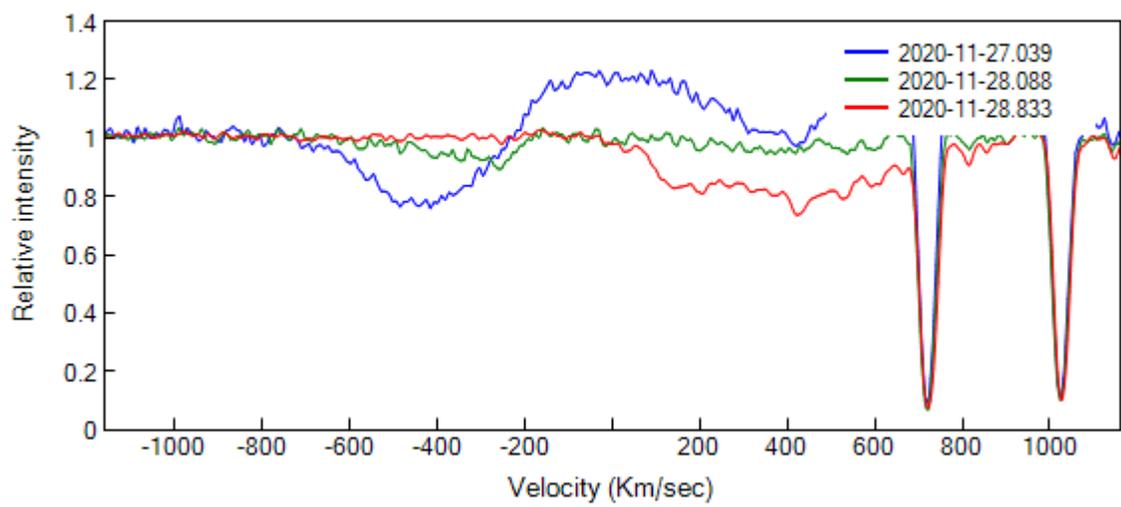


Nova Per 2020 Rise

Na I 5889.95 - Nova Per 2020

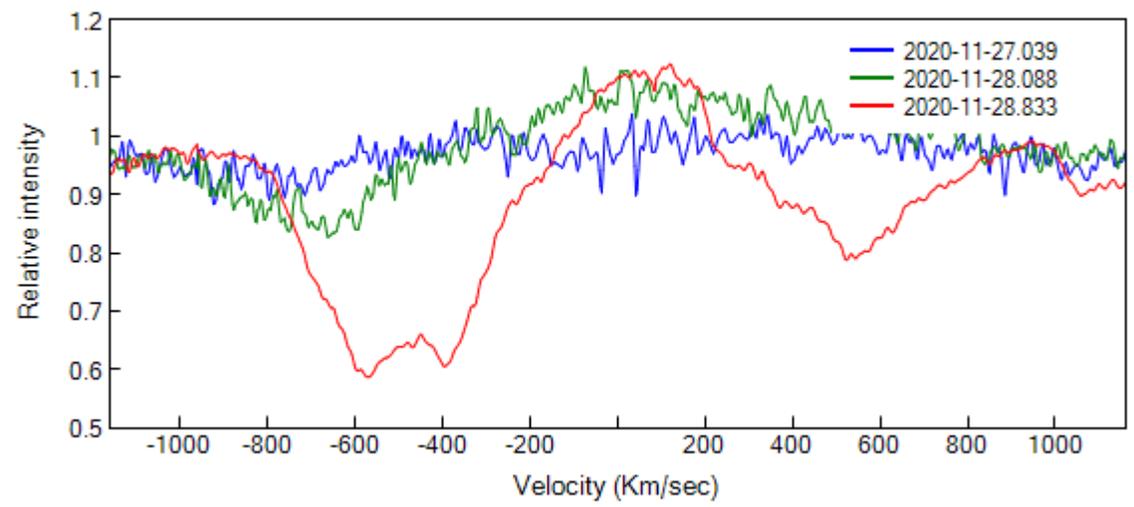


He I 5875.65 - Nova Per 2020



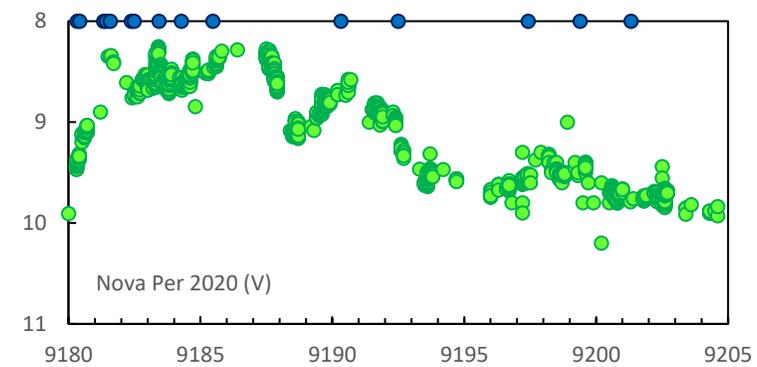
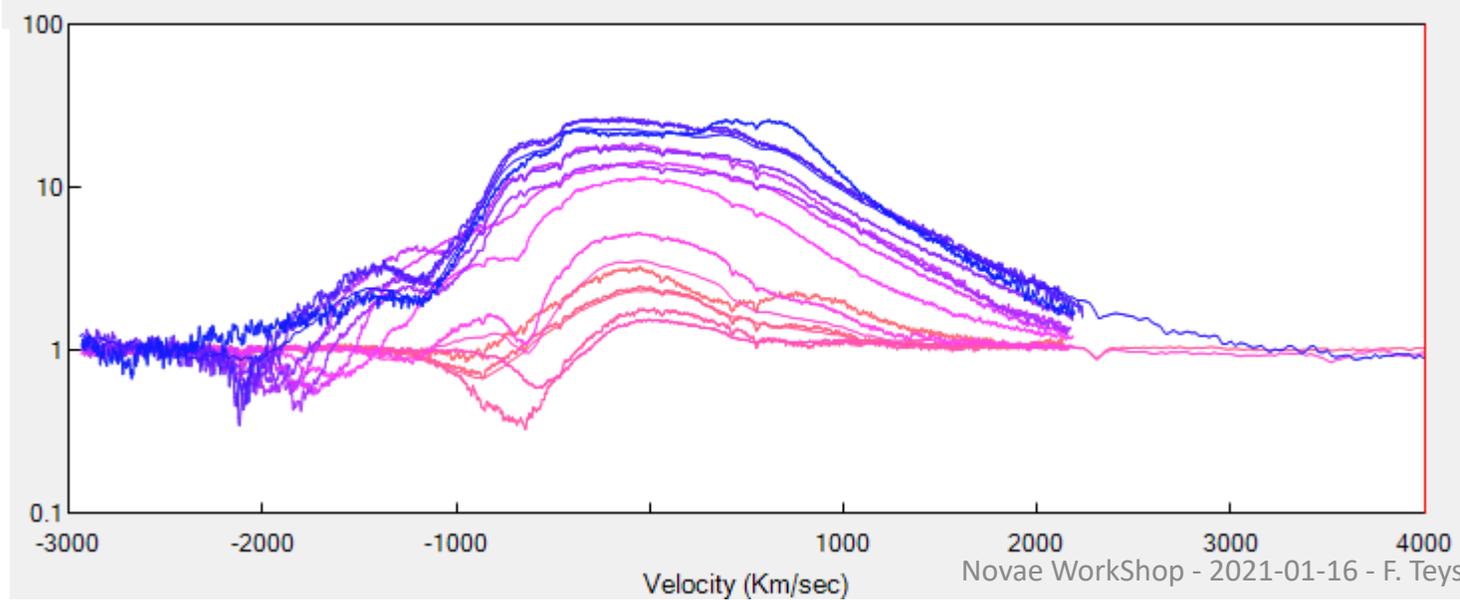
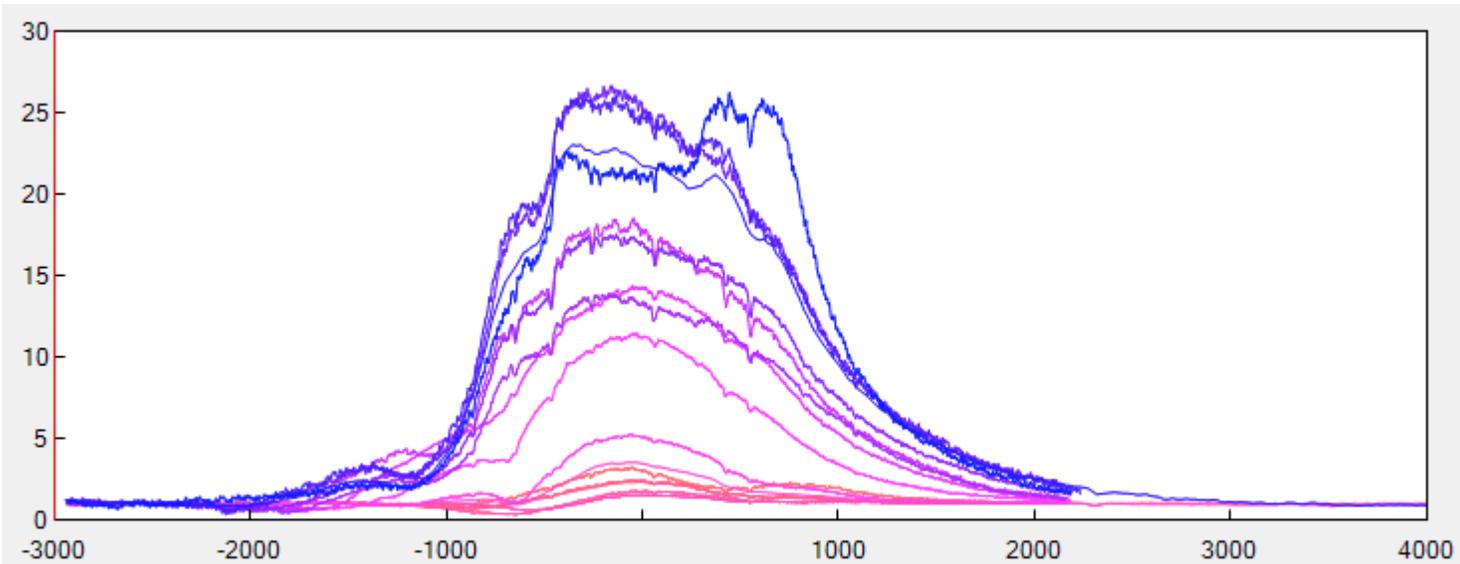
Spectres eShel Olivier Garde (26-27) et C. Buil (28)

Fe II (42) 5169.03 - Nova Per 2020



Nova Per 2020

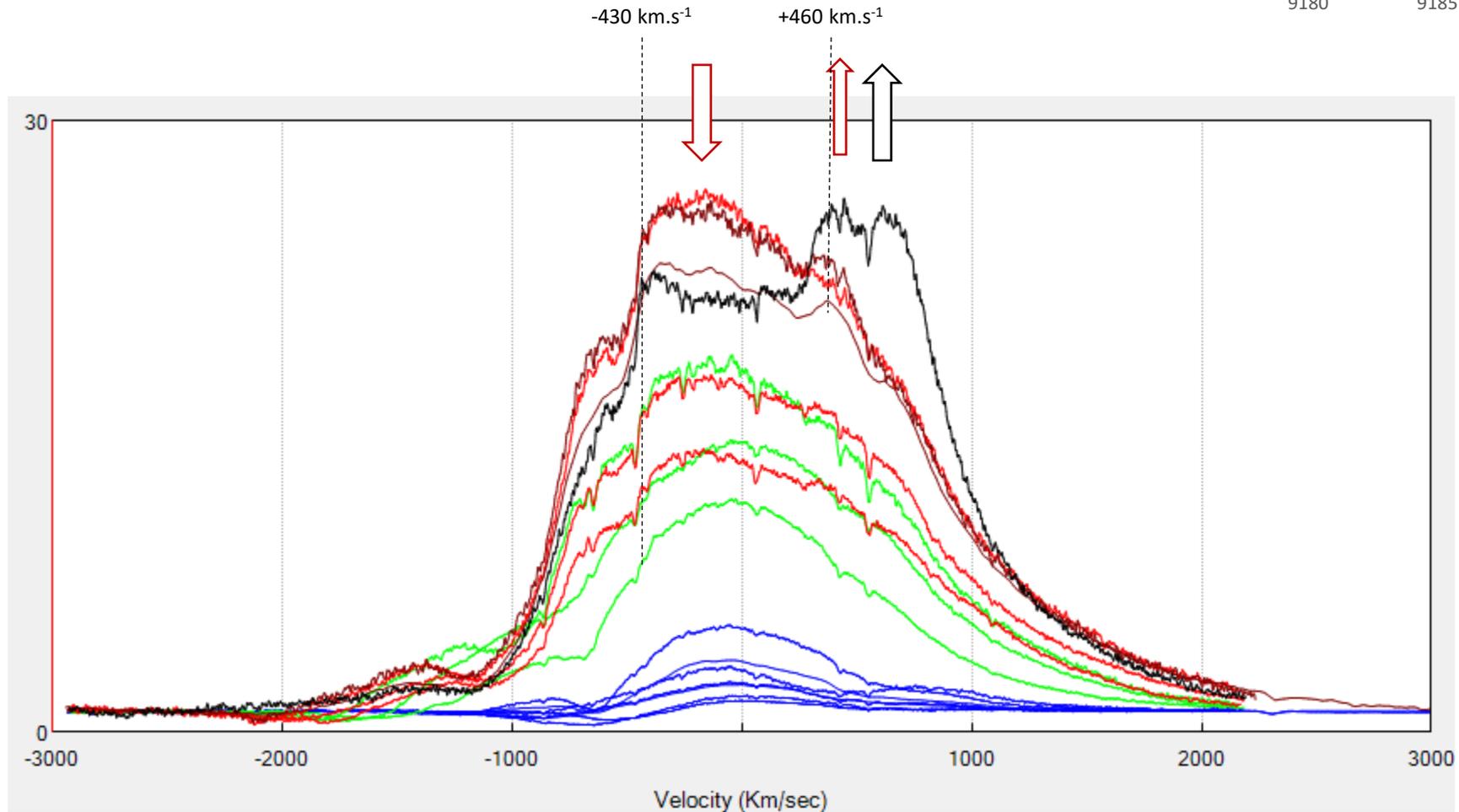
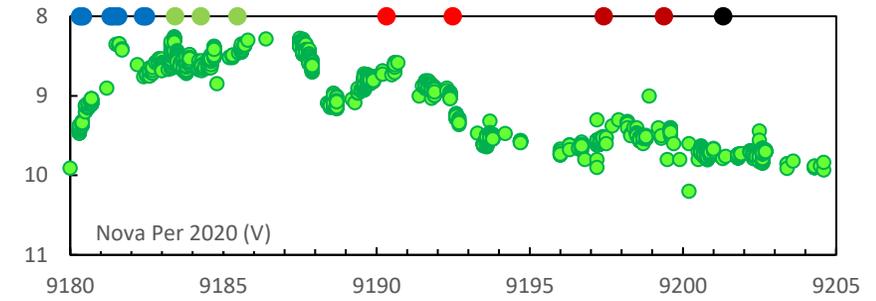
H α at high resolution



Lhires III
 EBE: Etienne Bertrand 2400 l/mm R= 15000
 Leadbeater: Robin L. 1200 l/mm R = 5500
 PSO: Peter Somogyi 2400 l/mm R = 21000

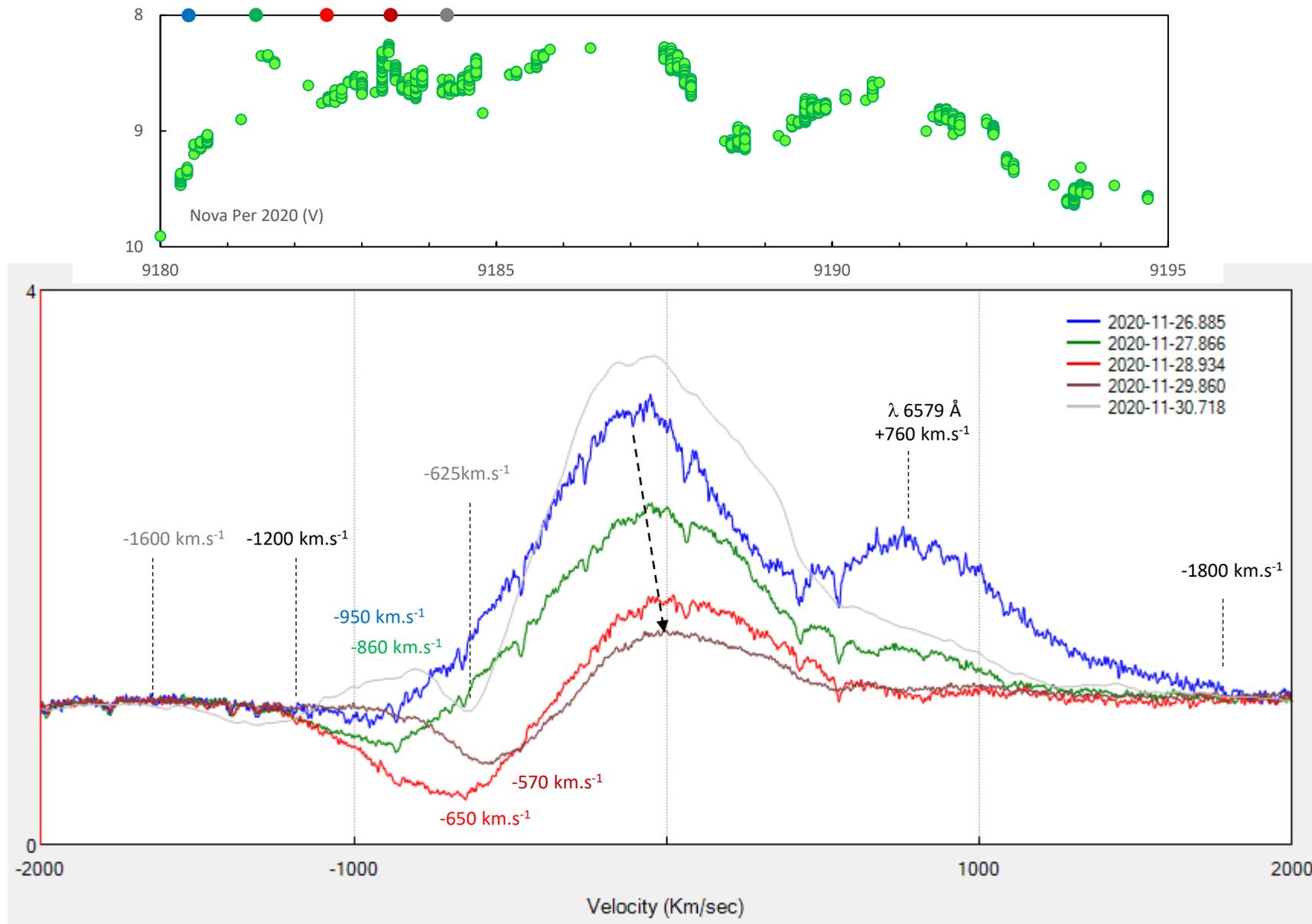
- 2020-11-26.885 EBE
- 2020-11-27.866 EBE
- 2020-11-28.051 Leadbeater
- 2020-11-28.934 EBE
- 2020-11-29.860 EBE
- 2020-11-30.718 Leadbeater
- 2020-12-01.930 EBE
- 2020-12-06.791 EBE
- 2020-12-08.958 EBE
- 2020-12-13.903 EBE
- 2020-12-15.855 EBE
- 2020-12-17.791 EBE
- 2020-12-24.910 EBE
- 2020-12-26.812 PSO
- 2020-12-30.835 Leadbeater
- 2021-01-02.778 EBE

Nova Per 2020 H α



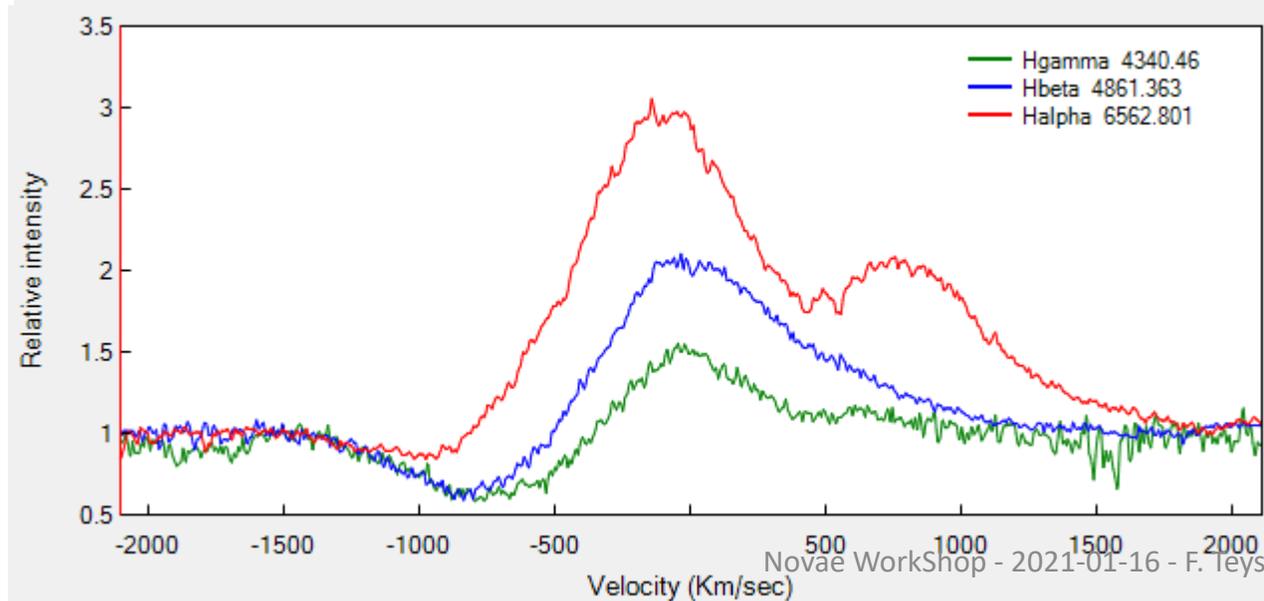
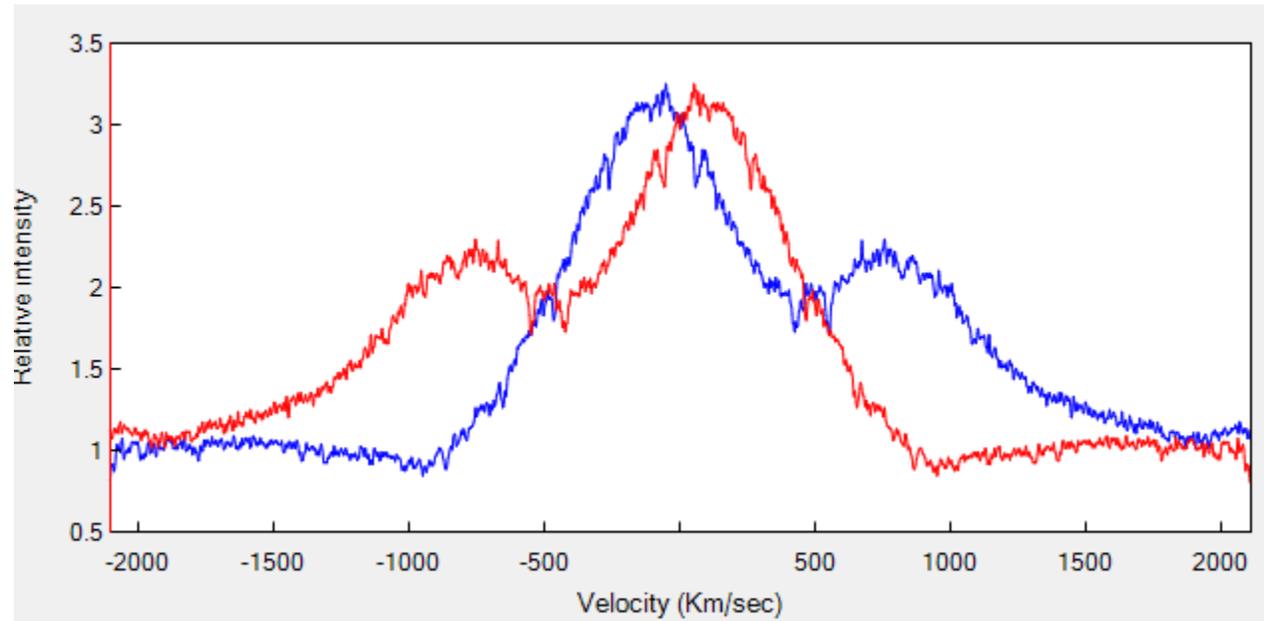
- 2020-11-26.885
- 2020-11-27.866
- 2020-11-28.051
- 2020-11-28.934
- 2020-11-29.860
- 2020-11-30.718
- 2020-12-01.930
- 2020-12-06.791
- 2020-12-08.958
- 2020-12-13.903
- 2020-12-15.855
- 2020-12-17.791
- 2020-12-24.910
- 2020-12-26.812
- 2020-12-30.835
- 2021-01-02.778

Nova Per 2020 H α



Nova Per 2020

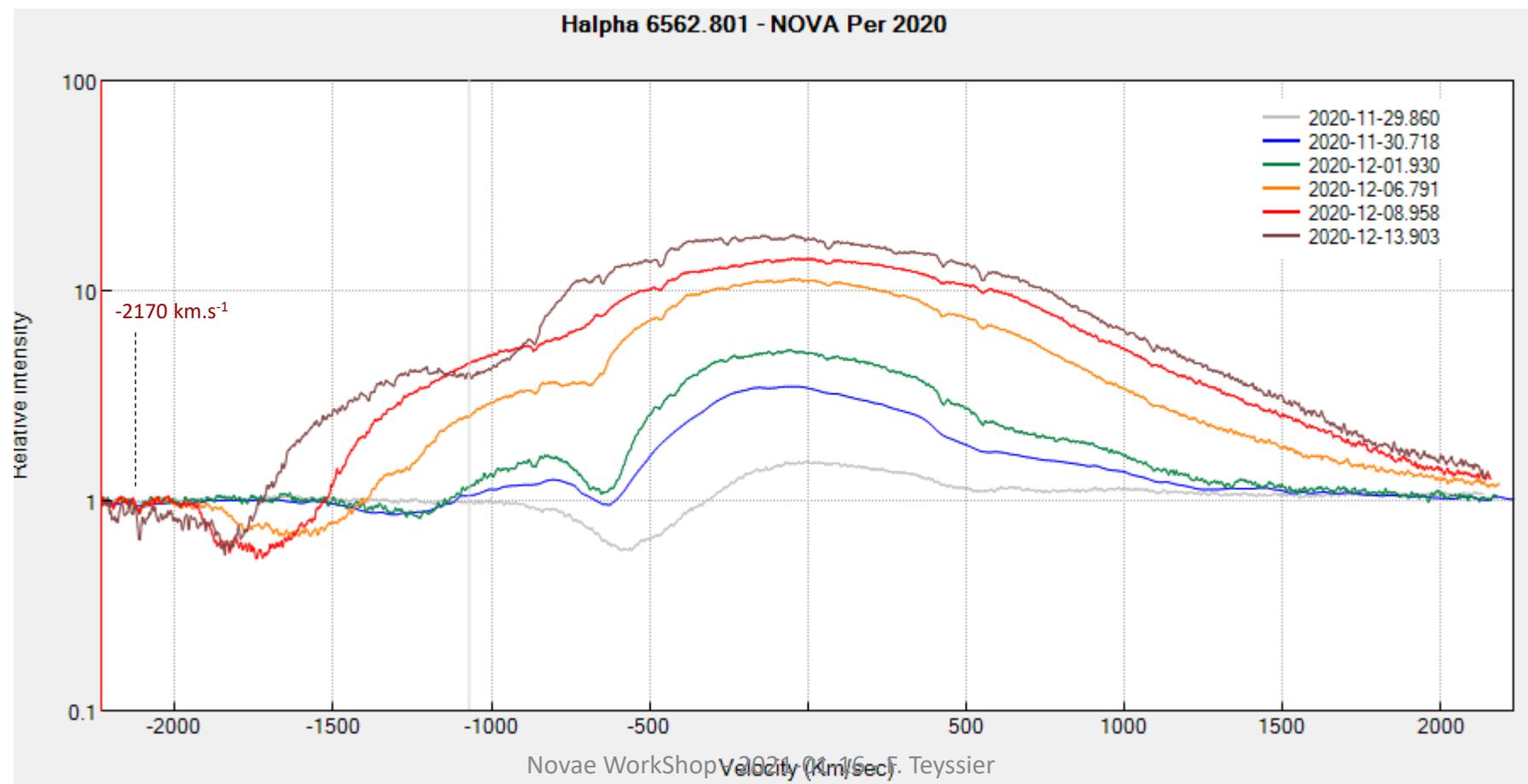
H α



Component λ 6579 Å
Does not belong to H α

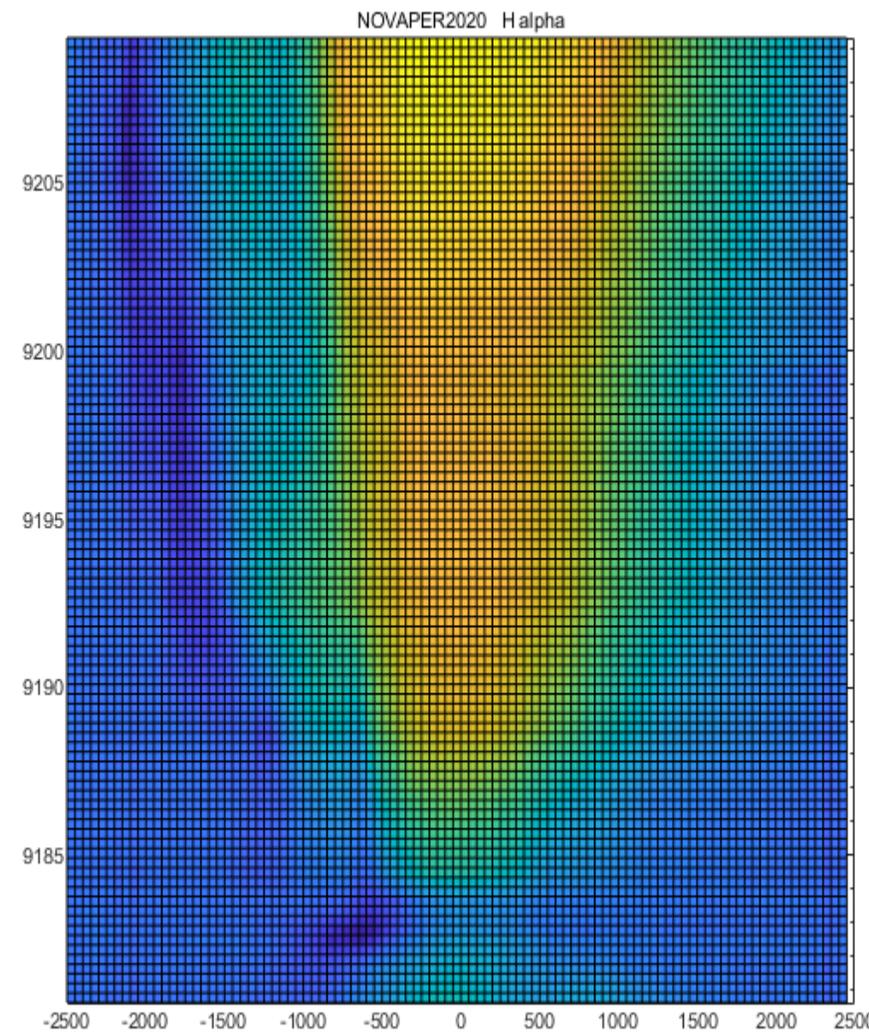
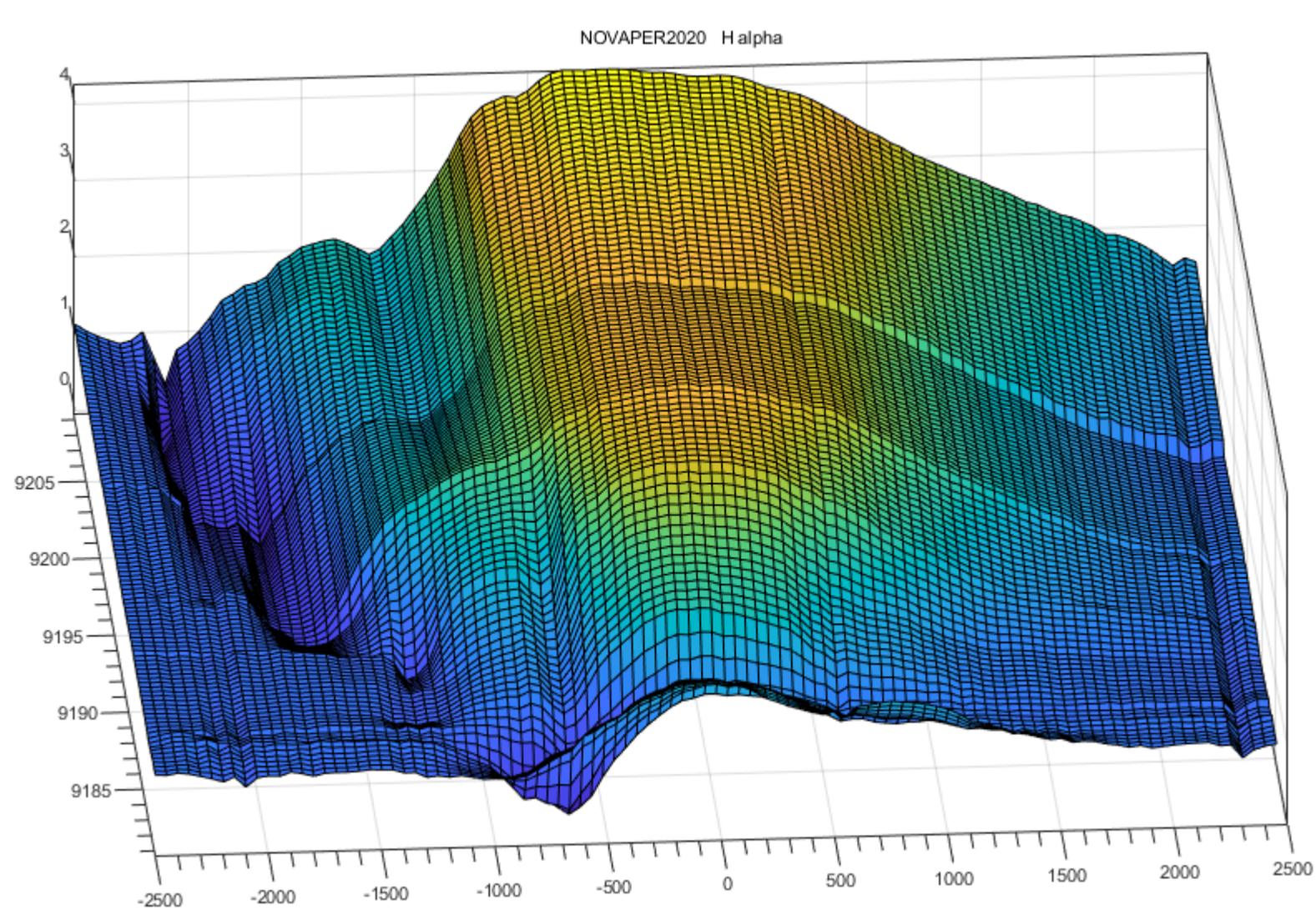
Nova Per 2020

H α



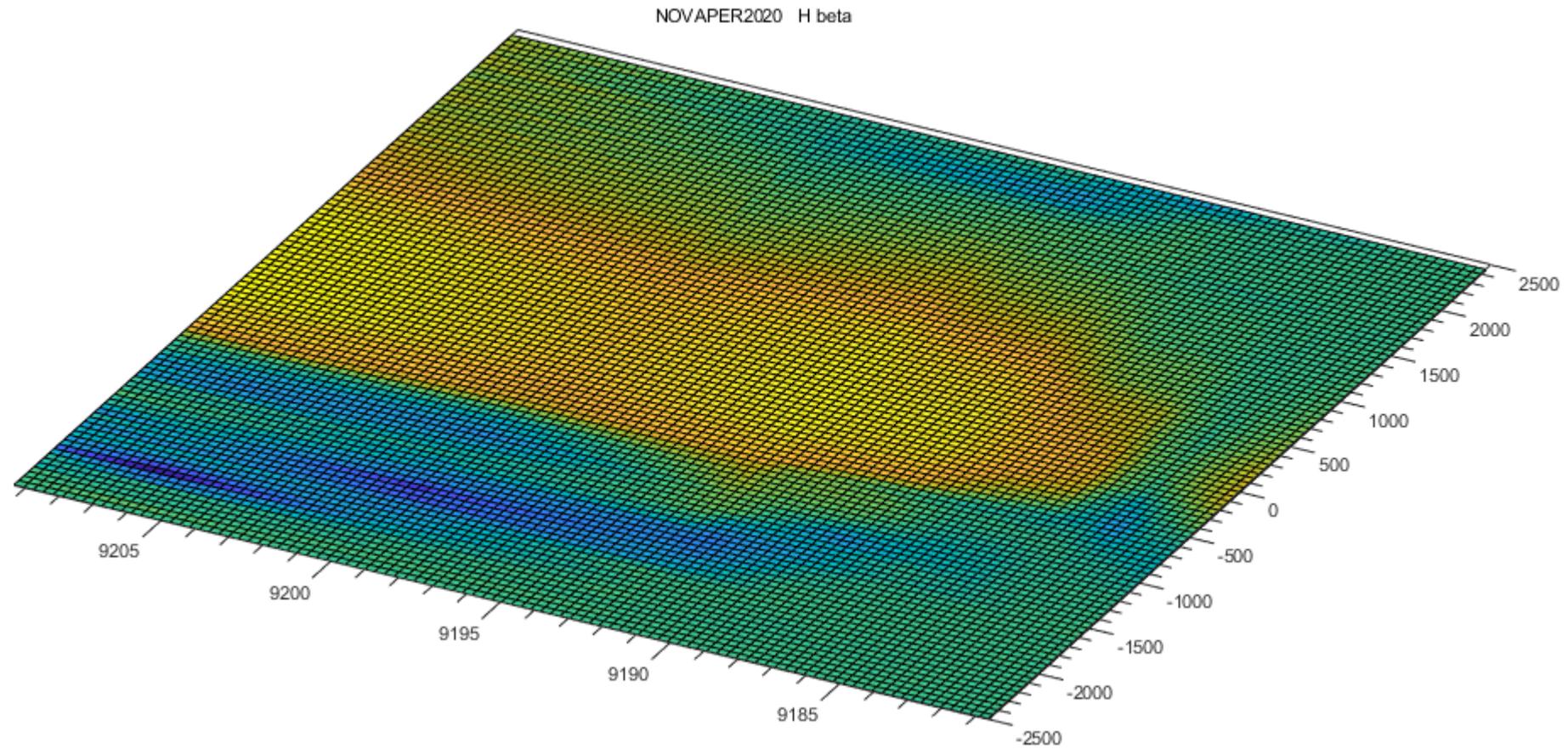
Nova Per 2020 H α

Echelle spectra (R = 10 à 14000) Olivier Garde, Stéphane Charbonnel, Joan Guarro, Tim Lester, Christian Buil, François Teysier



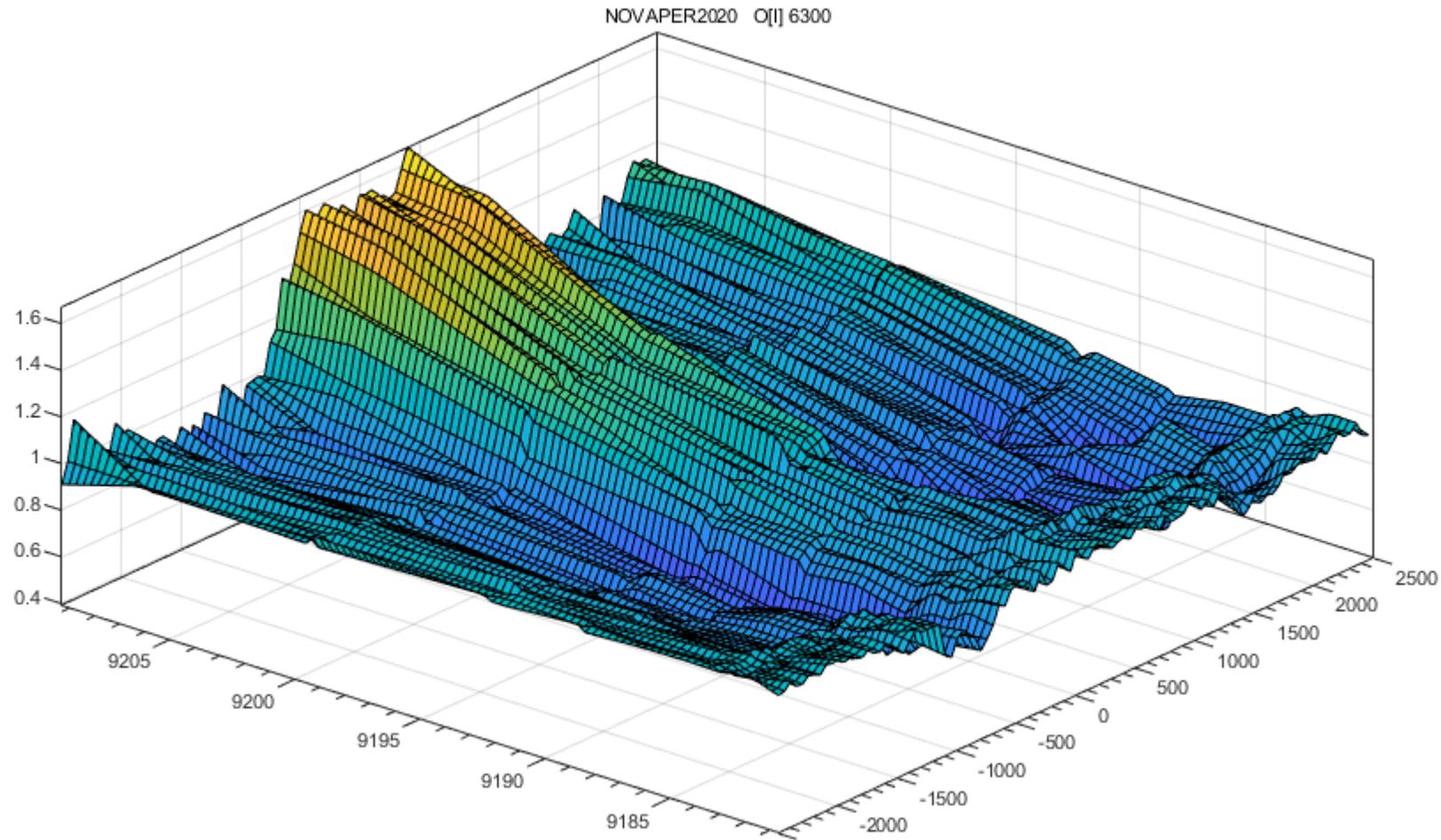
Nova Per 2020
H α

Echelle Spectra (R = 10 à 14000) Olivier Garde, Stéphane Charbonnel, Joan Guarro, Tim Lester, Christian Buil, François Teyssier



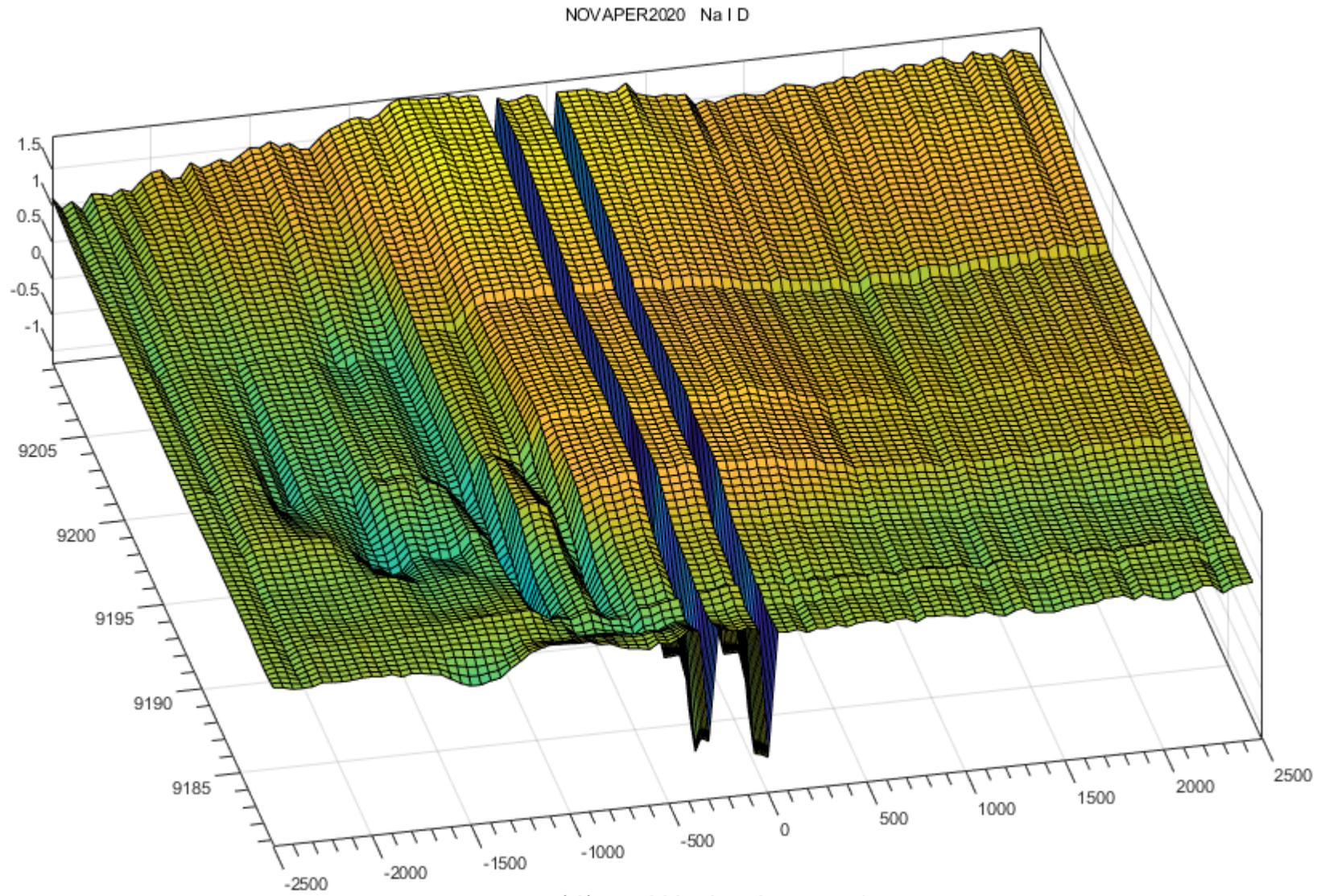
Nova Per 2020 H α

Echelle Spectra(R = 10 à 14000) Olivier Garde, Stéphane Charbonnel, Joan Guarro, Tim Lester, Christian Buil, François Teyssier

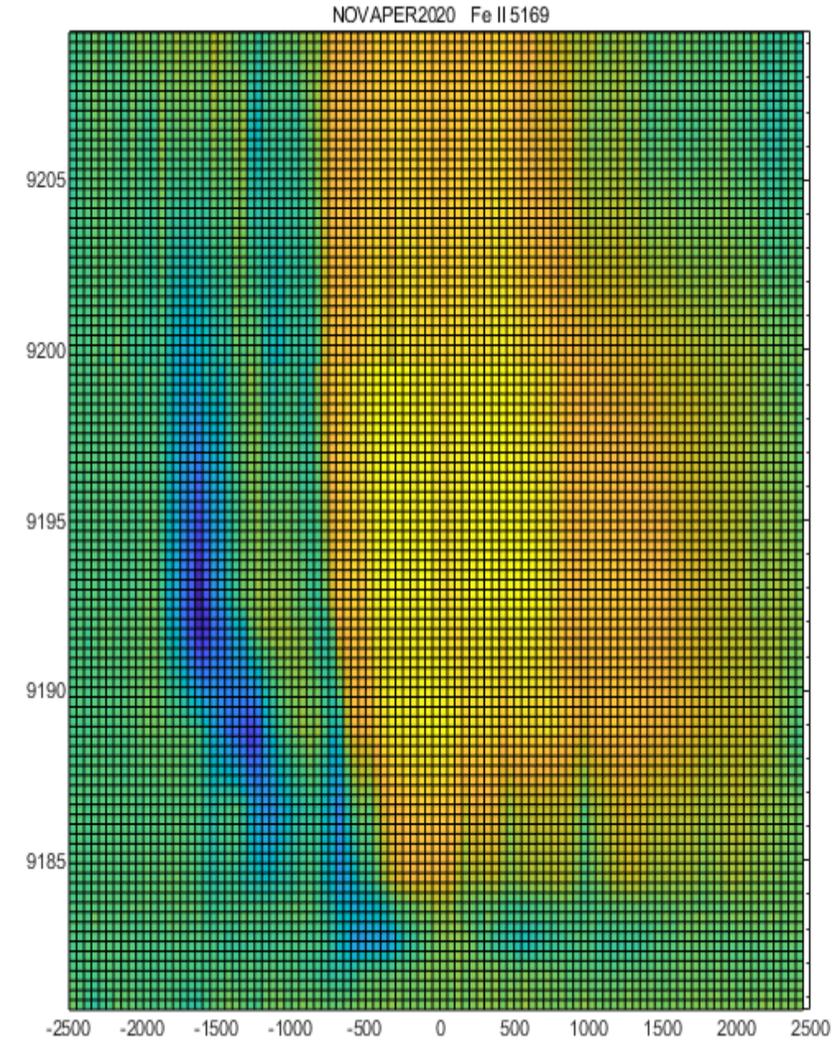
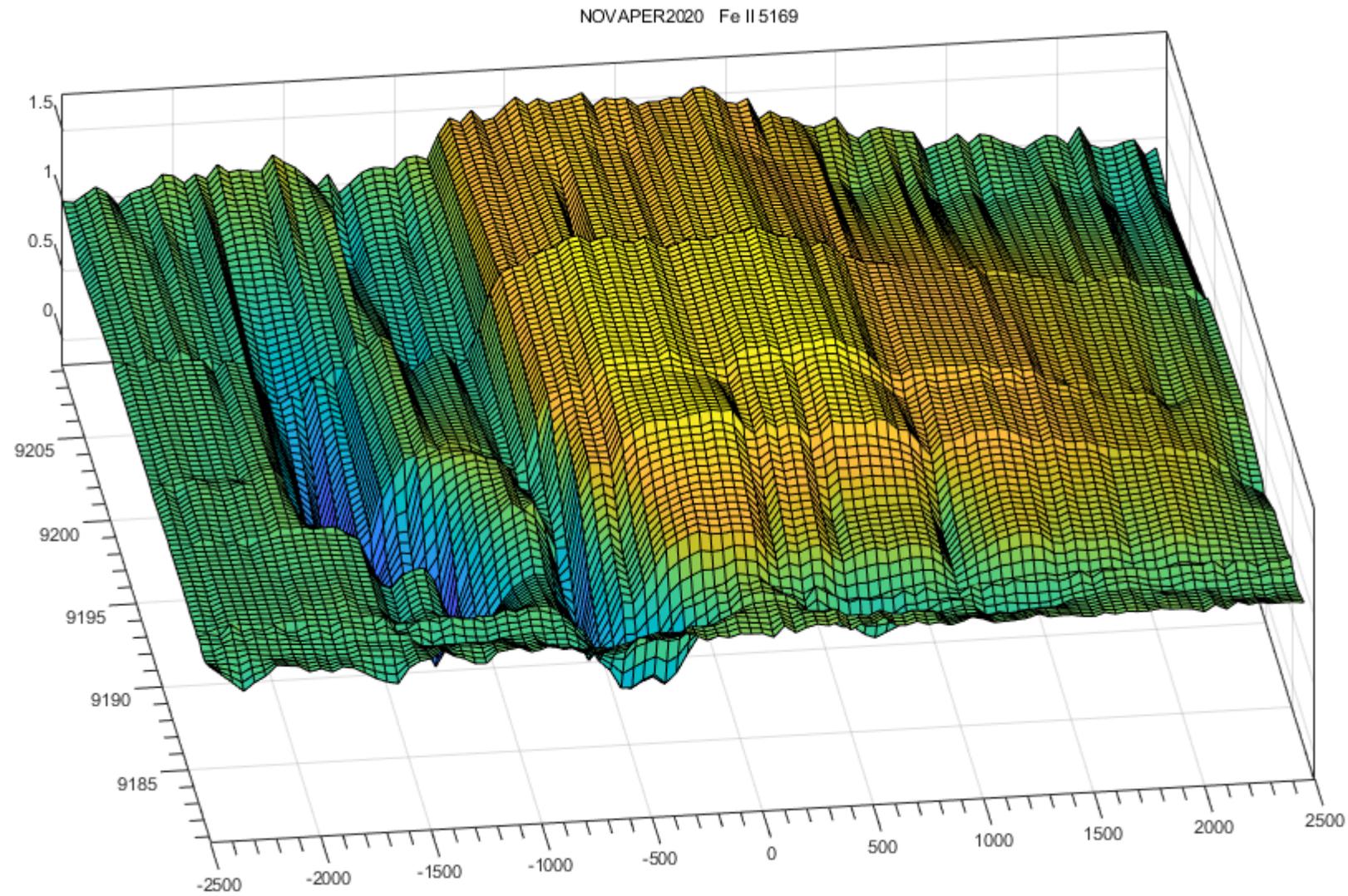


Nova Per 2020 H α

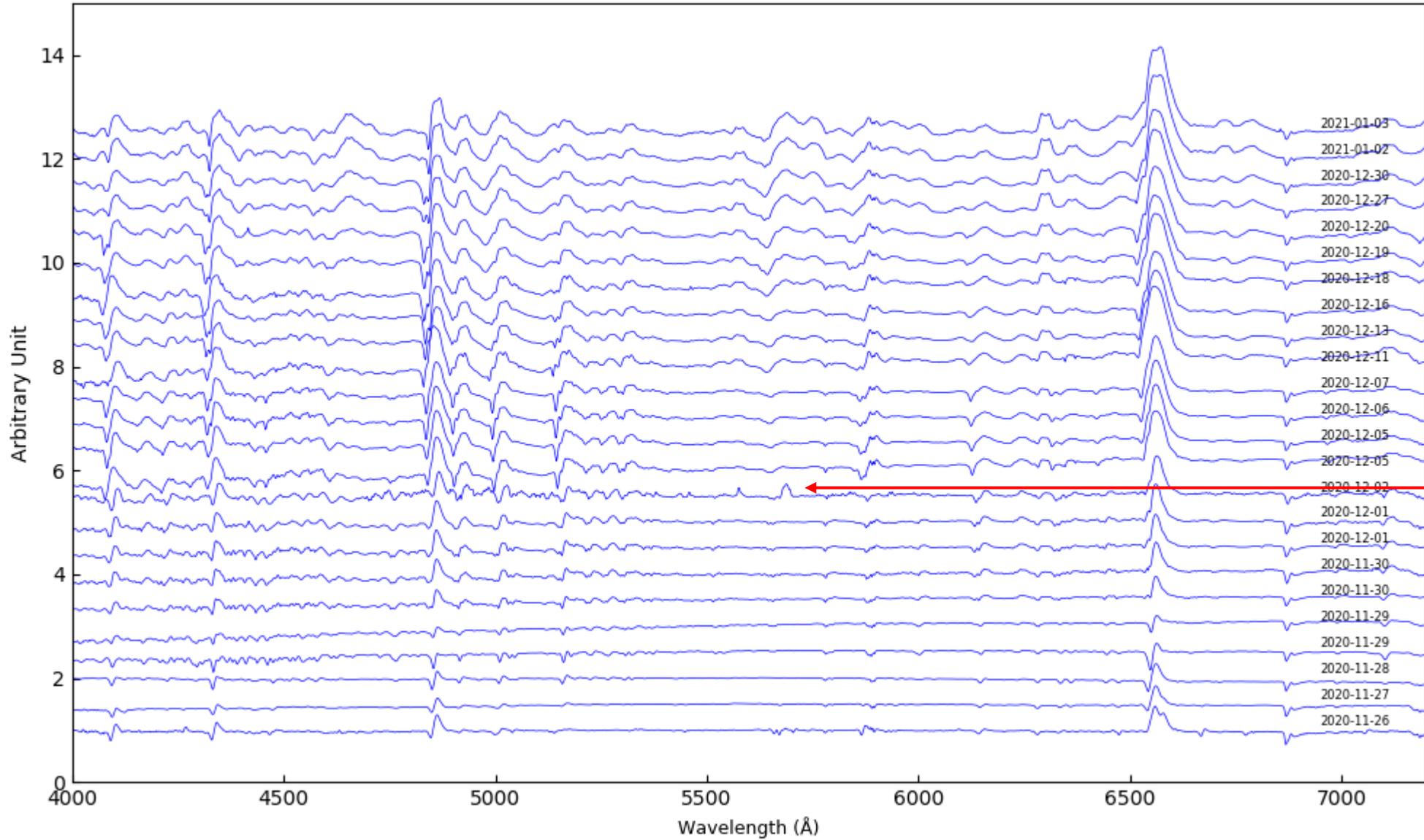
Echelle Spectra(R = 10 à 14000) Olivier Garde, Stéphane Charbonnel, Joan Guarro, Tim Lester, Christian Buil, François Teysier



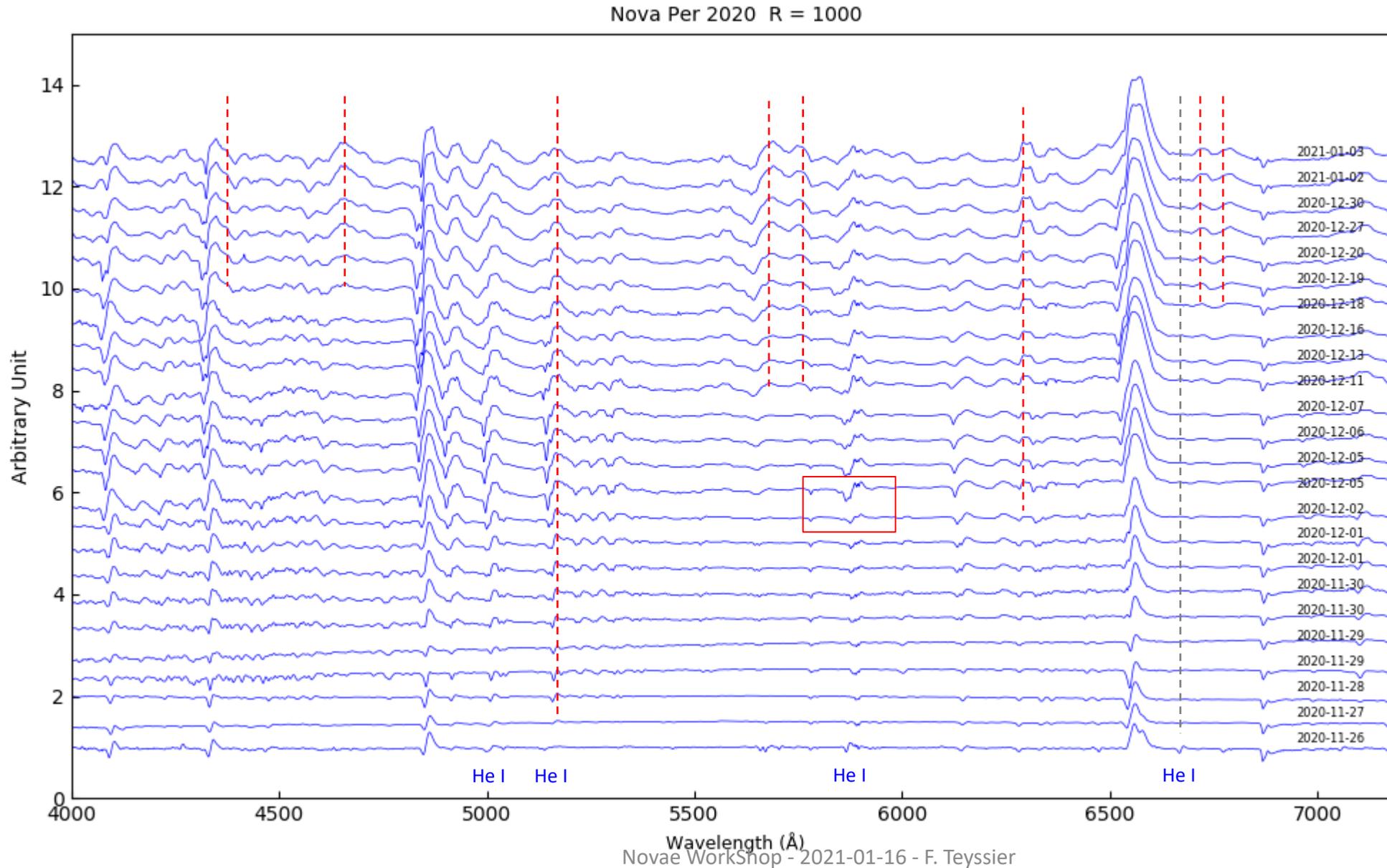
Identification des raies



Nova Per 2020 R = 1000

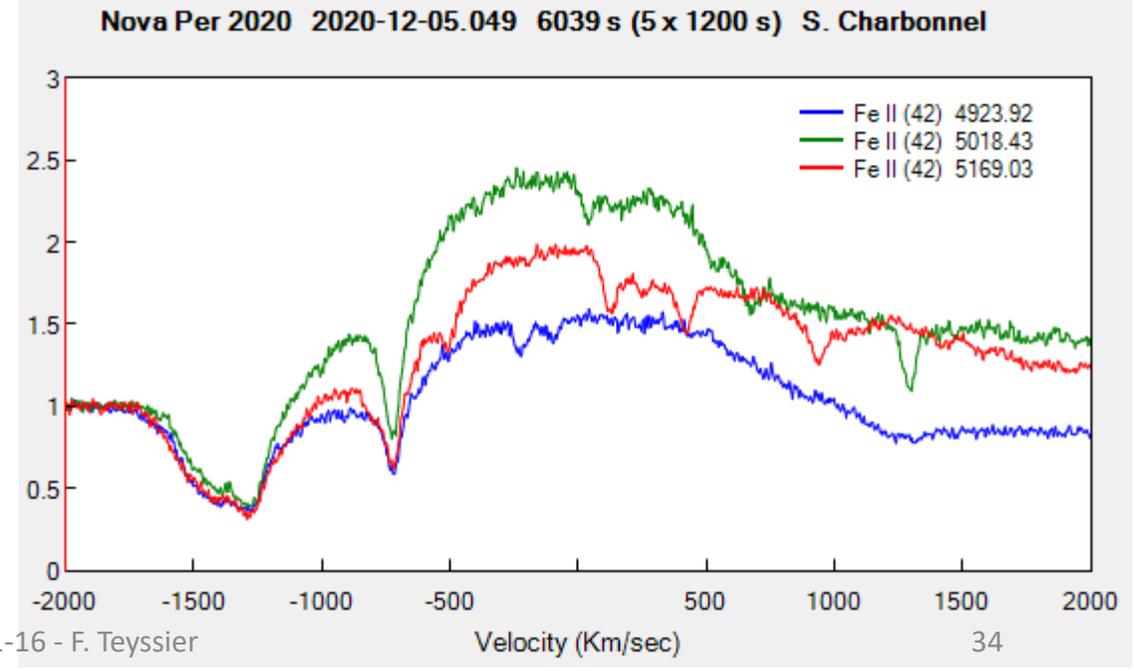
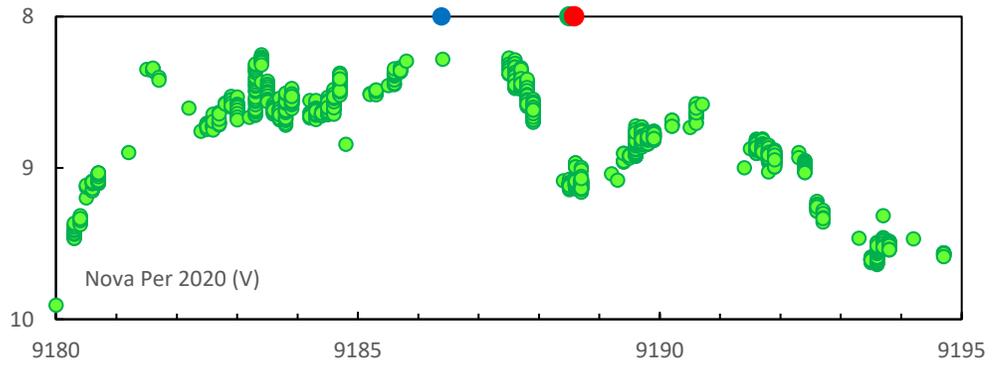
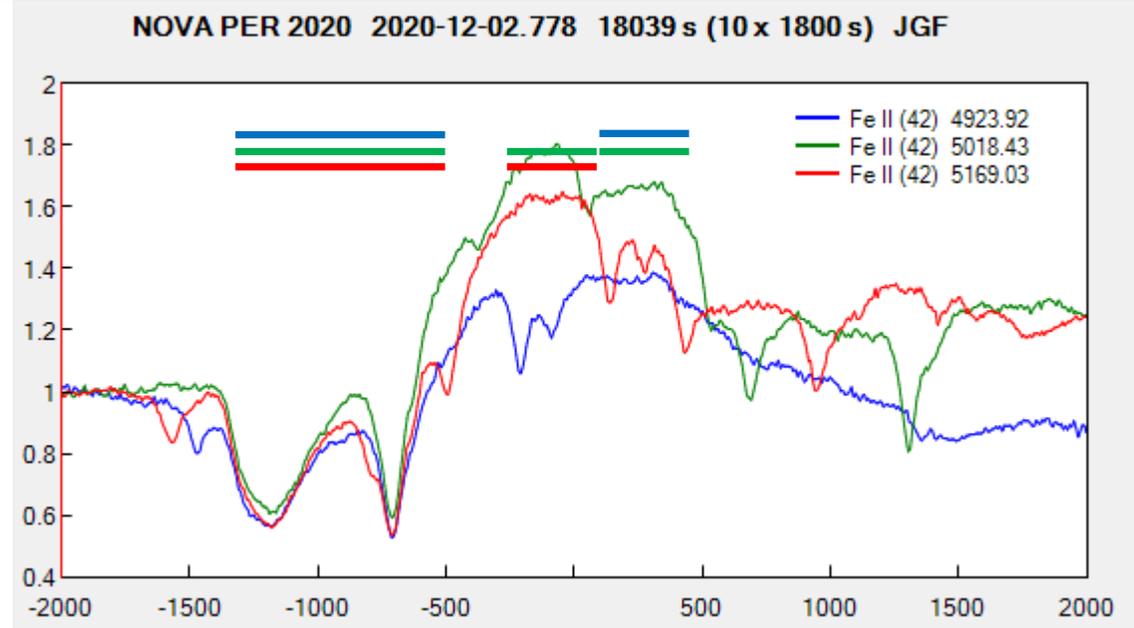
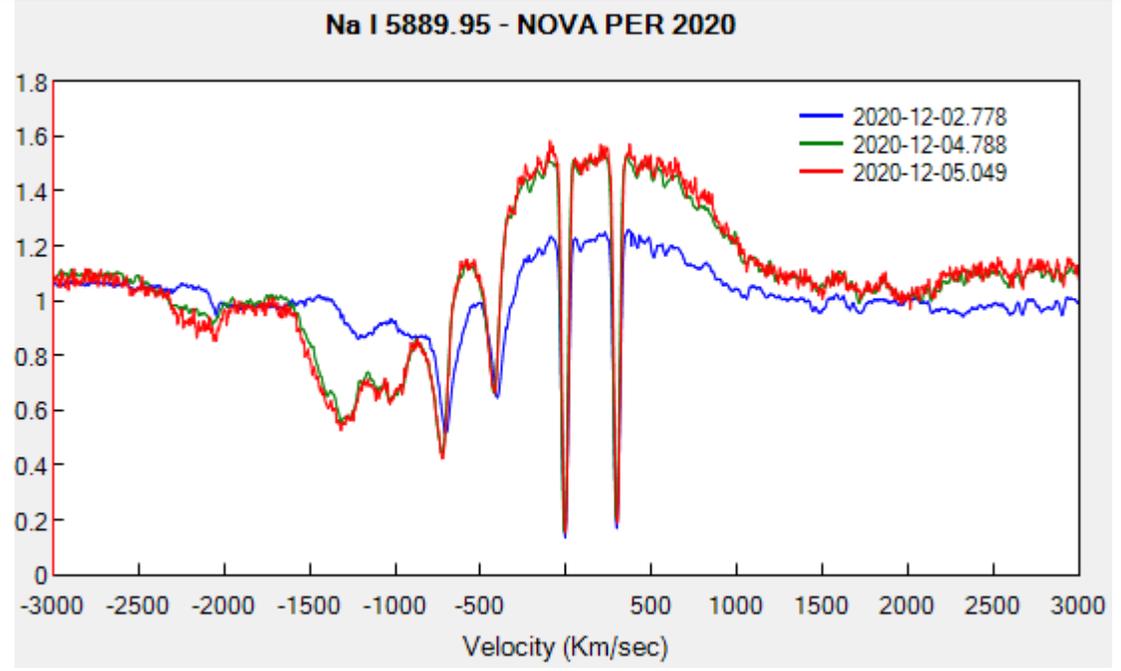


LISA R = 1000
Add Observers List



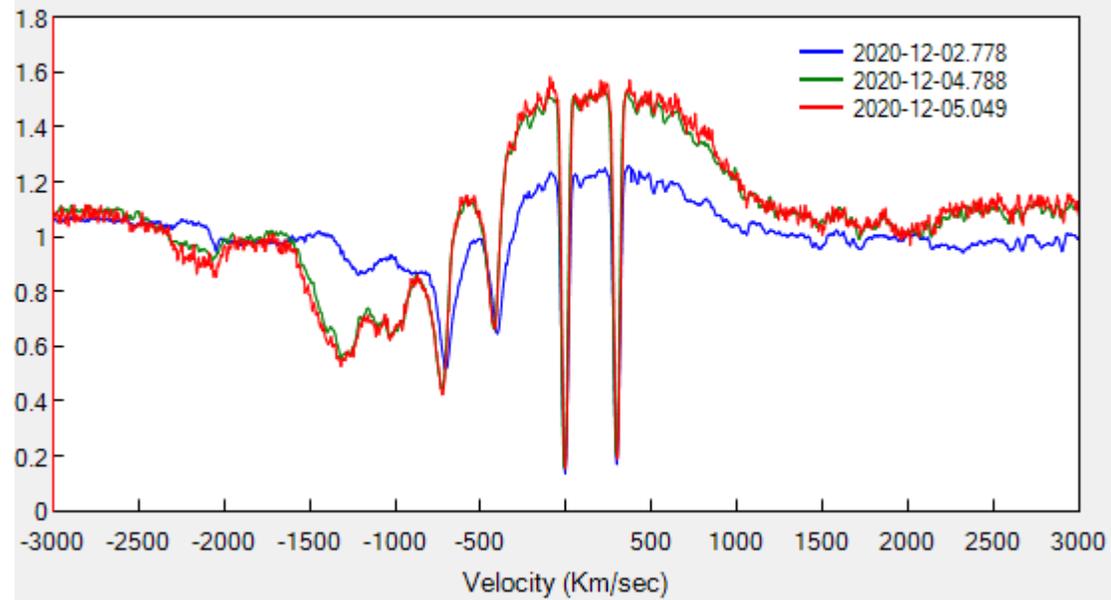
LISA R = 1000
Add Observers List

Novae Analysing the spectra

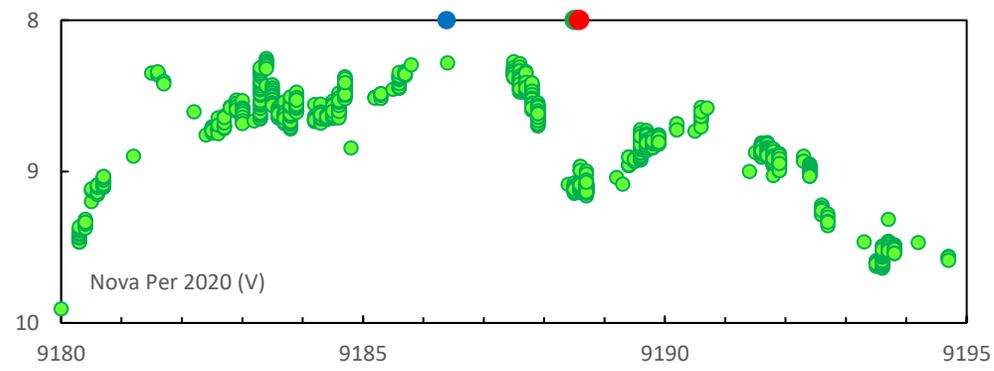
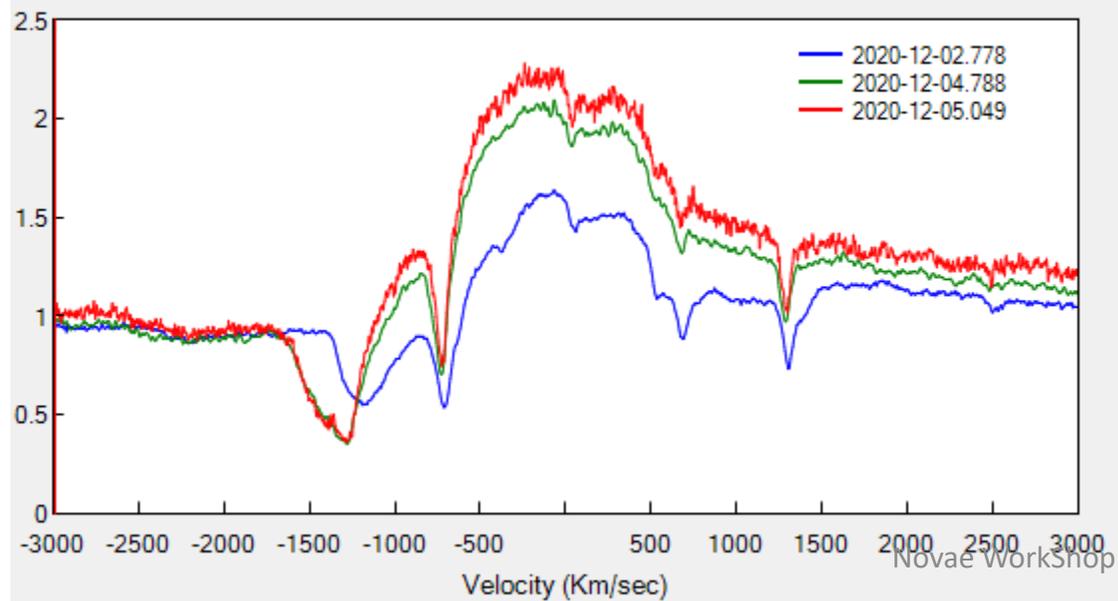


Right: the comparison of the lines of a multiplet allows tho determine what belong to the lines

Na I 5889.95 - NOVA PER 2020



Fe II (42) 5018.43 - NOVA PER 2020



Nova Per 2020

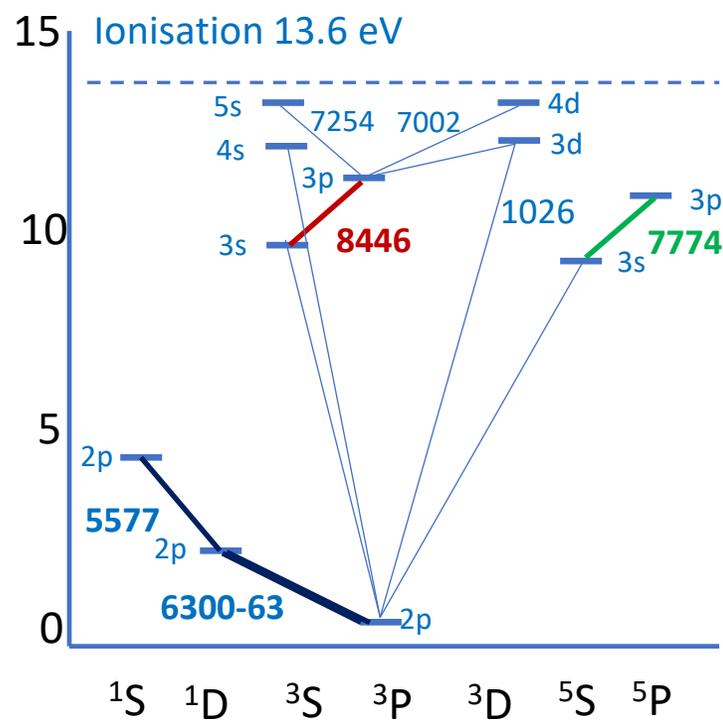
Oxygen

O⁰ OI EI = 13.6 eV

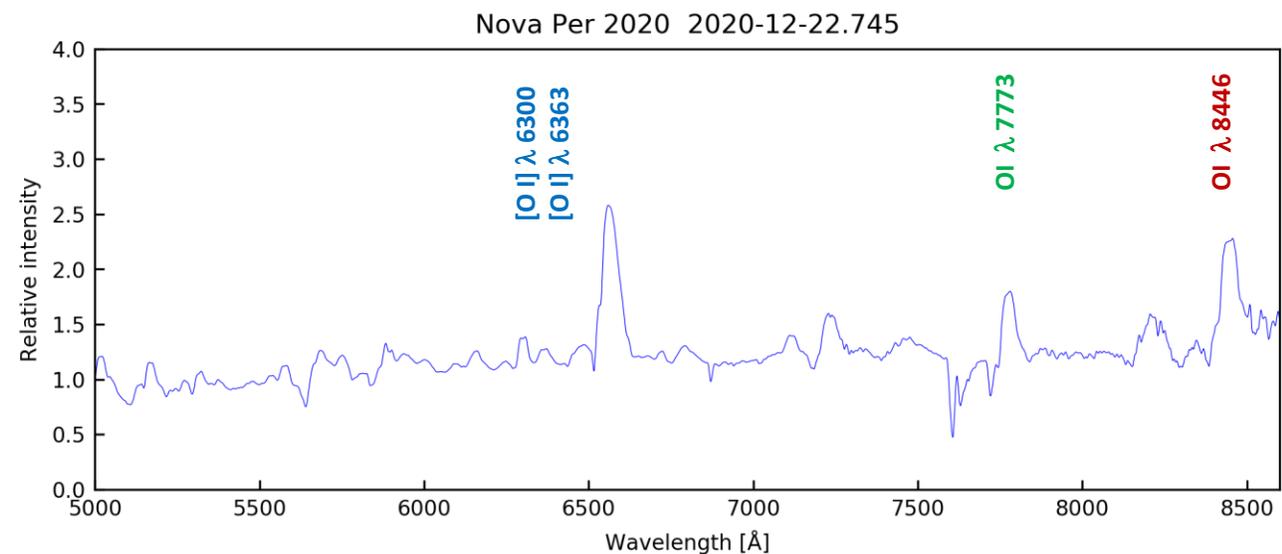
O⁺ OII EI = 35.1 eV

O⁺⁺ OIII EI = 54.9 eV

Raie	lambda (Å)
[O II]	3726.03
[O II]	3728.82
[O III]	4363.21
[O III]	4931.23
[O III]	4958.91
[O III]	5006.84
[O I]	5577.40
[O I]	6300.32
[O I]	6363.78
[O I]	6391.73
O I	7002.23
O I	7254.50
[O II]	7318.92
[O II]	7319.99
[O II]	7329.67
[O II]	7330.73
O I	7773.50
O I	8446.50



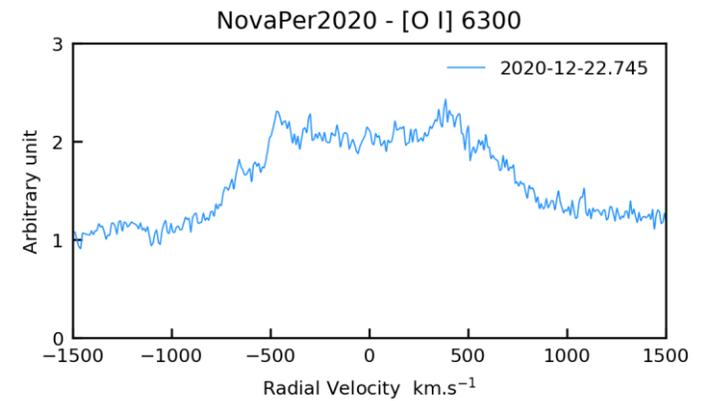
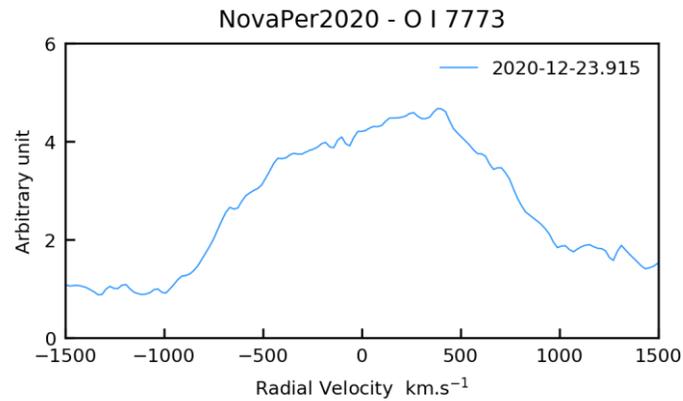
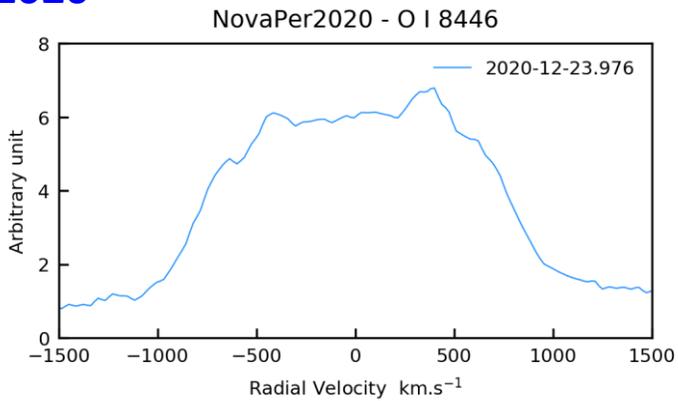
Singlets Triplets Quintets



Joan Guarro Echelle R = 10000
Gaussian filter + log scale

Nova Per 2020

O I



Transition

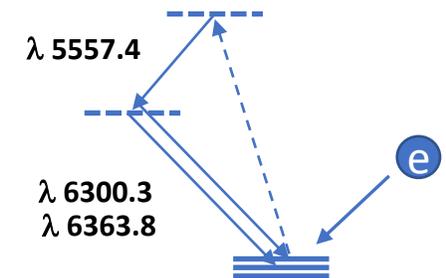
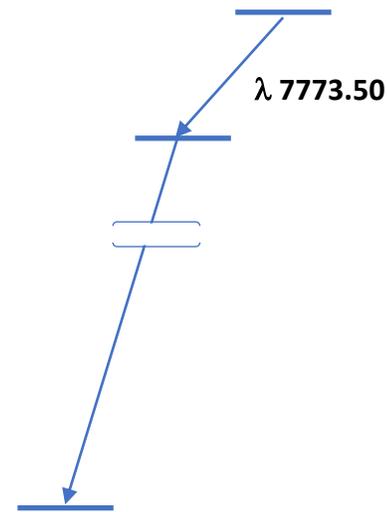
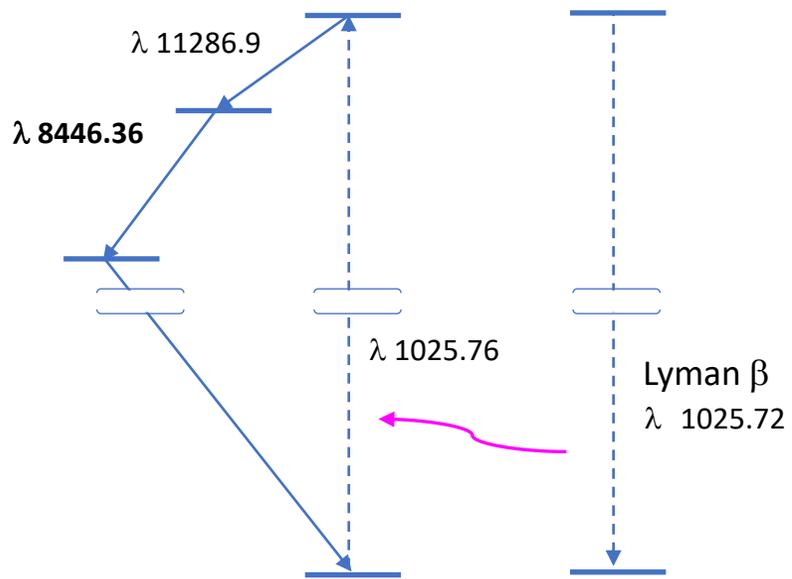
Physical conditions

O I
(O⁰)

H I
H⁰ H⁺

O I
(O⁺)

[O I]
(O⁰ N_e Weak)

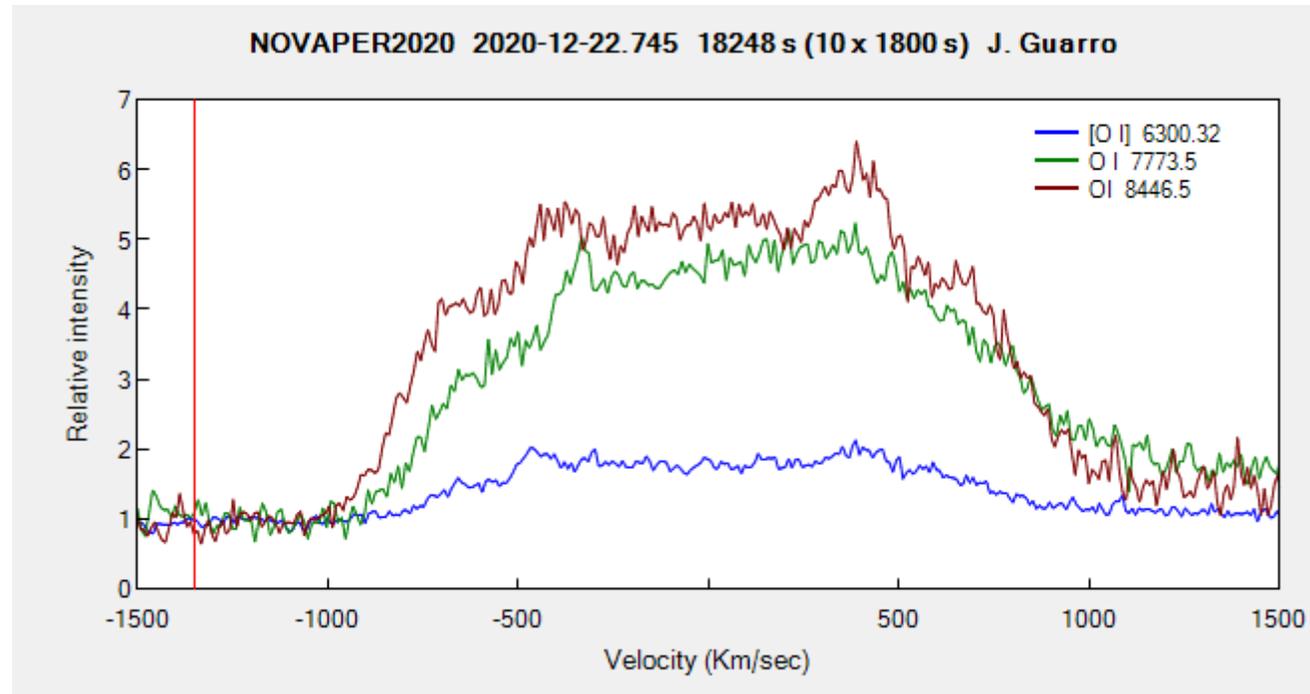


Main Process

Resonance-Fluorescence

Recominasion

Electronic Collision



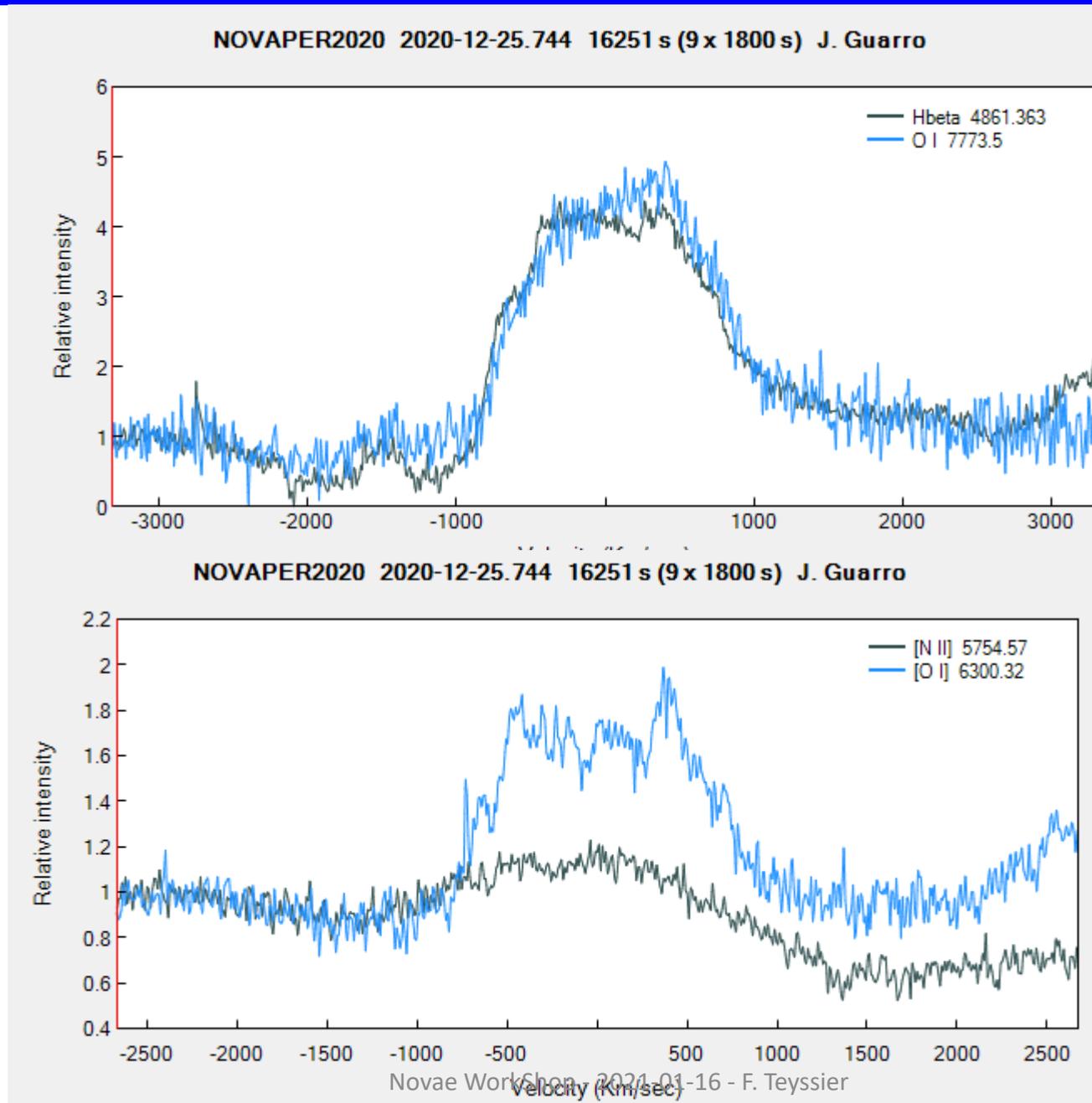
Nova Per 2020

O I

Iso-electronic sequence

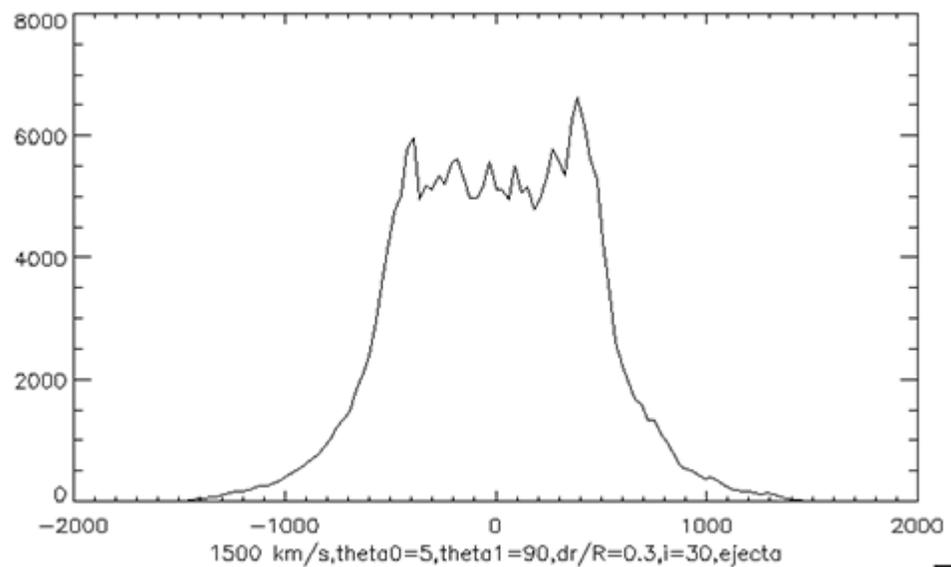
N II E.I. = 29.6 eV

O I E.I. = 13.6 eV

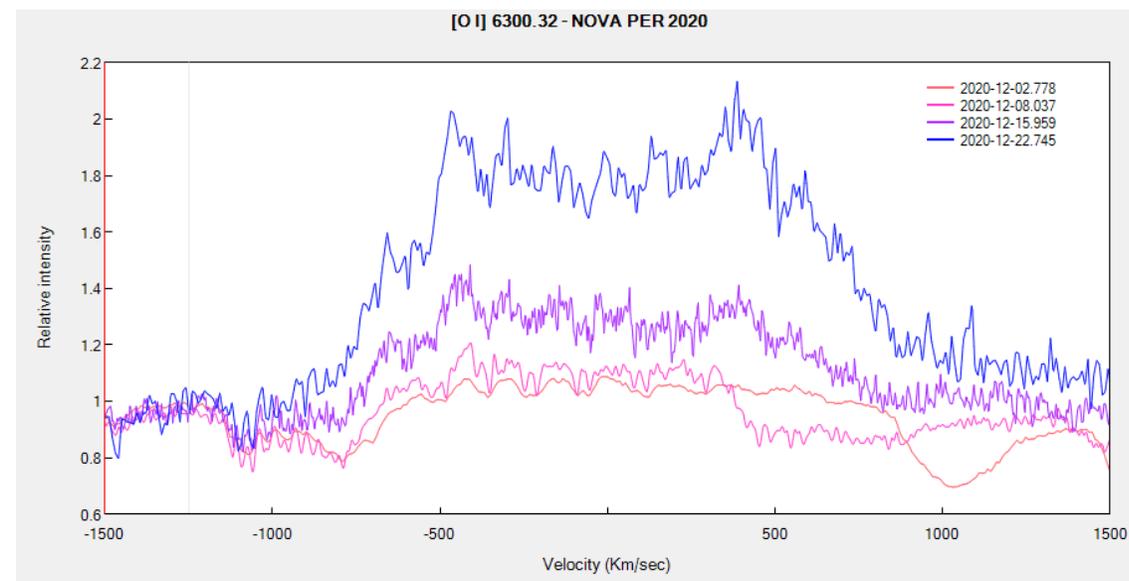


Nova Per 2020

O



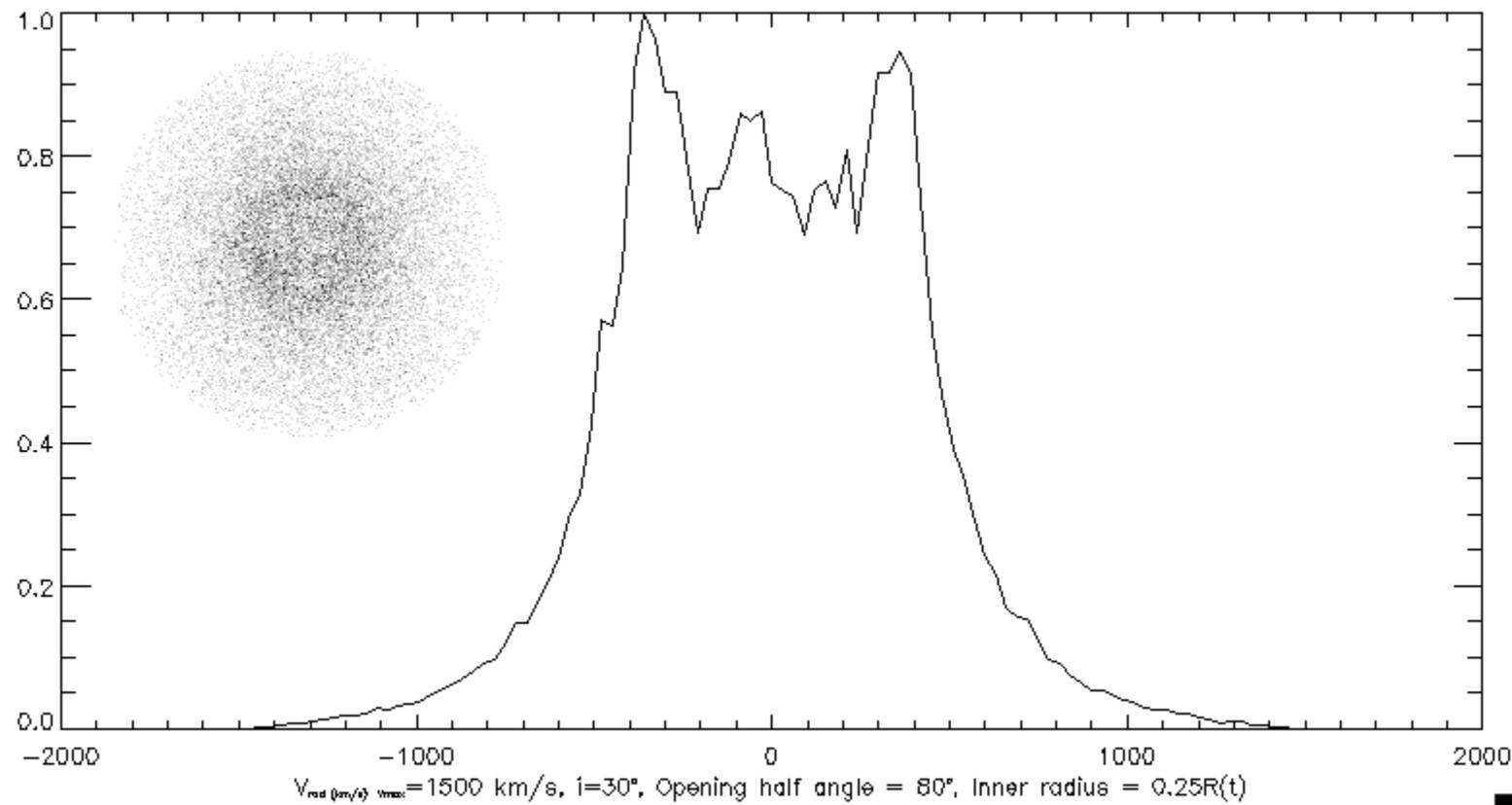
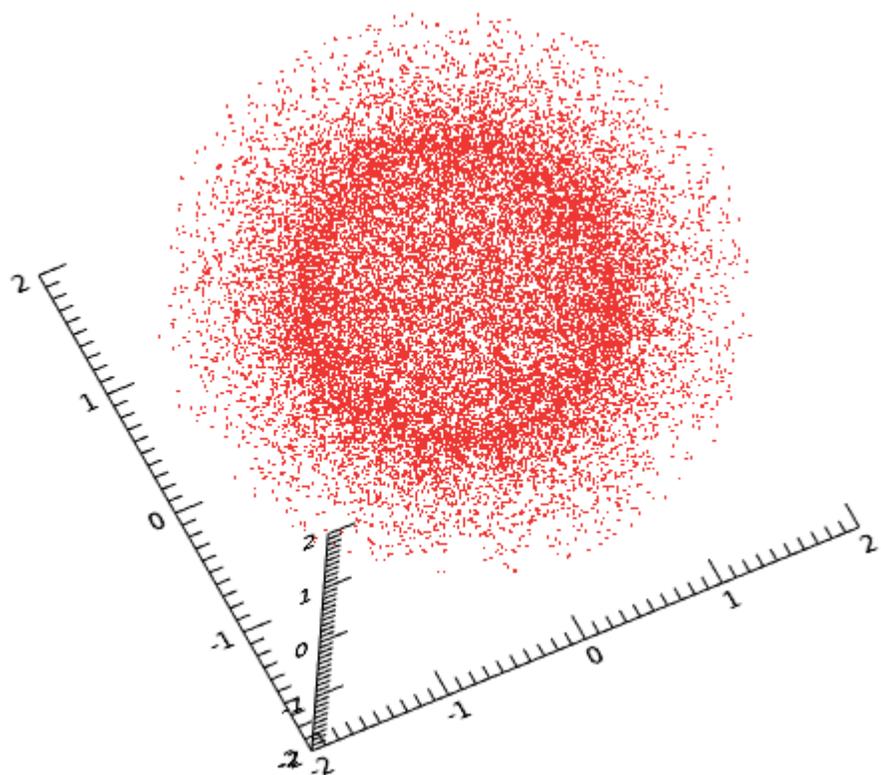
Model built by Steve Shore



Observations

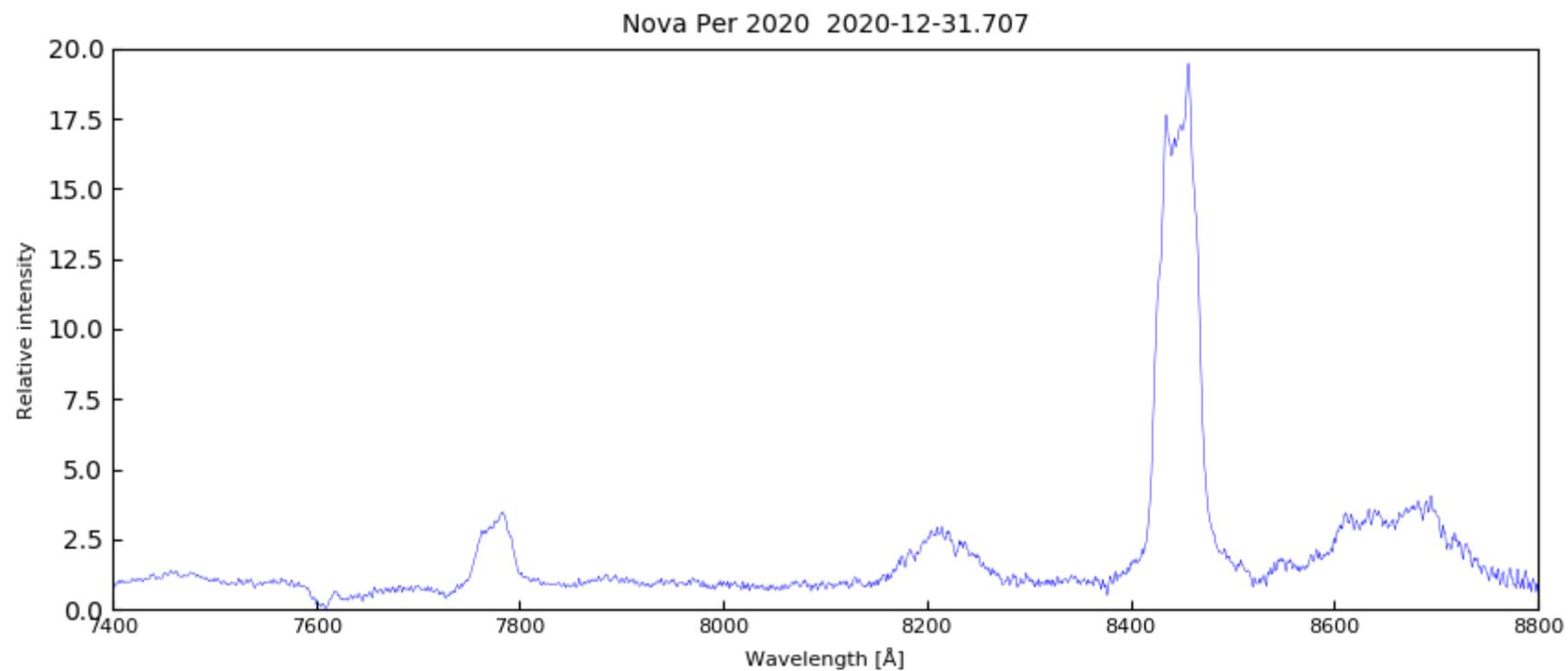
Nova Per 2020

O



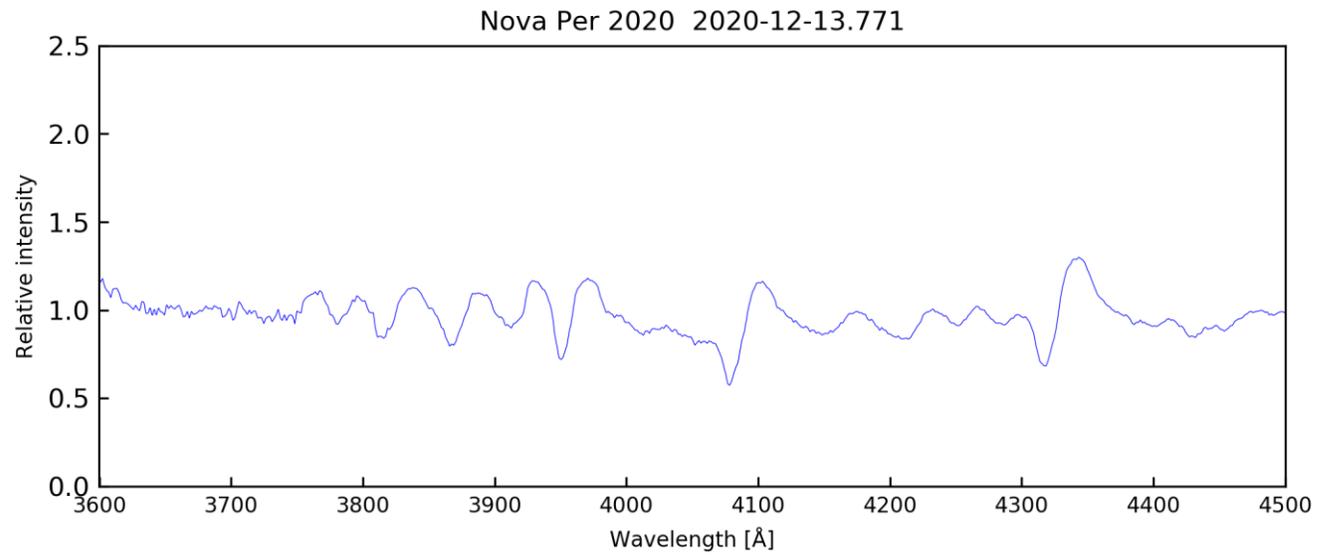
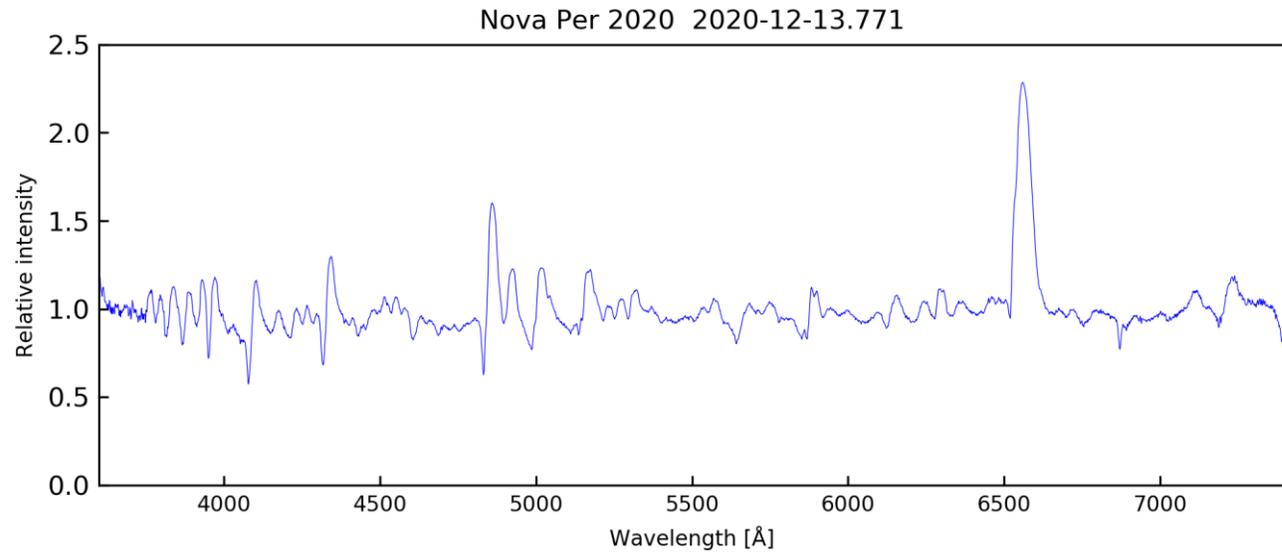
The ejecta modelized by Steve Shore

Spectres near IR Paolo Berardi, Umberto Sollechia, Robin Leadbeater



Spectre Umberto Sollechia Lhires III 600 l/mm R = 2400

Nova Per 2020
Proche UV



Pierre Dubreuil UVEX4

Nova Per 2020

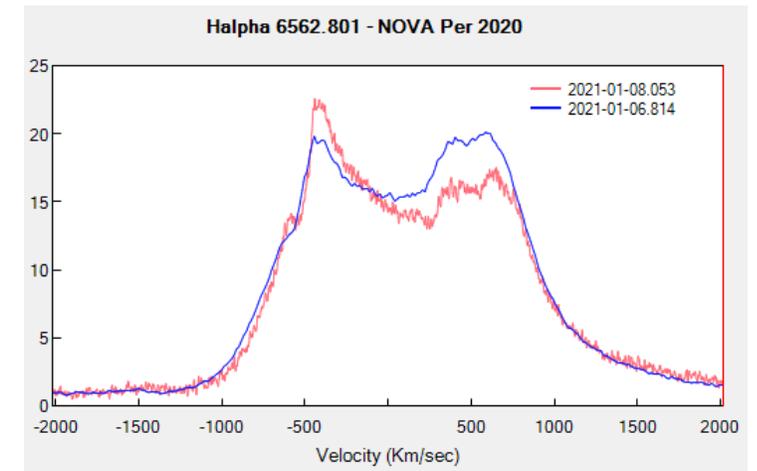
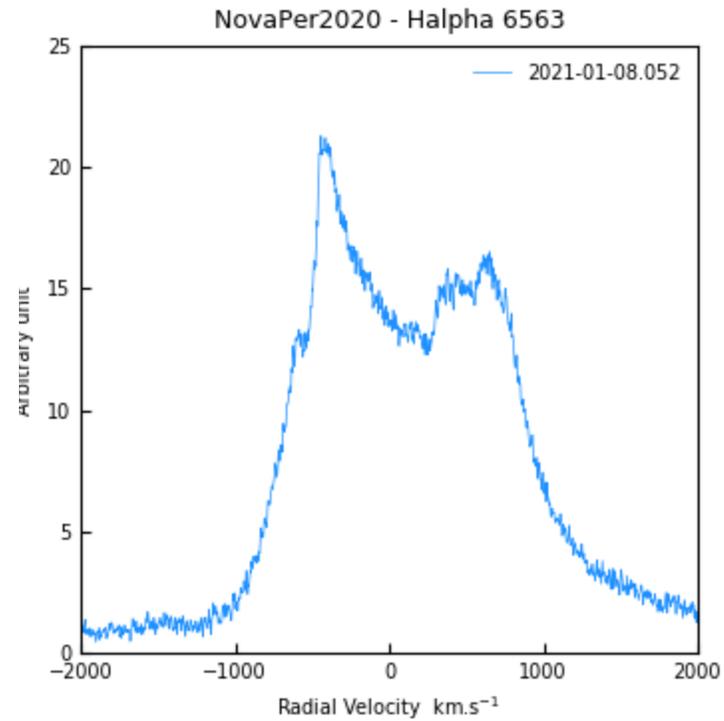
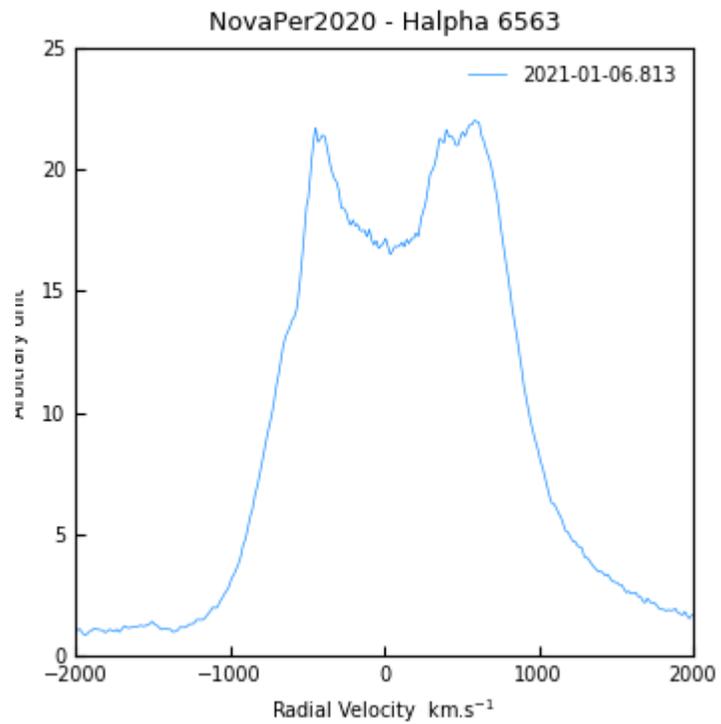
Low res current status

Forrest Sims Flux calibrated (V =)LISA R = 1000

Add last variations

Nova Per 2020

Derniers profiles H alpha



A.R.A.S Spectral Data Base

Novae

Aras Data Base

Number of stars 46
 Number of spectra 2756

send spectra to francoismathieu.teyssier at gmail.com
 and a copy to arasdatabase@gmail.com

#	Name	AD (2000)	DE (2000)	Nb. Of spectra	First spectrum	Last spectrum	Comments
0	V838 Mon			5	24/03/2017	02/11/2019	Red nova
1	V407 Cyg						Symbiotic nova
2	Nova Mon 2012			56	14/08/2012	06/05/2013	ONe nova
3	Nova Cep 2013			11	03/02/2013	15/02/2013	
4	VVV-NOV-003			15	21/07/2013	11/06/2014	Symbiotic nova
5	Nova Del 2013			1152	14/08/2013	15/09/2015	Bright nova Mag 4.3
6	Nova Cen 2013			160	05/12/2013	25/04/2020	Bright nova Mag 3.3
7	Nova Sgr 2014			2	02/03/2014	08/03/2014	
8	Nova Cep 2014			15	10/03/2014	23/05/2014	
9	Nova Cyg 2014			215	03/04/2014	27/06/2015	Peculiar light curve

+ ARAS observations in the web pages built by Christian Buil

ARAS Symbiotics Program

AG Draconis

RA (2000): 16 01 41.012
 DEC (2000): +66 48 10.131
 V (mag): 7.9 - 10.3

[New Online Database of Symbiotic Variables](#)

[SIMBAD](#)

Number of spectra: 675

First spectrum: 2013-04-03

Last spectrum: 2020-06-27

send spectra to [francoismathieu.teyssier \[at\] bbox.fr](mailto:francoismathieu.teyssier@bbox.fr)

Ongoing campaign

Orbital variations in low state upon the request of Jaroslav Merc & Rudolf Gális.

Search:

Date	Time (UT)	JD	Observer	Site	Resolution	λ_{\min}	λ_{\max}	File	Preview
2013-04-03	1:47	56385.584	BUI	CAS-FR	613	3782	7575	↓	👁
2014-03-20	0:46	56736.539	JMO	OLC-FR	610	3910	7380		
2014-03-23	22:44	56740.476	DBO	WCO-UK	663	3700	7550		
2014-03-23	23:27	56740.491	BUI	CAS-FR	665	3603	8698		
2014-03-28	22:51	56745.474	OGA	OTO-FR	702	3602	7599		



Eruptive stars spectroscopy

Cataclysmics, Symbiotics, Novae



Eruptive Stars

Information Letter n° 41 #2019-01 18-05-2019

Observations of Jan. - Mar. 2019

Main results in a quaterly newsletter

Produced by François Teyssier, David Boyd, Forrest Sims

46 issues downloadable: <http://www.astrosurf.com/aras/novae/InformationLetter/InformationLetter.html>

Indexed in NASA/ADS since January, 2019

Education of the observers:

With notes from

Steve Shore

Agustin Skopal, Natalia Shagatova

Rudolf Gális, Jaroslav Marc, Leedjarv

Margarita Karovska

....

Spectroscopic observations of novae in 2019-Q3

Show affiliations

Teyssier, F.; Boyd, D.; Sims, F.; Bohlsen, T.; Luckas, P.; Sollecchia, U.; Guarro, J.; Cazzato, P.; Dubovsky, P.; Garde, O.; Arlic, G.; Leveque, M.; Souchu, J.; Nougayrede, J. P.

2 classical nova events were observed during 2019-Q3: Nova SMC 2019 and nova Ori 2019. One spectrum of nova Sgr2015b in nebular phase, 4 years after its outburst. The recurrent symbiotic nova V3890 Sgr were observed along its third recorded outburst. 61 spectra were obtained from the peak of the outburst to magnitude 15.

Publication: Eruptive Stars Information Letter, vol.43, p. 2-18

Pub Date: December 2019

Bibcode: [2019ESIL...43...2T](#)

Keywords: Techniques: spectroscopic; Astronomical data bases; novae

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Merci à tous les observateurs qui ont contribué à accumuler plus de 2000 spectres de novae, avec une pensée particulière pour nos collègues de l'hémisphère sud, Terry Bohlsen, Paul Luckas, Colin Elridge.

Un grand merci à Colin Elridge pour son magnifique spectre échelle de CN Cha
Thank you to the professional teams who trusted us and used our spectra for their research and publications.

Thank you to them for respecting the rules for using the spectral base.

I would therefore like to thank, instead of Aydi + (2020):

R. Marcon, T. Napoleo, Terry Bohlsen, Joan Guarro, Christian Buil,

**which should have been done in this publication*.*

English workshop 2021-01-16 on youtube

Introduction to the Theory of Novae

<https://www.youtube.com/watch?v=Peo8w6j0jhc>

Analysing Nova Per 2020 spectra

<https://www.youtube.com/watch?v=CUHJBnh8QnA>

List of Observers of Nova Per 2020

Paolo Berardi
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Matthieu Le Lain
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Olivier Garde
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Antonino Ventura
Thierry Garrel
Pierre Dubreuil