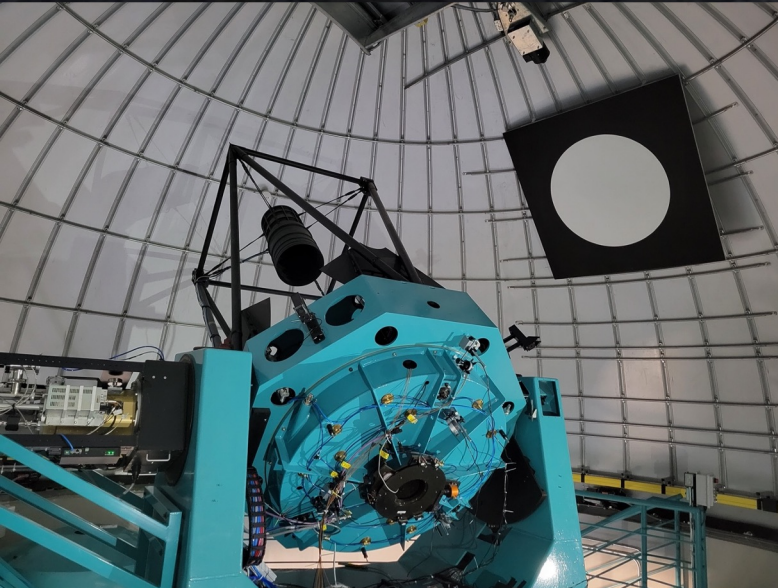


Equivalent widths and Bouguer lines (airmass-extinction curves)



Sylvie Dagoret-Campagne*, Jérémy Neveu, Marc Moniez,
Laurent Le Guillou, Martin Rodriguez Monroy
Dominique Boutigny (computing with DM-stack@CC)
IJCLab & LPNHE @ IN2P3-CNRS

LSST France, Annecy, May 16-18, 2022

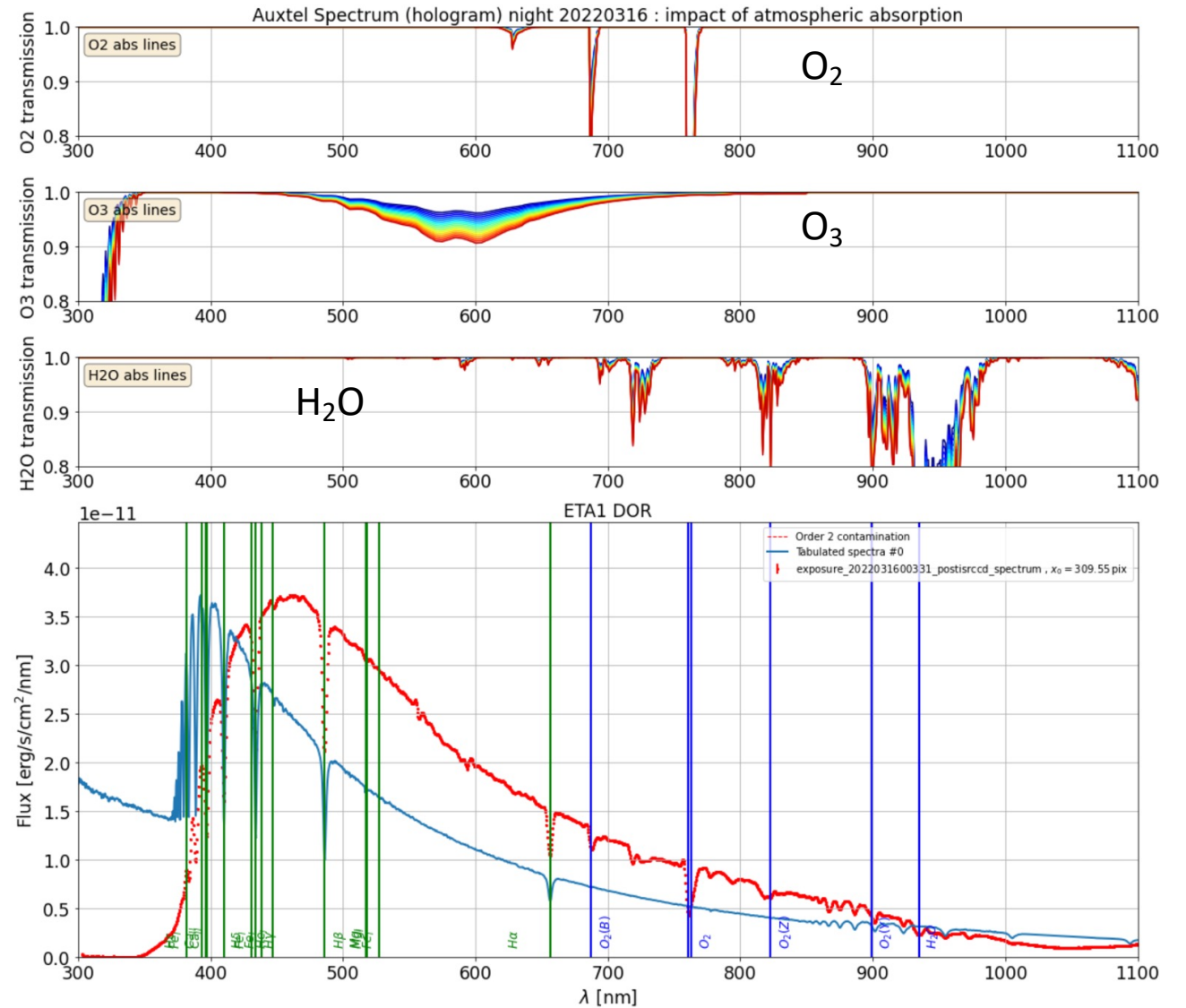
Outline of the talk

- **March 2022 data : dedicated to Equivalent width and airmass effect**
 - Night 03/16 : target ETA1DOR (bright standard)
 - Nice stellar absorption lines
 - Night 03/17 : target MuCOL (bright standard)
 - large range in airmass
- **Effect of atmospheric extinctions**
 - Equivalent width
 - Extinction lines

ETA1 DOR ($V = 5.6$ mag)

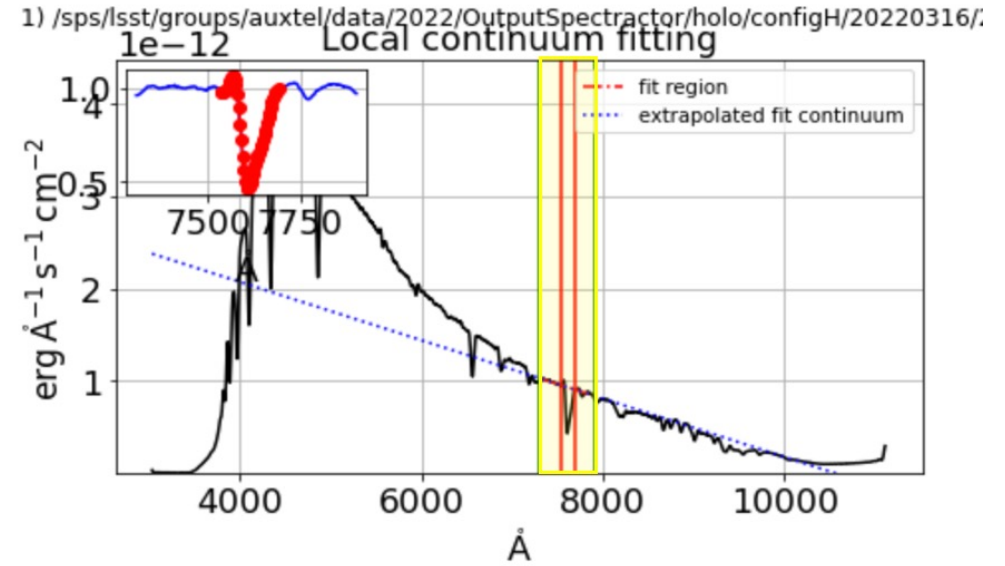
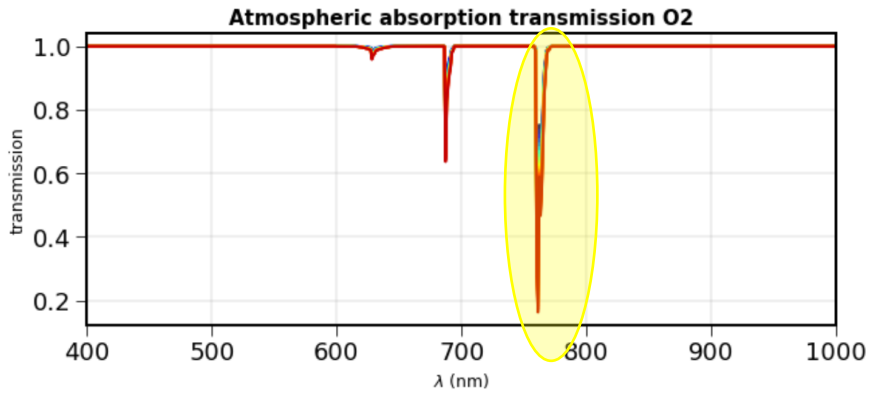
Libradtran atmospheric
transparency simulation
absorption pattern
(Rayleigh scatt and aerosols
scatt)

ETA1DOR spectrum
(reconstructed with
Spectractor)

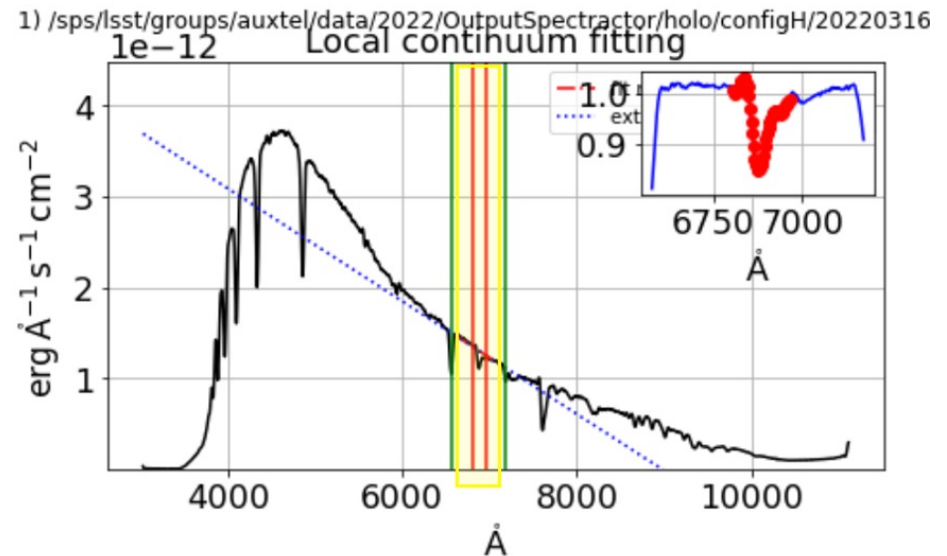
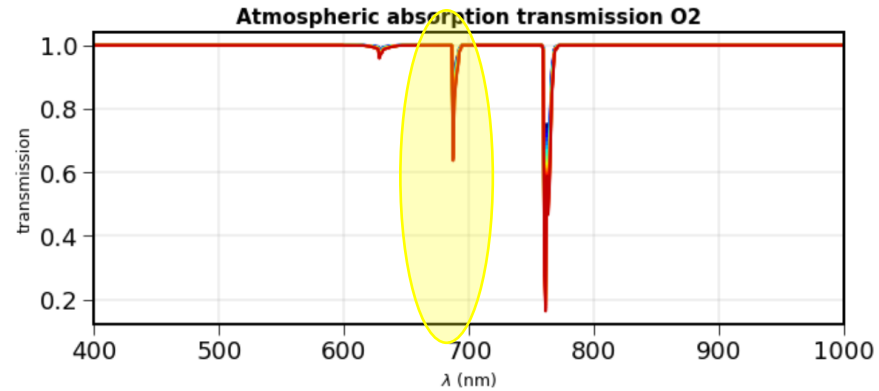


Examples of Equivalent width measurement for O₂

O₂(λ ~760 nm) absorption line

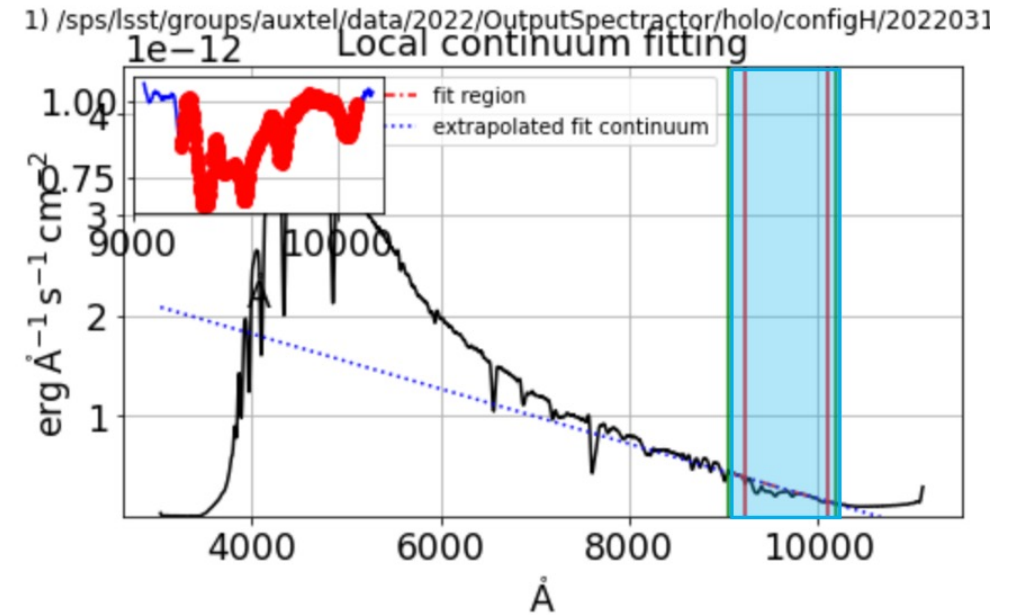
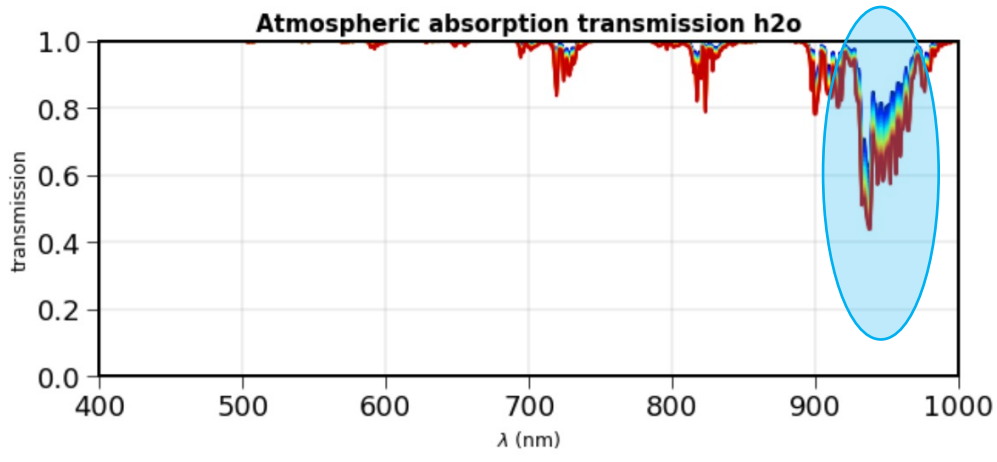


O₂B(λ ~687 nm) absorption line



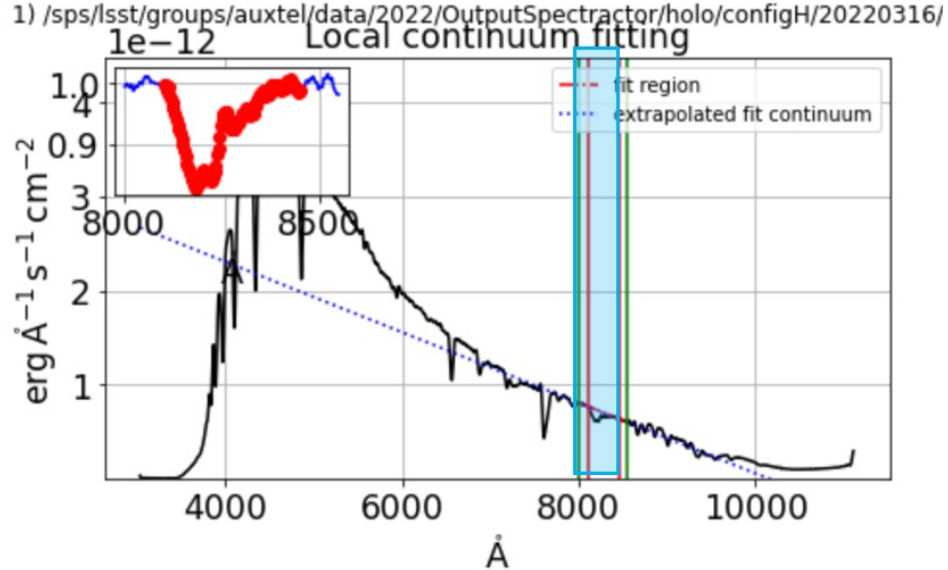
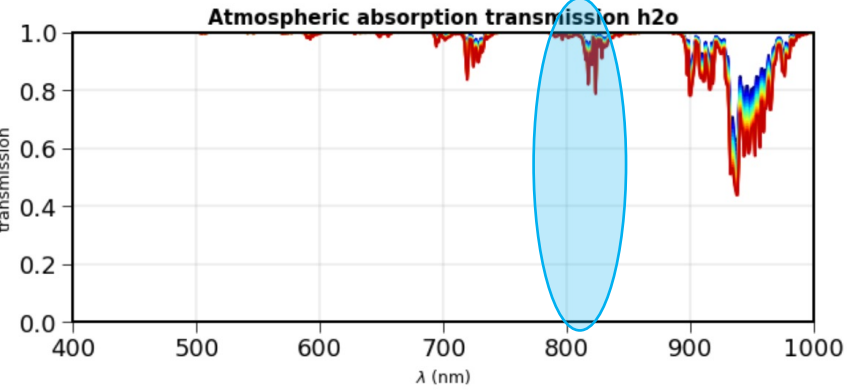
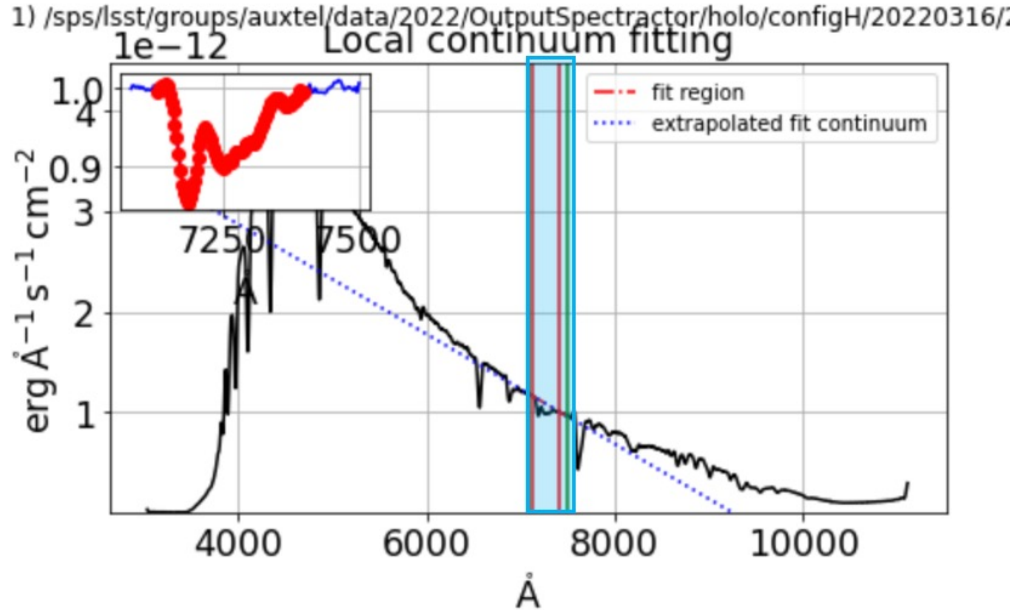
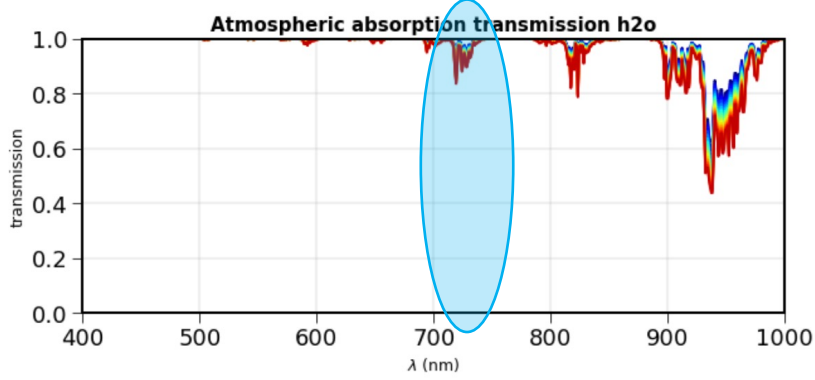
Examples of Equivalent width measurement

H₂O($\lambda > 900$ nm) absorption line

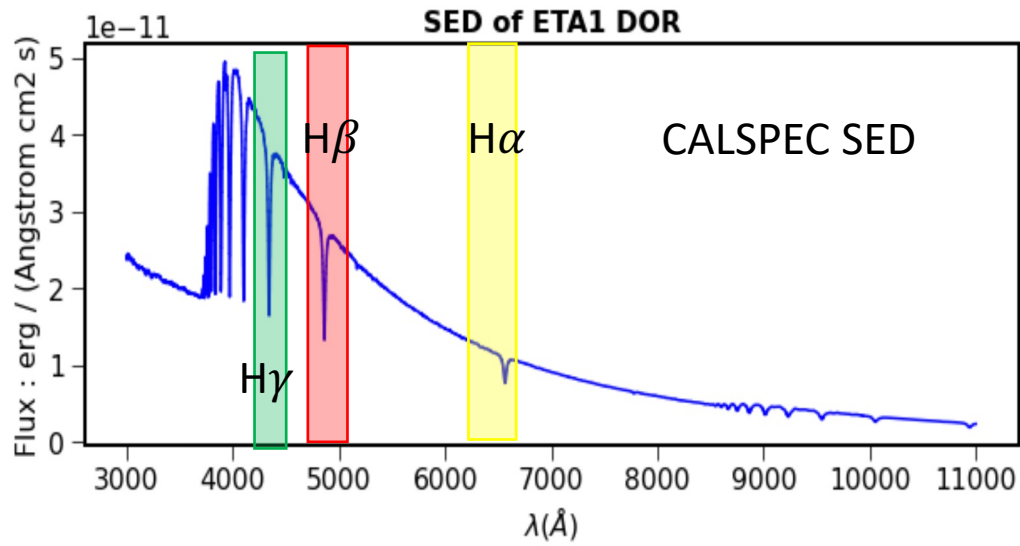


But very small signal/noise ratio due to low CCD transmission at $\lambda > 900$ nm

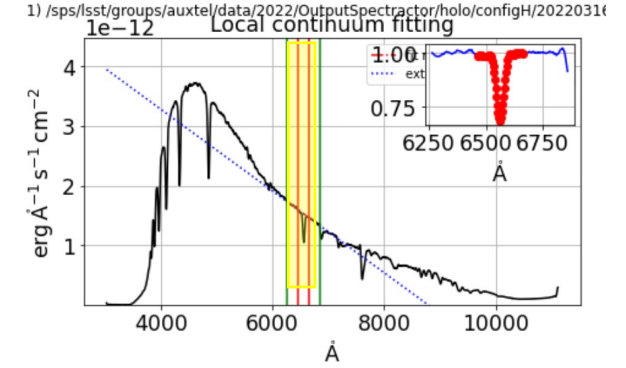
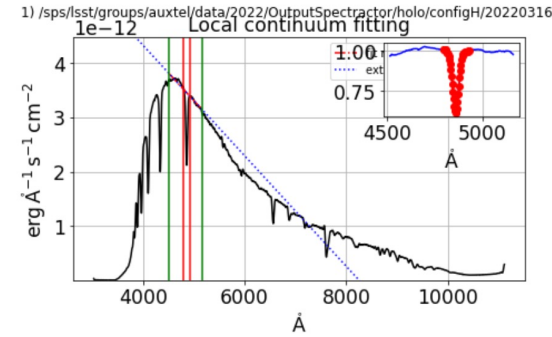
Higher precision on H₂O bas band at $\lambda=730$ nm and $\lambda=820$ nm



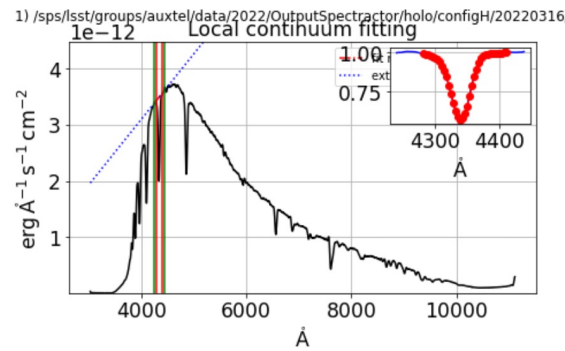
Equivalent width for Stellar absorption line for ETA1 DOR



CALSPEC SED

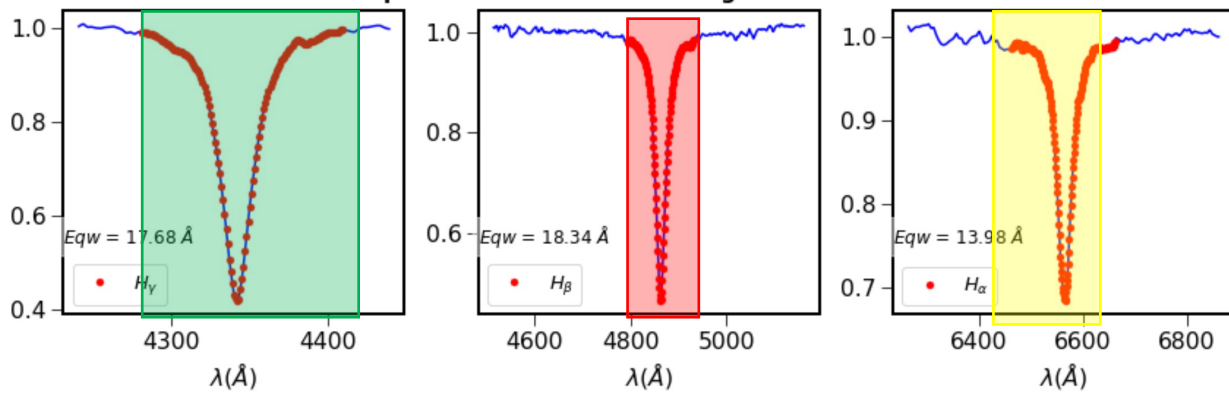


Auxtel spectrum data

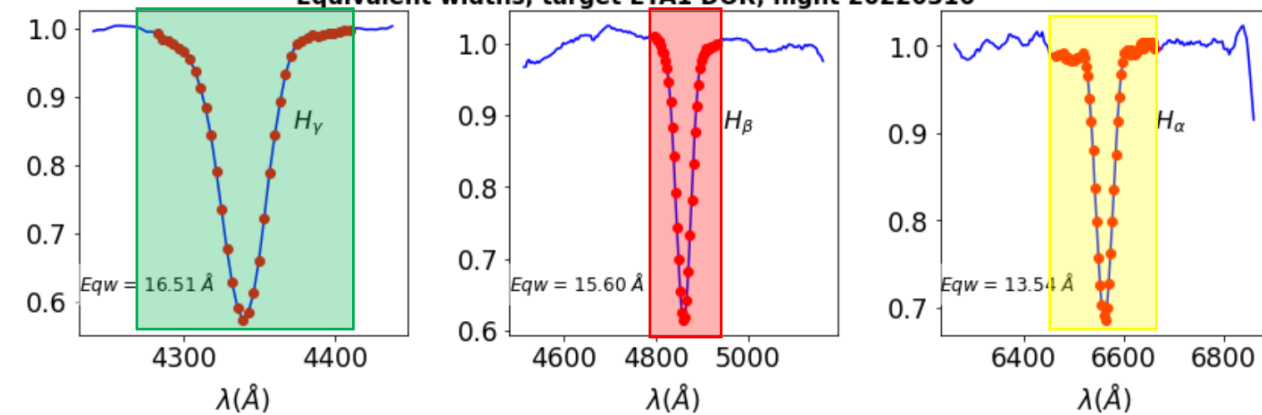


Auxtel abs line Data

Equivalent widths on SED target ETA1 DOR



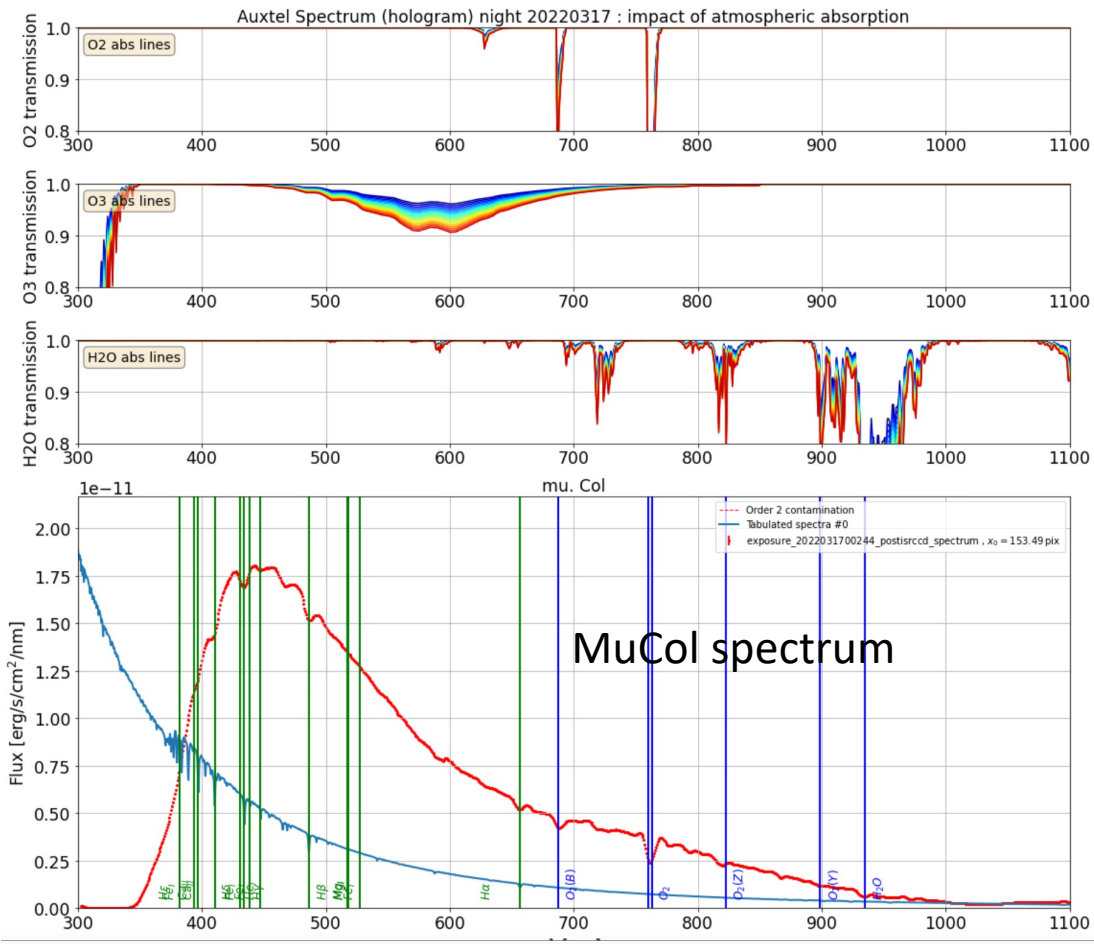
Equivalent widths, target ETA1 DOR, night 20220316



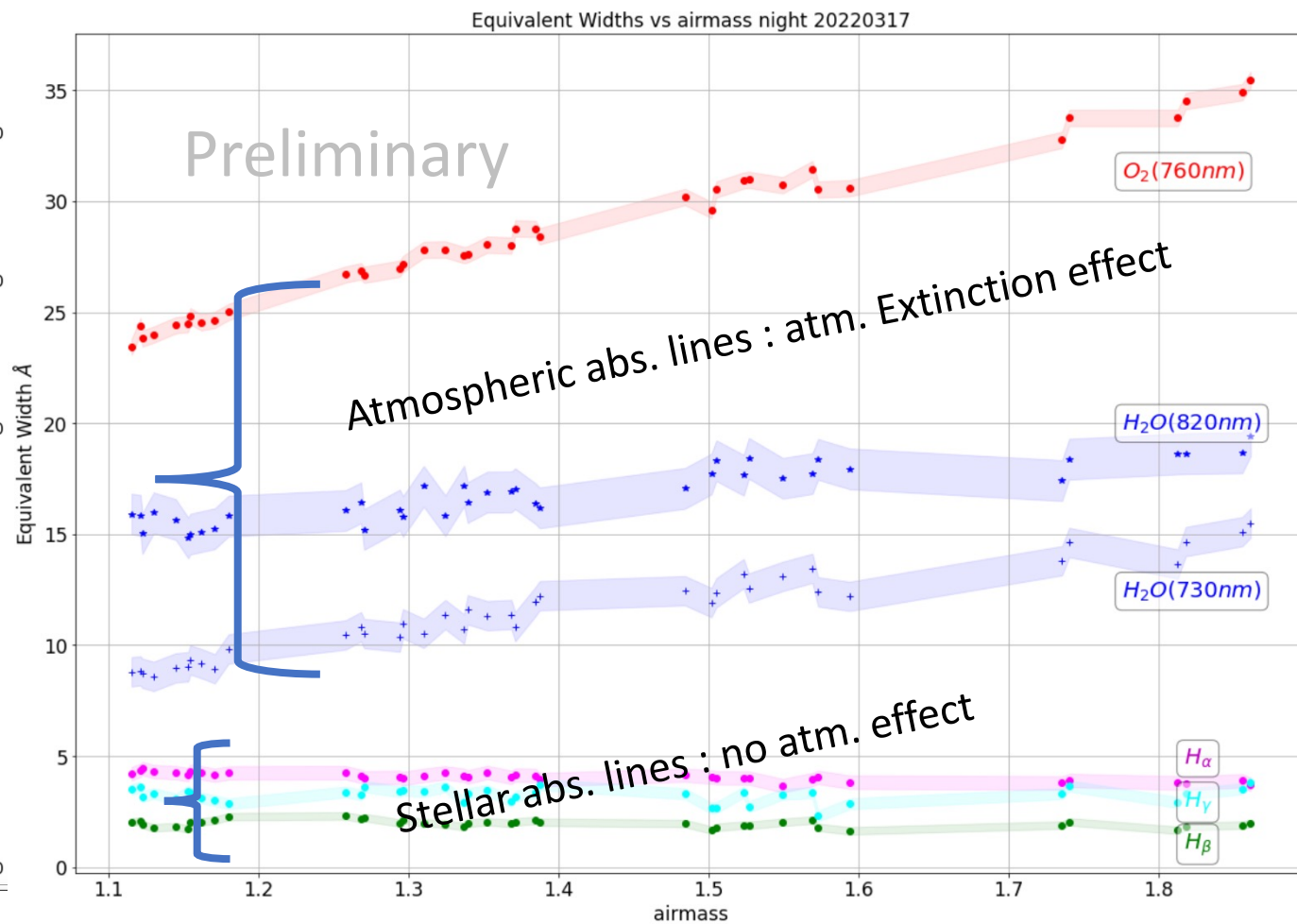
Impact of airmass on equivalent width (MuCol : V=5.2 mag)

(Data with large airmass range)

Simulated absorption transmission contribution

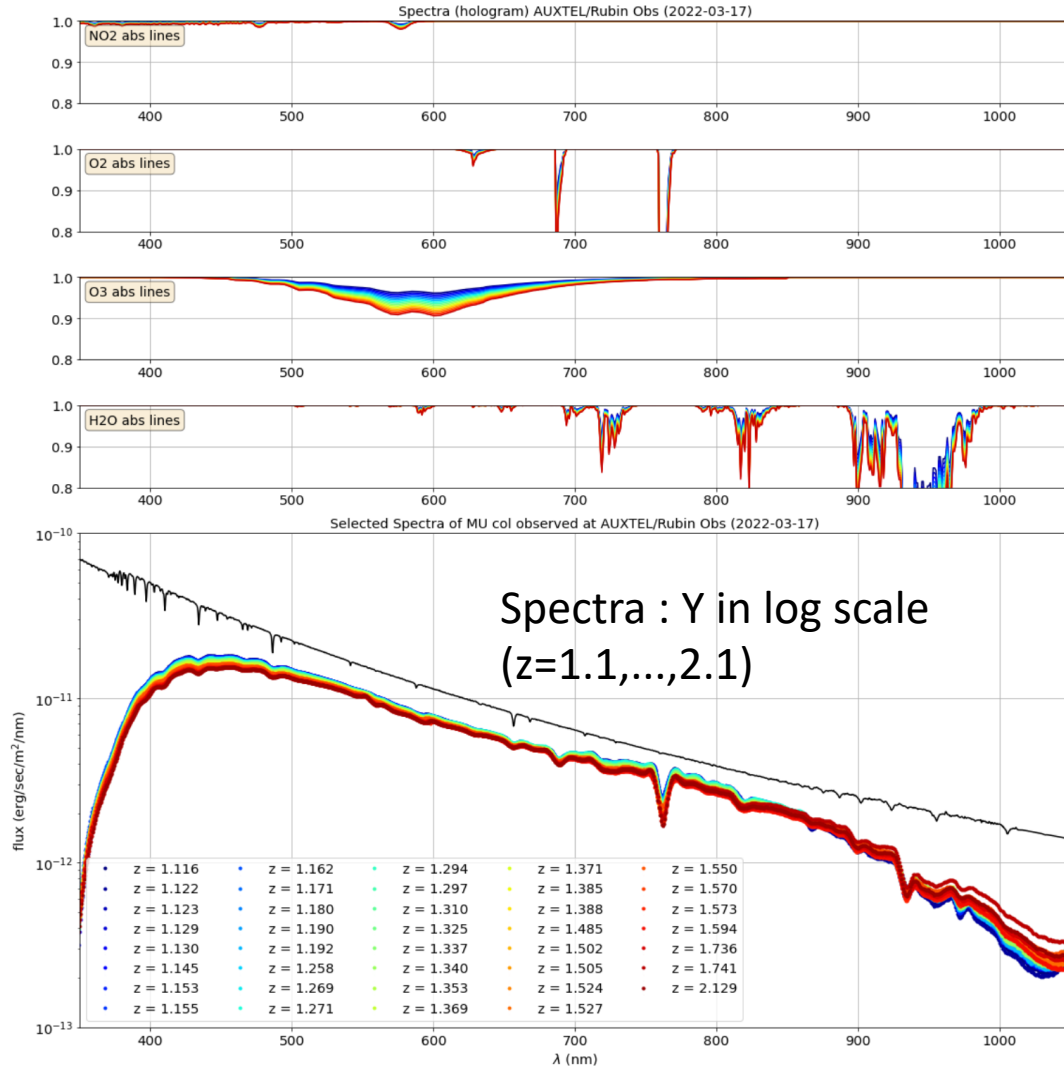


MuCol equivalent width vs airmass

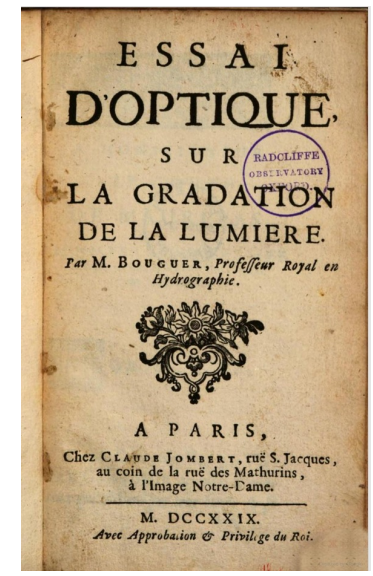


Atmospheric extinction lines : Bouguer lines

Simulation of atmospheric abs. Patterns (z=1,..., 2.5)



Pierre Bouguer (1698-1758)



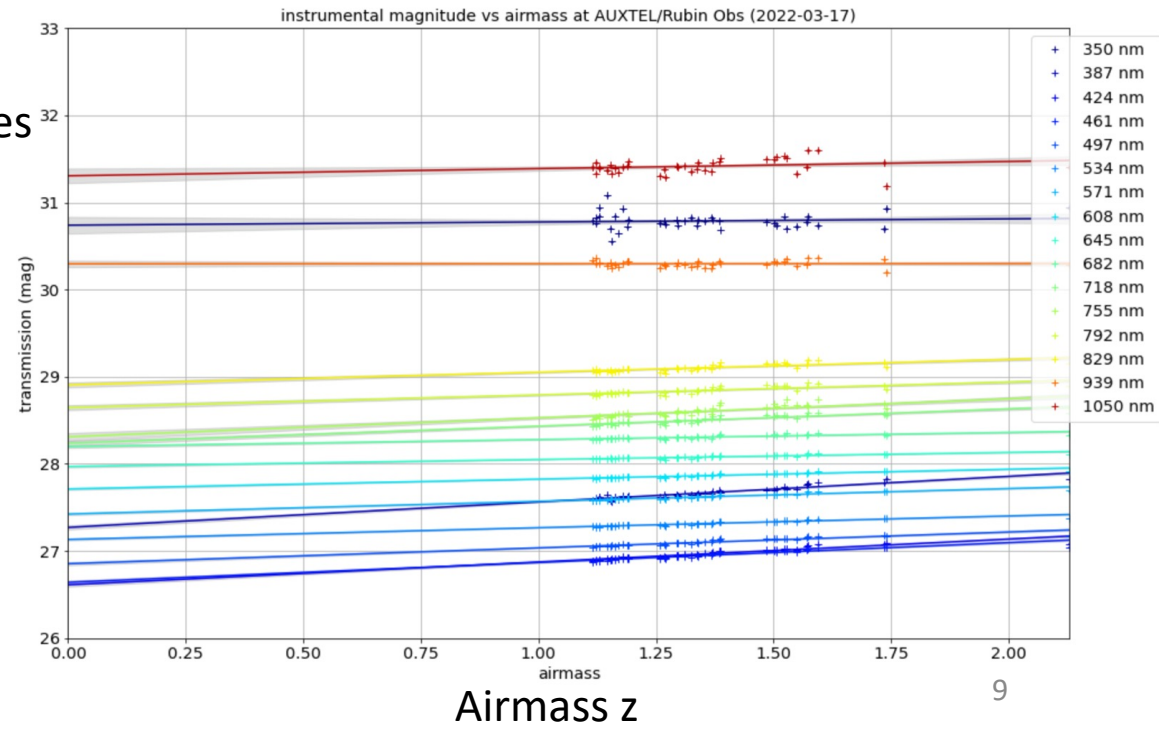
160 *Essai sur la Gradation*
Table des masses d'air contenues dans l'Atmosphere, & des forces qu'a la lumiere des Astres, après avoir traversé ces masses.

Hauteurs des Appareils	Masses d'air exprimées par des poudres équivalentes d'air qui se trouvent au bas.	Forces de la lumiere des Astres par des poudres équivalentes qui se trouvent au bas.	Hauteurs des Appareils	Masses d'air exprimées par des poudres équivalentes qui se trouvent au bas.	Forces de la lumiere des Astres par des poudres équivalentes qui se trouvent au bas.
Degrés	Toises		Degrés	Toises	
90	3911	8183	15	14860	4511
80	3970	8098	14	15880	4301
70	4161	8016	13	17012	4070
66°.11'	4173	7968	12	18244	3773
65	4314	7912			
60	4517	7866	11	19508	3472
55	4776	7719	10	21247	3149
50	5104	7614	9	23275	2797
45	5510	7454	8	26673	2433
40	6086	7237			
35	6813	6963	7	30596	2011
30	7781	6613	6	34400	1616
25	9191	6136	5	39291	1201
20	11141	5474	4	47480	802
19°.16'	11744	5318	3	58182	474
19	11890	5310	2	74419	292
18	12515	5142	1	100910	147
17	13220	4914	0	138223	5
16	14000	4711			

10000 exprime la force qu'a la lumiere avant d'entrer dans l'Atmosphere.

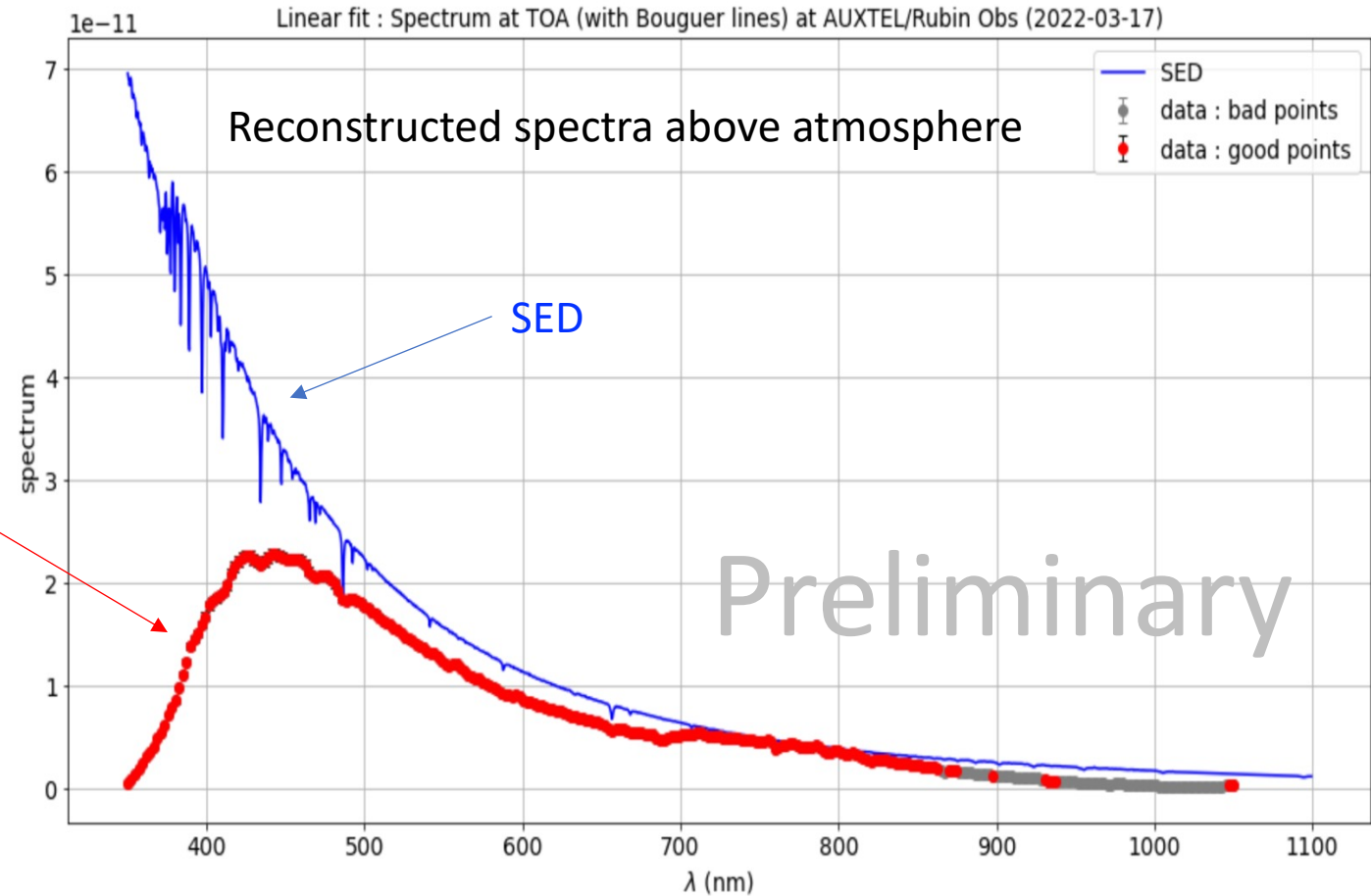
Bouguer Law
Better known as Beer-Lambert Law (1729)

Magnitudes of Spectra



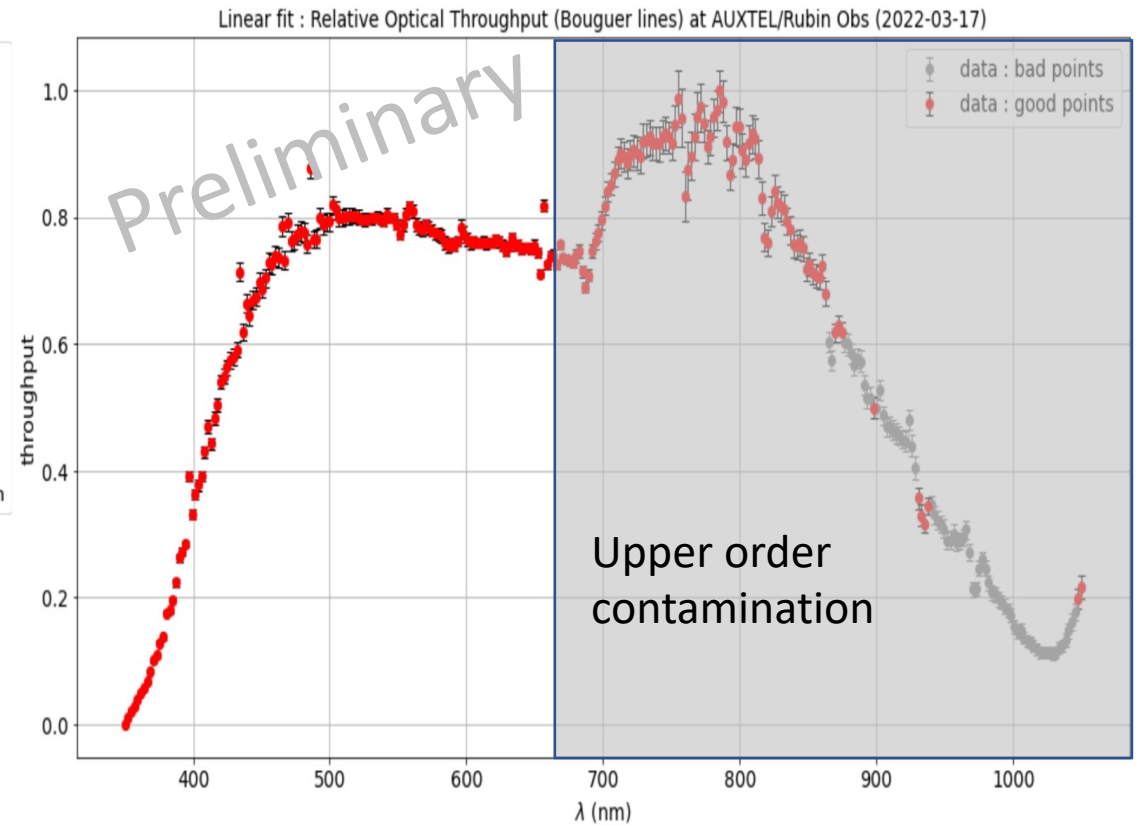
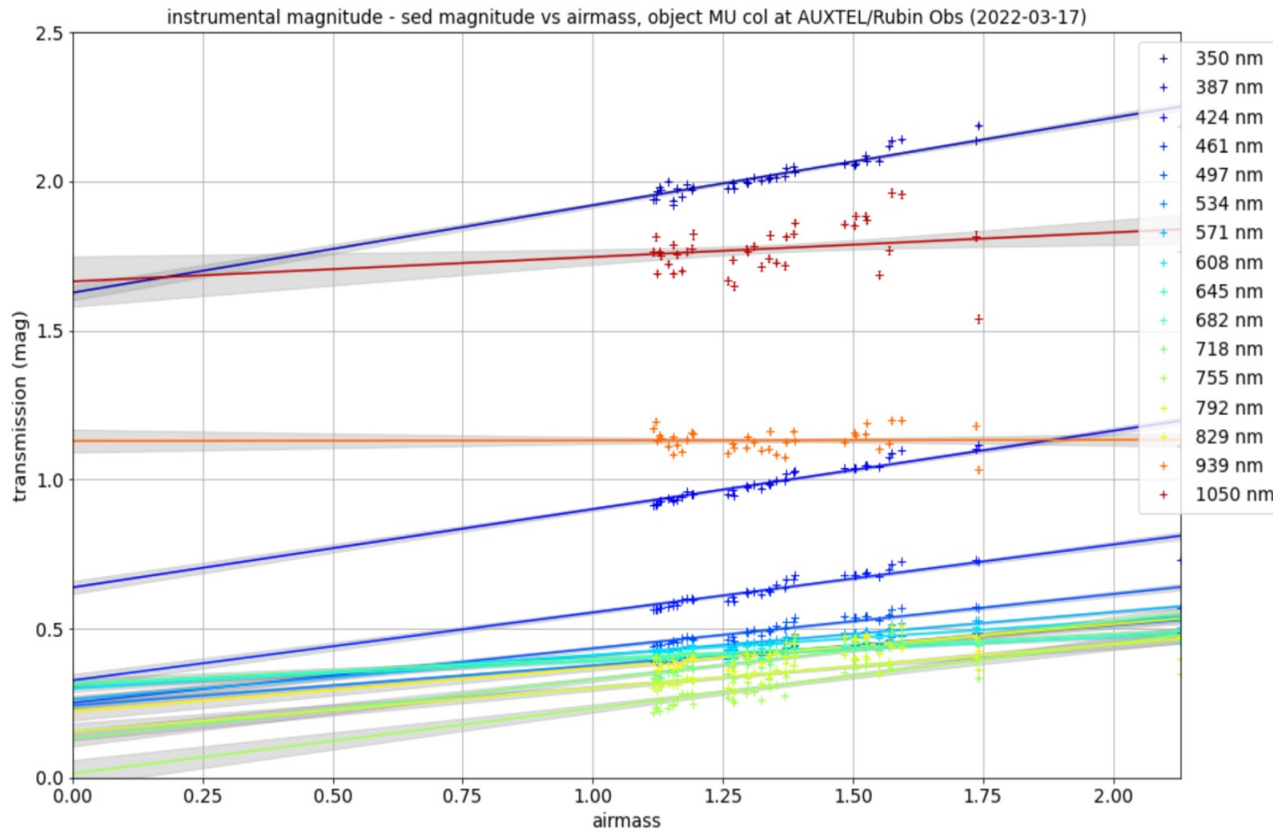
Bouguer lines extrapolated at the top of atmosphere

- Bouguer lines: Y axis in magnitude (log scale) on previous slide
- Spectrum: Y axis in $\text{erg}\cdot\text{cm}^2/\text{s}/\text{nm}$ (linear scale) From the Y intercept on previous slide



Total Throuput after removing SED

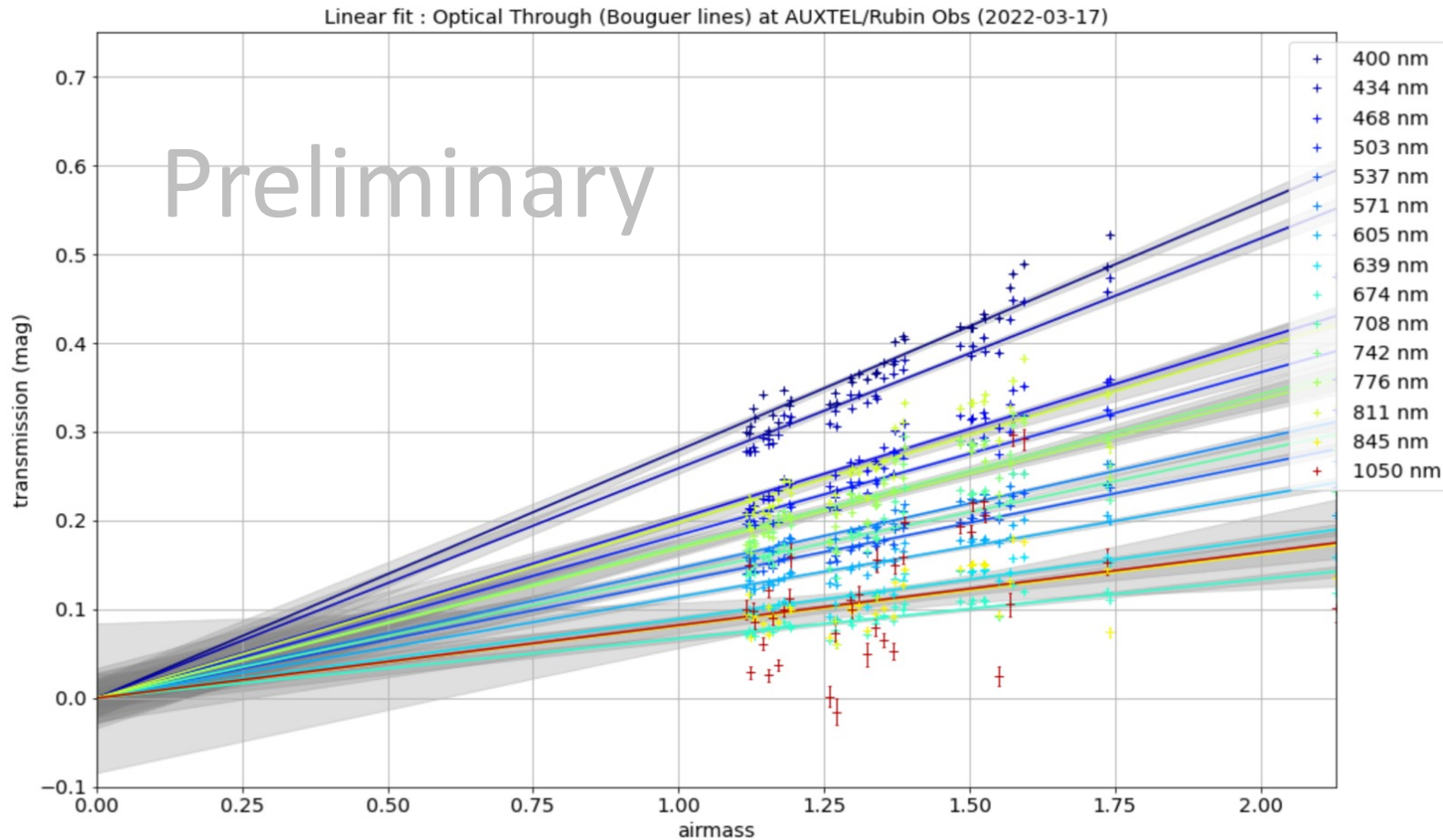
Subtract the known SED from previous line curves an extrapolate at airmass = 0 again



Obviously second order contamination for $\lambda > 700$ nm

Pure atmospheric extinction

Force all Bouguer lines having their intercept at airmass = 0



- See the point scattering around the fitted straight line
- Correlation at different wavelength
- Small grey extinction ?

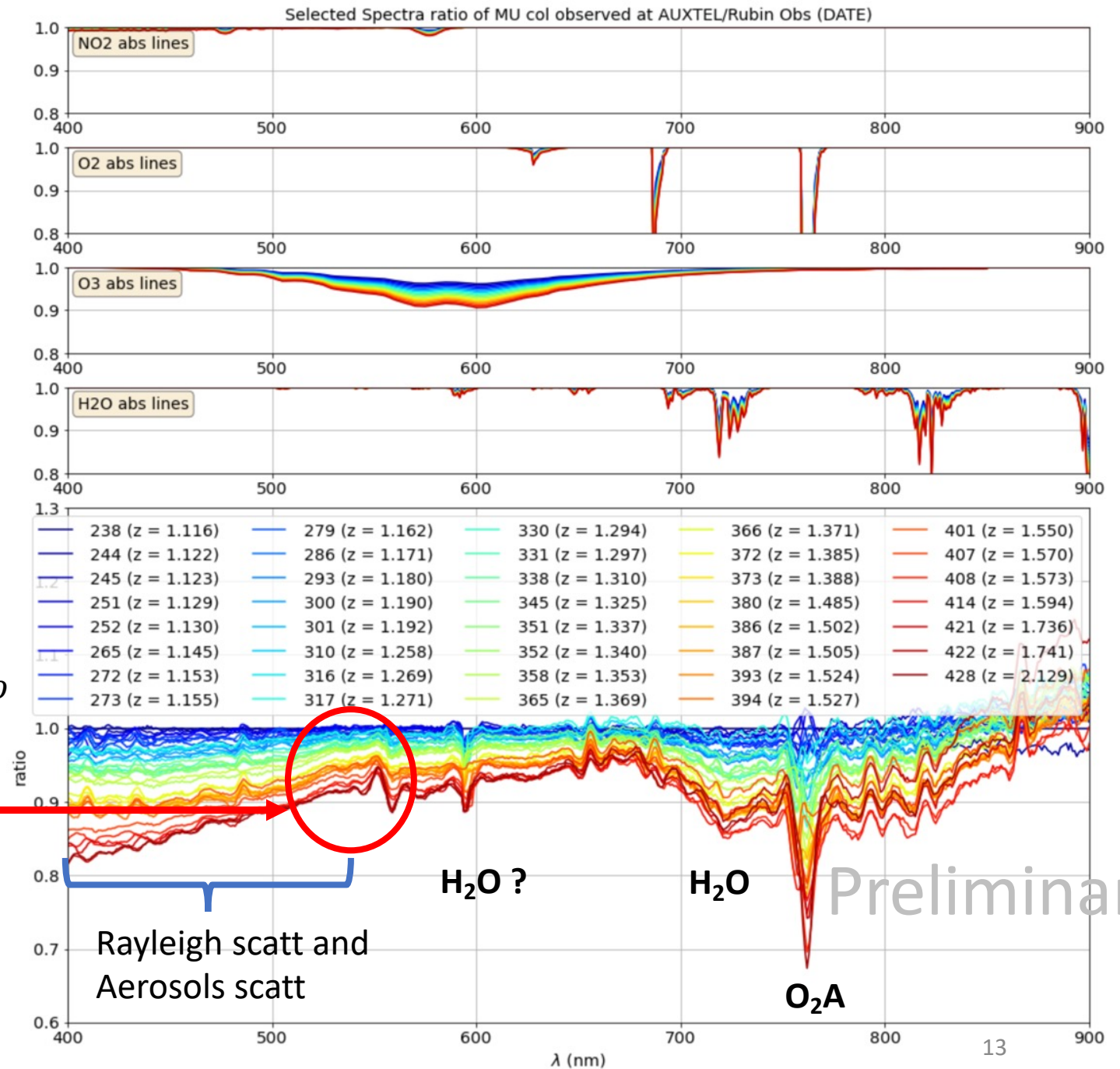
Spectrum ratio

Absorption features from
Atmospheric transparency simulation

- $\lambda < 550$: *Pure Rayleigh and aerosols scattering*
- No star absorption line $H\alpha$, $H\beta$, $H\gamma$ in the ratio

- CCD segment artifact

CCD segment stitching : Need flats



Work to be done

- Image reduction : Apply Flats
 - Reduce the noise structure of the spectrum.
 - See presentation of Martin R. Monroy
- Better removal of second order
 - Work on blue and red filters nights:
 - Red filter to remove second order component (piling up on red part of order 1)
 - Blue filter to see distinctly the order 1 and order 2 of the blue part of the spectrum.

In Spectractor one need the ratio $\text{order2}/\text{order1}$: this ratio is poorly known from optical bench for $\lambda < 400$ nm