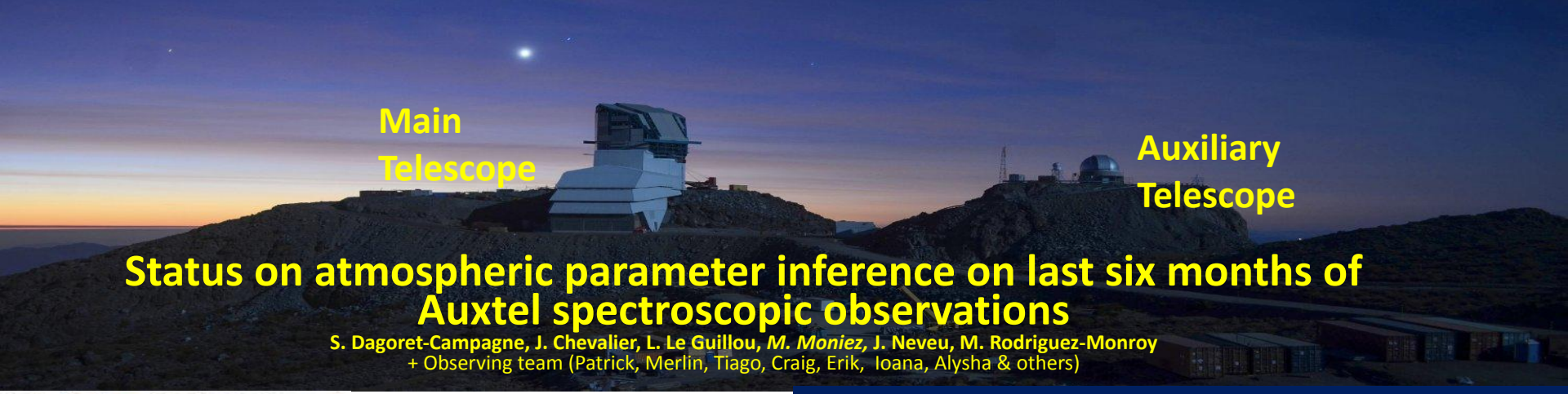
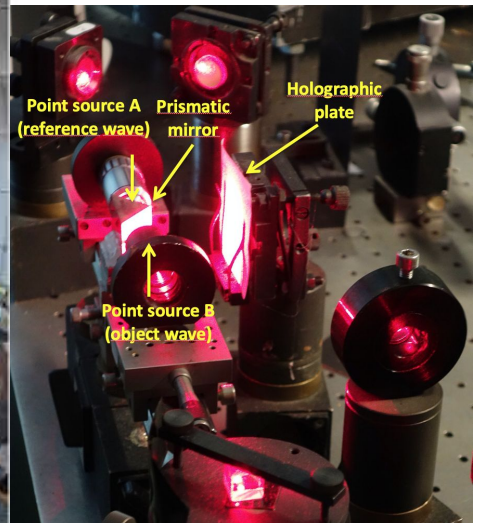


Status on atmospheric parameter inference on last six months of Auxtel spectroscopic observations

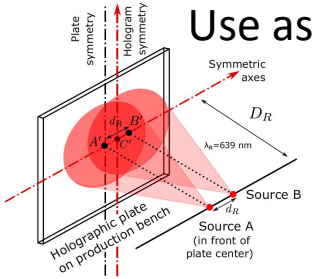
S. Dagoret-Campagne, J. Chevalier, L. Le Guillou, *M. Moniez*, J. Neveu, M. Rodriguez-Monroy
+ Observing team (Patrick, Merlin, Tiago, Craig, Erik, Ioana, Alysha & others)

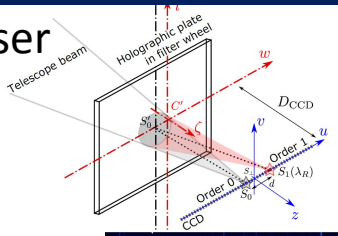
Rubin-LSST France, Grenoble, juin 2023

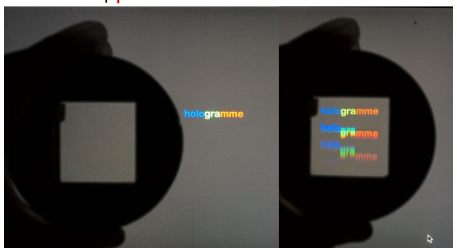
Hologram recording

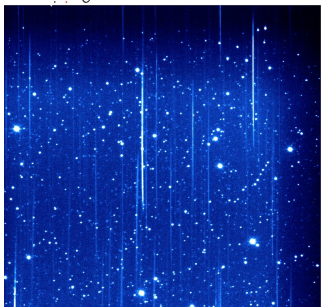


Use as disperser









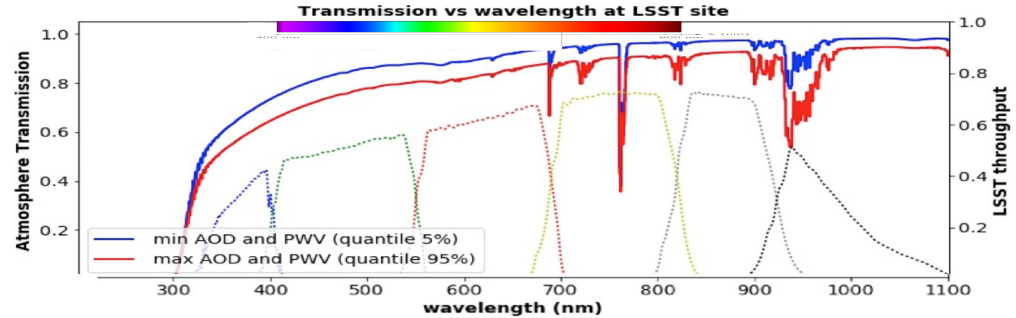
AuxTel spectrograph mission:

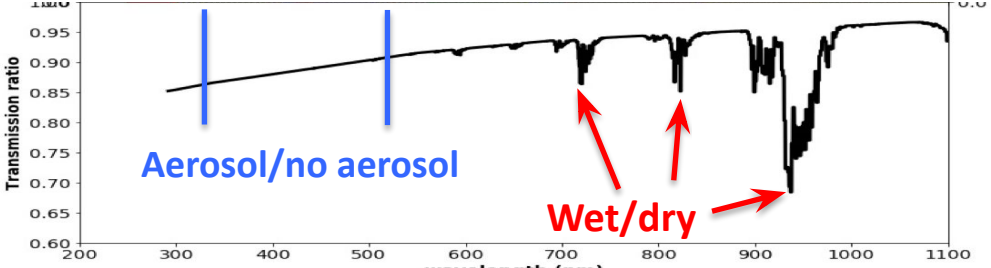
measure the atmospheric transmission to derive the expected fluxes for each object under standard atmospheric conditions

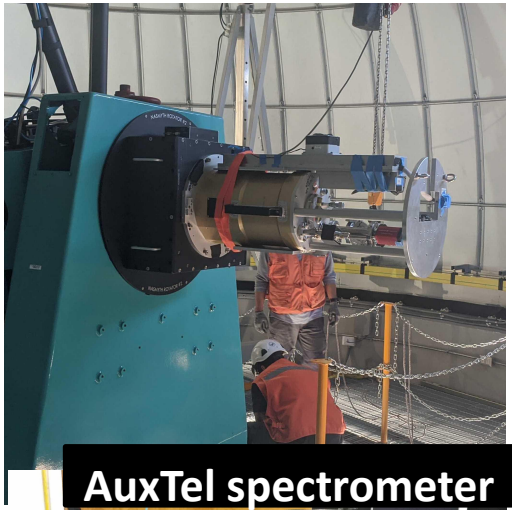
Estimate colour corrections, as functions of the atmospheric conditions and of the object UGRIZY in every LSST field

Example below

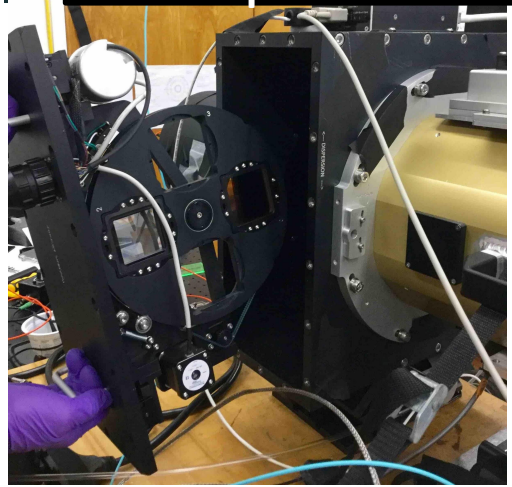
- Constant airmass, constant O_2 and O_3. No cloud
- Change only : **H_2O (PWV), Aerosols**



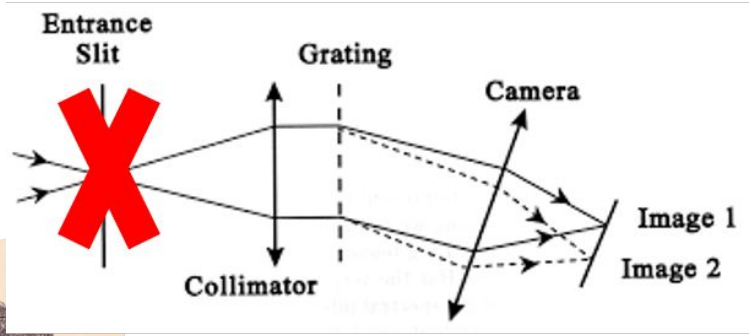


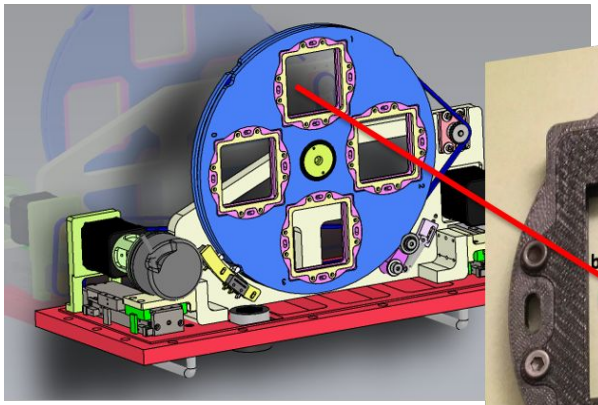


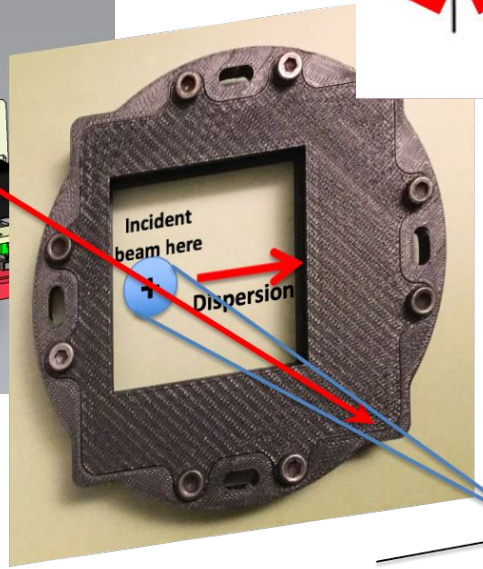
AuxTel spectrometer

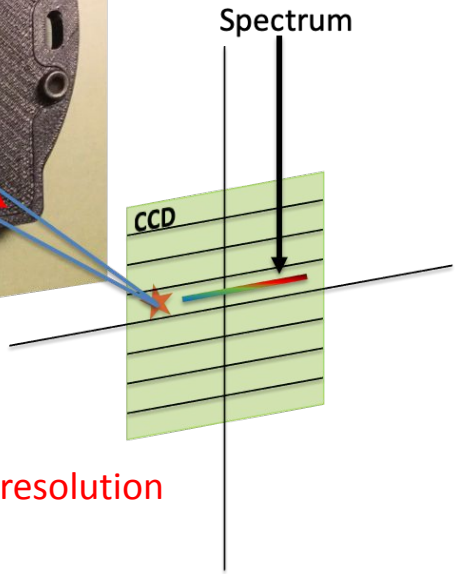


Our spectrograph is slitless equiped with an Holographic Optical Element









Slitless allows

- fast positioning
- spectrophotometry

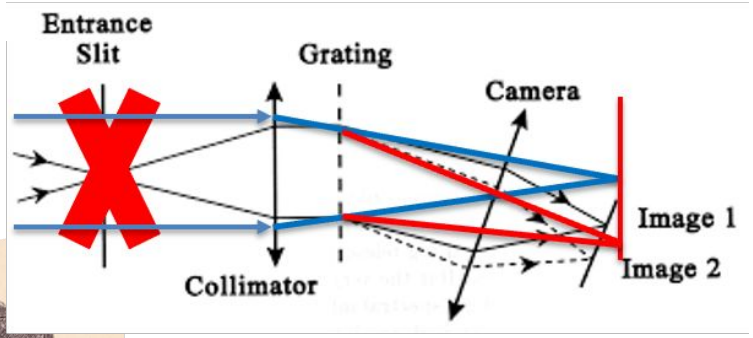
Limits: sky+stellar background

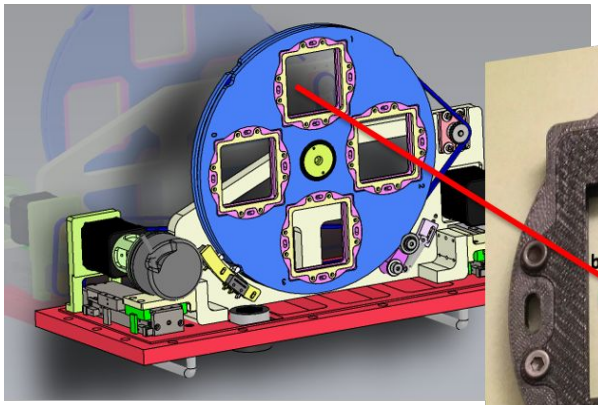
low resolution (seeing limited)

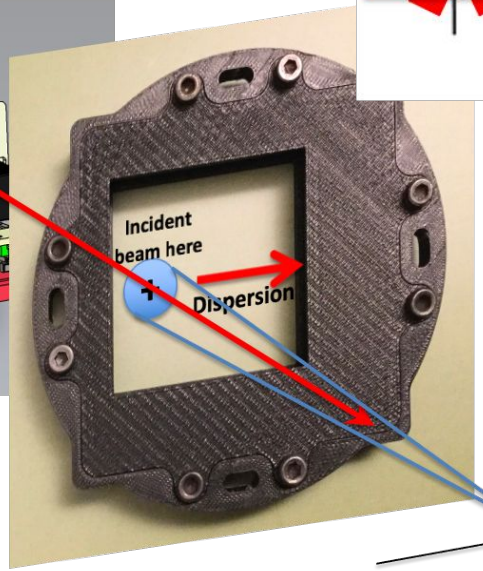
Phase hologram (dispersion+focus functionalities)

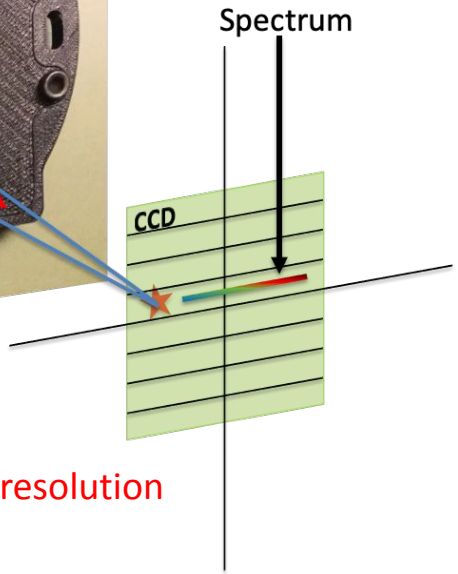
- Excellent focus for all λ with convergent beam -> nominal resolution
- More light -> better s/n

Our spectrograph is slitless equiped with an Holographic Optical Element









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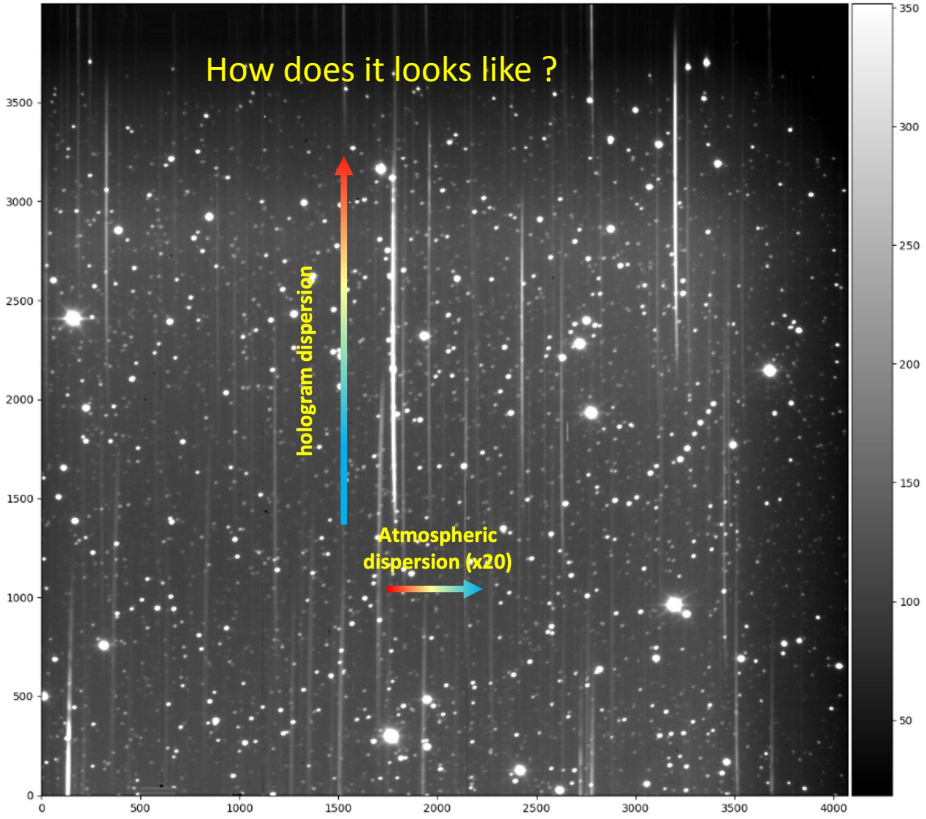
Data available (started in Feb. 2021)



auxtel-monitor_dayObs_2021-09-09_seqNum_177.png

3000 reconstructed spectra
since september 2022
Wavelength extension
[380-1050nm]

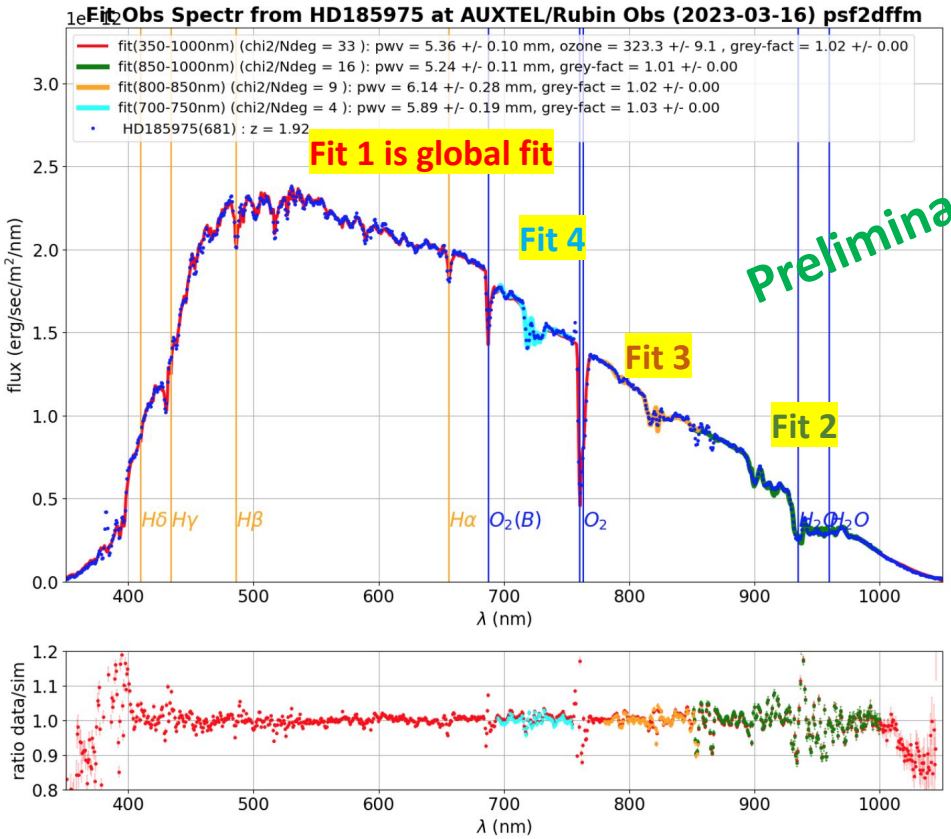
With various

- CALSPEC standards (alt,az)
- Airmasses
- Atmospheric conditions

Reconstruction software

- Spectractor v2.4
- Order2 subtraction

Atmospheric parameters



- **Data**

  Spectractor V2.4, 1D spectrum (order 1) + cov matrix

- **Model**
  - **SED (CALSPEC), smoothed**
  - **Throughput**
  - **Atmosphere**

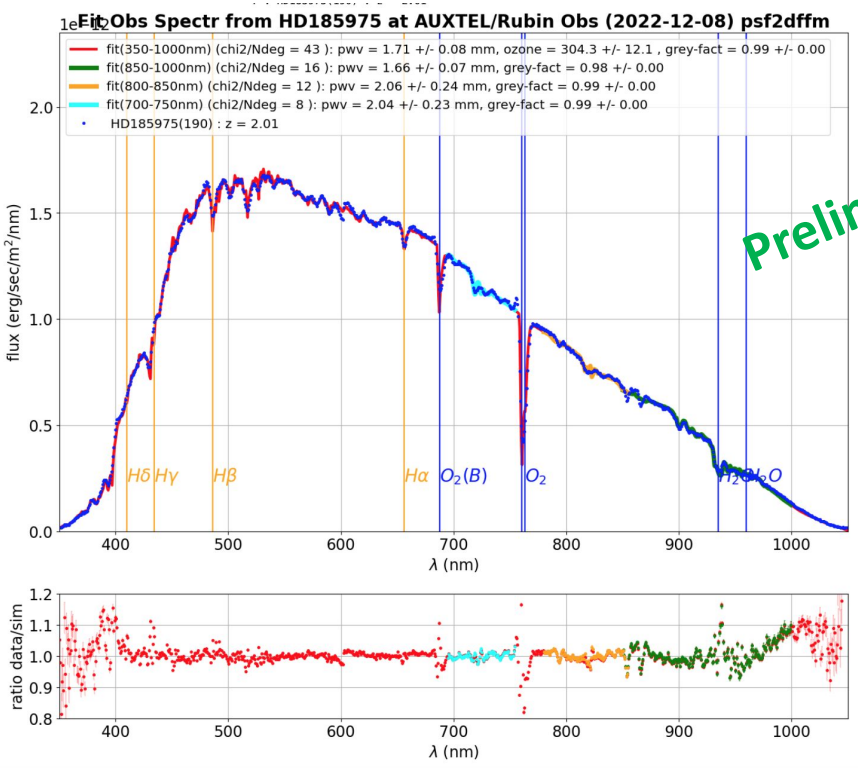
  libradtran at observed airmass

- Atm. parameter to fit: PWV, OZ, grey att.

Day by day fitted PWV vs time
(polar CALSPEC)

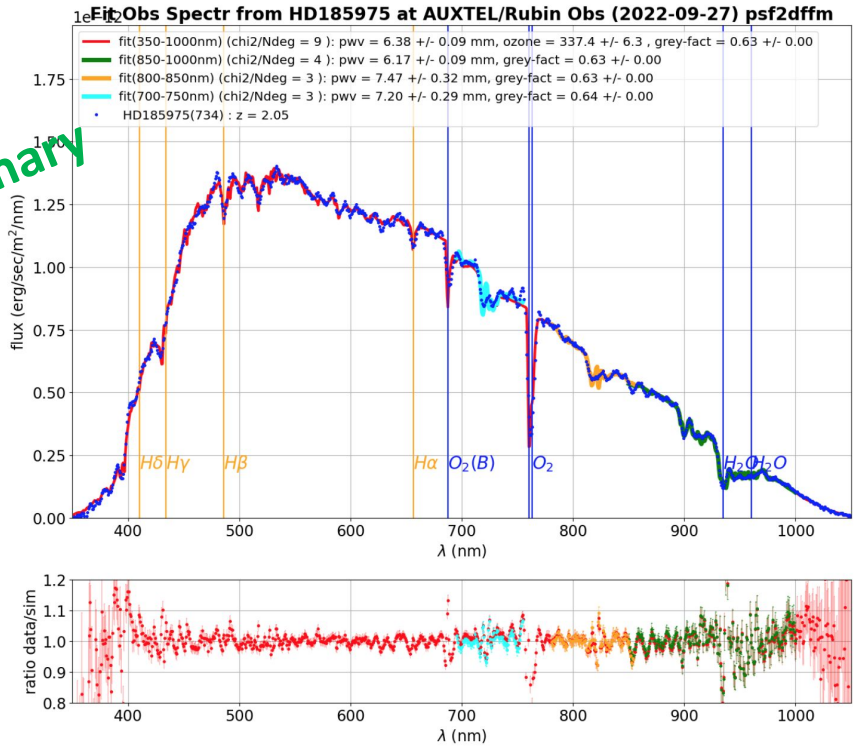
- Relatively stable during a single night
- Varies from 1mm to 7mm between nights

Low PWV in dec 22

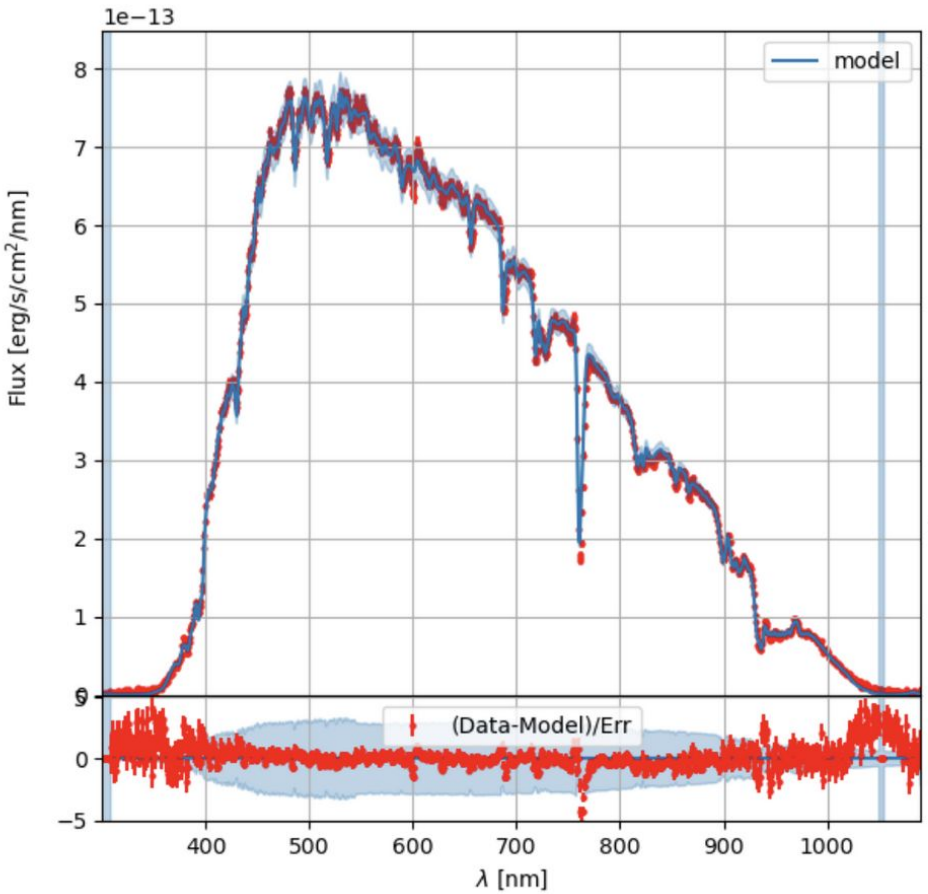


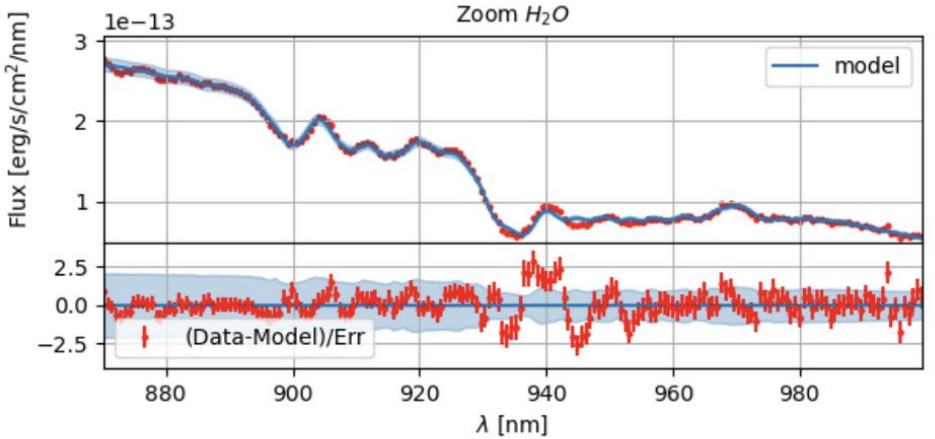
Preliminary

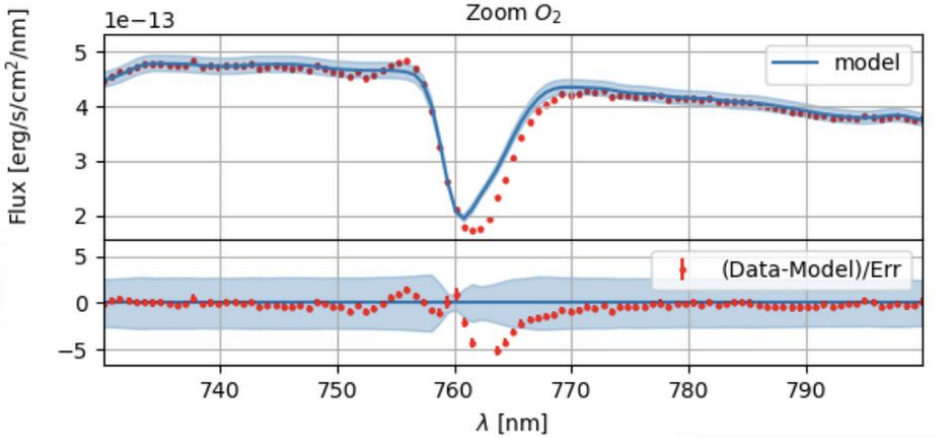
High PWV in sept 22



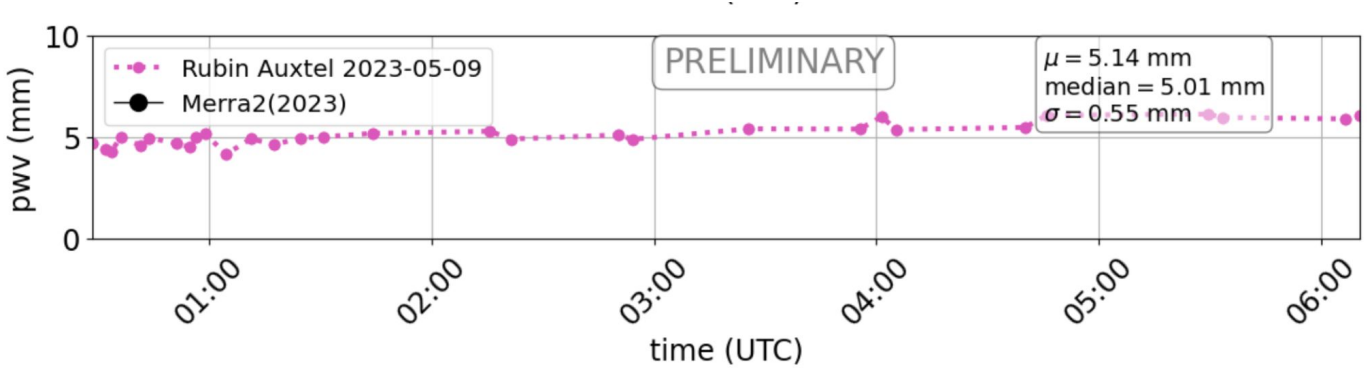
PS: pour le plaisir des yeux : 2023051000213



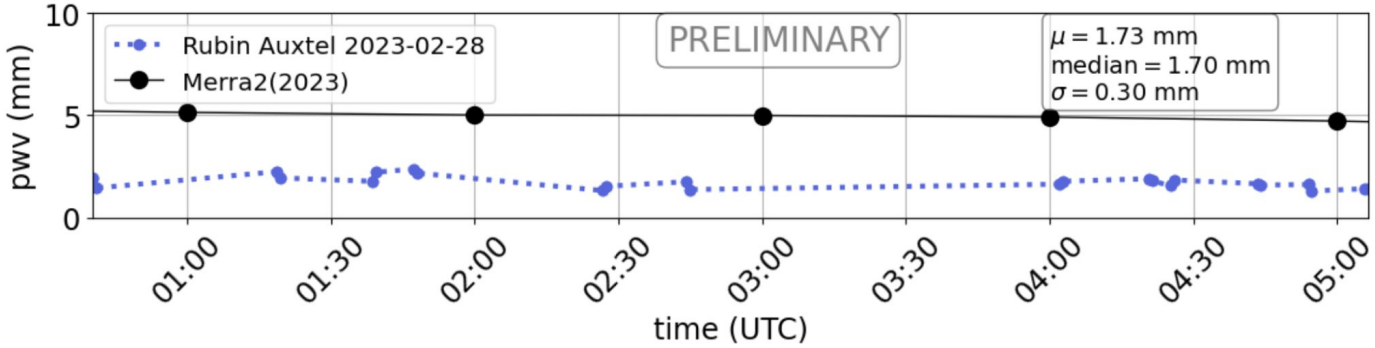




Selection of two typical nights low / medium PWV

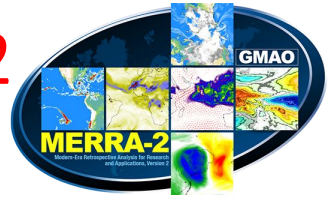


Medium PWV



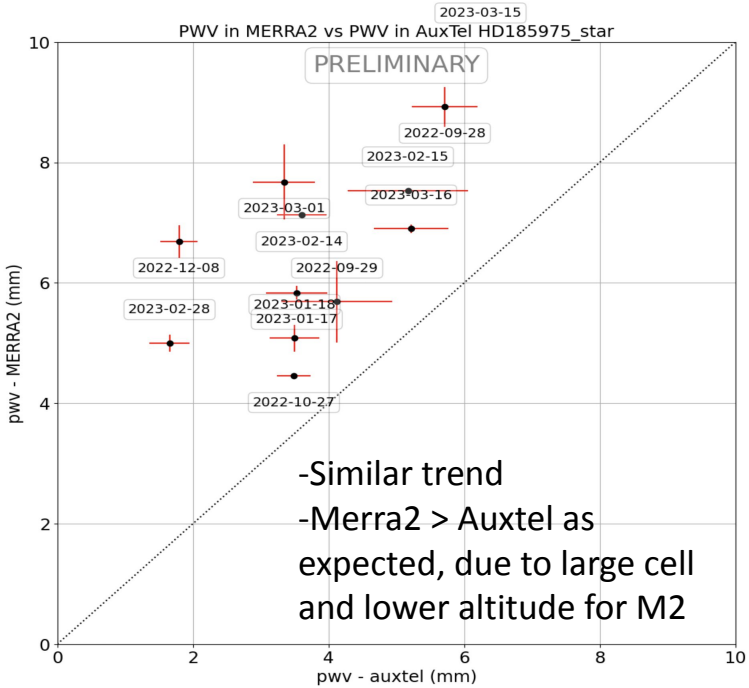
Low PWV

Comparison of PWV estimation with MERRA2



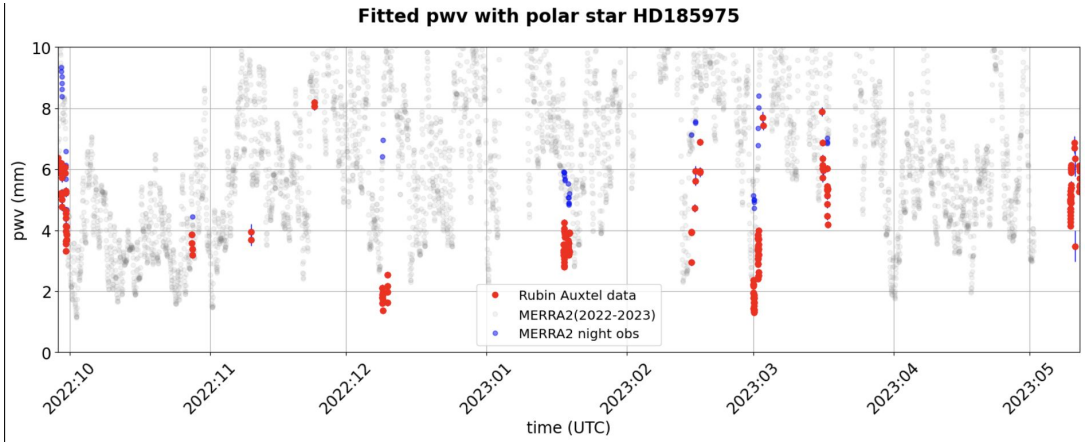
[MERRA-2 - Global Modeling and Assimilation Office - NASA]

- Full earth atmosphere modelling from many heterogeneous data all over the world
- Calculations in large size cells, at sea level
- Just a rough qualitative comparison



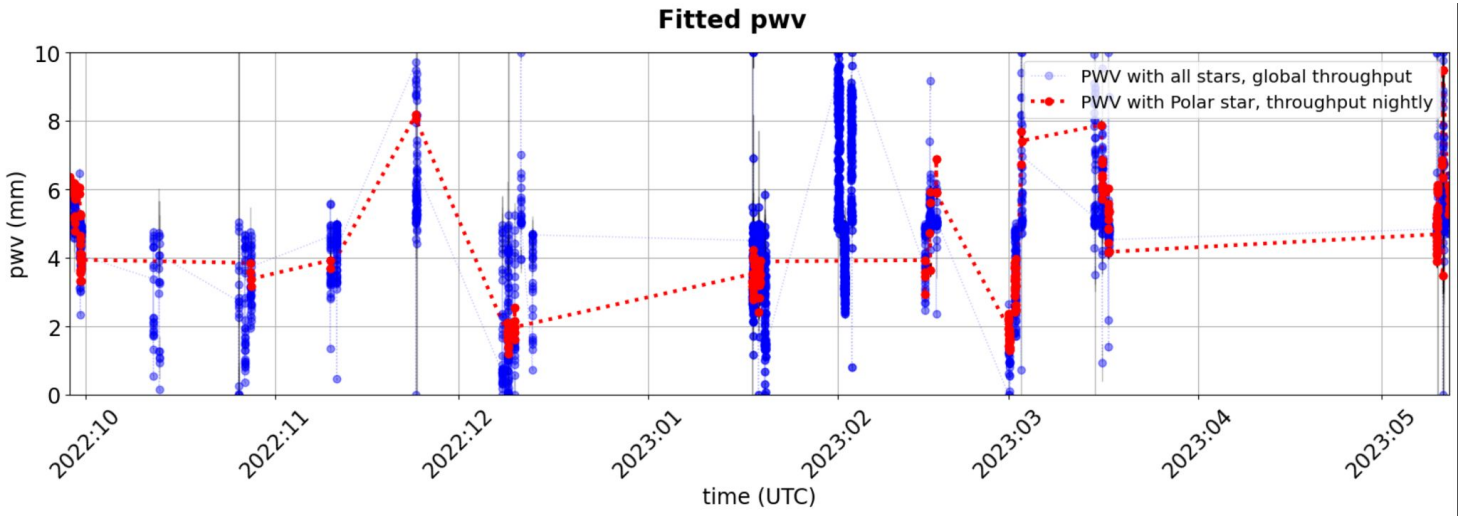
-Similar trend
-Merra2 > Auxtel as expected, due to large cell and lower altitude for M2

No known other local measurements to check



Comparison of Polar star / All standards PWV fit

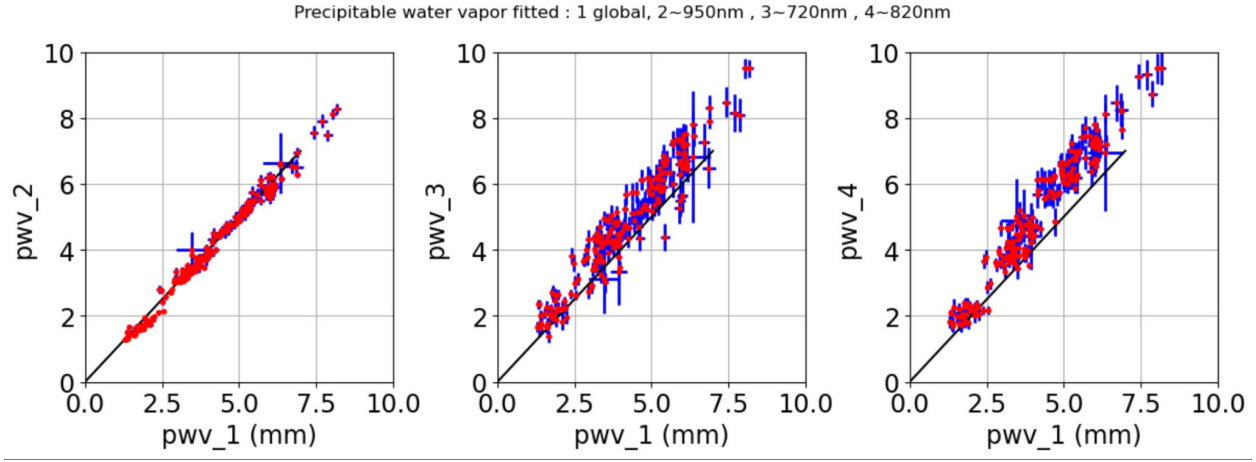
- Red : Polar star (airmass~2), one throughput fitted per night, remove bad spectra (by visual inspection)
- Blue : all standards, global throughput, all fits



Consistency between measurements in different spectrum wavelength regions

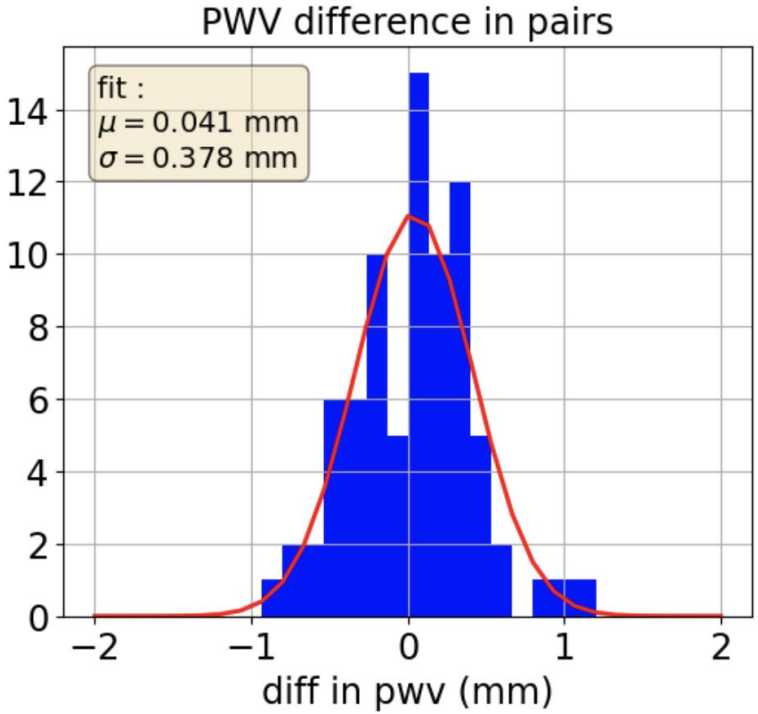
- pwv_1 : global fit
- pwv_2 : fit in 850-1000 nm
- PWV_3 : fit in 800-850 nm
- PWV_4 : fit in 700-750 nm

Quality criteria : chi2/NDF <100



Fit 2 contribution is dominant in global fit, fit 3 and 4 give somewhat higher pwv values

Repeatability for PWV estimation

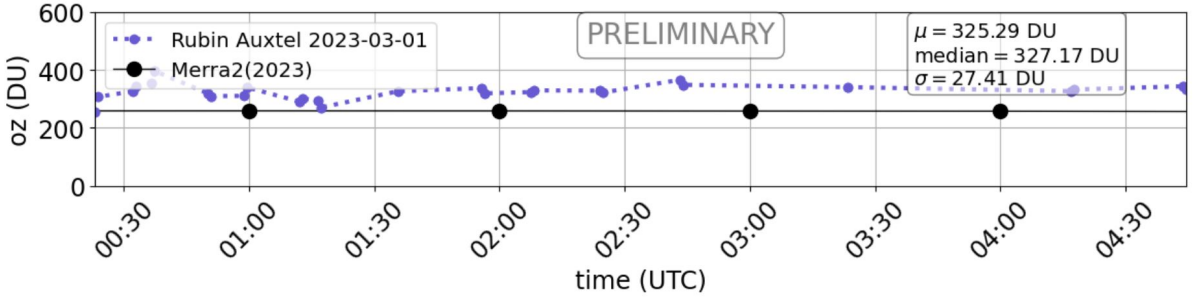


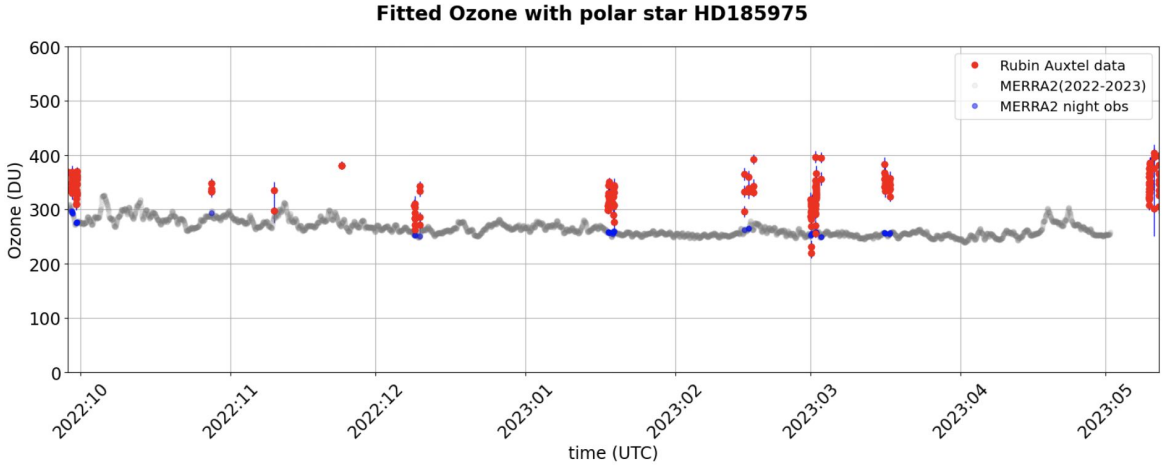
- All spectra are observed twice within 45 s

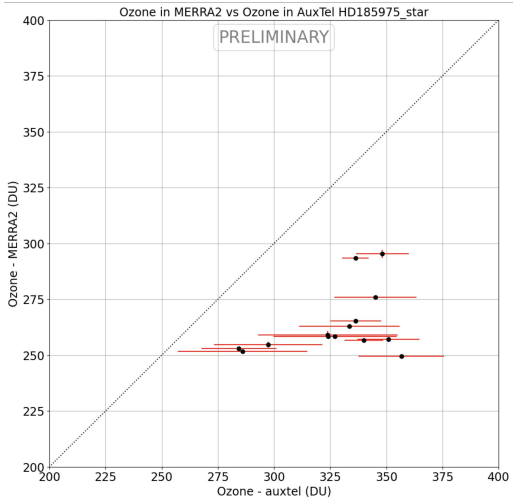
-> Ideal to test repeatability

- This histogram shows the differences of estimated pwv (from the global fit) in pairs of successive spectra
- repeatability ~ 0.4 mm

Comparison of Ozone estimation with MERRA2

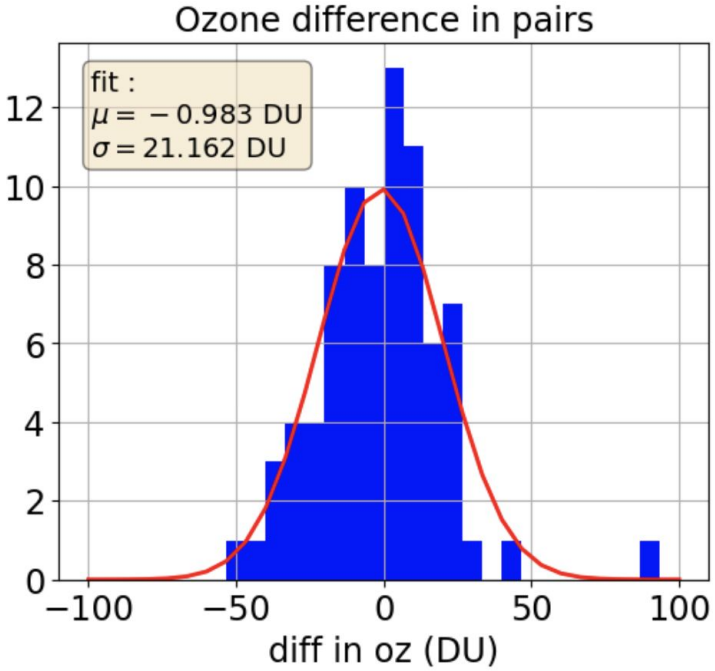






Trend to overestimate Ozone compared to MERRA2

Repeatability for Ozone estimation



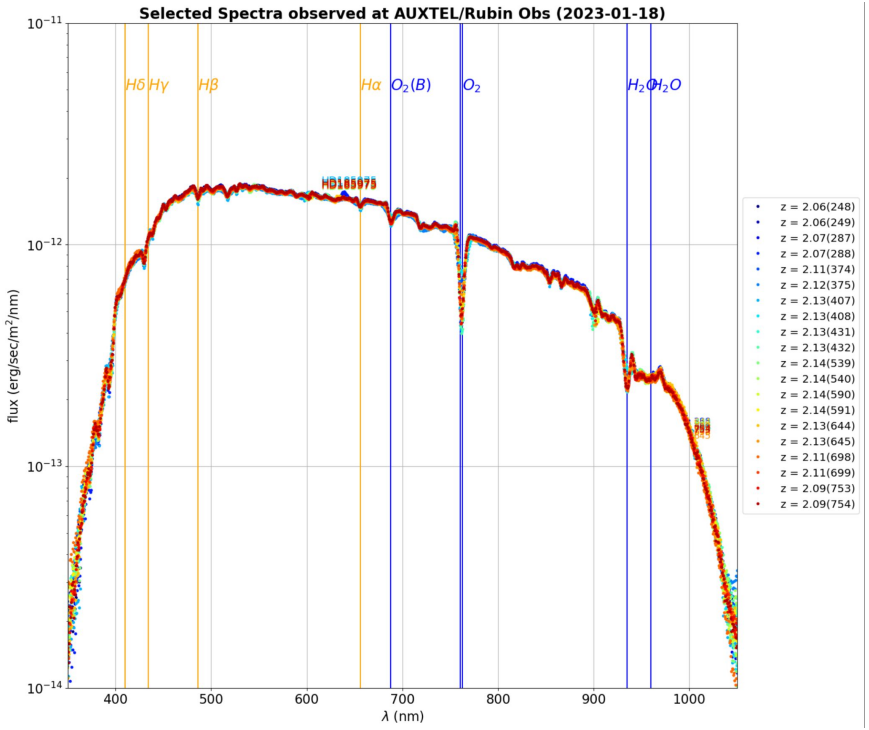
- All spectra are observed twice within 45 s

-> Ideal to test repeatability

- This histogram shows the differences of estimated Ozone (from the global fit) in pairs of successive spectra
- repeatability ~ 20 DU

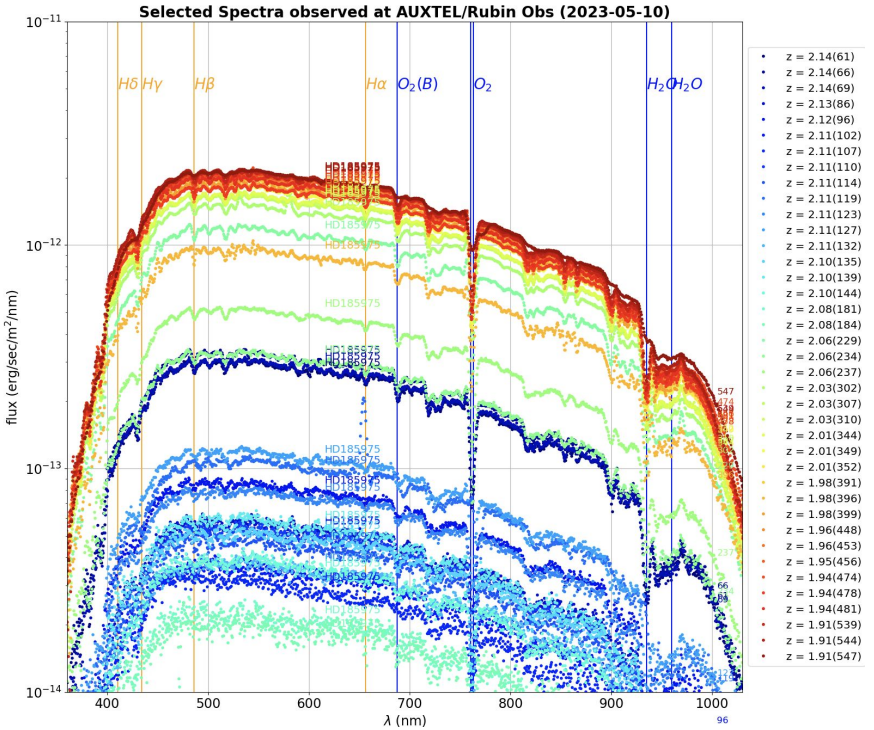
Example of spectra measured cloudy / clean night (polar star) -> grey absorption

Quasi Photometric nights 17/01 and 18/01 2023

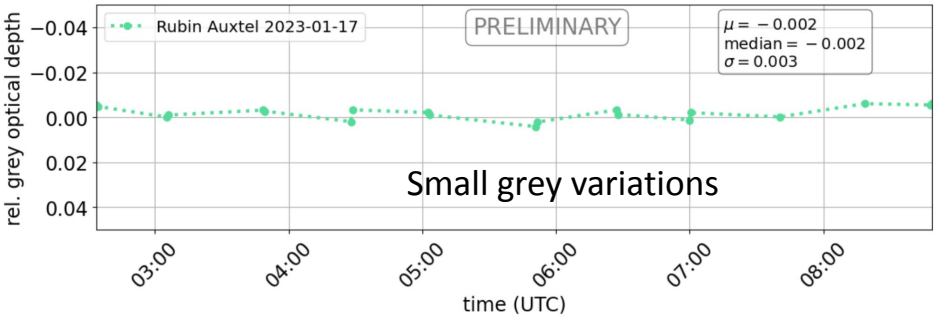


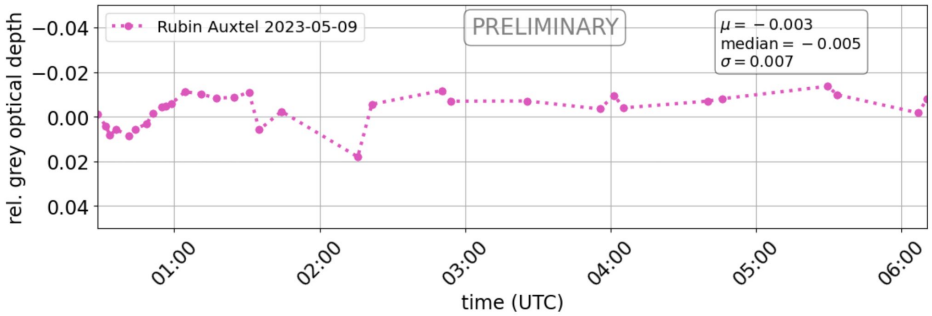
Cloudy nights 10/05 2023

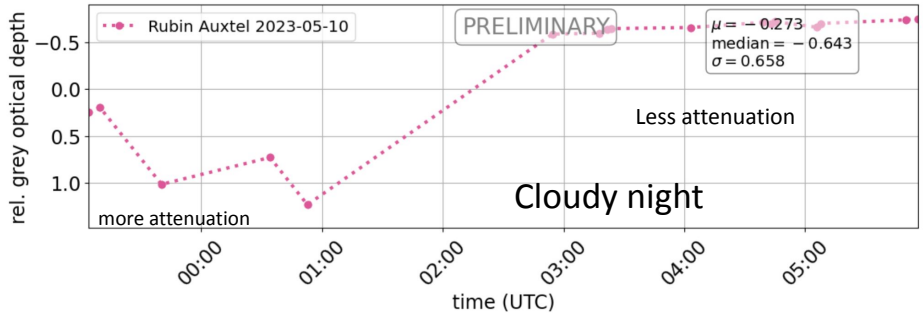
airmass



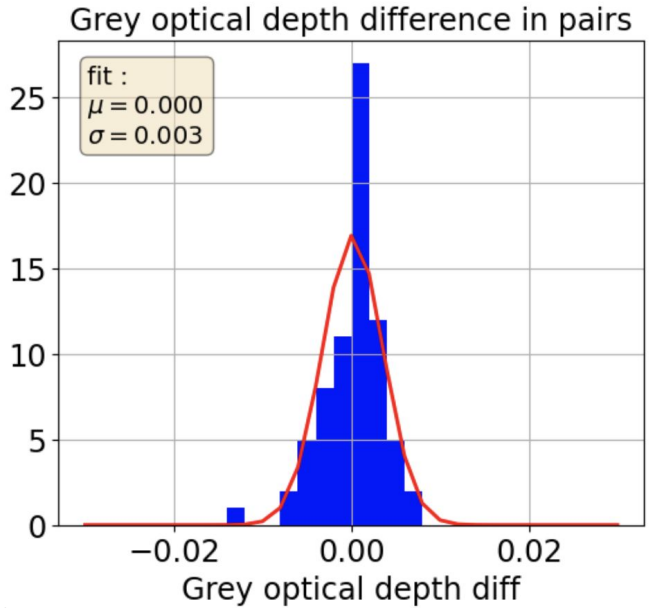
Fit of Grey optical depth





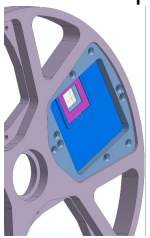


1.5 mag

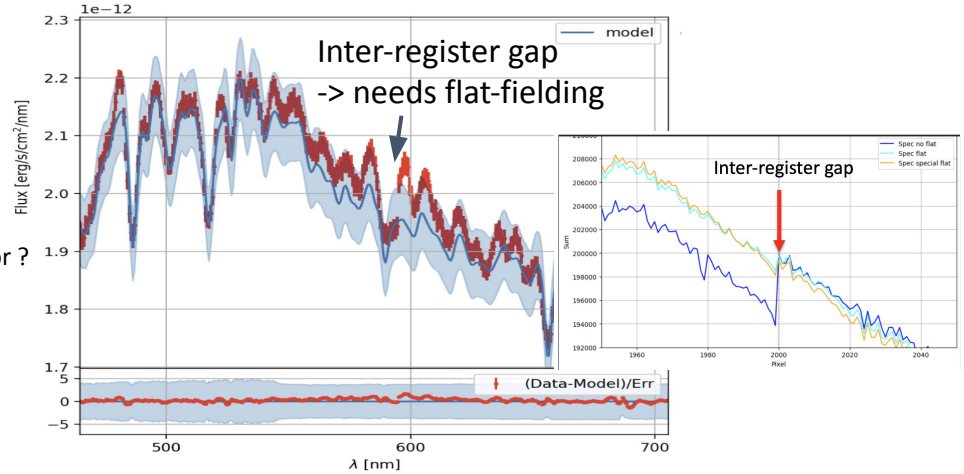


TODO see during parallel sessions

Technical improvements :

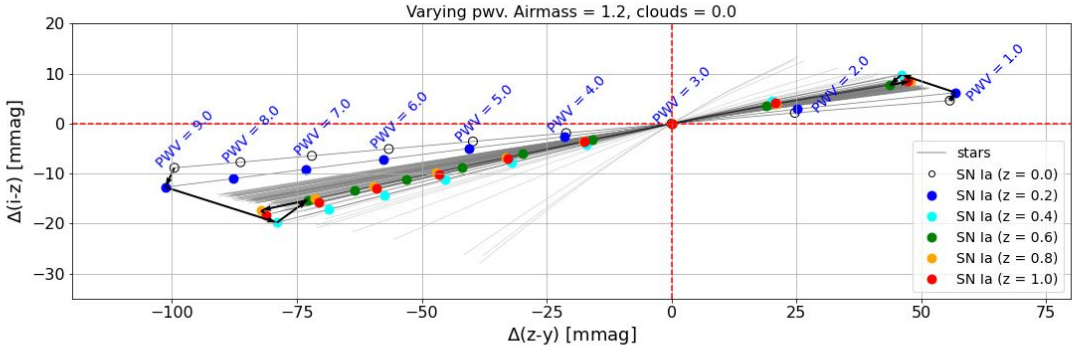


- Special flat-fielding for spectroscopy
- Update throughput with next Bouguer lines runs
- Increase software yield (Spectractor),
- Improve SED model taking into account PSF from Spectractor ?
- Hardware :
  - collimator to mitigate impact of field stars on the spectrum
  - Cylindrical lens for special flat-fielding



Atmospheric Science

- Compare results between various CALSPEC sources
  - Variation of PWV with the direction, with time ?
- Grey absorption variations
  - clouds + aerosols + throughput
- Aerosols once throughput is validated
  - Separate grey attenuation and aerosol component

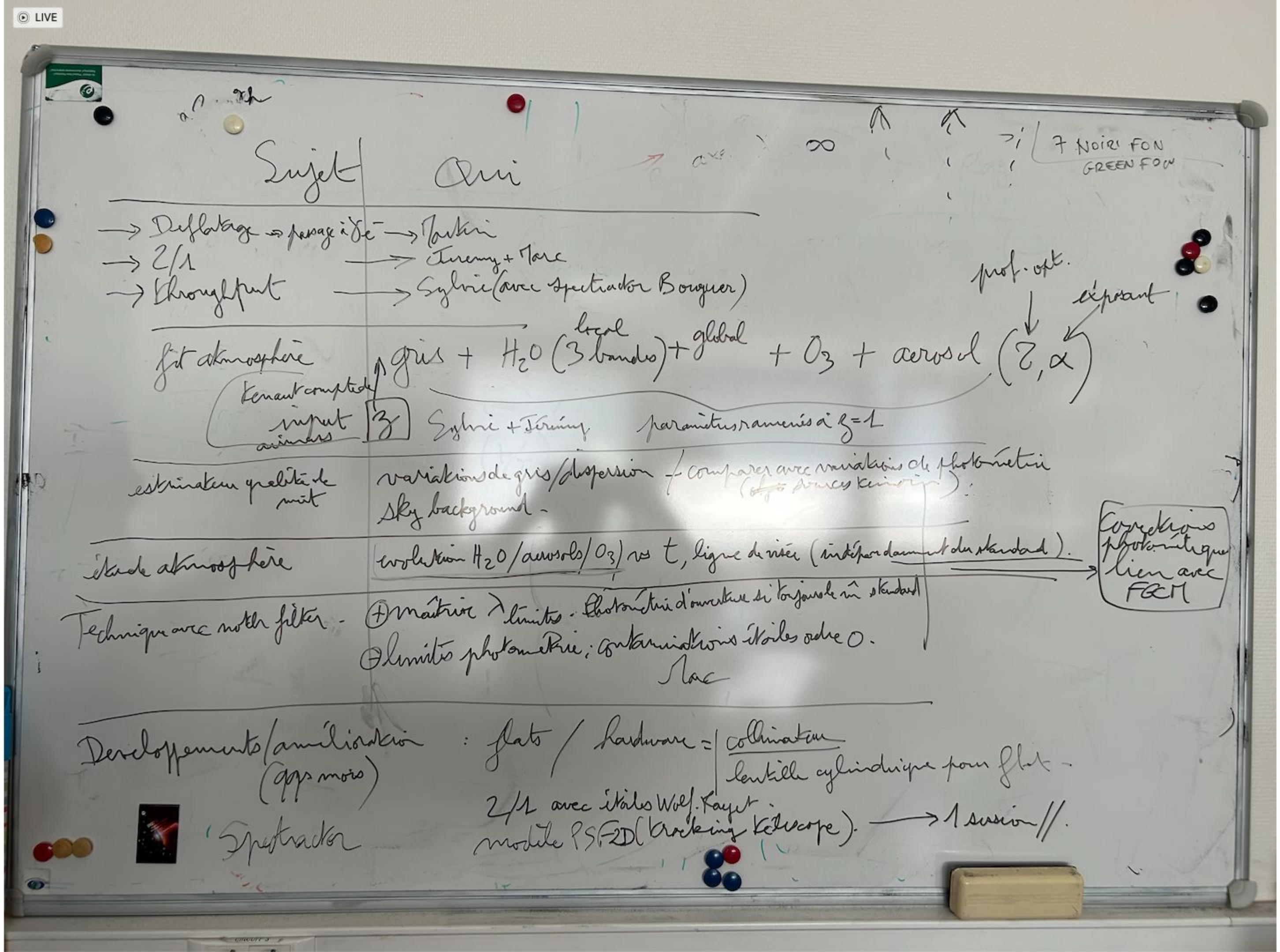


Photometric corrections

- Color corrections procedure for LSST photometry

Merci beaucoup

Backup


LIVE
7 NOIRS FOND
GREEN FOND
Sujet
Qui
→ Déflatage ⇒ passage à 3e → Martin
→ 2/1 → Jeremy + Marc
→ throughput → Sylvie (avec spectractor Bouguer)
prof. opt.
exposant
fit atmosphère
gris + H2O (3 bandes) local + global + O3 + aerosol (τ, α)
tenant compte de input auxiliaires
z
Sylvie + Jérémy
paramètres ramenés à z=1
estimateur qualité de nuit
variations de gris/dispersion
comparer avec variations de photométrie
sky background.
étude atmosphère
évolution H2O/aerosols/O3 vs t, ligne de visée (indépendamment des standards).
Corrections photométriques
lien avec FGCM
Technique avec notch filter
⊕ maîtrise λ limites.
⊖ limites photométrie; contaminations étoiles ordre 0.
Marc
Developpements/améliorations
(qqs mois)
: flats / hardware = collimation
lentille cylindrique pour flat.
2/1 avec étoiles Wolf-Rayet
modèle PSF2D (tracking telescope). → 1 session //
Spectractor

Some facts about AuxTel

- **D = 1.20m**, **f/D = 18**, **f = 21.6m**
- Depth of focus 1 arcsec (10 pixels) for **1.8mm** change in distance (small aperture).

- Secondary mirror (M2) Obturation: **0.3m**
- Total collection area : **S= 1.06 m^2** (taking into account M2 obturation)

- Plate scale: **105µm/arcsec** -> about **10 pixels/arcsec**.
- Field of view : **6.3 Arcmin**.

- Distance entrance window-CCD : 63.85mm. Light beam diameter at this distance : 3.55mm
- Distance disperser-CCD: about 191.4mm (tilted). beam diameter at this distance : 10.6mm
- Distance filter-CCD : 229mm (tilted).

- Saturation (no filter, no disperser, assuming seeing of 1''): **M_{sat}=13.35+2.5Log_{10}(Texp/30s)**

Data available (since 16 feb. 21)

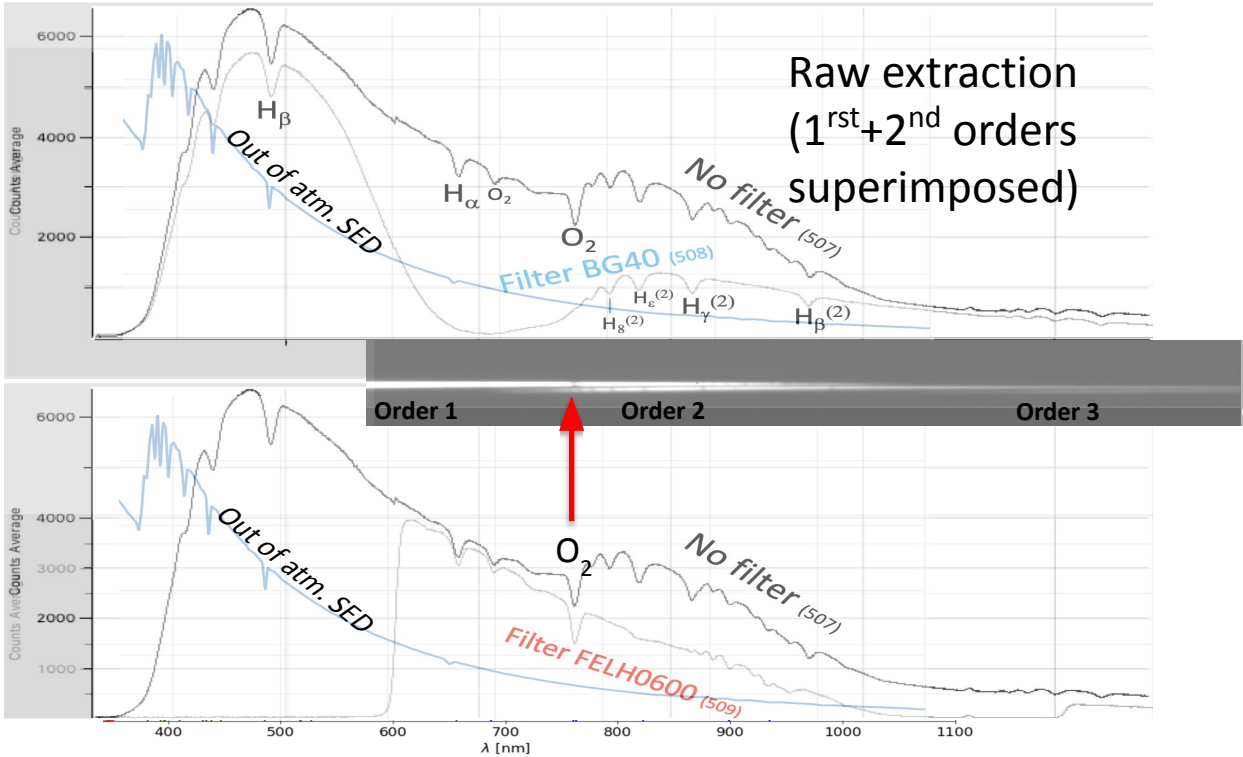
XXX spectra for

- Commissioning
  - ~~Geometry~~
  - ~~Resolution study~~
  - ~~Transmission~~
  - 2nd/1rst order : finalization
  - Bouguer lines: finalization for global telescope throughput
- With various
  - CALSPEC standards
  - atmospheric conditions
- with/without blocking filters
- but not that many with good quality

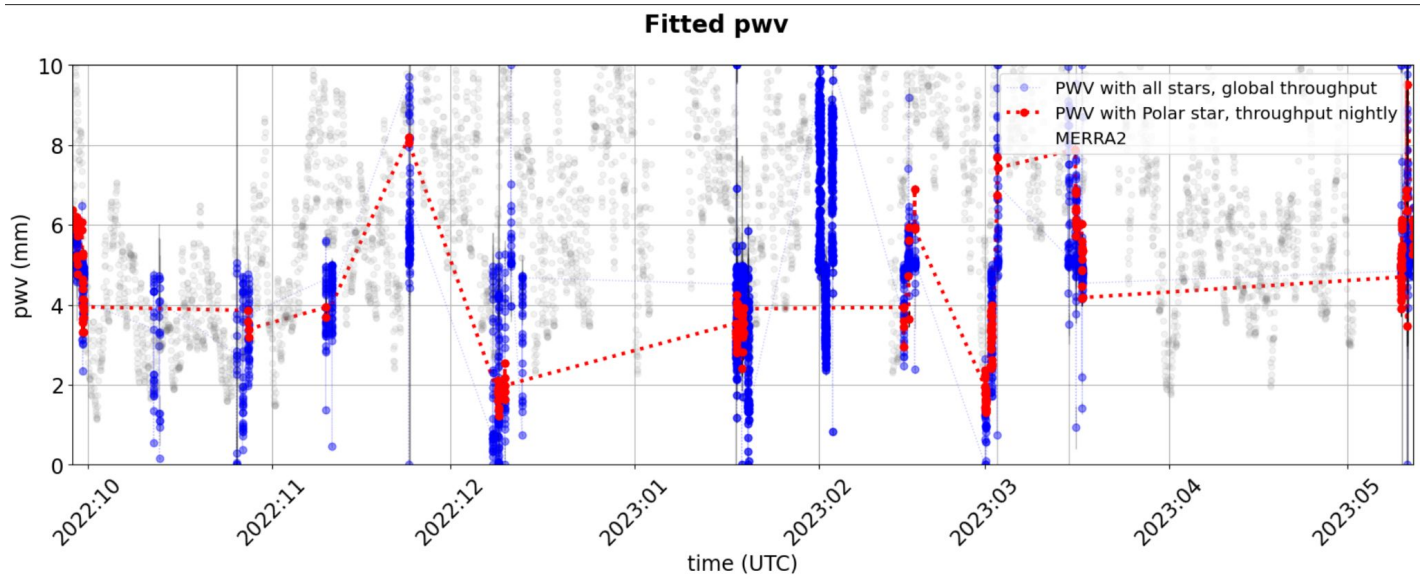
*->The best nights up to now seem to be **30th june and end sept. 2022**.*

- We need to acquire data in the largest domain of atmospheric Conditions.

Spectrum extends from ~ **342nm** to **1100nm**
Dispersion: 2.73 pixels/nm



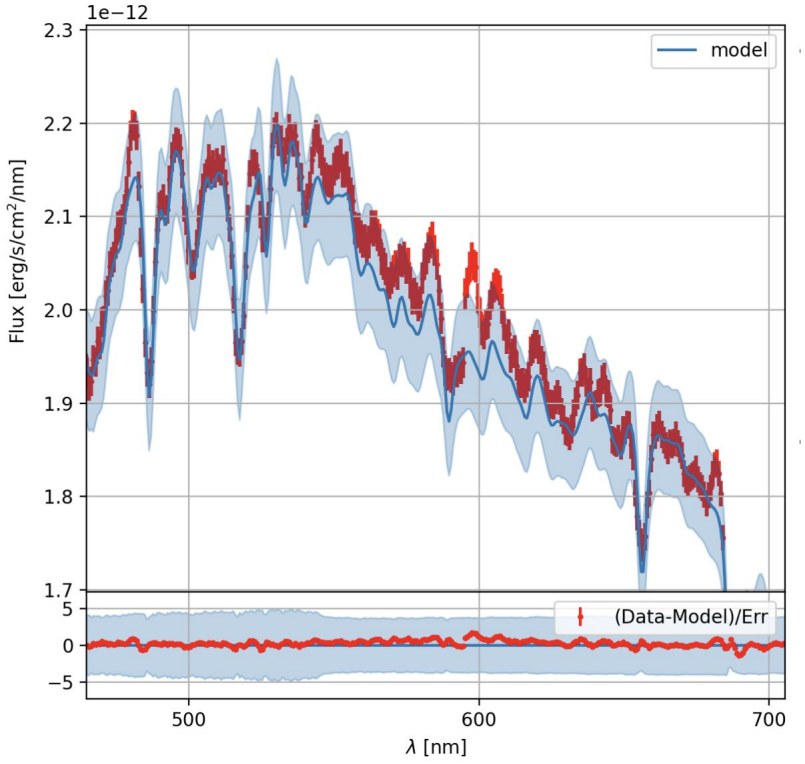
Combining Sylvie/Jeremy/MERRA2



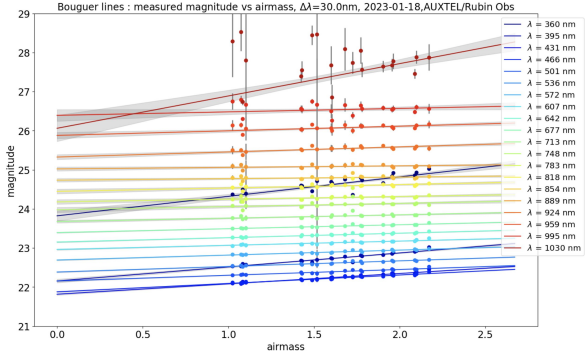
Pb Flats

PS: illustrer le soucis de flat dans la région de l'ozone :)

PPS: encore désolé pour mon absence en réunion, je vous envoie tous ces plots et on discutera une autre fois, sinon par email, là on file

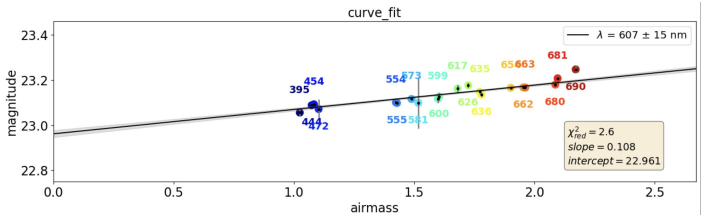


Estimation of total throughput

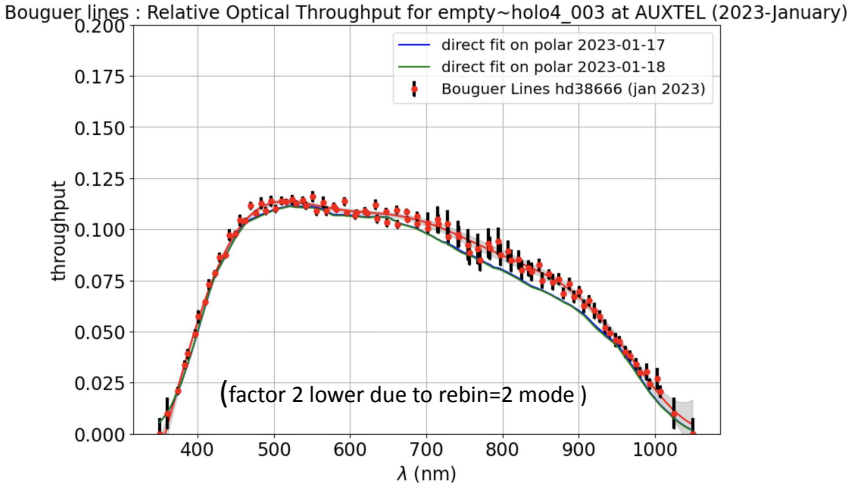


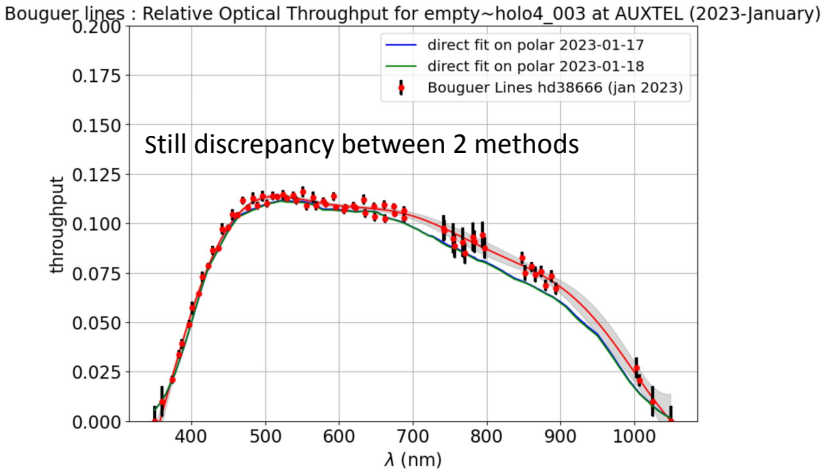
2 methods :

- Bouguer lines fits (airmass extinction wrt wavelength)
- Fit a common median throughput over a whole night series



Removing absorption lines

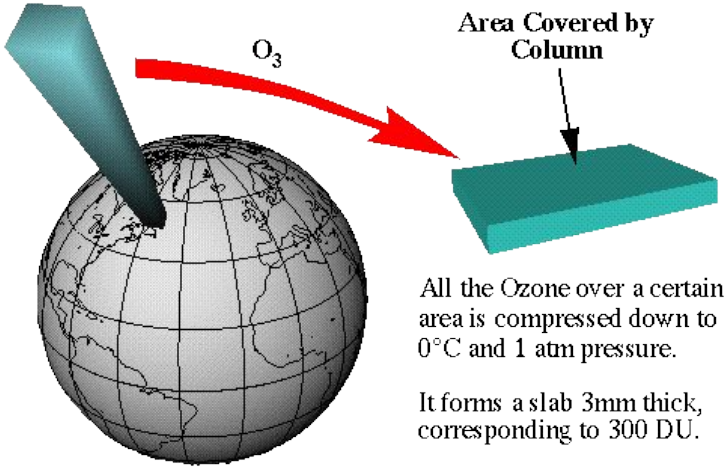




Atmospheric parameters: units

Aerosols = [DU] (Dobson Units):

The Dobson Unit is a way to describe how much ozone there would be in the column if it were all squeezed into a single layer. The average amount of ozone in the atmosphere is roughly 300 Dobson Units, equivalent to a layer 3 millimeters



PWV = [mm]:

When measured in linear units (millimeters, mm), it is the height (or depth) the water would occupy if the vapor were condensed into liquid and spread evenly across the column.