Holographic Optical Elements to measure atmospheric transmission with Auxiliary Telescope

Sylvie Dagoret-Campagne, Marc Moniez, Jérémy Neveu
Olivier Perdereau, (LAL/IN2P3/CNRS)
+ Marc Betoule and Laurent Le Guillou (LPNHE/IN2P3/CNRS)

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

sous la co-tutelle de

cnrs IN2P3 Institut national de physique nucléaire et de physique des particules

UNIVERSITÉ PARIS SUD

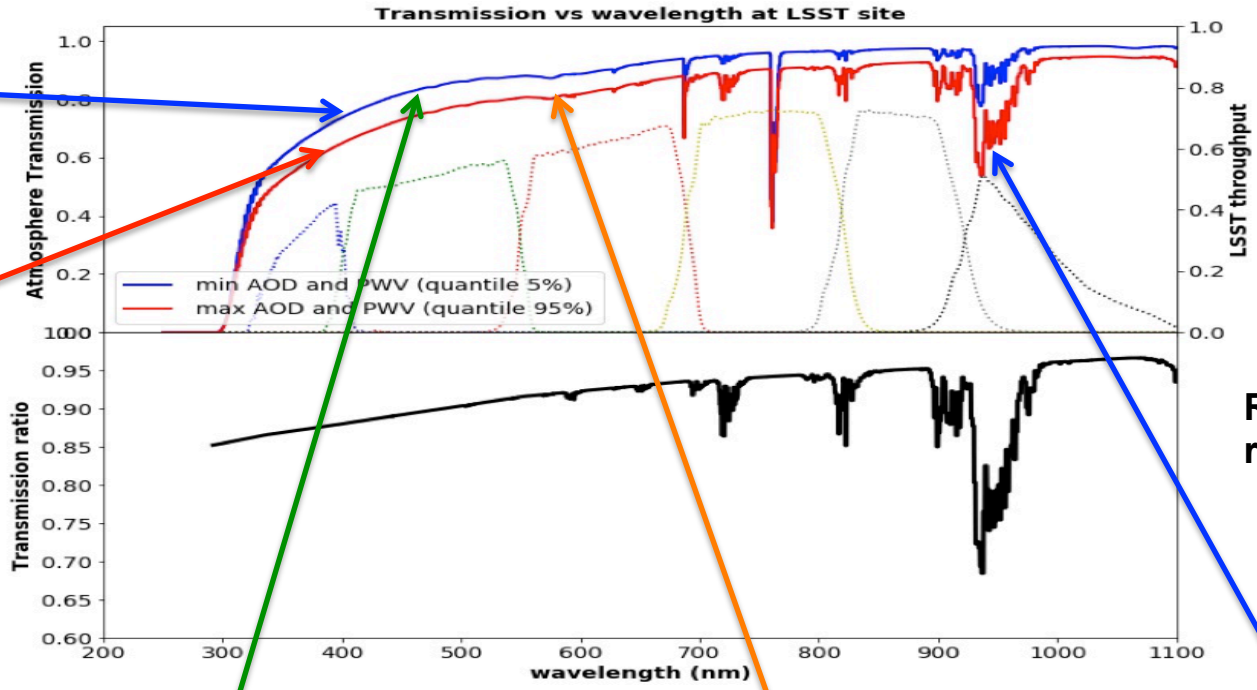
université PARIS-SACLAY

LSST DESC Dark Energy Science Collaboration

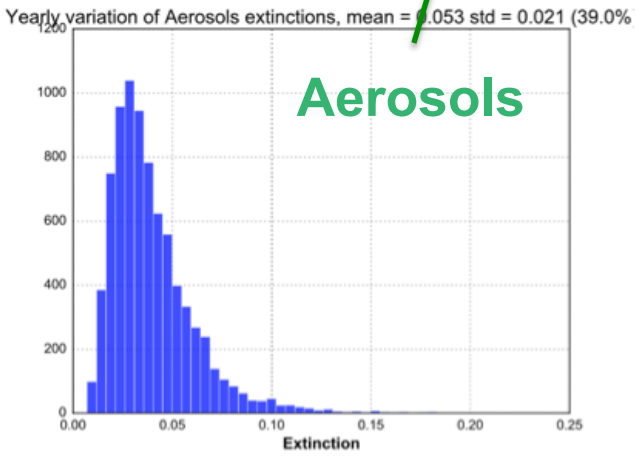
Atmospheric transparency Variation

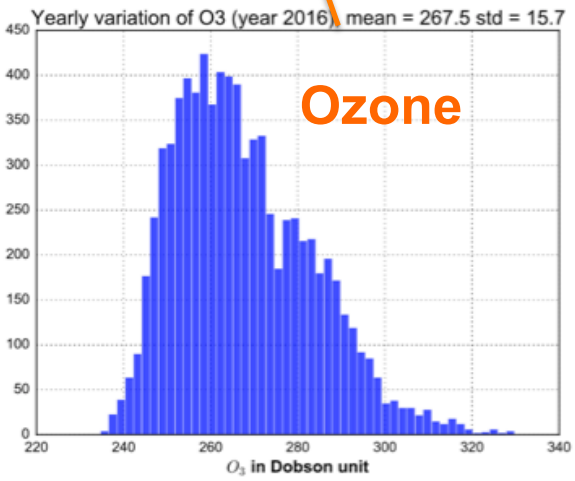
Max Transm

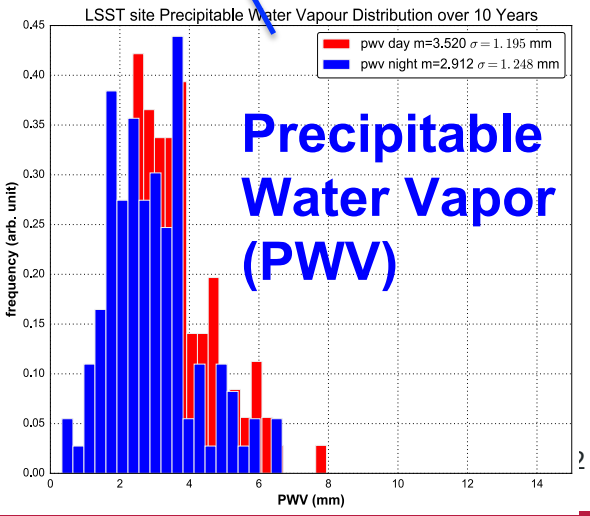
Min Transm



Ratio= red/blue transmission







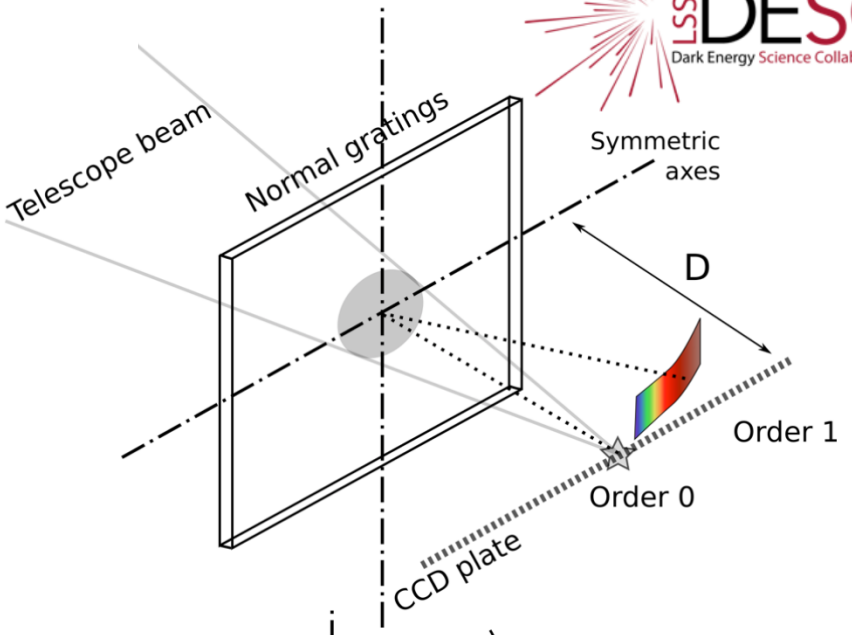
HOE for AuxTel

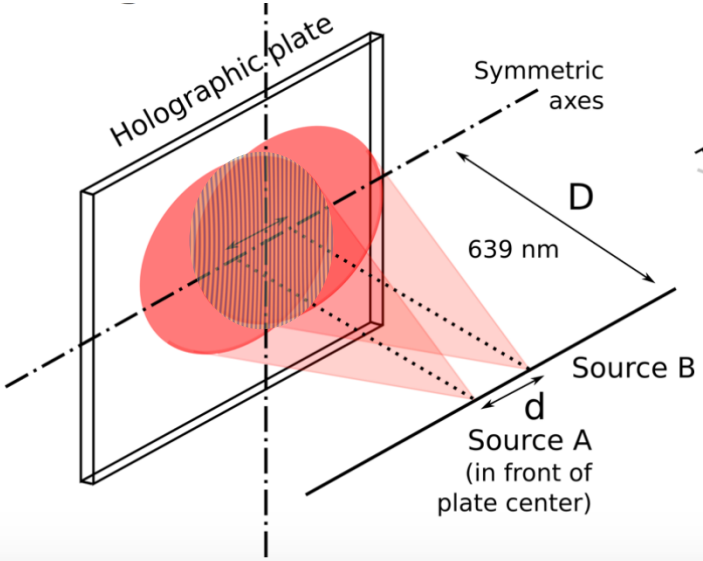
Usual gratings:

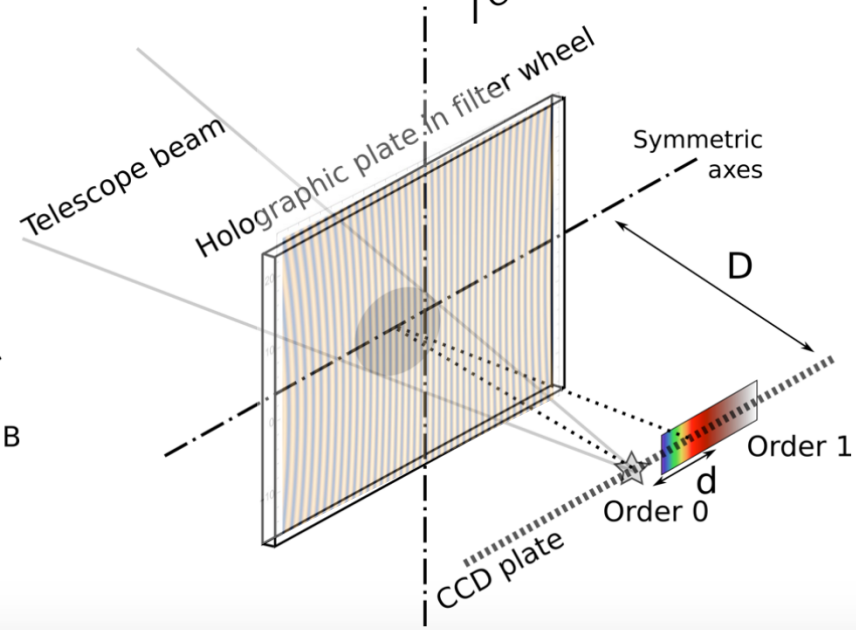
- all wavelengths not focused simultaneously due to optical path variation with the diffraction angle
- Distorsions (astigmatism) due to converging beam (not parallel)

Holograms:

- Focusing forced on the focal plane at all wavelengths
- No distorsions by design of the hologram
- Theoretical hologram (linear phase encoding): only -1, 0, +1 orders

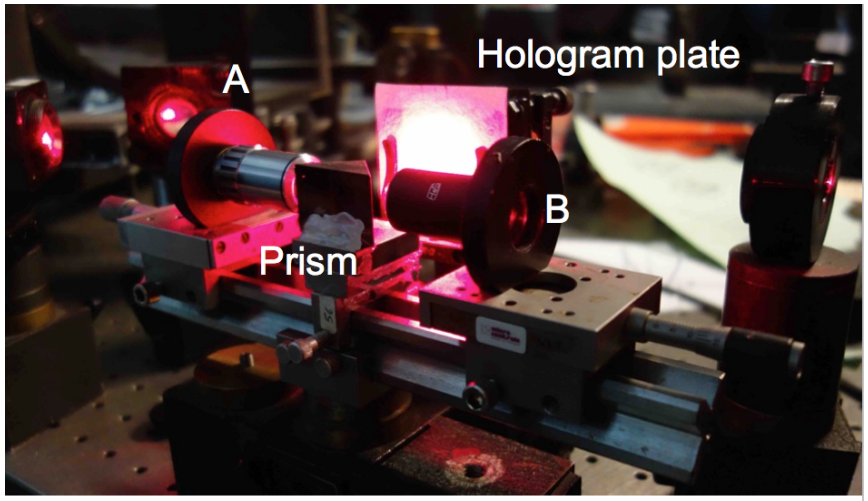


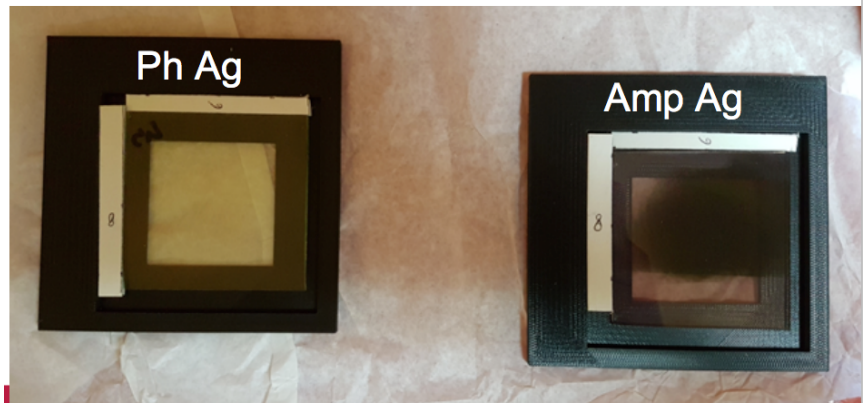




Realization of the HOE (Holographic Optical Element)

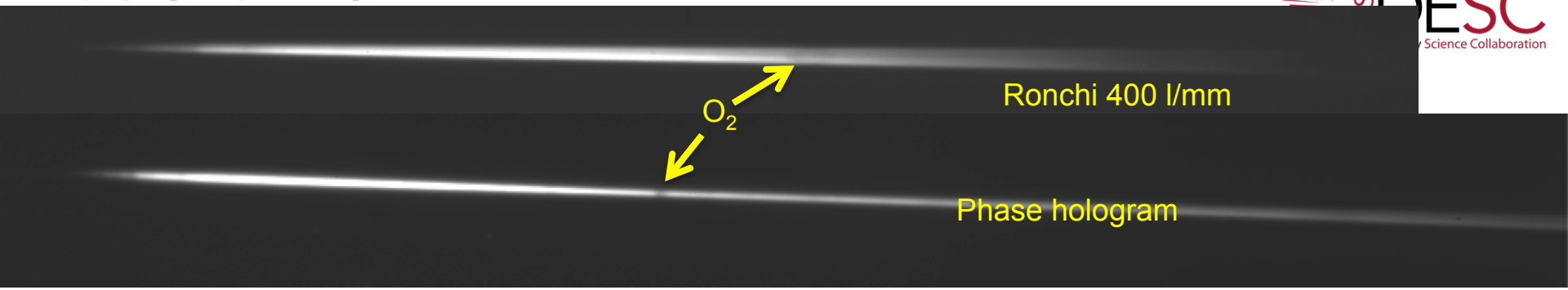
- **Ultimate holography company**: *makes the best holograms in the world.*
- **2 technologies**:
  - Amplitude holograms: transmission modulation
  - Phase holograms: phase modulation (2 techniques)
- Tested together with **Ronchi** and **blazed gratings** during may-june 2017 CTIO run (18 nights)

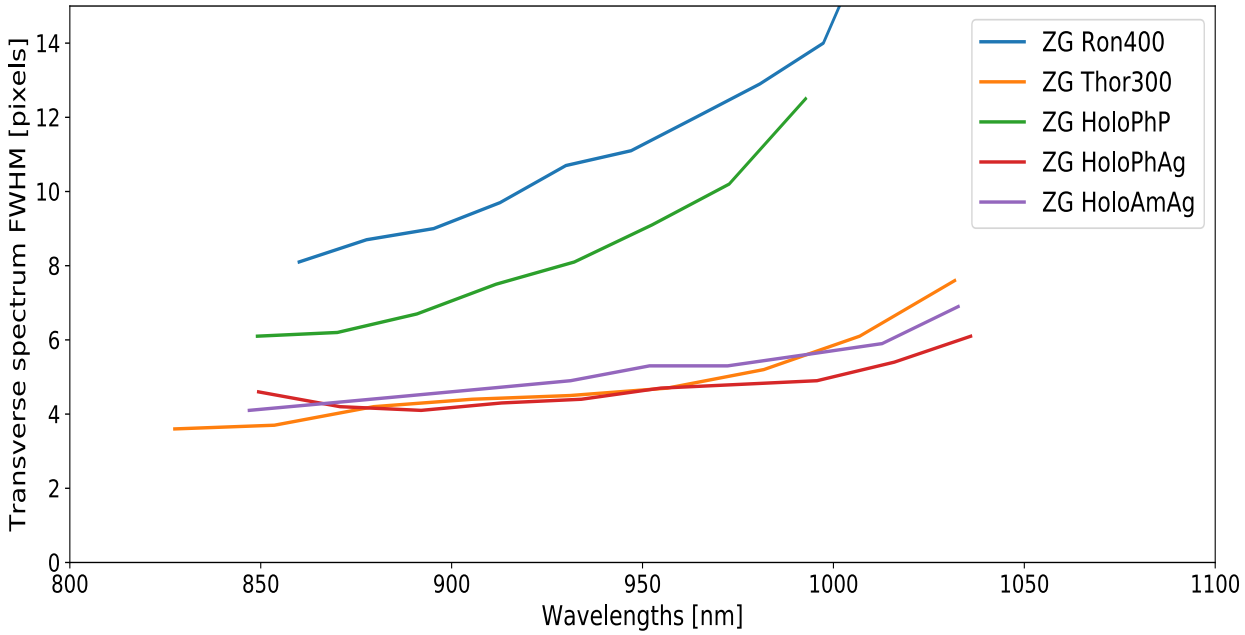




HOE performances: focus, resolution

Spectrum profile of CALSPEC standard star





Estimates of spectral finesse $R=\lambda/\Delta\lambda$ @Hα

Gratings

- Ronchi 400 l/mm: **R ~ 70**
- Blazed 300 l/mm: **R ~ 125**

Holograms

- Photopolymer : **R ~ 130**
- Phase argentic : **R ~ 280**
- Amplitude Ag : **R ~ 390**

Profile width of the dispersed first order light, vs the wavelength (Gunn-z passband)

-> Commensurable with the expectations from simulations (ZEMAX)

Tests on telescope
27 may-13 june 2017

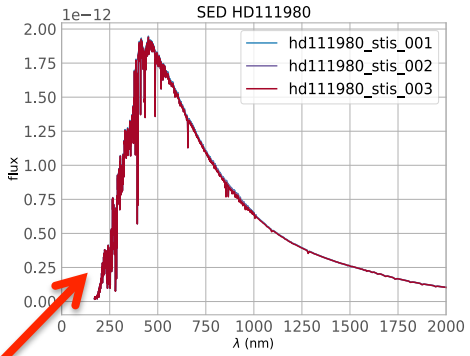
Objectives

- Compare **Ronchi, blazed gratings and holograms (phase & amplitude)**
- Obtain data with various atmospheric conditions

Observations made

- 16 clear nights with variable conditions (4 photometrics)
- Measures and comparisons of spectra from:
  - **HST** spectro-photometric **Standards** (**CALSPEC**)

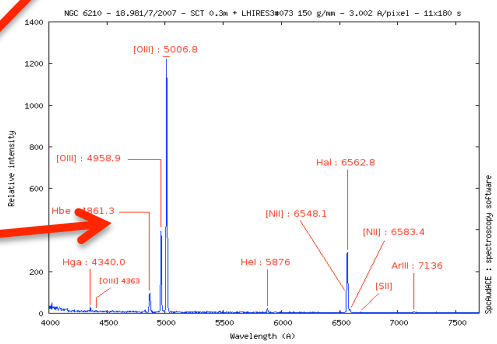
Series of consecutive measurements with variable airmass



- **Planetary nebulae**

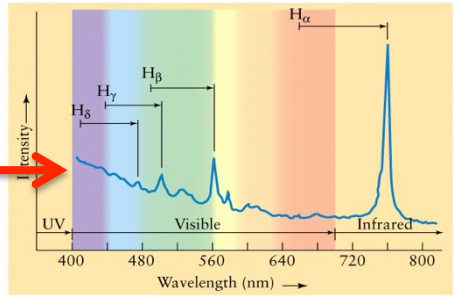
Narrow and strong emission lines

-> to study dispersion law and estimate spectral resolution



- **Quasars**

Strong redshifted Hα -> to test R et IR spectroscopy



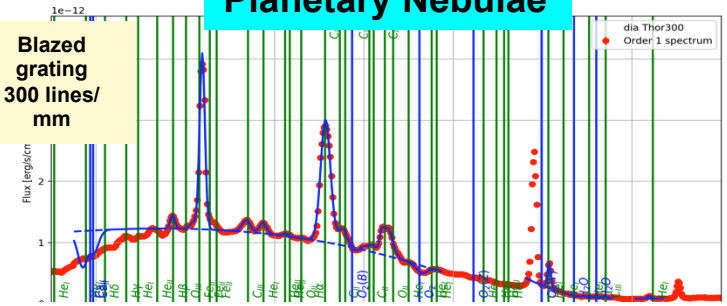
Planetary Nebulae

Quasar

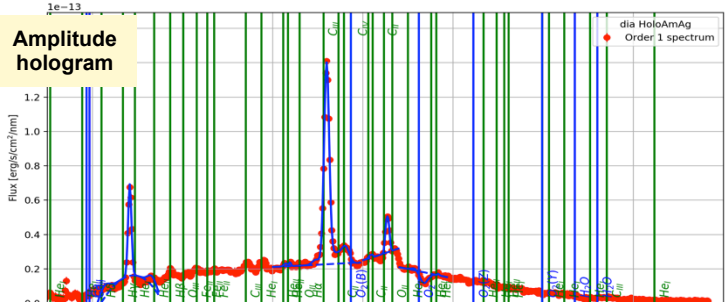
Planetary Nebula SED

Quasar 3C273 SED (redshifted z=0.158)

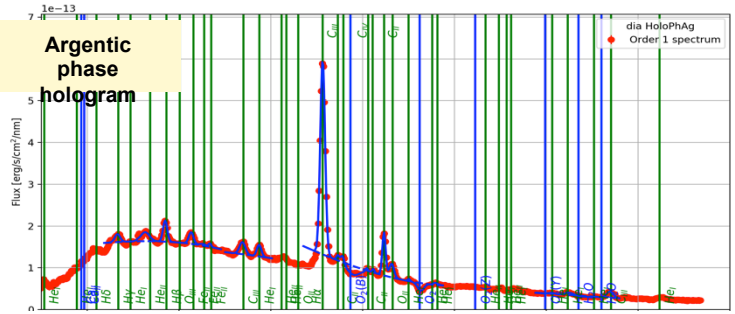
Blazed grating 300 lines/ mm



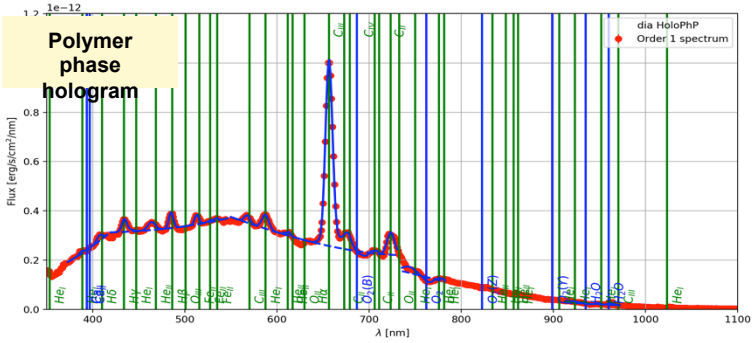
Amplitude hologram



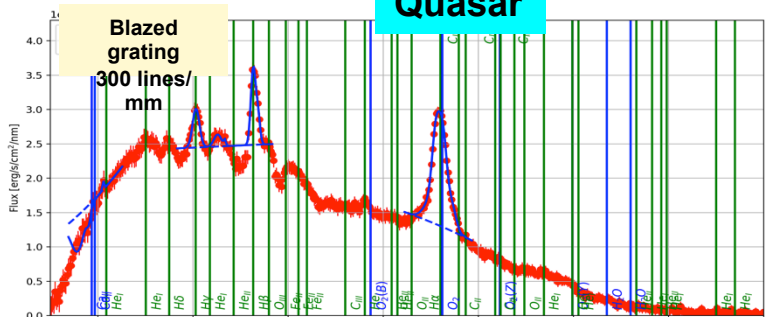
Argentic phase hologram



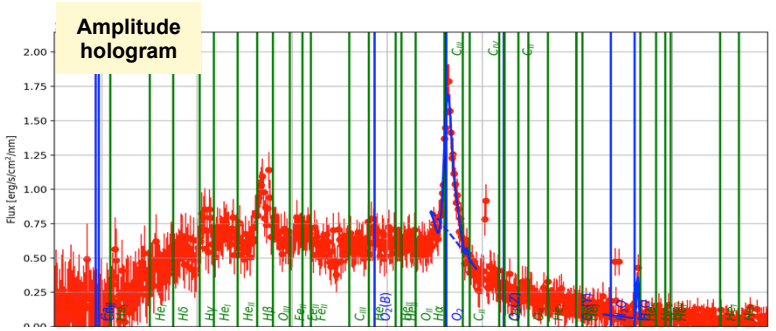
Polymer phase hologram



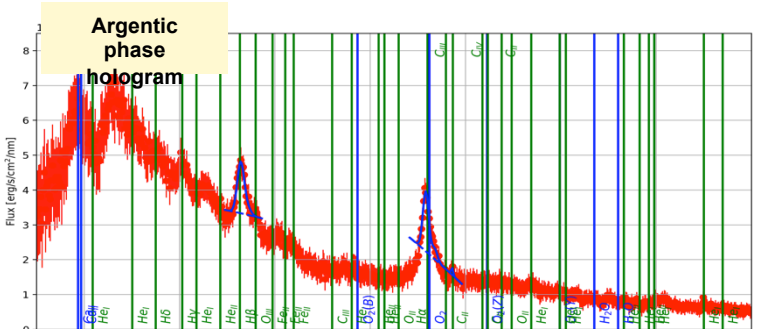
Blazed grating 300 lines/ mm



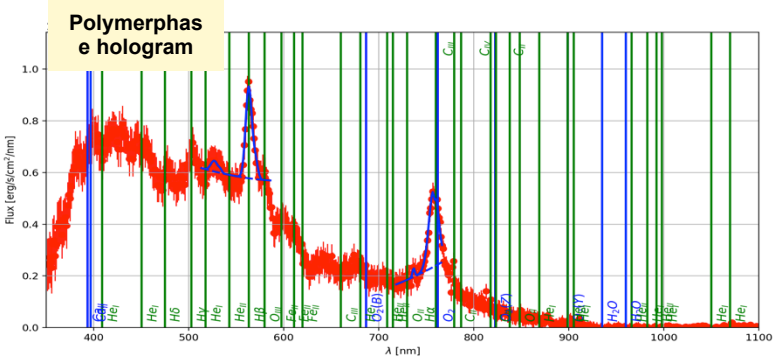
Amplitude hologram



Argentic phase hologram



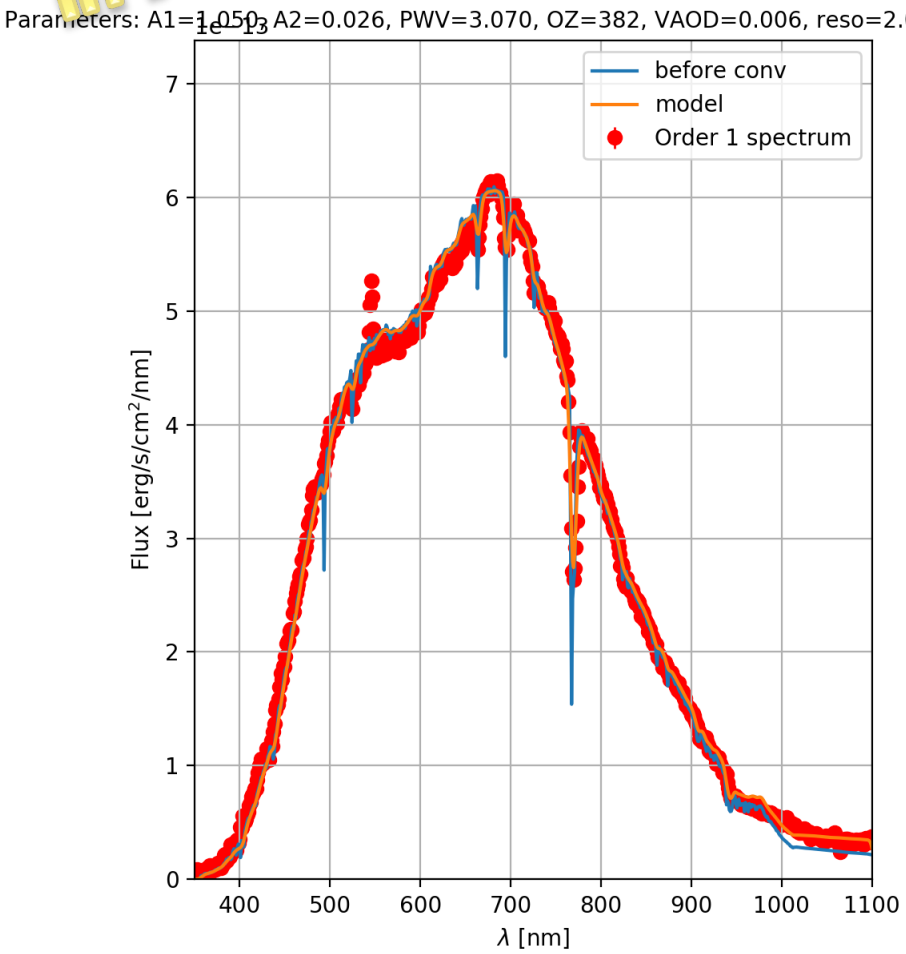
Polymerphase hologram

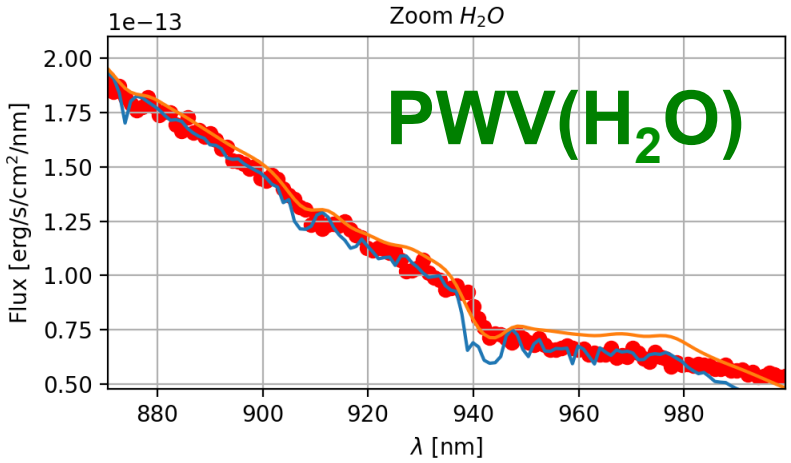


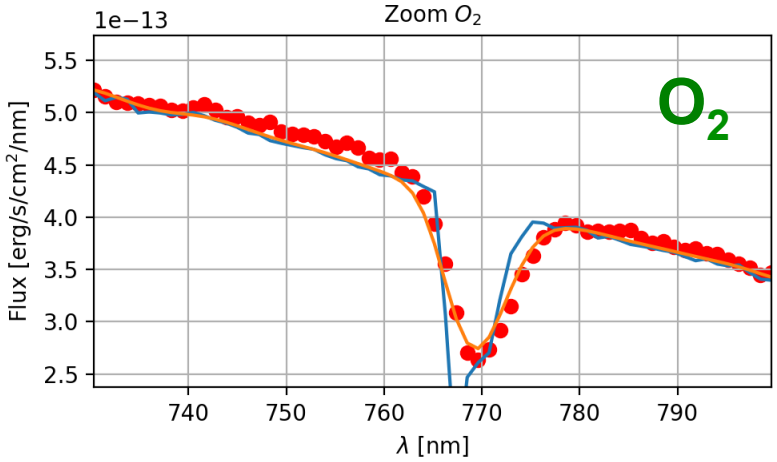
Measured spectrum/simulated spectrum of CALSPEC stars

Amplitude Ag Hologram

In Progresss

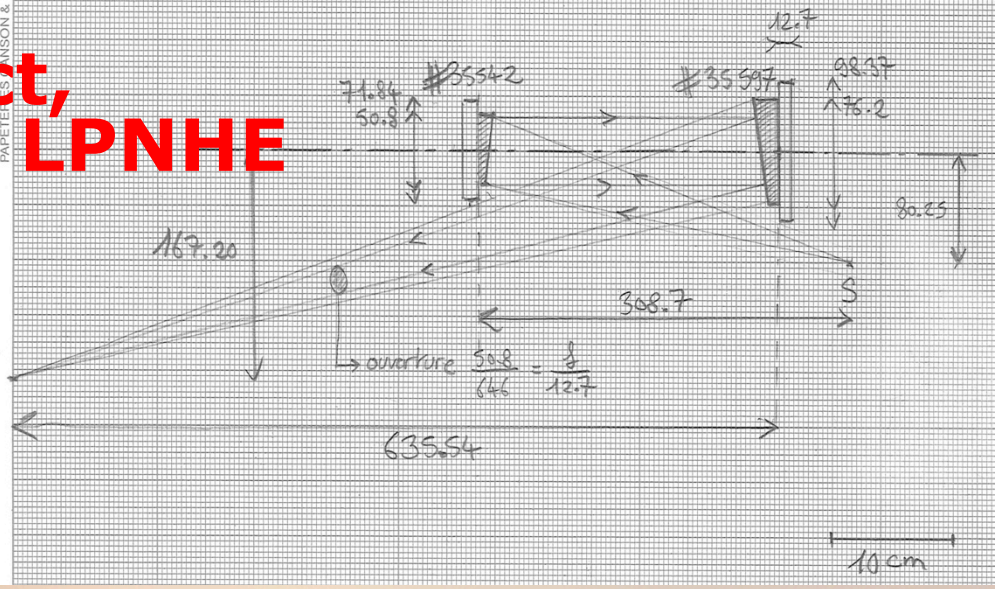




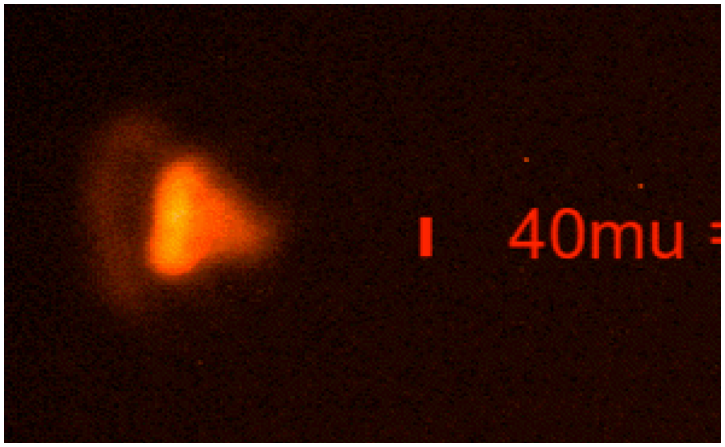


« HOLOSPEC » project, Optical Test-bench at LPNHE

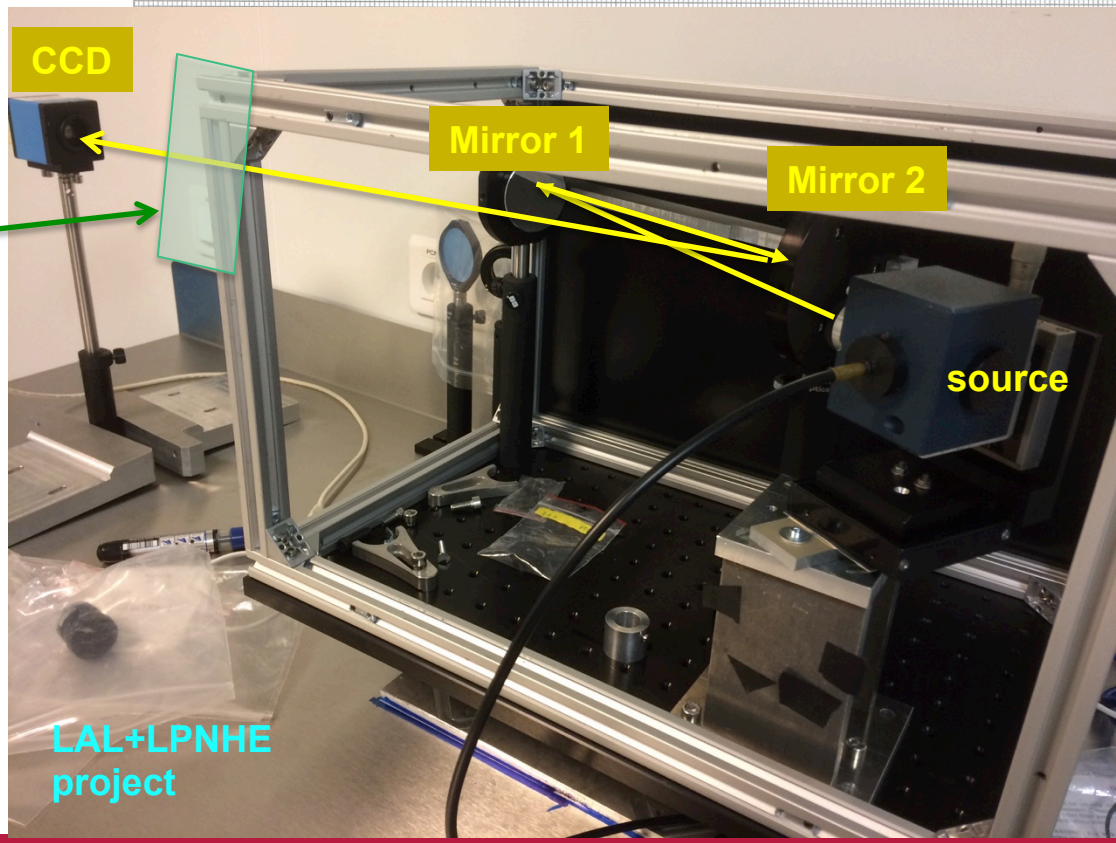
- **Light sources:**
- Red laser
- LED blue, green,IR
- Thermal lamp
- **Integrating sphere, diaphragm: 20µm**
- Uniform light beam AuxTel-like
- **CCD :**
  - ➢ Tuning with Astronomical CCD
  - ➢ Use with LSST- ITL/E2V (AuxTel)



Spot =0.5 arcsec << seing



hologram



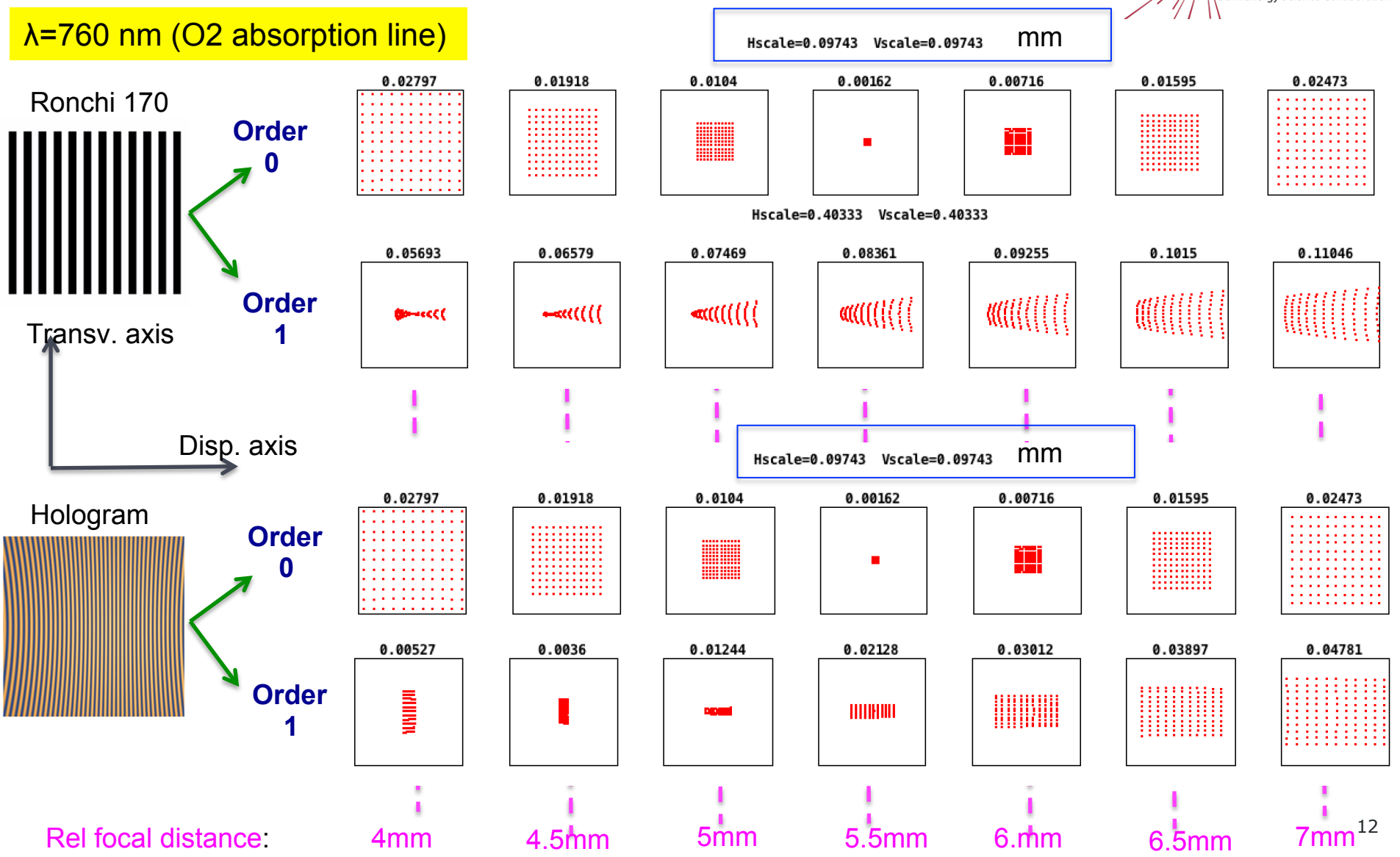
Perspectives

- We want to measure atmospheric transmission with low resolution spectroscopy (R >100) within [400-1050] nm
- Customized HOE (Holographic Optical Element) can provide perfectly focused spectrum for all wavelengths (+ same focus than zero order)
  => better resolution than standard Ronchi (simulation + observations)
  - Promising results from prototypes on CTIO telescope
  - Final production on its way for AuxTel customized holograms
  - Ready for extensive atmospheric studies for AuxTel operation starting march 2019

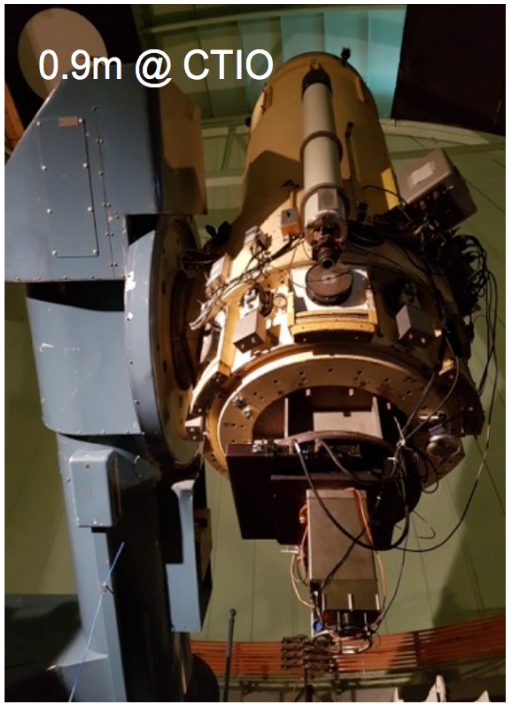
Backup

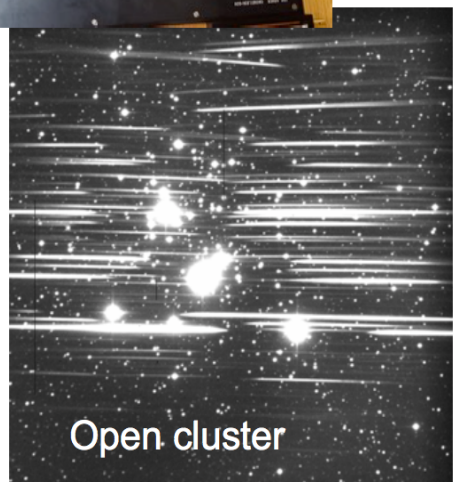
Simulated AuxTel Beam Spot on CCD plane wrt relative focal distance

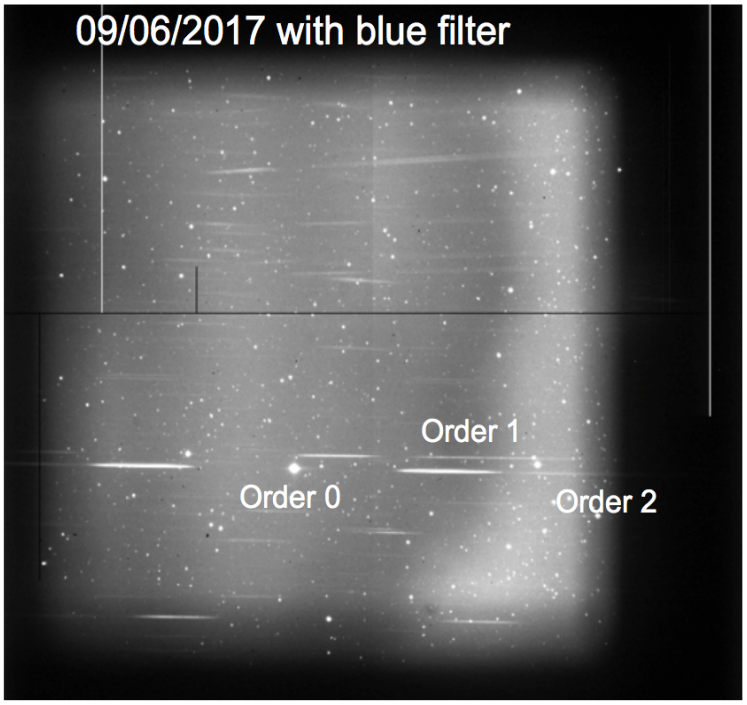
λ=760 nm (O2 absorption line)

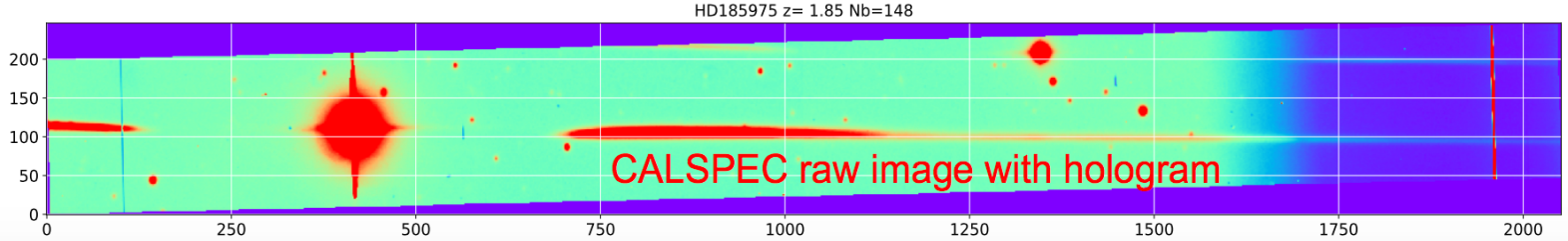


Holograms on a Telescope





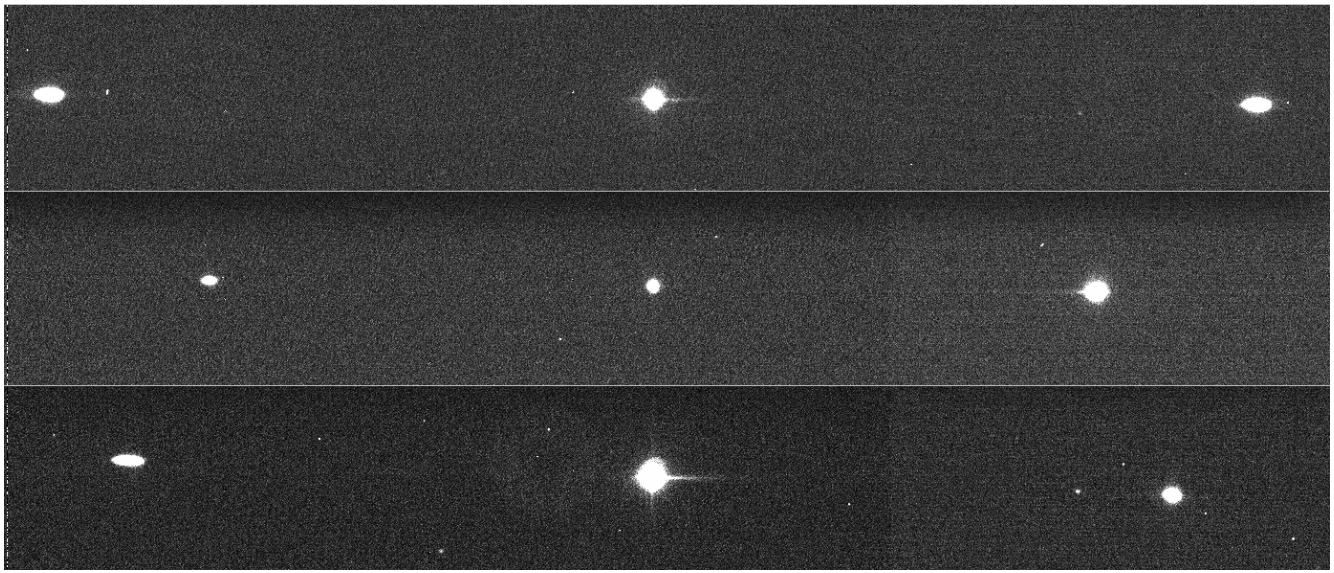




Disperser performances

HOE designed to compensate geometrical distortions for 1rst diffractive order, by design

- Tests with narrow **H_α** filter (FWHM = 6.4 nm)
- Best results with the +1 order of the hologram



Ronchi
400 lines/mm

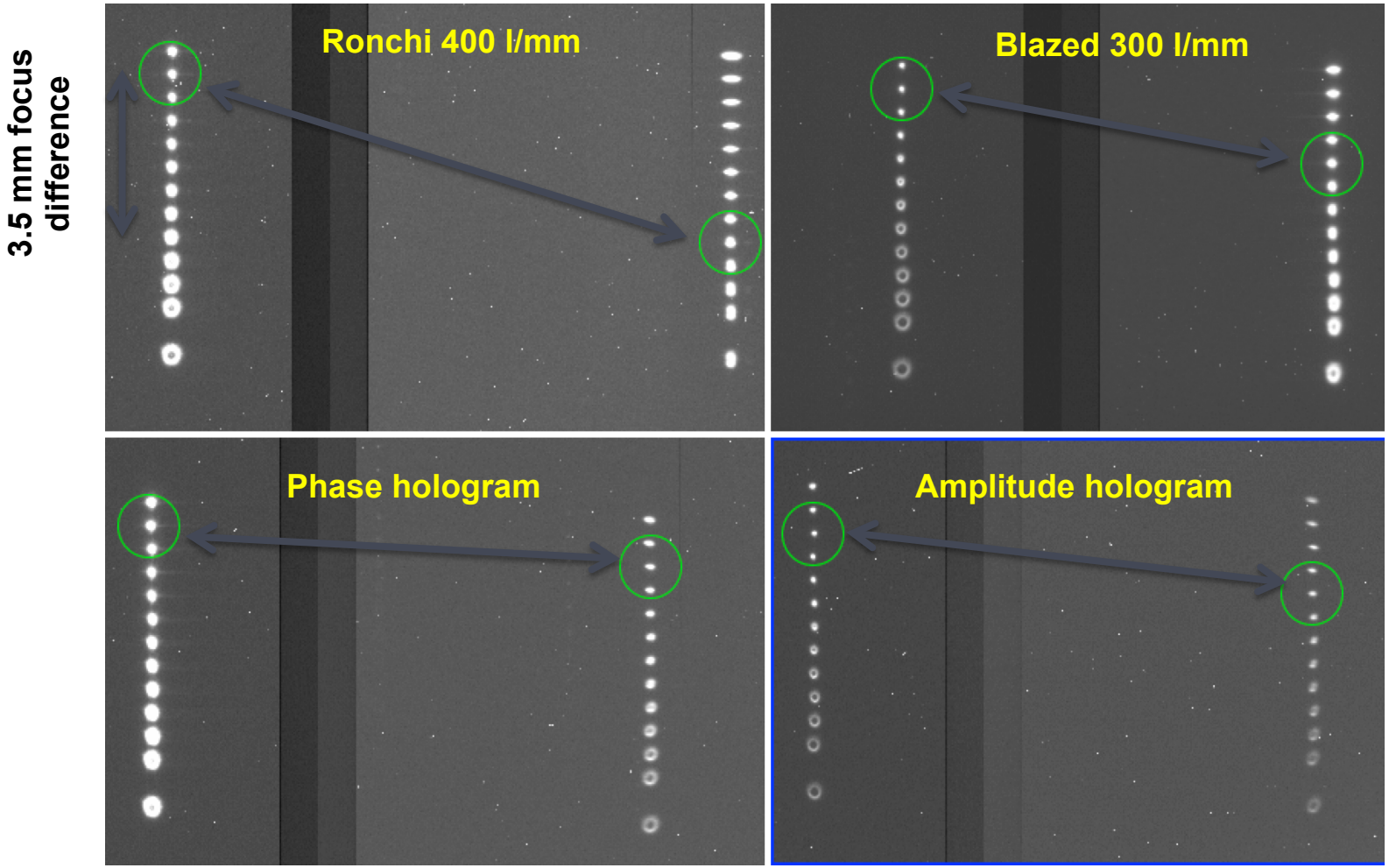
Blazed grating
300 lines/mm

Phase hologram
~365 lines/mm

Order -1 **Order 0** **Order +1**

Let's look in more details

- *SIMULTANEOUS focus procedures with the Hα narrow filter.*
  - 0 order focus (left) vs +1 order focus (right)

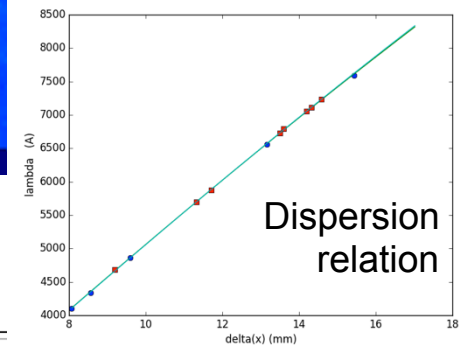


HOE performances: planetary nebula

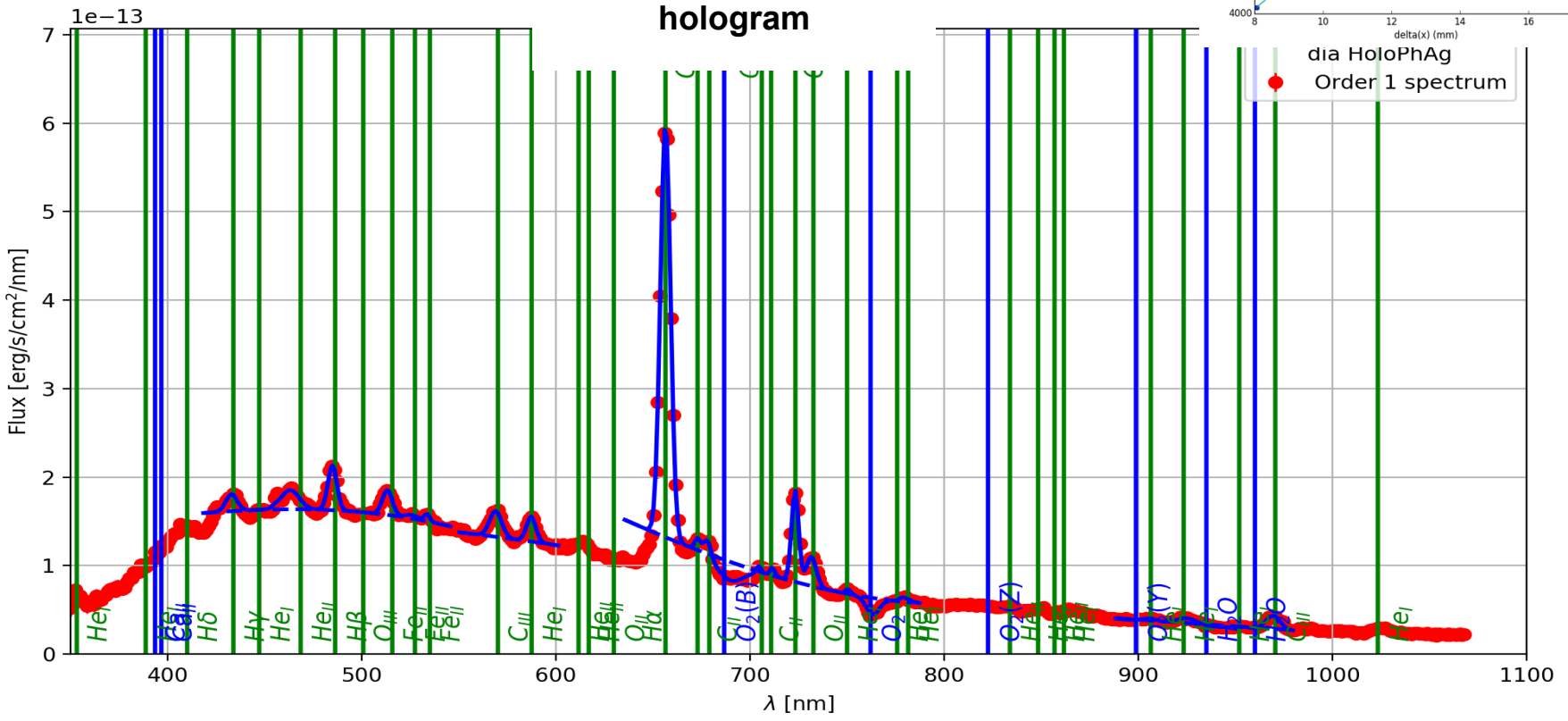
Why? narrow emission spikes with measured intensities
-> λ calibration, resolution, and (ε_{CCD} x $\varepsilon_{diffraction}$)(λ) estimates

Planetary nebula PNG032.9-02.8

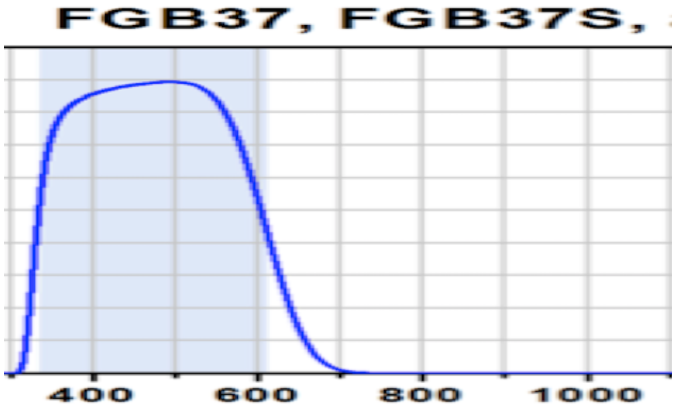
emission spikes



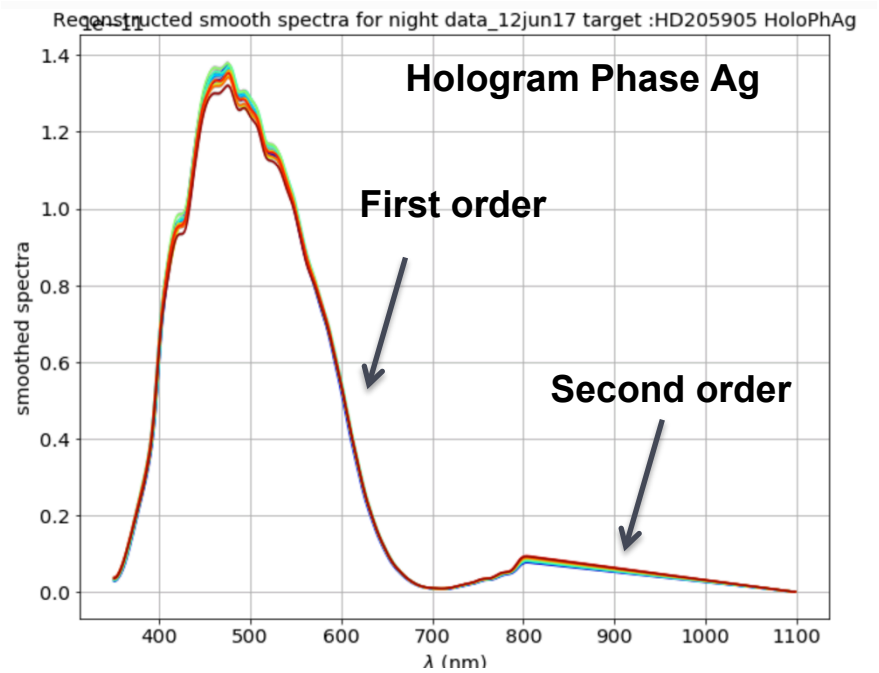
Argentic phase hologram

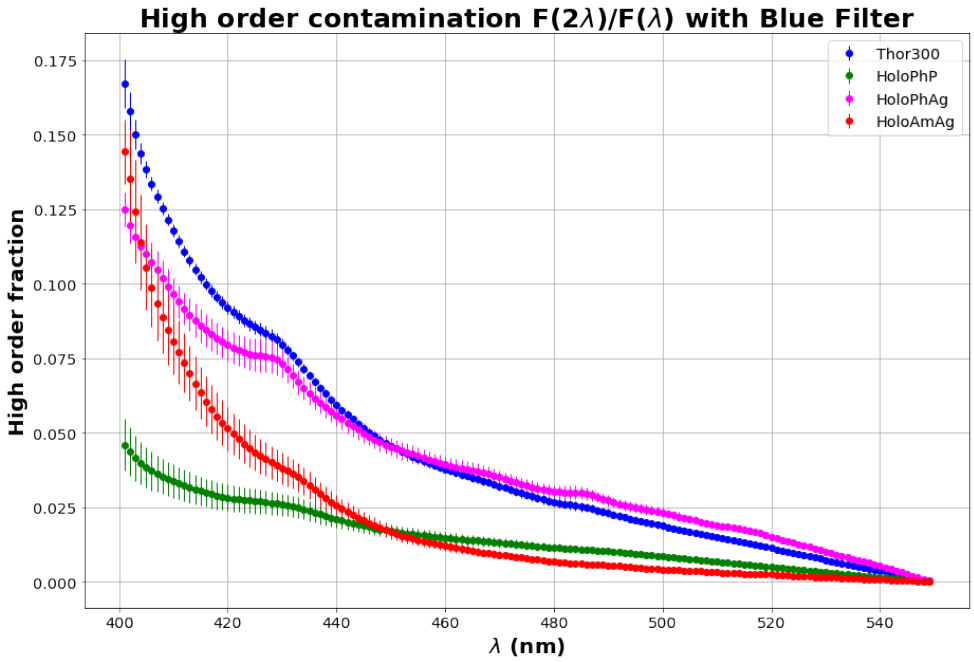


Disperser performances: 2nd order



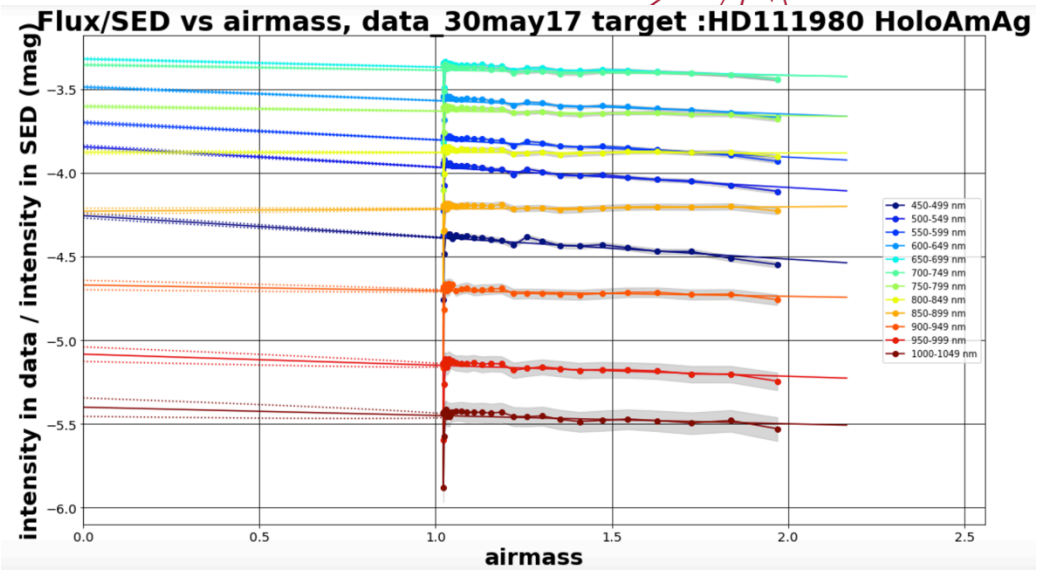
Blue filter allows to split 1rst/2nd orders

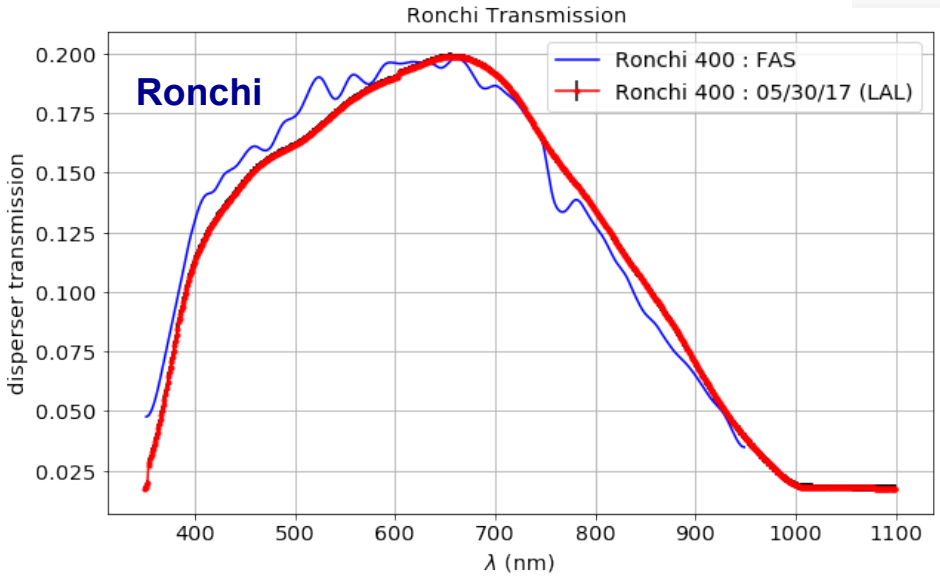


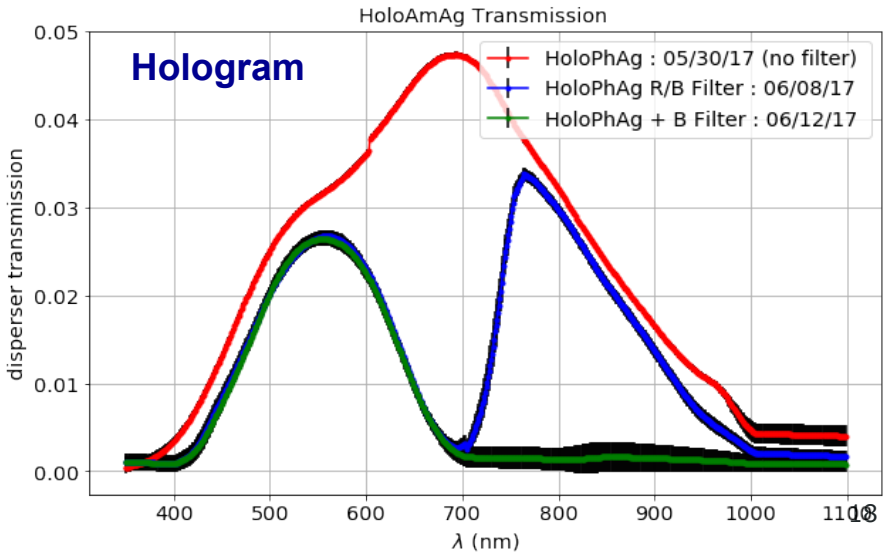


Absolute Throughput estimation (Qe x optics x 1st order disperser)

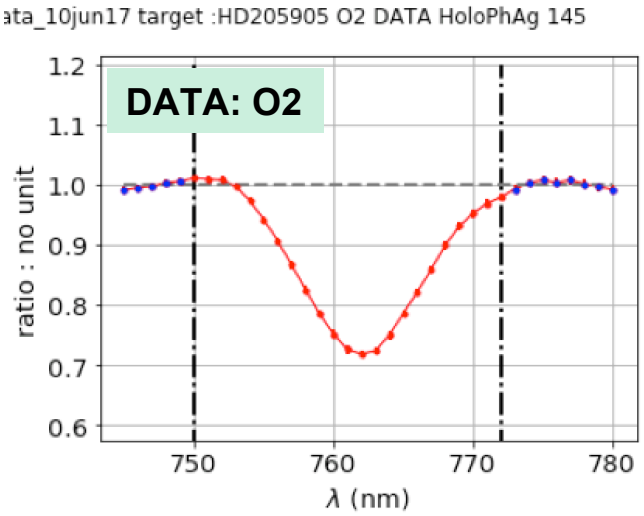
- Ratio=Flux/SED
- Ratio wrt Airmass z in Δλ
- Fit of Bouguer lines:
  - Intercept (z=0)→ total throughput

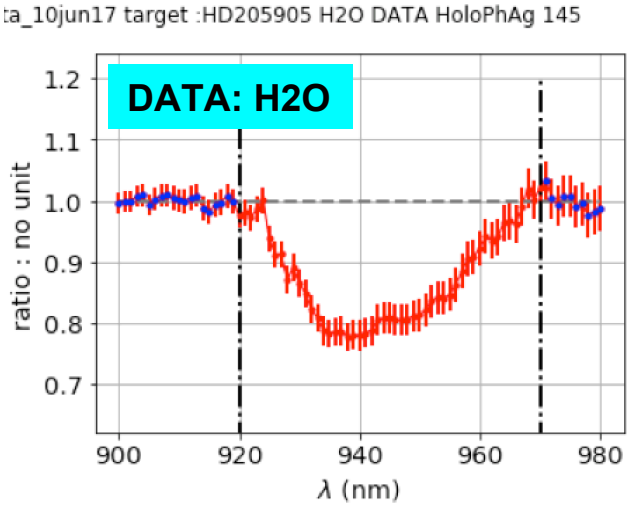


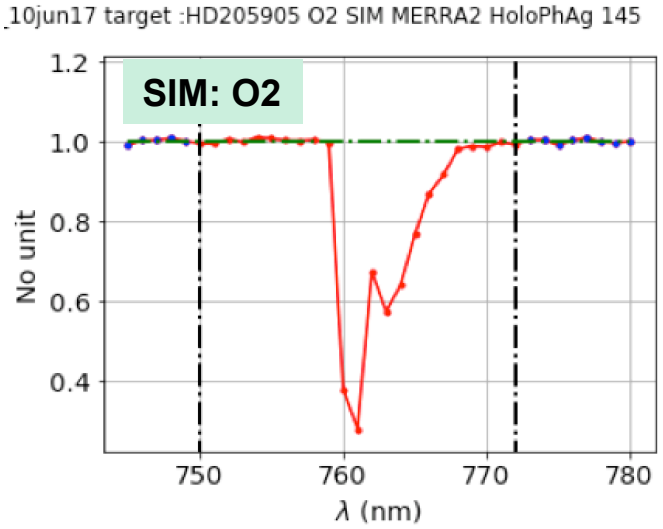


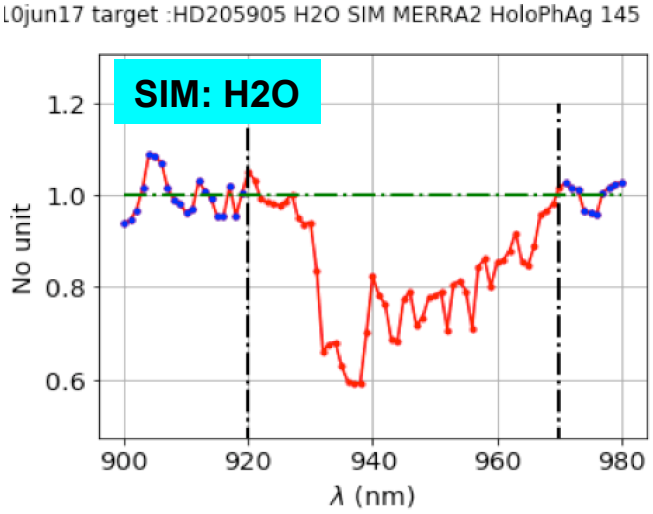


Equivalent width estimation

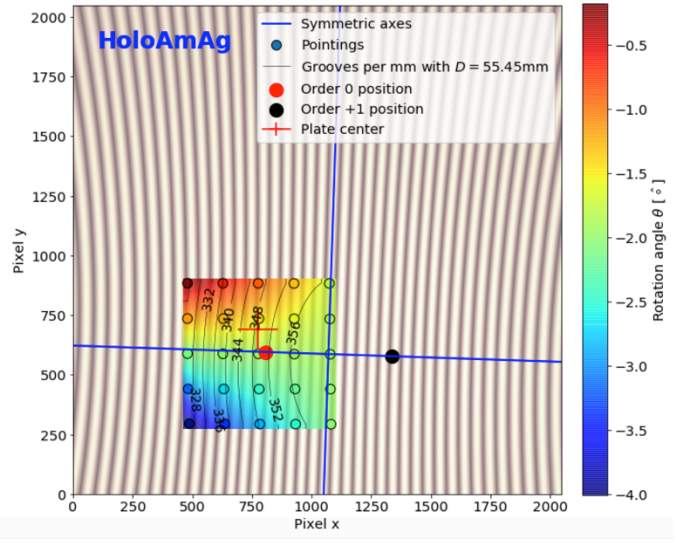


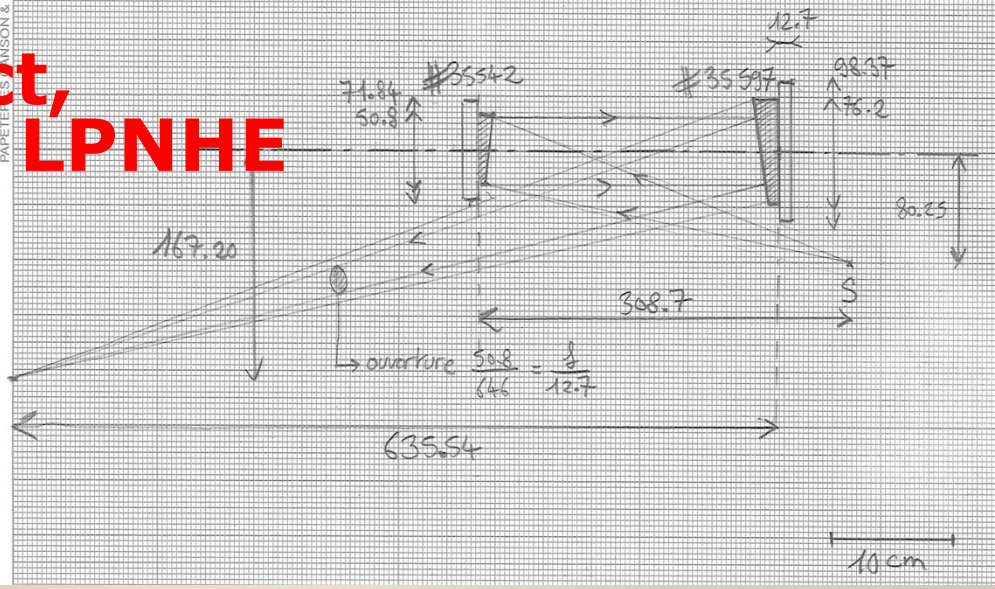




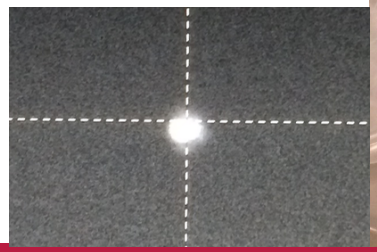


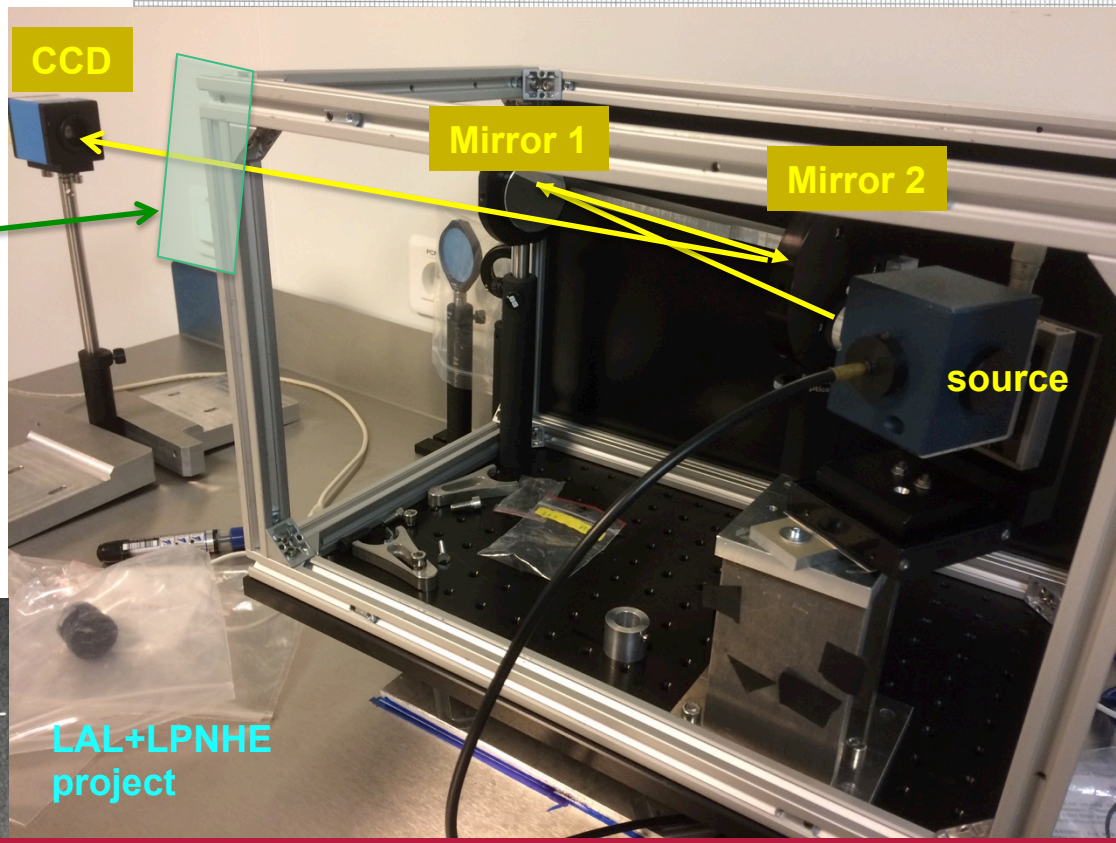
« HOLOSPEC » project, Optical Test-bench at LPNHE

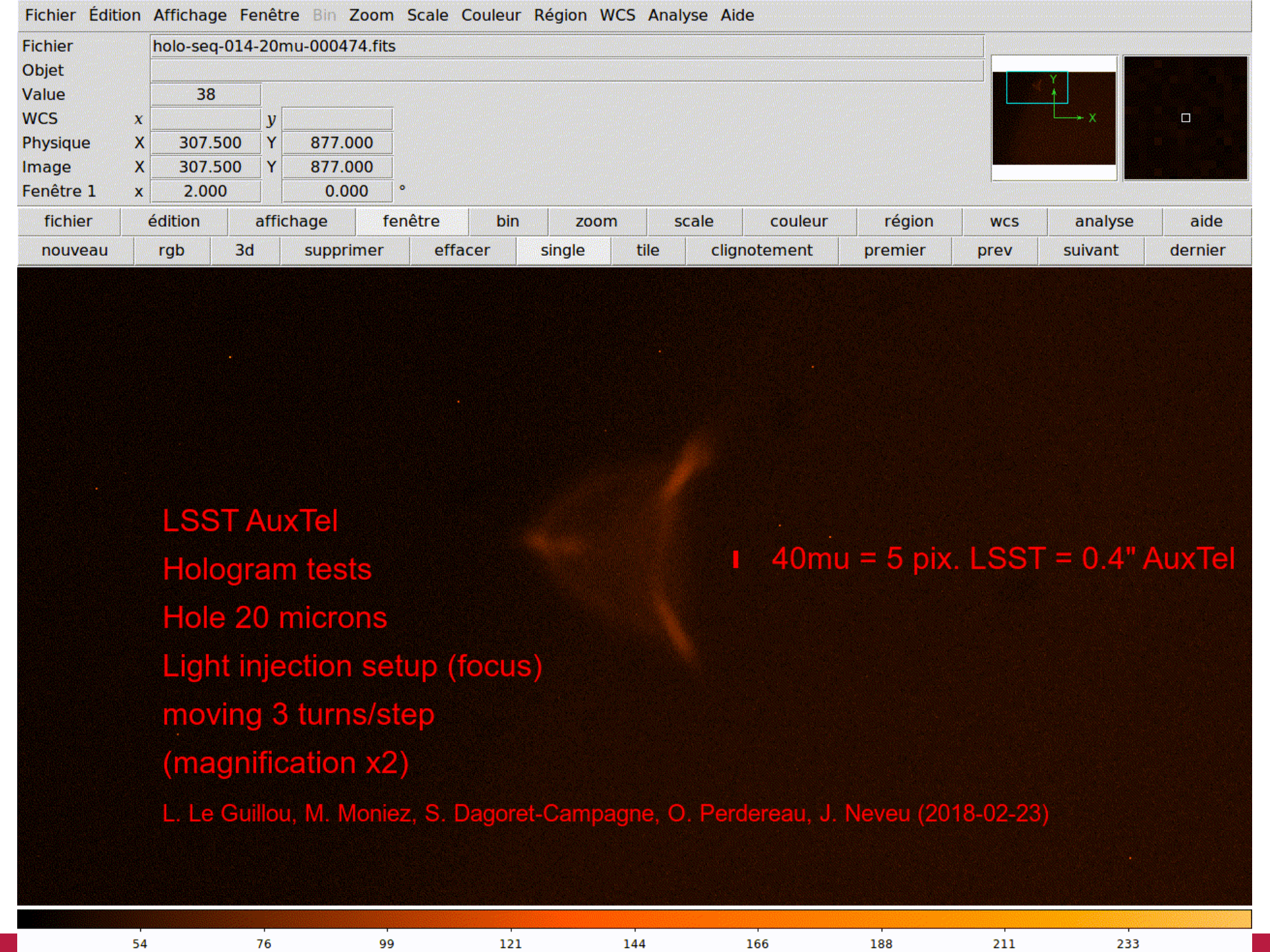




- **Light sources:**
- Red laser
- LED blue, green,IR
- Lamp
- **Integrating sphere, diaphragm: 20µm**
- Light beam : AuxTel beam-like
- **CCD :**
  - Astronomical CCD
  - LSST- ITL/E2V






Fichier Édition Affichage Fenêtre Bin Zoom Scale Couleur Région WCS Analyse Aide
Fichier holo-seq-014-20mu-000474.fits
Objet
Value 38
WCS x y
Physique X 307.500 Y 877.000
Image X 307.500 Y 877.000
Fenêtre 1 x 2.000 0.000 °
fichier édition affichage fenêtre bin zoom scale couleur région wcs analyse aide
nouveau rgb 3d supprimer effacer single tile clignotement premier prev suivant dernier
LSST AuxTel
Hologram tests
Hole 20 microns
Light injection setup (focus)
moving 3 turns/step
(magnification x2)
L. Le Guillou, M. Moniez, S. Dagoret-Campagne, O. Perdereau, J. Neveu (2018-02-23)
40mu = 5 pix. LSST = 0.4" AuxTel
54 76 99 121 144 166 188 211 233