New hologram prototypes designed for AuxTel spectroscopy

Production and tests

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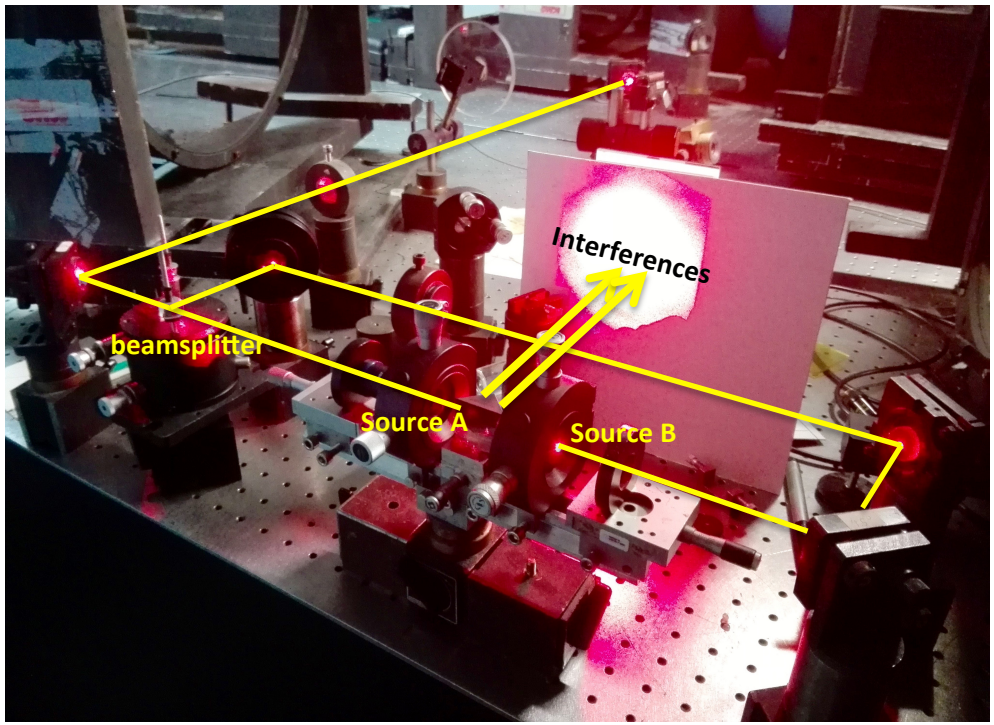
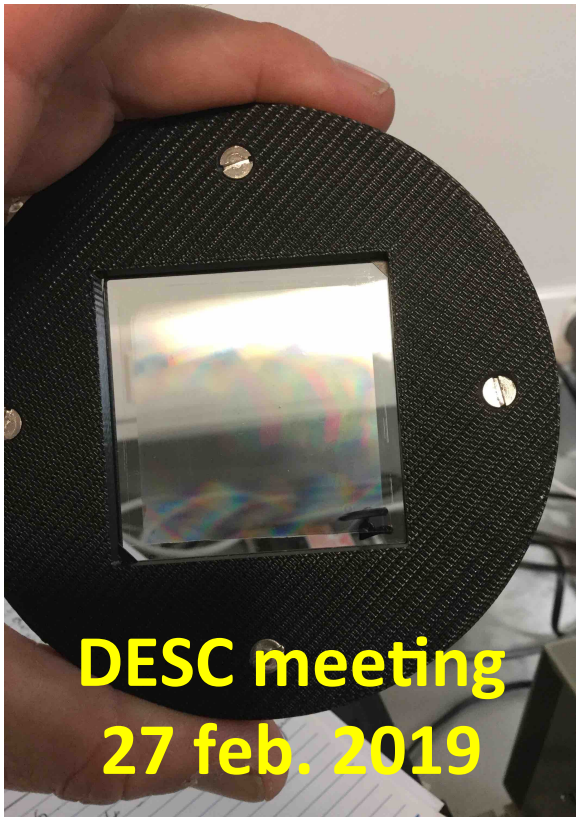
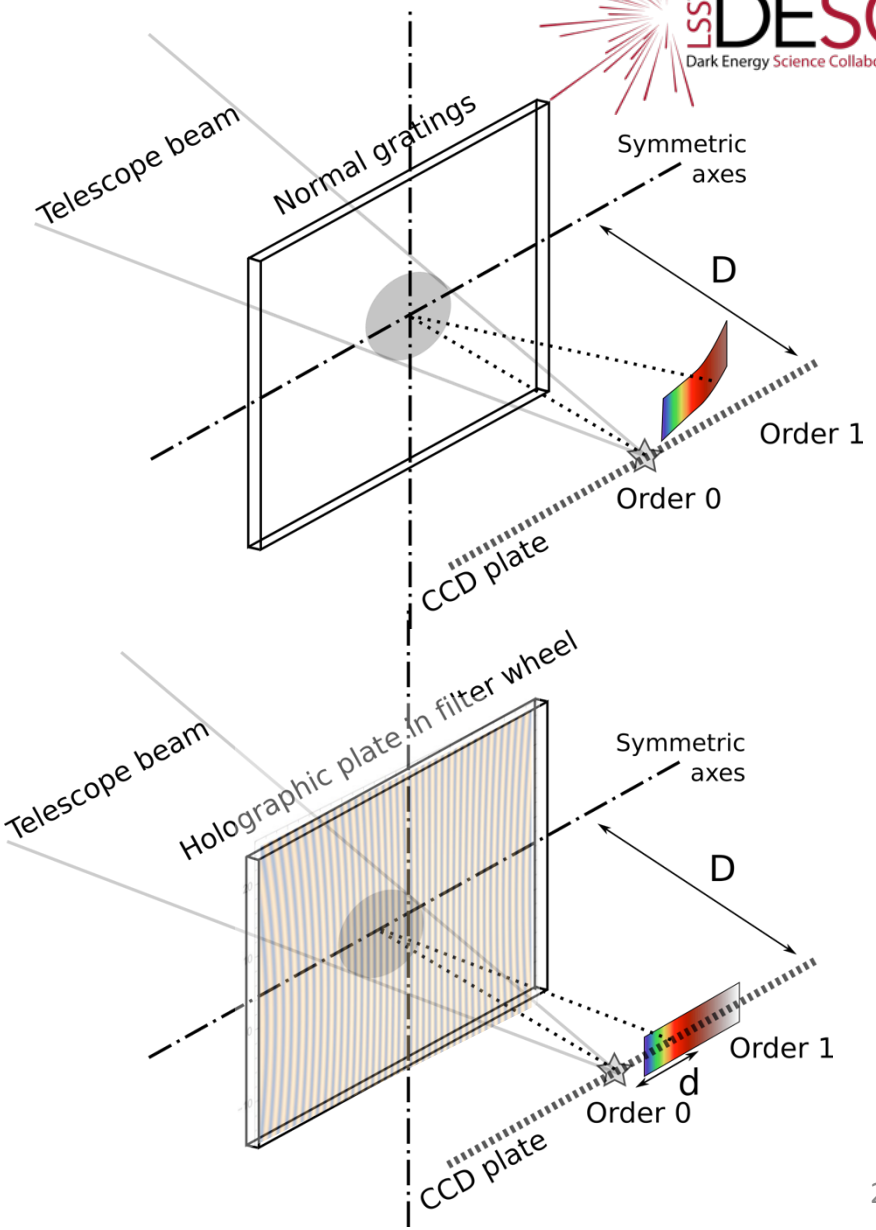




Holograms for AuxTel

- **Goal :** constrain atmospheric parameters by extracting spectrum of standards
- **Constraints**
  - Easilly switch imager / spectro.
  - Incident beam perpendicular to CCD-plane
- **Usual gratings:**
  - Defocus due to optical path variations with the diffraction angle
  - Distorsion when used with a converging beam
- **Holographic grating:**
  - forced focus on the focal plane at all wavelengths: **0th and 1rst order at same focus**
  - No distorsion by design of hologram



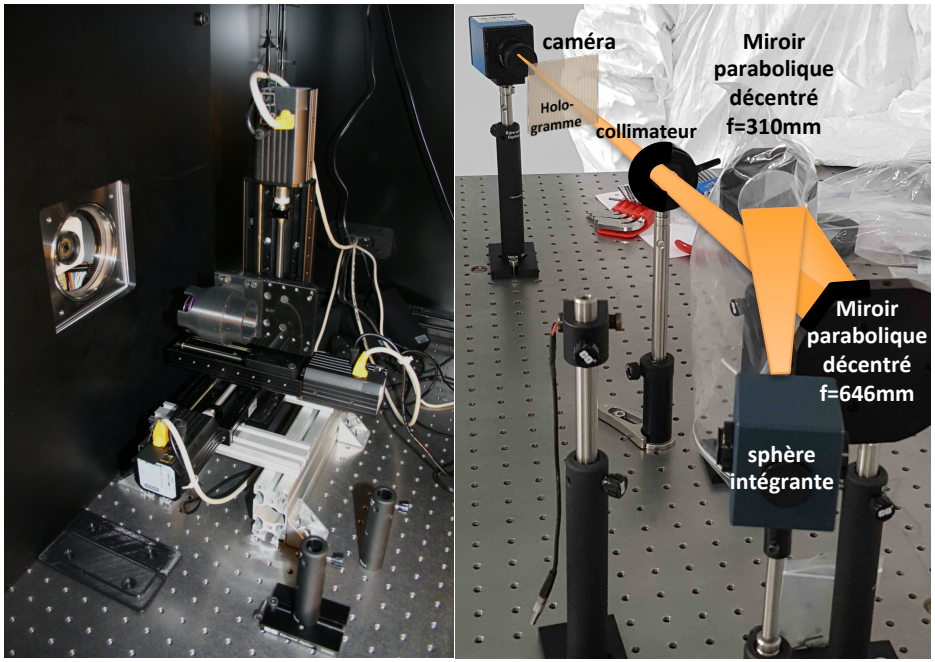
New holograms produced on 19 oct 2018

- 8 prototypes of **argentic phase holograms** with various exposure times/emulsions/processing

Geometry designed for AuxTel

- Based on *effective* (measured) distances of the spectrograph (KG)
- Assumes 0th order @3mm from the CCD edge
- Dispersion such that λ=1050nm is at 34.8mm (incl. tolerance)

-> Same spectrum dispersion than with a periodic grating of ~150 lines/mm



Test procedures

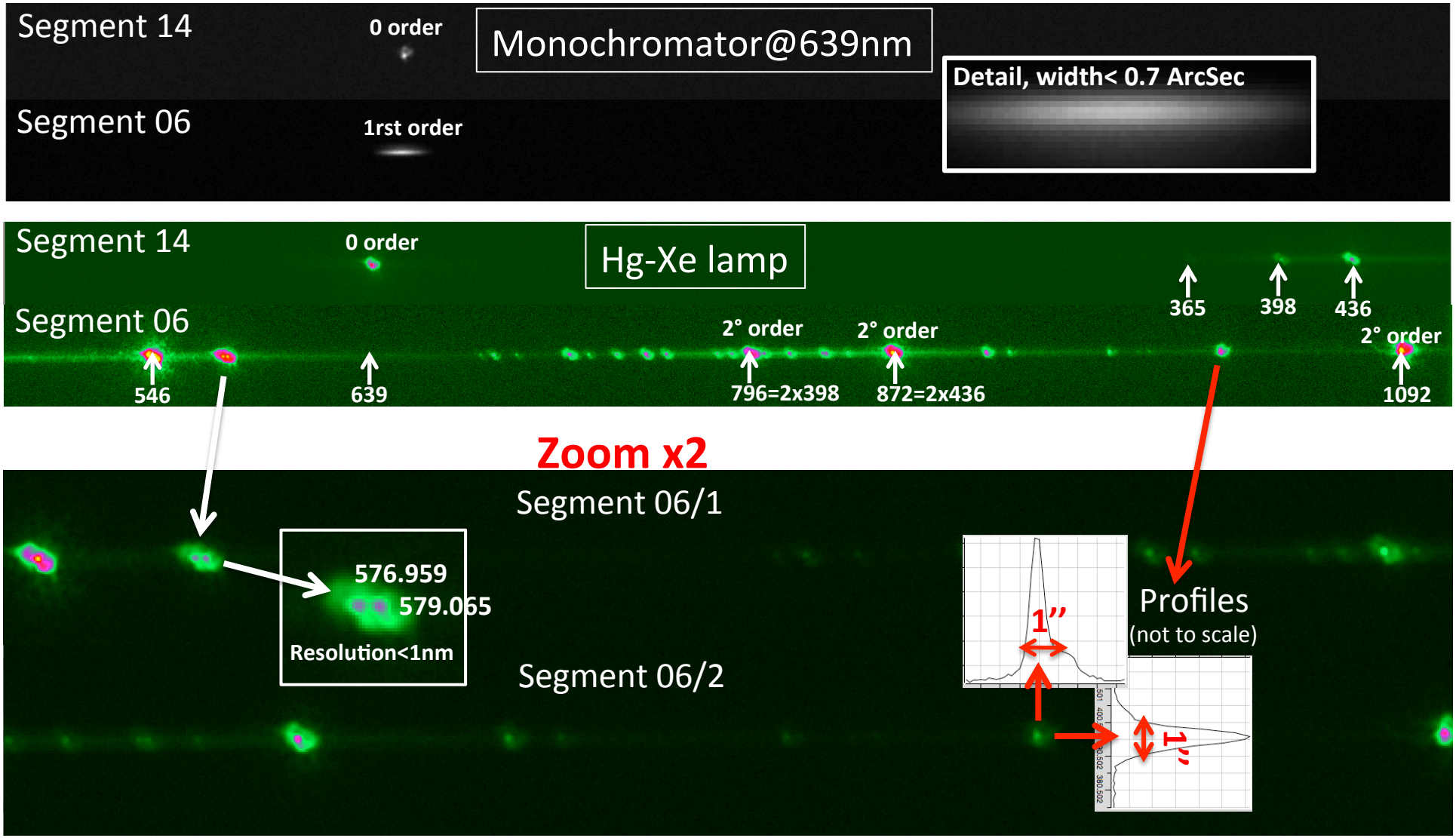
Use test-bench @LPNHE

- 4Kx4K LSST-like CCD
- **Achromatic** AuxTel converging beam simulator
- Sources: Monochromator / Hg-Xe lamp
- Efficiencies measured with hologram ON-beam and OFF-beam sequences (motorised XYZ mount)

On-sky test at the Pic du midi observatory

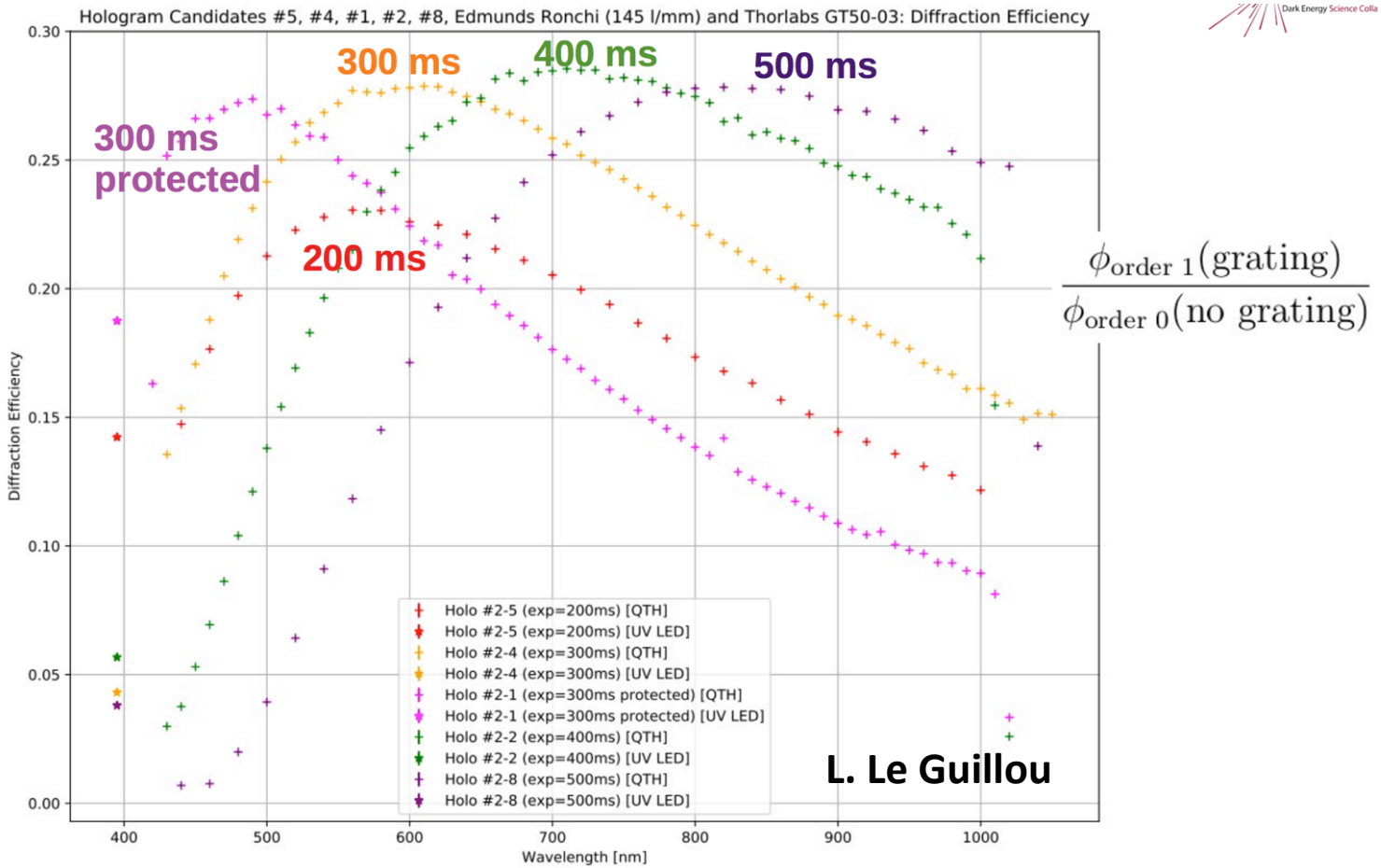
- Planetary nebulae
- CALSPEC spectrophotometric standard

HOE: focus / resolution @ LPNHE



Diffraction efficiency

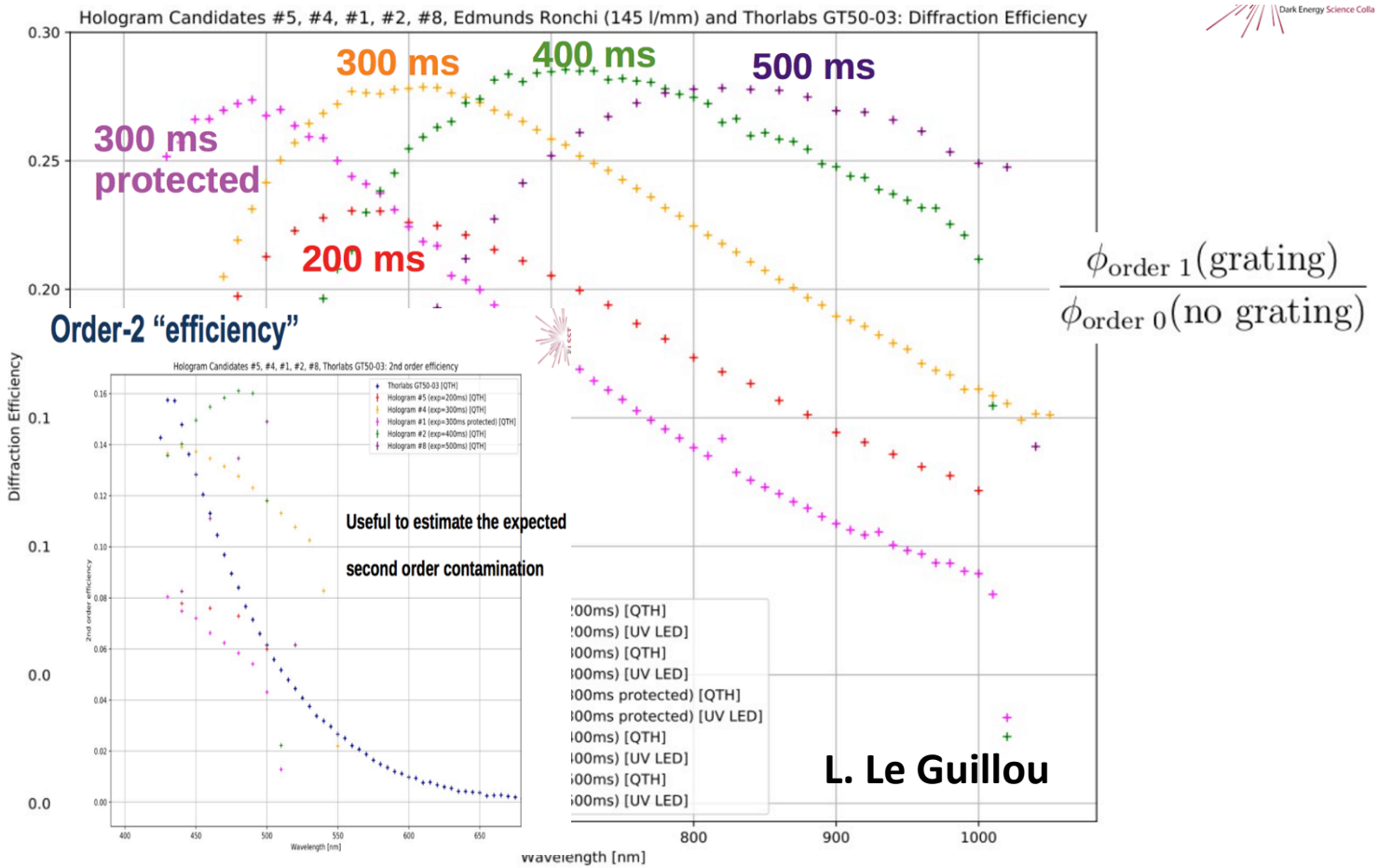
hologram prototypes processed with various illumination durations



$$\frac{\phi_{\text{order }1}(\text{grating})}{\phi_{\text{order }0}(\text{no grating})}$$

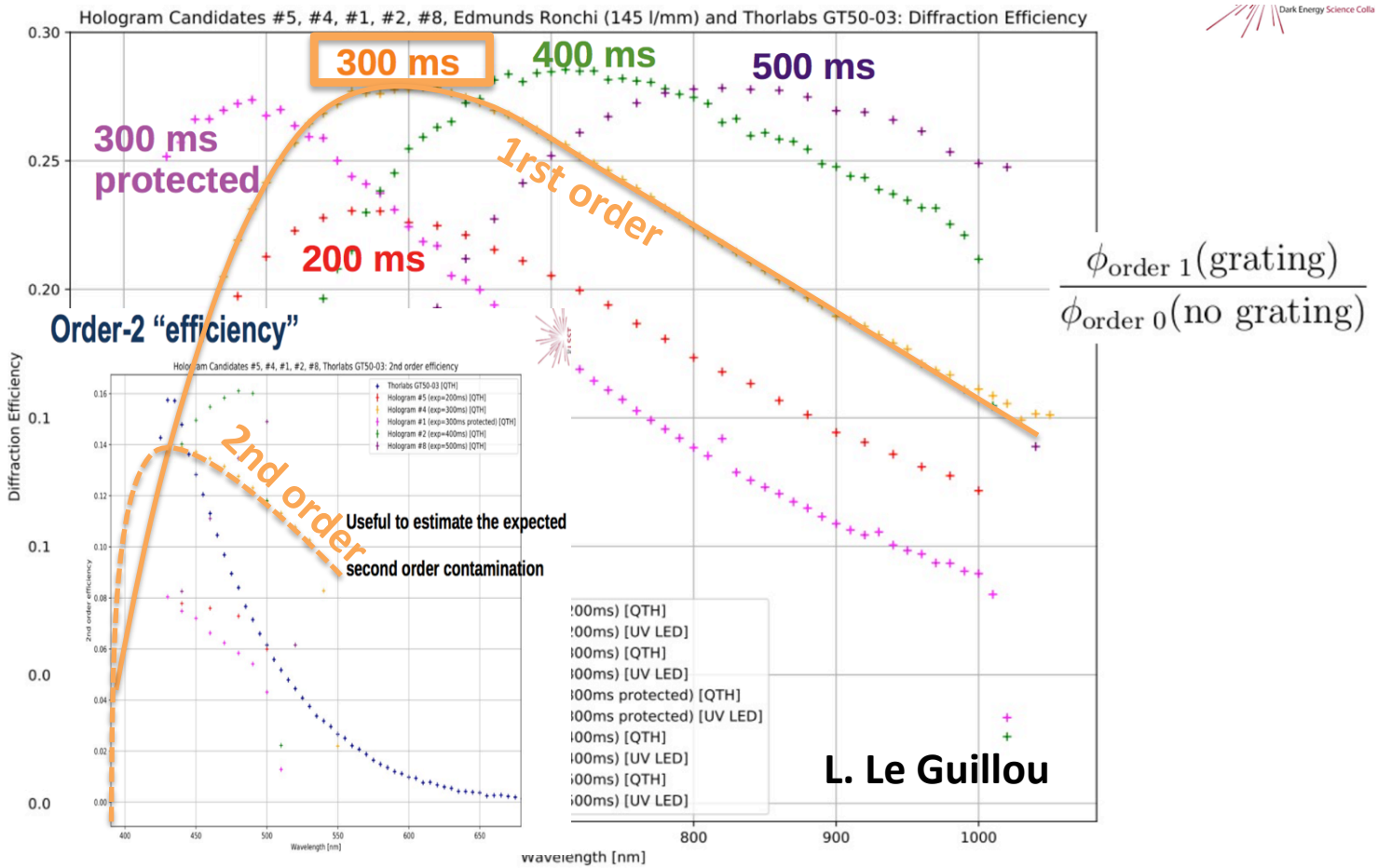
Diffraction efficiency

hologram prototypes processed with various illumination durations



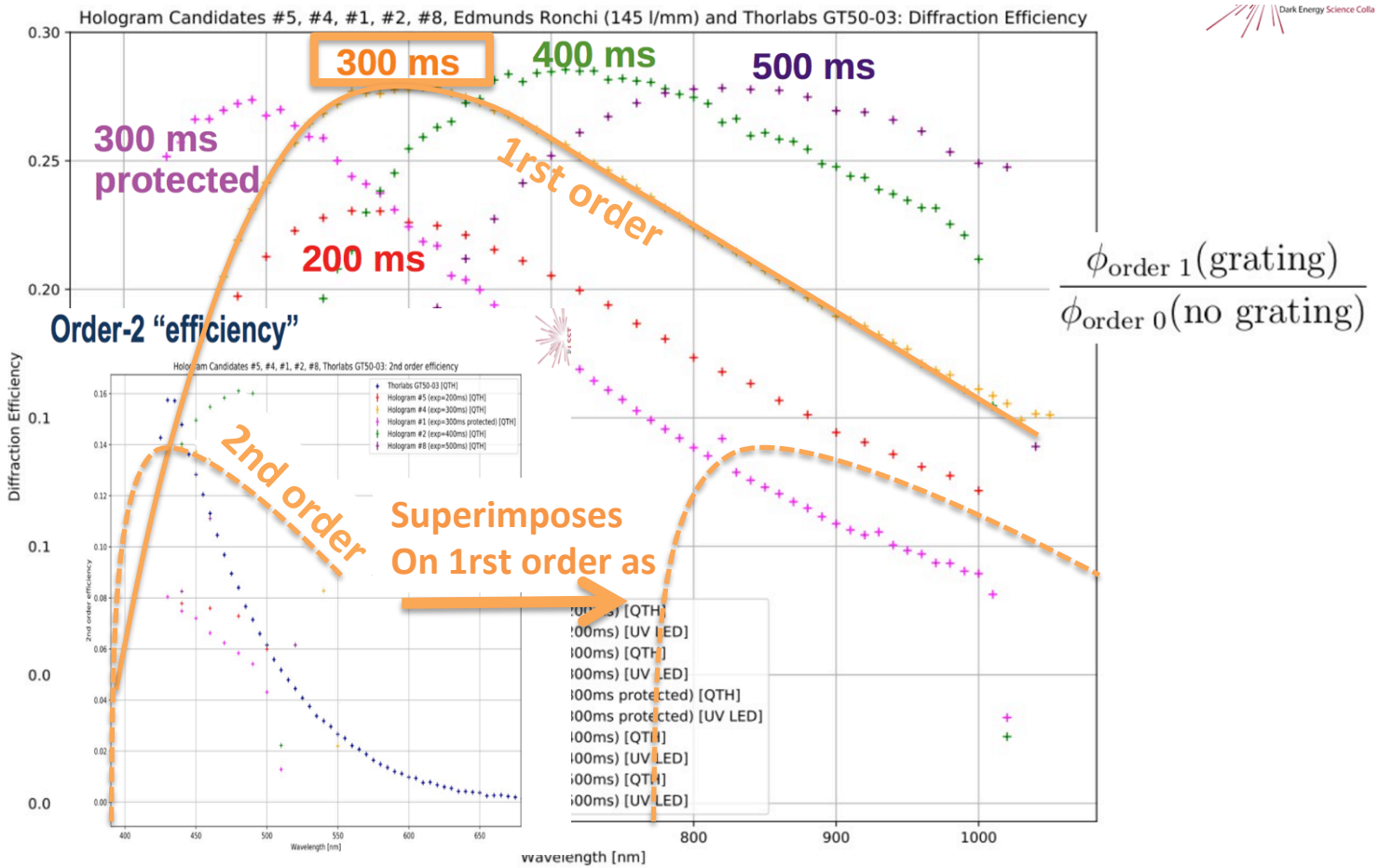
Diffraction efficiency

hologram prototypes processed with various illumination durations

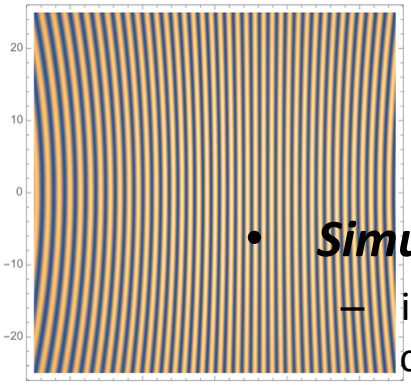


Diffraction efficiency

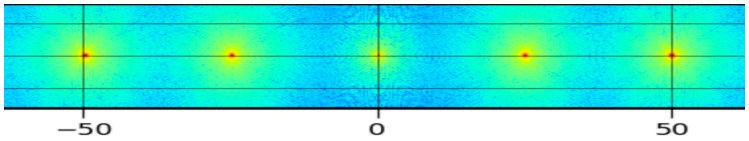
hologram prototypes processed with various illumination durations



Simulation for efficiency calculation



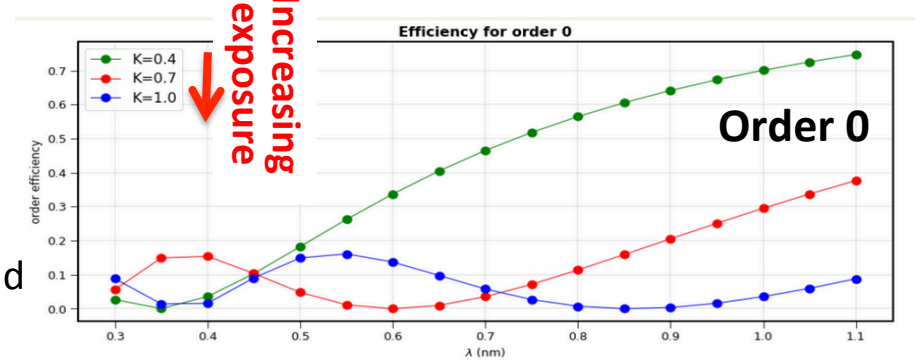
- ***Simulate (thin) holograms***
  - interference network from 2 coherent point sources
  - Modelize emulsion response to illumination: both amplitude and phase holograms
- ***Simulate Fraunhofer diffraction*** *of convergent beam (Holograms & Ronchi grating) -> FFT*



  - Image : fraunhofer approx. only

  -> can't account for Ronchi distorsions / defocalisation nor Hologram corrections at large angle

  - Diffraction efficiency OK
- ***Useful to chose the best process parameters***
  - *exposure, emulsion width…*



Behaviour of efficiency reasonably well understood

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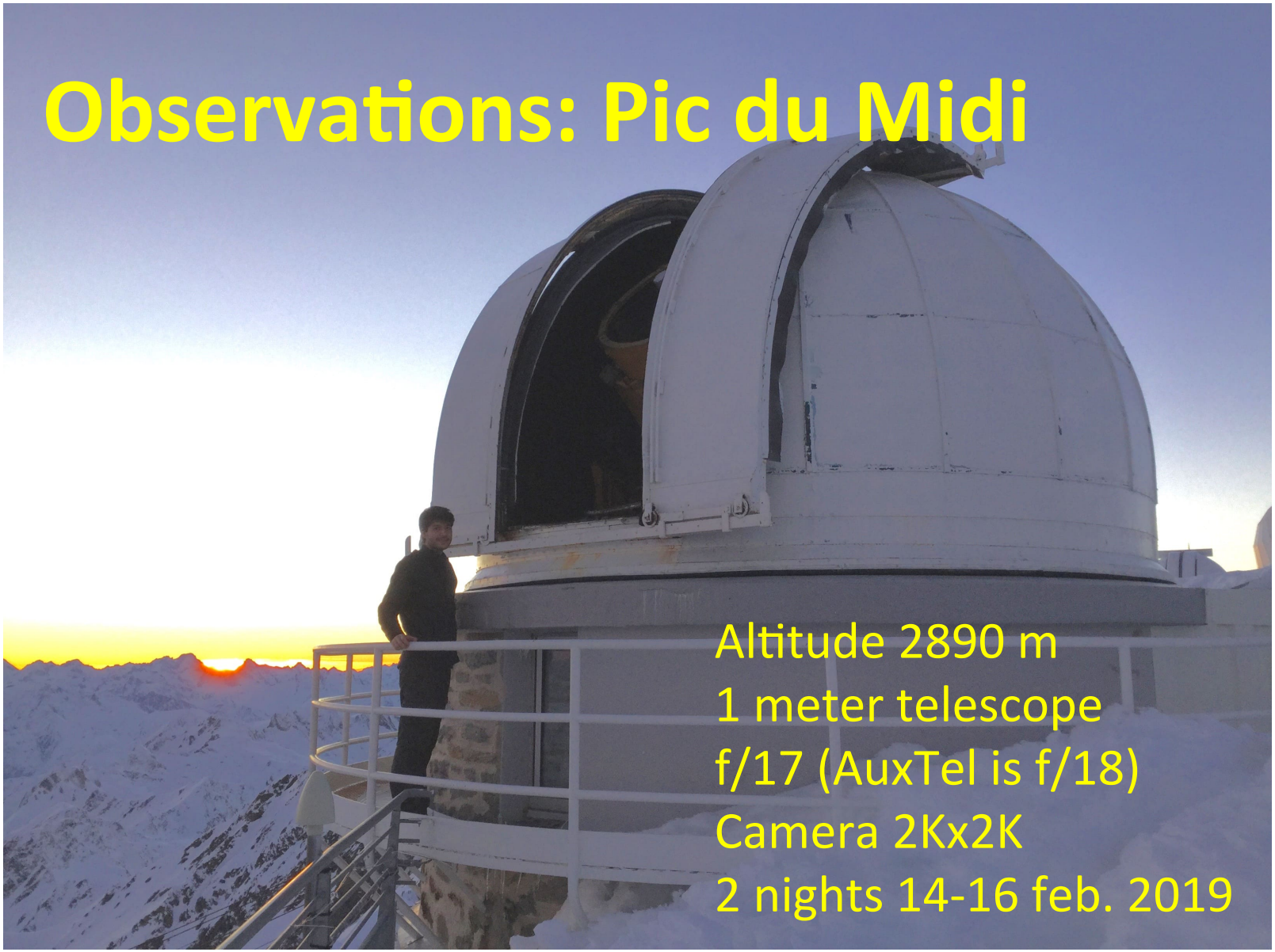

Observations: Pic du Midi
Altitude 2890 m
1 meter telescope
f/17 (AuxTel is f/18)
Camera 2Kx2K
2 nights 14-16 feb. 2019

Objectives

- Probe sensitivity of the performance with
  - Position of beam wrt optical axis
    - X, Y (+/- 5mm)
  - Position of hologram wrt CCD
    - Z (+/- 20mm from nominal 200mm)
  - Tilt (1° tested)

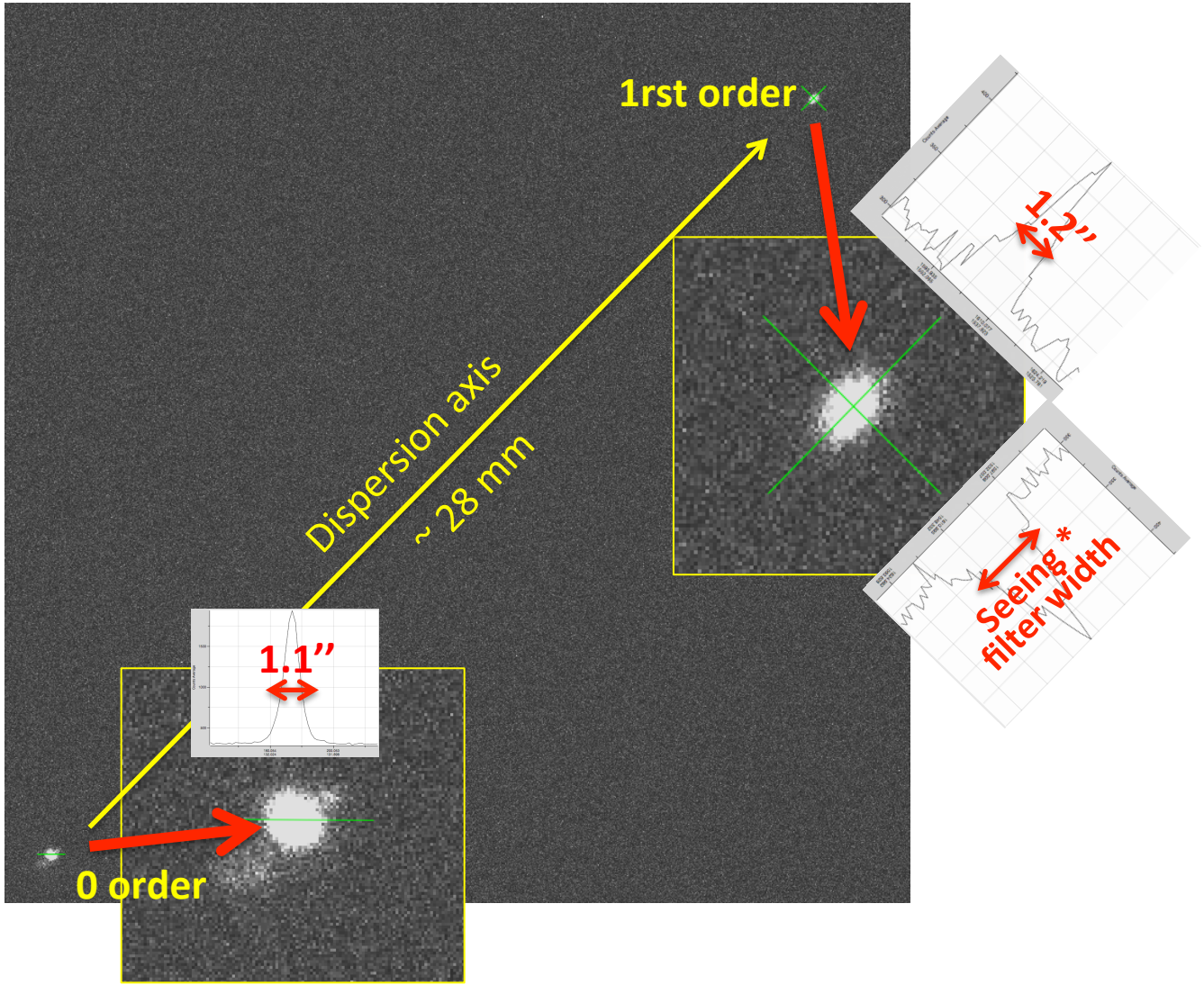
-> Image quality not affected ; in agreement with optical bench tests

- Simultaneous acquisition of
  - 0 order (not saturated)
  - and spectra with u'g'r'i'z' wide filters

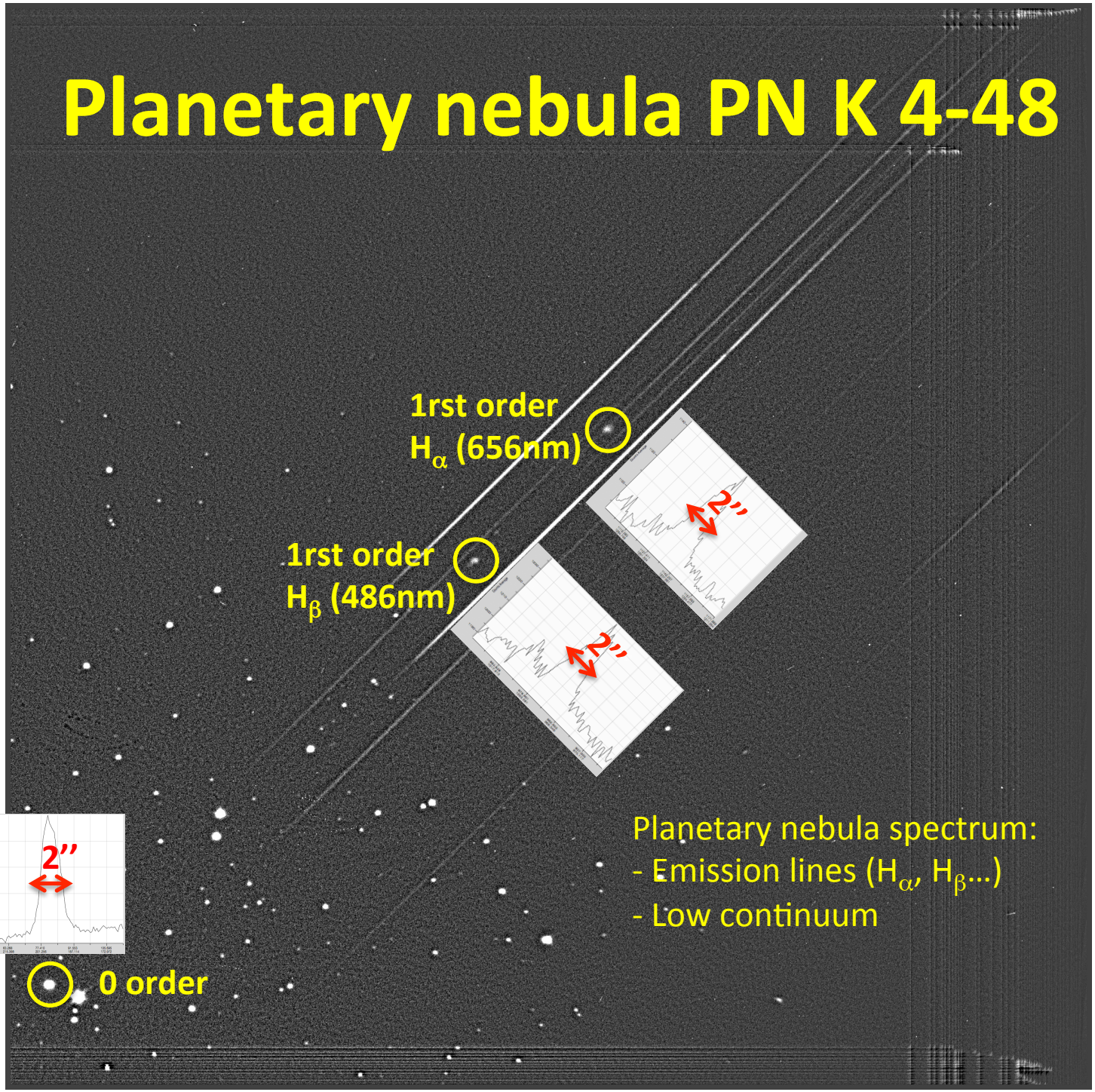
  - > Compare variations of 0 order photometry with integral of 1rst order spectrum
- Bouguer lines during stable night

-> Analysis in progress

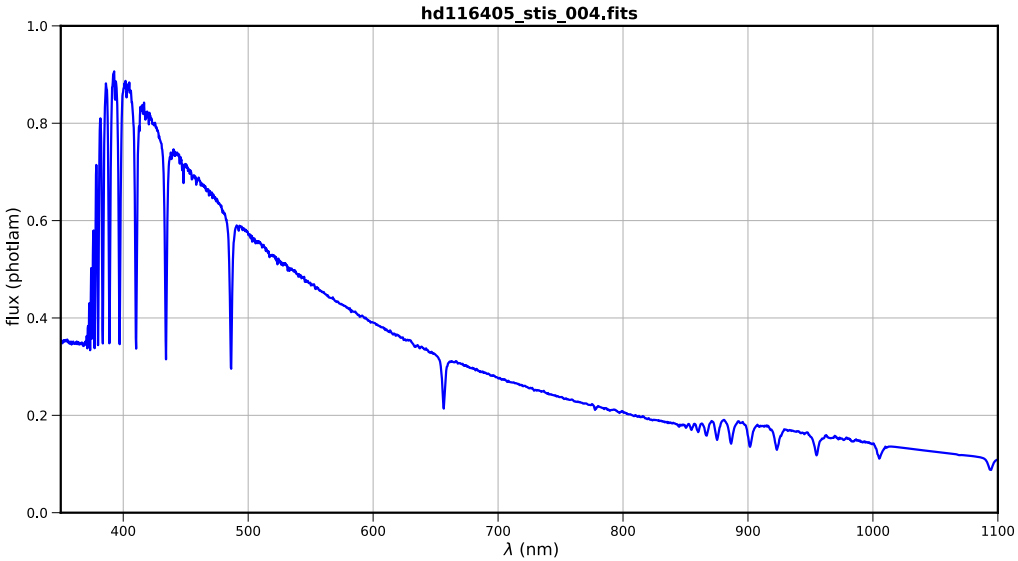
Narrow band filter λ=890nm



Planetary nebula PN K 4-48

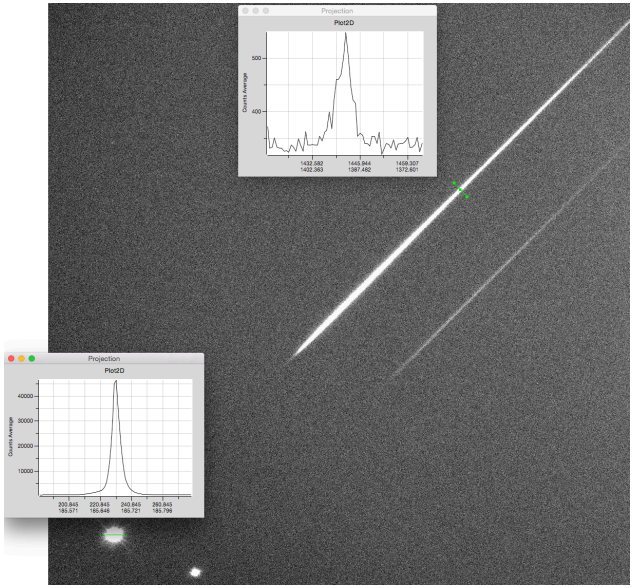


CALSPEC data



HD116405

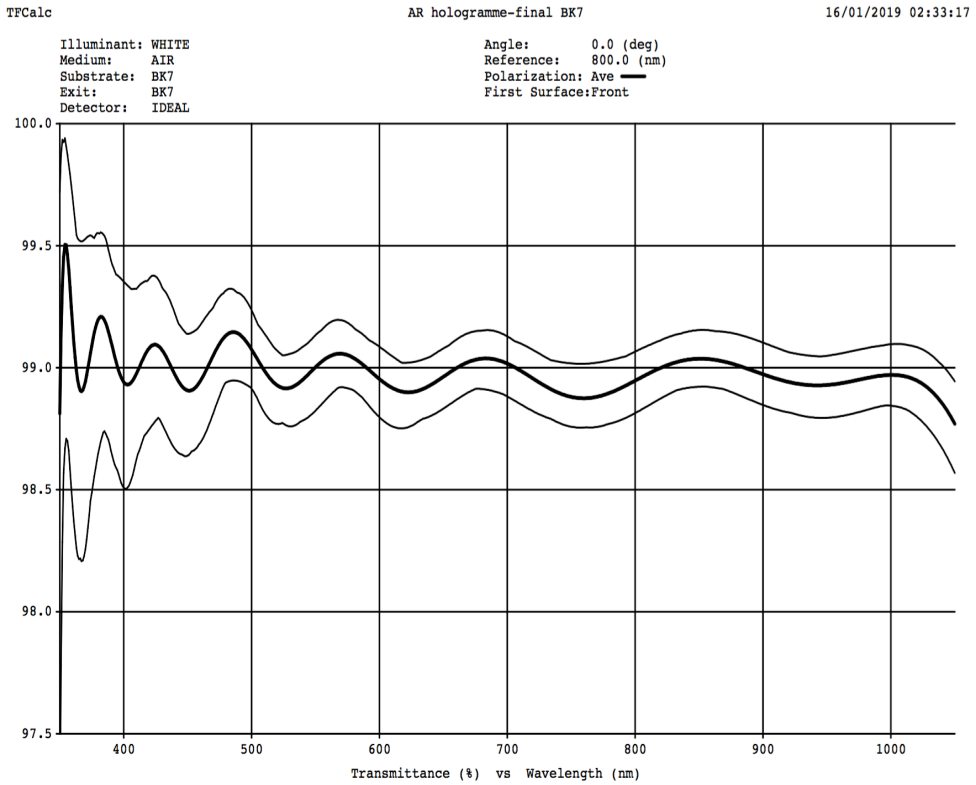
- Series of spectra through u'g'r'i'z' wide filters
- 0 order (not saturated)
- 1rst order
- Analysis in progress



- + Series of spectra without filters with varying airmass
- Bouguer lines (stable atmospheric conditions)
- Analysis in progress

Next (final) step: finalisation

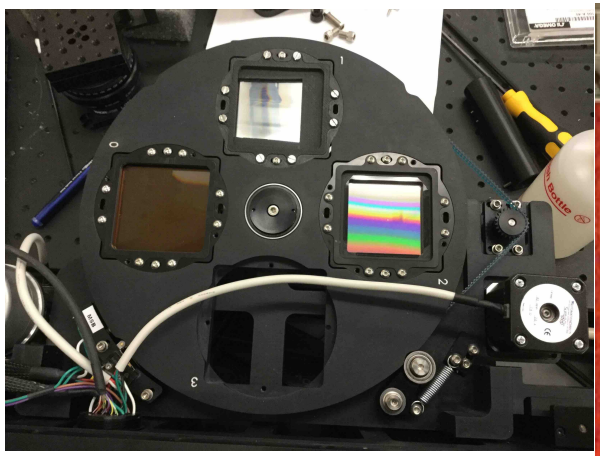
- Tune exposure/ sealing of HOE
- Anti-reflective glass (made by LMA)
- Garanteed for 30 yrs

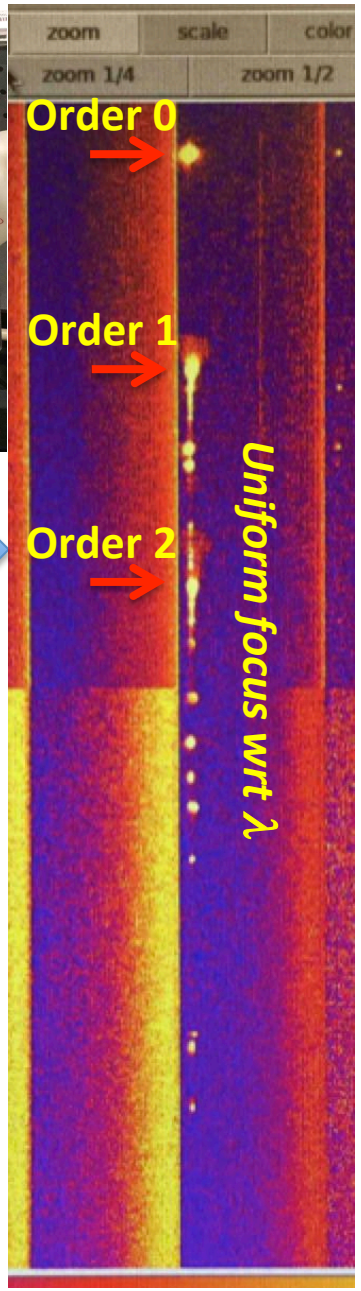


To be stabilized before finalisation

- Size of the HOE: 40mm x 40mm
- Width: 3mm + 3mm
- Distance CCD-HOE: 200mm
- Dispersion:
  - 0 order @3mm from the CCD edge
  - λ=1050nm @34.8mm (incl. Tolerance)
- Material: BK7 (HOE@20cm from CCD)

Planning





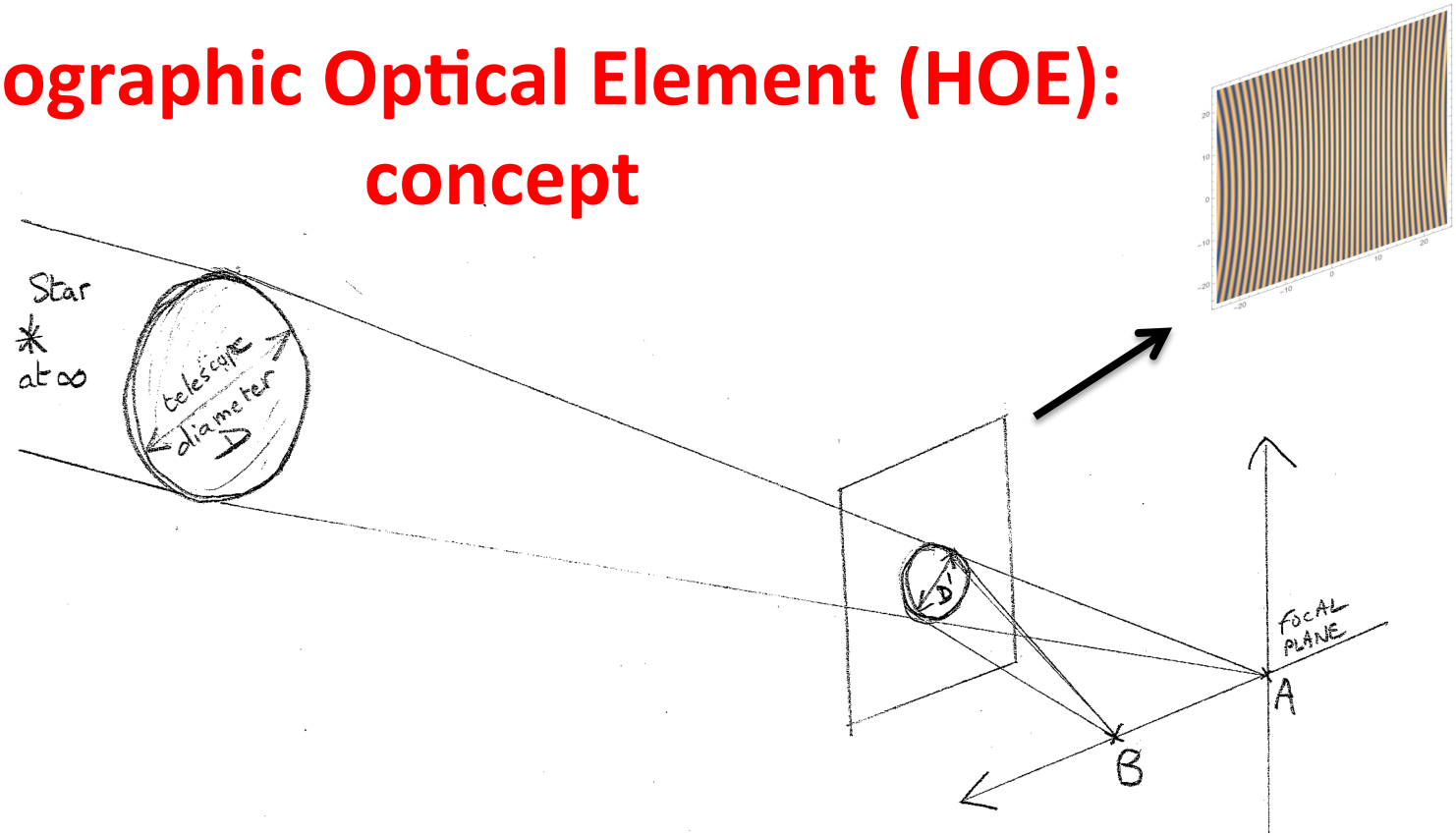
- *Prototypes* (not final) implemented on spectrograph in Tucson (23 feb.)

  -> comparisons with Ronchi 170 l/mm to be made *with distance (CCD-dispersor) = 200mm*

- Final holograms to be produced and completely characterised during spring (?)
- Commissionning of AuxTel from ? 2019

COMPLEMENTS

Holographic Optical Element (HOE): concept



Record the hologram: record interference pattern of coherent point-sources in A and B at the requested wavelength (λ = 639nm)

Read the hologram, the optical function: when illuminated by a beam converging in A, produces an **image at B for λ = 639nm**, and an **image along the AB line for other λ.**

In theory (infinite and perfect hologram): only 0, +1 and -1 orders

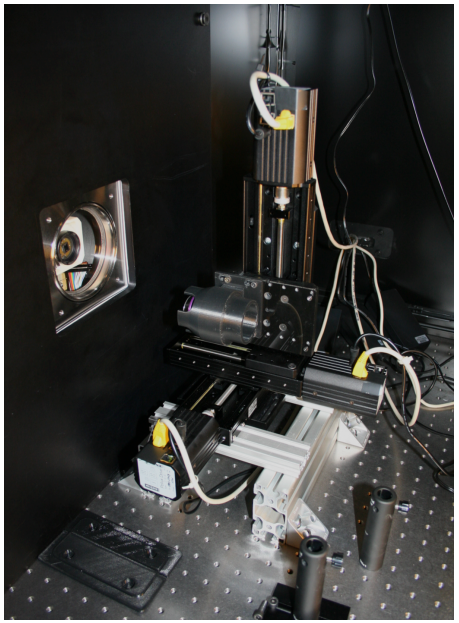
Optical Test-bench at LPNHE

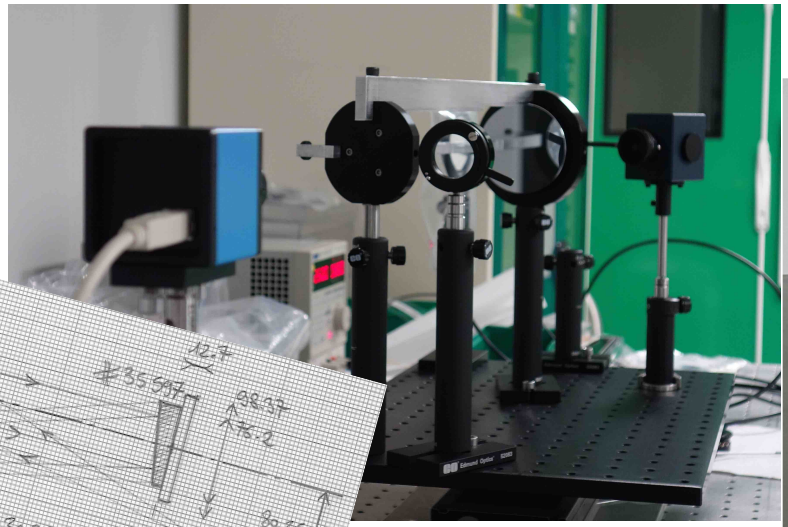
Simulation of the AuxTel convergent beam

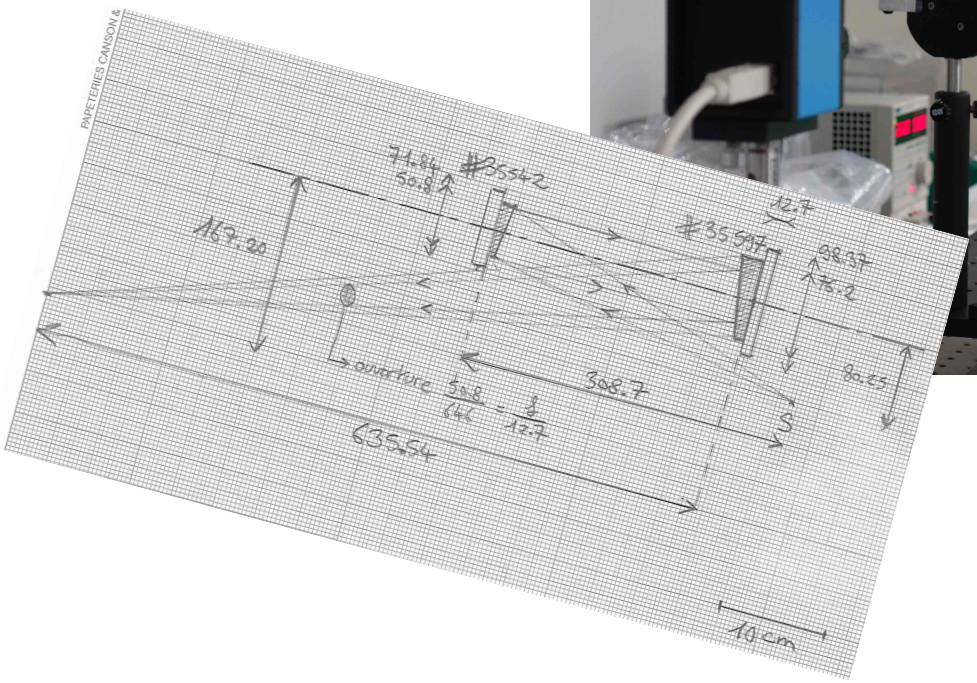
- Focus on a LSST-type CCD sub-arcsec equivalent PSF from converging beam
- Focus independent from the wavelength (mirrors)
- Uniform beam density obtained with integrating sphere + 20μ hole
- Hologram installed on a XYZ mounting

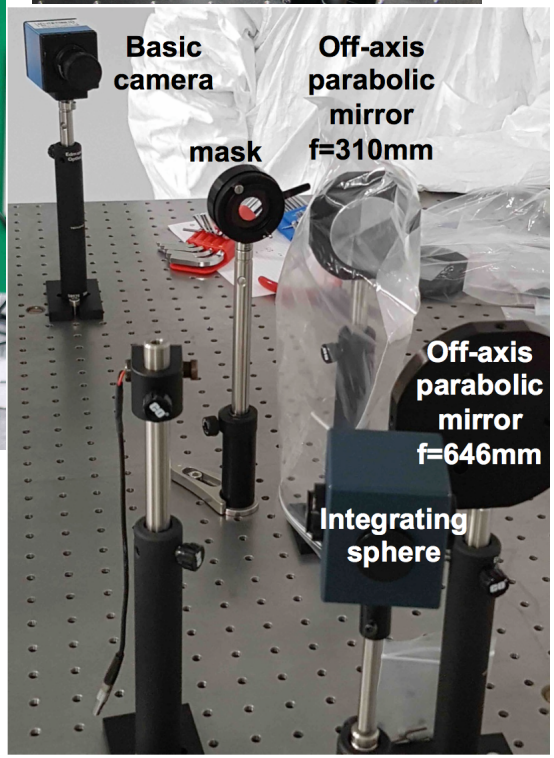
Measurements to do on every disperser

- Volume of validity ΔXΔYΔZ for acceptable use (>10mm10mm4mm)
- Spectral resolution λ/Δλ with emission line lamp and monochromator
- Transmission as a function of λ.

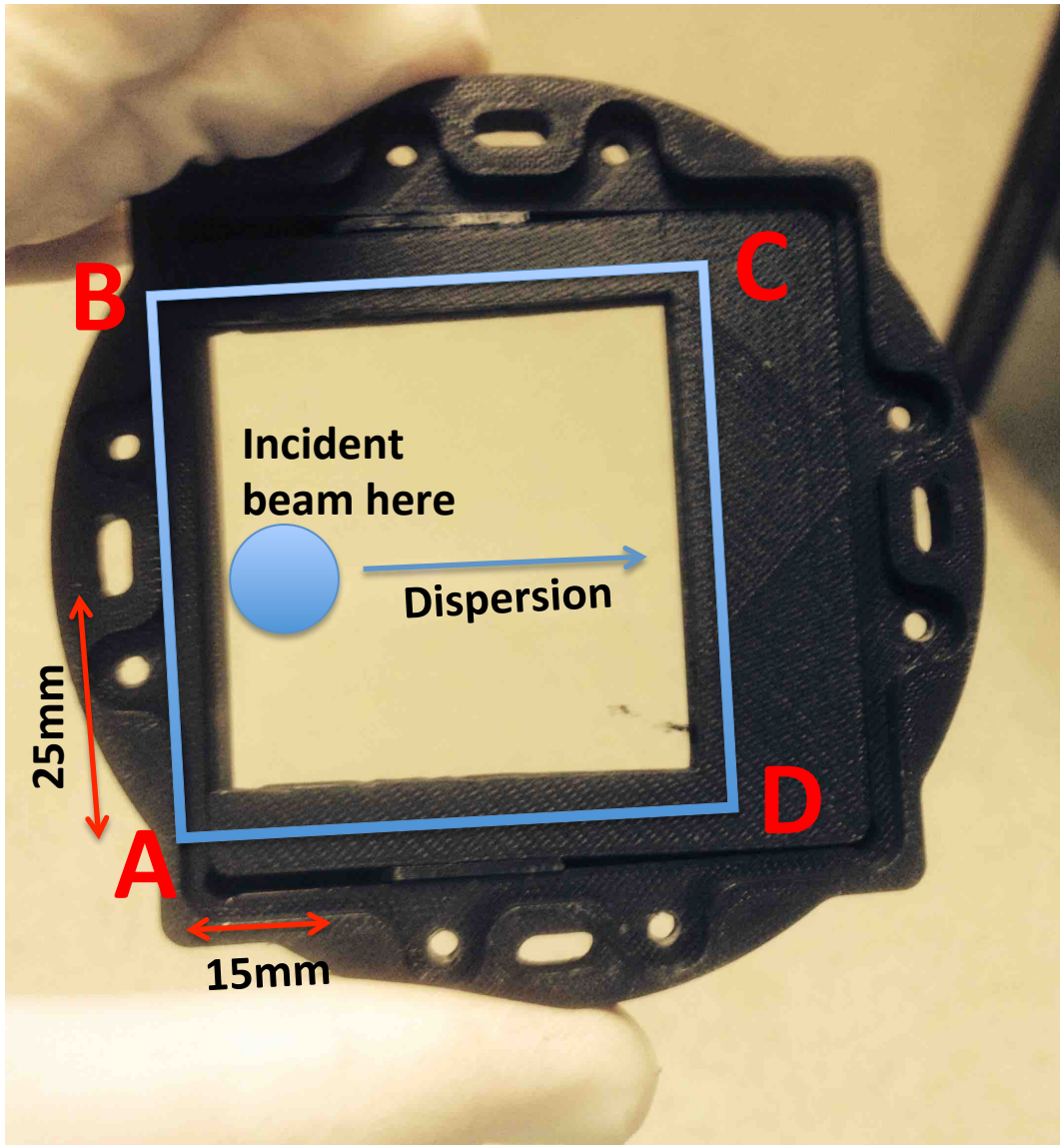








HOE Setup



Optimal:
Incident beam centered at (+15mm,+25mm) from A (reference point, corner of the glass)

Impact of the 0 order position

- HOE has an optical center (Ronchi is invariant by translation)
- -> Check the spatial uniformity of efficiency through measurements & simulations up to 4mm