

# Holographic Optical Element for the AuxTel spectrograph: status

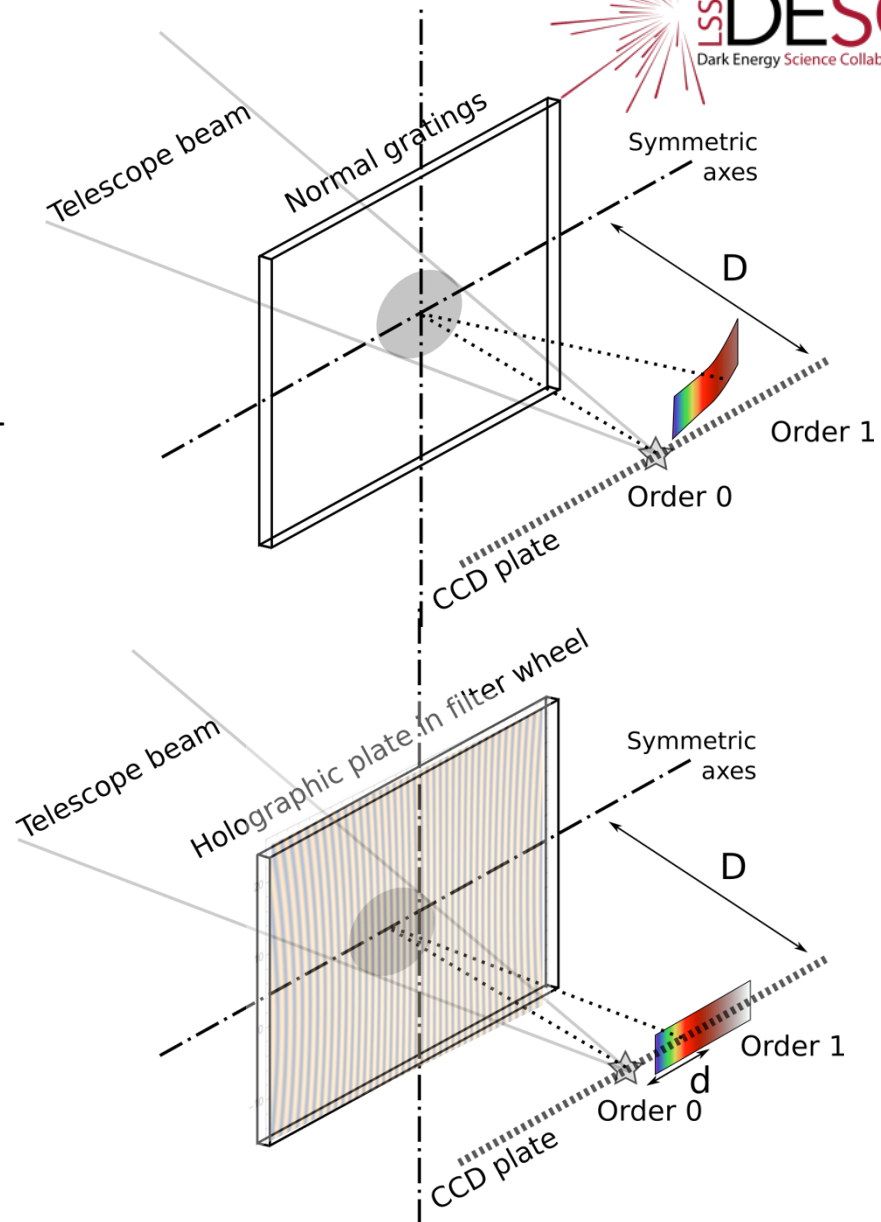
LSST/DESC calibration workshop, 2 october 2018

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# Holograms for AuxTel

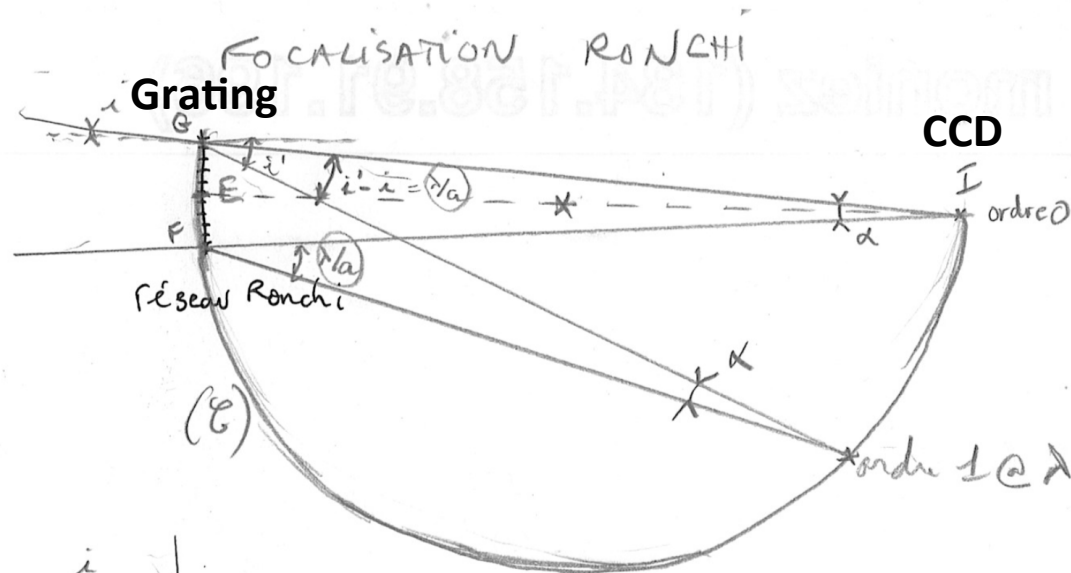


- **Goal:** constrain atmospheric parameters by extracting spectrum of standards
- **Constraints**
  - Easily switch imager / spectro.
  - Incident beam perpendicular to CCD-plane
- **Usual gratings:**
  - Defocus due to optical path variations with the diffraction angle
  - Distorsion when used with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



# Ronchi: focus

- Locus of focus is circle (C) centered in the middle of [disperser, CCD]



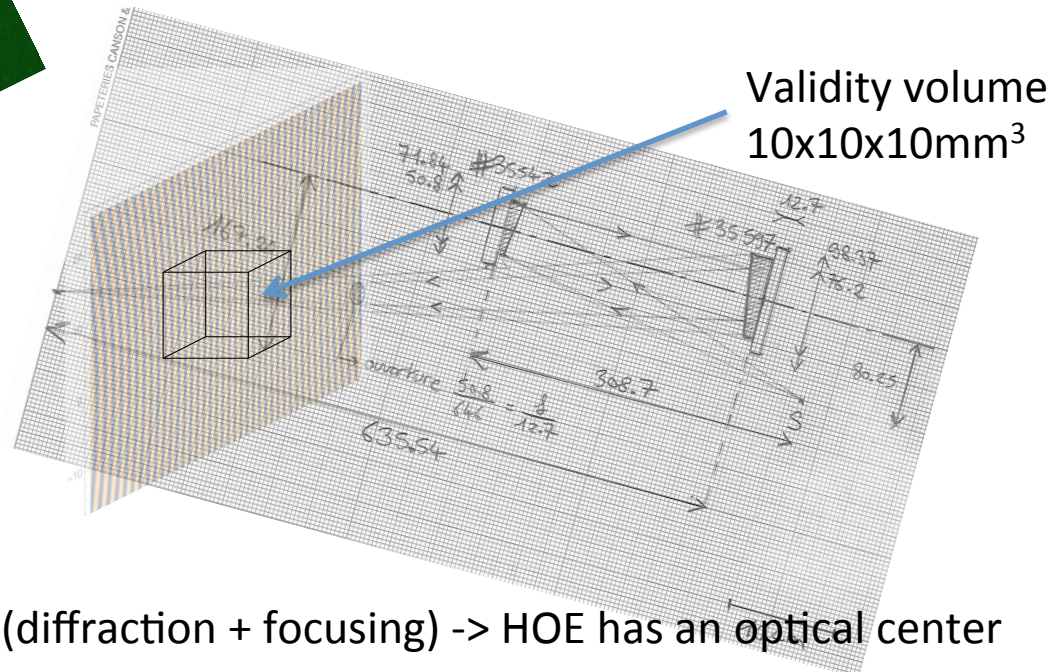
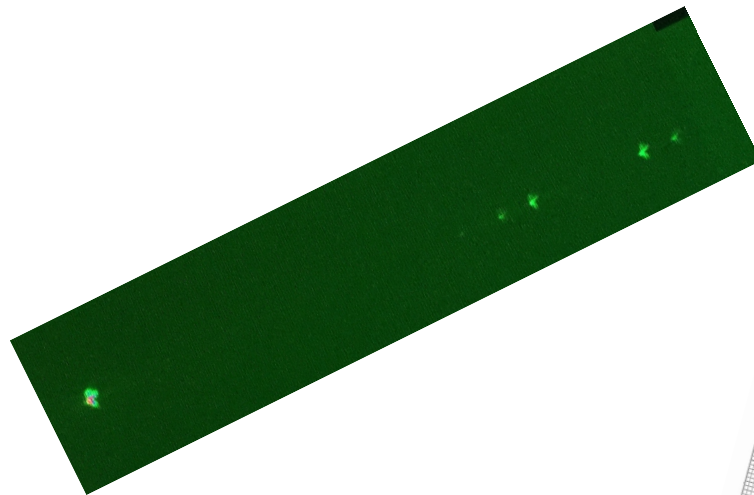
$$\text{ordre 1: } a(\sin i' - \sin i) = \lambda$$

$$\Rightarrow i' - i = \frac{\lambda}{a} = \text{cte} \quad \boxed{i' = i + \text{cte}} \quad (\text{déflexion constante})$$

le foyer se trouve sur le cercle C : lieu des points où l'on voit le segment FG sous l'angle constant, ( $\theta$  approximatif =  $\angle E$ )  
 → mais pour les ordres (mais  $i' - i = n \frac{\lambda}{a}$  alors),

# Study of the prototypes

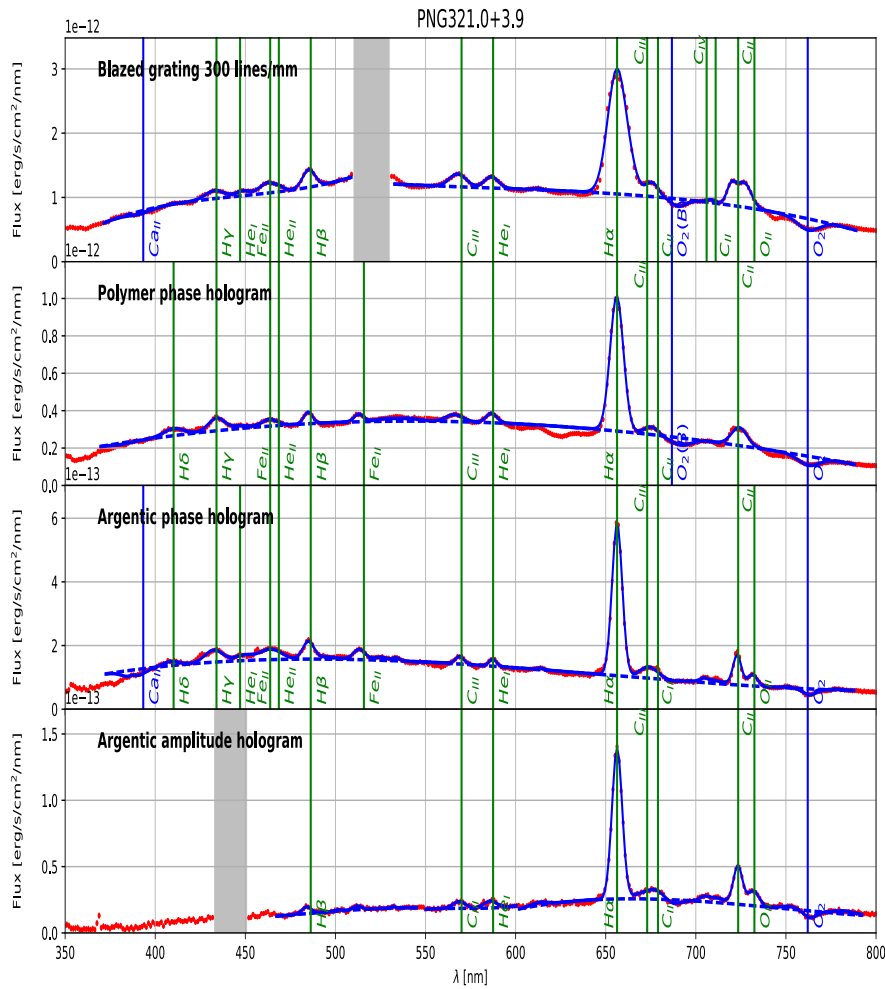
- Tests (18 nights) on telescope
  - *See DESC meeting talk*
- **New:** test bench in laboratory (*see previous talk*)
  - With CTIO/AuxTel simulated converging beam



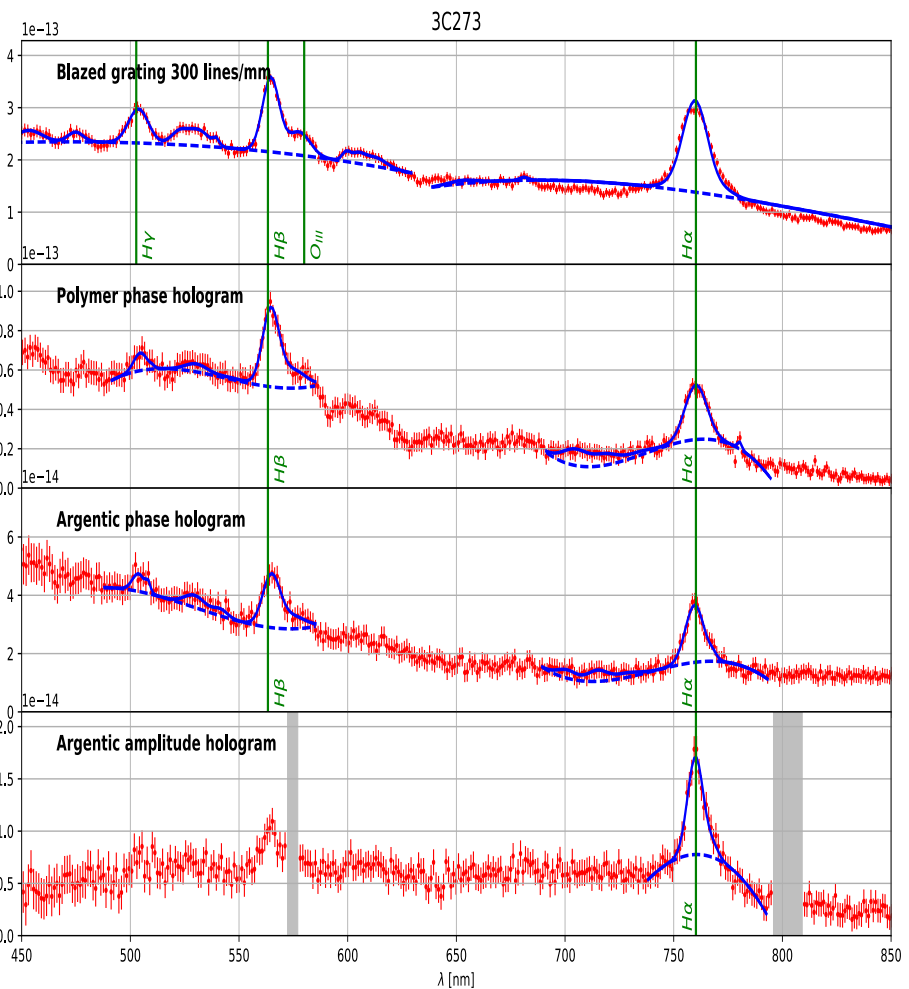
**Remember:** 2 optical functions (diffraction + focusing) -> HOE has an optical center



# Tests at CTIO (18 nights in June 2017): extraction of spectral features



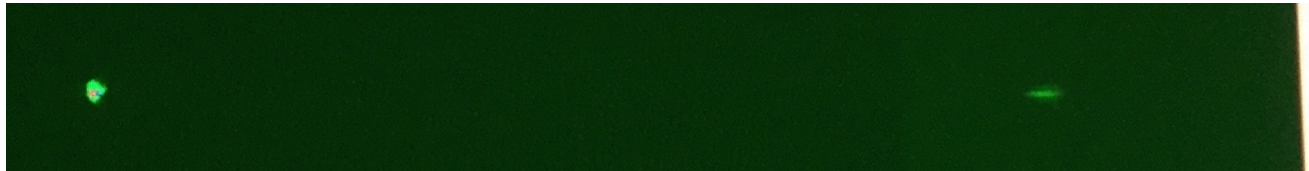
## Planetary nebula



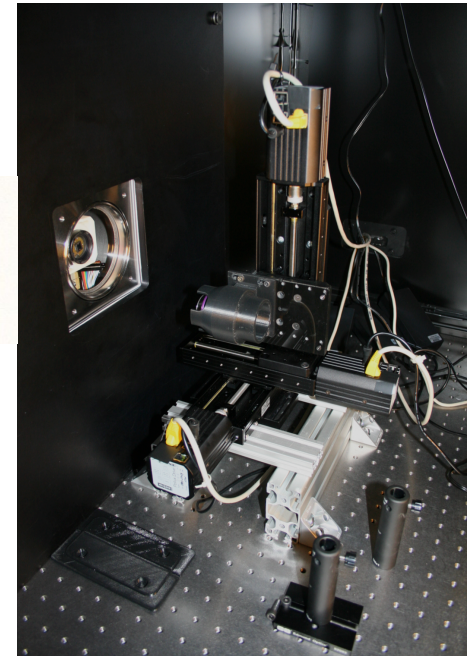
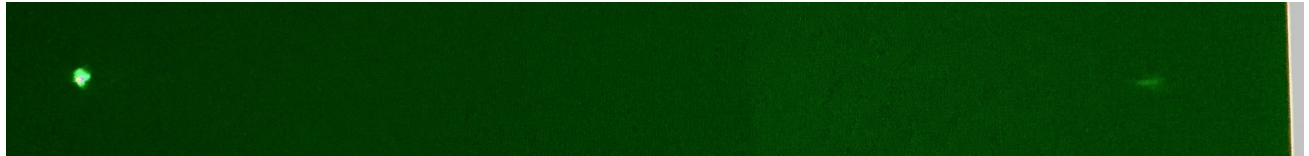
Quasar (redshifted)

# Tests of phase HOE on optical bench

Monochromator window (900nm)



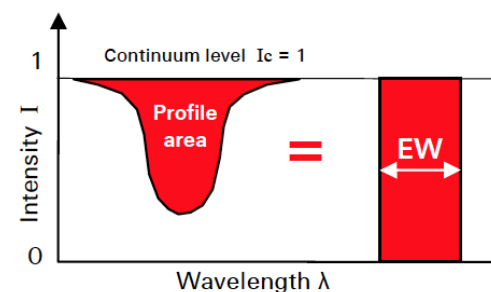
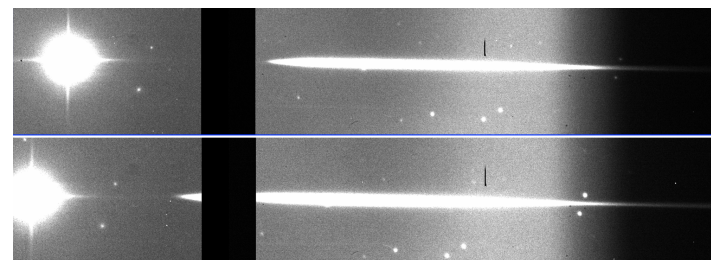
Monochromator window (1000nm)



# Hologram prototypes throughput




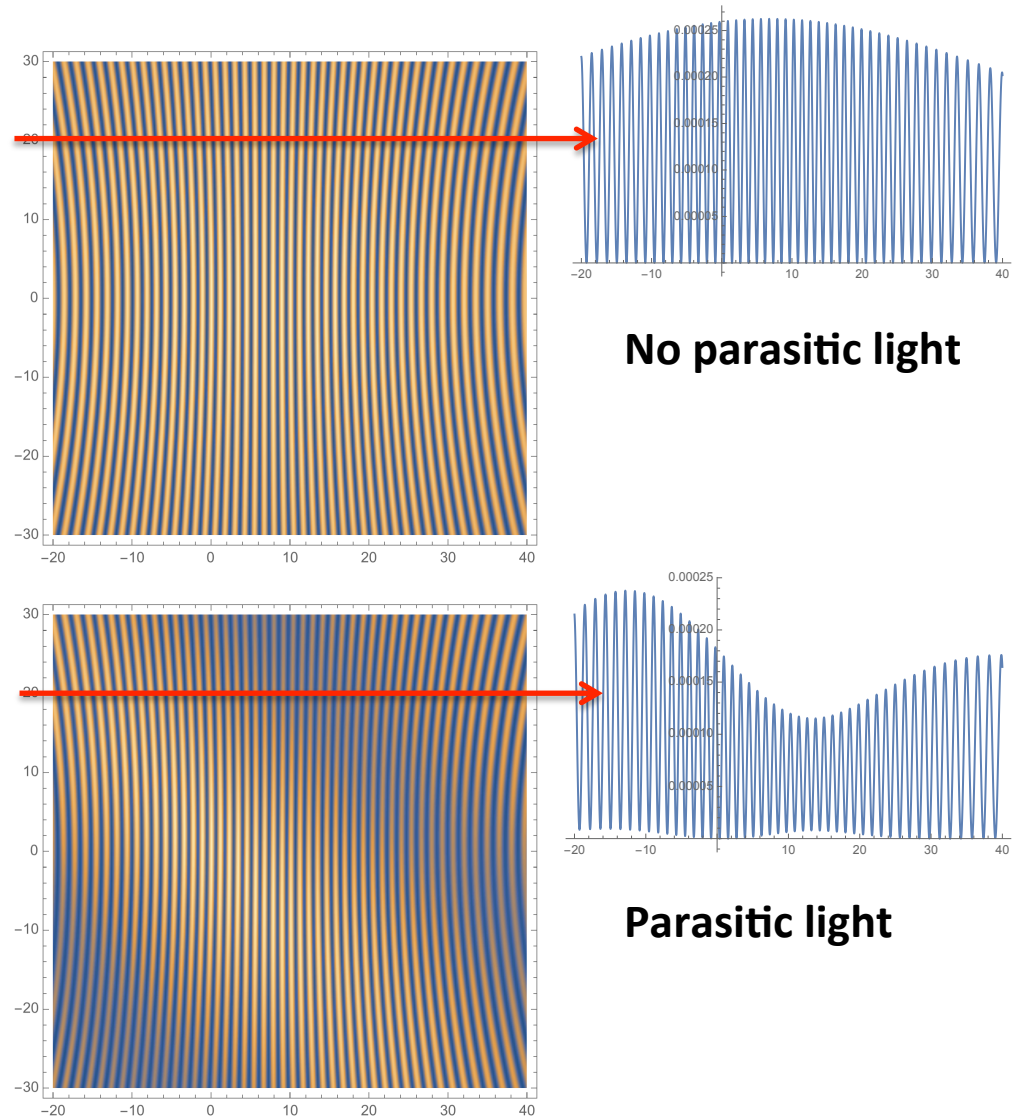
- Not measurable at CTIO because not uniform:
  - Prototypes are noisy (produced without filtering holes)
    - *fast varying (<1mm) transmission with incident beam position*
    - *Without tracking, beam moved (by >1.5mm) during the Bouguer-line data taking (5h30)*
    - *-> instrumental mag. vs airmass is NOT a Bouguer line...*
  - Nevertheless, equivalent width extraction still valid



- Solved with the **final holograms** + will be measured on optical bench + avoided with a good tracking

# Impact of parasitic interferences

- During recording, HOE prototypes did not benefit from filtering holes
    - Parasitic light
    - Parasitic interferences
- 
- varying contrast AND mean transmission
  - varying diffraction efficiency as seen on bench



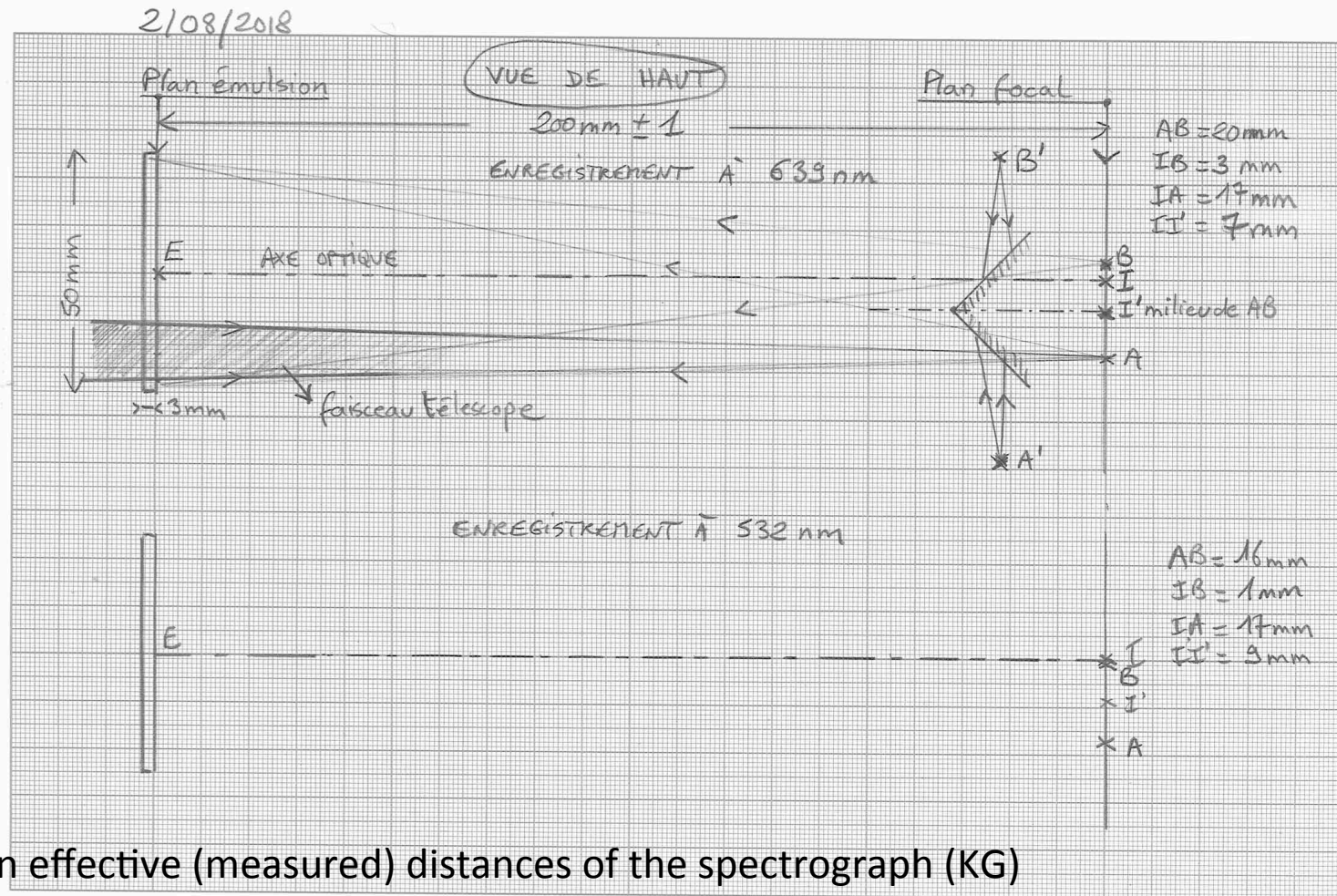
# Lessons learned

- Optical functions (diffraction + Fresnel lensing to compensate defocusing) are **robust**
- Diffraction efficiency
  - Sensitive to the noise -> **solved**
  - Much better with phase holograms -> **amplitude holography discarded**
- Higher orders
  - 2nd/1st  $\sim 0.1$  with argentic emulsions. Under study with bichromate gelatin
- Refined requirements include
  - Uniformity of transmission ( $<5\%$ )
  - Optimised 1st diffraction order





# HOE for AuxTel configuration



## Geometry

- Based on effective (measured) distances of the spectrograph (KG)
- Assumes 0th order @ 3 mm from the CCD edge
- Dispersion such that  $\lambda=1050\text{nm}$  is at 34.8 mm (incl. Tolerance of 1 mm on AB)
- -> Max. extension (equivalent to a grid of  $\sim 150$  lines/mm)



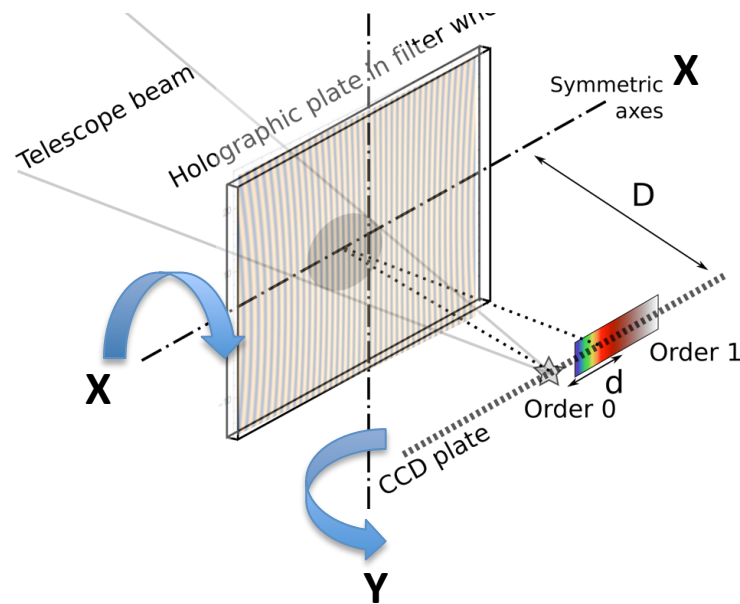
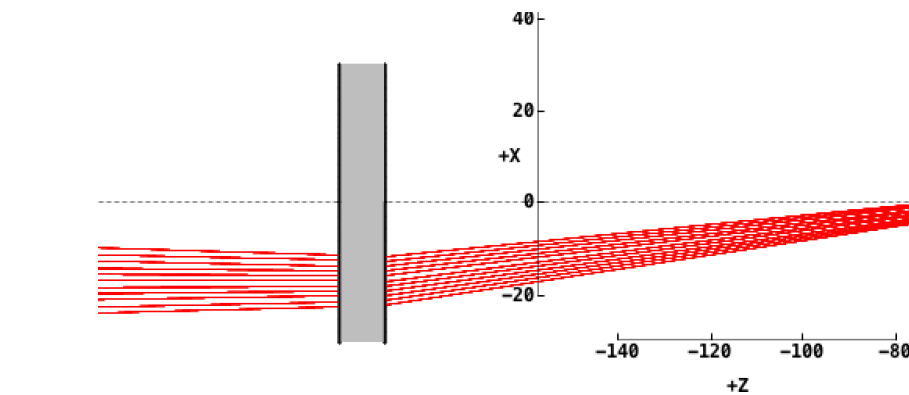
# **Specifications from CTIO to AuxTel**

- Take into account the CTIO prototypes studies
  - Diffracted light into order +1 > 10% (Ronchi)
  - (+2 order)/(+1 order) < 3%
  - Transmission uniformity < 5%

# Status of prototypes for AuxTel

- The « state of the art » with argentic emulsions (for phase holograms)
  - One prototype sent to us this week with
    - 25% from incident beam diffracted in order +1
    - 2.5% in order +2
  - Will be measured ASAP on the bench
  - According to the maker: limitation of ratio (2<sup>nd</sup>/1<sup>st</sup>) due to the max. width compatible with good transparency (5μm)
- Next step (coming weeks)
  - Bichromate (transparent) gelatin of 12-15μm should totally (?) cancel order 2

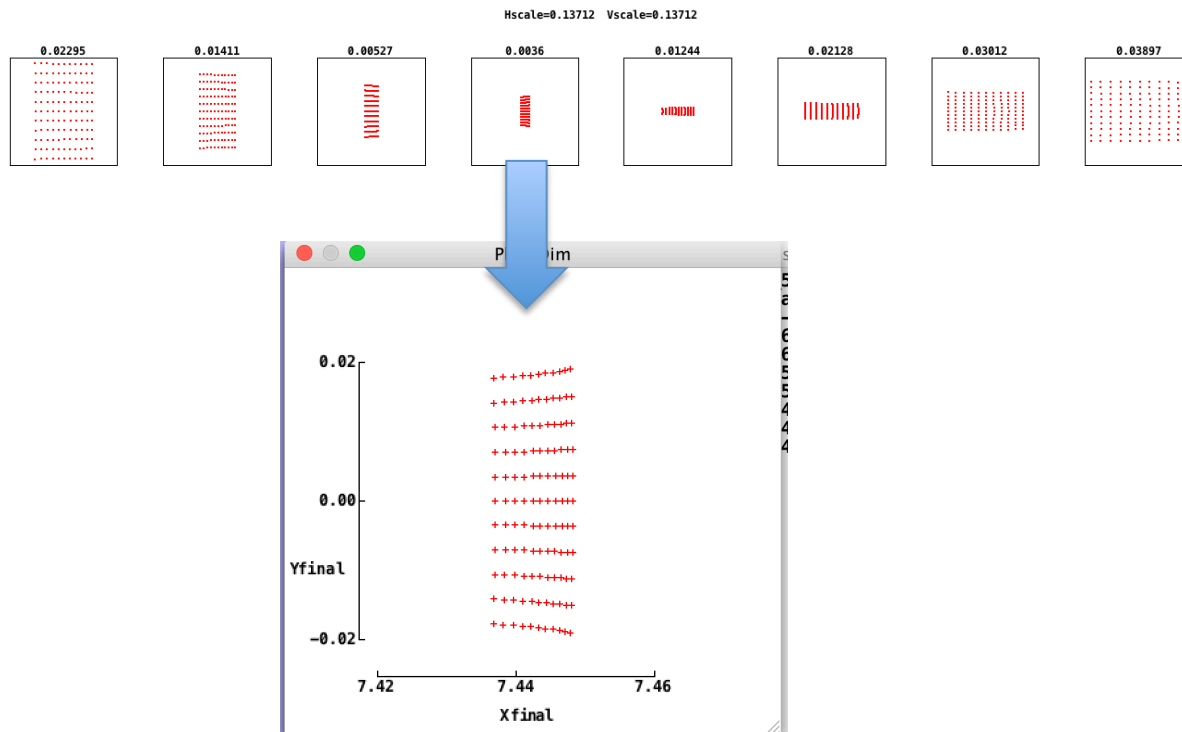
# Impact of tilting HOE



- Why this study?
    - The disperser will probably be tilted to shift ghosts
    - Check the robustness of optical response
  - Assume  $1^\circ$  to  $2^\circ$  tilt
- Note:  $1^\circ \leftrightarrow 1\text{mm}$  @  $5\text{cm} \leftrightarrow$  shift ghost at  $3.5\text{mm}$  from spectral line

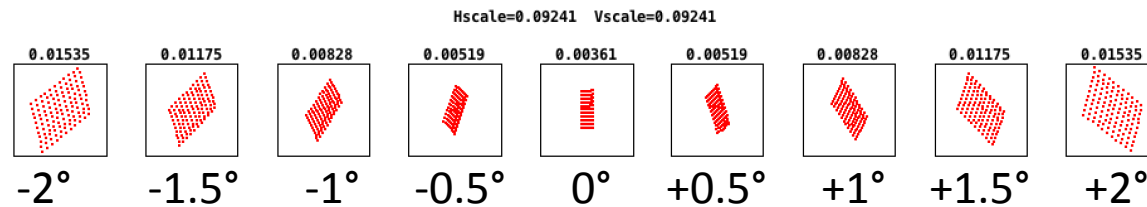
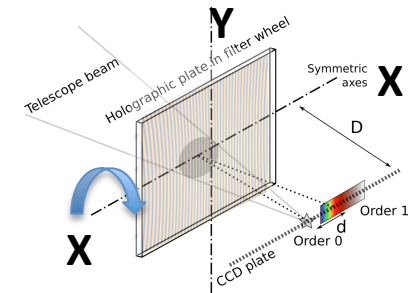
# No tilt

- Ray-tracing (beam4)
  - Squared beam
  - $\lambda=760\text{nm}$
  - Focus minimising  $\Delta X$  (spot extension  $12\mu$  along X)

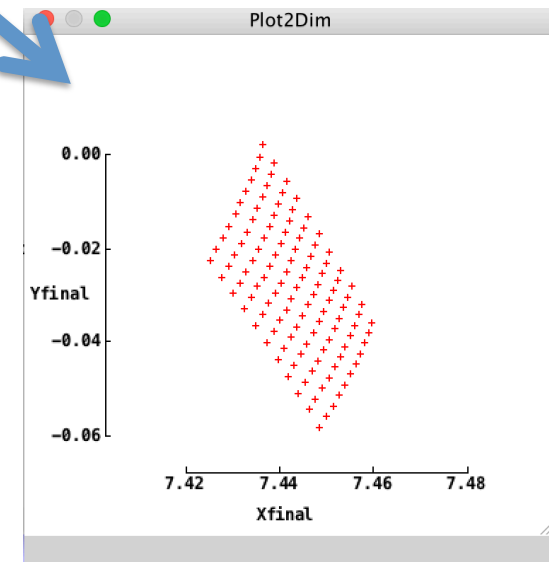
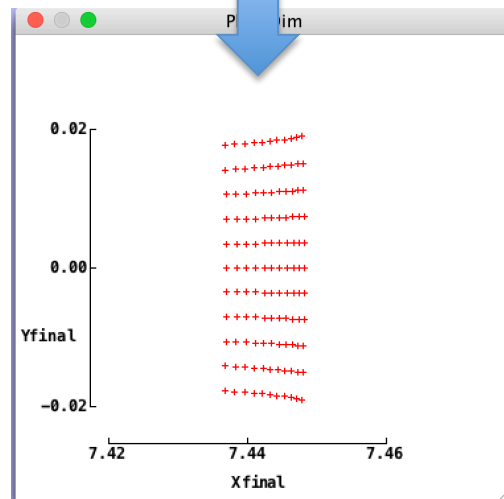


# Tilt (around X-axis)

- In  $[-2^\circ, 2^\circ]$ 
  - Fixed focus
  - For  $1^\circ$  tilt, spot extension  $40\mu$  along X

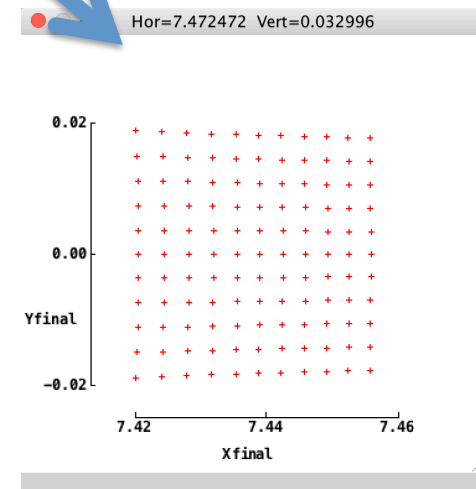
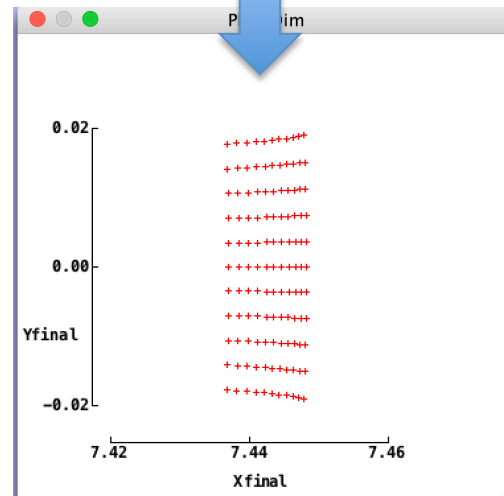
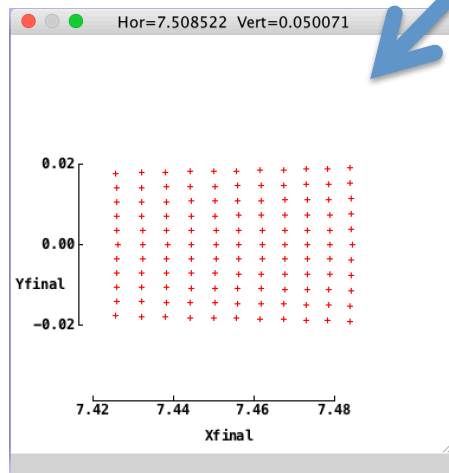
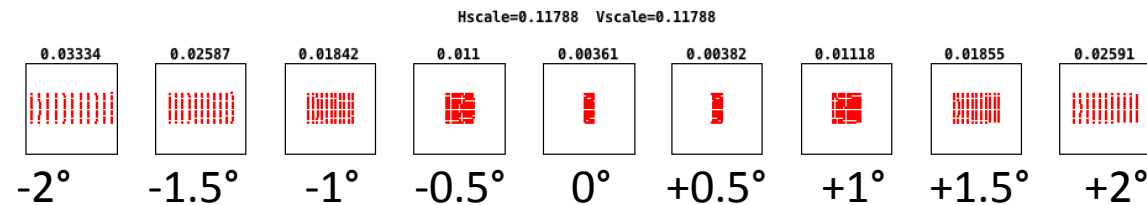
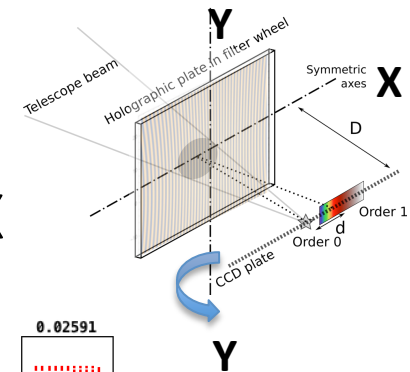


Symmetrical



# Pitch (around Y-axis)

- In  $[-2^\circ, 2^\circ]$ 
  - Fixed focus
  - For  $1^\circ$  tilt, spot extension  $40\text{-}60\mu$  along X





# COMPLEMENTS

# Search for makers

- University of Liège (created a startup 10 yrs ago)
  - Prof. Habraken: « *L'holographie peut faire des choses merveilleuses mais ... jamais rentable pour une PME!* »
- Wasatch Photonics
  - Did something special also for NASA 10 years ago
  - Would be expensive (?)
  - No availability before march 2019
- Holoeye...
- **Hard point:** a specific production bench is needed (converging beams instead of usual plane beams when periodic grids)