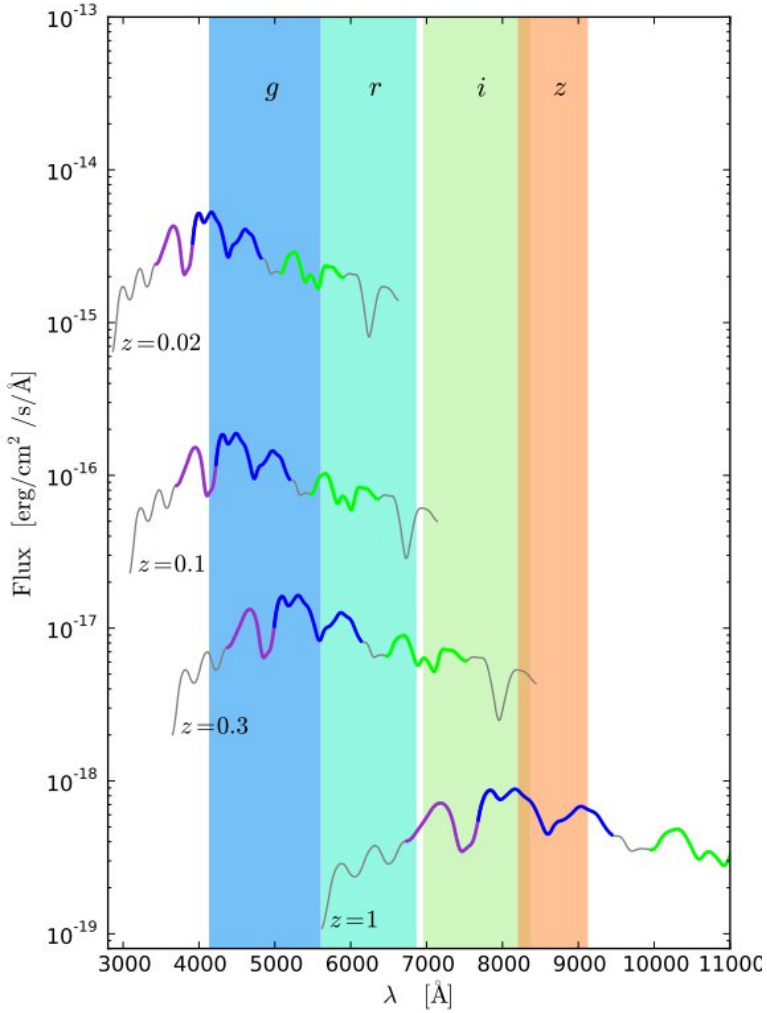
# StarDICE status overview

LSST-France

LPSC June 08th 2023

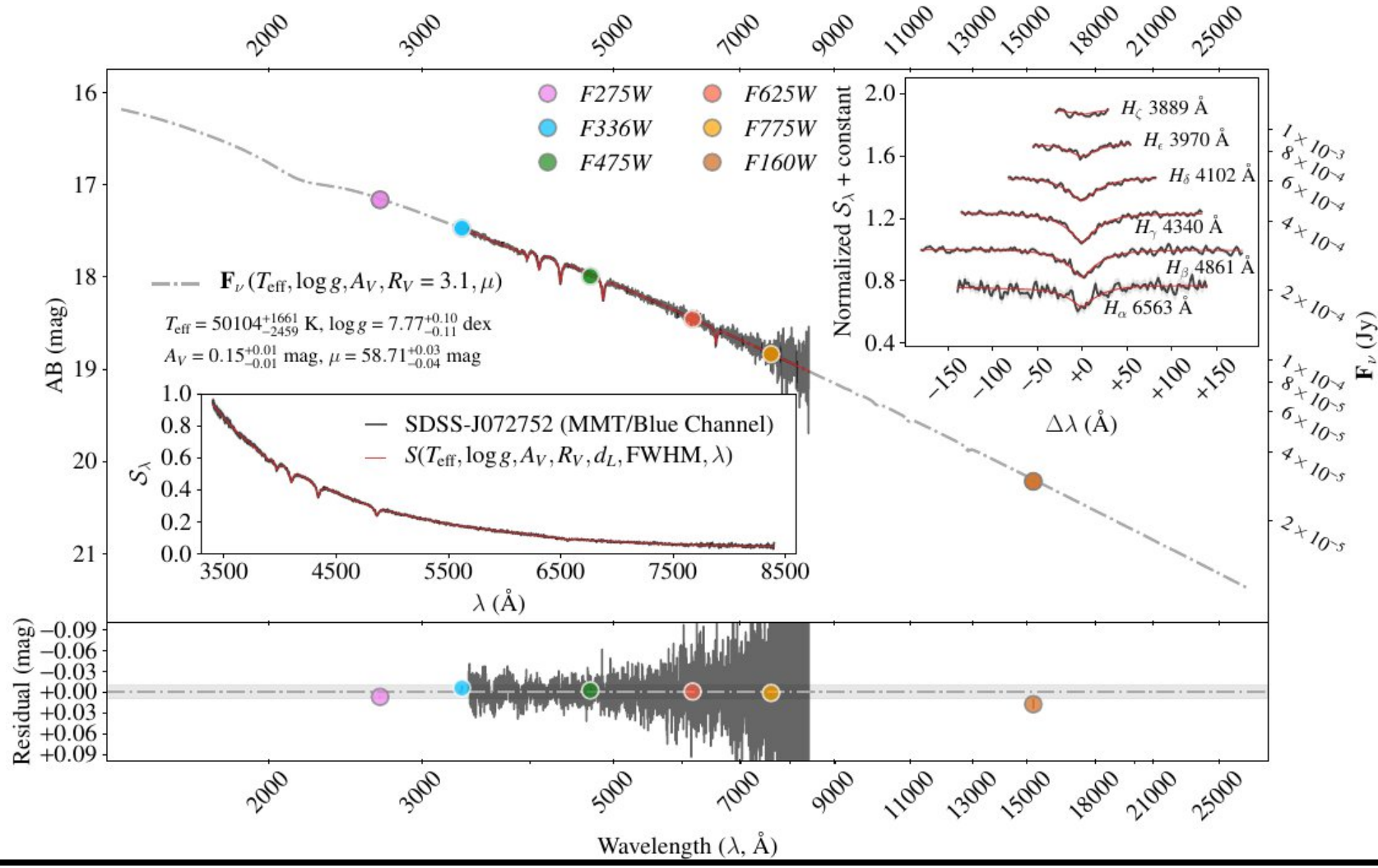
# Providing flux references for Supernovae distances




- Apparent flux of supernovae at different redshifts gives a noisy (~7%) measurement of distance -> Hubble diaggram
- VRO will provide thousands of SNe to beat this noise
- All SNe at a given redshift share one noise in common : The error on the survey passbands
- Large survey needs exquisite calibration references (standard stars)
- The goal of StarDICE is to provide such standards

# The only practical references to date are pure hydrogen WD

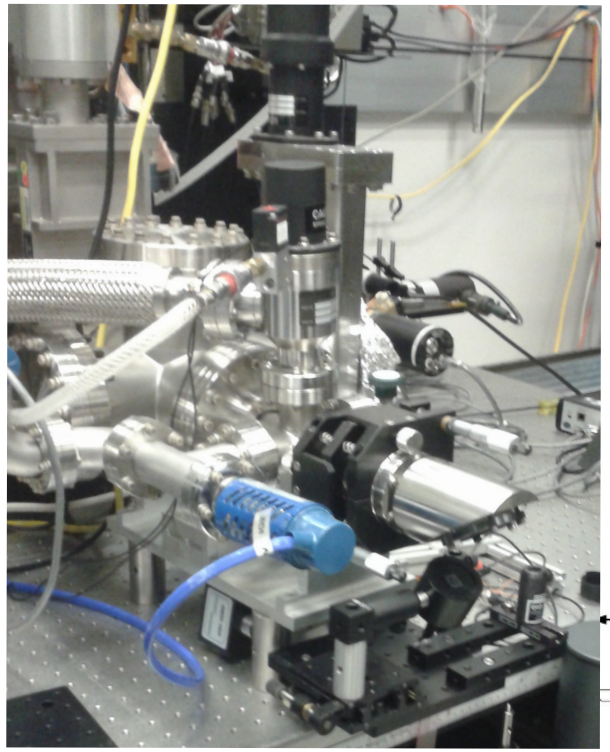
- Numerical model of the radiative transfer in the hydrogen atmosphere
- Model parameters infered from measurement of H profile in high-resolution spectrosopy
- Largest implementation to date : The cosmic flux standards program (Narayan et al. 2022)

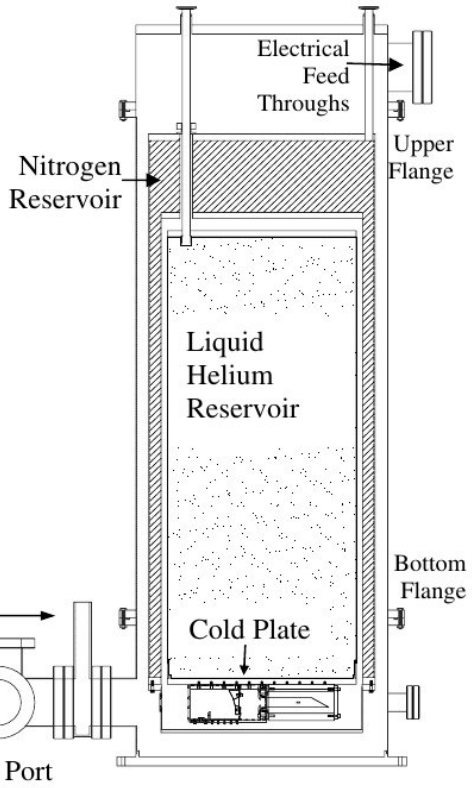



The proposal of the StarDICE experiment is to build an instrumental check of this model

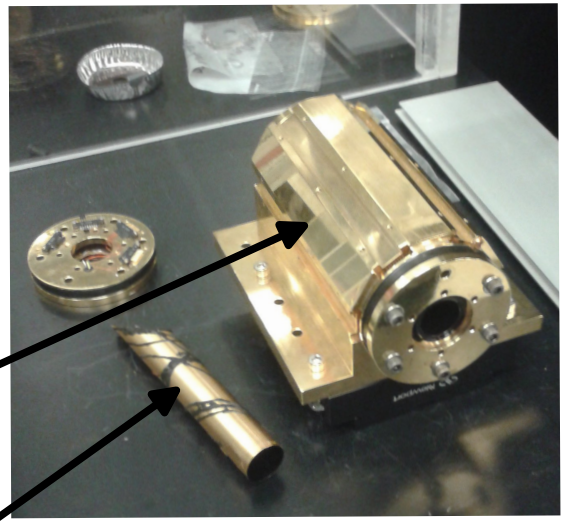
# The alternative standard

POWR: the Primary Optical Watt Radiometer
(Brown et al. 2006, Houston et al. 2006)
high-accuracy electrical substitution cryogenic radiometer

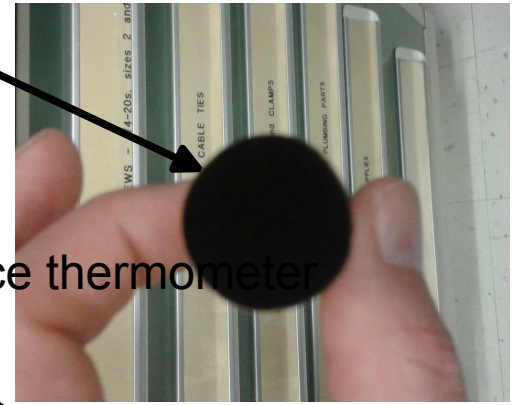




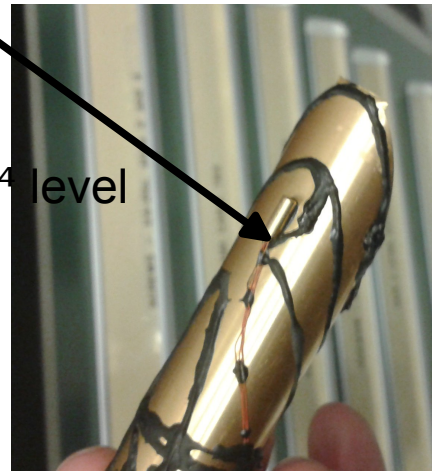

Cryogenic shelter



Black absorbing cavity

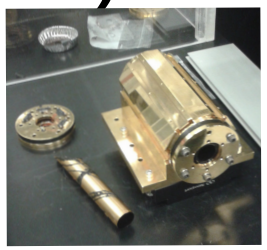


Germanium resistance thermometer



Claimed accuracy at the $10^{-4}$ level

# The original concept proposal for a path finder (2016-2019)

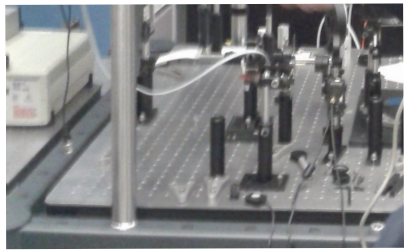


NIST POWR

$10^{-3}$W

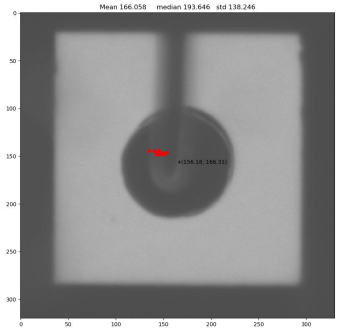
$10^{-6}$W

NIST SCF



NIST Photodiodes

Narrow spectrum LEDs with temperature monitoring



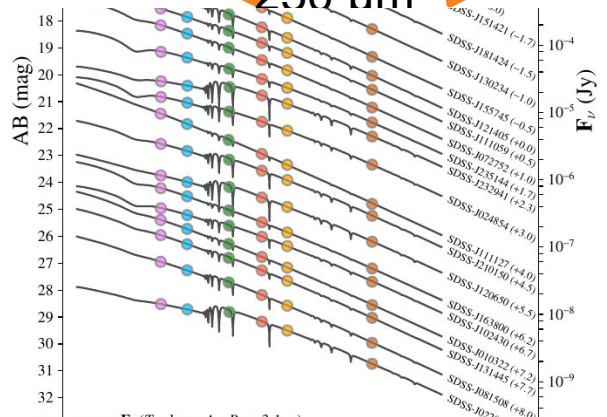

250 um

Small aperture telescope

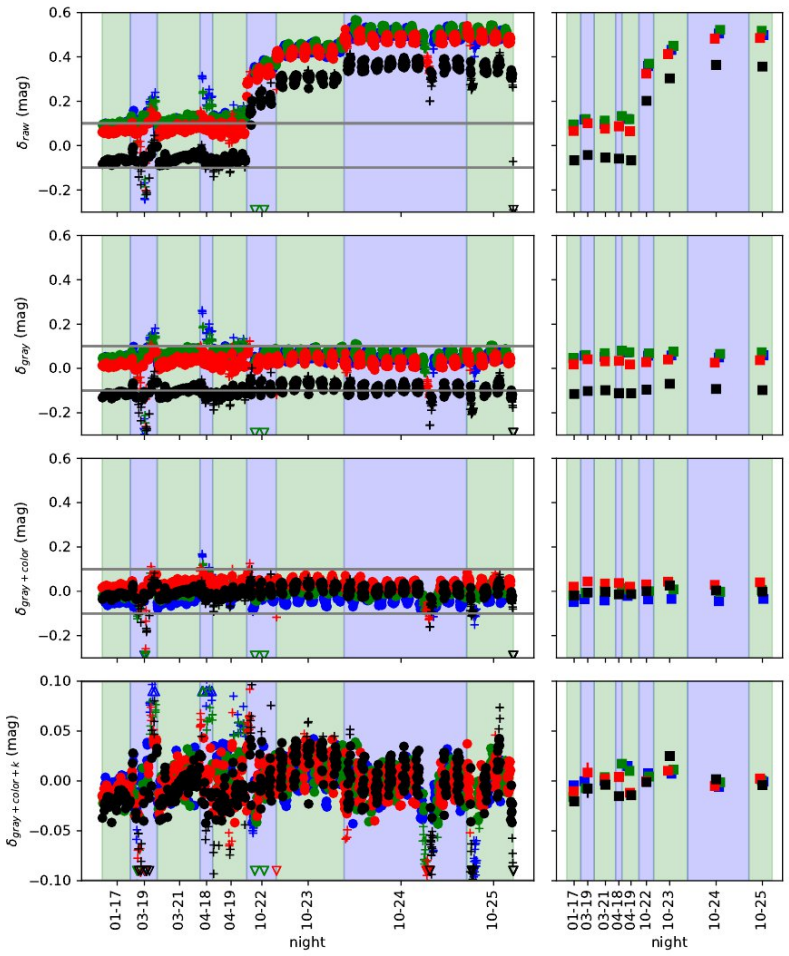
$10^{-17}$ W/cm²/nm

$10^{-19}$W/cm²/nm

Spectrophotometric standard stars

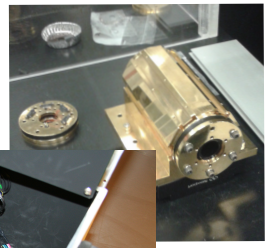


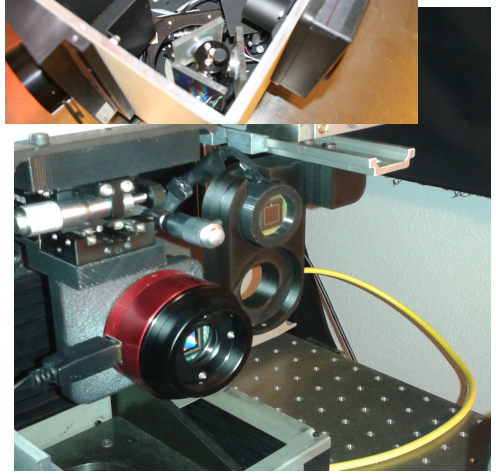
# Conclusion from F. Hazenberg thesis (2019)

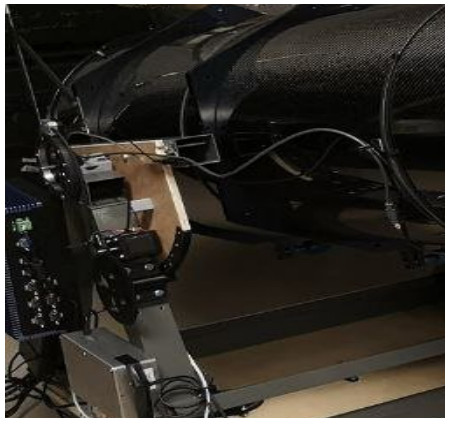



- Optically perfect : Full pupil and point like which makes the result absolutely Independent of any optics model
- Fast : full telescope calibration in 20min
- Stable : consistent results over 6 monthes at the % level
- Lessons learned for the upgrade:
- Current T monitoring accurate at .5%: new T proxy
- One step missing in the transfer: Calibration transfer bench
- Transfer hindered by clouds: IR instrument
- Estimated number of nights 200-400: Robotic Telescope
- Accurate determination of mirror reflectivity: Collaboration with CBP
- LEDs spectra at nominal (extremely low) flux not acquired: Spectrograph

# The revised StarDICE metrology chain







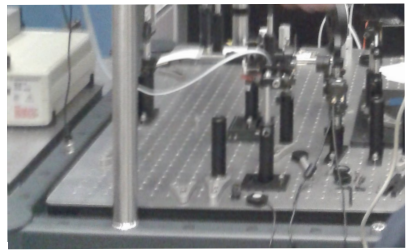
NIST POWR

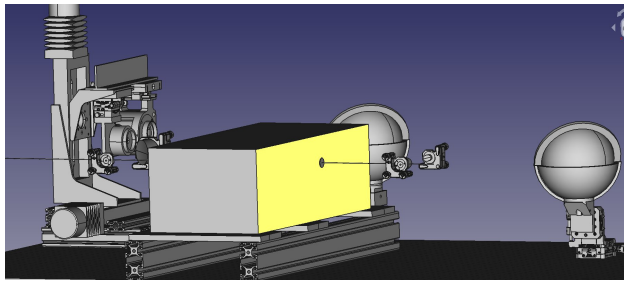
NIST Photodiodes

$10^{-3}$W

$10^{-6}$W

NIST SCF





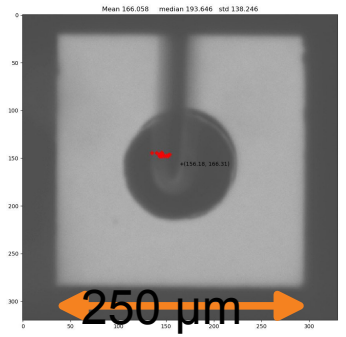
StarDICE transfer bench

CCD Camera and Calibration spectrograph

$10^{-13}$ W/cm²/nm

Small aperture telescope
+ 200 nights automated
+ passband measurement
+ Atmospheric monitoring

Narrow spectrum LEDs
with forward voltage monitorin




$10^{-17}$ W/cm²/nm

$10^{-19}$W/cm²/nm

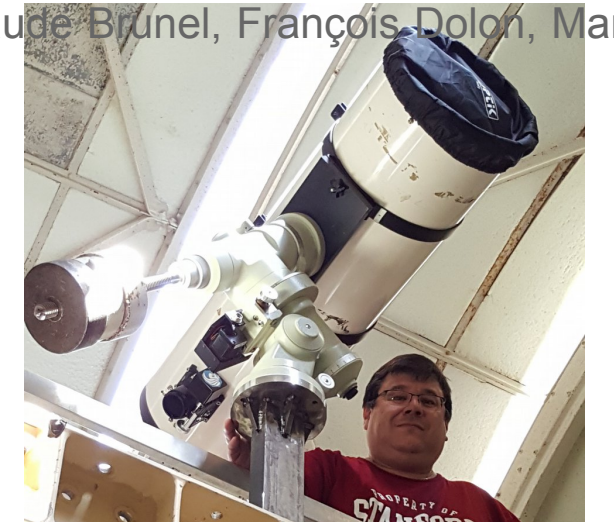
Spectrophotometric standard stars

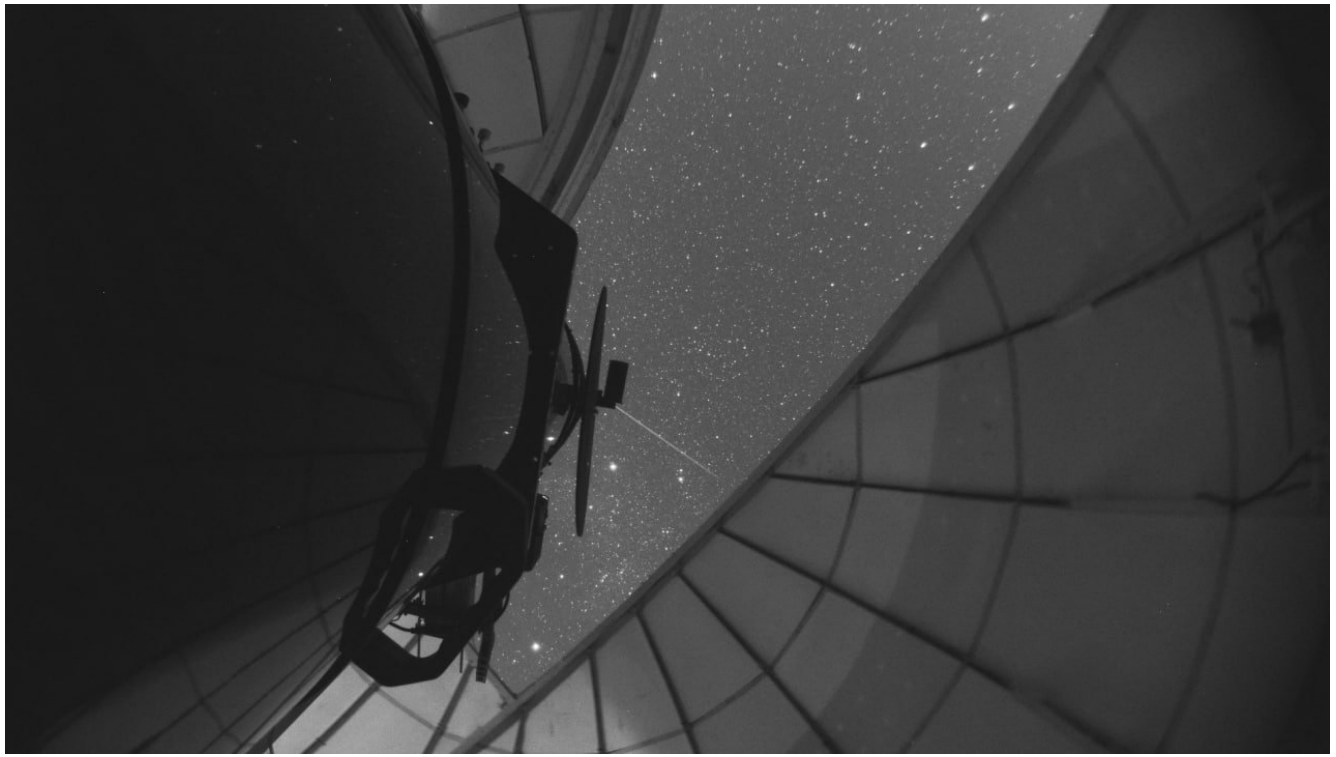
# StarDICE Milestones

- Sept. 2019: F. Hazenberg PhD thesis. The complete experiment is designed and requires ~200 - 400 nights
- 2020 Sept. 25 : MOU with OHP to host the experiment in one of its jumelé coupola, parallel work starts on the building, mount, optical instrument, calibration bench and artificial star.
- 2022 Mar. : CBP measurement of the optical instrument complete
- 2022 Nov. 11 : Acceptance of the StarDICE bench demonstration paper
- 2023 Mar. : Robotic telescope complete with optical and IR instrument
- 2023 Mai 28 : OHP review grants green light for remote operations

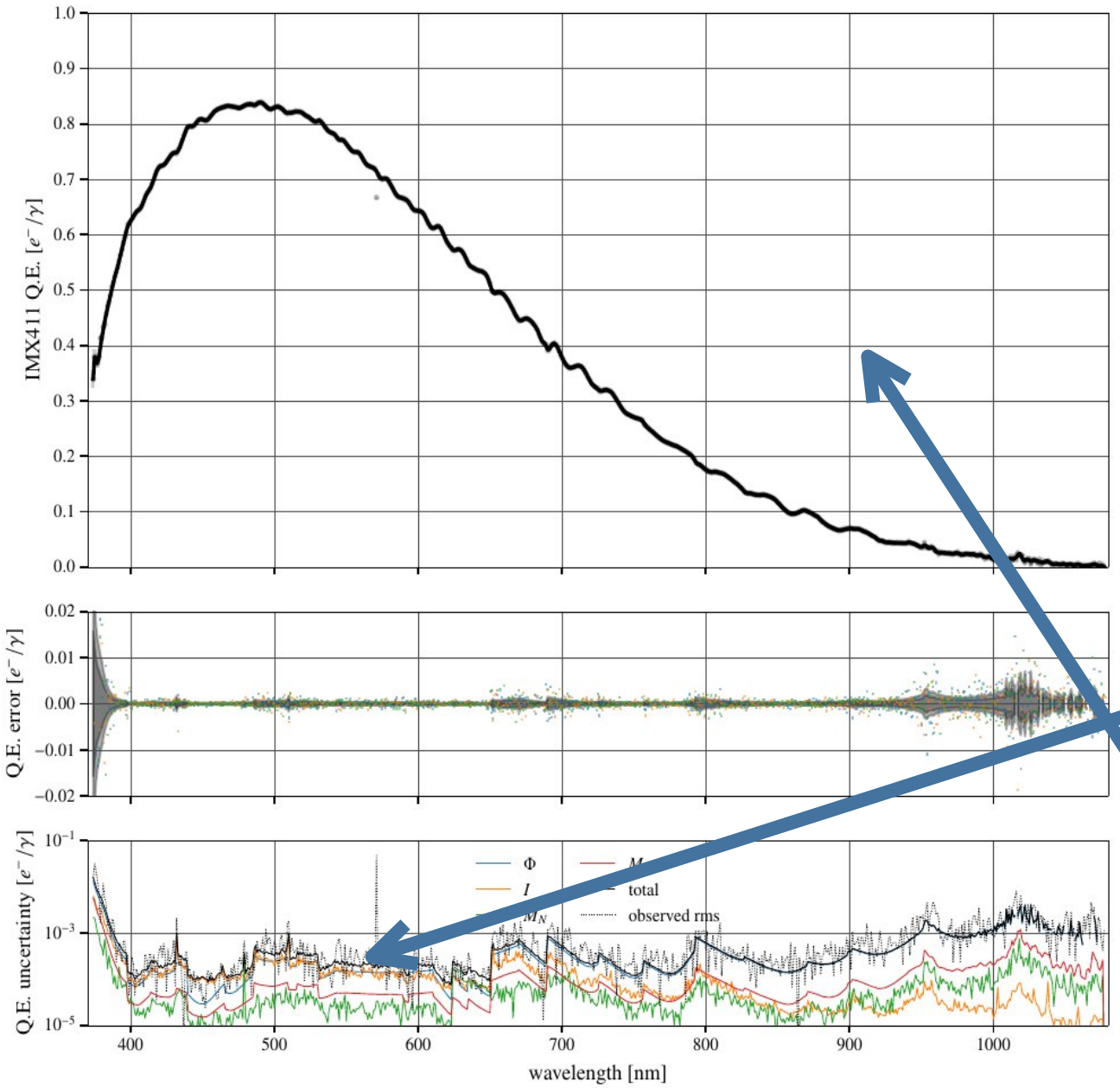
# From then to now

•**CPPM** : O. Angelini, S. Beurthey, S. Deguero, F. Feinstein
•**LPNHE** : P. Antilogus, Ph. Bailly, E. Barrelet, M. Betoule, S. Bongard, J. Coridian, M. Dellhot, P. Ghislain, A. Guyonnet, F. Hazenberg, C. Juramy, H. Lebbolo, L. Le Guillou, E. Pierre, N. Regnault, Ph. Repain, M. Roynel, K. Schahmaneche, E. Sepulveda, T. Souverin
•**LUPM** : J. Cohen-Tanugi, Eric Nuss, B. Plez, Kélian Summer
•**IJCLab** : J. Neveu, S. Dagoret-Campagne, M. Moniez
•**OHP** : Pierre-Eric Blanc, Auguste Le Van Suu, Jean-Paul Payan, Jean Claude Brunel, François Dolon, Marc Ferrari



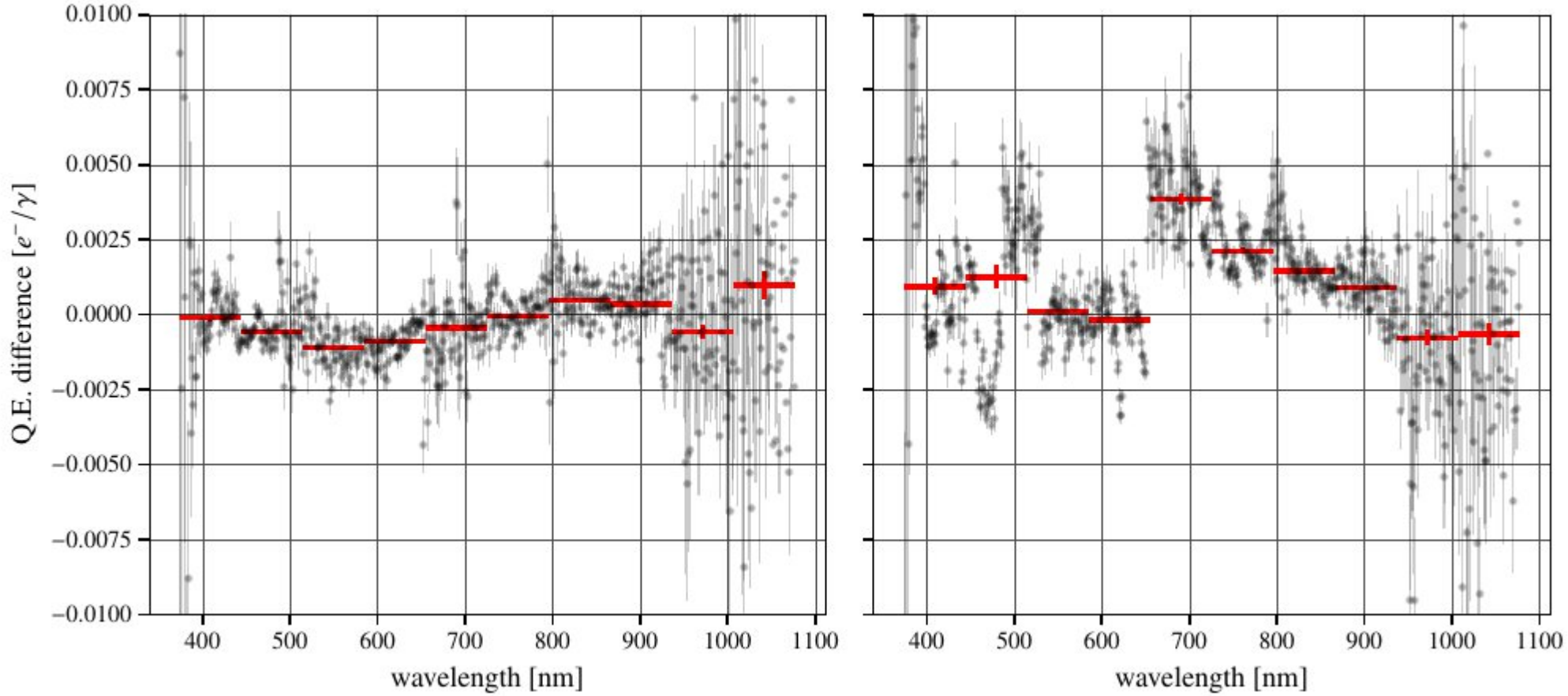


# Calibration bench



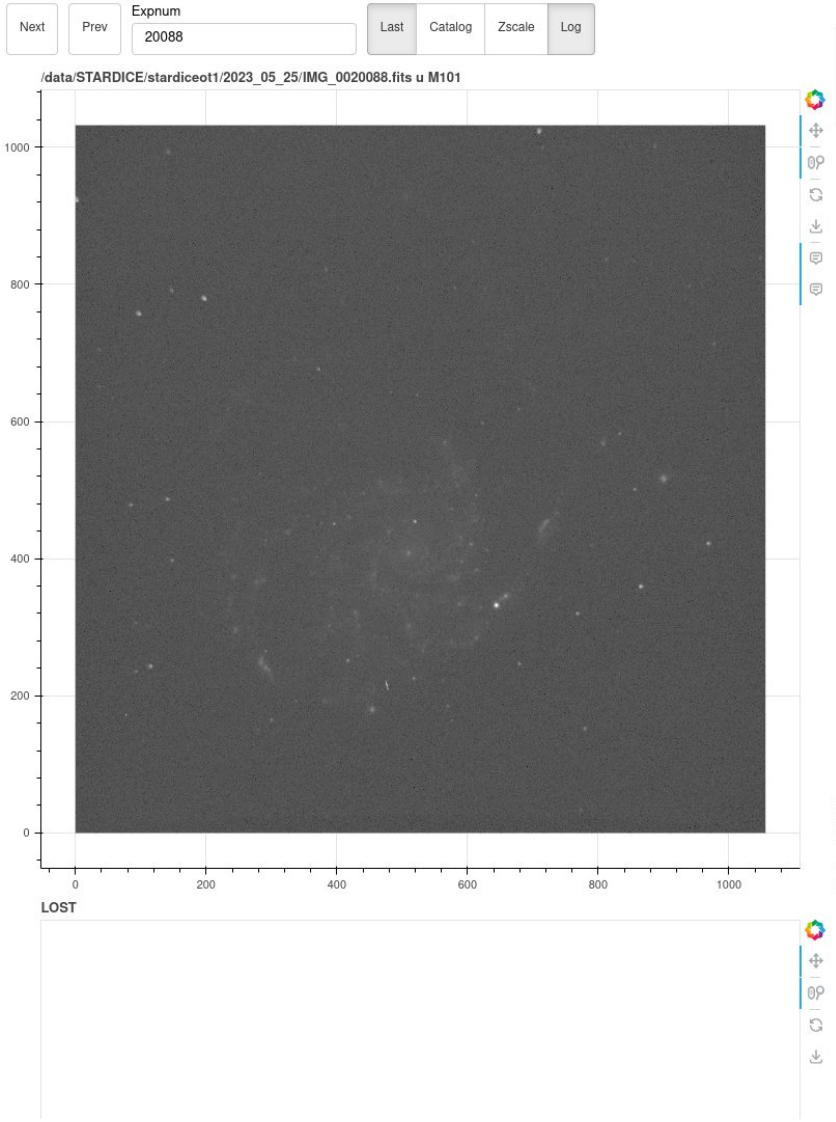

- The game is to calibrate a CCD sensor relative to the NIST Photodiodes at $10^{-3}$ over the range 400-1000 nm
- Already validated performance on v2 are sufficient for the validation survey
- A&A 2022_44973
- Work on v3 has started
  - Optimization of photodiode reading
  - Optimization of photocurrent extraction
  - Rework of the mechanical components
  - New CCD camera

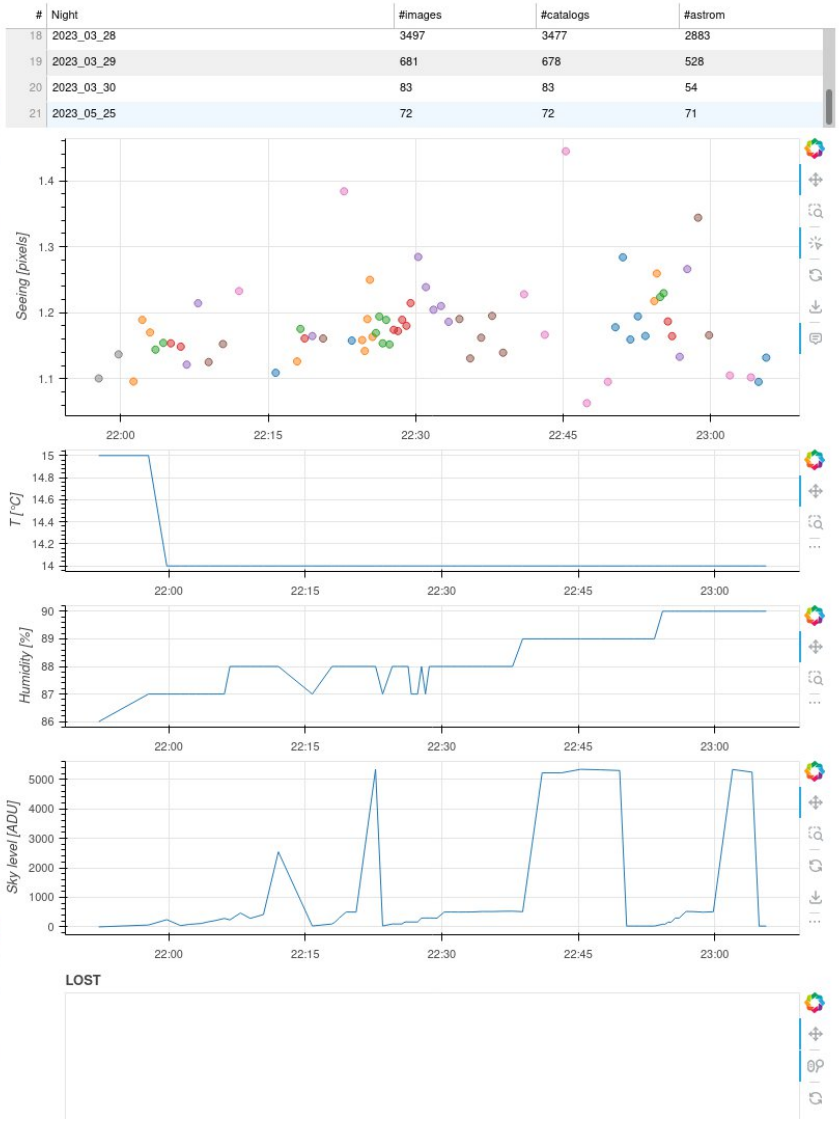
# Calibration bench systematic




- Main identified systematics is the linearity
- But at a non-critical level for the survey validation
- Still a bit more work to have a fully calibrated artificial star

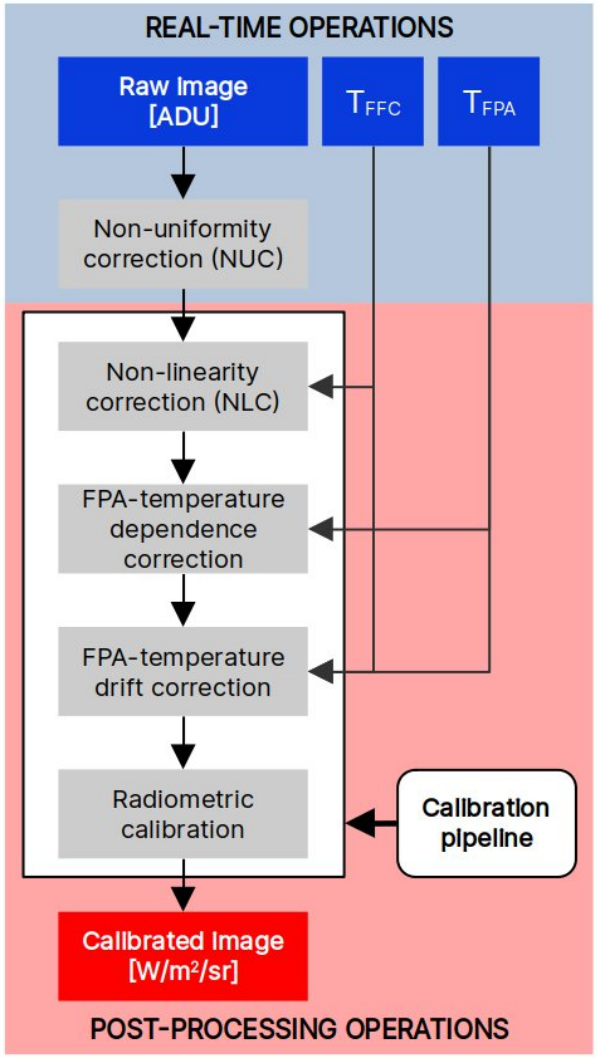
# Robotic instrument is ready

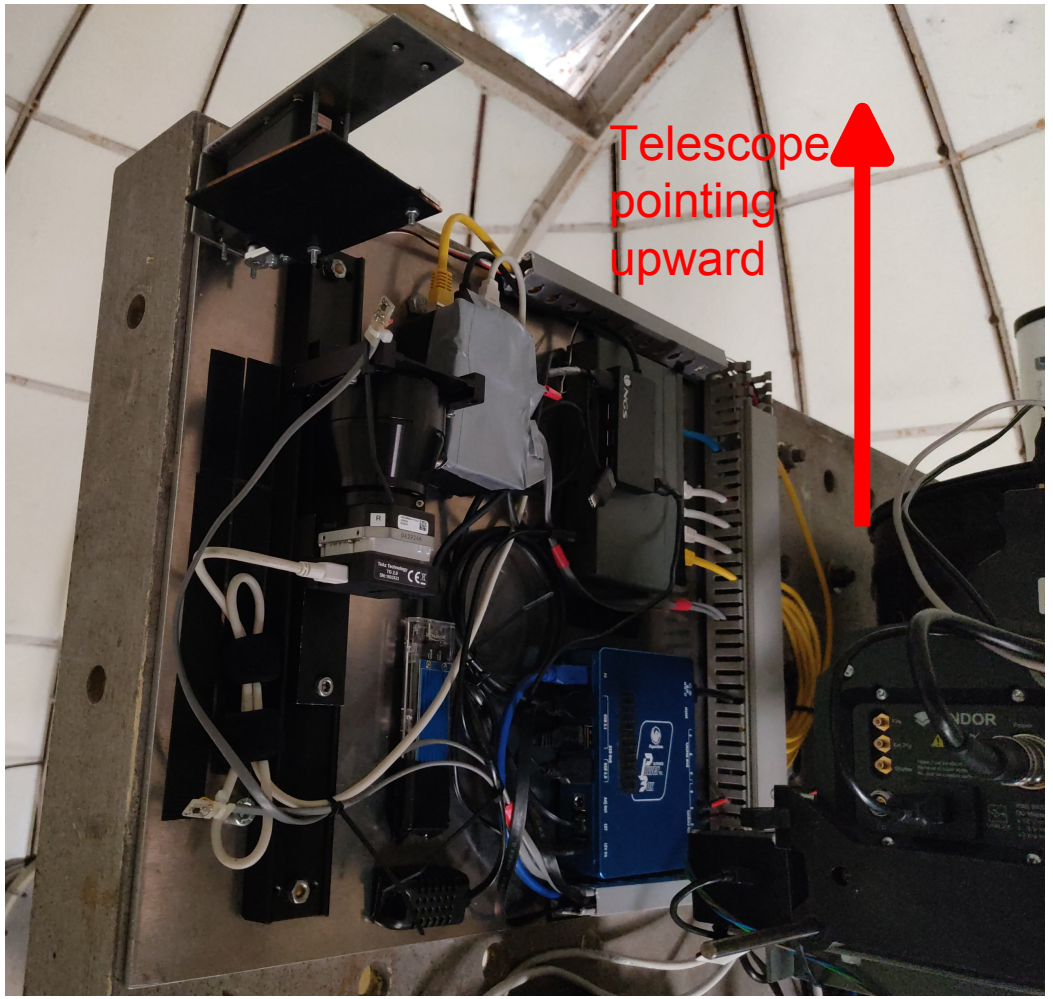


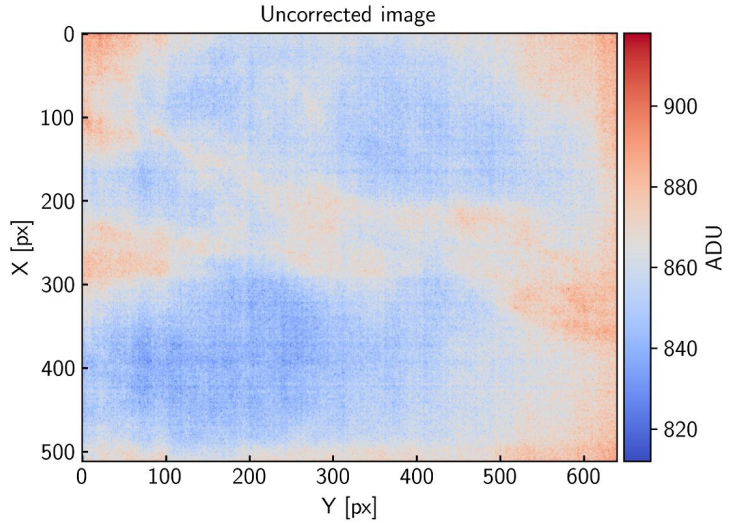



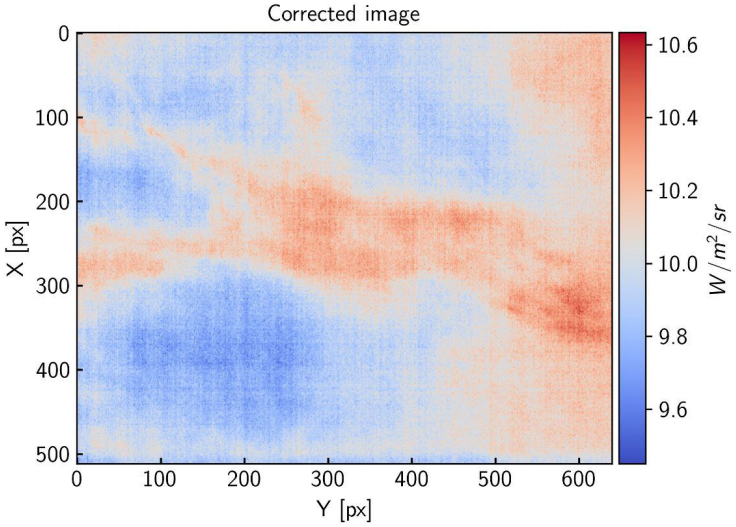

- Screenshot from the remote control
- 6 good nights accumulated
- Start a 20 night validation survey as soon as weather (and network) cooperate.
- See Jeremy's talk for details on the transmission measurement of the optical instrument
- And Thierry's talk for a first evaluation of the performances of the optical instrument

# Installation of the IR instrument at OHP



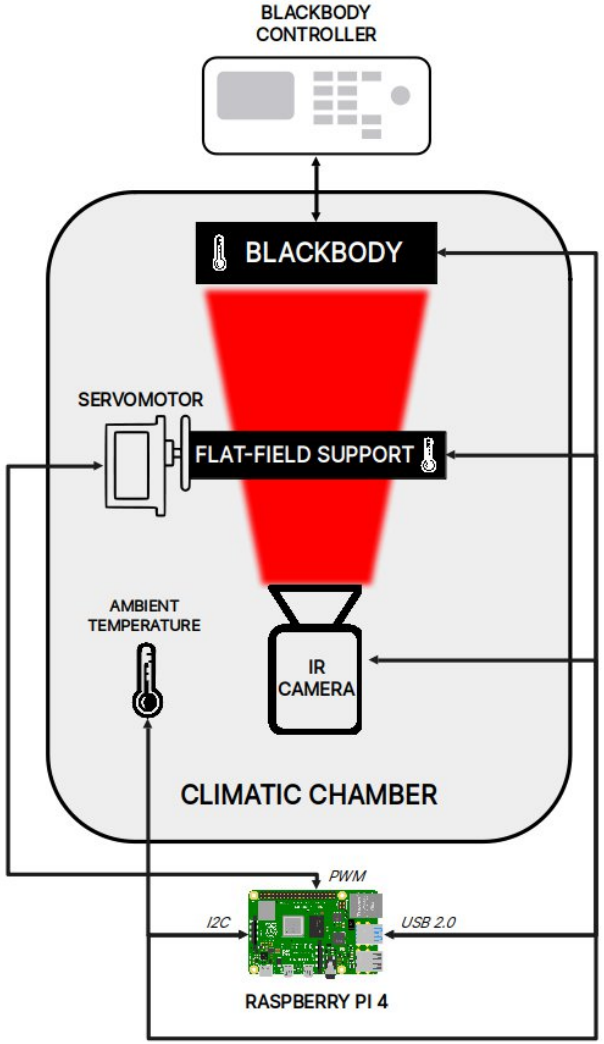



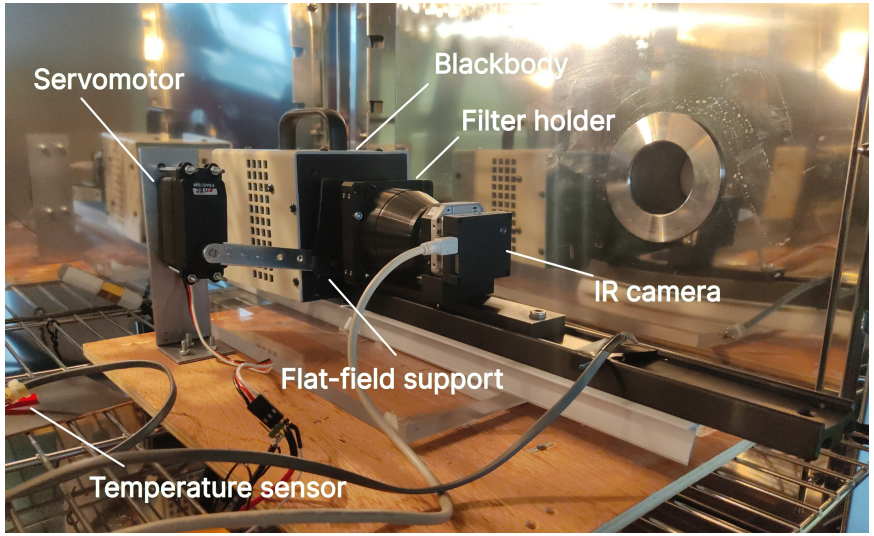



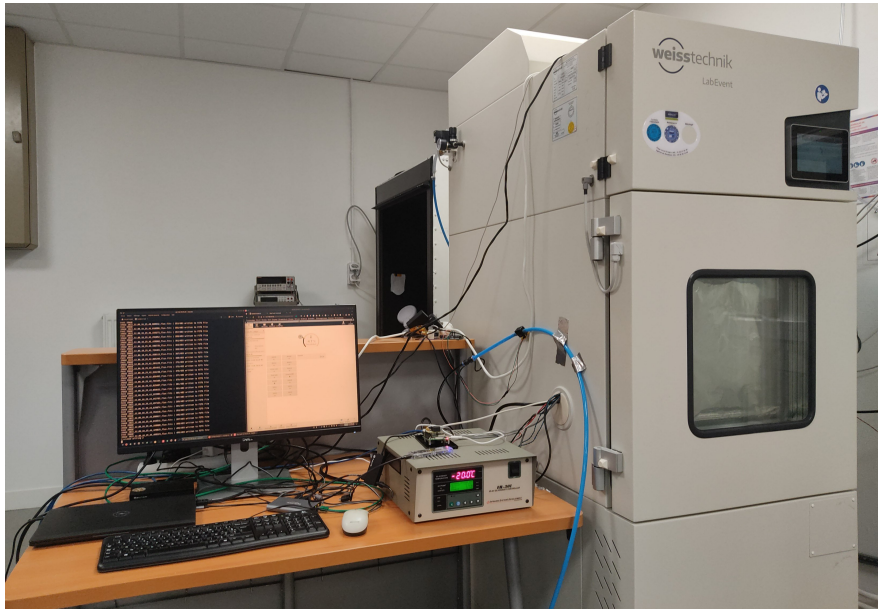



# Calibration of the bolometer array (1/2)

- **December 2022** : calibration data acquisition at IJCLab in ATLAS climatic chamber with S. Dagoret-Campagne and M. Moniez
- **Goal :** imaging a low-temperature/radiance blackbody at different camera operating temperatures
- → correct for various camera defects (non-linearity response, sensor temperature drift…)

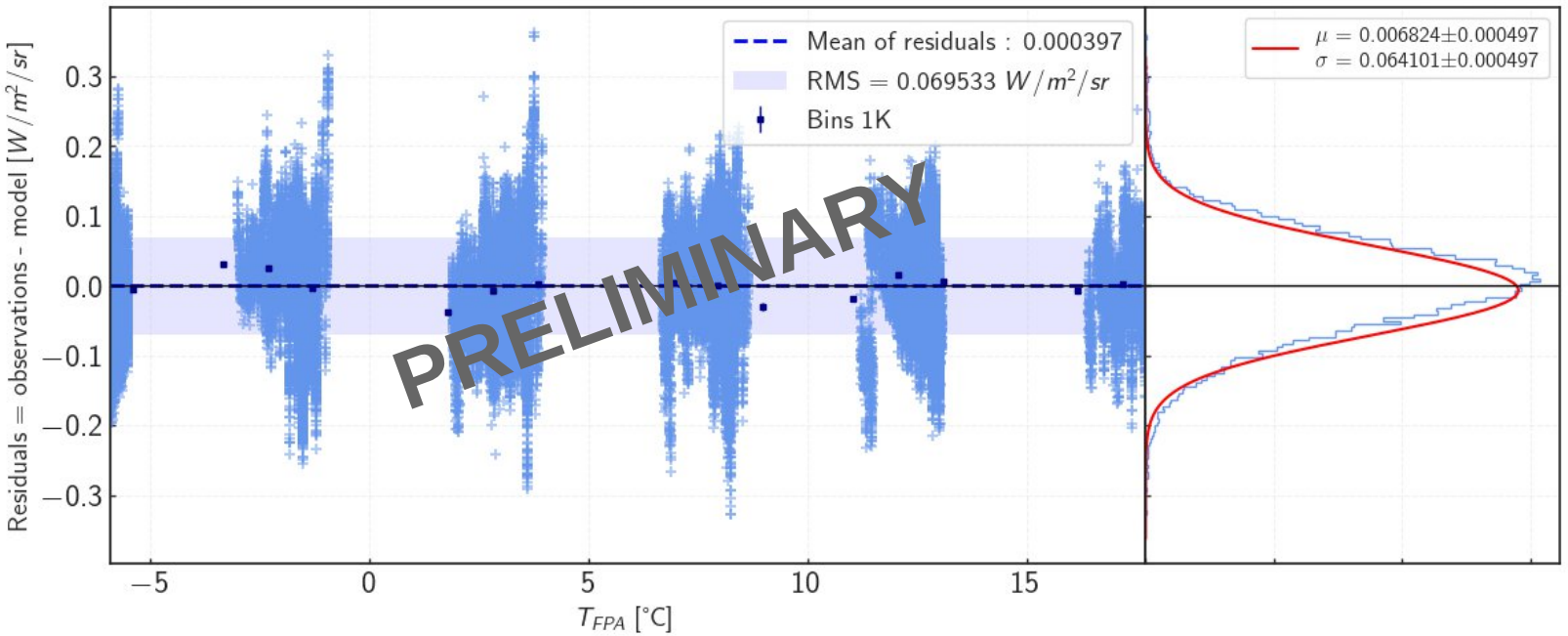


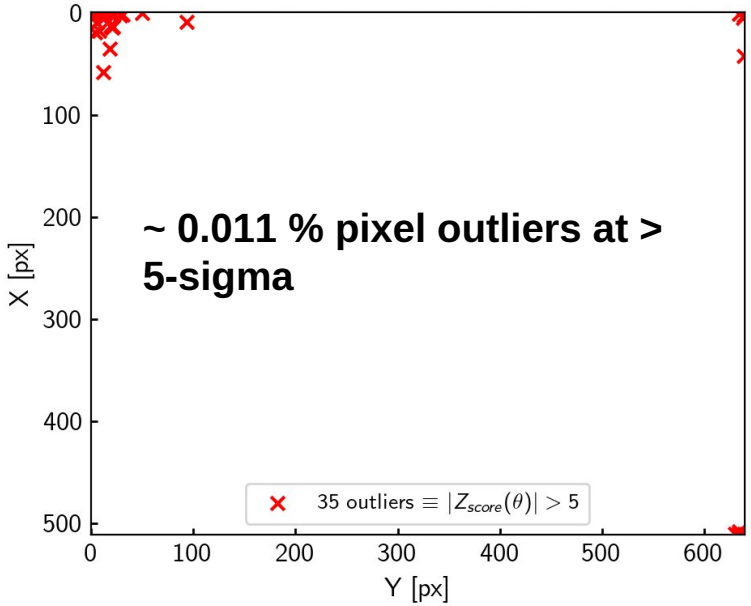



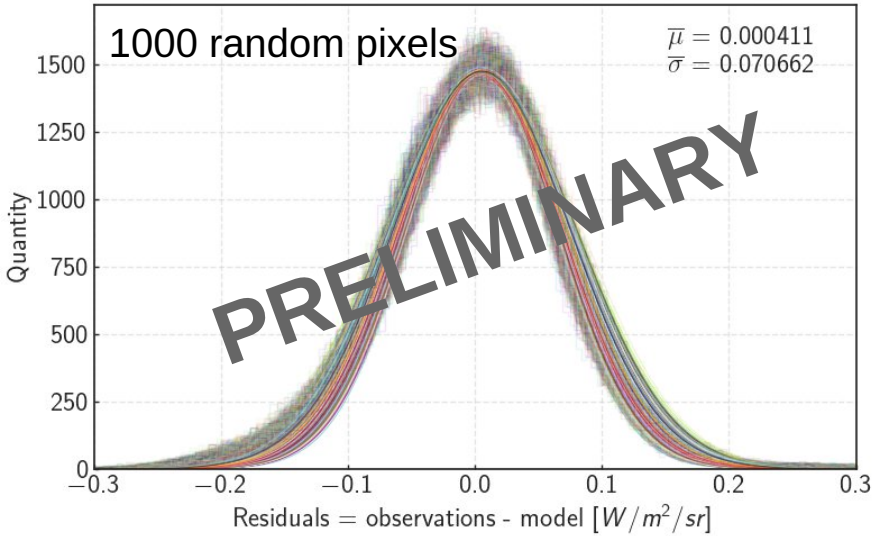
# Calibration of the bolometer array (2/2)

- Preliminary average uncertainty per pixel :
- **+- 0.07 (stat.) W/m²/sr**
- **+- 0.04 (syst. of calibration experiment) W/m²/sr**

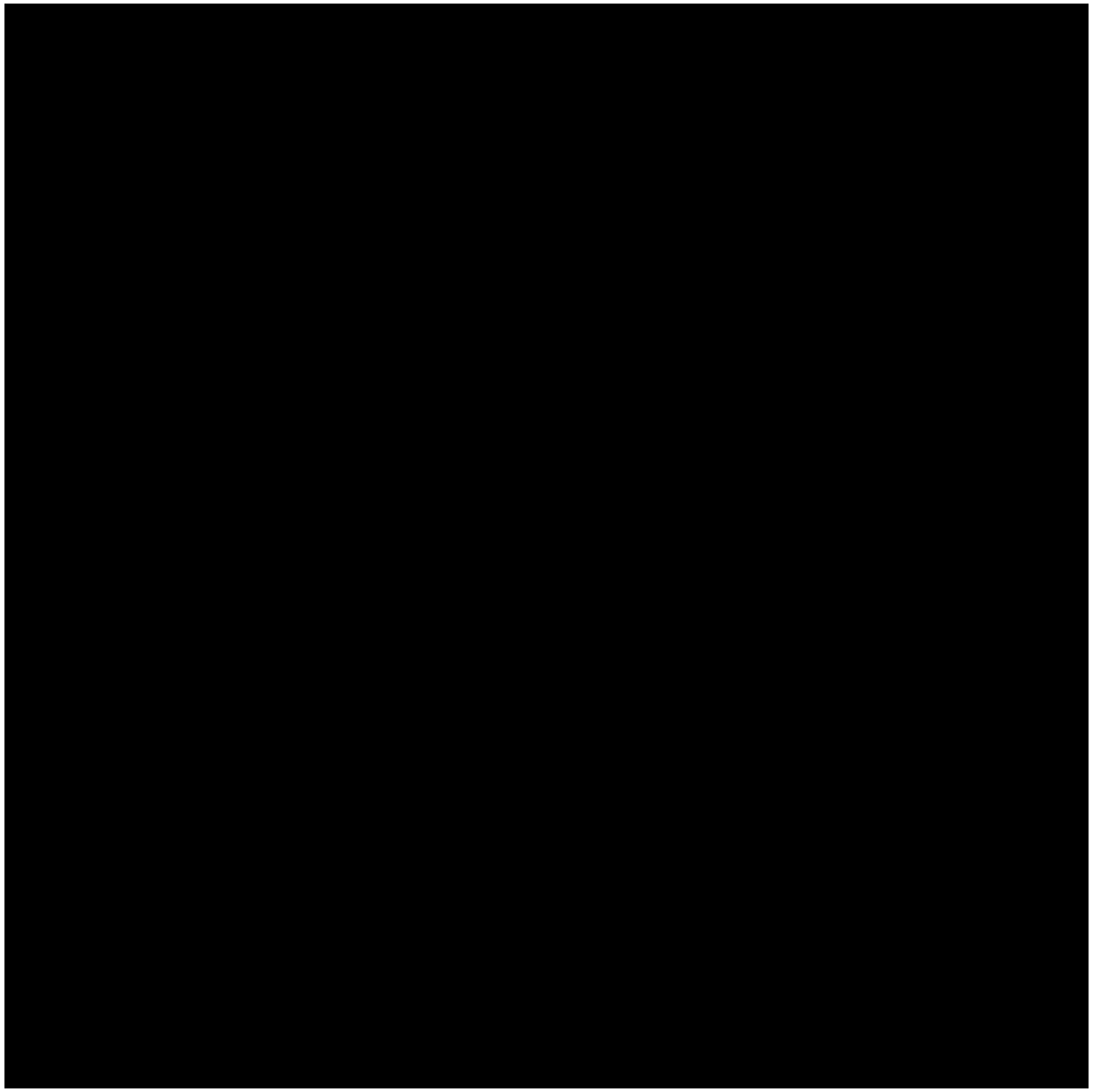



Residuals for the central pixel of the focal plane array between the corrected images and the scene radiance model. Temperature gaps are due to environmental conditions in the climatic chamber. [K. Sommer et al., in prep]



# First light at OHP



# Conclusion

- StarDICE robotic installation is up and running
- Up for a 20-night validation survey allowing to build the data analysis chain for the spectrophotometric and IR instruments
- Optimizing the observation strategy to learn the best way to beat the atmospheric noise
- On the hardware side, the focus is switching toward the finalisation of the calibrated artificial star