The high-resolution UV spectropolarimeter POLLUX@LUVOIR

original concept and necessary updates

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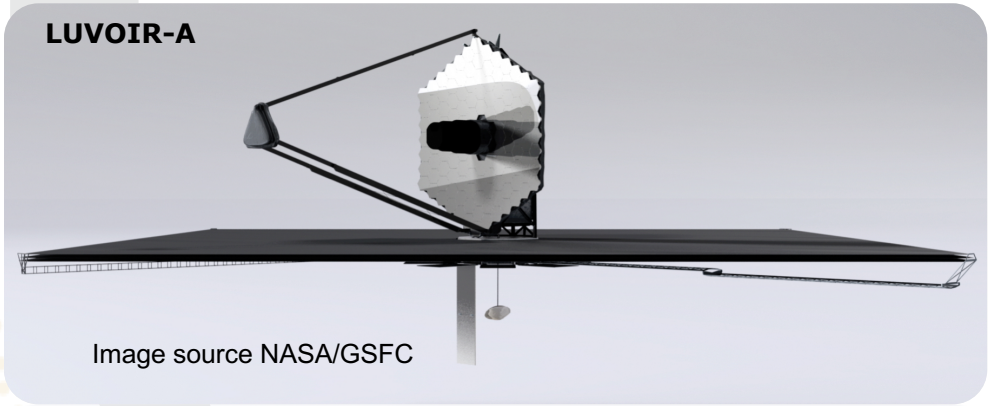
Context

NASA Decadal survey 2020

- LUVOIR: general purpose, multi-wavelength space observatory with broad science capabilities
- LUVOIR Science : ''From Big Bang to Biosignatures (and Everything in Bewteen..)''
- Two concepts: LUVOIR-A (15m) and LUVOIR-B (~8m)
    - Suite of imagers, and spectrographs to enable broad range of scientific investigations

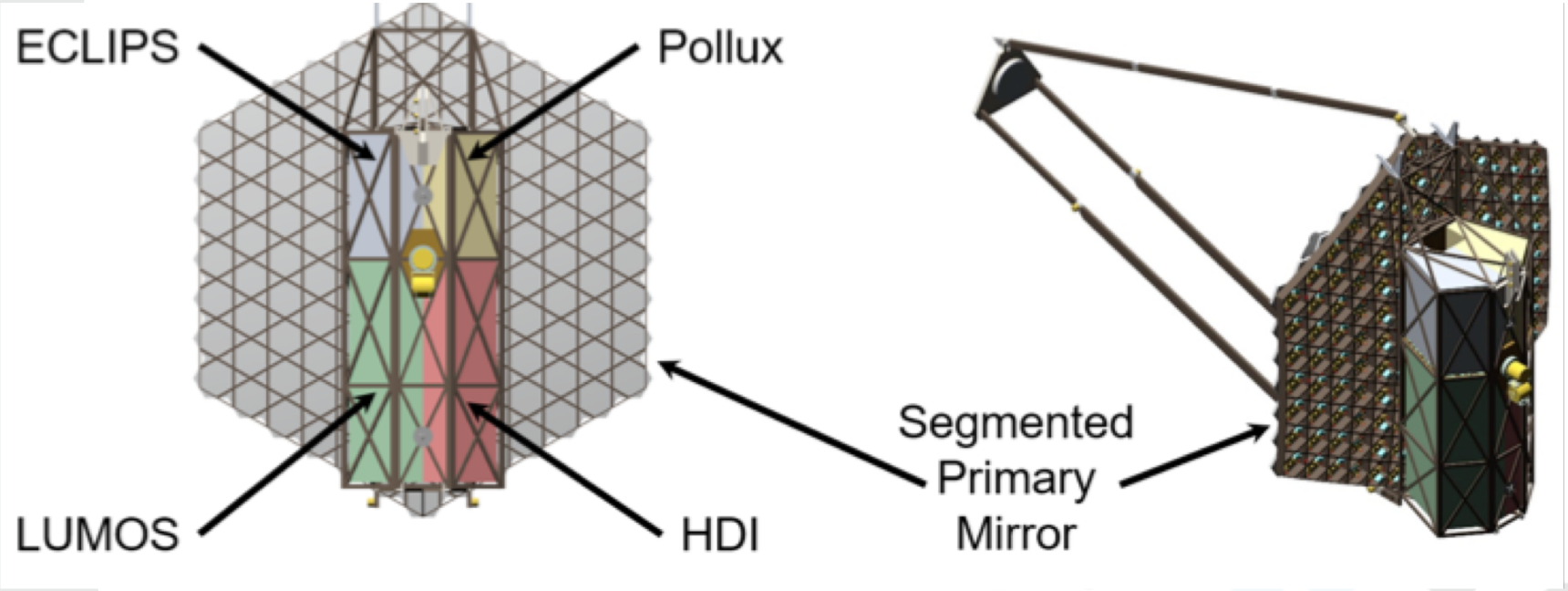


- 15 m mirror aperture
- Wavelength coverage 100 nm – 2.2 µm
- Diffraction limited at 500 nm
- Instantaneous Field-of-View: 10' x 8'
- Halo orbit about L2 point
- Serviceable and Upgradable
- Guest observer-driven program

https://www.luvoirtelescope.org

Context

- POLLUX, a high resolution UV spectropolarimeter for LUVOIR-A
- European contribution to LUVOIR study



Context

- Management ➔ CNES (France)
- PIs LESIA & LAM
- Consortium: more than 180 participants, 67 institutes, 13 European countries

Requirements & Objectives

Parameter	Requirement
Wavelength range	90 - 400 nm
Spectral resolving power	120,000
Observing modes	Spectropolarimetry and pure spectroscopy
Polarisation mode	Circular+linear (= IQUV)
Polarisation precision	10^{-4}

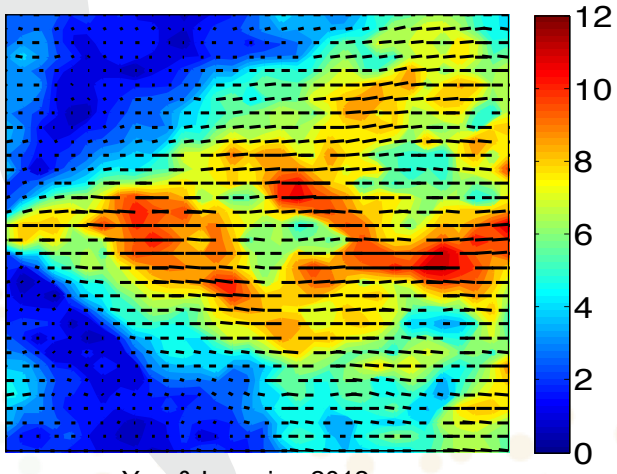
- Testing fundamental physics and cosmology
- Physics of Active Galactic Nuclei
- Interstellar and circumgalactic medium
- Stellar magnetic fields across the Hertzsprung-Russell diagram
- Exoplanets atmospheres and interactions with the host stars
- UV spectropolarimetry in the Solar System

Science Programs

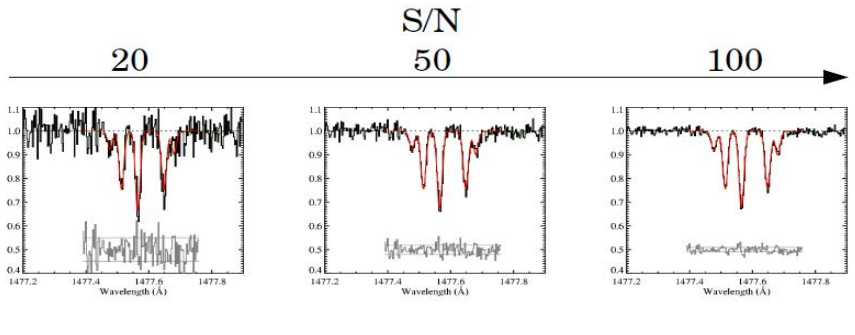
- **Cosmology:** probe the redshift evolution of the CMB temperature, measure the primordial abundance of deuterium, constrain the proton-to-electron mass ratio (μ) by observations of the Lyman and Werner bands of H2

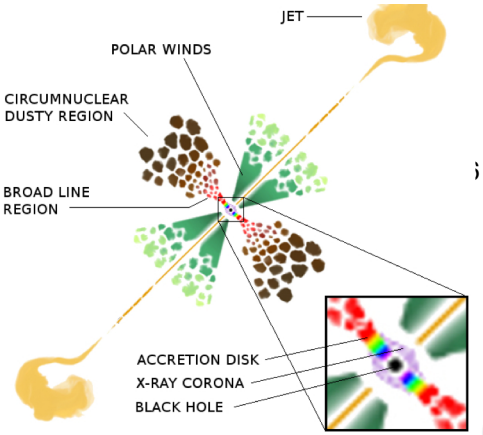
- **Extragalactic Astronomy:** Accretion disk physics, dust composition and B-fields strength of AGNs

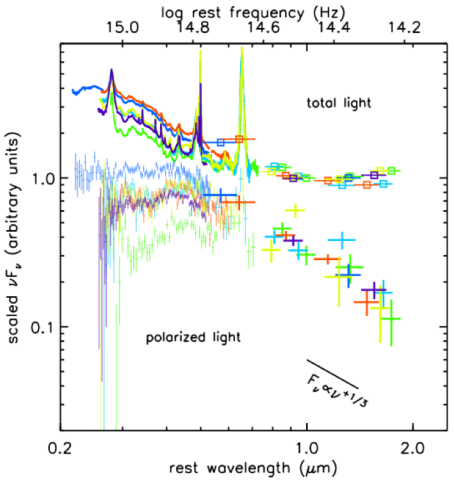
- **ISM/IGM Science:** The various phases of ISM/IGM



Yan & Lazarian 2012





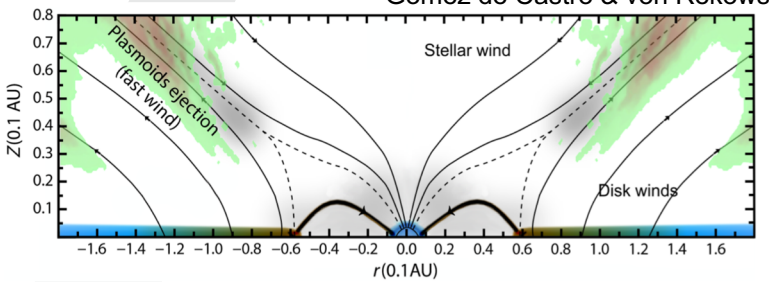


Kishimoto et al. (2008).

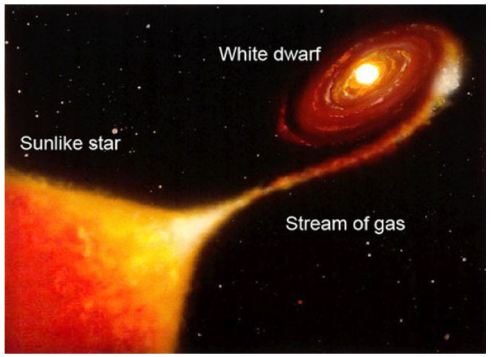
Aix*Marseille université
cnrs
cnes

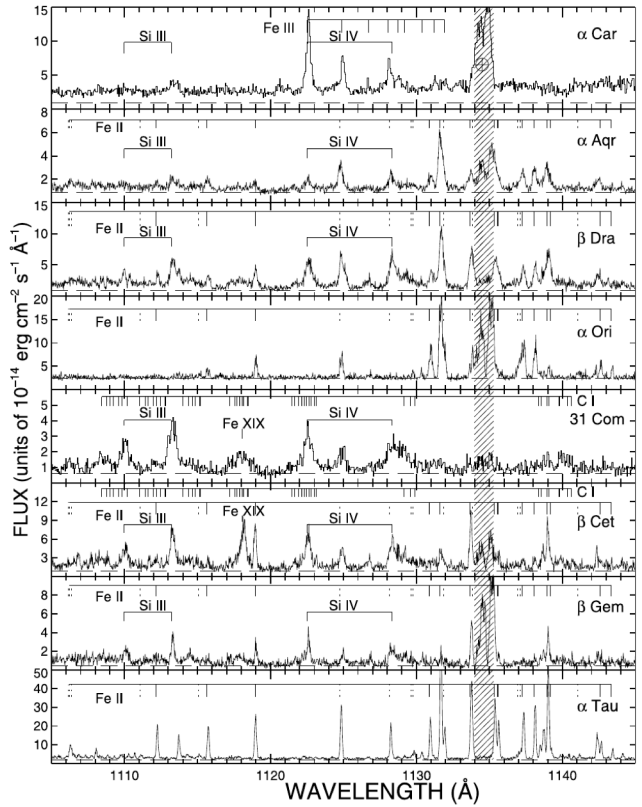
- Stellar magnetic fields across the Hertzsprung-Russell diagram

Gomez de Castro & von Rekowski 2011



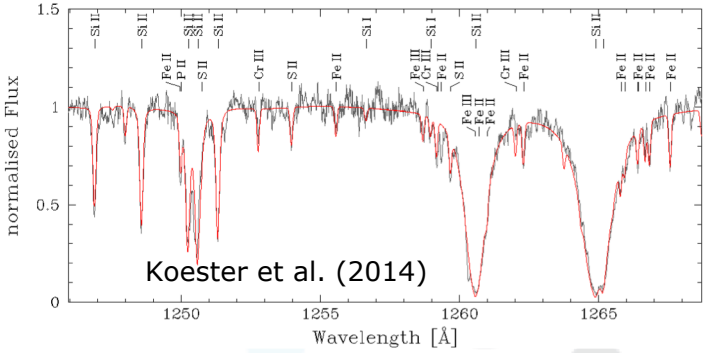
Pre-main sequence stars: star-disk interaction and accretion-ejection





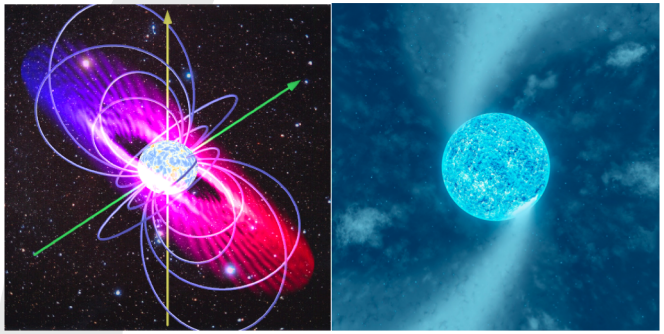
Dupree et al. (2005)

Chromospheric and coronal heating in evolved stars

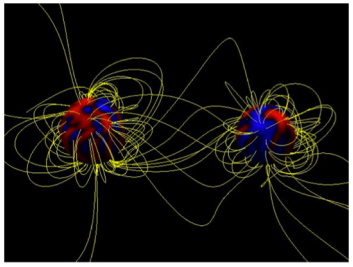


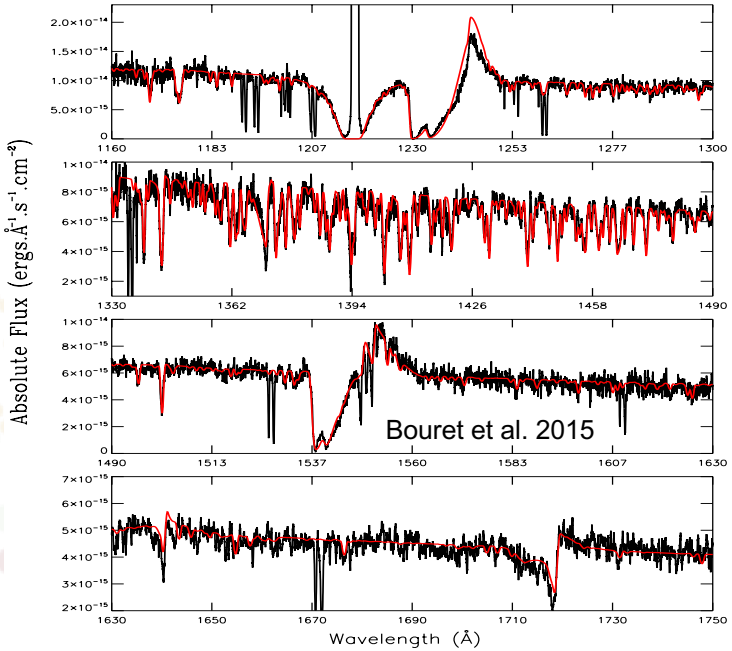
Koester et al. (2014)

- Origin of magnetic fields in white dwarfs
- The physics of accretion discs
- White dwarfs accreting planetary debris



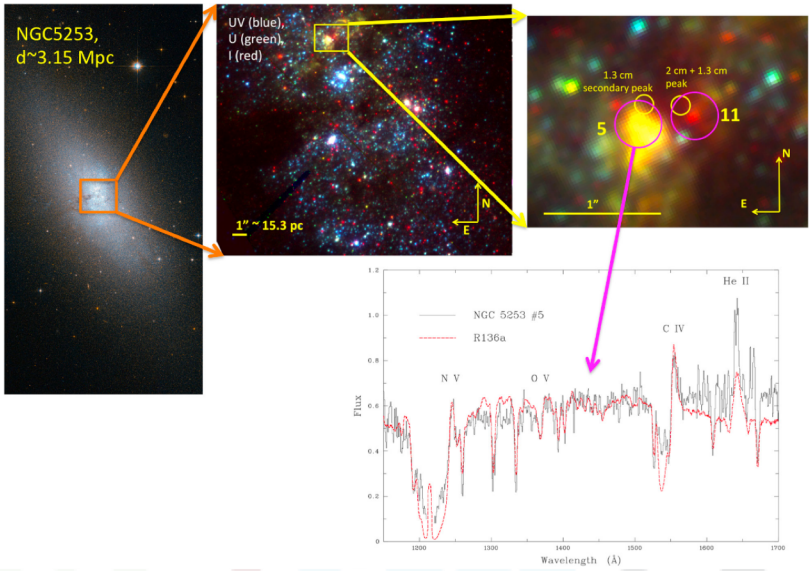
- 3D mapping of the environnement (magnetosphere, CIRs,...) and stellar surface (ejections...)
- Rotational modulation of wind confinement (UV resonance lines) → accurate determination of rotation period
- Magnetic reconnection in massive binaries
- Stellar magnetism in the MCs, impact of metallicity





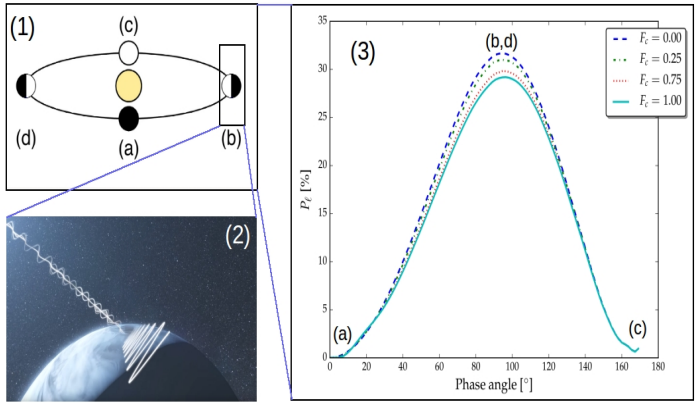
- High resolution spectroscopy of massive stars beyond the SMC → mass loss vs metallicity

- Very massive stars

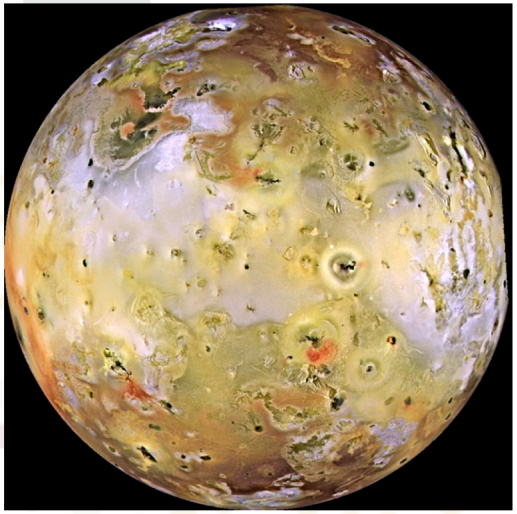


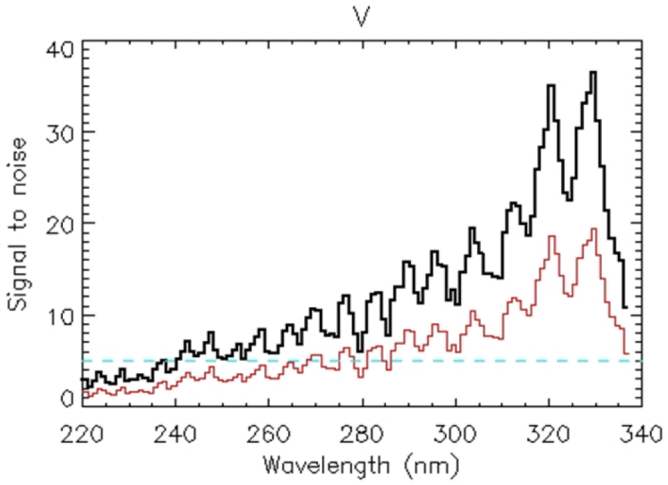
- The characteristics of exoplanet atmospheres and how do planets interact with the host stars

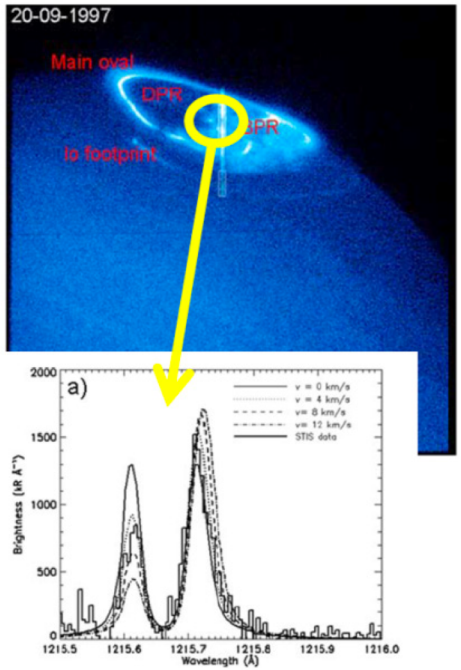
  - Unveil chemical and physical properties (aerosols, clouds particles) of exoplanetary atmospheres
  - Study Star-Planet Interaction: identify the stellar regions mostly affected by SPI to understand their origin
  - Study atmospheric evaporation of exoplanets down to Earth-mass planets



- Solar System: Planetary Surfaces, Planet atmospheric properties, magnetospheres and auroral emissions of the giant planets, cometary comae

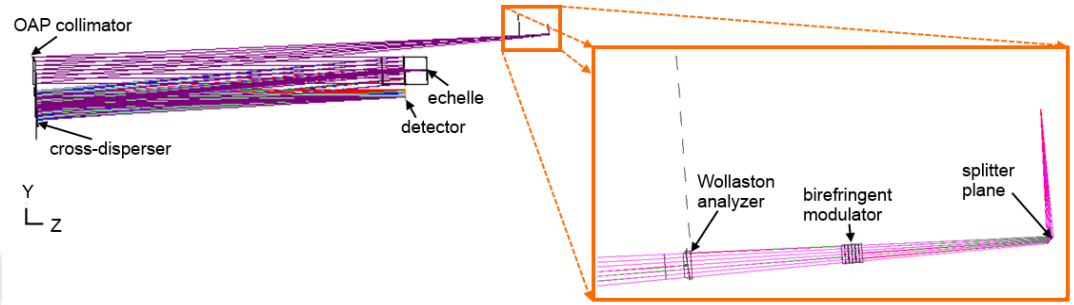


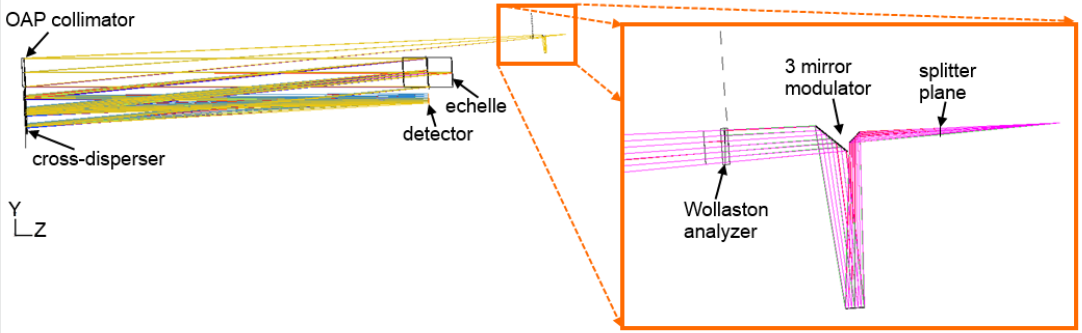


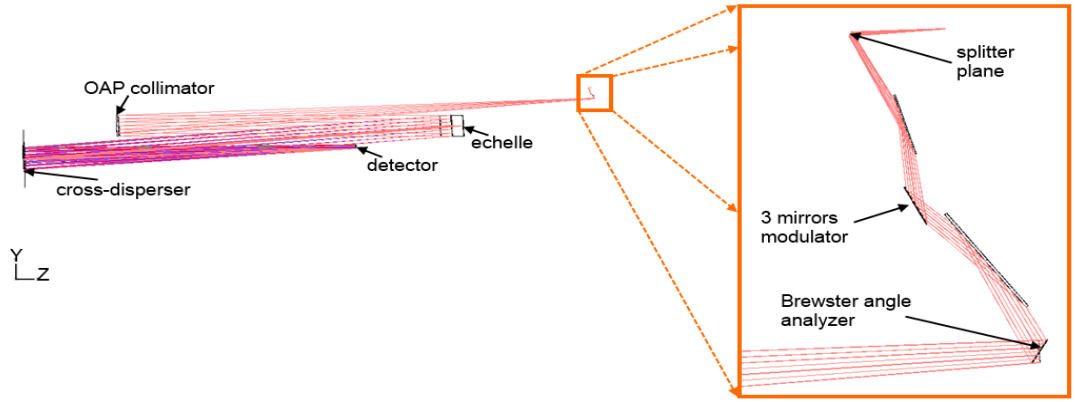


Design Solution

- High spectral resolution and large wavelength coverage ➔ echelle spectrograph







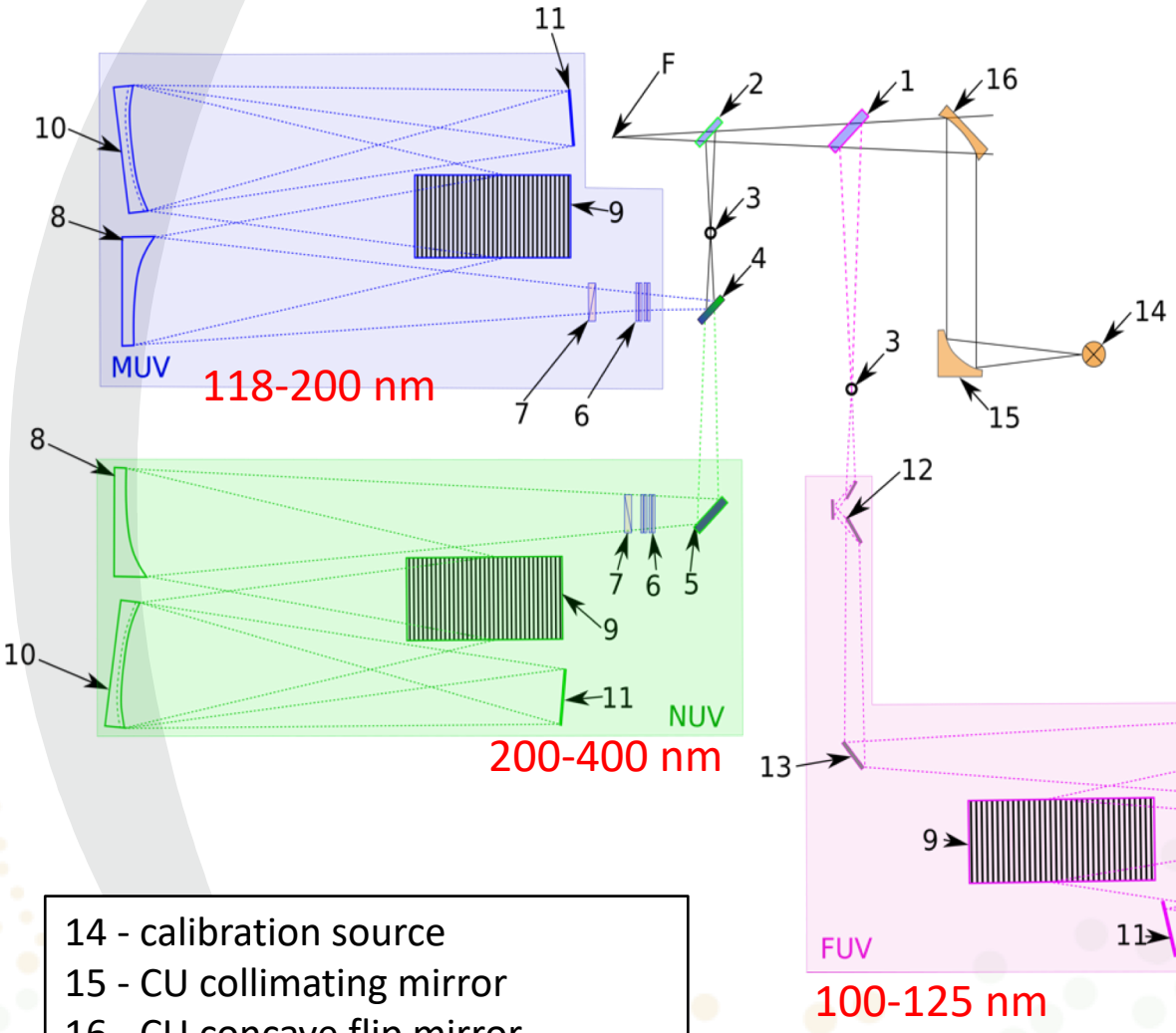
<u>Splitting in 3 channels</u>

NUV = 200 – 400 nm

MUV = 118.5 - 200 nm

FUV = 90 – 124.5 nm

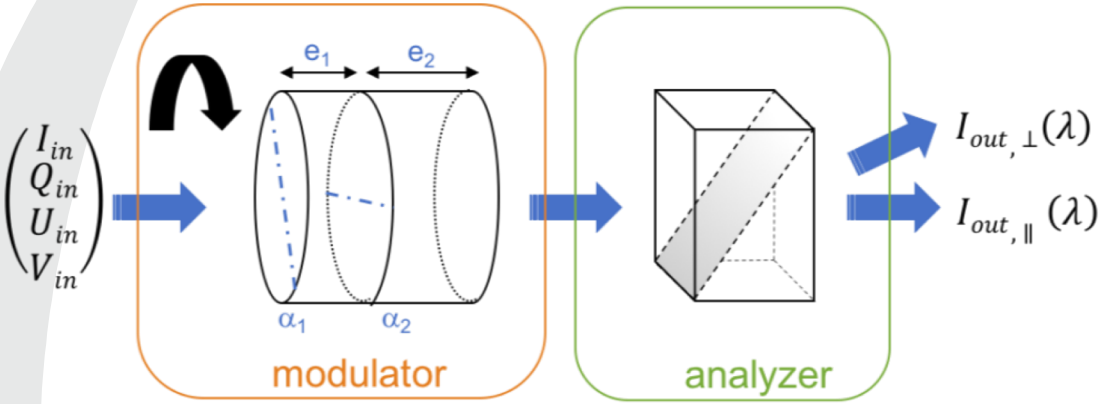
Concept



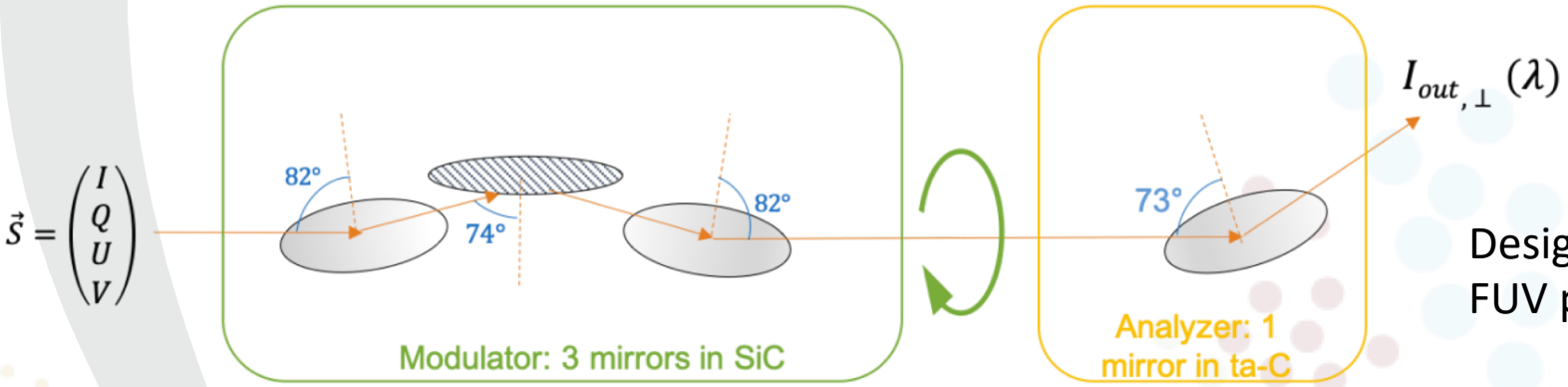
F - telescope focus
1 - FUV pick-off (flip) mirror
2 - pick-off mirror
3 - pinhole
4 - dichroic splitter
5 - NUV folding mirror
6 - birefringent modulator
7 - Wollaston prism
8 - OAP collimator
9 - echelle
10 - concave cross-disperser
11 - δ-doped EMCCD
12 - three-mirror modulator
13 - Brewster angle analyzer

14 - calibration source
15 - CU collimating mirror
16 - CU concave flip mirror

POLLUX: concepts for the polarimeters

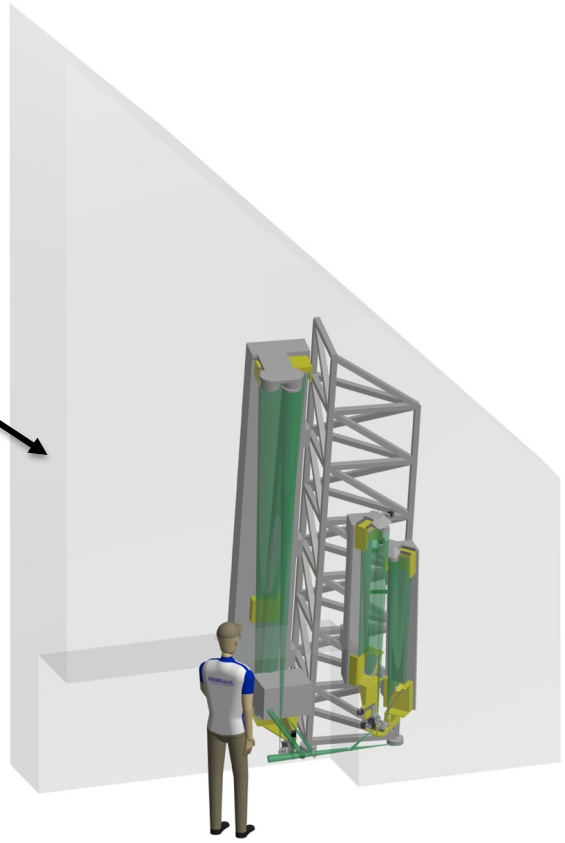


NUV and MUV polarimeters design.



Design of the FUV polarimeter

POLLUX: mechanical design



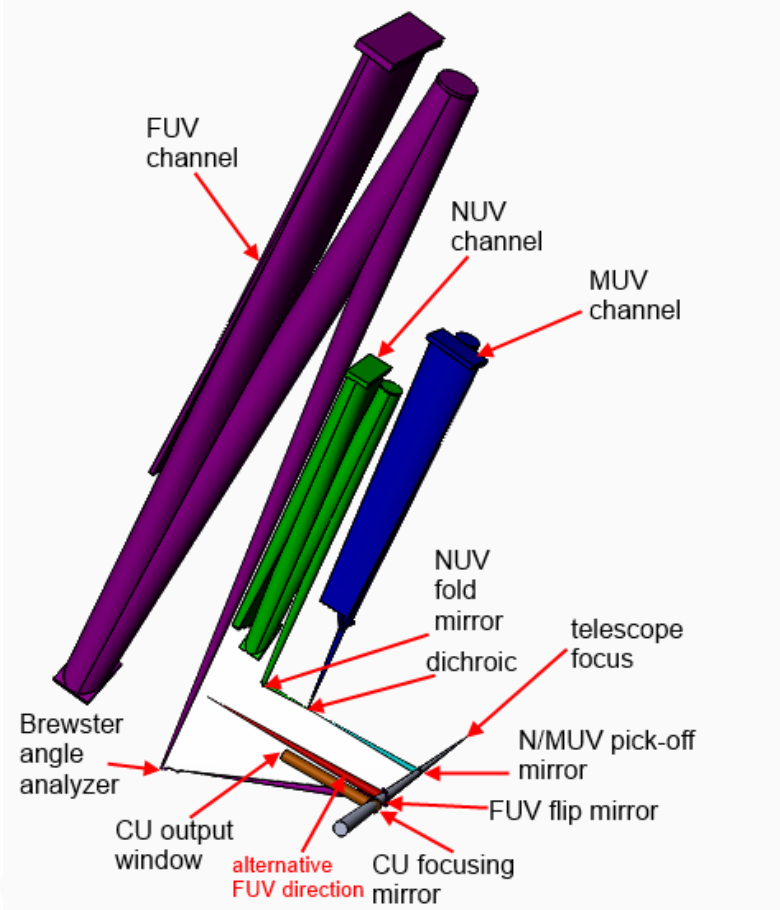
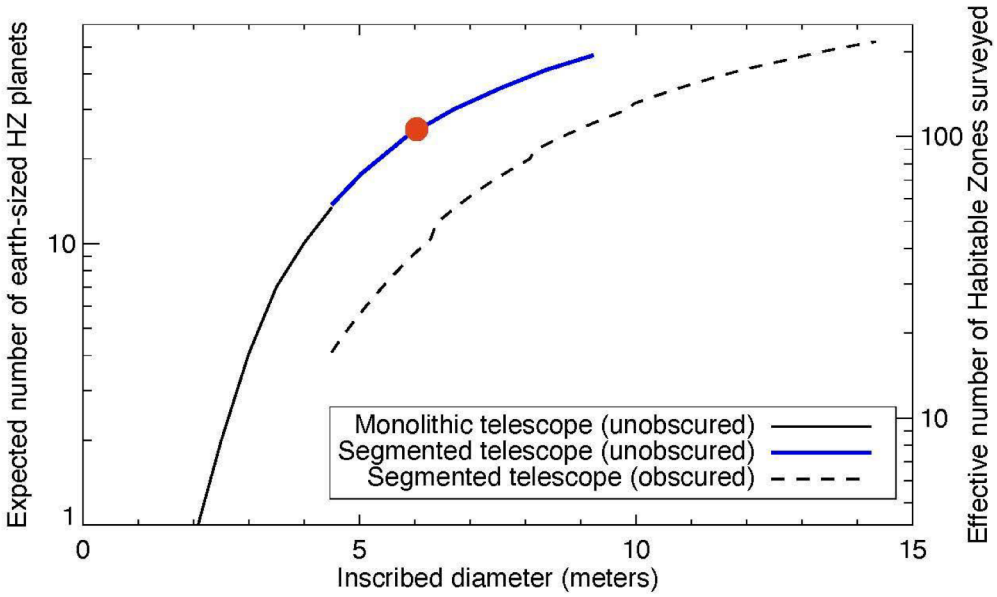


Figure 9: 3D rendering of POLLUX optical architecture

https://mission.lam.fr/pollux/index.html

Towards a new POLLUX definition

- Recommendation by NASA Decadal survey (11/2021) : An IR/O/UV Large Telescope Optimized for Observing Habitable Exoplanets and General Astrophysics
- ~6 m off-axis inscribed diameter
- Maturation program of ~six years before review and transition to mission adoption
- A major uncertainty: How many instrument slots? Is there room for a POLLUX in this new design (cf. proposition of polarimetric module for LUMOS-B) ?



- Off-axis ➔ Demodulation process less precise
  - Either requires very accurate/reliable ground calibation
  - Or additional device (mirrors) to compensate ➔ less flux on the detector

- Redesign POLLUX, redefine science cases: re-activate consortium, re-assign responsabilites, define a steering committee
- Support from CNES likely for funding R&D, missions etc…
- Try to seek support from other space agencies
- ESA ?? (ESA Voyage 2050 ➔ funding up to M-class for a contribution for next NASA's flagship mission)

Steps to take

- Re-activate POLLUX consortium
- Redefine Science Objectives
- **Global optical design of the instrument**
- **Design of polarimeters (build on the knowledge from the 1st iteration (+ ARAGO))**
- **Design of gratings and cross-dispersers (high-groove densities, free-form, incident angles etc…) to improve their efficiencies**
- **Dichroics**
- Optimized coatings for each channel
- Detectors
- …….