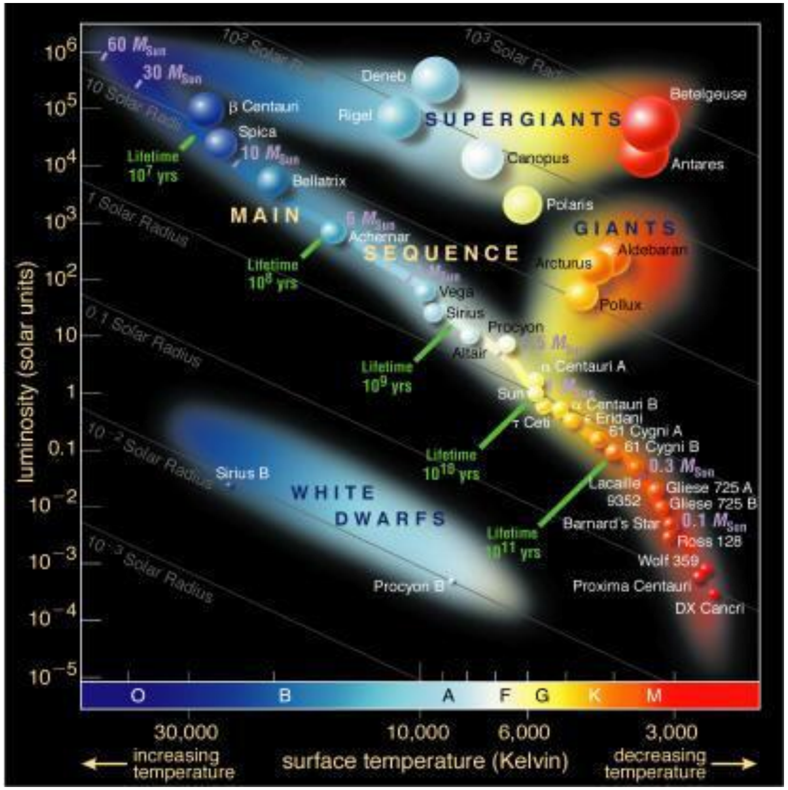
A CubeSat for UV Astrophysics

R. Desselle

Université
de Liège

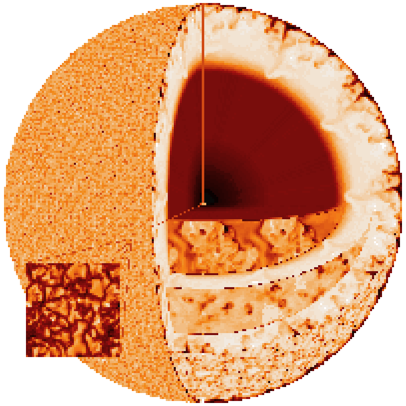
Nano-satellite for Astronomical Observations from Space (NAOS)

- **Feasibility study : Develop a new space-based UV imaging photo-polarimeter for acquiring time-series of bright/massive stars**
- **Platform : 3U CubeSat**
- **Acquire time-series of photo-polarimetry in the [2500-3500] Å range to study the variability and environment of bright stars (with special focus on hot stars of spectral types O and B)**



Scientific objectives

- **Photometry:**
  - Allows to study radial and non-radial pulsations of stars (i.e. asteroseismology)
  - Simultaneous observations in the near UV (our instrument) and the visible (e.g. BRITE) provide the best combination for precise and accurate mode identification
  - Studies of eclipsing binaries



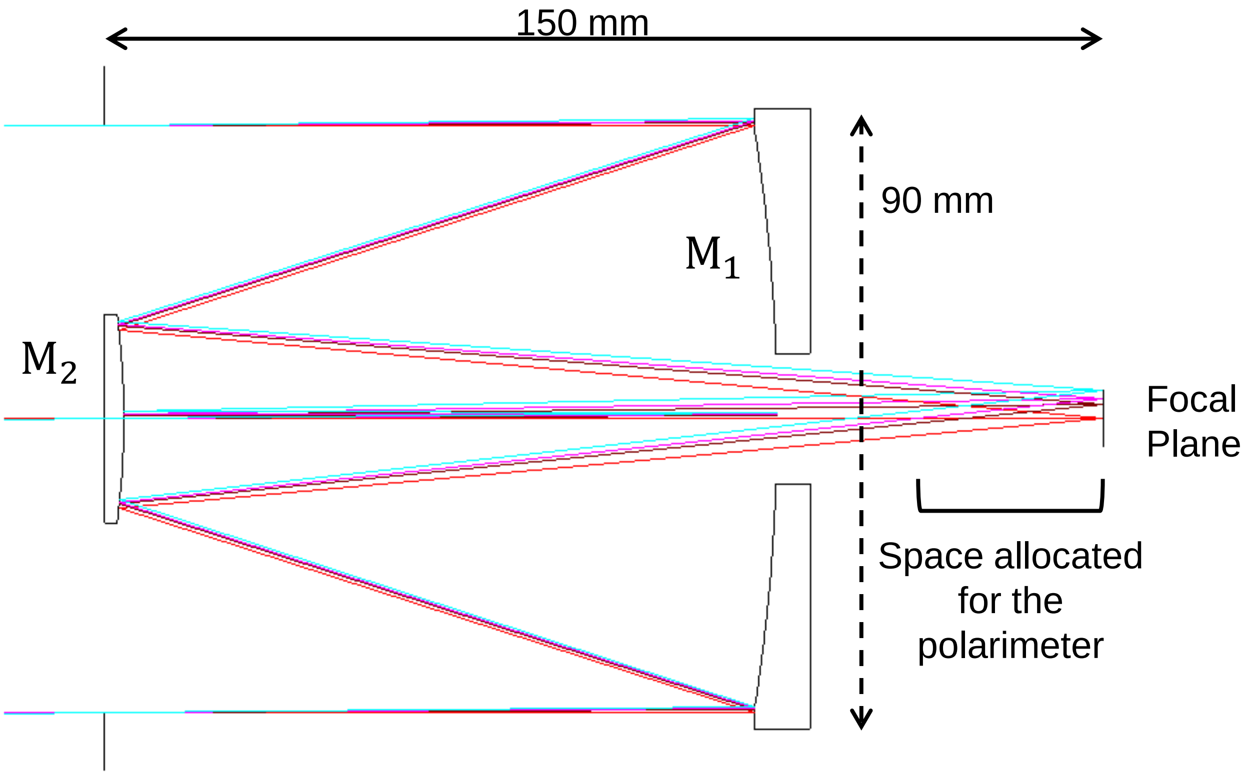
- **Polarimetry:**
  - Allows to constrain the time-dependence and the origin of outflowing disks surrounding bright Be stars
  - Allows to constrain the orbital inclinations of non-eclipsing massive binary systems, thereby allowing an accurate determination of the masses of the stars combining the results with spectrometric measurements

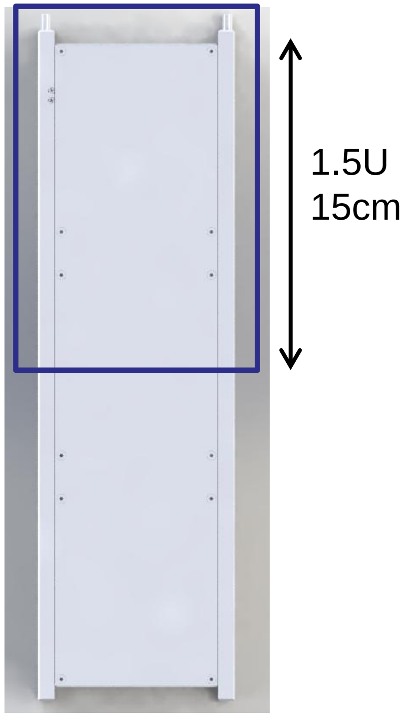
Scientific requirements

Requirement	Goal
Passband	2500 – 3500 Å
Angular resolution	15 arcsec
Field of view	1°
Magnitude of main targets	V < 4
Photometric accuracy	0.001 mag
Typical exposure time	< 5 min
Mission lifetime	2 years
Pointing accuracy	15 arcsec
Pointing stability	a few arcsec
Duty cycle	60%
Polarisation accuracy	0.1%

Payload

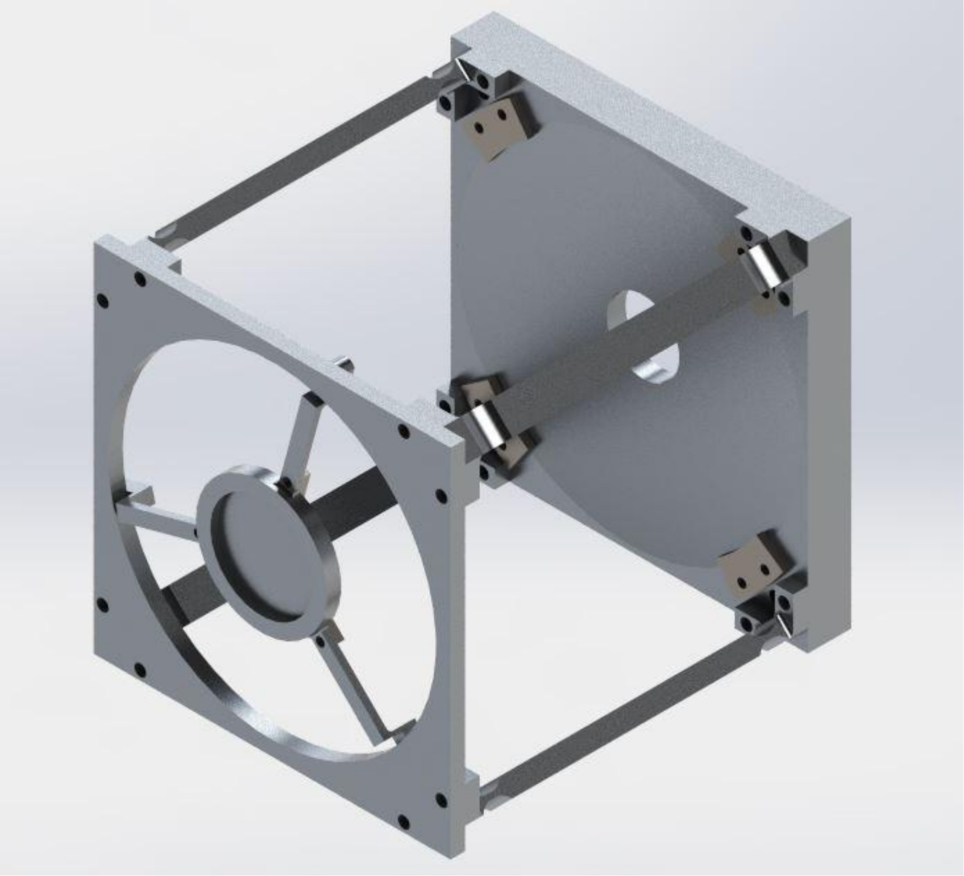
- **The photometer is a Ritchey-Chrétien telescope**
- **From end-to-end, the telescope fits into 1.5U**
- **Impact of the polarimeter is currently under investigation but it will be minor w.r.t. the optical design**





Payload

- **FoV = 1°**
- **Entrance pupil diameter = 90 mm**
- **Effective diameter = 80 mm**
- **PSF size = 4 pixels of 15 x 15 µm**
- **Angular resolution = 12.5 arcsec**
- **Telescope size = 1.5U**



Payload

- **The polarimeter will allow to test several technologies and raise their TRL for future missions such as the Arago M-class mission proposed to ESA (lead by CNES)**
- **Objectives are to measure all the Stokes parameters (I, Q, U and V)**

$$\begin{cases} E_x = \xi_x \cos(\omega t - kz) \\ E_y = \xi_y \cos(\omega t - kz + \delta) \end{cases} \Rightarrow \begin{cases} I = \xi_x^2 + \xi_y^2 \\ Q = \xi_x^2 - \xi_y^2 \\ U = 2\xi_x\xi_y \cos\delta \\ V = 2\xi_x\xi_y \sin\delta \end{cases}$$

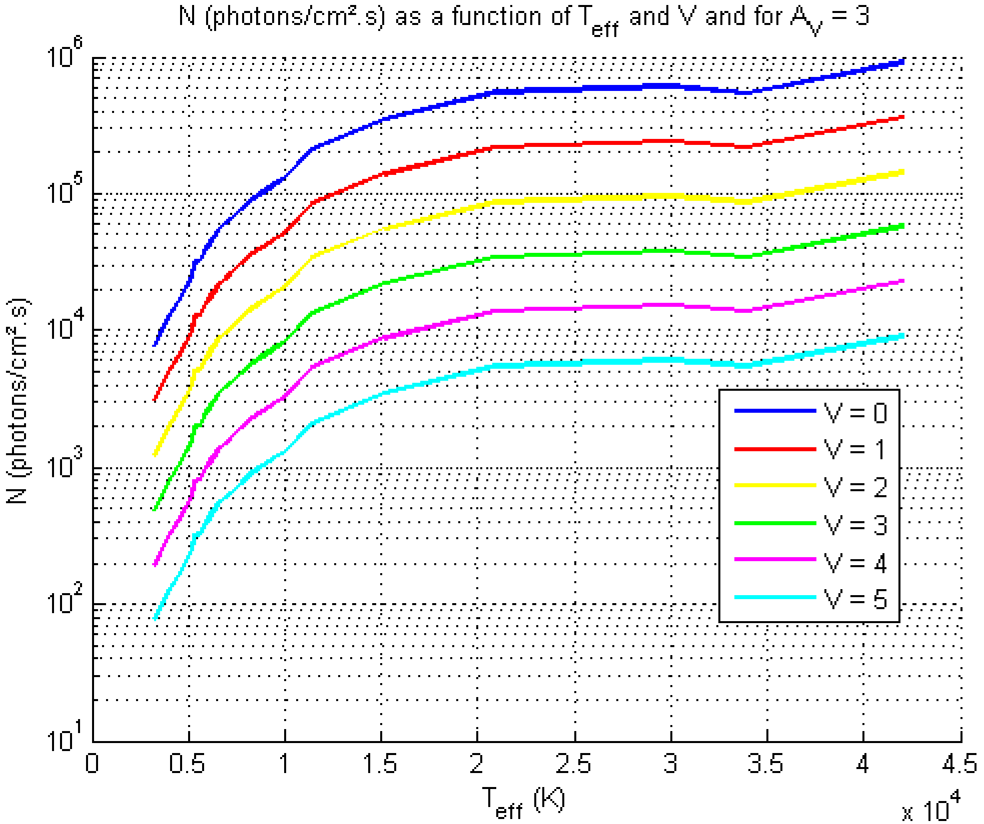
- **The polarimeter will be composed of a stack of 4 MgF2 plates with different fast-axis angle and thickness that will modulate the input signal**

Photometric budget

Photon flux ($photons\ cm^{-2}\ s^{-1}$) at the **entrance of the photometer**: $N = \int_{\lambda_1=2500\ \text{Å}}^{\lambda_2=3500\ \text{Å}} \frac{8.412*10^{34}10^{-0.4(V-A_V+BC+A_\lambda)}}{T_{eff}^4\lambda^4\left(\exp\left(\frac{1.439\ 10^8}{\lambda T_{eff}}\right)-1\right)}\ d\lambda$

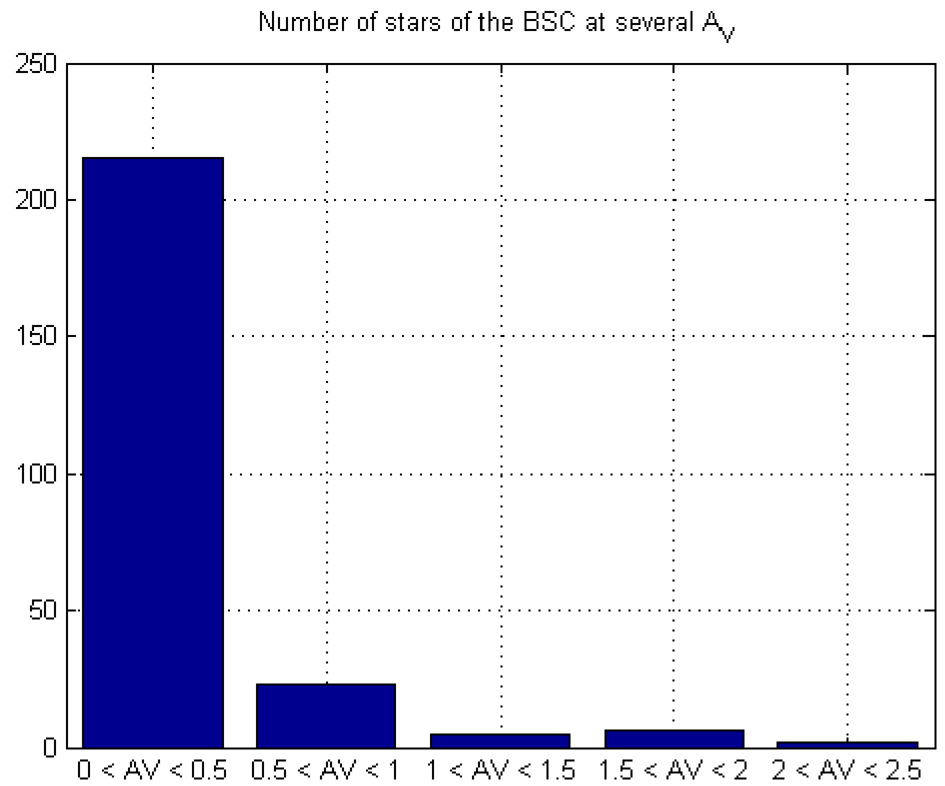
N can be evaluated as a function of V magnitude and T_{eff}.

A_V is assumed to be between 0 and 3 for bright stars.



Target baseline : Yale Bright Star Catalog

A_V values are coherent with our hypothesis :



Photometric budget

SNR_* computation : $SNR_* = \dfrac{n\,N\,A_{eff}\,t_{exp}\,\eta}{\sqrt{n\,N\,A_{eff}\,t_{exp}\,\eta + n\,PSF_{size}\,D\,t_{exp} + n\,PSF_{size}\,R^2}}$

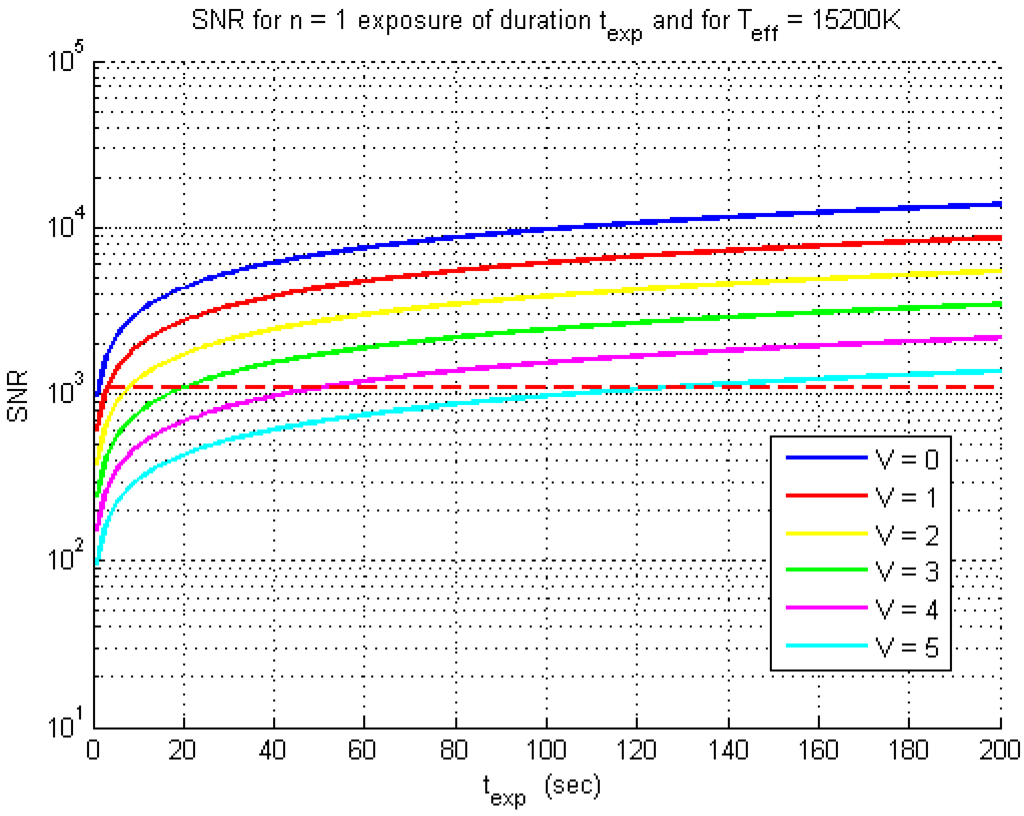
SNR_* can be computed as a function of T_{eff}, t_{exp}, n and V.

<u>Worst case:</u>

$n = 1$

$A_V = 3$

$T_{eff} = 15\,200\ K$



Conclusions

- **Scientific objectives & performances**
  - Optical design is optimized and responds to the scientific specifications
  - The accommodation to the 3U platform has been checked
  - The polarimeter has to be integrated

→ **There is no show-stopper at instrument level**

- **System level:**
  - Thermal model of the system should validate the feasibility of the mission with or without active thermal control
  - Power budget should show if deployable solar panels are needed or not
  - Assessment of data volume, storage capabilities and telemetry budget to be done
  - Pointing accuracy and stability are challenging