Feasibility study of a UV photometer on-board a 3U Cubesat for the study of bright massive stars

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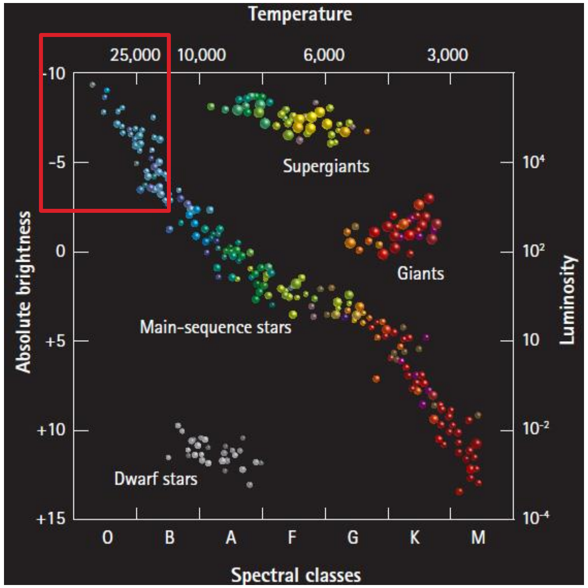
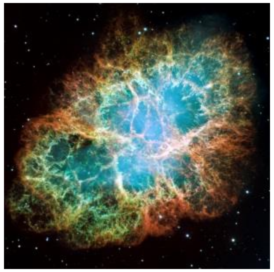
Introduction

- PhD Research topic
  - Feasibility study of a **UV photometer** on-board a **3U Cubesat**. The scientific purpose of the payload is to collect time series of photometric measurements of **bright massive stars**.
- Time schedule: from December 2013 to December 2017
- This research is funded through the ARC grant for Concerted Research Actions, financed by the Federation Wallonia-Brussels

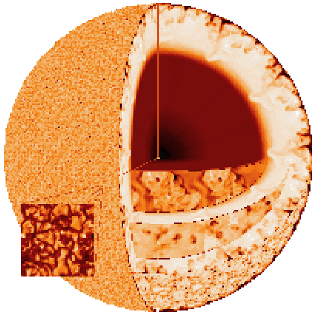
Project overview: bright massive stars

- Bright massive stars of spectral type B and O:
  - Surface temperatures $\in [15\,000, 120\,000]K$
  - Bulk of their luminosity is radiated in the **UV**
  - High mass-loss rates between 10^{-7} and 10^{-3} M_{Sun} per year
  - Strong ionizing radiation fields
  - Death in gigantic supernova explosions





Project overview: scientific objective



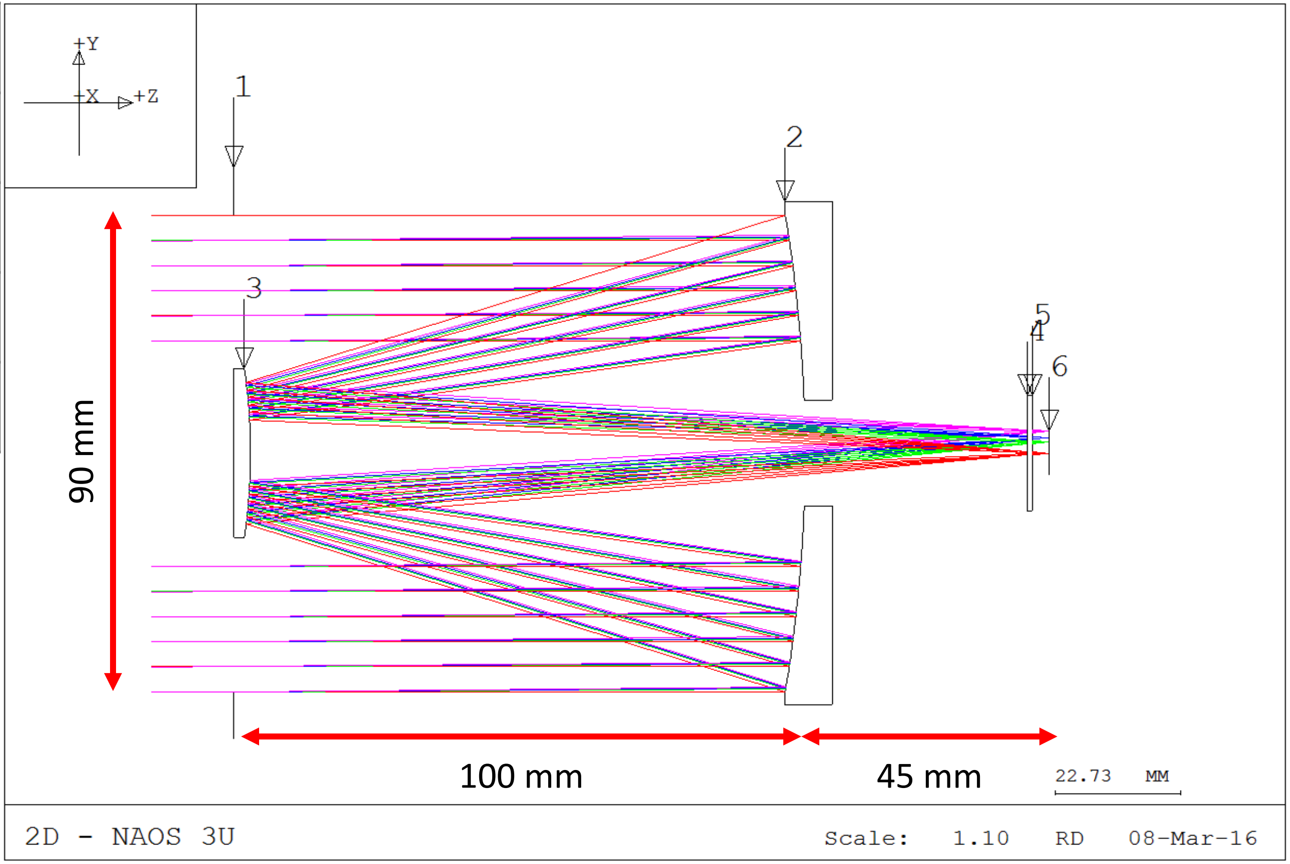
- Imaging photometric observations of bright massive stars between **250** and **350 nm**
- Space photometry:
  - Absence of signal perturbation by the atmosphere
  - Continuity of time-series
- Precise photometric variations measurements allows studying radial and non-radial pulsations of stars (**asteroseismology**)
- Coupled with observations in other wavelengths (BRITE for example), the results could improve the understanding of pulsating massive stars

UV Photometer design

- Optical performances needed:
  - Collect and focus star light from 250 to 350 nm (no wavelength dispersion)
  - Signal to noise ratio $\geq \mathbf{1000}$ in less than 5 minutes for star magnitude $\boldsymbol{V} \leq \mathbf{5}$
- Scientific optical requirements: **FoV** $\geq \mathbf{1°}, \boldsymbol{\Delta\theta} \leq \mathbf{15''}$
- Geometrical constraints:
  - Entrance pupil diameter $\leq$ **90 mm**
  - Payload volume $\leq$ **1.5U** (from entrance pupil to focal plane)

UV Photometer design

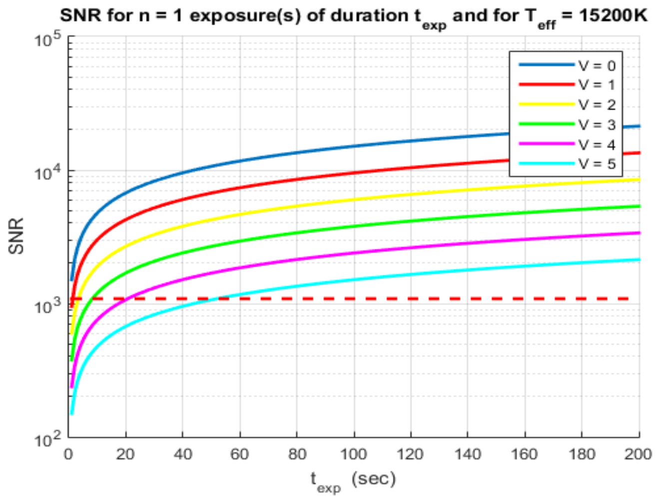
1	Entrance pupil
2	M1
3	M2
4-5	Bandpass filter
6	Focal plane



UV Photometer design

- Optimized FoV = 1°
- Entrance pupil diameter = 90 mm
- Effective diameter = 80 mm
- Angular resolution = 11 arcsec
- Detector: back-thinned CCD with 13X13 µm pixel size working in 2X2 binning mode

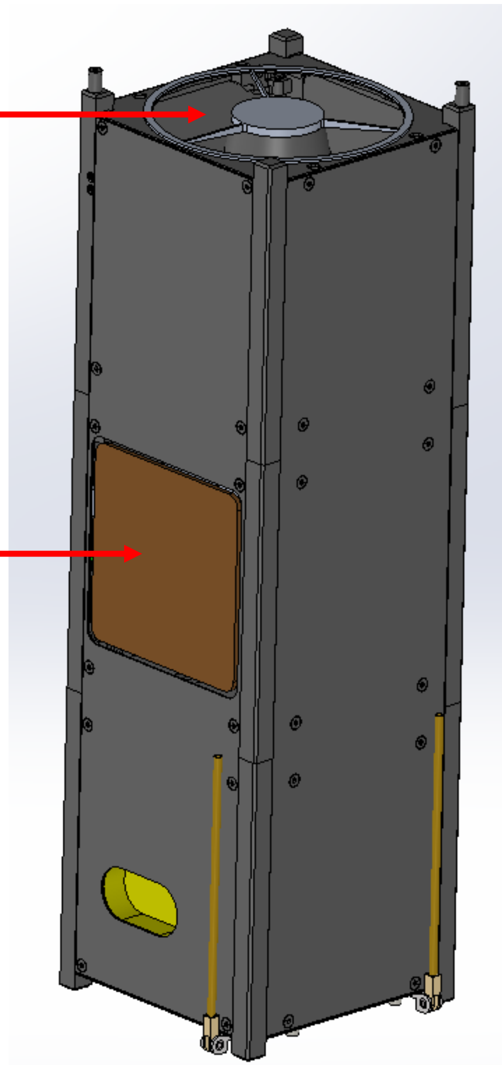
Worst case for photometric budget:

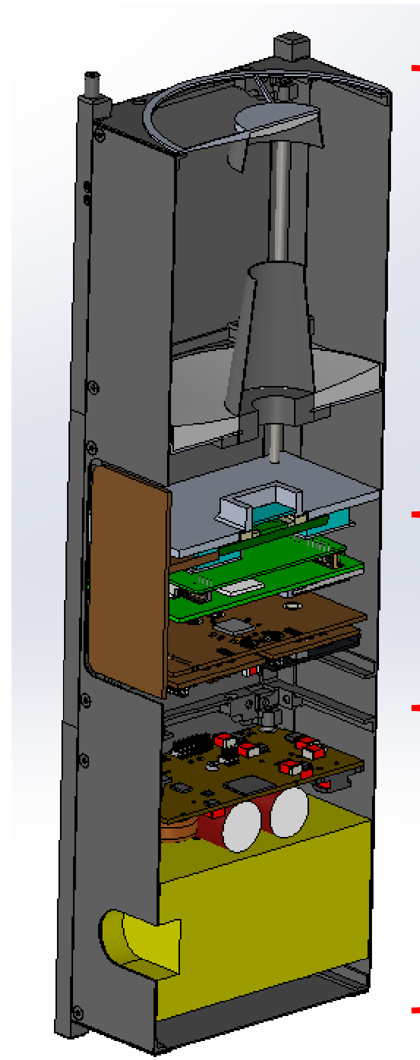


System integration

Entrance pupil and M2 holder

Detector's radiator





Payload (Mirrors and holders, baffles and detector assembly

Computer and controller

Battery, attitude control and antenna

Project status

- Payload design: completed
  - Photometric budget results are compliant
  - Optical quality and performances are compliant
- Sub-units identification: completed
- Mission analysis:
  - Orbit: sun synchronous LEO (launched as secondary payload)
  - Thermal analysis: detector and solar panels temperatures are in the operational ranges

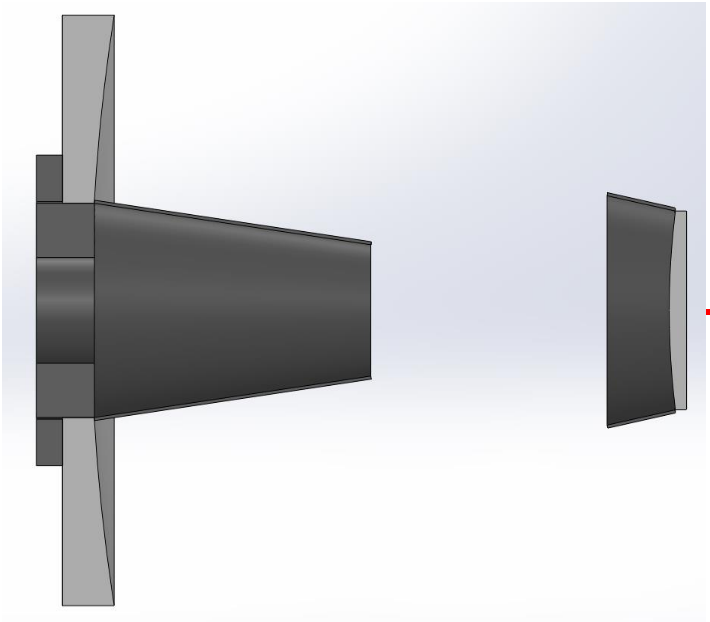
Conclusion & Perspectives

- The feasibility study of the 3U Cubesat project for the study of bright massive stars is close to its end
- Documentation under writing: article will be submitted soon to a scientific journal
- Heritage from the 3U Cubesat project:
  - The 3U study is currently extended to a 6U study that will carry a UV **spectropolarimeter** for the study of bright massive stars
  - The polarimeter is a static system that allows measuring the entire polarimetric state of the incident light. It could be used as a technology demonstrator

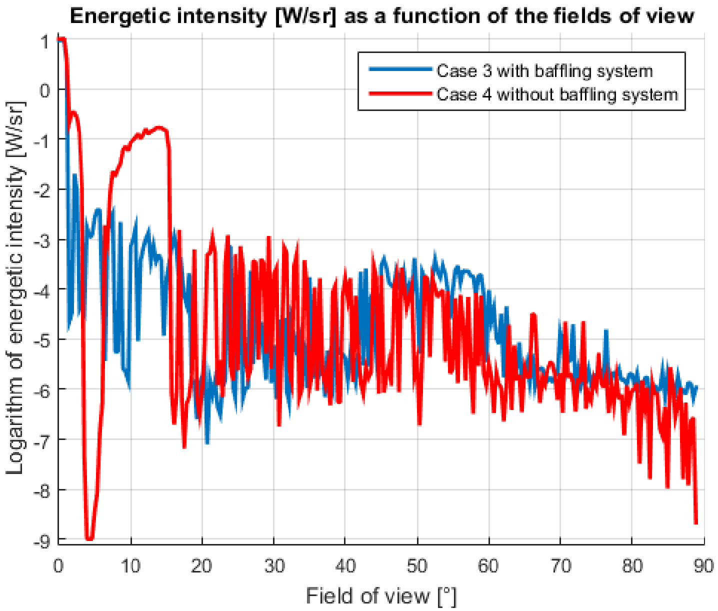
Backup slides

Baffling system and SL analysis

- Baffling system designed according Terebizh *et al.* 2001



Reduction of SL reaching the detector

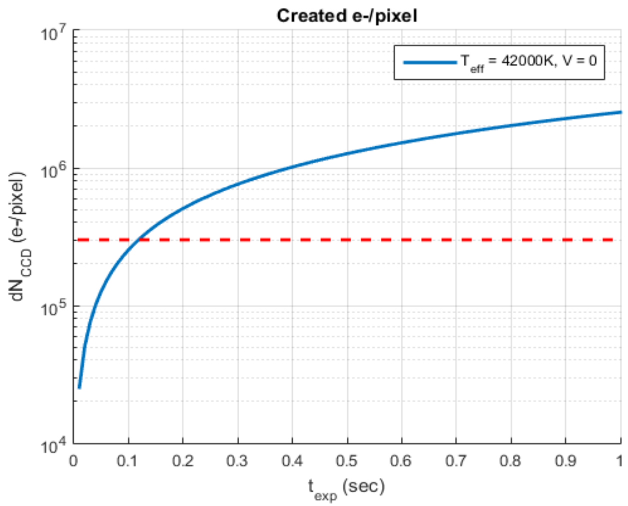


Photometric budget

- Signal to noise ratio computation:

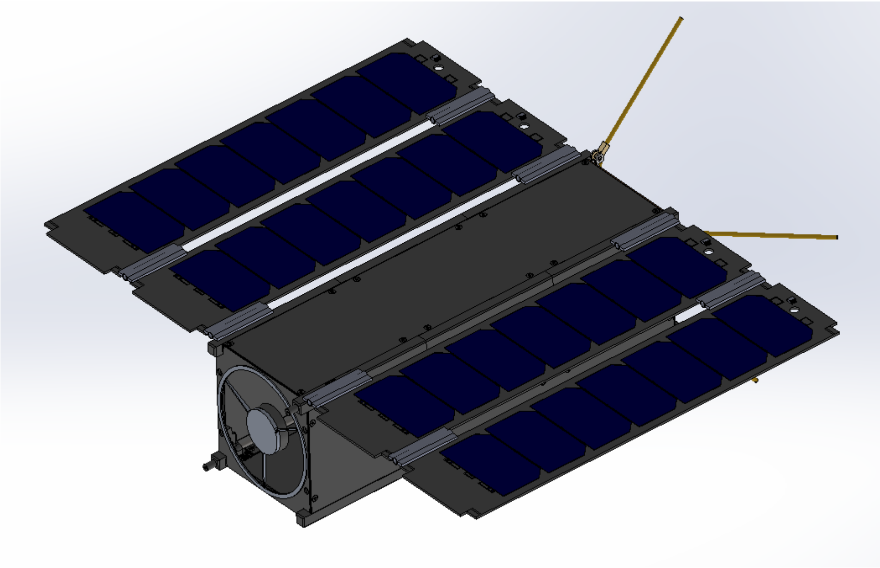
$$SNR_* = \frac{S}{\sigma_{CCD}} = \frac{n\,N\,A_{eff}\,t_{exp}\,\eta}{\sqrt{n\,N\,A_{eff}\,t_{exp}\,\eta + n\,\#Pix\,D\,t_{exp} + n\,\#Pix\,R^2}}$$

- Worst case: integration time ≈ 50 s
- Better case: saturation in 0.12 s → need to take several exposures and adapt the observation plan to every target

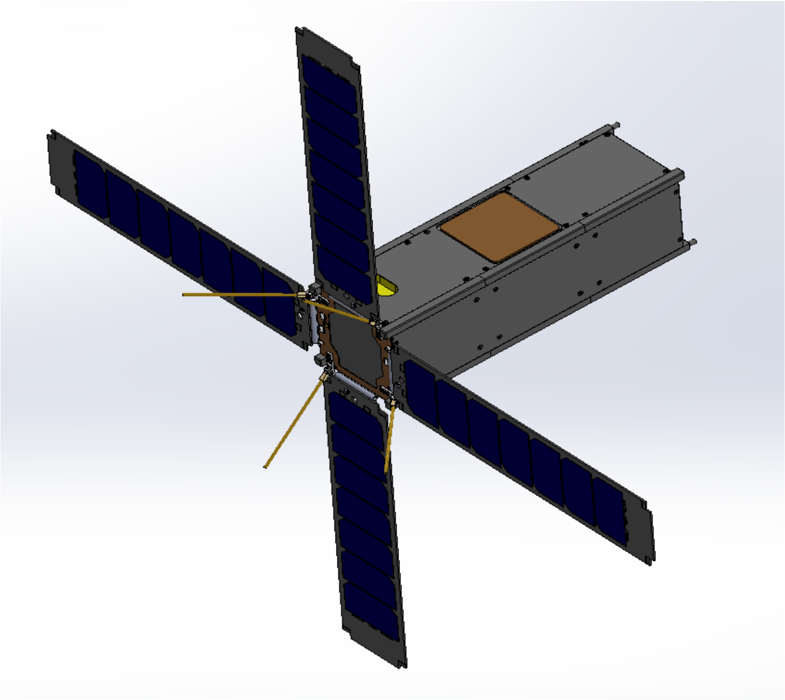


Solar panels configurations

Table configuration



Cross configuration



Orbit definition

- Sun-synchronous low Earth orbit:

Parameters	Value
$\boldsymbol{a}$ semi-major axis	7178.14 km
$\boldsymbol{e}$ eccentricity	5.70681e-16
$\boldsymbol{i}$ inclination	98.5880°
$\boldsymbol{\Omega}$ RAAN	190.128°
$\boldsymbol{\omega}$ argument of periapsis	0°
$\boldsymbol{\nu_0}$ true anomaly at launch	0.1089°
$\boldsymbol{T}$ period	100.8735 min