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

8th European Cubesat Symposium
London 07/09/2016

Richard Desselle\textsuperscript{1}, Christian Kintziger\textsuperscript{1}, Gregor Rauw\textsuperscript{2}, Pierre Rochus\textsuperscript{1}

\textsuperscript{1} Centre Spatial de Liège, Université de Liège
\textsuperscript{2} Groupe d’Astrophysique des Hautes Energies, Université de Liège
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 $10^{-3} M_{\odot}$ 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 $\geq 1000$ in less than 5 minutes for star magnitude $V \leq 5$

• Scientific optical requirements: $\text{FoV} \geq 1^\circ, \Delta \theta \leq 15''$

• Geometrical constraints:
  ▫ Entrance pupil diameter $\leq 90 \text{ mm}$
  ▫ Payload volume $\leq 1.5U$ (from entrance pupil to focal plane)
UV Photometer design

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Entrance pupil</td>
</tr>
<tr>
<td>2</td>
<td>M1</td>
</tr>
<tr>
<td>3</td>
<td>M2</td>
</tr>
<tr>
<td>4-5</td>
<td>Bandpass filter</td>
</tr>
<tr>
<td>6</td>
<td>Focal plane</td>
</tr>
</tbody>
</table>

Diagram:
- Entrance pupil
- M1
- M2
- Bandpass filter
- Focal plane
- Entrance pupil

Dimensions:
- Entrance pupil to M1: 90 mm
- M1 to M2: 100 mm
- M2 to Bandpass filter: 45 mm
- Bandpass filter to Focal plane: 100 mm
- Focal plane to Entrance pupil: 45 mm

Scale: 1.10
Date: 08-Mar-16

8th European CubeSat Symposium / Feasibility study of a UV photometer on-board a 3U Cubesat for the study of bright massive stars
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

Energetic intensity [W/sr] as a function of the fields of view

- Case 3 with baffling system
- Case 4 without baffling system

Field of view [°]
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 \( \approx 50 \) s
- Better case: saturation in 0.12 s \( \rightarrow \) need to take several exposures and adapt the observation plan to every target
Solar panels configurations

Table configuration

Cross configuration

8th European CubeSat Symposium / Feasibility study of a UV photometer on-board a 3U Cubesat for the study of bright massive stars
Orbit definition

- Sun-synchronous low Earth orbit:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) semi-major axis</td>
<td>7178.14 km</td>
</tr>
<tr>
<td>(e) eccentricity</td>
<td>5.70681e-16</td>
</tr>
<tr>
<td>(i) inclination</td>
<td>98.5880°</td>
</tr>
<tr>
<td>(\Omega) RAAN</td>
<td>190.128°</td>
</tr>
<tr>
<td>(\omega) argument of periapsis</td>
<td>0°</td>
</tr>
<tr>
<td>(\nu_0) true anomaly at launch</td>
<td>0.1089°</td>
</tr>
<tr>
<td>(T) period</td>
<td>100.8735 min</td>
</tr>
</tbody>
</table>