The CubeSpec space mission:
Asteroseismology of massive stars from time-series optical spectroscopy

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CubeSpec:

Low-cost, high-cadence, high-resolution, time-series optical spectroscopy from space

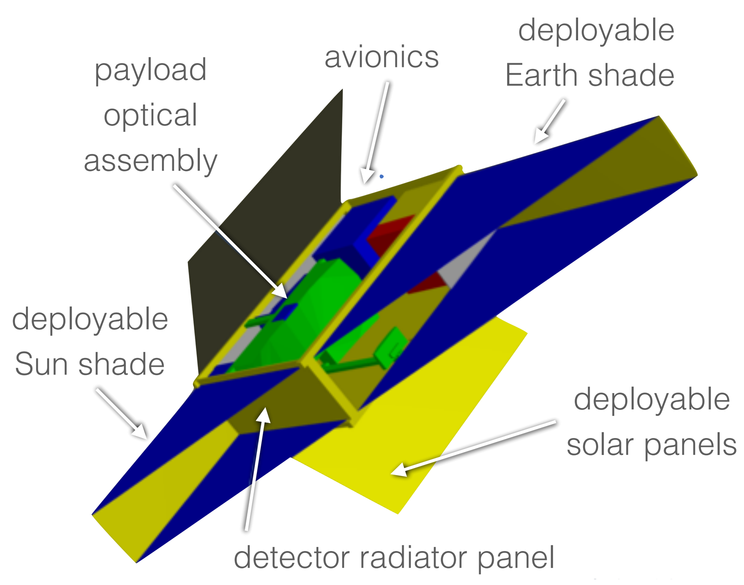
Introduction

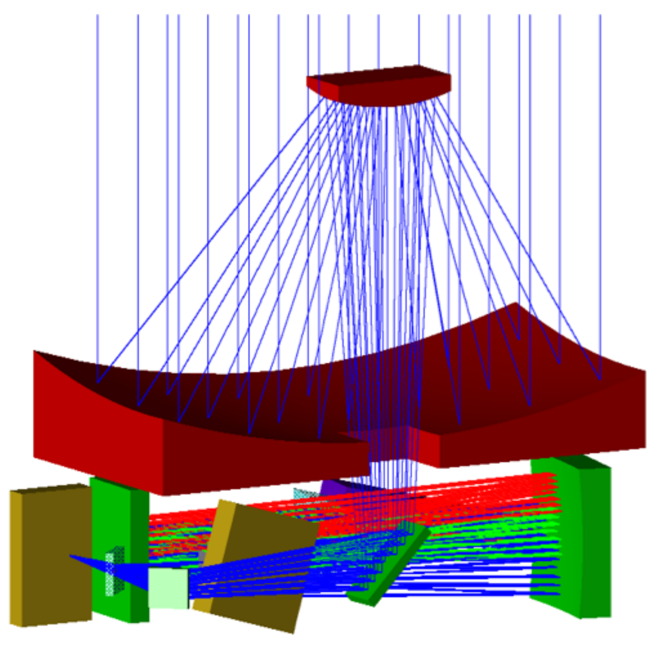
There is a need to constrain the interior rotation, mixing and angular momentum mechanisms within massive stars, as they strongly influence stellar evolution. **Asteroseismology** – the study of stellar structure from pulsations – is an excellent method for probing interior physical processes of massive stars [1]. The NASA **TESS mission** is providing high-precision light curves of thousands of massive stars [2], but time-series spectroscopy is highly advantageous in fully characterising their heat-driven pulsations.

The Belgian-led ESA/KU Leuven **CubeSpec mission** is specifically designed to provide low-cost space-based spectroscopy with specific capabilities to facilitate spectroscopic pulsation mode identification and asteroseismology of massive stars.

Technical Specifications

CubeSpec is a 6U cubesat to launch in **2024**. The platform includes a Cassegrain telescope with rectangular primary mirror (**9×19 cm²**) and a compact high-resolution echelle spectrograph (**R = 55000**) [3].

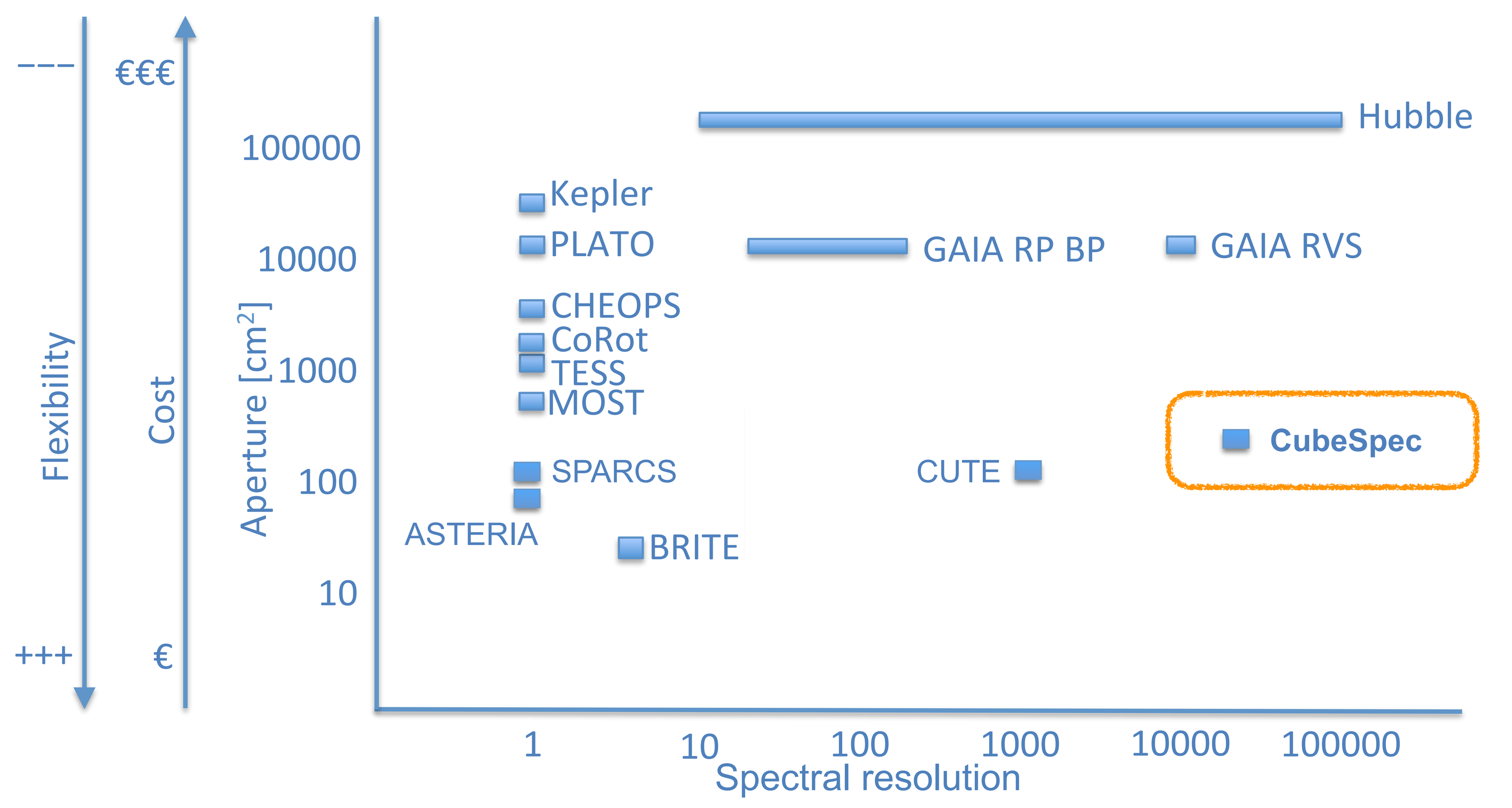




Asteroseismic science requirements:

- R ≥ 50000
- S/N > 200
- cadence < hours
- exposure time < mins
- time series > months
- wavelength range including silicon triplet: 4552, 4567, and 4574 Å

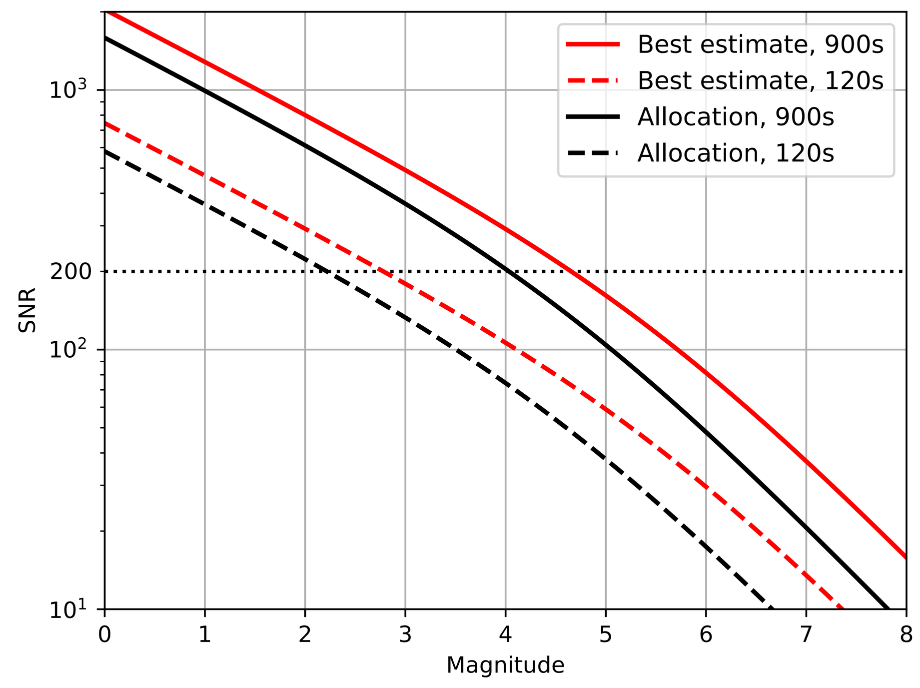
CubeSpec will enable **pulsation mode geometry identification** in terms of spherical harmonics from spectral line profile variability.

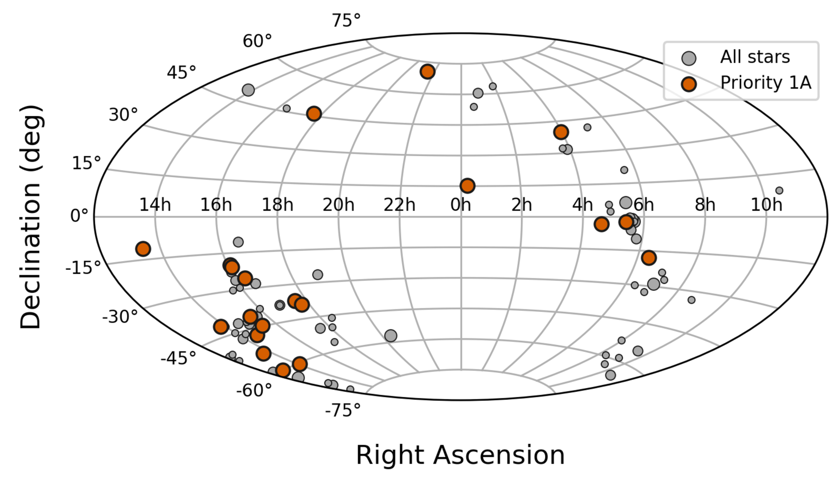


Prioritised Target List

A compact design requires bright (**V < 4 mag**) targets for asteroseismic science case.

Common type of pulsating massive star: **β Cep stars**, which have pulsation periods $2 < P < 8$ hr and masses $6 < M < 30\ M_\odot$ [1].





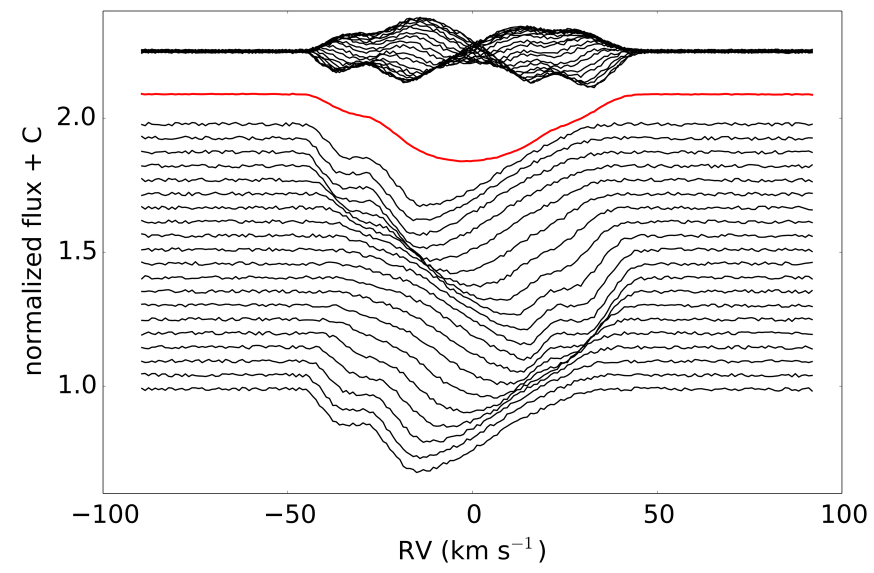
To maximise success, search for all known pulsating massive stars a priori was done using literature and new TESS light curves [4].

Identified **23 β Cep stars** from 90 bright targets. Highest priority are slow rotators with large amplitude and long period pulsators [4].

Expected performance

Simulations using `BRUCE` code [5]:

- R = 55000
- inclination angle of 60°
- $v \sin i = 25$ kms^{-1}
- cadence of 15 min
- noise to emulate S/N = 200



Line profile variability expected for β Cep with pulsation of 5.2498 d^{-1} [6].

Secondary Science Cases

- winds, mass-loss, magnetosphere variability
- absolute flux calibration of stellar atmosphere models
- diffuse interstellar bands
- exoplanet and stellar host activity
- asteroseismology of solar-type stars

Conclusions

- CubeSpec fills the niche for providing high-cadence, high-resolution, time-series optical spectroscopy from space.
- Spectral **line profile variability** in massive stars facilitates pulsation mode geometry identification.
- Highly complementary constraints to TESS light curves to empower **asteroseismology** of massive stars.

References:

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[4] Bowman et al. (2022), A&A, 658, A96
[5] Townsend (1997), MNRAS, 284, 839
[6] Aerts et al. (1994), A&A, 286, 109

Acknowledgements

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