Feasibility study of an interferometric CubeSat to detect exoplanets

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Every week, new exoplanets are discovered mostly by the transit method (77.1% of all discoveries according to NASA [1]). Even if this method is efficient at detecting planets, it is limited to a small fraction of the whole expected exoplanets population due to the low probability of planetary transit. Therefore, a direct method is needed to detect and characterize exoplanets around the nearest stars. In this case, the planet and the star are angularly separated and photons are distinguished. It leads to the detection of the planet. Moreover, it allows the possible characterization of the planet surface or its atmosphere.

One way to detect them through direct method is to use interferometry. With at least two sub-pupils (Bracewell interferometer [2]), coherent light from the target is recombined to form interference patterns. The angular resolution depends on the baseline (distance between the two sub-pupils) and not on the diameter of each sub-pupil. Instead of using a single large telescope (around 60 cm diameter), which does not fit into a CubeSat, one can use two small and well separated apertures (around 10 cm each) to synthesize this large telescope. Therefore, it increases drastically the resolution power of CubeSats.

In order to detect an exoplanet and get the direct light coming from it, the light from the star must be mitigated. It is called nulling interferometry. Thanks to a π phase shift induced in one arm of the interferometer, destructive interferences are produced on the line-of-sight in order to suppress the light of the star. The exoplanet, which is on constructive interferences (white fringes), is unveiled.

The Centre Spatial de Liège of the University is developing a space-based interferometer with a CubeSat. Goals are twofold: observe the nearest stars and demonstrate this technology in space, which will be a premiere. It is the first step towards a future large interferometry space-based mission which has the ambition to spectrally characterize Earth-like planets. The CubeSat will demonstrate light injection to optical fibers, recombination of the two beams, control of the delay-lines and detection.

CubeSats offer low-cost demonstrator capabilities with a fixed baseline and with no free-flying concept. Figure 1 represents one of the numerous architectures considered in our study.

Aside the technical challenges, the second part of our researches is focused on the detection possibilities with this type of nanosatellite.

We estimate by numerical simulations the possible science return for such an instrument. Fluxes from the star and the planet are computed as well as the nulling capability of the interferometer. Noises as the thermal background or local zodiacal disk emissions are considered. The integration time is computed to get a signal-to-noise ratio of 5, meaning a detection of the planet.

One major limitation of CubeSats is the baseline length. The maximal size without deployment is 60 cm (1x6x1U) thanks to the deployer from Nanoracks on the International Space Station [3]. However, researches show that this value can be increased up to 1.2 m as shown in Fig. 1.

Another important question for scientific objectives is the target. To simulate possible detections, putative planets are generated by the P-POP algorithm from Kammerer et Quanz (2018) [4]. Thanks to the statistics of the Kepler satellite, who detected more than 2600 transiting exoplanets, it generates potential planets around a catalogue of stars up to a distance of 20 pc. One can deduce an exoplanet detection yield for our CubeSat.

The last considered parameter for such a CubeSat is its orbit. A review of possible orbits was done to have a maximal visibility on the 5 closest stars with confirmed exoplanets (Proxima Centauri, Barnard's Star, Espilon Eridani, Ross 128 and Tau Ceti).

[1] https://exoplanets.nasa.gov (accessed on May 28, 2019)
[2] Bracewell, R. N. « Detecting Nonsolar Planets by Spinning Infrared Interferometer ». *Nature* 274, n° 5673 (août 1978): 780. https://doi.org/10.1038/274780a0.
[3] http://nanoracks.com/products/iss-cubesat-deployment/
[4] Kammerer, Jens, et Sascha P. Quanz. « Simulating the Exoplanet Yield of a Space-Based Mid-Infrared Interferometer Based on *Kepler* Statistics ». *Astronomy & Astrophysics* 609 (2018): A4. https://doi.org/10.1051/0004-6361/201731254.

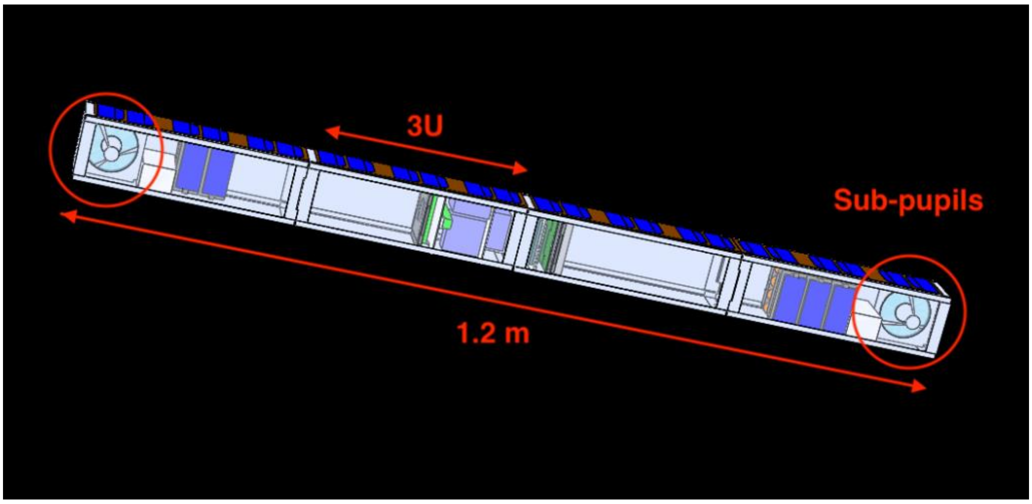

Figure 1 : 3D view of a studied architecture. 12U with deployment mechanisms.

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