ExoplanetSat: The Search for Earth-Sized Planets

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Abstract

ExoplanetSat combines the low cost CubeSat platform with an innovative two-stage attitude control system to detect exoplanets. ExoplanetSat will be capable of detecting transiting Earth-sized planets in the habitable zone of the brightest sun-like stars with a detection threshold of 7σ. The choice of targeting the brightest sun-like stars is motivated by the desire to conduct spectral follow-up observations to determine the habitability of exoplanet candidates. We present the design of the first three-unit ExoplanetSat, which will launch in the next two years under NASA's CubeSat Launch Initiative.

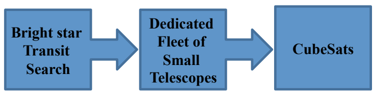
Science Objectives

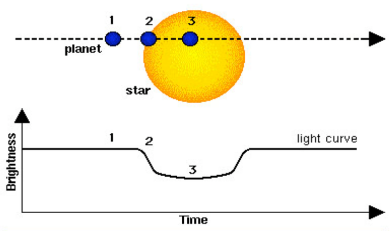
The Transit Method

ExoplanetSat will observe a characteristic drop in stellar flux due to a planet passing in front of the stellar disk. An Earth-sized planet transiting a Sun-sized star causes a transit depth of 84 parts per million (ppm).

Potential for Atmospheric Characterization

In order to characterize an exoplanet atmosphere, the target star must be bright enough to allow for spectrographic follow up observations. **No current transit missions observe the brightest sun-like stars.**

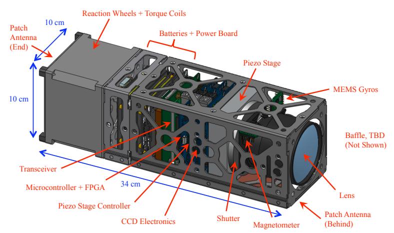




Key Performance Parameters

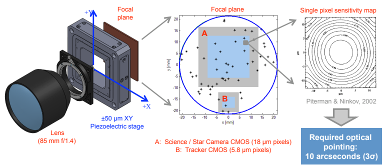
- **Shot noise-limited photometry over 1.5 hours for 0<V<6 target stars**
- **10 arcsecond (3σ) pointing precision**
- **Monitor each star for 2+ years**

Prototype Design: 3-Unit CubeSat



Optical Payload

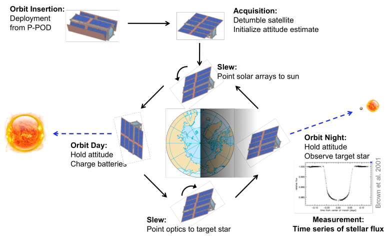
The optical system consists of an off-the-shelf lens focusing light onto a composite focal plane array.



- Zeiss 85mm f/1.4 lens
- Large CMOS (A): Star camera and science imager (deep wells, larger pixels)
- Small CMOS (B): Fine star tracker imager (small pixels, higher frame rate)
- The focal plane array is mounted on a two-axis piezo nanopositioning stage

Concept of Operations

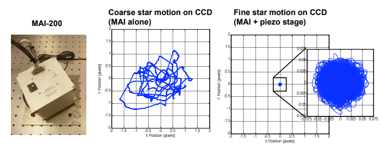
ExoplanetSat will be in a low Earth orbit (LEO) with a period of approximately 90 minutes, altitude of 650 km, and inclination close to 0°. ExoplanetSat will observe its target star during orbital night and recharge its batteries during orbital day.



Attitude Control System

Jitter noise is introduced when errors in spacecraft pointing (jitter) cause the target star to move between regions of different photosensitivity on the detector, both within a single pixel and between multiple pixels on the CMOS sensor.

The attitude control system is responsible for (1) pointing the spacecraft at the target star, and (2) minimizing noise due to spacecraft jitter in order to achieve a total noise floor of 10ppm. To achieve these goals, spacecraft attitude is determined by a magnetometer, gyros, and guide star centroid positions. An off-the-shelf reaction wheel assembly points the spacecraft to the target star with 60 arcsecond precision. In order to improve spacecraft pointing to 10 arcseconds, a piezoelectric stage uses star centroids from the CMOS detectors to adjust the position of the focal plane, compensating for jitter.



Target Stars

ExoplanetSat's target stars are main sequence G and K stars brighter than magnitude 7. The ExoplanetSat prototype will primarily observe **Alpha Centauri**, the nearest and brightest Sun-like star (V=-0.01). The prototype will also observe planets discovered by the radial velocity method, but whose transits have not yet been observed.

Planet Name	Mass (Earth Masses)	Period (days)	Vmag	Spectral Type
61 Vir b	5.1	4.2	4.7	G5
HD 102365 b	15.9	122.1	4.9	G3
mu Ara c	10.6	9.6	5.2	G3
55 Cnc e	7.6	2.8	5.9	K0
HD 69830 b	10.5	8.7	5.9	K0
HD 69830 c	12.1	31.6	5.9	K1
HD 97658 b	8.3	9.5	6.3	K1
HD 4308 b	12.8	15.6	6.5	G5
HD 1461 b	7.6	5.8	6.6	G5

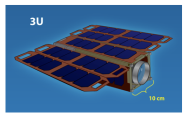
Future Work: Constellation

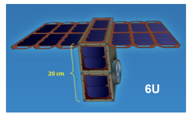
Phase II

- Add 3U and 6U models with 120 mm apertures
- Observe 20 brightest stars for Earth-sized transits
- 10-15 spacecraft needed

Phase III

- Observe bright stars to V = 8
- 95% confidence of 3+ planet detections
- Use existing 3U/6U constellation, possibly add larger units





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