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High precision astrometry mission for the detection and characterization of nearby habitable planetary systems with NEAT

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Abstract

The NEAT (Nearby Earth Astrometric Telescope) mission is a proposition submitted to ESA for its 2010 call for M-size mission within the Cosmic Vision 2015-2025 plan. The main scientific goal of the NEAT mission is to detect and characterize planetary systems in an exhaustive way down to 1 Earth mass in the habitable zone and further away, around nearby stars for F, G, and K spectral types. This survey would provide the actual planetary masses, the full characterization of the orbits including their inclination, for all the components of the planetary system down to that mass limit. Only extremely- high-precision astrometry, in space, can detect the dynamical effect due to even low mass orbiting planets on their central star, reaching those scientific goals. NEAT will continue the work performed by Hipparcos (1 mas precision) and Gaia (7 μas aimed) by reaching a precision that is improved by two orders of magnitude (0.05 μas, 1 σ accuracy). The NEAT mission profile is driven by the fact that the two main modules of the payload, the telescope and the focal plane, must be placed 40m away leading to a formation flying option that has been studied as the reference mission.

1. Science Objectives

The prime goal of NEAT is to detect and characterize planetary systems orbiting bright stars in the solar neighborhood that have a planetary architecture like that of our Solar System or an alternative planetary system made of Earth mass planets.

1.1. Nearby Planetary Systems

NEAT observations will allow the detection around nearby stars of planets equivalent to Venus, Earth, (Mars), Jupiter, and Saturn, with orbits possibly similar to those in our Solar System. The NEAT mission will answer the following questions:

- What are the dynamical interactions between giant and telluric planets in a large variety of systems?
- What are the detailed processes involved in planet formation as revealed by their present configuration?
- What are the distributions of architectures of planetary systems in our neighborhood up to D $\approx$ 15pc?
- What are the masses, and orbital parameters, of telluric planets that are candidates for future direct detection and spectroscopic characterization missions?

Special emphasis will be put on planets in the Habitable Zone (HZ) because this is a region of prime interest for astrobiology. Indeed orbital parameters obtained with NEAT will allow spectroscopic follow-up observations to be scheduled precisely when the configuration is the most favorable.

1.2. High Precision Astrometry

The principle for the detection of the planetary systems is to measure the reflex motion of the star due to the presence of the different planetary components (since the star orbits around the center of mass of the systems composed of the star and its planets). At 10 pc the reflex motion due the presence of Jupiter is about 500 μas, whereas the amplitude due to the presence of

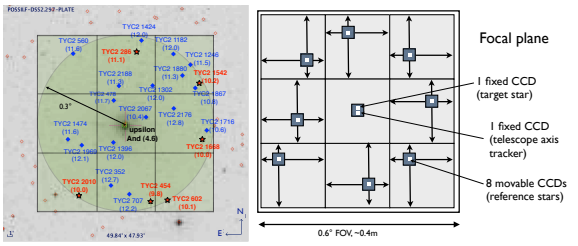

Figure 1: Left: 0.3° stellar field around upsilon Andromedae, a proposed NEAT target, with six possible reference stars in this field marked in red. Right: Schematic layout of the focal plane. The field of view is divided in 3×3 sub-fields. Exterior subfields have visible arrays which can be moved in X and Y directions to image the reference stars. The central field has two fixed arrays, one for the target star and one for the telescope axis tracker.

the Earth at 1 AU is 0.3 μas! NEAT aims at measuring motions down to a floor value of 0.05 μas, allowing detection of Earth-mass planets orbiting at 1 AU around Sun-mass stars located 10 pc away with a SNR of 6. The targets list corresponds to an exhaustive search of 1 Earth mass planets (resp. 5 Earth mass planets) around K stars located at distances from the Sun up to 6 pc (resp. 12 pc), G stars up to 10 pc (resp. 17 pc), and F stars up to 14 pc (resp. 19 pc), in the whole HZ of the star, excluding spectroscopic binaries and very active stars.

2. NEAT Concept

Left part of Fig. 1 shows a typical field around NEAT targets with the presence of about ten reference stars. With typical 1 m telescope and 10 μm-sized detector pixels, one needs $30,000 \times 30,000$-pixel detectors or alternatively, or ten 512×512 CCDs, from which 8 are mobiles in order to cover all possible reference stars (right part of same figure). To measure the angle between the target star and the several reference stars, one introduces an interferometric metrology calibration system. The idea is to project laser beams from the primary mirror to produce Young's fringes onto the focal plane that are used to calibrate the distances.

The NEAT concept (Fig. 2) is based on a long focal-length telescope with a single parabolic mirror rather than on a classical three-mirror anastigmat (TMA) design to avoid any beam walk errors, but also to because the unavailability of suitable metrology and stability of biases and robustness against proper motion that would kill any measurements at the required level

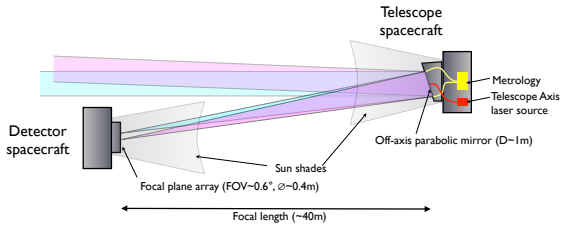

Figure 2: Proposed concept for a very high precision astrometry mission. It consists in two separated modules, the first one carrying the primary mirror (upper right) and the second one the detector plane (bottom left).

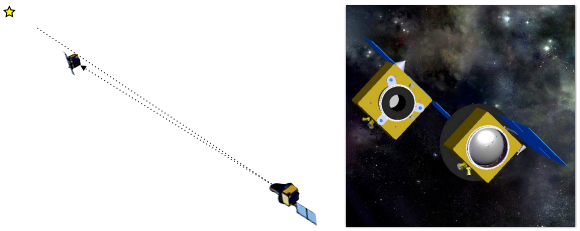

Figure 3: Left: NEAT spacecraft in operation with the two satellites separated by 40 m. Right: closer external view of the two satellites.

of precision.

Figure 6 shows NEAT spacecraft in operation. The telescope satellite is observing the star while the focal plane satellite is located 40 m away not far from the line of sight is looking back toward the telescope satellite.

3. Conclusion

One of the recommendation of the Cosmic Vision 2015-2025 plan is: *"On a longer timescale, a complete census of all Earth-sized planets within 100 pc of the Sun would be highly desirable. Building on Gaia's expected contribution on larger planets, this could be achieved with a high-precision terrestrial planet astrometric surveyor."* We have designed NEAT to be this astrometric surveyor. We believe that there is a place for a mission that is capable of detecting and characterizing planetary systems orbiting bright stars in the solar neighborhood that have a planetary architecture like that of our Solar System or an alternative planetary system partly com- posed of Earth-mass planets.

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Reference. Malbet et al. 2011, Exp. Astron.