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The ExoLife Finder Telescope (ELF) : an extremely large telescope dedicated to extremely high contrast

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Abstract

Detecting an exoplanetary life signal is extremely challenging with current technology because it requires a sensitive telescope and instrument that can measure the planet's reflected optical and infrared light, while distinguishing this from the star's scattered light and the terrestrial thermal noise background. This requires highly accurate adaptive optics, a coronagraphic system, and a specially designed and aligned giant telescope. We present here new strategies for building such a telescope with large circular segments using adaptive optics correction independently for each of these segments prior to cophasing the segments. The foreseen cophasing technique uses focal plane images that allow piston measurements and correction between all the segments. In this context we propose to derive the segment phase error using the inverse approach knowing the segment positions and the single aperture Airy function.

These measurements need to be coupled with ultra high precision wavefront sensing at for Extreme-AO. Ideally, a wavefront sensor for an Extreme-AO system should be very sensitive (to allow high speed wavefront correction), very accurate (to allow precise calibration of residual starlight vs. planet light in the focal plane) and allow to maintain very accurate cophasing of the pupil We describe our trade off results for selecting the best wavefront sensors scheme which meet all these requirements. We also investigate the performance of multi-segmented extreme adaptive optics and we present detailed simulations of the proposed cophasing/ Extreme-AO wavefront sensing and correction scheme in this context. At the end we demonstrate that a natural star can be successfully used to cophase in real time the ELF telescope and to drive the XAO system in order to reach very high contrast compatible with imaging of extrasolar planets and detecting exoplanetary life signal.

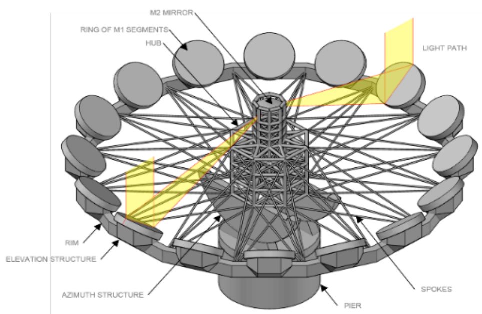


Figure 1: The ELF Gregorian-focus opto-mechanical configuration

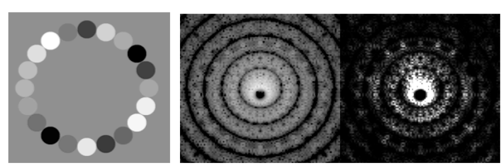


Figure 2: Synthetic PSF Left: phase (greyscale 0-360 deg), Center: Log10 PSF 8 decades, Right: Log10 RMS speckle noise 6 decades

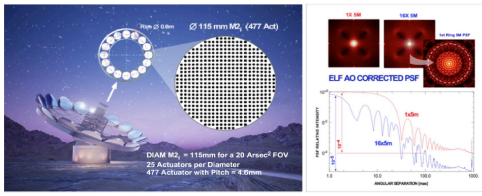
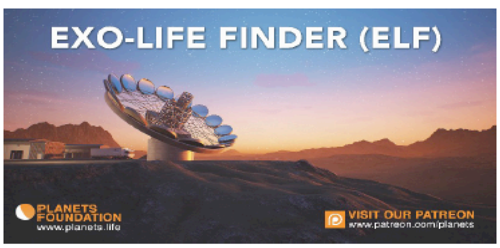


Figure 3: [Left] Each of M2i (i=1..16) is a locus for an independent deformable mirror of 115mm in diameter on a rim of 0.6m. For a field of view of 20 arcsec2 such deformable mirror M2i will be filled of 477 actuators, i.e. 25 actuators per diameter for a 4.6mm pitch. [Right] The initial parameters for simulations are 20cm 25x25 subapertures on a single 5m off-axis mirror M1i aperture; r0=0.17m, L0 = 25m, measurement noise is of 10 nm RMS; using the best re-constructor (MAP, generators, optimal pre conditioner).

Conclusions

The ELF optical configuration described here has the angular resolution of a 30m telescope and the light gathering power of a 20m telescope. A hybrid optic like this, dedicated to exoplanet direct imaging, will have unrivaled sensitivity to biomarkers and could map subcontinental surface features of habitable-zone exoplanets around nearby M-dwarf stars. The technologies described here could decrease the area mass density and cost of such giant remote sensing telescopes by an order of magnitude from the wide-field general astronomical ELTs now under construction.



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