Highlights of Spanish Astrophysics XI, Proceedings of the XV Scientific Meeting of the Spanish Astronomical Society held on September 4–9, 2022, in La Laguna, Spain. M. Manteiga, L. Bellot, P. Benavidez, A. de Lorenzo-Cáceres, M. A. Fuente, M. J. Martínez, M. Vázquez- Acosta, C. Dafonte (eds.), 2023

The ExoLife Finder project: a prototype hydrid interferometer telescope to be installed at Teide Observatory.

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Abstract

The IAC in Tenerife is collaborating with an international consortium involving the University of Hawaii, MorphOptic (USA), Dynamical Intelligent Structures (DiSL, Canada) and two institutes in Lyon (CRAL@CNRS + INSA; France), to design the future ≥40m ExoLife Finder (ELF), an optical hybrid interferometer telescope. The objectives of ELF are both scientific and technological: the discovery of biomarkers in the atmospheres of exoplanets and patenting tensegrity and ultra-light ultra-thin mirrors to reduce the weight of future large telescopes by at least a factor of ten.

The consortium embarked in building a 3.5-m prototype (nicknamed Small-ELF) as a demonstrator for ELF, made of 15 mirrors of 0.5m in diameter mounted on a "bicycle wheel" structure. Small-ELF will have high angular resolution astronomical capabilities in the near-infrared and will also serve as a technology demonstrator for the much larger ELF. The installation is planned in the coming years at Teide Observatory. The detailed design, which provides optical, mechanical, and electronic solutions with bottom-up cost estimates, is presented.

1 Introduction

Since the announcement of the first planet orbiting the 51 Peg star outside of our Solar system by Mayor & Queloz (1995) who received the Nobel prize in Physics in 2019 [1], the field of exoplanets have evolved dramatically with the discovery of more than 5000 exoplanets with a wide variety of physical properties. The main objective has now shifted to the detection and characterization of telluric exoplanets. The search for biomarkers in their atmospheres and imaging of continents on their surfaces motivate the construction of dedicated giant telescopes capable of unprecedented contrast, angular resolution, and spectral stability.

2 The ExoLife Finder

To be able to image exoplanets, several key observational and technical requirements are mandatory, including:

1. high spatial resolution = angular separation to detect close companions to the star
2. high dynamic range i.e. contrast photometry to detect faint companions
3. high sensitivity or depth to detect faint companions
4. never mind the field-of-view because the planet is close to its host star
5. observe in the infrared where the planet is brighter

There is a specific need for a large but light and cheap telescope dedicated to exoplanet science with the above characteristics. This new telescope, nick-named the "ExoLife Finder" (ELF), is an hybrid optical interferometer planned with a minimum diameter of 40m [4]. It will be the lightest and unique telescope world-wide dedicated to high-resolution high-contrast infrared imaging. The challenges of ELF to reduce the weight, hence, the cost by a factor of approximately ten, are both technological and scientific.

The main scientific goals of ELF is to detect biomarkers in the atmospheres of exoplanets orbiting the nearest and brightest stars to the Sun and reconstruct the surface of extrasolar planets in the near-infrared with inversion techniques [3, 2].

ELF will work as a hybrid optical interferometer. Its contruction and success relies on three major technological challenges outlined below:

- Tensegrity will use cables instead of trusses to join the bicycle wheel shape of the mechanical structure to the mirror support structure [5]
- Ultra-light, self correcting, "Live" Mirrors lowering mirrors aerial density and maximizing performance with non-abrasive, additive, 3D-printed novels technology [6]
- Wavefront sensing and control technologies to reach unprecedented planet-to-star contrast ($>10^8$) by correcting on the fly the atmospheric turbulence together with telescope co-phasing and nulling [7]

3 The Small-ELF prototype

The consortium, made of the Hawaii Institute for Astronomy, MorphOptic Inc, and Georgia State University in the US, DiSL in Vancouver (Canada), and the Centre de Recherche d'Astrophysique de Lyon (CNRS/CRAL) along with the Institut National des Sciences Appliquées (INSA) in Lyon (France), and the Instituto de Astrofísica de Canarias (IAC) is currently designing a 3.5-m prototype to be installed at Teide Observatory to develop, prove, and validate the three aforementioned key technologies. Small-ELF is a 3.5 m telescope that will have high angular resolution astronomical capabilities with bright sources that will serve as a technology demonstrator and prototype for ELF.

Our consortium has now a detailed design delivered and funded by the Spanish Ministry of Science's recovery plan that provides optical, mechanical, and electronic solutions with cost estimates. The basic optical design of the Small-ELF consists of a ring of 0.5m diametre lightweight primary mirrors (Figure 1). The ultra-light mirrors and the wavefront sensing technologies have recently been funded through European and french-national funds, respectively. The Small-ELF develops opto-mechanical and interferometric capabilities that are critical for the next generation of ultra-large optical telescopes and instruments. In particular, Small-ELF will demonstrate that new technologies such as synthetic optical aperture, light-weight mirrors, and tensegrity can be manufactured, assembled, tested, and installed efficiently and cost-effectively.

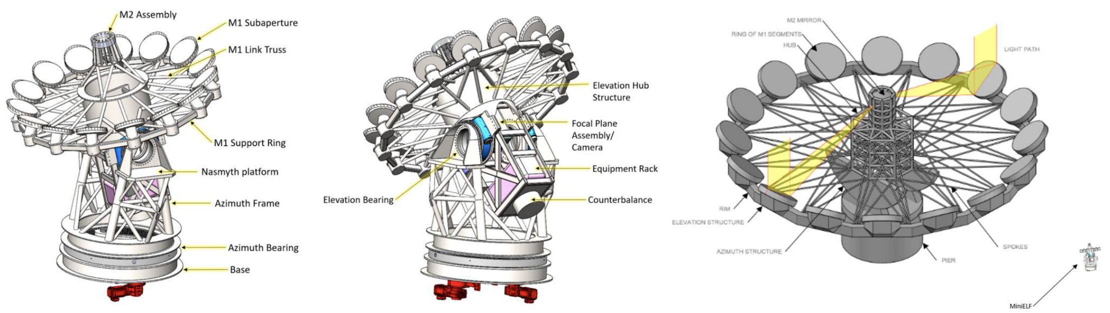

Figure 1: Detailed design of the Small-ELF 3.5-m prototype. *Copyright DiSL, IAC*

The construction of the mechanical structure of Small-ELF is planned in-house for the second half of 2024 and its installation a year later at Teide Observatory in Tenerife, Canary Islands (Spain). Small-ELF will provide a unique coronographic capability to the Spanish astronomical community to obtain high-contrast images of sources visible from the Northern Hemisphere. There is no other facility capable of provide images with such high contrast in the near-infrared available to the Spanish community.

4 Conclusions

Modern ground-based optics will far surpass space experiments for exoplanet observations. A dedicated exoplanet research facility like ELF is sorely needed to achieve both low scattered light and high photometric dynamic range in the next decades. We believe that ELF can be built in the next 10–20 years so that the new generation of astronomers can detect exolife during their career.

Acknowledgments

The design and construction of the Small-ELF prototype is partially finance by the European Union - NextGenerationEU - and the Recovery and Resilience Facility plan of the Spanish ministry. NL acknowledge support from the Agencia Estatal de Investigación del Ministerio de Ciencia e Innovación (AEI-MCINN) under grant PID2019-109522GB-C53.

References

[1] Mayor, M. & Queloz, D. 1995, Nature, 702, 27

[2] Berdyugina, S. V. & Kuhn, J. R. 2019, AJ, 158, 246

[3] Berdyugina, S. V. et al. SPIE, 10700E, 4IB

[4] Kuhn, J. R., Berdyugina, S. V., Capsal, J. -F., Gedig, M., Langlois, M., Moretto, G., Thetpraphi, K. 2018, SPIE, 10700E, 15K

[5] Zhou, Y. et al. 2022, SPIE, 12182E, 2JZ

[6] Moretto, G. et al. 2022, SPIE, 12188E, 0DM

[7] Moretto, G. et al. 2017, EPSC, 11, 893M