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The LIFE mission: a space mission designed to characterize terrestrial exoplanet atmospheres

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Summary

The atmospheric characterization of a significant number of terrestrial planets, including the search for habitable and potentially inhabited planets, is arguably the major goal of exoplanetary science and one of the most challenging questions in 21st century astrophysics. However, despite being at the top of the agenda of all major space agencies and ground-based observatories, none of the currently planned projects or missions worldwide - neither in Europe, nor in the US, China or India - has the technical capabilities to achieve this goal. Here we present the LIFE Mission, which addresses this issue by investigating the scientific potential and technological challenges of an ambitious mission employing a formation-flying nulling interferometer in space working at mid-infrared wavelengths [3, 1]. Breakthroughs in our understanding of the exoplanet population as well as significant progress in relevant technologies justify the need, but also the feasibility for a future mission like LIFE to investigate one of the most fundamental questions of mankind: are we alone in the Universe?

Context

One of the long-term objectives of extrasolar planet research is the investigation of the atmospheric properties for a large number (~ 100) of terrestrial exoplanets. This is partially driven by the idea to search for and identify potential biosignatures, but such a dataset is - in a more general sense - invaluable for understanding the diversity of planetary bodies. While exoplanet science is omnipresent on the roadmaps of all major space agencies and ground-based observatories and first steps in this direction will be taken in the coming 10-15 years with funded or selected ground- and space-based projects and missions, none of them will be able to deliver such a comprehensive dataset. An alternative to the currently discussed large space-based coronographic missions or the starshade concept is to separate the photons of the planet from those of its host star by means of an interferometer. In [2] for example we showed that Proxima B is an ideal target for a space-based nulling interferometer with relatively small apertures.

LIFE is a new project initiated in Europe with the goal to consolidate various efforts and define a roadmap that eventually leads to the launch of a large, space-based MIR nulling interferometer to investigate the atmospheric properties of a large sample of (primarily) terrestrial exoplanets. Centered around clear and ambitious scientific objectives the project will define the relevant science and technical requirements. The status of key technologies will be re-assessed and further technology development will be coordinated. LIFE is based on the heritage of ESA/Darwin and NASA/TPF-I, but significant advances in our understanding of exoplanets and newly available technologies will be taken into account in the LIFE mission concept.

First results

In [4] we used Monte Carlo simulations to demonstrate that a MIR space-based nulling interferometer, could yield at least as many exoplanet detections as a large, single aperture optical/NIR telescope. The details and exact number of planets depend on the assumed technical specifications and the underlying exoplanet populations, but from an exoplanet science perspective such an interferometer should be considered an attractive mission concept, at least complementary if not superior to an optical/NIR mission.

Future Steps

Our analysis also shows that getting a better handle on the overall planet statistics is crucial for planning larger future missions. Another key aspect that we will investigate more closely in the future is a specific treatment of stellar leakage and exozodical light in our simulations. A critical look at the stellar input sample and its properties is also warranted with a specific focus on multiplicity. Sensitivity, wavelength coverage and spectral resolution requirements will be defined using atmospheric retrieval analyses. As most detected planets will be warmer than Earth, going as short as 3 μm seems useful; at the red end 25 μm seems sufficient. This wavelength range features absorption bands of $CO_2, H_2O, O_3, CH_4, (N_2)_2$, and N_2O and also contains windows to probe surface emission. The spectral resolution (R $\sim$ 20-100) is very likely to be driven by the need to avoid line contamination of certain molecules such as N_2O and CO_2 around 4.15 μm, as well as CH_4 and also N_2O and H_2O between 7.7 and 8 μm.

References

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