TACKLING THE GREAT SCIENCE QUESTIONS OF OUR TIME

II CHAMELEON SCHOOL

CHAMELEON ITN

CHAMELEON is a Marie Curie Innovative Training Network for European Joint Doctorates. The network is developing a virtual laboratory to research exoplanets and protoplanetary disks that will play a key role in simulating yet unexplored physico-chemical environments. CHAMELEON aims to retrieve and predict chemical compositions of planet-forming disks and exoplanet atmospheres, transfer knowledge, codes and models between planet and disk communities, and share state-of-the-art scientific concepts with the wider community.

CHAMELEON is made up of 15 early stage researchers (ESRs) and a supervisory board. There are both single discipline ESRs (astronomy) and interdisciplinary ESRS (astronomy + social sciences). The single-discipline ESRs are using models and simulations to learn more about exoplanets and protoplanetary disks. The interdisciplinary ESRs are exploring the intersections that scientific topics from the network have with both the arts and education.

WINTERSCHOOL II

The CHAMELEON network holds bi-annual network schools. The second CHAMELEON school was held in January of 2022 and focused on putting the research that the network is conducting into the context of the big science questions of our time. For this, discussions were had about the science questions that are driving instrument development and future observational facilities and the processes and difficulties that accompany these developments.

The final project of the school consisted of the development of proposals for future space missions that would answer some of the big science questions of our time. These proposed missions were pitched to a panel of supervisors who provided feedback and assessed the value, feasibility and innovativeness of the missions. To develop the missions the ESRs were divided into four teams, with the exception of the multidisciplinary ESRs who acted as consultants. The consultations included helping with presenting and pitching the ideas to a general audience and helping to determine what these missions could bring to both the scientific community and society as a whole.

PROJECTS

PINEAPPLES   ALONE   PlaDiPro   SLOTH

Atmospheric Lunar Observatory for Non-Equilibrium

Can we find life on earth-like exoplanets by observing their chemical fingerprints?

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Introduction

The Atmospheric Lunar Observatory for Non-Equilibruim telescope (ALONE) is a telescope built in a crater on the moon, optimized to search for chemical disequilibrium in Earth-like exoplanets. ALONE will use microwave kinetic inductance detectors (MKIDs) to look for spectral features that indicate pairs of oxidizing and reducing agents (redox-couples) in the atmospheres of exoplanets which may be indicators for life.

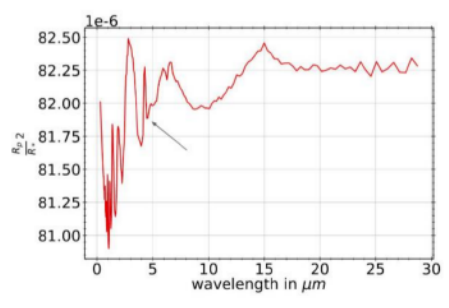
Scientific Background

What are the signs of life?

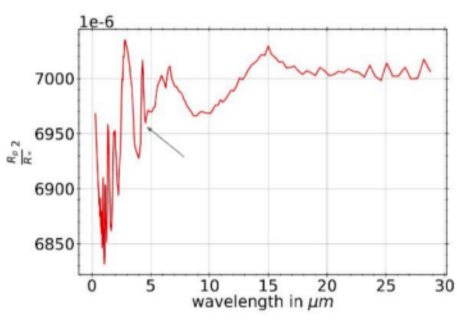
If there was a hypothetical little green alien on some distant planet looking for life on other planets, one of the ways that they may be able to find us would be by spotting the complex chemistry in our atmosphere. Life causes many complex chemical reactions, and results in what is known as dynamic kinetic stability, meaning that the system is stable although there are many dynamic reactions occurring all the time. Signs of life on a planet are known as biosignatures, and our atmosphere is full of them. Living creatures metabolising on a planet will result in a chemical disequilibrium that will disturb the chemical composition of the atmosphere by introducing more elements like carbon dioxide, oxygen and methane. However, most types of disequilibrium are often caused by processes that are not related to life such as clouds or volcanoes. For that reason, if we want to use disequilibrium as a biosignature, we need to find a type of disequilibrium that can only be caused by life, and here redox couples might be important.

Redox-Couples

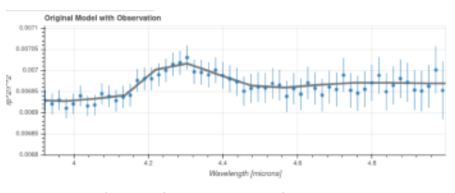
The exchange of electrons is the driving force of biology. Pairs of electron donors and receptors (reducing and oxidizing chemicals) make up what is known as redox-couples. Because the exchange of electrons is such an important process for life, having life on a planet will not only cause any type of disequilibrium in the atmosphere, but more specifically, disequilibrium among redox couples. Since this redox disequilibrium is rarely found in places without life, this might be a perfect biosignature.



Earth Spectrum Simulated with ARCiS



Trappist 1b spectrum simulated with ARCiS



PANDEXO Simulation of a Trappist 1b spectrum observed by JWST

ALONE

Goals

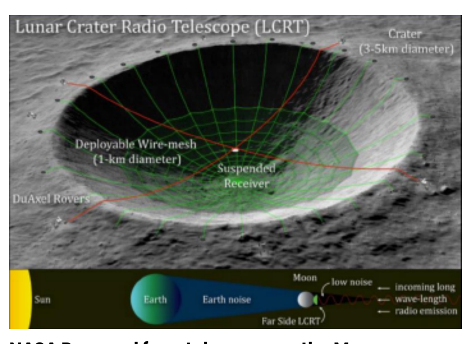
ALONE will place a large lunar telescope in a crater on the side of the moon furthest from the earth. This telescope will use microwave kinetic inductance detectors (MKIDs) to look at the spectrum (chemical composition) of exoplanet atmospheres. The goal of ALONE is to find atmospheres where the chemicals that make up redox-couples are in disequilibrium, as this may indicate that there is life on this planet. Ultimately, this mission aims to address the big question of: Are we alone in the universe?

	Luvex - 6b	Trappist - 1c
Stellar parameters		
Temperature [K]	5571 ± 48	2566 ± 26
Radius [$R_\odot$]	1.197 ± 0.016	0.1192 ± 0.0013
Mass [$M_\odot$]	0.991 ±	0.0898 ± 0.0023
Distance [pc]	3.652 ± 0.002	12.43 ± 0.02
Planetary parameters		
Radius [$R_\oplus$]	1.23 ± 0.12	1.095 ± 0.03
Mass [$M_\oplus$]	0.96 ± 0.21	1.156 ± 0.145
Period [days]	318.6	2.42
Equilibrium temperature [K]	~ 308	~ 340

Possible targets

Targets

ALONE is a follow up mission that relies on the data from exoplanet sensitive telescopes such as JWST, LUVOIR and HABEX. In order to perform spectroscopy on the planetary atmospheres, ALONE will focus on transiting planets such Trappist 1c. When the transiting planet passes in front of their host star, crossing the line of sight of the telescope, the light from the star will pass through the atmosphere of the planet allowing the spectrometer to clearly analyze the chemical composition of the atmosphere using spectroscopy.



NASA Proposal for a telescope on the Moon

NASA has already proposed building a telescope in a crater on the moon, this shows that this approach could be a promising and feasible option for exoplanet observation.

Large Lunar Telescope

ALONE proposes to build a telescope with a modular primary mirror of 20m in a parabolic shape inside a crater on the moon. This telescope will have a protective dome to shield it from meteorites, and will make use of MKID detectors to allow for a wide wavelength range.

The advantages of placing a telescope on the moon are as follows:

1. The moon has no atmosphere or clouds, so there is no atmospheric interference with the observations.
2. It is possible to build a bigger mirror on the moon than on earth as there is less gravity to weigh the mirror down, and there is ample space on the moon's surface.
3. It is easier to maintain and equip than a space telescope, as return trips are much more feasible.
4. There is a natural shield from the Earth-light noise. One of the large issues with earth based observatories is light pollution, but if the lunar telescope is placed on the side of the moon facing away from the earth, the whole of the moon acts as a natural light shield.

Scientific & Societal Output

ALONE will not only provide valuable scientific insight into the chemical composition of exoplanet atmospheres, but will also have a profound societal impact. As stated by one of the scientists behind the ALONE mission "Astrophysics is a beautiful luxury of human beings, and it is an important task to feed the curiosity of humanity". It is necessary to dedicate both time and money to the exploration of the universe, and to continue the search for life on other planets. In addition to looking for existing life on other planets for the sake of intrinsic human curiosity, by observing potentially inhabited planets, it is statistically probable that any life we did find would be at an entirely different stage of evolution than on earth. It could be that any life on the planet has long died and all that is left is the chemical fingerprint, or conversely, it could be that we find the signs of a budding new life on a planet. This could help us to answer questions about what life on earth may have been like when it began, or what our planet will look like once it is no longer inhabited.

"Really Compelling"

"One step closer to detecting life"

"The moon-crater telescope is a cool idea!"

The panel felt that the proposal was compelling, well fleshed out and was an exciting step that would progress our understanding of other planets. ALONE is a valuable follow up for missions such as LIFE and the panel liked that there would be a clear outline for the target list based on the results from Habex and LUVOIR. The panel was however hesitant that as the targets were M stars, as opposed to G stars like our own, this might make comparisons with our own solar system (and therefore insights into how 'special we are') difficult. There was also some concern from the panel about the technical difficulties associated with building a telescope in a crater on the moon, however they agreed that despite this it was a valuable and worthwhile mission!

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