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

Planets IN Extragalactic Areas Providing Population Levels: an Enormous Survey

A survey of planets outside of our own galaxy providing large scale exoplanet population statistics

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Introduction

Exoplanetary science is a growing field, and we are continuously getting a better understanding of the population of exoplanets, however all of the studies so far have focused on either our solar neighborhood, or else limited to a particular section of the night sky. The next step in understanding exoplanet populations is to begin to survey exoplanets outside of our own galaxy. Through PINEAPPLES (Planets IN Extragalactic Areas Providing Population Levels: an Enormous Survey), two hundred telescopes will be placed on the surface of the moon in order to observe exoplanets outside of our own galaxy. The sheer number of telescopes will allow for large amounts of light to be collected from the targets, even if the target is very far away and therefore not very bright as seen from within the Milkyway. Surveying exoplanets outside of our own galaxy will allow us scientists to learn more about topics such as the correlation between position in a galaxy and planet formation, and will help us to determine if our galaxy is 'special', or if there can be grander conclusions and predictions to be made about exoplanets on a universal level.

Scientific Background

Exoplanet Population Surveys

The first planet orbiting a star outside of our solar system was discovered in 1995. Since then, the number of exoplanets discovered has been growing almost exponentially. As of March 2022 there are now over 5000 confirmed exoplanets, in 3670 planetary systems, with 813 systems containing more than one planet. Exoplanets have been found using both ground and space telescopes, with a combination of methods.

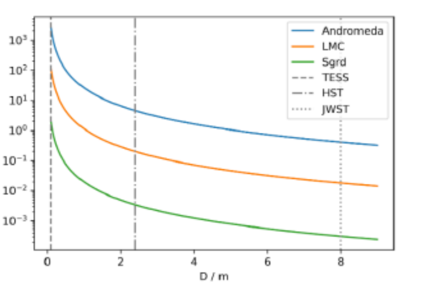
Ground based telescopes and some space telescopes use mainly transit photometry, along with some other planet-hunting methods, to detect planets relatively close to earth. However, most of the exoplanets we know of were discovered with the Kepler space telescope, which discovered thousands of exoplanets in a cone shaped field of view in one direction. There have also been a small number of very far away exoplanets discovered using gravitational microlensing, most of which are in the same direction as the center of the Milky Way. The farthest exoplanet discovered was near the center of our galaxy, about 25000 light years away.

PINEAPPLES

Goals

There are over 4000 confirmed exoplanets, and this number is ever growing. This number is very impressive, however there is still a lot of information missing and there is a bias within these exoplanet numbers that can be addressed. The exoplanets we have found have all been within a section of our own galaxy closest to us. The exoplanet information that we have is currently being used to derive everything that we know about exoplanets, however we do not know how unique our galaxy is in terms of its exoplanet population, so we do not know if the science currently being done with the exoplanet data we have will hold on an intergalactic scale.

PINEAPPLES (Planets IN Extragalactic Areas Providing Population Levels: an Enormous Surves) aims to conduct a population survey of exoplanets both within and outside of our own galaxy. Extragalactic planets are difficult to find due to their distance from us making them appear very dim and small, and all of the exoplanet missions so far have had limits on either the magnitude (brightness) that they can observe, or else on the angular resolution (how small of an object they can see) that do not allow them to see planets outside of our galaxy. In order to improve in both of these aspects, PINEAPPLES plans to place 200 telescopes across the surface of the moon and use all of them together to collect light from other galaxies. By using the large number of telescopes to collect light there will be a high photon efficiency, and due to the large area that the telescopes will cover there will be Robust statistics of exoplanet populations.



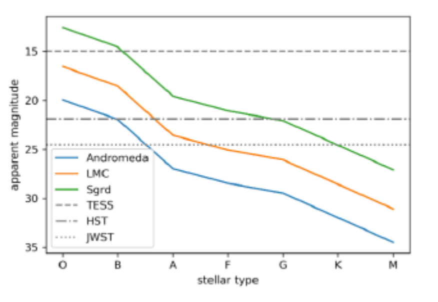
Comparitive Predicted Angular Resolution

This figure shows the number of stars in the area that can be resolved by a telescope (Ns) for a range of telescope mirror diameters (D/m). The coloured lines show the comparison for the Andromeda galaxy, the large magellanic cloud (LMC) and Sagittatius dwarf speroidal galaxy (Sgrd).

Target

PINEAPPLES plans to observe exoplanets both within and outside of the milky way. So far, exoplanets have only been observed about 27000 light years away from us, but the milky way spans over 52000 light years, so there is still a lot more of our galaxy that we are yet to explore.

Outside of the milky way, PINEAPPLES plans to observe targets including the Andromeda galaxy, the Large Magellanic Cloud and the Sagittarius Dwarf Galaxy.



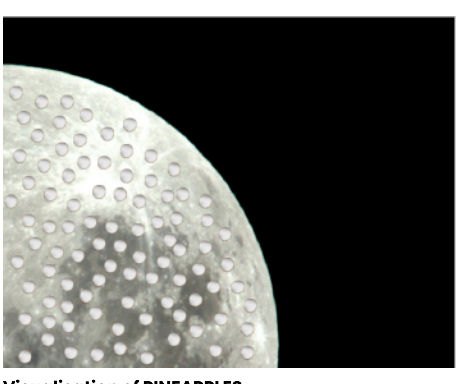
Comparison of magnitudes that can be observed

This figure shows the apparent brightness of different stellar types within three different targets. The dotted lines show the dimmest magnitude that each telescope can observe at. It is evident that PINEAPPLES has the capacity to observe the dimmest stars.

Technical Details

PINEAPPLES will make use of 200 3.5m mirrors that will cover a large area of the moon's surface. By placing the telescopes on the moon, it will be possible to maintain and upgrade the telescopes as needed. If the data that is collected from the telescopes is promising, it is also possible to add more telescopes in order to observe even dimmer, smaller, or further away stars. PINEAPPLES will be solar powered, as there is no need for fuel reserves when it is located on the moon. The lack of need for fuel reserves, combined with the upgradable, maintainable nature of the mission means that it can have a long mission lifetime.

PINEAPPLEs will make use of a similar Faint Object Camera as was used on the Hubble Space Telescope, with a wavelength range of 50nm - 1000nm and very high 'photon efficiency'. To achieve PINEAPPLES' goals it is important that individual stars in other galaxies can be resolved. Many of the previous exoplanet sensitive telescopes, for example TESS and the Hubble Space Telescope had 10 or more objects within a resolved unit, however with JWST (Launched in 2021) there is already a much higher resolution shown possible, JWST will be able to resolve bright individual stars. This means that the technology we already have is close to where it is needed for PINEAPPLES.



Visualisation of PINEAPPLES

Scientific & Societal Outcomes

The population statistics that will result from PINEAPPLES will give an unparalleled insight into exoplanet populations in the Milky Way and beyond. This will help us to understand if exoplanets are more common in certain positions within a galaxy, and ultimately help us to answer the big question of: is our galaxy special? By comparing the populations of exoplanets that we have studied within our galaxy, to those outside it, we can determine if the patterns we see within our own galaxy are also found in other galaxies. This will also help us to understand on a more universal scale where exoplanets are more likely to form, and if this has a relation to their position within a given galaxy.

PINEAPPLES will also provide additional outcomes, as well as the surveying of extragalactic exoplanets. The vast number of telescopes on the moon can be used in collaboration with other missions and telescopes in order to learn even more about our place within the galaxy, and within the universe at large.

Point	Cost	
Building	2 Bn	Approximated from Keppler mission with cost extrapolation
Launch	0.5 Bn	Future launch cost as projected by SpaceX
Landing	1 Bn	Estimation from next Mars rover mission
Operations (10yr)	0.5 Bn	Extrapolation from next Mars rover mission
Additional Science	1 Bn	Rough estimate of additional instrumentation
Unexpected costs	3 Bn	Learning from JWST and Berlin Airport
Total	6 Bn	Still Cheaper than JWST

Estimated Costs

"The idea of a huge moon telescope grid is great"

"Great idea!"

"It is good to look at a piece of the [exoplanet science] puzzle which is very important but less obvious"

The panel liked the innovative idea of making use of the size of the moon's surface. There was some discussion as to the benefits of exploring extragalactic planets, when there is still much to learn from planets within our galaxy. The panel liked that this was an innovative use for existing technology in order to learn more about exoplanet populations.

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