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CHEOPS,

CHEOPS presentation of the scientific program of the mission consortium

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Abstract

The aim of the scientific program of the CHEOPS consortium is to provide us with a comprehensive scientific program focused on exoplanet science. Its goal is to get unique sets of data allowing us to make progress in our understanding how planets form and evolve with the goal to improve universal model for planetary systems and further explore diversity in planetary systems This program has been assembled by CHEOPS Science Team and board members.

An overview including some program highlights will be presented in this talk

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A summary of the payload design for ARIEL

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Abstract

The Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (ARIEL) has been selected in March 2018 by ESA to be the next Cosmic Vision medium-class space mission (M4) due for launch in 2028. ARIEL will perform precise spectroscopy of ~ 1000 known transiting exoplanets using its metre-class telescope during a 4 years nominal lifetime, with a goal of 6 years of operation. The payload is provided by a nationally funded consortium with participation from teams from 14 ESA member states.

Three spectrometers cover without gaps a portion of the electromagnetic spectrum from a wavelength of 1.2 µm to 7.8 µm, with low resolution in the near-IR (R>10) and medium/low resolution in the mid-IR (R = 30-200). A three bands photometer completes the spectral coverage in the 0.5 to 1.2 µm spectral region, and it is used as a fine control guidance system as well as for science. The payload is designed to perform primary and secondary transit spectroscopy, and to measure spectrally resolved phase curves, with a photometric stability of < 100 ppm (goal of ~10 ppm).

From its orbit around the L2 Lagrange point, ARIEL data will enable us to obtain the first statistically significant spectroscopic survey of hot and warm planets. These are an ideal laboratory in which to study the chemistry, formation and evolution processes of exoplanets, to constrain the thermodynamics, composition and structure of their atmospheres, and to investigate the properties of clouds.

This paper presents the overview of the payload design foreseen for the mission, identifies the key driving requirements and outlines the expected performance.

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First Call for Proposals for the CHEOPS Guest Observers Programme

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Abstract

CHEOPS is the first exoplanet mission dedicated to the search for transits of exoplanets by means of ultrahigh precision photometry of bright stars already known to host planets. It is the first S-class mission in ESA's Cosmic Vision 2015-2025, and a partnership between Switzerland and ESA's science programme, with important contributions from 10 other member states. In this poster I give an overview of the Call for Proposals for the Guest Observers Programme, the mechanism by which the Science Community can apply for observing time on CHEOPS.

1. Introduction

CHEOPS (CHaracterising ExOPlanet Satellite) is the first exoplanet mission dedicated to the search for transits of exoplanets by means of ultrahigh precision photometry of bright stars already known to host planets. It is the first S-class mission in ESA's Cosmic Vision 2015-2025. The mission is a partnership between Switzerland and ESA's science programme, with important contributions from 10 other member states.

Foreseen to be launch ready at the very end of this year, CHEOPS will provide the unique capability of determining radii of planets in the super-Earth to Neptune mass range to ~10% precision. It will also provide accurate radii for new planets discovered by the next generation of ground-based or space transit surveys (from super-Earth to Neptune-size). The high photometric precision of CHEOPS will be achieved using a photometer covering the 0.35 - 1.1um waveband, designed around a single frame-transfer CCD which is mounted in the focal plane of a 30 cm equivalent aperture diameter, f/5 on-axis Ritchey-Chretien telescope.

20% of the observing time in the 3.5 year nominal mission will be available to the Community through the Guest Observers Programme that will be run by ESA.

In this poster I give an overview of the first Call for Proposals for the Guest Observers Programme, foreseen come out in September 2018.

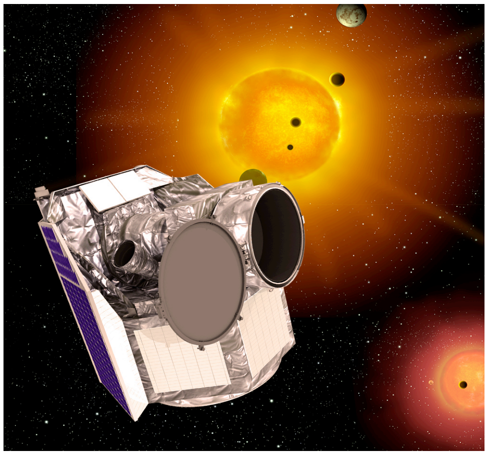

Figure 1: The CHEOPS satellite (ESA/C. Carreau).

Acknowledgements

The author acknowledges the key contributions of the CHEOPS Consortium led by Prof Willy Benz at the University of Bern (CH), the CHEOPS Project Team at ESTEC, ESA colleagues at ESTEC and ESOC, the prime spacecraft Contractor Airbus Defence and Space ECE (ES), GMV (ES), INTA (ES) and DEIMOS Engenharia (PT), without whom CHEOPS would not be possible.

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VUV Spectroscopy for terrestrial exoplanetary exosphere

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Abstract

The Earth's exospheric temperature is higher than those of Venus' and Mars'. The EUV irradiation at Proxima b is much higher than at Earth, and assuming that Proxima b is an Earth-like planet, it would have a far-extended exosphere. On the other hand, assuming that Proxima b is a Venus-like or Mars-like planet, its exosphere would not be so much extended. We performed a conceptual design of Ultraviolet Spectrograph for Exoplanet (UVSPEX) for World Space Observatory Ultraviolet (WSO-UV), which enables to distinguish the Earth-like from the Venus-like or Mars-like.

1. Introduction

Many Earth-sized planets have been discovered and some appear to lie in the habitable zone. Moreover, several Earth-sized planets were recently detected around low temperature stars near the solar system. However, it is difficult to characterize them as Earth-like or Venus-like because we have no information on their atmospheres. Transit spectroscopy for exoplanetary atmosphere has been performed to characterize larger exoplanets but it requires very high accuracy for Earth-sized planets because of their small size. Hydrogen exosphere has been detected around Neptune-sized exoplanet [1], but an Earth-sized exoplanetary exosphere has not been detected. Recently, Earth's hydrogen exosphere was re-investigated and it was revealed that the Earth's exosphere is extended to ~ 38 Earth radii [2]. On the other hand, Venus' and Mars' hydrogen exosphere is not so much extended because of its low temperature of upper atmosphere. The hydrogen density is estimated about 20 atoms/cm^3 at a distance of ~60,000 km in the Earth's exosphere. The same amount of density is expected to be observed at a distance 10,000-20,000 km in Venus and 30,000-35,000 km in Mars. This is caused by the difference of mixing ratio of CO_2 in the upper atmosphere. Venus and Mars have CO_2-rich atmospheres with a lower exospheric temperature. On Earth, CO_2 was removed from its atmosphere by a carbon cycle with its ocean and tectonics [3]. Translating these arguments to exoplanets in a habitable zone presents a possible marker to distinguish an Earth-like planet from a Mar-like or Venus-like planet. The expanded exospheres can be observed in UV, during the exoplanet transit event in a primary eclipse. It reduces the stellar flux, when an exoplanet orbiting in front of the host star.

2. EUV irradiation and exospheric high temperature

Theoretical exospheric models extrapolated these arguments to an oxygen exosphere. Then for oxygen line the predicted transit depths are shown in Fig. 1 assuming that Proxima Centauri b [4], at which the EUV irradiation is much higher than at Earth, is either the Earth-like, Mars-like or Venus-like.

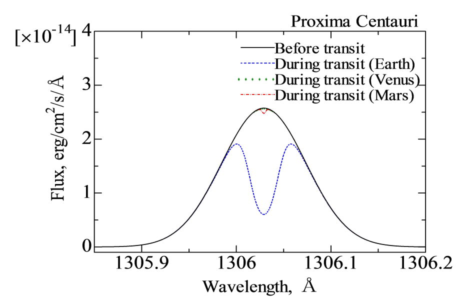

Fig. 1 Predicted theoretical transit photometric curves of Proxima Centauri exoplanet in oxygen OI spectral line at 130.6 nm of Earth-like – blue (dash-marked) line, of Venus-like green (dot-marked) line, of Mars-like red (dashed-dot) line in comparison with the non-transit curve black (solid) line.

The temperature of upper atmosphere for the Earth-like is estimated to be ~10,000 K [5]. On the contrary, those for the Mars-like and Venus-like are estimated to be ~300 K and ~600 K, respectively [6]. Then the transit depth at the line center for each case is 76%, 0.7%, or 3.8%, respectively. Due to the large difference in the transit depth, the Earth-like can potentially be distinguished from the Venus-like and the Mars-like. However, high dispersion is required to resolve absorption feature in the O I line shown in Fig. 1. The total transit depth of stellar emission integrated from 130.25 nm to 130.75 nm corresponds to 25%, 0.11%, or 0.20%, respectively, which are also distinguishable with low-dispersion spectrometer. Thus, we selected low-dispersion and high-efficiency design to observe M stars dark in the UV region and to simultaneously detect both hydrogen (~122 nm) and oxygen emission lines (~130 nm).

3. UVSPEX for WSO-UV

High sensitivity (photon counting) is required for M-type star faint in UV. Spectral resolution of 0.5 nm is enough for separating major emission lines of exospheric atoms. The spectral resolution will be achievable by spectrometers in the main WUVS block, however, it is difficult to measure the weak flux from M-type stars without a photon-counting detector. To realize exoplanet transit observations in oxygen spectral lines with the desired accuracy, we equip the WSO-UV telescope with the UVSPEX spectrograph. The main engineering requirements for the UVSPEX are following. The spectral resolution is better 0.5 nm to separate O I line from other spectral lines. The spectral range is to exceed the wavelengths from 115 nm to 135 nm to detect at least H Lyman alpha 121.6nm to O I 130 nm. The throughput is better 0.3% accounting more than four terrestrial exoplanets distanced at 5 pc. To achieve these requirements, a simple spectrograph design is proposed, containing the slit, the concave (toroidal) grating as a disperse element and the imaging photo-detector. This optical concept is conventional and used in the other space missions for UV spectroscopy.

Figure 2 shows the UVSPEX principal optical scheme. Spectrometer slit is aligned at primary focus of the telescope from off-axial sub-FoV, at Pos 10 (see Fig. 4). Slit width is 0.2 mm, corresponding to 5 arc-sec. The concave grating is laminar type with groove density of 2400 grooves per mm. It has a toroidal shape with the curvature radii of 266.4 mm in horizontal direction and of 253.0 mm in vertical direction. The effective area has nearly Ø 25 mm and the focal length is ~250 mm. The surface is coated by Al + MgF2 to increase the reflectance, and diffraction efficiency of ~29% can be achieved.

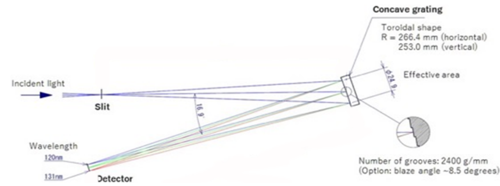

Fig. 2 Optical scheme of the spectrograph UVSPEX

If we assume a star with the same flux as Proxima Centauri at longer distance, the distance of detection limits for UVPSEX is 14 pc. Because low temperature stars in a vacuum are dark in the UV range, including the O I emission line, a large space telescope and spectrograph with high efficiency are required to characterize these planetary atmospheres.

Acknowledgements

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References

[1] Ehrenreich, D. et al., A giant comet-like cloud of hydrogen escaping the warm Neptune-mass exoplanet GJ436b. Nature 522, 459-461, 2015.

[2] Kameda, S. et al., Ecliptic North-South Symmetry of Hydrogen Geocorona. Geophysical Research Letters 44, 11,706-11,712, 2017.

[3] Abbot, D. S., Cowan, N. B. & Ciesla, F. J., Indication of insensitivity of planetary weathering behavior and habitable zone to surface land fraction, Ap. J. 756:178(13pp), 2012

[4] Anglada-Escude, G. et al., A terrestrial planet candidate in a temperate orbit around Proxima Centauri. Nature 536, 437-440, 2016.

[5] Tian, F. et al., Hydrodynamic planetary thermosphere model: 2. Coupling of an electron transport/energy deposition model. J. Geophys. Res. 113, 2008.

[6] Kulikov, Y. N. et al., A Comparative Study of the Influence of the Active Young Sun on the Early Atmospheres of Earth, Venus, and Mars. Space Sci. Rev. 129, 207-243, 2007.

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ARIELSim - the dedicated time domain simulator for the ARIEL mission.

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Abstract

With the selection of ARIEL for the ESA Cosmic Vision M4 mission a dedicated simulation tool that provides high accuracy time domain simulations of ARIEL observations will be necessary. Among various applications, this tool will provide a complete assessment of astrophysical and instrumental noise sources impacting ARIEL, and permit the verification of ARIEL's performance against requirements at all stages of development. Numerous other applications include the cross-validation of semi-analytical radiometric simulators and detailed studies of the impact of complex noise and systematics such stellar variability from pulsation and granulation, star spots, pointing jitter and detector systematics. By incorporating the time domain, correlated noise and time-dependent systematics can be modeled and their impact assessed. The simulator provides the nucleus for future observational planning, as well as the testing of data reduction pipelines and noise decorrelation and mitigation strategies. We build on the Phase A simulator for ARIEL, ExoSim, to develop ExoSim v2.0, and its dedicated version for this mission, ARIELSim.

1. ExoSim vs ARIELSim

During Phase A, the generic simulator ExoSim [1], was developed and was applied to the successfully to the design phase of the ARIEL mission. In Phase B, we will develop ExoSim v2.0 and a dedicated version for the ARIEL mission, ARIELSim.

ExoSim v2.0 will improve on ExoSim v1.0 with improved astrophysical and instrumental simulations, a future-proof architecture and and will utilize the same ARIEL pipeline that will be developed for the actual ARIEL data products. In ExoSim v2.0 we will address the issue of capturing widely differing time scales of time-dependent processes ranging from high frequency detector 1/f noise, to that of the planet phase curve or long-term thermo-elastic deformations. We will tackle this through a combination of recoding the way the time domain effects are simulated and more sophisticated memory management.

1.1. Astrophysical

We will expand the astrophysical component of the simulator with fully integrated models of stellar and planet time-dependent processes beyond the effects of the planet light curve. These will primary involve integrating stellar pulsation, granulation and spot/faculae models (already developed in Phase A) into ExoSim's astrophysics simulation as options for the user. It may also involve novel astrophysical simulations to assess ARIEL's sensitivity to detect phenomena such as exomoons, planet rotational effects, debris discs etc. The scientific expertise of the ARIEL consortium will be essential for selecting and implementing the required simulated scenarios.

1.2. Instrumental

We intend ARIELSim to be current at all stages of design, development and implementation of the mission, and to give the most accurate assessment of ARIEL's performance at all stages. As such ARIELSim's architecture will be modified to from that in ExoSim v1.0 to make it more 'future-proof'. This involves increased modularity so that as instrument components are developed and their characteristics become known, the model can be updated easily by recoding individual modular elements in isolation. It also involves a shift from complete generic capability to tailor-made modules for each instrument channel, that will capture any idiosyncrasies as they become known. The detector model will be greatly augmented to account for the readout architecture and will incorporate characteristics of the final detectors chosen for the mission, including non-linearlity, cross-talk, persistence etc, as well a model to capture cosmic ray impacts.

The ExoSim team will work in close collaboration with engineers and instrumental scientists to maintain the most accurate model of ARIEL's integrated optical description, as well as the detector chain (pixel array, ROIC, CFEE and DPU) and all sources of noise and systematics. This will involve descriptions of noise power spectral density (PSD) and correlation matrices provided by other groups.

1.3. Data pipeline

As ExoSim becomes more sophisticated, so does the pipeline that is used to reduce and process ExoSim data products. As a result in Phase B, ARIELSim products will be processed using the working version of the ARIEL data reduction pipeline. ExoSim thus provides a test-bed for this pipeline, as well as for the testing of noise decorrelation and mitigation strategies, and systematics corrections.

2. Summary

ExoSim v2.0 is now under development, and will be the most complete and accurate end-to-end model of transit spectroscopy so far developed. Although dedicated to the ARIEL mission, many of its elements will be appropriate for simulation of transit spectroscopic observations from other platforms and with some modifications, dedicated versions can be produces for other key instruments.

References

[1] Sarkar, S., Papageorgiou, A., and Pascale, E.: Exploring the potential of the ExoSim simulator for transit spectroscopy noise estimation, Proc. SPIE 9904, 99043R.

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Giant planet direct imaging with first light instruments on ELT

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Abstract

First light instrument on the ELT, namely MICADO, HARMONI and METIS, have been designed with coronagraphic facilities to achieve high contrast imaging at unprecedented angular resolution. We will review the current concept and the expected performance of these instruments and discuss also the long term goal.

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The JWST Early Release Science Program for Directly Imaging Exoplanetary Systems

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Abstract

To prepare for the upcoming launch of JWST, a broad range of proposals have been selected by the Space Telescope Science Institute under the Director's Discretionary Early Release Science Program (ERS). Our accepted 52-hour JWST ERS program will directly characterize two recently-discovered, directly imaged planetary mass companions over their full spectral range from 2-28 microns using photometry and spectroscopy. Ours will be among the first-ever observations of bona fide exoplanets at these wavelengths, and will be crucial test cases for atmospheric modelling that has mostly operated in the visible and near-infrared. Further, our program will demonstrate the degree to which atmospheric abundance analysis can be obtained from JWST spectroscopy, possibly providing clues to the planet formation process. As a bonus, our program will also perform deep, near-infrared, Sparse Aperture Masking on an exoplanet host star, as well as imaging of a debris disc out to 15 μm sampling the 3 μm water ice feature. Within the first few months of JWST operations, our program will rapidly produce publicly-available datasets in modes to be commonly used by the exoplanet direct imaging communities. In addition, I will describe how our team of 120 investigators will deliver science enabling products to empower a broad user base to develop successful future JWST investigations dedicated to direct-imaging surveys for low-mass exoplanets (e.g. Saturn mass) in Cycle 2 and beyond.

1. Equations

Below, you will find examples of two equations. You should use an equation editor of your word-processing program in order to include your equation(s). The equation number should be placed at the right side of the column and all equations should be consecutively numbered.

$$a^2 + b^2 = c^2 \tag{1}$$

$$E = m \cdot c^2 \tag{2}$$

2. Summary and Conclusions

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Acknowledgements

The Acknowledgements section should not be numbered. Here, you may include all persons or institutions which you would like to thank. We recommend that the abstract is carefully compiled and thoroughly checked, in particular with regard to the list of authors, **before** submission.

References

[1] Author, A., Author, B., and Author, C.: First example of a cited article title, First Example Journal, Vol. 1, pp. 1-100, 1999.

[2] Author, D. and Author, E.: Second example of a cited book, Example Publishing House, 2000.

[3] Author, F.: Third example of a cited conference paper, The Great Science Conference, 1–7 February 2001, Sciencetown, Sciencecountry, 2001.

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Exoplanet Spectro-photometry with Twinkle

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Abstract

Twinkle is a 45cm space telescope conceived to characterise extrasolar planets and Solar System objects over a broad wavelength range. From a sun-synchronous polar orbit vantage point, Twinkle's highly-stable instrument will allow the photometric and spectroscopic observation of a wide range of planetary classes around different types of stars, with a focus on bright sources close to the ecliptic. The planets will be observed through transit and eclipse photometry and spectroscopy, as well as phase curves, eclipse mapping and multiple narrow-band time-series.

1. Introduction

As of April 2018, over 3700 exoplanets have been discovered (nearly 3000 of which transit their stars) as well as 4500 Kepler candidate planets. On top of this, future surveys will detect thousands more. However, our current knowledge of their atmospheric, thermal and compositional characteristics is still very limited.

Twinkle, is a space science observatory equipped with a visible (0.4 - 1μm) and infrared (1.3 - 4.5μm) spectrometer (split into two channels at 2.42μm), designed to be launched within three to five years. Twinkle will operate in a low Earth, Sun-synchronous orbit and provide on-demand observations of a wide variety of targets within wavelength ranges that are currently not accessible using other space telescopes or accessible only to oversubscribed observatories in the short-term future.

The ability of Twinkle's infrared spectrometer to characterise the currently known exoplanets has been assessed. The spectral resolution achievable by combining multiple observations has been studied for various planetary and stellar types. Spectral retrievals have been simulated for some well-known planets (HD 209458 b, GJ 3470 b and 55 Cnc e).

TESS is predicted to find more than 4500 planets around bright stars [3] and Twinkle's capability to observe these potential future detections has also been studied.

2. Methodology and Results

Over 500 currently known transiting exoplanets lie within Twinkle's field of regard and the ESA radiometric model [2, 4] has been adapted to Twinkle's instrumentation to calculate its performance for each of these planets. A science requirement of SNR > 7 has been assumed and the resolution achievable with a given number of transit or eclipse observations determined [1]. This first iteration of assessing Twinkle's performance for exoplanetary science has shown that many planets are potentially observable with Twinkle and the achievable resolutions for a given number of transits/eclipses is shown in Figure 1.

In this study it is found that a large numbers of targets could be studied with simple photometry in a single observation. Simultaneous photometric measurements in the optical and infrared would allow for rigorous constraints on the planetary, stellar and orbital parameters of a system as well as precise measurements of transit timing variations (TTVs) present in some multi-planet systems.

Twinkle observations at higher spectral resolution will enable to probe atmospheric chemical and thermal properties, with the potential to revisit them many times over the mission lifetime to detect variations such as non-uniform cloud cover.

From the catalogue of predicted TESS detections it is found that the number of planets suitable for photometric follow up could triple whilst, for spectroscopy, the number of targets could double.

Spectral retrievals with Twinkle have been simulated using Tau-REx and Figure 2 shows the spectra obtained for 55 Cnc e assuming 10 eclipse observations.

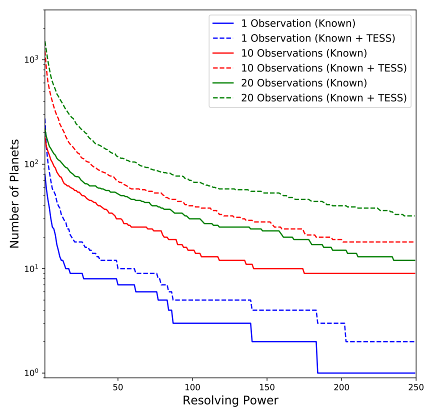

Figure 1: Number of known and predicted TESS planets with Twinkle's field of regard for which SNR > 7 is achievable at a given resolving power

3. Summary and Conclusions

From the exoplanets known today it has been found that Twinkle could probe a large number of planets. Further surveys will reveal thousands of new exoplanets, of which many will be located within Twinkle's field of regard. TESS in particular is predicted to discover many targets around bright stars which will increase the number of exoplanets Twinkle could observe and simulated TESS detections have been analysed to confirm this.

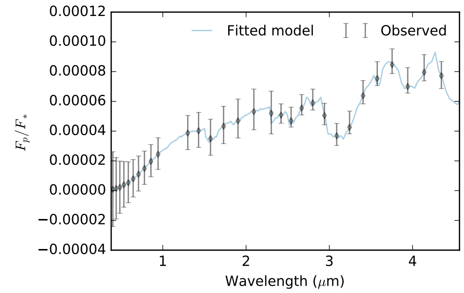

Figure 2: Spectra retrieved for 55 Cnc e (cloud free, CO = $1\text{x}10^{-3}$, C_2H_2 = $1\text{x}10^{-5}$, HCN = $1\text{x}10^{-5}$) at R = 10 ($\lambda < 2.42\mu$m) and R = 20 ($\lambda > 2.42\mu$m) with 10 eclipse observations

Acknowledgements

This work has been funded through the ERC Consolidator grant ExoLights (GA 617119).

References

[1] Edwards, B. et al., in prep, Exoplanet Spectrophotometry with the Twinkle Space Telescope

[2] Puig, L. et al.: The phase 0/A study of the ESA M3 mission candidate EChO, 2015, Experimental Astronomy

[3] Barclay, T., Pepper, J. and Quintana, E. V., 2018, A Revised Exoplanet Yield from the Transiting Exoplanet Survey Satellite (TESS), arXiv:1804.05050

[4] Sarkar, S. et al., 2017, ARIEL Performance Analysis Report, ARIEL-CRDF-PL-AN- 001

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PLATO Science: main goals and expected achievements

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Abstract

In this talk we will describe the science goals of PLATO (PLAnetary Transits and stellar Oscillations), the ESA next generation planet finding mission. PLATO main scientific target is the identification and bulk characterization (radius and mass) of terrestrial planets (including Earth twins) for habitability estimate.

PLATO main goals will be reached by: 1) planet detection and radius determination (3% precision) from photometric transits; 2) determination of planet masses (better than 10% precision) from ground-based radial velocity follow-up, which is part of the mission project; 3) determination of accurate stellar masses, radii, and ages (10% precision) from asteroseismology.

PLATO complete characterization of hundreds of planets, including the architecture of their planetary system will fundamentally enhance our understanding of their formation and evolution. PLATO will provide targets for exoplanet atmosphere studies with ELTs and future dedicated satellites.

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Twinkle – A Commercial Space Science Satellite

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Abstract

Twinkle is a small satellite designed to carry out cutting-edge space science with a new commercial funding model. The approach pioneered by Blue Skies Space Ltd. opens access to scientific satellites to universities and research institutes worldwide

Twinkle is a cost-effective spacecraft being built on a short timescale and planned for a launch by 2021. The satellite is based on an existing platform designed by Surrey Satellite Technology Ltd. Twinkle will carry a 45cm telescope with two instruments (visible and near-IR spectrometers - between 0.4 and 4.5μm with resolving power up to R~250) and will follow a sun-synchronous low-Earth polar orbit. The mission implementation is based upon a delivery approach that has been successfully applied in other demanding space disciplines, with Blue Skies Space Ltd. set up to commercially manage the mission.

Twinkle is being built to carry out cutting-edge science: Twinkle will use visible and infrared spectroscopy to analyse the chemical composition and weather of exoplanets in the Milky Way, including super-Earths (rocky planets 1-10 times the mass of Earth), Neptunes, sub-Neptunes and gas giants like Jupiter. It will also be capable of follow-up photometric observations of 1000+ exoplanets. Photometric measurements taken simultaneously in the visible and the infrared bands, will allow orbital parameters of systems as well as precise measurements of transit timing variations present in multiple planetary systems to be well constrained. The exoplanet targets observed by Twinkle will be composed of known exoplanets discovered by existing and upcoming ground- and space-based surveys (e.g. K2, GAIA, Cheops, TESS). Solar system objects ideally suited for spectroscopic and photometric observations with Twinkle include asteroids and comet comae, for which the broad wavelength range allows the observation of key hydration, organic and volatile features in their spectrum.

This presentation will provide a summary of the technical capabilities of the Twinkle Space Mission, the scientific possibilities with the satellite and a description of the funding model employed.

More information on the science possible with the Twinkle Space Mission can be found on our website: www.twinkle-spacemission.co.uk

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An Updated Study of the ARIEL Mission Reference Sample

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Abstract

ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) has been selected as the next ESA medium-class science mission and is due for launch in 2028. During its 4-year mission, ARIEL aims to observe 1000 planets exoplanets ranging from Jupiter and Neptune-size down to super-Earth size in the visible and the infrared with its meter-class telescope.

The analysis of ARIEL spectra and photometric data will deliver a homogenous catalogue of planetary spectra which will allow the extraction of the chemical fingerprints of gases and condensates in the planets' atmospheres, including the elemental composition for the most favourable targets. It will also enable the study of thermal and scattering properties of the atmosphere as the planet orbit around the star.

1. Introduction

As of May 2018, over 3700 exoplanets have been discovered (nearly 3000 of which transit their stars) as well as 4500 Kepler candidate planets. Additionally, TESS is predicted to find more than 4500 planets around bright stars [2] and other surveys will find thousands more.

ARIEL has a designed mission life of 4 years including a 6-month commissioning and calibration phase. Additionally scheduling constraints, such as telescope housekeeping, slewing between targets and data downlink reduce the available science time. Assuming that telescope downtime corresponds to 15 %, ARIEL will have 3 years of usable science time during its nominal life.

Given the current instrument design, the capability of the ARIEL spacecraft to meet the science goals within this time has been assessed from the population of known planets and predicted TESS detections.

2. Methodology and an Example Mission Reference Sample

An initial ARIEL mission reference sample has been undertaken by choosing the planets which require the fewest observations, with no preference towards producing a diverse list of planets or selecting interesting targets. The distribution of these planets by radius and temperature is displayed in Figure 1. Planets selected for tier 3 are also included in tier 2 and in turn tier 1 planets incorporate all those studied in tier 2.

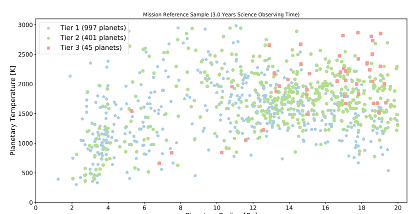

Figure 1: Example ARIEL Mission Reference Sample [1]

3. Summary and Conclusions

We find that ARIEL should be able to observe ∼1000 planets at various resolutions over the primary mission life. This sample of the exoplanet population has a diverse range of sizes, temperatures and stellar hosts. The target list will continue to evolve as new planets are discovered.

Acknowledgements

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References

[1] Edwards, B. et al., in prep, An Updated Study of the ARIEL Mission Reference Sample

[2] Barclay, T., Pepper, J. and Quintana, E. V., 2018, A Revised Exoplanet Yield from the Transiting Exoplanet Survey Satellite (TESS), arXiv:1804.05050

EPSC Abstracts
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A modular design for the ARIEL on-board electronics

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Abstract

The ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) Mission has been selected by ESA as the fourth medium-class (M4) scientific satellite of the Cosmic Vision Program, to be launched in 2028 [1].

ARIEL aims at the study of the atmospheres of a selected sample of warm and hot exoplanets mainly by means of primary and secondary transit spectroscopy [2].

The payload is based on a 1-m class telescope ahead of a suite of instruments: three spectrometric channels covering the band from 1.20 to 7.80 µm without spectral gaps and three photometric channels working in the range 0.5 to 1.2 µm.

AIRS, the ARIEL IR Spectrometer [3], is connected to and operated by the Instrument Control Unit (ICU), in charge of the overall Instrument Control, and by the Telescope Control Unit (TCU), whose actual aim is the thermal monitoring of the telescope and the fine thermal regulation of the AIRS detectors Control Thermal System (TCS).

Here we mainly describe the baseline ARIEL on-board electronics architecture, from the AIRS output to the electrical I/F to the Service Vehicle Module (SVM).

1. Introduction

The ARIEL Payload (P/L) is composed of many subsystems on both its cold and warm sides. The ICU, TCU and DCU (Detector Control Unit) are located on the warm part of the SVM, maintained at ambient temperature (~270-300 K).

DCU interfaces the FPA (Focal Plane Assembly) CFEE (Cold Front End Electronics) in order to control the detection process, and to the ICU to transfer the Science Data Packets towards the Spacecraft [4].

2. Warm electronics

The warm Units host analog and digital electronics, whose aim is to drive and control the overall data acquisition chain (scientific data and instrument housekeeping, HK), monitoring the telescope and the payload subsystems temperatures, commanding and provide the SVM with the scientific telemetries and the Instrument health status.

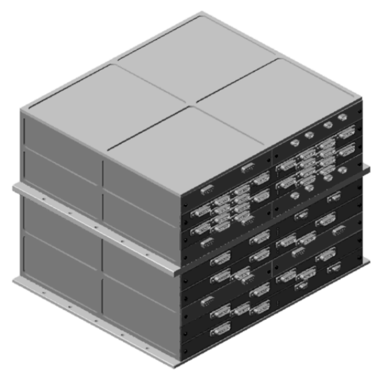

Figure 1: The modular design of the ARIEL-AIRS warm electronics, based on stacked drawers hosting the DCU, TCU and ICU analog and digital electronics.

2.1 Instrument Control Unit

The ICU [5] is interfaced on one side with the instrument and on the other side (Spacecraft, S/C, side) with the Data Management System (DMS) and the Power Conditioning and Distribution Unit (PCDU), both belonging to the hosting platform.

The ICU design is conceived for scientific data pre-processing and to implement the commanding and control of the AIRS Spectrometer. It will run the Application SW (ASW) [6] in charge of instrument management and scientific data processing and it will feed and control the TCU, in order to collect all the needed housekeeping for a proper active control of all the on-board subsystems (SS). In this sense, TCU is considered an ICU slave subsystem.

2.2 Telescope Control Unit

To constrain the P/L thermo-mechanically induced optical aberrations, the temperature of the primary mirror (M1) [7] will be monitored and finely tuned by means of an active thermal control system based on thermistors and heaters. They will be switched on and off to maintain the M1 temperature within ±1K thanks to a proportional–integral–derivative (PID) controller implemented within the Telescope Control Unit, the payload electronics subsystem mainly in charge of active thermal stabilisation of the TCS of two detectors belonging to AIRS, besides M1.

TCU shall also control the on-board IR calibrator by means of an accurate feedback-loop system, the M2 refocusing mechanism and will collect the HK of the controlled subsystems, forwarding them to the ICU.

2.1 Detector Control Unit

DCU interfaces internally to the AIRS FPA CFEE and the detectors to control the detection process and, externally, to the ICU to transfer the Science Data Packet. The main function of the DCU are:

- control data acquisition at detector level through the CFEE;
- process the data from the detector prior the formatting of the Science Data Packet done by ICU;
- ensure the proper interface with the ICU for TC reception, HK and Science Data Packet transmission.

3. Cold electronics

The detectors and their control electronics are located on the cold side of the Payload (P/L) to limit noise and efficiently detect the IR spectroscopic signatures of the selected exoplanetary atmospheres. Detectors shall work down-to 42 K, while the CFEE will be operated at a higher temperature.

The baseline design for the AIRS IR focal plane sensors is based on the adoption of the H1RG-type detectors from Teledyne coupled with the Teledyne SIDECAR ASIC, already developed to drive efficiently the H*RG detectors and tested in relevant space environments. Both detector arrays and ASIC are based on US technology.

In parallel, a particular effort is being planned in the ARIEL Consortium to provide an alternative solution for the AIRS focal plane assembly, based on European technology: the sensors are under study at CEA-Saclay (F) and the readout ASIC is under development at SRON (The Netherlands Institute for Space Research).

4. Summary and Conclusions

This short paper has shown the status of the ARIEL on-board electronics at the beginning of the Phase B1 of the Project. The selected architecture is still under consolidation as it will undergo two following reviews by ESA during the next two years, the P/L Preliminary Design Consolidation Review (PDCR) and the System Requirements Review (SRR).

Acknowledgements

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References

[1] L. Puig, et al., “ARIEL: an ESA M4 mission candidate”, Proc. SPIE. 9904, 99041W, 2016.

[2] G. Tinetti, et al., "The science of ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey)", Proc. SPIE 9904, 99041X, 2016.

[3] P. Eccleston, et al., "An integrated payload design for the Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL)", Proc. SPIE 9904, 990433, 2016.

[4] M. Focardi, et al., "The Atmospheric Remote-sensing Infrared Exoplanets Large-survey (ARIEL) payload electronic subsystems", Proc. SPIE 9904, 990436, 2016.

[5] M. Focardi, et al., "The ARIEL Instrument Control Unit design for the M4 Mission Selection Review of the ESA's Cosmic Vision Program", Special Issue on ARIEL, Experimental Astronomy, 2017.

[6] M. Farina, et al., "Ariel Spectrometer Instrument Control and Data Processing Software", EPSC 2017.

[7] V. Da Deppo, et al., "Design of an afocal telescope for the ARIEL mission", Proc. SPIE 9904, 990434, 2016.

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Preparing time-critical observations of transiting exoplanets with follow-up from the ground

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Abstract

In this presentation I will discuss a long-term project to monitor transiting exoplanets with small and medium scale telescopes from the ground. The main scope of the project is to observe stars that host exoplanets with the aim of improving their ephemerides and help their characterization. In the case of a project on characterising exoplanets, long-term continuous monitoring of targets is necessary. We have conducted more than 50 observations using the equipment of three observatories in Greece and Chile. For data analysis and light curve extraction, our team has developed The Holomon Photometric Software (HOPS).

We designed the software in a user-friendly way to ensure high data quality and reliability in the scientific results while enabling the analysis by as many partners as possible. I will present the methodology, tools and the first scientific results that have been produced out of this collaboration. We are open for contributions in our project either on the observation part or the data analysis. Our ultimate goal is to create a collective list of observations from transiting exoplanets to better identify their ephemerides and characteristics, in support of future instruments, such as the James Webb Space Telescope and the ARIEL mission.

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PLATO: the instrument and the science preparation

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Abstract

PLATO (PLAnetary Transits and Oscillations of stars) is the M3 mission in the ESA's Cosmic Vision 2015-2025 programme. It aims at finding a large number of exoplanets, at characterizing their bulk density with emphasis on the properties of terrestrial planets in the habitable zone around solar-like stars, and at studying exoplanetary systems evolution.

In order to achieve its scientific objectives, the PLATO satellite will perform uninterrupted high precision photometric by monitoring large samples of stars in FoV greater than 2200 square degree. High flexible mission scenario will allow performing a mixture of long period monitoring (up to years) alternating to step-and-stare phases, with the possibility to return back monitoring interesting fields/ objects. Ground-based follow-up is part of the PLATO project.

PLATO will use 26 cameras, based on all-refractive design, to deliver light curves useful for transit search and astreroseismic stellar characterisation.

In this talk we will address the way the payload, the preparatory science, and the ground segment are implemented and how the community can be involved in the PLATO preparatory and follow-up activities.

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The JWST Transiting Exoplanet Community Early Release Science Program

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Abstract

With a 6.5-meter diameter primary mirror in space and a wavelength coverage from the visible to the mid-infrared, the *James Webb Space Telescope* (JWST) will soon open new windows to scrutinize transiting exoplanets' atmospheres. It will provide missing clues to understand hot Jupiter's atmospheres such as the relative abundances of molecular species and the thermal structure over a wide range of altitudes, and will probe the atmospheres of terrestrial exoplanets. The transiting exoplanet community is joining forces to define a coherent strategy to evaluate JWST's capabilities during the Early Release Science (ERS) program. The aim is to accelerate the acquisition and diffusion of technical expertise for transiting exoplanet observations with JWST, and to provide representative and compelling datasets that will enable immediate scientific breakthroughs. To this end, we proposed a set of well chosen observations that will be executed in the first months of JWST science operations and will be accompanied by data analysis toolkits and guides for best practices developed by our team. This proposal has been accepted and the data and tools will be publicly available. In this talk, I will review the observing modes that will be available for transiting exoplanet spectroscopy with JWST and I will present the Transiting Exoplanet Community ERS program.

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The primary mirror of the ARIEL mission: study and development of a prototype

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Abstract

ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) has been selected by ESA as the fourth medium-class (M4) mission in the framework of the Cosmic Vision Programme. ARIEL is expected to be launched in 2028 [1].

ARIEL aims to study the atmospheres of a selected sample of warm and hot exoplanets mainly by means of primary and secondary transit spectroscopy [2].

The payload is based on a 1-m class telescope ahead of a suite of instruments: two spectrometric channels covering the band 1.95 to 7.80 μm without gaps, three photometric channels working in the range 0.5 to 1.2 μm, and a low resolution spectrometer in the range 1.25-1.95 μm.

The ARIEL telescope is based on an eccentric pupil two-mirror classic Cassegrain configuration coupled to a tertiary off-axis paraboloidal mirror.

The 1-m diameter primary mirror (M1) is one of the main technical challenges of the mission. A trade-off on the material to be used for its manufacturing was carried out, together with optical analyses and the realization of a mirror prototype.

1. Introduction

Following the detailed material trade-off analysis conducted in the assessment phase of the mission, the material adopted for the whole telescope, i.e. mirrors and structure, is aluminium [3].

For the fabrication of space telescopes observing in the infrared wavelength range, nowadays metals, like aluminium alloys, are frequently considered. In fact, aluminium alloys have proved to be an excellent choice both for IR small size mirrors and structural components, but the manufacturing and thermo-mechanical stability of large metallic optics still have to be demonstrated, especially at cryogenic temperatures.

So, a dedicated pathfinder mirror telescope program has been adopted to study, realize and test an ARIEL primary mirror prototype.

2. Telescope optical design

ARIEL is based on a 1-m class telescope ahead of two IR spectrometer channels covering the band 1.95 to 7.8 μm. In addition, photometric channels are used for fine guidance and photometry, three for visible and NIR light photometry (FGS1&2 and Vis-Phot) and one (NIRSpec) used as a low-resolution spectrophotometer [4].

The ARIEL system has a fore-module common afocal telescope that will feed the whole spectrometer and the photometric channels. The optical design of the telescope has been conceived to satisfy the scientific and optical requirements [5].

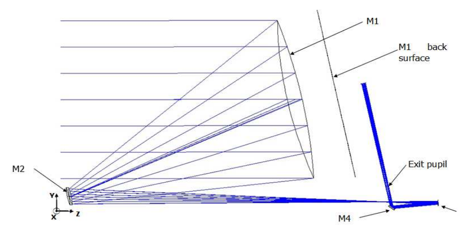

Figure 1: ARIEL telescope optical layout.

The telescope configuration is based on a classic Cassegrain layout (M1 and M2 mirrors) used with an eccentric pupil and coupled to a tertiary off-axis paraboloidal mirror, M3, (see Figure 1). A flat folding mirror (M4) redirects the beam towards the spectrometer and the photometric channels. The combination of M1 and M2 gives a 14 m focal length telescope. The optical design has been conceived to be diffraction limited, with a residual RMS wavefront error of about 20 nm.

3. The primary mirror

The ARIEL telescope will be realized on-ground, at 1 g and room temperature environmental conditions, but it shall operate in space at about 50 K. For this reason, a detailed tolerance analysis was performed to assess the telescope expected performance [6].

M1 is an off-axis section of a paraboloidal mirror and will be machined from a single blank as a stand-alone part. To prove the feasibility of such a large aluminium mirror, a pathfinder mirror program (PTM) has been started. The prototype, with the same size of the M1 flight model but a simpler surface profile, has been realized and tested, so far at room temperature, by Media Lario S.r.l.. Cryogenic testing of the prototype will be performed during Phase B1.

3.1 Pathfinder mirror program

Considering the time constraints and available funding, the planned baseline scope for the PTM was to manufacture, and test at ambient temperature, a full-size simplified spherical mirror, with surface and roughness quality less demanding w.r.t. the FM.

Figure 2: The PTM mirror prototype.

The curvature radius assumed for the PTM corresponds to the calculated best fit sphere of the considered off-axis paraboloidal part of the primary mirror.

The procured aluminium blank has been rough machined and lightweighted, then diamond turned. Finally, an ad-hoc set-up to avoid the effect of gravity has been first analyzed and then used to measure the actual mirror surface properties.

As for the obtained results, concerning the radius of curvature it is within 0.1% of its nominal value, while the residual surface shape accuracy is about 2 μm.

Further activities are in progress to test the figuring and polishing process.

4. Summary and Conclusions

The design and realization of a 1-m prototype aluminium mirror developed in the framework of the ARIEL ESA mission have been described.

The characteristics of the telescope optical design have been briefly described and the steps and aims for the development of a primary mirror prototype have been given.

Future activities are foreseen to be undertaken in Phase B to improve the manufacturing process and to assess the prototype behavior in cryogenic environment.

Acknowledgements

This work has been carried out with the financial support of the Italian Space Agency to the ARIEL project in the framework of the ASI-INAF agreement 2015-038-R.0.

References

[1] Puig, L. et al., ARIEL: an ESA M4 mission candidate, Proc. SPIE. 9904, 99041W, 2016.

[2] Tinetti, G. et al., The science of ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey), Proc. SPIE 9904, 99041X, 2016.

[3] Da Deppo, V. et al., ARIEL telescope material Trade-off, ARIEL-INAF-PL-TN-004_2.0, 2017.

[4] Eccleston, P. et al., An integrated payload design for the Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL), Proc. SPIE 9904, 990433, 2016.

[5] Da Deppo V. et al., An afocal telescope configuration for the ESA ARIEL mission, CEAS Space J., 2017.

[6] Da Deppo, V. et al., The afocal telescope optical design and tolerance analysis for the ESA ARIEL Mission, Proc. SPIE 10590, 105901P , 2017.

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Generating JWST transiting exoplanet time series data-set

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Abstract

To prepare JWST observations of transiting exoplanets, we have developed a generator of time series spectra from exoplanet(s)–star systems as the planet orbit its host star. When coupled with a telescope-instrument simulator, it generates representative sets of data, which are used to optimize data reduction methods, retrieval methods and to identify the impact of various effects (limb darkening, 3D versus 1D exoplanet models). One of the first applications is the simulation of JWST observations of the WASP-43b exoplanet with the MIRI instrument in slitless low-resolution mode.

1 Introduction

The James Webb Space Telescope, to be launched in 2020, will open new perspectives in astrophysics and especially in exoplanets observations. Twenty-five percent of the JWST observing time in the framework of GTO (Guaranteed Time Observations) and ERS (Early-Release Science) programs will be dedicated to exoplanet observations. Most of them aim at characterizing exoplanet atmospheres (vertical structure, molecular content, hazes, clouds, winds, etc.). The JWST will bring a large collecting area and a large wavelength coverage (0.5 – 28 microns), with 3 instruments in the 0.5-5 microns range (NIRISS, NIRCAM and NIRSPEC) and one instrument in the 5 – 28 microns range (MIRI). To take full advantage of the JWST capabilities when observing transiting exoplanets, relative spectro-photometry precision down to the 10 ppm level should be achieved. This is not easy and the lesson learned from Spitzer and Hubble observations is that good knowledge of the instrumental systematic effects and their corrections are necessary to infer robust conclusions on the exoplanet atmospheres from the data. As the choice of data detrending method may affect the scientific results, instrument simulators have been developed to create benchmark data for testing the data reduction pipeline of Spitzer transit observations [1] and of HST transit observations [2]. Here we present a first version of the spectrum compiler (exoNoodle) and its first results. Coupled with the JWST-MIRI instrument simulator (MIRISim [3]), it can deliver representative time series data sets.

2 exoNoodle and MIRISim

ExoNoodle is a spectrum compiler to create a time series synthetic spectrum for the JWST exoplanets program. At each step of a time series, the compiler calculates the spectrum expected from the star and planet(s) system. It comes as Python package. Even though exoNoodle is developed with MIRI-LRS study case, it can be easily used for other MIRI observational modes or other instruments.

The code has to be versatile, along with the possibility to manage individual contributions from diverse models. The fig.1 describes the configuration chosen to achieve this. It shows the sequence of a computation, for a single run. Special attention is taken to calculate precisely ingress and egress. Three different type of variables or objects are described:

External These are the objects of interaction with the user. The variables are represented in light grey and in dark grey the files themselves. The source files are the data created from exoplanet or star models.

Calculation In green are the elements necessary for the computation, that will be created by the software based on the information given in the configuration by the user. In light green are the variables or dictionary. The darker boxes are the objects and their content (method, specified).

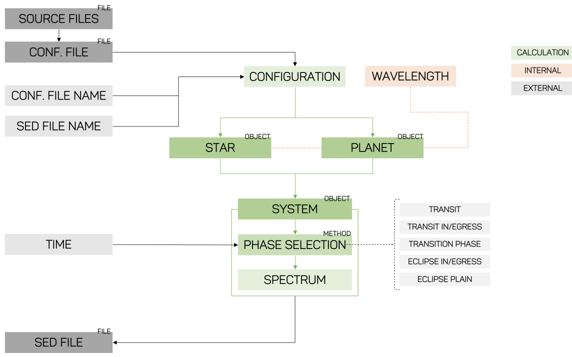

Figure 1: Sequential description of exoNoodel structure.

INTERNAL The internal variable, in light red, doesn't interfere formally with the computation. It is the wavelength on which all the λ-dependant variables are interpolated so that the computation is easier. The resolution of this wavelength array is chosen so that the sampling is good for JWST/MIRI LRS-Slitless, for further use by MIRISim. If no wavelength is chosen, this will be the star spectrum wavelength resolution.

The default values are the Sun/Jupiter system. The different models are read individually from files. The contributions taken are the following:

- **Star Spectrum**
  Default : Blackbody with temperature
  File : Modelled spectrum up to a map

- **Stellar Limb-Darkening**
  Default : Homogeneous star
  File : Values for various formulation of limb-darkening coefficients

- **Planet Emission Spectrum**
  Default : Blackbody with day and night temperature
  File : Modelled spectrum up to a map

- **Planet Reflection Spectrum**
  Default : Jupiter geometric albedo
  File : Albedo integrated on the surface or a map, especially with clouds, wavelength-dependent

- **Planet Transmission Spectrum**
  Default : None (no atmosphere)
  File : Modelled as a variable $R_p(\lambda)$, with possible inhomogeneities

It is already possible to combine several launches of the code to create a multi-planet system. This option will be better implemented in the package options later-on, along with the possibility to have a de-phase locked planet and the stellar spot activity (map).

3 Conclusions

We have created a software able to collect exoplanet and star models, to combine them and to create a representative transit, eclipse or phase curve data and to combine it with the instrument simulator. One of the first uses of the couple exoNoodle and MIRISim will be to provide data sets to test new spectral extraction, calibration and retrieval methods developed in the framework of the exoplANETS-A H2020 project. Another foreseen use is to generate a set of data representative of MIRI-LRS observations of WASP-43b as input for the data challenge to be organized in the framework of the 'Transiting Exoplanet Community Early Release Science program for JWST'.

Acknowledgements

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement 776403. M. Martin-Lagarde is partly funded by a CNES scholarship.

References

[1] James G. Ingalls, J. E. Krick, S. J. Carey, John R. Stauffer, Patrick J. Lowrance, Carl J. Grillmair, Derek Buzasi, Drake Deming, Hannah Diamond-Lowe and Thomas M. Evans: Repeatability and accuracy of exoplanet eclipse depth measured with post-cryogenic Spitzer, The Astronomical Journal, Vol. 152, 2016.

[2] R. Varley, A. Tsiaras, and K. Karpouzas: Wayne—A Simulator for HST WFC3 IR Grism Spectroscopy, The Astrophysical Journal, Vol. 231, 2017.

[3] MIRI European Consortium, MIRISim Documentation - Release 1.0.0, March 26, 2018

EPSC Abstracts
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Atmospheric characterisation of directly imaged exoplanets with JWST/MIRI

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Abstract

The next major space facility to characterise the atmosphere of exoplanets will be the JWST. Of particular interest is the Mid-Infrared Instrument (MIRI) which will give access, for the first time, to the 5 - 28 μm part of the spectrum of young giant exoplanets at a wide enough angular separation from their host star to be observed by direct imaging. Retrieving the precise set of parameters of these objects, such as luminosity, temperature, surface gravity, mass, and age is extremely important as it supplies information about the initial entropy of the planets and hence it allows us to shed light on their formation mechanism. The new extreme adaptive optic cameras (e.g., SPHERE, GPI) are already providing excellent constraints on these parameters, but the spectral range in which they operate is limited to near infrared so that the uncertainties are still significant. Observations taken on a longer wavelength range are mandatory for reducing them. In this context MIRI will play a key role allowing, in conjunction with shorter wavelength measurements, the exhaustive characterisation of the exoplanetary atmospheric properties. Additionally, MIRI will give us the opportunity to probe for the first time the presence of ammonia in the atmosphere of the coldest known young giants. Notice that the ammonia spectral signature is a further useful indicator of equilibrium and temperature in the planetary atmosphere. In this work we simulate the MIRI coronagraphic observations for a set of 8 known directly imaged exoplanetary systems by using the Exo-REM model. For each planet we estimated the signal-to-noise of MIRI coronagraphic observations as a function of various observing telescope conditions. Subsequently we measure to which accuracy the exoplanetary parameters can be determined when adding MIRI observations to existing near-infrared ones. Finally we provide the significance of the ammonia detection.

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NIRPS: Near-Infrared Planet Searcher to join HARPS on the ESO 3.6-m telescope

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Abstract

The Near-InfraRed Planet Searcher (NIRPS[1]) is a new ultra-stable infrared (*YJH*) spectrograph that will be installed on ESO 3.6-m Telescope in La Silla, Chile. Aiming to achieve a precision of 1 m s^{-1}, NIRPS is designed to find rocky planets orbiting M dwarfs, and will operate together with HARPS. Here we describe the NIRPS science cases and present its main technical characteristics.

1. La Silla - Paranal Observatory: a hub for extrasolar planet research

Our knowledge of the frequency and architecture of planetary systems and their nature has been revolutionized in the last two decades thanks to various detection techniques providing complementary measurements. Observational efforts were undertaken with ground- and space-based facilities, notably radial velocity (RV) surveys using high-precision spectrographs and transit surveys. The forthcoming space armada, initiated by the launch of TESS in 2018, CHEOPS and JWST in 2019, and PLATO in 2026, will only spark a new revolution in the field of extrasolar planets if it is complemented by efficient ground-based facilities. The LaSilla-Paranal Observatory has a key role to play as it already hosts prime ground-based planet-finding facilities like HARPS, ESPRESSO, SPHERE, TRAPPIST, and NGTS. NIRPS will enable complementary precise RV measurements in the nIR with a precision of 1 m s^{-1}, specifically targeting the detection of low-mass planets around the coolest stars.

2. M dwarfs: a shortcut to habitability and life

While the detection of an Earth analogue around a Sun-like star requires a precision of better than 10 cm s^{-1}, M dwarfs offer a more accessible and attractive means of achieving the above goals. The amplitude of the RV signal scales with $M^{-2/3}$, where M is the stellar mass. In addition, thanks to their much lower luminosity, the habitable zone of M dwarfs is typically 10 times closer than in the case of Sun-like stars. These combined effects imply that for a star of spectral type mid-M with an Earth-mass planet receiving an Earth-like insolation, the RV signal is on the order of 1 m s^{-1} and therefore detectable with state-of-the-art RV spectrographs. As M dwarfs are cool and emit most of their flux in the nIR, one needs to obtain RV measurements in this domain to reach the highest possible precision.

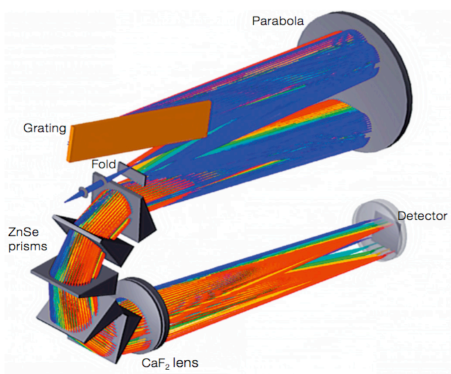
NIRPS has been designed to explore the exciting prospects offered by the M dwarfs, focusing on three main science cases:
- High-precision RV survey of M dwarfs
- Mass (and density) measurements of planetary candidates orbiting M dwarfs from transit surveys
- Atmospheric characterization via transmission spectroscopy

[1] *The NIRPS consortium is jointly led by Université de Montréal and Université de Genève and includes partners from Brazil (UFRN), France (IPAG, LAM), Portugal (Universidade de Porto and Universidade de Lisboa), Spain (IAC), Switzerland (University of Bern) and Canada (Université Laval, McGill University, Herzberg Institute of Astrophysics, Royal Military College of Canada, York University, University of Toronto, University of Western Ontario, University of British Columbia).*

3. Specifications, overall design and expected performance

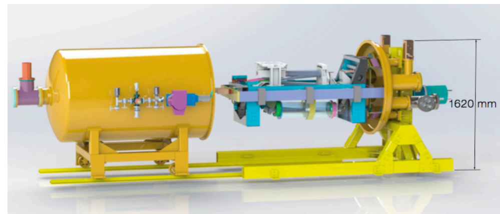
To achieve its science goals, NIRPS will operate in the *Y*-, *J*- and *H*-bands with continuous coverage from 0.97 to 1.8 μm. It will ensure high radial velocity precision and high spectral fidelity corresponding to 1 m s^{-1} in less than 30 min for an M3 star with H = 9. Its spectral resolution will be 100,000 to best exploit the spectral content. It will be operated simultaneously with HARPS without degrading the HARPS performance.

NIRPS is part of a new generation of adaptive optics (AO) fiber-fed spectrographs. NIRPS will use a 0.4-arcsecond multi-mode fiber, half that required for a seeing-limited instrument, allowing a spectrograph design that is half as big as that of HARPS, while meeting the requirements for high throughput and high spectral resolution. A 0.9-arcsecond fiber will be used for fainter targets and degraded seeing conditions.



The entire optical design is oriented to maximize high spectral resolution, long-term spectral stability and overall throughput. Light exiting from both object and calibration fiber links is collimated by a parabolic mirror used in triple pass and is relayed to an R4 echelle grating. The diffracted collimated beam is focused by the parabola on a flat mirror that folds the beam back to the parabola. The cross dispersion is done with a series of five refractive ZnSe prisms that rotate the beam by 180°. A four-lens refractive camera focuses the beam on a Hawaii 4RG 4096 × 4096 infrared detector. The instrument covers the 0.97 to 1.81 μm domain on 69 spectral orders with a 1 km s^{-1} pixel sampling at a resolution of 100,000 (HAM) or 75,000 (HEM). The global throughput of the spectrograph alone is estimated to be 30% at 0.97μm and 45% at1.81μm.

The spectrograph is installed inside a cylindrical cryostat (1.12-m diameter, 3.37-m long) maintained at an operating temperature of 80 K with a stability of 1 mK and an operating pressure of 10^{-5} mbar.



The HARPS and NIRPS spectrographs can be operated individually or jointly. The default operation mode will see both instruments operating simultaneously, except for high-fidelity polarimetric observations with HARPSpol.

4. Summary and Conclusions

In return for the manpower effort and financial contributions of the consortium to design, build, maintain and operate NIRPS for five years, ESO will grant the consortium a period of Guaranteed Time Observation (GTO) corresponding to 40% of the 3.6-m Telescope time, leaving ample time for community-driven science topics. In order to be in phase with future space missions such as TESS, CHEOPS, JWST and PLATO, NIRPS is being developed on a fast track; its first light is scheduled for the last quarter of 2019. As of mid-2018 the design of the instrument has been finalized and construction and integration has started.

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ARIEL Fine Guidance System Design

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Abstract

The Fine Guidance System (FGS) of the ESA M4 mission ARIEL is provided by the payload consortium and is designed as a science instrument with payload in the loop functionality. Its main task is to ensure the centering, focusing and guiding of the satellite, but it will also provide high precision astrometry and photometry of the target star for complementary science. In particular, the data from the FGS will be used for de-trending and data analysis on ground.

1. Mission and Instrumentation

ARIEL (Atmospheric Remote-sensing Exoplanet Large-survey) will observe known exo-planets with a metre-class telescope and gather spectroscopic and photometric data to study the planets' atmospheres [1]. Its instrumentation consists of a photometer for the 0.50-0.55 µm range (VIS-Phot), two FGS channels covering the 0.8-1.0 µm and 1.0-1.2 µm ranges, as well as NIR-Spec, an infrared spectrometer covering two medium-resolution channels (1.95-3.9 µm and 3.9-7.8µm) and one low-resolution channel (1.25-1.95 µm). All of the instruments operate simultaneously. They share the same input beam, which is divided by three dichroic beam-splitters and one band-pass filter. The spectrometer beam also contains a prism. This concept of the dichroic system with prism is shown in Figure 1.

1.1 FGS

While the VIS-Phot and the NIR-Spec instruments are controlled by the instrument control unit (ICU) [2], the FGS channels have their own independent electronics. Each FGS channel is able to provide guiding information to the spacecraft at a rate of 10 Hz with 0.01 arcsec precision. Each FGS also collects the image data of the target star, compresses and sends them to ground along with metrology and housekeepings.

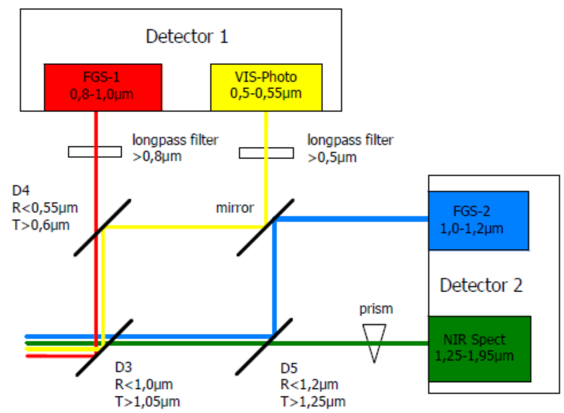

Figure 1: Scheme of the dichroics system. "Detector 1" denotes the visual channels and "Detector 2" denotes the NIR channel of the FGS and the spectrometer.

2. FGS Design

The FGS is composed of the optics box and the electronics box. The optics box is situated at the instrument optical bench (IOB) containing cryogenic optics with two detector modules at 50 K and the cold front-end electronics (CFEE).

The electronics part – FGS Control electronics Unit (FCU) is accommodated in the spacecraft service module at a temperature of 270-300 K. The FCU modules control and read the detectors and carry out the data processing for centroid calculation and image processing. The FGS systems are independent from the spectrometer instrument, thus have their own power and data interfaces with the spacecraft. The FGS is also involved in the focusing of the main telescope. This will be done using images from the two detector arrays, which have different focus offset. The procedure will be controlled interactively from ground.

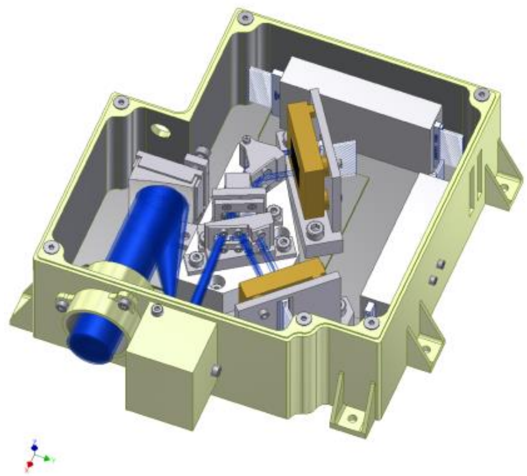

Figure 2: FGS module for optics and detectors.

2.1 Optical Design

The optical module has been designed with the following basic assumptions:

- FoV – max usable on sky FGS FoV is 25.2”, corresponds with ±0.19 deg (FGS internal)
- Spectral bandwidth: 0.5-1.95 µm is split into four bands
- MCT detector FPA with minimum array and pixel size (18 µm for MCT) and ~1024x1024
- Low distortion (< 1% level over FoV)
- Minimum bin/star image spread FWHM: 6x6 pixels
- Able to achieve centroiding to 1/10th of a pixel level
- WFE: 250 nm rms = telescope diffraction limit @ 3 µm + allocation for dichroics

The FGS uses an off–axis Gregorian mirror telescope internally. It has a focal length of 500 mm and an F-number of 25. Inside the optics box are the detectors and the cold read-out electronics. The baseline for the detectors is to use H1RG TELEDYNE devices with with its SIDECAR read-out electronics, a European detector option with a pixel size of 15 µm is optional and subject to the outcome of an on-going development study.

2.2 Electronics Design

The FGS has its own control electronics in the service module of the spacecraft to carry out all necessary communication, control and data processing tasks.

The FGS control electronics are housed in a typical warm electronics box, with a total mass estimation of 5.5 kg. They consist of power supply and digital electronics – the Data Processing Unit (DPU) – in a redundant configuration. The DPU design is base on the Aeroflex GR712RC processor and uses SpaceWire interfaces for communication.

2.3 Flight Software Design

The FGS application software will control and read the FGS detector electronics, establish a control loop with the spacecraft and deliver scientific data products. The telemetry contribution of the FGS is below 4 kbit/s if no images are sent and below 79 kbit/s for measurement mode. The FGS application software will offer its functionality in the form of ECSS service commands and reports. The software includes fault detection, isolation and recovery (FDIR) functionality and offers several modes of operation to support maintenance and calibration activities.

3. Conclusion

The FGS for ARIEL will be developed by CBK-PAS, the University of Vienna and RAL. It will ensure the high-precision guiding of the telescope and provide complementary science data.

References

[1] Tinetti, G., et al.: The science of ARIEL, EPSC 2017-713, September 2017

[2] Focardi, M., et al.: The ARIEL Instrument Control Unit design, Experimental Astronomy, November 2017.

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The Transiting Exoplanet Survey Satellite (TESS): Searching for Planets Around Nearby Stars

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Abstract

The Transiting Exoplanet Survey Satellite (TESS) is a NASA Explorer mission designed to find thousands of new exoplanets around bright, nearby stars. TESS was selected for Phase A (preliminary) design by NASA in 2011, and over the following seven years a wide array of partners worked together to make the mission a reality. TESS launched successfully on April 18, 2018, from Kennedy Space Center. Following the Commissioning period, TESS will enter science operation in June 2018. At this meeting, we will present the design of the TESS instrument along with the latest available information on instrument performance.

1. Introduction

At the time of this writing (May 15, 2018), TESS is still in the Commissioning phase. Early analysis of Commissioning data shows that the spacecraft and instrument are both performing well. Below, we briefly discuss the mission. A detailed discussion of the TESS instrument design can be found elsewhere [1].

2. The TESS Mission

The TESS instrument consists of four wide-field cameras, developed at Lincoln Laboratory and MIT's Kavli Institute, each with a field-of-view of 24°×24°; the four camera fields are lined up to give an instantaneous field of view of 24°×96°, extending from 6° above the ecliptic plane to 12° past the ecliptic pole. TESS stares at a given field, referred to as an observation sector, for two orbits (each orbit is 13.7 days), the advances forward to the next sector. In the first year of science operation, TESS will observe 13 sectors in the southern hemisphere, covering approximately 85% of the southern sky. This pattern will be repeated in the second year for the northern hemisphere.

Figure 1: The TESS cameras were integrated into the spacecraft at Orbital/ATK in Sterling, VA.

During the two-year prime mission, TESS will operate with two simultaneous data modes; for 200,000 stars, TESS will collect "postage stamp" data at a 2-minute cadence, spread across all 26 observation sectors. It will also collect full-frame images, encompassing the entire field-of-view, every 30 minutes.

Data from the spacecraft is downlinked once per orbit, and is subsequently processed at NASA's Ames Research Center, using a data reduction pipeline developed upon the Kepler pipeline. Once data reduction is complete, the processed data goes to the TESS Science Office at MIT for validation and verification. The first data release will occur 6 months after the start of science operations.

Figure 2: TESS, fully integrated at Orbital/ATK.

3. Expectations

TESS is expected to find thousands of new exoplanet candidates, from both the postage-stamp data and the full-frame images [2, 3]. With follow-up observations, both funded through the TESS Project and through the efforts of the broader community, it will be possible to confirm a significant fraction of these candidates. And, because these planets will be around relatively bright stars (typically 30-100x brighter than Kepler targets), they will be ideal candidates for follow-up observations with JWST, Ariel, and future large ground-based telescopes.

Acknowledgements

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT's Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Orbital ATK, NASA's Ames Research Center, the Harvard-Smithsonian Center for Astrophysics and the Space Telescope Science Institute. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

References

[1] Ricker, G. et al.: Transiting Exoplanet Survey Satellite (TESS), JATIS, Vol. 1, 4003, 2015.

[2] Sullivan, P., et al: The Transiting Exoplanet Survey Satellite: Simulations of Planet Detections and Astrophysical False Positives, ApJ, 809, 77, 2015.

[3] Barclay, T., Pepper, J., & Quintana, E.: A Revised Estimate of the Yield from the Transiting Exoplanet Survey Satellite (TESS), ApJ, submitted. arXiv:1804.05050

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The EXoplanet Infrared Climate TElescope (EXCITE)

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Abstract

The EXoplanet Infrared Climate TElescope (EXCITE) is a proposed low resolution 1-4 μm spectrograph that will measure emission spectra of hot Jupiters over their full orbits, providing phase resolved spectroscopy. These spectral measurements probe varying depths in exoplanets atmospheres thus contributing to our understanding into atmospheric physics, chemistry and circulation. Hot Jupiters provide an ideal laboratory for understanding atmospheric dynamics. EXCITE uses a commercially available 0.5 m diameter telescope pointed with high accuracy and stability using the successful Balloon Imaging Testbed (BIT) pointing platform. The telescope is coupled to a cooled spectrometer made from commercially available components. The combination of these elements results in a unique instrument for exoplanet atmospheric characterization. EXCITE's initial science will result from an antarctic long duration balloon flight.

1. Introduction

EXCITE will measure spectroscopic phase curves of bright, short-period extrasolar giant planets (hot Jupiters) over full orbital periods. The resulting phase-resolved spectroscopy maps the temperature profile and chemical composition of the planet as a function of planetary longitude. The wavelength range covers the peak in the planet's spectral energy distribution and H_2O, CO_2 , CO, CH_4 , TiO and VO spectral features. These data, combined with state-of-the-art 3D general circulation models (GCMs), will be used to study the atmospheric dynamics and chemistry in these strongly-irradiated planets. This will allow to to refine these models and improve their predictive power. Ultimately, the spectroscopic phase curves obtained from EXCITE can be used to study the links between the atmospheric properties of hot Jupiters and their formation, bulk properties, orbital dynamics and environment.

No existing instrumentation covers the whole EXCITE spectral range, essential to measure unambiguously the planet's global energy budget. Phase curves observations are time-consuming and observations are difficult to be allocated in the observing schedule of multi-purpose observatories. Flying on a long duration balloon (LDB), EXCITE will fulfill a critical need as the first dedicated instrument for exoplanet atmospheric characterization in the next decade, until the launch of the ARIEL space mission.

2. Science Objectives

The primary goal of EXCITE is to obtain spectroscopic phase curve observations to constrain the global energy budget and circulation in hot Jupiters. Because each phase curve probes multiple wavelengths and pressures, these observations will map out the exoplanet's longitudinal heat distributions and vertical atmospheric structures.

Comparisons of phase curves measured at a range of wavelengths reveal how the relevant radiative, chemical, and dynamical timescales vary as a function of atmospheric pressure. EXCITE will naturally observe secondary eclipses and transits as well. Phase curve allows to constrain the global and spatially resolved energy budget of the planet, whereas transit/eclipse spectroscopy will provide the chemical bulk-compositions at the day side and the terminator, as well as a direct measurement of the vertical temperature profile of the atmosphere at the day side. By observing through the peak of the exoplanet's SED ($\sim 2\,\mu$m), EXCITE can directly constrain the global energy budget and circulation patterns. EXCITE will make further advances in our understanding of the diversity of hot Jupiter and the differences in the physics and chemistry of their atmospheres, particularly with respect to cloud formation and distribution.

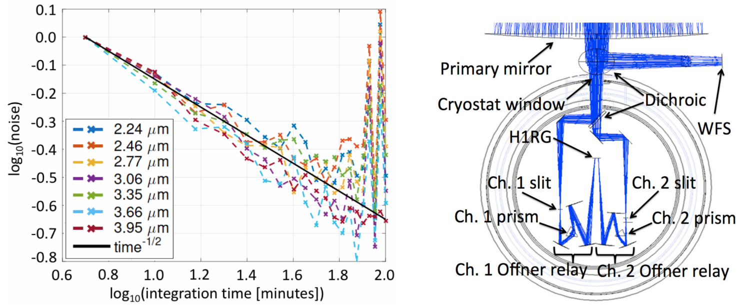

Figure 1: **Left**: Results of the EXCITE end-to-end simulation for an observation of the phase curve of WASP-18b. We show measurement noise across channel 2 as a function of integration time. Correlated effects do not contribute to the noise for measurements shorter than ~ 90 minutes. **Right**: Optics ray tracing.

3. Design and performance

EXCITE will use mostly off-the-shelf components. Optical ray-tracing is shown in Figure 1. The telescope from Officina Stellare has a diameter of 0.5 m. One ambient-temperature dichroic filter reflects wavelengths shorter than 1μm and transmits longer wavelengths. The reflected light is used to feed a fine pointing/wave-front sensor which provides the telescope attitude error. IR light propagates through cold optics (77 K) inside a long duration cryostat. Light is further split into two channels. Channel 1, covering the $1\,\mu$m to $2\,\mu$m, and Channel 2 from $2\,\mu$m to $4\,\mu$m with an extended sensitive tail to $5\,\mu$m. Cold slits are placed at the two prime foci, feeding two spectrometers with a spectral resolving power of $\lambda/\Delta\lambda \simeq 50$. The output of both spectrometers are imaged onto a single Teledyne H1RG detector ($\lambda_c = 5.3\,\mu$m). At a 77 K operating temperature the dark current is below $1e^{-}$/s. The BIT–type gondola and pointing system have demonstrated < 100 mas stabilization (Romualdez et al. ArXiv 2016).

Performance is studied through ExoSim's (Sarkar, SPIE 9904, 2016) time-domain end-to-end simulations. Simulations include photon noise from target, from the 4 mbar residual Earth atmosphere, and from instrument thermal emission. We have also implemented a balloon-specific model to account for the most challenging effects expected at stratospheric altitudes. Slit losses are made negligible by ensuring that input slit widths are at least one Airy diameter at the red-end of each spectroscopic channel. Photometric uncertainties arising from pointing jitter are made negligible by the combination of BIT's pointing stability and by Nyquist-sampling the spectral images in both spatial and spectral directions, reducing intra- and inter-pixel effects. Typical flight altitude fluctuations with ~ 1 km amplitude and 24 hr period, and ~ 50 m amplitude with ~ 5 min period induce atmospheric emission, transmission and instrument temperature variations. Simulations show that these effects are either negligible, or accountable in post-processing. Similarly, stellar variability over the time scale of the target orbital period are shown to be negligible post-processing. Simulation of all these effects and a post-processing pipeline are used to estimate the experimental uncertainties shown in Figure 1, and to compile the LDB target list.

4. Observations

The 1 to $4\,\mu$m region of the spectrum is not accessible by ground based or even airborne instrumentation due to atmospheric absorption. A Stratospheric balloon platform, reaching altitudes of $\sim$38 km, provides an alternative to space instrumentation. Flying from Antarctica during the Austral summer allows EXCITE to observe under stable conditions. The LDB target list includes 17 transiting hot jupiters that never set during the flight campaign (December–January). EXCITE will continuously observe a planet during one revolution, minimizing instrument-induced systematics. The target list includes, at the time of writing, WASP discovered planets in the Southern Hemisphere. It is expected that by the time EXITE will be flight-ready in 2022 the list will be enriched by new discoveries from ground based surveys, and space missions like TESS.

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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.

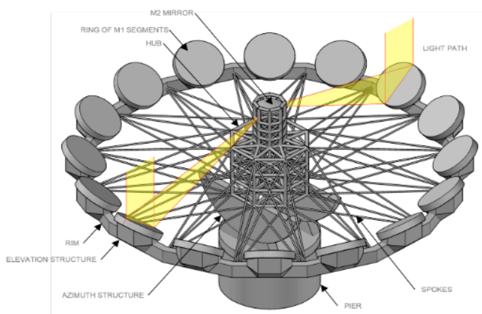


Figure 1: The ELF Gregorian-focus opto-mechanical configuration

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.

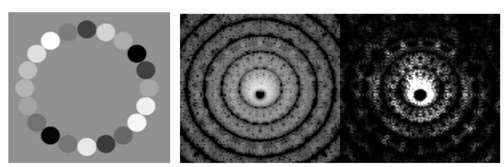


Figure 2: Synthetic PSF Left: phase (greyscale 0-360 deg), Center: Log10 PSF 8 decades, Right: Log10 RMS speckle noise 6 decades

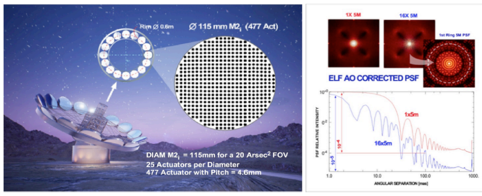
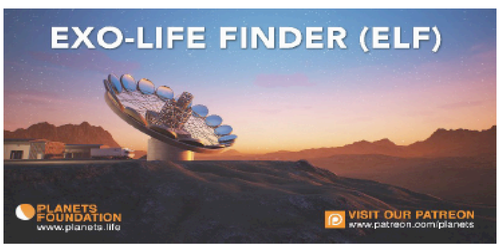


Figure 3: [Left] Each of M2i (i=1..16) is a locus for an independent deformable mirror of 115mm in diameter on a rim of 0.6m. For a field of view of 20 arcsec2 such deformable mirror M2i will be filled of 477 actuators, i.e. 25 actuators per diameter for a 4.6mm pitch. [Right] The initial parameters 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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References

[1] http://www.tmt.org
[2] http://www.eso.org/sci/facilities/eelt/
[3] http://www.gmto.org/
[4] Kuhn J.R., Berdyugina S.V., Langlois M., Moretto G., Harlingten C., Halliday D.: Looking beyond 30m-class telescopes: the Colossus project, SPIE Conf. 9145, 91451G, 8 pp. (2014).
[5] Kuhn, J. R. and Berdyugina, S.V., "Global warming as a detectable thermodynamic marker of Earth-like extrasolar civilizations: The Colossus project," Int. J. Astrobiology, submitted (2014)
[6] Berdyugina, S.V., & Kuhn, J.R.: Surface Imaging of Proxima b and Other Exoplanets: Topography, Biosignatures, and Artificial Mega-Structures, ApJ, arXiv:1711.00185 (2017).
[7] Capsal, J.-F. el al., "Enhanced electrostriction based on plasticized relaxor ferroelectric P(VDF-TrFE-CFE/CTFE) blends", Journal of Polymer Science Part B Polymer Physics 53(19) (2015)
[8] Baron, F., et al., "Unambiguous phase retrieval as a cophasing sensor for phased array telescopes", JOSA, A/25, 1000-1010 (2008).
[9] Lacour, S., et al. "A new interferometer architecture combining nulling with phase closure measurements", MNRAS 439, 4018-4035(2014).
[10] Loupias,M. ,Langlois, M.,Thiebaut, E., Tallon, M., Leger, J., Status of an extreme adaptive optics testbench using a self-referenced Mach-Zender wavefront sensor, SPIE, 9909, 4, (2016).