Exoplanets - The Ariel mission

Ariel Project Team

07/07/2022

Ground-based observatories

First discoveries of exoplanets in the 1990s opened up the field of exoplanet research. New innovations and discoveries continue to this day

Launch

1990 — **Hubble** (NASA, esa)

Probing the composition of exoplanet atmospheres

2003 — **Spitzer** (NASA)

Studying exoplanet signatures in infrared light

2006 — **Corot** (cnes, esa)

Pioneering stellar seismology and exoplanet hunting mission

2009 — **Kepler/K2** (NASA)

A targeted search for terrestrial and larger planets in or near the habitable zone of a wide variety of stars

2013 — **Gaia** (esa)

Revealing exoplanets through its all-sky survey of the position, brightness and motion of over one billion stars

2018 — **Tess** (NASA)

First all-sky transit survey satellite

2019 — **Cheops** (esa)

First step characterisation of known Earth-to-Neptune size exoplanets

Webb (NASA, esa, CSA)

Detailed characterisation of exoplanet atmospheres through transit studies and direct imaging

Plato (esa)

Studying terrestrial planets in orbits up to the habitable zone of Sun-like stars, and characterising these stars

Ariel (esa)

Performing a chemical census of a large and diverse sample of exoplanets by analysing their atmospheres

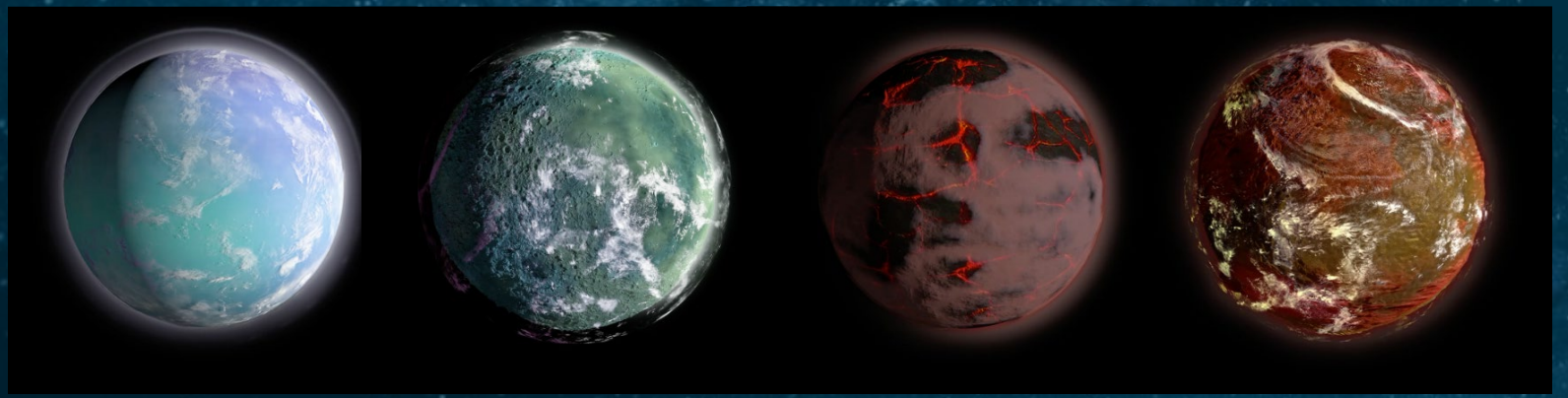
Dedicated exoplanet missions

Exoplanet-sensitive missions

Ariel: the next step to answer key science questions

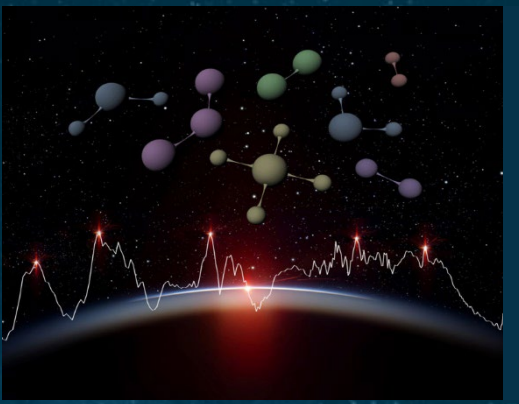
- *What are exoplanets made of?*
- *How do planets & planetary systems form?*
- *How do planets & their atmospheres evolve?*

Ariel will carry out the FIRST chemical census of a LARGE sample (av 1000) of DIVERSE Exoplanets



Examples of exoplanets which can be observed by Ariel:

1) Water covered, 2) Solid surface & clouded, 3) Seismically active, and 4) Hot Jupiter-like



Simultaneous wavelength coverage 0.5 – 7.8μm

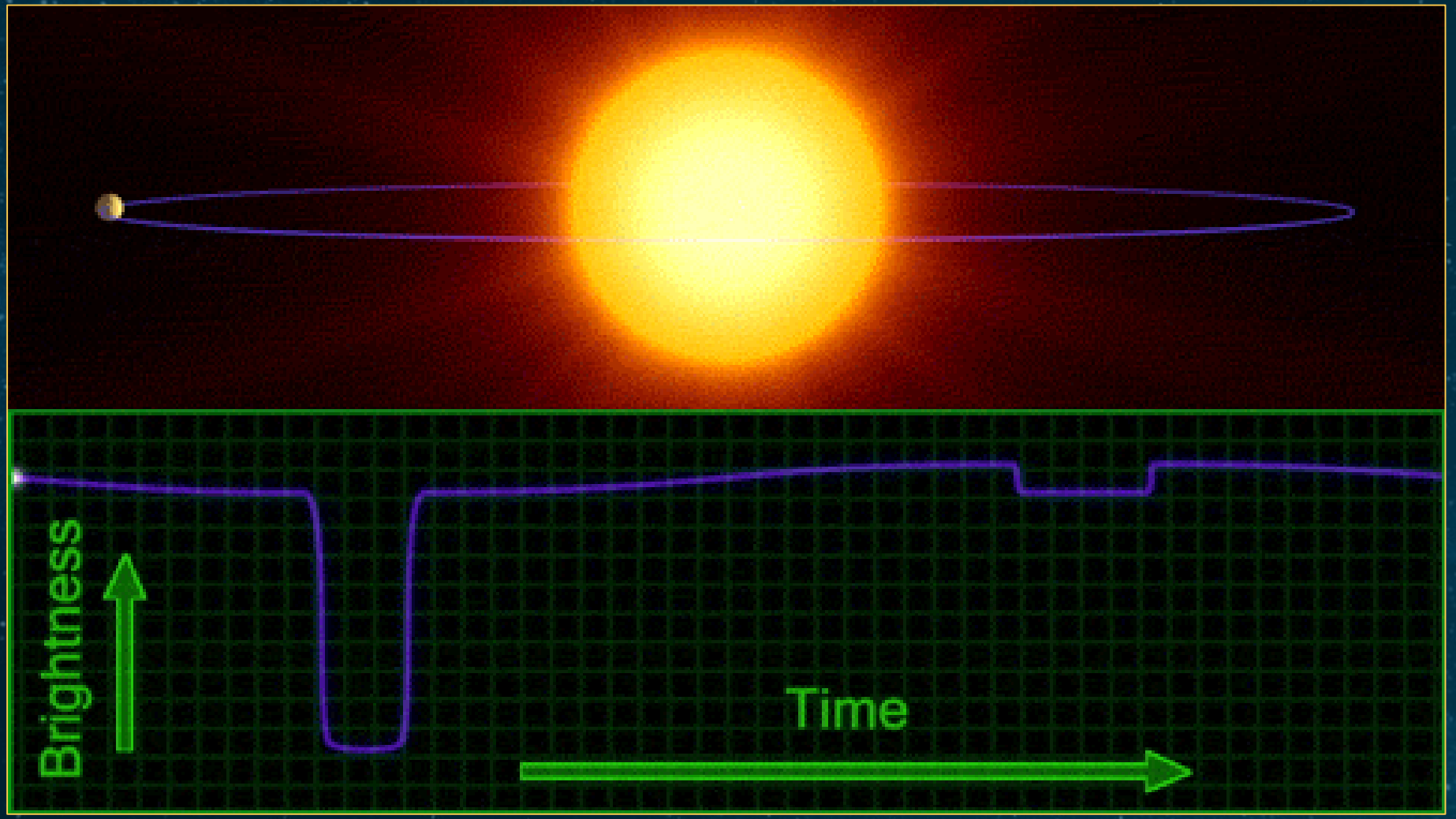
Molecules that can be detected by Ariel: atmospheric gases [H_2O, CO_2, CH_4 NH_3, HCN, H_2S] through to more exotic metallic compounds [TiO, VO, TiH, CrH] and condensed species

Progress in these areas fully relies on spectroscopic observations of hundreds of transiting planets, spanning different planet sizes, and equilibrium temperatures and orbiting a variety of stellar types. This is the goal of Ariel

Atmospheres of Exoplanets

Phase curve observations – light curves

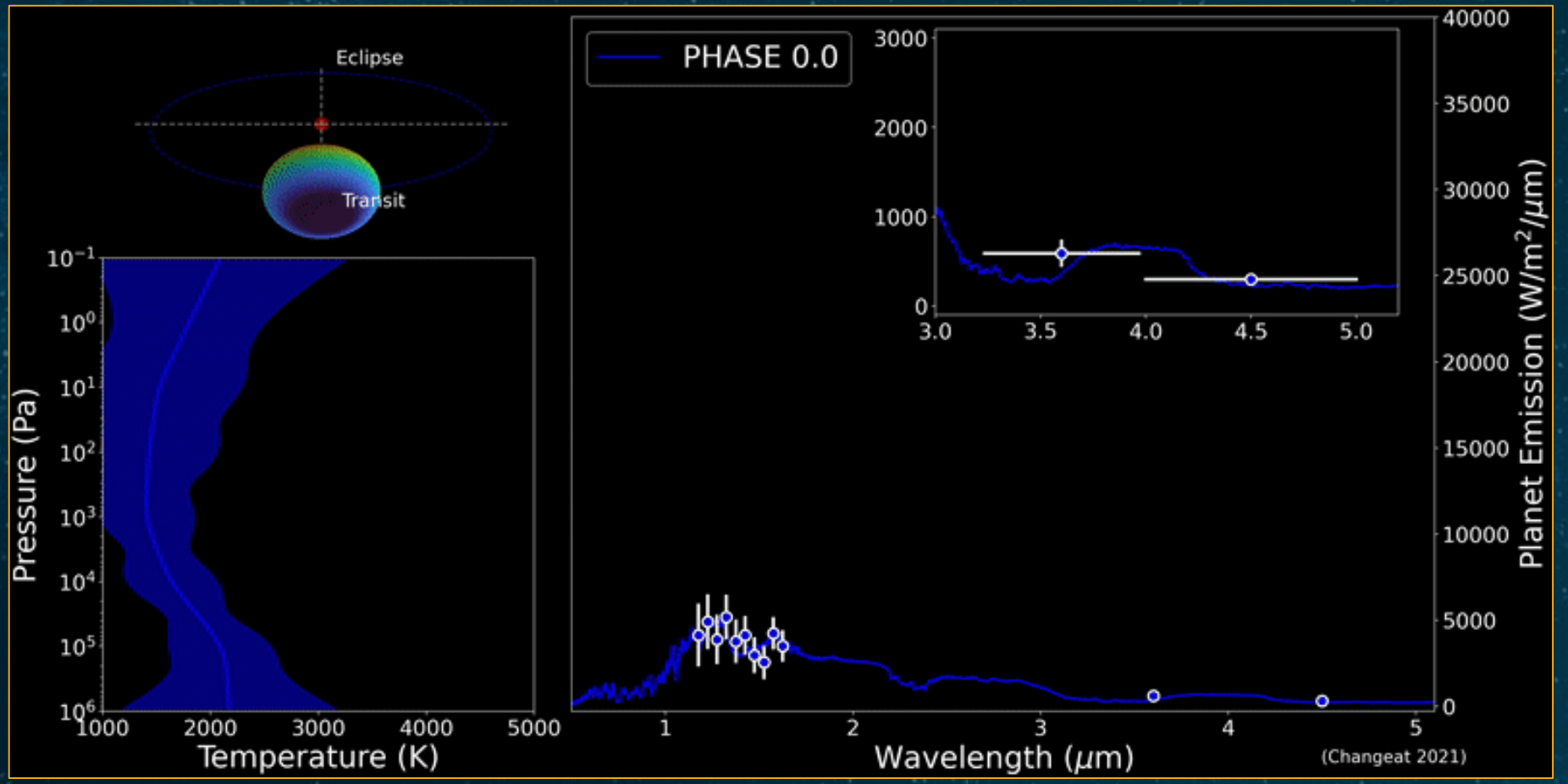
Observing the full rotational cycle



Atmospheres of Exoplanets

Phase curve observations - spectra

Observing the full rotational cycle spectroscopically



ARIEL FGS and AIRS instruments

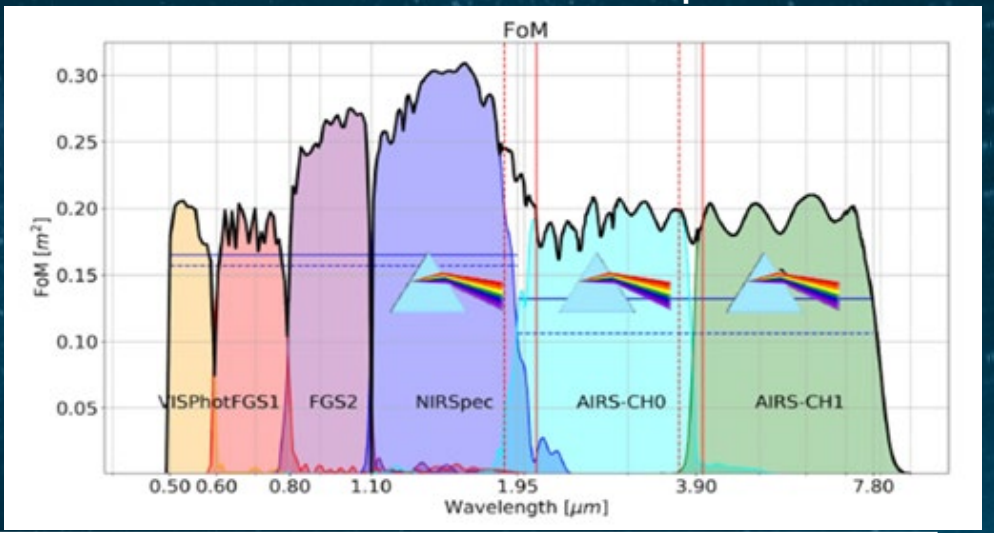
FGS Instrument:

Photometers (3 bands)
VISPhot, FGS1/2:
0.5-0.6, 0.6-0.8, 0.8-1.1 μm

Spectrometer
NIRSpec: 1.10-1.95 μm

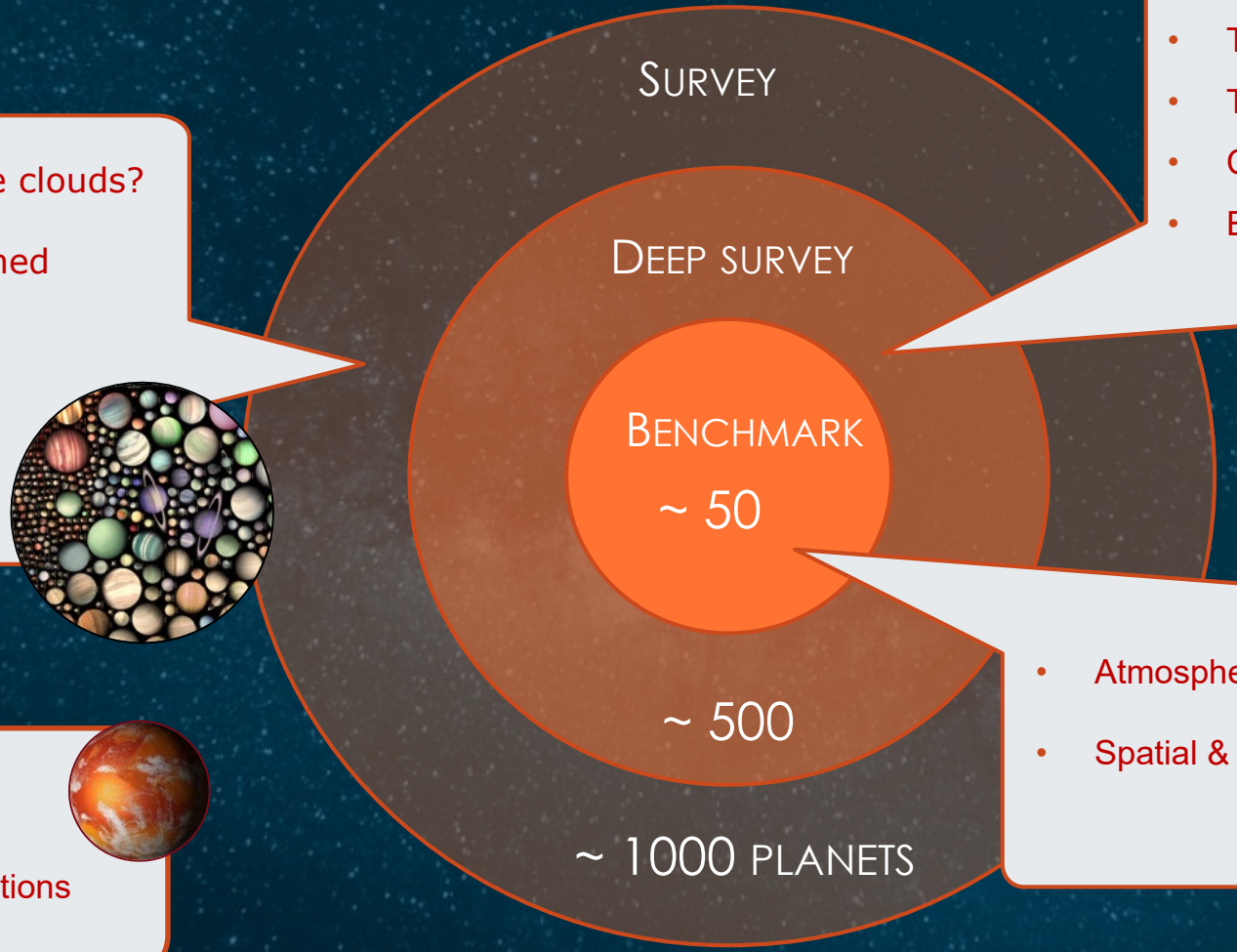
AIRS Instrument:

AIRS0: 1.95-3.90 μm
AIRS1: 3.90-7.80 μm



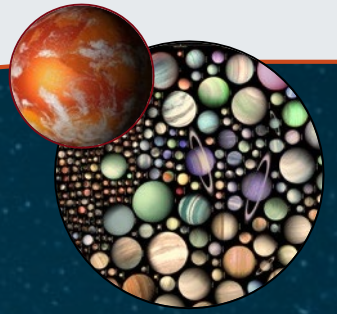
Ariel 3-Tier approach

INDIVIDUAL PLANETS & POPULATION ANALYSIS



- What fraction of planets have clouds?
- Have small planets still retained H/He?
- Colour-colour diagrams
- Refinement of orbital/planet parameters in IR

- Main atmospheric component
- Trace gases
- Thermal structure
- Cloud characterization
- Elemental composition



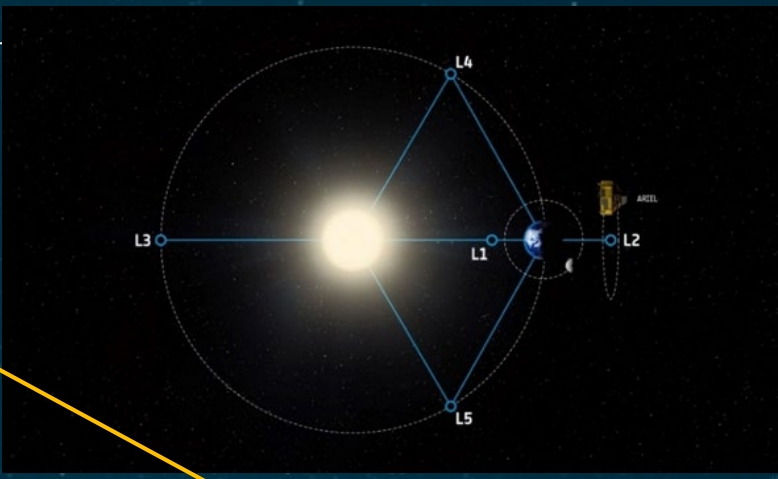
- Atmospheric circulation
- Spatial & temporal variability

- Phase-curves
- Tailored observations

Ariel mission baseline

- Double launch Ariel + Comet-Interceptor (**Dual Launch Structure (DLS)** to interface with the Comet Interceptor)

- **A62 launch** with a direct transfer to Sun-Earth L2
- **Eclipse-free (Earth and Moon) high-amplitude L2 orbit** throughout the entire lifetime to ensure thermal and power stability.
- **Lifetime of 4 years** + 2 year extension (goal).
- ≥ **85% observation efficiency (extension included)**.
- **~40% sky accessibility** at any time.
- De-orbiting manoeuvre at EoL to ensure low probability of Earth return, and minimum casualty risk on ground, complying with space debris regulations.

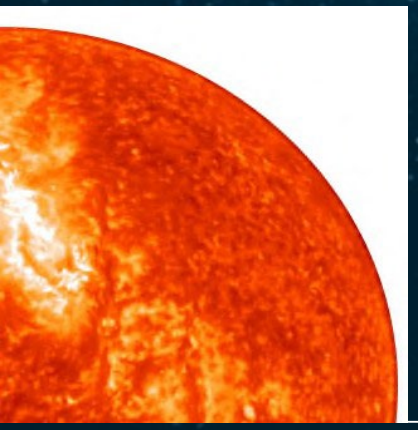


Ariel System – Mission

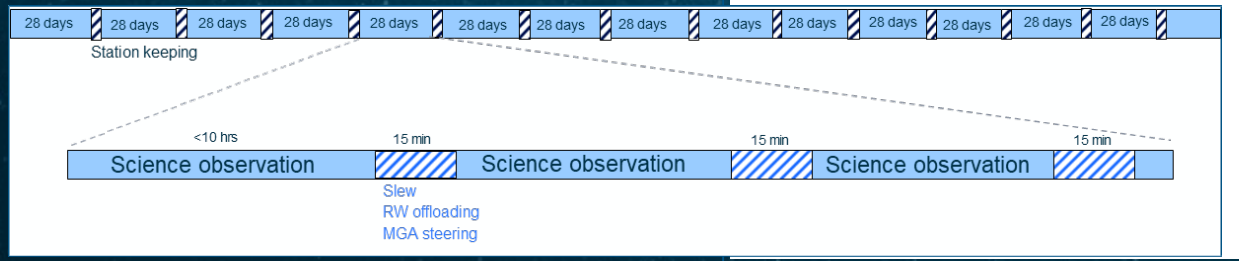
4 years nominal mission lifetime
2 years possible extension

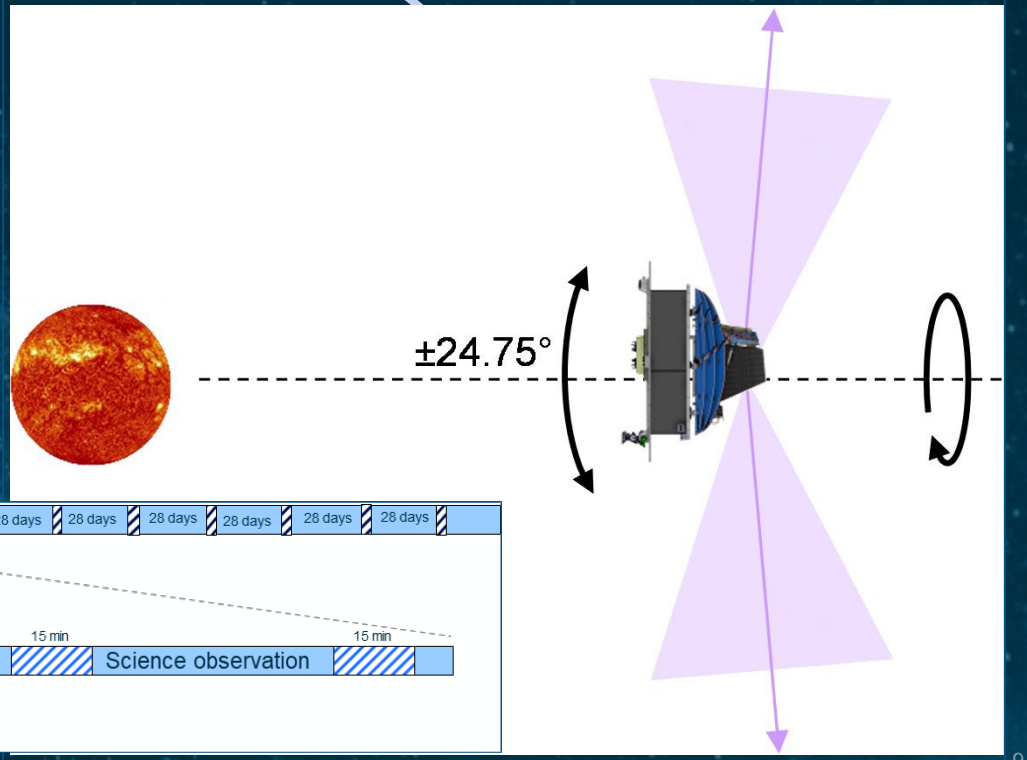
Operations from ESOC

ESTRACK



Ariane 6.2
From CSG

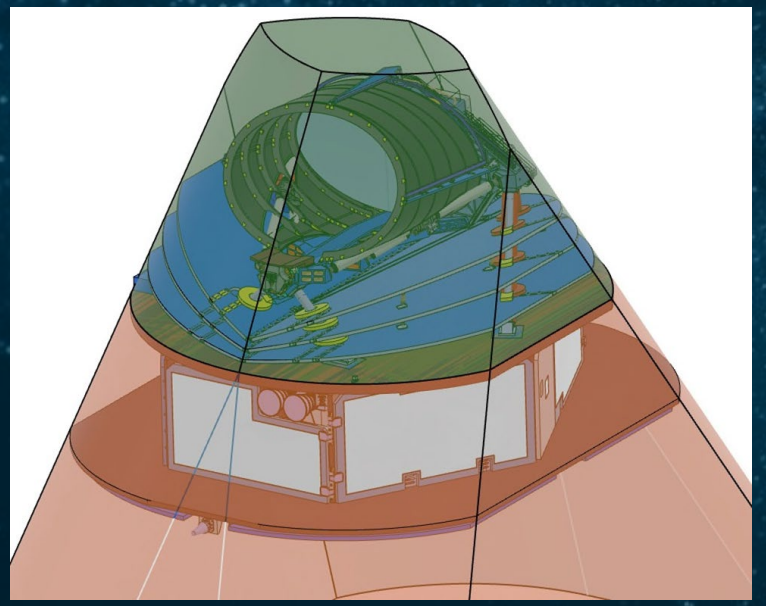


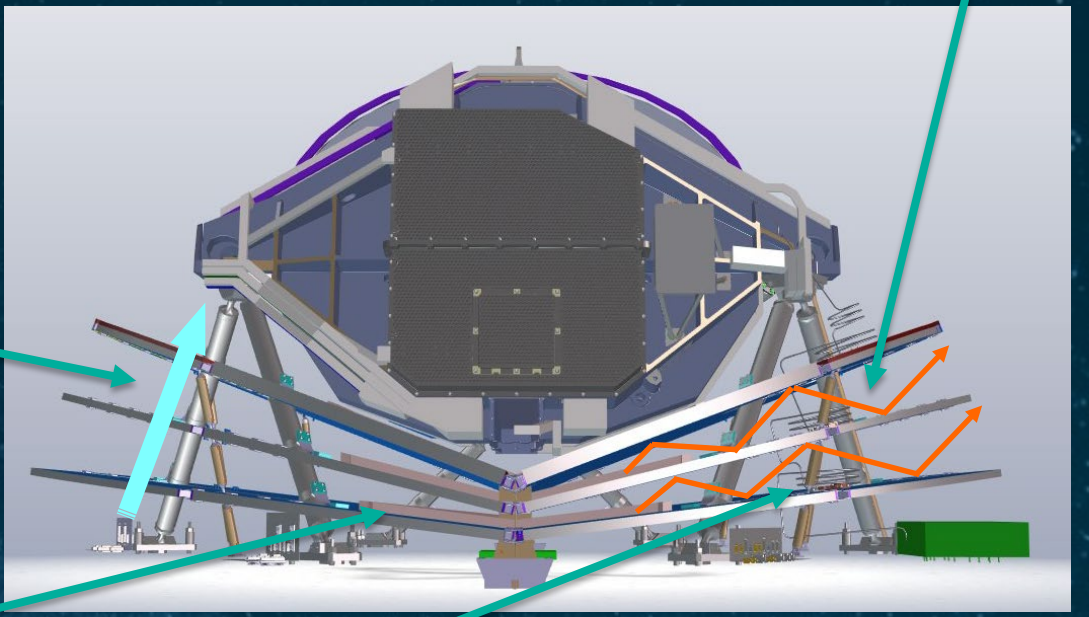


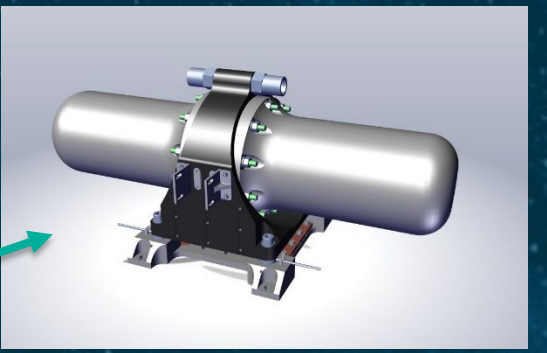
Ariel - From Science to Engineering

Infra-red detectors: need for a cold and thermally stable telescope:

- ✓ Passive cooling with the V-Grooves (// Planck SC).
- ✓ Active cooling with Neon J-T cooler.
- ✓ Payload maintained in a shadow cone.



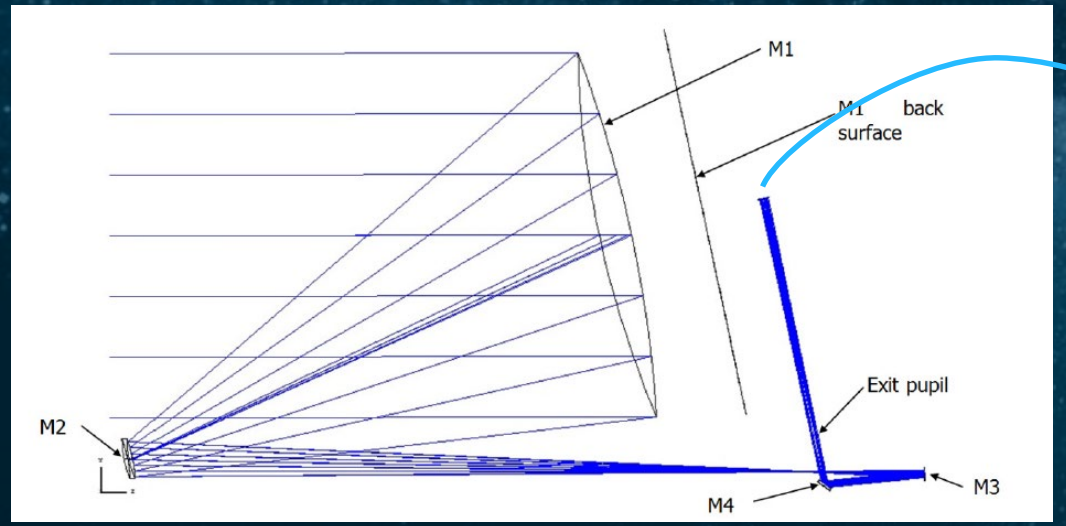


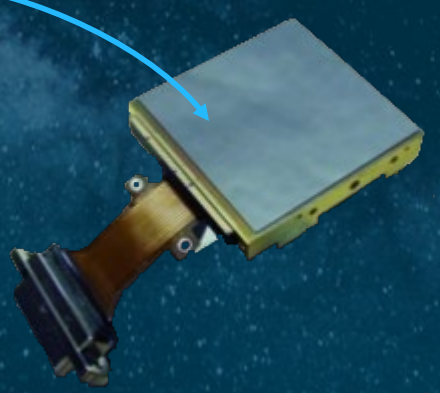


Ariel - From Science to Engineering

Long observation periods: need for high stability of the line of sight => the signal remains collected on the same areas of the detectors:

- ✓ Design of service module optimised to minimize thermo-elastic distortions (thick CFRP PLM interface panel, compensation heaters, flexible elements...).
- ✓ Reaction wheels and cryo-cooler compressor mounted on dampers to minimize micro-vibrations.
- ✓ Fine guidance system linked to the AOCS system of the spacecraft.

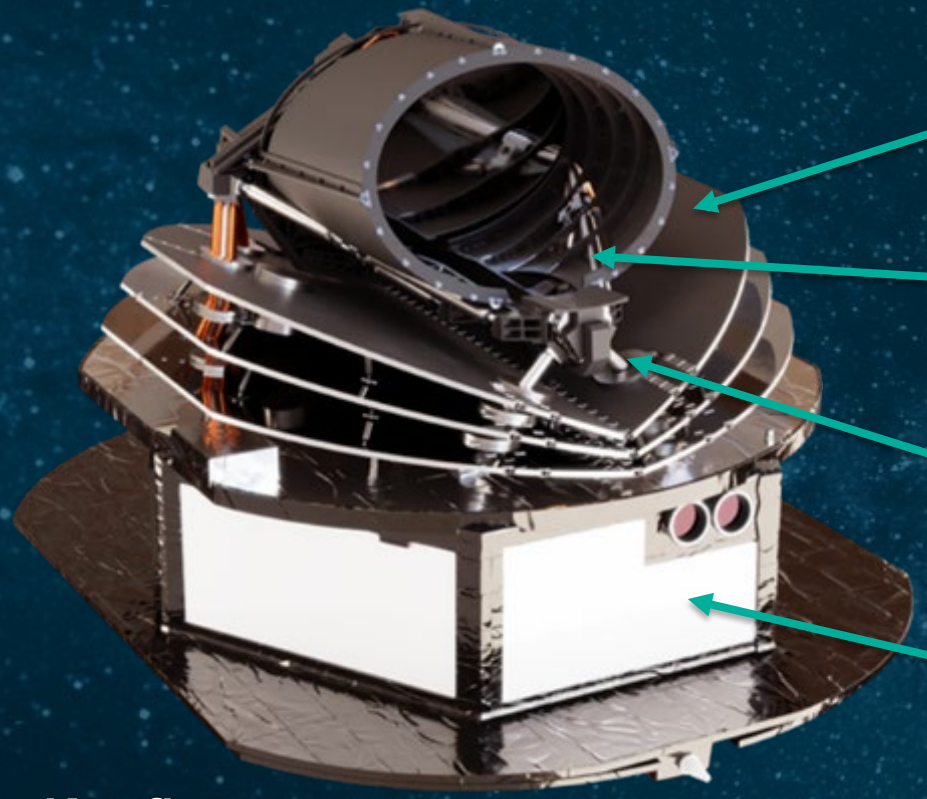




© Teledyne Imaging

FGS used for scientific measurements and to “lock” the SC on the target.

Ariel Spacecraft general design



Baffle against straylight

Off-axis Cassegrain all aluminium telescope with 1.1 x 0.7 m aperture (0.6 m2 collecting area), passively cooled to < 60K mounted on 3 CFRP bipods

M2 mirror mounted on a refocusing mechanism

SVM containing:
- ✓ payload warm units (including cooler)
- ✓ AOCS, power, data handling, propulsion, ... sub systems

Key figures:

Launch mass ≈ 1.4t (propellant 165 Kg)

Size: 3.3m x 2.7m – H 2.8m

Solar Array > 1kW EOL

Memory = 330Gbit EOL

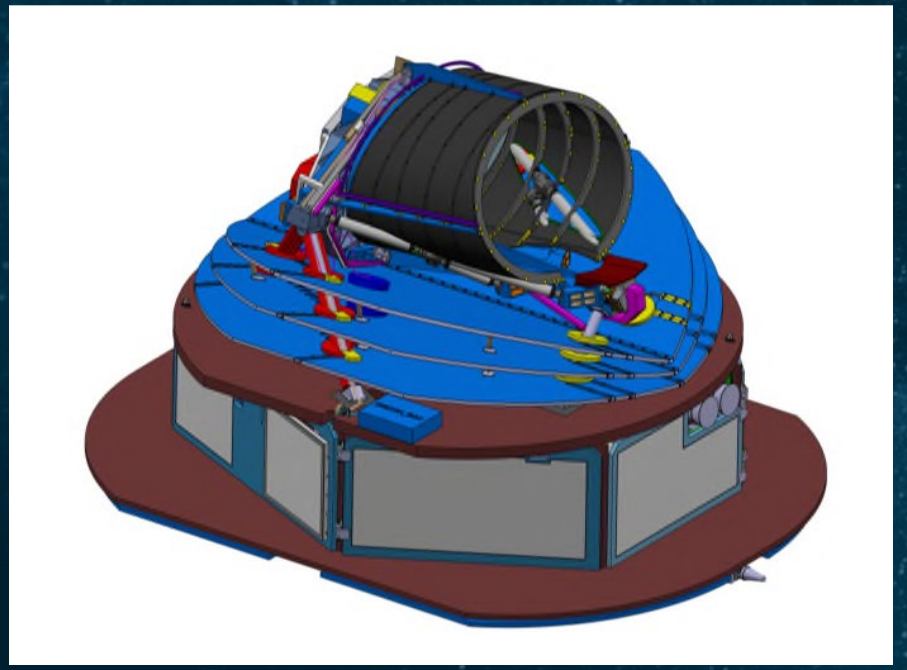
Data Rate > 236Gb/week

Fine pointing mode (across LoS):

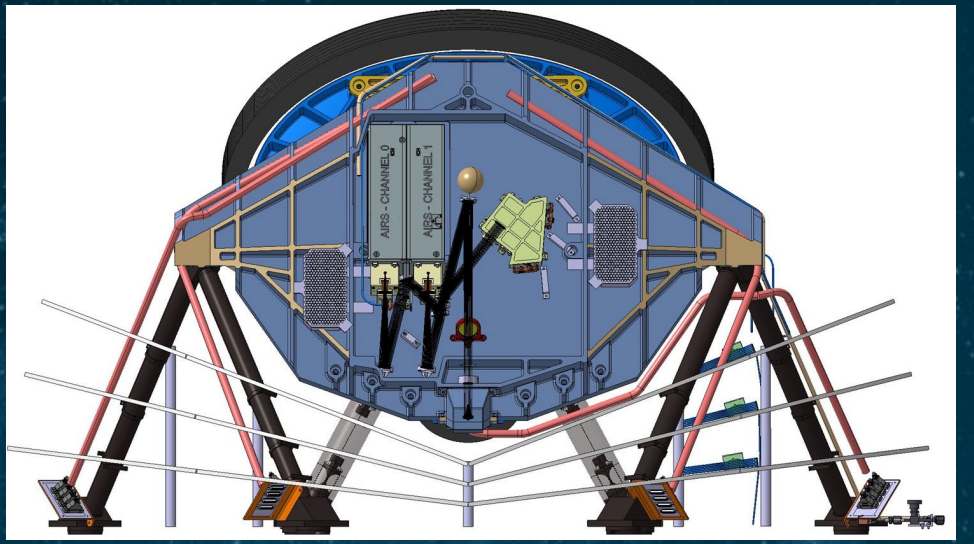
APE < 1.0 arcsec

RPE < 0.23 arcsec

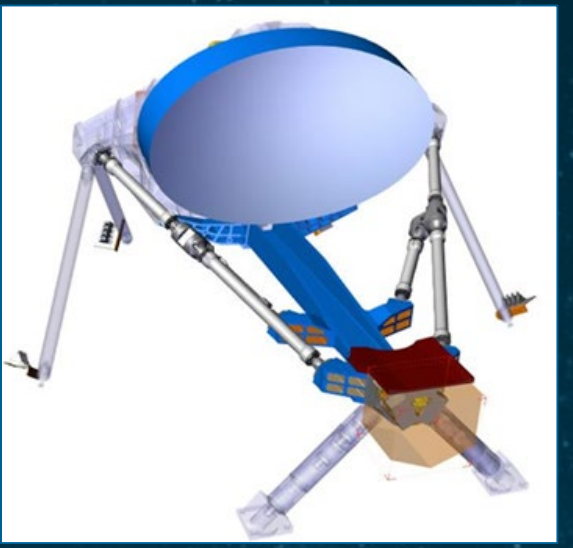
Ariel Spacecraft mechanical architecture



SC general view with service module



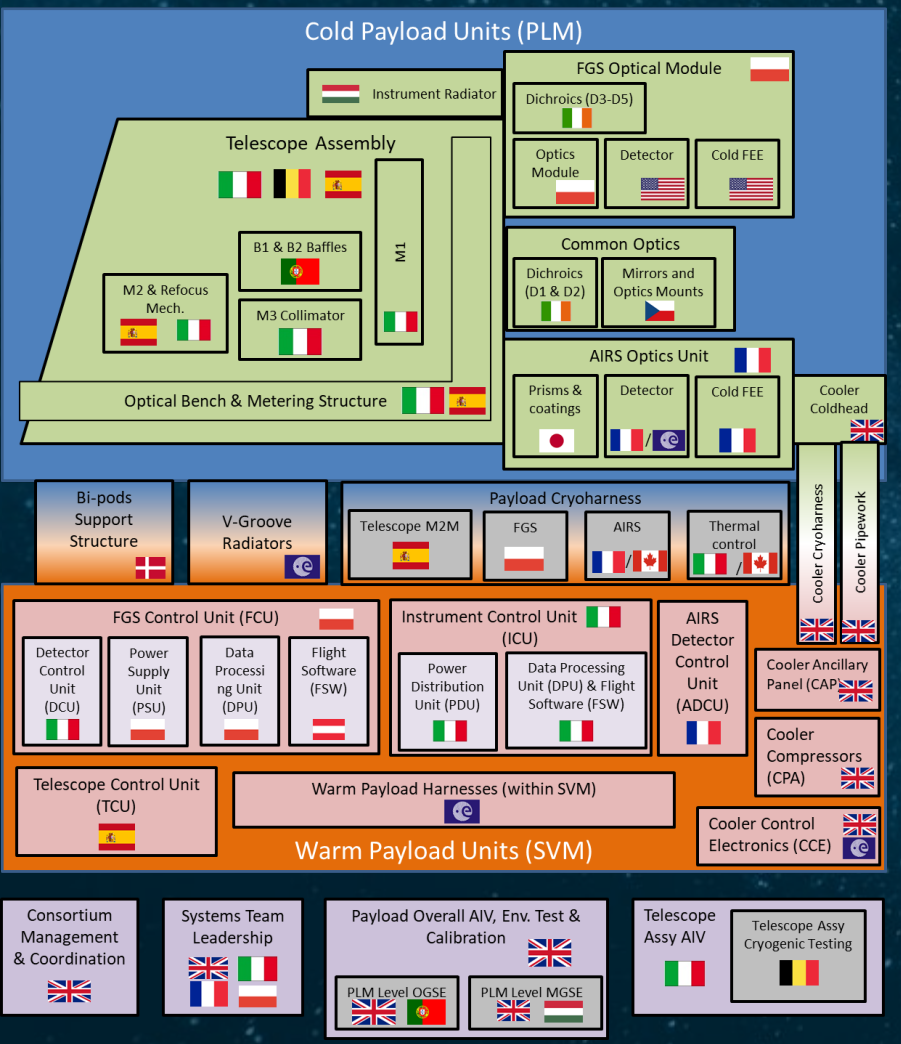
Telescope optical bench with instruments



Full aluminium telescope

Ariel Mission Consortium & Industrial organisation

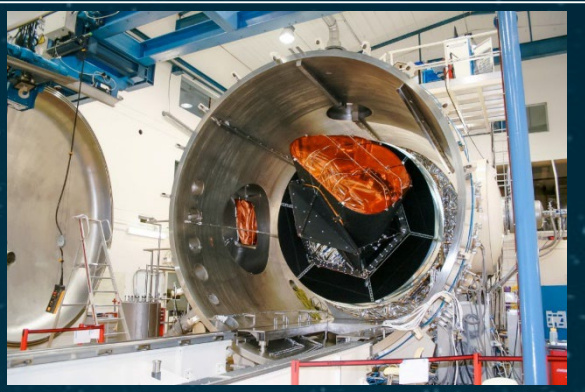
Payload consortium:



Spacecraft prime contractor:

Pre-selected item	Supplier			Subcontractor Consortium Composition		
Structure Subsystem (STS)		CH	APCO		CH	APCO
					PT	ACTIVESPACE
					BE	E.H.P
					BE	CSL
Chemical Propulsion Subsystem (CPS)		SE	OHB		SE	OHB
					DE	ARIANEGROUP
					DE	OMNIDEA RTG
					RO	INCAS
					NL	BRADFORD
					UK	NAMMO
					UK	EUROPEAN ASTROTECH
					IT	ELITAL
On Board Computer (OBC)		SE	RUAG			
Remote Interface Unit (RIU)		SE	RUAG		SE	RUAG
					AT	RUAG
					FI	RUAG
Power Conditioning and Distribution Unit (PCDU)		BE	THALES ALENIA SPACE			
Harness		RO	SONOVISION			
Rate Measurement Unit (RMU)		IE	INNALABS			
Acceleration Measurement Unit (AMU)		IE	INNALABS			
Medium Gain Antenna Main Assembly (MGAMA)		PL	SENER		PL	SENER
					PL	SYDERAL
					ES	SENER
					CH	SYDERAL
Thermal HW		AT	RUAG			
Mechanical and Thermal Analyses		CZ	L.K. ENGINEERING			

Current contribution from Belgium



AMC - Centre spatial de Liège:

- Predictions of optical performances of the telescope.
- Cryo-tests with optical performances measurement.

Industrial organisation:

- Heat pipes from Euro Heat Pipes (EHP).
- Power Conditioning and Distribution Unit (PCDU) from Thales Alenia Space Belgium

EURO HEAT PIPES

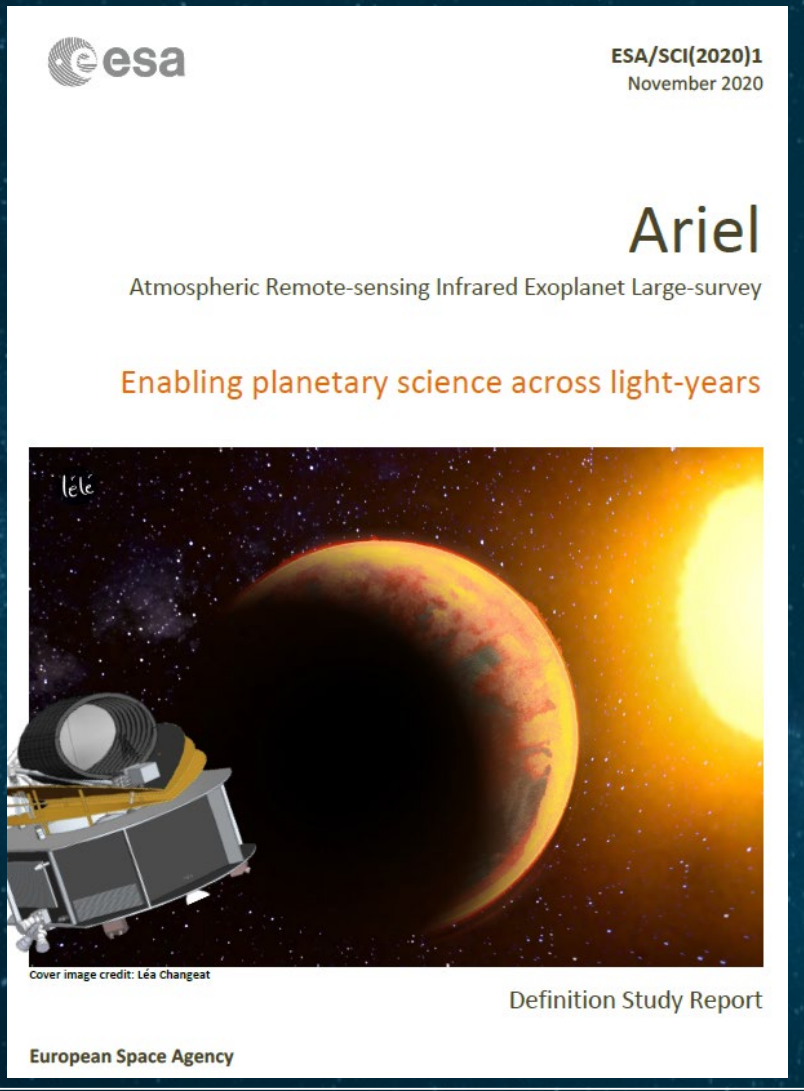
The European leader in Space Thermal Control

Open competitions to come for remaining hardware, software, support activities, ... including for example the communication sub-system.

Opportunities presented during Ariel Industrial days:
https://www.cosmos.esa.int/web/ariel-industry-day/home

More information about ARIEL science mission

Ariel “Red Book”: https://sci.esa.int/web/ariel/-/ariel-definition-study-report-red-book



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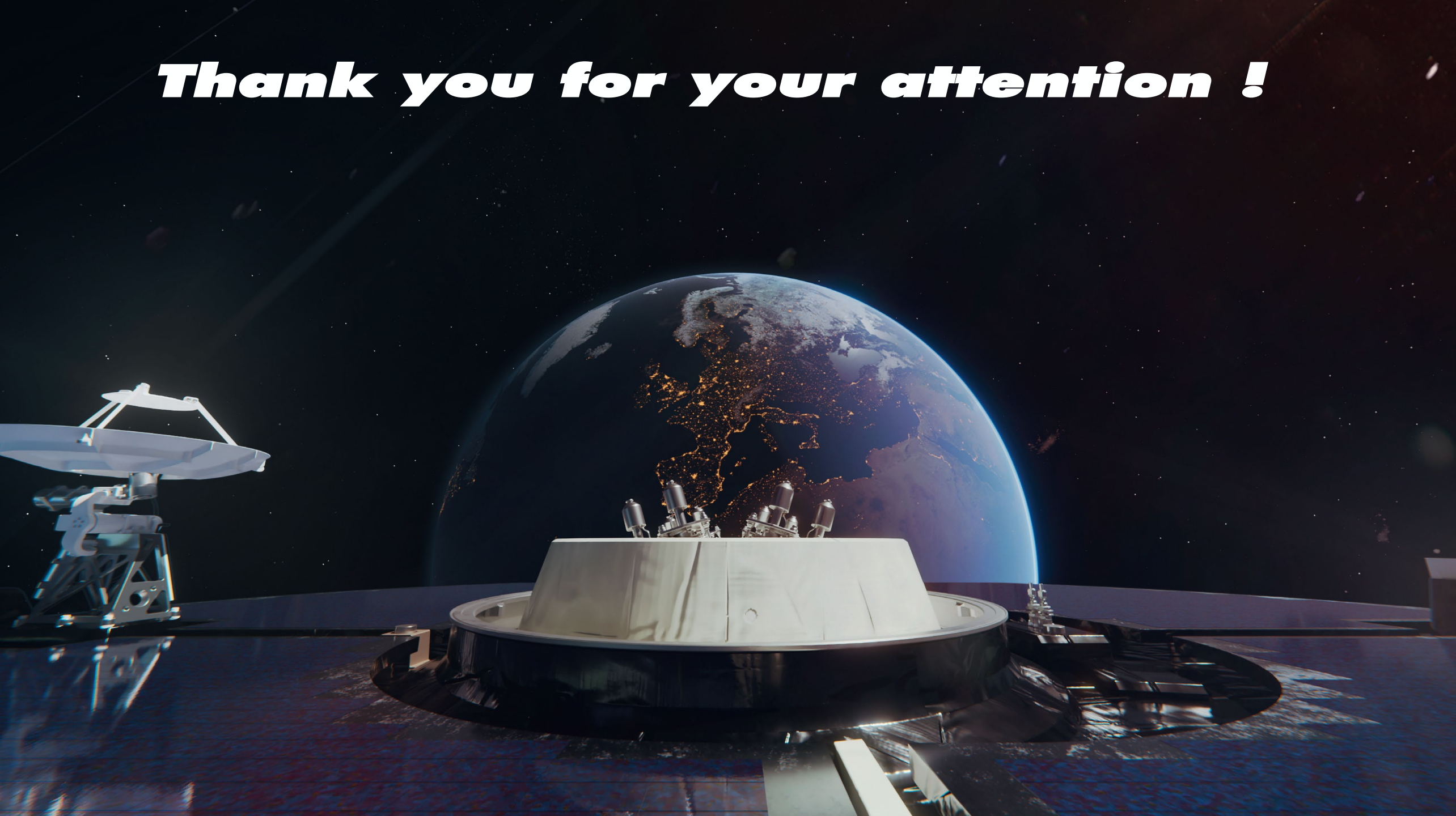
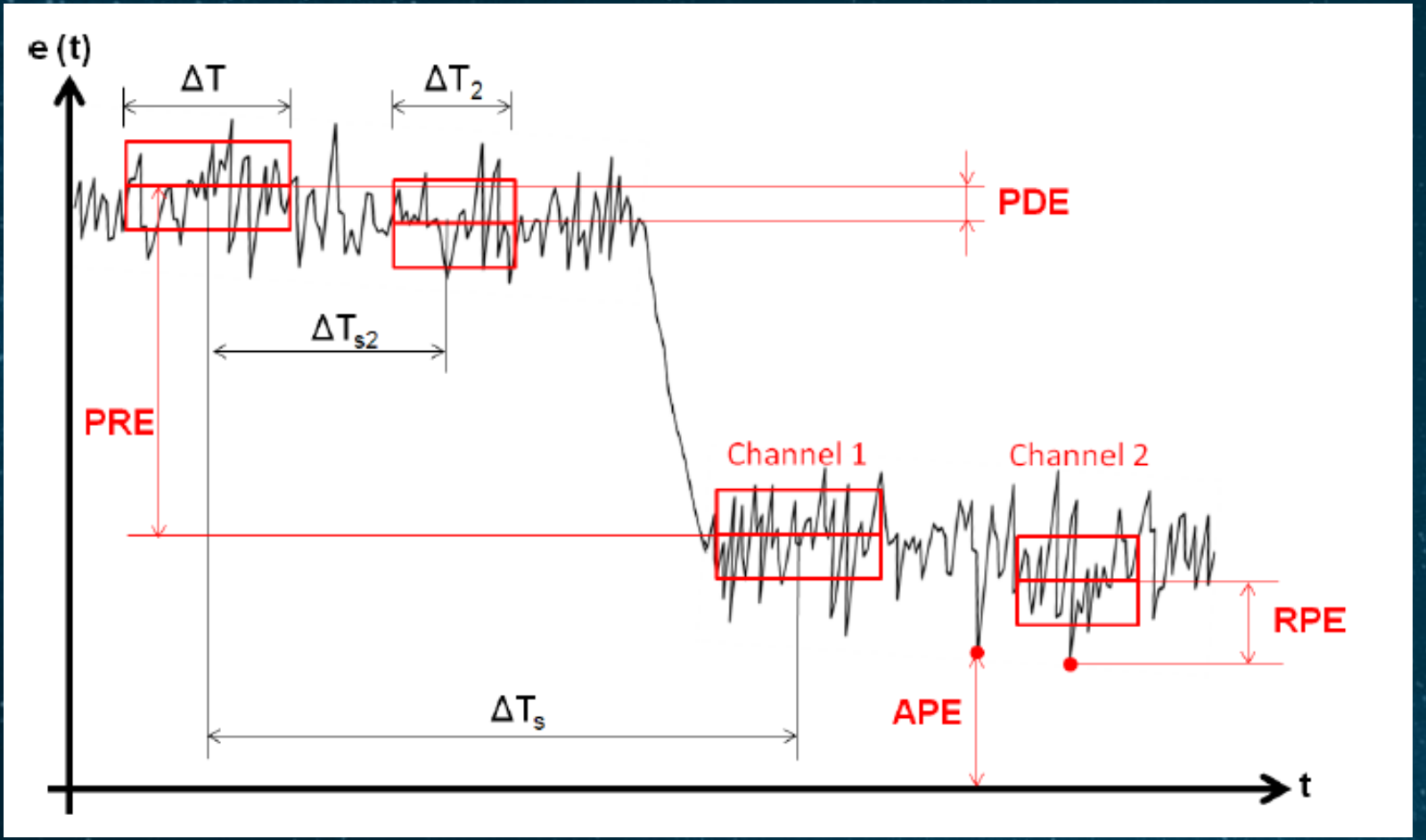


BACKUP SLIDES

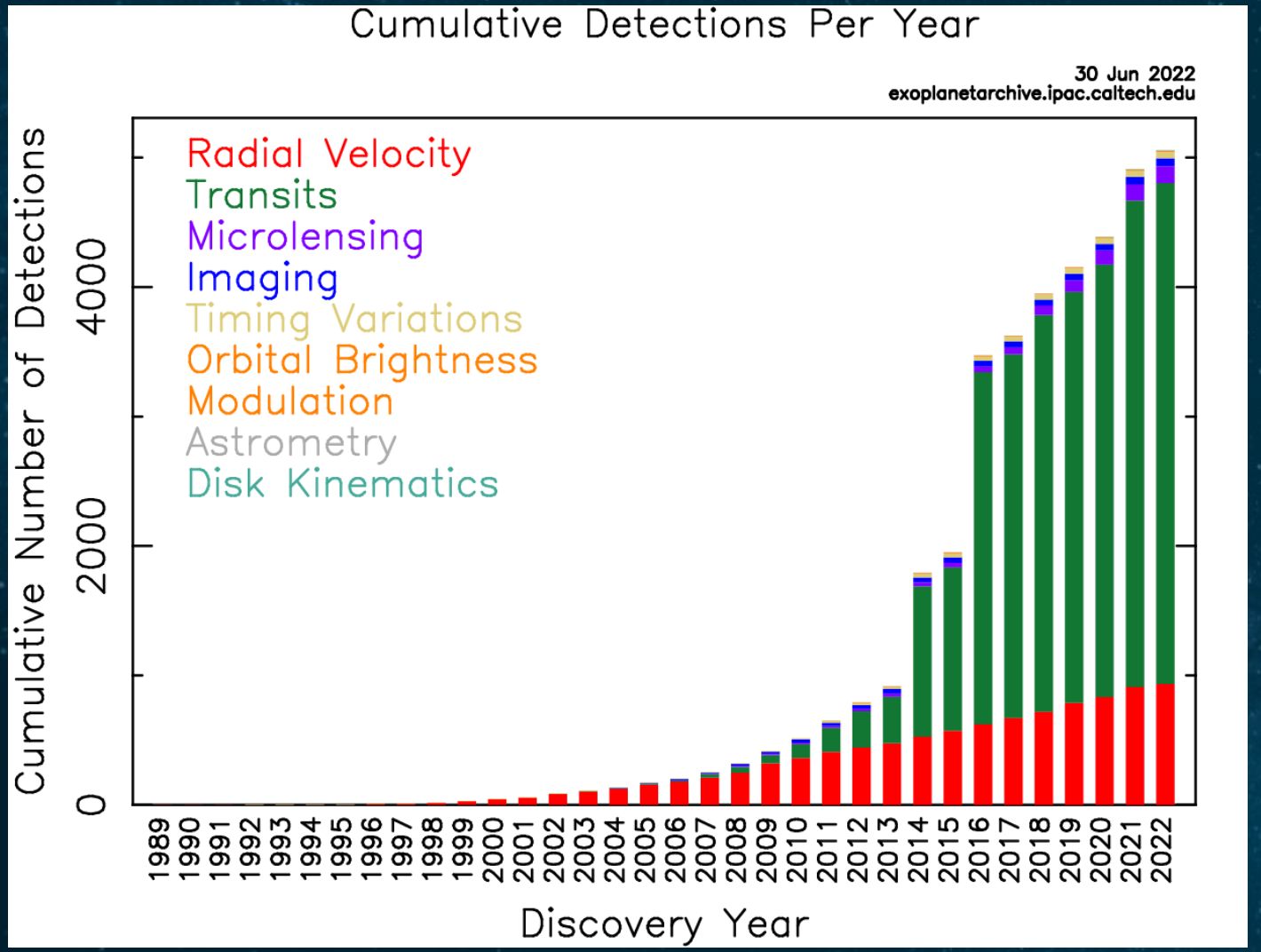
FGS and AIRS channels

Wavelength range	Resolving power	Scientific motivation
Blue filter 0.50 – 0.60 µm	Integrated band	• *Correction stellar activity (optimised early stars)* • *Measurement of planetary albedo* • *Detection of Rayleigh scattering/clouds*
Red filter 0.60 – 0.80 µm	Integrated band	• *Correction stellar activity (optimised late stars)* • *Measurement of planetary albedo* • *Detection of clouds*
NIR1 filter 0.80 – 1.10 µm	Integrated band	• *Correction stellar activity (optimised late stars)* • *Detection of clouds*
Low Resolution NIR Spectrometer (NIRSpec) 1.10 – 1.95 µm	R≥15	• *Correction stellar activity (optimised late stars)* • *Detection of clouds* • *Detection of molecules (especially TiO, VO, metal hydrides)* • *Measurement of planet temperature (optimised hot)* • *Retrieval of molecular abundances* • *Retrieval of vertical and horizontal thermal structure* • *Detection temporal variability (weather/cloud distribution)*
IR spectrograph (AIRS) – 1.95 – 7.8 µm	R≥100 (below 3.9µm) R≥30 (above 3.9µm)	• *Detection of atmospheric chemical components* • *Measurement of planet temperature (optimised warm-hot)* • *Retrieval of molecular abundances* • *Retrieval of vertical and horizontal thermal structure* • *Detection temporal variability (weather/cloud distribution)*

Pointing errors

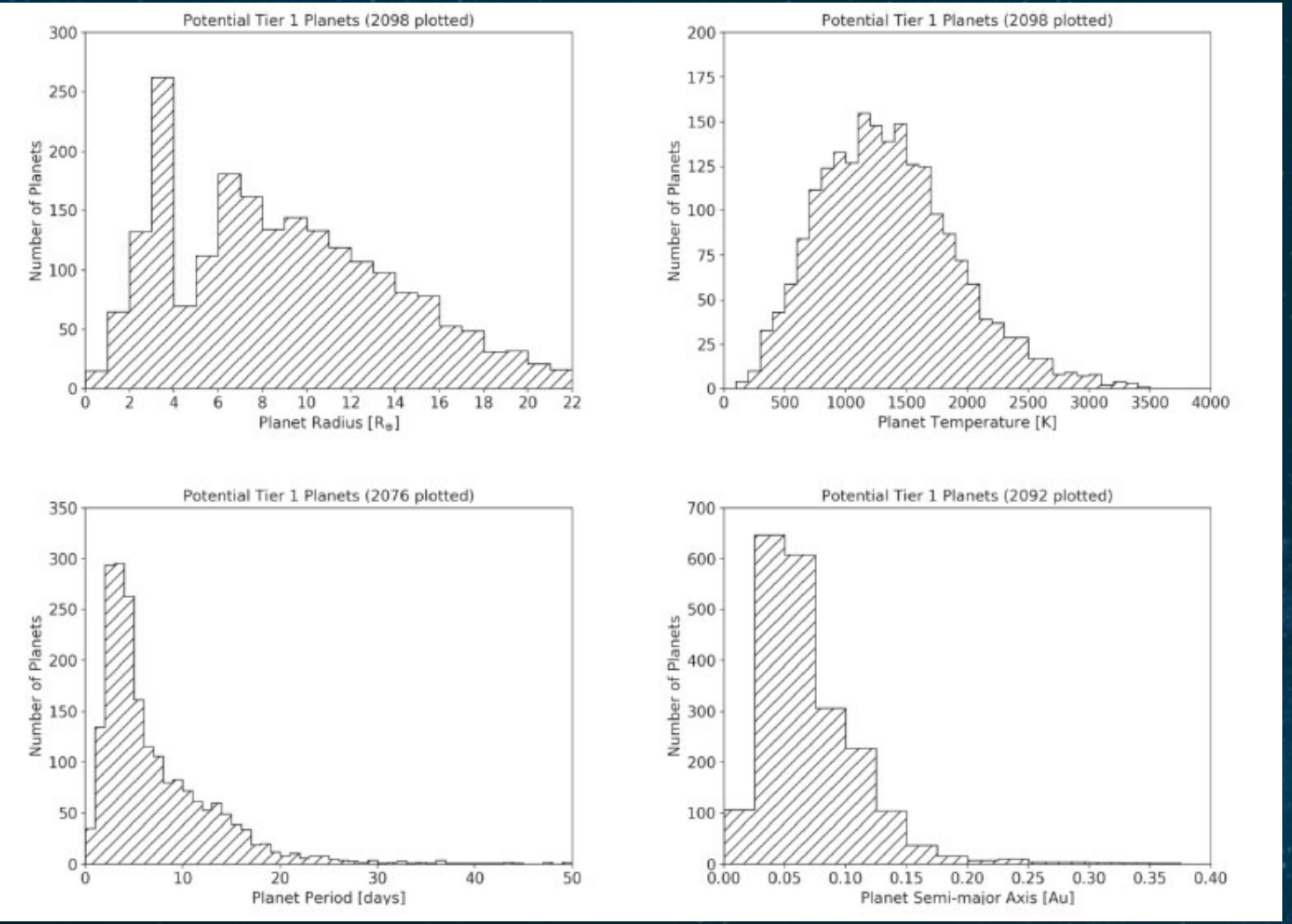


Detected exoplanets



5054 exoplanets detected as of today

Characteristic of potential Tier-1 planets



Relatively warm and large planets orbiting close to their star (1 Au = Earth-Sun distance = 150 millions Km).

L2 point at 1.5 millions Km from Earth.