



Agenzia  
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Italiana



UNIVERSITÀ  
DEGLI STUDI  
FIRENZE



SAPIENZA  
UNIVERSITÀ DI ROMA

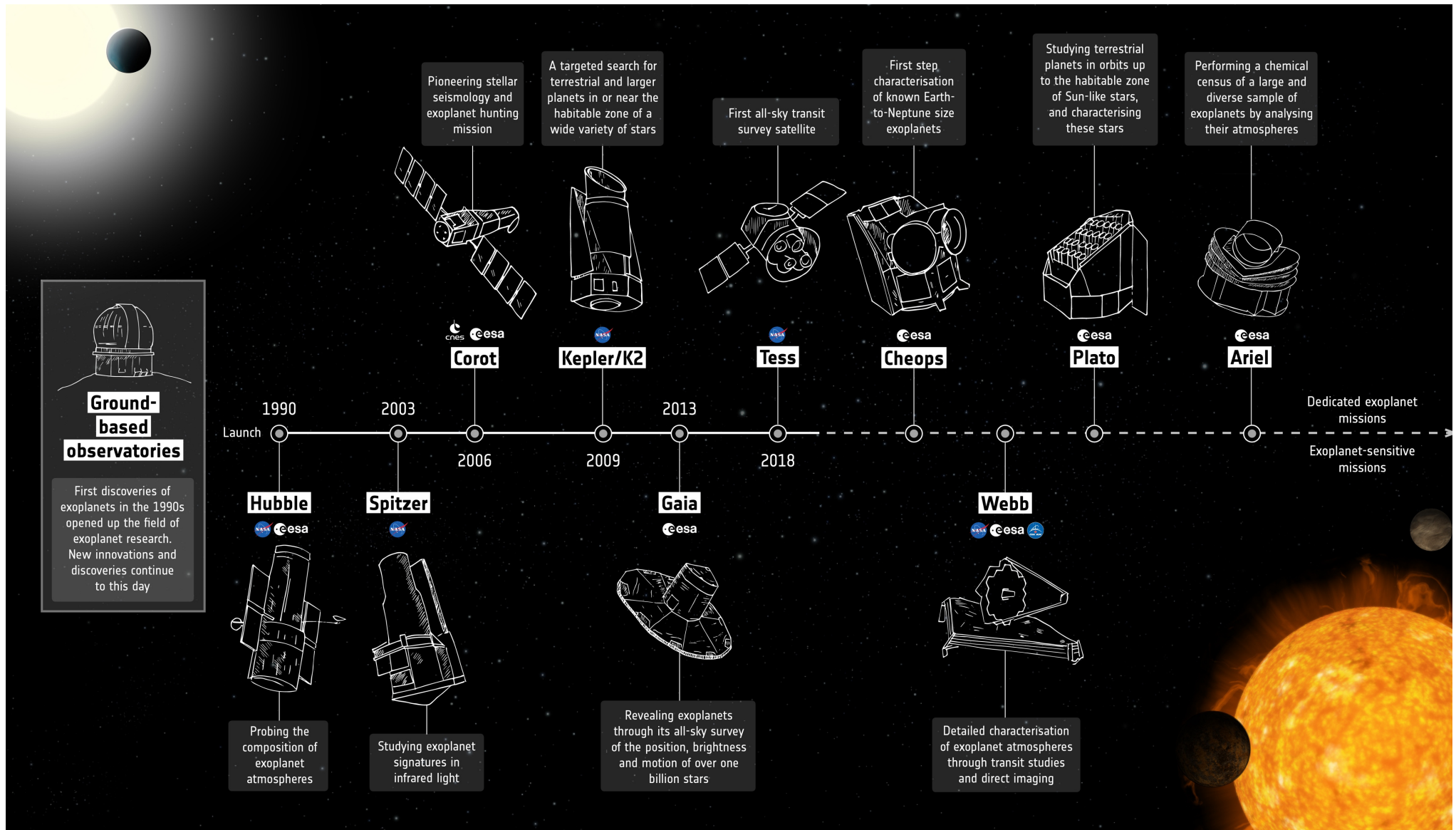
# The Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (Ariel)

*(G. Micela on behalf of the Ariel team)*

INAF - CSN-2  
19 May 2021



# Exoplanet missions



# ARIEL

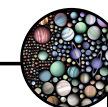
- M4 ESA mission (adopted Autumn 2020– Launch 2029)
- 1-m telescope, photometry+ spectroscopy from VIS to IR - Simultaneous coverage 0.5-7.8 micron ( $R = 1$  to 300)
- Payload consortium: 15 ESA countries + NASA
- Atmospheres of ~1000 exoplanets (rocky + gaseous), mainly transits and eclipse



## Individual planet

Chemical composition  
Atmospheric circulation + cloud pattern  
Equilibrium or non-equilibrium chemistry?  
Impact with stellar environment  
Coupling interior-atmosphere  
Impact of stellar environment & system history

## Large population of diverse planets



Chemical diversity  
Correlation clouds–temperature–stellar-type  
How fast atmospheres change through time?  
Correlation elemental composition planet provenance  
Coupling atmosphere-interior through time  
Transition between terrestrial planets and sub-Neptunes

# Observing Strategy: differential spectroscopy

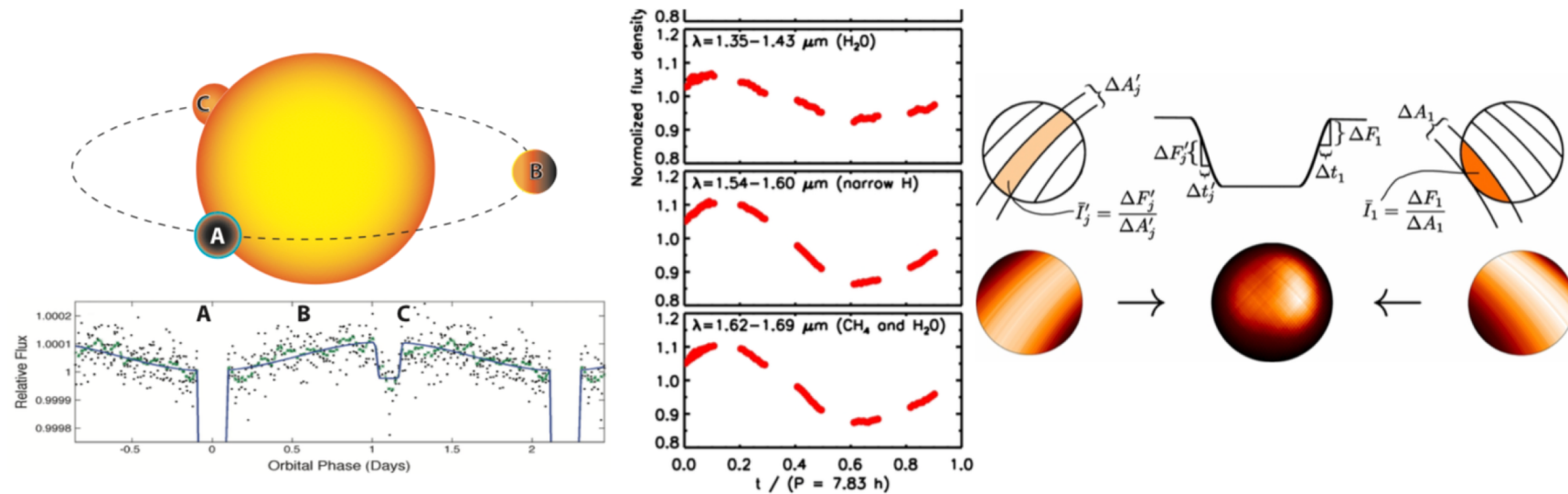
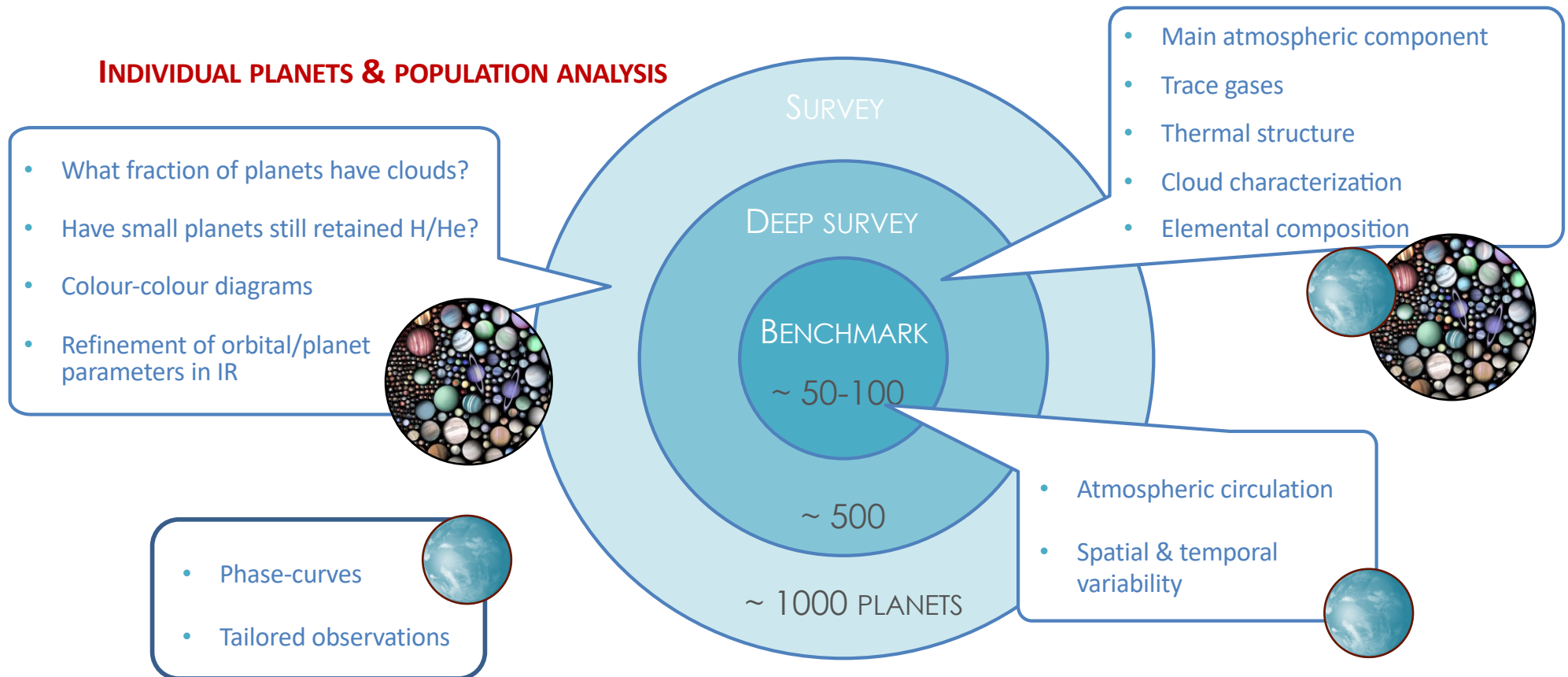


Figure 3-1: Methods adopted by Ariel to probe the exoplanet composition and structure. Left: phase-curve of the transiting exoplanet HAT-P-7b as observed by Kepler ([Borucki et al. 2009](#)). The transit and eclipse are visible. Centre: time series of brown-dwarf narrowband light curves observed with HST-WFC3 ([Apai et al. 2013](#)). The spectral bands have been selected to probe specific atmospheric depths and inhomogeneities in the cloud decks. Right: slice mapping with ingress and egress maps as well as a combined map of HD189733b at 8  $\mu\text{m}$ . These were achieved with Spitzer ([Majeau et al. 2012](#); [De Witt et al. 2012](#)).



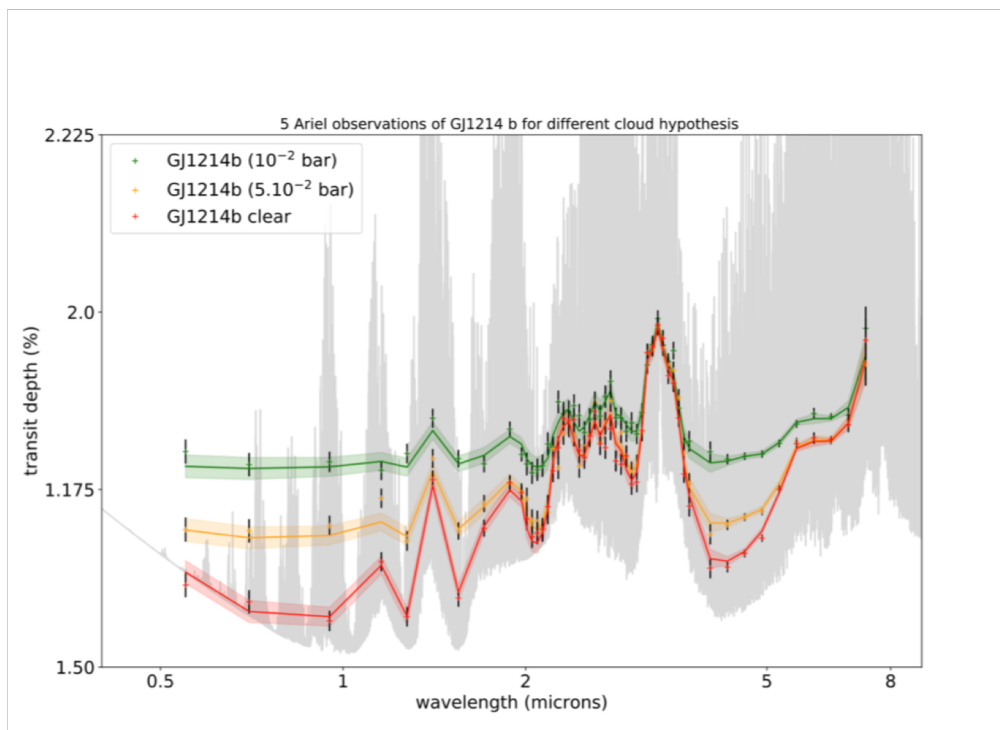
# ARIEL 4-Tier approach

## INDIVIDUAL PLANETS & POPULATION ANALYSIS



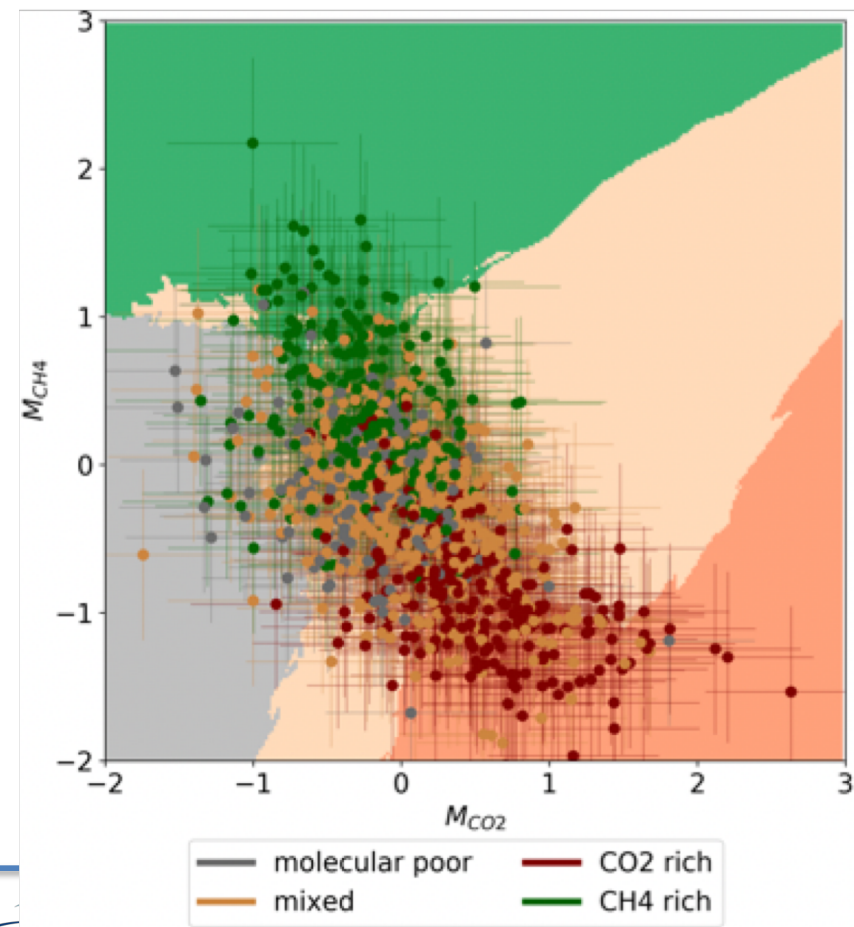
## Individual planet

*Simulated Ariel observations of the sub-Neptune GJ1214b with clouds at different pressures.*



## Population analysis

*Simulations of Ariel Tier 1 observations to identify families of planets*



# Science questions

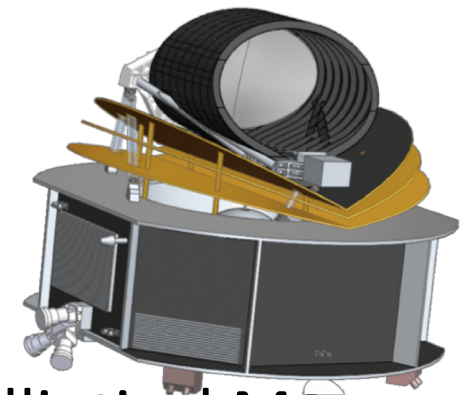
- Composition and structure of planetary atmospheres
- Planetary formation and evolution (evidence for migration)
- Planetary interiors structure
- Energy budget of planetary atmospheres (e.g. albedo, vertical and horizontal temperature structure, weather/temporal variations)
- Chemical processes (thermochemistry, photochemistry, transport, quenching)
- Clouds (cloud type, particle size, distribution, patchiness)
- Impact of stellar and planetary environment on exoplanet properties

# Connected science programs/projects

- **EXO-Atm, EXO-Young, EXO-SPI, EXO-Stars**
- **AMS:** - *ARIEL e il legame astrochimico tra dischi circumstellari e pianeti* (Turrini)
- **EXOGAL:** *Monitoraggio di sistemi stellari con esopianeti transianti* (Nastasi)
- **CLIMAX:** *Climate and chemistry: modeling the atmospheres of exoplanets* (Petrulia)
- **THE-StellaR-Path:** *Time-dependent High-Energy Stellar Radiation and Planetary Atmosphere interaction* (Maggio)
- **DAZZLING:** *Dust hAZe and clouds in exoplanetary atmospheres: the need for Laboratory measurements and numerical modeLING* (Jimenez)



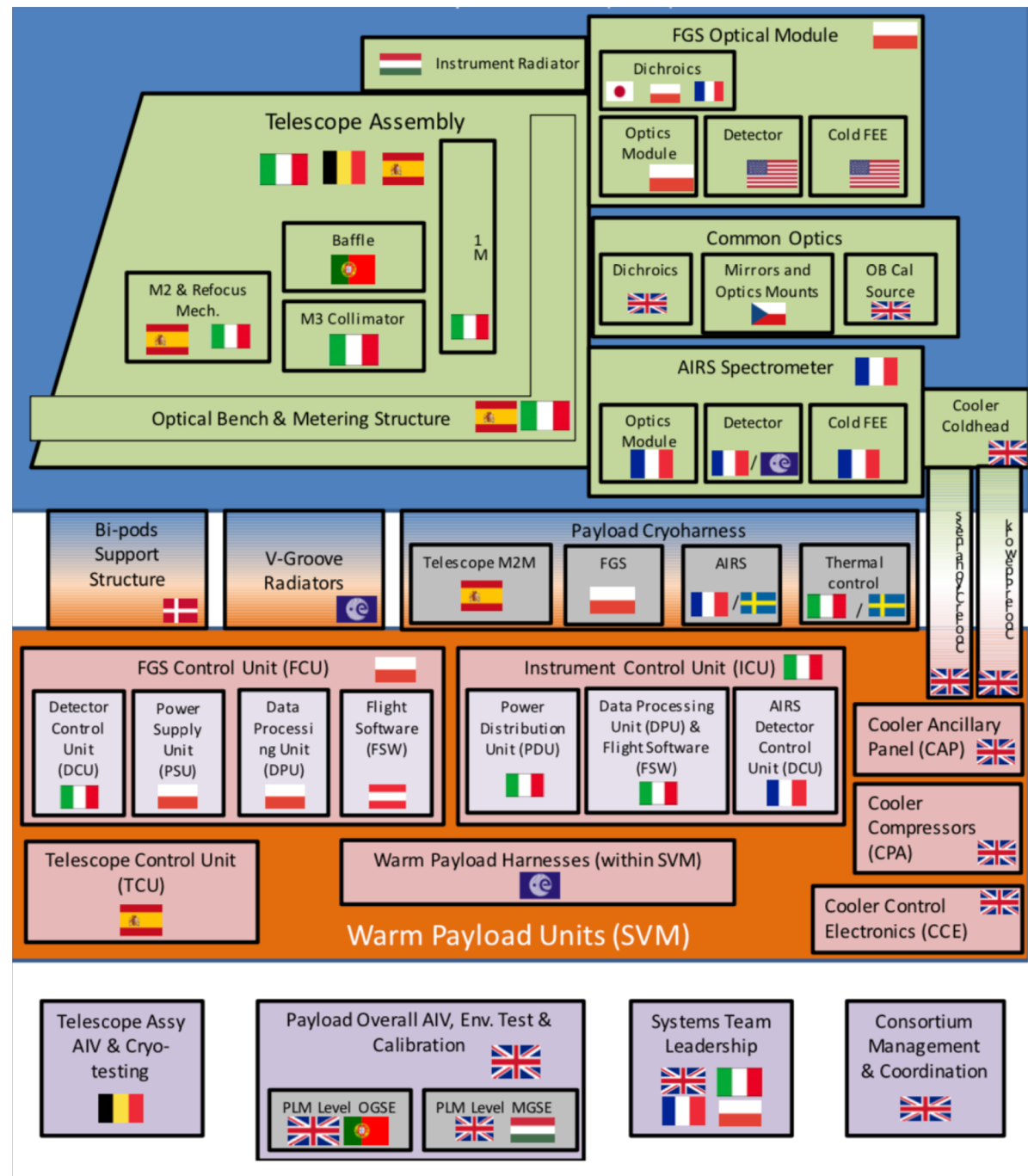
# The Payload



- Off-axis Cassegrain **telescope**, 1.1 m  $\times$  0.73 m elliptical M1; diffraction limited at 3  $\mu\text{m}$ . Mirrors, optical bench and telescope manufactured from Aluminium alloy for isothermal design with minimal thermo-elastic deformation.
- Ariel **InfraRed Spectrometer** (AIRS) -low/medium resolution ( $R=30\text{--}200$ ) spectroscopy in 1.95-7.8  $\mu\text{m}$  range.
- FGS includes **3 photometric channels** (two used for guiding as well as science) between 0.5-1.1  $\mu\text{m}$  + **low resolution NIR spectrometer** for 1.1-1.95  $\mu\text{m}$  range.

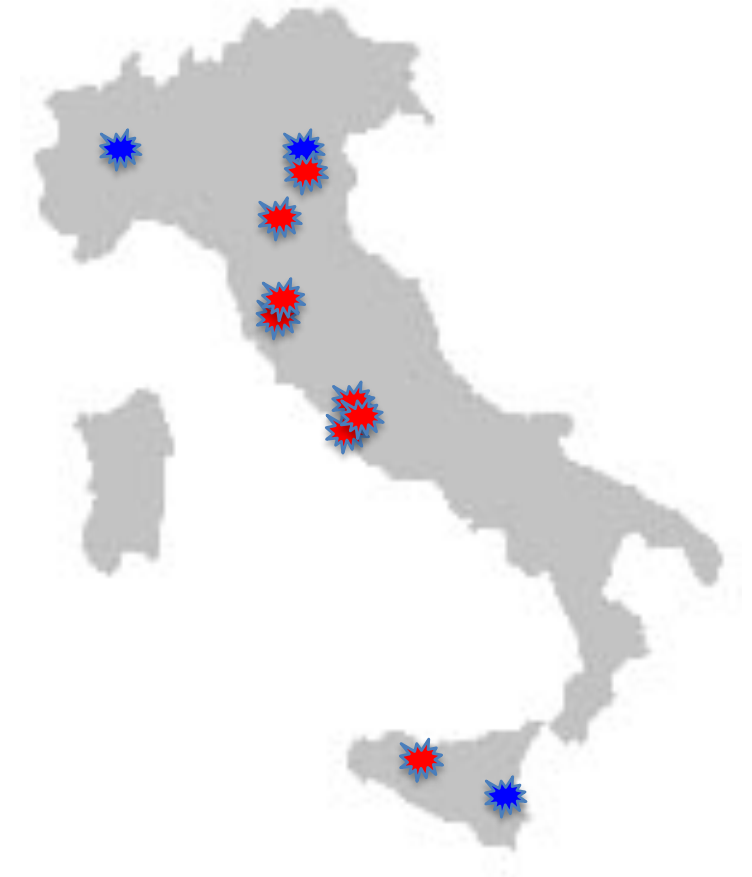
# Ariel Payload architecture and responsibilities

*(from the Ariel redbook)*



# The Italian players

- ASI
  - INAF
  - Università di Firenze
  - Università La Sapienza
  - CNR-IFN UOS Padova
  - SSDC/ASI
  - + science in other structures
- 
- 105 Italian members – growing – the largest community in the Consortium
  - ~50% technology/~50% science



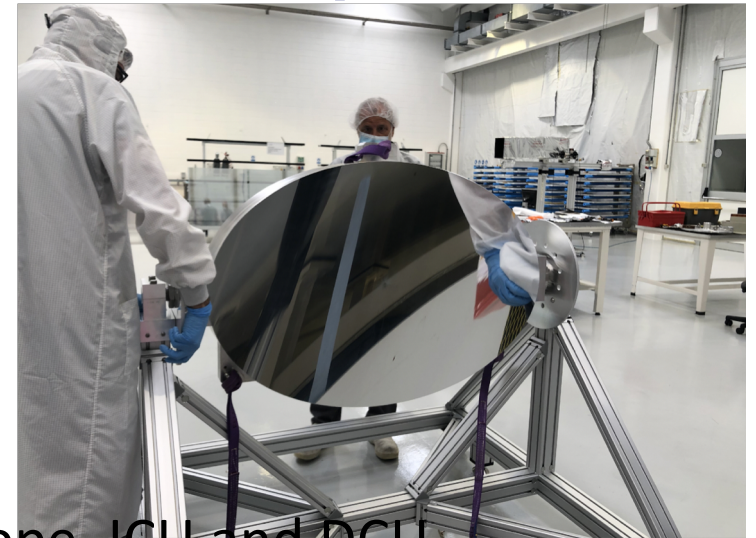
# Italian macroactivities

- Coordination of on-board electronics;
- Coordination of the Telescope Assembly;
- PLM Thermal architecture lead at the system level (including sub-systems and interfaces with the SVM);
- Coordination of the Consortium contribution to the Mission Science Ground Segment
  - *IOSDC - Instrument Operations and Science Data Centre management (also with input from SSDC/ASI)”*
- PLM performance evaluation and simulations;
- Science preparation.



# Main activities during Phase B2/C (2021-2023)

- ISRR –July 2021
- MSRR – second half 2022
- PDR –early 2023
- SGS (SOC+IOSDC)RR (end 2023)
- Advice for the industrial contracts – Telescope, ICU and DCU (managed by ASI)
- Breadboarding activity (Mirror, ICU)
- End-to-end simulations and data processing tools development
- Science preparation activities
  - Observing plan (target selection, stars, mass meas,...)
  - Data analysis to science (instr. and astroph. noise, models, calibr)
  - Science capabilities (planet formation, SPI, Synergy with Sol Syst, other instr.,...)

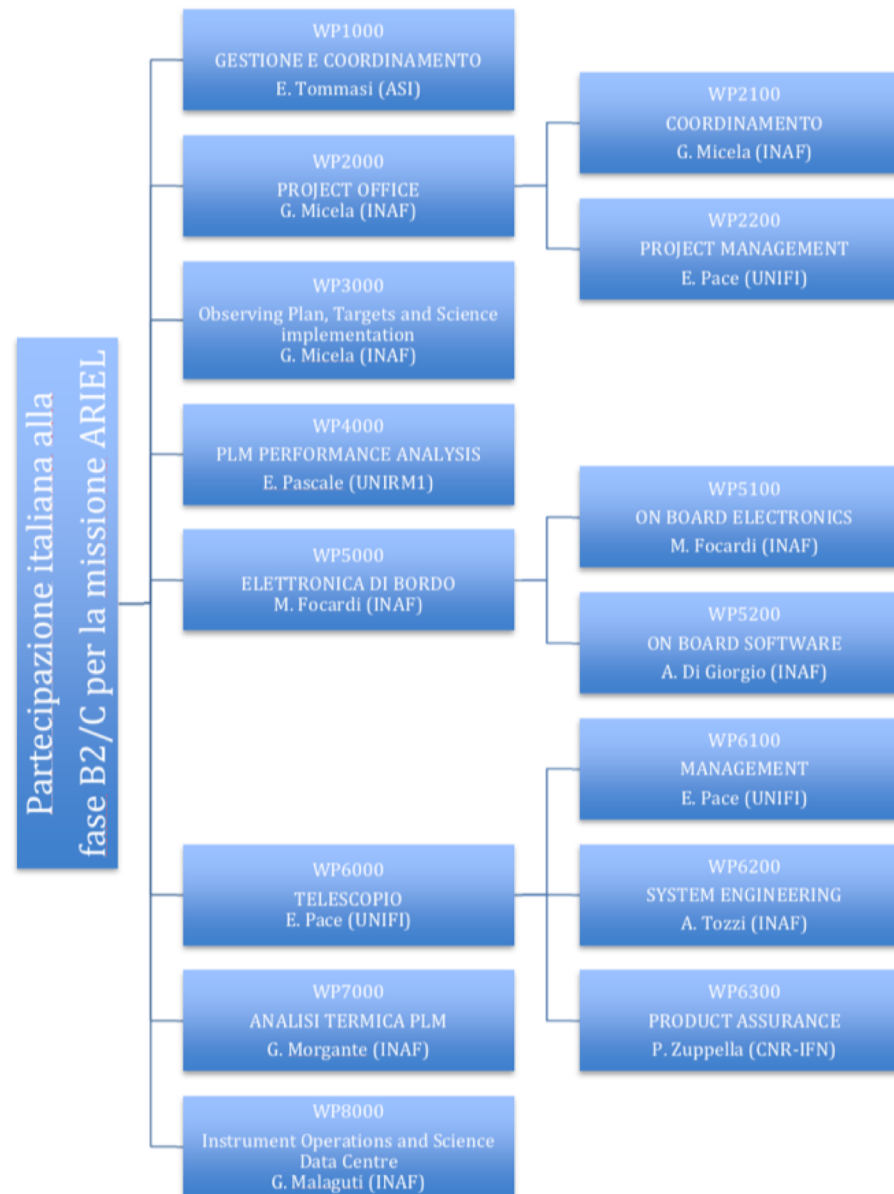


# INAF TEAM

Numero di partecipanti INAF al progetto: 68

Struttura	Nfte	N0	TI 21	TI 22	TI 23	TD 21	TD 22	TD 23	Nex	Extra
O.A. PALERMO	13	2	2.00	2.00	2.15	1.65	4.00	4.00	0	0.00
OAS BOLOGNA	9	0	2.15	2.15	2.20	0	0	0	0	0.00
O.A. ROMA	1	0	0.00	0.10	0.15	0	0	0	0	0.00
O.A. ARCETRI	11	7	2.25	2.50	2.85	0.30	0.30	0.30	3	0.30
IASF PALERMO	1	0	0.00	0.20	0.30	0	0	0	0	0.00
IAPS ROMA	12	3	0.90	1.00	1.30	1.30	1.40	1.20	1	0.10
O.A. TORINO	3	1	0.30	0.30	0.30	0.00	0.00	0.00	0	0.00
O.A. PADOVA	1	1	0.10	0.10	0.10	0.00	0.00	0.00	1	0.20
O.A. CATANIA	0	3	0.00	0.00	0.00	0.00	0.00	0.00	2	0.25
<b>Totali</b>	<b>51</b>	<b>17</b>	<b>7.70</b>	<b>8.35</b>	<b>9.35</b>	<b>3.25</b>	<b>5.70</b>	<b>5.50</b>	<b>7</b>	<b>0.85</b>

# Activity organizations (2021-23)



# Leadership

Italy, with ASI support, is one of the major contributing countries to Ariel,

- Ariel Consortium System Team key people:

- **Two co-Pis**
- Mission Scientist
- Telescope Project manager
- **Telescope lead**
- **Electrical, Thermal leads**
- **ICU PM & lead**
- **Software onboard lead**
- **IOSDC Manager**
- Chairs of science working groups:
  - **Mass Measurement**
  - **Planet formation**
  - **Stellar activity**
  - **Synergy with Plato and Cheops.**



# Capitalization on National expertises

- **Team – Bo:** *Thermal Engineering, Analysis and Modelling at Bologna* (Morgante)
- **TESICS:** *Technologies for Space Instrumentation Control Software* (Di Giorgio)

# Funds

- Funded by **ASI** to institutes + Industrial contracts)
- **ESA** grant (R&D for the developments of primary mirrors processes)
- **Dottorato Innovativo** con caratterizzazione industriale funded by «**PON Ricerca e Innovazione 2014-2020**» (cycle XXXIV)
- 2021-2023: **2050 kEu** (*ACCORDO ATTUATIVO ASI-INAF N. 2021-5-HH.0*)

# Several products so far

- **Ariel Prototype Mirror** (primary mirror real size) and mirror processes development
- **Primary mirror samples** (15cm and 2.5cm) thermo-mechanical and optical characterization of materials and coating
- **ARIEL Assessment Study Report** (Yellow Book)
- *Exp. Astronomy Special Issue (2018)*
- **Ariel Definition Study Report** (Red Book)
- *Exp Astronomy Special Issue (in press)*
- *Technical notes, Internal reports*
- Reports/notes delivered for ESA review
- **Several published papers (Science and Technology)**

# Critical issues

- **Team** growing (to be verify if it is sufficient, continuous monitoring)
- Capitalization on **INAF excellence** – in some areas we are a reference in Europe and now a few of them became under-sized.
- Recent developments of **new skills** both in science and technology need to be consolidated– **Young people**, few involved in stabilization (too recent activities)
- Be sure to be able to **exploit the science** (> 2029) – Careful preparations needed
- **Complex and long** administrative procedures