# Ariel + CASE

## Science & Community Engagement

Giovanna Tinetti (UCL) and the Ariel team

Image credit: UCL CSED

# Exoplanet facilities – next decade

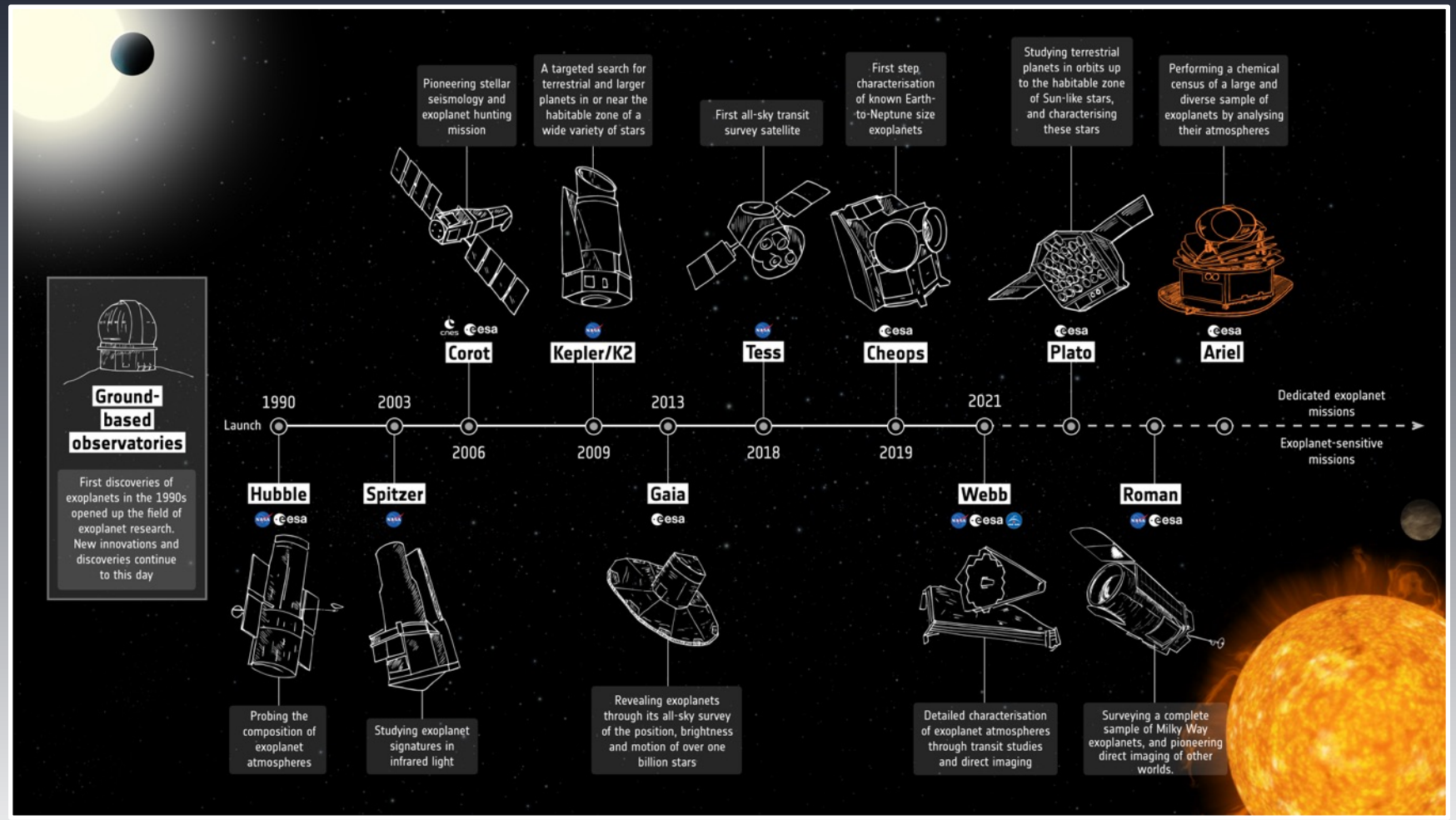
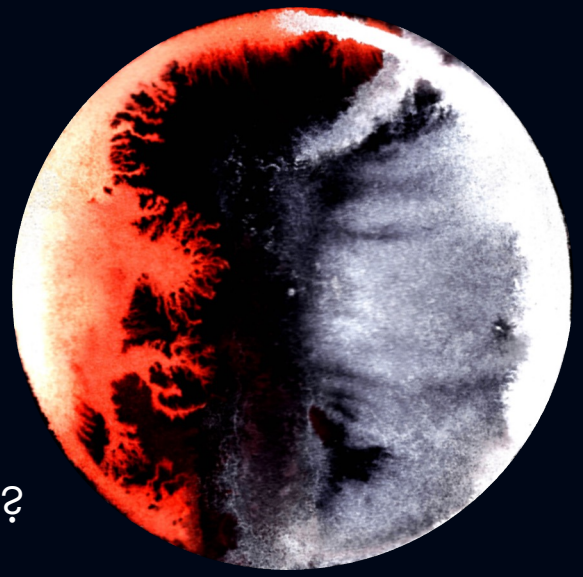



Image credit ESA

# Ariel science objectives

UNCHANGED FROM ORIGINAL M4 PROPOSAL SUBMITTED TO ESA IN 2015

- What are exoplanets made of?
- How do planets and planetary systems form and evolve?
- What are the physical processes shaping planet atmospheres?



Ariel Definition Study Report – Tinetti et al. 2021, arXiv:2104.04824

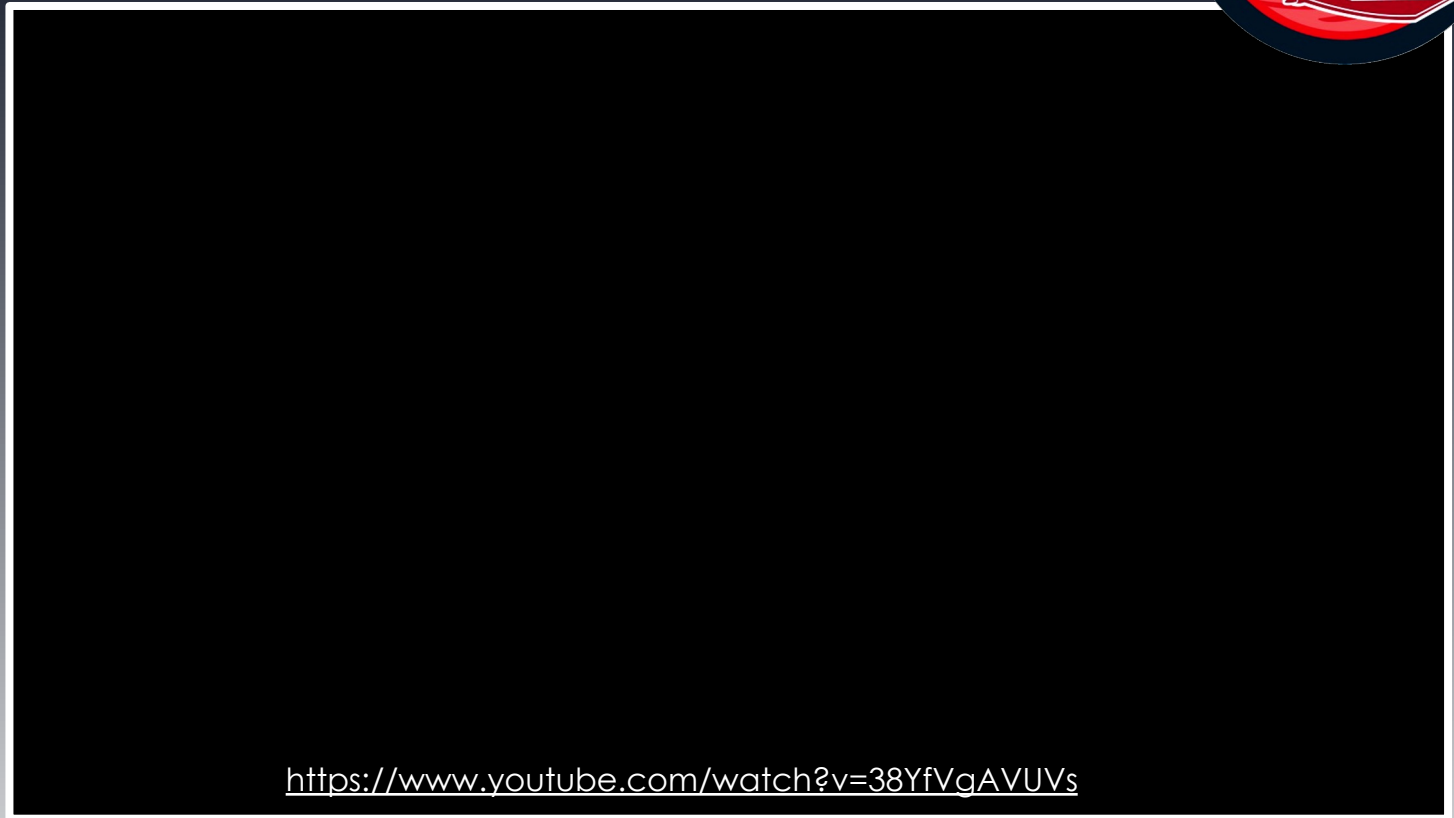
Image credit: Léa Changeat

# Ariel

- Adopted as ESA M4 in Nov. 2020
- PDR passed in May 2023
- Launch 2029 in L2 with CI

- 1m-class telescope
- Simultaneous coverage 0.5-7.8 μm

- ~1000 exoplanets observed
  - Rocky + gaseous; 300-3000K; stars A-M

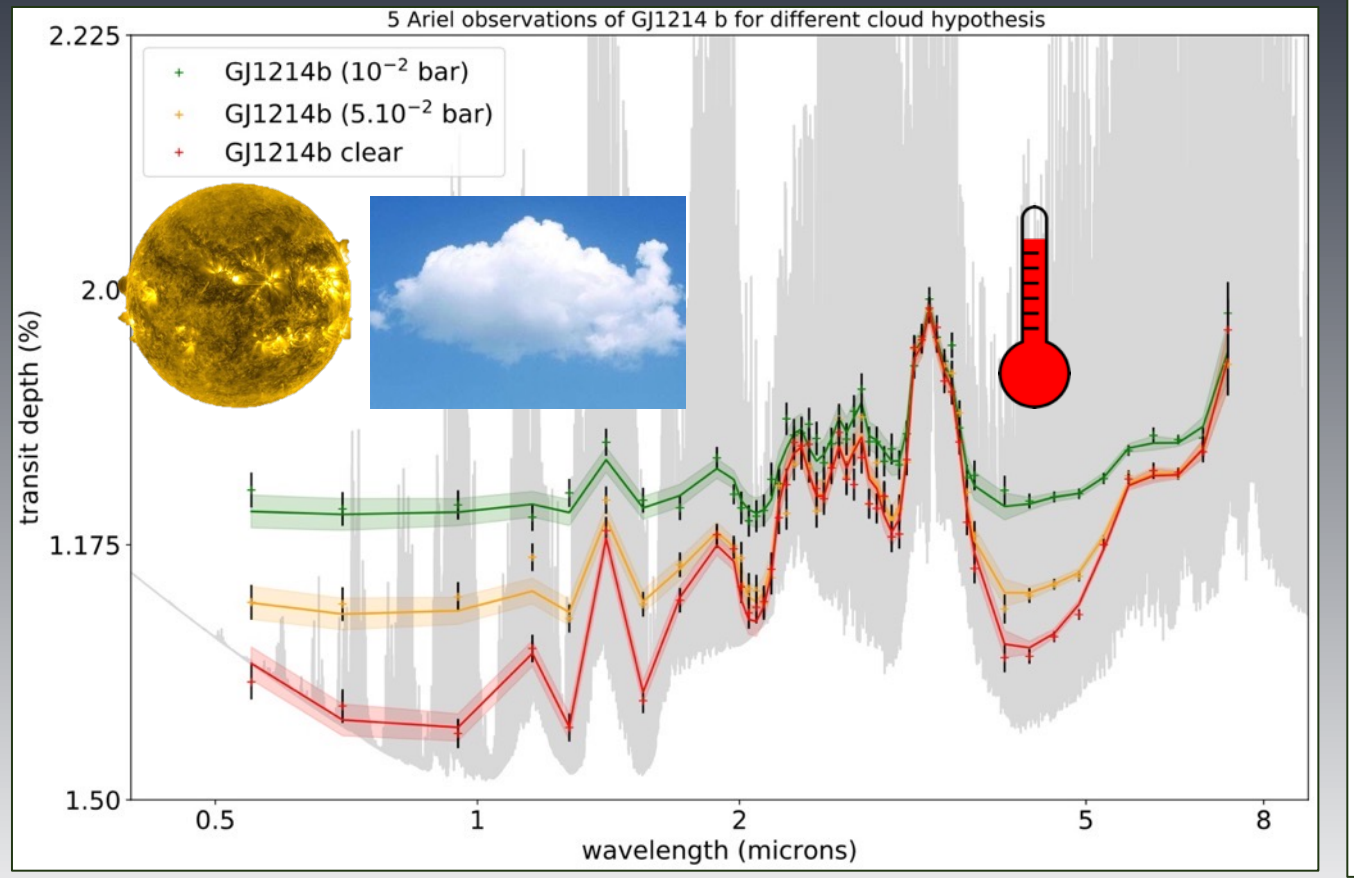


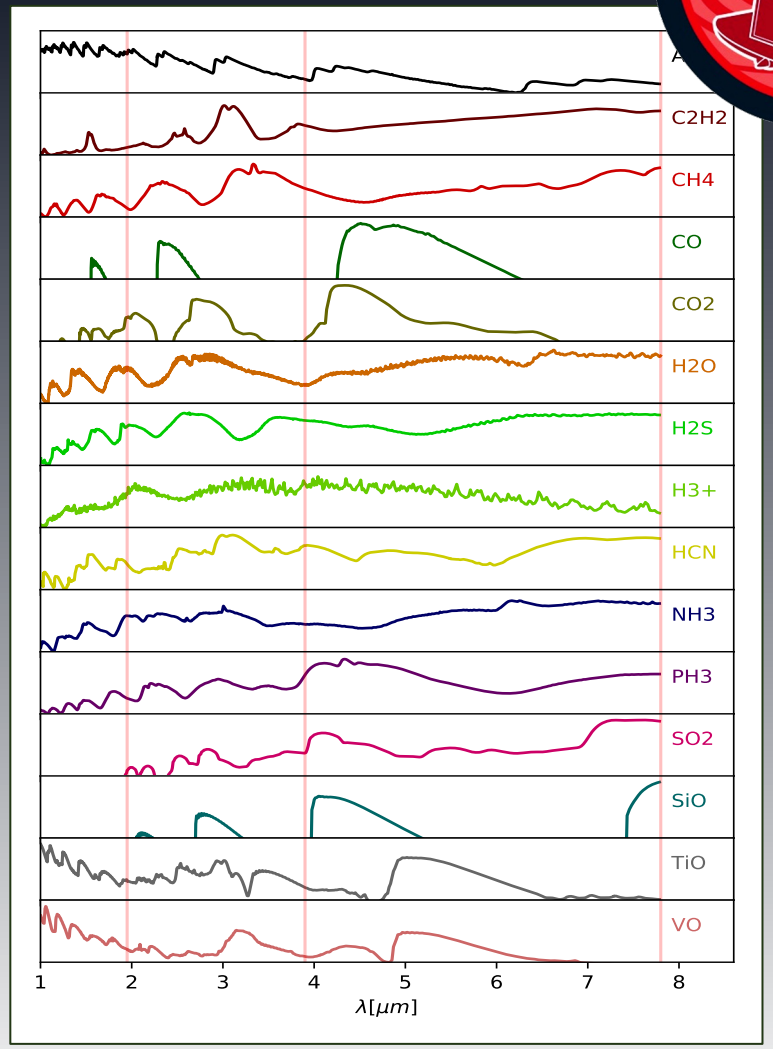
https://www.youtube.com/watch?v=38YfVgAVUVs

Ariel Definition Study Report – Tinetti et al. 2021, arXiv:2104.04824

# Ariel – Spectral range/resolution

SIMULTANEOUS COVERAGE 0.5-7.8 MICRON

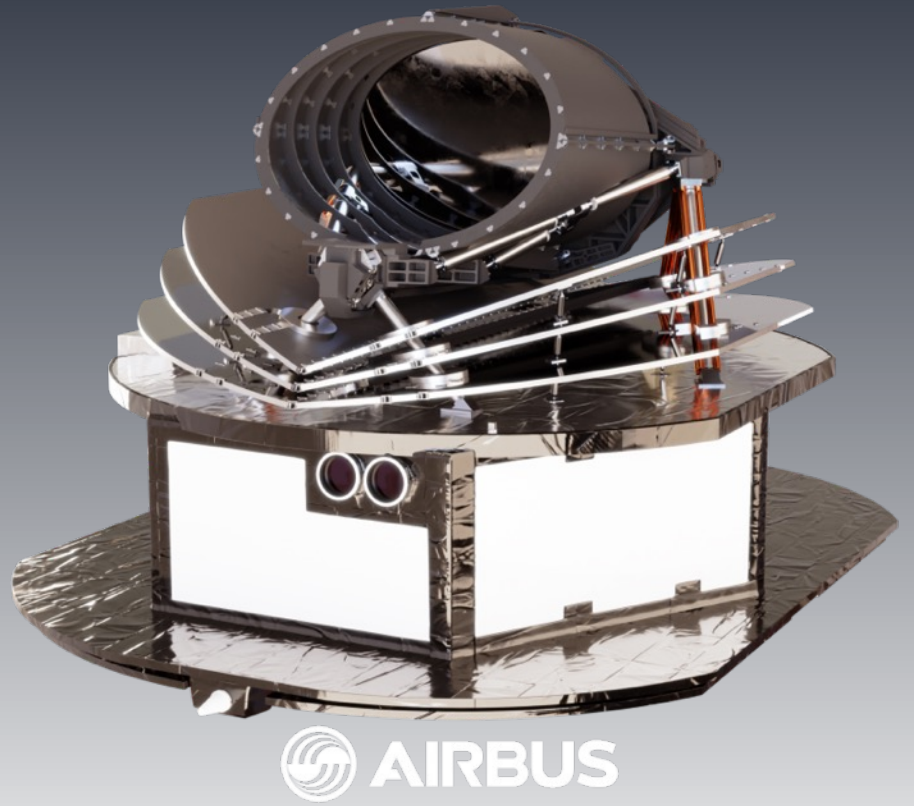



Ariel Definition Study Report – Tinetti et al. 2021, arXiv:2104.04824

# Ariel spacecraft & payload

PAYLOAD INTEGRATED AT RAL IN DIDCOT. SPACECRAFT FROM AIRBUS

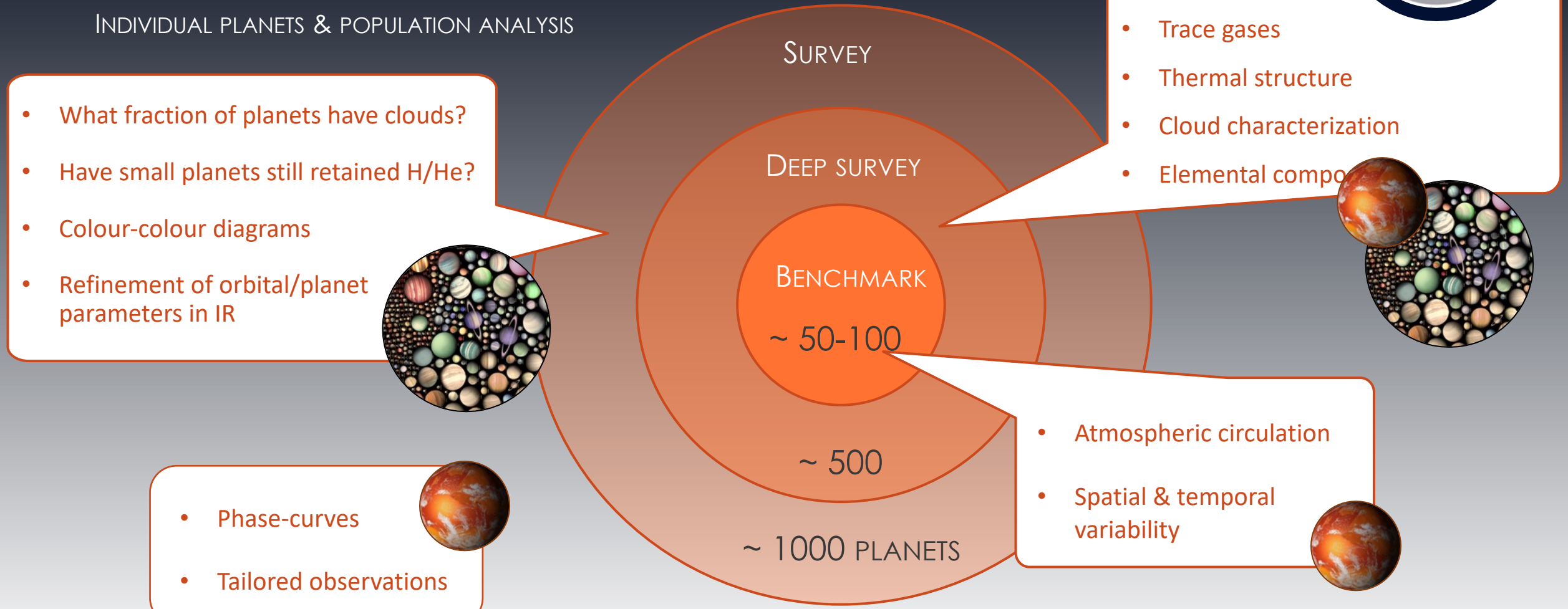
# Ariel payload consortium

600+ SCIENTISTS AND ENGINEERS FROM 16 ESA COUNTRIES + NASA, JAXA, AND CSA PARTICIPATION

A mission is more than flying hardware….
There is the human factor ☺

# Ariel 4-Tier approach

INDIVIDUAL PLANETS & POPULATION ANALYSIS



# Ariel Consortium Science WGs

22 WGs WORKING ON DIFFERENT SCIENTIFIC TOPICS

## Ariel WG Interiors

- **Coordinators:** Ravit Helled (rhelled@physik.uzh.ch ) (Stephanie.Werner@...o.uio.no )
- **51 Members**

## Ariel WG Atmospheric Chemistry

- Coordinators : Yamila Miguel (ymiguel@strw.leidenuniv.nl) & Olivia Venot (olivia...
- 78 members
- Understanding chemistry of exoplanet atmosp...
- Ariel observations
- We explore...

## Ariel WG Mass measure...

Coordinators: Lars Buchhave (bu...

32 members

Based on work done in previous ... al. in prep.)

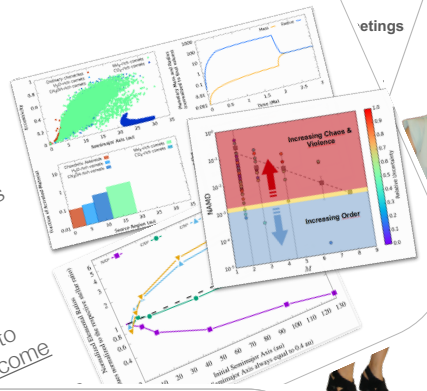
- Determine which targets requir...
- Monitor the literature for new m...
- Monitor, as far as possible, whic... velocity measurements campaign...

Organization: we will prepare a poll to v... for specific classes of targets (TBC), a...

## Ariel WG: Planet Formation

**Coordinator:** Diego Turrini (diego.turrini@inaf.it)

**Goals:** Identify metrics and methods to connect atmospheric composition to the history of planets




## Ariel WG: Synergy with JWST

...ierre-Olivier Lagage (pierre-olivier.lagage@cea.fr)

...oplanets observed by JWST

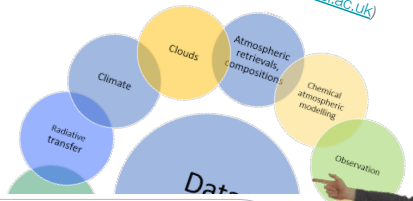
... data reduction and retrieval methods

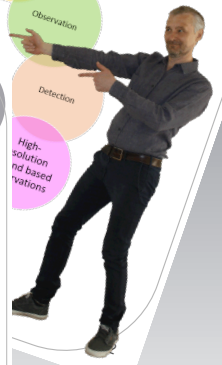
...ctral retrieval, performances

## Ariel WG Spectroscopic databases

Coordinators: Clara Sousa-Silva (clara.sousa-silva@cfa.harvard.edu) and Sergey Yurchenko (s.yurchenko@ucl.ac.uk)

30 members

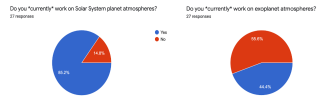



## Ariel WG *"Synergies with Solar System Planets' Atmosphere"*

**Coordinators:** *Gabriella Gilli (ggilli@oal.ul.pt) , Pedro Machado (machado@oal.ul.pt)*

Members: ~40 researchers working in both **Solar System** planets and **exoplanet** science



**Main goal:**
Foster synergies between SS and exoplanet scientific communities and take advantage of our knowledge of SS atmospheres for exoplanet studies (both observational and modeling)

**Organization:** Meetings every ~ 6 weeks, with *topics of discussion:*

- *"Observability of temperate exoplanets with ARIEL"*
- *"Non-LTE emission in the near-IR spectrum of (exo)planets"*
- *"Disentangling the CH4 abundance in Jupiter's upper atmosphere with ISO/SWS non-LTE emission measurements"*
- *"Exoplanets atmospheric characterization: exploring the transition from Super-Earth to Sub-Neptune"*
- *"3D cloud-resolving model of temperate tidally-locked exoplanets"*
- *"Transit of (exo)Venus (models and observations)"*

Ariel Consortium meeting 16-18 June 2021

## Ariel WG Stellar Characterisation

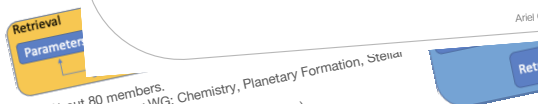
- Coordinator : Camilla Danielski (cdanielski@iaa.es)
- **Who?** 63 members
- Goal: **homogeneous** and **self-consistent** parameters determination of the host-stars in the Ariel Reference Sample (ARES) - Tier 1
- **What ?** Atmospheric parameters, abundances, activity indexes, mass, radii, ages
- **When ?** A meaningful choice of the final targets requires an accurate knowledge of the stellar properties, that need to be obtained well before the launch.
- **Why ?** to allow for robust statistical studies, correlation studies and comparison of 1000 planetary systems
- **How ?** Both model dependent & empirical approaches.
- Synergy with : Plan. Formation, Stellar activity, Plan. interior, Catalogue, Synergy with TESS WGs
- **Where ?** Dedicated splinter Wed 16th 10:25 AM CEST.

Ariel Consortium meeting 16-18 June 2021

## Ariel W...

Coordinat...

WG ques...




- About 80 members.
- Links with other WG: Chemistry, Planetary Formation, Stellar...
- Activity, ....
- Projects organised in streams (sub-topics).
- Meetings Wed 4:30pm (CEST) every 2 weeks.
- No need to be a retrieval expert or have a retrieval code.

Ariel Consortium meeting 16-18 June 2021

# Ariel Dry Run 2025

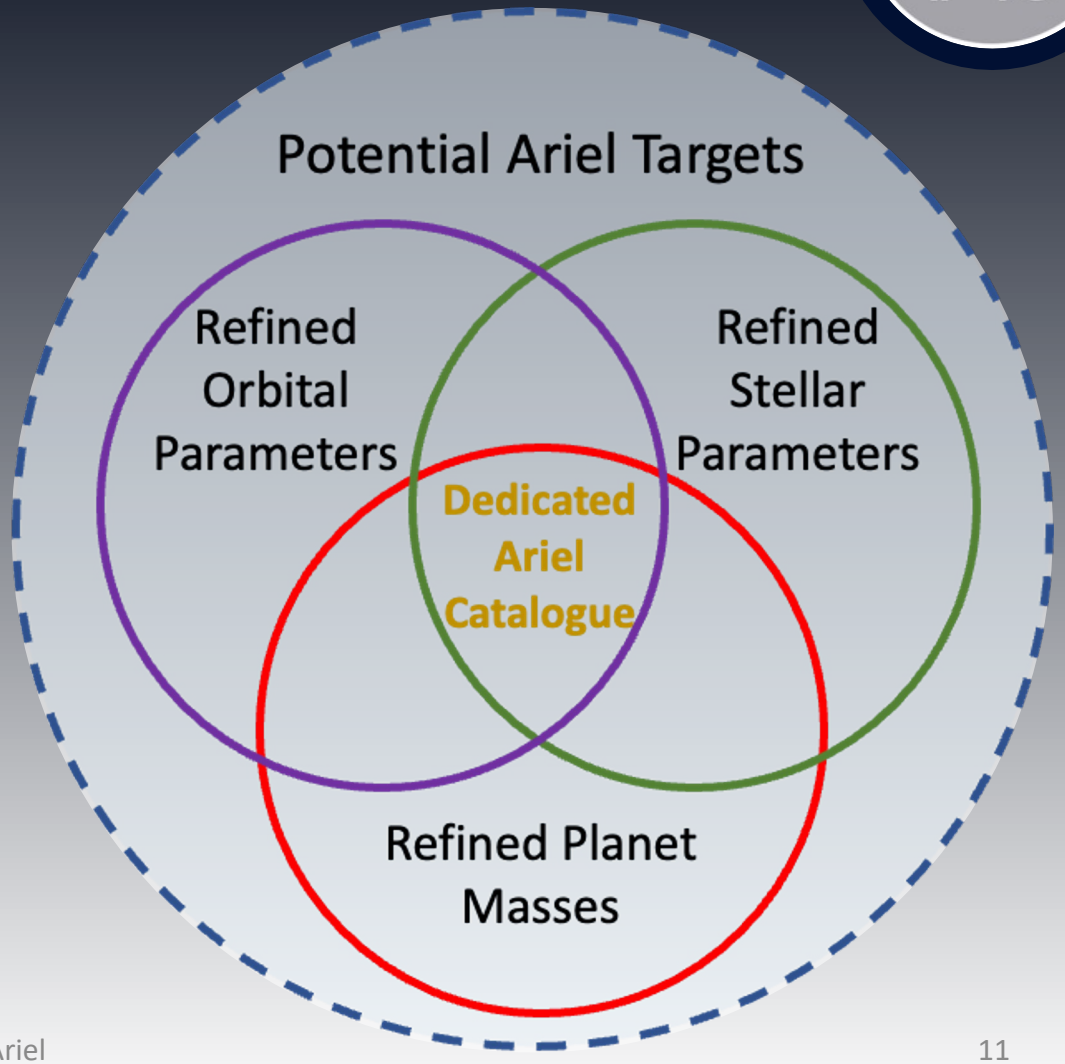
GETTING READY FOR 2029!

- Target selection, observational strategies, scheduling will be done *as if* Ariel were launched in 2025
- A great opportunity to prepare for the real launch in 2029! We will learn from mistakes about how to improve our approach
- Input from community encouraged through web tools, Ariel open conference 2025

# Towards an Ariel catalogue

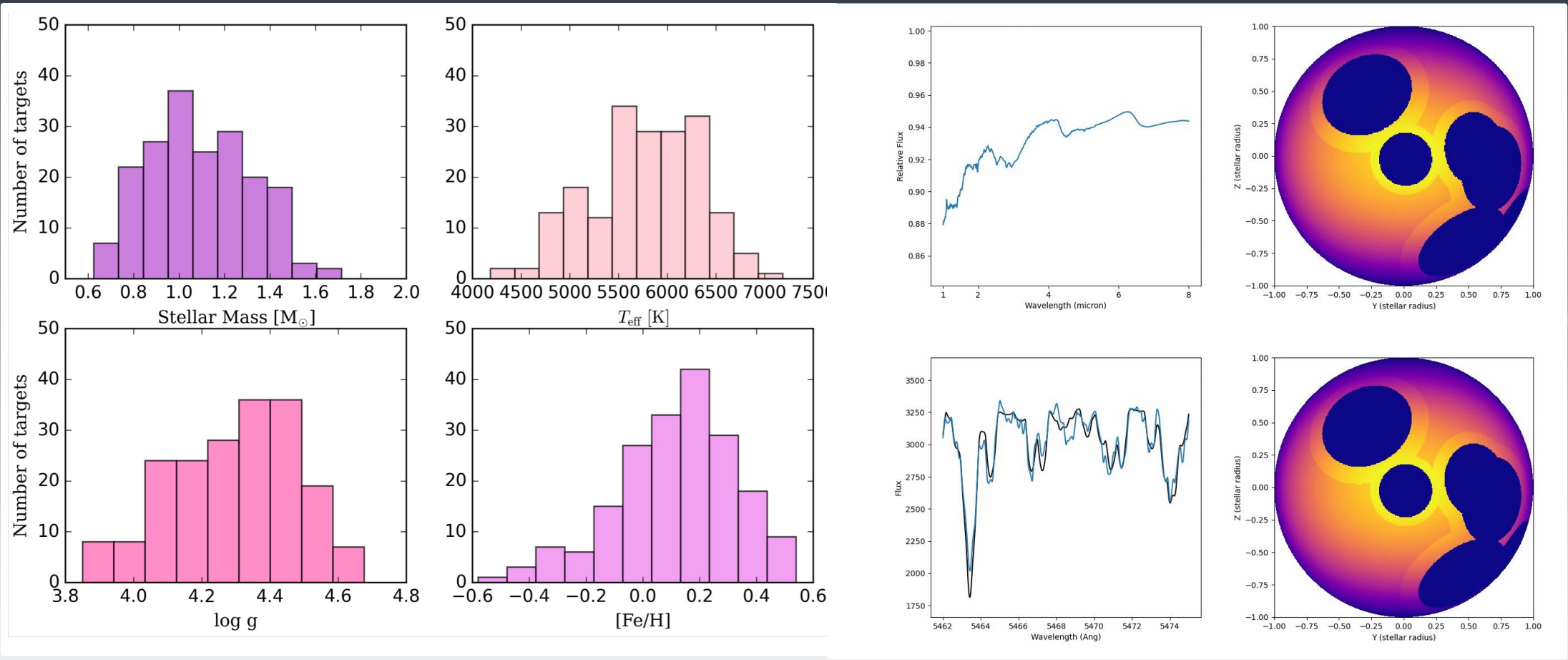
GETTING READY FOR 2029!

- Homogeneous characterisation of the basic parameters of all* potential Ariel targets and their host stars
- All is connected and contributes to the precision/accuracy of the data and models and the efficiency of the observations



# Ariel target candidates

STELLAR PARAMETERS REFINED BY STELLAR CHARACTERISATION WG; MORE WORK BY STELLAR ACTIVITY WG




Magrini et al. 2022; Thompson et al, 2023; Petralia et al. in prep.

# ExoClock: target ephemerides+

900+ PARTICIPANTS FROM 50 COUNTRIES (77% AMATEURS) ☺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ExoClock Project. II. A Large-scale Integrated Study with 180 Updated Exoplanet Ephemerides

A. Kokori[1], A. Tsiaras[1,2], B. Edwards[1,3], M. Rocchetto[1], G. Tinetti[1], L. Bewersdorff[4], Y. Jongen[5], G. Lekkas[6], G. Pantelidou[7], E. Poultourtzidis[7] + Show full author list

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The Astrophysical Journal Supplement Series, Volume 265, Number 1

Citation A. Kokori *et al* 2023 *ApJS* **265** 4

DOI 10.3847/1538-4365/ac9da4

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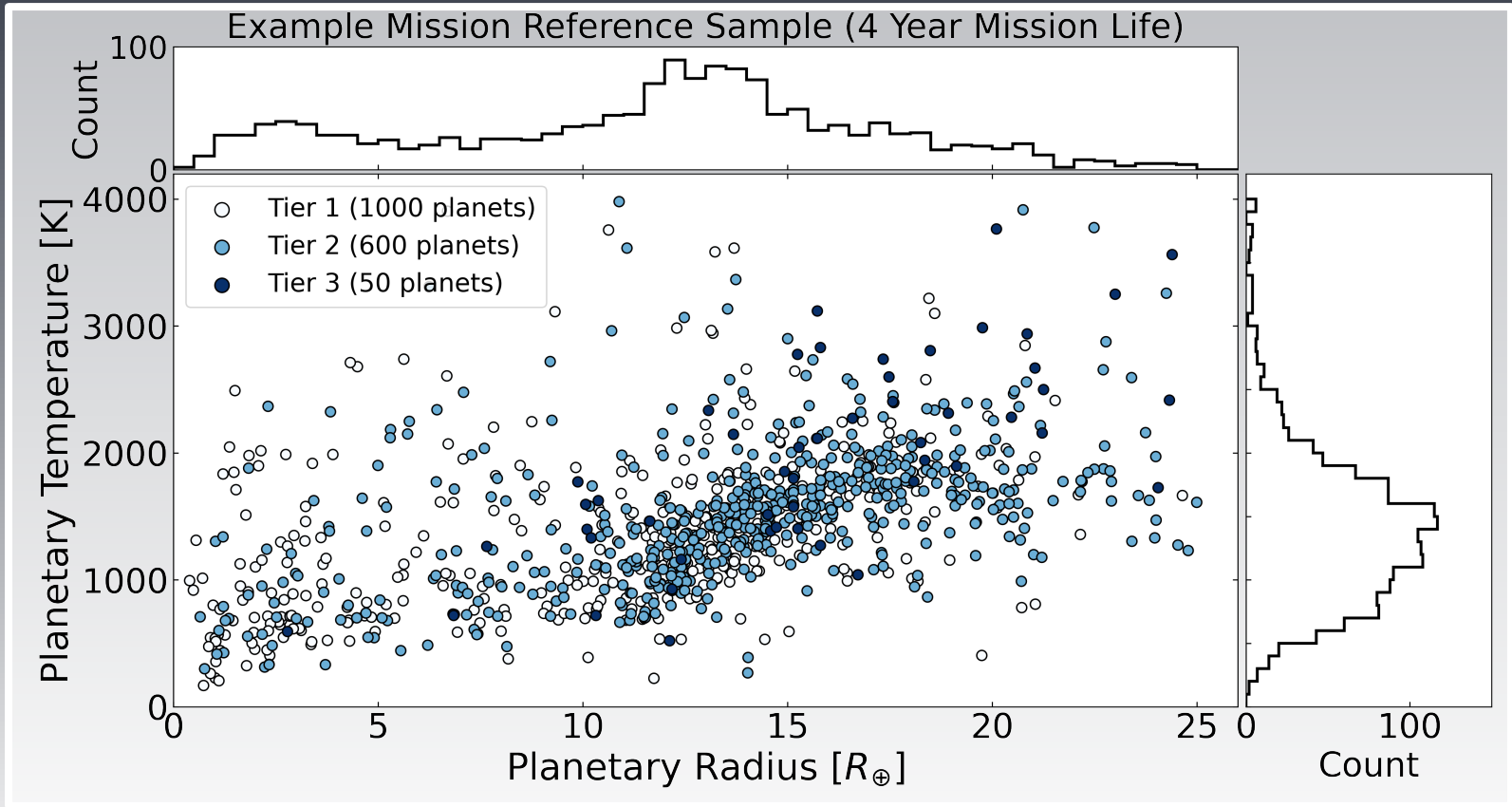
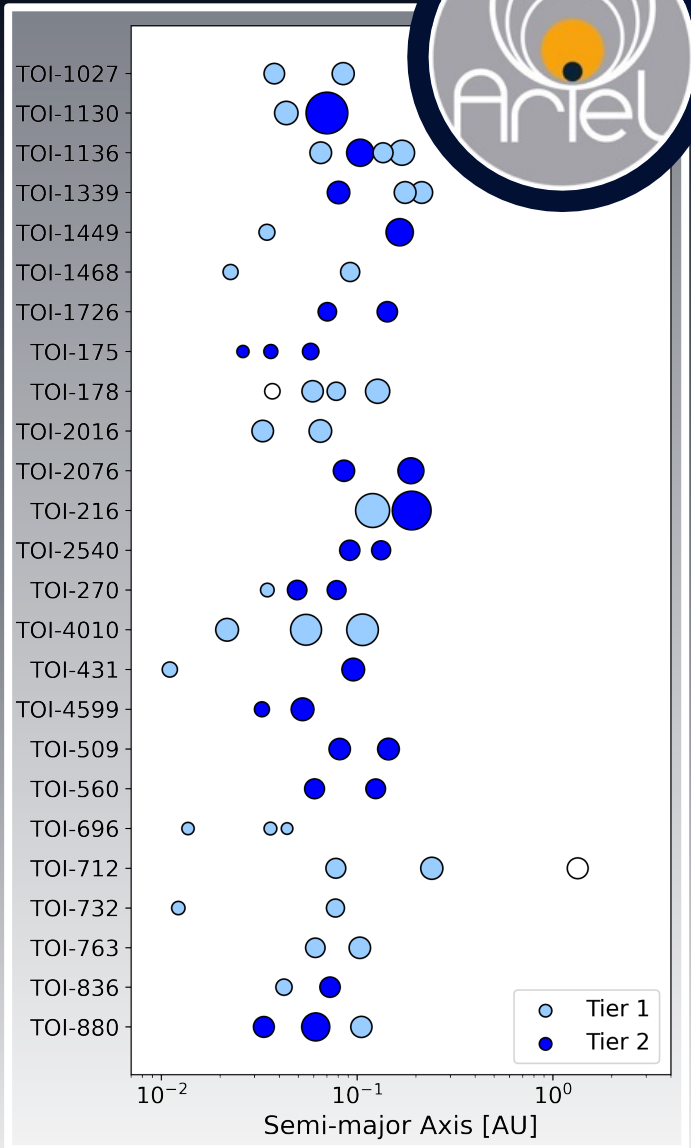
| | vs ExoClock II (180 planets) | vs initial (450 planets) |
|---|---|---|
| Significantly improved | 0.0% | 31.8% |
| Drifting | 1.1% | 12.7% |
| Improved | 29.4% | 40.9% |
| No change | 65.5% | 10.4% |
| TTVs | 3.9% | 4.2% |

https://www.exoclock.space

# Ariel target candidates

TARGET UPDATES FROM TESS AND TARGET SELECTION OPTIMISATION

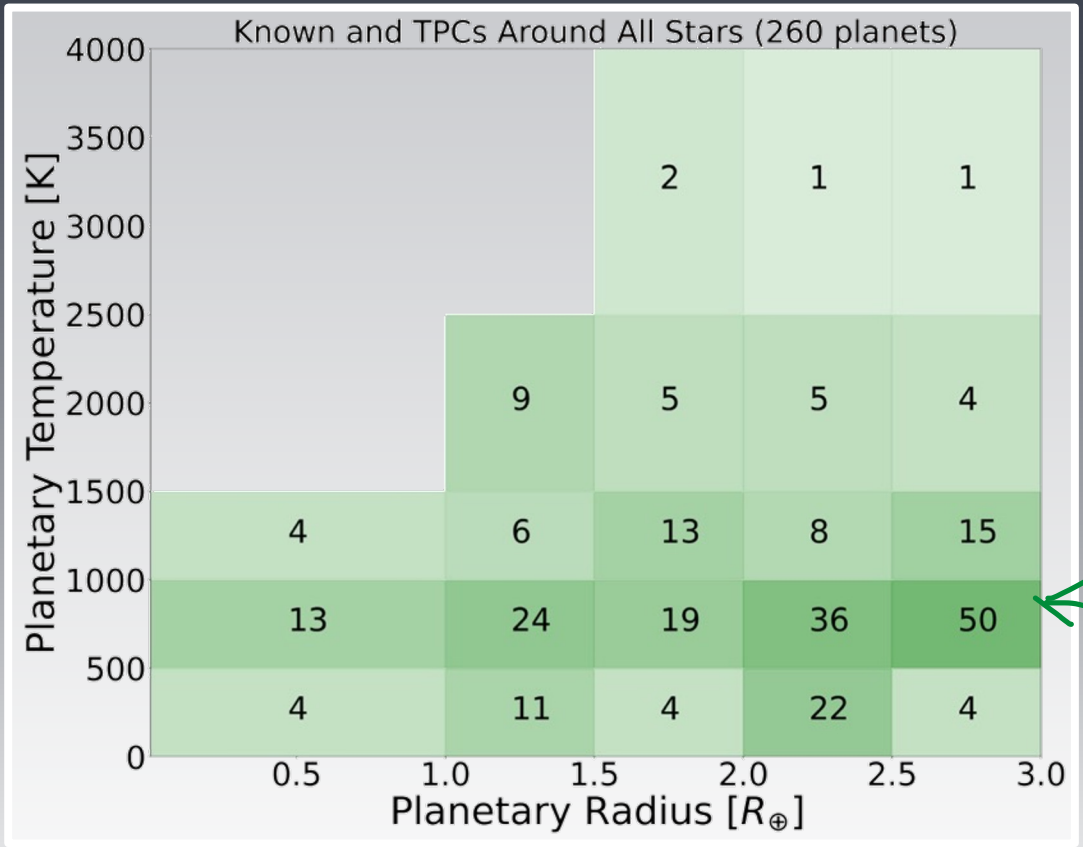


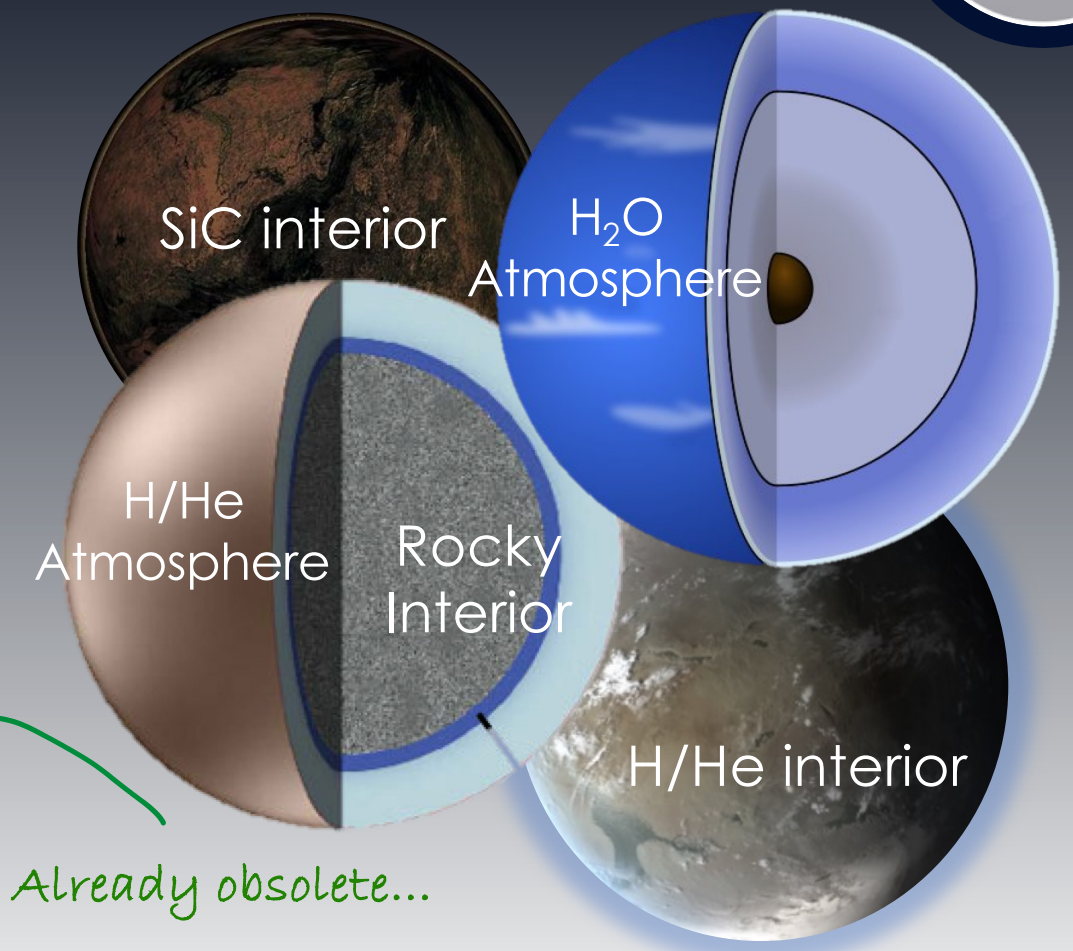




Edwards et al. 2022

# Ariel target candidates

MORE SMALL PLANETS DISCOVERED BY TESS FOR ARIEL!



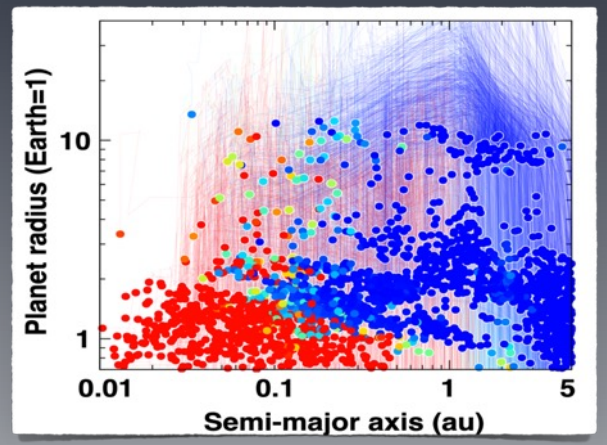




Already obsolete...

Edwards et al. 2022

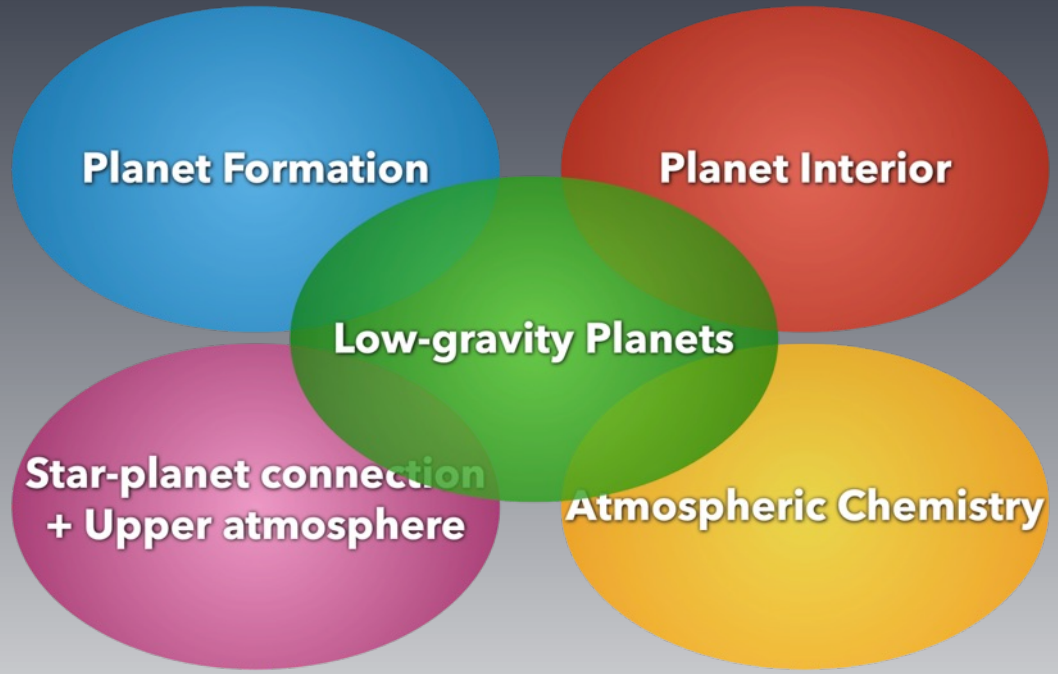
# Small planets

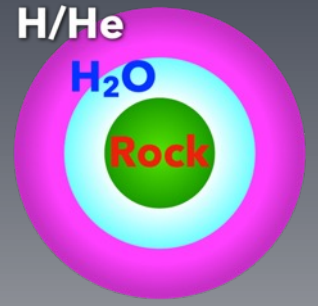
THEY ARE THE MOST NUMEROUS TARGETS, THEY ARE COMPLEX & INTERESTING

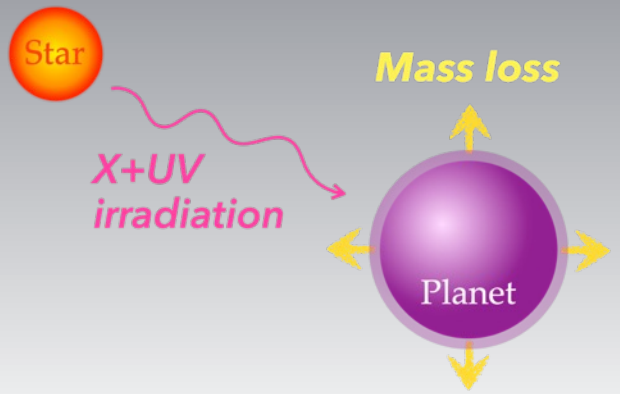


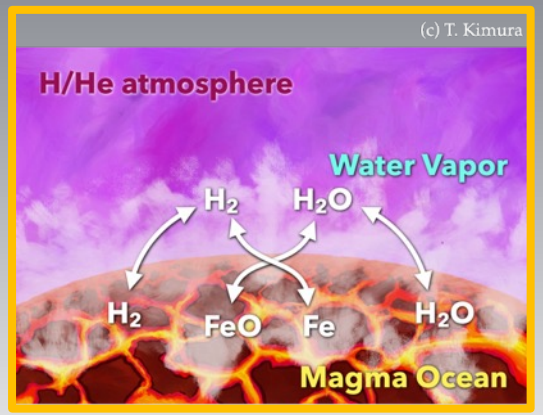

Kimura & MI (2022, Nat. Astron.)

Ikoma




Strong synergy among many WGs!

# Mass determination of Ariel targets

NEW GLOBAL PLAN TO COORDINATE RV MEASUREMENTS

1. Establish mass precision needed for Ariel science (Changeat+20; Di Maio+22,23)

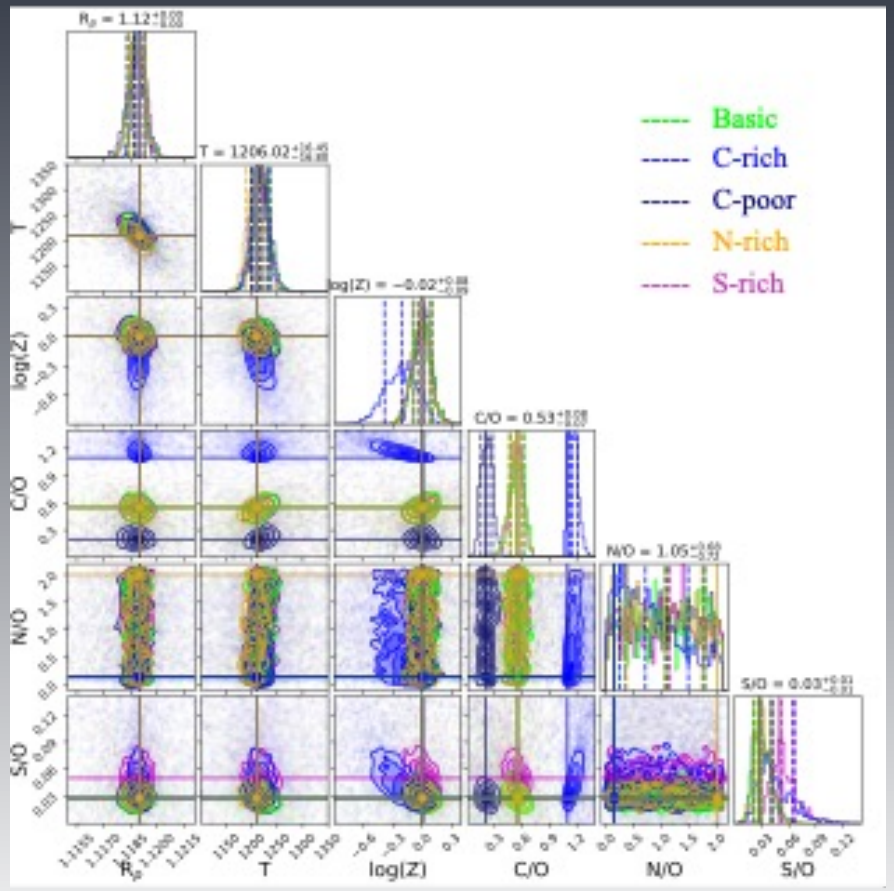
2. Identified targets which should be prioritized for Ariel

3. Coordination of community and Ariel team efforts for mass determination of Ariel targets

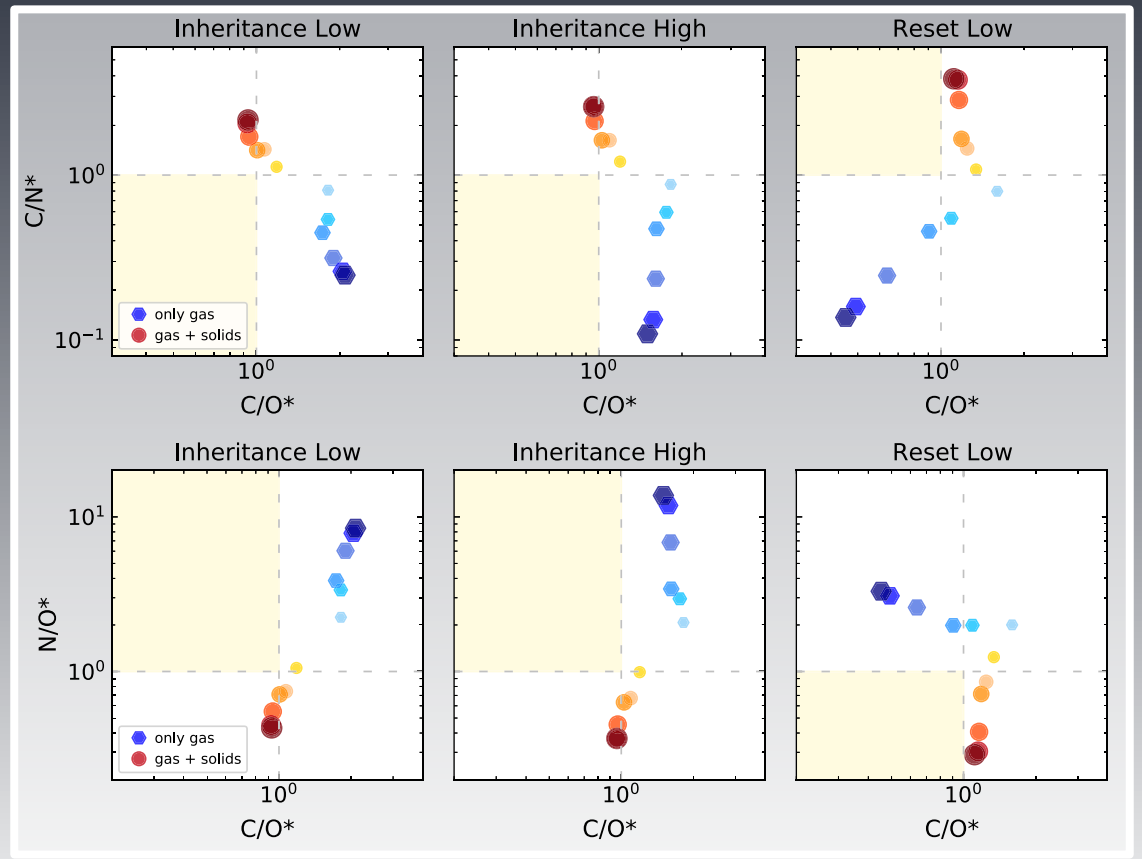
Mass-characterisation WG

# Link to planet formation

ARIEL ABILITY TO DETECT ELEMENTAL RATIOS IN GIANT PLANETS' ATMOSPHERES: BEYOND C/O



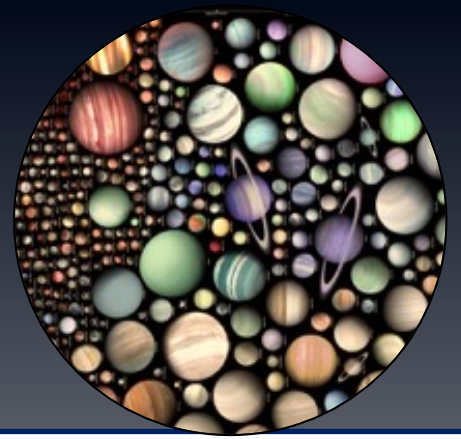

Fang et al. 2023



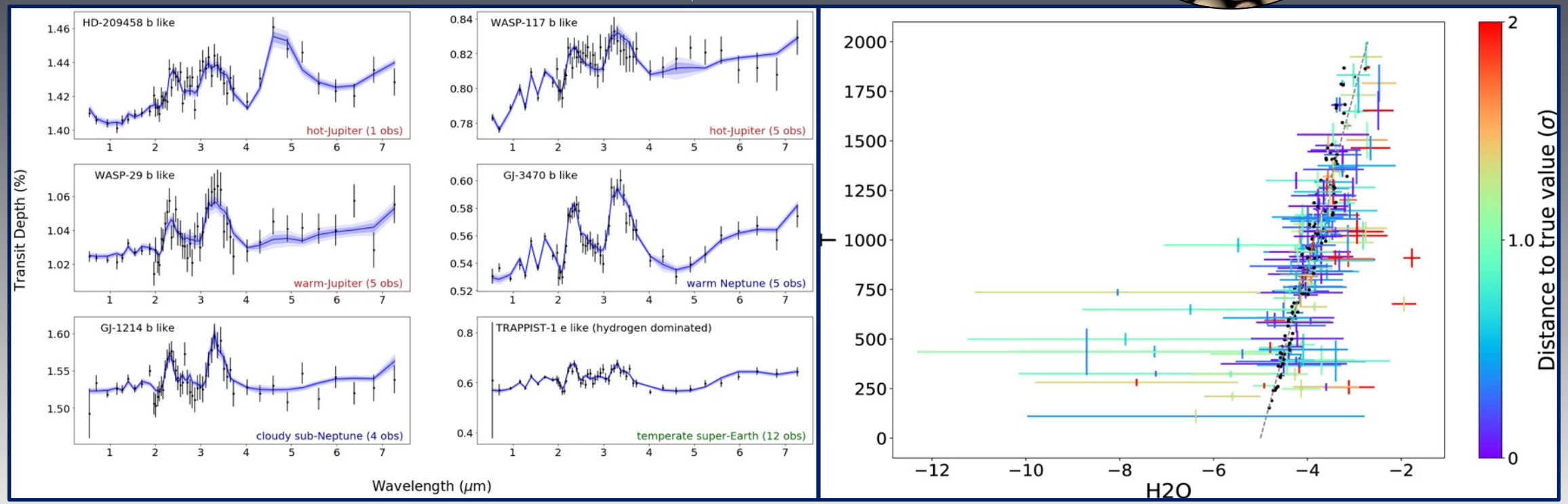

Pacetti et al 2022; Turrini et al. 2021

# Chemical trends?

SEARCHING FOR CHEMICAL AND CLOUD TRANSITIONS



Large scale simulations program

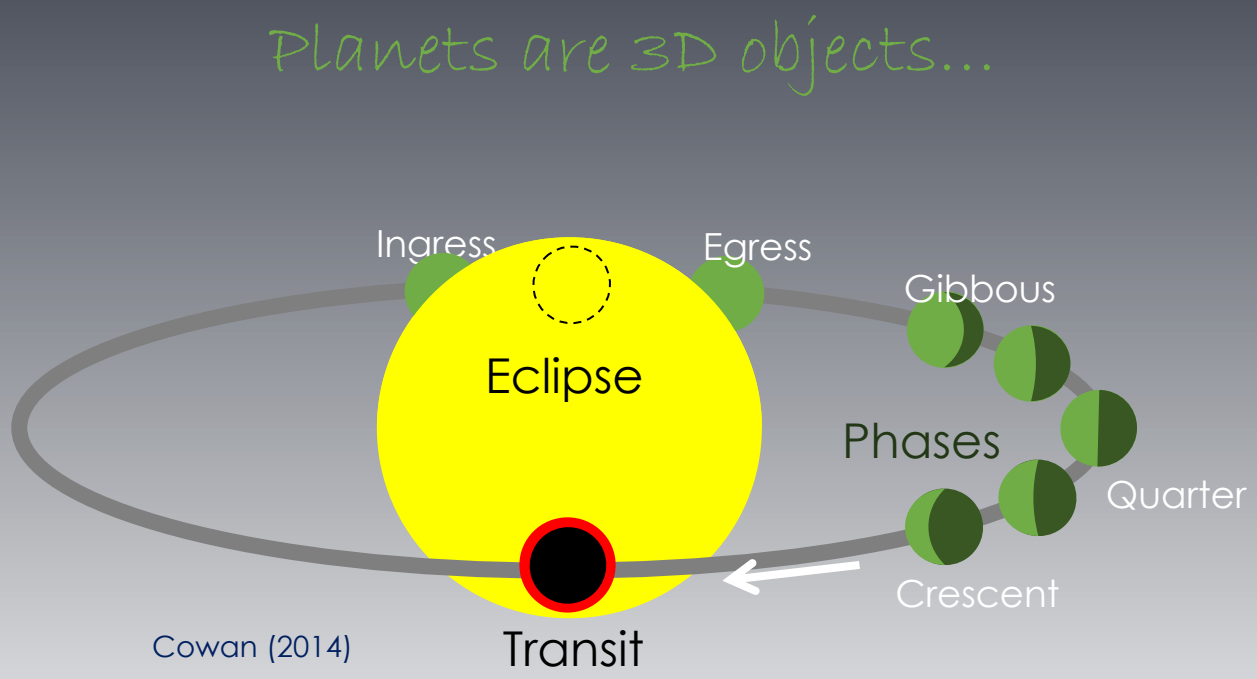


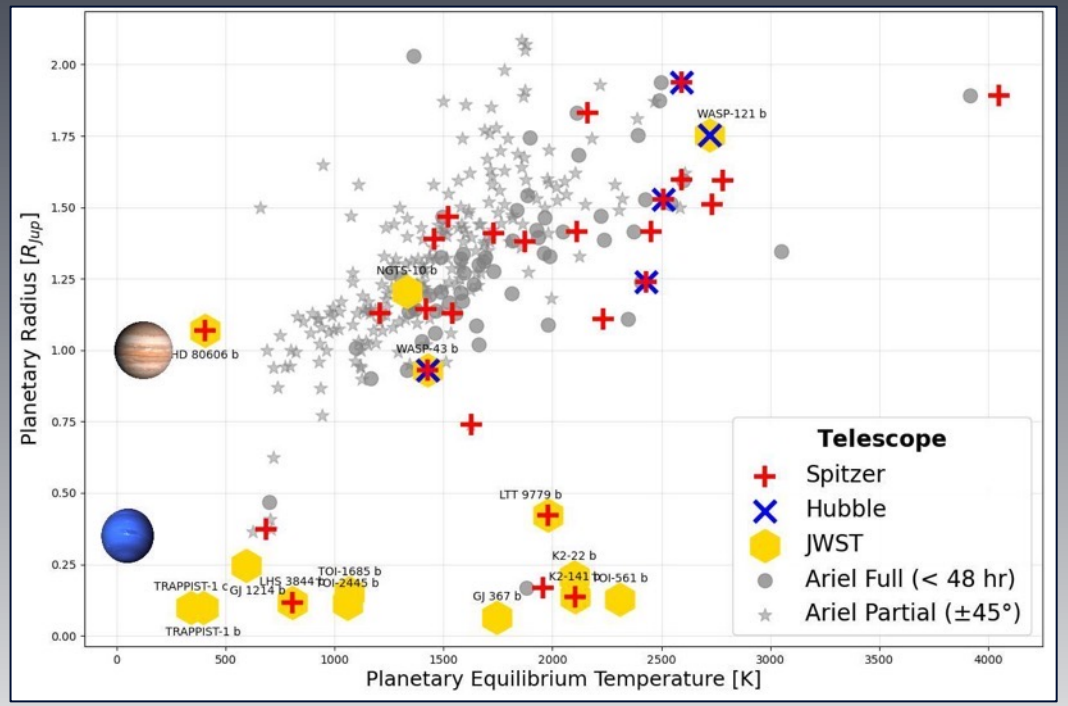

https://github.com/ucl-exoplanets/TauREx3_public

Changeat et al. 2020; see also Mugnai et al 2022, Bocchieri et al., Ma et al.

# Phase-resolved spectroscopy

MORE PHASE-RESOLVED OBSERVATIONS!!!

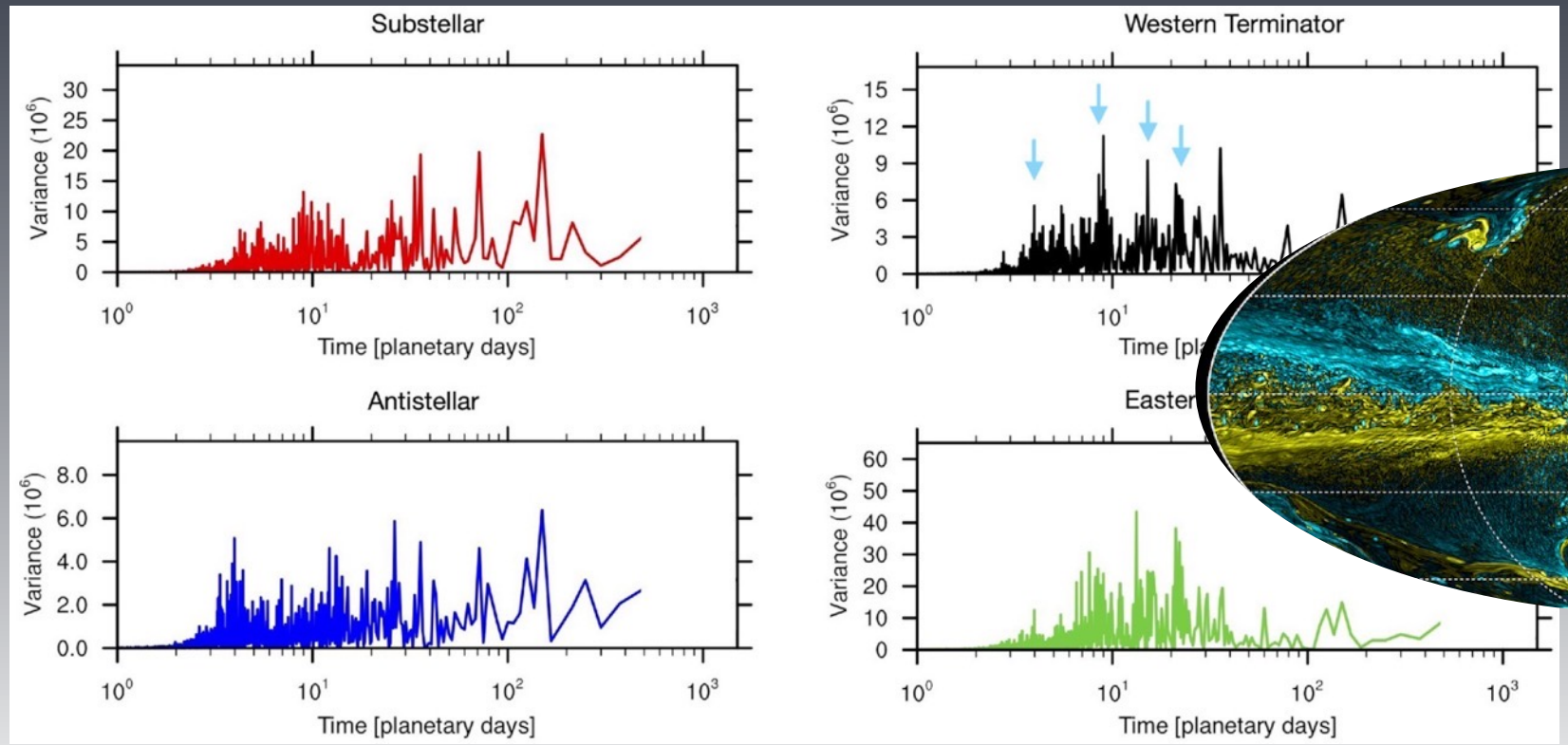


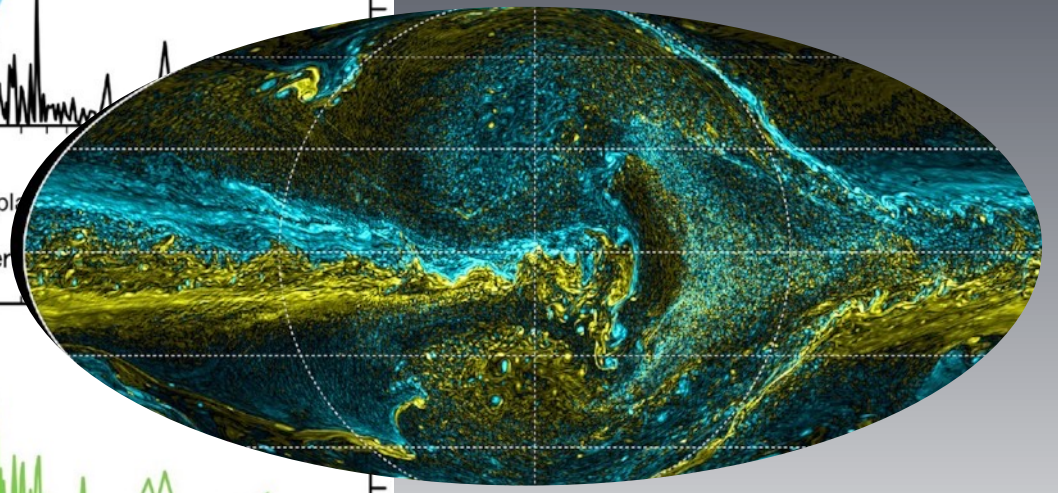




Courtesy of N. Cowan

# Atmospheric variability

OBSERVING THE VARIABILITY IN SPACE AND TIME: MORE REPETITIONS

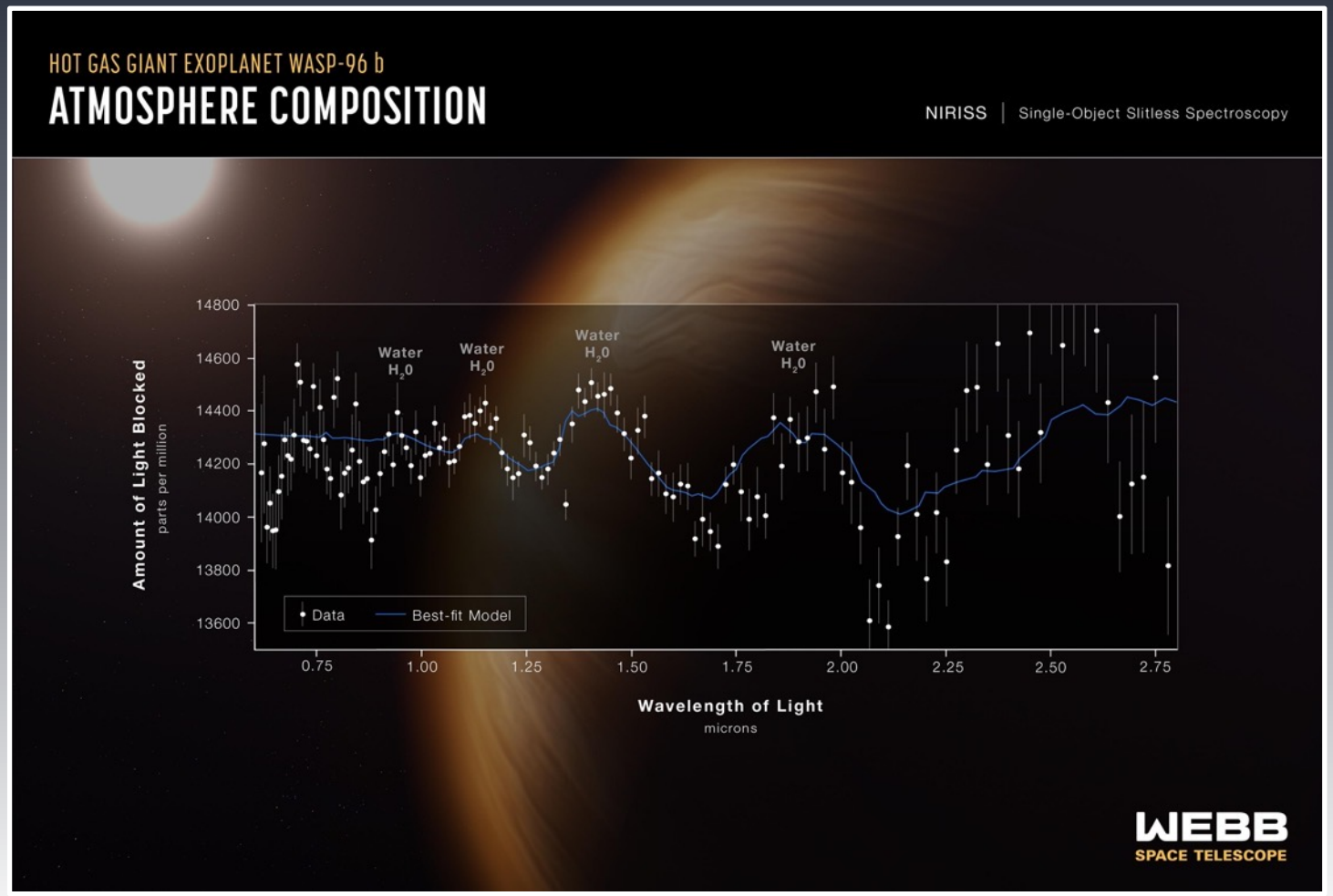


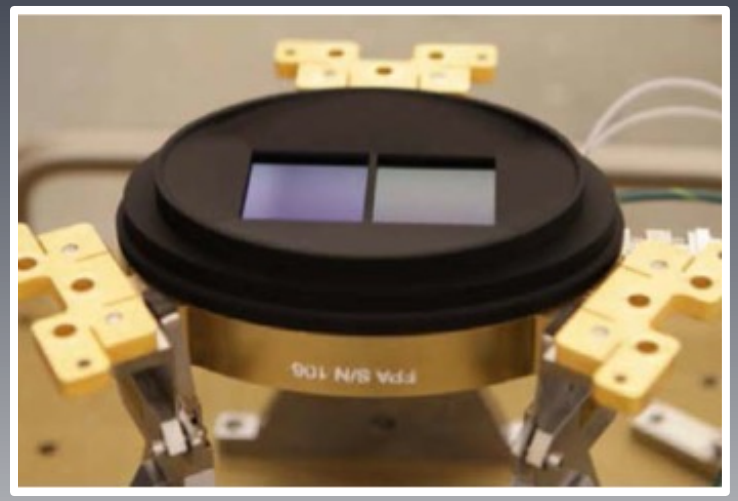
Skinner & Cho, 2022

# Synergies with JWST

UNPARALLELED OPPORTUNITY FOR THE SCIENCE BUT ALSO CALIBRATION STRATEGY, DETECTOR PERFORMANCE

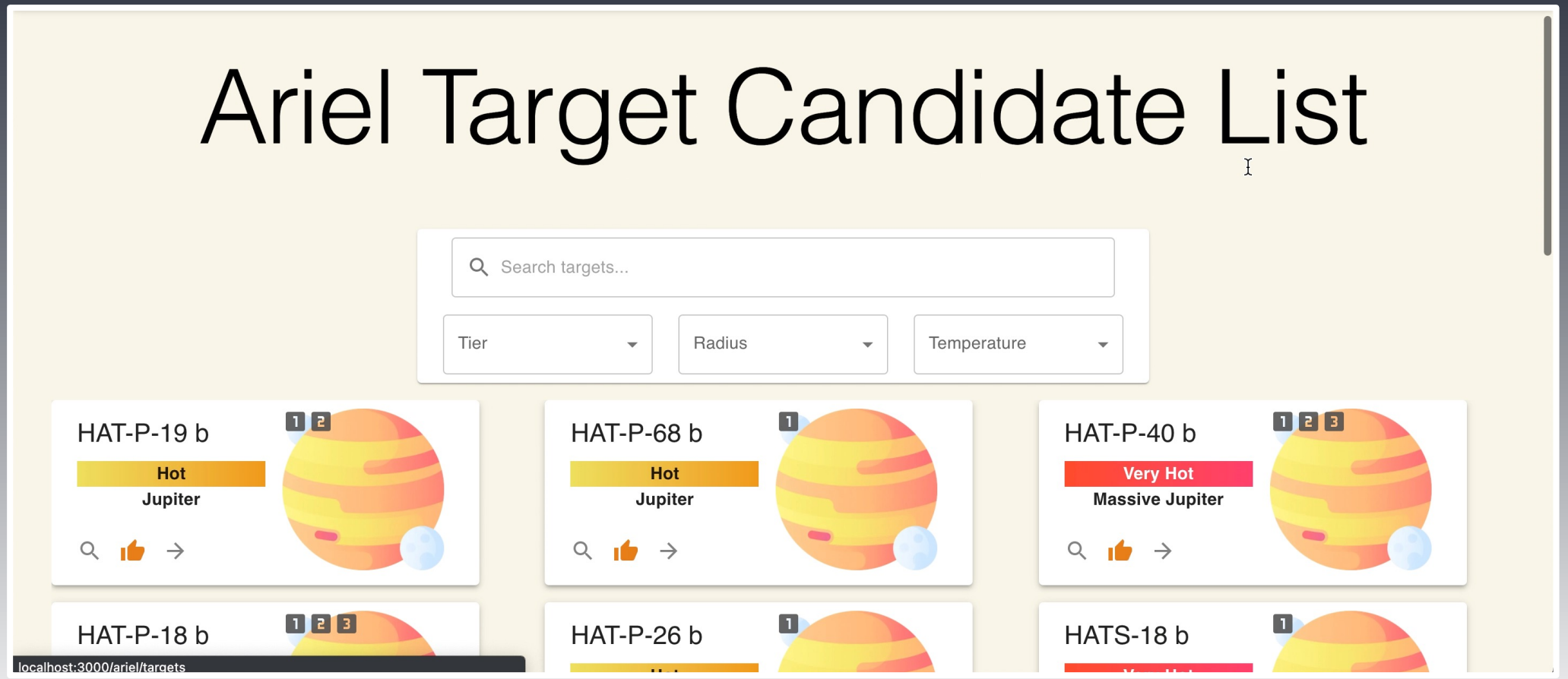



Lessons learned



# Ariel target candidates

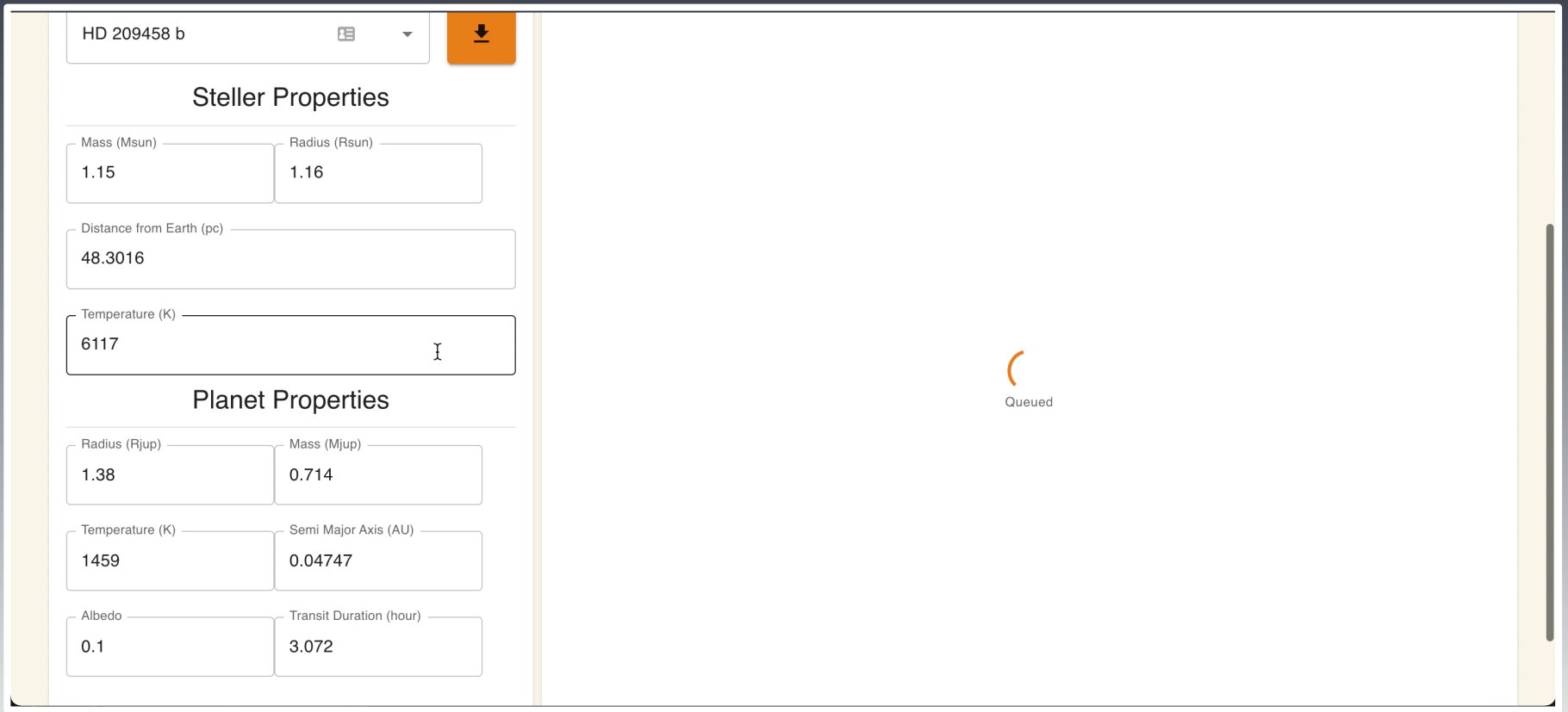
CATALOGUE AVAILABLE SOON THROUGH A NEW INTERACTIVE, WELL MAINTAINED WEBSITE




Al-Refaie et al. 2023; Edwards et al. 2022;

# Ariel target candidates

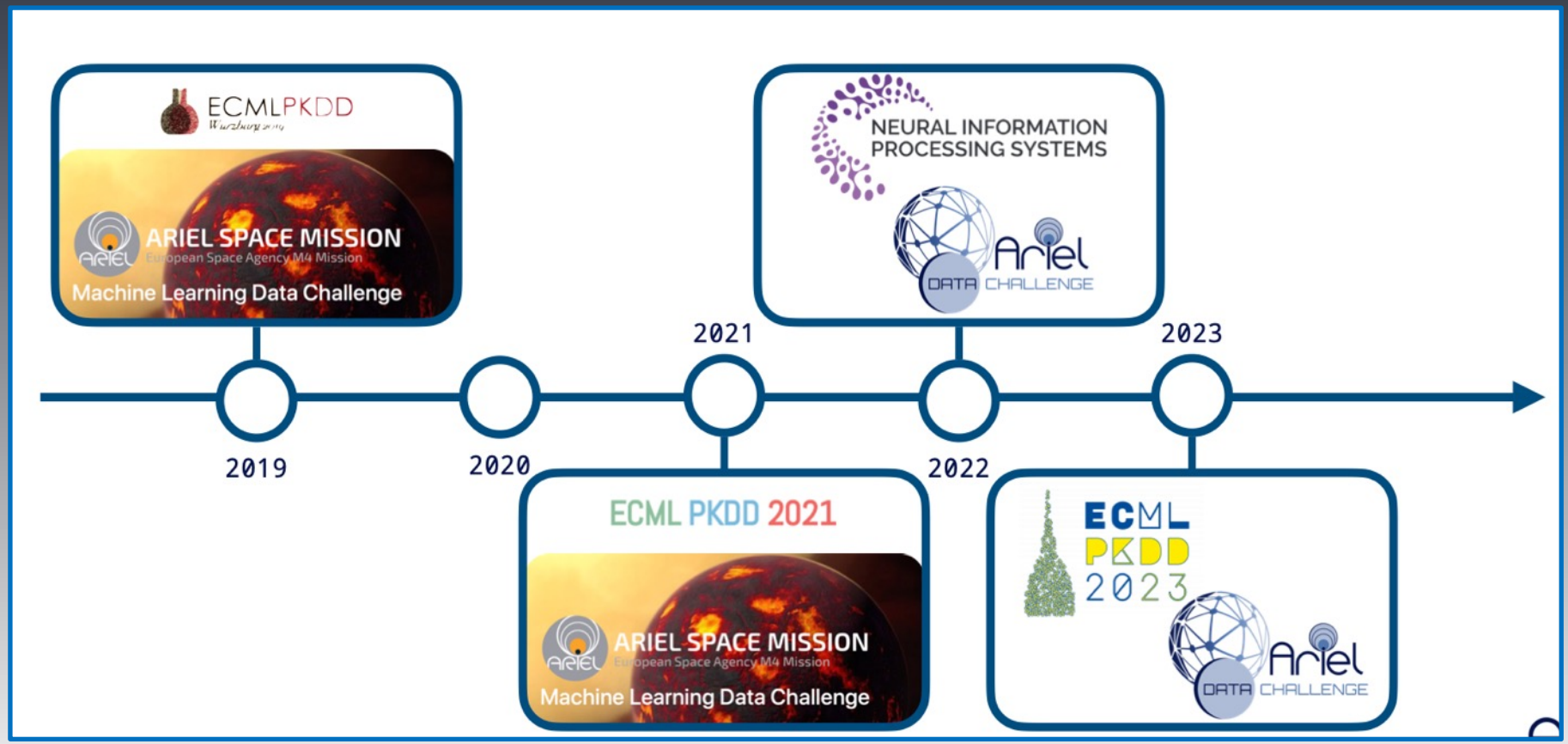
CATALOGUE AVAILABLE SOON THROUGH A NEW INTERACTIVE, WELL MAINTAINED WEBSITE




Mugnai et al, 2022

# Ariel Data Challenges

A HUGE GLOBAL SUCCESS. ADCS YEARLY PLANNED TO SUPPORT GROUND SEGMENT ACTIVITIES



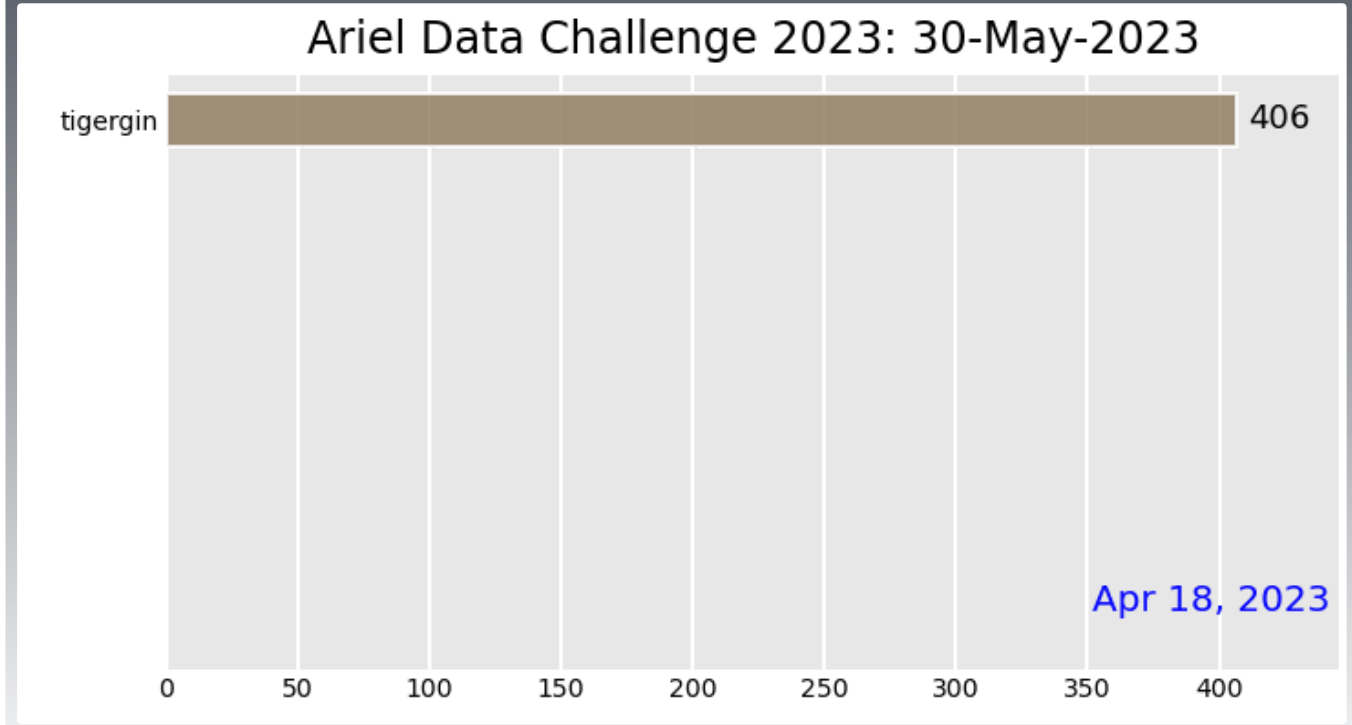

A mission is more than flying hardware....

There is AI ☺

# Ariel Data Challenges

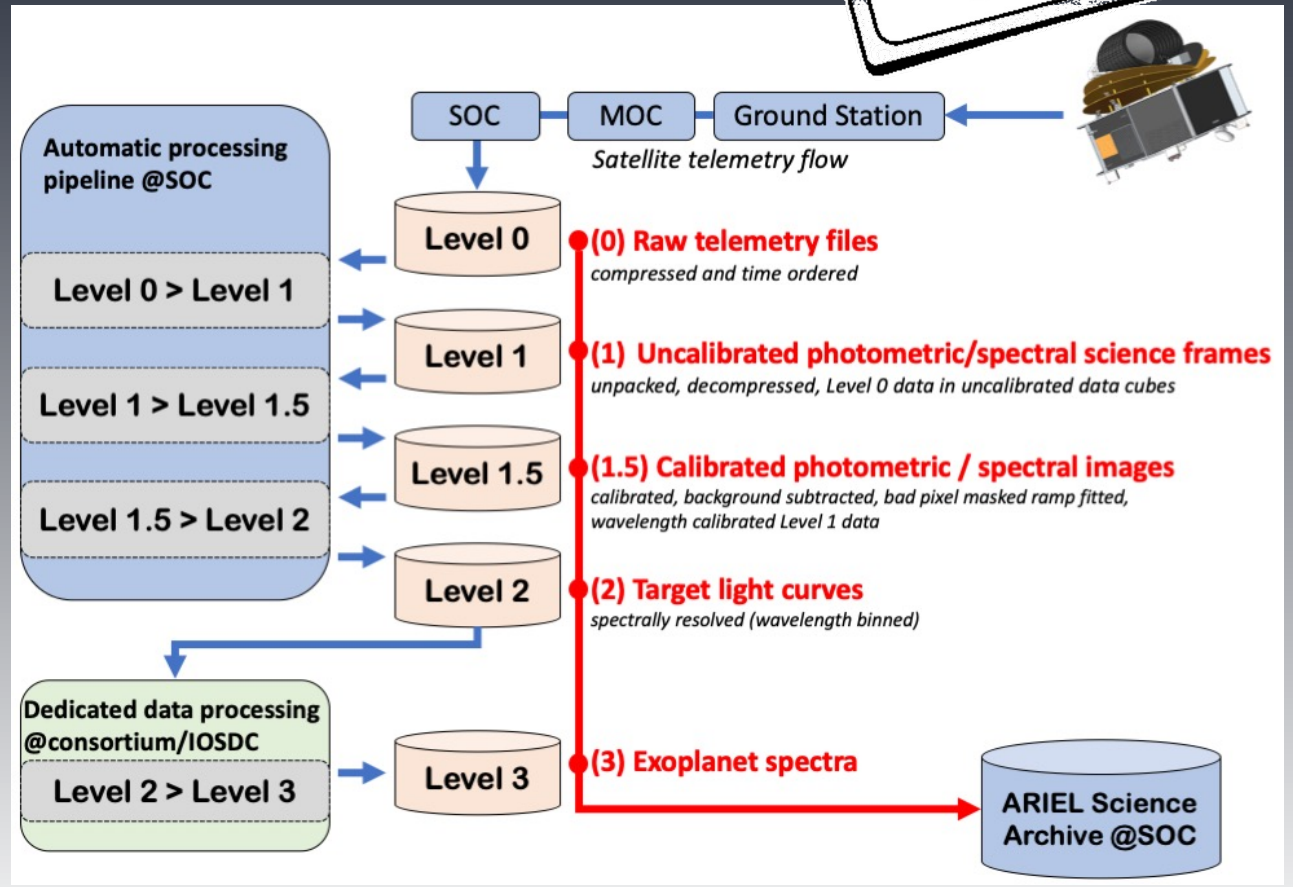
ADC 2023: THE RACE IS OVER…


https://www.ariel-datachallenge.space/



# Data release

A VERY OPEN APPROACH


## Science Demonstration Phase

Data will be released immediately after processing, consolidation and quality control up to Level 2 products.

## Nominal Science Operations Phase

- **Tier 1** data public immediately after quality control is completed;
- **Tier 2, 3** data public 6 months after quality control is completed;
- **Tier 4** data public 1 year after quality control is completed.

## Complementary Science data

- 5%-10% time available for other science, allocated through ESA calls
- Proprietary to the proposers for 6 months

# Conclusions

- Exoplanets appear to be ubiquitous in our Galaxy
- The number of discovered exoplanets is increasing exponentially, but we still know very little about them
- Ariel has been conceived to deliver the first chemical survey of ~ 1000 exoplanets, probing uniformly the gamut of planet and stellar parameters
- Input from the community is encouraged through open data policy, regular open workshops, information about target candidates available through interactive websites, Ariel exposure time calculators and open-source tools.

Interested in Ariel?

Let's talk at lunch ☺

Image credit: UCL CSED