



UNIVERSITY OF TARTU
Tartu Observatory



ARIEL MISSION IN ESTONIA

From stars to exoplanets

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UT Tartu Observatory

Image credit: Léa Changeat



11/01/2024

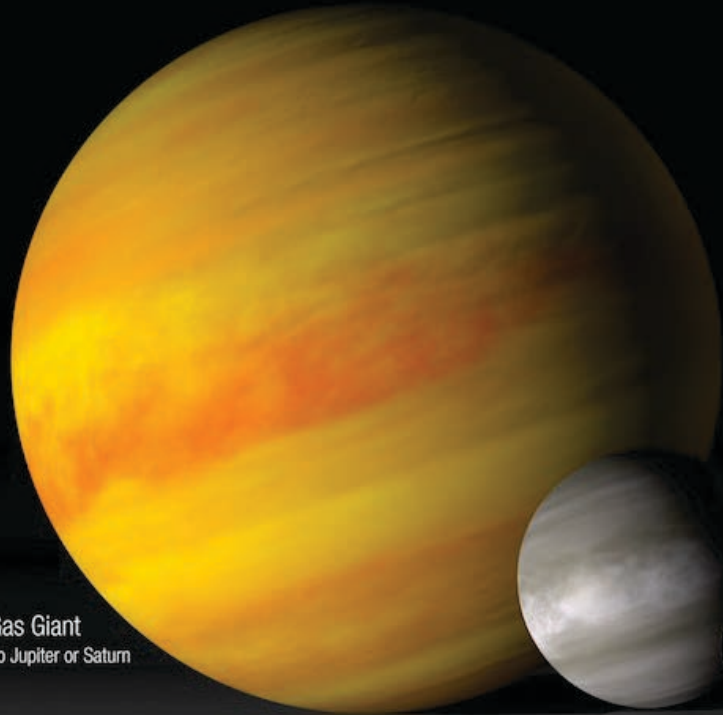


An exoplanet is a planet that's orbiting around the star that's not our Sun

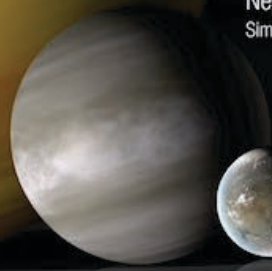




What's Out There? Exoplanet types



Gas Giant
Similar to Jupiter or Saturn



Neptune-Like
Similar to Uranus or Neptune

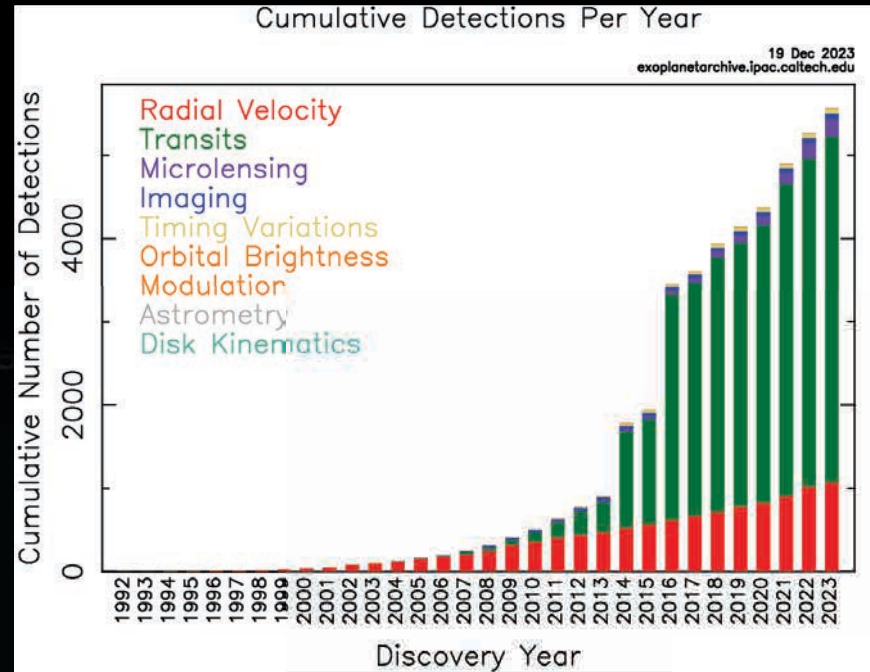


Super Earth
More massive than Earth,
lighter than Neptune



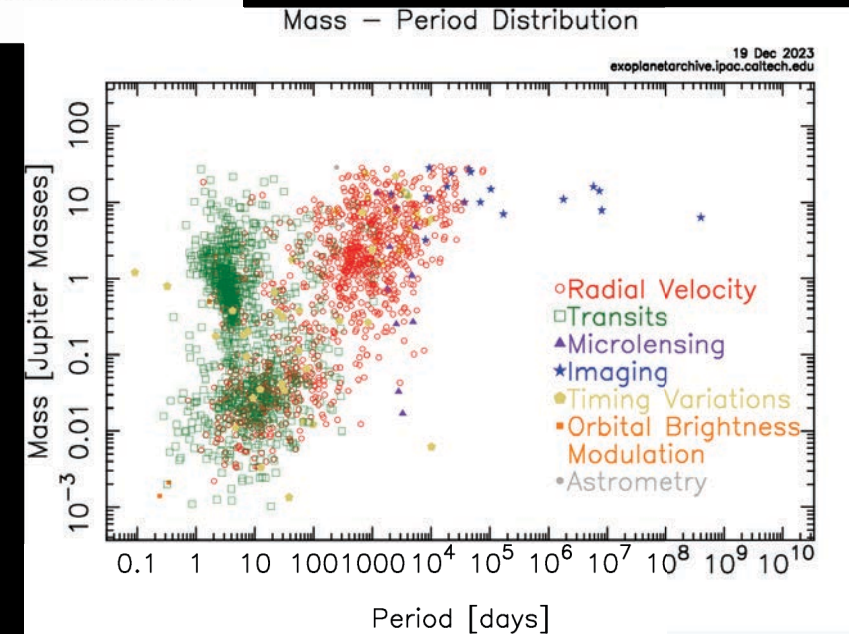
Terrestrial
Rocky, in Earth's
size range

Image credit: NASA-JPL/Caltech



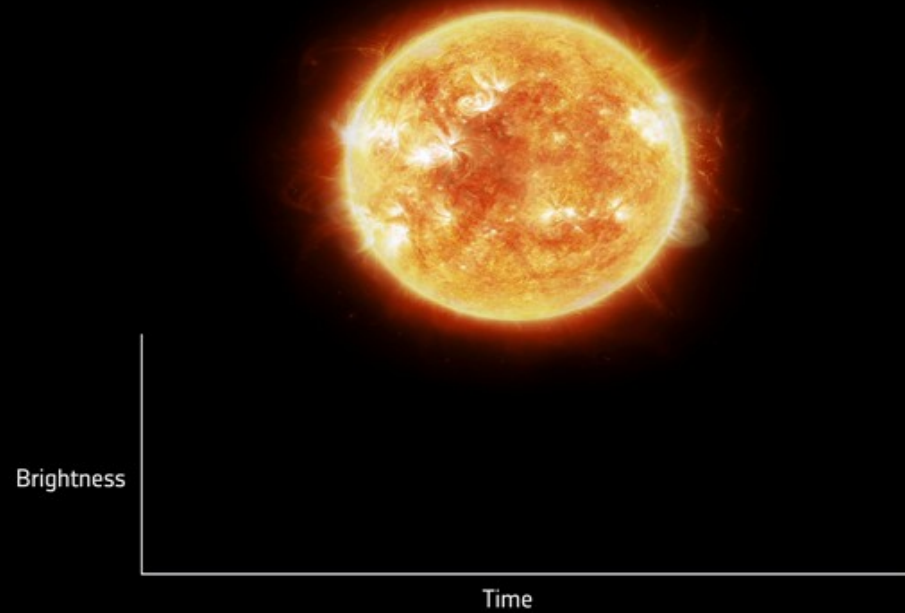
5 566
Confirmed planets
18.12.2023

Image credit: NASA Exoplanet Archive





Monitoring exoplanets with the transit method



Credit: ESA

The change in the star's brightness is less than one percent
A planet the size of Earth would cause a 0.008% change in the brightness of the Sun



ARIEL SPACE MISSION

European Space Agency M4 Mission

Key Science Questions

- What are exoplanets made of?
- How do planets and planetary systems form?
- How do planets and their atmospheres evolve over time?

Primary goal

- Large-scale survey of a diverse sample of about 1000 exoplanets

Image credit: Léa Changeat



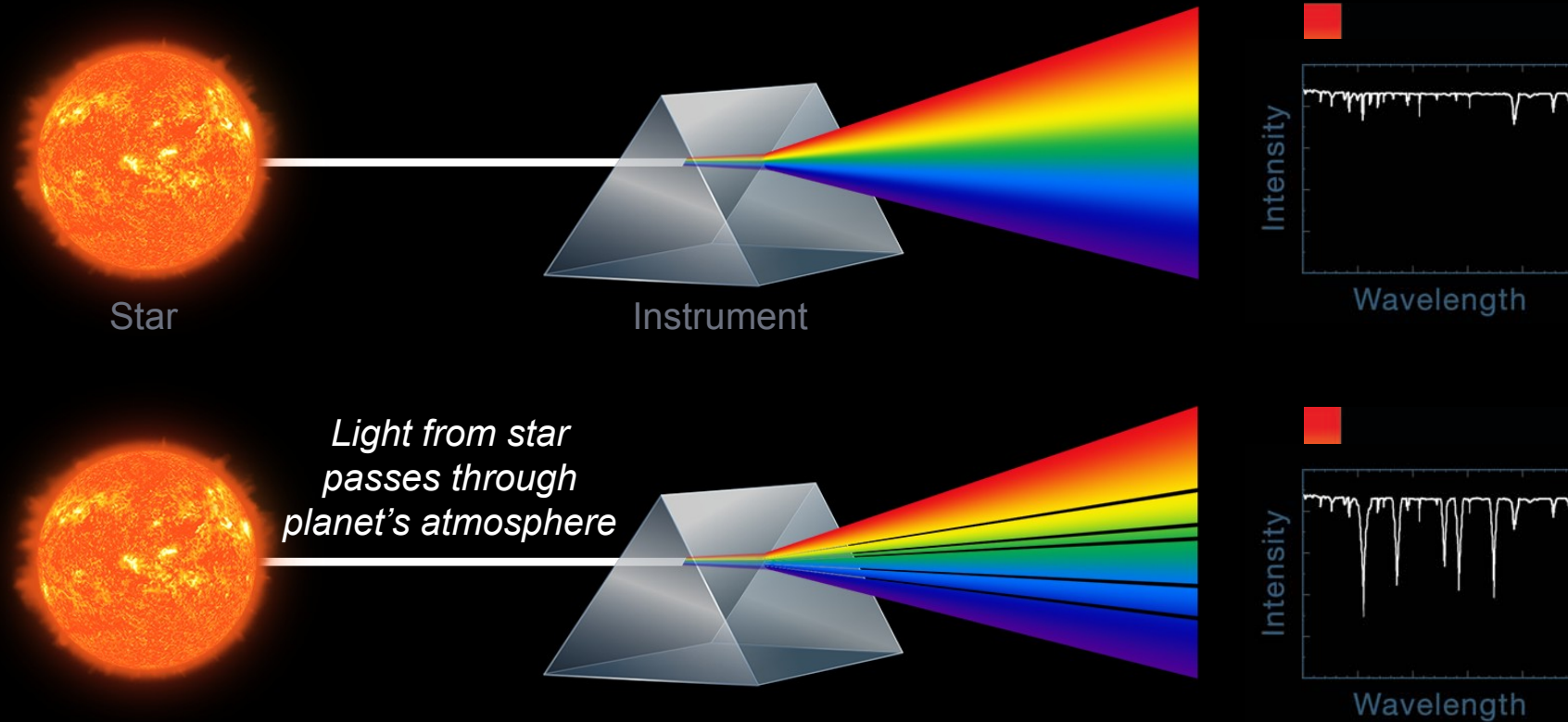


ARIEL SPACE MISSION

European Space Agency M4 Mission

Exoplanet Communications

Spectroscopy – Detection of Biosignatures



1/10/24

6

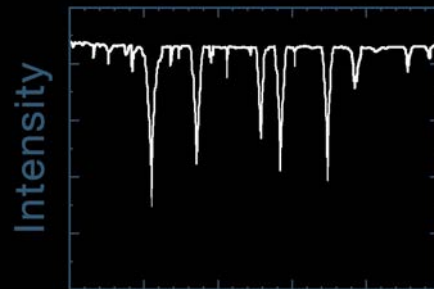


ARIEL SPACE MISSION

European Space Agency M4 Mission

Exoplanet Communications

Spectroscopy – Detection of Biosignatures

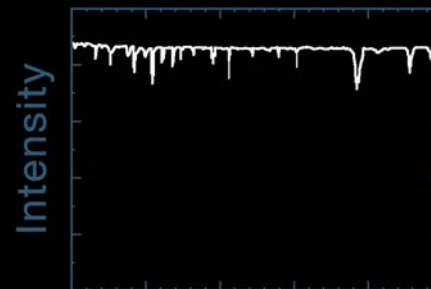


Wavelength

Light from
star & planet

minus

—

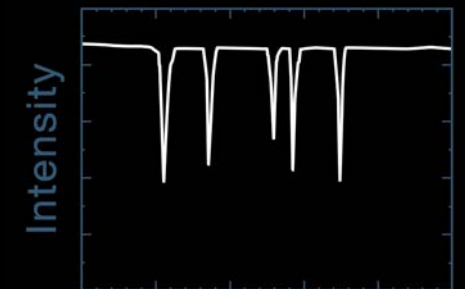


Wavelength

Light from
star only

equals

=



Wavelength

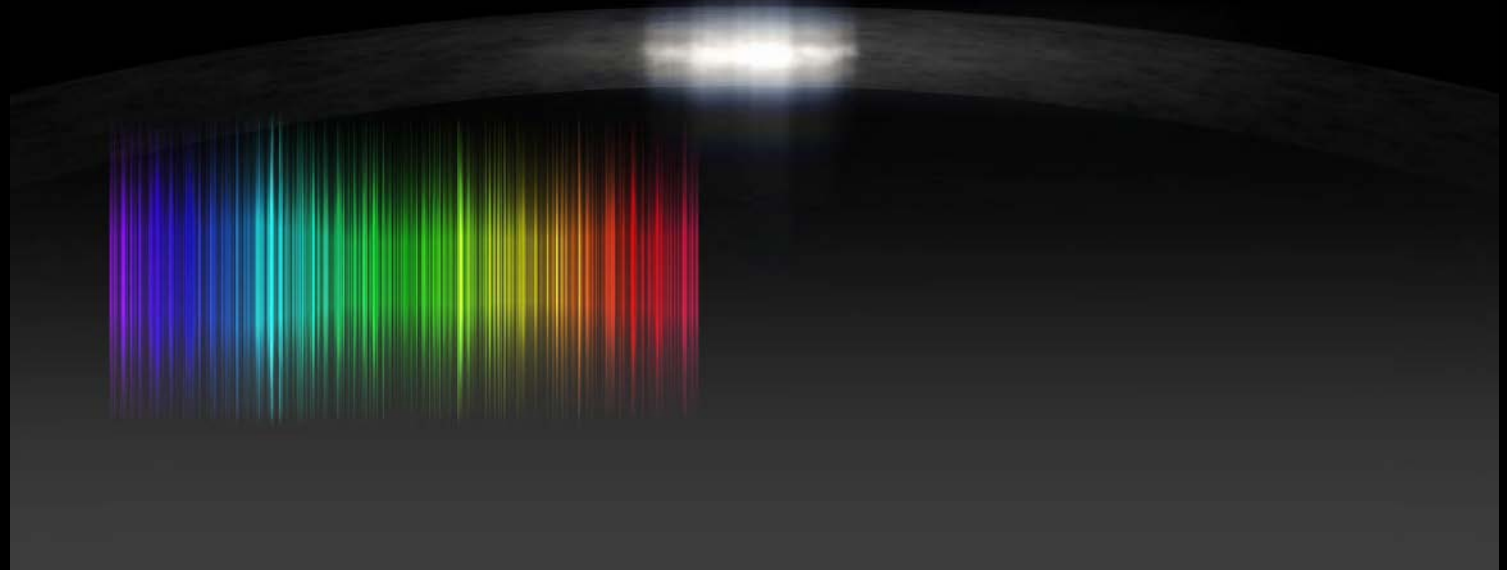
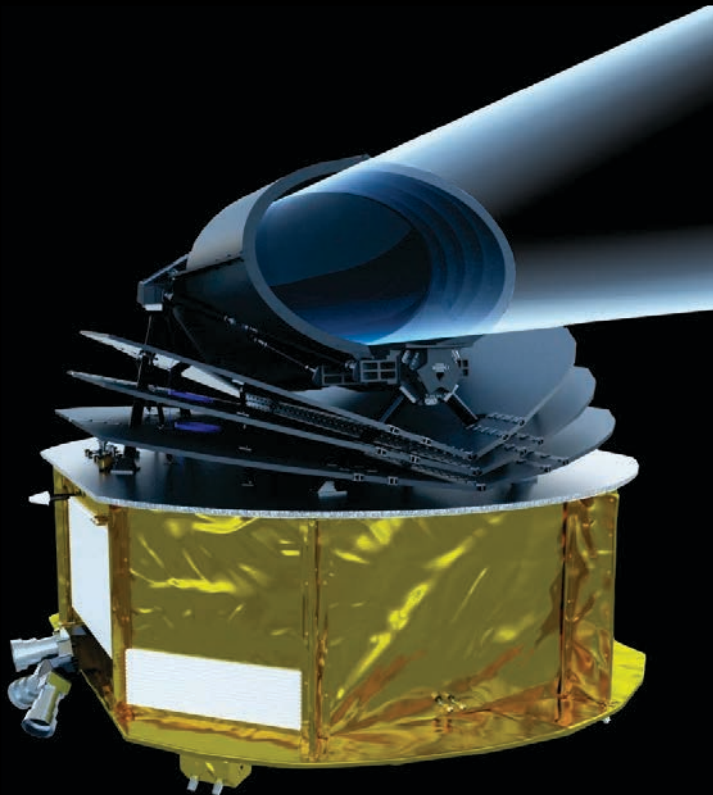
Light from
planet only

exoplanets.nasa.gov



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European Space Agency M4 Mission



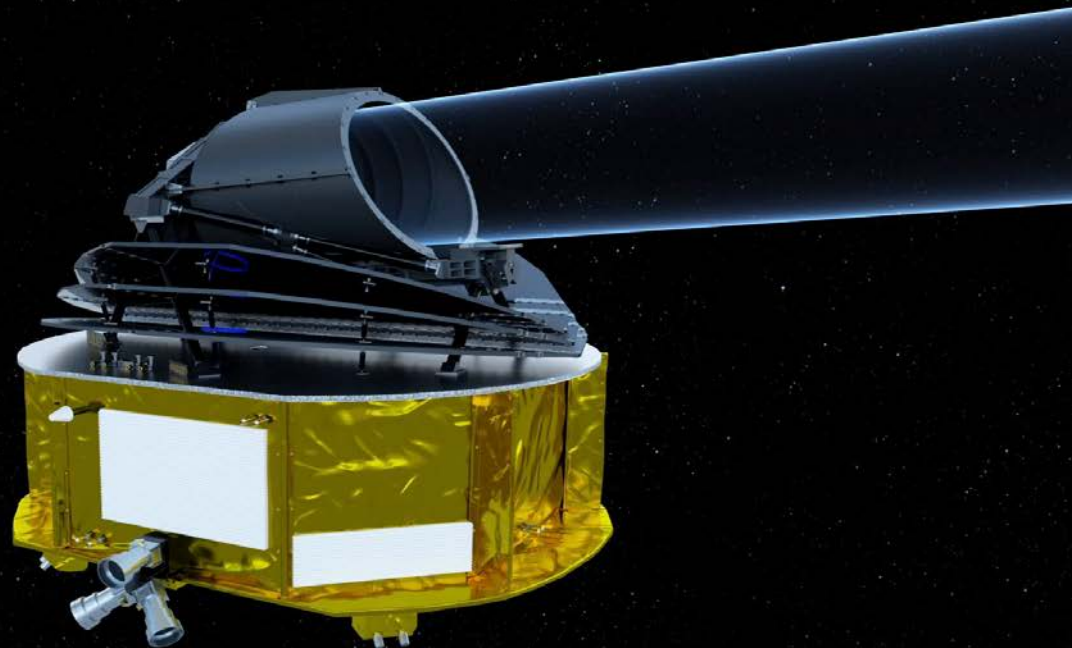
Ariel detecting light from a distant star

Credit: ESA/STFC RAL Space/UCL/UK
Space Agency/ ATG Medialab



ARIEL SPACE MISSION

European Space Agency M4 Mission



Payload

Off-axis **Cassegrain telescope**:
elliptical primary mirror 1.1 x 0.7m

Instrumentation

An **infrared spectrometer AIRS**:

- two medium-resolution channels
1.95-3.9 μm and 3.9-7.8 μm
- one low-resolution channel
1.25-1.95 μm

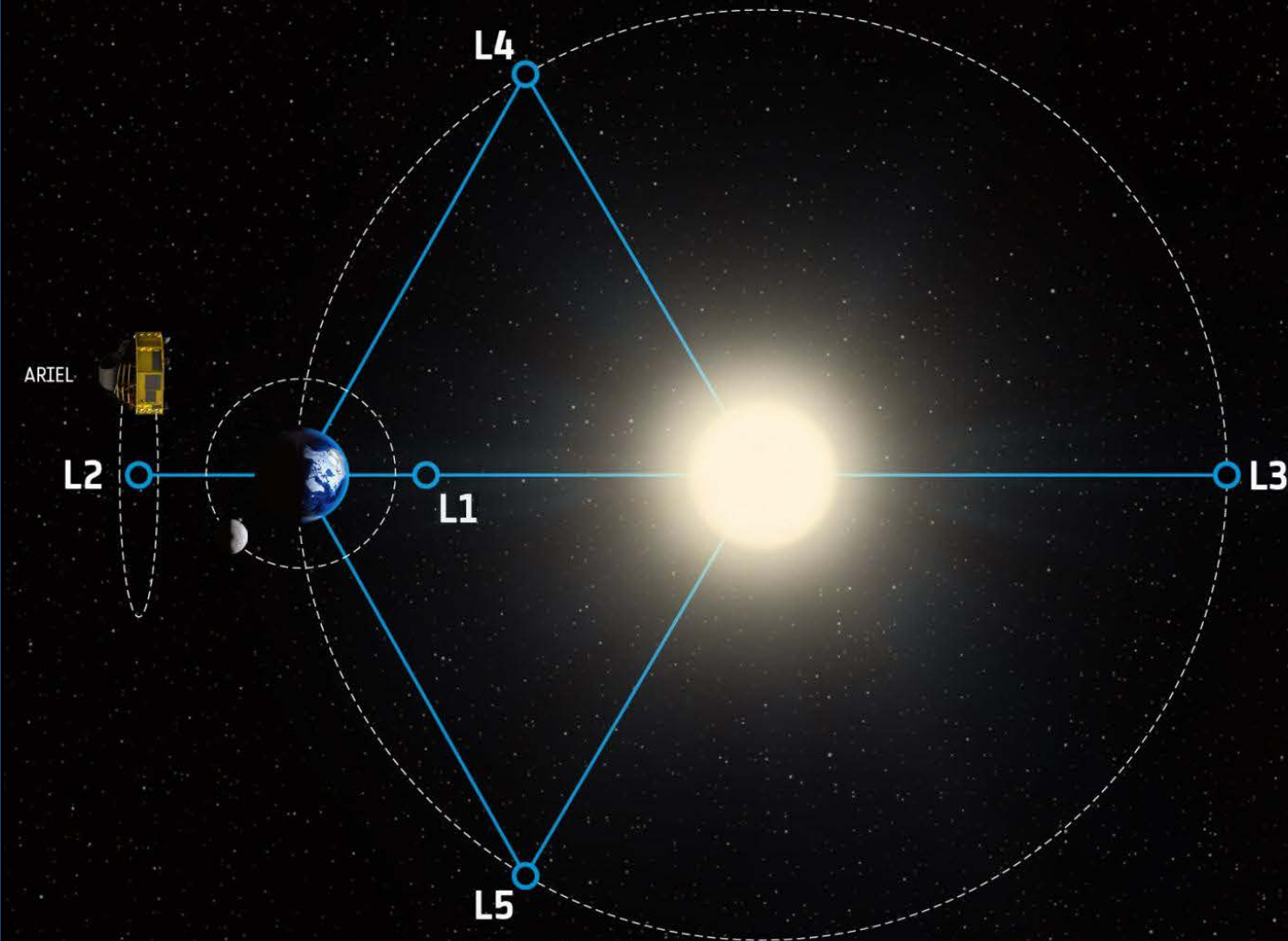
A **Fine Guidance System (FGS)**
with 3 photometric channels:

- 0.50-0.55, 0.8-1.0, 1.0-1.2 μm



ARIEL SPACE MISSION

European Space Agency M4 Mission



Launch date: 2029

Destination

halo orbit around Sun-Earth Lagrange point L2

Launch vehicle:

Ariane 6. Launch shared with Comet Interceptor

Lifetime:

Nominal 4 year operational timeline,
with a potential extended science operations



Ariel Mission Consortium

Principal Investigator
Giovanna Tinetti (UCL)

Consortium Project Manager
Paul Eccleston (RAL Space)

Consortium co-PI board



Estonia joined in 2019

WP 1: Management & PLM* System Level

WP 9: Science ground segment:
participation in and leadership of
in various science working groups



Science Working Groups

22 WGs working on different scientific topics

Ariel WG Atmospheric Chemistry

- Coordinators: Yamila Miguel (ymiguel@strw.leidenuniv.nl) & Olivia Venot (olivia.venot@cea.fr)
- 78 members
- Understanding chemistry of exoplanet atmospheres is crucial to get a proper picture of the diversity of planets
- Ariel observations
- We explore potential atmospheric compositions and the impact on chemical species
- We also check what can we learn about chemical processes, and 1D to 3D processes using models
- Different projects/specific questions
- planets + in relation with other WG (for synergy)
- Organisation: people choose which projects to work on

Ariel WG: Planet Formation

Coordinator: Diego Turani (diego.turani@anaf.it)

Goals: Identify metrics for atmospheric composition and planetary system architecture

WG question: How to connect the diversity of planets

Ariel WG Interiors

- Coordinators: Ravit Helled (ravelled@geo.uio.no) & Stephanie Warren (stephanie.warren@geo.uio.no)
- 51 Members
- Key Objectives:
 - Understand the connection between gas giants, intermediate-mass planets and their host stars
 - Connect the three aspects of planet formation, migration and interior evolution
- Meetings: we aim at more frequent meetings
- Organized connection with other WGs
- more details in "Ariel" document

Ariel WG: Synergy with JWST

Coordinator: Pierre-Olivier Lagage (pierre-olivier.lagage@cea.fr)

Key Objectives:

- Prepare Ariel data reduction and retrieval methods
- Prepare scientific results
- Analysis, Spectral retrieval, performances

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

Ariel WG Spectroscopic databases

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

Key Objectives:

- Develop a common framework for data production and data processing
- Develop a common framework for data analysis
- Develop a common framework for data storage
- Develop a common framework for data retrieval
- Develop a common framework for data visualization

Ariel WG Mass measurement

Coordinators: Lars Buchhave (luchhave@space.dtu.dk) & G... (in prep.)

32 members

Based on work in Ariel in prep.)

- Determine mass
- Monitor mass
- Monitor velocity

Organization for specific cases

Ariel WG Spectral Retrieval

Coordinators: Michiel Min, Joanna Barstow, Quentin... (in prep.)

WG question: From an observed Ariel spectrum, what can we learn?

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 WG Stellar Characterisation

Coordinator: Camilla Danielski (cdanielski@aa.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.

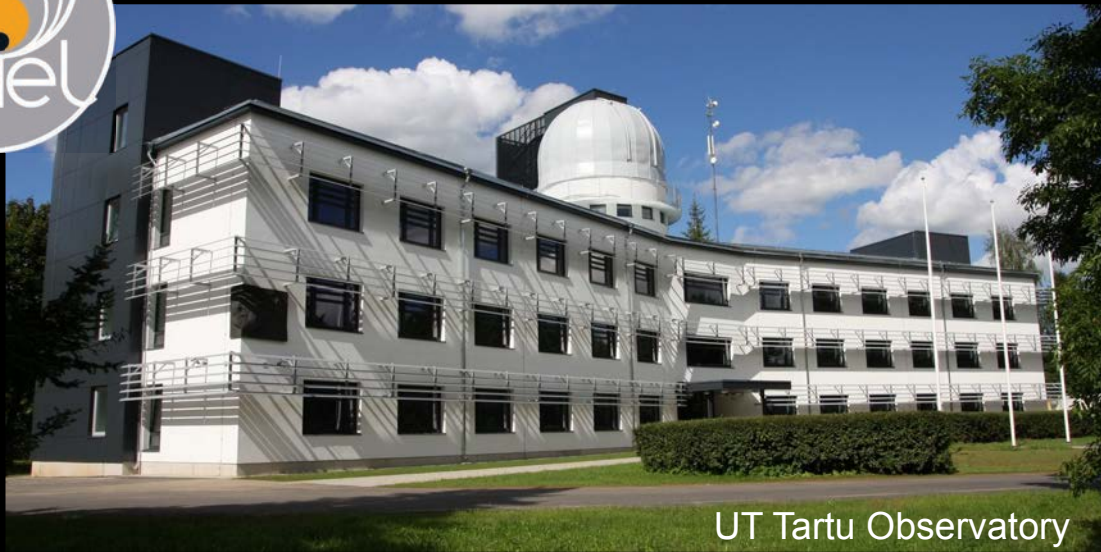
Data Reduction

Key Objectives:

- Develop a common framework for data production and data processing
- Develop a common framework for data analysis
- Develop a common framework for data storage
- Develop a common framework for data retrieval
- Develop a common framework for data visualization

Image credit: Giovanna Tinetti





UT Tartu Observatory



Stellar Characterisation WG

Goal :

homogeneous and self-consistent parameters determination of the host stars in the Ariel Reference Sample (ARES):

atmospheric parameters, abundances,
activity indexes, mass, radii, ages

Method : analysis of spectroscopic and photometric observations
Both model dependent & empirical approaches

Ephemerides WG



Goal :

Provide updated ephemerides (transit times) for the Ariel targets for precise scheduling of the Ariel observations

Method : photometry of exoplanet host stars



Project ExoClock : www.exoclock.space

Integrated platform to organise the follow-up effort, with contributions from professional and amateur observatories and from space-based telescopes.

Planet Formation WG

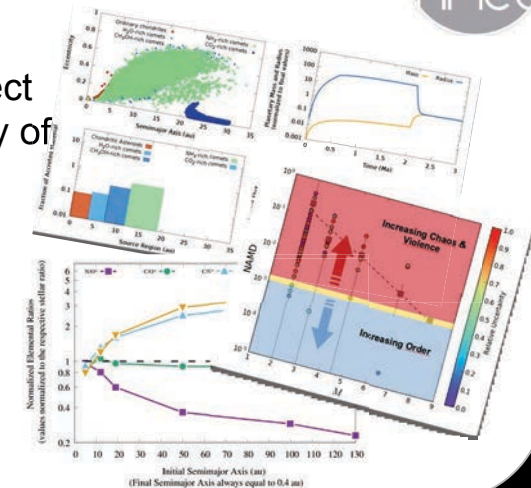


Goal :

Identify metrics and methods to connect atmospheric composition to the history of planets and planetary systems.

Themes: from star formation to planetary evolution

Coordinator: Diego Turrini (INAF)



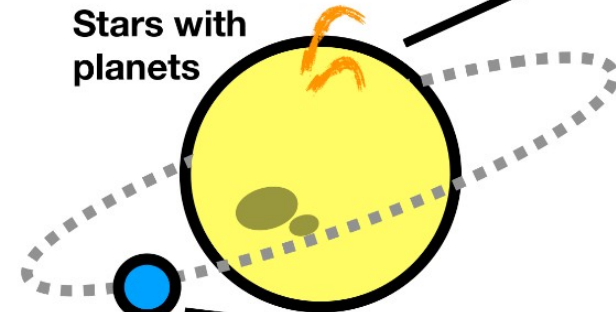


Stellar Physics @ Tartu Observatory University of Tartu



Stars with proto-planetary disks

Stars with planets



Planets

Tartu Obs.



Local data

- Optical stellar spectra
- Optical photometry
- Time-series monitoring

- Guaranteed access
- New echelle spectrograph & photopolarimeter
- High Northern sky coverage

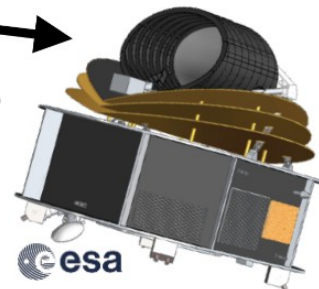
Team strengths

- Stellar astrophysics
- Observations & processing
- Planet-forming disks
- Exoplanetary science

Supplementary data

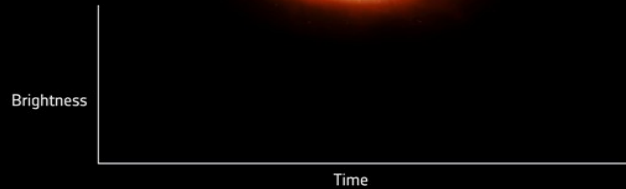
- ESO and other big facilities

ARIEL



ARIEL science consortium





Credit: ESA

Ephemerides WG



Goal :

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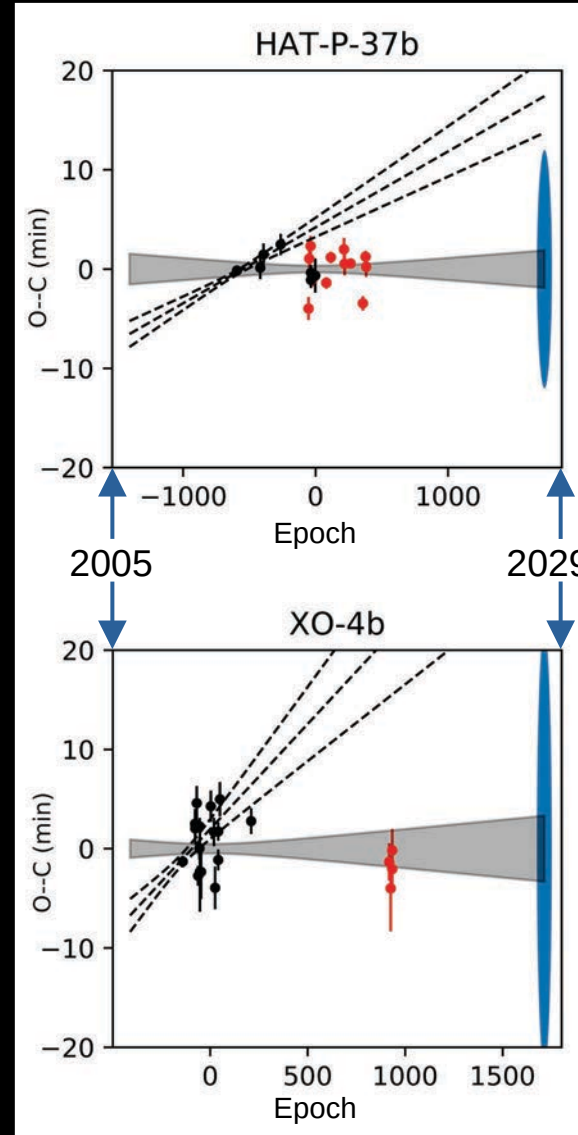
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Integrated platform to organise the follow-up effort, with contributions from professional and amateur observatories and from space-based telescopes.

Refined ephemerides by the ExoClock network



Initial: dashed lines
Updated: shaded area

Uncertainty by 2029:
blue

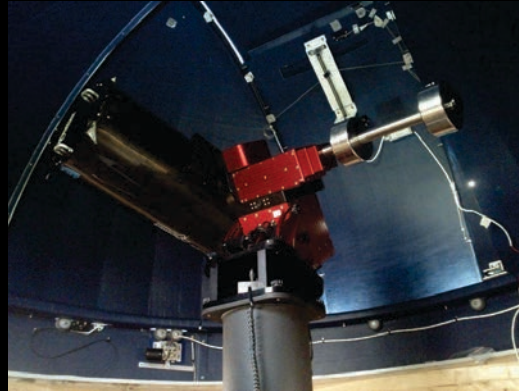
Credit: Kokori et al 2022



0.6-meter Zeiss 600



0.31-meter RAITS semi-robotic



Observations at UT Tartu observatory

Ephemerides WG



Goal :

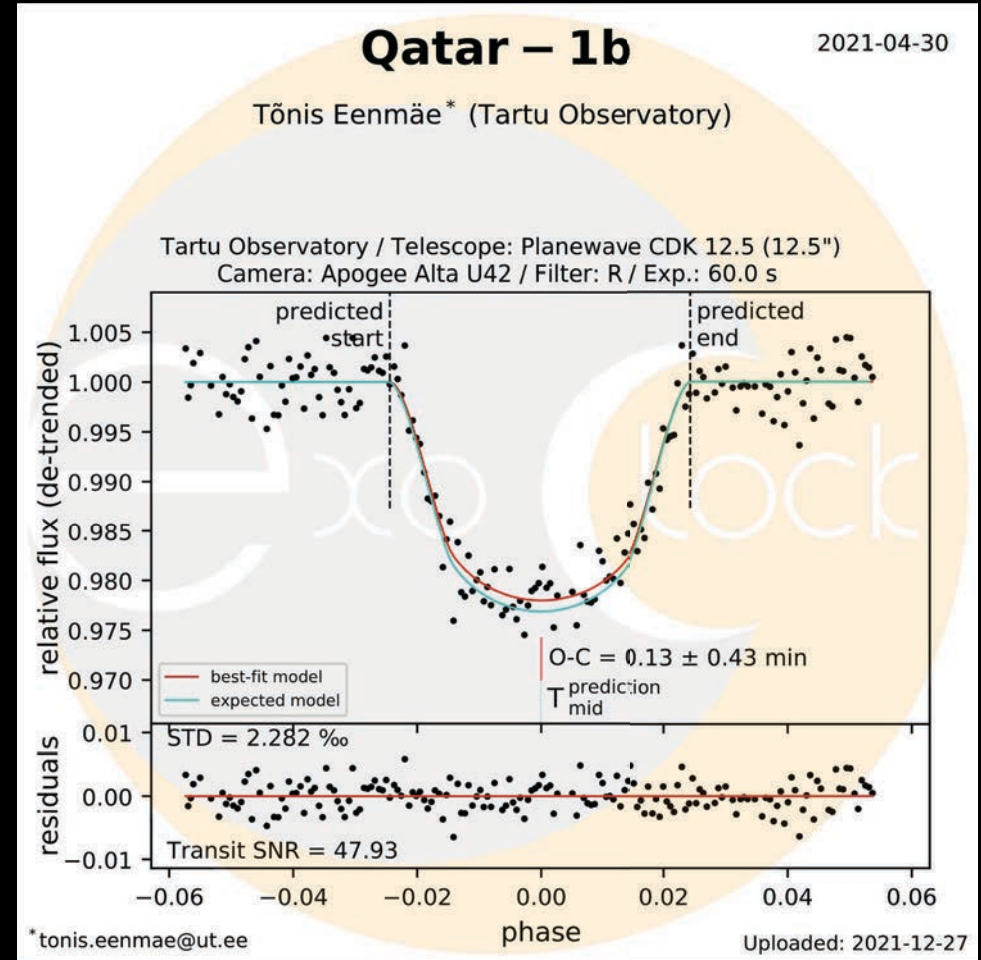
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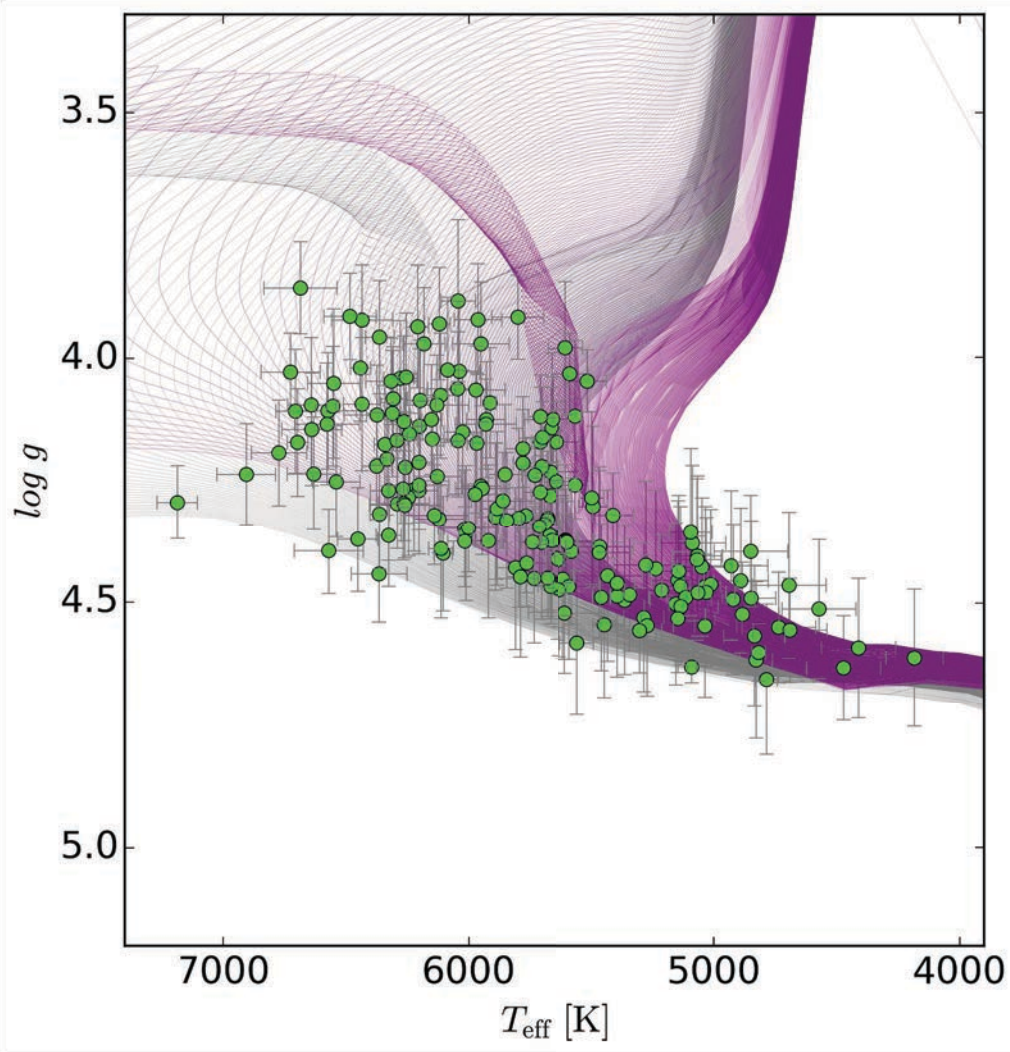
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Stellar parameters of 187 FGK planet host stars



Magrini et al 2022

Anna Aret (UT Tartu Observatory)



Stellar Characterisation WG

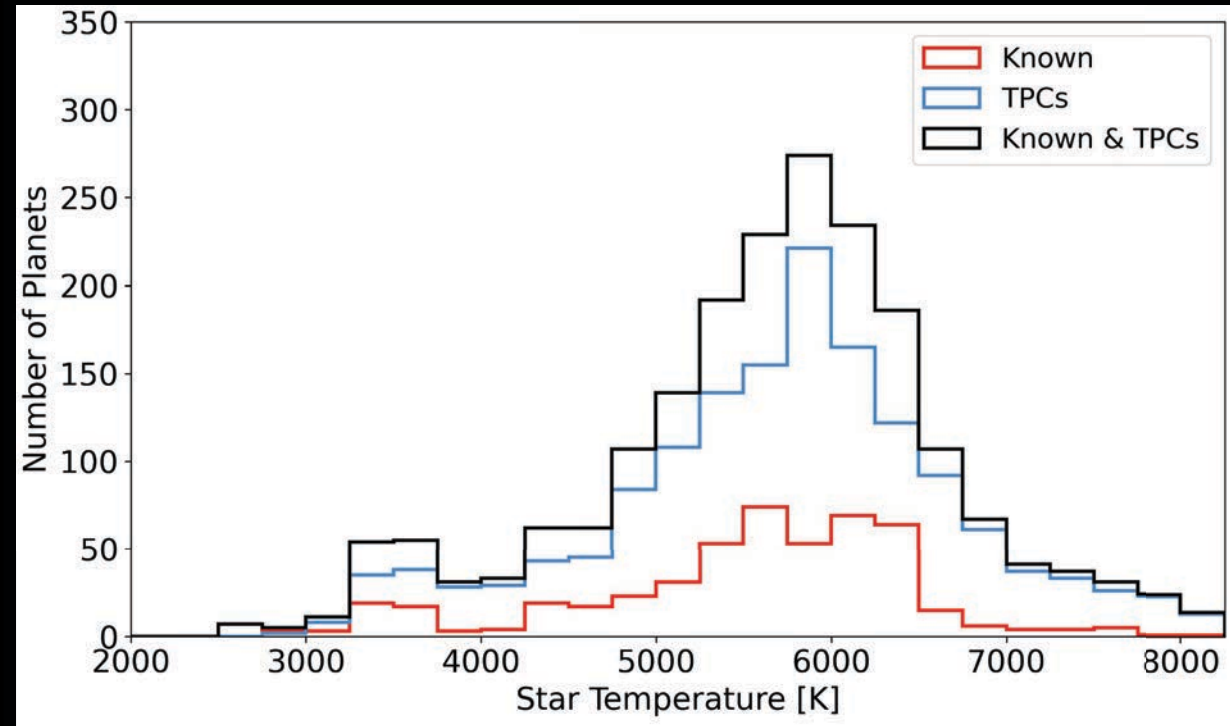
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Method :

analysis of spectroscopic and photometric observations
Both model dependent & empirical approaches



Edwards & Tinetti 2022

11/01/2024



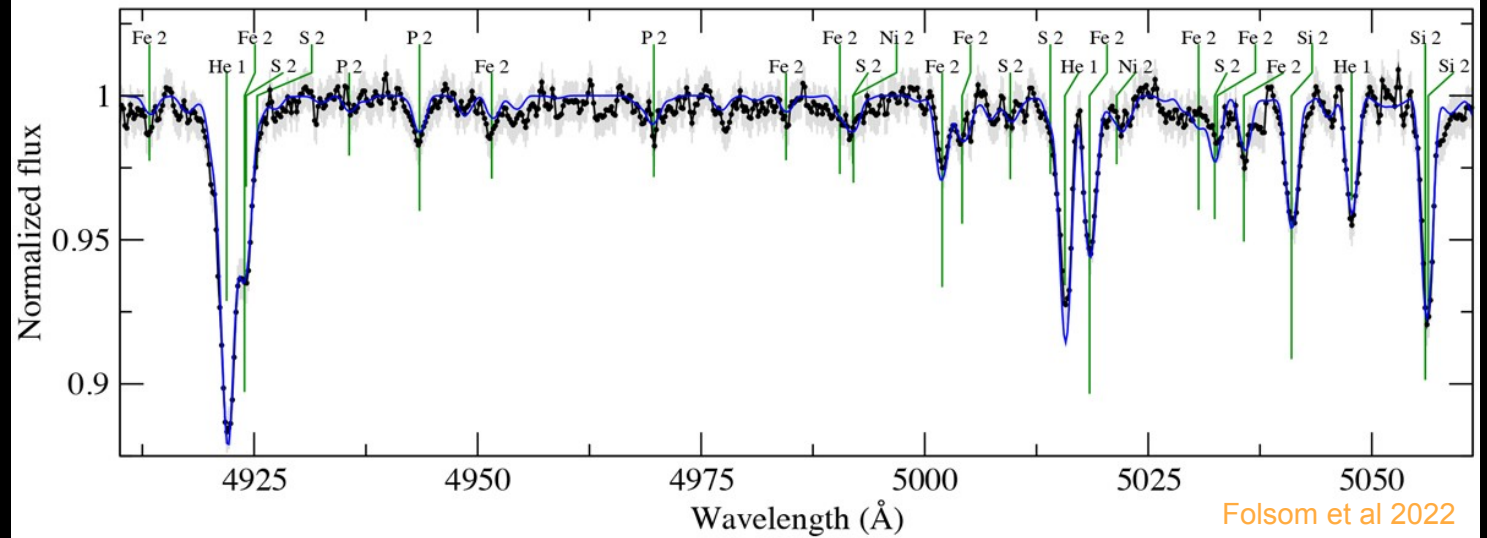
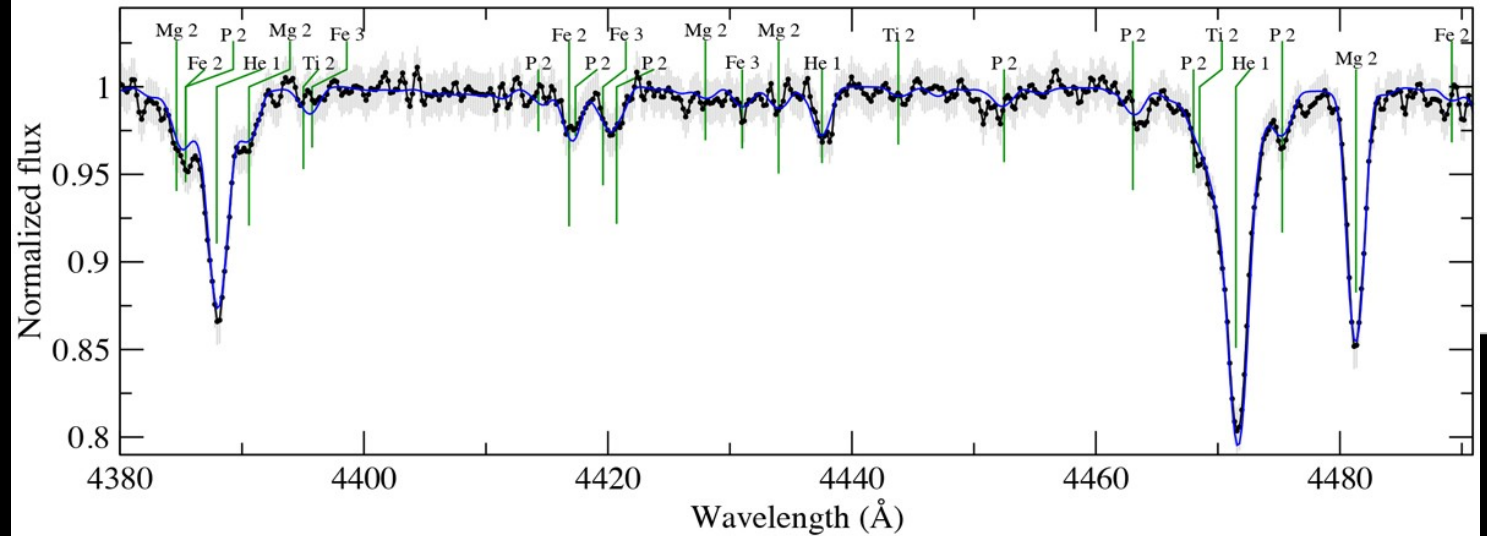
Stellar parameters and chemical composition

Observed spectrum: black dots
TO 1.5-m telescope

Synthetic spectrum: blue solid line
ZEEMAN spectra synthesis code



Stellar Characterisation WG

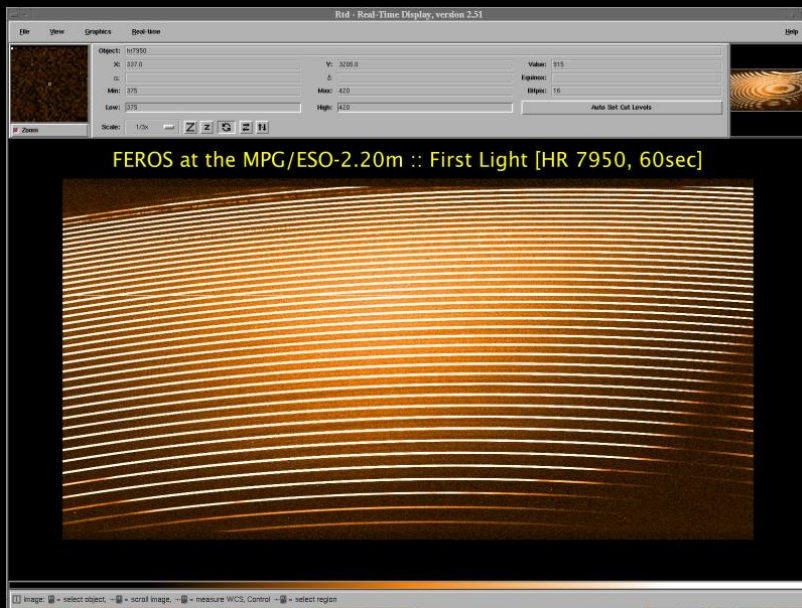




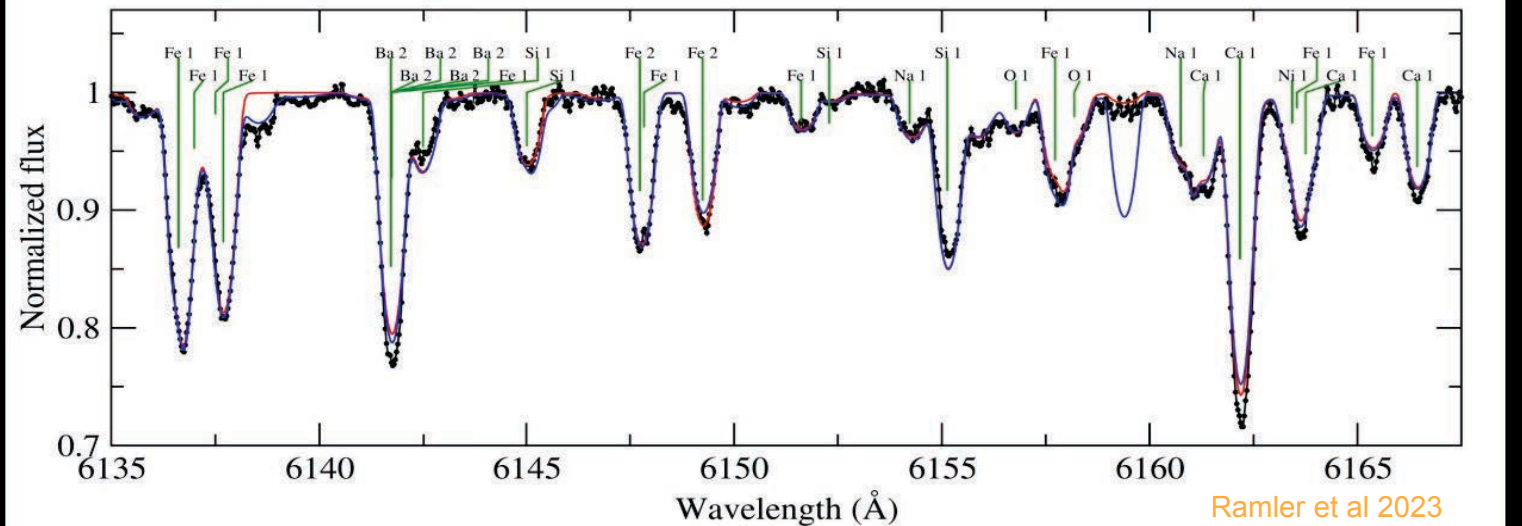
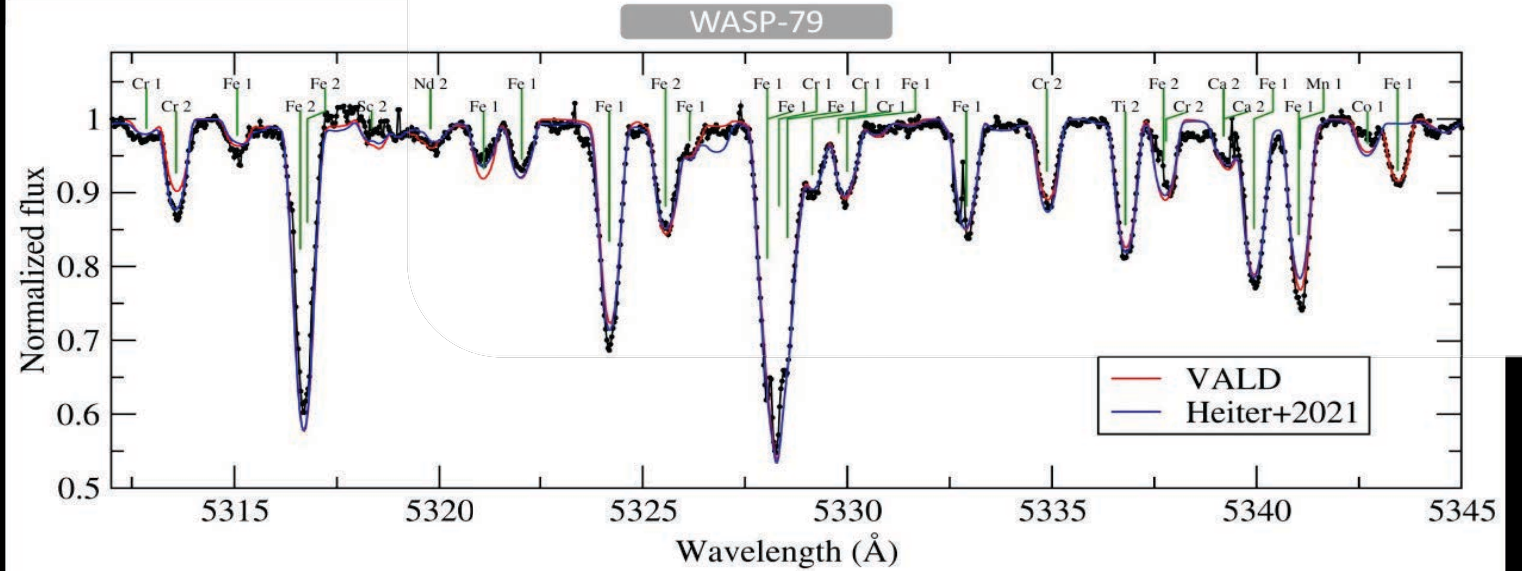
Stellar parameters and chemical composition

Observed spectrum: black dots
ESO FEROS spectrograph

Synthetic spectrum: blue solid line
ZEEMAN spectra synthesis code



Stellar Characterisation WG





Modelling birth and death

Evaporating gas giant

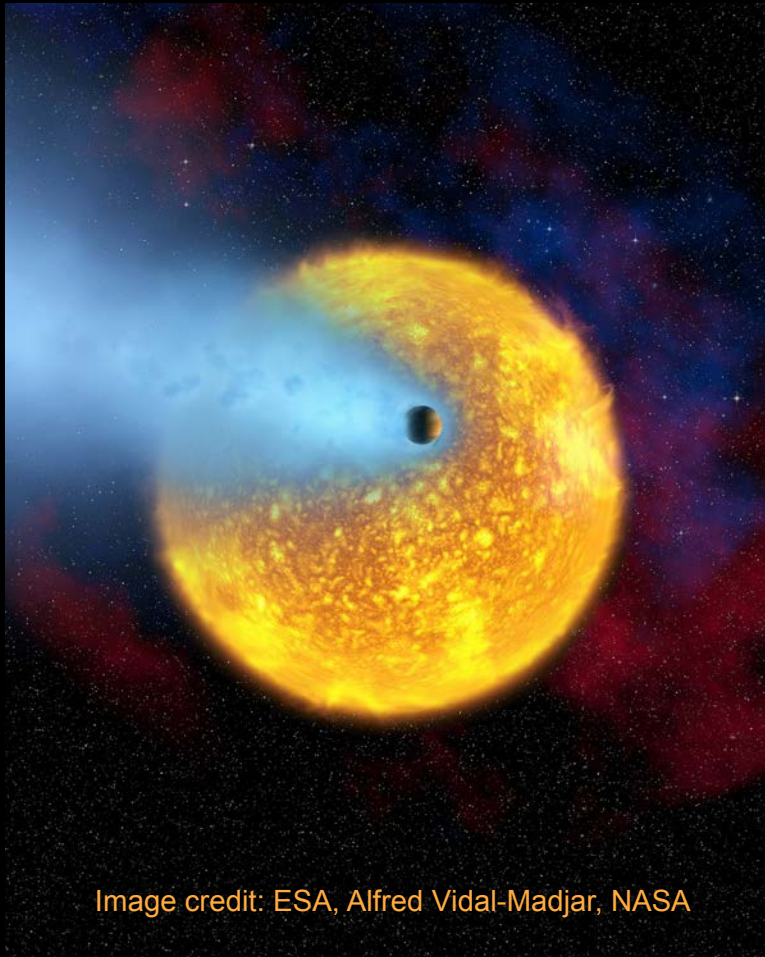
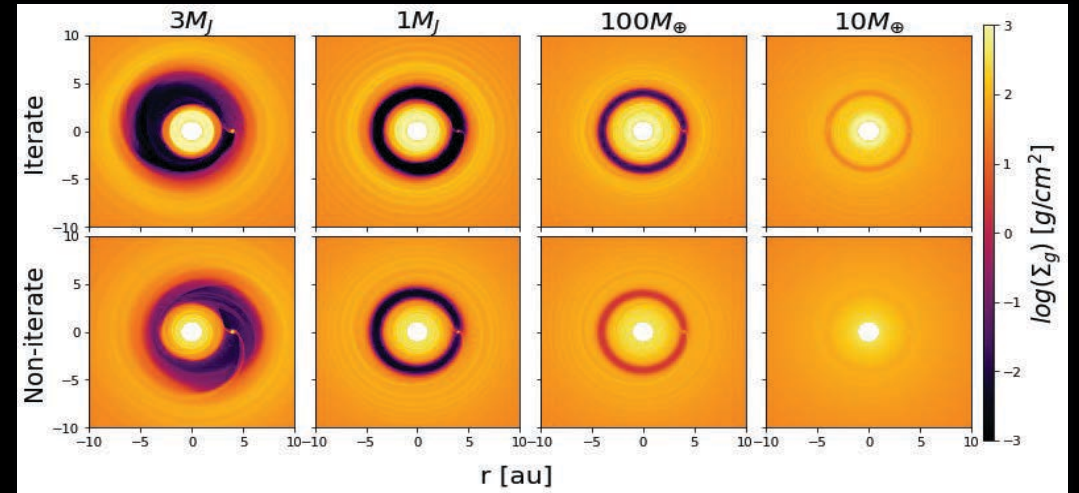


Image credit: ESA, Alfred Vidal-Madjar, NASA

Planet-induced gaps in protoplanetary disks



Chen, Kama, Pinilla, et al 2023

Planet Formation WG

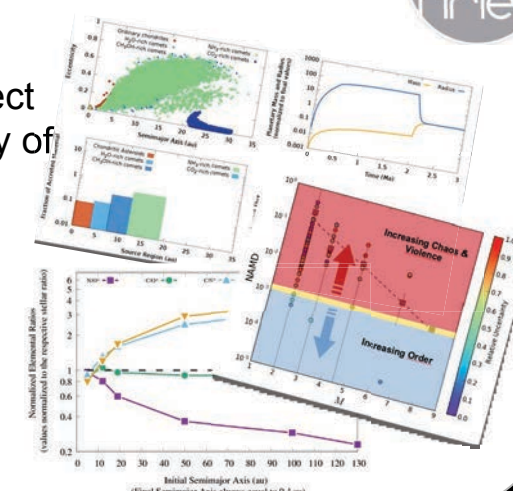


Goal :

Identify metrics and methods to connect atmospheric composition to the history of planets and planetary systems.

Themes: from star formation to planetary evolution

Coordinator: Diego Turrini (INAF)





EXOHOST

Spectral Characterisation of Exoplanet Hosts and Other Stars



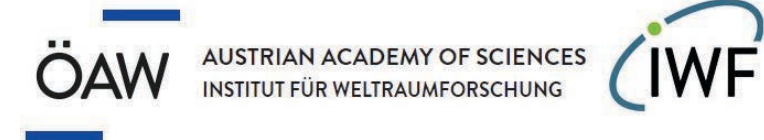
Horizon Europe Twinning project 2023–2025

Main science objective

Study properties of exoplanet and protoplanetary disk host stars

- Chemical composition holds clues to planet formation
Study relations between formation processes and diverse outcomes of star-planet systems
- Precision of exoplanet measurements depend on host star properties
Contribute to the ESA Ariel Mission Consortium

EXOHOST Consortium





WELCOME!

See you at the Ariel Consortium Meeting
on April 23-26th 2024 in Tartu

Image credit: Tarmo Haud

The 2024 spring Ariel Consortium Meeting will be hosted by the University of Tartu, Tartu Observatory

For any queries, please contact us at: arieltartu2024@ut.ee