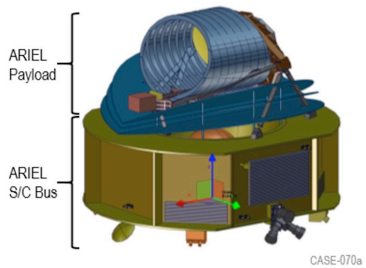
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

CASE Briefing to the Astrophysics Advisory Committee

June 24 2020

Mark Swain – Principal Investigator

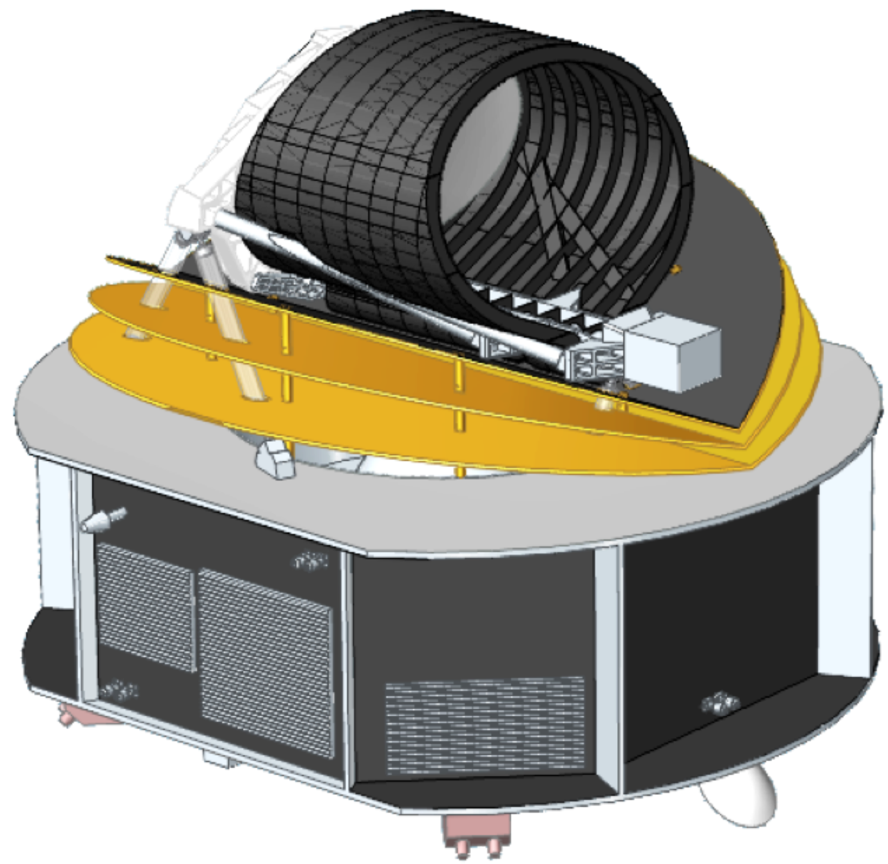


Agenda

- ARIEL mission overview
- CASE overview
- Baseline science
- Community value
- Science progress that makes CASE even more relevant

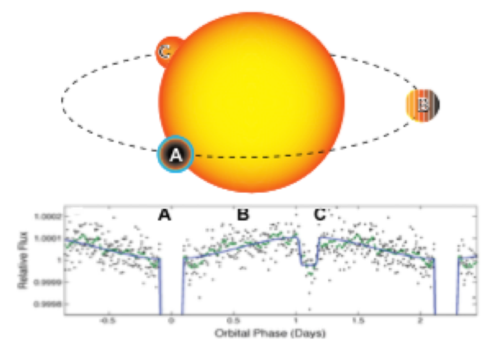
Ariel Mission Overview

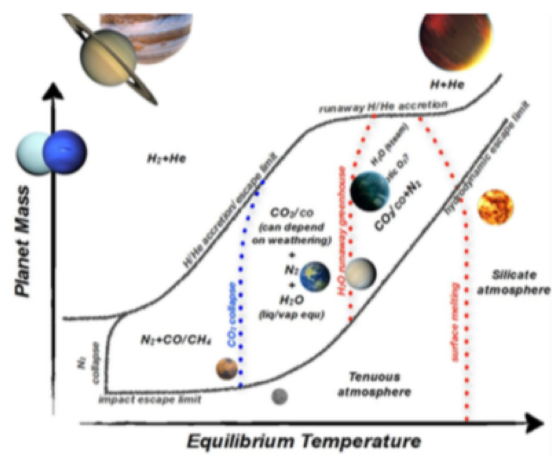
- ESA M4 mission
- Launch 2028
- L2 orbit
- 3.5 year prime mission
- Telescope 1 m effective diameter
- 0.5-7.8 μm wavelength coverage
- Surveys exoplanet atmospheres
- Observers ~1000 planets
- Payload consortium consists of 17 ESA member states + US contribution
- https://arielmission.space



Ariel Science Overview

- Key Questions
  - What are planets made of?
  - How do planets form?
  - How do planets evolve?
- Tiered Survey
  - Tier 1: Reconnaissance Survey
  - Tier 2: Deep Survey
  - Tier 3: Benchmark Survey
  - Tier 4: Phase curve Survey
- Targets defined by the ARIEL Payload Consortium Science Team members
- ESA/NASA data rights agreement is in process

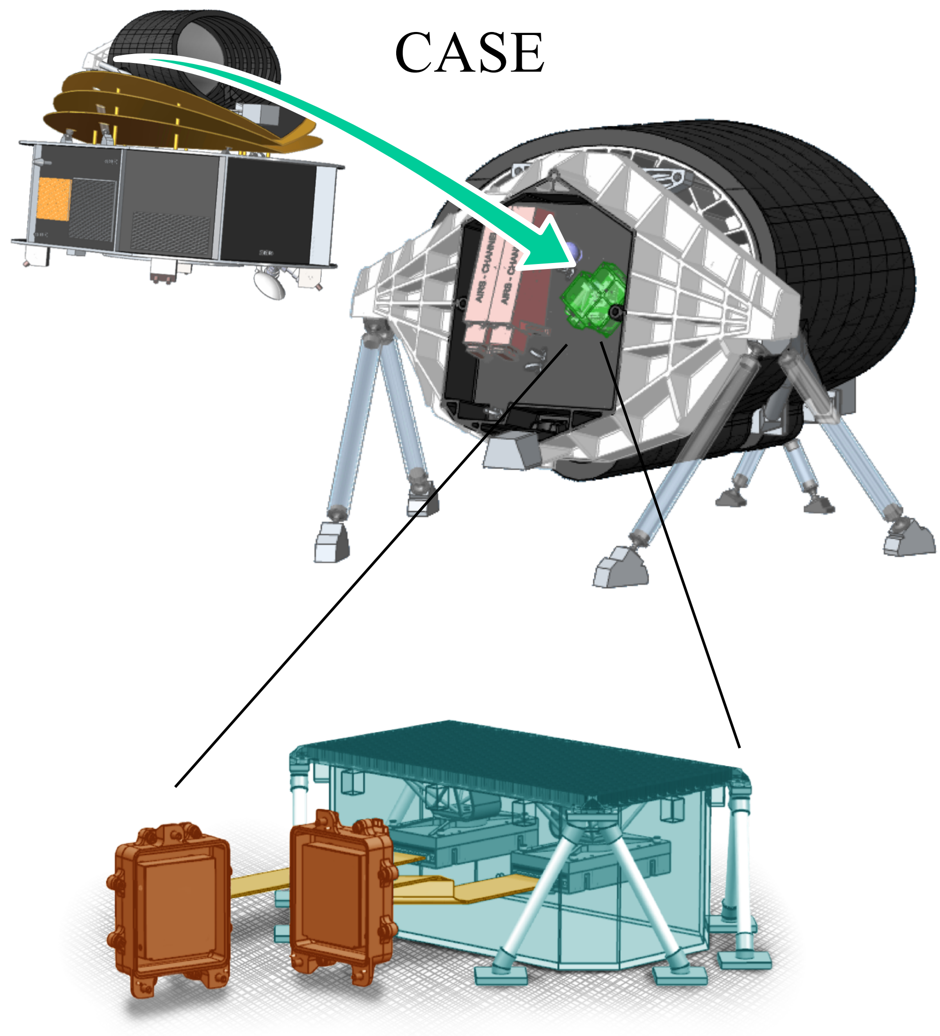




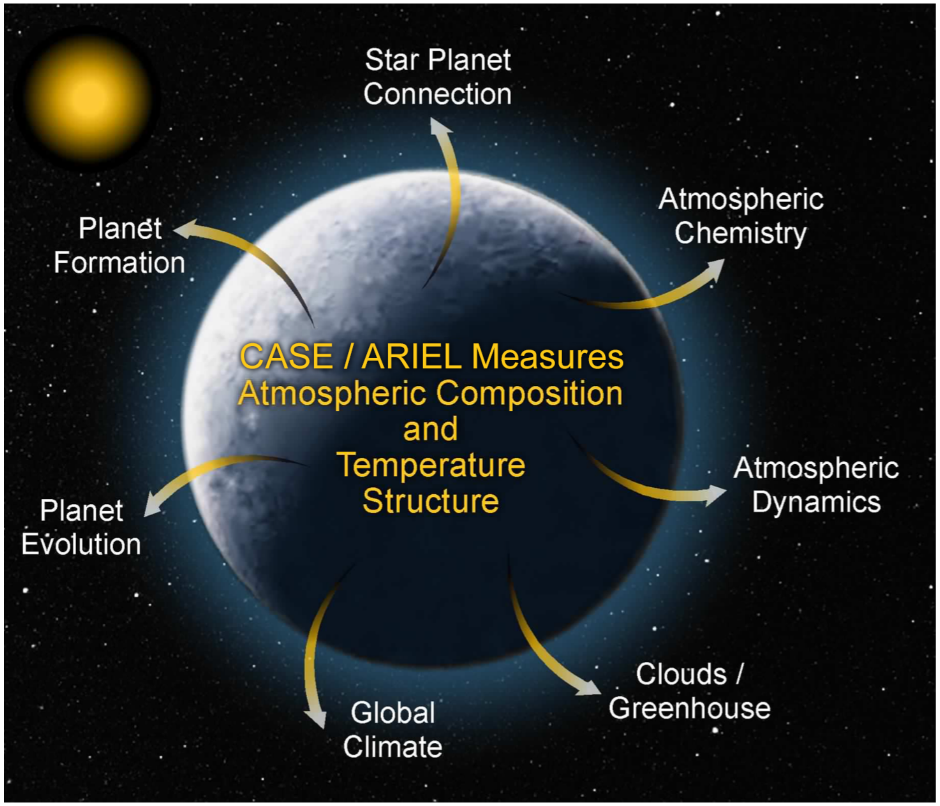
Figures from ARIEL Yellow Book
https://sci.esa.int/documents/34375/36249/1567260310680-ESA_SCI-2017-2_ARIEL.pdf

CASE Overview

- Contributes detectors and cold front end electronics, including packaging, thermal management, and cryoflex cables, for ARIEL Fine Guidance System.
- Processes FGS data to create science data products.
- Provides US participation in ARIEL mission survey design and scientific discoveries.



CASE/ARIEL Synergistic with JWST

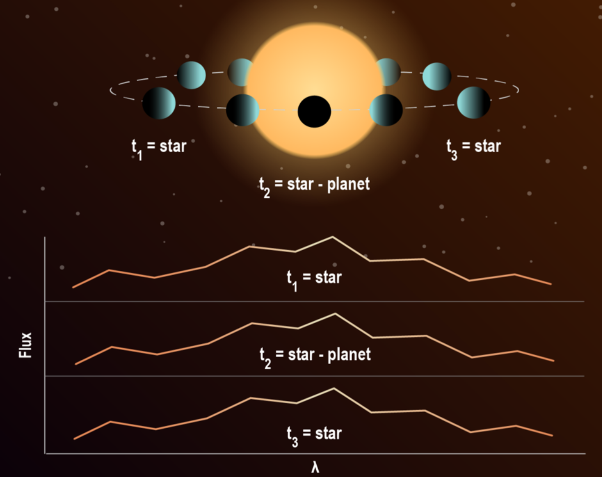


- Connects astrophysics and planetary fields
- Reveals how JWST exoplanet observations fit into the larger exoplanet family
- Addresses NASA Science Plan (2014) objective: "Discover and study planets around other stars, and explore whether they could harbor life"

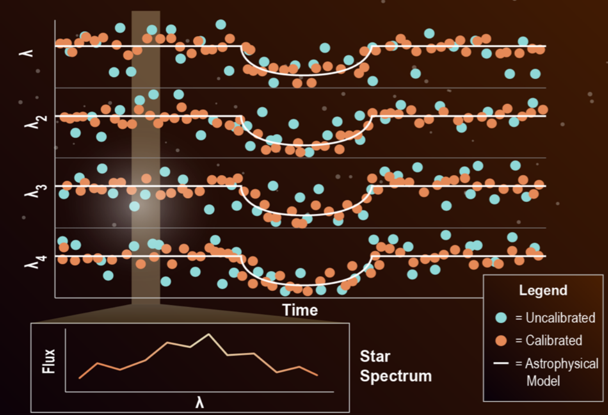
CASE and ARIEL will revolutionize the study of exoplanet atmospheres

Measurements to Knowledge

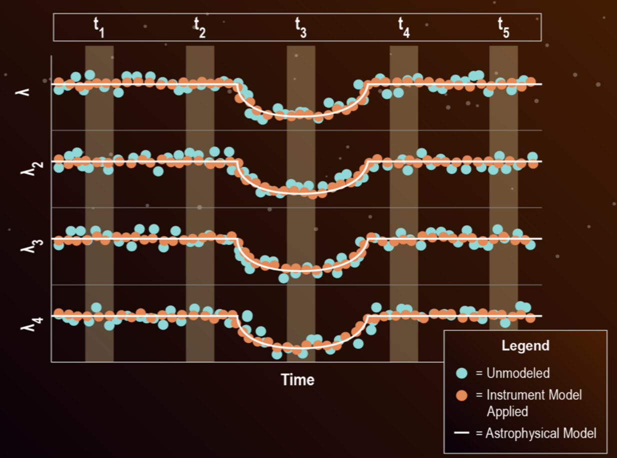
1 CASE records spectra (flux vs wavelength) of the light emitted by the star-planet system as the planet passes in front of the star.



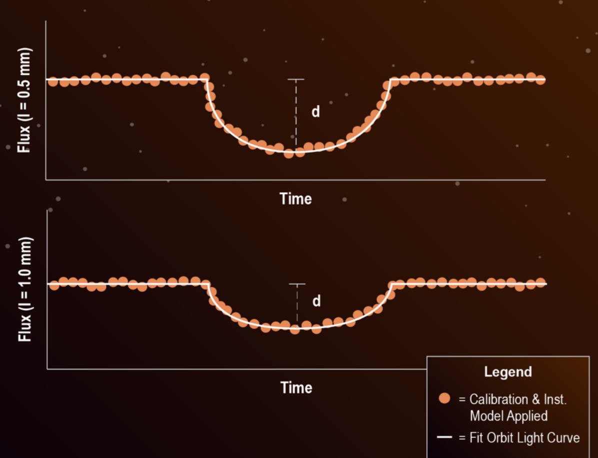
2 The measurements of the passage of the planet in front of the star are recorded at different wavelengths. We can view the star spectrum by taking data from a time either before or after the planet passes in front of the star. The data are calibrated which reduces the scatter around the astrophysical model. But there is still residual measurement scatter even after calibration.



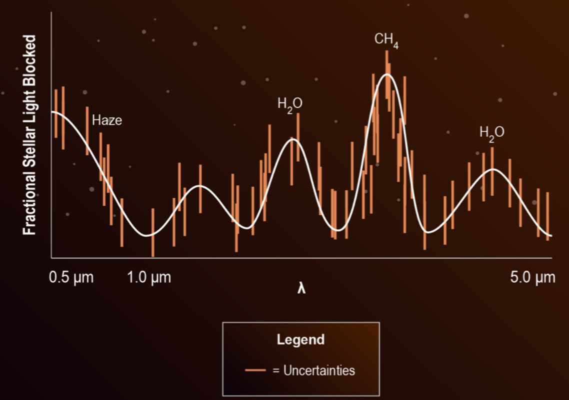
3 Further improvement in the measurement quality is possible by creating an instrument model and applying it to the data. The key science observable is how the spectrum changes during the measurement interval.



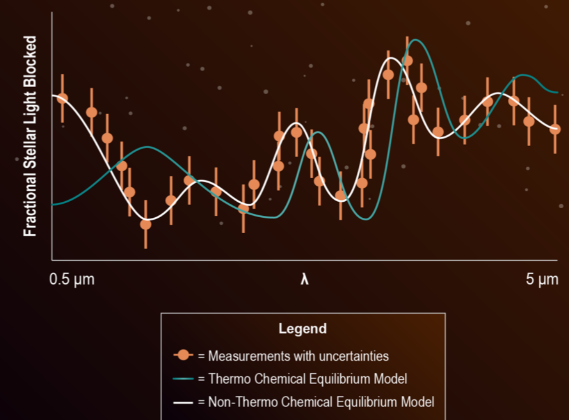
4 A light curve fit is performed at each spectral channel to determine the transit depth "d". The transit depth is a measure of the opacity in each spectral channel.



5 A planet without an atmosphere would have a uniform response. In a channel where the atmosphere has strong absorption, the exoplanet appears larger (more light blocked). Thus, change in fractional light in a spectral channel corresponds to a particular chemical constituent.



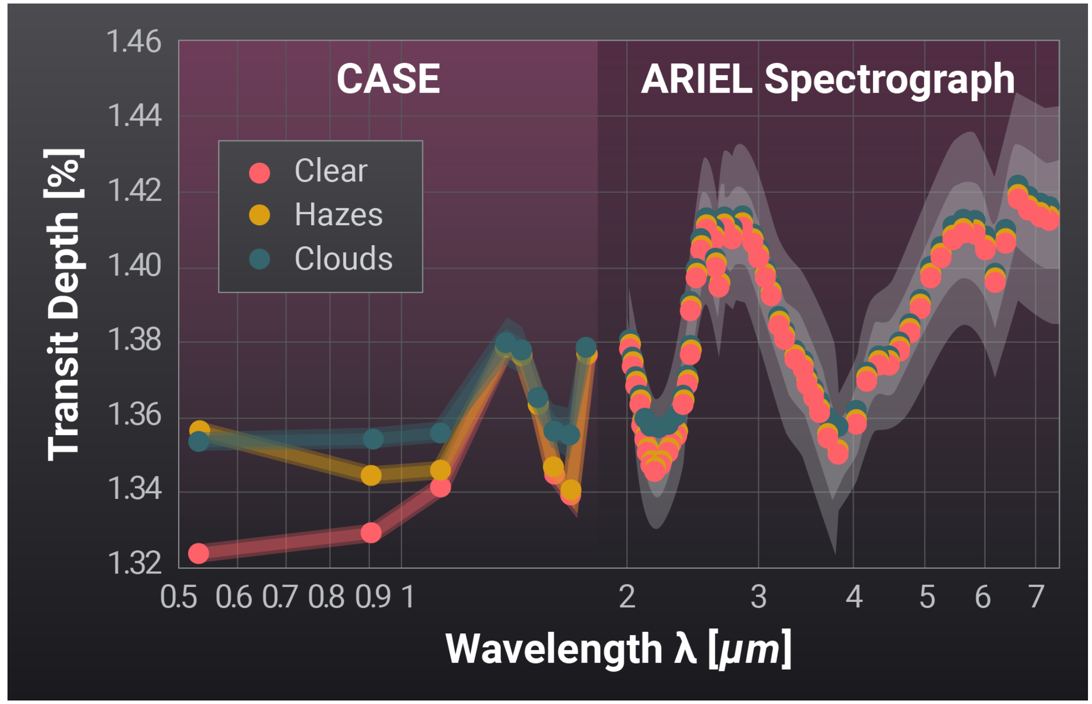
6 A retrieval algorithm is used to determine atmospheric composition. Exoplanet model parameters are varied, opacity is predicted and compared to measured and iterated to arrive at a best-fit of exoplanet atmospheric model.



CASE-074b

CASE Science Objectives

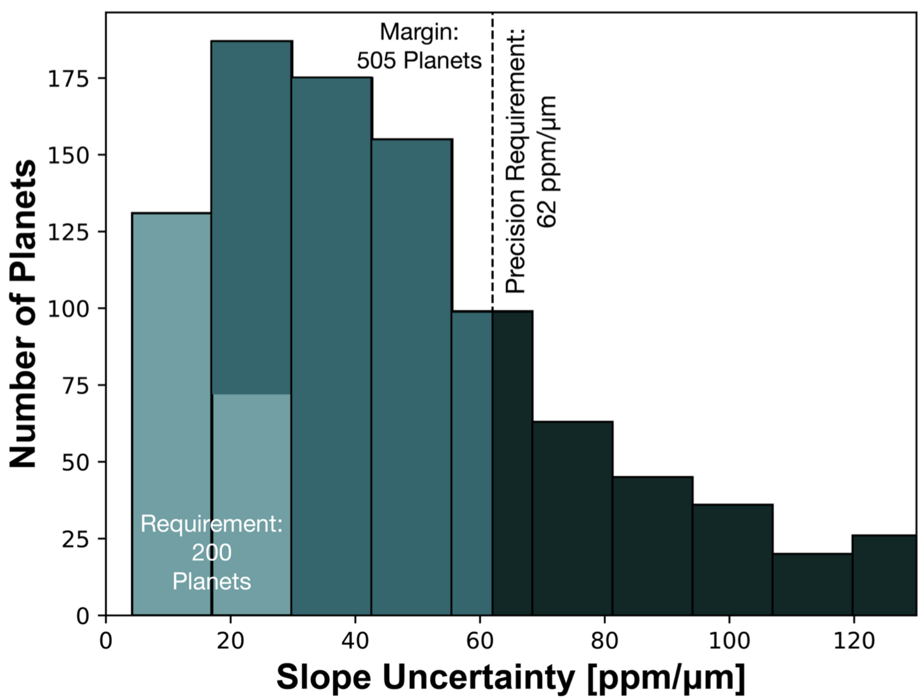
- Determine the occurrence rate of aerosols (clouds and hazes)
- Measure the geometric albedo of exoplanet atmosphere to constrain aerosol composition
- CASE wavelength coverage optimized for the science objectives

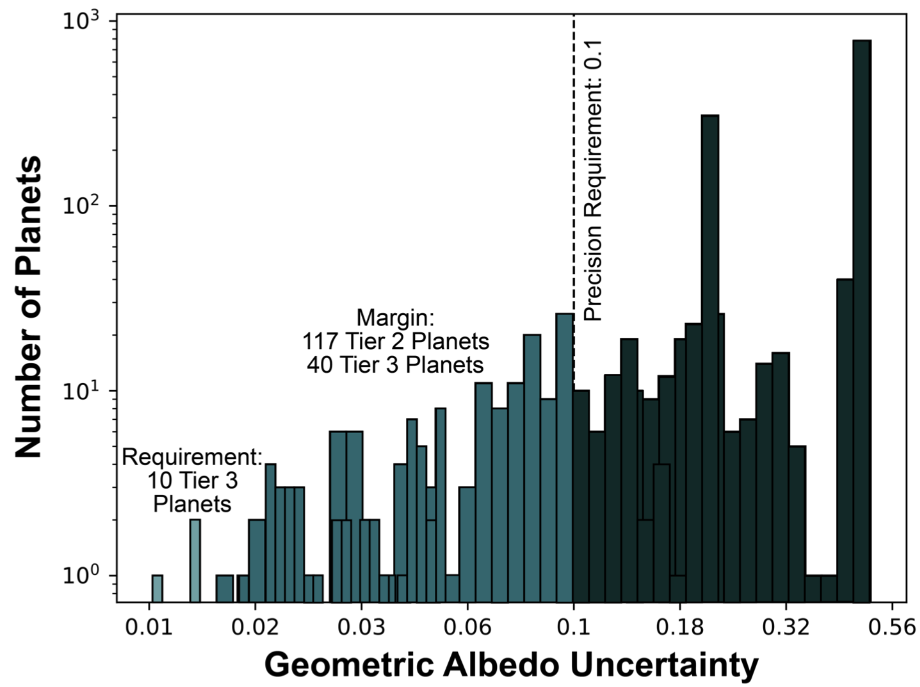


0.5-1.95 μm

Forecasted Performance

- Aerosol slop precision requirement 310 % margin
- Albedo precision requirement 400 % margin

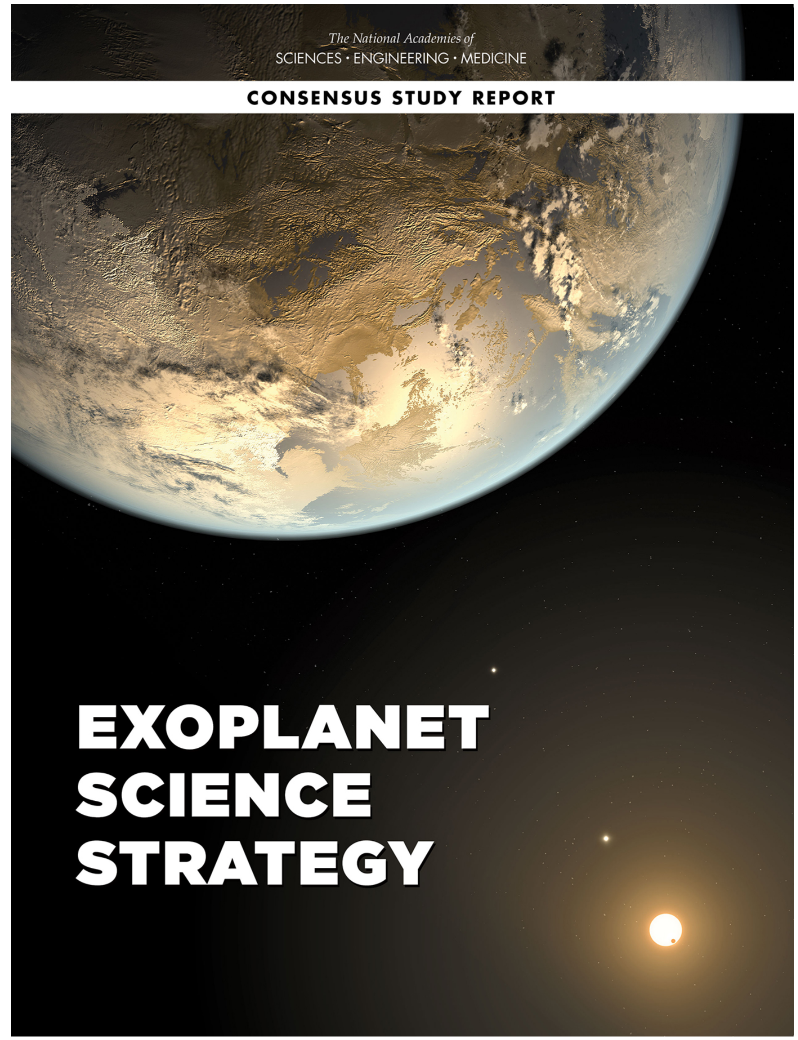




CASE Endorsement

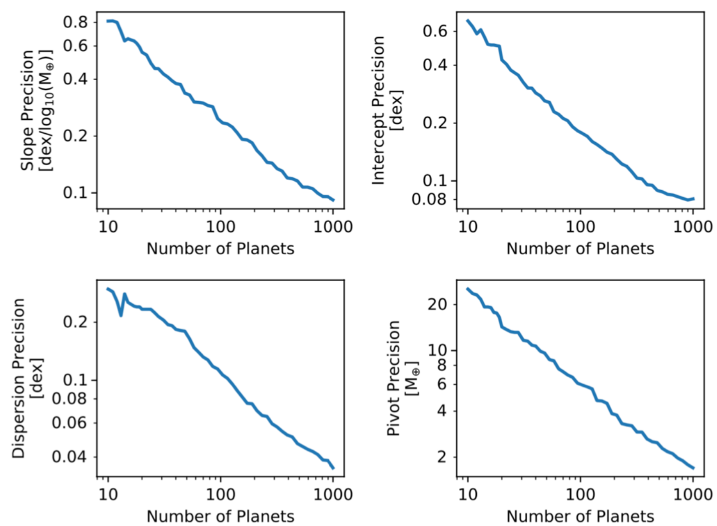
National Academy of Science
Consensus Study Report:
Exoplanet Science Strategy

- "The U.S. exoplanet community would benefit from participation in ARIEL."
- "U.S. scientists would benefit from the CASE mission by participating in the planning, execution, and exploitation of the ARIEL survey."

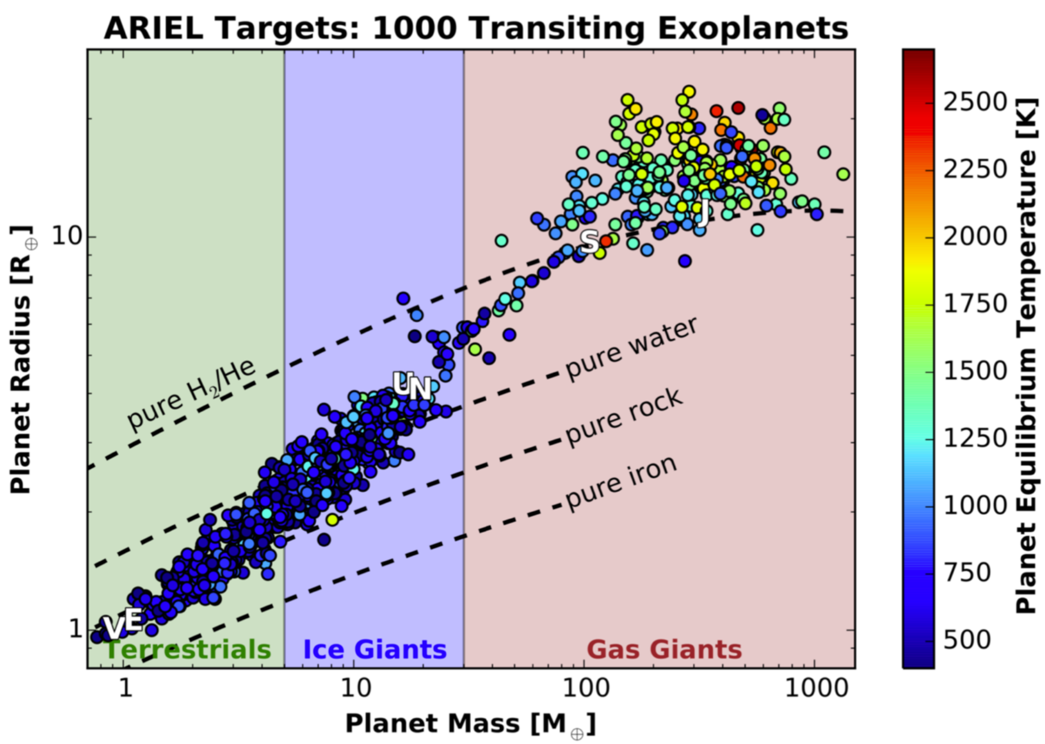


High Science Value

CASE team simulation finds ARIEL Tier 1 survey provides excellent constraints on planet formation by constraining the mass-metallicity relation.



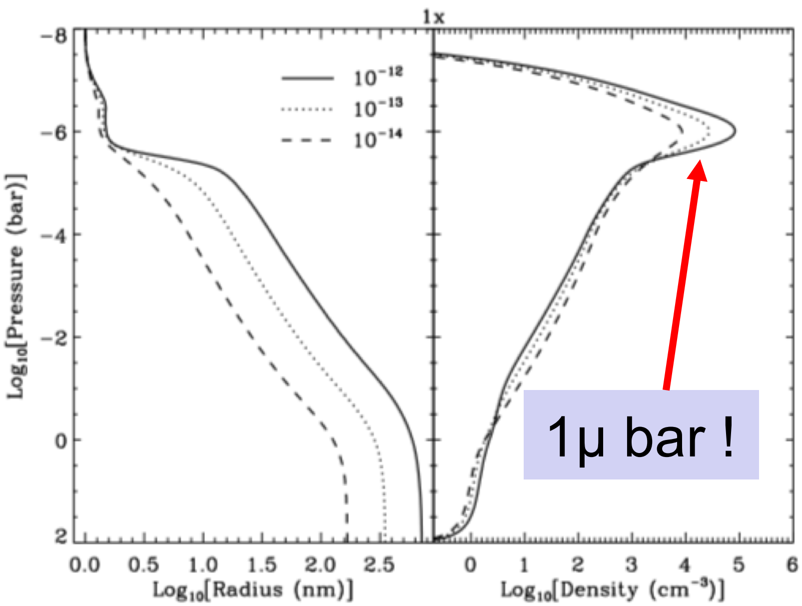
Zellem et al. 2019



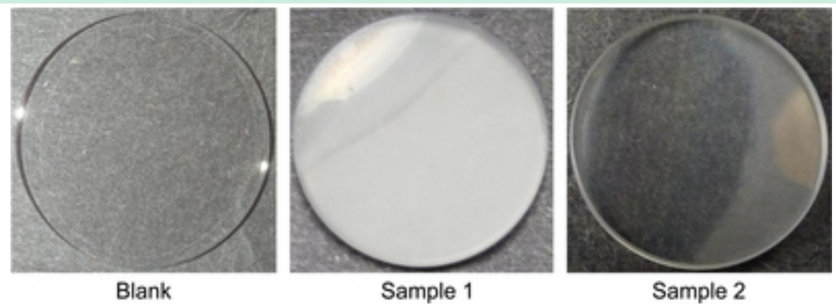
Recent Results Highlight Importance of Aerosols

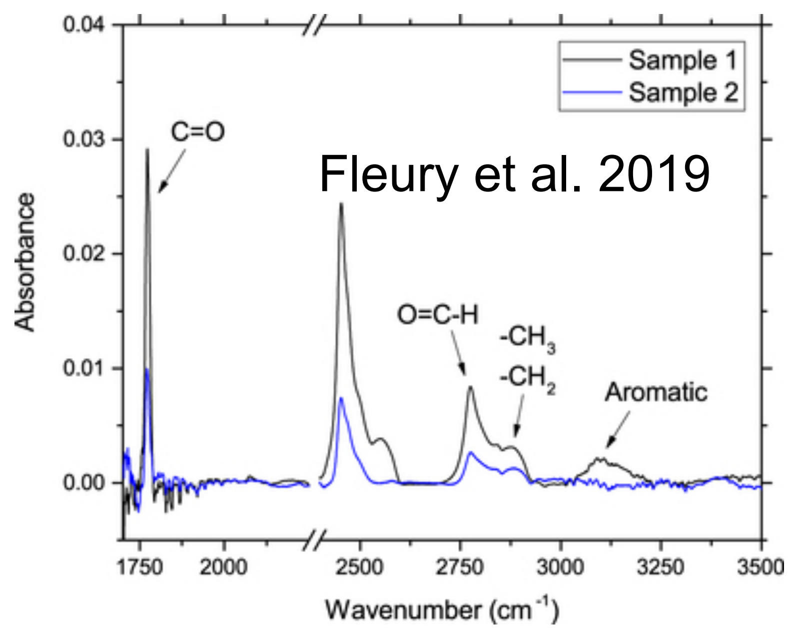
Micro-physics model predicts exoplanet haze formation at extreme altitude

Simulated hot-Jupiter atmosphere
1473 K H & CO + UV
makes aerosol material in lab



Lavvas et al. 2019

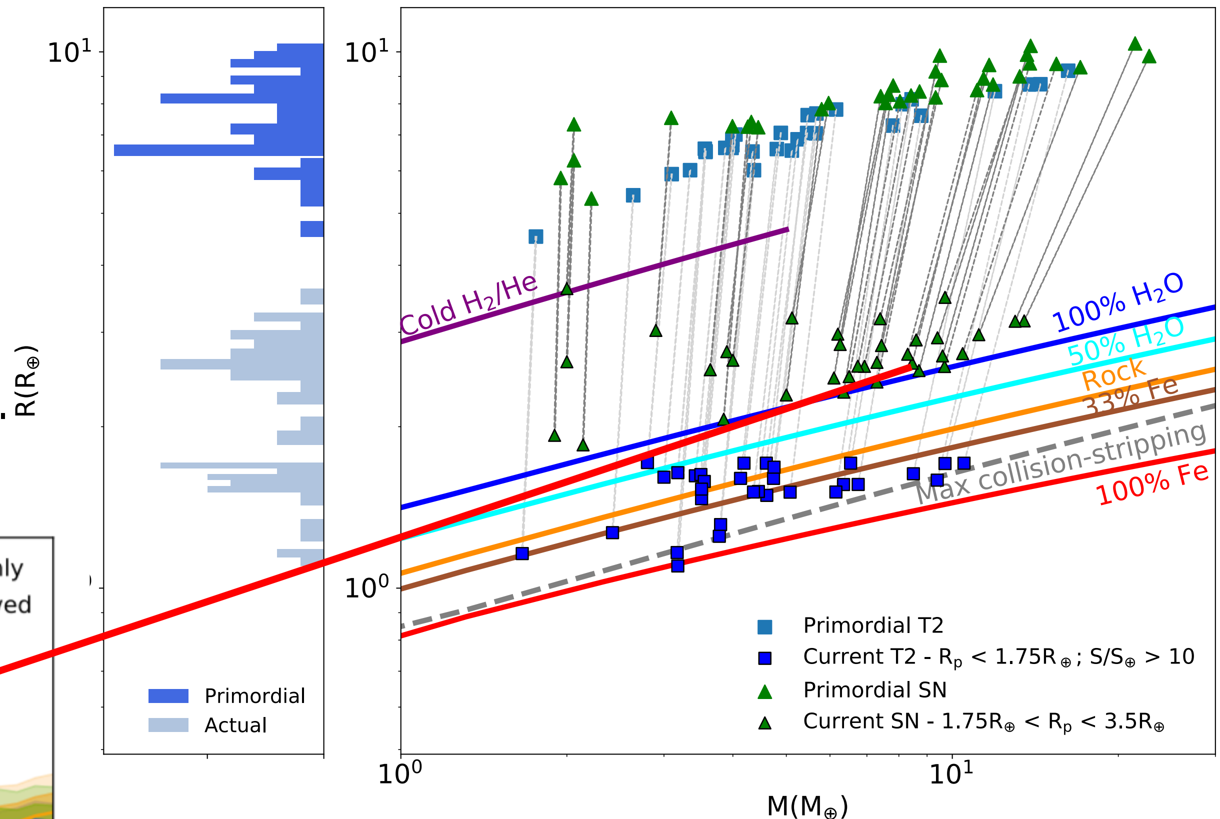




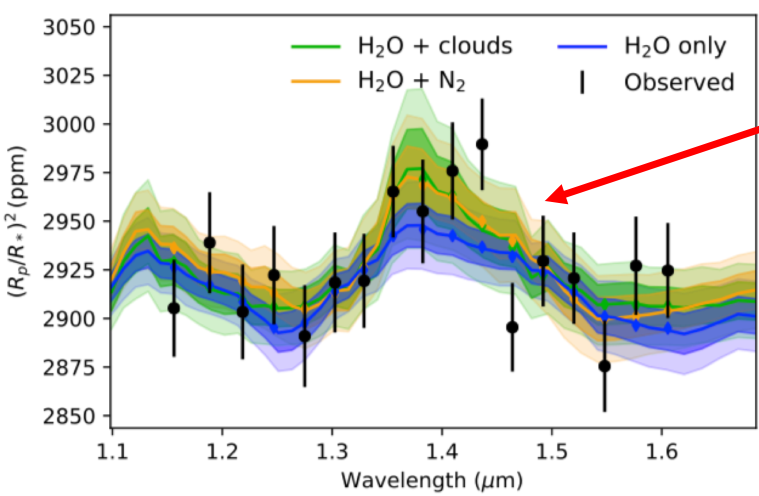
Fleury et al. 2019

New Science Opportunities

Super-Earth & sub-Neptune atmospheric evolution causes substantial H/He envelope loss with impacts on composition.



Estrela et al. 2020



Tsiaras et al. 2020

CASE Science Community Engagement

- Three major community engagement areas
  - Input on defining the observing priorities – JWST results will likely have a significant impact
  - Precursor observations (examples include ephemeris maintenance, improved planet and stellar parameters, system characterization)
  - Access to CASE/ARIEL data products
- CASE project will provide science data products to the community through NExScI
  - Aerosol and albedo data products
  - NExScI will also mirror ARIEL science archive data products
- CASE science team community engagement
  - Community meetings planned to start later this year
  - Opportunity for US community to provide input on ARIEL observing priorities through the CASE Science Team
  - Opportunity to participate in CASE modeled on the TESS community science team

CASE Science Team

Team Member	Role
Mark Swain (JPL)[1]	Principal Investigator
Robert Green (JPL)[1]	Instrument Scientist
Gautam Vasisht (JPL)[1]	Deputy Instrument Scientist
Gael Roudier (JPL)[1]	Data Subsystem Lead
Edward Wright (UCLA)[1]	Statistical processing expertise
Jacob Bean (U. Chicago)[1]	Science Team Lead, calibration
David Ciardi (IPAC)[1,2]	Archiving Lead
Nicolas Cowan (McGill)[3]	Climate and phase curve science
Jonathan Fortney (UCSC)[1]	Theory Lead
Caitlin Griffith (UoA LPL)[1]	Comparison with solar system
Eliza Kempton (U. of Maryland)[1]	Cloud models
David Latham (Harvard/SOA)[1]	TESS target coordination
Michael Line (ASU)[1]	Spectral retrieval
Suvrath Mahadevan (Penn State)[1]	Exoplanet masses
Jorge Melendez (U. São Paulo)[3]	Stellar characterization
Julianne Moses (SSI)[1]	Atmospheric chemistry
Vivien Parmentier (University of Oxford)[3]	Modeling condensable aerosols
Adam Showman (UoA LPL)[1]	Atmospheric dynamics
Andrew Howard (Caltech)	Exoplanet demographics
Laura Kreidberg (Harvard/SAO)[3]	Transit spectroscopy calibration
Evgenya Scholnik (ASU)[3]	Stellar UV flux and star spots
Kevin Stevenson (STScI)[3]	HST/JWST coordination
Yuk Yung (Caltech)[3]	Atmospheric chemistry

Key

- Mission Development and Operations Co-Is (teal)
- Science Team Co-Is (light green)
- Science Team Collaborators (light blue)