Rocky Worlds DDT Workshop

Data Challenge Results & Rocky Worlds DDT Science

November 16 – 18, 2026

Event Program

ROCKY WORLDS

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

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Event Description

This workshop is a community gathering focused on the science enabled by the Rocky Worlds Director's Discretionary Time (DDT) program, with particular emphasis on its JWST/MIRI observations. The workshop will serve as the culmination of the Rocky Worlds DDT Data Challenge, bringing participants together to compare analysis methods and discuss the results and their scientific implications. A key component will be the unveiling of the underlying data-generating process, enabling a direct and meaningful comparison across approaches.

Beyond benchmarking methods, the workshop is designed to spark broader conversations about the scientific interpretation of Rocky Worlds DDT data: how to understand differences between analyses, what level of agreement is needed for robust conclusions, and what these results imply for our understanding of rocky exoplanets. In addition to sessions centered on the Data Challenge (including a hackathon-style component), the program will include contributed talks and posters showcasing Rocky Worlds–related science, from data analysis and modeling to predictions and follow-up efforts. The goal is to use the Data Challenge as a springboard for collaboration and to shape the next phase of Rocky Worlds science.

Science Organizing Committee

- Hannah Diamond-Lowe (STScI; Co-Chair)
- Néstor Espinoza (STScI; Co-Chair)
- Zach Berta-Thompson (University of Colorado)
- Lisa Dang (University of Waterloo)
- Elsa Ducrot (CEA)
- Renyu Hu (Rutgers University)
- Jacob Lustig-Yaeger (JHU APL)
- Amélie Gressier (University of Montreal)
- Aishwarya Iyer (NASA Goddard)
- Ryan MacDonald (University of St Andrews)

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Local Organizing Committee

- Chair: Ryan Kunzer (STScI)
- Katie Bennett (JHU)
- Joshua Lothringer (STScI)
- Lupita Tovar Mendoza (JHU)
- Måns Holmberg (STScI)

Additional Information

- Rocky Worlds Program Website: http://rockyworlds.stsci.edu/
- Rocky Worlds Program Mailing List

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Event Schedule

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The Rocky Worlds DDT Workshop:
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November 16-18, 2026 at Space Telescope Science Institute

Workshop Schedule

Monday, November 16, 2026

Welcome to the Rocky Worlds DDT: School + Panel						
8:30am	• Breakfast: Café • Speaker Tech Check for Morning Speakers: Auditorium					
Rocky Worlds DDT School				**Rocky Worlds DDT & Beyond Panel Discussion**		
Time	**Topic**	**Speaker**	**Location**	**Topic**	**Panelists**	**Location**
9:00am	School Part I: Science	Zach Berta-Thompson	Café Conference Room			
10:15am	Coffee Break: Café					
10:45am	School Part II: Tools	Néstor Espinoza	Café Conference Room	Future of rocky exoplanet research	Panelists: Laura Kriedberg, Kevin Stevenson, Renyu Hu, Pierre-Oliver Lagage Moderator: Hannah Diamond-Lowe	Auditorium
12:00pm	• Lunch: Café • Poster Presenters should hang their posters in auditorium • Speaker Tech Check: Auditorium					

Session 1: Data Analysis and Systematics; Session Chair: Elsa Ducrot			
Time	**Topic**	**Speaker**	**Location**
1:45pm	Director's Welcome	Jen Lotz, STScI Director	Auditorium
2:00pm	Finding the Needle in the Haystack with JWST/MIRI	Megan Weiner Mansfield	Auditorium
2:25pm	TOI-270 b as a Pathfinder for Rocky Worlds: Joint JWST Transit–Eclipse Atmospheric Constraints and Eclipse Planning	Amélie Gressier	Auditorium
2:38pm	Mitigating MIRI Detector Systematics with Novel FN-PCA: Archival Reanalysis and Application to GJ 3929b	Nicholas Connors	Auditorium
2:51pm	First Results from the Rocky Worlds DDT Program	Qiao Xue	Auditorium
3:04pm	Lightning Talks: Antonio, Boehm, Esparza-Borges, Gressier, Kaya, Mandell, Salhi, Stevenson, Betti		Auditorium
3:15pm	• Coffee Break: Café • Posters: Auditorium • Speaker Tech Check: Auditorium		
Session 2: Stellar Environments and Contamination, Session Chair: Aisha Iyer			
3:45pm	Constraints and uncertainties in the lives of M dwarfs	Emily Pass	Auditorium
4:10pm	The Cumulative XUV Flux on Nearby M Dwarf Planets	Rory Barnes	Auditorium
4:23pm	Making Waves or Seeing Spots? Placing GJ 486b on the Cosmic Shoreline with JWST NIRISS/SOSS	Sten Vermeiren	Auditorium
4:36pm	TRAPPIST-1 Rocky Worlds as a Laboratory for Atmospheric Retention and Habitability of Exoplanets around M Dwarfs	Vladimir Airapetian	Auditorium
5:00pm	Shuttles back to host hotels: 5:30pm, 6:00pm, and 6:30pm		

5:00pm – 6:30pm Welcome Reception in Café

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Workshop Schedule

Tuesday, November 17, 2026

Time	Topic	Speaker	Location
8:30am	• Speaker Tech Check for Morning Speakers: Auditorium • Breakfast: Café		
Data Challenge			
9:00am	Data Challenge Reveal	Taylor Bell	Auditorium
9:25am	Winners Announcement	Néstor Espinoza	Auditorium
9:36am	Top Performer 1	Nicolas Crouzet	Auditorium
9:49am	Top Performer 2	Mark Fortune	Auditorium
10:02am	Top Performer 3	Salma Salhi	Auditorium
10:15am	• Coffee Break: Café • Speaker Tech Check: Auditorium		
10:45am	Data Challenge Panel Discussion	Panelists: Jegug Ih, Elsa Ducrot, Taylor Bell, Sebastian Zieba Moderator: Néstor Espinoza	Auditorium
11:30am	Panel-led Discussion and Mural	Moderator: Néstor Espinoza	Auditorium
12:00pm	Hackathon Topics		Auditorium
12:30pm	Group Picture		Front Entrance
12:45pm	Lunch		Café
1:30pm	Poster Session		Auditorium
Session 3: Atmospheric Modeling, Session Chair: Renyu Hu			
2:00pm	Modeling rocky exoplanet atmospheres: challenges and opportunities	Anjali Piette	Auditorium
2:25pm	Helium escaping from the temperate super-Earth LHS 1140b	Collin Cherubim	Auditorium
2:38pm	A Climate-Constrained Bayesian Inverse Method for JWST Rocky Exoplanet Eclipse Spectra: Case Study of LTT 1445A b	Nicholas Wogan	Auditorium
2:51pm	Atmospheric Characterization of Terrestrial Exoplanets with PICASO	Benjamin Liberles	Auditorium
3:04pm	Lightning Talks: Bhongade, Chen, Chen (w/Wendling, Lai, Cunningham), Feigelson, Nguyen, Whyte, Bennett		Auditorium
3:15pm	• Coffee Break: Café • Posters: Auditorium • Speaker Tech Check: Auditorium		
Session 4: Population Inference, Session Chair: Lisa Dang			
3:45pm	Where is the M Dwarf Cosmic Shoreline? On the Population-level Inference of Rocky Exoplanet Atmospheres and Its Challenges	Jegug Ih	Auditorium
4:10pm	Lava Lamps: A survey to search for silicate vapor atmospheres in the ultra- hot terrestrial planet population	Cole Smith	Auditorium
4:23pm	Uniform Reinterpretation of Rocky Exoplanet Secondary Eclipse Observations & the Impact of Stellar and Orbital Uncertainties	Christopher Monaghan	Auditorium
4:36pm	Benchmark Small Planets for the Rocky Worlds Era	Larissa Palethorpe	Auditorium
5:00pm	Shuttles back to host hotels (only): 5:00pm, 5:15pm, 5:30pm		

6:00pm-8:00pm Off-Site Event at R. House 301 W. 29th Street, Baltimore, MD 21211

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Workshop Schedule

Wednesday, November 18, 2026

Time	Topic	Speaker	Location
8:30am	• Speaker Tech Check for Morning Speakers: Auditorium • Breakfast: Café		
Hackathon			
9:00am	Hackathon, Part 1		Auditorium
10:15am	Coffee Break		Café
10:45am	Hackathon, Part 2: Present Hackathon Results (by group)		Auditorium
11:30am	Paper Brainstorming		Auditorium
12:00pm	Lunch		Café
1:00pm	Poster Session		Auditorium
Session 5: Surfaces and Solar System Connection, Session Chair: Amélie Gressier			
1:30pm	Bare Rock or Atmosphere? Solar System Science in the Context of the Rocky Worlds DDT	Kimberly Paragas	Auditorium
1:55pm	Dayside Thermal Emission Spectra of the Earth and Moon as References for Transiting Rocky Exoplanet Atmosphere Searches	Patcharapol Wachiraphan	Auditorium
2:08pm	Tiny rocky worlds: Hunting for Solar System asteroids in the Rocky Worlds DDT images	Nicolas Crouzet	Auditorium
2:21pm	Workshop Closing Remarks	Néstor Espinoza, Chair	Auditorium
2:30pm	Break (tea and cookies)		Lobby
2:45pm	Shuttle back to the hotels (for those leaving the event; no return shuttle)		
3:00pm	Colloquium: “Copernicus Revisited: is the Earth special?”	Laura Kriedberg	Auditorium
4:00pm	Shuttles back to the host hotels (only): 4:15pm, 5:00pm, 5:30pm, 6:00pm		

4:00pm-6:00pm Happy Hour/SDAS in Café

Rocky Worlds DDT Workshop

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Congratulations to our Rocky Worlds DDT Challenge Top Performers:

AstroMusers Team

IREx Team

Nicolas Crouzet

Mark Fortune

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Rocky Worlds DDT School Instructors

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Zach Berta-Thompson, Instructor

University of Colorado at Boulder

Zach Berta-Thompson is an astronomy professor in the Department of Astrophysical and Planetary Sciences at the University of Colorado Boulder. He uses large and small telescopes, both on the ground and in space, to observe exoplanets orbiting other stars and to characterize their atmospheres. He views each exoplanet as a laboratory experiment that can help us understand the processes that sculpt planetary evolution, and he builds methods and models in careful steps toward eventually determining whether life exists outside the Solar System. Zach grew up as the son of two ceramic artists in Michigan, he studied with caring astronomers at Princeton, Harvard, and MIT, and he started as a professor in Colorado in 2016. He leads a team of researchers and teaches students to practice using curiosity, creativity, coding, and kindness to learn more about how worlds work. Beyond astronomy, he enjoys yarn crafts, hiking with toddlers, and plants

Néstor Espinoza, Instructor

Space Telescope Science Institute

Dr. Néstor Espinoza is a tenured Associate Astronomer at the Space Telescope Science Institute (STScI), where he serves as the Mission Scientist for Exoplanet Science. His research focuses on the characterization of exoplanet atmospheres, spanning giant planets, sub-Neptunes, and rocky worlds orbiting nearby stars. He is particularly interested in developing observational strategies and statistical methods to extract robust physical constraints from high-precision astronomical observations.

He has been actively involved in atmospheric studies with JWST, including investigations of the TRAPPIST-1 planetary system and the challenges of detecting and characterizing atmospheres around temperate terrestrial exoplanets. He is also a keen developer of open-source scientific software, with juliet—a widely used Bayesian modeling tool for exoplanet observations—being one of his most notable contributions.

As a Core Implementation Team Lead of the JWST Rocky Worlds Director's Discretionary Time (DDT) program, he helps coordinate a large community effort aimed at understanding the presence and properties of atmospheres around rocky exoplanets. Through his work, he seeks to bridge observations, theoretical modeling, and statistical inference to push the boundaries of what we can learn about worlds beyond our Solar System.

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Invited Speaker Abstracts

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Taylor Bell, Invited Speaker

Space Telescope Science Institute

Building a Known Truth: Simulating JWST/MIRI Eclipses of LHS 1140 b for the Rocky Worlds DDT Data Challenge

Half of the Rocky Worlds DDT Data Challenge was built on data with a known answer: simulated JWST/MIRI 15 μm secondary eclipses of LHS 1140 b. Unlike real observations, simulations let us ask not only whether different analyses agree with one another, but whether they recover the truth with reliable uncertainties. On behalf of the team that built them, I will finally pull back the curtain on these simulations. I'll describe what we set out to test and how the dataset was assembled layer by layer: an astrophysical signal grounded in what we currently know about the system, a telescope that never sits quite as still as we'd like, and the detector quirks that make MIRI time-series data unique. Wherever reality proved too difficult to fake, we borrowed from it directly. And, of course, we couldn't resist including a few additional surprises along the way. I'll also explain how we scored submissions to the RWDDT Data Challenge. Finally, I will reflect on what we learned from building realistic simulations, touching on where they still fall short of real data and how these tools can support future Rocky Worlds analyses.

Jegug Ih, Invited Speaker

Space Telescope Science Institute

Where is the M Dwarf Cosmic Shoreline? On the Population-level Inference of Rocky Exoplanet Atmospheres and Its Challenges

Central to rocky exoplanet science with JWST is determining if and under what conditions rocky planets around M dwarfs have atmospheres, often discussed in the framework of the Cosmic Shoreline. In this talk, I will discuss how the goal of population-level inference informs target selection, then review the current status of observations and associated challenges. First, I will frame target selection as a combinatorial optimization ("knapsack") problem and show that detecting a Shoreline favors a "wide and shallow" survey. With this approach, 500 hours of JWST time could detect the Shoreline, if it takes the form we expect. Second, I will discuss the current observational results, which now include both shallow and anomalously deep eclipses that challenge the expected Shoreline, alongside approaches that constrain it by also considering gaseous planets. Finally, I will turn to the observational and theoretical challenges that remain in identifying atmospheres. These include false positives and negatives from aerosols and surface thermal effects, as well as the assumed ubiquity of CO_2. I will demonstrate follow-up strategies using other bands and phase curves to break these degeneracies. I will also highlight the need for a more complete understanding of atmospheric escape, particularly for secondary atmospheres. I conclude that the Rocky Worlds DDT can reveal much about the M-dwarf Cosmic Shoreline, but doing so robustly requires further follow-up observations as well as parallel theoretical efforts. Getting this right will shape how we search for and characterize atmospheres on rocky worlds beyond the Solar System, including with future missions.

Megan Weiner Mansfield, Invited Speaker

University of Maryland

Finding the Needle in the Haystack with JWST/MIRI

The Rocky Worlds DDT program aims to recover secondary eclipse signals on the most challenging targets ever observed by JWST – small, rocky planets with equilibrium temperatures reaching into the habitable zone. Extracting reliable signals from these faint, challenging targets will push the limits of our analysis techniques. In this talk, I will review what the community has learned from the last five years of JWST/MIRI observations of transiting exoplanets, discuss common instrument systematics and novel data analysis techniques, and present ideas for maximizing the scientific return from the Rocky Worlds DDT program.

Kimberly Paragas, Invited Speaker

California Institute of Technology

Bare Rock or Atmosphere? Solar System Science in the Context of the Rocky Worlds DDT

The Rocky Worlds DDT program is searching for atmospheres around rocky exoplanets orbiting M dwarfs by comparing their measured dayside emission to predictions of bare-rock surface and atmosphere models. The thermal emission of an airless planet is shaped by its surface, and decades of Solar System remote sensing have shown that surface spectra depend on many factors, such as composition, grain size, porosity, and viewing geometry. In this talk, I will distill key lessons from the study of Solar System rocky bodies for our interpretation of JWST observations of hot, rocky exoplanets. I will discuss work demonstrating that assumptions about surface properties can directly affect whether a planet is inferred to have an atmosphere. Lastly, I will highlight physical effects previously characterized for Solar System bodies but not typically considered in exoplanet surface models, and discuss how laboratory measurements and refined surface models can make atmospheric constraints more robust for the Rocky Worlds DDT.

Emily Pass, Invited Speaker

Massachusetts Institute of Technology

Constraints and uncertainties in the lives of M dwarfs

The present-day stellar environment gives us a snapshot of the forces that are currently driving atmospheric escape from a planet, but it does not give us the full picture: a planet's atmosphere is shaped by the evolving stellar environment over that planet's entire life. This is a much trickier quantity to estimate for any star, but especially for M dwarfs. In this talk, I will describe our current understanding of M-dwarf stars and how their rotation and activity evolution differ from Sun-like ones. This discussion will focus on both methods and uncertainties: how do we know what we know, and what unknowns are we sweeping under the rug with our simplifying assumptions? I will also connect this picture to the 'cosmic shoreline', the empirical dividing line in our solar system between planets that have retained atmospheres and those that have not. In this second section, I will attempt to answer two questions: 1) how does our current picture of M-dwarf evolution change the location of the shoreline relative to more massive stars, and 2) how might remaining unknowns shift this shoreline further?

Anjali Piette, Invited Speaker

University of Birmingham

Modeling rocky exoplanet atmospheres: challenges and opportunities

JWST observations of rocky exoplanets open a new window onto the mechanisms governing their atmospheric and interior evolution. The thermal emission from these worlds is sensitive to a wide range of processes, including atmospheric composition, temperature structure, and aerosols, as well as the outgassing and escape mechanisms that shape their atmospheres. However, these complex processes involve many parameters, which can become degenerate when interpreting observations.

In this talk, I will discuss the assumptions underlying models of rocky exoplanet atmospheres and the degeneracies that can arise. I will also consider how JWST observations can shed light on the atmospheric and interior evolution of these planets. This evolution is highly sensitive to interactions between the atmosphere and interior, our understanding of which relies heavily on laboratory experiments. Uncovering the true nature of rocky worlds is therefore an inherently interdisciplinary endeavor.

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Contributed Speaker Abstracts

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Vladimir Airapetian, Contributed Speaker

NASA GSFC/SEEC and American University

TRAPPIST-1 Rocky Worlds as a Laboratory for Atmospheric Retention and Habitability of Exoplanets around M Dwarfs

Close-in rocky planets orbiting active M dwarfs are exposed to intense X-ray and extreme-ultraviolet (XUV) radiation, stellar winds, and coronal mass ejections that can drive substantial atmospheric escape and ultimately determine long-term habitability. Whether the outer habitable-zone planets of the TRAPPIST-1 system can retain secondary atmospheres over billions of years remains a fundamental question for interpreting current and future observations.

We present new one-dimensional hydrodynamic simulations of N^+, O^+, and H^+ ion escape from the upper atmospheres of TRAPPIST-1 f, g, and h under both quiescent and flare-enhanced stellar XUV irradiation. Our calculations employ the updated Polar Wind Outflow Model (PWOM 7i), which self-consistently solves the multi-species ion-electron hydrodynamic equations from the exobase to the sonic point. A key advance of this work is the incorporation of lower-boundary temperatures and neutral density profiles derived from three-dimensional simulations with the Global Ionosphere Thermosphere Model (GITM), tailored to each planet's gravity, bolometric irradiation, and XUV environment.
Relative to previous studies that adopted scaled-Earth upper-atmosphere profiles, the GITM-based boundary conditions produce substantially different exobase structures and ion source populations, resulting in systematically higher heavy-ion escape efficiencies. Our simulations indicate that cumulative nitrogen and oxygen loss over the lifetime of the TRAPPIST-1 system may remove a significant fraction of the volatile reservoirs available to sustain dense secondary atmospheres, thereby reducing the long-term habitability of these planets.

These results provide a new theoretical framework for interpreting recent JWST constraints on the atmospheres of the TRAPPIST-1 planets and motivate future direct characterization of rocky exoplanets with upcoming observatories, including the LIFE, HOEE and Habitable Worlds Observatory.

Rory Barnes, Contributed Speaker

University of Washington

The Cumulative XUV Flux on Nearby M Dwarf Planets

We predict the XUV evolution of M dwarfs within 50 pc that are orbited by at least 1 planet with a period <100 days, a mass <25 Earth-masses and/or radii <2.5 Earth-radii to estimate how close the planets are to the "cosmic shoreline". We employ an XUV evolution model calibrated to solar twins as well as recently published empirical models of M dwarf rotational and X-ray evolution combined with an empirical relationship between stellar X-ray and XUV luminosities to compute the planets' cumulative XUV fluxes. We rigorously compared the models for GJ 1132 b and find that the M dwarf models predict 2-3 times larger cumulative XUV fluxes than the solar twin model, but with uncertainties that admit a ~1% chance that planet b is on the atmosphere-allowed side of the shoreline. The largest components of the uncertainty budget are the extrapolation from X-Ray to XUV luminosity, and the natural intrinsic scatter among M dwarfs. Our analysis reveals that age estimates are not a limiting factor in the cumulative XUV calculation because most XUV flux arrives during the pre-main sequence phase, which is less than 1 Gyr for all but the smallest M dwarfs. The new empirical M dwarf models predict that ~75% of well-characterized planets within 50 pc possess no atmosphere, even with uncertainties, but that only one, LHS 1140 b, is expected to maintain an atmosphere. We also find that several well-known mini-Neptunes have intercepted enough XUV flux for the cosmic shoreline model to predict they should be atmosphere-free, suggesting that initial volatile abundances play an important role in atmospheric lifetimes. Regardless, this new catalog of cumulative XUV fluxes, with uncertainties, can help interpret ongoing searches for exoplanet atmospheres such as the Rocky Worlds DDT program.

Collin Cherubim, Contributed Speaker

University of Chicago

Helium escaping from the temperate super-Earth LHS 1140b

Planetary atmospheric escape and volatile replenishment from planetary interiors compete to determine the mass and composition of planetary atmospheres. We developed a planetary evolution model, IsoFATE, to explore how gravitational separation of escaping atmospheric species, and exchange of those species with molten planetary interiors, shapes the composition of planets smaller than Neptune. Through IsoFATE simulations, we predicted an escaping helium-dominated atmosphere for LHS 1140b, a nearby super-Earth ($R_p = 1.730 \pm 0.025\ R_\oplus$; $M_p = 5.60 \pm 0.19\ M_\oplus$) orbiting a quiet mid-M dwarf in the liquid-water habitable zone ($T_{eq} = 226 \pm 4$ K). We collected a high-resolution, near-infrared transmission spectrum for LHS 1140b and its closer-in sibling planet, LHS 1140c, to test our predictions. In 2024, we measured a metastable helium absorption signal for LHS 1140b with a signal-to-noise ratio of 6.4 indicating ongoing atmospheric escape, and a null detection for LHS 1140c. Previous HST and JWST surveys ruled out clear-sky, hydrogen-rich atmospheres to explain the slight under-density of LHS 1140b compared to a purely terrestrial composition. Our results are consistent with a helium-dominated upper atmosphere above a water-rich layer or a metal-rich lower atmosphere depleted in non-condensing reducing species such as CH4. In 2025, we repeated the observation and found an upper limit on helium absorption of half the 2024 value, which we interpret as variable escape. A third follow-up observation is scheduled for October 30 2026. Our non-detection of escape on LHS 1140c is consistent with a JWST dayside emission spectrum that suggested an airless body or a very optically thin atmosphere. The LHS 1140 system represents an important benchmark for constraining atmospheric loss for planets orbiting low-mass stars, as it comprises one super-Earth on each side of the cosmic shoreline.

Nicholas Connors, Contributed Speaker

Université de Montréal

Mitigating MIRI Detector Systematics with Novel FN-PCA:
Archival Reanalysis and Application to GJ 3929b

A current priority of exoplanet research is determining whether rocky exoplanets orbiting M dwarfs can sustain atmospheres. A promising method for this is to take secondary eclipse photometry measurements of these planets at 15um to search for evidence of CO2 absorption. To help in achieving this goal, we have developed a novel method of detrending JWST/MIRI secondary eclipse data, Frame-Normalized Principal Component Analysis, which works to find and account for inter-pixel detector-level systematic effects. Using this technique, we reanalyze existing MIRI 15um data sets and perform an independent analysis on the full data set of GJ 3929b, the first completed target of the Rocky Worlds DDT. We find that detector settling is correlated to the brightness of the host star across these datasets, that our FN-PCA method is more robust against choice in extraction aperture size than our comparison baseline when analyzing GJ 3929b, and that our method yields largely consistent results compared to the existing literature.

Nicolas Crouzet, Contributed Speaker

Commissariat à l'énergie atomique et aux énergies alternatives (CEA), France

Tiny rocky worlds: Hunting for Solar System asteroids in the Rocky Worlds DDT images

Asteroids are remnants of the early Solar System and are possible reservoirs of organic compounds that can be delivered to planets. Besides, collisions with asteroids can alter the evolution of planets and their moons and pose a threat to life on Earth. We will present our project on detecting Solar System asteroids via their thermal emission using the JWST Mid-Infrared Instrument (MIRI) in the context of Solar System science and planetary defence. JWST MIRI opened up a new window to detect small and cool asteroids by observing at mid-infrared wavelengths with unprecedented sensitivity. The 500 hours of MIRI imaging data acquired via the Rocky Worlds Director's Discretionary Time (DDT) Program provide a mine to serendipitously detect asteroids that cross the field of view. In this presentation, we will describe our method to detect asteroids and show the results obtained on the images acquired via the MIRI Mid-INfrared Disk Survey (MINDS), which is part of the MIRI European Consortium Guaranteed Time Observation program, that we used as a test case. We detected 18 asteroids in this data set. Most of them were unknown, and these are one to two orders of magnitude fainter and up to 20 times smaller than the known ones. Then, we will present our plan to extend this search to the Rocky Worlds DDT Program images. This search with MIRI is complementary to those conducted at visible and near-infrared wavelengths with facilities such as VST/OmegaCAM, HST, Euclid, and LSST: their combination can yield the spectral energy distributions of asteroids, which constrain their temperatures, sizes, and surface properties. Overall, this study will help understand the physical properties of asteroids, their role in the formation of the Solar System and of planetary systems in general, and will contribute to assessing the risk of future collisions with Earth.

Amélie Gressier, Contributed Speaker

Université de Montréal

TOI-270 b as a Pathfinder for Rocky Worlds: Joint JWST Transit–Eclipse Atmospheric Constraints and Eclipse Planning

Secondary eclipses provide one of the few direct probes of the energy budgets and atmospheric circulation of temperate small exoplanets. Their detection requires precise orbital solutions, optimized observing strategies, and robust mitigation of instrumental systematics—key challenges for the Rocky Worlds DDT program.

We present a complete re-analysis of the TOI-270 system combining radial velocities from ESPRESSO, HARPS, and NIRPS, transit observations from TESS and JWST, and four JWST/MIRI eclipse observations of TOI-270 b, a target of the Hot-Rocks program. Our global fit significantly refines the system architecture and orbital eccentricities. We show that the improved constraints on the eccentricities propagate into eclipse timing predictions and probabilities, providing a practical tool for planning future JWST eclipse observations of small planets. Using four independent MIRI eclipses, we quantify the impact of extraction methods and fitting choices on the inferred eclipse depth. We measure 138 ± 20 ppm, corresponding to a dayside brightness temperature of ~715 K. The observations favor intermediate heat redistribution and, within the dynamical model of Wirth et al. (2026), are consistent with partial day-to-night heat transport and a volatile atmosphere rather than a bare rock.

Finally, we combine the thermal-emission measurement with the JWST transmission spectrum in the first joint transit–eclipse atmospheric retrieval of a warm rocky planet. Exploring grid-based and free retrievals, CLR chemistry, and Ghost-μ parameterizations, we show that the eclipse probes deeper atmospheric layers, breaking degeneracies between atmospheric composition, thermal structure, radius, and surface pressure. The joint analysis remains consistent with a volatile-rich, water-dominated atmosphere and strengthens the case for a high mean molecular weight atmosphere previously inferred from transmission spectroscopy alone.

Benjamin Liberles, Contributed Speaker

University of Texas at Austin

Atmospheric Characterization of Terrestrial Exoplanets with PICASO

The James Webb Space Telescope (JWST) enabled detections of planetary atmospheres around terrestrial planets for the first time, and the community has allocated 2300 hours in Cycle 1-5 General Observing programs and the Rocky Worlds Director's Discretionary Time (DDT) to address whether terrestrial planets around M dwarfs host atmospheres. However, our ability to definitively characterize and model the compositions of these atmospheres is limited, especially for atmospheres diverging from solar system analogs.

The future of characterizing atmospheres around terrestrial planets depends on building flexible modeling frameworks suitable for a diverse range of terrestrial worlds. PICASO is an open-source radiative transfer code that solves for the self-consistent temperature, chemical, and cloud structure of hydrogen-dominated atmospheres in radiative-convective equilibrium. I will present new atmospheric modeling tools adapted into the PICASO open-source radiative transfer and climate modeling framework, originally designed for gas giants and brown dwarfs, to model the physics of terrestrial planetary atmospheres by taking a deeper consideration of the chemistry and opacities relevant in the non-hydrogen-dominated small planet regime. Our development focuses on four key efforts: (1) introducing new adiabatic profiles for a wider range of atmospheric compositions; (2) implementing analytic heat redistribution to account for atmospheric circulation; (3) updating opacity data to include a broader range of species, including collision-induced absorption and rovibrational bands with appropriate broadening coefficients; and (4) adding a surface boundary condition, including a diverse range of rock compositions. I will present a new legacy set of PICASO atmospheric models for the nine DDT targets which will be used to interpret what terrestrial planet observations with JWST tell us about how well the cosmic shoreline extrapolates to M dwarf terrestrial planets.

Christopher Monaghan, Contributed Speaker

UCLA

Uniform Reinterpretation of Rocky Exoplanet Secondary Eclipse Observations & the Impact of Stellar and Orbital Uncertainties

Secondary eclipse observations are a powerful way to investigate whether or not a rocky exoplanet hosts an atmosphere, as an atmospheric presence would transport heat to the nightside and render the dayside colder than anticipated. The interpretation of the secondary eclipse observations relies, however, on models based on imperfect knowledge of the host star properties and the system parameters. Any uncertainties in such astrophysical variables will propagate into both atmospheric and bare-rock models, potentially leading to poorly constrained results and erroneous conclusions. In this work, we introduce a framework to efficiently account for the stellar and orbital uncertainties when modeling the emission spectra of rocky exoplanets, and demonstrate its use by reanalyzing the current suite of rocky exoplanets with published eclipse observations. Our analysis reveals notable uncertainty in the predicted eclipse depth even for a simple dark bare rock as a result of the finite precision of the system's parameters and treatment of the host star's flux. In some cases, the model uncertainty is comparable to the observational uncertainty, further complicating our capability to constrain an atmospheric presence from secondary eclipse observations. From our modeling schematic, we derive a linear correlation between the model uncertainty and the errors in Rp/R*, ap/R*, and T*, therefore enabling a more robust compositional analysis in future studies. The model uncertainty serves as a fundamental precision limit to surface analyses, and must be mitigated to strongly constrain the composition of exoplanets in future eclipse observations. We further investigate the impact of model uncertainty in the context of the ongoing Rocky Worlds DDT, focusing especially on the validity of photometric observations and planetary compositions sensitive to detection at 15 microns.

Larissa Palethorpe, Contributed Speaker

University of Bristol

Benchmark Small Planets for the Rocky Worlds Era

The emerging sample of rocky exoplanets accessible to JWST requires precise measurements of planetary masses, radii, and orbital architectures to place atmospheric observations in their proper physical context. Many small planets discovered by K2 and TESS still lack well-constrained bulk densities or sufficiently precise transit ephemerides for efficient long-term follow-up.

We present a uniform transit and radial-velocity analysis of six transiting systems observed with CHEOPS, combining new space-based photometry with archival K2, TESS, ground-based transit observations, and high-precision radial velocities from multiple spectrographs. Joint transit-RV modelling yields typical mass and radius precisions better than 15% and 5%, enabling robust density and interior composition constraints spanning rocky, volatile-rich, and intermediate planets. Several planets lie close to the super-Earth/sub-Neptune transition, providing new empirical constraints on the diversity of terrestrial and transitional worlds and on the processes shaping the radius valley.

We also refine transit ephemerides through a global analysis of all available timing data, extending the accessibility of these systems for future JWST, Ariel, and Habitable Worlds Observatory observations. Several systems show evidence for additional non-transiting companions, revealing dynamical architectures that may influence planetary formation, atmospheric evolution, and volatile retention. Together, these systems provide a set of well-characterised benchmarks that complement the Rocky Worlds DDT programme by supplying the planetary context needed to interpret atmospheric observations of small exoplanets.

Cole Smith, Contributed Speaker

University of Maryland

Lava Lamps: A survey to search for silicate vapor atmospheres in the ultra- hot terrestrial planet population

Understanding the cosmic shoreline requires observations of rocky planets spanning a wide range of irradiation environments. While the Rocky Worlds DDT program focuses on cooler planets that may have secondary atmospheres and habitable conditions, ultra-hot rocky planets (Tday>1700K) may have lava surfaces and rock vapor atmospheres, allowing direct exploration of their interior compositions. Because these atmospheres originate directly from the planetary surface, they provide a unique opportunity to constrain the bulk composition and mineralogy of rocky exoplanets in ways that are inaccessible for cooler worlds. Together, these populations provide complementary probes of rocky planets across the cosmic shoreline. We observed single JWST MIRI/LRS secondary eclipses for 10 ultra-hot rocky exoplanets and compared their computed dayside temperature with their expected temperature if they were a bare rock with no heat redistribution. We detect a trend in these planets with those with higher irradiation temperatures having a distinct drop in dayside temperature. With our current understanding of magma surfaces, this trend cannot be explained purely through surface composition and albedos. We discuss possible explanations for our observed trend like a silicate vapor atmosphere, a volatile rich atmosphere, and silicate vapor clouds.

Sten Vermeiren, Contributed Speaker

University of St. Andrews

Making Waves or Seeing Spots? Placing GJ 486b on the Cosmic Shoreline with JWST NIRISS/SOSS

Understanding if rocky planets (< 1.6 R⊕) can retain atmospheres around M-dwarf stars remains an open question, which is crucial for determining cosmic habitability. However, untangling true atmospheric signatures from stellar contamination remains a significant challenge. The Transit Light Source Effect (TLSE) can cause unocculted starspots on the host star to imprint wavelength-dependent signals in transmission spectra which mimic planetary spectral features, such as water absorption. The warm super-Earth GJ 486b (1.3 R⊕, 700 K) was observed with JWST NIRSpec (2.8–5.2 μm), revealing a water absorption feature. However, NIRSpec observations alone are not sufficient to distinguish between a water-rich steam world and a bare rock with stellar contamination. Here we present the first JWST NIRISS/SOSS spectra of GJ 486b (0.8–2.8 μm), extending coverage to the shorter wavelengths where the atmospheric and starspot scenarios diverge. Our transmission spectrum and atmospheric retrieval analysis span the combined NIRISS and NIRSpec wavelength range (0.8–5.2 μm), enabling us to resolve the true nature of GJ 486b. Our results demonstrate that multi-instrument, multi-epoch observations are key to truly understanding rocky exoplanet atmospheres, and take us one step closer to charting the cosmic shoreline.

Patcharapol Wachiraphan, Contributed Speaker

University of Colorado at Boulder

Dayside Thermal Emission Spectra of the Earth and Moon as References for Transiting Rocky Exoplanet Atmosphere Searches

With the capabilities of JWST, searching for atmospheric signatures on temperate rocky exoplanets has become a primary frontier in astrophysics. Surveys such as the Rocky Worlds Director's Discretionary Time (DDT) program use thermal emission measurements during secondary eclipses to distinguish between bare-rock and atmosphere-hosting worlds. However, interpreting these observations requires robust comparative models rooted in Solar System ground truth. While theoretical models exist, a fundamental comparative question remains: ``what would Earth and Moon thermal emission look like if observed by JWST?''

In this work, we present a comprehensive, observationally driven characterization of the Earth and the Moon to bridge this gap. This pair serves as an ideal baseline, representing two atmospheric end-members (a planet with atmosphere versus an airless body) subjected to identical insolation. We reanalyzed observational data from the NASA Aqua/AIRS instrument (Earth) and a combination of LRO/Diviner and Lucy/L'TES (Moon) to construct 2D spectroscopic thermal emission maps (6–15 μm for Earth; 6–20 μm for Moon). We derived dayside thermal emission spectra and calculated the throughput-weighted brightness temperature ratio (R = $T_{\rm day}$ /$T_{\rm max}$) to serve as a direct comparison for JWST/MIRI secondary eclipse observations. We demonstrate that the divergence in ΔR between the two bodies is maximized in the MIRI F1500W filter (CO$_2$ absorption) at 0.32, and minimized in F1130W at 0.19. Furthermore, we assess the phase curve constraints and precision that would be required to reconstruct thermal maps of these worlds. This work provides a necessary empirical baseline to decode the thermal signatures of rocky worlds, effectively linking Solar System and extrasolar planetary science.

Nicholas Wogan, Contributed Speaker

SETI Institute

A Climate-Constrained Bayesian Inverse Method for JWST Rocky Exoplanet Eclipse Spectra: Case Study of LTT 1445A b

The Rocky Worlds Director's Discretionary Time (DDT) program aims to search for atmospheres on warm rocky exoplanets with JWST secondary eclipse observations. However, it is challenging to extract atmospheric properties from DDT and complementary JWST eclipse datasets. Studies to date have generally interpreted eclipses by comparing select climate models to spectra, providing limited quantitative constraints on variables such as surface pressure.

Here, we develop a climate-constrained atmospheric inverse/retrieval method that more rigorously determines surface pressure and composition from JWST eclipse spectra. The framework performs a Bayesian fit to observations with model spectra derived from self-consistent pressure-temperature profiles at radiative-convective equilibrium, accounting for planetary, stellar, and model uncertainties. We demonstrate the method on the existing MIRI LRS eclipse spectrum of LTT 1445A b. We find that a bare-rock model adequately explains the data, so an atmosphere is not required. If an atmosphere is present, the 2σ upper limits on surface partial pressures are < 1 bar for an optically thin gas like O2, N2 or CO, < 0.1 bar CO2, < 1e-3 bar H2O and < 1e-4 bar SO2. Scheduled DDT MIRI F1500W observations could detect one of the thicker atmospheres permitted by the existing data if a precision of 20 ppm or better is achieved. Overall, we demonstrate that climate-constrained Bayesian inversion can turn rocky planet eclipses from the DDT program and other JWST datasets into the quantitative constraints needed to test population-level atmospheric retention hypotheses like the cosmic shoreline.

Qiao Xue, Contributed Speaker

University of Chicago

The Surprisingly Cold and Red Dayside of the Hot Rocky Planet TOI-2445 b

We present a 2–5 μm JWST/NIRSpec/PRISM phase curve of the M-dwarf rocky planet TOI-2445 b (P = 8.9 hr, T_eq ≈ 1000 K). The white-light eclipse depth of 120 ± 12 ppm corresponds to a brightness temperature ratio of R = 0.82 ± 0.06, cooler than the maximum expected for a zero-albedo airless surface. This is the first significant dayside thermal deficit measured for a hot (T_eq ≳ 600 K) rocky planet orbiting an M dwarf. The brightness temperature also tentatively (~2σ) declines with wavelength, from 1315 (+63/−68) K at 2.25 μm, matching a zero-albedo bare rock without heat redistribution, to 1041 (+96/−105) K at 4.75 μm. Reflected light matters for interpreting this spectrum: a bare surface with the albedo of ~0.3 required by the eclipse depths would contribute 20% of the signal. Fine-grained surfaces of felsic to ultramafic composition reproduce the spectrum, partly because their reflected light raises the short-wavelength brightness temperature, whereas a dark bare rock (A_B = 0) is disfavored at ~5σ. Such a reflective surface is, however, unlikely given the rapid space weathering expected in this close-in orbit. The spectrum is equally well described by ~1 bar O_2-dominated atmospheres with trace (≲10 ppm) absorbers such as CO_2. We do not detect nightside emission or a phase offset, but these non-detections remain compatible with a wide range of atmospheric scenarios, including the 1 bar atmospheres that best fit the dayside.

Rocky Worlds DDT Workshop

Data Challenge Results & Rocky Worlds DDT Science

November 16 – 18, 2026

Poster Abstracts

ROCKY WORLDS

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

Francielle Antonio, Poster Presenter

National Observatory, Brazil

Investigating the Impact of Stellar Activity on Radial Velocity Signals

Stellar activity is one of the main challenges in the detection and characterization of exoplanets through radial velocity (RV) measurements, as it can induce variations that mimic or obscure planetary signals and compromise the determination of orbital parameters. In this work, we investigate the candidate planetary system around CoRoT 104848249, initially identified by Boufleur et al. (2018), to reassess its RV signals and evaluate the influence of stellar activity.We analyzed high-resolution spectra obtained with HARPS and SOPHIE, complemented by new high-precision observations acquired with the MAROON-X spectrograph on the Gemini North Telescope. We also performed a photometric analysis of the host star, identifying a modulation period of approximately 2.2 days, consistent with stellar rotation and providing independent evidence of stellar variability.To investigate the impact of stellar activity on the RV measurements, we subtracted the orbital model from the observed RVs and compared the residuals with several spectroscopic activity indicators, including Hα, the S-index, BIS, FWHM, dLW, CRX, and Ca II IRT. No statistically significant correlations were found between the RV residuals and any of these diagnostics, suggesting that the remaining variability cannot be explained by classical spectroscopic indicators alone. These results highlight the importance of combining complementary datasets and analysis techniques to distinguish stellar variability from potential planetary signals, a challenge that is central to the characterization of exoplanet systems.

Anand Bhongade, Poster Presenter

University of Birmingham

Endogenous or accreted? Interpreting O & C in super-Earth and sub-Neptune atmospheres

The interior compositions of super-Earths and sub-Neptunes remain an important question in the field. A key challenge is that atmospheric observations probe the upper atmosphere rather than the bulk composition. Detections of several chemical species have been made in several super-Earths and sub-Neptunes including H2O, CH4 and CO2. However, different atmosphere-interior interactions could be responsible for this. For example, large amounts of H2O can be produced endogenously via atmosphere-mantle interactions or could have been accreted during formation. This raises the question: can endogenous vs accreted volatiles be distinguished observationally?

To address this question, we coupled a Global Chemical Equilibrium model with a 1D radiative–convective photochemical atmosphere model to investigate how volatiles are partitioned between the core, mantle and atmosphere. In particular, we test whether accreted vs endogenous water can be distinguished with atmospheric observations. We find that the abundance of O- and C-bearing species in the upper atmosphere is sensitive to the amount of accreted volatiles, the reactivity of the iron core, and the equilibration temperatures of the interior. For example, a reactive core can store large amounts of O, C and H, "hiding" accreted volatiles from view in the atmosphere. Population studies of super-Earth and sub-Neptune atmospheres may therefore have the potential to provide insights into the role of the iron core in sequestering planetary volatiles.

In this talk, I will discuss these trends and their implications for interpreting JWST observations of super-Earths and sub-Neptunes, focusing on how atmospheric abundances can provide insights into volatile origins, interior volatile storage, and the exchange of volatiles between interiors and atmospheres.

Victoria (Abby) Boehm, Poster Presenter

Cornell University

Testing the stellar contamination proxy method under different activity levels in the TRAPPIST-1 system

Stellar contamination from active host stars challenges efforts to characterize secondary atmospheres on rocky exoplanets, particularly for those orbiting M dwarf stars which have heavily spotted surfaces and flare frequently. In multiplanetary systems, overlap between the transit chords of an airless planet and another planet of interest may enable stellar contamination to be constrained and removed. Crucially, this technique works only if the stellar surface does not change substantially between the transit of the airless planet and the target planet. Here we present an analysis of three transits of TRAPPIST-1d paired with close-in-time transits of the airless TRAPPIST-1b as a probe of the stellar contamination along the transit chord. Our observations span a range of activity levels for TRAPPIST-1, allowing us to test how this method performs during relative quiescence, moderate activity, and large flares. Our work demonstrates the strengths and limits of the stellar contamination proxy method, which will be crucial in interpreting the results of any studies applying this method to multiplanetary systems around small stars.

Li-Jen Chen, Poster Presenter

NASA Goddard Space Flight Center

Electrodynamic Escape at LHS 1140b: How Star-Planet Coupling Shapes Transmission Spectra

LHS 1140b is one of the most promising nearby habitable-zone rocky planets for investigating atmospheric evolution and habitability. Recent Rocky Worlds DDT observations have provided new constraints on its atmosphere composition and bulk properties, necessitating a deeper understanding of the physical processes governing its atmospheric escape. As habitable-zone planets around magnetized M-dwarfs frequently reside inside the stellar Alfvén surface, strong electrodynamic coupling—such as Alfvén wings and field-aligned currents—can significantly influence both the escape rate and the interpretation of transit data. To investigate this, we use MHD modeling with atmospheric escape modules to simulate the star-planet Alfvén-wing connection. We aim to predict observable signatures driven by this coupling, such as ingress-egress asymmetries in transmission spectra. Ultimately, this study will establish the extent to which star-planet electrodynamic coupling influences atmospheric retention and shapes the observable signatures of LHS 1140b.

Li-Jen Chen, Poster Presenter

Co-authors: Colin Cunningham, Grace Lai and Austin Wendling

NASA Goddard Space Flight Center

Can LHS 1140b Retain Its Water? Atmospheric Escape on a Habitable-Zone Super-Earth

Can a habitable-zone super-Earth retain its water over billions of years? LHS 1140b provides a strong opportunity to address this question using Rocky Worlds DDT observations together with atmospheric escape models. We will use atmospheric constraints from JWST to model atmospheric escape and evaluate the long-term retention of water on LHS 1140b. Mars, where water escape has been extensively characterized by spacecraft observations, will serve as a benchmark to help identify plausible escape processes By combining observational constraints with physics-based modeling, we will explore the long-term evolution of LHS 1140b's atmosphere and water inventory.

Emma Esparza-Borges, Poster Presenter

European Space Agency (ESA)

JWST and cross-correlation techniques: Are they useful for Rocky Worlds DDT Science?

The application of cross-correlation techniques to JWST transmission spectra has opened an alternative pathway to studying exoplanet atmospheres. JWST observed the hot-Jupiter WASP-39b for the first time in July 2022 as part of the JWST Transiting Exoplanet Community Early Release Science (JTEC ERS) Program. Since then, several atomic and molecular species have been detected in its transmission spectrum. In the initial analysis, CO was detected using the NIRSpec PRISM transit observation. However, this detection could not be confidently confirmed in the initial analysis of the higher-resolution observations with NIRSpec G395H. We developed a cross-correlation technique that led to the detection of CO, H2O, and CO2 in the JWST NIRSpec G395H transmission spectrum of WASP-39b, including novel hints of CO isotopologues, which have been claimed as good indicators of planet formation scenarios and atmospheric evolution. Recently, cross-correlations have also been used to detect molecular species in smaller planets using other JWST observing modes—for example, the detection of CO in 55 Cnc e using NIRCam observations. In this talk, I will present the concept of applying cross-correlation techniques to JWST data and review the state of the art of studies involving this method. I will also explain its advantages and potential applications in the general context of JWST, assessing the feasibility of cross-correlation in the context of Rocky Worlds DDT Science.

Eric Feigelson, Poster Presenter

Eric D. Feigelson (PSU), Luis Welbanks (ASU) & Finnegan M. Keller (ASU)

The Pennsylvania State University

Statistical issues arising in JWST/MIRI small planet characterization

The Problem. JWST spectra of systems rich in molecular species – transiting planets, brown dwarfs, protoplanetary disks – are often difficult to model. With an unknown mixture of molecules, (often) low S/N data, and (sometimes) complicated continuum behaviors, the statistical modeling procedures are non-trivial. Statistical issues are now widely debated. Our discussion of various methodological issues is based on results and recommendations from mathematical statistics; many references are provided.

Our Advice. 1. Examine the spectrum without a model. [stop?] 2. Perform a fit with a single reference model of common species. 3. Examine goodness-of-fit. 4. Assess the residual structure. [stop?] 5. Fit a few additional post-hoc models with model selection and FDR correction. [stop?] 6. Perform exploratory modeling with many species with FDR correction.

Amélie Gressier, Poster Presenter

Université de Montréal

Is Helium Escaping from LHS 1140 b? A Multi-Epoch View with JWST NIRISS SOSS and NIRPS Ground-Based Spectroscopy

The recent detection of metastable helium absorption at 1083 nm with WINERED suggests ongoing atmospheric escape from LHS 1140 b, a temperate super-Earth and key target of the Rocky Worlds DDT program. Intriguingly, the signal was detected in 2024 but not in 2025, potentially indicating strong temporal variability. We present a homogeneous reanalysis of multiple JWST/NIRISS SOSS transits of LHS 1140 b and c to independently test this detection. Our preliminary analysis finds no significant helium absorption in any individual visit or in the combined transmission spectrum of LHS 1140 b. Injection–recovery tests demonstrate sensitivity to a WINERED-like signal, suggesting that the reported feature was not present at comparable strength during the JWST observations. No signal is detected for LHS 1140 c. We will complement these constraints with high-resolution NIRPS monitoring to investigate temporal variability and its possible connection with stellar activity. Confirming helium escape from LHS 1140 b would provide direct evidence for an atmosphere around one of the flagship rocky planets in the Rocky Worlds DDT sample, in the Habitable zone. On the other hand, establishing that the signal is transient—or not reproducible—would be critical for assessing the robustness of atmospheric detections. Combining this probe of the escaping upper atmosphere with upcoming MIRI eclipse measurements will be essential to determine whether LHS 1140 b has retained an atmosphere and to interpret atmospheric survival on rocky planets around M dwarfs.

Asaf Kaya, Poster Presenter

Washington University in St. Louis

Analysis of Two Rocky Worlds DDT Datasets

Secondary eclipses of transiting exoplanets enable the measurement of the effective dayside brightness temperatures of close-in exoplanets, providing an opportunity to rule out atmospheres if the measured planetary temperature is close to the maximum dayside temperature, suggesting no effective heat redistribution. We report our results for two Rocky Worlds DDT secondary eclipse datasets, 4 eclipses of GJ 3929 b observed with JWST/MIRI with the F1500W filter, and 9 eclipses of LHS 1140 b simulated with the same setup as part of the Rocky Worlds DDT Data Challenge. We use the Eureka! data reduction and analysis pipeline to obtain the light curves through aperture photometry, and implement an MCMC algorithm with emcee to extract posterior distributions of eclipse depths and mid-eclipse times. Manually clipping several hundred of the first integrations of each observation dominated by the detector settling ramp, and modeling the remaining systematics with second or third degree polynomials, we strive to keep our model as simple as possible. Our joint fit analyses of all light curves result in an eclipse depth of 151.8 ± 20 ppm for GJ 3929 b, and 62.4 ± 19 ppm for LHS 1140 b. Modeling the stellar spectrum of each of the hosts with PHOENIX models, these imply planetary dayside monochromatic brightness temperatures of 751 ± 61 K and 256 ± 21 K, respectively. Given the maximum disk-integrated dayside temperatures of these planets (740 K and 286 K, respectively), we conclude that an atmosphere cannot be confidently ruled out with the simulated eclipses of LHS 1140 b, while GJ 3929 b is likely a bare rock exhibiting minor thermal excess, consistent with the cosmic shoreline. We also use the offset from 0.5 phase of the mid-eclipse time posteriors to constrain orbital parameters, and find $e\cos(\omega) = -0.0024(+0.000034\ -0.000024)$ for GJ 3929 b, and $e\cos(\omega) = 0.0029(+0.000063\ -0.00013)$ for LHS 1140 b.

Avi Mandell, Poster Presenter

NASA Goddard Space Flight Center

Pinning Down the M-Earth Cosmic Shoreline Using Phase Curves of Non-Transiting Planets

JWST is making excellent progress in initial reconnaissance of highly-irradiated potentially rocky planets for signs of atmospheres using both transmission spectroscopy and thermal emission measurements. But atmospheric characterization of transiting exoplanets in the rocky-planet regime is still strongly limited by the magnitude of the signal and the distance to the nearest transiting targets -- and this is especially true of planets in the Habitable Zone.

However, next-generation radial-velocity (RV) surveys are beginning to rapidly identify the population of NON-transiting potentially Earth-like planets around the nearest stars. More than 50 small temperate planets around M-stars have been discovered within 20 pc, but only ~5 transit their star – and therefore detailed characterization is out of reach for the vast majority using traditional transit methods. If we are able to develop a strategy that can extract the planetary thermal emission signal from the star without using a secondary eclipse, it will open these planets up to detailed characterization.

We present a new analysis framework for spectral phase curves called Variable Planetary Infrared Excess, which extracts a planet's phase-dependent thermal emission spectrum without requiring the planet to transit – thereby providing heat redistribution and molecular abundance constraints from phase curves of non-transiting rocky planets around the nearest stars with a relatively modest telescope aperture. We provide several proof-of-concept analyses of simulated data, emulating both JWST as well as a future MIR-optimized telescope with a low-res spectrograph with broad simultaneous spectral coverage (3 - 17 um) designed for extreme flux measurement precision. Called the Mid-InfraRed Exoplanet Climate Explorer (MIRECLE), such a mission would be capable of measuring the atmospheric and surface characteristics of a statistically significant sample of temperate rocky planets around the nearest M-stars.