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NEWS RELEASE
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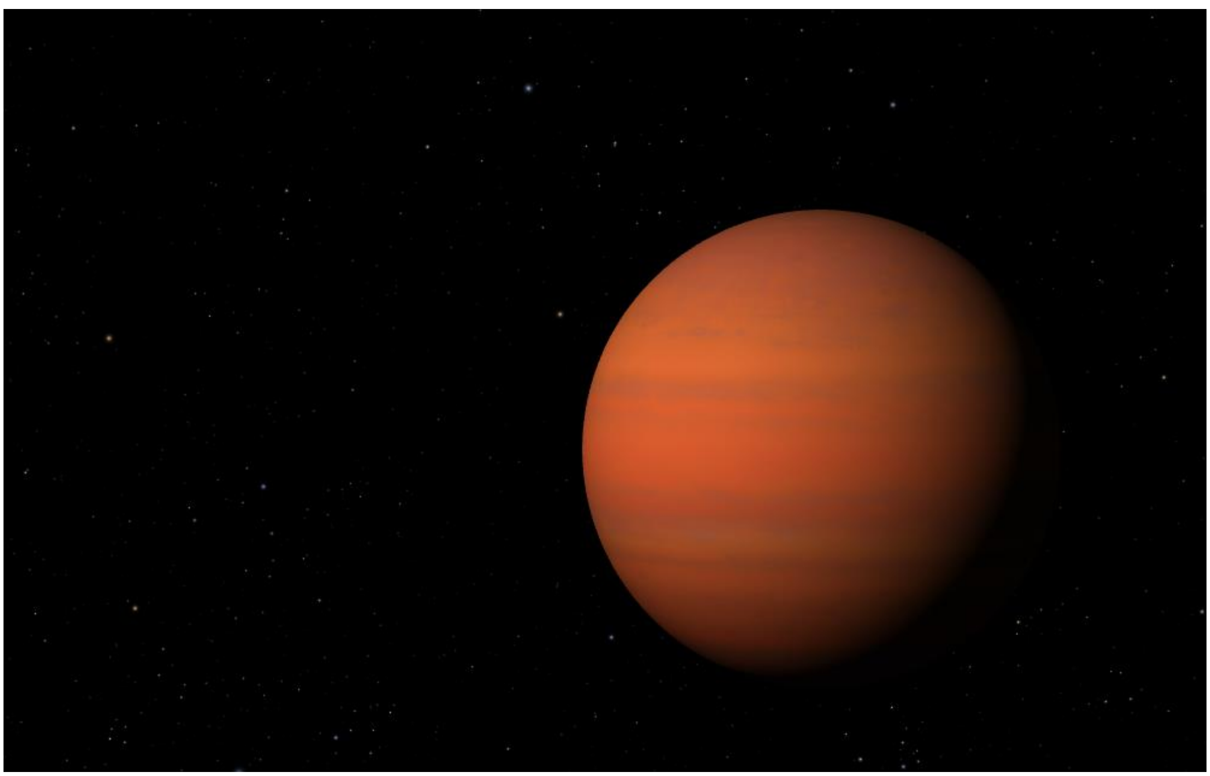
Secrets of a Hot Saturn and its Spotted Star Unlocked by Université de Montréal Astronomers

Dr. Jason Rowe of Bishop's University collaborates as co-investigator

Sherbrooke, January 14, 2024 - A team of astronomers, including Dr. Jason Rowe of Bishop's University, has unraveled the enigmatic atmosphere of the exoplanet HAT-P-18 b, shedding light on its intriguing blend of gases, clouds, and even the effects of its star's activity. Leveraging the James Webb Space Telescope (JWST) and sophisticated modelling techniques, their pioneering study provides a remarkable peek into the complexities of distant worlds and paves the way for a deeper understanding of exoplanetary atmospheres and the importance of considering their stars.



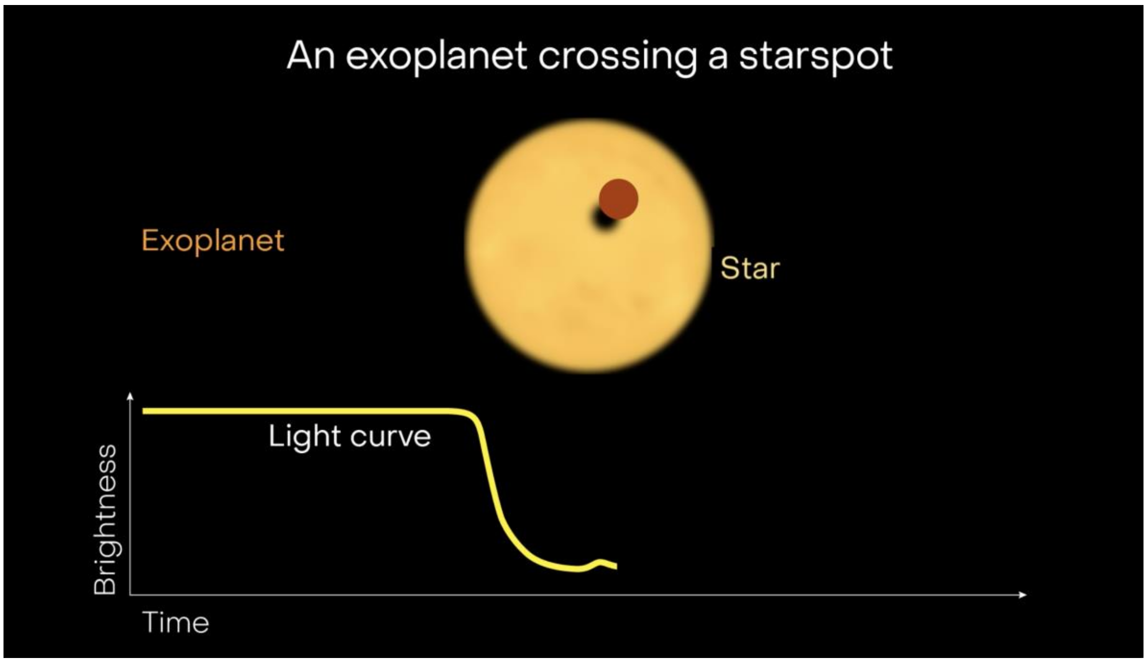
An artistic representation of the "hot Saturn" exoplanet, HAT-P-18 b. (Credit: NASA/Eyes on Exoplanets)

Exoplanets, planets located beyond our Solar System, captivate both scientists and the public, holding the promise of unveiling diverse planetary systems and potentially habitable worlds. Despite being very much not like our Earth, large gas giant planets found very close to their stars have proven to be ideal test targets for telescopes like the James Webb Space Telescope (JWST) to refine astronomers' methods of understanding exoplanets. One such planet is HAT-P-18 b, a "hot Saturn" type planet located over 500 light-years away with a mass similar to Saturn's but a size closer to that of the larger Jupiter. This gives the exoplanet a puffed-up atmosphere that is especially ideal for analysis.

Led by a team of researchers from the Trottier Institute for Research on Exoplanets at the Université de Montréal (UdeM), a team of astronomers, including Dr. Jason Rowe, Canada Research Chair in Exoplanet Astrophysics, and professor in the department of Physics and Astronomy, harnessed the power of the revolutionary Webb Telescope to study HAT-P-18 b. Their findings, detailed in the journal *Monthly Notices of the Royal Astronomical* Society (MNRAS), provide a comprehensive portrait of the hot Saturn's atmosphere while delving into the complexities of distinguishing atmospheric signals from stellar activity.

Passing over a spotted star

Observations from the Webb Telescope were taken while the exoplanet HAT-P-18 b was passing in front of its Sun-like star. This moment is called a *transit* and is crucial to detect and further characterize an exoplanet from hundreds of light-years away with surprising precision. Astronomers are not observing light that is being emitted directly by the distant planet. Rather, they are studying how the central star's light is being blocked and affected by the planet orbiting it.



The light curve shows the luminosity or brightness of the star over time. When the exoplanet passes over the star, known as a transit, part of the star's light is blocked by the exoplanet. As a result, the star's luminosity decreases. When a star spot is occulted on the star's surface, or when the exoplanet passes over the dark spot, astronomers can see a signal in the light curve in the form of a small bump in the bottom of the transit light curve. See the full animation of this infographic here. (Credit: B. Gougeon/Université de Montréal)

Exoplanet hunters must thus grapple with the challenge of disentangling signals caused by the presence of the planet and those caused by the star's own properties. Just like our Sun, stars do not have uniform surfaces. They can have dark star spots and bright regions, which can create signals that mimic a planet's atmospheric attributes. A recent study of the exoplanet TRAPPIST-1 b and its star TRAPPIST-1 led by UdeM Ph.D. student Olivia Lim witnessed an eruption, or flare, on the surface of the star, which affected their observations.

In the case of planet HAT-P-18 b, Webb caught the exoplanet right as it was passing over a dark spot on its star, HAT-P-18. This is called a *spot-crossing event*, and its effect was evident in the data collected for the study. The team also reported the presence of numerous other star spots on HAT-P-18's surface which were not blocked out by the exoplanet. To accurately determine the exoplanet's atmospheric composition, the researchers determined it was necessary to simultaneously model the planetary atmosphere as well as the star's peculiarities. They state that such consideration will be crucial in treating future exoplanet observations from the JWST to fully harness their potential.

"The lesson we have learned from observing Hat-P18-b is 'know-thy-star-know-thy-planet'.", states Dr. Jason Rowe, a co-investigator of the study. "We learn the characteristics of exoplanets by observing their shadow as they transit their host star. If the star is changing its appearance, those changes will be reflected in observed properties of the exoplanet transit. A better understanding of stellar astrophysics with unprecedented observations from JWST allowed the team to distinguish between the effects of star spots and exoplanet atmosphere abundances. "

H_2O, CO_2, and clouds in a scorching atmosphere

Following their careful modelling of both the exoplanet and the star in the HAT-P-18 system, the team of astronomers then performed a meticulous dissection of HAT-P-18 b's atmospheric composition. By inspecting the light that filters through the exoplanet's atmosphere as it transits its host star, the researchers discerned the presence of water vapour (H_2O) and carbon dioxide (CO_2). The researchers also detected the possible presence of sodium. Adding intrigue to the findings, the team observed strong signs of a cloud deck in HAT-P-18 b's atmosphere, which appears to be muting the signals of many of the molecules found within it. They also concluded that the star's surface was covered by many dark spots that can significantly influence the interpretation of the data.

While molecules like water, carbon dioxide, and methane can be interpreted as biosignatures, or signs of life, in certain ratios or in combination with other molecules, HAT-P-18 b's scorching temperatures of close to 600 degrees Celsius do not bode well for the planet's habitability.

The data used from the JWST in this study were collected by the Canadian-made NIRISS (Near-Infrared Imager and Slitless Spectrograph) instrument, which has provided astronomers with the unparalleled ability to differentiate many of HAT-P-18 b's atmospheric characteristics from one another. The results show that observations taken on the far-visible to near-infrared within the NIRISS instrument's wavelength range are essential to disentangle the signals from the planetary atmosphere and the star. Future observations from another JWST instrument, the Near Infrared Spectrograph (NIRSpec), would help refine the team's results, such as the CO_2 detection, and shed even more light on the intricacies of this hot Saturn exoplanet.

About this study

The paper "Near-Infrared Transmission Spectroscopy of HAT-P-18 b with NIRISS: Disentangling Planetary and Stellar Features in the Era of JWST" was published in *Monthly Notices of the Royal Astronomical Society* on December 9, 2023. The lead authors are Marylou Fournier Tondreau, previously an M.Sc. student at the Trottier Institute for Research on Exoplanets at the Université de Montréal (UdeM) and now a Ph.D. student at the University of Oxford, Ryan J. MacDonald, Fellow at the University of Michigan, and Michael Radica, Ph.D. student at UdeM. Other iREx researchers that contributed to this paper are David Lafrenière (UdeM), Caroline Piaulet (UdeM), Louis-Philippe Coulombe (UdeM), Romain Allart (UdeM), Kim Morel (UdeM), Étienne Artigau (UdeM), Loïc Albert (UdeM), Olivia Lim (UdeM), René Doyon (UdeM), Björn Benneke (UdeM), Jason Rowe (Bishop's U), Antoine Darveau-Bernier (UdeM), Nicolas Cowan (McGill), Neil Cook (UdeM), Frédéric Genest (UdeM), Stefan Pelletier (UdeM), Lisa Dang (UdeM), and Jake Taylor (UdeM and the University of Oxford). Additional contributors are based out of the Arizona State University, Cornell University, the University of Victoria, and the National Research Council of Canada's Herzberg Astronomy and Astrophysics Research Centre.

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