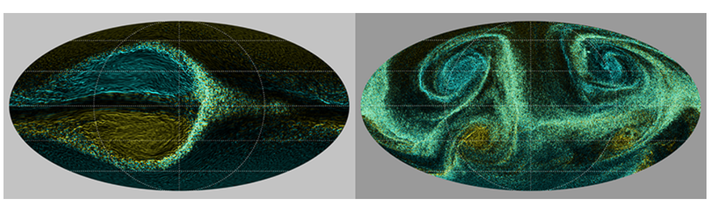
# “Deep Heating” of a Jupiter-Like Planet Causes New Storm to Blow

**Supercomputer simulations of the weather on a hot Jupiter reveal a previously unseen storm pattern in which cyclones are repeatedly generated and destroyed.**

By **Katherine Wright**

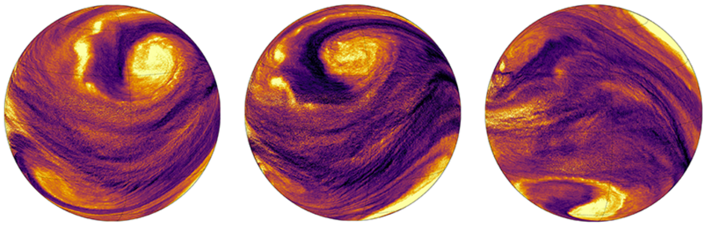
The exoplanet WASP-96b came to fame in 2022 when its atmospheric spectrum was included in the first public data release from the JWST observatory. Initial analyses of this spectrum confirmed earlier measurements made by other instruments that suggested that the planet’s atmosphere contains water. Those initial analyses also threw up some surprises, with evidence emerging that the planet might host clouds (scientists had expected none) and that heat from its parent star is absorbed by WASP-96b’s atmosphere at a greater depth than expected. Now Jack Skinner of the California Institute of Technology and his colleagues predict that this deep heating could lead to large cyclonic storm patterns developing on WASP-96b and other similar exoplanets [**1**]. These patterns are potentially detectable both in high-resolution JWST images and with planned future space telescopes such as Ariel, the Atmospheric Remote-sensing Infrared Exoplanet Large-survey telescope, which is expected to launch in 2029.



In hot-Jupiter atmospheres heated from the top, two planet-spanning vortices developed at the same height but at different latitudes (left). When the heating instead happened deeper in the atmosphere, four vortices formed (right).
**Credit: J. W. Skinner *et al.* [1]**

WASP-96b orbits a sun-like star some 1150 light years from Earth. With a mass that lies between that of Jupiter and Saturn, an orbit that takes less than three and a half Earth days, and permanent light and dark sides (WASP-96b is tidally locked to its star), this so-called hot Jupiter is unlike any planet in our Solar System. That makes it of particular interest to scientists looking to uncover the full scope of planetary possibilities. “Hot Jupiters are extreme laboratories that allow us to test laws of physics in physical conditions that cannot be created on Earth or elsewhere in the Solar System,” says Quentin Changeat, who studies exoplanet atmospheres at the Space Telescope Science Institute in Maryland. He was not involved in the new study.

The unexpected possibility of deep atmospheric heating in WASP-96b adds an additional element of intrigue. It is well known that the way a planet is warmed determines the large-scale dynamics of its atmosphere. But, Skinner says, past studies of hot Jupiters considered only a very narrow range of possibilities for the heating depth. The models used in these studies were largely based on observations of the hot Jupiter HD209458b, which has similar specs to WASP-96b. “With more accurate observations of planets, we are beginning to see that planets that we thought would have atmospheres with the same characteristics could actually have ones that are very different,” he says. “That tells us that we should be studying them on a planet-by-planet basis.”



Simulations of vortices on a deep-heated Jupiter. The simulations show the patterns on three consecutive days.
**Credit: J. W. Skinner/Caltech**

With that goal, Skinner and his colleagues performed high-resolution atmospheric simulations of tidally locked hot Jupiters with “shallow” and “deep” heating profiles similar to those thought to apply to HD209458b and WASP-96b, respectively. Aside from their different heating profiles, the simulated planets were otherwise the same. In the shallow-heating simulations, most of the heat from the star was absorbed at the top of the planet’s atmosphere at a pressure level of 1000 pascals (Pa). In the deep-heating ones, most of the heat was instead absorbed at a pressure level of 100,000 Pa. For reference, Skinner notes that the planets in their simulations had atmospheric pressures that ranged from 1,000,000 Pa at the bottom of the atmosphere to 1000 at the top. The simulations were run for up to thousands of the planets’ days.

Analyzing the atmospheric heat flows predicted by the simulations, the researchers observed very different storms raging on shallow-heated vs deep-heated planets. In atmospheres heated from the top, two planet-spanning vortices developed at the same height but at different latitudes. Together these vortices moved westward around the planet, completing one full circuit of the planet every 11–15 days. The centers of these storms captured hot air on the dayside and cold air on the nightside. “The storms were very stable and translated around the planet together,” Skinner says.

No such stability existed in the vortices gusting on deep-heated planets. On these hot Jupiters, Skinner and colleagues observed much more erratic behavior. The two coupled vortices seen on shallow-heated planets were replaced by four uncoupled ones on deep-heated planets. Each vortex lasted between 3 and 15 days before disappearing, with a new one then developing to take its place. Smaller-scale vortices also developed, with turbulence appearing at many length scales. “The behavior is completely new,” Skinner says. “We hadn’t seen it in any previous model.”

“These simulations show that different weather patterns occur depending on how the stellar radiation and internal energy are deposited in the atmosphere of a hot Jupiter,” Changeat says. “This is a very profound result, as this potentially allows us to understand the interplays between those extremely complex mechanisms by simply observing the global weather patterns of those planets.”

While no tool yet exists for making those observations directly for distant hot Jupiters, the simulations show that each storm type should have a unique brightness “fingerprint,” Skinner says. These fingerprints could be extracted from future observations by JWST and, once it launches, by Ariel. That ability, Changeat says, could allow scientists to conduct weather monitoring through repeat observations of a planet, and thereby learn more about the fundamental mechanisms generating storms on these tempestuous gas giants. Skinner agrees. “Our results show that if we observe two hot Jupiters with similar physical parameters but very different fluctuating light signals, those differences are real and expected,” Skinner says. “No two planets are the same.”

Katherine Wright is the Deputy Editor of ***Physics Magazine***.

## REFERENCES

1. J. W. Skinner, “Repeated cyclogenesis on hot-exoplanet atmospheres with deep heating,” **Phys. Rev. Lett. 131, 231201 (2023).**