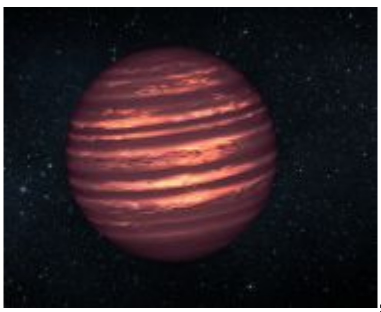
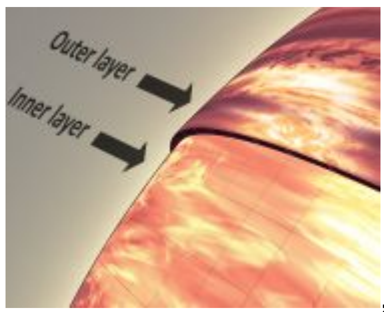
UANews

Published on *UANews* (http://uanews.org)

By Daniel Stolte/UANews and Whitney Clavin/JPL, | January 8, 2013

Pointing the Spitzer and Hubble space telescopes simultaneously at a brown dwarf, a UA-led team of astronomers has obtained detailed images of the stormy atmosphere that enshrouds these strange objects, which are not quite planets and not quite stars. Their forecast shows planet-sized clouds and showers of sandy and iron rain.

,

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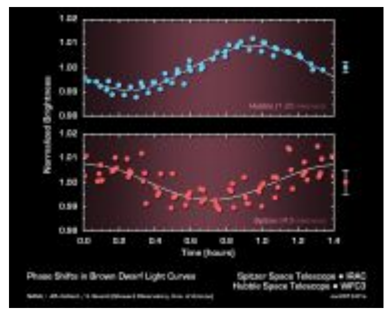

A University of Arizona-led team of astronomers for the first time has used NASA's **Spitzer** and **Hubble** space telescopes simultaneously to peer into the stormy atmosphere of a brown dwarf, creating the most detailed "weather map" yet for this class of strange, not-quite-star-and-not-quite-planet objects. The forecast shows wind-driven, planet-sized clouds enshrouding these strange worlds.

Brown dwarfs form out of condensing gas like stars but fail to accrue enough mass to ignite the nuclear fusion process necessary to turn them into a star. Instead, they pass their lives as dimly glowing, constantly cooling gas balls similar to gas planets with their complex, varied atmospheres. The new research is a stepping stone toward better understanding not only brown dwarfs but also the atmospheres of planets beyond our solar system.

"With Hubble and Spitzer, we were able to look at the layers of a brown dwarf, similar to the way doctors use medical imaging techniques to study the different tissues in your body," said **Daniel Apai**, the principal investigator of the research from the UA, who presented the results at the American Astronomical Society meeting in Long Beach, Calif. Apai is an assistant professor with joint appointments in the UA's departments of **astronomy** and **planetary sciences**.

A study describing the results, led by **Esther Buenzli**, a postdoctoral researcher in the UA's department of astronomy, is **published in the Astrophysical Journal Letters**.

The researchers turned Hubble and Spitzer simultaneously toward a brown dwarf called 2MASSJ22282889-431026. They found that its light varied in time, brightening and dimming as the body rotated around every 1.4 hours. But more surprising, the team also found that the timing of this brightening changed depending on whether they looked at it with Spitzer or Hubble using different wavelengths of infrared light (Hubble sees shorter-wavelength infrared light than Spitzer).

These variations are the result of different layers, or patches, of material swirling around the brown dwarf in windy storms as large as Earth itself. Spitzer and Hubble see different atmosphere layers because certain infrared wavelengths are blocked by vapors of water and methane high up, while other infrared wavelengths emerge from much deeper.

"What we see here is evidence for massive, organized cloud systems, perhaps akin to giant versions of the Great Red Spot on Jupiter or large-scale storm systems on Earth," said **Adam Showman**, a theorist with the UA's Lunar and Planetary Laboratory who was involved in the research.

"We were expecting the phases of the light variations to be in sync between the two telescopes, so we were really surprised that they were offset," said Buenzli. "This is the first time that we can probe variability at several different altitudes at the same time in the atmosphere of a brown dwarf."

"The deeper layers appear to lag behind the higher layers," Apai explained. "This tells us that the same or similar cloud distribution is present in the different layers, but the deeper you look, the later you will see the same clouds turning into view."

"We were very surprised to see such a big lag. Our best guess is this has to do with the brown dwarf's atmospheric circulation. The bigger picture here is that we see a very large-scale atmospheric structure in this brown dwarf."

"These out-of-sync light variations provide a fingerprint of how the brown dwarf's weather systems stack up vertically," added Showman. "The data suggest that regions on the brown dwarf where the weather is moist and cloudy deep in the atmosphere coincide with balmier, drier conditions at higher altitudes – and vice versa."

Ranging in size between Jupiter and the smallest stars and commonly weighing in at 30-40 Jupiter masses, brown dwarfs are cool relative to other stars but quite hot by our Earthly standards. This particular object is about 600 to 700 degrees Celsius (1,100 to 1,300 degrees Fahrenheit). Being quite warm, they emit strongly in the infrared, wavelengths picked up by Spitzer and Hubble.

At the cooler, outer layers of the star, gas condenses into smoke-sized particles, including sand and iron, which fall down into the interior as a sandy and iron rain. Just like on Earth, the iron and sand "raindrops" heat up as they enter the deeper warmer layer and eventually evaporate, triggering a rain cycle.

Apai said the atmospheric dynamics on brown dwarfs are very different from those here on Earth.

“On our planet, we have only one species of cloud - water,” he explained, “But on this brown dwarf, there is such a wide temperature range that we have many different species of clouds.”

In three ongoing Spitzer programs, Apai and his co-investigators have successfully explored the properties of cloud covers in about 50 brown dwarfs.

“As different wavelengths probe different pressures and different rotational phases probe different latitudes we will be able to explore the two or even three-dimensional structure of the atmospheres,” Apai said.

Buenzli said that theorists are excited to model the new data: a new era of weather reporting has begun.

“Eventually, we want to probe the atmospheres of exoplanets in a similar fashion,” she said.

“Currently, we can't get this type of data on exoplanets because their bright host stars blind our vision,” Apai said. “Brown dwarfs are the perfect laboratories for studying the exotic science of worlds beyond our own.”

The findings are the first published from a set of Spitzer and Hubble space telescope programs led by Apai. By mapping cloud systems in brown dwarfs, these studies are opening a new field, extrasolar atmospheric dynamics, which bridges astronomy and planetary science.

Apai is the principal investigator of the project Extrasolar Storms, which uses the Spitzer and Hubble space telescope together to follow the evolution of gigantic storms in the atmospheres of brown dwarfs over 1.5 years. Storms is one of the largest projects ever approved for the Spitzer Space Telescope, equaling two months of continuous observations with this $1 billion telescope. Launched in 2003, Spitzer has long exceeded its nominal lifetime. A group led by **UA Regents’ Professor George Rieke** developed one of Spitzer’s infrared detectors, the **Multiband Imaging Photometer**.

The Storms team includes 12 experts from the U.S., Canada and the UK, four of which are at the UA: In addition to Apai, Buenzli and Showman, Davin Flateau, another graduate student of Apai’s is part of the team.

“Brown dwarfs are fascinating and diverse,” said Apai. “Now we've got a new technique to chase their gigantic and violent storms.”
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