Planet-like object may have spent its youth as hot as a star

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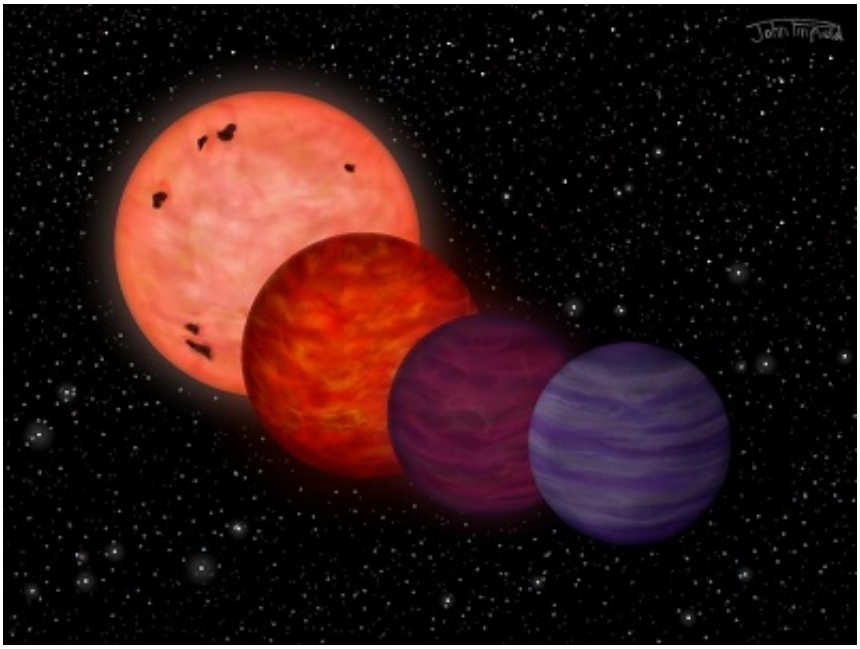

This is a four-stage sequence (left to right) showing the possible extreme temperature evolution for WISE J0304-2705. For about 20 million years, the object was as hot as a star, shining with a temperature of at least 5,100 degrees Fahrenheit (2800 degrees Celsius). After about 100 million years it had cooled to about 2,700 degrees Fahrenheit (1500 degrees Celsius), and by a billion years its temperature was about 1,800 degrees Fahrenheit (1000 degrees Celsius). The final stage is billions of years later, when WISE J0304-2705 has cooled to its current planetary temperature of 100-150 C. Artwork for this image is credited to John Pinfield. Credit: John Pinfield

Astronomers have discovered an extremely cool object that could have a particularly diverse history—although it is now as cool as a planet, it may have spent much of its youth as hot as a star.

The current temperature of the object is 200 to 300 degrees Fahrenheit (100 to 150 degrees Celsius), which is intermediate between that of the Earth and of Venus. However, the object shows evidence of a possible ancient origin, implying that a large change in temperature has taken place. In the past this object would have been as hot as a star for many millions of years.

Called WISE J0304-2705, the object is a member of the recently established "Y dwarf" class—the coolest stellar temperature class yet defined, following the other classes O, B, A, F, G, K, M, L, and T. Although the temperature is similar to that of the planets, the object is dissimilar to the rocky Earth-like planets, and instead is a giant ball of gas like Jupiter.

The international discovery team, led by David Pinfield from the University of Hertfordshire and including Carnegie's Yuri Beletsky, identified the Y dwarf using the WISE observatory—a NASA space telescope that has imaged the entire sky in the mid-infrared. The team also measured the spectrum of light emitted by the Y dwarf, which allowed them to determine its current temperature and better understand its history. Their work is published by *Monthly Notices of the Royal Astronomical Society*.

Only 20 other Y dwarfs have been discovered to-date, and amongst these WISE J0304-2705 is defined as "peculiar" due to unusual features in its emitted light spectrum.

"Our measurements suggest that this Y dwarf may have a composition and/or age characteristic of one of the Galaxy's older members," Pinfield

explained. "This would mean its temperature evolution could have been rather extreme."

The reason that WISE J0304-2705 undergoes such extensive evolutionary cooling is because it is "sub-stellar," meaning its interior never gets hot enough for hydrogen fusion, the process that has kept our Sun hot for billions of years, and without an energy source maintaining a stable temperature, cooling and fading is inevitable.

If WISE J0304-2705 is an ancient object, then its temperature evolution would have followed through an understood series of stages (as depicted in the illustration): During its first approximately 20 million years it would have a temperature of at least 5,100 degrees Fahrenheit (2800 degrees Celsius), the same as red dwarf stars like Proxima Centauri (the nearest star to the Sun). After 100 million years it would have cooled to about 2,700 degrees Fahrenheit (1,500 degrees Celsius), with silicate clouds condensing out in its atmosphere. At a billion years of age it would have cooled to about 1,800 degrees Fahrenheit (1,000 degrees Celsius), so cool that methane gas and water vapor would dominate its appearance. And since then it would have continued to cool to its current temperature, barely enough to boil water for a cup of tea.

WISE J0304-2705 is as massive as 20-30 Jupiters combined, which is intermediate between the more massive stars and typical planets. But in terms of temperature it may have actually "taken the journey" from star-like to planet-like conditions.

Having identified WISE 0304-2705, Pinfield's team made crucial ground-based observations with some of the world's largest telescopes—the 8-meter Gemini South Telescope, the 6.5-meter Magellan Telescope and the European Southern Observatory's 3.6-meter New Technology Telescope, all located in the Chilean Andes.

Team member Mariusz Gromadzki said: "The ground based measurements were very challenging, even with the largest telescopes. It was exciting when the results showed just how cool this object was, and that it was unusual".

"The discovery of WISE J0304-2705, with its peculiar light spectrum, poses ongoing challenges for the most powerful modern telescopes that are being used for its detailed study" remarked Maria Teresa Ruiz, team member from the Universidad de Chile.

WISE J0304-2705 is located in the Fornax (Furnace) constellation, belying its cool temperature.

There is currently no lower limit for Y dwarf temperatures, and there could be many even cooler and more diverse objects un-detected in the solar neighborhood. WISE went into hibernation in February 2011 after carrying out its main survey mission. However, by popular demand it was revived in December 2013, and is continuing to observe as part of a three-year mission extension.

"WISE gives us wonderful sensitivity to the coolest objects" said Pinfield, "and with three more years of observations we will be able to search the sky for more Y dwarfs, and more diverse Y dwarfs."

More information: The results are published in the paper D. J. Pinfield, M. Gromadzki, S. K. Leggett, J. Gomes, N. Lodieu, R. Kurtev, A. C. Day-Jones, M. T. Ruiz, N. J. Cook, C. V. Morley, M. S. Marley, F. Marocco, R. L. Smart, H. R. A. Jones, P. W. Lucas, Y. Beletsky, V. D. Ivanov, B. Burningham, J. S. Jenkins, C.Cardoso, J. Frith, J. R. A. Clarke, M. C. Gálvez-Ortiz and Z. Zhang, "Discovery of a new Y dwarf: WISE J030449.03-270508.3", *Monthly Notices of the Royal Astronomical Society*, in press, published by Oxford University Press. A pre-publication version of the paper is available on the arXiv:

arxiv.org/abs/1408.0284

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