A planetary system from the early Universe

A group of European astronomers has discovered an ancient planetary system that is likely to be a survivor from one of the earliest cosmic eras, 13 billion years ago. The system consists of the star HIP 11952 and two planets, which have orbital periods of 290 and 7 days, respectively. Whereas planets usually form within clouds that include heavier chemical elements, the star HIP 11952 contains very little other than hydrogen and helium. The system promises to shed light on planet formation in the early universe – under conditions quite different from those of later planetary systems, such as our own.

It is widely accepted that planets are formed in disks of gas and dust that swirl around young stars. But look into the details, and many open questions remain – including the question of what it actually takes to make a planet. With a sample of, by now, more than 750 confirmed planets orbiting stars other than the Sun, astronomers have some idea of the diversity among planetary systems. But also, certain trends have emerged: Statistically, a star that contains more "metals" - in astronomical parlance, the term includes all chemical elements other than hydrogen and helium – is more likely to have planets.

This suggests a key question: Originally, the universe contained almost no chemical elements other than hydrogen and helium. Almost all heavier elements have been produced, over time inside stars, and then flung into space as massive stars end their lives in giant explosions (supernovae). So what about planet formation under conditions like those of the very early universe, say: 13 billion years ago? If metal-rich stars are more likely to form planets, are there, conversely, stars with a metal content so low that they cannot form planets at all? And if the answer is yes, then when, throughout cosmic history, should we expect the very first planets to form?

Now a group of astronomers, including researchers from the Max-Planck-Institute for Astronomy in Heidelberg, Germany, has discovered a planetary system that could help provide answers to those questions. As part of a survey targeting especially metal-poor stars, they identified two giant planets around a star known by its catalogue number as HIP 11952, a star in the constellation Cetus ("the whale" or "the sea monster") at a distance of about 375 light-years from Earth. By themselves, these planets, HIP 11952b and HIP 11952c, are not unusual. What is unusual is the fact that they orbit such an extremely metal-poor and, in particular, such a very old star!

For classical models of planet formation, which favor metal-rich stars when it comes to forming planets, planets around such a star should be extremely rare. Veronica Roccatagliata (University Observatory Munich), the principal investigator of the planet survey around metal-poor stars that led to the discovery, explains: "In 2010 we found the first example of such a metal-poor system, HIP 13044. Back then, we thought it might be a unique case; now, it seems as if there might be more planets around metal-poor stars than expected."

HIP 13044 became famous as the "exoplanet from another galaxy" – the star is very likely part of a so-called stellar stream, the remnant of another galaxy swallowed by our own billions of years ago.

Compared to other exoplanetary systems, HIP 11952 is not only one that is extremely metal-poor, but, at an estimated age of 12.8 billion years, also one of the oldest systems known so far. "This is an archaeological find in our own backyard," adds Johny Setiawan of the Max

Planck Institute for Astronomy, who led the study of HIP 11952: "These planets probably formed when our Galaxy itself was still a baby."

"We would like to discover and study more planetary systems of this kind. That would allow us to refine our theories of planet formation. The discovery of the planets of HIP 11952 shows that planets have been forming throughout the life of our Universe", adds Anna Pasquali from the Center for Astronomy at Heidelberg University (ZAH), a co-author of the paper.

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Image caption
Artist's impression of HIP 11952 and its two Jupiter-like planets.
Image credit: Timotheos Samartzidis

Background information
The work described here is being published as Setiawan et al., "Planetary companions around the metal-poor star HIP 11952", in a forthcoming issue of the journal *Astronomy & Astrophysics*. The co-authors are Johny Setiawan (Max Planck Institute for Astronomy), Veronica Roccatagliata (University Observatory Munich, Space Telescope Science Institute and Max Planck Institute for Astronomy), Davide Fedele (Johns Hopkins University), Thomas Henning (Max Planck Institute for Astronomy), Anna Pasquali (Center for Astronomy, Heidelberg University), M. Victoria Rodríguez-Ledesma (Georg August University Göttingen), Elisabetta Caffau (Center for Astronomy, Heidelberg University), Ulf Seemann (Georg August University Göttingen and European Southern Observatory) and Rainer J. Klement (Department of Radiation Oncology, University of Würzburg, and Max Planck Institute for Astronomy).

A PDF of the article can be found here: http://www.aanda.org/articles/aa/pdf/forth/aa17826-11.pdf

Information about current theories of planetary formation and what they have to say about the role of metallicity can be found in C. Mordasini et al., "Extrasolar planet population synthesis IV. Correlations with disk metallicity, mass and lifetime", http://adsabs.harvard.edu/abs/2012arXiv1201.1036M

The earlier find, HIP 13044, was the subject of this MPIA press release:
http://www.mpia.de/Public/menu_q2.php?Aktuelles/PR/2010/PR101118/PR_101118_en.html

Questions and answers

How were the two planets detected?
HIP 11952 b and HIP 11952 c were found using the radial-velocity technique, a common method for detecting exoplanets that has been in use for more than two decades. A star and its planets move around a common center of mass - and the motion of the star, a tiny wobble back and forth, towards the observer and away again, caused by the presence of unseen low-mass companions, can be measured by observing how certain features in the star's light (spectral lines) shift over time.

Which telescopes and instruments were used?
The star HIP 11952 was monitored from 2009 until 2011 with the spectrograph FEROS (Fibre-fed Extended Range Optical Spectrograph), mounted on the 2.2 meter Max-Planck-Gesellschaft/European Southern Observatory (MPG/ESO)- telescope, located at ESO's La Silla observatory in Chile.

Why is the star called "HIP 11952"? And what about its planets' names?
HIP 11952 is the star's catalogue number (11952) in the catalog of stars observed by the Hipparcos astrometry satellite (hence the HIP). A star's planets are named, in order of discovery, by appending lower-case letters to the star's name, alphabetically, starting with the letter b.

What are the properties of HIP 11952?
The parent star has what astronomers call very low stellar metallicity – its atmosphere contains very few chemical elements heavier than hydrogen or helium. A common indicator for metallicity is the presence of iron. HIP 11952 has an iron abundance of only about 1% that of the Sun. HIP 11952 is said to belong to "(stellar) population II", a class of stars that includes the oldest and metal-poorest stars that have been observed.

Old and metal-poor stars such as HIP 11952 are very rare in the solar neighborhood, which is relatively metal-rich and mostly contains stars younger than 10 billion years. This makes it interesting to speculate about the birthplace of HIP 11952: It is possible that, like its predecessor HIP 13044, HIP 11952 is part of a stellar stream – the remnant of another galaxy that was swallowed by our own Milky Way galaxy billions of years ago.

How was the age of HIP 11952 determined?
Astronomers have fairly solid models of how stars evolve over time; during their evolution (which, in turn, depends on the star's initial metal content), properties such as the star's intrinsic brightness and its surface temperature change systematically over time. This, in turn, allows astronomers to give age estimates for stars for which those properties can be determined with reasonable accuracy. By this measure, HIP 11952 is about 12.8 billion years old.

The precise evolutionary status of the star is, however, unclear: At that age, the star could still be in the so-called main-sequence phase, where stars spend most of their lives, their radiation sustained by the fusion of hydrogen in their cores. The Sun, for instance, is a main sequence star; HIP 11952 could be either that or an "evolved star" that has left the main sequence.