Finding Planets in Archived Hubble Data

Taken from: *Hubble 2011: Science Year in Review*


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Finding Planets in Archived *Hubble* Data

Four giant planets are known to orbit the massive star HR 8799, located approximately 130 light-years from Earth and found in the constellation Pegasus, the Flying Horse. In 2007 and 2008, the first three planets were discovered by a team of astronomers using near-infrared, ground-based images taken with the W. M. Keck Observatory and the Gemini North Telescope, both in Hawaii. Then, in 2010, Christian Marois of the National Research Council in Canada led the team that uncovered the star’s fourth and innermost planet. All four of the planets orbit at distances comparable to the outermost planets of our own solar system and are estimated to be between seven to ten times as massive as Jupiter. This places them near the upper mass limit for planets (13 Jupiter masses); any larger and they would be classified as brown dwarf stars. To date, this is the only system where astronomers have obtained direct images of multiple exoplanets.

In 2009, David Lafrenière of the University of Montreal recovered an image of HR 8799’s outermost planet using *Hubble* data collected much earlier—in 1998—with the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). The NICMOS images were taken using a coronagraph, a masking device within the camera that blocks most of the star’s light. Lafrenière was the first to demonstrate the power of a new data-processing technique for retrieving faint planetary signatures from the glow of their central stars. Even with a coronagraph, however, this glow can quickly overwhelm the weak light reflected from orbiting planets.

Now, a painstaking reanalysis of the same archival NICMOS data performed by Rémi Soummer of the Space Telescope Science Institute in Baltimore has found visual evidence for all three of the outer planets. (The fourth, innermost planet cannot be seen because the NICMOS coronograph obscures it.) By finding these planets in older *Hubble* data, the team has demonstrated an invaluable tool for determining orbital motion that uses retrospective data to compare a planet’s previous position with those seen in more recent observations. It also demonstrates a novel approach for discovering additional planets in archived *Hubble* data.
Astronomers determine the orbits of planets by tracking their positions over time. This knowledge is critical to understanding the behavior of multiple-planet systems because massive planets can perturb one another’s orbits. Therefore, once an orbital shape is discerned, it sheds light on the overall stability of the system, the planetary masses involved, and the inclination of the system to our line of sight.

Usually, scientists have to wait years before observing significant differences in slow-moving planetary positions. Finding the planets of the HR 8799 system in archived Hubble data, however, effectively added an immediate ten-year gap between successive observations which otherwise would have required an additional decade to acquire.

Using the Hubble data, Soummer’s team determined that the three outer gas-giant planets complete their orbits, from outermost to innermost, in approximately 460, 190, and 100 Earth years (respectively). They found that the slowest-moving, outermost planet barely changed its position in 10 years; the next inner planet, only slightly more. The second planet from the star uniquely displayed a significant amount of motion.

**Software Advances Increase Planetary Detections**

When the Hubble observations were first taken in 1998, HR 8799’s planets were not discernible. The data analysis software used at the time subtracted the light from the central star, but noise from the remaining scattered light in
the image still masked the glow from the dim planets.

To improve this type of analysis, Lafrenière developed a software technique that employed a library of reference stars to remove the glowing “fingerprint” of the central star and its associated scattered light more precisely. Soummer’s team then built on Lafrenière’s method and used 466 images of reference stars taken from a library containing more than 10 years of NICMOS observations assembled by Glenn Schneider of the University of Arizona.

The Soummer team’s methodology further minimized residual starlight and increased the contrast in the images. They completely removed the crosshair-like diffraction spikes, common artifacts in telescope imaging systems. This allowed them to see the two faint inner planets of HR 8799 in the Hubble data—1/100,000th as bright as their parent star when viewed in near-infrared light.

Soummer and his team plan to analyze approximately 400 additional stars in the NICMOS archive with this image processing technique, which will effectively improve image quality by a factor of 10 over methods available when the data was originally collected. Stars with evidence of circumstellar dust are often associated with planet formation. The team intends to select stars from six Hubble surveys of young, nearby stars as prime targets for imaging exoplanets. Based on their analysis of NICMOS archival data, Soummer’s team aims to assemble a list of planetary candidates for confirmation.
The star HR 8799 is located just inside the western edge of the "Square of Pegasus." With a visual magnitude of 6, it is at the visibility limit of the naked eye from a dark location. (Photo credits: [left] Digitized Sky Survey, Space Telescope Science Institute, and Palomar Observatory/California Institute of Technology; [below] A. Fujii)
by ground-based telescopes. If new planets are seen from the ground, the team will determine the orbital motions, if any, which occurred in the intervening years.

This work demonstrates the utility of the Hubble data archive, which contains images and spectral information gathered from more than 20 years of observations. Astronomers accessing this historical library to augment their recent observations gain a much larger discovery potential than with just new observations alone.

Further Reading


Dr. Rémi Soummer is an assistant astronomer at the Space Telescope Science Institute, a position he has held since 2008. His research mainly focuses on direct imaging of exoplanets and the development of related instrumentation. Originally from the south of France, he obtained the Agrégation de Physique in 1997. After teaching physics for a few years, he completed a doctorate in astronomy and instrumentation at the University of Nice in 2002. He then moved to the United States and worked first as a NASA Michelson Fellow at the Institute, then as a Kalbfleisch fellow at the American Museum of Natural History. Dr. Soummer designed and built the coronagraph for the Gemini Planet Imager (to be commissioned in 2012) and is part of the science team for this instrument. He currently leads a research group that applies advanced image processing tools to coronagraphic images from the Hubble archive and develops new instrumentation concepts applicable in future missions that study exoplanets.