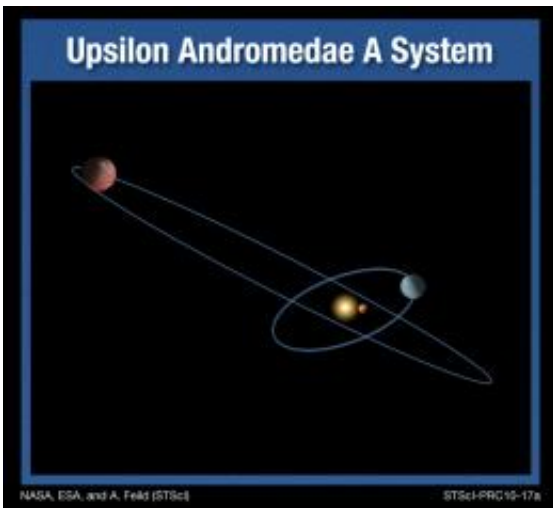


# Out of Whack Planetary System Offers Clues to a Disturbed Past

May 24 2010

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This is an artist's illustration of the Upsilon Andromedae A planetary system, where three Jupiter-type planets orbit the yellow-white star Upsilon Andromedae A. Astronomers have recently discovered that not all planets orbit this star in the same plane, as the major planets in our solar system orbit the Sun. The orbits of two of the planets are inclined by 30 degrees with respect to each other. Such a strange orientation has never before been seen in any other planetary system. This surprising finding will impact theories of how planetary systems form and evolve, say researchers. It suggests that some violent events can happen to disrupt planets' orbits after a planetary system forms. The discovery was made by joint observations with the Hubble Space Telescope, the Hobby-Eberly Telescope, and other ground-based telescopes. Credit: NASA, ESA, and A. Feild (STScI)

(PhysOrg.com) -- Astronomers are reporting today the discovery of a

planetary system way out of tilt, where the orbits of two planets are at a steep angle to each other. This surprising finding will impact theories of how multi-planet systems evolve, and it shows that some violent events can happen to disrupt planets' orbits after a planetary system forms, say researchers.

"The findings mean that future studies of exoplanetary systems will be more complicated. Astronomers can no longer assume all planets orbit their [parent star](#) in a single plane," says Barbara McArthur of The University of Texas at Austin's McDonald Observatory.

McArthur and her team used data from the [Hubble Space Telescope](#), the giant Hobby-Eberly Telescope, and other ground-based telescopes combined with extensive modeling to unearth a landslide of information about the planetary system surrounding the nearby star Upsilon Andromedae.

McArthur reported these findings in a press conference today at the 216th meeting of the American Astronomical Society in Miami, along with her collaborator Fritz Benedict, also of McDonald Observatory, and team member Rory Barnes of the University of Washington. The work also will be published in the June 1 edition of the [Astrophysical Journal](#).

For just over a decade, astronomers have known that three Jupiter-type planets orbit the yellow-white star Upsilon Andromedae. Similar to our Sun in its properties, Upsilon Andromedae lies about 44 light-years away. It's a little younger, more massive, and brighter than the Sun.

Combining fundamentally different, yet complementary, types of data from Hubble and ground-based telescopes, McArthur's team has determined the exact masses of two of the three known planets, Upsilon Andromedae c and d. Much more startling, though, is their finding that not all planets orbit this star in the same plane. The orbits of planets c

and d are inclined by 30 degrees with respect to each other. This research marks the first time that the "mutual inclination" of two planets orbiting another star has been measured. And, the team has uncovered hints that a fourth planet, e, orbits the star much farther out.

"Most probably Upsilon Andromedae had the same formation process as our own solar system, although there could have been differences in the late formation that seeded this divergent evolution," McArthur said.

"The premise of planetary evolution so far has been that planetary systems form in the disk and remain relatively co-planar, like our own system, but now we have measured a significant angle between these planets that indicates this isn't always the case."

Until now the conventional wisdom has been that a big cloud of gas collapses down to form a star, and planets are a natural byproduct of leftover material that forms a disk. In our solar system, there's a fossil of that creation event because all of the eight major planets orbit in nearly the same plane. The outermost dwarf planets like Pluto are in inclined orbits, but these have been modified by Neptune's gravity and are not embedded deep inside the Sun's gravitational field.

Several different gravitational scenarios could be responsible for the surprisingly inclined orbits in Upsilon Andromedae, "Possibilities include interactions occurring from the inward migration of planets, the ejection of other planets from the system through planet-planet scattering, or disruption from the parent star's binary companion star, Upsilon Andromedae B," McArthur said.

Barnes, an expert in the dynamics of extrasolar planetary systems, added, "Our dynamical analysis shows that the inclined orbits probably resulted from the ejection of an original member of the planetary system. However, we don't know if the distant stellar companion forced that ejection, or if the [planetary system](#) itself formed in such a way that some

original planets were ejected. Furthermore, we find that the revised configuration still lies right on the precipice of instability: The planets pull on each other so strongly that they are almost able to throw each other out of the system."

The two different types of data combined in this research were astrometry from the Hubble Space Telescope and radial velocity from ground-based telescopes.

Astrometry is the measurement of the positions and motions of celestial bodies. McArthur's group used one of the Fine Guidance Sensors (FGSs) on the Hubble telescope for the task. The FGSs are so precise that they can measure the width of a quarter in Denver from the vantage point of Miami. It was this precision that was used to trace the star's motion on the sky caused by its surrounding — and unseen — planets.

Radial velocity makes measurements of the star's motion on the sky toward and away from Earth. These measurements were made over a period of 14 years using ground-based telescopes, including two at McDonald Observatory and others at Lick, Haute-Provence, and Whipple Observatories. The radial velocity provides a long baseline of foundation observations, which enabled the shorter duration, but more precise and complete, Hubble observations to better define the orbital motions.

The fact that the team determined the orbital inclinations of planets c and d allowed them to calculate the exact masses of the two planets. The new information told us that our view as to which planet is heavier has to be changed. Previous minimum masses for the planets given by radial velocity studies put the minimum mass for planet c at 2 Jupiters and for planet d at 4 Jupiters. The new, exact masses, found by astrometry are 14 Jupiters for planet c and 10 Jupiters for planet d.

"The Hubble data show that radial velocity isn't the whole story," Benedict said. "The fact that the planets actually flipped in mass was really cute."

The 14 years of radial velocity information compiled by the team uncovered hints that a fourth, long-period planet may orbit beyond the three now known. There are only hints about that planet because it's so far out that the signal it creates does not yet reveal the curvature of an orbit. Another missing piece of the puzzle is the inclination of the innermost planet, b, which would require precision astrometry 1,000 times greater than Hubble's, a goal attainable by a space mission optimized for interferometry.

The team's Hubble data also confirmed Upsilon Andromedae's status as a binary star. The companion star is a red dwarf less massive and much dimmer than the Sun.

"We don't have any idea what its orbit is," Benedict said. "It could be very eccentric. Maybe it comes in very close every once in a while. It may take 10,000 years." Such a close pass by the secondary star could gravitationally perturb the orbits of the planets.

Provided by ESA/Hubble Information Centre

Citation: Out of Whack Planetary System Offers Clues to a Disturbed Past (2010, May 24) retrieved 25 April 2024 from

<https://phys.org/news/2010-05-whack-planetary-clues-disturbed.html>

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