LUNAR AND PLANETARY LABORATORY

Galaxy may be teeming with small planets

By Renu Malhotra

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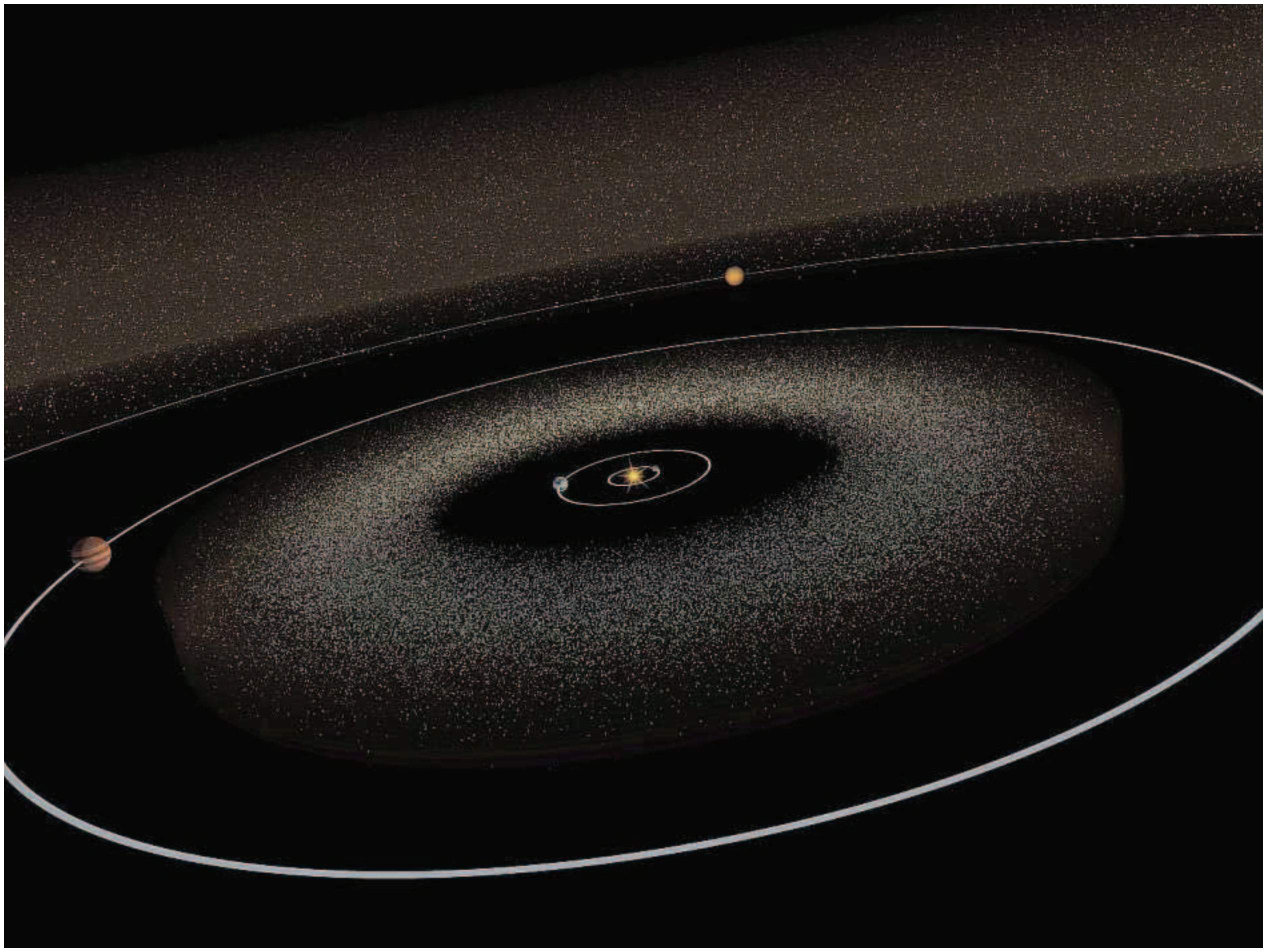
In the past two decades, astronomers have discovered nearly 2,000 planets orbiting sun-like stars in the solar neighborhood of the Milky Way galaxy, and humanity is now a little bit closer to answering the question of the ages: Are we alone in the universe?

But we still have some way to go.

The present techniques for discovery of extra-solar planets limit us to discovering relatively large planets that are orbiting relatively closely to their stars.

Moreover, discovery alone does not yield a planet's mass, the most fundamental property that allows scientists to use the laws of physics to broadly establish the nature of a planet, such as whether it is rocky or gaseous, whether it is likely to be internally differentiated and whether it can support an atmosphere and geological processes, possibly even biological ones as we know them on Earth.



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This artistic illustration shows the planetary system of a half-solar mass star in the Scorpius constellation. Two planets, analogous to Jupiter and Saturn, have been discovered; the Earth and Venus analogs and the two asteroid belts are hypothesized.

To learn the mass of an extra-solar planet, astronomers must follow up with complementary high-precision techniques, patiently collecting data over long periods of time.

One of the highest yields of extra-solar planet data has come from NASA's Kepler space observatory. Launched in 2009, Kepler continuously monitored about 100,000 nearby stars for almost five years to look for periodic dimming of starlight by orbiting planets that might happen to pass in our line of sight to the star.

A large team of astronomers has analyzed the huge amount of Kepler data to discover more than 1,000 planets, including more than 500 systems of two or more planets orbiting the same star.

What we know best about these planets is their orbital periods. What we would really like to know next is their masses, so we can assess the abundance of planets that have masses similar to Earth's.

Mathematics that link the orbital movements of planets to their masses can help us "see" beyond what our telescopes have seen thus far.

In the mid-19th century, this theoretical approach was used to predict the existence and mass of a distant planet in our own solar system, namely Neptune, from observations of the orbital motion of the planet Uranus, and it has also been used to establish the masses of several extra-solar planets.

Recently I extended this idea to calculate the statistics of planetary masses using the orbital period data of the discovered extra-solar planets.

The basic concept is that neighboring planets perturb each other by their gravity. The closer and more massive planets make larger perturbations. Consequently, to maintain stable orbital motion for long times, more massive planets tend to have larger orbital spacings than less massive planets.

This tendency can be expressed mathematically as an approximate statistical relationship between planet masses and orbital spacings in multi-planet systems.

The orbital period data from Kepler allow us to calculate orbital spacings in more than 500 planetary systems by using the laws of planetary motion that were first discovered by the 17th-century German astronomer-mathematician Johannes Kepler, the namesake of the Kepler space telescope. By treating these orbital spacings as a statistical distribution and using the approximate statistical relationship between orbital spacings and planet masses, we can arrive at the statistical distribution of planet masses.

When we extrapolate the resulting distribution to lower masses, we find that Earth-mass planets may be about 1,000 times as common as Jupiter-mass planets, and that Mars-to-lunar mass planets may be five to 10 times more common still.

It appears that the galaxy may be teeming with small planets. This is a small but significant step in our goal to assess the abundance of Earth-like planets among the diverse planetary systems in our galaxy.

ABOUT THE SCIENTIST

Renu Malhotra is a University of Arizona professor and director of the Theoretical Astrophysics Program. Her research investigates the orbital mechanics of planets, moons, asteroids, comets and interplanetary dust in our solar system as well as other planetary systems. She is a Galileo Circle Fellow of the UA College of Science and a member of the National Academy of Sciences and of the American Academy of Arts and Sciences.