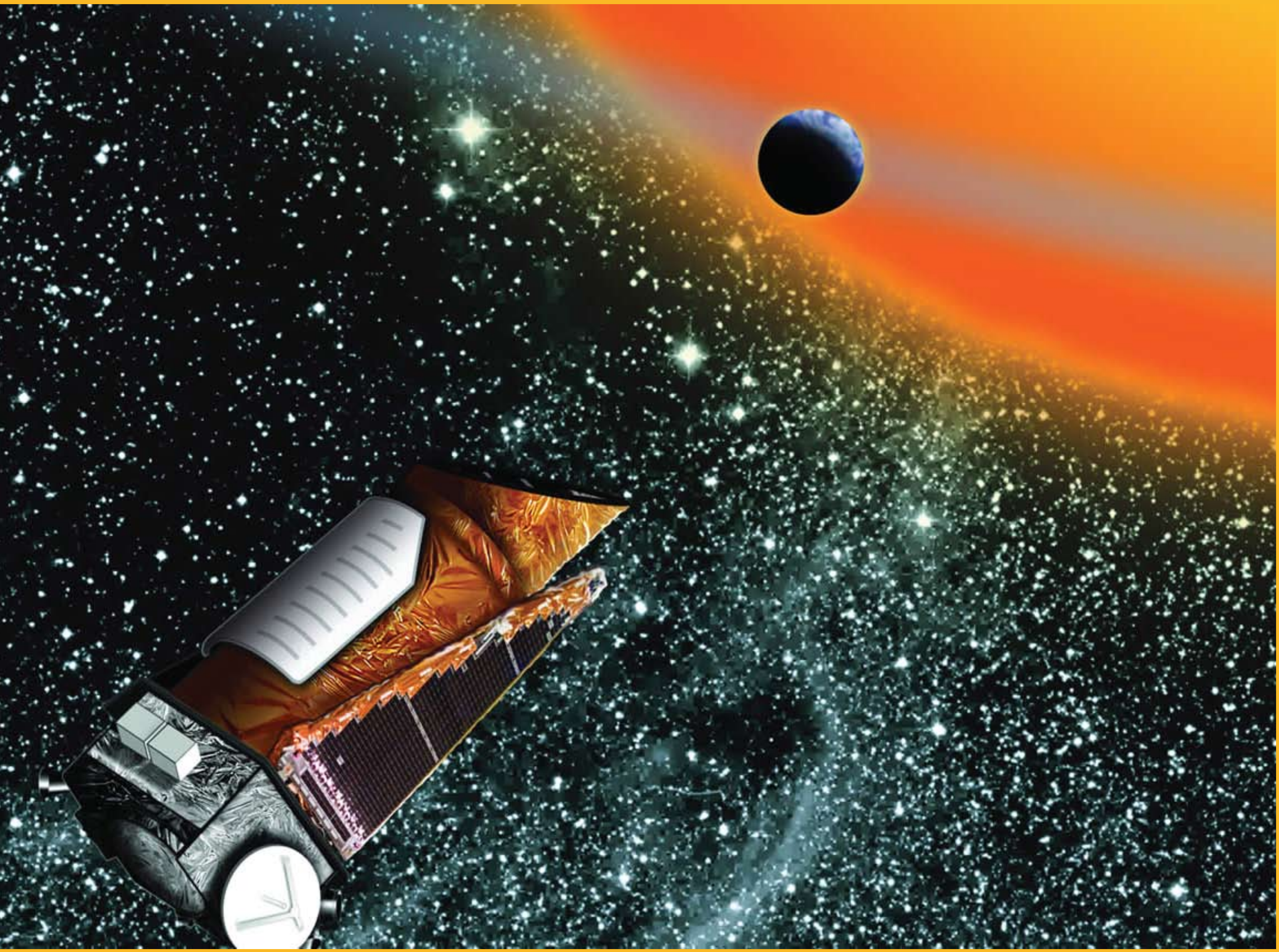
Share the Hunt for Other Earths



The Drake Equation:

$N = R^* f_p n_e f_l f_i f_c L$

where,

N = The number of communicative civilizations R^* = Th

Planetarium educators have a golden opportunity to inform, excite, and allow audiences to participate in great adventure that is the NASA Kepler Mission. This article discusses the basics of the mission and announces the availability of planetarium show materials from the NASA Kepler Mission Education and Public Outreach (EPO) team. You also are provided with a Kepler Mission poster with this issue of the *Planetarian*.

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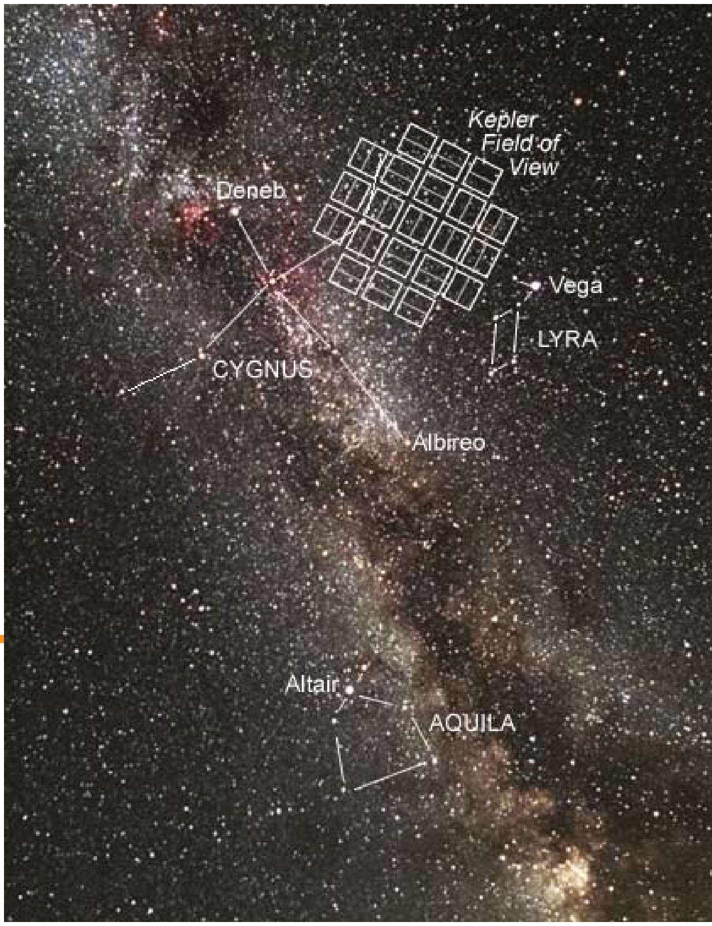


The size of the Kepler field of view. Milky Way photo by Carter Roberts.

Primary Mission Goal

How many humans have gazed at the heavens and wondered "Is Earth unique in the universe? Are there other worlds as brimming with life as Earth is? Are there other thinking beings out there?"

Many of us are familiar with Frank Drake's strategy for making an estimate of how many intelligent civilizations there may be in our galaxy, but real data does not exist for most of the factors in his equation. There is significant data for only the first two factors: rate of suitable star formation in the galaxy and number of stars with planets (giant planets only).

Now, with the discovery of more than 300 planets around other stars, we have just begun to get a sense of how many planets are out there—at least the giant ones. But for the next factor, how abundant other Earth-like planets are, the sum total of real data we have is 0.

NASA's Kepler Mission (kepler.nasa.gov and www.nasa.gov/kepler) seeks real data for determining the value of that factor. Is primary goal is to discover Earth-size planets in the habitable zone of stars. With Kepler's launch in March 2009, we will be on a path that will lead to us knowing—for the first time in human history—if there are planets capable of supporting life beyond our solar system.

We can safely say that the two key characteristics for a habitable planet are:

- It must have surface temperature allowing for liquid water, between 0° and 100° C. Just try reproducing on a world of ice continents or steaming hot desert!
- It must be large enough to have gravity sufficient to hang onto a life-sustaining atmosphere and not so large that its gravity hangs onto the lightest gases to become a gas giant. That would be between about 0.5 to about 10 Earth masses.

Detecting Transits

The most ubiquitous planet-finding technique up to now has been the Doppler shift (also known as spectroscopic) technique: detecting repetitive tiny red-blue spectral shifts caused by to-and-fro movement of the star being gravitationally dragged back and forth by a large orbiting planet. This technique can provide data to determine the orbital period of a planet.

Then, using Kepler's Third Law, we can determine orbital radius—a key factor in determining surface temperature, the first factor we mentioned for planet habitability.

However, for the second factor, the Doppler technique can only give a lower limit to the mass of the planet, and so is less helpful in determining planet size.

Thankfully, in the transit method of planet finding, minuscule drops in star brightness caused by planets moving in front of the star characterize not only orbital period and radius, but planet size as well. That's because the measured drop in brightness is directly proportional to the ratio of the area of the planet to the star.

For an Earth-size planet, the change in

e rate of formation of suitable stars (stars such as our Sun)

The "retina" of the Kepler photometer: a 42 CCD array with 95 million pixels. Images courtesy Ball Aerospace & Technologies Corp.

brightness is very small, about 1 part in 10,000, and lasts for about half a day or less. For a planet that is in the habitable zone of a star similar to our Sun, a transit would occur about once each Earth year, depending on its orbit.

The Kepler Mission team has built a super photometer—a highly sensitive light meter—consisting of a 0.95-m Schmidt telescope and a 95 megapixel detector with 42 CCDs. Its sensitivity is exquisite, more than adequate to detect a 0.01% brightness drop of an Earth-size transit of a magnitude 12 G2V (solar-like) star, and even smaller planets orbiting smaller stars.

The field of view is phenomenal by any standards: 105 degrees squared (about 15° diameter, equivalent to the size of your hand held out at arm's length). The mission plan is to keep the instrument pointed continuously at the same area of sky, in the Cygnus-Lyra area, for 3.5 years. More than 100,000 stars mostly similar to our Sun will be monitored that whole time; the spacecraft can't "blink" or waver lest we miss a vital transit event.

Once the photometry data collected over the 3.5-year observing run is in, the Kepler Mission will have detected Earth-size and smaller planets in the habitable zone of other stars. That is, unless they do not exist—which would be an even more important discovery indeed!

Additional Mission Goals

Along with the primary goal of discovering Earth-size planets around other stars, the Kepler Mission will return a treasure trove of photometry data, not only to explore the structure and diversity of planetary systems, but also the nature of the stars themselves. About planet systems, investigations will yield:

- the percentage of terrestrial and larger planets in or near the habitable zone of a wide variety of stars;
- the distribution of sizes and shapes of the orbits of these planets;
- how many planets are in multiple-star systems;
- the variety of orbit sizes, planet reflectivities, sizes, masses, and densities of short-period giant planets.

About the stars, we can find:

- the properties of those stars that harbor planetary systems;
- characteristics of surface features of stars, especially star spots;

- behavior of stellar oscillations caused by pressure waves bouncing around inside a star, which can be used for studying their inner structure. This is known as asteroseismology and works much in the same way that earthquakes are used to study the inner structure of Earth.

Kepler Poster

The Kepler Mission poster included with this issue of the *Planetarian* has an attractive and thought-stimulating illustration on the front that can be a visual basis for conversations about Kepler, and a back that includes overview information, reference material, and instructions for three classroom activities, all of which are also available at the Kepler Mission website: kepler.nasa.gov/ed/activities.html, along with other activities and educational material. The poster activities include:

Detecting Planet Transits, derived from the GEMS Space Science Sequence for grades 6–8, which lets students create models of planetary transits (a planet moving in front of a star) by standing in a circle with model star (light bulb) in the center, and observing a marble planet orbiting the star through rolled-up paper viewing tubes.

Human Orrery for grades 6-8 from the GEMS Space Science Sequence, which has students lay out and act out a kinesthetic model of the solar system in 3 dimensions: 2 of space and one of time.

Transit Tracks for grades 6–8, but easily adapted for high school, has students interpreting graphs of brightness vs. time to deduce characteristics of a star-planet system.

This is becoming part of a newly-revised edition of the Planetary Science course of the Lawrence Hall of Science (University of California, Berkeley, California) Full Option Science System. The entire poster can be downloaded from kepler.nasa.gov/ed/pdf, which also contains fact sheets and bookmarks.

On the Kepler website you can also find Kepler Star Wheels—one of "Uncle Al's Starwheels" series of inexpensive planispheres that are adjustable for any time of night in any month of the year, but having interchangeable star wheel disks for different functions, such as finding basic constellations or locating objects with a coordinates wheel. It also can be used to find the location of the Kepler target field of view as well as naked eye stars known to have exoplanets visible from the northern hemisphere.

These star wheels are based on the LHS Sky Challenger star wheels, which have even more star wheels. (Available at the LHS store; go to lawrencehallofscience.stores.yahoo.net and search for star wheel.)

Planetarium Show Materials

A wealth of images and animations that can serve as elements of planetarium shows about planet-finding (and Kepler Mission in particular) are available on the Kepler website, kepler.nasa.gov, in the multimedia section.

The Kepler EPO team at LHS and SETI Institute has been in collaboration with NASA Astrobiology Institute (NAI) and the Pacific Science Center (PSC) to produce an audience-participation planetarium show about planet-finding. The show is called *Strange Planets* and is designed as a 50-minute program about finding extrasolar planets, focusing especially on the transit method and the Kepler Mission.

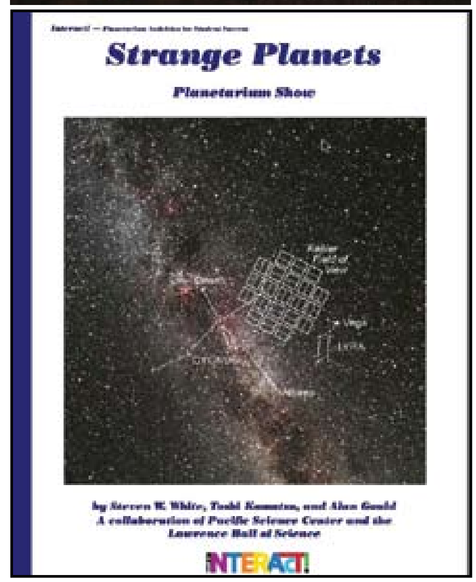
PSC originally designed the show for a sixth-grade audience, but the current version tested at LHS this past summer is for public audiences, ages 8-adult.

The primary goal of the show is for the audience to understand the difficulties of finding extrasolar planets and to understand how those difficulties are overcome by modern astronomy techniques. The audience considers interstellar distances and becomes aware of the two challenges of finding extrasolar planets: extrasolar planets are very far away and they are very dim compared to the stars they orbit. The show illustrates two ways that planet-finding can be done: through the spectroscopic and the transit methods.

Here is a simple plan for the show:

Introduction (5 minutes): Pose the context-setting questions: Are we alone? Do you think there might be other life out there? Audience learns hundreds of planets outside our solar system have been discovered.

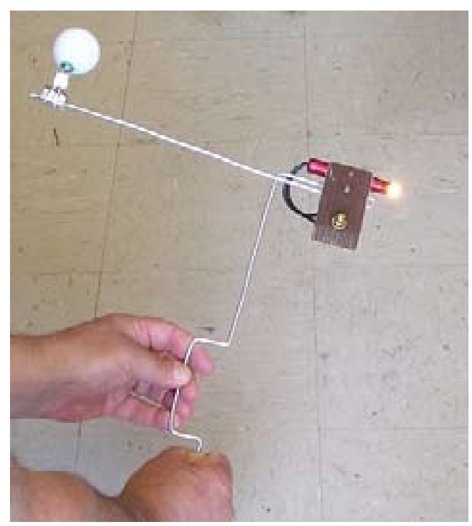
Spectroscopic Method (10 minutes): Audience appreciates the core difficulties in finding extrasolar planets: they are too faint to see in glare of the stars. They see a demonstration to model how gravity of an extrasolar planet causes a star to wobble, which in turn causes shifting spectral lines (the Doppler shift). Upon closer examination, they realize that how much a star wobbles depends on the


Strange Planets

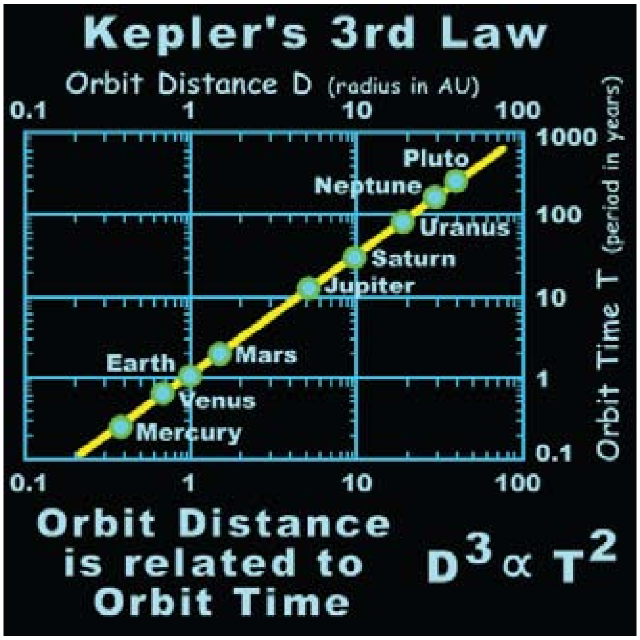
Planetarium Show

A collaboration of Pacific Science Center and the Lawrence Hall of Science

INTERACT!



Top: The Kepler Star Wheel. Center: The cover of the *Strange Planets* show script. Bottom: Prototype version of a model to demonstrate star wobble using a Maglite® model star and white ball giant planet. Images provided by authors.



The audience will understand the idea of Kepler's Third Law better by graphical representation rather than by simple mathematical formula alone. Graphic provided by the authors.

mass of extrasolar planet(s) going around it and how fast a star wobbles is an indicator of how close it is to its star and hence how high its temperature is.

Since larger planets make their star wobble more they are easier to detect, so it is more likely to discover uninhabitable Jupiter-type planets. Planets closer to their parent stars orbit than more quickly, so these were the first to be detected. These are so close to their stars that they are referred to as "Hot Jupiters."

Stars with Planets (5 minutes): Show two very easy-to-find stars with planets: Pollux (in Gemini) and Alrai (in Cepheus). Audience considers what it might be like to live on a "strange" planet, e.g. one with a binary star, or an orange star.

Kepler's Laws and Habitable Zones (5 minutes): Audience learns that a habitable planet is one that has temperature and conditions for liquid water; that planet orbits are oval or elliptical in shape (Kepler's First Law); and that how quickly a planet orbits its star depends on how close it is to its star, in accord with Kepler's Second and Third Laws.

Transiting Planets (10 minutes): Demonstrate how a light meter shows brightness changes and observe how finding extrasolar planets can be done by observing transits where a planet periodically blocks starlight, even though the planet is not visible. The audience sees the size of a planet is directly related to that amount of starlight it blocks and sees how often starlight is blocked is related to how close a planet is to its star, thereby inferring the planet temperature and habitability.

Finding an Earth-like Exoplanet (10 minutes): Analyze a light curve to make conclusions about an extrasolar planet's size and distance from its star (and hence, temperature).

Kepler Star Field/Conclusion (5 minutes): Conclude with more specifics about the NASA Kepler Mission, including where in the sky its target regions of study is.

As of this publication of the *Planetarian, Strange Planets* is in final stages of field-testing at several planetariums. The final version, revised based on field-test feedback, will be available to several dozen planetariums on a first come, first served basis.

The supplied show kit will include a script book, all still images and movies needed (in electronic format), and the following physical props needed for demonstrations:

1. Rainbow projector (diffraction grating mounted on a light source).

2. Star-planet models, one to demonstrate wobbling motion of a star and one orrery star-planet model with one to three planets (geared, hand-cranked).

3. Light sensor with computer interface and graphing software (Mac or PC). User must supply needed laptop, and video projector for projecting real-time light curves on the dome.

How to Get a Show Kit

If you are interested in receiving one of the *Strange Planets* show kits, visit the Planetarium Activities for Student Success (PASS) website at lhs.berkeley.edu/pass and look for the *Strange Planets* show kit sign-up page. The kits are expected to be distributed in summer of 2009 so that the show can be an exciting part of your International Year of Astronomy offerings in autumn of 2009: a nice conclusion to IYA. ☆

Johannes Kepler and the International Year of Astronomy

The United Nations declared 2009 the International Year of Astronomy (IYA) to commemorate the 400th anniversary of Galileo's use of a telescope to study the skies (astronomy2009.us and www.astronomy2009.org).

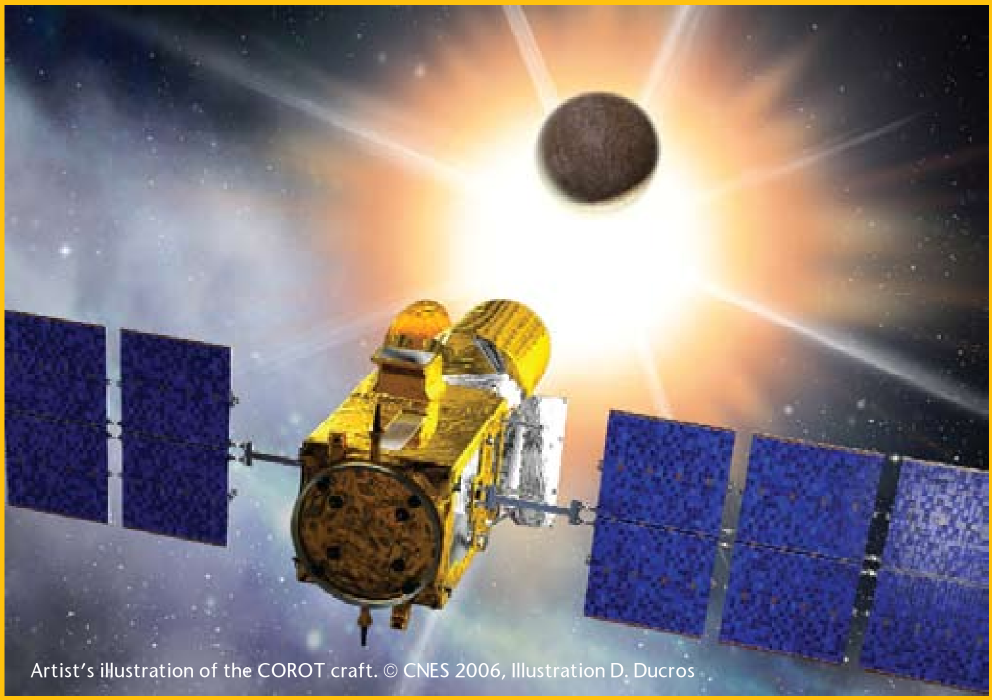
The Kepler Mission was named in honor of another great astronomer, Johannes Kepler (1564-1642), and as part of IYA is also celebrating Kepler's publication of *Astronomia Nova* in 1609, which explained the motion of Mars and published the Kepler's first two laws of planetary motion.

Carl Sagan described Kepler as "the first astrophysicist and the last scientific astrologer." He was the Imperial Mathematician for the Holy Roman Emperor, cast horoscopes for the Emperor, was a prolific scientist, and a religious man.

Above all, he sought to use mathematics to understand the universe. He first correctly explained planetary motion and thereby became the founder of celestial mechanics. He wrote the first "natural laws" in the modern sense of "laws" being universal, verifiable, and precise. Published 400 years ago, his three laws of planetary motion set us onto a course toward modern science.

Visit kepler.nasa.gov/johannes/ to see an annotated list of Kepler biographies. ☆

COROT's "Two Eyes" Find Smallest Exoplanet Yet



Artist's illustration of the COROT craft. © CNES 2006, Illustration D. Ducros

The Kepler Mission joins at least one other orbiting observatory in humanity's search for other worlds.

COROT—COnvection, ROtation and planetary Transits—was launched in December, 2006. This CNES (Centre National d'Etudes Spatiales) mission, in association with Centre National de la Recherche Scientifiques and several international partners, is using stellar seismology to look at the inner structure of stars and its CCD camera to sense the transits of extrasolar planets.

On February 3, 2009, the mission announced the discovery of the smallest exoplanet yet. Less and twice the size of Earth and orbiting a sun-like star, the planet is located very close to its parent star and has a high temperature, between 1000 and 1500°C. It may be covered in lava or water vapor.

The density of the planet is still under investigation: it may be rocky like Earth and covered in liquid lava. It may also belong to a class of planets that are thought to be made up of water and rock in almost equal amounts.

The existence of this kind of "ocean planet" has been theorized, but never proved so far. In theory, such planets would initially be covered partially in ice and they would later drift towards their star, with the ice melting to cover it in liquid.

"This discovery is a very important step on the road to understanding the formation and evolution of our planet," said Malcolm Fridlund, ESA's COROT Project Scientist. "For the first time, we have unambiguously detected a planet that is 'rocky' in the same sense as our own Earth. We now have to understand this object further to put it into context, and continue our search for smaller, more Earth-like objects with COROT," he added. This discovery benefited from complementary observations made thanks to an extensive European telescope network operated by various institutes and countries. The European Southern Observatory at Paranal and La Silla (Chile), the 80-cm telescope at the Canary Islands Astrophysics Institute, and the Canada-France-Hawaii Telescope on Mauna Kea, Hawaii (CNRS, CNRC, and University of Hawaii).

COROT has two "eyes" in its search for planets. The craft is oriented along the equitorial plane and twice a year, when the sun gets close to the orbit plane and is about to blind the telescope, the spacecraft performs a reversal attitude maneuver, dividing the year into two 6-month periods of observation (by convention, summer and winter). In the summer it is pointed toward the center of the Milky Way; in winter, towards the edge.

Fore more information, go to smsc.cnes.fr/COROT. ☆

COROT's two viewing locations. © CNES