BEYOND OUR SOLAR SYSTEM:

the new search for extrasolar planets

–By Madeline Ross

“Over two hundred extrasolar planets have been discovered since 1991, with more than 150 of these found in the last six years.”

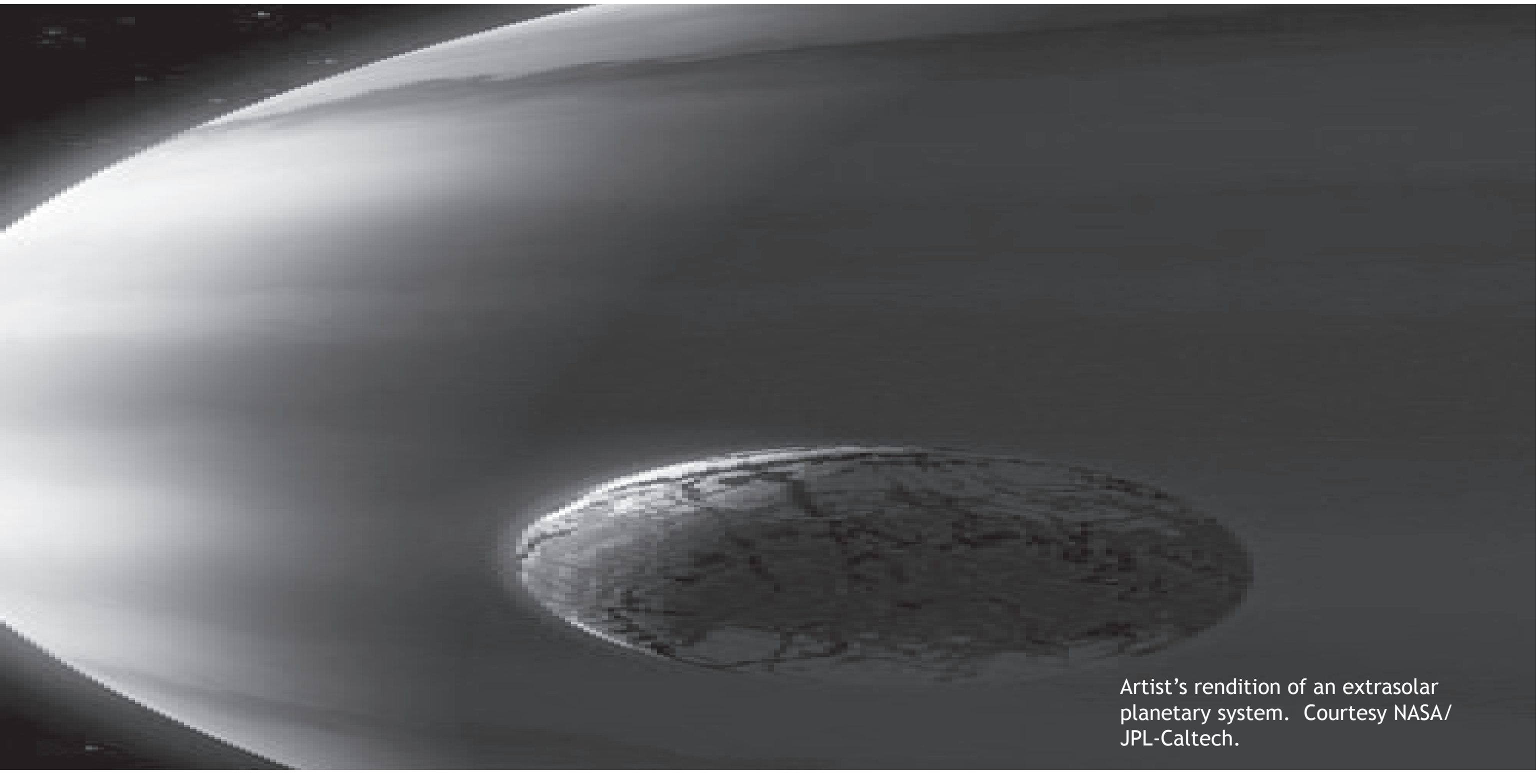
FROM PEGASI TO HOT JUPITERS – THE DISCOVERY OF EXTRASOLAR PLANETS

Twenty years ago, planets outside our solar system were the stuff of science fiction. Now, the existence of extrasolar planets is accepted as fact. We are at the beginning of what has been called the age of extrasolar planet discovery: over 200 extrasolar planets have been discovered since 1991, with more than 150 of these found in the last six years (1). If the trend continues, as technological improvements suggest it will, discoveries over the next twenty years could number in the thousands. As scientists learn more about the composition and nature of extrasolar planets, existing theories of planetary evolution are being turned on their heads. It’s becoming clear that planets outside our solar system are more diverse and more common then we ever knew.

THE BEGINNINGS OF EXOPLANET EXPLORATION

The idea of distant planets like our own has been popular since the 16th century when Giordano Bruno claimed there was not one Earth, but “a thousand” (he was later burned to death by the Catholic Church for this conjecture) (2). However, the modern extrasolar age did not begin until 1991 with a Polish astronomer named Alexander Wolszczan. His discovery of changes in the flow of radio energy from a star in the Virgo constellation revealed the presence of a planetary system (3). Wolszczan’s discovery did not attract great attention since the three planets were deemed uninhabitable due to deadly radiation (2). However, in 1995 came the discovery of another extrasolar planet that garnered greater attention. Astronomer Michael Mayor found that the star 51 Pegasi exhibited a strange oscillation due to the orbiting of a neighboring planet with a mass half that of Jupiter and at least 150 times that of Earth. 51 Pegasi was the first of many extrasolar planets that would drastically alter scientists’ views on planet formation and thus begin the modern search for extrasolar planets.

TECHNOLOGY CATCHES UP TO THEORY AND THE EXTRASOLAR AGE



Artist's rendition of an extrasolar planetary system. Courtesy NASA/ JPL-Caltech.

BEGINS

If extrasolar planets have been the subject of speculation for so long, why didn't scientists find them earlier? For centuries, technology lagged behind theory, preventing scientists from confirming or disproving the existence of extrasolar planets. Even with recent leaps in technology, the discovery of an extrasolar planet requires the integrated use of several methods. Scientists often start with a direct imaging telescope, like NASA's Spitzer Space Telescope to identify areas of probable planetary formation (4). The Spitzer uses spectroscopy with infrared imaging to detect the wavelengths emitted by planets when they reflect the light from their parent stars. No telescope can "see" extrasolar planets because the parent star (the star around which the planet orbits) outshines them at visible wavelengths. By imaging with infrared wavelengths, Spitzer reduces the relative difference and is able to discern both the composition and shape of circumstellar disks (5).

In May 2006, The Spitzer Space Telescope detected a suspiciously strong infrared excess encircling the star HD 69830, suggesting the presence of an asteroid or comet debris that might be related to an extrasolar planet (4). To further explore this finding, scientists used the High Accuracy Radial Velocity Planet Search (HARPS) telescope to examine the area surrounding HD 69830 (4). The radial velocity method used by HARPS relies upon the Doppler Effect, which describes the changes in observed wave frequency of light or sound as an observer and wave source move relative to each other. For example, the pitch of a police siren increases as it approaches an observer and decreases as the siren moves away. The Doppler Effect functions similarly with light waves: the emitted light waves of a star approaching the observer shift toward higher frequencies and the waves of a receding star move toward lower frequencies (6). Scientists use the Doppler Effect to measure the speed of a star; a speed that rhythmically changes can indicate the presence of a planet.

From tiny oscillations in a star's spectrum shift, scientists can detect the presence of a planet. When a planet is rotating about a star, these oscillations cause the star to move in its own small orbit around the solar system's center of gravity. This appears to observers on Earth as a rhythmic change in the star's radial velocity, known as a "wobble" (figure 2). The HARPS spectrograph was

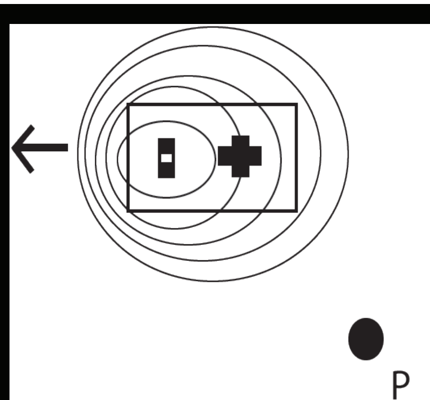


FIGURE 1: The Doppler Effect

When an ambulance passes Observer P, P perceives the sound waves of the ambulance to be higher in pitch as it approaches and lower in pitch as it retreats.

credit: Collier, R. and Young, J. *Annual Rev. of Cell and Dev. Bio.* 19 (2003): 45-70.

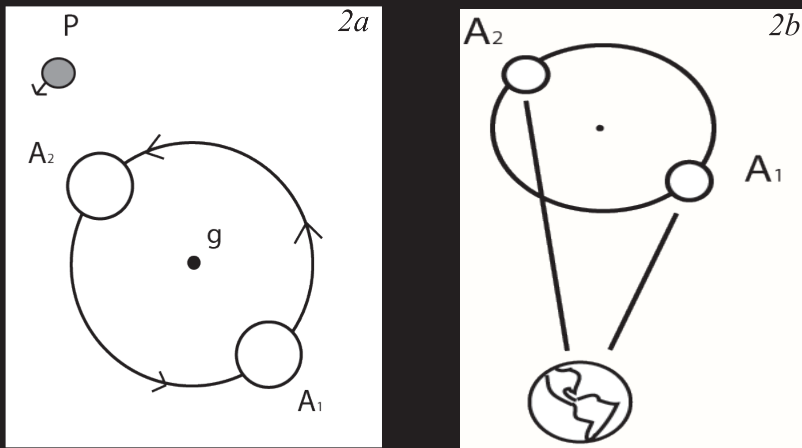


Figure 2a. Planet P exerts a gravitational pull on Star A which causes the star to to wobble around the gravitational center of the system.
Figure 2b. When observers on Earth measure the speed of the star with respect to Earth, they perceive a "wobble" caused by the change in speeds when A is in different positions (as in A_1 and A_2).

especially developed for the discovery of extrasolar planets with improved luminosity, spectral resolution, and thermo-mechanical stability (7). In the May 2006 discovery, radial velocities measured by HARPS confirmed the presence of the planetary system and determined the masses of the planets.

THE TRANSIT METHOD: MANY TELESCOPES AND ONE CURIOUSLY PUFFY PLANET

The most recent big discovery was found using neither the radial velocity method nor direct imaging, but with the "transit" method. The transit method searches for planets that are passing in front of their parent star, temporarily obscuring the parent star's brightness. Networks of robotic telescopes continuously photograph the night sky with an unceasing diligence that would be impossible with human-operated telescopes. Transiting planets produce a characteristic 'light-curve' whose shape enables scientists to ascertain the planets' density and composition (9). However, because it relies on a planet's ability to obscure a star's light, the transit method has difficulty detecting earth-like planets because of their small size. Instead, the transit method tends to detect "Hot Jupiters," the very large gaseous planets that revolve close to their parent stars (10). Most Hot Jupiters are around ten times the size of Earth with surface temperatures around 1,000 K (3).

In September 2006, HATNet, a network of telescopes located in Arizona and Hawaii, discovered a new "Super Hot Jupiter" (11). HAT-P-1b, dubbed by the popular media as the "puffy" planet (12, 13) has the lowest mean density of any known planet and forces scientists to reexamine their theories of planet development (11). Scientists previously assumed that the cores of Hot Jupiters contained sizable amounts of heavy elements, a fact that would support the core-accretion theory. Core accretion theory, currently one of the leading theories of planetary development, states that planets start out very small and gradually accumulate dust and debris from the disk they inhabit. Planets that evolve in this way would necessarily have a sizable metal core (14). However, the extreme low density of HAT-P-1b would be difficult to achieve with a sizable metal core. Such evidence countering the established core-accretion theory necessitates a rethinking of the way scientists understand the formation of planets.

FUTURE EXPLORATORY PROJECTS: THEIR ASTRONOMICAL GOALS (AND BUDGETS)

Hot Jupiters have dominated the last ten years of extrasolar planet discovery. The sheer size of these planets makes them easier to spot, but their gaseous compositions prevent them from supporting life. In the next twenty years, scientists hope to discover smaller, terrestrial planets. Both the European Space Association (ESA) and the North American Space Association (NASA) plan to launch new space telescopes capable of discovering inhabitable planets.

What makes these new projects so important? NASA's Terrestrial Planet Finder (TPF) and the ESA's similar DARWIN project will collect information not only about the gas giants, but also about Earth-size planets in inhabitable areas of planetary systems. NASA scientists predict that the TPF's telescopes will be able to determine the proportions of gases in earth-size planets and whether those planets could support life (15). This could open up new fields of knowledge, shedding further light on how Earth was formed. If signs of extraterrestrial life are found, it could have wide-reaching philosophical, as well as scientific, implications. With an optical telescope able to observe over 25 times more area than the Hubble Telescope (15), the Terrestrial Planet Finder represents the next big step in the search for life beyond our

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solar system.

However, this next step is becoming increasingly difficult to take. There is a large obstacle with extrasolar planetary detection technologies that must be surmounted: cost. In February 2006, the Terrestrial Planet Finder project was "indefinitely deferred" according to NASA's 2007 budget proposal (16). TPF is now back on schedule due to a June 2006 allotment of money from Congress (17), but NASA's financial situation remains precarious. However, the Bush Administration's proclamation that NASA and space exploration are a high priority (18) will not by itself eliminate the organization's budget crisis. Without funds, NASA and the ESA will have to cut programs and the age of extrasolar planet discovery may fizzle out before it has truly begun.

The arguments of those who oppose NASA's project are understandable. Extrasolar planet detection technologies are expensive and do not provide an instantly visible pay-off. Space exploration is not a branch of science, such as medicine or engineering, which tends to reveal its utility immediately. But to use such arguments as evidence of the futility of TPF and DARWIN is to miss the point of space exploration, and indeed of science. We do not explore the unknown solely for profit, but also to expand the breadth of human knowledge. It's undeniable that outer space and the possibilities it holds have a fascination for our culture; just consider the immense success of movies like Star Wars and E.T. Twenty years ago extrasolar planets were still science fiction; now they are fact. If we continue to invest in exploration beyond our solar system, who knows what else will become fact twenty years from now? H

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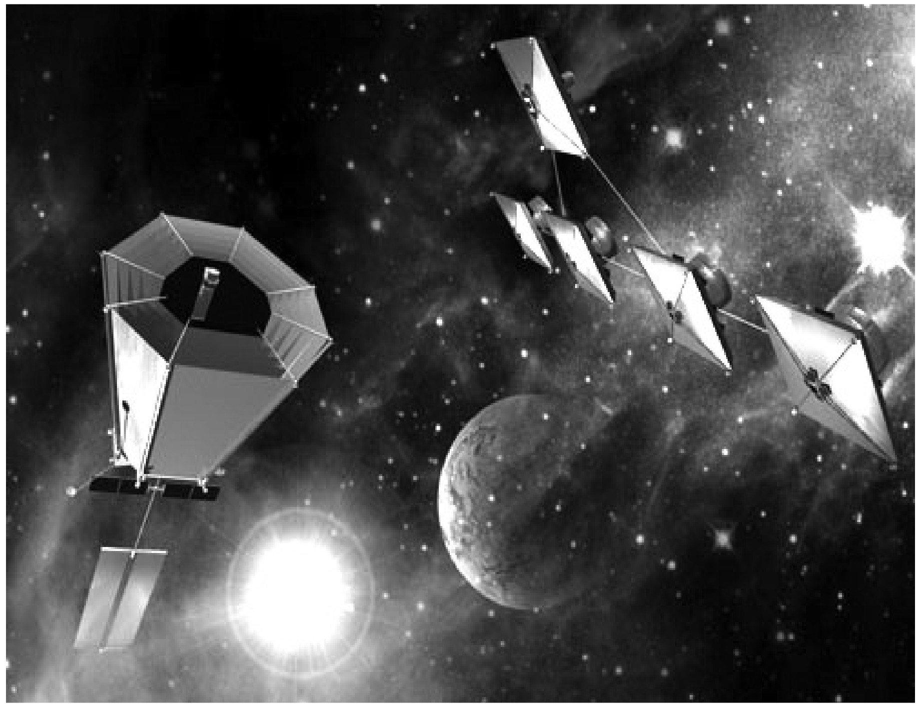

ABOVE: Artist's rendition of the future NASA Terrestrial Planet Finder's space observatories. High-sensitivity telescopes will be placed on multiple satellites to search for extrasolar planets. Courtesy NASA/JPL-Caltech.

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