Variable Star Of The Season

Fall 2004: The Transiting Exoplanets HD 209458 and TrES-1

Variable Stars
Variable Star of the Season
PDF Format
Archive of VSOTS stars
Powerpoint Intro
Stars Easy-To-Observe
Historical Light Curves
Naming
Harvard Designation
Types
Further Reading
Research: AAVSO in Print
Observing Manual

Main sections of web
The AAVSO
Variable Stars
Observing
Access Data
Publications
Online Store
Education: HOA

Pick a star

Create a light curve
Recent Observations
Find charts GO

Out of this World

For centuries, curious minds have pondered about the possibilities of other worlds. Why would our perfectly ordinary stellar neighbor, the Sun, be so unique as to be the only star with a planetary system orbiting about it? It now seems to be the stuff that science fiction movies are made of: scientists in search of foreign solar systems. Probing the heavens for extrasolar planets, or planets orbiting Sun-like stars, however, is not fiction or fantasy, but is rather a growing and exciting new field in astronomy.

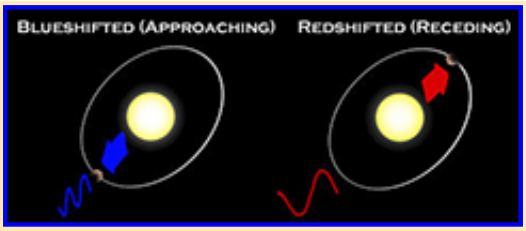
The above infrared image of 2M1207 may be the first picture of an extrasolar planet. Speculated to be a brown dwarf and 5-Jupiter mass planet system, the announcement was made on September 10, 2004 after being observed by astronomers using the European Southern Observatory's (ESO) Very Large Telescope (VLT). Click image to enlarge or refer to *Sky & Telescope* to learn more. Courtesy Gael Chauvin/ESO

The last planetary finding that we commonly think of occurred in 1930 when Pluto was discovered by Clyde Tombaugh of the Lowell Observatory. Some 65 years later a new planet was found, not in our own solar system, but around a 5th magnitude G2IV-type star in the constellation of Pegasus. The announcement came in October of 1995 when the Jupiter-like planet found circling 51 Peg was discovered by Michel Mayor and Didier Queloz (1995) following an 18-month study of Doppler measurements made with the Elodie spectrograph at the Observatoire de Haute-Provence. The massive planet orbits its star so closely that its year lasts only an impressive 4.2 days!

Since the detection of 51 Peg nearly a decade ago, astronomers have logged 117 planetary systems, with 133 planets and 13 multiple planet systems around main sequence stars, this according to The Extrasolar Planets Encyclopedia as of Sept 30, 2004. Many of the planets detected thus far seem to posses Jupiter-like masses and sweep around their star in an orbit commonly less than one-tenth the Earth-Sun distance (Castellano 2004). This close proximity heats the upper atmospheres of these planets, leading to them to be referred to as "hot Jupiters." Searches for planets more terrestrial or Earth-like in composition hold promise for finding habitable zones for life, but in the mean time astronomers are trying to learn as much as possible about these hot Jupiters. Unfortunately, professional astronomers do not have the telescope time to fully monitor this growing planet count. Realizing the important contributions that amateurs make to astronomy, professionals are again looking to collaborate with their invaluable friends with hopes of furthering our understanding of the extrasolar neighborhood.

The Search is on

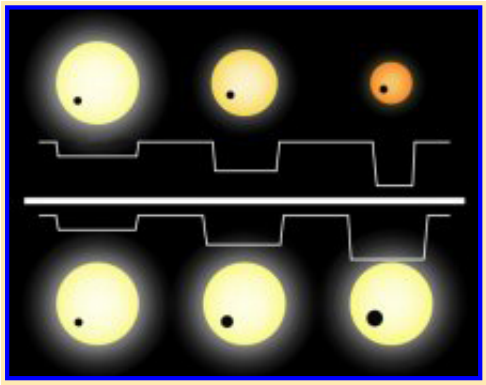
As with most problems, there is more than one way to find a solution and looking for extrasolar planets is no exception. Studies so far have incorporated technologies such as gravitational microlensing, astrometric searches, and direct imaging. Often one method checks and builds on information from another, but the most talked about and successful to date are the *radial velocity* and the *transit* techniques.



The blueshifting and redshifting of spectral lines is caused by the planet's tug on it star as it move toward and away from our line of sight, respectively. Click image to enlarge. Courtesy Gilbert Esquerdo/Planetery Science Institute

The *radial velocity* method was first suggested by Russian-American astronomer Otto Struve in 1952. By looking at the radial velocity signature, or the Doppler shift of a star's spectrum, astronomers can see the "wobble" caused by the planet exerting a small gravitational pull on its parent star. That is, the stars spectrum will be blue shifted as the planet tugs the star toward the observer's view and red shifted as it tugs away. Because the motion of the star's spectrum caused by orbiting planets is so small, this method is best suited for finding large planets in tight orbits, such as hot Jupiters. This technique, however, involves monitoring one star for a large amount of telescope time with a high-precision spectrograph. Thus, it can be somewhat time consuming. Regardless, the radial velocity is the most successful to date.

Another method that has had more recent results and is often used as means of confirmation is to look for *transits*. Transits occur when a planet crosses the face of a star, as seen here on Earth. Transits of extrasolar planets though are unlike those within our own solar system. Since the systems are far away we only see them as points of light and cannot see the "dark spot" made by the planet as it passes in front of its star. Therefore, astronomers look for changes or dips in the light output of the star, a process that variable star observers are quite familiar with. As suspected, the transit method works best when the planet's orbit is almost exactly in view with our line of sight to the star. Also, the further away a planet is from its star, the lower the probability that a transit will take place. Unlike the radial velocity method, a field of stars may be imaged and monitored using a CCD camera, making studies via this technique a feasible task for amateurs to tackle.



The brightness of the star is seen to gradually fade and brighten as the planet begins and ends its path across the front of the star, respectively. The depth and duration of the transit depends upon the relative size of the star and planet(s). Click image to enlarge. Courtesy Gilbert Esquerdo/Planetary Science Institute

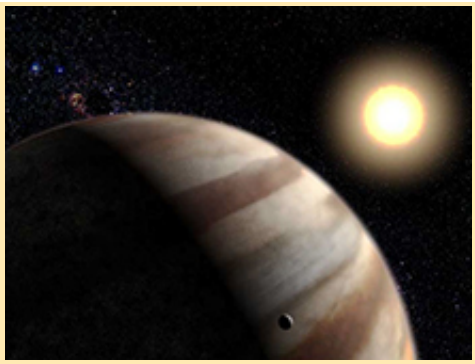
Amateurs Get Involved

Since increasing numbers of observers are now able to acquire affordable telescopes with CCDs and computers, amateurs can play an important role in monitoring extrasolar planets for possible transits, a step crucial to detection follow-up. In fact, a modest 8- or 10-inch telescope is suitable for such work. Astronomers Tim Castellano of NASA's Ames Research Center and Greg Laughlin of the University of California, Santa Cruz have developed a web site designed to help the amateur astronomer observe exoplanet transits. Observers from both the Northern and Southern hemispheres are encouraged to join in. The team provides transit information for select stars, tips for achieving precision photometry, and a discussion forum in exchange for the amateur's "enthusiasm and expertise." The search concentrates on known systems that have a high probability of displaying transits - those with short period planets. Transit times and targeted stars are posted on transitsearch.org web site.

Currently, astronomers know of six stars that are transited by exoplanets. Two of them have

been detected by amateurs and are in the AAVSO in the database:

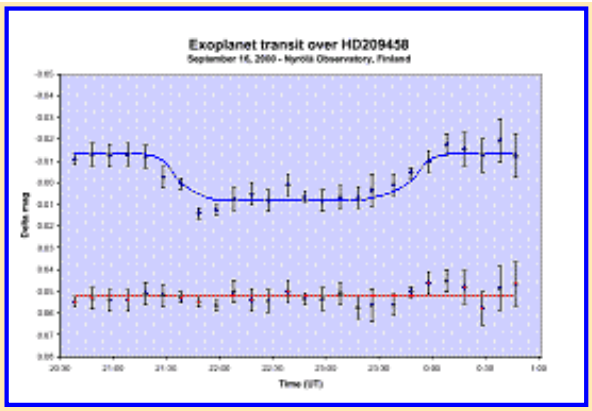
2158+18 V376 PEG = HD 209458



An artist's impression of a planet around the star HD 209458. Image credit: Greg Bacon (STScI/AVL)

In 1999 the 7.7-magnitude G0V-type star in the constellation of Pegasus, HD 209458, also known as V376 Peg, was found to have a Jupiter-like planet orbiting about it. The planet, HD 209458b, was discovered by the Doppler radial velocity method then found to transit as a result of photometric follow-up (see, for instance, Charbonneau et al. 2000 and Henry et al. 2000). This was the first confirmation by photometric means. As a result of observations with the two methods, HD 209458b has been calculated to be about 1/8 the average distance between the Sun and Mercury and has been found to move swiftly about its parent star completing an orbit every 3.524 days. The star's brightness decreases by 1.7% when the planet with a mass of 0.69 Jupiter and diameter of 1.43 Jupiters transits the face of the star. This drop in brightness lasts for about 3 hours (Castellano 2004). Radial velocity and light curves for HD 209458 can be found via the transitsearch.org web site.

In addition to learning about the orbital parameters surrounding HD 209458, astronomers have detected sodium, hydrogen, oxygen, and carbon in the atmosphere of HD 209458b. The atmosphere of the planet, however, has been found to contain less sodium than expected for a Jupiter-class planet. This may indicate the presence of high-altitude clouds in the atmosphere. The planet that transits the face of HD 209458 is a gas giant that is losing at least 10,000 tons of hydrogen per second. The reason, astronomers theorize, may be due to the atmosphere of the planet being puffed up by the heat of its parent star (Schilling 2003).



The first exoplanet transit detected by amateur astronomers Marko Moilanen, Jalo Ojanperä, Jouni Sorvari, Aki Id and Arto Oksanen, Nyrölä Observatory, Finland . Click image to enlarge.

Eager amateurs have proven to be successful in monitoring transits of HD 209458. Impressively, it is said that it was the detection of the HD 209458 September 16, 2000 transit by amateur astronomers Marko Moilanen (MMF), Jalo Ojanperä, Jouni Sorvari (SOW), Aki Id and Arto Oksanen (OAR) of the Nyrölä Observatory, Finland that prompted formation of transitsearch.org! Using a 16-inch Meade LX200 telescope and a SBIG ST7E CCD-imager with a photometric V-filter, and a Meade f6.3 focal reducer and JMI's NGF-S digital focuser, the group made the first amateur observation of an exoplanet transit when they saw the magnitude drop by 0.02 magnitudes. For information and accounts of their experiences, you can read more here or visit transitsearch . org.

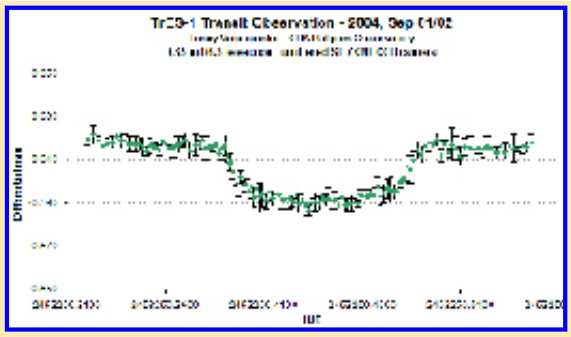
1900+36 GSC02652-0 = TRES-1

The transit of TrES-1, also known as GSC 02652-01324 or 2MASS 19040985+3637574, was discovered in August of 2004 and was the first to be detected by the transit method. The finding was made by an international team of astronomers using a 4-inch Schmidt telescope, named STARE and stationed in the Canary Islands, and mostly off-the-shelf equipment. STARE belongs to a network known as the Trans-Atlantic Exoplanet Survey (TrES, pronounced "trace"), with the other two locations being situated at Lowell Observatory and on Palomar Mountain. The

instruments making up the remaining TrES network include 4-inch camera lenses that sit on mounts using SBIG autoguiders, where the image is focused onto CCD cameras. The equipment used is akin to that available to amateur astronomers (Naeye 2004).

TrES-1 is located in the constellation of Lyra at a location 500 light-years away from us here on Earth. The K0-type star normally shines at a magnitude of 11.8. The planet, meanwhile, is about 0.75 Jupiter mass and has a diameter about 8% larger than Jupiter. The planet orbits its host star every 3.03 days and is about 0.04 astronomical units away. Transit depth of TrES-1 is about a 2% dip in magnitude (Alonso et al. 2004; Naeye 2004).

The discovery of TrES-1 was announced by professional astronomers on August 24, 2004. An impressive 8 days later, a transit of the same system was confirmed by an amateur astronomer in Belgium, Tonny Vanmunster (AAVSO observer VMT), as reported in an online *Sky & Telescope* article. Vanmunster used his Celestron C-14 telescope and an SBIG ST-7XME CCD camera (without filters) at his private observatory. The event was captured in real time using software he had written. As predicted, Vanmunster's transit took place on September 1, 2004 at 21:13 UT and lasted about 3 hours, where the brightness of the star dipped by about 0.03 magnitudes (Naeye 2004).



Tonny Vanmunster's photometric light curve for the September 1, 2004 transit of TrES-1. Click image to enlarge. Courtesy Tonny Vanmunster

David Charbonneau, coleader of the team to discover TrES-1 and of the Harvard-Smithsonian Center for Astrophysics commented, "I'm thrilled that this confirmation has come from an amateur. But perhaps we shouldn't be too surprised. He did, after all, have a telescope with an aperture three times larger than ours!" (Naeye 2004)

It is reported that a handful of other amateurs independently confirmed the transit as well: Ondrej Pejcha, Pertti Paakkonen (PPK), Samo Smrke & Nicolaj Stritof (SNJ), Robin Leadbeater, Joe Garlitz (GJP), Ron Bissinger, and Bruce Gary (GBL). Interested readers can find more details and light curves surrounding the independent findings here.

Join the Search

As an exciting new venture, the AAVSO has become a partner with the exoplanet transit community by teaming up with Dr.'s Castellano and Laughlin via transitsearch.org. Castellano and Laughlin will provide target information and advice, while the AAVSO will arrange for transit observing campaigns. Recently issued is a campaign to monitor the possible transit of a known planetary system, GJ 867 (see West 1996 for information about GJ 876). If you'll be by your telescope during the nights of October 20-23, 2004, then don't miss this chance. Be sure to see CCD View #326 for more information and tips about what you should be doing now to prepare for the upcoming transit.

If you are unable to catch the transit of GJ 876, don't despair. The AAVSO will continue to issue campaigns in connection with transitsearch.org. Be sure to stay connected with the various avenues of information that the AAVSO provides for news concerning exoplanet transits, such as: CCD Views, MyNewsFlash, and the Photometry Discussion Group. Also don't forget the success that amateurs have had with detecting transits of HD 209458 and TrES-1. Armed with the predicted transit times of HD 209458 and TrES-1 and the appropriate charts, then perhaps you too will join the exoplanet ranks. For help with getting started, visit transitsearch.org and the new AAVSO Transit Search Observing Program web page. Be sure to record your results as accurately as possible and submit your observations to the AAVSO so that we can keep track of

the activity and share it with the exoplanet community.

If you still can't get enough and want to get even closer to that special transiting exoplanet, a partnership forged between transitsearch.org and NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) can take you to the sky in a modified Boeing 747 jet in the year 2005 and beyond. SOFIA's Education and Outreach Program may allow exoplanet-observing volunteers to compete for time aboard the craft. The lower scintillation onboard SOFIA makes it possible to perform occultation measurements at much higher precision than from the ground.

Future of Exoplanets

With the search for extrasolar planets increasing in popularity and the findings on the rise, we can expect to see even more missions devoted to the project. For instance:

- The Keck Interferometer will study dust clouds around stars where planets may be forming.
- NASA's Kepler Mission, expected to launch in 2007, will search for terrestrial planets, or rocky, Earth-sized planets, in orbit around other stars.
- NASA's Space Interferometry Mission (SIM) is slated for a 2009 launch. One of the mission objectives is planet detection. With measurements of the position and distances stars several hundred times more accurate than any other mission to date, and to detect evidence of planets just slightly larger than Earth.
- The Terrestrial Planet Finder with an anticipated launch of 2012 will have imaging power 100 times greater than the Hubble Space Telescope and will look for the origins of stars, planets, and life.

Countless other missions are in the works as well (see, for instance Shiga's article listed below).

It is surely an exciting time to be joining such an important search. Don't miss your chance to help make history!

References and For More Information

- AAVSO Charts:
  - "e" scale chart for 1900+36 GSC02652-0 = TRES-1
  - "d" and "e" scale charts for 2247-14 IL AQR = GJ 876
  - *Note: the AAVSO does not have charts for 2158+18 V376 PEG = HD 209458 at this time. See transitsearch.org for more information about observing this system.*
- AAVSO Electronic Publications and Web Pages:
  - CCD Observing Manual; see the chapter on Introduction to Photometry
  - CCD Views
  - MyNewsFlash
  - Photometry Discussion Group; see in particular September's exoplanet thread
  - Transit Search Observing Program
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- Web Sites:
  - California & Carnegie Planet Search
  - Extrasolar Planets Encyclopedia
  - The Geneva Extrasolar Planet Search Programmes
  - Transitsearch.org

This month's **Variable Star of the Season** *was prepared by Kerri Malatesta, AAVSO Technical Assistant.*

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