U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE
AND
SUBCOMMITTEE ON RESEARCH

Exoplanet Discoveries: Have We Found Other Earths?

Thursday, May 9, 2013
10 a.m. – 12 p.m.
2318 Rayburn House Office Building

Purpose

The purpose of the hearing is to review the recent discovery of three super-Earth sized planets by the National Aeronautics and Space Administration's (NASA) Kepler space telescope. The hearing will also assess the state of exoplanet surveying, characterization, and research; NASA's Exoplanet Exploration Program; National Science Foundation's (NSF) Division of Astronomical Science; as well as coordination within the government and with external partners. NASA and NSF both contribute to the search for exoplanets. NASA provides space-based telescopes to identify potential planets, while NSF builds ground-based telescopes. Both agencies fund research that assists in categorizing and characterizing candidate planets.

Witnesses

- Dr. John Grunsfeld, Associate Administrator, Science Mission Directorate, NASA;
- Dr. James (Jim) Ulvestad, Division Director, Division of Astronomical Sciences, Directorate for Mathematical and Physical Sciences, NSF;
- Dr. Laurance Doyle, Principal Investigator, Center for the Study of Life in the Universe, SETI Institute, and member of the NASA Kepler Mission Science Team.

Overarching Questions

1. How is exoplanet research conducted and why is it important?
2. How do the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) support exoplanet research?
3. What does future exoplanet research hope to discover?

Background

The first definitive exoplanet discovery occurred in 1992 by NSF-funded researchers.[1] On September 29, 2010, the Keck Observatory announced that it had identified the first Earth-sized

[1] http://tech.mit.edu/V114/N22/psr.22w.html

planet orbiting a star in a "habitable zone," an area where a planet's distance from its sun increases the possibility it could have surface temperatures that could support the existence of liquid water. [2] On April 18, 2013, NASA's Kepler mission released details of its discovery of two new planetary systems that include three super-Earth sized planets in the "habitable zone."[3] These discoveries heightened speculation about the possibilities of finding life on another planet than Earth.

NASA

On March 6, 2009, NASA launched the Kepler space telescope. Part of NASA's Explorer program, Kepler's purpose is to survey the Milky Way galaxy to find Earth-size planets and similar solar systems. From space, Kepler is able to identify smaller targets than ground-based telescopes. Originally slated as a three and a half year mission, operations could be extended until 2015; however, recent technical problems with the spacecraft may limit its continued operations.

Other NASA-sponsored telescopes involved in exoplanet research include the Large Binocular Telescope Interferometer (LBTI), the Hubble Space Telescope, the Spitzer Telescope, and the Stratospheric Observatory for Infrared Astronomy (SOFIA). Exoplanet research will also be conducted by the James Webb Space Telescope (JWST) to be launched in fall 2018, the newly announced Explorer mission Transiting Exoplanet Survey Satellite (TESS), and potentially the Wide Field Infrared Survey Telescope (WFIRST).

In FY 2013, NASA spent an estimated $41.6 million on exoplanet research. The FY 2014 budget request is $55.4 million.[4] This amount includes funding for extension of the Kepler mission and NASA's partnership with the Keck Observatory used for all NASA astrophysics science programs.

NSF

NSF-funded facilities play key roles in exoplanet research, including the Gemini Observatory in Hawaii, the Atacama Large Millimeter/Submillimeter Array (ALMA) in Chile, and the Arecibo Observatory in Puerto Rico. The NSF reports that requests for exoplanet research grants are the fastest growing component of proposals submitted to the Division of Astronomical Science.[5] In 2013, approximately 16 percent of projects reviewed by the Astronomy and Astrophysics Research Grants program were for exoplanet research.[6] There are currently more than 40 active awards covering exoplanets.

The estimated budget for FY 2013 for NSF's Division of Astronomical Sciences (AST) was $234.55 million and the FY 2014 budget request is $243.64 million. Much of AST's budget is for grants using NSF funded ground-based telescopes. In FY 2014, NSF has also requested an additional $28 million to begin construction on the Large Synoptic Survey Telescope (LSST), which will be used, in part, for exoplanet research.[7]

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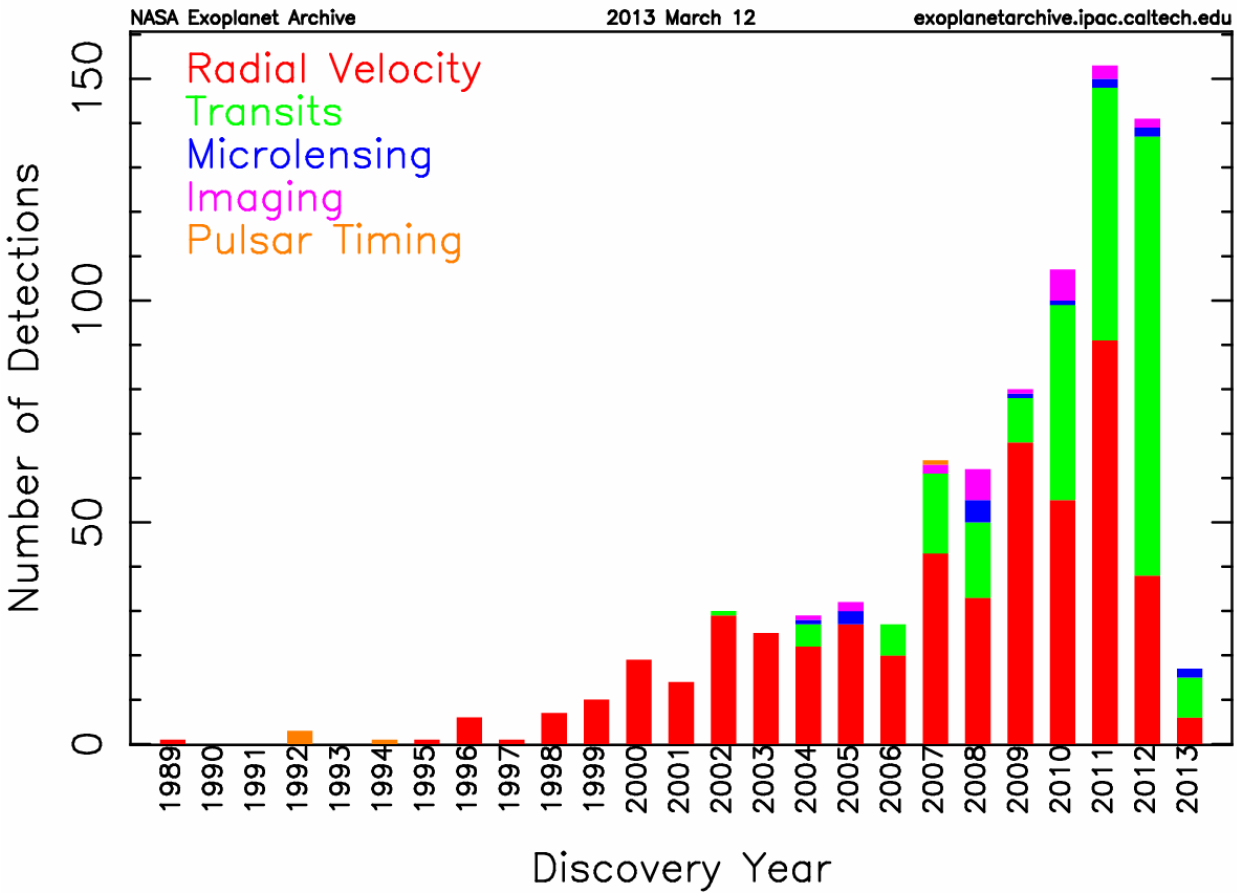
[2] http://keckobservatory.org/news/keck_observatory_discovers_the_first_goldilocks_exoplanet/
[3] http://www.nasa.gov/mission_pages/kepler/news/kepler-62-kepler-69.html
[4] http://www.nasa.gov/pdf/740512main_FY2014%20CJ%20for%20Online.pdf
[5] See Supra 4
[6] Ibid
[7] http://www.nsf.gov/pubs/2013/nsf13019/nsf13019.pdf

Key Detection Techniques[8]

In the past two decades, scientists have developed a variety of methods for detecting exoplanets. As the technology for observing planetary systems has improved, the number of new discoveries has increased and scientific interest in the field has grown. As of May 2013, there are roughly 900 confirmed exoplanets and more than 2,700 planet candidates.[9]

Exoplanet Discoveries[10]



Radial Velocity

The radial velocity technique uses infrared sensors and the Doppler Shift to detect a star's wobble as it is affected by the mass of an orbiting planet. This technique has identified 504 planets in 390 systems. *Example: NASA/Keck for discovery and Kepler for validation.*

Transit Technique

The transit technique uses optical measurements to detect a change in a star's brightness as a planet goes in front of or behind a star. This technique has identified 294 planets in 238 systems as well as

[8] NASA briefing to the House Science, Space, and Technology Committee, *NASA's Exoplanet Program: Leading the Quest to Discover and Characterize Planets Around Other Stars*, April 4, 2013.
[9] See Supra 4
[10] Ibid

more than 2,740 planet candidates. *Example: Kepler for discovery; Spitzer, Hubble &JWST for characterization.*

Direct Imaging

The direct imaging technique uses optical sensors to identify faint planets next to bright stars with coronographs and occulters. This technique has identified 30 planets in 27 systems. *Example: Hubble, JWST, and a potential New Worlds mission.*

Microlensing

Microlensing uses a star's gravitational field to bend light like a lens in order to find planets beyond the star. While this technique has only identified 19 planets in 16 systems so far, NASA's proposed WFIRST mission will use this promising technique to search for exoplanets. Where the Kepler mission is optimized for identifying planets close to stars, WFIRST will be optimized for planets farther away from stars.[11]

Habitability

Astronomers and astrophysicists use the term "habitability" as way to classify an exoplanet's potential for hosting organic life. This classification does not mean that the expoplanet may be habitable for human life, but that conditions exist where some kind of organic life could be found.

To calculate which exoplanets reside in a "habitable zone," scientists look at several factors[12]:

- Environment – the exoplanet's distance from its star helps determine the planet's stable temperature and orbital stability
- Planet size and mass – determining whether the planet has an active plate techtonic system (or rocky surface) and stable atmosphere provides scientists with evidence of an active carbon cycle
- Composition – evaluating the surface for the presence of water could be an indication of life

Exoplanets that appear to meet these criteria are referred to as "goldilocks" planets, because they are neither too hot nor too cold to sustain habitable conditions for life. Out of the 2700 planets identified by Kepler, 50 have been determined to be "goldilocks" planets.[13]

Future

The Astronomy and Astrophysics Advisory Committee (AAAC) advises NASA, NSF, and the Department of Energy (DOE) on common areas of astronomy and astrophysics. Established in the NSF Authorization Act of 2002, its purpose is to coordinate agency activities put forth in National Research Council (NRC) astronomy and astrophysics decadal surveys, assess programs, make recommendations, and to annually report on these findings to the participating agencies and Congressional committees of jurisdiction.

[11] http://wfirst.gsfc.nasa.gov/science/exoplanets/
[12] See Supra 7
[13] Ibid

The 2010 National Academies' decadal survey, *New Worlds, New Horizons in Astronomy and Astrophysics* referenced exoplanet research in the section titled "New Worlds: Seeking Nearby, Habitable Planets." The Academies listed the following questions regarding exoplanets:

- How do circumstellar disks evolve and form planetary systems?
- How diverse are planetary systems?
- Do habitable worlds exist around other stars, and can we identify the telltale signs of life on an exoplanet?[14]

In their March 8, 2013, report the AAAC released the following recommendations related to exoplanet research:

- NASA should continue funding the WFIRST mission, while concurrently funding completion of JWST.
- As the largest priority ground-based telescope in the 2010 NRC decadal survey "New Worlds, New Horizons in Astronomy and Astrophysics," NSF and DOE should continue funding development of the Large Synoptic Survey Telescope.[15]

The AAAC addressed exoplanet research specifically with their May 22, 2008 report of the Exoplanet Task Force titled "Worlds Beyond: A Strategy for the Detection and Characterization of Exoplanets." The Task Force developed a 15 year strategy for the detection and characterization of exoplanets and planetary systems, as requested by NASA and the NSF.[16]

[14] http://www.nap.edu/catalog.php?record_id=12951
[15] http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac_2013_130308finalreport.pdf
[16] For additional information, see http://www.nsf.gov/mps/ast/aaac/exoplanet_task_force/reports/exoptf_final_report.pdf