National Aeronautics and Space Administration

NASA's New Worlds News

The EXOPLANET EXPLORATION PROGRAM *Newsletter*

Issue 14 - October 2014

Please visit http://exep.jpl.nasa.gov/newslettersarchive-htmlfiles/2014Oct.html to view the HTML version of this newsletter.

HEADLINES

*Do you have an accomplishment or event you want to share in Community Highlights? Send it to us at **nasaexoplanetnews@jpl.nasa.gov**. Please limit your submissions to no more than 150 words.*

NASA Honor Award: Group Achievement Award recognizes excellence of NASA Exoplanet Archive

1. Solicitation for 2015 Carl Sagan Fellowships

The NASA Exoplanet Science Institute (NExScI) solicits applications for Sagan Postdoctoral Fellowships to begin in the fall of 2015. The deadline for applications and letters of reference and endorsement is ***Thursday, November 6, 2014 at 4 pm PST.*** The Sagan Fellowships support outstanding recent postdoctoral scientists to conduct independent research that is broadly related to the science goals of NASA's Exoplanet Exploration program.

In April NExScI announced the seven newest Sagan Fellows, read more about them here: http://nexsci.caltech.edu/sagan/2014postdocRecipients.shtml. See item 10 and item 11 for features on two of the current fellows: Jared Males and Rebecca Martin.

More information: http://nexsci.caltech.edu/sagan/fellowship.shtml
Questions: mailto:saganfellowship@ipac.caltech.edu

2. Program Manager's Update

By Gary Blackwood, Manager, Exoplanet Exploration Program Office

The purpose of the Exoplanet Exploration Program (ExEP) is to implement a fundamental aspect of the space science vision of NASA's Astrophysics Division:

PLANET COUNT

updated October 29, 2014

3,218 CANDIDATES
1,763 CONFIRMED
= 4,981 EXOPLANETS

For information on any of the stories or events below, please visit: http://exep.jpl.nasa.gov/newslettersarchivelist/

EXOPLANETS IN THE NEWS

October 24, 2014
Astronomers discover first "ice giant" exoplanet

October 9, 2014
NASA's Hubble Maps the Temperature and Water Vapor on an Extreme Exoplanet

September 24, 2014
NASA Telescopes Find Clear Skies and Water Vapor on Exoplanet

August 28, 2014
NASA's Spitzer Telescope Witnesses Asteroid Smashup

July 23, 2014
The most precise measurement of an alien world's size

July 21, 2014
Transiting Exoplanet with Longest Known Year

July 3, 2014
Newly spotted frozen world orbits in a binary star system

June 2, 2014
Because you can't eat just one: Star will swallow two planets

to detect and characterize exoplanets, determine their habitability, and search for signs of life. In the second half of fiscal 2014 we made progress towards these goals through projects and studies conducted at three NASA Centers and at several universities. The Program benefits from the strong participation of exoplanet community leaders through forums such as the Exoplanet Program Analysis Group (ExoPAG) and the Exoplanet Technical Analysis Committee (ExoTAC).

The Wide-Field Infrared Survey Telescope/Astrophysics Focused Telescope Assets (WFIRST/AFTA) is a major focus of the program. The coronagraph instrument for direct imaging and spectroscopy of exoplanets requires key new technologies. Development is proceeding as a focused, directed program managed by the WFIRST Study Office to reach Technology Readiness Level (TRL)-5 by the start of FY 2017. See Major Advances in Coronagraph Technology for details of the lab experiments at JPL and Princeton University. Also see this issue's Science Update for how the program manages the development of technology in support of NASA's exoplanet missions - including coronagraph and starshade technologies - identified from the science objectives of these missions.

Kepler-K2 is the continuation of the highly successful Kepler mission approved in April by the Astrophysics Division's Senior Review of operating missions. K2 has already completed Science Campaign 1 and Science Campaign 2 is underway. The community is invited to submit proposals for later science campaigns. The original Kepler mission will deliver long-period and short-period data products using the SOC 9.2 pipeline in November 2014 and March 2015, respectively. The final pipeline and archive of final data products (SOC 10.0) will be complete by the end of FY 2017.

The Large Binocular Telescope Interferometer (LBTI) continues to work towards full operation. Current instrument performance is 60 zodi (1-sigma) relative to the project requirement of 3 zodi. Two observing runs planned for May and July 2014 were unsuccessful due to operational unreliability in the right-side (DX) secondary mirror adaptive optics system. Repairs have been completed, and commissioning runs will commence in October 2014. Performance is expected to improve as these future runs proceed. The Operational Readiness Review (ORR) was postponed to April 2015.

The Exoplanet Program Analysis Group (ExoPAG) provides community input to the Astrophysics Division through the Astrophysics Subcommittee. It is open to anyone in the astronomy community who wishes to contribute. Three new members were appointed this year --- Margaret Turnbull (Global Science Institute), Rus Belikov (NASA Ames Research Center), and Lucianne Walkowicz (Princeton University). They replace members rolling off at the conclusion of their three-year terms. We thank Aki Roberge (NASA Goddard Space Flight Center), Tom Green (NASA Ames Research Center), and Lisa Kaltenegger (now at Cornell University) for their service.

Scott Gaudi (Ohio State University) and Sara Seager (MIT) were named Distinguished Visiting Scientists at the NASA Jet Propulsion Laboratory. They will work with both the JPL Center and the Exoplanet Exploration Program to advance exoplanet science.

The Keck Observatory Archive marked the 10th anniversary of operations. Since August 2004, it has served over 1 million data requests. The archive now houses over 30 TB of data extending as far back as 1994, and includes data from all Keck instruments.

You may view my presentation on the overview of the Exoplanet Exploration Program, given at the 2014 Sagan Summer Workshop, online at http://vimeopro.com/vcubeusa/caltech2014.

3. Message from NASA Astrophysics Division Director

By Paul Hertz, Director, NASA Astrophysics Division

As we approach the end of the 2014 fiscal year, it is time to reflect on our achievements and shortcomings, and plan for challenges ahead. We have been

April 17, 2014
NASA's Kepler telescope discovers first Earth-size planet in 'habitable zone'

April 17, 2014
NESSI - a new exoplanet finder in New Mexico

April 10, 2014
That's no moon, that's a...oh wait, maybe it is!

EVENTS

AAS-DPS
November 9-14
Location: Tucson, Arizona

Wide-field InfraRed Surveys: Science and Techniques
November 16-20
Location: Pasadena, California

ExoPAG-11
January 3-4
Location: Seattle, Washington

AAS Winter Meeting
January 4-8
Location: Seattle, Washington

Physics of Exoplanets: From Earth Sized to Mini Neptunes
February 23-27
Location: Santa Barbara, California

NRC Space Science Week 2015
March 31-April 2
Location: Washington, D.C.

Astrobiology Science Conference 2015 - June 15-19
Location: Chicago, Illinois

In the Spirit of Lyot 2015 - June 22-26
Location: Montreal, Canada

Pathways 2015: Pathways Towards Habitable Planets II
July 13-17
Location: Bern, Switzerland

extremely fortunate that our space-based missions, both large and small, have continued to make headlines with spectacular scientific discoveries that capture the mind of the public. We have learned more about the way the universe works, studied the birth of stars and galaxies, and made great strides in discovering and understanding exoplanets.

As I described during the NASA Town Hall at the American Astronomical Society meeting in Boston on June 2, 2014, we continue to make progress addressing the priorities of the 2010 Decadal Survey for Astronomy and Astrophysics. The appropriation that NASA Astrophysics received for FY 2014 and the Administration's FY 2015 budget request both support our plans for continued progress. The progress we are making toward the major recommendations of the 2010 Decadal Survey includes:

- A goal of the Astrophysics Division is to be prepared to start a new strategic NASA Astrophysics mission to follow James Webb Space Telescope (JWST) as soon as funding becomes available. Preformulation and focused technology development for a 2.4-m version of the Wide-Field Infrared Survey Telescope (WFIRST), a mission concept referred to as the Astrophysics Focused Telescope Assets (AFTA), are underway. NASA received $56M in directed funding for in FY 2014 for WFIRST/AFTA to continue preformulation activities and technology development. A recent National Research Council (NRC) study on WFIRST/AFTA offers a positive view of WFIRST/AFTA in the context of the Decadal Survey with concerns about technology and cost risks. The Administration's FY 2015 budget request supports an Agency/Administration decision for formulation of WFIRST/AFTA to begin no earlier than FY 2017, should funding be available.
- A new ROSES element, WFIRST Preparatory Science, was announced on April 21, with a goal to bridge from basic theory to observational modeling for WFIRST/AFTA; and more than 50 proposals were received on July 11. Investigators selected will coordinate efforts with the WFIRST Study Office and the WFIRST/AFTA Science Definition Team.
- The Administration's FY 2015 budget request includes augmentation of the Explorer program to enable more frequent flight opportunities, including a SMEX AO released on September 17 (see the AO at http://nspires.nasaprs.com/ and the additional information page at http://explorers.larc.nasa.gov/APSMEX/) and a MIDEX around FY 2017.
- Strategic technology investments are being made and partnerships are being discussed with the European Space Agency in their gravitational wave and X-ray observatories. NASA has joined ESA in supporting the ESA Science Study Team for the recently selected mission concept, "Advanced Telescope for High-ENergy Astrophysics" (Athena).
- Strategic technology investments are being made to advance the medium-scale programs, including technology for exoplanet missions and technology for detection of polarization of the cosmic microwave background.
- Modest augmentations have been made to small programs including R&A.

The FY 2014 appropriation for NASA provided $658M for JWST and $668M for the rest of NASA astrophysics. The FY 2015 Administration's budget request would provide $645M for JWST and $607M for the rest of NASA astrophysics. Both budgets support the continued development of JWST on plan toward its launch in 2018, and both budgets include funding for continued preformulation of WFIRST as described above. Both budgets also include funding for several new missions, including the Transiting Exoplanet Survey Satellite (TESS), the Neutron Star Interior Explorer (NICER), the next Astrophysics SMEX mission, the next Astrophysics Explorer Mission of Opportunity, and the NASA contribution to the European Space Agency's Euclid mission.

The Administration's FY 2015 budget proposes to place the Stratospheric Observatory for Infrared Astronomy (SOFIA) into storage by FY 2015 unless partners are able to support the U.S. portion of SOFIA costs. The NASA appropriation subcommittees in both houses of Congress, however, have proposed continued funding for SOFIA at a level sufficient to continue operations. NASA has continued to conduct the SOFIA program as planned during FY 2014.

Other program highlights since my last Newsletter include:

- SOFIA formally entered the Operations Phase in May. Second-generation instruments - High-resolution Airborne Wideband Camera (HAWC+) (U.S.), and German Receiver for

XXIX IAU General Assembly
August 3-14
Location: Honolulu, Hawaii

PROGRAM WEBSITES

Exoplanet Exploration Program (ExEP)

http://exep.jpl.nasa.gov/

PlanetQuest - Public Outreach Website

http://planetquest.jpl.nasa.gov/

NASA Exoplanet Science Institute (NExScI)

http://nexsci.caltech.edu/

NASA Science Astrophysics

http://science.nasa.gov/astrophysics/

NASA Cosmic Origins Program (COR)

http://cor.gsfc.nasa.gov/

NASA Physics of the Cosmos Program (PCOS)

http://science.nasa.gov/astrophysics/

Astronomy at Terahertz Frequencies (upGREAT) (German) - are under development. In late June, SOFIA was flown to Germany for a Heavy Maintenance Visit.

- Astrophysics research funding remains flat, retaining the growth realized since the Decadal Survey, with the success rate of proposals hovering between 15 and 24 percent. This is caused by a sharp increase in the number of proposals received.
- A Senior Review of operating missions was conducted in April. At that time, all operating missions other than the Spitzer Space Telescope were approved for continued operation. A full report of the Senior Review may be found at http://science.nasa.gov/astrophysics/2014-senior-review-operating-missions/.
- In July, the Science Mission Directorate made the decision to extend Spitzer operations for the next two years. The Spitzer observatory is an important resource for ongoing infrared observations for research programs across the Science Mission Directorate, and, subject to the availability of Congressional appropriations in FY 2015, it will be continued.
- Astrophysics approved some funds for education activities in FY 2014 and has continued a limited number of high impact activities.

Major activities planned for FY 2015 include confirmation of the TESS Explorer mission, launch of the International Space Station-Cosmic Ray Energetics and Mass (ISS-CREAM) experiment to the space station, Step 1 selection of the next Small Astrophysics Explorer and Explorer Mission of Opportunity Phase A studies, launch of ESA's Laser Interferometer Space Antenna (LISA) Pathfinder with NASA's Space Technology 7 (ST-7), completion of the WFIRST/AFTA science definition team report, conduct of the Astrophysics Archives Senior Review, start of the NRC Mid-Decade Review, and celebration of twenty five years of operation of the Hubble Space Telescope. All Astrophysics programs flow from the recently completed NASA 2014 Science Plan, which is available at http://science.nasa.gov/about-us/science-strategy/.

My entire presentation to the American Astronomical Society meeting is available at http://science.nasa.gov/astrophysics/documents/.

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4. Major Advances in Coronagraph Technology

By Ilya Poberezhskiy, NASA Jet Propulsion Laboratory
WFIRST Coronagraph Technology Manager

In the previous edition of this newsletter we described how the evaluation of various coronagraph technologies for the Wide-Field Infrared Survey/Astrophysics Focused Telescope Assets (WFIRST/AFTA) mission study resulted in the selection of the occulting mask coronagraph - an instrument that combines a Shaped Pupil Coronagraph (SPC) and a Hybrid Lyot Coronagraph (HLC). Since NASA's decision of the selection was announced in December of 2013, the technology development team at JPL and partner institutions has been rapidly maturing the coronagraph technology, and achieved a number of significant advances. Several highlights of this progress are described below.

In the heart of any coronagraph are the so-called "masks": shaped pupils for SPC and focal plane occulters for HLC. In each case, new designs had to be developed to achieve the required starlight suppression with the obscured 2.4 meter AFTA telescope. Both HLC and SPC teams presented viable designs in the fall of 2013, and during the course of 2014 the teams at JPL and Princeton University, respectively, have continued to improve their designs in order to increase the number of detectable exoplanets, reduce sensitivity to observatory pointing jitter, and make the masks easier to fabricate. As a result, exoplanet science that the WFIRST coronagraph can do under realistic conditions has improved significantly over the past year.

The new coronagraph mask designs contained features that had not been fabricated before, and in some cases were outright incompatible with the existing fabrication techniques. Thus new fabrication approaches had to be developed to make WFIRST/AFTA coronagraph masks. Over the past few months, both shaped pupil and hybrid Lyot mask fabrication teams were able to rise to this challenge and successfully produce both WFIRST/AFTA coronagraph masks.

The new SPC masks are of reflective rather than previously used transmissive type (Fig. 1a). While a portion of light in the pupil plane hits a highly reflective mirror surface, other light encounters specially processed "black silicon" regions. The black silicon process, performed at JPL's MicroDevices Lab (MDL) and Caltech's Kavli Nanoscience Institute, produces some of the

darkest surfaces in the world, with specular reflectance of less than 1 part in 10 million. The quality of the produced reflective masks was initially verified through extensive characterization, modeling, and analysis, and later validated using the ultimate test - achieving high contrast (starlight suppression) on the coronagraphic testbed. Narrowband contrast of ~6x10-9 and broadband contrast of ~9x10-9 have been achieved between working angles of 4.4 and 11 \0x03BB/D, with contrast levels expected to further improve in the future (Fig. 1).

Circular HLC masks have also been fabricated for the first time at JPL using two different approaches. A mask made at MDL is shown in Fig. 2. Since this mask is in the focal plane, it is much smaller than the shaped pupil masks - the part that does the bulk of the starlight suppression is less than 1 mm in diameter! The HLC testbed is currently being commissioned in a vacuum chamber and should begin starlight suppression experiments soon.

Another key part of the WFIRST coronagraph instrument that has been making steady progress is the Low Order WaveFront Sensing and Control (LOWFS/C) subsystem. It uses rejected starlight to measure the pointing jitter of the telescope, caused by rotation of the reaction wheels used for spacecraft attitude control, as well as optical wavefront errors caused by telescope's changing exposure to sunshine and Earthshine. After extensive analysis and modeling, the LOWFS team has selected Zernike wavefront sensing approach and is gearing up for its experimental demonstration. Together with the HLC design team, they verified for the first time the viability of co-designing the LOWFS mask with the HLC focal plane mask - a key advance that allows avoiding non-common path errors that would otherwise compromise the instrument's stability.

We will continue to report our progress as we further mature the key coronagraph technologies that will enable WFIRST/AFTA to acquire direct images and spectra of exoplanets.

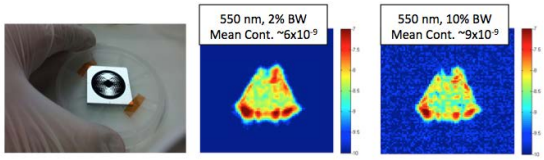


Fig. 1. (a) Reflective shaped pupil mask designed at Princeton University and produced at JPL; one-sided dark hole generated by the shaped pupil coronagraph in (b) narrowband light and (c) broadband light.

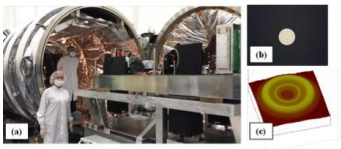
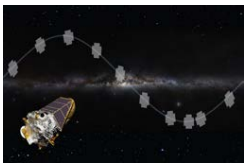


Fig. 2. (a) Hybrid Lyot coronagraph testbed moving into a vacuum tank for commissioning and starlight suppression experiments; circular hybrid Lyot coronargraph mask imaged under (b) optical and (c) atomic force microscope.

5. Kepler-K2 Mission Status



By Ingolf Heinrichsen, NASA Jet Propulsion Laboratory
Program Office Mission Manager for Kepler

The Kepler-K2 (K2) mission is an amazing story of perseverance and engineering ingenuity in the face of seemingly insurmountable obstacles. It is aptly named after the second highest mountain on Earth, which is generally considered harder to climb than Mount Everest.

Looking back, it is hard to believe that only a little more than a year has passed since we were faced with the fact that a second reaction wheel had stopped working on Kepler, no longer allowing us to control the fine attitude of the spacecraft. The data collection for the hugely successful Kepler mission had come to a sudden end. Today the K2 mission has completed its first science campaign, not only continuing the search for exoplanets, but contributing to a large variety of astrophysics topics.

When the idea was floated to continue a different mission with the remaining two reaction wheels, my initial reaction was: "We will never be able to make this work and if we can, we won't be able to afford it." But fortunately, the Kepler team proved me wrong.

The spacecraft had to relearn all of its basic functions. Procedures and software that normally take years to develop on the ground before launch had to be redone in only a few months, while

at the same time keeping the damaged spacecraft healthy and safe. How do we move without spending too much fuel? Can we point accurately and remain stable enough to communicate to the ground? Can we save the spacecraft when it is in trouble while avoiding pointing at the Sun? We can't hear the spacecraft in its science attitude, how can we make it work autonomously for several months without being able to intervene? The list went on and on and the clock was ticking, as every day without optimized pointing we were losing precious fuel we would need to execute the new mission.

The engineers at NASA's Ames Research Center and Ball Aerospace kept at it, solving one problem after another to get the spacecraft to balance the solar pressure on the ridge of its sunshield, compensating for the seasonal variations as Kepler revolves along its orbit around the Sun.

At the same time, the science community responded with overwhelming support through a flurry of white papers making the all-important science case to continue the mission, and NASA Headquarters gave the team the opportunity to submit K2 mission through the Senior Review process which in April recommended continuation of K2 for two years (through the end of FY16).

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6. Direct Imaging Missions at a Moderate Cost

By Keith Warfield, NASA Jet Propulsion Laboratory
Probe Study Office Manager

NASA's two Science and Technology Definition Teams (STDTs) are nearing completion of their respective "probe-scale" mission concepts. In May 2013, NASA selected the two STDTs to develop space mission concepts capable of directly imaging planets orbiting nearby stars at a cost below $1B - "probe-class." One team is studying a concept using a telescope and coronagraph and is being led by Karl Stapelfeldt of the NASA Goddard Space Flight Center. The other team is exploring a concept based on a spacecraft carrying a telescope and imager and flying in formation with a second spacecraft carrying an occulting starshade. That team is being led by Sara Seager of the Massachusetts Institute of Technology.

The STDTs have made considerable progress over this past year, much of which has been summarized in their Interim Reports released in April. To meet the challenging cost limit set by NASA, both designs are utilizing proven designs wherever possible. The coronagraph concept borrows heavily from the successful (and sub-$1B) Kepler mission, while the starshade concept uses elements from Kepler and commercial communications satellite designs. The starshade concept will also look into the feasibility and cost of a "follow-on" starshade mission to future space telescope missions such as Wide-Field Infrared Survey Telescope-Astrophysics Focused Telescope Assets (WFIRST/AFTA). Both concepts have been submitted for preliminary Cost and Technical Evaluation (CATE) review. The coronagraph concept's initial CATE estimate has been received and is close to meeting the $1B cost goal. The design is being adjusted based on these results. The initial starshade CATE is pending at this time.

Final reports on both concepts are due to NASA by the end of this coming January, with public release following shortly after the delivery to NASA. Final CATEs will be delivered to NASA in February. Both STDTs will give publicly available briefings on the concepts to the Committee on Astronomy and Astrophysics (CAA) of the National Research Council at the CAA's spring meeting.

You can read more about how these studies fit into the "big picture" in the 2012 NASA Astrophysics Implementation Plan. The work of the STDTs is of critical importance to both the CAA's mid-decade review and the coming Decadal Survey process. The studies will guide direct imaging technology development work and will define comparative design points for future Survey concepts.

More information on the STDTs and the probe-class direct imaging concepts - including team membership and the concept Interim Reports - can be found on the ExEP website at http://exep.jpl.nasa.gov/stdt/. Final reports and other publicly releasable information on the studies will be added to the site as the studies conclude in early 2015.

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7. Science Update

By Wes Traub, NASA Jet Propulsion Laboratory

Before we do science, we plan for doing science, and that is what I'd like to talk about for this newsletter. In particular, there has been a flurry of planning activity for exoplanet science with the WFIRST/AFTA mission. The Science Definition Team (SDT) for WFIRST/AFTA issued its interim report in May, available at http://wfirst.gsfc.nasa.gov/science/sdt_public/WFIRST-AFTA_SDT_Interim_Report_April_2014.pdf, and is now working on its final report, due in January 2015.

As part of planning for the coronagraph instrument (CGI) on board, relevant members of the SDT have been looking closely at the expected science results from the CGI, including modeling the expected detections and spectra of planets and disks. They have also held three face-to-face meetings with the engineers who are designing the instrument in an iterative process to ensure that all the science that we want to accomplish can be carried out by the mission, and that the instrument to do this can be built and tested on schedule and within budget. In the language of mathematical physics, we are solving a boundary value problem in four dimensions.

Precision Radial Velocity (PRV) has been a key technique for detection of exoplanets for the past two decades, and the databases built up over that time are a valuable resource for the WFIRST/AFTA coronagraph (and also for the two Probe-scale mission concept studies). Many of the likely candidate target stars have already been observed with PRV. So an important question to pose is: what range of planet sizes and orbit radii of interest to WFIRST/AFTA could have been detected by current PRV (or a continuation of those programs)? To this end, ExEP initiated a contract with Andrew Howard, University of Hawaii (representing the California Planet Search Team), to investigate the detectability of planets in this search space. The results will be made available to the three study teams.

Leslie Sage edited a five-article review of exoplanet science in the 18 September issue of Nature, well worth reading: http://www.nature.com/nature/supplements/insights/exoplanets/index.html

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8. Technology Development for Exoplanet Missions - How Do TDEMs Work?

By Nick Siegler, NASA Jet Propulsion Laboratory
Program Technology Manager

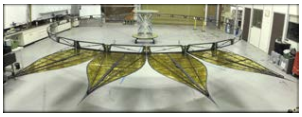
Before NASA decides to embark on an exciting space mission one of the questions it asks is "How certain is success?" Often that question is dependent on the maturity of the key technologies specific to that mission. In some cases, the technologies required have not yet even been invented! To help develop the exoplanet technologies NASA needs when they need them is a program called TDEM - Technology Development for Exoplanet Missions. This program identifies what NASA believes to be the areas of technology needing development and opens to the entire science community the opportunity to propose good ideas. These proposals are evaluated by an independent team of reviewers who rank the submissions in order of benefit to the exoplanet goals and feasibility. Depending on available funding, some number of the top proposals is selected.

A good example of how this process works is from NASA's quest to find life in the Universe. One of the key technologies is suppressing the bright light from a star so that we can see the reflected light from an orbiting nearby planet that is at least a billion times fainter! Back in 2009, NASA's Exoplanet Exploration Program made its first call for TDEM proposals and selected several to advance coronagraph and starshade technologies. Since that time selected proposals have focused on designing, fabricating, and demonstrating coronagraph masks and deformable mirrors. Others have developed starshade petals and deployment experiments. Thanks to that early foresight of its needs, these lab demonstrations are allowing exoplanet instruments to be ready for launch in the next decade.

For more information on past and current TDEM awardees and their reports please go to:

http://exep.jpl.nasa.gov/technology/

9. Starshade Deployment Testbed



By David Webb, NASA Jet Propulsion Laboratory
Starshade Mechanical Engineer

August 2014 brought the unveiling of the Starshade Deployment Testbed (SDT) at JPL. This testbed is meant to enable scientists and engineers to meet the challenging petal stowing and deployment requirements for a possible future Starshade mission. See a mission animation here...

The first sub-assembly test was the deployment of a 10m diameter expanding ring truss, to which the Starshade petals attach. Led by three early-career JPL engineers, the truss concept design began in February 2014 and involved a team of six interns and four student workers. By August, the truss concept with 4 of the design's 28 petals was ready for a functional deployment. The designing and building of this prototype provided the opportunity for these university students to be critical members in the flight path development of an exciting potential NASA mission.

This testbed, open to investigators from all institutions, will be a platform for advancing the technology readiness level of the many Starshade subsystems. These include the optical shield, petal stowing and unfurling system, and the many critical interfaces to the spacecraft.

This current development is already attracting attention, with the first powered deployment of the ring truss being filmed for an episode of the Science Channel program, "Strip the Cosmos," to air in November. Stay tuned.

10. 2014 Sagan Summer Workshop on YouTube!

By Dawn Gelino, Caltech
NASA Exoplanet Science Institute
Scientist & Task Lead, Science Affairs

At the end of July, NExScI hosted the 2014 Sagan Summer Workshop "Imaging Planets and Disks" on the Caltech campus. There were 150 participants in attendance from 13 different countries for this 15th, and second largest, of the Sagan/Michelson Summer Workshops. Workshop interactive features included attendee posters and oral pop presentations. In addition there were several hands-on sessions such as a competition to design your own mission, learning about multiple ways to reduce your imaging data to identify and characterize planets and disks, and a session to build your own coronagraph. All hands-on sessions made use of Amazon Web Cloud Computing Services. This is the second Sagan Workshop for which the Amazon Cloud has been used in this capacity. All presentations and electronic posters are available from the workshop website: http://nexsci.caltech.edu/workshop/2014.

You can also watch your favorite exoplanet YouTubers as they present the latest in exoplanet research! Videos of all of the science presentations from the 2014 Sagan Summer Workshop, "Imaging Planets and Disks," are now available on YouTube at the Sagan Exoplanet Summer Workshop channel. See http://goo.gl/AWNmw8.

11. On the Shoulders of Giants: Planets Beyond the Reach of Kepler

By Steve Unwin, NASA Jet Propulsion Laboratory
Program Deputy Chief Scientist

At the June 2014 Meeting of the American Astronomical Society, ExEP hosted a series of four science sessions motivated by this question: What kind of exoplanets lie at orbit radii of 1-2 AU - beyond the reach of Kepler? The session title derives from the famous quote from Isaac Newton in 1676: "If I have seen further it is by standing on the shoulders of giants," though the phrase has been

in use since the 12th century. In the current era, the Kepler mission has greatly advanced our understanding of exoplanets and allowed us to 'see further.' But because of its limited lifetime, Kepler's sampling of the planet population beyond about 1 AU is very incomplete.

Several techniques have been exploring this long-period orbit regime in the last two decades: we have a catalog of RV-detected planets, distant planets detected with microlensing, and several hot young planets at large radii from direct imaging, and imaging of the debris disks that provide clues to formation and evolution of exoplanets.

The sessions at the AAS Meeting covered these four topics:

- What we know today and what we would like to learn;
- Demographics of the exoplanet population, based on what we know from RV surveys, Kepler, and microlensing;
- Ground-based Imaging and Spectroscopy - direct observation of exoplanets with imaging and spectroscopy, and what we learn from debris-disks around planet-bearing stars;
- The Near Future - What we can expect to learn about this planet population in the near future, from ground and space based instruments.

The collection of 24 talks on these topics cover a broad sweep of current exoplanet research, presented by invited experts in the field. You can view PDFs of these presentations on the ExEP Presentations page.

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12. Introducing Sagan Fellow Jared Males

By Jared Males, University of Arizona
Sagan Fellow

Direct imaging is a key technology being developed to characterize habitable extrasolar planets. While taking a picture of an exo-Earth is out of reach with today's instruments, the latest adaptive optics (AO) systems are delivering performance good enough that we can begin looking for larger planets in the habitable zone (HZ). The goal of my research as a Sagan Fellow is to image Jupiter and Saturn sized planets in the HZs of nearby bright stars. The instrument I helped develop and am now using to search these nearby HZs is the Magellan AO system, or MagAO. MagAO has been used to image the exoplanet beta Pictoris b in the optical, discovered the planet HD 106906 b, and achieves 19 milli-arcsecond resolution at the wavelength of H-alpha.

You can find out more about MagAO and its infrared and visible-light imaging capabilities at http://visao.as.arizona.edu.

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13. Introducing Sagan Fellow Rebecca Martin

By Rebecca Martin, University of Colorado
Sagan Fellow

Planets are thought to form within a protoplanetary disc around young stars. Moons can form within a circumplanetary disc around giant planets. Thus, understanding angular momentum transport in these accretion discs is fundamental to explaining the formation of planetary and satellite systems and their survival after the disc has dispersed.

Most stars are found in binaries and thus it is important to understand the evolution of these systems. Recently, we found that if a disc is highly misaligned to the binary orbit, the disc may be unstable to large eccentricity and inclination oscillations (http://adsabs.harvard.edu/abs/2014arXiv1409.1226M). This is known as the Kozai-Lidov effect. We are now working to understand how this process affects the planetary systems that can form in binary star systems.

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14. 'Marvel'-ous Debut for Eyes on Exoplanets in Times Square

By Randal Jackson, NASA Jet Propulsion Laboratory
Program Internet Communications Manager

A new exhibit steeped in the cinematic world of "The Avengers" provides a super-powered dose of science and technology from NASA's Exoplanet Program. The unique, interactive educational display premiered at Discovery Times Square in New York City on May 30, 2014, for a six-month engagement.

NASA's Eyes on Exoplanets interactive is featured prominently in the Marvel Avengers S.T.A.T.I.O.N. - an acronym for Scientific Training and Tactical Intelligence Operative Network -- helping to place otherworldly content related to The Avengers' Thor into the context of real exoplanets.

While movie magic is the exhibit's main attraction, its developers approached JPL's visualization team to provide content that would enhance the authenticity of the experience and pique visitors' interest in real-world science and technology.

"Eyes" is powered by NASA's Exoplanet Archive and is available at http://eyes.jpl.nasa.gov/exoplanets/index.html. "Eyes on Exoplanets" was developed by the Visualization Technology Applications and Development group at JPL under sponsorship of the Exoplanet Exploration Program. More information about the exhibit is available at: http://stationexhibit.com.
