



Jet Propulsion Laboratory
California Institute of Technology

NASA's Exoplanet Exploration Program

Gary Blackwood, Program Manager

Nick Siegler, Program Chief Technologist

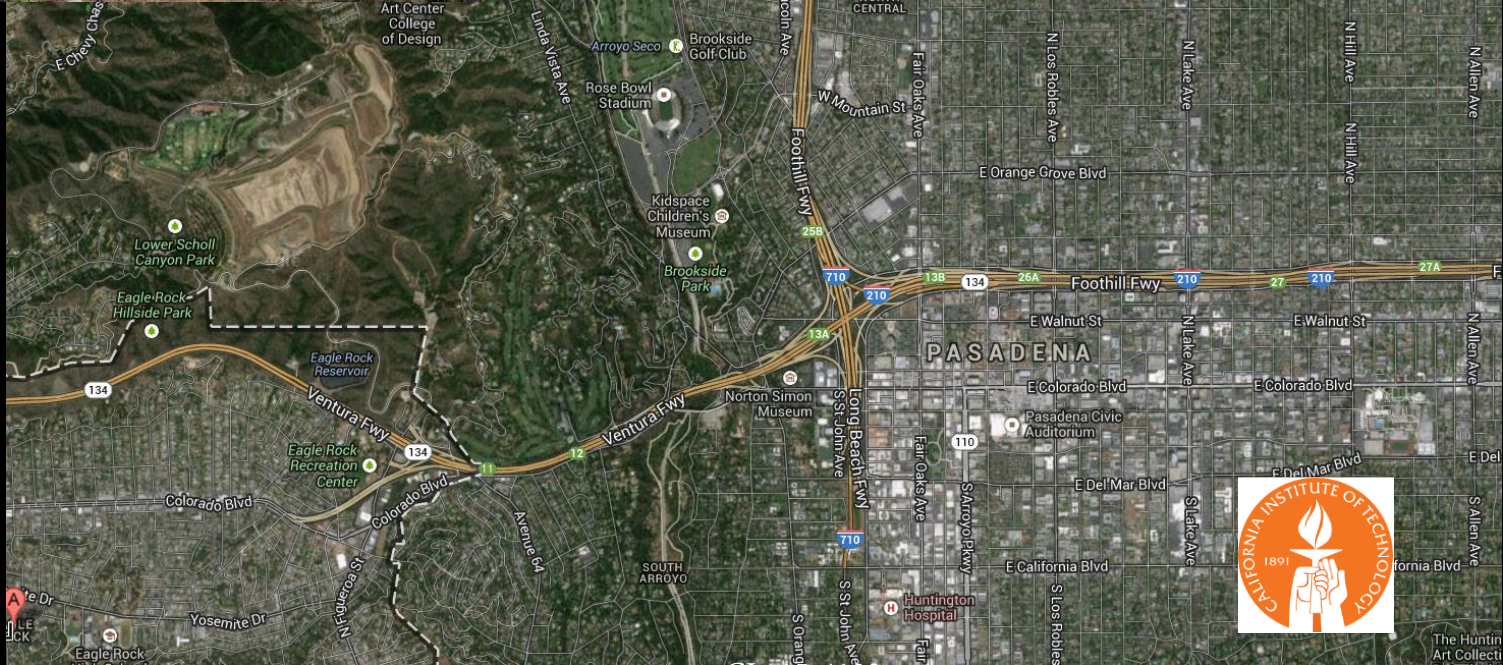
Ingolf Heinrichsen, Kepler & WFIRST Mission Manager

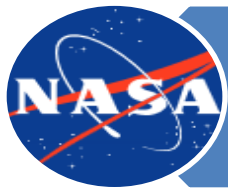
Phil Willems, LBTI & NN-Explore Project Manager

Ray Lemus, Program Business Manager

ExSoCal, September 24, 2015

California Institute of Technology, Pasadena CA





NASA
Government Agency for
Aeronautics, Space Exploration and Earth Science



Caltech
Educational Institution



Jet Propulsion Laboratory
Operating Division of Caltech;
Federally Funded Research & Development
Center

JPL has expertise in:

- Science
- Engineering
- Technology
- Programs/projects



NASA Exoplanet Exploration Program



Purpose described in 2014 NASA Science Plan

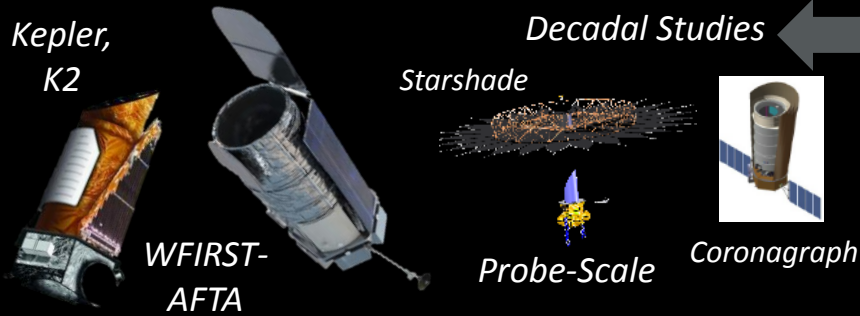
1. Discover planets around other stars
2. Characterize their properties
3. Identify candidates that could harbor life

The Search for Life in our Galaxy

ExEP serves the community and the science by implementing NASA's space science vision for exoplanets

NASA Exoplanet Exploration Program

Space Missions and Mission Studies



Public Engagement



Supporting Research & Technology

Key Sustaining Research



Large Binocular Telescope Interferometer

Keck Single Aperture Imaging and RV



NN-EXPLORE

Technology Development



Coronagraph Masks

High Contrast Imaging



Deployable Star Shades

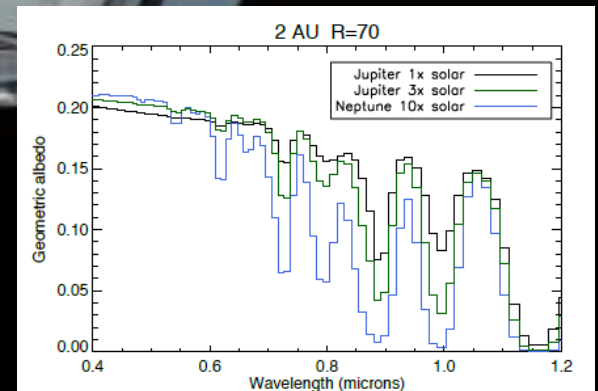
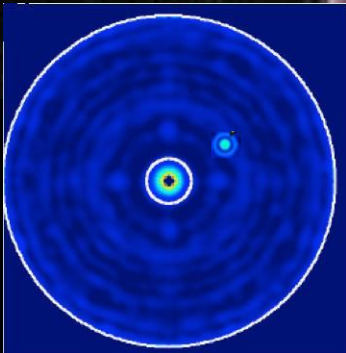
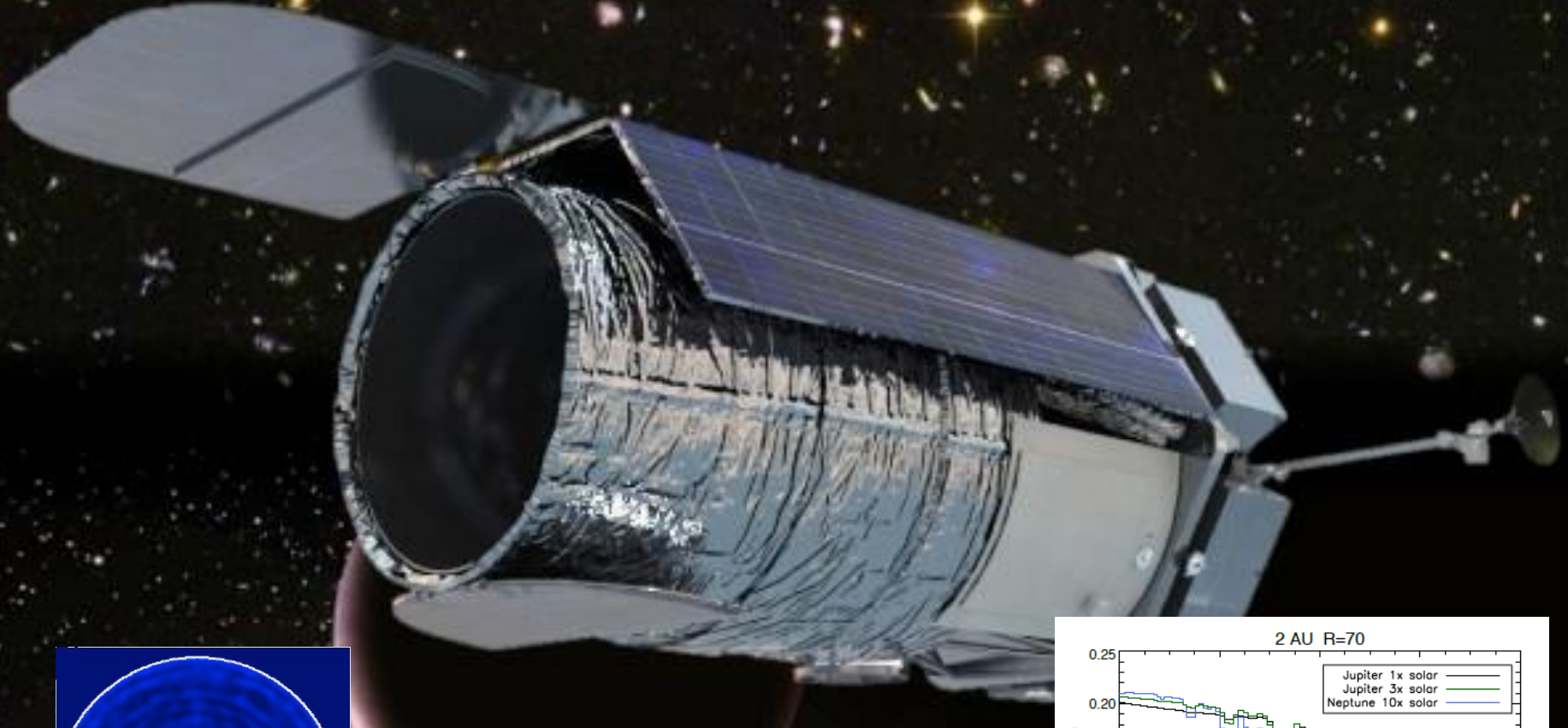
NASA Exoplanet Science Institute



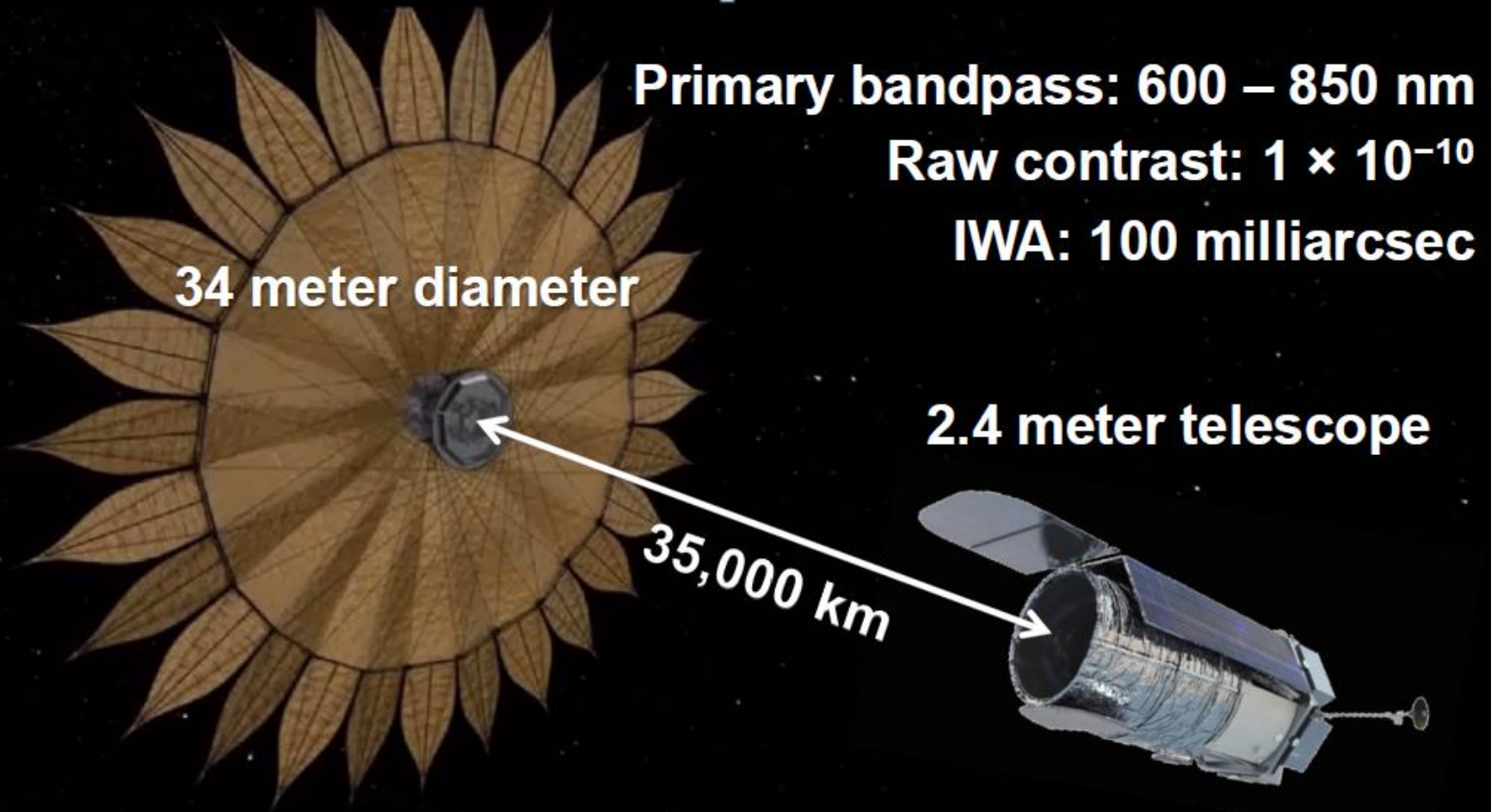
Archives, Tools, Sagan Fellowships, Professional Engagement

WFIRST / AFTA

Dark Energy, IR Survey, Exoplanet Census, Imaging and Spectroscopy

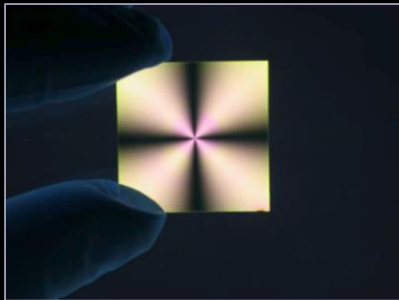


Starshade for a 2.4m telescope

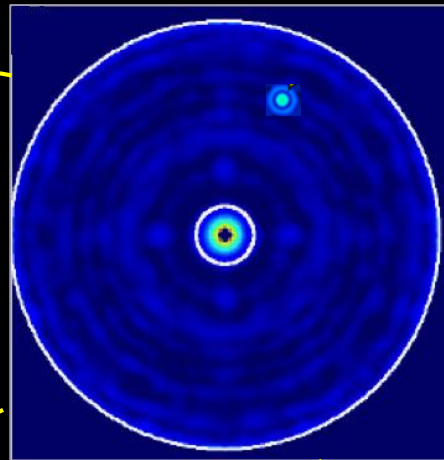


Technology Development for Coronagraphs

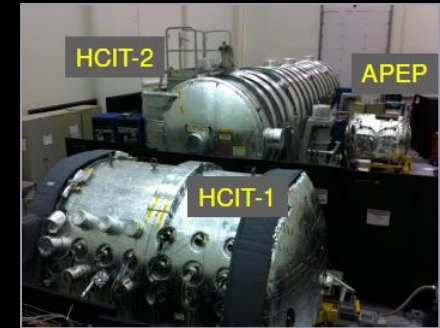
Occulting Masks/ Apodizers



Serabyn – Vector Vortex Mask

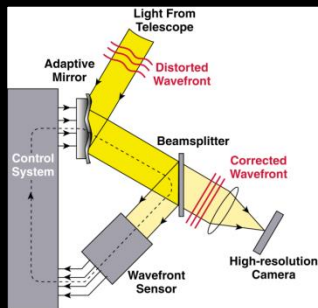


System Demonstration

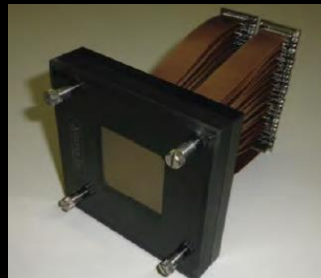


Jet Propulsion Laboratory

Low Order Wavefront Sensing and Control

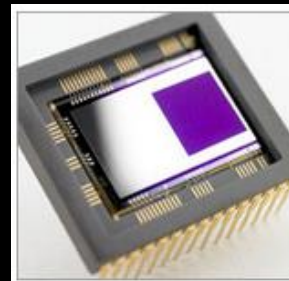


Deformable Mirrors



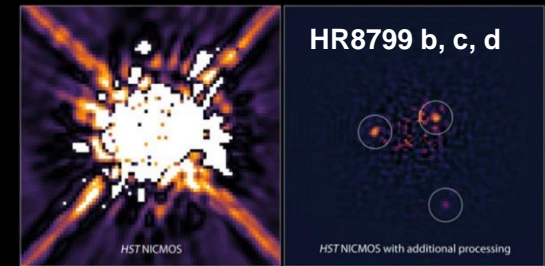
Xinetics

Ultra-Low-Noise Visible Detectors



e2v Electron Multiplying CCD
CL#15-4133

Image Post Processing

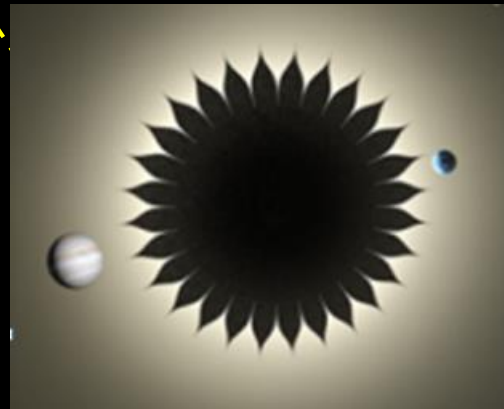
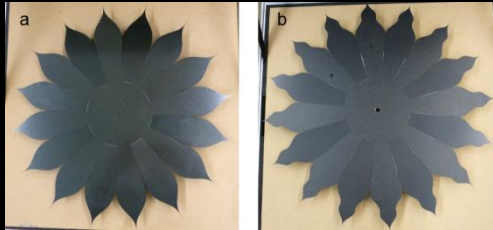


NASA, ESA, and R. Soummer (STScI)

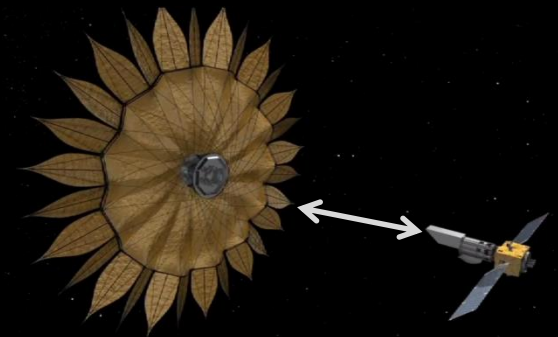
Soummer et al. 2011

Technology Development for Starshades (External Occulters)

Control of Scattered Light



Formation Flying



Validation of Optical Models



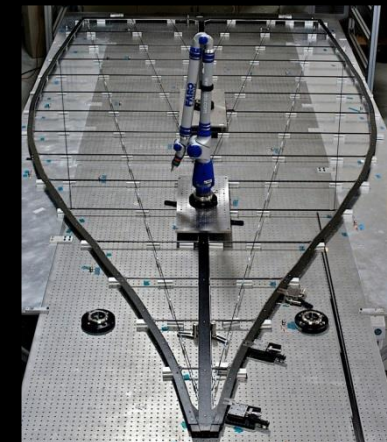
NGAS

Starshade Deployment



NGAS, Princeton, JPL CL#15-4133

Petal Prototype



Princeton, JPL

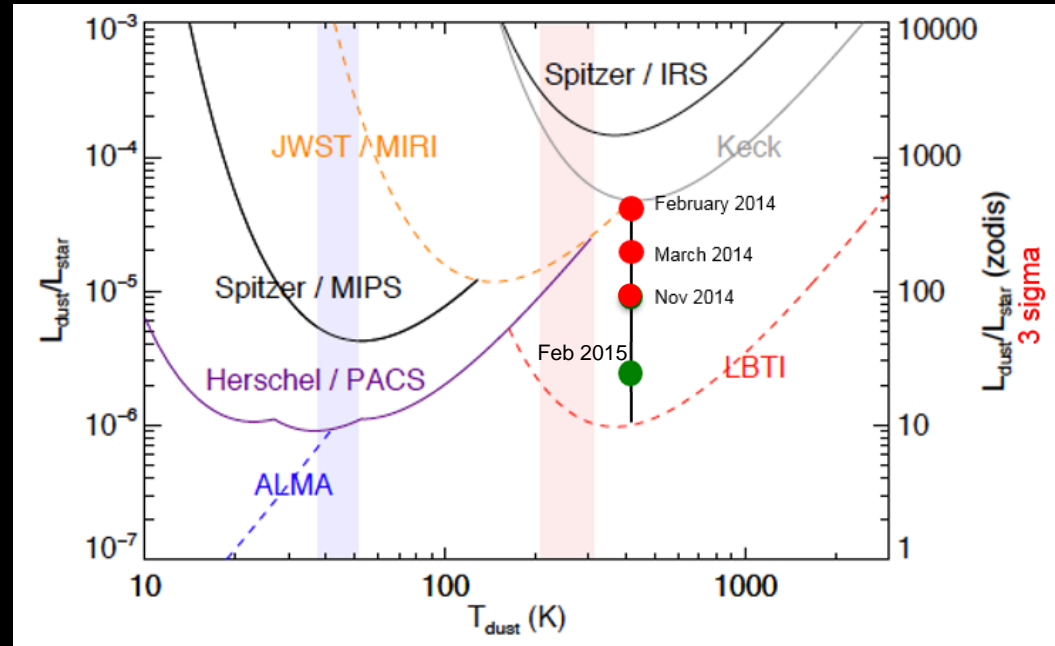
Large Binocular Telescope Interferometer

Measures exozodiacal dust in habitable zones

Phil Hinz, PI



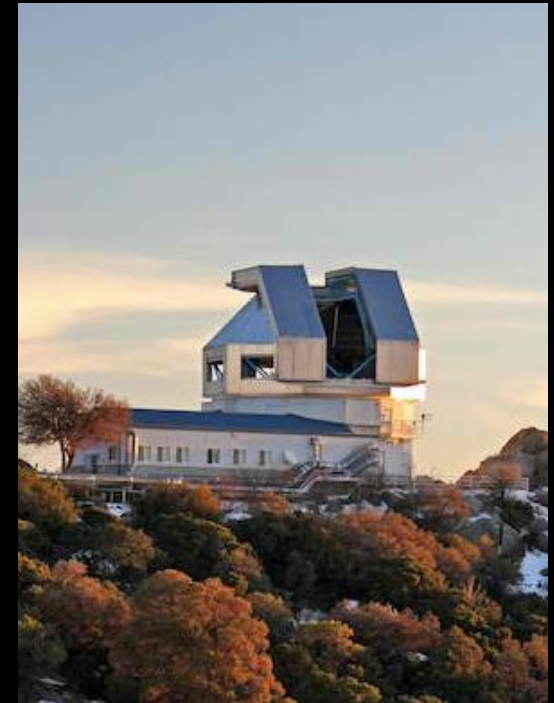
LBTI Performance



- Demonstrated 12 zodi sensitivity for a solar twin at 10 pc
- **Successfully completed Operational Readiness Review (ORR)** and now conducting Science Validation Phase
- Level 1 requirement: 3 zodi (baseline) and 6 zodi (threshold) on 50 stars
- LBTI nulling data available to public at <http://nexsci.caltech.edu/missions/LBTI/>



- **Scope:**
 - Exoplanet-targeted Guest Observer program with existing instrumentation on WIYN using NOAO share (40%) of telescope time
 - Facility-class extreme precision radial velocity spectrometer for WIYN telescope (commissioning plan: 2019)
- **Motivation**
 - Follow-up of current missions (K2, TESS, JWST)
 - Pathfinder observations inform design/operation of future missions



3.5m WIYN Telescope
Kitt Peak National Observatory
Arizona



Program Engages the Public

Many images and videos for education and engagement



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

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

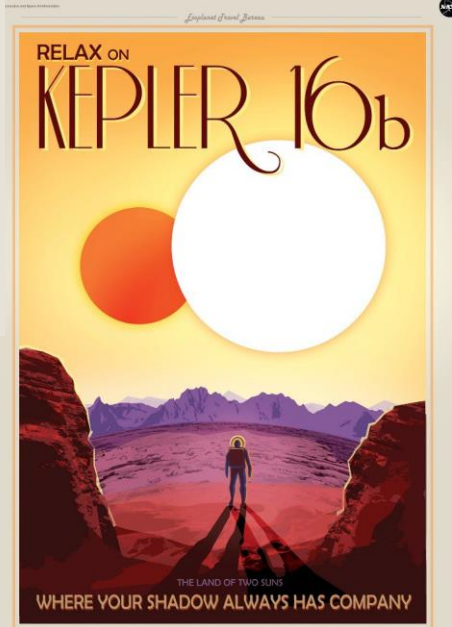
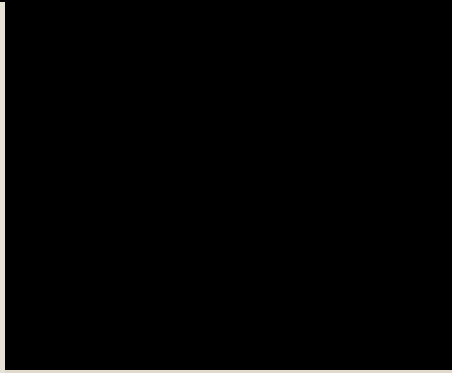


Where will exploration take us in 100 years? Introducing the *Exoplanet Travel Bureau*



The odd-angled it, it's super-odd. HD 40307 g is about twice the volume of Earth and eight times more massive, making it something in between a "super-Earth" and a "mini-Neptune". Planets in those categories were found in abundance by the Kepler mission, a serendipitous result that suggests our galaxy contains an abundance of small worlds. The "dwarf planet" Ceres, Saturn's Titan, and even the moons of our own planet are all well-established at this point, so the "dwarf planet" may be a realistic, as opposed to, a "mini-Neptune" world of gas and ice.

The Exoplanet Travel Bureau is a project of the NASA Exoplanet Exploration Program. Offer: www.nasa.gov/exoplanet



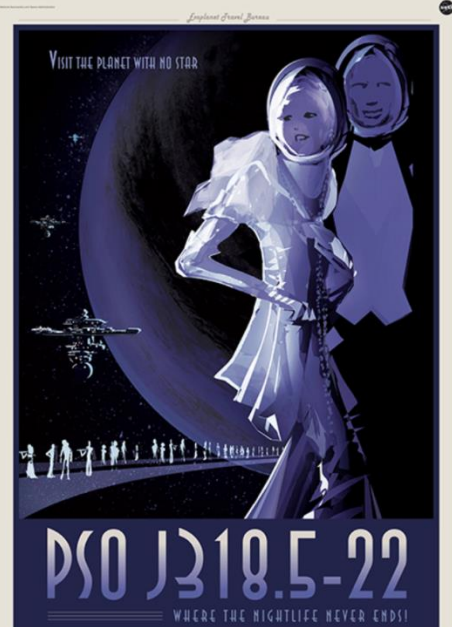
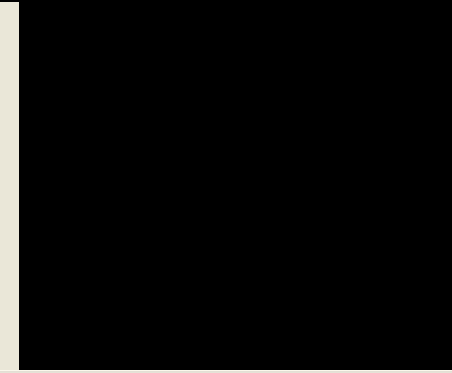
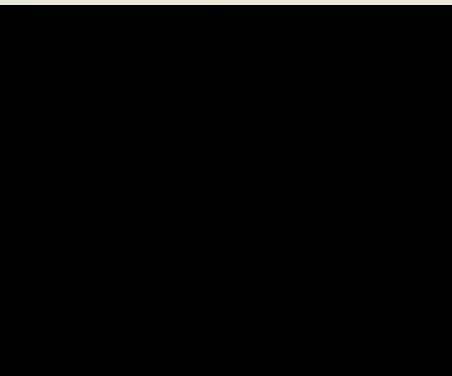
Like Linn, Kepler-16b is a rocky planet orbiting two stars. Kepler 16 is a pair of stars at a very close distance - about 3 times farther from the center of the star pair than the stars are from each other. Classified first as a terrestrial planet, Kepler 16 b might also be a gas giant like Saturn. Prospects for life on this unusual world aren't great, as there is water vapor in the star's day sky, but the discovery indicates that the moon's kinetic double-sunset is anything but science fiction.

The Exoplanet Travel Bureau is a project of the NASA Exoplanet Exploration Program. Offer: www.nasa.gov/exoplanet



Kepler 186 is the first Earth-size planet discovered in the galaxy. Unlike our planet and other stars, where liquid water could exist on the planet's surface. It has a rocky core and a water layer on top. Kepler 186 is also part of a planet the Kepler 186, the planet's surface could have been influenced by the star's red wavelength photons, making for a blue world that's very different from the planets on Earth.

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Discovered in October 2013 using direct imaging, PSO J318.5-22 belongs to a special class of planets called "free-floating planets," wandering alone in the galaxy. They do not orbit a parent star, but instead, it's thought they were once planets orbiting a star, but eventually got kicked out. They may be able to form stars or planets on their own, but they are still considered planets. These rogue planets are very hard to find, but they are out there. Only one other planet, they will be dancing in the dark. Confirmed and candidate exoplanets and all available data are listed in the NASA Exoplanet Archive.

The Exoplanet Travel Bureau is a project of the NASA Exoplanet Exploration Program. Offer: www.nasa.gov/exoplanet

Exoplanet Missions



W. M. Keck Observatory



Large Binocular
Telescope Interferometer



NN-EXPLORE

Ground Telescopes with NASA participation

CL#15-4133

¹ NASA/ESA Partnership

² CNES/ESA

Contacts and Opportunities

- Please visit us at exep.jpl.nasa.gov
- Come see us at JPL Open House – Oct 10, 11
- Get involved through ExoPAG (Program Analysis Group): Alan Boss (chair), Scott Gaudi (recent chair)
- Join us at lunch today:
 - Gary Blackwood, Program Manager
 - Nick Siegler, Program Chief Technologist
 - Ingolf Heinrichsen, Kepler & WFIRST Mission Manager
 - Phil Willems, LBTI & NN-Explore Project Manager
 - Ray Lemus, Program Business Manager



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National Aeronautics and
Space Administration

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California Institute of Technology
Pasadena, California

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 - University of Arizona
 - Northrop Grumman Aerospace Systems
 - National Optical Astronomy Observatory (NOAO)
<http://www.noao.edu/news/2015/pr1502.php>
 - Massachusetts Institute of Technology
 - Penn State University