Program Science Update

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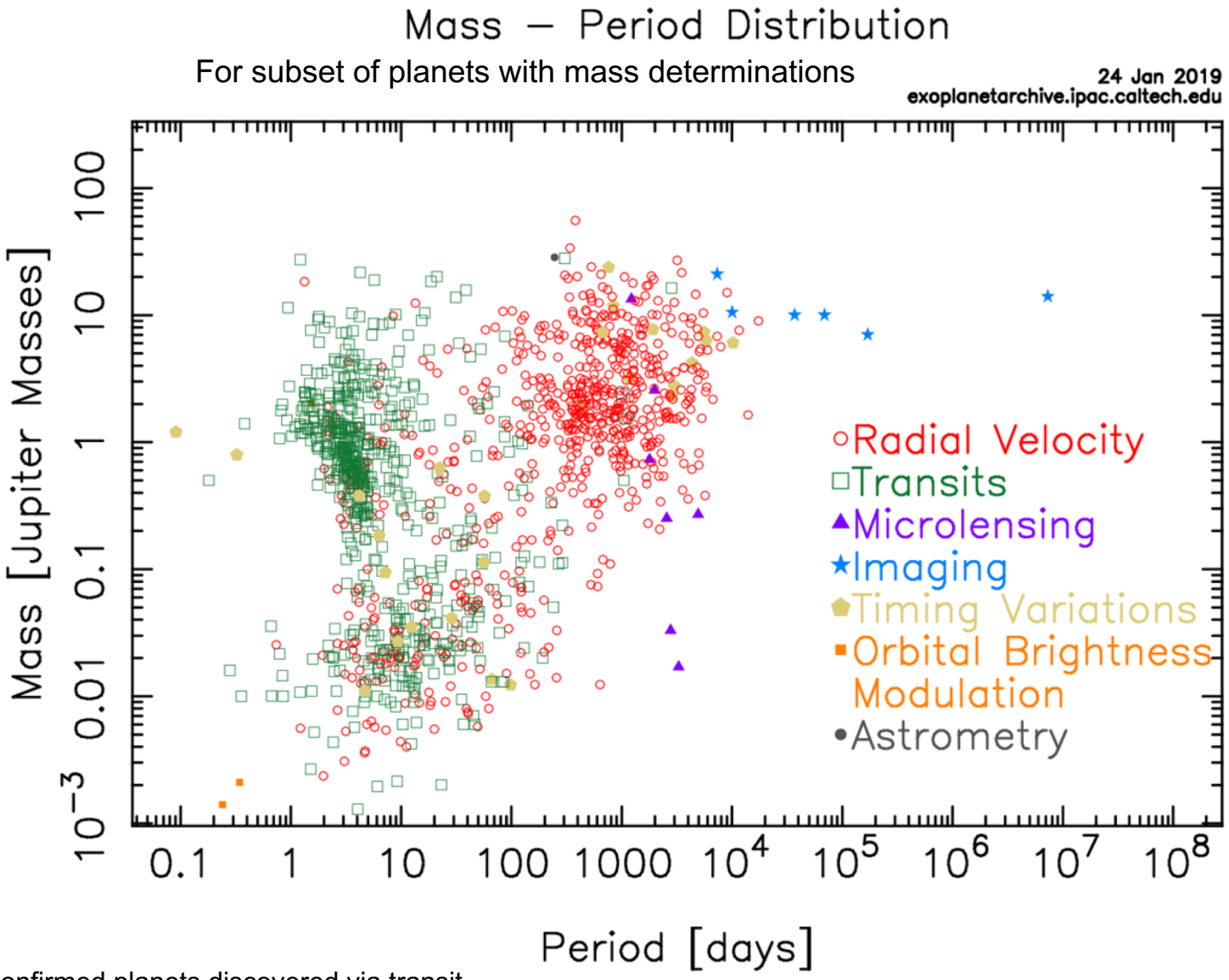
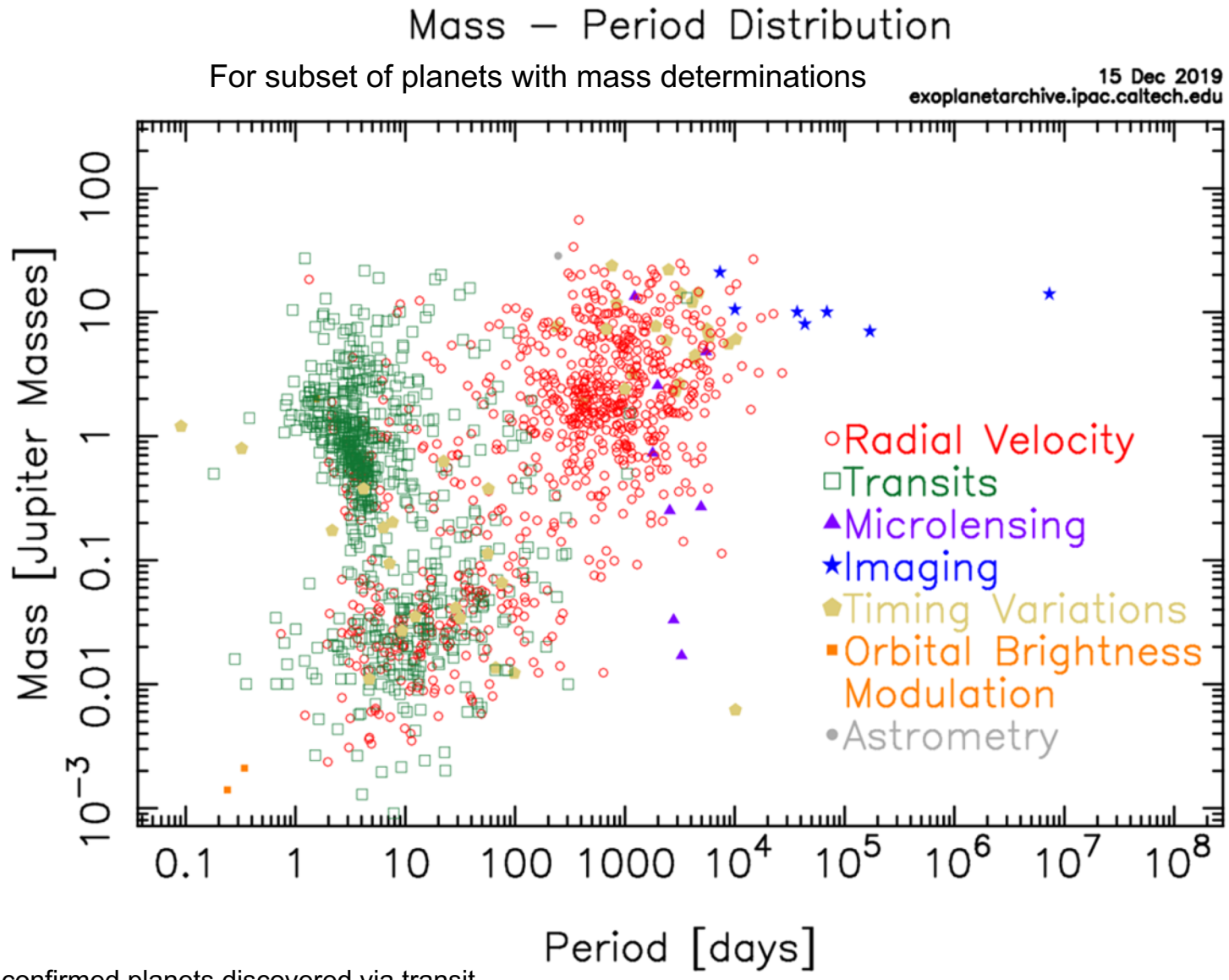
Confirmed Exoplanets from all methods



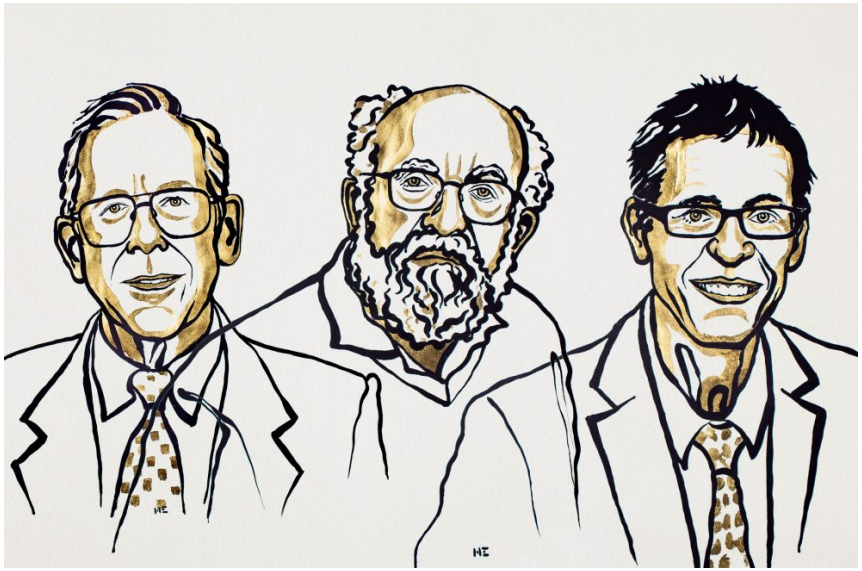
(~18% of confirmed planets discovered via transit method have measured masses w/uncertainties)

Confirmed Exoplanets from all methods



(~18% of confirmed planets discovered via transit method have measured masses w/uncertainties)

Exoplanet scientists share Nobel Prize in Physics



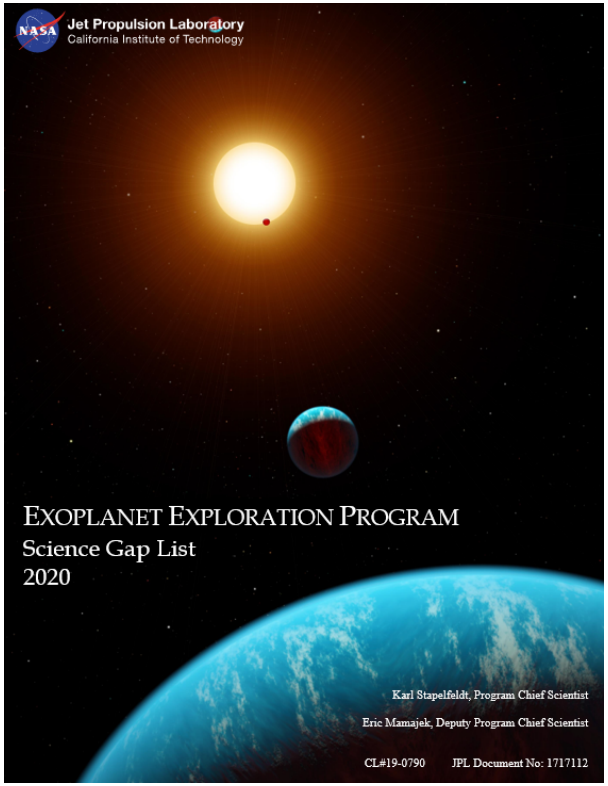
2019 Nobel Prize in Physics winners James Peebles, Michel Mayor, & Didier Queloz.

https://www.nobelprize.org/prizes/physics

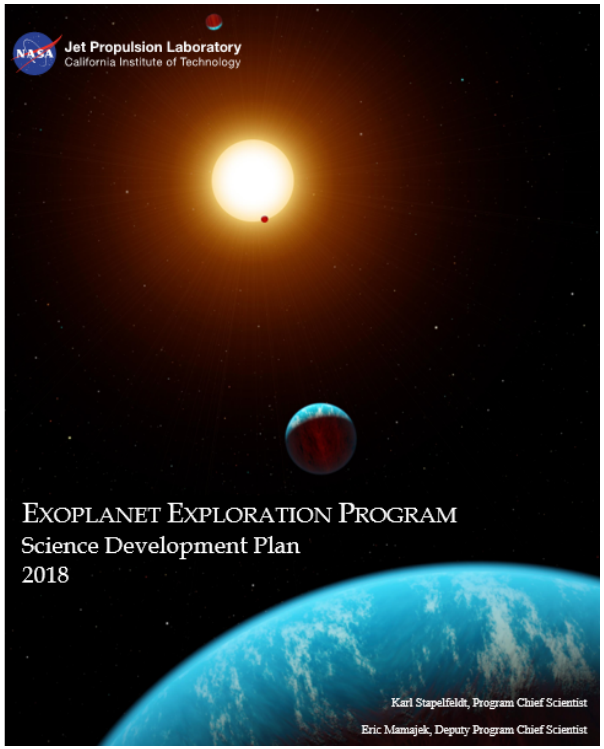
2019 Nobel Prize for Physics: James Peebles "*for theoretical discoveries in physical cosmology*" and Michel Mayor and Didier Queloz "*for the discovery of an exoplanet orbiting a solar-type star*". Mayor & Queloz advanced the Doppler spectroscopy technique of precision radial velocity, discovering 'hot Jupiter' 51 Peg b in 1995.

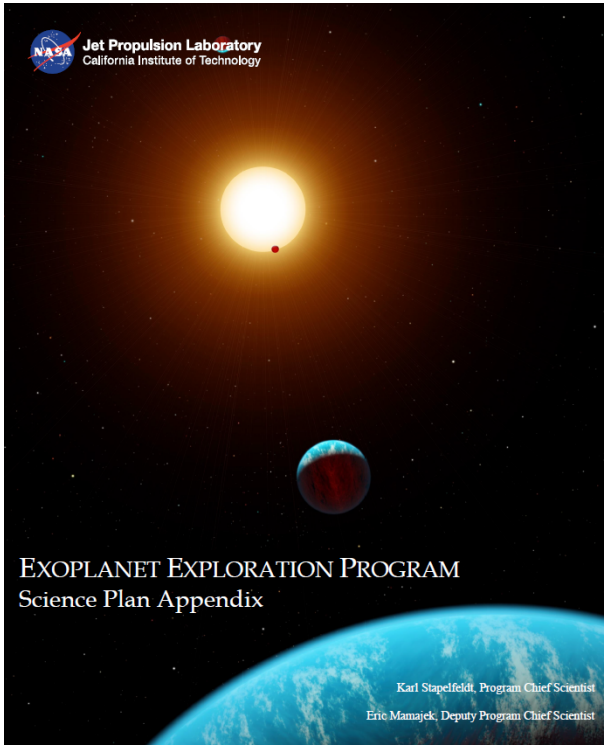
Queloz is now leading Terra Hunting Experiment to "*to discover Earth mass planets in Earth-like orbits around our nearest G and K-type dwarf stars*", and visited Penn State to tour NEID before it was shipped to Kitt Peak.

Three Exoplanet Program Science Plan documents



Authored by Program Chief Scientists
Stapelfeldt & Mamajek
Reviewed by ExoPAG EC and NASA HQ





Exoplanet Science Plan and Science Gap List

- The ExEP Science Plan has tactical scope for the implementation of science goals assigned to ExEP by NASA HQ and flowing from community policy documents. It now consists of
  - The **Science Gap List** (SGL) specifies areas where additional science work would advance Program goals
  - The **Science Development Plan** defines roles and relationships between exoplanet scientists at HQ, Program Office, ExEP Projects, NExScI, and ExoPAG. It also lays out the process for SGL updates.
  - The **Science Plan Appendix** provides background information on the state of the field, upcoming missions and facilities, and knowledge needed to inform ExEP objectives in five subdisciplines of exoplanet research. This longer document provides context for the SGL.
- Documents available at https://exoplanets.nasa.gov/science-overview
- The Science Plan documents are intended for use in proposal solicitation, writing, and evaluation

ExEP Science Gap List topics
(grouped by topic, no implied priority in ordering)

Spectral characterization of small exoplanets
Modeling exoplanet atmospheres
Spectral signature retrieval
Planetary system architectures
Occurrence rates for HZ exoplanets (e.g. $\eta_{\oplus}$)
Yield estimates for exoplanet direct imaging missions
Properties of exoplanet host stars
Mitigate stellar jitter as a limitation to exoplanet dynamical measurements
Dynamical confirmation of exoplanet candidates, determination of their masses & orbits
Precursor surveys of direct imaging targets
Understand the abundance and distribution of exozodiacal dust
Measurement of accurate transiting planet radii

2019 Revisions to the Science Gap List

- Community input on the 2018 SGL was solicited at the June 2019 ExoPAG meeting and by emails to the exopagannounce list, with a 3 month window for responses
- Program Chief Scientists held an October writing retreat to work on the gap list
  - Gap descriptions were updated to reflect research and programmatic progress, clarified in some cases, and revised to take into account the community inputs received
  - We felt that the community inputs could be adequately addressed by revising the gap descriptions without adding new gaps
- The revised gap list was completed just before the holidays. After HQ review the new version will be posted to the ExEP science website and advertised
- The same process & schedule will take place in 2020 and annually going forward
- In 2021 we will also update the Science Plan appendix to take into account the Decadal Survey recommendations and NASA's response (A new Astrophysics Implementation Plan)
- We welcome discussion of the ExEP Science Plan content at any time, please in touch with Karl.R.Stapelfeldt@jpl.nasa.gov & Eric.Mamajek@jpl.nasa.gov and/or approach us at meetings

Update on LBTI exozodi survey results

- λ= 10 μm nulling interferometer on the 2 x 8.4m Large Binocular Telescope
- HOSTS exozodi survey completed in May 2018 with 38 stars measured
- Ertel et al. final survey paper has been refereed, revised version will be submitted soon. Final results have changed since the 2018 interim paper
- Extended dust detected in 4 of 23 sun-like stars, at levels ≥ 150 zodis

- Best-fit distribution function now has median of 3 zodis, +1 σ level of 9 zodis, & 27 zodi upper limit at 95% confidence level [sun-like stars]
- Key implications: Future imaging missions can achieve their science goals against the nominal 3 zodi background. But uncertainty in the median affects the S/N and integration times for exoEarth spectroscopy, especially for smaller apertures such as WFIRST starshade rendezvous.
- HOSTS team working on several other papers, final meeting this summer

Should NASA invest in further work to reduce exozodi uncertainties ?

- Univ. of Arizona is studying potential upgrades to LBTI, will deliver a report to ExEP by March 2020. A potential "HOSTS II" survey ?
- More fully utilize ground-based near-IR interferometers for hot zodi studies ? (CHARA, VLTI)
- Might JWST's on-orbit performance be stable & calibratable enough to detect exozodi spectroscopically in the mid-IR ?
- WFIRST coronagraph Project & community teams have agreed to do a study of CGI's potential capabilities for an exozodi survey. Possible science program for after the tech demo ?
  - Two effects: detect scattered light extended outside IWA, and contrast floor degradation due to extended source inside the IWA
- Thermal-IR coronagraphy with ELTs ?
- ExoPAG input on these questions would be very helpful !

Target lists for Direct Imaging Missions

- There are multiple working target lists in the community (Stark, Savransky, Morgan, etc. … even back to the days of TPF)
- Led by Eric Mamajek, the new EPRV working group has been building from and improving on these to make a new list
  - Careful attention is paid to rotation and activity indices that will affect the achievable RV precision for these stars
- Working with ExoPAG, ExEP Chief Scientists plan to deliver a new "Mission Stars" list for hosting at NExScI, to provide a focus for precursor observations in the 2020s
- (Josh Pepper)^2 is proposing an ExoPAG finding noting the value of research & archiving work on direct imaging targets, to be discussed at the business meeting tomorrow

NASA role in ground based high contrast imaging ?

- The 2018 NAS Astrobiology Science Strategy recommended only two actions for NASA Astrophysics. One of these is *"NASA should implement high-contrast starlight suppression technologies in near-term space- and ground-based direct imaging missions"*
- ExEP is seeking input from the groundbased HCI community on specific ways NASA might support their work, keeping in mind that a strong connection to space mission technology and/or science support is needed.
- A discussion on this topic took place at the November meeting of the UC Center for Adaptive Optics. A short summary with three suggestions was captured by ExoPAG EC member Becky Jensen-Clem and provided to ExEP (Thanks !!). Next steps are to seek broader community input on the possibilities, followed by ExEP internal discussions of what NASA APD might want to do.
- Discussion of this topic by the full ExoPAG would be very helpful, or please approach ExEP staff here in Honolulu with your thoughts on this.

REQUEST FOR INFORMATION ON RESEARCH THAT FALLS IN A GAP BETWEEN CURRENT SMD SOLICITATIONS

- The NASA Science Mission Directorate is soliciting information on research that is aligned with the agency mission and SMD's Science Plan but falls in a gap between current solicitations, possibly because it is interdisciplinary or interdivisional. Responses to this Request for Information (RFI) will be used by NASA to inform a decision as to whether the portfolio of current program elements in the Research Opportunities for Space and Earth Science (ROSES) needs to be modified and/or expanded to provide the proper avenue for such research.
- Response due Date: Jan 31, 2020

- As one of NASA's most interdisciplinary science areas, exoplanet research seems likely to benefit by responding to this RFI. ExoPAG members should consider possible responses here and during AAS week, and ideally coalesce around one or more submissions.

NExScI Highlights

Dawn Gelino, Deputy Director
David Ciardi, Chief Scientist

Honolulu AAS/ExoPAG

January 2020

NExScI Highlights-Community Support

- **Sagan Program**
  - Held largest Summer Workshop:
    Astrobiology for Astronomers
    - 231 registered participants (including on-line viewers)
    - Hands-on sessions and demonstrations
  - Next Workshop is 20th Anniversary on Extreme Precision RV in July 2020
  - Supported NASA Hubble Fellowship program with selection of 6 Sagan (exoplanet) fellows in 2019 and 1st NHFP Fellows Symposium
- **Keck Observatory**
  - Supported 2019B-2020A proposal calls with ~3-4:1 oversubscription
  - Strategic science & mission support for WFIRST, Kepler/K2, TESS, JWST, Spitzer
  - Make pipeline tool available for analysis of radial velocity data from Keck/HIRES
- **Community Outreach**
  - Performed science outreach and advertised available resources at AAS, DPS, social media, email notifications, etc
  - Supported external conferences (PRV Hack-A-Thon, Kepler 10th, TESS Conference)
  - In FY20: Exoplanets in Our Backyard, Penn State SETI Workshop, ExSoCal

NExScI Highlights- Exoplanet Archive

- Exoplanet Archive includes 4104 confirmed planets w/37 from TESS
- Users Panel (Josh Pepper, chair) met in September 2019 to discuss implementation and long term goals for Exoplanet Archive and ExoFOP.
- User Survey: at NExScI Booth and https://www.surveymonkey.com/r/nasaexoplanetarchive
- Dedicated Table of Direct Imaging Detections coming in February and undergoing data validation

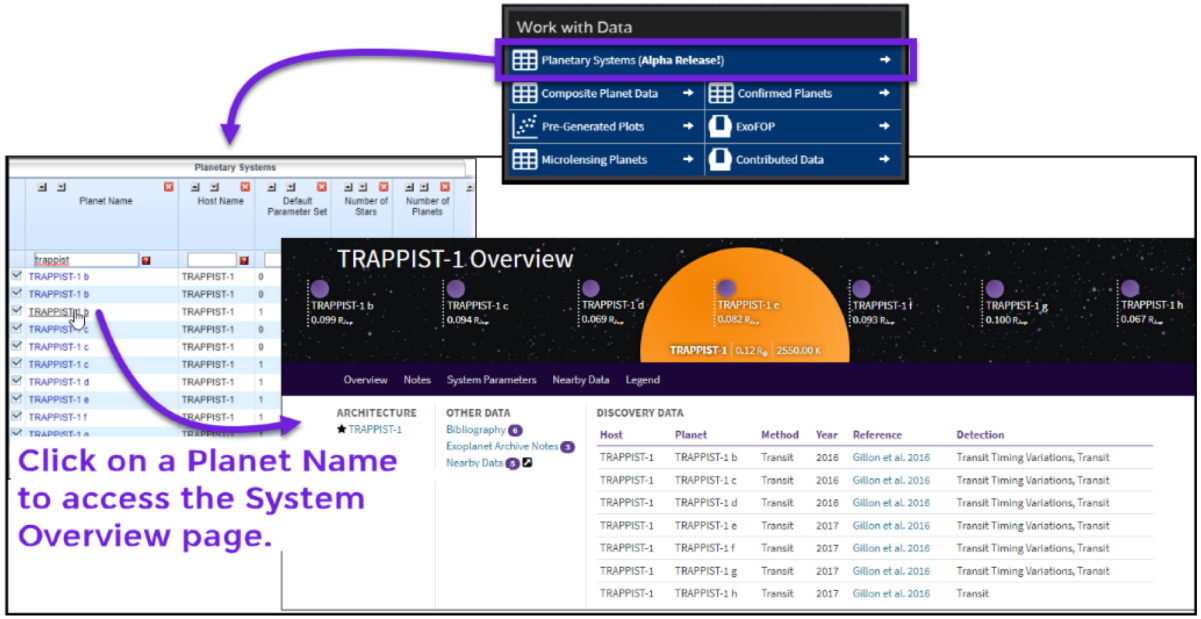
Direct Imaging

Planet Name	RA [sexagesimal]	Dec [sexagesimal]	Delta mag H-band (planet-host) [mag]	Projected separation star-planet [arcsec]	Projected separation star-planet [AU]	Position angle star-planet [deg]
51 Eri b	04:37:36.13	-02:28:24.8	14.43±0.194	0.449±0.007	13.2±0.2	170.4±3.0
51 Eri b	04:37:36.13	-02:28:24.8	14.43±0.227	0.449±0.007	13.2±0.2	
51 Eri b	04:37:36.13	-02:28:24.8	14.43±0.19	0.449±0.007	13.2±0.2	171.1±0.9
51 Eri b	04:37:36.13	-02:28:24.8		0.453±0.006	13.2±0.2	170.7±1.0
51 Eri b	04:37:36.13	-02:28:24.8	14.50±0.34	0.461±0.007	13.2±0.2	170.6±0.9
51 Eri b	04:37:36.13	-02:28:24.8		0.461±0.024	13.2±0.2	170.4±3.0
HIP 65426 b	13:24:36.10	-51:30:16.1	11.14±0.05	0.830±0.003	92.5±3.8	150±0.3
HIP 65426 b	13:24:36.10	-51:30:16.1	11.14±0.05	0.830±0	.5±3.8	150±0.3
HIP 65426 b	13:24:36.10	-51:30:16.1	11.14±0.05	0.830±0.003	92.5±3.8	150±0.3
HIP 65426 b	13:24:36.10	-51:30:16.1	11.14±0.05	0.830±0.003	92.5±3.8	150±0.3
HIP 65426 b	13:24:36.10	-51:30:16.1	11.14±0.05	0.830±0.003	92.5±3.8	150±0.3
HIP 65426 b	13:24:36.10	-51:30:16.1	11.14±0.05	0.830±0.003	92.5±3.8	150±0.3

HIP 65426 b

NASA Exoplanet Archive: Some Updates

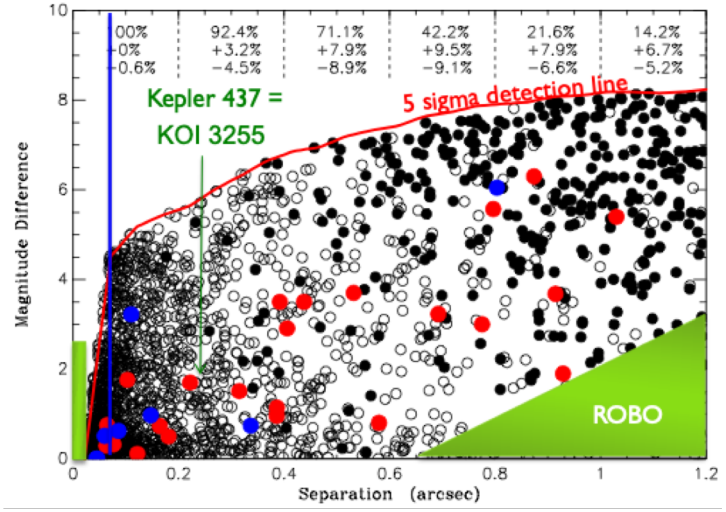
- New Planetary Systems Table (Alpha) Released
  - All Planetary Solutions for all systems in one table
  - Matched Stellar Solutions and Planetary Solutions per planet per solution
  - Added Orbit Obliquity
  - Adding TAP interface this month for API access
- New Overviews (Alpha) Released
  - All information about a system available/linked from one page
  - Added ability to handle complex Stellar multiplicity
- Confirmed Planets and Extended Planets table and Old Overviews to be phased out over the next 6 months after testing and validation (help us test and validate!)



NExScI Highlights-New Data Opportunities

- Partner with NN-EXPLORE
  - Provide pipeline operations and archiving for NEID PRV instrument
  - Provide Southern PRV access with CHIRON & AAT/VELOCE in 2020, perhaps also Minerva-South (under discussion)
- Support new NASA program to obtain speckle and near-infrared AO imaging of nearby stars to support TESS and advance of HABEX/LUVOIR
  - More sensitive than Robo-AO over wide range of separations.
  - More time available compared to HST (blue bar) or CHARA (green bar)
  - Optical + NIR enables determination of "boundedness" for any detected companions

Avi Shporer is first AAT/Veloce guest observer using remote facility at NExScI



Speckle imaging searches for companions within 1" of bright stars

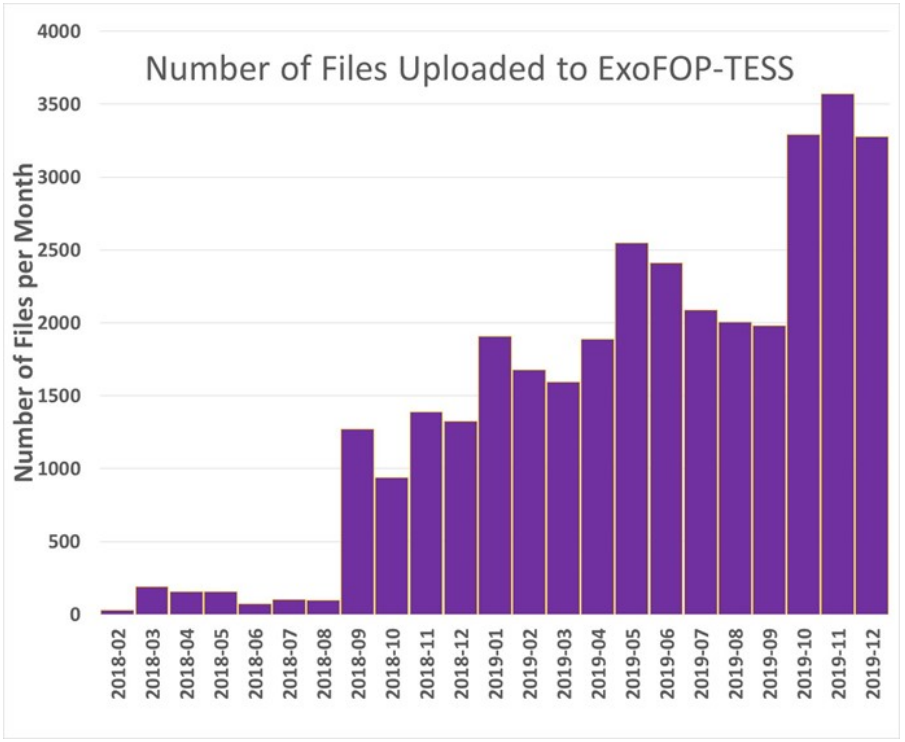
Speckle survey opportunity

Contact steve.b.howell@nasa.gov to get started

- Steve Howell's group at NASA Ames is funded to support community speckle interferometry observations
- Purpose: deblend host stars of transiting exoplanets so that reliable planetary radii can be derived
- Observations performed for the community and reduced data provided back to the proposer. 100s of targets can be observed in a single night.
- Instruments deployed to Gemini N, Gemini S and WIYN can resolve blends down to diffraction limit and $\Delta V \sim 6$ mag
- Get in touch with Steve to either
  1. Have him add your small target set to his run
  2. Well before the deadline, secure his assistance in preparing your own PI proposal for a large target set

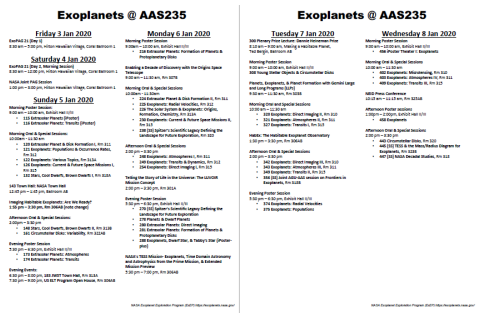
ExoFOP-TESS: Some Updates

- Integral part of the TESS Follow-Up Observation Program
  - 1588 TOIs and 282 Community TOIs (13 adopted as TOIs)
  - 33000+ files uploaded by the TFOP WG (and others)
  - 6000+ observations recorded by the TFOP WG (and others)
- 82 refereed papers citing ExoFOP, incl 66 for Kepler/K2, 18 for TESS
- myTarget functionality released: enables on demand updates for any TIC
- Search page for TOI content currently in testing.



What's Coming Up

- AAS splinter sessions relevant to ExoPAG:
  - Imaging Habitable Exoplanets, Sunday 1:55-3:30 PM in 305AB
  - Large mission concept studies:
    - Origins Space Telescope, Monday 9-11:30 AM in 307B
    - LUVOIR., Monday 2-3:30 PM in 301A
    - HabEx, Tuesday 1:30-3:30 PM in 306AB
  - NASA's TESS Mission, Monday 5:30-7:00 PM in 306AB



- Upcoming conferences
  - Exoplanets in our Backyard, Feb. 5-7 in Houston TX
  - 24th International Microlensing Conference, Feb. 17-19 in Beijing China
  - Towards Other Earths III, June 1-5 in Lamego Portugal
  - ExoPAG 22 meeting, Sunday July 19 in Pasadena CA
  - Sagan Summer Workshop on Extreme Precision Radial Velocity, July 20-24 in Pasadena CA

Follow NASA Exoplanet Exploration Activities

- Exoplanet Exploration Program public website:

  https://exoplanets.nasa.gov

- ExEP website for the scientific community:

  https://exoplanets.nasa.gov/exep

  Includes dedicated areas for ExoPAG, ongoing technology work, science planning, and a document archive of prior studies & reports

- NASA Exoplanet Science Institute with the NASA Exoplanet Archive:

  https://nexsci.caltech.edu

Sign up for the ExoPAG mailing list:
https://exoplanets.nasa.gov/exep/exopag/announcementList/
(almost 650 current subscribers)