SAG17 Update: Community Resources Needed For K2 And TESS Planetary Candidate Confirmation

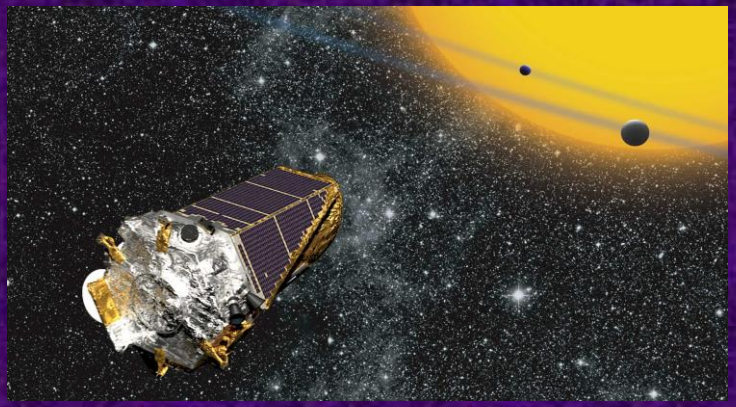
David R. Ciardi – NExScI/Caltech

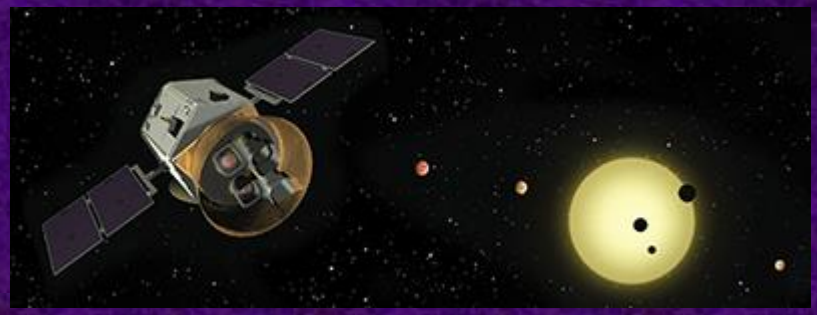
Joshua Pepper – Lehigh

Knicole Colon – NASA Goddard

Stephen Kane – SFSU

2017 June 18

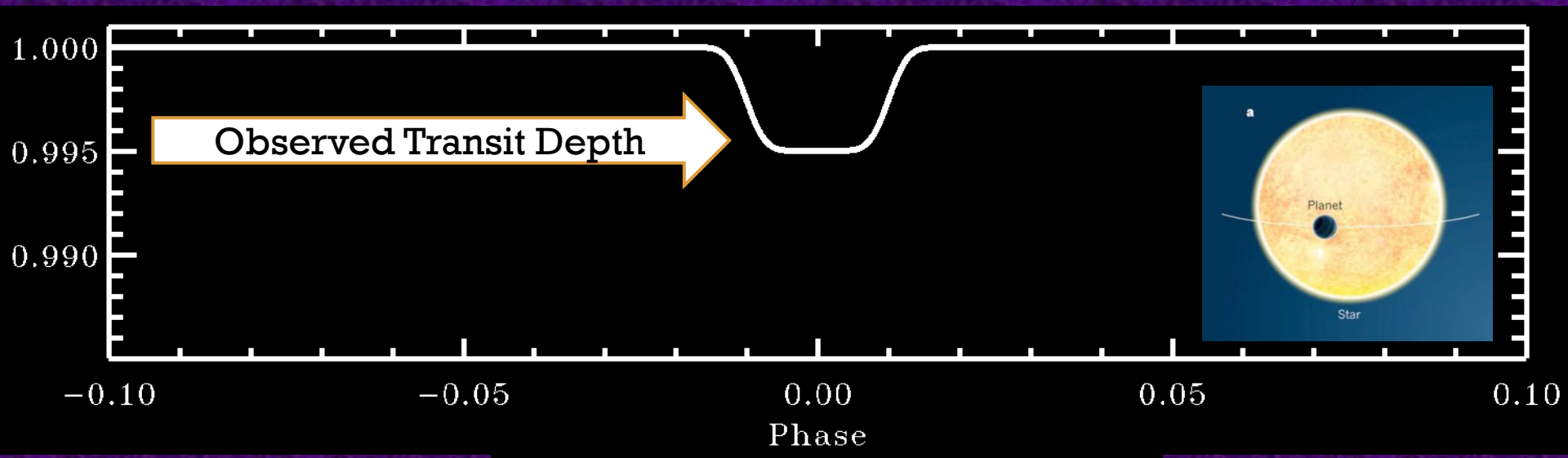




SAG17 Charter

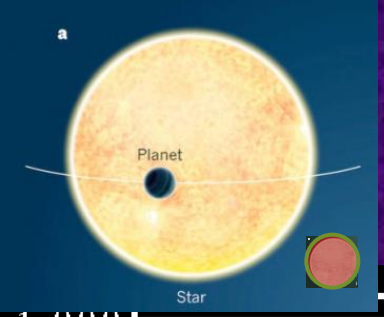
- Identify needed follow-up observations for K2 and TESS
  - Imaging: Seeing-limited and High Spatial resolution
  - Spectroscopy: Stellar parameters and radial velocity
  - Photometric Time – series
- Identify resources available to the US community
  - Telescopes and Instruments (space and ground)
  - Estimate available time
  - Financial
- Identify how archival resources can be utilized (e.g., Gaia)
- Identify how the community and resources can be organized
  - TESS FFIs analyzed, candidates identified, and candidates prioritized
  - Community communication – lessons learned from Kepler and K2
- Identify needs to ensure efficient and effective characterization with JWST (and WFIRST)
- Identify connections to other SAG efforts (e.g., SAGs 15 and 16)
- Identify synergies of resources with non-exoplanet science

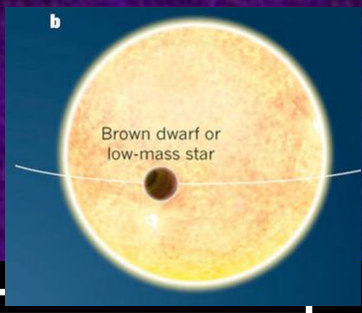
Transits Only Yield Derived Radii

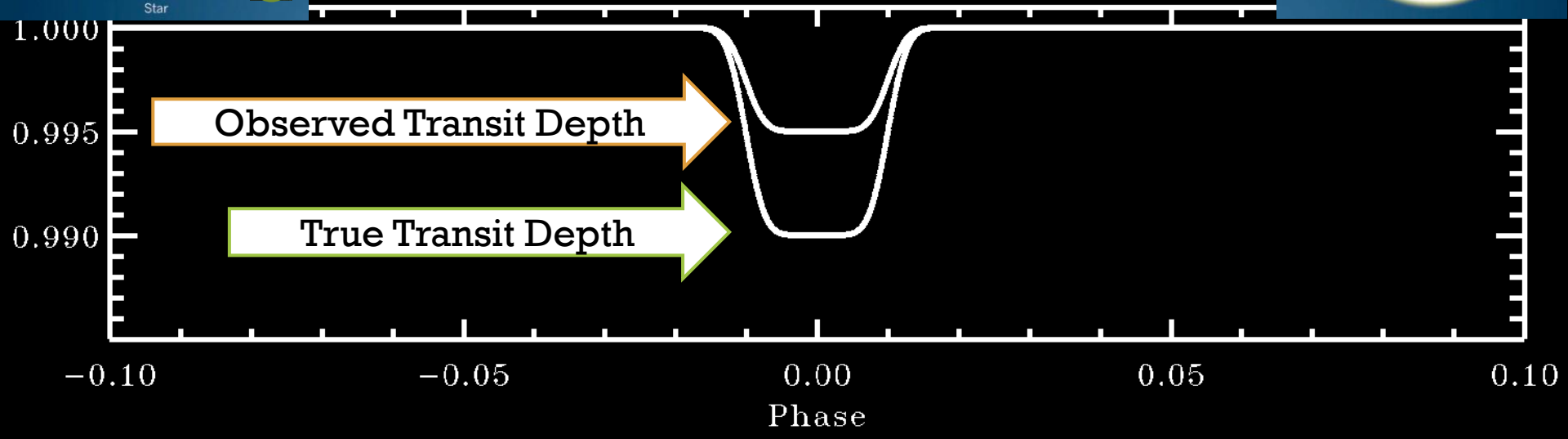


$$\delta_o = \left(\frac{R_p}{R_{t\star}} \right)^2$$

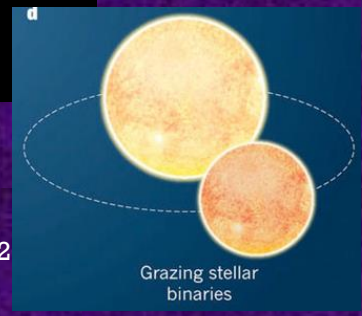
But Mimics Abound



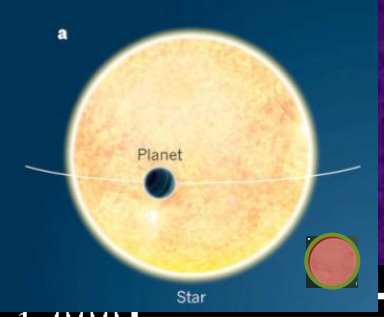


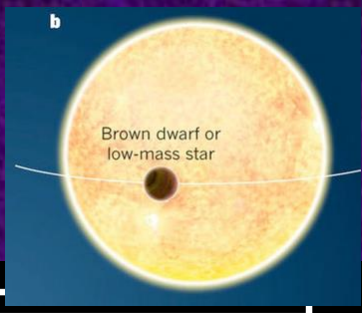


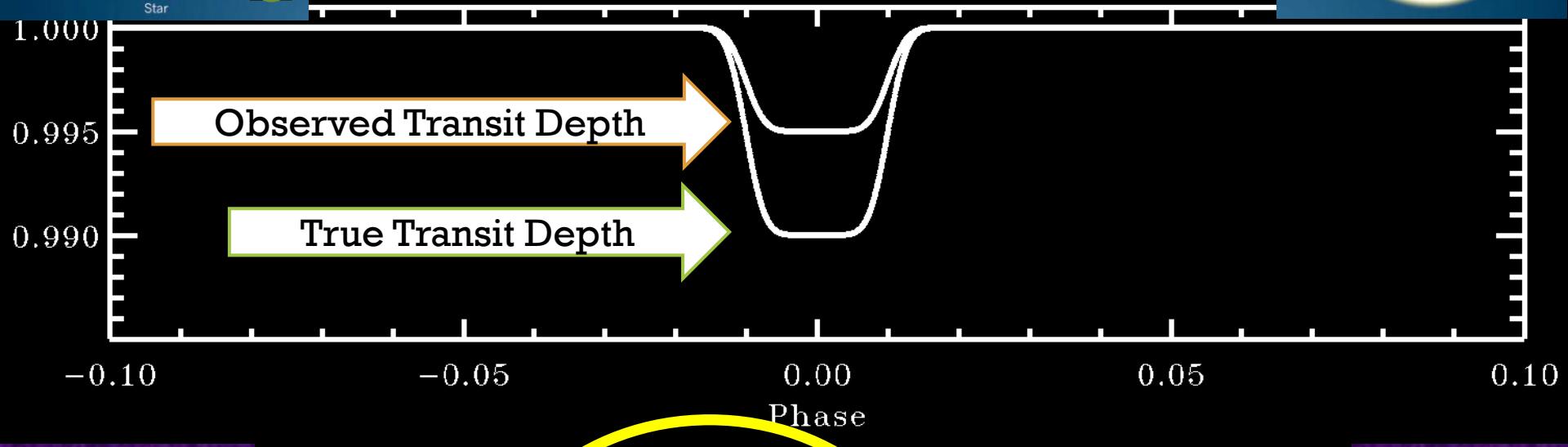
$$\delta_o = \left(\frac{F_t}{F_{total}}\right)\left(\frac{R_p}{R_{t\star}}\right)^2$$



Accurate Radii Require Accurate Stellar Radii *AND* Flux Dilution







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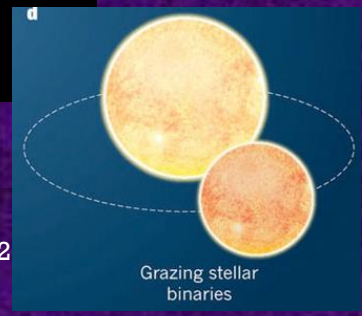
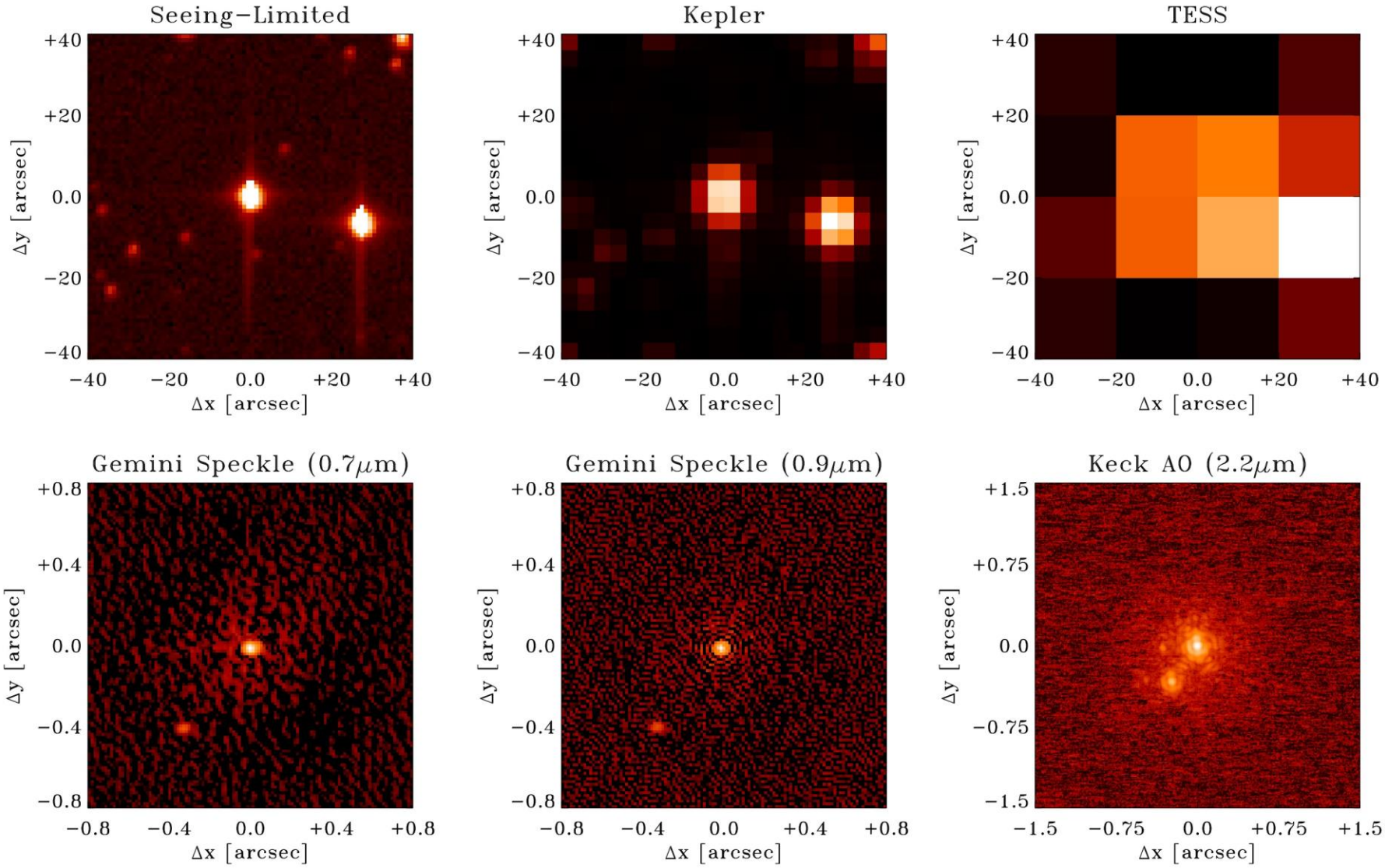


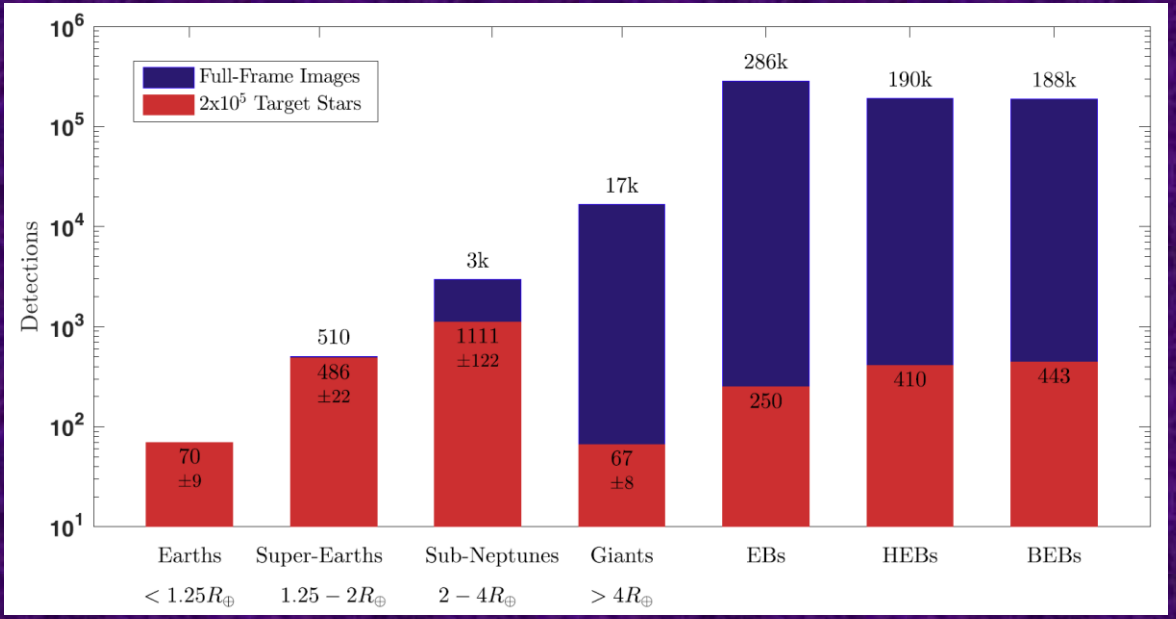

Seeing−Limited
Kepler
TESS
Gemini Speckle (0.7μm)
Gemini Speckle (0.9μm)
Keck AO (2.2μm)
Δx [arcsec]
Δy [arcsec]
+40
+20
0.0
−20
−40
+0.8
+0.4
−0.4
−0.8
+1.5
+0.75
−0.75
−1.5

Observations Necessary for Validation

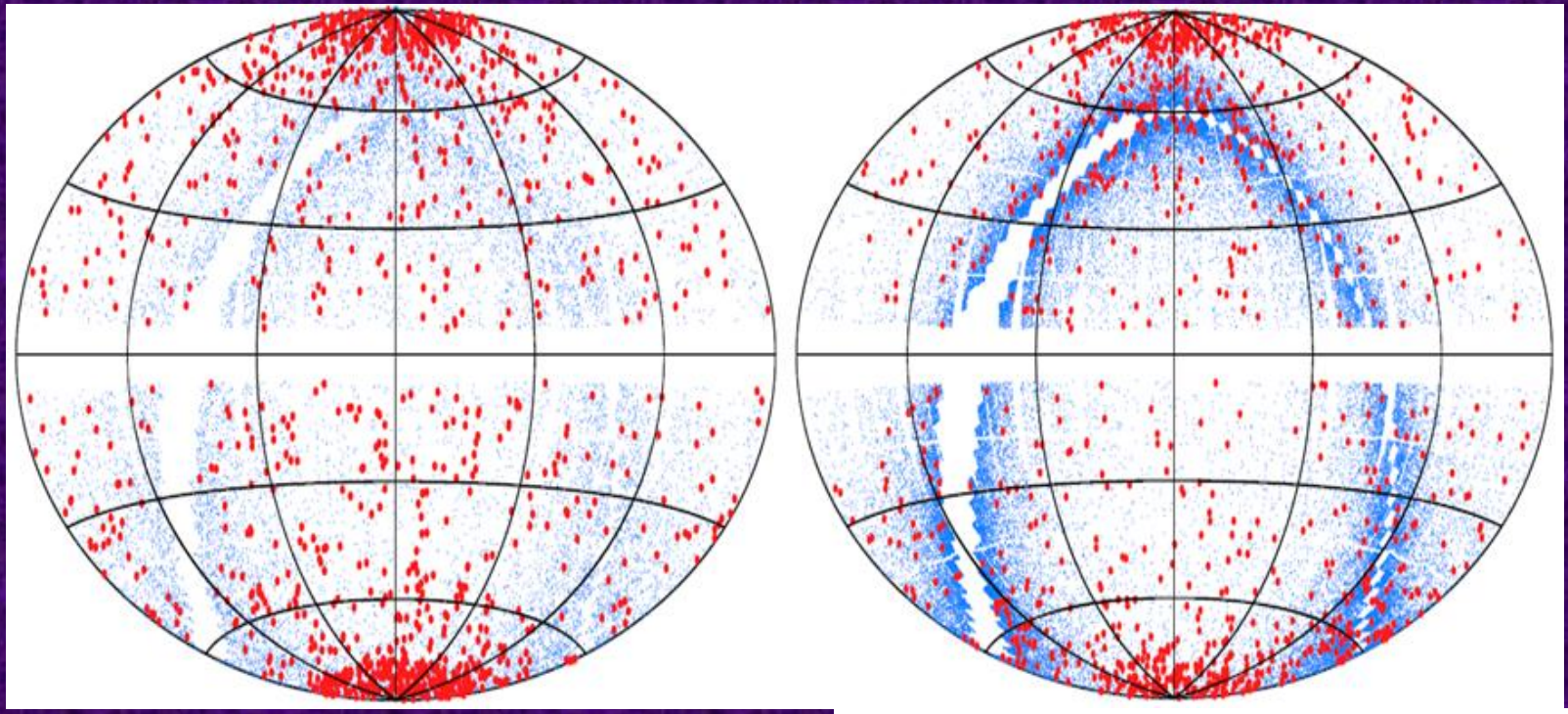
- Seeing-Limited Time Series Imaging
  - Identify and characterize blended nearby eclipsing binaries (multi-epoch)
  - Characterize the flux dilution (single-epoch)
- Spectroscopy
  - Stellar Characterization (single-epoch)
  - Radial velocity vetting (multi-epoch)
- High Resolution Imaging
  - Identify and characterize close-in bound companions (single-epoch)
- High Precision Radial Velocity
  - Planet masses (multi-epoch)
  - Orbits (multi-epoch)
  - Non-transiting planets (multi-epoch)

Number of Candidates

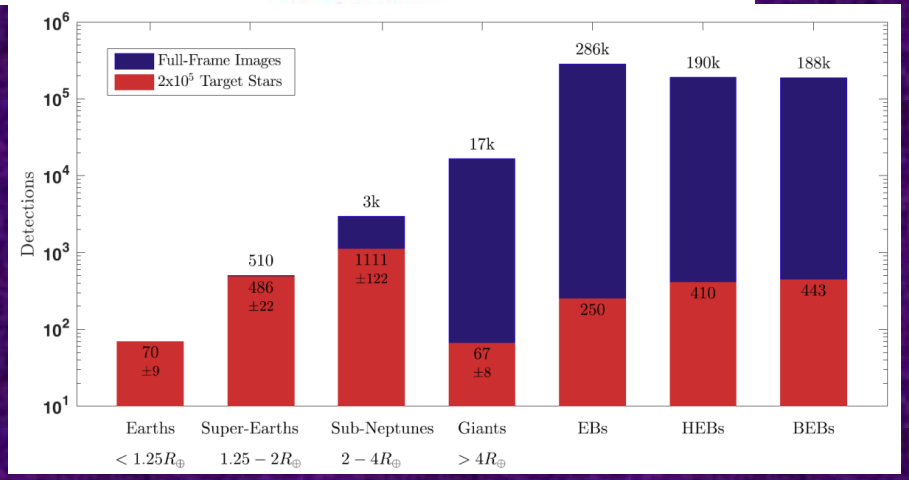
- K2
  - Currently data is available for12 fields
  - 19 Fields are planned (depending on fuel)
  - Typically, groups are finding ~50 – 100 candidates per field
  - ~1000 – 2000 candidates in total
  - Confirming about ~40 – 50 planets per field
- TESS
  - ~2000 planets from postage stamps
  - ~20000 planets from full frame images



False Positives Outnumber Planets

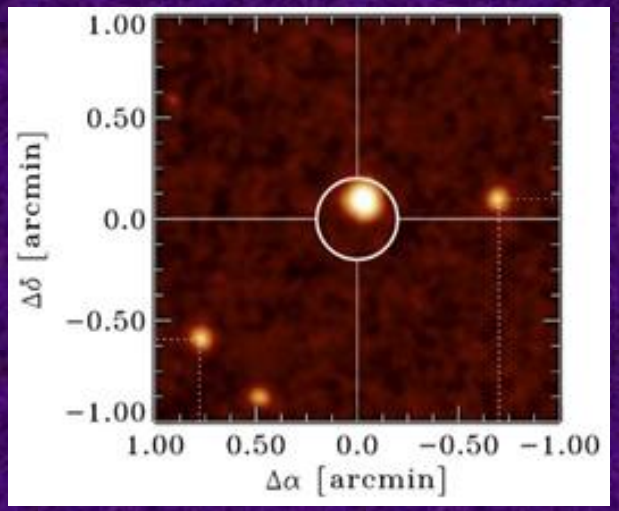


- TESS
  - ~1000 false positves from postage stamps
  - ~100,000 false positives from full frame images !!!!



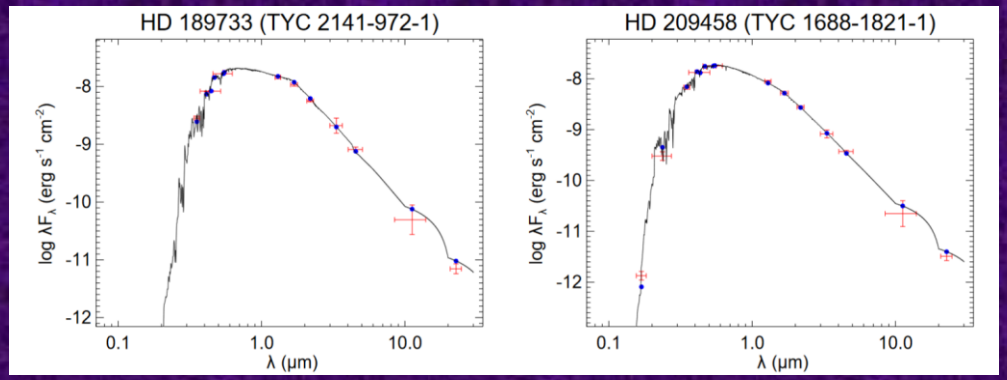
Resources: Seeing-Limited

- Time-series photometry
  - Detect nearby eclipsing binaries blended with primary targets
  - 1-meter class telescope or smaller is needed
  - Large number of professional and amateur resources available in both hemispheres
- Photometric Scene and blending
  - TIC based on Gaia catalog data
  - Older archival data → Proper Motion
  - Additional observations may be necessary for specific cases



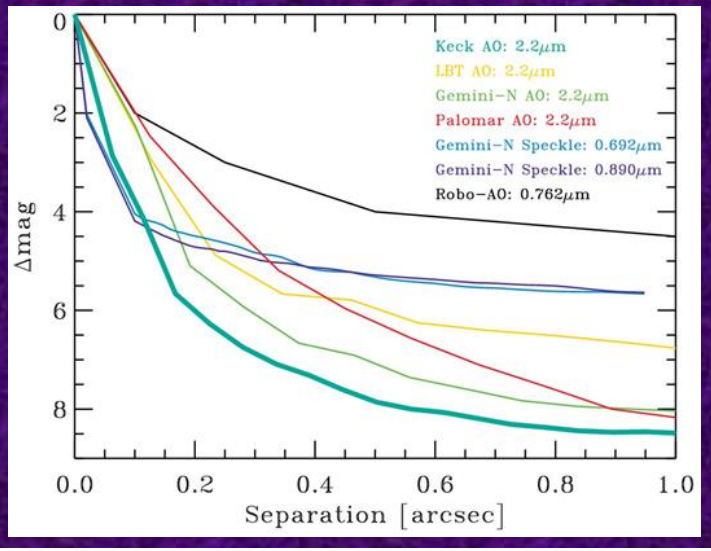
Resources: Spectroscopy

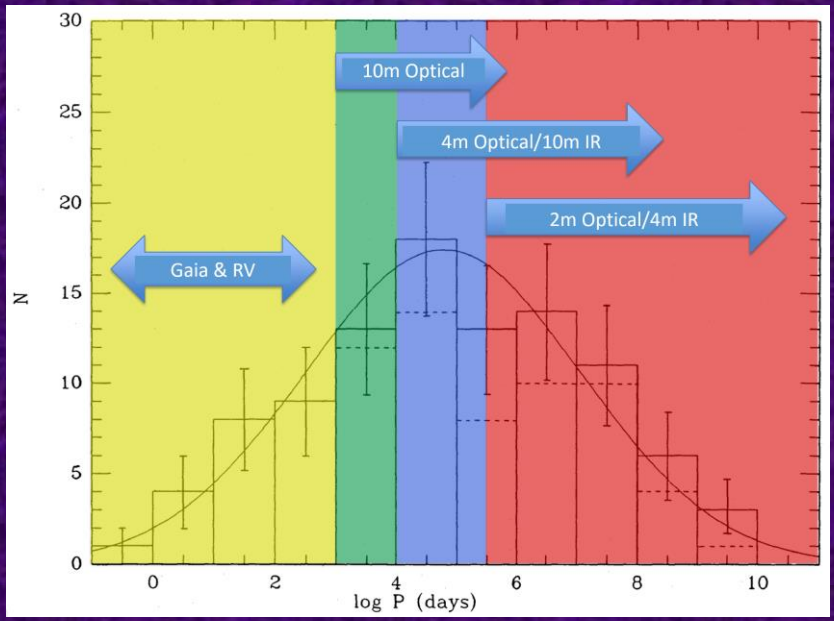
- Spectroscopic characterization of the host stars
  - Stellar atmospheric parameters — Teff, log(g), [Fe/H], vsini for refining stellar and planetary parameters, aiding analysis of confirmed planets
  - Activity Indices — Ca II H&K, Hα, etc. for judging activity levels, forming PRV strategy (observing cadence, activity corrections)
  - Composite Spectra — detect false positives, planets in binaries, poor targets for PRV follow-up
  - Radial Velocities — detect false positives, additional planets
  - Relatively large number of resources in both hemispheres
- Archival Gaia data
  - Colors, luminosities, and distances yield stellar parameters
  - Gaia spectroscopy yield stellar parameters



Resources: High-Resolution Imaging

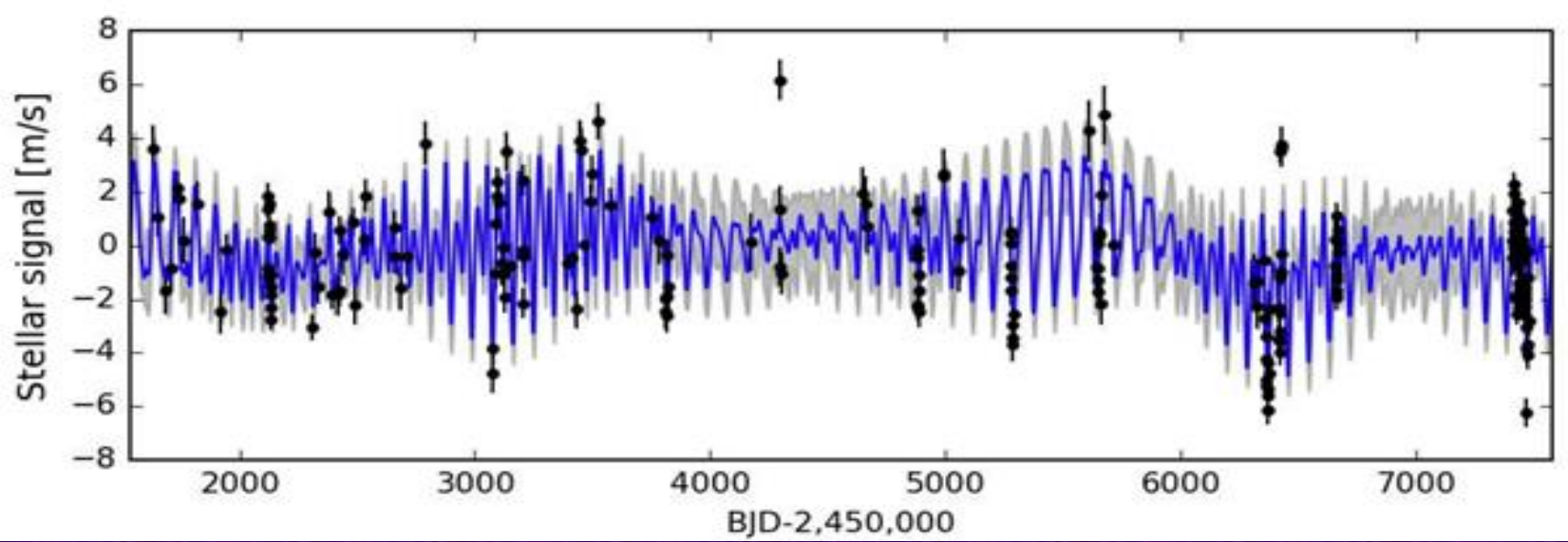
- Identify and Characterize Close-In Companions
  - Adaptive Optics Imaging
  - Optical Speckle imaging
  - Gaia imaging and astrometry
  - Spectroscopy radial velocity
- High resolution imaging resources are more scarce than seeing-limited or spectroscopy: more facilities available in the northern hemisphere
- Different capabilities complementary





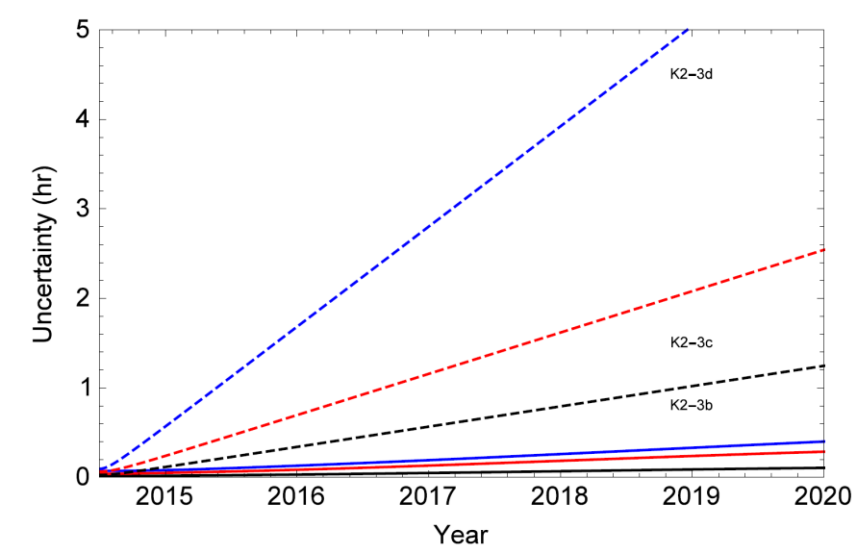
Resources: Precision Radial Velocity

- Most scarce resource
- Hand-full of facilities that can deliver precisions necessary for planetary detections and mass/orbit determinations
- Multi-planet systems needs large numbers of observations to disentangle the signals – with a time baselines akin to the orbital timescales (e.g., weeks to months)



Resources to Support Characterization

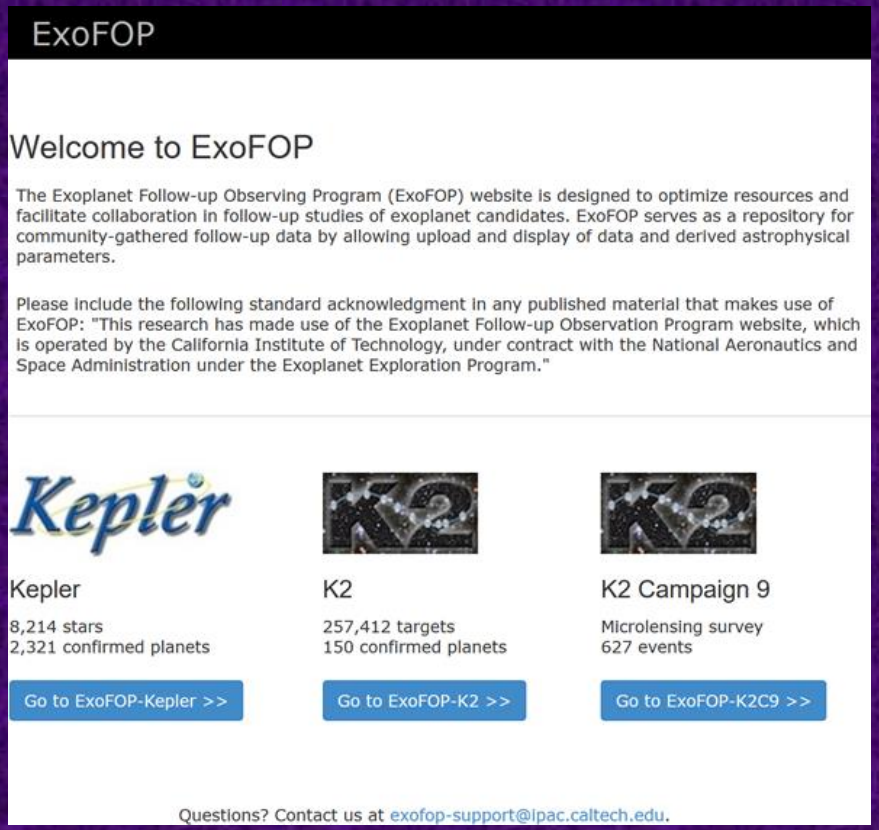
- A major aim of K2 and TESS is to find planets around stars that are bright enough to enable planet characterization
- Cornucopia of Characterization Studies
  - Atmospheric Composition
  - Atmospheric Structure
  - Bulk Densities and compositions
- All of these studies need supporting information/observations
  - Planet Radii and masses
  - Orbit determinations
  - Stellar properties



- Some supporting observations overlap with resources necessary for validation but updated/additional observations may be necessary

Organization of Resources

- As resources are limited, especially high resolution imaging, precision radial velocity, and characterization observations, enabling some form of organization can help with the efficient and effective use
- TESS Project is organizing the TESS Follow-Up Observation Program Working Group (TFOP WG)
- ExoFOP website to help the community share information about what data (and to what quality)
- Building on experiences from Kepler/K2 and the various collaborations



Outline of Report

1. Executive Summary [Section lead: Ciardi]
2. Introduction [Section lead: Colon]
3. Planet Confirmation & Exclusion of Standard False Positives [Section lead: Pepper]
4. Assembly of Essential Parameters of Planetary Systems [Section lead: Kane]
5. Characterization of Transiting Planetary Systems [Section lead: Colon]
6. Resources Necessary [Section lead: Ciardi]
7. Challenges [Section lead: Ciardi]

Next Steps

- Ciardi, Pepper, Colon, & Kane [CPCK] have a nearly complete draft but did not quite finish draft report by June 2017 ExoPAG
- Should be able to finish draft this July and circulate the draft among the community this summer
- Try to schedule a telecon for the community this summer

Know Thy Star – Know Thy Planet Conference

Assessing the Impact of Stellar Characterization on Our Understanding of Exoplanets

October 9-12, 2017, Pasadena, CA

Invited Speakers Include

Martin Asplund (ANU)
Heather Cegla (University of Geneva)
David Ciardi (Caltech/IPAC)
Courtney Dressing (Caltech)
Elliott Horch (Southern Connecticut State University)
Daniel Huber (University of Hawaii)
Paul Kalas (UC Berkeley)
Heather Knutson (Caltech)
Phil Muirhead (Boston University)
Ilaria Pascucci (University of Arizona)
Josh Pepper (Lehigh University)
Erik Petigura (Caltech)
Alessandro Sozzetti (INAF-Torino)
Rachel Street (Las Cumbres Observatory)
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Registration is Open; Abstract submission deadline: July 28, 2017