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

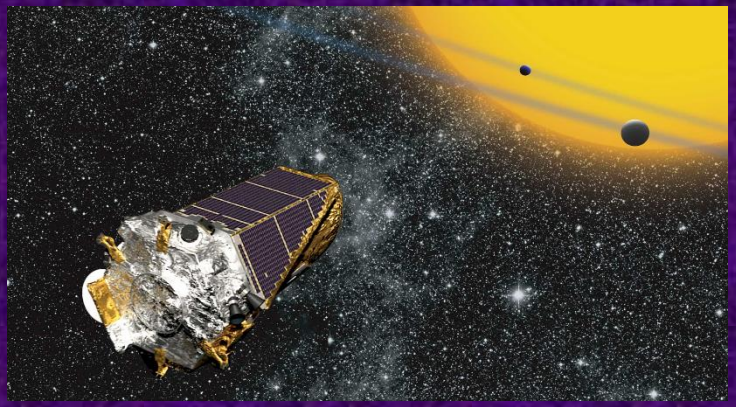
David R. Ciardi – NExScI/Caltech

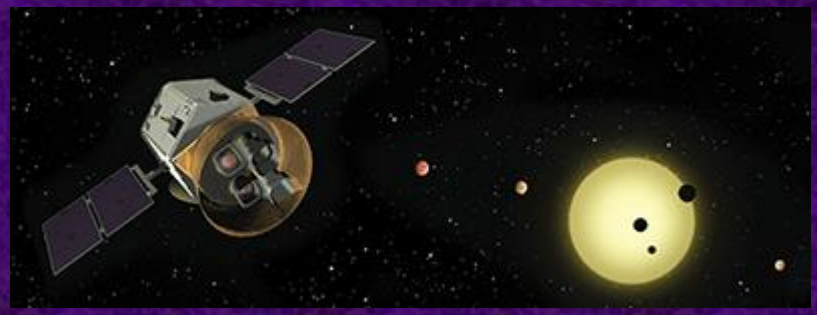
Joshua Pepper – Lehigh

Knicole Colon – NASA Goddard

Stephen Kane – UC Riverside

2018 January 07

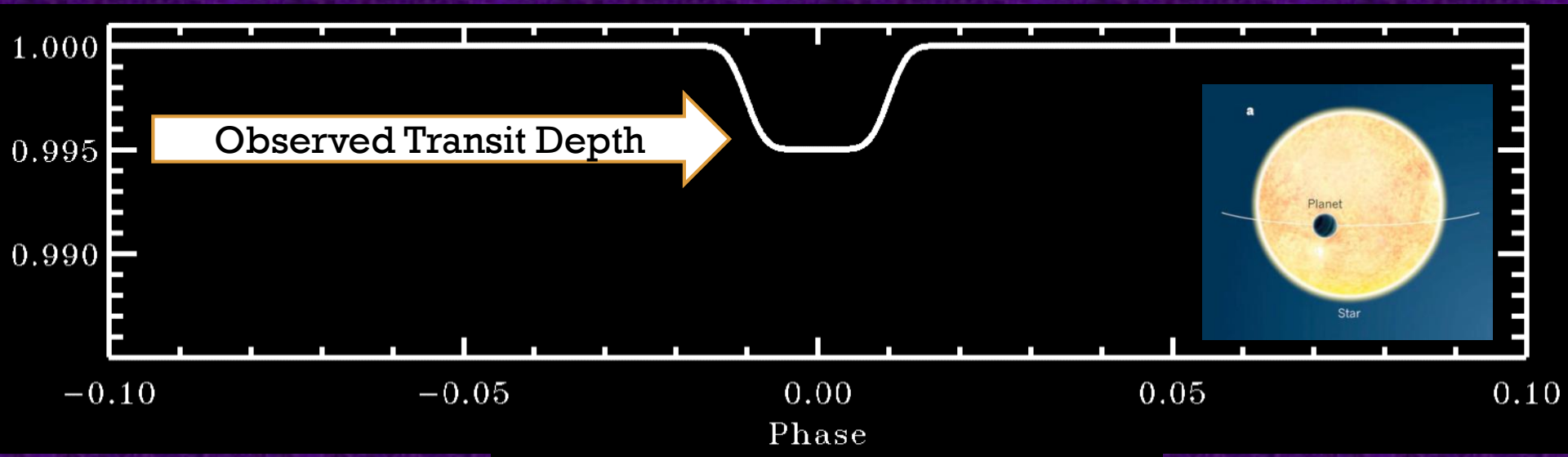




SAG17 Charter

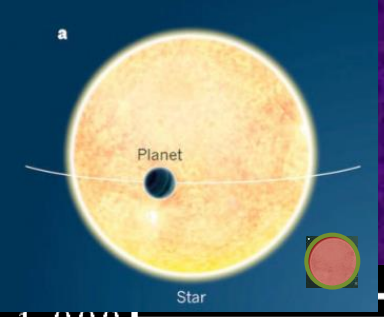
- Identify needed follow-up observations for K2 and TESS
  - Imaging: Seeing-limited and High Spatial resolution
  - Spectroscopy: Stellar parameters and radial velocity
  - Photometric Time – series
- Identify resources available to the US community
  - Telescopes and Instruments (space and ground)
  - 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

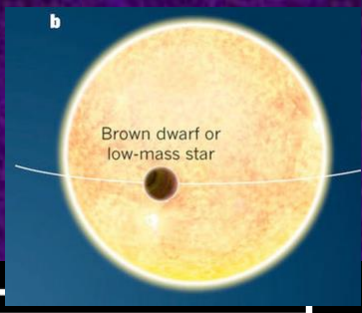
Transits Only Yield Derived Radii

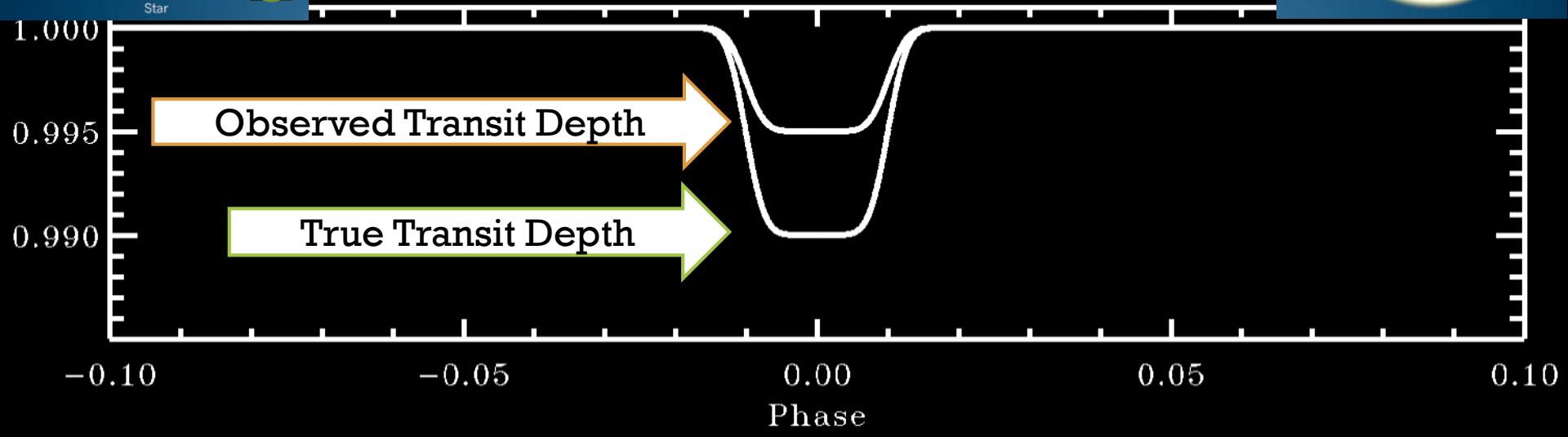


$$\delta_o = \left(\frac{R_p}{R_{t\star}} \right)^2$$

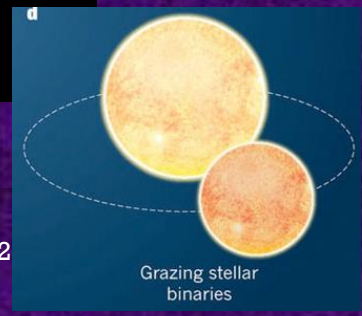
But Mimics Abound





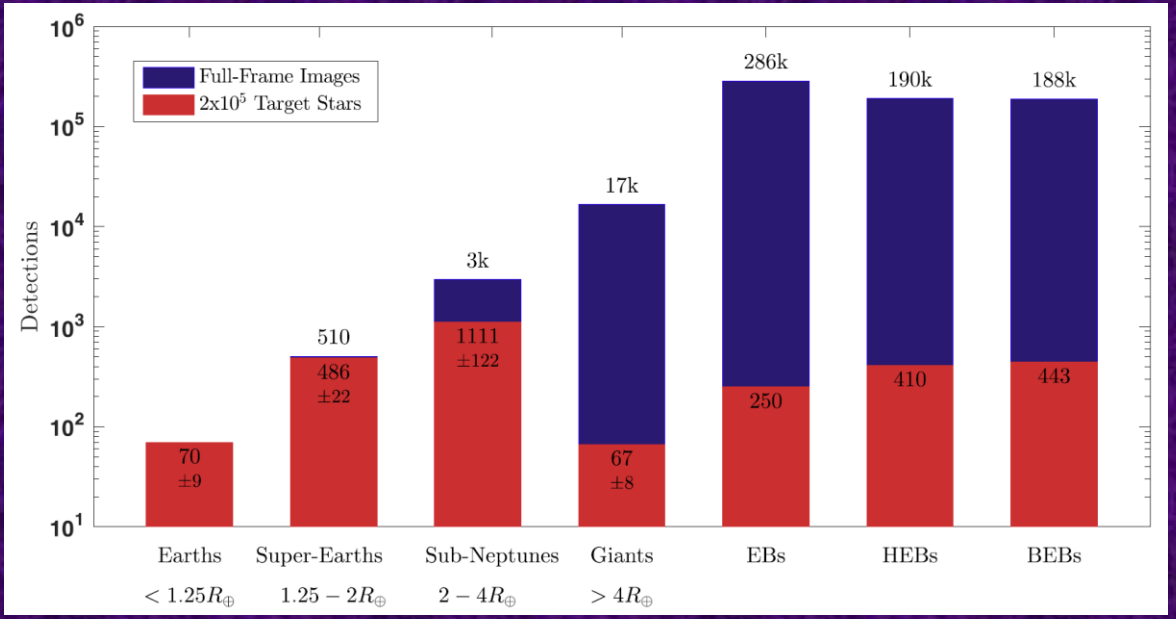


$$\delta_o = \left(\frac{F_t}{F_{total}}\right)\left(\frac{R_p}{R_{t\star}}\right)^2$$

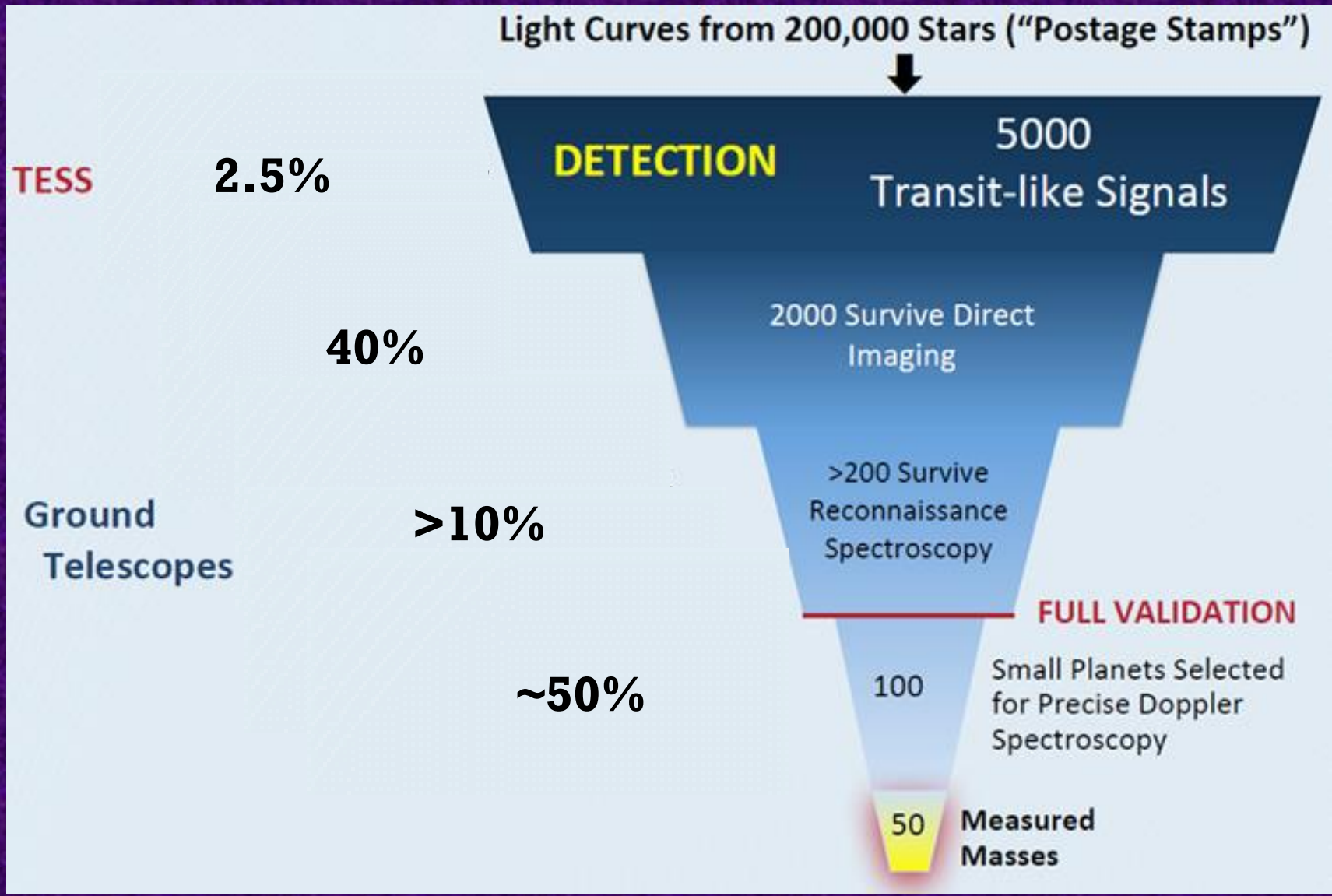


Number of Candidates

- K2
  - Currently data is available for 15 fields – Campaign 16 started 07 Dec
  - 19 Fields are planned (depending on fuel)
  - Typically, groups are finding ~100 candidates per field
  - ~1000 – 2000 candidates in total – about half have been published by various groups
  - Confirming about ~20 planets per field
- TESS
  - ~2000 planets from postage stamps
  - ~20000 planets from full frame images



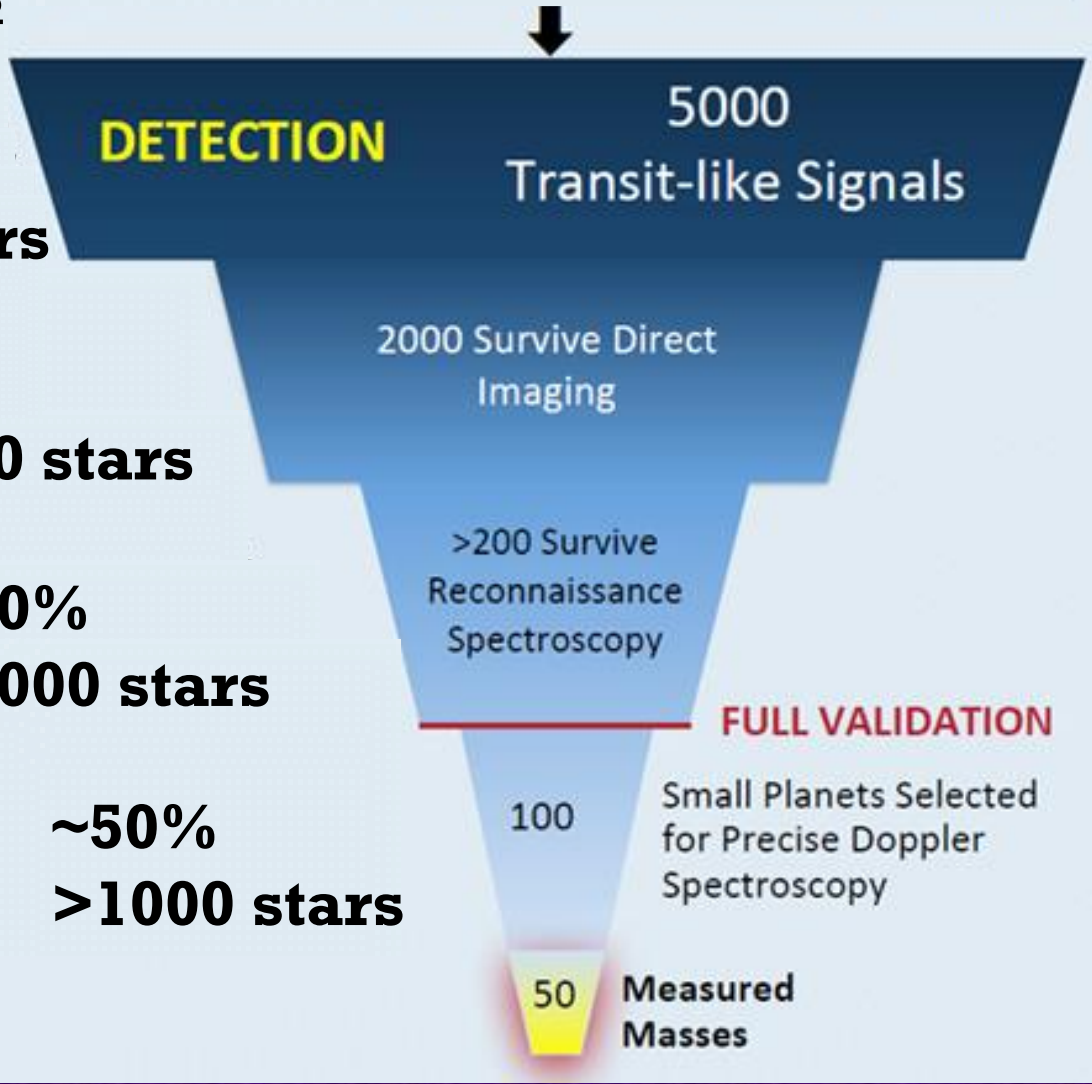
Expected Number Requiring Follow-Up



Expected Number Requiring Follow-Up

Full Frame Images

Light Curves from >2,000,000 stars



TESS

2.5%
>50000 stars

40%
>20000 stars

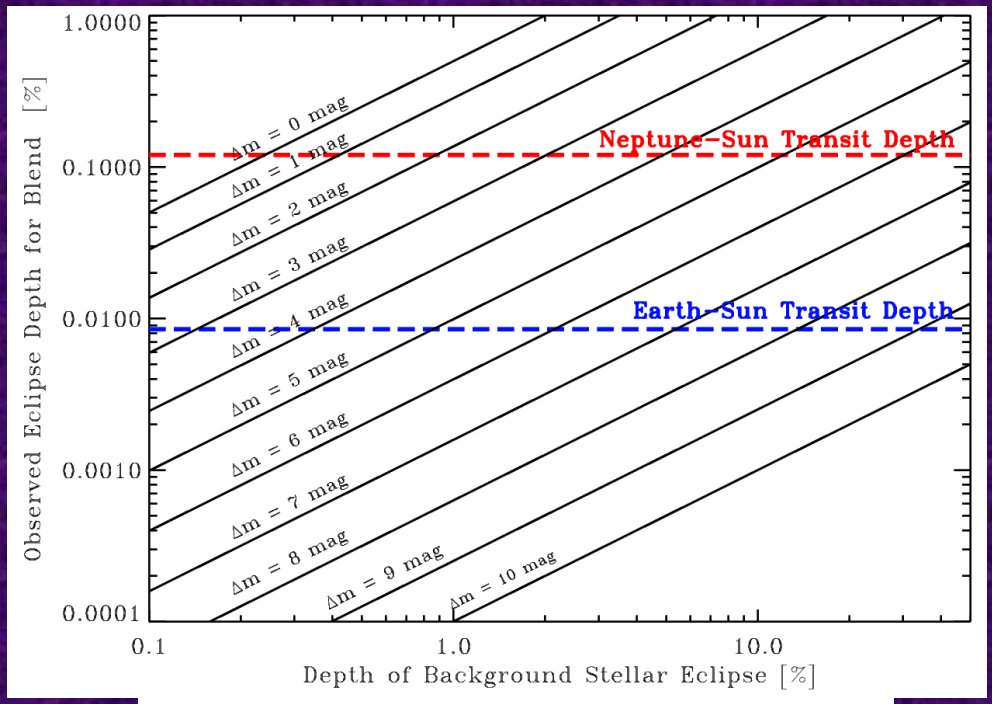
Ground Telescopes

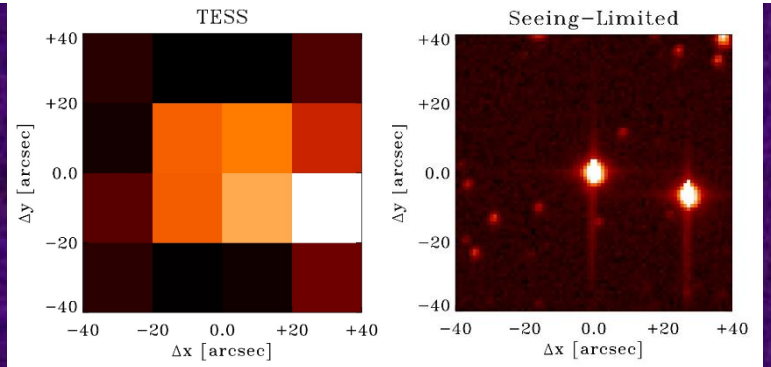
>10%
>2000 stars

~50%
>1000 stars

FOP: Seeing Limited Time Series

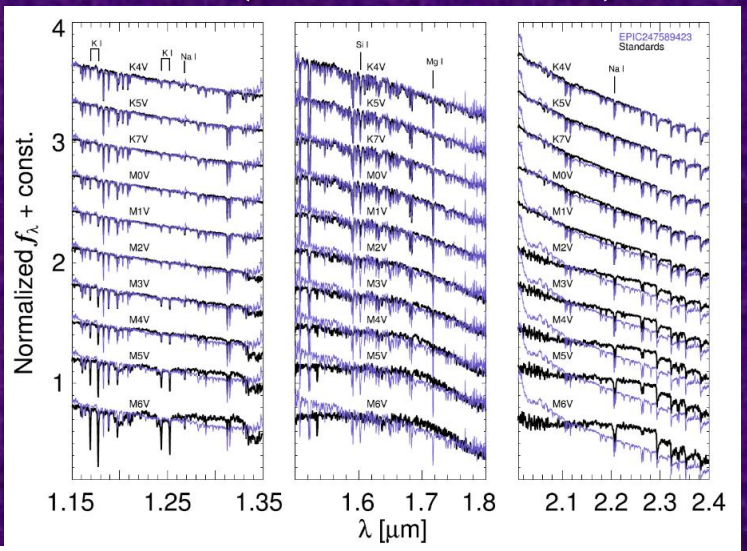
- In 'n Out of Transit Photometry to detect blended eclipsing binaries
  - Minimum set of observations include 3 observations (more is better)
  - Before – During – After Transit
  - Need
    - 1 arcminute FOV
    - Resolution ~1"
    - 0.5 – 1m telescopes
    - ~1% photometry
  - 5 – 10 minutes per observation
  - 15 – 30 minutes per star
  - PS Stars: ~1000 – 2000 hrs
  - FFI Stars: >10000 – 20000 hrs

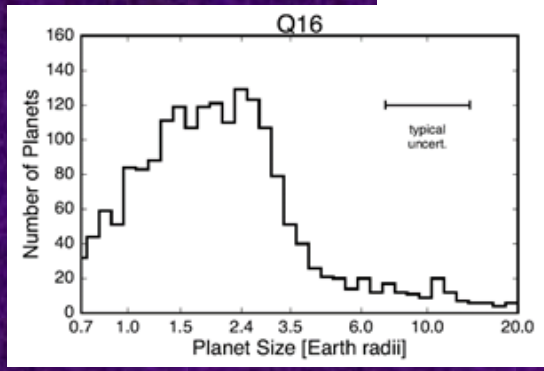


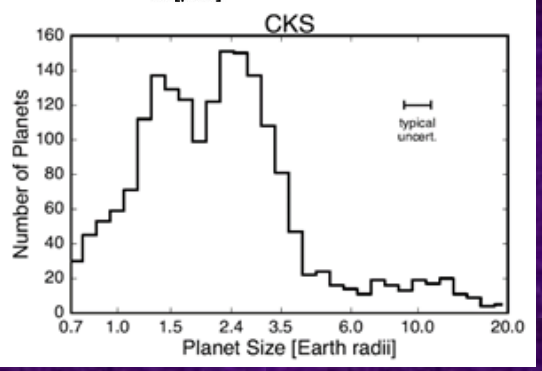


FOP: Reconnaissance Spectra

- Spectroscopic characterization of the host stars
  - Single Epoch Observations: Stellar parameters — Teff, log(g), [Fe/H], vsini
  - Multi-Epoch Observations: Stellar companion detection (minimum 2 obs.)
- Need
  - R ~ 5000 – 100,000 spectrograph
  - Stellar radii ~ 10%
  - RV ~ 0.5 – 1 km/s
  - 1 – 4m telescopes
- 5 – 10 minutes per observation
- 10 – 20 minutes per star
- PS Stars: ~500 - 1000 hrs
- FFI Stars: >5000 – 10000 hrs

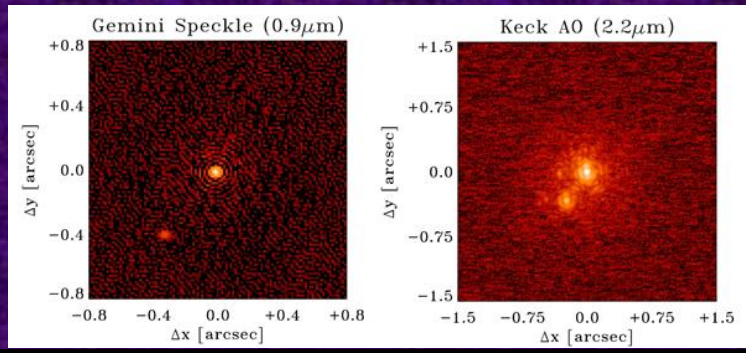


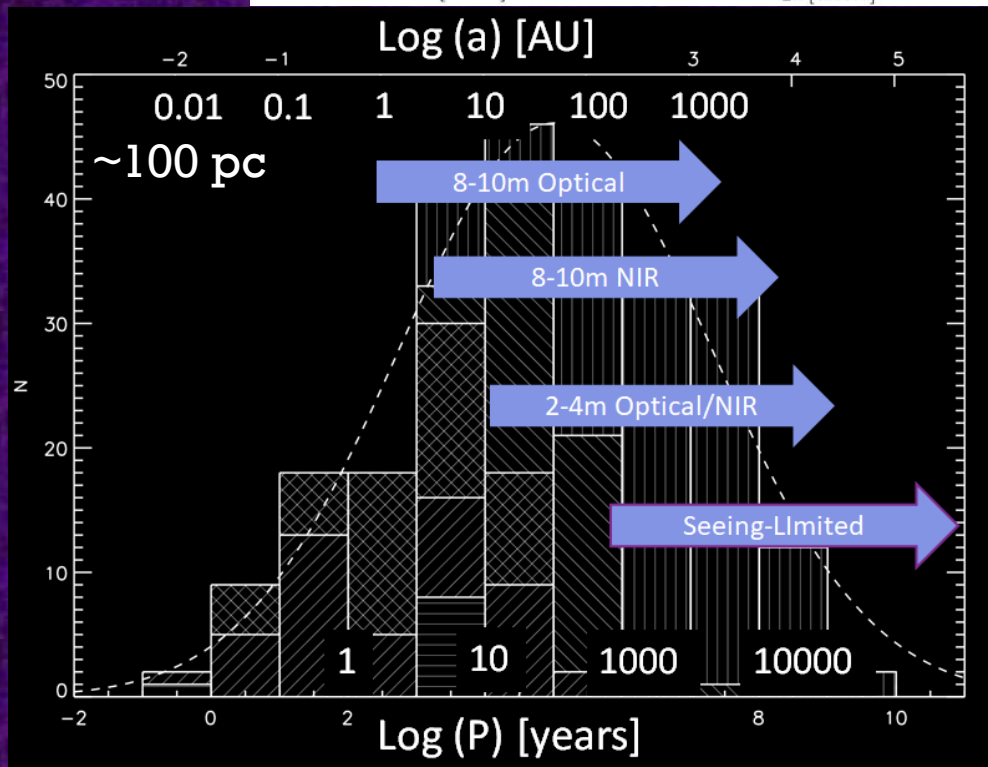




FOP: High Resolution Imaging

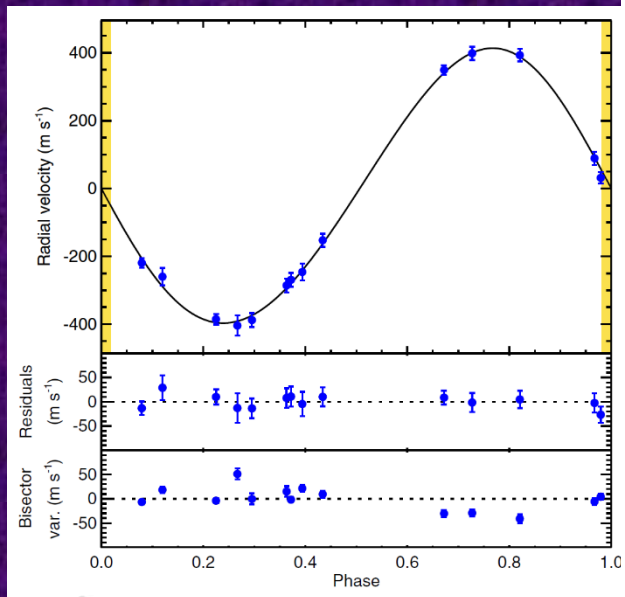
- Identify and Characterize Close-In Companions
  - Single Epoch Observations
  - Multiple filters Companion Characterization
- Need
  - High resolution imaging techniques such as adaptive optics or speckle
  - Resolutions 0.01” – 1”
  - 2 – 10m telescopes
- 5 – 10 minutes per observation
- 5 – 20 minutes per star
- PS Stars: ~500 - 1000 hrs
- FFI Stars: >5000 – 10000 hrs

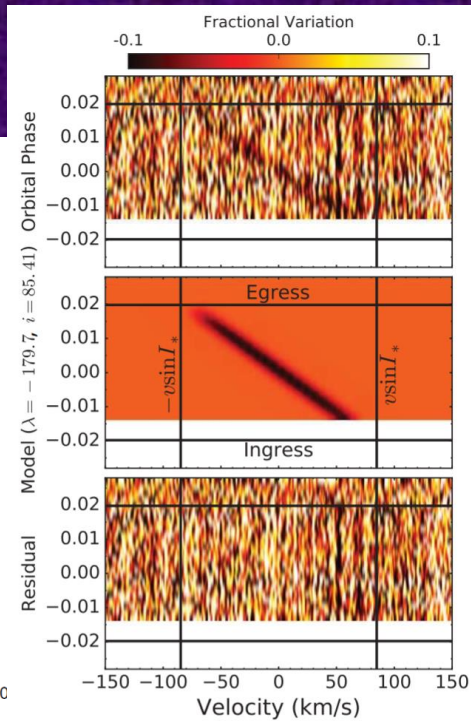


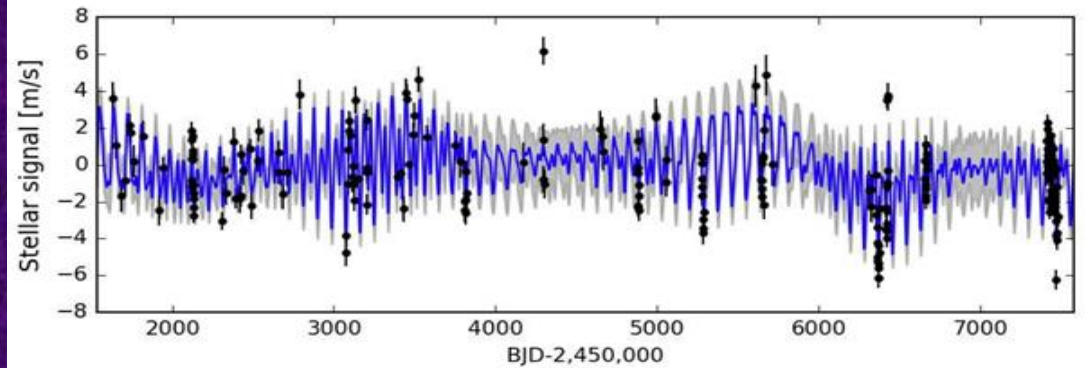


FOP: Precision Radial Velocities

- Confirmation and determination of planetary masses and orbits
  - Multi-Epoch Observations: 10s – 100s of epochs
  - Multiple filters Companion Characterization
- Need
  - High precision spectroscopic RV techniques
  - Precisions ~1+ m/s
  - 4 – 10m telescopes
- 5 – 10 minutes per observation
- 1 – 100s hours per star
- PS Stars: ~200 – 1000s hrs
- FFI Stars: >10000s hrs

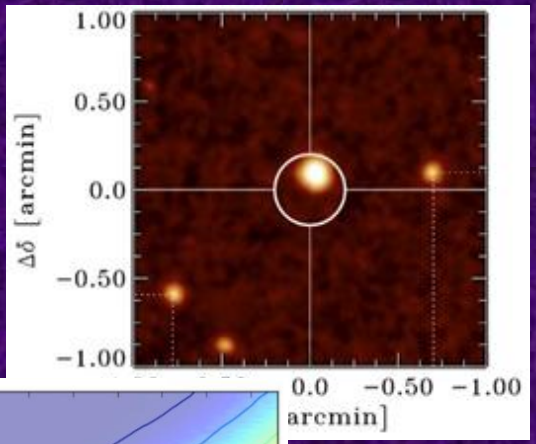


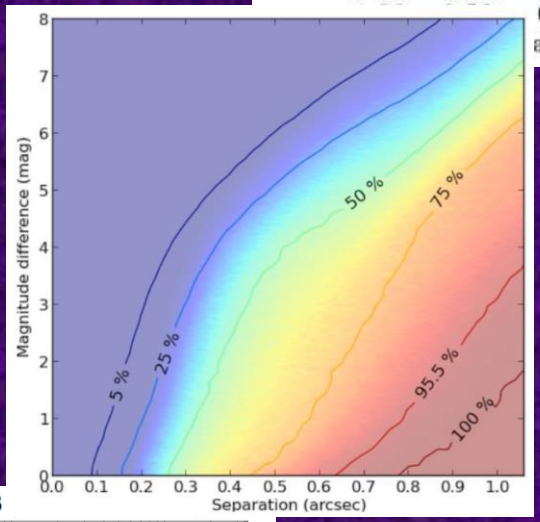


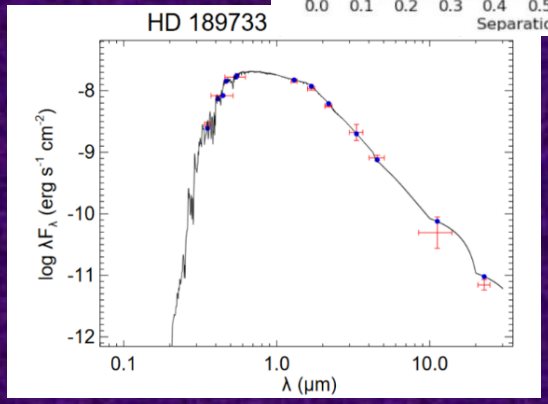


Other Resources: Archival Data

- Photometric Scene and blending
  - Gaia catalog data complements high resolution and seeing limited imaging
  - Older archival data → Proper Motion
  - Additional observations may be necessary for specific cases
- Stellar Parameters
  - Colors, luminosities, and distances
  - Gaia spectroscopy for stars brighter ~17mag
  - Astrometry yields binaries

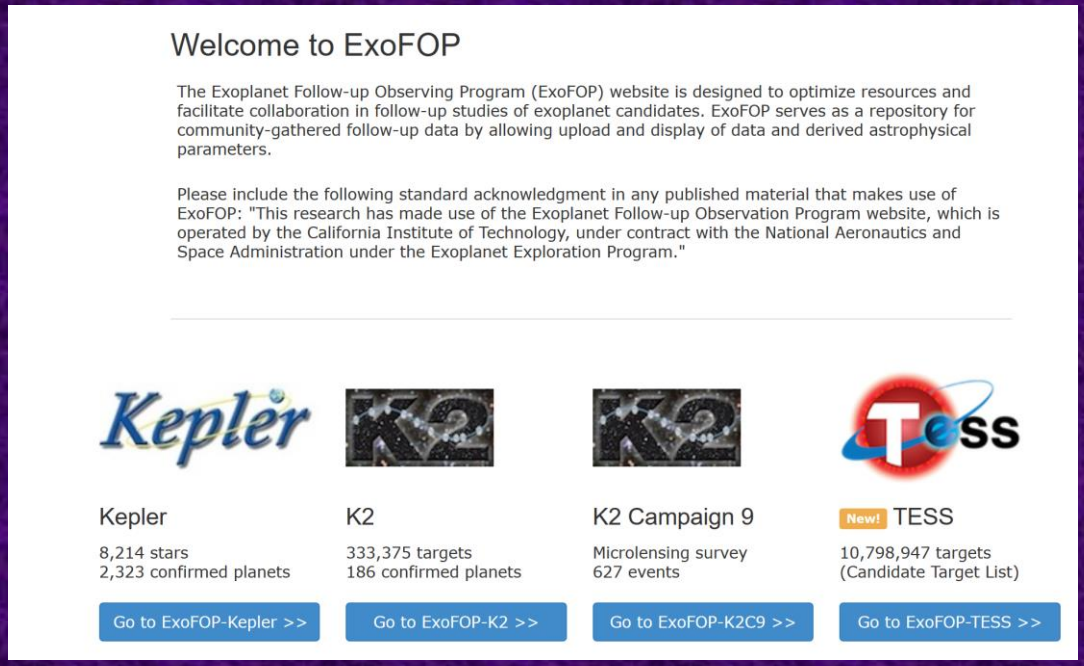






Organization of Resources

- 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
- 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



What US Public Resources are available?

- Most resources are private with limited or no access to the community
- Seeing-Limited Imaging Observation: 0.5 - 1.0 m telescopes
  - N • NOAO/LCO: North: 2x1m and 7x0.4m telescopes
  - S • NOAO/LCO: South: 8x1m and 5x0.4m telescopes
  - S • NOAO/SMARTS: CTIO1.3m and 0.9m
- Reconnaissance Spectroscopy: 1 – 4m telescopes
  - S • NOAO: CTIO Blanco 4m – COSMOS (Opt: R~2200), ARCoIRIS (IR: R~3000)
  - S • NOAO: SOAR 4m – Goodman (Opt: R~ 2000 – 14,000), OSIRIS (IR: R~3000)
  - N • NASA IRTF 3m: SpeX (IR: R~2000), iShell (IR: R~75000)

What US Public Resources are available?

- Most resources are private with limited or no access to the community
- High Resolution Imaging Observation:
  - N • NOAO: Gemini-N 8m – NIRI (NIR AO), Alopeke (Opt Speckle)
  - S • NOAO: Gemini-S 8m – GSAOI (NIR AO), DSSI (Opt Speckle)
  - N • NOAO: KPNO 2.1m – RoboAO (Opt AO)
  - N • NASA: Keck 10m – NIRC2 (NIR AO)
  - N • NASA: WIYN 3.5m – NESSI (Opt Speckle)
- Precision Radial Velocity
  - N • NASA: Keck 10m – HiRES (Opt)
  - N • *[NASA: IRTF 3m – iShell (NIR)]*
  - N • *[NASA/NOAO: WIYN 3.5m – NEID (NIR)]*
  - S • *[NOAO: AAT 4m – veloce (opt)]*

Challenges for the Community

- Limited public access to resources in Southern Hemisphere especially high resolution imaging and precision radial velocity
- Financial Support
  - Students and Post-doctoral researchers
  - Travel to the observatories
  - Data analysis: collection of the observations is not enough
  - Telescope time does not come with money except for Keck and NN-Explore both of which are limited in funds
  - NASA XRP is highly competitive, over-subscribed, and covers all of exoplanet research
  - TESS GI program: Ground-based effort can only be <30% of total program
- Combining data from different groups and observatories
  - Take time to understand how to combine data from different telescopes/instruments: a common set of observations are crucial
- Social
  - Willingness of community to share and collaborate
  - Lots of communication – especially with TESS FOP WG – is critical to help minimize duplication of observations

Next Steps (from June)

- Ciardi, Pepper, Colon, & Kane have a ne[illegible]mplete draft but did not quite finish draft r[illegible]y June 2017 ExoPAG
- Should be able to finish d[illegible]is July and circulate the draft among the co[illegible]y this summer
- Try to schedu[illegible]econ for the community this summer

"The best-laid plans of mice and men often go awry."

Next Steps

- Nearly complete draft but did not quite finish draft report by January 2018 ExoPAG
- Aiming for delivered draft end of January
- Community telecom in early with February
- Final delivery after community and ExEP feedback end of February