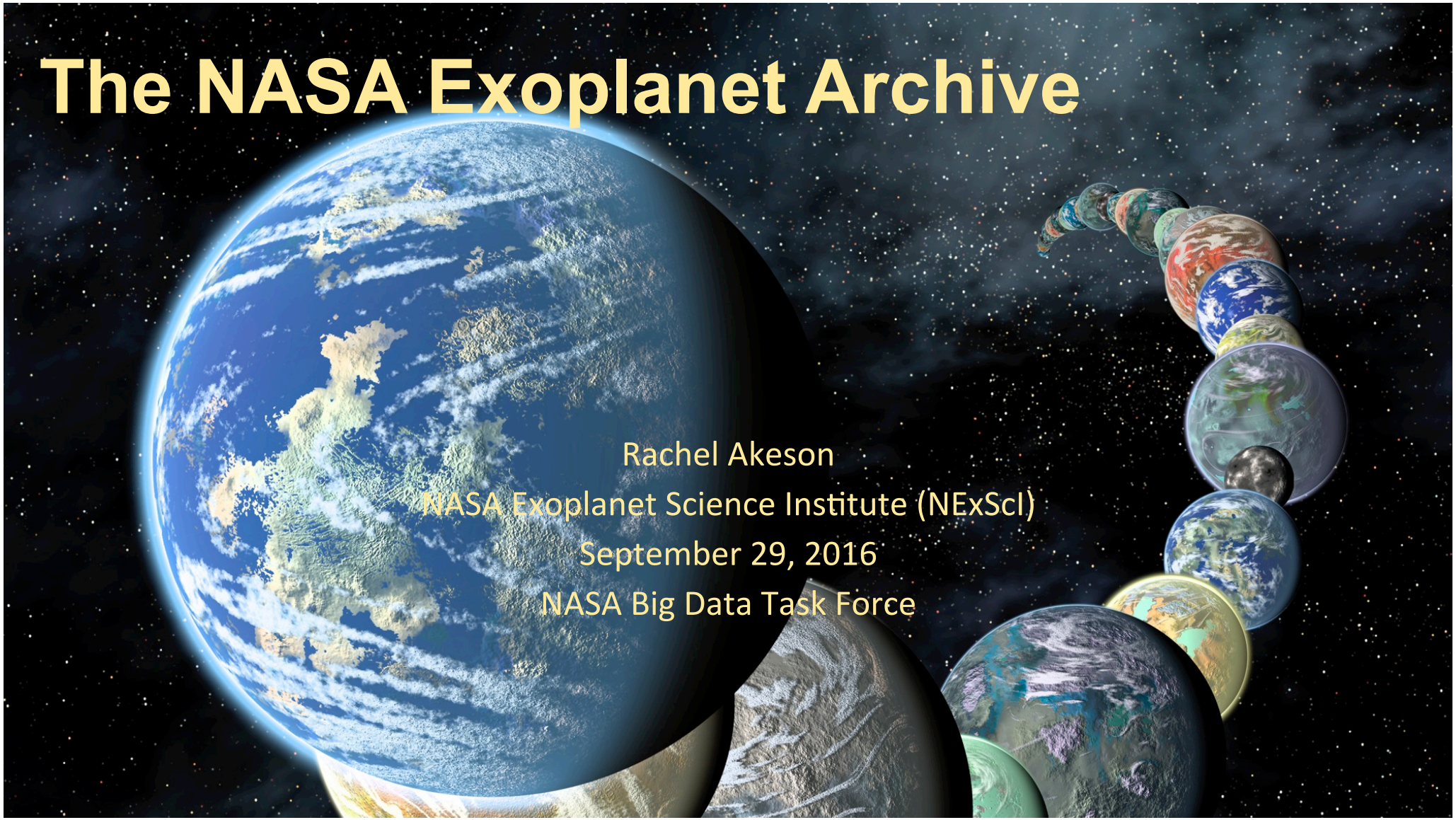
The NASA Exoplanet Archive



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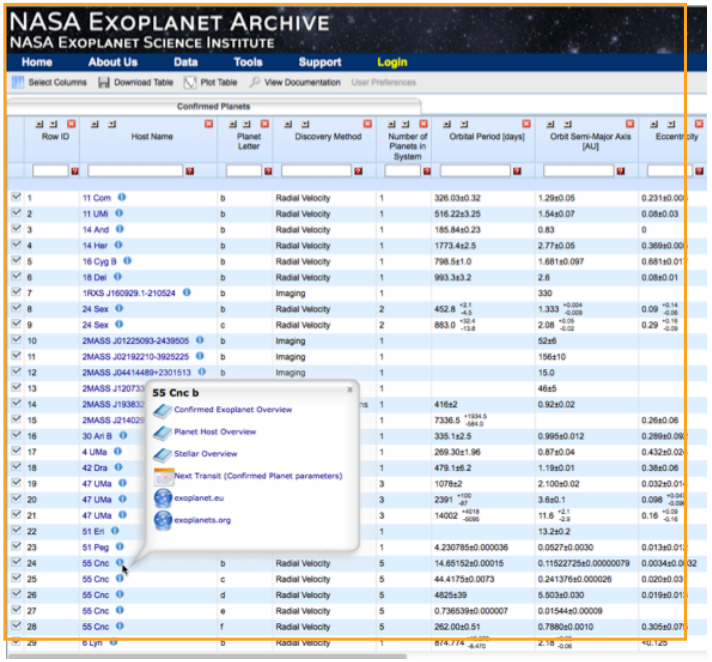
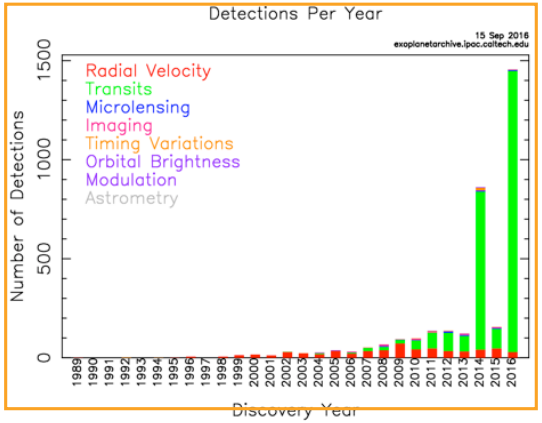
NASA Big Data Task Force

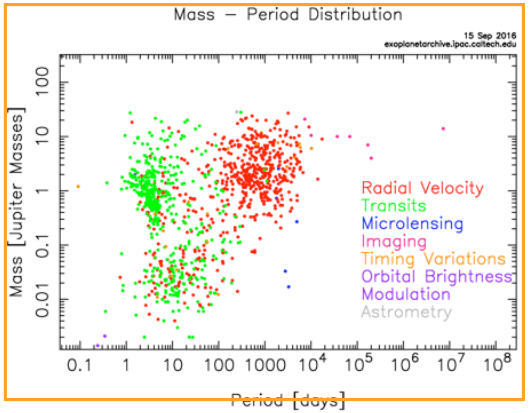
Overview: Data

NASA Exoplanet Archive supports both the exoplanet science community and NASA exoplanet missions (Kepler, K2, TESS, WFIRST)

- Data
  - Confirmed exoplanets from the literature
    - Over 80,000 planetary and stellar parameter values for 3388 exoplanets
    - Updated weekly
  - Kepler stellar properties, planet candidate, data validation and occurrence rate products
    - MAST is archive for pixel and light curve data
  - Additional space (CoRoT) and ground-based transit surveys (~20 million light curves)
  - Transit spectroscopy data
- Auto-updated exoplanet plots and movies



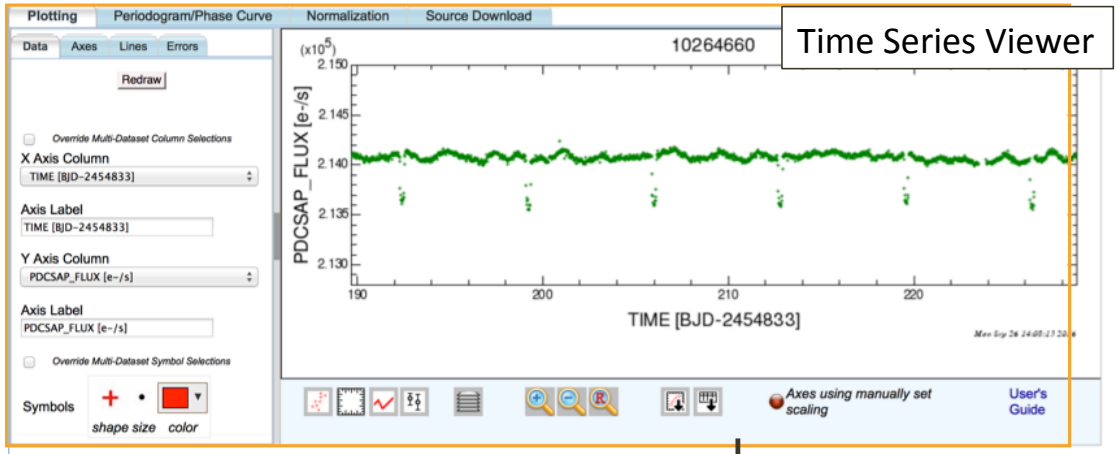


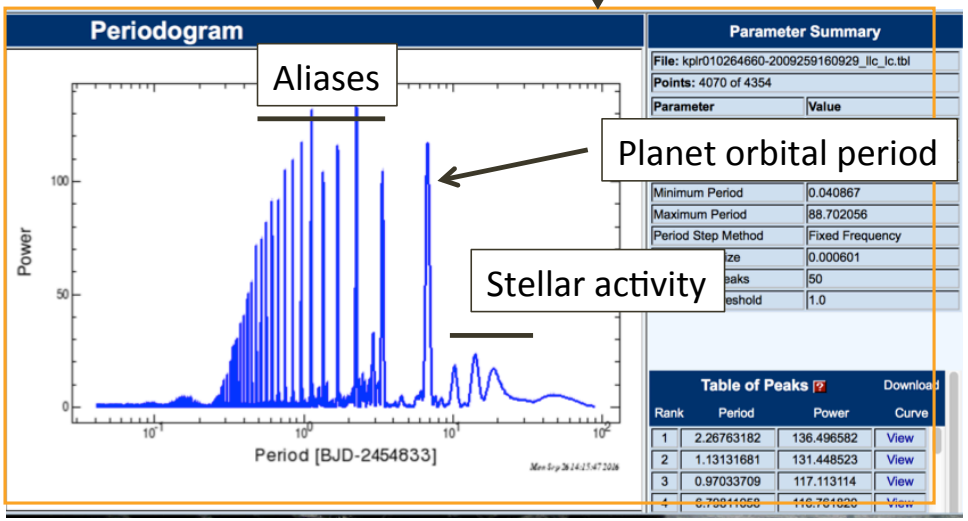


Overview: Tools

- Interactive tables and plotting for data
  - Includes light curve normalization
- Periodogram calculations
  - Searches for periodic signals in archive or user-supplied light curves
- Transit predictions
  - Uses value from archive to predict future planet transits for observation and mission planning
- URL-based queries
- Calculation of observable properties
- Web-based service to collect follow-up observations of planet candidates for Kepler, K2 and TESS (ExoFOP)
  - Includes user-supplied data, file and notes

Example: Kepler 14





Data Challenges and Technical Approach (1)

- Challenges with Exoplanet Archive are not currently about data volume but about providing CPU resources and data complexity
- CPU challenge
  - Issue: Several Exoplanet Archive tools are CPU intensive (periodogram, transit fitting) but demand is not constant
  - Solution: Provide tiered support
    - Internal resources for smaller jobs, Cloud computing for larger jobs, Provide code image to power users
  - Status: Periodogram tool built on AWS, evaluating which cloud provider (Amazon, Google, Caltech) cost model best matches our needs

Data Challenges and Technical Approach (2)

Data Complexity Challenge

Data within Exoplanet Archive comes from several projects (Kepler, ground-based surveys) and the published literature which needs to be integrated:

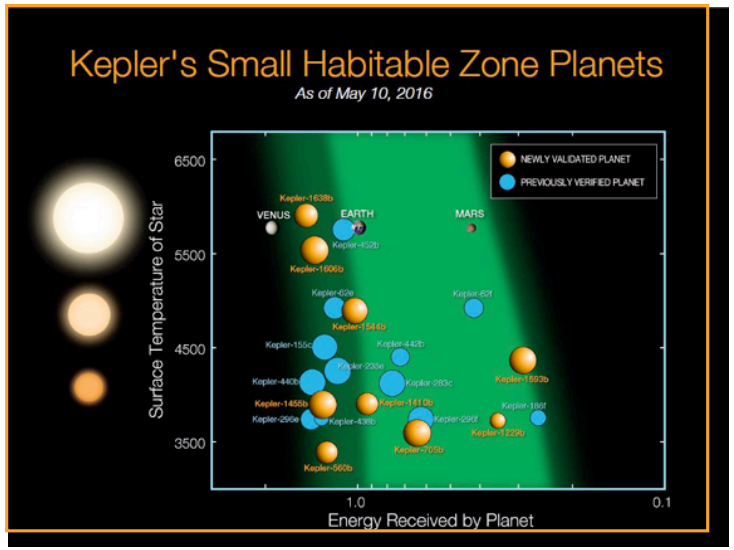
- Each paper must be searched for over 50 planetary and stellar parameters with inconsistent terminology
- Different discovery and observational methods result in heterogeneous information for each exoplanet
- Follow-up observations are time critical and require sharing information pre-publication

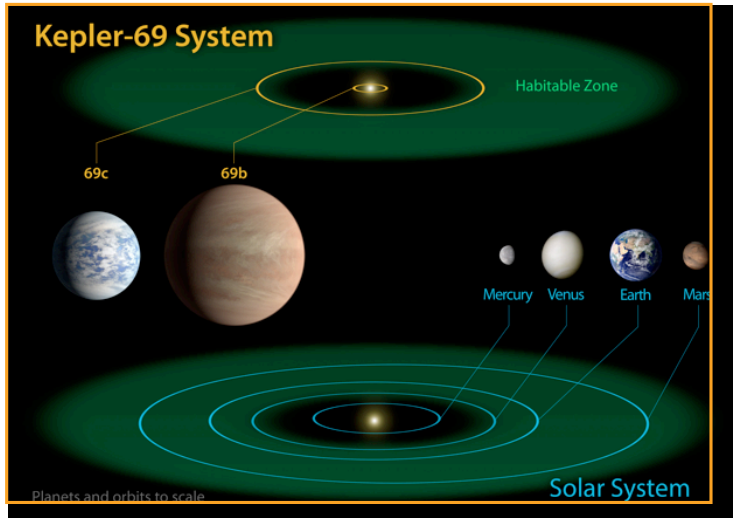
Solutions

- Present data with targeted use cases
  - e.g., All confirmed planets are in one table, but only those with transmission spectroscopy measurements are in a separate focused table
- Allow users to configure and save preferred columns, filtering and sorting
- ExoFOP website is supported by Exoplanet Archive infrastructure, but is a separate service to make clear distinctions between reviewed and non-reviewed data

Significant Science Results

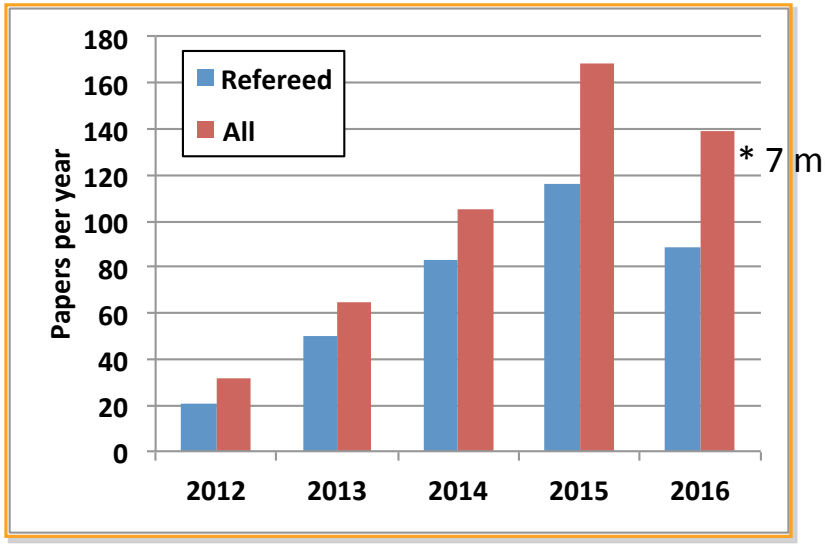
- **Over 2/3 of exoplanets are from discovery papers which reference the Exoplanet Archive**
- 1200+ Validated planets (Morton et al. 2016)
- Kepler candidate lists (Batalha et al. 2013, Burke et al. 2014, Rowe et al. 2015, Mullally et al. 2015)
- 700+ validated Kepler planets (Rowe et al. 2014)
- Kepler 69: SuperEarth in the HZ (Barclay et al. 2013)
- RV limits on planets around Barnard's star (Choi et al. 2013)
- WASP 103: possible tidal distortion of planet (Gillon et al. 2014)
- Transiting planet at the snow line (Kipping et al. 2014)
- Masses of small Kepler planets (Marcy et al. 2014)
- Review of observed exoplanet properties (Howard 2013)

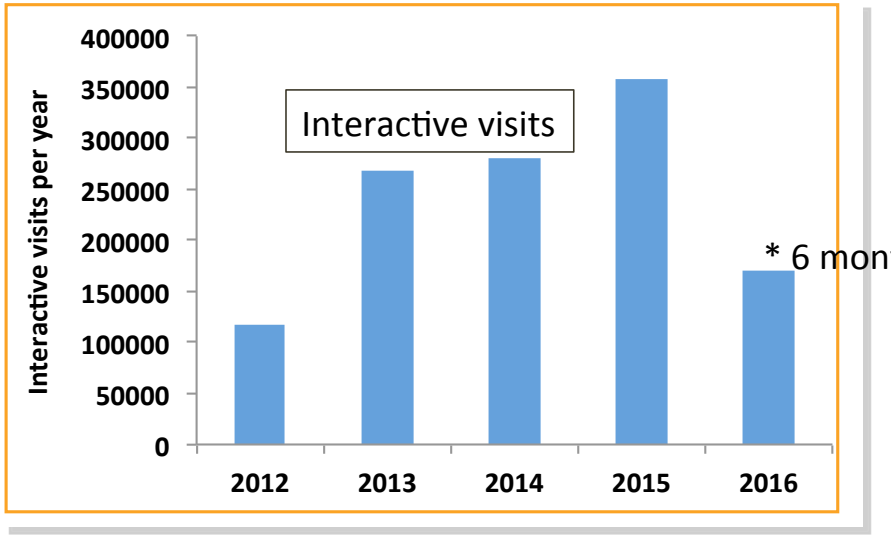


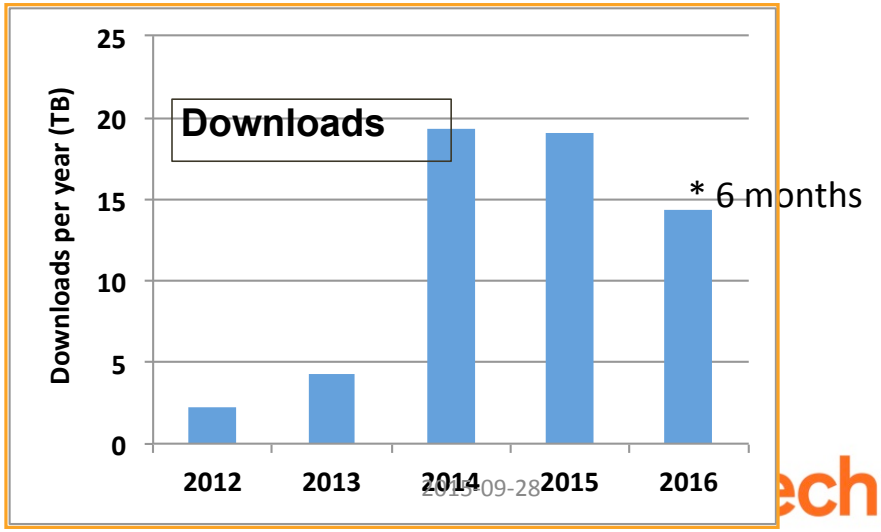


Archive Usage

Archive usage is steadily increasing since archive start in 2011





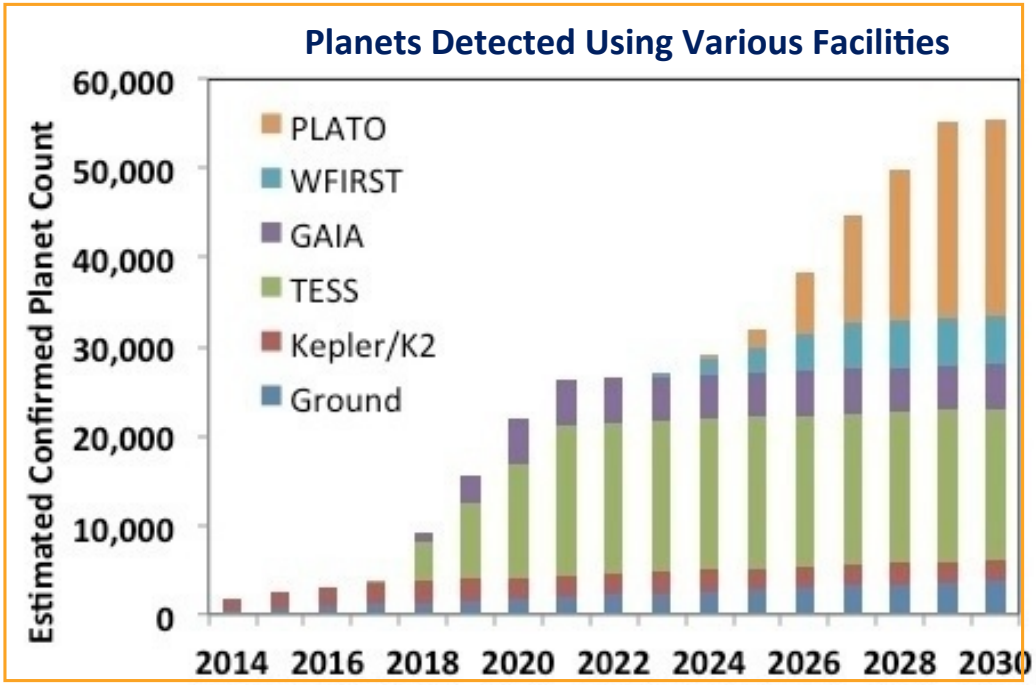


Q1: Planning

- **5 year plan presented at NASA Astrophysics Archive Strategic Review in 2015**
  - Developed in conjunction with Exoplanet Archive Users Group
    - ➢ Meets annually, provides guidance on data and functionality priorities
- **Users can request new data and functionality via the archive helpdesk**
  - Small requests are included in weekly data releases
  - Larger requests are prioritized in consultation with Users Group
- **Priorities**
  - Support NASA's exoplanet missions: K2, TESS, WFIRST
  - Maintain a comprehensive list of exoplanets for community use

Q2: Support termination

- The Exoplanet Archive has only been operational since 2011
  - ➢ Our concern is with scaling current tools to projected growth in exoplanets
- All currently supported data sets and tools are still relevant
  - ➢ Would utilize Users Group to prioritize effort once tools or data are less relevant



Q3: Interoperability

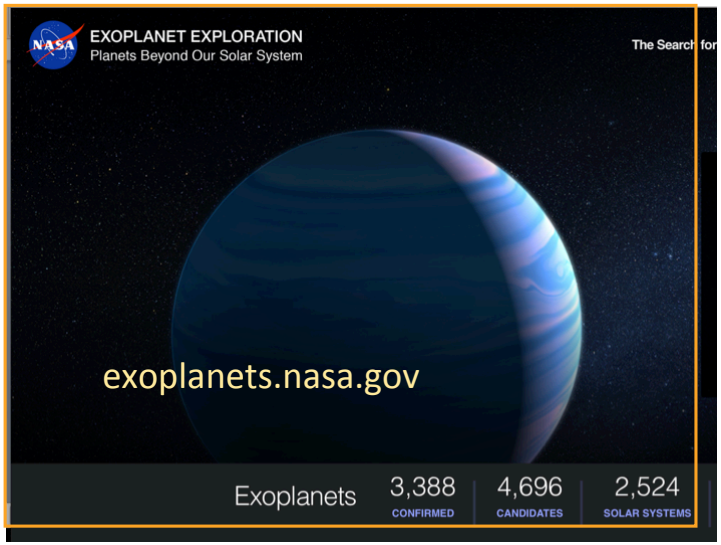
- Within exoplanet community
  - ➢ Exoplanet Archive directly supports other NASA and community sites: exoplanets.nasa.gov, Kepler discoveries page, PlanetHunters.org
- Between NASA archives
  - ➢ Coordinate with MAST on Kepler data releases
  - ➢ Links to IRSA and MAST

To Literature

  - ➢ All parameter values linked to relevant publication
  - ➢ Links to and from ADS

VO compatibility

  - ➢ Facilitate VO queries to exoplanet tables



Summary

- The exoplanet field is new and dynamic.
- The Exoplanet Archive started when less than 1000 exoplanets were known and has grown with the field.
- The Exoplanet Archive is an integral part of exoplanet research and is prepared for the expected growth in the next 10–15 years.

Backup

Archive Holdings

Confirmed Planets	
Number of Exoplanets	3,388
Number of Planet Parameters	25
Total Planet Parameter Values	43,485
Number of Stellar Parameters	19
Total Stellar Parameter Values (Hosts Only)	38,555
Total Photometry Values (Hosts Only)	32,510
Number of Peer-Reviewed References	1,672
Transit Spectroscopy Measurements	1741
Number of Associated Files	10,502

Additional Holdings	
SuperWASP Time Series	17,971,001
KELT Time Series	1,119,083
Mission Star Lists	2,419
Other Time Series (including CoRoT, XO, HATNet, TreS-Lyr1, KELT-Praesepe)	400,457
Associated Data Files from Literature	6,018
Correlated Mission Data Sets	
2MASS	WISE
Hipparcos	Gaia (coming soon)

The Exoplanet Archive is the archive for high level Kepler products: exoplanet candidates, data validation products and completeness calculations. MAST is the archive for pixel and light curve data products.

Kepler Pipeline Data	
Candidate Lists	7,367
Data Validation (DV) Reports	55,057
DV Light Curves	34,690
Stellar Table	593,110
Planet Detection Metrics	397,256

Additional Usage Metrics