# Final Report for SAG 22: A Target Star Archive for Exoplanet Science

Co-Chairs: Natalie Hinkel (LSU),
Josh Pepper (NASA HQ), Chris Stark (GSFC)

ExoPAG29 at the 243rd AAS meeting

https://tinyurl.com/SAG22-FinalReport

# Massive Thank You to the SAG22 Members

Jennifer A. Burt, David R. Ciardi, Kevin K. Hardegree-Ullman, Jacob Lustig-Yaeger, Ravi Kopparapu, Lokesh Mishra, Karan Molaverdikhani, Ilaria Pascucci, Tyler Richey-Yowell, E. J. Safron, David J. Wilson, Galen Bergsten, Tabetha S. Boyajian, J. A. Caballero, K. Cunha, Alyssa Columbus, Shawn D. Domagal-Goldman, Chuanfei Dong, R. M. Elowitz, Devanshu Jha, Archit Kalra, David W. Latham, Jacob Luhn, Carl Melis, Navya Nagananda, Eliad Peretz, Sabine Reffert, Kimberly Scarangella Smith, Keivan G. Stassun, Angelle Tanner, Noah Tuchow, Dimitri Veras, and Jennifer G. Winters

Highlighted people provided significant contributions, e.g. as a Task Force lead.

Orbital Properties

Stellar Activity

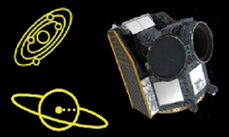
Direct Imaging

Asteroseismology

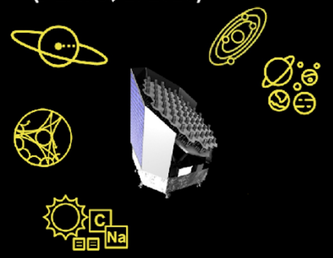
Stellar Abundances

# Stellar/Exoplanet Observations

ESA CHaracterizing ExOPlanets Satellite (CHEOPS, L. 2019)

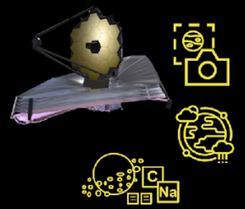


ESA PLAnetary Transits and Oscillations of stars (PLATO, L. 2026)

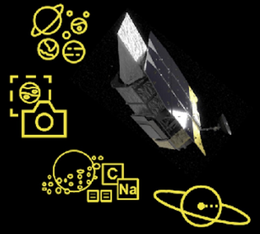



NASA Transiting Exoplanet Survey Satellite (TESS, L. 2018)

NASA James Webb Space Telescope (JWST, L. 2021)




NASA Nancy Grace Roman Space Telescope (L. 2025)




ESA Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL, L. 2028) + NASA Contribution to ARIEL Spectroscopy of Exoplanets (CASE)

Ground-based Observations (photometry, spectroscopy, giant telescopes)


Planet Radius

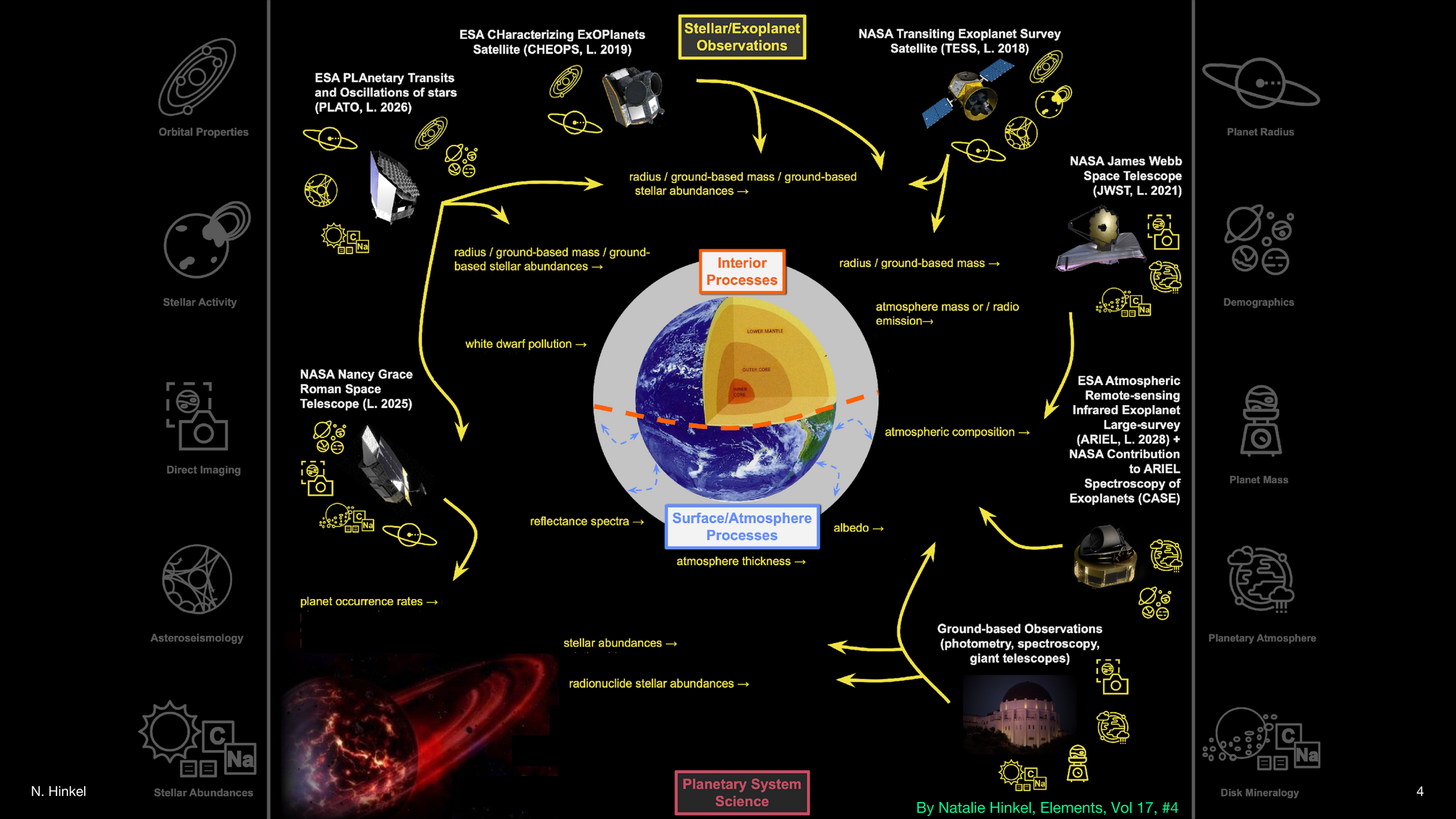
Demographics

Planet Mass

Planetary Atmosphere

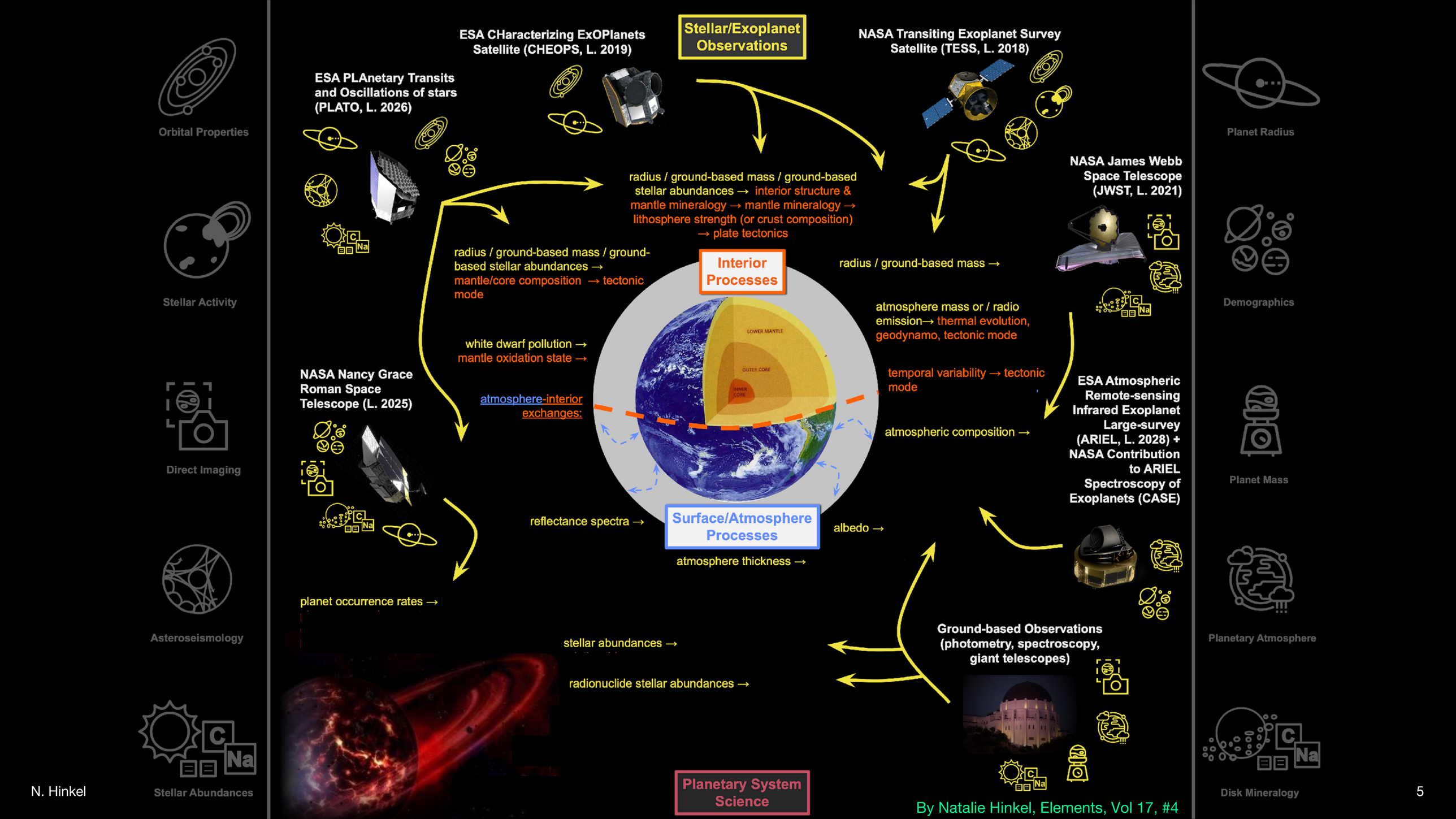
Disk Mineralogy

By Natalie Hinkel, Elements, Vol 17, #4

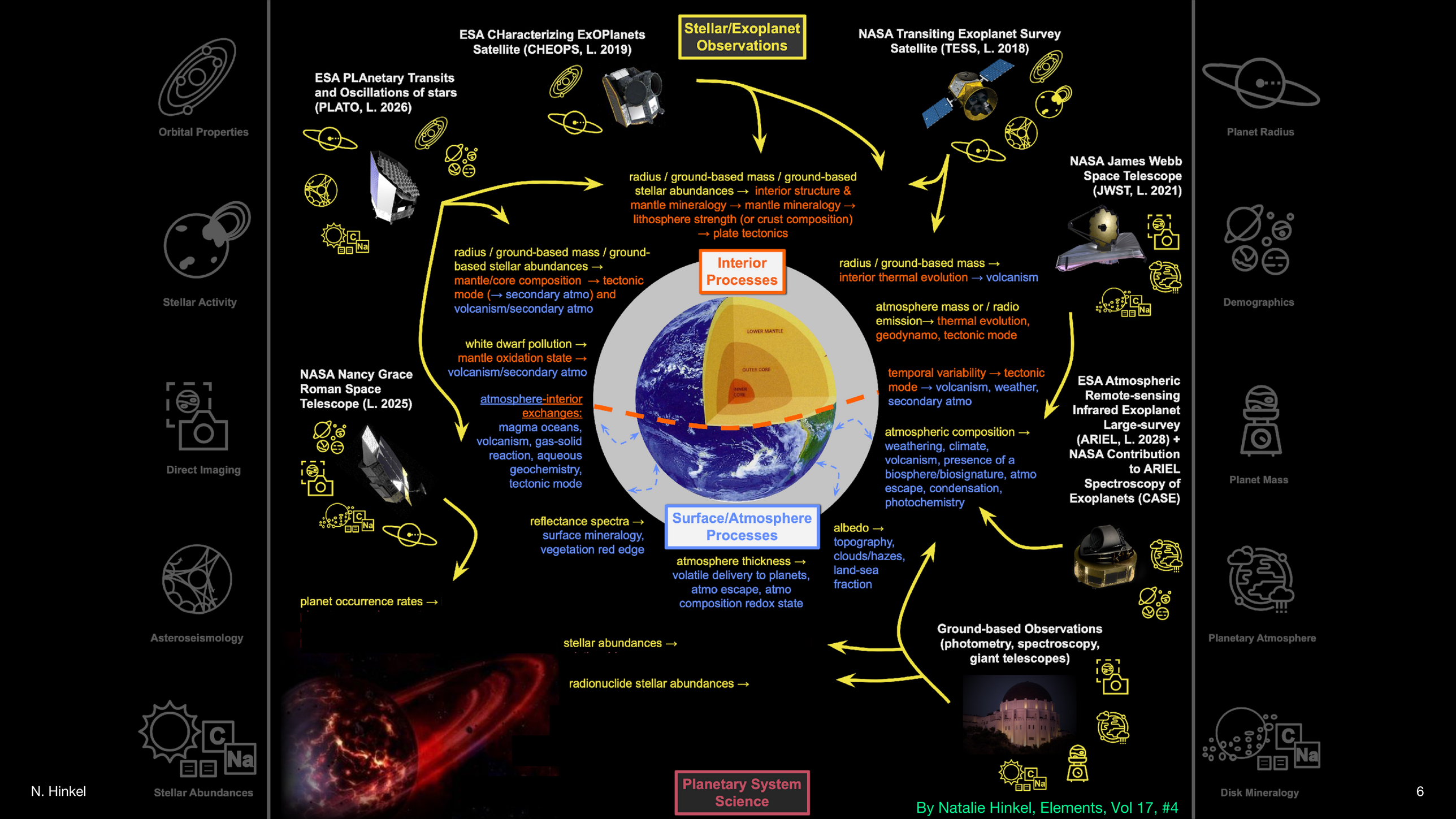




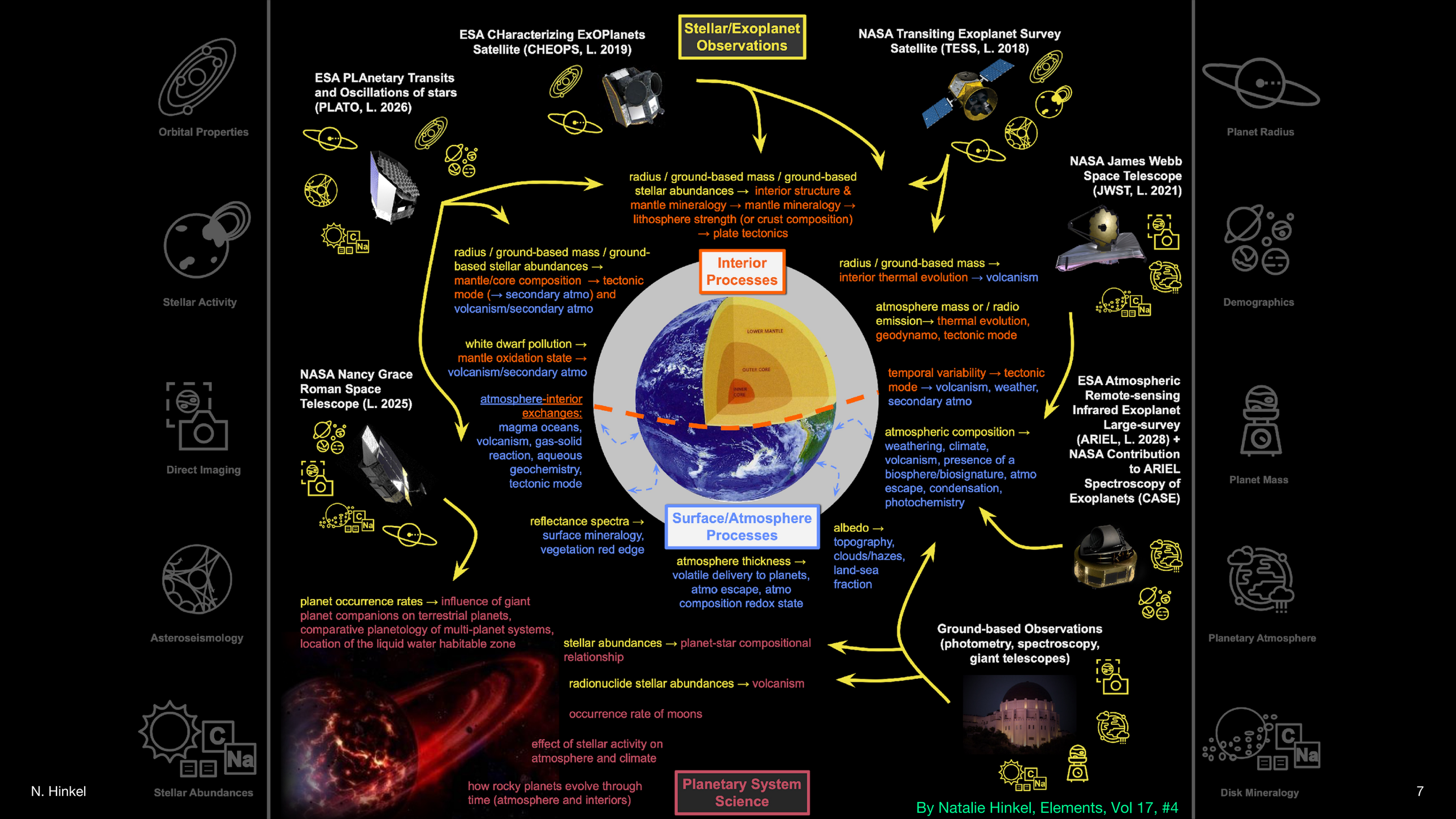

By Natalie Hinkel, Elements, Vol 17, #4




By Natalie Hinkel, Elements, Vol 17, #4




By Natalie Hinkel, Elements, Vol 17, #4

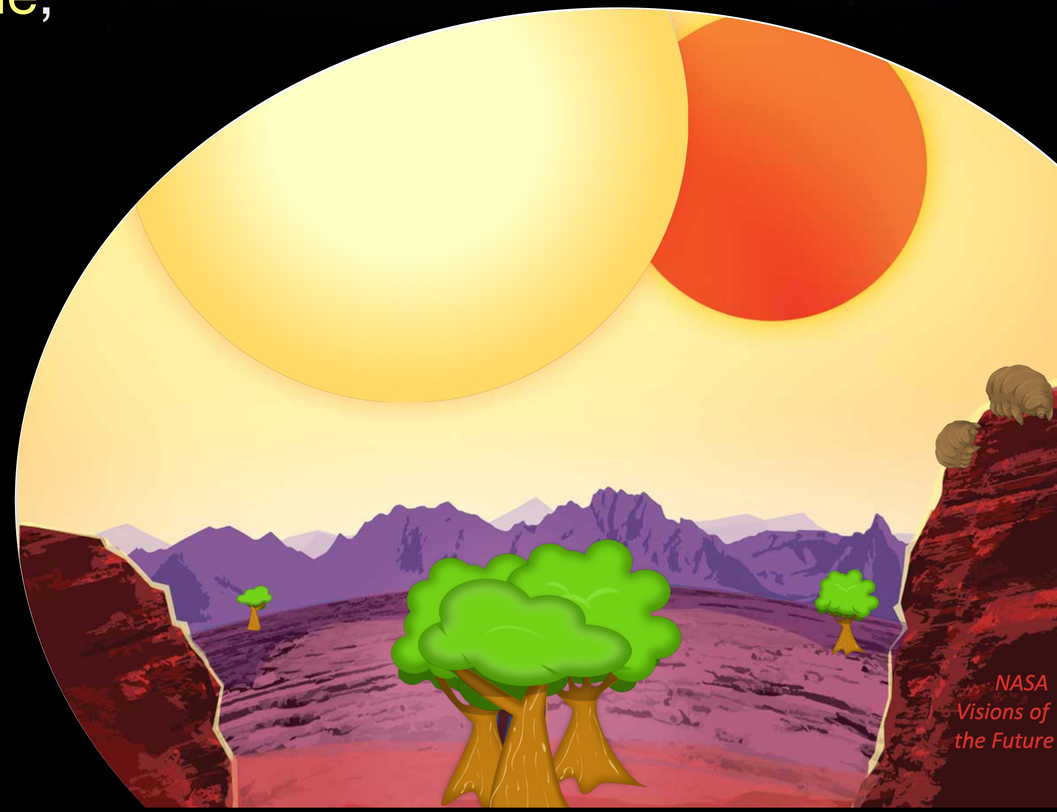



By Natalie Hinkel, Elements, Vol 17, #4

# Motivation for SAG22

To date, there does not exist a central repository or archive of comprehensive stellar *and* exoplanetary data, the absence of which leads to wasted time/effort. Therefore, SAG22:

- Defined attributes of a high priority stellar sample;
- Surveyed the broad exoplanet community (e.g., including planetary scientists, geologists, and biologists) to determine data required for characterizing stellar and planetary systems;
- Prioritized the most useful stellar properties;
- Identified categories of typical end users; and
- Considered pros and cons of various methods for archive implementation and maintenance.



NASA Visions of the Future

N. Hinkel

# SAG22 Organization

The SAG22 goal was to put together a roadmap for a target star archive for exoplanet science based on the needs of the community.

## Phase 1: Information Gathering

- Task Force 1: Mission Observations & Deliverables
- Task Force 2: Target Lists & Target Criteria
- Task Force 3: Interdisciplinary Use Cases
- Task Force 4: Existing Catalogs

## Phase 2: Synthesis

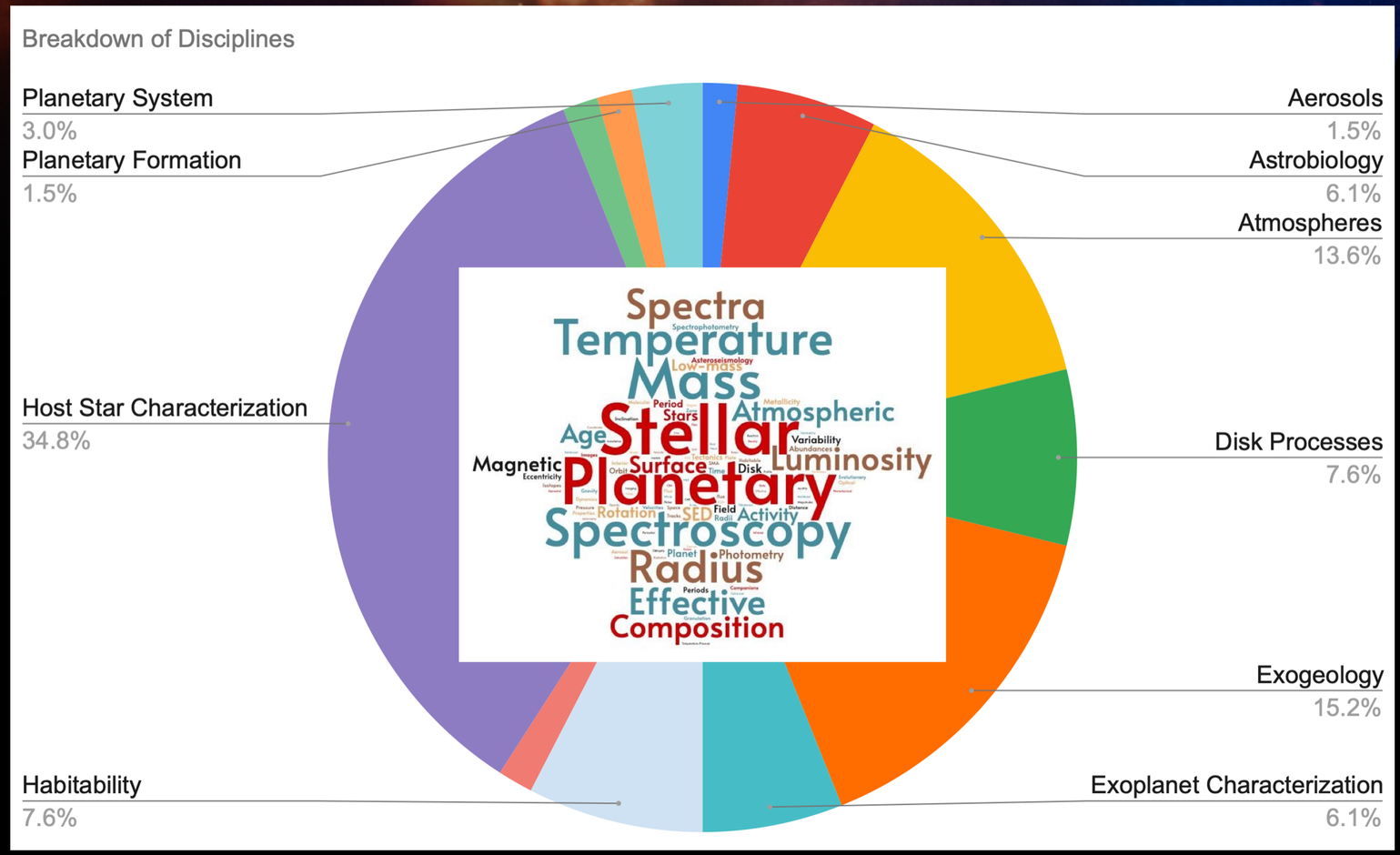
- User Base & Use Cases
- Targets
- Missing Information
- Archive Functionality

## Phase 3: Write Final Report

# User Base & Use Case

Current/upcoming NASA exoplanet missions will provide data that's applicable to a broad, scientific community including: geology, (astro)biology, planetary science, astrophysics, heliophysics, and others.

A survey was sent out to determine the data most desired for characterizing stellar and planetary systems.



# User Base & Use Case

The most common data products that all disciplines need are:

- Stellar physics parameters, including effective temperature, luminosity, mass, radius, age, chromospheric activity, magnetic activity, and spectral energy distributions
- Orbital and physical properties of known planetary companions, including eccentricity, mass, and radius
- Spectroscopy of both the star and planet, with accompanying compositional information, e.g. stellar elemental (Fe, Ca, K, Mg, P, S, Si, Al) & isotopic abundances as a proxy for planet composition, as well as direct planetary atmospheric composition (C, O) where available
- Focused observations of low-mass stellar systems, including rotation rates, EUV flux, long-term variability in UVOIR, including measurement of activity cycles.

Not commonly measured in host stars.

Only ~20% of all currently known exoplanets have both.

A total of ~70 hosts have all abundance measurements (minus P).

# Targets

The most highly targeted stars for exoplanet observations (i.e. where most methods overlap) will be the nearest FGK-type and early-M-type stars, where most stars are NOT known hosts.

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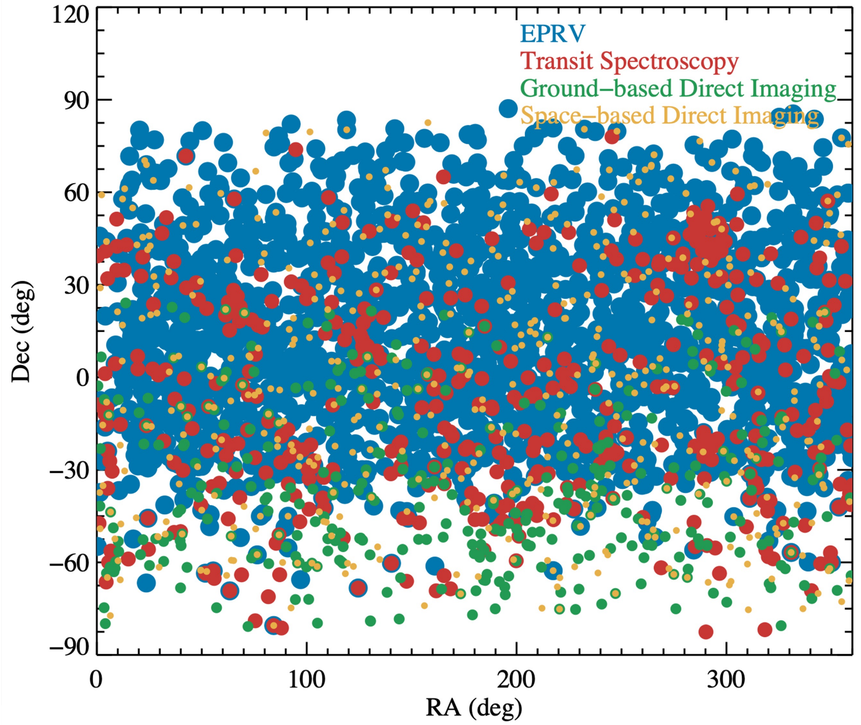
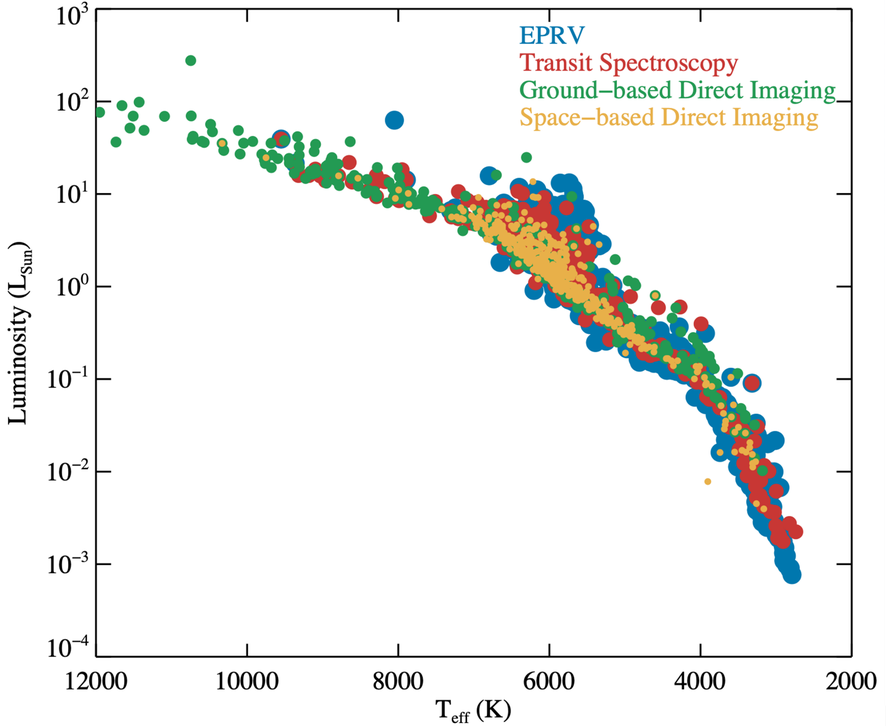
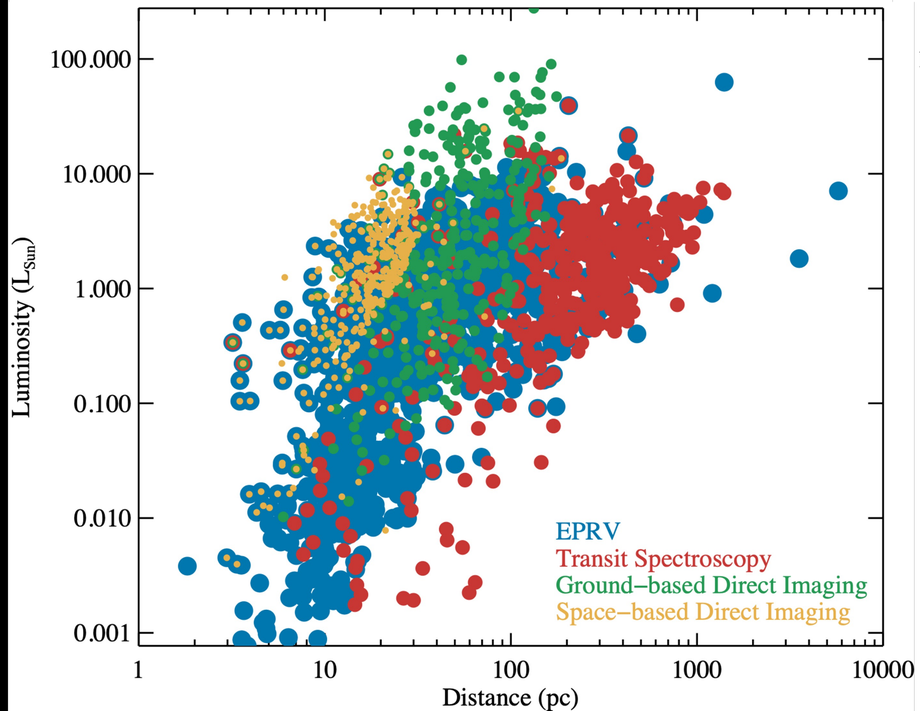
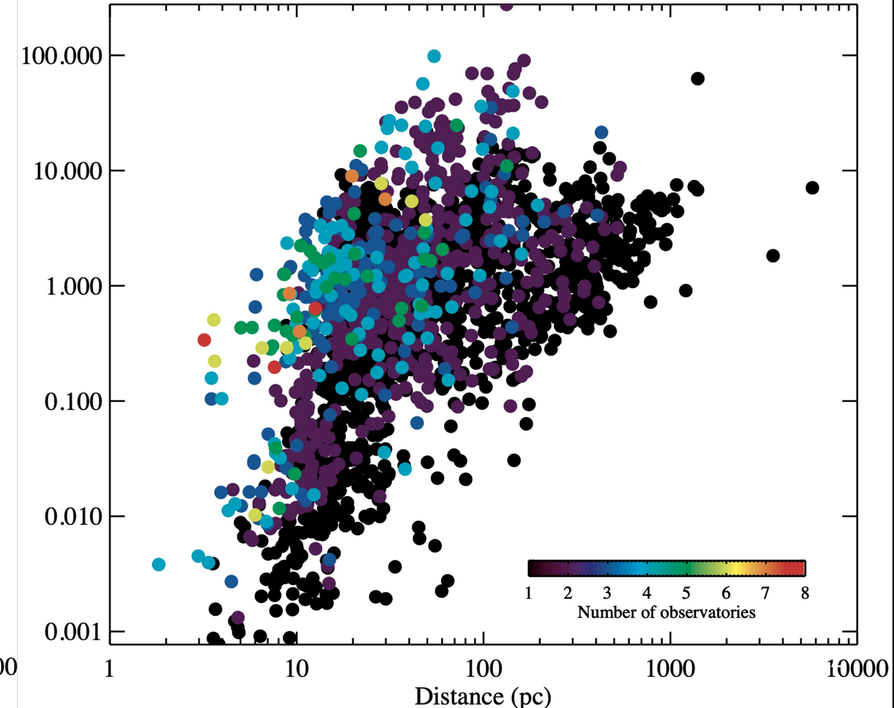


# Archive Functionality

- We consulted with the scientific community to learn what scientists would like to see for the front-end user experience of a target star archive.
- The full list of such requests categorizes items as:
  - “Needs” - the archive will be significantly deficient without the capability,
  - “Wants” - the archive can serve its core purpose without the capability, but the community would significantly benefit with its inclusion, and
  - “Ideas” - capabilities that are not immediately needed, but would provide benefits and should be considered when development resources are available.
- A target star archive would need to be a “living” archive that is regularly updated. It also needs to connect to and be interoperable with other current data archives, making it easier to cross-correlate target data from different resources -- whether active databases or telescope archives.

# Implementation of the SAG22 Report

- NASA ExEP created a HWO Precursor Science Catalog
  Go to NASA Exoplanet Archive → Data → HWO ExEP Precursor Science Stars Table
- The Precursor Science precursor solicitations are including target star science within their scope.
- The HWO START is putting together working groups, which will include further development of the HWO target list and identifying needed stellar information.
- Individually, Courtney Dressing won a Precursor Science Proposal focused on “A Pathway to Planet Properties” and Noah Tuchow is creating a HWO Preliminary Input Catalog (see his talk on Tues at 2pm in Rm 227).

Still….we need a curated, living archive!

# Thank you!

For more info: tinyurl.com/SAG22-FinalReport

Includes the individual Task Force reports.

Or feel free to email to the co-leads:

natalie.hinkel@gmail.com
joshua.a.pepper@nasa.gov
christopher.c.stark@nasa.gov

On a personal note: I'm looking to hire grad students and a postdoc at LSU.
Please come find me if interested.

# Mission Observations & Deliverables

Lead by Karan Molaverdikhani & David Wilson

Upcoming NASA facilities targeting stars with and without confirmed planets will gather a range of observational data, which will be used for a number of discovery and characterization investigations. This Task Force systematically developed a list of current and upcoming exoplanet missions, typical observing modes, and scientific outputs for the following missions:

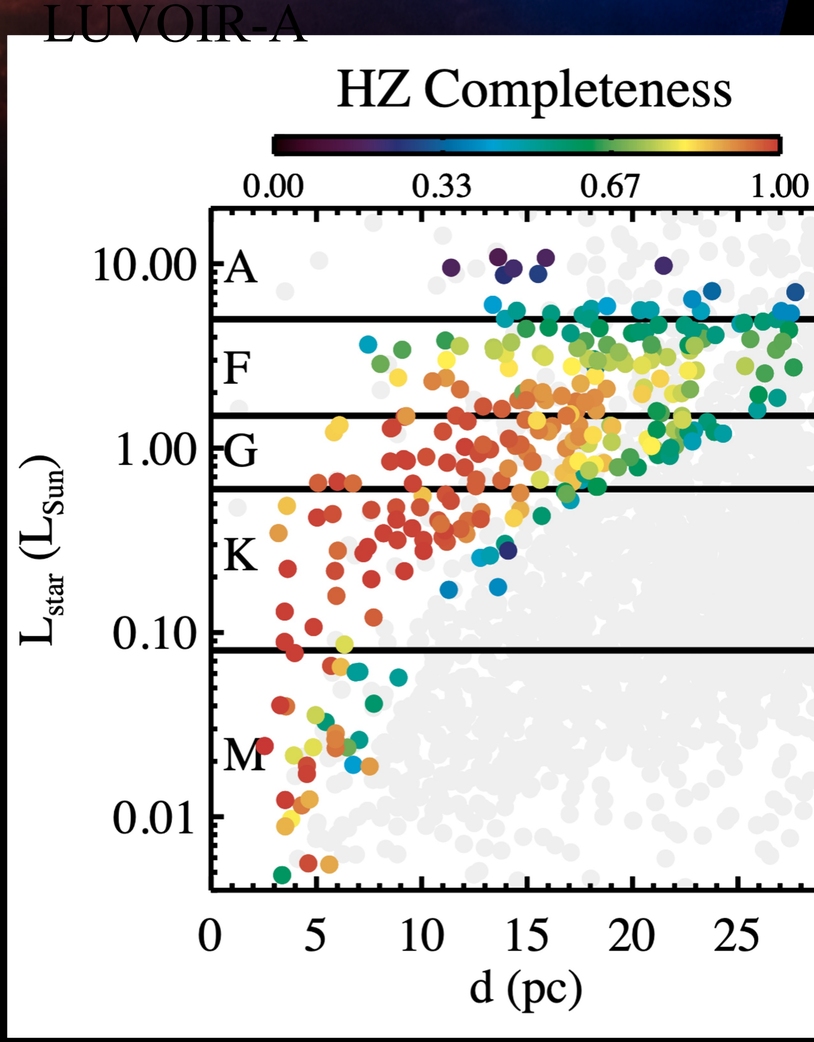
- Hubble Space Telescope
- Transiting Exoplanet Survey Satellite (TESS)
- Chandra X-ray Observatory
- James Webb Space Telescope (JWST)
- Habitable Exoplanet Observatory (HabEx)
- Large UV/Optical/IR Surveyor (LUVOIR)
- Origins Space Telescope (OST)
- Stratospheric Observatory for Infrared Astronomy (SOFIA)
- Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL) + Contribution to ARIEL Spectroscopy of Exoplanets (CASE)
- Roman Space Telescope
- Extremely Large Telescopes such as TMT and GMT

# Target Lists & Target Criteria

Lead by Ilaria Pascucci & David Ciardi

Several of the largest NASA exoplanet facilities/missions are planning to conduct intensive observations of stars and exoplanets. Given the requirements for such observations, most of the appropriate target stars will be drawn from the set of nearby bright dwarf stars, with additional possible restrictions based on stellar spectral type, activity level, stellar rotation, angular separation of star and planet, age, etc. Ultimately, these selection criteria are likely to lead to a similar set of targets for multiple missions.

This Task Force has collected target lists for most of the upcoming exoplanet missions, which were compiled to determine overlap. The input from the previous Task Force was taken into consideration to create visualizations of the target lists' overlap.

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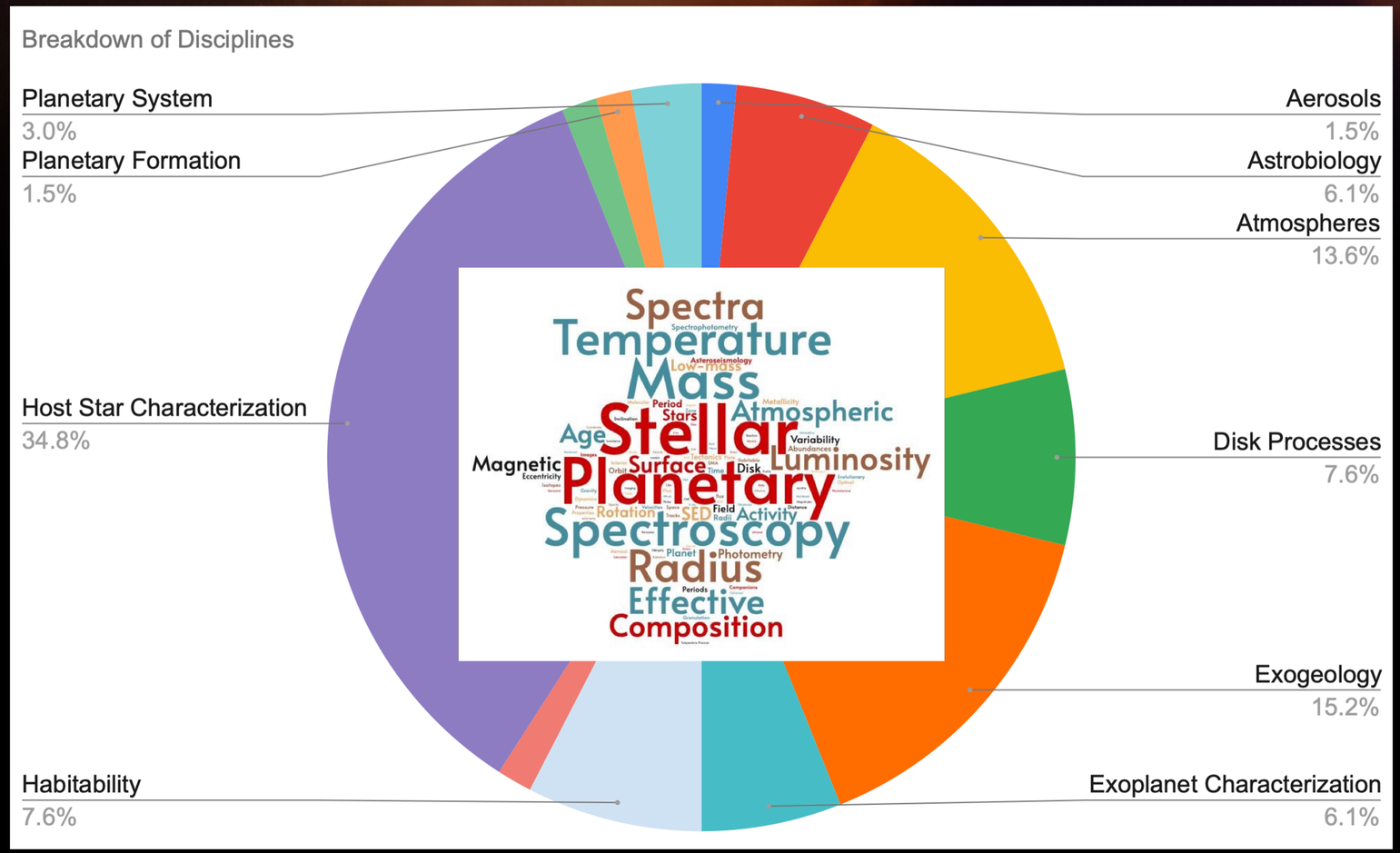
# Interdisciplinary Use Cases

Lead by Jacob Lustig-Yaeger & Ravi Kopparapu




The proposed archive should serve a broad user base, from those designing future missions, to those conducting observations and analyzing observations. This Task Force sent a set of questions to 100s of interdisciplinary scientists to understand their scientific questions, what specific stellar and planetary properties were important, the necessary precision, etc. This Task Force produced a number of visualizations to illustrate the similarity and differences, as well as the gaps between different exoplanet-related fields.

# Existing Catalogs

Lead by Jennifer Burt & Kevin Hardegree-Ullman

This Task Force documented existing catalogs of stellar physical+observational properties:

- Completeness of catalogs is not always well-documented, but having a compiled target list will be a good way to develop a testbed for completeness. Many large all-sky catalogs are especially incomplete for likely exoplanet targets, i.e. the nearest and brightest stars.
- This Task Force documented ~35 individual original catalogs of observed stellar parameters, and a limited set of ~10 compiled catalogs.
- Properties missing from the literature are:
  - Volume-limited stellar samples with reliable distances, proper motions, and multiband photometry
  - UV data including broadband, spectra, variability, and activity indicators
  - Spectral types (as distinct from $T_{eff}$)
  - Comprehensive information on multiplicity and cluster membership

| Frequency of responses regarding missing data in current databases |
| --- |
| (7) cross-correlated target data |
| (2) stellar activity indicators (any) |
| (2) stellar abundances for major components of planets |
| (2) spectroscopy of atmospheric gases |
| (2) broadband coverage |
| (1) UV SEDs |
| (1) X-ray SEDs |
| (1) stellar magnetic activity |
| (1) elemental isotope abundances |
| (1) CMEs |
| (1) realistic stellar models for a larger range of stars |
| (1) accurate measurement uncertainties |
| (1) predictions of direct imaging observations of Earth like exoplanets |
| (1) optical constants for organic aerosols |
| (1) database of exoplanet flux |
| (1) Zeeman doppler imaging |
| (1) high spectral resolution |
| (1) cross-referenced archival photometric data |
| (1) complete survey information |
| (1) oscillation modes |
| (1) cross-correlated planet and star data |
| (1) continuum opacities |
| (1) list of planets in the HZ |
| (1) asteroseismology data |
| (1) ease of use for multi-parameter searches |
| (1) UV data |
| (1) high precision EUV data |
| (1) planetary surface compositions |

# Data That Doesn't Exist

- The frequency (in parenthesis) of properties missing from current databases the survey of interdisciplinary scientists where highlighted properties are considered essential to characterizing stellar and planetary systems.
- The most common interdisciplinary concern was that it is difficult to cross-correlate target data from different resources, whether active databases or telescope archives.
- Stellar activity indicators and stellar elemental abundances (i.e. Fe, Mg, Si, Al, and Ca) are key for interdisciplinary science, but are not available for a wide range of stars.
- So not only do we need more data, but that data needs to be in accessible, tractable databases!