Contextualizing Planetary Systems and their Host Stars for the Habitable Worlds Observatory

Thematic Areas (Check all that apply):

☒ (Theme A) Key science themes that should be prioritized for future JWST and HST observations
☐ (Theme B) Advice on optimal timing for substantive follow-up observations and mechanisms for enabling exoplanet science with HST and/or JWST
☐ (Theme C) The appropriate scale of resources likely required to support exoplanet science with HST and/or JWST
☒ (Theme D) A specific concept for a large-scale (∼500 hours) Director's Discretionary exoplanet program to start implementation by JWST Cycle 3.

Summary: The Habitable Worlds Observatory (HWO) will be NASA's next flagship space telescope to search for biosignatures on terrestrial worlds in the habitable zones of nearby Sun-like stars. A list of the most promising stars has been released to the community to carry out precursor science and target vetting. We advocate for a comprehensive characterization of these host stars and their planetary systems through Legacy-scale programs with JWST and HST. High-contrast 2–5 μm coronagraphy using JWST/NIRCam will be used to identify giant planets and cold brown dwarf companions on Solar System scales. These will help inform the broader planetary system architecture, and many could be dynamically disruptive to habitable-zone planets. Non-detections will provide valuable context about what planet masses and separations can be excluded in these systems. The UV radiation environments of the host stars directly impact the photochemistry and energy balance of terrestrial planets discovered with HWO. This information is critical to correctly model and interpret the reflected-light spectra of planets. Host star chromospheric emission can be mapped from ≈1000–3000 Å with high-resolution spectroscopy using HST/COS and STIS, similar to the MUSCLES and Mega-MUSCLES Treasury Surveys. JWST and HST are the only facilities available to image the giant planets around HWO precursor targets and contextualize the host star UV radiation environments.

Anticipated Science Objectives: HWO will carry out a direct imaging survey of about 100 nearby main-sequence FGK stars in order to study a smaller sample of about two-dozen habitable-zone (HZ) rocky planets in more detail. NASA has recently released a list of 164 bright stars within 25 pc that represent the most promising targets for HWO to recover a HZ Earth (Mamajek & Stapelfeldt 2023). These stars have been selected based on the expected reflected-light planet contrast, brightness, and orbital angular separation for a nominal 6-m (inscribed) architecture. **However, surprisingly little is known about the planetary systems around many of these stars, as well as their high-energy radiation environments.** For instance, roughly one third of targets in this sample exhibit significant astrometric accelerations between Hipparcos and Gaia—enough to create substantial mission risk if these companions are located in or near the HZs. Are there Jovian planets that would dynamically disrupt Earth analogs? Are there previously unknown brown dwarfs? What are the chromospheric emission levels of these host stars? How will this impact photochemical reactions in the atmospheres of Earth analogs at ≈1 AU and our interpretation of planetary spectra?

We advocate for Legacy surveys with JWST high-contrast imaging and HST UV spectroscopy to address these questions with the following top-level goals:

• [JWST] Probe the planetary architecture of these systems to search for cold giant planets (≈200–500 K; 0.5–10 $M_{\rm Jup}$) on Solar System scales (≈1–30 AU). Coupling RVs, astrometry, and imaging will establish a full portrait of planets.

• [JWST] Assign priorities to the list of HWO precursor targets based in part on the presence and locations of giant planets and brown dwarfs in these systems.

• [HST] Measure chromospheric emission spanning ≈1000–3000 Å, especially Lyα. This range is relevant to photochemical dissociation, which can manifest as false positive biosignature signals (such as O_2 and O_3; e.g. [1]).

Urgency: JWST is the only facility capable of imaging old giant planets, which must be found soon to constrain orbits in the next decade. HST has a limited lifetime and is the only operating telescope that can obtain FUV and NUV spectra.

Risk/Feasibility: Dual-channel NIRCam photometry (e.g., F200W and F444W) would give color information to distinguish planets from background galaxies.

Timeliness: Establishing the best targets must be carried out as early as possible. These results will have implications for the primary mirror size, inner working angle, mission cost, and science goals of HWO.

Cannot be accomplished in GO cycle: The scale and long-term scope of this community survey is beyond what is possible in large GO or Treasury program.

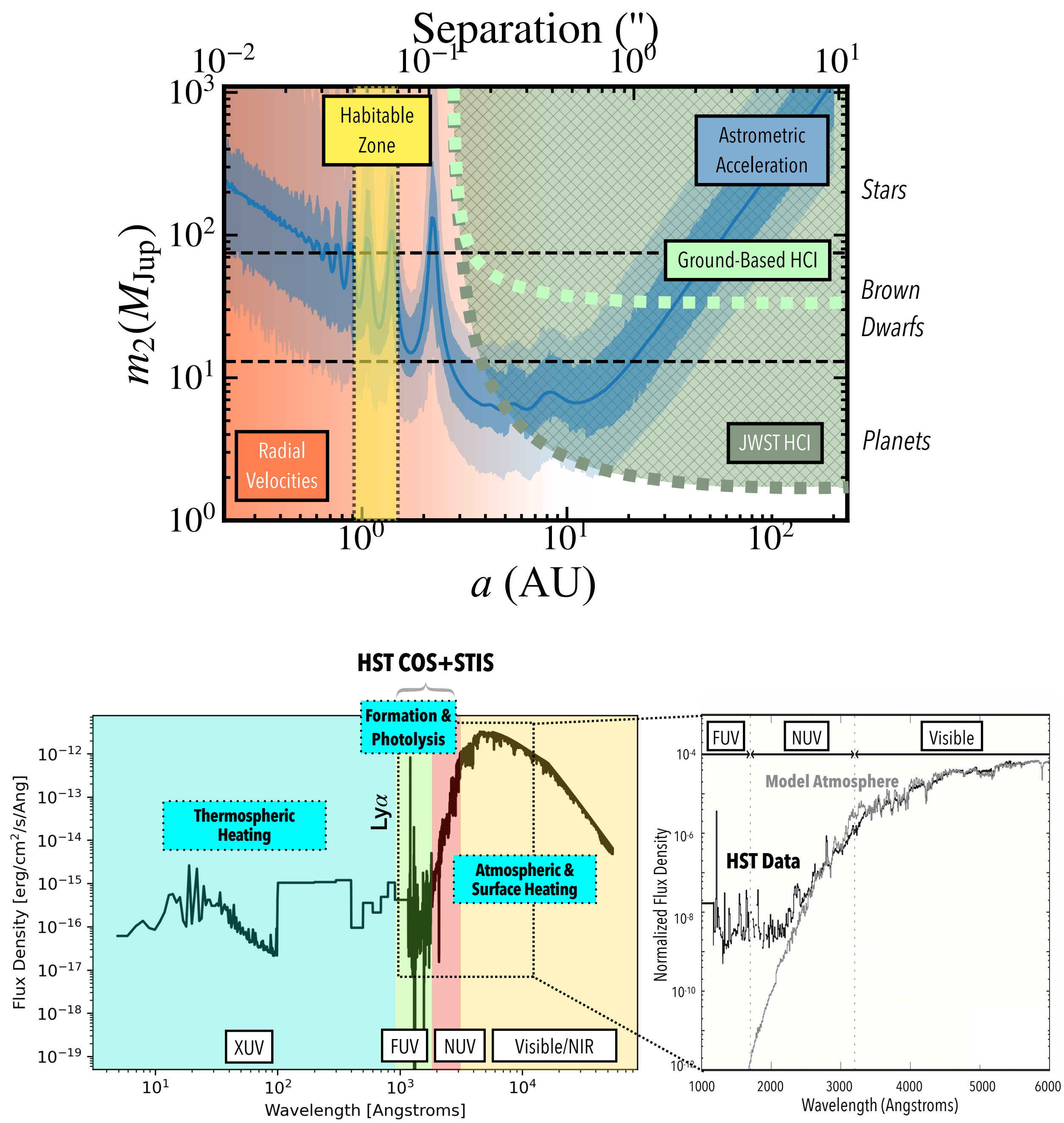

Figure 1: *Top*: Examples of companion mass and separation probed by radial velocities, astrometry, and high-contrast imaging from the ground and with JWST. Roughly one-third of HWO precursor targets exhibit astrometric accelerations which could be caused by stellar companions, brown dwarfs, or giant planets (e.g., [2, 3, 4, 5]). A Legacy-scale survey with JWST will map the outer architecture of HWO planetary systems to image mature giant planets, prioritize precursor targets, and provide a portrait of "planetary siblings" in preparation for detailed studies of habitable-zone terrestrial planets. *Bottom*: High-energy chromospheric (UV) and coronal (X-ray) emission can impact the photochemistry and energy balance of Earth-like planets, and potentially the emergence and evolution of life. A Legacy spectroscopic survey with HST/COS and STIS will establish the UV radiation environment of HWO precursor targets to properly model and interpret future reflected-light observations of planets. Figures adapted from [1] and [6].

References

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