From Cosmic Birth to Living Earths: The Future of UVOIR Space Astronomy

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The Associated Universities for Research in Astronomy (AURA) recently published a new vision for the 2030s entitled *From Cosmic Birth to Living Earths: The Future of UVOIR Space Astronomy.* The report caps a two-year AURA-chartered study of how the ambitious goals of exoplanet and cosmic origins science can be combined into a single flagship general observatory dubbed the "*High-Definition Space Telescope*" (*HDST*).

Led by co-chairs Julianne Dalcanton (University of Washington) and Sara Seager (MIT), the study panel defines *HDST* as a flagship 12-meter general observatory with broadband (0.1–3 micron) sensitivity, several novel modes of instrumentation such as high-performance optical/near infrared (NIR) coronography and far-UV multi-object spectroscopy (MOS), and unprecedented stability in support of high-precision astrometry, spectroscopy, and exoplanet characterization. *HDST*'s headline science goals are to: (1) detect and characterize dozens of Earth-like planets in the habitable zones of nearby stars, looking for biosignature gases in their optical/NIR spectra; and (2) to revolutionize studies of stars, galaxies, and the ultimate ingredients of life in the cosmos with high-resolution imaging and spectroscopy across the full Ultraviolet-Optical-Infrared (UVOIR) bandpass.

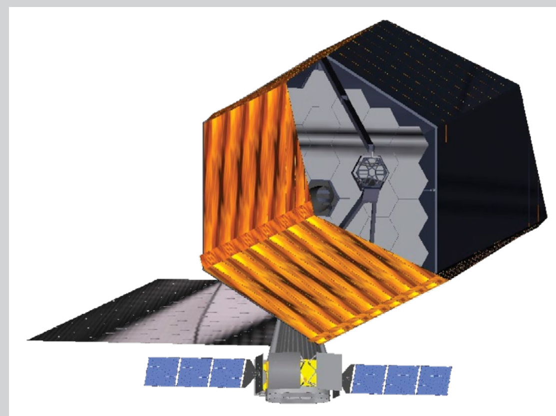

Figure 1: This is an artist's concept of *HDST*, which will be a flagship 12-meter general observatory that combines exoplanet and cosmic origins science. It will feature broadband sensitivity, high-performance optical/NIR coronography, far-UV multi-object spectroscopy, and unprecedented stability in support of high-precision astrometry, spectroscopy, and exoplanet characterization.

HDST builds on NASA and ESA's foundation of missions for exoplanet discovery and characterization: *Kepler*, *Webb*, *TESS*, and *Plato* have or are expected to make fundamental advances in finding and studying planets around other stars. But even if all these missions exhaust their full potential, they will not be able to find and examine the atmospheres of dozens of Earth-like planets in the habitable zones of nearby stars.

Webb in particular will excel at detecting the atmospheres of planets larger than Earth transiting stars smaller than the Sun (i.e., super-Earths orbiting M-dwarfs) where conditions are more favorable for an infrared telescope with coronagraphic contrast at only the 10^{5-6} level. Reaching the atmospheres of dozens of Earth-twin planets typically requires contrast ratios of order 10^{10}, and so is beyond even the future generations of giant ground-based telescopes, which might reach a handful of Earth-size planets by surveying up to a few dozen M stars.

NASA's *WFIRST* will advance key starlight-suppression technologies and search for giant planets and SuperEarths (1.25–2 Earth masses) at the ~10^9 level, but again will not reach dozens of Earth-twin planets. A large stride toward characterizing dozens of Earth-twin planets and searching them for biosignatures requires 10-billion-fold (10^{10}) starlight suppression and a collecting area large enough to obtain revealing exoplanet spectra, which in turn require a large telescope with an extremely stable wavefront coupled with advanced starlight-suppression technology (a coronagraph and/or starshade).

The AURA study advocates that NASA and its community and industrial partners take steps to meet these technological challenges while the array of current and near-future missions lays the groundwork for *HDST*'s search for "Living Earths."

HDST also promises revolutionary gains in capability that will make tremendous advances in our understanding of astrophysical objects and processes from the smallest stars to the most massive black holes. As a flagship in the mold of the Great Observatories, *HDST* will unleash the widespread creativity of the astronomical community with transformative capabilities: it will have 25 times the pixel density per area as *Hubble* in the optical, 4 times better resolution than *Webb* in the NIR, and up to 100 times the point-source UV spectroscopic sensitivity.

It also will be designed to have multi-object UV spectroscopy for up to 100 sources in a ~3 arcmin field of view, and extremely stable wavefronts to provide precise point-spread functions over long timelines. *HDST*'s optical-band spatial resolution corresponds to ~100 pc or finer physical scales *at all redshifts*, which will reveal the internal structure of high-*z* galaxies that even *Webb* will not resolve (Fig 1).

HDST will also have the UV sensitivity to map the weak emission from metals in the circumgalactic medium of galaxies at $z < 2$, where gas flows drive galaxy fueling and transformation. This same UV MOS

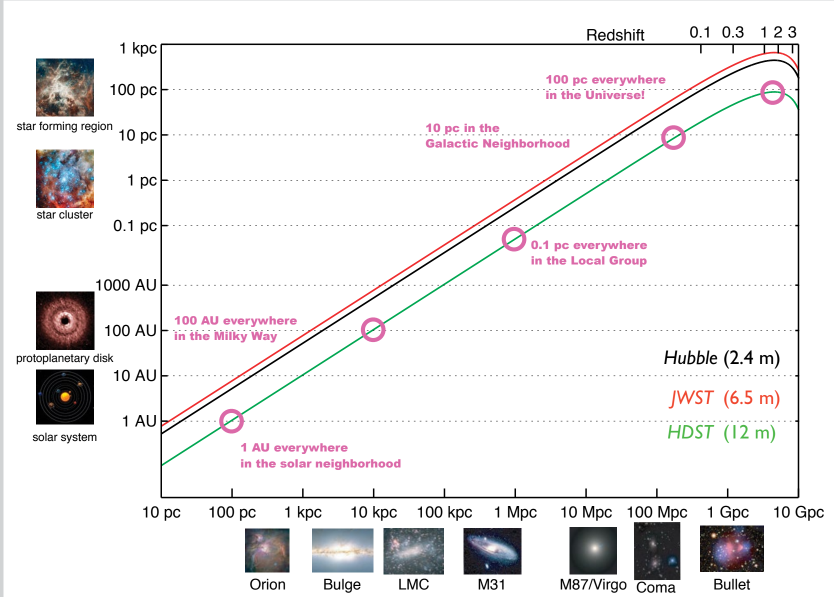

Figure 2: The physical size of *HDST*'s diffraction-limited spatial resolution element, as a function of distance/redshift. Note that the *HDST* resolution element is <100 AU anywhere in the Milky Way and <100 pc anywhere in the observable universe.

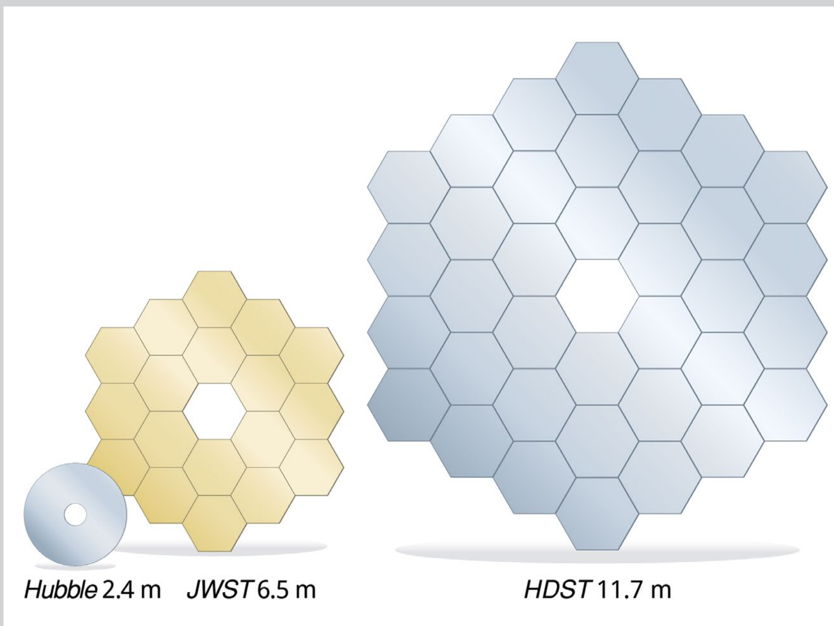

Figure 3: This is a direct, to-scale, comparison between the primary mirrors of *Hubble*, *JWST*, and *HDST*. In this concept, the *HDST* primary is composed of 36 1.7-meter segments. Smaller segments could also be used. An 11-meter class aperture could be made from 54 1.3-meter segments.

capability will enable detailed dissection of star-formation and AGN-driven feedback source-by-source in nearby galaxies. These new UVOIR capabilities promise to transform our understanding galaxies, stars, and the origins of the chemical elements.

The AURA study also carefully examined the technology requirements for *HDST* and concluded that, with the proper investments this decade, *HDST* will be feasible and affordable for a new start in the next decade and launch in the 2030s. The high degree of starlight suppression required for *HDST*'s exoplanet science is the greatest technology challenge, but new designs for coronagaphy are advancing rapidly. For cosmic origins science, the greatest technology needs are for large-format and high-quantum efficiency UV and optical detectors and UV coatings that support sensitivity down to 0.1 micron while minimally affecting the optical wavefront. The report makes specific recommendations on these points that the committee believes should be used to prioritize technology development funding in the next few years.

The AURA study committee is now engaging in discussions about *HDST* with the astronomical community at large, and with NASA and its international and industry partners. We welcome further discussions of *HDST* science and technology; more details and contact information are available at **www.hdstvision.org.**