Essential X-rays and UV characterization of stars that host exoplanets of high interest

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: We propose a joint effort to measure the X-rays and ultraviolet spectra of planet-hosting stars using the Hubble Space Telescope (HST) in conjunction with X-rays observatories, namely XMM-Newton or Chandra. We further propose three criteria to prioritize targets: stars that host benchmark gas giants, planets near the radius valley, and worlds with potential to detect biosignatures. These observations are fundamental for research advances in a wide swath of science cases, such as: the evolution of short-period, small exoplanets due to atmospheric escape driven by photoevaporation, habitability of rocky worlds, and photochemistry in their atmospheres. Given the limited lifetime of HST and the imminent loss of high-quality UV spectroscopy capabilities at the end of this decade, this program is of the highest urgency for our community.

Anticipated Science Objectives: The main objective of this effort is to carry out a survey of the high-energy spectra (X-rays to near-UV) of stars in the solar neighborhood that host planets of interest. For this program, we define planets of interest as: i) Those with the highest potential for atmospheric characterization [using, e.g., the TSM; 1]; ii) Those whose sizes span the radius valley [2, 3]; and iii) Those with potential for detection of biosignatures [4]. The data analysis will involve a combination of UV spectroscopy and X-ray data to derive the extreme-UV (EUV) luminosity and spectral energy distribution of the host stars using a differential emission measure (DEM) technique. DEM is widely regarded as the most reliable technique to indirectly determine the unobserved EUV spectrum of a star [5, 6]. These observations will yield critical constraints to model atmospheric escape in small planets, as well as photochemistry in gas giants and rocky worlds that will be observed with JWST and the Habitable Worlds Observatory (HWO). Since there are more host stars amenable for characterization than time available to carry out this survey, there will be a need to prioritize targets following the "planets of interest" criteria listed above.

Urgency: HST is the only spectrograph that is capable of high-sensitivity, high-resolution spectroscopy in UV wavelengths that are critical for the understanding of exoplanetary atmospheres and evolution. While there are future small missions that will perform UV observations, the sensitivity of Hubble's instruments is necessary to carry out this survey in a more efficient manner.

Risk/Feasibility: The DEM technique requires high-quality, high-resolution UV spectra to yield accurate results. We should aim to obtain SNR ~ 10 in UV emission lines. Similar previous surveys have allocated roughly 10 HST orbits per target [7]. A ULYSSES-scale survey could be expected to yield archival spectra for the 50 highest-priority targets.

Timeliness: With accurate high-energy SEDs of planet hosts, we can answer important scientific questions about planet evolution in the context of atmospheric escape and impact of photochemistry in exoplanet atmospheres, as well as efficiently plan future observing campaigns with JWST and HWO.

Cannot be accomplished in the normal GO cycle: A large, scientifically-broad effort that involves both HST and an X-ray facility is unlikely to be approved in a normal GO cycle. For example, previous programs with a similar objective focused on a particular subset of stars (e.g., M dwarfs in the MUSCLES survey and in the HAZMAT program; [8, 7], JWST transiting exoplanet targets [9]).

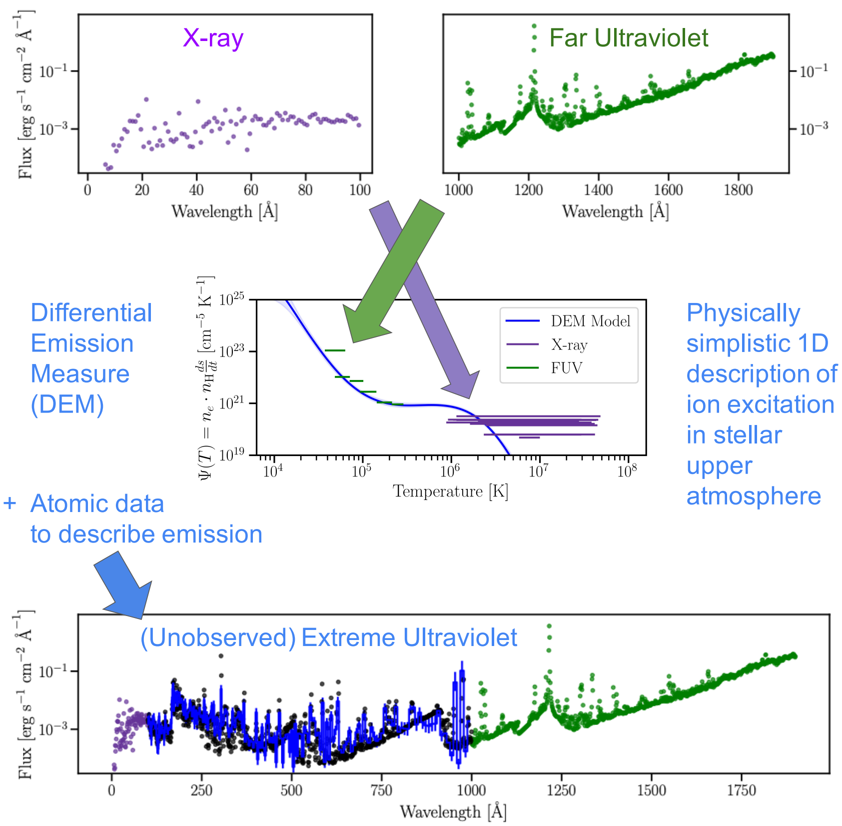

Figure 1: Simplified diagram demonstrating the Differential Emission Measure method to estimate the stellar EUV spectrum.

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