Exoplanet Environment Monitor

A moderate class UV space mission proposed by Jeffrey Linsky and Kevin France, University of Colorado

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One of the very interesting insights that has been inferred from the Kepler data is the high probability of finding habitable zone exoplanets very close to the Sun. Dressing & Charbonneau (2013) predicted, with 95% confidence, that the nearest exoplanet in its habitable zone is located closer than 5 pc, and Kopparapu (2013) presented new calculations that increase the habitable zone size and thereby increase the confidence that the nearest habitable zone exoplanets lie next door from an astronomical perspective.

The chemical composition of an exoplanet's atmosphere and indeed its ability to retain an atmosphere depend on the radiation and particle environment created by the host star. For example, photodissociation of important molecules including H_2O, CO_2, and CH_4 primarily results from very strong Lyman-α stellar radiation, which produces atomic H and O and by further reactions O_2 and O_3. The stellar extreme-UV (EUV) and X-radiation ionize H and heat and thereby expand the exoplanet's outer atmosphere where mass loss can occur by hydrodynamic processes and by stellar wind erosion. In particular, rapid mass loss can occur for exoplanets with weak magnetic fields by charge exchange between H atoms in their outer atmosphere and protons in the stellar wind leading to ion pickep by the stellar wind's magnetic field. Mars may have lost its atmosphere by these processes.

At present, some components of an exoplanet's environment are observed occasionally by existing spacecraft, but the complete environment seen by any exoplanet has never been observed at the same time. Since most exoplanet host stars are cooler than the Sun and many are highly variable, it is essential to monitor the many components of the environment over a sufficiently long time to characterize their mean values and their likely range. To accomplish this objective, we propose a moderate class space mission to continuously monitor the environment of selected host stars located within about 10 pc. The target stars will be host stars of terrestrial-like exoplanets in their habitable zones, with each star to be observed for at least one month. The TESS mission and MEarth observing program will provide lists of the most favorable host stars for this mission, which we call the Exoplanet Environment Monitor. If EEM flys at the same time as a larger mission (e.g., ATLAST), then EEM would provide continuous monitoring while the larger mission obtains occasional unique observations (e.g., high time resolution observations of transits). We will also monitor a few younger stars to identify the evolution of exoplanet environments. The environment components and their observing requirements are listed in the Table.

Environment Component	Observing Requirement
1. Stellar wind mass flux	High-resolution Lyman-α spectra
2. Stellar coronal mass ejections	Low-resolution spectra of the C IV lines
3. Total stellar Lyman-α flux	Reconstructed high-resolution Lyman-α spectra
4. EUV flux	Broad-band 100–600 Å flux
5. X-ray flux	Broad-band soft X-ray flux
6. Far-UV spectral energy	Low-resolution 1220–1700 Å spectra
7. Near-UV spectral energy	Low-resolution 1700–3200 Å spectra

1. The slowly varying component of the stellar wind can be measured from the excess absorption (produced by hydrogen in the stellar hydrogen wall) which is detected on the short wavelength side of the interstellar hydrogen absorption in the stellar Lyman-α emission line. This technique was developed by Wood et al. (2005). Spectral resolution comparable to the STIS E140M mode is required, but only for the 1210–1220 Å region.

2. Coronal mass ejections contribute only about 15% of the time-averaged solar-wind flux, but may contribute a much higher percentage for active stars and M dwarfs. Segura et al. (2010) calculated that a very large CME event on an M dwarf could reduce the amount of ozone in the exoplanet's atmosphere by 90%. Spectra of the C IV 1548, 1550 Å lines with a resolution of 1 Å would likely be sufficient.

3. The observations are the same as in (1), but the analysis requires the reconstruction of the stellar Lyman-α emission line to remove the large interstellar absorption. Wood et al. (2005) and France et al. (2013) have developed these techniques.

4. The EUV broad-band flux can be measured either with multilayer filters or grazing incidence optics.

5. The soft X-ray flux does not require spectral resolution.

6. The far-UV flux can be measured with 1 Å resolution spectra.

7. The near-UV flux can be measured with 1 Å resolution spectra.

The proposed mission should include all or at least most of the capabilities listed in the Table. All of the instruments will observe a given star continuously for at least one month, including transits. Each instrument will be built as small and simply as feasible to accomplish its limited task. Each instrument will likely have a different time resolution given the different fluxes to be observed. The time resolutions can be as short as seconds for tasks 5, 6, and 7, minutes for tasks 2, 4, and 5, and hours for tasks 1 and 3.