First results from the MUSCLES Treasury Survey of UV and X-ray Emission from K and M Host Stars

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Abstract

We present complete spectral energy distributions (SEDs) for 11 exoplanet hosting stars (4 K and 7 M dwarfs). The SEDs consist of contemporaneous X-ray observations by Chandra and XMM-Newton, UV spectra with the COS and STIS instruments on HST, and optical spectra. We reconstruct the Lyman-α fluxes (important for photochemistry of exoplanet atmospheres) and inter 100–912 Å EUV fluxes (important for computing planetary mass-loss rates). These high-resolution 5 Å–5.5 μm spectra, which are available on the STScI MAST website, are critical for assessing atmospheric chemistry and habitability.

1 Motivation and Observing Program

Although host star radiation is essential for understanding the chemical composition and evolution of exoplanet atmospheres and thus habitability, there are few available ultraviolet spectra of the most common host stars, M dwarfs, and no complete spectral energy distributions (SEDs) obtained at the same time for these variable stars. To satisfy the need for the shapes and absolute fluxes at all wavelengths, we have obtained contemporaneous X-ray, UV and optical data for 11 nearby host stars with the MUSCLES (Measurements of the UV Spectral Characteristics of Low-mass Exoplanetary Systems) Treasury Survey. Table 1 lists the properties of the target stars and their exoplanets. The UV and blue spectral coverage of the medium- and low-resolution COS and STIS grating observations during 125 orbits of HST time are listed in Table 2.

2 Spectral Energy Distributions (SEDs)


Figure 1: Fractions of dissociations due to flux in ranges of λ (Å).

Figure 2: Three exoplanet atmospheres with different compositions.

Figure 3: The SED of GJ169 showing the integration of the different data sets and the effect of each spectral region on the atmosphere of an Earth-like planet. The flux in the 100–912 Å region is inferred from the reconstructed Lyman-α flux.

Figure 4: The SEDs of the 11 target stars. All of the target stars and likely most or all M dwarf host stars emit X-ray and UV radiation. The most active stars show X-ray and EUV fluxes per Å that are approximately 10–7 of the bolometric flux.

Figure 5: The observed spectrum of GJ832 is orders of magnitude brighter than PHOENIX photospheric model in the NUV where abiotic photolysis of O2 and O3 is important and in the FUV where the creation of oxygen from the photolysis of H2O, CH4, and CO2 are important.

Figure 6: Ratios of the FUV (1217 Å) to NUV (1700–3000 Å) flux for M dwarfs (upper left) and K dwarfs (lower right) that control the abiotic oxygen budget in the upper atmospheres of exoplanets. The solar FUV/NUV ratio is 0.004.

Figure 7: Cumulative photodissociation spectra of different molecules for 3 stars: GJ581, the M star with the lowest FUV flux (dashed lines), α Eri, the K star with the highest FUV flux (solid grey lines), and the Sun (solid black lines). The curves show the increasing fraction of photodissociation with increasing wavelength assuming no attenuation of the stellar flux. Note the importance of Lyman-α for the dissociation of H2O and CH4.

Figure 8: Tentative evidence that star–planet interaction (SPI) deposits energy into the transition region of K and M host stars. The figure shows the correlation coefficients for Lyman-α (Lyα) vs. the ratio of planetary mass to semi-major axis for emission lines formed at different temperatures from the chromosphere (MgII) to the transition region (SiIV, CIV, and NV).

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