SPD Thomas Metcalf Travel Award Report

Sun-Climate Symposium
Flagstaff - AZ | 16-20 October 2023

Laura Amaral is a Postdoctoral Scholar Researcher at the Arizona State University in Tempe/AZ, working with Evgenya Shkolnik. Her research is focused on understanding how the atmosphere of exoplanets evolves with time and what is the role of stellar flaring in the atmosphere of exoplanets, through modeling. She is a Co-investigator at the Consortium on Habitability and Atmospheres of M-dwarf Planets (CHAMPs) and the Virtual Planetary Laboratory (VPL).

Oral contribution:
XUV-Driven Atmospheric Mass Loss of M Dwarf Planets due to Flaring

Laura Amaral, Rory Barnes, Antígona Segura, Rodrigo Luger

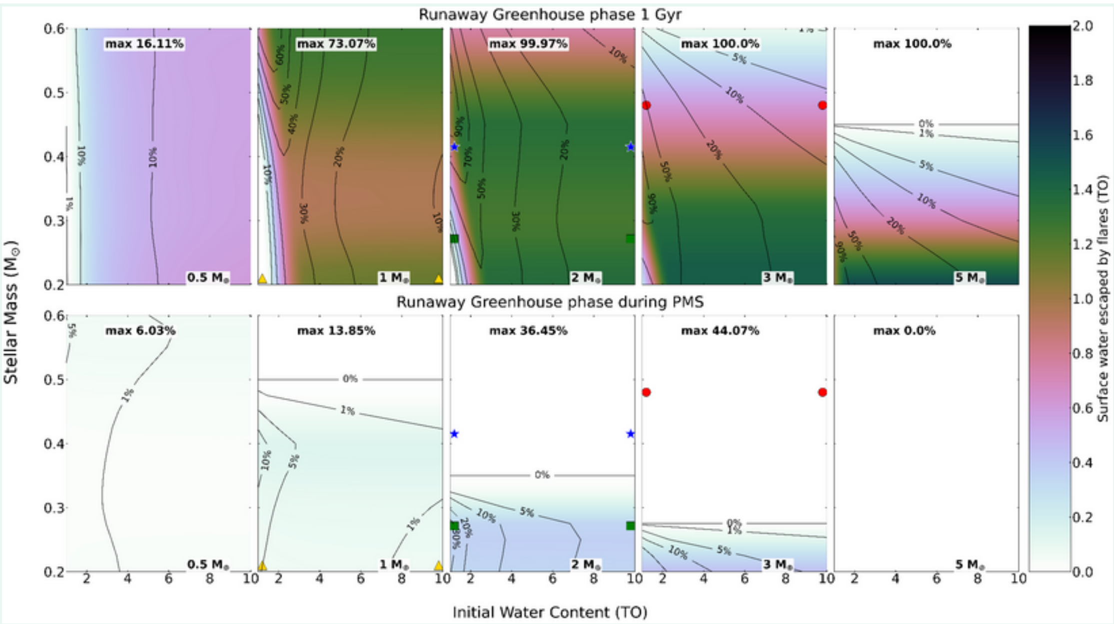

Figure 1:

Flare only contribution to the water lost in percentage (contour lines) and absolute amount (shades) in TO. In the top panels, the runaway greenhouse phase occurs throughout all the simulation. In the bottom panels, the runaway greenhouse effect stops when the planet enters the (optimistic) habitable zone (Amaral et al., 2022).

The M-type stars of the main sequence remain in this stage for about 100 Gyr (Baraffe et al., 1998). These stars are also very abundant in our galaxy, constituting about 70% of the total population (Bochanski. et al., 2010), and 48.6% of them are expected to have at least one Earth-like planet in their habitable zone (HZ) (Garrett et al., 2018).

However, the habitability of planets around these stars may be affected by the particular characteristics of these stars. The variation in the flux of XUV radiation, due to the emission of flares, is more frequent and energetic than in the Sun (Hawley et al., 2014). This range of wavelengths ionizes and heats the exosphere of the planetary atmosphere, generating an expansion of the atmosphere and facilitating the atmospheric escape (Luger et al., 2015).

The objective of this work is to calculate the contribution of the XUV due flaring in the atmospheric escape of potentially habitable planets around M dwarf stars using numerical simulations. For this purpose, a module was developed within the VPLanet code that includes the XUV emission of stellar flares. In this work, we consider planets with initial amounts of surface water between 1 and 10 terrestrial oceans (TO), a primordial envelope of hydrogen (< 0.001 Earth masses), and around stars with masses between 0.2 and 0.6 solar masses.

In this parameter range, we find that flares can remove up to two TO more than nonflaring stars, which, in some cases, translates to a doubling of the total water loss (Amaral et al., 2022). We also find that flaring can increase atmospheric oxygen partial pressures by hundreds of bars in some cases. The results show that planets with the same mass as the Tierra in the HZ of M dwarfs, lose little more than 56% of their surface water (see Figure 1).

These results consider scenarios in which these planets experience a short phase of runaway greenhouse effect, orbiting active stars. In this case, the flares are responsible for a 13% increase in water escape, when compared to scenarios when the star is in its quiescent state. This implies that even in an environment exposed to high XUV flux, as in the case of M dwarf stars, it is still possible to still have water on the surface of planets after a thousand years.

I am very thankful and honored to the AAS/SPD committee and Sun-climate Symposium for choosing me as a Thomas Metcalf Travel Awardee. I received fruitful feedback on my research and made two important collaborations because of my talk.