Stellar Proton Events and Exoplanetary Habitability

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Superflares of energies up to $10^{38}$ ergs have been studied from Kepler and Gaia observations, and estimates of their energy and frequency on different types of stars is improving rapidly. Flares with energies up to $10^{35}$ ergs occur about once every 2000-3000 years on slow rotating stars like the Sun, but the occurrence rate is $\sim 100$ times higher for younger, faster rotating stars of the same class. More than a dozen potentially habitable planets, like Proxima Centauri b and TRAPPIST-1 e, are in close-in configurations and their proximity to the host star makes them highly sensitive to stellar activity. Episodic events such as flares have the potential to cause severe damage to close-in planets, adversely impacting their habitability. Stellar Energetic Particles (SEPs) emanating from Stellar Proton Events (SPEs) cause atmospheric damage (erosion and photochemical changes), and produce secondary particles, which in turn results in enhanced radiation dosage on planetary surfaces. Taking particle spectra from 70 major solar events (observed between 1956 and 2012) as proxy, we use the GEANT4 Monte Carlo model to simulate SPE interactions with exoplanetary atmospheres. We have demonstrated that radiation dose varies significantly with charged particle spectra and an event of a given fluence can have a drastically different effect depending on the spectrum. Our results show that radiation dose can vary by about five orders of magnitude for a given fluence. In terms of shielding, we found that atmospheric depth is a major factor in determining radiation dose on the planetary surface. Radiation dose is reduced by three orders of magnitude corresponding to an increase in the atmospheric depth by an order of magnitude. We found that the planetary magnetic field is an important but a less significant factor compared to atmospheric depth. The dose is reduced by a factor of about thirty corresponding to an increase in the magnetospheric strength by an order of magnitude.