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How might stellar flares energize the atmospheres of rocky exoplanets?

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Space weather events sourced from host stars, including stellar flares, coronal mass ejections, and stellar proton events, can substantially influence an exoplanet's habitability and atmospheric evolution history. These time-dependent events may also affect our ability to measure and interpret its properties by modulating reservoirs of key chemical compounds and/or by changing the brightness temperature of the atmosphere. The majority of previous work however, used single-column models and focused on the photochemical effects of stellar flares. Here, using three-dimensional (3D) general circulation models with interactive photochemistry, we simulate the climate and chemical impacts of stellar flare sourced energetic particle precipitation and examine their effects on synchronously rotating TRAPPIST-1e-like planets on a range of spatiotemporal scales. We find that sudden thermospheric cooling is associated with NO and CO2 radiative cooling, and lower atmospheric warming is associated with transient increases in infrared absorbers such as N2O and H2O. In certain regimes, these changes in temperature are strongly affected by O3 variability depending on the flare spectra shape and energy, as found by previous work. The role of O3 in temperature change however, is reduced in the most extreme flaring scenario explored in our simulations. In addition to effects on planetary climate and atmospheric chemistry, we also find that strong flares can energize the middle atmosphere, causing regional enhancements in wind velocities up to 40 m/s in substellar nightsides between 30 and 50 km in altitude. Our results suggest that successive, more energetic eruptive events from younger stars may be an important factor in controlling the atmosphere dynamics of their planets, in addition to the properties of the planet itself.

Section

Solar System/Exoplanets

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