Window Of Opportunity for the Origin of Life: Impact of Stellar Activity on the Habitability of early Earth and Exoplanets. V. S. Airapetian[1], A. Glocer[1], G. Gronoff[2], E. Hébrard[3], S. Domagal-Goldman[1], W. Danchi[1]

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Introduction: The landscape of exoplanetary science has changed considerably with the great success of the *Kepler* mission, which has discovered thousands of transit candidates and hundreds of confirmed exoplanets around stars of widely different spectral classes (masses) and a few planets within habitability zones. *Kepler* also revealed thousands of superflares on hundreds of solar-type stars [1], which may suggest that host stars may have profound effects on the physical and chemical evolution of exoplanetary atmospheres. While we can only infer the course of our own Sun's early evolution and how it might have affected the early evolution of the Earth, possibly setting the stage for the origin of life, the observation of planets around sun-like stars may allow us to directly observe events which likely took place in our own solar system. A major question this leads to is: *Do the energy fluxes from catastrophic superflare events early in a host star's evolution direct the course of pre-biotic chemistry and by consequence the origin of life on primitive planets?*

In this study we focus on the role of the astrophysical drivers, specifically: the effects of ionizing radiation initiated by energetic eruptive events including solar/stellar flares, coronal mass ejections (CMEs) and associated particle events on the chemistry of Earth's and exoplanetary atmospheres. We employed a three-dimensional (3D) magnetohydrodynamic code (MHD) code to simulate the dynamics of interaction of a Super-Carrington CME (SCME) on the backgrpound of the solar wind with the early Earth's magnetic field. Our results suggest that the combined effect of the dynamic pressure due the magnetic cloud and the magnetic reconnection compresses the Earth's magnetosphere from 10 to at least 2 Earth's radii [2]. Intensive reconnection of the incoming SCME with the Earth's dipole field at 1.3 R_E from the surface produces global restructuring of the open magnetic field forms a substantial opening the magnetic field line at the day side that reaches 65% at 1.3 R_E. The boundary of the open-closed field shifts to 36 degrees in latitude. We complemented this model with the simulations of the atmospheric chemistry by two models, Aeroplanet model [3] and a coupled 1D photochemical-climate model, VPLANET [4-5]. These models are applied for the highly reducing nitrogen-dominated early Earth's atmosphere to calculate the effect of CME associated solar proton events (SPEs) with energies > 10 MeV and energy fluxes 10 times of July 2000 SEP event on the collisional dissociation of molecular nitrogen. We find that in the steady state model of particle precipitation, the production rate of atomic hydrogen reaches 3 x10^{14} cm^{-3} . Our model suggests that nitrogen fixation can be a dominant process in the first few 100 million years in the life of the young Sun. We discuss the implications this process has for nitrogen fixation for the sake of prebiotic chemistry and for biological productivity before the advent of biological nitrogen fixation. HCN and other N-containing species produced in these processes may be subsequently rained out into surface reservoirs. Finally, we demonstrate the effects of the energy deposition and chemistry changes resulting from these flare events on the climate of the Earth-like planet. This could have significant implications for the Faint Young Sun Paradox. We show the implications of these results on habitability of exoplanets around M and G-type stars.

References:
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