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Recent Observations of Stellar Flares and Possible Mass Ejections

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Flares are frequent energetic explosions in the stellar atmosphere, and are thought to occur by impulsive releases of magnetic energy stored around starspots. Large flares (so called "superflares") generate strong high energy X+UV emissions and coronal mass ejections (CMEs), which can greatly affect the planetary environment and habitability. Recent Kepler/TESS photometric data have revealed the statistical properties of superflares on G, K, M-type stars (e.g., [1] - [6]). Superflare stars are well characterized by the existence of large starspots on the surface, and their magnetic fluxes can explain well superflare energies ([3],[4],[7],[8]). Flare frequency/energy depends on stellar rotation period and stellar temperature. Young rapidly-rotating stars and cooler stars tend to have frequent flares, which can be more "hazardous" for the habitable planets. However, we still do not know the emission mechanisms of superflares, and how large CMEs are associated with superflares on these active stars ([9],[10]). Then recently, these active superflare stars have been investigated in more detail through recent multi-wavelength surveys. For example, Hydrogen chromospheric lines during flares show blue-shifted profiles, which can give us some hints on dynamics or mass ejections during superflares ([2],[11],[12],[13]). They could be the start point for quantitatively discussing the impacts of flares and CMEs on the environment and habitability of various planets including young Earth/Mars ([9],[14]).

In the early part of the talk, I briefly overview the recent statistical results of superflares from Kepler/TESS data. Then in the latter part, I discuss the results of recent multi-wavelength campaign observations of superflares, and discuss possible detections of mass ejections (stellar CMEs).

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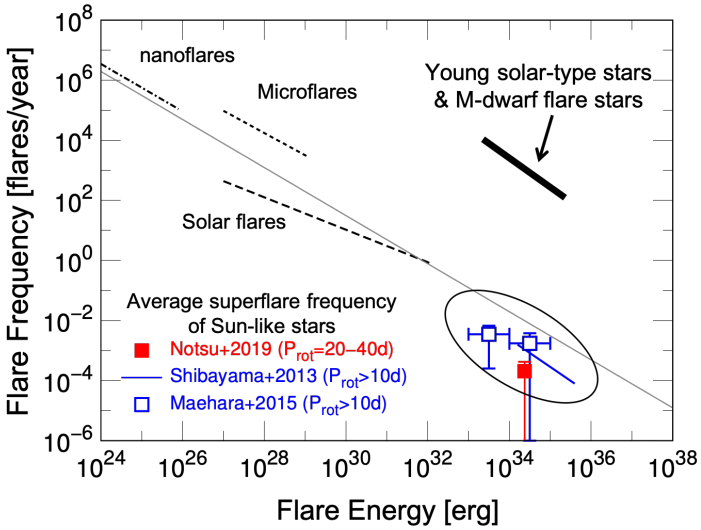

[Figure 1] Occurrence frequency distributions for solar flares and Kepler superflares on Sun-like stars, showing both to be consistent with the same power law (see [4],[6] for the details). A superflare having an energy of 1034 erg, about 100 times larger than the observed maximum solar-flare energy, occurs once every a few thousand years on slowly rotating solar-type stars. However, it occurs about 1,000 times per 1 year on young solar-type and M-type flare stars (cf. [15]).