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Characteristics of 29 Sustained-Emission >100 MeV Gamma-Ray Events Associated with Impulsive Solar Flares

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We detail the characteristics of 29 sustained-emission >100 MeV solar gamma-ray events observed by Fermi that are distinct from the associated impulsive flares. The >100 MeV gamma-ray emission is well fit by pion-decay spectra produced by >300 MeV protons following a power-law spectrum, or one that rolls over at high energy, and is inconsistent with bremsstrahlung from primary electrons. Sustained gamma-ray emission results: 1) temporal characteristics – onset times from CME launch to 80 min later, durations from 4 min to 20 hr that are correlated with >100 MeV SEP durations, neither due to tail of the impulsive flare nor post-flare episodic emission; 2) proton characteristics—spectra soften >100 MeV to a mean power-law index –4.5 > 300 MeV, evidence that spectra of long-duration events soften in time and that short-duration spectra harden in time, proton number >10 times that in the impulsive flare and 10-2 times that in accompanying SEP; 3) location: neither just from active region nor globally from Sun, but can extend tens of degrees from the AR; 4) associations: all with impulsive flare HXRs >100 keV and all but two with CMEs, bremsstrahlung from MeV electrons observed along with sustained gamma rays from a behind-the-limb flare. The sustained gamma-ray emission is likely produced by CME shock acceleration, common to that producing the associated SEPs, of a seed population that includes sub-MeV flare particles onto magnetic field lines returning to the Sun.

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