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The magnetic connectivity of coronal shocks to the visible disk during long-duration gamma-ray flares

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Solar gamma-ray emissions are attributed to energetic particles accelerated in the low corona during solar flares and generally associated to the concomitant eruption of Coronal Mass Ejections (CMEs). Solar flares and coronal shocks are two strong candidate accelerators for energetic particles that produce $\gamma-$rays. For many γ-ray events that last more than an hour, the so-called Long Duration Gamma Ray Flares (LDGRFs), a broad source location is invoked to explain the observations, this is particularly true in events associated with solar eruptions that emerged on the far side of the Sun since the flare loop and foot-points are not visible from Earth. Such configurations provide favorable case studies to investigate the possible role of shocks driven by CMEs in producing the energetic particles that lead to LDGRFs. We analyse three CMEs that (1) erupted behind the solar limb viewed from Earth, (2) were associated with the early formation of coronal shocks measured by ground-based radio spectrographs, (3) were associated with $\gamma-$ray events measured by the Fermi-LAT instrument. A 3D triangulation technique, based on observation in the Extreme Ultraviolet (EUV) and visible light, is employed to model the expansion of these three CME shocks from above the solar surface to the upper corona. We then used the HELCATS catalogue of CMEs to follow the interplanetary propagation of these CMEs. Coupling it with different models of the coronal magnetic field allows us to derive the time-dependent distribution of shock Mach numbers and the magnetic connection of the shock to the solar surface visible from Earth. In all of the three events, the shock front associated with the impulsive flare was magnetically connected to the visible solar surface rapidly after the start of the flare and before the onset of gamma-ray emission observed by Fermi-LAT γ-ray emission. These early connected parts of the shock surface are mainly the flanks of the pressure wave and are therefore quasi-perpendicular shocks. We also find connected regions with supercritical Mach numbers during the shock's transit in the corona. This study provides evidence for the CME shock origin of high energy protons and electrons impacting the visible solar disk during LDGRFs