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Fast acceleration of inner magnetospheric oxygen ions by shock induced ULF waves

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The interaction between interplanetary shocks and the Earth's magnetosphere manifests in many important space physics phenomena including particle acceleration. We investigated the response of the inner magnetospheric hydrogen and oxygen ions to a strong interplanetary shock impinging on the Earth's magnetosphere. Both hydrogen and oxygen ions are found to be heated/accelerated significantly with their temperature enhanced by a factor of two and three immediately after 1 min and 12 min of the shock arrival respectively. Multiple energy dispersion signatures of ions were found in the parallel and anti-parallel direction to the magnetic field immediately after the interplanetary shock impact. The energy dispersions in the anti-parallel direction preceded those in the parallel direction. Multiple dispersion signatures can be explained by the flux modulations of local ions (rather than the ions from the Earth's ionosphere) by ULF waves. It is found that the energy spectrum from 10 eV to 40 keV are highly correlated with the cross product of observed ULF wave electric and magnetic field (V = (E B)/B2), which indicate that both cold plasmaspheric plasma and hot thermal ions (10 eV to 40 keV) are accelerated and decelerated with the various phases of ULF wave electric field. We then demonstrate that ion acceleration due to the interplanetary shock compression on the Earth's magnetic field is rather limited, whereas the major contribution to acceleration comes from the electric field carried by ULF waves via drift-bounce resonance for both the hydrogen and oxygen ions. The integrated hydrogen and oxygen ion flux with the poloidal mode ULF waves are highly coherent (>0.9) whereas the coherence with the toroidal mode ULF waves is negligible, implying that the poloidal mode ULF waves are much more efficient in accelerating hydrogen and oxygen ions in the inner magnetosphere than the toroidal mode ULF waves. The duration of high coherence for oxygen ions with the poloidal mode ULF wave is longer than that for hydrogen ions, indicating that oxygen ions can be heated/accelerated more efficiently by the poloidal mode ULF wave induced by the interplanetary shock.