Meteoroid Sputtering as a Source for Lower-Thermospheric Metals and the Radio Science of High-Altitude Radar Meteors

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Observations of radar and optical meteors at altitudes above the ablation-defined meteor zone point to a "new" sputtering source of high-altitude metals while also yielding clues to the radio science of radar meteors. That high-altitude radar meteors (HARMs) are visible at altitudes of up ~180 km using the 50 MHz Jicamarca Radio Observatory (JRO) implies that a significant fraction of the directly-sputtered meteoroid material is ionized as the collisional MFP at these altitudes is many tens of meters. Also, that high-altitude **k**⊥**B** FAI (Field-Aligned Irregularity) trail-echoes are observed in association with HARM head-echoes yields insights into the meteor-associated plasma processes as well as the radar scattering mechanism. In particular, HARMs reveal the onset of radar scattering, as the meteoroid enters the upper atmosphere, which must be from the minimum, radar detectible, electron production. The maximum Radar backscattering Cross-Section (RCS) from N electrons, $\sigma_{BS} = 4\pi r_e^2 N^2$, is the result of totally coherent scattering from N, equally illuminated and closely spaced, electrons where r_e is the classical electron radius. An estimate for N is given. Overall, this approach yields a direct, physics-based path linking the RCS of observed head- and trail-echoes to the meteoroid sputtering process and to the ion atmospheric "capture" process whereby the head-echo "plasma" is embedded into the atmosphere.

In addition, recent lidar observations of atomic Fe, Na, and K at altitudes well above the traditional meteor zone violate the usual assumptions regarding atmospheric metals and present an instructive complication to the above scenario arise as many meteoroids appear to be fragmenting at high altitudes likely pointing to complex "dirty-ice" and "dust-ball" meteoroids comprised of small, dense grains weakly bound together by more volatile substances. These meteoroids may disperse into an extended "coma" that presents a more complex and larger area interaction region and interaction process with the atmosphere that can be better understood via radar meteor observations. We briefly discuss sputtering, the impact energies needed for onset of sputtering, sputtering yield, and the observational evidence available for interpretation of meteoroid sputtering as a source of aeronomically interesting metals above the classical meteor zone.