SPRITES AND BUBBLES

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ABSTRACT

Sprites observed above a storm are proposed electrified by bubbles nucleated in graupel. Electromagnetic (EM) energy produced during bubble nucleation by cavity quantum electrodynamics (QED) dissociates the water molecules on the bubble wall into hydronium H^+ and hydroxyl OH^- ions. Over the time before the sprites are observed the H^+ ions cluster with water molecules and migrate toward the lower ionosphere to form conductive paths in the stratosphere, the sprites observed as the red and blue corona from the collision of electrons with nitrogen in the discharge paths.

THEORY AND DISCUSSION

The EM energy produced by bubble nucleation finds its origin in the thermal kT energy of the water molecule, every molecule at ambient temperature emitting low frequency infrared (IR) radiation. Fig. 1 depicts graupel formation. Fig. 1(a)(b) show the rain droplet upon supercooling and expansion to nucleate the bubble. During nucleation, the bubble wall of radius R separates from a spherical core of water molecules of radius $R_o \sim 2S/P$, where S is surface tension and P is atmospheric pressure. Since the bubble at the instant of core separation has a high EM resonant frequency, cavity QED momentarily suppresses the low frequency IR radiation from the core. The suppressed EM energy is promptly conserved by the release of coherent multi-IR photons that combine at the bubble surface to Planck energy $E \sim (R_o/R)^2(R_o/\Delta)\, kT$, where Δ is the spacing between water molecules at liquid density, $\Delta \sim 0.3$ nm. For $S \sim 0.072$ N·m^{-1}, $R_o \sim 1.44$ μm. At $R \sim R_o$, $E \sim 120$ eV, which is in excess of the 4.9 eV necessary to dissociate a limited number of water molecules.

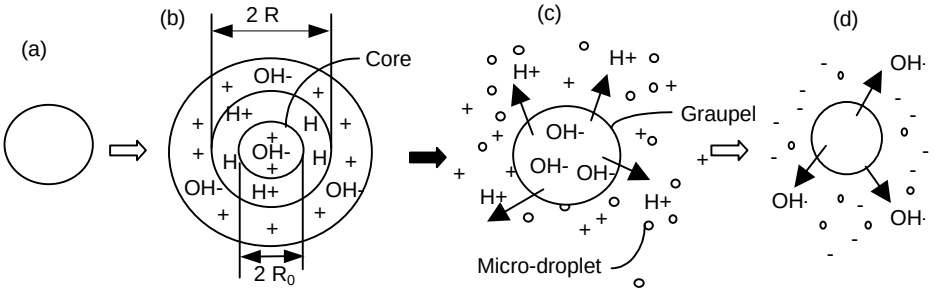

Figure 1 (a) Rain droplet (b) Supercooled (c) Freezing (d) Sublimation

Historically, Loeb in 1958 proposed that ionic charge might be separated by mechanisms whereby the charge of one sign collects in the vapor-state while the charge of the opposite sign collects in the liquid or solid-state. In a bubble, this condition is nicely satisfied for the H^+ and OH^- ions produced by cavity QED. Since rain has an acid pH, the bubble core and walls carry a positive background charge. Fig. 1(b) shows the hydronium H^+ ions repulsed to the bubble vapor while the companion hydroxyl OH- ions are attracted to the bubble core and wall. Fig. 1(c) depicts freezing. The graupel volume contracts and induces high pressure that forces the bubble vapor out of the graupel, the vapor promptly forming positive charged micro-droplets; whereas, the hydroxyl ions tend to remain behind leaving the graupel with a negative charge. Later, the graupel sublimates hydroxyl ions as shown in Fig. 1(d). Bubbles in graupel as a source of atmospheric electricity are therefore consistent with the charge distributions first measured by Cheng in 1973.

Bubbles as the source of atmospheric electrification permit sprites to be unified with more commonly observed weather phenomena. In the atmosphere, the H^+ and OH^- ions promptly cluster to form proton hydrate (PH) and non-proton hydrate (NPH) ions, respectively. The PH clusters form buoyant positive charged clouds, while the heavier NPH clusters tend to form negative charged clouds that fall to the earth. Cloud-to-cloud lightning is the discharge of NPH and PH clouds, while cloud-to-ground lightning is the discharge of the NPH clouds with the positive charged earth. Sprites are observed later in the storm over which time the PH clusters migrate toward the lower ionosphere forming conductive paths in the stratosphere. After a PH cloud strike to the ground, charge is conserved by the discharge of NPH clouds with the lower ionosphere, the breakdown producing high electrical currents in the upward leading pathways. Sprites are the red and blue corona from the collision of electrons with nitrogen in the pathways.