The Humming and Motion of Ball Lightning III: Experiments on the Maser-Soliton Theory and a New Cloud Electrification Process

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Introduction. Our Maser-Soliton theory of Ball Lightning (BL) easily and accurately explains all observed properties of BL as a solitonic and cavitonic repeated (quasi-periodic) spiking discharge in a huge atmospheric maser of several cubic miles, usually pumped by a streak lightning flash [1]-[3]. The periodic extinction and reignition of the solitonic discharge causes the humming sound often observed at the spiking frequency of the large atmospheric maser, e.g., in the 50-100 Hz range. The description as a caviton emphasizes the self-trapping of the electromagnetic field and the expulsion of ions in the nonlinear dynamical system of plasma and field that defines the soliton ignited by the large atmospheric maser. The initiation of the solitonic discharge in the maser-generated standing electromagnetic wave is described in [4]. The quasi-stationary states of the plasma solitons are described [2] based on a nonlinear "Schrödinger" Eq. in a way similar to [5]. The stability of these plasma solitons with size above a certain limit of the order of about 2 cm is proven in [6]., Finally, the experimental verification of the ability of these HF and microwave discharges to pass through glass panes of considerable thickness was demonstrated by Ohtsuki and Ofuruton [7]. The study of similar solitonic discharges at lower pressure was performed by Schneider and Handel [8]-[10].

Experiments Suggested for the Maser-Soliton BL Theory.

1. Outdoors Experiment. Both during a thunderstorm and in cloudy, humid, weather without a thunderstorm, we will measure atmospheric absorption in the 300-1,000 MHz frequency region. This way we will determine the reduction in the ab-sorption coefficient, caused by the thunderstorm, as a function of frequency, as shown below in Fig. 1. The absorption coefficient could go to zero or even change sign at a certain frequency. This will identify the maser molecular transition of BL.

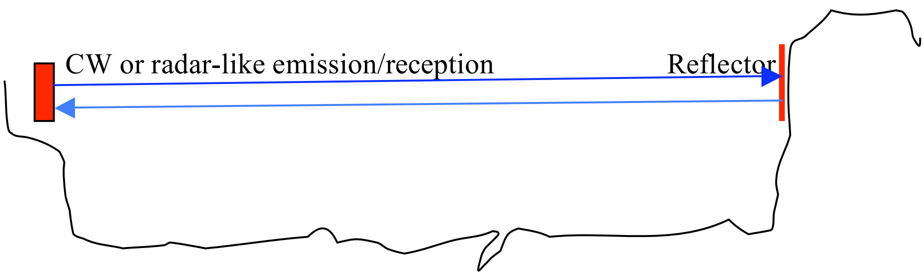

Figure 1.: Atmospheric absorption spectrum measurements during thunderstorms, e.g. over a distance of 1 km, in a flat area, using a tunable VCO (voltage-controlled oscillator), or other generators.

2. Pulse Experiment. We plan to apply a strong electric field pulse or other similar pumping agent inside a large metallic container with high H_2O vapor content, tunable as a resonator, and

a) Listen to VHF signals right after the pulse;

b) Measure a reduction in the absorption at certain frequencies, close to the resonance frequencies of the H_2O asymmetric rotor molecule;

c) Repeat the experiment with various levels of constant superposed electric field that may cause the many forbidden transition frequencies of H_2O vapor to become weakly allowed through Stark effect.

At atmospheric pressure the resonance frequencies are broadened into oblivion by the large frequency of intermolecular collisions. We count in all cases on the frequency narrowing phenomenon present at high Q-factors of the cavity employed. The narrowing corresponds in the time domain to snatching the energy out of the "jaws" of the collisions due to the large volume of an atmospheric maser. The large volume causes both a large Q even without cavity walls, and an extremely short rise time of the maser signal (or spike). That ultra-short rise time is needed, in order to extract the energy before the collisions can dissipate it.

d) Therefore, in order to get an initial value of the practically important resonance frequencies, we plan to do the points a-c above also at low pressures, and with additional gain in the tunable resonance loop. That will allow tuning of the cavity to the resonance frequencies at lower collision frequencies, and will increase the chances of success as we gradually increase the pressure up to the atmospheric domain. Note that the collision frequencies scale like the square of the density, or pressure. We also plan to add electron-scavenging impurities to the H_2O vapor, in order to discourage the formation of electric discharges in the applied electric fields.

3. Wind Tunnel Experiment. This repeats a previously successful exploratory experiment of the author with 2 students at the McDonnell Douglas Lightning Research Facility (no longer existent here at Boeing) in the mid-seventies, and is in essence a different, stationary flow based, implementation of points a-d explained above for the static case. In this case moist air is rushed through a portion of a wind tunnel between a pair of capacitor plates parallel to the flow. The portion of the wind tunnel right after the plate has metallic walls and represents a tunable high Q electromagnetic Helmholtz resonator, from which the signal is coupled out, as in points a-d above.

4. Laboratory Ball Lightning Generation. The author's Maser-Soliton BL theory allows for the first time not only to understand the natural phenomenon, but also to emulate it in the laboratory. This represents a new type of discharge.

This experiment is based on a 10-20KW Klystron amplifier with negative feedback, trying to simulate the behavior of the atmospheric maser. The klystron is connected through a directional coupler to a tuned resonator that serves as discharge chamber. From there, a wave guide completes the loop, as shown in Fig. 2. An optical feedback strengthens the natural tendency of the klystron to spike almost instantaneously when the load decreases. The discharge sought is a glow at atmospheric pressure, at much lower temperature than the lowest temperature arch discharge ever obtained so far at normal pressure.

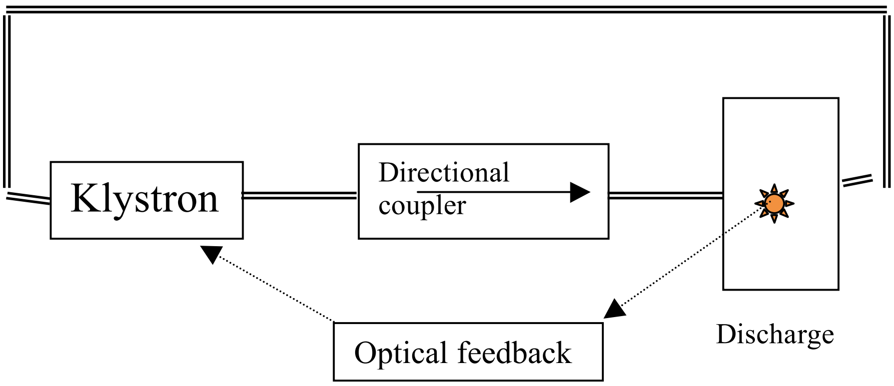

Figure 2.: Scheme of laboratory ball lightning generation, emulating the atmospheric maser with a klystron.

At these low temperatures there are no electrons that could sustain the discharge. However, right when the discharge is dying, a powerful klystron spike is automatically caused by the sudden decrease of the load. This extracts electrons through cold (Fowler) emission, and rekindles the discharge. However, like in the case of the atmospheric maser, the presence of the large spike automatically stops the klystron power. The optical feedback is responsible in part for the fast reaction. Then the spiking cycle repeats itself. The continued quasi-periodic cycle of successive extinctions and re-ignitions causes the perceived "***humming***" of BL, often reported by direct observers.

The present BL maser-soliton theory can be expanded to explain the nature and the behavior of UFO-type luminous effects in the atmosphere and "radar angels."

New Cloud Electrification Mechanism

The maser-soliton theory of BL has to be considered together with the polarization catastrophe (PC) theory of cloud and thundercloud electrification [11]. This clarifies also the origin of the positive ionospheric potential and the origination of sprites, elves and blue jets, as we show below, after the description of our suggested BL experiments.

Submicron and micron size ice crystallites, all nucleated heterogeneously on aerosol dust particles (e.g., SiO_2 nano- or submicron crystals advected from desert areas) have a giant ferroelectric saturation polarization. Our theory is based on research by Hentschel [12], Hipolito [13], Minagawa [14] and Dengel [15], which was neglected so far. Therefore, when the concentration c of submicron ice particles in a cloud exceeds $c_o=2.5 \cdot 10^{21}/\nu^2$ per cubic cm, where ν is an average number $\nu \cong 10^{11}$ of water molecules per crystallite, i.e., for $c>c_o= 0.25/cm^3=25/l$, the PC occurs. Then the ice crystallites, all nucleated heterogeneously on aerosol dust particles (e.g., SiO_2 nano- or submicron-crystals, advected, e.g., from desert areas) align their dipole moments in the same direction. Thus, a large polarization vector field **P**(**r**) appears in the cloud. It has negative polarization charges -div**P** on top, positive on the bottom, since it was initially induced by the fair-weather field.

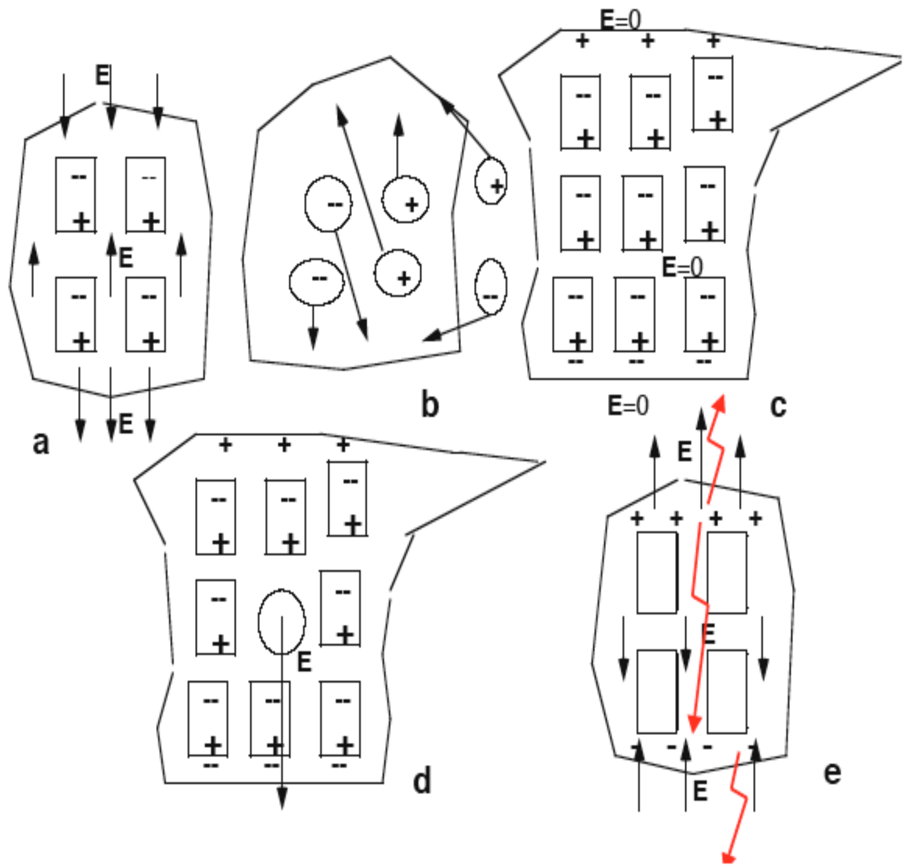

Figure 3: Generation ***a*** of the PC in the pre-existing fair weather field, masking charges ***b*** hiding it for hours ***c***, a large electric field E present ***d*** in a cavity betraying it, and the sudden colloidal instability setting free the masking charges ***d,*** thus contributing to atmospheric electricity ***e***.

Due to the large average number ν of water molecules in a crystallite, the PC (**Fig. 3**) is present in practically all clouds, lowering the free energy. The PC gradually grows in size from raising moist air, together with the whole cloud, in the fair weather field. It will be continuously compensated by masking charges, up to the charge density div**P**, which compensates the polarization charge**,** during the few hours while the cloud grows: positive masking charges on top and negative at the bottom (**Fig. 3**). In cumulo-nimbus (or thunder) clouds with large vertical convection, the collapse of the PC is rapid, with the remaining masking charges leading to IC and CG lightning, and in the upper atmosphere also to sprites, elves, and blue jets. In the quiescent stratus clouds, however, the PC collapse is slow, and only leads to dark currents that also contribute to charging the earth negatively.

The PC leads to reverse polarity in growing clouds (plus on the bottom, negative on top, because of the growing excess polarization charge), as compared with dissipating clouds (minus on the bottom, because of the growing un-compensated masking charges). This helps explain early, thin, charge-layers in terrestrial clouds, even with low rain rate, without excluding contributions from other mechanisms. It explains and proves as a natural instability the formation of many narrow horizontal space charge layers as detected with balloon-based instruments in the stratiform trailing region of mesoscale convective systems [16]. It also explains the electrostatic discharges in the C-ring of Saturn [17].

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