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Cluster formation in Hessdalen lights

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ABSTRACT

In this paper we show a mechanism of light ball cluster formation in Hessdalen lights (HL) by the nonlinear interaction of ion-acoustic and dusty-acoustic waves with low frequency geoelectromagnetic waves in dusty plasmas. Our theoretical model shows that the velocity of ejected light balls by HL cluster is of about 10^4 m s^{-1} in a good agreement with the observed velocity of some ejected light balls, which is estimated as 2×10^4 m s^{-1}.

1. Introduction

Unusual lights have been reported in Hessdalen area in Norway since 1940s or earlier (You-Suo Zou, 1995). The HL is a luminous ball of unknown origin floating above the ground level (Strand, 1990). Until present, there has been no proper physical explanation for these atmospheric lights. One explanation attributes the phenomenon to an incompletely understood combustion process in the air involving clouds of dust from the valley floor containing scandium (Bjorn, 2007). Some sightings, though, have been identified as misperceptions of astronomical bodies, aircraft, car headlights, and mirages (Leone, 2003). One recent hypothesis (Paiva and Taft, 2010) suggests that the HL are formed by a cluster of macroscopic Coulomb crystals in dusty plasma produced by the ionization of air and dust by alpha particles during radon decay in the dusty atmosphere.

A dusty plasma is a plasma containing nanometer or micrometer-sized particles suspended in it which also behaves like a plasma. Examples of dusty plasmas include comets, planetary rings, zodiacal dust cloud, and interstellar clouds (Horanyi and Mitchell, 2006). Dusty plasmas (and non-neutron plasmas) can form bizarre strongly coupled collective states where the plasma resembles a geometrical solid. Coincidently, in some cases (at low level of luminosity) HL explicitly shows visually some kind of geometric structure (Teodorani and Long-Term, 2004) by conventional photographs. Pictures of atmospheric light balls taken in the Hessdalen area clearly indicate the helical rotation of these luminous plasmas (Strand, 1992). Similarly, laboratory dusty plasmas can rotate in the presence of magnetic field (Dzlieva et al., 2006). Several images of HL show ejection of mini light balls from its central body and light ball clusters (Teodorani and Long-Term, 2004). Photos show no motion but a clearly distinguished green, smaller light ball standing still at a distance of about 100 m from the larger, white light ball. On the other side, fragmentation of HL in a cluster of light balls is showed in video images (EMBLA, 2007). The reason for this phenomenon is totally unknown. Laboratory experiments have demonstrated that charged particles are emitted into the air when rocks are fractured (Enomoto and Hashimoto, 1990). The rock fracture can be induced not by seismicity in the specific Hessdalen case but rather by freeze thaw weathering, the process by which the growth of ice inside the pore spaces of the rock gradually produces its fracture. Freeze thaw weathering occurs in alpine environments where temperatures regularly fluctuate above and below the freezing point of water. Rock experiments of Enomoto and Hashimoto (1990) showed that excessive indentation on rock did not increase the charge emission, but lower temperature could increase emission. It is interesting that wet rocks could emit 100–1000 times more charged particles than dry rocks. The strange lights observed in Norway all occurred in mountainous area, particularly in wintertime with temperatures below 0 °C (Teodorani and Long-Term, 2004), and some cases were near lakes or in wet places. These are conditions which improve the emission of charged particles from rocks. In the same temperature, the charge emission from hornblende andesite is higher than biotite granite because the specimens are hygroscopic and were easily fractured. The charge emission during fracture of hygroscopic rocks (andesite) is due to the chemisorption of chemically active species such as water and

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oxygen on charged layer of fractured surfaces. Excitation and dissociation of the molecules could then occur, producing free electrons and ions (Dickinson et al., 1985). The charge generated by hornblende andesite indentation fracture is of about 1.2×10^{-11} C/s. The volume of the fractured zone, estimated from size of the indent, was 0.02×10^{-9} m^3. Thus, the net production rate would be ~0.6 C/m^3/s (Enomoto and Hashimoto, 1990). If a massive fracture occurs during 1 s at ground, over an area extending some meters, the charge generated may be comparated to the total electric charge produced by one bolt of lightning (1 C). This may be sufficient to cause geoelectromagnetic disturbances. Ogawa et al. (1985) showed in laboratory experiments that rocks radiate wide-band EM waves (10 Hz–100 kHz) when they were struck by a hammer and fractured. Maki and Ogawa (1983) surveyed EM radiation covering 10 kHz–30 MHz from laboratory rocks. Very low frequency EM emission (0.01–10 Hz) was also observed from earth rocks before and during earthquakes according to Park et al. (1993). Satellites showed intense EM radiation at frequencies below 450 Hz (Serebryakova et al., 1992). These data, are in accord with the EM signals recorded by the spectrum analyzer and the magnetometer at Hessdalen covering the band of 0.5–80 MHz (Strand, 1990). So it appears that EM waves could have been emitted by rocks in the region where strange lights were observed. In this paper we propose a mechanism of light ball fragmentation (i.e., cluster formation) and light ball ejection, commonly observed in HL, by the nonlinear interaction between ion-acoustic or dusty-acoustic waves and dusty plasmas during rock stress. Our theoretical model shows that the velocity of ejected light balls by HL cluster is of about 10^4 m s^{-1} in a good agreement with the observed velocity of some ejected light balls, which is estimated as 2×10^4 m s^{-1}.

2. Model for ejection of light balls and cluster formation in HL phenomenon

Several images of HL show ejection of mini light balls from its central body. In many cases, the ejection of smaller light balls is shown under computer enhancement of both video frames and photographs (see Fig. 1). Video frames with a time-resolution of 1/30 s show the process as almost instantaneous. Photos show no motion but a clearly distinguished green, smaller light ball standing still at a distance of about 100 m from the larger, white light ball. According to Teodorani and Long-Term (2004), the ejection process has a close connection with the formation of light clusters. Here we proposed that light clusters are formed by nonlinear interaction between very low frequencies electromagnetic waves and dusty plasmas.

Very low frequency electromagnetic waves can propagate in the plasma, producing an ionic acoustic wave (see Fig. 2). An ionic-acoustic wave (IAW) is a longitudinal oscillation of the ions (and the electrons) much like acoustic waves traveling in neutral gas. The IAW velocity will be (Alexeff and Neidigh, 1961):

$$V_{IAW}=\sqrt{\frac{\gamma_e Z_i k_B T_e+\gamma_i k_B T_i}{\langle m_i\rangle}} \qquad (1)$$

where k_B is the Boltzmann's constant, $\langle m_i\rangle$ is the mean mass of the ion, Z_i is its charge, T_e is the temperature of the electrons and T_i is the temperature of the ions. Normally γ_e is taken to be unity, on the grounds that the thermal conductivity of electrons is large enough to keep them isothermal on the time scale of ionic acoustic waves, and γ_i is taken to be 3, corresponding to one-dimensional motion. In the plasma the electrons are often much hotter than the ions, in which case the second term in the numerator can be ignored. Thus, we have

$$V_{IAW}\sim\sqrt{\frac{\gamma_e Z_i k_B T_e}{\langle m_i\rangle}} \qquad (2)$$

According to Teodorani and Long-Term (2004), HL spectrum gives a gas (ion) temperature of about $T=5000$ K. Thus, considering $T_e=10\times T=50{,}000$ K, and mean ion mass as being

$$\langle m_i\rangle=\frac{m_i(O^+)+m_i(N^+)}{2} \qquad (3)$$

where $m_i(O^+)=2.3\times10^{-16}$ kg is the ionic oxygen mass and $m_i(N^+)=2.6\times10^{-16}$ kg is the ionic nitrogen mass, we have $V_{IAW}\sim10^4$ m s^{-1}. This is the velocity of the energetic wave packet of an ion acoustic wave in a dusty plasma. This value is close to the observed velocity of some ejected light balls from HL, which is estimated as 2×10^4 m s^{-1} (Teodorani, 2006).

On the other hand, fragmentation of HL in a cluster of light balls (Fig. 3) can be produced by interaction of low frequency electromagnetic waves through the dust-acoustic waves (see Fig. 2i). It is known that laboratory dusty plasmas are longitudinally fragmented by dust-acoustic waves (Barkan et al., 1995). Dusty acoustic waves (DAW) is a complete analog to the common ionic-acoustic wave, where the dust particles take the role of the ions and electrons take the role of the electrons in the ion-acoustic wave (Thompson et al., 1997) and is an extremely low velocity normal mode of a three-component dusty plasma comprising electrons, ions and massive micrometer-size charged dust grains.

Thus, the DAW is driven by the electron and ion pressure and the inertia is provided by the massive dust particle. Dusty acoustic waves have been observed experimentally in weakly coupled dusty plasmas (Barkan et al., 1995). In laboratory dusty plasmas DAW is seen as regions of high and low dusty density in scattered light. Dust-acoustic wave speed is given by

$$V_{DAW}=\sqrt{\frac{k_B T_i}{m_d}\in Z_d^2} \qquad (4)$$

As for the ion-acoustic wave, the wave speed is determined by the temperature of lighter species (T_i) and mass of the heavier m_d. In the DAW, the contribution of the high dust charge Z_d and

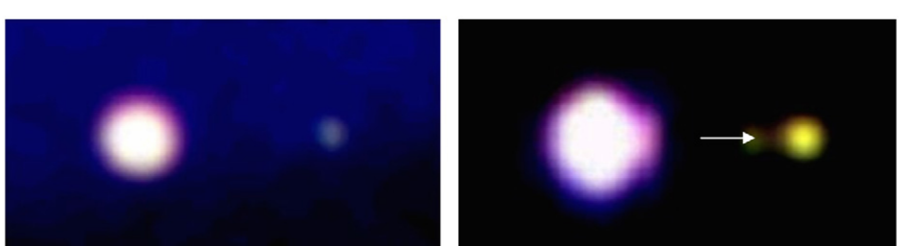

Fig. 1. Three photographic examples of ejection of a small green light ball from a larger white light ball (Teodorani and Long-Term, 2004) (see video *Amazing REAL looking UFO Sightings in INDIA Jan 26 2008*, 〈http://www.youtube.com/watch?v=pSKu2tlgoRY&feature=related〉).

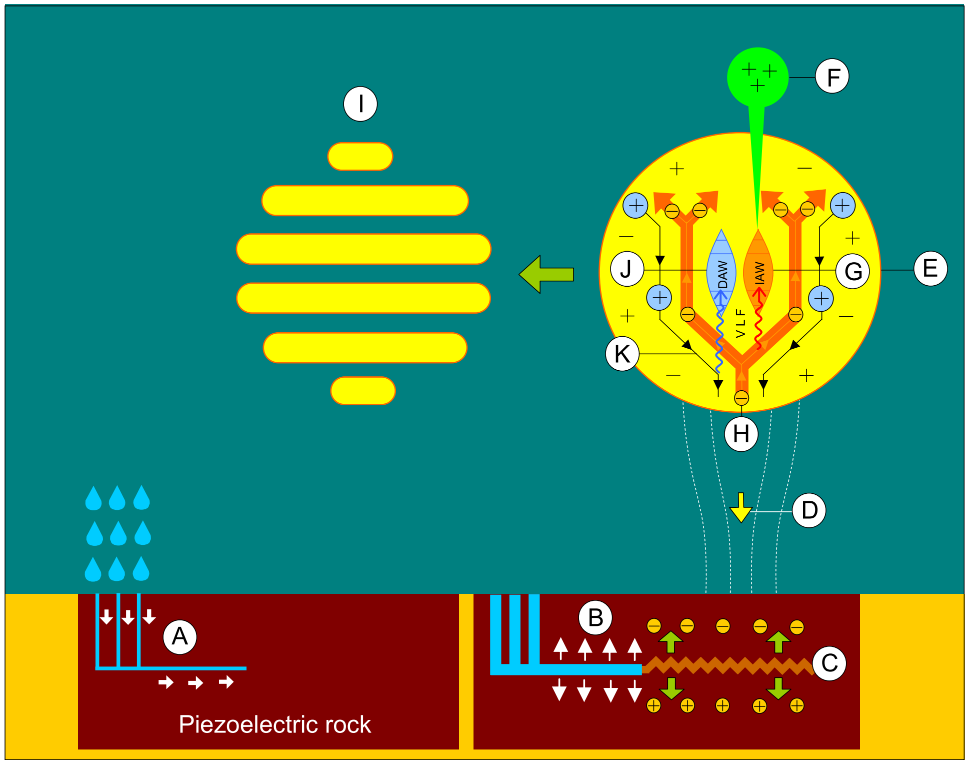

Fig. 2. Some physical mechanisms involving HL phenomenon. When water infiltrates in rocks (for example, piezoelectric hornblende andesite) (A) and freezes (B), the force of expansion is great enough to break the rock into smaller pieces because water takes up to around 10% more space as it freezes. The charge production during rapid fracture of rocks (C) is responsible by electrical charges formation between fractured surfaces producing high electric fields (D) on the ground and dusty plasmas (light ball) (E) in the atmosphere. Ejection of small light ball (F) from HL is due to interaction between very low frequency electromagnetic waves (VLF waves) and ions in the dusty plasma forming ion-acoustic waves (G), which are typically driven by an electron current in the plasma (H). HL fragmentation in a cluster of light balls (I) is due to interaction between very low electromagnetic waves and dust grains in a dusty plasma forming dusty-acoustic waves (J), which are typically driven by an ion current in the plasma (K).

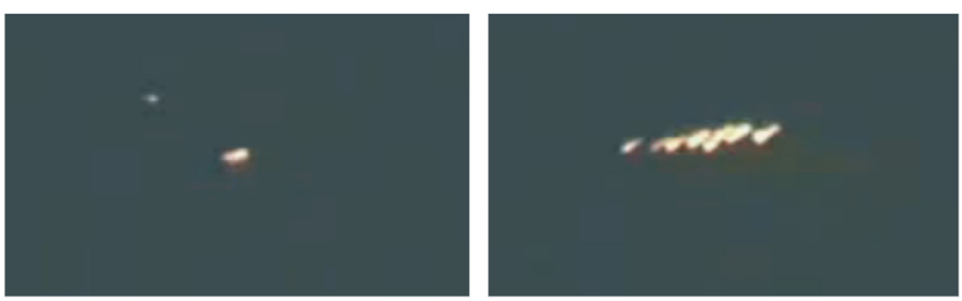

Fig. 3. Video frames showing the fragmentation of HL in a linear cluster of light balls. See the supplementary video *ufo hessdalen norway* 〈http://www.youtube.com/watch?v=fSgPBOBSJrI〉 Retrieved November 2010.

relative dust-to-ion concentration $\epsilon = n_d/n_i$ is retained. Thus, Eq. (4) can be simplified as (Amim et al., 1998):

$$V_{DAW} = \sqrt{\frac{k_B T_i}{m_d}} \tag{5}$$

Thus, let us consider a typical atmospheric dust particle radius $r = 0.1\ \mu m$, dry dust aerosol density $d = 2 \times 10^3\ kg\ m^{-3}$ (Maring et al., 2003), and ion temperature $T_i = 5000\ K$ we found through Eq. (5) a dust-acoustic velocity $V_{DAW} \sim 10\ cm\ s^{-1}$. Because the wave propagation involves the dynamics of the heavy dust particles with small charge-to-mass ratios, it is very slow and it can be interpreted as velocity of light balls during cluster formation during the fragmentation of HL. It is consistent with the video frames showed in Fig. 3.

3. Conclusions

Different from a classic plasma of free electrons and ions, HL is a complex (dusty) plasma formed by electrons, ions and dust immerse in it. The fragmentation and ejection of light balls from HL phenomenon is due to interaction, respectively, of dust-acoustic and ion-acoustic waves in atmospheric dusty plasmas. The speed of the ejected light ball (green light balls) is due to ion acoustic waves. On the other side, the fragmentation of plasma ball in a cluster of light balls is due to dusty-acoustic waves. On the other side, fragmentation of great light ball in a cluster of small light balls is relatively slow. Some theories, for example mini-black holes theory (Rabinowitz, 1999), spinning electric dipole theory (Endean, 1976), and some ball lightning models (Abrahamson-Dinniss, 2000), are sometimes invocated to explain the HL phenomenon. However, these models have not yet been demonstrated in laboratory scale and their predictions are not sufficiently able to match realistically the observations in the specific HL phenomenon. Rather, dusty plasmas are often studied and reproduced in laboratory scale. Therefore, a unified model of HL that can explain the totality of their properties and behavior can be based on dusty plasma model.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jastp.2012.02.020.

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