WORKING PAPER NO. 19

CHARGED DUST AEROSOLS - DUSTY PLASMAS

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ATMOSPHERIC PLASMAS AS REFLECTORS AND ABSORBERS

CHARGED DUST AEROSOLS - DUSTY PLASMAS

1. **Introduction** There are numerous reports of unidentified flying objects of cigar, toroidal, spherical and a host of other regular shapes moving in earth's atmosphere due to the action of forces of an unknown nature. Depending on the witness's perception at the time, the object can have 'navigation lights', 'searchlights', be of various single colours or even multiple colours. The objects reportedly can change flight direction suddenly, stop, accelerate or decelerate. Reports by aircrew have included "buzzed by shining glass balls or cones" or "like soccer balls made of glass". Mukharev (Russia) [1] takes all these factors into account in his hypothesis that aerosol aggregation can accumulate electrical charges due to the action of the same process (charge mechanisms) as in thunderclouds. There are several types of 'dusty plasma'. For example, 'Dusty Dense' plasmas and 'Dust in a Plasma' are different. In the former the particles remain electrostatically trapped in the plasma volume. A strong electric field is needed in the gas in order to increase ionisation rate and maintain the structure against electron loss. An equilibrium is achieved by the balance between ionisations in the plasma volume and the charged particles lost at the extremities. Within the core of the effect the particles take up an ordered structure (rather like a crystal lattice). Russia has taken a particular interest in combustion plasmas since 1994, and the science of dusty plasmas has recently achieved several milestones. Several researchers have used microspheres as the experimental medium [An area of potential military interest is in the possible use of microspheres as chaff to produce false targets].

2. When dust particles are between separated charges (e.g. visualise as in a volume between capacitor plates) the dust will suspend in a matrix and a balancing of the charges causes the dust to suspend in flat layers. By using a laser beam it has been shown that the dust can be moved, or the crystal lattice 'fractured'. The radiation intensity of a low power laser can also accelerate the particles and the momentum given to them depends on their size, distribution, surface area and mass. If the sustaining source is removed the dust falls under gravity. Since the particles can be made to form specified alignments, there are specific industrial applications being researched for this technology, but the UAP context is potentially a special case - since clearly if the charge suddenly leaked away, the plasma would vanish. The overall equilibrium of the charged particles in the medium is thus defined by external conditions. It is suggested that Dusty Plasmas may well be closely related to at least some of the UAP reports; which frequently describe what appears to be a plasma (often with several 'centres' of turmoil), which are either attracted towards each other, held by some type of mutual repulsion field at a set distance from each other for long periods, or merge or collapse.

3. Just as in thunderclouds, spark discharges can occur, leading to the formation of an electromagnetic field, it is postulated that because the EM field will vary through the volume (because of the renewal of particles as the cloud moves) this will give rise to a reactive force which will maintain its motion.

4. **Streamlined Shaping** For a high cloud velocity, it is suggested, that those particles which are retained are so held by the amount that the EM field exceeds the surface aerodynamic drag forces. Therefore, once motion commences the 'object' assumes a shape due to aerodynamic drag and naturally becomes 'streamlined' - for example aircraft

[1] Mukharev L.A. " Hypothesis on the Nature of Atmospheric UFO" Radiotekhrika Elektronika No. 8 1991 pp1437-1443

fuselage shaped, (e.g. cigar), flattening sphere (i.e. disc or fat cigar), or even triangular, with curved edges. As air drag will operate in all planes, then all extremities of the original aerosol charged body (whatever its original format) will tend to be 'smoothed'. Eventually the EM field within the charged envelope will dampen and dissipate and the more sharpened contours will disperse and either be no longer recognised as a shape (i.e. as a UAP), or will vanish completely.

5. If high intensity EM field values occur, a gas discharge is possible at its maxima, giving rise to 'bright lights' on the surface of the UAP. (see paragraph 13 below)

6. **UAP Model** Mukharev, commencing with a postulated spherical aerosol, considers the natural equations for the electrical and magnetic oscillation modes, and derives a model. It is postulated that the most probable initial excitation is by streak lightning [Comment: Note that this can be present in either a 'wet' or 'dry' electrical storm condition]. The model estimates the dielectric constant of the medium from which the sphere comprises and Mukharev points out that this is similar to the dielectric constant of a plasma. It is determined by the character of the time-dependence of the field in which the aerosol is located. The ratio of the internal and external dielectric constants sets the conditions. This will depend upon whether the aerosol is one which dampens out with time - in which case a negative dielectric constant is obtained; or one where the field is sinusoidal. Mukharev shows that the amount of energy of the EM field within, say, a $1m^3$ volume of the aerosol cloud is only ~8 Joules. Therefore, it is claimed that the field of the UAP could be excited by a spark discharge.

7. The postulation shows that the aerosol cloud can remain within boundary conditions which do not result in immediate breakdown, but have a finite lifetime. For the purposes of the model it is shown that the Lorentz Force (Earth's Magnetic Field) is negligibly small compared with the aerodynamic drag force. The outcome is a postulated UAP which has motion.

8. **Motion** As the cloud moves in the atmosphere the aerosol particles located at its surface are removed by the air stream. (The energy of the EM fields associated with these particles being transformed into EM momentum). As a consequence of the momentum conservation law, the EM momentum arising within the closed system of the cloud must be compensated by the mechanical momentum. Hence, a force arises at the leading edge of the cloud which causes the cloud to accelerate until the force becomes equal to aerodynamic drag. After some time the cloud gradually decelerates because of the dampening field.

9. **Particle Characteristics** The particles may be variable in diameter and the entire mass of material in the aerosol cloud may amount to only a fraction of a gram. It has been suggested that this low mass, resulting in absence of inertia, may be the reason for the exceptional 'manoeuvrability' suggested by UAP reports; and also a tendency towards rapid acceleration.

10. **Speed of Cloud** It is possible to relate particle size to the drag-force by using the Reynolds number for the particles moving in a laminar stream, at velocity v:

$$Re = \gamma r_a v/\eta$$

/where:

where: γ is the density of the atmospheric medium, r_a the particle radius for 1.5µm. The velocity of laminar noiseless motion is shown below

For this situation Re must be ≤10 (since the radius of the particles, their velocity for $\gamma = 1.29 kg.m^{-3}$ must be inter-related by the conditions $r_a < 1.4 \times 10^{-4}.v^{-1}$. Thus the higher the observed velocity of the UAP the smaller the dimensions of the particles forming it. Examples are:

Particle Radius	1.5µm	0.05mm
Velocity(metres per.second).	280[1] 2340[2]	3

Notes: [1] Up to an altitude of ~3Km

[2] At an altitude of 15Km, where the density of the atmosphere has decreased.

11. It is therefore noted that, at 15Km altitude, the aerosol cloud can move at up to about seven times the speed of sound. Hence, this correlates with reports of fast-moving UAPs, much faster than aircraft. An aqueous aerosol moves at high velocity and evaporates quickly. Hence, life time can be short. A long-lived aerosol cloud forming a UAP can only consist of solid dust particles of very small size.

12. The energy of the EM field in the cloud and the aerodynamic (i.e. atmospheric) drag force are proportional to the cloud volume. Therefore the velocity and path taken should not depend on cloud dimensions. For example, if a charged aerosol cloud has moved distance L (e.g. 40km) with a velocity v (e.g. $30 ms^{-1}$) a volume density can be calculated (in this case $4 \times 10^3 m^3$).

13. **Lights** For a high field potential (e.g. $>10^5 V_m^{-1}$) an electrodeless corona discharge should occur in the zones of maximum E field intensity; giving rise to light emission from the aerosol cloud. If the field intensity varies throughout the aerosol, localised luminous zones can occur - due to alternate regions of maxima and minima. Hence, it is postulated that 'navigation lights' are reported. In the E_{11} mode, for example two 'lights' or a luminous strip can be formed. If the number of discharge zones increases, the number of 'lights' will increase which will be equally distributed around the cloud as luminous zones or 'portholes'.

14. **Colours** It is suggested that different colours might be produced by the presence of particles in the discharge zones.

15. **Electrical Attraction** If the discharge connects with some conducting object (Earth's surface or aircraft), the 'beam' causes the aerosol cloud to re-orientate and even move along with a moving object such as an aircraft.

16. It is postulated that when 'searchlight beams' are reported from UAPs that most of the energy is concentrated in a discharge cone and can cause damage by the high voltage but very small intensity current. This can lead to involuntary closure of electronic and electrical circuits (switches) and have adverse health effects on humans (see Working Paper No. 25). On the ground the discharge can leave marks, bend grass etc.

17. **Radar Reflections** No information has been found on the possible radar reflectivity from charged dust aerosols, but some data is available on radar scatter from 'Dusty Plasmas'. There may well be some overlap in the terminology and applicability. The latter topic is covered at Working Paper No.5, on radar reflectivity.

SUMMARY

18. **Dusty Plasmas** The work reviewed above shows that it is theoretically possible for a charged cloud of particles to exhibit characteristics of visibility and motion similar to many UAP reports received. Further, the implication that atmosphere-borne particles must be present strengthens the proven circumstances where UAPs are reported more frequently in dust-laden scenarios, e.g. near volcanoes and earthquakes. For the uninitiated it would not take too much imagination to observe such a cloud, especially one with bright spots and turn this into a UAP, with portholes!

19. As the formation of clouds (of the charged aerosol type) would clearly depend on the presence of atmospherically-carried particles, it may well be worth making correlation studies of sightings of UAPs with geographical locations where dust is produced, e.g. quarries, or where other pollution particles are emitted (e.g. from power stations or factories). It may also be useful to compare the incidence of sightings in areas taken both during and after cessation of work where dust or other particles are produced. For example, where factories have closed or applied dust/smoke control regimes, or where dusty quarries operated but no longer do so. However, a considerable amount of effort would be required to properly investigate this suggestion. The critical information is not available on the database created for this study.

20. The topics of 'dust in plasmas' and 'dusty plasmas' have become of particular importance in the last two to three years. These plasmas can easily be produced under laboratory conditions, but much more research is required to understand all the mechanisms involved. This may well point towards an understanding of such plasmas in the atmosphere.

ATMOSPHERIC PLASMAS AS REFLECTORS & ABSORBERS

21. The electromagnetic properties of a plasma at atmospheric pressure is an inter-disciplinary topic, combining plasma physics, radio wave propagation, and air chemistry. Plasmas in the atmosphere can either reflect or absorb electromagnetic waves, depending on plasma characteristics. A high reflection co-efficient requires a grazing angle of incidence. A high absorption requires a high collision rate, a low plasma density and a plasma transition of about one wavelength. The power to sustain a plasma in air is high because of the short plasma lifetime unless continuously replenished. The bandwidth, as an absorber, can extend from Metric to I Band. However, absorption peaks at VHF/UHF. In an atmospheric plasma, electrons undergo numerous collisions with atoms and molecules in the background gas(es) and the collisions convert the electromagnetic energy which may be feeding the plasma to heat and damp the essential electron motion. The collision rate varies with pressure and temperature. Also water vapour has an effect - so that, for example, 50% relative humidity approximately doubles the sea-level dry air collision rate.

22. **Plasma Lifetime** The plasma lifetime depends on the electron density and the pressure (altitude). The presence of gases other than those normally in air can change lifetime significantly. For example by a factor of ~10,000 for helium.

23. **Reflection** If a rapid transition occurs, from free space to plasma (caused, for example, by the presence of large electrical/electromagnetic forces), the plasma will reflect. If the transition is diffuse, the plasma will reflect at a grazing angle. If the plasma transition gradient is too long, then the plasma patch will transmit (i.e. allow through) more energy than it reflects.

24. **Absorption** The absorption bandwidth depends on the collision rate and the plasma gradient. It is possible to generate a plasma absorber which is lightweight, has high attenuation per wavelength and can be switched on and off. Quite apart from any UAP-related properties, it is seen that there are potential military applications in the control of EM scattering and Low Observables.

25. The power requirements to sustain a plasma are dependent on the volume, the electron density required, the energy to generate electron-ion pairs and the lifetime required; and, of course the altitude (pressure) and the medium.

INTERACTIONS

26. **Plasma Interactions with Objects and Aircraft** The interaction of plasmas alone, or when surrounding other objects are complex, since plasmas can act both as absorbers and reflectors. In addition, for transmitters, it has been shown in practice that the presence of a plasma can introduce an inductive reactance into an antenna mounted on a body, thus modifying its performance, causing an increase, for example, in radiated power. The change in radiated power is a function of the ratio of plasma frequency to signal frequency. In the UAP context it seems likely that the response of an impinging EM wave-front on reaching a plasma might be affected. If the radiation from a plasma is capable of modifying an antenna on transmit, then presumably it will do so on receive - hence it seems possible that the presence of a plasma in proximity to a radio receiver (especially at VHF/UHF) may modify the receiver front-end characteristics and even off tune or dampen normal reception. This may well be the cause of reports that receivers, in what could be termed the 'near field' of a UAP, suffer loss of function (receive and transmit) until the UAP and receiver are separated. Usually the UAP moves away or if the vehicle ignition is working, it is hurriedly driven off. In the context of radio transmission, the frequency dependence of this phenomenon also depends upon the inductive reactance introduced by the plasma layer improving the antenna towards resonance and reducing the resistive losses, such that the efficiency is maximised. [Apart from the UAP-related aspects, a factor of military importance may be that the antenna can be made smaller].

27. **Interaction with Aircraft** Because it is usually unclear as to what the entity comprises, coupled with the surprise factor, most encounters with what are clearly charged masses have been assumed to have been with ball lightning (Working Paper No 2). Whether this is the case - and whether charged aerosols are a variation of the same physical realisation - is not currently clear. The laws of motion of a plasma ball and the effects when in close proximity to an aircraft in flight are of special interest to MOD. It is assumed that the charge on the ball diminishes with time, due to the leakage, where the air layer is adjacent to the ball's surface. In effect it is likely to behave as a non-deformable solid sphere, in aerodynamic terms, in a flow of non-compressible fluid. The charged mass is likely to be 'captured' by the exhaust of aircraft engines and to follow the aircraft, maintaining both its shape and keeping a constant distance from the tail assembly. It is further assumed that the force required (which, if it were a solid ball would be required to overcome drag and stay behind the aircraft.

This force would be several tons!) is much less in practice. It seems probable that the air-stream would lose some of its viscous properties over the surface of the sphere (i.e. the presence of the plasma, it is suggested, would reduce drag). This has been shown to be the case in experimental observations. Frequent reports in Russia suggest that plasmas/charged bodies start to respond to the presence of an aircraft at a range of about 10km. N. I. Gaidukov and others have published papers on this phenomenon. Frequently, large aircraft crews have found (and indeed the Russian Aviation authorities now advise them) that if the plasma appears ahead of the aircraft, while it is impossible to lose the attracted entity by acceleration, it is nevertheless possible to carry out manoeuvres to make the mass fall astern, where it will remain until it dissipates, with no further danger to the aircraft. The Russians have reportedly lost aircraft to ball lightning (it is not clear whether these are the same claims as the four fatalities they have had chasing "'UFOs"), hence their particular interest in the phenomenon, and the large number of published papers.

WORKING PAPER NO. 20

OPTICAL MIRAGES

OPTICAL MIRAGES

1. **Optical Conditions** An optical mirage is a phenomenon associated with the refraction of light in a cloud-free atmosphere, resulting in the apparent displacement of a distant object. The refraction is caused by abnormal air densities, which cause the light to travel in a curvilinear path. Object shapes can be distorted and scintillation can cause rapid changes in the observed colour, shape and position of the object. For a stationary observer the effect can last for hours; for a moving observer only seconds or minutes. Mirages have the following characteristics:-

- Mirage images are seen at low grazing angles near the horizontal plane.
- Mirages can only be seen if there is a long uninterrupted sightline.
- Mirages are associated with atmospheric gradients which give anomalous propagation
- Focusing and interference of the wavefronts can give rapid movement and enhanced brightening.
- Distortions and colour changes can be accompanied by multiple images.
- Objects on the surface (e.g. ships) can appear as if they are elevated.

2. **Object Position** The amount the object is apparently (visually) displaced from its true position (angle) depends on the variability of the density of the medium (hence its value of refraction index). The effect is well understood in physical optics, and is pressure (P), temperature (T) and wavelength (λ) dependent. The spatial variations can be expressed in terms of P, T and λ and the resulting practical values of refraction (minutes of arc per km) for the ratio of temperature to altitude is significant. In the simplest terms this means that:

- One degree of arc represents the largest angular change between the true and false (mirage) position of an object.
- When the image appears **above** the true position this is know as a **superior** mirage. When below the true position, the term used is an **inferior** mirage.
- There must be the coincident conditions of a temperature inversion **and** the presence of light to illuminate the object at grazing angle.
- Vertical stretching can lead an observer to **under estimate** the true distance to the luminous object.

UAP CONTEXT

3. The key factor in eliminating or including the mirage phenomena as a potential UAP event is that of low grazing angles and long distances, since it is unlikely (from the type of UAP details usually received) that the other detailed meteorological conditions will be known. In the UKADR the combination of long path lengths and low grazing angles is more likely to occur at sea.

WORKING PAPER NO. 21

IONOSPHERIC PLASMA

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1. **Formation Of Plasma** Within the troposphere operate powerful processes which orientate the separation of electric charges; for example, thunder conditions give rise to huge vertical separation of charges. Meanwhile it is understood, that wind is responsible for horizontal charge distribution. When charges are displaced it is possible for the creation of image charges which make the ionospheric plasma unstable, with the result that a downward electron stream is ejected from the bottom of the ionosphere which may produce 'airglow' in a narrow high altitude band. Because these visible manifestations can be seen at night, they are often described as 'nocturnal lights'. They appear to have a close connection with one class of UAP sighting.

Figure 1[1] Shows the mechanism, which is explained in the following sequence:

- Due to wind over the earth's surface in a hilly region a positive charge is deposited on the hills.
- A negative charge becomes attracted to the moving air mass (shown moving to the right on the figure).
- Corresponding 'mirror' charge images are formed with an upward E field (E_U) above the hills and a balancing downward field (E_D) restores equilibrium.
- At the ionosphere E_U causes instability and an electron stream from the ionosphere is downward-accelerated by the electric force.
- 'Airglows' (UAPs) are formed when electrons are stopped in the lower atmosphere.
- The glows or 'nocturnal lights' occur in a relatively thin altitude layer and visually appear as bright spots of appreciable angular size moving across the night sky.

2. The supporting theory is explained in some detail at [1]. It seems likely that the reports of 'silvery discs' at very high altitude are the same phenomenon. Below ionospheric altitudes researchers agree that air conductivity cannot prevent the onset of electric fields of considerable strength. In effect the middle atmosphere can become electrically de-coupled from the ionosphere. The ground and the ionosphere can be considered, in effect, two plates of an enormous capacitor. The conductivity of the ionosphere is of solar origin (hence, the investigations elswhere in this report on possible solar flux/solar flare coonections with the rate of UAP reports).

3. **Extent** The size of 'nocturnal lights', which is believed to be produced by an electron stream which penetrates to the lower atmosphere, is considerable, in order to be seen at long visual distances (slant ranges) of ~100km, where, it is calculated, the diameter can be several hundred metres. [As an example, an object of 905m diameter at 100km range has the same **angular** extent as that of the moon].

[1] BROVETTO P AND MAXIA V. "On the Instability of the Ionospheric Plasma...." ILNUOVO CIMENTO Italy 1995.

4. **Motion** A high angular velocity is produced because the phenomenon is light (i.e. nothing (no mass) actually moves physically). It is analogous to the movement of a CRT beam when the spot (i.e. UAP) moves. The very high angular velocity can give the impression that the light is at much lower altitude than is the case. The actual altitude of the nocturnal lights is ~50km.

5. **Power** Light emission occurs when ionized molecules or ionized atoms re-combine with electrons, with a sharp increase when the electrons are stopped. At the path end, when the electrons are stopped, a disc-shaped light is always originated, with its axis always parallel to the earth's geomagnetic field. The power of reflected light which is required for an observer on Earth (by comparison with that from other air-objects, including satellites) is estimated as between 0.3 and 3kW. A calculation of power (with its emission as visible energy) available from the postulated electric field phenomena, is 10 to 100kW, well exceeding that required.

6. **Radar Echoes** Radar echoes can be obtained due to the conductivity of the ionised air. The light emitting layer, caused by the electrons, is probably an effective radar target although, in some instances, this would be well above the elevation-slant range capability of typical terrestrial search radars, and beyond the slant range of air intercept radars. Radar detection of UAP is considered in Volume 2, Working Paper No 5 and at Volume 3.

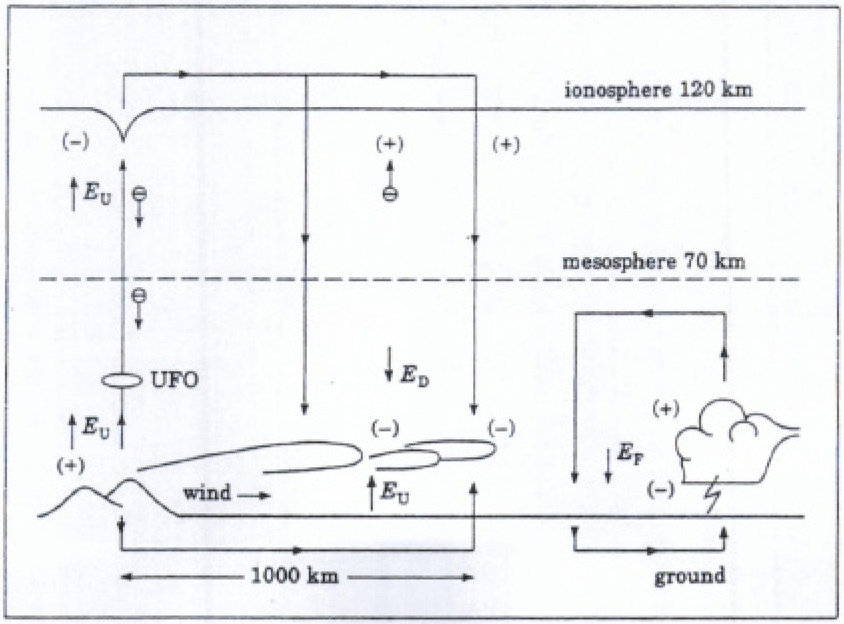

FIGURE 1: CONDITIONS FOR IONOSPHERIC PLASMA FORMATION

WORKING PAPER NO. 22

ARTEFACTS