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Extraterrestrial lightning in atmospheric dust clouds

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1. Abstract

Lightning is present in all solar system planets. Discharge phenomena occurs in dust devils on Mars, and on Earth also in the mineral clouds of volcano plumes. Cloud formation outside our solar system is possible in objects with much higher temperatures then cloud formation on Earth or Jupiter: Brown dwarfs and extrasolar planets form clouds made of mixed materials and of a distribution of grain sizes. These clouds are globally neutral obeying dust-gas charge equilibrium which is, on short timescales, inconsistent with the observation of stochastic ionization events of the solar system planets. We argue that a significant volume of the clouds in brown dwarfs and extrasolar planets is susceptible to local discharge events.

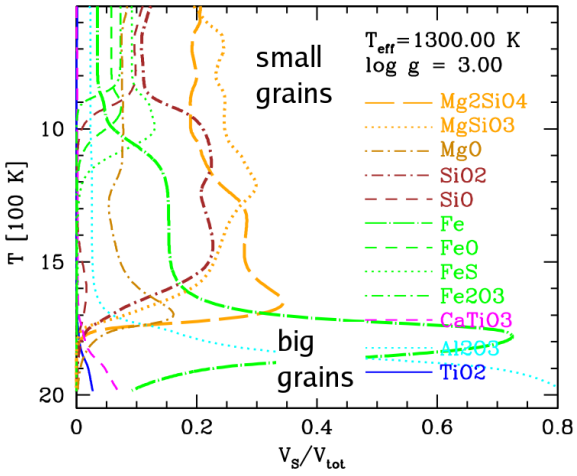

Figure 1: Dust cloud material composition in volume fractions V_s/V_{tot} in a giant gas planet atmosphere (Helling et al. 2008). The composition changes with atmospheric height indicated by the local temperature.

2. Formation of extrasolar clouds

Brown Dwarfs and gas giant planets outside our solar system will not form liquid cloud droplets, but solid dust particles condense inside their atmosphere. Such extrasolar clouds are composed of a mixture of mineral material due to the richness of the atmospheric precursor gas in these objects (Fig. 1). The dust formation process (seed formation, growth/evaporation) is influenced by gravitational settling, hence, particle growth speeds up while the grains fall inward along a positive density gradient. During this decent, the crystal structure of the cloud particles can change (Helling & Rietmeijer 2009). Figure 1 indicates that such clouds are made of small ($10^{-2}\mu$m) silicate particles at the top which change into large ($10 \ldots 100\mu$m) iron/TiO_2 particles. Furthermore, these cloud form in a highly convective environment which drives a vivid turbulence field that increases relative velocities between grains, and hence, their collisional energies.

3. Conclusions

Assuming that cloud particles are charged in Brown Dwarf and extrasolar atmospheres, than electron avalanche processes are initiated between two charged grains and develop to a streamer's ionisation front (Helling et al. 2011). We have argued that a large part of the clouds in Brown Dwarfs and extrasolar planets is susceptible to local discharge events which are triggered by charged dust grains. Such discharges occur on time scales shorter than the time required to neutralise the dust grains, and their superposition might produce enough free charges to suggest a partial and stochastic coupling of the atmosphere to a large-scale magnetic field. Discharge processes in Brown Dwarf and exoplanetary atmospheres can not connect to a crust as on terrestrial planets, hence, they will experience intra-cloud discharges comparable to volcano plumes and dust devils.

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References

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