Effects of radiation of quantum-structural elements of clouds in remote sensing of the atmosphere

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Abstract. The article shows that clouds and their elements are formed in the atmosphere in the form of large ensembles of quantum-structural (QS) clusters, which are able to radically change the radiation characteristics of the Earth's atmosphere and other planets. The unique abilities of large ensembles to form fluxes of high-energy particles, antiparticles, and gamma rays (dark lightning) in the atmosphere are explained. Theoretical studies are supported by the results of field and laboratory experiments with quantum-structural filaments (QSF).

1. Introduction
Remote sensing of the atmosphere using active and passive radar methods allows us to obtain valuable information about various processes occurring in the atmosphere. With the increasing capabilities of the measuring equipment, new events are being recorded and the effects associated with the formation of fluxes of high-energy particles, antiparticles, and gamma radiation that occur during cloud formation and their further development are being investigated. The theoretical description of these events and the analysis of experimental data are of particular interest for solving the problems of remote sensing, radar and radio wave propagation.

Therefore, the aim of the work was to provide theoretical and experimental justification for the processes occurring in the atmosphere and leading to the formation of quantum-structural cloud clusters with unique mechanical, electrical, optical and magnetic characteristics that cause the fluxes of high-energy particles, antiparticles and gamma radiation (dark lightning).

2. Quantum-structural properties of clouds and their elements
As you know, terrestrial clouds are formations that are formed as a result of condensation and crystallization of water vapor on the smallest nuclei (grains). In the process of cloud formation and evolution, nanoclusters appear [5-12]. Their origin is largely due to the variety of processes occurring in the atmosphere: coagulation, adsorption, accretion, electrification. Particles that have reached macro-dimensions fall out of the clouds as precipitation (table 1) [6-8]. Clouds of other planets are formed from aerosols of a different chemical composition, but the processes discussed below and their corresponding physico-chemical effects are similar to those on Earth.
Most of the cloud elements are liquid and crystalline nanoclusters, and the precipitation that has fallen from the clouds is significantly different from the cloud elements. The fundamental difference between nanoclusters and macroscopic elements is the manifestation of quantum-structural properties that can be formed on the surfaces of clusters, within the structures of single and local ensembles of clusters, as well as in large ensembles of clusters [6, 7, 10-22].

### Table 1. Geometric cross-sections of droplets in the clouds of the Earth's atmosphere.

|                | Drop radius min-max, m | Average drop radius, m |
|----------------|------------------------|------------------------|
| Condensation cores | $10^{-9}$–$10^{-6}$ | $10^{-7}$             |
| Cloud particles     | $10^{-6}$–$10^{-4}$ | $10^{-5}$             |
| Raindrops            | $\geq 10^{-4}$ | $10^{-4}$            |

#### 3. Surface properties of quantum-structural clusters

All snowflakes and hailstones have a normal ice crystal structure with two hexagonal faces perpendicular to the axis of hexagonal symmetry, and six rectangular faces. The growth of crystals in clouds occurs due to the addition of atoms, molecules, and CS clusters to any of the faces, edges, or vertices of the forming crystal. The rate of crystal growth in the directions is proportional to the free energy of the corresponding faces, edges, and vertices. During the growth of cloud crystals, the free energy changes in accordance with changes in the composition and state of the growing surfaces, for example, due to the drying of the liquid shells of the growing faces, the formation of nano- and microscopic defects on them, etc., which determines the variety of forms of crystallizing snowflakes and hailstones.

Using the data from [6-13], we can comment on the experimental Nakai diagram as follows (figure 1). At temperatures above 0°C and high supersaturation of vapors on the grains, water condenses. In the temperature range from 0 to -4°C, crystals form inside a liquid drop, and their faces remain covered with a quasi-liquid layer of ice. Therefore, the edges, whose atoms have a large number of unsaturated bonds, grow much faster than the faces, which leads to the formation of flat plate structures. At temperatures below -4°C, water crystallization on the face surfaces accelerates. The surfaces of the six-edge faces with a large area and a large surface energy are the first to dry. While the surfaces of the quadrilateral faces and edges remain wet, crystal growth occurs along the hexagonal axis, and hailstones take the form of elongated needles or prisms.

Below -10°C, the surfaces of all faces and edges freeze out, but the more stressed edges grow faster, which causes the formation of snow plates.

At temperatures below -20°C, cryogenic crystallization accelerates so much that the face surfaces do not have time to relax the mechanical overvoltages that cause nanoscopic defects. Since the rate of defect formation on the six-edge faces is higher than on the four-edge faces, the predominant growth occurs along the hexagonal axis of the crystal. Accordingly, the snowflakes take the form of elongated needles or prisms. The boundary values of the temperature intervals of the Nakai diagram are rather arbitrary, since in reality they depend on the presence of impurities, vapor saturation, pressure, and other conditions of formation. But its analysis allows us to assess the influence of the surface properties of CS clusters on their size and structure, and hence on the quantum properties of individual clusters and their ensembles. The results of the analysis of the diagram allow us to better understand the mechanisms of cloud formation and the nature of the dependence of their morphology on the temperature stratification of the atmosphere.

So, in the cold season (winter), negative temperatures begin already from the lower edge of cloud formation, and they are formed due to the sublimation of water vapor into ice crystals, bypassing the liquid phase. The uniformity of the composition of winter clouds (a small number of liquid drops, the density of which is 10% higher than that of ice) determines their predominantly horizontal development. In the warm season (summer, tropics), clouds in vertical development are able to pass all the temperature intervals of the Nakaya diagram, as it happens during the formation of cumulonimbus clouds. It should be noted that the morphology of summer and winter clouds of the same type will dif-
fer significantly, for example: summer layered rain clouds consist of liquid drops, and winter clouds consist of ice crystals.

**Figure 1.** Nakaya diagram showing the relationship between the morphology of snowflakes and the formation conditions that change the growth rate of ice crystallites on two types of faces.

The quantum properties of single and local ensembles of CS clusters are determined by the structures of clusters with sizes smaller than the critical ones, at which the CS properties are manifested. For example, when at least one of the geometric dimensions becomes commensurate with the de Broglie wavelength of the electrons, discrete energy levels arise in the cluster (like atoms). Adding new atoms to the cluster increases the number of valence electrons in the system, which leads to an overflow of degenerate energy levels and "extra" electrons populate higher energy levels. Filled electron shells create stable quantum states, which are characterized by specific values of the ionization potential, electron affinity, etc. It is these characteristics that change abruptly during the transition between the elements of the periodic table of D. I. Mendeleev. In particular, by analogy with the atomic law of G. Mosley, the characteristic frequencies of CS clusters increase (radioactivity should be expected). In addition, according to [7, 12-14], CS properties cause significant changes in the mechanical, electrical, optical, and magnetic characteristics of CS clusters, as well as their spins. In single clusters, the quantum mechanical properties are maintained by overlapping the electron orbitals of individual atoms, as well as by indirect exchange, dipole, induction, and other quasi-contact interactions.

**4. Quantum properties of large ensembles and clusters**

For a long time, it was believed that mixed structures (composite materials, colloids, aerosols) consisting of separate nanoclusters separated by macroscopic materials do not have such collective quantum properties as: quantum superposition, quantum coherence, and quantum entanglement. However, in the early 2000s, the developers of quantum computer systems revealed the properties of quantum dissect that provide quantum parallelism in long-distance CS clusters [15-18]. So, in China, successful experiments have already been conducted to preserve quantum entanglement at a distance of 1203 kilometers.
This allows us to talk about the presence of quantum effects in large ensembles of CS clusters with dimensions of several hundred kilometers, as well as about the manifestation of interactions with light and superluminal velocities of the type: radiation – field, radiation – matter, quantum entanglement.

Within the framework of the methodology of this article, atmospheric clouds are large ensembles of CS clusters. Since kilometer-long ensembles of CS clusters cannot be recreated in laboratory spaces, it is advisable to conduct studies of quantum processes occurring in clouds in polygon conditions using quantum-structural filaments. CSN are kilometer-long filaments with nano-cluster coatings. A number of significant experiments with CSN were carried out in the period from 2004 to 2009 on the basis of the SIC DZA-a branch of the GGO named after him. Voeykova [1–4].

5. Experimental studies
Tests at the Rzhev test site confirmed the hypotheses about the unique abilities of the CSN to repeatedly initiate lightning discharges, and their ability to initiate lightning not only in thunderclouds, but also in good weather conditions. Thus, in the 2005 experiment, 1 trigger lightning was recorded in a thundercloud with a power of 11 km, and 7 more discharges in the same cell when it degraded to 2.7 km. Thunderstorm activity of the post-thunderstorm cell containing the CSN was observed for more than 20 minutes. In 2009, a trigger lightning in a cloud with a capacity of 6 km was initiated with the help of the CSN. According to the ALVES system, this was the only lightning in a day within a radius of more than 500 km from the landfill.

In another experiment in 2009 (with layered clouds), simultaneous failures of all eight electronic devices that provide measurements and observations during experiments were recorded. In particular, there was a three-minute malfunction of the MRL-5 meteorological radar (at a distance of 10 km) and the Vaisala fluxmeter (at a distance of 3 km) specially designed for observations in conditions of powerful thunderstorm activity. It is necessary to pay attention that at the same time 8 devices failed, the equipment of which was protected by metal and plastic cases. This means that the CSN generated radiation of penetrating levels, i.e. more than 100 keV, at a distance of 10 km from the radiation source [19, 20]. Therefore, taking into account the ionization losses in the atmosphere, the energy of the primary particles can be estimated at a level of about 10 MeV or more. This conclusion is confirmed by the results of foreign studies. For example, in American experiments on trigger initiation, radiation levels of up to 8 MeV were recorded, as well as fluxes of fast electrons and positrons [19].

The radiation of such high levels is formed due to the combination of quantum effects in the design of the CSN, which trigger high-energy electronic and nuclear reactions. So, tests on the atmospheric-optical stand of the Institute of Atmospheric Optics named after him. 2) revealed the Compton and anti-Compton broadening of the laser radiation spectrum that occurs when the electric potential of the CSN increases. The experiment used filaments with a length of 10 m, and the voltage varied within ± 25 kV, which corresponds to a maximum field strength of 2.5 kV/m. This indicates an increase in the intensity of tunneling electron emission from the sharp edges of one-dimensional CSN structures with an increase in the electrical intensity within atmospheric variations.

Consequently, the electric field of the atmosphere can cause an intense emission of electrons from the surface of the CSN into the boundary layer of the air. In an electrified air shell, the emitted electrons can be accelerated by an external electric field to relativistic velocities with the formation of an avalanche-like breakdown on the escaping electrons [22]. Fast electron fluxes can be deflected into the atmosphere, forming ionizing radiation of a penetrating level. When the fluxes collide with the CSN atoms, they will excite the inner shells of the nanoclusters covering the filaments.

Ionization of the inner shells leads to the formation of X-ray characteristic radiation. At the same time, it should be taken into account that as a result of the manifestation of G. Mosley's law and the magic number effect (an increase in the number of crystals in particularly stable quantum states with closed shells), the energy of the characteristic radiation of kilometer-long CSNS can many times exceed the energy of the characteristic radiation of single and small ensembles of nanoclusters.
In the framework of this article, we are primarily interested in the ability of CSN and CS of cloud elements to form high-energy radiation. In this sense, it is interesting to consider the possible manifestation of quantum parallelism in their formation at kilometer distances.

As shown by the work of N. Gizan's group on the transmission of quantum entanglement over a distance of 10 km, the frequency conversion on quantum crystals can generate quantum entanglement and superposition, at least for simultaneously re-emitted photons \[18\]. The essence of the possible effect is that when the atoms of the crystal lattice and free electrons interact with the irradiating photons, the frequencies of the re-emitted photons must correspond to the law of conservation of momentum. It is important to recall that the frequency of a photon is related to the magnitude of its momentum by the linear Planck ratio. Therefore, the frequency spectrum of entangled photons re-emitted from the atoms of the crystal lattice will represent the beats of the frequencies of the irradiating photons. The interaction of photons with free electrons can ensure their synchronization, and the spectrum of re-emitted photons is shifted to the low-frequency region when interacting with escaping electrons (Compton's law), or to the high-frequency region when interacting with incoming electrons (anti-Compton's law).

It can be stated that in the maximum case, the pulse of the re-emitted photon will exceed the total value of the pulses of all photons received simultaneously (taking into account the Heisenberg uncertainty principle). Accordingly, its frequency will exceed the sum of the frequencies of the irradiating photons. High-energy radiation from quantum-structural clusters can trigger even more energetic quantum reactions. When the particle energy rises above 10 MeV, nuclear reactions are triggered, including nuclear fusion reactions.

6. High-energy radiation of quantum-structural elements of clouds
The ability of atmospheric clouds to exhibit quantum effects with energy levels that are inaccessible for individual and small ensembles of nanoclusters can be illustrated by the example of dark Lightning

![Figure 2](image-url)
Dark Lightning (DL). This name was given by NASA to a beam of positrons, electrons and photons of high energy (up to 20 MeV) coming from the Earth's atmosphere, discovered in 2006 by the Fermi orbiting observatory. According to the reports of the National Scientific Laboratory of Armenia (Mount Aragats), DLS with a particle energy of 100 MeV were recorded. In early publications about atmospheric ionizing radiation of the penetrating level, they were called "Terrestrial Gamma-ray Flashes" (TGF). Within the framework of well-developed high-energy physics, there is no explanation for how atmospheric clouds can form dark lightning, which is a stream of high-energy particles, antiparticles, and gamma rays. Our hypothesis is based on the analysis of significant similarities in the structures of snow and thunderclouds with CSN. First, they are large ensembles of CS clusters. Secondly, CS clusters of CSN, as well as snowflakes and hailstones, have a large number of one-dimensional nanoscale elements in their structure. As is known [12-14], one-dimensional nanoscale elements have a high ability to tunnel emission at low electric field strengths. As a result of tunnel emission, the density of free electrons in snow and storm clouds increases, and the magnetic moments of ionized crystals increase accordingly.

Third, at low temperatures (below the Curie and Neel temperatures of the corresponding CS clusters), the spin coherence and entanglement of not only electrons, but also nanocrystals increases. As a result, the entanglement and coherence of the quantum characteristics in clouds approaches similar properties of the CSN. This allows us to speak about the ability of low-temperature large ensembles of CS clusters (snow clouds, hail regions of cumulonimbus clouds) to form high-energy ionizing radiation. In cumulonimbus clouds, tunnel emission and ionizing radiation provide a forced breakdown.

The uniformity of the composition of winter clouds (which, as shown above, consist only of crystalline elements) determines the uniformity of the distribution of electric charges. Therefore, it can be assumed that in winter clouds, tunnel emission and radiation of crystal CS clusters do not cause a spark breakdown due to the low electric field strength.

The proposed hypothesis of the role of quantum-structural clusters in the formation of atmospheric formations and important meteorological processes is indirectly confirmed by experiments with quantum-structural strands and the lack of competitive explanations for such natural phenomena as:
- low electric field strengths at which lightning occurs (it is required for an independent discharge of 3000 kV/m, and natural lightning is formed at voltages of 2-40 kV/m, which is possible only with a breakdown on escaping electrons, or with an ionizing discharge);
- the occurrence of lightning in a "clear sky" (the long free path of ionizing particles in the air leads to the initiation of lightning away from sources of ionizing radiation);
- formation of natural dark lightning (large ensembles of nanocrystals can form streams of high-energy particles, antiparticles, and gamma radiation);
- increased number of aircraft damage and accidents associated with exposure to atmospheric electricity in snowy weather in the absence of thunderstorm activity.

Confirmation or refutation and clarification of the proposed hypothesis requires more detailed research, including:
- field, bench, and laboratory experiments on the study of quantum-mechanical atmospheric processes using quantum-structural filaments;
- remote (including space) sounding of the structures of cloud elements and the electromagnetic processes caused by them.

7. Conclusion
The described mechanisms of condensation and crystallization of aerosols with the formation of liquid and crystalline (less often – amorphous) nanoclusters and precipitation from the cloud as the particles grow to macroscopic sizes are common for the atmospheres of planets with different chemical compositions. They must be taken into account when remote sensing not only the Earth, but also other planets, as well as when studying their atmospheres and clouds. In particular, it is necessary to reject such models that allow mixing in a single layer of a cloud of crystals with significantly different crystalliza-
tion temperatures. The stratification of the physical and chemical structures of the layers of cloud elements occurs only in accordance with the temperature stratification of the atmosphere.

When processing and analyzing the results of sensing, it is necessary to take into account that the combination of atoms in nanoclusters shifts their characteristic spectrum to the high-frequency region. Corresponding changes in the frequency characteristics should be expected when probing snow and icer ice

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