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Self-Assembling of a Fractal from Nanodust in Electric Discharges: from Laboratory to Space

A.B. Kukushkin, V.A. Rantsev-Kartinov

NFI RRC "Kurchatov Institute", Moscow, 123182, Russia

1. Introduction. Observations of transverse-to-electric current, few-centimeters long straight filaments [1(A)] of anomalously long lifetime in the plasma of gaseous electric discharge, a Z-pinch, lead to a hypothesis [1(B)] that such filaments possess a microsolid skeleton which might be assembled during electric breakdown, prior to appearance of main plasma, from wildly formed carbon nanotubes (or similar nanostructures of other chemical elements). The proof-of-concept studies revealed the presence of skeletal structures of certain distinctive topology (namely, tubular and cartwheel-like structures, and their simple combinations) in various facilities, in a wide range of length scales (see Table 1). The laboratory data analysis is summarized in the survey [1(C)]. Further extension of the range of this phenomenon have included electrodynamic phenomena in the Earth atmosphere and cosmic space, to cover finally the range 10^{-5} cm - 10^{23} cm [1(D)].

Size,cm	10^{-6}-10^{-3}	~10^{-2}-10	~1-10	~10^{3}-10^{5}	~10^{11}-10^{23}
USS	Dust deposits in tokamak [2]	Electric discharge in tokamaks, Z-pinches, plasma foci, vacuum spark, laser plume; [1(A-C)]	Hail-stones [1(D)]	Tornado [1(D)]	Solar coronal mass ejection; supernova remnants; some galaxies [1(D)]
Data source	TEM, SEM images $^{+}$	Optical and x-ray imaging* of plasma (electronic optical converters, streak camera, Kerr cells)	Photos	Photos, video	Space telescopes (optical, x-ray)

Table 1. Phenomenon of universal skeletal structures (USS) in laboratory high-current electric discharges, severe weather phenomena, and space

($^{+}$) Transmission/scanning electron microscopy.

(*) Including the images taken at *electric breakdown* stage of discharge in tokamak, plasma focus and vacuum spark (see [1(C)]).

Two phenomena revealed in the range 10^{-5}-10^{23} cm, namely

(i) topological identity (i.e. the similarity) of above structures (especially, of the cartwheel as a structure of essentially non-hydrodynamic nature), and

(ii) trend toward assembling a structure from similar ones of smaller size (i.e. the trend toward self-similarity),

suggest all these skeletal structures, similarly to skeletons in the particles of dust and hail, to possess a fractal condensed matter of particular topology of the fractal [1(D)]. Specifically, this matter may be self-assembled from nanotubular blocks in a way similar to that in the skeletons found in the submicron dust particles [2].

Recent findings in the physics of carbon nanotubes gave some support to suggested probable microscopic picture of skeleton's assembling and its chemical composition, as well as to probable mechanisms for the macroscopic skeletons assembled from carbon nanotubes to survive (i.e., possess an anomalous longevity) in hot plasmas (for more detail see [1(D)] and references therein).

Here we briefly discuss some probable implications of the phenomenon of universal skeletal structuring for astrophysics and cosmology, with a stress on the probable underestimated role of electrodynamics, including that of plasmas, in the Universe.

2. Extending the role of electrodynamics in the Universe. The presence of skeletons self-assembled from nanodust and embedded in, and to some extent hidden by, an ambient plasma was suggested [1(B)] to provide observed unexpected longevity of some filaments in laboratory plasmas. The hypothesis [1(B)] for the presence of similar internal skeleton in the cosmic filaments as well allows, to our mind, to shed a new light on the approach [3] to the possible role of electrodynamics in the Universe. The conjecture [3] implies that the long-living filaments of electric current («plasma cables») may form electric circuits at cosmic length scales, in particular, of the entire Solar system size. That hypothesis was supported, at a rough qualitative level [1(A,E)], by the similarity of networks of filaments (of luminosity) seen in laboratory plasmas and space. The resolvability of fine structure of filaments and their networks in space (thanks to recent advances in the imaging of cosmic objects by the space telescopes), Earth's atmosphere and laboratory electric discharges enabled us [1(D)] to indicate phenomena which suggest the possibility to strengthen and substantially extend the approach [3].

Besides the distinctive topology of general layout of bright spots within skeletal structures (first of all, in the cartwheels as shown in Figures 1-4 in [1(D)]), another evidence for the phenomenon of skeletons comes from the resolution of fine structure of luminosity around, at first glance, solitary bright spots. The best relevant evidence seems to be an electric torch-like structure: it resembles the shining edge of a truncated straight filament which belongs to a skeletal network. Such a structuring, and its similarity at different length scales, suggests that the skeletons may work as a guiding system for (and/or a conductor of) electromagnetic signals. Local disruption of such an electric circuit (e.g., its sparkling, fractures, etc.), or the presence of an open end (in particular, when the circuit has dendritic structure), may self-illuminate it to make the circuit observable around such critical points [1(D)] (see Table 2).

Size (cm)	$\sim 10^{-2}$ - 10^{-1}	$\sim 10^{-1}$ - 1	$\sim 10^{3}$ - 10^{4}	$\sim 10^{17}$ - 10^{20}
«Hot spot» as the butt-end of a truncated straight filament	Z-pinches and plasma foci (Fig. 5 in [1(D)])	Tokamaks (Fig. 1 in [1(G)])	Tornadoes (Figs. 2, 6 in [1(D)])	Nebulae (Fig. 7 in [1(D)]), galaxies (Fig. 2 in [1(G)])

Table 2. Phenomenon of self-illumination of a skeletal structure in laboratory high-current electric discharges, severe weather phenomena, and space (an electric torch-like structure).

At extra-galactic length scales, self-illumination of a skeletal network in its certain, critical points may work as well, but the dramatic decrease, with increasing length scales, of the average density of *hot, radiating* (baryonic) matter reduces the observability of skeletons: their dim dotted imprints only may be seen, like e.g. mysterious dotted images of arcs, circles, and ellipses. Therefore, at largest observable lengths, more or less distinct examples of skeletal topology may be found only in the redshift surveys of *thin* slices of space (the redshift surveys are believed to provide a three dimensional distribution of galaxies, which may give, in particular, the side-on view on a thin conical slice of space). Despite the structuring revealed at cosmological lengths (see Fig. 3 in [1(F)]) is obviously much less distinct than that at galactic and smaller lengths, the correlation revealed makes it reasonable to suggest extrapolation of our hypothesis farther, to cosmological scales.

3. Major probable implications of the observed skeletal structuring for astrophysics and cosmology.

(1) Some mechanical strength (rigidity) of skeletal structures at galactic and extra-galactic length scales suggests the possibility to avoid the need to introduce a «dark

matter». Indeed, the well-known controversy between «apparent masses» and their gravitational dynamics may be resolved because the bright spots, which belong to a skeleton, may move faster than predicted for their masses estimated from their luminosity. (Also, the skeleton may involve the ambient gas/plasma in a faster motion.) The proposed reinterpretation is applicable to both historic sources of introducing a dark matter, namely to the periphery of rotating galaxies and, especially, to clusters of galaxies because the effect of rigidity is stronger just at larger lengths.

(2) A combination of the following observational facts, namely (i) skeletal structuring in the range 10^{-5} cm - 10^{23} cm [1(D)], and (ii) the signs of skeletal structuring in the range 10^{24}-10^{26} cm [1(F)], hints at the presence of a *baryonic cold skeleton* (BCS) of the Universe. At cosmological scale the temperature of the overwhelming part of such a skeleton (i.e. excluding its critical, burning points) should be equal to that of cosmic microwave background radiation (CMBR), ~2.7 K. Thus, BCS is dark in the sense of very poor emission of visible light but is not "dark" in the sense of sensibility to electromagnetic interaction. A qualitative analysis of the probable radiative and mechanical properties of nanotube-assembled skeletons suggests that such BCS has no unavoidable conflict with two major observational facts of modern cosmology (namely, the ultrahigh isotropy of CMBR and the high uniformity of Hubble's expansion of the Universe).

(3) Generally speaking, the purely gravitational description of the *large-scale* structure of the Universe is likely to be appended with a contribution of quantum electrodynamics to describe the fractal condensed-matter skeletons.

REFERENCES

[1] Kukushkin A.B., Rantsev-Kartinov V.A., **(A)** *Laser and Part. Beams* **16,** 445-471 (1998); *Rev. Sci. Instrum.* **70,** 1421-1426 (1999); **(B)** *Fusion Energy 1998* (Proc. 17th IAEA Conf., Yokohama, 1998) IAEA, Vienna, 1999, Vol. 3, pp. 1131-1134; Proc. 26-th EPS PPCF, Maastricht, Netherlands, 1999, pp. 873-876 (http://epsppd.epfl.ch/Maas/web/pdf/p2087.pdf); *Current Trends in International Fusion Research: Review and Assessment* (Proc. 3rd Symposium, Washington D.C., 1999), Ed. E. Panarella, NRC Research Press, Ottawa, Canada, 2002, pp. 121-148. **(C)** *Advances in Plasma Phys. Research*, 2002, Vol. 2 (Ed. F. Gerard, Nova Science Publishers, New York), pp. 1-22. **(D)** *Phys. Lett. A* **306**, 175-183 (2002). **(E)** *Rev. Sci. Instrum.* **70,** 1387-1391 (1999). **(F)** Preprint astro-ph/0205534 at www.arXiv.org. **(G)** AIP Conf. Proc., v. **703** (Eds. G. Bertin, D. Farina, R. Pozzoli. New York, 2004), pp. 409-412.

[2] Kolbasov, B.N., Kukushkin, A.B., Rantsev-Kartinov, V.A., Romanov P.V., *Phys. Lett. A* **269,** 363-367 (2000); *Phys. Lett. A* **291**, 447-452 (2001).

[3] H. Alfvén, *Cosmic Plasma,* D. Riedel Publ. Co., Dordrecht, Holland, 1981.