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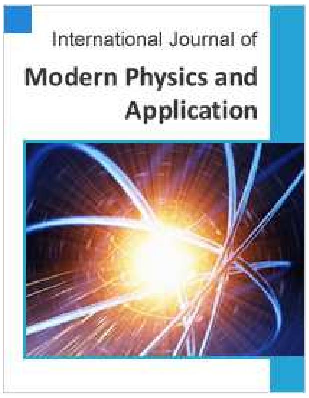

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Modern Physics Solution of the Saturn Rings Origin Problem – Electromagnetism and Superconductivity (The Possibility of the Unified Theory of the Planetary Rings Origin)

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Abstract
Low temperature near Saturn and presence of a planetary magnetic bring us an idea of the possible existence of the superconductivity of the particles forming rings system. Experimental study has confirmed this suggestion. Rings can be a result of the interaction of the superconducting carbon doped ice particles of the protoplanetary cloud with the nonuniform planetary magnetic field. After appearance of the magnetic field of planet all particles receive additional movement due to Meissner-Ochsenfeld phenomenon. Their Kepler's chaotic orbits start to shift to the magnetic equator plane and create the system of rings and gaps like an iron particles nearby magnet on laboratory table. The particles itself do not stuck together because they separated by magnetic field which is getting out from each one of them. Also gravity resonances of planet, it satellites and rings particles as well as other interactions play an important role in formation of the final ring's picture. The same scenario is applicable to the origin of the rings of Jupiter, Uranus and Neptune located behind the asteroid belt.

1. Introduction

The origin of the Saturn rings is puzzling phenomenon since it was discovered by Galileo in 1610. Then Pioneer (1979), Voyager-1 (1980), -2 (1981), and Cassini (from 2004 for today) imaged the ring system extensively. G. Galileo (1610), Ch. Huygens (1665), G. Cassini (1671), W. and G. Bond (1848), J. K. Maxwell (1859), S. Kovalevskaya (1874) and [1-25] have studied rings. In [26] found a universal particle distribution, but didn't explain it separation, the rings origin and electromagnetic phenomena. Different ring systems are morphologically quite distinct but all are shaped by a few common processes. In fact, orbital resonances between satellites, moons and ring particles play an important role in forming a specific structure of the rings and gaps. And experimental data confirmed importance of magnetohydrodynamic, gas-plasma, dusty plasma and electromagnetic phenomena for the rings origin and it existence.

There are two versions of the Saturn rings origin: 1. rings were originated from the debris of the asteroid-type body destroyed nearby the planet by gravity and centrifugal forces without electromagnetic influence; 2. the system of the rings was formed from the particles orbiting Saturn inside the protoplanetary cloud that initially surrounded Saturn.

We try to show which way the second model could work. Namely, the rings appeared as a result of the electromagnetic interaction of iced particles of the protoplanetary cloud with the magnetic field of Saturn. It could happen if particles possess superconductivity as Saturn has a magnetic field and nearby of it the temperature is low enough, 70-110 K.

We know the rings particles are relics of the early days of the Solar system, and it never subjected to excessive heating and coalescence. Our electromagnetic model would enrich classical theories of the rings origin in a consistent way.

The role of superconductivity for the origin of Saturn rings for the first time was presented by A. Yu. Pospelov and V. V. Tchernyi in 1995 [12] and discussed [12-26]. Also we expect the proposed model has initial fundamental feature for the Saturn rings origin. It allows enhancing classical theories of the planetary rings. Also it may help understand and explain better the data of the Cassini probe.

In 1933 W. Meissner and R. Ochsenfeld found that a superconducting material will repel a magnetic field. The high-temperature superconductivity was discovered by J. G. Bednorz and K. A. Muller in 1986 [27]. Superconductivity of ice was experimentally demonstrated by A. N. Babushkin et al in 1986 [28]. Superconductivity of C_{36} has been conjectured in 1998 [29]. So, even 7% of a glassy carbon composition of Saturn rings may contribute to its superconductivity. In 2011 scientists lead by G. Deutscher demonstrated how the exceptional large scale superconductor disc frozen with liquid nitrogen is trapped in a surrounding magnetic field and can be made to hover over a magnet in any position with any movements [30].

2. Discussion of Experimental Data

Thin Width and Sharp Edges of the Rings

Similar to the iron magnetic particles that create dense and rarefied regions in the nonuniform magnetic field, superconducting particles also form bands looking from outside like a system of rings. Superconducting particles collapse into the stable system of rings as a result of their exchange between the areas of the gradient of magnetic field within the plane of the magnetic equator with the force: $F = -\mu dH/dz$, where μ – the magnetic moment of the particle, dH/dz – the gradient of the magnetic field along the z axis of the magnetic dipole. The force of the diamagnetic expulsion forms sharp edges of the ring: $F= -\mu dH/dy$, where dH/dy – the gradient of the magnetic field along the radius of the ring. The accidental break in the ring will be stabilized by the force of the diamagnetic expulsion $F = - \mu dH/dx$, where dH/dx - gradient of the magnetic field in the tangential direction. The image of the magnetic field line deformation measured for the ring ***F*** by the Pioneer mission looks like the image of the magnetic field expulsed from the ring. It is of the same nature as for the well-known case of a small superconducting ceramic sample pushing out its own internal magnetic field, when exposed to a liquid nitrogen temperature.

The magnetic field in the plane of the rings disc is essentially non-unformed because each superconducting particle is push out magnetic field of its own volume. Magnetic field lines will strive to go through the region with the highest magnetic permeability. It is known that the superconducting powders possess gather in areas with low density of the magnetic field. Density gradient flow of the magnetic field pushes superconducting particles of each other, and also cleans the gaps within the rings system and forms a rigid thin structure of the separated rings. The density of the magnetic flow inside each ring will be lower than within surrounding its space. The difference of density of the flow will cause directed inward magnetic pressure on the each ring, therefore, the rings have sharp edges. This is the same as condition of the superconducting film in the magnetic field.

Radial Dust Flow

Superconducting material is characterized by the London's penetration depth λ_L of the magnetic field. For particles of size comparable with the London's penetration depth the influence of the magnetic field on superconductivity becomes appreciable. Smaller particles do not couple to the planetary magnetic field because they lose their superconductivity due to their small size. The dynamics of these particles is different from the dynamics of the particles with larger size, $>2\lambda_L$. Small particles will fall down to the planet due to gravity. Thus, existence of a radial planetary dust flux composed of submicron's size particles is related to a lack of superconductivity of the ring particles due to their small size. It is also possible for the particles to lose their superconductivity by collisions and by magnetic field fluctuations.

The Azimuthal Brightness of the Saturn A Ring

Present understanding of this phenomenon is based on: a) an assumption of a synchronous rotation of the ring's particles with their asymmetrical form as extended ellipsoids directed under a small angle to the orbit; b) existence of an asymmetrical albedo of the surface. Consider now our model for this phenomenon. If the superconductor is placed in the magnetic field, a magnetic moment directed oppositely to the external field is induced. The matter is magnetized not along the external magnetic field but in the opposite direction. A superconductive rings particle in the form of the rod attempts to align itself perpendicularly to the magnetic field lines. It is a known fact from science of ice [31] that growing snowflakes at the temperature below - 22^0 C take the form of prisms. Thus, the prism of the superconducting ice particle will be oriented perpendicularly to the field lines of the poloidal and toroidal components of the magnetic fields of the Saturn. It becomes now clear that the variable azimutal brightness of the Saturn's rings system *A* is related to the orientation of the elongated ellipsoid of the superconducting particles versus the direction of the planetary magnetic field.

Spokes in the B Rings System

Just as any wheel spokes, the spokes of the rings are aligned almost radially. The size of the spokes is about 10^4 km along the radius and about 10^3 km along the orbit of the rings. The matter of the spokes consists of micron and submicron size particles. There were many attempts to explain the nature of these spokes. Generally, all the models are based on the action of the force of gravity. Nevertheless a different idea was put forward that the nature of rotating spokes perhaps is related to the electromagnetic force. Analysis of the spectral radiation power of spokes provides a specific periodicity about 640.6±3.5 min which almost coincides with the period of rotation of the magnetic field of Saturn (639.4 min). Moreover a strong correlation of maxima and minima of activity of spokes with the spectral magnetic longitudes is connected to presence or absence of the radiation of Saturn's Kilometric Radiation (SKR). It enhances the assumption of the dependence of the spoke dynamics on the magnetic field of Saturn and testifies to the presence of large-scale anomalies in the magnetic field of Saturn. We can add the following explanation of it.

Superconducting ice particles of the ring matter are orbiting in accordance with the Kepler's law and have their own speed on each orbit. Further, a magnetic field of Saturn has its own anomalies along some radial direction from the planet. When the particles enter into this anomalous region, the diamagnetic expulsion force that is applied to the particles changes its value. The particles then begin to change their orbit. For the significant number of participating particles, for the external observer, this process appears as the turbulent cloud stretched along the radius in the form of spokes. After passing anomaly, particles return to their prior orbit and the common appearance of the rings is recovered.

Low Brightness and High Reflection of the Rings Particles in the Radiofrequency Range

This also can be explained by the superconductivity of the ice particles. Discovery in 1973 of the strong radar-tracking reflection from the rings of Saturn was surprising. It turned out that the rings of the Saturn actually have the greatest radar-tracking section among all bodies of the Solar system. It was explained by assuming a metallic nature of the particles. The data of the Voyager excludes this possibility. The disk of superconducting particles completely reflects radiation with frequencies below 10^{11} Hz and poorly reflects radiation with higher frequencies, as in the case of a superconductor. The superconductor practically has no electric resistance up to frequencies of 100 MHz. A threshold is about 100 GHz and above. From Fig. 1 we can see the sharp change of resistance. It may be caused by quantum phenomena in this range. Consequently it produces a specific dependence of the brightness.

Wide Band Pulse Radiation of the Rings

Data of Voyager have shown that the rings radiate intrinsic wide band pulse radiation within the 20 KHz - 40, 2 MHz. These waves probably are the result of an interaction of charged particles with the particles of ice and friction of ice particles when the co-striking occurs. These incidental radio discharges are called Saturn's Electrostatic Discharges (SED). The average period of SED is well defined by Voyager-1, -2 in between 10 hours 10±5 min and 10 hours 11±5 min. If the ring has a source of SED then the area of this source can be located at the distance of 107,990 – 109,000 km from the planet according to the measured periodicity.

Experimental data for SKR, SED and spokes activity specify the electromagnetic coupling between the planetary ring system and the magnetosphere of the planet. As it goes from consideration of the presented electromagnetic model, for superconducting particles approaching distance about 10^{-8} m or if they have a point contact, a superconducting transition can occur, as electrons can be tunneled through the gap. Consequently, this type of superconducting weak link begins to generate electromagnetic radiation – a non-stationary Josephson phenomenon for superconductors. The radiation frequency is proportional to the junction voltage, $\nu=2eV/h$, where 2e/h= 483, 6 MHz/μV, e is the charge of electron, h is the Plank constant.

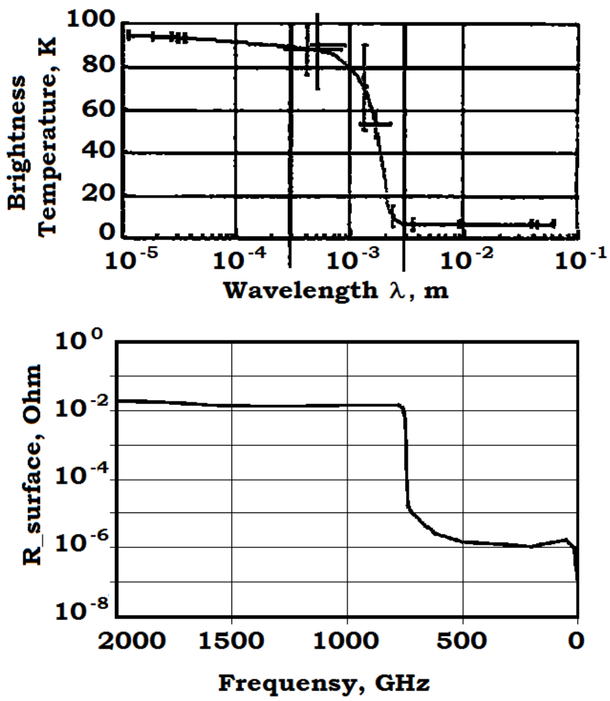

Fig. 1. *The top picture is the spectral dependence of the brightness temperature of the rings. Practically, we have a transition from black-body radiation to almost total reflection is observed [9, 10, 12]. The bottom diagram is dependence of the surface resistance of the superconductor on frequency for Nb at T=2K [Brinkmann R., Dohlus M., Trines D., Novokhatski A., Timm M., Weiland T., Hulsmann P., Rieck C.T., Scharnberg K., Schmuser P. March 2000. Terahertz Wakefields in the Superconducting Cavities of the TESLA-FEL Linac. Tesla Reports].*

Frequency Anomalies of Thermal Radiation of the Rings in the Range of 100μm - 1cm

The measured brightness temperature for the short wavelengths is less than the true brightness temperature of the rings and, for the longer wavelengths, the rings look much colder than in the case when the radiation corresponds to their physical temperature. Within the range 100 μm – 1 mm the brightness temperature of the ring (Fig. 1) sharply falls below the black body characteristics. For the wavelengths longer than 1cm a ring behaves as the diffusion screen, reflecting planetary and cold space radiation. The central part of the spectral range 100 μm – 1 cm is the most sensitive part of this dependence which may contain the important information for the fundamental properties of the substance of the particles. In the superconductor, electrons do not interact with the crystal lattice and do not exchange energy with it. That's why there is no heat transfer from one part of the body into another. Hence, when the substance passes into a superconducting condition, its heat conductivity is lowered. And for temperatures significantly below critical, there are very few ordinary electrons capable of transferring heat.

Color Difference in the Small Scale of Rings

The balance of the three forces determines the position of the superconducting particles in the gravitational and magnetic planetary fields: gravitational force, centrifugal one and magnetic levitation (diamagnetic expulsion), Fig.1. Following our model, we consider a distribution of three particles (a, b, c) with equal weights and being on nearby orbits. Let the particles a - entirely of a superconducting pure ice, b – the ice particles with an impurity of clathrate-hydrates of ammonia or methane (NH_3; CH_4H_2O), c – ice particles with impurities of sulfur, carbon and iron containing silicates (H_2S). Each impurity provides its own contribution to the superconductivity phase and it will determine the color of the particle. The force of a diamagnetic expulsion F_L depends on the volume of the superconducting phase. Therefore for each of the considered particles the balance of the three forces on the orbit has a different radius.

Anomalous Inversed Reflection of Circularly Polarized Microwaves for Wavelengths above 1 cm

The study of reflection of radiowaves with the wavelength more than 1 cm from the rings has been made by the ground based radar and by the space probe. The reflection appears rather large and the geometrical albedo is about 0.34 and it has no strong dependence on the wavelength or on the angle of the inclination of the ring's pitch. So the rings are strong depolarizers. That's why in order to get any information from reflections measurements it is necessary to measure a reflected signal of two orthogonal polarizations separately. The reflected portion of the signal of the same polarization as the incoming signal is called the signal of "observed" polarization. The perpendicular component is called a signal of "unobserved" polarization. A difference between these two signals provides information about so the called factor of polarization which indicates polarization properties of the object.

For the planets of the Solar system, a reflected signal of unobserved polarization is usually small. As for the Saturn rings, for the same range of wavelengths and angles of an inclination of the incident wave, the factor of polarization becomes much bigger. It has an explanation based on theory of electromagnetic waves reflection from a superconductor. The superconductor differs significantly from the ideal conductor. It has almost infinite conductivity and it also demonstrates an ideal diamagnetism. In case of a reflection from the superconductive ice particle rings, it means that if the incident wave of the radar signal with a circular polarization has certain chirality, then the same chirality should be for the reflected wave.

An Atmosphere of "Unknown" Origin of the Rings

The atmosphere of Saturn's rings can originate as a result of the thin balance of forces of gravitational attraction and diamagnetic expulsion of gas molecules. Levitation of gas molecules may be originated as a result of its diamagnetic expulsion from superconducting particles due to induced magnetic moments by a magnetic field of the planet. A similar situation can be observed under laboratory conditions when an atmospheric water steam is precipitated on a substance as a white-frost at the transition point of the substance from the superconducting into a conventional state.

Existence of Waves of Density and Bending Waves within the Rings System

The existence of the waves of density and bending waves in the Saturn rings has no complete explanation based only on gravitational phenomena. Let's use our model. Note that the external magnetic field is directed along a free surface of the diamagnetic fluid representing a disk of the rings. Consider a localized deformation of the disc surface at some point of the ring. It can be induced, for example, by fluctuating gravitational forces of Saturn moons or satellites, or due to magnetohydrodynamic, gas-plasma and dusty plasma effects. Then a ponderomotive force will be created and applied in the opposite direction to preserve an original disc surface. Therefore the planetary magnetic field enhances the stiffness and stability of the disc surface.

3. Solution of the Rings Origin from the Iced Particles of the Protoplanetary Cloud

Prior to emergence of the Saturn magnetic field, all the particles within the protoplanetary cloud are located on the Keplerian orbits exhibiting a balance of the force of gravity and the centrifugal force. With emergence of the Saturn magnetic field the superconducting particles of the proto-planetary cloud begin to demonstrate an ideal diamagnetism (Meissner-Ochsenfeld phenomenon). Particles begin to interact with the magnetic field and all the particles become involved in an additional azimuth-orbital motion. Let's estimate the result of this motion based on the superconductivity of the iced particles.

If the magnetic field of the planet is H and the planetary magnetic moment is μ, then the magnetic field at any particular point within the protoplanetary cloud located at the distance r can be presented as:

$$H = \frac{3 \cdot r \cdot (r, \mu)}{r^5} - \frac{\mu}{r^3} \tag{1}$$

Then the superconducting sphere of the radius R located within the protoplanetary cloud acquires the magnetic moment

$$\mathrm{M} = -R^3 \cdot \mathrm{H} \quad (2)$$

The energy of the superconductor in the magnetic field is:

$$U_H = -(\mathrm{M}, \mathrm{H}) = R^3 \cdot H^2 \quad (3)$$

Placing the origin of the coordinates at the center of the planet and directing the z axis along the magnetic moment of the planet (orthogonal to equator), the expression for magnetic energy then becomes:

$$U_H = \frac{R^3 \mu^2}{r^6}(3\cos^2\theta + 1) \quad (4)$$

Here θ - the angle between the vector r and the axis z. It can be seen from the expression (4) that the magnetic energy of the superconducting particle has a minimum value when the radius-vector r (the position of the superconducting particle) is in a plane of the magnetic equator and is perpendicular to the axis z (cos θ = 0). Consider now only one particle. Evidently its azimuth-orbital direction trajectory (orbit) can only be disturbed by the magnetic field. However in case of a significant amount of particles forming the protoplanetary cloud, after a transient time estimated as 1000 years or more, collisions between particles will compensate their azimuth-orbital movements, and as a result all orbits of the particles of the protoplanetary cloud should come together to the magnetic equator plane and create highly flattening disc around the planet. Within the disc of the rings all particles will become located on the Keplerian orbit where there is a balance of gravity, centrifugal and electromagnetic forces. At the same time orbital resonances (due to a gravity force) between satellites, moons and the ring particles would play an important role in forming a specific structure of the rings and gaps.

Separation and Collision of Rings Particles

Let's define the energy of the interaction of two superconducting particles with the magnetic moments μ_{1z} and μ_{2z} located at positions r_1 and r_2, respectively as:

$$U = -\mu_1 \mathrm{H}_2 , \quad (5)$$

The magnetic field H_2 induced by the magnetic moment μ_2 can be presented as

$$\mathrm{H}_2 = \frac{3(\mathrm{r}_1 - \mathrm{r}_2)(\mu_2(\mathrm{r}_1 - \mathrm{r}_2))}{|\mathrm{r}_1 - \mathrm{r}_2|^5} - \frac{\mu_2}{|\mathrm{r}_1 - \mathrm{r}_2|^3} \quad (6)$$

If the particle with the magnetic moment $\boldsymbol{\mu}_2$ is placed at the origin (r_2=0) then the expression for the energy of the interaction of two particles (5) will read:

$$U = -\frac{3(\mu_1 \mathrm{r}_1)(\mu_2 \mathrm{r}_1)}{|\mathrm{r}_1|^5} + \frac{\mu_1 \mu_2}{|\mathrm{r}_1|^3} \quad (7)$$

The planetary magnetic field in the plane of the Saturn rings coincides with the planet rotation axis. If the axis z is directed along the rotation axis of the planet, then the magnetic moment of the particles will be also directed along z. In cylindrical coordinate system (*ρ, φ, and z*) (7) is:

$$U = -\left(\frac{3z^2}{\left(\rho^2 + z^2\right)^{5/2}} - \frac{1}{\left(\rho^2 + z^2\right)^{3/2}}\right)\mu_{1z}\mu_{2z} = \\ = \frac{\rho^2 - 2z^2}{\left(\rho^2 + z^2\right)^{5/2}}\mu_{1z}\mu_{2z} \quad (8)$$

From (8) we can estimate an interaction of two superconducting particles for two different cases. The first one is when two particles located in the same plane within the sombrero of the rings (z=0), and the second situation is when two particles are located on the different planes but on the same axis (ρ=0). For the particles with the magnetic moments μ_{1z} and μ_{2z} located on the same plane, z=0, we get the interaction energy as:

$$U = \frac{\mu_{1z}\mu_{2z}}{\rho^3} , \quad (9)$$

From (9) it follows that both particles will repel each other and they will maintain a separate distance between them. This result has been confirmed by the data of Cassini mission: the particles are separated. If particles are located on the same axis but on different planes, the expression for the interaction energy is:

$$U = -\frac{\mu_{1z}\mu_{2z}}{|z|^3} , \quad (10)$$

Now both particles could attract each other; they could even collide or stick together and form bigger clusters or lumps of ice. This process has an experimental conformation by the Cassini mission. From the data of the Cassini mission it follows that the particles within the thickness of the rings can collide or even stick together and create bigger clusters of ice. Then, in the following process, big particles about ten meters diameter can be shattered into smaller pieces by a combined action of collisions, gravity and centrifugal force [6, 11]. Sized centimeters or less small particles may adhere to large particles, as it naturally happened with the snowball.

4. Conclusion

Thus, low temperature (70-100K) near Saturn due to its long distance from the Sun and the presence of a planetary magnetic field leads to the idea of the superconductivity of the particles forming a rings system. Electromagnetic modeling shows the rings system can be a result of the interaction of the superconducting carbon doped ice particles of the protoplanetary cloud with the nonuniform magnetic field. Initially, the particles move around the planet by chaotic Kepler's orbits. After appearance of the magnetic field of Saturn all particles receive additional movement due to Meissner-Ochsenfeld phenomenon and their chaotic orbits start to shift to the magnetic equator plane with the minimum of magnetic energy where particles redistributed and form the system of rings and gaps like an iron particles nearby magnet on laboratory table. The particles itself do not stuck together because they separated by magnetic field which is getting out from each one of them. Our estimation shows that the process of formation of the existing stable rings system might take about thousands or even more years.

The gravitational resonances and other interactions also play an important role and they help bringing the order to the system of rings and gaps. It becomes to be clear why the rings appear only for the planets with magnetic field outside the asteroid belt such as Jupiter, Saturn, Uranus and Neptune. Inside the asteroid belt Sun's heat is destroying superconductivity. Scenario of the rings creation for all planets could be the same. So we are coming to the unified theory of the rings origin.

All ring systems are morphologically quite distinct but all are shaped by a few common processes. In fact orbital resonances between satellites, moons and ring particles play an important role in forming a specific structure of the rings system gaps and enhancing the influence of the satellites as well as the gravitational, mechanical, magneto hydrodynamic, dusty plasma and gas-plasma, interactions. Our model allows enrich the well-known theories in a consistent way.

So, we are coming to a conclusion about the need to consider the natural superconductivity in the Solar system space outside the belt of asteroid. It may have a fundamental feature for analyzing data of the Cassini probe and striking parallels to other stars system.

We can see that the conclusion of H. Alfven [3] that the “solar system history as recorded in the Saturn rings structure” becomes a physical reality. Also strong magnetic fields frozen into meteorite grains provide clues to how early solar system evolved [32]. The superconductivity of the ring particles may reflect the fact that the ring particles are relics of the early days of the Solar system and the particles were never subject to coalescence and heating. The data from Cassini mission just confirming our model of the rings origin due to superconductivity of it particles.

And one thing is for sure, the planetary rings will continue to puzzle our species like one of the marvels of the Universe that we continue to unravel. To paraphrase R. Frost we may say: “The rings are lovely, dark, and deep, but we have promises to keep, and study them before we sleep”.

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References

[1] Maxwell, J. C., Brush, S. G., Everitt, C. W. F., Garber, E. (Eds.). (1983). *Maxwell on Saturn's rings.* MIT Press, Cambridge, MA.

[2] Safronov, V. S. (1969). *Evolution of protoplanetary cloud and formation of the Earth and planets.* Nauka, Moscow, (Russian).

[3] Alfven, H. (1981). Solar system history as recorded in the Saturnian ring structure”, *Astrophysics and Space Science*, 97, 79-94.

[4] Mendis, D. A., Hill, J. R., Ip, W. H., Goertz, C. K., Grun, E. (1984). Electrodynamics Processes in the Ring System of Saturn. *Saturn.* T. Gehrels, M. Mathews (Eds.), University of Arizona Press, Tucson, 546-589.

[5] Morrison, D., Owen, T. C. (2003). *The Planetary System*, Addison-Wesley Longman.

[6] Gor’kavyi, N. N., Fridman, A. M. (1994). *Physics of the planetary rings: celestial mechanics of continuous medium.* Nauka, Moscow, (Russian).

[7] Spilker, L. J. (Ed.). (Oct. 1997). *The Cassini-Huygens mission to Saturn and Titan.* NASA SP-533, JPL, Caltech, Washington, D.C.

[8] Rowan, L., Sanchez-Lavega, A., Gombosi, T. I., Hansen, K. S., Porco, C. C. et al., Flasar, F. M., Esposito L. W. et al., Gurnett D. A. et al., Waite, J. H., Jr. et al., Young, D. T. et al., Dougherty, M. K. et al., Krimigis, S. M. et al., Kempf, S. et al. (2005). Cassini at Saturn. *Science*, 307, 1222–1276. Doi.org/10.1126/science.307.5713.1222

[9] Dougherty, M., Esposito, L., Krimigis, T. (Eds.). (2009). *Saturn from Cassini-Huygens*, Springer, Dordrecht, Doi.org/10.1007/978-1-4020-9217-6

[10] Cuzzi, J. N., Burns, J. A., Charnoz, S., Clark, R.N., Colwell, J. E., Dones, L., Esposito, L. W., Filacchione, G., French, R. G., Hedman, M. M., Kempf, S., Marouf, E. A., Murray, C. D., Nicholson, P. D., Porco, C. C., Schmidt, J., Showalter, M.R., Spilker, L. J., Spitale, J. N., Srama, R., Sremčević, M., Tiscareno, M. S., Weiss, J. (2010). An evolving view of Saturn’s dynamic rings. *Science*. 327, 1470-1475. Doi.org/10.1126/science. 1179118

[11] Brilliantov N., Krapivsky P. L., Bodrova A., Spahn F., Hayakawa H., Stadnichuk V., Schmidt J. (2015). Size distribution of particles in Saturn's rings from aggregation and fragmentation. *Proceedings of the National Academy of Sciences,* 112 (31): 9536; Doi: 10.1073/pnas.1503957112; aRxive 1302.4097v5; Guimarães Ana H. F., Albers N., Spahn F., Seiß M., Vieira-Neto E., Brilliantov N. V. (2012). Aggregates in the strength and gravity regime: particles size in the Saturn's rings. *Icarus,* 220, 2, 660–678. Doi.org/10.1016/j.icarus.2012.06.005

[12] A. Yu. Pospelov, V. V. Tchernyi, "Electromagnetic properties material forecast in the planet rings by the methods of functionally physical analysis" (1995), *Proc. Intern. Scientific-Methodological Conf. on Innovative Design in Education, Techniques and Technologies,* Volgograd State Technical University, Volgograd (Russian), 75-77.

[13] Pospelov, A. Yu., Tchernyi, V. V., Girich, S. V. (1998). Planet's rings: super-diamagnetic model and new course of investigations. *Proc. SPIE 42nd Annual meet,* San Diego, CA, 1997 July 27- Aug. 1 *Small Spacecraft, Space Environments and Instrumentation Technologies,* SPIE, 3116, 117-128;

[14] Girich, S. V., Pospelov, A. Yu., Tchernyi, V. V. (1998). Radar data explanation via superdiamagnetic model of the Saturn's rings. *Annual Report of AAS, 30th Meeting Division of Planetary Science,* Madison, WI, 1998 Oct. 11-16, *Bulletin of the American Astronomical Society*, 30, 1043.

[15] Pospelov, A. Yu., Tchernyi, V. V., Girich, S. V. (1999 Aug. 20). Are Saturn rings superconducting? *University of Alabama, Huntsville, NASA Marshall Space Flight Center.* Huntsville Space Physics Colloquium.

[16] Tchernyi, V. V., Pospelov, A. Yu. (2005). Possible electromagnetic nature of the Saturn's rings: superconductivity and magnetic levitation. *Progress in Electromagnetic Research, PIER*, 52, 277-299. Doi.org/10.2528/PIER04082801

[17] Tchernyi, V. V., Pospelov, A. Yu. (2007). About hypothesis of the superconducting origin of the Saturn's rings. *Astrophysics and Space Science*, 307(4) 347-356. Doi.org/10.1007/s10509-006-9054-7

[18] Tchernyi, V. V., Chensky, E. V. (2005). Electromagnetic background for possible magnetic levitation of the superconducting rings of Saturn. *Journal of Electromagnetic Waves and Applications*, 19, 1997-2006. Doi.org/10.1163/156939305775570440; Tchernyi, V.V., Chensky, E. V. (2005). Movements of the protoplanetary superconducting particles in the magnetic field of Saturn lead to the origin of rings. *Geoscience and Remote Sensing Letters-IEEE,* 2(4), 445-446. Doi.org/10.1109/LGRS.2005.852767 Corrections, IEEE GRSL, 2006, 3(2). Doi.org/10.1109/LGRS.2006.872347

[19] Tchernyi, V. V. (2002 Aug. 7). Possible superconductivity of Saturn rings, *University of Hawaii, Institute for Astronomy,* Colloquia: Spring/Summer 2002.

[20] Tchernyi V. V., Kapranov S. V. (2005). Possible role of superconductivity for simplest life propagation within the interstellar space by electromagnetic force of magnetic levitation. *Journal of Electromagnetic Waves and Applications*. 19, 15, 1997-2006; Tchernyi V. V., Kapranov S. V. (2005). *Astrobiology and Planetary Missions*. Hoover R.B. et al. (Eds.). SPIE. 5906.

[21] Tchernyi V. V. (2006). About possible role of electromagnetism and superconductivity for the origin of Saturn rings. *Prikladnaya Fizika (Applied Physics)*, 5, 10-16 (Russian).

[22] Tchernyi (Cherny), V. V. (2009). Origin of the Saturn rings: electromagnetic model of the sombrero rings formation. *Space Exploration Research*, J. H. Denis, P. D. Aldridge (Eds.), Nova Science Publishers, NY. Chapter 11, 261-275; also please, see: Tchernyi (Cherny) V.V. (2009). Origin of the Saturn rings: electromagnetic model of the sombrero rings formation. *Journal of Magnetohydrodynamics, Plasma and Space Research*, 14(3-4), 385-398; (2010) 15(1), 39-52; Tchernyi (Cherny) V. V. (2012). *New Developments in Magnetohydrodynamics, Plasma and Space Research.* Talton, S., Theba, P.F. (Eds.). EBook. *Earth Science in the 21st century.* https://www.novapublishers.com/catalog/product_info.php?products_id=30109

[23] Tchernyi, V. V. (2009 Aug. 3-14). To discovery of initial formation (origin) of the sombrero rings of Saturn: role of electromagnetism, *Abstract book, Symposium No. 263 - Icy Bodies in the Solar System, Report No. 263-p:56, p. 63.* International Astronomical Union, Assembly, XXVII General Assembly, Rio de Janeiro, Brazil. http://www.observatorio.unal.edu.co/investigacion/archivos/AbsBookXXVIIga09.pdf

[24] Tchernyi (Cherny), V. V. (2013). Could superconductivity contribute to the Saturn rings origin? *Journal of Modern Physics (Special Issue on Superconducting Physics),* 4(6A), 17-23. Doi.org/10.4236/jmp.2013.46A005

[25] Cherny (Tchernyi), V. V. (2013). The Saturn rings origin: contribution of electromagnetism (to the unified theory of the origin of planetary rings). *American Journal Astronomy and Astrophysics,* 1(2), 15-22. Doi: 10.11648/j.ajaa.20130102.11

[26] Tchernyi, V. (2013). About role of electromagnetism to the Saturn rings origin - to the unified theory of the planetary rings origin. *International Journal of Astronomy and Astrophysics,* 3, 412-420. Doi/org/10.4236/ijaa.2013.34049

[27] Bednorz, J. G., Müller, K. A. (1986). Possible high Tc Superconductivity in the Ba−La−Cu−O System. *Zeitschrift für Physik B*., 64, 189–193. Doi.org/10.1007/BF01303701

[28] Babushkina, G. A., Kobelev, L. Ya., Yakovlev, E. N., Babushkin, A. N. (1986). Superconductivity of Ice Under High Pressure. *Physics of Solid State,* 28, 3732-3734 (Russian).

[29] Côté, M., Grossman, J. C., Cohen, M. L., Louie, S. G. (1998). Electron-phonon interactions in solid C36. *Phys. Rev. Lett,* 81, 697. Doi.org/10.1103/PhysRevLett.81.697

[30] Deutscher, G., Azoulay, M., Almog, B., (2011 Oct. 15-18). Quantum levitation, quantum locking, quantum trapping. *AASTC Conf., Maryland*, http://www.ted.com/talks/boaz_almog_levitates_a_superconductor.html

[31] Maeno, N. (1981). *The Science of Ice,* Hokkaido University Press, Sapporo.

[32] Fu R. R., Weiss B. P., Lima E. A., Harrison R. J., Bai X. N., Desch S. J., Ebel D.S., Suavet C., Wang H., Glenn D., Le Sage D., Kasama T., Walsworth R. L., Kuan A. T. (2014 Nov 28). Paleomagnetism. Solar nebula magnetic fields recorded in the Semarkona meteorite. *Science,* 346(6213), 1089-1092. Doi:

10.1126/science.258022. (Strong magnetic fields recorded in meteorite provide clues to how early solar system evolved. 2014 Nov 17. *Sci-News.com;* Magnetic fields frozen into meteorite grains tell a shocking tale of solar system birth. 2014 Nov 13. *http://phys.org/news*)