"Nature is simple and does not luxuriates in excesses."
I. Newton

The PFO–CFO hypothesis of Solar System formation: the birth of chemical elements

V.E. Ostrovskii, E.A. Kadyshevich,
Karpov Institute of Physical Chemistry, Moscow, Russia
(vostrov@cc.nifhi.ac.ru)
Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia
(kadyshevich@mail.ru)

Madrid, EPSC 2012

I. INTRODUCTION: WHY IS A NEW SOLAR SYSTEM FORMATION HYPOTHESIS TOPICAL?

E. Rutherford (1919) and M. Oliphant (1932) discovered the

$^{14}N + ^{4}He \rightarrow ^{17}O + ^{1}H$ **and** $^{2}D + ^{2}D \rightarrow ^{3}Li + ^{1}n$

fusion reactions, respectively.

The widespread stellar model is given by H. Bethe, C.F. Weizsacker (1932) et al., and the solar model is a special version of this general model.

The model is based on the assumption that the chemical elements are born within stellar cores as a result of fusion reactions.

This assumption seemed to be the only feasible one and was taken willingly by the community.

Meanwhile, the mechanisms of the birth of many of the elements are individual and manifold, the planet formation requires combination of, at least, two rare celestial events, and a number of celestial phenomena known today can not be explained on the basis of the available model.

We propose a principally new solar model, according to which all elements are born by one mechanism at the periphery of the presolar star.

Why do the hypothesis of fusion reactions, as the source of chemical elements, and the solar model resulted from it raise doubts?

(1) This hypothesis is based on a fiction, not supported originally by any observed phenomena or events and not implied by facts; it was a scientific fiction covered with a verbal shell rather than a scientific hypothesis; its allurement was caused by an elation from the recent discovery of fusion reactions and by the belief in the idea that the solar radiation can be produced by nothing but highly exothermic fusion reactions. The hypothesis played an important role because its testing led to a number of important discoveries; however, its boost required a number of strained argumentations, and, apparently, only the absence of any other plausible hypothesis can explain its 80-year viability.

(2) From the solar model, the $4\ {}^{1}H \rightarrow {}^{2}He_{2} + 2\ e^{+} + 2\ {}^{0}n_{0} + \varepsilon$ (${}^{0}n_{0}$ is neutrino) reaction proceeds at the central field of the solar core at about $15{\cdot}10^{6}$ K and 160 g/cm^3 (C formation from 3 ${}^{2}He_{2}$ proceeds at $200{\cdot}10^{6}$ K and $5{\cdot}10^{4}$ g/cm^3). However, simultaneous realization of such conditions and any atomized substance is under question, because the translational degrees of freedom are minimized at such densities and the rotational and vibration degrees of freedom may be overladen and any atomization of the substance may become impossible.

The results of the Solar System (SS) observations lead to some paradoxes and require answers to a number of unreciprocated principle questions.

Most important paradoxes and unreciprocated questions are as follows.

(1) Any isolated star early in its life is electrically neutral. As neutronization of a star proceeds, its electron and proton amounts decrease to the same degrees. Thus, at the stage of full neutronization, the collapsed neutron stars should have no electrons and should have zero magnetic moment. Meanwhile, the measured magnetic moments of neutron stars are extremely high. Why is it so?

(2) If the SS is the product of explosion of the presolar star, what is the mechanism of the transfer of the major portion of the star angular momentum to the planets, and, if the angular momentum was received from any other source, what is its nature?

(3) If the SS is the product of explosion of the presolar star, why is the total mass of all SS planets less than the Sun mass by a factor of almost 1000?

(4) If the SS is the product of explosion of the presolar star, what are the cause and the mechanism of the Sun appearance?

(5) This paradox was recently noted by the US National Research Council: ”If only one nebula is the progenitrix for the SS, why are the planets so different?” this paradox was qualified as the most important astrophysical problem (http://books.nap.edu/openbook.php?record id=12161&page=9).

(6) The earlier proposed mechanisms of the SS formation give no reliable explanation either for the 11-year cycles of the Solar activity or for their association with the enhancements in the solar magnetic moment.

(7) If it is taken that the SS originated as a result of collapsing of a giant cloud and if even to take aditionally that such a cloud could really exist and could be independent of its maternal object, it is hard to understand the cause that could stimulate compressing of this cloud by 99.9% into one center (with Sun’s rebirth) and the cause that, under the conditions of such a compression, allowed 0.1% of the total mass to escape the common lot, to stop not far from the center of the powerful attraction, and to form a number of objects that are very small as compared with the central one.

(8) What is the mechanism of formation of chemical elements? None hypothesis gives any definite answer to this question; according to the present opinions, neither sun-like nor massive stars and nor even supernovas can be sources of all chemical elements and the ways of the natural formation of some heavy and superheavy atoms are little known.

(9) None of the SS formation hypotheses explains different isotopic compositions inherent in many chemical elements at the surfaces of different celestial bodies and even in different rocks and fluids of individual celestial bodies; to explain this phenomenon, a hypothesis was proposed that two phenomena (star explosion and gas-dust cloud) participated in the SS formation process; however, even such an assumption is insufficient because more than two different isotopic ratios, (e.g., for carbon) are known (for example, at the Earth and Titan [1]).

(10) None of the SS formation hypotheses answers the question: why is the solar corona temperature much higher than the photosphere temperature?

(11) Recently, one more mysterious phenomenon was discovered: it turns out that the rates of rotations of the solar core and solar radiation zone (RZ) are different; this means that the star substance physical properties change not continuously along the star radius [2]. This feature can not be explained on the basis of any available solar model; meanwhile, it plaid an important role in formulation of a principally new understanding of the mechanism of natural processes, which determine the temporal transformations of the sun-like stars, origination of planetary systems including the Solar one, and birth of a renovated star after performance by the mature-age star of its maternal function.

The common principles applied by us when formulating the hypotheses of the Universe gross-scale events that occurred in remote ages [3, 4]

(1) The gross-scale processes in Nature proceed progressively in the direction of decrease in the free energy in the Universe subsystems that can be approximated as the isolated ones.

(2) All natural phenomena proceed as a result of regular and inevitable transformations regulated by the universal physical and chemical laws.

(3) Random phenomena doesn't just happen in Nature; if a phenomenon seems to be random, an expansion of the spatial and time framework of observations is capable of revealing its necessity.

(4) The Newton principle of simplicity ("…for Nature is pleased with simplicity, and affects not the pomp of superfluous causes").

(5) The principle of repetition of supposed events and of the presence of individual features in the reproduced events (Nature created many similar but somewhat differing events and no unique event without close analogues.).

(6) The principle of the unity of the event point. Separation of an event into several sub-events proceeding in different points with subsequent interaction between the sub-events decreases the probability of the resulted event, because it decreases many-fold the degree of repetition of the event as a whole.

(7) Nature makes no jumps (*Nature non facit saltus*, in Latin).

II. THE PFO–CFO HYPOTHESIS OF SOLAR SYSTEM FORMATION

II. 1. Collection of concepts and publications

We assume that an infantile stars, including the infantile presolar star, represent the matter–energy (below "matten", ω) unstructured amorphous pseudo-liquid spatial domain capable of materialization in time with formation of the p+ (proton) / ē (electron) / n (neutron) matter under the action of the processes of gravitation, pressing, and specific energy of the system. The presolar-star materialization began at its center when the degree of pressing reached a critical value and extended to the periphery as the subsequent gravitation proceeded.

A portion of the electrons floated up under the action of the buoyancy and formed an electron-enriched layer (ElEL), which divided the star into a core and an RZ and represented a "cushion" between them.

After ElEL formation, the star core and RZ transformed separately; the peculiarities of their transformations were regulated by the distance of their location from the center and periphery of the system.

The concept of the ElEL occurrence and of the star-core and RZ separate transformations has been initiated by the recent discovery [2] of a difference between the rates of the solar core and RZ axial rotations and by our own analysis of the possible precursors of the real stable elements (see below). It will be shown that this concept allowed formulation of the Solar System formation hypothesis, explanation of the Sun rebirth after the presolar-star explosion, and proposals relative to solutions of the paradoxes and unreciprocated questions listed above.

The RZ transformed similarly to the core; materialization of the RZ started at the ElEL–RZ boundary and was characterized by tunnel neutronization intensified by a high ē concentration in the ElEL–RZ boundary layer.

Different aspects of the PFO–CFO Hypothesis are considered in [5-17].

We consider the middle-aged presolar star and the today Sun as similar objects.

II.2. The birth of chemical elements

Thus, the matten ionization started in the central zone of the star when the ω density reached a critical value as a result of gravitation and extended symmetrically over the sphere as the outward layers compressed.

A portion of the produced ēs stabilized the p^+ collection and the rest ones diffused out of the central zone and formed a degenerate electron gas layer, which divided the presolar star into a core and an RZ.

The ElEL location was determined by the balance between the attraction to the positively-charged core, Archimedean force, superstratum inward pressure, gravitation, and other forces that, possibly, acted in this system.

The n/p^+ ratio over the core was controlled by the thermodynamic directedness of the processes and, apparently, increased from the periphery to the center and in the course of time.

Analogous processes proceeded within the RZ; a significant portion of electrons diffused through the RZ and formed a background magnetic field outside the RZ.

With time, the core and RZ positive charges, gravitational compressing, densities, and degrees of neutronization and the ElEL power increased; therewith, the RZ density, neutronization, and charge were behind of those for the core. A high ē-concentration in the ē-layer promoted neutronization of the RZ bottom field.

Thus, with time, the ē-gas pressure within the ElEL increased, the RZ became thinner and denser, and the degree of neutronization of the RZ bottom zone increased.

The electron capture at the RZ bottom led to materialization of the RZ, i.e., to formation of an p–n layer "diluted" with electrons.

The n/p ratio in this layer increased progressively.

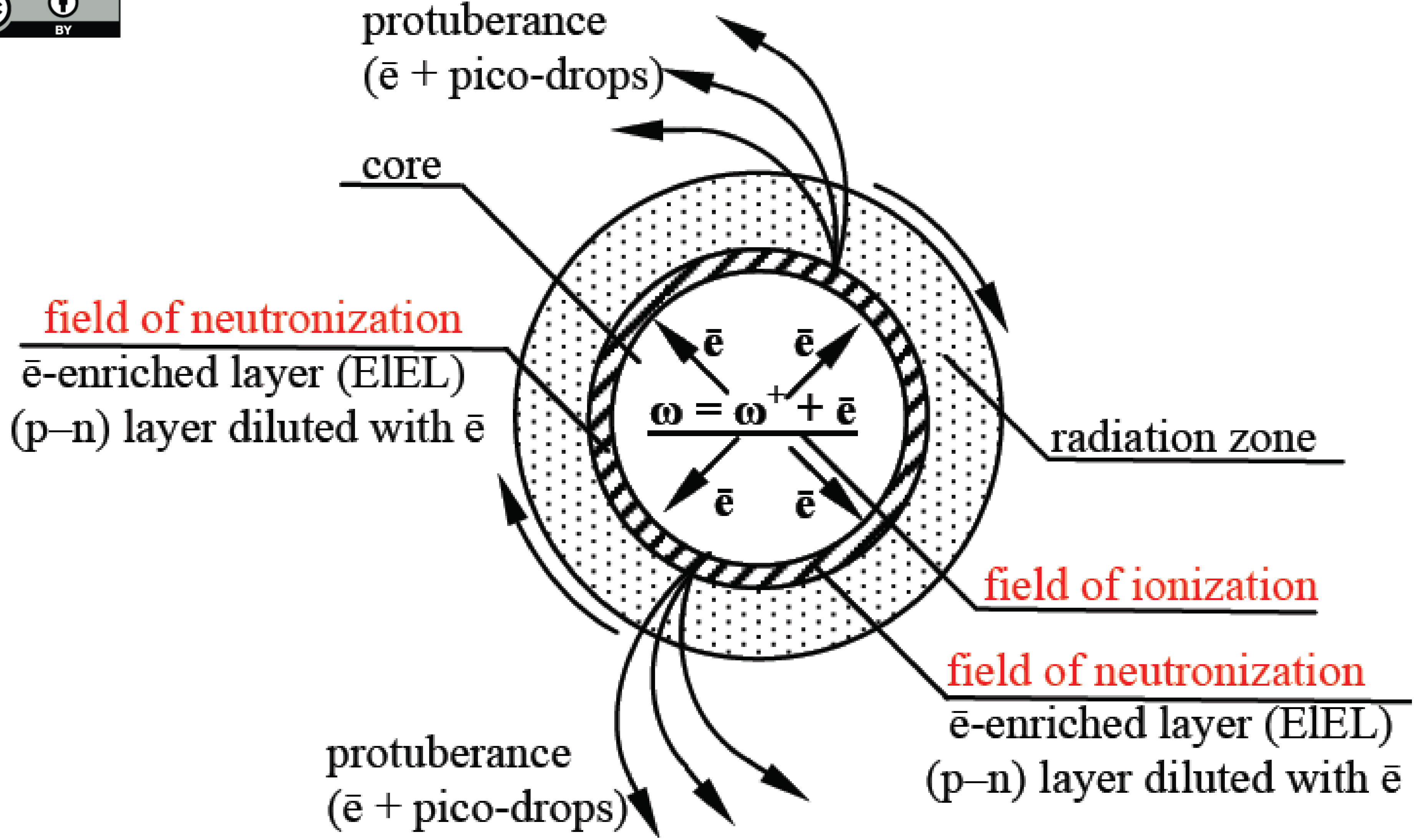


Figure 1: Electron-enriched layer formation, core and radiation zone segregation, protuberances formation, and pico-drops emission at middle-size middle-aged stars.

The ē-pressure within the ElEL occasionally reached a value at which RZ local disruptions appeared and the ē-jets (protuberances) carried pico-drops of the p–n substance out from the RZ bottom into the space.

The drops were radioactive or non-radioactive depending on the n/p value.

Since the overpressure was thrown off, the RZ holes "healed" and the ē-pressure in the ElEL began to increase again.

With time, the n/p over the RZ increased, RZ became denser, RZ and core rotation rates increased, and the pressure necessary to break through the RZ and the periods between the series of protuberances varied.

The stellar processes proceed slowly at the human life scale, and the duration of the quiet Sun periods seems to be constant; meanwhile, it changes from epoch to epoch. For our epoch, these periods are equal approximately to 11 years.

As a result of the star axial rotation, the pseudo-liquid RZ is the most thin in its equatorial zone; therefore, the protuberances occur just in this zone.

The ē-component of the protuberances causes the peak increase in the stellar magnetic moment during the stellar activity periods.

The protuberance power and the pico-drop size in the protuberances increase with the stellar age.

The n/p ratio of the picodrops is less or equal to that in the RZ bottom zone. The radioactive pico-drops transform into atomic nucleus of stable atoms as a result of their radioactive decays. These nuclei capture or not capture electrons into their atomic shells, form atoms or ions. The atoms or ions localize at circumstellar orbits and form convection zone (CZ), photosphere (PhPh), chromosphere (ChS), and corona (Cor).

The temperature increases in the sequence CZ<PhPh<ChS<Cor depending on the energy that was obtained by the nuclei as a result of the radioactive decays. The radioactive decays explain the high corona temperature.

All positively charged pico-drops, when diffusing through the RZ canals within the negatively charged ē-jets, gained unidirectional rotation moments, which were finally transmitted to the celestial objects produced from the atoms obtained from these pico-drops. This is the cause of the multi-fold excess in the integral planetary moment over the solar moment.

Thus, (i) the critical n_0/p_0 value at the RZ bottom and the maximum n_0/p_0 value in the protuberances increased progressively; the radioactive pico-drops after their decays and the non-radioactive pico-drops gave stable atomic nuclei for the subsequent SS origination;

(ii) the inter-protuberance intervals were constant for centuries because the processes develop slowly on a scale of the human epoch; from epoch to epoch, the critical pressure became higher and the protuberances became more powerful;

(iii) the temporal variability in the ēs and positive ions caused the non-constancies in the stellar magnetic field.

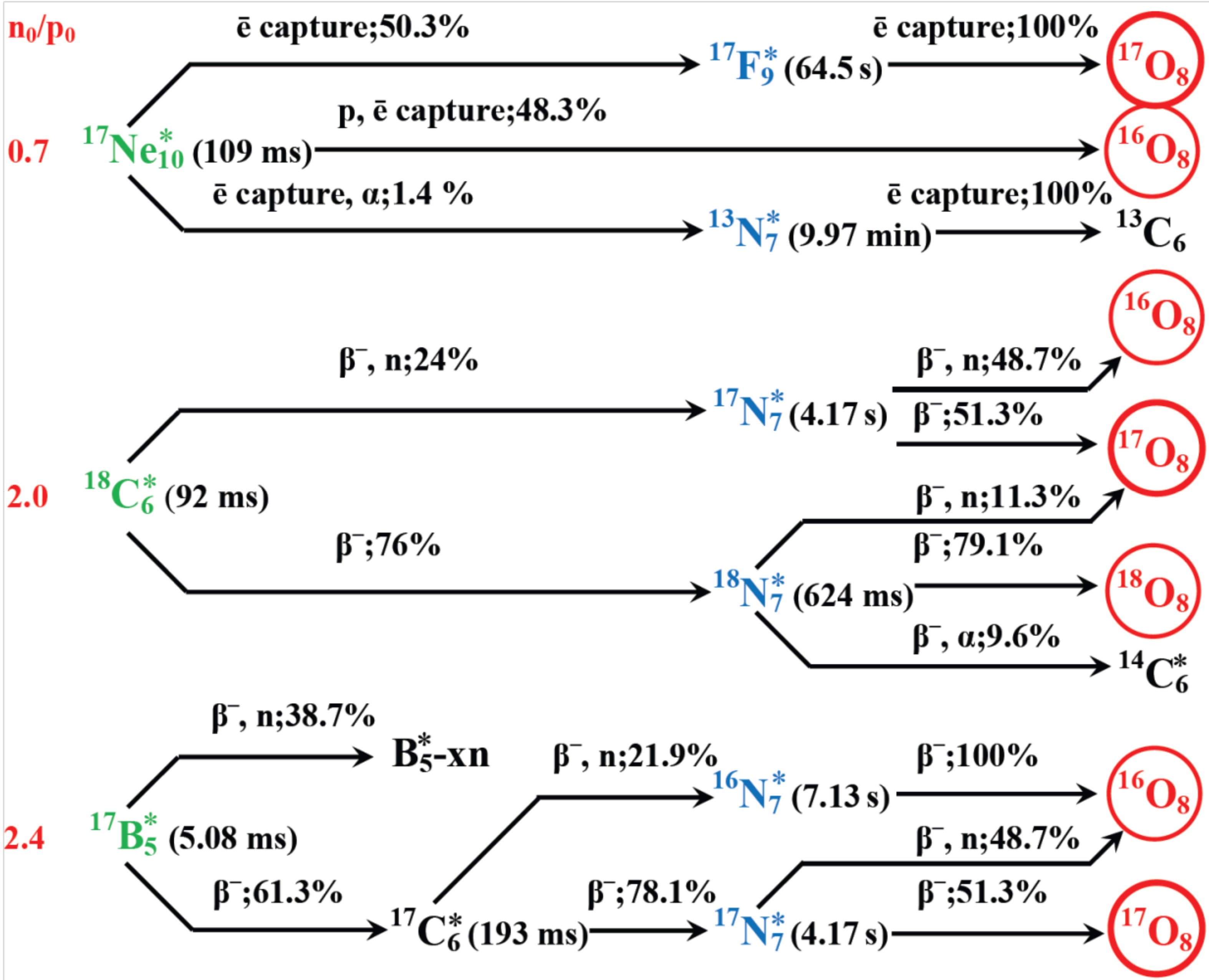
The following procedure was used to analyze the sequence of formation of different stable atoms from the radioactive pico-drops of the presolar-star substance as the n_0/p_0 increased.

For 160 stable isotopes of 56 arbitrarily chosen elements, each characterized by a proton number (p) in its atoms, we analyzed the n_0/p_0 ratios in the parental pico-drops by using the available data [18, 19] on the origin of stable isotopes and on decays of radioactive isotopes.

As an example, we present in Figure 2 one of the 160 graphs at the following slide. This slide characterizes different possibilities of the birth of ^{17}O atoms. Each line at this graph was specified from right to left. The graph contains information on all known sources of ^{17}O. The subsequent transformations of the $^{14}C_6{}^*$ and $B_5{}^*$ atoms are not shown because they do not give ^{17}O.

The graph shows the half-life, decay type, and percentages of decays in different directions for each step of the radioactive transformation.

Figure 2: Origin of ^{17}O atoms



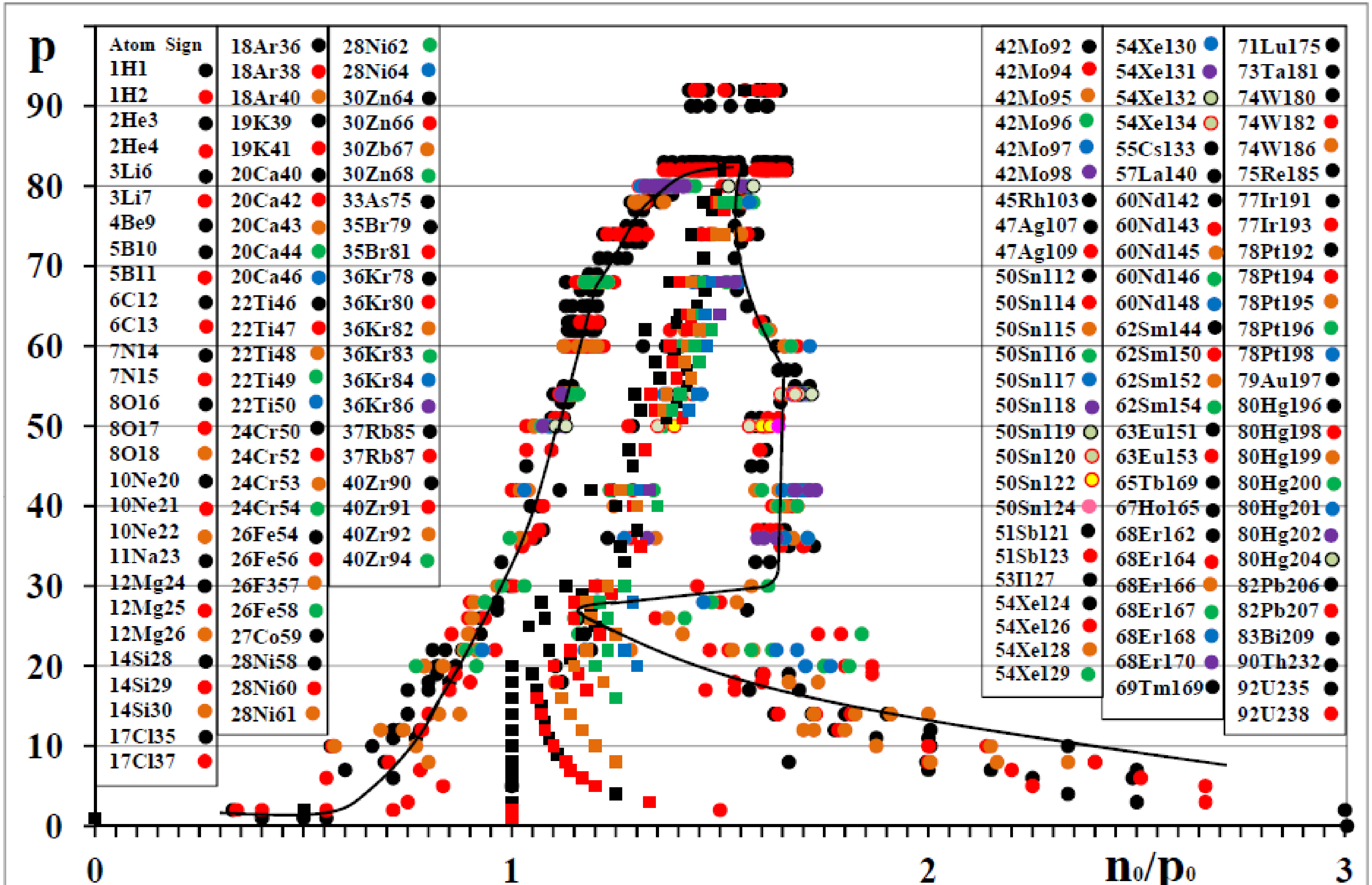
For each line, the half-life decreases from right to left. The sources of the leftmost atoms are unknown. The half-life for these atoms is very short; their n_0/p_0 ratios are given in the left red column. We take that their n-p compositions correspond to those of the star substance primary pico-drops.

For each stable atom with p protons, we found all sequences of radioactive decays, which could lead to its production and, thus, determined the n_0/p_0 ratios in all its parental pico-drops that were carried out from the p-n-ē matter by prominences.

Thus, we found that ^{17}O could be produced from pico-drops of $n_0/p_0 = 0.7$ (7n,10p), $n_0/p_0 = 2.0$ (12n,6p), and $n_0/p_0 = 2.4$ (12n,5p).

Such analyses of 160 stable isotopes led us to Figure 3.

Figure 3: **The p number in the atoms of different stable isotopes *vs.* the n_0/p_0 value in the parental radioactive drops**



Here, the squares and circles relate to the stable atoms produced from the non-radioactive and radioactive pico-drops, respectively, for 160 isotopes.

When the electron/pico-drop jets went through the RZ canals, they transformed to positively-charged atomic nuclei, and each ionized nucleus obtained an angular momentum because moving electrons initiated a magnetic field.

The protuberances contained not only radioactive but also non-radioactive pico-drops, which transformed to non-radioactive nucleus. Most likely, the non-radioactive pico-drops did not overstep the field of the convection zone and photosphere.

The radioactive pico-drops obtained additional energy as a result of their decays and could achieve high stellar orbits.

Just the radioactive pico-drops became the starting material for the SS formation.

The left upward branch in Figure 3 shows the following. Up to $n_0/p_0=1.0$ and $p=30$, the atom formation is possible only from radioactive drops. Then, along with such a process, atoms can be formed also from the non-radioactive drops.

Once the $n_0/p_0=1.0$ state is reached, Figure 3 predicts the sudden appearance of the most n-enriched isotopes from H to Ca (up to p=20) in the photosphere. Obviously, the today Sun already got past this point because the solar photosphere contains such elements as $^{26}Fe_{54}$ and $^{26}Fe_{56}$ [20] and the wind contains ^{36}Kr isotopes with 42, 44, 46, 47, 48, and 50 neutrons, and even ^{54}Xe isotopes with 70, 72, 74, 75, 76, 77, 78, 80, and 82 neutrons [21]. Therewith, $^{54}Xe_{82}$ flies, as it is obtained by us on the basis of [18, 19], at $n_0/p_0=1.40$ (there are grounds to doubt in the sufficiency of the data on the $^{54}Xe_{82}$ origin, however, this value is no less than 1.20).

This means that, by now, the Sun have passed a greater part of its way along the ascending branch of the curve to its sharply descending branch.

What did happened since the presolar star had arrived at a n_0/p_0 level of 1.5, and what is expectable when the Sun will approach to this limit?

With time, the RZ protonization and the power of the protuberances increased. At $n_0/p_0 \approx 1.40$, the RZ explosive disruption proceeded. Therewith, the RZ near-bottom layer of high n_0/p_0 value produced stable atoms with $30 < p < 82$ and the less-neutronized overlying RZ layers produced stable atoms with $18 < p < 30$. Meanwhile, the $\bar{e}$-flows, which diffused from the central zone of the presolar star core, destroyed its highly-neutronized outer layers and the pico-drops with $1.5 < (n_0/p_0) < 2.7$ led to formation of the atoms with $2 < p < 18$.

All these dramatic processes led to a significant deneutronization of the presolar star core, to returning of the most portion of the presolar substance back on the star, and to a significant transformation of the presolar star in the direction to its initial state.

Only a small portion of the presolar star transformed steadily into the present Solar System and the presolar star lives its second life up to now.

Our consideration gives us grounds for a rather sad conclusion that the Sun lives now the second half of its life, and, in our opinion, it's unlikely the remnant of its life will last gigayears.

This conclusion results from a comparison of the data of our last figure with the NASA information [22] and work [21], according to which at least 26 chemical elements from H till Xe are found in the today solar wind.

According to our analysis, such elements as $^{54}La_{83}$, $^{4}Be_{5}$, $^{20}Ca_{26}$, $^{42}Mo_{56}$, $^{47}Ag_{60}$, $^{60}Nd_{88}$, and $^{74}W_{112}$ should occur neither in the solar wind nor in the solar photosphere up to solar RZ explosive disruption. Indeed, none of these elements is observed in the experiments of [21, 22]. This fact counts in favor of our hypothesis. We mentioned that our hypothesis is capable of explaining a number of mysterious natural phenomena.

Light elements that originated as a result of radioactive decays at the early steps of the presolar-star neutronization were carried out by the protuberances to the remote cold space and became materials for the celestial Physically Formed Objects (PFO) (cold celestial bodies) as a result of physical processes, such as adsorption, nucleation, condensation, evaporation, gravitation, etc. [8, 9, 13, 17].

Metal and metalloid atoms of higher masses that respond to the ascending branch of the curve together with the atoms that originated as a result of radiation-zone explosion and respond to the descending branch of the curve became materials for the celestial Chemically Formed Objects (CFO) as a result of chemical combination reactions. The chemical reactions stimulated formation of localizations of masses and reaction heat resulted from highly-exothermal metal-metalloid reactions over the field of the space not so distant from the presolar star and initiated propagation of compressible vortexes, within which hot cores of future warm celestial bodies originated [8, 9, 13, 17].

The steep descent at $n_0/p_0 \approx 1.8$ corresponds to the RZ explosion and simultaneous ejection of picodrops of different sizes.

Light metalloid elements that originated at late steps of presolar-star neutronization and correspond to the tail of the descending branch of the curve participated in the metal–metalloid chemical combination reactions and could partially participate in formation of atmospheres of terrestrial planets.

The isotopic ratio variations observable for chemical elements at the SS celestial bodies and at their different localities are caused by repeated ejections of radioactive pico-drops of different sizes, which are the parental ones for different isotopes.

For example, the N and O atoms (their p-stable values are 7 and 8, respectively) are ejected twice, at ascending and descending branches of the curve, i.e., in the young age and old age of the presolar star.

Some principal questions answered by the hypothesis

(1) If all planets have only one source, why are they so different?

(2)What is the nature of the solar magnetic moments?

(3) What is the nature of cyclicity of the solar activity?

(4) Why is the solar corona heated much higher than photosphere?

(5) Why are the Sun-core and radiation-zone rotation rates different?

(6) Could Nature produce all chemical elements by one mechanism?

(7) Why are isotopic compositions of elements unequal over the SS?

(8) How did the SS planets acquire the so great angular momentum?

(9) How did the presolar star after its explosion transformed into the Sun?

(10)Why are most of the big celestial bodies within a space belt

located along the ecliptic plane?

III. CONCLUSION

All chemical elements in the Solar System were produced from the energy-matter substance of the presolar star as a result of its protuberance activity and explosion of its radiation zone.

The PFO-CFO hypothesis is capable of giving not only rather simple and non-contradictory mechanism for formation of the chemical elements and of explaining the isotopic anomalies over the SS. It is also capable of explaining a number of other paradoxes and of answering to a number of other questions associated with the history and the present state of the SS.

Apparently, there are neither principal phenomena nor facts which could contradict the PFO–CFO hypothesis . The simplicity of the hypothesis allows us to hope for its adequacy, because the nature is simple and does not luxuriates in excesses.

REFERENCES

[1] Brown R.H., Baines, K.H., Bellucci G. et al. Observations in the Saturn system during approach and orbital insertion, with Cassini's visual and infrared mapping spectrometer (VIMS). Astron. & Astrophys., 446 (2006) 707−716.

[2] Garcia R.A., Turck-Chieze S., Jimenez-Reyes S.J., Ballot J., Palle P.L., Eff-Darwich A., Mathur S., Provost J., Tracking solar gravity modes: The dynamics of the solar core, *Science,* 316 (2007) 1591-1593.

[3] Ostrovskii V.E., Kadyshevich E.A., Life Origination Hydrate Hypothesis (LOH-Hypothesis): Original Approach to Solution of the Problem, *Global J. Sci. Frontier Res. (A),* 12 (2012) (6), 1–36.

[4] Ostrovskii V.E., Kadyshevich E.A., Life Origination Hydrate Hypothesis (LOH-Hypothesis), *Life, Spec. Issue: The Origin of Life − Feature Papers*, 2 (2012) 135–164 (doi:10.3390/life2010135).

[5] Ostrovskii V.E., Kadyshevich E.A., The PFO-CFO hypothesis of Solar System formation: the presolar-star explosion mechanism, *EANA Proc.,* 2012, Stockholm, Sweden.

[6] Ostrovskii V.E., Kadyshevich E.A., The PFO–CFO hypothesis of Solar System formation: the birth of chemical elements, *EPSC Abstracts,* 7 (2012) EPSC2012-101.

[7] Kadyshevich E.A., Ostrovskii V.E., Formation of planetary systems around Sun-like stars (the advanced PFO–CFO hypothesis), *EPSC Abstracts*, 6 (2011) EPSC-DPS2011-314.

[8] Kadyshevich E.A., Ostrovskii V.E., Development of the PFO–CFO hypothesis of Solar System formation: Why do the celestial objects have different isotopic ratios for some chemical elements? *Proc. Int. Astron. Union, S274 (Adv. in Plasma Astrophys.),* Cambridge, UK, 6 (2011) 95–101.

[9] Ostrovskii V.E., Kadyshevich E.A., Physicochemical model of formation of the Solar System planets: the causes of differences in the chemical composition of planets. In: “*Physchemistry-2010”, Selected works (ed. A.S. Smolyanskii), LLC* “Rosinatal”, Obninsk, Russia, (2011) 46–61.

[10] Kadyshevich E.A., Ostrovskii V.E., Oxygen isotopic anomalies in the rocks of celestial objects: Are they the key to the planet formation mechanism? EPSC Abstracts, 5 (2010) EPSC2010-3.

[11] Kadyshevich E.A., The PFO–CFO Hypothesis of Planet Formation. *Meteorit.& Planet. Sci., 44* (2009), *A105.*

[12] Ostrovskii V.E., Hypothesis of the natural gas abiotic origin in the context of living matter origination. In: *Gas Chemistry at the Present Stage of Development (eds.*A.I. Vladimirov, A.L. Lapidus), Gubkin RSU NG, Moscow, Russia, (2010). 35–69. ,

[13] Kadyshevich E.A., The Planet Formation Hypothesis: Why Are the Solar System Planets Different in their Chemical Compositions? *EPSC Abstr.,* 4 (2009) *EPSC2009-1.*

[14] Ostrovskii V.E., Kadyshevich E.A., Solar system formation hypothesis: Why the chemical compositions of the planets are so different? *Geochim. Cosmochim. Acta,* 73 (2009) A 979.

[15] Ostrovskii V.E., Kadyshevich E.A., Hypothesis of formation of planets from nebula: Why are the planets different in their chemical compositions? *Orig. Life. Evol. Biosp.,* 39 (2009) No. SI, 217–219.

[16] Ostrovskii V.E., Kadyshevich E.A., Hypotheses of hydrocarbon-hydrate formation and living matter origination at the Earth. In: *Degassing of the Earth; geodynamics, geofluids, oil, gas, their parageneses* (2008), 374–377, GEOS, Moscow, Russia.

[17] Ostrovskii, V.E. & Kadyshevich, E.A. Generalized hypothesis of the origin of the living-matter simplest elements, transformation of the archean atmosphere, and the formation of methane-hydrate deposits. *Physics-Uspekhi (Advances in Physical Sciences),* 50 (2007) 175–196.

[18] Tuli, J.K., Nuclear Wallet Cards. Nat. Nucl. Data Center, Brookhaven Nat. Lab., Upton, N.-Y., (2005).

[19] Audi, G., et al, The Nubase evaluation of nuclear and decay properties. Nuclear Physics A 729 (2003) 3-128.

[20] Ipavich F.M., Paquette J.A., Bochsler P., Lasley S.E., Wurz P., Solar wind iron isotopic abundances: Results from SOHO/CELIAS/MTOF, In Solar and Galactic Composition, (ed. R.F. Wimmer-Schweingruber), (2001) 121-126, *AIP Conference Proceedings*, Melville, NY.

[21] Pepin R.O., Becker R.H., Rider P.E., Xenon and krypton isotopes in extraterrestrial regolith soils and in the solar wind, *Geochim. Cosmochim. Acta* 59, (1995) 4997-5022.

[22] Solar wind elements / isotopes observed by CELIAS MTOF, http://sohowww.nascom.nasa.gov/gallery/Particle/cel001.html

Thank you for your interest!