the general science journal

The Alternative to the Big Bang in Modern Physics

Kirill Vankov
kirill.vankov@gmail.com

2016-12-08

Abstract

There is a growing concern among Physical Community for the Big Bang Cosmology departure from physical reality and the signs of crisis. We propose a new Cosmology of the Grand Universe, which is a relativistic model of the steady-state, matter-antimatter symmetric Universe in infinite space-time. The Grand Universe consists of matter and antimatter bounded Typical Universes, which are floating in an infinite space filled with the physical Grand Universe Background. This is the place for an eternal evolution of Universes interacting with each other and with the Grand Universe Background itself. Our Observed Universe is thought to be an ordinary cosmological phenomenon resulting from an annihilating collision of a pair of Universes made of matter and antimatter, a survived part of matter now is seen in a decaying state. The Grand Universe methodology is based on Fundamental Principles of Classical Mechanics and Special Relativity Dynamics. We criticize the Standard Cosmological Model, consisting of two parts: the Big Bang followed by the short time Inflation, and the post-Inflation era of Expanding Universe. We consider the first part a not physical hypothesis, which should be rejected without criticism. The second part comes from solutions of the conventional General Relativity field equations without a rigorous analysis of their physical validity and applicability on the cosmological scales. We present a critical analysis of the General Relativity methodology in comparison with the Special Relativity Dynamics methodology, with the conclusion of rejection of the Standard Cosmological Model in favor of the Grand Universe Model. Issues of further studies of the Alternative Model in relationship with Relativistic Gravitation theories and Modern Physics branches are briefly discussed. A great attention is paid to Philosophical criteria of true versus false in Modern Physics.

Contents

"The growth of knowledge depends entirely upon disagreement."

— Karl Popper, *The Myth of the Framework*

1 Introduction

A challenging purpose of Cosmology at all times is to explain observations of Cosmos and Physical Nature. A history of Cosmology is rich in unexpected discoveries of puzzling Astrophysical and Cosmological phenomena, which, having no satisfactory explanation, remained mysteries. In this way, Physical Science, in general, has been developing from old ages, and *New Physics* often come to the scene, for good or for bad. Not only Physics Community but common people are eager to know "true stories" from "true science" in a layman's language, but how to distinguish between "truth" from "untruth", or "belief in truth"?

The problem is that what is seen in a far space is not always evident. With models becoming more sophisticated and hypothetical, a growing departure of cosmological models from physical reality toward New Physics finds its way. To compete with rival models, cosmologists often introduce additional ad hoc parameters. In this way, the model can be given a status of "a true theory" by the verification criterion of observational fitting. Another way of staying safe is to redefine model ingredients and parameters for a larger flexibility of fitting.

We think, the issue of *true* versus *false* in Natural Sciences must be subject to the epistemological judgment. Besides the fitting criterion, there is a philosophical and logical criterion, which requires a theoretical simplicity and minimal, if any, radical departures from fundamental physical principles cumulated the whole knowledge from past (Occam's razor philosophy). In this sense, none of the existing cosmological models can be considered satisfactory. For the sake of objectivity of judgment, the old philosophical question about a recognition of a truly new scientifically valued knowledge deserves paying more academic attention in Modern Physics and Philosophy.

A review of cosmological models in their historical stages of maturity shows a trend of encountering more strangeness with a penetration into Cosmos on enormous cosmic scales never seen before. It would be out of the scope of this work to discuss contemporary Cosmological models and General Relativity along with hundreds of remarkable Astronomical, Astrophysical, and Cosmological observations. The related numerous literature is easily available, e.g. [1, 2, 3, 4].

Nowadays, *the Standard Cosmological Model* (SCM) having several Big Bang versions, is still the leading model, though, in growing doubts. It is more complex and hypothetical than other physically reasonable rival models. This is by power of a mainstream collective belief, that the Model is taken for granted as the most feasible scientific conception of the Universe.

The proponents may insist that observations give us a solid scientific evidence of the existence of New Physics phenomena, which, though, looking

strange, are well fit to the Model, till a truly better alternative explaining New Physics comes to the scene. To disprove the SCM, one needs to get through a scrutiny of hundreds of parts of it. We argue, however, no matter how many accurate observations have been accounted for, it is still a tiny 4-spacetime slice of image of the Universe in its enormity. Even more doubts come with observations of progressive precision. They often bring new controversies rather than clarification.

The example of observations related to the key parameters in the Standard Model, – the densities of matter and energy, seems to be instructive in retrospect to discoveries of new strange phenomena, such as *Dark Matter*, *Dark Energy*, *Neutrino mass*, and others. Facing a failure of physical understanding, cosmologists labeled them with common language names, actually making the Big Bang in all its modifications the New Physics umbrella.

Here and after, the term *New Physics* is related to, firstly, observations, which permanently remained unexplained puzzles, labeled by some familiar name, for example, "Dark Matter", and in this way used in model parametrization, for example, "Dark Matter density"; secondly, theoretical concepts, conflicting with Science of Physics, for example "Early Universe after its singular origination". Such concepts may also come from a pure mathematical structure, which is considered a new non-observable phenomenon and used for parametrization of additional degree of freedom in a theoretical framework. This is *bad New Physics*, or pseudo-Physics, unlike real *good New Physics* arising from a discovery of a new phenomenon, physical explanation of which is seen in a logically meaningful generalization of old theories being approximations due to physical assumptions.

Concerns with conundrums and New Physics in the Standard Model piled up by the end of 20th Century, as shown in "Principles of Physical Cosmology" by the Father of Physical Cosmology, Princeton Professor P.J.E.Peebles [1], as well as in publications of other authors. The growing concerns are signs of the oncoming crisis.

We criticize the current leading model, the Standard Cosmological Model, for highly hypothetical assumptions, in fact, involving bad New Physics. The major assumptions are referred to the General Relativity (GR) gravitational field theory without an analysis of their relevance and applicability to the Cosmological Model framework. We propose the Alternative to the SCM. This obliges us to apprehend the GR assumptions and conduct an analysis of Einstein's field model and its methodological interpretation. The results of such analysis are presented in details restricted by the paper volume.

Our approach to developing a new cosmological model is guided by Fundamental Physical Principles and Special Relativity methodology, and driven by common sense and human creativity, – in a spirit of Karl Popper's Philosophy of Science. We support the current movement "to defend the integrity of Physics" [5] (in the noted article, clarity of the message to Physical community is impressive; the issue of "Crisis at the Edge of Physics" has reached out to public, see [6]).

We claim that the proposed Alternative Model explains all basic cosmological observations treated in terms of Fundamental Physics with new insights

into Physical Nature problems, and with no appeal to any kind of bad New Physics.

The following abbreviations are used:
- *Our Observed Universe* (OU);
- *Typical Evolving Universes* (TU);
- *The Grand Universe* (GU);
- *The Grand Universe Physical Background* (GUB);
- *Cosmic Rays* (CRs);
- *Standard Cosmological Model* (SCM);
- *Einstein's field equations* (EFE);
- *Cosmic microwave background* (CMB).

2 The Grand Universe Cosmological Model

2.1 Basic Physical concepts of New Cosmological Model

The GU conceptual idea was presented years ago, [7, 8, 9, 10], at the time when we have insufficient knowledge about exact solutions of Einstein's field equations and their significance in the cosmological models. It was clear that a promotion of alternatives to the Big Bang Cosmology would be hard without thorough understanding of the role of GR Theory. The studies have taken a lengthy time, and now, upon its completion, the proposal is put forward [11].

Among the main known cosmological problems, we consider puzzles of Matter-Antimatter Asymmetry and Ultra-High Energy Cosmic Rays the primary issues in Physical Cosmology. This consideration leads to the original idea of steady-state, matter-antimatter symmetric Grand Universe, which consists of bounded Typical Universes equally made of either matter or antimatter. They are floating in the infinite space-time filled with the physical Grand Universe Background. The latter is the space for bodies attracting by Newtonian gravitational force, subject to Special Relativity Dynamics, we use. Also, this is a physical vacuum, a field of a quantum carrier of the force, the long standing problem of relativistic gravitational field theory.

The GUB is a high-energy relativistic medium of gamma rays, particles, as well as matter and antimatter fragments. This is the place for an eternal evolution of Typical Universes interacting with each other and with the GUB itself. Notice, a physical process of matter annihilation and pair creation consists of single nuclear reactions between nuclear particles rather than bulk materials.

The GU is a world of gravitation, which always existed and will exist with no spatial boundaries, – there is no question about its origin. The scientific questions to be asked are about an evolution of its parts and a state on the whole. The GU is in the equilibrium state due to a balance of continuous matter-antimatter annihilation and creation and a statistical mechanism of matter-antimatter separation on the largest cosmic scale. Quite naturally, our Observed Universe is an ordinary cosmological phenomenon resulting from a collision of a pair of Universes made of matter and antimatter, when some

parts, survived or damaged, fly away, and some could be left at the center mass ares. The collision is not an annihilation catastrophe but rather a lengthy continuous explosion. It has various possible scenarios complicated by statistical randomness, in particular, leading to a recession of survived galaxies, as in the OU case.

An annihilation of matter is accompanied by a continuous release of kinetics energy of flying away galaxies, which loose their binding energies. In addition, a radiation pressure creates radial pushing forces and torques. As a results, galaxies fly away. Our place in the Observable Cosmology belongs to the initially large enough but limited volume containing the center of mass of colliding TUs.

Galaxies in freely floating TUs must be very different from those observed, say, in the Milky Way: they are expected to be much more bounded to the central super-massive core (say, "a Black Hole"), more densely packed and rotate about the Black Hole, the closer to the core, the higher their masses and speed. Hence, they would fly away in an orderly manner.

The receding galaxies are observable in the red-shifted light from our initial position occurred to be significantly void of matter in a large space volume. The redshift is explained in terms of SR Dynamics, namely, the motional Doppler effect, the gravitational time dilation, and some other factors, all in a relationship with the distance and time scales to be assessed from assumptions made in the reconstruction of annihilation collision involving two colliding TUs of different masses. Those special issues are discussed later in more details.

The detected Cosmic Microwave Background is a usual electromagnetic radiation, which is locally in thermal (black body) equilibrium with the surrounding matter including fragments and dust. The CMB temperature has been decreasing during the adiabatic process of matter expansion.

The GU conception gives a room to consistent explanations of basic cosmological observations, also provides with new insights within Fundamentals of Classical and Modern Physics and beyond.

We start with the issues of Matter/Antimatter and Cosmic Rays in Open Universe, which are not addressed in the SC Model and remained unresolved.

2.2 The issue of matter-antimatter symmetry in the GU Model

In literature, the problem is usually formulated in terms of Baryon Asymmetry while we are talking about the matter including positive protons (baryons) and negative electrons (leptons) with a change of sign of charge or magnetic moment in anti-matter. Consequently, the neutron has its counterpart, the anti-neutron, and so forth.

Our Observed Universe is apparently a matter dominated Universe. But could this fact justify the SCM, in which one of the Fundamental Physical Principles, – the Matter/Antimatter Symmetry, is broken for no particular reason? In our view, there is now sufficient evidence justifying the Principle breaking.

The idea to resolve the problem is to admit an existence of multiple Universes of symmetrically matter and anti-matter compositions having finite masses and sizes. We call them the Typical Universes evolving in an infinite space, which just exist in the Grand Universe being the Steady State Universe on the largest cosmic scales.

One needs to think about physical conditions, in which such a picture is possible. First of all, there is a mechanism of statistical separation of matter and antimatter in the process of annihilation and creation, [10]. Yet, the TUs evolutions should be viewed in the process of their interaction with each other and with the Grand Universe Physical Background. The GUB must be a relativistic physical medium containing massive and massless matter, the product of TUs distraction in matter-antimatter collisions. At the same time, the GBU has to provide material for the TU evolving.

Our Observed Universe is an exemplary case of TU interaction in the form of collision of two matter/antimatter TUs of significantly different sizes; one of them or both have to be perished. Overall conditions of TUs interactions with each other and with the GUB must be just right for the GU to be self-sustained in its continuous self-destruction and recreation of the eternal steady state.

The question arises: is there the antimatter in Our Observable Universe?

We believe that antimatter is actually around in a considerable amount. It is, indeed, hardly distinguishable from ordinary matter but its indirect consequences can be falsely recognized as unusual phenomena. In the GU model, the annihilation process is not abrupt and still observable. Here is not a full list of unusual phenomena in the SCM explained by observable matter/antimatter annihilation in different forms:

- Quasars: annihilation of large clouds;
- Star "explosions" and gamma bursts with release of huge amount of high energy;
- Universe large scale structure: walls and filaments separated by immense voids;
- Recently observed events of unusual radiation flares around the Milky Way bulge;
- X-ray busts of a huge intensity and strangeness of central Black Holes in galaxies.

2.3 The Primary Cosmic Rays and the Causality Principle

There are many galactic and intergalactic contributions to the observed Cosmic Rays. The problem is that they contain particles of ultra-high energies $E > 10^{21}\ eV$, physical origin of which is a mystery. For decades, physicists tried to unveil a mysterious mechanism of particle acceleration up to such an inexplicably ultra-high energy, though, physical mechanism of such accelerations are beyond a technical imagination.

The GU picture brings us to the issue of exposure of TUs to the GUB radiation, which is supposed to be highly energetic. The observed ultra-high CRs have so high energy that cannot be explained by any physically reasonable mechanism of their origination within the Observed Universe. Our explanation of this phenomenon is, as follows.

The Primary CRs come from the GUB radiation in the form of extremely high energy particles. During penetration through the Universe, they loose energy. The observed ultra-high energy tail is a contribution from the GUB radiation. The latter is transformed by the process of inelastic scattering leading to deceleration of primary GUB particles. The observed ultra-high energy particles are not due to the acceleration within the Observable Universe.

We predict that the observed CR ultra-high energy tail contains antimatter particles, since the Primary CRs must be matter-antimatter symmetric; hence, it must contain equal amount of protons and anti-protons as well as electrons and positrons. Also, it must contain gamma rays of ultra-high energy.

The question arises about the role of the Causality Principle in the GU hierarchy of TUs and their groups, clusters, and likely further, and how it affects relativistic properties of the primary GUB Cosmic Rays.

One can speculate that the GU Steady State is maintained under conditions of weakening casual connections between GU hierarchy members so that a total casual disconnection eventually occurs. Still, the order can originate in the form of GU long-distance spacial structures from a chaos of matter in the infinite space-time.

A breakage of the Causality Principle on the largest GU scale leads to some consequences. Particles departed from some, say, TU-1, can travel most of the time in the GU background at a distance exceeding a scale of casual connection that is, the time exceeding a TU lifespan. The particle could reach some another TU-2 having a relative speed with respect to the TU-1, at random value, however high. A relative velocity dispersion has to grow with a travel distance. This is the idea of a statistical formation of the Lorentz invariant energy spectrum of Primary CR with ultra-high energy particles.

Bearing in mind the above notes, let us formulate main physical properties of the GU and the GUB on the whole following from the observed phenomenon of Cosmic Rays:

- Hierarchal new structure;
- Origination of the primary Cosmic Rays in the GUB;
- Matter/antimatter symmetry;
- Long distance space transparency;
- Locally verifiable Causality Principle;
- Locally observable Lorentz invariant energy spectrum of the Primary CRs;
- Invalidity of the Cosmological Principle in the TU scale.

The above brief review the GU Model shows its radical difference from the SCM.

3 Critical Analysis of the SC Model and its GR methodological basis

There are more differences of the GU Model from the SCM, which are related to the SCM assumptions and hypotheses of bad New Physics category in treatments of observations of "strange" phenomena. This is a multi-aspect problem, which amounts numerous methodological issues concerning the SCM methodology, to be discussed in the following.

3.1 The necessity to analyze the GR role in the SCM

Physics and Mathematics.

While proposing the Alternative Cosmology, we take a responsibility to analyze the current SC Model to reveal its methodological deficiencies and problems to be eliminated or resolved, as concerns explanations and treatments of cosmological observations and predictions of new physical phenomena.

In [1], it is noted that the Big Bang predictions are model dependent. The current Big Bang version is the ΛCDM with the FLRW metric of space expansion, which has its own additional peculiarities.

We have two-fold basic objection to the Model. First of all, it concerns the Beginning and its earlier stage of the Inflation. This is a step-by-step description of instant appearance of physical world from nothing. Yet, it contains a suspiciously detailed picture of Bible-like fiction about passing through Plank and the Inflation epochs of about 10^{-33} second of duration after the Big Bang at zero time. Then, the light comes accompanied by appearance of different kind of non-charged then also charged particles,– star and galaxy seeds, with no idea about the matter dominance. We have no more comments since it cannot be scientifically criticized, though, for a philosophical mind, this picture may be acceptable. Many scientists refuse to accept and, for this sole reason, reject the whole Model.

We conduct a critical analysis of the post-Inflation scenario and its methodological basis borrowed from the solutions of Einstein's field equation and their GR interpretation. Our doubts and disagreements will be discussed in parts of physical and mathematical aspects in comparison with Alternative methodology. Specifically, the GR concepts in the SCM versus the Special Relativity Dynamics in the Alternative is discussed in view of radical differences in predictions of the two models.

Philosophy.

As seen from the Introduction, there is also an important philosophical part to be deliberated, first of all, the criteria of true versus false. Also, there are related issues concerning perceptions of Cosmological and GR concepts in

Philosophy of Modern Physics, branches of which typically comprise physical theories exploiting concepts of Abstract Mathematics.

In works devoted to Cosmological problems, typically disputed topics concern philosophical aspects of the Cosmological Principle, its meaning in the context of different Causality conditions and interfacing with other concepts such as "the observability of events", "the horizon", "the observer", "the observable universe", "the observable part of the universe", "the prediction", and others, e.g. [12, 13, 14, 15, 16].

While considering the values of the distance and the time, one must be sure, in which coordinate system they are defined: for example, it could be the proper, or the comoving, or some other quantity, again, with no firm consensus in literature on which case and in which situation it is appropriate in the specific problem formulation. In some version, the observer, in principle, could see any light epoch, and likely before the light appearance by means of neutrino and gravitational wave detection, at the expense of complication of the GR horizon concept.

There is no consensus among the experts on validity of theoretical versions, which could be given simplified rightly for public, or misinterpreted fundamentally in a textbook by some authors from the viewpoint of other authors. Controversies in the GR research is not a surprise in view of the fact that the meaning of Einstein's field equations was historically altered and were continually argued.

Overall, the chaos in the conceptual methodology seems to arise in the absence of agreement on the framework, which basic concepts are defined in (not to speak about "scientific noise" from authors of obviously mistaken works). To avoid ambiguity, we focus our attention on a specific topic of the SCM in the GR framework in comparison with the Alternative Model formulated in the SR Dynamics framework. The unambiguous definition of the framework in our analysis of the EFE field model, its solutions and treatments for comparison of the two models is paid special attention.

3.2 Review of the physical aspects of the Standard Cosmological Model

Expansion, and the Hubble's Law.

In the SCM, the Observed is viewed on accord with the Cosmological Principle postulated for the post-Inflationary era. It states that the Observable Universe is seen homogeneous and isotropic on the scale of galactic super-clusters. This means that any observer sees the same "smooth" picture of the observable part of the Universe regardless of observer's location.

In mathematical terms, the Universe Expansion is a metric expansion of the space with a scaling factor $a(t)$ in the flat metric. Currently, it is the Friedmann-Lemaître-Robertson-Walker (FLRW) metric, which is known as an exact solutions of Einstein's field equations. The above metric is embedded in the nowadays ΛCDM Model. Actually, the different FLRW authors derived and treated the expansion metrics differently, so that the one in current SCM

version takes the expansion idea.

In physical terms, the metric is characterized by the critical mass/energy density, Ω, which currently includes ordinary and dark matter, massive neutrinos, dark energy, and radiation, contributions of which change over time. In this form, the metric is put in the relationship with the observed redshift. In the end, the metric of space-time expansion defines the time/distance scales in the Hubble's Law.

The Model requires a carefully tuned balance of Dark Matter and Dark Energy with only about 4 percent of the ordinary matter in the Observed Universe. The Dark Energy due to the tiny cosmological constant Λ is dominant. It is not clear how this fact is related to to the GR vacuum concept, [17].

The recession of galaxies due to the metric expansion actually means that a locally moving galaxies must be eventually trapped by metric and dragged farther away with the expanding space. In our view, in Physics, a particle can be dragged by a field of forces but not by a metric unless the metric is formulated mathematically and used for description of a mathematical world apart from the Fundamental Physical Principles.

Lemaitre [18] was the first to put the GR metric in relationship with a redshift in the observed light emitted from a receding galaxy

$$z = \lambda(t_{em})/\lambda_{obs} - 1\,. \tag{1}$$

The formula is justifiable under suggestion of a simple physical picture, in which a wavelength of a photon emitted from an atomic oscillator increases proportionally to the scaling factor $a(t)$ at the emission time t counted from "the Beginning" of Universe till the present time t_0 (which is about 14 By.) so that $a(t) = 1$. The wavelengths are characteristics of the atomic oscillators, the photon emitter and the detecting absorber.

In the Lemaitre concept, the expansion model is assumed to be valid in the wide range of wavelengths, including both cosmological and microscopic scales. Some authors prefer a treatment of the redshift in terms of a frequency shift due to photon's climbing a potential well, which is a physically different process.

Hubble's Law connects a galaxy recession speed v_r, the distance $d(t)$, and the redshift z with expansion rate

$$H(t) = \dot{a}/a = \dot{d}/d\,, \tag{2}$$

a function of the matter/energy critical density $\Omega(t)$. The latter, as was noted before, currently includes dark matter, dark energy, neutrino, radiation, and a few percent of ordinary matter, all to account a quite sophisticated way

$$H(t) = f(\Omega, z, H_0)\,, \tag{3}$$

where $H_0 = 67.6$ km/Mps is the Hubble's constant. The equation (3) expresses the instructions for observational testing of the SCM.

Determination of absolute scalings of units from observations is the main problem of observational Astronomy and Astrophysics. The relative luminosity plays an important role in a calibration of distances d and times and assessments of Ω, z, and recession speed values.

The problem of the cosmological redshift in the SCM.

At small z, observations show linear dependences between z, d, and v_r, similar to that known from the kinetic Doppler effect. For a larger z, the used concept of the cosmological redshift z is drastically different from that in Classical and Relativistic theories.

In Astronomical observations of atomic linear spectra (first of all, the pronounced hydrogen Lyman-alpha line used in observations at $z > 2$), a precision worsens with z, what makes a determination of the space-time scaling problematic. At some $z \approx 6$, the Lyman-alpha line becomes shifted to the infra-red (invisible) range, and the redshift is assessed from the blue portion of optical spectrum having very little luminosity compared to the red light portion. The galaxy appears to disappear or dropout in blue light. The line spectrum is severely spoiled by high temperature thermal Doppler spread and clouds of gas and dust, which stars are wrapped in. Originally emitted photons, while coming through, have to be absorbed and re-emitted numerous times before a free flying and finally being collected by a telescope in a long exposition regime. Technological advance in methods of observations is of great importance for the precision improvement in fuzzy image observations.

The treatment of the redshift is based on a model dependent reconstruction of an evolution of the observed galaxy and its stars from highly diffused images. From the final database, the images are unfolded by a computer code following the criteria of fitting the observations to the Model (3). Details of high z observations are available in literature, e.g. [19, 20, 21, 22]. It is unknown how far the obtained effective value of z and the corresponding time-distance scales deviate from the true physical values (the term "true" is used in a sense of interpretation of observations in the physical framework based on the Fundamental Physical Principles with no New Physics).

We doubt the validity of the above formulation of the Hubble's Law, firstly, in part of its non-physical redshift observables z related to the Dark Matter, Dark Energy, secondly, in part of the non-physical GR metric of expanding Universe. The Hubble's Law composition (3) is claimed to be derived from the FLRW metric being the EFE solution. The latter involves the GR mathematical formalism and Einstein's methodology of the curved space-time as the gravitational force manifestation. This multi-facet issue has to be separately analyzed in details, as in the following.

3.3 Review of mathematical aspects of the Standard Cosmological Model

The energy-momentum-stress tensor in EFEs.

Now, let us discuss the metric solutions of Einstein's field equations, which are used in the SCM. The EFEs are differential non-linear equations in form of second rank tensors, namely, the Ricci curvature tensor $R_{\mu\nu}$, the metric $g_{\mu\nu}$ with Λ, the cosmological parameter, on the l.h.s., and the source, the

energy-momentum-stress tensor $T_{\mu\nu}$ on the r.h.s.

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = T_{\mu\nu}\,. \tag{4}$$

As further discussed, the tensor $T_{\mu\nu}$ is constructed phenomenologically. The only restriction is the requirement to be consistent with contributions to the tensor from matter/energy distributed over a space-time in a given problem formulation. This leaves a certain freedom of choice, partly, because the Ricci manifold is contracted from the Riemannian manifold, which is more rich in characterization of space-time curvature.

In view of this fact, the problem of exact EFE solutions are also formulated in terms of Riemannian manifolds [23, 24, 25]. The authors show that, to the next order precision, the gravity due to constant acceleration by a mechanical force is not equivalent to that from the gravitational force. We shall see that their equivalence is the essence of Einstein's gravity concept.

Manifolds, metrics, and geodesics.

An exact EFE solutions, in general, are Lorentzian manifolds, or metric spaces (with Ricci curvature, they are pseudo-Riemannian manifold). Each solution is provided with its metric and a Lagrangian varying with respect to the metric. Consequently, the metric gives rise to the geodesic equations, what is the goal of the solution.

The GR metric in the most general form is a generalization of the Minkowski flat metric (a diagonal metric tensor) in Special Relativity.

For a time-like flat space, in polar coordinates (with the unit speed of light), the SR metric quadratic form is given by

$$\mathrm{d}\tau^2 = \mathrm{d}t^2 - \mathrm{d}r^2 - r^2\mathrm{d}\theta^2\,. \tag{5}$$

Notice, the metric is defined in the proper space-time with the world line interval $\mathrm{d}s = \mathrm{d}\tau$.

The generalization assumes that the space-time is a curved space so that off-diagonal terms in the metric tensor $g_{\mu\nu}$ can have non-zero values:

$$\mathrm{d}s^2 = g_{\mu\nu}\mathrm{d}x^\mu \otimes \mathrm{d}x^\nu\,. \tag{6}$$

The GR geodesic equation in a general form is derived from (6) via the action principle

$$S = \int \mathrm{d}\tau\,, \tag{7}$$

then

$$\frac{\mathrm{d}^2x^\beta}{\mathrm{d}\tau^2} + \Gamma^\beta_{\alpha\nu}\frac{\mathrm{d}x^\alpha}{\mathrm{d}\tau}\frac{\mathrm{d}x^\nu}{\mathrm{d}\tau} = 0\,. \tag{8}$$

with Levi-Civita connections (the Christoffel symbols) $\Gamma_{\alpha\nu}$. Recall, we are interested in equations of GR particle dynamics (GR geodesics), and expect them to come out from (8).

In what kind of coordinate system are GR testable predictions made?

As seen from (8), GR geodesics from EFEs, are defined in the proper space-time with the time coordinate τ sunce Lorentzian manifolds are defined in the proper space-time. The matter is that Astronomical and Astrophysical observations related to the GR predictions of non-classical effects are conducted in the quasi-Euclidean (Minkowski) space with the time variable t, the so-called coordinate time defined in the coordinate systems of SR Kinematics and Dynamics. The variables τ and t are conceptually different quantities, so that τ cannot be replaced by t or vice versa in no circumstances. Mismatch of the GR theoretical reference frame and the reference frame, in which observations are conducted, is one of the known GR problems. It causes physicists to search for alternative interpretations of the GR predictions. However, this kind of mismatch is widely admitted in GR publications or even plainly ignored.

There are numerous works, in which GR effects (including the Mercury anomaly) are explained in the so-called PPN approximation (Parameterized Post-Newtonian formalism). This is made by linearisation of Schwarzschild metric with an arbitrary replacement of the time variable τ by t. It is claimed that the PPN formalism can explain the Mercury's problem and be extended to the case of the N-body problem, [26, 27], in spite of the fact (as noted above) that the problem not resolvable in GR in principle [24]. Nevertheless, after recommendations of the International Astrophysical Society, the NASA ephemeris system was improved by actually harmful PPN corrections [28]. This is an example of invasion of pseudo-Physics in Physical and Mathematical Sciences of Gravitation with tendency to dominate in technologically important applications at the international level.

The tensor $T_{\mu\nu}$, and the gravity physical phenomenon.

The stress-energy-momentum tensor $T_{\mu\nu}$ has two parts, the matter $T^M_{\mu\nu}$ and the field $t^F_{\mu\nu}$, the sum of them determines conservative field properties.

The tensor must be thought phenomenological and standardly constructed for the known fields such as in hydrodynamics, electromagnetic theory and the like, except for the genuine gravitational field, – call it the G-field, where the fundamental gravitational constant G is introduced in Newton's law of universal gravitation.

The problem of the EFE gravitational field model is that the field part is not a tensor. It is a pseudo-tensor, making conservative properties dependent on a coordinate system. Einstein understood this problem and tried to find a satisfactory solution. Eventually, it was constructed purely from the metric by Landau [29]. At the same time, the GR geodesics remain associated with the coordinate systems defined in the proper space-time. In [26], the pseudo-tensor term is thoroughly discussed as well as the fact that the GR concept of "gravitational field" is not rigorously defined and the theory is not compatible with the Special Relativity. Further, we shall see how the GR concept of gravity is associated with the space-time curvature apart from the physical phenomenon of Newtonian gravity.

3.4 Einstein's interpretation of gravitational field

Let us discuss the GR interpretation of the gravity as a space-time curvature in relationship with the EFE solutions, their metrics and geodesics. These topics are not popular in GR expertise literature because their significance and interpretations can vary among authors, or plainly ignored. However, they are vitally important for understanding of the GR fundamental role in the SCM.

According to Einstein's treatment of the EFE in terms of space-time curvature, the gravitational field, the subject of the EFE solutions, is not exactly the Newtonian G-gravity but rather "the gravity" being a result of space-time curvature. In particular, the curvature can arise in continuous massive media in the presence of fictitious forces (typically, in classically non-inertial frames).

The statement that a gravitational field indistinguishable from Newtonian gravity arises in any classically non-inertial frame is a version of the GR Equivalence Principle. According to the GR theory, a non-flat metric generate a gravitational field in the form of space-time curvature rather than in terms of gravitational force, potential and kinetic energies, and other concepts of Newtonian or SR Dynamics. Recall, concepts of forces, kinetic and potential energies, and others from Classical mechanics are foreign bodies in the GR conceptual arsenal, what is a separate disputable issue.

It is clear now that the fundamental gravitational constant G appears in metric solutions by virtue of Einstein's Equivalence Principle and formal analogy of Einstein's "curvature gravity" to the Newtonian physical G-gravity. Again, we conclude that genuine (Newtonian) Gravitational Physics is actually excluded from the content of the GR Gravitational Field Theory.

One should notice that the fictitious forces (or pseudo-forces) are actually real ones, they can produce work. On microscopic scale, they arise as reactions of electromagnetic forces due to solid body deformations when external mechanical forces act on a body in a state of motion by inertia. However, their treatment in gravity terms is irrelevant in any classical field theory. They do not use the concept of deformable body subjected to stresses. Instead, the point test particle probing a field of forces acting at distance is introduced. Consequently, there are no tidal, or fictitious forces, or stresses there. There is an ongoing search for a quantum carrier in the gravitational field theory, so far, with no results. We state that the problem cannot be resolved, in principle, in the conventional GR concept of gravity.

3.5 The types of EFE solutions, and the fundamental gravitational constant G

As was pointed out before, the EFE equations (the l.h.s.) are supposed to account for space-time curvature in a way compatible with the covariant conservative stress-momentum-energy tensor $T_{\mu\nu}$ (the r.h.s.). This constraint leads to solutions, which are Lorentzian manifolds. The goal is to obtain the Lagrangian geodesics for a given physical problem formulated in the form of test particle solutions bringing a compatibility of the both sides.

The unfortunate fact is that the EFE model of fields together with Einstein's concept of gravity due to curvature does not provide us with unambiguous instructions ensuring the existence and uniqueness of a solution. Recall, the EFE equations and their solutions are defined in the abstract proper space-time manifold with the world line $s(\tau)$. In the above circumstances, two types of the EFE solutions are typically looked for.

Vacuum solutions.

The first type of solutions, – the vacuum solutions, are obtained for $T_{\mu\nu} = 0$ leading to test particle geodesics. The Newtonian constant G is formally inserted in the metric or in the corresponding Lagrangian non-flat solution by analogy to the genuine Newtonian field. The problem of two or N isolated bodies of finite masses can not be considered in GR, in principle [24], hence, the Classical Newton's law of attraction of two bodies (or two Black Holes) $F = m_1 m_2/r^2$ is not derivable. In spite of this fact, approximate solutions of the problem of two BH collision with the gravitational wave emission are suggested and used in assessments of sensitivity of the waves detection, for example, in the LIGO facility.

The Schwarzschild metric with its geodesics is an example of a vacuum solutions for $T_{\mu\nu} = 0$ that is, for Ricci tensor $R_{\mu\nu} = 0$. Historically, Einstein first time derived the GR equation of Mercury's motion and its solution from the EFEs approximately in search for an explanation of non-classical anomaly.

Later, Schwarzschild derived from EFEs his diagonal metric with the time-like signature [+, -, -, -], ($c = 1$). In the polar coordinates, it is given by

$$\mathrm{d}\tau^2 = (1 - 2C/r)\mathrm{d}t^2 - (1 - C/r)^{-1}\mathrm{d}r^2 - r^2\mathrm{d}\theta^2\,. \tag{9}$$

The metric is defined in the proper space-time under conditions of the spherical symmetric field geometry with some constant C in the coefficient $(1 - 2C/r)$. By virtue of derivation, the metric is purely geometric with no conceptual connections with a momentum and an energy quantities required in the Lagrangian equation of a test particle motion about the coordinate center.

Those physical quantities appear by power of will when the constant is chosen $C = r_g/r = GM/c_2$ by analogy to the gravitational (dimensionless) potential $V(r) = r_g/r = GM/c^2$. At this point, the equation acquires a new, physical meaning due to introduced connections with the central mass M and then with momentum, potential and kinetics energies, and conservation laws characterizing the test particle motion. They are attributes of Newtonian Mechanics of motion in the gravitational field. They are foreign bodies in the GR methodology of space-time curvature associated with pseudo-gravitational fictitious forces.

In GR literature, it is a habitual tendency to avoid the issue of Einstein's interpretation of space-time curvature with the insertion of G, as well as the issues of incompatibility of GR with the SR theory and the replacement of τ by t in the equations of GR Dynamics.

Solutions for continuous uniform media.

This is the second type of the solutions, which are obtained with the tensor $T_{\mu\nu} \neq 0$ given a freedom of phenomenological construction depending on a physical problem formulation. Then, EFE solutions could be tried either by looking for all possible solutions compatible with a fixed $T_{\mu\nu}$, or having desired solutions, by constructing the corresponding momentum-energy-stress tensor in a consistent way. If the matter is of gravitating type, the gravitational constant G should be put in the tensor; usually, the constant $(8\pi G/3)$ is absorbed by the tensor and does not appear in the dimensionless expression. In a typical case of a dust matter, $T_{\mu\nu} = \rho u_\mu u_\nu$ with ρ, a covariant density, and the velocity $u_\mu = \mathrm{d}x^\mu/\mathrm{d}\tau$. The space expansion (FLRW) metric is the example.

3.6 Summing up

After studying of the GR methodology role in the SC Model, we come to conclusion that bad New Physics is mainly caused by use of Abstract Mathematics constructions, which describe the curved space-time concepts in terms of world line metric in the proper coordinate systems, while it is claimed to be valid in the observed Physical world actually described by observed values in the space-time coordinate system. The latter is defined in the Special Relativity Theory in terms of Lorentz transformations, which is incompatible with the GR gravitational concepts for exactly the reason of GR framework defined in the proper (world-line) space-time. As a result, the SCM metric of the expanding space and the corresponding redshift concept in the Hubble's law lost its firm physical meaning in the theoretical treatments of observations in the SR terms.

It is logical to expect that the EFE solutions can be put in a certain way in relationship with SR Relativistic Dynamics [30]. In our view, the incompatibility statement is historically made for arguable reasons, [26, 31]. Reinterpretation of the EFE field model and its solutions could restore the consistence of the conventional GR theory with the SR framework.

We consider Einstein's geometrical interpretation of gravity due to space-time curvature, in general, a natural point of view having a physical sense. However, to make geometrical and physical views consistent, Lorentzian manifolds in the EFE field model must be, in the first place, redefined in terms of SR Dynamics. This is a complex issue requiring a detailed discussion, starting with reviewing the contemporary methodology of SR Dynamics in comparison with the SR framework. The next section is devoted to the realization of the idea.

4 GR ideological reconciliation with the SR framework

4.1 Basics of SR Dynamics

Conventional formulation: the proper mass constancy.

Let us briefly review the conventional SR Dynamics, starting from the proper 4-spaces to make a transition to the coordinate 4-spaces.

In the first place, one needs to introduce the concept of a world line $s(x^\mu)$ with a metric quadratic form

$$\mathrm{d}s^2 = c_0^2 \mathrm{d}\tau^2 \,. \tag{10}$$

with usual convention $c_0 = 1$, and the proper unit 4-vector U^μ tangential to the line, so that the metric tensor is diagonal:

$$U_\mu U^\mu = 1, \quad U_\mu(\mathrm{d}U^\mu/\mathrm{d}\tau) = 0 \,. \tag{11}$$

A proper 4-coordinate infinitesimal displacement $\mathrm{d}x^\nu$ of the line in the proper 4-coordinate space x^μ is defined in connection with the 4-momentum (complementary) space P^μ through U^μ:

$$\mathrm{d}x^\mu = \mathrm{d}\tau(x^\mu)U^\mu, \quad P^\mu = m(x^\mu)U^\mu \,. \tag{12}$$

Now, the relativistic SR dynamics equation can be derived in terms of Minkowski (4-vector) force

$$K^\mu = \mathrm{d}P^\mu(s)/\mathrm{d}s \,. \tag{13}$$

A crucial point is the mapping of the proper spaces onto the coordinate spaces of observables by means of Lorentz coordinate transformations. The metric with the quadratic form $\mathrm{d}\tau^2$ is transformed into the Minkowski (non-flat) metric with the quadratic form $\mathrm{d}t^2$.

In the case of point test particles, there is no tidal or fictitious forces, so, the stress tensor $T_{\mu\nu}$ is reduced to the 4-momentum vector P^μ. Now, the next-level problem of relativistic theories of quantum fields of force carriers can be studied, in principle.

In the EFE field model, tensor fields in Lorentzian manifolds and their metrics are initially defined in proper spaces. To complete the process of transference, we want to transform them by means of Lorentz transformation to SR Dynamics metrics, which give rise to geodesics in the Relativistic Lagrangian formulation in terms of the coordinate time t.

Relativistic field-dependent proper mass.

In the above transformations, the proper time interval $\mathrm{d}\tau$ and the proper mass m are functions of the coordinate 4-vector x^μ. In the conventional SR theory, as well as in GR Dynamics, the proper mass is constant. We consider it a weak field approximation, after Synge, [30], who developed the theory accounting for the proper mass variation but thought the effect be practically negligible,

as a reasonable approximation. This point of view is widely accepted among the Relativistic Mechanics community. The history of this issue and the consequences of the approximation are discussed in [31], also see [32].

The GU Model methodology is based on the SR particle dynamics with the field dependent proper mass. In the spherical symmetric field, the proper mass dependence on a radius is

$$m(r) = m_0 \exp(-\rho_0/r) \tag{14}$$

where $m_0 = m(r)$ at $r = r_0$ (the radius fixed in the initial conditions $\rho_0 = r_g/r_0$). To consider the proper mass constancy an approximation would be methodologically wrong because the values of $\mathrm{d}\tau$ and m must be inversely proportional due to the complementarity of $\mathrm{d}x^\mu$ and P^μ. Then the scalar product of two should be constant, as it is indeed:

$$P^\mu \cdot \Delta x_\mu = m\Delta\tau \tag{15}$$

is the constant phase. This is seen from the Einstein-de Broglie relationship. There, a period of a quantum oscillation is related to the frequency, both field dependent

$$mc_0^2 = h\, f, \quad \Delta\tau = 1/f\,, \tag{16}$$

where h is Planck's constant, $c_0 = 1$, $m_0 = 1$. Next, we take $\mathrm{d}t = \Delta t$ to be meant a however small period of the standard quantum oscillator in the Einstein-de Broglie formula (16).

Proper and coordinate space connections in SR Dynamics in the spherical symmetric geometry.

The transference of manifolds defined in the proper space-time to the manifolds in the Minkowski coordinate space-time in the SR Dynamics is illustrated in an important example of particle motion in the spherical symmetric field, it corresponds to that in the Schwarzschild field in the GR Dynamics.

Having a magnitude of the proper coordinate 4-vector displacement $\mathrm{d}s = \mathrm{d}\tau$, and a magnitude of the proper moment vector $|P^\mu| = m$, consider their Lorentz transforms to the corresponding values in the coordinate space with the Lorentz factor $\gamma = (1-\dot{r}^2 - r^2\dot{\theta}^2)^{-1/2}$, the proper mass m_t in the coordinate space and m_τ in the proper space. With the Lagrangian L, the total energy (the Hamiltonian H) is found

$$H = \sum \dot{q}_i \frac{\partial L}{\partial \dot{q}_i} - L\,. \tag{17}$$

The metrics in the proper and coordinate spaces are correspondingly transformed. This is the crucial step of connecting the proper (abstract) and coordinate (observable) spaces to get the SR Dynamics equations, which are supposed to be used in treatments of Astronomical and Cosmological observations.

Actually, the equations of motion comes out from the expressions of conserved quantities derived from the Lagrangian. So, we have:

$$\mathrm{d}t = \gamma \mathrm{d}\tau \exp\left(r_g/r\right). \tag{18}$$

The Lagrangian

$$L = -\mathrm{d}\tau/\mathrm{d}t = -\exp\left(-r_g/r\right)/\gamma \tag{19}$$

to be used in the Hamiltonian Action Principle

$$\delta S = \delta \int_{t_1}^{t_2} L(q_i, \dot{q}_i, t)\,\mathrm{d}t = 0\,, \tag{20}$$

where $q_1 = r$, $\dot{q}_1 = \mathrm{d}r/\mathrm{d}t = \beta_r = \dot{r}$, and $q_2 = r\theta$, $\dot{q}_2 = \beta_\theta = r\dot{\theta} = r(\mathrm{d}\theta/\mathrm{d}t)$. Now, the SR Hamiltonian is defined in the coordinate space-time in relationship with the 4-momentum space. It describes the test particle motion in the spherical symmetric gravitational field due to a central mass M:

$$H = \sum \dot{q}_i \frac{\partial L}{\partial \dot{q}_i} - L\,, \tag{21}$$

from which

$$H = \gamma \exp\left(-r_g/r\right). \tag{22}$$

This is the conserved total energy ϵ. The conservation $\epsilon = \epsilon_0$ holds at any point $r = r_0$ from the initial conditions. It is convenient to fix it at $t = 0$, the values of $\beta_\theta = \beta_0$, $\beta_r = \beta_{r0}$ and $\gamma = \gamma_0 = (1 - \beta_{r0}^2 - \beta_0^2)^{-1}$

$$\epsilon_0 = (1 - \dot{r}^2 - r^2\dot{\theta}^2)^{-1/2} \exp\left(-r_g/r\right). \tag{23}$$

Similarly, for the conserved angular momentum $l = r\beta_\theta$

$$l_0 = r\beta_\theta\,. \tag{24}$$

The magnitude ψ of the 4-phase vector is conserved too:

$$\psi = \sqrt{m\Delta t} = \gamma = \gamma_0\,. \tag{25}$$

Notice, the SR Lagrangian is constructed from the line element $\mathrm{d}s = \mathrm{d}t$ in the coordinate (observable) 4-space as a result of the Lorentz transform of the world line element $\mathrm{d}\tau$ in the proper space-time. The Lagrangian returns the SR Dynamics geodesic obtained from the proper 4-momentum vector provided the proper mass field dependence (exponential) is introduced as a manifestation of the space-time curvature. Otherwise, the SR geodesic would be that of the SR flat metric with no forces.

4.2 Switching the EFE field model from the GR to the SR framework

Let us outline the EFE properties, as opposed to those in SR Dynamics.

- Any metric in the Lorentzian manifolds (regardless of a type of space-time) is the EFE solution provided it is compatible with the GR energy-momentum tensor, or the corresponding SR 4-momentum vector.

- Among others, we are interested in the vacuum solutions of point test particle motion in a field. Generally, in the conventional GR theory, the momentum-energy tensor is given a freedom of phenomenological construction consistently with the problem formulation. However, it vanishes in the vacuum solution problems, still, it is needed to search for the solution consistently with the momentum-energy characteristics accordingly to the problem formulation.

- In the SR case, the coordinate space-time and the corresponding 4-momentum space are inherently connected, what allows us to obtain a unique Lagrangian solution for the given initial conditions. Namely, the SR, metric solutions give rise to the Lagrangian (geodesic) solutions, in which a scalar curvature is created due to field dependence of the proper mass of the point test particle. The latter is considered a quantum oscillator characterized by the standard clock frequency f (the temporal part of the 4-momentum vector), or, equivalently, the corresponding time period $\Delta t = 1/f$ (the temporal part of the 4-coordinate displacement vector).

- The GR scalar curvature corresponds to the SR metric "non-flatness". The coordinate space-time SR curvature is quantitatively characterized by the exponential factor in the functions of $\mathrm{d}t(r)$ and $m(r)$ (in the spherical symmetric geometry).

- As emphasized, the conventional GR Dynamics is incompatible with the SR theory of Kinematics and Dynamics ensuring the Causality Principle. The fact is that, in the GR orbits under conditions of the Black Hole environment, the particle speed can exceed the speed of light, as a direct conflict with the Causality Principle.

Having all the above, the following switching rule is suggested:

> Given a formulated problem, consider the EFE field model as a mathematical "slot machine", input of which includes specific manifold ingredients defined in the proper space, to be Lorentz transformed and sent to the output in the form of metrics and geodesics in the coordinate and momentum 4-spaces of observables.

The proposed reset of the EFE input database to the SR framework eliminates all the above GR problems and controversies, including those related to New Physics. A methodological incorporation of SR Dynamics into the GR EFE field model saves Einstein's idea of creation of gravitation by space-time curvature, at the same time, it justifies the usage of SR Dynamics apart from GR.

Regardless of GR problems and their impact on the SCM, we propose the Alternative Cosmological Model based on Fundamental Physical Principles including those in SR theory. The current version of the SCM should be abandoned because it admits New Physics, as a price for observational fitting.

5 Back to the GU Model in the SR Dynamics framework

This section is intended to complete explanations of observation in the proposed alternative GU Model based on the SR Principles, as opposed to the criticized above conventional GR methodology in the SCM.

5.1 Random Statistics in the collision scenario in the GU Model

Having the Lagrangian equations in SR Dynamic laid out, we want to complete the explanations of observations in more details accounting for a complexity of the TU collision.

While the GU Model is fully based on Fundamental Physical Principles, it does not mean that it must be based on "analytic laws" describing a deep past and a far future. This is basically due to statistics of randomness in complex scenarios of the TUs collision and their disintegration, especially, on the verge of space-time scales.

The complexity of the GU Model is essentially predetermined by dealing with a high-order ladder of matter clustering in the SR Dynamics, as discussed next. Consequently, a reconstruction of the GU image in full space-time volume from an extremely limited sample of the OU data has an inevitable limitation of confidence. In these new circumstances, one has to recognize the benchmark and mock-up observed events, which could be most informative for a radical reconsideration of the space-time scales currently established in the SCM.

A statistical search for a scientific truth is usually made by the well working method of trial and error within the Bayesian approach with data regression by the maximum likelihood criterion. A scientific intuition and logics of beyond customary imagination would be of primary importance.

5.2 The hierarchy of matter clusters, and physical unit gauges

The hierarchy of matter clusters.

Gravitating matter naturally tends to cluster in a hierarchy of isolated systems known in the Observed Universe: a planetary system as a part of a galaxy, in its turn, a part of a galaxy cluster, likely, a part of a super-cluster. In the GU Model, there are more clusterings of higher order.

In the example of our (ideal) planetary system with the Sun's mass however greater than a mass of any planet $M \gg m$, we have the gravitational radius $r_g = GM/c_{inf}^2$ where c_{inf} is the speed of light at infinity. But what is infinity?

Let us consider, in GR or SR Dynamics, the geodesic equation of point test particle motion in the Sun's gravitational field in the ideal spherical symmetric geometry with the Sun in the center of the coordinate origin [33, 34]. The particle will loose its connection with the Sun, if its total energy (in the

dimensionless form) $\epsilon > 1$ at $r \to \infty$, formally, while practically, the radius should not exceed the size of our galaxy, the Milky Way, the Sun belongs to. In this case, the infinity corresponds to the background of galaxy potential field. The next level of infinity will be the gravitational field background of the galaxy in the inter-galaxy space. Notice, the center of attraction in reality is the center of mass determined by all masses of the N-body bounded system.

In a real example of NASA Pioneer-10 mission to reach the interstellar space, the spacecraft had, firstly, to overcome Earth's gravity and, next, the Sun's gravity pull. This mission (as well as other similar ones) failed [35] in precision of interstellar space tracking, and an open question remains, – why. In perspective, with enough fuel for kinetic energy, it would climb the next potential well created by Milky Way.

In the GU Model, the complete mission would include the potential well of the TU in order to get to the GUB medium of minimal mass density (let us call it "physical vacuum" at the so far ultimate infinity). In accordance to the GU Model, the ultimate background or the ideal physical vacuum does not exist, what is somehow a strange statement if applied to a field theory.

Physical unit gauges in clustering hierarchy.

In the presented SR Dynamics, unlike in the conventional one, masses of the proton and the electron are exponentially dependent on the outer field strength. When thrown to infinity, a particle became unbounded, and its mass reaches a maximal value of first level in a sequence m_{0j}, $j = 1, 2, 3, \ldots$.

We conclude that constancy of elementary particle masses in the inside of an isolated j-system and outside leading to the constancy of physical mass unit of kg (a fixed mass gauge), is an j-level weak field approximation with respect to the corresponding background field. Strictly, a definition of the 4-momentum space must account for the mass dependence on a field strength, as in our SR Dynamics. The concept of gauge dependence of standard clock rate applies to the space-time due to complementarity of the two spaces.

Thus, physical units (the meter, the second, the kilogram, and their combinations) are field dependent. The question arises about constancy of the fundamental physical constants such as the gravitational constant G, Planck's constant h, electric charge e). We postulate that the above fundamental physical constants remain intact.

For the light (a photon), the gravitational field serves as a refracting medium with the refractive index being field dependent. In the spherically symmetric geometry, it is a function of radius: $n = c_0/c(\rho) \geqslant 1$, where c_0 is the speed of light at infinity, $\rho_0 = r_g/r$ is the field strength. Hence, the speed of light is field dependent that is, the electric permittivity and magnetic permeability vary in gravitational, electric, and magnetic fields.

Unfortunately, the exact form of the dependence remains subject to ongoing studies within relativistic quantum field theories. In the proposed GU model, we have to cope with the above issues in some speculative manner. In [36, 37], the effective refractive index in the Schwarzschild field is suggested in the form $n = (1+2\,r_g/r)$, or in our SR Dynamic methodology, $n = \exp(2\,r_g/r)$,

what is allegedly confirmed in the light bending observations.

In the GU Model, the impact of clustering hierarchy in determination of space-time scalings is the problem aggravated by a non-stationary process of the TU collusion.

5.3 Black Holes and Dark Matter

We ignore the General Relativity concept of the BH phenomenon suggesting a matter collapse into a singularity point, since this suggestion cannot be scientifically criticized. A similarity of BH singular collapsing with elementary particle singular collapsing, and with the Big Bang singular out-bursting is a popular theme in literature.

We deny the so-called Astronomical BH concept, which provides the phenomenon, in addition to the gravitational collapse, with physical properties having nothing to do with the academic GR gravitational field theory (such as Hawking radiation, entropy, matter trap, information loss, and a lot more). Instead, we introduce a physical phenomenon, which naturally follows from the SR Dynamics with a field dependent proper mass resulting in the elimination of both coordinate and central singularities [38].

There, a central gravitational attractor could be of any finite size admitting the matter density not greater than that of nuclei's. This is the real Astronomical phenomenon of a huge mass and density observable in galaxy centers. The binding energy of the source is the proper mass defect $\Delta m = m(r) - m_0$, (14) which could be a large part of the rest mass at infinity to make an illusion of the missing mass (Dark Matter).

Our physical reasoning is actually in agreement with the Birkhoff's Theorem admitting the matter-filled internal solution of the Schwarzschild metric, also with the non-singular solution originally obtained by Schwarzschild himself [39].

In our view, Astronomical observations do not give a firm evidence of the missing mass but it is rather required for best fit in the SC Model. More comments on this issue are given in the Appendix.

5.4 The redshifts, the Hubble's Law, and comparison of the two Cosmological Models

The redshifts, the Hubble's Law.

In the GU Model, the redshift is a physical effect involving photons emitted from an atom (a quantum oscillator), in a vicinity of a gravitational source. When it is detected by the observer using the same quantum oscillator at some distance away, the redshift effect is observed due to photon frequency shift. As mentioned above, the effect should be described in terms of a photon motion in a gravitational field considered a refracting medium with the refracting index being a function of radial distance from an emitter to the detector. In general, the phenomenon includes three types of a frequency shift of Special Relativity Dynamics, which are observable in vacuum.

1. *The SR Kinematics Doppler effect in photons from an emitter moving by inertia away from a detector with a constant speed.* The Doppler technique is routinely used in Astronomy, Astrophysics, and in commercial applications.

2. *The effect of suppressing a proper frequency of the oscillator-emitter in the local gravitation field.* The emitted photon moves with that frequency unchanged and thus is detected appearing red-shifted (or blue-shifted when moving in reverse direction). The effect is actually associated with the so-called gravitational time dilation, when the time interval being inversely proportional to the frequency is recorded properly changed. The speed of light propagation and the corresponding length-wave must vary in the field respectively to keep the shifted frequency unchanged: $f = 1/\Delta t = c(r)/\lambda(r)$ [40].

3. *The effect of a change of physical unit gauge.* We believe that this new effects plays an important role in observed redshifts. As emphasized, a TU collision in the GU Model is a quite complicated non-stationary process. It is actually not observed in its main part of the collision beginning. The highest redshifts are allegedly observed in the deep field surveillance by the Hubble's telescope.

The anomalies could arise due disturbance by some opaque media, e.g. caused by a photon passing through a chromosphere layer (a refracting and scattering medium) of gas and dust in TU stars. These redshift anomalies should be also considered.

The SCM and the GU Model comparison.

We criticize the Hubble's Law formulation in the SCM in terms of metric expansion with involvement of New Physics and suggests the alternative interpretation of observed redshifts bearing in mind that the value of observed redshifts are model adjusted (or effective) rather than physically real. They are reconstructed from the fuzzy images by the computer code predetermined by the Hubble's Law governed by the GR metric expansion of space.

In the SR Dynamics framework the physical value could be appreciably less. So far, in the GU Model no specific criteria of quantitative description is suggested because of complexity of the observed picture of the TU collision. Given the GU model concept, further studies involving teams of specialists are needed.

The picture of receding galaxies in some way is analogous to a slow bomb explosion in a relatively large volume of TU collision with fragments (galaxies) flying away by inertia during a long period of time. The survived part of the bigger TU is the place we live in, from which a surveillance of the expanded volume much greater than it was at the beginning is conducted.

Distances to observed galaxies should be assessed in the Special Relativity framework with the use of the Minkowski metric. The latter is characterized by light-like and space-like intervals with respect to the imaginary Observer at

the origin of the coordinate system that is, at the Beginning point, the center of mass of the colliding TUs. Let us be the Observer.

To understand the idea, let us take the distance r scale in Bly units, and the coordinate time in By units be counted from right now moment $t = 0$. Assume that the peak of collision activity occurred 5 By ago, $t = -5$, at the place of Observer's location $r = 0$. For simplicity, assume the speeds of recession appreciably less then the speed of light to consider the problem in the Newtonian limit.

Our Observable Universe is seen now as a static picture of galaxies located in the whole range of distances r, from which the light comes. On average, they are thought being seen in some orderly manner: with the greater r, the smaller luminosity L, and, very roughly, the higher redshift z and the receding speed β, with no strict correlation of r, L, z, β. There is a practical limit at $r = R$ where $L \to 0$ (in the SCM, where the effective redshift $z \leqslant 10$).

Recall, the Observable Universe is defined at $t = 0$. Because galaxies are flying away, they are located right now at distances $r\prime > r$ depending on β. Let $r = 5$ and $\beta = 0.1$ at a maximal $r = R$. Then, the radial shift will be $\Delta r = 0.5$ what is relatively small in comparison with $R = 5$ in the picture of instant snap. In this thought variant, Our Observable Universe exits about 10 By since the exploding collision, in analogy with the Big Bang. The radical difference between the two models is in the interpretation of the Observable Universe.

The Observable Universe looks like made by the instant snap camera, and is a small part of the Universe history. The Universe, which existed at the time period $-0.5 < t < 0$ in the state of collision is not observable. Even less hints there are about what had occurred before the collision $t < -0.5$. Likely, we can predict something definite about the nearest future $t > 0$.

The problem with the time-scale determination is aggravated by the change of clock rate of the Observer due to the change of physical unit gauges. Now we are talking about the change of wristwatch frequency of the Observer, that is, the standard atomic clock frequency of the photon detector. It could happened in past that, while the space around the Observer was voided of the matter, the surrounding matter could start mowing away still having a great density and been bounded for this account. Then, given atomic clock frequency of the photon emitter, the Observer's clock would run faster so that the light coming from the flying matter, would appear additionally red-shifted due to the greater potential well. The situation with clocks changes, depending on the collision scenario.

The suggested Alternative Model is formulated in the form of a challenging unfolding problem in the Science of Physics. One has to work with the observed picture serving as the input for the code to be composed from the Model description, that is, the information on physical laws, mathematical equations, and the corresponding database determining the most probable scenario of evolution of the explosion in the GU concept. This is the human mind quest for understanding at a new level the Nature of world we live in.

Quite opposite, in the SC Model, Observable is, basically, readily made the whole Universe in its history of observations, from the instant appearance to

the ultimate disappearance.

5.5 The role of SR methodology in the GU Cosmology

Significance of the SR concept of field dependent proper mass.

As was noted, the conventional SR Dynamics admits the proper mass constancy. Yet, it is wrongly considered not applicable to the gravitational field problems. These unjustified restrictions are aborted in our methodology. The SR framework with the concept of field dependent proper mass (14) constitutes the GU methodological basis, that makes the Cosmological picture drastically different from that in the SCM. We state that an implementation of the SR concept of field dependent proper mass is required to preserve the complementarity of coordinate and and momentum 4-spaces. Also, it is vitally needed for further developing and deeper interconnecting of Modern Physics branches, such as Cosmology, Quantum Electrodynamics, Particle Physics, Relativistic Quantum Field Theories, in general, first of all, for solving the long standing problem of the gravitational field.

Infinities and renormalization.

The infinity curse and its remedy,- an artificial mathematical procedure of renormalization, needs to be conceptually apprehended and finally eliminated [29, 41, 42, 43]. Dirac did not accept infinities; he commented about the normalization "in theory neglecting infinities which appear in its equations, neglecting them in an arbitrary way. This is just not sensible mathematics. Sensible mathematics involves neglecting a quantity when it is small – not neglecting it just because it is infinitely great and you do not want it." [44, 45].

In general, the field dependent proper mass (14) is to be incorporated, as the unalienable property of the relativistic coordinate and momentum spaces. The exponential factor determines the relativistic gravitational dilation effect statically and dynamically, otherwise, it could not naturally appear in equations of motion and conservation laws [31, 46].

Quantization and unification problems.

The normalization problem goes hand in hand with the problem of quantization. The introduction of the de Broglie wave concept (16) in the SR Dynamics is the first step to resolving the quantization problem.

In the equation $m\,c_0^2 = h\,f$, both quantities m and f are field dependent temporal parts of the 4-phase vector describing the standard particle being quantum oscillator. From the spatial part, the de Broglie wave concept λ follows $p = h/\lambda$. Once the field dependent proper mass is introduced, one can see a similarity of introduction of the relativistic mass concept in the important cases of the $1/r$ potentials of gravitational and Coulomb spherical symmetric systems of particle motion about the attractor. This might be a clue to the unification of gravitational and electric forces [47].

6 Concluding discussions

6.1 The succession of Physical knowledge, and the Philosophy of truth

In our quest for comprehension of physical world at a deeper level, we distinguish between an imaginary world created human mind, and the observable original world of Harmony of Nature. From the viewpoint presented in this work, our intellectual a priori ability of doing Science is always restrained by a posteriori knowledge and means of its description by mathematical language and physical terminology. Abstract Mathematics can be abusive, as seen from the history of Modern Physics. Implementation of abstract mathematical concepts without their explicit connections with the observable physical world is a risky way to mix up Scientific Physics and bad New Physics, when a criterion of their distinction is diffused.

The 20th Century revolution in Physics with an advent of Special Relativity theory (by Einstein, Lorentz, Poincaré) has resulted in a radically new understanding of Classical Mechanics and Maxwellian electromagnetism. This transition to the new world-view was neither sudden nor smooth: there are still controversies and paradoxes, which are caused by a lack of opponents' understanding of the basic fact that the Special Relativity Kinematics is an approximation of motion in space-time free of forces. The motion in the presence of any type of forces is subject to Special Relativity Dynamics, development of which historically encountered methodological difficulties. Some of the fundamentally important problems remain unresolved, for example, the infinity problem.

In parallel, Quantum Mechanics has been developed classically (by Heisenberg, Schrödinger), and later semi-classically (by Dirac). It still lacks a full consistent implementation of the SR Dynamics Principles defined in the coordinate and momentum 4-spaces. Consequently, a development of the electromagnetic field theory has not been completed.

At the same time, the transition from the world-view of Newtonian Gravitational Physics to the Einsteinian General Relativity world-view was proclaimed but, strangely, with the General Relativity theory being estranged from the Classical and Modern Physics Fundamental branches, including the Special Relativity theory. This is equivalent to the departure from the empirical basis of Classical Newtonian and Relativistic Mechanics. As a severe consequence, the theory of relativistic quantum gravitational field in connections with Particle Physics came to the scene as a long-standing unresolved problem.

We consider the current Standard Cosmological and Particle Models satisfactory phenomenological models, but both deprived of the Physical Foundations. Incompleteness and misconceptions of methodological implementations of Fundamental Physics Principles are the reality of Modern Physics crisis, without recognitions of which the genuine nature of "gravity", "mass", "electricity", "charge", "spin", "physical vacuum", "quantum carrier of force" in their physical unity of quantum relativistic theories can never be unveiled.

Thomas Kuhn, philosopher and historian in natural Sciences, in his book [48] introduced the conceptual term of Paradigm Shift, which was rightly criticized in literature. However, for descriptions of scientific revolutions, this is a good term to apply to Modern Physics in a sense that the paradigm shift could be a real revolution, as happened with SR theory appearance. A fictitious revolution is usually promoted by the main stream, as the revolutionary GR world-view, which we consider a descent in Dark Ages. Fortuitously, the current main stream is an army of chaotically marching soldiers headed by confused generals.

Acceptance of an incomplete or even false theory is a normal and seemingly unavoidable occurrence in Physics history. Kuhn gives a quote in his book (p. 150) from Max Planck: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it".

However, this expectation does not seem quite realistic. Over generations' time, the main stream could strengthen and triumph its power of protecting dogmas and suppressing novelties, eroding the past knowledge and disseminating the scientific noise, – until the cry of evidences for physical reality different from exhibited could be heard, but would it?

The Standard Model of Particle Physics after the Higgs' discovery enjoys the state of perfect fit, which is considered by theoreticians a state of uncertainties, perplexity, and disappointment because of the failure to comprehend the Nature and the Universe origin from the first principles. Good New Physics from microscopic and cosmic perspectives has not come, and the door to gravitational field problem remained locked, the time is given for rethinking the problem from scratches [49, 50].

Still, suggestions of the post-Higgs revival are coming, which include a continuation of the search for signs beyond the Standard Model on the running LHC and new machines to be built. They are old thoughts persisting to explain the GR and Big Bang picture of Nature with no slightest doubt if the picture is real.

The main historic lesson one can formulate in the concise form is: Cosmology and related branches of Modern Physics are in deep crisis. This fact is actually admitted, however, it is seen differently by leading field experts. In Cosmology, Gravitational Physics, and related theories, bad New Physics is agreeably admitted with a hope for the better choice to seek for, [1, 2, 51, 52, 53]. A resistance to acknowledge the fact has to be overcome.

6.2 Why the GU Model

In the GU Model, the longstanding problems of matter-antimatter worlds and Cosmic Rays are recognized as the Cosmological problems and explained for the first time. The Model explains all basic cosmological observations with no appeal to bad New Physics. The Grand Universe Model, unexpectedly, reconciles or re-views in a certain way physical ideas having a common sense in the alternative theoretical models and theories, see references in [1, 3] and elsewhere in literature:

- Matter-Antimatter symmetry in the Plasma Universe;
- Space expansion from the beginning (Lemaître's primeval atom in the Big Bang);
- Continuous matter recreation in the Steady State Cosmology;
- A general idea of multiple Universes in different cosmological versions;
- The concept of cosmological background in relativistic field theories;
- The cosmological change of fundamental physical constants.

This paper carries a positive message to rethink over the beliefs in validity of theoretical models, concepts, and statements of principal importance. The important role of Modern Philosophy in critical analysis of Modern Physics theories in their unity reflecting the Unity of Nature, and verifiability by the criterion of True Nature is emphasized. The GU Model matches the philosophical concept of methodological naturalness currently propagated in Modern Physics theories and models.

We think, methodological features of the Model contribute to the current questioning Physics and Mathematics in Cosmology in relationship with other Modern Physics theories. In brief:

- The GU Cosmological Model has an explanatory and predicting power owing to its conceptual methodology based on Principles of Fundamental Physics and SR Dynamics. It gives a physical explanation of the Universe expansion and its beginning. Now we can avoid the SC Model with its miraculous Beginning, and the bad New Physics. The latter, as we understood, follow from the GR abstract mathematical concepts in their disconnection with physical reality and the related Modern Physics theories.
- The GU Model is constructive since questions are formulated in the form revealing the roots of certain unsolved problems and clues for their resolutions. There is a fresh look at the long-standing problem of gravitational field theory.
- The GU Model is enlightening since physical issues are raised in greater generality to the extent, where validity of Fundamental Physics Principles become questionable. It opens new space for deeper exploration and comprehension of the observed physical world in the eternal process of succession of knowledge about Uniqueness of Physical Nature.

6.3 Prognosis

In our view, to draw an uncertain prognosis for Tomorrow's Modern Physics would be a pessimistic view since a significant amount of evidence for misconceptions and flaws is revealed, and their common roots, at least, partly, are understood, or understandable, in terms of Physical Science of observable

world. This requires that observations are described by mathematical constructions consistently with Physical Principles, provided a succession of new knowledge with a minimal number of basic fitting parameters and physical constants is ensured. If so, the Modern Physics crisis turns to the revolving stage of being overcome.

It would be speculative to look too far into the future, instead, one can practically see Physics Tomorrow progressing from Physics Today with the proper actions undertaken, – the empirical and philosophical recognitions and rejection of false Physics in favor of true Physics.

The actions have actually been made in publications (some of them referred above) presenting critical views of bad New Physics and departure from physical reality in Modern Physics. In particular, we consider the paper on defense of Physics Integrity [5] "the wake up call" addressed to Physical Community. It is important to recognize and admit the crisis in Modern Physics branches. This is the Author's view, which one can disagree with and bring new arguments for that. The progress in Science is impossible without disagreement.

The present paper is intended to contribute to Physics Tomorrow by raising issues and questions aimed to analyze fundamental physical concepts in their verifiability, validity, and commonality in Modern Physics; to the defense of Physics Integrity by offensive actions against scientific stagnation caused by false beliefs in old dogmas.

We hope, scientists in Natural Sciences and Philosophy will read the paper with interest and respond with both critical and constructive comments concerning Modern Physics problems in relationship with the Alternative Cosmology.

In the Appendices, the SR Dynamics methodology is illustrated in comparison with Classical and GR methodologies, all applied to the Milky Way observation data in the GU scenario of two TUs collision. The MW physical characteristics, including the issues of Black Holes, Dark Matter and antimatter, are discussed in the context of the GU Model. The results of exact solutions of model equations describing a motions of stars in the central region of Milky Way are presented. Materials are illustrative since the detailed analysis of the corresponding observational database is out of the scope of the present work.

Acknowledgment

I am grateful to my Father, retired Physics Professor Anatoli Vankov, for fruitful discussions and advices in preparing this paper. I was influenced by and pledged to continue his passionate endeavor to study the Nature. In this paper, I follow his credo that Cosmology is Physical Science of Nature in utmost generality. It combines Physics describing conceptual rules and laws from observations of independently existing world; Mathematics providing us with scientific symbolic language of logical and physical formulations of the laws; Philosophy as Science about ability and objectivity of our mind to comprehend the real world from sensory images of the Observed Nature.

References

[1] Phillip James Edwin Peebles. *Principles of physical cosmology*. Princeton University Press, 1993.

[2] Steven Weinberg. *Gravitation and cosmology: principles and applications of the general theory of relativity*. Wiley New York, 1972.

[3] Steven Weinberg. *Cosmology*. Oxford University Press, 2008.

[4] Anatoli Vankov. General Relativity Problem of Mercury's Perihelion Advance Revisited. arXiv:1008.1811 [physics.gen-ph], 2010.

[5] George Ellis and Joe Silk. Scientific method: Defend the integrity of physics. *Nature*, 516(7531):321, 2014.

[6] Adam Frank and Marcelo Gleiser. A Crisis at the Edge of Physics. *New York Times*, June 5, 2015.

[7] Anatoli Vankov. On an alternative cosmology. arXiv:astro-ph/9811165, 1998.

[8] Anatoli Vankov. Baryon Asymmetry of the Observed Universe as a Clue to a Resolution of Dark Matter, Galaxy Formation and Other Standard Model Problems. arXiv:astro-ph/9812230, 1998.

[9] Anatoli Vankov. On the Cosmological Aspects of Observed High Energy Cosmic Phenomena. arXiv:astro-ph/9904045, 1999.

[10] Anatoli Vankov. On matter-antimatter separation in open relativistic material system. arXiv:astro-ph/9906279, 1999.

[11] Kirill Vankov. Physics Tomorrow: New Cosmology and Gravitation in Modern Physics. hal-01399327, November 2016. working paper or preprint.

[12] Tamara M Davis and Charles H Lineweaver. Expanding Confusion: common misconceptions of cosmological horizons and the superluminal expansion of the Universe. *Publications of the Astronomical Society of Australia*, 21(1):97–109, 2004.

[13] Yu. L. Bolotin and I. V. Tanatarov. A Thousand Problems in Cosmology: Horizons. arXiv:1310.6329 [physics.ed-ph], 2013.

[14] Dennis Dieks. Another look at general covariance and the equivalence of reference frames. *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, 37(1):174–191, 2006.

[15] John D Norton. General covariance and the foundations of general relativity: eight decades of dispute. *Reports on progress in physics*, 56(7):791, 1993.

[16] John D Norton. Did Einstein stumble? The debate over general covariance. In *Reflections on Spacetime*, pages 103–125. Springer, 1995.

[17] Joan Solà and Adrià Gómez-Valent. The $\bar{\Lambda}$CDM cosmology: From inflation to dark energy through running Λ. *International Journal of Modern Physics D*, 24(04):1541003, 2015.

[18] Abbe G Lemaitre. A homogeneous universe of constant mass and increasing radius accounting for the radial velocity of extra-galactic nebulae. *Monthly Notices of the Royal Astronomical Society*, 91(5):483–490, 1931.

[19] Matthew A. Schenker, Brant E. Robertson, Richard S. Ellis, Yoshiaki Ono, Ross J. McLure, James S. Dunlop, Anton Koekemoer, Rebecca A. A. Bowler, Masami Ouchi, Emma Curtis-Lake, Alexander B. Rogers, Evan Schneider, Stephane Charlot, Daniel P. Stark, Steven R. Furlanetto, and Michele Cirasuolo. The UV Luminosity Function of Star-forming Galaxies via Dropout Selection at Redshifts z 7 and 8 from the 2012 Ultra Deep Field Campaign. *The Astrophysical Journal*, 768(2):196, 2013.

[20] R.J. McLure, J.S. Dunlop, R.A.A. Bowler, E. Curtis-Lake, M. Schenker, R.S. Ellis, Brant E. Robertson, A.M. Koekemoer, A.B. Rogers, Y. Ono, et al. A new multifield determination of the galaxy luminosity function at z= 7–9 incorporating the 2012 Hubble Ultra-Deep Field imaging. *Monthly Notices of the Royal Astronomical Society*, 432:2696–2716, 2013.

[21] Richard S. Ellis, Ross J. McLure, James S. Dunlop, Brant E. Robertson, Yoshiaki Ono, Matthew A. Schenker, Anton Koekemoer, Rebecca A. A. Bowler, Masami Ouchi, Alexander B. Rogers, Emma Curtis-Lake, Evan Schneider, Stephane Charlot, Daniel P. Stark, Steven R. Furlanetto, and Michele Cirasuolo. The Abundance of Star-forming Galaxies in the Redshift Range 8.5-12: New Results from the 2012 Hubble Ultra Deep Field Campaign. *The Astrophysical Journal Letters*, 763(1):L7, 2013.

[22] D. Clowe, G. A. Luppino, N. Kaiser, and I. M. Gioia. Weak Lensing by High-Redshift Clusters of Galaxies. I. Cluster Mass Reconstruction. *The Astrophysical Journal*, 539(2):540, 2000.

[23] John Lighton Synge. *Relativity: the General theory*. North Holland Publishing Company, Amsterdam, 1964.

[24] Yvonne Choquet-Bruhat. *General relativity and the Einstein equations*. Oxford University Press, 2009.

[25] Hans Stephani, Dietrich Kramer, Malcolm MacCallum, Cornelius Hoenselaers, and Eduard Herlt. *Exact solutions of Einstein's field equations*. Cambridge University Press, 2009.

[26] Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler. *Gravitation*. W. H. Freeman and Co, San Francisco, 1973.

[27] Clifford M. Will. *Theory and Experiment in Gravitational Physics*. Cambridge University Press, 1993.

[28] M. Soffel, S. A. Klioner, G. Petit, P. Wolf, S. M. Kopeikin, P. Bretagnon, V. A. Brumberg, N. Capitaine, T. Damour, T. Fukushima, B. Guinot, T.-Y. Huang, L. Lindegren, C. Ma, K. Nordtvedt, J. C. Ries, P. K. Seidelmann, D. Vokrouhlický, C. M. Will, and C. Xu. The IAU 2000 Resolutions for Astrometry, Celestial Mechanics, and Metrology in the Relativistic Framework: Explanatory Supplement. *The Astronomical Journal*, 126(6):2687–2706, 2003.

[29] Lev Davidovich Landau and Evgenii Mikhailovich Lifshitz. *The classical theory of fields*. Pergamon Press, Oxford, 1971.

[30] John Lighton Synge. *Relativity: the special theory*. North Holland Publishing Company, Amsterdam, 1965.

[31] Anatoli Vankov. On Relativistic Generalization of Gravitational Force. *Foundations of Physics*, 38(6):523–545, 2008.

[32] Netsivi Ben-Amots. A new line element derived from the variable rest mass in gravitational field. arXiv:0808.2609 [physics.gen-ph], 2008.

[33] Kirill Vankov. The Problem of Particle Motion in the Schwarzschild Field: Critical Methodological Analysis, Exact Numerical Solution, and the Alternative. *The General Science Journal*, 2016.

[34] Kirill Vankov. General Relativity Mercury's Anomaly Prediction: What and How to Test? *The General Science Journal*, 2016.

[35] John D. Anderson, Philip A. Laing, Eunice L. Lau, Anthony S. Liu, Michael Martin Nieto, and Slava G. Turyshev. Study of the anomalous acceleration of Pioneer 10 and 11. *Phys. Rev. D*, 65:082004, Apr 2002.

[36] Christian Møller. *The theory of relativity*. Clarendon Press, Oxford, 1972.

[37] Vladimir Fock. *The Theory of Space, Time and Gravitation*. Pergamon, 1959.

[38] Kirill Vankov. Black Holes in Einstein's General Relativity versus Modern Theoretical Astrophysics, and Observations. hal-01150644, March 2015. Essay written for the Gravity Research Foundation 2015 Awards for Essays on Gravitation.

[39] Karl Schwarzschild. On the Gravitational Field of a Mass Point According to Einstein's Theory. *General Relativity and Gravitation*, 35(5):951–959, 2003. Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie. Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, Phys.-Math. Klasse 1916, 189–196.

[40] Anatoli Vankov. Testing Relativistic Mass-Energy Concept in Physics of Gravity and Electricity. *Annales de la Fondation Louis de Broglie*, 29(Hors série 2):1035–1056, 2004. Commemoration of the Yang and Mills paper on Non-Abelian Theories.

[41] Steven Weinberg. *The quantum theory of fields*, volume 2. Cambridge university press, 1996.

[42] Gerard 't Hooft. Nobel Lecture: A confrontation with infinity. *Reviews of Modern Physics*, 72(2):333–339, 2000.

[43] Frank Close. *The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe*. Basic Books, 2013.

[44] Paul A. M. Dirac. *Directions in physics*. John Wiley and Sons, Inc., 1978.

[45] Helge Kragh. *Dirac: a scientific biography*. Cambridge University Press, 1990.

[46] Anatoli Vankov. On Problem of Mass Origin and Self-Energy Divergence in Relativistic Mechanics and Gravitational Physics. arXiv:gr-qc/0311063, 2003.

[47] Anatoli Vankov. On the de Broglie wave nature. In *Annales de la Fondation Louis de Broglie*, volume 30, pages 15–34. Fondation Louis de Broglie, 2005.

[48] Thomas S. Kuhn. *The Structure of Scientific Revolution*. The University of Chicago Press, second edition, 1970.

[49] Interview with Gian Giudice: Head of CERN's Theory Department. `https://ep-news.web.cern.ch/content/interview-gian-giudice-head-cerns-theory-department`, June 2016.

[50] Matthew Chalmers. The new particle landscape. *Nature*, 488:30, 2012.

[51] Steven Weinberg. The revolution that didn't happen (Thomas Kuhn's view of scientific progress). *New York Review of Books*, 45(15):48–52, 1998.

[52] Frank Wilczek. The Origin of Mass. *MIT Physics Annual*, pages 24–35, 2003.

[53] John W Moffat. *Reinventing Gravity: A Physicist Goes Beyond Einstein*. Harper Collins, 2009.

[54] Ortwin Gerhard. Structure and Mass Distribution of the Milky Way Bulge and Disk. In José G. Funes and Enrico Maria Corsini, editors, *Galaxy Disks and Disk Galaxies*, volume 230 of *ASP Conference Series*, pages 21–30, 2001.

[55] Richard B. Larson. Galaxy Formation and Evolution. In G. Tenorio-Tagle, M. Prieto, and F. Sanchez, editors, *Star Formation in Stellar Systems*, page 125. Cambridge University Press, 1992.

[56] Hans-Walter Rix and Jo Bovy. The Milky Way's stellar disk. *The Astronomy and Astrophysics Review*, 21(1):1–58, 2013.

[57] Stephen William Hawking. Information Preservation and Weather Forecasting for Black Holes. arXiv:1401.5761 [hep-th], 2014.

[58] Niall Ryan. Galactic Disc Rotation: Analytic models and asymptotic results. arXiv:1301.5233 [astro-ph.GA], 2013.

[59] Gunther Witzel, Andrea M Ghez, Mark R Morris, Breann N Sitarski, Anna Boehle, Smadar Naoz, Randall Campbell, Eric E Becklin, Gabriela Canalizo, Samantha Chappell, et al. Detection of Galactic Center source G2 at 3.8 μm during periapse passage. *The Astrophysical Journal Letters*, 796(1):L8, 2014.

[60] MA Nowak, J Neilsen, SB Markoff, FK Baganoff, D Porquet, N Grosso, Yuri Levin, J Houck, A Eckart, H Falcke, et al. Chandra/HETGS observations of the brightest flare seen from sgr A*. *The Astrophysical Journal*, 759(2):95, 2012.

[61] Masayoshi Nobukawa, Syukyo G Ryu, Takeshi Go Tsuru, and Katsuji Koyama. New Evidence for High Activity of the Supermassive Black Hole in our Galaxy. *The Astrophysical Journal Letters*, 739(2):L52, 2011.

[62] G Ponti, B De Marco, MR Morris, A Merloni, T Muñoz-Darias, M Clavel, D Haggard, S Zhang, K Nandra, S Gillessen, et al. Fifteen years of XMM–Newton and Chandra monitoring of Sgr A*: evidence for a recent increase in the bright flaring rate. *Monthly Notices of the Royal Astronomical Society*, 454(2):1525–1544, 2015.

[63] Jimmy A Irwin, W Peter Maksym, Gregory R Sivakoff, Aaron J Romanowsky, Dacheng Lin, Tyler Speegle, Ian Prado, David Mildebrath, Jay Strader, Jifeng Liu, et al. Ultraluminous X-ray bursts in two ultracompact companions to nearby elliptical galaxies. *Nature*, 538(7625):356–358, 2016.

[64] G. Dubus and B. Cerutti. What caused the GeV flare of PSR B1259-63? *Astronomy & Astrophysics*, 557:A127, 2013.

[65] Benoit Cerutti, Gregory R Werner, Dmitri A Uzdensky, and Mitchell C Begelman. Gamma-ray flares in the Crab Nebula: A case of relativistic reconnection? *Physics of Plasmas*, 21(5):056501, 2014.

[66] S. Gillessen, F. Eisenhauer, S. Trippe, T. Alexander, R. Genzel, F. Martins, and T. Ott. Monitoring Stellar Orbits Around the Massive Black Hole in the Galactic Center. *The Astrophysical Journal*, 692(2):1075, 2009.

[67] Albert Einstein. Erklärung der Perihelbewegung des Merkur aus der allgemeinen Relativitätstheorie. Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, 1915. See also "The Collected Papers of Albert Einstein". vol. 6, Princeton University Press, (1996).

[68] L. Meyer, A. M. Ghez, R. Schödel, S. Yelda, A. Boehle, J. R. Lu, T. Do, M. R. Morris, E. E. Becklin, and K. Matthews. The Shortest-Known-Period Star Orbiting Our Galaxy's Supermassive Black Hole. *Science*, 338(6103):84–87, 2012.

[69] L. Meyer, A. M. Ghez, R. Schödel, S. Yelda, A. Boehle, J. R. Lu, T. Do, M. R. Morris, E. E. Becklin, and K. Matthews. Supplementary Materials for The Shortest-Known–Period Star Orbiting Our Galaxy's Supermassive Black Hole. `http://www.galacticcenter.astro.ucla.edu/research/1225506s.pdf`, 2012.

Appendices

A The Milky Way in the GU Model

A.1 The Milky Way before and after the collision

Our galaxy, the observed Milky Way (MW), is of type of a spiral disc with a massive attractor, the Black Hole (BH_{mw}) at the center surrounded by a bulge [54, 55, 56]. There is no any proven indication of the BH_{mw} gravitational collapse. It is possible in the GR theory but could not happen in the SR Dynamics; yet, its physical reality is arguable in literature, [57, 38]. So, we use the term of BH for a central gravitational source, which has a finite size, and a mass density not exceeding that in the neutron star.

In the collision scenario, the age of the observed MW galaxy could be approximately assessed provided random statistics of the complex history taken into account. Likely, the galaxy before had existed in some mature form before the collision of the two TUs. It is reasonable to suggest that the original MW was old enough when has reached a state of maximal mechanical stability. Such a state requires optimal conditions of reconciling an extreme binding energy, on the one hand, and the extreme angular momentum, on the other hand. Then, a system of stars could rotate about the central attractor of a great mass and density, while the stars comprised a thick galaxy disc and had orbits characterized by minimal eccentricities with no bulges, no spiral arms.

The observed MW structure was developed during the collision when the galaxy was significantly washed out by antimatter, but it survived in the currently observed crippled state. Indeed, the BH_{mw} is seen having the mass appreciably less then the rest of the galaxy. The original BH_{mw} was destructed during the collision, the bulge formation is one of the consequences.

Likely, the BH_{mw} mass was about two orders greater than at present; the total mass of stars was greater as well, the MW was a strongly bounded system. After the collision, the binding energy significantly decreased while a great amount of matter lost. This made the MW system dynamically unstable so that spiral arms were formed in the weakest parts of the disc.

A.2 Dark Matter issue

It looks like the current MW as a whole must be supported by additional gravitationally interacting material, at least, in the central area. It is thought that the "Dark Matter halo" is needed to explain the observed picture of the Milky Way and other spiral galaxies. In particular, it is argued that the observed rotational curve cannot be explained by the Newtonian (Keplerian) model of orbits without the Dark Matter hypothesis. Recall, in Classical Mechanics, orbits describe the test particle motion of however small mass in the spherical symmetric gravitational field due to a central source.

The observed MW galaxy is characterized by specific radial mass density distribution in spiral arms and noticeable disc rigidity due to a gravitational interaction of stars. Yet, the observations show their rotational curve being

flat. We state that the observations cannot be described by an analytic model like the Keplerian one. The correct description requires a complex model accounting for the MW characteristics with the use of numerical calculations. Some authors insist that the flat rotational curve can be also explained in a simplified approximate model with some additional assumptions about the galaxy physical structure, [38, 58]. We state that, in view of the collision scenario in the GU Cosmology, the Dark Matter argument is not valid.

A.3 Antimatter in galaxies

As was noted before, Astrophysical observations reveal strange phenomena, which we consider an evidence of antimatter presence in the MW and some other galaxies. In particular, it concerns often events of high intensity flares in the central MW part, also, unexplained physical properties of the BH_{mw} [59, 60, 61, 62], also, huge X-ray busts in some other galaxies [63, 64, 65].

A.4 The Milky Way center part

Since 1992 the center of the Milky Way galaxy has been observed by several research groups. As a result, many Keplerian stellar orbits are identified [66] in a process of data reconstruction from long-time observations of fussy star images. The Table 1 summarizes the unfolded orbital characteristics for several so-called S-stars: the semi-major axis a in meters, the eccentricity e, and the full time period in Earth's years.

Using the most directly observed parameters, we independently conducted the exact calculations of the orbits in the Classical, General Relativity, and SR Dynamics theories. The corresponding equations of motions, results, and discussions are presented below.

B Equations of particle motion in Classical, GR, and SR Dynamics

B.1 GR, Classic Dynamics

In polar coordinates, the conventional Einstein's equation [67] of the test particle in the spherical symmetric gravitational field is given by

$$\left(\frac{\mathrm{d}x}{\mathrm{d}\theta}\right)^2 = \frac{(\epsilon_0^2 - 1)}{l_0^2} + \frac{2r_g}{l_0^2}x - x^2 + 2r_g x^3\,, \tag{26}$$

where $x = 1/r$ is the inverted radius, ϵ_0^2 and l_0^2 are the particle conserved total energy and angular momentum, correspondingly (both are in the squared form), $r_g = \mu/c^2$ the gravitational radius, $\mu = GM$. Mass of the particle m is assumed however small with respect to the point-like source mass M, $m \ll M$. Customary units $c = 1$, $m = 1$ are used. The dimensionless parameter of field strength is introduced $\rho_0 = r_g/r_0$, where r_0 is the initial radius. Then, (26)

takes the dimensionless form

$$\left(\frac{\partial\xi}{\partial\theta}\right)^2 = \left(1 - \frac{2\rho_0}{\beta_0^2} - 2\rho_0\right) + \frac{2\rho_0}{\beta_0^2}\,\xi - \xi^2 + 2\rho_0\,\xi^3 \tag{27}$$

with the conserved total energy

$$\begin{aligned} \epsilon_0^2 &= 1 - 2\rho_0 + \beta_0^2 - 2\rho_0\beta_0^2 \\ &= 1 - 2\rho_0\xi + \beta_0^2\xi^2 - 2\rho_0\beta_0^2\xi^3 + \beta_r^2(\xi)\,. \end{aligned} \tag{28}$$

The radial component of velocity is

$$\beta_r^2(\xi) = f^2(\xi) = \epsilon_0^2 - \left(1 - 2\rho_0\xi + \beta_0^2\xi^2 - 2\rho_0\beta_0^2\xi^3\right)\,. \tag{29}$$

The dimensionless parameter of initial angular (squared) velocity is $\beta_\theta^2 = \beta_0^2$. The equation of temporal motion comes from (29) with $r(\tau) = r_0/\xi$

$$\beta_r(\xi) = \frac{\mathrm{d}r(\tau)}{\mathrm{d}\tau} = f(r)\,, \tag{30}$$

where $f(r)$ is an explicit function of τ due to $\theta(\tau)$ and $r(\tau)$, (30).

Notice, the time variable in the equations is the proper time τ by virtue of derivation. We argue that it must be the coordinate time t.

The above equations are reduced to the Classical case if the term of the cubic order is neglected, and the time variable τ must be replaced with t.

B.2 The Alternative Relativistic Dynamics

We use a relativistic dynamics theory [33, 31] different from GR. In the referred works, the principles of relativistic dynamics are given and illustrated in the spherical symmetric field. The orbital motion problem is described in brief, as follows.

A new concept of the relativistic proper mass $m(r)$ depending on field strength is introduced. From the Lagrangian problem formulation, it follows $m(r) = m_0/\gamma_r$, where m_0 is the initial value, $m(r) \to m_\infty$ as $r \to \infty$.

The revision of the proper mass concept is motivated by several reasons, first of all, because of the elimination of the central singularity (the traditional infinity). Besides, it is a necessity to introduce the 4-momentum vector P^μ in the form complementary to the 4-coordinate vector X^μ. The temporal component in X^μ is the proper time depending on the gravitational potential $\tau = \tau(r_g/r)$. Therefore, the temporal component m in P^μ should be $m = m(r_g/r)$. This explains the gravitational time dilation.

In polar coordinates, the 4-coordinate interval and the 4-momentum vectors are $\mathrm{d}X^\mu(r) = \gamma\,\mathrm{d}\tau(r)\ (1, \beta_r, \beta_\theta)$ and $P^\mu(r) = \gamma\, m(r)\ (1, \beta_r, \beta_\theta)$, where 3-velocity components and the Lorentz factor are functions of r and θ, $c_0 = 1$. The Minkowski 4-force $K^\mu = \mathrm{d}P^\mu/\mathrm{d}\tau$ acts on the test particle, and it naturally has the tangential component with respect to the world-line s and the orthogonal one, while the a point on the world line s is a function of 4-position.

There are two conservation laws, – for total energy ϵ_0, and the angular momentum L_0 formulated below for initial conditions $r(r) = r_0$, $\theta = 0$, $\beta_r = 0$, $\beta_\theta = \beta_0$. The total energy and the angular momentum are

$$\epsilon_0 = \gamma_0 \, \gamma_{r,0} = \gamma \, \gamma_r \, , \tag{31}$$

$$L_0 = \gamma_0 \, \gamma_{r,0} \, r_0 \, \beta_0 = \gamma \, \gamma_r \, r \, \beta_\theta \, . \tag{32}$$

Instead of (32), it is convenient to use a conserved quantity $l_0 = \epsilon_0 / L_0$:

$$l_0 = r \, \beta_\theta \, . \tag{33}$$

Here, a squared inverted Lorentz factor is $1/\gamma^2 = 1 - \beta_r^2 - \beta_\theta^2$, and $\beta_r = \mathrm{d}r/\mathrm{d}t$, $\beta_\theta = r \, \mathrm{d}\theta/\mathrm{d}t$. To get the angular equation, consider $\beta_r = (\mathrm{d}r/\mathrm{d}\theta)(\mathrm{d}\theta/\mathrm{d}t)$, and transform (33) into $\beta_\theta^2 = l_0^2/r^2$. After introducing a variable $\xi = r_0/r$, we arrive to the exact relativistic equation of orbital motion of confined particle. The equation is valid for a however strong field by the criterion r_g/r, compare with (27):

$$\left(\frac{\mathrm{d}\xi}{\mathrm{d}\theta} \right)^2 = \frac{1}{\beta_0^2} - \xi^2 - \frac{1}{\gamma_0^2 \, \beta_0^2} \, \exp\left(\frac{2 \, r_g}{r_0} \, (1 - \xi) \right) \, . \tag{34}$$

The Newtonian limit, or weak field conditions, is given by a linear approximation of the exponential function:

$$(\mathrm{d}\xi/\mathrm{d}\theta)^2 = (1 - 2 \, \sigma_r) + 2 \, \sigma_r \, \xi - \xi^2 - 2 \, \sigma_r \, (r_g/r_0) \, (1 - \xi)^2 \, , \tag{35}$$

where $\sigma_r = r_g/(r_0 \, \gamma_0^2 \, \beta_0^2)$ is the σ criterion in the relativistic case. It should be noted that

$$\mathrm{d}\xi/\mathrm{d}\theta = (\mathrm{d}r/\mathrm{d}t)/\beta_0 \, , \tag{36}$$

where $(\mathrm{d}r/\mathrm{d}t)^2 = \beta_r^2(r)$ is the radial (squared) component to the total (squared) speed $\beta(r)$:

$$\beta^2(r) = \beta_r^2(r) + \beta_\theta^2 \, , \tag{37}$$

with the angular speed term

$$\beta_\theta^2 = r_0^2 \, \beta_0^2 / r^2 \, . \tag{38}$$

The potential function in the radial motion is

$$V(r) = -\left(1 - \exp(-r_g/r)\right) \, . \tag{39}$$

The particle speed a free radial fall is:

$$\beta(r) = \left(1 - (1/\gamma_0^2) \, \exp(-2 \, r_g/r)\right)^{1/2} \, . \tag{40}$$

We applied all theories to compare the results of exact calculations of motion of stars in the central region of Milky Way.

C Results of calculations

C.1 Methodology and data

From the set of data in Table 1, it is seen that the evaluated orbits of the observed stars correspond to the motion under weak field conditions $r_0 \ll 1$, therefore, the expected differences in Classical, GR, and SR Dynamics theories will be small.

Let us fix the central mass and the eccentricity value and find the corresponding pericenter value together with all other orbital characteristics such as maximal velocity, semi-major axis, etc., to match the given time period within 0.001%. The results are presented in Table 2. As seen, the differences between the three theories are negligible.

From the GU Model viewpoint, the central mass should be initially much larger, say, $M_C = 2 \times 10^{39}$, as was discussed. Then, the stars would move 6-8 times faster and have correspondingly grater semi-major axis, see Table 3. At a pericenter, several stars would reach the speed about $\beta_0 \approx 0.1$, the star S14 reaching almost $\beta_0 \approx 0.2$, and the star S2 reaching $\beta_0 \approx 0.15$. Increasing the central mass up to $M_C = 1 \times 10^{40}$ will result in to $\beta_0 \approx 1/3$ for S14 and $\beta_0 \approx 2/7$ for S2, see Table 4. It is probable that, while the central mass was much larger before the collision, orbits of the stars were larger than observed, so that a motion of the stars could be characterized by a maximal speed not approaching the speed of light.

One of the stars closest to the galaxy center is the S2-star, which has been studied very thoroughly. Its orbital time full period is found to be about 16 years. Let us fix this period and the orbit eccentricity to reconstruct the orbit in each theory. The Classical Mechanics predicts faster velocities with increasing differences for larger central mass. In the SR Dynamics, a particle motion faster then light is impossible. However, Classical Theory gives, for central mass being over 4×10^{41} kg., the superluminal speed at pericenter, see Figure 1. General Relativity in this case predicts even faster velocities, moreover, for the central mass larger than 1.2×10^{41} kg the orbit type can be only either hyperbolic or a spiral fall. Recall, we deny the validity of the conventional GR gravitational field theory for the previously explained reasons.

For the values of the central mass larger than 1×10^{38} kg, there are noticeable differences in angular periods, see Figure 2. In GR theory the angular advance explodes very quick, while in exponential model the angular period shows some retardation.

The orbital characteristics calculated in the Classical, GR, and SR Dynamics models are provided by additional information in the following Tables to allow readers to interpolate the results to different combinations of initial conditions and illustrated graphically.

Table 1: Orbital data provided by [66, Table 7] with $M_C = 8.57 \times 10^{36}$ kg and $R_0 = 2.57 \times 10^{20}$ m. The last two entries are taken from more recent articles [68, Table 1] and [69, Table S4], where the central mass was estimated to be equal to $M_C = (4.1 \pm 0.4) \times 10^6 M_\odot \approx 8.15 \times 10^{36}$ kg and the distance $R_0 = 7.7 \pm 0.4$ kpc $\approx 2.38 \times 10^{20}$ m.

star	a (m)	e	T (years)
S1	6.330E+14	0.496	132.00
S2	1.533E+14	0.880	15.80
S4	3.714E+14	0.406	59.50
S5	3.115E+14	0.842	45.70
S6	5.433E+14	0.886	105.00
S8	5.122E+14	0.824	96.10
S9	3.651E+14	0.825	58.00
S12	3.838E+14	0.900	62.50
S13	3.701E+14	0.490	59.20
S14	3.190E+14	0.963	47.30
S17	3.876E+14	0.364	63.20
S18	3.302E+14	0.759	50.00
S19	9.944E+14	0.844	260.00
S21	2.654E+14	0.784	35.80
S24	1.321E+15	0.933	398.00
S27	5.658E+14	0.952	112.00
S29	4.947E+14	0.916	91.00
S31	3.714E+14	0.934	59.40
S33	5.109E+14	0.731	96.00
S38	1.732E+14	0.802	18.90
S66	1.508E+15	0.178	486.00
S67	1.365E+15	0.368	419.00
S71	1.322E+15	0.844	399.00
S83	3.471E+15	0.654	1700.00
S87	1.570E+15	0.423	516.00
S96	1.925E+15	0.131	701.00
S97	2.724E+15	0.302	1180.00
S2	1.417E+14	0.898	16.17
S102	1.219E+14	0.680	11.50

Table 2: Orbital parameters of S-stars for center mass $M_C = 8.57 \times 10^{36}$ kg, $r_g = 6.37 \times 10^9$ m, density $= 7.93 \times 10^6$ kg/m^3 in exponential theory and relative differences to classical and GR theories. The last two entries are computed with $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density $= 8.77 \times 10^6$ kg/m^3 as in [68, 69].

	exp model			relative difference to CLT			relative difference to GRT		
star	a (m)	r_p (m)	v_p/c	a	r_p	v_p/c	a	r_p	v_p/c
S1	6.31E+14	3.18E+14	0.0055	-9E-06	-9E-06	1E-05	-2E-05	-2E-05	4E-05
S2	1.53E+14	1.84E+13	0.0255	-8E-06	-8E-06	2E-04	-5E-05	-5E-05	5E-04
S4	3.71E+14	2.20E+14	0.0064	-1E-05	-1E-05	2E-05	-3E-05	-3E-05	6E-05
S5	3.11E+14	4.91E+13	0.0154	-1E-05	-1E-05	7E-05	-3E-05	-3E-05	2E-04
S6	5.42E+14	6.17E+13	0.0139	0E+00	0E+00	5E-05	-1E-05	-1E-05	2E-04
S8	5.11E+14	8.99E+13	0.0114	-1E-05	-1E-05	4E-05	-2E-05	-2E-05	1E-04
S9	3.65E+14	6.38E+13	0.0135	-1E-05	-1E-05	5E-05	-3E-05	-3E-05	2E-04
S12	3.83E+14	3.83E+13	0.0178	0E+00	0E+00	8E-05	-2E-05	-2E-05	3E-04
S13	3.70E+14	1.89E+14	0.0071	0E+00	0E+00	1E-05	-2E-05	-2E-05	6E-05
S14	3.18E+14	1.18E+13	0.0326	-1E-05	-1E-05	3E-04	-3E-05	-3E-05	8E-04
S17	3.86E+14	2.46E+14	0.0059	-1E-05	-1E-05	2E-05	-3E-05	-3E-05	5E-05
S18	3.30E+14	7.96E+13	0.0119	0E+00	0E+00	4E-05	-2E-05	-2E-05	1E-04
S19	9.91E+14	1.55E+14	0.0087	0E+00	0E+00	2E-05	-9E-06	-9E-06	7E-05
S21	2.64E+14	5.71E+13	0.0141	0E+00	0E+00	5E-05	-3E-05	-3E-05	2E-04
S24	1.32E+15	8.82E+13	0.0118	0E+00	0E+00	3E-05	-1E-05	-1E-05	1E-04
S27	5.65E+14	2.71E+13	0.0214	0E+00	0E+00	1E-04	-1E-05	-1E-05	4E-04
S29	4.92E+14	4.14E+13	0.0172	0E+00	0E+00	7E-05	-1E-05	-1E-05	2E-04
S31	3.70E+14	2.45E+13	0.0224	-1E-05	-1E-05	1E-04	-2E-05	-2E-05	4E-04
S33	5.10E+14	1.37E+14	0.0090	-8E-06	-8E-06	2E-05	-1E-05	-1E-05	7E-05
S38	1.73E+14	3.42E+13	0.0183	-2E-05	-2E-05	9E-05	-6E-05	-6E-05	3E-04
S66	1.50E+15	1.24E+15	0.0025	0E+00	0E+00	2E-06	-1E-06	-1E-06	1E-05
S67	1.36E+15	8.61E+14	0.0032	-1E-05	-1E-05	9E-06	-8E-06	-8E-06	2E-05
S71	1.32E+15	2.06E+14	0.0076	0E+00	0E+00	1E-05	5E-06	5E-06	4E-05
S83	3.47E+15	1.20E+15	0.0030	0E+00	0E+00	2E-06	-5E-06	-5E-06	1E-05
S87	1.57E+15	9.03E+14	0.0032	0E+00	0E+00	3E-06	-3E-06	-3E-06	1E-05
S96	1.92E+15	1.67E+15	0.0021	0E+00	0E+00	2E-06	-3E-06	-3E-06	8E-06
S97	2.72E+15	1.90E+15	0.0021	0E+00	0E+00	1E-06	-6E-06	-6E-06	8E-06
S2	1.53E+14	1.56E+13	0.0271	-7E-06	-7E-06	2E-04	-5E-05	-5E-05	6E-04
S102	1.22E+14	3.90E+13	0.0161	-2E-05	-2E-05	8E-05	-7E-05	-7E-05	3E-04

Table 3: Orbital parameters of S-stars for center mass $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3 in exponential theory and relative differences to classical and GR theories.

	exp model			relative difference to CLT			relative difference to GRT		
star	a (m)	r_p (m)	v_p/c	a	r_p	v_p/c	a	r_p	v_p/c
S1	3.88E+15	1.96E+15	0.0337	-1E-04	-1E-04	4E-04	-5E-04	-5E-04	1E-03
S2	9.44E+14	1.13E+14	0.1560	-5E-04	-5E-04	6E-03	-2E-03	-2E-03	2E-02
S4	2.28E+15	1.36E+15	0.0392	-2E-04	-2E-04	6E-04	-9E-04	-9E-04	2E-03
S5	1.92E+15	3.03E+14	0.0949	-3E-04	-3E-04	2E-03	-1E-03	-1E-03	8E-03
S6	3.33E+15	3.80E+14	0.0857	-1E-04	-1E-04	2E-03	-6E-04	-6E-04	6E-03
S8	3.14E+15	5.53E+14	0.0699	-2E-04	-2E-04	1E-03	-6E-04	-6E-04	4E-03
S9	2.25E+15	3.93E+14	0.0829	-2E-04	-2E-04	2E-03	-9E-04	-9E-04	6E-03
S12	2.36E+15	2.36E+14	0.1090	-2E-04	-2E-04	3E-03	-8E-04	-8E-04	1E-02
S13	2.28E+15	1.16E+15	0.0436	-2E-04	-2E-04	6E-04	-9E-04	-9E-04	2E-03
S14	1.96E+15	7.25E+13	0.1985	-2E-04	-2E-04	1E-02	-1E-03	-1E-03	3E-02
S17	2.38E+15	1.51E+15	0.0366	-2E-04	-2E-04	5E-04	-8E-04	-8E-04	2E-03
S18	2.03E+15	4.90E+14	0.0729	-2E-04	-2E-04	1E-03	-1E-03	-1E-03	5E-03
S19	6.10E+15	9.52E+14	0.0536	-9E-05	-9E-05	8E-04	-3E-04	-3E-04	2E-03
S21	1.63E+15	3.52E+14	0.0866	-3E-04	-3E-04	2E-03	-1E-03	-1E-03	7E-03
S24	8.11E+15	5.43E+14	0.0726	-7E-05	-7E-05	1E-03	-2E-04	-2E-04	4E-03
S27	3.48E+15	1.67E+14	0.1311	-1E-04	-1E-04	4E-03	-6E-04	-6E-04	1E-02
S29	3.03E+15	2.55E+14	0.1054	-2E-04	-2E-04	3E-03	-7E-04	-7E-04	9E-03
S31	2.28E+15	1.51E+14	0.1375	-2E-04	-2E-04	5E-03	-9E-04	-9E-04	2E-02
S33	3.14E+15	8.45E+14	0.0551	-2E-04	-2E-04	9E-04	-6E-04	-6E-04	3E-03
S38	1.06E+15	2.11E+14	0.1124	-5E-04	-5E-04	3E-03	-2E-03	-2E-03	1E-02
S66	9.26E+15	7.61E+15	0.0152	-6E-05	-6E-05	1E-04	-2E-04	-2E-04	4E-04
S67	8.39E+15	5.30E+15	0.0196	-5E-05	-5E-05	1E-04	-2E-04	-2E-04	6E-04
S71	8.12E+15	1.27E+15	0.0465	-6E-05	-6E-05	6E-04	-3E-04	-3E-04	2E-03
S83	2.13E+16	7.38E+15	0.0182	-3E-05	-3E-05	1E-04	-1E-04	-1E-04	3E-04
S87	9.64E+15	5.56E+15	0.0195	-5E-05	-5E-05	1E-04	-2E-04	-2E-04	5E-04
S96	1.18E+16	1.03E+16	0.0128	-4E-05	-4E-05	8E-05	-2E-04	-2E-04	3E-04
S97	1.67E+16	1.17E+16	0.0129	-2E-05	-2E-05	6E-05	-1E-04	-1E-04	3E-04
S2	9.58E+14	9.78E+13	0.1686	-5E-04	-5E-04	7E-03	-2E-03	-2E-03	2E-02
S102	7.64E+14	2.44E+14	0.1008	-6E-04	-6E-04	3E-03	-3E-03	-3E-03	1E-02

Table 4: Orbital parameters of S-stars for center mass $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density = 5.83 kg/m^3 in exponential theory and relative differences to classical and GR theories.

	exp model			relative difference to CLT			relative difference to GRT		
star	a (m)	r_p (m)	v_p/c	a	r_p	v_p/c	a	r_p	v_p/c
S1	6.64E+15	3.35E+15	0.0575	-4E-04	-4E-04	1E-03	-2E-03	-2E-03	4E-03
S2	1.62E+15	1.94E+14	0.2636	-1E-03	-1E-03	2E-02	-7E-03	-7E-03	6E-02
S4	3.91E+15	2.32E+15	0.0670	-6E-04	-6E-04	2E-03	-3E-03	-3E-03	6E-03
S5	3.28E+15	5.18E+14	0.1615	-7E-04	-7E-04	7E-03	-3E-03	-3E-03	2E-02
S6	5.70E+15	6.50E+14	0.1460	-4E-04	-4E-04	6E-03	-2E-03	-2E-03	2E-02
S8	5.38E+15	9.46E+14	0.1192	-5E-04	-5E-04	4E-03	-2E-03	-2E-03	1E-02
S9	3.84E+15	6.72E+14	0.1413	-6E-04	-6E-04	5E-03	-3E-03	-3E-03	2E-02
S12	4.04E+15	4.04E+14	0.1853	-6E-04	-6E-04	9E-03	-3E-03	-3E-03	3E-02
S13	3.89E+15	1.99E+15	0.0745	-6E-04	-6E-04	2E-03	-3E-03	-3E-03	7E-03
S14	3.35E+15	1.24E+14	0.3330	-7E-04	-7E-04	3E-02	-3E-03	-3E-03	1E-01
S17	4.07E+15	2.59E+15	0.0625	-6E-04	-6E-04	1E-03	-2E-03	-2E-03	6E-03
S18	3.48E+15	8.39E+14	0.1243	-7E-04	-7E-04	4E-03	-3E-03	-3E-03	1E-02
S19	1.04E+16	1.63E+15	0.0915	-2E-04	-2E-04	2E-03	-1E-03	-1E-03	7E-03
S21	2.79E+15	6.02E+14	0.1476	-9E-04	-9E-04	6E-03	-4E-03	-4E-03	2E-02
S24	1.39E+16	9.29E+14	0.1238	-2E-04	-2E-04	4E-03	-7E-04	-7E-04	1E-02
S27	5.95E+15	2.86E+14	0.2224	-4E-04	-4E-04	1E-02	-2E-03	-2E-03	4E-02
S29	5.19E+15	4.36E+14	0.1793	-5E-04	-5E-04	8E-03	-2E-03	-2E-03	3E-02
S31	3.90E+15	2.58E+14	0.2329	-6E-04	-6E-04	1E-02	-3E-03	-3E-03	5E-02
S33	5.37E+15	1.45E+15	0.0941	-5E-04	-5E-04	3E-03	-2E-03	-2E-03	9E-03
S38	1.82E+15	3.60E+14	0.1909	-1E-03	-1E-03	1E-02	-6E-03	-6E-03	3E-02
S66	1.58E+16	1.30E+16	0.0259	-2E-04	-2E-04	3E-04	-6E-04	-6E-04	1E-03
S67	1.43E+16	9.07E+15	0.0335	-2E-04	-2E-04	4E-04	-7E-04	-7E-04	2E-03
S71	1.39E+16	2.17E+15	0.0794	-2E-04	-2E-04	2E-03	-7E-04	-7E-04	5E-03
S83	3.65E+16	1.26E+16	0.0312	-7E-05	-7E-05	3E-04	-3E-04	-3E-04	1E-03
S87	1.65E+16	9.51E+15	0.0333	-2E-04	-2E-04	4E-04	-6E-04	-6E-04	2E-03
S96	2.02E+16	1.76E+16	0.0219	-1E-04	-1E-04	2E-04	-5E-04	-5E-04	1E-03
S97	2.86E+16	2.00E+16	0.0220	-9E-05	-9E-05	2E-04	-3E-04	-3E-04	8E-04
S2	1.64E+15	1.67E+14	0.2842	-1E-03	-1E-03	2E-02	-6E-03	-6E-03	7E-02
S102	1.31E+15	4.18E+14	0.1713	-2E-03	-2E-03	9E-03	-8E-03	-8E-03	3E-02

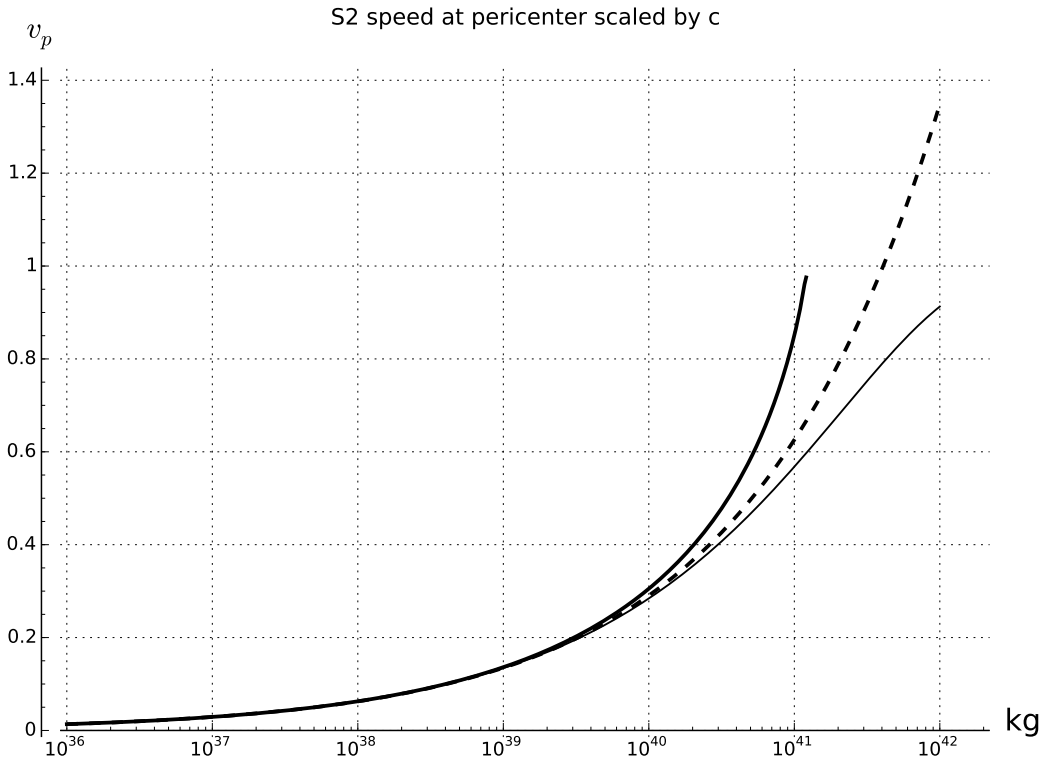

Figure 1: S2 speed at pericenter depending on the value of the central mass: dashed line for the Classical Theory, top solid line for GR, bottom line for our model.

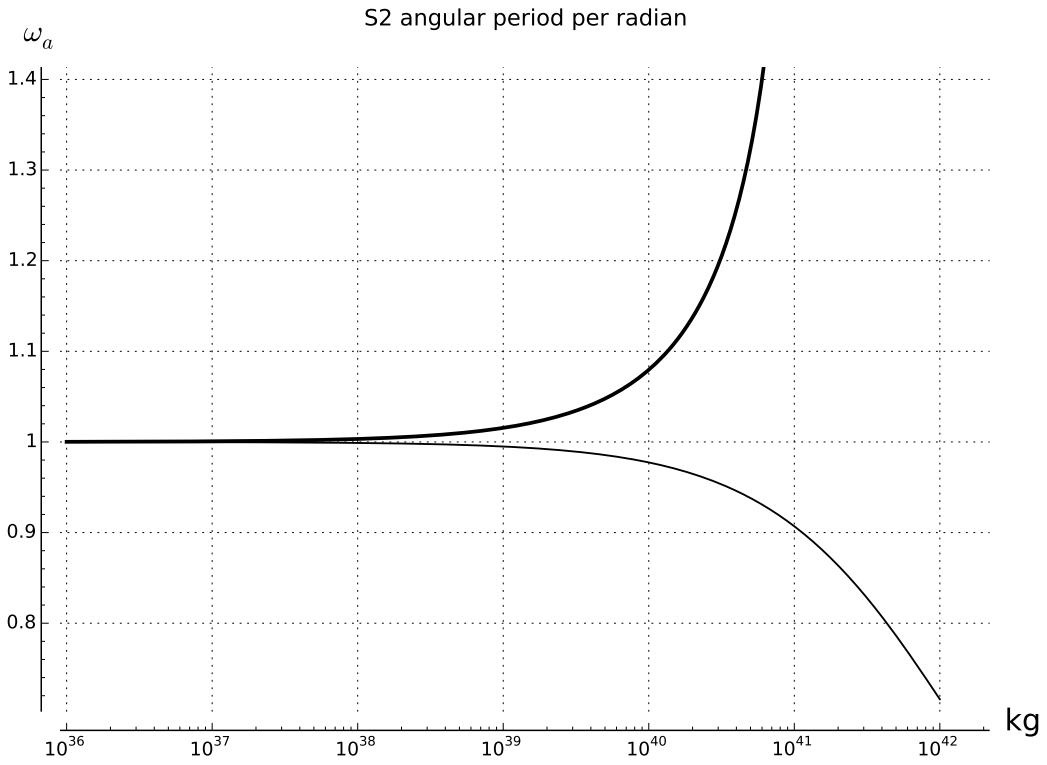

Figure 2: S2 angular period per radian: in Classical Theory it is constant 1, the top thick solid line corresponds to GR theory, thiner bottom line corresponds to our model.

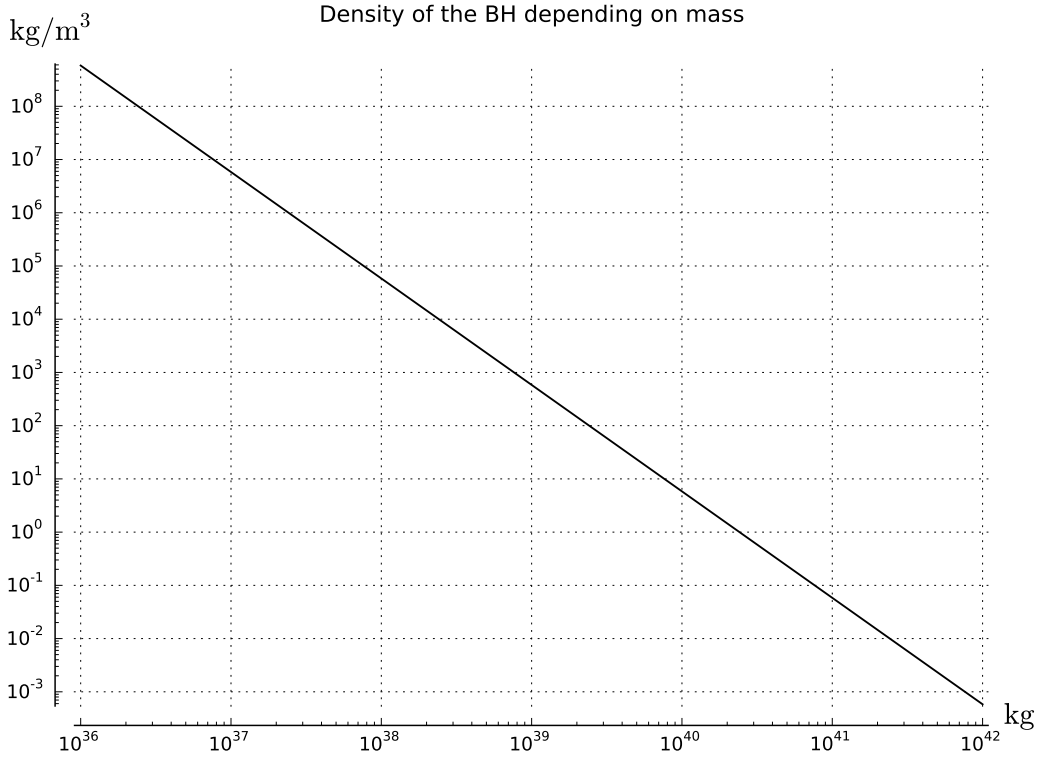

Figure 3: Central mass density

Table 5: Exponential model for $M_C = 8.57\times10^{36}$ kg, $r_g = 6.37\times10^9$ m, density $= 7.93 \times 10^6$ kg/m^3. The two last entries computed for $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density $= 8.77 \times 10^6$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.180E+14	9.438E+14	0.9999866	2.002E-05	2.995E-05	0.668
S2	1.839E+13	2.881E+14	0.9998159	3.462E-04	6.506E-04	0.532
S4	2.203E+14	5.215E+14	0.9999795	2.889E-05	4.062E-05	0.711
S5	4.915E+13	5.730E+14	0.9999297	1.295E-04	2.385E-04	0.543
S6	6.175E+13	1.022E+15	0.9999453	1.031E-04	1.944E-04	0.530
S8	8.986E+13	9.313E+14	0.9999612	7.084E-05	1.292E-04	0.548
S9	6.381E+13	6.655E+14	0.9999453	9.975E-05	1.820E-04	0.548
S12	3.833E+13	7.282E+14	0.9999126	1.661E-04	3.155E-04	0.526
S13	1.885E+14	5.508E+14	0.9999773	3.377E-05	5.031E-05	0.671
S14	1.178E+13	6.248E+14	0.9997248	5.405E-04	1.060E-03	0.510
S17	2.456E+14	5.267E+14	0.9999810	2.592E-05	3.536E-05	0.733
S18	7.960E+13	5.810E+14	0.9999545	7.997E-05	1.407E-04	0.569
S19	1.547E+14	1.828E+15	0.9999777	4.116E-05	7.590E-05	0.542
S21	5.710E+13	4.716E+14	0.9999375	1.115E-04	1.989E-04	0.561
S24	8.822E+13	2.545E+15	0.9999627	7.215E-05	1.395E-04	0.517
S27	2.714E+13	1.104E+15	0.9998799	2.345E-04	4.577E-04	0.512
S29	4.136E+13	9.433E+14	0.9999197	1.539E-04	2.949E-04	0.522
S31	2.445E+13	7.165E+14	0.9998654	2.603E-04	5.034E-04	0.517
S33	1.373E+14	8.832E+14	0.9999732	4.638E-05	8.028E-05	0.578
S38	3.419E+13	3.112E+14	0.9998967	1.862E-04	3.355E-04	0.555
S66	1.237E+15	1.772E+15	0.9999956	5.148E-06	6.064E-06	0.849
S67	8.612E+14	1.864E+15	0.9999946	7.391E-06	1.011E-05	0.731
S71	2.058E+14	2.432E+15	0.9999832	3.094E-05	5.705E-05	0.542
S83	1.199E+15	5.733E+15	0.9999968	5.307E-06	8.778E-06	0.605
S87	9.033E+14	2.228E+15	0.9999950	7.047E-06	1.003E-05	0.703
S96	1.669E+15	2.172E+15	0.9999966	3.814E-06	4.314E-06	0.884
S97	1.897E+15	3.538E+15	0.9999974	3.356E-06	4.369E-06	0.768
S2	1.561E+13	2.905E+14	0.9997957	3.879E-04	7.360E-04	0.527
S102	3.902E+13	2.049E+14	0.9999076	1.552E-04	2.607E-04	0.595

Table 6: Classical theory for $M_C = 8.57 \times 10^{36}$ kg, $r_g = 6.37 \times 10^9$ m, density $= 7.93 \times 10^6$ kg/m^3. The two last entries computed for $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density $= 8.77 \times 10^6$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.180E+14	9.438E+14	1	2.002E-05	2.995E-05	0.668
S2	1.839E+13	2.881E+14	1	3.462E-04	6.508E-04	0.532
S4	2.203E+14	5.215E+14	1	2.889E-05	4.062E-05	0.711
S5	4.915E+13	5.730E+14	1	1.295E-04	2.386E-04	0.543
S6	6.175E+13	1.022E+15	1	1.031E-04	1.944E-04	0.530
S8	8.986E+13	9.313E+14	1	7.084E-05	1.292E-04	0.548
S9	6.381E+13	6.655E+14	1	9.976E-05	1.821E-04	0.548
S12	3.833E+13	7.282E+14	1	1.661E-04	3.156E-04	0.526
S13	1.885E+14	5.508E+14	1	3.377E-05	5.031E-05	0.671
S14	1.178E+13	6.248E+14	1	5.405E-04	1.061E-03	0.509
S17	2.456E+14	5.267E+14	1	2.592E-05	3.536E-05	0.733
S18	7.960E+13	5.810E+14	1	7.997E-05	1.407E-04	0.569
S19	1.547E+14	1.828E+15	1	4.116E-05	7.590E-05	0.542
S21	5.710E+13	4.716E+14	1	1.115E-04	1.989E-04	0.561
S24	8.822E+13	2.545E+15	1	7.215E-05	1.395E-04	0.517
S27	2.714E+13	1.104E+15	1	2.345E-04	4.578E-04	0.512
S29	4.136E+13	9.433E+14	1	1.539E-04	2.949E-04	0.522
S31	2.445E+13	7.165E+14	1	2.603E-04	5.035E-04	0.517
S33	1.372E+14	8.832E+14	1	4.638E-05	8.028E-05	0.578
S38	3.419E+13	3.112E+14	1	1.862E-04	3.355E-04	0.555
S66	1.237E+15	1.772E+15	1	5.148E-06	6.064E-06	0.849
S67	8.612E+14	1.864E+15	1	7.392E-06	1.011E-05	0.731
S71	2.058E+14	2.432E+15	1	3.094E-05	5.705E-05	0.542
S83	1.199E+15	5.733E+15	1	5.307E-06	8.779E-06	0.605
S87	9.033E+14	2.228E+15	1	7.047E-06	1.003E-05	0.703
S96	1.669E+15	2.172E+15	1	3.814E-06	4.314E-06	0.884
S97	1.897E+15	3.538E+15	1	3.356E-06	4.369E-06	0.768
S2	1.561E+13	2.905E+14	1	3.879E-04	7.362E-04	0.527
S102	3.902E+13	2.049E+14	1	1.552E-04	2.607E-04	0.595

Table 7: GR theory for $M_C = 8.57 \times 10^{36}$ kg, $r_g = 6.37 \times 10^9$ m, density $= 7.93 \times 10^6$ kg/m^3. The two last entries computed for $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density $= 8.77 \times 10^6$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.958E+15	5.811E+15	0.9994933	7.586E-04	1.134E-03	0.669
S2	1.133E+14	1.774E+15	0.9930971	1.311E-02	2.435E-02	0.539
S4	1.357E+15	3.211E+15	0.9992223	1.095E-03	1.538E-03	0.712
S5	3.026E+14	3.528E+15	0.9973465	4.907E-03	8.998E-03	0.545
S6	3.802E+14	6.290E+15	0.9979351	3.907E-03	7.341E-03	0.532
S8	5.533E+14	5.734E+15	0.9985316	2.684E-03	4.884E-03	0.550
S9	3.929E+14	4.098E+15	0.9979353	3.780E-03	6.874E-03	0.550
S12	2.360E+14	4.484E+15	0.9967041	6.293E-03	1.189E-02	0.529
S13	1.161E+15	3.391E+15	0.9991424	1.279E-03	1.904E-03	0.672
S14	7.252E+13	3.847E+15	0.9897275	2.048E-02	3.941E-02	0.520
S17	1.512E+15	3.243E+15	0.9992807	9.822E-04	1.339E-03	0.734
S18	4.901E+14	3.577E+15	0.9982818	3.030E-03	5.315E-03	0.570
S19	9.521E+14	1.125E+16	0.9991552	1.560E-03	2.872E-03	0.543
S21	3.516E+14	2.904E+15	0.9976407	4.224E-03	7.507E-03	0.563
S24	5.431E+14	1.567E+16	0.9985884	2.734E-03	5.272E-03	0.519
S27	1.671E+14	6.796E+15	0.9954779	8.887E-03	1.720E-02	0.517
S29	2.546E+14	5.808E+15	0.9969698	5.832E-03	1.111E-02	0.525
S31	1.506E+14	4.412E+15	0.9949383	9.864E-03	1.890E-02	0.522
S33	8.451E+14	5.438E+15	0.9989863	1.757E-03	3.037E-03	0.579
S38	2.106E+14	1.916E+15	0.9961088	7.053E-03	1.263E-02	0.559
S66	7.613E+15	1.091E+16	0.9998344	1.951E-04	2.298E-04	0.849
S67	5.302E+15	1.148E+16	0.9997953	2.801E-04	3.831E-04	0.731
S71	1.267E+15	1.497E+16	0.9993648	1.172E-03	2.160E-03	0.543
S83	7.384E+15	3.530E+16	0.9998784	2.011E-04	3.326E-04	0.605
S87	5.561E+15	1.372E+16	0.9998124	2.670E-04	3.799E-04	0.703
S96	1.027E+16	1.337E+16	0.9998722	1.446E-04	1.635E-04	0.884
S97	1.168E+16	2.178E+16	0.9999023	1.272E-04	1.656E-04	0.768
S2	9.777E+13	1.819E+15	0.9920911	1.519E-02	2.842E-02	0.535
S102	2.444E+14	1.283E+15	0.9964025	6.077E-03	1.015E-02	0.598

Table 8: Exponential model for $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.958E+15	5.811E+15	0.9994933	7.586E-04	1.134E-03	0.669
S2	1.133E+14	1.774E+15	0.9930971	1.311E-02	2.435E-02	0.539
S4	1.357E+15	3.211E+15	0.9992223	1.095E-03	1.538E-03	0.712
S5	3.026E+14	3.528E+15	0.9973465	4.907E-03	8.998E-03	0.545
S6	3.802E+14	6.290E+15	0.9979351	3.907E-03	7.341E-03	0.532
S8	5.533E+14	5.734E+15	0.9985316	2.684E-03	4.884E-03	0.550
S9	3.929E+14	4.098E+15	0.9979353	3.780E-03	6.874E-03	0.550
S12	2.360E+14	4.484E+15	0.9967041	6.293E-03	1.189E-02	0.529
S13	1.161E+15	3.391E+15	0.9991424	1.279E-03	1.904E-03	0.672
S14	7.252E+13	3.847E+15	0.9897275	2.048E-02	3.941E-02	0.520
S17	1.512E+15	3.243E+15	0.9992807	9.822E-04	1.339E-03	0.734
S18	4.901E+14	3.577E+15	0.9982818	3.030E-03	5.315E-03	0.570
S19	9.521E+14	1.125E+16	0.9991552	1.560E-03	2.872E-03	0.543
S21	3.516E+14	2.904E+15	0.9976407	4.224E-03	7.507E-03	0.563
S24	5.431E+14	1.567E+16	0.9985884	2.734E-03	5.272E-03	0.519
S27	1.671E+14	6.796E+15	0.9954779	8.887E-03	1.720E-02	0.517
S29	2.546E+14	5.808E+15	0.9969698	5.832E-03	1.111E-02	0.525
S31	1.506E+14	4.412E+15	0.9949383	9.864E-03	1.890E-02	0.522
S33	8.451E+14	5.438E+15	0.9989863	1.757E-03	3.037E-03	0.579
S38	2.106E+14	1.916E+15	0.9961088	7.053E-03	1.263E-02	0.559
S66	7.613E+15	1.091E+16	0.9998344	1.951E-04	2.298E-04	0.849
S67	5.302E+15	1.148E+16	0.9997953	2.801E-04	3.831E-04	0.731
S71	1.267E+15	1.497E+16	0.9993648	1.172E-03	2.160E-03	0.543
S83	7.384E+15	3.530E+16	0.9998784	2.011E-04	3.326E-04	0.605
S87	5.561E+15	1.372E+16	0.9998124	2.670E-04	3.799E-04	0.703
S96	1.027E+16	1.337E+16	0.9998722	1.446E-04	1.635E-04	0.884
S97	1.168E+16	2.178E+16	0.9999023	1.272E-04	1.656E-04	0.768
S2	9.777E+13	1.819E+15	0.9920911	1.519E-02	2.842E-02	0.535
S102	2.444E+14	1.283E+15	0.9964025	6.077E-03	1.015E-02	0.598

Table 9: Classical theory for $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density $= 146$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.957E+15	5.810E+15	1	7.587E-04	1.135E-03	0.668
S2	1.132E+14	1.773E+15	1	1.312E-02	2.467E-02	0.532
S4	1.356E+15	3.210E+15	1	1.095E-03	1.540E-03	0.711
S5	3.026E+14	3.527E+15	1	4.909E-03	9.042E-03	0.543
S6	3.801E+14	6.289E+15	1	3.907E-03	7.369E-03	0.530
S8	5.532E+14	5.733E+15	1	2.685E-03	4.897E-03	0.548
S9	3.928E+14	4.097E+15	1	3.781E-03	6.900E-03	0.548
S12	2.359E+14	4.483E+15	1	6.295E-03	1.196E-02	0.526
S13	1.161E+15	3.391E+15	1	1.280E-03	1.907E-03	0.671
S14	7.250E+13	3.846E+15	1	2.049E-02	4.021E-02	0.509
S17	1.512E+15	3.242E+15	1	9.824E-04	1.340E-03	0.733
S18	4.900E+14	3.577E+15	1	3.031E-03	5.331E-03	0.569
S19	9.521E+14	1.125E+16	1	1.560E-03	2.877E-03	0.542
S21	3.515E+14	2.903E+15	1	4.225E-03	7.538E-03	0.561
S24	5.431E+14	1.567E+16	1	2.735E-03	5.286E-03	0.517
S27	1.671E+14	6.795E+15	1	8.889E-03	1.735E-02	0.512
S29	2.546E+14	5.807E+15	1	5.833E-03	1.118E-02	0.522
S31	1.505E+14	4.411E+15	1	9.866E-03	1.908E-02	0.517
S33	8.449E+14	5.437E+15	1	1.758E-03	3.043E-03	0.578
S38	2.105E+14	1.916E+15	1	7.056E-03	1.272E-02	0.555
S66	7.612E+15	1.091E+16	1	1.951E-04	2.298E-04	0.849
S67	5.302E+15	1.148E+16	1	2.801E-04	3.832E-04	0.731
S71	1.267E+15	1.497E+16	1	1.172E-03	2.162E-03	0.542
S83	7.384E+15	3.530E+16	1	2.011E-04	3.327E-04	0.605
S87	5.561E+15	1.371E+16	1	2.671E-04	3.800E-04	0.703
S96	1.027E+16	1.337E+16	1	1.446E-04	1.635E-04	0.884
S97	1.168E+16	2.178E+16	1	1.272E-04	1.656E-04	0.768
S2	9.772E+13	1.818E+15	1	1.520E-02	2.885E-02	0.527
S102	2.443E+14	1.282E+15	1	6.080E-03	1.022E-02	0.595

Table 10: GR theory for $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.957E+15	5.808E+15	1.0015256	7.590E-04	1.137E-03	0.667
S2	1.130E+14	1.771E+15	1.0216852	1.314E-02	2.538E-02	0.518
S4	1.355E+15	3.208E+15	1.0023463	1.096E-03	1.544E-03	0.709
S5	3.023E+14	3.525E+15	1.0081019	4.912E-03	9.139E-03	0.538
S6	3.800E+14	6.286E+15	1.0062789	3.909E-03	7.430E-03	0.526
S8	5.529E+14	5.730E+15	1.0044483	2.686E-03	4.926E-03	0.545
S9	3.926E+14	4.094E+15	1.0062797	3.783E-03	6.957E-03	0.544
S12	2.358E+14	4.480E+15	1.0101030	6.299E-03	1.212E-02	0.520
S13	1.160E+15	3.389E+15	1.0025884	1.281E-03	1.913E-03	0.669
S14	7.244E+13	3.843E+15	1.0329750	2.050E-02	4.197E-02	0.489
S17	1.511E+15	3.240E+15	1.0021691	9.830E-04	1.344E-03	0.731
S18	4.897E+14	3.574E+15	1.0052147	3.033E-03	5.368E-03	0.565
S19	9.518E+14	1.125E+16	1.0025486	1.560E-03	2.886E-03	0.541
S21	3.512E+14	2.900E+15	1.0071911	4.229E-03	7.610E-03	0.556
S24	5.430E+14	1.567E+16	1.0042733	2.735E-03	5.316E-03	0.514
S27	1.670E+14	6.792E+15	1.0139685	8.892E-03	1.767E-02	0.503
S29	2.545E+14	5.804E+15	1.0092714	5.836E-03	1.131E-02	0.516
S31	1.504E+14	4.408E+15	1.0156941	9.873E-03	1.948E-02	0.507
S33	8.445E+14	5.435E+15	1.0030622	1.759E-03	3.055E-03	0.576
S38	2.102E+14	1.913E+15	1.0119838	7.066E-03	1.292E-02	0.547
S66	7.611E+15	1.091E+16	1.0004973	1.951E-04	2.300E-04	0.848
S67	5.301E+15	1.147E+16	1.0006150	2.802E-04	3.835E-04	0.731
S71	1.266E+15	1.497E+16	1.0019136	1.173E-03	2.168E-03	0.541
S83	7.383E+15	3.529E+16	1.0003651	2.012E-04	3.329E-04	0.604
S87	5.560E+15	1.371E+16	1.0005636	2.671E-04	3.803E-04	0.702
S96	1.027E+16	1.337E+16	1.0003837	1.446E-04	1.636E-04	0.884
S97	1.168E+16	2.178E+16	1.0002932	1.272E-04	1.657E-04	0.768
S2	9.756E+13	1.815E+15	1.0250110	1.522E-02	2.980E-02	0.511
S102	2.438E+14	1.280E+15	1.0110652	6.093E-03	1.037E-02	0.588

Table 11: Exponential model for $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density $= 5.83$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.349E+15	9.939E+15	0.9985209	2.218E-03	3.311E-03	0.670
S2	1.939E+14	3.037E+15	0.9802277	3.831E-02	6.947E-02	0.551
S4	2.321E+15	5.493E+15	0.9977319	3.200E-03	4.487E-03	0.713
S5	5.178E+14	6.036E+15	0.9923037	1.434E-02	2.607E-02	0.550
S6	6.503E+14	1.076E+16	0.9939996	1.142E-02	2.131E-02	0.536
S8	9.464E+14	9.808E+15	0.9957258	7.846E-03	1.421E-02	0.552
S9	6.722E+14	7.010E+15	0.9940010	1.105E-02	1.996E-02	0.554
S12	4.037E+14	7.670E+15	0.9904573	1.839E-02	3.434E-02	0.536
S13	1.986E+15	5.802E+15	0.9974997	3.739E-03	5.554E-03	0.673
S14	1.241E+14	6.582E+15	0.9708387	5.986E-02	1.109E-01	0.540
S17	2.587E+15	5.548E+15	0.9979019	2.871E-03	3.906E-03	0.735
S18	8.385E+14	6.120E+15	0.9950032	8.856E-03	1.545E-02	0.573
S19	1.628E+15	1.925E+16	0.9975361	4.560E-03	8.374E-03	0.545
S21	6.016E+14	4.969E+15	0.9931520	1.234E-02	2.178E-02	0.567
S24	9.289E+14	2.680E+16	0.9958897	7.995E-03	1.533E-02	0.521
S27	2.858E+14	1.162E+16	0.9869509	2.598E-02	4.945E-02	0.525
S29	4.356E+14	9.935E+15	0.9912192	1.705E-02	3.214E-02	0.531
S31	2.576E+14	7.547E+15	0.9854182	2.883E-02	5.423E-02	0.532
S33	1.445E+15	9.302E+15	0.9970454	5.137E-03	8.852E-03	0.580
S38	3.604E+14	3.280E+15	0.9887579	2.061E-02	3.644E-02	0.565
S66	1.302E+16	1.866E+16	0.9995162	5.704E-04	6.716E-04	0.849
S67	9.067E+15	1.963E+16	0.9994019	8.190E-04	1.120E-03	0.731
S71	2.166E+15	2.561E+16	0.9981463	3.428E-03	6.301E-03	0.544
S83	1.263E+16	6.036E+16	0.9996446	5.881E-04	9.722E-04	0.605
S87	9.511E+15	2.346E+16	0.9994518	7.808E-04	1.110E-03	0.703
S96	1.757E+16	2.287E+16	0.9996265	4.226E-04	4.778E-04	0.885
S97	1.997E+16	3.725E+16	0.9997145	3.719E-04	4.840E-04	0.768
S2	1.673E+14	3.114E+15	0.9774097	4.438E-02	8.077E-02	0.549
S102	4.184E+14	2.197E+15	0.9896012	1.775E-02	2.936E-02	0.604

Table 12: Classical theory for $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density $= 5.83$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.347E+15	9.936E+15	1	2.218E-03	3.319E-03	0.668
S2	1.936E+14	3.033E+15	1	3.836E-02	7.212E-02	0.532
S4	2.319E+15	5.490E+15	1	3.202E-03	4.502E-03	0.711
S5	5.174E+14	6.032E+15	1	1.435E-02	2.644E-02	0.543
S6	6.500E+14	1.075E+16	1	1.142E-02	2.155E-02	0.530
S8	9.460E+14	9.804E+15	1	7.850E-03	1.432E-02	0.548
S9	6.717E+14	7.005E+15	1	1.105E-02	2.017E-02	0.548
S12	4.035E+14	7.666E+15	1	1.841E-02	3.497E-02	0.526
S13	1.985E+15	5.798E+15	1	3.742E-03	5.575E-03	0.671
S14	1.240E+14	6.577E+15	1	5.990E-02	1.176E-01	0.509
S17	2.585E+15	5.544E+15	1	2.873E-03	3.918E-03	0.733
S18	8.379E+14	6.116E+15	1	8.862E-03	1.559E-02	0.569
S19	1.628E+15	1.924E+16	1	4.561E-03	8.411E-03	0.542
S21	6.011E+14	4.964E+15	1	1.235E-02	2.204E-02	0.561
S24	9.287E+14	2.679E+16	1	7.996E-03	1.546E-02	0.517
S27	2.857E+14	1.162E+16	1	2.599E-02	5.073E-02	0.512
S29	4.354E+14	9.930E+15	1	1.706E-02	3.268E-02	0.522
S31	2.574E+14	7.543E+15	1	2.885E-02	5.579E-02	0.517
S33	1.445E+15	9.297E+15	1	5.140E-03	8.897E-03	0.578
S38	3.599E+14	3.275E+15	1	2.063E-02	3.718E-02	0.555
S66	1.302E+16	1.865E+16	1	5.705E-04	6.720E-04	0.849
S67	9.066E+15	1.962E+16	1	8.191E-04	1.121E-03	0.731
S71	2.166E+15	2.560E+16	1	3.428E-03	6.322E-03	0.542
S83	1.263E+16	6.036E+16	1	5.882E-04	9.728E-04	0.605
S87	9.509E+15	2.345E+16	1	7.809E-04	1.111E-03	0.703
S96	1.757E+16	2.286E+16	1	4.227E-04	4.781E-04	0.884
S97	1.997E+16	3.725E+16	1	3.719E-04	4.842E-04	0.768
S2	1.671E+14	3.109E+15	1	4.444E-02	8.435E-02	0.527
S102	4.177E+14	2.193E+15	1	1.778E-02	2.987E-02	0.595

Table 13: GR theory for $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density $= 5.83$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.343E+15	9.924E+15	1.0044842	2.221E-03	3.339E-03	0.665
S2	1.926E+14	3.017E+15	1.0682010	3.856E-02	7.857E-02	0.491
S4	2.315E+15	5.479E+15	1.0069168	3.208E-03	4.543E-03	0.706
S5	5.162E+14	6.018E+15	1.0243242	1.439E-02	2.729E-02	0.527
S6	6.491E+14	1.074E+16	1.0187328	1.144E-02	2.208E-02	0.518
S8	9.446E+14	9.790E+15	1.0131957	7.861E-03	1.457E-02	0.540
S9	6.704E+14	6.991E+15	1.0187416	1.108E-02	2.068E-02	0.536
S12	4.027E+14	7.651E+15	1.0305203	1.844E-02	3.638E-02	0.507
S13	1.981E+15	5.787E+15	1.0076362	3.749E-03	5.632E-03	0.666
S14	1.237E+14	6.560E+15	1.1077995	6.005E-02	1.340E-01	0.448
S17	2.580E+15	5.534E+15	1.0063907	2.878E-03	3.951E-03	0.728
S18	8.361E+14	6.103E+15	1.0155125	8.881E-03	1.591E-02	0.558
S19	1.627E+15	1.923E+16	1.0075133	4.565E-03	8.495E-03	0.537
S21	5.994E+14	4.951E+15	1.0215321	1.239E-02	2.267E-02	0.546
S24	9.282E+14	2.678E+16	1.0126644	8.000E-03	1.572E-02	0.509
S27	2.853E+14	1.160E+16	1.0427174	2.602E-02	5.359E-02	0.486
S29	4.347E+14	9.916E+15	1.0279270	1.708E-02	3.389E-02	0.504
S31	2.569E+14	7.527E+15	1.0482872	2.891E-02	5.934E-02	0.487
S33	1.443E+15	9.284E+15	1.0090449	5.147E-03	9.004E-03	0.572
S38	3.584E+14	3.261E+15	1.0364695	2.072E-02	3.897E-02	0.532
S66	1.301E+16	1.865E+16	1.0014567	5.707E-04	6.733E-04	0.848
S67	9.061E+15	1.961E+16	1.0018021	8.195E-04	1.123E-03	0.730
S71	2.165E+15	2.559E+16	1.0056297	3.430E-03	6.369E-03	0.539
S83	1.262E+16	6.034E+16	1.0010688	5.883E-04	9.742E-04	0.604
S87	9.505E+15	2.344E+16	1.0016512	7.812E-04	1.114E-03	0.702
S96	1.756E+16	2.286E+16	1.0011235	4.229E-04	4.788E-04	0.883
S97	1.996E+16	3.724E+16	1.0008582	3.720E-04	4.848E-04	0.767
S2	1.662E+14	3.093E+15	1.0795747	4.467E-02	9.312E-02	0.480
S102	4.152E+14	2.180E+15	1.0336032	1.789E-02	3.120E-02	0.573

C.2 Final note

The Milky Way observations are very well consistent with the GU Model predictions of the existence of matter-antimatter TUs and their evolution. The scenario of Milky Way state of destruction during the two TUs collision explains many puzzles and mysteries appeared from the observations.

It is emphasized that the treatment of a huge observational data base and search for the most likely variants of explanations of the Milky Way history and its future, as well as a treatment of observations beyond our galaxy in order to understand the GU numerous features require a significant resources of researchers and time. Potentially, such a collective work must bring more insights into Pristine Nature of the observable physical world and human mind capacity to comprehend it in the common inquiring language of Natural Sciences and Philosophy.