Cosmological distance scale. Part 17: Coincidence of coincidences

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Published online: 20 March 2024

Abstract

The article considers an alternative interpretation of data that were used to conclude the accelerated expansion of the universe in 1998–1999. This interpretation was prompted by doubts as to whether the neglect of the local void effect is justified, as well as by several results obtained when solving the measurement problems of cosmology using the specialized programs MCM-stat, MCM-stat M, and MMI-verification. The programs are designed to automate the statistical analysis of data in the verification and calibration of measuring instruments. The first two programs were applied in the structural and parametric identification of isotropic and anisotropic Friedmann-Robertson-Walker models, respectively, in the form of a relationship between the photometric distance and the redshift of Type Ia supernova in the class of power series. This dependence was analyzed as a mathematical model of the redshift cosmological distance scale. As a physical mechanism underlying the massive accelerated movement of galaxy streams, the study adopted the gravitational dipole of inhomogeneity of the large-scale structure of the universe. A dipole of this kind consists of a pair of superclusters and a supervoid on opposite sides of the celestial sphere. The uneven gravitational interaction in such a pair is perceived as an additional repulsive force of an order comparable to the effect of a supercluster. At least five gravitational dipoles of this kind are shown to exist, concentrating in the region of Galactic poles and forming a giant Galactic polar gravitational dipole. The coincidence of the Galactic polar gravitational dipole and the system of giant superclusters of galaxies in the northern Galactic hemisphere and the system of supervoids in the southern Galactic hemisphere is called the coincidence of coincidences; this fact is considered as a hypothesis alternative to the that about the accelerated expansion of the universe. However, in order to explain the observed facts, it is not necessary to introduce the exotic concepts of dark matter and dark energy.

Keywords Redshift · SNe Ia · Cosmological distance scale · Structural change · Change point · Rank inversion · Superclusters · Supervoid · Gravitational inhomogeneity dipole · Hubble dipole

Translated from Izmeritel'naya Tekhnika, No. 10, pp. 10–16, October 2023. Russian DOI: https://doi.org/10.32446/0368-1025it.2023-10-10-16

Original article submitted 08/30/2023. Accepted 09/13/2023

Introduction

The year 1998 was marked by three events significant for the theory of measurement problems.

First, RRT 507-98[1] clarified the terms direct, indirect, and joint measurements, as well as measurements in a closed series, from GOST 16263-70[2] in accordance with GOST 8.061-80[3] (clause 3.5) as methods for solving measurement problems by adding the word "method" without any loss of meaning, which helped to mathematically define the term inadequacy error.[4]

Second, the program of multivariate statistical analysis MCM-stat M [1] was developed and tested for the first time; its prototype was the universal program MCM-stat designed for the identification of interpretive models in the class of single-argument functions [2]. The criterion for selecting models of optimal complexity according to Andrey Kolmogorov was common in these programs—inadequacy error minimum.

Third, the problem of the structural and parametric identification of the four-dimensional logarithmic Hubble diagram for the redshift of 383 radio galaxies and quasars was solved for the first time when testing the MCM-stat M program as a function of equatorial coordinates, angular sizes, and stellar magnitudes as per [3]. It was found that for radio galaxies and quasars, the characteristics of the dipole anisotropy of redshift in the emission spectra not only coincide with the orientation of the Galactic polar axis but are opposite to the orientation of the maxima. This fact revealed a number of unexpected cosmological coincidences [4], which added to the list of unexpected results [5]. The choice of reference data [3] for testing the MCM-stat M program was prompted by the fact that the earlier statistical analysis of these data in the construction of a standard Hubble diagram as a dependence of the observed magnitudes of objects on their redshift was used to illustrate the applicability of the classical linear regression analysis [6].

In 1999, Prof. Vladimir Braginsky drew attention to unexpected coincidences observed for radio galaxies and quasars during the 10th Gravity Conference [7] and recommended continuing these studies.

In 2009, it was found [8] that the anisotropy centers of cosmic microwave background (CMB) [9] and redshift for radio galaxies and quasars are in the background of the large-scale structure formations of the universe. Such formations were superclusters of over 2500 galaxies in the constellation of Virgo in the $16°\times10°$ sector (Virgo Supercluster) and clusters of over 800 galaxies in the constellation of Coma Berenices in a 4° diameter region (Coma Berenices cluster). Large-scale galaxy streams to the Virgo Supercluster and to the Great Attractor in the constellation of Centaurus were observed back in the 1980s (see [10] for details). Alan Dressler called such centers attractors [11]. In addition, by 1993 it was known that relative to the CMB, the Sun was moving toward the border between the constellations of Leo and Crater ($\alpha = 11^h9^m$; $\delta = -6°40'$). This direction was reported by Marc Gorenstein and George Smoot [12].

In 2010, the segmentation of the celestial sphere into quadrants using the moving boundary method as per to the criterion of maximum inadequacy error helped to identify right ascension sectors in opposite directions: $\alpha = (0\pm3;\ 12\pm3)^h$ for radio galaxies and sectors $\alpha = (9\pm3;\ 21\pm3)^h$ for quasars [13]. The sectors for radio galaxies included the CMB dipoles, while the sectors for quasars included the redshift dipole maximum and the CMB antiapex. However, in addition to the anisotropic dipoles, these sectors included the superclusters of galaxies in the constellations of Leo, Virgo, and Centaurus—Leo Supercluster, Virgo Supercluster, and Centaurus Supercluster. The opposite sectors comprised supervoids in the constellations of Aquarius, Eridanus, and Cetus—Aquarius Supervoid, Eridanus Supervoid,[5] and Cetus void.

[1] RRT 507-98. GSI. Measurement Problems. Solution Methods. Terms and Definitions.

[2] GOST 16263-70. GSI. Metrology. Terms and Definitions.

[3] GOST 8.061-80. GSI. Hierarchy Schemes. Scope and Layout.

[4] For more details see. R 50.2.004-2000. GSI. Determination of Characteristics Defining the Mathematical Models of Dependences between Physical Quantities in the Solution of Measurement Problems. Basic Provisions.

[5] Eridanus Supervoid was discovered on August 23, 2007 by Lawrence Rudnik's group from the University of Minnesota as a cold spot of the cosmic microwave background detected by the WMAP satellite; it constitutes a supervoid having a diameter of about two billion and a depth of about 10 billion light years.

 https://doi.org/10.1007/s11018-024-02287-0

More accurate results were yielded by the dipole test on redshift [14]. In terms of right ascension, the maximum redshift for the quasars coincided with the giant Eridanus Supervoid and Cetus void at $\alpha \approx 2.6^h$, while the minimum coincided with the direction to the Virgo Supercluster and Centaurus Supercluster at $\alpha \approx 14.6^h$. A similar coincidence was also observed for radio galaxies, with the maximum at $\alpha \approx 22.1^h$ (Aquarius Supervoid) and minimum at $\alpha \approx 10.1^h$ (Leo Supervoid). The apex of the Sun's motion relative to the CMB was found to lie in the Leo Supercluster ($\alpha = 10^h23^m$–11^h34^m; $\delta = \pm 28°42'$), while Aquarius Supervoid ($\alpha = 20^h32^m$–23^h50^m; $\delta = -25°30'$–$+2°45'$) is located in the opposite direction.

The "supercluster-supervoid" pairs on opposite sides of the celestial sphere are referred to in [15] as inhomogeneity dipoles. The directrix of interaction in such a pair exhibits a gravitational imbalance, perceived as an additional repulsion by the supervoid. Subsequently, a more accurate name was given to this phenomenon-"gravitational inhomogeneity dipole."

On April 4, 2013, theoretical physicist Roger Penrose gave a lecture on the Big Bang at the Bauman Moscow State Technical University. The present author asked him to comment on the unexpected cosmological results and coincidences. Sir Roger Penrose started to answer, but there was a sudden hesitation. As Prof. Yu. Vladimirov noticed at that time, some cosmological terms were omitted in the simultaneous interpretation. Using carefully selected Russian words that are close in meaning, the present author clarified the question. Equally unexpected was Roger Penrose's response that he was not authorized to comment on the results of other researchers.

This hesitation was apparently prompted by a paper [16] published at the end of 1998 (a momentous year for the theory of measurement problems). In the specified paper, a conclusion was made on the accelerated expansion of the universe according to the Friedmann-Robertson-Walker isotropic model as the dependence of photometric distance on redshift for 37 Type Ia supernovae (SNe Ia). However, the authors [16] neglected the local void effect [17]—the accelerated motion of objects from the void toward the more massive surroundings. This phenomenon leads to the overestimation of the expansion rate in the estimation of the local Hubble constant. The debate on this issue continues.

In 1987, Brent Tully and Rick Fischer [18] discovered the Local Void at a distance of 23 Mpc centered at ($\alpha = 18^h38^m$; $\delta = +18°$), while in 2013, the KBC Void [19] was discovered: a giant spherical void having a diameter of about two billion light years, whose center is located several hundred million light years away from our galaxy. The KBC Void includes the Local Group and most of the Laniakea Supercluster, exceeding the Eridanus Supervoid in size. It was the KBC Void that predetermined the discrepancy between the Hubble constant estimates using galactic SNe Ia and cepheids [20] and CMB measurement data [21]. Therefore, the question about the unexpected results and coincidences expressed a clear doubt about the accelerated expansion of the universe and even a doubt about the Big Bang hypothesis.

Another reason for doubt was given by Brian Schmidt, head of the High-Z SN Search Team, in his Nobel lecture [22]: "In discussions ... with members of the SCP[6] in 1996, it became clear we were both grappling with how to deal with these statistical issues—it wasn't that they hadn't been solved by science, it was just that we were in new territory for us, and we were struggling to figure out a solution. Adam Riess, who had become adept at statistics in his thesis, ... came up with the solution of converting χ^2 to a probability ... It seems so passé now, but in 1996, none of us had ever seen this technique used before in astronomy."

So arose the question of the present author about the correctness of applying statistical methods in cosmology, posed in [23, 24] immediately following the publication of [16, 25]. One of the reasons was the careless application of the weighted least squares method.[7] It is surely possible to be unaware of the details regarding the emergence of the χ^2 minimum method in the middle of the last century. However, it would be helpful to

[6] SCP—Supernova Cosmology Project, the name of another group of cosmologists headed by Saul Perlmutter.

[7] A more complete list of applicability conditions for statistical methods and the consequences of their violation is given in [5] on the examples of cosmology problems.

know that the weighted average variance is less than the smallest variance among the summands, which can create the illusion of highly accurate results due to carelessness.

The article aims to analyze further extension of the list of unexpected cosmological coincidences [4].

Anisotropy as a violation of isotropy

Initially, the MCM-stat and MCM-stat M programs were used to solve measurement problems involved in the structural and parametric identification of the calibration characteristics of measuring instruments, which are functions inverse to the transformation functions of measuring instruments [26] as defined in GOST 8.009-84[8] (clause 2.1.1). The calibration characteristic enables the conversion of the output signal of the measuring transducer into the measurand value. A similar solution was found to the problem of identifying the dependence of the photometric distance $D_L(z)$ on the measured redshift for SNe Ia [16]. This is a typical graduation (calibration) problem solved using the method of joint measurements but with respect to the cosmological distance scale, whose mathematical model plays the role of a measurement transformation that implements the method of indirect measurement.

The MCM-stat and MCM-stat M programs identify isotropic and anisotropic photometric distance models, respectively, for the same reference points of the scale—SNe Ia. In addition to redshift, the anisotropic models include the angular coordinates of SNe Ia as input variables, which always yields a more accurate result as compared to isotropic models, even when taking change points into account[9] [27].

An odd coincidence was noted in 2016. While in the isotropic model of the photometric distance scale, the change point is accompanied by a rank inversion of SNe Ia,[10] in the anisotropic model, the angular coordinates of these supernovae at the boundaries of the change point intervals correspond to the directrices of gravitational inhomogeneity dipoles [28]. Prior to the discussion about the impasse in cosmology, which was initiated by the groups of Adam Riess [20] and Wendy Freedman [29] in connection with the discrepancy in Hubble constant estimates [20, 21], this coincidence was seen as accidental. Wendy Freedman believed that in order to resolve this situation, it was sufficient to increase the accuracy of extragalactic distance scale estimation to 1% [30]. However, the emergence of the impasse in cosmology is associated with what is called disregard for the inadequacy errors of mathematical models in the problems related to the applicability of statistical methods.

In 2016–2017, the group of Brent Tully performed large-scale simulations of the gravitational velocity field drawing on the Cosmicflows-3 compilation of 17,669 galaxy distances and discovered an attraction zone and two repeller basins [31]: one basin of repulsion (Dipole Repeller) is located near the antapex of the cosmic microwave background dipole (CMB Dipole$^-$) ($\alpha = 23^h9^m14^s$; $\delta = +6°40'20.4''$) in the constellation of Pisces, and the other is located in the direction nearest to the CMB Cold spot.[11]

Subsequently, the group of Brent Tully confirmed the position of the "Shapley Attractor–CMB Dipole$^-$" [32] inhomogeneity dipole as an extension of the Shapley Supercluster and ascertained the position of the Dipole Repeller in the constellation of Andromeda (with the nearest void, Pegasus Void, found at 33° in the constellation of Pegasus). The second repeller is reported as the Cold Spot Repeller in the direction of the Eridanus Super Void in the constellation of Eridanus. These data were consistent with those obtained in 2010–2014 [5, 13–15, 33], which is noted in [34].

In 2019, an analysis of the isotropic cosmological distance scale model for the SNe Ia used in the detection of the accelerated expansion of the universe [16, 25] showed that the deviations of SN Ia distance estimates

[8] GOST 8.009-84. GSI. Standardized Metrological Characteristics of Measuring Instruments.

[9] Change point is a violation of model continuity (see R 50.2.004-2000, clause 6.5).

[10] Rank inversion is a violation of monotonicity in a sequence of distance redshifts.

[11] The constellations of Pisces and Cetus contain the vast Pisces-Cetus void ($\alpha = 0^h$–2^h; $\delta = +5°$–$+15°$), and the constellation of Aquarius includes the Aquarius Supervoid ($\alpha = 20^h32^m$–23^h50^m; $\delta = -25°30'$–$+2°45'$).

 https://doi.org/10.1007/s11018-024-02287-0

from the position characteristic as a function of distance are multiplicative in nature [35]; toward the range limit of photometric distances, these deviations exceeded the requirements [30] by at least an order of magnitude.

The possibility of a significantly simpler way to detect gravitational inhomogeneity dipoles was also confirmed by a statistical analysis of the Hubble Deep and Ultra Deep Field data [36]. A total of five gravitational dipoles were identified.

Coincidence of coincidences

A question inevitably arises about the physical meaning of the relationship between the anisotropy of the mathematical model representing the cosmological distance scale, the change points of the isotropic model, and the gravitational dipoles of the large-scale inhomogeneity of the universe. In other words, it is a question of the relationship between the redshift anisotropy of the SNe Ia studied in [16, 25] and gravitational inhomogeneity dipoles in terms of discrepancies in Hubble constant estimation, which prompted the discussion about the impasse in cosmology.

Let us revisit the events of 1998. The first item in the list of unexpected cosmological coincidences for radio galaxies and quasars is the coincidence of the extremums of anisotropic dipoles in their redshift with the centers of galactic transparency windows. Subsequently, the CMB anisotropy and deceleration parameter dipoles were also added to this list. The most surprising addition to the specified list is the red-violet dipole of the Local Group [4], which includes the Milky Way.

The fact is that 167 Local Group galaxies with redshift in the emission spectrum are evenly clustered in the constellations of Canes Venatici, Coma Berenices, Virgo, and Centaurus toward the North Galactic Pole P_N. Thirty-seven galaxies of the Local Group with violet shift are stretched out into a horseshoe shape in the constellations of Andromeda, Camelopardalis, Ursa Major, Draco, and Pegasus with the center on the border of the constellations of Virgo and Leo [37], i.e., almost at the North Galactic Pole P_N in the constellation of Coma Berenices. This means that relative to the Earth observer, the galaxies of the Local Group move in opposite directions, which coincide with the orientation of the Galactic polar axis.

The situation becomes clearer when we consider the distribution of gravitational inhomogeneity dipoles (GR Dipole) across the celestial sphere, assuming GR Dipole- (by analogy with CMB Dipole$^-$) corresponds to a smaller average redshift; GR Dipole$^+$, to a higher redshift.

All five GR Dipoles$^-$, CMB Dipole$^-$, and South Galactic Pole P_S are located in the region formed by a system of supervoids: Eridanus Supervoid, Fornax Void, Perseus-Pisces Void, Pisces-Cetus Void, and Aquarius Supervoid ($\alpha = 20^h32^m–3^h30^m$; $\delta = –36°–+12°$)—Southern Polar super giant supervoid. All five GR Dipoles$^+$, CMB Dipole$^+$, and the North Galactic Pole P_N are located in the region formed by a system of superclusters: Shapley, Virgo, Vela, Coma, Hydra, Great Attractor, and Leo—Northern Polar super giant supercluster. This giant pair of large-scale formations of the structure of the universe constitutes the Polar Super Dipole. To this should be added the red-violet dipole in the Local Group, as well as the fact that the change points of the isotropic Friedmann-Robertson-Walker model and the rank inversions of data [16, 25, 38, 39] coincided with the cosmic jerks predicted in these works.

This truly is a coincidence of coincidences.

Conclusion

The possibility of neglecting the local void effect justified in [17] led to the conclusion about the existence of accelerated expansion of the universe [16]. The authors of [17] described this effect manifested as excess redshift, indicating that it can be detected using MLCS[12] and by fitting the template of an SN Ia visual light curve. The work [17] notes that if an overestimated expansion rate is mistakenly adopted as the global value, a false impression may be created of an increase in the expansion rate of the low-redshift SN Ia sample as compared to the expansion rate of the high-redshift SN Ia sample. It is also indicated that only a small part of the nearest sample used in [17] is within the Local Void.

A total of 44 SNe Ia were analyzed in [17], with distances derived from the shape of the light curve with the error not exceeding 6%. Assuming $\Omega_M = 1$ and $\Omega_\Lambda = 0$, the most significant detected deviation from Hubble's law is the outward flux of (6.5±2.2)%, which could be created by some void surrounded by a dense shell roughly coinciding with the local Great Walls: the density of matter inside it is about 20% less than the density of the shell. This is a specific object—Local Void centered in the constellation of Hercules ($\alpha = 18^h38^m$; $\delta = +18°0'$).

However, the work [17] was completed prior to the discovery of the gravitational inhomogeneity dipoles of the large-scale structure and the KBC Void [19]. This vast, relatively empty region of space contains the Local Group and most of the Laniakea Supercluster, significantly exceeding the Eridanus Supervoid and even the Giant Void in size. The repulsion effect is mostly associated with the KBC Void.

Another important point is that the Milky Way lies in the KBC Void having a diameter of about two billion light years, a few hundred million light years from its center.

In addition, studies using the MLCS and template fitting methods [17] excluded the unclassified supernova SN 1997ck from consideration and noted that the void would have been greater if a single outlier had been removed from the sample. However, this outlier was actually SN 1997ck at a redshift of $z = 0.97$ [16].

Thus, the local void effect, the neglect of which was justified in [17], was found to be considerably more significant, while the red-violet dipole was found to be a consequence of the Local Group deformation resulting from the differently accelerated movement of its members (located at different distances from its giant attractor) under the action of the gravitational Polar Super Dipole, with the colossal sizes and void depths of the Southern Polar super giant supervoid.

From this perspective, the coincidences of coincidences listed in the article can be considered as the basis for a hypothesis alternative to that about the accelerated expansion of the universe but without introducing exotic concepts of dark matter and dark energy.

Conflict of interest The author declares no conflict of interest.

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