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FUNDAMENTAL PROBLEMS OF METROLOGY

COSMOLOGICAL DISTANCE SCALE. PART 16: HUBBLE DIPOLE

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The paper considers significant cosmological events that occurred in 2007: the reason for discrepancies in Hubble constant estimates was established; the galactic polar redshift anisotropy within the spectra of extragalactic sources was indicated; a cold spot of cosmic microwave background was detected; the so-called extraordinary evidence of the accelerated expansion of the universe was obtained. This evidence is based on analyzing data on Type Ia supernovae belonging to the Hubble Deep and Ultra Deep Fields. A chain of results is described that led to an alternative hypothesis — acceleration of large-scale galactic flows under the action of the gravitational dipoles of large-scale inhomogeneity of the universe in the form of "giant void–massive supercluster" pairs on opposite sides of the celestial sphere. The author presents the results of testing (for inadequacy) the Friedmann–Robertson–Walker isotropic model of the calibration function of the cosmological redshift distance scale adopted in this extraordinary evidence. It is shown that structural changes and rank inversions of the isotropic model are interpreted as the action of gravitational dipoles due to the existence of a more accurate anisotropic model of the calibration function of the cosmological redshift distance scale. This hypothesis is an alternative to that about the accelerated expansion of the universe. It is shown that the Hubble Deep and Ultra Deep Fields are a gravitational dipole — Hubble dipole.
Keywords: *redshift, supernovae, SNe Ia, cosmological distance scale, change point, rank inversion, supercluster, giant void, gravitational inhomogeneity dipole, Hubble dipole.*

Introduction. The year 2007 was marked by several important events in the field of cosmology. According to observations under the HST Key Project within (10–20)^{o}, McClure and Dyer showed that at a redshift of $z < 0.08$, discrepancies in the estimates of the Hubble constant $\Delta H_0 = 9$ km·s^{-1}·Mpc^{-1} obtained by different research groups result from the honeycomb nature of the large-scale structure of the universe [1].

Dominik Schwarz and Bastian Weinhorst [2] obtained a similar result and, using data on Type Ia supernovae (SNe Ia), identified a χ^2-test significant Hubble diagram asymmetry at $z < 0.02$ with the maximum close to the orientation of the equatorial system. They believe that the evidence for the accelerated expansion of the universe is derived from indirect reasoning and is based on several untested hypotheses, as well as that a model-independent test fails to detect a statistically significant acceleration of the universe. Therefore, it is too early to consider the accelerated expansion of the universe as self-evident; it largely relies on a priori assumptions about the ΛCDM model [2].

On August 23, 2007, Lawrence Rudnik′s group from the University of Minnesota compared the cold spot of the cosmic microwave background (CMB) detected by the WMAP satellite at the point with the equatorial coordinates $\alpha = 03^h15^m05^s$; $\delta = -19^o35'02''$ with data from the National Radio Astronomy Observatory [3]. As a result, a giant void having a depth of about 10 billion light years — Eridanus Supervoid — was discovered in the constellation Eridanus [3].

The key 2007 cosmology event was a statement made by the High-Z SN Search Team. In [4], Adam Riess notes: "They allowed us to rule out gray dust and evolution and to clearly determine that the universe was decelerating before it began accelerating." This evidence, which Adam Riess called *extraordinary* in his Nobel lecture [5], was obtained from high-redshift extragalactic supernovae in the Hubble Deep and Ultra Deep Fields (HDF and HUDF). These are celestial

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areas having a diameter of a few angular minutes in the constellations Ursa Major at ($\alpha = 12^h36^m49.4^s$; $\delta = +62^o12'58''$) and Fornax at ($\alpha = 3^h32^m39^s$; $\delta = -27^o47'29.1''$) located in the region of the galactic poles.[1]

Due to the absence of foreground bright stars in these regions, the sample of 79 SNe Ia at $0.018 \le z \le 0.970$ [6, 7] with refined photometric distances is increased by 41 SNe Ia at $0.216 \le z \le 1.755$ [4].

The paper aims to interpret data on 41 SNe Ia in Hubble fields as the basis of *extraordinary evidence* for the accelerated expansion of the universe resulting from a cosmic jerk.

Gravitational dipoles of inhomogeneity. In 2009, a possible concrete explanation emerged for the dipole anisotropy of the redshift of radio galaxies and quasars discovered in 1998 [8], i.e., a connection with two giant formations of the large-scale structure of the universe [9]: a supercluster of over 2500 galaxies in the constellation Virgo in the $16^o \times 10^o$ sector; a cluster of over 800 galaxies in the constellation Coma Berenices in a 4^o diameter region.

In 2010, the redshift anisotropy of radio galaxies and quasars was linked via right ascension to "supercluster–giant void" pairs and CMB Dipole$^-$ or CMB Dipole$^+$ in sectors having a 12^h difference [10]. For radio galaxies: "$\alpha = (\mathbf{0} \pm 3)^h \to$ Aquarius Supervoid + Cetus Supervoid + Eridanus Supervoid, CMB Dipole$^-$;" "$\alpha = (\mathbf{12} \pm 3)^h \to$ Leo Supercluster + Virgo Supercluster + Centaurus Supercluster, CMB Dipole$^+$." For quasars: "$\alpha = (\mathbf{9} \pm 3)^h \to$ Leo Supercluster + Virgo Supercluster + Centaurus Supercluster, redshift Dipole$^+$; $\alpha = (\mathbf{21} \pm 3)^h \to$ Aquarius Supervoid + Cetus Supervoid + Eridanus Supervoid, redshift Dipole$^-$."

More accurate results on right ascension were yielded by the dipole test on diurnal harmonic: for the redshift of quasars — maximum at $\alpha \approx 2.6^h$ of "Eridanus Supervoid + Cetus Supervoid" and minimum at $\alpha \approx 14.6^h$ of "Virgo Supercluster + Centaurus Supercluster"; for the redshift of radio galaxies — maximum at $\alpha \approx 22.1^h$ of "Aquarius Supervoid" and minimum at $\alpha \approx 10.1^h$ of "Leo Supercluster" [11]. In addition, with respect to the CMB, the solar apex is located at the border of the constellations Leo and Crater,[2] with the following superclusters found in the same region of the celestial sphere: Shapley Supercluster, Virgo Supercluster, Vela Supercluster, Coma Supercluster, Hydra Supercluster, Great Attractor, as well as Leo Supercluster, a supercluster of galaxies and quasars that exceeds them in size [13]. In the same direction is the minimum of a cosmic muon flux. The solar antapex corresponds to the CMB temperature minimum in the constellation Aquarius and the maximum of the cosmic muon flux in the constellation Eridanus in the region with reduced temperature of background radiation; the Eridanus Supervoid having a transverse size of up to 3 Gpc is found there [13].

Thus arose the idea that the Milky Way is also moving in the direction of the North Galactic Pole toward a system of superclusters, leaving behind a giant system of voids "Eridanus Supervoid + Cetus Supervoid + Aquarius Supervoid" at ($\alpha = 21^h55^m$–04^h55^m; $\delta = -25^o30'$–$+2^o45'$) in the direction of the South Galactic Pole.

In 2012, the dipole anisotropy of the Hubble constant was considered along the axis from giant voids in the constellations Aquarius and Eridanus to the largest known superclusters of galaxies in the universe: "Eridanus Supervoid + Cetus Supervoid + Aquarius Supervoid" → "Great Attractor, Leo Supercluster, Coma Supercluster, Virgo Supercluster, etc." [14]. In 2013, it was also found that the anisotropic dipoles of the CMB, the Hubble constant, and the deceleration parameter coincide with the same axis and the "South Galactic Pole → North Galactic Pole" axis. The system along this common axis can be called a *dipole of inhomogeneity*. The Galaxy movement in this direction is accompanied by its rotation around the axis and is similar to the swirling of water at the gutter drop outlet [15, 16].

Thus emerged a list of unexpected coincidences [17] — a hypothesis about the *gravitational dipoles of inhomogeneity*, sources of unsteady gravity as the cause of large-scale galactic flows. At the top of the list is the galactic polar gravitational dipole "Eridanus — Cetus — Aquarius super void → Shapley — Centaurus — Leo — Coma — Virgo Supercluster" with a red-violet dipole in the Local Group.

A specific alternative to the accelerated expansion of the universe resulting from the cosmic jerk was a hypothesis about the gravitational dipole of inhomogeneity of the large-scale structure of the universe [10, Table 7], which is based on a giant void in the constellation Eridanus with the center at ($\alpha = 3^h11^m$; $\delta = -20^o37'$). Superclusters closest to the opposite celestial point ($\alpha = 15^h11^m$; $\delta = +20^o37'$) are as follows: a supercluster in the constellation Virgo — arc ($\alpha = 12^h13.8^m$–$12^h43.9^m$; $\delta = -3^o48'$–$+18^o11'$) with the M87 giant elliptical galaxy in the center ($\alpha = 12^h30^m49.42^s$; $\delta = +12^o23'49.04''$) of a supercluster in the constellation Hercules centered at ($\alpha = 16^h05^m15^s$; $\delta = +17^o44'55''$) and in the constellation Coma Berenices centered at ($\alpha = 12^h59^m48.7^s$; $\delta = -27^o58'50''$) about 3^o from the P_N.

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[1] Equatorial coordinates of epoch J1950.0 (α is the right ascension, δ is the declination): the North Galactic Pole P_N ($\alpha = 12^h40^m$; $\delta = +28^o$) in the constellation Coma Berenices, South Galactic Pole P_S ($\alpha = 0^h40^m$; $\delta = +28^o$) in the constellation Sculptor.

[2] The Sun is moving at 369.82 ± 0.11 km/s toward the CMB Dipole$^+$ at ($\alpha = 11^h9^m$; $\delta = -6^o40'$) [12].

In November 2013, a massive flat structure of galaxies measuring over 10 × 7.2 billion light years with a depth of 900 million light years, which is about 10% of the observable universe diameter, was discovered in this direction — "Hercules–Corona Borealis Great Wall" [18].

In the same year (2013), Keenan, Barger, and Cowie first concluded the existence of a giant, relatively empty region of space having a diameter of about 1–2 billion light years [19]. This giant void, containing the Local Group and most of the Laniakea Supercluster, significantly exceeding the Eridanus Supervoid and even the Giant void in size, was named the KBC Void. Its discovery essentially predetermined the discrepancy in the estimates of the Hubble constant H_0 for supernovae, cepheids, background radiation, and baryonic acoustic oscillations (see [20, Table 1]), simultaneously raising doubts about the negative conclusions [6, 21] about the local void effect.

The surprising discrepancy between the H_0 estimates provided by the High-Z SN Search Team and Plank Collaboration projects in 2016 initiated the discussion about the impasse in cosmology [22–25]. The discussion went on to consider the problems of anisotropy and violations of monotonicity of the cosmological redshift distance scale; the continuity of the model adopted by the High-Z SN Search Team [23] was not noted immediately:

$$D_L\left(z\right) = \frac{c}{H_0}\left(z + \frac{1 - q_0}{2}\, z^2 - \frac{1 - q_0 - 3q_0^2 + j_0}{6}\, z^3\right), \tag{1}$$

where $c = 299{,}792.458$ km·s^{-1} is the speed of light; q_0 is the deceleration parameter; j_0 is the jerk parameter.

In January 2017, Yehuda Hoffman, Daniel Pomarède, Brent Tully, and Hélène Courtois showed that the local galactic flow is dominated by one attractor, which is associated with the Shapley Supercluster, and one previously unidentified repeller [26]. It is the exact opposite of the Shapley attractor at ($\alpha = 13^h28^m$; $\delta = -31^o29'$) and its center must be at ($\alpha = 1^h28^m$; $\delta = +31^o29'$). However, the nearest void is Perseus — Pisces void centered at ($\alpha = 1^h$; $\delta = +10^o$).

Although it was not immediately clear what exactly was called the Dipole Repeller, in August 2017 an attraction zone was reported [27] as an extension of the Shapley Supercluster, as well as two repeller basins. One basin of repulsion, the Dipole Repeller, is located near the antapex[3] of the cosmic microwave background dipole (CMB Dipole$^-$) and the other is located in the direction nearest to the CMB Cold spot. In addition, galactic coordinates for the center of one repeller basin were specified ($l = 94^o$; $b = -16^o$),[4] with the dipole Repeller accounting for approximately half of the Milky Way motion; the center of the other basin located in the region of the negative velocity anomaly[5] in the constellations of Pisces and Cetus is given approximately: ($l = 168^o$; $b = -71^o$) [27].[6]

Previously, the isotropic model (1) for data on 120 SNe Ia [4, 6, 7, 30] was analyzed [29] using inadequacy tests for structural and parametric identification according to the criterion of minimum average modulus of inadequacy error (AMIE), which was used to conclude the accelerated expansion of the universe. The detected change points and rank inversions [31] are consistent with the prediction [7] about the transition from deceleration to acceleration at $z \approx 0.73$ and with the prediction [30] that for a simple expansion history model, the transition between the two epochs is bounded by $z = 0.46 \pm 0.13$. The latter estimate, however, is inconsistent with the fact that the very first data at about $z = 0.4$ suggest a slowing universe without the cosmological constant, yet seven measured points yield an excessive scatter [32]. Most importantly, the works [20, 29, 31] establish the redundancy of the 3rd-order isotropic model (1) for 79 SNe Ia [6, 7], and the optimal 2nd-order continuous anisotropic model $D_L(z, l, b)$ is found in Galactic coordinates. Moreover, for these data, the boundaries of continuity intervals reveal SNe Ia in the constellations having the possible observable sources of large-scale galactic flows — gravitational dipoles of inhomogeneity of the large-scale structure of the universe "Eridanus → Virgo" and "Eridanus → Leo" [33].

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[3]CMB antapex in the constellation Pisces — {$l = (84.021 \pm 0.011)^o$; $b = (-48.253 \pm 0.005)^o$} [28] or ($\alpha = 23^h09^m14^s$; $\delta = +6^o40'20.4''$). Suspiciously close are "Pisces Austrinus void + Cetus Supervoid" at ($\alpha = 0^h$–2^h; $\delta = +5^o$–$+15^o$) and "Aquarius Supervoid" at ($\alpha = 20^h32^m$–23^h50^m; $\delta = -25^o30'$–$+2^o45'$); however, they are not mentioned; the supercluster "Pisces — Cetus Supercluster" at ($\alpha = 23^h58^m$–1^h08^m; $\delta = -9^o18'$–$-31^o36'$) can weaken the effect of the repeller. Of note is that the estimates of the CMB Dipole coordinates diverge in [26] and [28].

[4]The point ($\alpha = 22^h23^m$; $\delta = +38^o17'$) in the constellation Lacerta. In terms of angular position, the nearest void is the Pegasus void at ($\alpha = 22^h$; $\delta = +15^o$).

[5]A hypercluster of superclusters is located here.

[6]The point ($\alpha = 1^h44^m$; $\delta = -13^o20'$) in the constellation Cetus.

Noteworthy is that large-scale galactic flows to the Virgo Supercluster and Great Attractor in the constellation Centaurus were discovered in the 1980s, while the CMB dipole on the Leo → Aquarius axis was detected in 1981 (for details, see [34]).

In 2020, a peculiar fact was noted: on average, the dipole anisotropy in the redshift of the SNe Ia of the Local Supercluster [6, 7] exhibits the maximum in the northern Galactic hemisphere [35], i.e., most of these galaxies are moving toward the South Galactic Pole. This is the exact opposite direction of the Sun′s motion relative to the CMB.

Detection of gravitational dipoles of inhomogeneity. The large-scale structure of the universe has a honeycomb structure, comprising combinations of galaxy clusters and superclusters with voids and giant voids between exotic "walls" and "chains" of galaxies. The list of superclusters on Wikipedia includes those in the constellations Draco, Ursa Major, Eridanus, Leo, Sextans, Virgo, and Coma Berenices. Particularly large superclusters form attractors. The lists of voids and giant voids include those located in the constellations Aquarius, Coma Berenices, Corona Borealis, Eridanus, Fornax, Leo, and Sculptor.

Initially, the assumption about the causes of change points and rank inversions in the isotropic models of photometric redshift distance scales within the radiation spectra of extragalactic objects was based on superclusters and attractors [9]. Subsequently, greater interest was expressed in large-scale galactic flows and the corresponding gravitational dipoles of inhomogeneity [10, 11, 13–15]. On opposite sides of the celestial sphere, they form pairs of massive superclusters of galaxies and giant voids, where the density of matter is less than the average by over 20–30%. In order to detect and characterize the superclusters of galaxies and giant voids, various methods [36, 37] and gravity models [38] are used, which require a sufficient variety of information and very complex calculations. In general, these methods are classified as indirect measurement methods according to R 50.2.004-2000.[7]

Complex calculations performed in [27] confirmed the significance of the contribution made by the giant void to the Milky Way motion when paired with a supercluster of galaxies. The analysis of [31] showed that the detection of dipoles of inhomogeneity can be simplified on the basis of the statistical inference logic of R 50.2.004-2000 adopted in the calibration of cosmological redshift distance scales.

The first step of this logic involves testing the hypotheses of degeneracy $\mathbf{H_0}$, continuity $\mathbf{H_{00}}$, and compositional uniformity $\mathbf{H_{000}}$ for the isotropic model representing the dependence of photometric distance on the redshift of extragalactic objects $D_L(z)$ [19, 29, 31]. Then the solution to the problem is provided by the method of joint measurements using the MCM-stat program, which reveals rank inversions and change points of the isotropic model that can be linked to the angular coordinates of SNe Ia.

Due to the preferability of the anisotropic model, the second step involves examining according to the criterion of minimum AMIE used in the MCM-stat M program whether the angular coordinates of SNe Ia in the region of change points and rank inversions of the isotropic model lie on the directrices (action sectors) of gravitational dipoles [20, 29, 31].

The *extraordinary evidence* obtained in 2004 and 2007 for the accelerated expansion of the universe has already been subjected to a standard analysis using tests for inadequacy. However, as in the case of analyzing the data on 79 SNe Ia [20, 31], it is now a matter of detecting the gravitational dipoles of inhomogeneity of the large-scale structure of the universe, the observable physical factors. In order to identify them, the results of the standard analysis of isotropic models in the regions of rank inversions and at the boundaries of change point intervals should be supplemented with lists of massive superclusters of galaxies and giant voids, if any, in the HDF and HUDF. Noteworthy is that the Milky Way is several hundred million light years away from the center of the KBC Void [19].

As of 2017, the list of gravitational dipoles and their elements was as follows.[8]

1. **Eridanus Supervoid** $\{(l = 207.8^o;\ b = -56.3^o) \pm 5^o/(\alpha = 03^h15^m05^s;\ \delta = -19^o35'02'') \pm 5^o\} \xrightarrow[\text{dipole}]{}$ directrix axis at ($\alpha = 15^h15^m05^s$; $\delta = +19^o35'02''$). **Virgo Supercluster** at ($\alpha = 12^h13.8^m$–$12^h43.9^m$; $\delta = -3^o48'$–$+18^o11'$); Hercules Supercluster with the center at ($\alpha = 16^h05^m15^s$; $\delta = +17^o44'55''$) and Coma Supercluster with the center at ($\alpha = 12^h59^m48.7^s$; $\delta = -27^o58'50''$) from the Hercules–Corona Borealis Great Wall [11].

[7] R 50.2.004-2000. GSI. Characterization of Mathematical Models Representing the Dependences between Physical Quantities when Solving Measurement Problems. Basic Provisions.

[8] The names of dipole elements (giant voids and galaxy superclusters) are in bold; curly brackets indicate that the data scatter refers to both coordinates; a slash indicates that the galactic coordinates were converted into equatorial coordinates by the present author and are not available in the cited source.

2. **Aquarius Supervoid** at ($\alpha = 20^h32^m$–23^h50^m; $\delta = -25^o30'$–$+2^o45'$) $\xrightarrow[\text{dipole}]{}$ directrix at ($\alpha = 8^h32^m$–11^h50^m; $\delta = -2^o45'$–$+25^o30'$). **Leo Supercluster** at ($\alpha = 10^h23^m$–11^h34^m; $\delta = +10^o33'$–$+49^o03'$); CL J1001+0220 cluster at ($\alpha = 10^h00^m56.96^s$; $\delta = +2^o20'09.32''$) [11].
3. Dipole Repeller: ($l = 94^o$; $b = -16^o$)/($\alpha = 22^h23^m$; $\delta = +38^o17'$), cosine of divergence from the CMB Dipole$^+$ direction ($\alpha = 11^h9^m$; $\delta = -6^o40'$) of $\mu = -0.99$ with agreement in the direction of 9^o [26]. Antapex of the cosmic microwave background dipole [27], CMB Dipole$^-$ at ($\alpha = 23^h9^m$; $\delta = +6^o40'$). The nearest void — **Pegasus void** at ($\alpha = 22^h$; $\delta = +15^o$) $\xrightarrow[\text{dipole}]{}$ directrix axis at ($\alpha = 10^h23^m$; $\delta = -38^o17'$). **Shapley Supercluster** at ($\alpha = 13^h25^m$; $\delta = -30^o$); Shapley attractor at ($\alpha = 13^h28^m$; $\delta = -31^o29'$).
4. **Cold Spot Repeller:** approximately ($l = 168^o$; $b = -71^o$)/($\alpha = 1^h44^m$; $\delta = -13^o20'$) in the negative velocity region in the constellations Pisces and Cetus [27], which according to [26] is located in the direction of the CMB Cold spot ($l = 209^o$; $b = -57^o$).[9] The authors of [27] state that according to Cosmicflows-3 data, the repeller in the CMB Cold spot direction is the dominant negative density function, and the 22^o deviation in the direction between the repeller basin and the Cold spot is within the measurement error. Pisces–Cetus Supercluster at ($\alpha = 23^h58^m$–1^h08^m; $\delta = -9^o18'$–$-31^o36'$). The nearest void is "**Pisces–Cetus void** at ($\alpha = 0^h$–2^h; $\delta = +5^o$–$+15^o$)" [39] $\xrightarrow[\text{dipole}]{}$ directrix axis at ($\alpha = 13^h44^m$; $\delta = +13^o20'$). According to [27], the main gravitational zone constitutes an extension of the Shapley Supercluster. However, the **Shapley Supercluster** — ($\alpha = 12^h50^m$–14^h10^m; $\delta = -20^o$–-40^o), Shapley attractor — ($\alpha = 13^h28^m$; $\delta = -31^o29'$), CMB Dipole$^+$ – ($\alpha = 11^h9^m$; $\delta = -6^o40'$), while the Virgo Supercluster with the center at ($\alpha = 12^h27^m$; $\delta = +12^o43'$).

Nevertheless, the analysis of all data suggests the following structural variants of gravitational dipoles, indicating deviations from the directrix axis in the right ascension $\Delta\alpha$.

Dipole GR-1: "Eridanus Supervoid — {($\alpha = 03^h15^m05^s$; $\delta = -19^o35'02''$)$\pm 5^o$}" $\Rightarrow$ directrix axis at ($\alpha = 15^h11^m$; $\delta = +20^o37'$) $\rightarrow$ "Corona Borealis Supercluster — ($\alpha = 14^h58.7^m$–$15^h45.0^m$; $\delta = +27^o11'$–$+36^o08'$) with the center at ($\alpha = 15^h25^m$; $\delta = +29^o30'$), Hercules Supercluster SCl 160[10] at ($\alpha = 14^h50^m$–16^h30^m; $\delta = +7^o$–$+42^o$), Coma Supercluster SCl 117 at ($\alpha = 11^h30^m$–13^h50^m; $\delta = +9^o$–$+36^o$), $\Delta\alpha = 1^h21^m$."

Dipole GR-2: "Aquarius Supervoid at ($\alpha = 20^h32^m$–23^h50^m; $\delta = -25^o30'$–$+2^o45'$)" $\Rightarrow$ directrix axis at ($\alpha = 8^h32^m$–11^h50^m; $\delta = -2^o45'$–$+25^o30'$) $\rightarrow$ "Leo Supercluster — ($\alpha = 10^h23^m$–11^h34^m; $\delta = +10^o33'$–$+49^o03'$)."

Dipole GR-3: "Dipole Repeller at ($\alpha = 22^h23^m$; $\delta = +38^o17'$)." Probably (author′s note) Pegasus void centered at ($\alpha = 22^h$; $\delta = +15^o$)? $\Rightarrow$ directrix axis at ($\alpha = 10^h23^m$; $\delta = -38^o17'$) $\rightarrow$ Shapley Supercluster SCl 124 at ($\alpha = 12^h50^m$–14^h10^m; $\delta = -20^o$–-40^o), $\Delta\alpha = 2^h27^m$.

Dipole GR-4: "Cold Spot Repeller $\approx$ ($\alpha = 1^h44^m$; $\delta = -13^o20'$) or Eridanus super void — ($\alpha = 03^h15^m05^s$; $\delta = -19^o35'02''$) $\pm$ 5^o" $\Rightarrow$ directrix axis at ($\alpha = 13^h44^m$; $\delta = +13^o20'$) $\rightarrow$ Virgo Supercluster — ($\alpha = 12^h13.8^m$–$12^h43.9^m$; $\delta = -3^o48$–$+18^o11'$), $\Delta\alpha = 1^h0.1^m$; Hercules Supercluster SCl 160 at ($\alpha = 14^h50^m$–16^h30^m; $\delta = +7^o$–$+42^o$), $\Delta\alpha = 1^h6^m$; Leo Supercluster SCl 93 at ($\alpha = 10^h23^m$–11^h34^m; $\delta = +10^o33'$–$+49^o03'$), $\Delta\alpha = 2^h10^m$.

All these gravitational dipoles are formed by the largest inhomogeneities in the structure of the universe.

Hubble dipole. From December 18 to December 28, 1995, the Hubble Space Telescope took 342 images of a 2.6′-diameter celestial area in the constellation Ursa Major; these images were used to obtain the image of the HDF in the northern Galactic hemisphere. From September 24, 2003 to January 16, 2004, the same method was used to obtain an image of the HUDF, a celestial area of almost the same size in the constellation Fornax, in the opposite direction in the southern Galactic hemisphere. Celestial areas with the minimum number of foreground stars were selected, which enabled images of distant high-redshift galaxies to be obtained and a sample of 41 SNe Ia [4, 30] to be generated, i.e., the basis for the extraordinary evidence [5]. Samples from the HDF and HUDF contain 27 SNe Ia at $0.460 \le z \le 1.755$ and 14 SNe Ia at $0.216 \le z \le 1.551$, respectively [29, Table 1]. An analysis of these data according to R 50.2.004-2000, when testing the hypotheses $\mathbf{H_0}$ and $\mathbf{H_{00}}$, revealed a change point in the systematic component of the calibration function in the isotropic model of the cosmological distance scale in the interval $z = [1.4; 1.551]$, which coincides with the rank inversion:

$$D_L\ (z)\big|_{0.216 \le z \le 1.390} = 4.1384932 \cdot 10^3 z + 3.7063162 \cdot 10^3 z^2 - 7.4000464 \cdot 10^2 z^4 \pm 698.7\ ;$$

[9] In equatorial coordinates — ($\alpha = 3^h10^m56.82^s$; $\delta = -20^o37'24.7''$).

[10] SCl — designation of superclusters in the catalog.

$$D_L\left(z\right)\Big|_{1.551\le z\le 1.755} = 6965.686275z\ .$$

After the change point, two SNe Ia from both fields with the largest redshifts of z = 1.551 and z = 1.755 yield an estimate of the Hubble constant H_0 = 49.78 km·s^{-1}·Mpc^{-1} for the linear dependence.

The rank inversion is formed by the supernovae SN 2002fx (z = 1.400; D_L = 11,376 Mpc) and SN HST04Mcg (z = 1.370; D_L = 11,117 Mpc) relative to SN 2003ak (z = 1.551; D_L = 10,327 Mpc), with the change point associated with the HUDF. The HDF is offset from the Draco Supercluster (center: α = $12^h10^m04.4^s$; δ = +64°01′19″) and Ursa Major Supercluster (center: α = $11^h53^m48.9^s$; δ = +52°19′36″) or (α = 11^h11^m–12^h11^m; δ = +50°29′–+58°37′) by about (10–12)°. The offset of the HUDF from the centers of Eridanus Supervoid at (α = $03^h15^m05^s$; δ = −19°35′02″) and Fornax void at (α = 03^h; δ = −30°) is even smaller. For comparison, the deviation of the Dipole Repeller from the Cold Spot (Eridanus Supervoid) is within 22° [27].

In other words, the question arises about the width of the directrix of the gravitational dipole whose elements can be located in not-strictly antipodal points of the celestial sphere. Further testing of the $\mathbf{H_{000}}$ hypothesis for isotropic models using data on the HDF and HUDF yielded the following result:

$$D_{L-\mathrm{HDF}}\left(z\right) = \begin{cases} 2007.844 + 4657.509z^2; \quad 0.460 \le z \le 1.340\ ; \\ 6782.545; \quad 1.390 \le z \le 1.755\ ; \end{cases} \tag{2}$$

$$D_{L-\mathrm{HUDF}}\left(z\right) = \begin{cases} -1839.783 + 8979.296z; \quad 0.216 \le z \le 1.307\ ; \\ 10787.25; \quad 1.370 \le z \le 1.551\ . \end{cases} \tag{3}$$

The boundaries of the continuity intervals in Eqs. (2) and (3) correspond to SNe Ia, the data on which are summarized in the Table 1.

While the difference in field orientations in terms of declination amounts to nearly a right angle, that in terms of right ascension of almost 9^h, factoring in the high-latitude location of the HDF, reduces the Hubble fields to the Galactic Poles P_N (α = 12^h40^m; δ = +28°) and P_S (α = 0^h40^m; δ = −28°).

Thus, the orientation of the HDF and HUDF toward "Fornax — Eridanus Supervoid → Draco — Ursa Major Supercluster" forms a dipole of gravitational inhomogeneity — Hubble dipole [40, p. 7]. The distribution of SNe Ia in this dipole corresponds to the asymmetry of SNe Ia distribution [6, 7] in the galactic polar gravitational dipole, i.e., it does not provide qualitatively new information about the redshift anisotropy of SNe Ia.

Noteworthy is that the change points and rank inversions in the isotropic models of the calibration function of the cosmological distance scale for the data [6, 7] coincide with the predictions of "cosmic jerks" and correspond to the gravitational dipoles "Eridanus → Virgo" and "Aquarius → Leo" [33].

TABLE 1. SN Ia Parameters

SN Ia	z	D_L, Mpc	α	δ	Dipole element	Constellation
HST04Yow	0.460	2793	$12^h36^m9.4^s$	+62°12′58″	"Draco Supercluster$^+$ Ursa Major Supercluster" at α = 11^h11^m–12^h11^m; δ = +50°29′–+58°37′	Ursa Major
2003dy	1.340	9638				
HST04Sas	1.390	9550				
1997ff	1.755	11749				
2002kc	0.216	1164	$3^h32^m39.0^s$	−27°47′29.1″	"Eridanus Supervoid$^+$ Fornax void" at α = 1^h44^m–4^h45^m; δ = −39°40′–−1°30′	Eridanus, Fornax
2003aj	1.307	9954				
HST04Mcg	1.370	11117				
2003ak	1.551	10328				

Notes on the nature of redshift. Issues concerning the relation of redshift within the spectra of extragalactic sources to the large-scale inhomogeneity of the universe, in fact, arose in the last century; however, they were obscured by the term "*peculiar velocity*," i.e., velocity relative to the local standard of rest [41]. The confusion was caused by the word "peculiarity," understood as *randomness* in relation to the regular component of the cosmological expansion rate of the universe. However, as noted in [42], the cosmological expansion models assume the inhomogeneity of matter distribution and, as a consequence, the expansion rate variability, provided this expansion actually occurs. Then, if we adopt the *principle of identity*, a large number of phenomena directly related to redshift must be examined from another perspective.

According to [43–44], a change in the expansion rate should alter the gravitational constant. The same conclusion was drawn by Hans-Jürgen Treder [45] when analyzing the Riemann–Mach mechanics. Here, we refer to the gravitational principle of identity rather than to that behind the identity of microparticles in quantum mechanics. Thus, it can be said that the failed attempts to detect the difference in gravitational and inertial masses suggest either identical velocity *dependence* (a certain analogy can be made for the gravitational potential) or that the idea of the experiment is flawed [42].

The problem is whether such a dependence exists or not. In fact, to put it simply, the redshift is determined by the difference in velocities, as well as by the difference in gravitational potentials at the radiation and reception points [46]. Acceleration means an increase in velocity due to the action of some force. The discussion about the existence of the dependence between the gravitational mass of an object and its velocity is still in progress, and, back in 1960, one of its participants proposed to face of the facts of absolute space-time (for details, see [47]).

Conclusion. In the theory of measurement problems, the problem associated with gravitational dipoles of inhomogeneity first arose during the validation of the MCM-stat M program [48] when four-dimensional Hubble diagrams were obtained [8] (see [49–51] for details). The divergent dipole anisotropy in the redshift of radio galaxies and quasars was noted by Prof. Vladimir Braginsky during the 10th Gravity Conference [8], while those who made this "discovery" at that time were interested in solving a complex measurement problem of multivariate statistical analysis in the calibration of measuring instruments for given conditions. The models of cosmological redshift distance scales constitute means for implementing the method of indirect distance measurement according to R 50.2.004-2000, and its application requires calibration according to SNe Ia, which serve as reference or calibration points in this situation.

According to [26], the heart of the problem associated with detecting dipoles of inhomogeneity lies in the fact that an excess of galaxies induces local group motion, and underdense areas repel as much as superdense areas attract; however, they lack light and therefore are difficult to map. A decade ago, it was suggested that the underdensity in the northern hemisphere was a significant factor in the local flow. The latter assumption is not confirmed as the giant voids are located in the southern Galactic hemisphere, and the effect of voids in the northern hemisphere is inhibited by the giant northern cluster of the polar dipole.

Tests for the inadequacy of the systematic component of the photometric redshift distance scale model proved to be an efficient and simple way to detect gravitational dipoles of inhomogeneity. The detection of a basin of attraction and two basins of repulsion [27] can be considered as an independent validation of this method.

Thus, the HDF and HUDF form the Hubble gravitational dipole; this is not *extraordinary evidence* for the accelerated expansion of the Universe but rather an argument against it.

The honeycomb nature of the large-scale structure of the universe results from a great number of giant clusters and voids; however, not every pair forms a gravitational dipole having a significant effect on the motion of galactic flows. The first large-scale galactic flows were detected in the 1980s. [49]. Therefore, a more important argument than the Hubble dipole is the giant gravitational dipole "Eridanus + Cetus + Aquarius Supervoid → Shapley + Centaurus + Leo + Coma + Virgo Supercluster" [35].

Thus, a new aspect of the measurement problem concerning the structural and parametric identification of the cosmological redshift distance scale model arises: accounting of the corrections for the local void effect, which was neglected in [6] and which represents the action of gravitational dipoles of inhomogeneity.

Here let us recall the brilliantly simple hypothesis of Mikhail Lomonosov about the nature of gravitation [52], which he expressed in a letter to Leonhard Euler: ***gravity is repulsion rather than attraction***.

This constitutes a fundamentally different approach to solving the problem.

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