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Research Article

Sobir Turaev* and Salakhutdin Nuritdinov

Can local inhomogeneity of the Universe explain the accelerating expansion?

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Abstract: This paper discusses the disordering of the principle of cosmology on a small scale, i.e. the possibility of interpreting the observational data of type Ia Supernovae (SNe Ia) through the inhomogeneity and anisotropy of the Universe. The expansion of the Universe may appear to be accelerating due to "dark flows", changes in the wavelength of light passing through "voids" and clusters, or anisotropy. Different sets of cosmological data are also considered without the need for a dark energy component.

Keywords: Universe inhomogeneity, accelerating expansion, anisotropy, cosmology, dark energy, supernovae

1 Introduction

The problems of dark energy existence are often focused on the most valuable cosmological models. According to the cosmological principle, the distribution of matter is isotropic and homogeneous in the Universe. But, on small scales, matter accumulates and merges into galaxies and galaxy clusters, forming large chains and cluster walls that exceed hundreds of Mpc. It is important that these largest structures, such as the Great Sloan Wall, are not associated with gravity. There are very large voids between these islands of matter where the matter density is very low. Gravity has different effects on the expansion of space depending on if you are in a void or a cluster. Recent studies suggest that all new SNe 1a data indicate the presence of weak dipole anisotropy. It is supposed that the accelerating expansion of the Universe will be slightly more in one direction and less in the opposite direction. Presumably, the backreaction of cosmological perturbations is a source of accelerating expansion (Kolb et al. 2005). The universe is not homogeneous due to the presence of cosmological disturbances. To describe the temporal evolution of a part of the Universe, we need to create an efficient dynamic from which we can obtain the average properties observed to characterize the size of our local Hubble radius. Of course, this implies a broad-based description of in-equality. Now

imagine that our Universe is filled with substances without pressure and no dark energy (Kolb *et al.* 2006).

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2 Inhomogeneous models

2.1 Timescape cosmology

The Timescape cosmological model was supposed as a potentially vital Wiltshire (2007) alternative to homogeneous and accelerating model with fluid-like dark energy. According to observations of voids, the current epoch of the Universe is inhomogeneous on smaller scales than the BAO (Baryon Acoustic Oscillation) in scale of $100h^{-1}$ Mpc, while exhibiting the density difference about 8% in density for sample volumes larger than this scale (Labini and Baryshev 2010). It is suitable to the increase in density is primordially different from the small oscillations $\sim 10^{-4}$ in dark matter from last scattering, without the assumption of expansion using a single Friedmann scale factor for the whole Universe (Aihara et al. 2011). The reason for the cutoff of 100 h⁻¹ Mpc forthis "scale of statistical homogeneity". In this scale the density divergences are finally amplified by acoustic waves in the primary plasma. Timescape cosmology was suggested an alternative to homogeneous dark energy cosmologies. This model find out cosmic acceleration arises when calibrating the cosmological parameters in the existence of gravitational energy gradients and spatial curvature, which become greater with the increase of inhomogeneities in later epochs. Indeed, galaxies, their groups, clusters and superclusters could be produced peculiar velocities inside the expanding flow in their vicinity;

Corresponding Author: Sobir Turaev: National University of Uzbekistan, Tashkent, 100174, Uzbekistan; Email: sobr8488@mail.ru

Salakhutdin Nuritdinov: National University of Uzbekistan, Tashkent, 100174, Uzbekistan; Email: nur200848@mail.ru



the absolute quantity of these velocities are practically inside the interval 100-1000 km s $^{-1}$. Therefore, for distances of 200 Mpc and above, any actual deviations are below the 10% level (Karachentsev *et al.* 2003). The most important feature that leads to the obvious acceleration for realistic parameters of cosmology is the residual in clock frequency of observers at the wall and average volume, which can usually grow to about 38% by the present epoch (Leith *et al.* 2007).

2.2 Backreactions

Backreactions from inhomogeneities in large scales could ensure a good interpretation of accelerating expansion without dark energy. Saulder et al. (2018) suggest a cosmological test for an inhomogeneous cosmology model, as timescape cosmology. Using larges scale galaxy surveys such a 2MRS and SDSS, they investigate the expanding variation which assumed by the ΛCDM model against common differential expansion from their own calibrations of borders proposed by timescape cosmology. Their test divines the Hubble flow systematic variations towards distant galaxy groups as a relationship with the matter division. Furthermore, from the viewpoint of the timescape model distinctions based on Hubble residuals never used below the scale of statistical homogeneity of the Universe, $z \le 0.033$, since a natural variation in the Hubble flow is expected from this scale (Smale and Wiltshire 2010). In an alternative approach, it could be possible to step into the foundations of modern cosmology. In cosmological principle, the universe is homogeneous and isotropic. However, this is not true on any scale: the universe is not made up stars, gases, and dark matter in the same distribution, but of galaxies, clusters, and voids. Only upon reaching the scale of 100–150 Mpc (z < 0.033) (Hogg et al. 2004).

2.3 Simplified model of voids

Balazs and Bene (2018) present a simplified model of voids. Using the model, they test the influence of inhomogenities on radiating propagation and calculate the suitable Hubble Diagrams and contrast them to the various cosmological models. They discovered that voids in the Universe containing non-relativistic matter can simulate accelerating expansion of the Universe since Hubble Diagrams are applied. Regardless of the fact that all what has ever been investigated are major Universe inhomogenities like stars, galaxies, clusters. Cosmological principle is a really true in a large scales (~ -150 Mpc). So, in this article authors

investigate the influence of voids. Furthermore, voids are only one significant part of the Universe together walls, clusters, filaments and ect. of the Hubble Diagram. Their paper concluded that their model needs great number of parameters to interpret the relation of luminosity-redshift and many other cosmological measurements like CMB peak, Lyman- α forests and local Hubble value observations. Behind every void the wavelength of light changes by a factor $\sqrt{\frac{1+W_+}{1-W_-}}$ meaning that belong to the nth void, in the nth FLRW-regime the redshift at the point of the axis where the light comes to cosmic time t_s ith scale parameter. This result reinforces the theory that local inhomogenities affect the SNe Ia measurements that it could be seemed the accelerating expansion of the Universe although each part of the Universe is decelerating.

2.4 Inhomogeneous relativistic model

Ishak et al. (2008) used the Szekeres (1975) inhomogeneous relativistic models in good suitable to combined data of SNe Ia observations. It is seen that with an option of the function of spatial curvature that is leaded by recent observations, the models suitable to the SNe Ia observation data almost like the ΛCDM model without demanding a dark energy element. The models of Szekeres were really derived as the same solution for Einstein's equations with a general metric that does not have any symmetries and are considered as good alternative model for observing Universe. A good suitable model discovered also consist of the demand of spatial flatness on the scale of the relic radiation. Initial results introduced suggest other investigations of local accelerating expansion using different inhomogeneous models and other constraints from CMB and too big scale need to discover further. Models of Szekeres have a suitable geometrical structure and are so looks like to correspond different cosmological observational data no need for a dark energy. The reason for this observation is that there is less substance inside the insufficiently dense region that slows down the expansion, and, therefore, the expansion rate in the insufficiently dense region is greater than in the superdense region or compared to the overall average expansion rate. Szekeres's inhomogeneous models allow a good correspond to the SNe Ia observational data and seems to support the accelerating expansion but many researches using these models are demanded to research this possibility. Among discussed alternative models only Relativistic Cosmological Model confesses the acceleration as ΛCDM cosmology.

2.5 Repulsive-gravity scenario

Villata (2012) researches if the proposed repulsive gravity scenario could take into account the aspects that are not explained in the standard cosmology. From simple dynamic considerations, he discovers that the Local Void may contain some amount of antimatter ($\sim 5 \times 10^{15} M_{sun}$) equal to the mass of a normal supercluster, thereby restoring the matter and antimatter asymmetry. On a great cosmological scale, repulsive gravitation from antimatter concealed in voids could accommodate more potential energy to operate accelerating expansion, without the need for an primordial "explosion" and dark energy. Moreover, the distinct division of the dark repulsors, as embarrassed to identically penetrating dark energy, also interpret dark streams and other observed immoderate anisotropies and inhomogeneities of the Universe.

Through a research executed on a database of about 1800 galaxies within 3000 km s^{-1} , the peculiar velocity of the Local Sheet. One of them (of 185 km s⁻¹) is attributed to the gravitational pull of the Virgo Cluster and its surroundings, at the same time, greater component (of 455 km s⁻¹) seems to be via an attraction on greater scales close to the direction of the Centaurus Cluster (Brent Tully et al. 2007). This probable energy conservation at various distances from the antigravity center verifies that the radial direction dynamics is actually affected by this repulsive interaction, and supports this scenario and antigravity could interpret both the accelerating expansion, and this theory also has the goodness of solving one of the greatest matterantimatter asymmetry problem.

2.6 Dark flows

The specific velocities in the large-scale cosmological paradigm are greater than expected. Specifically, The research of Kashlinsky et al. (2012), particularly, it is suggested coherent bulk motions with almost constant speed about 1000 km s⁻¹, reaching from 100 to 1000 Mpc (Kashlinsky et al. 2012). They are dark flows. In other words, data from SNe Ia can be the result of large scale specific motions, and if so, cosmology doesn't need for dark energy to analyze SNe Ia data. In regions where opposite sides the flowing, it is seemed the local acceleration in a decelerating expansion of the Universe. Whether or not this happens, the size of the influenced area connects with the density and the flow rate of the volume, the faster the peculiar motion and the lower the density, the larger the accelerating section and the smaller the decelerating rate. So the next question is whether the observations permit for sufficiently large peculiar velocities to cause such an apparent acceleration (Tsagas 2011).

The current standard cosmology, the ΛCDM , permits for local motions no faster than ~ 100 km/s about 100 Mpc that drop more as moving out to greater lengths. Recent independent surveys, however, have reported significantly faster bulk velocities on substantially greater scales, putting the standard picture in doubt. Reviews, in particular, point to peculiar velocities from $\sim 1000 \text{ km s}^{-1}$ to ~ 800 Mpc and possibly up to the Hubble radius. These values are converted to $v/\theta \approx 1/7$ at scales about 100 Mpc (assuming that $H_0 \approx 70 \ kms^{-1} Mpc^{-1}$ today) (Tsagas 2012). Indeed there are several disputations and new recommendations to the Dark Energy paradigm. If an alternative scenario is possible, Feoli and Benedetto (2016) try to follow Tsagas's hypotheses but they recommend a specific approach. They found that an observer with a corresponding acceleration comparative to the framing of reference motion, in the scope of the decelerating FRW Universe, defines the same result with cosmological redshift as standard cosmology. They assessed value of this acceleration is $\sim 1.4 \times 10^{-9}$ m/s² (Feoli and Benedetto 2016), and they calculated $V_{pec} \approx 600 \text{ km s}^{-1}$. They show that it is possible to reproduce the cosmological redshift in the standard cosmology using the FRW decelerating expansion of the Universe and a appropriate local acceleration.

2.7 Bulk flow

Colin et al. (2017) investigated "bulk flow" in the local Universe, which is faster and expands to greater scales than is expected from a characteristic observer in the ΛCDM model. This is expected to result in a scale-dependent dipole cadence accelerating rate obtained from observations of objects in the bulk flow. From the 740 SNe Ia, 551 are in the hemisphere. As for the volumetric flux of 372–127 km s⁻¹ in the model that corrected the redshifts of the local supernovae Ia, 632 SNe Ia are in the lower hemisphere and just 108 SNe Ia are in the upper hemisphere. Regarding the direction of anomalously high flux reported by 6dFGSv, the biggest and most homogeneous sample of specific velocities of local 9000 galaxies.

2.8 Peculiar velocity field

Hudson et al. (2004) also investigate in detail the peculiar velocity field traced by 56 clusters within 120 h⁻¹ Mpc in the "SMAC" (Streaming Motions of Abell Clusters) paradigm. The bulk flow of the SMAC paradigm is $687 \pm 203 \text{ km s}^{-1}$, toward $l = 260^{\circ} \pm 13^{\circ}$, $b = 0^{\circ} \pm 11^{\circ}$, at the 98% confidence level, a residual bulk flow of 372±127 km s⁻¹ toward $l = 273^{\circ}$, $b = 6^{\circ}$ which could be generated by sources excluded in the PSCz catalogue, that is, either beyond 200 h^{-1} Mpc, and a bulk flow of 225 km s⁻¹ toward $l = 300^{\circ}$, $b = 10^{\circ}$ at depths more than 60 h^{-1} Mpc is in accordance with all peculiar velocity surveys. 637 are in the lower semi-sphere while 103 SNe Ia are in the upper semi-sphere. From a maximum probabilistic analysis of the Joint Lightcurve Analysis (JLA) catalogue of SNe Ia, determined deceleration parameter has a greater dipole component ranged CMB dipole which falls exponentially with redshift z: $q_0 = q_m + q_d \hat{n} F(z, S)$ The best correspond to data yields q_d = -8.03 and S=0.0262 ($d\sim 100$ Mpc), dismissing isotropy ($q_d = 0$) with 3.9 σ statistical significance, while $q_m = -0.157$ and consistent with no acceleration $(q_m = 0)$ at 1.4 σ (Magoulas *et al.* 2016).

However, in particular, we should note the very important paper (Rubin and Heitlauf 2020), in which the reanalysis of the peculiar velocity and anisotropy of SNe Ia properties claims to have little effect on the acceleration evidence.

3 Conclusion

Although more than 20 years have passed since Dark Energy was proposed to explain the accelerating expansion of the Universe, we have no any information about it's composition. In this case, it is natural to propose other alternative models to explain the acceleration. Also, the proposed alternative models have more natural and unique scientific basis than Dark Energy. In most of the models we have considered, it is assumed that there are systematic or statistical errors in the SNe Ia observations.

Usually theories are initially developed theoretically and observations are made to prove them, but not all of them find their proof in observations. The superiority of SNe Ia cosmology was determined on the basis of its observational data and then it was developed theoretically. We must confess that alternative models are not at present as competitive as the SNe Ia cosmology in terms of giving better explanations of SNe Ia observations. In addition, a great debate exists among cosmologists on this topic and it is actively discussed in the literature.

It should be noted particularly that the proposed alternative models for SNe Ia cosmology may not provide reliable observational data, but it does not mean that they are completely denied or that SNe Ia cosmology is completely admitted.

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