Comment on arXiv:1009.2266

Willard Mittelman
Email: wmitt@uga.edu

Abstract

We discuss a recent attempt by Gogberashvili and Kanatchikov to derive the value of the fine structure constant α using cosmological parameters. We correct some errors in the proposed derivation, as well as modifying the authors' account of dark energy. As a result of these corrections and modifications, a viable derivation of α's value is obtained, thereby vindicating the basic approach of the above authors.

In [1], Gogberashvili and Kanatchikov (hereafter "GK") attempt to derive the value of the fine structure constant α using a Machian theory in which all particles in the universe are "gravitationally entangled," so that they interact nonlocally with each other. GK refer to the "Machian energy" of particles, by which they mean the energy arising from collective, nonlocal interactions between gravitationally entangled particles. In connection with their derivation of α's value, GK identify the total Machian energy of all particles in the universe with dark energy, which leads them to conclude that the ratio M_{Mach}/M equals the relative dark energy density Ω_Λ, where M_{Mach} is the total Machian mass of all particles in the universe (i.e., the mass equivalent of the total Machian energy). It is important to realize that M, for GK, is not simply the total mass of all particles in the universe; it is the total active gravitational mass of the cosmic fluid, and hence it includes all dark components [2]. Since dark energy thus contributes to M, and since M_{Mach} represents energy over and above the "normal" energy of matter, it is natural to associate dark energy with M_{Mach}, and to equate the ratio M_{Mach}/M with Ω_Λ, as GK do.

Before proceeding further, there is an important error in GK's attempted derivation of α that must be noted. GK obtain their value of α, which closely matches the measured value, from their equation (18), in which the expression that is equated with α contains the term "Ω_Λ^2," where $\Omega_\Lambda = M_{Mach}/M$. (See the appendix below for (18) and other relevant equations from [1].) This equation (18) is obtained in part from equation (17), which also contains "Ω_Λ^2." The occurrence of "Ω_Λ^2" in these two equations is an *error*, however; the correct term is simply "Ω_Λ" in both (17) and (18). This can be readily verified by following the procedure mentioned in [1] itself, *viz.*, using equations (1), (7), (8) and (16) together to obtain (17); the equation thus obtained contains "Ω_Λ" rather than "Ω_Λ^2." (In obtaining this equation, the relation R ~ c/H, where R is the radius of the universe and H the Hubble constant, is also useful.) It follows immediately that equation (18) too should contain "Ω_Λ" instead of "Ω_Λ^2." Unfortunately, replacing "Ω_Λ^2" with "Ω_Λ" here yields a value of α that is not particularly close to α's measured value, in contrast to the "good" value of α that GK obtain by (incorrectly) using Ω_Λ^2. As explained below, however, this problem can be remedied by hypothesizing the existence of *other* nonlocal interactions, besides those involving matter-particles, that *also* contribute to dark energy, so that nonlocal interactions between particles give rise to only a *part* of the total dark energy. First, however, there is yet another issue with GK's derivation of α that needs to be addressed. (N.B.: It is possible, of course, that the above-mentioned error will be corrected in a revised version of [1]. At the time of writing, however, this error is still present in [1].)

The expression for α in GK's equation (18) also contains the term "Ω_r/Ω_b," where the numerator "Ω_r" denotes the relative energy density of radiation, and the denominator "Ω_b" refers to the relative baryon energy density. GK use here the accepted values of Ω_b and Ω_r established by observation. At the same time, however, they regard Ω_b as reflecting (at least in part) the *Machian* energy E_b of baryons, which is a component of the total Machian energy E whose mass equivalent is M_{Mach}. E_b, therefore, is a constituent of dark energy and hence contributes to Ω_Λ. The accepted observational value of Ω_b, however, is for the energy density of baryonic *matter*, which is a component of Ω_m exclusively, and not of Ω_Λ. Consequently, GK's "Ω_b" is not the standard Ω_b, and the value of Ω_b that GK use must be modified to reflect this fact (thereby modifying the ratio Ω_r/Ω_b as well, of course). Specifically, Ω_b's value needs to be increased so as to reflect the addition of a dark-energy component.

Let us return now to the hypothesis mentioned above, according to which part of the total dark energy is due to nonlocal interactions that do *not* involve matter-particles. The energy of such interactions does not constitute part of the Machian energy of matter, since the interactions in question are, *ex hypothesi*, independent of matter-particles. Hence, in particular, these interactions do not contribute to the Machian energy of *baryons*; and as a result, they do not contribute to the above-mentioned increase in Ω_b's value, a point that must be kept in mind when calculating the amount of this increase. Now *if* the matter and non-matter components of dark energy are roughly equal, so that each is approximately 0.37 of the total energy density of the universe (taking Ω_Λ=0.74, and Ω_b=0.046 for the standard, unmodified Ω_b), then the modified ratio Ω_r/Ω_b, when plugged into the corrected version of GK's equation (18) in which "Ω_Λ^2" is replaced by "Ω_Λ," yields a value of α that is suitably close to the measured value. "Suitably close" here means "within the margin of error for the derived value of α," where this margin of error reflects the margin of error of the observationally determined values of Ω_r/Ω_b and Ω_Λ. The calculations here are straightforward, and so we simply give the results: namely, the modified value of Ω_b is 0.063, which yields a modified ratio $\Omega_r/\Omega_b = 0.796 \times 10^{-3}$ (the standard value of this ratio is 1.09×10^{-3}). Plugging these values into the corrected version of GK's equation (18), and using GK's estimate of the margin of error, we have that $\alpha \approx 7.398 \pm 0.4 \times 10^{-3}$. This value of α is, obviously, suitably close to the measured value of 7.297×10^{-3}.

The question that needs to be addressed now is this: what sort of nonlocal interaction that does *not* involve particles of matter can give rise to a dark energy that supplies the remaining 0.37 of the energy density of the universe (where the magnitude of the universe's energy density is $\sim V^{-½} \sim H^2$, with V being the four-volume of the universe in Planck units)? Here we appeal to recent work by the present author [3], in which nonlocal interactions between Planck-sized elements of spacetime that fluctuate in volume produce a widespread cancellation of these fluctuations. At any given time t, there are $\sim \sqrt{V}$-many elements whose fluctuations are uncanceled (again, V is in Planck units); hence, there is a net volume-fluctuation $\Delta V \sim \pm\sqrt{V}$ at t for the entire volume V. The volume-fluctuations here amount to fluctuations in the *density* of the spacetime elements; and we take the nature of these elements to be described by causal set theory [4]. At a given time t, the widespread cancellation of these density-fluctuations, combined with the presence of sparsely distributed *un*canceled fluctuations, gives rise to a quantum potential Q of spacetime with energy density ρ_Q. If the net volume-fluctuation is a *contraction*, i.e. if $\Delta V \sim -\sqrt{V}$, we have $\rho_Q \approx 0.35V^{-½}$; and for $\Delta V \sim +\sqrt{V}$, we have $\rho_Q \approx 0.39V^{-½}$. Hence, the average value of ρ_Q is approximately $0.37V^{-½}$, which is just what is needed here. We conclude, therefore, that when GK's derivation of α's value is corrected and modified appropriately, and is supplemented by certain additional ideas concerning dark energy, this derivation does indeed yield a suitable value of α. In our view, the existence of such a derivation is potentially of great significance, a fact which indicates that the Machian perspective developed in [1, 2, 5] deserves serious consideration.

REFERENCES

[1] M. Gogberashvili and I. Kanatchikov, "On the fine structure constant in the Machian universe" [arXiv:1009.2266]
[2] M. Gogberashvili, "Quantum behavior in Machian model" [arXiv:0910.0169]
[3] W. Mittelman, "Ever-present Lambda and the quantum potential of spacetime" Prespacetime Journal v.1 no. 7 (forthcoming 2010)
[4] M. Ahmed, S. Dodelson, P.B. Greene, and R. Sorkin, "Everpresent Lambda" Phys. Rev. D69:103523 (2004) [arXiv:astro-ph/0209274]
[5] M. Gogberashvili, "Machian solution to the hierarchy problem" Eur. Phys. J. C 54:671 (2008) [arXiv:0707.4308];
M. Gogberashvili, "'Universal' FitzGerald contractions," Eur. Phys. J. C 63:317 (2009) [arXiv:0807.2439];
M. Gogberashvili, "Thermodynamic gravity and the Schrodinger equation" [arXiv:1008.2544].

APPENDIX

Equations from [1]:

(1) $c^2 \approx MG/R$

(7) $-mc^2\Delta t \approx -2\pi\hbar$
(The rationale for this equation is explained in [1].)

(8) $\Delta t \sim 1/NH$
(N here is the number of particles in the universe; in the simplified model of [1], these particles are all identical, and each particle has mass m.)

(15) $\alpha = (\Omega_r/\Omega_b)(2NGm^2/ct)$

(16) $M_{Mach}/M = \Omega_\Lambda \approx N^2m/M$

(17) $m^2/\hbar = (2\pi c/NG)\,\Omega_\Lambda{}^2$

(18) $\alpha \approx 4\pi\,\Omega_\Lambda{}^2(\Omega_r/\Omega_b)$
(Note that (18) is obtained by plugging (17) into (15).)