Derivation of DM, DE and Λ, Supplement 1: the Nature of Dark Energy

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As the main text[1] has shown, dak matter (DM) is defined according to general relativity (GR) in the local frame of lower-scale structures *as the gravitational energy of the observable universe (OU) accreted as DM on the local Newtonian gravitational field g,* with a concentration

$$\rho_D = Qg \qquad (1)$$

in each point/event. For all lower-scale structures at and below the level of large super-clusters of galaxies, Q was fixed by the coefficient of the Tully-Fisher relations, at $Q=1.39\cdot10^{-16}$ gs^2/cm^4. This yields negligible effects on planets, on planetary systems, but not in galaxies, clusters and super clusters, where the DM obtained from Eq. (1) is larger, exactly describing the rotation curves of stars, the galactic halos and the stability of clusters. On all these lower scales of the universe, the cumulative DM contributions increase linearly with the distance r from the center, e.g., the galactic center, and ultimately also with the size of the structure (e.g., the galaxy). On all these lower scales of the universe, the cumulative DM contributions $M_<$ increase linearly with the distance r from the center, e.g., the galactic center, and ultimately also with the size of the structure (e.g., the galaxy). ***In this supplement we will further develop an equivalent geometric description of this accretion of DM from the OU on the local field g of lower scale structures. It clarifies the nature of DM and DE, by focusing on the local frame of reference.***

We consider an analogy with a curved surface, approximated, e.g., by a polar spheric surface segment, and a plane tangent to it in a point P. In the vicinity of P, the spherical surface element can be identified with its tangent plane. However, this local approximation with a plane also requires increasing corrections, as the area on the plane and the distance from the point of contact increase.

The same way, in GR the local vicinity of an event-point is approximated by Newtonian physics as an Euclidian space (E), with no curvature, in the local frame of reference. This Newtonian approximation (NA) requires increasing corrections as the size of the structure described in the local Newtonian frame approximation increases, e.g., to galactic dimensions. We suggest that these corrections come in form of added DM, needed in order to continue describing, e. g., the rotation curves of peripheric stars with Newton's laws of motion valid in the local E-frame. The concentration of this added DM accretion can again be described as a function f(g,g'), of the local gravitational field g and a parameter g', symbolizing the curvature of the OU in the point of contact, or event, P, e.g., at the center of a galaxy. We would then repeat the derivation that led to Eq. (10), *arriving to a complete equivalence between:*

-- the accretion of universal DM on the local g on one hand, and

-- DM introduced as compensation for the deviation caused by the use of the local Newtonian E-frame to describe the curved OU, on the other hand.

In this later, local frame case, the accreted concentration of DM would again be $\rho_D=Qg$, since symbolically, again g<<g', and we could develop the unknown correction function f(g,g') again in a Taylor series. The linear increase of the accumulated DM, $M_<$, with distance from the contact point P (from the center of the galaxy) would be a measure of the indefinitely increasing distance, and difference, between the local frame and the actual, curved, OU. It is zero at P, from Eq. (12'). Equation numbers from [1] are displayed in blue, as well as references from there.

In practice, in Astrophysics, also in the main text[1], these compensatory amounts of accreted DM defined in the local frames of various structures have been included as part of the OU, although they do not belong there. *To compensate for this error, also displayed by the perceived acceleration of the Hubble expansion , observed in the local E-frame of the OU, the DE was introduced into astrophysics*, as compensation for this error, as a negative energetic contribution per volume unit, $\rho_\Lambda=5.96\ 10^{-30}\ g/cm^3$.

We can see this compensation in the curved OU, displayed in Eq. (15)

$$4\pi\lambda G g'^2 M_b L_g - \rho_\Lambda 4\pi L^3/3 = 0. \qquad (2)$$

The first term on the left is the dark matter included erroneously, and the second is the compensating dark energy. ***This would explain also the nature of DE, connecting it to DM,*** *as mentioned at the end of the main text.*

We could thus eliminate both, the local frame concepts of *DM and DE* from the curved OU, but keep them as useful concepts, in any local E-frame of reference in GR. The counter argument expected, would ask how we can achieve closure for the OU this way? An answer to this question, would point out that there actually is a form of closure anyway in the OU, displayed in its local E-frame, with the compensation. The real need for DM and DE is only perceived in all local Newtonian frames, of lower-scale structures, and of the whole OU, that we are always using unwittingly! In a general hierarchic understanding of the whole universe, the OU would also correspond to some curvature bump of the universe, and *the hierarchy would continue further, way beyond the OU, notwithstanding the perceived "end of greatness"*. (The latter is an observed tendency to homogeneity and isotropy at scales above 100 Mpc or $3.2 \cdot 10^8$ ly, in the OU, as perceived in our local frame, agreeing with the cosmological principle.) In this picture, we have been perceiving the OU in its local, Euclidian frame, analog a tangent plane. A general solution of EE in the whole curved universe, also containing our OU has not been obtained yet. We only have been able to recognize some of the results of EE.

[1] P. H. Handel and K. E. Splett, Derivation of Dark Matter, the Cosmological Constant and Dark Energy as Features of Space-Time, Nature Physics, Submitted for publication.