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Research Article

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At what distance from us and when starts the Hubble expansion?

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Abstract

In this article we shall ask what may cause the uniformly distributed, cosmic matter to form singular local mass concentrations in a universe that has started, and according to the general belief never ended till now to expand since the event of the Big-Bang. Though the so-called Big-Bang till now is a physically rather nebulous cosmic event, all modern cosmology is centered around it and founded upon it. Our investigations here do show that in fact some forms of a cosmic Hubble expansion do allow for gravitationally driven local matter contractions - even though the universe as a whole is expanding to ever and ever larger space volumes. For a universe undergoing an unaccelerated, "coasting" Hubble expansion we can show that the forces connected with the centrifugal Hubble drifts are overcompensated by the centripetal forces of cosmic matter inside critical local space volumes and thus do form mass concentrations up to Mega-solar masses as soon as the coasting phase of the expansion has started. To the contrast, in an universe with an accelerated Hubble expansion which is nowadays favoured by many astrophysicists structure formation is, however, stopped soon after the accelerated expansion has started. That may serve as a criterion what form of the Hubble expansion in fact predominates in this actual universe.

Why and when in an expanding universe do distributed cosmic masses collapse?

It was Fred Hoyle who coined for the first time the stigmatic concept of a "Big-Bang"- universe for the scientific community. This was during a BBC interview in the year 1949. The denotation "Big-Bang" served furtheron as a paradigm for a universe which originates from a singularity with a gigantic explosion whose driver is unknown and it continues to expand since then. But not at all Hoyle did so, because he was convinced by this idea, rather to the opposite, because he wanted to blame his colleagues like Lémaître, de Sitter, Friedman and others for pushing, in his view, such an absurd scientifc idea. According to his view the idea of a Big-Bang as origin of the universe was a sheer nonsense. Nevertheless, however, this concept since these days till now is indoctrinating the vision of the whole cosmologic science community and its modern cosmic concepts.

The question coming up from such a BB-paradigm necessarily concerns the place where, if at all, this Big-Bang happened? And where were we and all the rest of the universe at this event? The answer is: We and everything else of this universe were exactly at the same place where the BB happened, namely at and within the same singularity. Somehow already the famous Nikolaus Kusanus, the later Bishop of Brixen, at 1400pC. did express it impressively with his visionary words: This world is a creation whose center is everywhere, whose border, however, is - nowhere! Though this perhaps is an intelligent paradigm for the true nature of the universe, it nevertheless provocates the fundamental question - if the universe started expanding with the event of the BB, - why? and when? then after that - did it stop to expand into larger and larger spaces – to instead locally create material structures like stars, planetary systems and galaxies? And only these latter things we infact do see when looking into the nearest and the farthest cosmic environments, while the BB we do not see. Somehow the BB, however, must have had a successor in form of the "BC", the "Big-Collapse" or at least the "LC", the "Local collapse" from where local cosmic structures originated.

What concerns the influence of the general Hubble expansion on more local structures like e.g. the solar system there exists already a long list of publications starting perhaps with the consideration of the problem of the "Einstein-Strauss vacuole" (Einstein and Strauss, 1945,1946) with the Einstein-Strauss radius as that distance where a smooth transition between the Schwartzschild geometry of the local gravitational field into the global Robertson-Walker geometry can be achieved. More recently this concept has been specifically applied to the case of our solar system and it has been shown there how the transition from the local to the global spacetime geometry can be probed by radio-trackings of space probes like especially the NASA space probe PIONEER-10 manifesting the spectacular Pioneer-10 radio tracking anomaly (Fahr and Siewert, 2007, 2008). But all these studies do take the solar system and the global Hubble expansion already as given facts, not asking how local mass structures can originate in a globally expanding universe. To study this latter point one rather has to pay attention to the following aspects:

Contraction of distributed matter in expanding universes

If matter is at rest with respect to an inertial rest frame, then it must move with respect to that frame when a force is acting upon it. If now somehow the cosmic inertial rest frame in fact is a general-relativistic, dynamic rest frame - like the cosmic Hubble-Lemaître rest frame - then a decoupling from the cosmic expansion is only possible, if a counter-expansion force K_c is acting on the matter which is larger than the Hubble-Lemaître force K_{HL} i.e. if $|K_{HL}| \leq |K_c|$. The force K_{HL} is connected with the general, differential cosmic Hubble drift $v_{HL} = H \bullet D$ in a distance D from the selected origin of the coordinate system and is given by:

$$K_{HL} = m\frac{d}{dt}v_{HL} = m\frac{d}{dt}(H \bullet D) = m[(\dot{H} \bullet D + H \bullet \dot{D}] = m[(\frac{\ddot{R}}{R} - \frac{\dot{R}^2}{R^2})D + H \bullet \dot{D}]$$

On the other hand, the counter-expansion force Kc may be imaginable as due to the gravitational attraction force of a central mass M_c at the origin of the selected coordinate system. This mass M_c is thought to be due to the accumulated cosmic, originally homogeneously distributed masses inside a sphere with radius D. Hence one finds, with G denoting Newton's gravitational constant and $\rho(R) = \rho_0 \bullet (R_0/R)^3$ denoting the actual average cosmic mass density at the cosmic scale R

$$K_c = -G\frac{mM_c}{D^2} = -\frac{4\pi}{3}\rho(R)D^3\frac{mG}{D^2} = -\frac{4\pi}{3}mG\rho_0 \bullet (\frac{R_0}{R})^3 \bullet D$$

Hereby the replacement of M_c was made by $D_c(R) = R \bullet [M_c/(4\pi/3)R_0^3\rho o]^{1/3}$, i.e. the quantity $D = \Delta o \bullet R$ and R are strictly proportional to each other. In order then to have the Hubble expansion reversed into a local contraction one needs to have $|K_c| \geq K_{HL}$, i.e.

$$\frac{4\pi}{3}G\rho_0(R_0/R)^3 \bullet D \geq \left|(\frac{\ddot{R}}{R} - \frac{\dot{R}^2}{R^2})D + H \bullet \dot{D}\right|$$

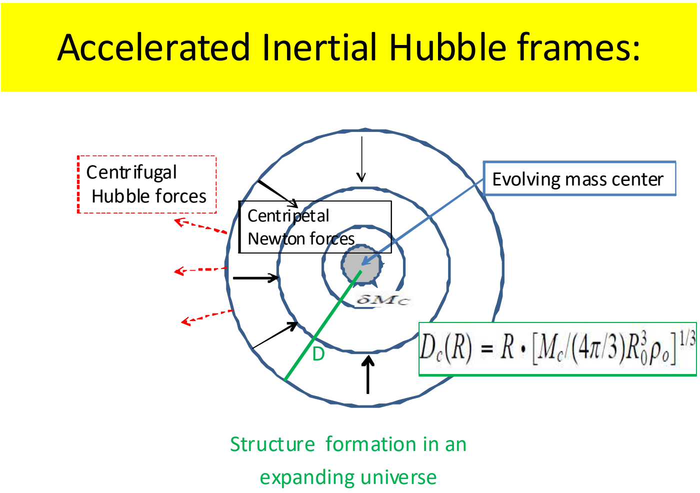

Figure 1: Schematic illustration of structure formation in a cosmic Hubble frame

To further study and analyse the meaning of this above relation, one needs to have a look into the Hubble dynamics which determines the quantities $\ddot{R}$ and $\dot{R}$ as functions of R. These relations are multiform and have a large variety of possible solutions under general cosmic conditions as recently again analysed in Fahr (2022). There it is shown that the Hubble parameter $H = H(R)$ is variable with the scale R of the universe in very many different forms dependend on the relative contributions ρ_b, ρ_d, ρ_v, ρ_Λ of densities of baryonic mass, dark matter mass, photons, and vacuum energy to the cosmic energy-momentum tensor.

Here in this article we do not play with all these possible options, instead we concentrate on one option mainly, namely the one leading to a so-called "coasting" Hubble expansion with $\ddot{R} = 0$, describing the unaccelerated universe. This particular case in fact always prevails, if vacuum energy density ρ_Λ dominates over all the other contributions ρ_b, ρ_d, ρ_v at later phases of the cosmic expansion, since as shown in Fahr and Heyl (2021) and Fahr (2022) ρ_Λ varies with the scale R like R^{-2}. Under these prerequisites the Hubble parameter $H(R)$ can be written in the form (Fahr and Heyl, 2021):

$$H^2(R) = \dot{R}^2/R^2 = \frac{8\pi G}{3}\rho_\Lambda = \frac{8\pi G}{3}\rho_{\Lambda,0} \bullet (R_0/R)^2$$

which allows to conclude that in this case one finds $\dot{R}^2 = 8\pi G/3\, \rho_{\Lambda,0} \bullet (R_0)^2$ = const, i.e. the so-called "coasting expansion".with $\ddot{R} =$ 0! and

$$H(R) = \sqrt{\frac{8\pi G}{3}\rho_{\Lambda,0}} \bullet (R_0/R) = H_0 \bullet (R_0/R)$$

in which case one finds the above derived requirement given by the relation

$$\frac{4\pi}{3}G\rho_0(R_0/R)^3\cdot D\geq\left|(-\frac{\dot{R}^2}{R^2})D+H\cdot\dot{D}\right|=\left|(-H_0^2\frac{R_0^2}{R^2})D+H_0\frac{R_0}{R}\cdot\dot{D}\right|$$

or :

$$\frac{4\pi}{3}G\rho_0(R_0/R)^3\geq\left|(-H_0^2\frac{R_0^2}{R^2})+H_0\frac{R_0}{R}\cdot\frac{\dot{D}}{D}\right|$$

and using now the proportionality between D and R given by

$D_c(R)=R\cdot[M_c/(4\pi/3)R_0^3\rho_o]^{1/3}$ one finds:

$$\frac{4\pi}{3}G\rho_0(R_0/R)^3\geq\left|(-H_0^2\frac{R_0^2}{R^2})+H_0\frac{R_0}{R}\cdot\frac{\dot{R}}{R}\right|=0\ !$$

That, interestingly enough, means for a coasting universe that this above requirement is always fulfilled, as soon and as long as the coasting expansion prevails, meaning that at all those times masses of all sizes M_c on the basis of the collapse of uniformly distributed cosmic matter density ρ_0 can be generated.

In contrast to the above, according to Einstein's introduction of the vacuum energy in the form of the constant vacuum energy density Λ (Einstein's famous cosmologic "constant"!) one obtains for the later phases of the cosmic expansion, derived from the two Friedmann equations (see Goenner, 1996):

$$H(R)=\sqrt{\frac{8\pi G}{3}\rho_\Lambda}=const$$

which means $\dot{H}=0$! and $\dot{R}=R\sqrt{\frac{8\pi G}{3}\rho_\Lambda}$. This in contrast to the above relation thus then implies

$$\frac{4\pi}{3}G\rho_0(R_0/R)^3\geq\left|H_0\cdot\frac{\dot{R}}{R}\right|=H_0^2$$

meaning that as soon as the cosmic density $\rho(R)\sim R^{-3}$ during the expansion of the universe has fallen off too much, no mass contractions can happen anymore during all the time of the ongoing expansion of the universe.

Conclusions

It may appear for cosmologists as one of the biggest enigmas that in an initially homogeneous universe under the ongoing Hubble expansion local mass structures like stars, stellar systems and systems of galaxies could have been formed. As we have, however, shown in this article here, structure formation is possible even under conditions of an expanding universe, though the form of the underlying expansion of the universe must, however, be specific for that purpose; it namely must be an "unaccelerated", "coasting" expansion, while under famous astrophysicists of these decades the accelerated expansion is strongly in favour. In order to explain the redshifts of galaxies with the most distant SN-1a supernovae Perlmutter et al.(1998), Schmidt et al. (1998) or Riess et al. (1998) have prefered an accelerated expansion of the universe, associated with the action of a constant vacuum energy density ρ_Λ as initially proposed by Einstein (1917). However, as we do show here, structure formation and build-up of solar systems and galaxies is impeded as soon as the universe starts expanding in an accelerated form, only as long as the expansion takes place in an unaccelerated, coasting form then structure formation can continue to happen in the universe. And this is important, since our solar system may live for about 10^8 years, but in a universe which is already about $8.7\cdot10^9$ years old, such systems must be reborn, in order to be visible at our time period. Perhaps this can be used as a criterion which form of a Hubble expansion is characteristic for our actual present universe.

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