Towards a More Well-Founded Cosmology

Hartmut Traunmüller

Summary of the model that emerged (in this paper)

Gravitation is an attractive elementary force between energy carriers, such as matter and radiation.

Classically, gravitation is described by a field with a scalar potential Φ. At distance r from a pointlike mass M,

$$\Phi = -\frac{GM}{r}. \qquad (-2)$$

In the rest frame of a test body, it gives rise to a force that is proportional to the local gradient of the gravitational potential and the mass m of the test body,

$$\vec{F} = -\nabla\Phi m \qquad (-1)$$

If the force that acts on a body at rest on the Earth discloses a gradient in the gravitational potential field of the Earth, the inertial force that acts on an accelerated body discloses a gradient in a field that is present in the co-moving reference frame of the accelerated body. In this frame, the rest of the Universe accelerates in the opposite direction and gives rise to a force in this direction. This force must be counterbalanced in order to accelerate the body. This alternative embodiment of Einstein's equivalence principle implements Mach's principle. It explains inertia.

Elementary forces are communicated at velocity c. This is the upper limit for a physical velocity. It is the escape velocity from the Universe. (Since the Universe includes everything that exists physically, nothing can really escape.)

In order for something to escape from a gravitational well, it must overcome a gradient. This causes a redshift.

Anything that moves at c faces such a gradient constantly: the gravity (shown to be finite) of the whole Universe attempts to pull it back. This is the cause of the cosmic redshift. (The gradient will be sub-proportionately smaller for anything that moves at $v < c$.)

The cosmic web of galaxy clusters, any smaller structures and angular distances D_a are not essentially affected,

$$D_a = D. \qquad (0)$$

The distance $2D$ can be thought of as measured by counting the periods of a stable monochromatic signal that is sent toward a reflecting target until the first period of the reflected signal returns.

The model is compatible with the "perfect cosmological principle", which says that on a sufficiently large scale (a Hubble sphere or larger), *the Universe is homogeneous and isotropic in time as well as in space.*

If this holds, the factor $(1+z)$ by which waves are stretched per unit of D is necessarily constant and everywhere the same, so that

$$1 + z = \exp(\frac{H}{c}D)\,; \qquad (1)$$

$$D = \frac{c}{H}\ln(1+z)\,. \qquad (2)$$

The Hubble parameter H remains constant.

Flux F of an object that radiates isotropically:

$$F = \frac{L}{4\pi D^2 (1+z)^2} . \qquad (3)$$

This means that the astronomical magnitude m of "standard candles" will satisfy the relation

$$m = 5 \log[(1+z) \ln(1+z)] + const., \qquad (4)$$

which is compatible with data from supernovae of type Ia [Section 4.1 in my previous paper].

The number of periods between a radiation source and the observer is conserved, as in Figure 1. The expanded distance D_{exp} is

$$D_{exp} = \exp(\frac{H}{c} D) - 1 . \qquad (9)$$

It is proportional to z,

$$D_{exp} = \frac{c}{H} z . \qquad (10)$$

The expansion occurs in the direction opposite to the propagation. Any field modulations that propagate or are maintained at c (gravitational as well as electromagnetic) are dilated in this way, whereby slopes and gradients are reduced. Eqs. (9) and (10) hold also for the effective lengths of lines of force.

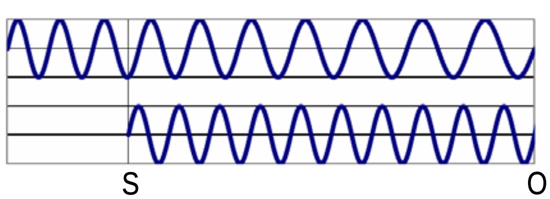

Figure 1. An unexpanded wave train (below) from source S to observer O at distance D = 0.5 Hubble length units (cH^{-1}) and its expanded equivalent (above). The chosen D gives a redshift z = 0.649 and an expanded distance D_{exp} = 0.649 cH^{-1} (= 1.297 D).

The gravitational potential Φ due to all the masses of the Universe, viz., those on the past light cone of a point in spacetime, can be calculated by summing up the contributions from all masses M at their distance r from the point. Classically,

$$\Phi = -G \sum \frac{M}{r} . \qquad (11)$$

In a homogeneous non-expanding universe, this Φ comes out as $-\infty$, but this is unrealistic.

In the present model, the effective r in Eqs. (-2) and (11) is not the static distance D but the expanded distance D_{exp} of Eqs. (9) and (10). With this distance, we get

$$\Phi = -G \sum \frac{MH}{cz} . \qquad (12)$$

In a universe in which matter is homogeneously and isotropically distributed, the potential can be obtained by integrating the contributions from shells of thickness dr at distance $r = 0$ to ∞:

$$\Phi = -4\pi G \rho \frac{H}{c} \int \frac{r^2}{z} \mathrm{d}r . \qquad (13)$$

The contributions to Φ by shells up to r = 8 cH^{-1} in Eq. (13) are shown in Figure 2 (continuous line). The integrated contributions (from $r = 0$ to ∞) are 4.80823 times larger than those calculated for a sphere without expansion and $r_{max} = cH^{-1}$.

Observable baryons account for < 1% of the critical density ρ_c. The CMB photons account for 0.005%. They have their origin in starlight. If this has been redshifted by a factor of 1600, its original energy, which is still present, mainly in gravitational form, accounts for 8%. Further, stars emit about 1.6 times as much energy in form of neutrinos. This brings us up slightly above the 20.8% of ρ_c that appear to be required if (13) is valid.

At the 2.725 K of the CMB, inflow of energy into the "Cosmic Ocean" balances outflow.

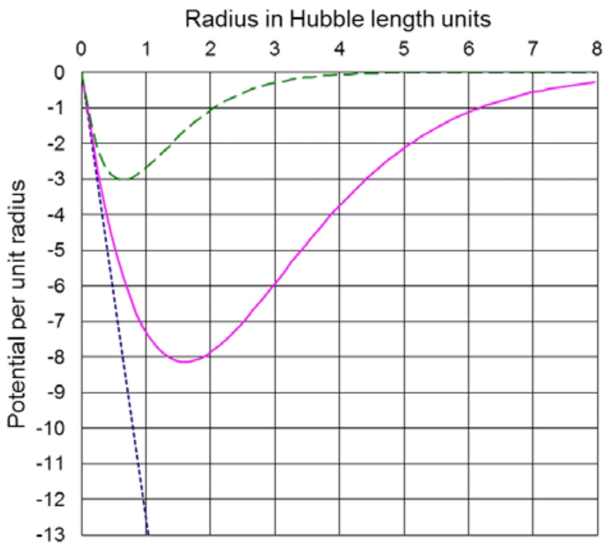

Figure 2. Potentials per unit radius in a homogeneous isotropic universe shown as a function of the radial distance (in Hubble length units cH^{-1}) from an observer. Naive contributions to Φ [as if Eq. (11) was valid] (dotted line) and those in a model in which Eq. (13) is valid (continuous line). These are less negative by the factor D/D_{exp}. The dashed line shows the contributions to the equivalent potential Φ_{equ} of Eq. (15), which are less negative by an additional factor of $(1+z)^{-1}$.

The Hubble acceleration cH causes an isotropic expansion (reduction) of all slopes and gradients of gravitational fields ab initio. The acceleration $\boldsymbol{a}_{\text{red}}$ that corresponds to the so reduced gradients is

$$\boldsymbol{a}_{\text{red}} = \frac{\boldsymbol{a}}{1+\dfrac{cH}{a}}. \qquad (14)$$

However, the acceleration of a distant mass seen by a test body is not $\boldsymbol{a}_{\text{red}}$ but its dilated equivalent, $\boldsymbol{a}_{\text{red}}\,(1+z)^{-1}$. The so further reduced contributions to an "equivalent potential" Φ_{equ} are

$$\Phi_{\text{equ}} = -4\pi G\rho \frac{H}{c}\int \frac{r^2}{z(1+z)}\,\mathrm{d}r. \qquad (15)$$

In Figure 2, Φ_{equ} is the area between the abscissa and the dashed line. It is smaller than Φ (the area between the abscissa and the continuous line, extended to $r = \infty$) by a factor of 0.168093 ($\Phi/\Phi_{\text{equ}} = 5.94910$). The same result is obtained by calculating the mean r of the distribution shown by the dashed line and finding the value of $(1+z)^{-1}$ for this r.

If the inertial force goes toward $\boldsymbol{F} = m\boldsymbol{a}$ at increasing accelerations, is given by a gradient in the field seen by an accelerated body, and gradients (slopes) are dilated as described by Eqs. (14) and (15), the equation for the inertial force becomes

$$\boldsymbol{F} = \frac{m\boldsymbol{a}}{1+\dfrac{0.168093\,cH}{a}}. \qquad (16)$$

This explains the observed galaxy rotation curves and their successful description by the phenomenological approach known as *Modified Newtonian Dynamics*.

Time dilation in the gravitational field of a body causes an isotropic blueshift not only of light from distant sources, but also of the slopes that communicate the acceleration of the rest of the universe. These appear steeper, whereby $\boldsymbol{F}$ is increased. With blueshift z_{g} in the range $0 > z_{\text{g}} > -1$, we get

$$\boldsymbol{F} = \frac{m\boldsymbol{a}}{1+z_g}. \qquad (17)$$

This is relevant in analyses of the anomaly observed in spacecraft flybys of planets. It predicts infinite inertial forces to act at an event horizon at which $1 + z_{\text{g}} = 0$.

Equation (18) is simply a combination of (16) and (17).