Appendix A
Useful Astronomical and Physical Constants

Astronomical units:

Astronomical unit AU $= 1.49597870 \times 10^{13}$ cm
Parsec pc $= 206\,265$ AU $= 3.0857\ 10^{18}$ cm $= 3.26$ ly
Light-year ly $= 0.9461 \times 10^{18}$ cm $= 0.3066$ pc
Hubble distance $= c/H_0 = 2997.9\ h^{-1}$ Mpc
Sidereal year 1 yr $= 365.2564$ d $= 3.156 \times 10^{7}$ s
Hubble time $T_{\mathrm{H}} = H_0^{-1} = 9.7776 \times 10^{9}\ h^{-1}$ yr
Solar mass $1\ M_{\odot} = 1.989 \times 10^{33}$ g

Physical constants:

Velocity of light $c = 2.9979 \times 10^{10}$ cm/s
Gravitational constant $G = 6.67 \times 10^{-8}$ cm^{3} g^{-1} s^{-2}
Planck's constant $h = 6.6256 \times 10^{-27}$ erg s
Boltzmann's constant $k = 1.3806 \times 10^{-16}$ erg K^{-1}
Mass of electron $m_{\mathrm{e}} = 9.1091 \times 10^{-28}$ g
Mass of proton $m_{\mathrm{p}} = 1.6725 \times 10^{-24}$ g
Mass of neutron $m_{\mathrm{n}} = 1.6725 \times 10^{-24}$ g

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Appendix B
Why General Relativity Is Principally Different from Field Gravity

There have been many discussions about the derivation of Einstein's field equations from the spin 2 theory (another name for the field theory), and hence about the possible identity of general relativity and the field approach.

In his lectures on gravitation, Feynman tried to derive the full Einsteinian Lagrangian by iterating the Lagrangian of the spin 2 field. Misner et al. (1973, Chap. 7) wrote that "tensor theory in flat spacetime is internally inconsistent; when repaired, it becomes general relativity". They refered to the papers by Feynman (1963), Weinberg (1965), and Deser (1970) on a "field" derivation of Einstein's equations.

However, Straumann (2000) pointed out internal inconsistencies in such attempts to derive Einstein's equations from the spin 2 field theory: (1) general relativity having black hole solutions violates the simple topological structure of the Minkowski space of the field gravity, and (2) general relativity has lost the energy-momentum tensor of the gravity field together with the conservation laws (a direct consequence of the global symmetry of the Minkowski space). In his review, Padmanabhan (2008) showed that all derivations of general relativity from a spin 2 field are based on some additional assumptions that are equivalent to the geometrization of the gravitational interaction.

Indeed, general relativity and field gravity rest on incompatible physical principles (such as non-inertial frames and Riemann geometry of curved space versus inertial frames with Minkowski geometry of flat space). The geometrical approach eliminates the gravity force, as already de Sitter (1916) noted: "Gravitation is thus, properly speaking, not a 'force' in the new theory". This however leads to the problem of energy precisely because the work done by a force changes the energy. Within the field approach the gravity force is directly defined in an ordinary sense as the fourth interaction and has quantum nature (Feynman 1971).

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Appendix C
The Gravitational Potential of a Fractal Matter Ball with Finite Radius

For a *homogeneous* matter distribution $\rho = \rho_0$ the solution of Eq. (9.5) inside the ball has the form (Baryshev and Kovalevski 1990):

$$\frac{\varphi(x)}{c^2} = -\frac{1}{2} + \frac{\mathrm{sh}(x)}{2x\,\mathrm{ch}(x_0)} \tag{C.1}$$

Here $x = r/R_\mathrm{H}$ is the dimensionless radius in units of the Hubble radius $R_\mathrm{H} = c/t_\mathrm{H} = c/(8\pi G\rho_0)^{1/2}$, $x_0 = r_0/R_\mathrm{H}$ and r_0 is the radius of the ball. The gravitating mass of this ball is

$$M(r) = M_\mathrm{H} x \left(1 - \frac{\mathrm{th}(x)}{x}\right), \tag{C.2}$$

where $M_\mathrm{H} = R_\mathrm{H} c^2/2G$ is the Hubble mass.

For sufficiently small distances ($r \ll R_\mathrm{H}$), the gravitational potential has Newtonian behavior, and for large distances ($r \gg R_\mathrm{H}$) the mass grows linearly so that the gravitational potential in the center of the ball asymptotically reaches the value $-c^2/2$.

In the case of the *fractal dark matter distribution* with $D = 2$ the rest mass density law is $\rho(r) = \rho_0 r_0/r$ and the solution of Eq. (9.5) inside the ball has the form (Nagirner 2006):

$$\frac{\varphi(x)}{c^2} = -\frac{1}{2} + \frac{1}{\sqrt{x}}\left[C_1 I_1(4\sqrt{x}) + C_2 K_1(4\sqrt{x})\right] \tag{C.3}$$

where I_1 and K_1 are the modified Bessel functions and x is the dimensionless distance. Using ordinary conditions for the gravitational potential of a finite ball with radius $x = x_0$, one finds that $C_2 = 0$ and $C_1 = 1/(4\,I_0(4\sqrt{x_0}))$, where $I_0(x)$ is the modified Bessel function.

The total gravitating mass inside the fractal ball of radius r is:

$$M(r) = M_\mathrm{H} x \left(1 - \frac{I_1(4\sqrt{x})}{2\sqrt{x} I_0(4\sqrt{x})}\right). \tag{C.4}$$

Here $x = r/R_\mathrm{H}$ is the dimensionless radius in units of the Hubble radius and $R_\mathrm{H} = c^2/(2\pi G\rho_0 r_0)$. ρ_0 and r_0 define the lower cutoff of the fractal structure and $M_\mathrm{H} = R_\mathrm{H} c^2/2G$ is the Hubble mass as above.

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