1.2 Basic observed properties of the universe

1. The universe is **old**.
   The oldest objects in the universe whose age has been estimated are about 10^{10} years old.

$$T_0 \gtrsim 10^{10}\,\mathrm{yr} \sim 10^{60} \tag{12}$$

2. The universe is **big**.
   No observable boundary or periodicity.

$$L_0 \gtrsim 10^{10}\,c\,\mathrm{yr} \sim 10^{60} \tag{13}$$

3. There is a **lot of matter** in the universe.

$$M_0 \gtrsim 10^{21} M_\odot \sim 10^{60} \tag{14}$$

4. The universe is approximately **homogeneous** and **isotropic** on the largest observable scales.

5. The observable universe is **expanding**.
   The expansion rate is given by the Hubble parameter H.
   The current value of the Hubble parameter is

$$H_0 \simeq 65\,\mathrm{km\,s^{-1}\,Mpc^{-1}} \tag{15}$$

$$\sim \frac{1}{10^{10}\,\mathrm{yr}} \sim 10^{-42}\,\mathrm{GeV} \sim 10^{-60} \tag{16}$$

6. The universe is **flat**.
   There is no observable large scale spatial curvature.

7. The universe is not exactly homogeneous and isotropic. **Density perturbations** have an amplitude $\sim 10^{-5}$ and an approximately **scale-invariant** spectrum on the largest observable scales.

8. The matter content of the universe is dominated by **cold dark matter** with about 15% ordinary matter.

$$\rho_{\mathrm{CDM}} \simeq 6\rho_{\mathrm{B}} \tag{17}$$

9. The **baryon** [1] to cosmic microwave background **photon ratio** is about 5×10^{-10}.

$$n_\gamma \simeq 2 \times 10^9 n_{\mathrm{B}} \tag{18}$$

10. The current temperature of the **cosmic microwave background radiation** is

$$T_{\gamma 0} = 2.73\,\mathrm{K} = 2.35 \times 10^{-4}\,\mathrm{eV} \tag{19}$$

    which corresponds to a photon number density

$$n_{\gamma 0} = 0.41\,\mathrm{mm^{-3}} \tag{20}$$

[1] A baryon is a particle made of three quarks, for example, a proton or neutron. At energies below the electro-weak scale, the number of baryons is conserved to a very good approximation.