Radboud Universiteit Nijmegen
Afdeling Sterrenkunde
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Newtonian Cosmology – 2010/11

Werkcollege 1 – 27.04.2011

1. The radius of the Milky Way is $3 \cdot 10^{20}$ m. Calculate the velocity of a spacecraft which crosses the diameter of the Galaxy in 300 years (measured on board the spacecraft). Express the result using $\gamma = 1/\sqrt{1-(v^2/c^2)}$.

2. Quasi stellar objects (quasars) radiate with a Doppler shift $z = (\lambda_{obs} - \lambda)/\lambda = 1.95$. λ is the observed wavelength. The observer is in rest relative to the radiation source. Calculate the velocity of the quasars relative to us. Calculate the distance to the quasars, assuming the Hubble law

$$v = H_0 \cdot r.$$

With the Hubble constant $H_0 = 70$ km/s/Mpc. Give the results in [m], [ly], and [pc].

3. Calculate the gravitational red shift of the 769.9 nm line of potassium emitted from the surface of the Sun.

4. The spectral energy density of the radiation emitted by a black body with temperature T is described by the Planck law

$$\rho(\nu, T)d\nu = \frac{2h\nu^3}{c^2}\frac{1}{\exp\left(\frac{h\nu}{kT}\right) - 1}d\nu.$$

Integrating over all frequencies ν gives the total radiation emitted by a black body. Calculate the total energy emitted, this is the Stefan-Boltzmann law. How does the radiated energy depend on temperature?

Remarks:

$$\int_0^\infty \frac{\xi^3 d\xi}{e^\xi - 1} = \frac{\pi^4}{15} \text{ and } \xi = \frac{h\nu}{kT}.$$

$c = 3 \cdot 10^8$ m/s is the speed of light, $h = 6.626 \cdot 10^{-34}$ Js the Planck constant, and $k = 1.38 \cdot 10^{-23}$ J/K the Boltzmann constant.

5. Suppose that the Milky Way galaxy is a typical size, containing $\approx 10 \cdot 10^{11}$ stars, and that galaxies are typically separated by a distance of one megaparsec. Estimate the density of the Universe in SI units. How does this compare with the density of the Earth?

$1\ M_\odot \approx 2 \cdot 10^{30}$ kg, 1 pc (parsec) $= 3.086 \cdot 10^{16}$ m.

The solutions will be discussed on 27.04.2011 at 15:30 in HG 01.029.
Course web site: http://particle.astro.ru.nl/goto.html?cosmology1011