INTERPRETATION OF THE HUBBLE LAW: EXPANSION VS THE SHIFT OF TIME WITH RADIUS

D.L. Khokhlov – Sumy State University – R.-Korsakov St. 2, Sumy 40007 Ukraine

In 1929 Hubble [1] reported the discovery of a relation between the distance and the redshift in the spectra of galaxies interpreted as a Doppler effect due to the radial motion of galaxies which obeys the law

$$v = Hr \qquad (1)$$

where H is the Hubble parameter. The standard cosmology, see, e.g. [2], explains the Hubble law as an expansion of the universe. According to the standard cosmological arguments, the dynamics described by the Hubble law is a consequence of a homogeneous distribution of self-gravitating matter, hence the Hubble law is valid for distances which are larger than the size of the cell of homogeneity.

Observations tell us that the size of the cell of homogeneity is 100-150 Mpc or more. But Hubble discovered his law at the distances which are of order of 20 Mpc. Recently Sandage [3] confirmed the fact of expansion in the local volume with the sizes from 1.5-2 to 20 Mpc, and the kinematical identity of the local (< 20 Mpc) expansion with the global (>> 100-150 Mpc) expansion has been proved with a high accuracy. It seems incompatible co-existence of the regular Hubble flow with the highly non-homogeneous matter distribution deep inside the cell of matter homogeneity. It seems even more puzzling that the linear Hubble flow is very quiet in the local volume: the local velocity dispersion about the mean local expansion rate is about or smaller than 60 km/s. From the standard viewpoint it is expected that the local velocity dispersion is of order of the bulk velocity. The largest bulk velocity for the sun is that towards the Great Attractor, this is about 600 km/s in the rest frame of the Cosmic Microwave Background. As Sandage [3] says, "explanation of why the local expansion field is so noiseless remains a mystery".

Analyses of radio Doppler and ranging data from distant spacecraft in the solar system indicated that an apparent anomalous acceleration is acting on Pioneer 10 and 11, with a magnitude $w_P = \left(8.74 \pm 1.25 \times 10^{-8}\right)$ cm/s^2, directed towards the Sun [4]. This anomalous acceleration is of order of the acceleration due to the Hubble law. When adopting the modern Hubble parameter $H = 60 \pm 10$ km/s/Mpc [5] the acceleration due to the Hubble law is given by

$$w_H = cH \rightarrow 6 \times 10^{-8} \text{ cm/s}^2. \qquad (2)$$

Hence one can interpret the anomalous acceleration acting on Pioneer 10 and 11 as that due to the Hubble law. Indeed such an interpretation is incompatible with the standard viewpoint since the solar system scale is much more smaller than the homogeneity scale.

So explanation of the Hubble law by means of the expansion of the universe is questioned. Observations tell us that the Hubble law is observed at scales smaller than the homogeneity scale and is not affected by the matter distribution. From this it is reasonable to assume that the background space of the universe is independent of the matter, and the Hubble law describes the behaviour of this background space.

Assume that the background space of the universe is the static Euclidean space independent of the matter. Let the size of the universe be given by

$$a = ct = \frac{c}{H}. \tag{3}$$

Let an observer be placed in the centre of the universe. Let the source placed at the distant r from the observer emit photon at the time t_e. The observer receives photon at the time t_r shifted with respect to the time t_e by the value

$$\Delta t = \frac{r}{c} = \frac{rt_r}{a}. \tag{4}$$

Then the time is shifted along the radius of the universe as

$$t_e = t_r - \Delta t = t_r(1 - r/a). \tag{5}$$

Due to the time shift one measures the shift (redshift) of the photon frequency with radius

$$\omega_r \equiv \frac{1}{t_r} = \omega_e(1 - r/a). \tag{6}$$

In view of the relation for the Hubble parameter $H = c/a$, eq. (6) yields the Hubble law

$$\frac{\omega_e - \omega_r}{\omega_e} = \frac{r}{a} = \frac{Hr}{c}. \tag{7}$$

Thus one can interpret the Hubble law as the shift of time with radius in the static Euclidean space.

Summarize the above consideration. The observed behaviour of the Hubble law, namely, that it is observed at scales smaller than the homogeneity scale and is not affected by the matter distribution, is not compatible with the standard cosmology. Recall that in the standard cosmology the background space of the universe is defined by the homogeneous matter distribution, and the Hubble law describes the expansion of the background space due to self-gravitation of the matter. The observed behaviour of the Hubble law makes it reasonable to assume that the background space of the universe is not defined by the matter. The background space is a static one, and the Hubble law can be interpreted as the shift of time with radius.

Bibliographical references

[1] E. HUBBLE, A relation between distance and radial velocity among extra-galactic nebulae, Proc. Nat. Acad. Sci., 15 (1929), 168-173.
[2] P.J.E. PEEBLES, Principles of Cosmology, Princeton University Press, Princeton (1993).
[3] A. SANDAGE, Bias properties of extragalactic distance indicators. VIII. H_0 from distance-limited luminosity class and morphological type-specific luminosity functions for Sb, Sbc, and Sc galaxies calibrated using cepheids, Astrophys. J., 527 (1999), 479-487.
[4] J.D. ANDERSON et al., Study of the anomalous acceleration of Pioneer 10 and 11, Phys. Rev. D 65 (2002), 082004.
[5] G. PATUREL et al., Hubble constant from sosie galaxies and HIPPARCOS geometrical calibration, Astron. Astrophys., 339 (1998), 671.