Interpretation of the Red-Shifts of the Light from Extra-Galactic Nebulae

IN his most recent contribution on this subject¹ Hubble mentions a red-shift of $+0.231 \text{ \AA}$. This corresponds to a velocity of recession of approximately 43,000 miles per second, nearly a quarter of the velocity of light! The conviction grows upon one that these fantastic velocities are not real.

Alternative interpretations of the red-shift have been proposed, but have failed to provide an acceptable explanation. No one has taken account of the fact that a list of the available determinations of the velocity of light shows a steady decrease of velocity with time, following a linear law, $c = 299,900 - 3.855 T$, for the epoch 1900² (see Table 1).

TABLE 1.

T	c
1902.4	299,901 $\pm$ 84 km./sec.
1924.6	299,802 $\pm$ 30
1926.0	299,796 $\pm$ 4
1928.5	299,778 $\pm$ 20
1932.1	299,774 $\pm$ 11
1937.7	299,764 $\pm$ 15
1938.5	299,761 $\pm$?

This may be due to a 'fatigue' phenomenon: there are in Nature no inexhaustible stores of energy, no examples of perpetual motion. There are tremendous stores of energy and the ensuing motion may continue without perceptible alteration for periods almost beyond reckoning, but neither lasts indefinitely. The energy of a photon is not considerable and an explanation of the slowing-down may be sought in a

admitted that the energy of a photon generated by an atom of the same element under the same conditions is the same in all sources near and far. For example, the energy of the photon giving the K line of Ca^+ has the same energy whether generated in a remote nebula or on the earth.

It follows from the above that light leaves a remote nebula with a velocity $c_0 > c$, and a wave-length λ_0 given by the relation $c_0 = n\lambda_0$ (2). During the light's journey, both c_0 and n decrease until, when the light reaches the earth, they have become c and n' respectively, with $c = n'\lambda$ (3) and n' is less than n . Since $c_0 > c$, from (2), $\lambda_0 > \lambda$, the corresponding wave-length of light from laboratory sources, and $\lambda_0 = \lambda + d\lambda$, which is the observed red-shift.

In Table 2, m_c is the luminosity of the fifth brightest nebula in each cluster (the clusters are so similar that this gives a precise measurement of distance) and $d\lambda/\lambda$ is the observed red-shift. R is the distance in light years, from the relation $\log r = 0.2 m_c + 4.803$; λ_0 is the initial wave-length of the K line of Ca^+ , calculated from the red-shift, taking its earth value as $\lambda = 3933 \text{ \AA}$.—It is the wave-length at both ends of the light's journey; n' is the frequency of the light from the nebula when it reaches the earth, and c_0 is the initial velocity of the light. The nebulae are in order of increasing distances. The data relating to Ursa Major II are inconclusive: they have been derived from a single spectrogram of a single nebula only.

TABLE 2.

Cluster	m_c	$d\lambda/\lambda$	r light-years	λ_0 of K line of Ca^+	n'	c_0
Virgo	10.49	0.0041 A.	8×10^6	($\lambda = 3933 \text{ \AA}$)	($n = 762.2 \times 10^{12}$)	($c = 299774 \text{ km./sec.}$)
Pegasus	12.88	0.0127	24	3919 A.	759.1×10^{12}	300990
Percus	13.48	0.0177	31.6	3937	752.6	303585
Coma	14.23	0.0245	44.6	4001	749.1	305030
U. Ma. I	16.12	0.0517	106.4	4029	744.0	307090
Leo	16.33	0.0653	117	4137	724.6	315320
Cor. Bar.	16.54	0.0707	129	4190	715.5	319360
U. Ma. II	17.73	0.1403	223.4	4211	711.9	320960
Boötes	17.89	0.1307	210.4	4485	668.4	341850
				4447	674.1	338950

decrease of frequency as the light journeys through space. It may be sought in the fact that the velocity of propagation of a vibration depends on the physical properties (gravitational, electrical, magnetic, atomic, thermal and probably others) of the space through which it is propagated, and that these properties are gradually altering. Whatever its explanation, the slowing-down is an observed fact.

Besides this, a satisfactory interpretation of the red-shifts must conform to the following further observed facts:

(1) Strömberg, by measuring the aberration of light from nebulae of the Ursa Major I cluster, has shown that the velocity of the light from this cluster is the same as that of light from laboratory sources³. Light from all sources, near and far, reach therefore the eye with the same velocity, c .

(2) Planck's constant h is constant, for Adams and Humason³ have shown that the relation $E\lambda = ch$ (1) holds good for sources of light near and far, by comparing a grating and a prism spectrogram of the emission spectrum of the nucleus of N.G.C. 4151.

(3) The wave-length is constant during the light's journey: this assumption is accepted as correct when measuring radial velocities.

(4) The frequency n of a newly generated photon of energy E is the same for all sources of light near and far, since (1) may be written $E = hn$, and it is

The slowing down of the frequency and of the velocity both follow linear laws: $n' (\times 10^{12}) = 762.2 - 0.4 T$; and $c_0 (\text{km./sec.}) = 299774 - 173 T$, where T is in millions of years.

Accordingly, 240 millions years ago, light travelled with a velocity approximately 13 per cent greater than now, and the wave-length of the K line of Ca^+ was 4447 A.

Should the above be confirmed, our measurements of stellar radial velocities will require a correction depending on the distance.

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June 29.

¹ Hubble, "The Observational Approach to Cosmology".

² NATURE, 120, 602 (1927). A later list of observations appears in *Ibid.*, 25 (2), No. 70 (Sept. 1927).

³ Reports Mount Wilson Obs., 1935-36.

Interrelation of Dissociation Energy and Inter-nuclear Distance for some Simple Di-Atoms in Ground States

HAVING recently suggested¹ that $D r_e^2$ (D dissociation energy, r_e internuclear distance) is approximately constant for C—C linkages in solid carbon and in hydrocarbons, I find further that $x = D r_e^2 n^{1/2}$