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A New Age for the Universe?

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A NEW AGE FOR THE UNIVERSE?

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The question of the age of the earth, the solar system, stars galaxies and the whole universe have intrigued man for a long time. The story of Bishop Ussher's use of biblical chronology in the early 1600s to date the creation at 4004 B.C. is the story of the earliest attempt to arrive at an answer to this question. The work of geologists, and physicists during the 1800s called this date into serious question. Investigations based on stratigraphy, salination of the oceans, and heat flow from a cooling earth put the age much greater than Ussher's estimate. Although these methods overlooked some possible sources of error, this combined work put the age of the earth between 40 and 400 million years. By inference, the universe must have been older than that.

It wasn't until the beginning of the 20th century that radioactive isotope dating techniques became available and age estimates for the earth in the neighborhood of three billion years old began showing up in the literature. Again, by inference, the universe must have been older than that. However, no reliable technique for determining the age of the universe itself existed until the 1920s and 1930s, when the true nature of galaxies was recognized. It was then determined that the systematic motions of galaxies suggested a common origin of all the matter of the universe that could be traced backwards into *time*.

In 1924, Edwin Hubble was able to determine the distance to galaxies utilizing cepheid variable stars. Earlier, Vesco Slipher had determined that the spectra of these objects had measurable red-shifts in their absorption lines. This implied recessional motions away from each other.

During the 1930's, Hubble determined the distance to a number of galaxies and obtained their recessional velocities and found that the more distant galaxies were receding faster than the closer ones. (Fig. 1.) This led to his classic work that showed we lived in an expanding universe. This expansion in accord with what came to be known as Hubble's Law. It is generally stated as: $V = Hd$, where V = Velocity of recession; H = Hubble's constant; and d = distance to the galaxy.

Galactic distances are usually expressed in million parsec units (Mpc) where one Mpc equals about three million light years (L Y). Recessional velocities are given in km/sec and Hubble's constant tells us how fast a galaxy is receding for each Mpc distance from our own galaxy. When Hubble first did his work it was determined that for each Mpc distance, a galaxy was receding at about 500 km/sec. For example, a galaxy two Mpc away was found to be receding at 1000 km/sec; one at three Mpc was receding at 1500 km/sec, *etc*.

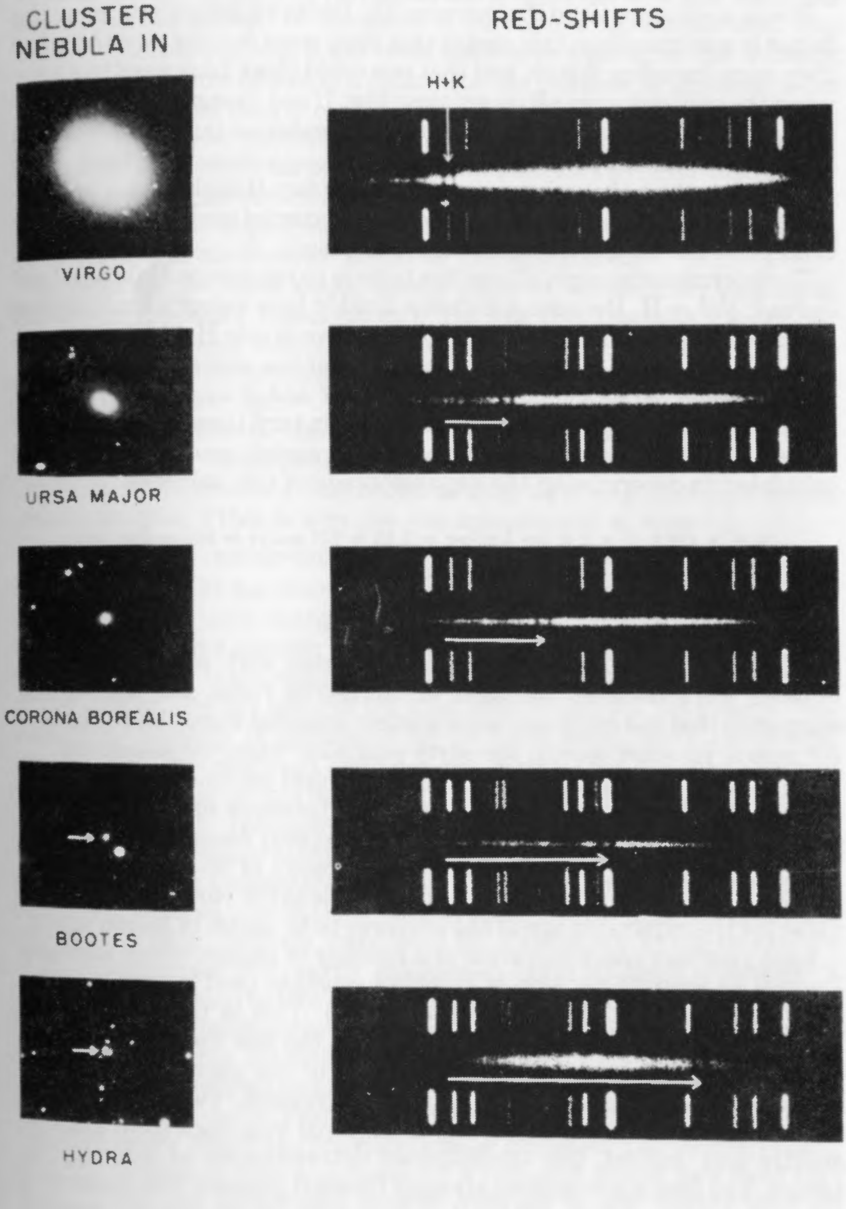

Fig. 1. Red-shifts are expressed as velocities, ch/h. Arrows indicate shift for calcium lines H and K. One light-year equals about 6 trillion miles or 6×10^{12} miles.

It was soon recognized that because the farther a galaxy was away the faster it was traveling, this meant that they were farther away *because* they were traveling faster, and that one could think backward to a time when the galaxies were all closer together. If one thought backward *far* enough, one could imagine a time when all galaxies (and the matter in them) was all at one place. This led to the concept of the "Big Bang," the moment at which the universe was born. In fact Hubble's Law permitted the estimation of how *long ago* that occurred and this led to the concept of the expansion *age* of the universe.

To determine this age, all one has to do is to rearrange Hubble's Law to read: V/d = H. Because a distance divided by a velocity leads us to a time: d/V = t, it is clear that 1/H = time. If we divide Hubble's constant into 1 Mpc, we can get the expansion age of the universe.

One million parsecs equals 3.26×10^6 L Y and if we multiply this by the speed of light (3×10^5 km/sec) and this in turn times the number of seconds per year ($= 3.15 \times 10^7$) we have a simple problem for a hand calculator in determining the expansion age of the universe.

$$\frac{3.26 \times 10^6 \text{ L Y} \times 3 \times 10^5 \text{ km/sec} \times 3.15 \times 10^7 \text{ sec/yr}}{500 \text{ km/sec}} = \text{expansion age}$$
$$= 6.16 \times 10^{16} \text{ sec}$$
$$= 1.9 \times 10^9 \text{ year}$$

This age, when first published was greeted with some skepticism because work done on the ages of terrestrial rocks and meteorites suggested that the earth and solar system material were older than 3×10^9 years! In other words, *the earth was older than the universe!*

As time progressed, improved astronomical techniques permitted more accurate determinations of galactic distances and the value of Hubble's constant gradually fell over the next four decades. A standard value now used suggests that it is in the range of 55 km/sec/Mpc. A similar calculation to the one done above leads to the currently accepted value for the expansion age of the universe to be about 18 billion years.

Last year saw the publication of a number of papers which strongly suggest an *upward* revision of Hubble's constant (and in turn a *downward* revision for the age of the universe). This is the first serious revision downward in the expansion age in the last forty years.

In order to understand the significance of the current work, it is appropriate to review how the value is determined. Two factors enter into this determination. First, the recessional velocities from galactic spectra and, second, the unambiguous determination of galactic distances. The first is a relatively straight forward process. One obtaines a galactic spectra and identifies what element is producing the galactic absorption lines. The amount of shift from the laboratory (rest) wavelength is obtained and then one uses the standard Doppler equation to establish recessional velocities. The second is far more difficult. Conventional distance measuring techniques fail completely for galactic distances (parallax, spectroscopic parallaxes, *etc.*) Other techniques, such as the use of cepheid variables, the brightness of bright stars and supernova are limited to distances of only a few million parsecs. The standard technique which has been used is to determine the intrinsic brightness of some object in a galaxy (or the intrinsic brightness of the whole galaxy) and then to compare it with the observed brightness. The difference in these values is an index of the distance to the galaxy. A major problem with this approach is the difficulty in determining how the light from the object is affected by intervening gas and dust. In other words, the object may look dimmer because of this observation and, therefore, its distance would be *over*-estimated.

In what is the most major recent piece of research on this topic, Aaronson (Steward Observatory), Huchra (Smithsonian Center for Astrophysics), and Mould (Hale and Kitt Peak Observatories) have devised a technique which has produced surprising new results concerning this expansion age.

Their techniques use the infrared brightness of galaxies to determine their apparent brightness. This technique permits them to "see" through the intervening dust better as long wavelengths of light better penetrate dust. (This is why the sun appears red at sunset.)

To determine the *intrinsic* brightness of galaxies, they used an indirect technique. It has been well established that the mass of a galaxy determines the total energy output of a galaxy. (The total number of stars determines a galactic mass, and their combined light produces the overall intrinsic brightness of the galaxy.) To determine the total mass of the galaxy, one can observe the rotational velocity of the galaxy. This rotational velocity is influenced by its total mass. Both theoretical studies and observational evidence has shown that the luminosity of spiral galaxies is proportional to the fourth power of the maximum rotational speed. These investigators used radio telescopes to determine the rotational broadening of the 21 cm radio wavelength which is produced by the neutral hydrogen in the galactic arms. Improvements in radio telescopes permit these measurements to be made out to at least *100* Mpc. These methods were used by Aaronson's group to explore Hubble's constant for nearby galaxies to *calibrate* their technique, a necessary first step before going to more distant galaxies. It was when they tried their methods on the more *distant* galaxies that their results begin to excite the astronimical community.

Four clusters of galaxies having Doppler red-shifts equivalent to 4000 to 6000 km/sec were examined and their methods put all of these clusters *closer* than have previously been assumed. The corresponding Hubble expansion rate was lower by a factor of almost two from currently accepted values and ranged from 89 to 104 km/sec with an average of 95 ± 4 km/sec/Mpc. The inverse of this value gives an expansion age for the universe of only *about ten billion years*.

This marks the first downward revision in this age since the method began. Its implications for astronomy and all of science, if verified by others, will be far-reaching!