The Hubble Law

DR DON B. DE YOUNG

ABSTRACT

The background of astronomer Edwin Hubble and his famous expanding universe law are reviewed. The significance of the Hubble constant is explained, along with the ongoing controversy regarding its actual value. Finally, a creationist view of the usefulness and limitations of the Hubble law is given.

INTRODUCTION

The Hubble name is closely connected with modern astronomy. There is the Hubble telescope, Hubble constant or parameter, Hubble length and diagram, and also the Hubble law. The Hubble constant *H* is of particular significance; it is defined as a measure of how fast the universe is expanding. Many astronomers believe that *H* also holds the key to learning the age of the universe. There is great confusion about the universe's age among people, at present, and for good reason. Every astronomy publication seems to present a different opinion on age, from 6 billion to 25 billion years or more. Occasionally it is even reported that certain globular star clusters seem to be older than the universe itself![1] The main reason for this confusion involves the Hubble constant. Its value has obsessed astronomers for decades, and yet it is still not known for sure. Actually, of course, the universe's age is just one of many unanswered questions in astronomy today. Appendix A presents a list of many other such fundamental questions.

EDWIN POWELL HUBBLE 1889–1953

Although gone for nearly a half century, the shadow of Edwin Hubble still dominates the field of astronomy. He practically defined the discipline, even to his authoritative, impersonal writing style so often found in modern astronomy. A typical Hubble sentence:

> *'Nebulae are found both singly, and in groups of various sizes up to the occasional, great compact clusters of several hundred members each.'*[2,3,4]

Edwin Hubble was born in Missouri, one of seven children. He was an honour student and also a star athlete in high school. At age 16 he entered the prestigious University of Chicago to study physics and astronomy. Next, a Rhodes scholarship took Hubble to Queen's College in Oxford, England, where he earned a law degree. The legal field did not sit well with Hubble, however, and he briefly became a basketball coach in Indiana. Then it was back to Chicago for a Ph.D. in astronomy, granted in 1917 just as America entered World War I. Hubble served with distinction for two years in Europe, then returned home to an astronomy career at Mount Wilson Observatory, Southern California.

For the next quarter century Hubble made many key discoveries using the 100-inch Wilson telescope. He brought a formal style to observing, always wearing a tie when on telescope duty. He produced two classic books, **The Realm of the Nebulae** (1936) and **The Observational Approach to Cosmology** (1937). Edwin Hubble was apparently not a religious man. Neither his books nor his biographers discuss any consideration of the Bible or biblical creation.

During World War II Hubble gave his talents to the US Army Ballistics Research Lab. At the same time, he helped plan the famous 200-inch Hale telescope on Mount Palomar, 50 miles from Mount Wilson. Hubble continued his research at Palomar until felled by a stroke in 1953.

HUBBLE'S DISCOVERIES

Hubble enjoyed a long career of successful research in astronomy. Three of his best known contributions will be mentioned here. First, Hubble greatly expanded the known stellar distance scale. For many years there had been a controversy concerning certain spiral nebular objects found in the night sky. This culminated in a famous 1920 'Shapley-Curtis debate' at the National Academy of Sciences. Harlow Shapley of Mount Wilson Observatory believed that the mystery nebulae were small, nearby gas clouds within our Milky Way galaxy. Heber Curtis of nearby Lick Observatory countered that the objects were actually galaxies in themselves, each being far distant and very large. About this time the new Mount Wilson 100-inch telescope was completed and saw its 'first light'. Edwin Hubble quickly began a detailed study of the spiral nebulae. One in particular interested him, called Andromeda, labelled as M-31 in the Charles Messier catalogue of space objects. What Hubble saw were individual stars within the spiral arms. Even more important, some of these stars were Cepheid variables which reveal their distance from earth (see Appendix B).

Hubble initially derived an inaccurate distance of 930,000 light years for Andromeda, today known to be about 2.2 million light years away. Heber Curtis had been correct in the 1920 debate; many of the nebulae were indeed remote galaxies. Sometimes these building blocks of the universe are incorrectly called 'island universes' themselves. Such galaxies typically contain 100 billion stars each. Also, about 100 billion distinct galaxies are known to exist. Thus there are presently known about 10^{22} (10 billion trillion) stars in the visible universe.

A **second** contribution from Hubble was the cataloguing of distinct types of galaxies. These include elliptical, spiral, barred spiral and irregular shapes. Many astronomers since Hubble have suggested that one type of galaxy evolves into another over billions of years. Some believe that ellipticals evolve into spirals; others say that change is in the opposite direction. Actually, evidence for such galaxy evolution is lacking. If galaxies **do** indeed change, the relativistic cosmology of Russell Humphreys offers a creationist explanation.[5] In this model, galaxies may have slowly aged in their own frame of reference, but on a completely different time scale from the young world as referenced to the earth.

Hubble is best known for his **third** astronomy contribution. This is the assertion that galaxies are moving outward in expanding space, and that their speed is proportional to their distance. Astronomer Vesto Slipher had reported red-shifts for nebulae back in 1912. However, it was Hubble who suggested an overall expansion of the universe. In a famous 1929 paper he described the 'law of red-shifts' which was soon known as the Hubble Law.[6]

The apparent expansion of the universe quickly became one of the chief evidences for the Big Bang theory of origins. It is interesting that Hubble always remained unsure of the velocity interpretation of stellar red-shift. He spoke of *'apparent velocities'*, although this qualification is seldom considered today.

In the creation view, universe expansion may well be reality, but the Big Bang interpretation is entirely unnecessary. Instead, the universe was most likely created in an expanding mode for **stability**. Without expansion, gravity would cause the universe to begin to collapse back on itself. Many other motions, like the orbits of planets and the rotation of stars and galaxies, also serve the same function of providing a stable, dependable universe.

THE HUBBLE CONSTANT

The velocity (v) – distance (d) relationship for galaxies can be written as

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

where H *is* the proportionality constant or Hubble constant. Here v is the *apparent* velocity, that is, the velocity which would produce the observed red-shift if velocity were really the cause of the red-shifts. The formula states that galaxy speed increases linearly with distance outward into space.

The Hubble relation is much used to measure galaxy distances on the scale of billions of light years. First, in this technique, nearby receding galaxies ('calibration galaxies') are sought for which v and d are both known. From these, the value of H can be determined. Then for other more distant galaxies, knowing their speeds from red-shift measurement, galactic distances can be calculated.

In actual practice things are not quite so simple. The calibration of the Hubble Law, that is the determination of H, has proved a difficult problem. The velocity v for galaxies can indeed be found, assuming that light red-shift is indeed due to stellar motion. But the galactic distance is a much greater challenge. One typically looks for Cepheid variables, stars of known distance in other galaxies (see Appendix B.) And these calibration galaxies must be far beyond Andromeda, for example, for which the Hubble relation does not apply. Andromeda galaxy is in our 'nearby' local group of about 30 galaxies. Andromeda actually moves **toward** the Milky Way due to gravity attraction and its light shows a slight blue-shift. Please note that it is space itself which expands in the Big Bang model. Galaxies are moved outward in this process.

Much recent activity has involved detecting pulsating Cepheids in the large Virgo cluster of galaxies, about 50 million light years away. These galaxies have provided a rough estimate for the constant H. In an extrapolation, the Hubble law is then used to estimate distances of galaxies that are hundreds of times further away than the Virgo cluster. This is called a 'bootstrap technique', whereby later conclusions are based strongly on earlier, critical measurements. A small mistake at the beginning can lead to meaningless results later on.

The units for the Hubble law are shown:

$$v \text{ (kilometres/second)} = H\, d \text{ (megaparsecs).}$$

Typical recessional speed for Virgo cluster galaxies is about 1,200 kilometres/second. A single parsec of distance is 3.26 light years; a megaparsec is a million parsecs, 3.26 million light years, or 18×10^{18} miles (29×10^{18}km).

In the Big Bang scenario, H is thought to have decreased with time because of the gradual braking effect of gravity. The constant is a measure of how fast the universe is expanding, and this expansion would have been greater when the universe was young. Thus H is more accurately not a constant, but a changing parameter. To Big Bang enthusiasts, the reciprocal of H becomes an upper limit on the age of the universe:

$$1/H = d / v \quad (2)$$

$$\frac{\text{seconds x megaparsecs}}{\text{kilometres}}$$

With these units, inverse H must be multiplied by 9.64×10^{11} to give an age in years. Thus if $H = 50$,

$$\text{Universe age} = 1/50 \times 9.64 \times 10^{11} \text{ years}$$
$$= 19.3 \text{ billion years}$$

Such values are handled loosely by astronomers because of their suspicion that H has decreased with time; the universe must therefore be somewhat younger. It is common practice to quote an actual age value of about 2/3 of the calculated result, in this case 13 billion years.

The uniformitarian universe size also follows from H by assuming that the furthest galaxies have been receding outward at speed c since the Big Bang:

$$\text{Universe size} = c/H \quad (3)$$

Again assuming $H = 50$, with proper units, this gives a size of 19.5 billion light years. The gravity reduction factor of about 2/3 is again sometimes applied as it is for age. Whether this length is universe radius, diameter, or even circumference depends on one's particular view of the geometry of space.

HUBBLE CONSTANT VALUES

The Hubble constant cannot be measured exactly, like the speed of light or the mass of an electron. Aside from questions about its possible variation in the past, there is simply no consensus on its value today. Table 1 lists representative published Hubble constant values over the years. In articles where the universe age was not given, it was derived from the inverse of H, using the 2/3 gravity factor discussed earlier. The published values of age show quite a range in gravity factors used by different authors.

Today there are two popular competing values for the Hubble constant. A smaller value of about $H = 50$ is promoted by Allan Sandage, Gustav Tammann and colleagues. This constant results in a universe age of about 19.3 billion years. A larger value, $H = 100$, is preferred by many other astronomers: Gerard de Vaucouleurs, Richard Fisher, Roberta Humphreys, Wendy Freedman, Barry Madore, Brent Tully and others. The $H = 100$ value gives a universe age half that of Sandage, 'just' 9 billion years or less, depending on the gravity factor used.

The point here is not which H value is more accurate. In the creation view, either H extreme may be allowable, while rejecting outright the age conclusions. Of greater interest is the uncomfortable corner that Big Bang cosmologists have found themselves in: If the universe is older ($H = 50$), then a large quantity of contrary data needs to be explained. And if the universe is younger ($H = 100$), then the 'ancient' globular clusters require explanation.

CREATION INTERPRETATION OF *H*

Recent creationists do not accept a 'slow' outward expansion of the universe from a Big Bang event. The initial 'spreading out' of the heavens by the Creator may well have been a near-instantaneous event. Following this origin, a slower outward expansion may have continued, as is measured today. Thus the actual H value may have been a step function as shown in Figure 1.

The near-infinite value of H would have applied to the fourth day when the sun, moon, stars and galaxies were created. Just for fun, this H value can be approximated from equation (2)

Author	Publication Year	Hubble Constant	Universe Age (billions of years)
Hubble[7]	1929	320	2
Harwit[8]	1973	75	9
Pasachoff[9]	1992	36	18
Gribbin[10]	1993	26	25
Freedman[11]	1994	65–99	8–12
Hawking[12]	1994	43	15
Kuhn[13]	1994	54	12
Matthews[14]	1994	80	8
Ross[15]	1994	38	17
Schmidt[16]	1994	64–82	10–12
Wolff[17]	1994	50	13

Table 1. *Representative published values of the Hubble constant and universe age. Universe ages are published values, or else calculated from Equation (2) using the 2/3 gravity reduction factor.*

$$\text{Time} = H^{-1} \; (\text{x } 9.64 \text{ x } 10^{11} \text{ years})$$
$$1/365 = H^{-1} \; (\text{x } 9.64 \text{ x } 10^{11} \text{ years})$$
$$H = 352 \text{ trillion.}$$

If a shorter creation time is selected, a partial day, then the Hubble value approaches infinity. Inflationary cosmologists, who support the extreme upper values for *H*, could never comprehend a value **this** large!

My point is that the Hubble law simply does not apply to the creation period when the universe expansion rate was **far** beyond the speed of light. The Hubble law may well apply to the present-day universe, however, with galaxy recession proportional to distance. The *H* transition from Day Four to the present time may have been either a sudden drop or an exponential decay (dotted lines in Figure 1). Because of the singular nature of the creation event, there is no easy way to verify this alternative history for the Hubble constant.

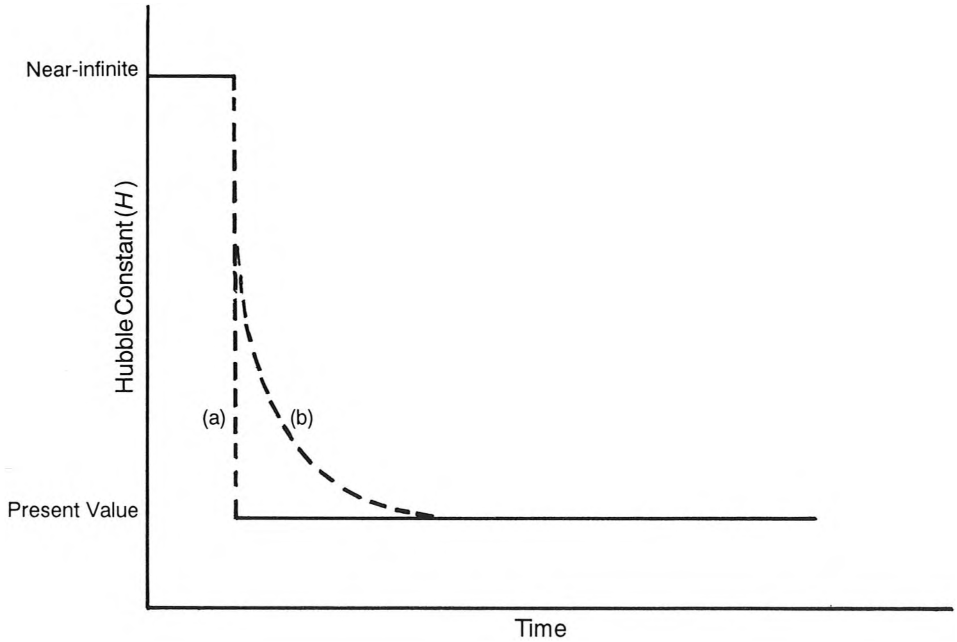

Figure 1. *A possible creationist prediction of the Hubble parameter H plotted against time. The near-infinite H existed on the fourth day, when the heavens were spread out. Afterward it dropped either directly (a) or exponentially (b) to its current value.*

CONCLUSION

What conclusions can be drawn from the Hubble law, $v = Hd$, from a recent creation viewpoint? Consider these points:–

(1) Velocity (v) determinations for galaxies, based on the red-shift of starlight, may well be accurate. The universe could have been created in an expanding mode for stability. Of course, this light evidence comes from deep space where our knowledge of conditions is limited.

(2) Distance (***d***) determinations based on Cepheid variables (millions of light years) could also be quite accurate. More remote distances (billions of light years) based on the Hubble law may be **somewhat** accurate, although limited by the uncertainty of *H*.

(3) The actual Hubble law, $v = Hd$, may be valid today. A value of *H* in the range 50–100 may well describe the present-day universe. If valid, however, the expression has existed only since the heavens were supernaturally spread out.

(4) The use of inverse *H* to approximate universe age must be rejected. This method assumes a uniform universe expansion over time. The method also assumes that *H* has been more or less constant since the beginning. In the creation view it clearly has not been constant (see Figure 1).

(5) The use of the ratio c/H to measure the maximum size of the universe must also be rejected. This method assumes that *H* has remained largely constant and that galaxy recession has been uniform over a vast time period.

(6) A creationist prediction for consideration is that the universe may be far different in size than cosmologists believe. In view of the number of galaxies in space, this size certainly must be larger rather than smaller. In fact, the physical universe may be near-infinite in size, if for no other reason than that *'the heavens declare the glory of God'* (Psalm 19:1).

The Hubble law has been called the greatest contribution to modern astronomy. It describes a general understanding of the expansion of the universe. At the same time, however, the gross uncertainty in *H* shows the limited understanding of basic details such as galaxy distance, and universe age and size. Clearly there need be.no embarrassment in the creation position that the universe is much younger than commonly thought.

Origin theories continually come and go, and 'constants' like *H* wax and wane in magnitude. How refreshing is the creation view, in contrast, where there are absolutes guaranteed by the Creator Himself!

APPENDIX A

The following is a partial list of important, unanswered questions in secular astronomy today. Although the popular media may state otherwise, these remain current issues:–

(1) What is the true value of the Hubble constant?

(2) Why is the solar neutrino flux less than half its expected

value?

(3) Why has extra-terrestrial life not been detected in many other places in space?

(4) What was the origin of the assumed Big Bang 'kernel' of mass-energy, and why did it 'explode'?

(5) How did the first stars and galaxies spontaneously form?

(6) Are there actual planets circling other stars?

(7) Is the red-shift of starlight actually due to universe expansion, or could there be another cause?

(8) What is the origin of the moon?

(9) How far away are the quasars, and what actually are they?

(10) Do galaxies evolve with time?

(11) Where is the missing mass required by the Big Bang? This is also variously called hidden, dark, cold or exotic matter.

(12) What is the origin of cosmic radiation?

APPENDIX B

Henrietta Leavitt and Cepheid Variables

Every star is somewhat variable in its light output, including the sun. One category of variable stars, in particular, is very useful in astronomy; they are called Cepheid variables. These stars change in actual size by about 10 per cent, expanding and contracting over a period of several days. They are brightest when at their larger size. The first such variable was seen in the constellation Cepheid in 1784. Several hundred are known today, including Polaris.

An important property of Cepheids was discovered by astronomer Henrietta Leavitt a century ago. She spent many years cataloguing Cepheid variables, especially their brightness and period of brightness change. As Miss Leavitt wrote in 1908, *'It is worthy of notice . . . that the brighter variables have longer periods.'* More exactly, the period over which the star varies is proportional to the star's intrinsic, actual brightness. This means that Cepheids can be used as the most accurate distance indicators to other nearby galaxies. The steps to follow in the process are:–

(1) Measure the period of variation and the apparent brightness or magnitude for a particular Cepheid.

(2) From the time period, determine the star's actual brightness, also called the absolute magnitude.

(3) Knowing both the apparent and actual star magnitude, its distance can then be closely determined.

Cepheid variable stars tend to be extra bright. Thus their pulsating nature can be seen in other galaxies. Cepheids actually form the basis for all universe size estimates today. They calibrate the Hubble law by providing accurate distances out to about 50 million light years. Miss Leavitt's initial observational work was with the Magellanic Clouds, the nearest galaxies to the Milky Way. Edwin Hubble later discovered a dozen Cepheid variables in the Andromeda galaxy in 1923–1924, showing that galaxy's great distance from the earth.

Henrietta Leavitt (1868–1921) was the daughter of a prominent Congregational minister. She held to the conservative virtues of her Puritan ancestors. Miss Leavitt spent her star gazing career at the Harvard College Observatory in Massachusetts. Although not trained in astronomy, she quickly showed a unique proficiency in analyzing photographic plates. She became chief of photographic photometry, this in a day when women weren't always welcome in science. Miss Leavitt had a shining testimony:–

> *'She was a devoted member of her family circle . . . unselfishly considerate of her friendships, steadfastly loyal to her principles and deeply conscientious and sincere in her Christian life and character.'*[18]

REFERENCES

1. Hogan, C. J., 1994. Cosmological conflict. **Nature, 371**:374–375.
2. Overbye, D., 1991. **Lonely Hearts of the Cosmos**, Harper Perennial, New York, p. 17.
3. Osterbrock, D. E., Gwinn, J. A. and Brashear, R. S., 1993. Edwin Hubble and the expanding universe. **Scientific American, 269**(l):84–89.
4. Gillispie, C. C. (ed.), 1970. **Dictionary of Scientific Biography** (in twenty volumes), Charles Scribner's Sons, New York, Volume VIII, pp. 105–106.
5. Humphreys, D. R., 1994. **Starlight and Time**, Master Books, Colorado Springs.
6. Hubble, E., 1929. A relation between distance and radial velocity among extra-galactic nebulae. **Proceedings of the National Academy of Science, 15**:168–173.
7. Hubble, Ref. 6.
8. Harwit, M., 1973. **Astrophysical Concepts**, John Wiley and Sons, New York, p. 61.
9. Pasachoff, J., 1992. **Journey through the Universe**, Saunders College Publishing, New York, p. 366.
10. Gribbin, J., 1993. Thumbs up for an older Universe. **New Scientist, 140**(1897): 14–15.
11. Freedman, W., Madore, B., Mould, J., Ferrarese, L., Hill, R., Kennicutt, R. Jr., Saha, A., Stetson, P., Graham, J., Ford, H., Hoessel, J., Huchra, J., Hughes, S. and Illingworth, G., 1994. Distance to the Virgo cluster galaxy M100 from Hubble space telescope observations of Cepheids. **Nature, 371**:757.
12. Hawking, S., 1994. **Black Holes and Baby Universes**, Bantam Books, New York, p. 46.
13. Kuhn, K., 1994. **In Quest of the Universe**, West Publishing Co., New York, p. 556.
14. Matthews, R., 1994. Cosmology: spoiling a universal 'fudge factor'. **Science, 265** (5173):740–741.
15. Ross, H., 1994. **Creation and Time**, NavPress, Colorado Springs, p. 95.
16. Schmidt, B., Kirschner, R., Eastman, R., Philips, M., Suntzeff, N., Hamuy, M., Maza, J. and Aviles, R., 1994. The distances to five type II supernovae using the expanding photosphere method, and the value of H_o. **Astrophysics Journal, 432**:42–48.
17. Wolff, M., 1994. **Exploring the Physics of the Unknown Universe**, Technotron Press, Manhattan Beach, California, p. 164.
18. Mitchell, H. B., 1976. Henrietta Swan Leavitt and Cepheid variables. **The Physics Teacher, 14**:162–167.

Dr Don DeYoung holds a physics Ph.D. from Iowa State University in the United States of America. His special interests include astrophysics and impact crater studies. Don has produced several books and many technical articles which explore creation topics. He is a Professor of physics and astronomy at Grace College, Winona Lake, Indiana.