specially designed organo-metallic precursors? Currently, the limiting factor for experimentalists is the lack of magnetic materials that are precisely controlled at the atomic scale. Armed with the information available to date, it is extremely important to manufacture micromagnetic structures with a detailed characterization of the particle morphology and of the atomic constituents. Both of these variables play an important role in controlling quantum dynamics in small magnetic structures. Advances in the engineering of micromagnetic materials combined with ongoing theoretical efforts in this area of science make nanometer-scale magnets important tools to help reveal the significance of quantum mechanics in the macroscopic world.

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The Age and Size of the Universe

Sidney van den Bergh

Modern distance determinations to galaxies were reviewed and placed on a uniform and self-consistent scale. Based on eight separate but not entirely independent techniques, the distance to the Virgo cluster was found to be 15.8 ± 1.1 megaparsec. Twelve different determinations yield a Coma/Virgo distance ratio of 5.52 ± 0.13 and hence a Coma distance of 87 ± 6 megaparsec. With a cosmological redshift of 7210 kilometers per second, this gives a Hubble parameter H_0 (local) of 83 ± 6 kilometers per second per megaparsec. From the velocity-distance relation of rich clusters of galaxies, the ratio of the value of H_0 (global) to the value of H_0 (local) was determined to be 0.92 ± 0.08. In other words, the cluster data do not show a statistically significant difference between the local and global values of the Hubble parameter. If one nevertheless adopts this relation between H_0 (global) and H_0 (local), then the value of H_0 (global) is 76 ± 9 kilometers per second per megaparsec. This observed value differs at the $\sim 3\sigma$ level (where σ is the standard deviation of the distribution) from values in the range $36 \leq H_0 \leq 50$ kilometers per second per megaparsec, which are derived from stellar evolutionary theory in conjunction with standard cosmological models with a density parameter (Ω) that is equal to 1 and a cosmological constant (Λ) that is equal to 0.

The expansion of the universe was discovered with the Mount Wilson 100-inch (2.5-m) telescope by Hubble (*1*) and Hubble and Humason (*2*). During the last decade, it has become clear (*3*) that the velocity-distance relation for galaxies exhibits considerable intrinsic scatter. To determine the present value of the Hubble parameter (H_0) from the relation $V = H_0D$, one must therefore measure the distance (D) of remote galaxies with recession velocities (V) that are at least an order of magnitude larger than the expected deviations from a smooth Hubble flow. However, Hubble noted (*4*, p. 202):

> With increasing distance, our knowledge fades, and fades rapidly. Eventually, we reach the dim boundary—the utmost limits of our telescopes. There, we measure shadows, and we search among ghostly errors of measurement for landmarks that are scarcely more substantial.

In distant galaxies even the brightest objects of standard luminosity are dim and difficult to measure. As a result, the determination of distances to remote galaxies is particularly challenging. This results in considerable uncertainty in the numerical value of the Hubble parameter, which is a measure of the scale size and hence the age of the universe.

Recently, the availability of charge-coupled devices (CCDs) has revolutionized the study of faint stars and galaxies (*5*). The quantum efficiency of CCDs is ~50 times greater than that of the fastest photographic emulsions that had previously been used to study such objects. Furthermore, CCDs are linear panoramic devices with a large dynamic range that are particularly well suited to data reduction by high-speed computers.

In this article, an up-to-date review is given of presently available observational evidence on the extragalactic distance scale. All modern distance determinations have been placed on a uniform and self-consistent scale (*6*, *7*). The recent discoveries of the type Ia supernovae 1991T (which was overluminous) and 1991bg (which was very underluminous) have made it clear that such supernovae cannot be regarded as reliable distance indicators of standard luminosity. In addition, the diameters of supergiant spiral galaxies are not reliable "yardsticks" for measurement of the extragalactic distance scale. The brightest galaxies in some types of rich clusters were found to have a small luminosity dispersion, and these galaxies can therefore be used to place significant constraints on the possible difference between the local and global values of the Hubble parameter.

Here, the plan of attack on the distance scale problem was as follows: first, CCD observations of Cepheids variables, RR Lyrae stars, and other objects of known intrinsic luminosity were used to determine the distances to a small number of key nearby galaxies such as the Magellanic

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Table 1. Distances to key nearby galaxies (*8*).

Galaxy	Distance
Large Magellanic Cloud	49 ± 2 kpc
Small Magellanic Cloud	58 ± 4 kpc
Andromeda nebula (M 31)	725 ± 35 kpc
Triangulum nebula (M 33)	795 ± 75 kpc
NGC 300	1.6 ± 0.15 Mpc
NGC 3031 (M 81)	3.3 ± 0.2 Mpc
NGC 5128	3.45 ± 0.25 Mpc

Table 2. Determinations of distances to the Virgo cluster.

Method	Distance (Mpc)
Planetary nebulae luminosity functions	14.1
Surface brightness fluctuations	14.9
Tully-Fisher (spiral galaxy rotations)	15.0
Globular cluster luminosity functions	19.7
Novae	18.2
Red supergiants	13.8
Supernovae of type II	20.9
Galaxy diameters	12.9

Table 3. Comparison of recent distances with those of Sandage (*10*).

Galaxy	New distance (*8*) (Mpc)	Sandage distance (*10*) (Mpc)
NGC 6822	0.54	0.62
M 31	0.725	0.67
IC 1613	0.765	0.77
M 33	0.795	0.87
Sextans A	1.1	1.74
NGC 3109	1.2	1.58
NGC 300	1.6	1.66
Pegasus	1.6	2.51
M 81	3.3	5.75
Virgo cluster	15.8	21.9

Clouds, the Andromeda nebula, and M 81. These galaxies were used as "stepping stones" to the more distant Virgo cluster. Then, the ratio of the distance of the Coma cluster to the distance of the Virgo cluster was determined with the use of as many different techniques as possible. The velocity of recession of the Coma cluster (with a small correction for retardation of the Local Group by the gravitational attraction of the Virgo cluster) was then combined with the distance to the Coma cluster to derive a value for H_0 (local). Finally, the velocity-distance relation for the bright cD galaxies in rich clusters was used to derive the value of the ratio of H_0 (global) and H_0 (local) and hence a value for H_0 (global). In the present context, the term "local" is used to refer to the region of the universe with a velocity of recession <10,000 km s^{-1}.

Distance Calibration

Most methods of astronomical distance determination are subject to systematic errors resulting from various factors, such as differences in metallicity (that is, the abundance of elements heavier than helium), evolutionary history, selection effects, and so forth. It is therefore prudent to use as many different techniques of distance determinations as possible. The distance to the Large Magellanic Cloud (LMC) has, for example, been determined (*8*) from Cepheid variables, RR Lyrae variables, Mira stars, novae, planetary nebulae, and supernova 1987A. The excellent internal agreement of these diverse distance determinations shows that the distances to most key nearby galaxies, which are members of the Local Group, are now each known to better than 10%. It is particularly gratifying to see that there is close agreement between distances to the nearest galaxies that are derived from young distance indicators (Cepheids) and old distance indicators of standard luminosity (RR Lyrae stars). A compilation of distances to key nearby galaxies (*8*) is given in Table 1.

Distance to the Virgo Cluster

The Virgo cluster is the nearest giant cluster of galaxies. Historically, the determination of the distance to the Virgo cluster has therefore played a key role in efforts to derive the Hubble parameter. In particular, Tully (*9*) has shown that researchers who assume a small distance to the Virgo cluster invariably derive a large value of the Hubble parameter, whereas investigators who find a large Virgo distance always end up deriving a small value for H_0. A compilation of recent distance determinations (*8*) to the Virgo cluster is given in Table 2. All modern distance determinations are seen to fall in the range 12.9 to 20.9 Mpc. Most of the errors of individual distances are probably systematic, rather than statistical, in nature. To avoid subjective bias, it seemed most prudent to adopt the unweighed logarithmic mean cluster distance of 15.8 ± 1.1 Mpc. (The majority of Virgo distance determinations are based on measurements of the stellar magnitudes of objects of known intrinsic luminosity. Logarithmic means of individual distances are therefore appropriate.) The adopted standard deviation of the distance to the Virgo cluster may slightly (but not significantly) underestimate the true distance of this cluster because most of the quoted individual distance determinations are based on the same set of distances to Local Group galaxies. It will be important to strengthen this distance determination to the Virgo cluster by observation of long-period variables and Cepheids in Virgo spiral galaxies.

It should be noted that supernovae of type Ia have not been used to estimate the distance to the Virgo cluster. The reason for this is that the two most recent supernovae of type Ia in Virgo (SN 1991T and SN1991bg) have shown that these objects are both spectroscopically and photometrically peculiar. This shows that supernovae of type Ia are not all identical objects, and they are therefore probably not reliable luminosity standards at maximum light. (The brightest and faintest well-observed supernovae of type Ia in the Virgo cluster differed in luminosity at maximum light by a factor of 33!)

Long- Versus Short-Distance Scale

Table 3 shows a comparison between the most recent determinations (*8*) of the distances to various galaxies and clusters and those given in 1986 by Sandage (*10*). Inspection of the data in this table shows reasonable agreement for objects with $D <$ 3 Mpc but a large systematic difference for most distant objects. It is this difference that lies at the root of the so-called distance scale problem. The differences between the Sandage and modern distance determinations for distant galaxies and clusters are the result of a variety of causes. The most important of these are probably systematic errors in faint photometric sequences, overcorrection for Malmquist bias (*11*) due to overestimation of the intrinsic dispersion in the Tully-Fisher relation (*12, 13*), reliance on supernovae of type Ia as objects of standard luminosity, and inappropriate use of H II regions (*14*) and galaxy diameters (*15*) as standard yardsticks.

The Coma Cluster

The mean redshift of galaxies in the Virgo cluster is (*16*) $\simeq$1100 km s^{-1}. This value is larger, but not much larger, than deviations from a smooth Hubble flow, which typically (*17*) amount to a few hundred kilometers per second. It is therefore not possible to derive a reliable value of the Hubble parameter from the distance and redshift of the Virgo cluster. I therefore attempted to derive the Hubble parameter from the redshift of the more distant Coma cluster.

The rich Coma cluster is particularly suitable for the determination of H_0 because it is reasonably well isolated in redshift space (*18*) and because its peculiar velocity relative to the Hubble flow is likely to be small compared to its redshift of ~7000 km s^{-1}. Furthermore, the Coma cluster is located almost perpendicular to the direction of the large-scale streaming motion (*19*) that appears to extend from Pisces-Perseus

Table 4. Magnitude difference, Δ, between similar objects in the Coma and Virgo clusters. $L(r)$, luminosity within aperture r; σ_r, radial component of the velocity dispersion; D_n, the diameter within a standard isophate; E, elliptical galaxy; S0, lenticular galaxy; Mg_2, magnesium line-strength index.

Method	Δ	Reference
V band versus U-B band	3.66 ± 0.14	(34)
H band Tully-Fisher	3.69 ± 0.16	(35)
B,H band Tully-Fisher	3.70 ± 0.17	(36)
$L(r)$ versus σ_r	3.76 ± 0.12	(37)
Mass-luminosity	3.4 to 3.8	(38)
D_n versus σ_r (ellipticals)	3.65	(39)
D_n versus σ_r (spiral bulges)	3.67	(40)
D_n versus Mg_2	3.99	(39)
Reduced radii	4.07	(41)
Tully-Fisher (M 31–like)	3.42 ± 0.22	(42)
UVJK band versus σ_r (E + S0)	3.70 ± 0.09	(43)
UVJK band versus σ_r (E only)	3.59 ± 0.06	(43)

to Hydra-Centaurus.

The distance to Coma is best determined from the difference (Δ) between the magnitudes of objects of standard luminosity in the Coma and Virgo clusters. Table 4 gives a compilation of determinations of this magnitude difference. The table shows excellent agreement, with 8 out of 12 determinations falling in the range $3.60 \leq \Delta \leq 3.82$. An unweighted mean of all these determinations gives a value for Δ of 3.71 ± 0.05, which corresponds to a ratio of D(Coma) to D(Virgo) of 5.52 ± 0.13. With the value of D(Virgo) equal to 15.8 ± 1.1 Mpc, this yields a value for D(Coma) of 87 ± 6 Mpc.

The Coma cluster has a mean heliocentric radial velocity of 6925 km s^{-1}. After correcting this value for a Virgocentric infall velocity of 300 km s^{-1}, Fukugita *et al.* (*11*) obtain a cosmological redshift of 7210 km s^{-1} for the Coma cluster. A quite similar velocity of 7203 ± 45 km s^{-1} was derived from slightly different input parameters by Staverley-Smith and Davies (*20*). Combining a cosmological velocity of 7210 km s^{-1} with a distance of 87 ± 6 Mpc yields a Hubble parameter H_0 (local) of 83 ± 6 km s^{-1} Mpc $^{-1}$.

The Global Hubble Parameter

Recently, Turner, Cen, and Ostriker (*21*) have argued that significant differences might exist between locally and globally determined values of the Hubble parameter. This hypothesis may be tested by observation of the brightest galaxies in rich clusters located at various distances. Such first-ranked galaxies in clusters of Bautz-Morgan classes I and I-II are excellent standard candles that are found (*15*) to have a luminosity dispersion of only 0.31 magnitudes. From a study by Hoessel, Gunn, and Thuan (*22*) of a complete sample of Abell clusters with richness class ≥1 and distance class ≤4, it has been found (*8*) that the ratio of H_0 (global) to H_0 (local) is equal to 0.92 ± 0.08, where local refers to objects with redshifts <10,000 km s^{-1}. It should be emphasized that this result does not imply that a statistically significant difference has been found between the local and global values and the Hubble parameter. If one nevertheless adopts a ratio of H_0 (global) to H_0 (local) equal to 0.92 ± 0.08, together with the value of H_0 (local) equal to 83 ± 6 km s^{-1} Mpc^{-1}, then one obtains a value for H_0 (global) of 76 ± 9 km s^{-1} Mpc^{-1}.

Nonconventional Determinations of H_0

Staverley-Smith *et al.* (*23*) have used observations of the rotation of the gas-rich dwarf galaxy UGC 12578, together with the assumption that this galaxy contains no dark matter, to derive a value for H_0 of 70 ± 7 km s^{-1} Mpc^{-1}. However, if dark matter is present in the galaxy, their result should be interpreted as a 95% confidence lower limit on the Hubble parameter of 59 km s^{-1} Mpc^{-1}.

Theory suggests that supernovae of type Ia produce ~0.6 mass of the sun ($M_\odot$) of ^{56}Ni. Arnett, Branch, and Wheeler (*24*) have used the luminosity of supernovae of type Ia predicted from the radioactive decay of this amount of nickel to derive a value for H_0 of 59 ± 14 km s^{-1} Mpc^{-1}. However, Ruiz-Lapuente, Lucy, and Danziger (*25*) have shown that the type Ia supernova 1986G contained only 0.38 ± 0.03 $M_\odot$ of ^{56}Ni. This results in a lower supernova luminosity and hence in a larger value of H_0.

The time delay between light variations in two images of a gravitationally lensed object can, in principle, be used to derive the value of the Hubble parameter. A practical difficulty is, however, that the density distribution of the dark matter surrounding the lensing object is usually not known. From a review of presently available data on the lensed quasar 0957+561, Kochanek (*26*) finds a value of $H_0 \lesssim 90 \pm 30$ km s^{-1} Mpc^{-1}.

Soucail and Fort (*27*) have interpreted the velocity gradient along a luminous arc in the cluster A 2390 as being the result of rotation in a lensed background galaxy. Application of the Tully-Fisher relation to this object yields a value for H_0 of 95 ± 26 km s^{-1} Mpc^{-1} if the curvature constant (q_0) = 0 (an open hyperbolic universe model) and of 75 ± 20 km s^{-1} Mpc^{-1} if q_0 = 0.5 (Euclidean geometry).

X-ray observations of the hot cluster gas, in rich clusters, together with the decrement in the observed brightness of the microwave background attributable to Compton scattering of photons passing through the cluster gas, may, in principle, be used to determine (*28*) both H_0 and q_0. In practice, this has proved to be exceedingly difficult because of the clumping of gas, errors in the x-ray temperature determinations, and systematic bias in the microwave decrement observations.

The Age of the Universe

Abundance ratios of radioactive elements (*29*) may be used to show that the age of the Milky Way Galaxy probably lies in the range 10×10^9 to 20×10^9 years. By fitting stellar evolutionary tracks to the color-magnitude diagrams of stars in the oldest globular clusters (*30–33*), one obtains galactic ages that lie in the range of 12×10^9 to 17×10^9 years. Allowing $\sim 1 \times 10^9$ years for the proto-Galaxy to accumulate and for globular clusters to form, one then obtains an age of the universe in the range 13×10^9 to 18×10^9 years. For standard cosmological models with a density parameter (Ω) equal to 1 and a cosmological constant (Λ) equal to 0, the corresponding values of the Hubble parameter lie in the range $36 \leq H_0 \leq 50$ km s^{-1} Mpc^{-1}. These values, which are predicted from cosmological models and stellar evolutionary theory, differ at the ~3σ level from the observed value for H_0 (global) of 76 ± 9 km s^{-1} Mpc^{-1}. The reason for this discrepancy is presently not understood.

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E2F: A Link Between the Rb Tumor Suppressor Protein and Viral Oncoproteins

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The cellular transcription factor E2F, previously identified as a component of early adenovirus transcription, has now been shown to be important in cell proliferation control. E2F appears to be a functional target for the action of the tumor suppressor protein Rb that is encoded by the retinoblastoma susceptibility gene. The disruption of this E2F-Rb interaction, as well as a complex involving E2F in association with the cell cycle–regulated cyclin A–cdk2 kinase complex, may be a common mechanism of action for the oncoproteins encoded by the DNA tumor viruses.

Considerable attention has recently focused on the tumor suppressor genes and their role in the regulation of cell proliferation (*1*). One intensely studied example is the retinoblastoma susceptibility gene (*RB1*). Loss of *RB1* function is associated with the loss of cellular proliferative control, and the introduction of a wild-type *RB1* gene into cells that lack *RB1* can suppress cell growth and tumorigenicity (*2, 3*). Moreover, injection of the *RB1* gene product (Rb) into G1 cells can block cell cycle progression (*4*). Thus, the elucidation of the molecular mechanism of Rb action should illuminate the process of normal cell growth control as well as the steps involved in oncogenesis.

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A major advance in the search for Rb function was the finding that the Rb protein is a target for the oncogenic products of the DNA tumor viruses. Initial studies demonstrated that the adenovirus E1A (early region 1A) protein forms a complex with Rb that is dependent on sequences in the E1A protein important for E1A oncogenic activity (*5*). The SV40 T antigen (*6*) and the human papillomavirus (HPV) E7 protein (*7*) also form complexes with Rb. Again, the formation of these complexes requires viral protein sequences that are also necessary for oncogenic activity. Thus, the interaction of these viral proteins with Rb would appear to be an important aspect of their oncogenic capacity, achieving an inactivation of Rb function equivalent to a deletion or mutation of *RB1*. Nevertheless, the mechanism of Rb action, and the identification of cellular targets for Rb action, remained unclear.

A variety of recent analyses have demonstrated a physical interaction between the Rb protein and the cellular transcription factor E2F (*8–10*) or a factor termed DRTF1 (*11*) that may be related or identical to E2F. Although identified in the context of adenovirus early region 2 (E2) gene transcription, E2F is important for the transcription of cell cycle–regulated genes such as c-*myc* (*12, 13*) and the gene that encodes dihydrofolate reductase (DHFR) (*14*). The interaction of Rb, as well as a related protein termed p107, with E2F appears to control the transcriptional activating capacity of E2F (*15, 16*).

The identification of E2F as a target for Rb is the result of a convergence of two distinct lines of investigation into the mechanism of action of E1A. Related studies have shown that E2F is also involved in cell cycle–regulated interactions, thus placing E2F in a broader role in cell cycle events. Most importantly, these studies have provided a mechanism of action for the DNA tumor virus oncoproteins and a functional link between the action of a tumor suppressor protein and the viral oncoproteins.

Two Approaches to Define a Mechanism of E1A Action

The *E1A* gene encodes a regulatory activity essential for the activation of the early pattern of viral gene expression (*17, 18*) (Fig. 1A). Previous experiments established that *E1A*, along with the viral *E1B* gene, was also responsible for the oncogenic activity of the adenovirus (*19*).

One approach to investigating the function of E1A focused on its role in transcriptional activation. The *E2* gene is one of six viral transcription units that are activated during the early phase of viral infection in response to E1A (*20*) (Fig. 1A). The cellular transcription factor E2F was considered a likely target for E1A activation of E2 transcription for several reasons. (i) E2F is a DNA binding protein that recognizes the duplicated sequence element TTTCGCGC within the E2 promoter, and E2F DNA binding activity is elevated after adenovirus infection (*21*). (ii) The duplicated E2F sites within the E2 promoter are critical for E1A-induced transcription (*22*). (iii) A single E2F site can confer E1A regulation to a test promoter (*23*).

Although E2F specifically recognizes and binds to sites within the E2 promoter, this interaction is unstable. The stability of binding is markedly enhanced by the interaction of a 19-kD product of the viral *E4* gene with E2F (Fig. 2A). The E4 protein enables E2F to bind cooperatively to the two adjacent E2F sites in the E2 promoter, generating a very stable DNA-protein com-