this we estimate that the quantity of OH in the ground $^2\pi_{3/2}$ state does not exceed 10^{16} cm $^{-2}$ column.

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*Naval Research Laboratory,
Washington, D. C.*

Baum, W. A. Photoelectric determinations of redshifts beyond 0.2 c.

The conventional method of measuring redshifts of remote galaxies by photographing their spectra has yielded firm results out to 60,000 km/sec, or 0.2 c. This corresponds, for the brighter members of a typical cluster of galaxies, to about 17th or 18th photovisual magnitude. Beyond this, spectrographic observations become difficult. The limit of the method is set not so much by the length of exposure required as by the presence of the spectrum of the night sky against which the superimposed spectrum of a faint galaxy must be observed. Near the limit it is not always easy to recognize features in the spectrum of a galaxy nor to distinguish them with certainty from accidental groupings of photographic grains.

This situation has led us to consider alternative methods by which redshifts beyond the present spectrographic range can be adequately estimated. There are, in fact, at least four magnitudes of unexplored territory between the spectrographic limit and the faintest galaxies detectable by direct photography, and it is now clear that observations within that territory will be vital to any definitive cosmological result. In addition, the high precision of spectrographic redshifts is not needed; we can well afford to trade a factor 10 in precision for the opportunity of reaching galaxies at larger distances.

The problem is now being explored with a photoelectric technique which has already yielded some significant results for galaxies with large redshifts. By means of the photon counter at Palomar, multicolor observations have been obtained for ten galaxies in five clusters, two of which have redshifts considerably greater than 0.2 c. These data are reduced to spectral-energy distribution curves $E(\lambda)$. The amounts by which these $E(\lambda)$ curves are shifted as a whole toward the red provide a measure of the redshifts, while

the areas under them provide a measure of bolometric magnitudes without the need for K corrections. The curves also provide K corrections by which conventional two-color observations of additional galaxies can be reduced to the same bolometric system.

The redshift procedure rests on two conditions: (1) these $E(\lambda)$ curves should be on a true scale of energy per unit wave length; (2) galaxies being compared must be intrinsically similar, that is, the differences between them must be due largely to their redshifts and not to a Stebbins-Whitford effect. Since Whitford now finds that there is no pronounced peculiarity out to $z = 0.2$, and since evolutionary changes would tend to appear gradually rather than suddenly, we are probably quite safe until extremely large redshifts are reached.

While redshift-magnitude considerations are based on mean $E(\lambda)$ curves for several galaxies in each cluster, the data for individual galaxies show that ellipticals are not all exactly alike and that those of low luminosity tend to have broader and flatter maxima than those of high luminosity. An unexpected result of this work is the high infrared point at 1 micron, suggesting that the $E(\lambda)$ curves may actually have a second hump out in the infrared.

The bolometric magnitudes must all be adjusted for absorption as a function of galactic latitude, for absolute magnitude as determined by rank, and for the degree to which the outskirts of each galaxy were included in the diaphragm of the photometer. This last effect, which has tended in the past to introduce systematic errors with distance, was handled here by observing individual galaxies through a sequence of concentric diaphragms to obtain intensity profiles.

The final result is a plot of the logarithms of the redshifts against corrected bolometric magnitudes, each cluster being represented by a single point. The present data extend all the way from the nearby Virgo cluster to Cluster 1448 whose redshift was found to be 120,000 km/sec (or $z = 0.4$), and the points all fall remarkably close to a straight line of slope 5. There is no clear indication that the points favor a bend in either direction. In a sense, the apparent linearity of this relation may be rather a coincidence, because it corresponds to a cosmological model which is only an intermediate case in a continuum of possible cases.

While a small departure from linearity one

way or the other cannot be excluded, the amount of curvature recently estimated by Humason, Mayall, and Sandage would definitely be at variance with the present results. In this connection, the following points should be mentioned: In the first place, the present photometric data are all photoelectric, whereas the critical parts of the earlier work were photographic. In the second place, the present material extends to roughly twice as large a redshift. In the third place, all of the earlier material can be recalibrated by means of the photoelectric data and added to the diagram; when this is done, the picture is not significantly altered.

Robertson's formula for the redshift-magnitude relation has the form: $m_{bol} = 5 \log cz + 1.086(1 - q - 2\mu)z + \text{constant}$, where q is a parameter identifying the cosmological model and where μ is an omni-purpose term to accommodate evolutionary changes in the absolute magnitudes, evolutionary changes in the K correction (that is, a Stebbins-Whitford effect), and intergalactic obscuration. The values of these factors comprising μ are presently not well known, but the available evidence suggests that μ is likely to be considerably less than unity. If $\mu \sim 0$, the observed redshift-magnitude relation yields $q \sim +1$. Values from, say, $+0.5$ to $+1.5$ fall within the presently acceptable range. These results indicate that the universe either is Euclidean or is mildly curved inward, that is, closed and finite. The Euclidean case $q = +0.5$ is represented by the Einstein-de Sitter model in which the expansion continues indefinitely. The closed models, $q > +0.5$, represent the oscillating solution in which the expansion eventually halts at a finite radius and the universe then starts contracting. Strongly curved models, either inward or outward, would not be compatible with the present results, nor would the steady-state model of Hoyle, Bondi, and Gold.

From the value of q and the associated value of k , we can compute the radius of the universe, the age of the universe, and the mean density of matter in it, on the assumption that the cosmological constant is zero. The formulae for these quantities are reviewed in a paper by Hoyle and Sandage in the August issue of *Pub. A. S. P.* If we adopt as expansion constant 150 km/sec per megaparsec, the Euclidean case yields the age 4.3 billion years and mean density 4.2×10^{-29} g/cm³, while the closed models yield smaller ages and larger densities. Although the present material would not be incompatible with a closed

model as young as 2.6 billion years (radius = 1400 mpc, density = 12.7×10^{-29} g/cm³), other evidence tends to favor something closer to the Euclidean case.

*Mount Wilson and Palomar Observatories,
Carnegie Institution of Washington,
California Institute of Technology,
Pasadena, Calif.*

Bell, Graydon D. Absolute f -values for lines of CuI, MnI, and FeI.

Absolute f -value measurements have been made on some elements of the iron group by means of atomic beam experiments. Extensive work was carried out on CuI in order to check the theory and technique of the atomic beam method. By means of variations in evaporation temperatures and multiple traversals of the light beam, a curve of growth for CuI has been developed and compared with the theoretical curve. Experiments were designed to determine the possible presence of Cu₂ molecules in the beam, impulse measurements for the depositing atoms, and checks were made on the density distribution across the beam. Results of f -value measurements for the resonance lines of CuI, MnI, and FeI are obtained.

*California Institute of Technology,
Pasadena, Calif.*

Bidelman, William P. and McKellar, Andrew. Double lines in the spectrum of ρ Cassiopeiae.

Many strong lines in the spectrum of the unusual variable supergiant star ρ Cassiopeiae were found to be double with a separation of 35 to 40 km/sec in 1951 (Strömberg 1952). We now present measurements of these double lines made on spectrograms taken at the McDonald and Dominion Astrophysical Observatories. The radial velocities of the components of these lines have been sensibly constant from 1951 through 1955. In recent years emission has been present at H α and at the intercombination line $\lambda 6573$ of CaI; it is suspected also at the sodium D lines and at the lines of BaII. It is probable that this star presents a similar problem to that of RW Cephei, the somewhat cooler supergiant star that has recently been found to possess complex lines by Merrill and Wilson (1956).

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*Lick Observatory,
University of California,
Mt. Hamilton, Calif.*