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Cosmology and galactic angular momenta

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COSMOLOGY AND GALACTIC ANGULAR MOMENTA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In man's quest to understand the nature of physical reality, he has accumulated an ever increasing amount of data. He observes and then attempts categorical description of the phenomena observed. These descriptions become more accurate as increasing amounts of information are obtained. In seeking information about the physical world of times long past, the scientist uses a knowledge of the present as a foundation and builds upon it with what data of earlier periods are available to him. As he examines the more distant periods of the past, the observable data diminish and in many instances become obscure as to their meaning. What he terms as the physical begins to merge with the metaphysical and transcendental ideas enter the picture. Whenever physical data are untrustworthy or absent, rational thought turns toward philosophical speculation. This is very much the case with universal creation hypotheses in which man seeks to penetrate ever further into the "ultimate truth or reality" of creation.

The thinking world of the present day approaches the subject of creation in basically two ways. One group maintains that the universe is essentially evolutionary in nature and there is a fixed point or instant of creation in time and space. The other group favors a steady state theory in which a process of continuous creation operates over a time period of infinite extent. At the time of the writing of this paper, neither of the two basic views has been conclusively proven wrong.

The object of this paper will be to make note of certain observations of natural phenomena and apply the information contained within these observations to the basic problem of whether the universe is evolutionary or steady-state in nature. In support or rejection of either of these views, one must deduce what is possible from observational data on the universe as it appears to him today.

In the formation of most hypotheses, scientists gather data and then attempt to explain the results of these observations within the boundaries of their hypotheses. Often, a very simple concept present is forgotten in the masses of data accumulated. In cosmology, the problem of angular momentum has usually been ignored. In the books listed in the bibliography of this paper and in others the author has consulted, the subject of angular momentum remains largely neglected. There is a tremendous excess of angular momentum in the universe which remains largely unaccounted for. The main point to be made in this paper is the simple calculation of the local excess and a criticism of the existing cosmological theories based upon this excess.

Perhaps it would be appropriate at this point to examine the world around us about which the observations mentioned above can be made. What sort of a picture does one obtain when he scans the heavens with optical and radio telescopes and interprets the data obtained from spectrographic analysis? He finds that he is the inhabitant of a planet in orbit around a sun which is an average star in size and temperature.[1] It is located in the arm of a great spiral galaxy or ordered group of stars which resembles a sphere with trailing arms in the plane of an imaginary disc about the sphere. It is approximately 40,000 parsecs in diameter, the nucleus or spherical center being approximately 5,000 parsecs in diameter.[2] Our sun is located in one of the spiral arms about 8,000 parsecs from the center of the galaxy. From spectroscopic analysis, it is found that our galaxy is rotating and that the spiral arms trail. There are enormous dense clouds of hydrogen gas and dust distributed in the region of the spiral arms. The condensation of these clouds of hydrogen and dust due to gravitational attraction is believed to be the primary process in the formation of stars. Our galaxy

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[1] Otto Struve, Beverly Lynds, and Helen Pillans, Elementary Astronomy (New York: Oxford, 1959), p. 260.

[2] Ibid., p. 388. One parsec = 3.09×10^{18} cm., 3,262 light years, or 1.92×10^{13} miles. It is the distance of a star whose parallax is one second of arc, or the distance from which the radius of the earth's orbit subtends an angle of one second of arc.

is not unique but is one of many such systems which are mere specks against a background of what is thought to be primarily empty space. These systems are not all spiral in structure, some being elliptical and irregular in shape.[3] These "island universes" are found to the limit of present day observation which appears to be approximately 3×10^9 parsecs.[4] There is an observed tendency for galaxies to cluster into groups, termed supergalaxies by some authors.[5] There is also an observable expansion of the universe which appears to be a linear function of the distance between the expanding object and the observer. The farther away a galaxy is, the faster it is receding from us. It should be emphasized that this expansion is one of galaxies with respect to each other and not of individual stars within a galaxy.

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[3]Harlow Shapley, Galaxies (Philadelphia: Blakiston Co., 1943), pp. 20-31.

[4]Martin Ryle, "Support for the Big Bang," Time Magazine, Vol. LXXVII, No. 9 (February 24, 1961), p. 33.

[5]Dennis Flanagan (ed.), The New Astronomy (New York: Simon and Schuster, 1955), pp. 99-106. The article is written by G. Vancouleurs.

CHAPTER II

OBSERVATIONAL DATA

I. EXCESS ANGULAR MOMENTUM

The plan of this paper is to present some observations and then in subsequent chapters to examine the two basic cosmological ideas in the light of these observations.

The first of the observations involves an estimate of the angular momentum in a given volume of space and the ratio of this momentum to the mass or number of nucleons in the given volume. We therefore wish to obtain a rough estimate of the angular momentum in that part of the universe which man may call his immediate surroundings, i.e., the solar system and galaxy.

In the solar system, the rotational angular momentum may be considered negligible with the exception of the sun. Taking the average rotational velocity as 5×10^4 cm/sec the sun's rotational angular momentum is

$$A_{\odot} = mvr \simeq (2\times10^{33})(5\times10^{4})(5\times10^{10}) \simeq .05\times10^{50}\ \frac{gm\,cm^2}{sec}. \qquad (1)$$

[6]

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[6]Struve, Lynds, and Pillans, op. cit., p. 220.

To this quantity must be added the orbital angular momentum of the planets, the data for which is listed in tabular form in Table I.

Adding the values of A in the table, the sum of the angular momentum of the planets is found to be

$$\sum A_i orb \simeq 3.22 \times 10^{50} \frac{gm\ cm^2}{sec}. \tag{2}$$

When the rotational angular momentum of the sun is added to this, the total angular momentum is found to be

$$A_{ss} = \sum A_i orb + A_\odot \simeq 3.27 \times 10^{50} \frac{gm\ cm^2}{sec}. \tag{3}$$

Considering the total mass, the mass contributed by the planets is negligible and thus

$$\sum m_i = m_\odot = 2 \times 10^{33} gm. \tag{4}$$

The mass of a nucleon is given by

$$m_p = 1\ amu = 1.66 \times 10^{-24} gm. \quad ^{7} \tag{5}$$

The number of nucleons in the solar system is then given by

$$N_{ss} = \frac{\sum m_i}{m_p} \simeq 1.21 \times 10^{57} nucleons. \tag{6}$$

Thus, the angular momentum per nucleon is

$$A'_{ss} = \frac{A_{ss}}{N_{ss}} \simeq 2.62 \times 10^{-7} \frac{gm\ cm^2}{sec\ nucleon}. \tag{7}$$

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[7]<u>Ibid.</u>, p. 388, table of constants.

TABLE I

ORBITAL ANGULAR MOMENTUM OF THE PLANETS

Planet Name	Planet symbol	m=mass in gm x 10^{27}(a)	v=orbital vel. in cm/sec x 10^{6}(b)	r=orbital rad. in cm x 10^{13}(c)	A=mvr in gm cm^2/sec x 10^{46}
Jupiter	♃	2000	1.5	7.8	20000
Earth	⊕	5.98	2.98	1.5	27
Mercury	☿	0.32	4.79	0.57	0.88
Venus	♀	4.87	3.5	1.08	18.4
Mars	♂	0.64	2.41	2.3	3.55
Saturn	♄	567	0.96	14.3	7780
Uranus	♅	87	0.68	28.7	1700
Neptune	♆	103	0.54	45	2500
Pluto	♇	5	0.47	59	138

[a] Otto Struve, Beverly Lynds, and Helen Pillans, Elementary Astronomy, p. 111, table 10.1.

[b] Ibid., p. 105, table 9.2.

[c] Ibid.

Let us now examine our galaxy and attempt to determine the momentum-nucleon relationship. The angular momentum of the galaxy relies upon the mass and velocity distributions within it. These distributions are not known to a high degree of accuracy and one must base his calculations upon approximate figures. There seems to exist some disagreement among writers as to the correct velocity distribution. The calculations in this paper must be based largely on approximations but the nature of the application of the results does not demand a high degree of accuracy.

Consider the galaxy as an idealized sphere or central mass within a disc of negligible thickness composed of the trailing spiral arms (fig. 1). First consider the velocity distribution as a whole. A rough graph of the velocity distribution as a function of the radius is given by Massey and is reproduced on page 10. Thus the maximum occurs at 6,000 parsecs and is approximately 180 miles per second or 200 km/sec. This is not in agreement with Struve. He gives the tangential velocity in the neighborhood of our sun (at a radius of 8,000 parsecs) as 300 km/sec.[8] Using Massey's distances and maximum, the curve may be approximated with the function

$$v(r) = a' r e^{-ar}. \qquad (8)$$

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[8]Struve, Lynds, and Pillans, <u>op. cit.</u>, p. 248.

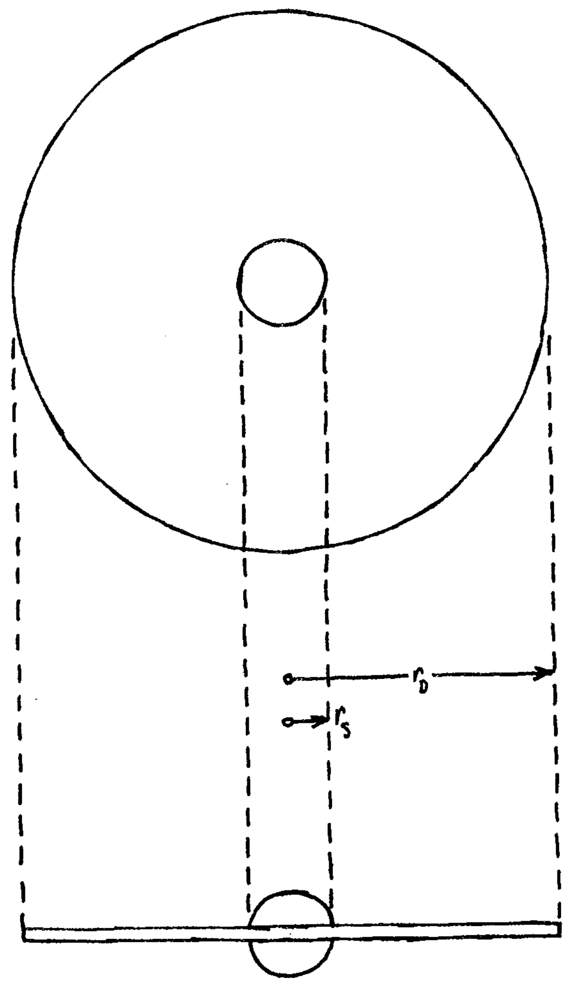

FIGURE 1

IDEALIZED DRAWING OF THE GALAXY

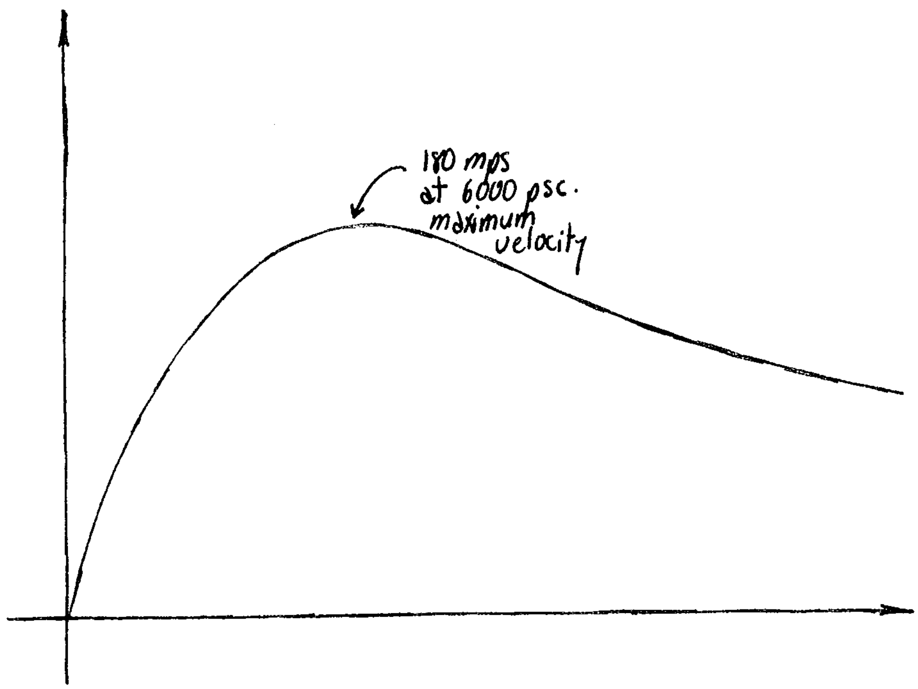

FIGURE 2

VELOCITY DISTRIBUTIONS IN THE GALAXY[9]

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[9]H. Massey, The New Age in Physics (New York: Harper & Bros., 1960), p. 264.

The constants a and a' must now be determined. At the maximum velocity, the derivative of v(r) must be zero, or

$$\frac{dv}{dr} = a'(e^{-ar} - are^{-ar}) \\ = a'e^{-ar}(1-ar) \\ = 0. \tag{9}$$

Assuming $a' \neq 0$ and $e^{-ar} \neq 0$, this relation becomes

$$1 - ar = 0 \tag{10}$$

Taking the maximum at 6,000 psc = 1.86×10^{22} cm, the result is

$$1 - a(1.86 \times 10^{22}) = 0, \\ a = \begin{Bmatrix} 5.38 \times 10^{-23}, & r \text{ in cm.} \\ 5.38 \times 10^{-18}, & r \text{ in Km.} \end{Bmatrix} \tag{11}$$

Struve gives the rate of change of velocity at the radius of the sun as -3 km/sec per 1,000 light years, or 9.5×10^{15} km, thus at 8,000 psc = 2.48×10^{17} km,

$$\left.\frac{dv}{dr}\right|_{r=2.48\times10^{17}} = \frac{-3 \text{ Km./sec.}}{9.5 \times 10^{15} \text{ Km.}} \\ = -3.16 \times 10^{-16}. \qquad (12)^{10}$$

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[10] G. J. Whitrow, The Structure and Evolution of the Universe (New York: Harper & Bros., 1959), p. 168.

But
$$\frac{dv}{dr} = a' e^{-ar}(1 - ar) \tag{13}$$

Or
$$a' = \frac{dv}{dr} \frac{e^{ar}}{1-ar} = 3.57 \times 10^{-15}. \tag{14}$$

Consider the inner sphere. The total mass may be calculated from Newton's modification of Kepler's third law

$$(m_1 + m_2)\, P^2 = a''^3, \tag{15}$$

m_1 amd m_2 being the masses of the bodies, P the period of rotation, and a" the distance between the centers of the bodies. From this relation, Struve obtains

$$m_s + m_\odot \simeq 2 \times 10^{11} m_\odot \simeq 4 \times 10^{44} gm. \tag{16}$$[11]

where m_s is the mass of the sphere and $m_\odot$ is the mass of our sun. As a rough approximation, the radius of the sphere may be estimated at

$$r_s \simeq 2500\ psc \simeq 7.71 \times 10^{21}\ cm. \tag{17}$$

The angular momentum of the sphere is given by

$$A_s = \omega(r) I_s = \int \omega(r) r^2\, dm_s, \tag{18}$$

where the angular velocity

$$\omega(r) = \frac{v(r)}{r} = \frac{a' r e^{-ar}}{r} = a' e^{-ar}, \tag{19}$$

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[11] Struve, Lynds, and Pillans, loc. cit.

and

$$dm_s = \rho\, 4\pi r^2 dr. \tag{20}$$

Then

$$\begin{aligned} A_s &= \int \omega(r) r^2 dm_s \\ &= \int_0^{r_s} a' e^{-ar} r^2 \rho\, 4\pi r^2 dr = 4\pi\rho a' \int^{r_s} e^{-ar} r^4 dr \\ &= -4\pi\rho a' e^{-ar_s}\left(\frac{r_s^4}{a} + \frac{4r_s^3}{a^2} + \frac{12r_s^2}{a^3} + \frac{24r_s}{a^4} + \frac{24}{a^5} - \frac{24e^{ar_s}}{a^5}\right). \end{aligned} \tag{21}$$ [12]

Recalling that the mass of a sphere is given by

$$m_s = \frac{4}{3}\rho\pi r_s^3 \tag{22}$$

the angular momentum of the sphere is

$$A_s = \frac{A_s m_s}{\frac{4}{3}\rho\pi r_s^3} = \frac{3a' e^{-ar_s} m_s}{-r_s^3}\left(\frac{r_s^4}{a} + \frac{4r_s^3}{a^2} + \frac{12r_s^2}{a^3} + \frac{24r_s}{a^4} + \frac{24}{a^5} - \frac{24e^{ar_s}}{a^5}\right). \tag{23}$$

The term $\frac{24e^{ar_s}}{a^5}$ may be expanded in the form of a power series and since

$$e^{ar_s} = 1 + ar_s + \frac{a^2r_s^2}{2} + \frac{a^3r_s^3}{6} + \frac{a^4r_s^4}{24} + \frac{a^5r_s^5}{120} + \frac{a^6r_s^6}{720} + \frac{a^7r_s^7}{5040} + \dots, \tag{24}$$

one obtains

$$\frac{24e^{ar_s}}{a^5} = \frac{24}{a^5} + \frac{24r}{a^4} + \frac{12r_s^2}{a^3} + \frac{4r_s^3}{a^2} + \frac{r_s^4}{a} + \frac{r_s^5}{5} + \frac{ar_s^6}{30} + \frac{a^2r_s^7}{210} + \dots \tag{25}$$ [13]

By substitution, (23) then becomes

$$\begin{aligned} A_s &= 3a' e^{-ar_s} m_s\left(\frac{r_s^5}{5} + \frac{ar_s^6}{30} + \frac{a^2r_s^7}{210} + \dots\right) \\ &= 3a' e^{-ar_s} m_s\left(\frac{r_s^2}{5} + \frac{ar_s^3}{30} + \frac{a^2r_s^4}{210} + \dots\right), \end{aligned} \tag{26}$$

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[12] H. B. Dwight, Tables of Integrals and Other Mathematical Data (3rd ed.; New York: Macmillan Co., 1957), p. 127, 567.8 and 567.3.

[13] Ibid., p. 125, eq. 550.

the series converging for the values of a and r_s given in (14) and (17). Substituting the values of a', a, r_s, and m_s as given in (11), (14), (17), and (16) above, the result is

$$A_S \simeq (3)(3.57\times10^{-15})(.660)(4\times10^{44})(1.27\times10^{43}) \simeq 3.6\times10^{73}\ \frac{gm\ cm^2}{sec}. \quad (27)$$

Consider now the outer disc. It is sufficient to estimate the mass as being approximately ten per cent of the mass of the sphere.[14] This gives a mass of

$$m_D \simeq .4\times10^{44}\ gm. \quad (28)$$

The outer radius may be estimated as approximately

$$r_D \simeq 20000\ psc \simeq 6.17\times10^{21}\ cm. \quad (29)$$

the inner radius remaining

$$A_D = \int \omega(r)\, I_D = \int \omega(r)\, r^2 dm_D, \quad (17')$$

The angular momentum of the disc is given by

$$r_S \simeq 7.71\times10^{21}\ cm. \quad (30)$$

where the angular velocity is given by the above equation (19) and

$$dm_D = \rho\, 2\pi r\, dr. \quad (31)$$

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[14] E. M. Burbidge, G. R. Burbidge, W. A. Fowler, and Fred Hoyle, Rev. Mod. Phys. 25, 632 (Oct., 1957).

Then

$$A_D = \int \omega(r) r^2 dm_D$$

$$= \int_{r_s}^{r_D} a' e^{-ar} r^2 \rho \, 2\pi r dr = \int_{r_s}^{r_D} 2\pi \rho a' e^{-ar} r^3 dr \qquad (32)^{15}$$

$$= 2\pi\rho a' \Big[e^{-ar_D}\Big(\frac{r_D^3}{a} + \frac{3r_D^2}{a^2} + \frac{6r_D}{a^3} + \frac{6}{a^4}\Big) - e^{-ar_s}\Big(\frac{r_s^3}{a} + \frac{3r_s^2}{a^2} + \frac{6r_s}{a^3} + \frac{6}{a^4}\Big)\Big].$$

Recalling that the mass of the thin disc is given by

$$m_D = \rho\pi(r_D^2 - r_s^2), \qquad (33)$$

the angular momentum of the disc is

$$A_D = \frac{A_D m_D}{\rho\pi(r_D^2 - r_s^2)}$$

$$= \frac{2a' m_D}{(r_D^2 - r_s^2)} \Big[e^{-ar_D}\Big(\frac{r_D^3}{a} + \frac{3r_D^2}{a^2} + \frac{6r_D}{a^3} + \frac{6}{a^4}\Big) - e^{-ar_s}\Big(\frac{r_s^3}{a} + \frac{3r_s^2}{a^2} + \frac{6r_s}{a^3} + \frac{6}{a^4}\Big)\Big]. \qquad (34)$$

Substituting the values of a', a, r_D, r_s, and m_D as given in (11), (14), (29), (17'), and(28) above, the result is

$$A_D \simeq 3.7 \times 10^{73} \frac{gm\ cm^2}{sec}. \qquad (35)$$

Combining A_s and A_D as given in (27) and (35), the angular momentum of the galaxy is

$$A_G = A_s + A_D \simeq 7.3 \times 10^{73} \frac{gm\ cm^2}{sec}. \qquad (36)$$

This is only a rough estimate. There are no available figures to this degree of accuracy and one should realize

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[15] Dwight, <u>op. cit.</u>, p. 127, eq. 567.3.

that an error of ± 5 x 10^{73} gm cm^2/sec is possible. It cannot accurately be determined exactly where the edge of the sphere or disc is, and the mass values are only approximations. As was stated before, the nature of the application of this result does not demand a high degree of accuracy.

Proceeding as for the solar system in determining the angular momentum per nucleon, the total mass of the galaxy is found from (16) and (28) to be

$$m_S + m_D \simeq (4 \times 10^{44}) + (.4 \times 10^{44}) \simeq 4.4 \times 10^{44} \text{ gm.} \tag{37}$$

Then the number of nucleons in the galaxy is given by

$$N_G \simeq \frac{(m_S + m_D)}{m_p} \simeq \frac{4.4 \times 10^{44}}{1.66 \times 10^{-24}} \simeq 2.7 \times 10^{68} \text{ nucleons,} \tag{38}$$

and the angular momentum per nucleon is

$$A_G{}' = \frac{A_G}{N_G} \simeq \frac{7.3 \times 10^{73}}{2.7 \times 10^{68}} \simeq 2.8 \times 10^{5} \frac{\text{gm cm}^2}{\text{sec nucleon}}. \tag{39}$$

Now the intrinsic angular momentum of a proton is given by

$$A_p = \hbar [s(s+1)]^{\frac{1}{2}} \tag{40}$$

where s=½ is the spin quantum number and $\hbar$ is Planck's constant divided by 2π, i.e.,

$$\text{Thus} \quad \frac{h}{2\pi} = 1.05 \times 10^{-27} \text{ erg sec.} \tag{41}$$
[16]

$$A_p = (1.05 \times 10^{-27})\left[\tfrac{1}{2}\left(\tfrac{1}{2}+1\right)\right]^{\frac{1}{2}} = 9.1 \times 10^{-28} \frac{\text{gm cm}^2}{\text{sec}} \tag{42}$$

Considering the values of the angular momenta per nucleon obtained in above equations (7) and (39) in terms of the intrinsic angular momentum, one obtains

$$A'_{SS} \simeq 2.9 \times 10^{20} A_p \tag{43}$$

for the solar system, and

$$A'_G \simeq 3.0 \times 10^{32} A_p \tag{44}$$

for the galaxy.

Thus, it appears that our galaxy possesses angular momentum far in excess of what would be expected if the original spin angular momentum were the only source. There is a remote possibility that the net angular momentum of any spiral galaxy might be zero if one reasons along the following lines. It is known that most of the neighboring globular clusters are arranged in a random spherical distribution, the radius of the sphere being approximately

$$r_G \simeq 30000 \text{ psc} \simeq 9.28 \times 10^{22} \text{ cm.} \tag{45}$$
[17]

(See fig. 3.)

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[16] R. D. Evans, The Atomic Nucleus (New York: McGraw-Hill Co., Inc., 1955), p. 142.

[17] Whitrow, op. cit., p. 31.

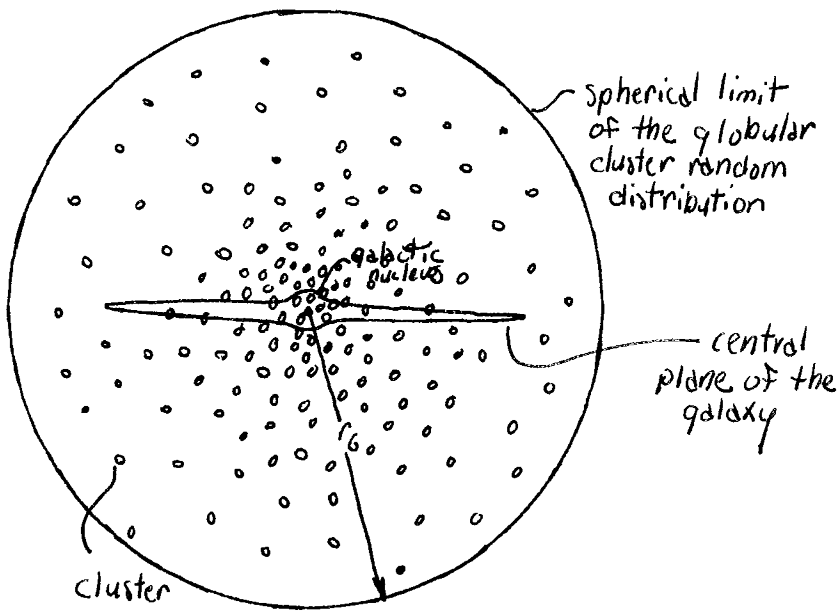

FIGURE 3

DISTRIBUTION OF GLOBULAR CLUSTERS

There is also vague evidence that there are magnetic fields and radiation that might produce a shearing effect of sorts upon the central plane of the galaxy (i.e., nucleus and arms).[18] If the globular clusters and radiation are periodically rotating in the opposite direction from the spiral arms, it is conceivable that the net angular momentum could be zero. Their velocities would not have to be too great, since most of them are at a rather large radial distance from the center of the galaxy. It must be said, however, that no conclusive evidence of this rotation has been obtained and hence we must accept the net excess of angular momentum at the present stage of interpretation of observational data.

II. THE DISTRIBUTION OF ANGULAR MOMENTUM IN SPACE

The second of the observations is that the distribution of angular momentum in the galaxies as one looks out at the celestial sphere (or sphere with the earth at center upon which the stars are projected) is at least to within a few per cent random in nature. There has not been a great amount of statistical work done in this area and, excepting some indications of order on a small scale, galactically speaking, the distribution seems to be accepted

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[18] Information obtained in a discussion with Dr. Richard W. Michie, Astronomy Department of the University of California at Berkeley.

as random by most astronomers.[19] This subject is rarely mentioned in the works which the author of this paper has consulted.

III. THE ABSENCE OF HYDROGEN BURNING STARS

The third of the observations is that there do not appear to be any pure hydrogen burning stars left in the universe, or at least there is no evidence of such an effect.[20] In looking for evidences of pure hydrogen burning, it is not sufficient to examine only the region of our galaxy. The length of time required for condensation would allow sufficient time for contamination to occur from products of the explosions of massive stars. Outside of the denser regions, this should not be the case and there should be some evidence of hydrogen burning found in the future, if there is any. Present day observational methods may not be of sufficient accuracy to enable one to locate extra-galactic pure hydrogen burning. Attention should be given to this matter when more accurate measuring devices are available.

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[19] Information obtained in a discussion with Hyron Spinrad, Astronomy Department of the University of California at Berkeley.

[20] Burbidge, Burbidge, Fowler, and Hoyle, <u>op. cit.</u>, p. 556.

CHAPTER III

THE STEADY STATE THEORIES

I. GENERAL DESCRIPTION OF THE STEADY STATE THEORIES

The steady state theories as put forth by Hoyle, Bondi, and Gold differ from all evolutionary models in the acceptance of the perfect cosmological principle. The perfect cosmological principle implies that the universe appears the same to a fundamental observer wherever in space or time he is located.[21] Evolutionary theories in general validate the cosmological principle only to the extent that spatially the universe has the same appearance at any given time. The theory of Bondi and Gold incorporates the cosmological principle as its fundamental assumption whereas in Hoyle's theory the need for a perfect cosmological principle is seen to arise from his modification of the general relativity field equations.[22]

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[21] H. Bondi, Cosmology (2nd ed.; Cambridge, Cambridge University Press, 1960).

[22] Ibid., pp. 140, 153.

It is either a known fact or a grand delusion that the universe is expanding (cf. Ch. I). Distant galaxies and clusters recede from each other at the amazingly high rates of nearly one-third of the speed of light. If the perfect cosmological principle is to be realized there must be some sort of compensation for the rapidly decreasing density of matter which is an obvious result of this expansion. The steady state theory provides this compensation in the hypothetical creation of matter from nothing.[23] Thus there is conservation of matter "in any proper volume of space," but a continual increase in matter on the overall scale, which is constantly expanding out of our realm and disappearing.

> High-entropy energy (in the form of radiation) is constantly being lost through the operation of the Doppler shift in the expanding universe, while low-entropy energy is being supplied in the form of matter.[24]

Thus there is a continual creation of hydrogen and a constant occurrence of the galaxy and star forming processes. Any "proper volume" will therefore contain a constant proportion of "old" galaxies and newly condensing masses of both newly created hydrogen and dust from old supernovae in random amounts.[25]

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[23] Ibid., p. 144.

[24] Ibid.

[25] Supernovae are exploding stars.

If the perfect cosmological principle holds, one cannot speak of a finite universe as far as time is concerned, since the aspect must not change over any period of time. There is therefore no unique beginning in time.

II. COMMENTS UPON THE STEADY STATE THEORIES

In the above discussion of angular momentum per nucleon in the galaxy, the values were found to be very large in comparison to the intrinsic spin angular momentum of a proton. In other words, there now exists an over-all excess of angular momentum which has to be accounted for in some way. The creation of a hydrogen atom with only its spin angular momentum cannot explain this excess amount. Thus if one is to accept a steady state theory, he must accept the implication of creation of hydrogen with an enormous excess of angular momentum or some sort of operative process by which the angular momentum in the universe can be increased, i.e., that angular momentum is not conserved in the large.

Bondi maintains that the created hydrogen does have an initial velocity with respect to a fundamental observer and that a preferred direction of creation does exist in space-time.[26] However, the concept of creation with the

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[26] Bondi, op. cit., p. 150.

observed excess angular momentum does not seem too attractive, especially in terms of the velocity required. Consider a proton at a distance r_p = 6000 psc = 1.86×10^{22} cm from the center of our galaxy. Its velocity is (see fig. II) 290 km/sec = 2.9×10^7 cm/sec and its momentum is

$$A_p' = mvr \simeq (1.66 \times 10^{-27})(2.9 \times 10^7)(1.86 \times 10^{22}) \simeq 8.95 \times 10^5 \frac{gm\, cm^2}{sec} \quad (46)$$

The kinetic energy of the proton is

$$T_p = \frac{mv^2}{2} \simeq \frac{(1.66 \times 10^{-24})(2.9 \times 10^7)^2}{2} \simeq 6.98 \times 10^{-10} \text{ ergs} \simeq 436 \text{ electron volts}. \quad (47)$$

These values are rather large and imply hydrogen creation with large amounts of kinetic energy if the velocity distribution of the galaxy is an average one. Although the excess angular momentum and energy may be accounted for as the result of galactic formation processes, their existence in the large cannot be accounted for unless one accepts the idea of creation with a large initial velocity. If conservation of energy holds for a given volume of space, these amounts of excess energy must always have been present. The only other alternative would be a secular increase in angular momentum as suggested by Milne.[27]

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[27] C. A. Milne, Kinematic Relativity (London: Oxford University Press, 1948), pp. 93-94.

The steady state theories also imply that due to continuous constant hydrogen formation, all processes which have operated from $t=-\infty$ will operate at $t=+\infty$ and are operating now. This means that condensation into hydrogen burning stars must be happening now. Since the steady state theories are based upon an acceptance of the perfect cosmological principle, it must be concluded that hydrogen burning stars are observable in our immediate area of space-time. Observations, however, have not confirmed this as no evidence has been found of pure hydrogen burning (see Ch. II).

In a similar manner, the steady state theories imply that there would be an infinite number of infinitely old galaxies.

> Moreover, even if it proves possible to resolve the paradox of indefinitely massive galaxies, the steady-state theory will still have to face the problem of infinitely old galaxies. For, without some additional hypothesis concerning the spontaneous disappearance of matter--the counterpart of spontaneous creation--as suggested by Kapp, it follows that an infinite number of infinitely old burnt-out galaxies must necessarily exist. Since our own cluster is not burnt-out and other clusters as they stream away from us are only observable for the earlier part of their histories, no such clusters can be expected within the observable region. But they must exist somewhere, and hence it follows that our region cannot be typical of every region in the universe. Strictly speaking, this is contrary to the perfect cosmological principle on which the theory is based, and a more careful formulation of the fundamental hypotheses is therefore an urgent logical requirement.[28]

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[28] Whitrow, op. cit., p. 147.

Thus, the observational data indicate that either the infinite number of infinitely old galaxies do not exist, or the perfect cosomological principle is not satisfied. But the perfect cosmological principle is a basic premise of the steady state theories and a logical contradiction exists.

One additional paradox seems to be present in the steady state theories, which is explained ably by Whitrow:

> There is a peculiar difficulty associated with gravitational attraction in the steady state model. It has been specifically stated by Bondi that, although there may be small variations, "the creation rate per unit volume per unit time cannot vary widely from place to place." Let us consider what happens to an old cluster of galaxies which will have acquired in and around it an exceedingly powerful local gravitational field through the continual creation of new matter over a long period of time. This field would more than counterbalance the tendency to recession in its immediate neighborhood (as already there is no evidence of mutual recession within the local group of galaxies). Such a cluster would tend to become ever vaster in extent without limit. Since the theory presupposes that all regions of the universe are equivalent, this situation would occur statically everywhere. Moreover, as it is a fundamental assumption of the theory that there is no evolution of the universe (only of individual stars and galaxies), what will happen in the future must have already occurred in the past. Hence, it would seem that there could be no expansion anywhere at any time. For, if it is maintained that clusters of indefinitely large mass occur only outside the region which we can observe, then it would follow that not all regions of the universe are equivalent and that our own region would in fact change with lapse of time as our local group becomes more massive.[29]

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[29] *Ibid.*, p. 146.

An expanding system is also a basic premise of a steady state universe. The continual creation of matter and the perfect cosmological principle imply that this expansion cannot exist and has not existed. Thus we are again led to a contradiction. Some workers, notably Sciama, have attempted to resolve this paradox, but their theories cannot be now regarded as established.[30]

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[30] Ibid.

CHAPTER IV

THE EVOLUTIONARY THEORIES

I. GENERAL DESCRIPTION OF THE EVOLUTIONARY THEORIES

The evolutionary theories of the universe differ from each other in a number of ways and many models are discussed in various books.[31] They all possess one characteristic in common, some sort of variation in time. The perfect cosmological principle is not to be found in any evolutionary theory. An excellent account of possible models together with a brief mathematical basis of them is given in Bondi's Cosmology.[32] Many of the models may be derived using either Newtonian concepts or the more powerful tools of general relativity. There are two major lines of thought in regard to evolutionary models. One group favors a limitless expansion, i.e., the kinetic energy of expansion is and remains greater than the gravitational attraction between the galaxies acting as mass points. The other group favors one of oscillating nature, which

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[31] Bondi, op. cit.; Dennis Flanagan (ed.), The Universe (New York: Simon and Schuster, 1957); George Gamow, The Creation of the Universe (New York: Viking Press, 1956).

[32] Bondi, op. cit., pp. 75-122.

implies that expansion eventually slows due to gravitational attraction being stronger than the kinetic energy of expansion and eventually getting the upper hand.[33]

In an evolutionary universe one may speak of a fixed time of creation and hence an "age" of the universe. This age, if accepted, is governed by observational data and thus has a well defined lower limit and upper limit. The lower limit is at present defined by the known age of the earth, which is at least 2.6×10^9 years and may be up to 4.5×10^9 years in the light of recent determinations.[34] In proceeding to establish an upper limit, one must take into account the velocity-distance relationship of Hubble. The relative velocity of any two galaxies is given by the simple relation

$$V = \frac{r}{T}, \tag{48}$$

where r is the distance between the galaxies and T is a constant which is partially dependent upon the intrinsic luminosity of a galaxy.[35] Present day observational data suggests a value of $T \simeq 1.3 \times 10^{10}$ years which constitutes

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[33]Gamow, op. cit., pp. 140-42. A discussion of the kinetic energy of expansion may be found on these pages.

[34]Burbidge, Burbidge, Fowler, and Hoyle, op. cit., p. 607. Calculated from the U^{235}/U^{238} ratio.

[35]Bondi, op. cit., pp. 38-40. An outline of the derivation of the velocity-distance law is given on these pages.

an upper limit for the age of an evolutionary universe. The recent determination of Ryle of the existence of galaxies 9×10^9 light years away (implying an age of as many years) agrees with this value remarkably well (see also Ch. V).[36]

II. COMMENTS UPON THE EVOLUTIONARY THEORIES

The excess angular momentum which does not seem to fit the steady state theories seems much more plausible in connection with an evolutionary theory. The necessarily great explosion at the beginning implies a great release of energy and a resulting turbulence. The random distribution of galactic angular momenta could easily be a result of this sort of situation. Although local galactic excesses exist, the net sum of the angular momenta would be zero. As greater volumes are taken into consideration, the galactic angular momenta will tend to "cancel each other" due to their random orientations and distribution. There does not appear to be any operative process in a steady state universe which would produce these turbulences and the resulting local momentum excess.

The absence of hydrogen burning stars is what would be expected of a universe which has evolved a sufficient period of time for the hydrogen burning processes to have terminated.

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[36]Ryle, <u>loc. cit.</u>

CHAPTER V

CONCLUSIONS

In conclusion, it must be said that the observational evidence discussed in this paper seems to favor an evolutionary universe of some sort. Considering the angular momentum of the solar system and galaxy with respect to the number of nucleons, one reaches values far in excess of what would be expected if the only origin of this momentum were the spin of the original material. Though the observations are only on the local scale, they are by no means unique, as galaxies are seen rotating much as our own out to the limits of observation. The random nature of the angular momentum distribution rules out any theory of a non-thermal momentum origin which can be verified by observation.

As to the nature of the universe, the excess angular momentum presents the following possibilities:

(i) The universe is evolutionary in nature.

(ii) The universe is one of continuous creation in which the created matter has an excess of energy, i.e., is created with a definite velocity with respect to a fundamental observer.

(iii) The universe is one of continuous creation and there is an increase of angular momentum with respect to time.

To the limits of observation there appear to be no "young areas" in which hydrogen is gravitating to form pure hydrogen burning stars. One would expect to find evidence of this if a continual hydrogen supply were being created. The possibility of contamination due to the presence of heavy explosion products in denser volumes is a factor not to be neglected. However, hydrogen is not all created in these dense volumes. Where it is not, evidences of pure "young" condensation should be found. This is an area in which more observational information is needed. Extragalactic observations of this nature have been largely neglected. If the universe is evolutionary, one would not expect to find pure hydrogen burning stars as all condensations would be sufficiently old to have synthesized helium and the heavier elements. The change from hydrogen to major helium burning occurs in approximately one billion years in the average star, although there is a small amount of helium burning before the change.[37] The age of the universe, if finite, far exceeds this. Thus one is led tentatively to accept possibility (i) rather than possibilities (ii) or (iii), until more data pertaining to the presence of hydrogen burning stars outside the galaxy is obtained.

A recent support to this view has been given by Martin Ryle, who has been counting the number of distant colliding

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[37] Burbidge, Burbidge, Fowler, and Hoyle, op. cit., p. 558.

galaxies using a sensitive radio-telescope which can detect the 21 cm wavelength emission line of atomic hydrogen which is produced when the electron jumps from a higher to a lower substate of the n=2 state of the atom.[38] At a distance of 3×10^9 parsecs, he has found a density eleven times greater than that which would be expected in a universe satisfying the perfect cosmological principle. This is a good indication that long ago, the density of the galaxies in a given volume was much greater than it is now. In a steady state universe, the density per unit volume should remain a constant in space-time, i.e., a very distant unit volume will contain the same amount of matter and radiation as one which is nearer to us. As the universe continually expands, the new matter which is created "fills in the gaps" and keeps the density per unit volume constant. Since the total aspect is unchanging with respect to time, there was no superdense state in the past. This is necessarily not so in an evolutionary universe which incorporates the principle of conservation of matter. In an expanding universe with a constant amount of matter, there must have been much higher densities in the past. The total amount of material then occupied a much smaller volume.

Ryle's data definitely give support to a concept in which the density per unit volume changes with respect to

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[38] Ryle, loc. cit.

time, i.e., an evolutionary universe.

Finally, additional support of possibility (i) may be obtained from the old galaxy paradox. The logical implication of an infinite number of infinitely old galaxies is contradicted by observational data and the perfect cosmological principle. There is also the contradiction involving expansion put forth by Whitrow. Here an infinite gravitational field is encountered if one is to accept both the continuous creation of matter and the perfect cosmological principle. It would seem that a universe infinite in space-time implies many other undesirable infinities which are easily contradicted by present day observations. Perhaps future observations and theories will give us some insight into these paradoxes, but they seem irresolvable in the light of present day data.

The results obtained in this paper are not conclusive. Much work needs to be done in investigating the problem of galactic angular momenta in relation to contemporary cosmologies. Observational data are needed concerning the extragalactic presence of pure hydrogen burning stars. Accurate statistical analysis of momentum distributions is lacking. The possibility of rotation outside of the main plane of the galaxy should be investigated to establish conclusively the net galactic angular momentum. Until more work is done in these areas, one cannot decisively accept any of the present day theories as law. Man remains an unenlightened mortal as to the ultimate "reality" of creation, but he is learning at least some of the ways of nature. He must learn that he cannot hope to penetrate fully the secrets of nature for

> Any man of real quality necessarily feels the call of the absolute. Before long he encounters the inescapable tragedy of any absolute commitment: there are countless absolutes. One gives up infinite possibility for concrete finitude.[39]

However, the future holds a possible infinitude of ideas and understanding if only they are sought.

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[39] Abner Stephen Mann Thomas, letter of October 1959.

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