Thus the data strongly favor an exponential rather than a linear fit. To predict, then, what evolutionists will be saying in the future one may use Equation 3 and extrapolate. Extrapolation can lead to large errors; but an evolutionist should be the last person to complain, since he extrapolates from the present to over four billion years ago.

The inevitable conclusion in that in 4,000 A.D. evolutionists will assert that the earth is $6.932.10^{41}$ years old, and in 10,000 A.D. that it is $9.560.10^{136}$ years old.

Or is the conclusion that evolutionists expounding on the age of the earth, like fishermen describing the one that got away, tell a bigger story each time?

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Editor's Note: Dr. Rodabaugh and I have noticed with interest that, according to Equation 3, the age of the earth would have been estimated at about 5,600 years about 1600 A.D. Thus "the beginning" would have been set about 4000 B.C., as a straightforward reading of Genesis would seem to indicate. Now in fact, about that time most learned men, at least in Christendom, would have subscribed to some such estimate of the age; it was around that time that Ussher issued his chronology. But not long afterwards, the age of the earth began to be inflated.

It may be noticed that Equation 3 indicates an exponential increase; and another way of stating such an increase in to say that the thing concerned (here the age claimed for the earth) doubles in a certain time. The time to double can be calculated from Equation 3; and it comes to be about 20 years. It interested me very much that Dr. Gerardus D. Bouw, Ph.D. of Rochester, New York, remarked quite independently, in correspondence, that the age claimed for the earth is doubling about every 20 years.

GALAXY CLUSTERS AND THE MASS ANOMALY

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Various proposals which have been proposed to resolve the so-called "missing mass" or "mass anomaly" in galaxy clusters are reviewed here. Basically, these hypotheses can be broken down into two types of proposals: the missing mass hypotheses and the missing physics ideas. The presence of the mass anomaly has been used, in the past, in support of a young cosmos. The validity of such an approach is reviewed.

Introduction

It seems that no matter how hard secular man attempts to describe and affect his environment without reference to the Creator, there is always a vague, uneasy "something's missing" aspect to that endeavour.

This "missing" factor has manifestations in every humanistic search for truth and can be seen in many forms; from the three existential questions of philosophy—Who am I? What do I? and How be I?—to the missing links of evolutionary biology; from the missing volatiles of Mars[1] to that missing factor in each human life which many scientists deem necessary to complete that life. The Christian reader will recognize this vacuous state as the quest for Christ who is the Way, the Truth and the Life.

In this study one particular "missing" property is singled out for a more detailed look. This property is variously called the "missing mass"—by those who hold that the mass is actually present in some undetected form—or the "mass anomaly"—by those who are not sure whether there really is an undetected source of mass or whether modern physics is really applicable in it present form on such a grand scale.

The mass anomaly is made evident by estimating the total mass of a galaxy or galaxy cluster by two different methods. The first of these involves a straightforward count of the members coupled with a mass estimate for each member. The second method is based on the dynamics of the system. In practice the two mass estimates differ by factors of two or more for galaxies, but 10 to 400 for galaxy clusters.

The Problem on the Galactic Scale

The smallest systems for which this phenomenon is currently recognized is for galaxies; in particular, the Milky Way. This is not because of anything special about galaxies or their sizes so much as that the next smallest system for which comparable dynamic data exist is the solar system. For the Galaxy the two methods of estimating the mass are as follows:

(1) The number of stars per unit volume in the neighborhood of the sun is counted. These are grouped into brightness classes via the mass-luminosity function.[2] Hence, given the luminosity (intrinsic brightness),

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the star's mass can be estimated and summing over all the types of stars per unit volume gives a stellar mass-density estimate. Add to this the gas density from radio and optical interstellar lines and a local density of about 6.0×10^{-24} gm cm^{-3} is arrived at.

(2) The second mass-estimating method involves using the space motions of the local stars relative to the galactic center as based on the analysis of 21-cm radio line profiles in the Galaxy and estimates of the distance from the sun to the Galactic center. This yields a force law or rotation-curve from which the amount of matter necessary dynamically to bind the system can be calculated. Doing so yields a local density of 10.0×10^{-24} gm cm^{-3} which, considering the range of individual density determinations, is about a factor of two greater than the count-mass.[3]

The Problem on the Galaxy Cluster Scale

The mass anomaly does not end there. Two orders of magnitude greater than the scale-length of a galaxy and 10^{10} times that of the solar system lies the scale-length of the galaxy cluster. Here, too, the mass anomaly is evident but to a far greater degree. There are now three methods for determining the mass of a cluster of galaxies.

(1) The first of these is analagous to the luminosity-determined mass-density for the solar neighborhood mentioned above. It involves a straight-forward count of the number of galaxies of each type in the cluster.

For each of these types one can derive an estimate of the mass-to-light ratio based on observing the rotation-curves of individual galaxies also by statistical velocity considerations of multiple galaxy systems. Given an estimate of the distance to the galaxy a mass-to-light ratio can be calculated. These, in turn, also appear to be on the high side.

It has been noted that the mass-to-light ratio for the Galaxy is about 2. More detailed analysis[4] indicates a value of 3. The Galaxy is of morphological type Sb to Sc and the mass-to-light ratio usually assumed for an Sb galaxy is 20 while that for an Sc is 10. From the count of the galaxies in the cluster a total mass for the cluster can be derived. Intracluster mass is assumed negligible.

(2) The second method of determining the cluster mass is to invoke the virial theorem. The theorem was originally derived for application to the kinetic theory of gases but has found wide application in kinetics and dynamics. Basically, it amounts to balancing the gravitational attraction force by the centripetal force; but instead of using the orbital velocity directly, it is inferred from the radial velocity distribution and dispersion about the mean of the members of the cluster. Given the standard deviation about the mean velocity of the radial velocity distribution, σ, the mass, M_v, is given by:[5,6]

$$M_v = 3\,R\sigma^2/KG \qquad (1)$$

where R is usually taken to be the cluster radius, G is the gravitational constant, and K is a near-constant which is a weak function of galaxy size and estimates of which range from 0.29 to 3. Depending only in part upon the value of K assumed, the virial theorem mass-estimates can be from 10 to 400 times that of the "number-mass" estimates.[7,8]

(3) The third method, presented for the first time in the preceding issue[9] of the *Quarterly* and hereafter referred to as paper 1, involves observation of rotation of the cluster and computation of the amount of matter required to hold the system together. It yields mass estimates which are comparable to those obtained via the virial theorem and, for the Virgo cluster, it yields an empirical value for K of 0.96 ± 0.26 in Equation 1.

Missing Mass Proposals

A sizeable number of proposals have been expounded in an attempt at resolving the aforementioned discrepancy. The main concern here involves clusters of galaxies; so the problem will not be reviewed for individual galaxies. The latter case can, however, be considered as a subset of the former.[10]

(1) **Neutral hydrogen (HI) gas** If the missing mass were present in the form of neutral (unionized atomic) hydrogen then it should be directly observable by its 21-cm radio emission line. This has been searched for with negative results.[11]

(2) **Molecular hydrogen (H_2) gas** The presence of a sizeable amount of molecular hydrogen would be difficult to detect directly from earth-based stations. It has been argued, however, that most of the hydrogen should be photodissociated into atomic hydrogen on account of the intense ultraviolet radiation from galaxies. Case 1 would then apply.[12]

(3) **Ionized gas** If the atomic hydrogen were totally ionized then there would be no 21-cm emission expected. X-ray observations have indicated the presence of ionized gas at temperatures of millions of degrees[13] but the amount of gas indicated is far to little to account for the missing mass.[14,15] Another problem with the ionized gas postulate in an evolutionary frame-work is that the gas does not get hot enough until the cluster has reached a point of maximum collapse. This takes about 25 billion years, more than the age of the universe according to commonly accepted estimates.[16]

(4) **Fine dust** If fine dust were a major constituent of the intra-cluster material then light passing through it should be reddened and dimmed; much more so than has been observed.[17]

(5) **Coarse dust** The presence of coarse dust would not directly effect the reddening of light. Indirectly, however, collisions of particles more than 10^{-2} cm in diameter would vaporize or pulverize the particles so that it is difficult to explain a sizeable amount of coarse dust without the presence of gas or fine dust, at least in a billions-of-years-old framework.[18]

(6) **Dwarf galaxies** In the vicinity of bright, nearby galaxies, dwarf systems exist. These tend to cluster in a broad cone about the polar axes of the bright galaxies.[19] The problem of how such cones could originate or be maintained in an evolutionary frame-work aside, this indicates that such dward galaxies could possibly contribute sizeably to the cluster mass. A photometric study[20] of the Coma cluster indicates, however, that neither faint dwarfs nor intracluster stars could contribute significantly to the total mass of the cluster.

(7) **Black dwarfs** It has been suggested[21] that the mass anomaly could be resolved by extending the theoretical lower limit to the mass of a star to the point that stars of

sufficiently small mass, from 0.1 to 0.01 solar mass, could form in sizeable numbers. These objects, intermediate between true stars and planets, would not be expected to start nuclear burning and would thus only radiate a negligible amount, cooling to invisibility after some 2×10^7 years.

These black dwarfs are postulated as being formed in globular clusters and then evaporating from their parent protogalaxies as a result of tidal shocks during collapse of the protogalaxy. The theory continues with the assertion that the parent protogalaxies are only able to become elliptical galaxies because observational anomalies would arise if black dwarfs were to form in the same way about spirals. This presupposes that a globular cluster which is in formation has some way of knowing whether or not its protogalaxy is going to become an elliptical or not.

It has also been noted that the presence of black dwarfs could account for the mass anomaly within the Galaxy itself, but if this were so then they must be strongly concentrated toward the galactic plane,[22] an observation which runs contrary to the proposed production mechanism.

(8) **Neutrino rest mass** It has been proposed[23] that neutrinos may not really be massless particles but that they may have a rest mass of the order of 10^{-33} to 10^{-32} gm. A rough estimate of the neutrino flux of about 10^6 neutrinos cm^{-2} sec^{-1}, can be arrived at on the assumption that for every neutron in the cosmos there exists a neutrino which was released upon formation of that neutron.[24] The resulting 1 MeV* per neutrino in the flux might close the universe as well as account for the missing mass.

A recently published report[25] which indicates that the neutrino is massless cannot be invoked here as contrary evidence since the upper limit on the neutrino rest mass which resulted from that experiment is several orders of magnitude greater than that proposed.

The reason that a rest mass is proposed for a neutrino at all is the result of an interesting inconsistency in relativity theory. According to said theory massless particles such as a photon should not exhibit a gravitational field.

Hence, it is understood that in order for a neutrino to be able to contribute to the gravitational field of a galaxy cluster it must have a rest mass. The inconsistency arises when one notes that his contradicts Einstein's hypothesis that mass and energy are interchangeable; the test of which is the deflection of a ray of light in a gravitational field.[26] This, then, is still an open question, ableit it doesn't work for the galaxy case.

(9) **Black holes** Two mass ranges of black holes have been considered. On the basis of tidal distortions in member galaxies it has been demonstrated[27] that the number of objects, other than galaxies, with masses in the range of 10^8 to 10^{13} solar masses in the Virgo cluster is negligible. This would include massive black holes.

The case of less massive black holes has also been considered[28] but is far less conclusive and is based on a uniformitarian approach. The expression for the mass loss as a fraction of the total mass, $\delta M/M$, is:

$$\delta M/M \cong Gm^2/MRv^2 \qquad (2)$$

where m is the mass of the black hole, M is the mass of the galaxy, R is the radius of the galaxy, and v is the collision velocity. This equation, then, describes the evaporation of stars and black holes from a galaxy. Dr. Peebles concludes that the results are reasonable in an evolutionary framework and hence that the missing mass cuold exist in the form of small black holes.

This indicates that from 90 to 99.8 percent of all the mass in the cluster (and the universe) is trapped in black holes. This seems extremely high. One could also expect that the black holes might tend to cluster into separate systems but these systems would be subject to the limitations delineated above for the case of massive black holes. A major fraction of the mass in the form of black holes should produce a tremendous flux or x- and γ-rays, but no such flux has been identified (see point 3).

(10) **Mass loss by gravitational radiation** The possible detection of gravitational waves from the galactic center has led to another proposed source of missing mass. If the source of the observed radiation radiates isotropically, then the resulting energy loss would be equivalent to an annual mass loss of 100 solar masses. Assuming that the mass loss rate obeys an exponential decay law, the remaining mass, M, as a function of time, t, is given by:[29]

$$M = M_0 e^{-t/\tau} \qquad (3)$$

where τ is a time constant and M_0 is the initial mass of the galaxy.

At a loss rate of 10 suns per year per galaxy τ is 10^{10} yr and half the mass of the cluster would be lost after 8×10^9 years. Furthermore, by 6.2×10^9 years the cluster would become unbound; but no great change in cluster radius would be expected by 8×10^9 years by which time the mas anomaly would be a factor of 7.

For the mass loss rate of 100 suns per year per galaxy, the mass remaining after 8×10^9 years would only be $0.0003\ M_0$. For a single galaxy, then, M_0 would have a value of 10^{14} suns, about a tenth the mass of the larger galaxy clusters today.

The cluster would become unbound after only 0.68×10^9 years and would be virtually unrecognizable as a cluster after 8×10^9 years, when the anomalous mass ratio would only have a value of 70. This latter value is closer to observation, than the former; but one can also recognize galaxy clusters quite distinctly, so that if mass loss by gravitational radiation is confirmed and found to be a general property of galaxies then here, too, a young age is indicated for galaxy clusters. Needless to say, if not all galaxies lose mass at the prescribed rate, then gravitational radiation cannot explain the mass anomaly.

It should be noted that if the galaxy were radiating mass at a rate of 100 suns per year and if it had been doing so for a long time, then the galaxy should be expanding. This effect has been looked for[30] and the result is negative; if anything it is contracting. It could not have been expanding for more than 10^7 years. It would seem that gravitational radiation cannot account for the mass anomaly.

*MeV means million electron volts. An electron volt is the energy given to an electron by accelerating it through a potential difference of one volt.

(11) **Errors in the cosmic distance scale** This proposal is probably the most abhorrent to most astronomers. If the distance estimates to the clusters were about a tenth that of current estimates then the mass anomaly would disappear. There are several objections to this proposal.

First, it would indicate that the Galaxy is one of the largest in the cosmos. Second, if the universe were 10 times smaller and still expanding at the present held rate, then the currently held cosmic time scale would also be reduced to a tenth of its present value.

The expansion rate, as well as the distance scale, are all based on a 7-step progression beyond the distance scale of the solar system. These are: parallax and proper motions; zero age main sequence (ZAMS) fitting; cepheid variables in our own and nearby galaxies; brightest stars; H II regions; bright Sc galaxies; and brightest elliptical galaxy in a cluster.

The error introduced at each step varies somewhat but averages about 10 per cent. Normally one might expect that this range would be too high in one step and too low in another so that in toto the errors would cancel. Estimates hover about 30 per cent to the most distant galaxies.[31]

It should be noted, however, that after the de-centralization of the earth with the Copernican revolution, there has been a steady view that neither sun nor Galaxy should occupy any special or central location. Also, to preserve the billions-of-years-old-cosmos hypothesis, a large cosmos is required.

As it is, the expansion age of the universe is less than that estimated by other methods.[32] All this contributes to the errors being on the high side; acting in the same direction. This would indicate that the actual cosmic distance scale could be as small as $0.9^7 = 0.48$ that presently assumed. In this light a factor of 10 or so in not as improbable as might be suspected at first sight.

Missing Physics Proposals

(12) **Matter-antimatter repulsion** The proposal[33] assumes that a significant fraction of the cosmos is made up of antimatter and that matter (koinimatter) and antimatter repel each other gravitationally. This has yet to be shown. If there were a sizeable antimatter component in the universe, however, cosmic rays should contain some antimatter which is not observed.[34]

The proposal would require matter and antimatter to coexist in the same cluster. Interactions between galaxies in the same cluster are believed to be common on a uniformitarian time scale, but none which have been proposed as interacting systems exhibit any energy flux which would require matter-antimatter galaxies to explain. Interaction between matter and antimatter would place many of the same constraints as were covered in topic 10 on the clusters.

(13) **A non-zero cosmological constant** This suggestion is a particular one of a set which can be classed as proposed modifications of the Einstein field equations.[35] It is the only one currently under consideration. Originally the cosmological constant was introduced into the field equations by Einstein to account for both Olber's paradox, and to answer the question as to why the cosmos had not collapsed inward over the billions of years of existence. It postulates that at large distances matter repels rather than attracts.

When it was decided that the universe was expanding the constant was no longer needed and it dropped from vogue; but with the advent of the mass anomaly it was reinstated, but with a sign change, making it an attractive force. Simply put, the force term, including the cosmological constant, λ, is:

$$\mathbf{F}' = \lambda m\mathbf{r}/3 \qquad (\lambda < 0) \qquad (4)$$

where $\mathbf{F}'$ is the force per unit mass, m is the particle mass (galaxy mass in this case) and $\mathbf{r}$ is the position vector. The force law predicts that at large values of $\mathbf{r}$, the velocity, v, should be directly proportional to $\mathbf{r}$. This is not confirmed in paper 1 which yields:

$$v(r) \propto r^3/\exp[(3/2n)r^n] \qquad (5)$$

where n is a constant of the observed rotation-curve. Hence it appears that a cosmological constant cannot account for the mass anomaly.

(14) **Changes in the Newtonian force law** These are of two types. One involves changing the exponent of the radial term in the denominator of the force expression and the other involves the variable G proposal. Although no continuous (as a function of size or diameter) modification of the gravitational law has been propse, a specific modification for the case of a cluster of galaxies has appeared in print.[36] The proposed formulation is that the force, F, is given by:

$$F = G'Mm/R^z \qquad (z < 2) \qquad (6)$$

where M is the mass of the cluster interior to a radial distance, R, from its center; m is the mass of a galaxy, and z is a constant. G' is a different value of the gravitational constant from that which would apply for the solar system. In particular, a value of $z = 1.7$ appears to fit through a plot of the anomalous mass ratio versus cluster radius. But it has been noted[37] that the above relationship predicts that the mass-ratio be independent of the velocity dispersion; a conclusion which runs contrary to observation.

The variable G hypothesis has been indicated recently as quite a viable explanation from a uniformitarian framework.[38] Based on lunar occultation studies, Thomas van Flandern of the U. S. Naval Observatory announced evidence of variation in the gravitational constant at the 1974 meetng of the American Astronomical Society in Rochester, New York, indicating a rate per unit G of $\dot{G}/G = -(7.5 \pm 2.7) \times 10^{-11}$ yr^{-1}. This can translate into an effective expansion to a system of 73 km sec^{-1} $megaparsec^{-1}$, a number comparable to estimates of the expansion rate of the universe (the Hubble constant).

If van Flandern's variability of G is confirmed in later work then the Big Bang hypothesis will effectively be disproven and evolutionists will have to consider a new type of cosmogonical model. Outside of Special Creation the Hoyle-Narlikar model appears to be indicated. This proposal can apparently deal with the phenomenon of the mass anomaly on the galaxy cluster scale. It cannot deal with chains of galaxies with discordant redshifts. Neither can it deal with the mass anomaly in galaxies.

Implictions for a Young Earth

In the past, the mass anomaly has been used in support of a young-cosmos hypothesis. It was argued that given the conditions inside a cluster of galaxies revealed by the application of the virial theorem, the mass anomaly indicated that the clusters are not bound and that in a billions-of-years-old universe they would have dissipated long ago. With the discovery reported in paper 1 that clusters of galaxies exhibit a rotation-curve, this approach has suffered a set-back. In paper 1 it was noted, though, that two other problems arose for evolutionists.

At present the mass anomaly appears to mean that astronomers do not understand the cosmos well enough to draw any definite conclusions. The fact that gravity is so poorly understood that it cannot be related to other fields (forces) underscores this point. The cause of a variable G, if confirmed, is totally unknown. To Creationists it would not seem possible that variable G could account for the mass anomaly, since the implication would be that galaxies have been around long enough that such a slow rate of change could occur.

The problem could simply be one of perspective. As Shakespeare put it: "The fault, dear Brutus, is not in our stars, but in ourselves . . .".[39] Man tends to view time as a unidirectional flow of events. If, however, it is part of a four-dimensional continuum, there might be longer and shorter time-paths between the same events. It would be somewhat as in a baseball diamond; from home to third the right way around is 270 feet, but only 90 the reverse way.

In any case, no satisfactory suggestion has been made which can account for the mass anomaly. Some seem most attractive, such as the distance-scale and variable G proposals, but the last word is still far from in. It is an extremely fundamental consideration, and there is some evidence that the mass anomaly may even occur in star clusters[40, 41] although the ratio there only appears to be about 1.7 ± 0.2. After all who today is really any closer to understanding what mass and inertia are than Newton was?

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Note added in proof. Recent X-ray observations [1977, *Science News* 112(3):36] have produced evidence that a hot medium may be present in galaxy clusters, having possibly 5 to 20 times the mass observed at other wavelengths. While this is held to be enough to account for the missing mass, a factor of 10 is the *minimum* discrepancy observed. The average exceeds a factor of 100; so the X-ray observations would account for only about 10% of that. Since the temperature is estimated to exceed 60 million degrees, the age constraint mentioned in proposal (3) applies.