DETERMINATION OF TRUE VELOCITY DISPERSION AND THE DARK MATTER PROBLEM IN CLUSTERS OF GALAXIES

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Abstract. According to the convention normally followed the redshifts of the galaxies in a cluster are assumed to be of purely dopplerian origin. The resulting velocity dispersion, when used in the virial theorem, leads to a very large proportion of dark matter to be present in the galaxy clusters. However, the recently proposed model of velocity dependent 'cosmic' drag cause redshifts of photons and it is necessary to develop a procedure to determine the true velocity dispersion from the gross redshift data. A method for this has been presented in the paper. Coma and Perseus clusters have been investigated using this procedure and the M/L ratios for both were found to be approximately of the order of 30, i.e., approximately the order of M/L ratios for individual galaxies. A study of the $m - z$ relation indicates that the galaxies with higher redshifts have fainter magnitudes. Distortion of the redshift plots and the typical elongation of the core regions along the line–of–sight is also explained.

Key words: Galaxy Clusters, Dark Matter, Redshifts

1 Introduction

Dynamical study of galaxy clusters, assuming the observed redshifts of the individual galaxies to be of purely dopplerian origin, results in the presence of a disproportionately large amount of gravitating matter as compared to the luminosity and the number count of galaxies. This has led to the interpretation that most of the universe is composed of dark matter (DM). It is also found (Ostriker et al 1973 and Trimble 1987) that the ratio of the dark matter to the luminous matter increases with the size of the system considered. This raises some doubt about the nature of the redshifts. If a major fraction of the observed redshift is an indicator (in the presence of the proposed cosmic drag machanism to cause the redshifting of the photons)of the distance rather than the recessional velocity of a galaxy along the line–of–sight then it is obvious that the redshift dispersion indicates the diameter of the system of galaxies under consideration. On the other hand, increase of the ratio of the dark matter to the luminous matter with the size of the system is difficult to explain whatever may be the nature of dark matter distribution. Furthermore, the $m - z$ relationship shows that the galaxies with fainter magnitudes posses higher redshifts. Thus, it is reasonable to assume that a major fraction of the redshift is a distance indicator rather than the

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velocity. Jaakkola (Jaakkola 1983) and Arp (Arp 1993) also express similar suspicions.

In this paper a method has been proposed to extract the true velocity dispersion from the gross redshift data in case of spherically symmetric rich galaxy clusters. The author considers the velocity dependent inertial induction, which has yielded consistent results in a number of cases (Ghosh 1984, 1986a, 1986b, 1988a, 1988b, 1993), for producing redshifts approximately proportional to the distance. Coma and Perseus clusters have been investigated using the proposed procedure.

2 Determination of True Velocity Dispersion

The method for separting the true velocity dispersion from the gross redshift data presented below assumes rich clusters to be spherically symmetrical. The model of velocity dependent inertial induction (Appendix) applied to a quasistatic, infinite, homogeneous universe shows that a photon is subjected to a cosmic drag $h\nu\sqrt{\pi G_o \rho}/c$ where, h is the Planck's constant, ν is the frequency of the photon, G_o is the constant of gravitation, ρ is the mean density of the universe and c is the speed of light. It can be easily shown that this drag leads to a redshift approximately proportional to the distance as follows (Ghosh 1984, 1986a, 1992):

$$z = \frac{\Delta\lambda}{\lambda} \approx \frac{\sqrt{\pi G_o \rho}}{c} x = Kx \quad (\text{for} z << 1) \tag{1}$$

where z is the fractional redshift, λ is the photon wavelength at the source, $\Delta\lambda$ is the increase in the wavelength, x is the distance of the source and K is the proportionality constant (which is equivalent to the Hubble constant H_o when multiplied by c, the speed of light). Since this redshift is generated by some interactive mechanism it is reasonable to assume that the intensity of the mechanism (and, therefore, the value of K) is dependent on the matter density in the path of a photon.However to startwith let us neglect the effect of local variation of K. The redshift of a galaxy in a cluster will be primarily due to two reasons (the magnitudes of the intrinsic redshifts are comparatively small and, therefore, neglected) as follows:

(i) Cosmological redshift proportional to the distance of the galaxy, z_c.

(ii) Doppler red (or, blue) shift due to the line–of–sight component of the velocity of the galaxy, z_v.

Thus, z_c can be taken as a distance indicator and when z_c (to some scale representing the distance) is plotted against the distance from the core centre (with the same scale) the diagram will be of approximately semicircular shape as shown in Fig.1. This is because it will be nothing but the diagram

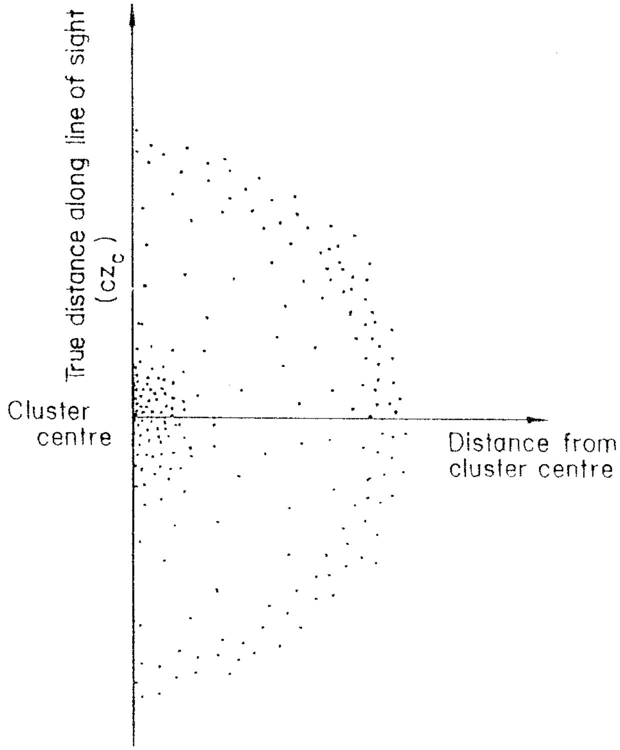

Fig. 1. Redshift - distance from centre plot of a galaxy cluster.

obtained by folding the circle (representing the projection of the spherical cluster on the plane containing the line–of–sight) about the diameter along the line of sight. The total redshift of a galaxy

$$z = z_c + z_v \tag{2}$$

Since z_v is due to the velocity component along the line of sight, when z is plotted against the distance from the cluster centre the diagram will be elongated along the line–of–sight. This is because many galaxies near the boundary of the far side of the cluster have velocities away from the observer causing the upper quarter circle (of the semicircle shown in Fig. 1) to move up by an amount corresponding to $z_v(= v/c$, where v is the velocity of such galaxies and c is the speed of light). Similarly many galaxies near the cluster boundary at the near end move with velocity v towards the observer. Thus a blueshift of magnitude z_v will result in a lowering of the bottom quarter circle of the semicircle shown in Fig. 1. Thus, the plot of the total redshift (in a suitable distance scale) against the distance from the cluster centre will have the appearence of two split quarter - circles as shown in Fig. 2. Since

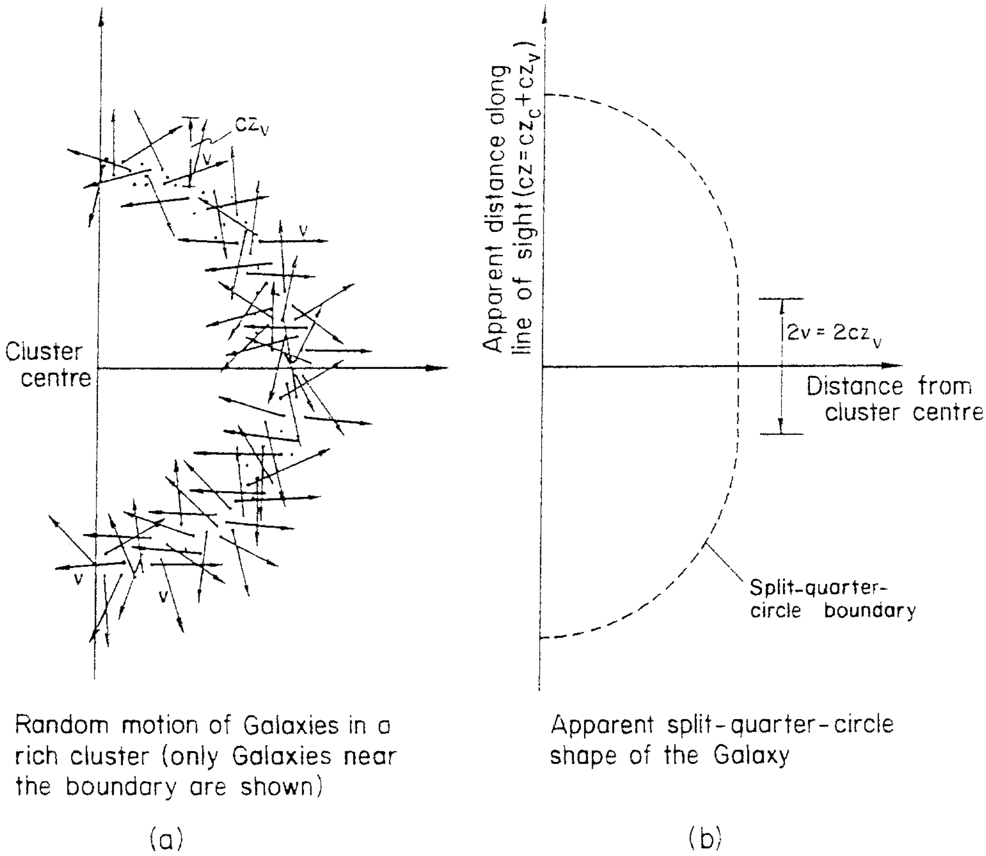

Fig. 2. Split quarter–circle appearance due to velocity dispersion

the redshift - distance relation given by (1) is used, the order of magnitude of the true velocity v is given by cz_v where z_v is determined from the amount of the split of the quarter circles (as shown in Fig. 2).

3 Effect of Local Fluctuation in K and Shape Distortion

The density at the core of a rich cluster is much more than the average density of the universe. So, if the cosmological redshift z_c is due to velocity dependent inertial induction then the local value of $K(= H_o/c)$ inside the core region will be much higher introducing substantial distortion in Fig. 1 because of intensified local interaction as the matter density in this region is more. Figure 3 shows two diametrically opposite galaxies A and B on the outer boundary of a cluster along the line–of–sight. The distance between

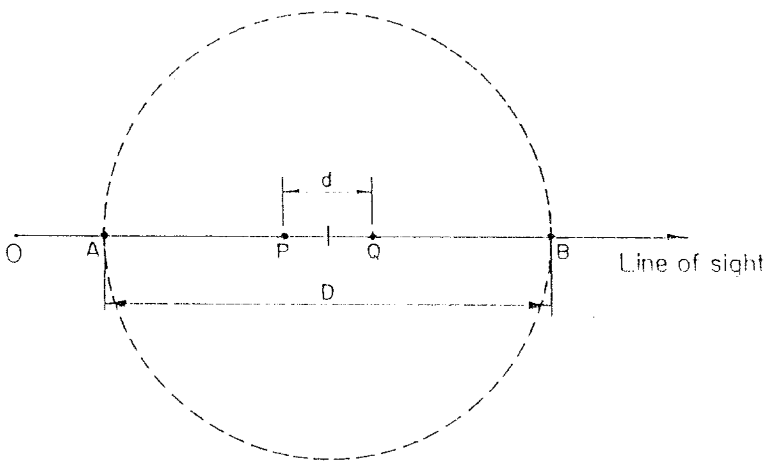

Fig. 3. True Nature of distribution of galaxies in a spherical rich cluster

these two (i.e., the diameter of the cluster), D, depends on the redshift difference as follows:

$$z_{c_B} - z_{c_A} = K_{BA}.D \tag{3}$$

where K_{BA} is the local average value of K when a photon travels from B to A, respectively. Similarly, for the distance, d, between two galaxies P and Q at the core region (Fig. 3) we get the following relation:

$$z_{c_Q} - z_{c_P} = K_{QP}.d \tag{4}$$

where z_{c_P} and z_{c_Q} are the cosmological redshifts of P and Q, respectively, and K_{QP} is the local average value of K for a photon going from Q to P.

Taking the orders of magnitude of the values from the data for Coma it is seen that $K_{BA} \approx K$ whereas $K_{QP} > K$ using the model of inertial induction (Ghosh 1986a, 1993). As a result the shpherically symmetric core, when plotted using z_c as the distance indicator with K as the average universal value of the proportionality constant, appears to be elongated along the line of sight. However, the outer shape of the cluster remains undistorted once the redshift due to the true velocity dispersion is determined (in a manner discussed in the previous section) and subtracted from the gross redshift data. This is so because

$$d_{ap} = \frac{z_{cQ} - z_{cP}}{K} > \frac{z_{cQ} - z_{cP}}{K_{QP}} = d$$

and

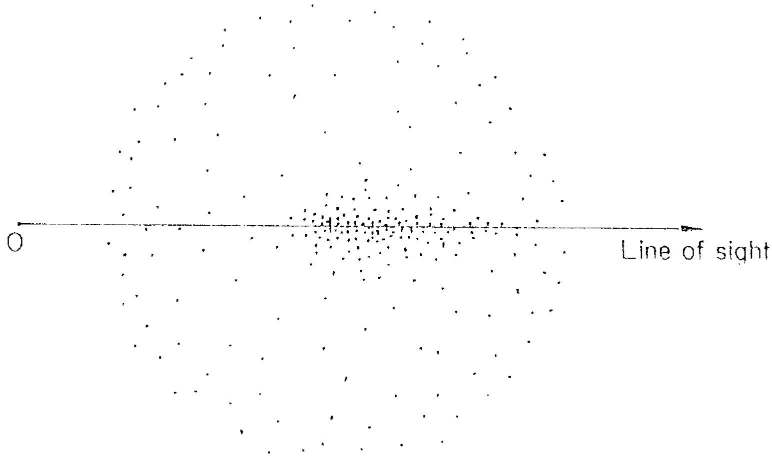

Fig. 4. Apparent nature of distribution of galaxies from the redshift data

$$D_{ap} = \frac{z_{c_B} - z_{c_A}}{K} \approx \frac{z_{c_B} - z_{c_A}}{K_{BA}} = D$$

where d_{ap} and D_{ap} represent the apparent diameters of the core and the cluster, respectively. Figure 4 shows the apparent shape from the cosmological redshift plot.

The mean position of the elongated core also gets shifted away from the observer and the geometric centre of the cluster as indicated in Fig. 4. This happens because of the systematic excess redshifts of the galaxies behind the cluster centre.

4 Dependence of Apparent Magnitude on Redshift

Since a major fraction of the observed redshift is proposed to be due to velocity dependent inertial induction, a larger redshift, in general, also implies a larger distance. Assuming the average intrinsic luminosity of the galaxies of a particular type to be constant the apparent magnitude should increase with redshift. However, it is difficult to observe this effect distinctly because of the smallness of the effect and a large scatter in the intrinsic luminosities of the galaxies of a particular type in a cluster. Spiral galaxies are most suitable for this study because of the relatively smaller scatter in their luminosities.

If two galaxies A and B with equal intrinsic brightness be at distances x_A and x_B, $(x_A > x_B)$ respectively, their apparent magnitudes, m_A and m_B, should satisfy the relation

$$m_A - m_B = 5 \log_{10}(\frac{X_B}{X_A}) \tag{5}$$

5 Analysis of Coma and Persus Clusters

Both Coma and Perseus clusters are rich clusters and have been studied quite extensively (Kent and Gunn 1982, Kent and Sargent 1983). Though Coma is a very clean system with spherical symmetry, the extent of Perseus is not that well identified. Figure 5 shows a plot of the line - of - sight distance against the distance from the core centre taking a value of $K(\equiv H_o)$ equal to 50 km s^{-1} Mpc^{-1}. It should be noted that the result will not depend on this choice as both the line - of - sight distance scale and the scale for the distance from the cluster centre depend on this choice. A numerical value has been adopted only for the convenience of representation. It appears that if Coma is spherically symmetric then certain galaxies in the foreground and in the background do not truely belong to the cluster though so far they have been treated as members of the cluster because of their small angular distance from the centre.

The split - quarter - circle configuration is quite obvious from the figure. Following the procedure developed earlier in this paper the order of magnitude of the overall true velocity dispersion is found to be about 350 km s^{-1} (Fig.6). Application of the virial theorem yields an M/L ratio of about 30 (instead of about 180 as estimated in the conventional manner) which appears to be more realistic and closer to the value of M/L ratios for individual galaxies.

Figure 7 shows the $m - z$ relation for the spiral galaxies in Coma which agrees well with the relationship predicted in (5). Arp (Arp 1988) has also obtained a similar dependence of m on z. Figure 6 also shows the elongation of the core region as per the expectation because K in the core region is a few times more than that used for converting the redshift into distance. It is not only the shape which is elongated, the mean position of the core is also shifted away from the geometric centre of the cluster as predicted.

An analysis of the data from Kent and Sargent 1983 indicates the possibility that Perseus could be in reality two smaller clusters one behind the other along the line–of–sight. Converting the redshift data into the apparent distances and plotting these against the distance from the centre (to the same scale) results in the diagram shown in Fig.8. There are two split - quarter - circles representing two spherical clusters. The velocity dispersions of these clusters are of the order of 380 km s^{-1} and 120 km s^{-1} as shown. If the unusually high conventional value of 1200 km s^{-1} is replaced by 380 km s^{-1} M/L drops from a conventional value of 300 to about 30. Am $m - z$ plot for the galaxies in Perseus was not attempted as adequate data on spiral galaxies were not available.

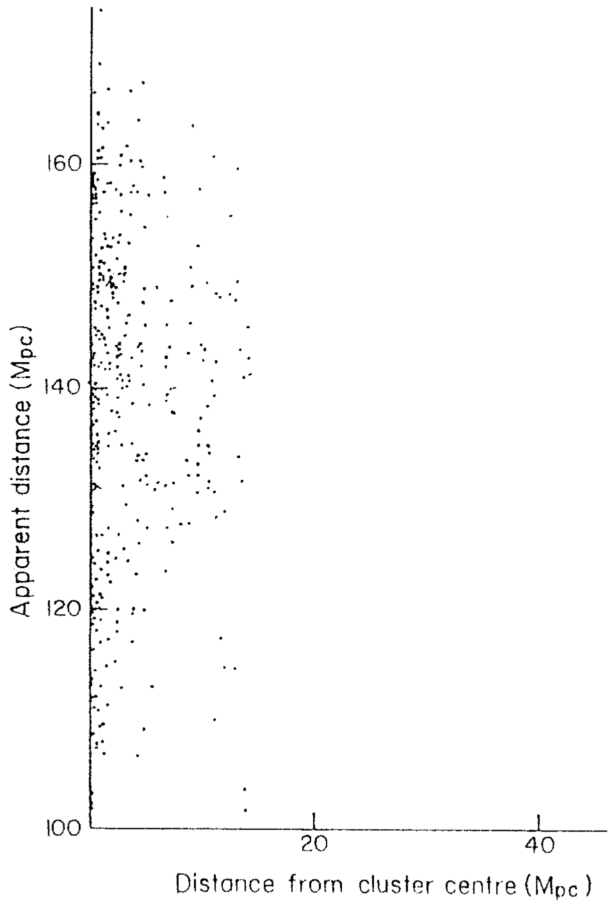

Fig. 5. Plot of Coma cluster

6 Concluding Remarks

If the redshifts of the galaxies in clusters are assumed to represent primarily the distance (rather than velocity) because of some interactive mechanism (like velocity dependent inertial induction) causing the photons to undergo redshifts, it is possible to limit the M/L ratio to the values obtained for individual galaxies. A method for extracting the true velocity dispersion of the clusters from their gross redshift data has been developed which yields cosistent results. The typical elongation along the line–of–sight is explained. Analyses of Coma and Perseus yield realistic results with a much lower value of M/L. It is also found that Perseus may be in reality two smaller clusters side by side along the line–of–sight.

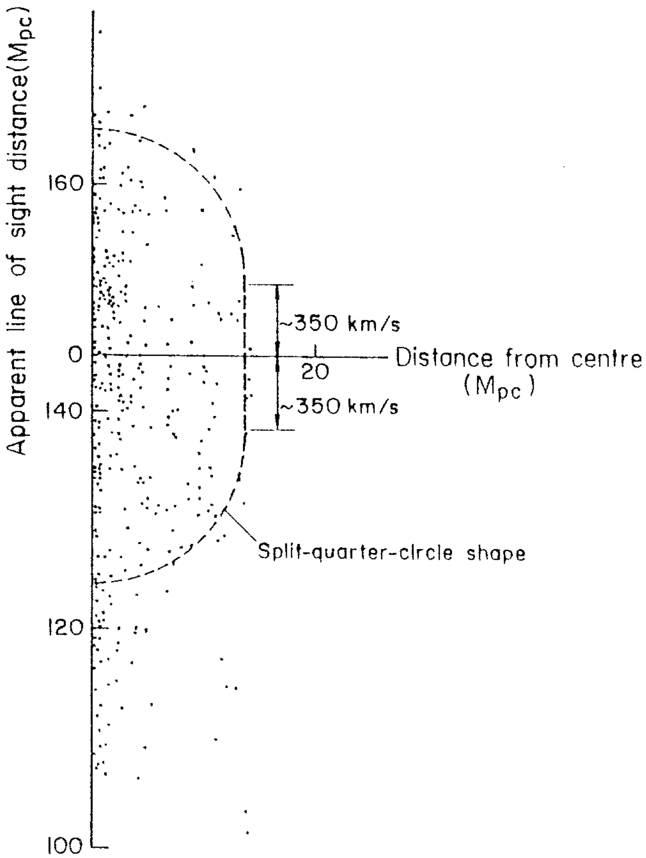

Fig. 6. Determination of true velocity dispersion for Coma cluster

7 APPENDIX

According to the phenomenological model of inertial induction the gravitational force on a body A due to another body B is given by (Ghosh 1986a, 1993).

$$\boldsymbol{F}_{AB} = -\frac{Gm_A m_B}{r^2}\boldsymbol{u}_r - \frac{Gm_A m_B}{c^2 r^2} v^2 \boldsymbol{u}_r f(\theta) - \frac{Gm_A m_B}{c^2 r} a \boldsymbol{u}_r f(\phi)$$

where $\boldsymbol{r}(= r\boldsymbol{u}_r)$, $\boldsymbol{v}(= v\boldsymbol{u}_v)$ and $\boldsymbol{a}(= a\boldsymbol{v}_a)$ are the position, velocity and acceleration of body A with respect to B ($\boldsymbol{u}_r, \boldsymbol{u}_vand\boldsymbol{u}_a$ being the unit vectors). $f(\theta)$ and $f(\phi)$ (with $\cos\theta = \boldsymbol{u}_r.\boldsymbol{u}_v$ and $\cos\phi = \boldsymbol{u}_r.\boldsymbol{u}_a$) represent the inclination effects, m_A and m_B are the relativistic gravitational masses of A and B, respectively. In this work we have assumed $f(\theta) = \cos\theta.|\cos\theta|$ and $f(\phi) = \cos\phi.|\cos\phi|$ Using the above model the force on a particle of

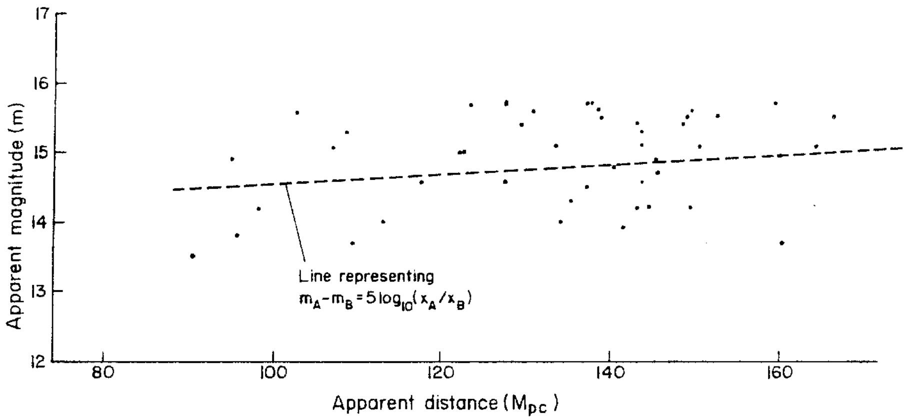

Fig. 7. Apparent magnitude-redshift relation for the spiral galaxies in Coma cluster

relativistic gravitational mass m due to matter in an infinite, quasistatic non expanding universe can be shown to be (Ghosh 1984, 1986a, 1993)

$$F = -\frac{k}{c} m v^2 \boldsymbol{u}_v - m\boldsymbol{a}$$

where $k = \sqrt{\pi G_o \rho}$ with G_o as the local value of gravitational constant, ρ is the mean density of mass-energy in the universe, boldmath$v(= v u_v)$ and $\boldsymbol{a}$ are the velocity and acceleration of the particle with respect to the mean rest frame of the universe. The first term indicates that a cosmic drag acts on a body even if it moves with a constant velocity and the second term implies Newton's second law of motion alongwith the equivalence of gravitational and inertial masses.

Local interactions according to the proposed model lead to a number of interesting observable effects and in all cases the observations have supported the theoretical prediction. A consolidated discussion of all these phenomena is presented in (Ghosh 1993).

8 Acknowledgment

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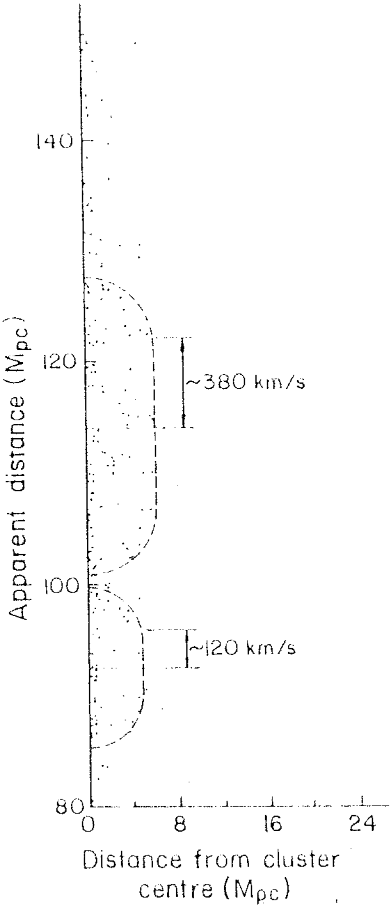

Fig. 8. Determination of true velocity dispersion for Perseus cluster

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