Understanding Galaxy Cluster Phenomena

The implications of the *clumpiness* of the universe as illustrated in figure 1 and described elsewhere are profound. An overall uniformity must not dissuade one from accepting the opposing adjective as a reality at a different scale, just as I accept that the surface of my desk is smooth unless I were to look at it through an electron microscope. The universe is the same in all direction, including its average mass and energy densities as well as its thermal radiation density. But those are averages over vast regions of space for which even a representative galaxy cluster is like a mere molecule on a smooth surface. So it is representative galaxy cluster cells to which we turn our attention as microcosms of the universe itself. The properties of the material in my desk derive from the atoms of which it is comprised; similarly galaxy cluster phenomena determine cosmological realities.

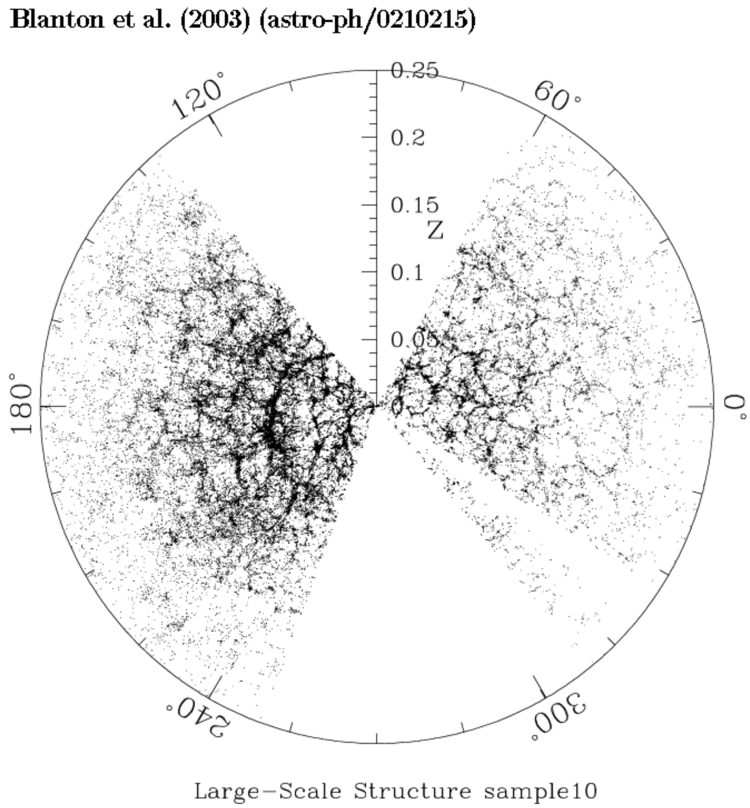


Figure 1: Distribution of galaxies

There is now a massive amount of data on galaxy clusters, but there are interpretational biases to be dealt with as well. Distance to clusters and through them are measured in redshift but these refer to different metrics. Distances to the centers of cluster cores are in units of cosmological redshift but distances from the closest to the furthest galaxy in a single cluster though measured in redshift are greater by far than the dimension of the cluster cell to which it belongs by the first metric. Cosmological redshift is very closely associated with distance via a redshift-distance relationship, which for various reasons to be discussed elsewhere cosmologists today use the cold dark matter ΔCDM version of that metric. See the plot in figure 2. Over short distances (up to redshifts of about 0.5) cosmological redshift and distance are directly proportional as z = Ho d. Agreement with the Δcdm 'comoving distance' parameter out to a redshift of ten is obtained using the relation ln(z+1) = Ho d as shown.

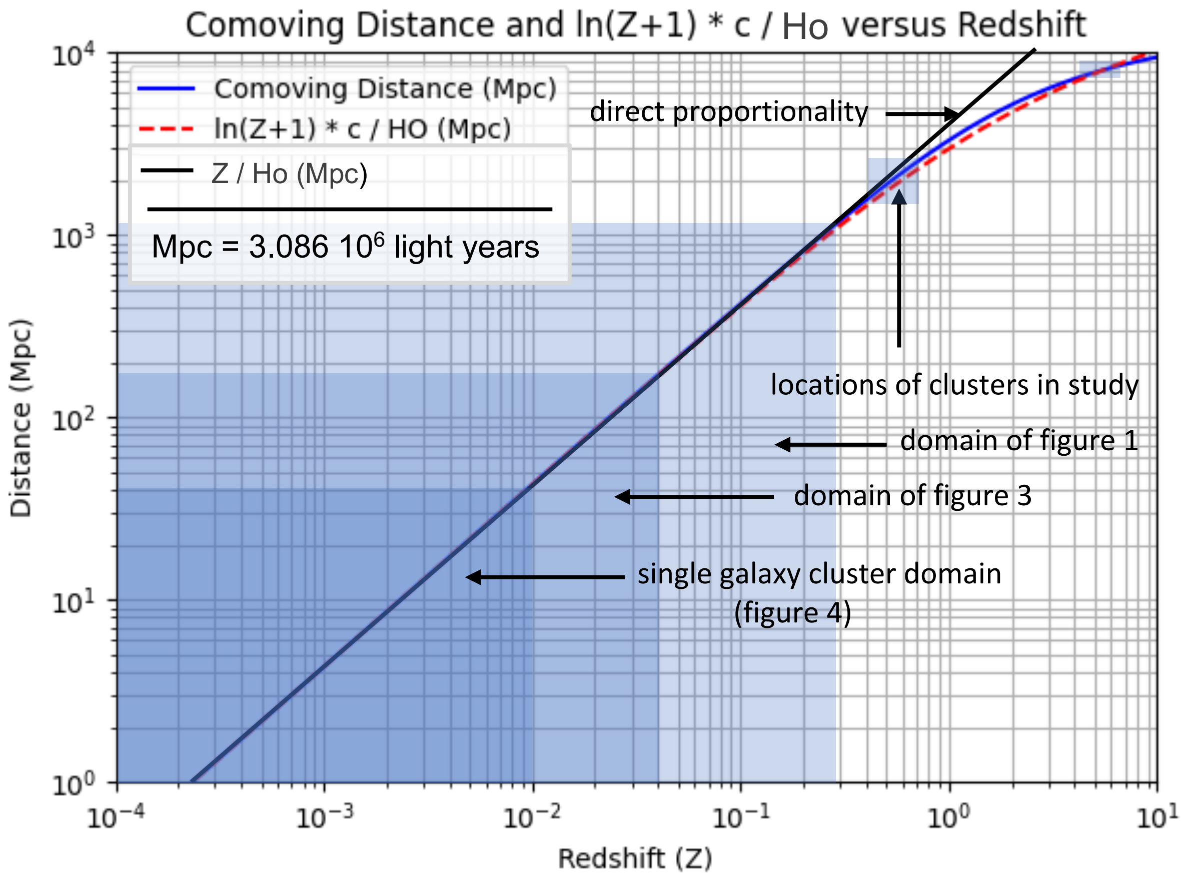


Figure 2: Comparison of comoving distance in ΛCDM, naïve Hubble relationship, and logarithmic functionality of cosmological redshift-distance relationship

The redshift through a cluster exhibits a different functionality altogether and although it is simply added to the cosmological redshift location of the cluster on redshift surveys as illustrated in figure 3, the near linearity that applies to the cosmological redshift-distance relationship for dimensions that would seem to apply within cluster domains, does not apply. The reasons that it doesn't apply have been attributed to various causes, but primarily by established cosmologists to dark matter. Additional gravitational (as against thermodynamic) matter would add considerably to the observed baryonic matter of the cluster and propel major increases in orbital velocities that would then contribute massively to the observed redshift dispersion through the cluster by the Doppler redshift effect. The virial theorem expresses the relationship of the added mass to the increased dispersion in redshift. That is the now time-honored method of accounting the disproportionate amount of redshift that occurs in light passing through or near the core region of a galaxy cluster. In more recent expanded surveys like that shown in figure 1, aligned galaxies are less apparent because of the scale of the surveys that dwarfs them.

Application of the Doppler effect to account for redshift effects is, of course, how cosmological redshift is typically accounted as well – in that case due to theorized expansion of the universe such that more distant galaxies appear more redshifted than those that are closer. Hence redshift is virtually always given in technical papers as velocity in units of the velocity of light. But redshift is not velocity; it is a unitless ratio of the observed wavelength of radiation divided by the emitted wavelength of that radiation. That's all redshift is, and as seen in figure 2, cosmological redshift values increase in direct proportion to the distance to the object that emitted the radiation out to distances of a billion light years.

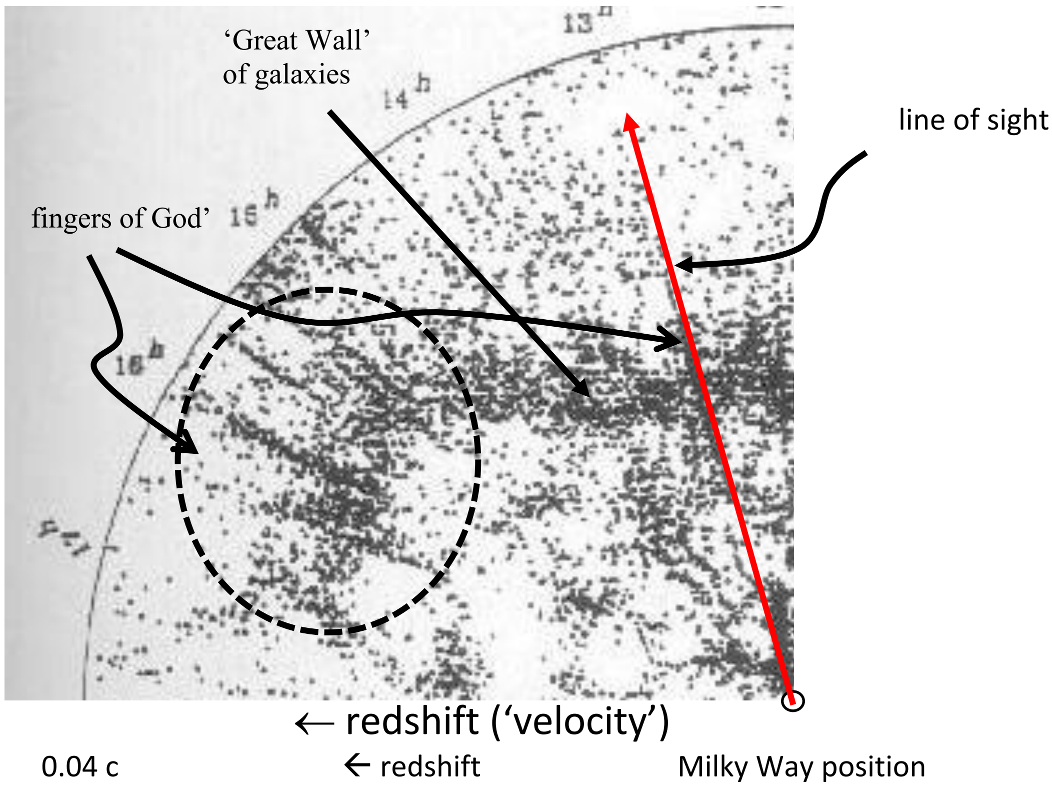
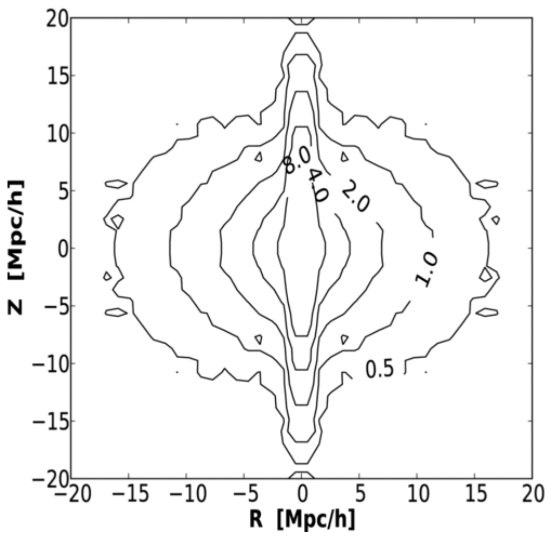


Figure 3: Portion of the early SDSS distribution of galaxies by angle and redshift showing the fingers of god phenomena

Redshift effects have virtually all been attributed to recessional velocities producing a Doppler effect on wavelength, but there is an alternative in Einstein's theory of relativity involving transverse as well as recessional velocities. Transverse Doppler is a second order effect, i.e., it involves $(v/c)^2$ rather than v/c, that produces unilateral increases in wavelength in secondary scattered radiation propagating through high temperature plasma electrons typical of the gaseous intergalactic medium. This effect of secondary radiation scattering results in a redshift-distance relation that is $d = \ln(z+1) / Ho$. It is described in articles under the aegis of 'cosmological papers' on this site. The mechanism relies on the pressure in high temperature plasma in galaxy cluster cores to produce this redshift.

To be clear, orbital velocities of galaxies about cluster cores contribute to redshift dispersion. But the baryonic matter directly observed and/or inferred are insufficient to produce the huge spread of galaxies that appear as spokes in a wheel centered at observatories here in the Milky Way galaxy. These straight lines of galaxies seen in figure 3 are referred to as 'fingers of God'. When the redshift difference between leading and trailing galaxies is attributed to galaxy orbital receding and approaching velocity differences; it is appreciable with respect to the speed of light when interpreted in this way for which the baryonic matter would be insufficient to keep galaxies from escaping the cluster.

Research into the nature of the redshift that occurs in light passing through these galaxy cluster domains was addressed by Martin White, et al (2011) under the heading of 'halo occupation modeling'. The paper addresses a class of extremely luminous galaxies identified in the Baryon Oscillation Spectroscope Survey (BOSS) that they have selected from three regions in the survey that possess redshifts in the range 0.4 to 0.7 but narrowly centered at 0.5. The majority reside in core regions of cluster domains with masses in the range of 10^{13} solar masses, although 10% are satellites of much more massive cluster domains. The paper uses comoving distance assuming the ΛCDM version of the standard cosmological model with density parameters: $\Omega m = 0.274$ and $\Omega_\Lambda = 0.726$. Distance measures assume $H_0 = 70$ km s^{-1} Mpc^{-1}. The article provides excellent data, although intended for purposes other than investigating alternative causes of the dispersion effect. We proceed with the data provided in that paper and defer to the paper itself with regard to the observations and analyses that provide the redshift profiles. The massive galaxies are easily observed at the distance with measured redshifts. Figure 4 is taken from figure 4 in the cited paper.



"Figure 4.
Contours of the redshift-space correlation function, ξ(*R*, *Z*), for our $0.4 < z < 0.7$ galaxy sample (see the text). Note the characteristic elongation in the *Z* direction at small *R* (fingers-of-god) and squashing at large *R* (super-cluster infall). [This] panel shows the results from the BOSS data."

Mpc = 3.26 10^6 lt. year

What figure 4 demonstrates is the correlation between galaxy distance and redshift within six symmetric regions of space surrounding a cluster core. This has been interpreted to mean that the redshift of galaxies within the region incur incremental amounts of redshift proportional to the values associated with the region. The paper assumes incurred redshift is due to a projection of orbital velocities about the center of the domain. The data is binned to support analyses to assign net redshift increments across the domain. The resulting data is then plotted as the amount of redshift realized at each radial distance from the center of the cluster domain. See figure 5 below.

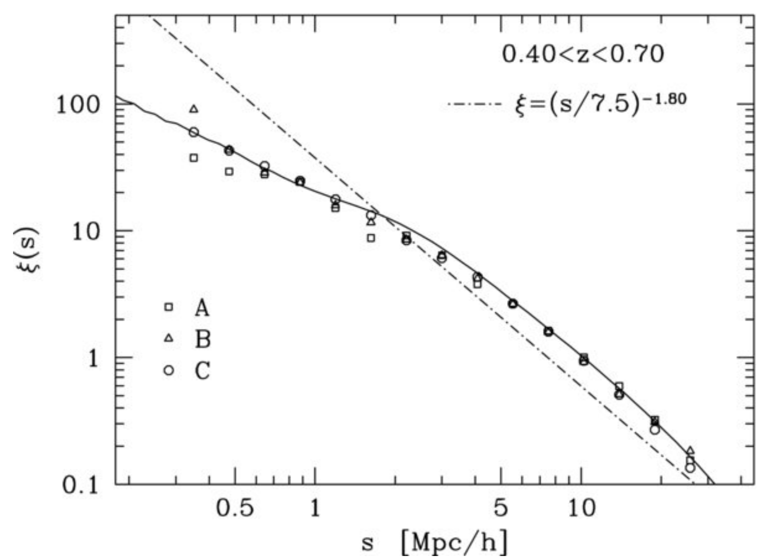


Figure 5: Redshift correlation with radial distance from the center of galaxy cluster cores

"**Figure 7.** Redshift-space, isotropic correlation function for the $0.4 < z < 0.7$ sample in regions A, B, and C (points). The same power-law correlation function which fits the w_p data on intermediate scales, with $s_0 = 7.5\ h^{-1}$ Mpc, is shown as the dot-dashed line while the solid line is the prediction for ξ(*s*) from the best-fitting HOD model to w_p, assuming no velocity bias for satellites and that central galaxies are at rest in their halos. The good agreement below a few Mpc is an indication that the satellite fraction in the model is close to that in the data and any velocity bias is small."

Using the raw data provided as figure 4, an independent binning of the data has been performed as shown in figure 6 with an 8 by 16 grid of bins in which proportionate redshift increments are tabulated in Table I below the figure and then totaled to obtain column densities of redshift. These totals do not reflect totals of either galaxy or redshift densities at the radial distances. They are merely the totals at the given cylindrical radial distance, but the column densities at that distance must be divided by two pi times the radii to obtain proper column densities. Thus, although fifty percent of galaxies exist outside of cluster cores as satellite galaxies, the densities of galaxies or intra-cluster gases outside the core is very much smaller. These column densities are shown in the plot in figure 7.

Cosmologists implicitly accept that the baryonic and whatever other matter comprises the universe exists in sizeable clumps rather than continuously as uniform substance with the overall mass density over any appreciable region of space the same everywhere throughout the current universe. In contrast, cosmological redshift is assumed to be a continuously increasing quantity in all directions. Exception is made for Doppler effects due to orbital motions in galaxy clusters, with the exaggerated amounts attributed to dark matter. But what if the majority of the redshift occurring through galaxy cluster domains is not attributable to orbital velocities but rather the plasma pressure along the propagation paths of light? Then this too would be clumpy? Paths through or near cluster cores would experience large amounts of redshift whereas those further from such centers would experience less. After passing through many such clusters, what if the average equaled the cosmological redshift we observe just as density is leveled by distance? That is the cosmological model we are exploring.

Galaxy cluster phenomena is most accurately described by what is called the beta model that characterizes the temperature, density, and pressure as functions of the radius from the center of the domain. Cluster domain stability depends upon a balance of hydrostatic pressure of the outward thermodynamic forces that counter a gravitational tendency to collapse. At boundaries between clusters there are no forces in the three-dimensional voronoi network of cluster structures described elsewhere.

It is a matter of observation that baryonic and whatever other matter comprises the universe exists as sizeable clusters rather than continuously distributed as uniform substance, but overall mass density

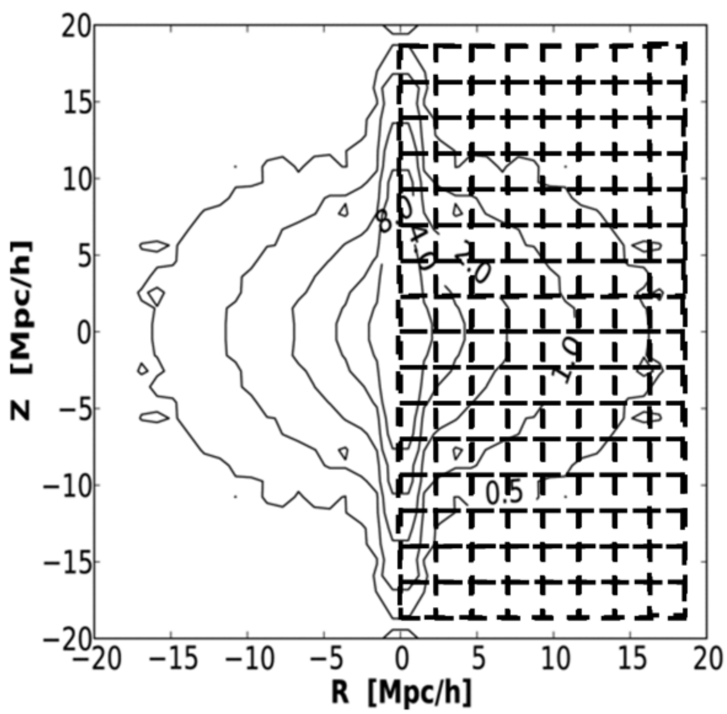


Figure 6: Redshift-space correlation bins for determining redshift column densities

Table I: Redshift Column Densities

Z \ R	1.25	3.75	6.25	8.75	11.25	13.75	16.25	18.75	21.25
21.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.75	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.25	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.75	1.05	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11.25	1.95	0.55	0.40	0.35	0.00	0.00	0.00	0.00	0.00
8.75	2.50	0.95	0.65	0.50	0.45	0.15	0.00	0.00	0.00
6.25	3.40	1.40	1.00	0.80	0.50	0.50	0.35	0.00	0.00
3.75	3.60	2.10	1.50	1.00	0.60	0.50	0.35	0.00	0.00
1.25	3.90	2.8	2.00	1.00	0.85	0.50	0.45	0.10	0.00
1.25	3.90	2.8	2.00	1.00	0.85	0.50	0.45	0.10	0.00
3.75	3.60	2.10	1.50	1.00	0.60	0.50	0.35	0.00	0.00
6.25	3.40	1.40	1.00	0.80	0.50	0.50	0.35	0.00	0.00
8.75	2.50	0.95	0.65	0.50	0.45	0.15	0.00	0.00	0.00
11.25	1.95	0.55	0.40	0.35	0.00	0.00	0.00	0.00	0.00
13.75	1.05	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.25	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.75	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals:	**34.6**	**16.8**	**10.1**	**8.0**	**4.7**	**3.3**	**2.3**	**0.2**	**0.0**

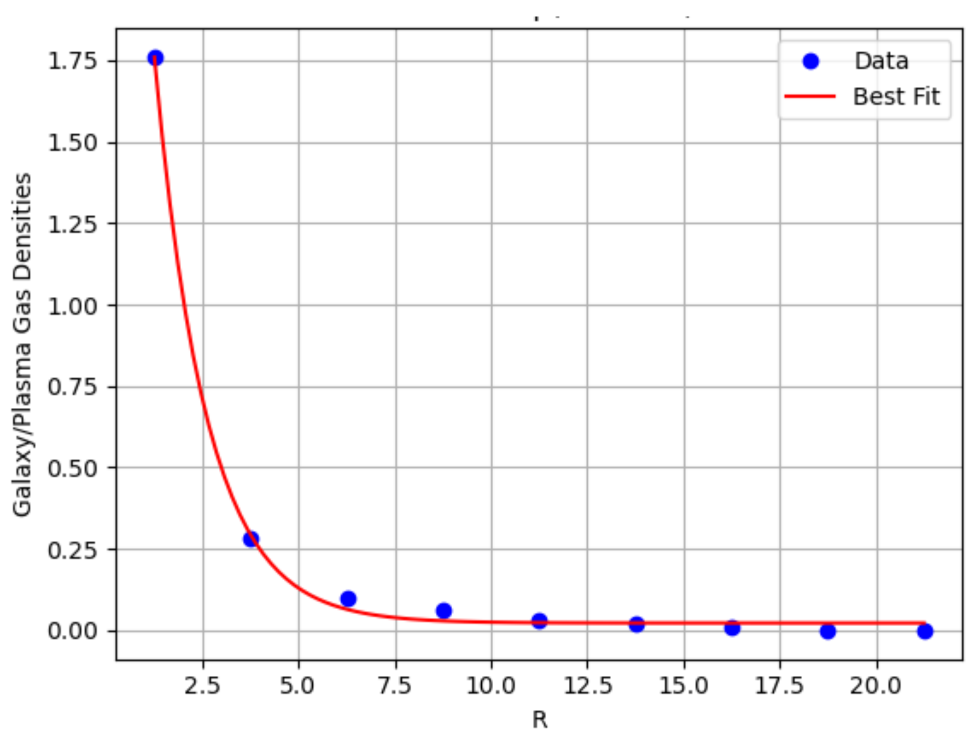


Figure 7: Density of galaxies and gases at cylindrical radii from the center of BOSS clusters

of any appreciable region of space is the same everywhere throughout the current universe. It is estimated that over 99.9% of the baryonic matter (including galactic structures) is in the plasma form. The composition of galaxies with their stellar matter comprises only ten percent of the baryonic matter in the universe; the rest is in intergalactic plasma gases. Galaxies, intergalactic plasma gases, and dark matter, to the extent that it is more than the effects attributed to it, are all observed to be distributed in the same proportions throughout clusters. Observations of the distant universe are all facilitated by forward scattering through these plasma gases, free electrons providing a photon replication process.

The 'beta model' of galaxy cluster phenomena is widely used by cosmologists to study the properties of the plasma gases in galaxy clusters, including their X-ray emission, Sunyaev-Zel'dovich effect, and gravitational lensing. It provides a simple and convenient way to describe the plasma gas density distribution in these systems. The simplified mathematical model captures essential aspects of the intra-cluster plasma gas. The model assumes gas in the cluster is in hydrostatic equilibrium for which gas pressure balances tendencies of gravitational collapse in the clusters. Hydrostatic equilibrium equations accommodate estimation of the thermodynamic parameters: temperature, density, and pressure. In this equilibrated situation, plasma gas density and baryonic matter density generally, are clumped in these spherically symmetric thermodynamic parameter distributions.

The plasma gas density profile in a representative cluster is plotted in figure 8 using the following beta model formula:

$\rho(r) = \rho_0\, [1 + (r/r_c)^2]^{(-3\beta/2)}$, where:

$\rho(r)$ is the electron density at a radial distance r from the center of the cluster. ρ_0 is the central electron density of the cluster. $\rho_0 = 0.1\ cm^{-3}$ was used in this study. r_c is the core radius of the cluster at which the gas density starts to decline rapidly. $r_c = 0.1$ Mpc was used in this study. β is a parameter that controls the steepness of the density profile. A larger value of β corresponds to a steeper decline in the density. $\beta = 0.9$ was used in this study.

The plasma gas temperature profile is the following:

$T(r) = T_0\, [\rho(r) / \rho_0]^{\beta}$, where:

T_0 is the central X-ray producing temperature of the cluster. $T_0 = 10^8$ K was used in this study.

Pressure is determined by the thermodynamic relation:

$p(r) = k\, \rho(r)\, T(r)$

In addition to these values of the parameters at given radii from the center of the cluster, averages of the parameters as functions of the distance from the center of the cluster are also computed. These are presented in brackets, where <x(r)> is the average of the parameter x out to the distance r. In addition we have plotted the column 'density' of the pressure along lines of sight through a cylindrical volume of space containing the spherically distributed cluster. These plots are provided as figure 9.

In contrast to the structural lumpiness of matter, cosmological redshift has been assumed to be a continuously increasing quantity caused by space expanding in all directions. Exception is made for Doppler effects due to orbital motions in galaxy clusters, with the exaggerated amount attributed to dark matter. But if the majority of the redshift occurring through galaxy cluster domains cannot be attributed to orbital velocities of caused by baryonic matter then the redshift must be caused directly by plasma pressure along propagation paths. We have plotted the column density of dynamic pressure in figure 9 because this quantity is proportional to the amount of redshift accumulated by radiation passing through that column according to the plasma scattering model that is being advocated in other papers on this site.

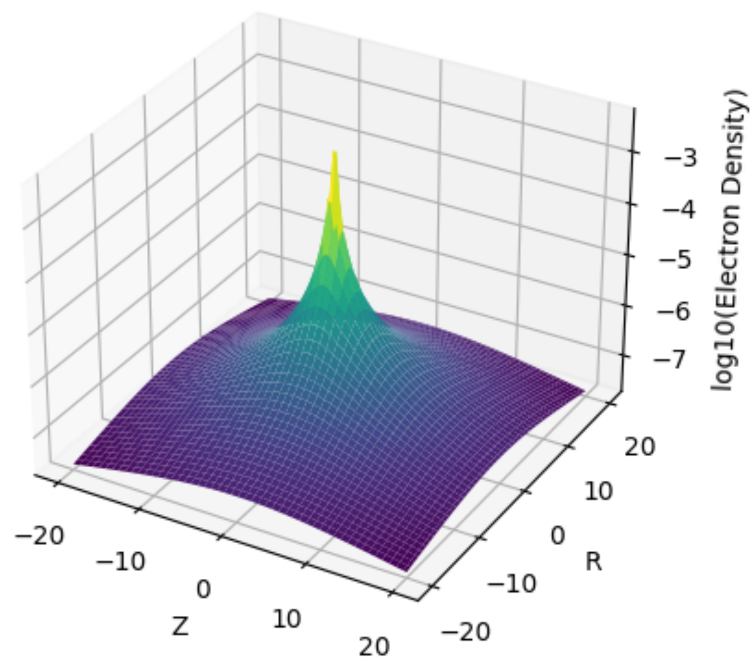


Figure 8: Electron density in representative galaxy cluster using the beta model

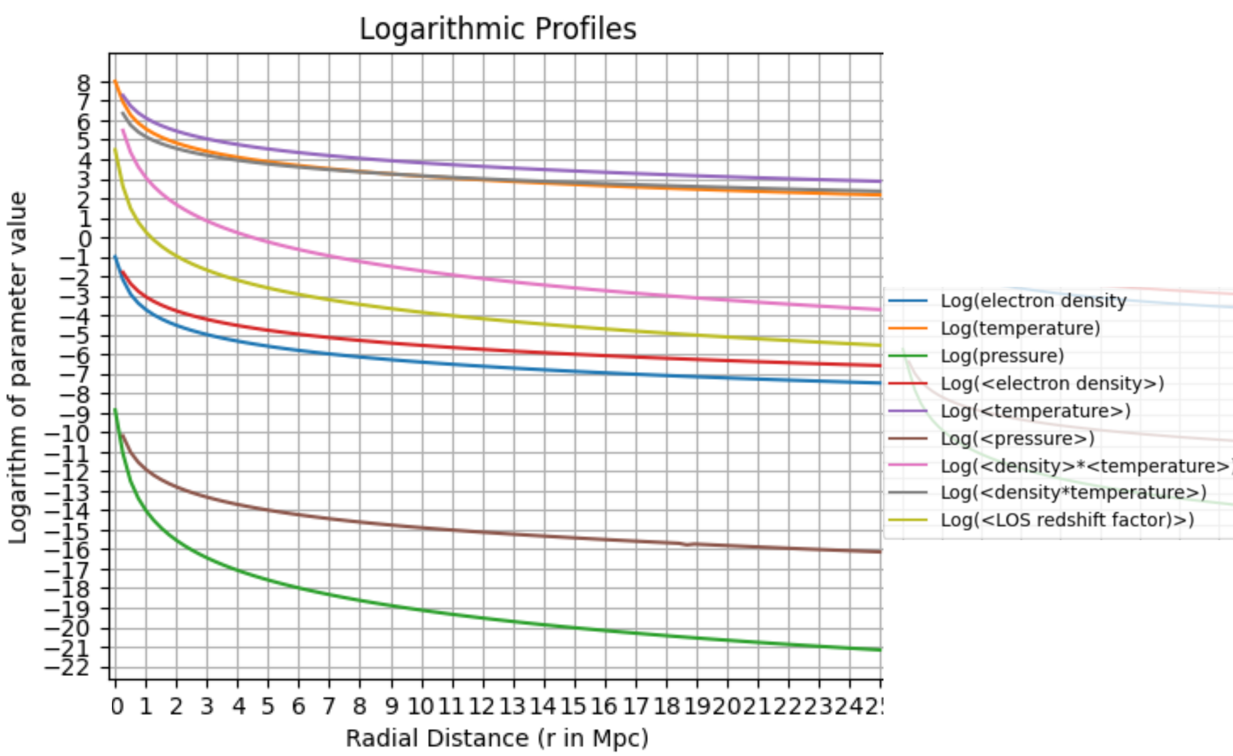


Figure 9: Parameters in representative galaxy cluster using the beta model

Light paths through or near cluster cores experience large amounts of redshift whereas those further from such centers experience less. The column density of pressure is plotted separately in figure 10 which exhibits features extremely close to the functionality demonstrated by White, et al. in figure 5. More significantly, the average of these column densities of pressure over the extent of a representative cluster is equal to the cosmological redshift we observe for the depth of such representative clusters; This was what we were wished to determine from observed redshift-space correlation data as provided by White's conclusions. In our previous post of the article Evolution of Models of Our Stationary State Universe, we showed the regular periodicity that occurs in cosmological redshift that was never adequately explained. That is an implication of a natural tri-level structuring of the redshift occurring through a single galaxy cluster.

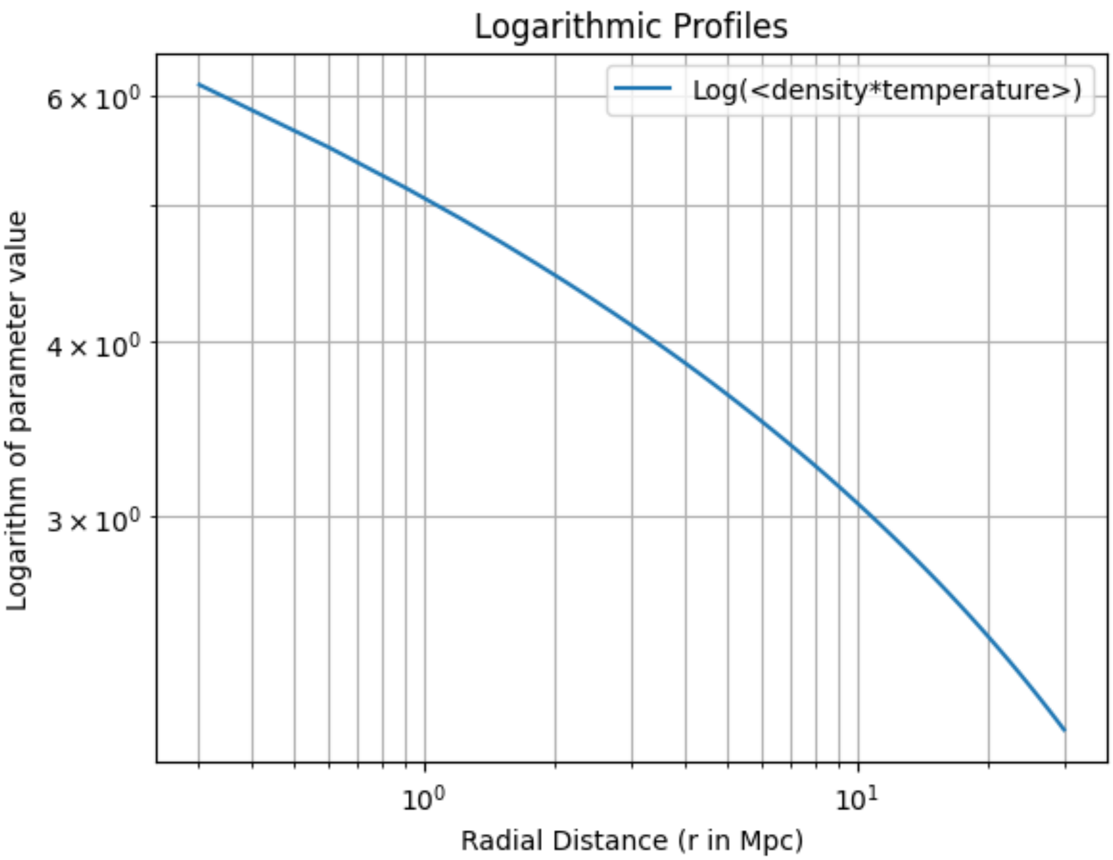


Figure 10: Redshift correlation with radial distance as the column density of the dynamic pressure as a function of cylindrical radial distance from the center of galaxy cluster cores