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ON THE ORIGIN OF THE DIPOLE ANISOTROPY OF THE COSMIC MICROWAVE BACKGROUND: BEYOND THE HYDRA-CENTAURUS SUPERCLUSTER

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RESUMEN. Se discuten las propiedades de una importante concentración de galaxias en la dirección del cúmulo de Centauro pero a una distancia muy superior. Se encuentra que la mayoría de las galaxias están a una distancia cercana a cz ~ 14000 km s^{-1} y que definen un supercúmulo de masa próxima a las 2.5×10^{15} $M_{\odot}$. Esta masa no es suficiente para explicar el movimiento peculiar del grupo local con respecto al fondo cósmico de microondas en la dirección de Centauro-Hydra. La región no contiene galaxias con velocidades entre 6000 y 8000 km s^{-1} por lo que si este movimiento es debido a un exceso de masa en la dirección de Centauro ésta debe ser obscura o estar situada más allá de los 14000 km s^{-1} del supercúmulo de Centauro.

ABSTRACT. We discuss the properties of a large concentration of galaxies located in the direction of the Centaurus cluster but at a much larger distance. We find that the majority of the faint galaxies in the region are clustered around cz ~ 14000 km/sec and define a rich supercluster having a dynamical mass close to 2.5×10^{15} $M_{\odot}$. We show that this mass is not sufficient to explain the peculiar velocity of ~ 600 km/sec of the Local Group with respect to the cosmic microwave background in the general direction of Centaurus. We find no luminous galaxies in the redshift range 6000-8000 km/sec in that direction. This implies that any mass overdensity related to the anisotropy of the Hubble flow must be either dark, hidden by the galactic plane or considerably more distant than 14000 km/sec.

Key words: COSMIC BACKGROUND RADIATION

I. INTRODUCTION

The simplest and most reasonable interpretation of the dipole anisotropy of the cosmic microwave background (CMWB) invokes a peculiar motion of the sun of 377 ± 14 km/sec towards l = 267, b = 50 (Smoot et al., 1985). After correcting for the motion of the sun relative to the Local Group (V_o = 300*CosA) this implies a peculiar velocity of the Local Group relative to the CMWB of about 610 km/sec towards l = 269, b = 28 (Tammann and Sandage, 1985 and references therein). Only a small part of this peculiar velocity can be explained by the "infall" of our galaxy towards the centre of the Local Supercluster (about 300 km/sec towards M87; Aaronson et al., 1986 and references therein). The remaining component (~ 500 km/sec towards l = 274, b = 12) has been, until recently, generally believed to be due to the motion of the Local Supercluster (LSC) towards its nearest neighbour, the Hydra-Centaurus supercluster (Tammann and Sandage, 1984). Recent observations, however, have shown this view to be wrong. Dressler, and collaborators (1986) have observed a complete sample of elliptical galaxies out to a redshift of 6000 km/sec and have found that out to that distance the Hubble flow is perturbed by a streaming velocity (relative to the CMWB) of ~ 700 km/sec towards l = 290, b = 2. Since the Hydra-Centaurus supercluster is at a distance of about 3000 km/sec (possibly extending to cz = 4500 km/sec; Lucey et al., 1986) the dipole anisotropy of the Hubble flow cannot be due to an overdensity of mass within R ~ $4500/H_0$ Mpc.

In this paper we investigate the structure of a large concentration of galaxies located in the same region of the sky as the Hydra-Centaurus complex (l ~ 300, b ~ 30) but at a much larger kinematical distance (cz ~ 14000 km/sec). We find that the mass of this supercluster falls more than one order of magnitude short of the mass required to accelerate the LSC to its observed peculiar velocity in a Hubble time.

We also find that the Centaurus region contains virtually no galaxies of redshifts between 6000 and 9000 km/sec. Thus, if the CMWB anisotropy is due to an overdensity of galaxies in the direction of Centaurus it must consist of dark matter, of galaxies at a redshift larger than 14000 km/sec or of "something" hidden by the galactic plane.

II. DATA

Redshifts for a large number of galaxies in the Centaurus region have been obtained by one of us (J.M.) in collaboration with H. Quintana as part of a long range study of the properties of southern X-ray clusters of galaxies of moderate redshifts (Melnick and Quintana, 1981).

The observations comprise an area of about 60 square degrees centered approximately at the position of the rich cluster SC1326-311 (Melnick and Quintana, 1981). In total, radial velocities for 354 galaxies were obtained only a few of which are in common with previous observations. This is because the study of Melnick and Quintana was aimed at clusters of redshifts close to cz ~ 15000 km/sec and therefore systematically avoided (whenever meteorological conditions allowed) low redshift galaxies, while previous observations have concentrated on galaxies at the redshifts of the Centaurus and Hydra clusters (cz < 4500 km/sec; Da Costa et al., 1986; Hopp and Materne, 1985; Lucey et al., 1986). Thus the present study complements and extends previous observations.

Positions and finding charts for some of our galaxies have already been published (Melnick and Quintana, 1981; 1984). The rest will be published separately in a forthcoming paper (Quintana and Melnick, in preparation).

III. RESULTS

Several groups and clusters of galaxies can be identified in the region, some of which were previously known from the work of Klemola (1969), Sandage (1975, SA), and Lugger (1978, SC). Table 1 summarizes the relevant parameters of these groups and clusters including

TABLE 1. Properties of the Principal Groups and Clusters in the Centaurus Region

Cluster/Group	position	$\langle V_r \rangle$	σ N	ρ_c	Comments
CE1250-296	12 50.5 -29 45	14000	---	---	Klemola 22
SC1251-290	12 52.0 -28 57	16050	740/39	---	Klemola 21
CE1316-315	13 16.2 -31 34	-----	---	---	
CE1321-314	13 21.3 -31 25	14700	590/12	180	
NGC 5108	13 21.8 -31 12	8800	---	(3)	
SC1326-311	13 25.1 -31 14	14300	1250/91	400	cD, central
IC 4255	13 25.2 -27 06	10100	470/11	(30)	
NGC 5153	13 26.5 -29 29	4100	---	(7)	
CE1327-292	13 27.1 -29 15	13750	600/9	160	
SC1329-314	13 28.6 -31 34	13300	1050/10	340	
CE1329-327	13 29.3 -32 45	14850	830/10	190	
CE1331-313	13 30.8 -31 18	10780	---	---	Overlapping
CE1331-313b		15060	920/12	220	complex
IC 4296	13 33.6 -33 42	3650	---	(8)	SA
CE1344-326	13 44.6 -32 37	11900	1150/30	220	cD cluster
SC1341-301	13 46.2 -30 03	4320	---	(10)	Klemola 27, SA

the central positions, the projected central densities (ρ_c, galaxies per square degree), mean radial velocities ($<V_r>$) and their dispersions (σ). For small groups, the approximate number of galaxies is indicated (within parentheses) instead of the central density. Together with the velocity dispersion we indicate the number of radial velocities used in its determination. The central densities were estimated counting all galaxies down to approximately 3 magnitudes fainter than the first ranked galaxy, within an area of 0.1 square degrees centered at the densest position of each cluster which was estimated by eye. For comparison, the mean densities of the field far from clusters but within the supercluster are ρ_c = 50 gal/sq.deg.

Figure 1 presents radial velocity histograms for the clusters of the table.

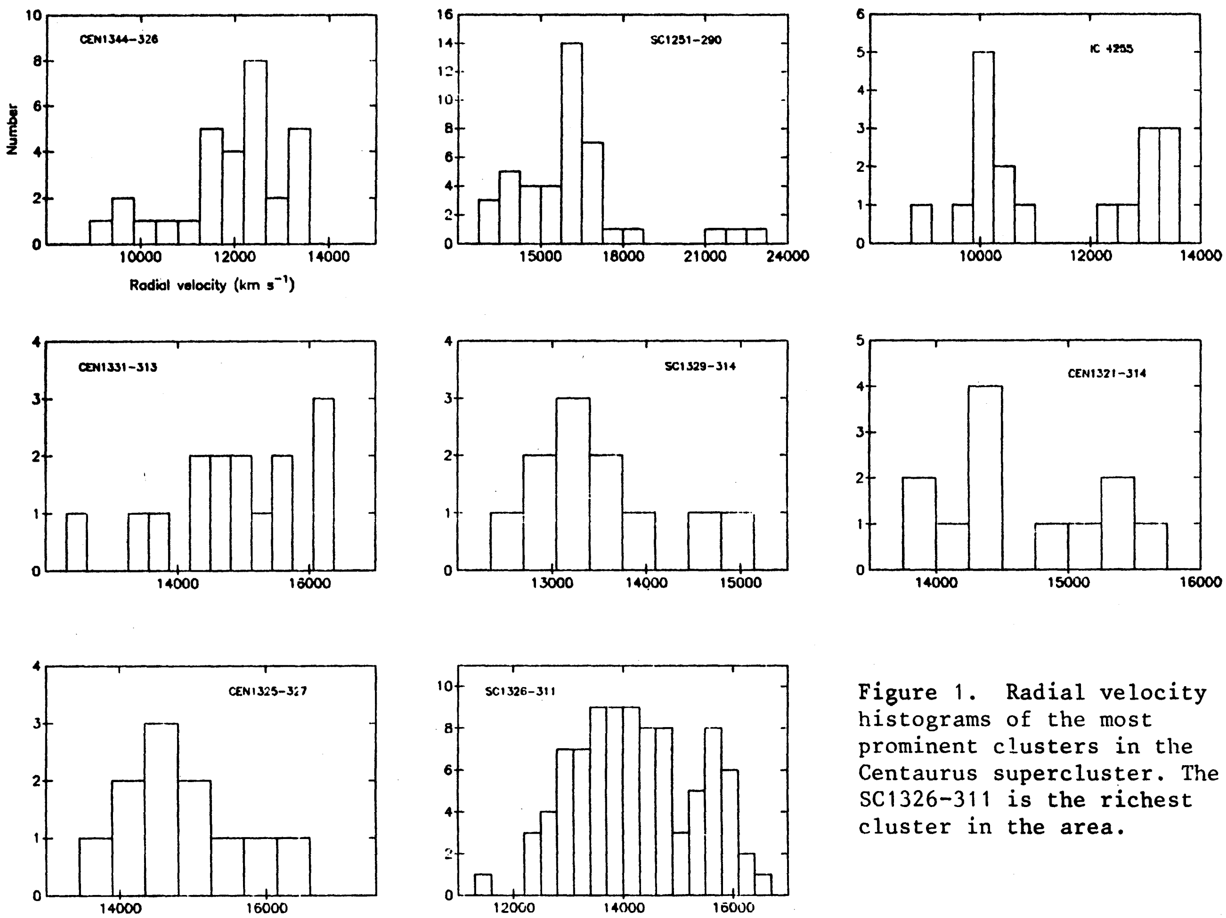

Figure 1. Radial velocity histograms of the most prominent clusters in the Centaurus supercluster. The SC1326-311 is the richest cluster in the area.

Figure 2 presents a radial velocity histogram of all the galaxies observed. The distribution shows 4 well defined peaks centered approximately at cz = 4000, 10000, 14000 and 16000 km/sec. A similar distribution was hinted by the study of Da Costa et al. (1986) which, however, contains only a few galaxies with redshifts larger than 12000 km/sec.

Besides the large concentration of galaxies around cz = 14000 km/sec which we identify as the Centaurus supercluster, the other important feaures of the radial velocity histograms are the absence of galaxies brighter than B ~ 19 mag having radial velocities between 6000 and 8000 km/sec and a strong concentration of galaxies around cz = 4500 km/sec. The latter suggests that the secondary peak in the radial velocity distribution of the Centaurus cluster at cz ~ 4500 km/sec (Lucey et al., 1986) may be due to field contamination rather than to a bimodal structure of that cluster as suggested by these authors.

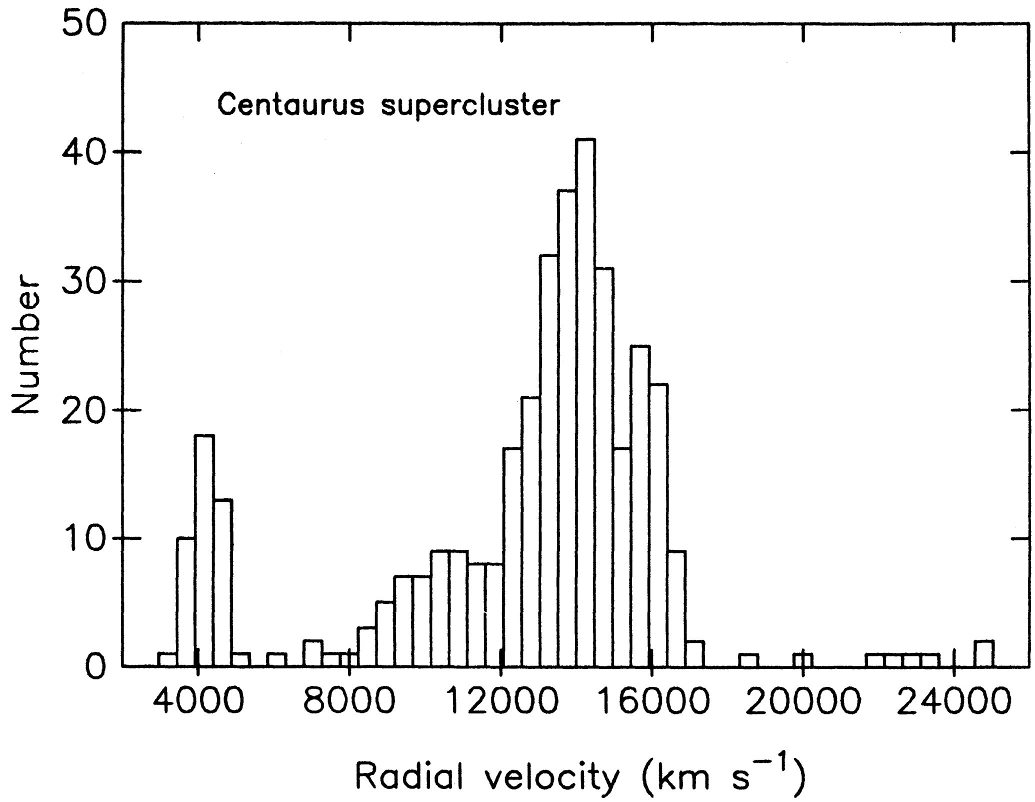

Fig. 2. Radial velocity distribution of 354 galaxies observed in the Centauros region. The sample is biased towards the higher redshift galaxies but the "void" between 6000 and 8000 km s^{-1} is real.

IV. THE CENTAURUS SUPERCLUSTER

We lack coordinates and magnitudes for a large enough sample of galaxies to probe the structure of the Centaurus supercluster using appropriate cluster analysis techniques; thus we will limit the discussion to a simple minded dynamical analysis of the complex. The mass of the supercluster can be obtained as (Huchra and Geller, 1985),

$$\frac{M}{M_{\odot}} = 1.2 \times 10^{15}\ \theta_H \left(\frac{V_r}{10000}\right) \left(\frac{\sigma}{1000}\right)^2 h^{-2}$$

where θ_H is the angular harmonic radius of the cluster in degrees, σ its projected velocity dispersion and V_r its radial velocity, both in km/sec. H_o = 100h km/sec/Mpc. Table 2 summarizes the masses we obtain for the Centaurus complex using various assumptions for supercluster membership. We estimate given the appearance of the supercluster on the ESO/SRC charts that $\theta_H = 1$ is a reasonable estimate for the harmonic radius which, in any event, cannot be larger than twice that value. It is difficult to decide without more information the size of the supercluster in velocity space; the three velocity ranges included in the table satisfy a 3σ membership criterium but the clusters with cz ~ 16000 km/sec (e.g. Klemola 21) are far from the centre of the supercluster and thus are probably not members. Thus, a reasonable estimate of the mass of the Centaurus supercluster is $M = 2.5 \times 10^{15}\ h^{-2}\ M_{\odot}$.

TABLE 2. Dynamical Parameters of the Centaurus Supercluster

Redshift range	Number	$<V_r>$	σ	$M/(10^{15}\ M_\odot)$
				$(\theta_H=1,\ h=1)$
10000-18000	291	13920	1596	4.4
11500-16500	255	14160	1206	2.5
12500-15500	185	14000	765	1.0
Central cluster				$(\theta_H=0.25,\ h=1)$
10000-20000	91	14310	1249	0.7
10000-18000	90	14250	1106	0.5

V. DISCUSSION

The excess of mass within a radius $R = V_r/H_o$ required to accelerate the Local Supercluster to a radial velocity δv in a Hubble time is approximately given by (Davies and Peebles, 1983),

$$\frac{\delta M}{M_\odot} = 3.5 \times 10^{14} \left(\frac{\delta v}{100}\right) \left(\frac{V_r}{1000}\right)^2 \Omega_o^{0.4}\ h^{-2}$$

where Ω_o is the density parameter of the Universe. For $\Omega_o = 1$ this expression coincides with the Newtonian expression $\delta v = a\delta t$.

Even for small values of Ω_o (say $\Omega_o = 0.1$) the mass required to produce the observed velocity of the local group with respect to the CMWB is more than one order of magnitude larger than the most optimistic estimate of the mass of the Centaurus supercluster (Table 2). Since there are no luminous galaxies of redshifts between 6000 and 8000 km/sec we conclude that the required mass overdensity is either dark, or is located beyond the Centaurus supercluster. Alternatively, the overdensity may be hidden by the galactic plane (Tammann and Sandage, 1985).

The first two possibilities may be tested by mapping the Hubble flow out to cz ~ 15000 km/sec using either HII galaxies (Melnick, Terlevich and Moles, 1986) or elliptical galaxies (Dressler et al., 1986). Such a study is now under way.

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