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GREAT ATTRACTOR - A NEW TEST FOR COSMOLOGICAL MODELS

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ABSTRACT. *A model of the Great Attractor (GA) as a large-scale peak of the adiabatic gaussian perturbations is analysed in the framework of the two-component (dark matter and baryons) Universe. The conditions of realization of such peaks and their observational display in different cosmological models are investigated.*

1. INTRODUCTION

Discovery of considerably large-scale disturbances of the Hubble expansion in the neighbourhood of the Local Group of galaxies has become the most important result of experimental cosmology for the last few years. More than 10 years ago Rubin et al. (1976) discovered a large peculiar velocity of the Local Group (~ 450 km/s) relative to the sample of 96 spirals at distances up to ~ $50h^{-1}$ Mpc (h=H/100 (km/s)/Mpc, H - the Hubble constant). Collins et al. (1986) discovered that the peculiar velocity in this region has an even larger value - ~ 970 km/s.

From analysis of a sample of 400 elliptical galaxies in a region with a size of ~ $40h^{-1}$ Mpc Dressler et al. (1987) and Lynden-Bell et al. (1988) discovered the internal structure of the flow - the large-scale motion has a character of spherically-symmetric infall toward the centre - the Great Attractor. Faber and Burstein (1989) have included in the analysis other samples containing spirals and have confirmed the convergent character of the large-scale flow, and have made more accurate definition of the flow parameters: distance to the GA centre $r_{LG} = 42h^{-1}$ Mpc, our peculiar velocity V_{LG} = 535 km/s. The new data (Burstein et al., 1990; Dressler & Faber, 1990;

Dressler & Faber, 1990a; Mathewson, 1990) suggest the existence of galaxies with negative peculiar velocities beyond the GA centre.

Such a large-scale flow of galaxies proved to be a serious problem for the theory of origin of the large-scale structure of the Universe. In the most popular cosmological scenarios the structure is formed by gravitational growth of initially small random Gaussian density fluctuations. The peculiar velocities in the GA region are considerably larger than r.m.s. ones, predicted in realistic models of the Universe (Bardeen et al., 1987). Additional difficulties of GA interpretation caused the necessary explanation of the roughly spherical convergent flow with increasing velocity in the direction of the centre. Therefore in that scenario, the GA-event may be interpreted as only the large-scale peak in the field of the random Gaussian perturbations.

Our purpose is to find the initial density fluctuation profile which results in GA-event, to investigate the possibility of realization of such peaks in Gaussian density fluctuation field, to evaluate the concentration of GA-precursor peaks, the observational evidences of their nonlinear stages of evolution, and the generation by GA-precursors of the anisotropy of cosmic background radiation temperature in the different models of the Universe.

For realization of such a program we performed numerical calculations of nonlinear evolution of the adiabatic growing mode of disturbances in the two-component flat (Ω_{tot} = 1) Universe dominated by weakly interacting non-relativistic particles. The second component is the hydrogen-helium primordial plasma with a relative density $\Omega_b \ll 1$. The evolution of baryon matter was investigated in hydrodynamical approximation and that of dark matter - in N-body simulation. Heating and radiation processes in the gas component are derived in terms of non-stationary kinetics.

The results that follow are presented in (Gnatyk et al., 1991a,b,c; Novosjadlyj & Gnatyk, 1991).

2. CHARACTERISTICS OF PEAKS - PRECURSORS OF GA

We have taken eight spectra, corresponding to different models of the large-scale structure formation into account, (Table 1): HDM with one (1) and three (3) sorts of massive neutrinos (Bond & Szalay, 1983), CDM (Davis et al., 1985), hybrid HC (hot+cold) Bardeen phenomenological DI (double inflation) (Turner et al., 1987), CDM+X (with additional power scale) (Bardeen et al., 1987), and analogous, but optimal for large-scale structure CDM+Z (Gnatyk et al., 1991b) (see also this issue). All spectra were normalized by the J_{3g}- integral with biasing parameter b_g (Gnatyk et al., 1991c). Here σ_{og} is the *r.m.s.* density fluctuation on the scale (Gaussian filter) R_f = 0.35h^{-1} Mpc. We took h=0.5.

Table 1. The parameters of cosmological models

	HDM(1)	*HDM(3)*	*CDM*	*HC*	*DI*	*CDM+X*	*CDM+Z*
Ω_b	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ω_{CDM}	-	-	0.9	0.5	0.9	0.9	0.9
Ω_{HDM}	0.9	0.9	-	0.4	-	-	-
b_g	0.64	0.51	1.62	1.00	1.47	1.69	1.76
σ_{og}	2.00	2.00	2.89	2.25	3.03	2.58	2.34

For the initial shape of density peaks we choose mean profiles according to the statistical theory of random Gaussian fields (Doroshkevich, 1970; Bardeen et al., 1988). The peak of high amplitude δ_0, such that $\nu=\delta_0/\sigma_0 >> 1$, tends to be spherically symmetric with the mean profile

$$\delta(r;R_f) = \delta\rho/\rho = \nu\sigma_0^{-1}\ \xi(r;R_f), \tag{1}$$

where $\sigma_0 = \xi(0)^{1/2}$ and the correlation function of density perturbations $\xi(r)$ depends on the spectrum and on the peak scale, the latter being proportional to the Gaussian filter R_f. Normalization for the GA peculiar velocity V_{LG} = 535 km/s at the Local Group distance r_{LG} = 42h^{-1} Mpc for the redshift z = 0 leaves us with one-parameter family (1) of the initial conditions.

3. EVOLUTION OF GA-SCALE PEAKS

The calculations of the peak evolution "backward in time" show that the real peaks realizing GA within the observational accuracy have rather determined characteristics: amplitude $\delta_0(z)=(1-2)/(z+1)$, size $R_{\sigma_0/2}$ = (10-20)/(z+1)h^{-1} Mpc for $z>>1$.

Although such peaks may be realized in all cosmological models, their realization probability is different for different models. The parameters of the mean profile peaks which model acceptable upper and lower limits of the observational profile are listed in Table 2. Here $\delta(0)$ is the linear amplitude at z=0, GA expansion turns out to the collapse at z_s, with contraflows in the collisionless component appearing at the GA-centre at z_c, and N is the total number of GAs within the contemporary horizon with the mean distance d between them.

Table 2. The parameters of GA-event in different models of the Universe

1		HDM(1)		HDM(3)		CDM	
2	R_f, Mpc	24.00	30.00	20.00	30.00	22.00	30.00
3	$R_{\sigma_0/2}$, Mpc	39.60	49.00	41.60	53.40	40.00	52.60
4	ν	5.80	4.80	2.10	1.70	10.50	8.60
5	$\sigma(0)$	2.20	1.32	1.98	1.02	1.90	1.03
6	z_s	1.07	0.24	0.86	0.04	0.79	0.03
7	z_c	0.30	-0.22	0.17	-0.40	0.12	-0.39
8	N	6	580	$2\cdot10^6$	$2\cdot10^6$	10^{-15}	$2\cdot10^{-8}$
9	N_{ls}	0	12	$5\cdot10^4$	$3\cdot10^4$	0	0
10	d, Mpc	$1\cdot10^4$	2300	150	170	$2\cdot10^9$	$7\cdot10^6$

Table 2. (continuation)

1	HC		CDM+X		DI		CDM+Z	
2	20.0	24.0	14.0	24.0	23.0	30.0	13.0	20.0
3	42.2	46.8	33.6	45.6	42.2	51.2	31.2	38.0
4	4.2	3.7	5.8	4.2	6.1	5.2	5.5	4.1
5	1.87	1.38	1.88	0.83	1.85	1.10	1.87	0.98
6	0.76	0.29	0.77	-0.23	0.74	0.03	0.76	-0.08
7	0.10	-0.19	0.11	-0.51	0.09	-0.35	0.10	-0.47
8	10^4	$4\cdot10^4$	13	$7\cdot10^3$	1	100	100	10^3
9	260	830	0	150	0	2	2	270
10	840	570	8200	1000	$2\cdot10^4$	4200	4200	830

As is seen, GA-phenomena are extremely improbable in the CDM-model, more promising for HC and DI spectra, and still very rare in CDM+X and CDM+Z spectra. In HDM-models GA's occur much more frequently.

The mean profile peaks which model the upper limit of the observational profile - the Faber-Burstein approximation (Faber & Burstein, 1989) - must have higher amplitudes (and correspondingly smaller sizes R_f, respectively). Such peaks with initial linear amplitudes $\delta_o>1.67/(z+1)$ develop to strong non-linearity near the GA centre: contraflows in the dark matter, and shock wave in the baryon component with the appearance of X-ray emitting gas as a consequence. So in the case of the GA-precursor peak with $\delta_o=0.20$ (CDM+Z spectrum, h=0.5) the contraflows and shock wave are generated at $z=0.30$. By the time $z=0$ the shock wave has passed the distance ~5 Mpc and heated the gas up to a high temperature, $T=10^8$ K, with X-ray luminosity $L_x \sim 10^{44}$ erg/s. A small part (<10%) of gas in the central region of GA is cooled down to $\sim 10^4$ K.

As a result of contraflows, large peculiar velocities of galaxies near the centre ($V_{pec} > 1000$ km/s) are expected. However, there are many reasons for the absence of the violent hydrodynamical events: nonspherical collapse, fragmentation of infalling gas etc.

The CDM-model predicts the absence of such attractors at the stage of violent relaxation of central regions inside the contemporary horizon. A few of such objects may be in the case of CDM+X and CDM+Z spectra, but in the HDM(3)-model their number is $\sim 2\times10^6$ with a mean distance of ~ 200 Mpc between them.

4. GA AND COSMIC MICROWAVE BACKGROUND ANISOTROPY

The intersections of the GA-precursor peaks by the last-scattering surface cause temperature fluctuations of CMB radiation via the Sachs-Wolfe, Doppler and Silk effects. Our calculations show (Novosjadlyj & Gnatyk, 1991a) that even minimum amplitude of the GA-precursor peak ($\delta_o=1/(z+1)$) creates a fluctuation - hot spot - with $\Delta T/T>4\times10^{-5} \approx 2\sigma_T$ on the angular scale ~ 30′ which is, in principle, accessible to registration by the existing technique. Here σ_T is the present upper limit of CMB anisotropy on this scale ($\Delta T/T<3.5\times10^{-5}$ at 90% confidence level (Berlin et al.,1984).

If GA is not a unique object, it is necessary to have ~ 50 GA-precursors inside the horizon in order to have one such spot on the sky.

The expected number of detectable spots N_{LS}, like the number of GA-events, is different for different models (Table 2). So, in the case of optimal CDM+Z-spectrum there will be 270 hot spots with $\Delta T/T>3\sigma_T$ on the whole sky or one spot in the area $12^\circ\times12^\circ$. The same number of cold spots is expected.

5. CONCLUSION

In the framework of the gravitational instability theory the GA-precursor is the density peak with the amplitude $\delta_o=(1-2)/(z+1)$ and half-width $R_{\delta/2}$ = $(10-20)/(z+1)h^{-1}$ Mpc.

Such peak is a rare event in all cosmological models based on initially random Gaussian fluctuations. Moreover, in a standard CDM model GA-events are extremely improbable. Even in CDM+X and CDM+Z spectra with additional power on large scales, such that r.m.s. peculiar velocity is close to the observable one in the sample volume, GA as the fluctuation with the Faber-Burstein (1989) approximation characteristics is still rather a rare case.

The central regions of GA-like objects are now at the nonlinear stage of evolution perhaps with virialization processes including high peculiar velocity of galaxies and shocked X-ray emitted gas.

On the CMB temperature map the GA-precursor generates a hot spot with $\Delta T/T > 4\times10^{-5}$ accessible to registration on the scale ~ 30′. The CDM+Z spectrum predicts 270 such hot spots (and accordingly the same number of cold spots) on the whole sky, or one hot spot in the area $12^{\circ}\times12^{\circ}$.

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