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FORMATION OF VOIDS FROM NEGATIVE DENSITY PERTURBATIONS

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RESUMEN. Se estudia la formación de huecos a partir de un espectro negativo de perturbaciones, tomando en cuenta la expansión del Universo, arrastre por fotones, enfriamiento por fotones, fotoionización, ionización colisional, enfriamiento Lyman α y la formación y enfriamiento de moléculas H_2. Nuestros resultados predicen la existencia de regiones $\lesssim$ 1/10 de la densidad promedio para regiones de masa 10^9- $10^{10}\,M_\odot$.

ABSTRACT. In the present paer we study the formation of voids from a negative spectrum of perturbations taking into account the expansion of the Universe, photon-drag, photon-cooling, photoionization, collisional ionization, Lyman α cooling and the formation and cooling of H_2 molecules. Our results predict the existence of regions $\lesssim$ 1/10 the average density for regions of mass 10^9 - $10^{10}\,M_\odot$.

Key words: CLUSTERS-GALAXIES — COSMOLOGY

I. INTRODUCTION

The formation of voids from negative density perturbations, present in the recombination era, is of appreciable interest and several investigations on the subject have been mac

The previous investigations, in general, include only the effect of gravity, neglecting: photon-drag, photon cooling, photoionization, Lyman α cooling, collisional ionization and the formation and cooling of H_2 molecules. In the present investigation, we study the effect of these nongravitational physical process in the formation of underdense regions (see also de Araujo and Opher 1990).

We use a perturbation distribution used for positive perturbations by de Araujo ar Opher (1988) and postulate that a similar distribution exists for negative perturbations (de Araujo and Opher 1990):

$$\delta_i = \frac{\delta_\rho}{\bar{\rho}} = - (M/M_o)^{-\alpha}\ (1+z_{rec})^{-1} \qquad (1)$$

where M_o is the mass scale and z_{rec} is the redshift at the recombination era.

In section II we present the model and the calculations and in section III we present the conclusions and discussion.

II. MODEL AND CALCULATIONS

We assume spherical negative uniform density perturbations given by equation (1). W obtain the radius and the density of the clouds as a function of time, in particular at the present era.

We begin the calculations at T_r = 4000K (beginning of recombination), (T_r - radiati temperature). We study an open universe with $\Omega_o = 0.1$ ($\Omega_o = \rho_o/\rho_{oc}$, ρ - present density, and ρ_{oc} - present critical density) with a Hubble constant h = 1.0 (in units of 100 km s^{-1} Mpc^{-1}).

We take $\alpha = 1/3$ (as suggested by Gott and Rees 1975) in equation (1) with $M_o = 10^1$ 10^{15} and $10^{16}\,M_\odot$ as well as $\alpha = 1/2$ (which corresponds to a white noise Poisson perturbation spectrum) with $M_o = 10^{15}\,M_\odot$.

We also performed calculations neglecting nongravitational processes, in order to evaluate the importance of the nongravitational physical processes.

In Table 1 we present the results of the calculations for $M = 10^6 - 10^{12}\,M_\odot$. We not n general that lower the mass, M, lower the present density (i.e., lower the ratio of the resent density of the perturbed region to the ambient density, ρ_p/ρ_o). We also note that the ongravitational physical processes are particularly important for small M. We also note in able 1 the present radius $\overline{r}_p$, of the underdense regions.

TABLE 1. Present Ratio of Density to Ambient Density,(ρ_p/ρ_o), and Present Radius ($\overline{r}_p$), for Perturbed Regions of Mass M, Including Nongravitational Physical Processes (NPP) and Neglecting NPP.

	With NPP		Without NPP	
$M/M_\odot$	ρ_p/ρ_o	$\overline{r}_p$(Mpc)	ρ_p/ρ_o	$\overline{r}_p$(Mpc)
	A. $M_o = 10^{14} M_\odot$, $\alpha = \frac{1}{3}$			
10^6	0.0063	0.11	0.0029	0.14
10^7	0.017	0.17	0.011	0.20
10^8	0.050	0.26	0.035	0.29
10^9	0.13	0.41	0.096	0.45
10^{10}	0.28	0.67	0.22	0.73
10^{11}	0.49	1.2	0.42	1.3
10^{12}	0.69	2.3	0.63	2.4
	B. $M_o = 10^{15} M_\odot$, $\alpha = \frac{1}{3}$			
10^6	0.0012	0.19	0.00044	0.27
10^7	0.0048	0.26	0.0029	0.31
10^8	0.016	0.38	0.011	0.43
10^9	0.049	0.56	0.035	0.63
10^{10}	0.13	0.87	0.096	0.97
10^{11}	0.28	1.5	0.22	1.6
10^{12}	0.49	2.6	0.42	2.7
	C. $M_o = 10^{16} M_\odot$, $\alpha = \frac{1}{3}$			
10^7	0.00082	0.47	0.00044	0.58
10^8	0.0045	0.58	0.0029	0.67
10^9	0.016	0.81	0.011	0.92
10^{10}	0.049	1.2	0.035	1.4
10^{11}	0.13	1.9	0.096	2.1
10^{12}	0.28	3.1	0.22	3.4
	D. $M_o = 10^{15} M_\odot$, $\alpha = \frac{1}{2}$			
10^9	0.00073	2.3	0.00044	2.7
10^{10}	0.0086	2.2	0.0058	2.5
10^{11}	0.0049	2.6	0.035	2.9
10^{12}	0.20	3.5	0.15	3.9

In general, from Table 1, we produce underdense regions of present radii, $\overline{r}_p$, on he order of several megaparsecs. This is appreciably less than the recently discovered voids f tens of megaparsecs, which may have been produced by hierachical clustering of smaller voids n conjunction with hierarchical clustering of galaxies (produced by the positive density erturbation spectrum).

III. CONCLUSIONS AND DISCUSSION

Our main conclusions are:

1) The inclusion of nongravitational physical processes (NPP) act as a "drag", impeding the formation of voids, and increasing the present density to ambient density ratio, ρ_p/ρ_o.

2) The ratio ρ_p/ρ_o decreases with increasing M_o.

3) Using Eq. 1 for $M_o/M_\odot = 10^{14}$, 10^{15}, and 10^{16} with $\alpha = 1/3$, and $M_o/M_\odot = 10^{15}$ with $\alpha = 1/2$, we produce underdense regions with present radii $\bar{r}_p$ on the order of several megaparsecs.

The distribution function of dwarf galaxies can show, in principle, the underdense regions predicted above. Crane and Saslaw (1986) compared the distribution function f(N) of galaxies predicted for a quasi-relaxed gravitating system, with the observed distributions of galaxies in the Zwicky catalog. The Zwicky catalog, based on the Palomar Sky Survey plates, is reasonably complete to $m_{Zw} = 14.5$ and has a magnitude limit of $m_{Zw} = 15.5$. The Zwicky catalog is primarily sensitive to galaxies of mass $\gtrsim 10^{11}$ $M_\odot$. With the inauguration of the Hubble Space Telescope, and new large aperture telescopes, we can expect the obtaining of galaxy distributions with a magnitude limit $\gtrsim 21$ mag and distributions of galaxies of mass $\sim 10^9$ $M_\odot$ can, in principle, be obtained. It would then be of interest to obtain for a given range of redshifts the distribution of dwarf galaxies of masses $\sim 10^9$ $M_\odot$ for small neighbor distances ($< 1^o$) (corresponding to fig. 2 of Crane and Saslaw (1986)).

Our results predict the existence of regions $\lesssim 1/10$ the average density over small neighbor distances ($< 1^o$), and the distribution of dwarf galaxies of masses $M \sim 10^9$ $M_\odot$ are sensitive to these underdense regions of mass $\sim 10^9 - 10^{10}$ $M_\odot$.

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