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SIMULATION OF STAR FORMATIONS IN COSMOLOGICAL VOLUME $(240\ Mpc/h)^3$

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Abstract

In this paper the Lambda Cold Dark Matter (ΛCDM) model was used for studying star formation inside a box of size $(240Mpc/h)^3$ by simulating eight million dark matter particles and eight million gas particles together with cosmological density Ω=0.25, dark energy density Ω_Λ=0.75, baryon density Ω_b=0.04, fluctuation amplitude σ_8=0.9 and Hubble constant H_0=100h $kms^{-1}Mpc^{-1}$. The gadget-2 code was used for simulating the particles from early Universe, z=30 (450 million years) to z=0 (13.4 billion years).

In the box the structures formation were shown including galaxy clusters, voids and filaments which observed clearly at low redshift, z=0.

In the temperature-density planes, the thermal processes of cooled gas show the density and temperature values which were different at each redshift, and the gas cooled in the box at nearly 10^4K caused star formations at certain redshifts. It was also found that stars were formed from z=7.3 which increased with decreasing redshifts. In addition, the total number of star formed in the box was 226217 stars.

Sixteen processors of high performance supercomputer of Nottingham University-England were used in the simulation.

Keywords: Simulation of star formation, simulation in box $(240\ Mpc/h)^3$, Lambda cold dark matter model.

Introduction

A star is born when gravity causes a cloud of interstellar gas to contract to the point at which the central object becomes hot enough to sustain nuclear fusion in its core. The inward pull of gravity is balanced by the outward push of gas pressure, a balance that is called gravitational equilibrium. Gravity does not always succeed in making an interstellar cloud contract, because the cloud’s internal gas pressure can resist gravity. Two processes can help gravity win out over pressure and start the collapse of the cloud. First, higher density in the gas cloud help gravity because packing the gas particles closer together make the gravitational forces between them stronger. Second, lower temperature in the gas cloud help gravity, because lowering a cloud’s temperature reduces the gas pressure. Therefore, star forming clouds is expected to be colder and denser than most other interstellar gas [1,2].

The star-forming clouds are called molecular clouds. Once, a large molecular cloud begins to collapse, gravity pulls the gas toward the cloud’s denser regions, causing it to fragment into smaller pieces that each forms one or more new stars. Each shrinking cloud fragment heats up as it contracts. The source of this heat is the gravitational potential energy released as the gravity pulls each part of the cloud fragment closer to the center of the fragment. Early in the process of the star formation, the contracting gas quickly radiates away much of this energy, preventing the temperature and pressure from building enough to resist gravity. The astronomers believe that the first stars were formed from primordial metal free hydrogen gas at temperature nearly less than 10^4K [1,3].

Since gas is pre-stellar stuff, it is expected that the gas mass fraction during the initial stages of galaxy formation should be of greater percentage of the baryons. The evolution in the gas mass fraction with time must be intimately connected with the evolution of the stellar content. Clearly, this is true at the moment of their formation [4]. Therefore, the history of each galaxy includes a short but eventful epoch when its matter (a cloud of gas separated from a protocluster shortly before) was compressed by its own gravitation. The separation of protogalactic condensations appeared to occur owing to hydrodynamic processes in gaseous protoclusters, the further evolution of protogalaxies was primarily controlled by their own gravitation, which contracted these thin clouds, thus shaping the galaxies of the observed sizes. Gravitational contraction was unimpeded by the forces of pressure because the protogalactic gas could easily cool to a temperature about10^4K. The contraction of a protogalaxy lasts about 3000 million years. It takes this time to transform a gaseous cloud into a stellar system [5].Radiative cooling is the crucial mechanism responsible for the condensation and the collapse of baryonic gas into galaxies and inside galaxies for the occurrence of star formation[6].

Cosmological Simulation

Numerical simulation in cosmology has become one of the most important theoretical tools for exploring the complicated problem of galaxy formation including radiative cooling, star formation, feedback processes and mechanical properties of galaxies formation[7].

The basic equation describes the dark matter and stars is Boltzmann equation which includes independent variables [8]:

$$\partial_t f(\vec{x},\vec{v},t) + \vec{v}\cdot\partial_{\vec{x}} f(\vec{x},\vec{v},t) + \vec{a}\cdot\partial_{\vec{v}} f(\vec{x},\vec{v},t) = 0 \qquad \text{................................}(1)$$

The thermal history of galaxy cluster is one of the important mechanisms for understanding the way galaxies form and evolve in the Universe. To understand this thermal history, one needs to study the basic thermodynamic laws governing the thermal processes in hydrostatic systems and the initial components and density of stars.

Equation of state in galaxy clusters can be written as follows [9]:

$$P = \frac{\rho k_B T}{\mu m_P} \qquad \text{...}(2)$$

where k_B is Boltzmann's constant, T is the temperature in Kelvin degrees, μ is the mean molecule weight, and m_p is the mass of the proton, the quantity is more often used in astrophysical theory of galaxy clusters.

Galaxy formation and development were simulated in different models and techniques.

Pearce et al 2001[10] have simulated the formation of galaxies by using more than 2×10^6 particles in cubic volumes of side 100 Mpc, for studying gas cooled and star formation. Springle and Hernquist 2003 [11] studied the history of star formation in a ΛCDM universe at red shift z~20 to the present. In addition to gravity and ordinary hydrodynamics, the model includes heating, cooling of gas and star formation. were performed in five different box sizes, ranging from 100Mpch^{-1} to 1Mpch^{-1}. For each box size, a number of simulations have been run with particle number between 2×64^3 and 2×324^3 employing an equal number of dark matter and gas particles. Springle et al 2005 [12] have presented a ΛCDM model simulation of the growth of dark matter structure using $(2160)^3$ particles in a cube shaped region 2230 billion light years on a side. The millennium simulation was carried out with a customized version of the gadget-2 code. Rudnik et al 2006 [13] have measured the evolution of luminous galaxies at different redshifts. In the study star formation was studied depending on ΛCDM model with gadget-2 code. De lucia and Blaizot 2007 [14] have studied the hierarchical formation of the brightest cluster galaxies at different redshifts using gadget-2 code. In the simulation the stars were formed.

In the present work the ΛCDM model was used for studying star formation inside a box of size $(240\text{Mpc/h})^3$ by simulating eight million dark matter particles and eight million gas particles together with cosmological density Ω=0.25, dark energy density Ω_Λ=0.75, baryon density Ω_b=0.04, fluctuation amplitude σ_8=0.9 and Hubble constant H_0=100h kms^{-1}Mpc^{-1}, where the uncertainty (h) has the value : h=0.73.

In the present work also the gadget-2 code[15] was used for simulating the particles from early Universe, z=30 to z=0. Sixteen processors of high performance of Nottingham University-England were used in the simulation.

Results and Discussion

Figures (1 a and b) represent the two points of view of the galaxy formation inside a box $(240\text{Mpc/h})^3$ at z=0 which constructed by simulating 8 million dark matter particles with eight million gas particles. This box gives the real picture of the Universe of a big size containing many more particles. In this box, many clusters of galaxies, filaments are obtained and many voids are surrounding them. Also the gas cooled into fragments which subsequently collects and merges to form the large galaxies with star formation.

Figures (2a-o) represent the gas cooling from z=17.7 to the present day. Figure (2)a shows the very low density distribution at less than 50g.cm^{-3} and temperature less than 200K for the most particles. The other components of gas distribution do not still exist because this epoch represents the early epoch of the Universe.

From Figure (2)b some shock-heated gas particles appear as another distribution of some gas particles. These processes of gas distributions in different density and temperatures continue to the redshift, z=0 (Figure o). Although few gas particles of very overdens distribution can be seen at low temperature from Figure (2)c, but the cutoff curve can be seen clearly at nearly 10^{4}K from Figure (2)f. With time the cooling of gas particles continues and causes to convert these particles to stars inside the halos of the galaxies.

In Figure (2o) the cutoff curve at temperature near 10^{4} is shown clearly and some particles have left the fluid to convert to stars.

The star formation begins at the redshift, Z=7.3 in the box as given in the Table (1). The number of new star also changes with redshifts. From the table it is clear that stars are not formed at some redshifts, but the total number of stars.

Figure (3) shows the number of total stars formation at redshifts from (1.2 to 0). The low redshifts are shown because the number of the total stars increases from high redshifts. Inside this box the number of the total stars at redshift z=0 is 226217 stars.

Figure (4) shows star formations in the box at the present day. The number of total stars in this volume of the Universe is 226217 stars. It is clear that this figure is in a good agreement with the stars seen in the sky.

The structure constructions of galaxies formation in the present work are in a good agreement with the Millennium simulations 2005[12].

The shapes of the figures of gas cooling are in a good agreement with that obtained by Yosida et al 2002[16].

Conclusions

The conclusions of the present work can be summarized as follows :

1- In the present work, the cold dark matter was used as main components of the galaxy formations because it is the matter of halos construction which surrounds the galaxies. Any simulation of galaxy formation without this matter is unsuccessful.
2- The baryon gas was also used in the simulation because it is the seed of the star formation in the galaxies. Any simulation of galaxy formations of the gas particles must be taken into considerations.Star formations is a resultant of gas cooling process which causes the equilibrium state between pressure outward a protostar and collapsing toward the protostar.
3- Gas particles cooled at nearly 10^{4} K to form stars and star formations increase more in the very low redshifts.
4- Number of stars formed in this size of the box is 226217 stars which is in a good agreement with the star distributions in the real sky.

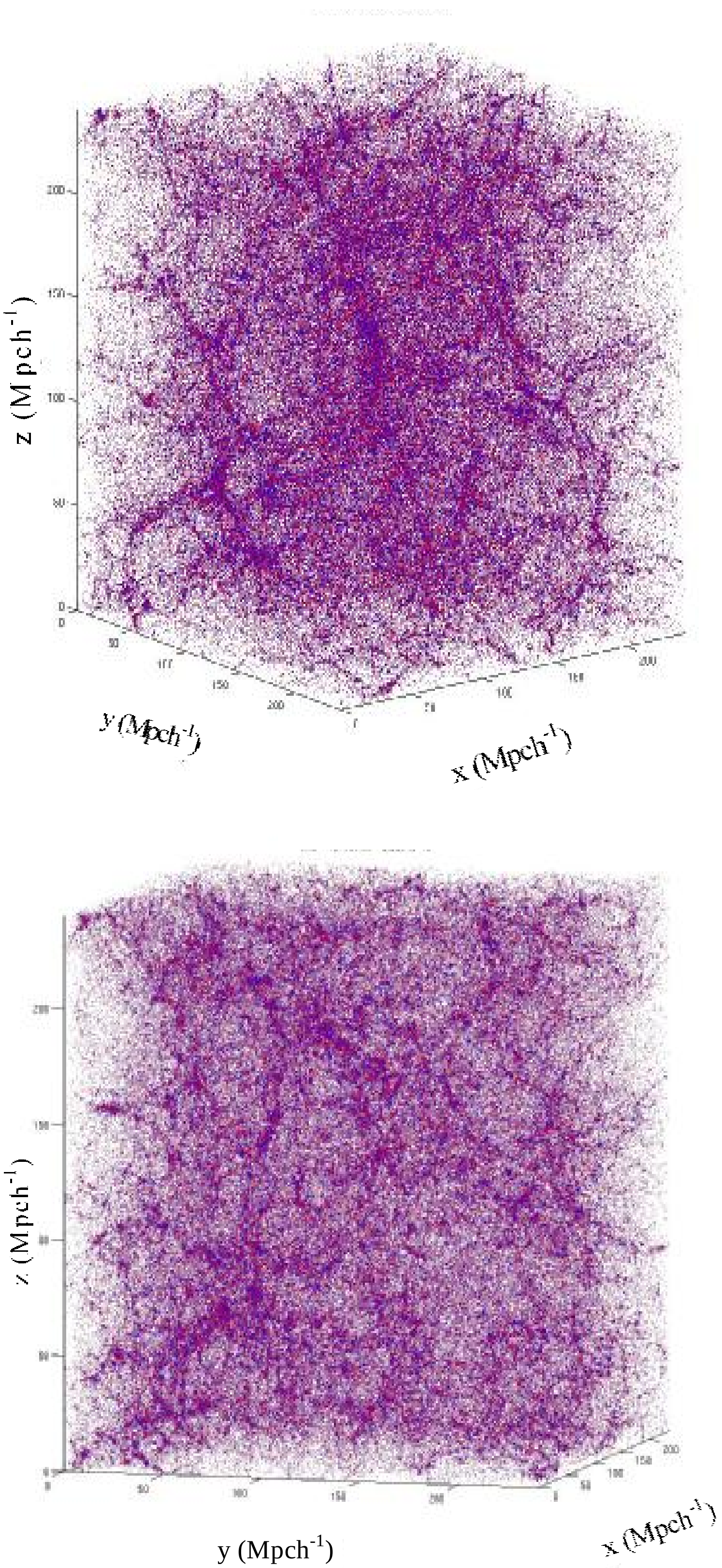

Fig.(1) : Simulation of 8 million dark matters and 8 million gas particles at Z=0 at two points of vie.

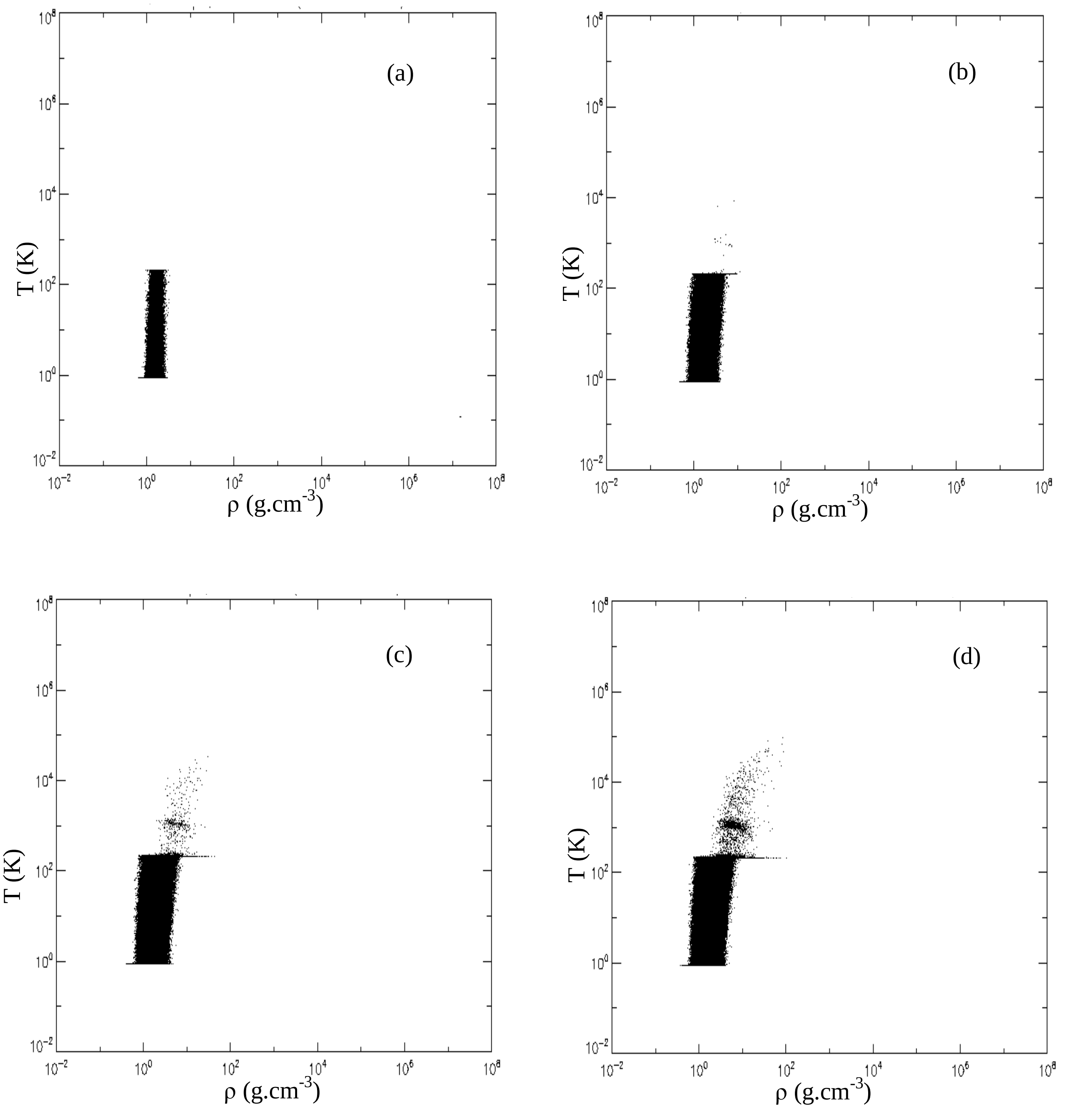

Fig.(2) :Temperature- density planes at different redshifts:
a) Z=17.7 b) Z =10.2 c) Z =8.13 and d) Z =7.41.

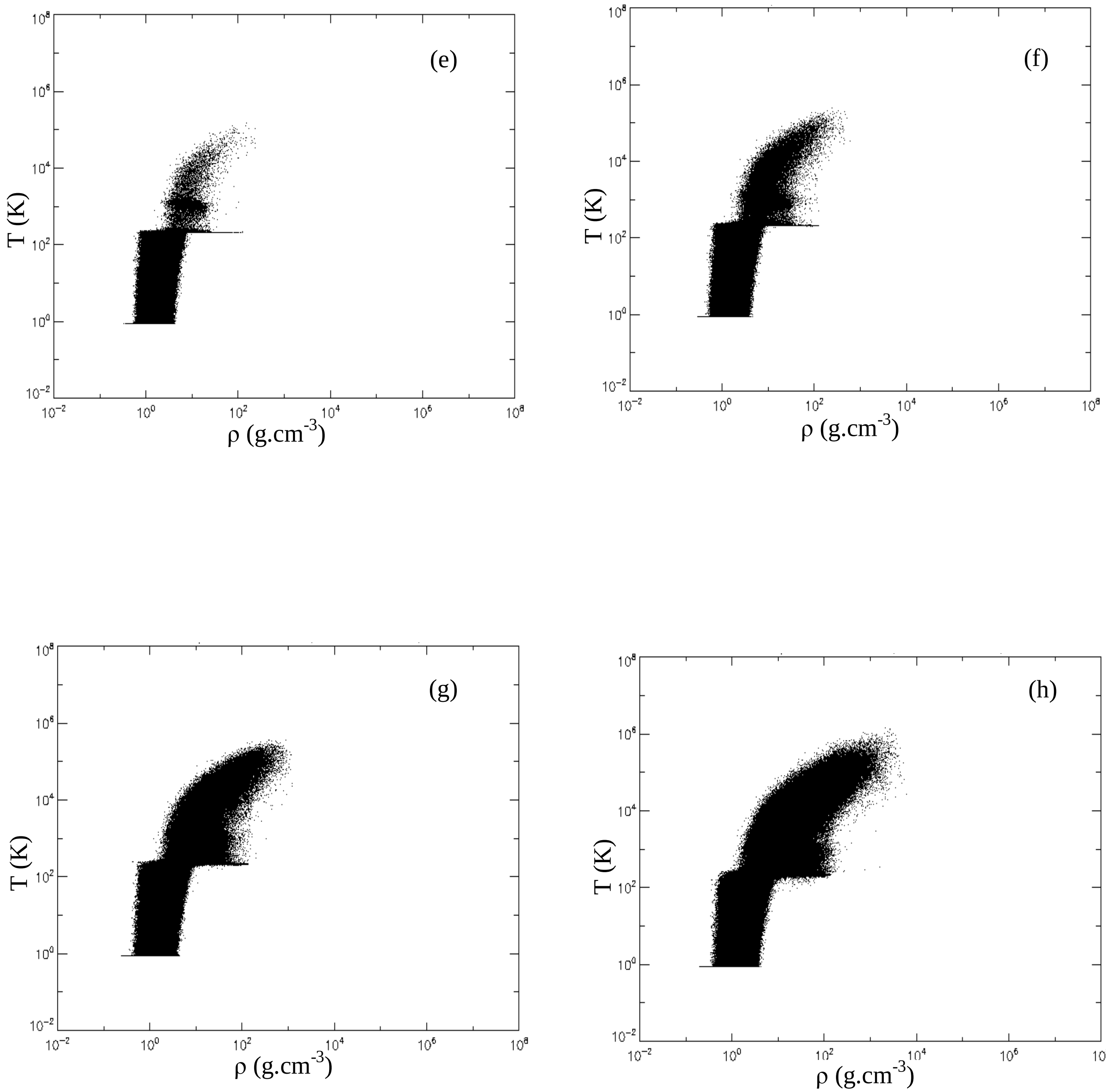

Fig.(2) :Continued
e) Z =6.3 f) Z =5.19 g) Z =4.01 and h) Z=3.04 .

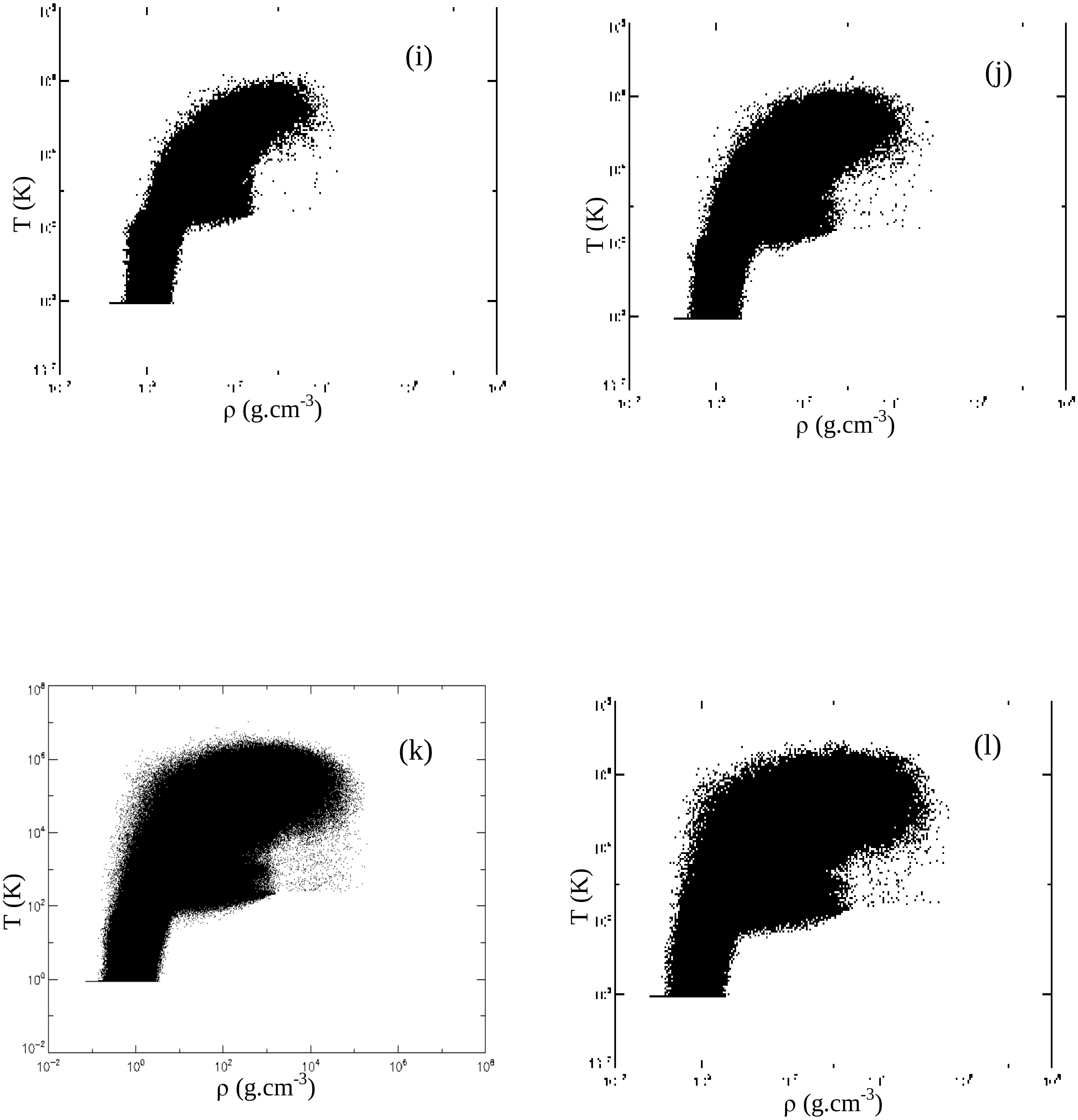

Fig.(2) :Continued
i) Z =1.95 j) Z =1.25 k) Z =0.6 and l) Z =0.3.

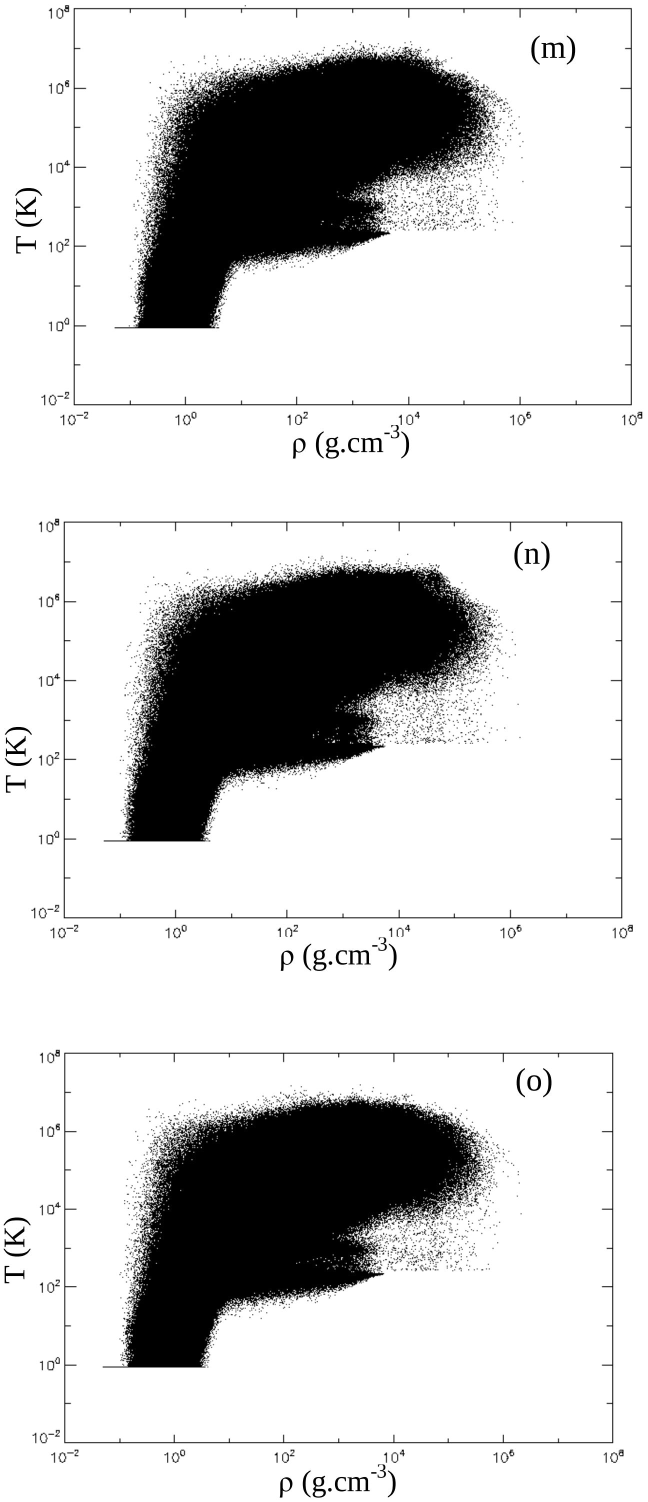

Fig.(2) : Continued:
m) Z = 0.1 n) Z =0.05 and o) Z= 0.

Table (1)
The number of new and total star formation at different redshifts.

Redshift	No.of new stars	Total No.of stars
7.4	0	0
7.3	1	1
7.2	0	1
7.1	0	1
7	1	2
6.9	2	4
6.8	0	4
6.7	0	5
6.6	0	5
6.5	0	5
6.4	0	6
6.3	0	7
6.2	1	11
6.1	5	16
6	6	22
5.9	5	27
5.8	8	36
5.7	15	51
5.6	17	69
5.5	1	90
5.4	1	118
5.3	25	165

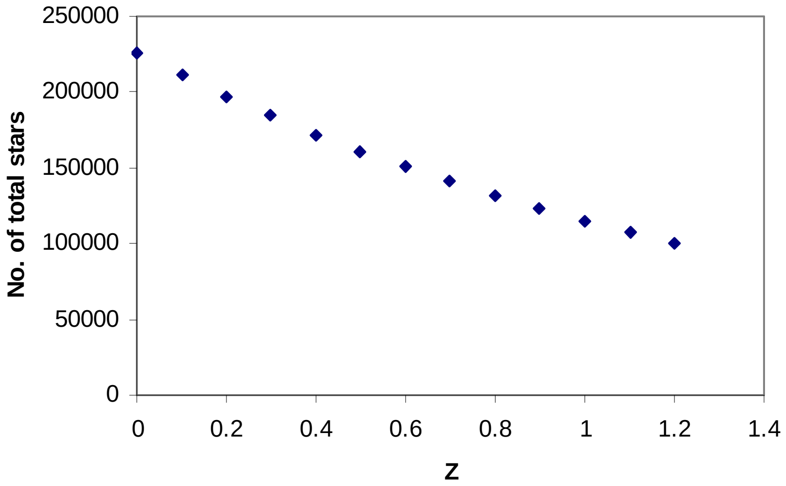

Fig.(3): The number of total stars versus redshifts.

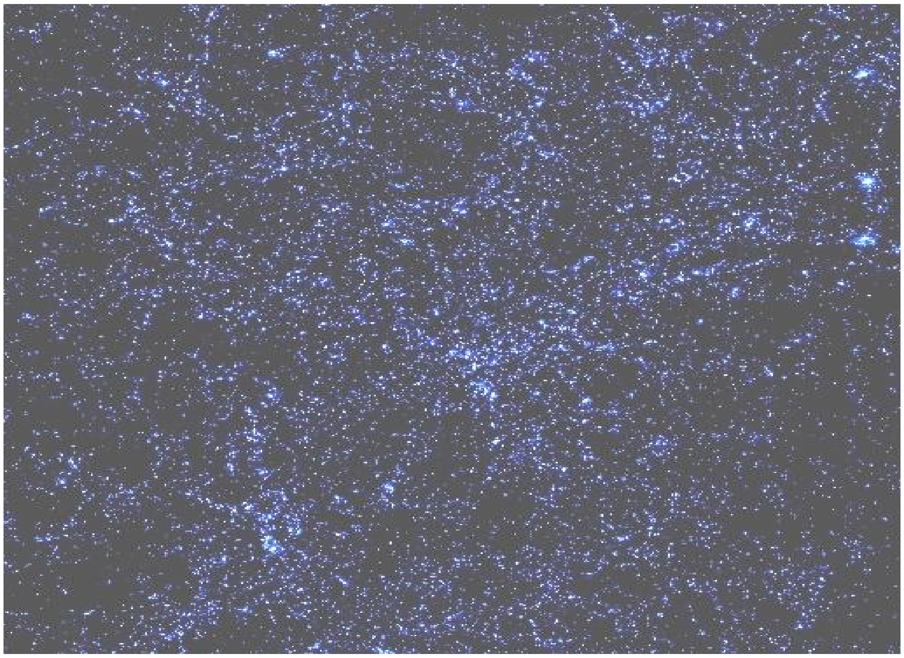

Fig.(4): A view of star formation in box (240Mpc/h)^3.

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الخلاصة

في هذا البحث تم استخدام موديل(ΛCDM) لتكوين النجوم داخل صندوق ذي حجم$(240Mpc/h)^3$ باستخدام ثمانية ملايين جسيم من المادة الداكنة الباردة مع ثمانية ملايين جسيم غاز سوية عندما $H_0=100h\ kms^{-1}Mpc^{--1}$, $\sigma_8=0.9$, $\Omega_\Lambda=0.73$, $\Omega=0.25$ وذلك بواسطة كود gadget-2 لمحاكاة الجسيمات فى الماضي السحيق للكون عند ازاحة الحمراء z=30 (450million years) الى الزمن الحالي للكون عند الازاحة الحمراء z=0 (13.4billion years) .

شوهدت بوضوح داخل الصندوق تكوين التراكيب كعناقيد المجرات ،الفتائل وكذلك الفجوات في الإزاحات الحمراء الصغيرةz=0 .

في مستويات درجات الحرارة –الكثافة اظهرت العمليات الحرارية أن قيم الكثافة ودرجة الحرارة تختلف باختلاف الازاحات الحمراء، وكذلك ظهر تبريد الغاز عند درجة حرارة 10^4K تقريبا والتي تسبب في تكوين النجوم داخل الصندوق لازاحات حمراء معينة.

لقد وجد ايضا بان النجوم تكونت من Z=7.3، وان عدد النجوم إزداد مع نقصان الإزاحات الحمراء.بالاضافة الى ذلك فأن عدد النجوم التى تكونت في الصندوق كان226217 نجما.

تم استخدام ستة عشرة معالجا لسوبر كومبيوتر جامعة نوتنغهام البريطانية في المحاكاة.