STUDY OF STAR FORMATIONS IN LAMBDA COLD DARK MATTER MODEL

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Abstract

Star formation inside a box of size $(120Mpc/h)^3$ was studied using Lambda Cold Dark Matter (ΛCDM) model by simulating one million dark matter particles and one million gas particles. The particles were simulated from early Universe, z=30 (450 million years) to z=0 (13.4 billion years).

In the simulation galaxy clusters, voids and filaments were constructed at low redshift, z=0. Stars were formed from redshift z=5.99. The formations increased with decreasing redshifts but at some redshifs stars were not formed and the total number of star formed in the box was 28443 stars.

The gadget-2 code was depended in the simulation and sixteen processors of high performance supercomputer of Nottingham University-England were used.

دراسة تكوين النجوم في نموذج لامدا للمادة الداكنة الباردة

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الخلاصة

في هذا البحث تمت دراسة تكوين النجوم داخل صندوق ذي حجم $(120Mpc/h)^3$ باستخدام نموذج LCDM وذلك بمحاكاة مليون جسيم من المادة الداكنة الباردة مع مليون جسيم من الغاز. تمت محاكاة الجسيمات من الازاحة الحمراء z=30 (450 million years) الى الازاحة الحمراء z=0 (13.4 million years) .

في المحاكاة تكونت عناقيد المجرات، في الفتائل، والفجوات في الازاحات المنخفضة، ووجد تكوين النجوم من الازاحة (z=5.99) وازدادت تكوين النجوم مع انخفاض الازاحة الحمراء ولكن في بعض الازاحات لم تتكون النجوم. وكان عدد النجوم في الصندوق ٢٨٤٤٣ نجما.

تم استخدام كود Gadget-2 في البحث وذلك باستخدام ستة عشرة معالجا لسوبر كومبيوتر جامعة نوتنغهام البريطانية

Introduction

Galaxies contain large number of stars with differing properties of interstellar material. The masses of galaxies range from a few million solar masses to a few trillion solar masses. Their diameters mostly range from a few thousand light years to a few hundred thousand light years [1].

Because the telescopes cannot yet see the birth of galaxies, we must use theoretical modeling to study the earliest stages in galaxy evolution. The most successful models of galaxy formation assume that galaxies formed as gravity pulled together regions of the Universe that were so slightly denser than their surroundings.

Gas collected in protogalactic clouds, and star began to form as the gas cooled [2]. The formation completes by mixing gas with the invisible dark matter then the gas heats by shocking. Finally, it cools by radiation and forms stars [3].

Hierarchical clustering is at present the most successful model for structure formation in the Universe, in which the structure grows as object of progressively larger mass merges and collapses to form new system [4].

A typical simulation follows evolution of matter in a large cubic box at which the Universe becomes homogeneous. Starting from the initial conditions of N-body simulations is an important step, because it affects boundaries and resolutions on the final results. So one needs to be able to set up the initial conditions for a numerical simulation in a manner appropriate to the cosmological model under consideration. Star formation depends on many complex mechanical and thermal processes such as the gravitational forces among the clouds of gas, heating and cooling of the gas particles. Morphology of clusters evolution, Peculiar velocity of galaxy clusters, the populations of clusters and galaxies in voids are important properties for understanding the origin of galaxy clusters [5, 6, 7].

More recent proofs that the Universe grows older and consequently, has a finite lifetime comes from astronomical observations of many types of extragalactic objects at high redshifts and at different wavelength. High redshifts correspond to earlier times, and what is observed are clear changes in the populations and the characteristic as one looks toward earlier epochs [8]. Observations of celestial bodies and their properties such as star formation, galaxy distribution, and large scale structures agree well with Big Bang simulations. So simulation is an integral part of astronomical systems which falls into the category of N-body problems such star clusters, the stars in a galaxy, interacting of galaxies and cluster of galaxies [9].

Star formations were simulated by many researchers. Peebles 1970 [10], Davis et al 1985 [11], McCarthy et al 2007 [12].

Simulation

Depending on tree particle mesh method, gadget-2 treats the particle positions and forces.

In tree code, the simulation volume is taken to be a cube. Simulations of galaxy formation start from the early Universe which is the high redshift to the present day as is the lowest redshift z=0. For such works supercomputers are needed for solving huge particle properties. Therefore, the Nottingham university supercomputer was chosen for simulating the galaxies formation in the present work. One million dark matter and one million cooling gas in a box $(120\text{Mpc/h})^3$ were simulated which includes star formation for the dense and cold gas. Star formation is obtained in the box after cooling the gas. This formation is important in the life of any galaxy because the stars are the main components of the galaxies.

In the simulation 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 $\text{kms}^{-1}\text{Mpc}^{-1}$. The gadget-2 code was used for simulating the particles from early Universe, z=30 to z=0.

Sixteen processors of high performance supercomputer of Nottingham University-England were used in the simulation. This run took three hours to complete.

The Boltzman's equation and the Poisson's equation were depended in the gadget-2 code which treats the characteristic of the dark matter as given below [13]:

$$\frac{\partial f}{\partial t} + \frac{\partial f}{\partial x} \cdot \frac{P}{m} + \frac{\partial f}{\partial P} \cdot F = \frac{\partial f}{\partial t} \qquad \text{.......} (1)$$

F(x, t) is the force field acting on the particles in the fluid, and m is the mass of the particles.

The term on the right hand side is added to describe the effect of collisions between particles; if it is zero then the particles do not collide.

The Poisson's equation is given by [4]:

$$\vec{\nabla}^2 \Phi(x) = 4\pi G \rho(x) \qquad \text{.......} (2)$$

Where $\vec{\nabla}\Phi(x)$ is the gravitational potential filed generated by density ρ.

Because the gas particles are collisional fluid and gravitational in addition to the modeling and gas dynamic the code treats the thermal processes of the gas, such as the gas cooling by radiation and Compton cooling.

Results and discussion

Figures (1 a, b and c) show the three redshifts z=30, 1.2, and 0. The collection of the particles in each epoch is different .Figure (1a) represents the initial epoch of gas in the box. The dark matter and gas particles distributed homogenously in the box.

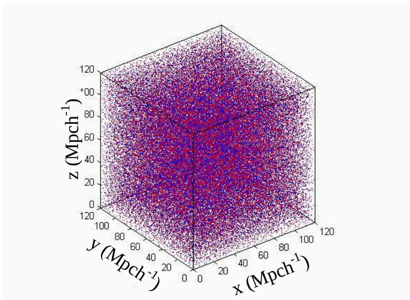

Figure 1a: Simulation in box (120Mpc/h)^3 at z=30

Figure (1b) shows simulation of gas cooling at z =1.2 inside the box. It is clear how the particles of dark matter and gas cooling attracted each others by gravitation force to construct small clumps and displace particles from their origin by this attraction and gas cooling.

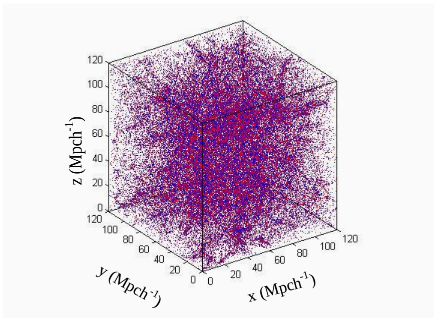

Figure 1b: Simulation in box (120Mpc/h)^3 at z=1.2

Figure (1c) shows the clumps and particles positions at the present epoch which are differ from the other epochs. The gas clumps inside the halo are shown and the cluster of galaxies voids and filaments clearly appear at this epoch.

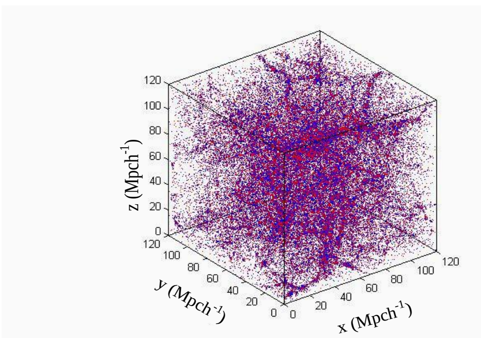

Figure 1c: Simulation in box (120Mpc/h)^3 at z=0

Figures (2 a, b and c) show the xy, xz and yz of gas cooling at z =30, 1.2 and 0, respectively. From the figures, it is obviously shown the structure change of the clusters of galaxies, filaments and voids inside the box.

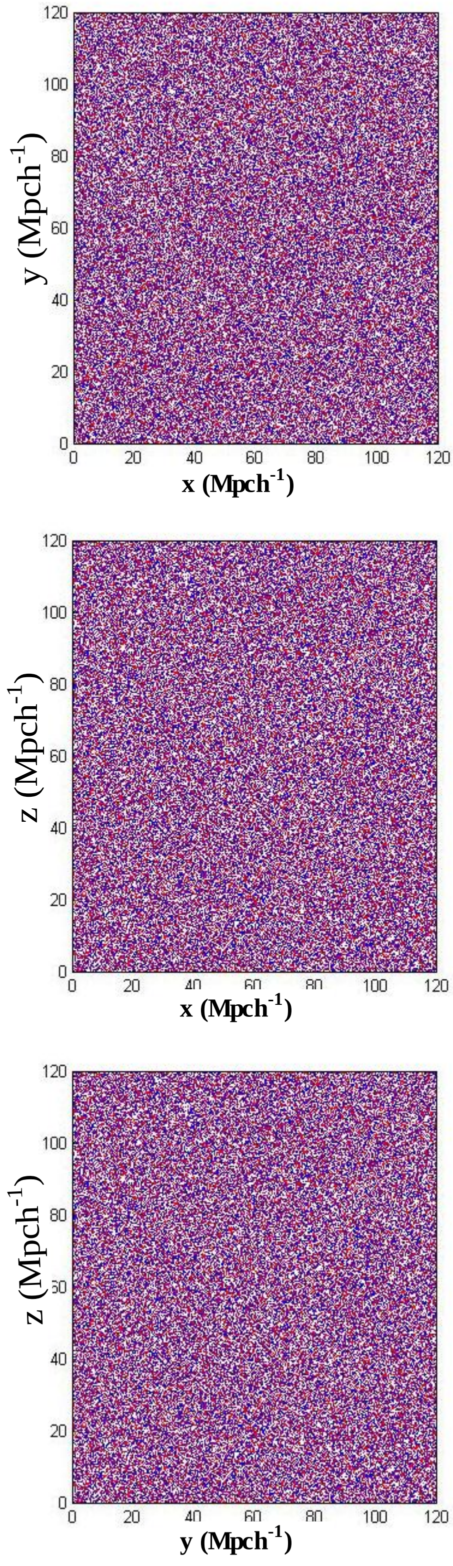

Figure 2a: Gas cooling in xy, xz and yz plan at z=30

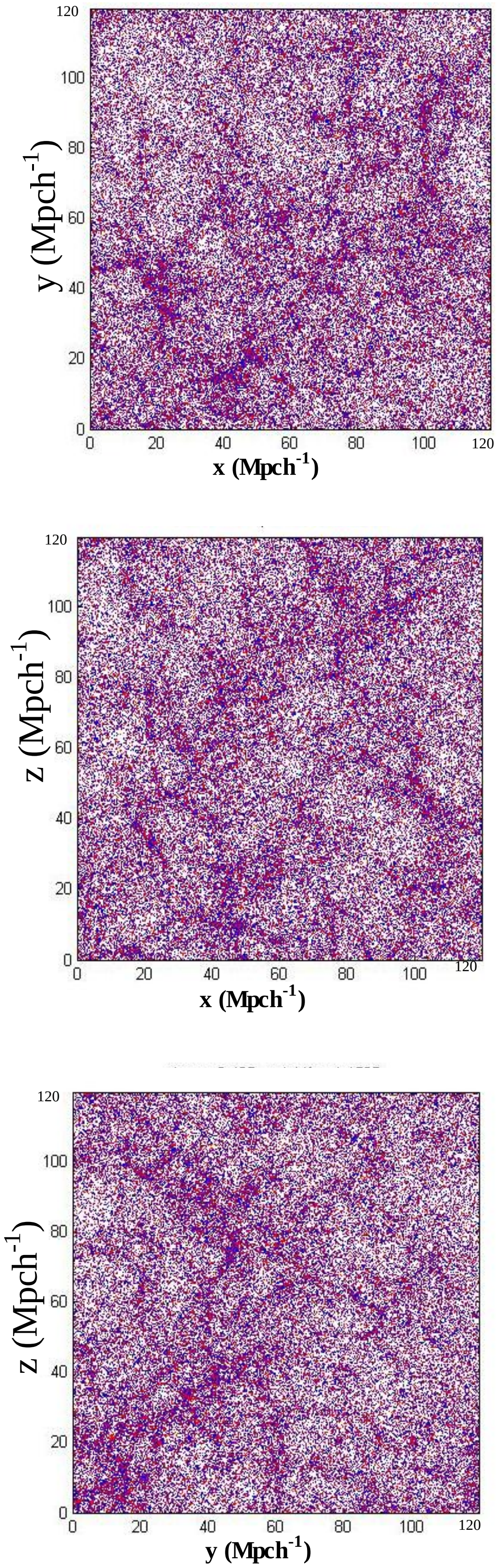

Figure 2b: Gas cooling in xy , xz and yz planes at z=1.2

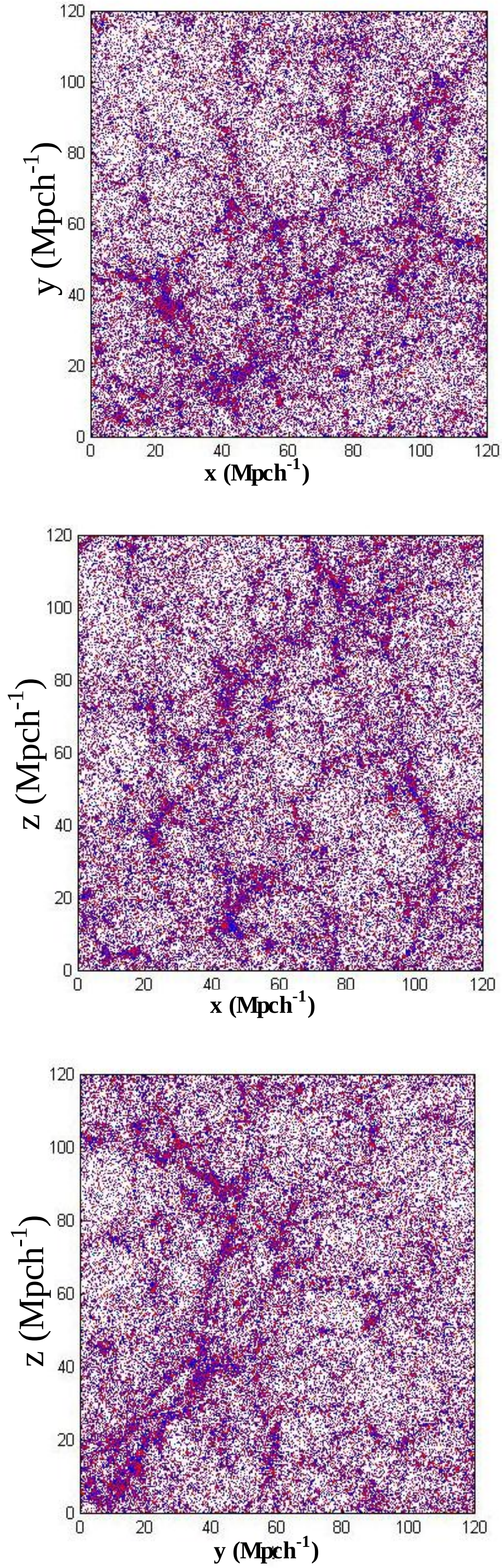

Figure 2c: Gas cooling in xy , xz and yz planes at z=0

Figure (3a) shows cooling of gas at z=6.3 in which the most of gas particles are distributed in the low density lower than $10 gm.cm^{-3}$ and temperature less than 200K. Some particles have shock-heated to more than 10^4K, but few particles have very overdense value.

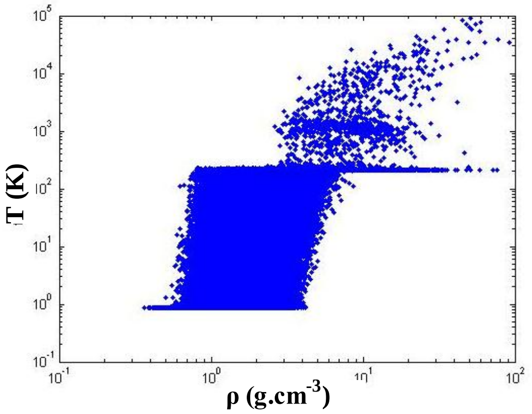

Figure 3a: Temperature-density plane of gas cooling in box $(120Mpc/h)^3$ at z=6.3

Figure (3b) represents another epoch of the Universe at which z=1.2. It is clear that this epoch differs from the previous because of the attraction effects and more cooling of the gas, so the positions and the density change. The cut-off in the curve in this figure is nearly at the temperature 10^4K. It is clear that the very overdense cooled gas particles have left the fluid to convert to stars inside the halos of the galaxies in the clusters.

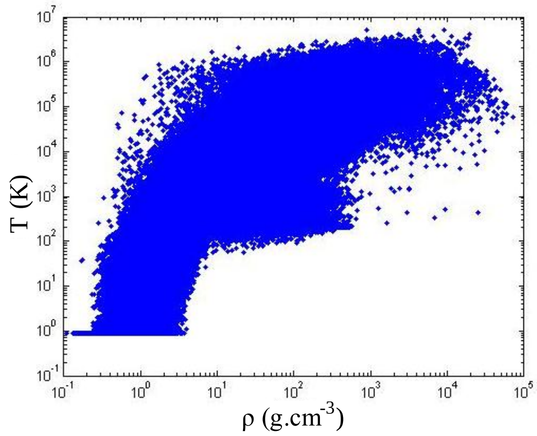

Figure 3b: Temperature-density plane of gas cooling in box $(120Mpc/h)^3$ at z=6.3

Figure (3c) which indicates the present day, shows that the density is more than that of the previous because of the continuous cooling of the gas and the great attraction force in this epoch. The cut-off also obtained at temperature about 10^4K which represents the radiatve cooling of the gas particles. From Fig(3c) it is shown that the very overdense particles of cooled gas have left the fluid to convert to stars.

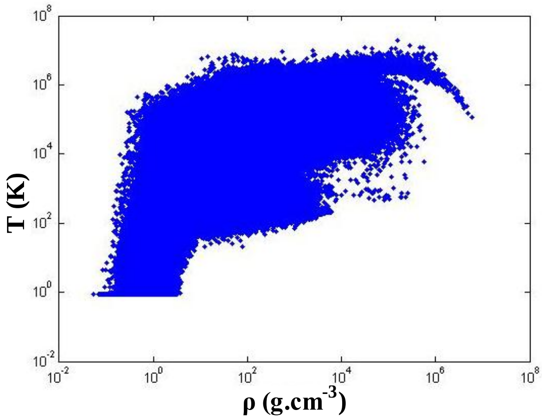

Figure 3c: Temperature-density plane of gas cooling in box $(120Mpc/h)^3$ at z=0.

Star born at some different redshifts as given in the Table (1). From the table, it is clear that at some redshifts there are no star formations while at other redshifts there are one or more star forms. In the box the star formation started from redshift z= 5.99.

Table 1: Number of new and total number of star formation at different redshifts.

z	No.of new stars	Total no.of stars
6.04	0	0
5.99	1	1
5.94	0	1
5.9	0	1
5.8	1	2
5.71	0	2
5.58	0	2
5.49	0	2
5.45	1	3
5.4	0	3
5.36	1	4
5.28	2	6
5.19	1	7
5.11	1	8
5.07	1	9
5.03	9	18
4.99	1	19
4.95	14	33
4.91	0	33
4.87	5	38

Table (2) gives the number of star formation inside the box at redshift, z=1.2 to the present day. It is also clear that the stars are born at some redshifts. And at the redshift, z=0 the number of the new stars is 49 stars inside the box.

Table 2: Number of new stars from redshifts z=1.2 to the present day.

Redshift	No.of new stars
1.2	0
1.1	3
1	0
0.9	1
0.8	0
0.7	3
0.6	0
0.5	0
0.4	2
0.3	4
0.2	3
0.1	0
0	49

Figure (4) shows number of total star formations at redshifts (z= 1.2 till now) in the box. The number of the total stars increase from high redshifts to low redshifts. And Inside the box the number of the total stars at redshift z=0 is 28443 stars.

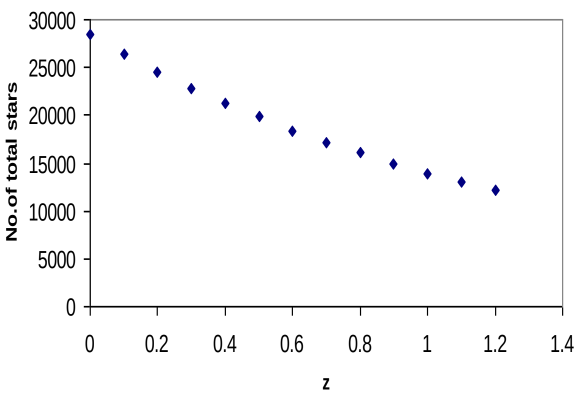

Figure 4:The number of total stars versus redshifts

The galaxies formation in the present work are in a good agreement with the Millennium simulation 2005[14].And the star formations is also in a good agreement to that obtained by Rasheed and Ameen, who simulated the galaxies in cosmological box of size $(240Mpc/h)^3$ [15].

Conclusions

From the present work it was found that the simulation is the best tool for studying the galaxy and star formations, and the Gaget-2 code is a suitable code for such simulations. It was found also that the star formed inside the box size $(120Mpc/h)^3$ at different redshifts starting from the redshift z=5.99, although at some redshifs the star formations were not obtained. At high redshits the total number of stars was small comparing with low redshifts. At z=0, the total number of stars was 28443 stars. The temperature-density diagram shows how from the cooled gas a large number of stars were formed.

References

1. *Encyclopedia of astronomy and astrophysics*, **2001**. Nature Publishing group and Institute of Physics Publishing UK.pp.1332.
2. Bennett, J., Merrifield M., Schneider N., and Voit H. **2007.** *The essential cosmic perspective*, fourth edition, Peason education, Inc., USA. pp.421-433
3. Carraro, G.; Lia, C. and Chiosi, C. **1998.** Galaxy formation and evolution-1.The padua Tree-SPH cod (PD-SPH), *MNRAS*, **297**. Pp.1021-1040.
4. Steinmetz, M. **2003**. Early formation and evolution of galaxies, *Astrophysics and Space Science*, **284**, pp.325-334.
5. Pearce, F. and Thomas, P.A. **1991.** Morphological evolution of clusters, MNRAS, **250**. Pp.607- 610.
6. Colberge, J.M.; White, S.D.M.; Macfarland, T.J.; Jenkins, A.R.; Pearce, F. R.; Frenk, C.S.; Thomas, P.A. and Couchman, H.M.P. **2000**. Pecular velocit-ies galaxy clusters, *MNRAS*, **313**.pp.229-236.
7. Springle,V.; White, S. D.M.; Tormen, G. and Kauffmann, G. **2001**. Populating a cluster of galaxies-1.Results at z=0, *MNRAS*, **328**. p.726.
8. Roos, M. **1997**. *Introduction to cosmology*, second edition, John Wiley and Sons Ltd. England.
9. Berstchinger, E. **1998**. Simulations of structure formation in the Universe, *Annual Review of Astronomy and Astrophysics*, **36**, pp.599-654.
10. Peebles P.J.E., **1970**, Structure of the coma cluster of galaxies, The Astronomical Journal, **75** (13).
11. Davis, M.; Efstathion, G.; Freak and White, S. **1985**. The evolution of large-scale structure in a universe dominated by cold dark matter, *The Astronomical Journal*, **292**.pp.371-394.
12. McCarthy, I.G.; Bower, R.G.; Balogh, M.L.; Voit, G.M.; Pearce, F.R.; Theuns, T.; Babul, A.; Lacey, C. and G. **2007**.

Modeling shock heating in cluster mergers-I. Moving beyond the spherical accretion model, *MNRAS*, **376:**497.

13. Huang, K. **1987**. *Statistical Mechanics*, Wiley & Sons, Inc.
14. Springle, V. **2005**. The cosmological simullation code Gadget-2 code, *MNRAS*, **364**. pp. 1105-1134.
15. Rasheed M. A. and Ameen M. M. **2009** Simulation of Star Formations in cosmological volume (240 Mpc/h)^3 *J of Al Nahrain University- science*, **12**(3):75-85.