JOURNAL OF THE KOREAN ASTRONOMICAL SOCIETY
29: S165 ~ S166, 1996

BOTTOM-UP MODEL FOR THE FORMATION OF GMC'S

GUO-XUAN SONG
Shanghai Observatory, Chinese Academy of Sciences, 80 Nandan Road, Shanghai 200030

ABSTRACT

A bottom-up model for the formation of GMCs is described, where the observed GMCs are the aggregates of less massive clouds. The aggregates are getting more and more massive in the process of consecutive collision between clouds.

Key Words : aggregation formation, molecular clouds

I. INTRODUCTION

Molecular clouds, especially, Giant Molecular Clouds (GMCs) with mass greater than $10^5 M_\odot$, are the major sites, where the star birth takes place. GMCs will be fragmented to less massive clouds by expanding HII region, stellar wind and supernova explosion by the star birth, particularly, the massive stars within them. If there was no effective formation of GMCs from less massive clouds, the star birth would stop.

The coalescence formation of GMCs was studied by Kwan and Valdes(1987). The observational evidence indicates that the massive cloud consists of emission cores, which could pose the question: if the collision between clouds leads to the coalescence.

Clifford and Elmegreen(1983) pointed out that due to the existence of the magnetic field in galaxies, there are much more indirect collisions between clouds than direct ones and the indirect collision is inelastic. The numerical simulation on the formation of GMCs is studied along with this line in this paper.

II. MODEL

A series of experiments on the formation of GMCs with numerical simulation, which models the evolution of molecular clouds and provides with a very intuitive consequence of their evolution, were carried out based on the idea that when two less massive clouds collide each other, this collision is inelastic and dissipates the relative kinetic energy of two colliding clouds, which leads to the aggregation of colliding clouds and the formation of GMCs.

In these experiments, all less massive clouds are taken to have same mass, $10^4 M_\odot$(i.e., unit clouds) which are randomly distributed in a ring between 3 kpc and 7 kpc with thickness of 200 pc initially. The total mass of molecular matter in this ring is $1.2 \times 10^9 M_\odot$, which means we have 120,000 unit clouds. The effect of the star disk on the motion of molecular matter is supposed to be replaced by a given gravitational potential as the mass in the star disk is two orders of magnitude higher than that in the molecular matter, which is composed of two parts: one is an axisymmetrical gravitational potential plus a spiral perturbation in the disk plane, the other is in the direction perpendicular to the disk plane, which is a harmonic motion with the frequency 0.1/Myr. The self-gravitation among unit clouds is included with a cut-off range of 10 times the effective diameter of unit clouds in order to save the computer time. The self-gravitation among clouds is crucial to the aggregation of clouds(Song,1996).

Our test showed that when the coefficient of restitution, which is the ratio of the relative velocity of two colliding clouds after collision to that before collision, is equal to or less than 0.5, the aggregation of unit clouds is efficient(Kahn and Song, 1994). In all our experiments the coefficient of restitution is adopted as 0.3.

The initial velocities of the unit clouds are composed of both the differential rotation, determined by the axisymmetrical gravitational potential of the star disk, and the dispersion velocities.

The **apparent** GMCs are sorted out by the percolation scheme and the fragmentation of GMCs due to star birth is described by a disruption probability. When a GMC is identified as disruptive, all unit clouds within this GMC are redistributed in either whole ring or the neighborhood of this disruptive GMC as two extreme cases.

III. RESULTS

The initially randomly distributed unit clouds in the ring are gradually getting to aggregate. When the star birth is included, the fragmentation of GMCs will be induced. Therefore, two phenomena, some massive aggregates are forming and some are fragmenting, will lead to a quasi-steady distribution of aggregating unit clouds. The experiments disclose that this quasi-steady distribution of unit clouds has been established since 300 Myr after the beginning of the numerical runs.

The fraction $F(M)$ of molecular matter in aggregates with mass $10^5 M_\odot$ and greater is derived to be between 31.5 % and 39.9 % in different models, which is less than the observed one of 90 % (Sanders, Scoville and Solomon, 1985). Does our model fail to study the formation process of GMCs? CO observation indicates that the mass of molecular clouds ranges from $10^2 M_\odot$ through $10^6 M_\odot$ and more. However, in the plot of observed $F(M)$ vs $\log M$ the clouds with mass greater than $10^4 M_\odot$ only are taken into consideration. In the simulation the unit clouds have mass $10^4 M_\odot$. From the numerically derived $F(M)$, where the unit clouds have mass $10^4 M_\odot$, it is known that about 40 % of total molecular matter exists in the isolated unit clouds and 10 % appears to be binaries of unit clouds. If these two parts are excluded in the derivation of $F(M)$, $F(10^5 M_\odot)$ could increase greatly.

From the plot of $F(M)$ vs $\log M$ derived from our experiments the mass spectrum of GMCs could be described by the power law with index -1.6, which matches the observational result.

Does spiral perturbation promote the formation of GMCs? The simulation tells us that in the models with same parameters except either presence or absence of the spiral perturbation in the star disk, the efficiency of the formation of GMCs in whole disk is nearly same. The presence of spiral perturbation just makes more GMCs form in the arm region, which is compensated by less GMCs in the interarm region. This result is supported by the observation of CO content in early type galaxies, mostly lenticular galaxies(Wiklind and Henkel, 1989).

IV. SUMMARY

Through the simulation and the analysis it discloses that the aggregation formation of GMCs is efficient and the results derived from it can match the observational evidence. Of course, the refinement of the model is needed. Especially, the effect of the mass of unit clouds on the formation process has to be explored further.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China and the National Major Project of China.

REFERENCES

Clifford P. and Elmegreen B., 1983, MNRAS, 202,629.

Kahn F. and Song G.X., 1994, Ap&SS, 211, 127.

Kwan J. and Valdes F., 1987, ApJ, 315,92.

Sanders D.B., Scoville N.Z. and Solomon P.M., 1985, 289, 373.

Song,G.X., 1996, Annals of Shanghai Observatory, 17,237.

Wiklind,T. and Henkel C., 1989, ApJ, 225, 1.