Chapter 3

Activated Molecular Cloud Cluster Model

3.1 Formation of Molecular Cloud Cluster

Molecular cloud is a cloud of hydrogen rich matters in the forms of gas and dust contaminated with some of heavy elements originated from the explosion of dying stars. In this section, the collapsing factor, which indicates that the irregular-shape molecular cloud could be collapsed partially to form a cluster, is determined.

Before the interaction era, material distribution in protogalaxy was very rough; random motion made the turbulences that distorted molecular clouds, the clouds were always irregular shape. A large molecular cloud could collapse partially in many regions where the density is higher-than-average. A large cloud was divided, then, finally became a cluster.

However, the partial collapse still depends on the free-fall collapsing time (Stephen, 1999) or collapsing factor given by

$$t_{ff} = \sqrt{\frac{\pi^2 R^3}{8GM}} \tag{3.1}$$

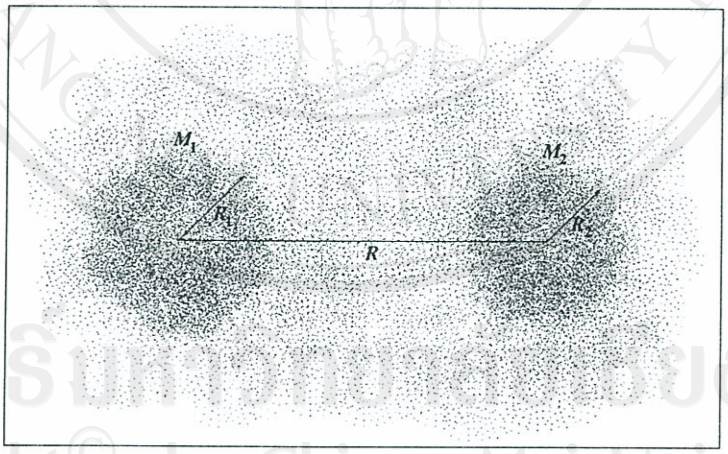

Figure 3.1 A simple molecular cloud that has two high-density regions.

For a simple system shown in Figure 3.1, the partial collapse begins when $t_{ff}^{M_1}$ and $t_{ff}^{M_2}$ are less than t_{ff}^{M} or

$$\frac{R_1^{\,3}}{M_1}, \frac{R_2^{\,3}}{M_2} < \frac{R^3}{M} \qquad ; M = M_1 + M_2 \tag{3.2}$$

Comparison of free-fall time (t_{ff}) indicates that which one of clouds would collapse faster. Furthermore, from Equation 3.1, it is obvious that t_{ff} is proportional to the radius R rather than the mass M; thus, the larger cloud may collapse slower than the smaller one. For example, from Figure 3.1, if we neglect the effect of surrounded material and with approximation, $M_1 \cong M_2 = \overline{M}$ and $R_1 \cong R_2 \cong \frac{R}{4}$, then

$$t_{ff}^{M_1} \cong t_{ff}^{M_2} = \left(\frac{1}{4}\right)^{\frac{3}{2}} \sqrt{\frac{\pi^2 R^3}{8G\overline{M}}} \tag{3.3}$$

and

$$t_{ff}^{M} = \left(\frac{1}{2}\right)^{\frac{1}{2}} \sqrt{\frac{\pi^2 R^3}{8G\overline{M}}} \tag{3.4}$$

It is obvious that

$$t_{ff}^{M_1} \cong t_{ff}^{M_2} < t_{ff}^{M} \tag{3.5}$$

Therefore, the cloud M_1 and M_2 will collapse before the collapse of their system, the clouds are distinguished and the system become a cluster.

3.2 Activated Molecular Cloud Cluster Model

The first idea of this model was inspired by McCrea's protoplanet theory (1960) in the concepts that the original system had already been a stellar cluster before collapsed and the motion of protoplanet was adjusted by the role of resisting medium. However, this model has many differences in details, especially the formation of satellite and the distribution of angular momentum.

The main hypothesis of this model is that "the formation of the solar system may be related to the evolution of galaxy especially the spiral pattern forming processes". The spiral arm is the high-density region of galaxy where most of stars are formed and our solar system is situated. It is expected that the gravitational and rotational forces should play the important roles in the early stage of evolution. Then, the evolutions of the system, in this model, are mainly based on the effects of these two forces. In this section, the sequences of solar system evolution are described.

In general, most of observable galaxies in the universe are distributed as a cluster, see Figure 3.2; therefore, the interactions between galaxies are commonly occurred. In early stage of evolution, the galaxy was a collapsing gigantic molecular cloud cluster made almost entirely of hydrogen and helium, called protogalaxy. During collapsed, the protogalaxy rotated to conserve its own angular momentum, and with the interactions between the clouds, it finally rotated in a certain direction and flattened like a disk. At the same time, the dynamics of protogalaxies in cluster were complex like n-body system; when they closed together, the tidal induction could be taken place.

Figure 3.2 A typical cluster of galaxies. (Eric, 2002)

Firstly, this model considers only the interaction between two protogalaxies, primordial Milky Way Galaxy and nearby protogalaxy. Their motion was Keplerion around the center of mass, and the distance between them at pericenter had sufficient for the high-density-regions induction to occur. Before the interaction took place, the molecular clouds in protogalaxy had randomly distributed like cluster with various sizes and distances between them. Some molecular cloud clusters could collapse to form the protostar solely before, if they had proper size and density, while other cluster in the rest of protogalaxy were waiting for the high-density-regions induction to induce their collapse.

When the interaction began, all molecular cloud clusters were pulled into two opposite regions under the influence of perturbed field from its companion as described in Section 2.4. The molecular clouds in every cluster in these regions were activated to clump together as shown in Figure 3.3; then the cluster was small and began to collapse by its own gravity.

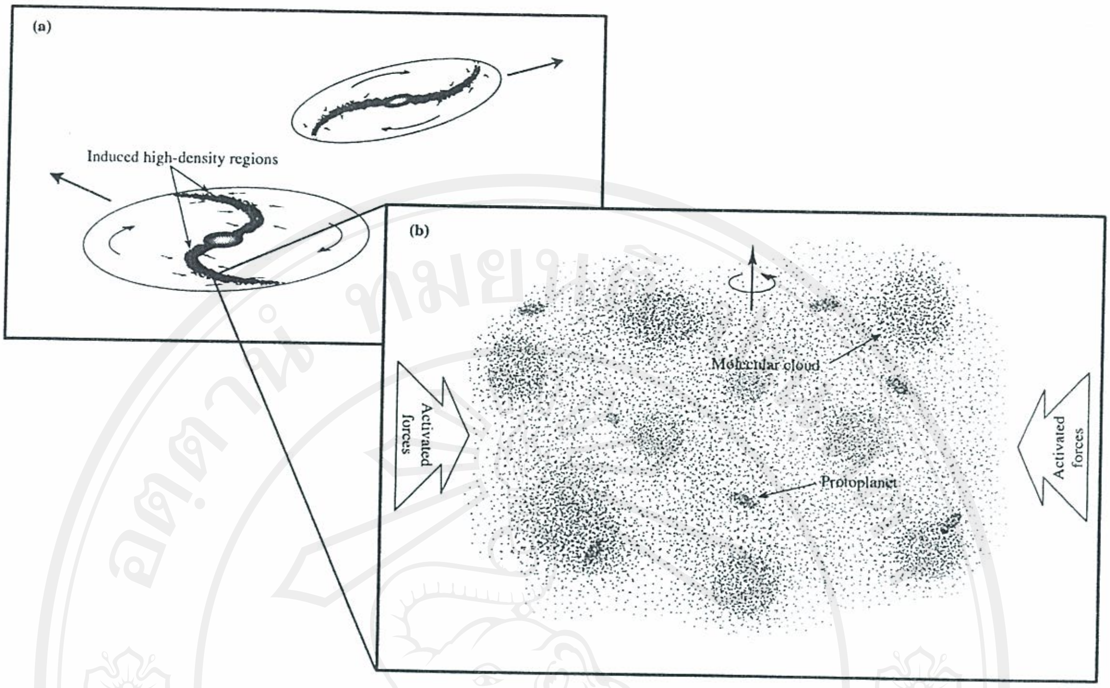

Figure 3.3 (a) High-density-regions induction between two galaxies. (b) Collapsing of molecular cloud cluster in high-density region.

For solar system, the solar cluster was composed with the irregular-shape molecular clouds and protoplanets (a small self-collapsed molecular cloud). The motion of all objects in the solar cluster was influenced by their gravitation and the compression from the nearby interstellar turbulent materials. The cluster would be clumped rapidly with mass transfer and collision between the cloudy objects around the center; the heat could be generated and the system became flat, the protosun was formed at the center as shown in Figure 3.4. During the collapsing process went on, protoplanets moved around the protosun with high eccentricity through the solar atmosphere that composed with gas and dust dispersed from the center. The motion of protoplanets would be retarded and more circular as described in Section 2.3.

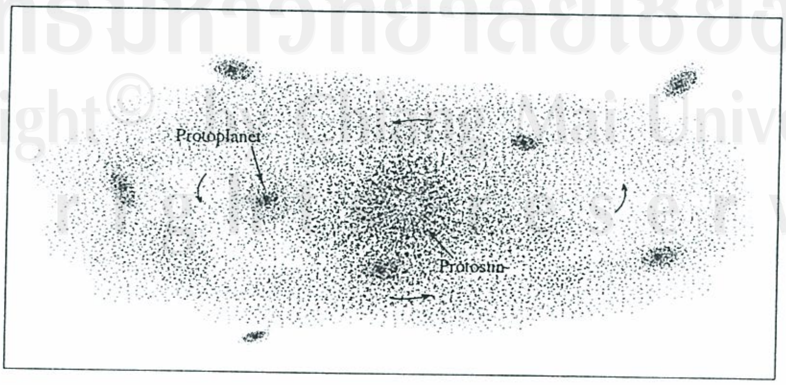

Figure 3.4 The primordial solar system with a protosun at the center surrounded by protoplanets and the atmospheric materials.

At the center, the protosun accumulated masses from the surrounding materials but not all materials were fallen into the protosun, because the motion of all material particles were Keplerion, the surrounding materials then pulsated radially. However, the random pulsation of them was always asynchronous, then the orbital collision with transferring angular momentum among them could be occurred; the loser would fall into the center to merge with protosun, the gainer received a new larger orbit. Therefore, the angular momentum of protosun was small comparing with the surrounding materials.

While the protoplanets moved around the protosun with elliptical orbit, the high-density-regions induction could take place. The fragmented material rings (see Section 3.3.3) of protoplanet would be compressed to form the high-density objects, called protosatellites. Materials, which forming protosatellite, were collided strongly together. The rapid increasing temperature would melt the dusty materials to form a molten chunk at the center. The protosatellites continued to grow with cooling down their average temperature to be the satellites of planet.

Long time later by the way of orbital collision, the pulsation of the turbulent surrounding materials may have become synchronous. The temperature and the pressure of protosun would be increased periodically. In this model, the protosun was larger and more massive than the Sun today, thus, it could expand and collapse, or pulsate, along its poles by the compression of materials in a plane. By a chance of synchronous collapse in overall directions, the hydrogen at the center of protosun would be ignited to start the nuclear fusion reaction. The heat was generated immediately by the strong radiation from the central protosun; the explosion began, and the surrounding materials near the protosun were pushed away out of the solar system. The gravitational potential of the central mass decrease followed the ejected materials caused the planets shifting their orbit. The central protosun became the Sun.

The solar system was clean and more coplanar. In this stage, the Sun had strong radiation with solar wind. Two kinds of planet, terrestrial and jovian, are distinguished. Cooling down of the system solidified all terrestrial planets and satellites.

The present data show that there are many small icy objects orbit around the solar system extending from Neptune orbit to more than 100 AU, called Kuiper belt (Figure 3.5 (b)). It is believed to be the origin of short-period comets (orbital period less than 200 years). For this model, the Kuiper belt objects are expected to be some evidence of the solar explosion; this belt may be the outermost pulsating material rings of early solar system. While the protosun exploded, this materials ring may situated at the edge of system, the materials wind from explosion and the potential decrease effect would retard their collapse and brought them to the new orbits as today.

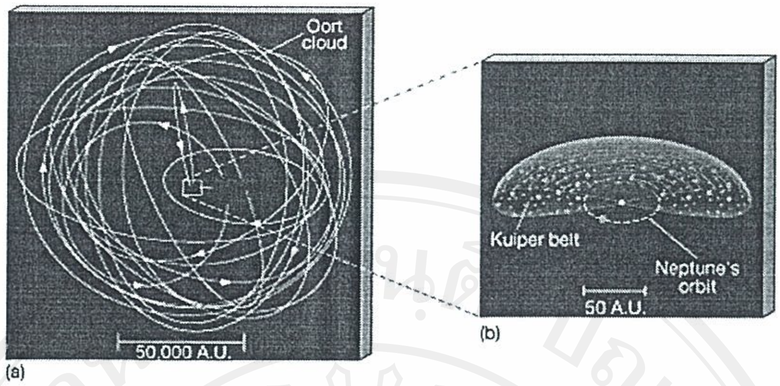

Figure 3.5 (a) The Oort cloud and some cometary's orbits. (b) The Kuiper belt, the origin of short-period comets, locates beyond the Neptune's orbit (Eric, 2002).

Furthermore, astronomers also believed that, for the origin of long-period comets (orbital period less than 200 years), there must be a huge cloud of comets envelop the solar system extends up to $50{,}000AU$ in radius, called Oort cloud (Figure 3.5 (a)). This model also expects that it may be the solar materials that ejected by the explosion of protosun in the past with velocity higher than the escape velocity. These materials would never fall down again except for some of them collided with the interstellar objects or influenced by gravitation of the passing star. The existence of Oort cloud may support this model, but the investigation is too hard.

3.3 Model Features

The Activated Molecular Cloud Cluster Model gives both theoretical and descriptive explanations to the formation of solar system. The main problems are clarified by introducing the concept of the radial pulsation, the orbital collision, the motion in the resisting medium and the tidal induction, to the evolution of the system. The main features of this model are described as follows:

3.3.1 The Angular Momentum of the Sun

During the interaction between two protogalaxies, the molecular cloud cluster would be activated to collapse by the influences of distorted gravitational field and the compression of nearby interstellar turbulent materials. All molecular clouds and protoplanets were fallen into the center of mass of cluster. They were close enough whether mass transfer or collision could occur; both interactions produced heat and grew a larger cloud. In this stage, the system could possibly clump into a single, double, or multiple protostar. However, the stability of system is indicated inversely by the number of protostar it has. For the solar system, protosun was a single protostar surrounded by dispersed molecular clouds and protoplanets.

The system became a pulsating system by the role of Keplerion motion of all particles. Every orbit of particle has its turning points determined by Equation 2.17

$$\left.\begin{aligned} r_{min} &= \frac{\alpha}{1+\varepsilon} \\ r_{max} &= \frac{\alpha}{1-\varepsilon} \end{aligned}\right\} \tag{2.17}$$

These two points of each particle could be changed all the time by the effect of non-uniform gravitational field and orbital collision between particles. Both effects can change the angular momentum and the total energy of particle which are related to α and ε in Equation 2.17 through the Equation 2.16

$$\left.\begin{aligned} \alpha &= \frac{\ell^2}{\mu k} \\ \varepsilon &= \sqrt{1+\frac{2E\ell^2}{\mu k^2}} \end{aligned}\right\} \tag{2.16}$$

The non-uniform gravitational field is generated by the random-rough distribution of mass in the system. It gives non-radial forces or torques to change the angular momentum and distort the eccentricity of particles via the potential term of the total energy. Now we leave to mention about its detail because the study of random distribution is very complicated and beyond this work. However, the effect of the orbital collision is also important to describe how the angular momentum and the total energy of the system are distributed; this model applies it to justify the angular momentum problem of the Sun.

As mentioned roughly in Section 3.2, the protosun could be accreted by two processes; the first one is the direct collision between molecular clouds, another one is the orbital collision of surrounding materials. In the former process, the collision is inelastic, thus momentums of particles in the clouds would be lost through the conversion of kinetic energy into heat Q.

$$T_{initial} + U_{initial} = T_{final} + U_{final} + Q \tag{3.8}$$

where

$$T = \frac{1}{2}\frac{p^2}{\mu} + \frac{1}{2}\frac{\ell^2}{\mu r^2} \tag{3.9}$$

This process, however, could not bring all colliding masses into the center because only molten masses can lump together whereas the solid masses remain scattered out of the collision region. Thus, the protosun would not be grown larger by this process. The later process (orbital collision) must be invoked.

When the protosun was formed, it was a small molten chunk surrounded by many low-density molecular clouds dispersing to the rim of system and covering all protoplanets. The asynchronous radial pulsation of molecular clouds brought their materials collide together.

From Equation 2.34a and 2.34b, we see that the angular momentums of recoil particles depend on m_1, m_2, ℓ_1^{ori}, and ℓ_2^{ori}. Rearrange both equation again by using the mass ratio $m = \frac{m_1}{m_2}$, we have

$$\ell_1^{rec} = \left(\frac{m-1}{m+1}\right)\ell_1^{ori} + \left(\frac{2m}{m+1}\right)\ell_2^{ori} \tag{3.10a}$$

and

$$\ell_2^{rec} = \left(\frac{2}{m+1}\right)\ell_1^{ori} - \left(\frac{m-1}{m+1}\right)\ell_2^{ori} \tag{3.10b}$$

Divide Equation 3.10a by 3.10b and use the angular momentum ratio $\ell = \frac{\ell_1}{\ell_2}$,

$$\ell^{rec} = \frac{(m-1)\ell^{ori} + 2m}{2\ell^{ori} - (m-1)} \tag{3.11}$$

This equation represents the angular momentum ratio of recoil particles relative to mass ratio m and original angular momentum ℓ^{ori}. If we fix m to some values between $0 \rightarrow 1$, the angular momentum ratio ℓ^{rec} can be illustrated as Figure 3.6.

The exchange of angular momentum can be studied in various cases. It is more convenient to determine which case momentum is exchanged by determining which case it does not. From Equation 3.10a and 3.10b, the angular momentum does not exchange when $\ell_1^{rec} = \ell_1^{ori}$ and $\ell_2^{rec} = \ell_2^{ori}$, so

$$\ell_1^{ori} = \left(\frac{m-1}{m+1}\right)\ell_1^{ori} + \left(\frac{2m}{m+1}\right)\ell_2^{ori} \tag{3.12a}$$

and

$$\ell_2^{ori} = \left(\frac{2}{m+1}\right)\ell_1^{ori} - \left(\frac{m-1}{m+1}\right)\ell_2^{ori} \tag{3.12b}$$

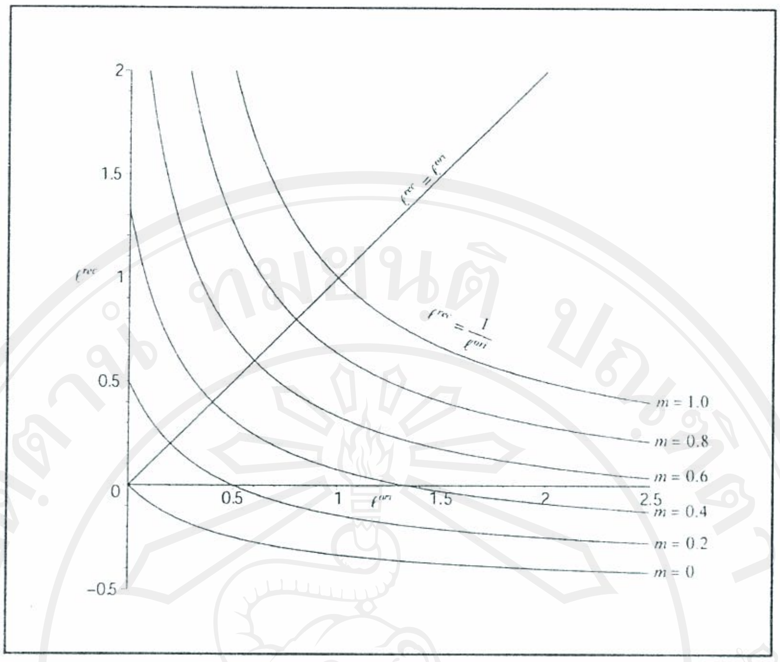

Figure 3.6 The relation between the angular momentum of recoil particles ℓ^{rec} and their original angular momentum ℓ^{ori} with mass ratio m from 0 to 1.

Both equations (3.12a and 3.12b) give the same result that

$$\ell_1^{ori} - m\ell_2^{ori} = 0 \tag{3.13}$$

or

$$\ell^{ori} = \frac{\ell_1^{ori}}{\ell_2^{ori}} = \frac{m_1}{m_2} = m \tag{3.14}$$

This case is presented in Figure 3.6 where the line $\ell^{ori} = m$ is intersected. It is concluded that there is no exchange of angular momentum when $\ell^{ori} = m$.

Furthermore, there is an extraordinary case when $m = 1$; all collision in this case, the angular momentum of both particles are absolutely interchanged. From Equation 3.10(a and b) and 3.11, we find that, when $m = 1$

$$\ell^{rec} = \frac{1}{\ell^{ori}} \tag{3.15}$$

and

$$\left.\begin{aligned} \ell_1^{rec} &= \ell_2^{ori} \\ \ell_2^{rec} &= \ell_1^{ori} \end{aligned}\right\} \tag{3.16}$$

The angular momentums are absolutely interchanged.

The chance of non-exchange cases is small compared with all possible cases presented in Figure 3.6. In a real system of particles around protosun, almost all cases could be taken place; the angular momentum would be transferred outwardly with a new larger orbit of the angular-momentum-gainer particles, whereas the angular-momentum-loser particles fell to merge with protosun. Therefore, the protosun became a house of the angular-momentum-losers that cause it spun slowly.

Although the angular momentum of the loser is very small, the radial momentum is not. It depends on the position in the orbit, which can be determined from the energy conservation condition:

$$E = \frac{1}{2}\frac{p^2}{\mu} + \frac{1}{2}\frac{\ell^2}{\mu r^2} - \frac{GMm}{r} = \text{constant} \tag{3.17}$$

or

$$p = \sqrt{2\mu\left(E + \frac{GMm}{r} - \frac{1}{2}\frac{\ell^2}{\mu r^2}\right)} \tag{3.18}$$

Differentiated p with respect to r gives

$$\frac{\partial p}{\partial r} = \frac{\mu\left(-\frac{GMm}{r^2} + \frac{\ell^2}{\mu r^3}\right)}{\sqrt{2\mu\left(E + \frac{GMm}{r} - \frac{1}{2}\frac{\ell^2}{\mu r^2}\right)}} \tag{3.19}$$

p is maximum when $\frac{\partial p}{\partial r} = 0$, thus

$$-\frac{GMm}{r^2} + \frac{\ell^2}{\mu r^3} = 0$$

$$r = \frac{\ell^2}{\mu GMm} \tag{3.20}$$

$$= \frac{\ell^2}{\mu k} = \alpha$$

where α is a half of latus rectum of orbit. If the protosun had radius about α, it would be bombarded with the particle that has radial kinetic energy about

$$T_{rad} = \frac{1}{2}\frac{p_{max}^2}{\mu} \tag{3.21}$$

Finally, the clouds in the system would tend to distribute as the pulsating fragmented rings, especially the innermost ring which its pulsation affects the pressure and the temperature of the protosun. By a chance of synchronous pulsation in overall directions the pressure and the temperature of the protosun increased over the threshold of nuclear fusion reaction, the protosun became the Sun with slow spin. The angular momentum problem of the Sun is now clarified.

3.3.2 Orbital and Rotational Properties of Planets

After the molecular cloud cluster had collapsed, all protoplanets moved around the central mass of cluster, which became flat by the influence of gravitation and orbital collision between the particles of molecular clouds lies in a plane of rotation. Four main factors may have been responsible for the orbital adjustment of the protoplanets; the details are described as follows:

1. Non-Uniform Gravitational Field

In early stage, the distribution of mass in the system was very complex and random that caused the gravitational field non-uniform. The total force acting on protoplanet would be non-radial; the angular momentum could be changed together with the change of orbit. If the direction of non-radial force (or torque) and the direction of protoplanets motion were the same, the force enhanced the motion; the orbit would be larger and more circular. However, if both directions were opposite, the result was reverse.

2. Resisting Medium

Most solar materials were diffused after the molecular clouds had collided together to form a central protosun. Their distribution would be in the forms of low-density cloud moving elliptically around protosun in a certain plane of rotation. The clouds could change the orbit of protoplanets by the orbital collision. However, considering this problem as the motion of object in the resisting medium (Section 2.3) is more convenient.

If we roughly approximate that the distribution of clouds is homogeneous and rotate circularly around protosun as a circular disk (Figure 4.7), the equation of motion of protoplanet in a disk cloud can be written as

$$\frac{d^2\mathbf{r}}{dt^2} = -\frac{GM(r)}{r^3}\mathbf{r} - \frac{1}{2}\frac{c\rho A}{m_{pro}}\left|\frac{d\mathbf{r}}{dt} - \mathbf{u}\right|\left(\frac{d\mathbf{r}}{dt} - \mathbf{u}\right) \qquad (3.22)$$

where $M(r)$ is the mass enclosed by the cylinder radius r and thickness h.

The Equation 3.22 can be solved by numerical calculation; the simulation results illustrate in Section 4.2 show that the orbit of object can be shifted from an original elliptical orbit to a new circular one.

Moreover, the effect of resisting medium could also bring the non-coplanar object into a plane by the resisting force in vertical component as shown in Figure 4.9. Therefore, the orbital adjustment by the role of resisting medium could possibly bring the orbit of protoplanets more circular and more coplanar.

However, the efficiency of this process still depends on the density ρ of the medium: if the density is low, it may take long time to gives any change. Fortunately, distribution of clouds in the real system would never be homogeneous, so the density would be high enough in some regions. Furthermore, the system before the explosion of protosun was not large as today (if Neptune's orbit is farthest) because the mass of protosun and surrounded materials would greater than the mass of the Sun. Thus, all protoplanets would evolve with small orbit and high velocity; the orbital shift may be fast.

Finally, the question: *"Why our solar system has no retrograde revolving planet?"* is now answered. It is because the motion of retrograde protoplanets (if they exist) would encounter the strong wind of materials; the retarding force acting on them would be very high that could decrease their orbit rapidly till merging with protosun (Woolfson, 2000) or the friction may burned them out to disperse as the hot gas.

3. Solar Explosion

After the nuclear reaction had been ignited by a strongest synchronous radial pulsation of surrounding materials around protosun, the shock condition of explosion ejected all surrounding materials out suddenly with high initial speed over the escape speed at those positions:

$$v_{explosion} = \sqrt{v_{rad}^2 + v_{azi}^2} >> \sqrt{\frac{2GM_{sun}}{R_{ave}}} = v_{escape} \tag{3.23}$$

where R_{ave} is an average radius of surrounding materials. The materials were spread out in all directions, thus it will be more convenient to consider the spreading materials as a hollow sphere shown in Figure 3.7.

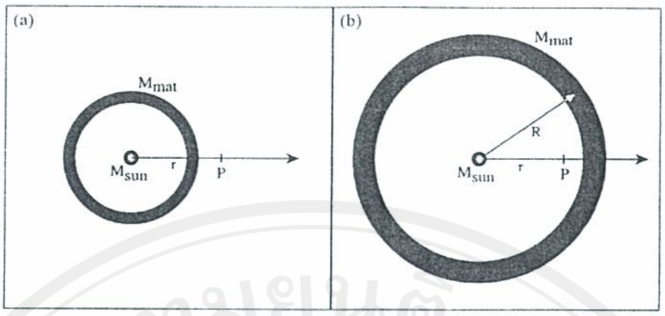

Figure 3.7 Hollow sphere of materials ejected from the Sun.

In Figure 3.7 (a) and (b), the potential energy at point P are given by

$$V_P^{(a)} \cong -\frac{G(M_{sun} + M_{mat})m}{r} \tag{3.24a}$$

and

$$V_P^{(b)} \cong -\frac{GM_{sun}m}{r} - \frac{GM_{mat}m}{R} \tag{3.24b}$$

It is obvious that $\left|V_P^{(b)}\right| < \left|V_P^{(a)}\right|$, thus after the materials cloud had passed, the orbit of protoplanet at point P would be changed via the relation

$$E(r,t) = \frac{1}{2}\mu\dot{r}^2 + \frac{1}{2}\frac{\ell^2}{\mu r^2} - V_P(r,t) \tag{3.25}$$

and Equation 2.16. In this case, the angular momentum is approximately constant.

The result of solar explosion brought protoplanet a new larger orbit; but the eccentricity still depends on the decreasing rate of potential energy, which is more complex.

4. Many-Body Motion

After the explosion, the solar system was cleaned by strong solar wind; every planet (or some still protoplanet) had its own orbit, which may not more circular. The system nevertheless tended to be adjusted again by the effect of many-body motion. In this case, the real equation of motion is given by

$$\mathbf{F}_j = \sum_{\substack{i=1 \\ i \neq j}}^{N} \frac{Gm_i m_j}{r_{ij}^3}\mathbf{r}_{ij} \tag{3.26}$$

where $N = 9$ for the solar system, includes the Sun excepts Pluto.

Although the solution looks complicate, the result is not because the Sun is relatively large compared with all planets and the distances between every object are too far. Thus, the effect of many-body motion on each object is only perturbation; the orbital adjustment by this effect is gradually small.

This model proposed that the orbit of planets were adjusted by those four factors mentioned above; however, there may be some specific condition we have never known, which played together with those factors to create a wonderful characteristics we see today.

For the orientation of planet's spin, this model assumes that protoplanet was formed from a small-and-dense molecular cloud, which can collapse by its own gravity directly without the influences of external forces. Therefore, all protoplanets are independent in their intrinsic properties; for example, spin direction and composition. When they became planets, their spin needed not to point in the same direction and their composition would be different as they are nowadays.

3.3.3 Formation of Satellites

In the molecular cloud cluster, protoplanet was a high-density molecular cloud, which could be collapsed by its own gravity. It would be flat like a disk by the same manner as protosun but cooler. The evolution of protoplanet would be faster because its size is relatively small, compared with a whole system; thus, the materials in a disk could be distributed faster too. The disk would be stable in the form of fragmented rings: the non-homogeneous distribution of material clouds around protoplanet with small radial pulsation like Saturn rings but thicker.

Each fragmented ring could not collapse by its own gravity because its density is not high enough. However, every time protoplanet moved close to protosun, the tidal interaction from protosun would distort the fragmented rings by the role of high-density-regions induction. The fragmented rings would be compressed azimuthally into two active regions to form protosatellites.

The materials of fragmented rings in both active regions were strongly collided together; the heat would be generated, the dusty materials were melted to be the hot molten protosatellites, which grew further and revolved around their protoplanet. The orbit of protosatellites would not high eccentric because the former orbits of fragmented rings are more circular.

Finally, the orbit of protosatellites would be adjusted again by the same processes as planet, mentioned in Section 3.3.2, but faster. The protosatellites eventually cooled down and became the satellites of planet. The simulation results of collapsing ring are shown in Section 4.3.

3.3.4 Terrestrial and Jovian Planets

For the two categories of planets, this model ***hypothesizes*** that all planets, which evolved gradually from protoplanets, must only be jovian planets (Jupiter, Saturn, Uranus and Neptune), while the terrestrial planets (Mercury, Venus, Earth and Mars) were originated from the protosatellite of some innermost protoplanets, which were torn apart during experienced the strong high-density-regions induction by protosun. In the other hand, the terrestrial planet used to be the transient protosatellite of some protoplanet. The basic reason of this hypothesis is that the terrestrial planets are solid, high density and rocky like most satellites whereas the jovian are not: they are gaseous and low density.

To support this hypothesis, let us consider the collision between the comparatively light particle mass m_1 such as a gas molecule, a tiny dust grain, etc and the comparatively heavy particle mass m_2 such as a big dust grain, an icy object, etc, which surrounded the protoplanet. Their mass are very different in contrast, the collision between them should be the cases of $m = m_1/m_2 \cong 0$ in Figure 3.6. In these cases, if the lighter has angular momentum that makes $\ell^{ori} > m$, it will lose its angular momentum or gain the negative. The light particles, especially gas molecules, would be lost their orbit and fallen into the center, while the heavy particles obtained their new larger obit. Therefore, most central mass of protoplanet would be the accretion of light elements or light molecules such as H_2, He, CH_4, etc while the surrounding materials composed with the heavy elements or heavy objects.

The protosatellite that formed from the high-density-regions induction should be rocky rather than gaseous because most of rocky materials had surrounded the protoplanet. Moreover, rocky materials can be melted by collision to form a molten chunk better than the gas molecules. Then the terrestrial planet, the next generation of protosatellite, would be rocky.

3.3.5 Rotation of Solar System

This model ***suggests*** that the solar system would rotate in the direction opposite to the rotational direction of galaxy because the rotation of induced high-density regions tends to be *retrograde* against the rotation of whole system as shown in Figure 3.8 and simulation results in Section 4.3.

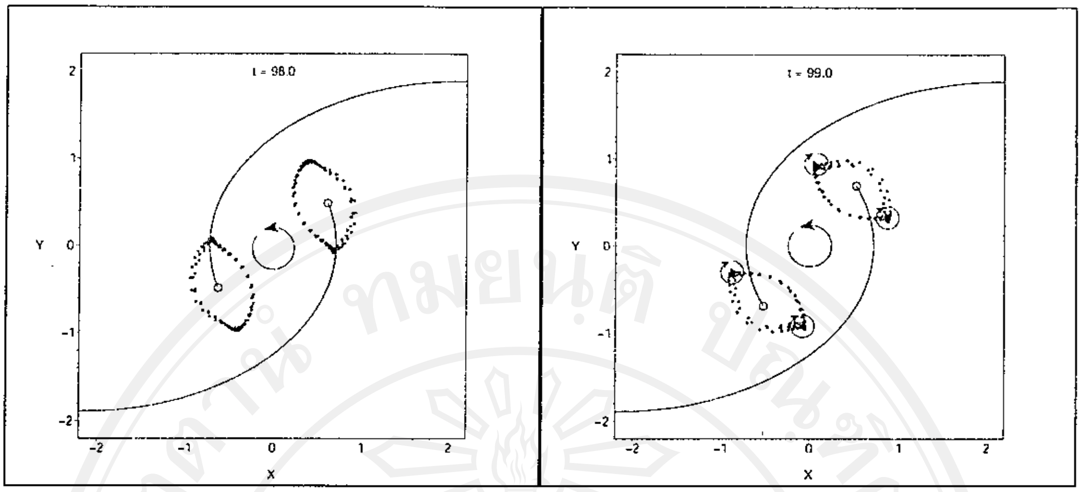

Figure 3.8 Retrograde rotations of induced high-density regions against rotation of system.

This suggestion fit with the observational data: the solar system rotates counterclockwise while the galaxy is clockwise; they are relatively retrograde. The motion of solar system and galaxy is shown in Figure 3.9.

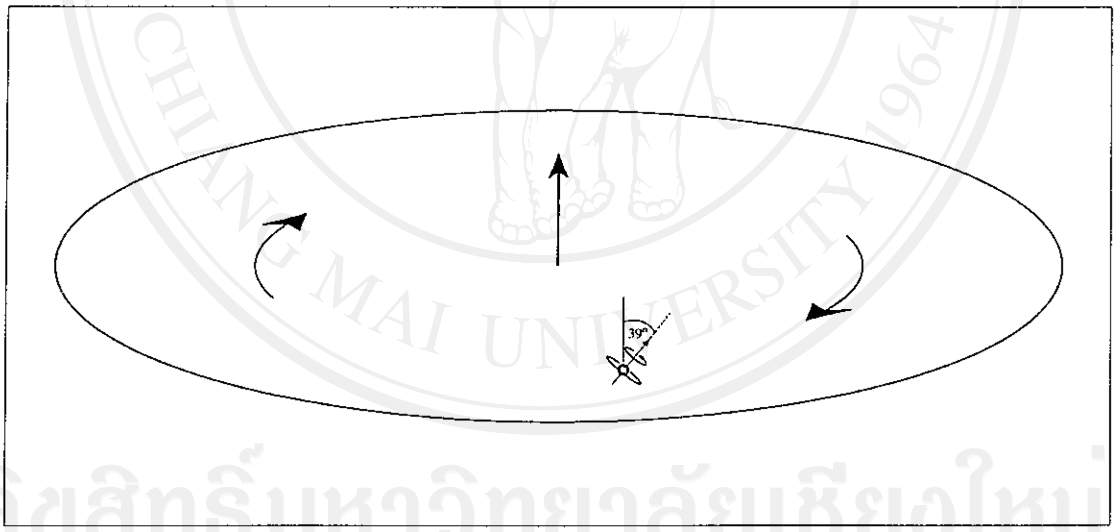

Figure 3.9 Rotation of solar system compared to galaxy is retrograde. Note that the spin of galaxy does not belong to the right-hand rule.

3.4 Summary

The solar system, in this model, was made from the molecular cloud cluster (Section 3.1) that had been activated to collapse by high-density-regions induction between the primordial Milky Way Galaxy and nearby protogalaxy. Motion of all objects in the cluster was Keplerion that made the system pulsated radially. Protosun was accreted by the role of orbital collision at the center with variation of pressure and temperature belongs to the radial pulsation of the surrounding materials (Section 3.3.1).

Some high-density molecular clouds could be collapsed by its own gravity to form protoplanet. When it moved closing to protosun, the tidal induction would induce the fragmented material rings around it to collapse azimuthally to form protosatellites (Section 3.3.3). The orbit of protoplanets would be mainly adjusted to be more circular and coplanar by the role of motion in the resisting medium (Section 3.3.2). Some innermost protoplanets, which experienced strong tidal induction, would be torn apart; some of their survived protosatellites later cooled down to form terrestrial planets (Section 3.3.4).

Some evidence that may support this model is the retrograde rotation of the solar system against the rotation of galaxy. This can be explained by the simulation result of high-density-regions induction, which shows that the rotation of induced high-density regions is retrograde against the rotation of system (Section 3.3.5).