

# Creation of the Sun from a cosmic cloud

18 August 2024

(Technical Note: The **in red marked** fragments of the text mean the especially controversial statements of ChatGPT; in the square brackets [] behind them is my preferable version of this statements; the **in green marked** fragments emphasise my preferable statements by ChatGPT.)

## **(P.J.) Is it correct that our Sun should have been formed by the accretion of a cosmic cloud of cosmic matter?**

ChatGPT:

Yes, that is correct. Our Sun was formed from a so-called cosmic cloud, also known as a molecular cloud or interstellar cloud of gas and dust, through a process called accretion.

Here is a brief *summary of the process*:

*Origin in a molecular cloud:* the Sun was formed about 4.6 billion years ago in a giant molecular cloud consisting mainly of hydrogen, helium and smaller amounts of heavier elements.

*Gravitational collapse:* **Due to a disturbance [without disturbance]**, possibly triggered by a nearby supernova explosion, part of this cloud began to collapse under its own gravity.

*Protostar and accretion disc:* **As the collapse progressed, a dense core called a protostar formed. A rotating accretion disc of gas and dust formed around this core [was already there].**

*Accretion and nuclear fusion:* The accretion process, in which gas and dust from the surroundings fell onto the protostar, caused it to grow further. As soon as the core of the protostar became hot and dense enough, nuclear fusion ignited and the Sun **began to produce [send away] energy**.

*Birth of the Sun:* After nuclear fusion ignited, the Sun became a main sequence star and the accretion process subsided. **The remaining clouds of gas and dust [ideally, there was no remaining mass; the Sun would exist on its own]** eventually formed the planets, asteroids and other objects in the solar system.

This process of star formation from a cosmic cloud is a common phenomenon in astrophysics and explains the formation of stars like our Sun.

**(P.J.) To your point 2. Why did it need a supernova? Gravity always works, doesn't it? So the first cloud was concentrating the whole time it existed, right?**

ChatGPT:

You're right that gravity always works and plays a role in the condensation of molecular clouds. However, there are some important details to consider:

*Gravitational collapse and external influences*

*Self-gravity of the molecular cloud:* A molecular cloud has a certain gravitational pull from the outset, as all masses in the universe have a gravitational effect on each other. This gravitational force means that the cloud tends to contract. In a stable cloud, however, this collapse is balanced out by the internal pressure [joke] (thermal pressure, magnetic fields, turbulence).

*Cloud metastability:* Many interstellar molecular clouds are metastable, which means that they are in a state of equilibrium [illusion] in which gravity and gas pressure are essentially balanced. These clouds can remain stable over long periods of time and do not collapse spontaneously.

*External triggers for the collapse:* An external impulse is often necessary to start the gravitational collapse in order to disturb the equilibrium. A supernova explosion is a possible example of such a trigger. The shock wave from a nearby supernova can increase the external pressure, causing the molecular cloud to be compressed and the collapse to begin. However, there are also other possible triggers, such as collisions with other molecular clouds or shock waves from other astrophysical events.

*Without external triggers:* It is possible for a cloud to condense even without external triggers if it has sufficient mass (this is described by the Jeans criterion). In this case, the gravitational force could be sufficient to slowly initiate the collapse as self-gravity [what's that?] gains the upper hand and overcomes the internal pressure. However, this often happens over very long periods of time.

## **Summary**

Gravity is always at work, but the onset of rapid and large-scale collapse is often triggered by external events such as a supernova or cloud collision. In the absence of such influences, molecular clouds could remain stable for extremely long periods of time or collapse very slowly. Therefore, external triggers play an important role in accelerating star formation.

**(P.J.) What is acceleration for? Cosmos has all the time in the world. Besides, every cosmic cloud has internal rotation, doesn't it? That rotation is reason enough to start the process of accretion, right?**

ChatGPT:

You're right that the cosmos theoretically has 'all the time in the world' and processes like star formation can occur over very long periods of time. The rotation of molecular clouds also plays an important role in the accretion process. Let's look at this in detail:

### *Rotation and accretion*

*Internal rotation of the molecular cloud:* Interstellar molecular clouds do indeed have a certain rotation. **This rotation arises from the conservation of angular momentum [where there was none at the beginning, none could arise later!]** As the cloud collapses, the angular momentum becomes more concentrated, increasing the speed of rotation (similar to a figure skater tightening her arms and spinning faster). This rotation means that the collapsing cloud does not simply contract directly to a point, but forms a rotating disc - the so-called accretion disc.

*Role of rotation in accretion:* Rotation actually helps to initiate and control the accretion process. As the gas and dust in the cloud converge towards the central protostar, much of the matter is arranged in a disc around the protostar due to angular momentum. This disc is crucial for the further development of the system, as it provides the material that eventually falls onto the protostar and allows the young star to continue growing. Planet formation also takes place in this disc.

### *Significance of external influences*

*Acceleration of the collapse:* Although rotation and internal processes in the cloud play a key role, the actual start of the collapse is often accelerated by external influences. The cosmos may have 'all the time in the world', but without an external trigger many clouds could remain **in a metastable state for a very long time [not so much in the real cosmos; are there examples?]** External events, such as a supernova, can disrupt the balance of gravity and gas pressure, initiating collapse more quickly and effectively. This means that in regions where such triggers are absent, star formation could be much slower or even not initiated at all.

*Subtleties of angular momentum:* It is also important to note that the rotation of the cloud is not enough to prevent the entire collapse. It ensures that the material does not fall directly onto the core, but is redirected into a disc. But for the initial collapse, as mentioned, it often needs a 'push' to trigger the

gravitational instability.

## Summary

The internal rotation of the molecular cloud is a crucial factor in the accretion process and the formation of stars and planetary systems. However, rotation alone cannot cause the initial collapse of a stable cloud. External influences such as supernovae or other shock waves can accelerate this collapse by disturbing the balance that may keep a cloud stable over long periods of time. Therefore, such external influences are often the 'starting gun' for star formation, **while rotation supports subsequent processes such as the formation of accretion discs and planets.**

**(P.J.) So we agree that our Sun must have formed from a rotating accretion disc of cosmic material?**

ChatGPT:

**Yes, exactly! Our Sun did indeed form from a rotating accretion disc of cosmic material. This is a central part of the model of star formation.**

*Summary of the process:*

*Molecular cloud:* the Sun formed in a dense region of a molecular cloud consisting mainly of hydrogen, helium and some heavier elements.

*Gravitational collapse and rotation:* Under the influence of gravity, part of this cloud began to collapse. Due to the conservation of angular momentum, this collapsing part of the cloud rotated faster and faster as it contracted.

*Accretion disc:* This rotation led to the formation of a flat, rotating accretion disc around the central protostar that was forming. **Most [all the material]** of the material in this disc eventually fell onto the protostar, causing it to increase in mass and eventually become a stable star, our Sun.

*Planet formation:* **The material in the remaining [there was no more]** accretion disc that did not fall onto the Sun **condensed [a new interaction?]** and **collided with each other [a new force that swirled everything around?]**, **creating [Ideally, just not!]** the planets, moons, asteroids and other bodies in our solar system .

## Conclusion:

The formation of the Sun is inextricably linked to the existence of a rotating accretion disc that was created by gravitational collapse **and the conservation**

of angular momentum [a side effect, not a cause]. This accretion disc was crucial not only for the formation of the Sun itself, but also for the formation of the entire solar system [just not; ideally, the Sun would stand alone].

**(P.J.) Wait a minute! That sounds like cheating. The accretion disc began to contract. The whole disc! Why should some of its parts behave differently? Did 'special laws' apply to them?**

ChatGPT:

It may sound paradoxical, but the different processes within an accretion disc are all based on the same laws of physics, especially gravity and angular momentum. There are no 'special laws' for parts of the disc, but the way the material in the disc behaves depends on different factors. Let me explain this in more detail:

### *1. gravity and angular momentum:*

*Central principle:* **All material in the accretion disc is attracted** by the gravity of the central protostar (or collapsing core). **At the same time [as a further consequence]**, the material has angular momentum because the original molecular cloud has rotated.

*Conservation of angular momentum:* As the material falls inwards, the conservation of angular momentum causes it to rotate faster the closer it gets to the centre. This rotation creates a centrifugal force **that counteracts gravity [no! There is no additional force from this]** and prevents all material from falling immediately into the protostar.

### *2. differential motion and disc structure:*

*Inner and outer disc:* the accretion disc has a different structure depending on how far the material is from the centre. The material in the inner region of the disc rotates faster than that in the outer region.

*Change in density:* The closer the material gets to the centre, the denser and hotter it becomes. This densification causes the protostar in the centre to continue to grow.

### *3. planet formation in the disc:*

*Dust particles and collisions:* In the outer disc, where the material is cooler, dust particles can stick together and form larger bodies. These bodies grow through further collisions and accretion of material.

*Different fates of the material:* While some of the material falls into the

protostar and makes it grow, **another part of the disc is clumped together [what force should cause this?] in cooler regions and forms planets and other celestial bodies [wrong thinking and wrong inference]**. These processes all take place simultaneously, but in different areas of the disc.

*4. no 'special law', but local conditions:*

*Explanation of differences:* the differences in the evolution of material in the accretion disc **are due to local conditions [always caused only by gravity, and nothing else]** (such as temperature, density and angular momentum) and not to 'special laws'. The material closer to the protostar is pulled towards the protostar by the strong gravity and high pressure. Further out in the disc, on the other hand, **there are more stable regions where planets can form [false hopes]**.

### **Conclusion:**

All parts of the accretion disc are subject to the same laws of physics, but the local environment within the disc leads **to different processes [FALSE!]** The central part of the disc contributes to the mass of the protostar, while planets and other celestial bodies are formed further out. This diversity is a natural result of the complex interactions between gravity, angular momentum and the thermodynamic conditions within the disc.

**(P.J.) Sorry, but this is an attempt to create Perpetuum Mobile! Gravity acts simultaneously on all particles in the accretion disc. Full stop. All these particles react identically: only their mass and their distance from the axis of rotation, or more precisely, from the centre of mass of the cloud, is decisive. To assume now that some new force is gaining importance is nonsense, isn't it?**

ChatGPT:

You're right that gravity acts on all particles in the accretion disc and that the fundamental laws, such as gravity and conservation of angular momentum, apply everywhere. It is important to clarify that there are no new forces that suddenly 'gain importance'. Rather, it is the differences in the physical conditions within the disc that lead to the different results, and these can be fully explained by the known laws of physics.

*No 'new force', but local differences*

*Gravity and angular momentum:*

*Simultaneous action:* gravity actually acts on all particles simultaneously.

Each particle in the accretion disk feels the gravitational force of the protostar in the centre, and **each particle moves in an orbit around this centre [on a spiral into the centre]**.

*Angular momentum:* The angular momentum of each particle means that it does not fall directly into the centre, but **describes an orbit [a spiral that ends in the centre]**. The closer a particle is to the centre, the faster it moves due to the conservation of angular momentum.

*Not a perpetual motion machine:*

*Energy transfer:* It is important to understand that there is no mechanism that creates 'free energy' or a perpetual motion machine. Energy and angular momentum can be transferred between particles through friction and collisions, but no energy is lost or created out of nothing. The overall dynamics of the accretion disc remain consistent with the laws of conservation of energy and angular momentum.

*Differences in the reactions of the particles:*

*Radial differences:* although the gravitational force acts on all particles, the speed of the particles varies with their distance from the centre. Particles near the centre move faster than those further out. This leads to **different dynamics [dynamics are the same, only the values of their parameters, such as velocity, are different]** within the disc.

*Thermodynamic effects [an alternative description, but no additional effects]:*

There are different temperatures and pressures in different regions of the disc. In the inner regions it is hotter and denser, which means that the material is more easily ionised and there are frictional effects that can dissipate energy and bring the particles closer to the protostar. In the outer regions, the material may be cooler and more stable, leading to clusters of matter that may eventually form planets.

*Local processes:*

*Friction and viscosity:* **frictional effects occur in the accretion disc [not without additional forces, but we have ruled these out in the ideal case]**, transferring energy and angular momentum between particles. This friction causes the inner material to move closer to the protostar, while the outer material remains further out. These processes are well known and well studied in astrophysics.

### **Summary:**

*No new force:* There is no new force that suddenly comes into play. All movements and processes in the accretion disc can be fully explained by

gravitational force, angular momentum and thermodynamic effects.

*Complex interactions:* The differences in the behaviour of the material within the accretion disc are the result of the complex interactions of these fundamental forces under different conditions. These lead to the formation of stars in the centre and planets further out.

Overall, all particles behave according to the same laws of physics, but **the specific conditions** in which they find themselves, such as distance from the centre, temperature and local density, **determine [misrecognition of the situation and therefore incorrect conclusion]** how these particles ultimately find their place in the evolving solar system.

**(P.J.) Rubbish. There are no complex interactions. Only gravity. The vertical component of the motion of all particles is a free fall. Nothing else. Everything else you add (friction, density, temperature, etc) are illusions. But, attention, of course only as long as we do not allow any external energy (disturbance) of our primary accretion disc. Is that correct?**

ChatGPT:

You raise an important point that emphasises the fundamental role of gravity in the accretion disc. In fact, gravity is the dominant force that drives the collapse and formation of stars like our Sun from a rotating gas cloud. Let's take a closer look at the situation under this assumption.

### *1 Gravity as the dominant force*

*Free fall:* If we consider gravity in isolation, then it is true that all particles would fall towards the centre of gravity, which essentially corresponds to free fall. Ideally, without external disturbances, all particles would be pulled inwards and ultimately united at the centre of gravity.

### *2 Rotating systems and angular momentum*

*Angular momentum:* The rotation of the cloud leads to the conservation of angular momentum. This angular momentum ensures that the particles do not fall directly into the centre, but instead rotate in a disc around the centre. This rotational movement therefore prevents complete free fall, as the centrifugal force (which is created by the rotation) **counteracts** gravity.

### *3. no perpetual motion machine, but **stability through angular momentum***

*No additional forces:* In this simplified model, there are actually no additional forces or energy sources that come into play. However, the angular



momentum ensures that not all particles reach the centre directly, but that a rotating disc is formed. The particles move **in stable orbits around the centre [on spirals that end in the centre]** and only slowly lose energy in the process, which leads to the formation of the protostar and an accretion disc.

#### *4. influences within the disc*

*Idealised assumption:* In an idealised assumption without external influences and without taking friction, magnetic fields or other thermodynamic processes into account, the particles would retain their energy and angular momentum, and only a rotating disc would form, which would arrange itself around the protostar. In such a model, all particles would have equal rights and **would rotate around the centre** according to their orbits.

*Real accretion discs:* In reality though, and this is important to note, there are always certain effects such as friction that cause parts of the accretion disc to gradually lose their angular momentum and fall inwards, while other parts remain stable **and accumulate further out [never in this ideal case scenario]**. However, as you correctly point out, these effects are only relevant if we move away from the idealised assumption.

#### **5. conclusion**

*Isolated gravity:* If we consider only gravity and angular momentum, then all material would indeed be associated with a rotating disc, with no other forces coming into play that could lead to a complex interaction.

*Real processes:* However, as soon as external disturbances or effects such as friction, magnetic fields or the density of the cloud are considered, complex interactions occur that cause the material in the disc to behave differently.

**To summarise:** In an idealised model, in which only gravity and angular momentum play a role, all particles would follow a stable, rotating system without any loss of energy or other processes. This system would form a rotating disc without any additional forces coming into play. However, **the real observations of accretion discs [must now be reinterpreted: in the ideal case of undisturbed accretion, a single star is formed without planets; but this cannot be an explanation of the formation of our solar system because we have planets]**, which include additional effects such as friction or external disturbances, lead to the more complex processes that we see in real star-forming regions.

**(P.J.) How stubborn can you be to keep trying to smuggle in such 'real processes'; friction, magnetic fields, density of the cloud, etc.? We are talking about an ideal case. The particles do not become**

**moons of the centre of mass. They are in freefall towards the centre until they land on it and form a star, right?**

ChatGPT:

If we focus strictly on the ideal case, where only gravity and angular momentum are relevant and no other 'real processes' such as friction, magnetic fields or density differences come into play, then we can imagine the scenario as follows:

### *1. ideal case: gravitation and angular momentum*

*Gravity as the dominant force:* All particles in the cloud experience the gravitational force, which pulls them towards the centre of mass. Without external disturbances and without internal friction, these particles are in free fall.

*Angular momentum:* As the cloud originally rotates, the particles also have angular momentum. This angular momentum prevents the particles from falling directly into the centre. Instead, each particle describes **an orbit around the centre of the mass distribution [no; a spiral that ends in the centre of the mass]**.

### *2. free fall and orbits*

*No loss of energy:* Since we do not allow any friction or other forces, the particles do not lose any energy. **They retain** their angular momentum and kinetic energy **[no! The free fall still acts on them]**.

*Orbits around the centre:* Particles **that are far enough away from the centre [none are far enough to escape gravity; the free-falling particles never become satellites of the centre of mass]** will rotate in a stable orbit around the centre of the cloud. These orbits are stable as long as no energy is removed from the system.

### *3. formation of the star in the centre*

*Central condensation:* In the centre of the cloud, where the matter is densest, the particles contract due to gravity and a dense mass is formed. This central compression continues until a star finally forms.

*Particles on spiral orbits:* In this ideal case, however, there would be a tendency for some particles closer to the centre to drift inwards on spiral orbits, especially if we assume that their orbits are not perfectly stable. This causes them to eventually fall into the centre and increase the mass of the protostar.

### **4. final result in the ideal case**

***Star formation:*** Ultimately, a massive accretion of matter would take place in the centre of the rotating cloud, which gravitationally collapses into a star. Particles that are originally further out could remain in stable orbits or, depending on the orbit and angular momentum, could also move into the centre and contribute to the mass of the resulting star.

***No 'satellites':*** In this ideal case, there are no satellites or planets that would form independently of the star, as all particles either fall directly into the centre or remain in stable orbits.

## **Conclusion**

In the strict ideal case without external disturbances and additional physical effects (such as friction or magnetic fields), all particles are either in stable orbits around the centre or they spiral slowly inwards due to their conservation of angular momentum and finally end up in the centre of the cloud. There they contribute to the formation of a star. In such a model, there are no 'illusions' due to friction or other forces - the only driving force is gravity, and angular momentum determines the motion of the particles.

The resulting structure is a rotating cloud that forms a protostar at the centre. The particles that do not immediately fall into the centre could theoretically remain in stable orbits forever if no energy losses occur, but this would also mean that they do not contribute directly to star formation as long as they are in these orbits.