# Comparing the standard view and TGD vision of the formation of astrophysical objects

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## Contents



**Abstract**

I learned of a very interesting empirical finding related to the attempts to understand the process leading to the formation of light molecules $H_2$ and HD from atoms. According to the standard view, this process precedes the ignition of the nuclear fusion made possible by gravitational condensation. This process is not so well-understood as one might think and the findings challenge the prevailing view.

The gravitational collapse leading to the formation of a star requires low temperature and large enough mass. In the formation of first stars, $HeH^+$ molecules act as coolants of the gas cloud. In standard view, this helps to reach gravitational instability inducing a gravitational collapse leading to the formation of a star and initiation of nuclear fusion. The surprise was that the rate for the reactions removing the coolant does not decrease with temperature as expected. This finding challenges the prevailing view about the formation of the first generation stars and inspired the comparison of the standard view of the formation of galaxies, stars and planets with the TGD view.

# 1 Introduction

The gravitational collapse leading to the formation of a star requires low temperature and large enough mass. In the formation of first stars, $HeH^+$ molecules act as coolants of the gas cloud. In standard view, this helps to reach gravitational instability inducing a gravitational collapse leading to the formation of a star and initiation of nuclear fusion. The surprise was that the rate for the reactions removing the coolant does not decrease with temperature as expected. This finding challenges the prevailing view about the formation of the first generation stars and inspired the comparison of the standard view of the formation of galaxies, stars and planets with the TGD view.

## 1.1 The standard view

First a brief summary of the standard view of early cosmic evolution leading from the formation of neutral atoms to the ignition of nuclear fusion.

1. In the beginning there was plasma: hydrogen and $^4$Helium ions dominated but also Lithium ions were present.

2. As 380,000 years had passed, the temperature was so low that electrons could bind to atomic nuclei for form neutral atoms. Radiation decoupled from matter at temperature $T \sim .3$ eV. $^4$He stabilized first because of its high binding energy.

3. As temperature lowered further, chemical reactions producing molecules became possible. $^4$He $H^+$ was the first molecule that formed. The reactions $^4HeH^+ + H \rightarrow {}^4He + HH^+$ and its counterpart with H replaced with D, took place. $H_2$ and HD were produced from the final state and they became stable as the temperature lowered. Their presence was a prerequisite fusion at sufficiently high temperatures and densities. As 200 million years had passed, the temperature started to increase by gravitational condensation and the fusion was ignited.

4. For the formation of stable molecules, it was important to achieve a sufficiently low temperature and cooling was needed. States with a sufficiently low energy difference scale, in which energy was stored and from which it was then radiated away, were needed.

   This allowed the cooling to proceed to low temperatures quickly and the formation of molecules, especially $H_2$ and HD, became possible. $^4HeH^+$, for which the rotational temperature can be low, is a good candidate for a coolant. $^4HeH^+$ absorbs energy into rotational degrees of freedom and radiates it away.

   However, $^4HeH^+$ +D produced $^4$He + $HD^+$ and by the electron recombination $^4HeH^+$ so that the coolant was lost. On the other hand, the final states produced $H_2$ and HD molecules, with a binding energy of about 5 eV needed in fusion. They were stabilized by the presence of the coolant.

5. Gravitational condensation heated the system and ignited nuclear fusion by releasing a huge amount of heat.

## 1.2 Observations

What was observed in the experiments was as follows.

1. The experiment was carried out around $T = -267$ C. Both electron recombination and the reaction $^4HeH^+ + D \rightarrow {}^4He + HD^+$ involving proton exchange lead to the removal of $^4He H^+$ and the cooling efficiency decreased.

   According to standard model thinking, this reaction should slow down at low temperatures as this requires thermal energy so that the cooling efficiency would not be affected.

2. The surprise was that the reaction rate did not decrease as a function of temperature as predicted by the models so that the cooling efficiency decreased. $^4HeH^+ + D \rightarrow {}^4He + HD^+$ would have cooled the gas faster than assumed when $20 < z < 300$. On the other hand, it would have produced $H_2$ and HD more efficiently.

In the standard scenario, the fusion would have been ignited earlier than assumed. As a non-professional, I can ask an innocent question whether the densities of these molecules could have remained too low for the ignition of the nuclear fusion after gravitational condensation to take place?

3. As already noticed, there are two mechanisms for the elimination of $^4HeH^+$. What is essential for fusion is not so much the removal of coolant but the production of $H_2$ and DH necessary for the ignition of the fusion.

   In the $z < 20$ region, where the rate of electronic recombination would be very small for $^4HeH^+$ and recombination would not contribute to the removal of coolant.

### 1.3 How to understand the strange temperature independence in the TGD framework?

The article mentions a model that could explain the naively unexpected temperature independence. The following proposal for the strange temperature independence relies on the new physics predicted by TGD.

1. In TGD new physics could be involved regardless of whether the reaction is important for star formation or not. In the standard framework the reaction seems to require tunnelling through a potential barrier. Thermal energy would make this possible. In the proposed model this would not produce a dependence on temperature, in other words there would be no potential barrier. This looks somewhat strange to me.

2. How would the reaction then occur in the TGD Universe? The view of analog of dark matter as large $h_{eff}$ phases of ordinary matter residing at magnetic monopole flux tubes suggests an answer. The proton could temporarily transferred from the $^4HeH^+$ to a dark proton at a monopole flux tube and the flux tube to a bound state partner of D to give $H^+D$, which would transform by after electron transfer to $HD^+$.

During years I have developed a rather detailed view of TGD based cosmology and astrophysics [L11, L9, L10, L12] and the above considerations inspired the idea about collecting the basic ideas of the TGD vision and comparing the standard view of the formation of galaxies, stars and planets with the TGD view. This also allowed to unify the rather unorthodox TGD based views about the formation of galaxies, stars and planets to a single logically coherent vision.

## 2 Comparing the standard view of the formation of galaxies, stars and planets with the TGD view

Star formation is not so well understood as one might think. TGD approach even inspires the question whether it is actually possible to understand the gravitational generation of sufficiently large local densities needed to ignite the nuclear fusion.

According to the standard view, a gravitational instability leads to a formation of gravitational bound states such as stars and planets. The generation of gravitational instabilities is opposed by the pressure gradient of the condensing gas. The generated heat must be radiated away to keep pressure low and in this way make gravitational instabilities possible. Therefore a coolant is needed. In the example considered, the disappearance of the coolant would produce $H_2$ and HD. At some point, however, the temperature must increase by gravitational condensation to a high enough value for the fusion to start. Can this situation be reached at all?

### 2.1 The formation of stars and planets in the standard framework

Gravitational instability plays a crucial role in the formation of stars and planets. Regions of high density in space, such as giant molecular clouds, become gravitationally unstable when the inward pull of gravity overcomes the outward pressure of the gas. This instability leads to the collapse of these regions, eventually forming stars. Google search gives nice AI summaries about the standard view of the formation of stars and planets by gravitational collapse and are warmly recommended for the interested reader.

The force due to the pressure gradient competes with gravitation. Gravitational instabilities are eliminated by the generation of sound waves as density and pressure oscillations. The slower the sound velocity $c_s$, the higher the stronger the tendency for the generation of gravitational instability. $c_s$ is determined by the ratio of pressure and mass density. For ideal gas, the pressure is proportional to the temperature. The lower the pressure and temperature and the larger the total mass of the cloud, the stronger the tendency to collapse gravitationally.

Jeans criterion (see this) can be given in terms of the Jeans length $\lambda_J$ defining the minimal size of the spherical cloud above which it suffers a gravitational collapse. By dimensional analysis based on the above picture one can deduce the expression for the $\lambda_J$ as $\lambda_J = c_s/\sqrt{G\rho}$. From this one can deduce Jean's mass in terms of Jean's length.

Similar mechanism applies in the model of the formation of planets from a 2-dimensional disk, which is rotating. Typical instabilities are spiral waves assigned to the spiral galaxies. Besides the generation of sound waves, rotation also tends to oppose the gravitational collapse.

The Toomre's stability criterion makes it possible to estimate when the system becomes unstable against gravitational collapse. The Toomre's parameter (this) is a dimensionless number determined by dimensional considerations based on the proposed general physical view and given by $Q_{gas} = c_s\omega/G\sigma$, where $\omega$ is rotational velocity and $\sigma$ is the surface mass density. For $Q_s \leq 1$ the situation becomes unstable against gravitational collapse. Also shear instability is possible.

## 2.2 How could galaxies form in the TGD Universe?

Consider first a possible mechanism for the formation of galaxies in the TGD Universe.

1. TGD leads to a vision of the formation of galaxies and stars [L11], which is very different from the standard vision based on gravitational collapse. In the simplest version of the model, the formation of monopole flux tube tangles from thickened long cosmic strings (4-surfaces with 2-D $M^4$ projection) would generate galaxies to galaxies. This explains the finding that galaxies tend to form linear structures. It also correctly predicts the flat velocity spectrum of distant stars around the galaxy. Galactic dark matter would correspond to the classical energy of the cosmic string consisting of volume energy and Kähler magnetic energy.

   The subtangles of the galactic tangles would in turn produce stars, or rather the first star generation. The mechanism of star formation would be completely different than has been believed and proceed from long scales to short scales by explosion rather than vice versa by gravitational collapse.

2. The gravitational instability would be replaced with the instability of a cosmic string or monopole flux tube against thickening, which transforms its classical Kähler magnetic and volume energy to ordinary matter. This process is somewhat analogous to a decay of the inflaton field [L11]. The outcome would be flux tube tangle. For blackhole-like objects this flux tube tangle would fill the entire volume.

3. In the case of galaxies, this instability could be induced by the topologically unavoidable intersection of two cosmic strings or flux tubes topologically condensed at a larger space-time sheet.

   At the level of embedding space, the intersections of cosmic strings consist of a discrete set of points of $CP_2$ but if their Hamilton-Jacobi structures are identical, the intersection consists of 2-D string world sheets. Denote the transversal long cosmic strings by A and B. A could turn and run parallel to B before turning back to its original direction. A triple cosmic string would be formed if A turns, runs parallel to B and returns parallel to B before continuing in the original direction.

   For cosmic strings the union would correspond to a double or triple string world sheet and a discrete set of points of $CP_2$. The two strings would be parallel in the central region and transversal outside it. A possible interpretation could be in terms of galactic bar and bulge.

The TGD view challenges the standard cosmological narrative.

1. The origin of the CMB might not be the same as in the standard model. There are empirical findings, which force to challenge the view that CMB was formed as neutral atoms were formed [L13] (see this). The formation of galaxies and stars by the TGD based mechanism could have contributed considerably to the CMB. In the TGD framework, it is not clear how high the density of plasma and gas was before the formation of first stars and galaxies by this mechanism.

2. The TGD framework also suggests a dramatical modification of the narrative about the first 3 minutes leading to the formation of the atomic nuclei if ordinary matter is generated in the phase transitions thickening cosmic strings and already existing monopole flux tubes and liberating energy as ordinary matter. This transformation could be occurring even in the surface layers of stars and produce their radiation and stellar wind [L12].

## 2.3 How could stars form in the TGD Universe?

Also the TGD view of the formation of stars differs from the standard view.

1. Stars can be classified to populations I and II. Population I consist of young metal rich stars. Population II consists of old metal poor stars. Standard cosmology also predicts population III consisting of the very old first generation stars but its existence has not been demonstrated empirically. A possible explanation is that they are very massive and therefore short-lived. Population III stars should have formed from neutral gas consisting mostly of light atoms whereas other populations could have formed from the supernova remnants of the earlier generations.

   Population I stars reside at the arms of spiral galaxies and population II stars in the region of the galactic bulge. Could the intersection of the cosmic string, transverse to the galactic plane with a cosmic string in the galactic plane, explain populations I and II. Could the intersection of cosmic strings, giving rise to double or even triple cosmic string, explain the bulge and galactic bar and also explain the differences between population I and II. Could star formation have started in the collision regions and proceeded to the arms? There is no obvious candidate for population III stars in the TGD Universe.

2. The notion of star generation is central in the standard astrophysics: the remnants of a star generated in a supernova explosion would serve as a material for the stars of the next generation. In the standard model of stellar core, this could explain the evolution of the metallicities.

Could the gravitational condensation as a mechanism for the formation of higher star generations have a TGD counterpart?

1. Zero energy ontology (ZEO) [L4, L8] predicts that the TGD counterpart of the ordinary state function reduction (SFR) reverses the arrow of geometric time. These SFRs a predicted to be possible even in astrophysical and cosmological scales and could explain stars older than the Universe. Two BSFRs would give rise to a temporary time reversal and to a rebirth of the system. In astrophysics this could mean the birth of a new star generation from the remnants of a supernova explosion [L14].

2. This view forces us to consider a non-standard view of stars themselves [L12]. Stars would be local tangles along a long galactic cosmic string. They could form networks connected by monopole flux tubes connecting them also to the galactic nucleus and possibly also galactic blackhole-like objects.

   Nuclear fusion in the stellar interior might not be necessary since radiation and solar wind would be produced at the surface layers of the star. New hadron physics, I have called it $M_{89}$ hadron physics having mass scale scaled up by factor 512, would play a key role and the decay of $M_{89}$ hadrons to ordinary $M_{107}$ hadrons at the surface layer would produce stellar wind and stella radiation. If fusion occurs in the interior at all, it could be dark fusion. Also the planetary formation could involve dark fusion. This process could be seen as a special case of a process analogous to inflaton decay in which the energy of a local tangle of thickened long cosmic string transforms to ordinary matter and radiation [L11].

## 2.4 About the formation of planets in the TGD Universe

In TGD, I have considered the possibility that dark fusion as the TGD counterpart of "cold fusion" occurs as the first step in the ignition of nuclear fusion. Dark fusion need not lead to the ignition of ordinary nuclear fusion and could give rise to the formation of planets. Also higher star generation could involve dark fusion.

1. Dark fusion, explaining the so called "cold fusion" anomaly [L1, L5, L2], is one of the basic predictions of TGD distinguishing it from the standard model. In principle, dark fusion could heat the gas to a sufficiently high temperature so that the ordinary nuclear fusion could start. Gravitational instability should first increase the density of the matter to a sufficiently high level to initiate dark fusion. The required temperature would be much lower than needed to initiate ordinary fusion. It is also possible that the ordinary fusion is not initiated at all and only dark fusion takes place. This could be the case for planets in the TGD based model for their formation [L9, L11],

2. The above discussed two reactions involving $^4HeH^+$ could serve as the precursor of dark fusion involving dark protons and produced $H_2$ and DH. I have proposed that this could have occurred outside stars and could have been important even in the planetary formation.

3. I have discussed a non-standard model for the planetary formation assuming that the planets are generateed in "mini Big Bangs" exploding a layer of the Sun [L9, L10, L11, L12]. This surface would suffer a gravitational collapse to form a planet. This process would be the TGD analog of what is assumed to happen for the proto-planetary disk in the standard model but dark fusion would replace ordinary fusion and explain why ordinary nuclear fusion is not ignited.

## 2.5 The notion gravitational magnetic body and the mysterious shortening of the day by 1.6 ms

One of the basic predictions of TGD is that quantum coherence is possible in astrophysical and even cosmological scales. Classical gravitational/ electric fields would be accompanied by phases with very large gravitational/electric Planck constant [K1, K2] [L3, L6, L7]. Various numerical miracles support this prediction.

I encountered an interesting posting in the Deep in Space group providing additional support for an effect supporting the notions of magnetic body and gravitational Planck constant. A shortening of the day by 1.6 ms would be in question. I also found a popular article about the effect (see this). There are many effects causing a variation of the length of the day but the shortening of the day has not found any convincing explanation in terms of the known physics.

Here is the copy of the posting of the Deep in Space group:

*On multiple days this summer including July 22 and August 5 — Earth spun faster than usual, making the day shorter by up to 1.6 milliseconds. Even July 11 was confirmed by atomic clocks as the shortest day of 2025 so far. This isn't just a one-off quirk. The unusual speed-up was first noticed in 2020 and has continued into 2025, baffling researchers. While our planet's rotation naturally wobbles and shifts, this sustained acceleration is unprecedented.*

*Scientists have theories: shifting ocean currents, atmospheric patterns, movements in Earth's molten core, even the Moon's changing position relative to the equator. But here's the twist: none of these fully explain what's happening.*

*"Nobody expected this," says Leonid Zotov of Moscow State University. And that's the unsettling part: we don't know why our days are shrinking. Could it be a natural cycle we don't yet understand? Or is there something deeper, hidden in the rhythms of our planet? For now, the mystery continues and the clock is quite literally ticking faster.*

The finding of a standard physics based model for the finding has turned out to be very difficult. There are two basic options according to whether there is external angular momentum feed or not.

### 2.5.1 External angular momentum feed seems to be needed

There is no convicing standard physics explanation for the shortening of the day. As an example, one can consider one particular attempt, which starts from natural question whether angular momentum conservation and perhaps even energy conservation could be used to model the effect. One can perform a quantitative estimate demonstrating that this is not possible.

1. Assume that the rotation velocity of an object, which is some part of the Earth, most naturally the entire Earth since the increased rotation rate is observed at the surface of the Earth. Also outer core, inner core, or innermost core can be considered.

   Idealize the rotating object as a solid ball with radius $R$, having a constant density $\rho$, which in the first approximation is the average density of Earth. The mass is $M(R) = (4\pi/3)\rho R^3$ and the moment of inertia is $I = xMR^2 = xM_E R_E^2, x = 2/5$.

   If the rotating object is liquid (outer core is liquid), its inertial momentum is smaller due to the varying velocity field of the liquid. Suppose this gives a correction factor $y$ so that one has

$$I = yxMR^2 \quad , x = \frac{2}{5} \quad . \tag{2.1}$$

2. Assume angular momentum conservation in the transition in which the rotation frequency changes. The Earth would be like a skater contracting itself so that its momentum of inertia would be reduced. For a spherical solid body with constant density, the angular momentum is

$$L = I\omega = yxMR^2\omega \quad . \tag{2.2}$$

   The conservation condition gives

$$\frac{\Delta R}{R} = -1/2 \times \frac{\Delta\omega}{\omega} \quad . \tag{2.3}$$

   $\Delta\omega/\omega$ is from $\Delta T = 1.6$ ms given by $\Delta\omega/\omega \simeq 3.1 \times 10^{-8}$. At the surface of the Earth this would give an unrealistically large value of $\Delta R \sim .09$ m. This alone excludes the assumption that angular momentum is conserved.

   Obviously a model, which assumes also energy conservation is doomed to fail.

### 2.5.2 Could external momentum feed from the gravitational body of the Earth and Sun explain the shortening of the day?

It seems that external angular momentum feed must be assumed. It also seems that new physics might be involved.

1. The notion of gravitational magnetic/field represents new astrophysics predicted by the TGD based view of space-time as a 4-surface in $H = M^4 \times CP_2$.

2. Holography = holomorphy principle (H-H) is an essential part of TGD and forces the introduction of what I call zero energy ontology (ZEO). This means that the space-time surface, analogous to Bohr orbit, replaces 3-surface as a fundamental object. This surface turns out to be a minimal surface except at singularities and is slightly non-deterministic as also 2-D minimal surfaces for which a given frame allows several minimal surfaces. This non-determinism forces ZEO, which solves the basic problem of quantum measurement theory.

3. Number theoretical vision predicts a hierarchy of effective Planck constants, involving gravitational and also electric Planck constant assignable to long range classical fields. This predits quantum coherence in astrophysical scales and predicts a large number of numerical miracles in astrophysical scales.

Could one identify the shortening of the day as a quantum transition involving an angular momentum transfer from the gravitational magnetic body of the Sun-Earth system to the Earth where it becomes classical angular momentum?

1. The gravitational Planck constant $\hbar_{gr}$ introduced originally by Nottale [E1], characterizes the magnetic body of the Sun-Earth system in the TGD framework [L3, L6, L7, L9, L10]. $\hbar_{gr}$ is given by

$$\hbar_{gr} = \frac{GM_S M_E}{\beta_0} \quad , \beta_0 \simeq 2^{-11} \quad . \tag{2.4}$$

   This prediction follows from the Bohr orbit model of the planetary orbits of Nottale. Here the solar mass is given by $M_S = .333 \times 10^6 M_E$.

   The minimal feed of the angular momentum would be $\hbar_{gr}$ and classically corresponds to $\Delta L = x M_E R^2 \Delta\omega$, $x = 2/5$.

2. Assume that the transferred angular momentum becomes classical angular momentum of the Earth. In the general case the increase of the angular momentum for the Earth is quantized and given by

$$\Delta L = I\Delta\omega = \frac{2}{5} M_E R^2 \Delta\omega = n\hbar_{gr} = n\frac{GM_S M_E}{\beta_0} \quad . \tag{2.5}$$

   Here $n$ is an integer. This gives the condition

$$\frac{2}{5}\frac{R_E}{cT_s} = \frac{GM_S}{\beta_0} = n\frac{r_S(Sun)}{R_E}\frac{1}{2\beta_0} \quad . \tag{2.6}$$

   The basic numbers are $r_s(Sun) = 3$ km and $R_E = 6.3734 \times 10^6$ m giving $r_s(Sun)/R_E = .471 \times 10^{-3}$. $T_s = 1.6$ ms gives $R_E/cT_s = 13.279$. The above equation gives $5.31 = .471n$ and is satisfied for $n = 11.27 \simeq 11$. The transition with $\Delta L = 11\hbar_{gr}$ would give a reasonable result. There are different estimates for the value of $T_s$ varying from 1.2 ms to 1.6 ms so that the values of $n$ are in the range [8,11].

The effect could be interpreted as a transfer of angular momentum from the Sun to the Earth. The effect could serve as a direct evidence for the notion of gravitational magnetic body and the notion of gravitational Planck constant. The quantization of the effect gives hope of testing of the model.

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