Article

Why Don't Airplanes Fall Down?

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Abstract

What causes the lift on the wing of an airplane? Surprisingly, this problem is still poorly understood mathematically and perhaps also physically. The Kutta's formula for the lift force works in the case of airfoil with a sharp rear but not generally. Taha and Gonzales proposed a variational principle based on so called Appellian, in which hydrodynamic acceleration replaces velocity. The predicted expression for the velocity circulation associated with the vortex around the wing is reported to work in more general situations than Kutta's formula.

In this article I will concentrate on the question of what creates the vortex. The TGD based quantum hydrodynamics leads to a view about how vortices are generated and how they decay. The vortex around the airfoil would be accompanied by magnetic flux structure, which is quantum coherent in the scale of the object. The generation of the vortex would compensate for the momentum loss of fluid as the boundary layer is formed.

The variational principle of Taha can be translated to the TGD framework. Also a simpler variational principle based on Z^0 magnetic energy is considered. In the TGD framework the velocity field is assumed to be proportional to Z^0 gauge potential: this assumption generalizes a similar assumption in superconductivity. This implies a quantization of velocity circulation as multiplies of effective Planck constant $h_{eff} = nh_0$ having as largest values the gravitational Planck constant $h_{gr} = GMm/\beta_0$ for Earth and Sun.

1 Introduction

I learned of an interesting step of progress in the description of the fluid flow over a lifting airfoil (https://cutt.ly/mLHg3bh) from a popular article "Pursuit of useless knowledge leads to a new theory of lift" (https://cutt.ly/mLHg7gh). The theory of Haithem Taha and his student Cody Gonzales is described in the article A Variational Theory of Lift [1] (https://cutt.ly/nLHheYH).

1.1 What causes the lift on flying object?

The challenge is to explain the lift in terms of hydrodynamics. Surprisingly, this problem is still poorly understood mathematically and perhaps also physically. We do not understand why airplanes do not fall down! Partial progress in the understanding of the problem has however occurred.

1. Lord Rayleigh found the exact solution for a 2-D potential flow around an open disk. The incompressibility condition implies that the potential for the flow satisfies Laplace equation. The boundary condition is that the flow is tangential and the fluid and body move with the same velocity at the surface.

   By the conformal invariance of the Laplace equation, the problem can be solved for a general cross section of the object by mapping the geometry to that of the cylinder. The solution is however not unique: one can add to the flow vortices, which are irrotational except at the core of the vortex. The vortices appear in the real flow above the critical value of the Reynolds number and are essential for the occurrence of lift. The problem is to understand the generation of the distribution of the vortices. As a matter of fact, the generation and decay of turbulence as the generation and decay of vortices is an unsolved problem of hydrodynamics [3].

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2. Kutta's formula meant a progress in the understanding of the lift force. Kutta-Joukowski theorem assumes that the lift is caused by a single vortex surrounding an airfoil (`https://en.wikipedia.org/wiki/Airfoil`) and gives an explicit formula for the lift force. The lift force is identified as Magnus force (`https://cutt.ly/ALHhy1H`) L per span l on a fixed airfoil or any infinite 2-D shape with a rear becoming infinitely think at large distance is given by $\rho_\infty v_\infty \Gamma$. ρ denotes the density of the fluid. Γ is the velocity circulation around the object outside the viscous region (`https://cutt.ly/LLHg1Zy`). The interpretation is that the lift force is due to the viscosity.

   The formula of the lift force given by Kutta-Joukowski theorem holds true for a general geometry but conforms with empirical findings only in very special geometries in which the trailing edge of the wing is very sharp.

1.2 A variational principle for lift

Instead of Euler equations, which are essentially Newton's equations, Taha and Gonzales [1] (`https://cutt.ly/nLHheYH`) propose a variational principle. One assumes a single vortex also now and the variational principle involves the circulation Γ as a single variational parameter, whose value is fixed by the minimization of the analog of action. There is no attempt to describe the generation of the vortex or its generation.

1. The variational principle at single particle level is Hertz's principle of least curvature (or acceleration). The analog of action, known as Appellian, is a 3-D integral of a quantity obtained from kinetic density by replacing velocity with acceleration: $\rho v^2/2 \rightarrow \rho a^2/2$. More generally, the deviation from the extremal of an action principle would be minimized instead of the action itself. This would allow non-extremals near to extremals.

   This gives as a special case solutions of Euler equations. Energy conservation must be assumed separately.

2. In the particle description there are two kinds of forces: external forces F_i and constraint forces R_i. In this situation, Gauss's Principle states that the quantity to be minimized is $\sum_i (m_i/2)(a_i - F_i)^2$. The constraint forces are eliminated by allowing a more general variational principle. At the continuum limit one obtains instead of sum a volume integral.

3. Hertz's principle is obtained by putting $F_i = 0$. Equivalently, force density f vanishes. For a steady state hydrodynamical flow the acceleration can be expressed as $a = v \cdot \nabla v + \nabla p + g$. In the approximation $f = (\rho(\nabla p + g) = 0$, one indeed obtains Hertz's principle.

4. One can start from an incompressible potential flow and add vortices to it. The simplest example is a single vortex rotating around a planar object, which is conformally related to a cylinder. In this case one has $u(\Gamma) = u_0 + \Gamma u_1$, where u_0 is a solution of the Laplace equation in absence of vortices representing potential flow and u_1 is a vortex solution with unit vorticity.

   The vorticity is given as $\Gamma = \oint u \cdot dl =$ (only u_1 contributes and gives $\oint u_1 \cdot dl = 1$). The integral is taken over a flow line around the object but staying outside the surface layer where the flow is not gradient flow fails. Note that one stays away from the region where the viscosity matters.

5. The varied quantity is known as Appellian

   $$S(\Gamma) = \frac{\rho}{2} \int a^2 dV = \frac{\rho}{2} \int [u(\Gamma) \cdot \nabla u(\Gamma)]^2 dV \quad ,$$

   where one has $a = v \cdot \nabla v$. One takes vorticity Γ as the basic variable and minimizes Appellian S with respect to the value of Γ.

6. This approach works in the general case and predicts the value of the vorticity and therefore also the lift force by Kutta-Joukowksi formula (`https://cutt.ly/LLHg1Zy`).

2 The TGD based model for the lift

In the following I will consider a TGD based microscopic model for lift assuming that the generation of the vortex is involved. The TGD based model involves new physics but is consistent with the model of Taha and also fixes the circulation of the vortex.

2.1 Some TGD inspired quantum hydrodynamics

The TGD inspired model for the lift involves the basic ideas of quantum hydrodynamics and these are discussed first.

2.1.1 h_{eff} hierarchy and the analogy with super-conductivity and super-fluidity

If the velocity field v is proportional to a gauge potential as in super-conductivity, the quantization of the circulation as quantization of angular momentum fixes the value of the parameter Γ and Kutta-Joukowski formula gives the value of the lift force.

1. The TGD based view of hydrodynamics involves macroscopic quantum coherence in an essential manner. Magnetic body consisting of magnetic flux tubes carrying ordinary particles as $h_{eff} = nh_0$ phases of ordinary particles is the role of controller of ordinary matter. In particular, gravitational Planck constant $\hbar_{gr} = GM_Em/v_0$ defining gravitational Compton length $\Lambda_{gr} = GM/v_0$ corresponds to the largest dark scale and would be important at quantum criticality accompanying ordinary thermodynamic criticality.

   The induced Kähler form decomposes to electromagnetic and Z^0 parts and both can be important. Z^0 vortices could accompany hydrodynamic vortices, which would imply a very close analogy between the descriptions of superconductivity and superfluidity. For instance, the very large value of $h_{eff} = h_{gr}$ can explain the fountain effect of super-fluidity as delocalization in scales, which are larger than gravitational Compton length $\Lambda_{gr} = GM_E/v_0$.

2. Also zero energy ontology (ZEO) is involved. ZEO predicts the possibility of ordinary ("big") state function reductions (BSFRs) in macroscopic scale. Generation of hydrodynamical turbulence and its decay are not understood in the standard framework based on Navier-Stokes equations.

   Quantum criticality associated with the flow near the boundary and BSFRs could play a central role in the generation of turbulence and its decay. The arrow of time changes in BSFR and this could explain hydrodynamic self-organization as dissipation with a reversed arrow of time.

2.1.2 Generation and decay of turbulence as quantum processes

The TGD inspired view of hydrodynamics [3] leads to a proposal that the notion of viscosity is length scale dependent.

1. Kinematical viscosity ν has dimensions of L^2/T and ν/c has dimensions of length. This suggests for the ordinary kinematic viscosity a parameterization $\nu/c = L = f(T)\hbar/m$, which is indeed used.

2. The hierarchy of Planck constants $h_{eff} = nh_0$ suggests a hierarchy of length scales $L(n)$ and an associated hierarchy of viscosities defined as $L(n) = \nu(\hbar_{eff}/\hbar)/c = k\hbar_{eff}/m = kn\hbar/m$, $n = \hbar_{eff}/m$ and k a numerical constant possibly depending on temperature.

   Here the counterpart of Compton length is used. One can also consider the counterpart of de-Broglie wavelength and start from the length scales $L = UD/c = \beta D$, $\beta = U/c$ appearing in the definition of Reynolds number as $R = UD/\nu$. This would give a hierarchy of length scales $D_{dB}(n) = L(n)/\beta$.

Gravitational Planck constant $h_{gr} = GM/m$ defines a good candidate for the largest length scale in the hierarchy. The natural candidates for the large mass M are masses of Earth and Sun and the considerations of [5, 6, 4] combined with earlier considers in [3] suggest that both are important in both ordinary hydrodynamics and in quantum biology.

1. The original definition of gravitational Compton length as $\Lambda_{gr} = GM/\beta_0$. The gravitational de-Broglie length define as $\Lambda_{gr,dB} = GM/\beta_0\beta$, where β is a typical velocity, say in a hydrodynamical system was also considered in [3].

   The physical interpretation of β_0 has remained somewhat unclear: in any case, for (quantum) hydrodynamics at the surface of Earth $\beta_0 = 1$ seems to be an excellent approximation [3, 4].

2. One can ask why the velocity parameter β_0 appearing in the formula could not actually correspond to β so that $\Lambda_{gr} = GM/\beta_0$ for $\beta_0 < 1$ would correspond to $\Lambda_{gr,dB}$ for β_0. The problem is that it is difficult to physically interpred the $\beta_0 = 1$ case applying at the surface of Earth. What could be the hydrodynamical entities flowing with light velocity? The rather science fictive candidate that comes into mind are dark N-photons forming Galois confined bound states of photons. For these states there exists quite recent experimental evidence [2]. The fluid would consist of dark photons!

3. A natural guess would be that at the critical values of Reynolds number $R = UD/\nu$, the scale $L = UD/c$ coincides with a dark Compton or de-Broglie length for a particle of the fluid flow.

   This hierarchy of viscosities would apply to the description of the hydrodynamic turbulence as a generation of vortices in long scales characterized by a large value of h_{eff} quantum coherent in the scale.

   At quantum criticality new longer quantum coherence length would appear and lead to generation of larger vortices giving rise to turbulence. The decay of turbulence would be a reverse process. Vortices would decay in a cascade-like matter to smaller vortices characterized by smaller values of h_{eff}. Decay cascade would lead to the atomic level, where ordinary kinematic viscosity associated with $h_{eff} = h$ is a useful concept.

2.2 What prevents airplanes from falling down?

Could this conceptual framework provide insights to the question of what prevents airplanes from falling? Could the new physics predicted by TGD explain what happens in the generation of the vortex (or vortices). Could the variational principle introduced by Taha be interpreted in terms of this new physics?

1. It is known that vortices are essential for the generation of the lift force. They are generated above critical Reynolds number at the surface of the flying objects where the separation of the flow takes place. I have proposed that quantum criticality is associated with the critical Reynolds number: whereas superconductivity emerges below critical temperature, vortices emerge above critical Reynolds number. This is called flow separation.

   Flow separation is thought to occur in the following way (`https://cutt.ly/xLHhf3C`). The velocity of the fluid in the surface layer approaches zero at the surface. This increases the pressure near the surface and the average pressure in the layer. What happens is that the flow detaches from the surface via the formation of vortices and the pressure becomes constant.

2. One can express this more quantitatively. The conservation of energy along a flow line, expressed as $\rho v^2/2 + p = constant$, would imply that v decreases. Instead of this, a separation of flow occurs and vortices are generated and the average value of v inside the surface layer stays constant. For vortices the pressure increases near the core of the vortex so that the increase of pressure at the surface layer is replaced by its increase near the surfaces of vortices.

Separation occurs above critical value R_{cr} of Reynolds number $R = UD/\nu$, where U is the velocity of flow above the surface layer, D is an appropriate length scale, say the distance from the tip of the airfoil, and ν is kinematic viscosity.

3. Separation generates vortices and in TGD they would correspond to quantum objects, perhaps Z^0 magnetic vortices inducing hydrodynamic flow. The simplest situation is that a single vortex for which fluid rotates around the object around axes orthogonal to the flow, is generated. This situation is assumed in the model of Taha. It is highly plausible that this vortex is unstable against decay to smaller vortices occurring also in standard hydrodynamics.

4. The conclusion of Taha and Gonzales [1] is that momentum conservation is what matters rather than viscosity. If the fluid sticks at the surface of the moving body at the boundary layer, fluid flow loses momentum and could be transformed to the momentum of the vortices with respect to the rest system of fluid at larger distances.

   Viscosity usually associated with the loss of momentum and energy in microscopic scales would be replaced with a transfer of momentum and energy to the vortices. The vortices would decay in a cascade-like manner to smaller ones and eventually the momentum and energy would be transformed to microscopic degrees of freedom. In a stationary situation there would be distribution of vortices of various sizes.

   In the ZEO based picture, the occurrence of BSFR would change the arrow of time and the dissipation with a reversed arrow of time would in standard time direction look like self-organization based on the extraction of energy and momentum from the main flow to that of vortices.

5. The big vortex is analogous to a spinning object moving in fluid and would experience Magnus effect as a lift: Magnus force is proportional to the cross product of mass current and the angular velocity Ω of vortex defining vorticity and would cause the lift of the vortex. Since the object is inside the vortex, also the object would be lifted. This mechanism does not depend in an essential manner on the shape of the wing except it should be such that separation and generation of vortices is possible.

2.2.1 The strength of the lift force from the quantization of magnetic flux

TGD leads to a view about hydrodynamics [3] involving a new view about classical fields and quantum coherence possible even in macroscopic scales. Actually, quantum hydrodynamics would be a more appropriate term.

It has been already found that the quantization of the Z^0 magnetic magnetic flux for the vortex fixes the possible values of Γ. Therefore variational principle is not needed for this purpose.

1. This gives a connection with the breaking of super-conductivity by a generation of vortices. In the TGD view about superfluidity, velocity vortices would correspond to Z^0 magnetic vortices carrying quantized monopole flux, whose existence distinguishes between TGD and standard model.

2. The unit of quantization would be $h_{eff} = nh_0$ and there would be a hierarchy of values of h_{eff} assignable to the hierarchy of vortices. The decay of vortices would decrease the scale of quantum coherences. The largest value of h_{eff} could correspond to h_{gr} with $\Lambda_{gr} = GM_E/v_0$ defining a lower bound for vortex scale.

   For $v_0 = c$, the scale would be above $\Lambda_{gr} = .45$ cm. Intriguingly, this scale occurs as a scale of snowflakes which are associated with the criticality of water against freezing: the TGD interpretation is in terms of quantum fluctuations associated with the quantum criticality of water generating a hierarchy of quantum phases with $h_{eff} \leq h_{gr}$ [4].

3. This interpretation predicts a quantization of vorticity due to the quantization of $q\oint A \cdot dl$ as magnetic flux, completely analogous to that in super-fluidity. The quantization corresponds to a quantization of angular momentum for a particle of flow, such as proton. The quantization requires a non-standard value $h_{eff} = nh_0 > h$ of Planck constant or a very large value m of flux quanta for a small value of h_{eff}. The values of h_{eff} in the hydrodynamic situation are considered in [3].

   Conservation of angular momentum requires that the vortex characterized by integer $n = h_{eff}/h_0$ decays to vortices characterized by integers n_i satisfying $n = \sum n_i$. If the vortices are identical ($n_i = n_1$) one has $m = n/n_1$ vortices and n_1 must divide n. If this condition holds true, the decay process corresponds to a division of n to its factors.

4. This quantization would take place even in ordinary hydrodynamics and would imply superfluidity-like phenomenon at the level of the magnetic body. The quantization of the magnetic flux as a multiple of h_{eff} fixes the value of the vorticity parameter Γ, which is also fixed by the minimization of Appellian so that it is not quite obvious whether the minimization of the counterpart of Appellian is needed.

   The quantization corresponds to that for the Kähler magnetic monopole flux of the flux tube. It would be interesting to test whether the quantization giving rise to a quantization of the lift force takes place. Outside the core at least, velocity vortices would naturally correspond to Z^0 vortices with vanishing electromagnetic B.

2.2.2 Bohr quantization for angular momentum as quantization of Kähler magnetic monopole flux

The Bohr quantization condition for angular momentum or equivalently quantization of Kähler magnetic flux having purely topological origin implies the quantization of circulation $\Gamma = \oint v \cdot dl$ as multiples of $\hbar_{eff}/M$, where M is the mass of the basic hydrodynamic unit.

1. The most plausible interpretation for velocity v would be as being proportional to a vector potential A for an analog of magnetic field, in a neutral fluid most naturally the induced Z^0 gauge potential A_Z, which would be proportional to Kähler gauge potential in the situation considered:

   $$A_Z = q_Z A_K \quad .$$

   Flow lines would be along those of A_K.

2. The covariant constancy $(p_t - qA_t)\Psi = 0$ satisfied along the flow lines has the condition $\oint (p - qA) \cdot dl = 0$ and stronger condition $p = Mv = q_Z A$ as classical counterparts. This gives the condition $v = A/M$ for the flow lines in the case of vortices.

3. The Bohr quantization of angular momentum for particle with mass M gives

   $$M \oint v \cdot dl = m\hbar_{eff} = N\hbar \quad N = mm \quad .$$

   The mass M can correspond to a mass of dark particle and proton is the most plausible candidate. In superfluidity it would be ^3He or ^4He atom which suggests that also atomic mass, which in a reasonable aprroximation is multiple of proton mass, is possible.

4. It is not completely clear whether the quantization for the gauge flux should be posed for Kähler flux associated with A_K or for Z^0 gauge potential. The quantization of Kähler flux follows from topology and is automatically satisfied. In fact, the quantization gives the same results under the conditions poses also in the model discussed in [3].

One would $p - A_K = mv - q_Z A_K = 0$ along the flow line. q_Z would correspond to the Z^0 charge of proton, or atomic nucleus which in good approximation is proportional to the neutron number (protonic Z^0 charges is roughly 2 percent of that for the neutron).

The interpretation of A as Z_0 gauge potential proportional to Kähler gauge potential conforms with the model developed in [3]. Depending on the situation, A can be reduced to electromagnetic or Z^0 gauge potential as in hydrodynamics.

5. If one has $A_Z = q_Z A_K$, the two quantization conditions are indeed equivalent. If one has $h_{eff} = nh$ (this is a special case of the most general condition $h_{eff} = nh_0$ satisfied if rationals are replaced with ground state extension of rationals with $h_{eff} = h = n_0 h_0$), one has

$$q_Z \oint A_Z \cdot dl = q_Z \int B_K \cdot dA = q_Z m\hbar_{eff} = q_Z mn\hbar = q_Z N\hbar \ .$$

The Bohr quantization condition for angular momentum would be therefore equivalent with the quantization of Kähler magnetic monopole flux.

The situation is quantum critical.

1. Since the several values of $h_{eff} = nh_0$ correspond to the same value of total flux $N = mn$ for single flux quantum. There would also be a large degeneracy corresponding to various decompositions $N = mn$ to a product of integers. This degeneracy can be interpreted in terms of quantum criticality involving fluctuations in the value of h_{eff}.
2. One can also have a decomposition to several flux quanta analogous to a decomposition of a vortex to a set of vortices. The interpretation would be as a decomposition of the big vortex to smaller ones.

2.2.3 Appellian or a magnetic part of gauge action for a massive gauge boson?

One can consider two basic options for the choice of the magnetic action based on hydrodynamic and gauge theoretic intuition respectively.

1. For the model of vortex associated with the lift forces, the vector potential $a_0 \propto v_0$ would define a vanishing Z_0 magnetic field and satisfy the analog of gauge condition $\nabla \cdot A_0 = 0$. The vector potential assignable to v_1 would give a magnetic field, which is non-vanishing along a line singularity that is a thin Kähler magnetic monopole flux tube.
2. The counterpart of Appellian follows from hydrodynamic intuition and would be proportional to $S = \int (A \cdot \nabla A)^2 dV$ and would be varied with respect to Γ, which is however fixed to an integer N by flux quantization.

   Without the core contribution the minimization would reduce to minimization with respect to $N = mn$. The core with a finite size would give a finite contribution proportional to N^2. Appellian contribution from the exterior of the core would give terms coming as powers of $(n/A)^k$, $0, 1, 2, 4$, where A is the transverse area of the core tube.

   Therefore the minimization is with respect to the value of n and the parameter characterizing core size, say the area A. For $h_{eff} = h$ the value of m is very large so that one has a quasi-continuum for the values of N. For large values of h_{eff} only few values of m are possible. Flux quantization would fix the value spectrum of N and minimization with respect to $1/A$ would fix the value of A for a given value of N as a root of a third order polynomial in (N/A). A further minimization with respect to $m = N/n$ would fix the value of m.

3. Gauge theoretic intuition motivates the consideration of the analog of magnetic energy density for a massive gauge field. The Maxwellian contribution would be proportional to $\int B^2 dV$ and concentrate to the vortex core. By flux quantization, one would have $\int B^2 dV \propto m^2\Phi_n^2 L/A = m^2 n^2 \Phi_0^2 L/A$, where $\Phi_n = (h_{eff}/h)\Phi_0 = n/n_0$ is flux quantum, m is the number of flux quanta, A is the transverse area of the flux tube and L its length. Minimization with respect to A would allow only $n = 0$.

   By adding the analog of mass term $m^2 \int A^2$ would give rise to terms proportional to powers $(n/A)^k$, $k = 0, 1, 2$. Outside the vortex core this option corresponds to Eulerian $\rho v^2/2$ option and apart from flux quantization to standard hydrodynamics.

   The minimization for a given value of N would fix the value of A as a root of a first order polynomial. A further minimization with respect to m, would fix the value of m for a given value of n.

2.2.4 Electromagnetic gauge invariance is not a strict gauge invariance

For both options, the action fails to be gauge invariant. For the second option the presence of the A^2 term could be interpreted as reflecting the massivation of the Z^0 magnetic field. This also takes place for electromagnetic fields in superconductivity, where the cores of flux quanta correspond to regions, where super-conductivity is broken.

In TGD the breaking of gauge invariance is only apparent since gauge invariance is broken by classical gravitation from the beginning and the breaking becomes large in presence of monopole flux tubes not possible in the standard model and in general relativity.

1. The gauge transformations for the induced Kähler form correspond to symplectic transformations of CP_2 and affect the induced metric and therefore also Kähler action unlike genuine gauge transformations would do: the effect is small for Einstein space-time regions with large 4-D M^4 projection since it is gravitational. In long scales, where Einsteinian space-regions with 4-D M^4 projection dominate, this leads to huge spin glass degeneracy and approximate gauge invariance.

   As a matter of fact, the sub-algebra SSA_n of super-symplectic algebra SSA with conformal weights coming as n-ples of those of SSA annihilate the physical states as also does the commutator $[SSA_n, SSA]$. SSA_n acts effectively as gauge transformations and gauge symmetry for conformal weights smaller than n is replaced with isometries of the "world of classical worlds" (WCW): they correspond to long length scales. One can assign to these generators charges of dynamical symmetries emerging in long scales.

2. For the magnetic flux tubes, which are deformations of string-like entities with 2-D M^4 projection, the effect of gauge symmetry breaking can be large. One indeed assigns the breaking of gauge invariance to the cores of the flux quanta in superconductivity.

   Electromagnetic gauge invariance is believed to break down in superconductivity. This is in conflict with the expectation from the standard model. This conforms with the TGD view of electromagnetic gauge invariance as an approximate gauge invariance. Symplectic transformations of CP_2 are however identified as isometries of WCW and one can say that the in symmetry breaking only those symplectic transformations corresponding to SSA_n remain gauge transformation and the rest become genuine symmetries generating dynamical symmetry group.

   It should be also noticed that in the general case classical em and Z^0 gauge potentials contain besides the Kähler part also an $SU(2)$ part.

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