SUPPLEMENT: Investigations on science history concerning the GAIA 5.0 project.

1.1 The question about space and motion -- from Descartes vs. Newton to Maxwell & Faraday

According to Poincaré's philosophy, it should be assumed that there is a reality, inaccessible to us, but accessible to some being standing outside Poincaré's *cloudy planet* (Granek, 2001). The question, "La terre tourne-t-elle?", was famously posed by Henri Poincaré in a philosophical essay wherein he "doubts" the rotation of the Earth because if we want to talk about the rotation of the earth, we must first ask the fundamental question: what is motion? ,"The Earth rotates", and,"it is more convenient to assume that the Earth rotates", have one and the same meaning. Poincaré was certainly aware that the Earth moves, but he provocatively asks:

> "What means do we have to distinguish absolute movement from relative movement; for example, why do we prefer the Copernican system to that of Ptolemy because it is simpler, and we conclude not only that it is more convenient, but that it is more real ?" (Poincaré,1904b)

Before we introduce here the concept of an ontologic higher-dimensional space which might sound strange or even awkward to some readers, let us make briefly some historic associations:

What is remarkable about the higher-dimensional space configurations is that they must be regarded as 3D spaces in movement. This assumption goes back to the French philosopher Renée Descartes' (1596–1650) who not only invented the Cartesian coordinate system but who was the first who mentions interconnected coordinate frames for its representation. (Descartes, [1637], 1902). Descartes also re-introduced the millenia old idea of an ether into science in *Principia philosophiae* (1644). He assumed that the aether particles were in constant motion. This assumption was heretic at that time and Descartes very probably got poisoned by a Vatican missionary for North Europe because his rational ideas about higher dimensions were considered as rivaling with religion and would prevent Queen Christina of Schweden of her prospected conversion to Catholicism (Ebert, 2009). Newton felt uncomfortable mentioning the ether because he turned into Christianity and also because he had no explanation for it (Newton, 1679 Letter to Robert Boyle). His followers et drop the idea that for Newton the „absolute space" was filled with ether.

Isaac Newton opposes Descartes ideas, by saying,

> "If Descartes handles the translation ·that real movement involves· not in terms of the individual particles of the vortices but in terms of the 'generic space' (his phrase) in which those vortices exist, then at last we have something we agree on. And he does say that when we are distinguishing space from bodies, **we ought to understand motion in terms of space.**
>
> —- This is all wrong! Any possible motion must have a definite speed and direction." (Newton, 1699)

However, speed and direction became the core issues in modern physics while Renée Descartes' idea that all matter is just a result of transformations of spaces conforms to group theoretical descriptions of particles, celestial mechanics and Noether's theorem which proves that the symmetries of space are responsible for the conservation of energy. As Poincaré says, 5-dimensional space is appropriate for Group theory. This mans that is not only a visualisation based on fantasy but a higher-dimensional approach -- whose attempts always failed due to a lack of imagination -- should inspire to a paradigm change that can possibly help to understand a complex living systems like the Earth.

In effect, the hyper-Euclidean method we use is merely a dynamic digital vision of Euclidean geometry which Newton acknowledged as abstract reality when he said,

> "So there are everywhere all kinds of figures [= 'shapes'], everywhere spheres, cubes, triangles, straight lines, everywhere circular, elliptical, parabolic and all other kinds of figures, of all different sizes, even though we don't actually see them. A physical drawing of any figure doesn't launch that figure into space; the figure was there

already, though we couldn't sensorily detect it; and the drawing is merely a corporeal representation of that already existing figure." (Newton, 1699, 9)

But since Newton not only Euclidean geometry and the ether but also space and time lost their ontologic status:

> 'in Newtonian physics, if we take away the dynamical entities, what remains is space and time. In relativistic physics, if we take away the dynamical entities, nothing remains. We have learned so far to give up the notions of ''space and time entities'' entirely since the "world is made by dynamical fields".' (Rovelli, 2006)

Recall that the notion of fields goes back to Michael Faraday (1791—1867) who used artistic methods, made drawings and experiments and developed the electro-magnetic theory which Clark C. Maxwell put into mathematical formalism. Together they were pondering the possible reality of 'lines of force' as fabric of space.

"Since at every point of space such a direction may be found, if we commence at any point and draw a line so that, […] the resultant force at that point, this curve will indicate the direction of that force for every point through which it passes, and might be called on that account a line of force. We might in the same way draw other lines of force, till we had fi**lled all space with curves indicating by their direction that of the force at any assigned point.**" (Maxwell, 1855)

These 'lines of force' may be found in our 5-dimensional space model where we use the parallels of the cubic grid (c-.f. Ammann bars, the one-dimensional version of the Penrose Pattern) where straight parallel lines into 5 directions of space can be assigned to electricity and curved lines to magnetism. From partitions of these grid of lines we can imagine -- or build in digital 3D geometry -- a discrete dynamic space similar to the phase space used in meteorology The difference to the n-dimensional phase space is that our model is composed of a 4-dimensional space in imaginary movement (C) around the 3-dimensional „compact" sphere (R^3).

2. Chiral dynamics and fractal characteristics of 5D space

The flat grid model (fig. 2.) finds its equivalence in the 3D representation of the infinite 5-dimensional space (fig. 2.
The concept of a discrete space as visualized by the epita-dodecahedron comprises the geometrical fact that he faces of the space cells can be enfolded into smaller and smaller regions resulting in a fractal nature of space. The logarithmic spiral is a generation method for Penrose Patterns (Kappraff, 2001). Hence both characteristics of cyclones, their fractal and chiral nature could be explained by the assumption of an underlying dynamic higher-dimensional space.
Chirality remains also an intrinsic feature of the fractal higher-dimensional dodecahedral space created by the 3D representation of the Penrose Kites & Darts Tiling. Therefor any chiral and fractal characteristics of shapes and dynamics could be traced back to this feature of space.

Passive scalar turbulence also characterizes many phenomena in the natural world, like the dramatic temperature variations between nearby points in the ocean. In that environment, the ocean currents "mix" temperatures the way stirring mixes black paint into white. Based on the continuum hypothesis that the macroscopic behavior of fluids behave as if they were perfectly continuous sine the turbulence of a small fraction will spread over the whole system, the Australian mathematician and fluid dynamicist George Batchelor (1920–2000) predicted that these patterns follow an exact, regimented order (Batchelor, [1967] 2000). This arising self-similarity is mathematically expressed by Batchelor's law which was recently mathematically proven by exploiting randomness (Bedrossian, Blumenthal, Punshon-Smith, 2019). It was suggests that in hydrodynamic turbulence each vortex contains other vortices similar to the way the nested figurines comprise a Russian doll by following an exact ratio (Hartnett, 2020).

In the context of the here presented space concept we may refer to icosahedra quasicrystals, long-range-ordered materials that lack translational invariance with 5-, 10- or 12-fold rotational symmetries. They need the same number (5-, 10- or 12-) of dimensions in order to gain a fully ordered picture. Our approach stand in the tradition of some classicists of crystallography who emphasized a connection between crystal structures and musical harmony (C.S. Weiss, J. Grassman, V. Goldschmidt, etc.). It is taking into account that Erwin Schrödinger named living bodies as "aperiodic crystal" (Schrödinger, 1948), one can suppose that biological structures are also connected with musical harmony (Stepanyan, Petoukhov et al, 2015). Hence, if we apply the same geometrical concepts which are used for quasicrystals, namely the Penrose Pattern as model for its atomic arrangement, we derive a higher-dimensional perspective on biology and the Earth as living system in the framework of a unified quasicrystallography as proposed by Alan L. Mackay (1977).

This way our hyper-Euclidean framework based on the 3D representation of the Penrose kites & darts leads us to principles of a generalized crystallography where Platonic symmetries, golden ratio and Fibonacci sequences can be observed in nature on all scales (He & Petoukhov, 2017).

3. The Coriolis effect -- kinetic energy and the *Vis Viva*

It seems notable that Coriolis was first using the term mv for kinetic energy then referred to as *forces vives* (from Latin *vis viva*, for *living force*) in his two articles on relative movements of machines (Coriolis, 1829, 1832).
In his 1829 book „Calcul de I'effet des machines" Coriolis presented mechanics in a way that could be used by the industry. He established for the first time the correct relation between potential and kinetic energy, and showed that their sum remained constant in the absence of any external force. Another 20 years later in 1853, William Rankine (1820–1872) coined the phrase 'kinetic energy' in 1853 and Lord Kelvin and P. G. Tait (1831--1901) the phrase 'potential energy' in 1862.
The *vis viva* was vividly discussed 100 years before between Gottfried W. Leibniz (1646--1716) and Émilie du Châtelet (1706–1749). She was not only translating Newton's *Principia Mathematica* into French and made him popular on the continent, but predicted in her theory of light what is today known as infrared radiation. She corrected Newton's assumption **mv** and squared the velocity (**v**) which resulted in the formula, 1/2 $\mathbf{mv}^2$ for kinetic energy. (Leibniz, 2009)
Châtelet introduced the concept kinetic energy as *Vis Viva* and first proposed and tested that the total energy of an isolated system remains constant, means is conserved over time. In the 20th century the French philosopher Henri Bergson (1874–1948) referred to it as 'élan vital' in order to overcome the resistance of inert matter in the formation of living bodies. The kinetic energy (KE) — force × displacement = kinetic energy — of an object is the energy that it possesses due to its motion. But where would this energy stem from?
Earth' constant rotation is contributed to inertia. Inertia is expressed in Newton's first axiom, 'A body will remain at rest or will continue to move with constant velocity in a straight line unless acted on by an external force' is based on Aristotelian physics. The *moment of inertia* describes how difficult it is to change an object's rotational motion but it does not explain the rotational motion itself.
Despite elaborate mathematical tools which make celestial motion calculable, a philosophical demur remains: There is no celestial table from which the book which has a stored potential energy can drop to the floor. Therefor the more elegant group theoretical approach. Moreover, how much the image of Coriolis effect, -- the circle M according to Joseph Bertrand's concept (1847) which is predating Coriolis-- corresponds to the circles representing the 4D space around the Earth compact zone" with its inner core as depicted by Inge Lehmann who first determined the inne structure of the Earth (1936), here suggested can be seen here:

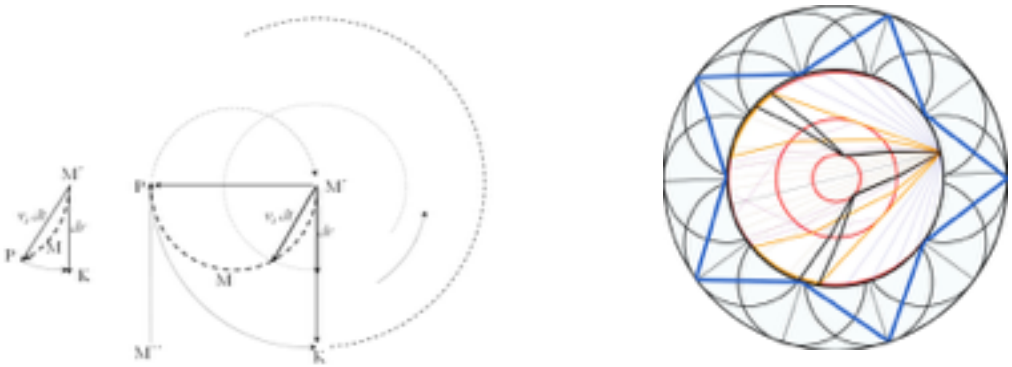

Figure 1 a) The tangent PM'' measures the deflective angle 2ωdt which is twice the change of direction due to the rotation ωdt. & figure inserted in the total rotational system. When this system has rotated 90^0 (PM´ is perpendicular to M'K) the direction of the deflected motion (along PM'') is parallel to its original direction (along M'K) and the moving object has followed a semi-circle, half of an "inertia circle" (Persson, 2019, 17, fig.17 b) Earth as Hypersphere with Earth's inner cores after an illustration from Inge Lehmann's 1936 paper *P'*(sketch rczq, 2020)

3.1. The vis-viva equation and symmetries of space

In astrodynamics, the *vis-viva equation*, also referred to as orbital-energy-invariance law, is one of the equations that model the motion of orbiting bodies. It is the direct result of the principle of conservation of mechanical energy. Noether's theorem (discovered 1915) connects the symmetry of the action of a system (the integral over time of the Lagrangian equation for the energy of a system) with conservation laws. The Lagrangian is a generalization of the formulations on constants of motion in mechanics (valid in nay dimension) which derives conserved quantities from spacial symmetries.

Actually, Noether's theorem and the conservation of energy must be linked to a 6-dimensional group of symmetries. In physics gauge symmetry or gauge theory is used to describe or "explain" natural forces in particle physics but also in celestial mechanics. — This gives rise to the *artistic* assumption that the symmetries of higher dimensional spaces act effectively as *fields of forces* that make the Newtonian description of gravity *superfluous*.

This approach would allow to regard all kinds of complex self-moving systems, such as atoms, living cells, the sun system and the universe as well as the earth as basically 6-dimensional system that relies on the geometry of space.

For the ancient Greeks the motion of the planets, light and consciousness were connected to the all-permeating aether. If we now (re-)discover higher-dimensional space configurations based on 5-dimensional geometry which Plato had in mind, the millenia old ether concept shines in a new light.

4. A short comparison of ether concepts in the 19th century and the 5D space grid

For Poincaré the negation of all metaphysics is still a metaphysics; and this is precisely what he called modern metaphysics (Poincaré in a letter to Flammarion, 1904). He was not convinced that Einstein found a way to eliminate the ether although he predicted that it could be declared as superfluous before him.

Relativity cannot treat action-at-a-distance and uniform rotations without retaining some kind of ether, so he changed his mind several times (Granek, 2001). Thus, the ether re-emerges as the *Je Ne Sais Quoi of Physics* (Browne, 1999). The nobel laureate Frank Wilzcek calls it a myth, repeated in many popular presentations and textbooks, that Albert

Einstein (1879–1955) swept the ether into the dustbin of history, because “renamed and thinly disguised, dominates the accepted laws of physics“ and “modern quantum field theory is a direct descendant of the ether“ (Wilczek, 1999).

Many artists were fond of the ether in the early twentieth century. The values of modernism was found in the complexities and contradictions of modern physics provided a fertile ground for the development of new artistic languages (Navarro, 2018). -- Mainly mute colorful comments to physics concepts which should be overcome in the 21st century by giving artists a voice (at least in SciArt publications).

Generally speaking, British scientists of the 19th century who laid the foundations of meteorology favored the existence of an all-pervasive ether. French physicists would prefer corpuscular models, while Dutch physicist H.A Lorentz as well as Maxwell were favoring non-mechanical variants of the ether. There were two competing theories, one by Augustin J. Fresnel (1788–1827) who assumed the aether was to pass freely through the Earth and one by Sir George Gabriel Stokes (1819-1903), who believed the aether was entrained by the motion of the Earth so that the velocity of the aether would be equal to that of the Earth (only near its surface). The Irish Mathematician James MacCullagh (1809-1847) contributed valuable geometrical constructions valuable geometrical constructions for the ether concept that remind us of features of the 5-dimensional space. He presented the first optical field theory in which he imagined an ‘elementary parallelepiped’ to be described in the ether when at rest, and then all its points to move according to the same law as the ethereal particles which compose it (MacCullagh, 1839). A parallelepiped is a three-dimensional figure formed by six parallelograms just like the subspaces of a hypercube. It corresponds also the volume to the 5D cubic grid and the model. For the same purpose, in order to find the appropriate shape of the space which enables all sorts of matter, Johannes Kepler designed rhombic √5- parallelepipeds, which turned out to be 4-dimensional polyhedra -- later rediscovered as Bilinski's rhombic dodecahedron -- and again re-designed as models for quasicrystallography (Levine & Steinhardt, 1986). For MacCullagh's new medium, to develop a potential function for a dynamical theory for the transmission of light is not any more a 'elastic solid’ but the potential energy depends only on the rotation of the volume-elements. These volume elements remind us of the 12 respectively 12 spaces which make up the 5-dimensional space as visualized in the epita-dodecahedron

MacCullagh's equations may readily be interpreted in the electro-magnetic theory of light: e corresponds to the magnetic force, **p** curl **e** to the electric force, and curl e to the electric displacement, -- the same appears later in Maxwell’s electrodynamics (originally relying on a mechanical-based aether) and Kelvin’s theories of vortex motion, which regard rotation as analogue to magnetic force (Whittaker, 1910).

From this Lord Kelvin developed a 'Gyrostatic Adynamic Constitution for Ether' (1890) and which lead Joseph Lamor to publish a preliminary version of Lorentz transformations together with Fitzgerald’s time dilation and length contraction (Lamor, 1900) which found a new interpretation in the framework of relativity theory.

This means that the principle of counter-rotation (which appears as imaginary movement √-1), in the geometry of 5-dimensional space configuration, in which epitahedra (E±) can be considered as counter-rotating volume-elements, can depict Lorenz transformation (as shown below). Our visualisation meets surpassingly Lord Kelvin’s ideas since he also suggested as a solution for the problem of space-filling cells (the Kelvin problem) a 14-sided polyhedron (a bitruncated cubic honeycomb with curved faces and edges) based on foam experiments and dodecahedra (1887). Hence, Lord Kelvin's gyrostatic and the dodecahedral considerations are converging in the epita-dodecahedron model where the double heptahedra E± together also exhibit 14 faces. Also the famous formula $E= mc^2$ was originally deduced from an ether model (Preston, 1875) and also deduced of John Poynting’s celebrated electromagnetic Theorem by Henri Poincaré in 1900 (Auffray, 2006)

It may be an irony of history that in a mega version of Michelson's interferometer (the Laser Interferometer Gravitational-Wave Observatory LIGO) -- originally adapted to the ether-drift experiment to detect the relative motion of the Earth and the ether as proposed by Maxwell -- served meanwhile for the defection of gravity waves (Abbott et al. 2016), originally predicted by Poincaré (1905) as ultimate proof of relativity theory while ether-drift measurements and the determination of the absolute motion of the Earth was discussed but got never validated.

Notably, the first gravitational-wave signal from merging black holes was communicated by means of art: Colorful paintings and animations, including a musical score composed of converted frequency of the detected gravitational ripple, a bird-like “chirp” (Chen, 2019).
However, Poincaré’s relativity theory (1895, 1902, 1905) is not concerned because his who gave the transformation the name of Lorentz-- remain valid. They describe the invariance of Maxwell's equations and must be understood in terms of symmetries of space.
However, this is what interests us here in Poincaré’s 'Lorentz transformations' is the electro-magnetic field on Earth, which can be visualized in the here presented higher-dimensional model for the Earth, particularly in the 2D model of the 4-dimension embedded in 5-dimensional space (see Figure. 2. (a) The 5-dimensional space-grid and the embedding of the planet and (b) as the hyper-sphere).

4. 2 The Phase space in meteorology -- fluctuations in the epita-dodecahedral space concept

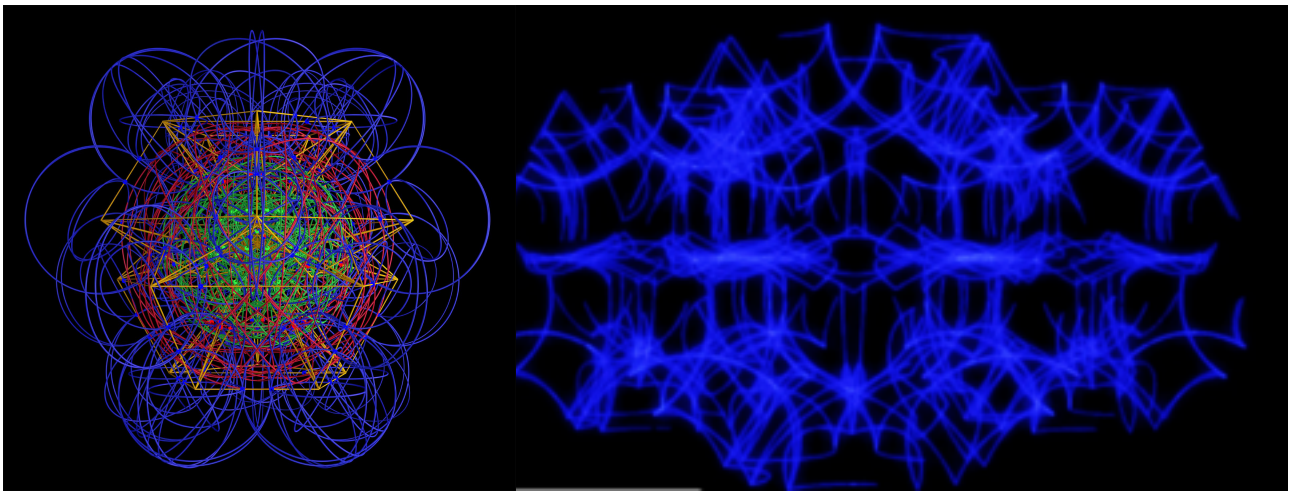

Figure 2 a) Epita-dodecahedron with rotated circular decoration, b) circular decoration of the blue lines only; (rczq, QC-film, Epitahedron examples, https://vimeo.com/50019507)

The phase space concept, a space in which all possible states of a system represented by a unique point was developed by Henri Poincaré, Ludwig Boltzmann & Josiah W. Gibbs. This space is full of potentially spinning points which have a physical meaning in thermodynamics and quantum physics. Therefor it is suggested that the phase space also in meteorology could not only be regarded as representation form but that its physical effects could be taken under account. A thermodynamic system consists of N particles, then a point in the 6N-dimensional phase space describes the dynamic state of every particle in that system with three-position variables and three momentum variables.
A discrete phase space is not a manifold, but admits triangulations which result in flat triangles forming simplexes. Hence the 5-dimensional unit cells used in the GAIA.5.0 film are considered as 5-simplices and therefor a viable hyper-Euclidean representation form for the 6-dimensional phase space. Especially if we consider the epita-dodecahedron as fractal entity which may be tessellated into smaller and smaller fractions of spaces we can use the circular decoration of the triangle for the representation of fluctuations that could enable the visualization of the atmospheric turbulences in detail.

Chaotic fluctuations in the atmosphere could be visualized in the epita-dodecahedron model by fractals of circles in a dynamic way.

The circular waves inside the epita-dodecahedron could be developed towards a model for the simulation of fluctuations on a fractal level. In fig.18 the circular decoration of the triangles (according to the Conway decoration of the Penrose kites & darts tiling in red & blue, green circles added) is rotated and exhibits circles in motion. Here looks the epita-dodecahedron like a hypersphere. Especially the side view of rotating circles only (fig 18.b) gives an idea about the dynamic fluctuations resulting from moving points on circles. So far we can only imagine those fluctuations in a fractal manner, but a 3D animated visualization of fluctuations in a fractal epita-dodecahedral space would be a challenging art endeavor for a follow-up project.

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