A Data-driven Approach to Astrophysics: Towards Quantum Geophysics and Quantum Astrophysics

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ABSTRACT	Following our previous article which recommends physicists to build models in the light of principle of parsimony, and also a review on A. Yefremov's research in the past few years (PSTJ, 2021), here we discuss a data-driven approach to astrophysics. Part of inspiration for this article came from a paper by Brunton, Proctor & Kutz (*PNAS*, April 12, 2016) and also lecture by the late Hannes Alfven. We begin with a review on how Newton's recipe to interpret Kepler's elliptical orbit law, actually led to a number of problematic questions. While we agree with Alfven that one should not infer the history of solar system just from the nature of planetary orbits (or deviations from that), and not from other present astronomy data, because those present data may be of little value to reveal the past history; instead from the data and improving Titius-Bode law, therefore we suggest to come up with a new hypothesis: "*quantum matter inside a Newtonian universe.*" In other words, in the second section we will discuss how quantum geophysics and quantum astrophysics emerge into the scene.
KEYWORDS	Data-driven modeling; astrophysics; quantum astrophysics; quantum geophysics; solar system.

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INTRODUCTION

There are some really interesting remarks that we can read from the late Hannes Alvfen's Nobel lecture in 1970. Among other things, he wrote that one should not infer the history of solar system just from the nature of planetary orbits (or deviations from that), and also not from other present astronomy data, because those present data may be of little value to reveal the past history of solar system. He also suggests a new term: "*hetegony,*" which can be interpreted as description on how things are arranged or paired together. [1]

In this context, in this paper we will discuss how we can rethink a data-driven approach in astrophysics. Brunton, Proctor & Kutz wrote to summarize how such an approach is of significance in science and also in engineering in general, which can be paraphrased as: "Removing overseeing conditions from information is a focal test in numerous assorted spaces of science and designing. Information are bountiful though models regularly stay slippery, as in environment science, neuroscience, biology, money, and the study of disease transmission, to give some examples models. In this work, we join sparsity-advancing methods with nonlinear dynamical frameworks to find administering conditions from uproarious estimation information." [2]

Of course, first of all we shall discuss how Kepler reported his study of planetary motions in the solar system, which led him to come up with his three laws. To quote Brunton *et al.*[2], which can be paraphrased as follows:

"Kepler, outfitted with the most broad and exact planetary data of the period, fostered an information driven model for planetary movement, resulting in his renowned elliptic circles. Notwithstanding, this was an

attractor-based perspective on the world, and it didn't clarify the principal dynamic connections that bring about planetary circles, or give a model to how these bodies respond when irritated. Newton, in contrast, found a uniqueconnection between force and energy that depicted the basic cycles answerable for these elliptic circles."[2]

Nonetheless, in the light of three problems which appear persistently even since Newton era, namely: Bentley's problem, Zwicky's dark matter problem, and accelerated expansion or more known as dark energy problem, and also from the data and improving Titius-Bode law, in the second section we suggest to come up with a new hypothesis: "*quantum matter inside a Newtonian universe.*"

In other words, we will discuss how quantum geophysics and quantum astrophysics emerge into the scene, more or less based on reading the data themselves. This approach seem like repeating what Kepler himself did, especially if he lives today and got new collection of astrophysics data which were not available in his time.

A. FROM KEPLER TO NEWTON TO ZWICKY

A.1. Short review of Kepler's result
Tycho Brahe at the time was a master of observation of celestial bodies by his new telescope. But later on he recruited a young assistant, Johannes Kepler. In 1609, Johannes Kepler revealed that the planet Mars moves in a circular circle. What sort of power makes a planet move in a circular way? What is the power law — the law that indicates how the power F(r) relies upon the distance r between the Sun and the planet? This Kepler issue tested the regular rationalists of the seventeenth century.[3]

A.2. Newton's interpretation
Newton's proof of the connection between elliptical orbits and inverse-square forces ranks among the "top ten" calculations in the history of science. Isaac Newton solved Kepler problem in his *Mathematical Principles of Natural Philosophy*, published in 1687. [3]

J. Prentis *et al*. [3] argue that there is the so-called Newton's Recipe which anyone can follow:
"Newton's Recipe depends on a secret jewel in Newton's *Principia*—the "PQRST Formula," which is a basic mathematical adaptation of F = m.a. Given any sort of orbital bend (curved, twisting, and so on), this recipe permits one to reason the power just by estimating the lengths of three line sections—the "shape boundaries" of the circle."[3]

J.Prentis *et al*. also explain further what are the steps in Newton's recipe, which can paraphrased as follows:

Given just two ingredients-the state of the circle and the focal point of the power—"*Newton's Recipe*" permits one to compute the general power at any orbital point. The formula comprises of following advances:
1. *The inertial path:* Draw the digression line to the circle bend at the point P where the power is to be determined.
2. *The future point:* Locate any future point Q on the circle that is near the underlying point P.
3. *The deviation line:* Draw the line portion from Q to R, where R is a point on the digression, to such an extent that QR (line of deviation) is corresponding to SP (line of power).
4. *The time limit:* Draw the line section from Q to T, where T is a point on the spiral line SP, with the end goal that QT (stature of "time triangle") is opposite to SP (base of triangle).
5. *The force measure:* Measure the shape boundaries QR, SP, and QT, and compute the power measure QR/(SP x QT).
6. *The calculus limit:* Repeat stages two to five for a few future focuses Q around P to get a few power measures. Take the cutoff Q→P of the succession of power measures to track down the specific worth of the power measure at P.

The above steps summarize Newton's steps to prove that there is a dynamical force, or the so-called *governing equations* for planetary orbits around the Sun. That would mean that at the time Kepler and Newton followed a data-driven approach to solar system.

But is that correct inlight of more precise measurements? It is known, that even in Newton's era there were critics to his theory.

A.3. Three problems up to present

A.3.a. Bentley's paradox

As Michio Kaku wrote about the paradox:

But Newton's theory also reveals paradoxes that inherent in the theory of a finite or infinite universe. Simple questions lead to chaos contradiction. Even while Newton rejoices with fame thanks to the publication of the *Principia*, he discovered that his theory of gravity no doubt filled with paradoxes. In 1692, a priest, Rev. Richard Bentley, wrote a simple but troublesome letter to Newton. After careful thought, Newton wrote back that he find loopholes in the argument. He prefers nature the universe is infinite but uniform. Thus, if a star being dragged to the right by an infinite number of stars infinity, this is thwarted by the equivalent drag of the star sequence another infinity in the other direction. All styles are balanced in each direction, resulting in a static universe. So, if gravity always attract, the only solution to the Bentley paradox is natureinfinite but uniform universe.Newton did find a loophole in Bentley's argument. But Newton was smart enough to realize the weakness of his answer alone. He admitted in a letter that the solution was not solid, though technically correct. [4]

A.3.b. Zwicky

Another observation made by Fritz Zwicky around 1930s, who suggested that the galaxy does not follow the Newton's law. It seems more like flat instead of following the inverse square law. There seems to be a large mass, which then it is called "dark matter." The problem is : despite so many theories of dark matter have been proposed, including MOND etc., but most of them cannot be detected nor observed in lab. There is something really missing here.

A.3.c. Accelerated expansion / dark energy

If the above two problems are quite perplexing, there is more perplexing problem: dark energy or mysterious force which accelerates the expansion of the universe. Along with dark matter, dark energy seems also repel most theoretical models.

The above three problems make us wondering if there is something missing not only in General Relativity scenario, which was set by Einstein to give more or less same result to Newton in limiting cases.

B. ANOTHER APPROACH TO DATA-DRIVEN MODELING

Therefore, let us begin from a fresh starting point: Since 1700s, there were two scientists who suggest pattern of orbit distances, known as Titius-Bode law. Albeit their method is different from Kepler's observation, but nonetheless these are also data which have value in themselves to be studied.

And many papers have been written on the physical meaning of Titius-Bode law, especially with respect to *Old Quantum Theory* of Bohr and Sommerfeld (before 1920s) and also to *New Wave Mechanics* of Schrodinger etc. In other words, does it mean we shall begin to consider a *quantum version of astrophysics*? Or to speak more precisely: can we speak of a *quantum explanation* of planetary orbit distances?

Definition of quantum astrophysics: "The uses of quantum mechanical principles to describe astrophysical phenomena and processes."[1]

Question: Which quantum mechanical principles are applicable to large-scale astrophysical bodies?

Remark: With the above question, we point out that there are several different approaches of QM, and even the meaning of quantum wave function in wave mechanics, remains a debatable issue among experts. And which interpretation of quantum wave function corresponds better to quantum phenomena, such as planetary orbit distances? We will discuss this topic in our paper: "*Dialogue between two chief worldview systems...*" (forthcoming).

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[1]Note: Actually this term is not really new, as McCrea has discussed quantum mechanical laws in astrophysics, back then around 1950s. See also for instance : Elena Muchikova, *Astrophysical Applications of Quantum Mechanics*, PhD dissertation submitted to Caltech, 29th May 2018.

In this regards, allow us to tell a story of us. We will review the work and results during the past 17 years or so. The basic assumption here is that the Solar System's planetary orbits are quantized. But how do their orbits behave? Do they follow Titius-Bode's law? Our answer can be summarized as follows:

Navier-Stokes equations --> superfluid quantized vortices --> Bohr's quantization rule   (1)

Our predictive model based on that scheme has yielded some interesting results which may be comparable with the observed orbits of planetoids beyond Pluto, including what then was dubbed as Sedna. And it seems that the proposed model is slightly better compared to Nottale-Schumacher's gravitational Schrödinger model and also Titius-Bode's empirical law. (*Note*: Prof. Laurent Nottale is a senior astronomer at *Observatoire de Paris, Meudon*, France.) See table 1 below.

Table 1: Comparison between Laurent Nottale's results, Titius-Bode law, CSV, and observed data

Object	No	Titius-Bode	L. Nottale (in 10 AU unit)	CSV (in 10 AU unit)	Observed (in 10 AU unit)
-	1		0.4	0.43	
-	2		1.7	1.71	
Mercury	3	4	3.9	3.85	3.87
Venus	4	7	6.8	6.84	7.32
Earth	5	10	10.7	10.70	10.00 (1 AU)
Mars	6	16	15.4	15.4	15.24
Hungarias	7	-	21.0	20.96	20.99
Asteroids	8	-	27.4	27.38	27.00
Camilla	9	-	34.7	34.6	31.5
Jupiter	2	52	-	45.52	52.03
Saturn	3	100	-	102.4	95.39
Uranus	4	196	-	182.1	191.9
Neptune	5	-	-	284.5	301
Pluto	6	388	-	409.7	395
2003EL61	7	-	-	557.7	520
Sedna	8	722	-	728.4	760
2003UB31	9	-	-	921.8	970

 (Source: After V. Christianto, *Apeiron*, July 2004. URL: http://redshift.vif.com) [6].

The above evidences of quantization of planetary orbit distances seem to suggest to *wave mechanics model at large scale*. [6-11] See also Peter Coles [12].

C. TOWARDS QUANTUM GEOPHYSICS AND QUANTUM ASTROPHYSICS

C.1. Quantum Geophysics
It is known that most Professors and college students would write Newton gravitation law as follows:

F=m.a   (2)

But that is only half correct. The correct definition provided by Newton is that gravitation force is the *rate of change of momentum,* or:

F=dp/dt   (3)

Or we can write:

F=d[mv]/dt   (4)

Or

F=m.dv/dt + v.dm/dt   (5)

In other words, there can be certain processes where rest mass of the celestial bodies can vary, i.e. it is called varying mass. Recent paper suggesting hydrodynamics description of gravity also provides a possible mechanism of expanding earth and red shift. [16]

In literature, there are some proposals on what kind of plausible mechanisms for such a *matter-creation* process, for instance VMH (*variable mass hypothesis*) of Narlikar & Arp, and later on C-field model of Prof. Jayant Narlikar, but there can be more advanced explanations, such as *neutron repulsio*n behind the inner core of the Sun (and may be also in Earth and other planets) as proposed by Kuroda-Manuel, and low energy nuclear reaction, or even some kind of biological-like transmutation, as discussed by Louis Kervlar and J.P. Biberian (see J.P. Biberian's papers at JCMNS). This topic deserves a separate paper, so we will discuss later on.

Going back to our data-driven approach, such an expanding earth hypothesis may be associated to *Pangaea hypothesis*, which is known to paleo-geology studies etc. See some figures below.
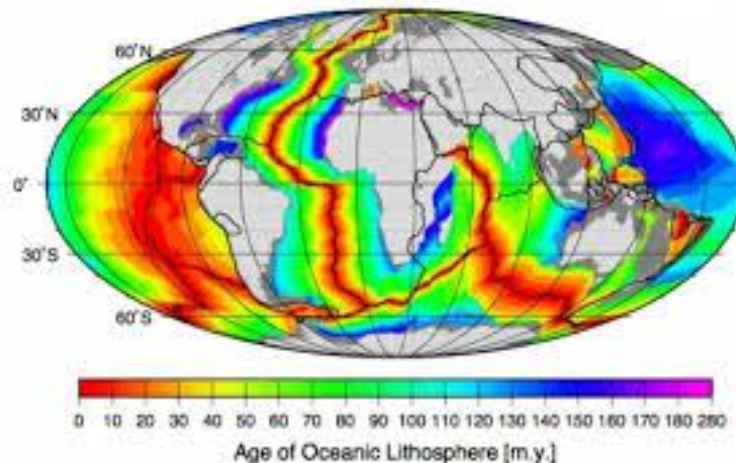

Figure 1:

Figure 2:

Interestingly, there is also an ancient *Piri Reis* map (circa 1513) which is different from the map that we know today.

Figure 3:

C.2 Quantum Astrophysics
Provided the above interpretation of quantization of planetary orbit distances can be accepted (based on assumption of Bohr-type quantization to improve Titius-Bode law), then we can deduce a number of interesting implications, which are discussed more fully in our forthcoming paper [5].

Although it is known that "One of the cornerstones of inflationary cosmology is that primordial density fluctuations have a quantum mechanical origin," as Kanno & Soda wrote, however, most physicists consider that such *quantum mechanical effects disappear* in CMB data due to decoherence. [13] At this point, we can ask: Is that really so?

We have discussed before that cosmological entanglement has been observed, which in turn it can be attributed to superfluid turbulent interstellar medium.

Now, there is a recent striking report by Charlotte Olsen *et al.*, suggesting that 36 galaxies seem to have "coordinated" in a such way that they appear to give *synchronized stars formation.* From Olsen *et al*.'s paper, they don't give a possible theoretical explanation. [14]

However, by hypothesizing that a spin supercurrent mechanism can happen at galactic scale because of superfluid interstellar medium, we can come up with a plausible explanation; that such a coherent star formation is due to some kind of "*galactic synchronicity.*"

We are aware that such a term is not available yet in present cosmological vocabularies, but we can foresee that time for that term will come too, as there is also a book, suggesting that synchronicity is likely to appear universally in the Universe; just like in our ordinary life, we sometimes meet an old friend without arrangement - and such an event can be viewed as Divine Synchronicity (cf.C. Jung). [15]

In the meantime, while it can be shown that such a galactic synchronicity may be associated to *cosmological-scale entanglement,* it remains to be seen if we need to modify macrodescription of electromagnetic phenomena towards cosmic electromagnetic theories. See for instance: Hoyle & Narlikar [17], and also Hannes Alfven [18].

A hetegony: plausible explanation for Pluto-Charon pairing
According to Stern et al.: "Given just two ingredients-the state of the circle and the focal point of the power—"*Newton's Recipe*" permits one to figure the overall power at any orbital point. Pluto's uncommon orbit compared to the giant planets provoked different hypotheses about its beginning and provenance from the1930s to the1990s. ... Most famously Kuiper (1951) suggesting Pluto was the harbinger of a huge "trans-Neptunian" population of comets and larger bodies. ... This drove to a number of telescopic searches for that cohort populace" which was finally detected by the discovery of the primary Kuiper Belt (KB) Object (Jewitt & Luu, 1993). See S.A. Stern et al. [19].

There are extensive studies on Pluto-Charon pair system, see for instance [19-22]. For example, it is known that there are a number of satellites orbiting such a binary system, as Showalter and Hamilton wrote: "Four small moons—*Styx, Nix, Kerberos and Hydra*—follow near-circular, near-equatorial orbits around the central "*binary planet*" comprising Pluto and its large moon, Charon. New observational details of the system have emerged following the discoveries of Kerberos and Styx. Styx, Nix and Hydra are tied together by a three-body resonance, which is reminiscent of the Laplace resonance linking Jupiter's moons: Io, Europa and Ganymede."[21]

Regarding the origin of Pluto-Charon binary system, there is a suggestion of giant collision.[22] While such a possibility may not be excluded, we argue in a previous published paper, that there could be a far more interesting possible explanation, provided we accept the aforementioned quantum explanation of orbital distances, that the Pluto-Charon pairing is an indicator of "*planetary equivalent*" to Cooper pairing in the outer solar system. As we wrote: "Pairing of Pluto-Charon and other TNOs/KBOs seem to be attributed to the BCS/BdG pairing condition pointing to low temperature physics model of Solar System." [23]

Nonetheless, we admit that for now and may be until a few years later,conventional readers are likely to consider such a suggestion a bit weird. However, we are more than sure that given more data will be available in the coming years, our hypothesis of quantum astrophysics will be confirmed eventually. Let history be the judge.

CONCLUDING REMARKS

In this paper we review on how Kepler and Newton began their scientific explorations based on the available observation data at their time. In other words, that indicates a *data-driven modelling* approach, as discussed by Brunton *et al.*[2] (Or if we can speak in social science terms, shall we use "*grounded approach*" in physical sciences too?)

We also discuss that even in Newton era, there were some critics to his book, notably Richard Bentley's letter to Newton. Other problems and paradoxes are also known until now, including by Zwicky etc. In the second section, we discuss that provided we accept such a data-driven approach, starting from Titius-Bode law may suggest a possibility of quantum explanation of planetary orbit distances, hence a *quantum astrophysics*.

Finally we make a few remarks on plausible implications, including to explain the Pluto-Charon pair system. Conventional explanation of their origin includes giant collision in the past. Nonetheless, there could be a far more interesting possible explanation, provided we accept the aforementioned quantum explanation of orbital distances, i.e. that the Pluto-Charon pairing is an indicator of "*planetary equivalent*" to Cooper pairing in the outer solar system.

To summarize, I believe that the proposed quantum astrophysics and quantum geophysics are more feasible and achievable, compared to quantum gravity which is so elusive goal despite decades of efforts (really sorry for so many PhD students devoting time for that topic); *especially with respect to evidence-based physics and evidence-based mathematics* principles that we argue elsewhere [25].

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