

Johannes Kepler and The Magnetic Unification of Terrestrial and Cosmic Physics

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Introduction

The unification of physics as a fundamental goal is older than modern science. Thales argued that water was the universal substance; the earliest attempt at a unified natural philosophy. The hypothesis of unification is that diverse, complex, and apparently unrelated phenomena, can be unified under a single principle that unifies the phenomena under the aegis of a simpler and more elegant law or principle. Johannes Kepler (1571-1630) is the first scientist of the modern era to attempt a unification of physics, in the modern sense, on a grand scale, by unifying terrestrial and cosmic physics under the aegis of the force of magnetic attraction. The concept which he develops is an attempt to explain the cosmic physics of the external universe based on an extension of the known principles of terrestrial physics using the principle of magnetic attraction. Kepler's goal is to unite astronomy and physics,

“I believe that both sciences are so closely interlinked that one cannot attain completion without the other.”¹

Kepler's new natural philosophy is inspired by William Gilbert's magnetical philosophy, which Kepler extends to create a theory of planetary revolutions. This attempt at unification, like Gilbert's attempt to unify terrestrial physics under magnetism, was not successful. But his ideas formed the basic framework which enabled Isaac Newton to successfully complete the unification under the principle of universal gravitation using the new science of mechanics.

The decline of magnetic philosophy during the course of the seventeenth century accounts for the little recognition that has been given to the magnetic theories of Gilbert and Kepler. The age soon abandoned the type of philosophy which they advocated. It was primarily Aristotelian and neo-Platonic in language, although it was firmly founded on experimental principles. Newton said that he succeeded because he stood upon the shoulders of giants. Kepler was certainly one of the giants, but in many ways his accomplishment was greater than Newton's.

Kepler blazed the trail which made the Newtonian unification of physics possible. Kepler demonstrated the mode of thought which conceived a need to apply physical principles to the heavens. This is the bold step that creates the scientific revolution. It is a revolution that is embodied in the new science of astronomy, and then spreads. We should not underestimate the importance of the invention of new astronomy by Kepler. Kepler's contribution was far greater than his discovery of the three laws of planetary motion; Kepler imagined a new conception of the universe that linked the terrestrial and heavenly realms in the trinity of the creator.

Historians dub the new astronomy the Copernican revolution, but in truth it should be the Keplerian revolution, because the real innovations and discoveries come from Kepler. He conceived that the Copernican system needed a divine law or principle to unify it into a single divine entity. A universe created by God. But, Kepler was more than a theologian, he was a

natural philosopher who saw God's work in the unity of heaven and earth. Kepler imagined that it was a physical unity created by God. Kepler's problem was to discover God's plan and make it intelligible to the mind of man. This was accomplished by observation of God's work in terms of God's divine laws expressed mathematically.

Copernicus heliocentric theory of the cosmos made the revolution of the planets around the sun into a viable theory, which demonstrated sufficient reason, but it did not possess the elements of necessary reason. Copernicus' arguments merely demonstrated the possibility that the sun was at rest in the center of the universe. Kepler's initial arguments for heliocentrism made it a theological necessity; it was God's divine plan that required the sun at the center of the universe. Kepler's later and more developed arguments for heliocentrism made it into a physical necessity, because the sun was envisioned as the motive force for the planetary revolutions. To understand Kepler's approach, we must appreciate that it was more than a scientific argument. His proofs of heliocentrism were based on the proofs of natural philosophy as well as theology and metaphysics.

Kepler's Life

Kepler was born in Weil in the state of Württemberg, Germany in the year 1571, twenty years after the publication of Copernicus heliocentric theory. He studied theology at the University of Tübingen, intending to become a protestant pastor. He learned Astronomy from Mastlin, who introduced him to the Copernican theory. Kepler wrote a paper on the reconciliation of the Copernican view with Sacred Scripture, because his principle desire was to enter the ministry. But his career path was changed by his mathematical talent, when he was offered the post of mathematician and teacher at Graz, in Styria (modern Austria), in 1594. At Graz his duties did not fully occupy his time, and he had the leisure to study philosophy. This set him on the path to mathematical natural philosophy.

In 1595 Kepler made a discovery that inspired him to become an astronomer. He wrote that: "God in creating the universe and regulating the order of the cosmos had in view the five regular bodies of geometry as known since the days of Pythagoras and Plato." This idea inspired the publication of his first book, "The Cosmic Mystery". The book was a success and gained the attention of Tycho Brahe and Galileo. In 1598, Protestants were banned in Styria, and Kepler accepted an offer to work for Tycho Brahe in Prague. The following year, upon Tycho's death, he succeeded Tycho in the post of Imperial Astronomer. In this new position, he had access to Tycho's detailed astronomical observations of the planetary positions. In 1602 he wrote an astrological treatise "On The More Certain Foundations of Astrology." In 1604 a treatise on Optics, and in 1611 on Dioptries. But his most important work was his analysis of the motions of Mars completed in 1609, titled "New Aetiological Astronomy or Celestial Physics together with Commentaries on the movements of the Planet Mars", in which he stated his first two laws of planetary motion.

Meanwhile dark clouds were gathering over Germany as the upheaval that would culminate in 30 years of religious warfare was getting underway. In 1619, a year after the beginning of the war, he published "The Harmonies of the World". In 1618 the first part of the "Epitome of Copernican" astronomy appeared. Then for the next three years he continued to publish this

extensive textbook on astronomy that was highly influential. In it he published his third law of planetary motion. Finally, in 1627, he published the Rudolphine Tables, which were the latest and most up to date predictions of planetary positions for many years. He died two years later, in November 1630. His epitaph reads “I had measured the heavens; now I measure earth’s shadows. Mind came from the heavens, Body’s shadow has fallen.”

The Cosmic Mystery

In 1596 Kepler published his first book, the *Mysterium Cosmographicum* (Cosmic Mystery). It records his personal revelation that “God in creating the universe and regulating the order of the cosmos had in view the five regular bodies of geometry as known since the days of Pythagoras and Plato.” This landmark work lays out the blueprint for Kepler’s plan. He conceives of the universe as a harmonious mathematical unity created by God and laid out based on a geometric law for planetary revolutions. He presented the idea that the movement of the planets derived from the sun. His conception, the *anima motrix*, conceived a motive power emanating from the sun and pulling the planets around in their orbits. The concept was crude and ill formed, but it showed that Kepler recognized the need to explain why the planets performed infinite continuous revolutions about the sun which Kepler placed at the center of the solar system. This is the fundamental imaginative idea that forms the center of the new astronomy and makes heliocentrism a physical necessity.

When Kepler wrote the *Cosmic Mystery* he had already conceived of the importance of the need for activating forces to cause the planetary motions around the sun. His *anima motrix* was the species he postulated for the cause of the planetary revolutions, but he also recognized the need to explain the rotation of the earth and avoid the objection that objects thrown upward return to the same place. Kepler explains this as follows:

“How is it possible that a sphere thrown vertically upward-while the earth rotates meanwhile-does return to the same place? the answer is that not only the earth but together with the earth, the magnetic invisible chains rotate by which the stone is attached to the underlying and neighboring parts of the earth and by which is retained to the earth by the shortest, that is, the vertical line.”

Here he invokes a conception of the magnetic force which holds the sphere in its grasp and carries the sphere around as the earth rotates. This idea is fundamental to Kepler’s concept of the activating force of gravity as we will see in his later developments of it.

The *Mysterium Cosmographicum* served to introduce Kepler’s new ideas to the Danish astronomer Tycho Brahe; creator and founder of the first European observatory. Tycho, who was the world’s foremost observational astronomer, urged that Kepler temper his ideas with knowledge of the observations of planetary positions. This initiated a short collaboration when Kepler was hired as Tycho’s assistant. Kepler was assigned to derive the orbit of Mars. This led to the discovery of Kepler’s first two laws; that planets revolve in ellipses, and that they travel with a non-uniform velocity. The results were published in 1609 in his book *Astronomia Nova* (New Astronomy). This presented a new theory of the *anima motrix*, renamed as *anima immateriata*,

based on the force of magnetic attraction. In a letter written in 1605 Kepler describes his plan to a colleague:

“I am much occupied with the investigation of the physical causes. My aim in this is to be likened not to a divine organism but rather to a clockwork..., insofar as nearly all the manifold movements are carried out by means of a single, quite simple magnetic force, as in the case of a clockwork all motions [are caused] by a simple weight. Moreover I show how this physical conception is to be presented through calculation and geometry.”¹

The Cosmic Mystery interpreted the sun as a divine source of the motive force. The New Astronomy makes the sun into a physical source of the motive force and a physically necessary principle to explain the motion of the planets. The change in emphasis was a decisive turning point, but notice that for Kepler, the change from the species motrix, an immaterial force due to divine soul, to the species immateriata, also an immaterial force similar to magnetism was motivated by a desire to make the cause physical. But, to the modern reader, there is no real difference.

Kepler however conceived that they were different. When he was engaged in writing the Cosmic Mystery, his idea was that the animating force was a “motory intelligence” in the traditional idea of the concept, but Kepler moved beyond this in his search for a physical reason as he explains in an annotation to the second edition of the Cosmic Mystery of 1621:

“If you substitute for the word “soul” the word “force,” you have the very principle on which the celestial physics of the treatise on Mars etc. is based...Formerly I believed that the cause of the planetary motion is a soul, fascinated as I was by the teachings of J.C. Scaliger on the motory intelligences. But when I realized that these motive causes attenuate with distance from the sun, I came to the conclusion that this force is something corporeal, if not so properly, at least in a certain sense.”

This statement, taken at face value by the modern reader, is certainly confusing. What does he mean? It is clear he means that he desires a material cause but that the force itself is not. Otherwise we are forced to conclude he is saying magnetism is corporeal, and he is not. The answer is a change in emphasis upon the source of the force. For Kepler, and Gilbert, this force originates within the material cause. For Gilbert, magnetism was an immaterial force expressed from within the earth as if from its soul. Hence Kepler saw corporeal bodies as the source of the species immateriata that caused them to move, just as the magnetic species moved the iron to the lodestone.

The Roots Of The magnetic Philosophy

When Kepler read Gilbert’s “On The Magnet”, it profoundly changed his thinking regarding the motion of the planetary bodies. But, it is also clear that he had a magnetic concept prior to this, when he wrote the “Cosmic Mystery.” He did not need Gilbert to suggest to him the idea that the planets were influenced by magnetic attractions, this idea was already widespread as a result of the teachings of astrology. In a sense it is logical for Kepler, an astrologer, and mathematician by profession should combine ideas fundamental to astrology, with the new Copernican physical

ideas to create a physical astronomy based on cosmic influence of heavenly bodies. This idea had been fundamental to the teachings of astrology for thousands of years. What was new in Gilbert's formulation, that Kepler borrowed, was that a physical principle, mathematically demonstrable, was asserted as the cause of celestial motions. This physical principle was magnetism. It wasn't magic, it was a real provable force of vigorous action, that could not be dismissed as unreal, magical, or superstitious. The rationalist Aristotelians had been forced to accept it for two thousand years, because magnetism was indisputably real.

The primary claim of astrology is that the heavenly realm influences the earthly one.

“The object of astrology...is [first] to measure the motions of the elements from the motions of the stars and the changes of time; then to measure the motions of the cosmos itself; then, of its parts, [and to do these] both generally and specifically...so the astrologer turns from a certain sensible instruction of experience to the natural [relations] of heavenly bodies...And thus he recognizes the definitive power and natural force of the stars and planets by reason of their effects...” (Olson p. 185)

The most evident of these influences, is the correlation of the moon's motion with motion of the water element. The motion of the ocean seas through the rising and falling tides was correlated with the movement of the moon. This correlation was noticed by the ancients and claimed as proof of the truth of astrology.

In 1269AD when Petrus Peregrinus wrote his letter concerning the magnet, astrology played a large role in his magnetic theory. Peregrinus thought that the magnetic force was astrological, with its source in the divine heavens. This explained why the compass always pointed north-south a result of the astral influence from the poles of heaven. Gilbert changed this source from the heavens to inside the earth, so that the magnetic power emanated from within the earth, because inside the earth was a source of divine vigor which was manifested in the form of magnetism. Since Gilbert extended this divine soul to all the stars and planetary bodies, his philosophy became an extension of astrology, but with a rational physical basis for its claims.

Kepler's New Astronomy

Kepler's New Astronomy takes up the issue of magnetic attraction as the unifying force for the solar system. He does this by an imaginative innovation that extends Gilbert's concept of the orb of virtue. Kepler's magnetic force is extended throughout space as a magnetic field. Kepler's conception is one of a magnetic field made sensible to the intellect by his imagination. His descriptions of the field show that he understood Gilbert's concept and that by extending the force into the vast space surrounding the sun, that the magnetic force could be made to explain the revolutions of the planets around the sun. A fundamental aspect of this idea was the extension of Gilbert's idea of magnetism as an immaterial species like light which Kepler envisioned extended into the ethereal realm from the sun. Kepler tells us that,

“If anyone were to ask my opinion of the body of the Sun from which emanates the motive species [which makes the planets rotate], I should tell him to pursue the analogical argument further, and to examine more closely the example of the magnet.”

The innovation developed in the New Astronomy, is Kepler's modified concept of the species motrix, which is remarkably similar to the modern idea of a field of force. Kepler's species motrix plays the role of the field in his physics of planetary motion. It communicates to the planets via an immaterial force the rotary motion of the sun which emanates it into the surrounding vastness of space. Kepler's field theory is principally based on the ideas of the Aristotelian scholastics. An immaterial species, the species motrix, is envisioned as emanating from the sun just as the luminous solar energy is propagated into the surrounding space. Hence, light serves as Kepler's model for the "effluxus" or propagation of the magnetic field into space. The field is envisioned by a representation which sounds like the modern idea of line of force. Kepler envisions a field of fibers surrounding the sun which act upon the planets to impart to them their rotary motion derived from the sun. This is an imaginative concept that represents how the species motrix acts to transfer the sun's rotary motion to the planets.

In his imagination, Gilbert saw the magnetic force emanating from Mother Earth causing it to rotate on its axis, while for Kepler, it was the Sun which held the planets to their revolutionary courses by its magnetic force. Kepler's explanation was based on his imaginatively descriptive idea of magnetic filaments or fibers which extended outward from the sun.

"However a magnet does not attract [Iron] by all its parts, but possesses filaments or rectilinear fibers (the seat of the motive force), extended in length in such a way that a strip of iron placed at the midpoint between the heads [poles] of the magnet is not attracted to it, but only brought parallel to the fibers".²

Kepler's idea was that the force of motion was propagated outwards from the sun as an immaterial species just as light does. The force imparted motion to the planets,

"In fact this force, which extends from the Sun to the planets, moves them in a circle round the body of the Sun, which remains in the same place. Now, this cannot happen, nor be understood by the mind, except in one way: the force itself must travel the same path on which it carries the planets, as occurs in ballistae and all violent motions."

Kepler saw the motive force as a field emanated from the sun and rotating with it. But the rotation was not rigid. The more distant parts rotating more slowly than the nearer. Hence the motive force was contained entirely within the field and derived motion from it. Furthermore, the motive force was magnetic, as Kepler says:

"The conclusion is therefore plausible: because the Earth moves the Moon by its species, and is a magnetic body; and because the sun moves the planets in a similar manner by the species which it emits, therefore the Sun, too, is a magnetic body"

A set of these circular fibers was envisioned surrounding the sun like the latitude coordinate circles on a globe which "turns also with the sun..." and drags the planets along with it. He describes the fibers surrounding the sun as follows:

“...it possesses circular fibers extending around it in the plane which is defined by the circle of the Zodiac. Therefore as the Sun turns eternally [on its axis], the sphere of the motive force or the defluxus (effluvium) of the species, which is spread throughout the whole of planetary space by the magnetic fibers of the sun, turns also with the Sun.”²

Later he explains in more detail.

“In fact, the Sun's magnetic filaments do not of themselves produce motion; they do so only because the Sun, by rotating very rapidly where it is placed, carries them round and causes them to turn together with the motive species which emanates from them.”²

In order to account for his discovery that the orbital velocity of the planets varied with distance, the motive force was envisioned to vary with the distance from the sun. Kepler's summary description captures the essence of his idea as follows:

“The Sun, remaining in its place, turns as though upon a lathe, and sends into the vastness of the Universe an immaterial species from its body, similar to the immaterial species of light: which species in consequence of the rotation of the solar body, rotates in the manner of a very rapid whirlpool which extends throughout the whole extent of the Universe, and carries the planets along with it, bearing them in a circle with a stronger, or weaker, raptus according as the density of this species is less, or greater, in conformity with the law of its effluxus.”²

This powerful image of the planets trapped in a rotating whirlpool would later become the basis for the Cartesian theory of planetary motion.

Kepler's' Epitome Of Copernican Astronomy

From 1618 through the year 1621, Kepler published his extensive work entitled Epitome Of Copernican Astronomy. It was a large work published in three volumes. In the preface to Book Four Kepler tells us that,

“.. Celestial causes...of all the magnitudes, movements, and proportions in the heavens are explained....This book is designed to serve as a supplement to Aristotle's On the Heavens.”

It is significant because it presents Kepler's mature thinking regarding cosmic physics. The theory of the species matrix is further clarified, leaving no doubt that he considers it to be magnetic. He spells out the sources of his inspiration:

“I build my whole astronomy upon Copernicus' hypothesis concerning the world, upon the observations of Tycho Brahe, and lastly upon the Englishman, William Gilbert's philosophy of magnetism.”

He further develops the magnetic thesis to account for the elliptical motion of the planets and other orbital discrepancies. The imaginative representation of the field as fibers or threads is continued.

Unfortunately the *Epitome* is disappointingly unclear regarding the physics of magnetic attraction. The concept of the species motrix, which was well developed in the New Astronomy is undeveloped in the *Epitome*. The magnetic threads or fibers are used to illustrate the magnetic actions but the actual physics remained vague. The reason seems to be that the audience is not the expert astronomers and savants of natural philosophy, but a larger more diverse audience of educated scholars and aristocrats. This detracts from its usefulness, because the explanations are more elementary and less specific than in the New Astronomy.

The Magnetic theory Of The Tides

The easily observed cyclical and rhythmic undulating movement of the ocean's tides, was correlated with the motion of the moon in very early times. The Greek philosophers Eratosthenes, Seleucus, Hipparchus, and Posidonius knew it as well as the Romans Cicero, Pliny the Elder, and Strabo. Ptolemy the Egyptian Greek, astronomer and astrologer also knew that the moon influenced the motion of the oceans, but what was the cause of this influence which the moon exerted upon the oceans?

This was a subject of considerable controversy. Rationalist, astrological, and sympathetic theories were offered. Ptolemy advanced an astrological theory that supposed that the moon exerted a particular virtue towards the waters of the oceans: a kind of astrological sympathy. This of course was rejected by the rationalists, who tried the theory that light from the moon caused the tides. This idea however, was easily seen to be false, because the tides were as great during new moon as full moon. Some other occult influence must be at work. But in order to be acceptable to the rationalist Aristotelians, this influence could not be merely an occult virtue. Hence, when William of Auvergne suggested magnetism, "by comparing the action of the moon on the water to the action of the magnet on iron," in his book titled *De Universo* the objections of the rationalists were avoided. The action of the magnet was a rational cause, and this became a popular explanation for the cause of the tides. The explanation was also "made to order" for the astrologers, who saw magnetism as an astrological influence.

In 1595AD, there was a rationalist reaction. Giovanni Pico della Mirandola denied the power of heavenly bodies to exert an influence on the earth below. He rejected explanations involving astrology as well as magnetism. He declared that the magnetic theory of the tides was erroneous. This was quickly met with a publication by Lucius Bellantius, a physician of Siena. Bellantius argument was decisive and ended the debate: "the rays by which the moon chiefly acts when it attracts and swells the waters of the sea are not the rays of moonlight, for at the time of conjunctions there would be no ebb and flow whereas we can and do notice them then; it is by means of virtual rays of influence that the moon attracts the sea as the magnet attracts iron. With the aid of these rays we can easily resolve all the objections concerning this matter".

The magnetic theory of the tides was therefore the only logical theory left and it became the accepted explanation up to the publication of Gilbert's "On the Magnet", even if did not receive enthusiastic support from the rationalists. Gilbert of course endorsed it. It is Kepler, however, who, while endorsing the idea of a magnetic like influence, extended the concept in a way that suggests the modern concept of gravity. This "gravity" was for Kepler an extension of the

magnetic force to a different kind of attraction. This however was an idea that occurred to him after he had written his main works in astronomy. In a note written in 1643 Kepler says that:

“The moon does not act like a humid or humidifying celestial body, but like a mass related to the mass of the earth; it attracts the waters of the sea by a magnetic action, not because they are humors but because they are endowed with terrestrial substance to which they owe their gravity.”

Here we see Kepler rejecting the astrological theory of a sympathy between the moon and water in favor of a more universal idea, that the substance of the earth and moon are the same, and that they are attracted by a law of nature based on a kind of magnetic like attraction, between bodies of the same substance.

Latter in the same letter, Kepler makes a statement that shows just how close he was to our modern idea of gravitational force.

“If the moon and earth were not retained in their respective orbits by an animal force or by some equivalent force, the earth would climb toward the moon and the moon would descend toward the earth until these two heavenly bodies were joined. If the earth ceased attracting the waters covering it, the sea waves would all rise and flow toward the body of the moon.”

This statement shows that the really important idea of universal gravitation was already present in Kepler's thinking. The only pieces of the puzzle that remained were the force preventing the union of the orbiting earth-moon system; ie, centripetal force, and its rigorous expression in a theory of motion; ie Newton's three laws. The reason is clear. Gilbert's concept of magnetic coition had already demonstrated that this was the force that urged two magnetically attracted bodies mutually towards each other. Hence what was needed was a mechanics which fully expressed this concept, combined with a theory of orbital motion. Curiously, magnetism was again crucial. Newton tells us that his invention of the third law of motion, the missing piece of the puzzle, was inspired by magnetic experiments of the same kind which suggested to Kepler the conclusions given in the above quotation. Newton's third law, for every force there is an equal and opposite force, was derived from experiments performed on magnets floating in a tub of water.

The Identification of Magnetism With Gravity

William Gilbert's idea that magnetism was the unifying force or vigor of the universe, the earth as well as stars and planets, is known as the magnetic philosophy. It was a compelling idea because it made the Copernican hypothesis physically possible. The resulting Copernican physics is generally seen as the beginning of modern science. But, it was fundamentally based on the science of magnetism, which had been developing slowly but steadily during the Christian Era. Without the magnetic hypothesis, the successful development of Newtonian mechanics would have been delayed. The fundamental idea of the new astronomy was the existence of a universal gravitational force. This idea was resisted when it was introduced, as we will analyze in detail when we consider the eighteenth century. It was the reality of magnetism which was

decisive. The existence of an occult force of gravity was clearly not an acceptable metaphysical idea except in view of the fact that the reality of another occult force; ie, magnetism, could not be dismissed. Hence, action-at-a-distance had to be accepted, despite metaphysical objections.

The use of magnetism as a template for the idea of universal gravitation was not Gilbert's fundamental idea. He insisted that they were the same metaphysical reality. Kepler's viewpoint is not as clear. If in the beginning he thought that magnetism and gravity were the same, he later came to discard this idea. Another difficulty in dealing with Kepler's viewpoint is his erroneous concept regarding magnetism. He conceived, incorrectly, that the magnetic fibers, held the planets in a magnetic grasp, which pulled them around the sun as it rotated. This was contrary to the experimental evidence produced by Gilbert and others. Gilbert had demonstrated attraction and rotation but not any kind of magnetic force which caused circular motion. Hence Kepler's astronomical theory based on this concept of magnetism was false. But Kepler's failure did not prevent others from pursuing the same idea.

Conclusion

Kepler's development of the magnetic force concept was clearly a precursor to the magnetic field idea. The presence of the following elements shows how carefully the concept had been developed. Kepler contributes two new ideas to complete the field concept. These are: the analogy with the immaterial species of light to explain how the motive power is propagated out into empty space and the concept of magnetic fibers or filaments to visualize the action of the magnetic force. These are the two main imaginative ideas that allow Kepler to develop a representation of the distant action of the sun's magnetic force. They are not present in Gilbert's concepts.

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