03-P5) Johannes Kepler, “New Astronomy” (1609)¹

Introduction

It is extremely hard these days to write mathematical books, especially astronomical ones. For unless one maintains the truly rigorous sequence of proposition, construction, demonstration, and conclusion, the book will not be mathematical; but maintaining that sequence makes the reading most tiresome, especially in Latin, which lacks the articles and that gracefulness possessed by Greek when it is expressed in written symbols. Moreover, there are very few suitably prepared readers these days: the rest generally reject such works. How many mathematicians are there who put up with the trouble of working through the Conics of Apollonius of Perga? And yet that subject matter is the sort of thing which can be expressed much more easily in diagrams and lines than can astronomy.

I myself, who am known as a mathematician, find my mental forces wearying when, upon rereading my own work, I recall from the diagrams the sense of the proofs, which I myself had originally introduced from my own mind into the diagrams and the text. But then when I remedy the obscurity of the subject matter by inserting explanations, it seems to me that I commit the opposite fault, of waxing verbose in a mathematical context.

Furthermore, prolixity of phrases has its own obscurity, no less than terse brevity. The latter evades the mind’s eye while the former distracts it; the one lacks light while the other overwhelms with superfluous glitter; the latter does not arouse the sight while
the former quite dazzles it.

These considerations led me to the idea of including a kind of elucidating introduction to this work, to assist the reader’s comprehension as much as possible.

I conceived this introduction as having two parts. In the first I present a synoptic table of all the chapters in the book. I think this is going to be useful, because the subject matter is unfamiliar to most people, and the various terms and various procedures used here are very much alike, and are closely related, both in general and in specific details. So when all the terms and all the procedures are juxtaposed and presented in a single display, they will be mutually explanatory. For example. I discuss the natural causes which led the ancients, though ignorant of them, to suppose an equant circle or equalizing point. However, I do this in two places, namely, in parts three and four. A reader who encounters this subject in part three might think I am dealing here with the first inequality, which is a property of the motions of each of the planets individually. And indeed, this is the case in part four. However, in the third part, as the summary indicates, I am discussing that equant which, under the name of the second inequality, varies the motion of all the planets in common, and primarily governs the theory of the sun. Thus the synoptic table will serve to make this distinction clear.

Nevertheless, the synopsis will not be of equal assistance to all. There will be those to whom this table (which I present as a thread leading through the labyrinth of the work) will appear more tangled than the Gordian Knot. For their sake, therefore, there are many points that should be brought together here at the beginning which are presented bit by bit throughout the work, and are therefore not so easy to attend to in passing. Furthermore. I shall reveal, especially for the sake of those professors of the physical sciences who are irate with me. as well as with Copernicus and even with the remotest antiquity, on account of our having shaken the foundations of the sciences with the motion of the earth— I shall, I say, reveal faithfully the intent of the principal

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chapters which deal with this subject, and to propose for inspection all the principles of
the proofs upon which my conclusions, so repugnant to them, are based.

For when they see that this is done faithfully, they will then have the free choice
either of reading through and understanding the proofs themselves with much exertion,
or of trusting me, a professional mathematician, concerning the sound and geometrical
method presented. Meanwhile, they, for their part, will turn to the principles of the
proofs thus gathered for their inspection, and will examine them thoroughly, knowing
that unless they arc refuted the proof erected upon them will not topple. I shall also do
the same where, as is customary in the physical sciences, I mingle the probable with
the necessary and draw a plausible conclusion from the mixture. For since I have
mingled celestial physics with astronomy in this work, no one should be surprised at a
certain amount of conjecture. This is the nature of physics, of medicine, and of all the
sciences which make use of other axioms besides the most certain evidence of the
eyes.

The reader should be aware that here are two schools of thought among
astronomers, one distinguished by its chief, Ptolemy, and by the assent of the large
majority of the ancients, and the other attributed to more recent proponents, although it
is the most ancient. The former treats the individual planets separately and assigns
causes to the motions of each in its own orb, while the latter relates the planets to one
another, and deduces from a single common cause those characteristics which are
found to be common to their motions. The latter school is again subdivided.
Copernicus, with Aristarchus of remotest antiquity, ascribes to the translational motion
of our home the earth the cause of the planets' appearing stationary and retrograde.
Tycho Brahe, on the other hand, ascribes this cause to the sun, in whose vicinity he
says the eccentric circles of all five planets are connected as if by a kind of knot (not
physical, of course, but only quantitative). Further, lie says that this knot, as it were,

revolves about the motionless earth, along with the solar body. [ . . . ]

My aim in the present work is chiefly to reform astronomical theory (especially of the motion of Mars) in all three forms of hypotheses, so that our computations from the tables correspond to the celestial phenomena. Hitherto, it has not been possible to do this with sufficient certainty. In fact, in August of 1608, Mars was a little less than four degrees beyond the position given by calculation from the Prutenic tables. In August and September of 1593 this error was a little less than five degrees, while in my new calculation the error is entirely suppressed.

Meanwhile, although I place this goal first and pursue it cheerfully. I also make an excursion into Aristotle's *Metaphysics*, or rather. I inquire into celestial physics and the natural causes of the motions. The eventual result of this consideration is the formulation of very clear arguments showing that only Copernicus's opinion concerning the world (with a few small changes) is true, that the other two are false, and so on.

Indeed, all things are so interconnected, involved, and intertwined with one another that after trying many different approaches to the reform of astronomical calculations, some well trodden by the ancients and others constructed in emulation of them and by their example, none other could succeed than the one founded upon the motions' physical causes themselves, which I establish in this work.

Now my first step in investigating the physical causes of the motions was to demonstrate that [the planes of] all the eccentrics intersect in no other place than the very center of the solar body (not some nearby point), contrary to what Copernicus and Brahe thought. If this correction of mine is carried over into the Ptolemaic theory, Ptolemy will have to investigate not the motion of the center of the epicycle, about which the epicycle proceeds uniformly, but the motion of some point whose distance from that center bears the same ratio to the diameter [of the eccentric] as does the distance of the center of the solar orb from the earth for Ptolemy. which point is also on the same line,

2 [Note on the Prutenic Table ??]
or one parallel to it.

Here the Braheans could have raised the objection against me that I am a rash innovator, for they, while holding to the opinion received from the ancients and placing the intersection of the [planes of the] eccentrics not in the sun but near the sun, nevertheless construct on this basis a calculation that corresponds to the heavens. And in translating the Brahean numbers into the Ptolemaic form, Ptolemy could have said to me that as long as he upheld and expressed the phenomena, he would not consider any eccentric other than the one described by the center of the epicycle, about which the epicycle proceeds uniformly. Therefore I have to look again and again at what I am doing, so as to avoid setting up a new method which would not do what was already done by the old method.

So to counter this objection, I have demonstrated in the first part of the work that exactly the same things can result or be presented by this new method as are presented by their ancient method. [. . . .]

Thus for Ptolemy I have demonstrated that his epicycles do not have as centers those points about which their motion is uniform. Similarly for Copernicus I have demonstrated that the circle in which the earth is moved around the sun does not have as its center that point about which its motion is regular and uniform. Similarly for Tycho Brahe I have demonstrated that the circle on which the common point or knot of the eccentrics mentioned above moves does not have as its center that point about which its motion is regular and uniform. [. . . .]

However, if I place the common point or knot of the eccentrics in the center of the solar body, then the common circuit of both the knot and the sun is indeed eccentric with respect to the earth, and tends towards Cancer, but by only half the eccentricity shown by the point about which the sun’s motion is regular and uniform. [. . . .]

For whether it is the earth or the sun that is moved, it has certainly been demonstrated that the body that is moved is moved in a non-uniform manner, that is, slowly when it is farther from the body at rest, and more swiftly when it has approached
this body. [ . . . ]

First, Ptolemy is certainly exploded. For who would believe that there are as many theories of the sun (so closely resembling one another that they are in fact equal) as there are planets, when he sees that for Brahe a single solar theory suffices for the same task, and it is the most widely accepted axiom in the natural sciences that Nature makes use of the fewest possible means?

That Copernicus is better able than Brahe* to deal with celestial physics is proven in many ways. (*Of whom, in all fairness, most honest and grateful mention is made, and recognition given, since I build this entire structure from the bottom up upon his [Tycho's] work, all the material being borrowed from him.)

First, although Brahe did indeed take up those five solar theories from the theories of the planets, bringing them down to the centers of the eccentrics, hiding them there, and conflating them into one, he nevertheless left in the world the effects produced by those theories. For Brahe no less than for Ptolemy, besides that motion which is proper to it, each planet is still actually moved with the sun’s motion, the two being mixed into one, the result being a spiral. That it results from this that there are no solid orbs, Brahe has demonstrated most firmly. Copernicus, on the other hand, entirely removed this extrinsic motion from the five planets, assigning its cause to a deception arising from the circumstances of observation. Thus the motions are still multiplied to no purpose by Brahe, as they were before by Ptolemy.

Second, if there are no orbs, the conditions under which the intelligences and moving souls must operate are made very difficult, since they have to attend to so many things to introduce to the planet two intermingled motions. They would at least have to attend at one and the same time to the principles, centers, and periods of the two motions. But if the earth is moved. I show that most of this can be done with physical rather than animate faculties, namely, magnetic ones. But these are more general points. There follow others arising specifically from demonstrations, upon which we now begin.
For if the earth is moved, it has been demonstrated that the increases and decreases of its velocity are governed by its approaching towards and receding from the sun. And in fact the same happens with the rest of the planets: they are urged on or held back according to the approach toward or recession from the sun. So far, the demonstration is geometrical.

And now, from this very reliable demonstration, the conclusion is drawn, using a physical conjecture, that the source of the five planets motion is in the sun itself. It is therefore very likely that the source of the earth’s motion is in the same place as the source of the other five planets’ motion, namely, in the sun as well. It is therefore likely that the earth is moved, since a likely cause of its motion is apparent.

That, on the other hand, the sun remains in place in the center of the world, is most probably shown by (among other things) its being the source of motion for at least five planets. For whether you follow Copernicus or Brahe, the source of motion for five of the planets is in the sun, and in Copernicus, for a sixth as well, namely, the earth. And it is more likely that the source of all motion should remain in place rather than move.

But if we follow Brahe’s theory and say that the sun moves, this first conclusion still remains valid, that the sun moves slowly when it is more distant from the earth and swiftly when it approaches, and this not only in appearance, but in fact. For this is the effect of the circle of the equant, which, by an inescapable demonstration, I have introduced into the theory of the sun.

Upon this most valid conclusion, making use of the physical conjecture introduced above, might be based the following theorem of natural philosophy: the sun, and with it the whole huge burden (to speak coarsely) of the five eccentrics, is moved by the earth; or the source of the motion of the sun and the five eccentrics attached to the sun is in the earth.

Now let us consider the bodies of the sun and the earth, and decide which is better suited to being the source of motion for the other body. Does the sun, which
moves the rest of the planets, move the earth, or does the earth move the sun. which moves the rest, and which is so many times greater? Unless we are to be forced to admit the absurd conclusion that the sun is moved by the earth, we must allow the sun to be fixed and the earth to move. [ . . . ]

At this point, a modest (though not too modest) commendation to the learned should be made on behalf of Brahe’s opinion of the form of the world, since in a way it follows a middle path. On the one hand, it frees the astronomers as much as possible from the useless apparatus of so many epicycles and, with Copernicus, it includes the causes of motion, unknown to) Ptolemy, giving some place to physical theory in accepting the sun as the center of the planetary system. And on the other hand, it serves the mob of literalists and eliminates the motion of the earth, so hard to believe, although many difficulties are thereby insinuated into the theories of the planets in astronomical discussions and demonstrations, and the physics of the heavens is no less disturbed.

So much for the authority of holy scripture. As for the opinions of the pious on these matters of nature, I have just one thing to say: while in theology it is authority that carries the most weight, in philosophy it is reason. Therefore, Lactantius is pious, who denied that the earth is round, Augustine is pious, who, though admitting the roundness, denied the antipodes, and the Inquisition nowadays is pious, which, though allowing the earth’s smallness, denies its motion. To me, however, the truth is more pious still, and (with all do respect for the Doctors of the Church) I prove philosophically

3 In De Revolutionibus, in his dedicatory letter to Pope Paul III, Copernicus also mentions Lactantius as a revered theologian whose cosmological opinions are acknowledged as false, see 3.1.2 Copernicus, “Revolutions”, pp. 000 above.
not only that the earth is round, not only that it is inhabited all the way around at the antipodes, not only that it is contemptibly small, but also that it is carried along among the stars.

But enough about the truth of the Copernican hypothesis. Let us return to) the plan I proposed at the beginning of this introduction.

I had begun to say that in this work I treat all of astronomy by means of physical causes rather than fictitious hypotheses, and that I had taken two steps in my effort to reach this central goal: first, that I had discovered that the planetary eccentrics all intersect in the body of the sun, and second, that I had understood that in the theory of the earth there is an equant circle, and that its eccentricity is to be bisected.

Now we come to the third step, namely, that it has been demonstrated with certainty [. . . ], that the eccentricity of Mars’s equant is also to be precisely bisected, a fact long held in doubt by Brahe and Copernicus.

Therefore, by induction extending to all the planets [. . . ], since there are (of course) no solid orbs, as Brahe demonstrated from the paths of comets, the body of the sun is the source of the power that drives all the planets around. Moreover, I have specified the manner [in which this occurs] as follows: that the sun, although it stays in one place, rotates as if on a lathe, and out of itself sends into the space of the world an immaterial species of its body, analogous to the immaterial species of its light. This species itself, as a consequence of the rotation of the solar body, also rotates like a very rapid whirlpool throughout the whole breadth of the world, and carries the bodies of the planets along with itself in a gyre, its grasp stronger or weaker according to the greater density or rarity it acquires through the law governing its diffusion. [. . . ]

But my exhausting task was not complete: I had a fourth step yet to make towards the physical hypotheses. By most laborious proofs and by computations on a very large number of observations, I discovered that the course of a planet in the

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heavens is not a circle, but an oval path, perfectly elliptical.

Fig. 3.5.1) Kepler’s Elliptical Orbit

Geometry gave assent to this, and taught that such a path will result if we assign to the planet’s own movers the task of making the planet’s body reciprocate along a straight line extended towards the sun. Not only this, but also the correct eccentric equations, agreeing with the observations, resulted from such a reciprocation.

Finally, the pediment was added to the structure, and proven geometrically: that it is in the order of things for such a reciprocation to be the result of a magnetic corporeal faculty. Consequently, these movers belonging to the planets individually are

9.—Donahue
shown with great probability to be nothing but properties of the planetary bodies themselves, like the magnet's property of seeking the pole and catching up iron. As a result, every detail of the celestial motions is caused and regulated by faculties of a purely corporeal nature, that is, magnetic, with the sole exception of the whirling of the solar body as it remains fixed in its space. For this, a vital faculty seems required. [. . .]

All this has been said for the sake of the physicists. The astronomers and geometers will find the rest in the [. . .] individual chapters, each in its proper place. [. . .] I therefore ask the reader to consider it well.