Galileo meets Kepler: Motion in the Heavens

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Personae Dramatis:

Galileo Galilei (Scientist and Astronomer)---------- Robert Carson

Johannes Kepler (Emperial Mathematician and Astronomer)---------Pierre Boulos

Cardinal Robert Bellarmine (Master of Controversial Questions)--- Ian Winchester

Introduction

The year 1609 was a watershed year for physics and astronomy. Galileo worked out the principle of a newly developed optical instrument from Holland and built one powerful enough to view the heavenly bodies, the Moon, that stars, and the planets, especially Jupiter were all brought significantly closer. In the same year, Kepler published his *Astronomia Nova* which is now generally recognized as one of the canonical works of the scientific revolution. In the spring of 1610 Galileo published his "Starry Messenger", which was an instant sensation it Italy and throughout Europe. The discovery of the satellites of Jupiter supported the Copernican system of the heavens.

In the spring of 1611, Galileo came to Rome to "exhibit the new discoveries and to explain their great consequences". Clearly he was referring to the recent discoveries he made about motion and especially the celestial observations made in 1609 that required the use of his optical instrument, such as the mountains on the surface of the moon, the moons of Jupiter, and later in 1610, the phases of Venus. He believed that the last two of these implied the correctness of the Copernican solar system. His basic work on terrestrial motion, the period of a pendulum, the law of free fall and the parabolic motion of projectiles, was essentially complete before the advent of the new optical instrument in 1609. He now turned his attention to the construction of a good optical instrument in order to study the moon, the stars and the planets.

One of the first persons he visited in Rome was the famous Jesuit mathematician Christopher Clavius, a professor at the Collegio Romano, now an old man. Galileo was invited by the Jesuits of the Collegio to a meeting where one of the Jesuits delivered an oration praising the "Starry Messenger". At this meeting Galileo found out that Cardinal Bellarmine, the protector of the Church, a Jesuit,theologian and scholar, who tried to make science conform to scripture, asked the venerable Clavius and three other members of his college, to send him a formal report on Galileo's claimed celestial discoveries. He was told that, indeed, all four signed a statement, confirming Galileo's findings. However, they hastily added that even though they agreed with the correctness of his findings, they did not agree with his interpretation of those findings.

However, what really excited Galileo was his arranged meeting with Kepler in Rome.
This. of course, is our inclusion of historic fiction: Galileo and Kepler never actually met, although they exchanged many letters over a long period.) Kepler was at that time still in the

employ in Prague of Emperor Rudolph II as Imperial Mathematician. He had just published an enthusiastic reply to Galileo's "A Starry Messenger" as well as a study of the optics of lenses and the design of a optical instrument that was different from Galileo's.

While in Rome, Galileo also had an audience with the above mentioned Cardinal Bellarmine, a Jesuit and a noted scholar and theologian, also known as "Master of Controversial Questions", who was a secret admirer of Galileo. We assume that he was able to persuade the Cardinal to meet with him and Kepler, prior to the induction of Galileo as a member of a new academy of science. The Cardinal first hesitated to accede to Galileo's request, but in our play he is curious to meet the great Kepler and discuss motion on Earth and in the Heavens with the two acknowledged masters of terrestrial and celestial motion. However, he does not think it to be appropriate for him to stay for the induction ceremony.

The Plac The meeting takes place in Rome, at the newly formed Accademia dei Lincei, at the Palazzo Corsini, on the 14th of April, 1611. The Academy was founded in 1603 by Federico Cesi, an 18 year old nobleman and three of his friends. The aim of the academy was to "find truth, based on the mathematical and natural sciences". The academy was to be devoted to the study of natural phenomena by observation and experiment in place of rhetorical displays common to most Italian academics at that time. It is notable that members were not allowed to join a religious order. When Galileo arrived in Rome in the spring of 1611, the young academy had six additional members, including the famous polymath Giovanni Battista della Porta. Significantly, there were no professors among them.

Galileo is to be inducted into the academy, and a banquet is prepared for this occasion. Galileo is clearly pleased to be invited into the exclusive club, especially since he recently had left the university and now had intellectual communication with the growing and sympathetic membership of this new group.

The Play: One Act, about 1 hour long.

Galileo, Kepler, and Cardinal Bellarmine are standing around a long table, that has three large comfortable chairs placed on the far side. On the table we see glasses of water, a bowl of fruit (apples, oranges and grapes), and a small optical instrument, neatly placed in front of the bowl. There is a pendulum on a stand with a wooden sphere attached to a string and beside it a large wooden inclined plane with various spheres made of metal and wood placed at the foot of the plane. There is also a large globe of the Earth, identifiably a contemporary model. Finally, a long U shaped glass tube is placed beside a small tank of water. There are also three glasses and a large pitcher of water on the table.

Note: Since Kepler did not speak Italian, the discussion is conducted in Latin (read German, or English).

Galileo:
Thank you, your Grace, for agreeing to have this meeting to discuss motion on Earth and in the Heavens. I have always been guided by Aristotle's injunction that "Ignorance of motion is ignorance of nature".

Bellarmine:
I am pleased that your are still quoting the great Aristotle.
I have been looking forward to this meeting, Signor Galilei. I have read your recent publication "The Starry Messenger". It seems to have made quite an impression on scholars and the public alike.
Looking toward Kepler:

I am also acquainted with your early work, Signor Kepler, *Mysterium cosmographicum*, and have a passing understanding of your recent publication, *Astronomia nova.* You have reviewed Galileo's book very favorably, immediately after publication in the spring of 1610. He has a very strong ally in you, the Imperial Mathematician from Prague.

Kepler:
Thank you, your Grace. I bring greetings from his Royal Highness, Emperor Rudolph II.

Bellarmine:
Thank you.
He pauses and then looks at Galileo:

Signor Galilei, I do not know your response to Kepler's early work or to the recent *Astronomia nova*. I am looking forward to find out.

But before discussing motion in the heavens, I would like to hear Signor Galilei present briefly his ideas about motion on Earth. I am especially curious about the responses of Master Kepler.
He pauses for a moment and looks at both and smiles first and then becomes serious.

Finally, and most importantly for me and the Holy Church, I would like to hear from both of you how you can reconcile your ideas and findings with the teachings of the Bible. I believe what is at stake here is the truth as we find it in Holy Scriptures.
He adds gravely:

The Church and the Holy Father insists that there must be no contradiction between your science and the teaching of the Bible.
There is a pause. Galileo and Kepler look ill at ease. The Cardinal then smiles and says reassuringly:

Gentlemen, may I emphasize that this is not a session conducted by the inquisitor, but only a platform for clarification.
Galileo and Kepler look thoughtful but smile uneasily.

Galileo:
Thank you, your Grace.
I will only highlight some of my important findings about motion on Earth.
Pointing to the pendulum.

Your Grace, this pendulum represents my first youthful insight into motion. One day I noticed that the time it took for one swing was always the same, even though the angle of the swing was getting smaller and smaller.

Bellarmine:
Very curious. But how did you measure the time of the swing?

Galileo:
I used my pulse and counted the beats.

Kepler:
You must have a very steady pulse, Galileo.

Galileo:
Galileo smiles.

I have to admit that, when I discovered this, my pulse was went up. But soon my pulse became steady again

Bellarmine;
Hm., I never thought about the motion of pendulums. Very interesting. Is this true also for swinging chandeliers in cathedrals?

Galileo:
Indeed your Grace, I found that the time for a swing was the same for all displacements.
He demonstrates this using the pendulum.

I also found other interesting theorems connected to this motion. For example, I discovered that the time it took for a ball to roll down an inclined plane whose length is the same as the chord of a circle that has a radius equal to that of a pendulum was longer than the time of half a swing.
He demonstrates this.

Kepler:
This is surprising, defying common sense, because the length of the arc of the swinging pendulum is longer that the chord! But how does this affect different weights on the pendulum?

Bellarmine:
I know that Aristotle taught us that the heavier an objet is the faster it falls. Granted he did not perform experiments and, as far as I know, he did not talk about the motion of a pendulum.

Kepler:
I believe, he would have said that the motion of the pendulum is a combination of natural motion and violent motion. That is all.

Galileo:
Well, we have to go beyond Aristotle, as far as understanding motion on Earth is concerned.
Galileo picks up a grape and an orange and holds them in his hands, at a height of about three feet from the table. He looks at the Cardinal.

What would Aristotle have said about the time of fall of these two objects, your Grace?

Bellarmine:
I suppose he would have said that the orange will fall to the table first.

Galileo:
Well, let us see.
He drops the grape and the orange. They hit the table top at the same time.

Bellarmine:
Looks a little surprised.
I am surprised…

Kepler:
Your Grace, I will try to defend Aristotle. If you dropped the grape and the orange from a great height, the orange would surely fall to the ground first.

Galileo:
I agree, Master Kepler. But if the resistance of the air is taken away, then they would fall at the same rate.
He looks at the Cardinal.

Bellarmine:
But I believe Aristotle said that motion in a vacuum would be instantaneous.

Galileo:
Oh, I know that Aristotle insisted that a vacuum cannot exist. But I have argued, and shown by experiment, that speed in any medium depends on the relative weights of the body and the medium so that the bodies of the same kind, regardless of weight, move naturally with the same speed in a given medium.

Kepler:
But this brings into question your results for free fall, my dear Galileo. You based your conclusion for the law of free fall on the motion of a metallic sphere moving down an inclined plane.

Galileo:
That is true. Of course, I am aware of this problem. But I have argued that the motion of rolling ball is moving along the inclined plane is governed by the same law as the free fall of the same ball. I have actually tested my law of free fall by directly measuring the time of fall of a metallic sphere from a height of about 10 feet.

Kepler:
And how did you find the time for the fall? It must be a blink of an eye.

Galileo:
Oh, yes! I thought of an ingenious method using a long pendulum that was placed to hang along a wall. Pulling the ball at the end of the string a small distance from the wall I had an assistant drop a metallic ball from a height so that the time of the fall and the time for the pendulum to hit the wall coincided.

I should add, that this is a tedious task, but it demonstrates that one can actually measure free fall directly. Of course, using the inclined plane and extrapolate to free fall produces more accurate and precise results.
He explains this with a sketch on the black board

Kepler:
Really ingenious, my dear Galilei. But you did experiments of projectile motion quite recently. Tell us about those.

Galileo:
Aristotle, of course, had difficulty explaining this kind of motion, for example the motion of a javelin.

We can do a little demonstration right now. I used an elevated inclined plane from which a metallic sphere ball to the edge and from the edge we can see the motion of the trajectory.
He raises the inclined plane, places a metallic ball on the top and releases the ball. The ball rolls down the inclined plane and then bounces off the edge, hitting the floor.

You can see that the flight of the ball makes a curve that turns out to be a parabola. The clue to understanding the motion of a projectile, like that of a cannon ball, is to understand that the motion is a combination of two independent motions, one that is vertical and accelerates like in free fall and the other a constant velocity which is horizontal and is acquired by the fall from the height of the inclined plane.

He asks Kepler to help him demonstrate that if a ball is dropped from the height of the table at the same time as the ball rolling down the inclined plane leaves the table they both fall to the ground in the same time..

Bellarmine:
Looks surprised.

Gentlemen, I must admit this contradicts common sense!

Galileo:
Yes, indeed. Understanding motion is a complex business, Aristotle knew this.

Kepler:
What I find interesting here, my dear Galileo, is the shape of the trajectory, namely a parabola. That is, as you well know, one of the conic sections, studied by Apollonius about 1800 years ago.

Later, when we discuss motion in the heavens, I will talk about another conic section that is connected with my first law of planetary motion, namely the ellipse. I would like to know how theses motions are related, one on Earth and the other in the Heavens.

Bellarmine:
At this point I feel quite dizzy following your discussion of motion on the Earth.
Perhaps we could now go on to discuss motion in the heavens. This motion interests me more because here we have clear unalterable biblical guidance.
He stops for a moment and then continues.

Well, gentlemen, let us say that as far as motion on the Earth is concerned, some of Aristotle's ideas may be questionable. After all, he was human and therefore fallible. But motion in the heavens that is another thing.

Kepler:
Your Grace, before discussing motion in the heavens, we should look at the question of evidence for believing that the Earth is moving. Cardinal Bellarmine, you have often said and written that there are no such demonstrations.
He pauses and looks at the Cardinal.

Bellarmine:
That is so.

Kepler:
I think Galilei and I have now both terrestrial and celestial evidence for believing that the Earth moves.

Bellarmine:
I am willing to listen to your arguments. If you really have good evidence for believing that the Earth moves, as Copernicus claims, then we can possibly revise our opinion.

Galileo:
Of course, I agree with your Grace, both the Earth-centered and the Sun-centered, that is the Ptolemaic and the Copernican hypothesis, can equally well support the observed phenomena in the heavens.

Bellarmine:
Exactly, no observable phenomenon shows clearly that the Earth moves and since the Copernican hypothesis contradicts the Holy Scripture, it must be rejected. We will discuss this fundamental article by the Church further, as soon as we have heard your arguments
I have always understood Copernicus to say that he spoke about his system only hypothetically.
He looks at both using a serious expression.

By the way, may I remind both that the Council of Trent forbids the interpretation of the scriptures in a way contrary to the common agreement of the holy Fathers.

Kepler:
Very well, your Grace.
But what if there were incontrovertible proof that the Earth moves, as we do believe is the case?

Bellarmine:
If there were a real proof, a proof that the Sun is in the centre of the Universe, that the Earth is in the third sphere, that is, moves outside the spheres of Mercury and Venus, and the Sun does not go around the Earth but the Earth around the Sun, then we should have to proceed with great circumspection in explaining passages from Scripture which appear to teach the contrary, and we should rather have to say that we did not understand them than declare an opinion to be false which proved to be true.
He stops and then continues emphatically:

But I do not think there is any such proof, since none has been shown to me.
Galileo and Kepler look at each other and Kepler indicates that he wants to answer, but the Cardinal continues.

Let me say this again: To demonstrate that the appearances are saved that the Sun is at the center and the Earth is in the heavens is not the same thing as to demonstrate that in fact the Sun is in the center and the Earth is in the heavens.

Kepler:
Your Grace, we now do have very strong physical and observational evidence to argue decidedly in favour of the Copernican hypothesis. I think Galileo would agree.

Galileo:
Yes, emphatically.
Let us then begin by talking about what physical evidence we now have for believing that the Earth moves. First of all, I believe with Copernicus that the Earth has a double motion, one around the Sun once a year, and another around its axis once a day. But this belief must be supported by strong evidence.

He goes to the globe and explains.

Let us see if we can raise at least some doubt in your mind in favour of the Copernican hypothesis.

In the last two years I have discovered three distinct and independent phenomena to support the hypothesis that the Earth moves. These are: the tides, the motion of the satellites of Jupiter, and the phases of Venus

Kepler:
SignorGalilei and I completely agree on the cause of the last two but have a long slight disagreement on the causes of the tides.

Bellarmine:
You see, you are already quarreling about the cause of the tides, so why should I take your other two agreements seriously?

Galileo:
Galileo smiles and then continues.

I believe that the idea of Master Kepler that the Moon is the sole cause of the tides is completely wrong. However, I think I do have the correct hypothesis, that is, I am certain that the double motion of the Earth causes the waters to ebb and flow.
Kepler smiles and interjects.

Kepler:
Let me explain, your Grace. Some time ago, Galileo and I exchanged letters in which we discussed what was the cause of motion of the tides. I argued that no explanation of the tides could be correct which did not involve the moon, because anything caused by motion of the earth would be a forced motion, whereas the tides must be caused by what Aristotle called natural motion.

Galileo:
First of all, your Grace, I no longer differentiate motion according to the Aristotelian categories of natural and forced motion. I believe that any motion must be explained in terms of another motion rather than by appealing to other causes, as my colleague Master Kepler believes. Lunar, like all the other celestial influences, so favoured by astrologers, could be nothing more than such mysterious, hidden causes.

Kepler:
My good Galillei, in my recent publication, *Astronomia Nova*, that I believe you claim to have read, you will find that I refer to the influence of the Moon on Earth, not as a mystical but an actual physical influence that creates a tidal bulge.

Galileo:
My dear Kepler: A force that is supposed to affect the Earth from a distances of 30 Earth diameters must be an occult phenomenon. How can a force acting over such an enormous distance influence the waters of the ocean.
Only magicians and witches have such powers!

Kepler:
But I do not speak of occult powers, Signor Galilei.. If the earth ceased to attract the waters of the sea, the seas would rise and flow into the moon . In my *Astronomia Nova*, I argue that if the attractive force of the moon reaches down to the earth, it follows that the attractive force of the earth, all the more, extends to the moon and even farther.

Galileo:
I still believe that the influence of the Moon, as you describe it, smacks of occultism!.

Bellarmine:
Gentlemen, you must come to some consensus, otherwise you will loose your powers to pursuade!
He laughs and seems to be delighted by this debate.

Galileo:
Your Grace, we (Kepler and I) agree and are convinced of the correctness of the Copernican system, even though we don't agree on the details on how to show physical evidence that the Earth moves as Signor Galileo described it. *Kepler nods in agreement. Galileo continues.*

I argue that the two independent motions of the Earth, as we discussed earlier, give continually varying speeds on widely separated points on Earth. These varying speeds have an effect on water but not on the solid part of the Earth.
He goes to the table and illustrates the motion using a tank of water and also draws a sketch on the black board.

The weight of the displaced water then will cause the water to go back to the level stage and in so doing cause an oscillation with a definite period. This period depends on the East-West length of the sea and with the average depth of the water.
He lifts one end of the water tank and lets go.

You can see the oscillation I produced in this small tank.
For the Mediterranean it is well known that this period is about six hours and twelve minutes, from high to low tide.

Bellarmine:
Signor Galilei, I would like to know how this double motion that you claim the Earth has explains two tides, about 12 hours apart.

Galileo:
Galileo goes to the blackboard and sketches this double motion.

You can see that for 12 hours a point on the Earth's surface will move eastward, and for 12 hors westward. The composition of these motions causes a slowing down and then a speeding up. Thus we have a very plausible mechanism for the phenomenon of the tides.

Bellermine:
Let me see, if I understan what you say, Signor Galileo.
The tides were caused by the sloshing back and forth of water in the seas as a point on the Earth's surface speeded up and slowed down because of the Earth's rotation on its axis and revolution around the Sun.

Galileo
I could not have said it better myself, your Grace**.**

Bellarmine:
This explanation makes sense …as a hypothesis. But I am not convinced that the Earth in reality has a double motion.

Kepler:
But….if this hypothesis were correct, there would be only one high tide per day.
Signor Galileo, you are clearly aware of this problem because, even I who live in Germany know that there are two daily high tides at Venice instead of one, about twelve hours apart.

Galileo:
Yes, but that is the result of several secondary causes, including the shape of the sea, its depth, and other factors.
But let us return to Master Kepler's "Moon influence" hypothesis.
Kepler is about to say something but Galileo interjects.

Galileo:
I would like to know how Master Kepler is able to explain two tides during a 24 hour period. Sureley, there are is only one Moon that is able to attract the waters. The Dutch engineer and mathematician Simon Stevin actually claimed that the "empty" space on the other side of the Earth-Moon connection can also influence the waters. I find such claims laughable.

Bellarmine:
Smiling with satisfaction intervenes:
Look how they are fighting among themselves!
He becomes serious again and continues:

So, Signor Galilei, you are implying that the tides' occurrence, when the Moon and the Earth are in the same line of sight, is just a numerical coincidence and not evidence for assuming that the hypothesis of Signor Kepler of the influence of the Moon on the tides is acceptable?

Galileo:
Exactly.
Signor Kepler does not seem to have any other evidence for his hypothesis. Remember that he lived in southern Germany, Austria and now lives in Bohemia, where he had no opportunity to observe tides and had to rely on indirect information.
He smiles and then continues

You also included in your otherwise excellent book, some strange ideas, such as the claim that the Earth and the planets revolve around the Sun in elliptical motion instead of in perfect circles.
He stops for a moment and shakes his head.

Only a German mathematician could defend such abstract and wild ideas!

Kepler:
My dear Galileo: I will respond by first saying that 10 years of careful observation, measurement and long nights of calculations and recalculations have convinced me that these motions are indeed elliptical. The motion of the Earth around the Sun is actually almost a circle.
He looks at Galileo who does not seem to be convinced.

Secondly, I would like to remind you that a circle is an ellipse! An ellipse with an eccentricity of zero!

Bellarmine:
Gentlemen! We are going astray here. I do recognize the diligence of Master Kepler in trying to map the motions of the planets and I admire his mathematical wizardry .
However, I, too, believe that Master Kepler has been deluded or lead astray by his mathematical efforts, and that the planets, if they indeed rotate around the Sun, would do so in perfect circles.
He stops for a moment and then continues, turning toward Galileo.

Signor Galileo, how did you get the idea for your hypothesis of tidal motion?

Galileo:
The idea of large masses of water oscillating came to me when I was in Venice, where large barges carrying water were suddenly slowed down. Of course my studies with the oscillation of a pendulum also helped me to understand this phenomenon.
He goes to the table, picks up the large glass tube and fills it about half full of water. Then he lifts up the tubes, and places it vertical, showing the period oscillation
You see how this motion is like that of a pendulum oscillating.

Bellarmine:
Gentlemen, let me say this: As far as I understand , we have two competing hypotheses about the causes of the tides. One is based on the double motion of the Earth and the other on the imagined, what Signor Galileo calls a mystical attraction of the Moon on the Earth.
He looks at Galileo first and then at Kepler.

Of course, I would choose the hypothesis of the attraction of the Moon, mystical or not mystical. We don`t need any movement of the earth for this hypothesis.

Kepler:
May I suggest that perhaps the true explanation is a combination of these two.

Galileo:
No! Definitely not. In my scientifi thinking we can only allow ideas and conceptions that are physically testable. Strange attractive forces are not part of my scientific practice.

In fact, my hypothesis of the tides being able to explain the tides convinced me about 10 years ago already that the Copernican model of the solar system is correct.

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Bellarmine:
Let us conclude the discussion of the causes of the tides for now.
Signor Galileo, what other reasons do you have for believing in the Copernical system?

Galileo:
Gladly.
Goes to Kepler and shakes his hand. They smile.
Galileo continues

When I first examined the optical instrument given to me in 1609, I was impressed by the possibilities for both terrestrial and celestial observations. But celestial observations attracted me more, so that forsaking terrestrial observations, I began by observing the Moon. The Moon appeared in my instrument as if it were about two Earth radii away.

I then observed often with wondering delight both the planets and the stars.

Kepler;
I now know the feeling of delight you must have had when first looking at the sky with a powerful optical instrument.

Galileo:
I found that the surface of the moon is not smooth, uniform, and precisely spherical as Aristotle thought, but uneven, rough, and full of cavities. From the lengths of the shadows I estimated the height of a mountain to be almost 4 miles! The flat parts of the Moon that maybe oceans, very much like those on Earth..
And the Milky Way is actually a collection of thousands of stars!

Kepler:
After reading your “Starry Messenger” I constructed my own optical instrument and studying the sky I found all those things that you mentioned. But remember, Signor Galileo, there were astronomers who came to the same conclusion earlier.
did not calculate the height of a mountain on the Moon. A mountain 4 miles high! Incredible.

Bellarmine:
These are all fantastic claims, gentlemen, but not evidence for the Copernican system.

Kepler:
Your Grace, it seems to me that the fact that there are mountains on the Moon, strongly suggests that Aristotle was wrong when he assumed that there is a difference between the celestial materials and the terrestrial ones, And …if all this Earth-like matter in the heavens moves why not the Earth itself?

Galileo:
My celestial discoveries also suggest that the Earth may be moving.
People aften wondered why in the Copernican system all planets revolve around the Sun and only the Moon, as an Aristotelian planet, remained revolving around the Earth.

In January this year I discovered other moons in our solar system, four satellites of Jupiter. I studied their motion carefully over many weeks. I believe that this discovery provides us with good evidence for the correctness of the Copernican hypothesis of the heavens.

Kepler:
I agree with Signor Galileo. First, moons are different from planets. Secondly, the orbits of the Jupiter moons intersect the crystal sphere of this planet –which has to exist according to Aristotle. That means: Aristotel is also wrong in this case. There are no crystal spheres in the sky. Third, there is at least one centre in the universe, that is different from the Earth, around which we see celestial bodies orbit.
Then, why is it not possible that around the much larger Sun we also have planets orbiting?

Bellarmine:
He ignores Kepler and turns to Galileo

Explain to me then how you made these celestial discoveries

Galileo:
Picks up the optical instrument and shows it the Cardinal.

You see, your Grace, to make a optical instrument like this one that I constructed, one needs only two well- shaped lenses.
He shows two lenses, one is a divergent and the other a convergent lens.

Perhaps later we can go out and look at the Moon and the stars

Bellarmine:
Moves away from the instrument and holds up his hands.
I am afraid I cannot do that, Galileo, lest I…

Galileo:
I am disappointed, your Grace.

Bellarmine:
Someday, maybe I will look through your instrument.
But from what I have heard, very few have verified the sighting and there are many good arguments against such a celestial phenomenon.

Kepler:
Your grace, I have found that these arguments range from those that are understandable and cogent to those that are simply silly.

Galileo:
I agree. It is very hard to argue against those who refuse to look through the optical instrument because they firmly believe that the instrument was devised by the devil, and against those who looking through it argue that it is an optical illusion.
However, one is certainly dumbfounded by the recent argument of the astronomer Francesco Sizzi who said that "The satellites are invisible to the naked eye and therefore can have no influence on the Earth, and therefore would be useless".

Bellarmine:
You both know what my argument is, I do not need to tell you. But I, too, was a little annoyed when I read that silly statement by Sizzi.

Kepler:
We thank you for that, your Grace.
But now ,I would like to ask Signor Galileo why he did not respond in 1597 to my wish for him to comment on my *Mysterium Cosmographicum* that I sent him.

Galileo:
But I did send you a note the same day I received your book. Granted, it was hastily composed because your emissary, I believe it was Paul Hamberger, had to leave for Germany the same evening. I wrote that I was delighted that you embraced the Copernican system.

Kepler:
I did receive your note. However, I was disappointed that you never sent me a detailed assessment of my work later.

Galileo:
I actually only read the preface to the book at that time. I recognized that you were a convinced Copernican and was delighted to find so powerful an ally. I also remember receiving two more copies from you with your request to "pay" for them, not with money but with a very long letter.

He pauses and then continues.

I did not like the idea of your *polyhedral hypothesis* based on the Plato's regular geometric solids. Why should one accept theses exotic geometric figures as the basis for an explanation of the structure of the Universe?
That does not sound sufficiently physical to me. I also found your philosophical arguments to justify your model of the solar system to be almost mystical

Kepler:
Well, nevertheless, the results I obtained fitting the solar system using this idea were very impressive. In fact, The great Tycho Brahe, after reading my book, invited me to be his assistant and rescued me from my retched existence in that secondary school in Graz.
He smiles and then continues, looking directly at Galileo.

But the tables turned when last year you sent me a note requesting assistance in confirming the results of your telescopic observations in the "Starry Messenger". This time the note was sent to the Imperial Mathematician, and not to the lowly school teacher in Graz.

Galileo:
Yes, I admit I was embarrassed and certainly did not expect such an enthusiastic response, endorsing my findings and my arguments. I am, of course, grateful to the Imperial Mathematician, that is, if he does not demand that I must follow all his strange hypotheses.
He bows toward Kepler.

Bellarmine:
Gentlemen, let us have a reconciliation. After all it, is a Christian charitable act.
He pauses and then continues.

But I am not convinced, at least so far, that we have established a ground for a reconciliation between the Copernican model of the Universe and the teaching of the Holy Scriptures.

There is also the phenomenon of the phases of Venus. By the way, here Senior Galileo also was not the one to have discovered this.

Bellarmine:
Oh, yes**.** I understand that Senior Galileo believes he saw Venus displaying phases like the moon that revolves around the Earth.

Galileo:
Indeed. I saw them and I EXPLAINED THEM! But many self-appointed discoverers want to steal my fame.
This fact shows that Venus could not always stay between the Earth and the Sun, as Ptolemy thought but rather it must completely move around the Sun as Copernicus believed.
He demonstrates this on the blackboard .

Bellarmine:
But this idea goes back to the Greeks. Many thought that it may be possible that Mercury and Venus orbited the Sun. Not to mention that your great teacher, Tycho Brahe, Master Kepler, proposed a system in which these inner planets- together with the other planets- revolved around the Sun. The Sun and the planets then revolv around the Earth.

Therefore, we don't need to think of the Earth as moving, even if we have all the planets orbiting around the Sun!
He sketches the model of the solar system of Tycho Brahe on the black board.

I am therefore not persuaded that any of these motions in the Heavens you have described contradict the Aristotelian or Ptolemaic universe. After all, with respect to the power of the Mover, which is infinite, it is just as easy to move the universe as the Earth, or for that matter a straw.

Galileo:
What Kepler and I are saying, your Grace, is , with regard not to the mover, but only the movables. We are giving our attention to the movable bodies and not questioning that it is a shorter and readier operation to move the Earth or the Universe.
Of course, your Grace knows that more than 200 years ago, Nickolas Oresme, a Christian priest and philosopher, found
it is much more probable that the diurnal motion belongs to the Earth alone than to the rest of the Universe!

Actually, this kind of argument is supported by a very true maxim of Aristotle himself which teaches that …"it is pointless to use many to accomplish what may be done with a few."

Kepler:
Your Grace, what attracted me first to the Copernican system was precisely this argument of simplicity. Copernicus said that his system was "more pleasing to the mind". He believed that God placed the sun at the center, reposing, unmoving and illuminating the whole solar system.

I was also impressed that in the Sun-centered system it is possible to calculate the periods as well as the relative distances of the planets from the Sun. This was not possible in the Ptolemaic system. I think this is a significant improvement over the Ptolemaic system

Bellarmine:
Signor Kepler, still looking at the sun-centered system only as a hypothesis, but not fact, how did you extend the solar system of Copernicus? Is your improved version that you call *Astronomia nova*, let's call it the Keplerian universe, simpler and why is it closer to what you think is the true solar system,?.
He stops and then looking at Kepler, continues

Is Signor Galileo correct when he claims that your strange mathematical ideas of elliptical motion are more mathematical than physical?

Kepler:
In my recently published *Astronomia Nova* you will find that I have abandoned the requirement of circular orbits as well as the epicycles, still part of the Copernican system. I am convinced that epicycles are not physically possible, because they are empty at the center.
He draws a picture of epicylcles on the black board.

Such epicycles are surely more unrealistic mathematical ideas than my ellipses.
Striving toward the simplicity of only orbits, without epicycles, I first established the orbit of the Earth by observing Mars at the same time in the sky over many years. That was a tedious task, indeed.

The orbit of the Earth seemed almost circular, with the Sun a little off center.

Bellarmine;
You are telling us that you established the orbit of the Earth before knowing the orbit of Mars?

Kepler:
Indeed. Having found the orbit of Earth I then established the orbit of Mars. Finally, I set about calculating the entire orbit of Mars, using the geometrical rate law (my second law) and assuming an egg-shaped ovoid orbit.

Bellarmine:
Oval? Like the shape of an egg?
I cannot believe that the Creator would have chosen such a shape.

Kepler:
Yes, indeed. This also puzzled me for a long time until I thought of the work of Appolonius on conic sections. It turned out that the orbit of Mars is elliptical. So my first law is simply that all planets move in ellipses around the Sun with the Sun on one focal point.
Pauses and then continues

Actually, my "war with Mars" was a long and arduous affair. And it is not over, the war continues! After approximately 40 failed attempts, in early 1605 I at last hit upon the idea of an ellipse, which I had previously assumed to be too simple a solution for earlier astronomers to have overlooked.

I really must thank my teacher Tycho Brahe, for establishing the motion of Mars by his ingenious observations, 20 times more accurately than Ptolemy
Finding that an elliptical orbit fit the Mars data , I immediately concluded that *all planets move in ellipses, with the sun at one focus* — the first law of planetary motion.
He lifts up a sketch to show the elliptical motion, including the area law

Galileo:
Sounds like both the area law and the elliptic shape law are based on the study of the motion of Mars alone. This so-called area law was based on what observations?

Kepler:
By comparing the speeds of the Earth and that of Mars at the closest (apogee) and the farthest (perigee) approach to the Sun. I found that the speeds vary inversely proportional to the distance. That means that the closer a planet is to the Sun the faster it is moving with respect to the Sun.

Galileo:
So you arrived at your area law based on one, perhaps two numerical values?

Kepler:
Yes. But I found the result so compelling that I am convinced that the law applies to all planets.

Galileo:
And your conclusion that all planets move in elliptical trajectories is based only on the result of the motion of Mars?

Kepler
He does not seem to have heard the last remark, or he simply ignores it.

This may be a good time to mention what I am doing now. I am looking for a third law, what I consider a necessary law of planetary motion, namely a relationship between the periods of the planets and their distances from the Sun.

It looks like the Creator found harmony in mathematical relationships and as well as in geometry.

Bellarmine:
You are trying to read the mind of God again, Kepler!

Kepler:
With apologies, your Grace, I was trying to find celestial harmony using geometry. But now I am convinced that this harmony is found in mathematical relationships.
Galileo:
I do agree with you that the laws of nature are written in the language of mathematics.
But I cannot believe in your artificial ellipses!

Kepler trhows up his hand and is silent

I, too, have tried to do a few calculations with astronomical distances after I discovered my law of free fall. I hypothesized, and I admit this was a bold speculation, that there is a place beyond Saturn from which all the planets could have been dropped in uniformly accelerated motion toward the Sun, each reaching its observed orbital speed at its present distance from the Sun. But I was unable to find a satisfactory proportionality statement between the distances and the speeds, so I abandoned the project

Kepler:
Very interesting, Signor Galileo.
I am going to spend the future completing my work on planetary motion. And when I find my third law, which I will call ”The Law of Harmonies”, my work will be done. But I believe that I have been fortunate that Tycho asked me study Mars a long time ago. I now firmly believe that by the study of the orbit of Mars, we must either arrive at the secrets of astronomy or forever remain in ignorance of them.

Galileo:
I still believe that the planets move in perfect circles around the Sun.

Kepler:
You are a stubborn man , my dear Galileo! May I remind you, that when you viewed the motion of the satellites of Jupiter you saw ellipses and not circles!

Galileo:
But we have already mentioned that a circle viewed at angle looks like an ellipse!
He stops and then continues with emphasis.

Of course if you find that third law and you can show that it works for all planets, I may change my mind.
Bellarmine:
My mind boggles with all this scientific talk! My sons, how can you expect to convince me of the Sun-centered solar system if you cannot even agree amongst yourself?

Galileo:
Your Grace, natural philosophers and astronomers do not always agree.Even theologians need discussions, as you well know, your Grace.
But, as I have already stated, we have complete agreement about the main idea, namely that the Sun is the centre and the planets revolve around the Sun.

Bellarmine:
I still believe that the Earth is the center of the Universe, this is a statement of faith, based on the Holy Scriptures.
However, I am afraid that neither of you has been able to provide a decisive argument against the successful model that goes back to the ancient Greeks.

However, I will ask one more question: If the Earth actually revolved around the Sun, then it should be possible to view a star from two positions six months apart .and show that the direction is different. In a previous conversation with Galileo I seem to remember that he mentioned this as a test to confirm the Copernican system. Has this been done?

Kepler:
Well, this is still an observational problem, your Grace.
He makes a sketch on the black board

I remember writing to Galileo, I believe it was in 1597, asking him to undertake some careful astronomical observations, in the hope to determine the annual parallax of a fixed star. He did not answer me.

Galileo:
Actually, Signor Kepler, I considered measuring such a parallax.
I studied a double star in the constellation Great Bear. One of the stars of this duo seemed mush farther away. The star that is closer to the Earth then is expected to move quicker. One should be able to observe in a period of six months that there is a difference in distance between the stars. But I have not been able to find this. I believe with Aristarchus, that the stars are so far away that such a measurement cannot be made using the instruments we have today.
But we will improve our optical instruments and then perhaps soon we will be able to measure this apparent motion.

Kepler:
As Copernicus also knew, some 1800 years ago, Aristarchus proposed a Sun-centered solar system. Even the great Archimedes argued that if the planets revolved around the earth we should be able to find that the stars would shift their position as seen six months apart.. Since Aristarchus was unable to show this shift, Archimedes rejected the Sun-centered Universe.

Galileo:
And of course, if the great Archimedes rejected it the Sun-centered model could not survive!
But we have gone beyond the Greeks in many ways. Take for instance, the dom of St. Peter in Rom. No Greek architect was as great as Michelangelo, and that holds equally for sculptures and paintings. Is it not a fact that the Holy Church has conquered many regions of the world that were completely unknown to the ancient world? So why is it not possible for us to discover new continents in the Universe?

Bellarmine:
Well, gentlemen, we have to discover new things but...we also have to protect old truths.
I am not persuaded that the Copernican or the Keplerian system have been supported by sufficient

Kepler:
Your Grace, I believe we still need to mention one other celestial occurrence, namely the two stella nova appearances. On November 11, 1572, Tycho observed a very bright star which unexpectedly appeared in the constellation Cassiopeia, and I observed another star appear in October of 1604.

Bellarmine:

I have heard of these sightings. I know that astronomers in general believe the incorruptible nature of the celestial spheres, and see the sudden appearance of these flares as a sub-Lunar phenomenon.

Kepler:
Your Grace, what I found interesting is that the brightness of the appearance changed very quickly and I studied its fading luminosity. I used the lack of observed parallax to argue that it was in the sphere of fixed stars, I believe further undermining the doctrine of the immutability of the heavens. There have been attempts to find a parallax but none was found.
He stops for a while and then continues.

It should be mentioned that if the source of the appearance had been inside the Moon'a orbit a parallax would have been found. Indeed, the comets that we fear and have observed for thousands of years, are also harmless celestial objects beyond the Moon.

Galilei:
Again a figment of Master Kepler's imagination! Here I agree with Aristotle: Comets belong to the region close to the Earth, and are simply atmospheric phenomena like clouds, but far away.

Bellarmine:
I think we have exhausted the possible physical arguments for claiming that the Sun is at the center, not moving, and the Earth and all the planets are revolving around the sun, either in circular or elliptical orbits. Let us now turn to the theological and philosophical arguments.
He stops for a while and then continues.

Here I I believe, I am a little more expert than you both.
He smiles and Galileo and Kepler nod.The Cardinal continues.

There are many passages in the Bible that argue against the coperican system
, the outstanding being the one in Joshua, relating how Joshua commanded; "Move not. O sun, toward Gabaon, nor thou, O moon, toward the valley of Ajalon".

Galileo:
Yes, your Grace, we are acquainted with that passage from the Bible.
The Cardinal looks at him with a severe expression.

Bellarmine:
Please let me finish.
We then read that "the Sun and the Moon stood still, until the people revenged themselves of their enemies". And again: "The sun rises and goes down and returns to his place, and there rising again, makes his round by the south and turns again to the north".
Both Galileo and Kepler are silent. The Cardinal continues.

Scripture also specifies that the Earth is immovable in the face of these solar and lunar peregrinations. We read in Psalm 92 that God "has established the world which shall not be

moved" and again in Psalm 95 we read that "God has corrected the world , which shall not be moved."

And finally: No les an authority than the Catechism of the Council of Trent, states that: "God commanded the Earth to stand in the midst of the world, rooted in its own foundation."

Kepler:
Are we to understand the Bible literally or are we allowed to interpret these statements in the light of our discoveries using our God-given senses and rational thinking?

Galilei:
In the Scriptures we also find that God became angry. But biblical scholars generally agree that God does not have lowly human characteristics. How can we then interpret the Bible? Always literally?

Bellarmine:
Indeed, you are obliged to interpret these statements as the holy Fathers have undrstood them! But the holy Fathers never talked about the motion of the Earth!

Galileo:
Your Grace, is the Bible such a secure book about nature? Many important phenomena are nort even mentioned. For eaxample, it does not discuss the motion of the planets, in fact, they are not even mentioned. I do believe that there is only one reference made to the planet Venus under the name of Lucifer.

Bellarmine:
I do not find that to be a 'sin of omission' on the part of the Creator. He clearly assumed that it would be self evident that if the Sun and stars move around the Earth, so do the planets, the "wanderers" in the sky.
He stops for a while and then continues and says emphatically:

I believe that He created the epicycles of the planets to test our face in his Word.

Galileo:
But your Grace, it seems to me that if the sacred scribes had had any intention of teaching people certain arrangements and motions of the heavenly bodies, or had they wished us to derive such knowledge from the Bible, then they would not have spoken of these matters so sparingly in comparison with the infinite number of admirable conclusions which are demonstrated in that science.
The Cardinal remains silent.

May I remind your Grace that Nicholas Copernicus was not only a Catholic, but a priest and a canon. He was in fact so esteemed by the church that he was called to Rome from the most remote parts of Germany to undertake its reform.

Kepler:

I agree with Signor Galilei. Copernicus was acquainted with the Bible, and he interpreted his Sun-centered system, referring to God's mind and the simplicity of the Sun-centered system.

Bellarmine:
May I remind you, gentlemen: In the book of Copernicus: *De Revolutionibus,* there is a preface that the content of the book is only a mathematical hypothesis. And as a mathematical hypothesis, that aids the computations of the motion of the planets, we are allowed to discuss it. How can anyone read God's mind and claim that he knows what the reality of the universe is? I find this a sacrilege.

Galileo:
I would like to go back to the Bible, your Grace, without trying to read God's mind, of course.

Far from pretending to teach us the constitution and motions of the heavens and other stars, with their shapes, magnitudes, and distances, the authors of the Bible intentionally not did speak of these things, though all were quite well known to them.
He stops for a while and then continues and says emphatically:

Permit me to quote a passage by St. Augustine, your Grace, that has always inspired me

Bellarmine:
Please do. I am also a great admirer of St.Augustine. But I do not always agree with him.

Galileo:
Thank you, your Grace.
He opens a book and reads:
:

"What is it to me whether heaven, like a sphere surrounds the earth on all sides as a mass balanced in the center of the universe, or whether like a dish it merely covers and overcasts the earth?"

And a little later he says:
"Some of the brethren raise a question concerning the motion of heaven, whether it is fixed or moved. If it is moved, they say, how is it a firmament? If it stands still, how do these stars which are held fixed in it go round from east to west, the more northerly performing shorter circuits near the pole, so that the heaven may seem to revolve upon some axis, or may be thought to move as a discus?

To these men I reply that it would require many subtle and profound reasonings to find out which of these things is actually so; but to undertake this and discuss it is consistent neither with my leisure nor with the duty of those whom I desire to instruct in essential matters more directly conducing to their salvation and to the benefit of the holy Church."

Bellarmine:
Remember, Signor Galileo, St. Augustine lived in the 6th century. Those were different times. There was no concerted challenge made to upset the Aristotelian and Ptolemaic Universe.

Galileo:
Your Grace, this may be a good place to stop our discussion. It is getting late and Master Kepler and I have to join the members of the Academia dei Lincei, where I will be inducted into this August group.

But in conclusion I would like make my position clear: I think that in the discussion of natural problems we ought to begin not with the Scriptures, but with observations, experiments, and demonstrations.
He stops and then continues.

I firmly believe that God is known by nature in his works, and by doctrine in his revealed word. These are two truths , which may contradict each other. But we humans see contradictions that perhaps do not exist in God'd mind.

Kepler:
I, too, would like to make a final statement, your Grace.
Geometry is unique, eternal and perfect, a reflection of the mind of God. That mankind shares in it is because man is an image of God.

Bellarmine:
Let me conclude with yet another quote from St. Augustine: "The intention of the Holy Ghost is to teach us how one goes to heaven and not how the heavens go".

Galileo:
Your Grace, thank you for agreeing to be here.

Bellarmine:
I am afraid, gentlemen, I have to leave and cannot join you in the celebrations. I have an audience with the Holy Father in the Vatican.
Enjoy the festivities of the your induction, Galileo, in the Lincean Society. I do not approve of the goals of the society but….
He looks at Kepler.

Kepler, please convey my regards to the Emperor in Prague.
Turns to Galileo and says gravely:

A word of advice, Galileo: Be careful how you tell others of your ideas about motion in the heavens. Your findings about motion on Earth you can teach as you see fit, even if they seem to contradict Aristotle. But your ideas about motion in the heavens should only be discussed as a hypothesis and not a fact!
You live here in Italy, close to the Holy Office. You must not disagree with the doctrines of the holy Fathers.
He looks at Galileo with a severe expression

If you don't, you will encounter serious problems with the Holy Inquisition

Kepler and Galileo bow. The Cardinal takes his leave.

Galieo:
Kepler, you see, in spite of our severe differences we have the same enemies! let us go and meet the members of society. The president, Prince Federico Cesi
tells me that after my induction they will announce the suggested name given to this optical instrument that seems to cause so much controversy.
He picks up it up and looks at it.

Apparently, it was named by a young Greek artist and theologian. Actually, the Prince already told me the name suggested for this magical instrument. It will be called a *telescope*, from the Greek *tele*, far, and *skopein*, to look or see'. I think it is a good name for this instrument.

Kepler:
Yes, I like that name. Telescope –like -television.-
Perhaps in the future we will , who knows, be able to see the Heavens, and who knws what else, directly shown in our homes. But I doubt that this will be enlightening to the general public
They leave talking to each other.

Postscript

To be added…..

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