The Frontiers Collection

Relativity and the Nature of Spacetime

Bearbeitet von
Vesselin Petkov

1. Auflage 2011. Taschenbuch. XIII, 316 S. Paperback
ISBN 978 3 642 24235 9
Format (B x L): 15,5 x 23,5 cm
Gewicht: 510 g

Chapter 2
On the Impossibility of Detecting Uniform Motion

> Facts which at first seem improbable will, even on scant explanation, drop the cloak which has hidden them and stand forth in naked and simple beauty.
>
> Galileo [2, p. 401]

One of the major events that marked the beginning of modern science in the seventeenth century was the acceptance of the heliocentric system of the world. In 1543 Copernicus [3] published his book on the heliocentric model of the solar system, but the acceptance of the new revolutionary view became possible only after the works of Kepler [4] and especially Galileo [5].

In this chapter we will see that Galileo played a crucial role in the Copernican revolution. He was the first scientist to apply systematically what we now call the hypothetico-deductive method (formulating hypotheses, deducing conclusions, and testing them experimentally) which is recognized as the key ingredient of a genuine scientific activity that leads to the formulation of a new theory. This approach helped him realize why Aristotle's view on motion had been the main reason for the dominance of the geocentric world system due to Aristotle and Ptolemy over the two preceding millennia. And indeed Aristotle's view on motion looked self-evident even in the seventeenth century since it appeared to be in perfect agreement with the common-sense view based on people's everyday experience. This view was almost certainly the ultimate reason for the rejection of the first heliocentric model put forward by Aristarchus of Samos (310–230 B.C.) immediately after Aristotle's geocentric system of the world.

With this in mind we can better appreciate Galileo's role in the acceptance of the heliocentric system. His disproof of Aristotle's view on motion was so important that one may wonder how many more years would have been needed for the ideas of Copernicus to be recognized if Galileo had not written his *Dialogue Concerning the Two Chief World Systems – Ptolemaic and Copernican*.

V. Petkov, *Relativity and the Nature of Spacetime*, The Frontiers Collection, 2nd Edn.,
DOI 10.1007/978-3-642-01962-3_2,

2.1 Aristotle's View on Motion

Aristotle did not hold any counter-intuitive views on motion as the Eleatics did.[1] His view reflected people's everyday experience and was summarized in the first sentence in Book VII of his *Physics*: "Everything that is in motion must be moved by something." Aristotle believed that there were two types of motion – natural motion of a body which tends to reach its natural place (the center of the Earth) and violent motion which is the motion that needs a mover. Aristotle himself realized that his view led to a problem since it could not explain the motion of projectiles [8, Book VIII, Chap. 10]:

> If everything that is in motion with the exception of things that move themselves is moved by something else, how is it that some things, e.g., things thrown, continue to be in motion when their movent is no longer in contact with them?

This is really an obvious argument against the way Aristotle explained motion: if we throw a stone it should stop at the moment it leaves our hand but this is not what is observed – the stone continues its motion *on its own* until it hits the ground. Aristotle seemed to believe that the observed continuing motion of projectiles can be explained by assuming that the medium in which projectiles travel is moving them. In the case of the stone it is our hand, while throwing the stone, that moves the medium (the air) which in turn acts as a mover of the stone.

Before discussing Galileo's crushing arguments against Aristotle's view on motion, let us examine in more detail how it contradicts the heliocentric system. Here is an excerpt from Ptolemy's *The Almagest* in which he employs Aristotle's view on motion in order to demonstrate that the Earth does not move [9]:

> Now some people, although they have nothing to oppose to these arguments, agree on something, as they think, more plausible. And it seems to them there is nothing against their supposing, for instance, the heavens immobile and the earth as turning on the same axis from west to east very nearly one revolution a day; or that they both should move to some extent, but only on the same axis as we said, and conformably to the overtaking of the one by the other.
>
> But it has escaped their notice that, indeed, as far as the appearances of the stars are concerned, nothing would perhaps keep things from being in accordance with this simpler conjecture, but that in the light of what happens around us in the air such a notion would seem altogether absurd. For in order for us to grant them what is unnatural in itself, that the lightest and subtlest

[1] The Eleatic school of philosophy held that the observed motion and change are just illusions; the true reality, according to them, is an eternal existence [6, 7]. The Eleatic view is amazingly similar to the view suggested by special relativity, as we will see in Chap. 5.

> bodies either do not move at all or no differently from those of contrary nature, while those less light and less subtle bodies in the air are clearly more rapid than all the more terrestrial ones; and to grant that the heaviest and most compact bodies have their proper swift and regular motion, while again these terrestrial bodies are certainly at times not easily moved by anything else – for us to grant these things, they would have to admit that the earth's turning is the swiftest of absolutely all the movements about it because of its making so great a revolution in a short time, so that all those things that were not at rest on the earth would seem to have a movement contrary to it, and never would a cloud be seen to move toward the east nor anything else that flew or was thrown into the air. For the earth would always outstrip them in its eastward motion, so that all other bodies would seem to be left behind and to move towards the west.
>
> For if they should say that the air is also carried around with the earth in the same direction and at the same speed, nonetheless the bodies contained in it would always seem to be outstripped by the movement of both. Or if they should be carried around as if one with the air, neither the one nor the other would appear as outstripping, or being outstripped by, the other. But these bodies would always remain in the same relative position and there would be no movement or change either in the case of flying bodies or projectiles. And yet we shall clearly see all such things taking place as if their slowness or swiftness did not follow at all from the earth's movement.

The above arguments can be summarized in a single argument discussed by Galileo in his *Dialogue Concerning the Two Chief World Systems – Ptolemaic and Copernican* published in 1632 [5, p. 139]. Consider dropping a stone from the top of a tower. If the Earth is not moving as the Ptolemaic view holds, the stone will fall at the base of the tower. Assume now that the Earth is moving (consider just its rotation). During the time a stone dropped from the tower falls the Earth will move and the stone will not fall at the base of the tower. Since no one had ever observed such an effect the supporters of the Ptolemaic system maintained that the heliocentric system was wrong.

The arguments against the heliocentric system, which appeared to be so convincing for centuries, are based on Aristotle's view that everything that moves needs a mover. And indeed if we assume that the Earth is moving and we are on the top of the tower holding a stone, it does follow from Aristotle's view that the stone will stop moving with the tower at the moment our hand releases it – the mover (our hand) is not acting on the stone any more and it will stop moving in a horizontal direction. For this reason it will land at a given distance from the tower. At first sight such arguments appear irrefutable, and this is perhaps the most probable explanation for why the Ptolemaic system prevailed over the heliocentric system of Aristarchus of Samos.

2.2 Copernicus and Ptolemy's Arguments Against the Earth's Motion

In the sixteenth century Nicholas Copernicus (1473–1543) again argued that the Earth was not stationary at the center of the cosmos but rather rotated on its axis and also orbited the Sun. In his fundamental work *On the Revolutions of the Heavenly Spheres*, he advanced the argument that it was more natural to assume that the Earth is orbiting the Sun. However, as seen from the following quote he did not disprove Ptolemy's arguments against the Earth's motion [3, p. 519]:

> But let us leave to the philosophers of nature the dispute as to whether the world is finite or infinite, and let us hold as certain that the Earth is held together between its two poles and terminates in a spherical surface. Why therefore should we hesitate any longer to grant to it the movement which accords naturally with its form, rather than put the whole world in a commotion – the world whose limits we do not and cannot know? And why not admit that the appearance of daily revolution belongs to the heavens but the reality belongs to the Earth? And things are as when Aeneas said in Virgil: "We sail out of the harbor, and the land and the cities move away." As a matter of fact, when a ship floats on over a tranquil sea, all the things outside seem to the voyagers to be moving in a movement which is the image of their own, and they think on the contrary that they themselves and all the things with them are at rest. So it can easily happen in the case of the movement of the Earth that the whole world should be believed to be moving in a circle. Then what would we say about the clouds and the other things floating in the air or falling or rising up, except that not only the Earth and the watery element with which it is conjoined are moved in this way but also no small part of the air and whatever other things have a similar kinship with the Earth? Whether because the neighbouring air, which is mixed with earthly and watery matter, obeys the same nature as the Earth or because the movement of the air is an acquired one, in which it participates without resistance on account of the contiguity and perpetual rotation of the Earth.

Copernicus essentially *postulated* that all objects should participate in the Earth's motion. As the history of science has shown, this was not the best way to respond to an argument. Given the fact that Aristotle's view on motion was still the accepted doctrine in the sixteenth century, the arguments against the Earth's motion, which were based on Aristotle's view, were at that time valid arguments that had to be addressed properly. That is why the resurrection of the heliocentric system by Copernicus' ideas only became possible after Galileo disproved both Aristotle's view on motion and Ptolemy's arguments against the Earth's motion.

It is tempting to assume from this text that Copernicus implicitly advanced the idea of relative motion. A careful reading of his argument, however, shows that he simply wanted to point out that, just as it appears to the sailors that the harbor and the cities move away (whereas in fact it is the ship that is moving), it only looks to us that the heavens are rotating, whereas *in reality* it is the Earth that (absolutely) moves.

2.3 Galileo's Disproof of Aristotle's View on Motion

Galileo clearly realized that the arguments against the motion of the Earth and therefore against the heliocentric system were based on the Aristotelian doctrine of motion. For this reason he critically examined it and found it to contradict well-known facts about motion at that time. He did that in two independent ways. First, he showed that Aristotle's explanation of the motion of projectiles was wrong – in reality, once thrown, projectiles move on their own, not by the medium in which they travel. Second, he presented analyses of different experiments which independently arrived at the conclusion that in order to maintain their uniform motion, bodies do not need a constant mover. On the basis of the new view on motion, Galileo demonstrated that the arguments against the Earth's motion no longer hold, and this paved the way for the acceptance of the heliocentric model of the solar system.

Let us now see how Galileo achieved such an enormous result. In his *Dialogue Concerning the Two Chief World Systems – Ptolemaic and Copernican*, Simplicio defends the Ptolemaic system, whereas Salviati and Sagredo provide arguments against it.

First, Galileo gives an example of how a scientific debate should be conducted by stating the main arguments of his opponents. He does this through Salviati [5, p. 126]:

> As the strongest reason of all is adduced that of heavy bodies, which, falling down from on high, go by a straight and vertical line to the surface of the earth. This is considered an irrefutable argument for the earth being motionless. For if it made the diurnal rotation, a tower from whose top a rock was let fall, being carried by the whirling of the earth, would travel many hundreds of yards to the east in the time the rock would consume in its fall, and the rock ought to strike the earth that distance away from the base of the tower. This effect they support with another experiment, which is to drop a lead ball from the top of the mast of a boat at rest, noting the place where it hits, which is close to the foot of the mast; but if the same ball is dropped from the same place when the boat is moving, it will strike at that distance from the foot of the mast which the boat will have run during the time of fall of the lead, and

> for no other reason than that the natural movement of the ball when set free is in a straight line toward the center of the earth.

Now the stage is set for Galileo to show that these arguments against the Earth's motion are not irrefutable. As we will see the power of Galileo's arguments, presented by Salviati and Sagredo, is determined by the fact that they combine references to experiments and logical analysis. As one cannot perform the tower experiment on a moving Earth and on a motionless Earth to test whether it will produce different results, Salviati concentrates on the ship version of the experiment and asks Simplicio [5, p. 144]:

> You say, then, that since when the ship stands still the rock falls to the foot of the mast, and when the ship is in motion it falls apart from there, then, conversely, from the falling of the rock at the foot it is inferred that the ship stands still, and from its falling away it may be deduced that the ship is moving. And since what happens on the ship must likewise happen on the land, from the falling of the rock at the foot of the tower one necessarily infers the immobility of the terrestrial globe. Is that your argument?

After Simplicio agrees, Salviati continues [5, p. 144]:

> Now tell me: If the stone dropped from the top of the mast when the ship was sailing rapidly fell in exactly the same place on the ship to which it fell when the ship was standing still, what use could you make of this falling with regard to determining whether the vessel stood still or moved?

Simplicio's reply is: "Absolutely none". Salviati's next question is on whether Simplicio ever carried out "this experiment of the ship". He did not do it himself but insisted he believed the authorities "who adduce it had carefully observed it." At this point Salviati provides perhaps the clearest hint that Galileo performed the experiment with a stone falling from the mast of a moving ship [5, pp. 144–145]:

> For anyone who does will find that the experiment shows exactly the opposite of what is written; that is, it will show that the stone always falls in the same place on the ship, whether the ship is standing still or moving with any speed you please. Therefore the same cause holding good on the earth as on the ship, nothing can be inferred about earth's motion or rest from the stone falling always perpendicularly to the foot of the tower.

As Simplicio remains skeptical about what the result of a real experiment will be, Salviati virtually threatens him to make him realize the true conclusion without the need of any experiment [5, p. 145]:

> Without experiment, I am sure that the effect will happen as I tell you, because it must happen that way; and I might add that you yourself also know that it cannot happen otherwise, no matter how you may pretend not to know it – or

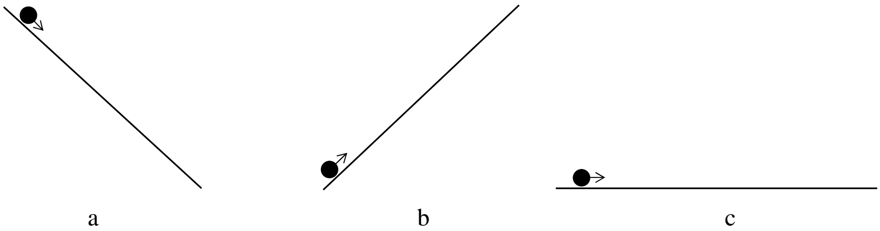

Fig. 2.1 Galileo's experiment with inclined planes

> give that impression. But I am so handy at picking people's brains that I shall make you confess this in spite of yourself.

What Salviati had in mind is the famous experiment involving inclined planes (see Fig. 2.1a) [5, p. 145]:

> Suppose you have a plane surface as smooth as a mirror and made of some hard material like steel. This is not parallel to the horizon, but somewhat inclined, and upon it you have placed a ball which is perfectly spherical and of some hard and heavy material like bronze. What do you believe this will do when released?

Simplicio gives the obvious answer: "the ball will continue to move indefinitely, as far as the slope of the surface is extended, and with a continually accelerated motion." Then Salviati asks what will happen to the ball if it is made to move upward on an inclined plane by a forcibly impressed impetus upon it (Fig. 2.1b). Simplicio does not have any difficulty responding to this question either [5, p. 146]:

> The motion would constantly slow down and be retarded, being contrary to nature, and would be of longer or shorter duration according to the greater or lesser impulse and the lesser or greater slope upward.

After discussing the two types of slope, Salviati takes the next logical step [5, p. 147]:

> Now tell me what would happen to the same movable body placed upon a surface with no slope upward or downward.

Simplicio seems to be a little perplexed [5, p. 147]:

> Here I must think a moment about my reply. There being no downward slope, there can be no natural tendency towards motion; and there being no upwards slope, there can be no resistance to being moved, so there would be an indifference between the propensity and the resistance to motion. Therefore it seems to me that it ought naturally to remain stable.

Now Salviati asks the crucial question [5, p. 147]:

> But what would happen if it were given an impetus in any direction?

Since Simplicio "cannot see any cause for acceleration or deceleration, there being no slope upward or downward," he unavoidably comes to the conclusion that the ball will continue to move "as far as the extension of the surface continued without rising or falling." This conclusion makes him agree with what Salviati said [5, p. 147]:

> Then if such a space were unbounded, the motion on it would likewise be boundless? That is, perpetual?

Salviati continues his argument [5, p. 148]:

> Now as that stone which is on top of the mast; does it not move, carried by the ship both of them going along the circumference of a circle about its center? And consequently is there not in it an ineradicable motion, all external impediments being removed? And is not this motion as fast as that of the ship?

After Simplicio admits that "this is true, but what next", Salviati urges him to [5, p. 148]:

> Go on and draw the final consequence by yourself, if by yourself you have known all the premisses.

Simplicio does see what follows from the premisses [5, p. 148]:

> By the final conclusion you mean that the stone, moving with unindelibly impressed motion, is not going to leave the ship but it will follow it, and finally will fall at the same place where it fell when the ship remained motionless.

However, he still refuses to accept the final conclusion and offers a counter-argument based on Aristotle's explanation of the motion of projectiles [5, pp. 149–150]:

> I believe you know that the projectile is carried by the medium, which in the present instance is the air. Therefore if that rock which was dropped from the top of the mast were to follow the motion of the ship, this effect would have to be attributed to the air, and not to the impressed force; but you assume that the air does not follow the motion of the ship, and is quiet. Furthermore, the person letting the stone fall does not need to fling it or give it any impetus with his arm, but has only to open his hand and let it go. So the rock cannot follow the motion of the boat either through any force impressed upon it by its thrower or by means of any assistance from the air, and therefore it will remain behind.

Simplicio fails to see the obvious – that the motion of the boat is impressed upon the stone by the hand of the person holding it; the stone is merely being pulled in the direction of the moving ship. As Simplicio's last defense is the issue of projectiles, Salviati has finally to deal with the weakest, but crucial element of Aristotle's view on motion – his account of what moves projectiles [5, p. 150]:

> Seeing that your objection is based entirely upon the non-existence of impressed force, then if I were to show that the medium plays no part in the continuation of motion in projectiles after they are separated from their throwers, would you allow impressed force to exist? Or would you merely move on to some other attack directed toward its destruction?

Simplicio agrees [5, p. 150]:

> If the action of the medium were removed, I do not see how recourse could be had to anything else than the property impressed by the motive force.

Before starting his attack on Aristotle's explanation of the motion of projectiles, Salviati asks Simplicio to state clearly Aristotle's view on "what the action of the medium is in maintaining the motion of the projectile" [5, p. 150], which he does [5, p. 151]:

> Whoever throws the stone has it in his hand; he moves his arm with speed and force; by its motion not only the rock but the surrounding air is moved; the rock, upon being deserted by the hand, finds itself in air which is already moving with impetus, and by that it is carried. For if the air did not act, the stone would fall from the thrower's hand to his feet.

Salviati then starts the formulation of his devastating argument [5, p. 151]:

> And you are so credulous as to let yourself be persuaded of this nonsense, when you have your own senses to refute it and to learn the truth? Look here: A big stone or a cannon ball would remain motionless on a table in the strongest wind, according to what you affirmed a little while ago. Now do you believe that if instead this had been a ball of cork or cotton, the wind would have moved it?

Not suspecting what will follow Simplicio confidently answers the question [5, p. 151]:

> I am quite sure the wind would have carried it away, and would have done this the faster, the lighter the material was. For we see this in clouds being borne with a speed equal to that of the wind which drives them.

Salviati asks Simplicio to answer one more question [5, p. 151]:

> But if with your arm you had to throw first a stone and then a wisp of cotton, which would move the faster and the farther?

Again Simplicio does not anticipate how much he is undermining his own position [5, p. 151]:

> The stone, by a good deal; the cotton will merely fall at my feet.

Now Salviati makes it impossible for anyone to defend what Aristotle assumed to be the cause for the motion of projectiles [5, p. 151]:

> Well, if that which moves the thrown thing after it leaves your hand is only the air moved by your arm, and if moving air pushes light material more easily than heavy, why doesn't the cotton projectile go farther and faster than the stone one? There must be something conserved in the stone ...

This is one of most Galileo's brilliant arguments – he uses Aristotle's own explanation of how projectiles move to disprove this same explanation. It seems certain that Galileo recognized the crucial role of the issue of projectiles in Aristotle's view. In order that his arguments against Aristotle's explanation be as convincing as possible, he gave several arguments against it. Here is another devastating argument which this time is offered by Sagredo [5, p. 152]:

> But there is another point of Aristotle's which I should like to understand, and I beg Simplicio to oblige me with an answer. If two arrows were shot with the same bow, one in the usual way and one sideways – that is, putting the arrow lengthwise along the cord and shooting it that way – I should like to know which one would go the farther?

For one more time Simplicio is about to face the hidden contradictions between the Aristotelian doctrine of motion and our intuition obtained from everyday experience [5, p. 153]:

> I have never seen an arrow shot sideways, but I think it would not go even one-twentieth the distance of one shot point first.

Sagredo now exposes one of those contradictions [5, p. 153]:

> Since that is just what I thought, it gives me occasion to raise a question between Aristotle's dictum and experience. For as to experience, if I were to place two arrows upon that table when a strong wind was blowing, one in the direction of the wind and the other across it, the wind would quickly carry away the latter and leave the former. Now apparently the same ought to happen with two shots from a bow, if Aristotle's doctrine were true, because the one going sideways would be spurred on by a great quantity of air moved by the bowstring – as much as the whole length of the arrow – whereas the other arrow would receive the impulse from only as much air as there is in the tiny circle of its thickness. I cannot imagine the cause of such a disparity, and should like very much to know it.

Simplicio still does not seem to realize the contradiction [5, p. 153]:

> The cause is obvious to me; it is because the arrow shot point foremost has to penetrate only a small quantity of air, and the other has to cleave as much as its whole length.

Sagredo's explanation delivers the final blow to the view that it is the medium which continues to move projectiles after they are thrown [5, p. 153]:

> Oh, so when arrows are shot they have to penetrate the air? If the air goes with them, or rather if it is the very thing which conducts them, what penetration can there be? Do you not see that in such a manner the arrow would be moving faster than the air? Now what conferred this greater velocity upon the arrow? Do you mean to say that the air gives it a greater speed than its own?
>
> You know perfectly well, Simplicio, that this whole thing takes place just exactly opposite to what Aristotle says, and that it is as false that the medium confers motion upon the projectile as it is true that it is this alone which impedes it. Once you understand this, you will recognize without any difficulty that when the air really does move, it carries the arrow along with it much better sideways then point first, because there is lots of air driving it in the former case and little in the latter. But when shot from the bow, since the air stands still, the sidewise arrow strikes against much air and is much impeded, while the other easily overcomes the obstacles of the tiny amount of air that opposes it.

The conclusion that projectiles do not need a mover is inevitable. Once it becomes clear that projectiles move not by the medium but on their own, Aristotle's view – everything that is in motion must be moved by something – is essentially finished. The motion of an object which moves on its own is now called motion by inertia. It is controversial whether Galileo clearly realized the idea of inertial motion. Arguments which appear to show that he did not are easily found, mainly in the still rather Aristotelian terminology he used – motion "along the circumference of a circle about its center", "impressed motion", "impressed force", etc. What ultimately matters, however, is the essence of his arguments – that a body left on its own moves on its own and does not need a constant mover. And this is the very core of the fundamental idea of inertia. Galileo had tried to answer the question of why free bodies would continue to move on its own forever, provided that nothing prevents them from doing so, by assuming that the continued motion of a projectile is impressed upon it by its thrower. We have not done better than him – inertia still continues to be an outstanding puzzle in physics. The inertial motion of a body involves two questions:

- why does a free body move uniformly forever?
- why does a body resist the change in its uniform motion when it encounters an obstacle?

The first question will be addressed in Chap. 5, whilst Chap. 9 tries to outline a possible answer to the second.

2.4 Galileo's Principle of Relativity

Let us summarize the way Galileo disproved the arguments against the motion of the Earth. As these arguments were based on Aristotle's view on motion, Galileo carried out a brilliant analysis and convincingly demonstrated that, contrary to what Aristotle said, a body set free continues to move on its own without the need of a mover. Then Galileo employed the new view of motion to both the tower and ship experiments and showed that a stone dropped from the tower or the mast of the ship preserves its motion and lands at the base of the tower or the mast, respectively. It is almost certain that Galileo carried out the experiment of releasing a stone from the top of a ship's mast and found that it always fell at the foot of the mast no matter whether the ship was moving or was standing still, which confirmed his arguments. In this way he demonstrated that experiments involving a stone dropped from a tower or from the mast of a moving ship always produce null results and therefore cannot be used to detect the motion of the Earth or the ship.

Therefore the motion of a body cannot be discovered by performing mechanical experiments (the type of experiments Galileo considered) on the moving body itself. Now we call this conclusion, which is derived from experimental facts, Galileo's principle of relativity: by performing mechanical experiments, the uniform motion of a body cannot be detected.

Before asking the question of the physical meaning of this principle in the next chapter let us end this chapter with another famous excerpt from Galileo's book which demonstrates the nullity of all experiments designed to show that the Earth is not moving [5, pp. 186–187]:

> For a final indication of the nullity of the experiments brought forth, this seems to me the place to show you a way to test them all very easily. Shut yourself up with some friend in the main cabin below decks on some large ship, and have with you there some flies, butterflies, and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle that empties drop by drop into a wide vessel beneath it. With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distances being equal; jumping with your feet together, you pass equal spaces in every direction. When you have observed all these things carefully (though there is no doubt that when the ship is standing still everything must happen in this way), have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving

or standing still. In jumping, you will pass on the floor the same spaces as before, nor will you make larger jumps toward the stern than toward the prow even though the ship is moving quite rapidly, despite the fact that during the time that you are in the air the floor under you will be going in a direction opposite to your jump. In throwing something to your companion, you will need no more force to get it to him whether he is in the direction of the bow or the stern, with yourself situated opposite. The droplets will fall as before into the vessel beneath without dropping toward the stern, although while the drops are in the air the ship runs many spans. The fish in their water will swim toward the front of their bowl with no more effort than toward the back, and will go with equal ease to bait placed anywhere around the edges of the bowl. Finally the butterflies and flies will continue their flights indifferently toward every side, nor will it ever happen that they are concentrated toward the stern, as if tired out from keeping up with the course of the ship, from which they will have been separated during long intervals by keeping themselves in the air. And if smoke is made by burning some incense, it will be seen going up in the form of a little cloud, remaining still and moving no more toward one side than the other. The cause of all these correspondences of effects is the fact that the ship's motion is common to all the things contained in it, and to the air also.

Springer

http://www.springer.com/978-3-642-01952-4

Relativity and the Nature of Spacetime
Petkov, V.
2009, XIII, 316 p. 70 illus., Hardcover
ISBN: 978-3-642-01952-4