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Principles of Classical Mechanics

Objects in Motion

物体与运动

by Paul Fleisher

[美] 保罗·弗莱谢尔 著

王岩松 译

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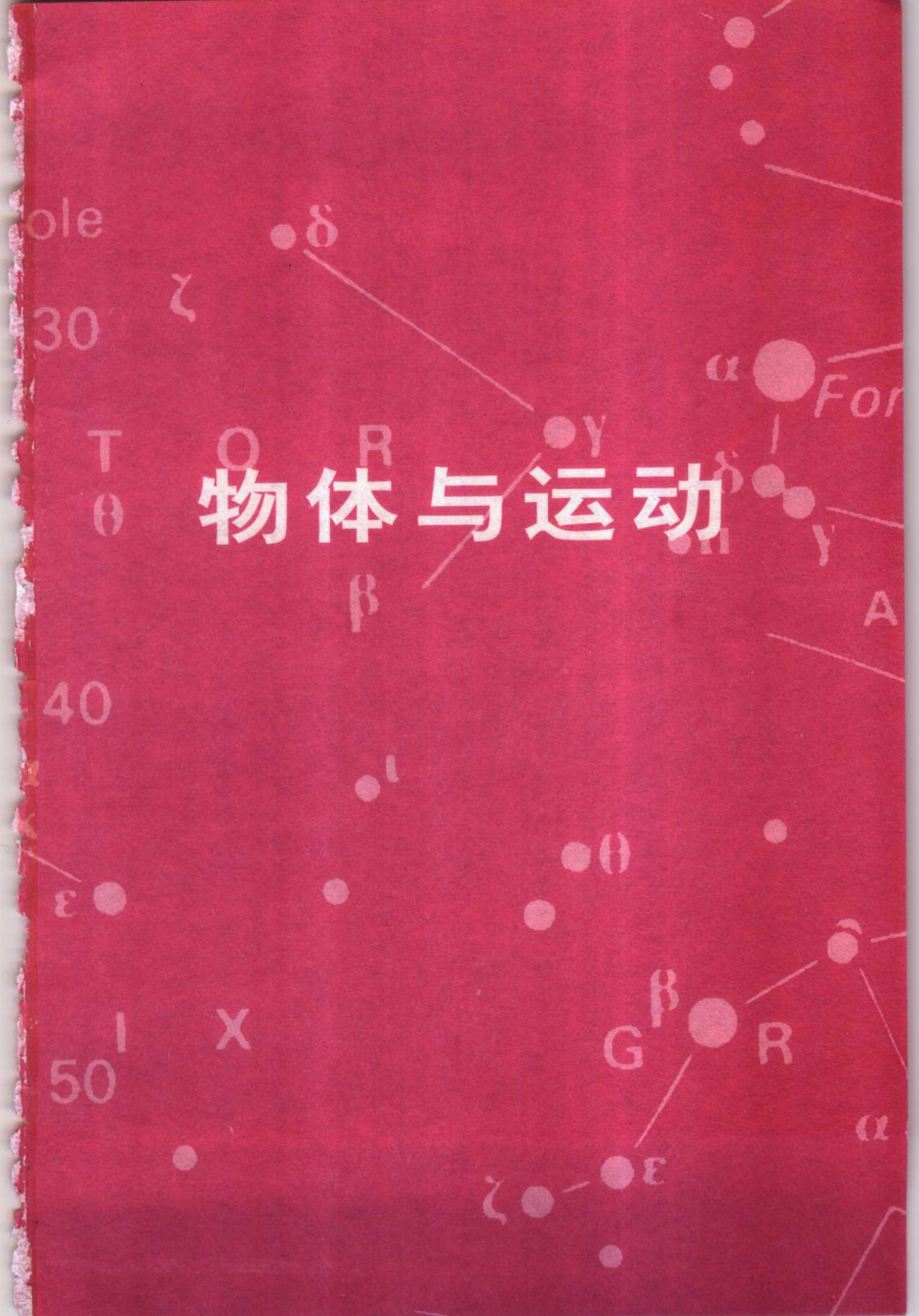
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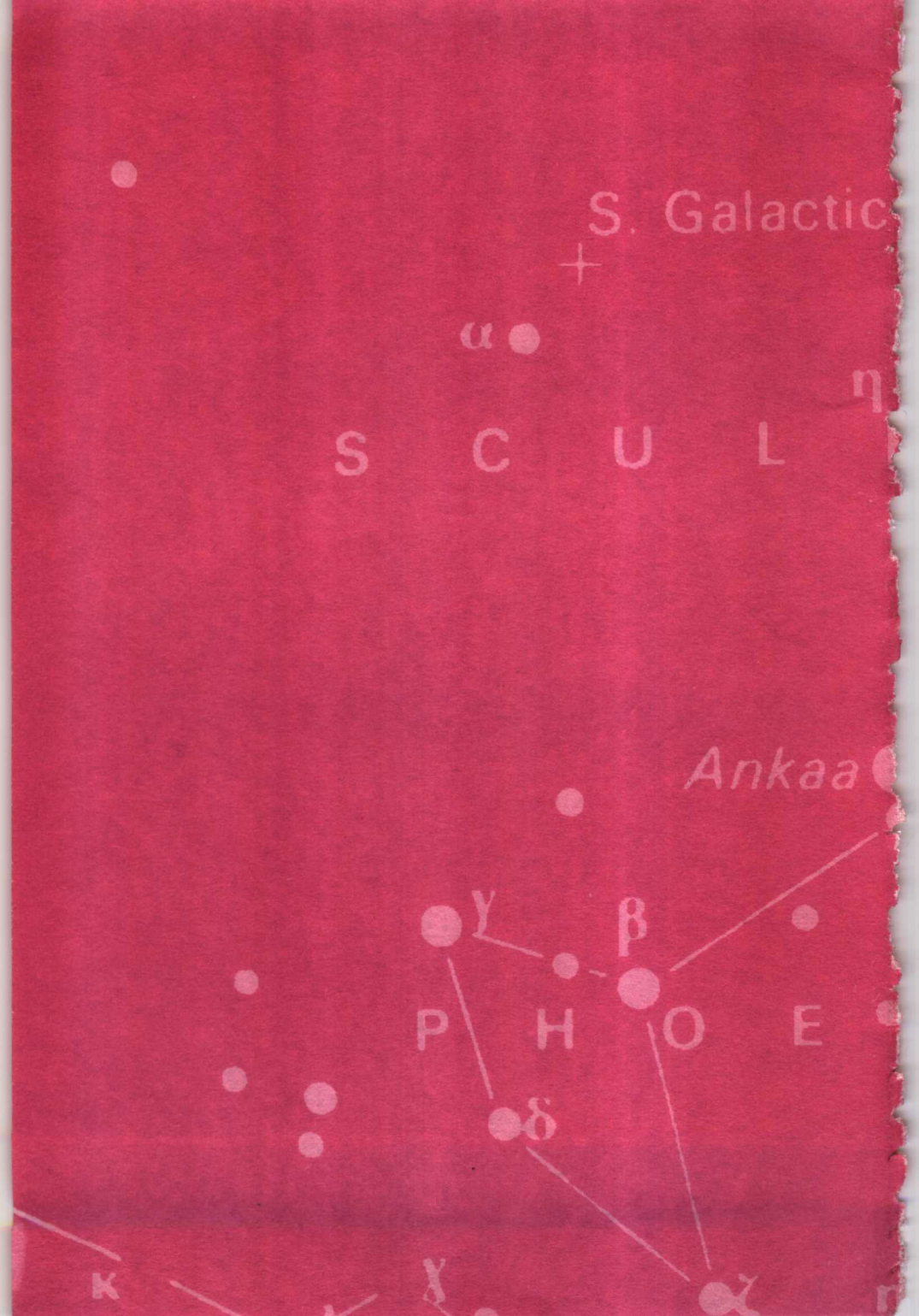
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Contents
目 录

INTRODUCTION
引言

What Is a Natural Law?

Everyone knows what a law is. It's a rule that tells people what they must or must not do. Laws tell us that we shouldn't drive faster than the legal speed limit, that we must not take someone else's property, that we must pay taxes on our income each year.

Where do these laws come from? In the United States and other democratic countries, laws are created by elected representatives. These men and women discuss which ideas they think would be fair and useful. Then they vote to decide which ones will actually become laws.

什么是自然定律？

人人所共知法律是一种准则，它告诉人们必须做什么或不得做什么。法律告诉我们开车不应超过法定的速度限制，不得拿别人的东西，必须每年缴纳所得税。

这些法律从何而来呢？在美国及其他民主国家，法律是由民众选举的代表制定的。这些男男女女讨论他们认为公平、有益的见解，然后他们投票决定哪些将真正成为法律。

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tax *n.* 税，税额
democratic *a.* 民主的
representative *n.* 代表

But there is another kind of law, a scientific law. You probably have heard about the law of gravity, for example. Where did that law come from? Who made it, and what could we do if we decided to change it?

The law of gravity is very different from a speed limit or a law that says you must pay your taxes. Speed limits are different in different places. On many interstate highways, drivers can travel 105 kilometers (65 miles) per hour. On crowded city streets, they must drive more slowly. But the law of gravity works exactly the same way no matter where you are. In the country or the city, in France, Brazil, or the United States, when you drop a ball, it will fall down. And it will always fall at the same rate.

Sometimes people break laws. When the speed limit is 88 kph (55 mph), people often drive 97 kph (60 mph) or even faster. But what happens when you try to break the law of gravity? You can't. Here on Earth, if

但是还有另一种法——科学定律。例如，你也许听说过引力定律。这条定律是从何而来的呢？是谁制定的这条定律？如果我们要改变定律的话，能做些什么呢？

引力定律与限速法规或者要求你必须交税的法律有很大区别。限速法规在不同的地方有不同的规定。在许多州际高速公路上，司机可以将车开到每小时105千米（65英里）的速度。在拥挤的城市街道上，司机就得将车开得慢多了。但是不论你在哪里，引力定律都以完全相同的形式起作用。在乡村或者城市，在法国或者巴西，亦或是美国，当你扔下一个球时，它就会下落。并且它下落的速度总是一样的。

有时人们会违犯法律。速度限制是每小时88千米（每小时55英里），而人们经常把车开到每小时97千米（每小时60英里）甚至更快。但当你企图违反重力定律时会出现什么情况呢？你是做

crowded *a.* 人多的，拥挤的

you drop a ball a thousand times, it will fall down at the same rate of speed every time. It will never fall up or sideways, or just float in place.

The law of gravity doesn't apply just to people, either. All objects obey this law—plants, animals, water, stones, and even entire planets and stars. And we know that gravity stays in effect whether people are watching or not.

The law of gravity is a natural law, or a rule of nature. Scientists and philosophers have studied events in our world for a long time. They have made careful observations and done many experiments. And they have found that certain events happen over and over again in a regular, predictable way.

You have probably noticed some of the same things yourself. Gravity is a good example. When you let an object go, it will drop. Objects on Earth don't just float away. You know

不到的。在地球上，即使你扔一千次球，它每次都会以同样的速度下落。它永远不会上升或者斜着下落，或者浮在原处。

引力定律也不仅仅适用于人类。所有的物体都遵守这一法则——植物、动物、水、石头，甚至全部行星和恒星。我们知道，不论人们是否注意到它，引力定律总是在起着作用。

引力定律是一个自然法则，或者叫自然的规则。科学家和哲学家们研究我们这个世界上的现象有很长时间了。他们做了细致的观察，也做了许多次实验。他们发现有一些现象会以有规律的、可以预见的方式反复多次地出现。

你自己也许会注意到一些同样的现象。重力就是一个好的例子。你抛出一个物体后，它会下落。地球上的物体是不会无缘无故飘走的。通过实验就可以知道

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apply *v.* 有效，适用
entire *a.* 全部的，整个的
philosopher *n.* 哲学家

that from experience. Would you bet your life savings that a baseball tossed up into the air will fall back down again? It would be a safe bet. You'd be certain to win.

A scientific law is a statement that explains how things work in the universe. It describes the way things are, not the way we want them to be. That means a scientific law is not something that can be changed whenever we choose. We can change the speed limit or the tax rate if we think they're too high or too low. But no matter how much we want to float instead of fall, gravity remains in effect. We cannot change it; we can only describe what happens. A scientist's job is to describe the laws of nature as accurately and exactly as possible.

The laws you will read about in this book are universal laws. That means they are true not only here on Earth, but elsewhere throughout the universe too. The universe includes everything we know to exist: our

这一点。你愿不愿意用一生的积蓄打一个赌，赌被抛上半空的棒球会再次落下？这是一个保险的赌注。你肯定能赢。

科学定律是用来解释说明宇宙中的事物是如何作用的。它是描述事物是什么样子的，而不是描述我们想让它们成为什么样子的。这就是说，不是我们什么时候想改变科学定律，它就能改变的。要是我们认为速度限制太高或太低、税率太高或太低的话，我们可以改变它。但不论我们多么想让物体浮着而不下落，重力总是在起作用。我们改变不了它，我们只能描述发生的现象。科学家的工作就是尽可能精准和确切地描述自然法则。

在本书中你将要读到的定律都是通用法则。这就意味着这些定律不仅在地球上是对的，而且在整个宇宙的其它地方也是对的。宇宙包括我们所知的存在着的一切东西：我们所在的行星、

planet, our solar system, our galaxy, all the other billions of stars and galaxies and all the vast empty space in between. All the evidence that scientists have gathered about the other planets and stars in our universe tells us that the scientific laws that apply here on Earth also apply everywhere else.

太阳系，我们所在的星系，其它所有的数十亿颗恒星和星系及它们之间的广阔空间。科学家们搜集到的宇宙中有关其它行星和恒星的所有证据使我们确信，适用于地球的科学定律也适用于其它的各个地方。

In the history of science, some laws have been found through the brilliant discoveries of a single person. The law of universal gravitation, for example, is the result of Sir Isaac Newton's great flash of individual understanding. But ordinarily, scientific laws are discovered through the efforts of many scientists, each one building on what others have done earlier. When one scientist receives credit for discovering a law, it's important to remember that many other people also contributed to that discovery. Even Newton's discovery was based on problems and questions studied by many earlier scientists.

在科学史中，有些定律是通过个人的非凡发现而确立的。比如，万有引力定律就是艾萨克·牛顿爵士个人伟大智慧灵光一闪的结果。但是一般来说，科学定律是通过许多科学家的努力而发现的，每一个科学家的工作又建立在其它较早的科学家研究工作的基础之上。当一个科学家由于发现了一个定律而赢得了赞赏的时候，重要的是要记住还有许多别的科学家也为此做出了贡献。牛顿的发现也是建立在许多早期科学家研究的问题和课题之上的。

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galaxy *n.* 星系

brilliant *a.* 杰出的、非凡的

Scientific laws do change, on rare occasions, but they don't change because we tell the universe to behave differently. Scientific laws change only if we have new information or more accurate observations. A law changes when scientists make new discoveries that show the old law doesn't describe the universe as well as it should. Whenever scientists agree to a change in the laws of nature, the new law describes events more completely, or more simply and clearly.

在极少数情况下，科学定律会有所改变，但它们发生改变，不是因为我们让宇宙以不同的方式发生作用。只有我们在获得新的信息或更加准确的观察结果时，科学定律才会改变。当科学家取得了新的发现，证明旧的定律不能像所希望的那样描述天地万物时，它就会改变。每当科学家同意对自然定律进行修改，新的定律会更加完整或更加简洁清楚地描述现象。

The laws that describe how planets move around the Sun are good examples of this. Astronomers once thought that the planets, the Sun, and the Moon all orbited the Earth in perfect circles. But new discoveries and improved measurements of the planets' paths forced two great scientists, Copernicus and Kepler, to rewrite the laws that describe the planets' motion. The Sun doesn't revolve around the Earth after all, they realized. The

有一个定律可以作为很好的例子用来说明这个问题，这个定律描述了行星是如何围绕太阳旋转的。天文学家曾经认为行星、太阳、月亮都沿着规则的圆形轨道绕地球运转。但是新的发现和改进后的对行星轨迹的测量方法使两位伟大的科学家哥白尼和开普勒，重新制定了描述行星运动的定律。他们认识到，太阳根本不是围绕地球旋转的。地球和其它的一些行星是围绕太阳旋转

observation *n.* 观察　　revolve *v.* 旋转

Earth and the other planets revolve around the Sun! Once scientists realized this, they had to rewrite the laws that described the motion of the planets.

的！一旦科学家们认识到了这一点，他们就得重新制定描述行星运动的定律。

Natural laws are often written in the language of mathematics. This allows scientists to be more exact in their descriptions of how things work. For example, Newton's law of universal gravitation is actually written like this:

自然定律常常是用数学语言写成的。这就使得科学家在描述事物发生作用的方式时能够更加准确。比如，牛顿的万有引力定律实际上是这样表述的：

$$\text{引力}\ F = \underset{\text{引力系数}}{G} \times \frac{\overset{\text{质量(1)}}{m(1)} \times \overset{\text{质量(2)}}{m(2)}}{\underset{\text{距离}^2}{d^2}}$$

Don't let the math fool you. It's still the same gravity you experience with every step. Writing it this way lets scientists compute the actual gravitational force accurately in many different situations here on Earth and elsewhere in the universe.

不要让数学把你搞糊涂了。它仍然是你每迈一步时都会体验到的同样的引力。将定律用这种方式写出，使得科学家能准确地计算出在地球上的许多不同地点和宇宙里别的地方的实际引力大小。

The science of matter and energy

有关物质和能量及其如何作

experience *v.* 感觉，体验　　situation *n.* 局面，形势

and how they behave is called physics. In the hundreds of years that physicists have been studying our universe, they have discovered many natural laws. In this book, you'll read about several of these great discoveries. There will be some simple experiments you can do to see the laws in action. Read on, and share the fascinating stories of the laws that reveal the secrets of our universe.

用的科学叫做物理学。几百年来，物理学家一直在研究我们所在的宇宙，他们发现了许多自然定律。在本书中，你将会读到其中的几个伟大发现。书中有一些你可以做的简单实验，以便让你可以直观地看到这些法则。请读下去，来分享这些有关揭示宇宙奥秘的定律的精彩故事。

CHAPTER 1
第 1 章

Planetary Motion

Every morning the Sun rises in the east. It travels across the sky in a great arched path. Every evening it sets in the west. The Moon follows a similar path. So do the stars. It looks as though these objects must be traveling in great circles around the Earth.

People have watched the sky and kept track of the paths of the Sun, the Moon, and the stars since the earliest times. And for thousands of years, astronomers thought that all those heavenly lights circled around us while the Earth stood still. After all, we can see the stars moving in the sky.

行星运动

太阳每天早晨从东方升起。它沿着一个巨大的拱形轨道穿越天空。每天傍晚太阳从西方落下。月亮也沿相似的轨道运行。星星也是如此。看起来好像这些物体一定是沿着巨大的环形轨道绕地球旋转。

从很早的时候起，人们就开始观察天空，研究太阳、月亮、星星的运行轨迹。几千年以来，天文学家一直认为所有的天体都围绕我们旋转，而地球静止不动。毕竟我们能看到星星在天空移动。站在地球上，我们好像一点儿也不动。几乎每个人都认为地

planetary a. 行星的

heavenly a. 天上的

Standing here on the Earth, we don't seem to be moving at all. Almost everyone agreed that the Earth was the center of the universe and that all other heavenly objects revolved around it in perfect circles.

But there was a problem. A few objects in the sky didn't fit into the pattern. Sometimes these objects seemed to stop, move backward for a while, stop again, and then resume their paths across the sky. Because these heavenly objects didn't follow a regular path like the stars, the Sun, and the Moon did, they were called *planets*, which means "wanderers" in Greek.

Astronomers plotted more and more complicated maps to keep track of the planets' strange wanderings. They drew maps with circles on circles on circles. But these complex arrangements still didn't solve the problem. The rules of science tell us that the simplest explanation is usu-

站在地球上，我们似乎一点也没有运动。几乎每个人都同意地球是宇宙的中心，其它的所有天体都沿着规则的圆形轨道绕地球旋转。

但是有一个问题。有一些天体不符合这种模式。有时这些天体好像停了下来，向后运动一段时间，又停下来，然后继续沿它们的轨迹穿越天空。由于这些天体不沿着像恒星、太阳、月亮那样的规则轨迹运行，人们称它们为“行星”，在希腊语中意为“漫游者”。

天文学家绘制了越来越复杂的图，以追踪行星的奇特漫游轨迹。他们画的图上圆圈套着圆圈。但这种复杂的安排依然解决不了问题。科学规律告诉我们，最简单的解释通常是最好的解释。看来天体并不是以这样复杂的模式运行的。天文学家开始认

pattern *n.* 模式、方式
regular *a.* 有规律的、定期的
complex *a.* 复杂的

ally the best. It seemed unlikely that the heavens worked in such a complicated pattern. Astronomers began to realize that the whole system didn't make sense. They needed a simpler explanation for the movements of the stars and planets.

识到整个体系是不合理的。他们需要一个对恒星和行星运行方式的更简单的解释。

In 1543, the astronomer Nicolaus Copernicus published a new explanation. Copernicus believed that the Earth was also a planet. He said that the Earth and the other planets revolved in circles around the Sun. Many people found this new idea very disturbing. Human beings thought of themselves as being at the center of the universe. But Copernicus's theory said that the Earth was just one of several travelers around the Sun. It made the Earth seem less special.

1543 年，天文学家尼古拉斯·哥白尼发表了一种新的解释方法。哥白尼认为地球也是一颗行星。他说地球和其它行星都沿圆形轨道绕太阳旋转。许多人对这种新观点感到非常不安。人类认为自己是宇宙的中心。但哥白尼的理论却说地球只不过是许多绕太阳旋转的行星中的一颗。这使得地球好像不那么特别了。

Another reason why many astronomers disagreed with Copernicus at first was that the Earth doesn't seem to move at all. It feels as if the Earth is standing perfectly still. However, others realized that everything on our

起初，许多天文学家不同意哥白尼学说的另一个原因是地球看上去根本没有在运动。从感觉上来讲，地球好像是完全静止不动的。然而，另一些人认识到我们星球上的一切物体都在随着星

publish *v.* 印行，发表