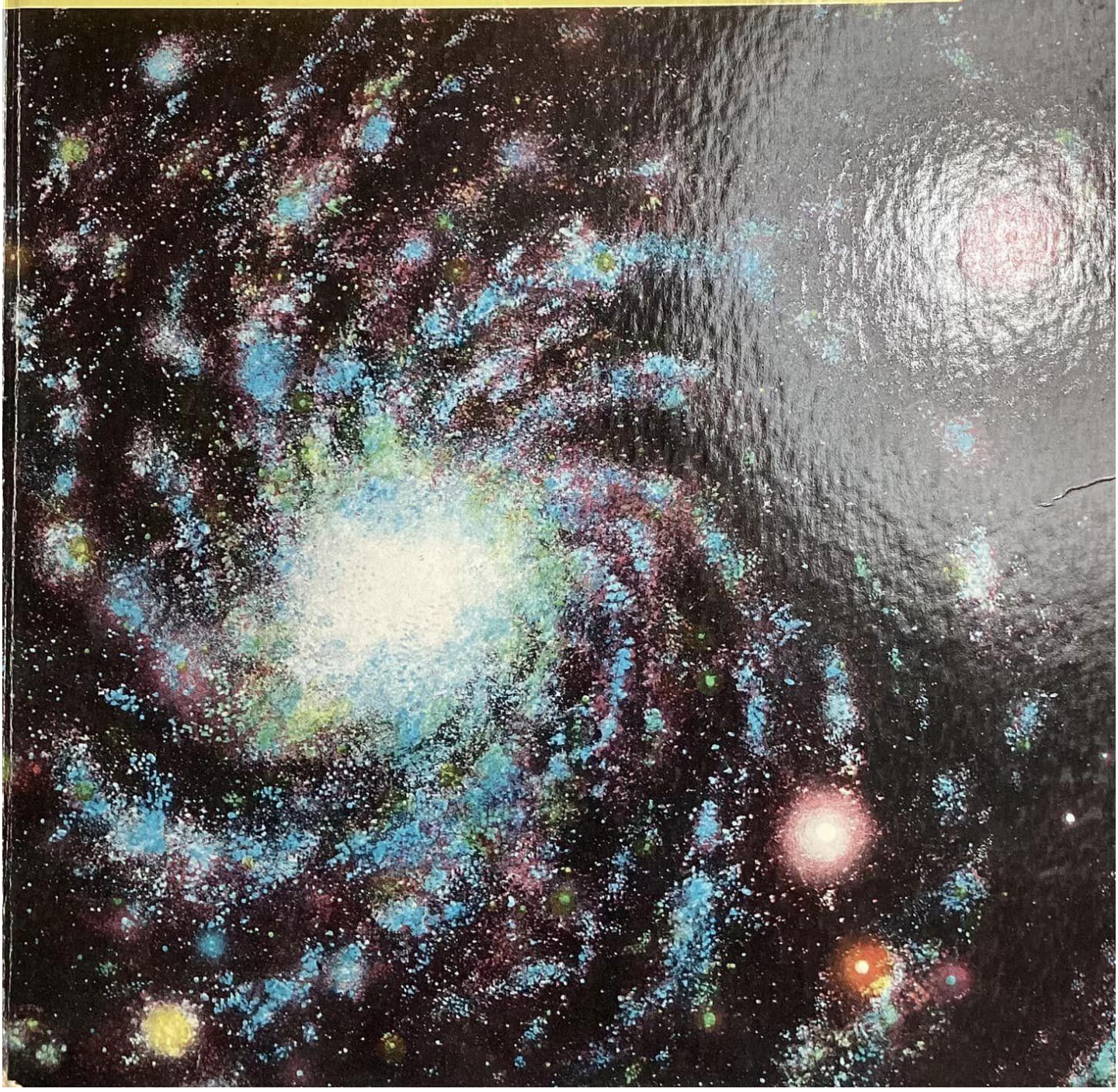
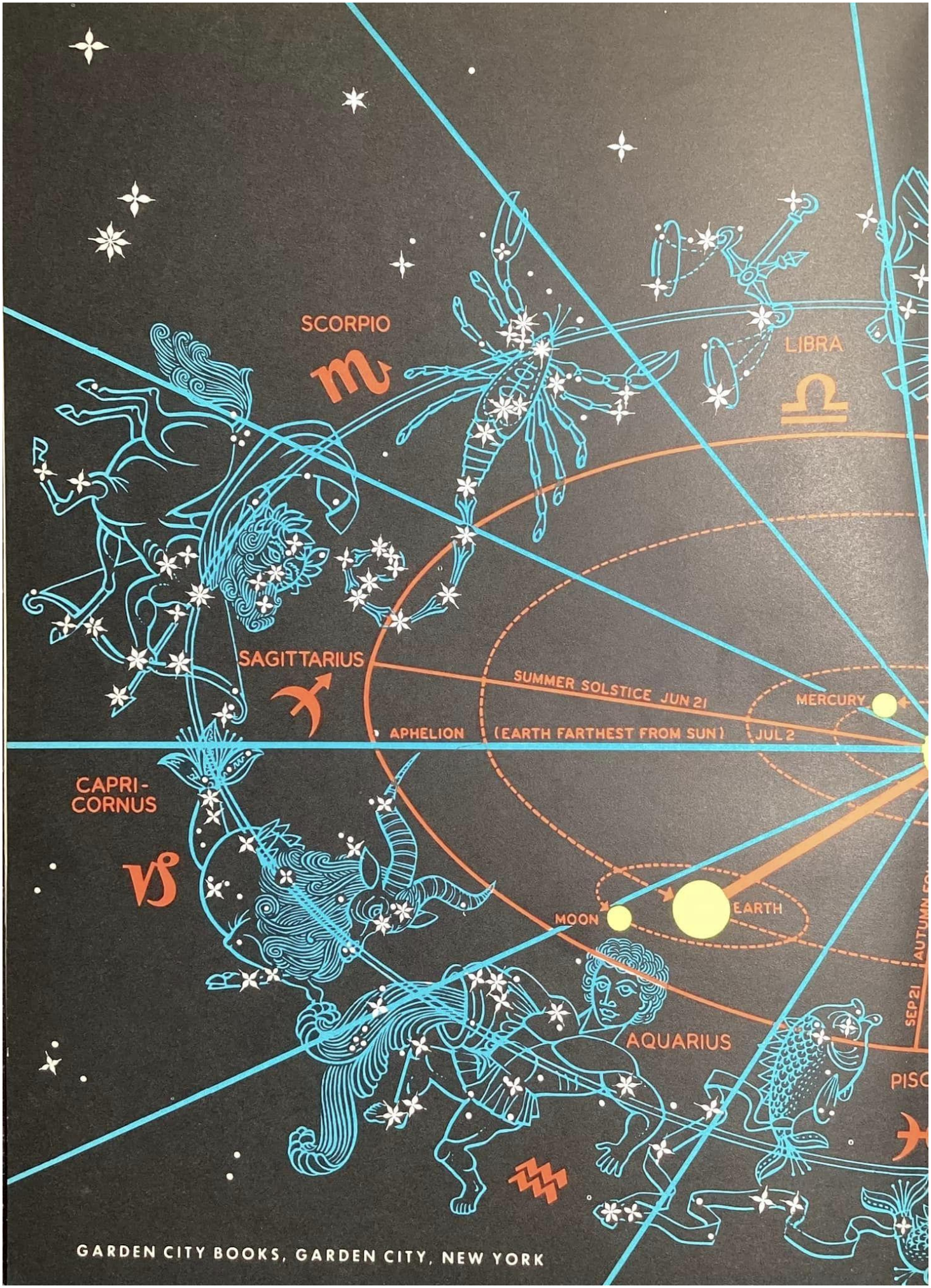
exploring the universe

by Roy A. Gallant · illustrated by Lowell Hess

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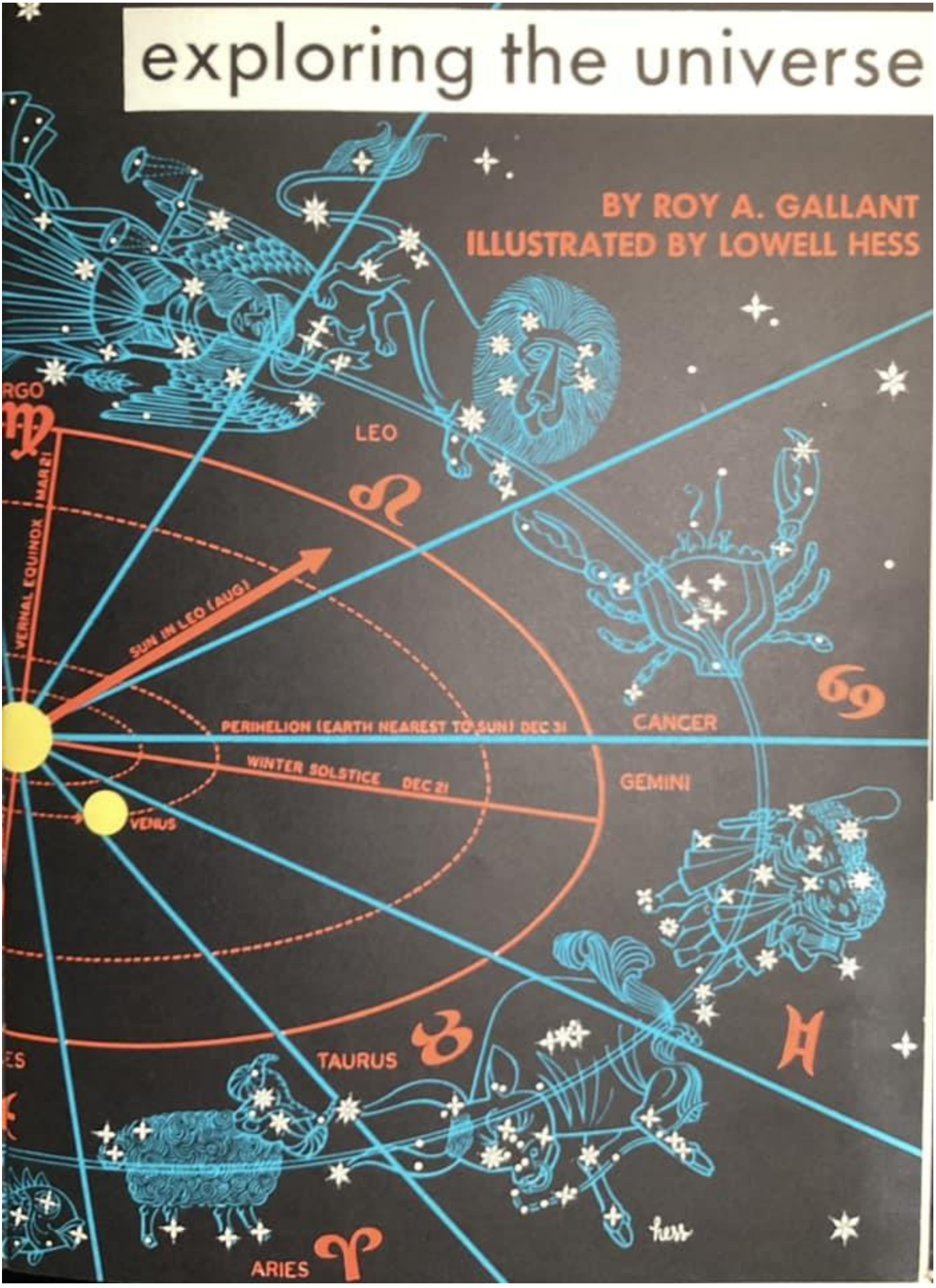
BY ROY A. GALLANT
ILLUSTRATED BY LOWELL HESS



FOR JONATHAN

THE AUTHOR'S THANKS TO LLOYD MOTZ, ASSOCIATE PROFESSOR OF ASTRONOMY,
COLUMBIA UNIVERSITY, FOR HIS HELPFUL SUGGESTIONS
REGARDING THE MANUSCRIPT OF THIS BOOK.

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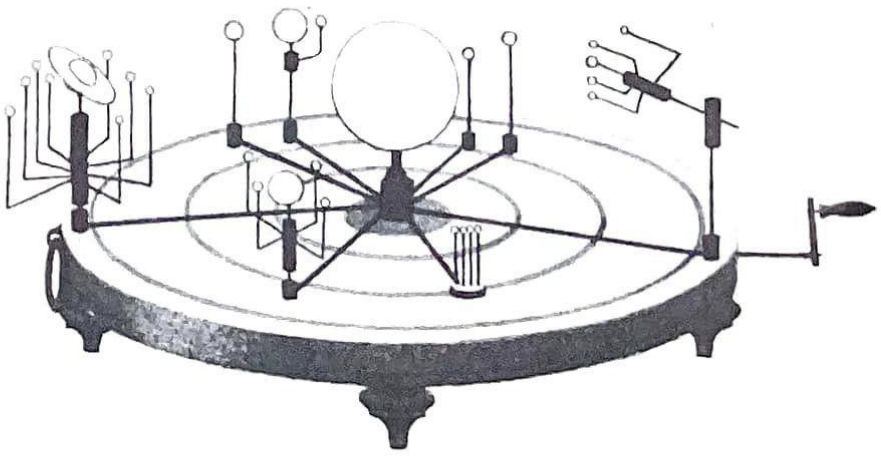


the astronomer-magicians

"Will the sun rise tomorrow?" one astronomer asked another.

"No," came the answer. "I say that the sun won't rise tomorrow. Can you prove that it will?"

"Well," said the first astronomer, "my star book says that tomorrow, December 28, the sun will rise at 7:12 A.M. Isn't that proof enough?"

"No," answered the other astronomer stubbornly. "That isn't *proof*. Your star book tells me only that some writer thinks that the sun will rise tomorrow. I want *proof*."

After an hour the first astronomer finally gave up. He had to admit that he could think of no way to prove that the sun would or would not rise the next day.

This story tells us something very important about how astronomers and other scientists think and how they have tried to solve some of the mysteries of the universe we will be talking about in this book. They begin by asking themselves a question. Then they perform an experiment to find the answer. Nearly every day in your own home you perform experiments, too, but you are usually not aware that you are acting like a scientist. For example, if it's a cloudy day, before going to work your father might ask you, "Is it raining out?" Chances are you will go to the window or stick your head outside to find out. On the other hand, you might tell him, "Well, I think it must be raining. Last night the newspaper said

it would rain today." In this case your father probably would become impatient and find out for himself by looking out the window. He wants to know if it is *actually* raining.

To depend on the newspaper for your weather report puts you in the same boat with the astronomer who looked at his star book to convince his friend that the sun would rise the next day. But the troubled astronomer was asked to prove something beyond his power. All the star books in the world couldn't help him.

Luckily, not all of the problems of the universe are beyond proof. Today our scientists have many special instruments which can tell them how far away the stars are, what they are made of, and why they behave the way they do. But in the days before cameras, telescopes, and spectroscopes were invented, men thought of the universe as a huge cosmic puzzle. And they saw so many pieces that they had little hope that the puzzle would ever be put together properly.

As far back as we can trace written records we find that men have been curious about their universe. Night after night as an endless river of stars flowed across the heavens, men have wondered about those pinpoints of light and asked themselves many questions: What are the stars? Where do they come from? How large are they? Does our own planet shine like a star? What is the Sun's place in the universe? But early men had no way of finding the correct answers to these questions. Yet they tried. Nearly 5,000 years ago in Egypt we find men were very much interested in astronomy. But their interest in the stars was not to bring understanding to their fellow men. Nor was it to encourage the growth of scientific knowledge. They were more interested in the political power that astronomy could bring them.

Why did politics and astronomy go so well together? Nearly 5,000 years ago one of the world's great civilizations was centered in Egypt along the banks of the great river Nile. Farming was the main means of livelihood for these people and the success of their crops depended on the Nile's flooding its banks every year. The annual flood was a signal for all agricultural activity to begin. But at this time in Egypt's history there was no reliable calendar to tell the farmers when to expect the flood so they could do their planting at the most advantageous time.

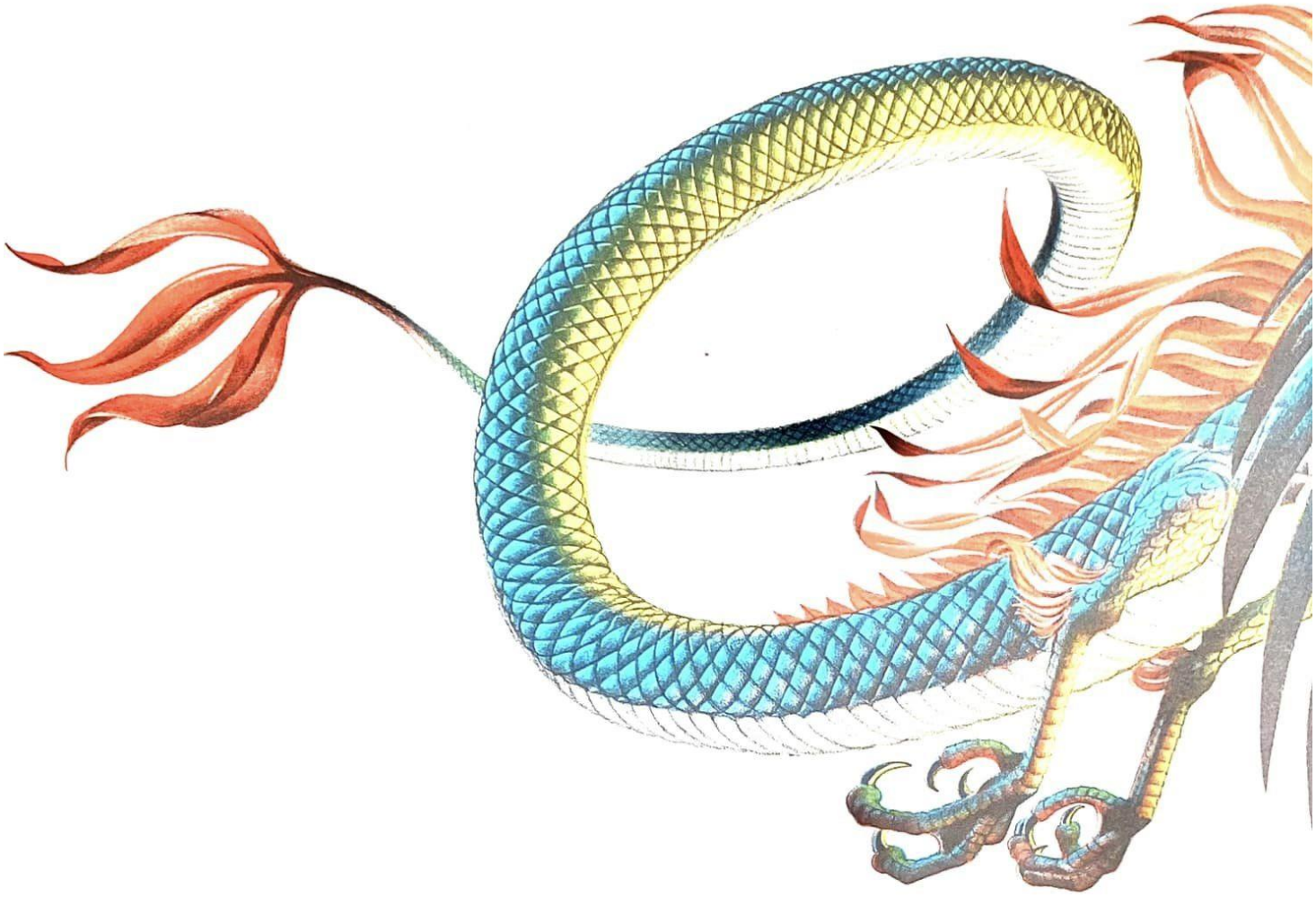
Egypt's King Menes, however, soon discovered a way to predict the

coming of the flood. After years of observing the heavens his court astronomers noticed that at the flood season the star Sirius was the last one appearing on the horizon before dawn. With this secret knowledge each year Menes' court astronomers would announce the coming of the floods and advise the farmers to begin their planting. To the ignorant peasants, being able to predict the floods meant being able to cause them. So King Menes and his astronomers enjoyed the status of "magicians" who held the power to direct the course of all events. Or at least they made the people think they held this power of magic. For centuries politicians of ancient times in Egypt and Babylonia tried to hold their people in ignorance. They knew that knowledge of the "secrets" of the heavens meant political power and prestige.

Not all the astronomer-magicians of ancient times were as lucky as those who served under Menes. Some made blunders in their predictions and had to pay dearly for their mistakes.

There is the strange case of Hsi and Ho, two Chinese court astronomers who served under the emperor Chung K'ang, the fourth emperor of the Hsia Dynasty. Our story takes us back more than 4,000 years, to a time when the Chinese believed that the Sun was forever in danger of being "eaten." Every so often, they said, dragons would sweep down out of space and attack the Sun, taking huge bites of it. At such times the Sun would "go out" for a while, but its brightness would return after K'ang's men shot arrows into the sky, shouted, beat drums and heavy gongs. All this wild activity was supposed to frighten the dragons away. The job of Hsi and Ho, the two court astronomers, was to predict when the dragons were going to attack the Sun so that K'ang's warriors could get ready for them. Today, of course, we know that the Sun's "going out" was nothing more than an eclipse.

The point of the story is that even 4,000 years ago some astronomers knew enough about eclipses to predict them accurately. Hsi and Ho were two such astronomers. Their fame, however, didn't last long because one day there was an eclipse which they didn't predict. Slowly the Sun began to lose its light. It grew darker and darker until there was barely a glimmer. In great fright K'ang called out his men to fire their arrows, beat their gongs and drums to frighten away the dragons. To everyone's relief, a few moments later the Sun reappeared, so all was well—but not



dragon taking a bite out of the sun

for Hsi and Ho. Emperor K'ang arrested them and ordered that they be killed for neglecting their duties.

Astronomers think that this story provides us with the earliest record of an eclipse. History is a bit fuzzy about exactly why Hsi and Ho were executed. A second version of the story says that the two unhappy astronomers misbehaved during the eclipse and were killed for this reason, not because they failed to predict the eclipse. Whatever the reason, we can conclude that being an astronomer-magician in those days was a dangerous business.

From what we have seen of the early astronomers so far, they made

few attempts to study the heavens objectively. In other words, the astronomer-magicians were most interested in the personal power their knowledge could bring them. They never bothered to ask themselves *why* does an eclipse take place? Or *why* do the stars behave as they do?

To find men who tried to understand why the stars behave as they do, the world had to wait 1,500 years. It wasn't until about 500 B.C.,

during the "golden age" of learning in Greece, that we find men trying to explain what the Earth and the stars are made of, and why the universe behaves as it does.

One of the earliest of these men is Anaximenes, a teacher. He taught his pupils that the Earth was flat, "like a table" hanging in the air. All the stars and the planets, he said, were made from moisture rising from the ground. As the moisture rose it became thin and changed to fire. And so the stars were born. He also told his pupils that there were no stars under the Earth-table. The stars, he said, move around the Earth "as a cap turns round our head." And "the Sun is hidden from sight, not because it goes under the Earth, but because it is hidden by mountains, and because its distance from us becomes greater."

It's hard to understand how Anaximenes' pupils could have been fooled by such nonsense. They could have gone outdoors any clear night and watched the stars rise in the east and set in the west as the Sun does. This would have shown them that the heavenly bodies do move "under" the Earth-table, and do not move "as a cap turns round our head."

If you think that Anaximenes had strange ideas, there were others with even stranger notions. Xenophanes, another Greek philosopher, said that the Earth was a large rectangle floating in space. And the stars, he said, are clouds which each night are set on fire and rise into the heavens. The Sun, he told his pupils, gives us heat and light, but the Moon does nothing and is useless.

It would be interesting to know if any of Xenophanes' pupils ever had the courage to ask him who set the clouds on fire each night. And he probably would have been quite interested to know that without the Moon we would not have such grand ocean tides.

Another Greek philosopher, Heraclitus, preached that the heavenly bodies were all made of fire, and that each one rested in a bowl. At night when we can see the stars, he said, the mouths of the bowls are turned toward us. But during the day the bowls turn upward and hide the stars from view.

Anaxagoras had one of the most imaginative theories of all to explain how the stars were formed. In the beginning the Earth was a great spinning body, he said. As it spun around it threw off huge "earth stones" which became heated and which now shine in the sky as stars. When

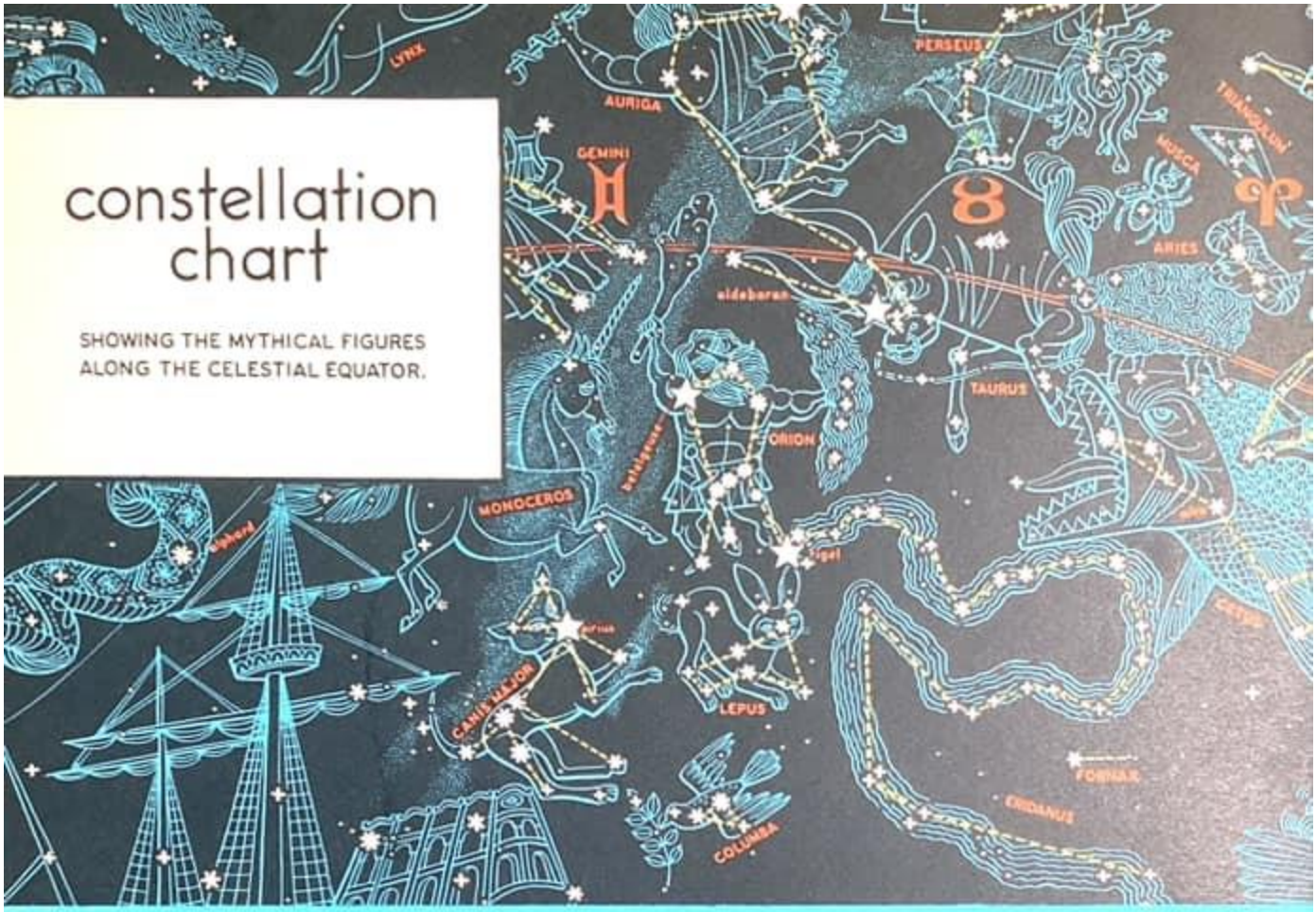
Anaxagoras announced his theory he got into trouble for saying that the Moon and the Sun were nothing more than large stones. People of the day regarded the Sun and Moon as powerful gods.

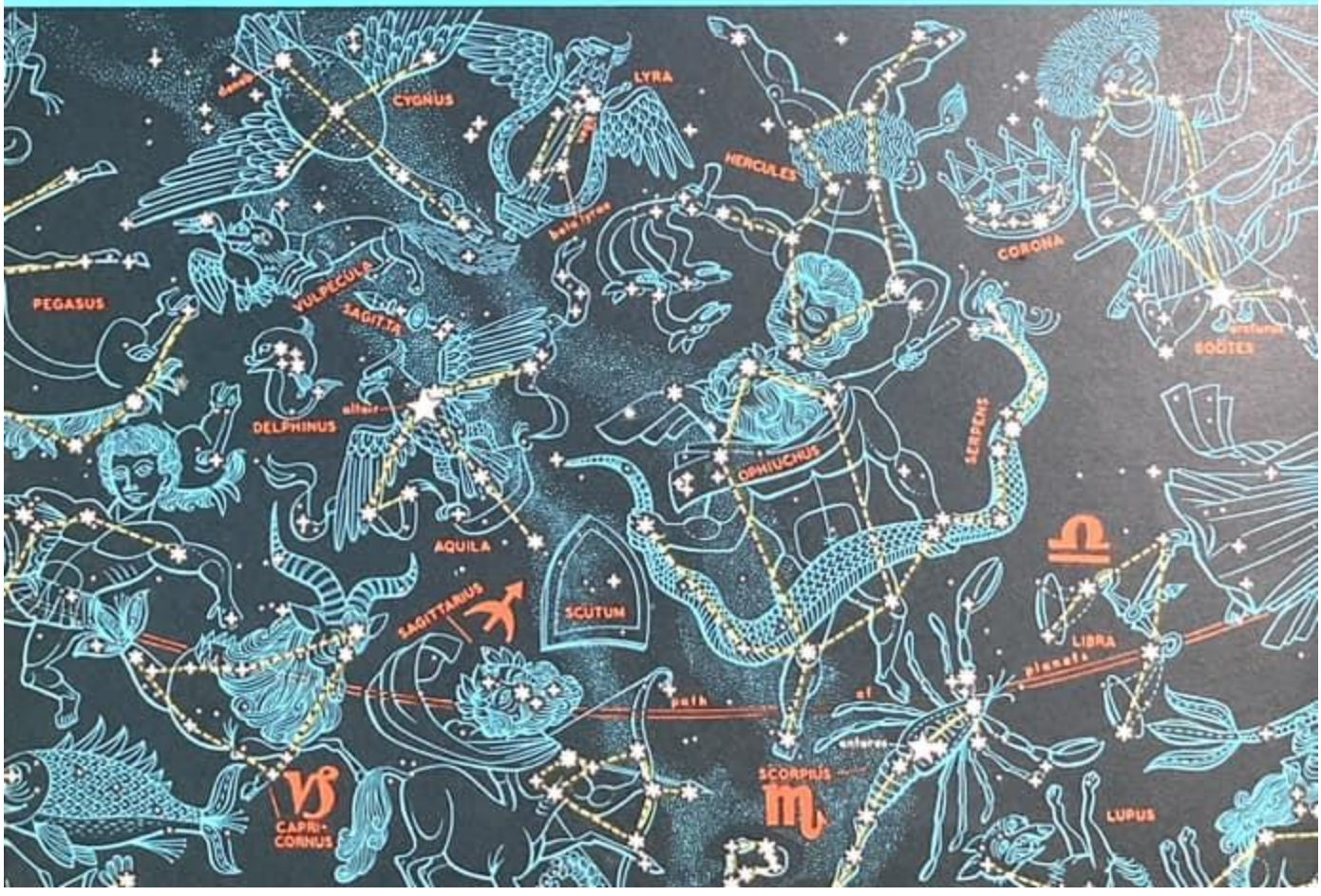
From the point of view of astronomy today, the "golden age" of learning in Greece was a slightly tarnished one, at least if we are to judge by what these famous men believed and taught their students. Most of them were convinced that the Earth was flat and that our planet formed the center of the universe. Today, of course, we know that the Earth is ball-shaped and that, like the other planets in our solar system, it circles the Sun. We also know that the Sun is nothing more than a very small star among countless billions of other stars that make up the universe. But we should not be too hard on the Greek philosophers. They did not have telescopes or spectroscopes; nor did they have a good system of mathematics, which plays a very important part in astronomy. So all in all it's not surprising that many of their beliefs were wrong.

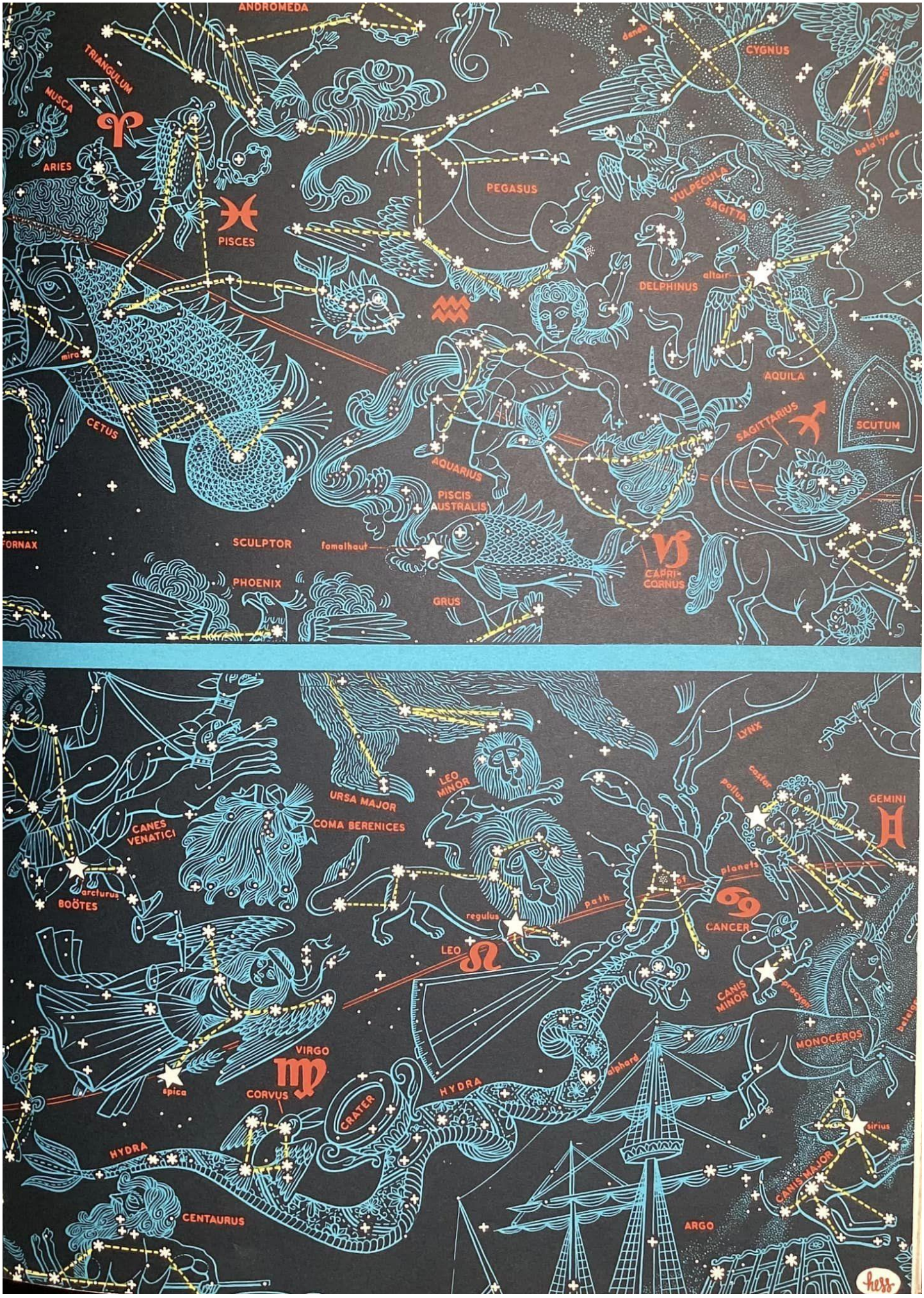
Like the astronomer-magicians of Egypt and China, the Greeks could do little more than gaze into the starry heavens and wonder at the beauty, sometimes in admiration and sometimes in fear.

constellation chart

SHOWING THE MYTHICAL FIGURES ALONG THE CELESTIAL EQUATOR.






ANDROMEDA
TRIANGULUM
MUSCA
ARIES
PISCES
PEGASUS
deneb
CYGNUS
vega
beta lyrae
VULPECULA
SAGITTA
altair
DELPHINUS
AQUILA
SCUTUM
SAGITTARIUS
CAPRI-CORNUS
AQUARIUS
PISCIS AUSTRALIS
mira
CETUS
FORNAX
SCULPTOR
fomalhaut
PHOENIX
GRUS
LYNX
castor
pollux
GEMINI
LEO MINOR
URSA MAJOR
COMA BERENICES
CANES VENATICI
arcturus
BOÖTES
planets
sol
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CANCER
regulus
path
LEO
CANIS MINOR
procyon
MONOCEROS
betelgeux
VIRGO
spica
CORVUS
CRATER
HYDRA
alphard
HYDRA
sirius
CANIS MAJOR
CENTAURUS
ARGO
hess

dragons, truth, and trials

If we blame the ancient astronomer-magicians for their lack of sound thinking about the stars and planets, we cannot say that they lacked imagination. When they drew maps of the heavens they passed on to us a most confusing picture of the stars.

As we all know, the stars are divided into groups called constellations —the Great Bear (better known as the Big Dipper); Draco, the dragon; Cassiopeia; and many, many others. As long ago as 4,000 years court astronomers in Babylonia began inventing constellations. Later the Greeks and Romans added star groups of their own. In fact, as recently as the sixteen hundreds astronomers were still inventing constellations.

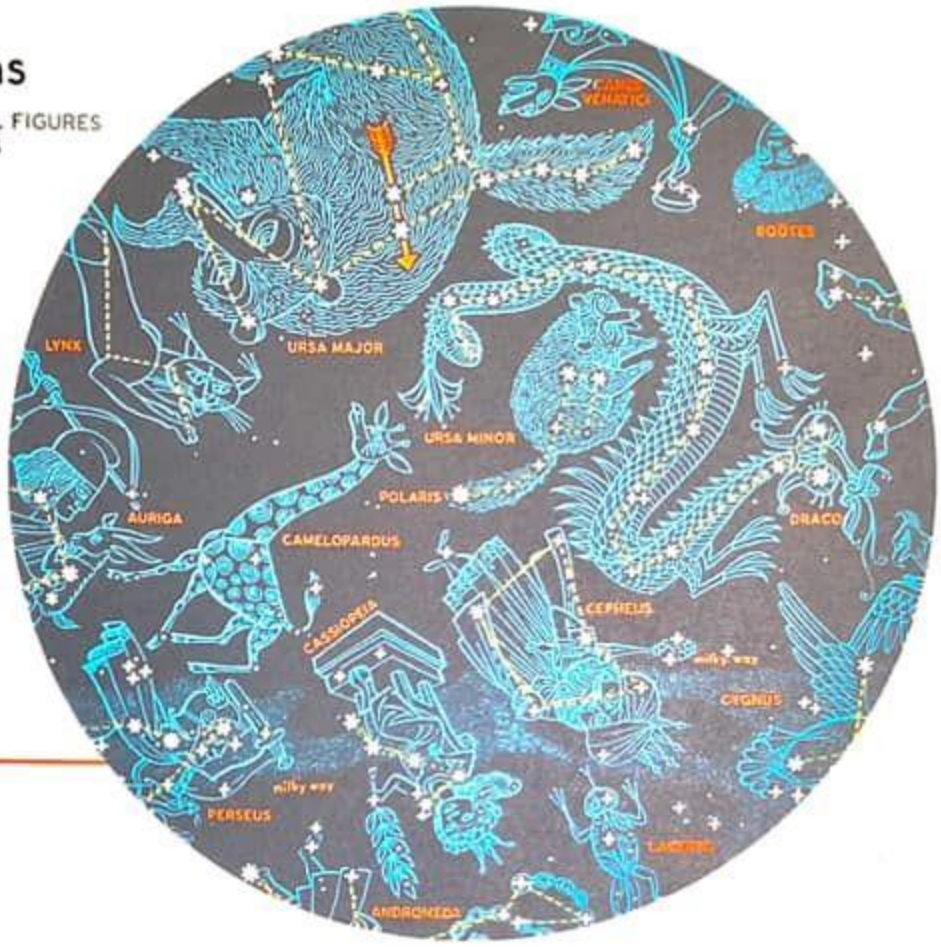
Nearly all of the star groups we use today were named several hundred years ago and come from Greek and Roman myths. They represent dragons, giants, serpents, and many other creatures. How these star groups are supposed to look like their namesakes has baffled many a stargazer. Take Orion, the hunter. This group of thirty-four stars is supposed to represent the great hunter with his club raised over a wild animal he has just killed. But any resemblance between these stars and any hunter is purely imaginary.

For centuries the constellations have served a very useful purpose.

constellations

SHOWING THE MYTHICAL FIGURES
OF THE POLAR REGIONS

north pole



south pole

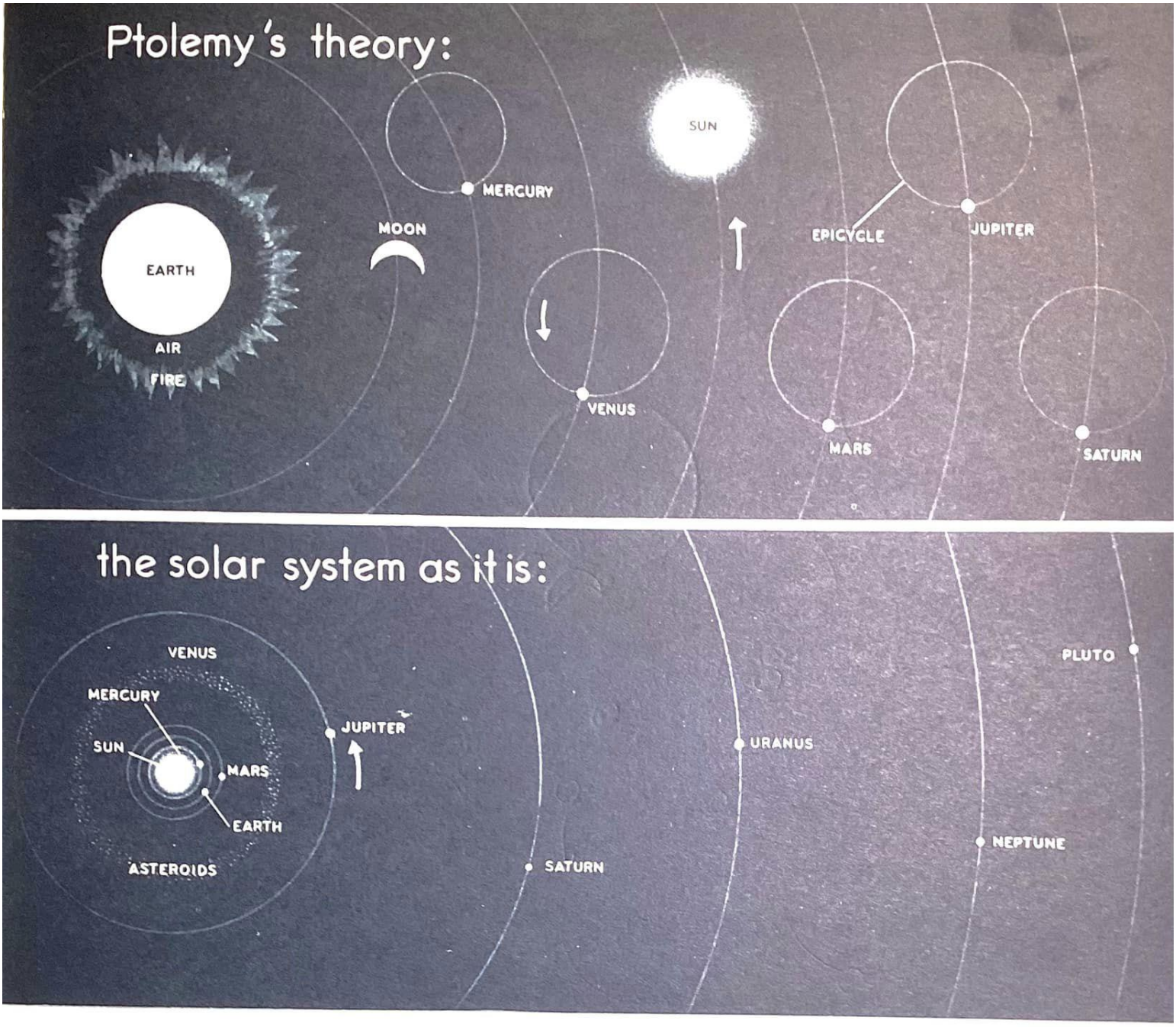
They help us find the stars we want to observe and assure astronomers that they are talking about the same star when an argument becomes heated. Instead of trying to point to a star several millions of miles away with your finger which is about three inches long, it's much easier to say, "The star I'm talking about is the bright one that forms Orion's right shoulder." In other words, the constellations are much like a road map. Their outlines are like the boundaries of states and countries, and their individual stars are like the map's dots which represent towns and villages.

Nearly 2,000 years ago a man named Claudius Ptolemaeus of Alexandria— or Ptolemy for short—gave the world its first "official" map of the heavens. Although his map was not completely accurate, it was a step in the right direction. Ptolemy simply drew the constellations which had been handed down by the early Egyptians, Babylonians, Greeks, and Romans. Possibly he added one or two of his own. In all, Ptolemy's map showed forty-eight constellations. Today astronomers recognize a total of eighty-six star groups.

While Ptolemy's map of the heavens was an important gift to astronomy, his teachings about the solar system were even more important. In the light of what we know today about the behavior of the Sun and the planets, Ptolemy's ideas seem quite strange and amusing. But in spite of their strangeness they were to set the stage for many events over the next 1,500 years.

First of all, Ptolemy knew that the Earth was not flat, as many of the ancients had believed. He was sure that our planet is a giant globe. Up to this point Ptolemy's thinking was sound. But when he began explaining the solar system he became hopelessly confused. Ptolemy's scheme placed the Earth at the center of the universe. The Moon, he said, circled the Earth. Next came Mercury, then Venus, the Sun, Mars, Jupiter, and Saturn. Each was supposed to revolve about the Earth in a perfect circle. In Ptolemy's system the Sun was little more than an exceptionally bright "planet" circling the Earth as the fourth most distant object. Ptolemy also thought that the Earth was motionless—that it did not spin like a top. If the Earth did spin, Ptolemy reasoned, birds would have their perches whipped out from under them.

Today, of course, we know that Ptolemy's thinking was wrong, and we know that the planets do not move in perfect "circles." They move



in ellipses, or ovals, like a race track. The reason Ptolemy chose perfect circles is an interesting one. In those dim days the circle was considered to be the "perfect" form, and surely, Ptolemy thought, where the heavens are concerned there must be "perfection." So the planets must move in perfect circles, he concluded.

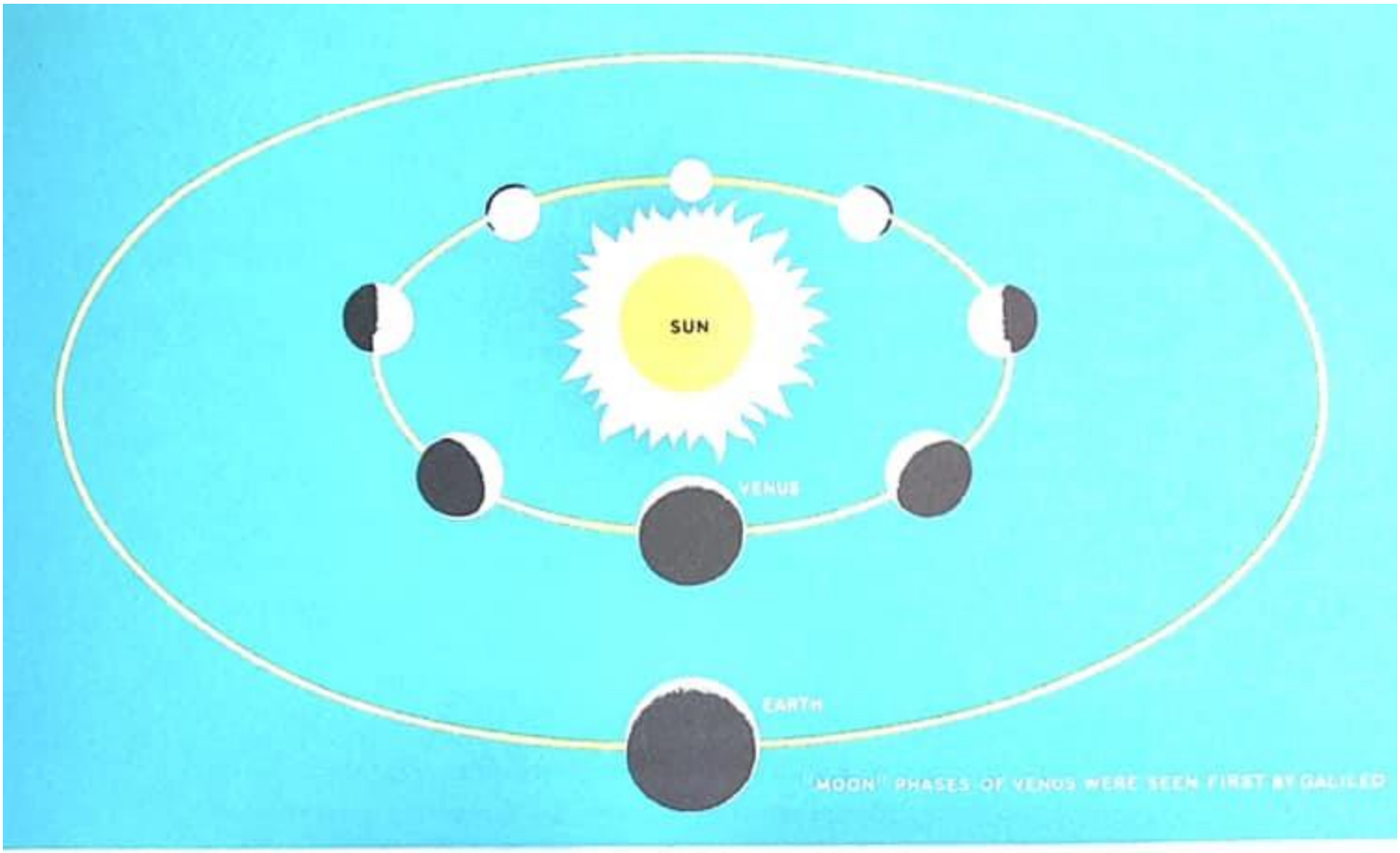
Over the years Ptolemy's strange picture of the solar system became the "official" explanation. The Church, which was extremely powerful during the Middle Ages, put its stamp of approval on Ptolemy's explanation of the solar system. To believe in a different kind of solar system, said the Church, was unforgivable.

Nearly 1,500 years passed before anyone had the knowledge and courage to show that Ptolemy's thinking was wrong. The enlightened person to do this was Nicolaus Copernicus, a Polish scientist, and oddly enough, an officer of the Church. Copernicus was a cautious man, firm in his beliefs, yet reluctant to express his beliefs if they did not agree with what the Church taught. Soon after Columbus set sail for America, Copernicus began studying astronomy at the University of Cracow, in Poland. Next he went to Italy, where he continued his studies at the University of Padua. And in 1499 he began teaching at the University of Rome. During this time Copernicus had been reading the old theories of the Greeks as set down by Ptolemy. And the more he read the more he was convinced that most of Ptolemy's thinking was wrong. In the year 1530, when Copernicus was fifty-seven years old, he completed what was then the most startling theory on astronomy ever written. Today his theory is regarded as one of the great contributions to science.

The Sun, not the Earth, said Copernicus, is the center of the solar system. The Earth is nothing more than one of many planets circling the Sun. The Earth spins on its own axis and so accounts for day and night. Our seasons are caused by the Earth's revolving about the Sun. And the stars, Copernicus said, are great fiery globes so far away that we cannot begin to imagine their great distances.

When Copernicus explained his ideas to some of his close friends, they urged him to announce his theory to the world by publishing it as a book. Copernicus said no. He knew that the Church would object to his views, and that such a book would cause great trouble. Finally, after thirteen years had passed, he agreed to publish his findings. The title of his book was *On the Revolutions of the Heavenly Spheres.* To protect Copernicus from an attack by the Church, one of his friends wrote the following words at the beginning of the book: "This is written to present NOT a scientific fact, but a playful fancy." As it turned out, there was little need to protect Copernicus. He died a few days after his great work was published.

One of Copernicus' admirers was an Italian scientist named Galileo Galilei, born in 1564. Galileo was convinced that Copernicus' idea about



the solar system was the right one, and that the Church was doing a great wrong by hiding the truth. But Galileo had no way to *prove* that what Copernicus said was true. He was in much the same position as the philosopher who tried to prove that the Sun would rise the next day.

In 1608, however, Hans Lippershey, a Dutch eyeglass maker quite by accident invented the telescope. Galileo heard about the discovery and within a year was hard at work studying the planets and stars through his "optik tube." Imagine his thrill on first seeing the giant craters and jagged mountains on the Moon—and at peering into the depths of the Milky Way and realizing that this great shining cloud was actually made up of billions of "suns." Night after night Galileo marveled at the wonders his telescope revealed to him.

As he watched the planets move across the sky he noticed something strange about Venus. It behaved much like the Moon. At times it was "full," other times it was a crescent, and still other times it disappeared. At once Galileo realized what this meant. Here was *proof* that Copernicus was right—Venus was revolving about the Sun, not about the Earth.

Another discovery Galileo made was that the great planet Jupiter has four moons circling it. When he first saw these moons of Jupiter,

Galileo realized that he was gazing on a miniature model of the solar system. It was time, Galileo thought, that the world must be shown the proof of Copernicus' beliefs—in spite of what the Church might do. He wrote down his observations, which he published in a book. When the Pope saw the book, he instructed Church officials to deny that Jupiter had moons and that Venus went through phases. Galileo, the Church said, has bewitched his telescope; do not believe the nonsense this man preaches. Galileo refused to be silenced. He continued to preach what he knew was the truth about the planets. Finally the Church summoned him to trial and publicly forced him to deny that the Earth circles the Sun. According to legend, when Galileo left the court he was heard to say: "In spite of what I have been forced to say here, the Earth *does* circle the Sun."

Today Galileo stands as a bright beacon shining strongly through the darkness of superstition and hypocrisy. His concern for scientific truth and his careful examination of the heavens place him among the greatest scientists of all times. In his thinking he was worlds apart from the superstitious astronomer-magicians of China who beat gongs and shot arrows at the Sun when "dragons" threatened to devour it and bring perpetual darkness to mankind.

exploring the universe

When and how the universe was born is one of the greatest mysteries of science. It is a question that has baffled men since they first turned their eyes toward the heavens and saw endless streams of stars flowing across the night sky. On a clear night nearly 6,000 stars can be seen by the naked eye. Through a small telescope you can see more than 2 million stars. And through the giant 200-inch telescope at Palomar scientists can see countless billions of stars. As we peer farther and farther into the depths of space we are able to see an ever increasing number of individual stars and star clusters. There seems to be no limit to the size of the universe.

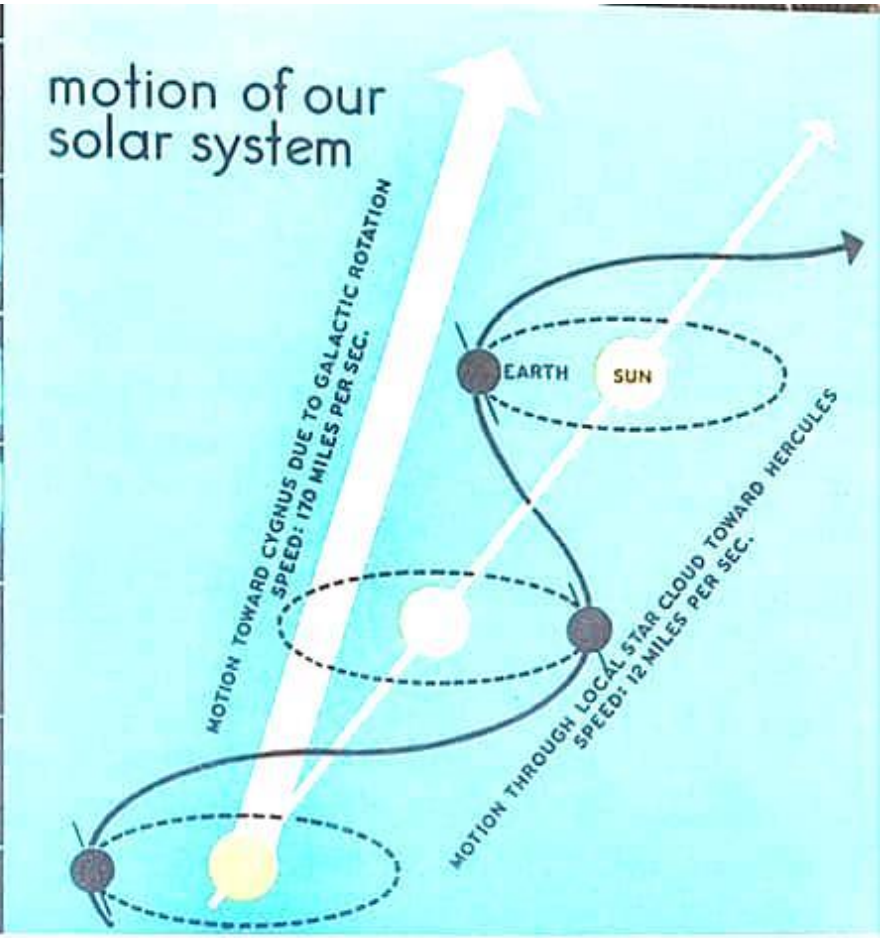
For more than three hundred years astronomers have been studying the universe through telescopes. They have measured the temperature of stars so far away that we cannot even imagine their great distances. They have spent years counting the number of stars which form mammoth clusters known as galaxies. And they have photographed vast clouds of gas and dust, called nebulae, swimming endlessly in the black ocean of outer space. Yet all of their work, which could fill the shelves of a library, still leaves one of the most tantalizing questions unanswered.

How was the universe born?

If you ever asked an astronomer this question, he would most likely say, "We aren't sure. We can do little more than guess." Then he would tell you about the many theories which attempt to explain the nature of the universe. And he would tell you what our scientists know to be true about the stars, galaxies, and nebulae.

One theory tells us that in the beginning the limitless sea of space was filled with an extremely thin gas, many many times thinner than the air we breathe. Over billions of years the gas collected into countless numbers of great patches measuring several millions of miles across. Slowly the patches closed in on themselves. As they became smaller they grew dense and began to glow. Eventually they became hot fiery globes which men named "stars." Our Sun is one such star and belongs to a great cluster, or galaxy, which we call the Milky Way.

A second theory—and a disturbing one indeed—has been advanced by a British astronomer named Fred Hoyle. Hoyle tells us that possibly there was no beginning to the universe, nor will there ever be an end. His "continuous creation" theory says that quite mysteriously "matter simply appears." In other words, the gas from which stars are formed appears as if by magic. If his theory is true it means that new stars and



galaxies are constantly being formed to replace the old ones that die out.

Before we become too deeply involved in questions that can't be answered, let's turn to some we can answer.

how big is the universe?

"Let's see who can name the highest number," one philosopher said to his friend. After twenty minutes of thinking, the second philosopher said, "Three." An hour later the first philosopher said, "I give up, you win."

Why did the first philosopher give up? He knew that if he said "Four," his friend would have said five, then seven, nine, and so on. In short, he realized that there is no such thing as "the highest number."

Trying to determine the size of the universe is much the same as trying to find the largest number. As soon as an astronomer thinks he has counted all the galaxies, someone builds a more powerful telescope which can see farther into space, where there are still more galaxies to be counted. But there *must* be an end, you're probably thinking. Well, if there is an end, or a limit to the size of the universe, no one has found it yet.

On any clear night when you look into the sky you can see a luminous, hazy band of stars parading across the heavens. But the naked eye cannot distinguish these stars as individual points of light. Today we call this band the Milky Way. More than a hundred years ago when Sir William Herschel first studied the Milky Way, he decided that it must be in the shape of a large disc. And our Sun, he thought, was somewhere near the center. Since Herschel's time we have learned many things about our galaxy. For example, we now know that the Sun is not near the center. It is located near the outer edge and is one of the faintest stars among the 100 billion others which make up the Milky Way. And the reason our galaxy appears as a long belt stretching across the sky is because of the way we see it. From our position near the rim we are looking edgewise through the galaxy, so we are unable to see it as a disc. Astronomers have named only a few of the stars in the Milky Way, the brightest ones and those closest to us. If we attempted to name all 100 billion, it would take us more than 4,000 years if we named one every second.

When astronomers talk about the Milky Way's stars and the great distances between them, they use a special system of numbers. If they tried to express these distances in miles they would end up with figures like this: 17,000,000,000,000,000 miles. To simplify matters they say, for example, that the star Sirius is roughly nine *light-years* away from the Sun. One light-year is the distance light travels in a year. Remembering that light travels 186,000 miles a *second,* this would mean that Sirius is 52 trillion miles away! Yet Sirius is considered to be a fairly close neighbor of ours. To express a light-year still another way, if the star Sirius should explode tonight, we would not see the blinding flash until nine years from tonight. It would take the flash that long to make the journey to our planet. Because the stars are so far away, when astronomers see changes in distant worlds they are looking back into time, seeing things that happened many thousands of years ago.

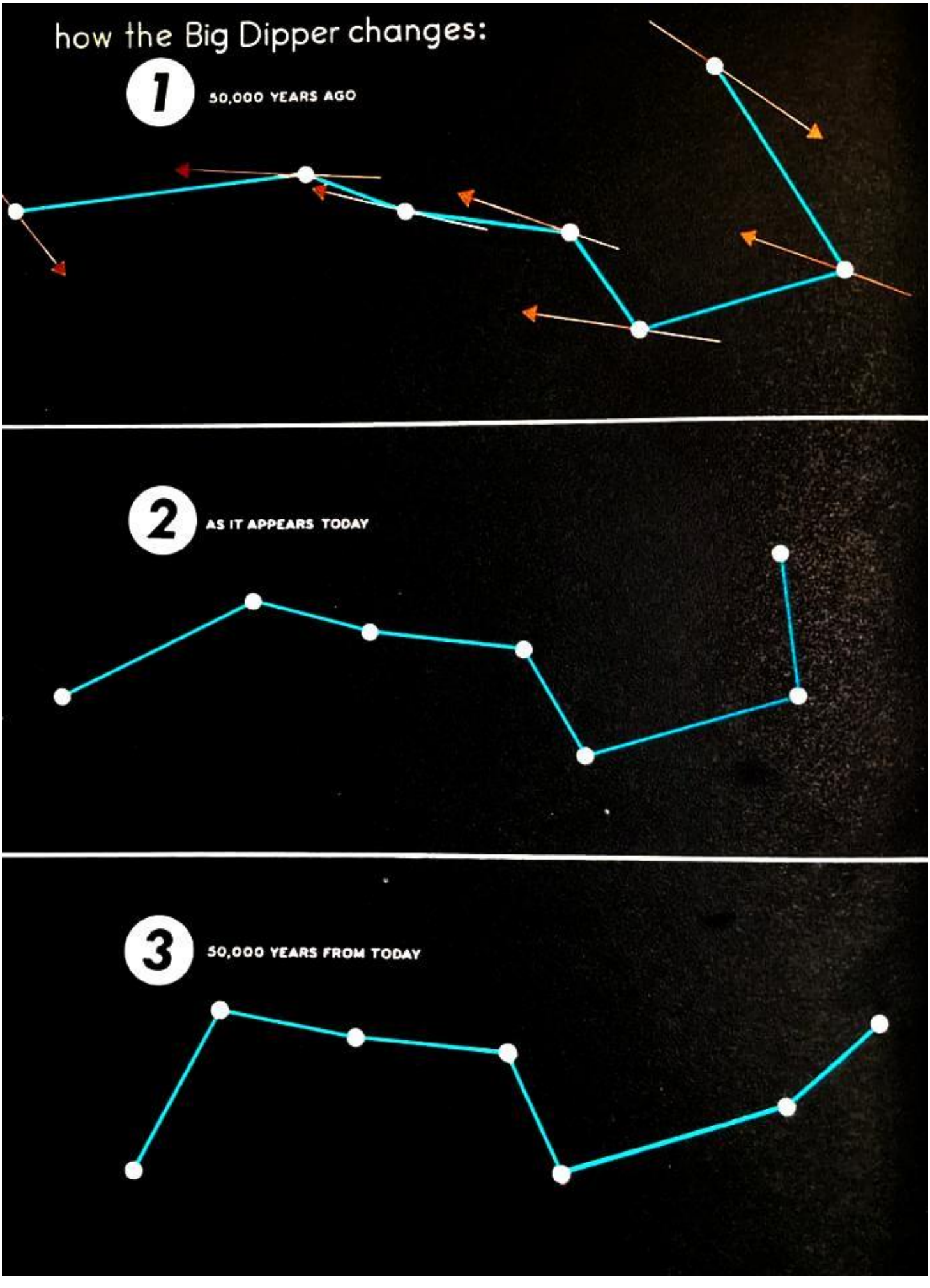
Applying our light-year yardstick to the Milky Way, we come up with some interesting figures. For example, the distance from one end of our galaxy to the other is 100,000 light-years. And the thickness at the center of our giant disc of stars is 10,000 light-years. Located near the rim of the Milky Way, our Sun with its system of planets is about 30,000 light-years from the center of the galaxy.

Like other galaxies, the Milky Way has its thickest cluster of stars at the center of the disc. Toward the rim the stars begin to thin out, the distances between them becoming greater. If this is true, you might ask, why is it we are unable to see the bright center of the Milky Way? For years astronomers asked themselves the same question. One day they discovered that between us and the bright center are many dark clouds of interstellar dust and gas hiding what is probably the most exciting view in the entire galaxy.

In the early days of astronomy stargazers divided the heavenly bodies into two groups—the "fixed" stars and the "wanderers." The planets were called the wanderers because it was an easy matter to watch them change their positions from night to night. But the stars presented a different picture. To detect their position change—different from their rising and setting motion—requires special instruments and many years of observation. They are so far away from us that they appear to stand still. For this reason the ancients called them "fixed" stars. Today we know that the stars are speeding through the heavens at about 40,000 miles an hour. If the old astronomers had been told this they probably would have denied it. They might have said, "If the stars move, then why don't the shapes of the constellations change?" Actually the constellations' shapes are changing, but so slowly that we don't notice the change. One hundred thousand years from now the Big Dipper will have a completely different shape. People of the future will probably tax their brains trying to figure out why we ever chose the name "Big Dipper."

While the individual stars have motions of their own, they also move as a group. The Milky Way is forever spinning like a giant Fourth of July pin wheel, but its spin is much slower than that of a pin wheel. Astronomers say that in the last 2 billion years or so, our galaxy has made fewer than ten complete turns. But in spite of its "slowness" the stars on the rim of the galaxy are thought to be whipped around at hundreds of miles a second. Astronomers think that this pin-wheel motion is what has caused our galaxy to flatten out in the shape of a disc.

What does all this mean? The next time someone accuses you of moving too slowly you can tell him that you're really traveling several thousand miles an hour. Add to your own motion: (1) the speed of the Earth as it spins like a top; (2) plus the Earth's speed as it circles the Sun; (3)


how the Big Dipper changes:
1
50,000 YEARS AGO
2
AS IT APPEARS TODAY
3
50,000 YEARS FROM TODAY

plus the Sun's speed as it wanders through space; (4) plus the Sun's speed as it is whipped around by our galaxy; (5) plus the speed of the galaxy as it moves through space.

For many years astronomers thought of the vast collection of stars seen in the Milky Way as being the entire universe. Beyond the limits of our star system there was nothing, only the black empty sea of outer space. If this were so, our problems of understanding the universe would be much simpler than they are. For many years Galileo and his followers peered through their telescopes in an attempt to understand the millions of pinpoints of light dancing before their eyes. Occasionally their view became blurred by huge clouds hovering in the dark regions of space. Usually they ignored these mysterious clouds and turned their telescopes toward a clear patch of stars and continued their gazing.

One such astronomer was a Frenchman named Messier. His main interest in astronomy was watching comets. While some people like to collect sea shells and military buttons, Messier liked to collect comets. For years he scanned the heavens in search of comets, and whenever he saw one he was delighted. But too often he would find his telescope pointed at misty patches of light in the sky. He had little interest in them but, like a good astronomer, he made a record of each one he saw, listing all of them as "objects to avoid." In 1771 he published a booklet containing a total of forty-five of the light patches which we now call nebulae.

In 1773, when Sir William Herschel began his work in England, he suspected that Messier's misty clouds might actually be giant clusters of stars. For years he studied these clouds. Finally he drew two conclusions about them. One kind of nebulae, he felt, most certainly was a series of giant star clusters. But the other kind, he said, was most likely made up of huge clouds of interstellar gas and dust. Both, he thought, were contained within the Milky Way. But as the years passed and Herschel studied the heavens more carefully, he began to wonder: Is there a possibility that these star clusters are not part of the Milky Way? Could they be hovering trillions of trillions of miles out in space? And if they are, *does this mean that there is more than one "universe?"*

It wasn't until 1923 that these questions were answered. The man to provide the answers was an American astronomer named Edwin Hubble. Working with the 100-inch telescope at the Mount Wilson Observatory,

Hubble showed that the Great Nebula in Andromeda and others like it were many thousands of light-years outside our galaxy. Some of the clusters were so far away that Hubble could distinguish individual stars only near the outer edges of the star colonies. The bulky parts of the nebulae

appeared only as gas clouds, but he felt sure that they were made up of billions of individual stars. Hubble began wondering how many star clusters could be seen through a powerful telescope—and how many lay beyond the limits of our field of vision.

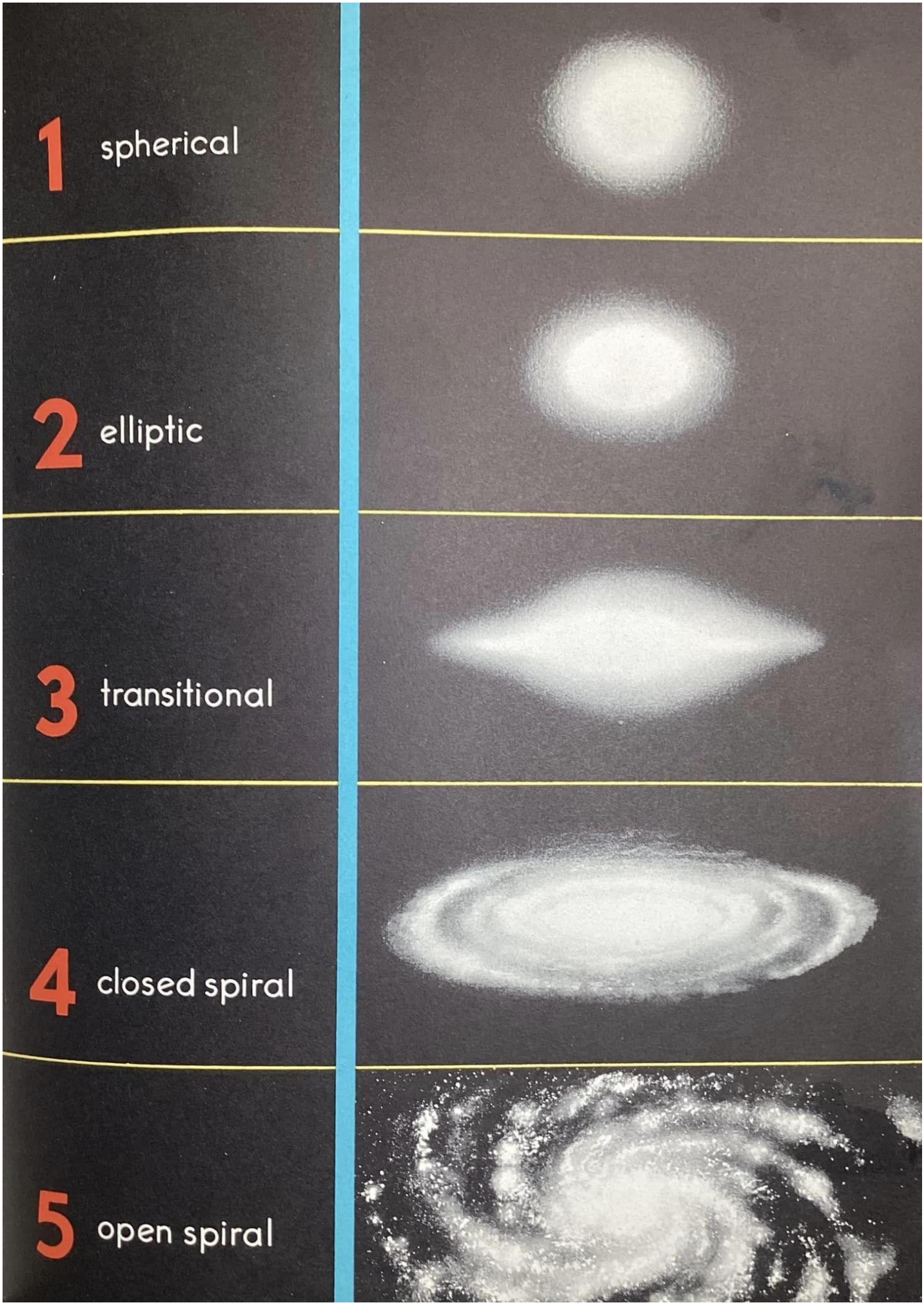
The number of these "island universes" in the heavens is staggering to the imagination. A good telescope will bring into view more galaxies than the naked eye can see stars. If you should examine only the cup section of the Big Dipper you would see a group of more than 300 galaxies. And this area makes up only 1/2000 of the entire heavens. In all, astronomers think that about a billion galaxies can be seen through our largest telescopes! How many more lie beyond is anyone's guess.

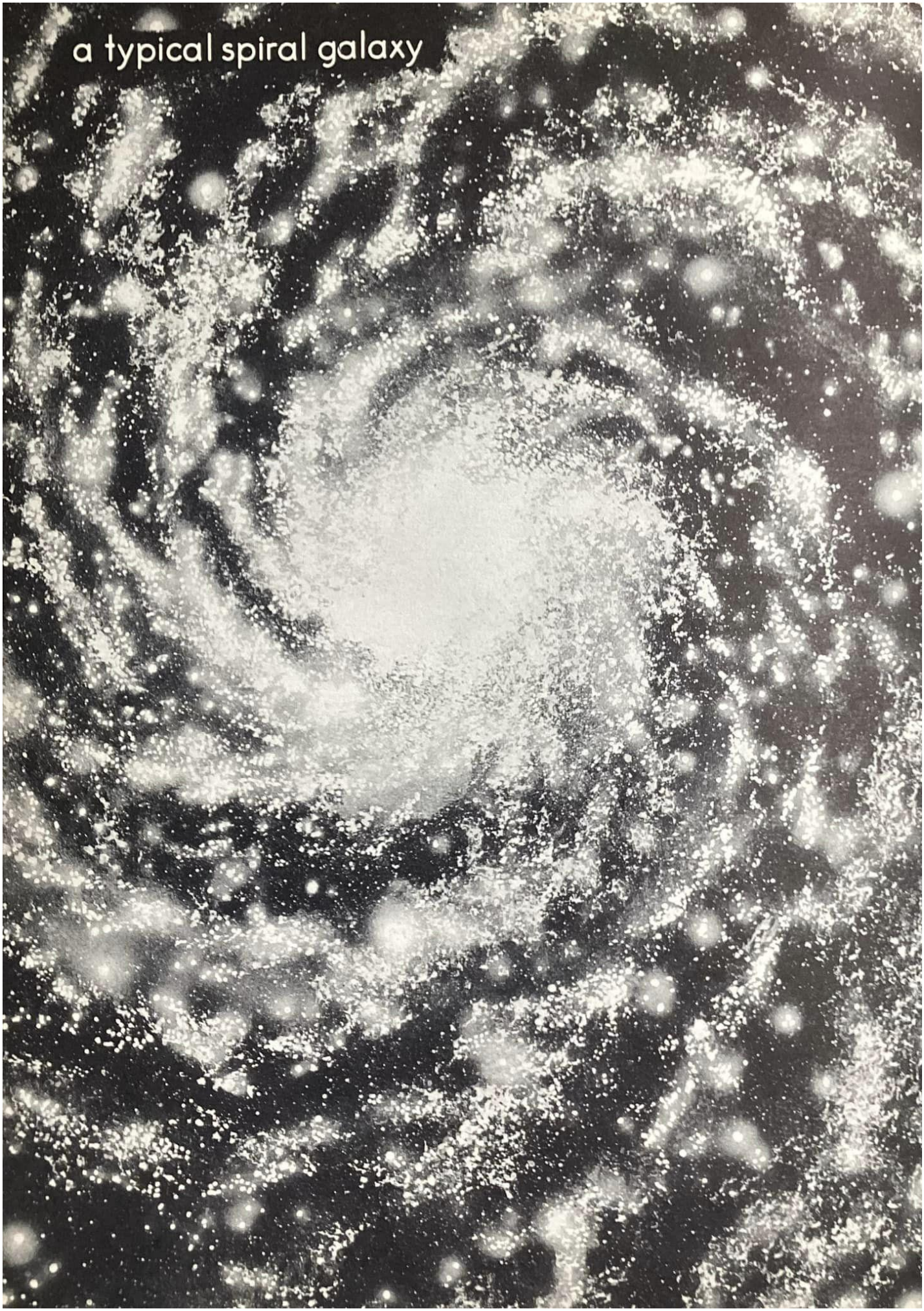
Galaxies seem to group themselves into clusters which number from a few to several hundred of star groups. They are held together by gravitation, as our planets are held close to the Sun. When we begin to talk about the great distances separating the galaxies the numbers become so large that they are meaningless to most people. For example, the Great Nebula in Andromeda is our closest galaxy neighbor. Yet it is 1.5 million light-years away.

By studying and photographing many of the galaxies, astronomers have discovered several different types. One scientist, George Gamow, thinks that the galaxies come in five different models. First are the *spherical galaxies,* which are shaped like globes with fuzzy edges. Next are the *elliptic galaxies,* which are shaped something like eggs. The *transitional galaxies* look like large cosmic footballs. The fourth kind is the *closed spiral galaxy.* A slow-moving pin wheel will give you an idea of what this kind looks like. And the fifth kind is the *open spiral galaxy.* This one looks like a swiftly spinning pin wheel shooting long arms of fire.

By arranging the galaxies into such groupings, Mr. Gamow and other scientists think that it's possible to tell a galaxy's age. For example, the globe-shaped galaxies are supposed to be the youngest ones, and the spiral galaxies the oldest. As the gaseous matter within the galaxy begins to contract, the galaxy itself begins to spin. The greater the contraction, the faster the spin. So the old-age galaxies are thought to be those with the long pin-wheel arms. They are spinning so fast that they shoot great streams of stars out into the cold depths of space.

The study of galaxies is so new that astronomers have not yet come to an agreement about what the shape of a galaxy has to do with its age. Most astronomers suspect that there is no connection. They think that all galaxies are about the same age. Their different shapes come from the spinning speeds the galaxies were given at their birth and from the amount


1 spherical
2 elliptic
3 transitional
4 closed spiral
5 open spiral


a typical spiral galaxy

of dust and gas they have. Those having a lot of dust have spiral arms. The others do not.

If you should spend several nights at a telescope studying the Milky Way and its neighbor galaxies, you would probably become annoyed by several mysterious clouds that would spoil your view. These are the true nebulae—vast cosmic clouds of fine dust and gas. One of the most spectacular nebulae in the heavens is one called the Horse-head, located in the constellation Orion.

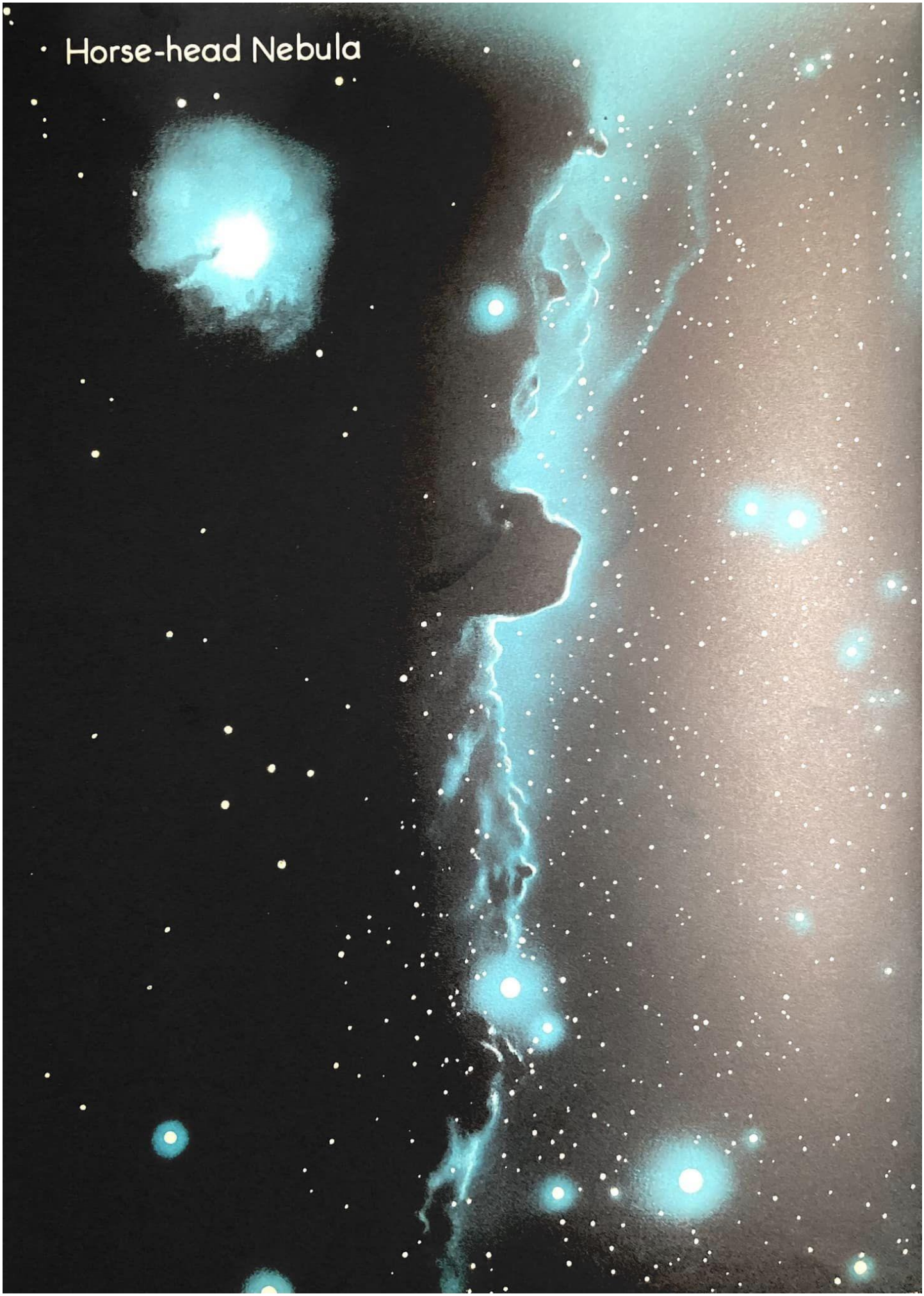
Astronomers think that these mammoth clouds are the stuff out of which the universe is created. Over periods of millions of years these great clouds close in on themselves. As they contract they form individual globes of matter which become fiery-hot and begin spinning. As the heat becomes greater, the hydrogen in the globes changes to helium, which is similar to what happens in an H-bomb, and a star is created. Our own Sun is one such "H-bomb," or star. Astronomers think that this is the way galaxies are created.

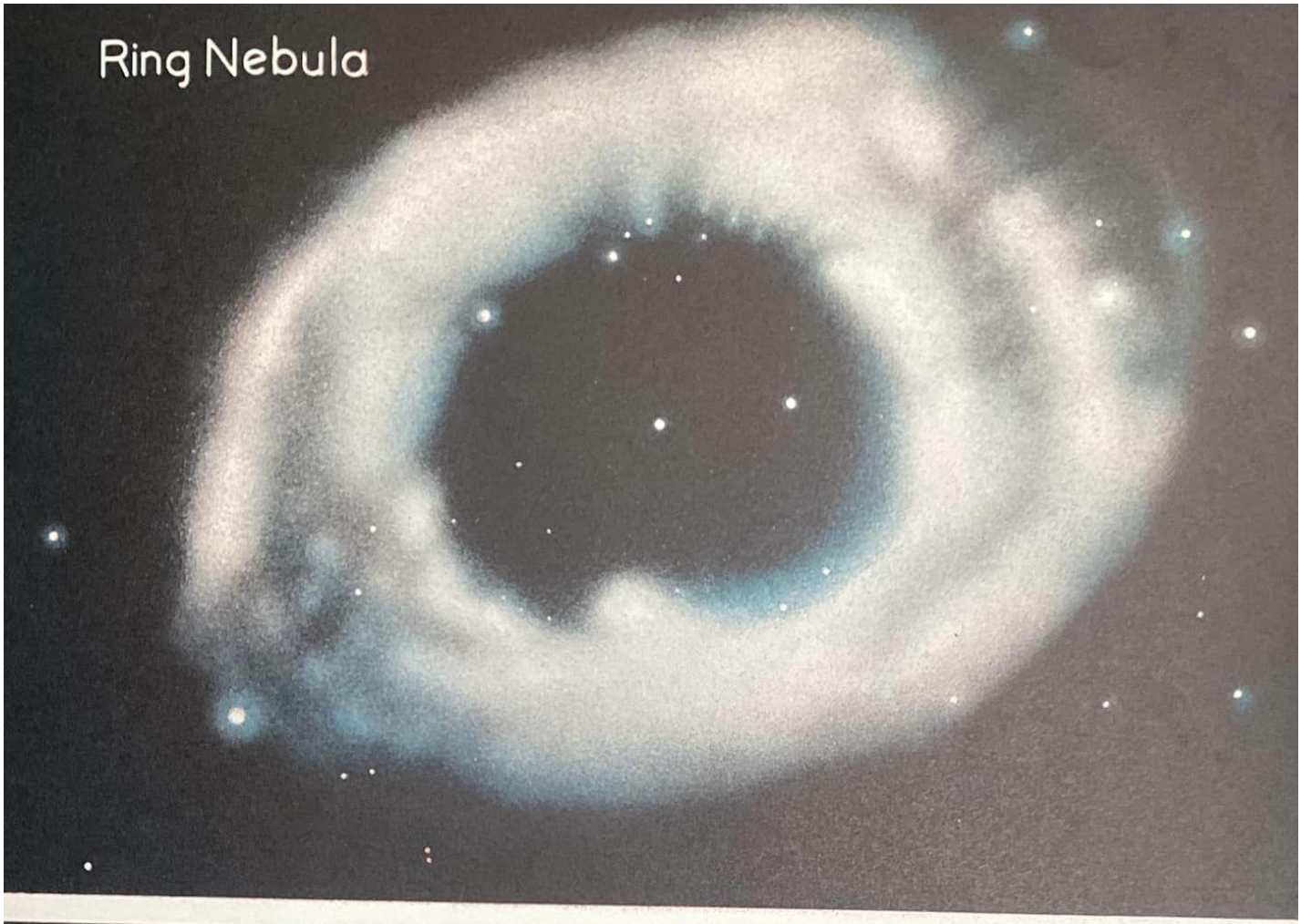
Not all of the dust clouds in galaxies become stars, however. Some of the clouds simply drift through space, never closing in on themselves. The Horse-head Nebula is one such cloud. Another is the famous Ring Nebula, which in fact may once have been blown out by the star it surrounds. It looks like a giant smoke ring floating in space. Actually it is a huge shell of dust and gas. Seen from a distance, it appears denser around its edge and so takes on the shape of a ring.

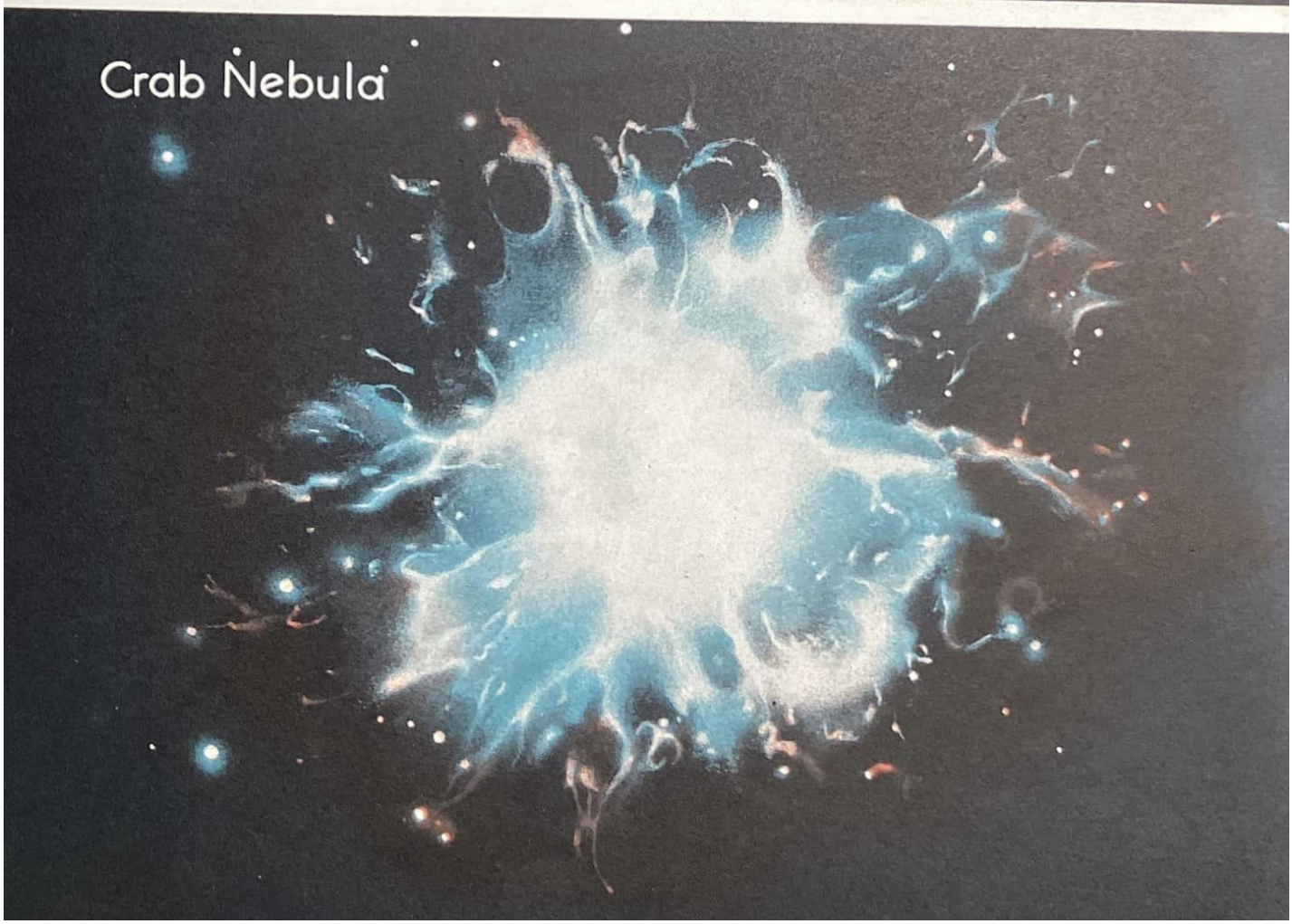
One of the strangest nebulae in the skies is one called the Crab Nebula. According to records left by Chinese astronomers, in the year 1054 a star was seen to explode. The result: a huge gas cloud which has been mushrooming out ever since. For more than 5,000 years this cloud has been spreading out at the rate of 684 miles a second. Today it stretches more than 17,700 billion miles across the heavens. Yet through a telescope it looks like a patch about the size of a penny.

red and blue giants

To the naked eye the stars appear to be little more than flickering pinpoints of white light hanging in the black depths of endless space. Yet a close look, even with the naked eye, reveals them as jewels shining with


Horse-head Nebula


Ring Nebula


Crab Nebula

every imaginable color—red, pink, yellow, violet, blue. The different colors of stars interest astronomers because the colors help determine the star's age and temperature.

Astronomers divide all the stars into two large groups. In the first group are the stars found in the rings and arms of spiral galaxies, and in certain other galaxies. The brightest and largest stars in this group are called the blue-white giants, whose surfaces burn at temperatures up to 100,000 degrees F. Spread out over a large area, these stars give the arms of spiral galaxies their typical light blue color. The blue-white giants are thought to be the youngest of all the giant stars.

In the second group are the stars found in the crowded centers of spiral galaxies, in elliptical galaxies, and in globular clusters. The brightest and largest in this group are the red giants. They are in the later stage of life and are relatively cool. Their surfaces burn at temperatures up to 6,000 degrees F. A thick grouping of these stars glows with a light red tint.

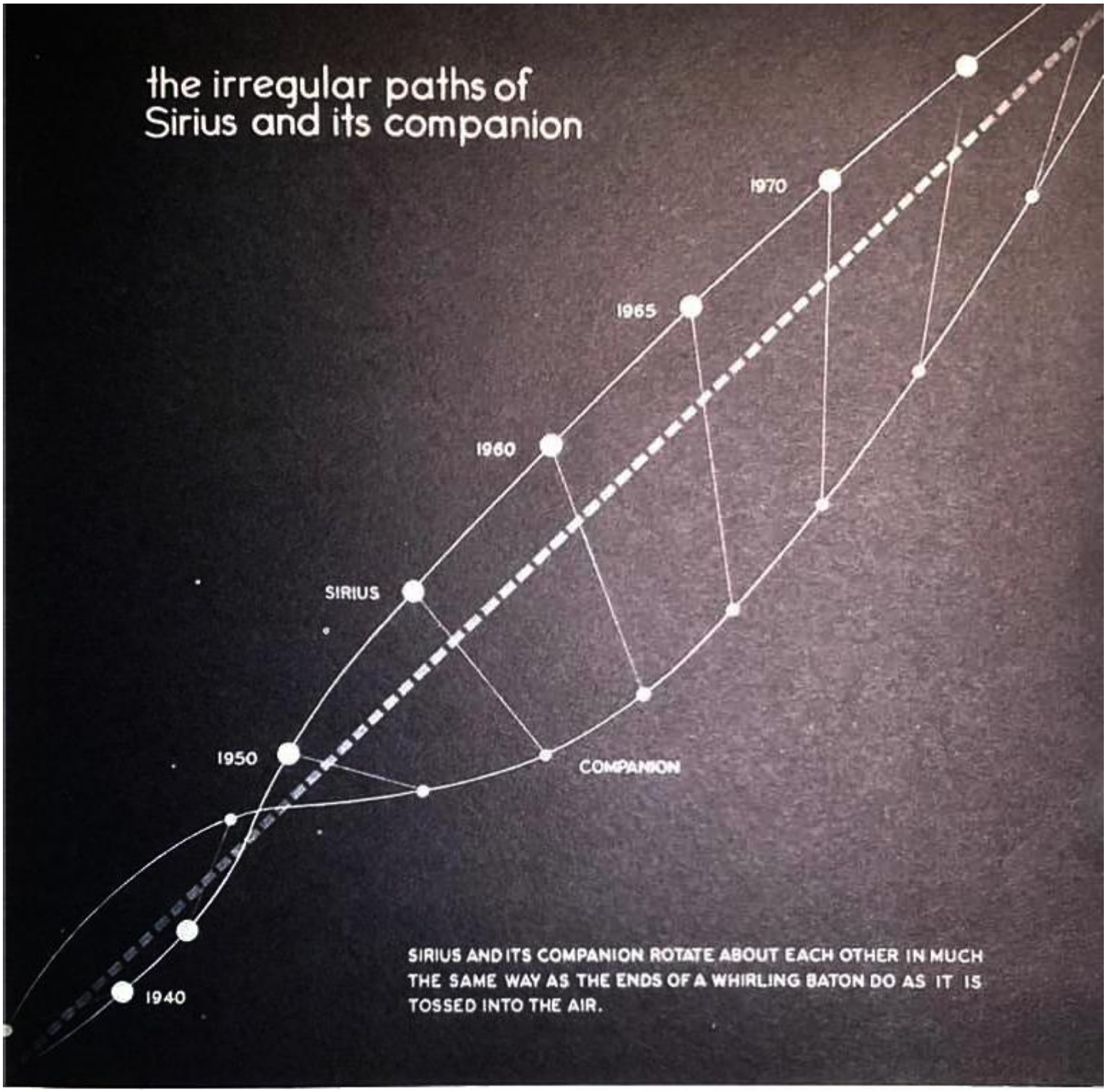
If you were to chart the life of a star you would come up with a picture something like this: Early in the star's life it burns evenly without change. When it uses 15 per cent of its fuel it begins to be wasteful. In a short time it burns the remaining 85 per cent. Soon it swells up, and as it expands, it cools, growing 50 to 100 times its normal size. When it reaches this stage the star earns the name "red giant," or supergiant. Astronomers are not sure what happens next. They think that in its dying stages the star may simply collapse suddenly and end its life as a small intensely bright star.

How long does the average star live? For about 50 billion years. Taking our own Sun as an average star, it is in its youth—a mere 3 or 4 billion years old.

In many ways the death of a star can be much more exciting than its rather dull and monotonous life. Stars can die in either of two ways. They may simply burn themselves out slowly, in which case they become white dwarfs. Or they may explode as a nova.

white dwarfs

In 1862 an astronomer watching the blue giant Sirius noticed something strange about its path across the sky. When he studied the star more

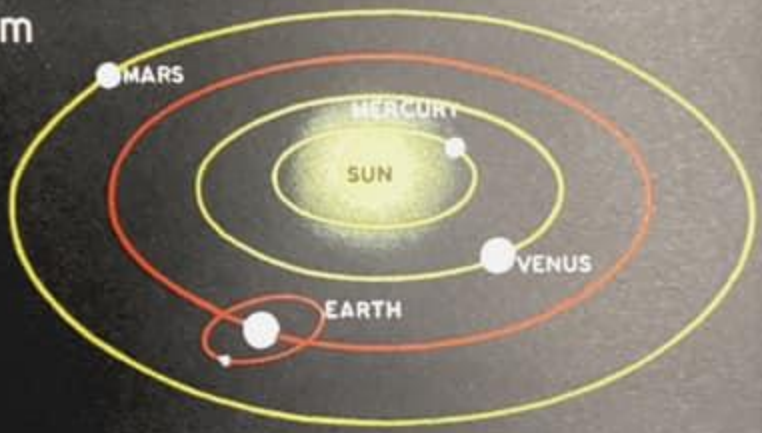


closely he discovered that Sirius traced a wobbly path through the heavens. The reason for the star's strange behavior was that it was found to have a small companion star. Together the two stars circled each other and so accounted for Sirius' mysterious motion.

The companion star of Sirius burns with an intense white light. It is a star in its dying stages. It has burned up all of its fuel and glows only

1 Earth-Moon system

2 the solar system



ONLY THE FOUR INNER PLANETS ARE SHOWN.

3 star cloud

OUR SUN IS A STAR IN A STAR CLOUD.


4 our galaxy
GALAXY IS MADE UP OF SWIRLING STAR CLOUDS. SUN IS IN CENTER OF CIRCLE.
sun


5 group of galaxies
OUR GALAXY IS ONE OF A LOCAL GROUP OF 16.

because it is contracting—becoming smaller and smaller. Stars like this, in their last stage of life, are the white dwarfs. As they burn up their fuel they shrink over periods of millions and millions of years until they become as small as planets. Gradually their light goes out and eventually they become small black globes which float through space unseen by even the most powerful telescopes.

pulsating stars

For several years astronomers have been watching the strange behavior of a class of stars known as Cepheid variables, or pulsating stars. Like giant throbbing hearts, these stars swell up and then shrink, becoming bright and then dim, over and over again like heavily breathing monsters. For hundreds of years they repeat this dramatic performance. The really large pulsating stars may take as long as two or three years to com-

plete one cycle of swelling and shrinking, but the smaller ones are quicker. They take only a few days, or even hours, to expand and contract.

nova

In the year 1054, Chinese astronomers watching the skies saw something that terrified them. A normal star mysteriously grew brighter and brighter until it was the most brilliant object in the heavens. In 1572 the astronomer Tycho Brahe saw a similar star so bright that he could watch it during the day. In 1918 another extra bright star appeared.

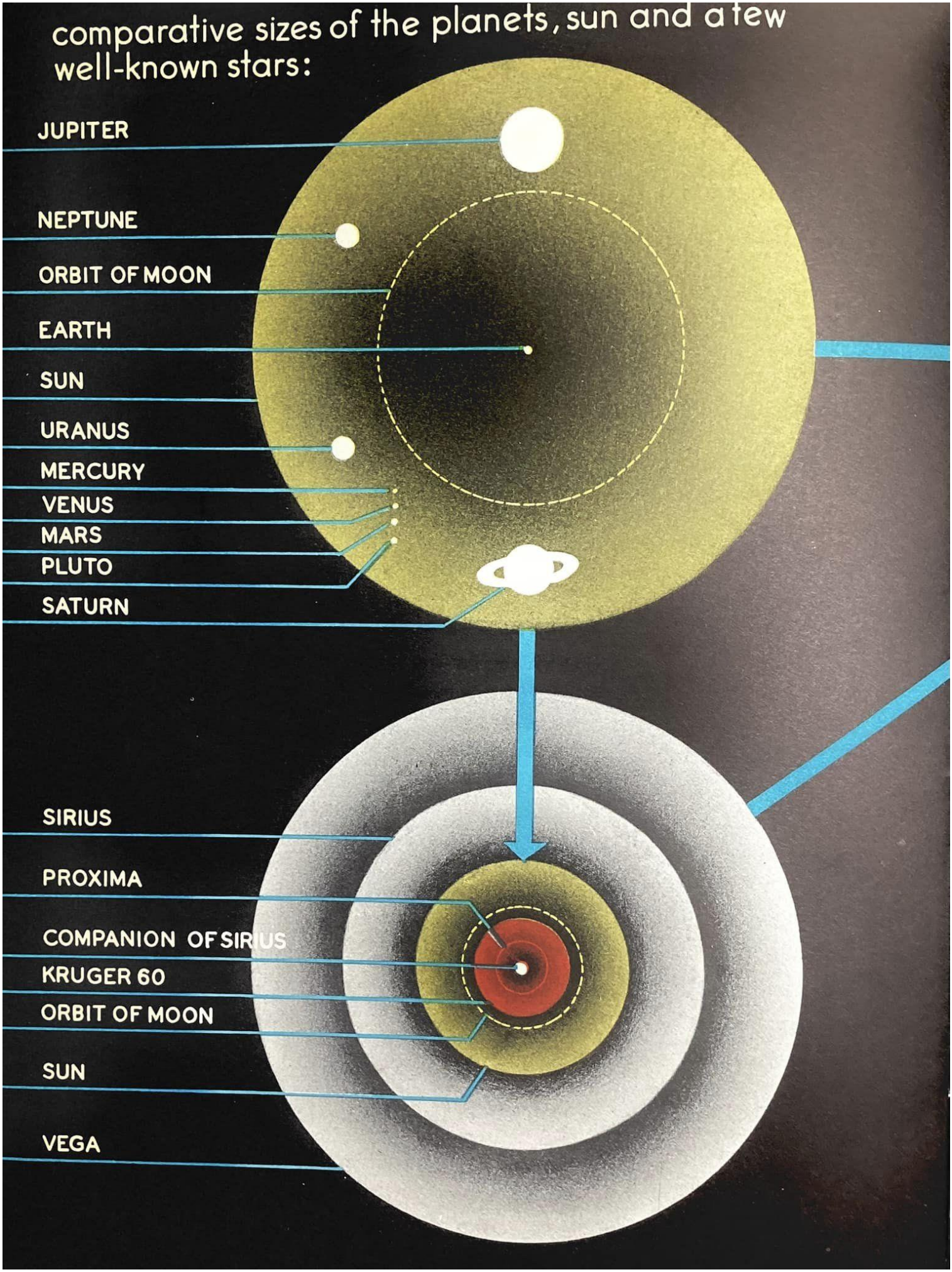
Astronomers call these high blood pressure stars novae and supernovae. Why they suddenly become intensely hot and bright is still a mystery. When a nova is in the making it is seen as a normal star that suddenly begins to burn brighter and brighter until it rules the heavens. It may remain bright for several years. Then it will slowly grow dim, returning to its normal stage. In 1934 the Nova Hercules was observed. Astronomers think that this is one such rare star that exploded and broke in two. Today the two small pieces can still be seen rushing away from each other at thousands of miles a second.

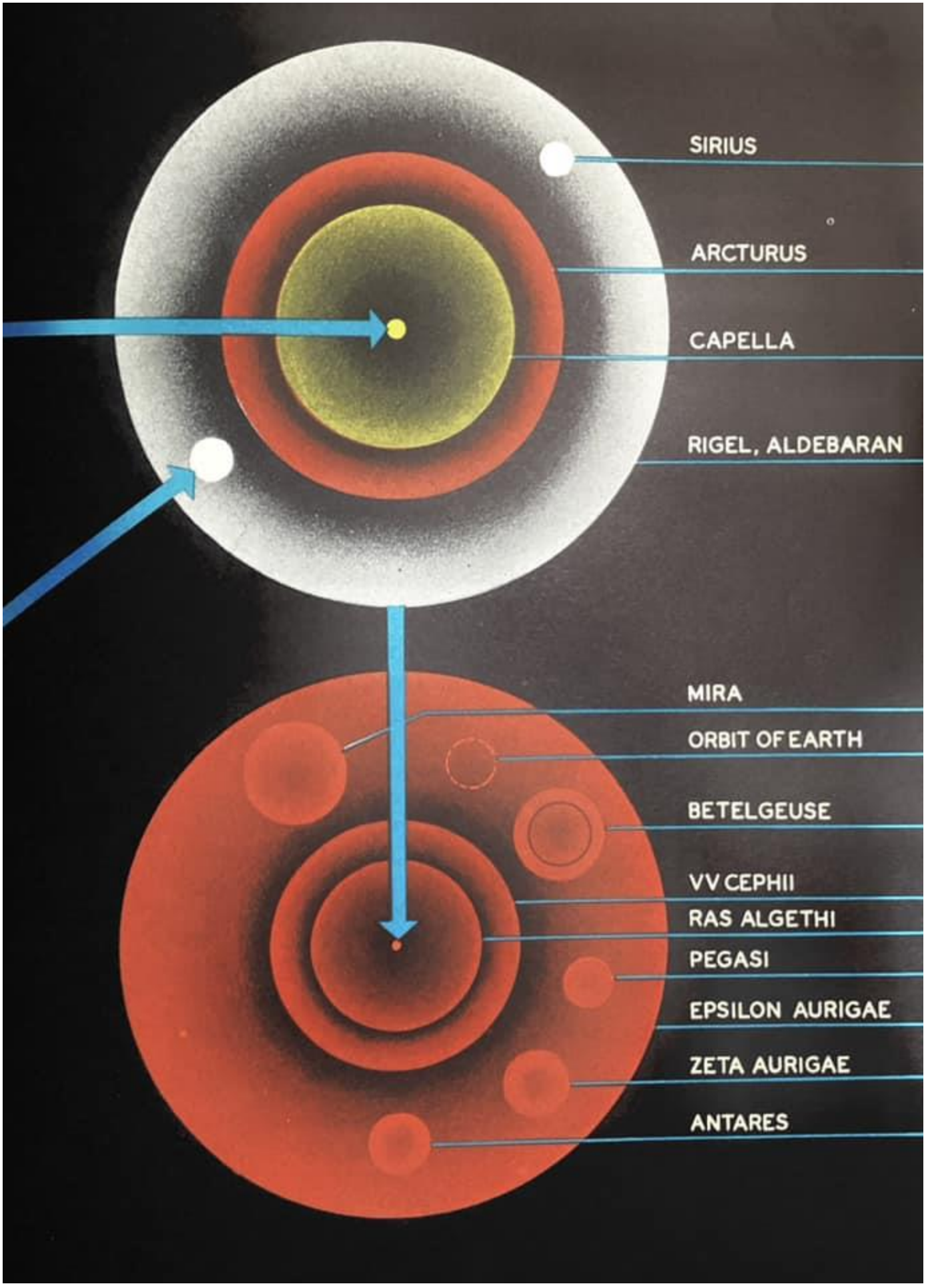
The supernovae are usually much more dramatic. They seem to be normal stars that suddenly explode and become as bright as a whole galaxy. These stars do not return to their normal state.

What causes a nova? Astronomers don't know. Here is one theory they have thought of but have recently discarded. The great cosmic clouds in space are much like patches of fog along the highway. If a star, traveling at thousands of miles a second, should pass through one of these clouds, friction would cause it to burst into bright light. As attractive as this theory sounds, astronomers have discarded it, for it cannot account for all the different kinds of novae which are seen every year. So the cause of novae and supernovae still remains one of the many unsolved mysteries of science.

double stars

In size and brightness our Sun is a typical, or average star. It wanders through the galaxy with a small group of other stars. More than


comparative sizes of the planets, sun and a few well-known stars:
JUPITER
NEPTUNE
ORBIT OF MOON
EARTH
SUN
URANUS
MERCURY
VENUS
MARS
PLUTO
SATURN
SIRIUS
PROXIMA
COMPANION OF SIRIUS
KRUGER 60
ORBIT OF MOON
SUN
VEGA


SIRIUS
ARCTURUS
CAPELLA
RIGEL, ALDEBARAN
MIRA
ORBIT OF EARTH
BETELGEUSE
VV CEPHII
RAS ALGETHI
PEGASI
EPSILON AURIGAE
ZETA AURIGAE
ANTARES

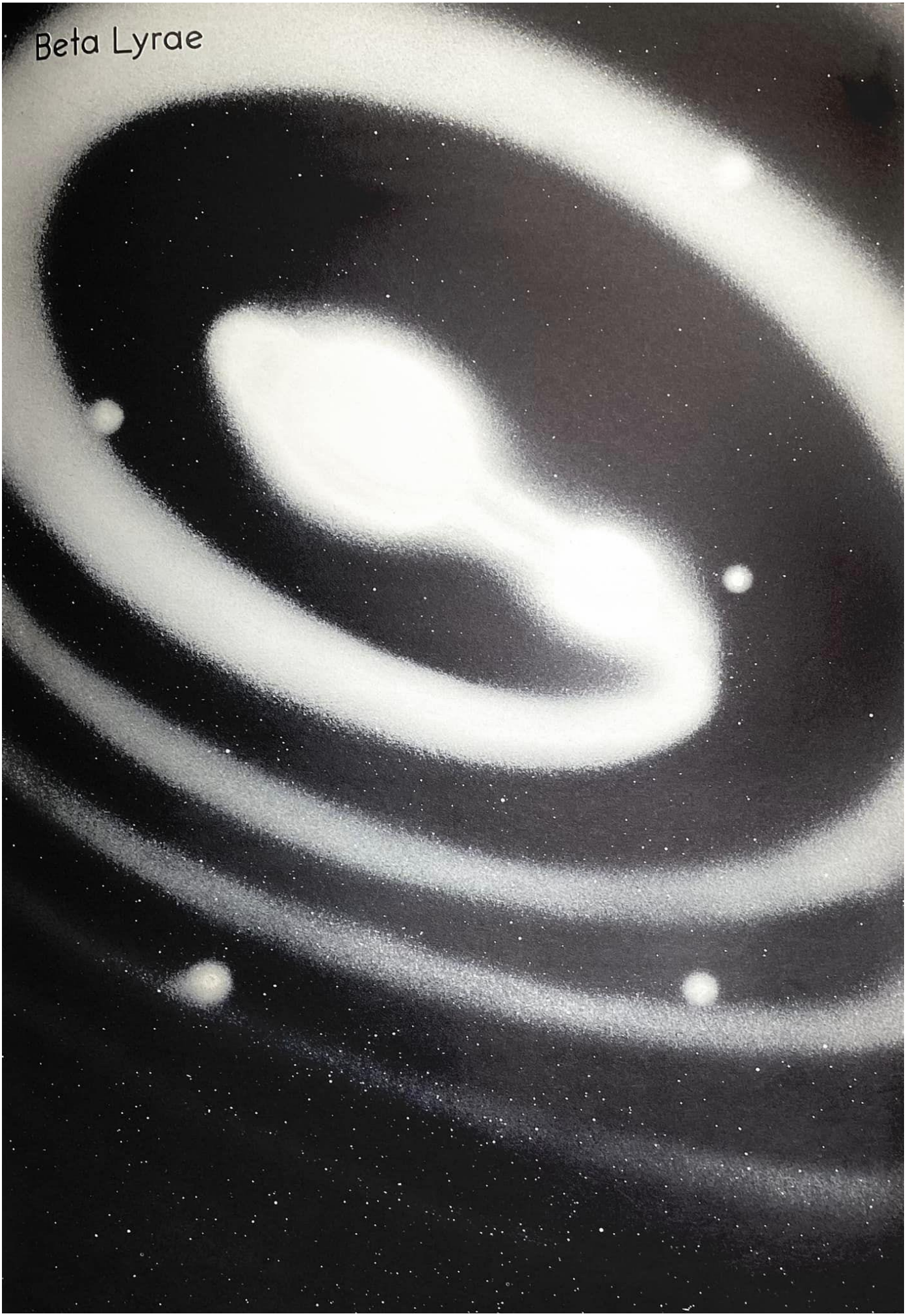
three fourths of all the stars in our galaxy belong to partner systems, or are members of a family of stars clinging closely together. Sometimes star families have hundreds of members. Yet many of the families do not exceed two, three, or four stars. Among the most interesting stars having companions are the double stars.

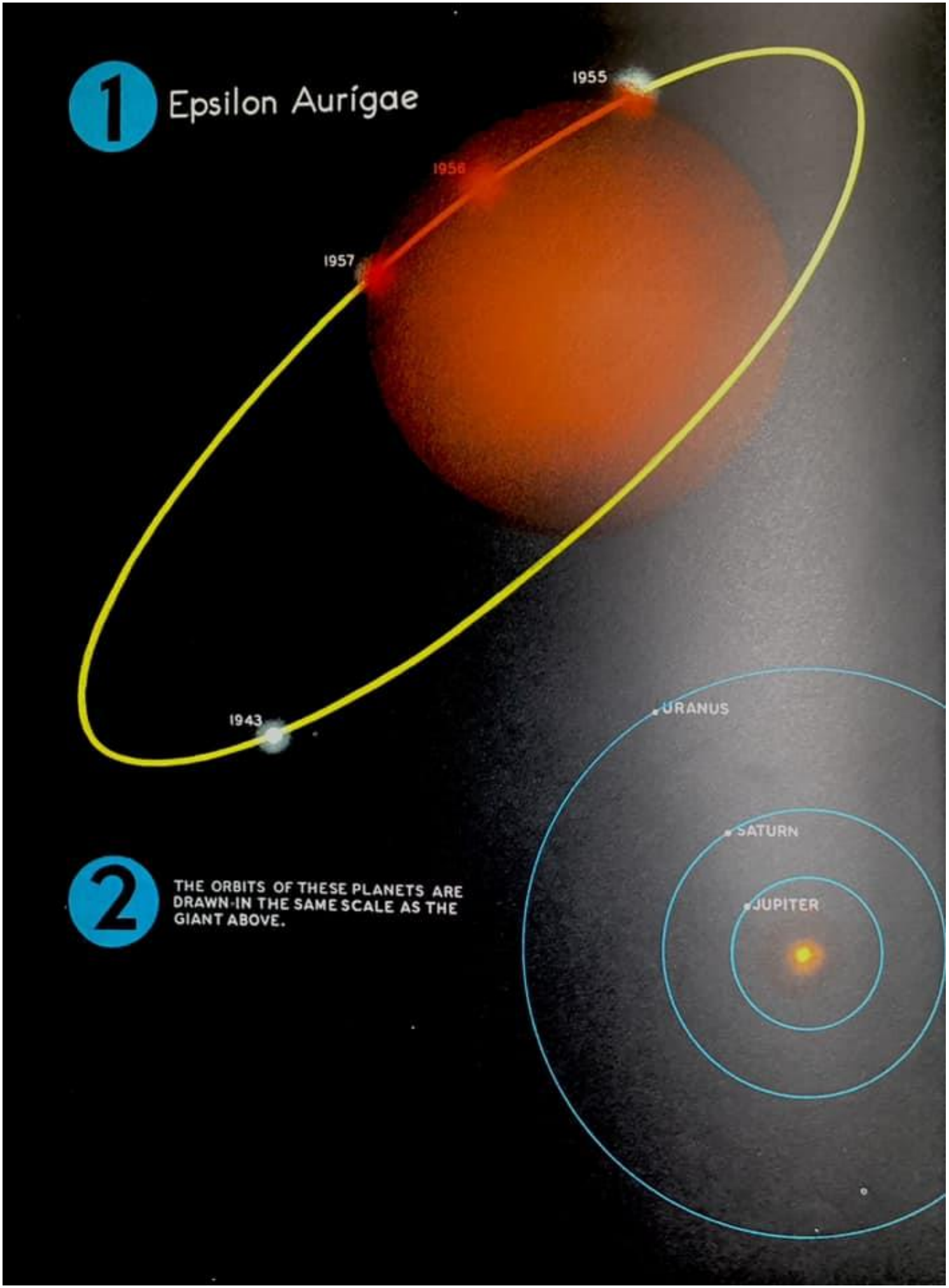
When two stars are situated close together and circle about each other they are called a double star. Sometimes they circle one another so rapidly that they shoot out long colorful streamers of gas. One of the most exciting displays of this type is the double star known as Beta Lyrae, made up of a large blue star and a smaller yellow one. The larger star is spinning so fast that it shoots out luminous gas which glows red against the blackness of space. The smaller star catches some of the gas, with the result that the two stars are circled by a narrow red belt. The gas which the smaller star does not keep is hurled out in a mammoth red spiral which forms an intriguing pattern in the heavens. Beta Lyrae is the only double star known to put on such a colorful show.

The first small family of stars ever to be seen is Mizar, which is located in the handle of the Big Dipper. Two members of this family can be seen by the naked eye. Another double-star system is made up of the blue giant Sirius, known as the Dog Star, and a white dwarf companion called the Pup. The smaller star is so dense that a tablespoon-sized chunk of it weighs more than a ton!

The granddaddy of all the double stars is Epsilon Aurigae. One of its stars is a yellow supergiant 250 times bigger than our Sun. But its companion is even bigger—3,000 times the size of the Sun. Many of the stars we see each night are actually double or triple stars, yet the naked eye sees them as only one star. The North Star, for example, is actually made up of three single stars. Castor is made up of six.

Because of the strange nature of double stars you might expect that they lead rather spectacular lives. Oddly enough they behave quite properly, as stars go. They burn steadily throughout their lives, then die quietly by growing dimmer and dimmer until they lose their last spark of light. On the other hand, the single stars like our own Sun are the unpredictable ones. In their old age they usually kick up their heels by turning into novae.


Beta Lyrae


1 Epsilon Aurigae
1955
1956
1957
1943
URANUS
SATURN
JUPITER
2 THE ORBITS OF THESE PLANETS ARE DRAWN IN THE SAME SCALE AS THE GIANT ABOVE.

visitors from outer space

meteors

The time is around noon, June 30, 1908. The place is northern Siberia, barren wastelands stretching across thousands of miles. At the time of our drama most of the inhabitants of this area were reindeer. There were few human beings. Suddenly there appeared in the sky a dark object which seemed to be about half the size of the Moon. At thousands of miles an hour it was plunging toward the Earth. As it sped closer it set up a deafening roar—then with a terrifying explosion it smashed into the swampy ground.

Hundreds of miles away primitive tribes paused in their work as they heard the meteorite strike. For fifty miles around the explosion area trees and shrubs were bent to the ground like blades of grass, their branches and bark burned off by the meteorite's terrible heat. This meteorite is probably the biggest visitor from outer space that has plummeted into the Earth since man has inhabited our planet. We say "probably" because it wasn't until nineteen years after the event that a Russian expedition explored the wilderness area to see how much damage the meteorite had caused. But by the time they arrived most of the evidence had disappeared. The swampy ground had swallowed most of the me-

teorite's fragments, so the expedition could do little more than guess at the actual size of the giant.

Had this monster from outer space landed on New York, London, or Paris, it would have blasted the city into total ruin. Not a single per-

son would have survived. Even the H-bomb, man's most destructive weapon, would have had to bow to the great Siberian meteorite.

In the history of mankind only a few really large meteors are thought to have crashed into our planet. And records of them have long since

been lost. In North America, however, scientists have found two mammoth meteor scars which must have been made long before men walked the earth. One of the giant pits is in Arizona, and measures about 600 feet deep and three quarters of a mile wide. An even larger one is located in northern Quebec, Canada.

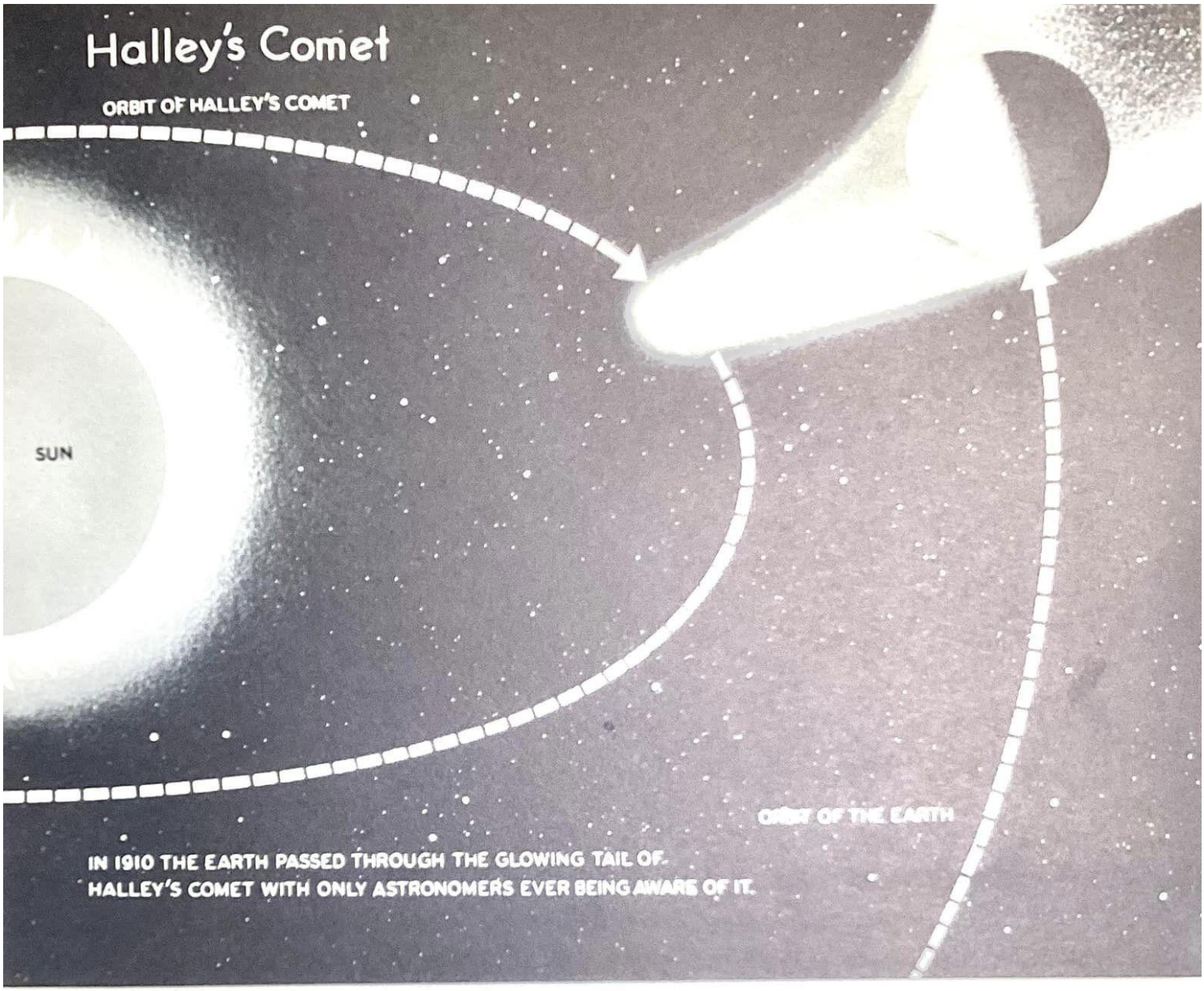
When really large meteors plummet to the Earth they do not simply bury themselves in the ground, as many people think. The speed of some is so great that when they strike they explode like a large bomb and vaporize. And the only evidence we have of them is an explosion pit and the few pieces of metal or stone scattered over the surrounding countryside.

When a meteor survives the difficult trip through our atmosphere and manages to strike the ground it is known as a meteorite. All of the meteorites found so far can be divided into two groups—those made of stone, and those made of metal, part nickel and part iron. Of all the meteorites that have been examined, none is made of material that cannot be found on our own planet. This destroys the theory that some meteors might have "secret" and "mysterious" properties.

On most clear nights you can see meteors at the rate of about ten an hour. Arthur C. Clarke, the British astronomer, tells us that countless billions of meteors rush into our atmosphere every day. But of this great number we see only a few. The reason is that most of them are no larger than grains of sand. And seconds after they enter our atmosphere they burn up, never completing their journey to the Earth's surface.

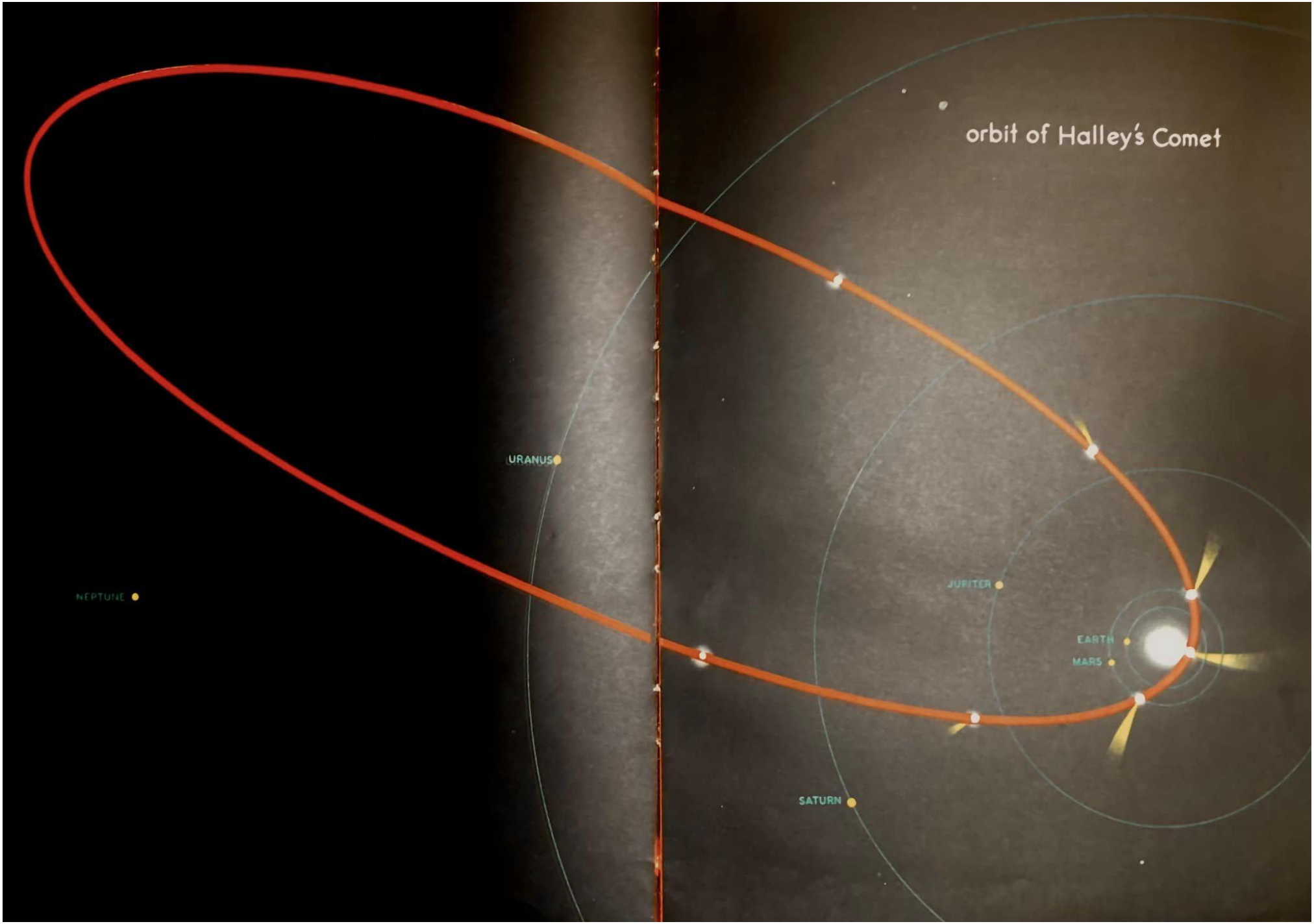
For many years people referred to meteorites as "shooting stars." The ancients may well have thought of them as stars that somehow lost their way and came tumbling down on the Earth. But to call meteorites "stars" today would sound silly. We know they are nothing more than chunks of stone and metal.

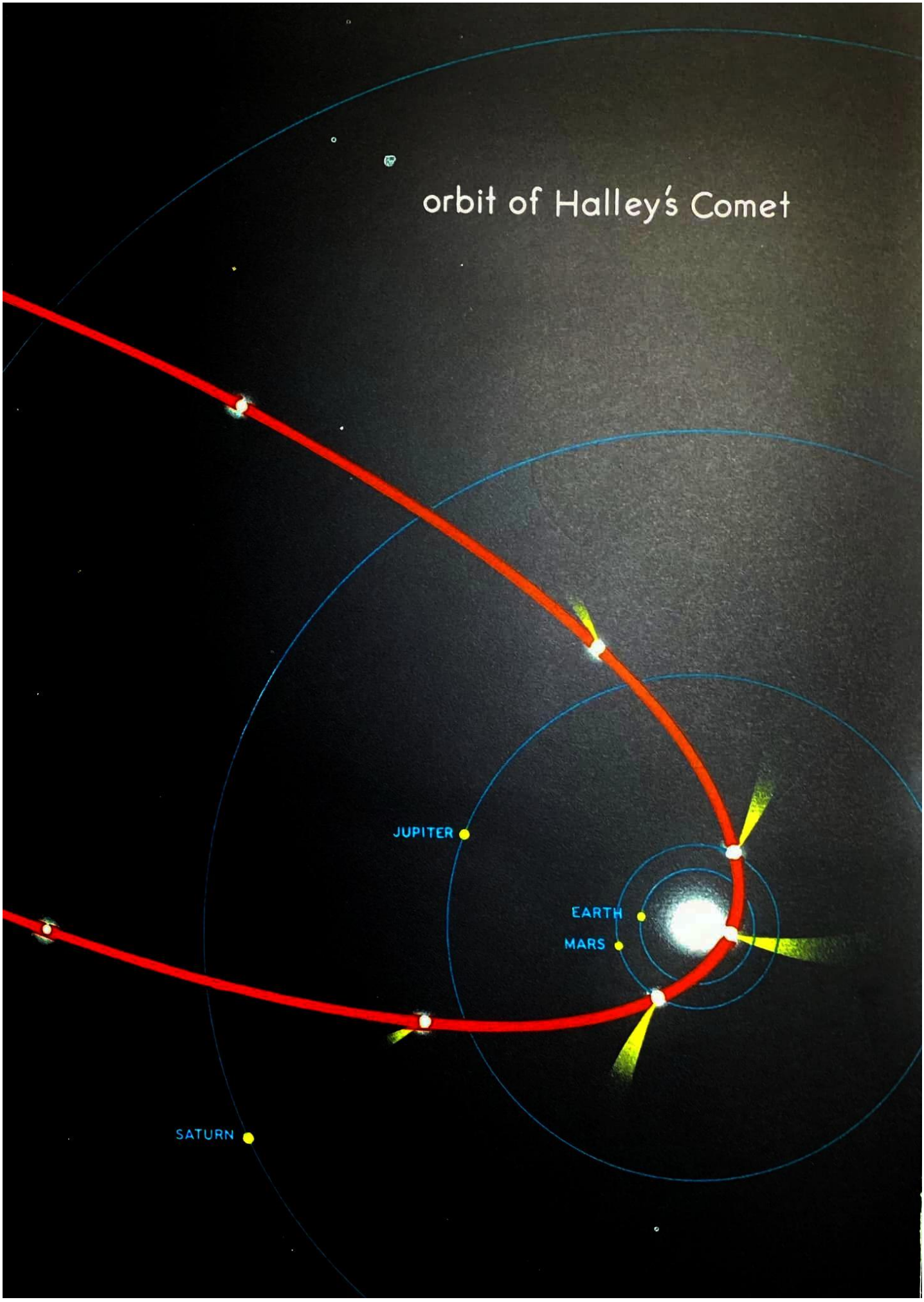
Astronomers have found that meteor showers can be predicted, that at certain times they put on their own Fourth of July displays. The reason for this is that many meteors travel in swarms, like bees. At the present time astronomers think there are about 600 such swarms circling the Sun as the planets do. Whenever a swarm comes close enough to our planet, many of its members are pulled toward the ground by Earth's gravity. At such times we see meteor showers.



comets

On the morning of May 13, 1910, millions of people sleepily climbed out of their beds to watch one of the most spectacular of all heavenly displays—the arrival of Halley's comet. When it finally came into view, many ignorant watchers were terrified. Like the ancients, they thought that some great disaster was in the making for man and his world. What they saw was a large luminous globe which appeared to be the size of a star. Behind it a long shining tail stretched across the heavens for thousands of miles. Rising and setting like the Sun, for many days the bright comet blazed a path across the sky until it finally disappeared from view.


orbit of Halley's Comet
URANUS
NEPTUNE
JUPITER
EARTH
MARS
SATURN


orbit of Halley's Comet
JUPITER
EARTH
MARS
SATURN

Had the people who were terrified known what a comet is, they probably would have laughed at their fear. Today we know that comets are among the most harmless objects in the sky. Their heads are made up of loose collections of small meteors capsuled in a large globe of gas. The gas picks up light from the Sun and so shines brightly as the comets stream across the heavens. And their long tails are nothing more than an extremely thin gas trail, so thin in fact that even weak stars can be seen shining through it.

Like the planets, comets circle the Sun. For this reason we can predict when they will be seen from Earth, as we can predict when the other planets will pass most closely to our own planet.

Halley's comet got its name from the famed British astronomer Edmund Halley. In the year 1682, Halley saw the comet now bearing his name. He was sure that it had to be the same comet that had been seen in 1531 and in 1607. So certain was he that he predicted the comet would make another visit in 1758. Unfortunately Halley died before 1758 but, true to his prediction, the comet returned in that year. For this reason it was named in his honor. The famous comet is due to make another appearance within our lifetime, in 1986. Like clockwork, Mr. Halley's comet appears every seventy-six years, and was first reported as long ago as 240 B.C.

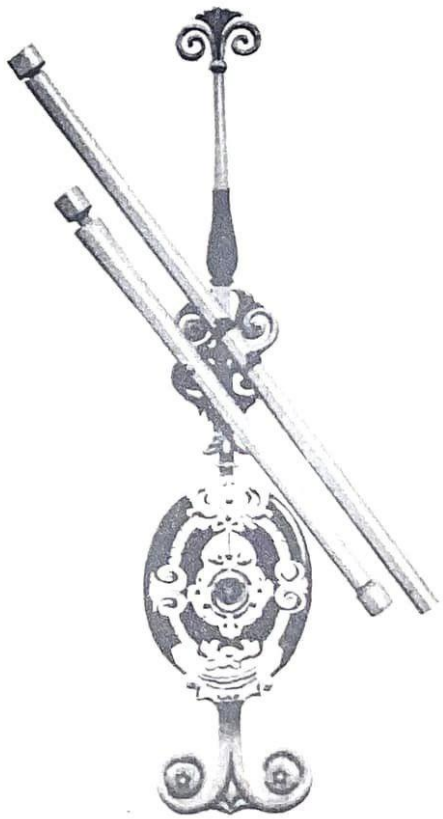
One of the strangest of all comets that have ever been seen was Biela's comet. It was first recorded in 1826, and is most likely the same comet that trailed the skies in 1772 and 1805. As predicted by Biela, the comet came back six and three quarters years later, in 1832. But in 1839, when it was scheduled for another return, it was difficult to see; then in 1845 it was back again in full view. Somehow though, something strange began happening to it. The comet seemed to have split in two. As astronomers studied this freak of comets they were surprised to see that the smaller of the two heads grew brighter while the second one became dim. Slowly the two comets began drifting apart, and by the time they made another appearance in 1852, more than a million miles of space separated them. By this time astronomers were deeply interested and looked forward to the comets' next scheduled displays in 1859 and 1866—but, oddly enough, the comets did not appear.

In 1872, however, astronomers were in for a real surprise. For a third

time the comets failed to appear—but in their place came a brilliant storm of meteors! What happened? The famous comet somehow lost its globe of gas and so was demoted to a meteor swarm. Today astronomers think that many of the 600 meteor swarms streaming through the skies are the heads of dead comets returning year after year, each time losing an increasing number of their members, which are pulled to their death by Earth's gravity.

Up to this point we have been so concerned with the individual parts of the universe—comets, meteors, planets, double stars, and galaxies—that we have not taken a look at the universe as a whole. It's as though we have been looking at a painting in an art gallery. We have been so busy examining the colors and other details that we have not had time to step back and view the painting from a distance.

To step back and view the universe from a distance means looking at it through the world's most powerful telescopes. And to see exactly what's happening requires more than one look. In fact, it has taken astronomers several years to paint a picture of the mysterious behavior of the universe. And what a picture it is—more exciting than the most thrilling mystery novel ever written.




the expanding universe :
IMAGINE ALL OTHER GALAXIES AS BEING SPOTS PAINTED ON A BALLOON WHICH IS EXPANDING. THUS EACH GALAXY RECEDES FROM THE NEXT
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the runaway universe

In 1929 astronomer Edwin Hubble made a discovery so startling that he seriously wondered if anyone would believe him. Yet he had evidence—unique photographs of distant groups of stars. And all of the strange pictures showed the same thing: unmistakably the universe was running away; or, more properly, it was expanding. Recently the 200-inch telescope at Mount Palomar has confirmed Hubble's theory. And so have scientists working in radio astronomy by studying the electrical impulses sent out by distant "radio stars."

Exactly what did Hubble's observations tell him? And why did his runaway universe theory cause an uproar among astronomers?

Hubble's photographs showed him that extremely distant galaxies are rushing away from each other at fantastic speeds of about 38,000 miles a second. The universe, Hubble said, is expanding and will eventually become "lost" in the vast empty regions of outer space, as a puff of smoke vanishes into the night air.

What started Hubble off on his expanding universe theory was something called the "red shift."

To understand what the red shift is all about, it's necessary to know how a spectroscope works. It's one of the instruments astronomers use when they study the planets and stars. All it does is break down the stars'

white light by separating it into individual colors. This makes it possible for astronomers to tell what kinds of matter stars are made of.

After studying a number of distant galaxies with a spectrograph, Hubble noticed something curious. As the white light was broken up, it crowded toward the red end of the spectrum. And the farther away the galaxy was, the more its light shifted toward the red. This told Hubble two things: that the galaxies were moving away from his telescope, and that those the farthest away were moving the fastest.

What the spectrograph showed Hubble is much the same as what you hear each time a whistling express train speeds past. As the train rushes away from you, the pitch of the whistle noise becomes lower—like E-E-E-O-O-o-o. What happens is that as the source of sound speeds away from you, each sound wave reaching your ears has farther to travel than the last—and so, a change in pitch. The same thing happened with Hubble's sources of light. As the galaxies were rushing away from his telescope, each light wave had farther to travel than the last one. For this reason they showed up on the red end of the spectrum. If light waves could make noise, they would sound like our express train speeding off into the night.

No matter in what part of the sky Hubble pointed his telescope, the picture was the same. The galaxies were speeding away from one another in all directions and at fantastic speeds, rushing off into the cold, empty regions of outer space. To visualize this, picture a half-inflated balloon painted with dots which represent the galaxies. As the balloon is inflated and expands, the dots themselves expand, and at the same time the distance between them becomes greater. This is just what our universe would look like to an observer stationed far out in space.

Most astronomers today agree with the expanding universe theory, but they disagree on what it means.

One group maintains that the galaxies will continue rushing away from each other forever, with no chance of ever being pulled back together again. In a long cosmic sigh the universe is gradually disappearing, they tell us. A second group, however, believes that the expanding action is merely one half of a cycle. Their theory is that ever since the universe was created it has constantly been swelling up and shrinking like a huge breathing ball. During the contraction or shrinking period,

they explain, all the galaxies tumble in toward a common center and are pressed into a mammoth elastic sphere which explodes, then starts the expanding or swelling action all over again.

There's only one thing wrong with the second theory. According to what scientists now know about matter and how it behaves, it would be impossible for the galaxies to be drawn back together once they expanded. It seems then that the upper hand is held by the "cosmic sigh" group, which maintains that we're expanding into nothingness, with no chance of a rebirth.

To date, our astronomers don't have enough information about the universe to make either theory stick. But many hope that eventually the giant telescope at Mount Palomar will give us the answers. Until it does, the expanding universe will continue to remain one of science's most baffling mysteries.