

CHAPTER TWENTY-EIGHT

METEORS AND COMETS

עַל הַזִּיקִין...אוֹמֵר בְּרוּךְ שְׁפָחוּ וּגְבוּרָתוֹ מְלֵא עוֹלָם.

On [seeing] *zikin*...one says “Blessed [are You, Hashem, our G-d, King of the Universe] Whose power and might fill [the] world.”

Berachos 9:2

WHAT ARE ZIKIN?

The term *zikin* can refer to either of two different things one might be fortunate enough to see in the night’s sky: comets and meteors.¹ To appreciate what these are, we will first need a little introduction to the vast **Universe** that surrounds us.

In this chapter, we include a variety of remarkable photographs of various celestial bodies (such as of the Moon and planets). The Mishnah says that Rabban Gamliel kept certain pictures of the Moon.² The Gemara points out that there are halachic restrictions on images of celestial bodies and asks how he was permitted to have them.³ The Gemara provides several answers, the last of which is that he was permitted to have these images to understand and teach about them (“לְמַד לְהַבִּין” וּלְהוֹרוֹת”). Based on that Gemara, Harav Nissim Karelitz, *zt”l*, ruled that any pictures of the celestial bodies whose purpose is to learn and understand them are also halachically permitted.⁴ Based on that ruling, and after showing the full contents of this chapter to leading English-speaking contemporary *posek*, Harav Yitzchak Berkovits, *shlita*, who reviewed and confirmed that the text and images of this

1 *Mishnah Berurah 227:1.*

2 *Rosh Hashanah 2:8.*

3 *Rosh Hashanah 24a–b (and Avodah Zarah 43a–b).*

4 *Chut Shani, dinei Asias Tzueros*, found at the back of the volume on *Pesach*, p. 233.

chapter do not violate halachah, we present the full contents of this chapter in the spirit of the famous words of the *Rambam*:

וְהַיֵּאֵךְ הִיא הַדֶּרֶךְ לְאַהֲבָתוֹ וְיִרְאַתוֹ. בְּשָׁעָה שֶׁיִּתְבוּנֵן הָאָדָם בְּמַעֲשָׂיו וּבְרוֹאֵיו הַנִּפְלְאִים הַגְּדוּלִים וְיִרְאָה מֵהֵן חֲכָמְתוֹ שֶׁאֵין לָהּ עֶרְךָ וְלֹא קֶץ מִיד הוּא אוֹהֵב וּמְשַׁבַּח וּמְפָאֵר וּמְתַאֲוֶה תְּאֻוֶּה גְּדוּלָה לַיָּדַע הַשֵּׁם הַגְּדוֹל. כְּמוֹ שֶׁאָמַר דָּוִד צְמָאָה נַפְשִׁי לְאַלְקִים לְקַל חֵי. וְכִשְׁמַחְשֵׁב בַּדְּבָרִים הָאֵלּוּ עֲצָמָן מִיד הוּא נִרְתַּע לְאַחֲזֵרְיוֹ וַיִּפְחַד וַיִּוָּדַע שֶׁהוּא בְּרִיָּה קְטַנָּה שֶׁפְּלֵה אֶפְלָה עוֹמְדָת בְּדַעַת קְלָה מְעוּטָה לִפְנֵי תְּמִים דְּעוֹת. כְּמוֹ שֶׁאָמַר דָּוִד כִּי אֶרְאֶה שָׁמַיִךְ מַעֲשֵׂי אֲצִבְעֶיךָ מָה אֲנוֹשׁ כִּי תִזְכְּרֵנּוּ. וּלְפִי הַדְּבָרִים הָאֵלּוּ אֲנִי מְבַאֵר כְּלָלִים גְּדוּלִים מִמַּעֲשֵׂה רַבּוֹן הָעוֹלָמִים כְּדִי שֶׁיְהִיוּ פֶתַח לְמַבִּין לְאַהֲבַת הַשֵּׁם. כְּמוֹ שֶׁאָמְרוּ חֲכָמִים בְּעִנְיַן אֶהְבָּה שְׂמִתוֹךְ כִּךָ אֶתָּה מְכִיר אֶת מִי שֶׁאָמַר וְהִיָּה הָעוֹלָם:

And what is the path to love and fear [Hashem]? When a person thinks about His works and His great and wonderful creations and sees in them His inestimable, infinite genius, one will immediately love and praise and exalt [Hashem] and be filled with a great desire to know His great name. As [King] David said: “My soul thirsts for G-d, for the living G-d” (Tehillim 42:2). And when one thinks of all these matters, he will immediately be taken aback and stricken with awe, realizing that he is a puny creature, lowly and dim, standing with an insignificant and minimal knowledge in the presence of the All-Knowing, as [King] David said: “When I see Your heavens, the works of Your fingers—what is a human that You should take note of him?” (ibid. 8:4) So, for these things I [shall] explain major principles of the works of the Master of the Universe, so that they shall be a conduit for one who understands to love Hashem. As the Sages said on the matter of love: “Out of it you will recognize the One who spoke, and the Universe came to be.”⁵

THE UNIVERSE IN A NUTSHELL

Seeing thousands of glittering stars on a moonless night is one of life’s most awe-inspiring sights, and the more you understand what you are actually seeing, the more incredible it becomes! The night sky has the potential to help us feel just

⁵ *Rambam, Hilchos Yesodei HaTorah 2:2.*

how immense and powerful Hashem is. The blessing in this Mishnah provides us with an opportunity to direct and express those intense emotions.

When astronomers explore the Universe through their telescopes, they see a wide variety of objects, such as **planets**, **stars**, and **galaxies**. All these objects are moving. This “dance of the heavens” is all controlled by **gravity**, the force of nature that causes everything to be attracted to everything else. It is gravity that causes your pen to fall toward the Earth when you let it go, and it is also gravity that prevents the **Moon** from flying off into space as it travels around our planet.

The tiny stars that we see twinkling at night are actually enormous balls of **gas** held together by gravity. The **atoms** of the star’s gases are pressed together so tightly by gravity that their **nuclei** combine explosively, releasing unimaginable amounts of **energy**, much like an ongoing nuclear bomb. This is also what is happening inside our **Sun**, which is a star just like all the others, only it looks much brighter because it is so much closer to us than they are.

Gravity also causes the stars to be attracted to each other. A group of stars that are moving together around a common central point is called a galaxy. The Sun is part of a galaxy called the Milky Way. In fact, every star you see at night is part of the Milky Way galaxy. Since we are inside the Milky Way, we cannot observe its shape directly. However, scientists have determined that it looks similar to the spiral galaxy shown in Figure 28.1.

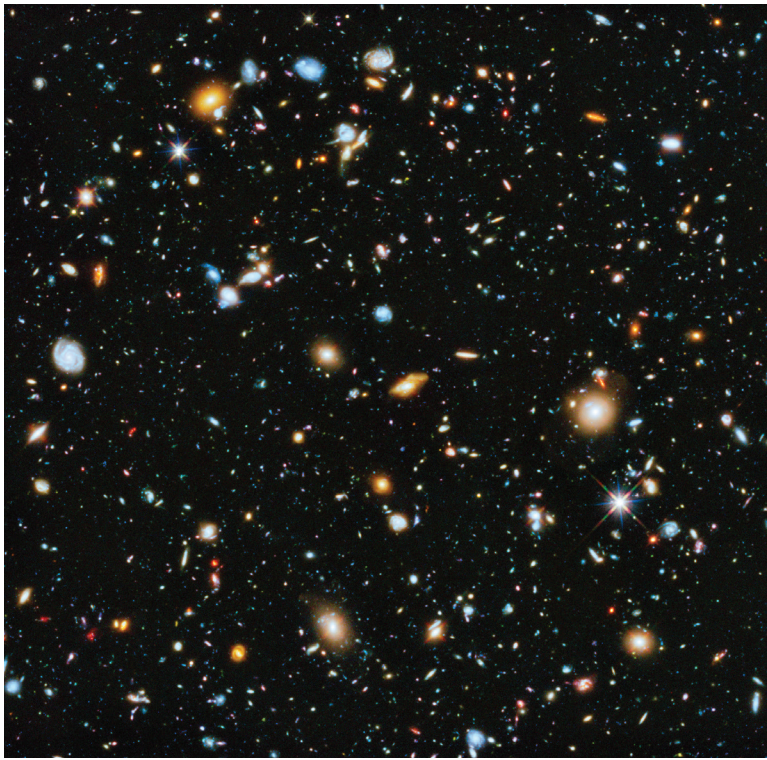


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FIGURE 28.1. A spiral galaxy called “M81” as seen with a powerful telescope. Each spiral arm of the galaxy contains billions of stars too small to see individually. All the individual stars you can see in the image are in the foreground from our own galaxy.

On a very dark night, when you look at the sky, you might be able to see about a thousand stars, but there are many more stars that you cannot see! In fact, our Milky Way is home to about 100,000,000,000 (one hundred billion) stars, so for each star you see at night, there are about 100 million more in the Milky Way that you are not seeing (see Figure 28.2)! That should make you realize that the Universe is much bigger than you could possibly imagine! But it is much, much bigger than even that! The Milky Way is just one of about 200,000,000,000 galaxies (see Figure 28.3)! So, if you multiply together the number of stars in our galaxy by the number of galaxies, you get a rough calculation of how many stars there are in the part of the Universe that we can see: 20,000,000,000,000,000,000! It is simply not possible to understand that number—and yet each one is a giant star! It is also not possible for us to see the entire Universe, so there may be a great deal many more stars than that. We will never know how big the Universe that Hashem created really is.



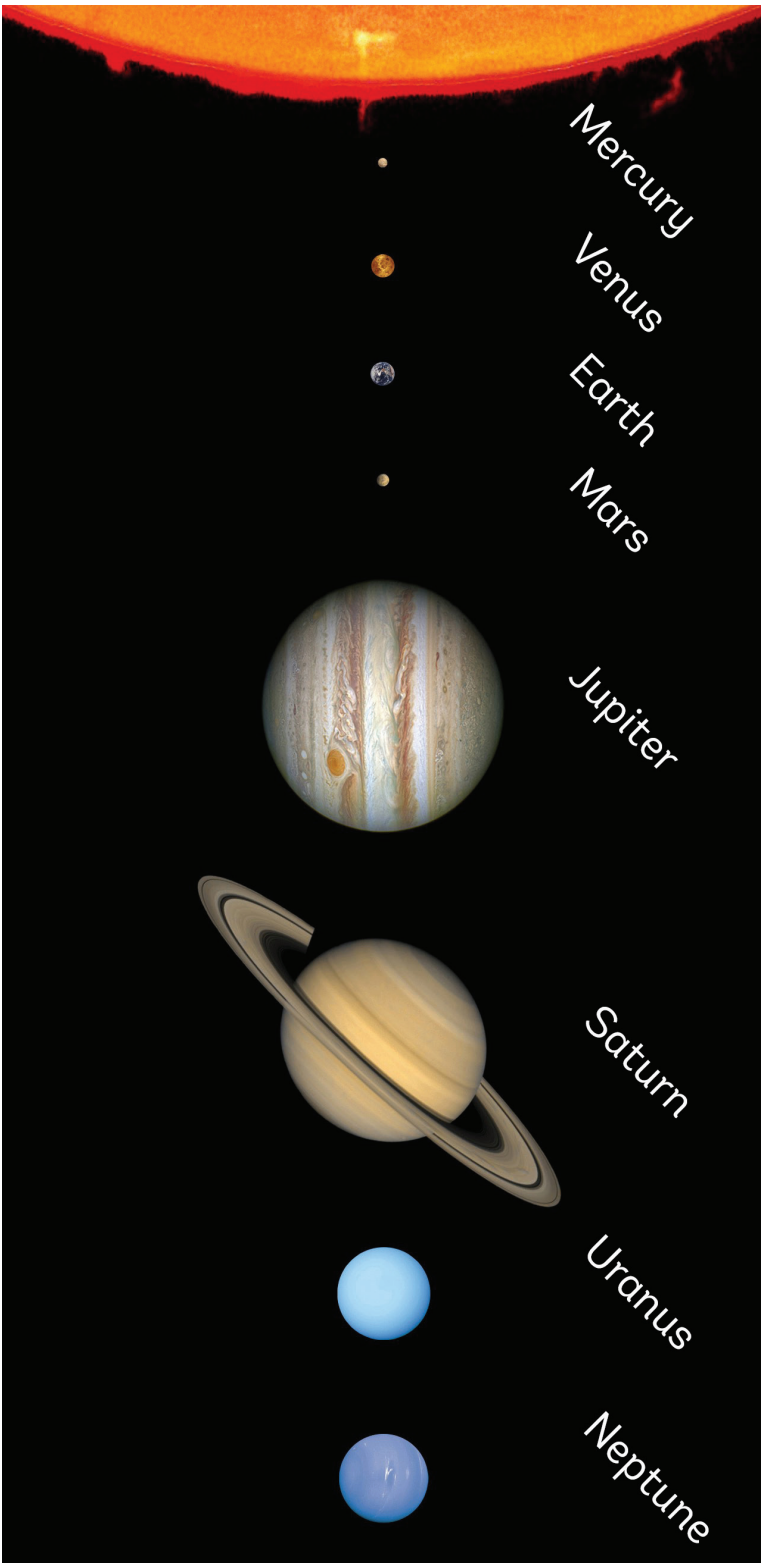
FIGURE 28.2. A tiny fraction of the 100,000,000,000 stars in our galaxy, as seen through a powerful telescope. Each point of light is a star. There are also some glowing gas clouds in the image.



◀ FIGURE 28.3. A tiny fraction of the approximately 200,000,000,000 galaxies in our Universe, as seen through the Hubble Space Telescope. Even the tiniest individual points of light in this picture are entire galaxies! There is at least one star caught in this image from our own galaxy. Can you find it?

THE SOLAR SYSTEM

Our Sun has a number of different types of objects moving around it, such as planets, moons, **asteroids**, and comets. Collectively, the Sun and everything that is bound to it by gravity is called the **Solar System**. When smaller objects revolve around a larger one, we say they are “in orbit.” Large spherical objects that are not big enough to be stars themselves are called planets. As far as we know, the Solar System has eight planets. The four planets orbiting closest to the Sun (Mercury, Venus, Earth, and Mars) are made of rock and are relatively small. The four that are further away (Jupiter, Saturn, Uranus, and Neptune) are much larger and are made mostly of gas and ice with a relatively small rocky **core**. Figure 28.4 shows a picture of all eight planets drawn to scale. All eight planets orbit the Sun in enormous, almost circular paths. Our trip around the Sun takes about $365\frac{1}{4}$ days, which is the definition of a solar (secular) year.



◀ FIGURE 28.4. The planets of the Solar System and the Sun (a sliver of which is on the top) shown in their correct order and with their accurate relative sizes, but not with their correct relative distances. You will surely notice that Saturn has an impressive set of rings around it. These are made of trillions of tiny rocks in orbit around that planet.

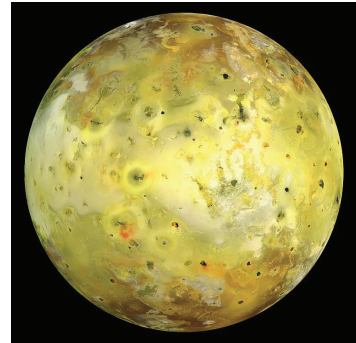
Objects that orbit around planets are called **satellites** or moons. The Earth has one natural satellite, which we call *the* Moon (with a capital “M”), because when it got its name, nobody realized there were others. Since 1610, when the famous astronomer Galileo discovered four moons orbiting Jupiter, scientists have been discovering more and more of them. Most of the eight planets have moons; Jupiter and Saturn each have more than ninety! Figures 28.5–28.10 show a few of the moons in our Solar System.



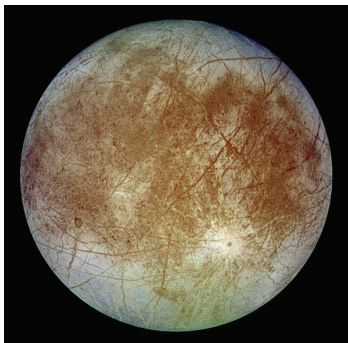
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FIGURE 28.5. The Moon orbits Earth. Its diameter of 3,475 km (2,159 miles) is more than a quarter that of Earth’s diameter. No other planet has such a relatively large satellite.



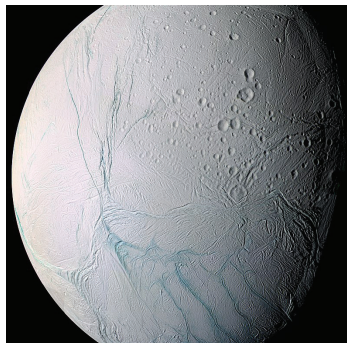
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FIGURE 28.6. Phobos is a small moon with many craters that orbits Mars. At 22 km (14 miles) in diameter, it is too small for gravity to make it spherical.



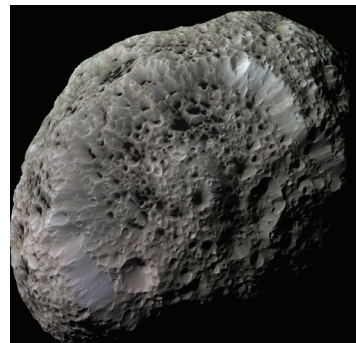
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FIGURE 28.7. Io (pronounced like “eye-oh”) orbits Jupiter. It is 3,643 km (2,264 miles) in diameter. Covered in **sulfur volcanoes**, it is the most volcanically active object in the Solar System.



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FIGURE 28.8. Europa orbits Jupiter. It is 3,121 km (1,940 miles) in diameter. A thick layer of ice covers its surface, and beneath that is a huge ocean of water.



▲
FIGURE 28.9. Enceladus orbits Saturn. It is covered in snow that continually forms from the water that sprays up from the geysers on its surface. It is 504 km (314 miles) in diameter.



▲
FIGURE 28.10. Hyperion orbits Saturn. It is a potato-shaped moon, mostly made of ice, which looks a lot like a sponge. It is 360 km (224 miles) long and 205 km (128 miles) wide.

The hardest thing to grasp about space is how huge it is. Although the Sun is gigantic compared to our planet, in the vastness of space, the Sun is utterly tiny! The actual distance from the Sun to the Earth is about 150 million kilometers (93 million miles).

You could fit 23,000 Earths lined up side-by-side in this distance! If we imagine the Sun as the size of an exercise ball (67.5 cm in diameter), then the Earth would be the size of a baby pea (0.62 cm in diameter), about one hundredth the diameter of the Sun (see Figure 28.11). At this scale, we would need to put the Earth 75 meters (240 feet) away from the Sun to accurately represent how far apart they are (see Figure 28.12)! Jupiter (the largest planet) would be nearly 400 meters away from the exercise-ball-Sun, Saturn would be 700 meters, and the farthest planet, Neptune, would be more than 2 km away! Just imagine those eight little balls of our solar system orbiting that blue exercise ball in an area about 12 times larger than the Old City of Yerushalayim! All this makes you start to realize how truly vast and utterly empty space is. But you have actually not even begun to fathom it at all. At this scale, the closest star to our Sun, named Proxima Centauri, would be a mind-



▲
FIGURE 28.11. With a diameter 109 times larger than the Earth, if the Sun were the size of the exercise ball, the Earth would be the size of a small pea.

blowing 20,000 kilometers away from the exercise ball. That is more than the distance from New York to Yerushalayim and back again!

Besides for the eight planets and their satellites, there are billions of smaller objects that orbit the Sun. Most of these are found in two bands. Between the orbits of Mars and Jupiter is