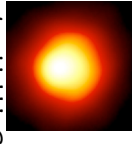


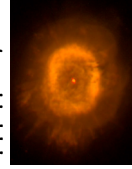
Shown above is a Hubble Space Telescope image of Betelgeuse. This is the first detailed image of the surface of a **star** other than the **Sun**. Betelgeuse is a "red supergiant". It is 1 000 times the size of the **Sun**. Ten million years ago, it was a blue **star**, only 5 times larger than the **Sun** and with a surface temperature of 30 000° C (now it is 3 600° C).

All **stars** evolve. During most of their lives, they burn hydrogen in their cores but they do not change on the surface. When the hydrogen fuel runs out, the cores shrink while the external layers swell and cool. A giant **star** forms.



1 000 000 000 000 m

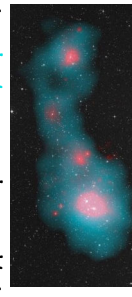
Shown above is a Hubble Space Telescope image of the **planetary nebula** BD+30-3639. **Planetary nebulae** have nothing to do with **planets**! They are the last episodes in the life of **stars** similar to the **Sun**. After a **star** has become a giant, it loses its external layers. What remains of the **star** is just a dense core which shrinks and heats up to very high temperatures and is able to excite the ejected matter. BD+30-3639 is one of the smallest **planetary nebulae** studied in detail. Yet its diameter is 1.2 10<sup>15</sup> m, and exceeds that of the Solar system.



1 000 000 000 000 000 m

Most **galaxies** are clumped into **clusters of galaxies**, and clusters into **superclusters**, which are the largest structures known in the **Universe**.

The **Shapley supercluster** contains about 8000 **galaxies** and extends over 100 million light-years. It is permeated by hot gas whose mass dominates that of the **galaxies**. The above image shows its core. We can see the hot gas detected in X-rays (in pink) and at microwave wavelengths (in blue), as well as hundreds of **galaxies** (the small white dots).



1 000 000 000 000 000 000 000 m

This is an **asteroid** threatening to impact the **Earth** as imagined by Oliver Denker.

In February 2018, the **asteroid** named 2002 AU129 flew past the **Earth** at a distance of 4 million km. Its size is estimated to be 1 km. Scientists think that the impact of an asteroid only ten times larger than this killed all the dinosaurs on **Earth**, about 60 million years ago.



1000 m

The tallest waterfall in the world, **Kerepakupai-meru** in Venezuela, is nearly 1 km high.



The Universe in my pocket

The sizes of celestial bodies

TUIIMO No. 11 THE UNIVERSE IN MY POCKET

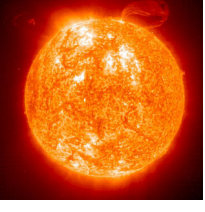
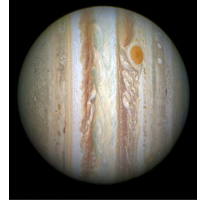
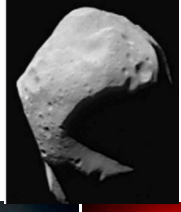
Grażyna Stasińska Paris Observatory



Classify these objects in order of increasing size

Answers on overleaf

Quiz

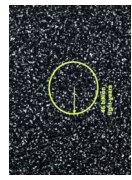


10<sup>27</sup> m: The observable Universe

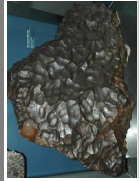
The **observable Universe** is a sphere containing all the matter that could in principle be observed. Its size depends on the age of the **Universe** and on its expansion rate. It is estimated to be almost 10<sup>27</sup> m in diameter.

It is impossible for us to know what happens beyond this sphere, since the light emitted beyond has not had time to reach us in the 13.8 billion years that the **Universe** exists.

In the picture shown above, the **Universe** is the same outside the boundaries of the **observable Universe**.



1 m: Meteorites



**Meteorites** are also debris of **comets** or **asteroids** that have reached the ground, but they are larger than **micrometeorites**. Their sizes go to several meters.

They come in various shapes and compositions. The composition tells scientists about their origin. The **Murchieson Meteorite** found in Australia in 1909 and shown above is made of iron and is about one meter in size.



Just like a four-year-old boy!

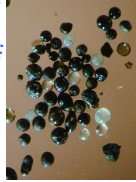
1 m



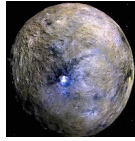
0.001m

The image on the right shows sand grains. They are similar in size and shape to micrometeorites.

**Micrometeorites** are small debris of **comets** or of **asteroids** which have managed to reach the **Earth** as tiny spheres of roughly one millimeter in diameter. It is by melting during their journey through the **Earth's** atmosphere that they acquire their shape. At night, **micrometeorites** can be observed as shooting stars.



$10^{-3}$  m: Micrometeorites



$10^6$  m: Dwarf planets

Like a **planet**, a **dwarf planet** orbits a star, and is rounded by its own gravity. But, while **planets** are able to remove smaller bodies near their orbits by collision or capture, **dwarf planets** are not massive enough to do this. The **dwarf planet** Ceres, shown above, has a diameter of 1000 km. The **planets** of the Solar system have diameters between 5000 km and 140000 km.



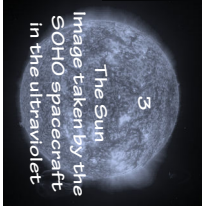
**Asteroids** are smaller than **dwarf planets** and are not round. The dwarf planet Ceres is about the size of Colombia.

1 000 000 m

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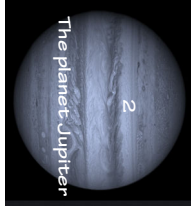
To learn more about this series and about the topics presented in this booklet, please visit <http://www.tumip.org>



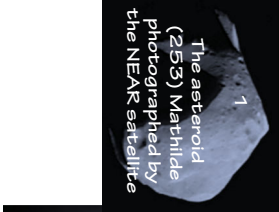
3  
The Sun  
Image taken by the SOHO spacecraft in the ultraviolet



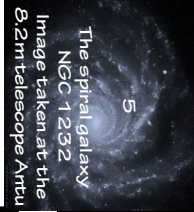
4  
The Cat's Eye planetary nebula  
Photo taken by the Hubble Space Telescope



2  
The planet Jupiter



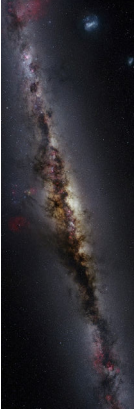
1  
The asteroid (253) Mathilde  
photographed by the NEAR satellite



5  
The spiral galaxy NGC 1232  
Image taken at the 8.2m telescope Arita

**Stars and planets** look like glittering dots on the sky, while the **Sun** and the **Moon** look rather like oranges on a tree. This is because all these objects lie at very different distances: The farther they are, the smaller they appear with respect to their true size. Some celestial bodies are so far away (or so intrinsically faint) that they can be detected only by the largest telescopes. But did you know that some celestial bodies can also be found on **Earth**? In this booklet we explore celestial bodies from the smallest ones that we can see to the largest. On each page the size of the object shown is one thousand times larger than on the previous page. You will discover the amazing range of sizes in the **Universe!**

2



$10^{21}$  m: The Milky Way galaxy

This image is a combination of 37000 exposures collected from all over the **Earth** by Nick Risinger to show the entire Milky-Way galaxy. The Milky Way is a normal spiral galaxy whose disk has a diameter of more than 100000 light years. It contains over 100 billion stars. From **Earth**, it appears as a ribbon of light because the **Sun** is inside the disk. The light from the stars combines in a diffuse glow. The dark patches are due to interstellar dust hiding the light from the stars.

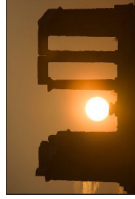
1 000 000 000 000 000 000 m



$10^{18}$  m: A globular cluster

Above is an image of M13, the Hercules Globular Cluster, taken by Martin Pugh. Its diameter is 120 light-years (one light-year, the distance travelled by light in one year, is almost  $10^{16}$  m). Globular clusters are dense groups of old stars. Most are older than one billion years. About 150 globular clusters are known in the Milky Way. M13 contains about 300 000 stars. The central zone is densely populated. It contains more than 300 stars in a sphere of 2 light-years radius. In the same volume around the **Sun** there is only one star: the **Sun** itself!

1 000 000 000 000 000 000 m



$10^9$  m: The Sun

This is a sunset at Cape Sounion, in Greece. Because the **Sun** lies so far from the **Earth**, it looks smaller than the ruins of the temple. But its real size exceeds one billion meters (to be exact it is  $1.39 \cdot 10^9$  m). Aristarchus of Samos, a Greek astronomer, was the first to estimate the size of the **Sun**, about 2 250 years ago. He also suggested that the **Earth** revolves around the **Sun**. That the **Sun** is just a nearby star had already been suggested by the Greek philosopher Anaxagoras, two hundred years earlier.

1 000 000 000 m