



# Let's Observe M31 and M45!

## Observation and Sketch

An 18 century French Astronomer, Charles Messier made a catalogue of celestial objects that appeared blurry. These objects were later called by their number with a "M" at the beginning. Later astronomers have found that his catalogues included many different kinds of celestial objects. The true nature of M31 was especially ground-breaking. Let's observe and compare M31 and M45 and try to discover their true natures.

Name \_\_\_\_\_

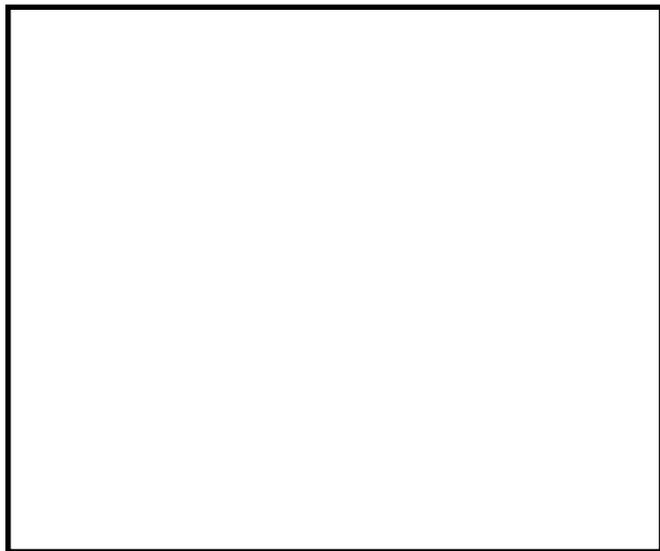
Address \_\_\_\_\_

Age \_\_\_\_\_

■ M45 and M31 look completely different from each other when seen through a telescope. Let's Observe, Sketch and Compare.

**M31** Date    Month    Day    :  
Site    \_\_\_\_\_

Diameter of Telescope    \_\_\_\_\_ cm    Power    \_\_\_\_\_ x



**M45** Date    Month    Day    :  
Site    \_\_\_\_\_

Diameter of Telescope    \_\_\_\_\_ cm    Power    \_\_\_\_\_ x



\* The Power of the Telescope can be calculated by dividing the focal length of the telescope with the focal length of the eyepiece.

\* M31 is darker than M45, so it's hard to find and see.

If you couldn't see it this time, try again when you are visiting places that are darker in the night.

■ Write down what you noticed, and anything peculiar you found.



# Let's Observe M31 and M45!

## Post Observation Study

Name \_\_\_\_\_

■ The photos below are of M31 and M45 taken using a telescope with a large diameter.

Center of M31



M45



Photos provided by  
National Astronomical Observatory of Japan

■ Let's list the characteristics of M31 and M45 from our sketches, observations and photos above.

M31

M45



# Let's Observe M31 and M45!

## Post Observation Study

Name \_\_\_\_\_

### ■M45

M45 is also known as Pleades, or "Seven Sisters" (in English), and "Subaru" (in Japanese)

You can see that M45 is a cluster of stars.

It includes a couple hundred stars and it resides at around 400 light years\* from Earth.

How many stars could you count with your Telescope?

(\*1 light year = the distance light travels in a year = 9.5 trillion km = 5.9 trillion miles)

### ■M31

M31 looks spread out and blurry. You cannot tell whether it is a cluster or not from the pictures or sketches, as you could with M45.

Observations performed in the 19th century proved that M31 was also a cluster of stars.

The reason M31 was blurry and the stars could not be distinguished was because M31 was even further than M45.

## ❓ So, how far is M31? ❓

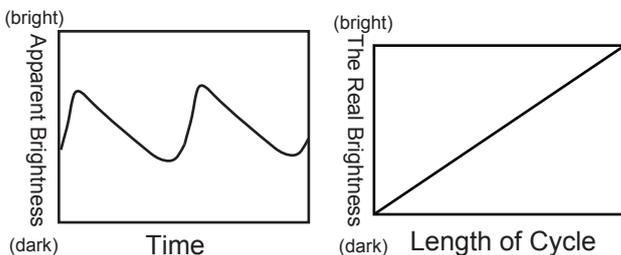
■ There was a debate held between two American astronomers, Harlow Shapley and Herber Curtis, over how far M31 was. Did M31 reside within our Milky-Way Galaxy, or did it exist outside of our galaxy independently?



■ This problem was later solved by Hubble. He used the two following facts.

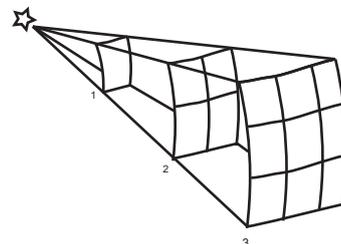
#### 1. Cepheid variable stars

These are stars that turn bright and then dark cyclically. The length of the cycle and brightness correlate: brighter stars have a longer cycle. This means we can calculate the true brightness of a star from its cycle.



#### 2. Relationship between apparent brightness and distance.

As the figure below shows, light disperses as distance increase. If the distance doubles, the brightness decreases to 1/4. If the distance triples, the brightness decreases to 1/9. This means that the apparent brightness of a star is inversely proportional to the square of distance. Thus, we can calculate the distance by comparing the actual brightness of a star and its apparent brightness.



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Name \_\_\_\_\_

## Post Observation Study

Hubble calculated the distance to M31 using these two properties.

First, he measured the cycle of a cepheid variable star in M31.

→ From the cycle, he calculated that star's true brightness.

→ From the difference between the apparent and true brightness he calculated the distance.



**M31 is at 900,000 light years away!**

1 light year = the distance light travels in a year = 9.5 trillion km = 5.9 trillion miles

■ This was three times larger than the width of our galaxy estimated at that time by Sharply: 300,000 light years.

This means ( ) Was right!

→ The Universe is far larger than our galaxy!

→ The fact that M31 looks spread even though it is so far away

means M31 is a very large celestial object!

(Modern Astronomers estimate the size of our galaxy at around 100,000 light years and M31 at around 120,000 light years. The distance between Earth and M31 is estimated at around 2,300,000 light years)

■ Let's draw the relative positions of the Milky-Way Galaxy, M45 and M31 into the figure space at the right.

Let's use a reduced scale of 100,000 light years = 1 cm

(10,000 light years → 1mm)

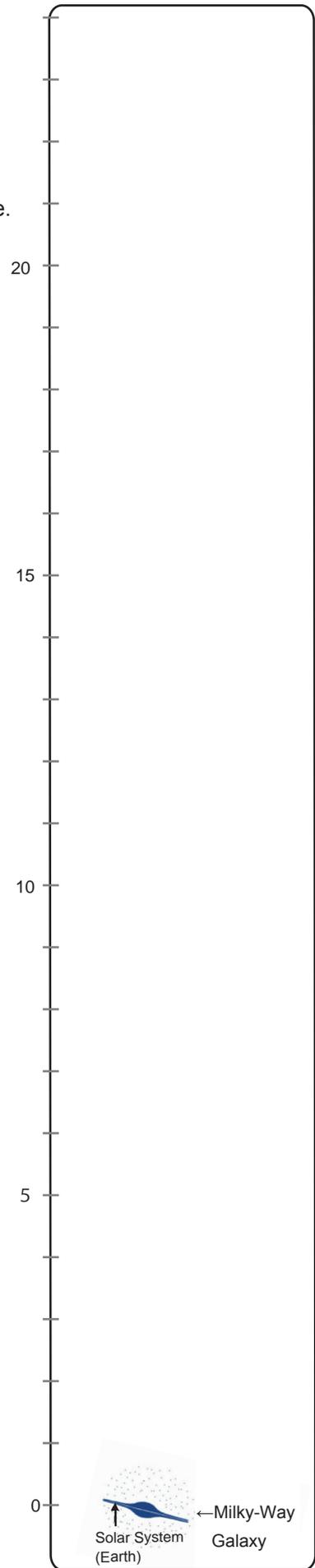
- Milky-Way Galaxy: around 100,000 light years → 1 cm
- M31: around 120,000 light years → cm
- Distance between our galaxy and M31: 2,300,000 light years → cm
- Distance between Earth and M45: 400 light years → mm

(M45 is in the Milky-Way Galaxy)

...Way too close to draw!

\* Earth and M45 are too small to be for its shape to be drawn at this scale. Represent them with dots.

\* You can see that M31 is very large compared to Earth and M45 and that it is very far.



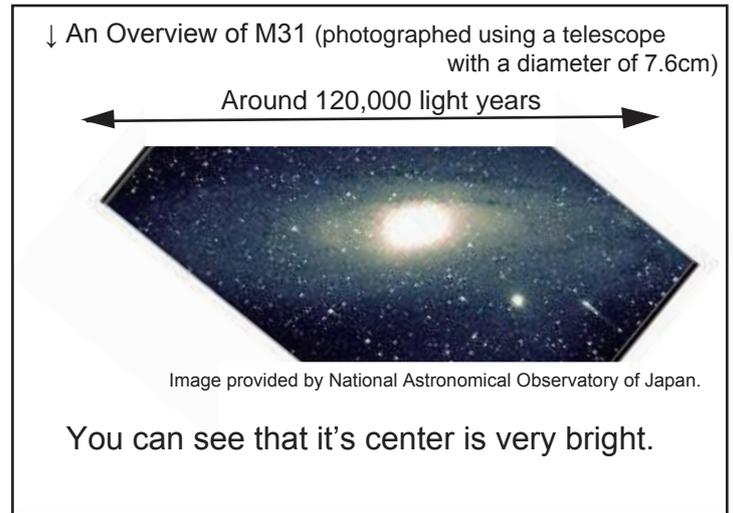
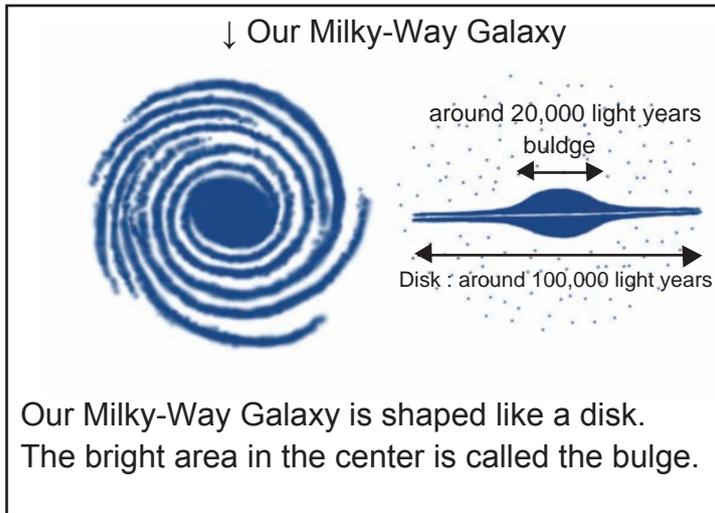


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## Post Observation Study

Name \_\_\_\_\_

What is the true nature of M31 that is so large and far away? Let's consider this by comparing M31 against our Milky-Way Galaxy.



What is M31? Let's write down our thoughts.

This is a image of a part of M31 photographed using the Subaru Telescope.

→ You can see individual stars as white dots!

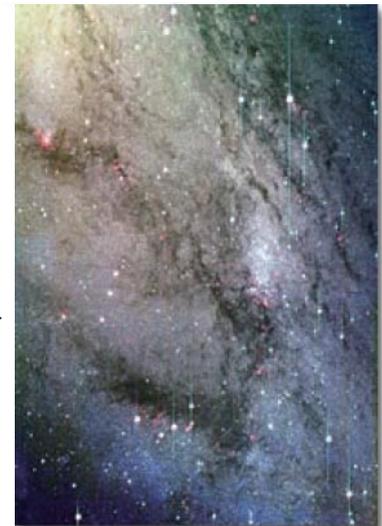


Image provided by National Astronomical Observatory of Japan.

■ Write down what you have learned, and what you want to learn in the future.