

# Tutorial: Looking at Distant Objects – Part I

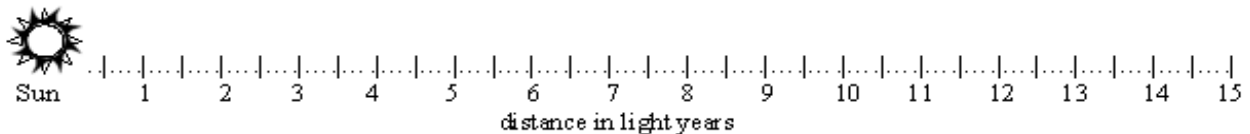
(Adapted from *Lecture-Tutorials for Introductory Astronomy*, ©CAPER Team, Preliminary Edition, 2002)

01. Describe what a light year is (is it time? distance? speed?), giving some measurement comparisons that will help someone who has never taken an astronomy class understand.

Imagine that you have received six pictures of six different children who live near six of the closest stars to the Sun. Each picture shows a child on his or her 12<sup>th</sup> birthday. The pictures were each broadcast directly to you via radio waves on the exact day of the child’s 12<sup>th</sup> birthday. From the closest to the most distant the children are:

- Savannah lives on a planet orbiting Alpha Centauri, which is **4.3** ly from our Sun.
- Peter lives on a planet orbiting Barnard’s Star, which is **6.0** ly from our Sun.
- Celeste lives on a planet orbiting Sirius, which is **8.6** ly from our Sun.
- John lives on a planet orbiting Ross154, which is **9.5** ly (light year) from our Sun.
- Inga lives on a planet orbiting Epsilon Eridani, which is **10.8** ly from our Sun.
- Ron lives on a planet orbiting Procyon, which is **11.4** ly from our Sun.

02. Here is a rough scale, marking the distances from the Sun. We’ll assume – although this is highly improbable – that these stars are situated all in a straight line away from the Sun. Locate each of the six stars accurately on this scale, including each child’s name with his or her star.



03. What were the shortest and longest lengths of **time** that it took for any one of the pictures to travel from the child to you? Relate your answer to the distances to those children.

04. How old did each child look in his or her picture?

05. If each child was 12 years old when he or she sent his or her picture to you, how old was each of the children—in **their** time frame—when you received their picture?

Savannah \_\_\_\_\_ Peter \_\_\_\_\_ Celeste \_\_\_\_\_ John \_\_\_\_\_ Inga \_\_\_\_\_ Ron \_\_\_\_\_

06. Is there a relationship between the current age of each child and his or her distance away from Earth? If so, describe this relationship.

07. Let's change the circumstances a bit. Imagine that the six pictures were broadcast by satellite to you from those planets and that **they all arrived at exactly the same time**. For this to be true, does that mean that all of the children sent their pictures at the same time? Explain your answer.

08. In order for all of the pictures to reach you at the same time, which child sent his or her picture first and which child sent his or her picture last?

9) We can think of a way for these pictures to arrive all at the same time. The child that is the farthest away sends his or her picture first. The next farthest child waits until he or she receives **that** picture, and then sends his or her picture right away. This continues as signals travel to Earth. Figure out how much time passes between each child before he or she receives the pictures from those children farther away, and mark it on the distance scale above.

10) The telescope image at the right was taken of the Andromeda galaxy, which is located 2.5 million light years away from us. Is this an image showing how the Andromeda galaxy looks right now, how it looked in the past, or how it will look in the future? Explain your reasoning.



11) In 1987, astronomers discovered a new supernovae in the Large Magellanic Cloud (the "LMC"), which they named SN1987A. However, the Large Magellanic Cloud is **~50 kiloparsecs** away. When did this supernova actually occur? (Remember that 1 parsec = 3.1 light-years, so that 1 kiloparsecs = 3100 light-years)

12) Although they are many thousands of light-years away, the Andromeda galaxy and the Magellanic Clouds are actually quite close to us, compared to the many other galaxies in the Universe. Astronomers can routinely detect galaxies that are as far as **11 billion light-years** away! Although we are just detecting the light from these galaxies now, how many years ago was the light from these galaxies emitted?

13) Assuming that the Universe is 13 billion years old, what is the maximum possible age of the distant galaxies *as we detect them in these images*? Since the maximum age any galaxy can have today is 13 billion years, are the *apparent* ages of these distant galaxies very young or very old? Explain your reasoning.

## Tutorial: Looking at Distant Objects – Part II

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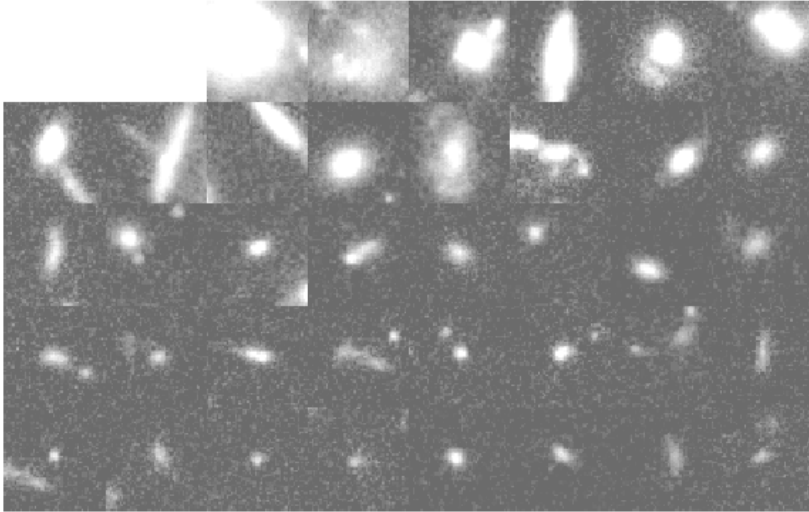
**NOTE: Higher quality, colored pictures will be shown in lecture or in sections.**

Below are snapshots of four groups of distant galaxies. Within each panel, the galaxies are all at similar distances, and show a mixture of bright giant galaxies and lower luminosity dwarfs. However, each of the four panels shows a group of galaxies at progressively larger distances. Thus, each panel shows a collection of galaxies of comparable age, with the first panel showing the oldest, nearest galaxies and the fourth panel showing the youngest, most distant galaxies. You can use these types of images as a Time Machine, letting you observe how the properties of galaxies change with time! (Note: The panels are labeled with the “redshift”  $z$  of the galaxies – the redshift is a measure of a galaxy’s distance, with bigger redshifts indicating larger distances. See information on Hubble’s Law.) Please answer the following questions after carefully reviewing these panels.

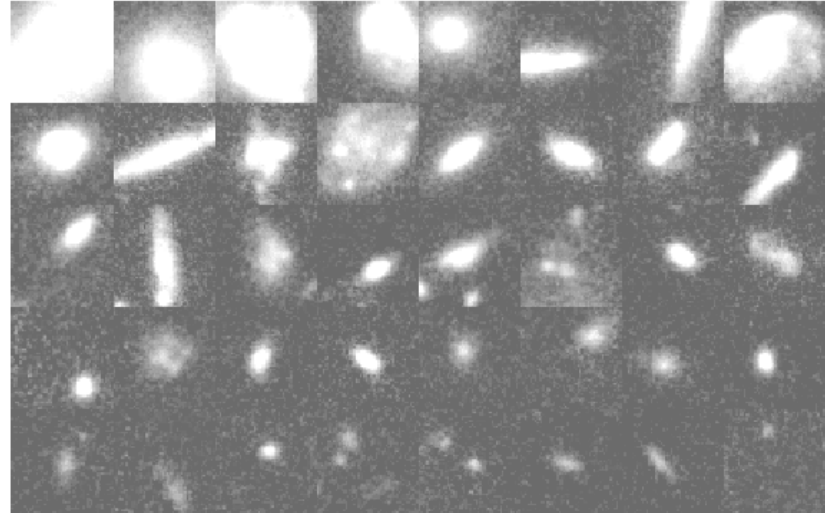
14) How do the morphologies (i.e. shapes) of galaxies change with time? Smoother or lumpier? Bigger or smaller? Add some descriptive comments of your own.

15) Images like those below can be used to explore how the *population* of galaxies evolves with time. However they cannot be used to study how a specific individual galaxy changes with time. Explain why not. If it helps, you may wish to return to thinking about people with identical birthdays sending photographs to you from different planets.

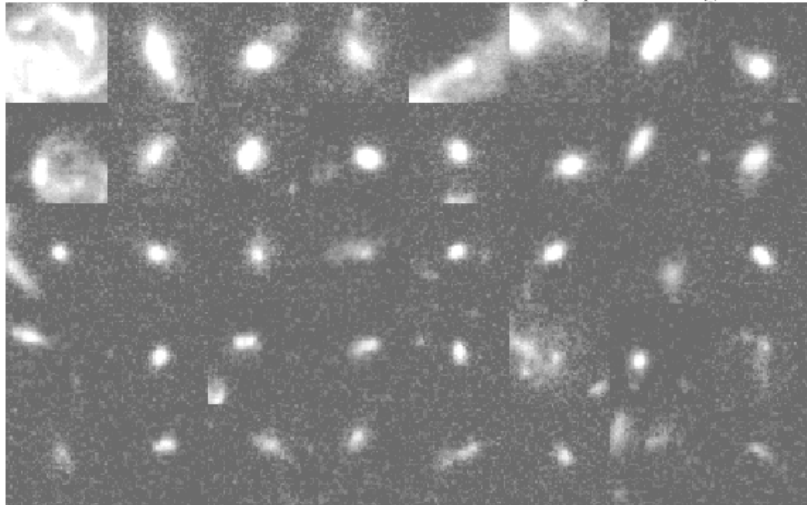
Galaxies at  $z=0.09$ , ~90% of the Universe's present age



Galaxies at  $z=0.63$ , ~50% of the Universe's present age



Galaxies at  $z=1.16$ , ~30% of the Universe's present age



Galaxies at  $z=3.21$ , ~10% of the Universe's present age

