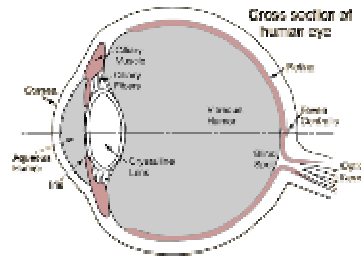
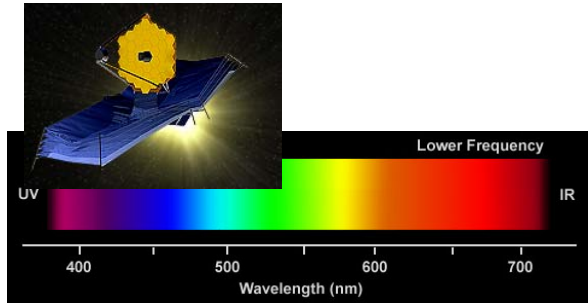


# Relating to the James Webb Space Telescope

measure the performance of your eyes



Our eyes are like telescopes. Both have an opening to collect light and an optical element (lens or mirror) to focus that light into an image.

Our eyes are also like the instruments attached to telescopes. Both have light sensors at the focus to respond to the image and both produce data that the brain interprets.

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## I. "Light Gathering Power"

In daylight the opening in the human eye is about 1-2 millimeters across. At night the eye becomes "dark adapted" and the opening enlarges to about 6 millimeters to collect more light. The opening of JWST is 6 meters across, about 1000 times larger, so it lets in more light than the naked eye. Since the eye and JWST have circular openings, they collect light over the area of those openings, not just the width. For this reason, JWST is one-million times (1000x1000) more light sensitive.

How sensitive is your eye? Use the attached star chart of the Orion constellation to measure the "limiting magnitude" of your eye while you get dark adapted to the night sky. Fill in the blanks below to characterize your eye.

My eye can see to a "limiting magnitude" of \_\_\_\_\_.

It takes my eye about \_\_\_\_\_ minutes for my eye to get fully dark adapted.

## II. "Exposure Time"

More light can also be collected during a long exposure. The human eye takes about 10 pictures every second, one picture every 0.1 second. Instruments on JWST, like NIRCams, can take much longer time exposures to collect even more light and record much fainter objects.

How much more light would be collected if your eye could take a one hour exposure instead of its normal 0.1 second?

\_\_\_\_\_ (minutes per hour) **times** \_\_\_\_\_ (seconds per minute) **times 10** (eye exposures per second) = \_\_\_\_\_

So, JWST collects more light than the human eye for two reasons: larger area and longer time exposures. Together these effects mean allow JWST to see \_\_\_\_\_ times fainter than the human eye.

### III. "Field-of-View"

The human eye is designed to see a wide angle all at once. It has a large "field-of-view" of about 180 degrees. In contrast, JWST is designed to study small regions in great detail so it has a small field-of-view, about 1/60th of a degree (one arc-minute).

The Orion constellation is about 20 degrees across between the stars Betelgeuse and Rigel. Go outdoors to view Orion and try to estimate the angle between the three stars in Orion's belt. The angle between Mintaka and Alnilam appears to be about \_\_\_\_\_. The angle between Alnitak and Alnilam appears to be about \_\_\_\_\_.

### IV. "Resolution"

The diameter of a telescope determines its ability to "resolve" small details in an object of interest. JWST is 1000 times wider than the human eye so JWST makes images about 1000 times sharper than the human eye.

You can compare the resolution of your eye to that of a telescope by examining the stars in the Pleiades star cluster.

The Pleiades cluster is about 2 degrees across. My eye can see stars in the Pleiades separated by about this angle \_\_\_\_\_ degrees.

The binoculars will also collect more light than your eye and reveal stars that are invisible to the eye.

How many Pleiades stars can you count using your eye alone?: \_\_\_\_\_

How many Pleiades stars can you count using binoculars?: \_\_\_\_\_

### V. "Spectral Response"

The human eye has a "retina" to sense the presence of light. The retina has "rods" to sense the amount of "visible" light and "cones" to sense particular color (blue, green, red).

If you have excellent color vision and light sensitivity, you may be able to see that the stars Betelgeuse and Rigel in Orion have much different colors.

The color of Betelgeuse is \_\_\_\_\_. The color of Rigel is \_\_\_\_\_. The color of stars in the Pleiades is \_\_\_\_\_.

JWST is designed to sense "infrared" colors of light about 3-30 times redder than the limit of the human eye. Infrared light penetrates into the gas and dust of the Orion Nebula to reveal newly formed stars emerging from their cocoons. If your eye could see radio wavelengths of light, the glowing gas clouds of star formation in the Orion Nebula would appear more than 10 degrees across!!

## VI. "Look Back Time"

Compared to our naked eyes, modern telescopes collect more light and reveal fainter objects. Celestial objects are often fainter because they are farther away, so it takes their light some time to make the journey to us. Thus, the light that reaches us is old, and we see objects as they appeared in the past. JWST's near-infrared camera (NIRCam) is designed to see the **first** objects that began to shine in the early Universe, some 13 billion years ago. How far back in time has your eye seen during various parts of this Astronomy Camp?

A. What is the most distant object you have seen with your naked eye during the daytime?

\_\_\_\_\_

What is its distance?:

\_\_\_\_\_

B. What is the most distant object you have seen with your naked eye during twilight?

\_\_\_\_\_

What is its distance?:

\_\_\_\_\_

C. What is the most distant object you have seen with your naked eye at night?

\_\_\_\_\_

What is its distance?:

\_\_\_\_\_

D. What is the most distant object you have seen with your eye through the 60" telescope?

\_\_\_\_\_

What is its distance?:

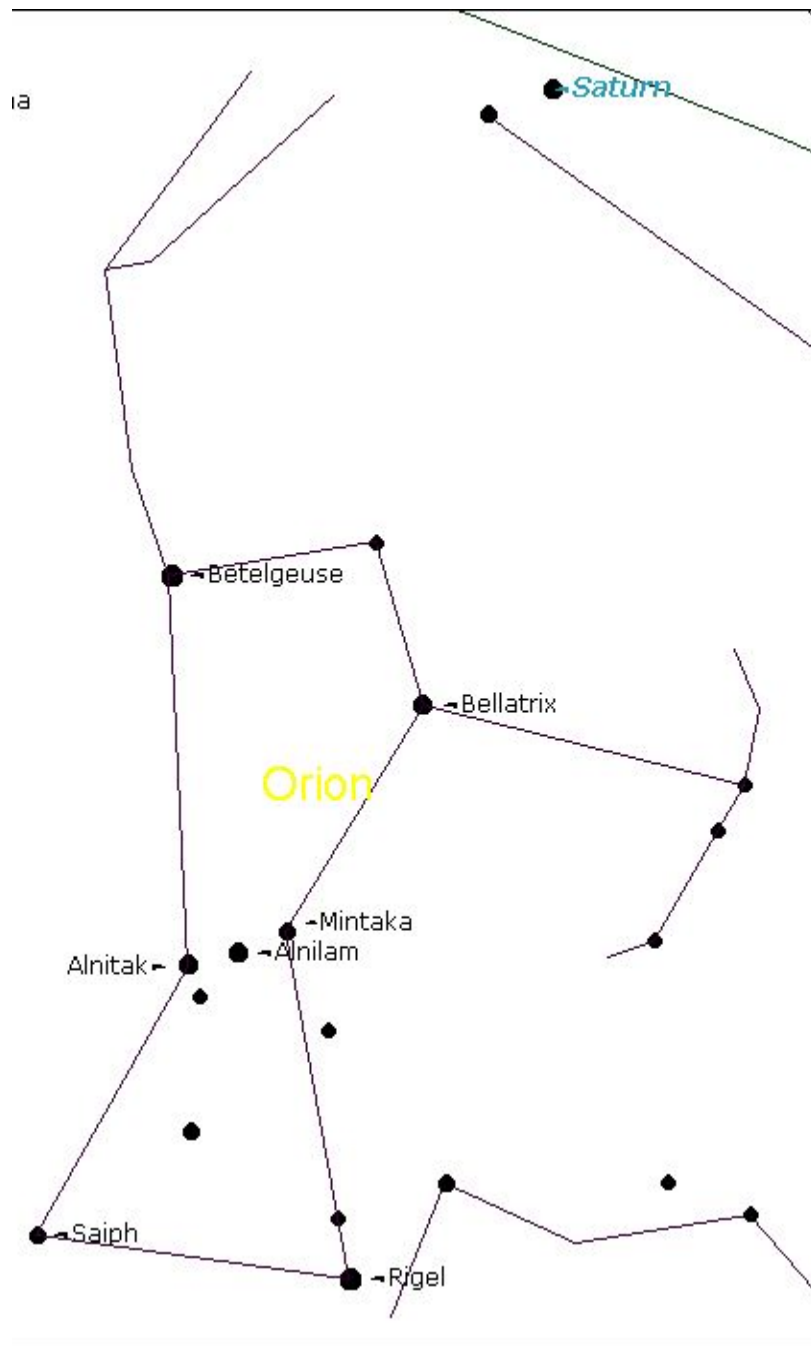
\_\_\_\_\_

E. What is the most distant object you have seen with a CCD camera and the 12" telescope?

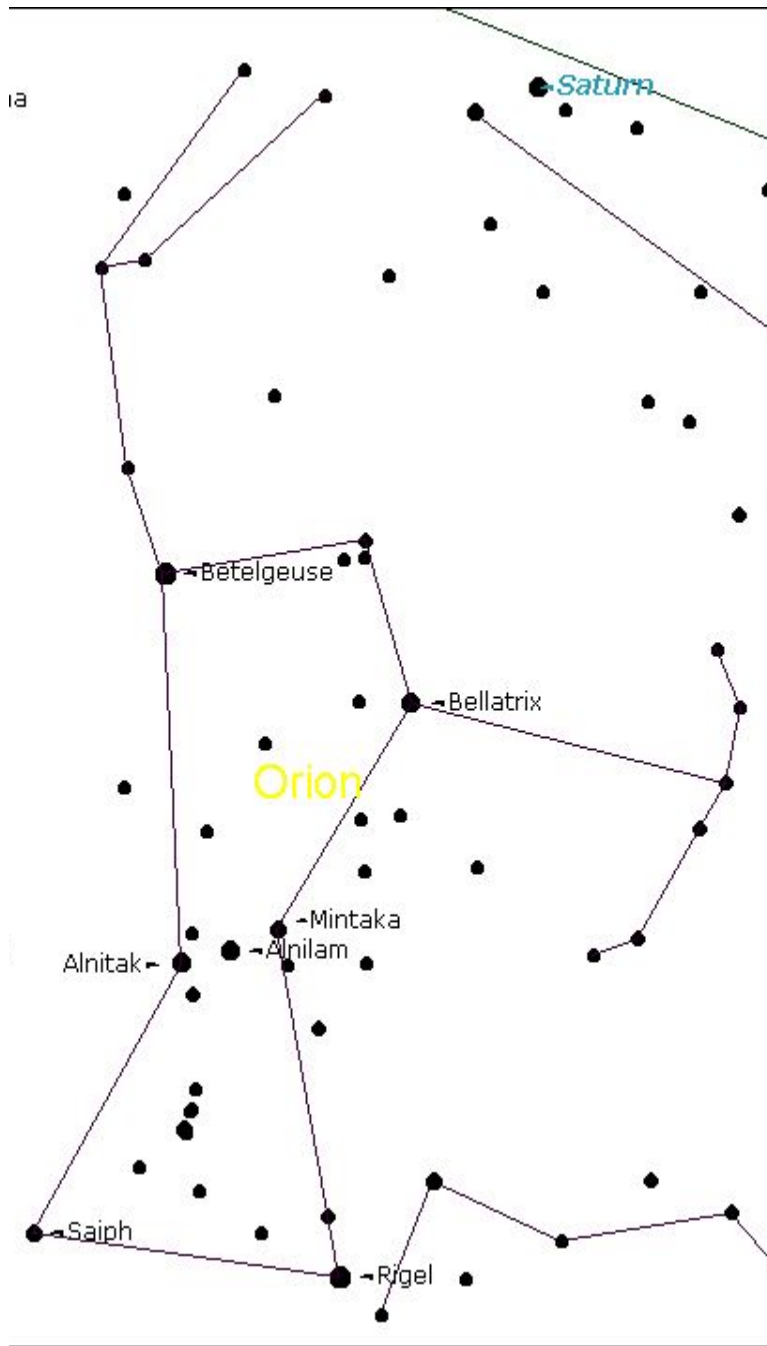
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What is its distance?:

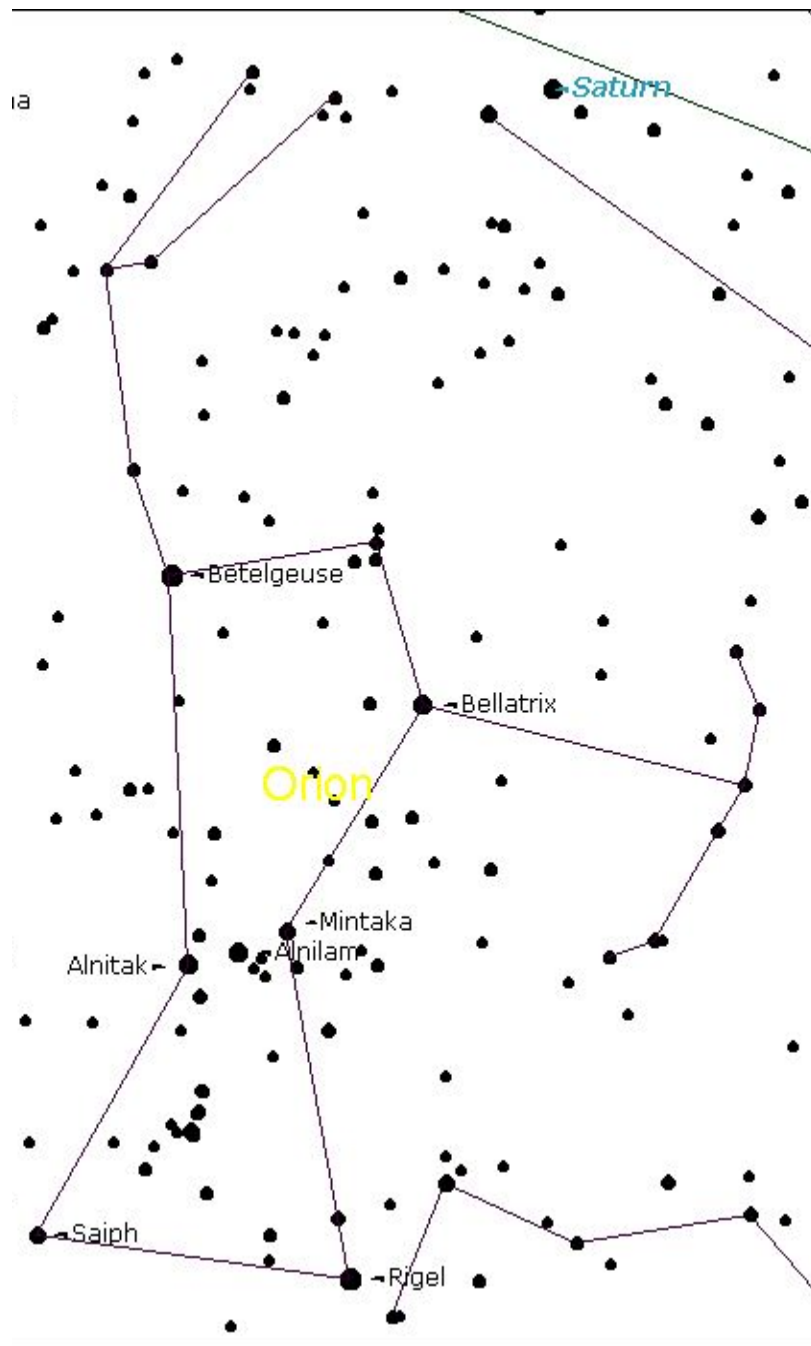
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**Limiting magnitude = 4<sup>th</sup> magnitude.**



**Limiting magnitude = 5<sup>th</sup> magnitude.**



Limiting magnitude = 6<sup>th</sup> magnitude

