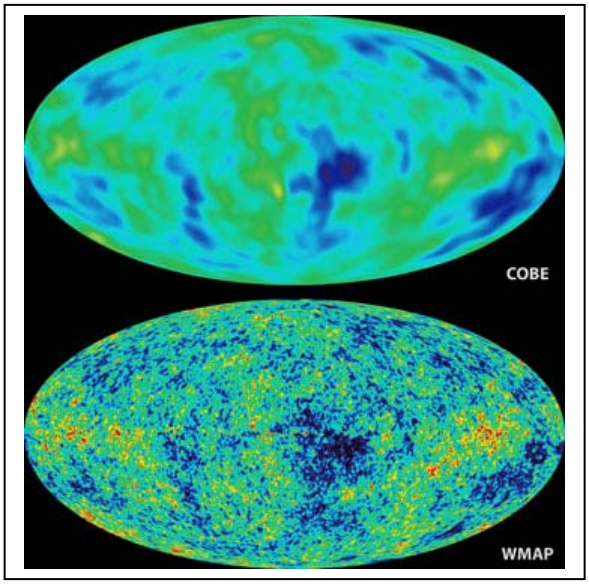

The Webb Space Telescope uses a very large mirror to enable astronomers to see distant objects more clearly. This is a very important goal of this telescope since astronomers know so little about how objects look far from Earth. In the universe, viewing objects at a great distance also means that you are seeing them as they were long ago.

The scientific mission of the Webb Space Telescope is to study how galaxies like the Milky Way formed when the universe was only a few million years old compared to its current age of over 13 billion years.

The image above shows the sky imaged by the COBE satellite with a 7-degree resolution compared to the WMAP satellite with a 1/2-degree resolution. Note the increased detail with WMAP.

The sky is measured in angular units (degrees, minutes, seconds) but we would actually like to know how many kilometers a given angular measurements corresponds to. The simple formula below relates size to distance and angular width:

$$L = \frac{\theta}{206265} d$$

where θ is the angular diameter in arcseconds, d is the distance to the object in light years and L is the actual diameter of the object in light years. Note that for closer objects, L and d will both be in units kilometers.

The smallest feature that the human eye can see on the moon has an angular width of about 2 arcminutes or 120 arcseconds. The smallest feature that the Webb Space Telescope Near Infrared Camera (NIRcam) can see clearly has a width of about 0.032 arcseconds per pixel.

Problem 1 - What is the width of the smallest feature that the human eye can see on the moon at the distance of Earth, d = 384,000 kilometers?

Problem 2 - How far, d, would a planet the size of Earth (L = 12,800 km) have to be in order for the Webb Space Telescope to just see it (θ = 0.032 arcseconds)?

Problem 3 - Suppose that the most distant object that can be detected by the Webb Space Telescope is located 13 billion light years from Earth. What would be the minimum diameter of this object, L, at the maximum resolution of the telescope?

Problem 1 - What is the width of the smallest feature that the human eye can see on the moon at the distance of Earth, d = 384,000 kilometers?

Answer: $L = \frac{120}{206265} x 384,000 km$ so L = **220 kilometers**

Problem 2 - How far, d, would a planet the size of Earth (L = 12,800 km) have to be in order for the Webb Space Telescope to just see it (θ = 0.032 arcseconds)?

Answer: $d = \frac{206265}{0.032} x 12,800 km$ so **d = 83 billion km**.

Problem 3 - Suppose that the most distant object that can be detected by the Webb Space Telescope is located 13 billion light years from Earth. What would be the minimum diameter of this object ,L, at the maximum resolution of the telescope?

$L = \frac{0.032}{206265} x 13 \text{ billion light years}$ so **L = 2,000 light years**

Note: In Problem 3, no correction has been made for the fact that over these great distances, the curvature of space causes the relationship between angular size and distance to be different than the formula used, which is only valid for the geometry of flat 'Euclidean' space.