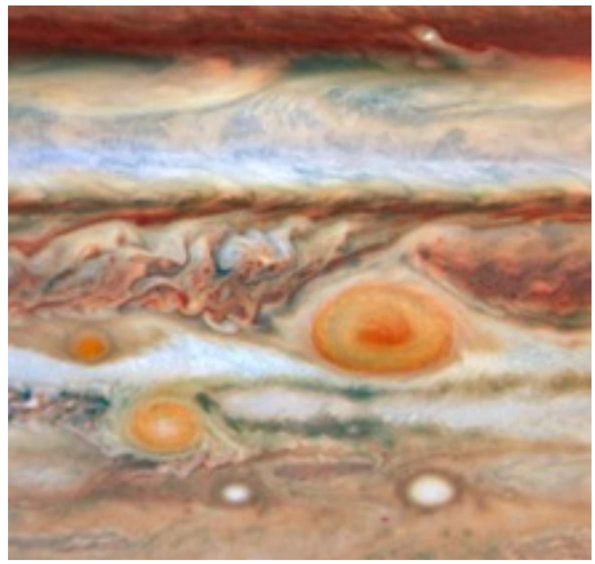
Computer science is no more about computers than astronomy is about telescopes.
Edsger Dijkstra

Giant Eyes

Hi Astronomy 111. In this module, we will explore the two most important properties of a telescope and the basic designs of telescopes.

Small gathering area

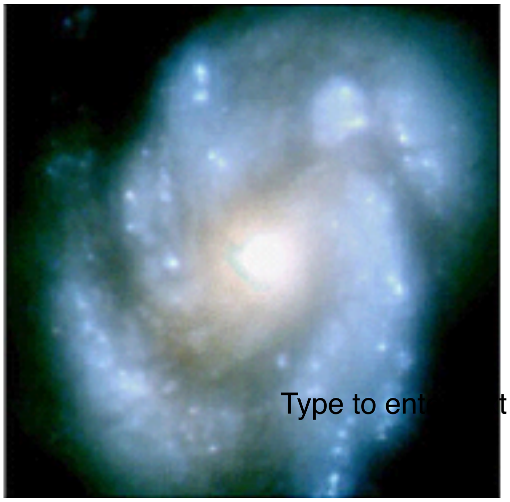
Credit: NASA



Large gathering area

The first important property of a telescope is its light-collecting area. They're light buckets, so the bigger the bucket, the more dim light you can get, the more information you get out of the light. Size matters.

Jupiter through a 10 inch telescope on Earth, a light bucket that's 10 inches across, is shown in the left image above. The image on the right is a zoom on near Jupiter's Great Red Spot from a 96 inch telescope in space (Hubble), so the light bucket is almost 10 times bigger. There's clearly a difference in the amount of light that you get from the image. This is one reason why astronomy keeps building larger and larger telescopes: so that you can see fainter and fainter objects, because you're getting more and more photons. Your light bucket is getting bigger, and so you can see farther, you can see dimmer.



Low

Credit:Wikipedia,
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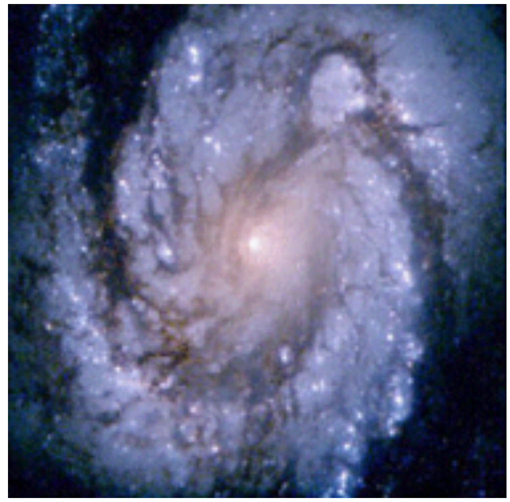


High angular

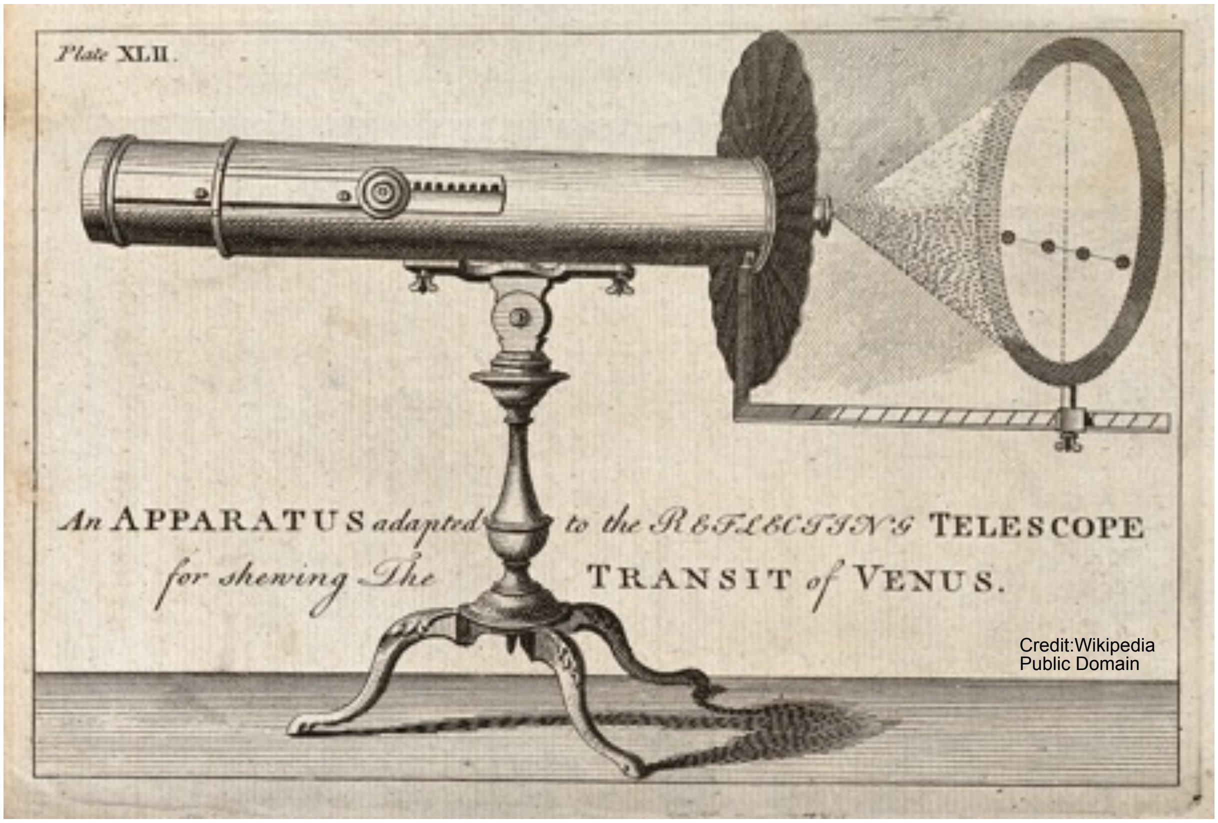
The second important property of a telescope is its angular resolution -- how much detail it shows. The image on the left above shows a low angular resolution galaxy. The image on the right shows a high resolution version of the same galaxy, and clearly there's more detail in the one on the right. It's not so blurred out.

There are lots of factors that affect the angular resolution, from just the quality of the optics that you're using to the scattering effects of Earth's atmosphere. But the ultimate limit is from the interference of light waves, and it's called the diffraction limit. That diffraction limit depends directly on the size of your telescope, on the size of your light bucket. So the size of that telescope affects the two main properties: it affects how much light you get, and it affects the resolution that you get from the telescope. Hence the drive to build bigger and bigger telescopes, not only to get more light, but you get more resolution for that light that's coming in.

In summary, the two reasons we build larger telescopes are:

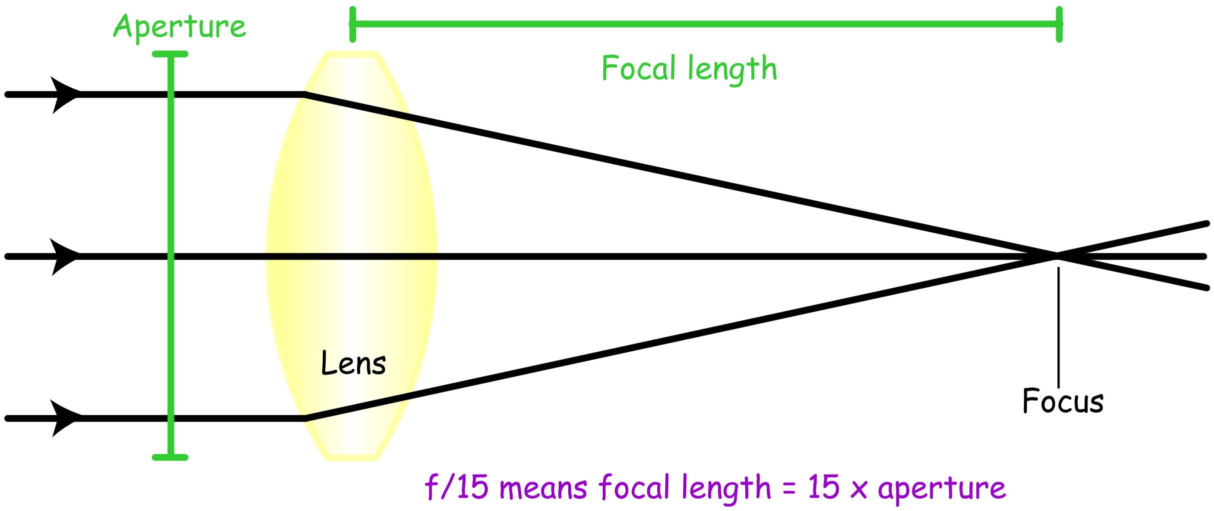
1. **To collect more light, so we can detect dim objects**

2. **To have higher resolution, so we can produce clearer images**



An unimportant property of a telescope is its magnifying power. Since the amount of detail that you get an image is set by its angular resolution, high magnification doesn't show you any more detail. If you've got a crappy image, making it big doesn't make it any better. Then you just have a big crappy image. So magnifying power is not important in a telescope.

Let’s put this in perspective. A microscope magnifies to show us things too small to see. So here magnifying power means a lot. Magnifying power is what you want out of a microscope. A telescope gathers light to show us things too faint to see. So if you go out and buy a telescope, never buy a one based on the fancy advertising, like the image above, that brags about its magnifying power. It’s an unimportant property. What matters is the size of the light bucket, the size of your lens, the size of your mirror.



Credit:F.X. Timmes

So there are two basic designs in telescopes: lenses and mirrors. They're called refracting telescopes and reflecting telescopes. An example of a refracting telescope is shown above. Basically, a lens is like your eye. The light comes in from infinity, gets focused down into a focal point, which is where you put your detector - your CCD detector, your film, your photomultiplier tube. This is an older technology, but for certain classes of observations, it's still the preferred type of telescope.

Credit: Wikipedia
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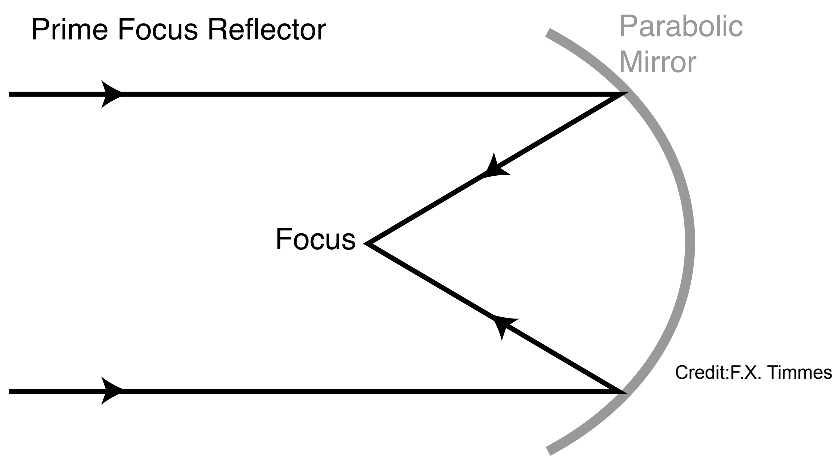
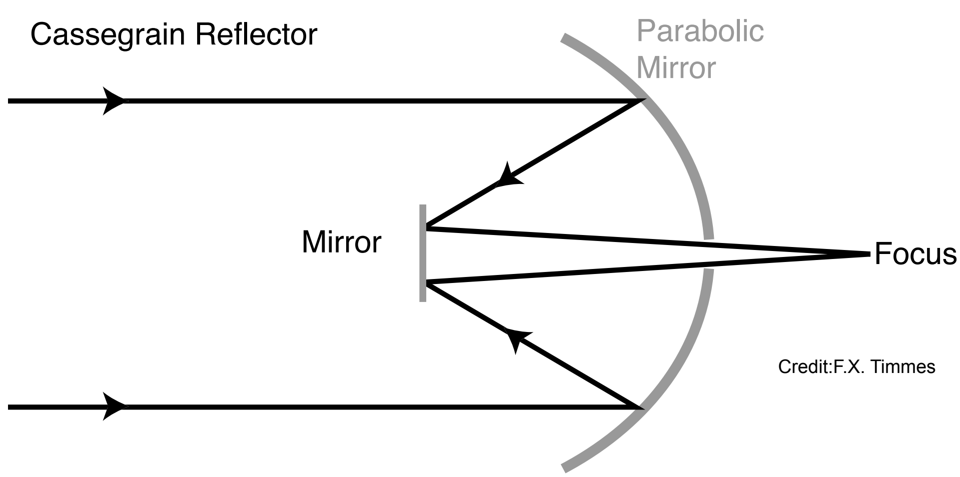
The biggest refractor telescope in the world is shown above. That's at Yerkes Observatory in Wisconsin. That's about a 60 foot tube! That's kind of the maximum size you can build a refracting telescope, because if you build one any bigger, the sheer weight of the lens causes it to deform in Earth's gravity. The lens starts to sag and distorts the image. And so that's about as big as you make a refractor. Plus they're very heavy and they take a big dome, because a 60 foot tube that spins around needs a pretty large space.

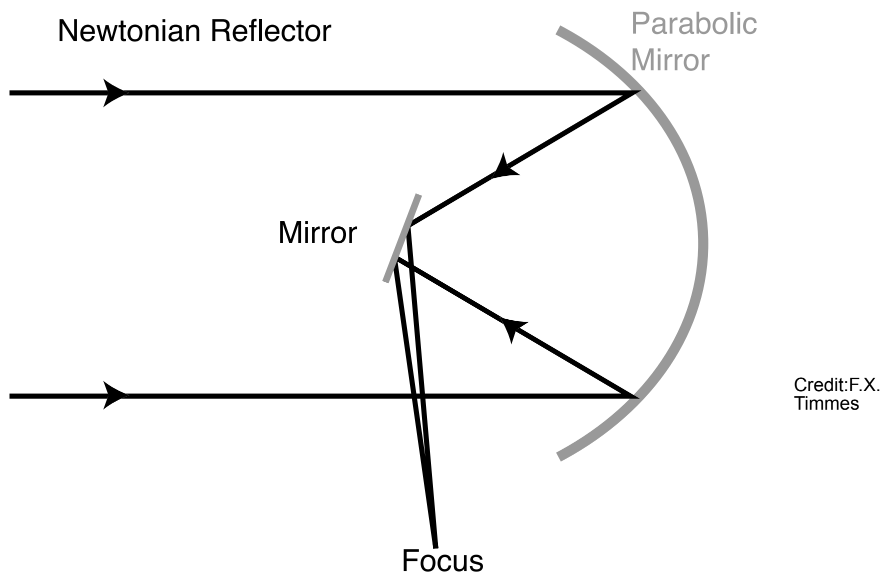
The second type of telescope is a reflecting telescope, which forms an image by focusing light with mirrors. This first came up in an art show in Paris in about the 1850s or so, where some enterprising artist had found out a way to deposit aluminum on glass to create a shiny aluminized vase. Astronomers picked up on this technology of putting a reflective surface on a piece of glass, and they pointed it toward the sky. And this is the most common design these days, a reflecting telescope.



So it's a parabola -- light comes in from infinity, it hits the mirrored surface of the mirror, and focuses it to a point, as illustrated by the image above. Then somehow, you're going to put your detector there. Obviously, you can't just hang your detector, your CCD, or your film right there at the focal point, because it would have no support, plus you'd block out some of the light. So you have to decide, how are you going to get the light away from the focal point? The most popular design today is referred to as a Cassegrain. That's shown in the image below, where the light comes down the tube and hits your primary mirror. It then hits a small, flat secondary mirror, which then redirects the light through the back end of the telescope.



Once you've decided you're going to put a little secondary there to redirect the light, you've lost that area. So make lemonade from a lemon. Put a little hole in the back of the mirror, and that's where the light is focused after it hits the secondary, as shown in the image above. The focus is where you put your detectors -- on the back of the telescope where you've got all kinds of structural support. This design also has the advantage of effectively folding the telescope in half. So instead needing a 60 foot tube for the same size mirror, you only need a 30 foot tube to cover the telescope.



There are other kinds of designs. One of them is called a Newtonian, where you focus the light on the side of the telescope tube as shown above.

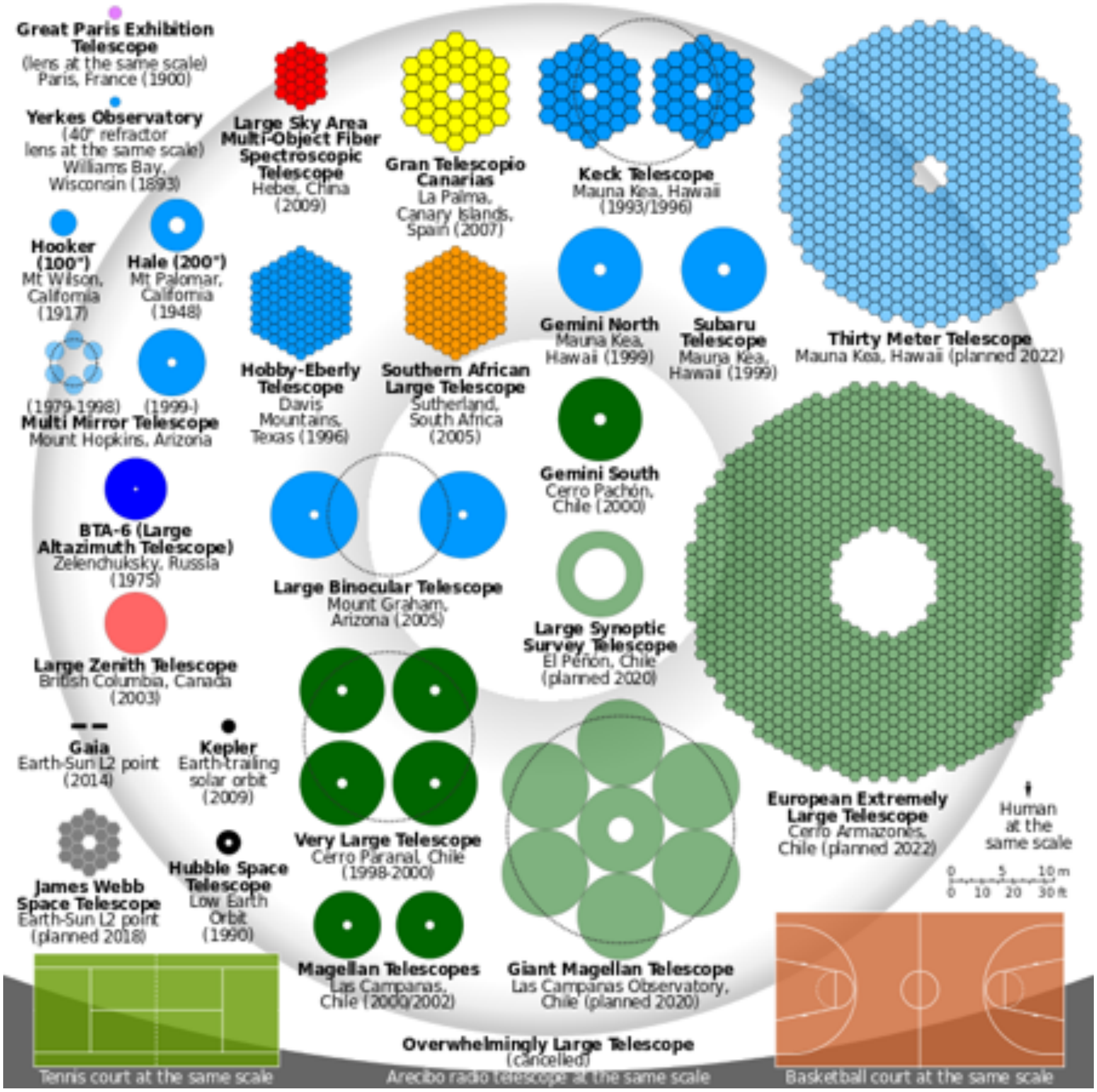
So even mirrors, if you make them big enough -- which is the driver, bigger light buckets -- they start to deform under Earth's gravity. You can only make them so massive. So starting around the 1990s, all kinds of new technology came on to start making ever bigger mirrors, but by not making them as massive as if you had a single piece of glass.

One type of technology, shown in the history of telescopes image below, is to use a bunch of small hexagonal mirrors, like honey bee combs. Behind every bee comb are accentuators, push-pull rods that then tilt and bend each thin hexagonal mirror into the right shape, so that the whole configuration acts as one big mirror.

Obviously this requires some fancy computer technology and servo technology so that you can get all of these things operating in unison at once, in real time. But it can be done and is used nightly at the twin Keck telescopes in Hawaii.

Another technology is to make the glass super thin, as though it were a contact lens. Again, you apply the same computer controlled push-pull rods to bend the contact lens into the correct parabolic shape. An example of technology in the image below is the Large Binocular Telescope in Arizona.

Thanks! Bye Bye.



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