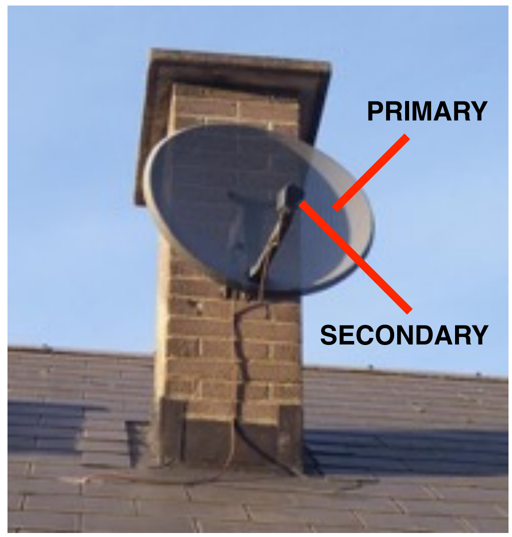
Science, my lad, is made up of mistakes, but they are mistakes which it is useful to make, because they lead little by little to the truth.

Jules Verne

Catching Bullets of Light

In this module we'll finish our explorations of light and telescopes before moving onto planets proper. We'll talk a little bit about how telescopes view other types of light, X-rays, gamma rays, ultraviolet, infrared. And how stringing multiple telescopes together can work as one large telescope.

Credit: Wikipedia
Public Domain



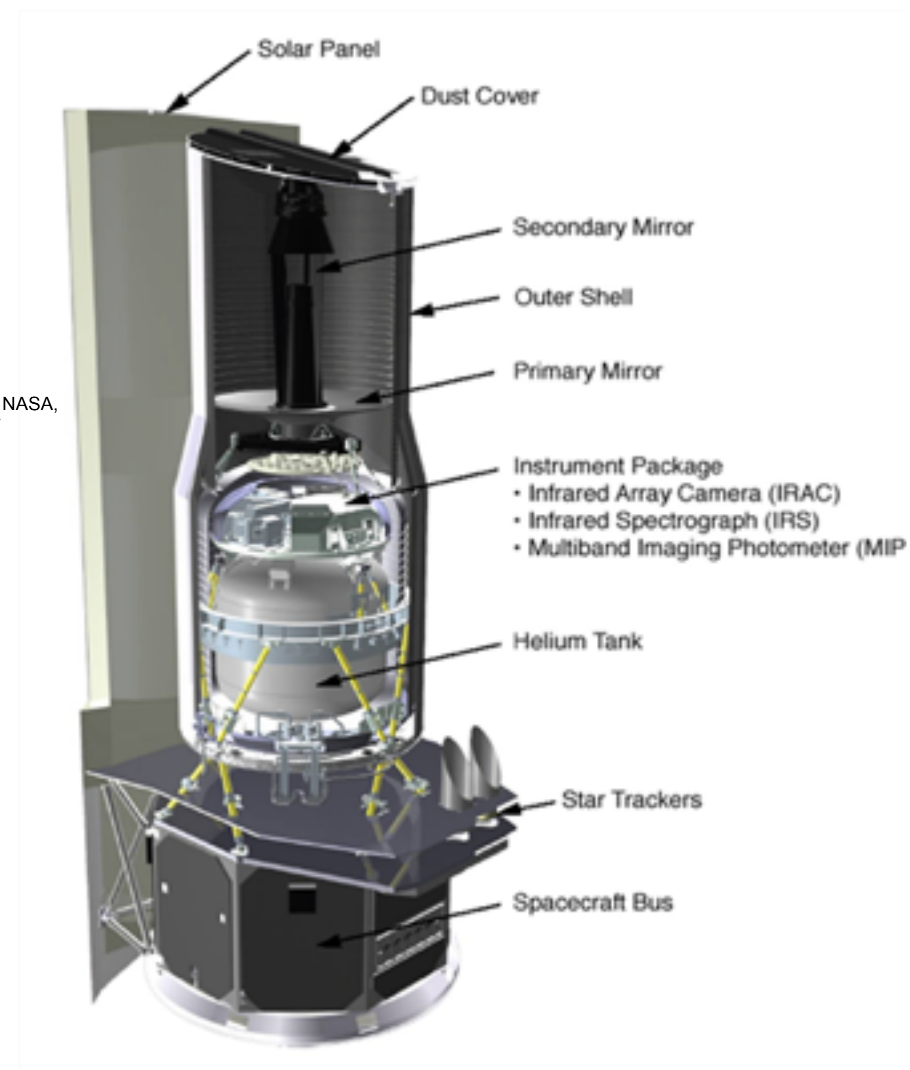
For longer wavelengths, such as radio waves, telescopes often use variations on the design of a reflecting telescope for optical light. You're probably already familiar with this as TV dishes from the 1980's looked liked the image on the left while a modern TV dish looks like the one on the right. The television signal, which is at radio wavelengths, come in. They bounce off that dish, known as the primary. They are then focused onto the collector, the secondary. From there, the signals are transformed into the signals your television can interpret to form images and sound.

Credit: Wikipedia
Public Domain

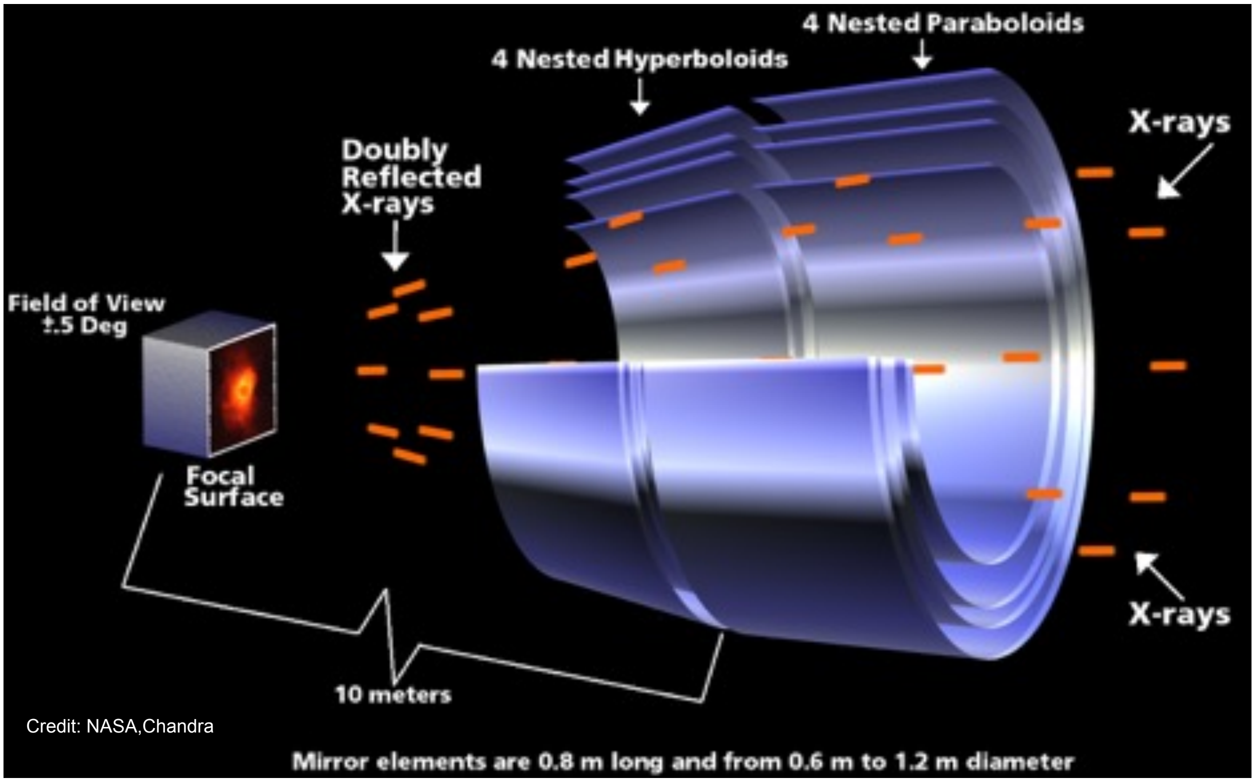
As you go to longer wavelengths, you need bigger dishes, because you need to fit at least one wavelength across the diameter of the dish. The image below is an example of a large radio telescope to pick up long wavelength radio waves. This is the Arecibo telescope in Costa Rica. It sits in a natural crater, and was featured in the movie Contact. You can walk right under it. It looks solid from this angle, but it's actually mesh with holes a couple of inches in size. Those holes don't matter because they are much smaller than the wavelengths being caught.

As usual, the radio waves hit the parabolic primary dish and are reflected up to the focal point where the detectors are located. The detectors are above the dish hanging off of the support structures. From there the information is relayed down to the control room, where it's put into images and spectra of whatever you happen to be looking at.

At shorter wavelengths but still longer than visible light wavelengths, is the infrared. Typically infrared instruments need to be cooled, because lots of stuff radiates in the infrared. Humans radiate in the infrared. Planets radiate in the infrared. Warm telescopes radiate in the infrared. All of that heat will create a background of noise that obscures the tiny bit of heat that we from distant astronomical objects. So in order to get the signal-to-noise down, typically you have to cool the instrument down.



Credit: NASA, Spitzer



The image above is an example of an infrared telescope - the space-borne Spitzer telescope. Basically you're putting all your detectors inside a cold bottle, a dewar, cooled with liquid helium or nitrogen. Its cooled in order to drop the temperature of the instruments so the internal heat from the telescope camera itself doesn't wipe out any chance of detecting infrared radiation from the distant Universe.

For short wavelength, high-energy, photons like X-rays, everything is very different. These things are basically like bullets. You're not going to catch a bullet with a baseball mitt, i.e. a reflecting dish. The X-ray will pass right through it. But you angle the mirror so that the X-ray doesn't it hit dead-on, you can skip the X-rays photons off of multiple mirrors and bring them all to a focal point that way. You make them bounce at grazing incidence, like skipping a rock across the water: Ding, ding, ding, ding. And then into the X-ray detector.

That's what is shown above for the space-borne Chandra telescope. A photon will come in. Its path is bent a little by one of the conical "mirrors". It then goes to the next metal cone, which bends the path a little more. Through a series of multiple reflections, you eventually focus the X-rays onto your detector. Since each reflection only bends the path of the bullet a little bit, the telescope needs to be rather long so that you can get enough bend in the bullet's path to focus it. That's why the Chandra telescope is about 10 meters in length.

Finally, there are advantages to having big telescopes. The larger the telescope, the more light you can collect and the better your angular resolution. But having one big telescope is horribly expensive and very hard to make because things start to sag in Earth's gravity.

One way around this limit is to use lots of smaller telescopes in an array. This is called an interferometer. Interferometry allows multiple telescopes to be linked, which allows them to act as a single, much larger telescope.

It requires exquisite timing, because you have to be able to detect when light comes in one telescope and when light comes in another telescope. And combine those two signals together as though you had one big dish. But we have this kind of timing technology. We have atomic clocks. These atomic clocks are used in GPS, for example. So we can routinely nail time to the billionth of a second. With this kind of timing, you can run interferometry arrays.


Credit: VLA

There's a great example of interferometry in the New Mexico desert, the Very Large Array. Consider visiting it sometime if you get the chance. It's cool. It's 27 radio telescopes, each weighing about 200 tons. They are on railroad tracks arranged in a “Y” configuration. Each arm of the “Y” is 13 miles long. You can have a compact “Y” like what's shown above or a spread out “Y” configuration; depending on what one is trying to observe. In the future we'd like to put such an interferometer on the far side of the Moon.

So these are interferometry arrays, and it's the trick of using multiple telescopes, small ones, to act as one large telescope.

Thanks. Bye Bye.