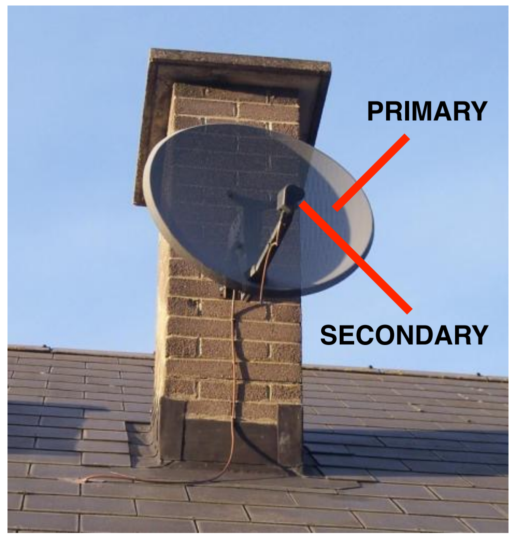
Science, my lad, is made up of mistakes, but they are mistakes which it is useful to make, because they lead little by little to the truth.

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 look 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., 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.

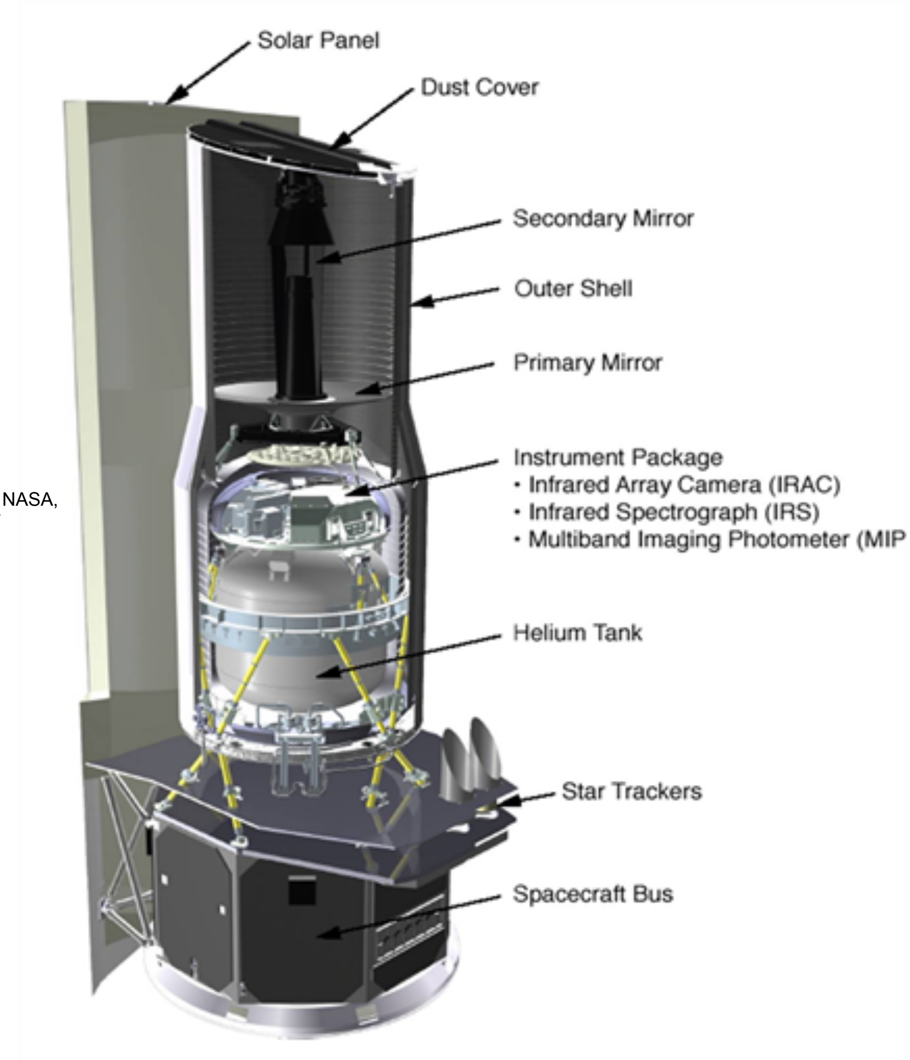
Credit: Wikipedia
Public Domain

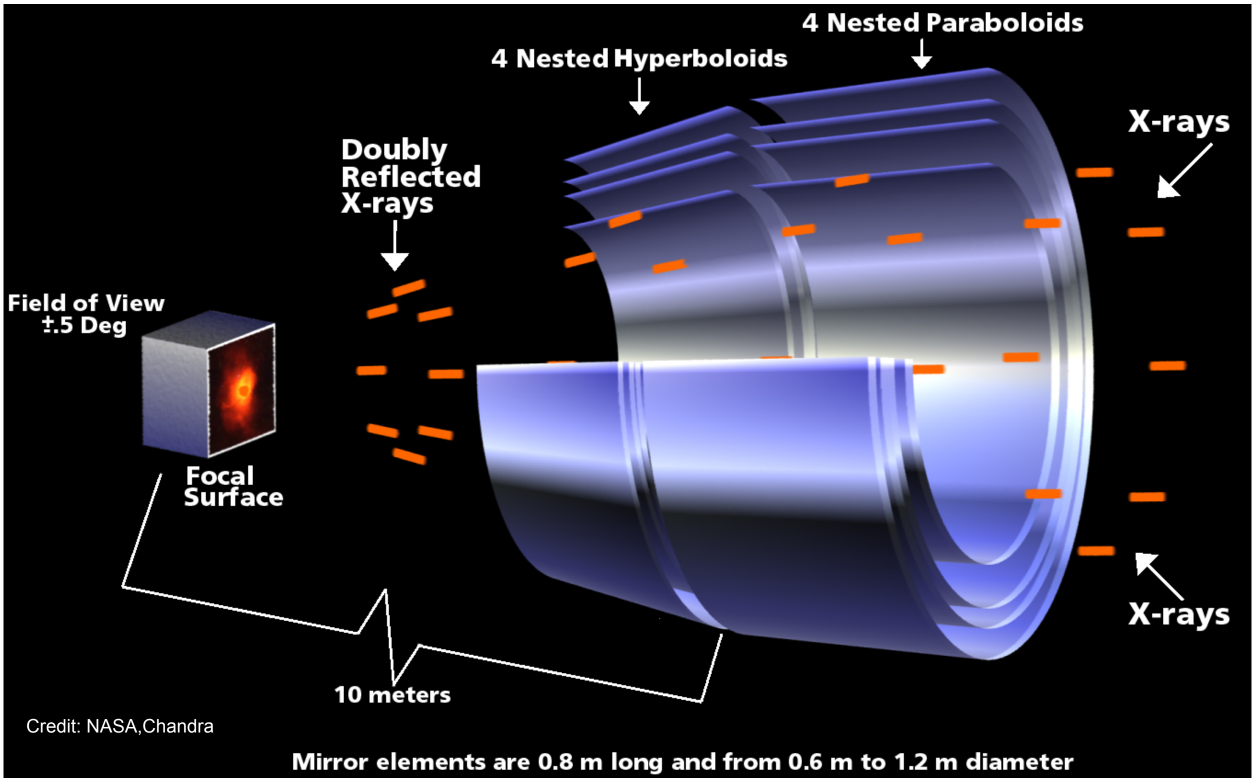
As you go to longer wavelengths, you need bigger dishes. You want to fit at least one wavelength across the diameter of the dish. The image below is an example of a large radio telescope to pick up a long wavelength radio waves. This is the Arecibo telescope in Costa Rica. And it sits in a natural bowl.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

As usual, the radio waves hit the parabolic primary dish and are reflected up to the focal point where the detectors are located. That’s them above the dish hanging off 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. In order to get the signal-to-noise down, typically you have to cool the instrument down.

Credit: NASA, Spitzer





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 they don't significantly contribute to the measurements.

For short wavelength, high-energy, photons like X-rays, these things are basically like bullets. You're not going to catch a bullet with a baseball mitt, i.e. a reflecting dish. The idea then for X-rays or gamma-rays is to skip the photons, to bounce them, to a focal point. You make them bounce at grazing incidence, like a skipping a rock across the water, Ding, ding, ding, ding.

That's what shown above for the space-borne Chandra telescope. A photon will come in. It's path gets bent a little bit off by one of the conical "mirrors". Then it goes to the next metal cone, which bends the path a little bit more. And 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 that 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. Its cool. Its 27 radio telescopes, each weighing about 200 tons. They are on a 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; depends 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.