Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Dishes.*

The idea of using a reflecting dish to concentrate light and light fires dates back to the ancient Greeks, including the apocryphal tale of Archimedes using solar-focusing mirrors to burn an invading Roman fleet. I say apocryphal since the fleet did apparently invade and Archimedes was apparently killed in the process. Still, building an Archimedes death ray is a useful thought experiment to try and get to grips with the principles of parabolic dish design.

1. Parabolic dish design

Consider a standard satellite dish - you've got a curved reflecting surface with a receiver positioned at a focal point, which is about twelve inches away. This is all very useful for TV reception, but not much help in destroying an invading fleet of Romans. To do that you've got to make your dish shallower so the light rays don't converge to a point so quickly - meaning the focal point is further away from the dish's surface. Or to put it another way, a shallower dish gives you a longer focal length.

Trouble is that means you have less concentrating power to set those boats alight – which means you need to build a bigger dish with more surface area which will reflect more photons at that distant focal point. But if you do have the right technology, that allows you to build giant dishes, which is something Archimedes didn't have, then the boats will burn.

OK, so having successfully wiped out the Romans, let's now turn all that around to think about reflector telescope design.

2. Reflector telescope design

A bigger parabolic mirror is good because you capture more photons. This doesn't contribute anything to magnification - you just get better resolution - that is, the greater number of photons collected with a big dish gives your image a lot more detail - and it makes it brighter.

Better image resolution is important before you can start applying a lot of magnification. If you start with a grainy, blurred image, applying magnification will just give you bigger grains and more blur. So, good resolution is important, but then getting magnification involves yet another key issue in telescope design.

3. Magnification

If you want your telescope to deliver a more magnified image – what you really want is for your reflecting mirror to deliver a larger image. After all, getting a larger image is what magnification really means - it's like in photography we talk about getting a photo blown-up to allow you to see more of the fine detail that's in that photo.

Getting that larger blown-up image is all your telescope's focal length. It's a bit like using a slide projector on a screen - if you move the projector further away from the screen - you can still get a focused image, but it will necessarily get bigger as you move it further away. So, in a nutshell, increasing the focal length of a telescope increases its magnification power, while increasing the size of the telescope's aperture, increases its resolution. And of course, the size of the aperture of a reflecting telescope is the size of its reflecting dish.

4. But what about telescope eyepieces?

The reason I've given you that slightly tortuous explanation, about aperture size and focal length is to now try and now make sense of how eyepieces work. Remember that your magnifying telescope is delivering a blown-up image as a result of its longer focal length. But from there, you want to achieve even more magnification with your eyepiece - you want to concentrate in on a small part of that whole blown-up image that your telescope is delivering. So, what you actually want is an eyepiece with a short focal length and a narrower field of view. An eyepiece with a long focal length is going to give you a wide field of view of the image - which might look really good, but it won't be magnified as much.

In case you think I'm making all this up, the formula for telescope magnification is objective focal length divided by eyepiece focal length. Which is just saying that you increase magnification by either increasing the length of your telescope to blow the image up - or by decreasing your eyepiece's focal length to concentrate down on a small area of that blown-up image. It's a bit like using a slide projector to expand an image out onto a screen and then look at a small part of the screen through a magnifying glass.

Anyhow, having explained that magnification is all about focal length, while dish size is all about resolution and eyepieces determine how much of your magnified image you want to look at, I know want to tell you about the biggest dishes there are – that is, radio telescope dishes.

5. A radio telescope dish is really just a Cassegrain telescope that works in radio light.

A Cassegrain telescope is a certain type of Newtonian telescope. A Newtonian telescope has a parabolic mirror. The traditional design bounces light up to a straight diagonal mirror positioned at the focal point, which then directs the focused image out the side of the telescope tube to your eyepiece.

But, with a Cassegrain reflector, the parabolic mirror has a hole in the middle. So, light comes into the scope - bounces off the parabolic mirror, up to a secondary mirror, or sub-reflector, that is positioned before the focal point. This sub-reflector, which is hyperbolic, then bounces light down to the focal point at the end of the telescope, which is where you put your eyepiece.

So, this all very useful because it means your focal length can actually be much longer than the length of your telescope tube - because the sub-reflector makes the light beam double back on itself. So you get a short compact telescope that still has great magnification.

But, you might ask, why is the sub-reflector hyperbolic?

6. Optics is mostly about geometry

Start by imagining a standard head light on a car. It has a parabolic dish - and at its focal point is a light globe. This globe radiates light in a big sphere - like an expanding bubble. When the spherical wave front hits the parabolic mirror it is bounced outwards in a beam of straight lines. So now turn all that around. Light comes into a telescope in straight lines, but in a reflector telescope , it then hits the parabolic mirror which turns that light beam into a contracting spherical wave.

If the sub-reflector was also parabolic it would just turn that spherical wave into a straight and unfocused beam, so that's no good – and if it was a flat mirror it would reflect back an spherical wave that expanded, so that's no good either.

Essentially to bounce your contracting spherical wave from the main reflector into a still contracting spherical wave that is moving in the opposite direction - you need what is essentially the opposite of a concave parabola - that is, a convex hyperbola.

7. Why we can build really big radio telescopes

The good thing about radio astronomy is that very long wavelength radio light can be reflected with minimum diffraction without needing the precision-polished surfaces required to reflect short wavelength optical light. So we can build giant 70 to 100 metre dishes just out of shaped aluminium - which as far as radio light is concerned is a perfect mirror. All we need to do is get the geometry right.

Older radio telescope designs have their radio receivers mounted on the dish itself, which means that even though the light path is still being bounced off the sub-reflector before it hit its focal point, the focal point is actually positioned above the dish surface where the receiver cone is – so this is not quite the same as a Cassegrain.

More modern radio telescopes use beam wave guide technology. Here there is no receiving cone mounted on the dish - instead the radio light path is directed down through a hole in the dish's surface to the focal point - from where the image may be further reflected by diagonal, but otherwise flat mirrors which reflect the focused image down underground to the radio receivers - which then don't have to be mounted on the dish and can be kept out of the weather.

And that's why, if you want to understand astronomy, you should do the dishes first.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we reflect, and even concentrate, on astronomy. No ads, no profit, just good science. Bye.