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Tapping, Ken

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IN SEARCH OF LIGHT

Ken Tapping, 7th April, 2015

As we move further from a light, it looks fainter; why? The answer to this interesting question is what drives our need for bigger and bigger telescopes. Imagine you are looking at a 100 Watt light bulb from a distance of 100 metres. The light bulb is emitting more or less equally in all directions, so from where you are standing, the 100 Watts is spread over a sphere with a radius of 100 m. Every square metre of the sphere is getting its share of the 100 Watts – about 8 ten-thousands of a Watt. If you are looking at the light, your eye will collect far less, but still enough to see. However, as you move further from the light, the energy gets even more spread out, until the amount your eye collects falls below your detection threshold; the light becomes too faint to see. The solution is to use a bigger collector. A pair of binoculars with 50mm diameter objective lenses will collect about 100 times more light than your unaided eye. When we are probing out to the depths of the universe we run into the same issue. The objects we are trying to study are extremely faint. We have to collect as much light as we can, which means using the biggest light collector we can build (or afford).

Convex lenses (the ones that are thicker in the centre) are excellent collectors and fulfil that role in our eyes, binoculars and small telescopes. However, if we need a bigger collector we have a problem. Since light has to pass through them, lenses can only be supported at the edges, where they are much thinner. So above a certain size the glass either sags or breaks under the strain. The biggest lens made for telescope use has a diameter of about a metre.

Luckily Isaac Newton shows us a way around that problem. We can use concave mirrors as light collectors. These have the great advantage that light does not have to pass through them, so we can put a substantial support structure behind the mirror. Another advantage is that the mirror, with all its weight, sits at the bottom of the telescope, not at the top. This has made it possible to make big mirrors, as big as 5 metres in diameter, which are rigid enough to stay in shape. Such a mirror will collect about a million times more light than an unaided eye. However, to probe out into space towards the beginning of the universe requires even bigger light collectors, but we cannot make rigid mirrors bigger than about 5 metres; they sag out of shape under their own weight. More innovative solutions are needed.

One solution is to make the mirror thinner and lighter, and to support it with a huge number of computer-controlled actuators. These sense the flexing and bending of the mirror as the telescope is pointed in different directions and push it back into shape. We are using this technology for telescope light collectors around 10 metres in size. Unfortunately it turns out that even these are not big enough, which brings us another problem. We cannot manufacture even thin mirrors larger than that. We have to divide the mirror into panels, which have to be mounted very solidly and then kept in shape by actuators. A telescope with a light collector 100 m across is being built using this technology.

In radio astronomy we often make a big collector out of lots of small ones. Combining the radio emissions collected by all the antennas is something we have known how to do for decades. However, doing the same thing with light is far more difficult, and as yet we have come up with no good technologies to do this. No doubt this problem will be cracked at some point, but for the foreseeable future we will continue to be in the business of making big telescopes.

Venus is spectacular in the western sky after sunset. It looks like an escaped aircraft landing light. Jupiter, high in the southern sky overnight is almost as bright. Saturn rises around midnight. The Moon reaches Last Quarter on the 11th.

Ken Tapping is an astronomer with the National Research Council's Dominion Radio Astrophysical Observatory, Penticton, BC, V2A 6J9.
Tel (250) 497-2300, Fax (250) 497-2355
E-mail: ken.tapping@nrc-cnrc.gc.ca