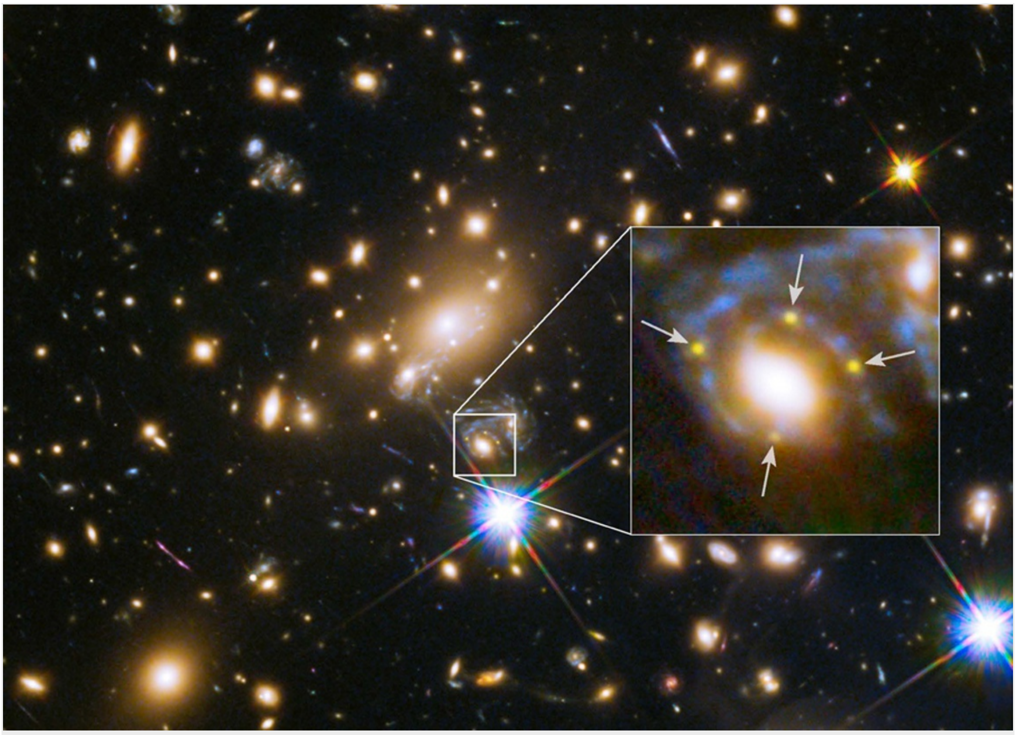
Supernova 'kaleidoscope' seen for first time

Rare cosmic alignment produces images that could help to measure the expansion of the Universe.

Maggie McKee

05 March 2015



NASA/ESA/STScI/GLASS team/FrontierSN team/Frontier Field team/CLASH team

The yellow supernova Refsdal appears four times (arrows) in this Hubble Space Telescope image.

Sometimes the stars really are aligned. A rare configuration of cosmic objects has produced the first kaleidoscopic image showing the same exploding star multiple times. If further images of the supernova appear, the system could provide a new way to measure the Universe's growth rate.

On 12 November last year, Patrick Kelly, an astronomer at the University of California, Berkeley, was looking for supernovae in images taken two days earlier by the Hubble Space Telescope. He found one, but it looked like no supernova that he or anyone else had ever seen: it appeared as four separate images in the same frame. He and his collaborators report the quadruple vision in *Science*[1].

The images, which form a symmetrical arrangement known as an Einstein cross, came thanks to a rare line-up of objects that began with the supernova some 2.8 billion parsecs (9 billion light years) from Earth and ended with Hubble in Earth's orbit. In between lay a galaxy that was embedded within a larger cluster of galaxies about 1.5 billion parsecs (5 billion light years) away — both of which acted as cosmic magnifying lenses, bending and boosting the light from the exploding star. Light rays taking different paths around the lenses created the four different images.

Cosmic constant

The rare alignment may one day serve as a new cosmic yardstick. Determining distances in astronomy is a tricky business that often relies on inferring a supernova's actual brightness from its apparent one, a relationship that can be muddied by factors such as intervening dust. But pinning down distances is crucial because it allows astronomers to gauge how fast the Universe is expanding (the distance to a given object would be greater if the Universe were expanding faster).

The rate of expansion, known as the Hubble constant, provides a measure of the age and size of the Universe. Various methods have been used to measure the Hubble constant, but worryingly, they tend to arrive at slightly different values, so astronomers want to use every tool at their disposal to settle the question.

The latest yardstick takes advantage of the fact that the light rays from the supernova took different amounts of time to travel their different paths. Each image in the Warhol-light set appeared — and then showed the telltale rise and fall of the exploding star's light — at a staggered time. Measuring these delays can help to reveal the actual distance travelled by the light along each path.

A better measurement

Astronomers have used the same basic concept to measure the Hubble constant before, but instead of a supernova they have used multiple, lensed images of a bright, flickering type of object known as a quasar[2]. A supernova brightens and fades in a more predictable way than a quasar, which "should make it easier to measure the time delays", says Sherry Suyu, an astrophysicist at the Academia Sinica Institute of Astronomy and Astrophysics in Taipei, who has run the calculation using lensed quasars.

This particular supernova, named Refsdal after Sjur Refsdal, the Norwegian astrophysicist who proposed the lensing yardstick in 1964[3], may not offer such an improvement, however. The time delays between images depend not only on the different paths taken by the light rays, but also on the gravitational fields that the rays encounter along each path. And those fields are difficult to model in this double-lens system, because one of the lenses is a large and lumpy galaxy cluster.

The modelling could get better if light battling its way through the dense centre of the cluster emerges to form a new image of the supernova within the next decade, as the researchers expect. Exactly when the image appears will help researchers to pin down the distribution of matter in the cluster, and could lead to a measurement of the Hubble constant, says Kelly.

But it is not clear whether the Hubble Space Telescope will be looking at the cluster often enough in that time period to catch the image's arrival, says Adam Riess, an astronomer at Johns Hopkins University in Baltimore, Maryland, and a co-author of the latest paper. "It's hard to say how well you can measure the expansion rate with this," he says.

In any case, the chances of finding other matched sets of supernova images will improve when an observatory called the Large Synoptic Survey Telescope begins frequent sweeps of the southern sky[4]. The observatory is expected to open in 2022.

Nature | doi:10.1038/nature.2015.17062

References

1. Kelly, P. L. *et al*. *Science* **347**, 1123–1126 (2015).
2. Suyu, S. H. *et al*. *Astrophys. J.* **711**, 201–221 (2010).
3. Refsdal, S. *Mon. Not. R. Astron. Soc.* **128**, 307 (1964).
4. Oguri, M. & Marshall, P. J. *Mon. Not. R. Astron. Soc.* **405**, 2579–2593 (2010).