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Earth & Space

A natural close-up of a pierced galaxy 18 billion light-years away

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ABSTRACT

Something has poked a hole in the interstellar gas in a distant galaxy. This allows us the first ever direct view of what young, massive stars look like in far-ultraviolet light – and thanks to a natural, cosmic lens, the whole thing is magnified hundredfold and shown in 12 copies.

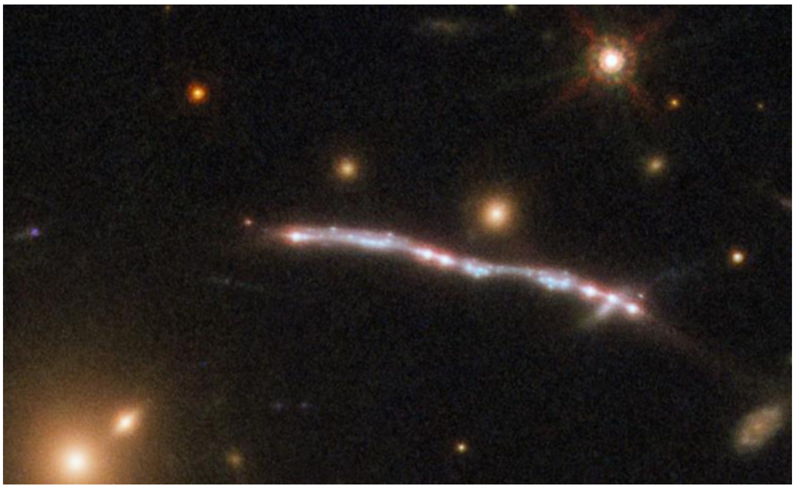

Image credits: ESA/Hubble, NASA

Einstein's general theory of relativity predicted that gravity not only acts between two masses but also affects light which has no mass. We cannot see this effect in everyday life, but when light travels over vast intergalactic distances and is affected by the incredibly large masses of entire galaxies or galaxy clusters, the effect, called gravitational lensing, can become stunningly dramatic. It can also act as a natural, cosmic telescope, letting astronomers study extremely distant galaxies in far better detail than would otherwise be possible.

Gravitationally lensed galaxies and quasars have been studied in large numbers since the first lensed quasar was found in 1979, and have given many exciting results like a multiply imaged supernova, and some of the most distant galaxies ever observed.

PSZ1-ARC G311.6602−18.4624, nicknamed the *Sunburst Arc*, is the brightest lensed arc ever observed. It is a young galaxy, currently located 18.5 billion light-years from Earth. Its light that reaches our telescopes now was emitted almost 11 billion years ago, long before the sun had even started to form. Usually, such a distant galaxy would be extremely faint, but the gravity from a giant cluster of galaxies located a mere 5.5 light-years away bends and focuses its light, acting as a natural lens and magnifying it around 200 times. On top of that, individual galaxies from the foreground cluster happened to line up in a way to break the light up into no less than 12 images, strung along a large circle like beads on a string, each image magnified around 20

times.

This is already quite spectacular, but the real thrill for our team was found in some less impressive looking details, as it often goes. Galaxies consist of a collection of stars seeping in a sauce of interstellar gas, mainly hydrogen (plus a bunch of Dark Matter, but let's leave that out for now). The gas contracts under its own gravity to form stars, which in turn emit light and hot particles in a "wind" that spreads the gas, which then contracts again in calmer places to form new stars. The largest of these new-formed stars are extremely hot and emit enormous amounts of ultraviolet light. Some of this light (called Lyman-continuum or, for short, LyC) has enough energy to ionize hydrogen atoms, leaving a plasma of free-floating protons and electrons. In the process, the ultraviolet light gets absorbed, so if a galaxy contains enough neutral hydrogen, none of the LyC light will get be able to escape it. If there is only a little gas, or most of it is already ionized, some of the ionizing light might escape.

At first glance, the Sunburst Arc is a relatively typical young galaxy with low mass, forming stars rapidly. Looking at observations from the Magellan telescope in Chile, our team found that it does contain enough hydrogen to trap most or all ionizing light inside it. But we also found signs that something has poked a hole in the hydrogen layers – a deep and narrow channel almost completely empty of neutral hydrogen, straight into the young, hot stars at its heart. Such channels have previously been predicted by theorists, but not directly observed. This one looks like it is pointing directly at Earth. If this hypothesis was correct, ionizing light could pour freely through the channel, like narrow sunbeams that break through little gaps in the clouds (hence the nickname). To test this, we applied to observe the Sunburst Arc with the *Hubble Space Telescope* using a filter that only lets the ionizing light through. If they were correct, the galaxy would look completely dark in this filter, except from a bright point where the channel is, which was exactly what the observations showed – in 12 bright copies around the arc!

The number of factors that needed to line up to make this happen is mindblowing in itself, but it also presents unique opportunities for astronomers. It can us help figure out how ionizing light escaped the first galaxies and ionized 99.9% of the hydrogen in the Universe during the first billion years after the Big Bang. It can help us study the distribution of hydrogen between the galaxies. The direct opening to the massive stars allows us to study the properties of their ionizing light in a level of detail which has never been possible before, not even inside the Milky Way.

But it is also just really, really pretty.