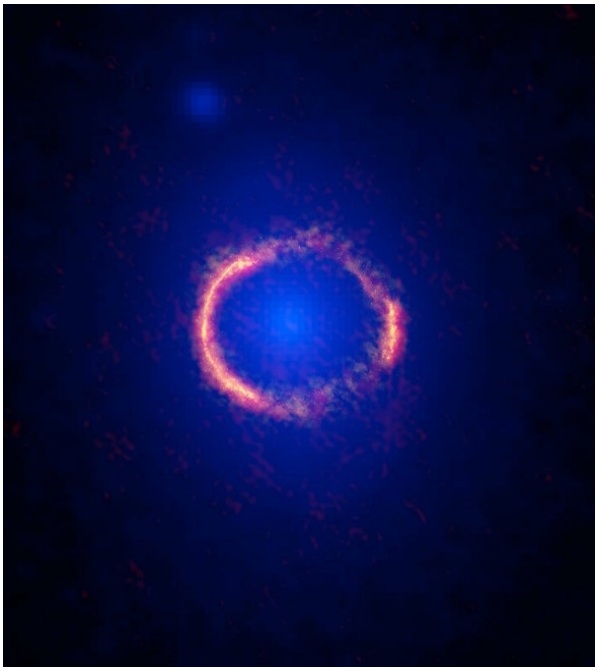
GRAVITATIONAL LENSING

Astronomers have discovered that a distant galaxy -- seen from Earth with the aid of a gravitational lens -- appears like a cosmic ring, thanks to the highest resolution images ever taken with the Atacama Large Millimeter/submillimeter Array (ALMA), an astronomical interferometer of radio telescopes in the Atacama desert of northern Chile. Consisting of 66 x 12-metre and 7-metre diameter radio telescopes it was constructed on the Chajnantor plateau at 5,000 metres altitude to take advantage of the high and dry atmosphere, crucial to millimeter operations. **ALMA is an international partnership among Europe, the United States, Canada, East Asia and the Republic of Chile. Costing about US$1.4 billion, it is the most expensive ground-based telescope in operation**.



ALMA/Hubble composite image of the gravitationally lensed galaxy SDP.81. The bright orange central region of the ring reveals the glowing dust in this distant galaxy. The surrounding lower-resolution portions of the ring trace the millimeter wavelength light emitted by carbon monoxide. The diffuse blue element at the centre of the ring is from the intervening lensing galaxy, as seen with the Hubble Telescope.

Gravitational lensing is now widely used in astronomy to study the very distant, very early Universe because it gives even our best telescopes an impressive boost in power. **It occurs when a massive galaxy or cluster of galaxies bends the light emitted from a more distant galaxy, forming a highly magnified, allthough much distorted image**.

In this particular case, the galaxy known as SDP.81 and the intervening galaxy line up so perfectly that the light from the more distant one forms a nearly complete circle as seen from Earth. **This striking ring-like structure is a rare and peculiar manifestation of gravitational lensing as predicted by Albert Einstein in his theory of general relativity.** With the astounding level of detail in these new ALMA images, astronomers will be able to reassemble the information contained in the distorted image we see as a ring and produce a reconstruction of the true image of the distant galaxy. Discovered by the Herschel Space Observatory, SDP.81 is an active star-forming galaxy nearly 12 billion light-years away, seen at a time when the Universe was only 15 % of its current age. It is being lensed by a massive foreground galaxy 4 billion light-years away. **The SDP.81 images were taken in October 2014 as part of ALMA's Long Baseline Campaign, an essential program to test and verify the telescope's highest resolving power, achieved when the antennas are at their greatest separation: up to 15 kilometres apart.**

ALMA antennas linked up as one huge interferometer

The highest resolution image of SDP.81 was made by observing the relatively bright light emitted by cosmic dust in the distant galaxy. This striking image reveals well-defined arcs in a pattern that hints at a more complete, nearly contiguous ring structure. Other slightly lower-resolution images, made by observing the faint molecular signatures of carbon monoxide and water, help complete the picture and provide important details about this distant galaxy.

This intriguing interplay of gravity and light in SDP.81 has been studied previously by other observatories, including radio observations with the Submillimeter Array and the Plateau de Bure Interferometer, and visible light observations with the Hubble Space Telescope, but none has captured the remarkable details of the ring structure revealed by ALMA. The exquisite amount of information contained in the ALMA images is important for our understanding of galaxies in the early Universe. Astronomers use sophisticated computer programs to reconstruct the lensed galaxies' true appearance. This unravelling of the focused light will allow us to study the actual shape and internal motion of this distant galaxy much more clearly than has been possible until now. **For these observations, ALMA achieved an astounding maximum resolution of 23 milliarcseconds, which is about the same as seeing the rim of a basketball hoop atop the Eiffel Tower from the observing deck of the Empire State Building**.

It takes a combination of ALMA's high resolution and high sensitivity to unlock these otherwise hidden details of the early Universe, and these results prove that ALMA can indeed deliver on its promise of transformational science. SDP.81 is one of five targets selected for study during the ALMA Long Baseline Campaign. The others include the protoplanetary disk HL Tau, the asteroid Juno, the star Mira, and the quasar 3C138. AK, from Wiki