Dusty substructure in a galaxy far far away

April 1 2015, by Hannelore Hämmerle

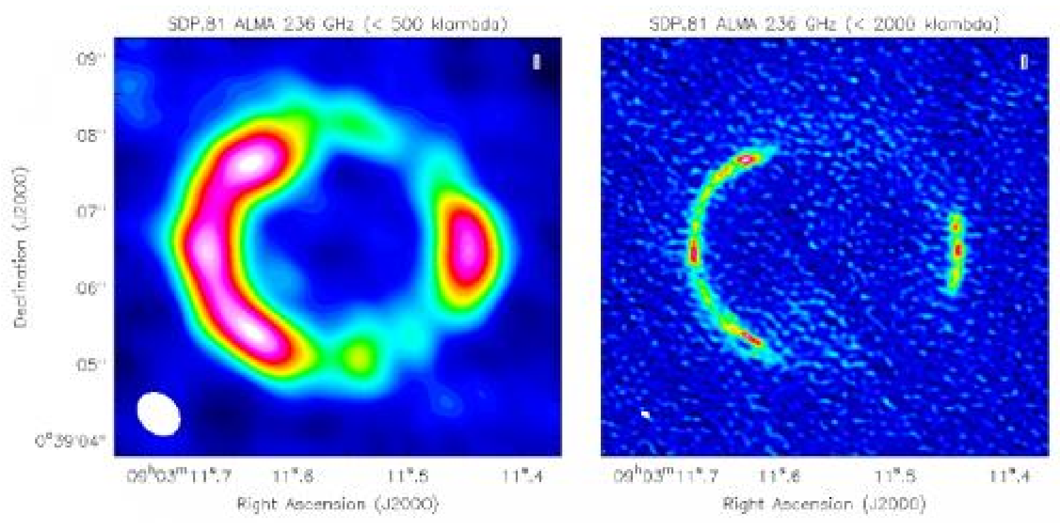

Fig. 1 The ALMA image of the continuum emission at 236 GHz of the lensed galaxy SDP.81 at two angular resolutions. The lensed system consists of four images with an extended, low-surface brightness Einstein ring.

Scientists at the Max Planck Institute for Astrophysics (MPA) have combined high-resolution images from the ALMA telescopes with a new scheme for undoing the distorting effects of a powerful gravitational lens in order to provide the first detailed picture of a young and distant galaxy, over 11 billion light-years from Earth. The reconstructed images show that star formation is heating interstellar dust and making it glow strongly in three distinct clumps embedded in a broader distribution, suggesting that object may be a rotating disk galaxy seen nearly edge-on.

Galaxies are constantly forming new stars within dense clouds of interstellar material. The star formation rate in today's galaxies is, however, much lower than it used to be. When the universe was about a quarter its current age, star formation was at its peak, and so astronomers are keen to learn about this period. Looking back in time is possible because of the finite speed of light, but only by looking out to great distances, which in turn means that young galaxies appear very small and very faint. In addition, most of their new-born stars cannot be seen directly, because their radiation is absorbed by dust in the surrounding gas cloud and is re-emitted at far-infrared wavelengths.

As a result, star-forming regions in distant galaxies are one of the prime targets for the Atacama Large Millimetre/submillimetre Array. ALMA will consist of 66 high precision antennas, located on the Chajnantor plateau at 5000 meters altitude in northern Chile. The data from the individual antennas can be combined interferometrically, and the 15 kilometre span of the telescope provides resolution of better than a tenth of an arc-second. On its own, however, even this capability is not sufficient to make detailed pictures of young galaxies at the peak of their star formation.

"At a recent conference, ALMA scientists presented data they had used to verify the scientific capabilities of their array, among them an image of a strongly gravitationally lensed system, which immediately raised our interest", remembers Simona Vegetti, postdoctoral scientist at MPA. "Because of the lensing, the background galaxy is strongly magnified, by 17 times actually, which is why we can see it at all. Together with ALMA's unique angular resolution, this gave us the chance to try and see details in the distribution of dust in such a far-away galaxy for the first time."

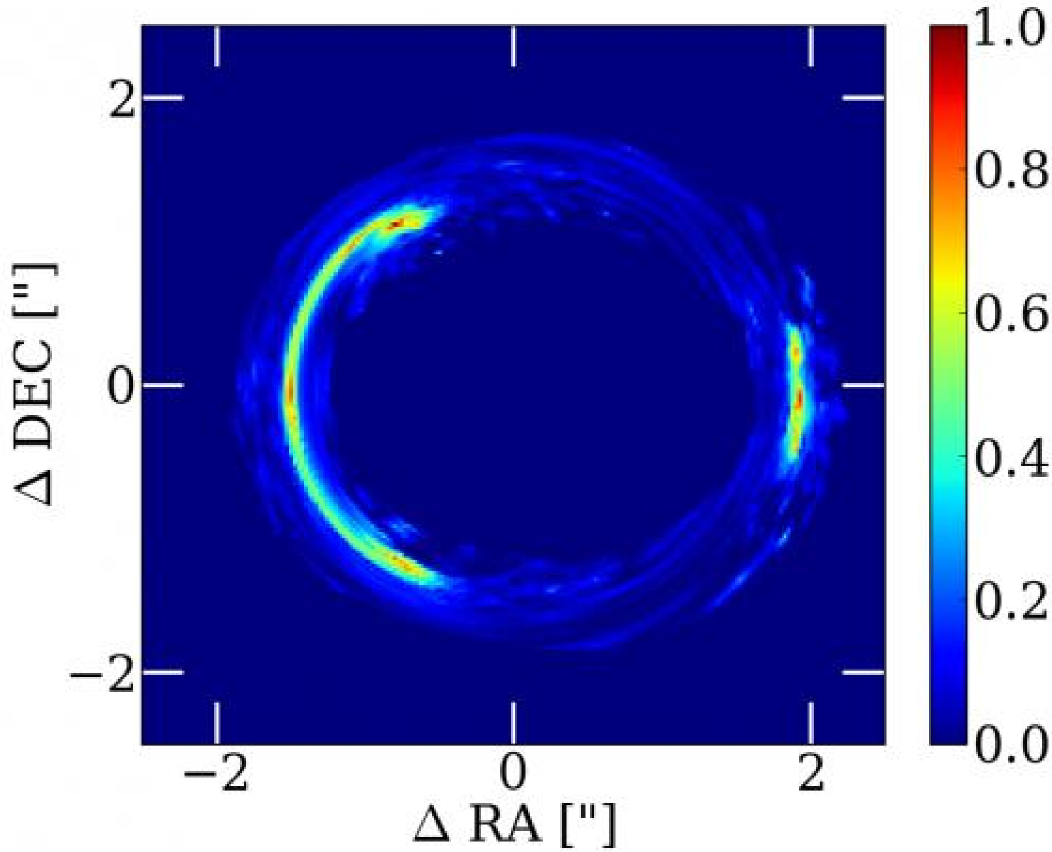

Fig. 2 The modelled sky-brightness distribution for the image in Fig. 1 (left) and the reconstructed surface brightness distribution (right) of the background galaxy. There are three areas with enhanced emission, which could indicate a disk galaxy seen edge-on.

Strong gravitational lensing happens when a background galaxy is closely aligned with a foreground mass concentration such as a cluster of galaxies, which bends light-rays from the source on their way to the observer. The foreground lens is, however, an imperfect optical system, leading to very large distortions (see Fig. 1). Nevertheless, from the properties of the lensed images, the mass distribution of the lensing system can be determined and a "true" (i.e. undistorted) image of the distant galaxy can be reconstructed. "Previous attempts to do this had assumed the background galaxies to be smooth and regular", explains

Matus Rybak, who carried out the computer modelling at MPA. "This seems likely to be a very poor approximation to the structure of a strongly star-forming galaxy, and the raw ALMA images gave clear hints that this background source is complex. The new, more general approach we have developed is much better suited to irregular systems."

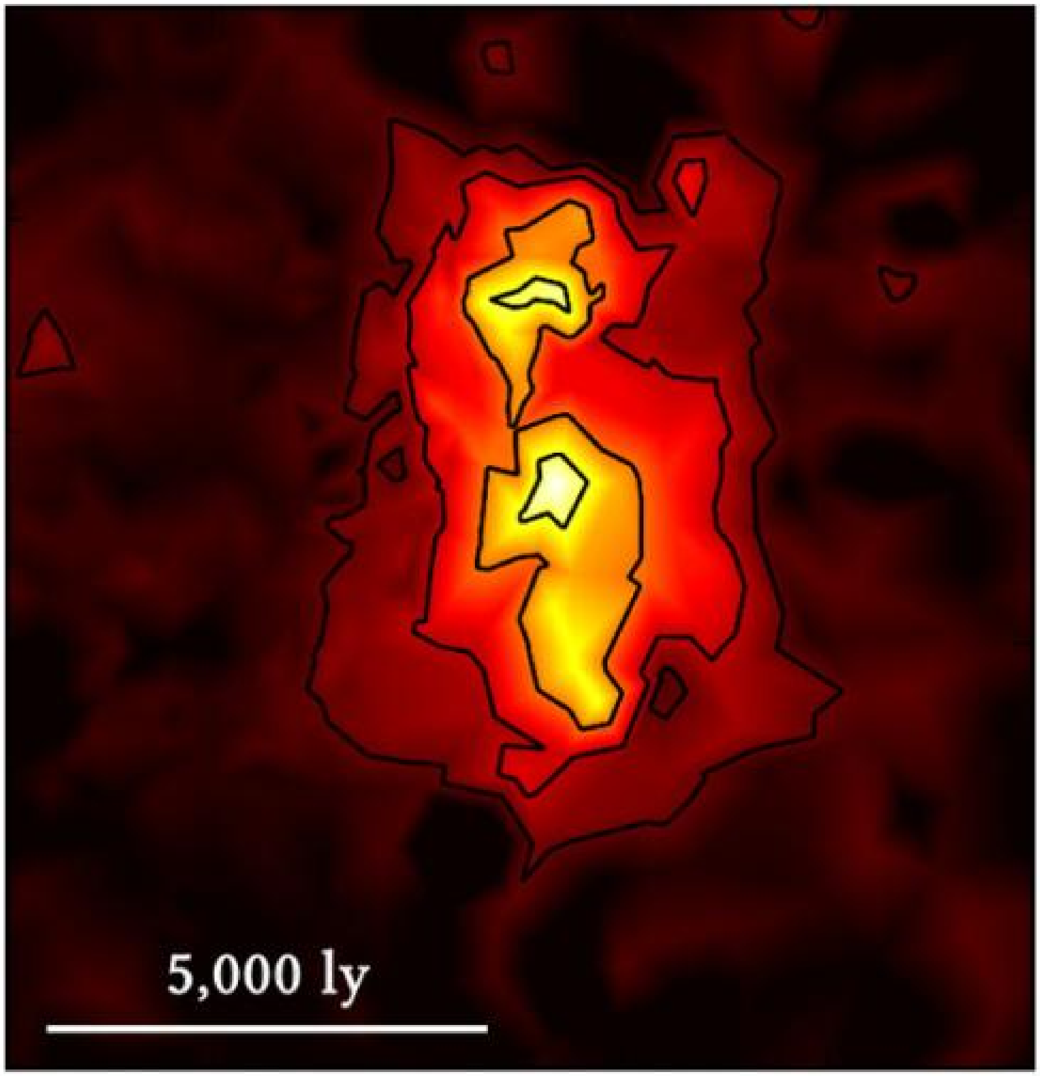

Fig. 3 This map shows the reconstructed star formation rate of the distant galaxy, which is actually quite small (as indicated by the length scale in light-years). The colour coding shows the amount of dust heated by radiation from the young stars.

This intuition is borne out by the reconstructed image of the galaxy SDP.81 which shows star formation to be concentrated in three distinct regions (see Fig. 2). "This is the first time, that we can see structure in the dust emission of a z=3 galaxy on scales smaller than 150 light-years", points out Simona Vegetti. At this cosmic time, typical galaxies were forming stars at their peak rate, and indeed SDP.81 is forming about 300 solar masses of stars every year. (In our Milky Way, the star formation rate is about 3 solar masses per year.) The complex structure of the galaxy may indicate that it is a rotating disk with a central bulge that is seen (and lensed) edge-on; alternatively it may be a system which is undergoing a merger in which the separate components are still visible. To distinguish between these possibilities, data on the motions of gas within the galaxy are needed, so the next step for the MPA team together with their colleagues Paola Andreani at ESO and John McKean at the University of Groningen and the Netherlands Institute for Radio Astronomy (ASTRON) will be to analyse the molecular line observations of this system which ALMA has also obtained.

More information: "ALMA imaging of SDP.81 - I. A pixelated reconstruction of the far-infrared continuum emission." de.arxiv.org/abs/1503.02025

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