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In the news

NUTS AND BOLTS OF SEEING A BLACK HOLE

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On 10 April 2019, the Event Horizon Telescope (EHT) collaboration released the first images of the radio emission and a dark shadow from the supermassive black hole at the centre of galaxy Messier 87. These images are the result of years of development in instrumentation and data processing.

The target of EHT's observations takes up a region <40 μas in the sky. To see such a small object requires a telescope as large as the Earth, as the angular resolution of a telescope is inversely proportional to its diameter. The EHT achieves a theoretical resolution of ~25 μas by networking receivers up to 10,700 km apart in a very long baseline interferometer (VLBI) array. VLBIs cross-correlate signals from pairs of receivers, acting as an effective aperture as large as the baseline length.

On top of having a small angular size, the emissions from around black holes are obscured by scattering from the interstellar medium. This scattering prevents established VLBIs that work at wavelengths of 3.5 mm from accurately imaging the event horizon. Interstellar scattering scales as wavelength squared, so the EHT operates at 1.3 mm to reduce scattering effects. The shorter wavelength also increases the EHT's angular resolution. However, at 1.3 mm, new challenges arise.

A major hurdle is that receivers working at shorter wavelengths tend to be smaller and less efficient than longer-wavelength receivers. A key strategy of the EHT to overcome this limitation was to increase the amount of recorded data. The collaboration developed new digital backend instrumentation that brought the recording rate to 64 gigabits per second, an order of magnitude higher than typical VLBI arrays operating at centimetre wavelengths.

Receivers in the EHT yield petabytes of data at a time, which had to be converted into the megabyte-scale data sets that were released. The data processing workflow emphasized automated procedures, reproducibility and internal review. To this end, the initial data processing was run over three independent pipelines that were then cross-validated.

Planned improvements to the EHT are already underway. Improved angular resolution will come from extending EHT operation to 0.87 mm, or alternatively by increasing baseline lengths by deploying antennae in space. Image fidelity will be improved by adding new receivers; two additions are already planned in the next 2 years. The backend itself is now being upgraded to exploit new receiver technologies. However, the existing high-bandwidth backend is able to make use of receivers with a diameter as small as 6 m. Adding many smaller receivers would enable snapshot capabilities, a step towards making movies of black holes.

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