How interferometry works, and why it's so powerful for astronomy

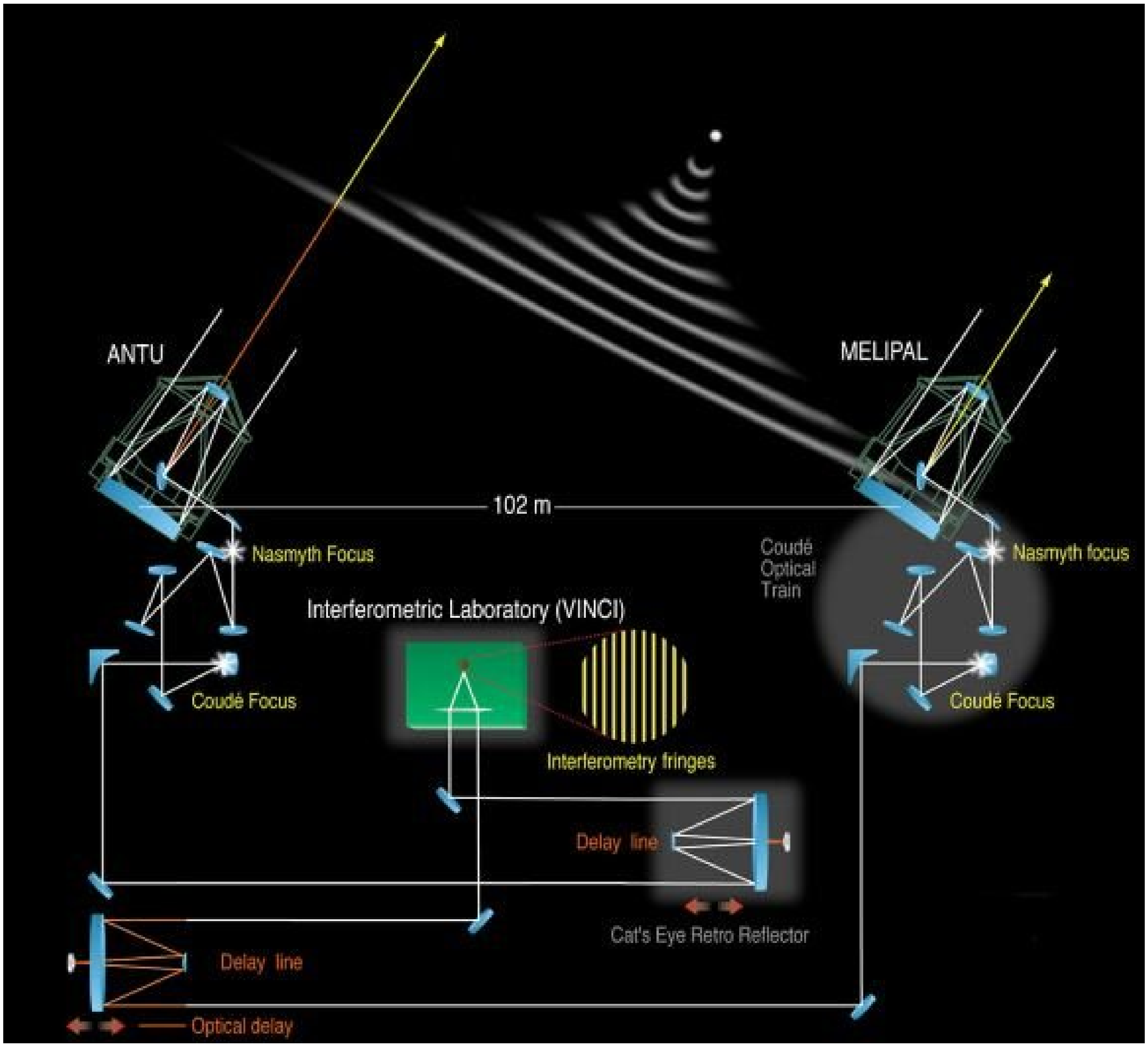
February 24 2020, by Brian Koberlein

The Five-hundred-metre Aperture Spherical Telescope (FAST) has just finished construction in the southwestern province of Guizhou. Credit: FAST

When astronomers talk about an optical telescope, they often mention the size of its mirror. That's because the larger your mirror, the sharper your view of the heavens can be. It's known as resolving power, and it is due to a property of light known as diffraction. When light passes through an opening, such as the opening of the telescope, it will tend to spread out or diffract. The smaller the opening, the more the light spreads, making your image more blurry. This is why larger telescopes can capture a sharper image than smaller ones.

Diffraction doesn't just depend on the size of your telescope, it also depends on the wavelength of light you observe. The longer the wavelength, the more light diffracts for a given opening size. The wavelength of visible light is very small, less than 1 millionth of a meter in length. But radio light has a wavelength that is a thousand times longer. If you want to capture images as sharp as those of optical telescopes, you need a radio telescope that is a thousand times larger than an optical one. Fortunately, we can build radio telescopes this large thanks to a technique known as interferometry.

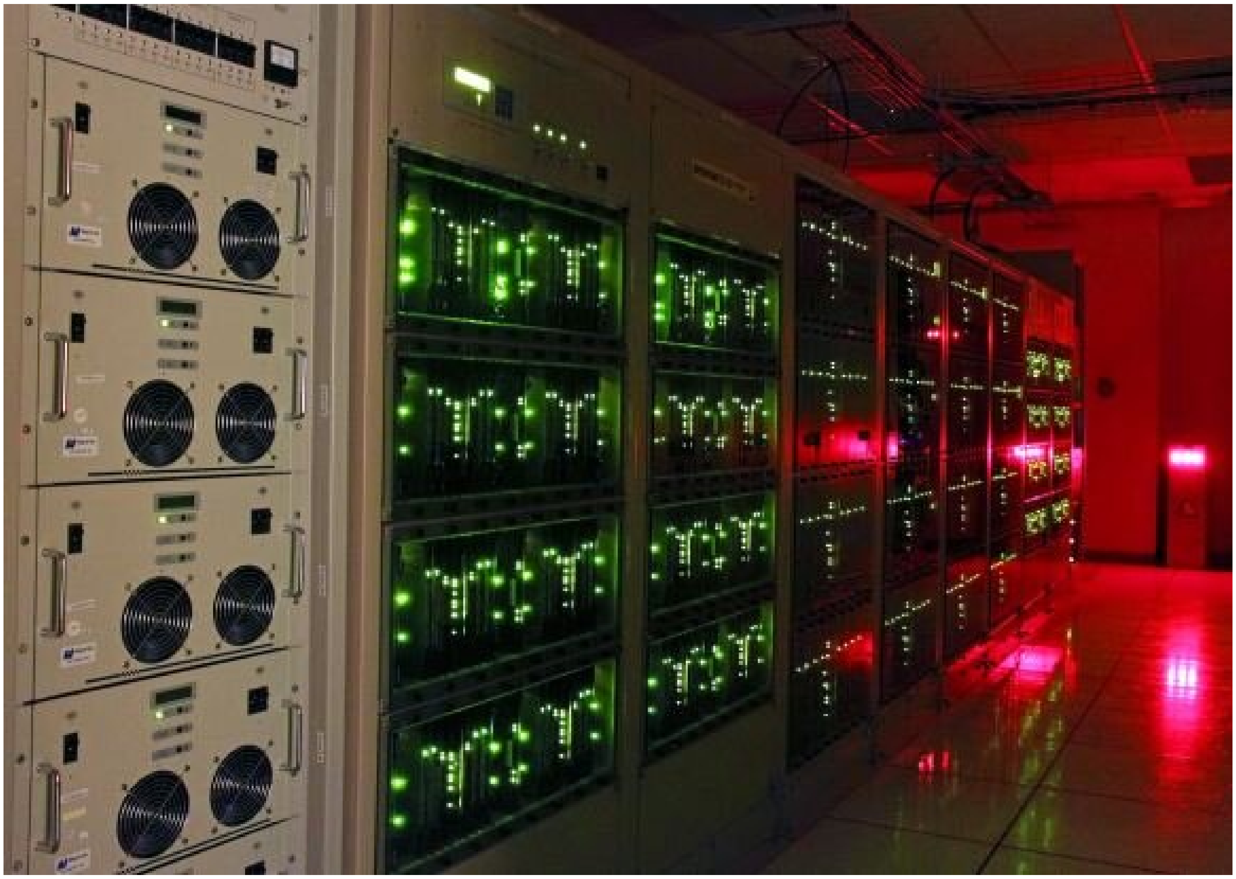
To build a high-resolution radio telescope, you can't simply build a huge radio dish. You would need a dish more than 10 kilometers across. Even the largest radio dish, China's FAST telescope, is only 500 meters across. So instead of building a single large dish, you build dozens or hundreds of smaller dishes that can work together. It is a bit like using only parts of a great big mirror instead of the whole thing. If you did this with an optical telescope, your image wouldn't be as bright, but it would be almost as sharp.



Light from a distant object strikes one antenna before another. Credit: ESO

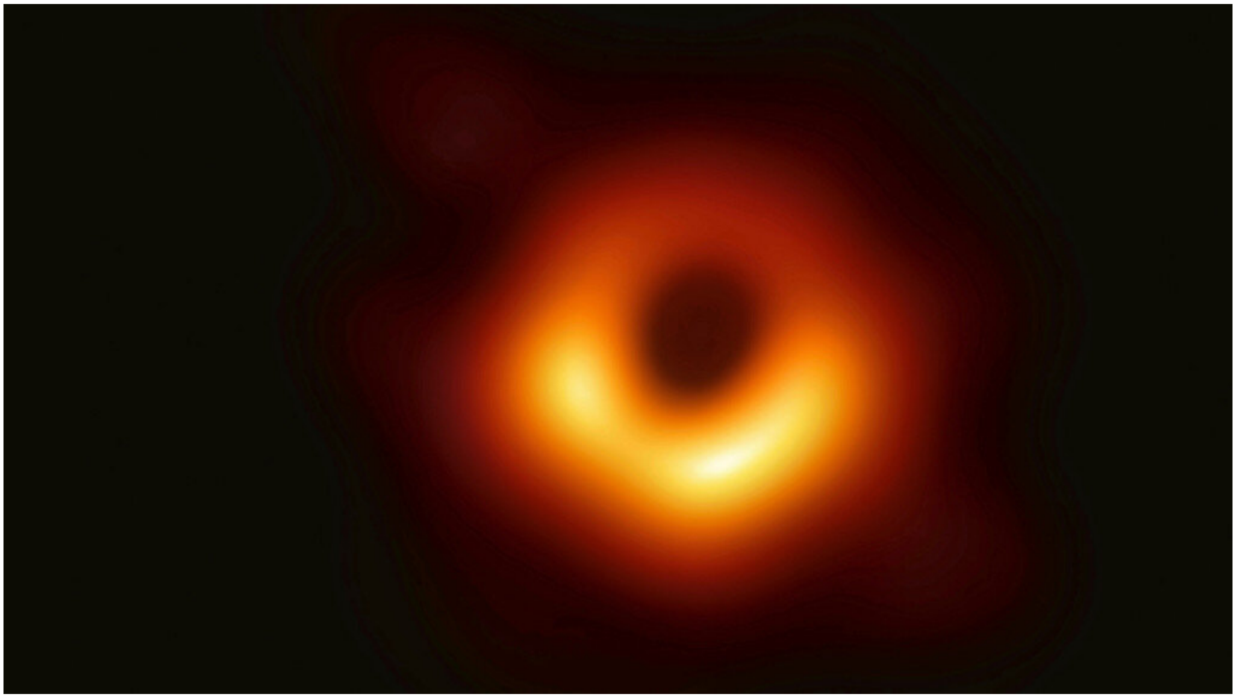
But it's not as simple as building lots of little antenna dishes. With a single telescope, the light from a distant object enters the telescope and is focused by the mirror or lens onto a detector. The light that left the object at the same time reaches the detector at the same time, so your image is in sync. When you have an array of radio dishes, each with their own detector, the light from your object will reach some antenna detectors sooner than others. If you just combined all your data you would have a jumbled mess. This is where interferometry comes in.

Each antenna in the array observes the same object, and as they do they each mark the time of the observation very precisely. This way, you have dozens or hundreds of streams of data, each with unique timestamps. From the timestamps, you can put all the data back in sync. If you know that dish B gets a single 2 microseconds after dish A, you know signal B has to be shifted forward 2 microseconds to be in sync.



The correlator computer at ALMA Observatory. Credit: ALMA (ESO/NAOJ/NRAO), S. Argandoña

The math for this gets really complicated. In order for interferometry to work, you have to know the time difference between each pair of antenna dishes. For 5 dishes that's 15 pairs. But the VLA has 26 active dishes or 325 pairs. ALMA has 66 dishes, which makes for 2,145 pairs. Not only that, as the Earth rotates the direction of your object shifts relative to the antenna dishes, which means the time between the signals changes as you make observations. You have to keep track of all of it in order to correlate the signals. This is done with a specialized supercomputer known as a correlator. It is specifically designed to do this one computation. It is the correlator that lets dozens of antenna dishes act as a single telescope.



The Event Horizon Telescope (EHT) — a planet-scale array of eight ground-based radio telescopes forged through international collaboration — was designed to capture images of a black hole. In coordinated press conferences across the globe, EHT researchers revealed that they succeeded, unveiling the first direct visual evidence of the supermassive black hole in the centre of

Messier 87 and its shadow. The shadow of a black hole seen here is the closest we can come to an image of the black hole itself, a completely dark object from which light cannot escape. The black hole's boundary — the event horizon from which the EHT takes its name — is around 2.5 times smaller than the shadow it casts and measures just under 40 billion km across. While this may sound large, this ring is only about 40 microarcseconds across — equivalent to measuring the length of a credit card on the surface of the Moon. Although the telescopes making up the EHT are not physically connected, they are able to synchronize their recorded data with atomic clocks — hydrogen masers — which precisely time their observations. These observations were collected at a wavelength of 1.3 mm during a 2017 global campaign. Each telescope of the EHT produced enormous amounts of data – roughly 350 terabytes per day – which was stored on high-performance helium-filled hard drives. These data were flown to highly specialised supercomputers — known as correlators — at the Max Planck Institute for Radio Astronomy and MIT Haystack Observatory to be combined. They were then painstakingly converted into an image using novel computational tools developed by the collaboration. Credit: Event Horizon Telescope Collaboration

It has taken decades to refine and improve radio interferometry, but it has become a common tool for radio astronomy. From the inauguration of the VLA in 1980 to the first light of ALMA in 2013, interferometry has given us extraordinarily high-resolution images. The technique is now so powerful that it can be used to connect telescopes all over the world.

In 2009, radio observatories across the world agreed to work together on an ambitious project. They used interferometry to combine their telescopes to create a virtual telescope as large as a planet. It is known as the Event Horizon Telescope, and in 2019, it gave us our first image of a black hole.

With teamwork and interferometry, we can now study one of the most mysterious and extreme objects in the universe.

Source Universe Today

Citation: How interferometry works, and why it's so powerful for astronomy (2020, February 24) retrieved 14 May 2024 from https://phys.org/news/2020-02-interferometry-powerful-astronomy.html