From Medicine to Wi-Fi

Technical Applications of Astronomy to Society

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"Preserving knowledge is easy. Transferring knowledge is also easy. But making new knowledge is neither easy nor profitable in the short term. Fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth." [1]

– Ahmed Zewail, winner of the
Nobel Prize in Chemistry (1999)


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Introduction

Astronomy has always had a significant impact on our world. Early cultures identified celestial objects with the belief systems and took their movements across the sky as prophecies of what was to come. Astronomy has also been used to measure time, mark the seasons, and navigate across vast oceans. Now, as our understanding of the world progresses, we find ourselves and our view of the world even more entwined with the Universe. The discovery that the basic elements that we find in stars, and the gas and dust around them, are the same elements that make up our bodies has further deepened the connection between us and the cosmos. Astronomy also helps us to broaden our perspectives and to think on grander scales. Our connection to the cosmos and the awe it inspires is perhaps the reason that the beautiful images astronomy provides us with are so popular in today's culture.

Astronomy and related fields are at the forefront of science and technology; answering fundamental questions, pushing engineers to new levels and driving innovation. It is for this reason that the International Astronomical Union's (IAU) strategic plan emphasises technology and skills, science and research, and culture and society.

This booklet aims to highlight some of the technical applications that have been supported and driven by astronomy research and development. From medicine to airport security, astronomy visibly holds an integral role in our daily lives.

Children are shown how to use a telescope in Ethiopia as part of the 2019 International Astronomical Union's 100 Hours of Astronomy event.

Credit: Mekbeb Tamrat

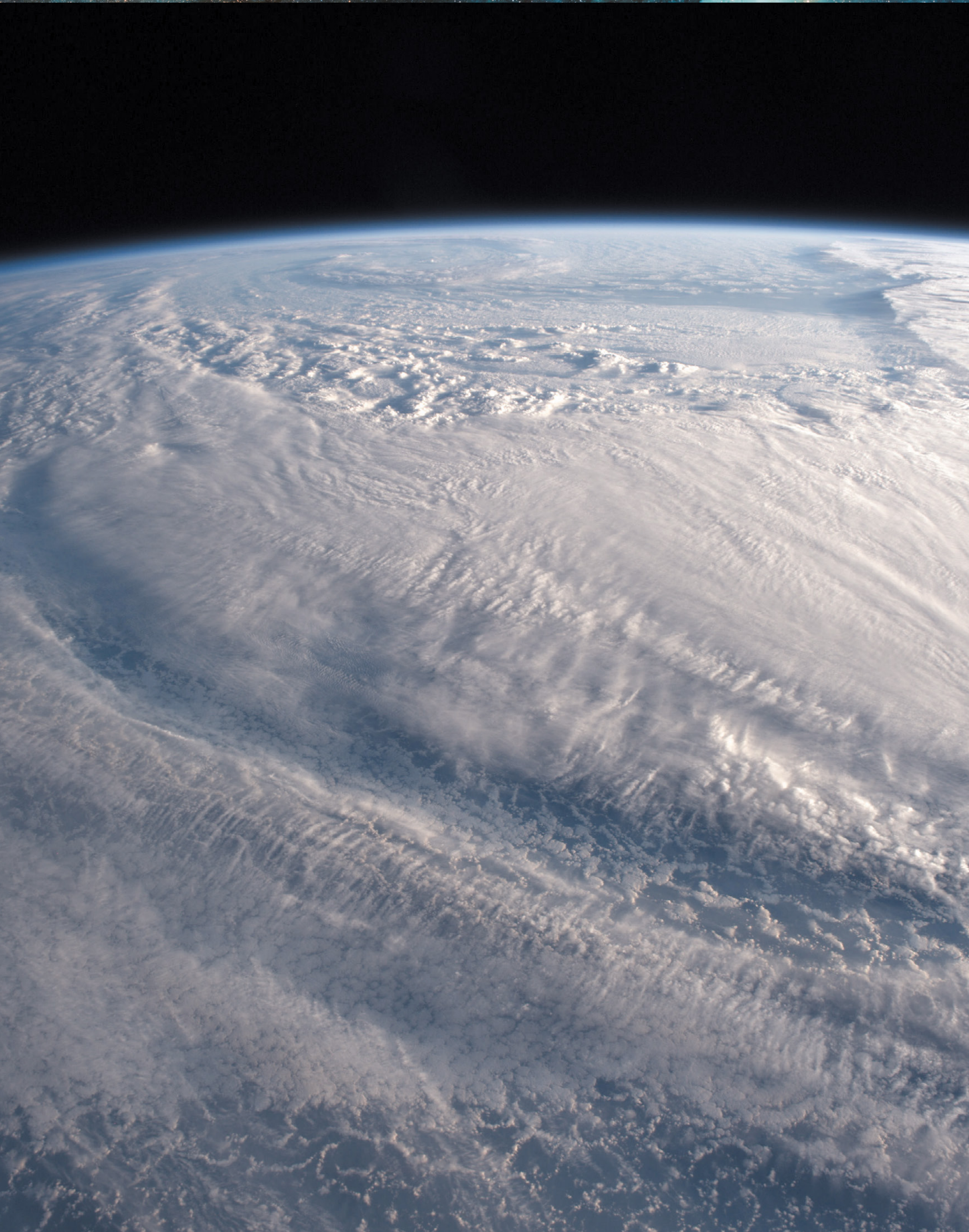
Medicine

The applications of astronomy to medicine are quite vast, from improved diagnostic techniques to enhanced image processing.

One of the most integral technology transfers between these domains is the interferometry technique used by astronomers to obtain high-resolution images of the radio-sky. Interferometry simulates the effect of a very large dish by electronically combining the signal from many small, single-dish, radio telescopes that are distributed over a large distance. The technique of combining data from multiple telescopes to produce a single image is known as ‘aperture synthesis’, developed by the radio astronomer and Nobel Laureate, Martin Ryle. One important application of aperture synthesis is Magnetic Resonance (MR) to enhance the imaging details and to reduce the scan time in medical diagnoses. Magnetic Resonance Imaging (MRI) uses powerful magnets and radio frequency pulses to polarize and excite single protons of water molecules in the human tissue. When the pulses are turned off, the protons ‘relax’ and emit radio waves. These waves are seen by radio frequency receivers in the MRI machine, recorded and processed into an image similar to an interferometric image. This technology is also used in computerised tomography (also known as CT or CAT scanners), positron emission tomography (PET) and many other medical imaging systems.

Another important example of how astronomical research has contributed to the medical world is in the development of clean working areas. The manufacture of space telescopes requires an extremely clean environment to prevent dust or particles that might obscure or obstruct the mirrors or instruments on the telescopes[2]. The cleanroom protocols, air filters, and bunny suits that were developed to achieve this are now also used in hospitals and pharmaceutical labs[3].

The manufacturing of space-based telescopes and satellites has contributed to medicine by improving standards and development of clean working areas.
Credit: NASA/Dominic Hart



Climate Change

Technology and research methods developed in astronomy have also developed valuable means of understanding Earth's systems and climate change.

By studying the planet Venus using astronomical techniques, researchers have developed a better understanding of our own climate. With a similar size and composition to Earth, Venus provides a valuable opportunity to study an evolving climate system like Earth in our own solar system. Today, the Venusian atmosphere is more than 90 times thicker than our own, as it is believed that the planet experiences a runaway greenhouse effect following rising surface temperature and greater levels of atmospheric water. Climatologist James Hansen used radiative transfer models that calculated the transfer of electromagnetic radiation through the atmosphere of Venus and effectively used these techniques to model the climatic effects of trace gases and aerosols in Earth's atmosphere[4,5].

More recently, the development of polarimetric techniques to study the atmospheres of exoplanets has also led to a suite of SPEX (Spectropolarimeter for Planetary EXploration) instruments to study the effects of particles in the Earth's atmosphere on our health and climate. This technology is being commercialised for ground-based air pollution measurements and has been further adapted for operation on an Earth-observing satellite platform[6].

Image of Earth taken by ESA astronaut Alexander Gerst in 2014 from the International Space Station.

Credit: ESA/NASA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Computing

The processing of astronomical data has supported the development of improved computing methods, including grid and distributed computing, and large astronomical citizen science initiatives.

Over recent decades, the amount of data obtained by astronomers has grown dramatically. New telescopes and space missions have all contributed to the development of new tools and methods to analyse the data they obtain. Vast amounts of computational resources are needed for their processing. Grid computing, through which computers are widely distributed and connected together across a common network, is an efficient method of sharing and using these vast amounts of collected resources. Astronomers are gathering exponentially greater amounts of data, often referred to as the era of “big data”, which is changing how science is done.

The search for extra-terrestrial intelligence by radio astronomers has also been formative in spawning grid computing – the pooling of vast numbers of machines, distributed around the world, for crowd computing efforts to solve complex scientific problems.

Historically, the first two public distributed computing projects were initiated to solve mathematical (GIMPS, 1996) and cryptographic (distributed.net, 1997) problems. The third (and the most famous) project was the SETI@home initiative that began in 1999. SETI – the Search for Extra-Terrestrial Intelligence – sought to find signs of other intelligent forms of life through the transmission of radio signals. SETI@home is the first of many new citizen science projects that collaboratively contribute to valuable scientific initiatives, in ways that were never possible before. This work continues today and has already harnessed the engagement of more than 1.7 million users, that all contribute their computing power to SETI@home.

Data Centre at the European Southern Observatory (ESO) Headquarters in Garching bei München, Germany, which archives and distributes data from ESO’s telescopes.
Credit: ESO

Time Keeping

The position of the Earth and the stars in the sky has held an integral role in time keeping, from the earliest calendars to today's satellite navigation and positioning services.

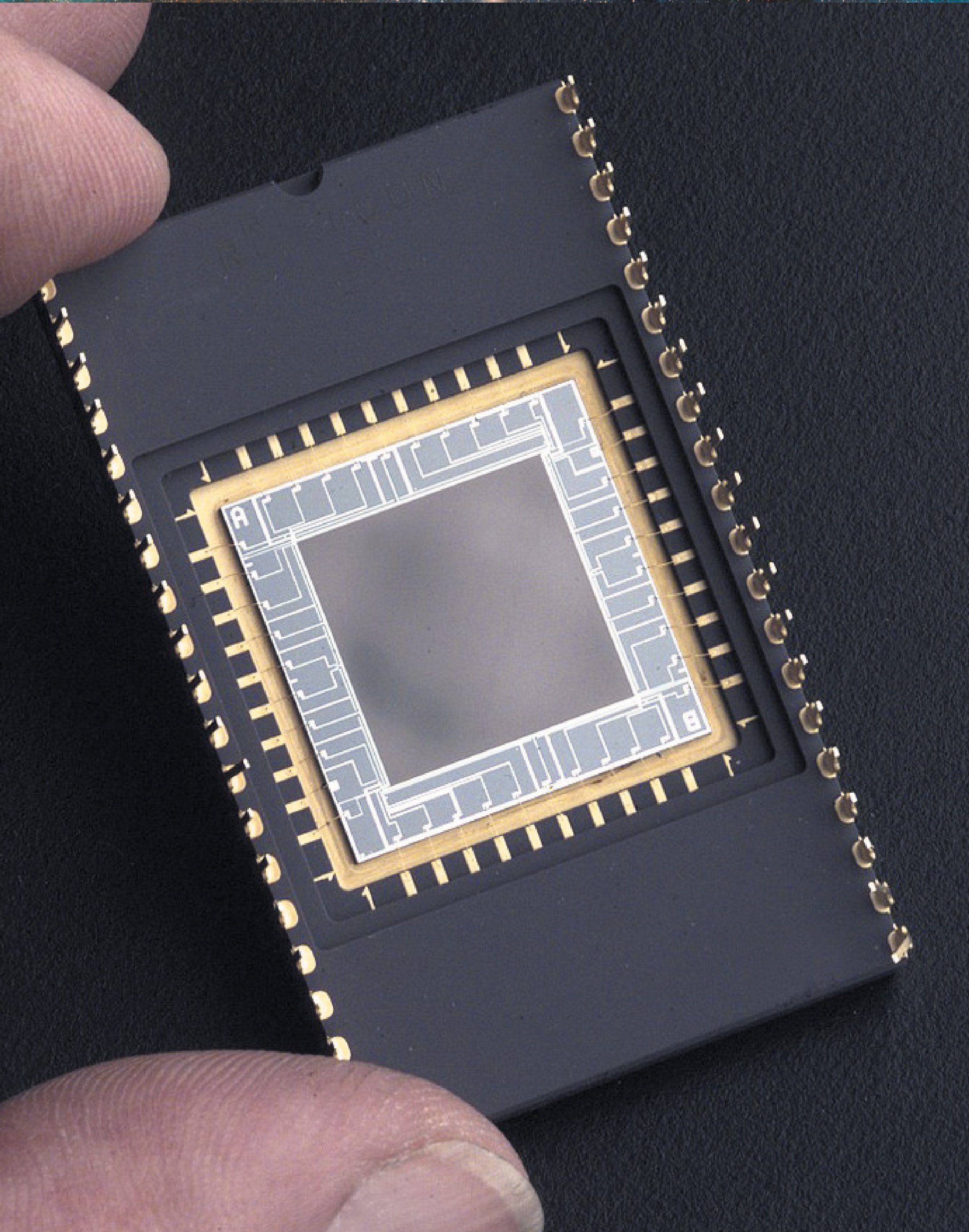
Throughout history, many calendars have been developed, primarily tied to culture or region. The concept of time was conceived through observation of the apparent motion of the Sun, Moon and stars and the rhythm of night and day. The notion of a day was connected to the motion of the Sun and the conception of a month came from observations of the changing phases and positions of the Moon. The concept of an hour can be traced back to the Egyptians who divided the day into 10 parts, with an extra part before and after to allow for sunrise and sunset.

Today, keeping accurate time is done with high precision atomic clocks, in which the frequency of an atomic transition is used as a standard to keep time. The world's time is based on International Atomic Time, which is kept by a few hundred atomic clocks at various institutions around the world.

The task of combining the time of all atomic clocks around the world is carried out by the International Bureau of Weights and Measures and the International Earth Rotation and Reference Systems Service. This service is responsible for keeping clocks in synchronization with the motion of the Earth around the Sun and the Earth's own rotation. These are measured very precisely using strong and distant radio astronomy sources – radio galaxies and quasars – as a reference frame, known as ephemeris time.

The ability to keep accurate time is essential for the Global Positioning System (GPS) satellites, which have accurate atomic clocks on board that are tuned to ephemeris time. The precise knowledge of the time and their positions makes it possible to use their signals for accurate position determination on the surface of the Earth.

The Global Positioning System (GPS) satellites rely heavily on the accurate keeping of time. Each satellite is equipped with an atomic clock onboard that is tuned to ephemeris time.
Credit: Los Angeles Air Force Base



Imaging

Some of the most useful examples of technology transfer between astronomy and industry include advances in imaging and communications.

A film called Kodak Technical Pan is used extensively by medical and industrial spectroscopists, industrial photographers, and artists, and was originally created so that solar astronomers could record the changes in the surface structure of the Sun.

In 2009, Willard S. Boyle and George E. Smith were awarded the Nobel Prize in Physics for the development of another device that would be widely used in industry[7]. The sensors for image capture developed for astronomical images, known as Charge Coupled Devices (CCDs), were first used in astronomy in 1976. These sensors quickly replaced film not only on telescopes, but also in personal cameras, webcams and mobile phones. The improvement and popularity of CCDs is attributed to NASA's decision to use super-sensitive CCD technology on the Hubble Space Telescope[8]. Today, CCDs are the detector of choice in astronomical observatories worldwide, whether in-space or on the ground, and for observations ranging from the infrared to X-rays. CCDs are also implemented in amateur telescopes, which has improved the feasibility of astronomical observation from within cities.

Along with these improved imaging techniques, astronomy has contributed to the development of various programming languages that make image processing much easier, including IDL and IRAF. These languages are widely used for medical applications[9].

Various astronomy instruments have also found their way into airports. Technology developed for distant X-ray observations is used in current X-ray airport luggage belts. A chromatograph, a device used for separating and analysing compounds, was compacted and improved for use on a Mars mission. This smaller and lighter adaptation is now used to survey and image baggage for drugs and explosives.

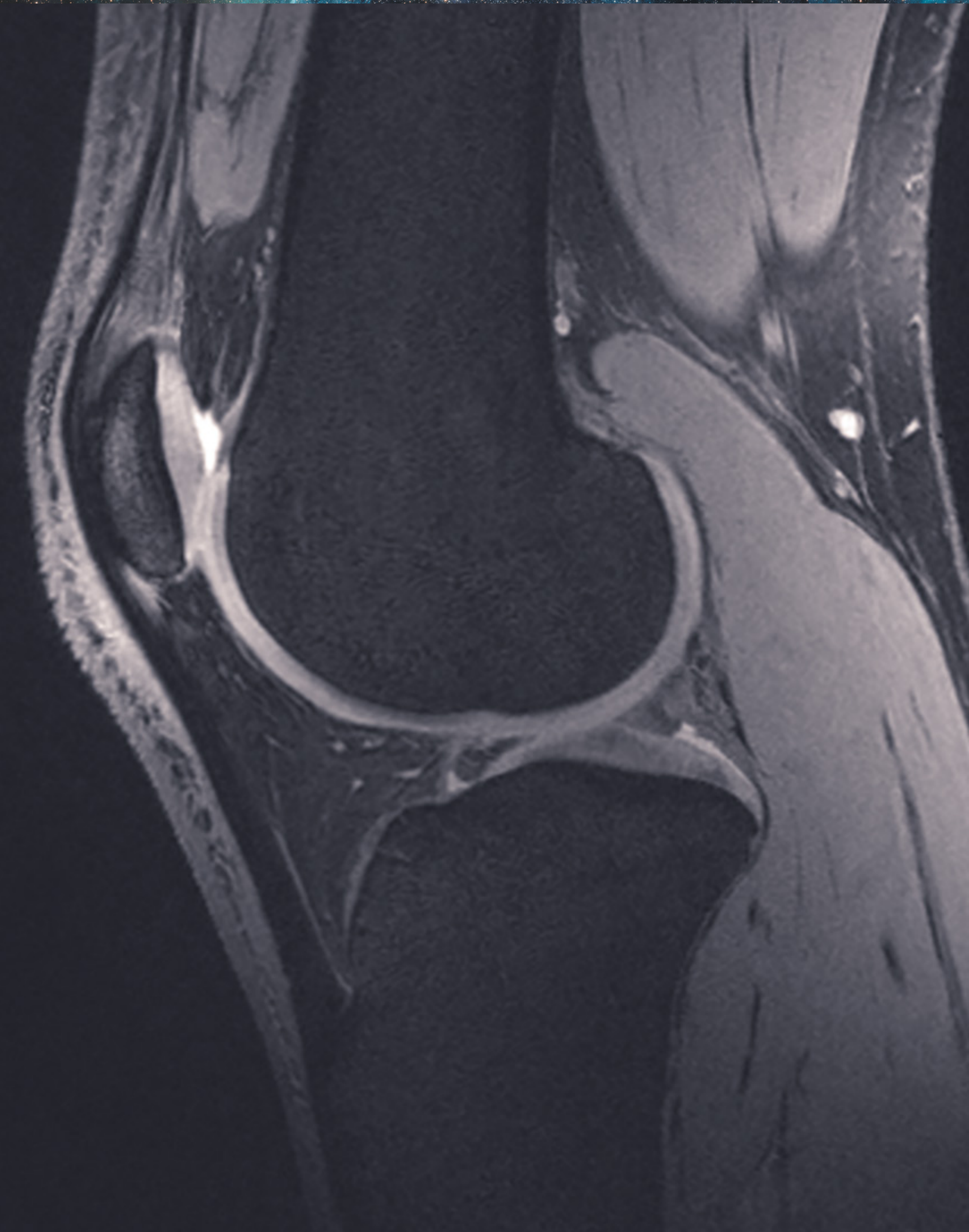
Charge Coupled Devices were first used in astronomy but have since become a common component of personal cameras and mobile phones.

Wi-Fi

In the realm of communication, radio astronomy has provided a wealth of useful tools, devices, and data-processing methods. Many successful communications companies were originally founded by radio astronomers.

Radio astronomy is also credited for contributing to the invention of Wi-Fi. Using techniques which were developed for analysing radio emission from black holes, a team of scientists at the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia developed a new technique for transferring information wirelessly[10]. They developed a microchip that enabled radio waves to be used in complex environments where the signal's reflection off many surfaces can confuse the information transfer. The patents awarded to the inventors paved the way for companies around the world to begin using Wi-Fi to exchange information between networks and portable devices. Modern life depends critically on the flow of data, and science – including radio astronomy – will continue to produce technologies to benefit all humankind.

45-meter radio telescope at the Nobeyama Radio Observatory in Japan.
Credit: Nobeyama Radio Observatory (NRO), NAOJ



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The astronomical technique of combining data from multiple telescopes to produce a single image, known as ‘aperture synthesis’, has been applied to Magnetic Resonance (MR) to enhance the imaging details and to reduce the scan time in medical diagnoses.

Credit: ESA

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