This Crab Nebula image is formed through combining telescope data obtained in different bands: Spitzer Space Telescope (colored yellow, in infrared band), Jansky Very Large Array Telescope (colored red, in radio band), Hubble Space Telescope (colored green, in visible light band), XMM-Newton space telescope (colored blue, in ultraviolet band), and Chandra X-ray Observatory telescope (colored purple, in X-ray band). Copyright/NASA

Universe Panorama --

Audio-visual feast of the multi-band galaxy world

By Daniel Zhu
Photos by virtue of Zheng Yun

Amazing Multi-Band Astronomy
--Visible plus Invisible parts: A Real Universe

Gorgeous celestial bodies are far beyond our imagination, not because of limited human imagination but because our naked eyes cannot see the full picture of the universe. The Earth is protected by a natural layer of atmosphere which filters out high-energy photons, protecting the life on earth from harmful radiation from space, but depriving earth life of the chance to evolve eyes that receive all electromagnetic waves. In fact, the visible light is a tiny fraction of the full spectrum of electromagnetic waves, and the bands beyond the visible light can offer us far more information. The γ-ray, X-ray, ultraviolet ray, infrared ray, visible light and radio bands combined make up the true picture of the universe.

The invention of telescope in 1608 ushered in a new era of astronomical observation, bringing us so many key discoveries and thus broadening people's horizons about the universe. Since the 1940s, great progress in science and technology, especially the rapid development of probes and space technology, has contributed to the advent of the space era of astronomy when many branches beyond the visible light astronomy have sprung up and developed, which, together with traditional visible light astronomy, form the multi-band astronomy covering all the bands of electromagnetic wave radiation from celestial bodies.

Multi-band astronomy refers to the science of observing and studying celestial bodies in two or more different bands, which is an important means of modern astronomy research. It enables the imaging of the target celestial body in different bands so as to obtain multi-aspect information of the celestial body. Different celestial bodies tend to radiate different types of rays, for example, a supernova explosion will release massive γ-ray photons, the dusts in star-forming regions contain more infrared information, while interstellar molecules are easily detected in the radio band.

TIPS Electromagnetic Bands

1. Radio band, covering a wavelength range of 1 mm to 30 meters, can be further divided into radio wave, microwave, etc.

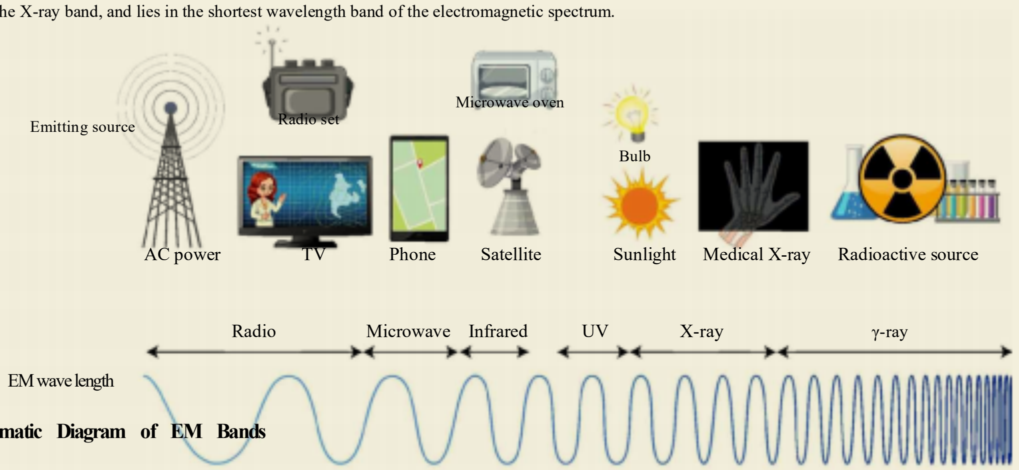
2. Infrared band, covering a wavelength range of 700 nm to 1 mm, usually divided into two regions: the near-infrared region of 0.7 to 25 μm and the far-infrared region of 25 to 1000 μm; it can also be divided into three regions: near-infrared region of 0.7 to 3 μm, mid-infrared region of 3 to 30 μm and far-infrared region of 30 to 1000 μm.

3. Visible light band, covering a wavelength range of about 380 to 780 nm.

4. Ultraviolet band, covering a wavelength range of 10 to 400 nm, lies between the violet end, the shortest part of the visible light band, and the X-ray band. Ultraviolet light with a wavelength shorter than 100 nm is also called extreme ultraviolet radiation.

5. X-ray band, covering a wavelength range of 0.001 to 10 nm, can be further divided into soft X-rays and hard X-rays. Soft X-rays refer to X-rays with a wavelength between 0.1 and 10 nm, while the wavelength of hard X-rays is generally considered to be between 0.01 and 0.1 nm.

6. γ-ray band, with a wavelength shorter than 0.001 nm, a type of electromagnetic radiation with shorter wavelength and carrying higher energy than the X-ray band, and lies in the shortest wavelength band of the electromagnetic spectrum.



Schematic Diagram of EM Bands

Optical imaging of galaxies
-- Masterpiece of the 2.4-meter telescope in Lijiang, Yunnan

Galaxies are the "islands" in the universe. Some of them have existed as long as over ten billion years, but people had little knowledge of galaxies until more than 100 years ago. With the increase of observation means and the development of observation devices, astronomers have gained further knowledge of galaxies, and the multi-band observation approach has allowed us to gradually discover many phenomena unknown to us before. Among all the bands for galaxy observations, the visible light band plays an unparalleled role. Whether space-based devices such as James Webb Space Telescope and Hubble Space Telescope or large-aperture ground optical telescopes, they all seek to enable fine-structure imaging of galaxies. Appreciating the pictures of gorgeous galaxies is just like you are in the galactic arms, dusts or star clusters.

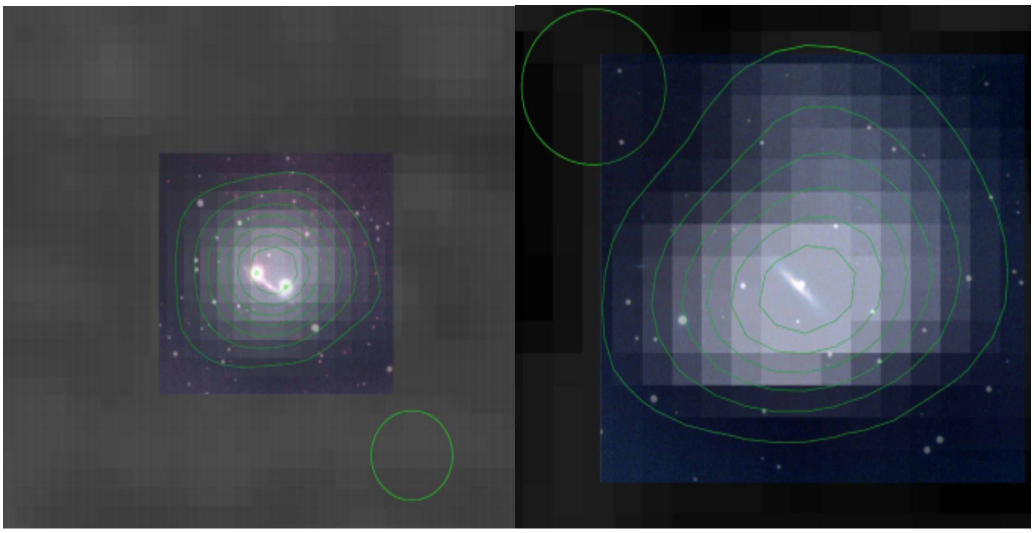
The 2.4-meter telescope located in Lijiang in China's Yunnan Province focuses on high-resolution imaging and high-precision photometry of astronomical objects. With a high altitude, high atmospheric transparency and low atmospheric extinction, Lijiang in Yunnan Province is currently one of the best sites for astronomical observation in China. Compared with other optical telescopes, the Lijiang 2.4-meter telescope is characterized by better image quality, higher imaging resolution, higher pointing and tracking accuracy, and higher degree of automation, which provides sound technical support for its high-precision and high-resolution observation.

Using the Lijiang 2.4-meter telescope, we shot the photos of two galaxies: UGC 1865 and UGC 1033. These are two distant galaxies, not as widely known as the Messier objects, and thus receive little attention from amateur astronomers. The UGC 1865, located in the Triangulum Galaxy, is a Sc D-type spiral galaxy with a B-magnitude 14.9. In the image we have got, it seems like a short a short line drawn between two bright stars. We cannot see its spiral arm structure because what we see is a sideview, just like we are seeing the edge of a plate. The two stars close to the galaxy seem like a pair of eyes, making the galaxy look like a lovely smiling face. The two stars are TYC 2323-736-1 and TYC 2323-176-1, both with a brightness of magnitude 11, much brighter than the galaxy. This is because they are just within the Milky Way, very close to us in the light of cosmic scale. The UGC 1033, located in the constellation Pisces, is a bit brighter, having a B-magnitude 14.4, also a Sc D-type spiral galaxy. We choose the two galaxies because their sideviews make it easy to better identify the differences between the observation results obtained in different bands.

Hear the sound of galaxies
-- Data received by the FAST radio telescope in Guizhou province

Thanks to the atmospheric window of the earth, the collection of electromagnetic waves in the radio band can be carried out on the earth's surface. Emerging in the 1930s, the radio astronomy has a short history of less than a hundred years but has contributed to four major astronomical discoveries in the 20th century: quasars, pulsars, interstellar molecules and cosmic background radiation. This field has contributed five Nobel Prize winners, making it the cradle of the Nobel Prizes in astronomy. Two indicators can be used for evaluating the basic performance of a radio telescope: sensitivity and resolution. Increasing the aperture of a telescope is one of the main ways to improve its sensitivity and resolution. The Five-hundred-meter Aperture Spherical Radio Telescope (FAST) located in Guizhou is the largest single-aperture radio telescope in the world. FAST not only has high efficiency in sky survey, but also supports different observation modes: FAST supports both drift scanning observation and fixed-point tracking observation, and the observation mode can be adjusted for different observation tasks at any time.

The observation of galaxies by a radio telescope is performed primarily through observing neutral hydrogen. Hydrogen is the most abundant element in the universe, and hydrogen atoms are abundantly distributed in the universe. The diffusely distributed hydrogen atoms consist of two main forms: neutral hydrogen and ionized hydrogen. When the electrons and protons in neutral hydrogen atoms transit between the spin-parallel and anti-parallel states due to collision or other reasons, a hyperfine structure transition spectral line with a frequency of 1.4204057517667 GHz will be generated. Because the wavelength corresponding to this frequency is about 21 cm, this spectral line is often called the 21-centimeter hydrogen line. By detecting the galactic 21cm hydrogen line, FAST can help us understand the formation process of hydrogen molecules, and other dynamics processes of a galaxy.



As such, we have observed the intensity landscape of the 21-centimeter hydrogen lines in the UGC 1865 and UGC 1033 galaxies respectively. Unlike optical photos, what a radio telescope observes is the distribution of intensity of radio waves at a given frequency, delivering a contour diagram similar to the annual rings of a tree. The closer to the galactic center, the smaller the rings are, and the higher the signal intensity is. A comparison of the radio intensity image and optical image of the UGC 1865 may find that the two differ totally in their forms. Contrary to the long and slim optical form, the radio intensity image shows a circular shape, and we can see that two foreground stars also have radio radiation. The radio intensity distribution image of the UGC 1033 is somewhat special, presenting a pear shape, much different from the sideview of the galaxy. Thus, the characteristics of matter distribution in a galaxy are clear: the glowing ionized hydrogen and the stars make up a spiral galaxy, while neutral hydrogen, invisible to the naked eyes but emitting radio waves, show a shape of spherical halo. This may be where the magic of multi-band astronomy lies.

Executive editor: Zhang Chao

About authors

Daniel Zhu, amateur astronomer, studying at Dulwich College Beijing. Having a passion for astronomical telescopes and astronomical observations, he participated in the ‘Payload Solicitation Program for Chang’e-7 Lunar Exploration Mission’ and the ‘Pursue My Mars Dream’ popular science activity, winning prizes in both activities.

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