Stratospheric Observatory for Infrared Astronomy SOFIA

Active Astronomy: Classroom Activities for Learning About Infrared Light

"Sensing the Invisible" Section 5 Images

Objects at Multiple Wavelengths

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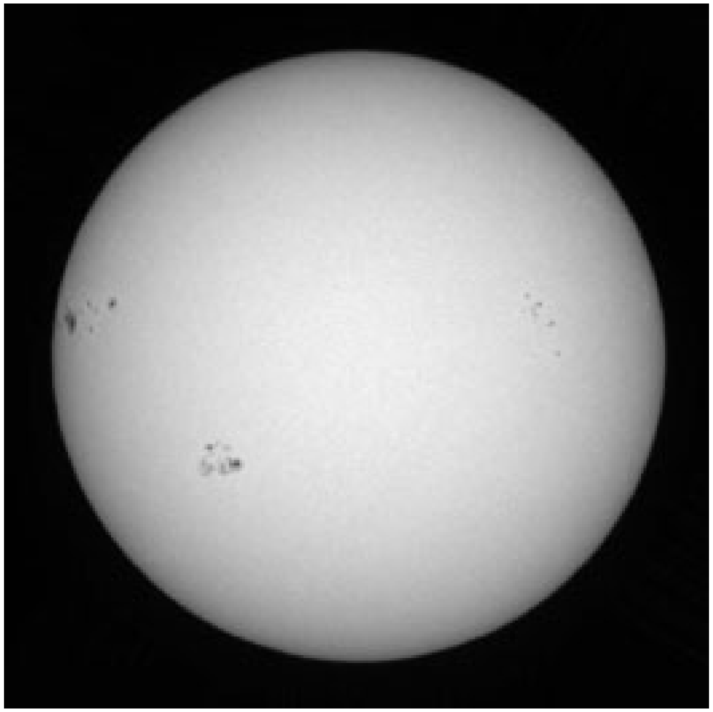
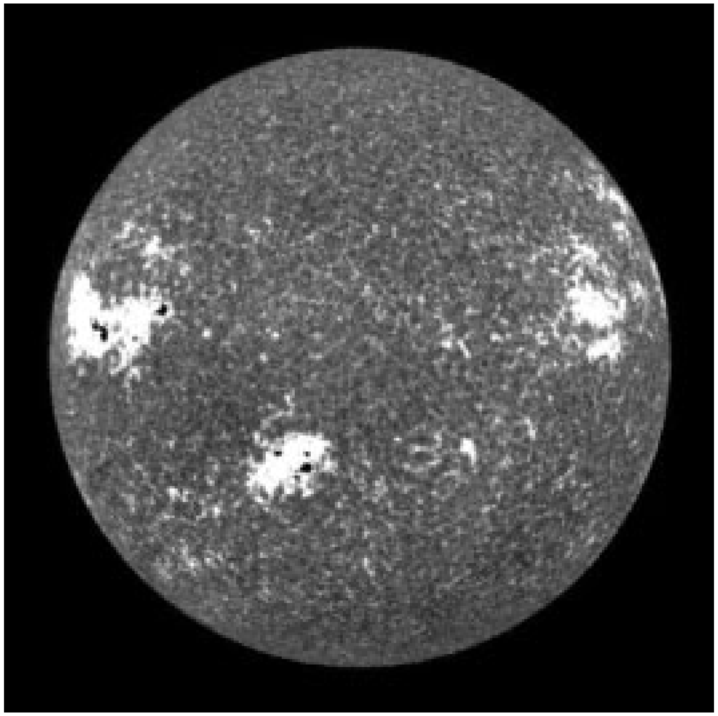


Visible: White Light BBSO



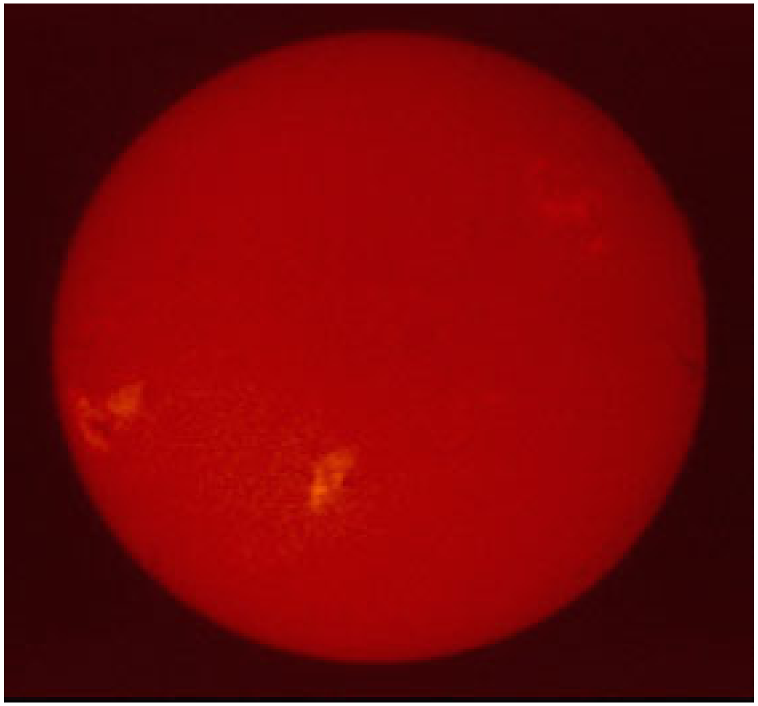
Visible: Calcium-K BBSO

The two images above were obtained at California's Big Bear Solar Observatory. The white light image (above left) is the result of collecting all of the visible light waves (that is, all of the colors in the rainbow). The black-and-white image shows the solar photosphere, with a diameter of about 1.4 million kilometers. [Photos is the Greek word for light.] While the Sun is essentially a very large ball of glowing gas, the photosphere is normally taken to define the solar surface, the region where most of the light originates. The temperature of the photosphere is about 5600-5800 Kelvin (K), or degrees (Celsius) above absolute zero.

The dark splotches on the leftmost (eastern) limb, and scattered elsewhere in the image, are sunspots. These features are cooler than elsewhere in the image, are sunspots. These features are cooler than the surrounding photosphere and are associated with regions of high magnetic fields. Sunspots can be tracked across the face of the Sun as it rotates (with proper viewing precautions, of course!). Whereas the earth rotates every 24 hours, the Sun has a differential rotation period. The rotation periods vary from 25 days at the equator to 36 days at the poles. Sunspot appearances vary on timescales ranging from days to weeks.

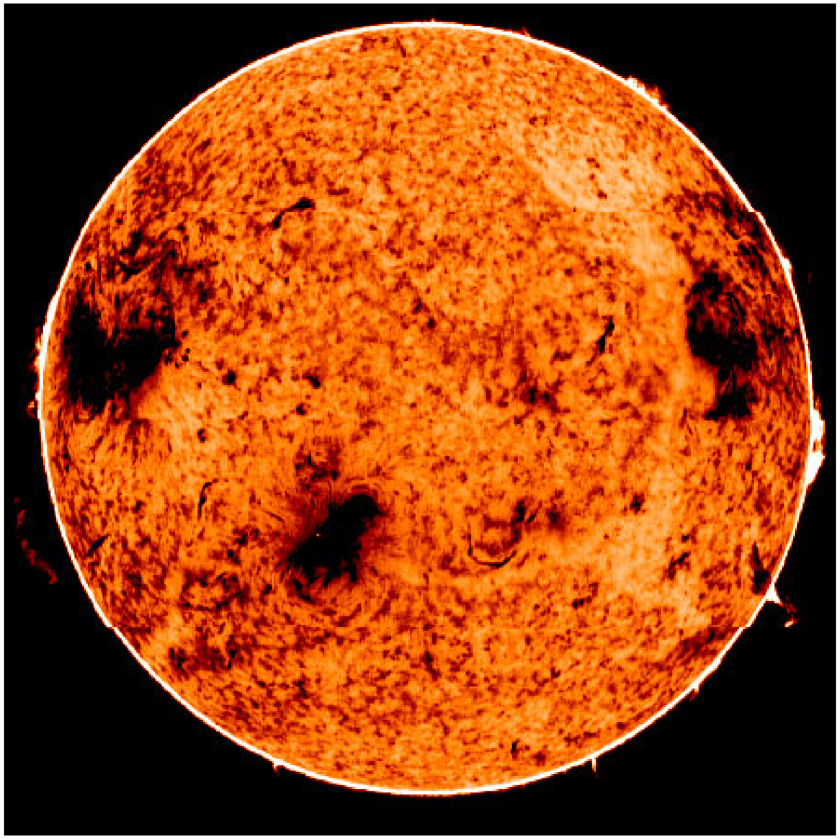
The other black-and-white photograph (above right) is the result of passing the Suns visible light through a narrow-band filter, to selectively detect only light of a particular wavelength. In this case, the Calcium-K filter measures blue light at a wavelength of 393 nanometers (nm). The source of this light is the chromosphere, and is hotter (6000 K to 20,000 K) than the underlying solar photosphere. [Chromos is the Greek word for color.] The (dark) graininess of the photo is due to a solar feature called supergranulation. These convection cells are larger than the diameter of the Earth, and signify that hot gas is being vertically transported within the chromosphere, much like bubbles in a boiling pot of water.

To ascertain what is happening within the white portions of the Calcium-K image, compare their positions on the disk to those of the sunspots seen in the other photograph above (taken a short time earlier). The positions are similar! Apparently, the strong magnetic fields associated with sunspots tend to inhibit the formation of supergranules in the chromosphere.



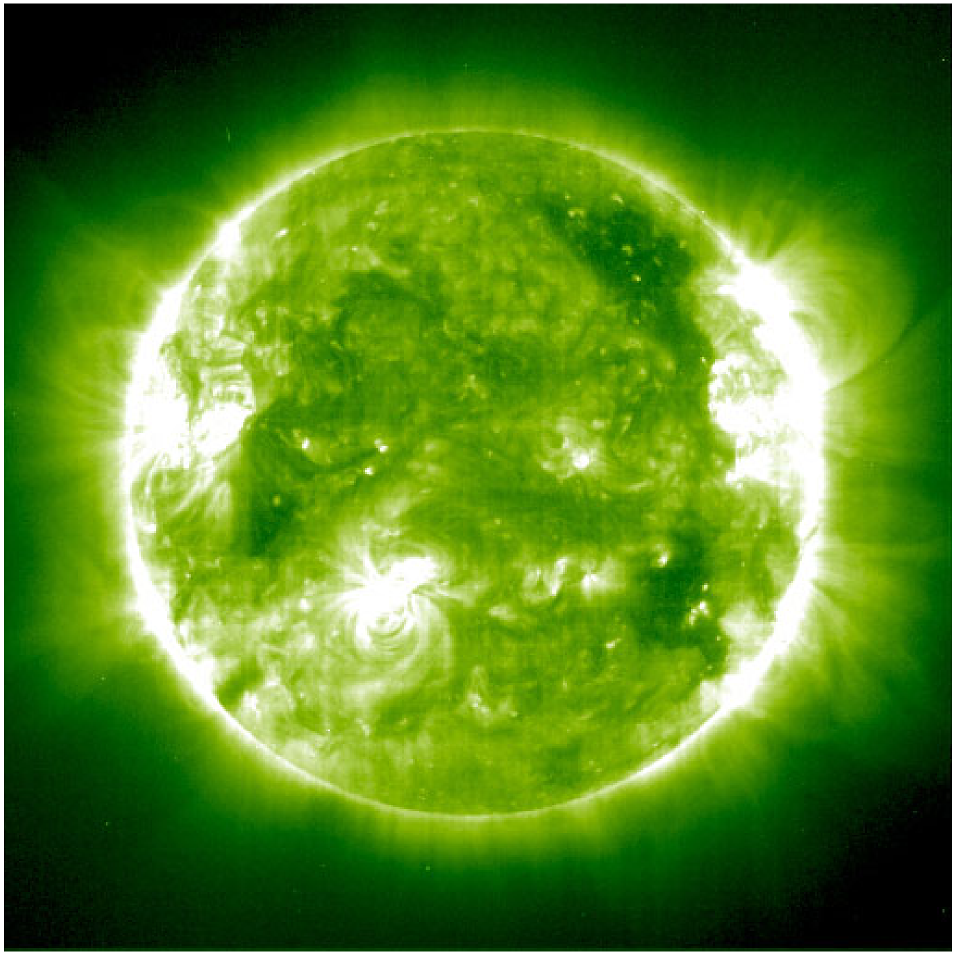
Visible: H-alpha Learmonth

The color image (above) is taken through another visible-light filter, and was obtained at the Learmonth Solar Observatory in Western Australia. The hydrogen-alpha filter admits red light at a wavelength of 656 nanometers, also originating in the solar chromosphere. The lighter regions again correspond to regions with sunspot activity.

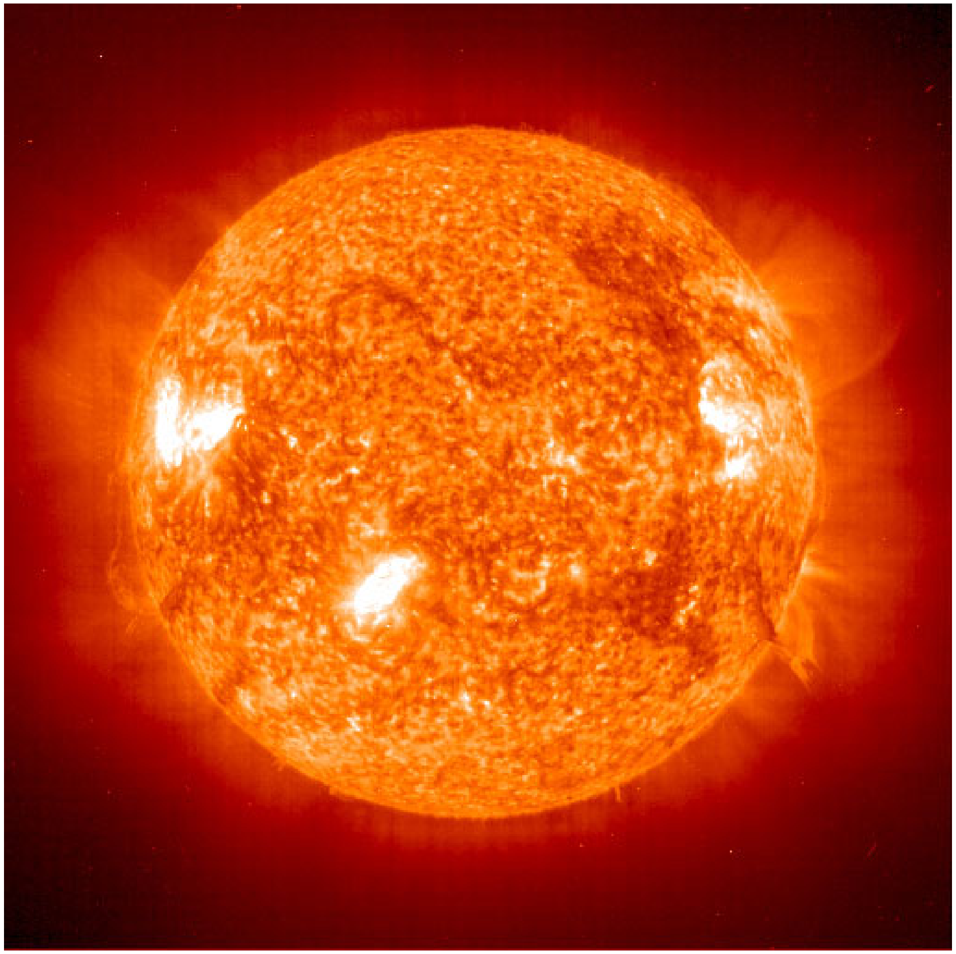


Infrared: NSO

The near-infrared image (above) of our Sun was obtained at a wavelength of 1083 nm (or 1.083 microns) at the National Solar Observatory atop Kitt Peak in Arizona. The darker regions are areas where the gas is cooler and denser, and where some of the IR light is absorbed. If you look closely at the southwest (lower right) limb, you may be able to see a solar prominence. This is an eruption of gas from within the solar corona, the outermost layer of the Sun. In this region, the temperatures reach two million degrees!

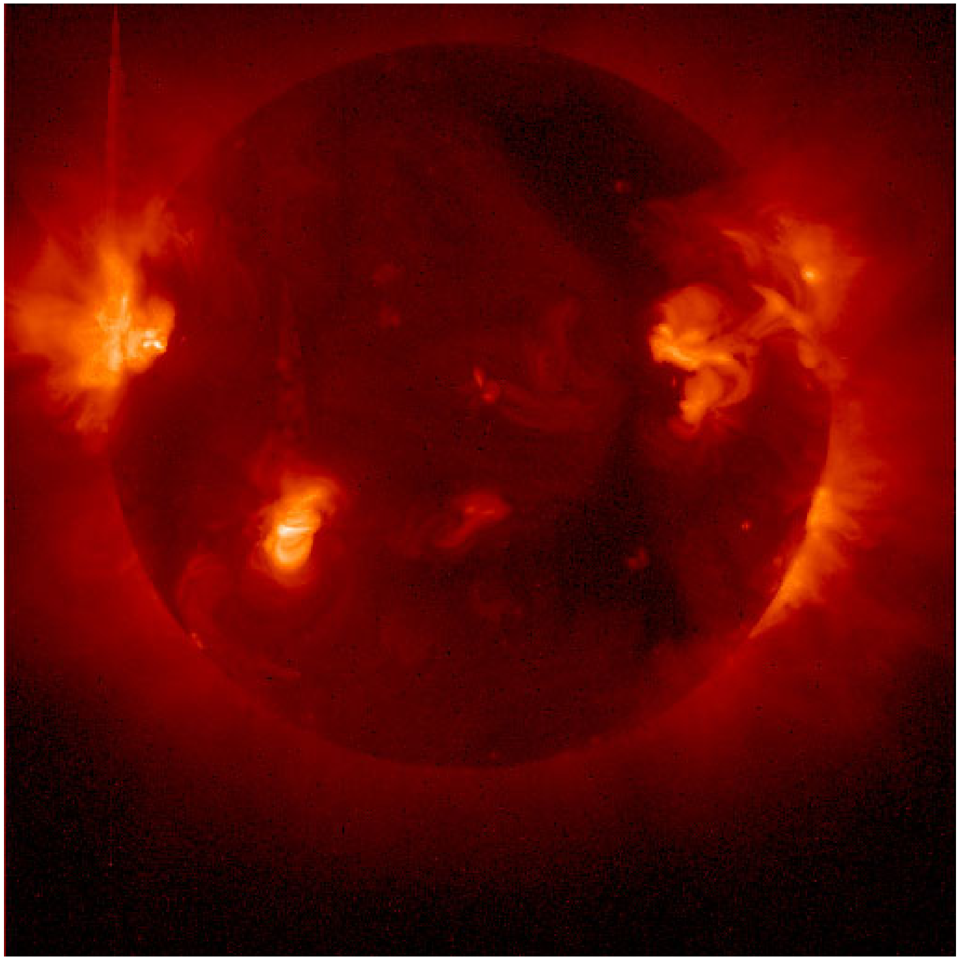


Ultraviolet: SOHO-EIT



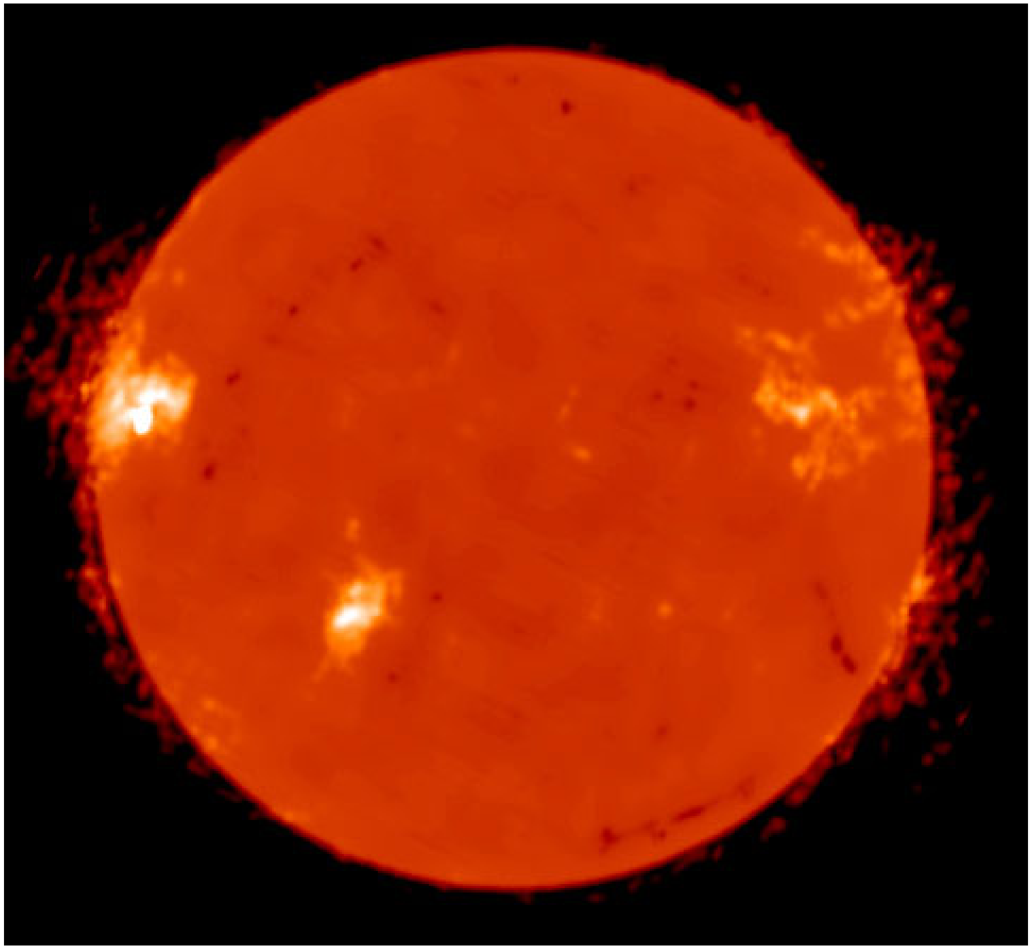
Extreme UV: SOHO-EIT

The ultraviolet (UV) and extreme-UV (EUV) photographs (above), at wavelengths of 19.5 nm and 30.4 nm respectively, were obtained by the Extreme Ultraviolet Imaging Telescope aboard the space-borne Solar and Heliospheric Observatory (SOHO), a collaboration between the European Space Agency and NASA. The UV light originates from the upper chromosphere and lower corona, whereas the EUV light comes from lower regions in the chromosphere. At these wavelengths, we are starting to observe active regions, denoting some of the higher energy phenomena associated with the Sun. These include such features as flares and coronal mass ejections. Lighter regions correspond to the hottest, or most energetic, regions.



X-Ray: Yohkoh

The spectacular x-ray image of the Sun was obtained by the Japanese observatory Yohkoh (Sunbeam), a collaborative effort with the US and UK. Launched in 1991, Yohkoh took the above image at wavelengths corresponding to a few nanometers, and these x-rays originate from the Suns corona. Note the amazing variety of coronal loops and streamers, seen in edge-on projections along the solar limb. Darker regions denote cooler areas where the gas is more quiescent (less active) and denser.

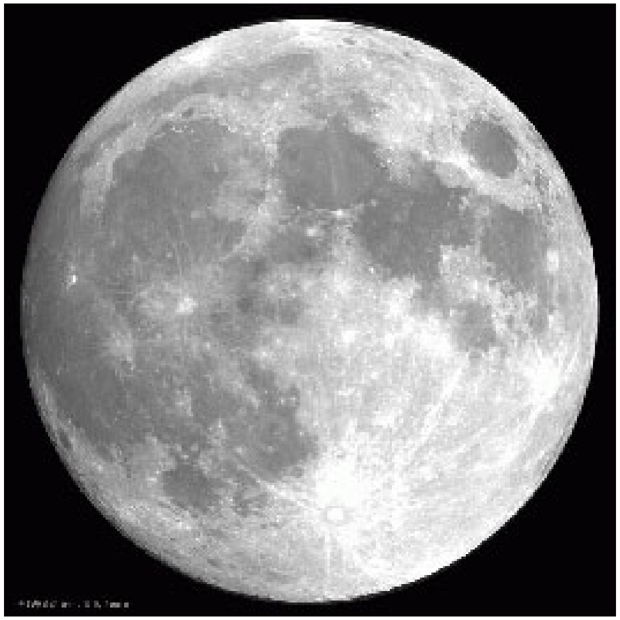


Radio: Nobeyama Radio Obs

We close our solar journey with a quick look at a radio image (above) taken from Japan's Nobeyama Radio Observatory at a wavelength of 1.7 centimeters. As in the other photos, the most active regions are the most luminous.

Visible: SEDS

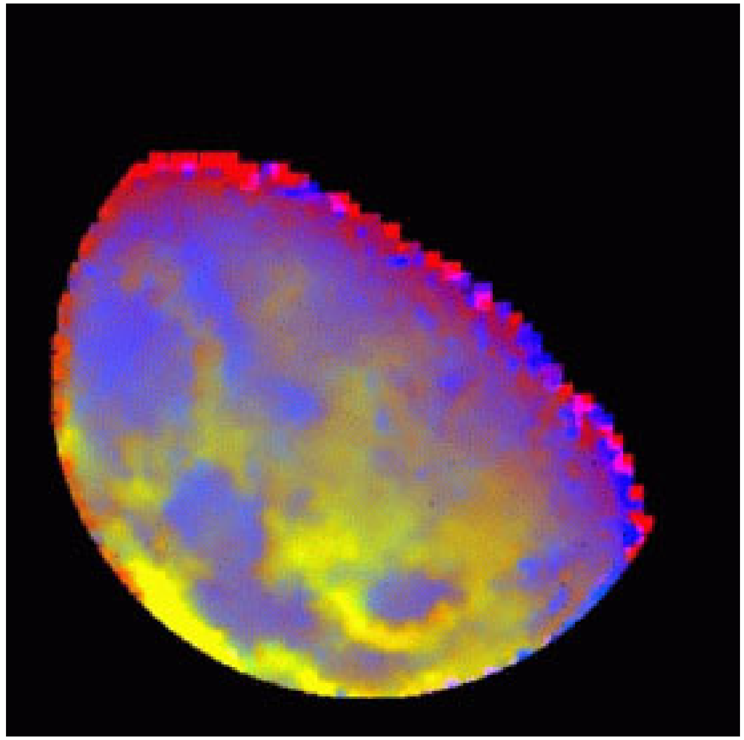
Visible Color: Galileo



Visible: TIE - Colleen Gino

These three images (above) were obtained during a full moon phase, where Earth lies between the Sun and the Moon. If all three bodies were to lie in the same orbital plane, we would see a lunar eclipse, in which the Moon moves through Earth's shadow for a few hours. In the case where a new moon is situated between the Sun and Earth in the same orbital plane, it is possible to experience a total solar eclipse of a few minutes duration.

The Moon shines by the reflection of sunlight, and the various gray shades across the lunar disk reveal variations in reflectivity. The darker and flatter regions correspond to large craters and lunar mare (Latin for seas), areas where less sunlight is reflected. The brighter regions are more rugged, and correspond to lunar highlands and mountains, areas with lower solar reflectivity.



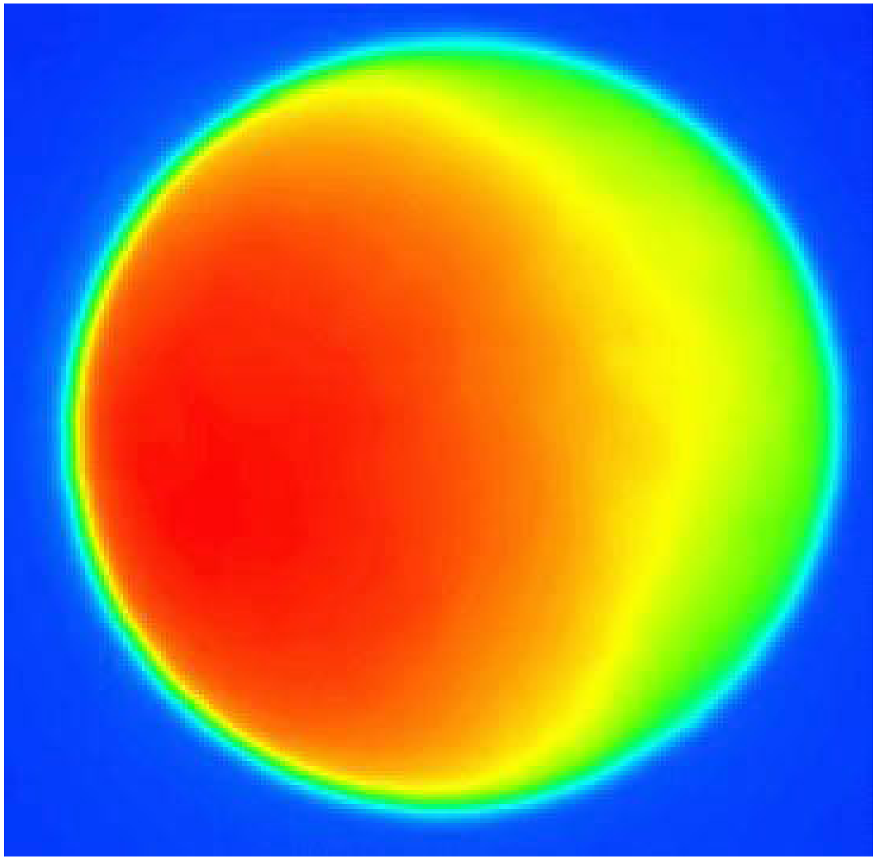
Near Infrared: Galileo

This near-infrared view (above) of the Moon was obtained with the Near-Infrared Mapping Spectrometer instrument aboard the Galileo spacecraft in 1992. In this image, taken at a wavelength of 1 micron (1000 nm), just beyond the red portion of the visible-light spectrum. In this false-color photograph, regions of low reflectivity are coded as blue and the high-reflectivity mountains appear as yellow. The red is an artifact of data processing, created by numerical modeling that becomes increasingly unreliable when approaching the terminator or the limb of the Moon.

Mid Infrared: MSX

The mid-infrared image (above) of the Moon was taken during a 1996 lunar eclipse by the SPIRIT-III instrument aboard the orbiting Midcourse Space Midcourse Space Experiment (MSX) satellite. This mission was primarily devoted to monitoring activities funded by the US Department of Defense, but also spent about ten percent of its time looking upwards and obtaining astronomical data! At these wavelengths, MSX was able to characterize the thermal (heat) distribution of the lunar surface during the eclipse. The brightest regions are the warmest, and the darkest areas are the coolest.

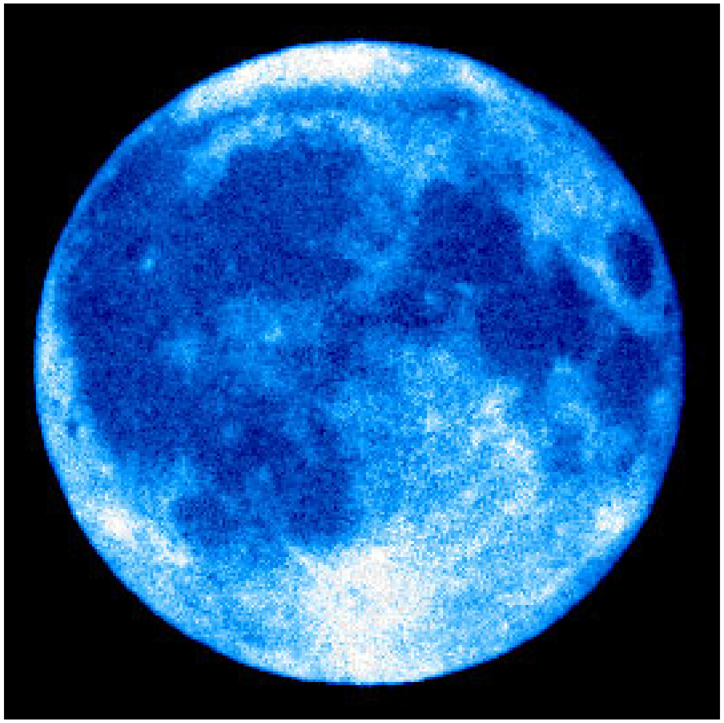
In this amazing image, the well-known crater Tycho is the bright object to the south of center. Numerous other craters are also seen as bright spots, indicating that their temperature is higher than in the surrounding dark mare. The Moon is geologically inactive for the most part, and any temperature differences are a result primarily of variations in solar heating (rather than volcanoes, for example). The Moon lacks any appreciable atmosphere to moderate temperatures, which can vary from 130 degrees Celsius in the sun to 110 degrees in the shade.



Radio: NRAO VLA

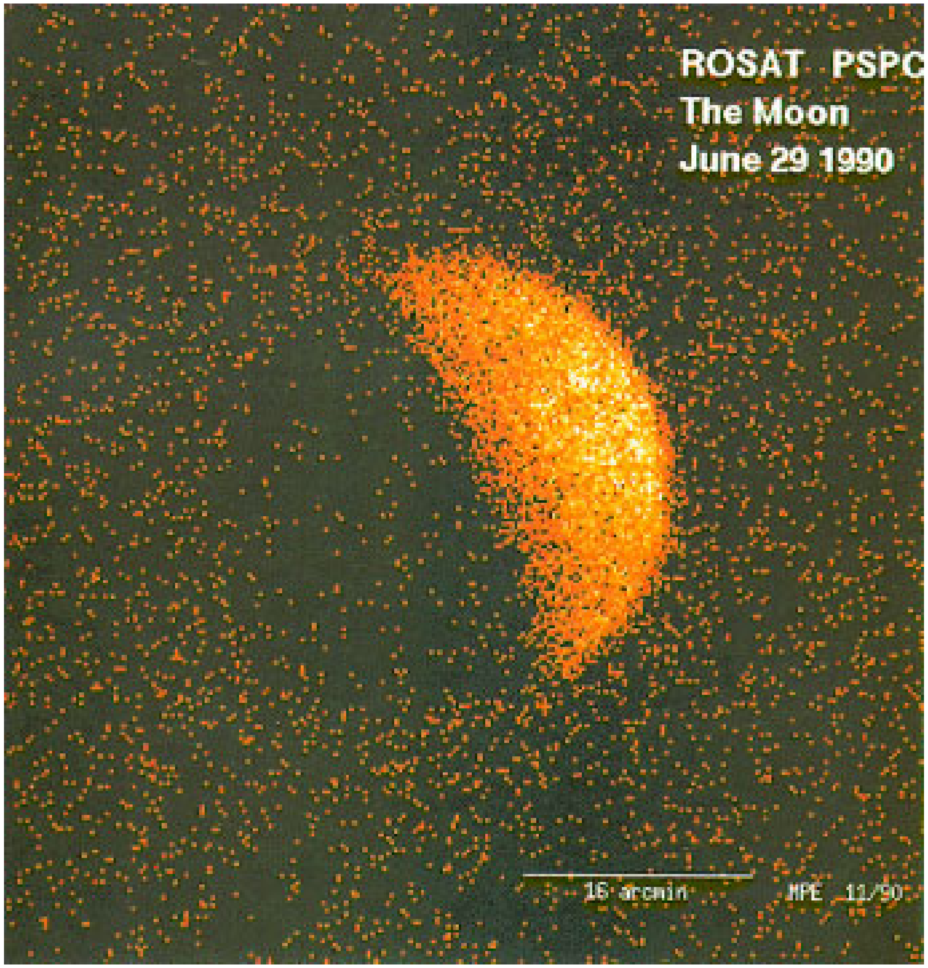
The brightly-colored radio image of the Moon was made using the National Radio Astronomy Observatory 140-foot diameter telescope in Green Bank, West Virginia. This telescope was taken out of routine astronomical service in 1999. The red regions are the brightest radio emission, and blue is the faintest. When this image was obtained, the illuminating Sun was clearly to the east (left). You may be interested to know that some astronomers are exploring the feasibility of constructing a low-frequency (long-wavelength) radio telescope on the far side of the Moon!

Why? The pressure to fully utilize the radio portion of the electromagnetic spectrum for a wide variety of human communications is causing increased levels of radio interference. The weak celestial signals collected and studied by astronomers are being swamped by stronger man-made emission sources. Despite international protection of certain frequencies for science, some visionary astronomers want to locate a radio observatory on the far side of the Moon. Because this side is perpetually turned away from Earth, it would be protected from the noisy environment that is our home planet.



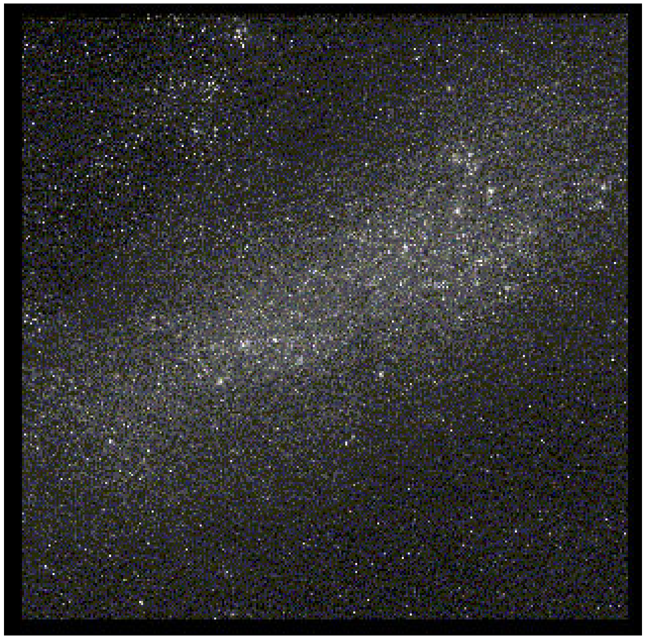
UV ASTRO-2 UIT

Turning our attention back to shorter wavelengths, we now examine the ultraviolet view of the Moon (above), courtesy of the Ultraviolet Imaging Telescope aboard the Shuttle-borne Astro-2 payload. This photograph was taken with a camera sensitive to wavelengths ranging from 120 nm to 320 nm. The general appearance of the lunar surface in the UV regime is similar to the visible-light pictures studied earlier, albeit with lower spatial resolution

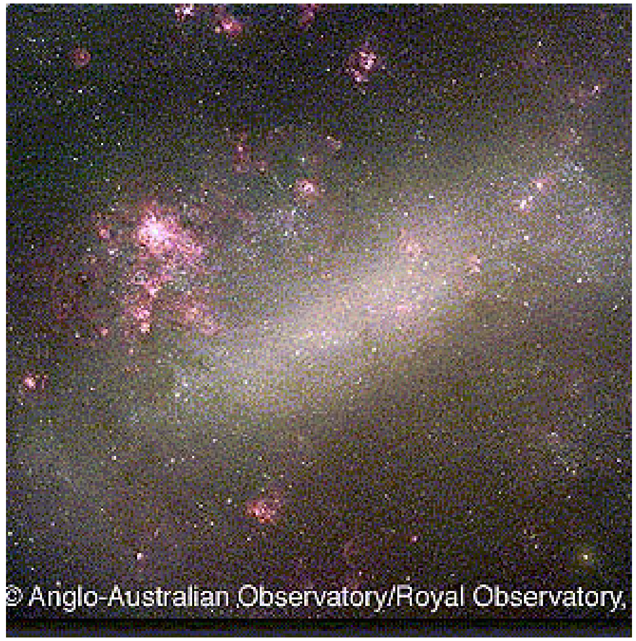


X-Ray: ROSAT

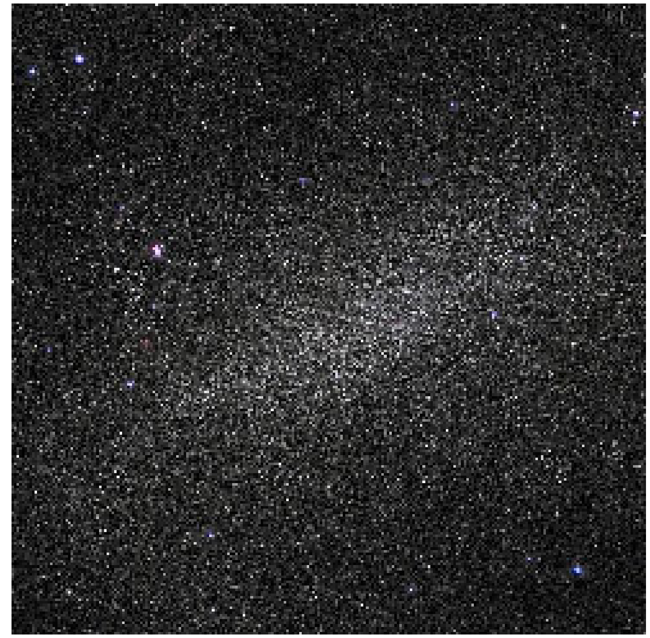
The very short wavelength x-ray image shows the Moon but barely! Celestial x-rays are normally associated with energetic (and even explosive!) phenomena Given the sedate nature of the Moon, we should not be surprised to see that it is very faint at x-ray wavelengths. If not for the fact that our lunar companion orbits so close to earth, we would be unable to detect x-rays from the Moon. Note that the weak x-rays originate primarily from the bright, Sun-lit side. A careful analysis by astronomers has revealed that the x-ray light from the dark side is only 1 percent of that from the bright side. The mottled (speckle) appearance throughout the image is the result of instrument-induced noise, the astronomical equivalent to static on a portable radio.



Visible: DSS

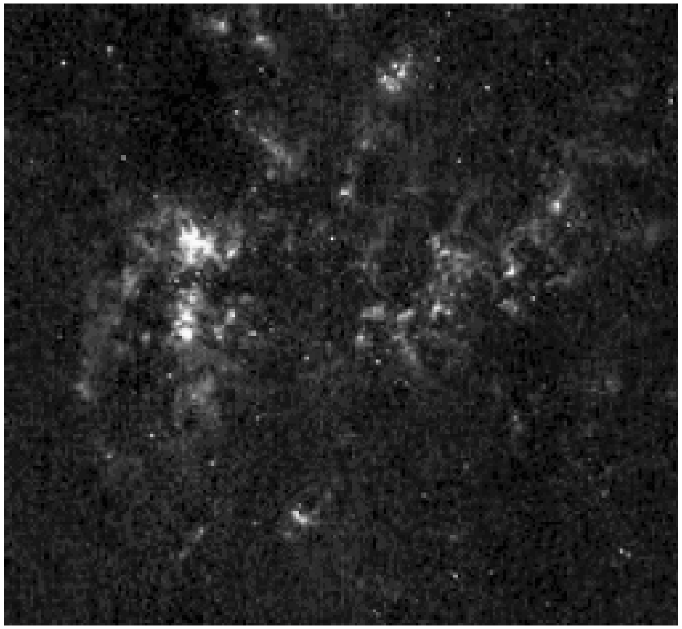


Visible: AAO/Malin



Near-Infrared: 2MASS

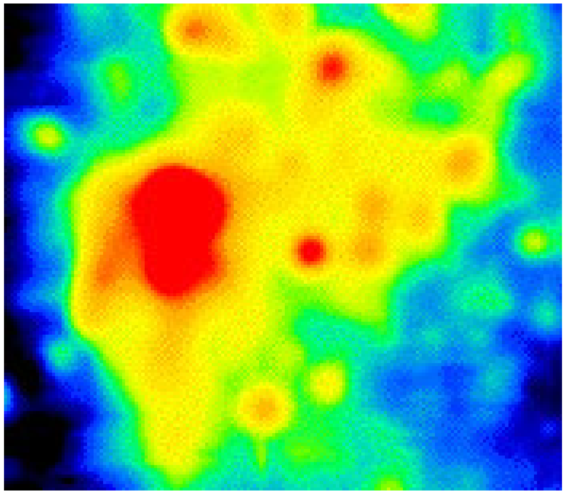
The visible-light images (above, left and center) reveal the diffuse and fuzzy nature of the LMC. In neither case can you define a clear center to the galaxy. The color image is a composite of three images (using B, V and R filters) taken with long exposures of 40-60 minutes. The color image is obviously more sensitive then the black-and-white DSS image. Moreover, the red filter easily identifies the supergiant H II regions, regions where the hydrogen is ionized by the ultraviolet and visible light from newborn stars. The most prominent of these regions is known as 30 Doradus, or the Tarantula Nebula, located to the east and north (left and top) of the image center. The near-infrared photograph (above right) is a short exposure, and bears a resemblance to the DSS visible-light image. At these wavelengths, we are seeing primarily the older and redder stars in the LMC. The core of the Tarantula Nebula can barely be discerned.



Mid-Infrared: MSX

Far-Infrared: IRAS, Jason Surace

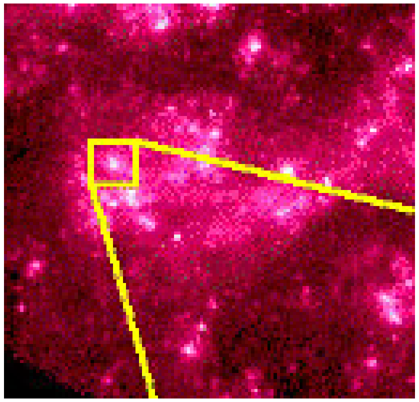
These infrared images (above) were obtained at longer IR wavelengths. The mid-infrared photo was obtained at 6-11 microns, or about ten times the wavelengths of visible light. The photos were taken by the Midcourse Space Experiment (MSX), a military satellite. The small infrared telescope aboard this 1996-1997 satellite spent most of time its time studying infrared backgrounds near the limb of the Earth, but also devoted roughly ten percent of its observing time to mapping the plane of the Milky Way Galaxy and other selected regions of astronomical interest. In addition to the Tarantula Nebula, numerous other regions of glowing gas can be seen in the mid-infrared. These are areas of ongoing and future star formation. The far-infrared mosaic is composed of images obtained at 12, 25, and 60 microns by the Infrared Astronomical Satellite (IRAS) in 1983. This spectacular image has been mathematically enhanced to improve the effective spatial resolution. The redder colors represent longer wavelength emission, and show infrared emission from interstellar dust. The bluer colors correspond to shorter wavelengths and help to identify individual stars. The streaks emanating in a radial pattern from the bright Tarantula Nebula are an artifact of data processing.



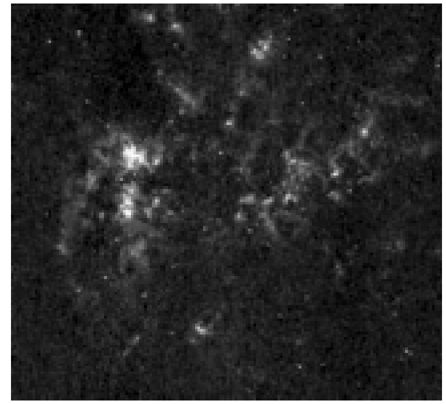
Radio: © RAIUB/MPIFR Bonn

Far-Infrared: IRAS, Jason Surace

This pair of images contrasts the radio emission from the LMC (above left) with the previously studied far-infrared mosaic. The image was obtained at a wavelength of 21.4 cm using the 64-m diameter Parkes Radio Telescope in Australia. The dominant feature in this low-resolution image, false-colored as red, is again the Tarantula Nebula. The distribution of far-infrared and radio emission in galaxies is often similar, since they portray different evolutionary phases of the same stellar population: massive stars. The infrared light results from heating of dust grains by young stars, while the radio luminosity results from synchrotron emission resulting from supernova explosions. You should be able to discern similarities between the pattern of red knots in the radio image and the brightest regions of infrared image in the IRAS mosaic.

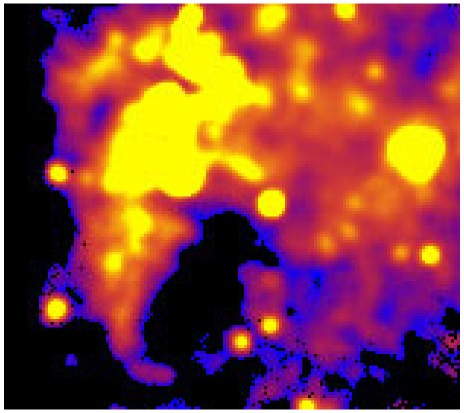


Ultraviolet: Sounding Rocket

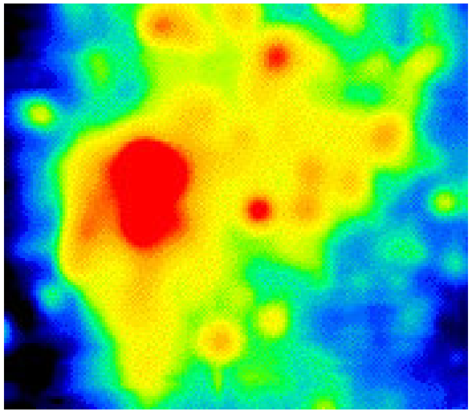


Mid-Infrared: MSX

In this pairing, we compare the ultraviolet photograph (above left) with the previously examined mid-infrared data. The UV data were obtained in a sounding rocket experiment, in which a small rocket carried the science payload to an altitude of 50-160 km for about 5 minutes, before it returns to Earth. Such low-cost rockets are useful for exploring the Universe at altitudes that cannot be reached by balloon-based experiments. In the UV image, the Tarantula Nebula is located within the yellow box. Newborn stars emit large amounts of ultraviolet light, and hence the UV image nicely traces the distribution of star-forming regions in the LMC. Many of these areas are also bright in the mid-infrared, where the UV light has been absorbed and re-radiated by dust grains.



X-Ray: ROSAT



Radio: © RAIUB/MPIFR Bonn

Finally, we compare the x-ray image with the previously examined radio wave photograph. Both are of relatively low spatial resolution. The Tarantula Nebula is buried within a broad region of extended x-ray emission denoting very hot interstellar gas within the LMC. X-ray emission is also seen from discrete point sources, many of which are supernova remnants. Another phenomena that can account for some of the point sources are X-ray binaries. These are a special class of binary star system, where one of the members is a neutron star. The intense gravity of the neutron star sucks gaseous material off of the companion star and heats it to millions of degrees, thereby creating x-rays.