A NEW RADIO TELESCOPE

[Revised May 15, 2012]

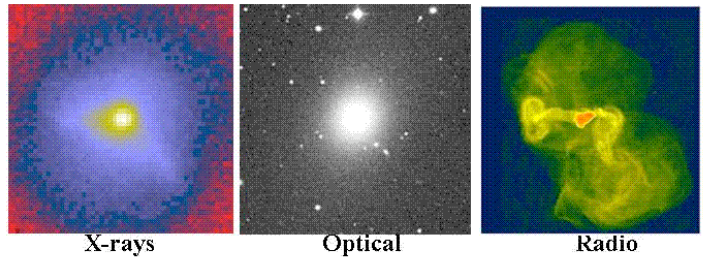

Fig. 2. Images at three wavelengths of the peculiar galaxy M87 in the constellation Virgo.

Space is full of many fascinating things - stars including the sun, clouds of gas and molecules between the stars, the remains of exploded stars called supernova remnants, pulsars, planets, and other objects. These objects are collected into galaxies or even clusters of galaxies and some have spectacular cores such as quasars. They all produce radiation over a large range of wavelengths (see Fig. 1). Radio waves and X-rays are really just extensions of the spectrum to colors we can't see. Essentially radio waves are even redder than infrared and X-rays are more violet than ultraviolet. We are all familiar with visible light and seeing pictures of the object producing that radiation; digital recordings of radio waves can be rendered to produce the same kind of images that can be viewed like regular pictures.

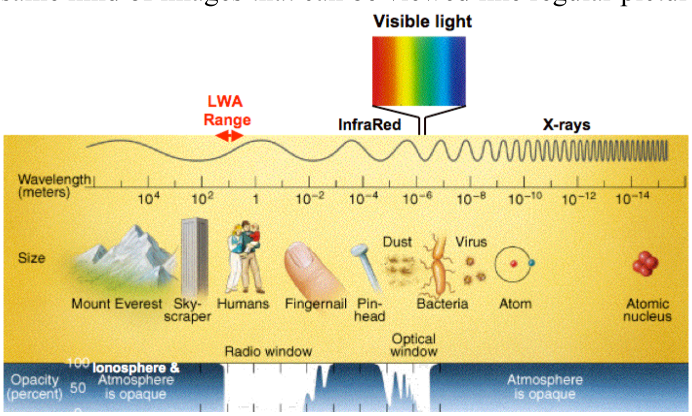

Fig 1. The electromagnetic spectrum showing where the LWA fits.

The characteristics of the emitted radiation depend on the kind of object, such as the sun, a planet or molecular cloud, its structure and other physical conditions including temperature, density, magnetism, and composition. To fully understand them, astronomers must investigate these objects over the full range of wavelengths, requiring a variety of telescopes and techniques. In Fig. 2, the giant elliptical galaxy M87 in the center of a cluster of galaxies shows fascinating differences among wavelengths. The X- rays are from very hot gas at several million degrees, the optical is starlight, and most of the radio emission comes from cosmic-ray electrons accelerated by interstellar magnetism.

One of the least studied regions of the spectrum is that of long-wavelength radio waves. This is for three reasons: (1) there are many man-made signals, including TV and FM radio that completely overwhelm the signals from space; (2) a region of charged particles in the Earth's upper atmosphere, called the ionosphere, can seriously affect these radio waves as they travel through it to reach the earth and even become opaque at the longest wavelengths (see Fig 3); and (3) the pinpointability of a telescope depends on its size in wavelengths. Therefore, to get high resolution with a long wavelength radio telescope requires huge sizes covering many miles.

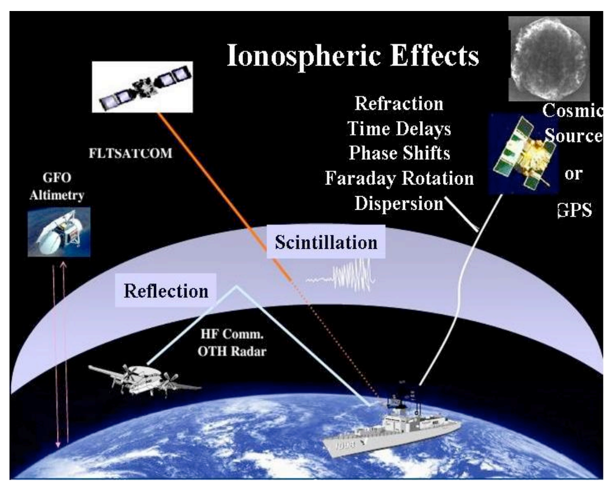

Fig. 3. Some effects of the earth's ionosphere on radio waves from terrestrial, satellite, and cosmic sources.

To investigate this important end of the spectrum, several institutions* are collaborating to construct a new radio telescope for wavelengths between 4 and 30 meters called the Long Wavelength Array (LWA). Because we cannot completely cover the whole area, the LWA will consist of up to 50 separate "stations" spaced throughout southwestern New Mexico to mimic a larger telescope many miles across. The low population of this area produces very low levels of man-made radio interference.

In addition to producing fine detail rather than a blurred image, the large extent also helps the studies of the ionosphere which can vary over scales of tens of miles.

A station consists of 256 individual elements within a fenced boundary just over 100 yards on a side or about 2 football fields side-by-side. The first station, LWA1 is situated just south of the center of the VLA (Fig. 4). It replaced a Long Wavelength Demonstrator Array of only 16 elements used to check concepts and do initial science on astronomical sources.

The elements themselves look like plastic and metal pyramids about 5 feet high and about 9 feet across the base. They are the correct size to resonate at the wavelength of interest. The stations need multiple elements because the cosmic signals are so very-very faint that we need to add together many radio "eyes" to detect them at all. It is like using an optical telescope that is much larger than your eye to allow you to see faint objects. The signals from all elements in a station are combined through underground cables to the small white electronics shelter on the edge of the array for initial processing and then sent via fiber-optic cable from the station to a centrally located processing facility. A wire mesh is placed below each element to reduce the effects of variations in the conductive properties of the ground under different weather conditions. Each individual element sees the whole sky but careful electronic combination of their signals allows us to steer the detailed response to chosen directions in the sky.

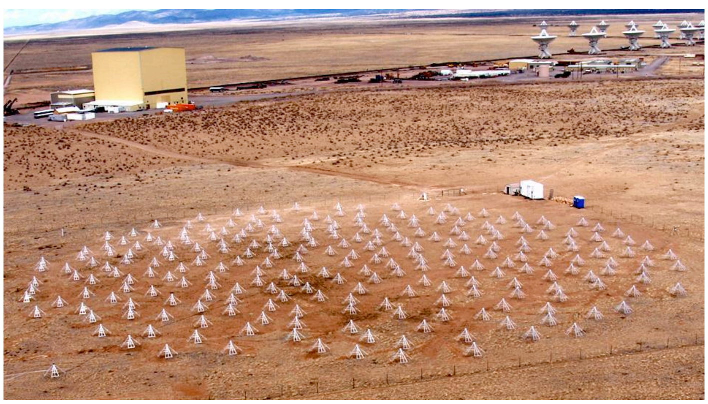

Fig. 4. All 256 elements of station LWA-1 with the VLA in the background taken on April 1, 2010, the date of the official LWA groundbreaking.

The LWA will perfectly complement the Very Large Array (VLA) that operates at shorter wavelengths in the Plains of St. Augustine. Using them together will greatly expand our knowledge of the energetics and properties of many cosmic objects and events, the sun, and the ionosphere.

Fig. 5. Staff and students build an LWA1 antenna.

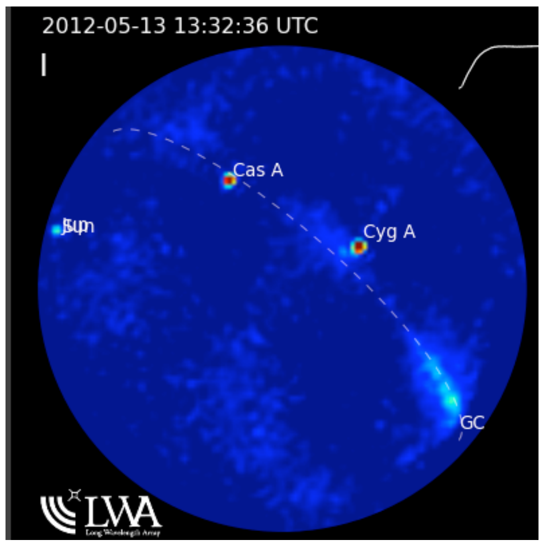

Fig. 6. A low-resolution snapshot in time of the entire sky visible to the LWA1 at 74 MHz showing three bright sources of radio emission. Cas A is the remains of a star that exploded in about 1680. Cyg A is a very energetic distant galaxy. The label GC marks the center of the bright extended emission from the inner plane of our Milky Way Galaxy.

* U. New Mexico, U.S. Naval Research Lab., Jet Propulsion Lab., Los Alamos National Lab., Virginia Tech, National Radio Astronomy Observatory, Air Force Office of Scientific Research,

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