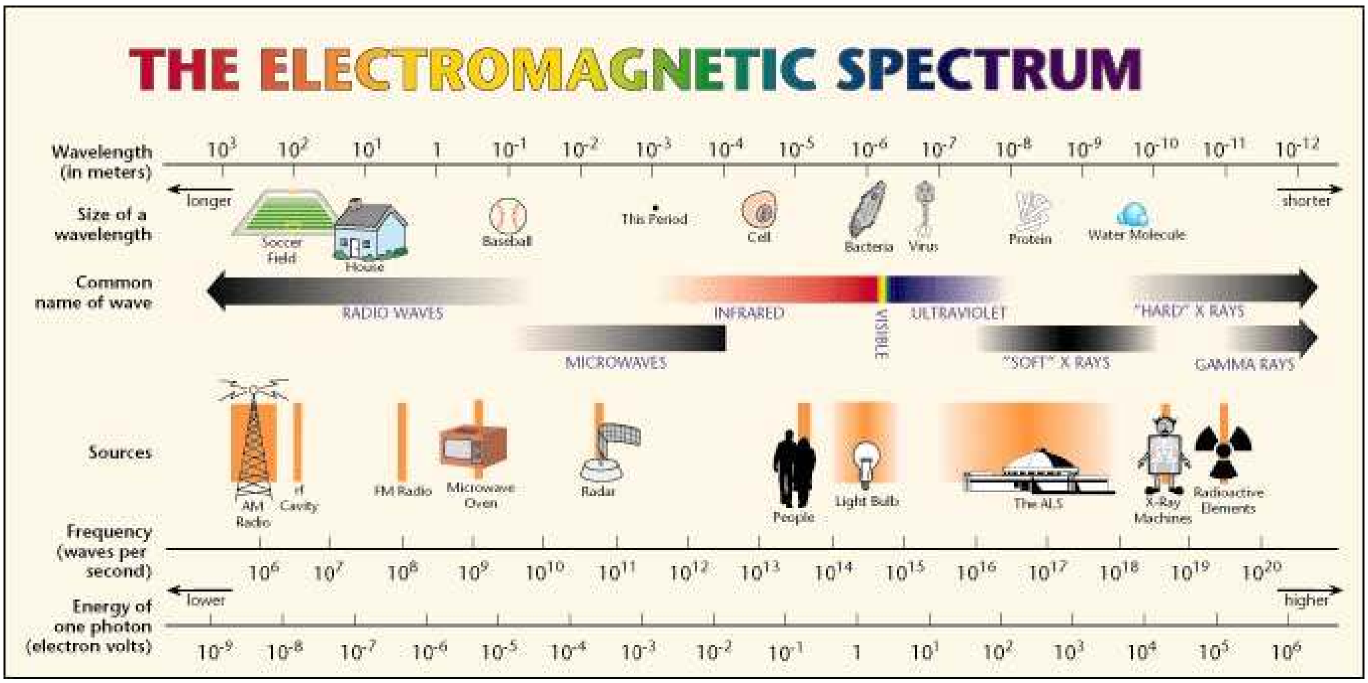
Introduction to Radio Astronomy

What is Radio?
Radio is part of the Electromagnetic Spectrum (EM) along with Light.

The Electromagnetic Spectrum
Whenever an electric charge changes speed or direction it gives off an electromagnetic (EM) wave. How fast the wave ‘wiggles’ determines what kind of EM radiation is created. EM can be placed in order from lowest energy to highest energy as follows: Radio, Infrared, Visible Light, Ultraviolet, X-Rays, and Gamma Rays. The chart below also shows Frequency and Wavelength as well as Energy. These three are related through two equations: $f=c/\lambda$ and $E=hf$ (f=Frequency; c=speed of light (~300,000km/sec); λ=wavelength; E=energy; h= Planck’s constant ($\sim 6.626 \times 10^{-34}$ Joules·sec)). The equations show that as the energy increases, the wavelength decreases and the frequency increases.

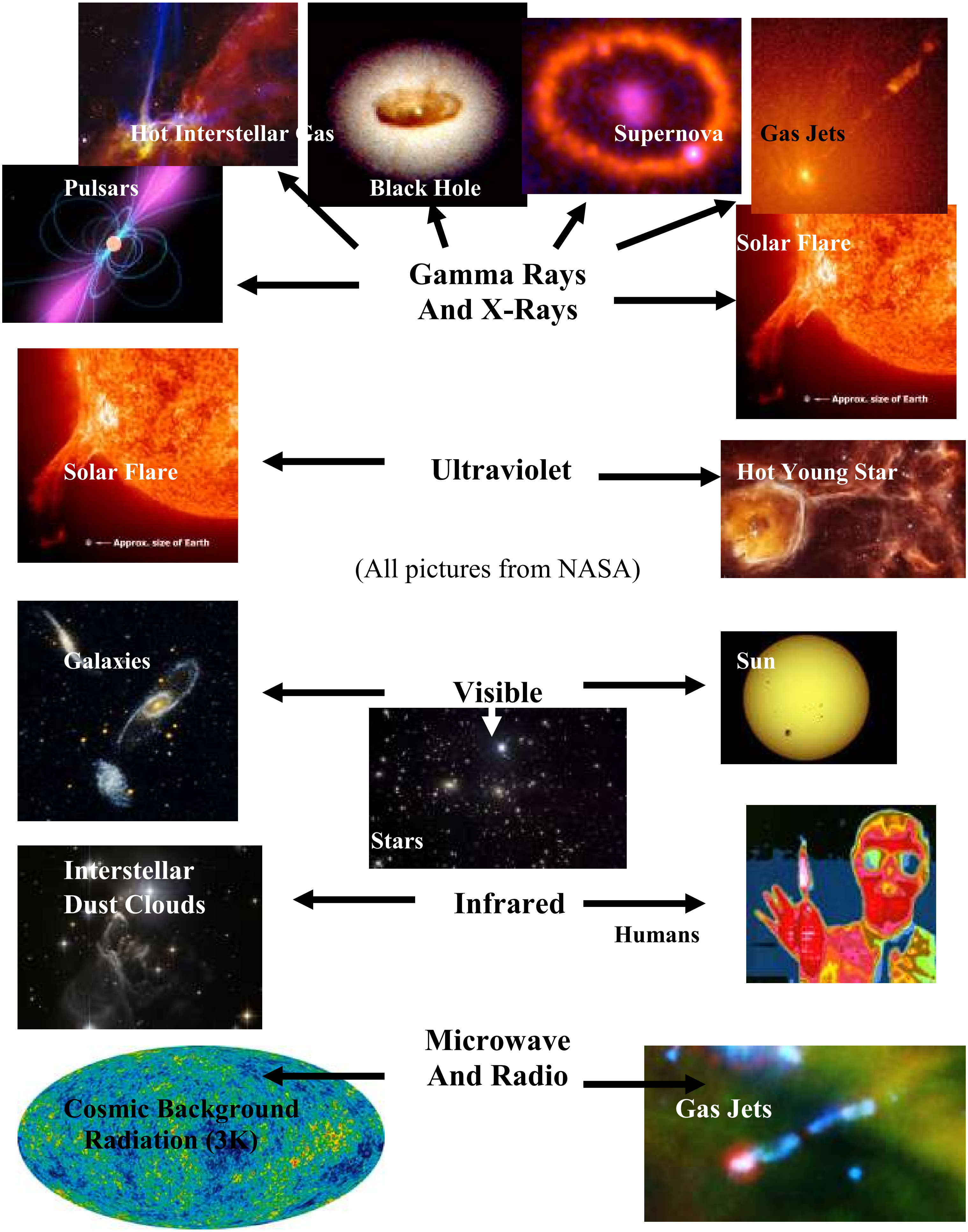


http://son.nasa.gov/tass/images/cont_emspec2.jpg

EM vs. Sound
What are the differences between these two?

- Sound is longitudinal (travels with the wave direction) while light is transverse (travels perpendicular to the wave direction).
- Sound travels at about 1,100 ft/sec while light travels at about 186,000 miles/sec.
- Sound travels only in matter while light can travel through a vacuum.
- Sound is vibrating matter while light is vibrating electrons.

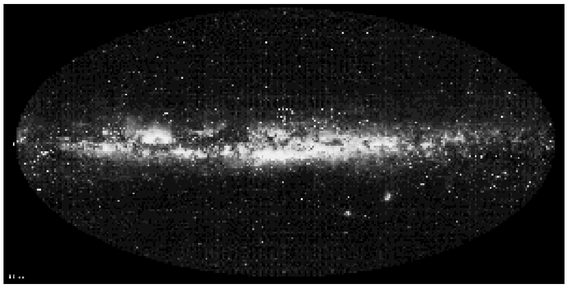
The EM Spectrum and Objects You Can See With It
As the picture below shows, many objects are viewed better in different types of electromagnetic (EM) radiation. Remember that the higher up in the picture you go, the more energetic the object has to be. Therefore, cooler objects will be near the bottom while really ‘hot’ objects will be near the top. Remember that all pictures that are not visible light are representations in false color (i.e.: made so we can see them as if we could see that frequency of the electromagnetic spectrum).

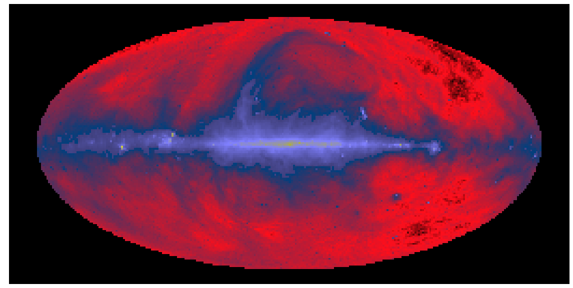


(All pictures from NASA)

The pictures below are of the Milky Way galaxy – the galaxy we live in - and are a 360 degree representation like opening the globe of the Earth into an oval as is often done in classroom wall charts of the Earth. *(All pictures below are from NASA)*

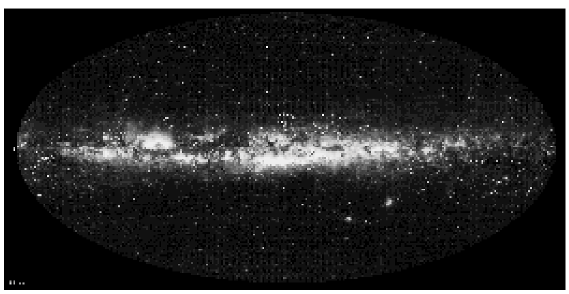
The EM Spectrum - Radio

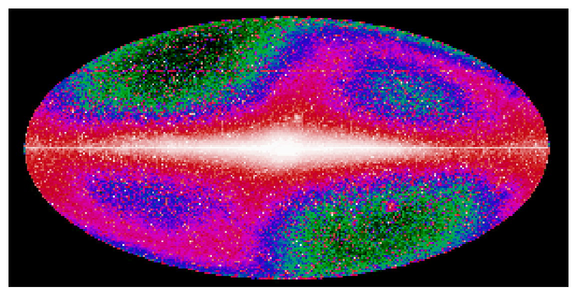




Radio signals are able to reach Earth and so many large radio observatories have been built to look at objects through this large portion of the EM spectrum. The pictures above shows the Milky Way galaxy in a 360 degree map view in both visible light (left) and radio radiation (right - 408 MHz). Remember that radio radiation allows us to look at objects that emit relatively low energy. This includes dust and gases in the galaxy and solar system.

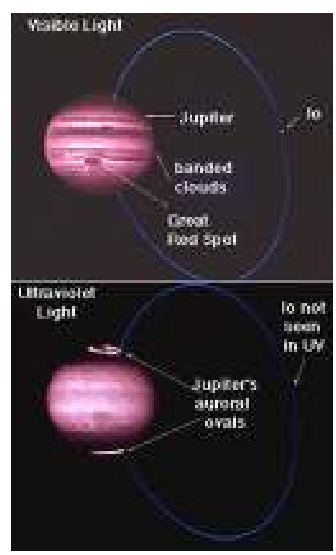
The EM Spectrum - Infrared





In terms of energy and frequency, Infrared radiation (IR) is the next ‘band’ of radiation above radio frequencies. It is what we associate with heat (the lamps used to keep food warm at fast-food places). These two pictures show the Milky Way galaxy in visible light (left) and Infrared (right). Infrared radiation is used to view moderately warm objects. You can see the galaxy clearly in both pictures but using the IR image we can now see the dust in the solar system. (The ‘S’ shaped pink curve in the right picture). This allows astronomers to ‘see’ dust and gas that is invisible to our eyes and optical telescopes.

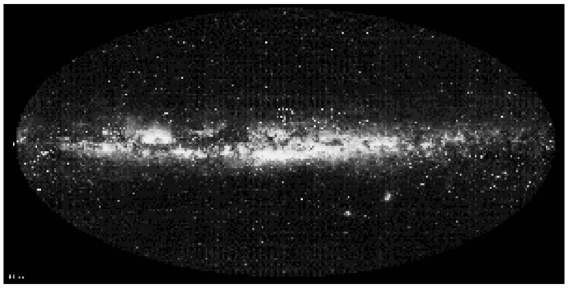
The EM Spectrum - Ultraviolet

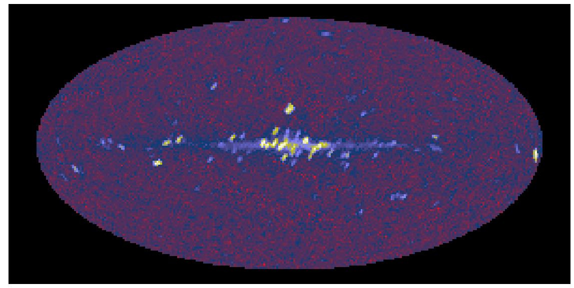


Remember that visible light comes after IR and UV comes after visible light in terms of energy. The picture to the right shows features on Jupiter in both visible light (top) and ultraviolet (UV) (bottom). The auroras on Jupiter are only seen using the UV pictures because they are created by highly energetic particles being drawn to the poles by the magnetic field of Jupiter (or any planet with a magnetic field, including Earth).

Ultraviolet radiation shows objects that are fairly energetic. In the picture of the M74 galaxy (at the right), we can see the distribution of energetic particles and gases - things we cannot see as well in visible light.

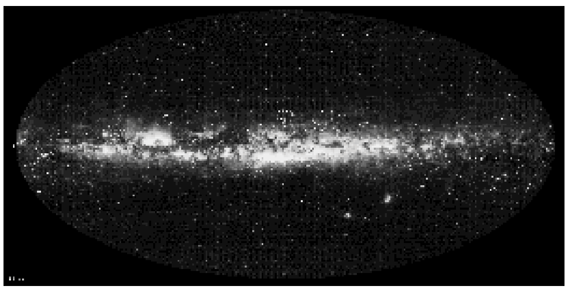
The EM Spectrum - X-Rays

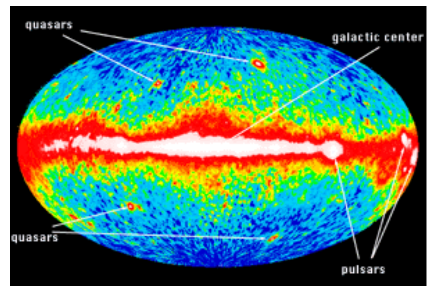




These two pictures show the Milky Way galaxy in visible light (left) and X-Rays (right). X-Ray radiation is used to view very hot objects. You can see the galaxy clearly in both pictures but using the X-Ray image we can now see very energetic objects that are invisible to our eyes and optical telescopes. Note that not all of these objects are within the plane of the galaxy (majority of mass is oriented horizontally in this view).

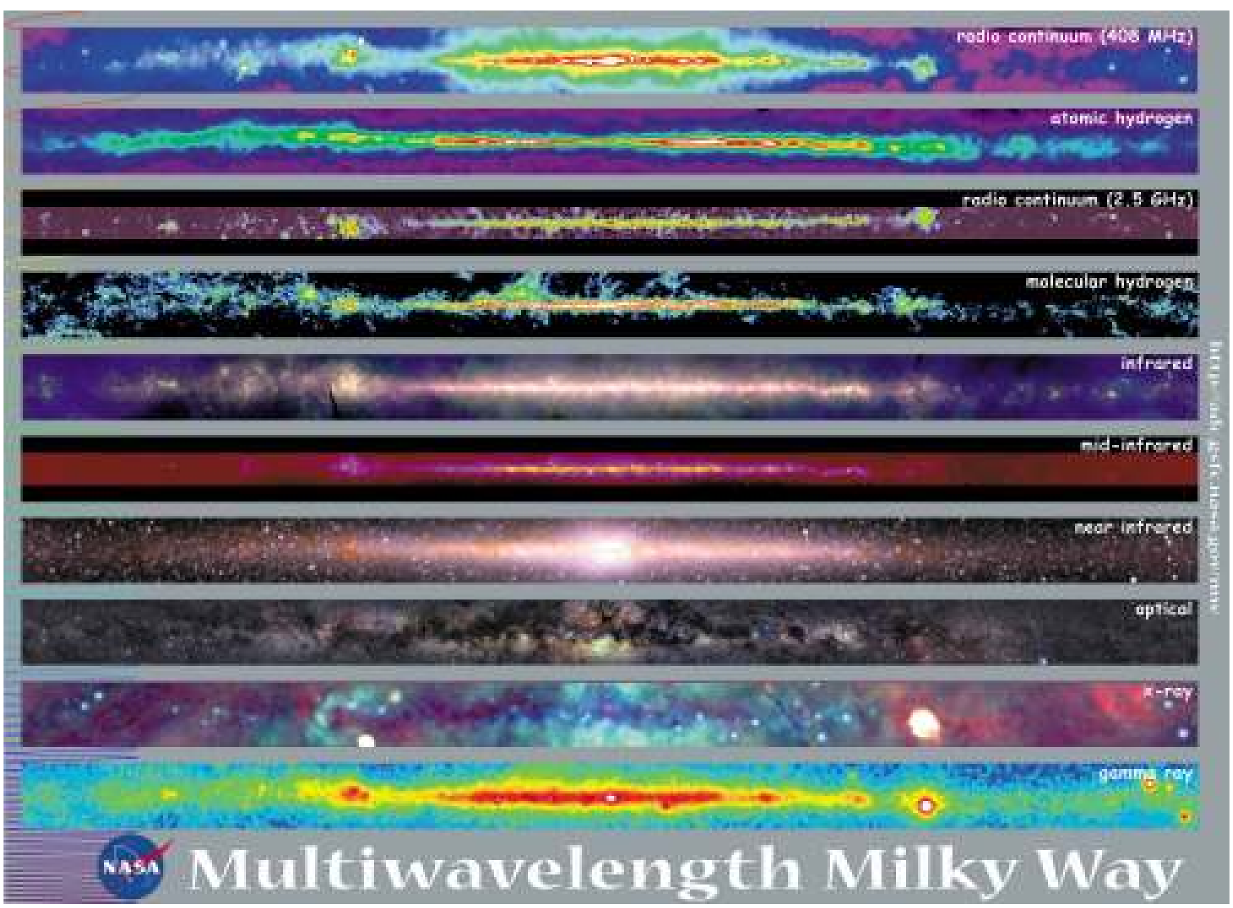
The EM Spectrum-Gamma Rays





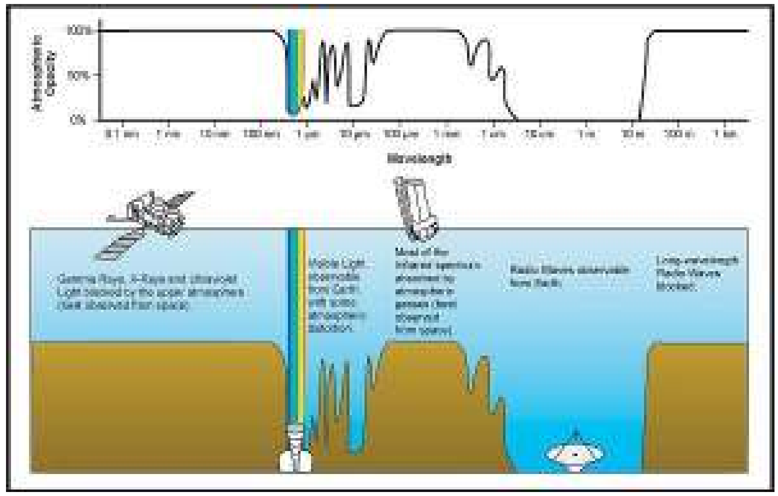
These two pictures show the Milky Way galaxy in visible light (left) and Gamma Rays (right). Gamma Ray radiation is used to image the most energetic objects. You can see the galaxy clearly in both pictures but using the Gamma Ray image we can now see the most energetic objects in our part of the universe that are invisible to our eyes and optical telescopes. Note that not all of these objects are within the plane of the galaxy.

Milky Way Galaxy at Different Wavelengths



Why Radio?
Wavelengths Available From Earth

As you can see from the picture to the right, only light and radio are readily available from Earth's surface (a few wavelengths of IR are as well). If you want to observe from Earth's surface, you need optical or radio telescopes. Also note that radio offers at least 100 times more observable wavelengths than optical.



Picture from: ipac.jpl.nasa.gov/media_images/large_jpg/background/transgraph_colorized.jpg

What Causes Radio Emissions?

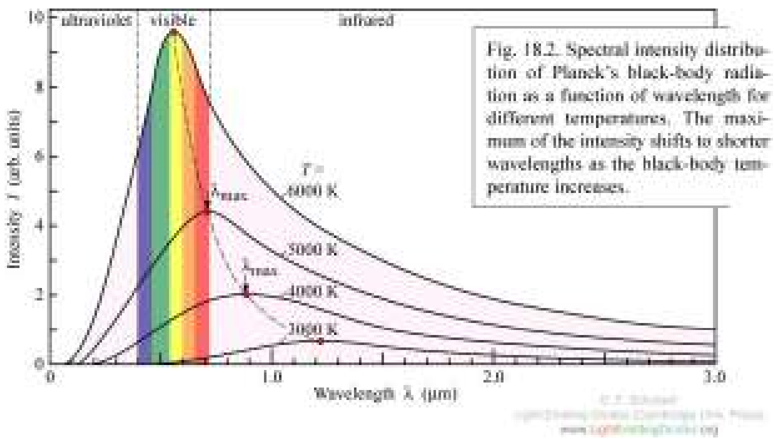
I. Thermal Radiation

All objects with a temperature emit radiation in proportion to their absolute temperature (more accurately - proportional to T^4). Thermal Radiation is the most basic form of EM radiation. There are three types of thermal radiation observed:

- Blackbody
- Free-Free
- Spectral Line

Blackbody Radiation and Temperature

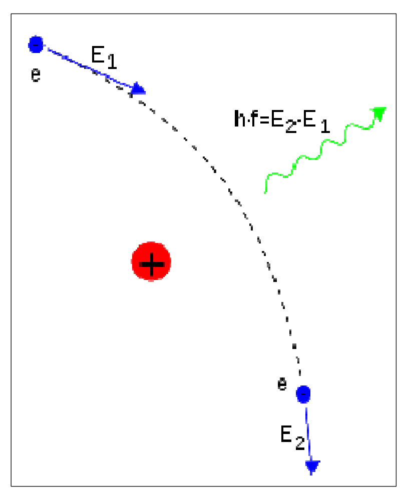
The radiation given off by any object is related to its temperature. The lower the temperature, the lower the energy or frequency of radiation given off and vice versa. A blackbody is a theoretical object that completely absorbs all of the radiation that hits it, and reflects nothing. The object reaches a stable temperature and re-radiates energy in a characteristic pattern (spectrum). The spectrum peaks at a wavelength that depends only on the object's temperature.



Picture from: www.ecse.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap18/F18-02%20Planck%20black%20body.jpg

Free-Free Thermal Radiation

Another form of thermal emission comes from gas which has been ionized. Atoms in the gas become ionized when their electrons become stripped from the atom. This results in charged particles moving around in the ionized gas. As this happens, the electrons are accelerated by the charged particles, and the plasma emits radiation continuously. This type of radiation is called "free-free" emission or "bremsstrahlung".
Some sources of free-free emission in the radio region of the EM spectrum include ionized gas near star-forming regions or Active Galactic Nuclei (AGN).



Picture from: en.wikipedia.org/wiki/File:Bremsstrahlung.svg

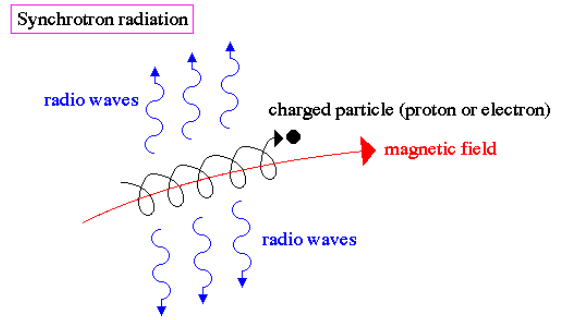
Spectral Line Thermal Radiation

Spectral line emission involves the transition of electrons in atoms from a higher energy state to lower energy state. When this happens, a photon is emitted with the same energy as the energy difference between the two levels. The emission of this photon at a certain discrete energy shows up as a distinct "line" or wavelength in the EM spectrum.

Non-Thermal Radiation

Non-thermal emission does not have the characteristic curve of blackbody radiation. It turns out to be the opposite, with radiation increasing at longer wavelengths.
There are 2 basic types:

- Synchrotron (see picture at right for explanation)
- Maser



synchrontron radiation occurs when a charged particle encounters a strong magnetic field – the particle is accelerated along a spiral path following the magnetic field and emitting radio waves in the process – the result is a distinct radio signature that reveals the strength of the magnetic field

Picture from: http://abyss.uoregon.edu/~js/images/synchrotron.gif

Synchrotron radiation is caused by a charged particle spiraling around a strong magnetic field line and emitting radio signals. (A similar radiation is cyclotron radiation which occurs when the field and particle values remain constant – rare in astronomy). This occurs at Jupiter and many other objects in the sky such as galaxies and black holes.

Masers are naturally occurring stimulated radiation at a single frequency associated with a particular chemical such as water, hydroxide (OH) and many others. They are generated in much the same way that lasers are. Atoms are forced into excited energy states and can amplify radiation at a specific frequency. These atoms are placed in a chamber that creates feedback and produces coherent radiation (all one frequency of radiation – like a laser). Objects that may have masers in them range from comets, planetary atmospheres, stars, nebulae, supernova remnants and galaxies.

Noise and its Nature

There are several sources of noise in radio astronomy. First, there is the noise associated with objects in space. Any object will emit EM radiation at varying intensities and frequencies therefore generating a random noise background level. Second, there are man-made signals which bleed into our frequencies of interest. Anyone who has attended the SARA Conference and met Wes Sizemore knows about NRAO's efforts to rid themselves of interference from electric blankets, cell phones, laptops, digital cameras and the like. Third are the electronic noise sources brought about by quantum fluctuations within chips and other electronics.

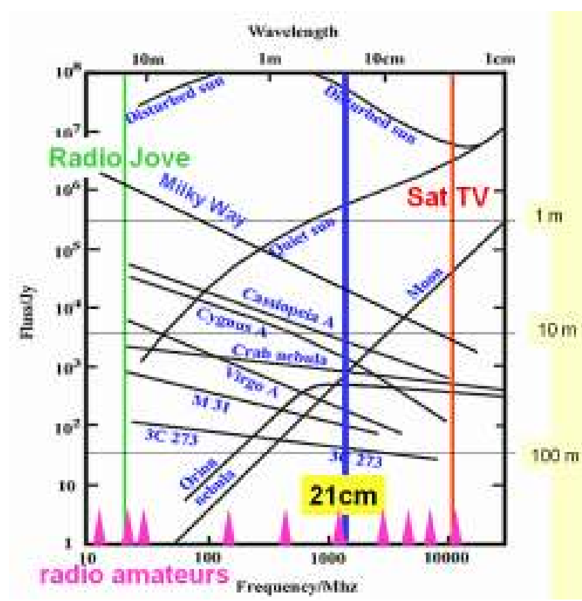


Chart from: astro.u-strasbg.fr/~koppen/Haystack/basics.html

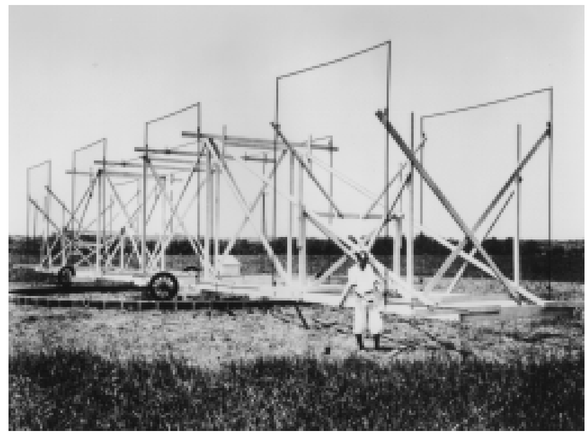
In many radio astronomy observation programs, the signal is many times smaller than the background noise and the signal must be detected using a variety of techniques (see chart on right). These include using a larger antenna to gather more signal, longer integration times (averaging of data), extensive filtering and data processing strategies, cooling of electronics, etc.

How Was Radio Astronomy Discovered? (Pictures in this section from the NRAO website)

Karl Jansky – 1905-1950

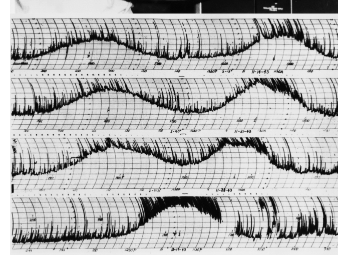
Karl Jansky joined the staff of the Bell Telephone Laboratories in Holmdel, NJ, in 1928. Jansky had the job of investigating the sources of static that might interfere with radio voice transmissions at “short wavelengths” (wavelengths of about 10-20 meters). These wavelengths were being considered for transatlantic radio telephones. After recording signals from all directions for several months, Jansky identified three types of static:

- nearby thunderstorms
- distant thunderstorms, and
- a faint steady hiss of unknown origin.



Jansky spent over a year investigating the third type of static. It rose and fell once a day, leading Jansky to think at first that he was seeing radiation from the Sun. The signal repeated not every 24 hours, but every 23 hours and 56 minutes (sidereal time – the motion of the stars). This is characteristic of the fixed stars, and other objects far from our solar system. He eventually figured out that the radiation was coming from the Milky Way and was strongest in the direction of the center of our Milky Way galaxy, in the constellation of Sagittarius. The discovery was widely publicized, appearing in the New York Times of May 5, 1933. Jansky wanted to follow-up on this discovery but Bell Labs did not. Although fascinated by the discovery – no one investigated it for several years.

Grote Reber – 1911-2002



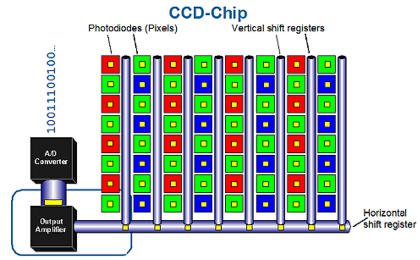
Grote Reber learned about Karl Jansky's discovery (1932) of radio waves from the Milky Way Galaxy and wanted to follow up this discovery and learn more about cosmic radio waves. Reber built a parabolic dish reflector in his backyard in Wheaton, IL in 1937 because this shape focuses waves to the same focus for all wavelengths. Reber spent long hours every night scanning the skies with his radio telescope. He had to do the work at night because there was too much interference from the sparks in automobile engines during the daytime. After two failed attempts he finally succeeded with a receiver at 160 MHz (1.9 meters wavelength) to detect radio emissions from the Milky Way. In the years from 1938 to 1943, Reber made the first surveys of radio waves from the sky and published his results both in engineering and astronomy journals, ensuring radio astronomy’s future.

For more on the history of radio astronomy check out the history section of the NRAO’s website: www.nrao.edu/index.php/learn/radioastronomy/radioastronomyhistory

Imaging: Radio vs. Optical

Optical Imaging

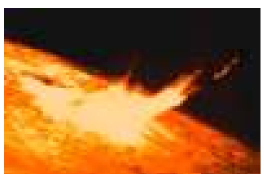
Images taken on modern optical telescopes use CCD cameras (digital cameras) which use millions of dots (pixels) to represent the data. Photodiodes collect light energy and convert these to voltages which are downloaded by row and column to maintain their position information and allow the re-construction of the image. Pixels are obvious in the image below. One optical image contains millions of pixels – all captured at the same time! They become more noticeable at higher magnifications and lower resolutions. (See picture to left)



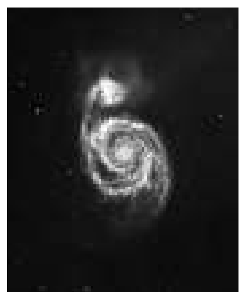
Picture from: www.axis.com/edu/axis/images/ccd.gif

Below are some examples of digital astronomy images taken with a CCD camera (note: all recent astrophotography have been done with CCD cameras).

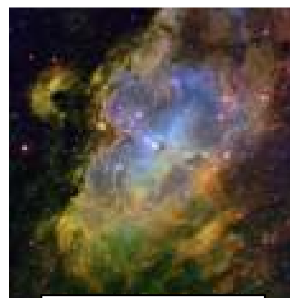
Picture from: photo.net/equipment/digital/basics/pixels.jpg



Solar Flare



M 51 Galaxy



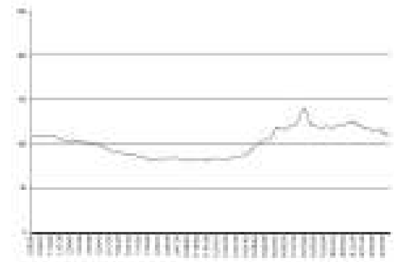
Eagle Nebula

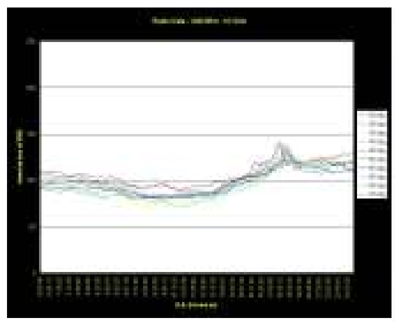
M 13 Globular Cluster

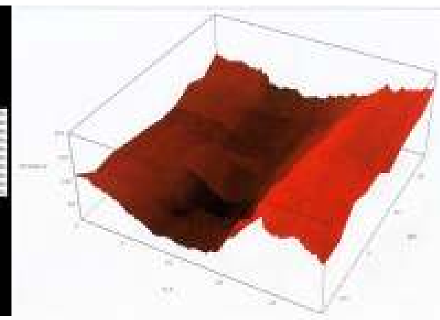
Pictures from www.noao.edu/image_gallery

Radio Imaging

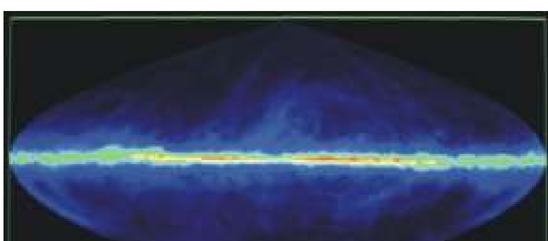
In contrast, radio telescopes can only collect one pixel at a time! Each radio image is a composite of many data collections. Each image take hours, days, or even years! (One full sky image of an amateur's back yard sky could take years!). A big advantage of professional radio astronomy imaging is angular resolution (the ability to separate two different objects). Professional radio telescopes (the VLBI – Very Long Baseline Interferometry) can observe much smaller than a milliarcsecond (This is the angle a hair makes at 10 miles!) whereas, optical telescopes can resolve only to 5 milliarcseconds with the Keck Telescope. Radio telescopes can resolve better because you can simulate much larger radio telescopes by linking many radio telescopes together. Their effective size is based on the diameter of the farthest linked telescopes! On the other hand, an amateur can only achieve expect to achieve at best a few degrees of resolution due to our small antenna size. For example, a 10' dish observing at 1.42 GHz would have a resolution of about 4-5 degrees. Below left is an example from an amateur radio telescope's data showing a 24 hour drift scan of detected voltages made up of thousands of pixels. (One pixel every 10 seconds – this time is called integration time). To make this chart, the radio telescope is locked in position and the sky rotates by. As objects enter the antenna's view (beam), their energy (detected voltage) increases compared with the background sky and peaks are recorded (See the twin peaks of the Milky Way galaxy's core ¾ of the way through the chart). When enough single charts have been collected they can be combined to get a multiple chart. When all charts are put together, they can be assembled into an image (middle picture below). The far right picture shows the same data in image form using black (low intensity) and red (high intensity).





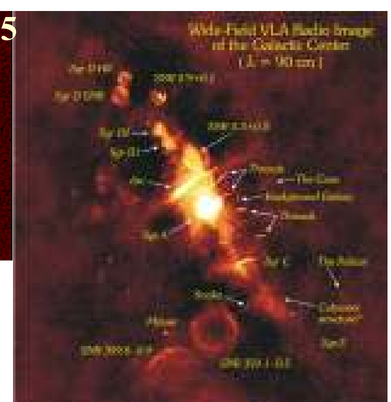


Professional Radio Images

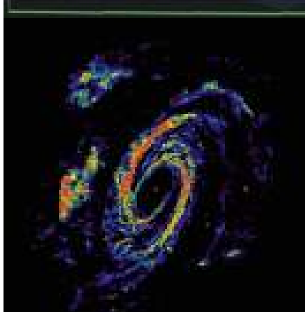


The Neutral Gas Disk of the Milky Way

Radio Quasar 3C175



Galactic Center



Atomic Hydrogen in M81

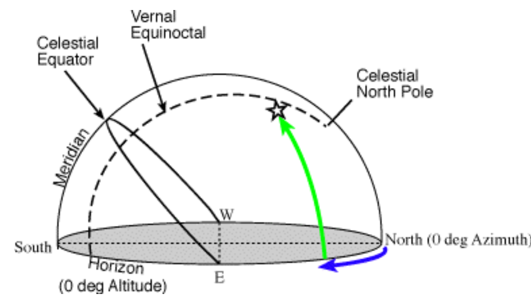
Radio Galaxy 3C288

Saturn

Images from: www.nrao.edu/imagegallery/php/level1.php

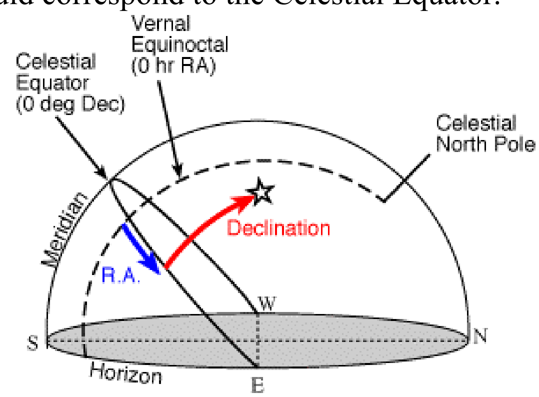
Locating radio objects in the sky (RA and DEC)
To share information with others, a reference system must be adopted. The system used by astronomers is the celestial coordinate system. After years of teaching that the night sky is not a sphere that rotates around the earth, it is ironic that this is what we are going to envision for our coordinate system. Since both the surface of the earth and the celestial sphere are surfaces of spheres (or nearly so) we can define any point on those surfaces with two coordinates. In nearly the same way that we use Longitude and Latitude to find a point on the surface of the earth, we use Right Ascension (RA) and Declination (DEC) to find objects on the celestial sphere.

Azimuth and Altitude
If you were to go out tonight and try to show someone the 'Big Dipper' you'd probably point to the object and use Azimuth and Altitude. Azimuth is the angle around the horizontal from due north and running clockwise. It corresponds to the compass directions with 0 degrees representing due North, 90 degrees due East, 180 degrees due South, and 270 due West. Altitude is the height of the object, in degrees above the horizon. Altitude can range from 0 degrees (on the horizon) to 90 degrees (directly overhead). A good approximation of these to use at night is your hand at arm's length. Your whole hand (thumb through pinky) is about 10 degrees and each finger is about 2 degrees. Although Altitude and Azimuth are useful for observing at night and showing others constellations and other objects, it is not helpful for us. This is because none of us are at the exact same latitude and longitude and so my altitude and azimuth information for the 'Big Dipper' would be different for you. Also, as the object rises and sets, it changes position in the sky. (See picture above)



Graphic used by permission from Dr. Jim McDonald

Right Ascension and Declination
As I mentioned above, Right Ascension (RA) and Declination (DEC) are similar to longitude and latitude. If you picture the earth's North Pole projected into the sky this would correspond to the Celestial North Pole. And if you project the earth's equator into the sky this would correspond to the Celestial Equator. The longitude lines on a celestial sphere are called Right Ascension. Right Ascension is measured on the celestial equator in an easterly direction. Instead of measuring in degrees though, it is measured in hours, minutes, and seconds. A full rotation corresponds to 24 hours, roughly the time it takes for the sphere to rotate once around. Each hour of right ascension is about 15 degrees on the celestial sphere. The Right Ascension of 0 hours occurs on the Vernal Equinox (first day of spring – equal day and night – 12 hours each). Declination corresponds to latitude and is measured in degrees above or below the celestial equator. An object above the celestial equator has a positive declination; an object below the celestial equator has a negative declination. Since this coordinate system is relative to fixed objects in the celestial sphere, the Right Ascension and Declination do not change and can be shared with anyone on the earth. (See picture above)



Graphic used by permission from Dr. Jim McDonald

Practical Applications/Examples

Optical:

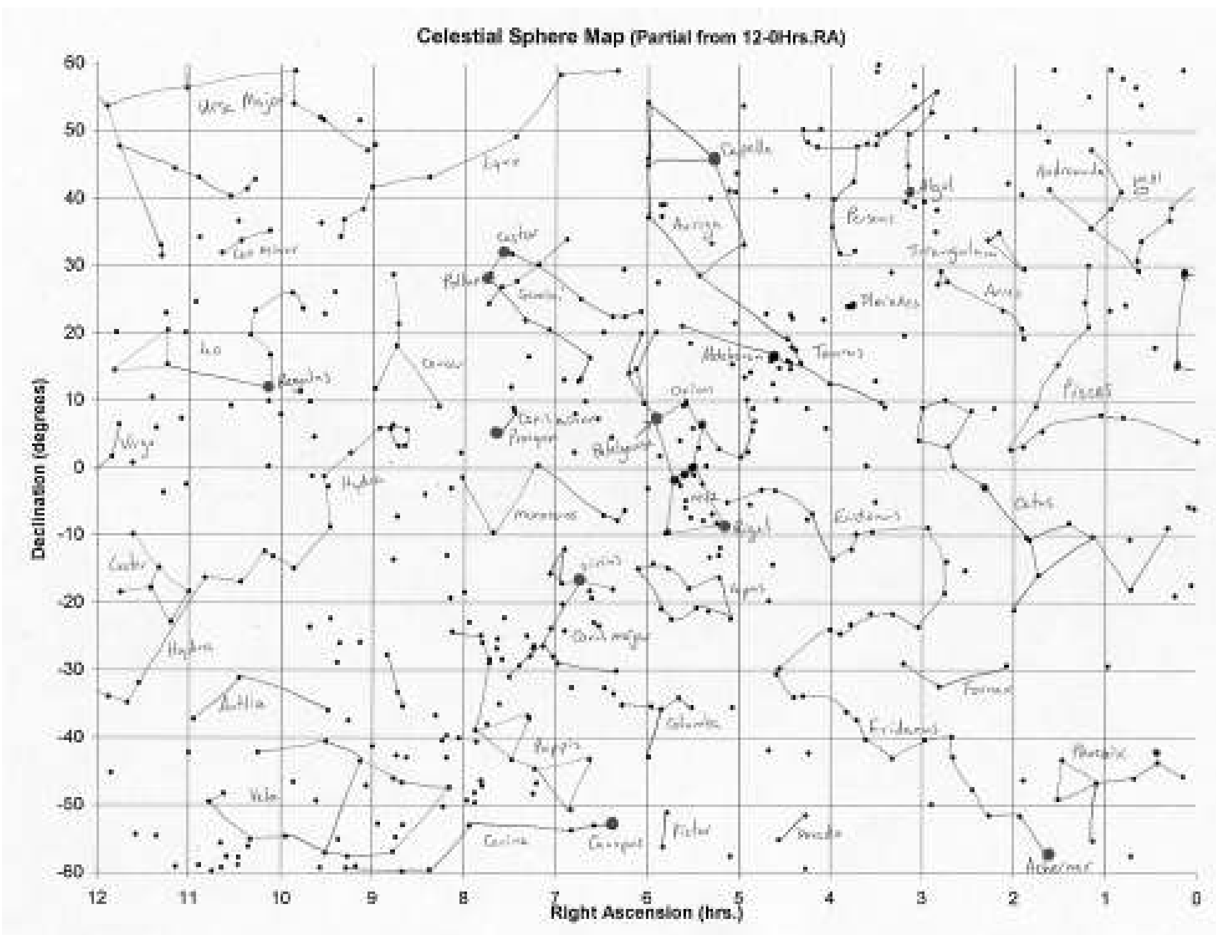
Now that we have a working knowledge of celestial coordinates, let's take a look at how to use them by looking at a portion of an optical sky map and do a few examples. Use the chart below to answer the following questions.

Find the star name and the constellation for the following:

Star #	RA	Dec	Star Name	Constellation
1	6:43	-17		
2	7:43	+28		
3	5:53	+07		

Find the RA and Dec for the following stars:

Star #	RA	Dec	Star Name	Constellation
4			Castor	Gemini
5			Capella	Auriga
6			Rigel	Orion

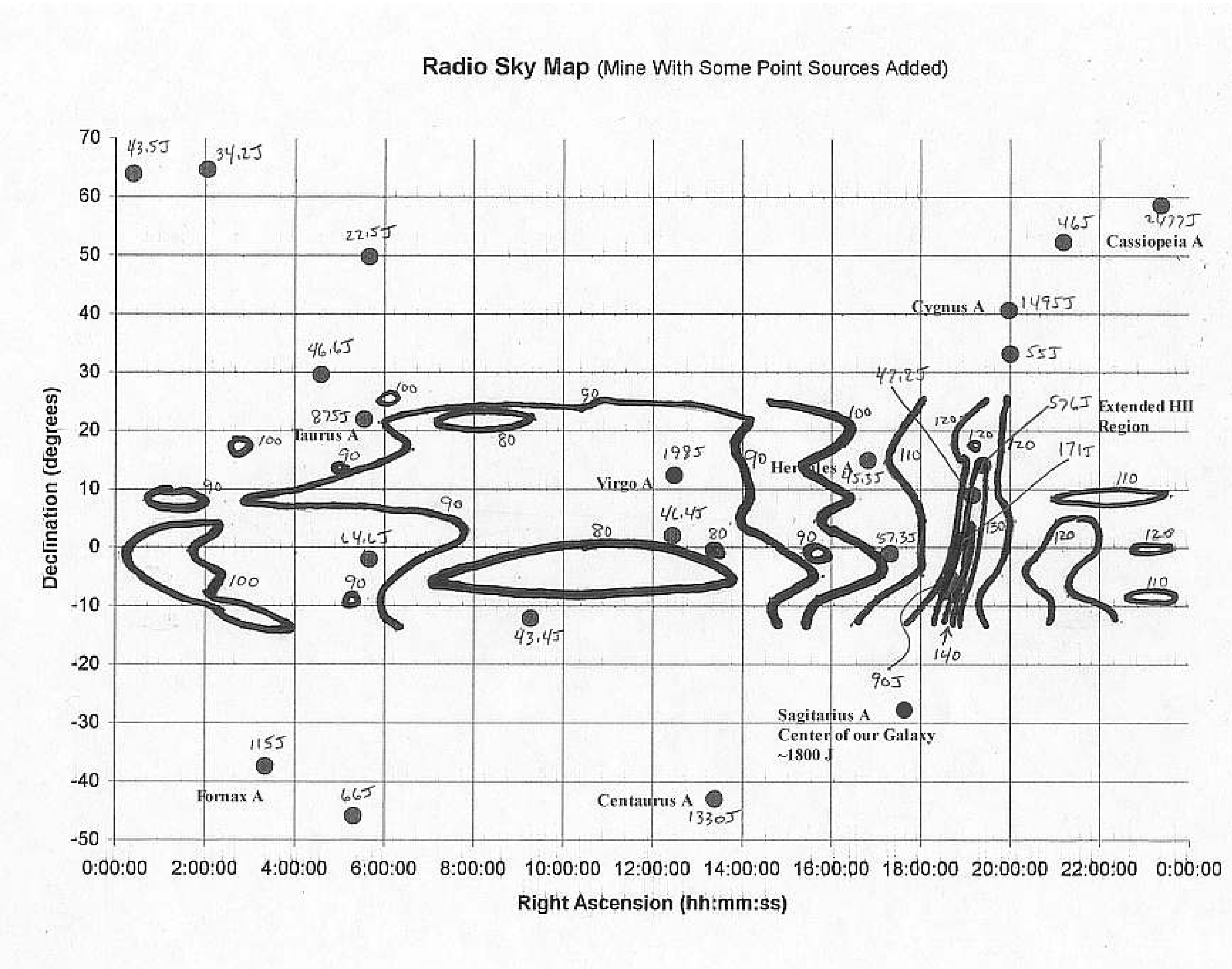


The answers are as follows:
Star #1 = Sirius, Canis Major
Star #2 = Pollux, Gemini
Star #3 = Betelgeuse, Orion
Star #4 = 7:30, +32
Star #5 = 5:14, +46
Star #6 = 5:13, -08

Radio:

Below is a map I made of my observations with some point sources from charts with their flux in Janskys. Try the following examples:

#1) You find a large peak at 05:33:00 RA, +21:59:00 Dec - What object is it?
#2) You find a small peak at 16:49:00 RA, +15:02:00 Dec - What object is it?
#3) You find a large peak at 12:29:00 RA, +12:31:00 Dec - What object is it?



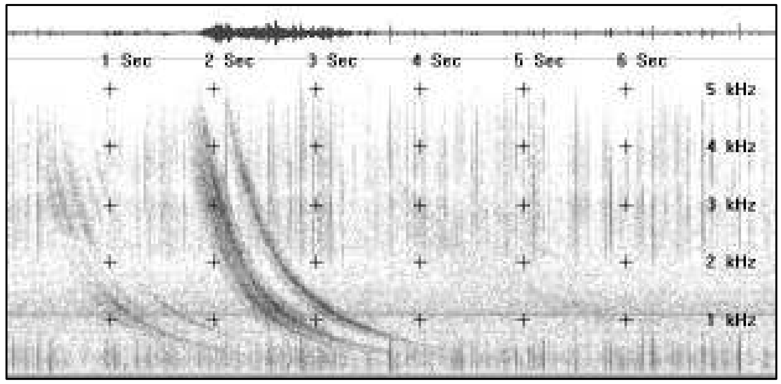
Answers to Radio Examples:
#1 Taurus A
#2 Hercules A
#3 Virgo A

Deciding on a Project
Now you are better able to start deciding on a project. This will ultimately depend on several factors including: your electronics "know-how"; the types of recordings you want to make; the expense; help you may need; Mentors that are available and willing to work on your project and information on the SARA website (www.radio-astronomy.org/).

Common Amateur Radio Projects (by Frequency)
The table below lists most of the radio projects I've ever heard of and will give you a good idea of the types of projects that you can attempt. Projects will be discussed in a bit more detail following this table.

ITU Radio Bands	**Radio Projects**	**Sources of Radio Signal**
SLF (30-300 Hz) ULF (300-3000Hz) VLF (3-30KHz) LF (30-300KHz)	Whistler Radios and VLF Radios	Earth-based phenomena associated with lightning, auroras, and solar activity.
	SID (Sudden Ionospheric Disturbance) Radios - (AAVSO (American Association of Variable Star Observers) and Stanford/SARA are sources for these radios and plans for them as well.)	Ionosperic disturbances caused by the sun. Some have investigated Gamma Ray Bursts with these radios as well.
HF (3-30 MHz)	Jupiter and Solar (18-30 MHZ) (Radio Jove is a source for these radios) Pulsar Detection	Jupiter storms due to Io charged particles. Solar storms - Flares et. al. Some Pulsar work has been done in this band.
VHF (30-300MHz)	FM Meteor Detection	Meteor detection - signal bounces off ionized meteor trails.
UHF (300-3000 MHz)	Continuum/Drift Scan (usually at 406 MHz; 1420 MHz (Hydrogen gas spectral line); 1667 MHz (OH molecule spectral line).	Galactic Sources - Supernova remnants, Active star forming regions, etc. Gamma Ray Bursts / SETI (Search for Extra Terrestrial Intelligence - uses the "water hole" (H and OH lines) as a search frequency zone.
	Spectral Scans (1420 MHz)	Doppler shift work - usually within regions of our own galaxy (the Milky Way).
SHF (3-30 GHz)	Extraterrestrial satellites.	Cassini, Venus probe, Planck, etc.
	Itty-Bitty radio Telescope (IBT)	Demonstration telescope and possible research capabilities.
	SETI (Search for Extra Terrestrial Intelligence)	

ELF/Whistler Radio Astronomy (INSPIRE), etc. **(easy to make but requires special location to observe)*



Spectrogram from data on Steve Mc Greevy's Web site – http://www-pw.physics.uiowa.edu/mcgreevy/

Whistler radios (named for the whistle-like sound heard when radio signals from lightning bounce along magnetic field lines and disperse) detect the electromagnetic radiation (EM) from lightning and other effects on the Earth as they react with the atmosphere. Events such as lightning, aurora, solar flares, etc. produce EM. Sometimes these signals travel along magnetic field lines and the frequencies become dispersed producing whistlers.

I use the program Spectrogram 12 by Richard Horne www.visualizationsoftware.com/gram.html to view sonograms of my data and visualize sferics (clicking sound from lightning that is close by), tweeks (musical sounds like a musical saw created by lightning at a distance up to hundreds of miles away), whistlers (described above) and chorus (auroral radiation creates sounds like those of crickets and birds chirping). The best time to observe is pre-dawn in an area far from power lines.

For more information be sure to check out the

- SARA website: www.radio-astronomy.org
- INSPIRE website: theinspireproject.org/
- QEX Magazine – March/April 2010 – available with permission on the SARA website

VLF radio astronomy & Solar radio astronomy **(easy to make and use)*

Solar Flares are a tremendous explosive burst of light, material and energy from the sun. This energy can affect the ionosphere, changing the height of the D, E and F layers and affects communications, etc. The flare induced changes in the ionosphere can be detected using various radio frequencies. The AAVSO (American Association of Variable Star Observers) has chosen to use VLF. Within the VLF I chose to use the 24.0 KHz signal from Cutler, Maine. Check out the AAVSO site for all the relevant information and schematics: www.aavso.org/committees/solar/equipment.stm

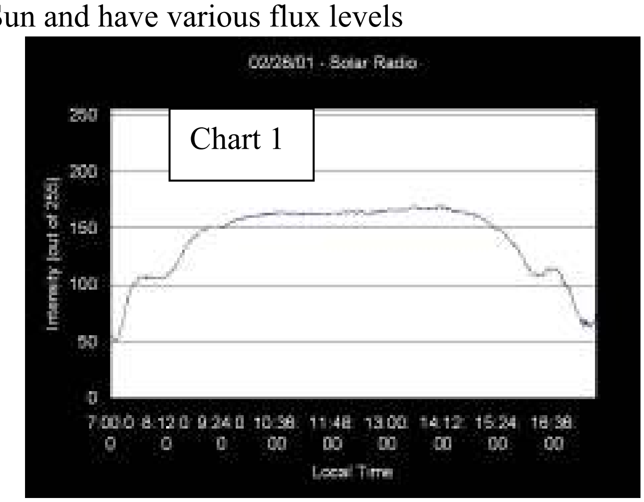
There are circuit boards available that make it much easier to build. Most parts are available from Radio Shack. The antenna is easy to make but consists of 125 turns of wire! This is an easy project, well within the skills of most members. There is also a great VLF radio available through SARA called SuperSID that allows you to observe several VLF stations. Check out the link below for more information.

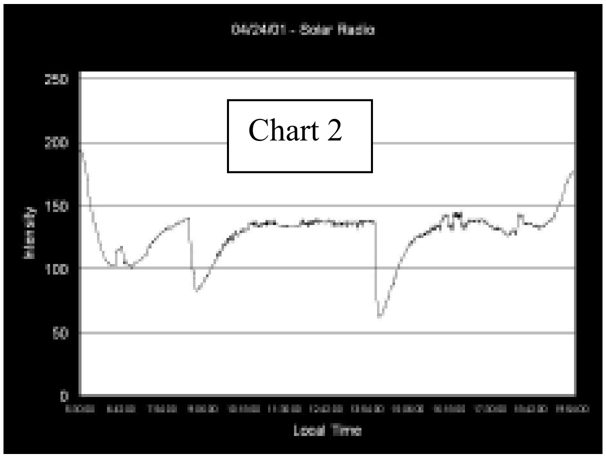
Radio Flares

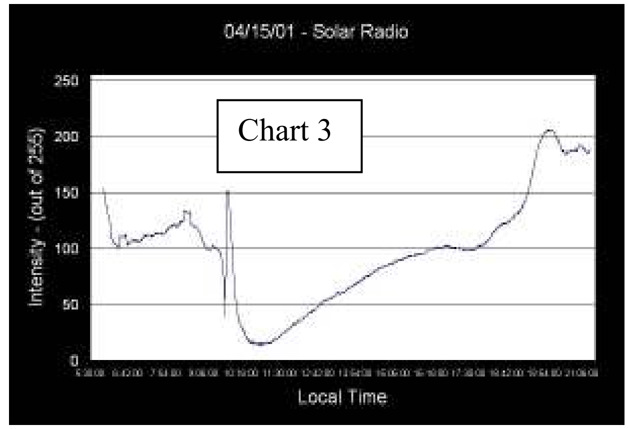
Detected flares are generally caused by X-Ray Flares on the Sun and have various flux levels (energy/particle flow levels) associated with them.

The Charts

In chart 1 a quiet day with no flares present is shown - note the peaks on both ends - called the "sunrise effect". Chart 2 shows a day with several large flares. Flares usually appear as upward peaks - on my receiver they appear as downward troughs. These are M1.6 & M2.3 flares (respectively). Chart 3 shows a day with an amazing X 14.4 flare! Flares are classified as A, B, C, M and X in order of increased energy. The higher the letter and higher the number the more energetic the flare is. An X 14.4 is an amazing flare!







For more information be sure to check out the

- SARA website: www.radio-astronomy.org
- AAVSO website: www.aavso.org/solar-sids
- SuperSID website: solar-center.stanford.edu/SID/sidmonitor/
- QEX Magazine – January/February 2010 – available with permission on the SARA website

Jovian radio astronomy (Radio Jove)/**Decametric radio astronomy/Planetary radio astronomy**

**(Radio Jove is fairly easy to make and use but requires a large antenna – you can use SW radio as well)*

This project requires a large antenna size which can be a determining factor. A receiver was set-up at the SARA conference the last two years and it was fascinating to listen to. The radio noise storms of interest can be heard from about 18-30 MHz. Two types of storm noise can be heard: L-bursts (long bursts) sound like waves crashing on a shore while S-bursts (short bursts) sound like popcorn popping. Sometimes these radios will detect lightning noise which can sound like popping so be aware of the weather in your area when interpreting your recordings. Solar storms can also be detected with this radio and sound like changes in static levels. There are several levels of activity you can detect. Check out the sites below for more information.

For more information be sure to check out the

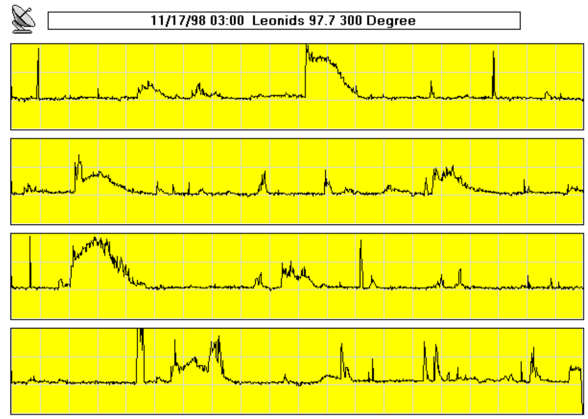
- SARA website www.radio-astronomy.org
- QEX Magazine – May/June 2010 – available with permission on the SARA website

For more information and to hear sound samples check out

- Jim Sky's website at www.radiosky.com/rjcentral.html
- Radio Jove website at radiojove.gsfc.nasa.gov/

Meteor Detection by Radio *(You can use FM or SW radio for some detections so it's fairly easy to use)*

Radio signals bouncing off meteors is a popular 'sport' with ham operators. As meteors pass through the atmosphere they ionize gas and radio signals can bounce off the ionized trail and be detected. An FM antenna and FM radio are often used to observe. You look up a radio station that is a long way away from you (several hundred miles) and can not be heard. You then point an antenna toward the station direction on a meteor shower night and record meteor signals on a sound recorder or other device. Signals sound like stations fading in and then out again – sometimes quite quickly.



Graphs from: members.bellatlantic.net/~vze2n9fe/meteor/meteor.htm

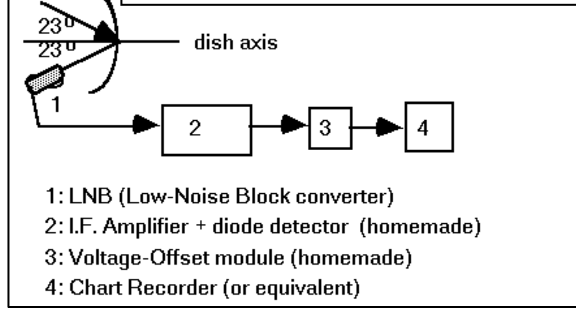
For more information be sure to check out the

- SARA website www.radio-astronomy.org
- Spaceweather Radio Meteor website: spaceweather.com/glossary/forwardscatter.html
- Sky Scan Science Awareness Project website: www.skyscan.ca/radio_meteor_detection.htm
- A Student Project Using FM to Detect Meteors: members.bellatlantic.net/~vze2n9fe/meteor/meteor.htm

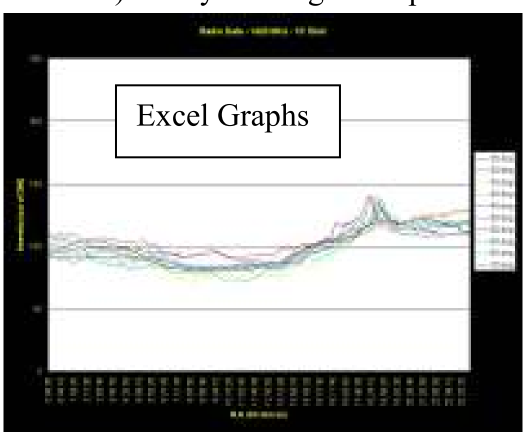
Continuum Radio Astronomy/Hydrogen Line (OH and Other Lines) Radio Astronomy/Spectral Scans
**(Requires specialized equipment – difficult to make – you can buy units from Radio Astronomy Supplies)*

Common Project: Drift Scan/Total Power Radio-1420 Mhz. Mapping

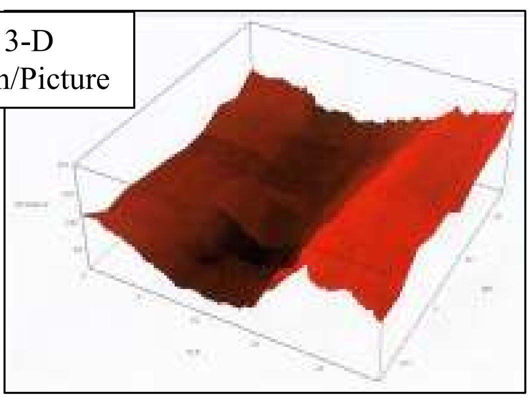
Generalized radio telescope
http://www.ap.smu.ca/~lonc/radiotel.html



If you've ever taken a digital photo you know that you can take millions of pixels with one shot. Unfortunately, radio astronomy uses a one pixel per observation instrument and it takes a long time to compile enough data for a picture. Many people want to create a picture of the sky from their backyard. A generalized radio telescope is shown at the right. The *LNB* amplifies the detected signals and converts them to a lower 'intermediate' frequency (I.F.) to avoid loss in the cables (lower frequencies travel with less loss through cables). The *I.F. amplifier* then amplifies the lower frequency signal and passes it to a *diode detector* which detects only the signal's strength not all the oscillations of the signal itself. The *voltage offset* allows us to adjust the signal's position on our chart and the *chart recorder* tracks the final signal detected. There are dealers who sell these instruments (see below links). A typical radio telescope is shown below. After ten years of data collection there were enough charts (twelve of each altitude) to create graphs of each altitude from 25-75 in five degree increments. They were averaged and created the Excel graph of all eleven altitudes shown below. (The large peak is the Milky Way galaxy). The data was then used in Mathematica to create a 3-d graph of the data and thus a final picture (see picture below). Ten years to get one picture!



Excel Graphs



Final 3-D Graph/Picture

My 1420 MHz Total Power Telescope – 10' dish with horn leading to temperature controlled LNA, IF Amp, detector (in cooler), then leading to voltage amp (foam box), then to A/D device and computer (in plastic bin). Power supplies are on wooden stand.

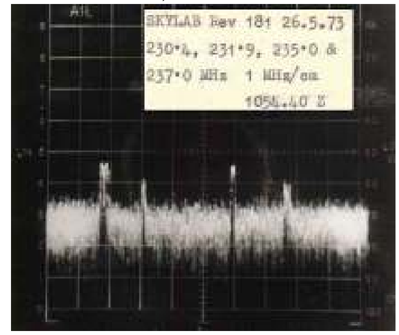
For more information be sure to check out the

- SARA website: www.radio-astronomy.org
- Radio Astronomy Supplies website: www.radioastronomysupplies.com/
- QEX Magazine – July/August 2010 – available with permission on the SARA website

Artificial satellite detection

**(You can use SW radio for some detections so it's fairly easy to use – you need tracking information from the web and may need specialized antennas for more distant or weak object detection)*

Many ham radio operators and/or SARA members have tried this. Since some satellites can be detected with standard SW radio equipment this project should be within the reach of any ham or amateur radio person. Internet tracking sites are available (see below).



Spectrograph from: http://www.svengrahn.pp.se/trackind/Skylab/Skylab.html

For more information be sure to check out the

- SARA website www.radio-astronomy.org
- Space Tracking Notes website: www.svengrahn.pp.se/trackind/trackin1.htm.

Itty-Bitty radio Telescope (IBT)

**(In its simplest form (a satellite detector and dish antenna) it is quite simple to make and use – the more advanced model described below can be obtained through the SARA/NRAO Navigators program)*

The IBT is built using a satellite TV dish antenna and a satellite finder usually hooked to a meter to show signal strength. In 1998 SARA member Chuck Forster started investigating using a satellite dish antenna as a portable radio telescope since many were available. Unfortunately, a back end could not be found and was difficult to design. Later that year SARA member Kerry Smith was the first to realize that the Channel Master satellite finder could be used as a back end after helping a friend reposition his satellite dish with the meter. Kerry later modified the Channel Master to support a DC analog output, a MAX 187 A/D output to be used with Jim Sky's SkyPipe software as well as amplifying the oscillator to provide an audio output so signal strength could be heard as a pitch change. This was a great step forward for educating students since most can not see the meter movement clearly but none can miss the change in pitch associated with a signal. Chuck named it the LBT (Little Bitty Telescope) but later NRAO (the National Radio Astronomy Observatory) Education Officer SueAnn Heatherly named it the IBT and that name stuck. Kerry and SARA later teamed up with NRAO to create a group called "Navigators" which is a team of people that bring the IBT to schools and other group meetings and show people what radio astronomy is. A CD and DVD set was developed to provide IBT users with videos of IBT use as well a support material such as PowerPoint presentations, lessons, and ideas on presenting to groups. A more advanced version of the IBT is currently being developed which will be sensitive enough to use for student research projects as well as education. It is hoped that it will be put into production soon and they may be available to SARA members in a year or so.

An IBT showing the LNB on top for easier aiming, the DSS dish, the Channel Master (bottom left) with amplified speaker, and the battery pack below.

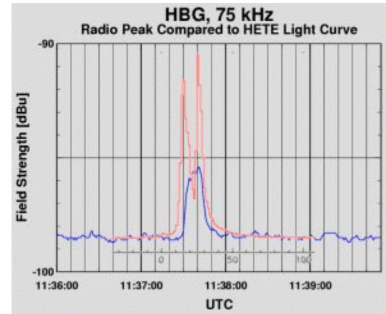
For more information be sure to check out the

- SARA website www.radio-astronomy.org
- NRAO IBT website: www.gb.nrao.edu/epo/ambassadors/ibtmanualshort.pdf
- David Fields' IBT website: www.roanestate.edu/obs/IBT%20TAO%20poster.ppt

Advanced Radio Projects *(Difficult projects – probably not for beginners)*

Gamma Ray Bursts

Lately, Gamma Ray Bursts (GRBs) have been in the news. This high-energy radiation comes from distant and mysterious cosmic explosions. Scientists are not sure what causes these bursts, but they do know that GRBs come from some of the most distant regions of the universe and that they produce the most powerful explosions ever witnessed. This is a more difficult project but SARA member Jim Van Prooyen has observed several GRBs. Check out his article below.



Graph from: www.qsl.net/df3lp/projects/sid/

For more information be sure to check out the

- SARA website www.radio-astronomy.org
- Jim Van Prooyen's article: www.radioastronomyresearch.com/radio_astronomy_articles/post-29-Gamma-Ray-Bursts.htm
- Another article about detecting GRBs: www.qsl.net/df3lp/projects/sid/

Pulsars

When a star supernovas, its core is often crushed into a neutron star with tremendous magnetic fields (at least 1000 times Earth's magnetic field) and spin. The spin sweeps out a powerful beam of EM that can be detected from Earth. Many of these objects are extremely accurate time keepers and are used to check accurate clocks. Since these objects spin at a rate of a second or less, the pulses are swept past Earth at this rate. This makes detection by amateurs a real challenge. First you must detect a very small signal. Second, the pulsar's period of rotation needs to be detected and this can be done by amateur only after setting the recording interval (integration time) to an even fraction of the period (i.e.: you must know the period of what you are trying to observe). With this timing and many observations it is hoped that the pattern will emerge.

For more information be sure to check out the:

- SARA website www.radio-astronomy.org

Advanced Radio Projects (continued)

Interferometry

Picture from:www.nrao.edu/epo/amateur/amastropg2.jpg

Combining two or more signals into a coherent signal you can study is another real challenge. Both antennas must be pointing very accurately and timing of the received data is critical. The receivers must be phase-locked together. A phase-locked loop is a circuit that uses a stable, generated frequency (usually using a stable crystal) and a circuit that compares a tuning frequency to the generated frequency. The difference between the two is used to adjust the tuning frequency to essentially lock the phases of the two signals together. This creates a lock between the two and a very stable tuning system and allows the tuning between two radio telescopes to be comparable. The advantage of interferometry is that you can simulate a much larger antenna with smaller ones. This method is being used by professionals because of the relatively inexpensive smaller dishes available now and modern computing power and software. This combination allows them to gather finely resolved data (down to milli-arcseconds). Several SARA members are currently experimenting with this including Bruce Randall who gave a talk on this topic at the SARA conference in 2010.

For more information be sure to check out the

- SARA website www.radio-astronomy.org
- Amateur Interferometry Project: www.nrao.edu/epo/amateur/N2I2.pdf
- ERAC (European Radio Astronomy Club) Basics of Radio Interferometry PPT: www.eracnet.org/workshop/doc/basics.pdf

First draft written by:
Jon Wallace