MEASURING SPECTRAL INDICES OF THERMAL AND NON THERMAL SOURCES

Introduction

Radio sources fall broadly into two main categories - thermal sources and non-thermal sources. The mechanism for creating the radio emission is different in these two categories. In the case of thermal sources one emission mechanism is the blackbody radiation from the source. If a source is at a particular temperature then its frequency spectrum is defined by the blackbody equation. By measuring the intensity of emission from the source at several frequencies the slope of the blackbody curve can be measured.

Non-thermal emission mechanisms are usually from motions of electrons around magnetic field lines (cyclotron). If the motions are relativistic the phenomenon is called synchrotron. Synchrotron emission also has a characteristic frequency dependance. Most of the non-thermal emission from radio sources are due to synchrotron emission.

Spectral line emission from the rotation of molecules also causes radio emission. Most spectral line emission is thermal in nature although there are some types of emission such as maser emission that are non-thermal. We will discuss more of the spectral line radio emission in other projects. The project described here mainly deals with continuum emission.

The spectral index defines the slope of the emission vs frequency curve. Knowing this slope can determine the nature of the emission mechanism for the particular source. The best thermal sources to observe are planets. Good strong non-thermal sources are supernova remnants or some quasars.

Experiment

1. Find a planet that is up - strongest ones are Venus, Jupiter and Saturn.

2. Observe the planet at two frequencies - preferably one in the K-band system (21-24 GHz) and one in the Q-band system (36-43 GHz).

3. Since the aperture efficiency at the two frequencies is slightly different, it is advisable to observe another planet in order to obtain the aperture efficiency. Otherwise one can get it from a plot in the Introduction to Haystack manual.

4. Do a discrete source scan (DSS - see Umbrella manual for description) or a drift map (Umbrella manual) on the planet of your choice. Either method will give a measure of the peak antenna temperature at the chosen frequency.

5. Correct the antenna temperature for the efficiency - this will give you the brightness temperature.

6. Repeat steps 4 and 5 for the second frequency.

7. Convert the brightness temperature to flux in Janskys (S_ν).

8. The spectral index can be obtained by solving the equation $S_\nu = K\nu^{-n}$. In this equation K is a constant, ν is the frequency and n is the spectral index. With observations at two frequencies the equations can be solved for n by taking a ratio of the two equations.

9. The above experiment can then be repeated (Steps 3-8) on a non-thermal source such as the Crab nebula or Cygnus A (which is an extragalactic source with a two sided jet). In these cases one can only do a drift map of the source and fit the temperature of the peak of the emission.

10. For extended sources one also needs to worry about the difference in beam sizes at the two

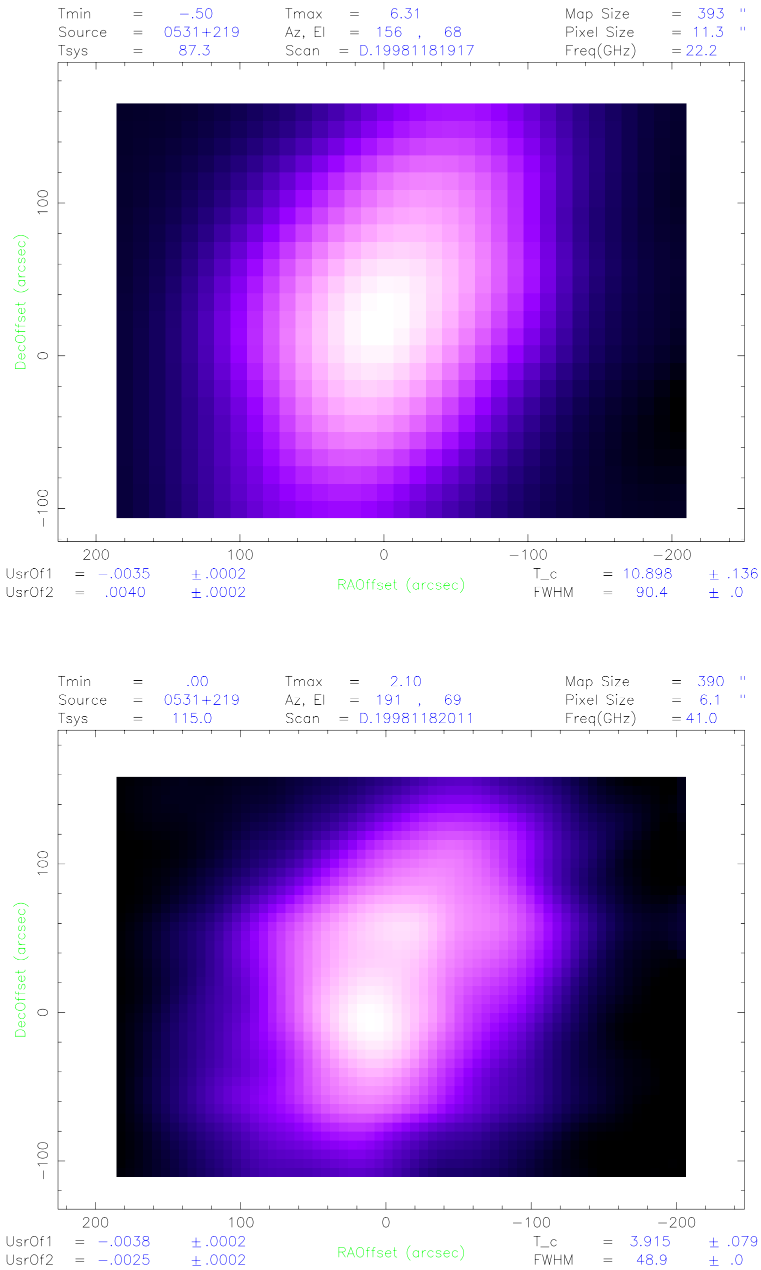

Fig. 1.— 22 GHz (top) and 41 GHz (bottom) drift maps of the Crab nebula made with the Haystack 37-m antenna.

frequencies which will result in differing resolutions for the two maps. The beam size in radians(θ) is given by $\theta = 1.2\lambda/D$, where λ is the wavelength of the observation and D is the diameter of the antenna. The way to account for this difference is to obtain the 43 GHz map and then degrade its resolution to that of the 22 GHz map.

Analysis

The data from the planets can be placed on theoretical blackbody curves to determine the blackbody temperature. The non-thermal sources can be studied to understand the nature of the emission causing mechanism and the physical properties of the source that would cause this kind of emission.