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ASTRONOMICAL OBSERVATIONS OF GALACTIC RADIOSOURCES WITH ESCORT: AN SMALL RADIOTELESCOPE

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The aim of this work was to measure the radio flux density at 3.7 GHz of thermal (HII regions) and nonthermal emissions (synchrotron radiation) of Galactic radio sources. The observations were made through ESCORT, the 2 meter diameter antenna of the radioastronomy center at Universidad de Oriente (UDO), situated in Ciudad Bolívar, Venezuela. The antenna temperature and system temperature were calibrated by using the transit time and the flux density of the sun as reference. In adition, the HPBW and effective aperture of ESCORT were determined.

1. INTRODUCTION

ESCORT is the name of the radio telescope of the radioastronomy center at UDO. This small radio telescope is capable of continuum observations in the range from 3.4 to 4.2 GHz. This inexpensive equipment provides everything needed to introduce students and amateurs astronomer to field of radioastronomy. We used ESCORT observations to study the radio flux emissions from HII regions (Orion Nebula and Rosette Nebula) and the radiation of nonthermal emissions from Taurus A and Cassiopeia A, the most intense supernova remnants of our galaxy.

2. RADIO TECHNICAL TERMS AND FORMULAS

The observed flux density of a radio source or the antenna temperature may be evaluated with the aid of the following relation:

$$S = \frac{2kT_a}{A_e} \tag{1}$$

where S is the flux density [Jy], T_a is the antenna temperature [K], A_e is the effective area of the parabolic reflector [m^2] and k the Boltzmann's constant.

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2.1. *System temperature and Y-Factor*

When we measure with the antenna the flux density of a source, we do not only get the antenna temperature but we also measure the system temperature, which results from the intrinsic noise from the radio receiver and the temperature of the sky. In order to know the *system temperature* a calibration had to be done. The calibration process consists of measuring, first, the flux of the *cold sky* (system temp. and sky temp.) and second, the flux of the sun (source temp., system temp. and sky temp.)

The relation $T_{sys(sun)}/T_{sys(sky)}$ defines the so called Y-factor, which was measured. The Y-factor of the sun is given by:

$$Y_{sun} = \frac{T_{sun} + T_{sys} + T_{sky}}{T_{sys} + T_{sky}} \tag{2}$$

Using Eq.(1) and Eq.(2) one gets to a formula for the system temperature:

$$T_{sys} = \frac{S_{sun}\ A_e}{2k(Y_{sun} - 1)} - T_{sky} \quad [\mathrm{K}] \tag{3}$$

The flux density for a radio source can be calculated using the equation

$$S_{source} = \left(\frac{Y_{source} - 1}{Y_{sun} - 1}\right) S_{sun} \tag{4}$$

2.2. *Using the sun for antenna calibration*

A calibration of the receiver is necessary to provide an absolute scale of antenna temperature. A suitable calibration source is the sun. The flux for a determined time can be found on the homepage of the Space Environment Center (`http://www.sec.noaa.gov`) or the Australian Space Weather Agency (`http://www.ips.oz.au/asfc/data/`).

Solar observations served several purposes. First, they serve as a mechanism for telescope alignment. By observing the centering of the feedhorn shadow on the center of the parabolic reflector, the telescope can be turned in azimuth manually to the proper alignment. Consequently, a sharp rise in the antenna temperature in the real-time data acquisition is observed. This situation indicates a source tracking

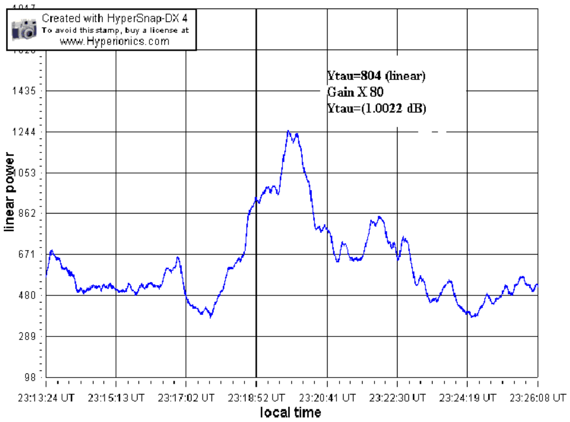

Fig. 1. Transit of Taurus A, S_{tau} = 689 Jy, T_a =578 mK, T_{sys} = 242.83 K.

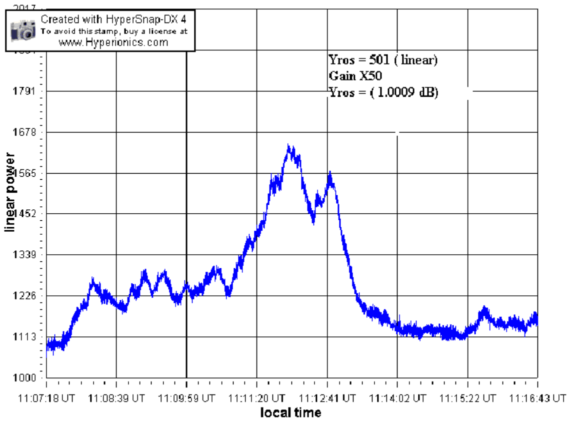

Fig. 2. Transit of Rosette nebula, S_{ros} = 271 Jy, T_a =228 mK, T_{sys} = 233 K.

through the path of the telescope. Second, measurements of the sun can be used to determine the half-power beam width of ESCORT. The solar transit in azimuth direction at 3.7 GHz has been used to calculate the $HPBW$ and the effective aperture of ESCORT telescope. Since the main lobe axis was directed to the same point in the sky (transit), the angle between halfpower points can be calculated using the sidereal rotation velocity of the earth, ω_{earth} = 0.004 deg s^{-1}, and the declination of the sun at the time of observation, $\delta = -8.126$ deg. Thus, $HPBW = (680 \pm 5\text{s})\, \omega_{earth}\, \cos(\delta) = 3.23 \pm 0.02$ deg and Y_{sun} = 14305 (4.155 dB).

The $HPBW$ for small radiotelescopes is given by

$$\theta_{HPBW}(\text{rad}) = 1.2 \left(\frac{\lambda}{D}\right) \tag{5}$$

where λ is wavelength, D the diameter of the dish. Using equation 5, we estimated an efficiency η = 0.738 and the flux observed was S_{sun} =988 KJy.

3. GALACTIC RADIO SOURCES OBSERVATIONS

The measured of density flux of synchrotron radiation was made at 3.7 GHz from the galactic supernova remnants Taurus A and Cassiopeia A. Figure 1 shows the Taurus A drift scan example.

We only measure the thermal emission from Orion (M42) and Rosette nebula, both well known ionized hydrogen clouds. The observation of Rosette nebula is shown in figure 2.

4. MINIMUM DETECTABLE FLUX DENSITY OF ESCORT

The sensitivity (minimum detectable temperature) T_{min} of this radiotelescope is equal to rms noise temperature T_{rms} of the system, as given by:

$$\Delta T_{min} = \frac{\gamma T_{sys}}{\sqrt{\Delta w \tau}} \tag{6}$$

where γ is a system constant, Δw the bandwidth of receiver [Hz] and τ the integration time. For ESCORT radio telescope, T_{sys} =240 K, Δw =36 MHz, and τ = 10 s, and γ =1.5. This gives a T_{min} =1.89 mK, and a minimum density flux detectable of 23 Jy. According to this formula, the T_{min} is significant for this radiotelescope despite of being small.

5. CONCLUSION

Most of amateur and semiprofessional radio telescopes are capable of resolving far below 1 K and also capable of detecting and measuring many individual radio sources. The use of sky sources for system calibration is far more accurate than the use of the sun or moon as their signal are not constant in time. One of the best references in the Sky is M1 (Taurus A), since the flux is very stable and accurately known.

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