Solar observations with the Small Radio Telescope

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Abstract. We present observations of the Sun made with the Small Radio Telescope (SRT), located at the Sofia Astronomical Observatory. The SRT was acquired for introducing radioastronomical observations to the education of the students and the young scientists. The observations were conducted at 1.4 GHz in the months February and March 2010. The resulting intensities and brightness temperatures of the solar radio emission are in good agreement with those of the Sagamore Hill Solar Radio Observatory.
Key words: solar radio observations; radiotelescope SRT; radio flux; brightness temperature

Слънчеви наблюдения с радиотелескопа SRT

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Представяме наблюдения на Слънцето, направени с радиотелескоп SRT, разположен в Астрономическата Обсерватория, София. Той е доставен за въвеждане на радиоастрономичните наблюдения в обучението на студенти и млади учени. Наблюденията са направени при честота 1.4 GHz за месеците февруари и март 2010 г. Пресметнататите интензитети и яркостни температури на слънчевото радиоизлъчване съответстват добре на тези, получени в Sagamore Hill Solar Radio Observatory.

1 Introduction

The solar radiation spectrum covers all frequencies ranging from radio to optical. The solar radiance and temperature are a function of the wavelength. In the optical range (100-nm to 1000-nm wavelength), the Sun can be treated as a blackbody with a constant temperature of about 6000 K. The radiation flux is quite stable, with very small changes over the solar cycle. However, in the radio frequency band (1 cm to 30 cm wavelength, approximately), the radiance for a disturbed Sun and for a quiet Sun is significantly different from that of the blackbody in the optical range [1].The spectral density becomes much greater than at longer wavelengths for both a quiet and disturbed Sun and these elevated fluxes come mainly from the contribution of the solar corona and the chromosphere.

Radio emission at meter- and decimeter-wavelengths from flares is quite different from emissions at centimeter and millimeter wavelengths. This has to do with the fact that at the shorter wavelengths the emission is caused by incoherent gyrosynchrotron radiation mechanisms while at the longer wavelengths the emission comes from coherent plasma radiation. The 1-3 GHz frequency range appears to lie at the transition between the two types of emission mechanisms.

Here we present daily observations of the Sun's emission at 1.4 GHz conducted with the Small Radio Telescope (SRT). The instrument is located at the Astronomical Observatory of the Department of Astronomy, University of Sofia. Its main purpose is to demonstrate radio observation techniques of both stellar and non-stellar sources including the Sun.

2 Observations and Data Reduction.

We used the Small Radio Telescope (SRT) at the Astronomical Observatory in Sofia to make daily measurements of the radio flux of the Sun at the frequency of 1420.406 MHz during the months February and March 2010. Because of the conditions (e.g. cold weather) we were able to obtain data for only 10 days during that period (see Table 1). SRT has 2.3 m diameter antenna, 7 degrees beam width, 1420.406 MHz central frequency and 40 kHz width of one spectral channel. The central channels of the spectrometer were averaged to obtain a total power measurement. The data were converted into an antenna temperature ($\mathrm{T_A}$) using the electronic noise calibration system on the SRT. The measurements were made in a continuous mode. Pointing measurements were made on period of 20 minutes. The pointing is done by performing a 25-point grid measurement around the Sun and fitting a 2-dimensional gaussian to the intensity. The flux calibrations were made using the standard radio sources Cassiopeia A and the Moon.

The results from the solar observations are presented in the Table 1.

Table 1. Solar data from SRT during the months February and March 2010. Columns show: day of observation, average antenna temperature, the error of the antenna temperature value, and integration time for the given day.

Day	$T_A(K)$	ΔT_A	*time(min)*
33	172	8	20
36	176	8	100
44	218	8	30
48	200	8	80
51	208	8	50
55	201	8	120
63	191	8	20
77	208	8	80
78	212	8	60
80	199	8	140

3 Data analisys

The antenna temperatures were then converted to solar flux and corrected to Sun-Earth distance of 1 AU (Table 2). The flux was calculated using the formula [2]:

$$\mathrm{F} = \frac{\eta \mathrm{A T_A}}{2\mathrm{k_B}}, \tag{1}$$

where A is the geometrical area of the antenna (4.15 m^2 for 2.3 m dish), η is the antenna efficiency, F is the flux density of a radio source in Janskys (1 Jy = 10^{-26} W m^{-2} Hz^{-1}) and $\mathrm{k_B}$ is the Boltzmann's constant.

The comparison of our fluxes to those of the Sagamore Hill Solar Radio Observatory [4] is shown in Figure 1. Experimentally obtained values of the daily solar fluxes with radiotelescope SRT coincide satisfactorily with Segamore's data.

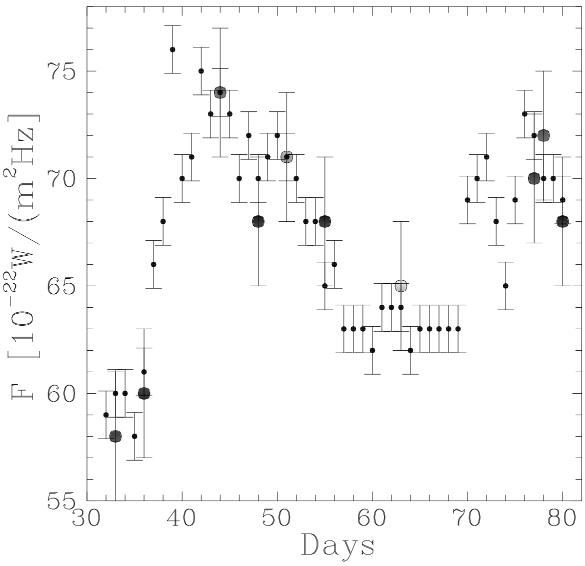

Fig. 1. Solar flux at 1.4 GHz during the months February and March 2010. Our data is shown with big dots, while Sagamore data is shown with small dots.

Experimentally obtained values of the daily solar fluxes with radiotelescope SRT coincide satisfactorily with Segamore's data.

Based on the fluxes and using the Rayleigh-Jeans approximation for blackbody radiation [1]:

$$\mathrm{F} = 2\mathrm{k_B T_B} \Omega_\mathrm{s}/\lambda^2, \qquad (2)$$

where Ω_s (rad^2) is the solid angle subtended by the source and λ (m) is the wavelength, we were able to calculate the brightness temperature (T_B) of the source region of the emission. We list it in Table 2.

Another comparison of our fluxes to those of the Sagamore Hill Solar Radio Observatory [4], based on Table2, is shown in Figure 2.

The theoretical brightness temperature for a quite Sun is shown in Figure 2 (curve A). To get this curve, it is assumed that there is a 10^6 K corona and a 30 000 K chromosphere. It is seen that the brightness temperature decreases from 2×10^5 K at 1 GHz to 6000 K at 100 GHz [1]. Consequently, our calculated brightness temperatures of the solar radio emission are similar to those reported in the literature.

Table 2. Calculated radio flux and brightness temperature of the Sun at 1.4 GHz during the months February and March 2010. Sagamore Hill fluxes are shown for comparison. Fluxes are in Solar Flux Units (SFU, where 1 SFU = 10^{-22} $Wm^{-2}Hz^{-1}$)

Day	$F^{SRT}(SFU)$	$F^{Seg}(SFU)$	$T_B^{SRT}(10^5K)$
33	58 ±3	60 ± 1	1.54± 0.1
36	60 ±3	61 ± 1	1.58± 0.1
44	74 ±3	74 ± 1	1.95± 0.1
48	68 ±3	70 ± 1	1.79± 0.1
51	71 ±3	71 ± 1	1.87± 0.1
55	68 ±3	65 ± 1	1.80± 0.1
63	65 ±3	64 ± 1	1.72± 0.1
77	70 ±3	72 ± 1	1.86± 0.1
78	72 ±3	70 ± 1	1.90± 0.1
80	68 ±3	69 ± 1	1.79± 0.1

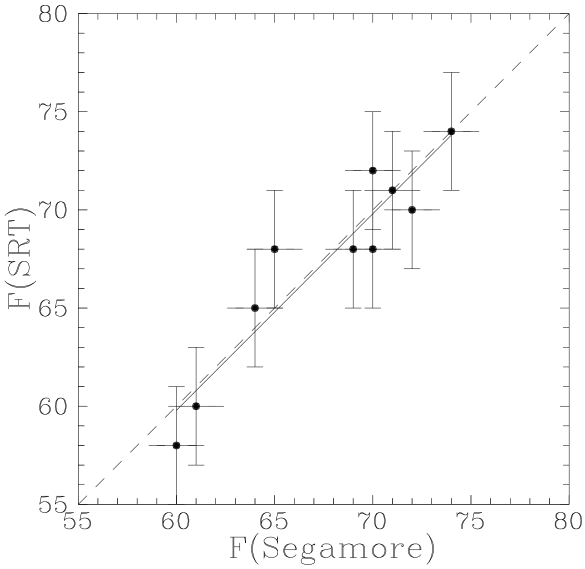

Fig. 2. Comparison between the measurements of the solar flux in Sagamore and by the STR, given in Table 2. The solid line presents the regression agreement and the dashed line presents the just agreement.

Discussion.

In the radio frequency range, the Sun has both slowly varying and rapidly varying components. The fluxes at different wavelengths come from different regions of the Sun. The milimeter-wavelength flux is radiated from the visible photosphere, while longer wavelengths originate from the higher (outer) regions of the Sun (e.g., the corona) [5]. The emission at 1.4 GHz most likely originates at the lower corona and is due to free-free emission [6].

There are two types of solar flux variations: long-term and short-term. The long-term variations include annual and 11-year solar cycle variations, while short-term variations usually mean changes within days. As a next step a detection of the 28 day of rotation of the Sun is planned as well as the detection of solar flares. Solar flares are sometimes accompanied by Coronal Mass Ejections (CMEs), which move away from the Sun at speeds exceeding 1000 km/s carrying strong magnetic fields and energetic particles. If Earth-directed, these CME events can couple significant amounts of energy into Earth's charged upper atmosphere and trigger geomagnetic storms.

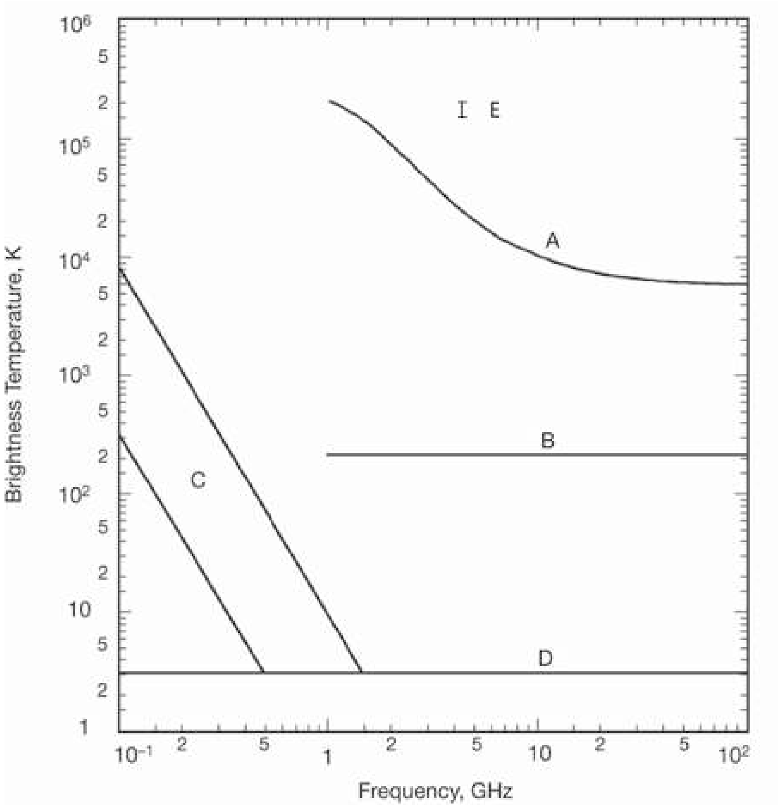

Fig. 3. Brightness temperature as a function of frequency for different radio sources. Line *A* is from a quiet Sun, while line *B* is from the Moon (all with 0.5-deg beam width diameter). Galactic T_B (C, maximum to minimum) and cosmic background (D) are also shown [1]. Our results in Table 2 fall into the bar noted by E.

The solar fluxes at 1.4 GHz presented in this paper are in good agreement with those reported in the literature which suggests that the SRT is capable of obtaining good esimates of the daily solar flux and can be used for monitoring the Sun's activity at 1.4 GHz. The radiotelescope SRT is also suitable for training students and young researchers in the basics of radio astronomical observations.

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References

[1] Ho C., Slobin S., 2008, *IPN Progress Report, p.42–175*

[2] MIT Department of Physics: 2004, *Daily Solar Observations with the SRT*, http://www.haystack.mit.edu/edu/undergrad/srt/SRT%20Projects/solar.html.

[3] MIT Department of Physics: 2004, *Measuring Aperture Efficiency*, http://www.haystack.mit.edu/edu/undergrad/srt/SRT%20Projects/srtCasseff2.PDF.

[4] Segamore Radio Hill Observatory, ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_RADIO/FLUX/Sagamore_Hill/.

[5] Valley S. L., 1965, *Handbook of Geophysics and Space Enviroments*, Air Force Cambridge Research Laboratories, Shea L. Valley, ed., New Work: McGraw-Hill Book Company, Inc.

[6] Dulk, G. A., 1985, *Radio emission from the sun and stars*, ARA&A, 23, p. 169 – 224.