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Secular Decreases in the 927 MHz Emission from the Supernova Remnants Cas A and Tau A

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Abstract

This paper presents 927 MHz flux densities for the SNRs Cassiopeia A and Taurus A relative to those for the radio galaxies Cygnus A and Virgo A and for the Orion Nebula. The measurements were made in October–December 1977 with the 10 m radiotelescope at the Staraya Pustyn' (NIRFI) Radioastronomical Observatory. Comparison between these data and the absolute flux density measurements of Razin and Fedorov (1963) yields an annual decrease in flux density of 0·95% ±0·04% for Cas A and 0·18% ±0·01% for Tau A (14·2% ±0·6% and 2·7% ± 0·1% respectively over the past 15 years).

Introduction

The aim of the present paper is to define values for the annual decrease of the radio emission from the SNRs Cassiopeia A and Taurus A at a frequency of 927 MHz ($\lambda = 32\cdot4$ cm) from a comparison between absolute measurements carried out in October 1962 by Razin and Fedorov (1963) and relative measurements made by us 15 years later in October–December 1977. The absolute radio flux-density measurements of Razin and Fedorov for the five most intense radio sources (Cassiopeia A, Cygnus A, Taurus A, the Orion Nebula and Virgo A) were made with an 8 m radiotelescope calibrated using a black disc radiator. Our present relative measurements were made with the 10 m radiotelescope at the radioastronomical station NIRFI in Staraya Pustyn'.

Table 1. Relative flux densities for Cas A and Tau A over 15 years

Supernova remnant	Comparison source	m_1	δm_1 (%)	m_2	δm_2 (%)	K (%)	σ_K (%)
Cas A	Cyg A	1·65	3·6	1·42	0·3	−14·2	0·6
Tau A	Ori Neb.	2·42	5·0	2·36	1·6	−2·4	0·6
Tau A	Vir A	3·29	4·1	3·19	1·0	−2·9	0·2
Tau A	Cyg A	0·488	4·2	0·474	0·9	−2·8	0·2

Measurements

Table 1 lists values of 927 MHz flux density ratios m_e for Cas A and Tau A relative to one or more of the comparison sources Cyg A, Vir A and the Orion Nebula. Thus we have

$$m_e = S_e^S / S^C,$$

where S^S_e and S^C are respectively the 927 MHz flux densities of the SNR and the comparison source expressed on a common scale (without taking into account the differences in brightness temperature of the galactic radio emission near the SNR and the comparison source), while e denotes the epoch of the observation ($e = 1$ signifies 1962·8 and $e = 2$ signifies 1977·8). The table also lists the relative change K in the flux density of the SNR over the 15 years between epochs. Thus we have

$$K = (S^S_2 - S^S_1)/\mathscr{S}^S_1 = (m_2 - m_1)S^C/\mathscr{S}^S_1, \tag{1}$$

where $\mathscr{S}^S_1$ is the absolute radio emission flux density at 927 MHz for the SNR measured at epoch 1.

From Table 1 we have a mean relative flux density decrease $\langle K \rangle = 2{\cdot}7\%$ for Tau A. The annual decreases d can then be obtained by dividing the negative of the secular changes K by 15. In addition, the 927 MHz absolute flux densities of Cas A and Tau A at epoch 2 can be obtained from their epoch 1 values by correcting for the secular changes. Thus we have

	d (%)	σ_d (%)	$S_{1977 \cdot 8}$ (Jy)	$\delta S_{1977 \cdot 8}$ (%)
Cas A	0·95	0·04	2827	5·1
Tau A	0·18	0·01	997	5·3

Discussion

Let us consider briefly the secular decrease of the radio emission of Tau A. According to Shklovsky's (1960, 1976) theory of the adiabatic expansion of SNRs (in which the magnetic field strength H decreases as R^{-2} for a uniformly expanding nebula of radius R), the annual decrease in flux density is given by

$$d = (4\alpha + 2)/T, \tag{2}$$

where α is the spectral index of the radio source, defined by $S \propto \nu^{-\alpha}$, and T is the age of the SNR in years.

Substituting $\alpha = 0{\cdot}26$ and $T = 900$ in equation (3) gives $d = 0{\cdot}34\%$. This is essentially larger than the value obtained in the present paper. However, if in addition to the adiabatic expansion (with the same dependence $H \propto R^{-2}$) there is injection of relativistic electrons at constant velocity during the entire expansion then the theoretical decrease in the radio flux density of the SNR will be halved (Kardashev 1962; Shklovsky 1976) and so we obtain a decrease of 0·17% in a year. This value agrees well with the 0·18% value obtained here and, together with other factors (see Shklovsky 1976), supports the belief that there is a constant injection of relativistic electrons in the Crab Nebula.

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