OBSERVATION OF VARIABLE CIRCULAR POLARIZATION IN THE OPTICAL EMISSION OF THE X-RAY SOURCE Sco X - 1

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The expected circular polarization of the optical radiation from the cosmic x-ray source Sco X - 1 was estimated in [1] under the assumption that the region of the continuous optical emission in a magnetoactive plasma sheath.

The circular polarization of Sco X - 1 was observed for 14 nights in the period from 23 June to 29 July 1971, using a single-channel photoelectric polarimeter placed in the Cassegrain focus of the 48-cm reflector AZT-14 of the Byurakan station of the Astronomical Observatory of the Leningrad State University. The observations were made predominantly in the long-wave color band (λ_{eff} = 0.639 μ, limits at the 50% level 0.54 and 0.71 μ), where the observed effect was most strongly pronounced. The first observations were made in the short-wave color band (λ_{eff} = 0.396 μ, limits at the 50% level 0.35 and 0.44 μ), where no statistically significant polarization was observed. In these two color bands, we used mica 90° phase plates chosen and installed in such a way that the systematic errors due to the monochromaticity of the plates and due to errors in their orientation were negligibly small compared with the random observation error, as was indeed confirmed by subsequent special studies of the instrument.

The calibration of the sign of the observed polarization (and a simultaneous verification of the correctness of the readings of our apparatus) was based on observations of the circular polarization of the white dwarf Gw70° 8247, for which it is known from [2, 3] that the polarization is constant in time, and whose direction of rotation of the electric vector and the polarization as a function of the wavelength are also known. Our observations yielded p_V ∓ -3.12 ± 0.44% and -3.00 ± 0.41% in the short and long wave regions, respectively, in good agreement with the data of [3]. The "minus" sign in our observations corresponds to clockwise rotation of the electric vector as seen by an observer looking at the star. During the 14 observation nights we made a total of 15 short-wave and 122 long-wave observations. The random error of one polarization observation, according to our estimate, was on the average approximately 1% and fluctuated somewhat about this value, depending on the brightness of the object and on the observation conditions. The time of one observation was 10 - 15 minutes.

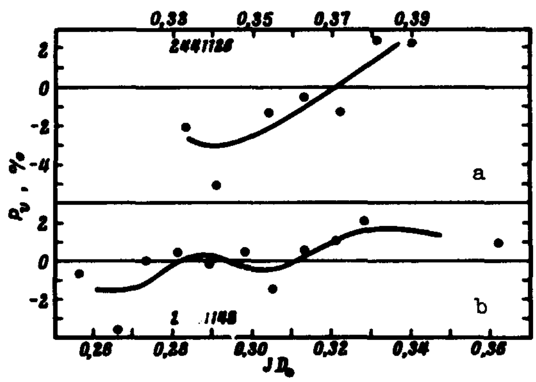

Fig. 1. Observed dependence of the degree of circular polarization on the time (in Julian days): a - 23 - 24 June, brightness B = 13.8^m; b - 15 - 16 July, B = 12.4^m.

A complete list of our observation results will be published in the Astronomical Circular. Here we present only the main conclusions drawn from the observational material: 1) In the overwhelming majority of cases it is possible to trace, against the background of appreciable random errors, regular sinusoidal variations of the degree of circular polarization p_V (Fig. 1).

2) There is no dc component of p_V.

3) The amplitude of the oscillations of p_V amounts on the average to 1 - 1.5%, but it is probably not constant and has a tendency to decrease with increasing brightness of Sco X - 1. 4) There is apparently no strict periodicity in the oscillations of p_V; one can speak only of one or several prevailing periods. 5) The average brightness of the object increased gradually from $B = 13.8^m$ at the start of the observation period to $B = 12.2^m$ at the end of July.

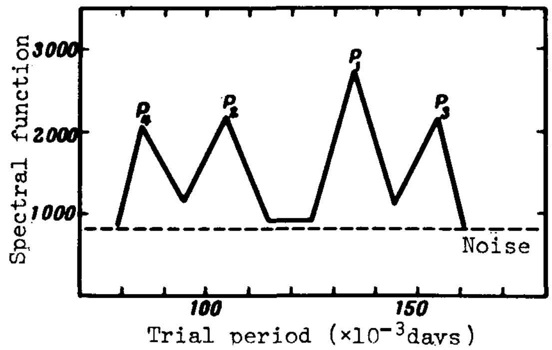

Fig. 2. Periodogram calculated from the observation data. The noise level corresponds to double the rms error.

To determine the periods in the changes of the polarization, our observations were Fourier-analyzed by a method described in detail in [4]. We investigated the dependence of the spectral function H on the trial period $\mathcal{P}$:

$$H(\mathcal{P}) = \left[\sum_n p_V(n) \cos \frac{2\pi}{\mathcal{P}} t_n\right]^2 + \left[\sum_n p_V(n) \sin \frac{2\pi}{\mathcal{P}} t_n\right]^2 .$$

An analysis of the periodogram confirms that there is no strict periodicity in the variations of the polarization, but there are several notable predominances of the periods, which are manifest either individually or in superposition. Figure 2 shows a periodogram averaged with intervals 0.01^d, which yields the following predominant periods: $\mathcal{P}_1 = 3^h14^m \pm 7^m$, $\mathcal{P}_2 = 2^h31^m \pm 7^m$, $\mathcal{P}_3 = 3^h43^m \pm 7^m$, and $\mathcal{P}_4 = 2^h02^m \pm 7^m$. In addition, our observation data do not exclude the possible existence of a predominant period $\sim 1^h$. It is interesting to note that the periods obtained by us agree well with the values of the periods estimated from an analysis of the brightness of Sco X - 1 [5]. They agree also with the expected characteristic times of activity of Sco X - 1, as predicted in [6]. If the model proposed in [1] is valid, then our observations make it possible to estimate the magnitude of the magnetic field and to attribute the change of the polarization to a change of its structure. Apparently the change of the structure of the magnetic field can also explain the observed variation of the brilliance of Sco X - 1 with the characteristic periods found in [5]. According to [1], an average amplitude $\sim 1\%$ corresponds to a magnetic field $\sim 2 \times 10^6$ G. The calculated value of the magnetic field agrees well with the model developed in [7], where it is proposed that Sco X - 1 is a neutron star with a magnetic field $\sim 10^{12}$ G, surrounded by a thick sheath of hot plasma.

The observed irregular periodicity does not contradict the following quantitative picture: When a time-periodic magnetic field is superimposed on a nonlinear medium, including a plasma, an instability develops, such that pairwise coupled waves are parametrically excited (magnetic pumping) [8]. The interaction of the waves with one another, their reaction on the pump field, and also the presence of a random magnetic-field component can lead to a "smearing" of the periodic regime. For Sco X - 1 such a pumping might be realized by rotation of the neutron star, but it is necessary at the same time to take into account the effect of differential rotation. If it is assumed that the pump period with allowance for the differential rotation is $\sim 3^h$, then the remaining periods can be explained as being the result of interaction of waves excited by magnetic pumping.

It must be emphasized that electrons will be effectively accelerated in such a plasma [9]. The spectrum of the accelerated electrons does not contradict the results of observations of the hard x-rays from Sco X - 1 [10], if it is assumed that these rays result from synchrotron radiation of these electrons. We note also that the characteristic polarization-variation time obtained by us are comparable in order of magnitude with the time of slow variation of the x-radiation of Sco X - 1 [6].

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SPIN ECHO ON Mn^{55} NUCLEI IN EASY-PLANE ANTIFERROMAGNETS $CsMnF_3$ AND $MnCO_3$

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The investigation of NMR on Mn^{55} nuclei in antiferromagnets with small anisotropy has been the subject of a large number of papers, for example [1 - 3]. Interest in this research is justified, since effects due to the Shul-Nakamura interaction [4 - 6] become manifest here already at T ≈ 4°K. There appears in the NMR spectrum an acoustic branch

$$\omega^2 = \omega_{n0}^2 \left[1 - \frac{2H_E A < m_z >}{\omega_e^2}\right] \qquad (1)$$

the line width of which is given by the formula

$$\Delta\omega \approx \left[\frac{I(I+1)}{2\pi S^2}\right]^{1/2} \frac{\omega_{n0}^2}{(\omega_E \omega_e)^{1/2}} . \qquad (2)$$

Here $\omega_{n0} = \gamma_n H_n$ is the frequency of the hyperfine interaction, ω_e is the AFMR frequency, $\omega_E = \gamma_e H_e$ is the exchange frequency, and $<m_z>$ is the mean value of the projection of the nuclear spin on the electron spin.

The experimental spectra are well described by formula (1), but the line widths differ strongly from those predicted theoretically [1]. It becomes necessary to measure directly the relaxation times with the aid of spin echo. So far, however, the possibility of such an experiment in antiferromagnets