NEW METHODS FOR THE SEARCH FOR HOT GAS IN GLOBULAR CLUSTERS

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ABSTRACT: Two new methods for the detection of hot gas in globular clusters are proposed: 1. measurement of the position change of a radio source due to refraction and 2. determination of the concentration of hot gas using the Faraday rotation of the polarization plane of the background radio source radiation.

Recently, an observational result was obtained, which can be interpreted as evidence for the presence of hot gas in globular clusters. A detection of diffuse X-ray emission from three globular clusters has been made: 47 Tuc, ω Cen and M 22 with the Einstein Observatory (Hartwick et al. 1982, Grindlay et al. 1984). Hartwick et al. (1982) supposed that these regions contained hot gas and that their luminosities were due to bremsstrahlung. They estimated the gas temperature and the emission measure (See Table III, in their paper.). The purpose of this report is to propose new methods of search for hot gas in globular clusters. A few of the methods may prove to be more sensitive than X-ray observations.

Distant (e.g. extragalactic) radio source emission from behind a globular cluster will undergo refraction if there is a sufficient amount of hot gas in the cluster. The effect will show up in the fact that the position of the background radio source will change with wavelength. We shall estimate the effect using the evaluations of hot gas densities from X-ray observations by Hartwick et al. (1982) and the formula in Wright and Nelson (1979)

$$\Delta\alpha = -(2\pi e^2 L/m\omega^2)\,\mathrm{grad}_{\perp} n \quad (1)$$

where $\Delta\alpha$ is the angular displacement of the ray due to refraction, ω is the frequency of emission, e is the electron charge, n is the electron density and L is the characteristic length of the refraction region. The density gradient is calculated transversely to the line of sight.

Assuming the electron density varies with distance according to

$$n = n_o(r_c/r)^2 \quad (2)$$

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where r_c is the radius of the globular cluster core, the angular displacement $\Delta\alpha$ is given by

$$(\Delta\alpha)'' \approx 3 \times 10^{-8} n\lambda^2. \quad (3)$$

For example, the angular displacement of a radio source for $n = 2 \times 10^2$ and $\lambda = 20$ cm will reach $(\Delta\alpha) = (2 \times 10^{-3})''$, which is quite observable with the VLBI. In our opinion decameter interferometry is more suitable for this purpose. With a wavelength $\lambda = 20$ cm and densities $n = 3$ cm $^{-3}$ and $n = 2 \times 10^2$ the angular displacement will be equal to 0.4" and 0.5" respectively.

Another effect which can be used for a determination of the hot gas density in a globular cluster is that of the Faraday rotation of the polarization plane of an extragalactic radio source projected onto the globular cluster field. The rotation angle is given by

$$\Delta\Psi = 2.62 \times 10^{-17} \lambda^2 nB\ L \quad (4)$$

where B is the magnetic field component along the path of view, L is the characteristic size of a hot gas region. The strength of the magnetic field may be estimated using the equipartition between the magnetic and thermal energy densities:

$$B_{\parallel} \sim B\ ;\ B^2/8\pi = nkT;\ B = \sqrt{8\pi nkT}. \quad (5)$$

Then from (4) and (5) it follows

$$\Delta\Psi \approx 1.5 \times 10^{-24} \lambda^2 n^{3/2} \sqrt{T}\ L. \quad (6)$$

With the hot gas parameters $T = 10^6$ K, $n = 0.6$ and $L = 7$ pc the measure of the Faraday rotation in the centimeter range ($\lambda = 2$ cm; 20 cm) reaches

$$\Delta\Psi = 0.05;\ \Delta\Psi = 5, \text{ respectively.}$$

This estimate shows that a noticeable Faraday depolarization of the background radio source radiation may take place if the magnetic field of the hot gas is random.

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