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A STUDY OF THE CALIFORNIA NEBULA AT 750 MC/S

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ABSTRACT

Radio observations of NGC 1499 were made at 750 Mc/s with the 85-foot Howard E. Tatel radio telescope. These show that the brightness distribution of this extended H II region corresponds very well with the optical position and shape of the nebula. The integrated flux density at 750 Mc/s is $77 \times 10^{-26} w\ m^{-2}(c/s)^{-1}$. An emission measure of 1300 cm^{-6} pc is derived. From a simple model the mass is estimated to be 240 solar masses and the root-mean-square electron density 12 cm^{-3}.

I. INTRODUCTION

The California nebula (NGC 1499) has long been recognized as an H II region. A study of the nebula was therefore made at 750 Mc/s (40-cm wavelength). The only reported radio observations of this nebula are those by Lynds (1961) at 1400 Mc/s.

The exciting star of this nebula is ξ Persei (HD 24912). It is an 07 type star with apparent V magnitude 4.02 and is a member of the II Persei association. The distance to this star has been determined by several different authors in different ways. Cederblad (1946) reports a distance of 400 parsecs from the mean of the spectroscopic parallax, parallax from interstellar line intensities, and the parallax from the proper motion studies. Morgan, Whitford and Code (1953) report a distance of 360 parsecs for the II Persei association, and Hiltner (1956) gives a distance modulus of 8.0 or 398 parsecs for ξ Persei, which is in agreement with Cederblad's value. Blaauw (1961) computes a distance of 430 parsecs from the age of the II Persei association and the relative radial velocity of ξ Persei.

ξ Persei lies south of a large dark cloud which has several comet-tail structures that may indicate expansion. Mayall (1953) shows that the radial velocity of this nebula is +53 km sec; this agrees with the radial velocity of ξ Persei which is +67 km/sec. Blaauw (1961) believes that ξ Persei is a high-velocity "runaway" star. From its motion and position relative to the II Persei association he has estimated a kinematic age of 1.6×10^6 years, which agrees with the value of 1.5×10^6 years derived for the association as a whole.

The existence of several bright rims have been reported by Pottasch (1956). There are no other early-type stars known near this H II region that may contribute to the ionization of the gas.

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Table 1 shows a comparison of the position of the optical center of NGC 1499 with the derived position of maximum intensity at 750 Mc/s and 1400 Mc/s. The position ξ Persei is also given.

Table 1

POSITION OF NGC 1499 AND ξ PERSEI

	$\alpha_{(1950)}$	$\delta_{(1950)}$
Optical	$04^h\ 00^m.1$	+ 36° 17'
1400 Mc/s	$03^h\ 58^m$	+ 36° 15'
750 Mc/s	$03^h\ 59^m$	+ 36° 20'
ξ Per	$03^h\ 55^m\ 42^s.9$	+ 35° 38' 56"

In general there is good correspondence between the radio-brightness distribution of the region and the position and the shape of the emission nebula.

II. OBSERVATIONS

The radio observations were obtained with the Howard E. Tatel 85-foot paraboloidal antenna and a Dicke-type radiometer. At 750 Mc/s the half-power beamwidth of the antenna was 69'.

The observations were made by simultaneously tracking the antenna at a given right ascension and scanning in declination between the limits +39° 00' and +33° 00'. Scans were made at intervals of two minutes in right ascension between $03^h\ 45^m.0$ and $04^h\ 11^m.0$. Three complete sets of observations were made, each set consisting of four declination scans per right-ascension setting. Also a series of scans in right ascension were made in order to tie together the declination scans. The right-ascension scans were made from $03^h\ 45^m.0$ to $04^h\ 11^m.0$ at +38° 00', +36° 00' and +34° 00' in declination.

The intensity scale of the radiometer output was calibrated every four declination scans by means of an argon noise tube. This helped to minimize the effects of gain changes in the receiver, which have periods longer than the interval between calibrations. The absolute value of the calibration was found by daily comparison with the standard source 04N3A (3C 123). The flux density of this source at 750 Mc/s has been determined by Heeschen (1961) and is reported to be 80.2×10^{-26} w $m^{-2}(c/s)^{-1}$.

In order to convert the antenna temperatures into intensities or brightness temperatures we have to know the beam efficiency of the antenna. The beam efficiency E_b is defined as

$$E_b = \int_{\substack{\text{main}\\ \text{beam}}} f(\Theta, \varphi)\, d\Omega \Bigg/ \int_{4\pi} f(\Theta, \varphi)\, d\Omega \qquad (1)$$

where f is the radiation pattern of the antenna. A Bessel function approximation with halfwidth of 69 minutes of arc was used for the beam pattern and the numerator of equation (1) was found to be 4.06×10^{-4} steradian. The equation for the antenna temperature of a source with flux S can be written as

$$T_a = \frac{\lambda^2 E_b S}{2k \int_{\substack{\text{main}\\ \text{beam}}} f(\Theta, \varphi)\, d\Omega} . \tag{2}$$

The observed antenna temperature for the standard source 04N3A was 6.58 °K; hence

$$T_{a_{(04N3A)}} = 11.5\ E_b \tag{3}$$

and

$$E_b = 0.57 .$$

The uncertainties lie in the assumptions of the Bessel approximation for the antenna pattern, the adopted flux for the standard source and the antenna temperature of the standard source. The error from these is estimated to be less than $\pm$ 10 per cent.

All the observations were recorded digitally and reduced with an IBM 1620 computer. The reduction program removed the linear component of any zero-level change occurring during the course of an observation. The final reductions gave a table of apparent brightness temperatures relative to the standard source, with the standard deviation of each point over the grid.

For the calculation of the flux density the summation method of Bracewell (1956) was adopted. According to Bracewell

$$\int_{\text{source}} \Delta\ T_b\ d\Omega = \alpha\beta \sum_{\text{source}} \Delta\ T_b \tag{4}$$

where α and β are the grid spacings in radians. This reduces to

$$S = \frac{2k\alpha\beta}{\lambda^2} \sum_{\text{source}} \Delta\ T_b . \tag{5}$$

For NGC 1499 this formula gives a flux density of 77×10^{-26}w m^{-2}(c/s)$^{-1}$ with a statistical uncertainty of 7 per cent. The contour diagram (Figure 1) gives the intensity distribution in arbitrary units. The position of ξ Persei is indicated by a black dot labeled ξ. A comparison of the optical and radio features of NGC 1499 is provided by Plate 1. The correlation of the optical and radio structure is as good as the radio resolution will permit.

III. PHYSICAL PROPERTIES

Comparing the derived flux density of NGC 1499 at 750 Mc/s with the value 76×10^{-26}

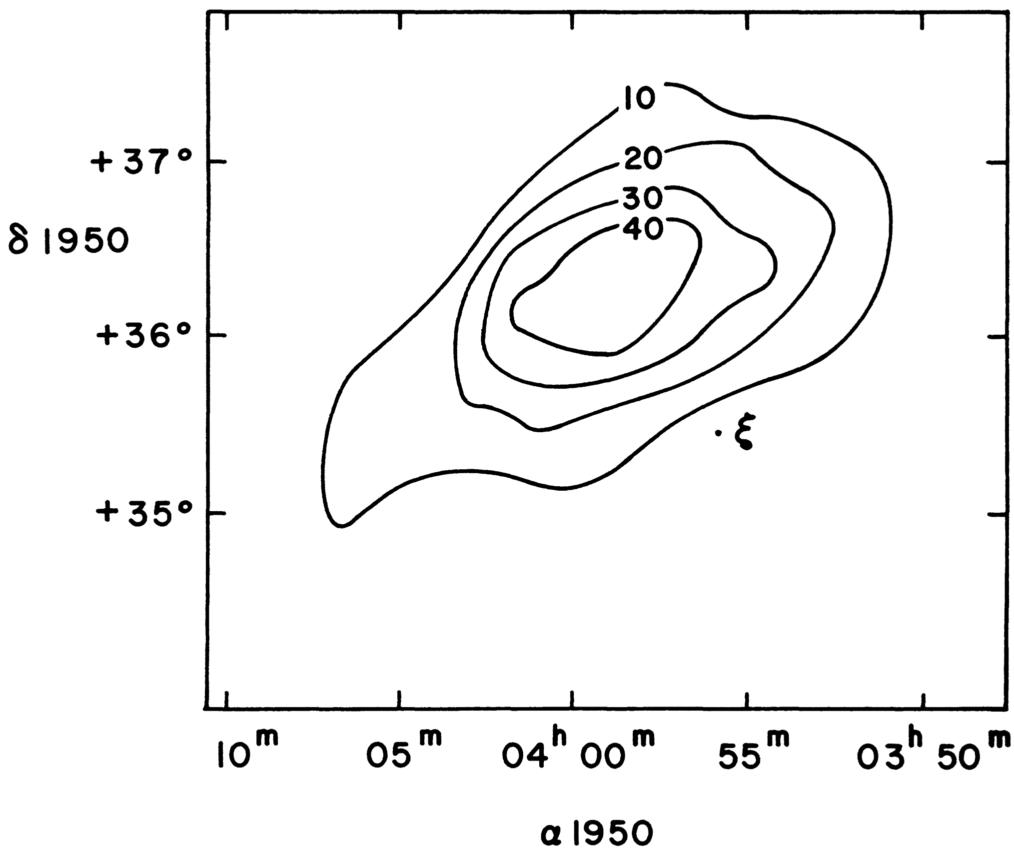

Fig. 1. — Contour map of NGC 1499 in arbitrary units. The position of ξ Persei is indicated. No correction for antenna smoothing has been made.

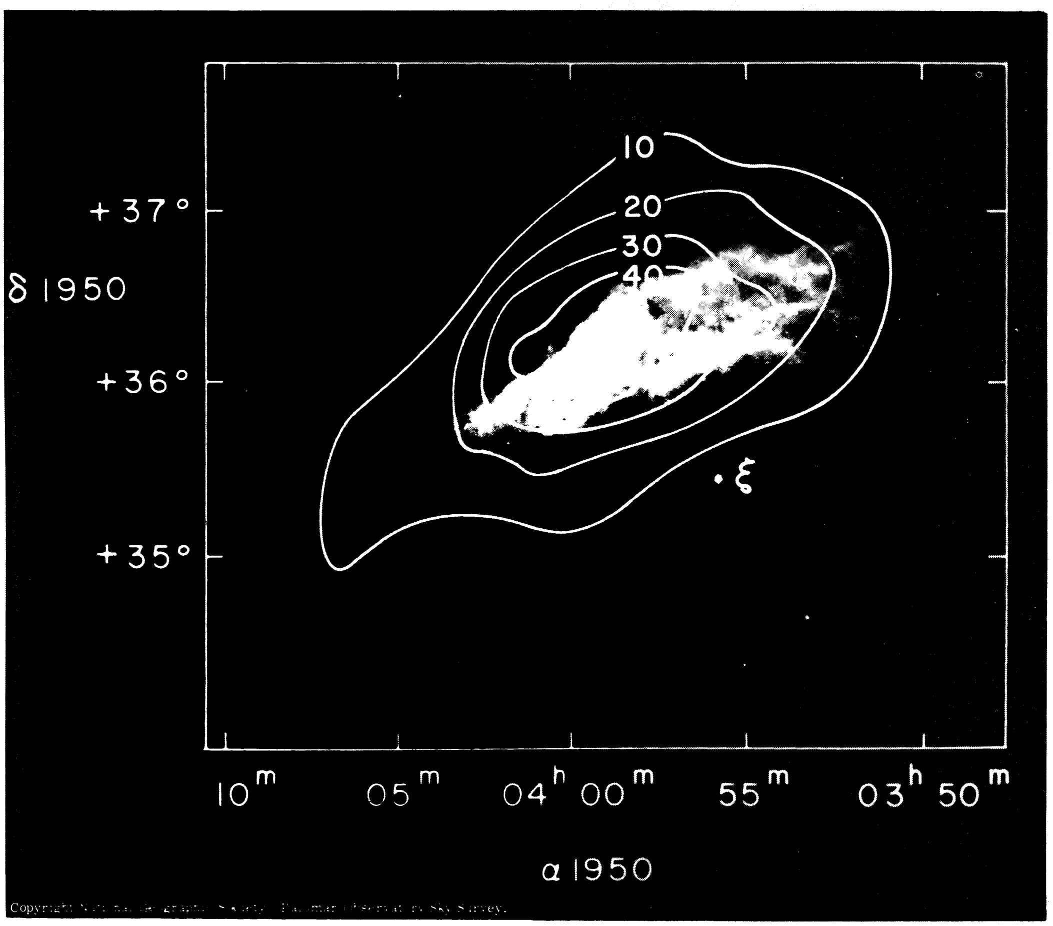

Plate 1. — Superposition of the radio map on the red-sensitive Palomar 48-inch Schmidt plate.