ON THE SPIRAL STRUCTURE OF M33

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Abstract. The spiral structure of M33 has been examined on the basis of 197 associations. The parameters of the orientation of the plane are derived. It is supposed to be a system consisting of seven logarithmic spirals. Two principal arms have been interpreted through the use of the density-wave theory. The remaining multiple arm features of M33 may be explained with the stochastic self-propagating model. The distribution of surface brightness segments speaks for the existence of different mechanisms of star formation in M33.

1. Introduction

Stellar associations appear to be good tracers for studying the spiral structure of M33. Humphreys and Sandage (1980) (hereafter referred to as HS) identified 143 associations in M33. Sandage and Humphreys (1980) (hereafter SH), using deep plates, assumes there were ten logarithmic spirals and a severely warped plane in M33. Kennicutt (1981) and Krakov et al. (1982) indicated the shape of the arms intermediate between the logarithmic and hyperbolic spirals. Considere and Athanassolla (1982), after examining the distribution of the emission nebulae, adopted two logarithmic spirals. Recently, Maucherat et al. (1984) have used surface photometry and an intense distribution of H I regions. They found a satisfactory fit to two logarithmic spirals. The southern one may be hyperbolic. They did not establish a severe warp in the plane. There is a discrepancy among the various authors in the value of the position angle (PA) and the inclination of the plane of the galaxy M33 to the plane of the sky (i).

In the present paper we made an attempt to obtain the PA and i of the plane and the pitch angle of the arms of galaxy M33. We consider there is a connection between the associations and the other spiral tracers. We hope to be able to theorise on the mechanism of maintenance in the spiral structure.

2. Arm Pattern of the Associations

We extended HS's numeration adding 54 new OB associations by comparison of U and B plates taken with the 2-m RCC telescope of Rozhen Observatory (Kunchev and Ivanov, 1984; hereafter referred to as Paper I). We have used 197 associations (143 from HS and 54 identified by us). The positions of the associations are shown on Figure 4 in Paper I. The distribution of the associations in the outer region could be represented by an ellipse. The position angle of its major axis is $PA = 22^\circ \pm 5^\circ$. This value is in good agreement with those derived from de Vaucouleurs (1959), Boulesteix et al. (1974), and Maucherat et al. (1984). We accept the inclination of the plane of galaxy M33 as $i = 57^\circ$. This value gives the deprojected plan of M33 on which the outer associations are distributed by a circuit.
The observed coordinates of the centre of the associations were transformed in the deprojected equatorial plane of M33. Polar coordinates were obtained for each association, the distance from the centre \( R \) in kpc and the angle in the plane of the galaxy \( \theta \), measured counterclockwise in radians. The associations are plotted in \( \ln R, \Delta \theta \) coordinates (Figure 1). The number of arms is shown in Figure 2. The value of \( \Delta \theta \) in Figure 1 gives the relative growth of the angle \( \theta \). By the least squares method we obtained the inclination in Figure 1 as \( \ln R/\theta = 0.69 \pm 0.04 \); the pitch angle \( \mu = \arctan 0.69 = 34\degree6 \); the logarithmic spirals \( R = R_0 \exp(0.69\theta) \) with an appropriated value \( R_0 \) well fitting the arms of the bright associations. They are drawn on a \( B \) plate taken with the 2-m RCC telescope of the Rozhen Observatory where 197 associations were superimposed in Figure 2. The distribution of associations in this figure could be represented by a system of seven arms – four in the northern part and three in the southern part of the centre. The arms N1 and S1 coincide with those of SH. The arms N2–N4, S2, and S3 differ slightly from those of SH. In the central region (8 arc min from the nucleus) a couple of arms – N1 and N2, N3 and N4, and S1 and S2 – nearly coincide. In this way the spiral structure in the central region could be represented by four arms, as we assumed in Paper I. In the outer region these arms seem to widen and branch into subarms. The logarithmic spirals in Figure 2 trace better the distribution of the associations in the outer region of M33 than was shown in Paper I. The spiral arms in the southern and northern parts of the centre are symmetrically disposed to each other concerning their numbers. N4 was the only arm that did not have a corresponding arm in the southern region.

Fig. 1. The position of the stellar associations in the spiral arms N1, N3, S1, and S3 on \( \ln R, \Delta \theta \) plot, using \( PA = 22\degree \) and \( i = 57\degree \).