INTERGALACTIC MAGNETIC FIELDS AND THE MORPHOLOGY OF SPIRAL GALAXIES

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ABSTRACT. The influence of the hypothetical extragalactic magnetic field upon the peripherical morphological features of spiral galaxies is examined. When the angle between $\vec{B}$ and the rotation axis is neither 0° nor 90°, warps are expected to be produced. In such a case the spatial distribution of warps should not be random. This fact seems to be confirmed by observations. From the distribution it is possible to obtain the direction of $\vec{B}$ in the 20Mpc-neighborhood of the Milky Way.

Since the work of Sancisi (1976) it became evident that warps are an usual morphological feature in many galaxies; even it could be considered the possibility that most spiral galaxies are more or less warped (Sanchez-Saavedra et al. 1989).Their study is therefore of greatest interest and different hypothesis have been formulated to explain warps. Sasaki (1987) includes an excellent review.

Extragalactic magnetic forces could be another tentative hypothesis explaining the warp phenomenon, as has been proposed by Battaner et al. (1989 a, b). In these models it is proposed that extragalactic magnetic fields induce warps if they are neither parallel to the rotation axis, nor contained in the galactic plane, being an angle of 45° with respect to the rotation axis the most efficient direction. About the modulus of the magnetic field strength, which would be required to distort the disk, it can be estimated that it should lye in the range $10^{-7}-10^{-8}$ gauss.

Most gravitational models would predict that the spatial distribution of warps is random. However, an examination of 18 warped disks reported in the literature shows that this is not the case. If an extragalactic field, homogeneous at least in the region where the studied

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galaxies flow (≤ 20 Mpc), is responsible of all warps, some systematic trend should be expected.

If the direction of the extragalactic field around each galaxy is calculated, all directions are found to be noticeably aligned. The scattering is low, which indicates that the random component of the field is low, the mean value of B_r^2 being less than about 0.2 B_u^2.

The direction of the field responsible of the warp of the Milky Way itself is [$b^{II} \cong 45°$, $l^{II} \cong 74°$], very close to the field responsible of the warp of M31 and M33 (Florido et al. 1989). The mean direction obtained by means of all galaxies in our sample was not far from the direction found by Ruzmaikin and Sokoloff (1977) for radio sources with redshift less than 0.8.

When the extragalactic magnetic field is parallel to the rotation axis or contained in the plane, other effects are expected. In the first case,a highly inclined galaxy should adopt a "bow-tie" appearance, with a z-width increasing with r. In the second case, a face-on galaxy would present to us an isophote map remembering a "boiled-egg", the outermost isophotes being more excentric than the inner circular ones. However, these features are similar to features induced by other effects and therefore more difficult to identify.

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VERSCHUUR: If intergalactic magnetic fields play a role in warping galaxies then we would expect symmetric warps. In the best studied case of a warped galaxy, the Milky Way, the warp is highly asymmetric. This has been well explained by gravitational models involving the presence of the Magellanic Clouds. Surely you cannot ignore the effect of gravitational fields in accounting for galactic warps.

BATTANER: The magnetic field hypothesis explains adequately the warp of the Milky Way but it cannot be excluded that gravitational effects produce warps in some galaxies. There are some clear examples. Even, they could explain the asymmetries of the Milky Way warps. But if future additional data confirm the systematic orientation in the distribution test, the gravitational interaction theory cannot be a general explanation.

PARKER: Can you explain the physics of the effect? How can a field of only 10^{-9} G warp the disk of a galaxy? The tension in 10^{-9} G is only 8.10^{-20} dynes/cm^2. The pressure is only 4.10^{-20} dynes/cm^2. The stress in the field of several microgauss within the disk of a galaxy is 10^7 times stronger.

BATTANER: Magnetic forces are the result of the magnetic field which must be present at the rim of the galaxy. We have not had time to show the detailed formulae and computations. In the internal part of the disk there is a much larger strength, but warping is a peripheric phenomenon where gravity and magnetic field are much lower. In fact, order-of-magnitude calculations were used to deduce our lower limit estimation of 10^{-8}–10^{-9} G.

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