COMPARISON OF RADIO AND OPTICAL POLARIZATION IN EXTENDED EXTRAGALACTIC RADIO SOURCES

II. Implications for the magnetic fields

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Although optical synchrotron light from an extragalactic source - the jet in M 87 - has been discovered more than 30 years ago (Baade 1956) there are still only a handful extended radio sources with established optical synchrotron emission (see Röser 1989 and references therein, also Meisenheimer *et al.* 1989b). We outline the relevance of optical studies and summarize some results concerning the magnetic fields in extragalactic radio sources.

1. The relevance of optical observations

Typical magnetic field strengths in the brightest parts of extended extragalactic radio sources range between 10 and 100 nT (0.1 to 1 mG). Accordingly the emission of optical synchrotron light requires electrons with Lorentz factor $\gamma = E/m_e c^2 > 10^5$ (see Meisenheimer et al. 1989a, in the following called HSS for **H**ot **S**pot **S**pectra). These electrons would lose half of their energy in a few hundred years. Thus we know that the electrons responsible for the optical synchrotron radiation could hardly have escaped their place of acceleration by more than $\simeq 100\,\mathrm{pc}$. On the other hand, electrons producing the bulk of the radio emission ($\gamma \simeq 10^3$) might radiate at 100 times larger distances from their accelerator either after streaming along open field lines or after advection with the flow of magnetized plasma. Thus an optical image will represent the distribution of "fresh" electrons. Since the flux density $S_\nu \sim \nu^\alpha$ strongly depends on the transverse field ($S_\nu \sim B_\perp^{1-\alpha}$ with $B_\perp = |B| sin\theta$) radio maps, however, show regions of enhanced magnetic field. A simple consequence of these propagation effects are the *broken powerlaw* spectra observed in several radio hot spots (Heavens, Meisenheimer 1987, HSS).

The overall synchroton spectra of radio hot spots and jets cut off at about optical frequencies. This leads to rather steep optical spectra ($\alpha_{\mathrm{opt}} = -1 \ldots -5$) which make the observable effects of both propagation losses and magnetic field variations much stronger in the optical waveband than in the radio.

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2. Results

Optical polarimetry shows that the magnetic field in the optical emission region always is orthogonal to the jet axis, supporting the standard model in which particle acceleration in the hot spot occurs at a strong shock. Furthermore, we determined the overall synchrotron spectra of optically detected radio hot spots by millimetre and near-infrared observations (HSS). The incidence of a $\Delta\alpha = -0.5$ break in the radio-to-optical spectra allows to estimate the field strength independently of the minimum energy argument (Meisenheimer, Heavens 1986). We find a good coincidence of both field estimates around $|B| = 30\,\mathrm{nT}$ (HSS).

Photo-polarimetric observations of the M 87 jet (Schlötelburg 1989, Schlötelburg *et al.* 1988) resulted in detailed maps of optical polarization and spectral index. The most remarkable result of the radio-optical comparison is the small difference in both total intensity and polarization structure (Meisenheimer *et al.* 1989b). This finding argues against propagation effects playing an important role. The very smooth optical spectral index along the entire length of the jet requires either a continous re-acceleration of electrons or a transport of ultra-relativistic electrons ($\gamma \geq 10^6$) without any significant losses over $> 1\,\mathrm{kpc}$ (Owen *et al.* 1989).

By new CCD-observations of the 3C 273 jet (see part I: Observations) we detected firm polarimetric evidence for a faint optical counterpart of the strong radio hot spot. However, our new I-band images with much higher S/N than those published by Röser, Meisenheimer (1986) do *not* support an extremely steep optical hot spot spectrum. Although other groups supported the steep spectrum (Keel 1988, Fraix-Burnet, Nieto 1988) we have to withdraw our original claim: even if the *radio-to-optical* spectral index of the radio hot spot is significantly steeper ($\alpha_{\mathrm{ro}} = -1.15 \pm 0.01$) than that of the "optical knot" ($\alpha_{\mathrm{ro}} = -1.06 \pm 0.01$) the *optical* spectral index itself is not dramatically different between the two.

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Baade, W. : 1956, *Astrophys. J.* **123**, 550

Fraix-Burnet, J., Nieto, J.-L. 1988, *Astron. Astrophys.* **198**, 87

Heavens, A.F., Meisenheimer, K. 1987, *Mon. Not. R. astr. Soc.* **225**, 335

Keel, W. 1988, *Astrophys. J.* **329**, 532

Meisenheimer, K., Heavens, A.F. 1986, *Nature* **323**, 419

Meisenheimer, K. *et al.* 1989a, *Astron. Astrophys.* **219**, 63 (HSS)

Meisenheimer, K., Röser, H.-J. and Schlötelburg, M. 1989b, in *"Extranuclear Activity in Galaxies"*, ESO workshop Garching, ed. Fosbury, Meurs

Owen, F. *et al.* 1989, in Meisenheimer, K., Röser, H.-J (ed.) 1989, *"Hot Spots in Extragalactic Radio Sources"*, proceedings of Ringberg Workshop, Springer Lecture Notes 327

Röser, H.-J. 1989, in Ringberg proceedings, see above.

Röser, H.-J., Meisenheimer, K. 1986, *Astron. Astrophys.* **154**, 15

Schlötelburg, M. 1989. *Ph.D. thesis*, Heidelberg

Schlötelburg, M., Meisenheimer, K. and Röser, H.-J. 1988, *Astron. Astrophys. (Lett.)* **202**, L23