Oxford Astrophysics Workshop on "Evidence for the Torus" (1994) ed. M.J. Ward

Polarimetry and the torus

J H HOUGH, S YOUNG, A EFSTATHIOU

Division of Physical Sciences, University of Hertfordshire, Hatfield, AL10 9AB, UK

Abstract

While the torus plays an obvious role in blocking direct light, and thus increasing the observed polarization from scattering, its role in directly producing polarized flux is less clear. Contributions to the infrared polarization from aligned grains within the torus are discussed.

1. Introduction

Polarimetry, particularly spectropolarimetry, has been extremely effective in showing that at least some type II Seyfert galaxies have type I nuclei which are normally obscured from direct view, but whose broad lines can be observed in the polarized flux spectrum. Radiation from the nuclear region, escaping along the polar axis of the torus, is scattered towards us, thus producing polarized radiation. Although the phenomenon was first observed for NGC1068 (Antonucci & Miller 1985, Bailey *et al.*1988), perhaps the best example to date is that of IRAS110548-1131 (Young *et al.*1993), in which broad Hα lines of FWHM 7600 km s^{-1} are prominent.

While at optical wavelengths scattering clearly produces the polarization, at longer wavelengths the situation is far less clear.

2. Near-IR polarimetry of Seyfert IIs with obscured broad-lines

We have used the Hatfield Polarimeter (Hough *et al.*1990) to make broad band polarization measurements in the UBVRIJH&K bands of a number of Type II Seyfert galaxies which have been shown to have broad lines in their polarized flux spectrum.

For a number of galaxies (*e.g.*, Was49b, Mkn348, Mkn1210) we find that the polarization increases in the near-IR (see Figure 1), quite unlike the situation for type I Seyferts, in which the polarization decreases smoothly from the blue through to the IR (Brindle *et al.*1990a&b). Further, the above galaxies show no evidence of broadlines in their IR spectrum, indicating that the broadlines are not viewed directly, presumably because of the high extinction along the line of sight, through the torus. Increasing polarization in the near-IR is also seen for NGC1068 (Bailey *et al.*1988), and again there is an absence of broad lines in the total flux spectrum (De Poy, 1987), indicating a very large extinction to the BLR.

For NGC1068 it is clear that electrons are responsible for the scattering of nuclear radiation into our line of sight (Antonucci & Miller 1985, Miller, Goodrich & Mathews 1991, Young *et al.*1994), and as electron scattering is wavelength independent, it might be expected that the same mechanism is responsible for producing the polarized flux in the near-IR, even when the degree of polarization is seen to rise at these wavelengths. Young *et al.*(1994), have shown, however, that NGC1068 would have to have an underlying nuclear spectrum

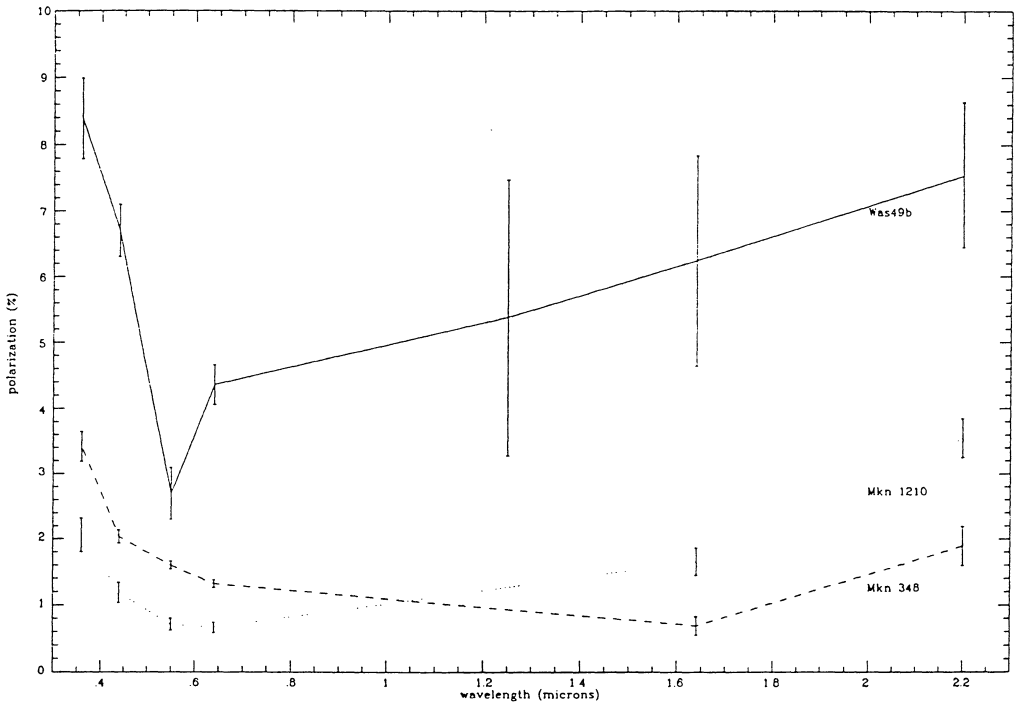

Figure 1. Optical and near-IR broadband polarimetry

substantially more luminous in the near IR, for the same UV luminosity, than probably all other Seyfert 1 galaxies, in order to account for all the near-IR polarized flux by electron scattering.

3. Polarization produced by aligned grains

For NGC1068, evidence that another polarization mechanism is operating comes from the change of position angle of polarization between the optical (where it is perpendicular to the parsec scale radio jet, at position angle $\approx 0^o$), and the near-IR (where it is perpendicular to the large scale [OIII] and radio structure, at position angle $\approx 35^o$). Furthermore, Aitken *et al.*(1984), have shown that the polarization at $10\mu m$ is at a position angle of $\approx 55^o$, which is approximately perpendicular to that at near-IR wavelengths. The simplest model to fit this data is to assume that the near-IR polarization is produced by the dichroic absorption of nuclear light through the torus, and that the $10\mu m$ polarization is produced by emission from grains with the same alignment. Young *et al.*(1994) actually require an extinction corresponding to an A_V of $\approx$ 45 magnitudes, and assuming a Serkowski law (Serkowski 1973), with $\lambda_{max} = 0.55\mu m$ and a $P_{max} = A_V$, in order to produce the observed degrees of polarization in the near-IR. As this is probably less than the extinction to the BLR, Young *et al.*argue that the geometrical paths to the BLR and to the near-IR emitting regions are different.

Preliminary modelling of other objects, with increasing polarization in the near-IR, shows that polarization from dichroic absorption is also required, with total visual extinctions to the IR-emitting regions ranging upto 70 mags.

3. Summary

We believe there is strong evidence that the near-IR polarization of Seyfert II galaxies, with heavily obscured broad line regions, is largely produced by the passage of radiation through aligned grains in the obscuring torus. Polarimetry at longer wavelengths, for example with ISO, when the polarization will be seen in emission, with the position angle of polarization rotated through 90^o relative to that in the near-IR will be important in confirming this picture.

References

Aitken, D.K., Bailey, J.A., Briggs, G., Hough, J.H., & Roche, P.F., 1984, *Nature*, **310**, 660.

Antonucci, R.R.J., & Miller, J.S., 1985, *Ap. J.*, **297**, 621.

Bailey, J.A., Axon, D.J., Hough, J.H., Ward, M.J., McLean, I & Heathcote, S.R., 1988, *M.N.R.A.S.*, **234**, 899.

Brindle, C., Hough, J.H., Bailey, J.A., Ward, M.J., Axon, D.J., Sparks, W.B., McLean I.S., 1990a, *M.N.R.A.S.*, **244**, 577.

Brindle, C., Hough, J.H., Bailey, J.A., Ward, M.J., Axon, D.J., Sparks, W.B., McLean I.S., 1990b, *M.N.R.A.S.*, **244**, 604.

DePoy, D.L., 1987, *in IR Astronomy with Arrays*, ed. C.G.Wynn-Williams, E.E.Becklin & L.H.Good (Honolulu: University of Hawaii), p. 426.

Hough, J.H., Peacock, T., & Bailey, J., 1990, *M.N.R.A.S.*, **248**, 74.

Miller, J.S., Goodrich, R.W., & Mathews, W.G., 1991, *Ap. J.*, **378**, 47.

Serkowski, K., 1973, *in IAU Symposium 52 "Interstellar dust and related topics"*, ed. J.M.Greenberg & H.C.van de Hulst (Reidel: Dordrecht), p. 145.

Young, S., Hough, J.H., Bailey, J.A., Axon, D.J., Ward, M.J., 1993, *M.N.R.A.S.*, **260**, L1.

Young, S., Hough, J.H., Axon, D.J., Bailey, J.A., Ward, M.J., 1994, *M.N.R.A.S.*, in press.