Table 2 Comparison of some properties of 3T3 cells 'poorly responsive' or 'highly responsive' to EGF

Cell type	Passage no	No. of binding sites	Binding affinity	ED_{50}	% Thymidine incorporation
Highly responsive	2–5	40,000–70,000	2.5–4.0	5–20	600–1,100
Poorly responsive	12–26	40,000–70,000	2.5–4.0	1,000–2,000	170–250

Binding affinity is the concentration of ^{125}I-EGF ($\times 10^{10}$ M) required to achieve half-maximal binding, determined by incubating 3T3 cells in monolayer with increasing concentrations of ^{125}I-EGF (300,000 c.p.m. per ng) for 45 min at 37 °C, as described in ref. 14. The ED_{50} is the concentration (pg ml^{-1}) of EGF producing half-maximal stimulation of DNA synthesis. Thymidine incorporation is expressed as the per cent stimulation with maximal concentrations of EGF compared with that in the absence of the mitogen (100%).

Mechanisms which involve self-aggregation require lateral mobility of receptor sites in the plane of the plasma membrane. This was predicted earlier[17,18] and demonstrated recently for EGF and insulin receptors of 3T3 fibroblasts[9,10]. The significance of receptor–receptor aggregation has previously been suggested in receptor-mediated processes as well as in other biological systems. Kahn *et al.* have shown that antibodies to insulin receptors (obtained from patients with insulin-resistant diabetes) can mimic insulin in stimulating glucose oxidation in adipocytes[19,20]. The Fab′ fragment derived from these antibodies competes with ^{125}I-insulin for binding but does not stimulate glucose oxidation. However, cross-linking with anti-Fab′ antisera restores activity[20]. Antibodies raised against the purified insulin receptor[21], and plant lectins which are known to bind to insulin receptors[22] may also produce biological responses by cross-linking insulin receptors. Conditions which cause degranulation of mast cells and basophils also cause clustering of Fc receptors[23]. When B lymphocytes, which contain immunoglobulin molecules as an integral component of the plasma membrane, interact with bivalent antigens, they are triggered to proliferate and differentiate[24].

The present studies could have important applications to other polypeptide hormone systems. For example, in certain types of insulin-resistant diabetes, or other similar states, defects may exist that impair receptor self-aggregation.

Note added in proof: Anti-insulin antibodies have now also been shown to enhance substantially the biological effects of this hormone on fibroblasts[25]. Although this effect is accompanied by an increase in the apparent affinity of binding of insulin, in the case of EGF, antibodies do not significantly increase the binding of this hormone to fibroblasts or liver membranes[25].

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1. Savage, C. R. Jr, Inagami, T. & Cohen, S. *J. biol. Chem.* **247,** 7612–7621 (1972).
2. Cohen, S. & Taylor, J. M. *Recent Prog. Horm. Res.* **30,** 533–550 (1974).
3. Cohen, S. & Savage, C. R. *Recent Prog. Horm. Res.* **30,** 551–574 (1974).
4. Hollenberg, M. D. & Cuatrecasas, P. *Proc. natn. Acad. Sci. U.S.A.* **70,** 2964–2968 (1973).
5. Westermark, B. *Biochem. biophys. Res. Commun.* **69,** 304–310 (1976).
6. Gospodarowicz, D., Ill, C. R. & Birdwell, C. R. *Endocrinology* **100,** 1108–1120 (1977).
7. Rose, S. P., Pruss, P. M. & Herschman, H. R. *J. cell. Physiol.* **86,** 593–598 (1975).
8. Carpenter, G. & Cohen, S. *J. Cell Biol.* **71,** 159–171 (1976).
9. Shechter, Y., Schlessinger, J., Jacobs, S., Chang, K. J. & Cuatrescasas, P. *Proc. natn. Acad. Sci. U.S.A.* **75,** 2135–2139 (1978).
10. Schlessinger, J., Schechter, Y., Cuatrecasas, P., Willingham, M. C. & Pastan, I. *Proc. natn. Acad. Sci. U.S.A.* **75,** 5353–5357 (1978).
11. Schlessinger, J., Shechter, Y., Willingham, M. C. & Pastan, I. *Proc. natn. Acad. Sci. U.S.A.* **75,** 2659–2663 (1978).
12. Shechter, Y., Hernaez, L. & Cuatrecasas, P. *Proc. natn. Acad. Sci. U.S.A.* **75,** 5788–5791 (1978).
13. Savage, C. R. Jr & Cohen, S. *J. biol. Chem.* **247,** 7609–7611 (1972).
14. Hollenberg, M. D. & Cuatrecasas, P. *J. biol. Chem.* **250,** 3845–3853 (1975).
15. Stanworth, D. R. & Turner, M. W. in *Immunochemistry* (ed. Weir, D. M.) 10.0–10.97 (Blackwell, Oxford, 1973).
16. Maxfield, F. R., Schlessinger, J., Shechter, Y., Pastan, I. & Willingham, M. C. *Cell* **14,** 805–810 (1978).
17. Cuatrecasas, P. *A. Rev. Biochem.* **43,** 169–214 (1974).
18. Bennett, V., O'Keefe, E. & Cuatrecasas, P. *Proc. natn. Acad. Sci. U.S.A.* **72,** 33–37 (1975).
19. Kahn, C. R., Baird, K. L., Flier, J. S. & Jarrett, D. B. *J. clin. Invest.* **60,** 1094–1106 (1977).
20. Kahn, C. R., Baird, K. L., Jarrett, D. B. & Flier, J. S. *Proc. natn. Acad. Sci. U.S.A.* **75,** 4209–4213 (1978).
21. Jacobs, S., Chang, K. J. & Cuatrecasas, P. *Science* **200,** 1283–1284 (1978).
22. Cuatrecasas, P. *J. biol. Chem.* **248,** 3528–3534 (1973).
23. Segal, D., Taurog, J. D. & Metzger, H. *Proc. natn. Acad. Sci. U.S.A.* **74,** 2993–2997 (1977).
24. Singer, S. J. in *Control Mechanisms in Development* (eds Meints, R. H. & Davies, E.) 181–192 (Plenum, New York, 1974).
25. Schechter, Y., Chang, K.-J., Jacobs, S. & Cuatrecasas, P. *Proc. natn. Acad. Sci. U.S.A.* (in the press).

letters

Circular polarisation and the magnetic dipole model

THE magnetic dipole model for a compact extragalactic radio source proposed by Sanders[1,2] and discussed by Milgrom and Bahcall[3] and by Sanders and DaCosta[4], accounts for one of the features observed in a few of these sources—the apparently superluminal separation of two components (see ref. 5). However, the magnetic dipole model requires a strong, well-ordered magnetic field and predicts that the radio emission will have a substantial degree of circular polarisation unless the double source appears highly symmetric to the observer, or the radiation is by positrons and electrons in nearly equal numbers. For the past five years we have been monitoring extragalactic variable radio sources for circular polarisation at 8 GHz, and we have recently begun observations at 4.8 GHz. We present evidence here that the circular polarisation observations made by us and by other observers conflict with the predictions of the magnetic dipole model.

Our circular polarisation monitoring program and the observing procedure has already been described[6]. Averages for all our observations of several sources at 8 GHz between October 1973 and October 1978 are presented in Table 1. The standard deviations are based on the scatter of the observations about their mean values and therefore reflect any possible

Table 1 8.0 GHz circular polarisation measurements October 1973 to October 1978

Source	V (%)	σ_v (%)	N†
0235+164	0.040	0.096	30
*3C84	−0.075*	0.015	109
3C120	0.031	0.030	64
0J287	0.056	0.090	42
4C39.25	0.031	0.024	80
*3C273	−0.056*	0.010	110
3C279	0.148	0.017	63
3C345	−0.058	0.021	127
2134+004	0.065	0.031	39
BL Lac	0.168	0.078	20
3C454.3	0.036	0.022	68

* Significant variations in V were detected during the observing period[6].
† Number of days observed.

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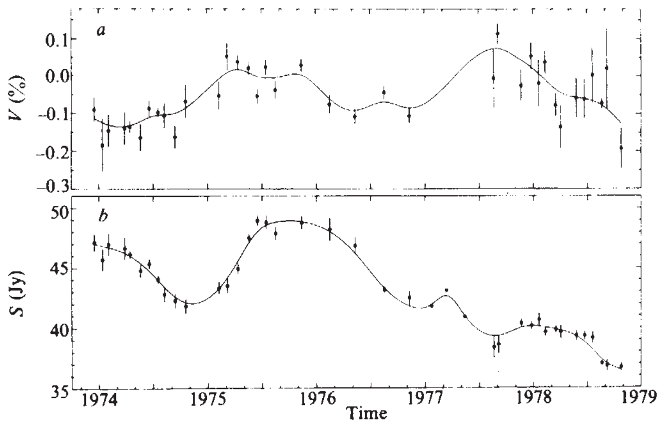

Fig. 1 Monthly averages of the degree of circular polarisation (*a*) and total flux density (*b*) for 3C273 at 8 GHz.

variations. Four bright radio sources have exhibited superluminal expansion[5]: 3C120, 3C273, 3C279 and 3C345. The degrees of circular polarisation which we have observed at 8 GHz for these and other sources have been less than or about 0.1% (ref. 6 and Table 1). Degrees of circular polarisation up to a few tenths of a per cent have been detected by other observers at lower frequencies (see refs 7–9). We have detected variations in the circular polarisation from at least two sources, 3C84 and 3C273 (ref. 6). Figures 1–3 show monthly averages of the total flux densities and degrees of circular polarisation at 8 GHz for 3C273, 3C279 and 3C345 respectively. Smoothing cubic splines[10] have been fitted to the data. Throughout the period of observation the degree of circular polarisation did not rise substantially above ~0.1%.

In the magnetic dipole model[1–4] the relativistic electrons stream out along the magnetic field lines with moderately small pitch angles during an outburst. The required magnetic field strengths must be at least the equipartition value to maintain the geometry of the field. The four sources which have shown superluminal expansion have estimated equipartition magnetic field strengths of about 0.1–1 G (ref. 11). Fields of this strength and pitch angles of 20°–30° yield 1–3% circular polarisation at 8 GHz for a transparent synchrotron source[12]. (Sanders and DaCosta[4] suggest larger magnetic fields and smaller pitch angles, which would increase the degree of circular polarisation to 10–15%.) In contrast, very long baseline interferometry (VLBI) indicates typical values of $\leqslant 10^{-3}$ G for the transverse component of the magnetic field $\mathbf{B}_\perp$ in these sources[13]. This can be reconciled with the equipartition values if the pitch angles are quite small, $\leqslant 10^{-3}$ rad, which would produce degrees of circular polarisation approaching 100%[14].

As Sanders and DaCosta[4] pointed out, no circular polarisation would be produced if the radiation were generated by comparable ensembles of electrons and positrons. The following discussion considers the case when the radiation is primarily by electrons, so that the individual source components would be highly circularly polarised.

A significant degree of cancellation of the circular polarisation is expected in the magnetic dipole model because the magnetic field points towards the observer in one component and away from the observer in the other component, so that the sense of circular polarisation will be opposite in the two components[1,4,12]. The net circular polarisation will, in general, still be non-zero because the total flux densities and magnetic field strengths of the two emitting regions are not expected to be identical. For an observer out of the equatorial plane of the dipole (as is required for separation rates in excess of 4.4*c*), the magnetic fields and pitch angles in the two components would be different even if the dipole geometry were perfectly symmetrical[3]. The polarised flux densities of the two components must differ by less than about 10% to be consistent with our observations, but the possibility that the known superluminally expanding sources are highly symmetric is excluded by VLBI[15–18]. For example, Shaffer *et al.*[15] found that the two components of 3C345 differed by more than 10% in total flux density and that one component had $\mathbf{B}_\perp \sim 1$ mG where the other had $\mathbf{B}_\perp \sim 100$ mG.

The conflict between the model and the observations can be reduced if both source components are opaque to the observer. The degree of circular polarisation from an opaque synchrotron source is about one-third as much as from a transparent source[19]. However, unless the observer is in the equatorial plane of the dipole, the two components will become transparent at different times (because of the different distances of the emitting regions from the dipole centre), thus producing a large imbalance between the components some time during the development of the burst. Our observations (see Figs 1–3) show no evidence for periods of large circular polarisation. Except for the possibility that the radiation from extragalactic sources is generated by both positrons and electrons, the asymmetries observed by VLBI together with our measurements of low degrees of circular polarisation in these sources do not seem to be reconcilable with the magnetic dipole model.

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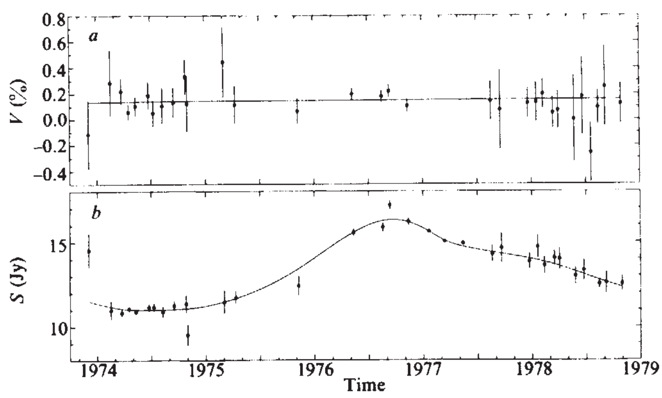

Fig. 2 As Fig. 1 but for 3C279.

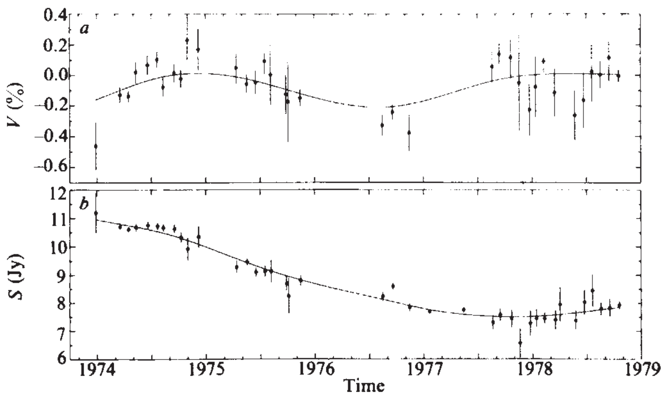

Fig. 3 As Fig. 1 but for 3C345.

Received 22 January; accepted 12 March 1979.

1. Sanders, R. H. *Nature* **248,** 390 (1974).
2. Sanders, R. H. *Proc. Pittsburgh Conf. BL Lac Objects* (in the press).
3. Milgrom, M. & Bahcall, J. N. *Nature* **274,** 349 (1978).
4. Sanders, R. H. & DaCosta, L. N. *Astr. Astrophys.* **70,** 477 (1978).
5. Cohen, M. H. *et al. Nature* **268,** 405 (1977).
6. Hodge, P. E. & Aller, H. D. *Astrophys. J.* **211,** 669 (1977).
7. Seielstad, G. A. & Berge, G. L. *Astr. J.* **80,** 271 (1975).
8. Roberts, J. A. *et al. Aust. J. Phys.* **28,** 325 (1975).
9. Weiler, K. W. & Raimond, E. *Astr. Astrophys.* **52,** 397 (1976).
10. Reinsch, C. H. *Numer. Math.* **10,** 177 (1967).
11. Jones, T. W., O'Dell, S. L. & Stein, W. A. *Astrophys. J.* **192,** 261 (1974).
12. Legg, M. P. C. & Westfold, K. C. *Astrophys. J.* **154,** 499 (1968).
13. Kellermann, K. I. & Pauliny-Toth, I. I. K. *Astrophys. J. Lett.* **155,** L71 (1969).
14. Epstein, R. I. *Astrophys. J.* **183,** 593 (1973).
15. Shaffer, D. B. *et al. Astrophys. J.* **218,** 353 (1977).
16. Kellermann, K. I. *et al. Astrophys. J.* **211,** 658 (1977).
17. Legg, T. H. *et al. Astrophys. J.* **211,** 21 (1977).
18. Seielstad, G. A. *et al. Astrophys. J.* (in the press).
19. Pacholczyk, A. G. & Swihart, T. L. *Astrophys. J.* **170,** 405 (1971).

Tropospheric circulation and interplanetary magnetic sector boundaries followed by MeV proton streams

TRANSITS of some interplanetary magnetic sector boundaries across the Earth were shown by Svestka *et al.*[1] to be followed by streams of protons with energies in the range of a few MeV. These proton boundary transits were associated with a characteristic decrease[2-4] of the vorticity area index (VAI) during Northern Hemisphere winter that was about twice as large as the decrease associated with all the other boundary transits during the same interval. I show here that the MeV proton streams associated by Svestka *et al.*[1] with certain sector boundary transits apparently select boundary transits associated with unusually active conditions in the solar wind. These proton boundary transits were associated with a larger change in tropospheric circulation than were the other boundary transits observed during the same interval of time. New information in the present study of sector boundary transits relating changes in solar wind velocity, density and magnetic field to the resulting terrestrial changes in vorticity area index, geomagnetic activity and cosmic ray flux at Earth may provide a test for proposed physical mechanisms.

Svestka *et al.*[1] summarised what they observed: "There are certain magnetic sectors in interplanetary space in which the density of low-energy protons is increased. The increased proton flux is first observed when the western boundary of the sector passes across the Earth. After that time the flux remains enhanced for two or more days. In some cases the duration of the enhancement corresponds to the width of the magnetic sector, but generally this is not the rule; the duration is usually shorter, but it can be even longer than the sector width. In some cases the enhancement is observed once again when the sector returns to Earth after 27 days. More often, however, the proton increase is not recurrent."

Table 1 of Svestka *at al.*[1] gives a list of the transits of magnetic sector boundaries associated with MEV proton streams. The overlap in time between this table and the interval studied in refs 2–4 includes the winters in 1963–69 during which there were 18 proton boundary transits. During the same winter months there were 62 other well defined boundary transits tabulated by Svalgaard[5,6].

Figure 1*a* shows a superposed epoch analysis of the classical VAI of Roberts and Olson[7] computed at 500 mb in the Northern Hemisphere for the 18 proton boundary transits described above (solid line) and for the 62 other boundary transits in the same interval of time (dashed line). The proton boundary transits were associated with a narrower minimum that was about twice as deep as the minimum associated with the other boundary transits.

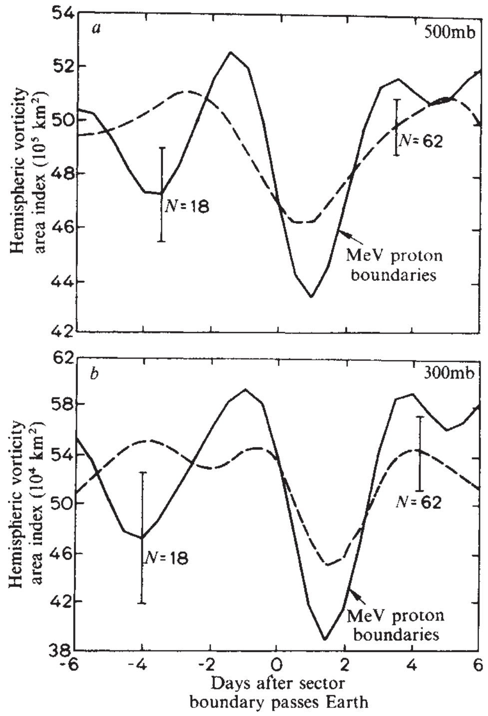

Fig. 1 *a*, Superposed epoch of the vorticity area index during Northern Hemisphere winters 1963–69 about sector boundary transits. The solid curve represents MeV proton boundary transits (see text) and the dashed line represents all other boundary transits in the same time interval. The VAI was computed at 500 mb as the sum of the area in which vorticity was greater than or equal to $20\times10^{-5}\,s^{-1}$ plus the area in which vorticity was $\geq 24\times10^{-5}\,s^{-1}$. In all figures the error bars indicate ±s.e.m. *b*, The same as (*a*) except that the vorticity area index was computed at 300 mb for the area in which vorticity was $\geq 28\times10^{-5}\,s^{-1}$. Note that the ordinate in (*b*) is about 10 times smaller than that in (*a*).

As the depth of the minimum in the VAI may depend on the number of boundary transits considered, an analysis was made using 1,000 groups of 18 boundary transit times selected at random from the 62 'other' transits. A quantitative measure of the depth D of the minimum is defined as the average VAI at day −2 and at day 4 minus the VAI at day 1. (This definition is based on the minimum observed from 162 transits during the winters from 1 November 1963 to 31 March 1976.) For each of the 1,000 groups of 18 transit times the value of D is computed. For the 1,000 values of D the mean is 3.54 ($\times10^5$ km^2) and the standard deviation is 2.04. For the solid curve in Fig. 1*a* the value of D is 7.32, which is almost two standard deviations larger than the mean. This is consistent with the fact that only 30 (3%) of the 1,000 random values of D were larger than 7.32.

Figure 1*b* is the same as Fig. 1*a* except that the VAI was computed in a different part of the troposphere, namely at a height of 300 mb for vorticities $\geq 28\times10^{-5}\,s^{-1}$. The VAI in Fig. 1*a* was computed at 500 mb for the area with vorticity $\geq 20\times 10^{-5}\,s^{-1}$ plus the area with vorticity $\geq 24\times10^{-5}\,s^{-1}$. Note that the area of the troposphere computed in Fig. 1*b* is about 10 times smaller than in Fig. 1*a*, but in Fig. 1*b* the minimum associated with MeV proton boundary transits is again at least twice as deep as the minimum associated with the other boundaries. A very similar effect was thus observed in rather different conditions in the troposphere.

Figure 2 shows a superposed epoch analysis of geomagnetic activity (Mudyaud's index[8] am) associated with the proton boundary transits (solid line) and the other boundary transits (dashed line). There was a large increase of geomagnetic activity following the proton boundary transits and no significant change