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than the full-length dynorphin₁₋₁₇ — thus the potency of the octapeptide was markedly increased when a cocktail of peptidase inhibitors was added to the assay system. This is in keeping with a putative transmitter role for dynorphin₁₋₈, whereas the longer peptide, dynorphin₁₋₁₇, may be more important in a hormonal function, perhaps after secretion from the pituitary. The companion peptide, α -neoendorphin, is pharmacologically similar to dynorphin₁₋₈.

Whether these two peptides represent a distinct new family of endogenous ligands for the κ sites in brain and spinal cord remains to be established, but this is certainly an intriguing possibility. The function of these sites remains obscure, but κ -selective drugs, for example ethylketocyclazocine and bremazocine, are known to be effective analgesics and do not substitute for morphine in preventing with-

drawal symptoms in morphine-dependent animals⁹ (they seem to have only low addiction liability). Drugs with such a profile clearly have therapeutic potential, and a better understanding of the κ -receptors and their endogenous ligands is urgently needed. □

1. Hughes, J. *et al.* *Nature* **258**, 577 (1975).
2. Rossier, J. *Nature* **298**, 221 (1982).
3. Weber, E., Evans, C.J. & Barchas, J.D. *Nature* **299**, 77 (1982).
4. Goldstein, A. *et al.* *Proc. natn. Acad. Sci. U.S.A.* **76**, 6666 (1979).
5. Goldstein, A. *et al.* *Proc. natn. Acad. Sci. U.S.A.* **78**, 7219 (1981).
6. Kangawa, K. *et al.* *Biochem. biophys. Res. Commun.* **99**, 871 (1981).
7. Cavkin, C., James, I.F. & Goldstein, A. *Science* **215**, 413 (1982).
8. Corbett, A.D. *et al.* *Nature* **299**, 79 (1982).
9. Minamino, N. *et al.* *Biochem. biophys. Res. Commun.* **95**, 1475 (1980).
10. Seizinger, B., Holtt, V. & Herz, A. *Biochem. biophys. Res. Commun.* **102**, 197 (1981).

Plasma astrophysics at Santa Barbara

from R. Rosner*, E. Zweibel† and V. Trimble‡

At the workshop on 'Space and Astrophysical Plasmas' held this summer at the Institute for Theoretical Physics at the University of California, Santa Barbara, three topics held sway: hydromagnetic shocks and particle acceleration, the interaction of hot and cold plasmas, and hydromagnetic flows. A diverse group of theorists from the laboratory plasma, space plasma and astrophysics communities took part.

The possibility that particles can be accelerated to high energies in the vicinity of collisionless shocks — yielding solar and galactic cosmic rays and relativistic particles in extragalactic radio sources — has received wide attention in recent years. The outstanding problems include the structure of collisionless shocks (the mechanisms which produce a shock transition in collisionless plasmas), the 'injection problem' (how thermal particles can be extracted from the background plasma and accelerated to high energy), the shock efficiency and — most difficult — the interaction between the accelerating particle population and the processes determining shock structure and acceleration efficiency.

These difficult issues can be at least partially addressed by observations of the terrestrial bowshock, produced by the interaction between the solar wind and the terrestrial magnetosphere. E. Greenstadt (TRW) showed that while the shock layer is quite thin when the interplanetary magnetic field is nearly normal to the direction of motion of the shock (quasi-perpendicular case), it is highly irregular and quite extended in space in the quasi-

parallel case (magnetic field nearly parallel to the direction of motion of the shock). A fraction of the incoming solar wind particles is reflected back upstream, and these particles excite low-frequency electromagnetic waves which exert a retarding force on the solar wind. A diffuse energetic ion component is also observed. The terrestrial bowshock (and interplanetary shocks) will evidently provide important 'laboratory' constraints on theoretical studies of shock structure and particle acceleration.

The problems of internal shock structure, including the details of ion dynamics, were addressed by a number of theorists by powerful numerical simulations of collisionless shocks. The simulations show reflected ions and short-wavelength electromagnetic turbulence (D. Forslund, Los Alamos), in reasonable agreement with observations, with ions bent back upstream by the enhanced magnetic field in a postshock magnetic overshoot layer (C. C. Goodrich, University of Maryland). However, the need of an electrostatic potential layer to slow down electrons (in quasiparallel shocks) remains unresolved by the present simulations and observations.

The basic model of shock acceleration, the starting point for discussions at the workshop, is a steady-state model in which

cosmic rays diffuse in the vicinity of a high Mach number quasi-parallel shock which is approximated to by a discontinuity in flow speed. Observations of cosmic-ray secondaries ($E \sim 1$ to 100 GeV) constrain the extent to which cosmic rays can be accelerated to high energies by successive passage through interstellar shocks because the volume in which acceleration occurs does not exceed 10 per cent of the confinement volume (W. I. Axford, Max-Planck Institut). The cosmic rays are scattered by magnetic irregularities, which are assumed to be nearly stationary in the frame of the flow; thus, because of the jump in flow speed across the shock, particles are accelerated by a first-order Fermi process as they scatter back and forth across the shock front, with the well known result that the energetic particle spectrum is quite similar to that of galactic cosmic rays.

Some major issues remain unresolved, however. Thus the efficiency of the shock (the fraction of energy which goes into relativistic particles) is not determined, and the properties of the hypothetical scattering centres, which determine the cosmic ray diffusion coefficient, must be specified *ad hoc*. If the scattering mean-free path is not large compared with the width of the shock transition, the detailed fluid velocity profile must determine the acceleration. But the flow itself is modified by the coupling between the cosmic ray momentum flux and pressure and the thermal gas, the modification being highly sensitive to the details of the coupling (D. Eichler, University of Maryland; H. Volk, Max-Planck Institut/University of Chicago).

There is a very different problem in the transfer of energy between hot and cold plasmas. Thus the structure of the transition layer between the solar chromosphere and corona is crucial to an understanding of the energetics of these plasmas, but the construction of valid model atmospheres is complicated by the high degree of spatial inhomogeneity (including the probable existence of unresolved features), flows in the boundary layer region and the general absence of steady-state conditions (R. Rosner, Harvard University). Even if these difficulties were not present, calculations show that the electron distribution function in the transition region (E. Shoub, Stanford University) is significantly non-Maxwellian. The distribution at a given height is 'contaminated' by superthermal particles representative of the temperature of overlying layers, possibly significantly altering the rates of collisional ionization and excitation (and the heat flux). Thus, the diagnostic problem remains a major difficulty in modelling solar thermal boundary layers.

Different problems arise in heat transport in laser-irradiated plasmas (C. Max, Lawrence Livermore). Experiments show the heat flux often to be much less than predicted by classical transport

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formulae. The solution may lie in improved classical calculations; in the suppression of heat flux by plasma instabilities (ion acoustic waves, Weibel instabilities and so on) which increase the electron-scattering frequency; or in the inhibition of thermal conduction by strong (megagauss) d.c. magnetic fields (which occur because the isothermal and isodensity surfaces do not coincide, as in the classic Biermann 'battery' dynamo). In any case, the observed heat flux appears to limit at about 3–9 per cent of the free-streaming value, a result which the simulations do not as yet reproduce.

This observation is clearly relevant to models of heat exchange between tenuous hot plasma and much cooler gas in the interstellar medium of galaxies (discussed by C. McKee, University of California, Berkeley, and S. Balbus, MIT). In such models, the crucial parameters controlling the dynamics are the ratio of the thermal electron mean free path to the dimension of the cool plasma embedded in the hotter gas phase; and the dimensionless coefficient marking the reduction of the heat flux below its free-streaming value. Present calculations have now explored the parameter space of the hot electron-cold plasma interaction in some detail; presumably, the 'zoo' of possible solutions must be constrained by observations (which are likely to lend considerable insight into the dominant mechanisms of energy transport across such steep temperature boundary layers) and by the laboratory laser work (which reduces the arbitrariness of assigning a reduction factor to the saturated heat flux).

The discussions on hydromagnetic (MHD) flows indicated that although much is understood in restricted contexts, and there is an appreciation of the connections on the observational level, an integrated theoretical view of the problem (as is now emerging in the above two cases) is not yet at hand. At the very fundamental level, it is apparent that study of equilibria may be of limited usefulness because, for example, one can now show (E. N. Parker, University of Chicago) that 'most' perturbations lead to departures from equilibrium conditions characterized by some symmetry property (these are indeed the only known equilibria). Furthermore, MHD equilibria which have been shown to be stable to (analytical) perturbations have only remote connections with observed magnetic structures (on, for example, the Sun). It is likely that further progress will require sophisticated numerical (MHD) simulations, as experience in laboratory fusion work has indicated.

There is considerable interest in studying the dynamic interaction between hydrodynamic flows and ambient magnetic fields, such as occurs both within the solar wind and in its interaction with planetary magnetospheres (T. Holzer, HAO); and in the interaction between the relativistic plasma and ambient magnetic fields

surrounding pulsars (J. Arons, University of California, Berkeley). In the case of solar wind streams the origin of the high speeds remains a basic question. Observations have now placed stringent constraints on the available wave momentum flux below the solar corona, which seem severely to constrain the popular Alfvén wave-driven models. Another outstanding problem remains the construction of a self-consistent magnetosphere, a problem which is, as pointed out by Arons, very reminiscent of the global terrestrial magnetosphere problem discussed earlier by J. M. Cornwall (University of California, Los Angeles).

In both cases, local theories encounter the difficulty that the current flow is determined by boundary conditions which, in fact, simply reflect global structure. An interesting further example of hydro-magnetic flows which seem to be ubiquitous are the 'bi-polar' flows, or jets,

discussed by A. Königl (University of California, Berkeley); these are perhaps best known in the context of radio galaxies and relatively exotic objects such as SS433, but are apparently also associated with protostellar objects. The mechanisms responsible for the initial plasma acceleration and for the high degree of collimation are at the heart of current theoretical studies; Königl focused particular attention on radiative driving and on the beaming resulting from the planar symmetry and stratification of gas in accreting protostellar objects.

On the whole, our impression was that this workshop gave substance to the long-rumoured emergence of plasma astrophysics as a well defined discipline; the discussions indicated that a community of scholars has 'gelled' in at least two of the three principal topics of discussion and that the much-discussed, but often in practice neglected, contact with laboratory and space plasma physics has been made. □

Key structures in transposition

from N. Symonds

It is widely agreed that transposition is normally a replicative process but little is known about the location of replication origins within transposons or the events which herald the initiation or termination of DNA synthesis. Of undoubted importance are the sequences at the ends of transposons which remain constant during transposition and, in nearly all cases, are inverted repeats of one another. It was this symmetry in the structure of transposons, together with a considerable amount of genetic data, which led Shapiro¹ to propose his model for transposition which has become the archetype for the numerous alternative schemes subsequently put forward.

The model involves a symmetric intermediate structure possessing two replication forks for DNA synthesis (Fig. 1a). It has been successful in explaining the properties of such transposons as Tn3 and $\gamma \delta$, but it fits less well with the properties of phage Mu from which most of Shapiro's early genetic data were obtained and which, ironically as it turned out later, seems to be the only transposon lacking inverted repeats at its ends.

As well as discrepancies in the genetic data, earlier electron-microscope studies by Harshey and Bukhari² had indicated that the intermediate structures in Mu transposition were not as predicted from the Shapiro model but consisted of 'keys' having circles of variable size attached to

tails of variable length. This led these authors to propose a modification to the Shapiro model with an intermediate structure essentially as depicted in Fig. 1b. The main innovation is that it contains a single replication fork starting from one end only of the transposon: the second end of the target molecule is left unligated until the last stage in the transposition process and in the interim is held by a protein complex which could be the replication complex itself. Protease treatment of such an intermediate then yields a key molecule with a free end.

To obtain definitive evidence that the key structures are indeed transposition

Fig. 1 The initial intermediate structures in transposition according to *a*, the original model of Shapiro (two replication forks); and *b*, the modification of Harshey and Bukhari (one replication fork). Solid lines: donor DNA containing the transposon (heavy lines). Dotted lines: target molecule. The circle represents a protein complex and could be located at the replication fork. Normally the donor and target molecules would be on different circular genomes, or at different locations on the same circular genome.

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