magnetic neutral (null) line situated about 100 Earth radii ($R_E = 6,400$ km) downstream from the Earth which separates plasma sheet field lines of opposite polarity. At the start of the substorm a near-Earth or 'substorm' magnetic neutral line forms (Fig. 1b) about 15 R_E downstream from the Earth, leading to the rapid disconnection of a giant bubble of hot plasma threaded and held together by closed loops of magnetic field. This remarkable structure, a plasmoid, has a length of around 75 R_E , a width of 20 R_E and a height of around 12 R_E . It is propelled downstream by a magnetic slingshot force at speeds of around 500 km s⁻¹ (Fig. 1c).

The process responsible for the magnetic neutral lines and for the magnetic slingshot force is magnetic reconnection — a concept formulated in the 1950s by solar physicists attempting to explain solar flares. Magnetic reconnection releases magnetic energy into plasma jets and particle heating and its key features are illustrated in Fig. 2a. The process occurs when two plasma regions having oppositely directed magnetic fields are pushed together at a current sheet. Provided these plasmas have finite resistance, the field lines may break and reconnect in new combinations, resulting in a magnetic null situated where the field lines apparently cross in the magnetic field. Magnetic energy is converted into plasma motion (labelled 'jets') when the reconnected field lines are catapulted away by the magnetic tension force acting at the hairpin bend in the field lines.

Despite much research, the detailed characteristics of the reconnection process remain elusive. In a widely held view, the current sheet initially breaks up spon-

taneously into a series of magnetic islands or current filaments having a loop-like magnetic field (Fig. 2b, time t_1). This configuration is unstable to the coalescence instability (J. M. Finn & P. K. Kaw *Phys. Fluids* **20**, 72–78; 1977) by which the magnetic islands move towards each other owing to the attractive force of parallel currents (time t_2). With resistivity, this instability leads, through reconnection, to the merging or coalescence of neighbouring islands (time t_3).

Satellite observations of current filaments and plasmoids in the Earth's magnetotail current sheet led Richard *et al.* to investigate whether plasmoids could form through the coalescence of several current filaments, rather than directly through the large-scale reconnection at a neutral line implicit in the neutral line model (Fig. 1). They used a computer simulation, using the standard magnetohydrodynamic and Maxwell equations to simulate numerically the two-dimensional plasma behaviour implied by these governing equations. Quantities calculated included the plasma density, plasma pressure, flow velocity, magnetic field and current density. Two types of system were investigated: a current sheet containing an infinite chain of islands and one where the island chain was finite. The former case is relevant for studying how the coalescence process might occur in a local region of the magnetotail current sheet, and the latter is appropriate for examining the larger-scale consequences of coalescing islands and is of more immediate interest here.

The simulations were initialized by having a chain of magnetic islands whose size decreased down the magnetotail current sheet. Coalescence soon leads to the

FIG. 2a Basic physics of the magnetic reconnection process. Solid lines indicate the magnetic field direction, open arrows the plasma flow direction and the dotted region is a current sheet. b, Basic physics of the magnetic coalescence instability — a process which Richard *et al.* suggest may lead to plasmoid formation and to the driving of magnetic reconnection of a scale larger than the original magnetic islands. The sketches illustrate the magnetic topology at three times t_1 , t_2 and t_3 . At t_1 a chain of magnetic islands forms within a current sheet (shown dotted) separating two plasma regions with oppositely directed magnetic fields. The currents associated with each island are parallel thereby leading to island attraction, as indicated by the heavy arrows. At t_2 two neighbouring magnetic islands start to coalesce leading to the formation of a larger island (at t_3).

100 years ago A chimpanzee's humour

IN a recent lecture Mr. Romanes is reported as having strongly denied the existence of even a trace of any feeling of the ludicrous in the renowned chimpanzee "Sally".

Being alone with a friend in Sally's house, we tried to get her to obey the commands usually given by the keeper. I said "Give me two straws, Sally." At first she appeared to take no notice, I repeated the request with no further result; but on a second or third repetition she suddenly took up a large bundle of straw from the floor and thrust it through the bars at us, and then sat down with her back to us. Our request was perhaps unreasonable, seeing that we had no choice morsels of banana with which to reward her. She did not, however, seem ill-tempered at our presumption, and the next instant was as lively as ever. It seems to me that her action on this occasion certainly came very near to an expression of humour. Rather sarcastic humour perhaps it was, but she certainly appeared to take pleasure in the spectacle of something incongruous, and this surely lies at the base of all sense of the ludicrous.

HAROLD PICTON.

From *Nature* **40**, 224; 4 July 1889.

formation of a large ($50 R_E \times 4 R_E$) magnetic island, or plasmoid, whose size is much greater than the sum of the areas of the original coalescing filaments. The simulations also show that the motion of this plasmoid down the magnetotail leads to magnetic reconnection being established at a magnetic neutral line on a scale much larger than the original filament size. These findings are repeatable for a wide range of initial values of the plasma resistance, viscosity and ratio of plasma to magnetic-field pressure.

Richard *et al.* focus on an interesting question: how is a plasmoid born? Not all their results are new but the paper provides the best argument for plasmoids forming through the coalescence of magnetic islands. As plasmoids are three-dimensional structures, further work is clearly necessary to extend the present simulations to three dimensions. It is also necessary to demonstrate that coalescence occurs sufficiently fast to match the 5–10 minute timescale for the expansion phase of a substorm. Further *in situ* observations of current filaments in the magnetotail current sheet are also desirable, to provide a more solid empirical base for the simulations. If such structures are indeed common, Richard *et al.* have made a useful contribution to the exciting field of substorm research. □

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