Sudden Events

THE importance of sudden events has become increasingly evident to astronomers in recent years. Perhaps such occurrences are noticed most commonly in some of the quasars. Typically what happens is that an intense component of radio emission, with a very small angular diameter, becomes visible for a period of a few months. During this time it contributes an appreciable proportion to the energy output of the whole quasar at radio frequencies. The radio emission at a given frequency first rises with time, reaches a maximum, and then decays; the higher frequency components achieve their maximum intensity before the lower frequency components. The whole effect can be explained beautifully on a model which was proposed by van der Laan several years ago. According to his ideas the radiation is generated in a giant bubble consisting of relativistic plasma mixed up with a magnetic field. As the bubble expands, the electrons lose energy and the magnetic field strength decreases. This gradually shifts to lower values both the frequencies at which the electrons emit most effectively and those at which the bubble is just transparent.

The model has one drawback, though. It says nothing about the way in which the relativistic plasma is given its energy in the first place. This is rather an important point, for the total energy required by the bubble depends very sensitively on the way in which it is started off. The early phases of its life are the most expensive in energy. But so far there are no observations of such a relativistic bubble in a quasar at the beginning of its life. In any case it may well be that the early phases of its evolution take place under conditions of such high density that it is impossible to observe directly just what is going on.

It is therefore fortunate that just over six months ago an outburst occurred in our Galaxy which looks very much like a small scale replica of such a sudden event in a quasar. The occasion was first observed on September 2, when the intensity of the radio emission from the X-ray source Cygnus X-3 suddenly increased by some orders of magnitude over its usual quiescent value. The subsequent events were comprehensively described in the October 23 issue of *Nature Physical Science*. It was found that the later evolution of the Cygnus X-3 outburst could be very well accounted for by the same model that van der Laan had proposed for sudden events in quasars (although the physical parameters such as magnetic field strength and total energy content had to be scaled down to the more modest proportions of this particular explosion). But it turned out that the observations made on the first day after the outburst did not fit the model too well. In particular there were oscillations in intensity at the higher frequencies that could not possibly be explained.

In an article on page 173 of this issue of *Nature* an attempt is made by Peterson to improve understanding of the early phases in the development of the bubble. He makes the modification that the relativistic plasma is not injected into the bubble all at once, but over a period of about a day. He postulates a particular form for the law governing the injection of plasma and then varies a set of parameters until he obtains the closest possible fit between his model and the observed evolution of the spectrum of the radio outburst. His conclusion is that the injection continued for about 30 h and that the minimum size of the bubble was about 10 AU.

Now this is most interesting, but also most tantalizing. How does all this agree with what is known about X-ray sources? Observations show that the X-ray emission from these sources often has quite short period oscillations, of the order of seconds. In the usual way one concludes that the underlying object must therefore be very compact; the only likely candidates are neutron stars or black holes. Somehow the release of the energy must have occurred in the underlying object. The energy was then propagated away from the source; later it was given to the radio bubble, which was observed after September 2. But neutron stars and black holes do not have dimensions as large as 10 AU; an estimate of 1 to 10 km would be much nearer the mark. There are therefore two problems: where did the energy come from, and how was it transmitted to the much larger region where the radio bubble began its existence?

Most probably the source of the energy is connected with the release of gravitational energy. It will be interesting to study how this happened, particularly if it turns out that the central object of Cygnus X-3 is actually a black hole. The transfer of energy, one would guess, must have occurred by some electromagnetic process, but under rather unfamiliar conditions. A reasonable picture might be as follows. Suppose that a mass of plasma falls towards a black hole or onto the surface of a neutron star. Suppose further that a quantity of magnetic flux is linked with the plasma. During the final stages of the collapse the magnetic dipole moment due to this flux will undergo rapid changes. One consequence is the emission of low-frequency electromagnetic radiation: the intensity of the emission increases up to the moment when the plasma gets lost in the black hole or the neutron star. If the plasma cloud has angular momentum the process may be augmented by the emission of low-frequency radiation from a rotating dipole, rather as is the case in some theoretical model of pulsars.

In either case one would expect a radiation field with characteristic frequencies in the region of 10 kHz. This radiation field has waves of low frequency but it carries much energy. Its mode of propagation through any ambient plasma is, however, not well understood; the waves have such a large amplitude that they cause large variations in the mass of the charged particles of the medium through which they are travelling. Any theoretical attempt at understanding this process leads at once to a difficult non-linear problem, whose solution is known in only a few special cases. But it does seem likely that in sudden events of this kind the relativistic electrons in the radio bubble have been energized by interaction with a set of low-frequency waves.

It is quite natural therefore that strenuous attempts should be made to understand these electromagnetic phenomena. The outburst of Cyg X-3 provides the best set of observations from which to derive data about the actual behaviour of such waves. The analysis by Peterson shows how one can extract much additional information from the records of the event.

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