NEWS AND VIEWS

The Universe Considered as Hole

DURING the past few years, astronomers have gained an insight into black holes (or collapsars) which has made the study of these phenomena an increasingly important part of astronomy. This field of research was once largely the preserve of mathematicians concerned with the nature of space-time in an abstract way; observational developments now suggest, however, that collapsars play a vital part in the evolution of stars, galaxies, and the Universe as a whole. The latest calculations pointing to the possible importance of collapsars in binary systems appear in this issue of *Nature* (page 465). G. W. Gibbons and S. W. Hawking have followed up the line of investigation pointed to by Trimble and Thorne (*Astrophys. J.*, **156**, 1013; 1969) and conclude, from a study of the properties of seven systems shown to be binary stars by the Doppler motion of lines in their spectra, that there is suggestive evidence for the presence of black holes in some binaries. This must also lend weight to the contention made by Cameron and supported by Stothers that there is a collapsar in the system ε Aurigae (*Nature*, **229**, 178 and 180; 1971).

But what exactly is a collapsar? The general scientific imagination may well be captured by this concept of a "hole in space", but all too often it is felt that, because the prediction of this effect stems from Einstein's general theory of relativity, an understanding of it requires specialized mathematical knowledge. This is far from the truth. Like many of the fruits of this elegant theory the prediction, once made, can easily be understood in physical terms. Any star with more than 1.4 solar masses left when it has exhausted its nuclear fuel cannot support itself against gravitational collapse. The pressure at the centre of the cold star becomes so great that the fundamental nuclear forces are overcome, and matter is compressed beyond the density of atomic nuclei. This process is self sustaining, because such compression results in a higher density, a stronger gravitational field, and thus still more rapid collapse. Eventually, the collapsar has the properties of a point source of infinitely dense material. Curious as this is, it is the effect of the gravitational field produced on the space outside the collapsar which is responsible for the current wave of interest in black holes.

Within a critical radius (the particle horizon), the field is so intense that no matter, nor any radiation, can escape from the collapsar, although material can continue to be absorbed from the Universe. Hence the name black hole—the only way in which these objects can be detected is by their gravitational fields. This has great appeal to cosmologists, many of whom believe that there should be more matter in the Universe than can be seen in the form of bright galaxies. It also opens the way to intriguing mathematical games concerned with the possibility of extracting energy from these sources.

The most extravagant suggestion is that matter swallowed up by black holes re-emerges into the Universe from white holes, which lie at the centres of active galaxies and quasars. This could ensure the overall conservation of mass/energy while offering some explanation of the extremely violent events observed in some astronomical objects. At a more sophisticated level, it seems that energy could be extracted from the immediate vicinity of a collapsar by the break up of another object passing nearby. During a conference held from July 19 to 21 at the Institute of Theoretical Astronomy in Cambridge, which will shortly be reported in *Nature*, there was discussion of the properties of the ergosphere, a region just outside the particle horizon. A mass passing through this region can break up under certain conditions in such a way that one fragment falls into the black hole while the other is accelerated, gaining energy in the same way that the proposed grand tour space probes will gain energy from the rotational energy of the giant planets—a slingshot effect. But the escaping fragment can gain so much kinetic energy that it leaves the region of the collapsar with more mass/energy than that of the entire incident mass.

This mechanism must unfortunately remain a toy for the mathematicians, because the collapsars required to explain the activity of many observed galactic nuclei in terms of this effect would be implausibly large. For the present, however, practical astronomers and physicists would prefer to seek some other energizing process for these active galaxies and quasars. Black holes need not, however, be quite so extremely violent as this conventional picture conjures up. To be sure, objects like stars can only disappear inside their own particle horizons when compressed to very great densities. But while the mass of a sphere of matter at some uniform density varies as the cube of the sphere's radius, the gravitational force falls off only as r^2. For any density chosen there is some critical mass above which the sphere is within its particle horizon, or, alternatively, for any mass there is some critical density for which this occurs, and the greater the mass chosen the smaller is the required critical density. So although gravity is a weak force, its action over very great distances implies that a reasonably dense galaxy—that is, one with a density comparable to the density of some stellar clusters in our galaxy—could contain enough mass to prevent the escape of matter or radiation from its immediate vicinity.

Once again, the cosmologists who wish for more matter in the Universe are delighted—now, it seems, whole galaxies can be hidden in black holes. But why do the cosmologists want yet more matter in the visible galaxies? In short, it is to provide enough mass for the Universe to be closed. This would solve many problems regarding the nature and origin of the Universe, and would fit many of the observations of distant sources made at radio, optical and other wavelengths. But if the Universe is closed—the finite, yet unbounded three-dimensional analogue of the surface of a sphere—then the world is in essentially a rather large black hole. The corollary to this is that the expansion of the Universe must ultimately be reversed, eventually producing a compression to densities where present understanding of physics breaks down, with, perhaps, a further expansion from the primaeval matter in a cycle of pulsations which had no beginning and will have no end.