Progress on accretion disks

from J. Craig Wheeler

ASTROPHYSICISTS are wrestling with the study of a new kind of star, the flat two-dimensional configurations known as accretion disks. Accretion disks exist in a variety of contexts where mass is deposited to swirl around a compact star such as a white dwarf or a neutron star. They are suspected to play a part in more exotic situations, like active galactic nuclei and quasars, where the central object is imagined to be a supermassive black hole. The study of these objects is still in its infancy, analogous to the early days of Eddington when stars were modelled using elementary scaling laws without benefit of knowledge of the nuclear processes which powered the stars. Similarly, the power by which accretion disks radiate is suspected to come from a form of turbulent friction, the basic physics of which is known only at the crudest level. Most of the current literature on accretion disks is couched in terms of parametrized scaling laws which avoid direct confrontation with our most basic levels of ignorance. The letter by Abramowicz in this issue of *Nature* (p.235) adds needed rigor to our understanding of the structure and evolution of accretion disks while exploring an instability in the disk structure which has plagued earlier models.

Accretion disks were first defined as astronomical entities in the context of cataclysmic variables. In these systems, which include novae, matter from the outer layers of an ordinary star is attracted by the gravitational influence of a nearby orbiting white dwarf star. The matter lost from the ordinary star cannot strike the surface of the tiny white dwarf directly, but settles into nearly keplerian orbit. The viscosity in the disk causes heating and radiation and a slow spiralling of the material onto the surface of the white dwarf.

The rapid advances made in X-ray astronomy in the past decade have identified similar systems in which the accretion disk whirls about a neutron star rather than a white dwarf. The inner reaches of the accretion disk extended deeply into the gravitational potential of the neutron star where very rapid motion is the rule. The energy released by friction and the actual raining of the material from the disk onto the surface of the neutron star is so great that the radiation comes off in a powerful flood of X rays. In at least one binary system explored by X-ray astronomers, Cygnus X-1, the object in the centre of the accretion disk is thought by many to be a black hole, the ultimate form of collapsed matter.

Complete understanding of the outbursts of cataclysmic variables and X-ray production by neutron stars demands knowledge of the associated accretion disks. Through such study may also come deeper insight into phenomena such as active galaxies where matter from millions of stars may gather around a gigantic black hole in the galactic centre.

Previous work has shown that portions of accretion disks are unstable, leading to the clumping of matter into rings or bloating into a fat hot doughnut, in contradiction to assumptions that the disks are geometrically thin. However, there is no observational evidence that accretion disks do, in fact, suffer from these instabilities. Abramowicz argues that these instabilities may not occur in reality, and he shows that added gravitational effects due to general relativity alter the potential compared with the standard newtonian case in such a way that the instabilities are removed.

Ironically, this work may have most direct application in the case of accretion disks around supermassive black holes where observational confirmation of the basic picture is weakest. Abramowicz argues that the major inner radiating portions of such a supermassive disk will be stabilized in this case. The relativistic effects of which he speaks should also apply to putative stellar mass black holes, as in the case of Cygnus X-1, but this system is know to undergo some transitions in its radiative properties which have been discussed in terms of disk instabilities. For systems with white dwarfs and neutron stars the surface of the star or the presence of a surrounding magnetosphere may dominate the inner portions of the disk and overwhelm the relativistic effects described by Abramowicz. Even in the case of supermassive black holes there is speculation that the inner region consists of a nearly spherical, differentially rotating configuration, so that the basic assumptions underlying a thin disk analysis do not apply.

This discussion serves to illustrate the complexity of the phenomena known collectively as accretion disks. Progress towards understanding them will involve defining and solving restricted problems just as was done, and continues to be done, for ordinary spherical stars. The work by Abramowicz gives a new valuable example of the care which must be taken before reaching definitive conclusions regarding accretion disks. ☐

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Geomechanics in the laboratory

from Neville G. W. Cook

THE increasing use of the ground beneath us, whether in mining activities, underground construction or in the disposal of toxic wastes, requires, as does an understanding of earthquakes, a much deeper knowledge of the behaviour and properties of rocks than has sufficed in the past. To understand the behaviour and properties of rock masses, *in situ* tests are possible but they are costly and time consuming[1-3]. As became clear at a recent conference (see *Geophysical Research Letters* **8**, 1981 for the proceedings) there is a need for laboratory tests on a scale of the same order as that of the *in situ* tests, both to avoid many of the restrictions of *in situ* tests and to bridge the gap between them and usual laboratory tests.

The most common kind of laboratory test on rock is the 'triaxial' test first introduced in 1911 (see ref.4). Right circular cylinders of rock, usually a few centimetres in diameter and several times greater in length, are subjected to axial compression between the platens of a mechanical press and an equal radial compression, applied through an impermeable membrane by a confining fluid pressure.

There are fundamental differences in the problems faced by laboratory testing in increasing deformation leads to decreasing engineering mechanics and in geomechanics. In engineering mechanics, man-made materials are generally used and laboratory specimens can be expected to have similar properties to those of structural members made of the same material. Such materials are relatively simple in composition and structure compared with the composition and structure of most rocks. Again, laboratory test specimens of man-made materials are usually within an order of magnitude of the size of structural members whereas the dimensions of excavations and geological features can be many orders of magnitude greater than those of the rock specimens.

A further problem is that systems comprising conventional, soft testing machines and specimens of brittle rock become unstable at or beyond the peak of the stress strain curve[5]. Until the advent of stiff or servo-controlled testing machines, it was impossible to study the 'work-softening' deformation of rock, where increasing deformation leads to decreasing

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