hole. K. Chen[2] has described how the observed line profiles can be used to infer various properties of the accretion disk. If the disk were perfectly smooth and unvarying, it would not be the mass of the central black hole that would be determined, but the ratio M/R, where M is the central mass and R is the radius of the disk. But nature is not so perfect (fortunately, in this case), and ubiquitous fluctuations in luminosity could, in principle, provide the extra piece of information needed to determine both M and R. In several AGNs it is known that variations in the luminosity of the nucleus are echoed, several days later, in the strengths of the emission lines. Imagine, as Stella suggests, that a source of ionizing radiation at the centre of an accretion disk illuminates the surface in bursts. With each burst, a wave of fluorescent emission will travel over the surface at the speed of light, disrupting the observed line profile in an organized and predictable way. Bumps will drift across the line profile as the illuminated region of the disk moves from the inner, high-velocity boundary to the outer, low-velocity edge. The drift time reveals the absolute radius of the disk, and hence the mass of the black hole. Stella's proposal is an application of the reverberation mapping technique, first elaborated by Blandford and McKee[3], which he generalizes to include relativistic effects.

In reality, a number of doubts cloud this idealistic vision. Among the AGNs, only a handful have Balmer line profiles that bear any resemblance to the simple disk models, so it is by no means certain that the bulk of the line emission arises in disks. Even a double-peaked, asymmetric profile is not uniquely attributable to a relativistic keplerian disk. But an independent test involving spectropolarimetry of the line has been proposed[2,4], and could be carried out with existing instruments. In X-ray binaries, the as-yet-undetermined shape of the iron Kα emission lines could be affected by non-gravitational effects, such as Compton scattering in a hot corona above the disk, and several different ionization stages of iron may contribute to an unresolved blend of closely spaced lines. On the optimistic side, the iron lines observed in Cygnus X-1 — the prototype black-hole candidate — and the X-ray transient 4U 1543–47, are too broad and too low in energy to be described as a blend of different ionization stages. Doppler and gravitational redshifts near a black hole remain the most probable explanation. Also, detailed models for iron lines that would be produced in an accretion disk[5] seem to indicate that rotational broadening is more important than the effects of Compton scattering in a hot corona, at least for the properties of the coronae that are thought to exist in X-ray binaries.

So there is ample hope that Stella's procedure for weighing a black hole will be implemented. Black-hole masses in AGNs are expected to range between 10^6 and 10^{10} solar masses. For a 'typical' object of 10^8 solar masses, the visible line-emitting portion of the accretion disk is perhaps 1,000 times the size of the Earth's orbit. The spectrum should be monitored at daily or shorter intervals to observe the drifting features (predicted to cross the disk at the speed of light). This is no more difficult than a recent, successful international campaign to observe a Seyfert galaxy once every four days for seven months. If the X-ray lines in AGNs also come from the disk, then they will arise even closer to the black hole, requiring more frequent sampling to follow the drifting features. Although the relativistic effects are more extreme for the X-ray lines, the greater precision and light-gathering power of optical spectroscopy now allow a more accurate determination of the disk's parameters. However, the energy resolution of the order of 2 per cent which is anticipated for the next generation of X-ray satellites (such as Astro-D, AXAF and XMM), will also be adequate to test relativistic disk models. In the case of X-ray binaries, with black holes of perhaps ten solar masses, light travel times across the disk are a few milliseconds, so that it may be impossible to follow individual drifting features. Nevertheless, cross-correlation methods which compare time delays between different portions of the line profile may yield the same information. And in X-ray binaries, the same techniques would apply if the compact object were a weakly magnetized neutron star, for which the inner edge of the accretion disk could reach close to the stellar surface.

Currently, the best way to elevate an X-ray source to the exalted status of black-hole candidate is to determine a sufficiently large lower limit for its mass, using the orbital parameters of the binary. It is hard to argue against Kepler's laws. But to achieve this, some estimate of the mass of the companion star is necessary. Stella's method obviates the role of the companion star entirely, making direct use of the strong gravitational field near the black hole, and making it possible for the test to be applied to any compact object with line emission from an accretion disk. □

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DAEDALUS

Instant metal

MANY traditional technologies, from plastering to wedding-cake decoration, employ a fine powder which rapidly sets when made into a paste with water. Some of these powders, like cement and plaster, react with the water; others, like mud and icing sugar, do not. In either case, the paste sets by the growth and interlocking of small needle-crystals throughout the drying material.

In this connection Daedalus recalls how a chemist 'ripens' a precipitate for easy filtering by keeping it suspended in excess solvent. Thanks to its high surface energy, a fine-grained precipitate is slightly more soluble than a coarser one. So fine crystals slowly dissolve, giving a solution supersaturated with respect to coarser crystals. These precipitate out, freeing the solvent to dissolve more fine crystals. Even a highly insoluble precipitate can be rapidly coarsened in this way. So, says Daedalus, almost any fine powder, wetted with a solvent that dissolves it slightly, should 'ripen' to a hard cement, provided its crystals interlace strongly as they grow.

Inspired by this reasoning, DREADCO's chemists are seeking a metallic cement. They are preparing ultra-fine metal powders by mechanical grinding, chemical precipitation and vapour deposition, and wetting them with a variety of solvents. Few solvents dissolve metals at all well. The best are probably liquid ammonia and mercury (as used in dental amalgam, an existing metallic cement). Neither is an ideal component for a safe commercial cement. But with good fortune some fairly harmless chemical relative of ammonia will show the modest solvent ability required, and DREADCO's 'Metallic Plaster' will become a commercial reality.

It should be widely welcomed. The huge electronics business will drop hot soldering with a sigh of relief, and take to cold plastering instead. Garages, plumbers and light-engineering firms will similarly lay aside their blow-lamps and welding torches. Domestic handymen will have a wonderful new material for their traditional bodging, and dentists will gladly abandon poisonous mercury amalgam for hygienic silver-plaster fillings.

Metallic Plaster may even become a material of construction in its own right. Effortlessly moulded, but almost as strong as dense metal, it will be ideal for prototype components and short production runs. Its residual porosity could be 'filled' by immersion in a lower-melting metal, giving a sort of coarse alloy, or even in a plastic monomer or ceramic slip, giving a totally novel metallic composite. Even on its own, Metallic Plaster may encourage a reflowering of the wonderful rococo engineering decorations that the Victorians used to make out of cast iron. David Jones