ACCRETION DISK FLARES

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Flare activity on the sun may be attributed to the distortion of coronal magnetic field caused primarily by vortical (Shearing) photospheric motion. If an accretion disk is permeated by a magnetic field, the strong differential rotation of the disk will lead to similar stressing of the magnetosphere, and one may expect similar flare activity to occur. It is likely that the density of plasma in the maganetosphere is sufficiently large that the "frozen flux" condition is satisfied, and sufficiently small that the magnetic field will be substantially in the force-free state.

We have calculated the evolution of a model force-free magnetic-field configuration. For simplicity, the configuration is assumed to be of cylindrical symmetry. Differential rotation will tend to develop cylindrical symmetry, but any convection will tend to destroy it. It is assumed that the foot points of the magnetic field experience the differential rotation to be expected in an accretion disk. We consider the simple case that, on one side of the disk, the source of the magnetic field is provided by two narrow rings of opposite magnetic polarity. We assume that the field is initially in a current-free state and study the effect of progressive differential rotation.

We find that the principal effect of differential rotation is an "inflation" of the magnetic field that can be attributed to the pressure of the toroidal component produced by the differential rotation. We find that differential rotation can lead to magnetic free energy (excess energy compared with the current-free state) that is comparable with or even larger than the energy of the original current-free configuration.

The limiting state of the configuration is the open field configuration. Since the open field configuration contains an extended current sheet, the tendency to produce an open field is also a tendency to produce intense current densities. Such a situation is susceptible to magnetic reconnection by the tearing-mode instability The resulting particle acceleration will depend critically on the environmental conditions: magnetic field strength, plasma density, and photon density. The effect of reconnection on the magnetic-field topology is to restore the original current-free configuration but, in addition, to create a closed toroidal magnetic-field configuration (a "smoke ring").

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In a real situation, the reconnecting flux will be only a small part of the total flux of the magnetosphere: In this case, the toroidal plasmoid will be subject to the stress of the ambient magnetospheric field in such a way as to cause ejection of the plasmoid by the "melon-seed mechanism" (Schluter 1957).

In the real situation arising in an accretion disk, it is likely that the magnetic-field configuration is not cylindrically symmetrical. In this case, it is likely that plasmoids will be ejected at an angle to the rotation axis, although the average direction of ejection must lie along the axis. It is proposed that any single ejection may be responsible for a compact radio source which, in certain circumstances, may be detected as a "superluminal" source. The cumulative effect of flare-produced ejections may be a sequence of plasmoids moving more or less along the rotation axis: this may be the origin of the jets that are produced by some quasars and active galactic nuclei.

The generation and destruction of toroidal magnetic field also constitutes a mechanism for exchanging angular momentum between different regions of an accretion disk, contributing to the process normally attributed to viscosity (Pringle 1981). It therefore represents a procedure for converting gravitational energy into nonthermal electromagnetic energy. The efficiency of this process depends primarily on the comparative importance of angular momentum coupling by magnetic field with respect to angular momentum coupling by viscosity (including turbulent viscosity).

Although the large-scale structure of quasars and radio galaxies may be symmetric, the small-scale structure (compact radio sources and small-scale jets) is typically one-sided. Moreover, it is known that most quasars are radio-quiet. These considerations suggest that the magnetic field of an accretion disk develops episodically, by sporadic dynamo action, and that the two sides of the disk operate independently. We may suppose that, at any moment, there is probability p that dynamo action is occurring on either side of the disk. Then the probability that dynamo action is occurring on neither side is $(1-p)^2$, the probability that dynamo action is occurring on one side or the other is $2p(1-p)$, and the probability that no dynamo action is occurring is p^2. Since only a few percent of quasars are "radio-loud," we would infer that p is of order a few percent. Then p^2 is sufficiently small to explain why no quasar produces ejections in both directions. If dynamo action comes and goes on a time scale short compared with the time scale for development of the large-scale radio structure, we can understand why the large-scale structure may be more or less symmetric.

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REFERENCES

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