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A magnetised black hole torus disrupted by stellar fly-by

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Rotating fluid tori exhibit various oscillations when perturbed in the gravitational field of a central body. In strong gravity of a supermassive black hole, characteristic frequencies of oscillations reveal the space-time properties. The material of the torus may start overflowing onto the center or it may be accelerated out of the system.

We examine an axisymmetric toy model of an inviscid torus that experiences a mechanical disturbance in the vertical direction, tentatively representing a star passing on an inclined trajectory around the black hole (near its horizon but still above the tidal radius).

We consider a polytropic fluid that is immersed in the magnetic field with a large-scale toroidal topology. We explore the resulting evolution numerically, neglecting self-gravity (we assume a test fluid in General Relativity) while taking into account the role of non-constant angular-momentum profile, $l \equiv l(R) \propto R^q$, and the plasma magnetization, $\beta \equiv P_{\rm g}/P_{\rm m}$.

A small density perturbation induces oscillations close to internal modes of the torus (e.g. epicyclic frequencies of the orbital motion in Kerr metric), whereas a large perturbation leads to a combination of episodic accretion and ejection. This brings more material into the coronal region near the black hole horizon. Fraction of the torus material overflows on the black hole while another part is expelled. We show an example where almost 70% of the torus mass and the corresponding angular momentum are transferred before the perturbation is switched-off and a new equilibrium emerges. While the torus oscillations are gradually damped by accretion (and numerical viscosity), they can be driven by recurrent passages of a star which crosses the disc at a suitable radius.