Reconnection in black hole magnetospheres

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The unique electromagnetic and gravitational properties of black holes and their magnetospheres, accretion disks, jets, and coronae, make them the perfect laboratory to study extreme plasma physics. Recent breakthroughs in observations of event-horizon-scale plasma flows near Sgr A* and M87* allow us to probe fundamental plasma dynamics in extreme high-energy environments. Black holes are also known as powerful sources of multiwavelength electromagnetic emission, including high-energy near-infrared, X- and gamma-ray radiation in the form of flares. The dynamics of the strongly magnetized, collisionless plasma that produces these emission signatures is still poorly understood. The typically non-thermal radiation of flares implies a power-law distribution of emitting electrons and requires a kinetic description. Furthermore, the energetic plasma engages strongly with radiation fields: the quantum electrodynamic interaction of photons may lead to electron-positron pair creation. Finally, because of strong gravity general relativity is a necessary part of the equation. It requires a novel combination of general relativistic kinetic and magnetohydrodynamics methods to study both large scale dynamics resulting in the formation of instabilities that can power flares, as well as small scale plasma dynamics governing particle acceleration and radiation. With magnetohydrodynamics simulations we find that the interplay of interchange, ballooning and tearing instabilities drives the accretion flow to form large-scale current sheets at the event horizon. We then employ relativistic kinetic simulations to study how magnetic reconnection in this current sheet can power the observed energetic gamma-ray, X-ray and near-infrared flares. Our global general relativistic kinetic simulations will also address the important theoretical question of how well magnetohydrodynamics reproduces accretion dynamics of collisionless plasma.