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Simulations of the Magnetospheres of Accreting Millisecond Pulsars: Torque Enhancement, Spin Equilibrium, and Jet Power

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The interaction of a rotating star's magnetic field with a surrounding plasma disc lies at the heart of many questions posed by neutron stars in X-ray binaries. I will present global simulations of this interaction, performed in the force-free (high-magnetization) limit of relativistic MHD, showing the opening of magnetic field lines, the formation and reconnection of magnetospheric current sheets, and a substantial increase in the spin-down torque applied to the star by the pulsar wind. When the disc conductivity is high, the principal simulation results can be captured in a simple analytic model for the disc-opened flux, the torques exerted on the star by the magnetosphere, and the power extracted by the electromagnetic wind. Using this model, I will describe the conditions under which the system enters an equilibrium spin state, in which the accretion torque is instantaneously balanced by the pulsar wind torque alone. For magnetic moments, spin frequencies, and accretion rates relevant to accreting millisecond pulsars, the spin-down torque from this enhanced pulsar wind can be substantially larger than that predicted by existing models of the disc-magnetosphere interaction, and is in principle capable of maintaining spin equilibrium at frequencies less than 1 kHz. This mechanism may account for the non-detection of frequency increases during outbursts of SAX J1808.4-3658 and XTE J1814-338, and may be generally responsible for preventing spin-up to sub-millisecond periods. If the pulsar wind is collimated by the surrounding environment, the resulting jet can satisfy the power requirements of the highly relativistic outflows from Cir X-1 and Sco X-1. In this framework, the jet power scales relatively weakly with accretion rate, and would be suppressed at high accretion rates only if the stellar magnetic moment is sufficiently low; this may be consistent with the absence of soft-state jet quenching in some observed neutron-star X-ray binaries.

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