Poster Contributions: Emission Processes

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THE STRUCTURE OF RELATIVISTIC MHD JETS

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An analytic model for a stationary force-free relativistic magnetized jet is presented [2]. In those models a poloidal current provides the tension that balances the internal pressure. Our ignorance of the detailed conditions in the collimation zone is accounted for by specifying the current distribution as an (essentially free) function of the flux surfaces. The asymptotically cylindrical Grad-Schlüter-Shafranov (GSS) equation is solved for a nonlinear current distribution, $I(\Psi) = c(1 - \exp(-b\Psi))$ which covers both diffuse ($b \ll 1$) and sharp ($b \gg 1$) pinches, and weak (small c) and strong (large c) currents.

It is the first equilibrium that properly accounts for the relativistic effects: the electric field reduces the collimating tension of the toroidal magnetic field. Consequently, relativistic jets are more difficult to collimate only by means of their self-generated fields [1]. It is therefore proposed that in the innermost part jets are collimated with the help of external pressure. In the course of propagation the ambient pressure falls off, and the jet expands until it is held again by the tension of its toroidal magnetic field. The light cylinder (LC), which in the force-free aprroximation coincides with the Alfvén surface is a critical point in the GSS equation. Regularity already completely determines the structure of the jets. Prescribing boundary conditions outside the LC overdetermines the problem. This probably also holds for the 2D case and would explain why attempts to numerically solve the pulsar equation produce kinks at the LC (e.g. Michel 1982, Rev. Mod. Phys. 54, 1).

The plasma flows within the nested magnetic surfaces. Beyond the light cylinder it decouples from the magnetic field, and rotates essentially with constant angular momentum. Sufficiently far from the light cylinder plasma rotation becomes unimportant and the material streams with a constant poloidal velocity u_{p}.

The jet structure is characterized by a current-carrying core and a current-free envelope. The core radius R_{c} is the relevant scale for any physical quantity in the jet. It is related to the poloidal jet velocity u_{p} and the light cylinder R_{L} by $R_{\mathrm{c}} = u_{\mathrm{p}} R_{\mathrm{L}} \simeq 10^{16} \gamma_{\mathrm{jet}} M_9\,\mathrm{cm}$. It is shown how the form and the strength of the current determine the shape and the profile of the jet. A sharp pinch with a strong current generally produces narrower jets. A minimum current is required for an equilibrium to exist. Less current is needed for sharp pinches and relativistic velocities.

The jet luminosity is in electromagnetic form, and it is not homogeneously distributed across the jet. The Poynting flux is instead concentrated at the core radius. This provides an off-axis energy reservoir, which, if it can be tapped, could be responsible for the origin of the VLBI knots. The rest frame magnetic field in

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the core is essentially parallel to the axis, and toroidal in the envelope. Its pitch angle is given by $\tan\theta' = R/R_c$.

The propagation of a jet is treated as a sequence of quasi-equilibria along the jet's path. Self-confinement and confinement by external pressure is considered. We conclude that not much current is leaking during the propagation, but it tends to concentrate in the innermost flux surfaces. This situation applies most likely to the powerful jet sources.

References

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