High resolution numerical modeling of the force-free pulsar magnetosphere

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I consider a force-free magnetosphere of an aligned rotator. Its structure is well described by the Grad-Shafranov equation for the poloidal magnetic field, the so called "pulsar equation". This is a second-order non-linear partial differential equation of elliptic type. No analytical solution for dipolar magnetic field with poloidal current has been found. Previous attempts to solve this equation numerically suffered from poor numerical resolution. Results of these calculations are inconsistent with each other and with analytical solutions near the critical point at the light cylinder. I developed a multigrid code for solving the pulsar equation with the high numerical resolution. On the fine numerical grid, a current layer along the last closed field line could be accurately incorporated into numerical procedure. All physical properties of the solution such as the Goldreich-Julian charge density, drift velocity, energy losses, etc., could be accurately calculated. Here I report results of these simulations. Among other interesting properties, the solution is not unique, i.e. the position of the last closed field line (and hence the pulsar energy losses) is not determined by a global magnetospheric structure and depends on kinetics of electromagnetic cascades. I discuss the properties of the solutions and their implications for pulsars.