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Geometrical constraints on pulsar emission II

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We have concluded our investigation of the geometry of the open field line structure of an oblique dipole rotator, with a view to understanding better the geometry of pulsar beams in the polar cap model of pulsar emission, which was first reported in the XVI ASI Meeting at Pune (Kapoor & Shukre 1995). The effects relevant here are the inclination between the rotation and the magnetic axes of the pulsar, change in the dipole magnetic field geometry and bending of light due to the stellar gravitational field, and aberration of light. We find that due to their opposing nature, these effects surprisingly leave the Goldreich-Julian type beam essentially unaltered.

The pulsar radio emission is currently believed to be described by the polar cap model and despite difficulties it provides still the only intelligible framework for the pulsar radio emission phenomenology and therefore a plausible basis for further theoretical developments.

We have investigated the geometry of the open magnetic field line structure of an oblique dipole rotator, in order to understand better the geometry of pulsar beams in the polar cap model. It was reported earlier (Kapoor & Shukre 1995) that the open field lines divide into two branches both of which are required to describe the full polar cap. These are q^{+}_{c} and q^{-}_{c} roots respectively, derived in a coordinate system in which the axis of rotation of the pulsar is along the z-axis. In addition, we have investigated in detail the possible change in the shape of pulsar beams due to the space-time curvature caused by the neutron star and the special relativistic aberration. Barring the light bending which is treated numerically, we have incorporated all other effects analytically. The formalism can be used for an arbitrary emission altitude and for all inclination angles between the magnetic and rotation axes. The effect of stellar gravitational field on the dipole magnetic field is to 'squeeze ' it, and narrow down the pulsar beam by about 14% at the star's surface. However, the effect of light bending is opposite and tends to widen the beam, by about 11%. The general relativistic effects at most give a 4% beam squeeze at the surface and are negligible beyond a distance of ~ 2 stellar radii. The effects due to aberration are more easily noticeable at high emission altitudes. The emission cone is shifted in longitude such that it arrives earlier in phase; it also undergoes a small twist around the magnetic axis. This is due to the variation in corotation velocity over the emission cone. It should be noted that the phase shift due to aberration will be countered by 'magnetic field sweepback'. The combination of all these effects surprisingly leaves the Goldreich-Julian type beam essentially unaltered, due to the mutually opposing nature of these effects. At a finer level, the possibility of seeing the resultant small effects in pulsar observations exists.

A detailed account of this work appears in Kapoor and Shukre (1988). A preliminary report of the applications of these results to the geometry of the core and conal emissions can be found in Kapoor and Shukre (1996). The elaboration of this as also the specialization of above the results to the case of millisecond pulsars is in progress (Kapoor and Shukre 1999).

References

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