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地球弓激波的旋转非对称性

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Rotational asymmetry of earth's bow shock

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摘要

通过对太阳风-磁层-电离层系统的全球MHD模拟，研究地球弓激波相对日地连线的旋转非对称性．模拟限于太阳风速度沿
地球磁偶极矩和行星际磁场（IMF）与日地连线垂直的简单情况．模拟结果表明，即便对于IMF强度为零的情况，弓激波相
也不具备旋转对称性质：终端面（晨昏子午面）及其向阳侧的弓激波截线的东西宽度大于南北宽度（约9%~11%），终端
激波截线东西宽度小于南北宽度（约8%）．在存在IMF的情况下，弓激波的位形同时受到磁层顶的形状和快磁声波速度各
响．磁层顶向外扩张并沿IMF方向拉伸，且其扩张和拉伸程度随IMF由北转南而增强．在磁鞘中，垂直于磁场方向的快磁声
平行方向．因此，磁层顶拉伸方向与快磁声波速度最大方向垂直，它们对弓激波位置的效应恰好相反；弓激波的最终形状取
效应占据主导地位．对于终端面尾侧，快磁声波速度的各向异性起主导作用，弓激波截线沿IMF垂直方向的宽度大于平行方
终端面及其向阳侧，弓激波截线的形状与IMF取向有关：在准北向或晨昏向IMF情况下，弓激波截线沿IMF垂直方向的宽度
方向；在准南向IMF情况下，弓激波截线沿IMF垂直方向的宽度小于平行方向的．鉴于弓激波形状同IMF取向之间的密切关
议以IMF为基准方向，提取弓激波截线的平行半宽度$R_{b\parallel}$和垂直半宽度$R_{b\perp}$作为尺度参数．这些尺度参数和通常引入的弓激
东西半宽度y_b和南北半宽度z_b相比，更为合理地表征了弓激波的几何性质．模拟结果表明，在终端面上，y_b/z_b和$R_{b\parallel}/R_b$
向同性取向下的统计平均值均低于1，与观测得到的结论一致．

关键词： 地球磁层 行星际磁场 弓激波

Abstract:

In terms of global magnetohydrodynamic (MHD) simulations of the solar wind-magnetosphere-ionospher
this paper investigates the rotational asymmetry of the Earth's bow shock with respect to the Sun-
We are limited to simple cases in which the solar wind is along the Sun-Earth Line, and both the Earth's
dipole moment and the interplanetary magnetic field (IMF) are perpendicular to the Sun-Earth line. It
that even for the case of vanishing IMF strength the bow shock is not rotationally symmetric with resp
Sun-Earth line: the east-west dimension of the cross section of the bow shock exceeds the nc
dimension by about 9~11% on the terminator plane (dawn-dusk meridian plane) and its sunward
becomes smaller than the north-south dimension by about 8% on the tailward side of the terminator pla
presence of the IMF, the configuration of the bow shock is affected by both the shape of the magneto
the anisotropy of the fast magnetosonic wave speed. The magnetopause expands outward, being stretc
the IMF, and the extent of its expansion and stretch increases when the IMF rotates from north to sou
magnetosheath, the fast magnetosonic wave speed is higher in the direction perpendicular to the mag
than that in the parallel direction. Therefore, the stretch direction of the magnetopause is perpendicu
maximum direction of the fast magnetosonic wave speed, and their effects on the bow shock position a
opposite. The eventual shape of the bow shock depends on which effect dominates. On the tailward s
terminator plane, the anisotropy of the fast magnetosonic wave speed dominates, so the cross sect
bow shock is wider in the direction perpendicular to the IMF. On the terminator plane and its sunward
shape of the bow shock cross section depends on the orientation of the IMF: the bow shock cross sect
wider in the direction perpendicular to the IMF under generic northward or dawn-dusk IMF cases, but i
narrower in the direction perpendicular to the IMF instead under generic southward IMF cases. In lig

intimate relationship between the shape of the bow shock and the orientation of the IMF, it is propose the IMF as the datum direction so as to extract the parallel half width $R_{b\parallel}$ and the perpendicular half as the dimension parameters. In comparison with the commonly used east-west half width y_b and the nc half width z_b, these parameters provide a more reasonable description of the geometry of the bc Simulation results show that under the assumption of isotropic orientation of the IMF, the statistical av y_b/z_b and $R_{b\parallel}/R_{b\perp}$ are both smaller than 1 on the terminator plane, which agrees with relevant obs conclusions.

Keywords: Earth's magnetosphere Interplanetary magnetic field Bow shock

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