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Observational Evidence for Magnetic Field Amplification in SN 1006

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We report the first observational evidence for magnetic field amplification in the north-east/south-west (NE/SW) shells of supernova remnant SN 1006. SN1006 is one of the most promising sites of the production of galactic cosmic ray (CRs) through diffusive shock acceleration (DSA), although the detailed process of DSA is not well understood. Particularly, the magnetic field strength and structure are vital for determining the maximum energy of particles that can be accelerated in the shock. In previous studies, the strength of magnetic fields in these shells was estimated to be $\mathrm{B_{SED}}$ ⊠ 25μG from the spectral energy distribution, where the synchrotron emission from relativistic electrons accounted for radio to X-rays, along with the inverse Compton emission extending from the GeV to TeV energy bands. However, the analysis of broadband radio data, ranging from 1.37 GHz to 100 GHz, indicated that the radio spectrum steepened from $_1$ = 0.52±0.02 to $_2$ = 1.34±0.21 by $_{12}$= 0.85 ± 0.21. This is naturally interpreted as a cooling break under strong magnetic field of $\mathrm{B_{HS}}$⊠2.5 mG. The break indicates that the radio-to-X-ray spectrum may not connect smoothly as the previous study, which is supported by the fact that the optical/ultra-violet counterpart of SN 1006 is extremely faint except for the bright Hα filament in the north-west shell. Therefore, we suggested "double"electron population for the broadband SED; the first population is responsible for the synchrotron emission in hot spots where the magnetic field is 2.5 mG. The second population radiates another synchrotron emission in the "average"magnetic field, B=25μG. Moreover, we investigated the high-resolution MeerKAT image and discovered that the width of the radio NE/SW shells was broader than that of the X-ray shell by a factor of only approximately 10, as measured by Chandra. The ratio of the observed shell width of shells $\mathrm{D_R/D_X}$ also indicates that the magnetic fields, which mainly contribute to the radio and X-ray emissions, $\mathrm{B_R}$ and $\mathrm{B_X}$, can not be the same. Assuming $\mathrm{D_R/D_X}$⊠10, we except $\mathrm{B_R/B_X}$⊠100. This exactly agrees with the amplification ratio which is independently estimated from the SED. If the magnetic field is enhanced by a factor of a ⊠ 100 within "hot spots"along the NE/SW shells, we argue that the filling factor of such hot spots must be as low as k ⊠ 2.5×10^{-5}.

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