A theory of the roll effect in prominence eruption

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It is often observed in prominence eruptions that the top part of the prominence ribbon bends in one direction to make the ribbon horizontally flat. Also the legs of the erupting prominence undergo twisting motions of opposite senses. This effect is discovered and named as “roll effect” by S. F. Martin. The sense of rolling is found to depend on the chirality of the prominence. The roll effect acts for breaking of the geometrical symmetry of the system. Unless the prominence environment is systematically asymmetric, the symmetry-breaking evolution of a prominence can hardly be understood in the framework of the conventional magnetohydrodynamics (MHD) with isotropic electrical conductivity. When the electrical conductivity is anisotropic, the symmetry of the system is not conserved. We investigate the solar magnetic field evolution with anisotropic electrical conductivity. Now the motion of the magnetic field is not tied to the plasma center of mass motion, but has a component against the current direction. Thus, the rising motion of the magnetic field is skewed to a certain direction conditioned by the current. When magnetic reconnection takes place in a magnetic loop or arcade, the direction of the current in the current sheet region and in the legs of the current sheet is almost opposite to the current direction in the underlying reconnected loops. This explains why the Doppler shift at the top and outer parts of the erupting prominence is of the opposite sense to that in the bottom part between the prominence legs. Furthermore, this reasoning can account for how the sign of the roll effect depends on the chirality of the prominence as observed.