Tracing the connectivity of magnetic flux ropes to solar surface

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It is known that almost all coronal mass ejections (CMEs) at 1 AU exhibit the large and coherent internal field rotations characteristic of magnetic flux ropes (magnetic clouds). But there are still unsolved questions; do CMEs eventually disconnect completely from the Sun?; how long does it take for such complete disconnection to occur? We contribute to the solutions of these questions from the analysis of two CMEs occurred on March 7 and July 12, 2000, observed by the Nozomi and other spacecraft.

July 12, 2000 CME event: A magnetic flux rope was ejected from solar surface associated with a CME and an X1.9 class flare which occurred in solar active region AR 9077. Two days after, on July 14, another large solar flare (X5.7 class) occurred on the same region AR 9077 (Bastille event). On the same day, Electron and Ion Spectrometer (EIS) onboard the Nozomi spacecraft observed unidirectional field-aligned 200--800 keV electrons whose flux level is more than 10 particles/[keV sec cm2 sr] at the peak and the Magnetic Field Measurement (MGF) instrument on the spacecraft observed magnetic flux rope, when the spacecraft was about 1 AU distant from the Sun but 1 AU far from the Earth. From its high level of flux it is considered that the second flare near the solar surface accelerated these electrons. From a pitch-angle distribution of the electrons and the active region where these flares occurred, it seems that the electrons propagated along the magnetic flux rope that was ejected on July 12, and reached the Nozomi spacecraft. These considerations suggest that at least one of the footpoints of the magnetic flux rope has been connected to the solar surface for two days at least. These are consistent with the results of the images from Yohkoh/HXT and SXT, and SOHO/MDI.

March 7, 2000 CME event: We searched for another event similar to the above event: Energetic electron anisotropy within a magnetic flux rope. We found a CME event on March 7, 2000 observed by Nozomi spacecraft which was 1.1 AU distant from the Sun. We could not find the corresponding solar flare events because the area of the solar disk Nozomi facing is almost different from that facing the Earth. However, we confirmed that this event also shows at least one footpoint of the magnetic flux rope connected to the solar surface for more than two days, because (1) the magnetic flux rope structure fits the model of cylindrical magnetic flux rope with constant alpha which is predicted from MHD theory, (2) the strong anisotropy of electrons is observed within the rope, and (3) solar wind velocity predicted by the result of the fit is not so fast as that of the July 12, 2000 CME event.

We conclude that from these two CME events one of the footpoints of the magnetic flux ropes has been connected to the solar surface at least several days.