Coronal magnetic field modeling using stereoscopic constrains

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The solar atmosphere is permeated by a magnetic field which in some places may be 1000 times stronger than the Earth's field. Different from the Earth's atmosphere, the solar atmospheric gas is highly ionized which causes the solar magnetic field to efficiently control the dynamics of the atmosphere. It dominates in sunspots, and drives spectacular phenomena like prominences, flares, and coronal mass ejections (CMEs). Some of these are so energetic that they may even harm communication, navigation and electric power supply on Earth. In this work, we could understand the solar magnetic field better, because we invented a new magnetic field reconstruction which uses more observations.

Given the huge impact of the solar magnetic field, it would be vital to know its continuously changing configuration for understanding these dynamical processes and for predicting them. However, it is extremely difficult to measure the solar magnetic field except in a thin layer near the solar photospheric surface where the gas density is large enough. These surface measurements are routinely provided by solar observatories in space and on Earth.

Because of the lack of coronal magnetic field measurements in corona, the upper bulk of the solar atmosphere, the magnetic field has to be derived indirectly from the observations at hand. One now well established approach, the nonlinear force-free field extrapolation (NLFFF) models the magnetic field from its photospheric measurements high up into the corona assuming that the field configuration is near equilibrium and gas pressure is negligible compared to the field energy density. An alternative way to constrain the coronal magnetic field is based on the geometry of the magnetic field lines that can be identified as bright thin flux tubes in solar EUV imaging data. These EUV images can only be produced by space-born solar observatories because the Earth's atmosphere blocks almost all UV light.

In the past, researchers were puzzled by discrepancies between the extrapolated field models and the EUV flux tubes from simultaneous magnetic field and EUV observations. These discrepancies are assumed to be caused by an accumulation of errors with increasing altitude in the badly conditioned extrapolation calculations. We have recently succeeded to combine the traditional extrapolation calculation with the information from simultaneous EUV flux tubes so that a more consistent magnetic field model may emerge. The EUV flux tubes have to be observed from two vantage points, data which is regularly provided by the two STEREO space craft. From these images, we produce a stereoscopic reconstruction of the flux tubes' shapes. These three-dimensional shapes are then used to constrain the extrapolation calculation. The new extrapolation method is termed S-NLFFF (S for stereoscopy).

In a recent investigation (Chifu et al., 2017), we have shown that the new S-NLFFF code can successfully produce coronal magnetic field models consistent with the observed surface fields and the reconstructed flux tube geometries. The initial implementation is restricted to small domains in the solar atmosphere. We are presently working on an extension to a spherical geometry which allows reconstructions covering the entire solar surface. Another of our future goals is to further constrain the extrapolation with more observables such as magnetic field measurements in the chromosphere.

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