3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Steady States for Solar Coronal Loops

Linda E. Sugiyama[1], M. Asgari-Targhi[2]
[1] Laboratory for Nuclear Science, MIT, [2] Harvard-Smithsonian Center for Astrophysics
e-mail (speaker): sugiyama@mit.edu

The bright solar coronal loops that almost always exist on the surface of the sun are believed to be curved magnetic flux ropes that contain plasma hotter than the surrounding corona or the underlying solar surface. The importance of understanding coronal loops and their stability is rapidly increasing, because they underlie the violent plasma instabilities on the sun that produce solar flares and coronal mass ejections (CMEs). Large flares and mass ejections expel large amounts of highly energetic radiation and plasma particles into space. If these reach the earth, they can disrupt or even destroy part of the critical infrastructure that supports the modern electronic age, including satellites, GPS, and electrical power grids. The damage can be reduced or avoided by advance warning, so plasma models are important. A steady state coronal loop has many similarities to the magnetically confined toroidal plasmas developed for fusion energy. The first model for their structure[1,2] approximates a loop as a segment of a skinny torus with both ends tied to surface of the sun, using ideas developed for magnetically confined plasmas. The solar gravity produces a nonuniform, nonaxisymmetric plasma density that is larger at the bottom of the loop. The model results are consistent with the observed heights of thin loops in solar active regions. Comparison to recent, more systematic loop observations generally agree, but suggest that the observed loops, which can be seen only in the line radiation from small amounts of partially ionized ions such as Fe that are many times heavier than the hydrogen ions of the main plasma, may not show the entire loop structure. Detailed loop models remain a difficult question because of the complex structure of the corona, which varies from partially ionized near the surface of the sun (the photosphere) to fully ionized over the higher corona, the lack of sufficiently high resolution measurements to see the detailed structure of a loop, and the general lack of measurement of the interior of the sun below the photosphere. Larger flares and CMEs often occur in thicker loops or multiple-thin-loop structures that are growing dynamically in height due to unknown sources in the solar interior. The simple steady state plasma loop model can give clues to some of these questions.

References
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