Invisibility of Solar Active Region Umbra-to-Umbra Coronal Loops: New Evidence that Magnetoconvection Drives Solar-Stellar Coronal Heating
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Abstract
Coronal heating generally increases with increasing magnetic field strength: the EUV/X-ray corona in active regions is 10--100 times more luminous and 2--4 times hotter than that in quiet regions and coronal holes, which are heated to only about 1.5 MK, and have fields that are 10--100 times weaker than that in active regions. From a comparison of a nonlinear force-free model of the three-dimensional active region coronal field to observed extreme-ultraviolet loops, we find that (1) umbra-to-umbra coronal loops, despite being rooted in the strongest magnetic flux, are invisible, and (2) the brightest loops have one foot in an umbra or penumbra and the other foot in another sunspot’s penumbra or in unipolar or mixed-polarity plage. The invisibility of umbra-to-umbra loops is new evidence that magnetoconvection drives solar-stellar coronal heating: evidently, the strong umbral field at both ends quenches the magnetoconvection and hence the coronal heating in the loop. The hottest coronal loops have one foot in an umbra and the other foot in opposite-polarity penumbra or plage (coronal moss), the areas of strong field in which convection is not as strongly suppressed as in umbrae. The loops rooted in mixed-polarity flux at one or both of their feet are also among the brightest. We plan to extend this work quantitatively, and by using many non-flaring ARs with fully developed sunspots of opposite-polarity field.

Summary and Outlook: We find that the convective freedom at the feet of a coronal loop, together with the strength of the field, determines the extent of the coronal heating in the loop. The hottest coronal loops have one foot in an umbra and the other foot in opposite-polarity penumbra or plage (coronal moss), the areas of strong field in which convection is not as strongly suppressed as in umbrae. The loops rooted in mixed-polarity flux at one or both of their feet are also among the brightest. We plan to extend this work quantitatively, and by using many non-flaring ARs with fully developed sunspots of opposite-polarity field.