Constraining coronal heating in solar active regions with microwave data

Gregory Fleishman[1]

[1]New Jersey Institute of Technology, Hillsborough Township, United States, [2]Institute for Solar Physics, Freiburg, Germany

Why the tenuous solar outer atmosphere, the corona, is much hotter than the underlying layers remains one of the greatest challenges for solar theory and modeling. Traditionally, diagnostics of the coronal thermal structure come from extreme ultraviolet (EUV) emission, which is produced by heavy ions in various ionization states and depends on the amount of these ions (elemental abundancies) and on plasma temperature and density. Since 2010, the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) has dazzled scientists and the public alike with its high-resolution, full-Sun images of myriad coronal loops in several EUV passbands; however, our understanding of the coronal heating processes is still lagging behind. Here I report our progress in understanding the magneto-thermal coupling and processes of the coronal heating in solar active regions (ARs) by 3D quantification of the magnetic and thermal structure of the ARs with modern multi-messenger high-resolution observations and advanced theory and 3D modeling [1-3]. A significant novelty is the use the synergy and complementarity of newly-available multi-frequency microwave imaging data—uniquely sensitive to both thermal and magnetic structures—and more traditional EUV data, as input to guide the construction of such coupled models. In this talk I describe the data-constrained modeling fine-tuned by the model-to-data comparison of ARs jointly observed in the microwave and EUV domains and discuss new constraints on the coronal heating in coronal loops, diffuse surroundings, and bright TR patches in 3D context. I report new outcomes needed to understand and quantify the key fundamental AR physics; in particular, 3D distributions of the coronal volumetric heating rate, the power and frequency of the heating episodes, and the cooling times. These new findings are discussed within current ideas of the coronal heating physics such as low-frequency (e.g., by nanoflares) or high-frequency (e.g., by waves) heating.

References:

[1] Fleishman, G. D., Anfinogentov, S., Stupishin, A., Kuznetsov, A. A., Nita, G. M. 2021. Coronal Heating Law Constrained by Microwave Gyroresonant Emission. ApJ, 909: 89

[2] Fleishman, G. D., Kuznetsov, A. A., and Nita, G. M. 2025. Steady-state Heating of Diffuse Coronal Plasma in a Solar Active Region, ApJ, 988: 100

[3] Kuznetsov, A. A., Fleishman, G. D., Nita, G. M., and Anfinogentov, S. A. 2025. Magneto-Thermal Coupling and Coronal Heating in Solar Active Regions Inferred from Microwave Observations, 991: 186