Sunspot Structures

Sanjiv K. Tiwari

NASA Marshall Space Flight Center, USA

e-mail: sanjiv.k.tiwari@nasa.gov

Sunspot physics has seen a major revolution in the 10 years of the Hinode-era. Unprecedented observations of sunspots by Solar Optical Telescope on-board Hinode have revealed or clarified several small-scale aspects of sunspots, especially umbral dots and light bridges in umbra, filaments, spines and jets in penumbra, field gradient inversions in inner penumbra and peripheral downflows in outer penumbra. Some enduring controversies about the complex penumbral structure, e.g., whether strands of more vertical field (spines) are warmer or cooler than strands of more horizontal field, whether the Evershed flow mainly takes place in dark or bright penumbral strands or there is no correlation between flow and brightness, whether more horizontal fields are found in darker or brighter penumbral regions, etc., have been resolved by uncovering the fact that spines and parts of filaments have some properties in common. Penumbral filaments behave as elongated magnetized convective cells, in line with the results of recent magnetohydrodynamic simulations. Spines are observed to be true outward extension of umbral field. Sunspot penumbras are formed entirely of spines and filaments, no third component is present. In this review, we will summarize some of the latest developments in establishing thermal, flow and magnetic properties of sunspot structures both at small and global scales. We will also discuss the questions, which have emerged as a result of these new observations, about sunspot structure, dynamics and their connection with the upper atmosphere, and point out the need of multi-height/multi-temperature observations at a higher resolution and cadence that are needed to answer them and that are anticipated from Solar-C mission.