Magnetic-topology dependence of sulfur fractionation in the solar corona: a Solar Orbiter/SPICE survey

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Résumé

Elemental composition provides a key diagnostic of plasma conditions and magnetic topology in the solar chromosphere and corona, and a tracer of solar-wind source regions through its transport from the corona into the heliosphere. Elemental composition variations in the solar atmosphere are commonly described by the First Ionization Potential (FIP) effect, which refers to the overabundance of elements with FIP below ∼10 eV (low-FIP elements) in the corona compared to their photospheric abundances. However, intermediate-FIP (mid-FIP) species such as sulfur (10.36 eV) are predicted to show distinct fractionation behaviour and may therefore provide additional constraints on where and how fractionation operates. We present a large-scale survey of Solar Orbiter/SPICE EUV spectroscopy designed to characterise sulfur fractionation across a broad range of solar magnetic structures, including coronal holes, plume and interplume regions, extended fan or open-like structures, and active regions and their boundaries.

Using a consistent analysis methodology applied to an extended three-year SPICE archive of composition observations across multiple targets, we derive sulfur-based composition diagnostics with uncertainty propagation and quantify their variability across structures. The resulting maps are interpreted in the context of magnetic topology using photospheric magnetograms and magnetic-field extrapolations, allowing us to relate sulfur fractionation patterns to different magnetic configurations.

The survey indicates that sulfur fractionation does not follow the typical low-FIP behaviour. Sulfur enrichment preferentially appears in open or open-like magnetic configurations, whereas compact closed-loop environments remain closer to photospheric sulfur abundances, in contrast to the low-FIP enrichment commonly observed in such loops. These trends support scenarios in which the depth and efficiency of fractionation depend on magnetic topology and on wave and reconnection conditions that control Alfvénic energy deposition in the chromosphere. The results establish sulfur as a practical mid-FIP constraint for fractionation physics and motivate combining low- and mid-FIP diagnostics to improve solar-wind source identification and connectivity studies.

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