2025.

New criterion for fluid model applicability in space plasmas — The space between planets, stars, and galaxies is filled with an extremely rarefied magnetized conductive gas called space plasma. In the simplest case, space plasma is considered a fluid, and some of its models are based on this assumption. However, space plasma is so rarefied that the particles that constitute it can travel cosmic distances without ever colliding with each other. This calls into question the validity of the fluid description, as one of its fundamental assumptions is that the particles that make up a fluid continuously redistribute kinetic energy and momentum among themselves through frequent collisions. Recent results [1] suggest that in a magnetized plasma, field-particle interactions can effectively substitute for particle collisions in keeping the velocity distribution compatible with the fluid picture. Thus, the characteristic scale of magnetic field variations replaces the mean free path in the fluidity criterion, proving that fluid description can be applied to a significantly wider range of space plasmas than previously thought.

Effect of Nonlinear Surface Inflows into Activity Belts on Solar Cycle Modulation. — We investigated how surface inflows, the converging flows observed around bipolar magnetic regions, can act as a nonlinear feedback mechanism that regulates the solar cycle. In surface flux transport (SFT) models, these inflows appear as time-dependent perturbations to the meridional flow, with strengths that increase with magnetic activity. By systematically exploring a grid of 1D SFT simulations that include latitude quenching (and in some cases tilt quenching), we showed that inflows reduce the net build-up of the Sun's axial dipole moment by about 10–25%, weakening the polar field and providing a stabilizing "self-limiting" effect on the dynamo. When inflows are combined with latitude and tilt quenching, the simulated polar field remains within $\pm 1\sigma$ of an average solar cycle and correlates well with it (correlation ≈ 0.85). We further found that the relative importance of latitude quenching versus inflows depends strongly on the dynamo effectivity range λ_R, with inflows behaving similarly to tilt quenching and helping shift the transition between different saturation regimes. Overall, the results support the idea that nonlinear surface inflows are a physically motivated mechanism contributing to the saturation of the Babcock–Leighton solar dynamo. [2]

Propagation of Interplanetary Shocks in the Inner Heliosphere. — Interplanetary shocks are among the most dynamic and influential phenomena in the heliosphere. They are generated when fast solar wind streams or coronal mass ejections (CMEs) propagate through slower solar wind, forming shockwaves that travel through interplanetary space. These shocks can accelerate energetic particles, generate plasma waves, and trigger geomagnetic storms that affect satellites, communication systems, and power grids on Earth. In their 2025 study [3], Lkhagvadorj and collaborators investigated how interplanetary shocks evolve as they propagate through the inner heliosphere. The researchers reconstructed the geometry of the shock surfaces (see Fig. 1) using magnetic field and plasma data. Their findings demonstrate that interplanetary shocks are not always simple structures but can develop asymmetric shapes depending on the surrounding solar wind environment. Understanding their evolution is essential for improving space weather forecasting and mitigating the effects of solar storms on modern technology.

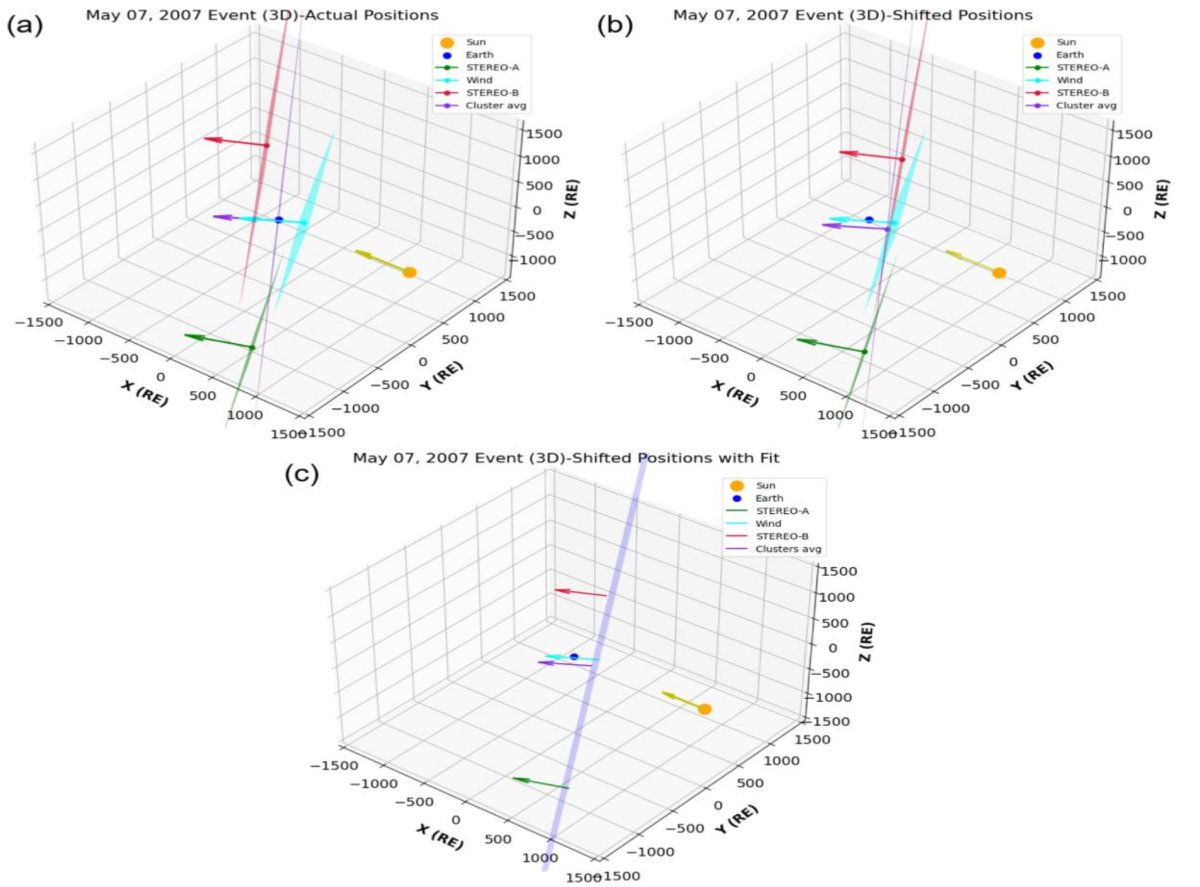

Figure 1. 3D sketch of the propagation of the IP shock through spacecraft Wind, STEREO-A, and STEREO-B, and the average position of the four Cluster satellites on May 7, 2007. (a) Actual positions of detected shocks. (b) The positions of STEREO-A, STEREO-B, and the average positions of the four Cluster spacecraft are shifted back in time to the shock detection time of the Wind spacecraft. (c) The time-shifted positions are fitted with a plane. The arrows indicate the direction of the normal vector, and the planes perpendicular to the normal vectors indicate the shock surface orientations. The sizes of the planes are arbitrary.

References:

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[3] https://doi.org/10.3847/1538-4357/ad9d12