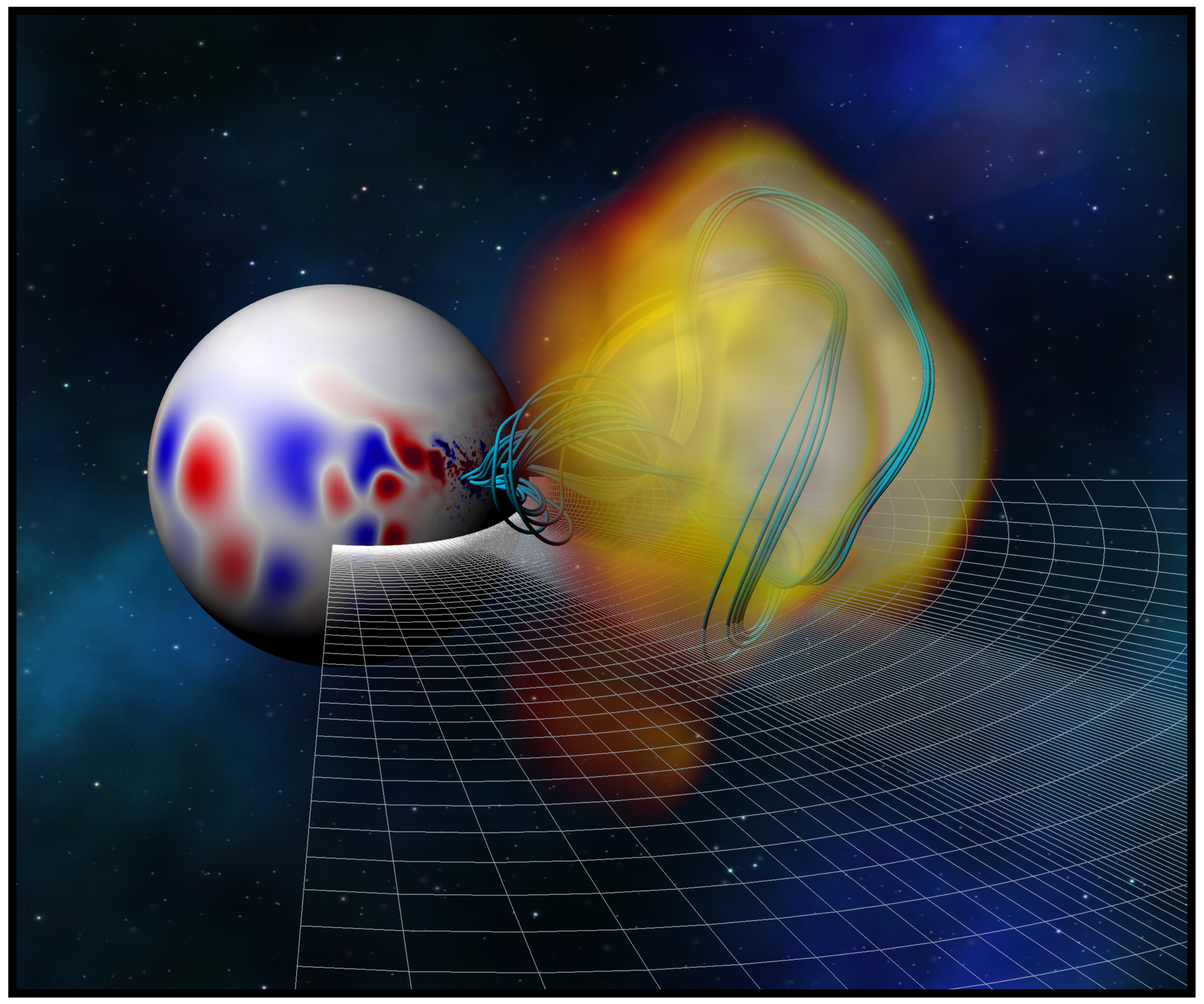
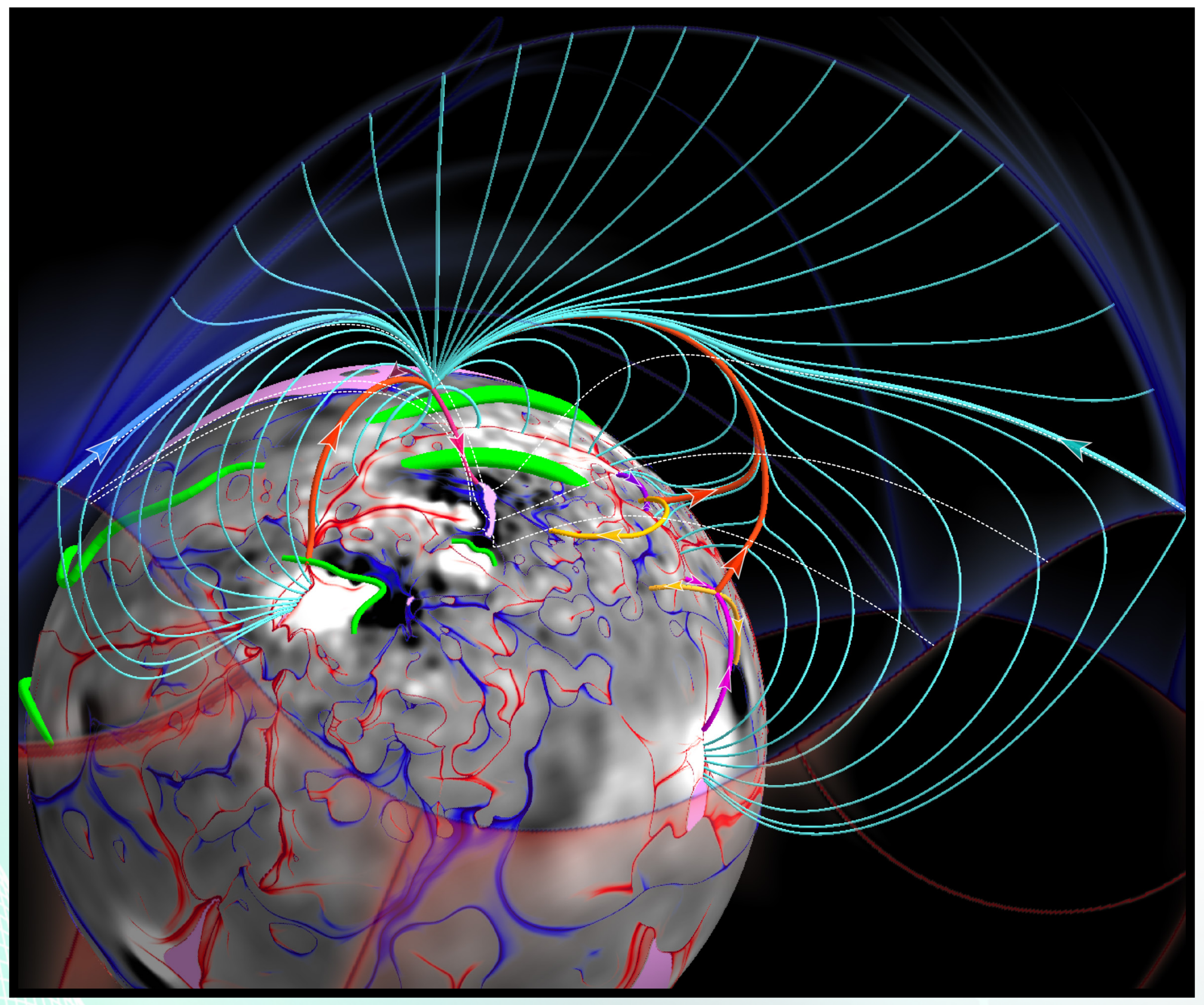
Unlocking the Secrets of Solar Storms



Snapshot from a simulation of the Bastille Day eruption (July 14, 2000), showing a volume rendering of the radial component of the velocity, selected magnetic field lines, and the surface radial magnetic field from data collected by the Solar & Heliospheric Observatory's Michelson Doppler Imager, smoothed for use in the computation. *Tibor Török, Ronald Caplan, Predictive Science, Inc.*



Topological analysis of the magnetic field in the Sun's corona. Identifiable features include coronal holes, a separatrix curtain, bald patches and null points, and the separator field lines that join them (thick lines with arrows). The green tubes show the location of filaments prior to eruption. This form of analysis is key to understanding the topology of the pre-eruptive magnetic field and the consequent energy release. *Viacheslav Titov, Predictive Science, Inc.*

Solar storms, including flares and coronal mass ejections, are large explosive events on the Sun that are capable of ejecting billions of tons of magnetized, million-degree plasma into space. When these storms reach Earth, they can disrupt radio transmissions, damage satellites, and severely impact power transmission grids, leading to extended large-scale power outages. Predicting such eruptions and their trajectories is a major goal of NASA's Heliophysics Research Program. Understanding the storms' underlying magnetic/plasma structure and evolution is vital for developing predictive capabilities. Our group is pursuing several avenues of research towards this goal. Key advancements include:

- New methods for producing pre-eruptive magnetic field structures, including the use of analytic flux-rope models embedded in observed magnetograms.
- Validating the behavior of eruptive events through simulation using our global 3D model, Magnetohydrodynamic Algorithm outside a Sphere (MAS). The simulations require grids of over 50 million cells, and each run uses thousands of processors for several days on NASA's Pleiades supercomputer.
- New post-processing techniques, including sophisticated analysis of the topological properties of magnetic fields and the generation of simulated phenomena (such as extreme ultraviolet and X-ray emission images) that can be compared with observations.
- Enabling researchers to run simulations online using the MAS code via NASA's Community Coordinated Modeling Center (CCMC).

Continued improvements in our understanding of solar storms will form the cornerstone of future predictive capability, which will eventually allow for early warning systems to prevent potentially catastrophic power outages and satellite failures.

Ronald Caplan, Zoran Mikić, Predictive Science, Inc.