Towards Near Real-Time Flare Forecasting

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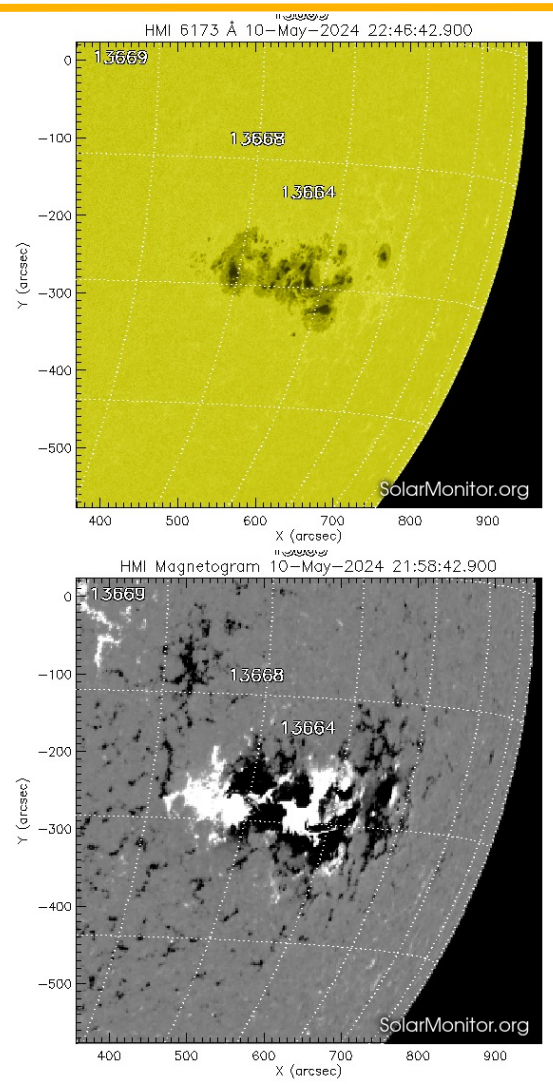
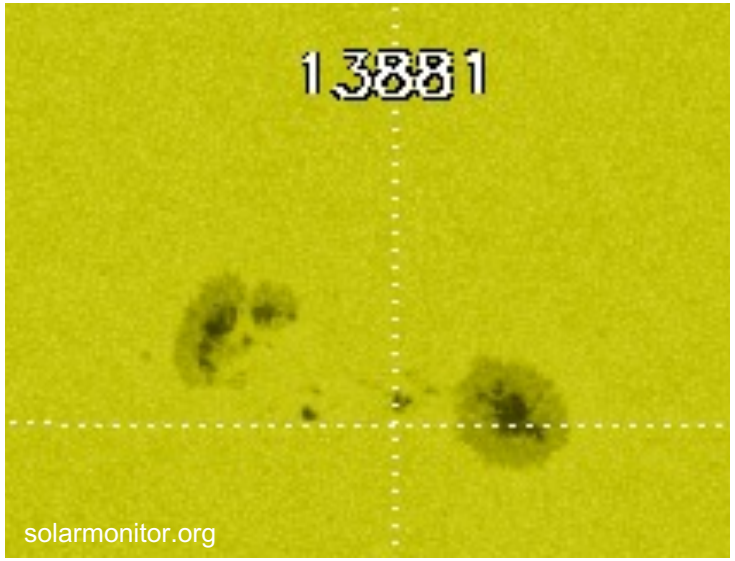
11/22/24

Space weather in history

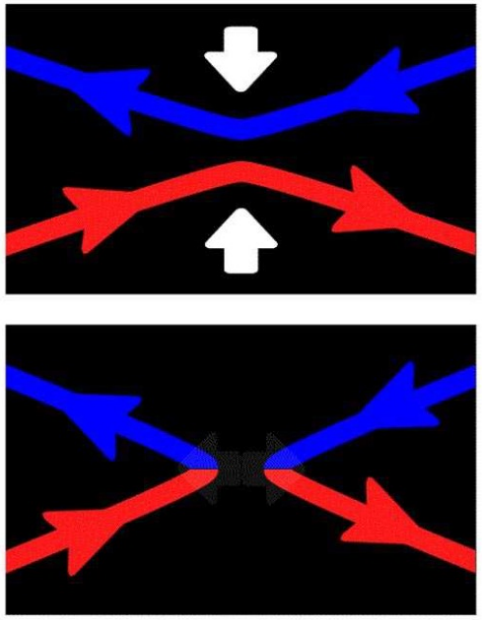
- 1859: Carrington Event
  - Induced current in the Earth's atmosphere took telegraphs across the country out of commission.
- 1967: Jammed Radio Communications
  - Radio and radar communications at US polar surveillance sites became jammed for hours. Air Force prepared aircrafts for war before being informed about a solar storm.
- 2024: Mass migration of LEO satellites
  - Thousands of spacecrafts lost altitude and were forced to thrust back to altitude without considering collision avoidance systems.



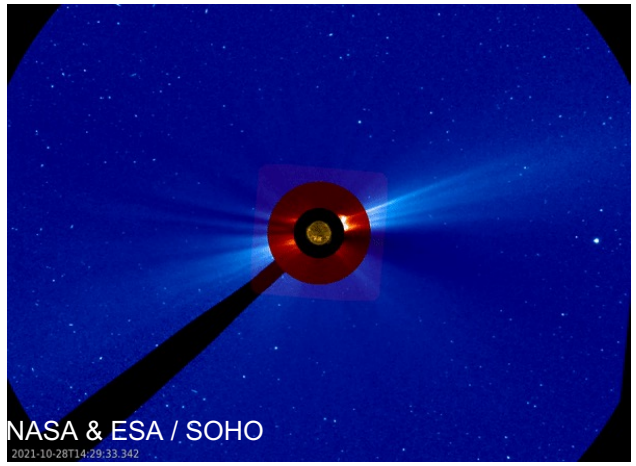
Sunspots and flares 101



Dense concentrations of magnetic field lines burst through the Sun's surface.



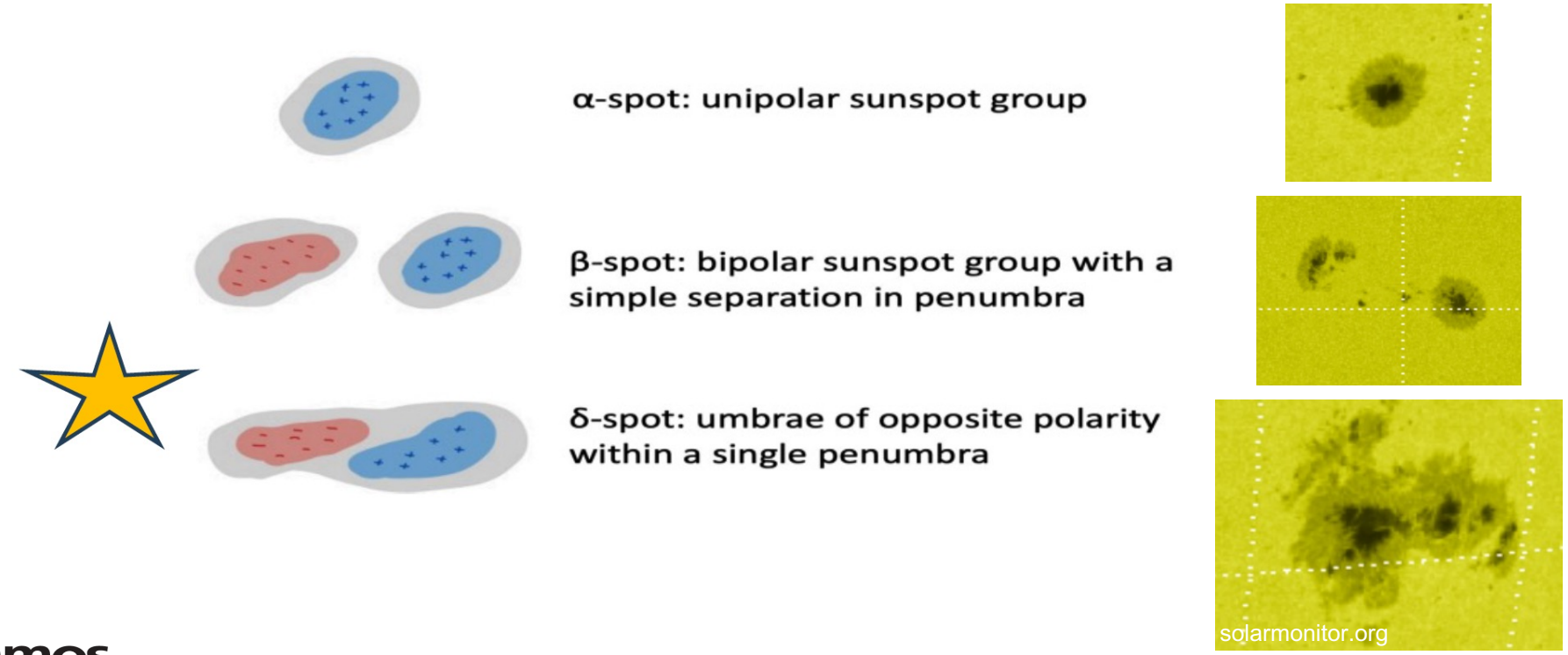
Magnetic reconnection: release energy across the EM spectrum when opposite polarity field lines connect.



Strongest flares are often linked to coronal mass ejections (CMEs) and solar energetic particles (SEPs).

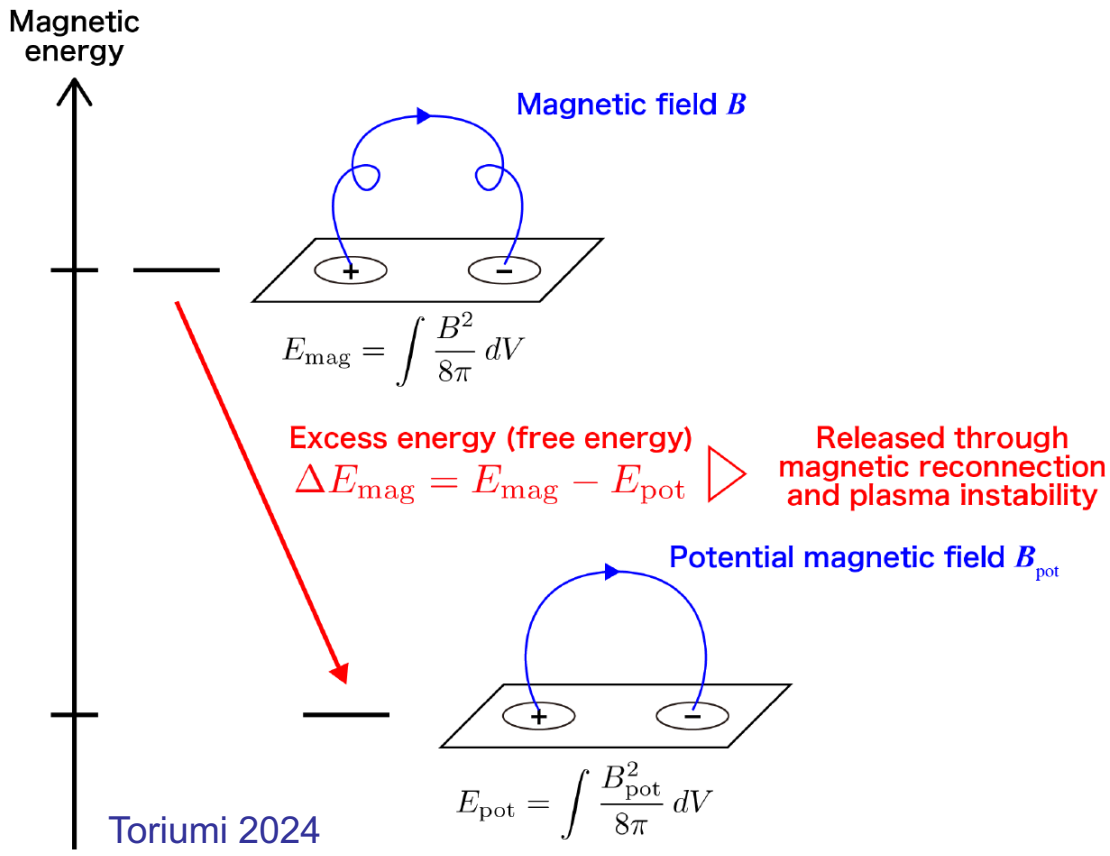
Delta-class sunspots: flare progenitors

- **>90% of X class flares originate in delta sunspots**, despite accounting for fewer than 10% of active regions.



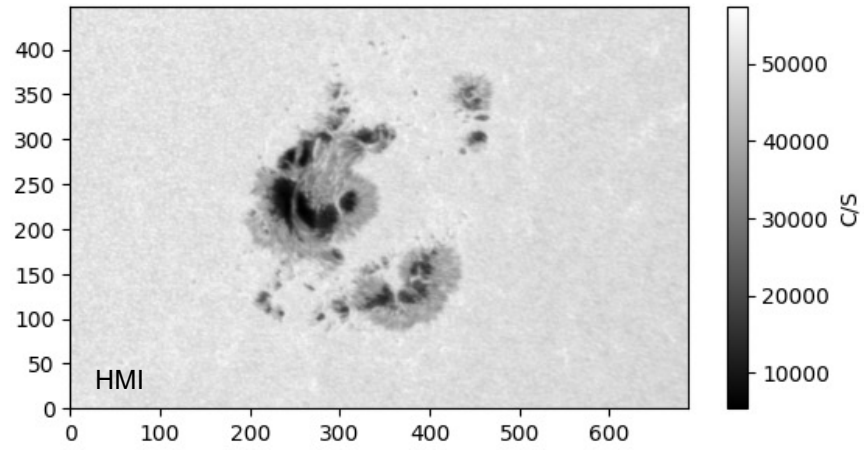
Parameters for flare prediction

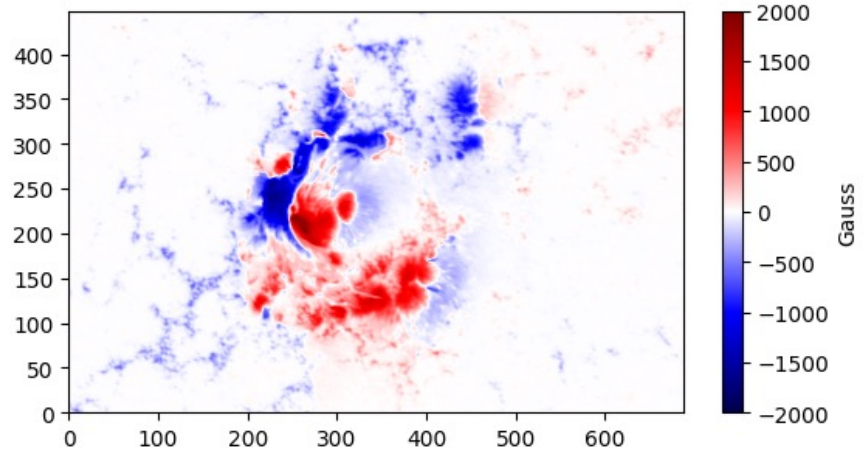
- **Energy budgets:** estimate free magnetic energy accumulation.
- **Magnetic field evolution:** assess flux emergence rates, rotation rates, polarity separation.
- **Field connectivity:** Quantify flux imbalance and open field lines.

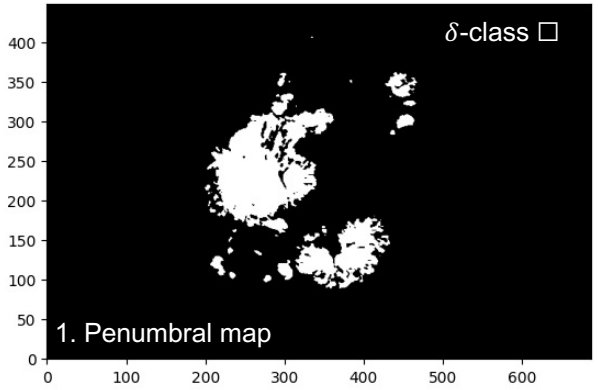


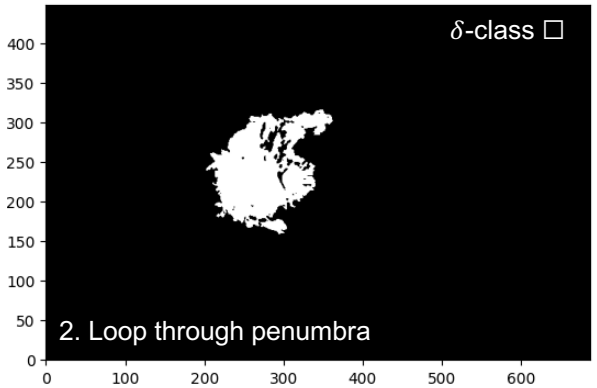
How can we analyze these physical processes in near real-time?

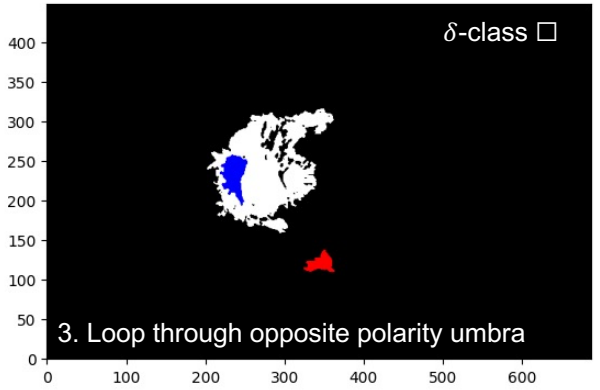
Automated delta-class sunspot detection

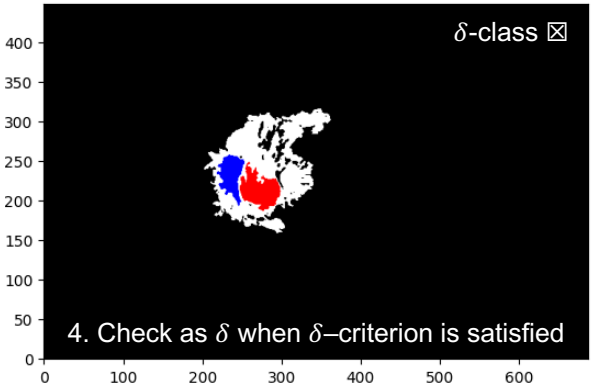












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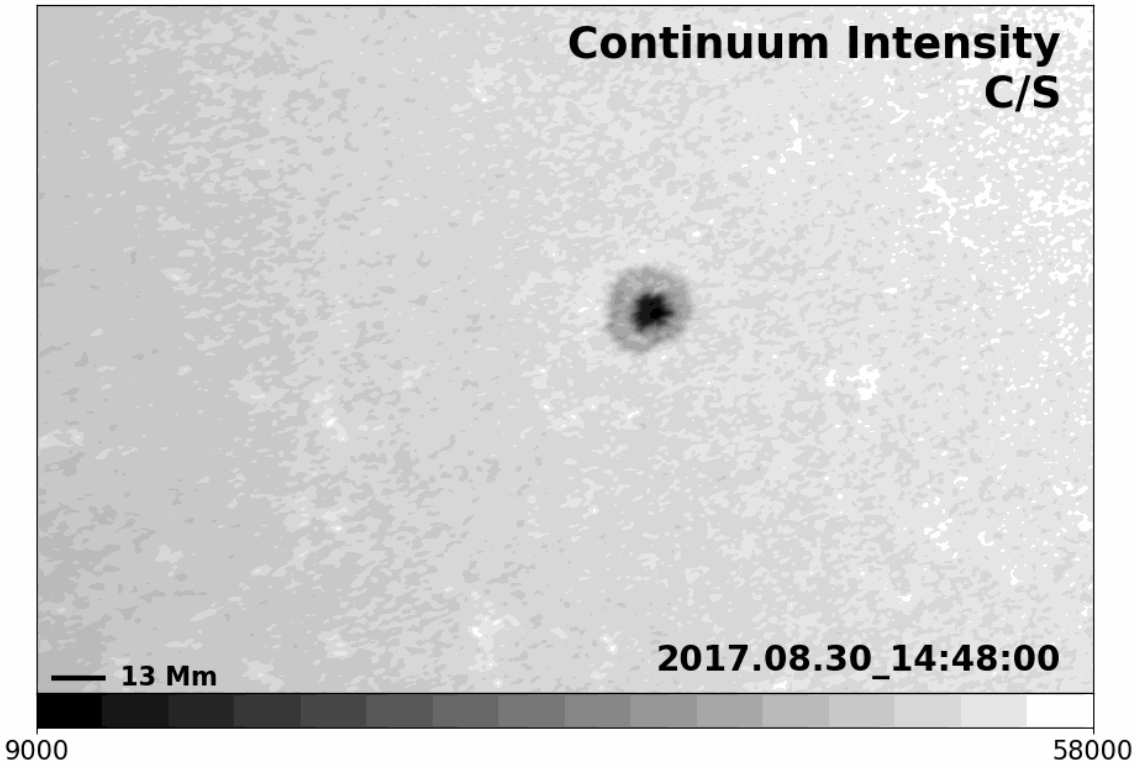
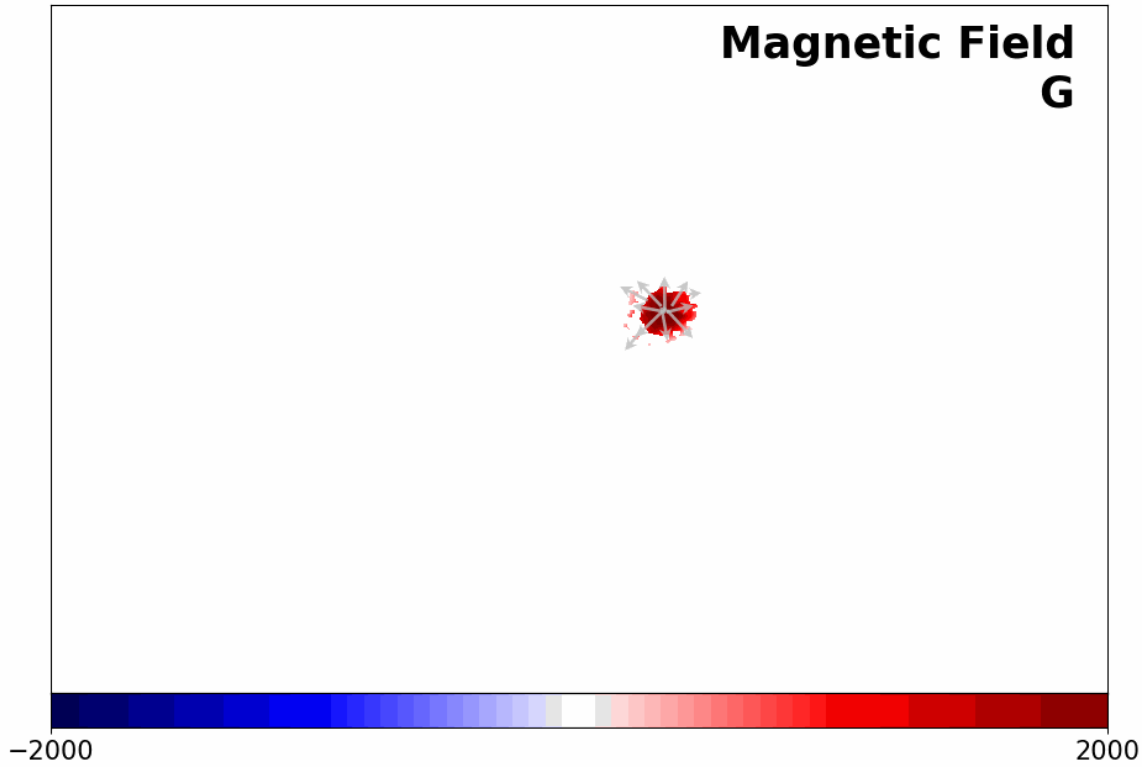
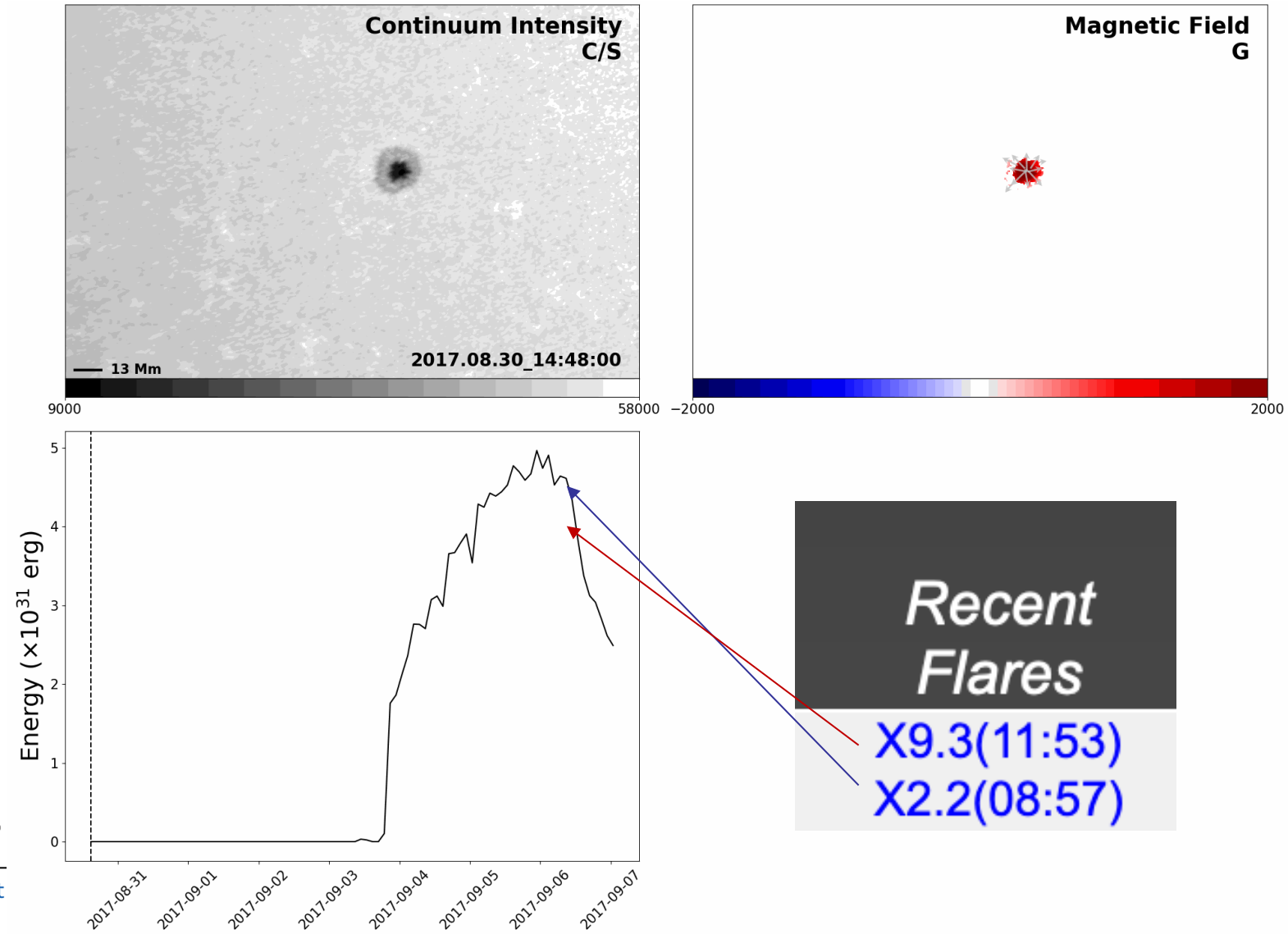


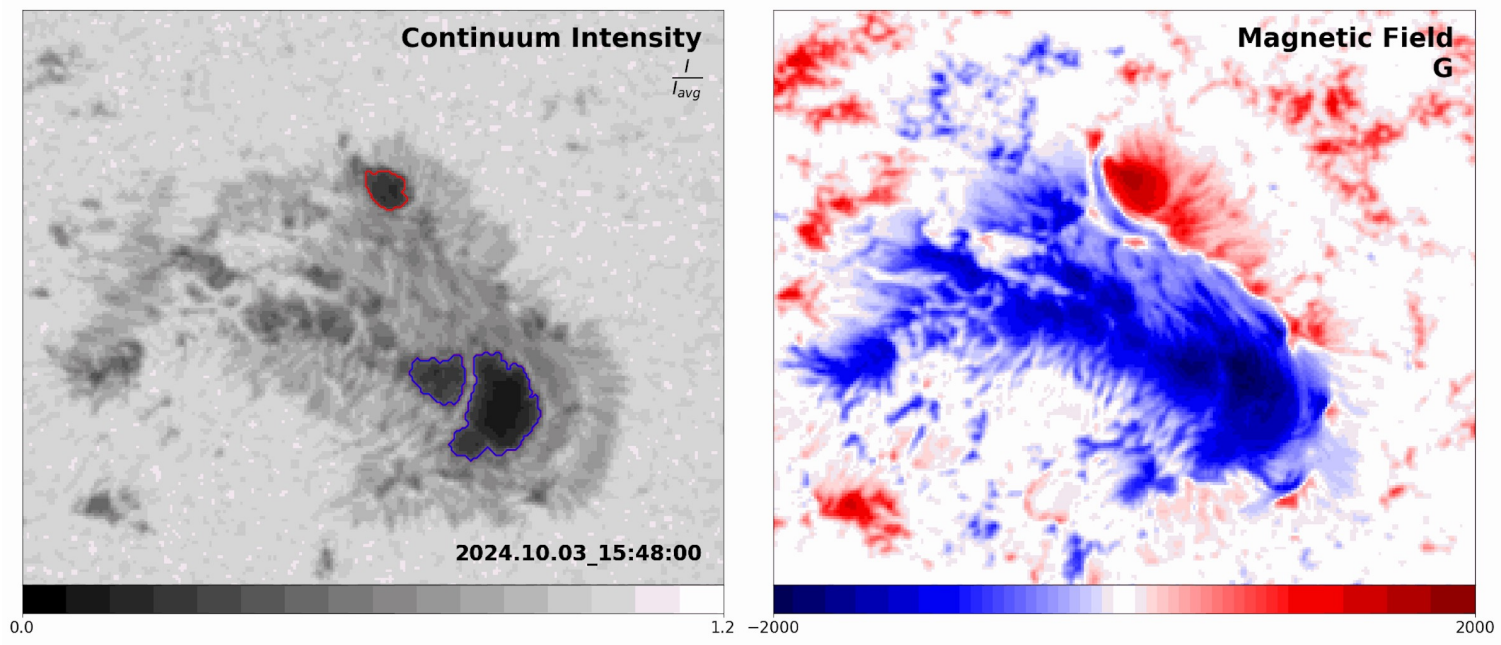


Tracking parameters: free energy budget



Flare forecasting

- HMI Quicklook data enables near real-time harvesting of live observations.
- Physical parameters can be analyzed in near real-time as sunspots evolve.
- Leverage forensic insights and physical understanding to enhance real-time analysis and forecasting.



Going forward

- Transitioning from processed data to near real-time data analysis shows strong potential.
- Identify and monitor physical properties driving energy injection into active regions in near real-time.
- Develop a tool to provide spatiotemporal flare warnings.