

Space weather and why it matters: from active Sun to economy.

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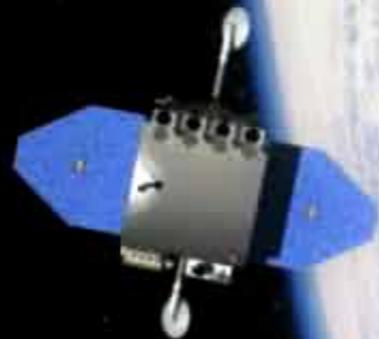
and

Alan Title, Marc DeRosa, Sarah Mitchell
and many more ...



2010/02/11:

Solar Dynamics Observatory ... over 2 terabytes/day



SDO: covering everything
on the visible hemisphere



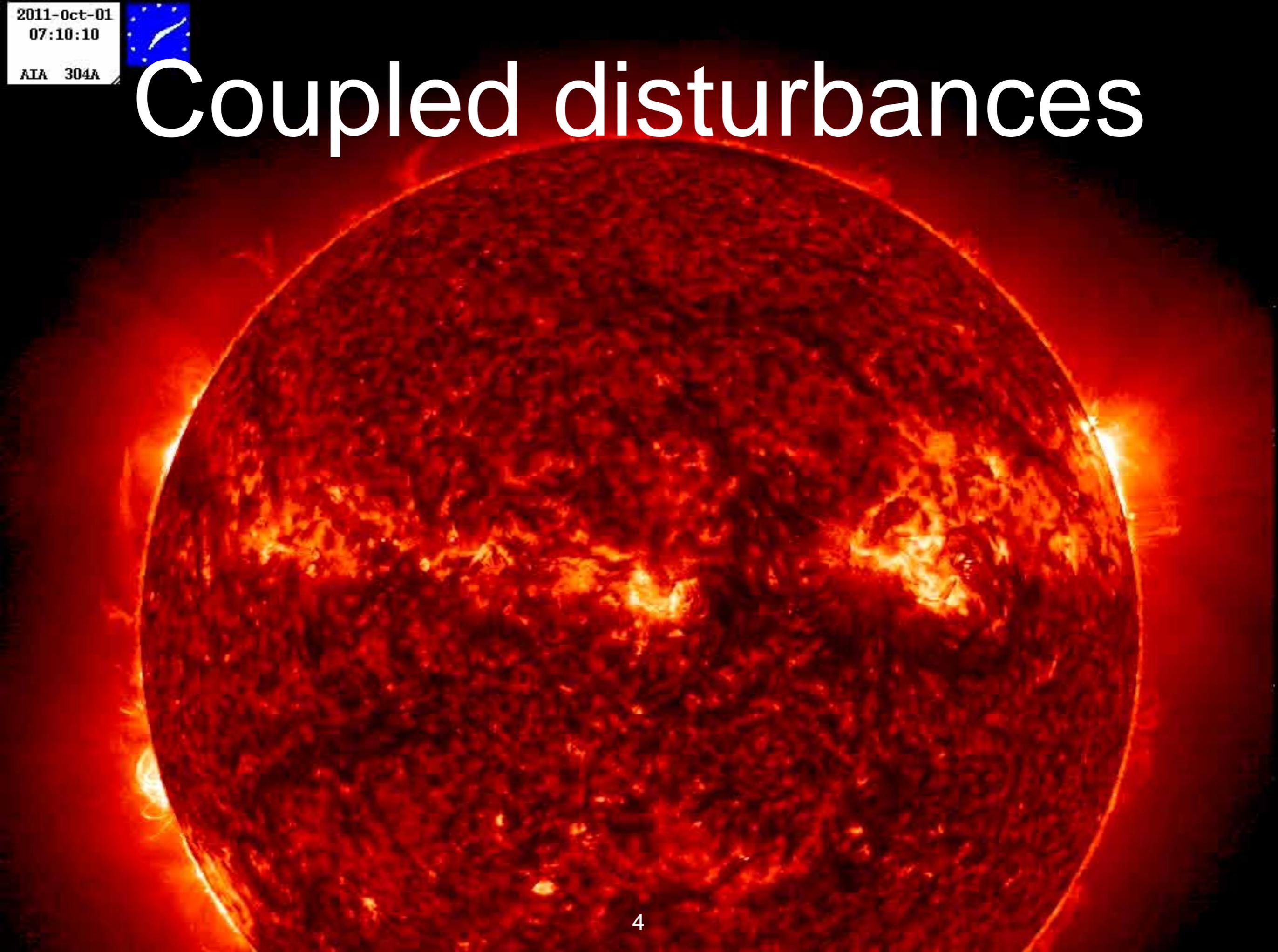
2011-Oct-01

07:10:10

AIA 304A

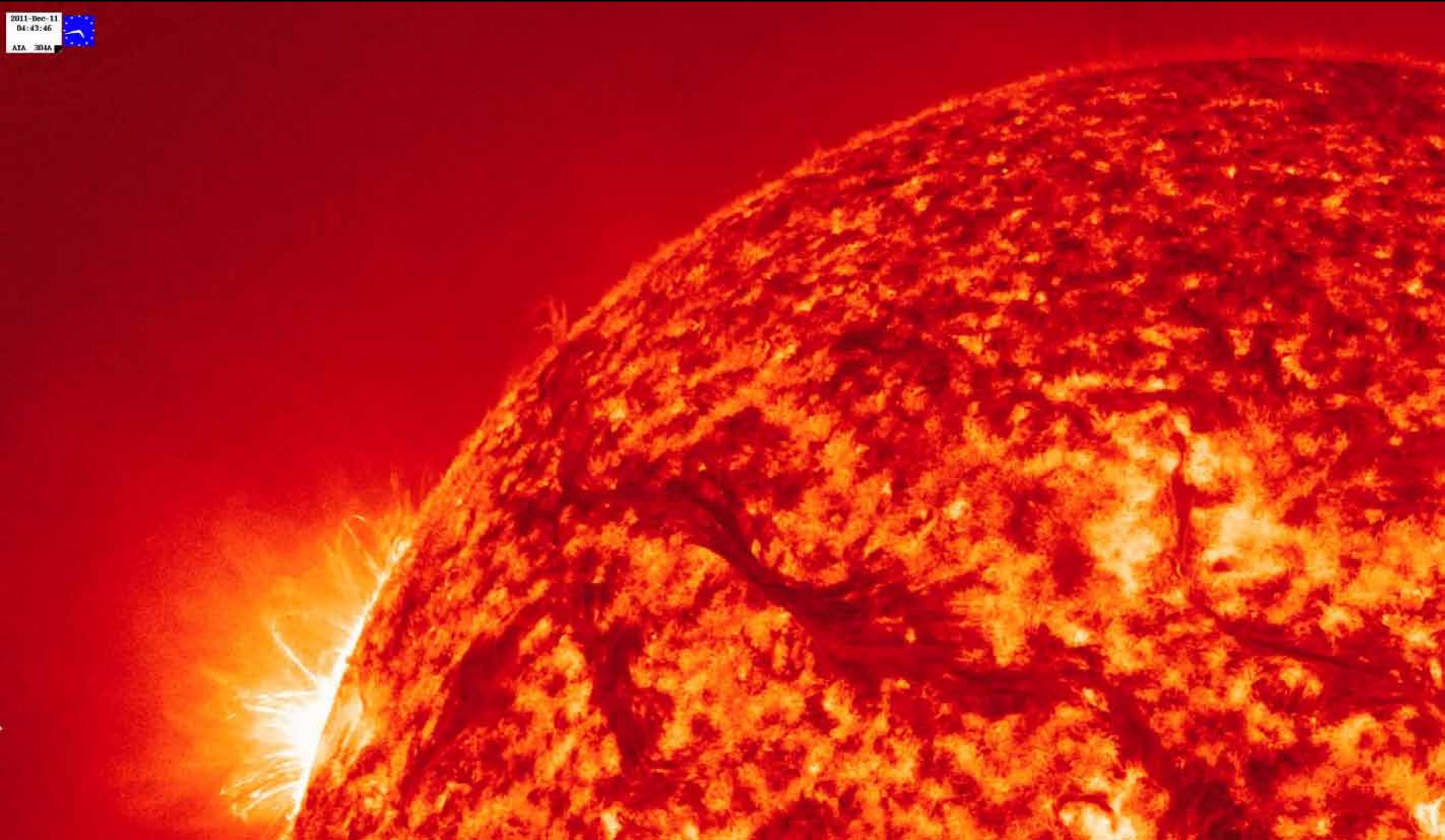


Coupled disturbances

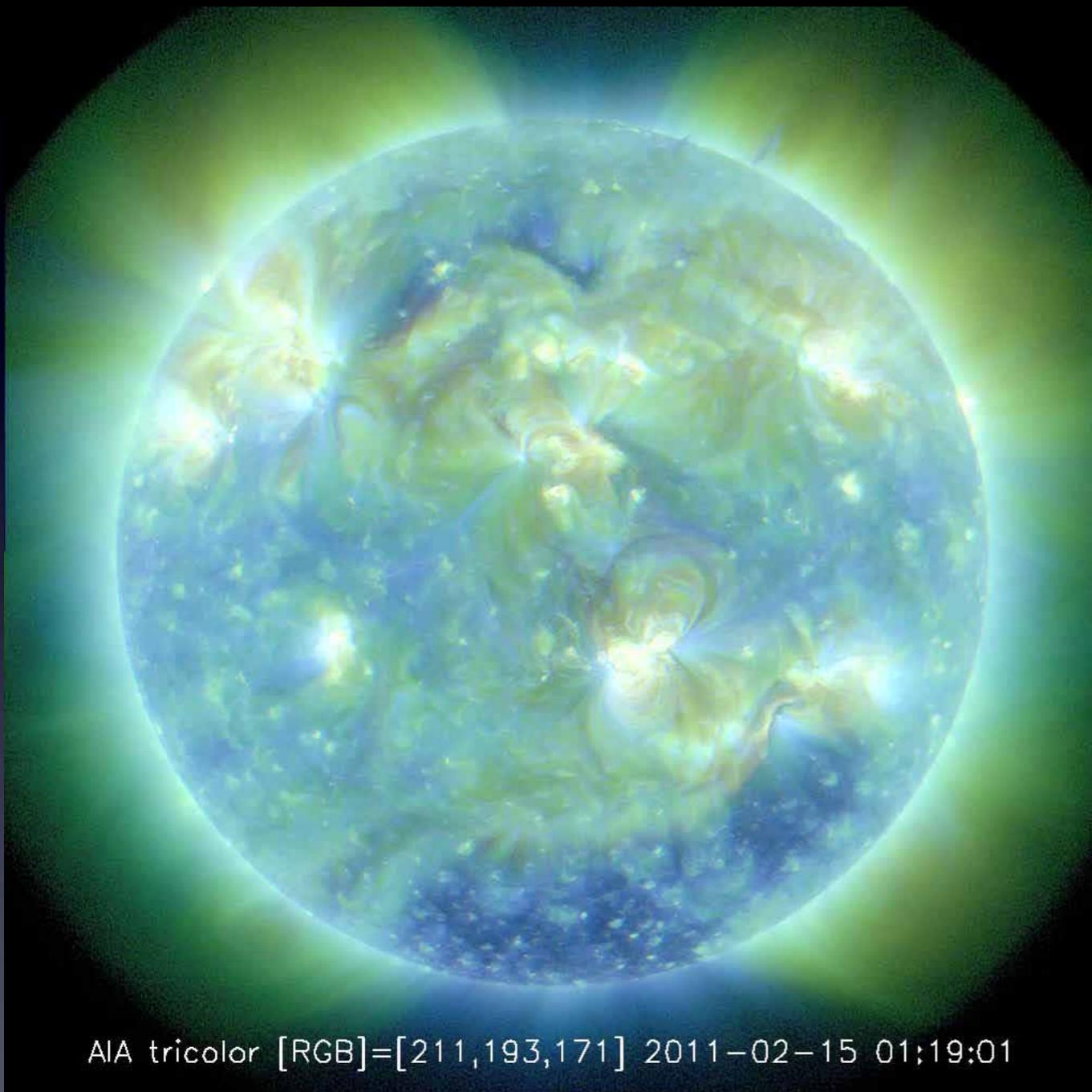
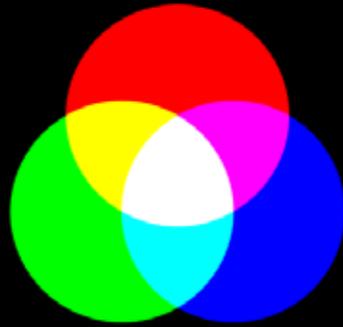


Coupled disturbances

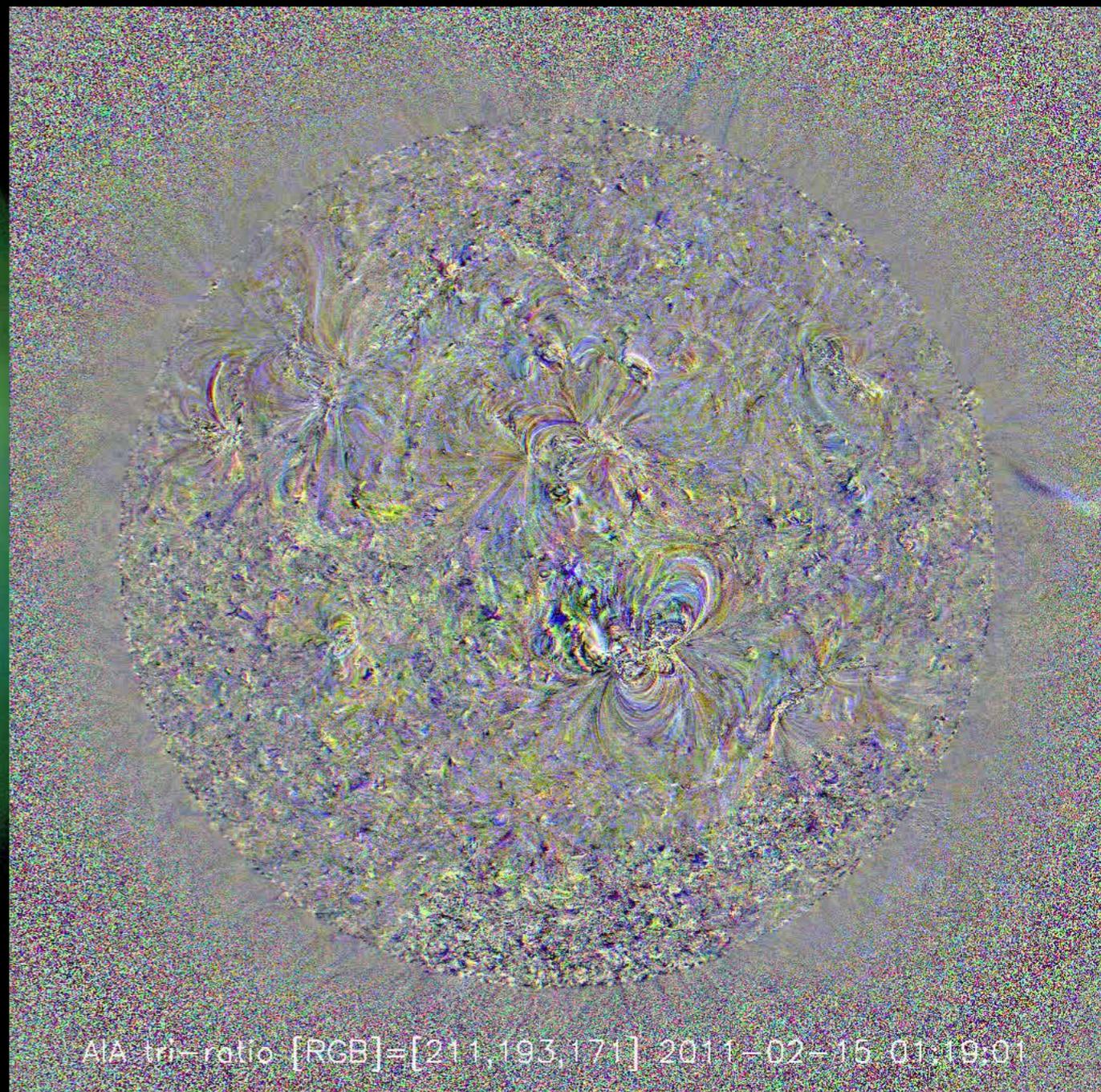
2011-Dec-11
04:43:46
ATA 304A



Long-range disturbances



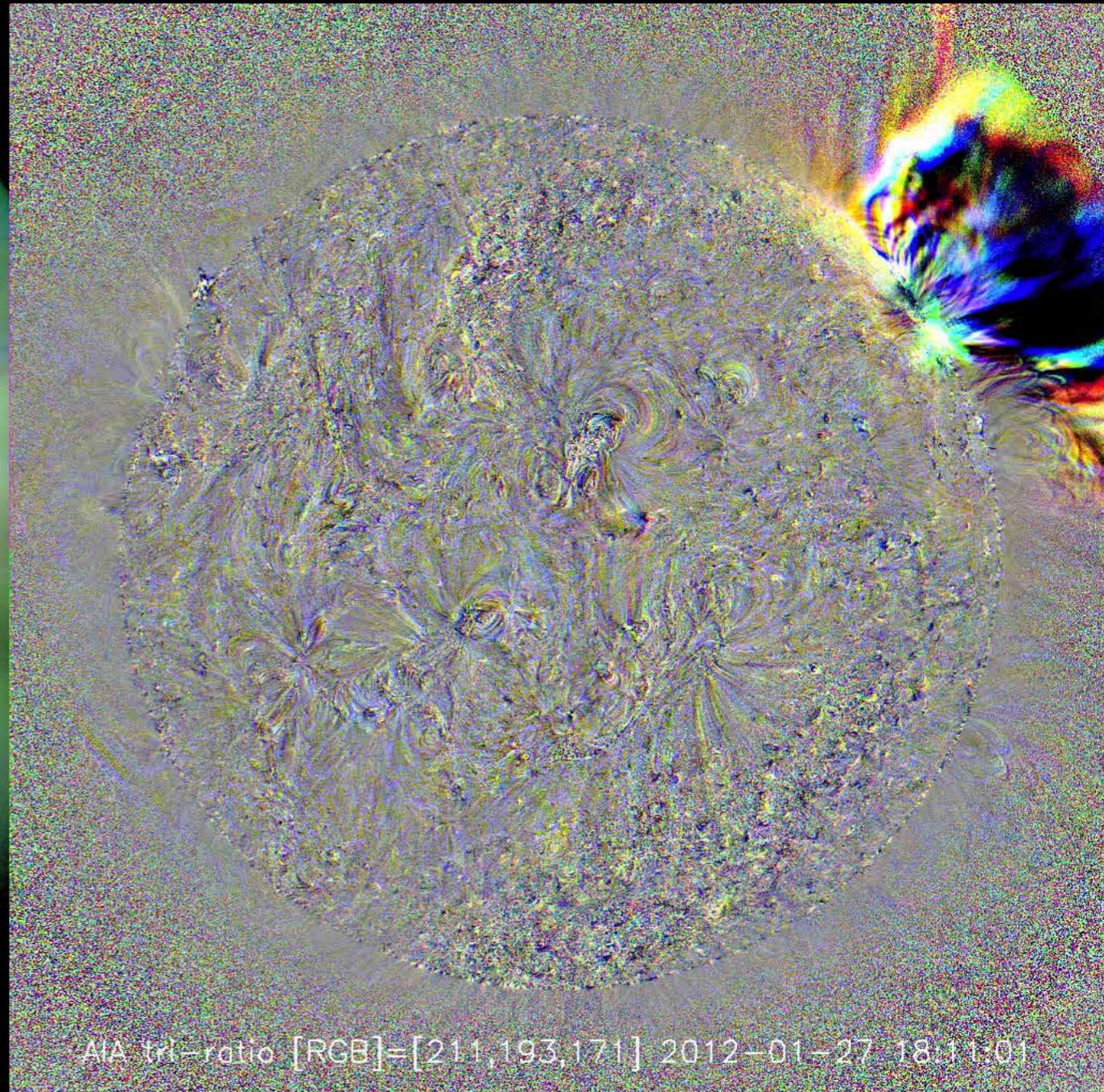
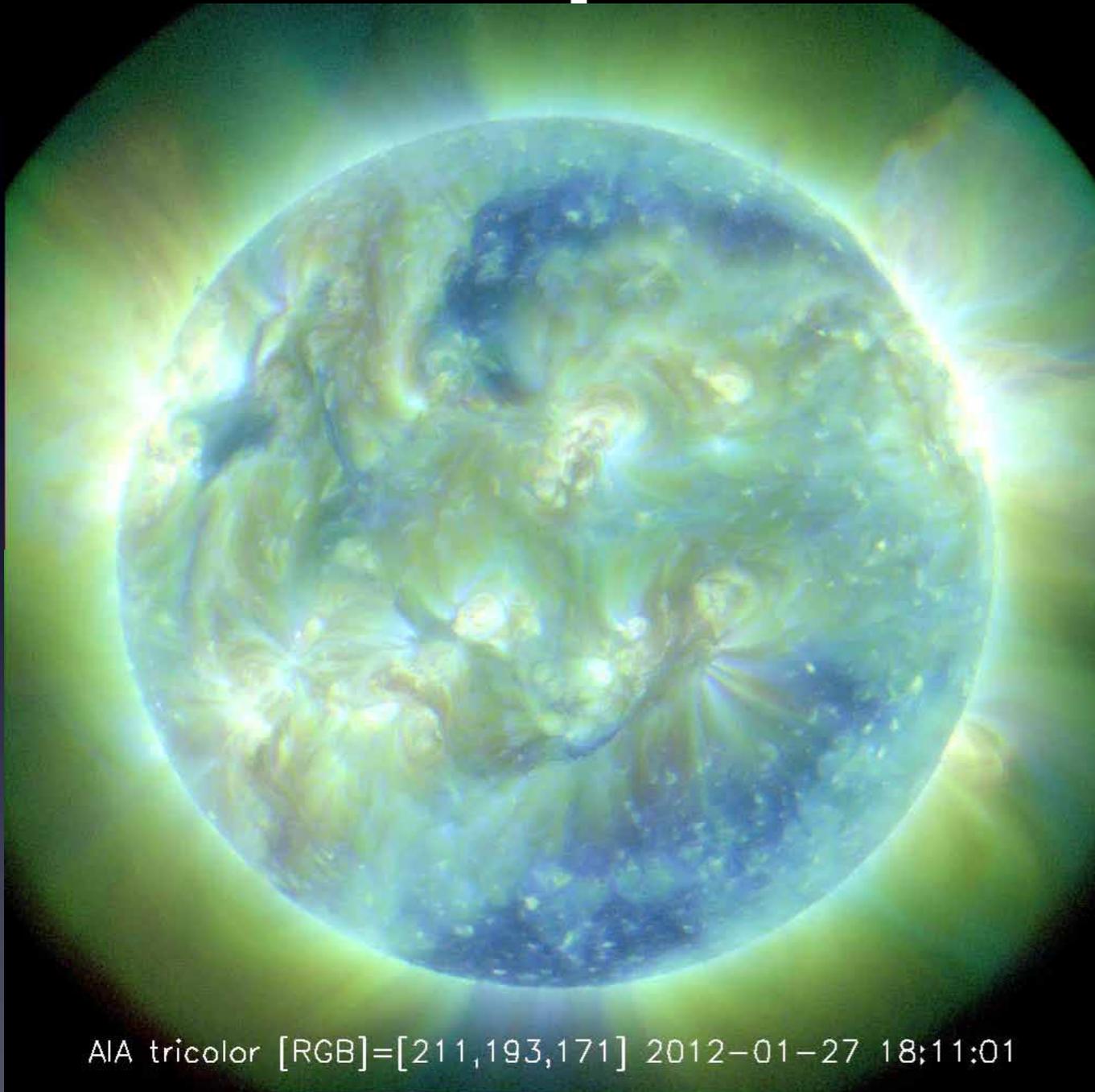
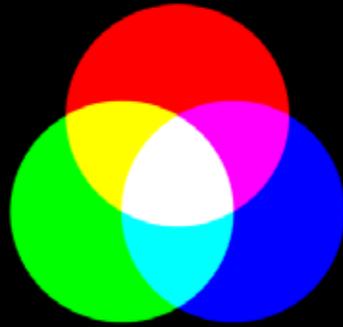
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AIA tri-ratio [RGB]=[211,193,171] 2011-02-16 01:19:01

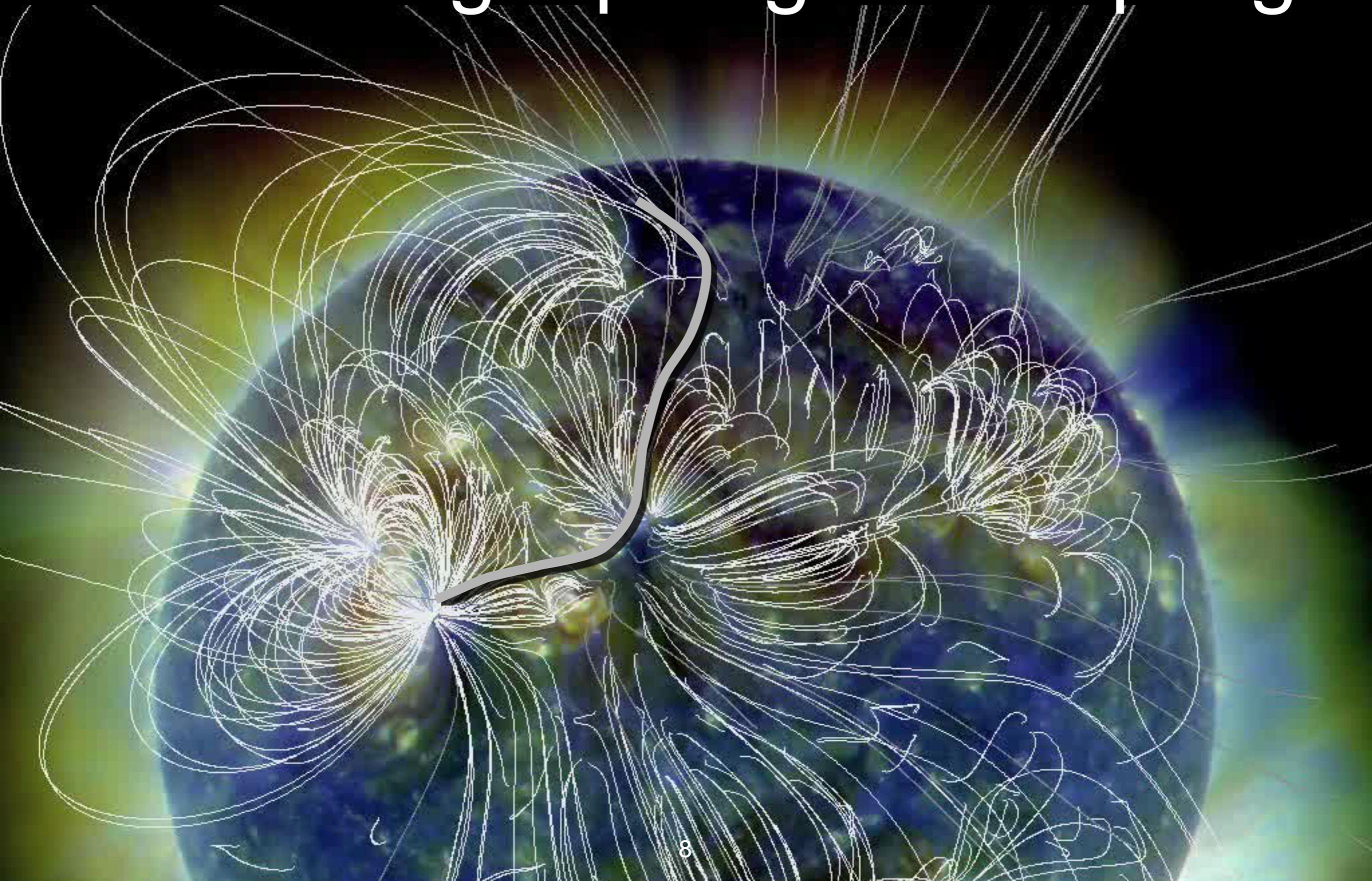
- Left: intensities Red/Green/Blue: ~2, 1.5, 1 million degrees
- Right: “running ratios”, showing relative intensity changes

Coupled disturbances



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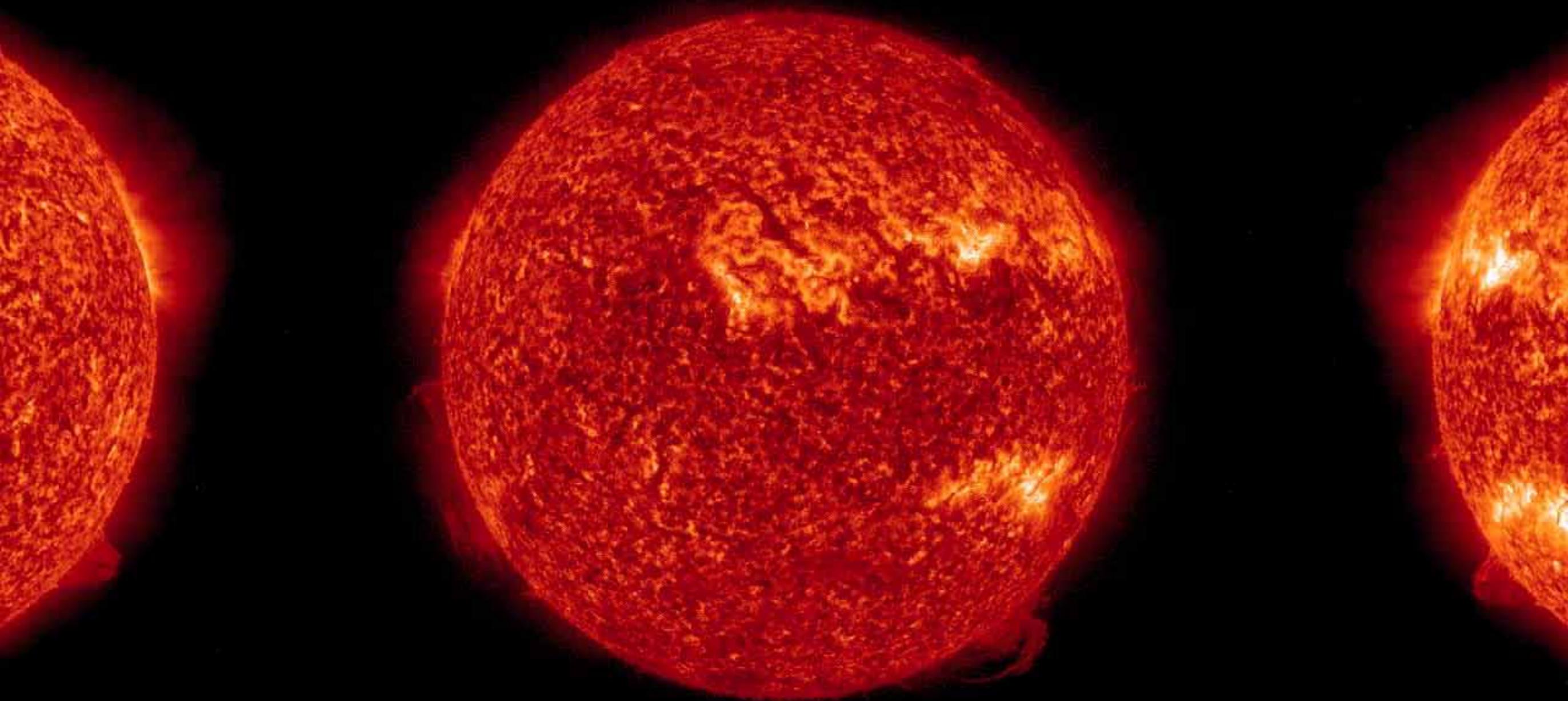
Visualizing topological coupling



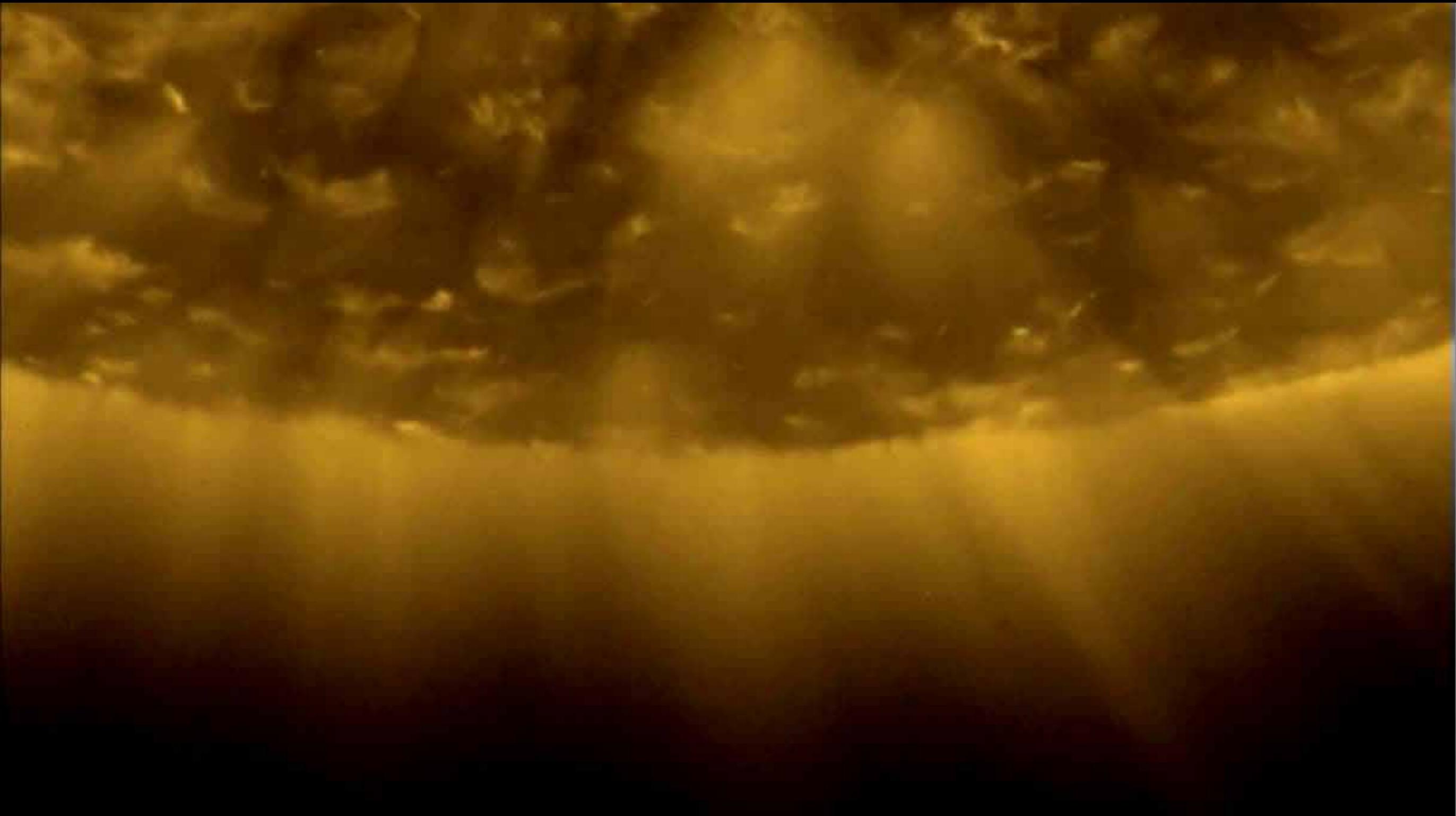
Visualizing topological coupling



SDO + STEREO A/B: global view of the nearest star

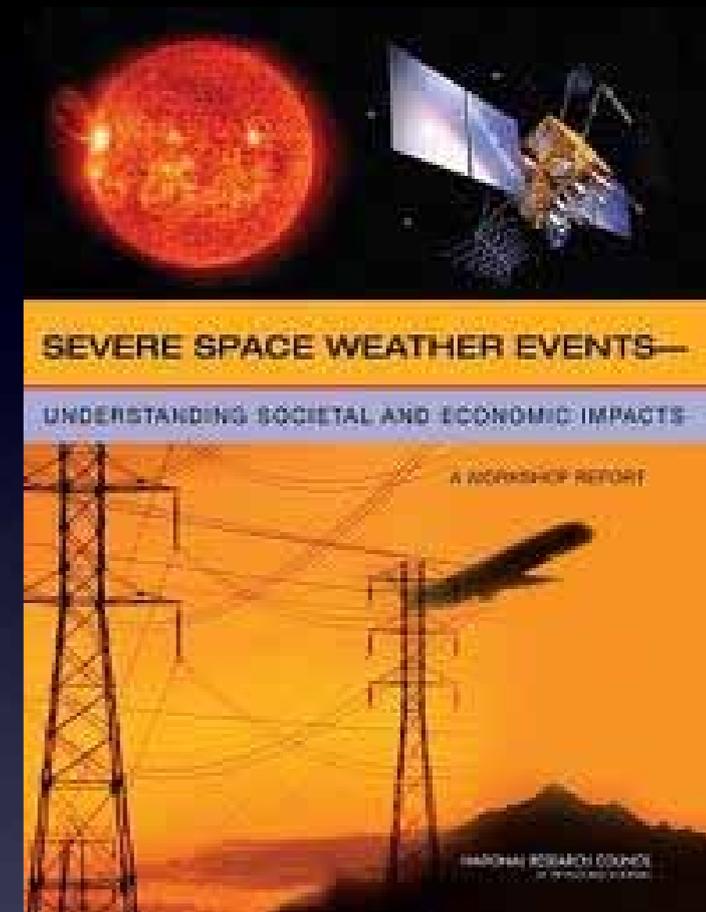


NOVA / Nat'l Geogr. special 2012, April 25



Space-weather impacts:

- *Nation at large:*
- "What are the societal and economic impacts of severe space weather? [...] While this workshop, along with its report, has gathered in one place much of what is currently known or suspected about societal and economic impacts, it has perhaps been most successful in illuminating the scope of the myriad issues involved, and the gaps in knowledge that remain to be explored in greater depth than can be accomplished in a workshop. A quantitative and comprehensive assessment of the societal and economic impacts of severe space weather will be a truly daunting task [...]" "[...] **an estimate of \$1 trillion to \$2 trillion during the first year alone was given for the societal and economic costs of a “severe geomagnetic storm scenario” with recovery times of 4 to 10 years.**"



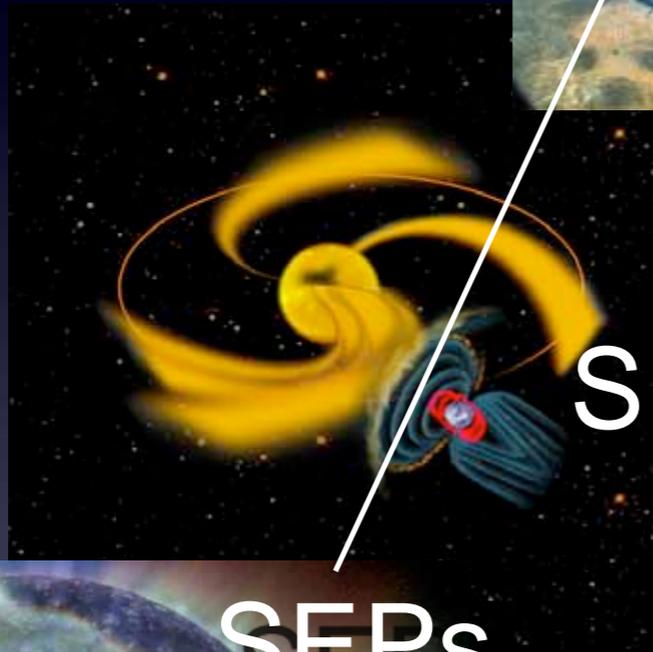
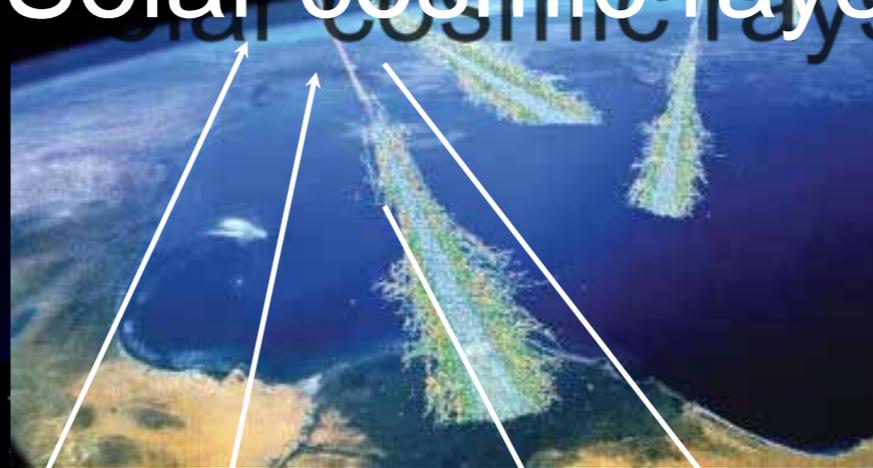
Space weather and

- In media and ~~in studies~~ **Society** the emphasis was on “extreme events” and “Doomsday scenarios”
- We could not find the expertise to assess the validity of these scenarios.
- So, we* assembled experts ...
- * *Alan Title and Karel Schrijver @ LM, Mike Hapgood & Richard Harrison @ UK/STFC, Pete Worden and Stephanie Langhoff @ NASA/Ames, Tom Bogdan @ NOAA/SWPC*

Pre-historic* records of solar activity

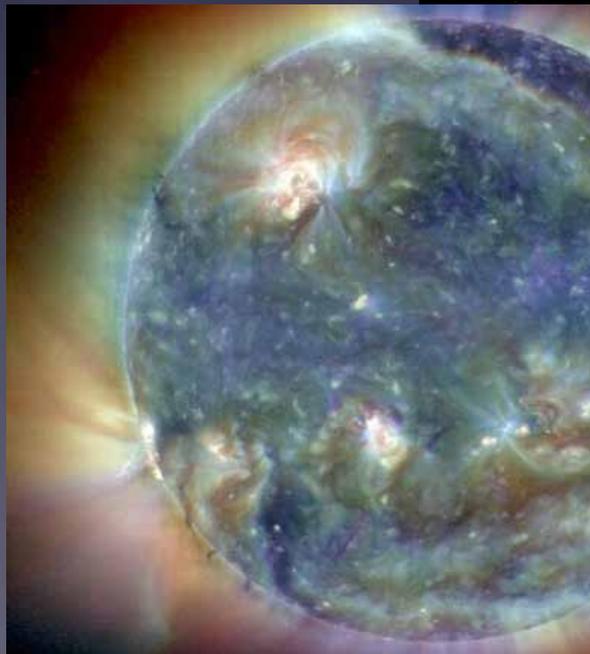
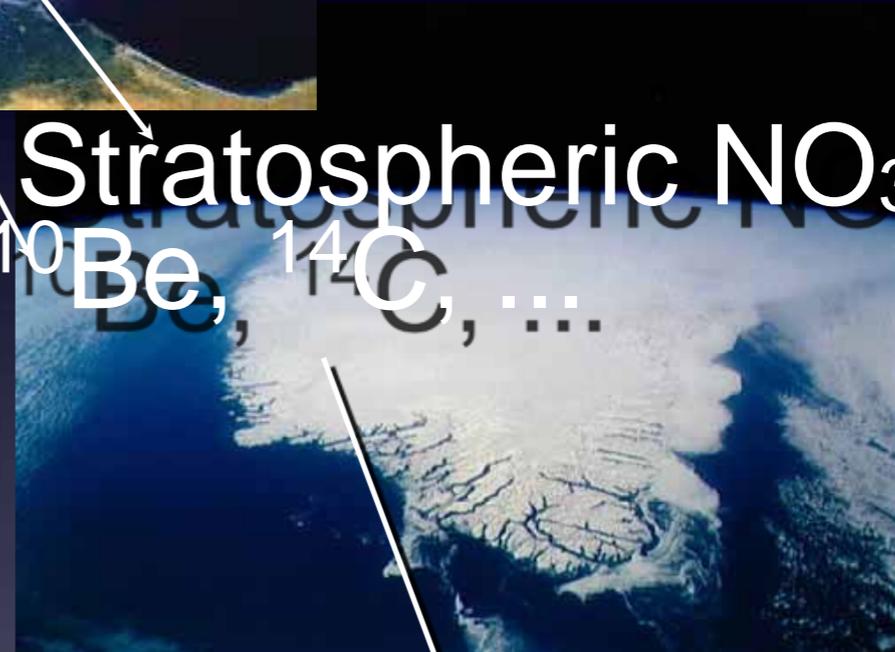
*Before ~1950

Solar activity
Solar cosmic rays

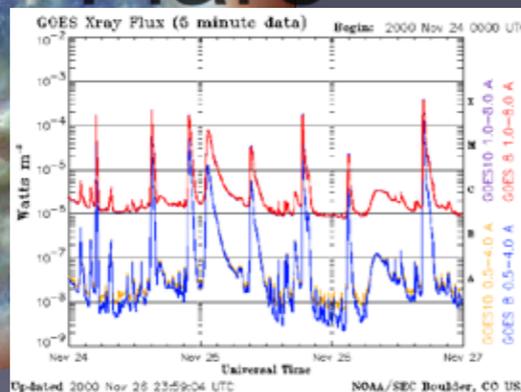


SEPs

Stratospheric NO_3
 ^{10}Be , ^{14}C , ...



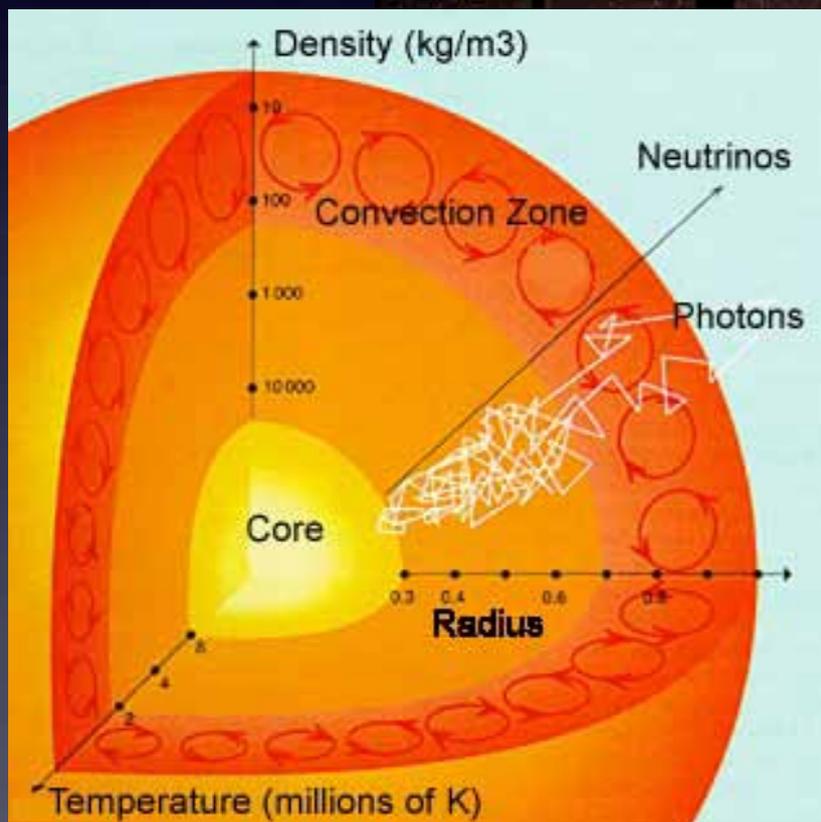
SEPs
Flare



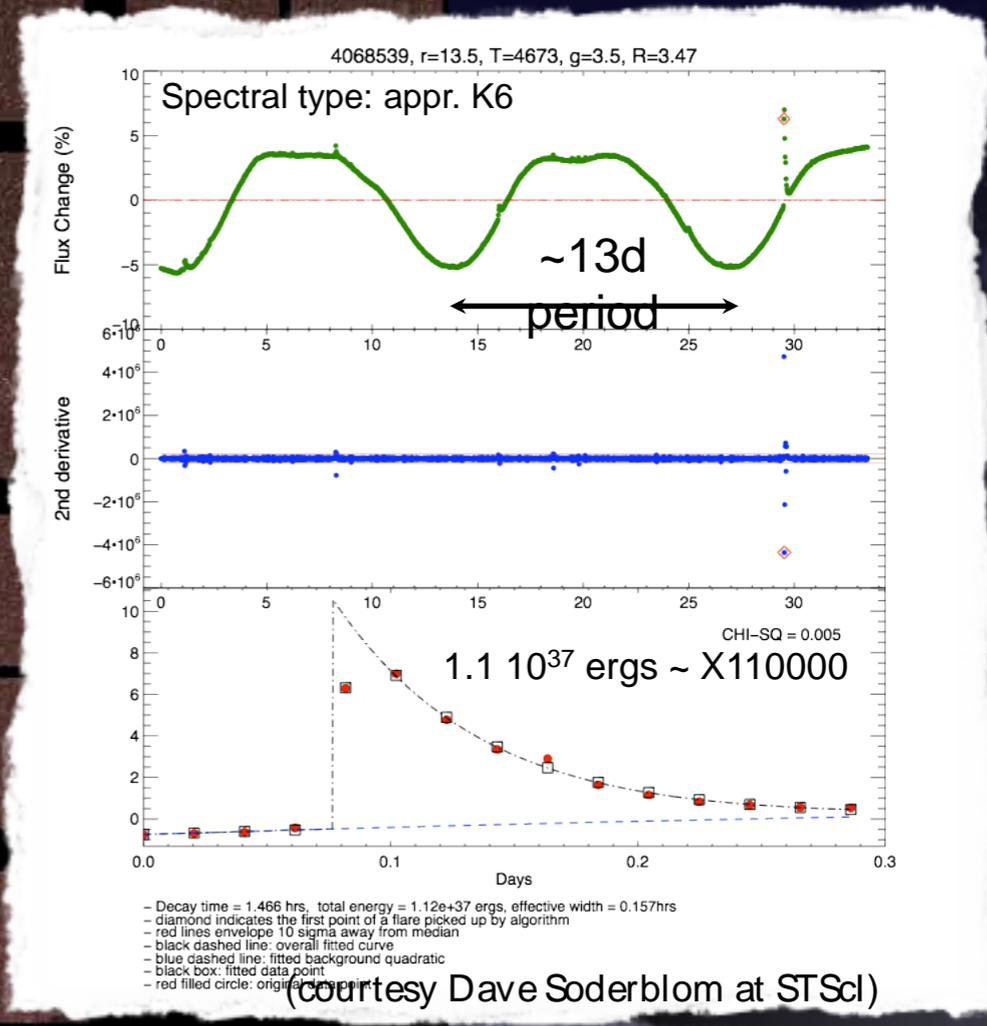
Ice cores:
~~chemicals,~~
radionuclides

Solar-like stellar activity

NASA's Kepler mission monitors ~150,000 stars.



All rotating stars with convective envelopes exhibit atmospheric magnetic activity.



So, how bad can it get?

- Solar & stellar data suggest that flares larger than ~X40 have not happened in past centuries*.
- How do we establish the probability of really bad space weather? Combine studies of the Sun with data on many Sun-like stars to be sure.
- This study required interdisciplinary expertise: Sun-Stars-heliosphere-geospace-atmosphere-ice.

** That includes the 1859 Carrington events. From Cliver and Svalgaard (2005): "In this study we used the great solar-terrestrial disturbance of 1859 as a point of departure for an investigation of the limits of extreme space weather activity. We considered the various aspects of space weather disturbance: sudden ionospheric disturbance, solar energetic particles, solar wind, geomagnetic storm, and aurora. For each of these effects, we compiled (with varying degrees of completeness) size-ordered lists of the top events of the last ~150 years. We found that in each of these categories the 1859 event had close peers or superiors."*

Space weather and disturbances in the US power grid

DOE and NERC publish reports on “power grid disturbances”.

Based on 1216 reports from 1992 through 2010, we find a significant ($>4\sigma$) increase in grid disturbances in periods following severe solar and geospace activity.

The correlation of grid disturbances with major solar flaring reveals a weakness in the US power grid not recognized to date.

The economic impact of space weather on the US economy likely exceeds **\$3 billion per year**. Compare that to the oft-cited Hydro-Quebec blackout in March, 1989, with an estimated impact of \$2 billion.

In conclusion

- Even though extreme solar events are unlikely to be much more extreme than what we have already experienced, the susceptibility of our technological infrastructure is larger than we realized, with costs of billions each year in the electric power grid alone.
- An appropriate response to the societal impacts of space weather requires
 - (i) a dedicated organization for interdisciplinary studies to assess the coupling of solar activity and US economy and safety, and strategies for prevention and mitigation, and
 - (ii) an observing system from Sun to geospace for science and forecasting.

