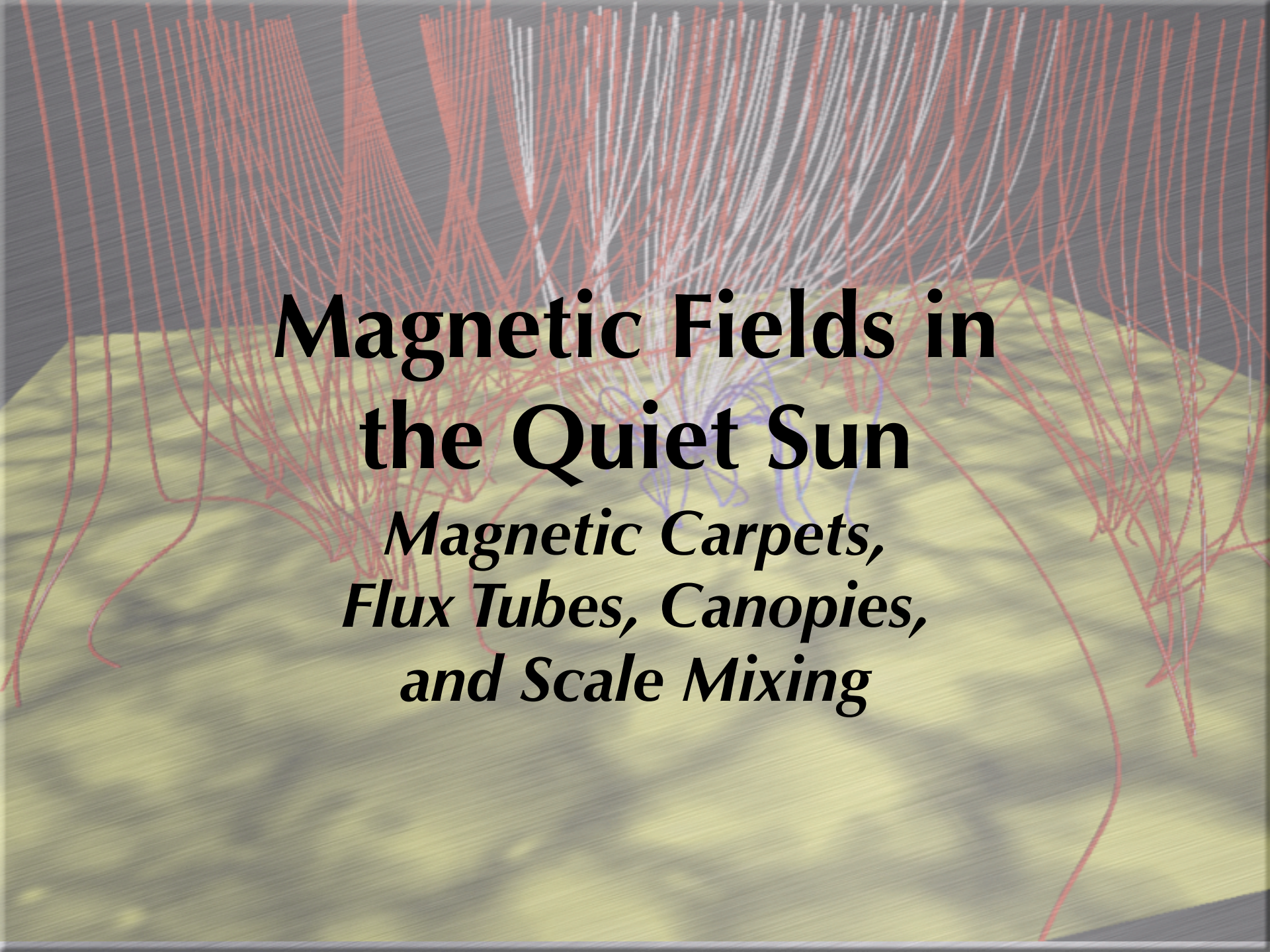


Magnetic Fields in the Quiet Sun

Magnetic Carpets, Flux Tubes, Canopies, and Scale Mixing

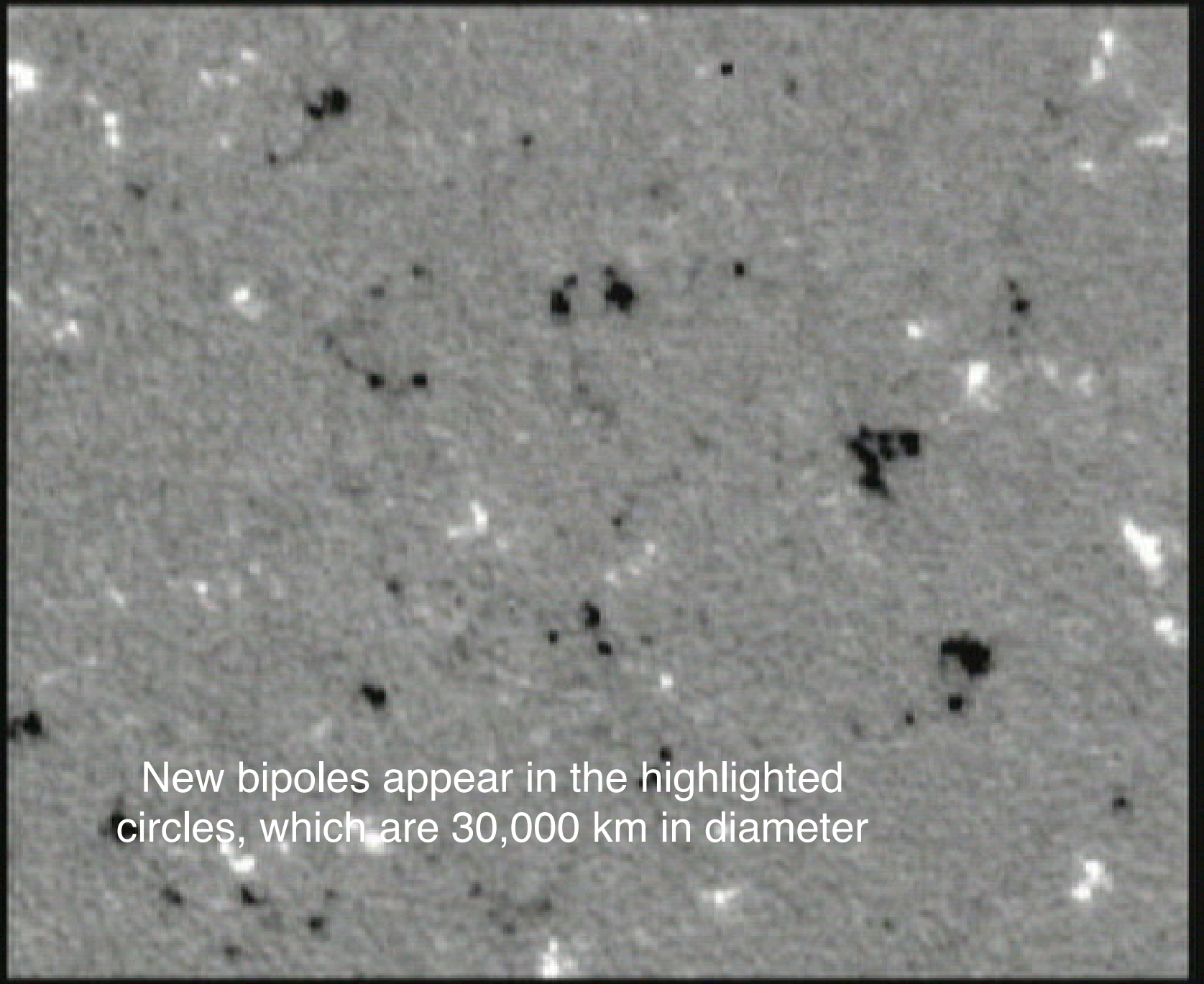
What is the impact of the Quiet Sun Flux?

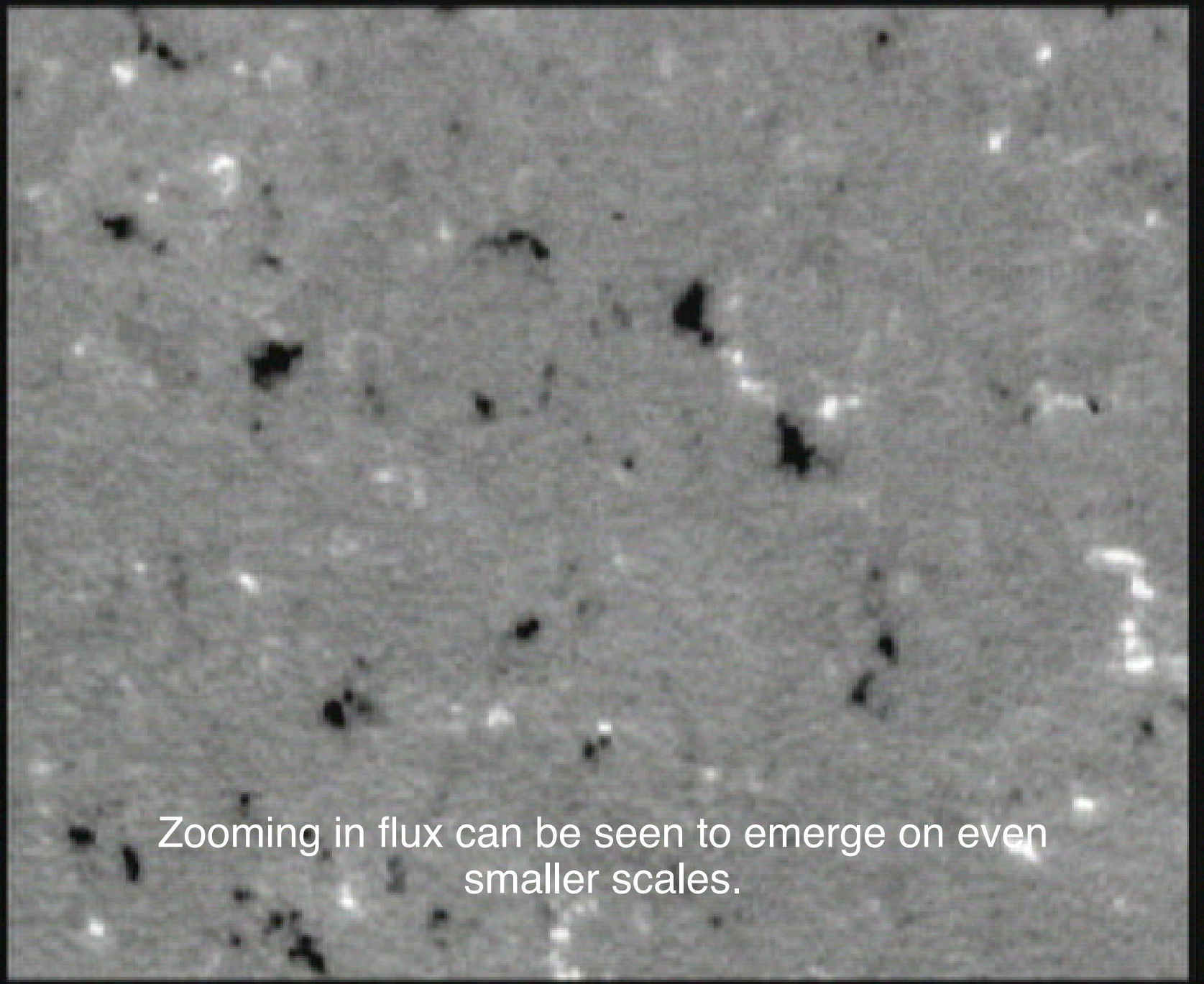
- How much energy is transmitted from small scales to larger scale fields?
- How much of the energy for heating of the Chromosphere, Transition Region, and Corona comes from the interactions of the small scale fields?
- How does presence of the mixed polarity fields effect the connectivity of the active region fields?

What are the Major Questions?

- How much Quiet Sun flux is there and what is its strength?
  - What are the distributions functions of the field strength and how do the distributions change as a function of the field strength?
- Where does the Quiet Flux come from?
  - Local Dynamo Action?
  - Distributed Dynamo Action?
  - Reprocessing of the Active Region flux?
  - Some combination of the above?
- Can we estimate the amount of mixed flux in our resolution elements?

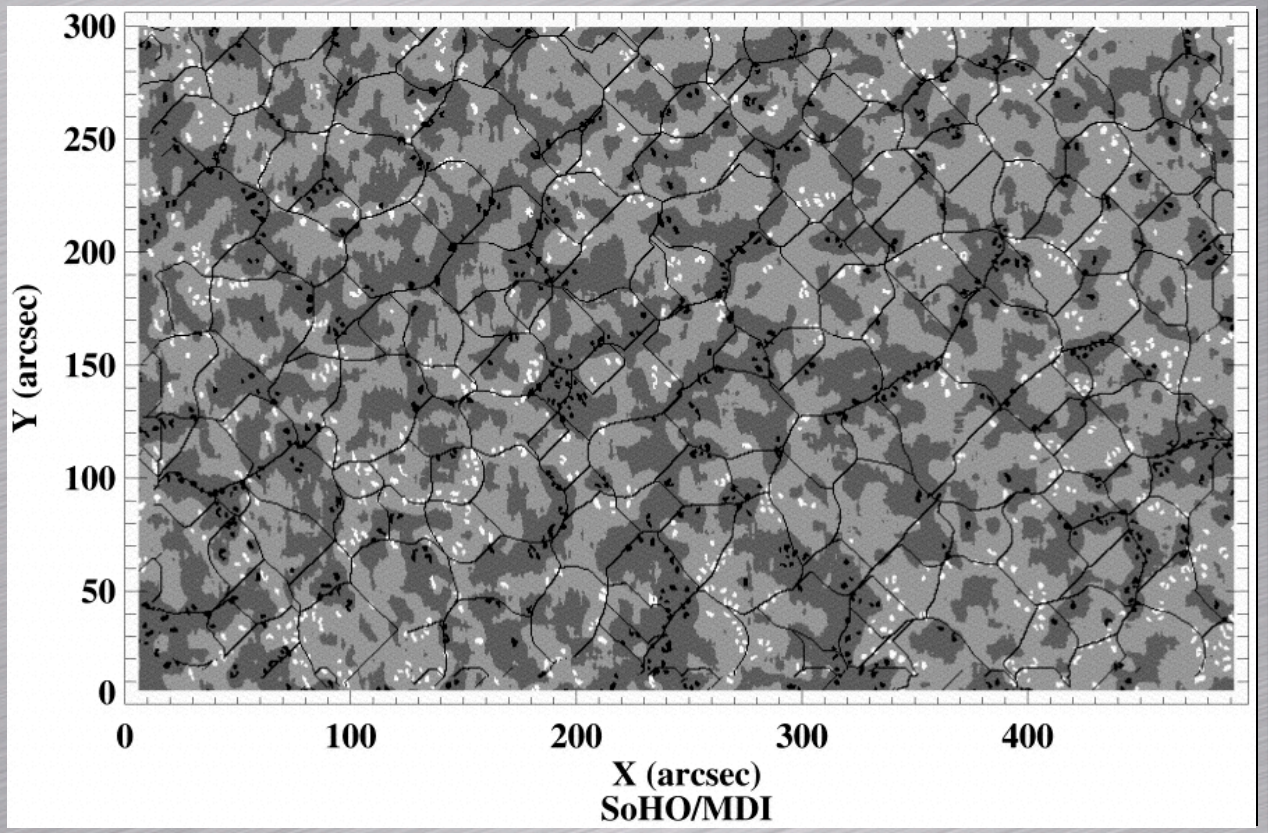
The mixed polarity magnetic fields in the presence of convection implies the fields are continuously replaced on the scale of the convective turnover time ~ 10 to 20 hours for supergranulation and 10 to 20 minutes for granulation.


New bipoles appear in the highlighted
circles, which are 30,000 km in diameter


Zooming in flux can be seen to emerge on even smaller scales.

The Quiet-Sun network

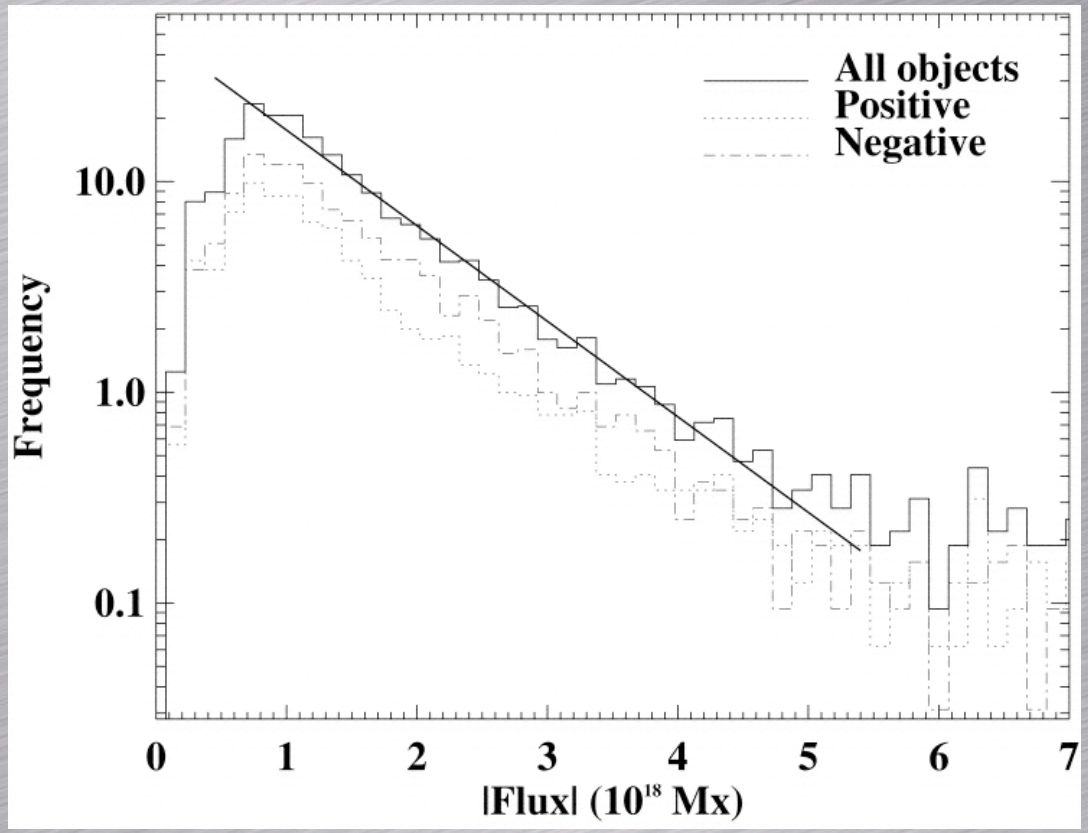
- The Quiet-Sun magnetic network is a statistical balance between flux emerging in ephemeral regions and canceling in chance encounters. Flux concentrations live for hours to days, not months!



From: Schrijver et al. (1997) ApJ 487, 424

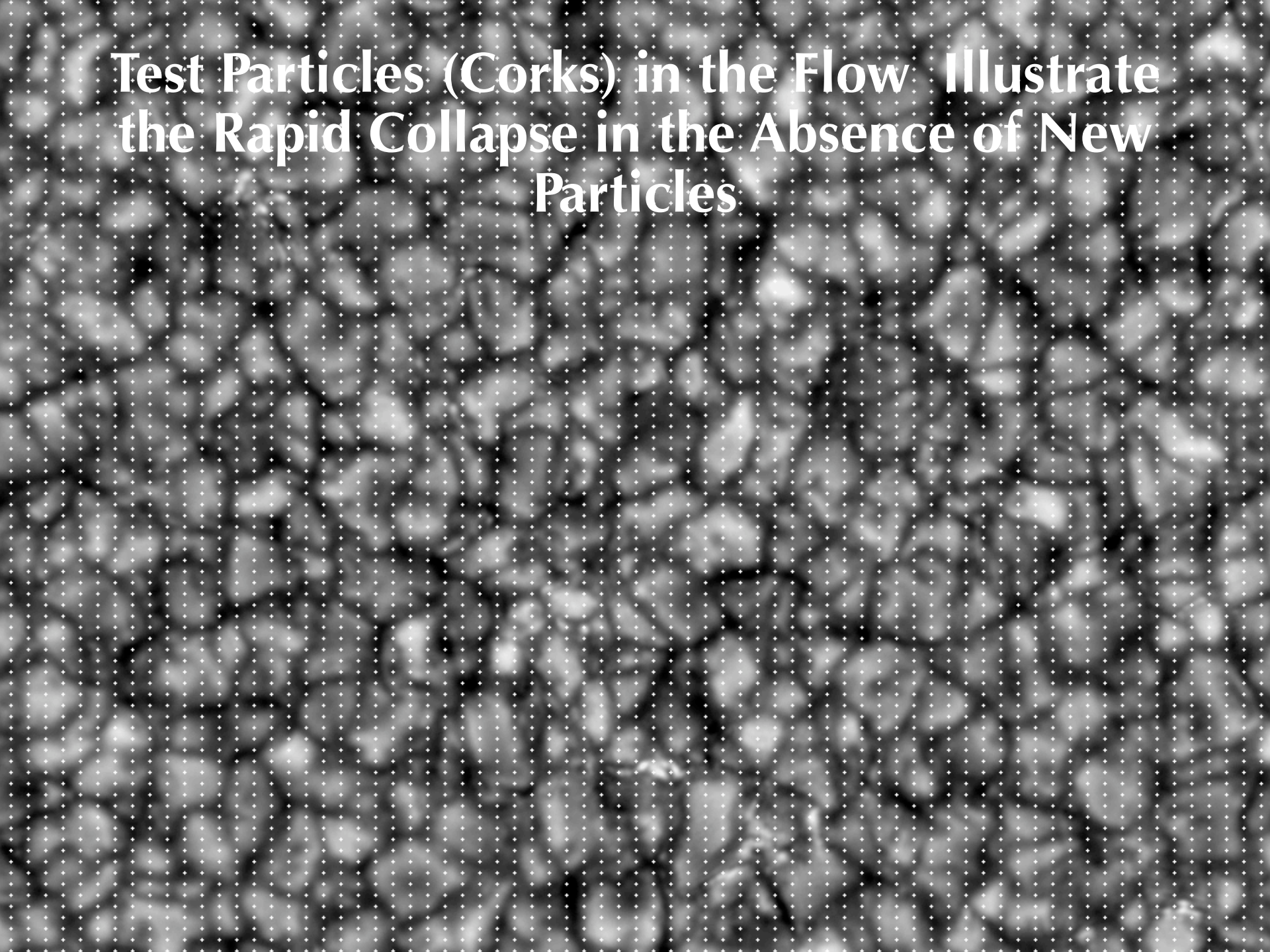
Magneto-chemistry

- Collisions and fragmentations lead to a quasi-exponential distribution of fluxes;
- the flux source-spectrum is of little importance;
- fragmentation rates and collision "cross sections" combined determine the spectrum.



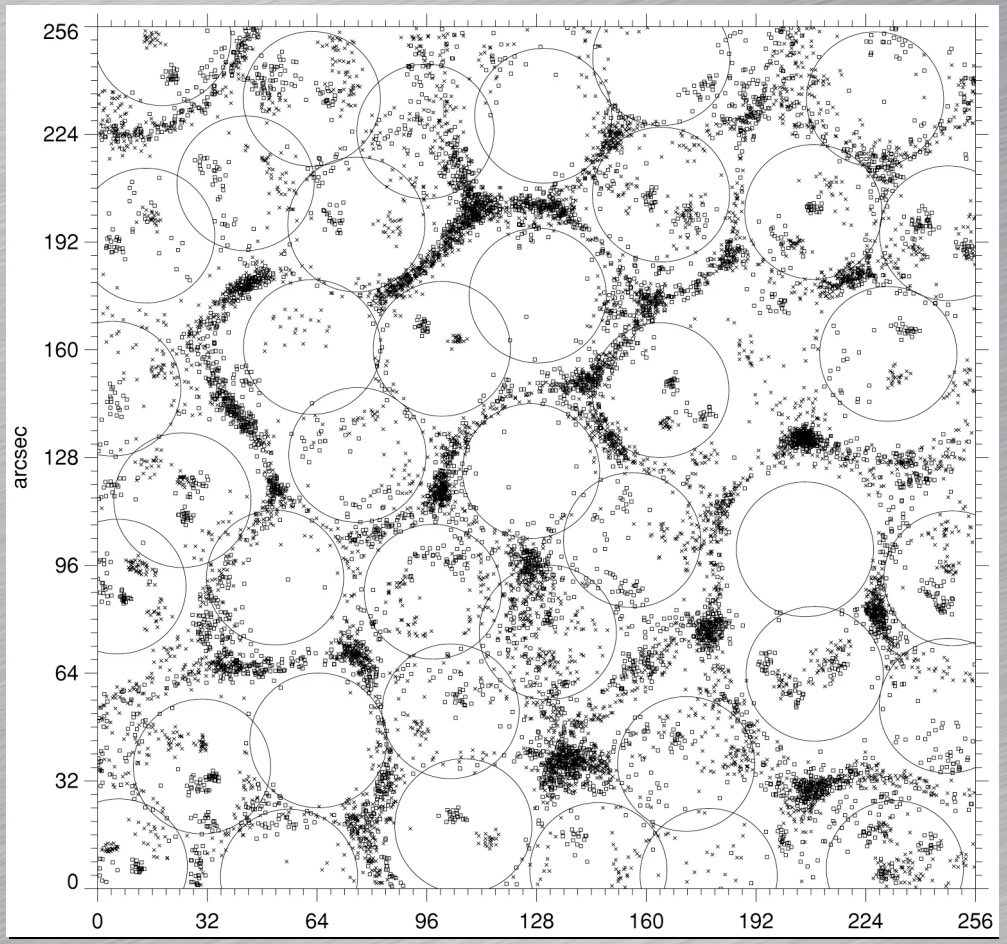
From: Schrijver et al. (1997) ApJ 487, 424
Also: Parnell (2002) MNRAS 35, 389

Test Particles (Corks) in the Flow Illustrate the Rapid Collapse in the Absence of New Particles

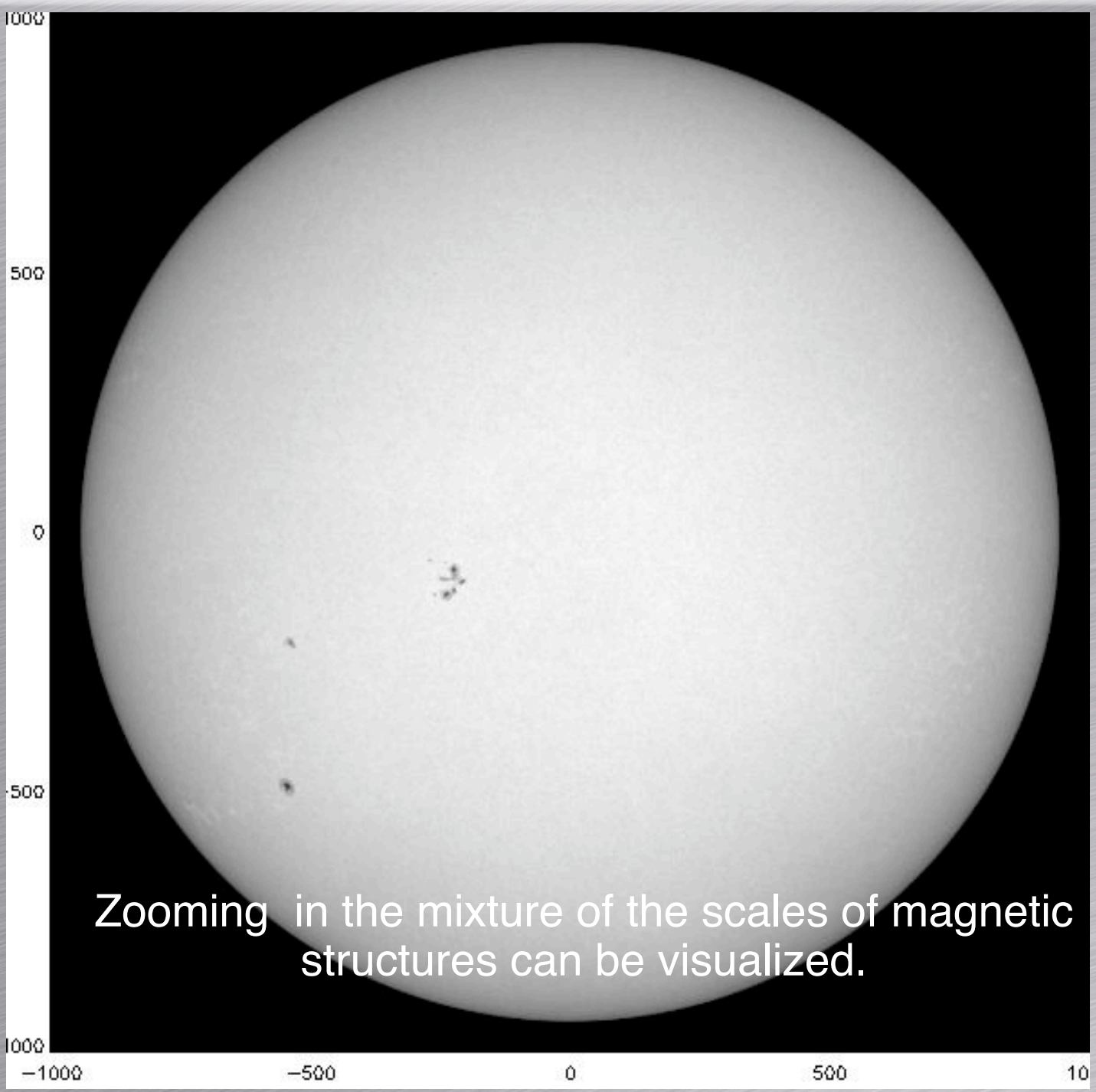


Network pattern

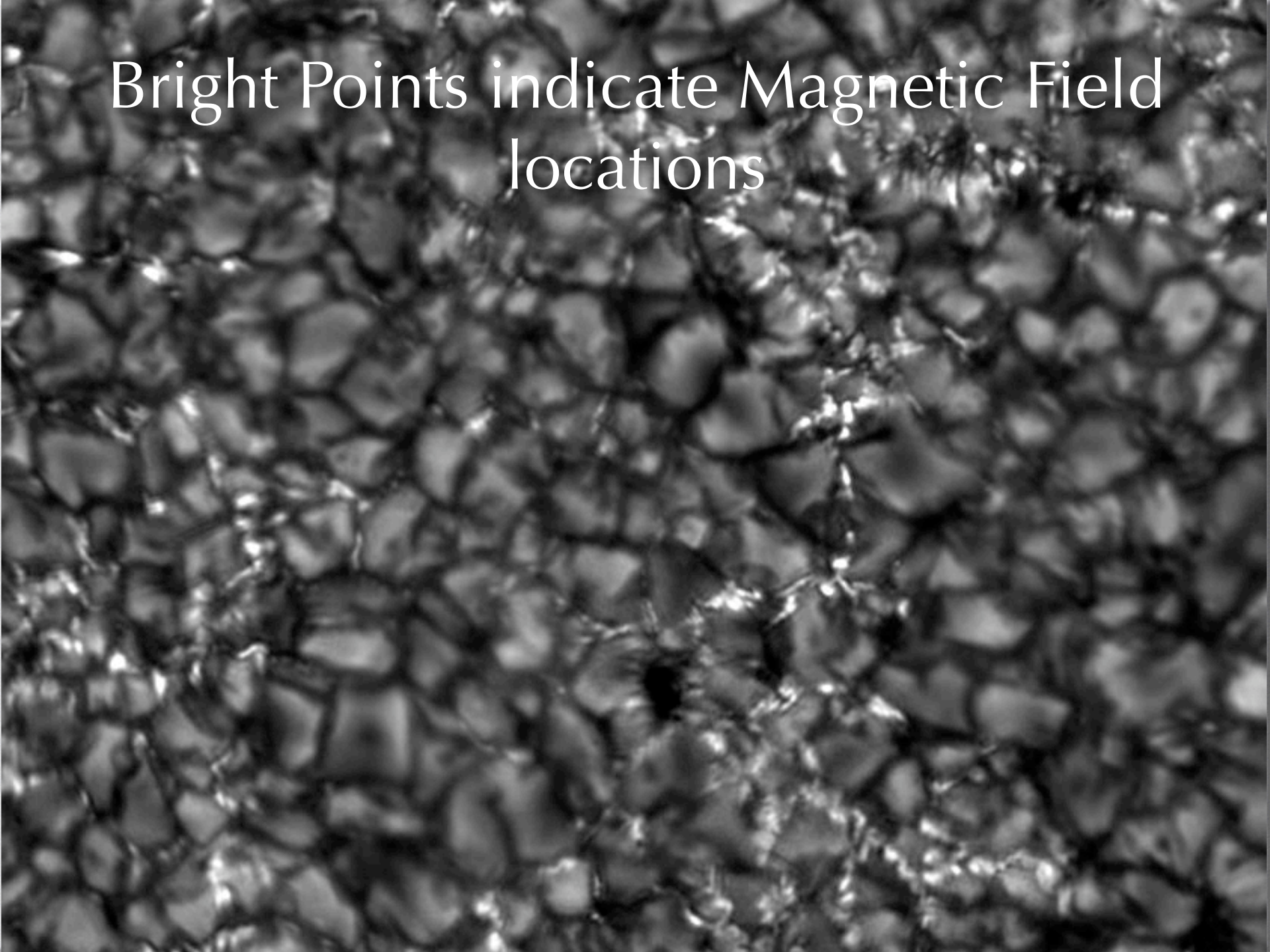
- 2D simulations confirm that the pattern of the network is maintained in a statistical "detailed balance."

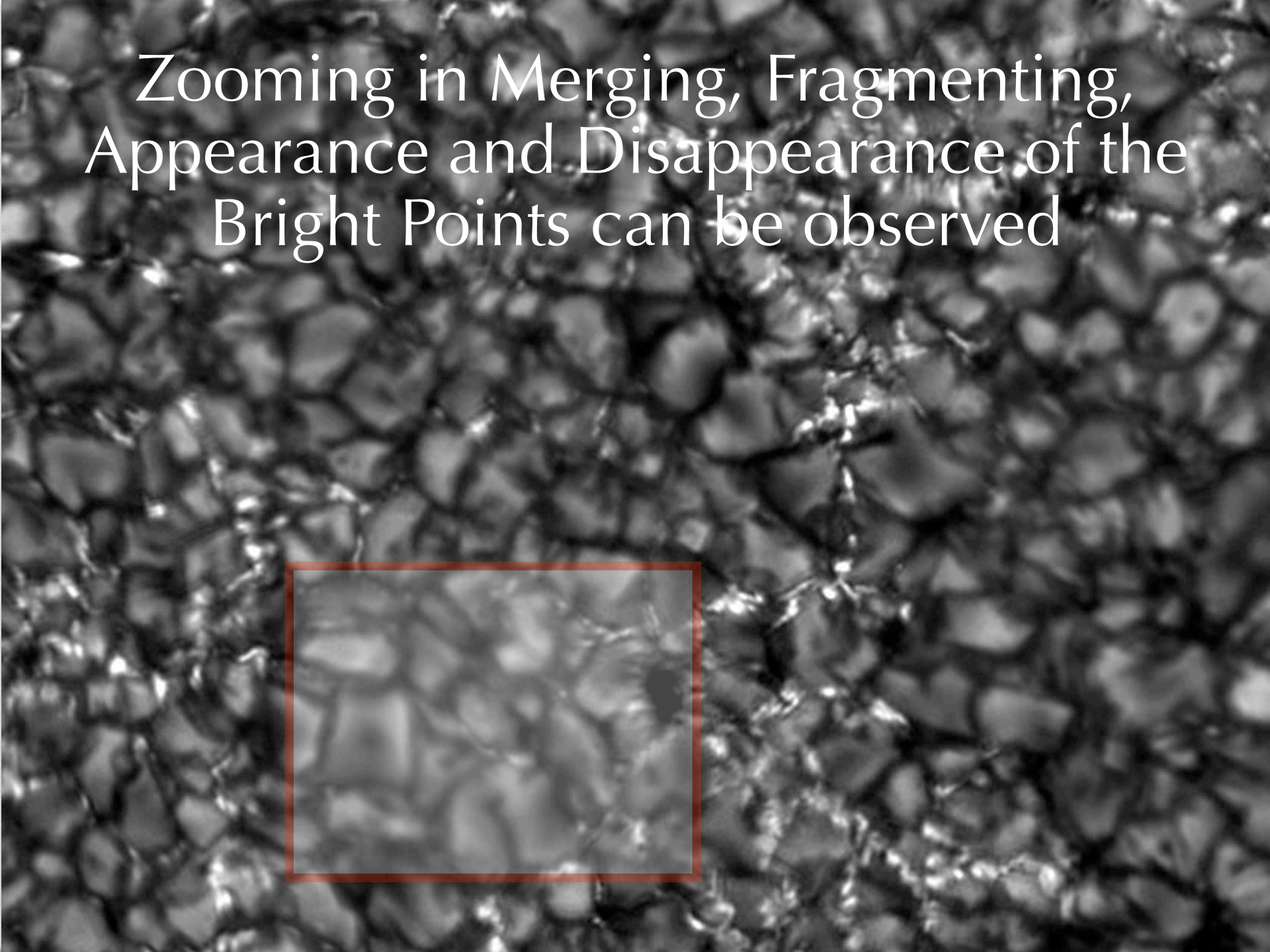


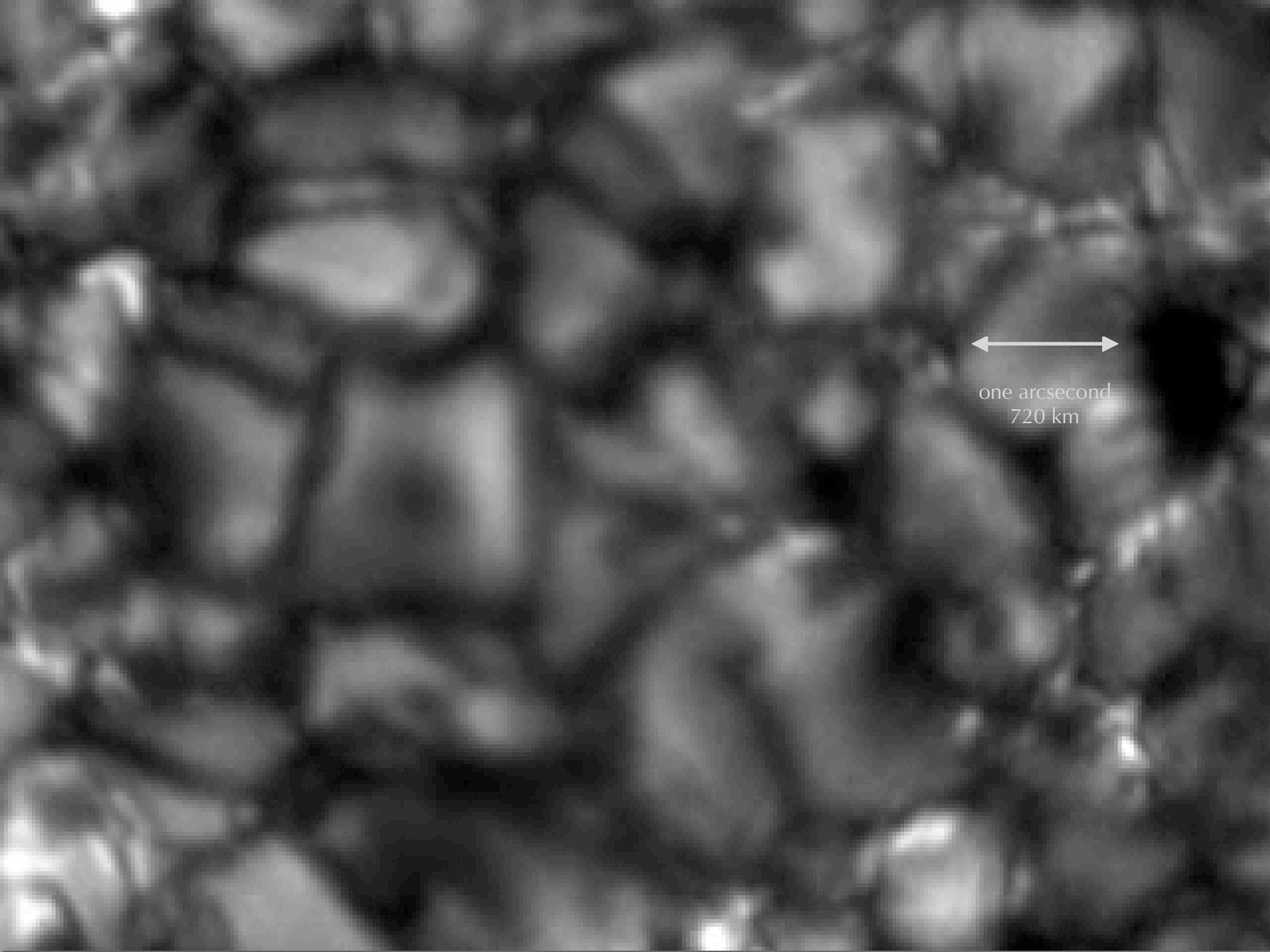
From: Simon, Title, Weiss (2001) ApJ 561, 427

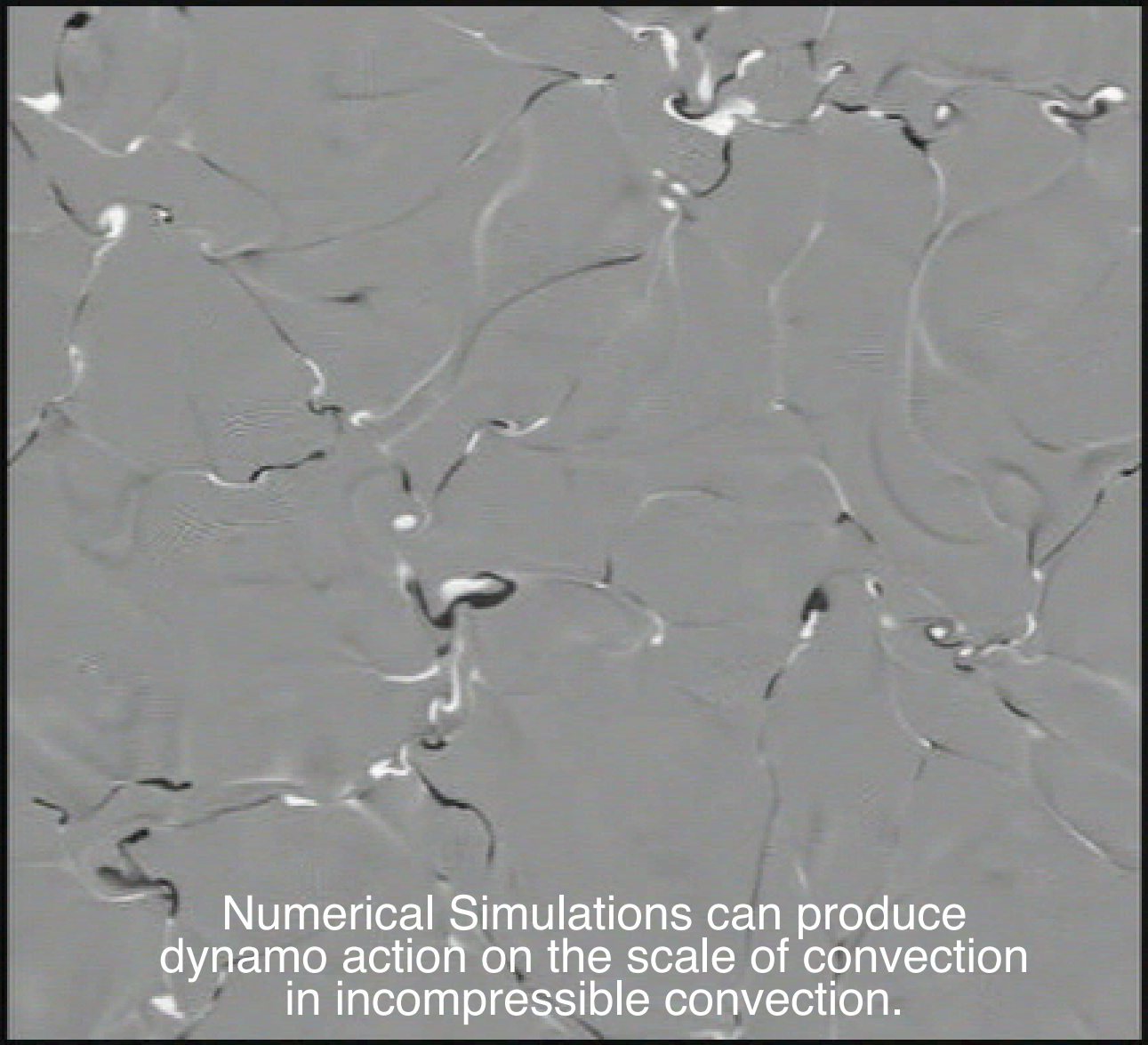


Zooming in the mixture of the scales of magnetic structures can be visualized.

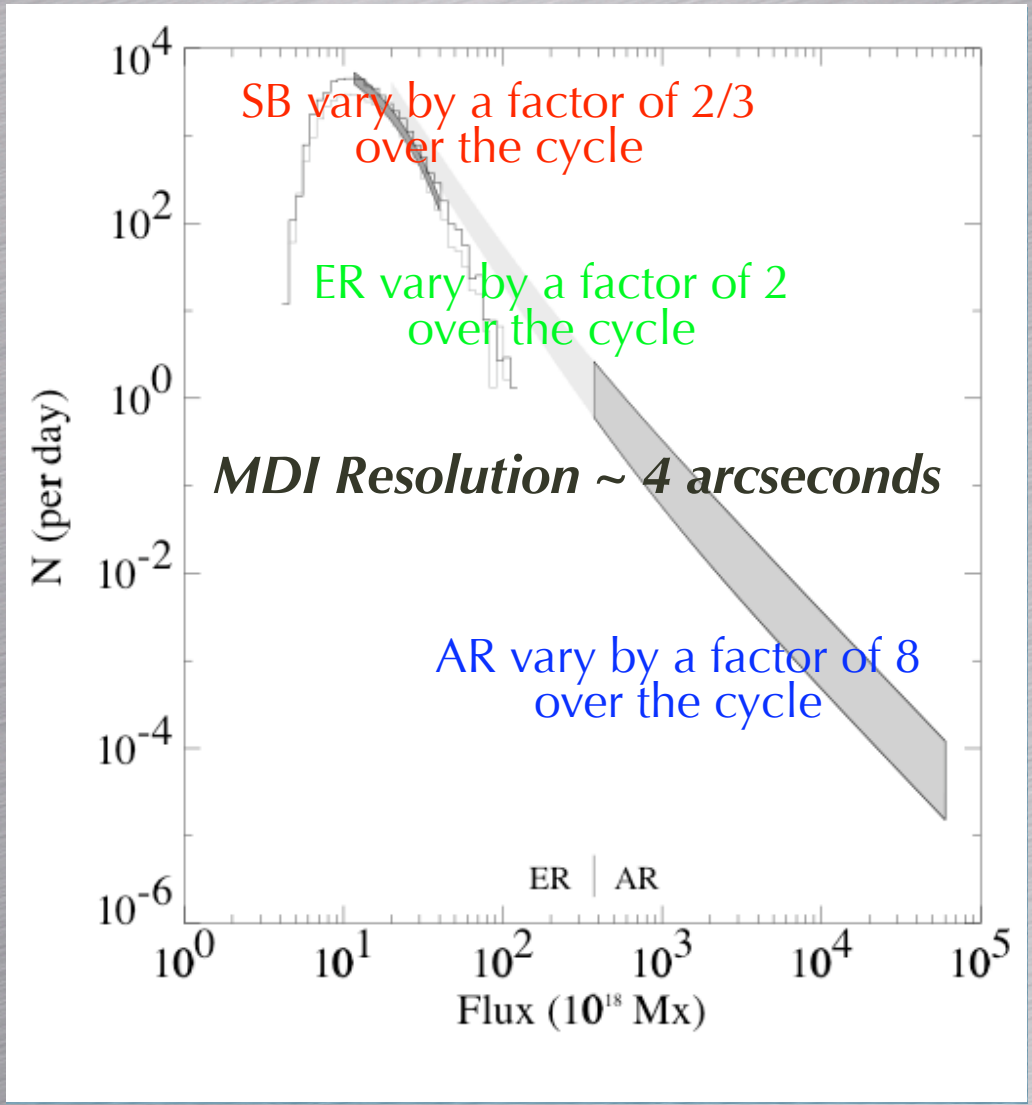

Bright Points indicate Magnetic Field locations


Zooming in Merging, Fragmenting,
Appearance and Disappearance of the
Bright Points can be observed


one arcsecond
720 km

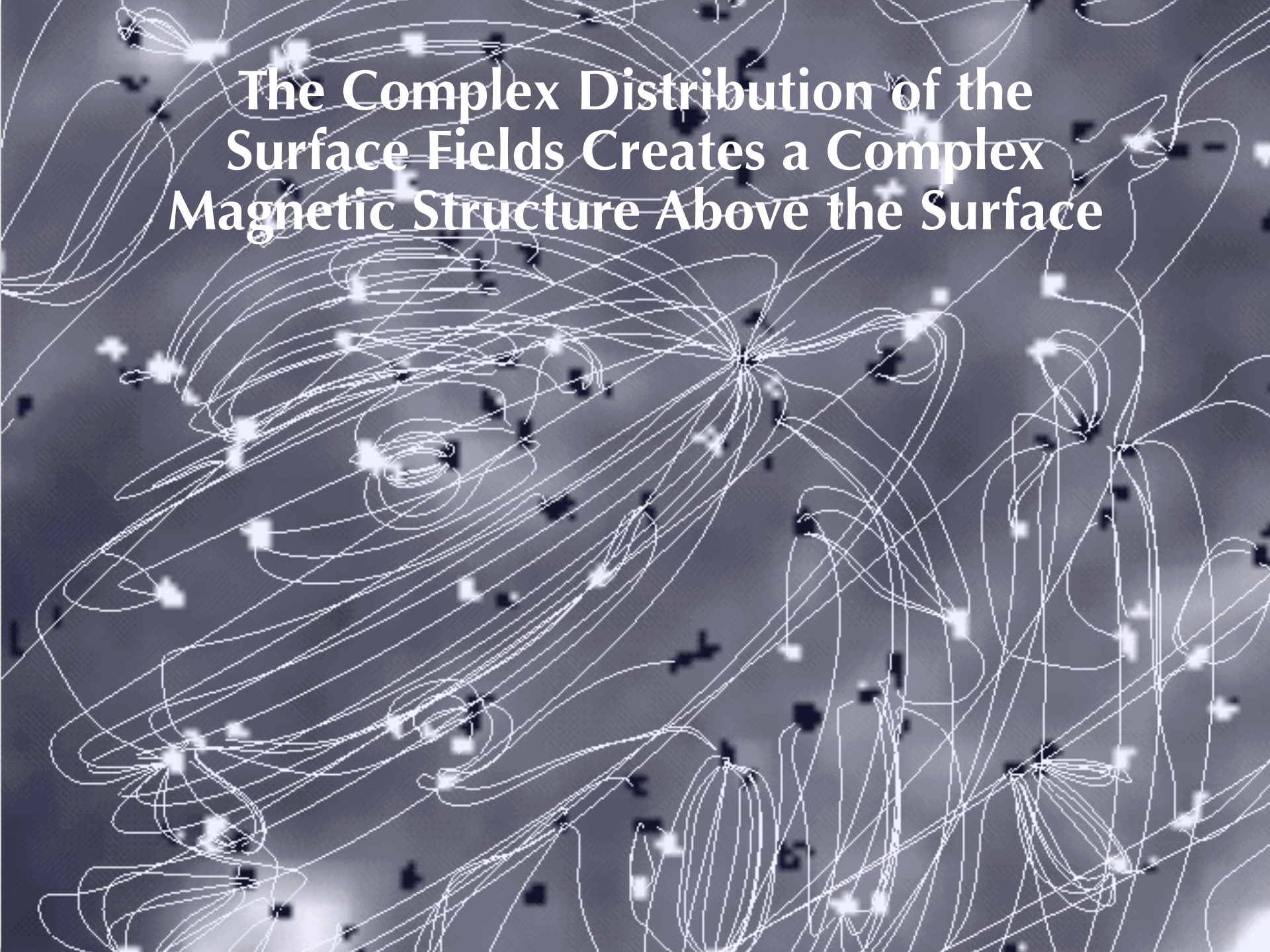

Numerical Simulations can produce
dynamo action on the scale of convection
in incompressible convection.

Distribution Functions of MDI Magnetic Features



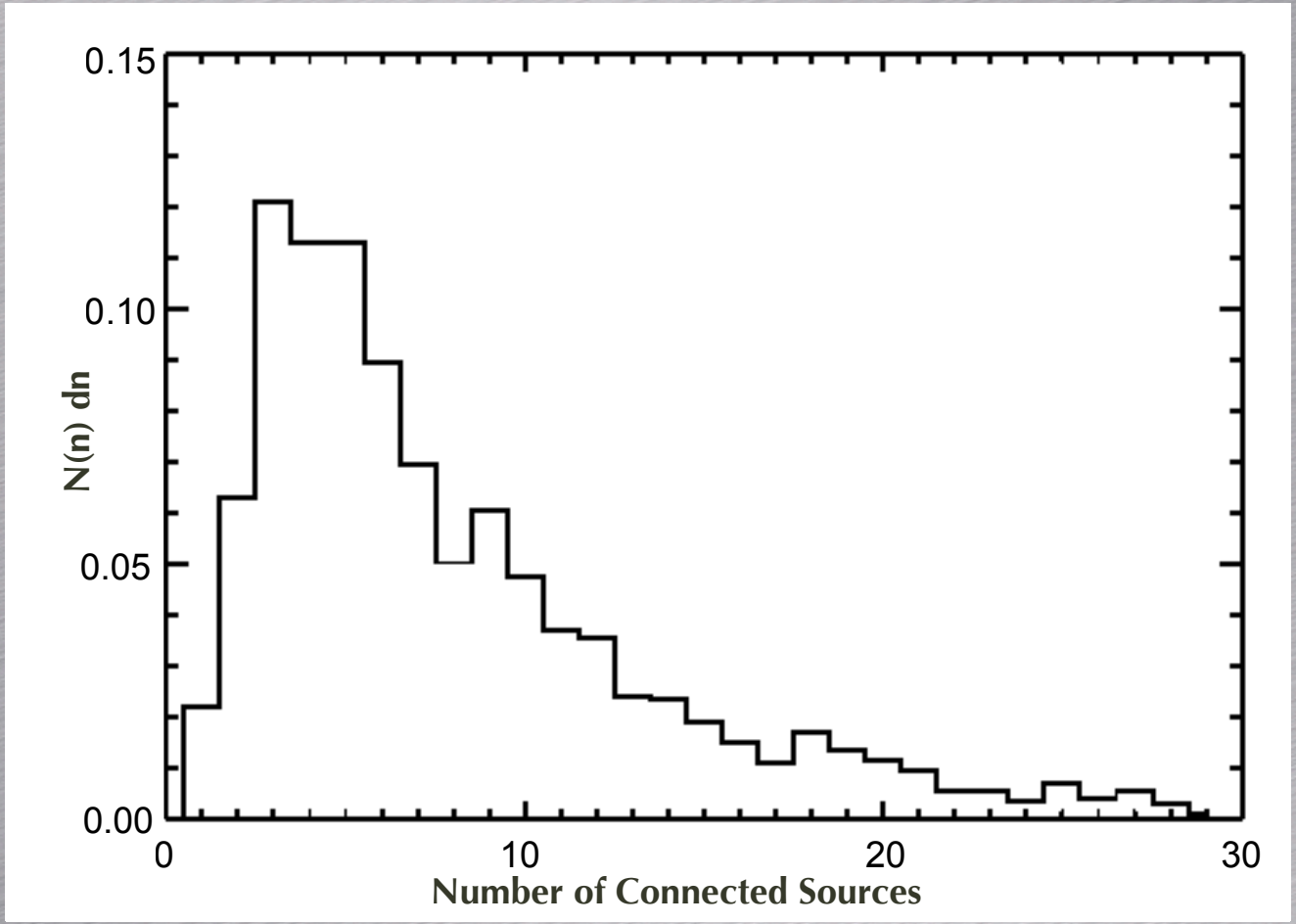
Convection and Large Scale Flows in the Solar Surface Determine the Conditions in the Outer Atmosphere

- Supergranulation with a spatial scale of ~ 20,000 km and a lifetime ~ 24 hours acts to diffuse the magnetic field over the solar surface.
- The large scale meridional flow with a velocity ~ 10 m/s carries flux toward the poles.
- The turbulent convection cells that cover the surface, solar granulation, have a spatial scale of ~1000 km and a lifetime ~ 10 minutes.
- Granules move and maintain the local surface fields in their downflow boundaries. The constant motion merges, fragments, cancels, and braids the field forcing continuous restructuring above the surface.

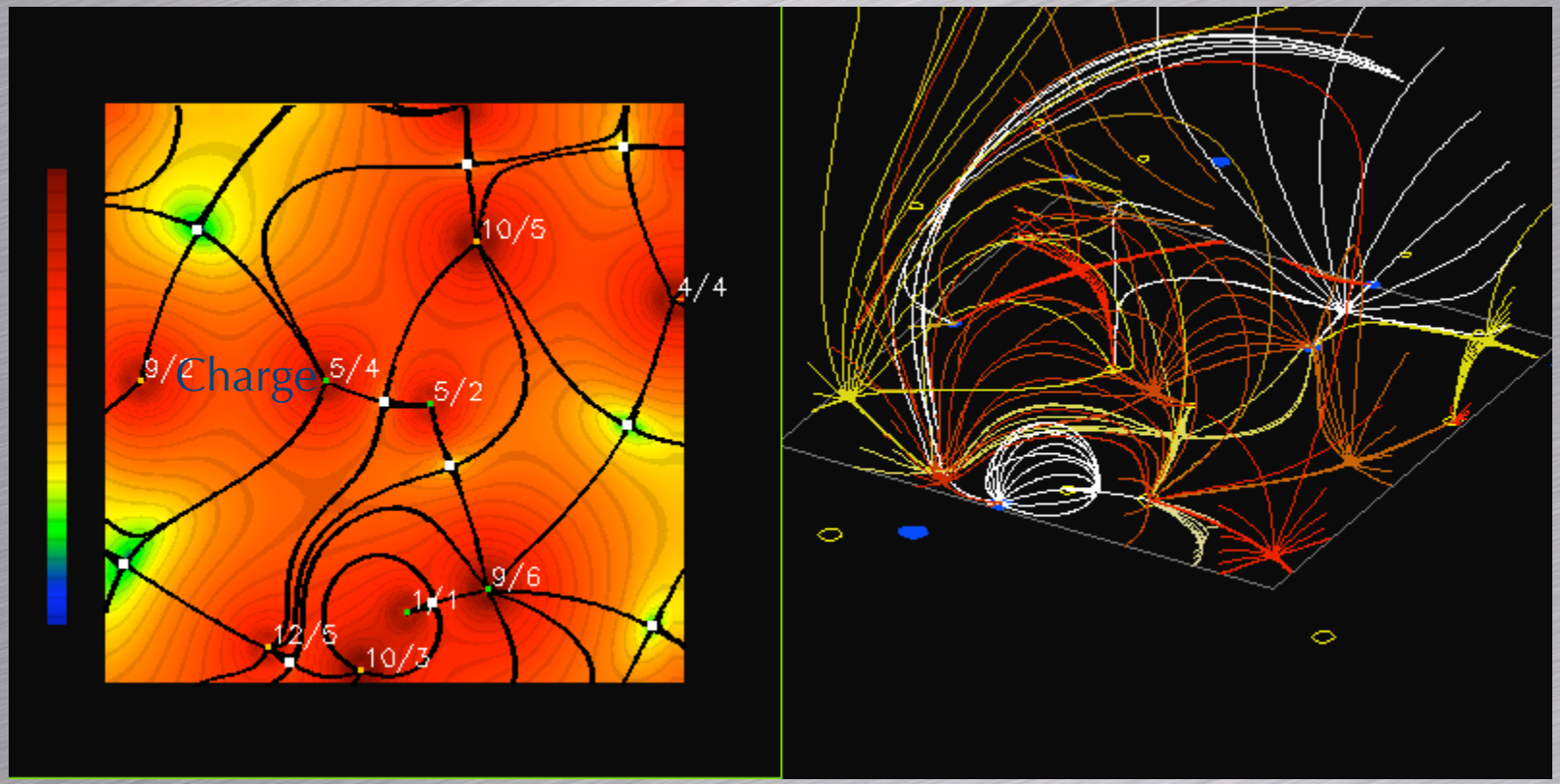

The Complex Distribution of the Surface Fields Creates a Complex Magnetic Structure Above the Surface

Distribution Function of the Number of Sources Connected to Each Source

- Most flux connects to the nearest neighbors.
- A small fraction connects further; that small fraction, however, constitutes most of the high, coronal, magnetic field.

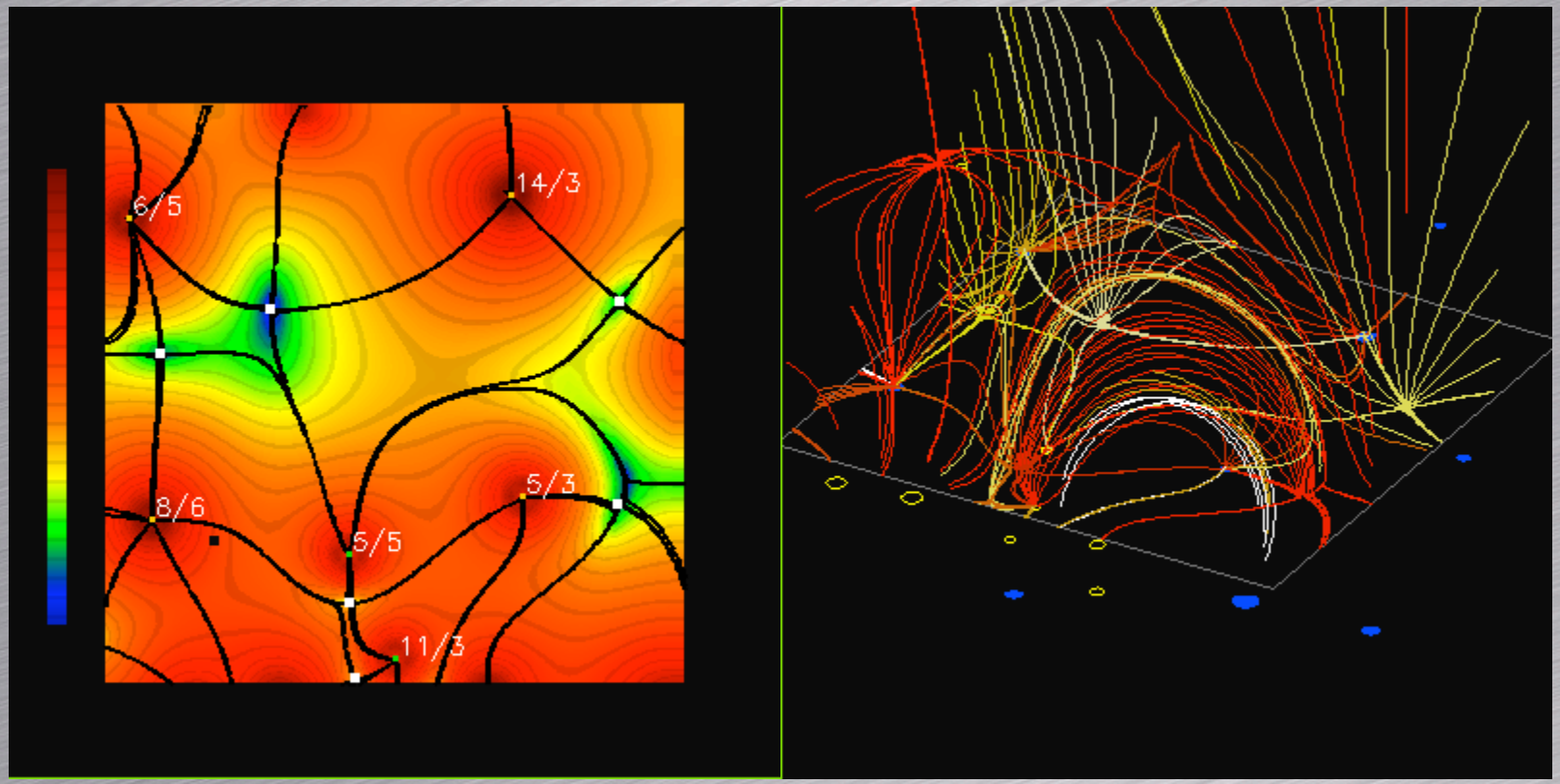


Quiet-Sun Corona Connection Patterns



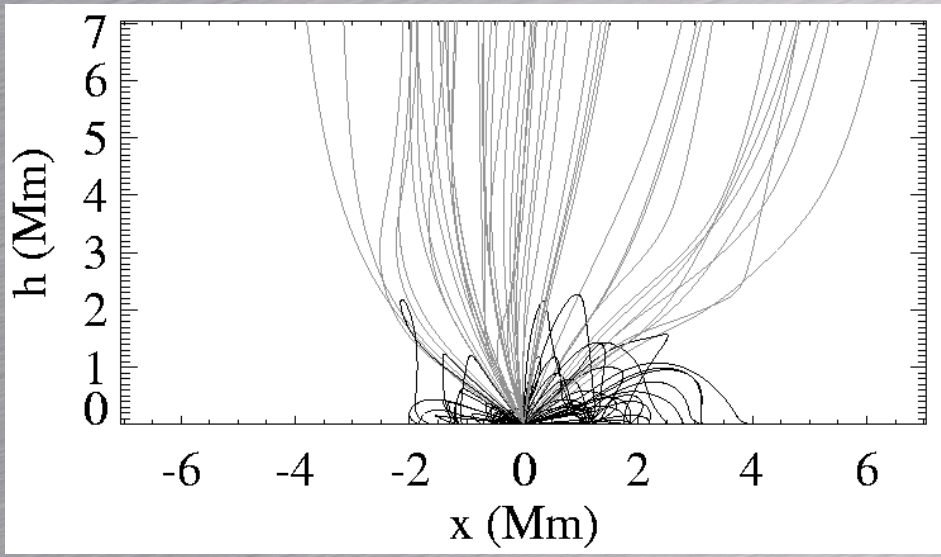
The potential field of a mixed polarity pattern results in a multitude of connections.

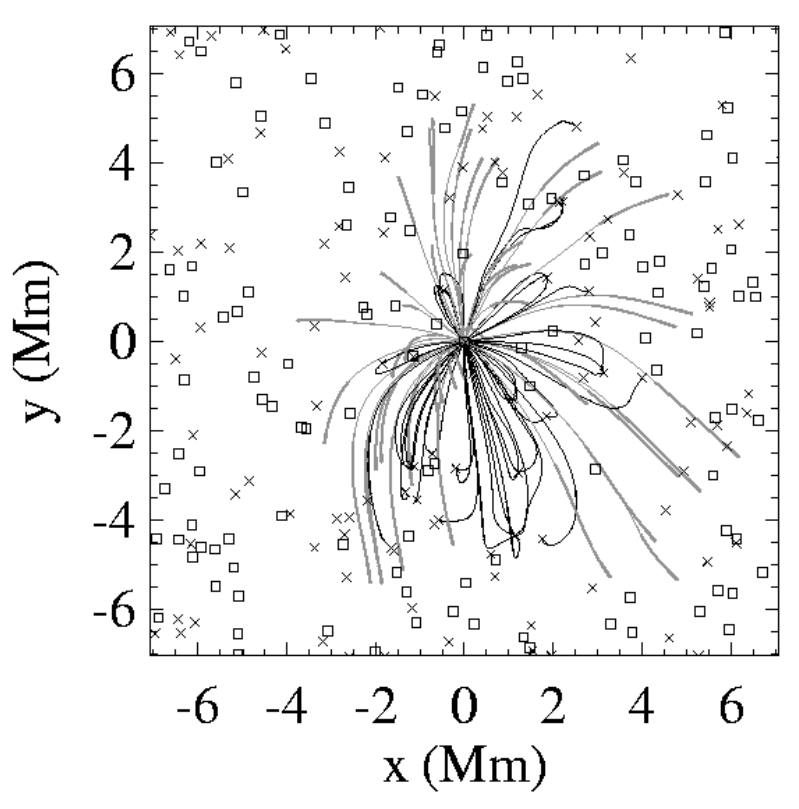
Quiet-Sun Corona Connection Patterns



http://www.lmsal.com/~schryver/Public/TRACE/fieldgeometry

Photosphere-Corona Magnetic Connection

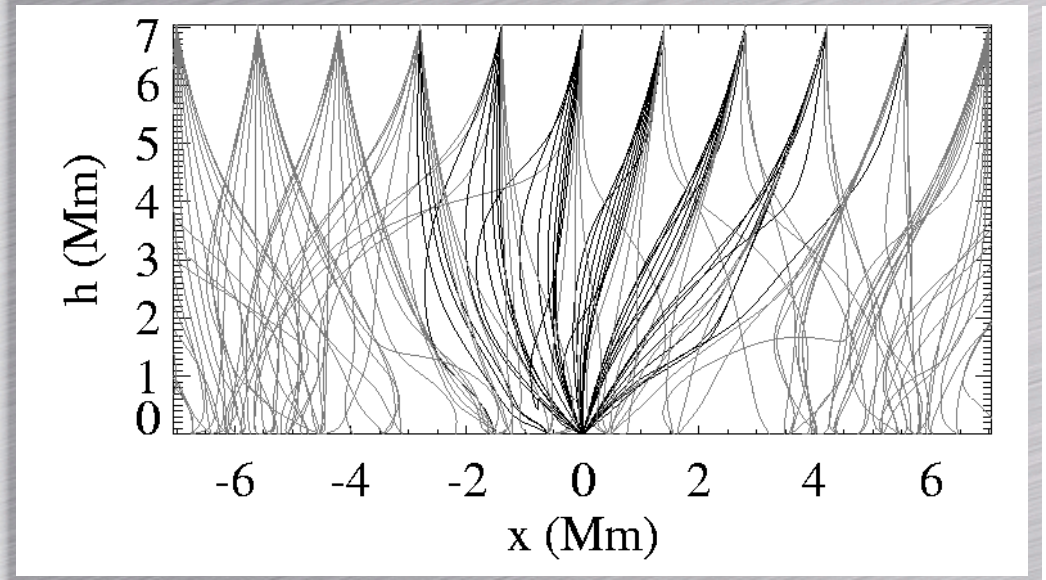


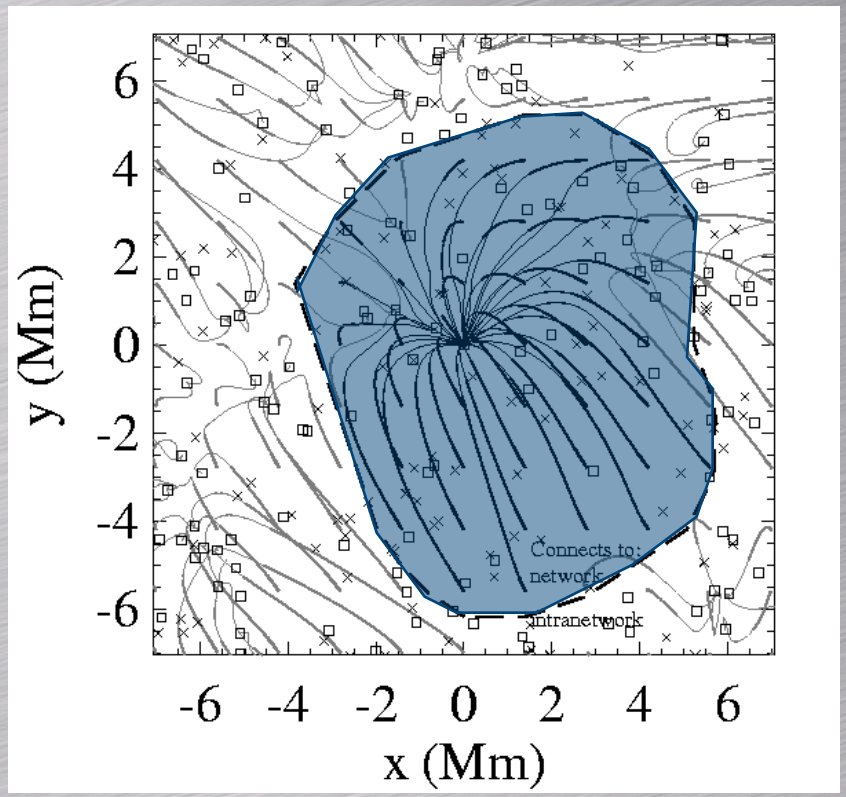


Potential field above unipolar network and mixed-polarity intranetwork; side and top view. These plots show fields starting from the solar surface.

The "intranetwork" field steals flux from the network, creating a field geometry that is inconsistent with the classical canopy concept.

Photosphere-Corona Magnetic Connection



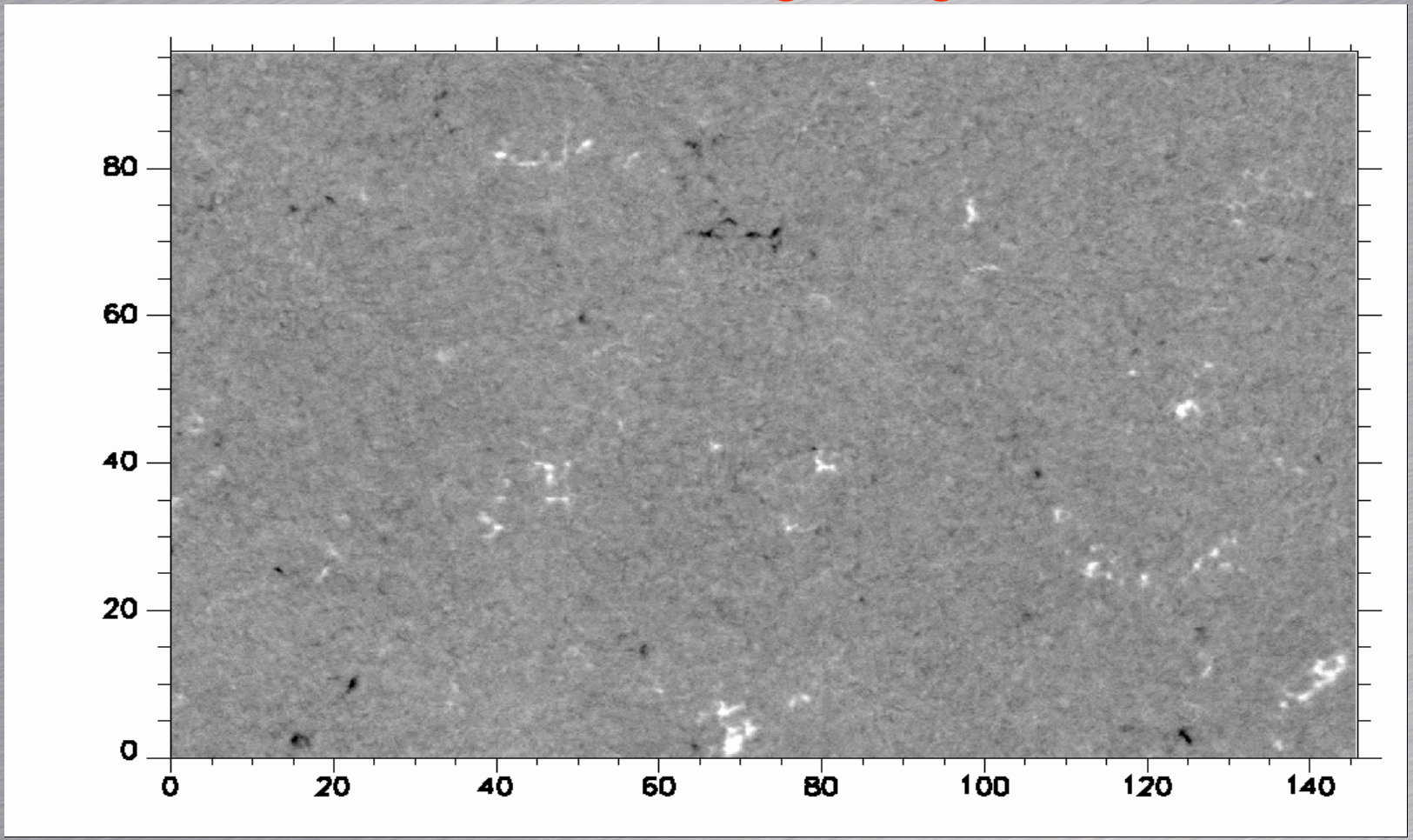


Potential field above unipolar network and mixed-polarity intranetwork; side and top view. These plots show field lines starting well above the surface.

The "intranetwork" field steals flux from the network, creating a field geometry that is inconsistent with the classical canopy concept.

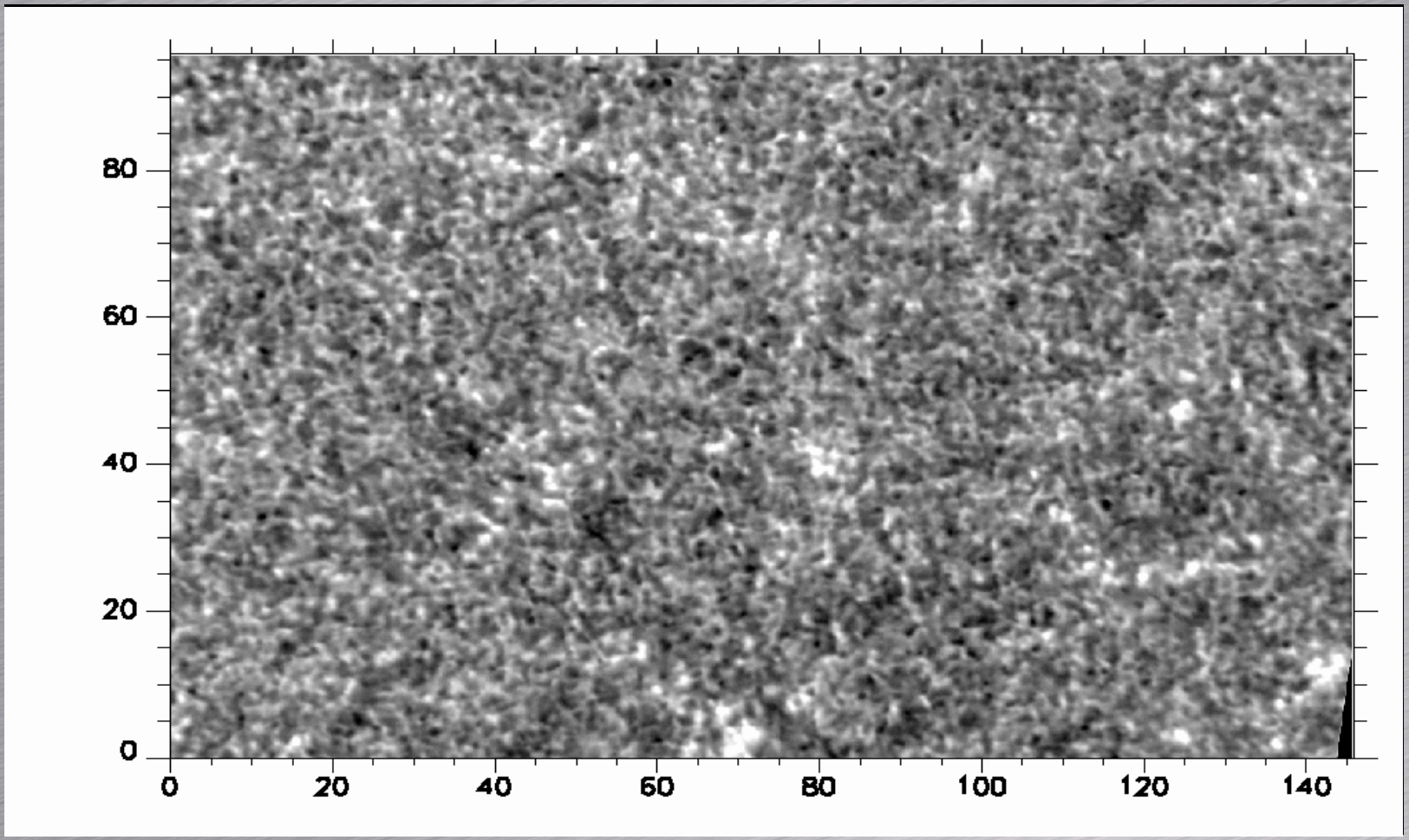
Observational Consequences

Fe I 6302Å Magnetogram



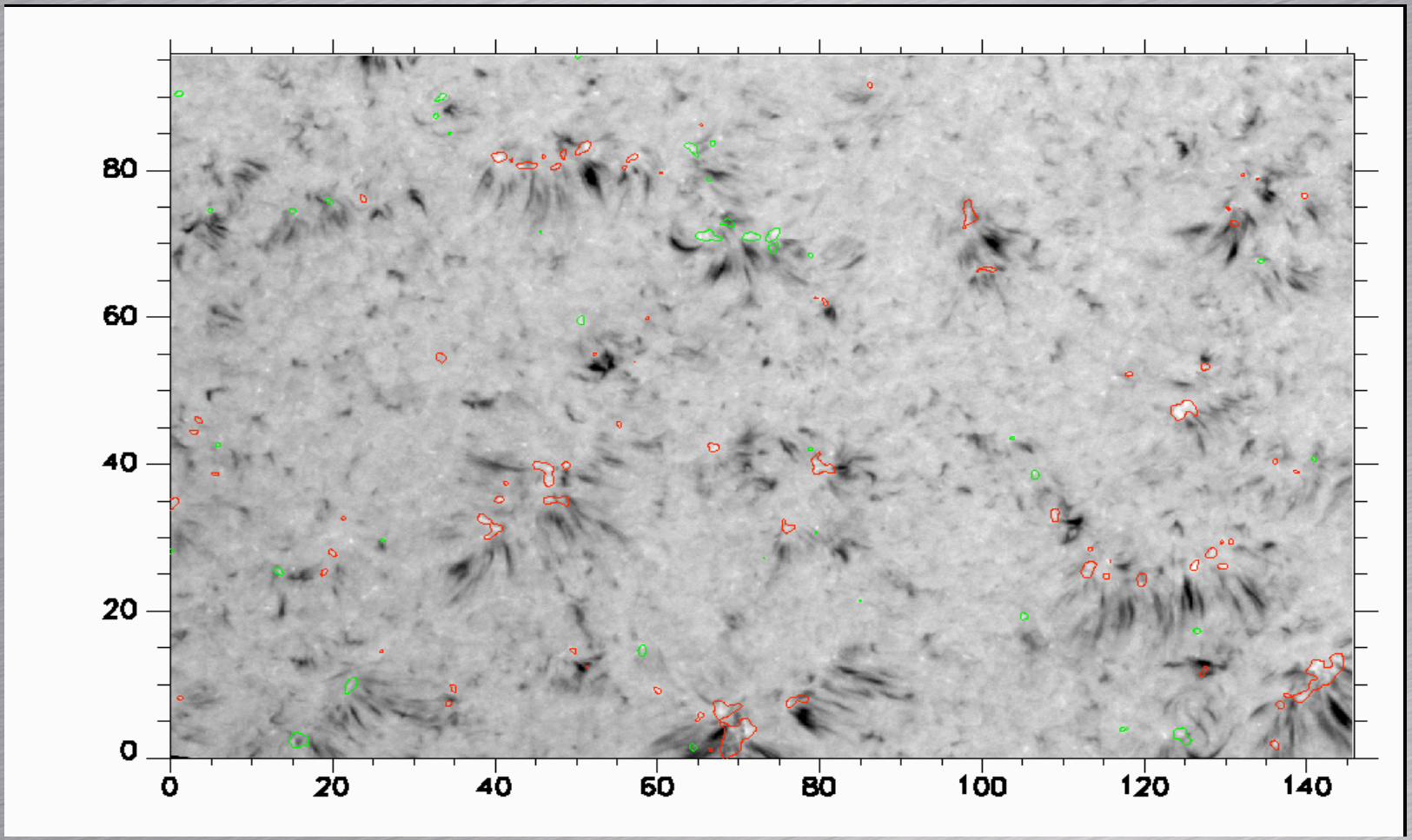
Observational Consequences

Ca II K-line



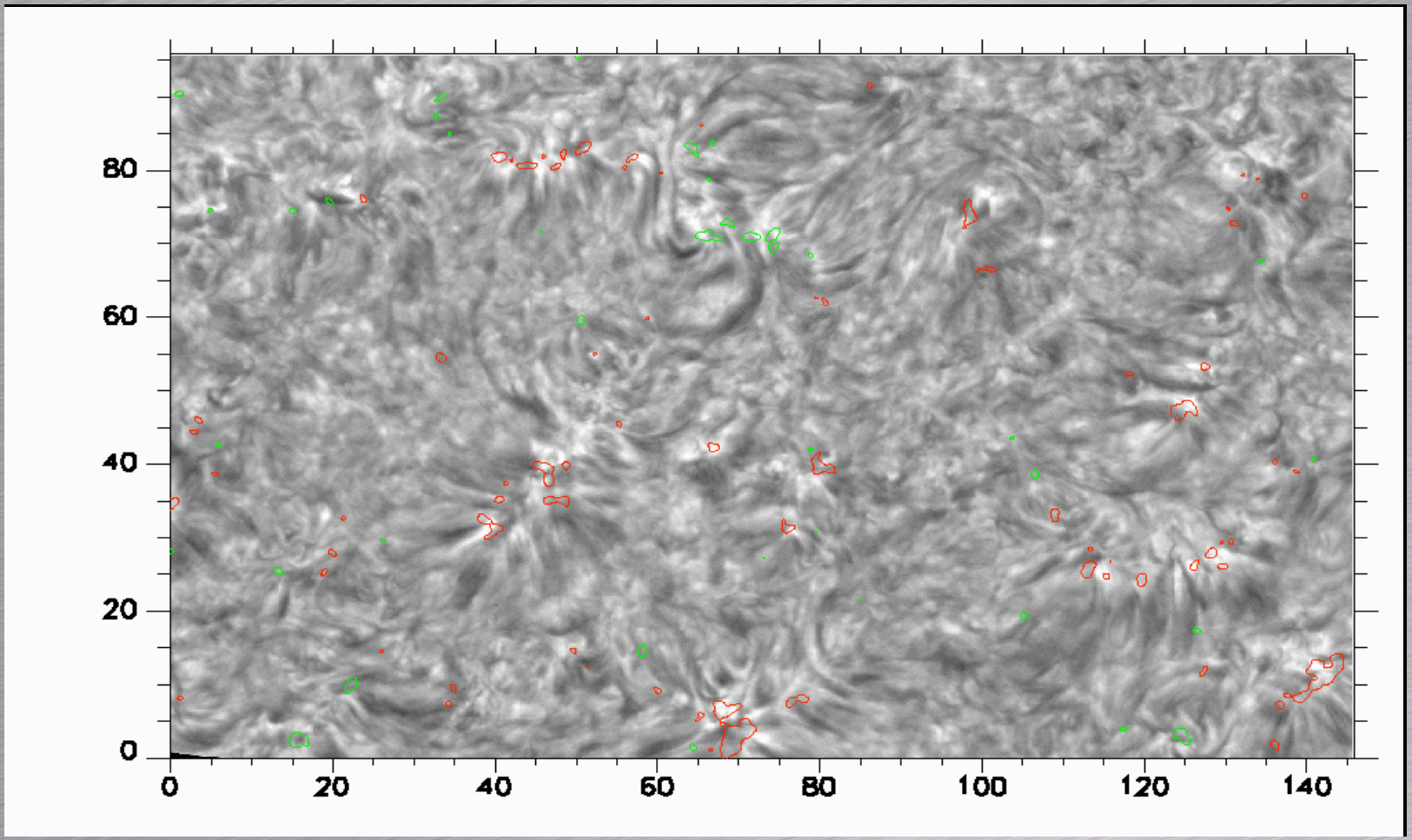
Observational Consequences

Hα -700 mÅ

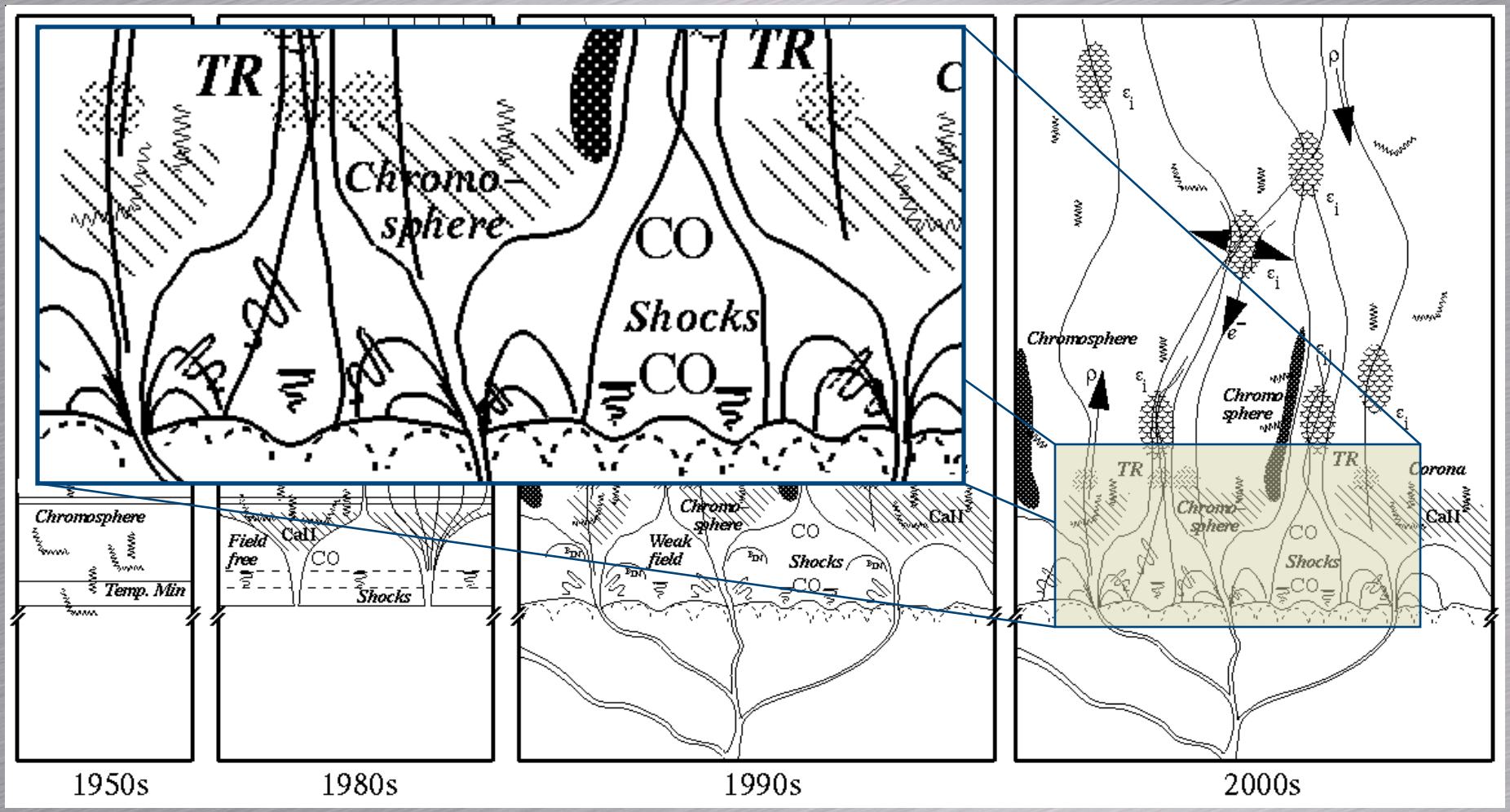


Observational Consequences

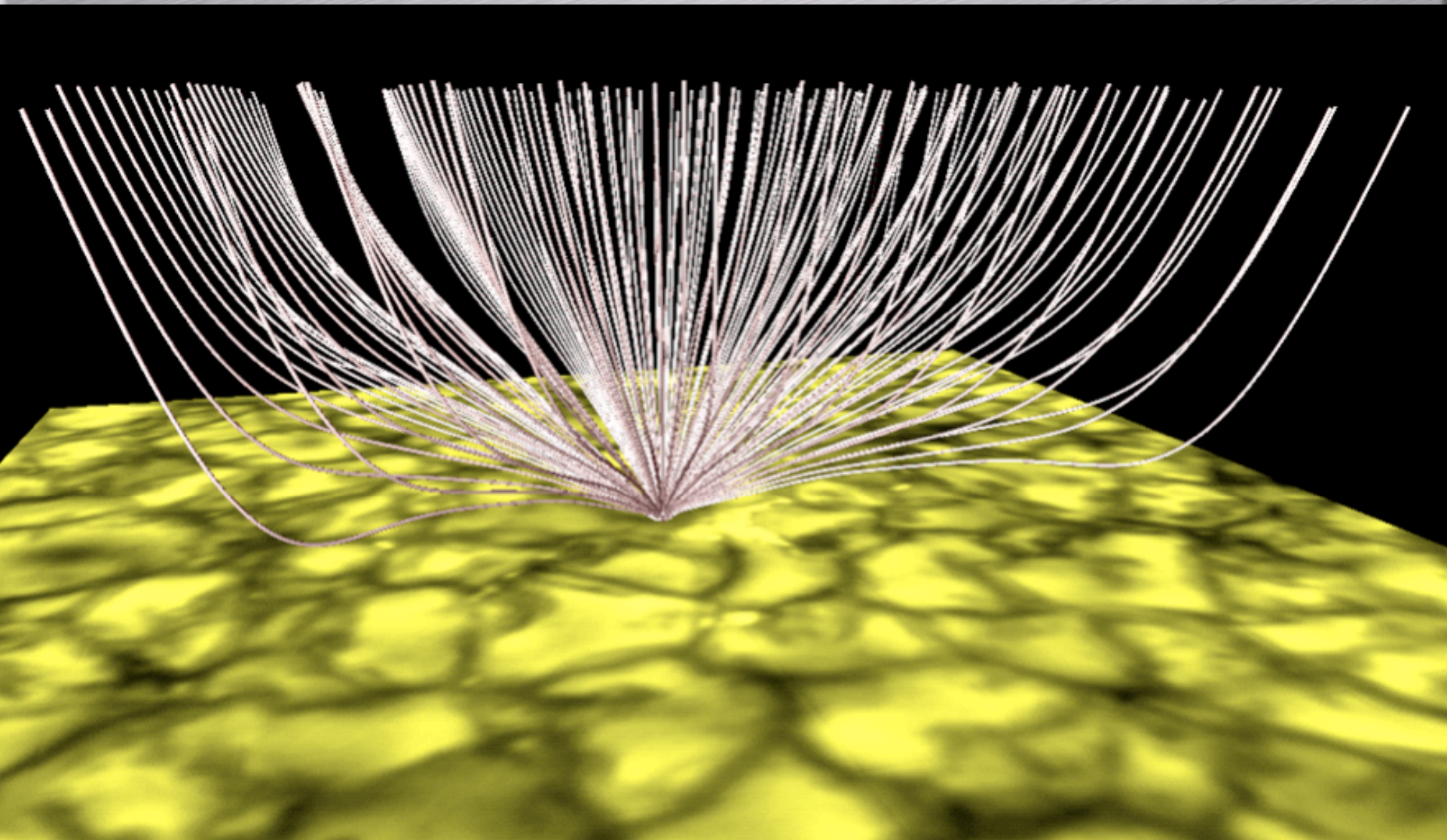
Hα line center



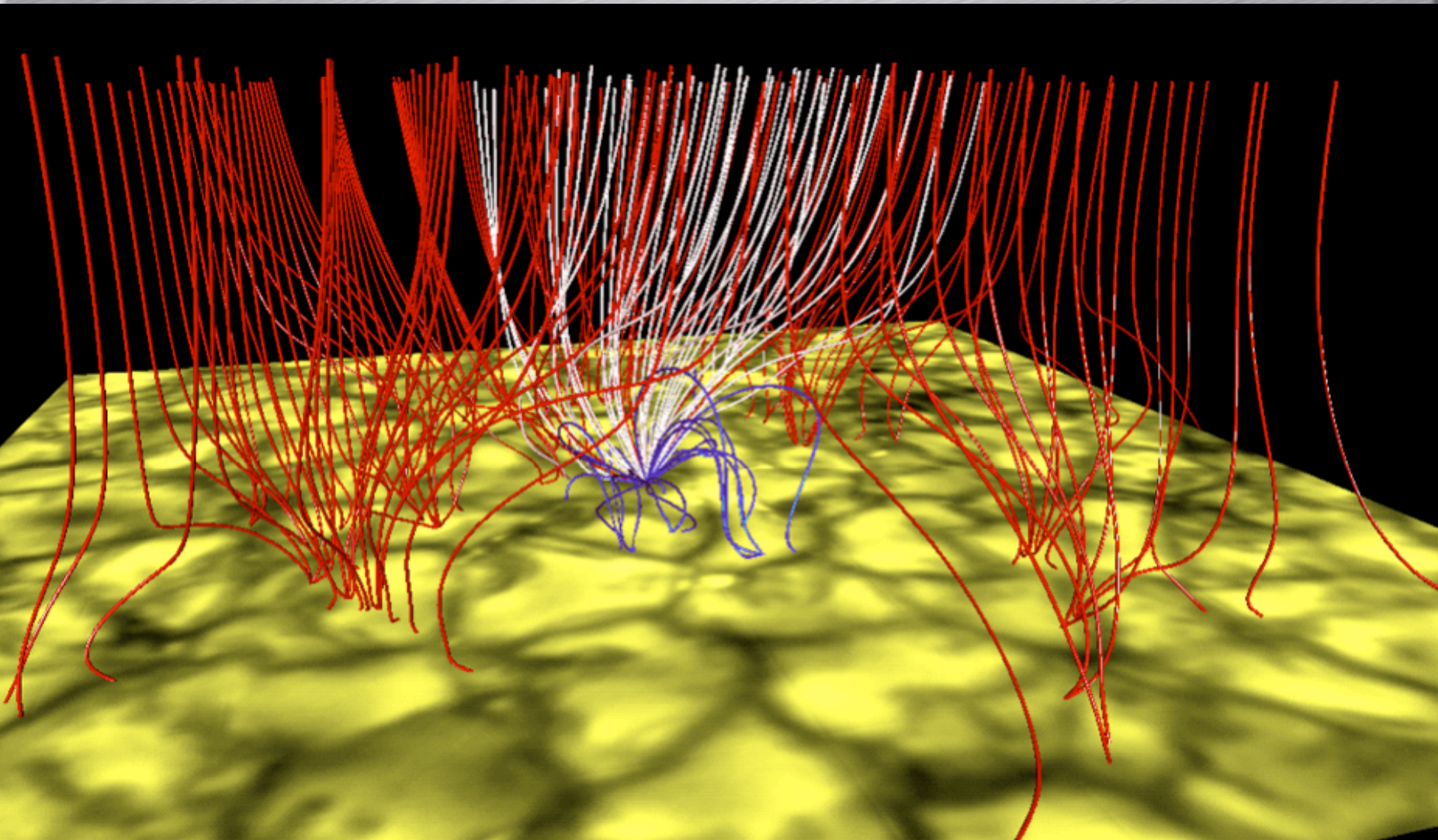
Our Changing View



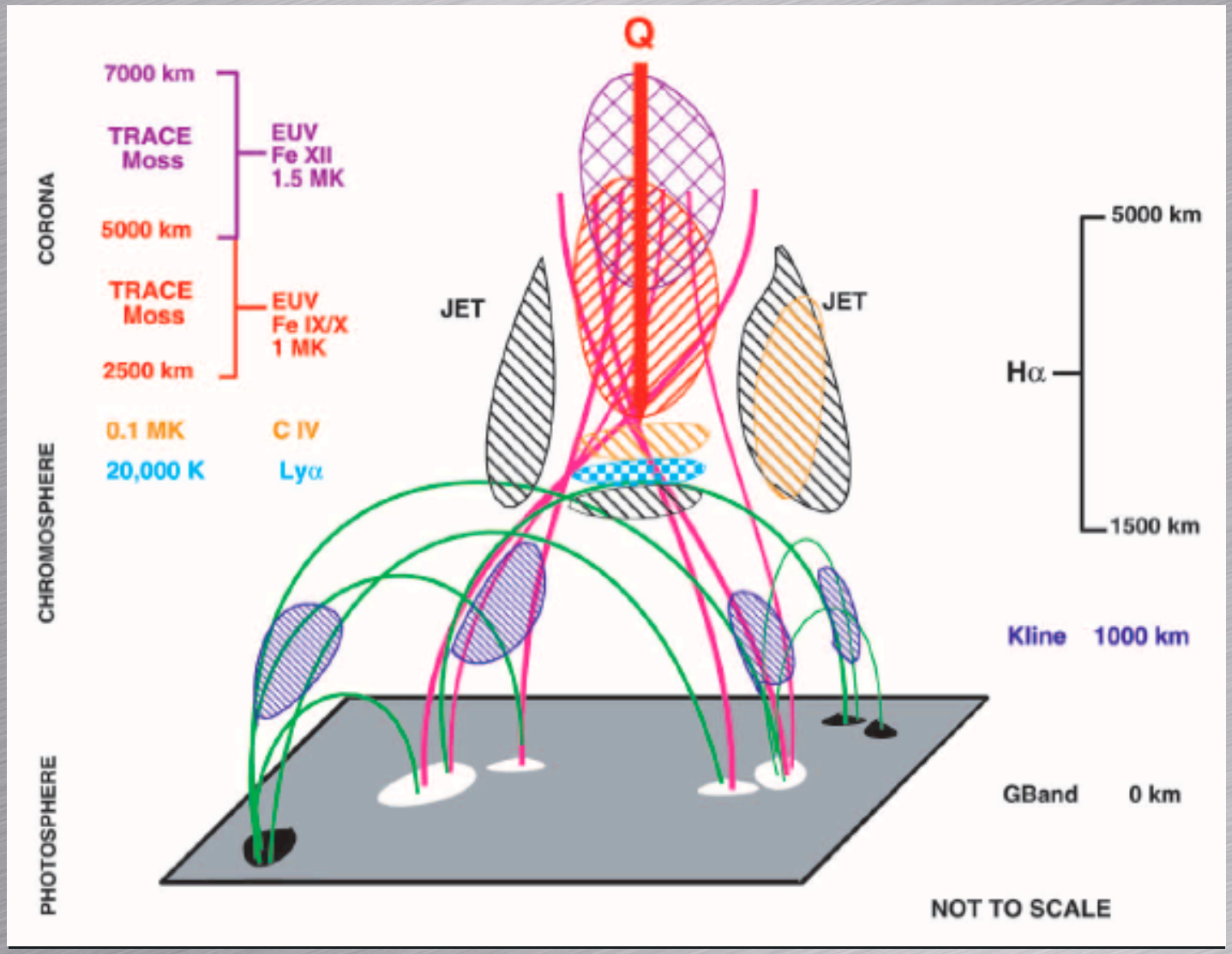
Old View of the Surface-Corona Connection

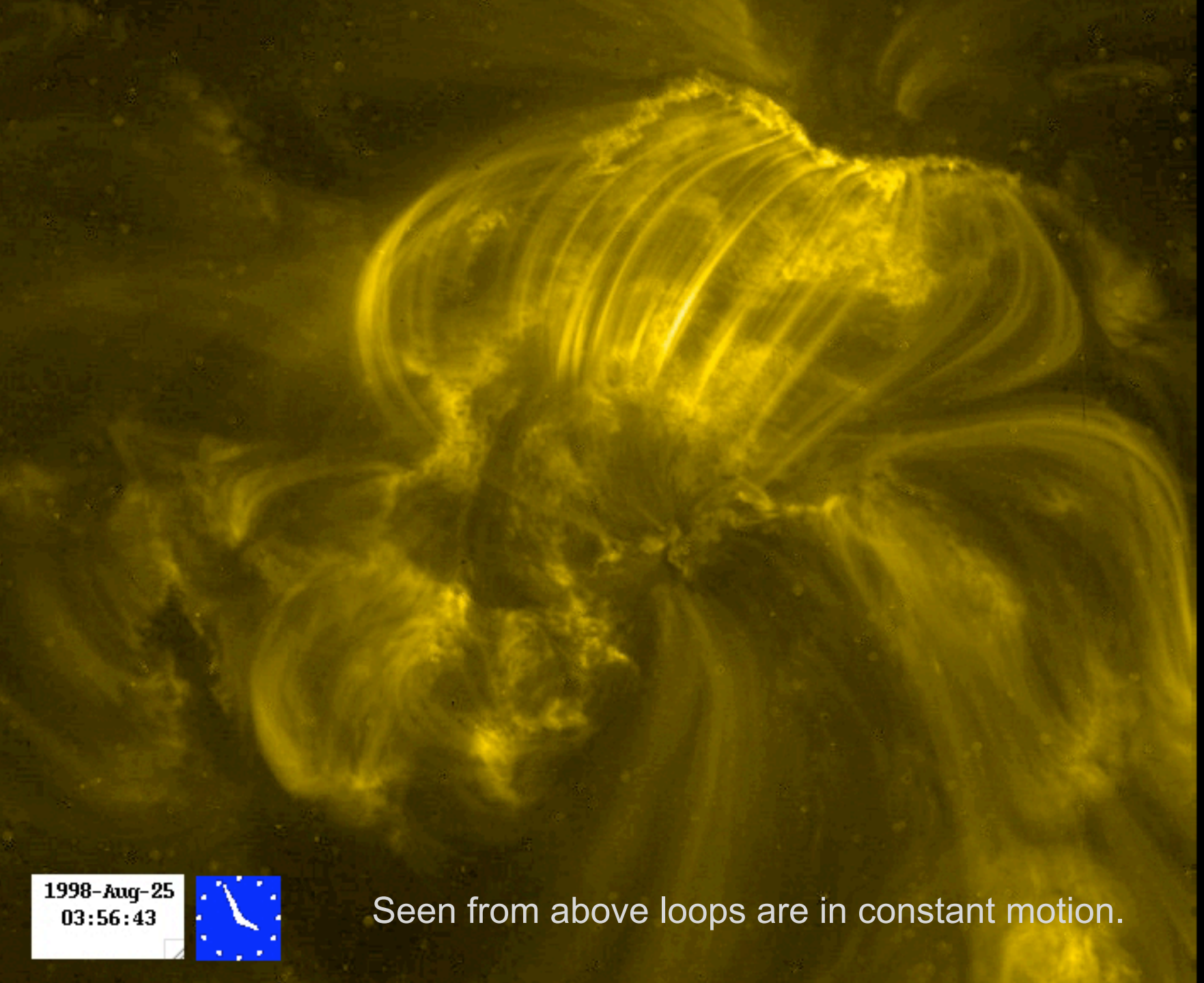


New View of the Surface-Corona Connection

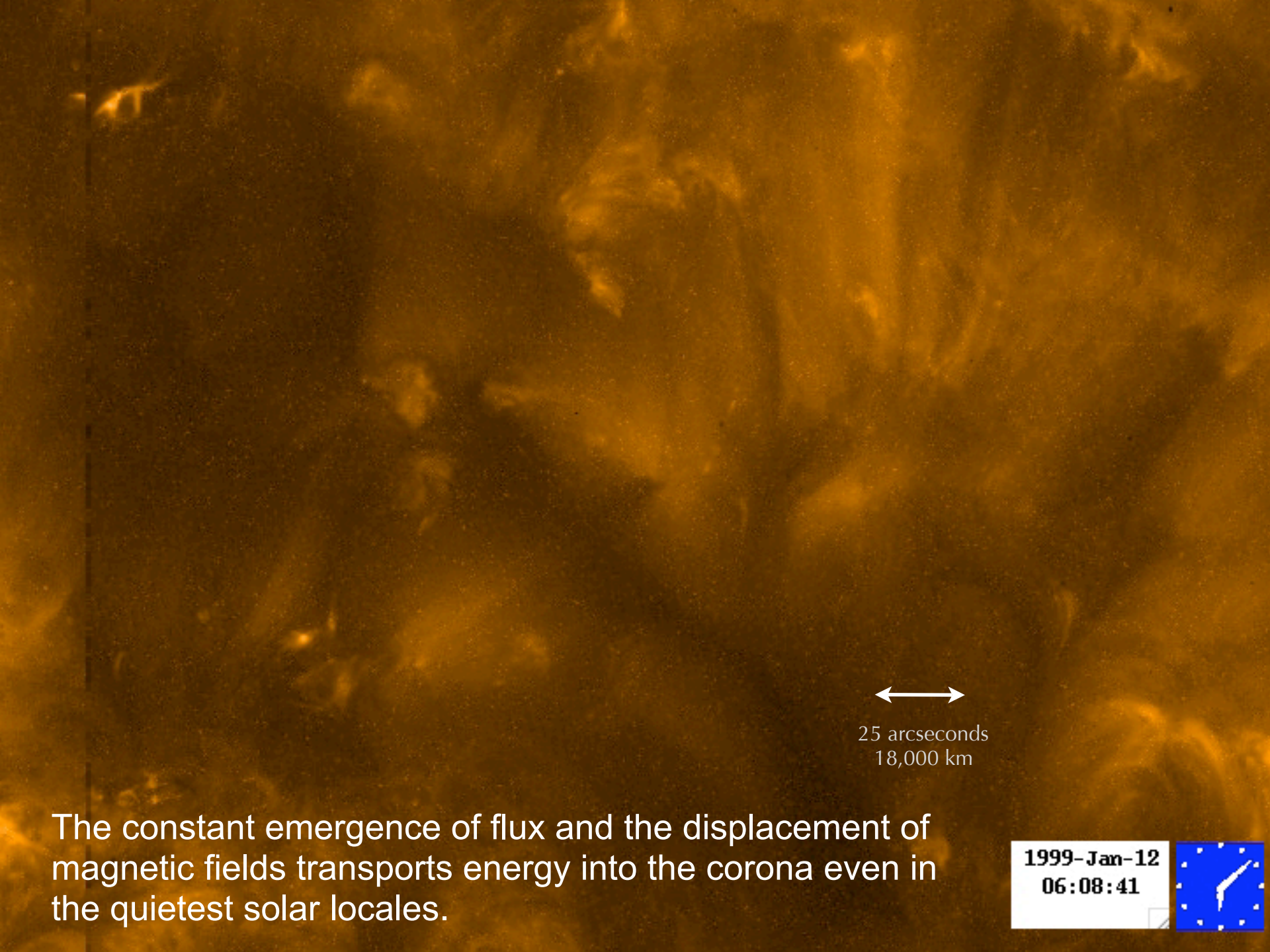


Schematic Picture of the Connection between Surface and Coronal Fields

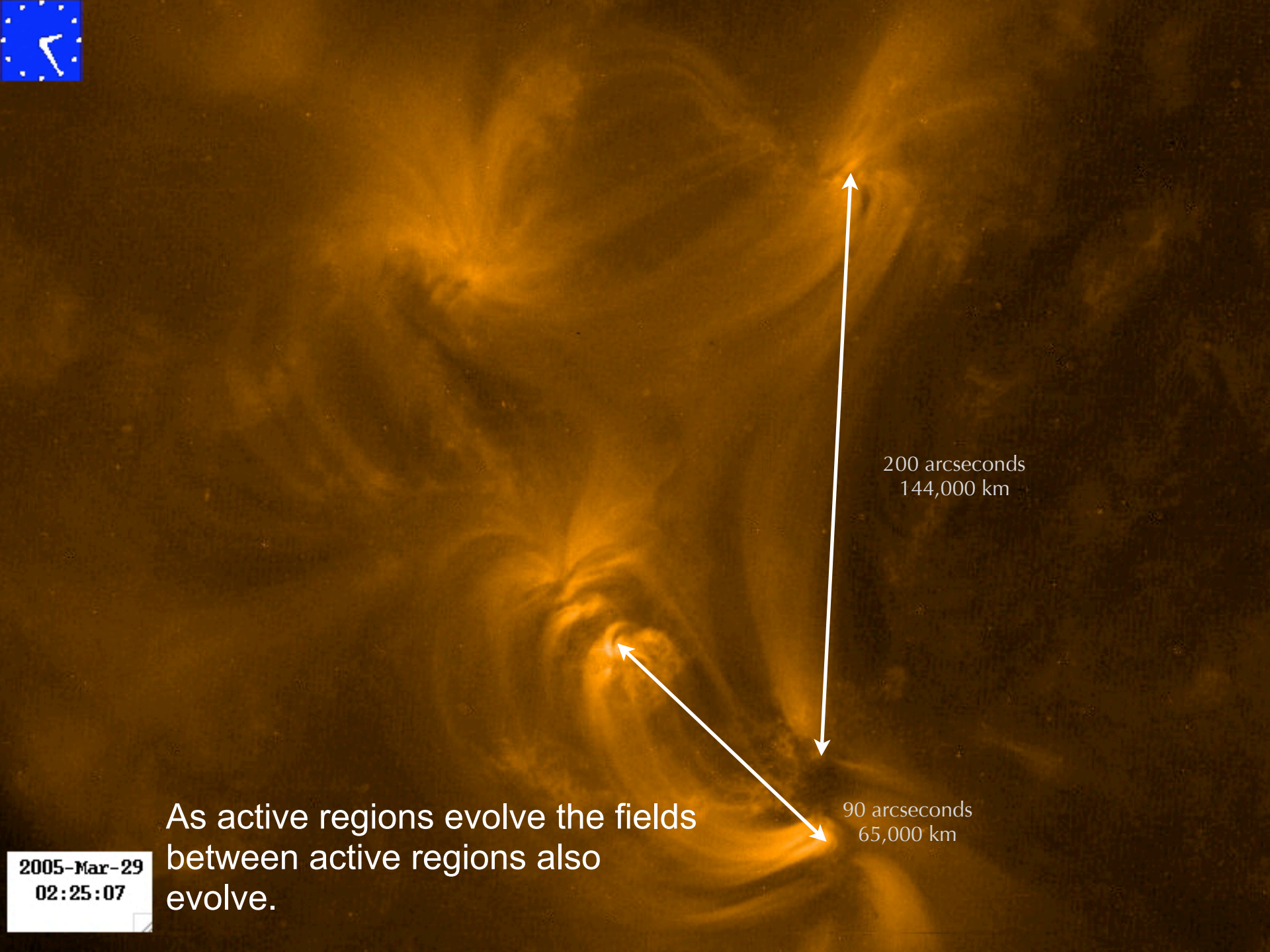




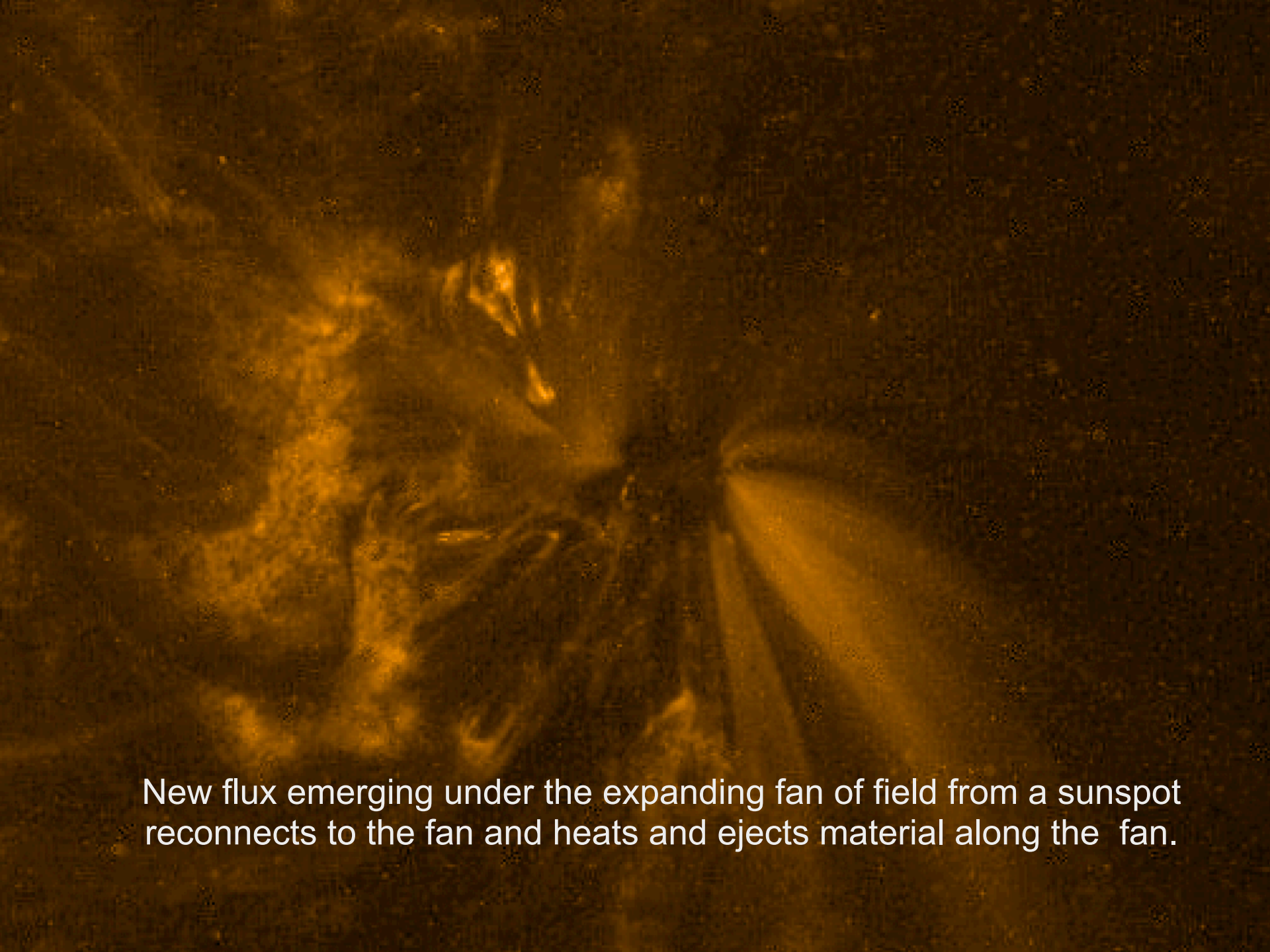
Seen from above loops are in constant motion.



The constant emergence of flux and the displacement of magnetic fields transports energy into the corona even in the quietest solar locales.



As active regions evolve the fields between active regions also evolve.



New flux emerging under the expanding fan of field from a sunspot reconnects to the fan and heats and ejects material along the fan.

Conclusions

- Flux concentrations live for minutes, hours to days, then cancel, fragment, or coalesce. Their apparent lifetime is a strong function of resolution.
- Flux concentrations contain a mixture of field strengths and the distribution in any concentration continuously evolves.
- Scales couple efficiently,but probably not immediately.
- "Loops" are ill-defined objects; perhaps bundles of flux domains.
- The magnetic canopy needs re-conceptualization.
- The quiet Sun is remarkably complex. A consistent picture of the quiet Sun is a work in progress.