The Solar Chromosphere

Recent Advances in Determining the Magnetic Fine Structure

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Rocks'n'Stars 2012

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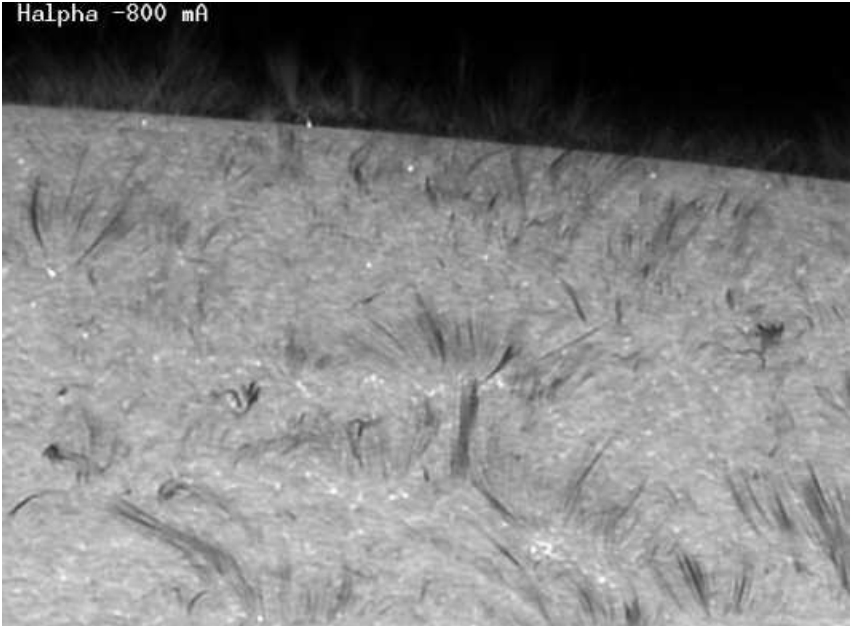
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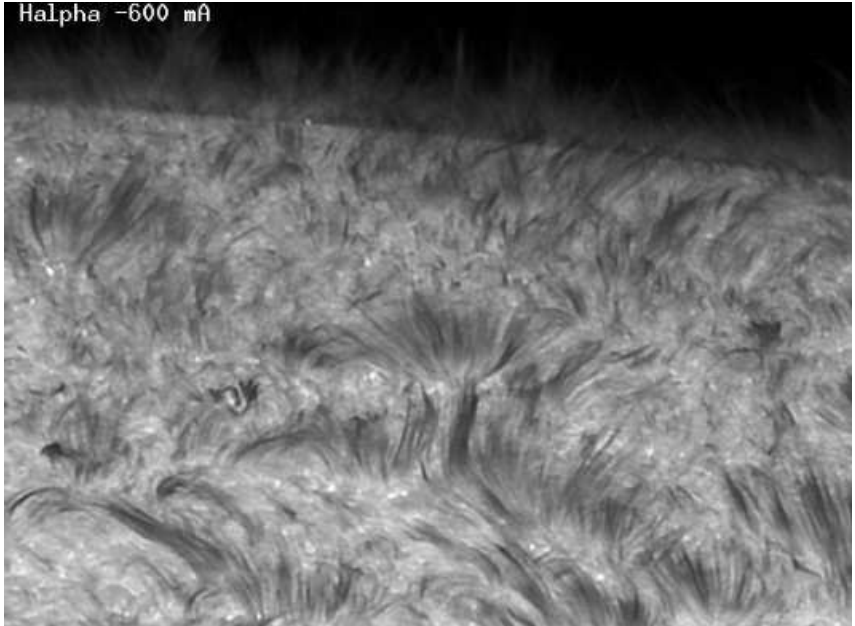
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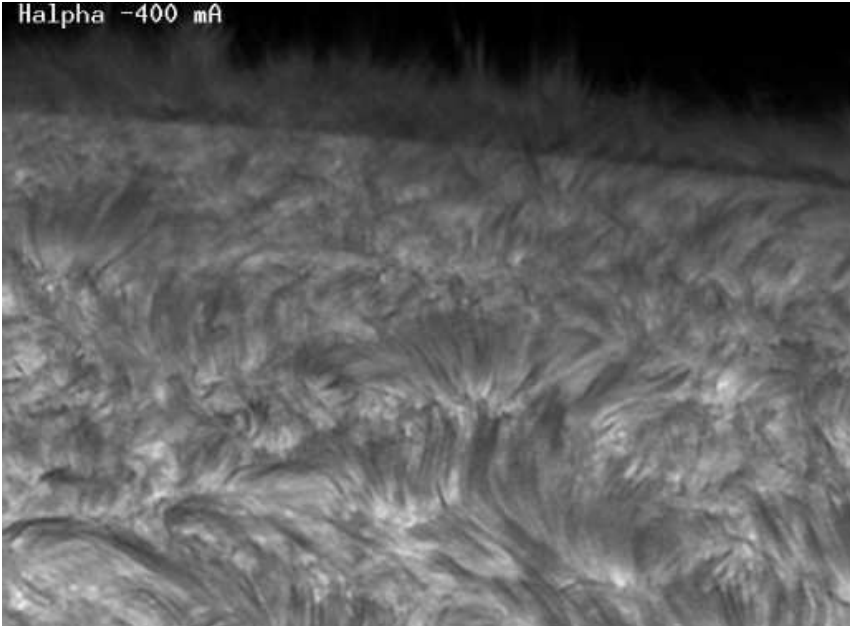
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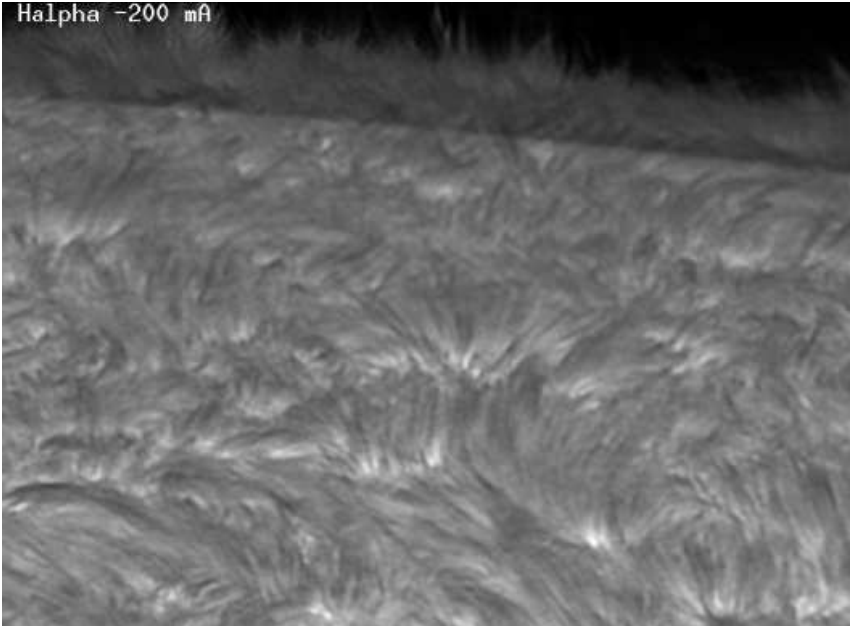
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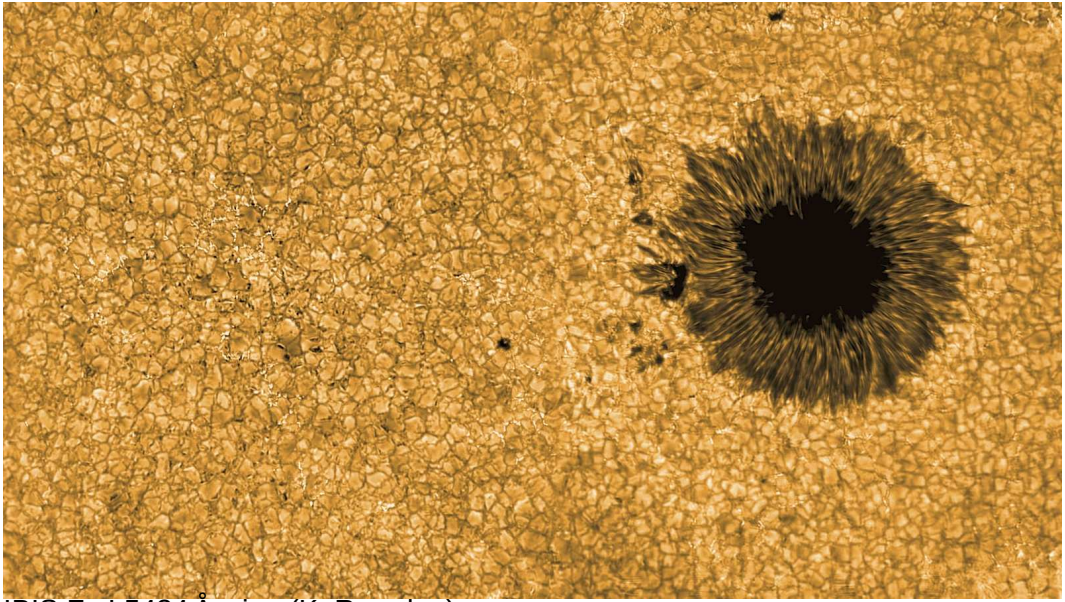
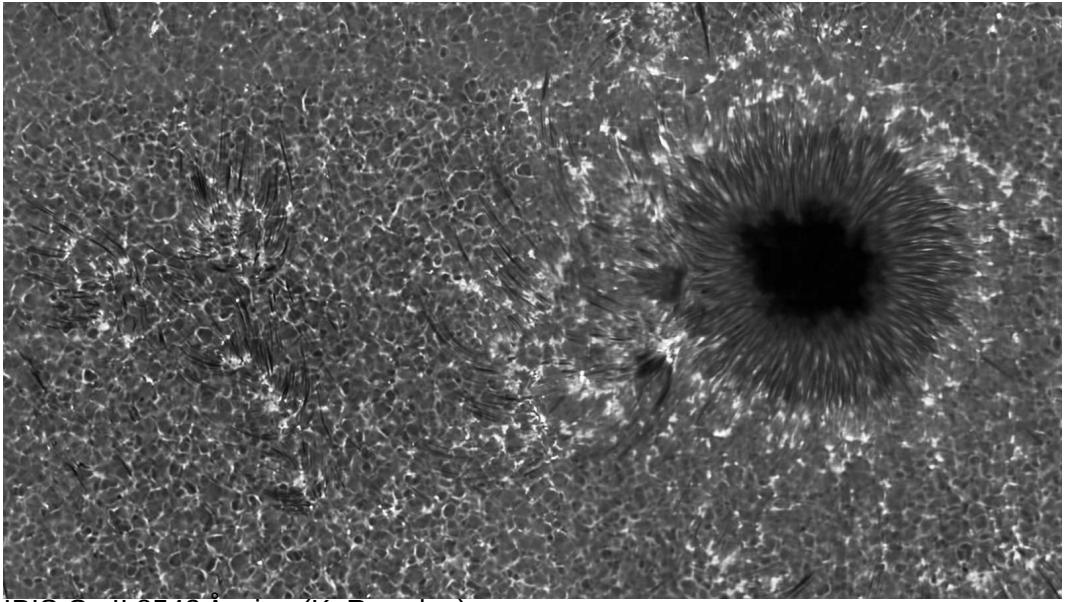
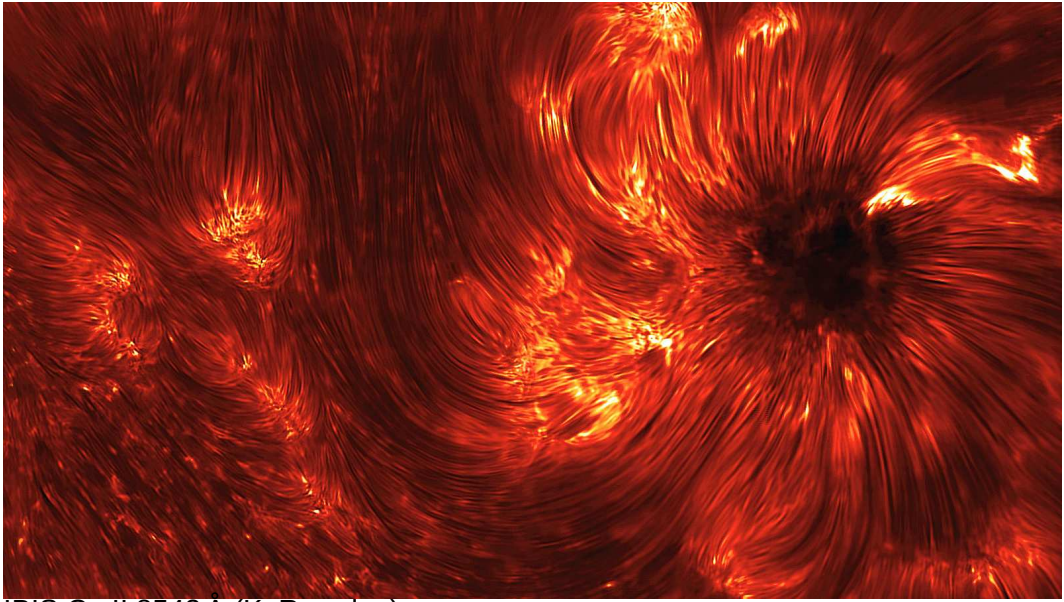


IBIS Fe I 5434 Å wing (K. Reardon)



IBIS Ca II 8542 Å wing (K. Reardon)



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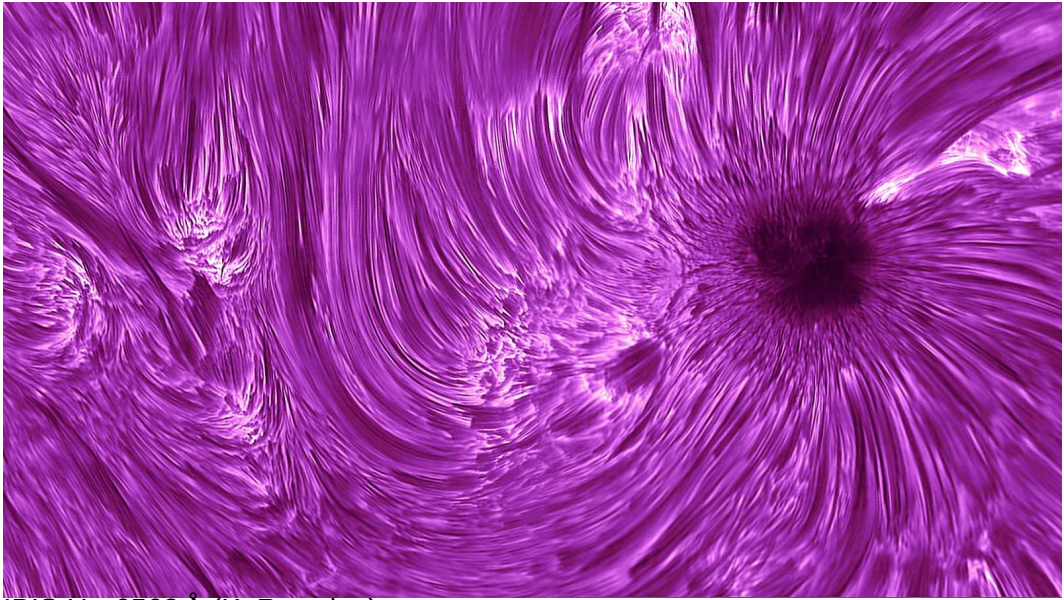
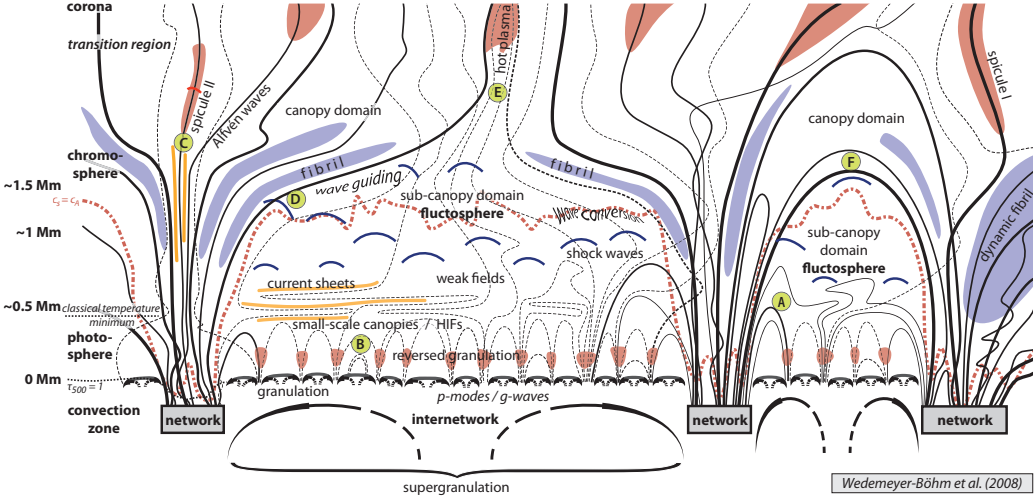
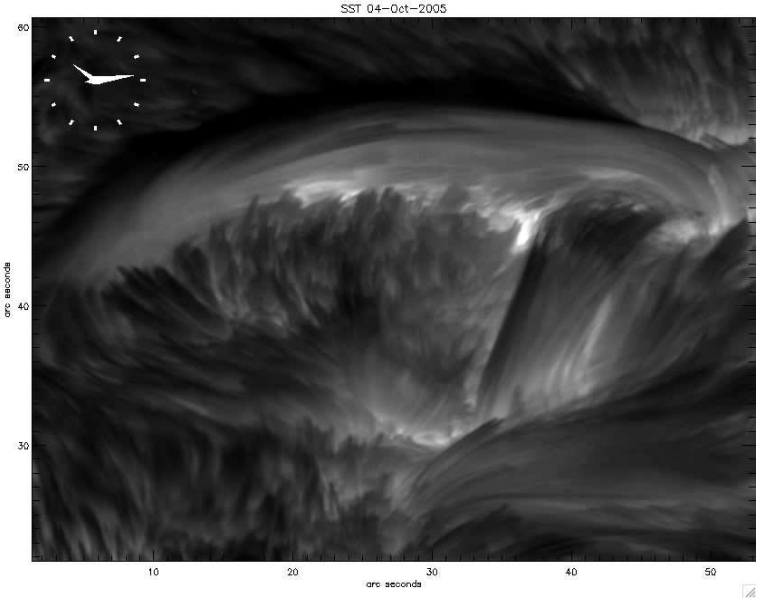


IBIS Hα 6563 Å (K. Reardon)

Complex Chromosphere



Wedemeyer-Böhm et al. (2008)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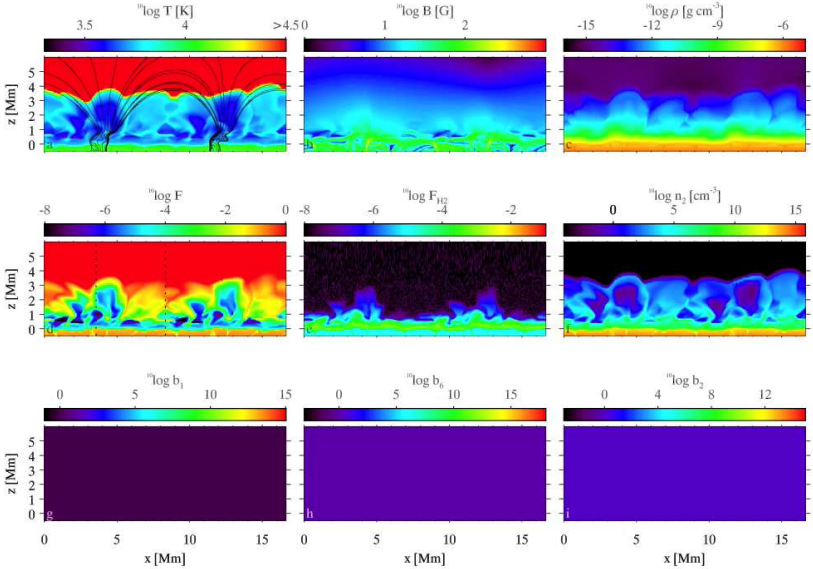

Leenaarts et al. (2007)

Why is it so complex?

Physical Conditions

- non-LTE
- partial frequency redistribution (PRD)
- non-equilibrium hydrogen and helium ionization
- scattering
- 3D radiative processes

Observational

- extremely short timescales
- low density plasma above bright background
- fine structure (fibrils)
- weak signals
- complex interpretation

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The Key is the Magnetic Field

Rutten (2012)

The principal ingredients defining chromospheric structure and dynamics are, for decreasing activity, magnetic reconnection, current heating, Alfvén waves, magnetically guided and/or converted acoustic waves, possibly gravity waves and torsional waves, and photon losses in strong lines.

Accessing B_{Chromo}: Extrapolations

Method

- Use photospheric magnetic field vector (ideal: 3D vector field, 180° ambiguity resolved)
- Preprocessing: use e.g. Hα images to constrain magnetic field orientation
  - $\rightarrow$ consistent boundary data for nonlinear force-free modeling
  - $\rightarrow$ preprocessed boundary data are chromospheric-like

expert: Thomas Wiegelmann (MPS)

Problems

- errors in boundary conditions
  - measurement errors
  - ambiguity removal
  - height of measurement
- model assumptions
- “interesting regions” not well-behaved
- ...

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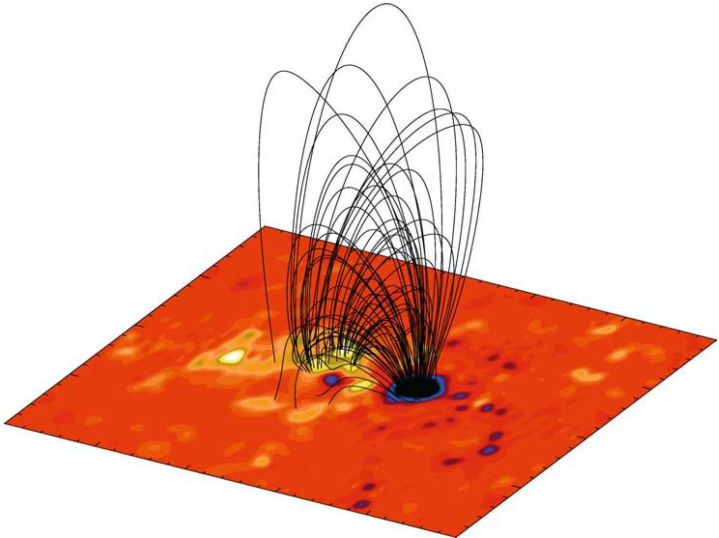
Extrapolations - Example



Wiegelmann et al. (2005)

Accessing B_{Chromo}: Measurements

- gyroresonant emission: Radio obs. of strong fields ($>$250 G)
- Bremsstrahlung emission: Radio
- coronal loop oscillations: EUV, coronagraphy
- Zeeman effect: spectropolarimetric observations UV - IR
- Faraday rotation: radio observation
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Option 1

Full non-LTE 3D treatment (Ca II H&K, Ca II IR)
$\rightarrow$ e.g. Oslo group (M. Carlsson, J. Leenaarts)

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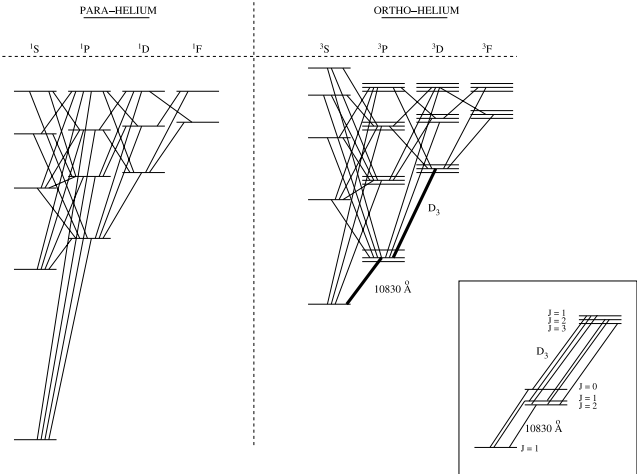
Option 2

Hanle & Zeeman diagnostics using the He I 1083.0 nm triplet
→ this talk

The He I 1083 nm triplet



Centeno et al. (2008)

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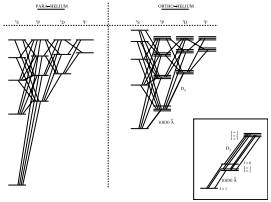

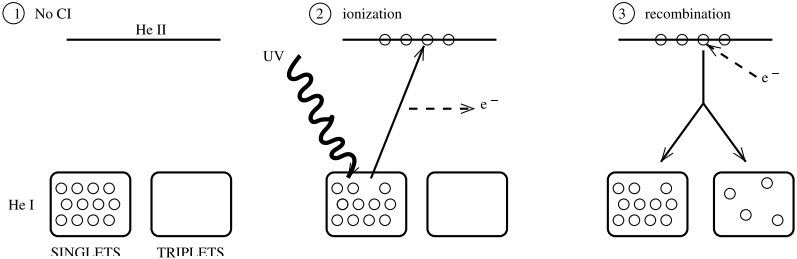

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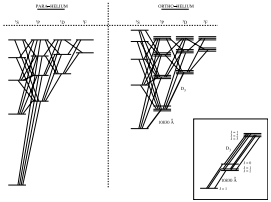

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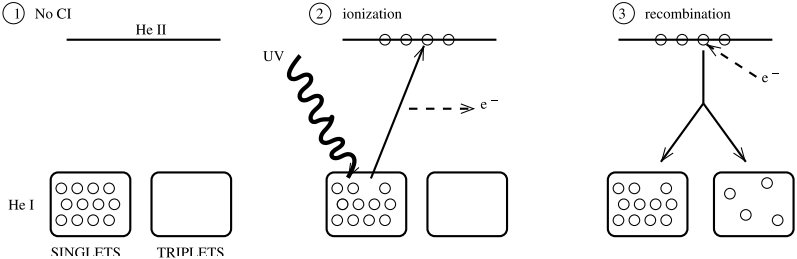
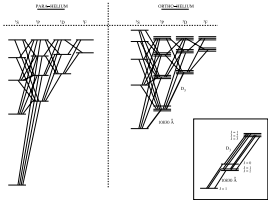


Clue: For $\lambda < 504\,\text{Å}$ ($= 24.6\,\text{eV}$)

- radiation originates in corona
- cannot penetrate deeply

$\rightarrow$ illuminates only upper chromosphere

The He I 1083 nm triplet



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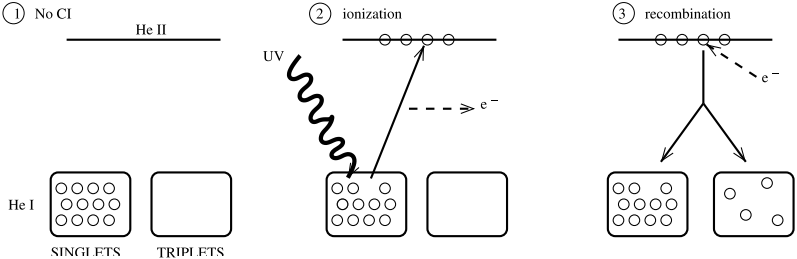
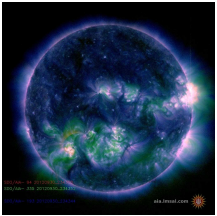
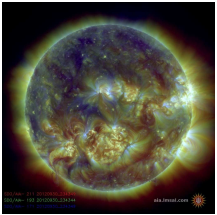


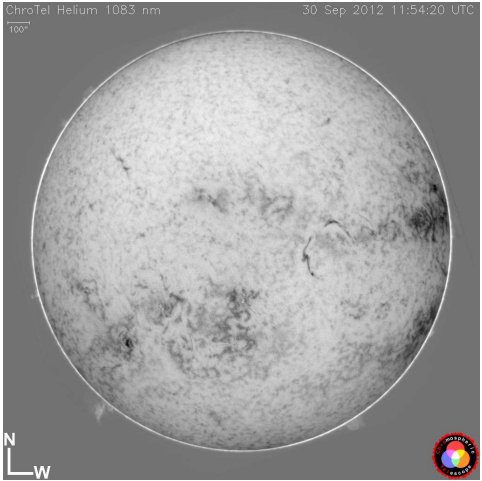
Pros and Cons

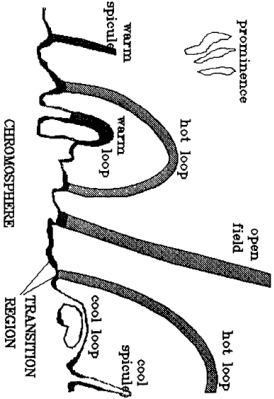
- simple: thin slab atmosphere
- Zeeman effect (+ simple Hanle)
- restricted height information
- weak signal in quiet Sun

The He I Sun of 2012-09-30









Avrett et al. (1994)

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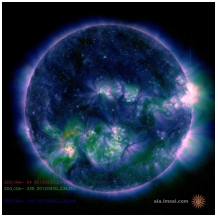
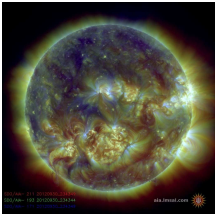
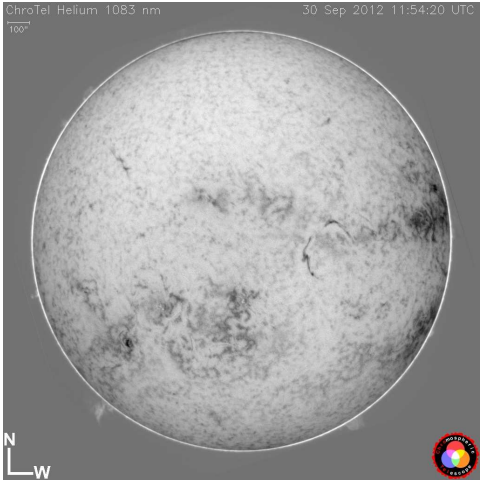
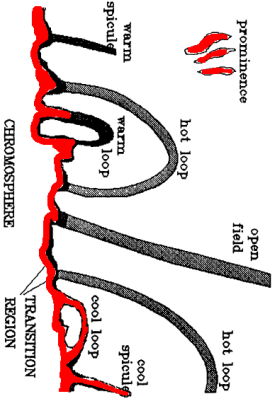


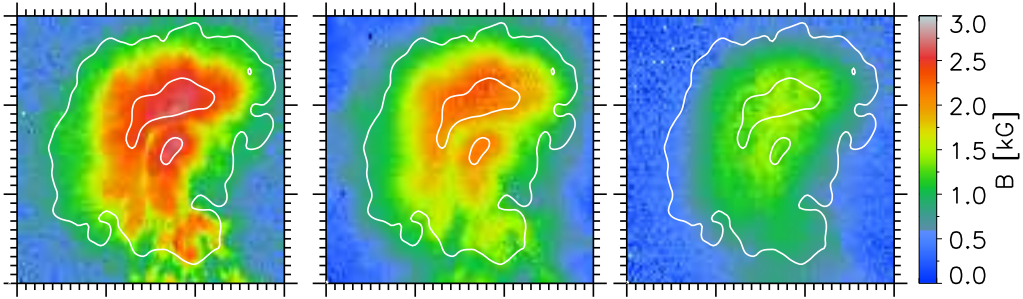






Avrett et al. (1994)

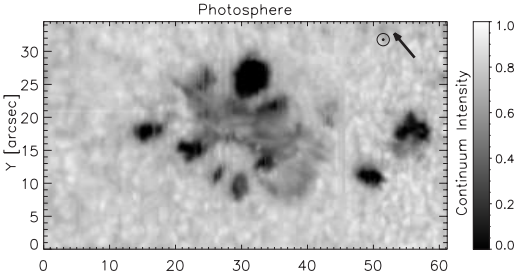
Sunspot Magnetic Field

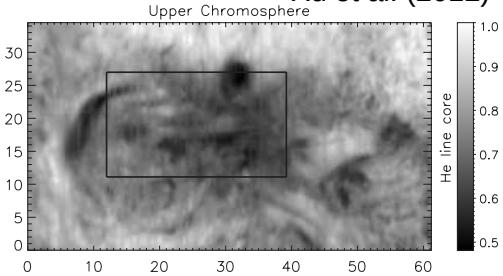


stay tuned for
Joshi et al. (2012)
14:50 - 15:10

Active Region Filament

Xu et al. (2012)





Continuum image

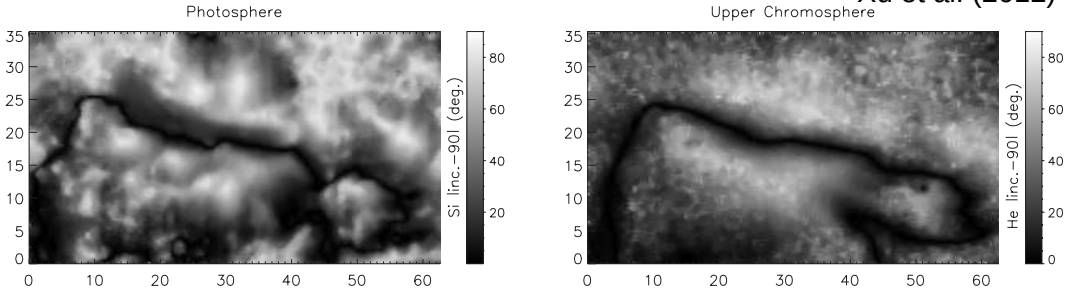
- opposite polarities on both sides
- large penumbra-like structure roughly along the neutral line

He I line core image

- Hα outlines complete filament
- He I only visible along few elongated field-aligned features

Active Region Filament - Inclination

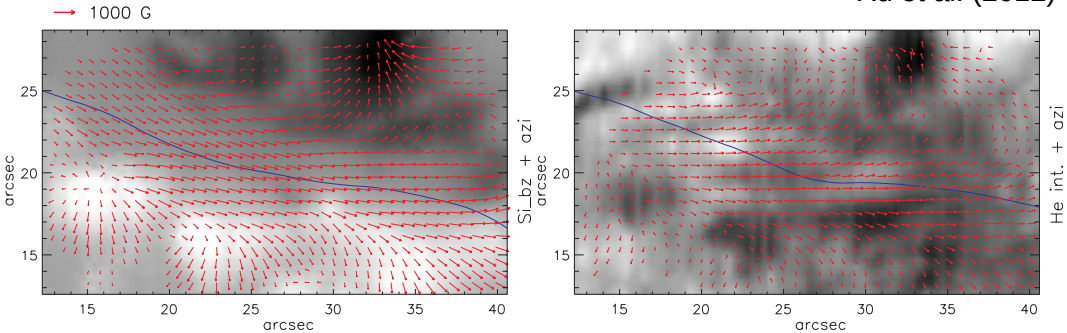
Xu et al. (2012)



- Opposite polarities in the chromosphere closer to each other than in the photosphere
- Chromosphere: small upflows along the PIL and inside the segmented He filaments. Downflows are found at its sides.

Active Region Filament - Azimuth

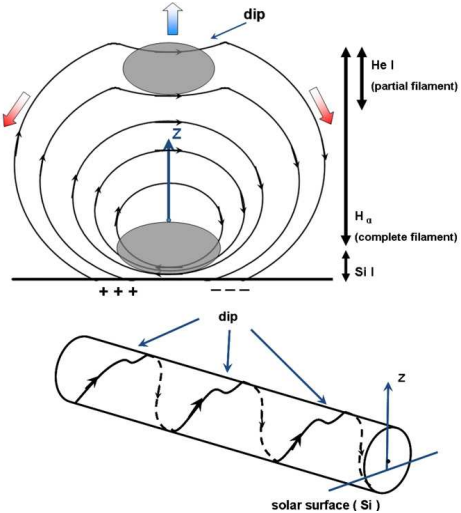
Xu et al. (2012)



- nearly aligned along the PIL
- concave structure

- angle to PIL: 20–30°
- Corona: the EUV loops even more perpendicular to the PIL

Active Region Filament - Scenario

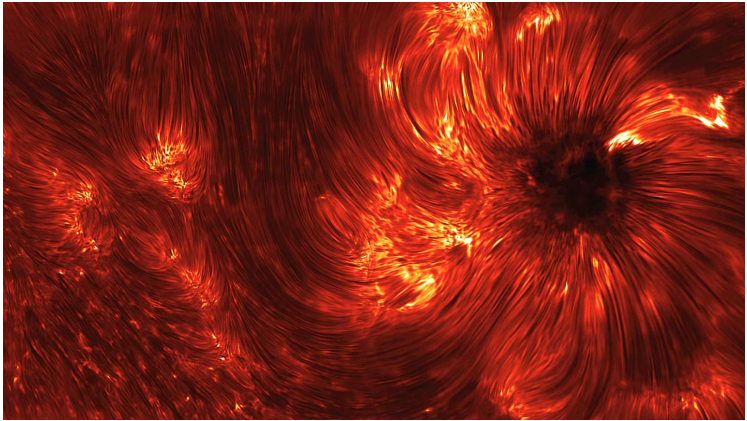


Xu et al. (2012)

- Characteristic signatures of a strong-field (600–800 G) flux rope
- Flux rope produces filament during emergence
- 2 filaments overlying each other:
  1. lower: concave topology
  2. upper: normal configuration (unstable)

Chromospheric field is not aligned with visual structure!

Fine Structure & Short Timescales



IBIS Ca II 8542 Å (K. Reardon)

Ground Based

- GREGOR: 1.5 m on Tenerife
- NST: 1.6 m Big Bear
- ATST / EST: 4 m

Space Borne

- Solar-C: 1.5 m, end of this decade

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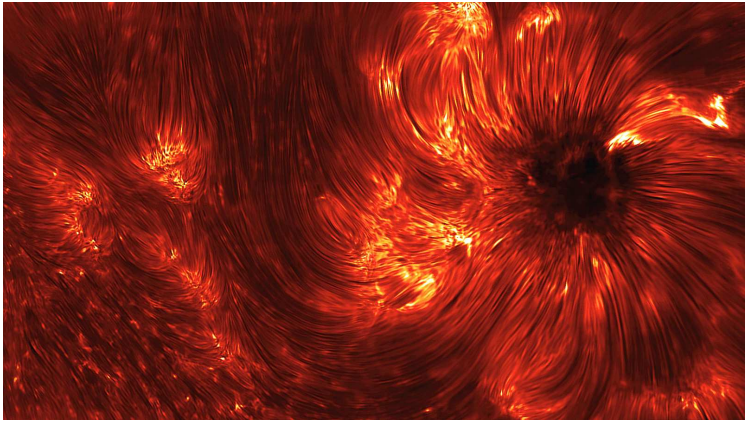

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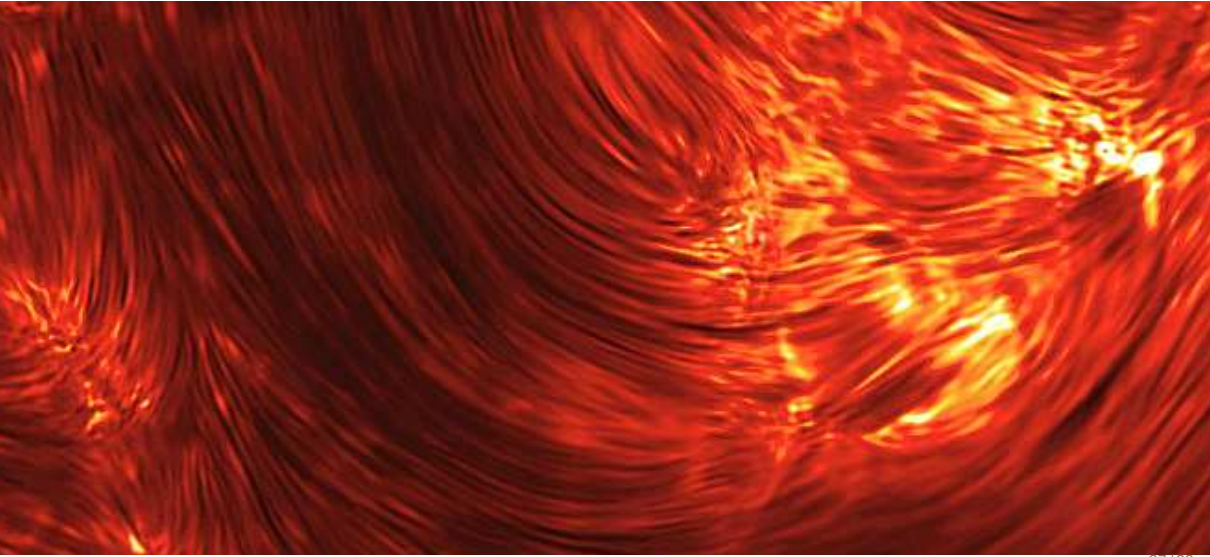

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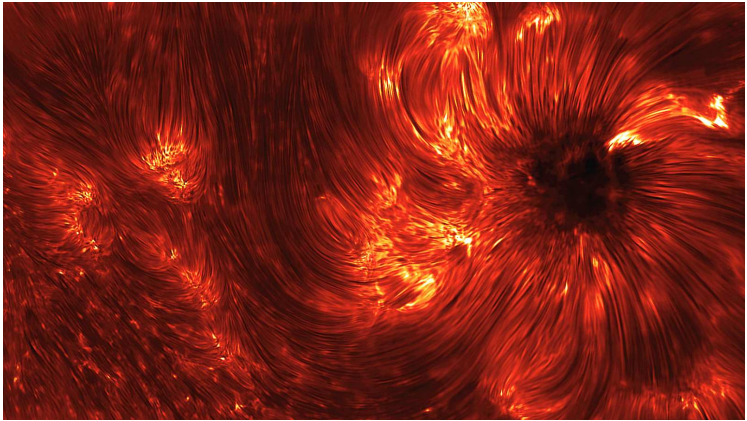

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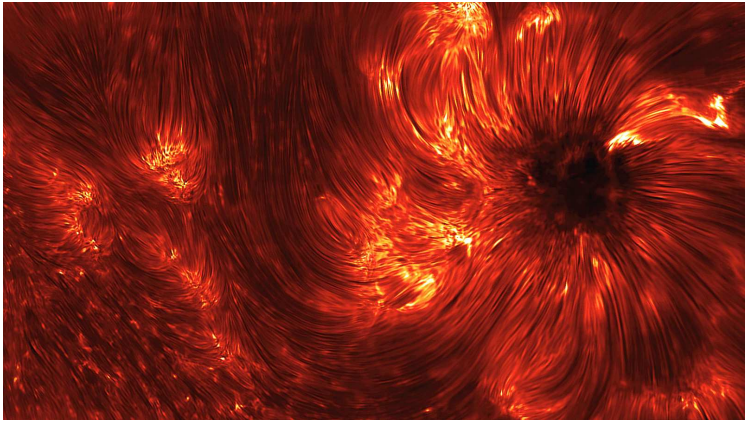

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Summary & Outlook

Conclusions

- Measuring chromospheric fields is high priority science goal

→ Instrument developments:
GRIS (GREGOR), FIRS, IBIS (NSO), Solar-C, Chinese Giant Solar Telescope (VIS-IR, 8 m)

→ Model improvements:
combined Hanle & Zeeman (MPS, IAC), 3D non-LTE modelling of chromospheric lines (Oslo, soon: MPS)

- Missing link between photosphere and corona to be completed soon

Bilbiography

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