# A granular light bridge in a sunspot observed with Hinode

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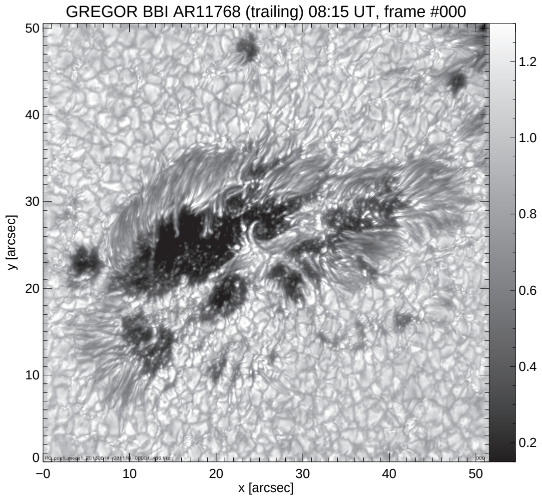
# Table of Contents

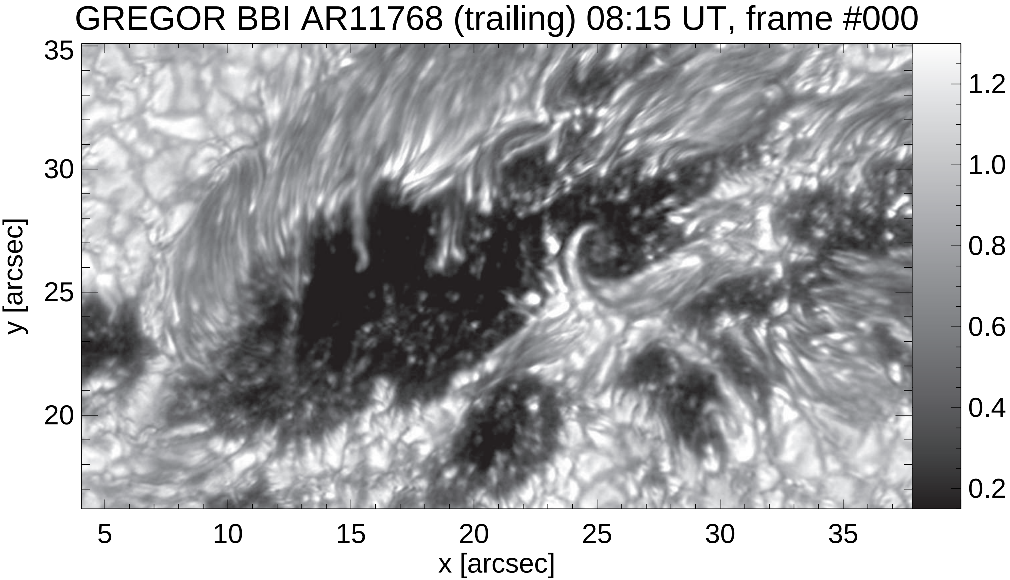
# Light Bridges

## Shimizu (2011)

- long bright structures
- separate umbrae in two magnetically similar polarity regions
- source: convective motions
- weak field plasma penetrates from below photosphere
- magnetic canopy configuration at surface

GREGOR BBI 486 nm, 14-Jun-2013
Sunrise II ?




GREGOR BBI AR11768 (trailing) 08:15 UT, frame #000
35
30
25
20
y [arcsec]
5
10
15
20
25
30
35
x [arcsec]
1.2
1.0
0.8
0.6
0.4
0.2

# Light bridges Sobotka et al. (1993)

## faint LBs

e.g. Shimizu (2011)

- ”elongated umbral dots”
- dark lane: elevation of log $\tau$ layer caused by enhanced density in cusp
- often formed after penumbral intrusions

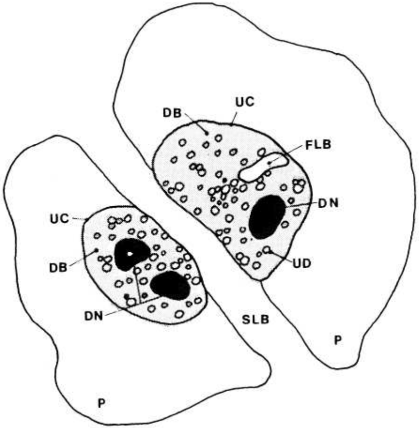



FIG. 1.—Ideal drawing of a spot showing the structures described in the paper and the nomenclature used. *P*: penumbra; *UC*: umbral core; *SLB*: strong light bridge; *FLB*: faint light bridge; *UD*: umbral dot; *DB*: diffuse background; *DN*: dark nucleus.

# Light bridges Sobotka et al. (1993)

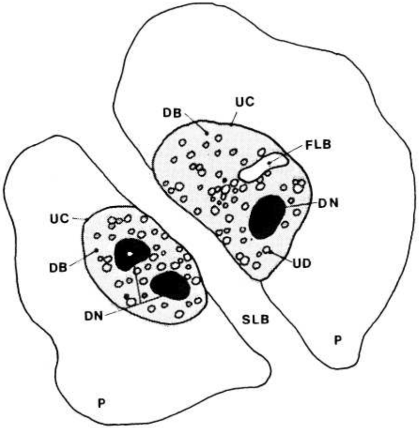
## strong LBs

e.g. Sobotka et al. (1993); Rimmele (2008)

## granular LBs

e.g. Rouppe van der Voort et al. (2010)

- LB consists of fully developed granular cells

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# Light bridges

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### strong LBs

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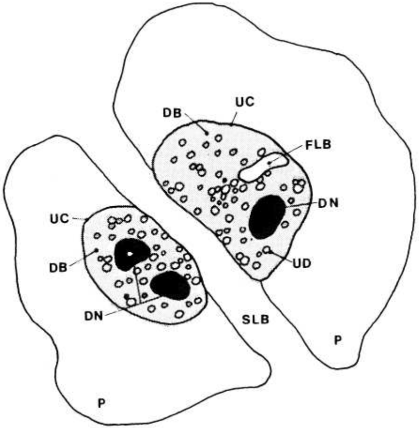
LBs: signatures of convection in the umbra normally inhibited by the umbral field.

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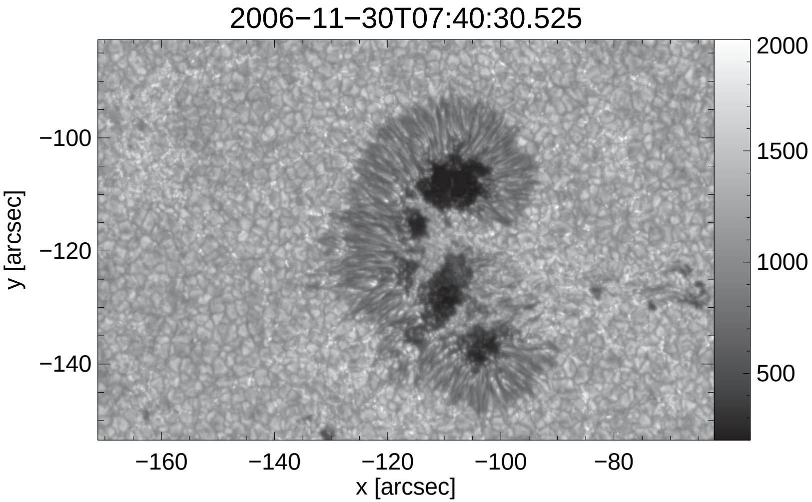
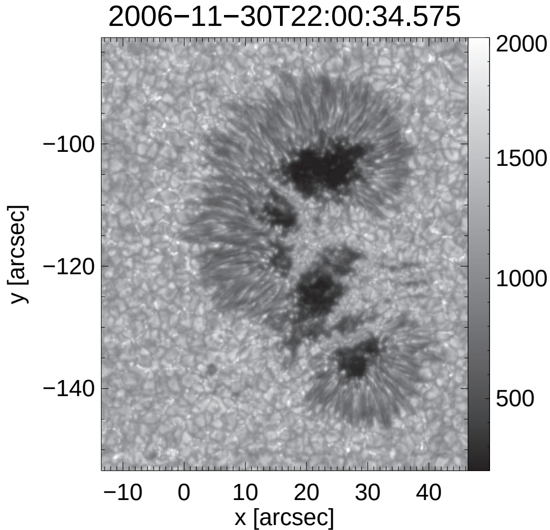
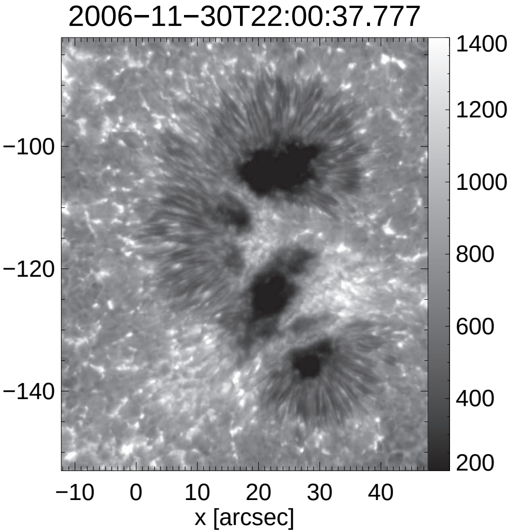
# AR10926, G-band, temporal evolution



# AR10926 G-band Ca IIH temp. evolution



# Spatially coupled inversions

## van Noort (2012)

- ”ideal” instrument: 1:1 mapping of detector pixel to solar surface

→ every pixel measures Stokes vector *IQUV* of this solar area

- real instrument: PSF distributes information over several pixels
- Inversion
  1. compute *IQUV* for every pixel
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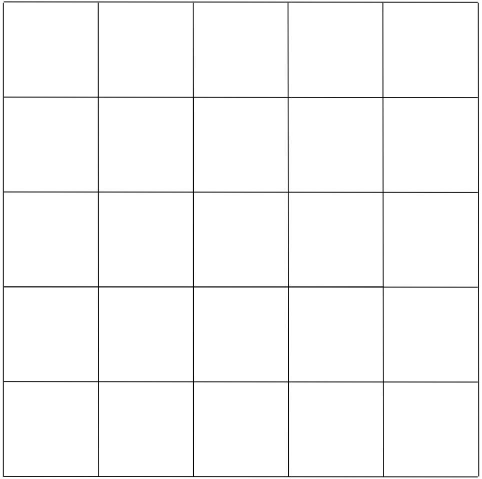

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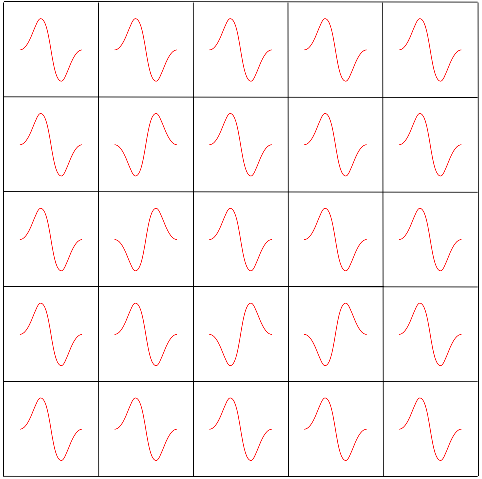

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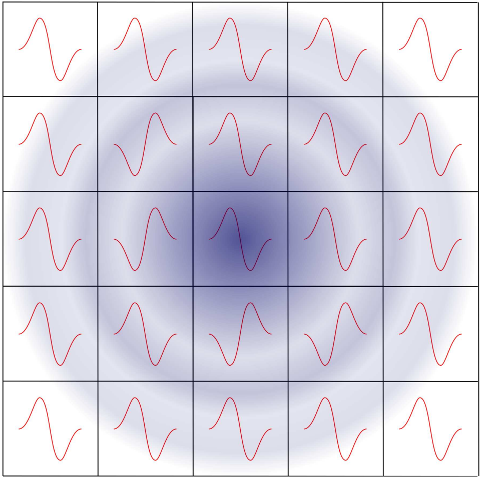

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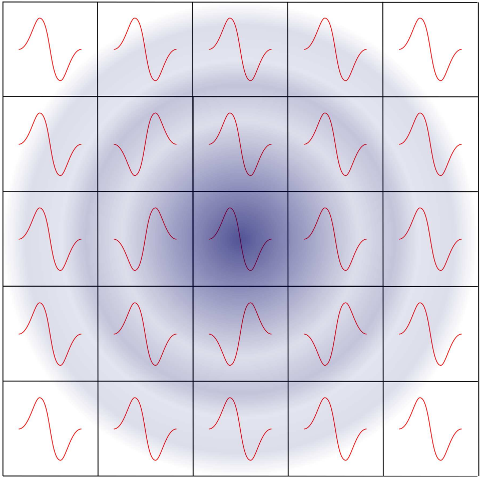

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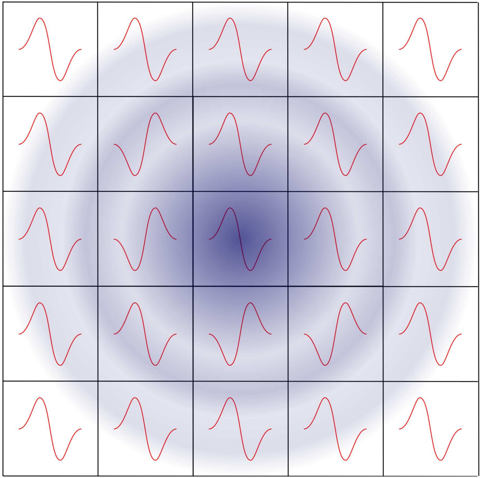

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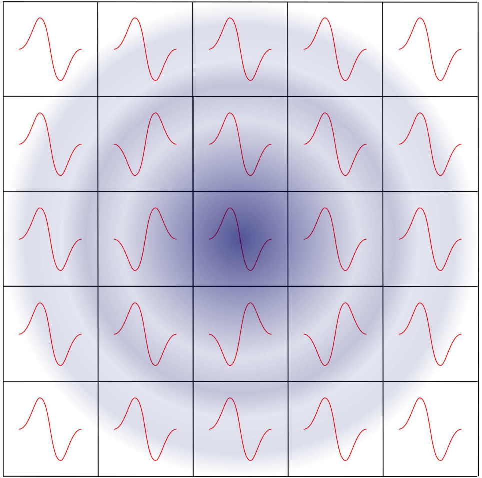

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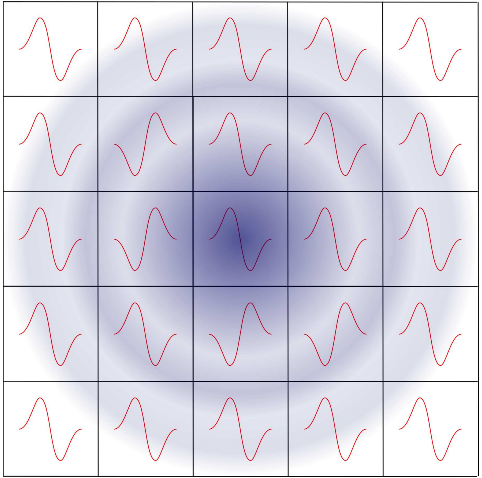


# Inversion setup

## Atmosphere

Free parameters:

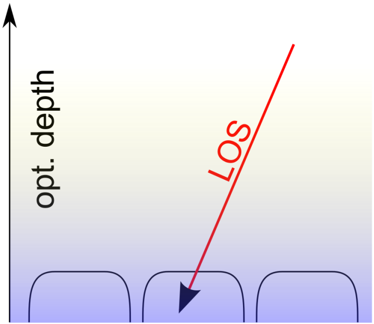
- temperature: $T$
- magnetic field vector: $B$, $\gamma$, $\chi$
- line of sight velocity: $V_{\mathrm{LOS}}$
- micro turbulence: $v_{\mathrm{micro}}$
- 3 height nodes per parameter
- spline $-4.0 \leq \log \tau \leq +0.5$

$\rightarrow$ 18 free parameters / pixel

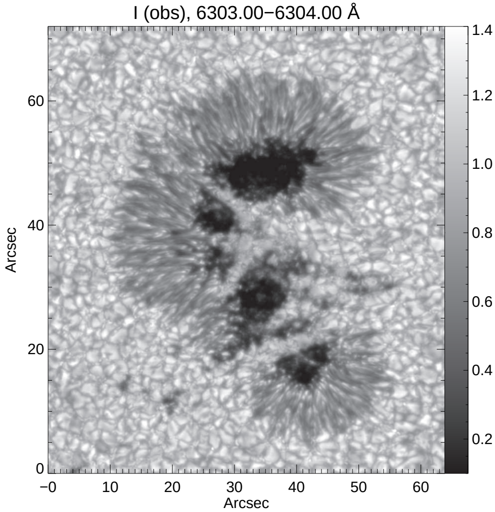
$\rightarrow$ $4 \times 112$ measured values / pixel

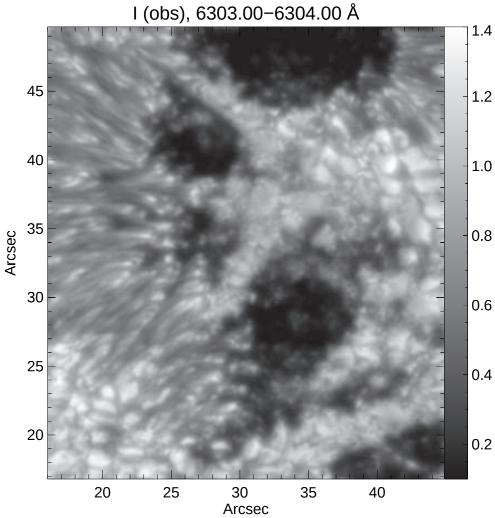
## Radiative Transfer Equation

solution involves atomic physics, collisions, opacities, telescope, . . .

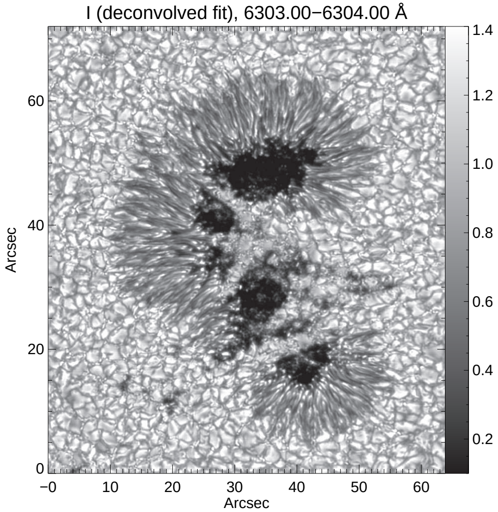


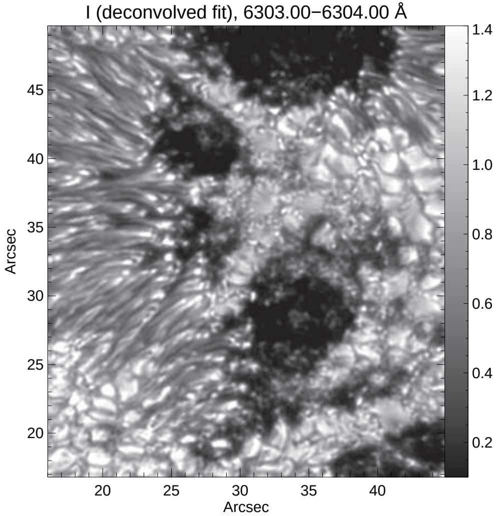
# AR10926, $\mu$=0.96, Intensity



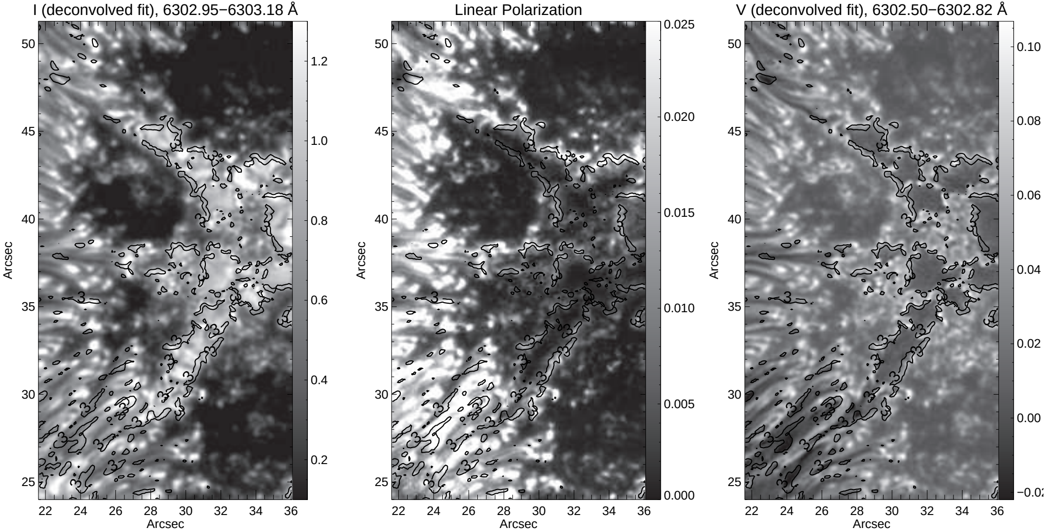



# AR10926, $\mu$=0.96, intensity - deconvolved

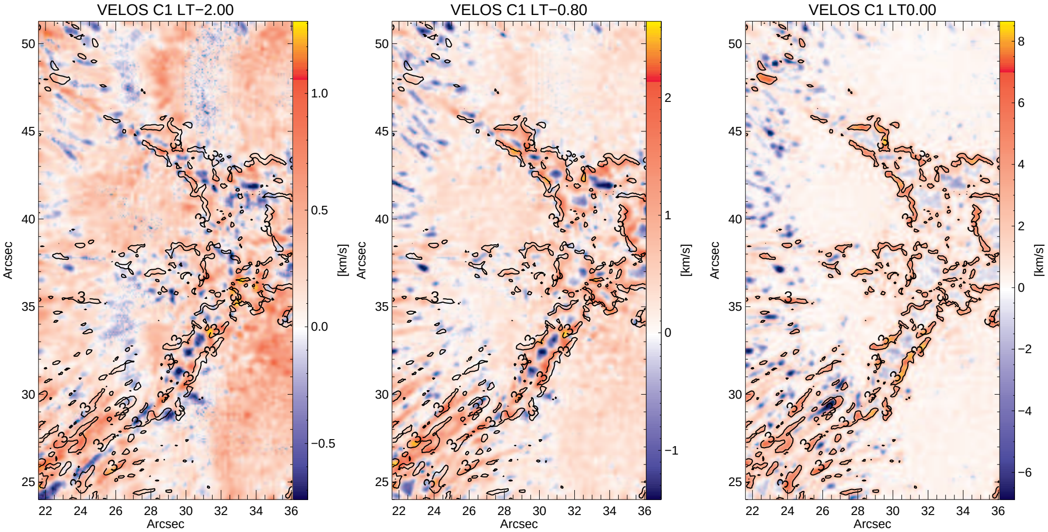


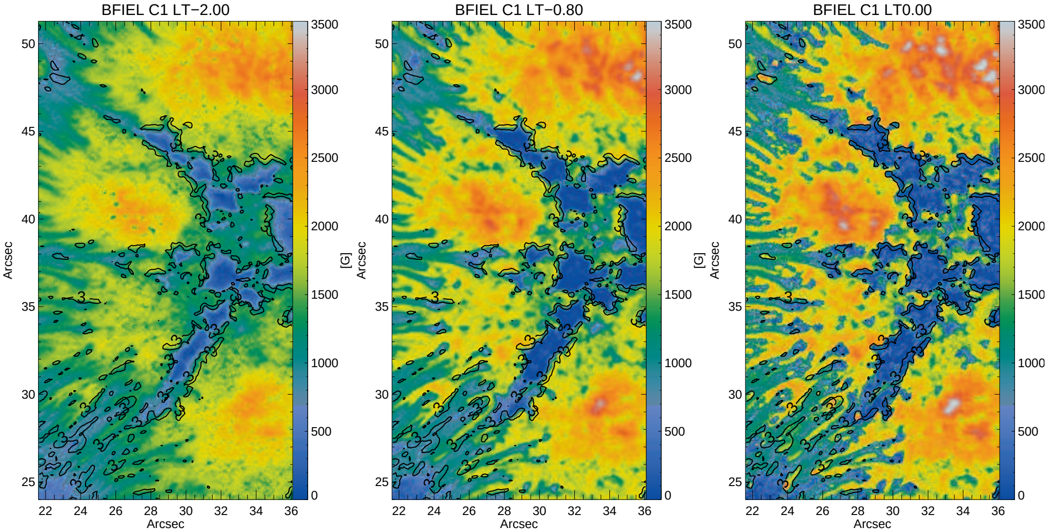
# Stokes Parameters: *I* LP *V*



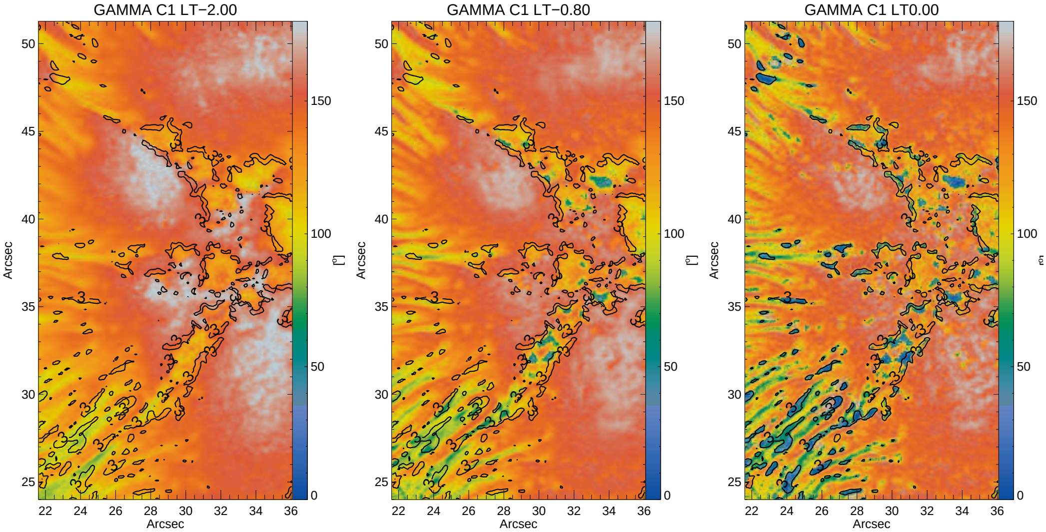
# LOS velocities



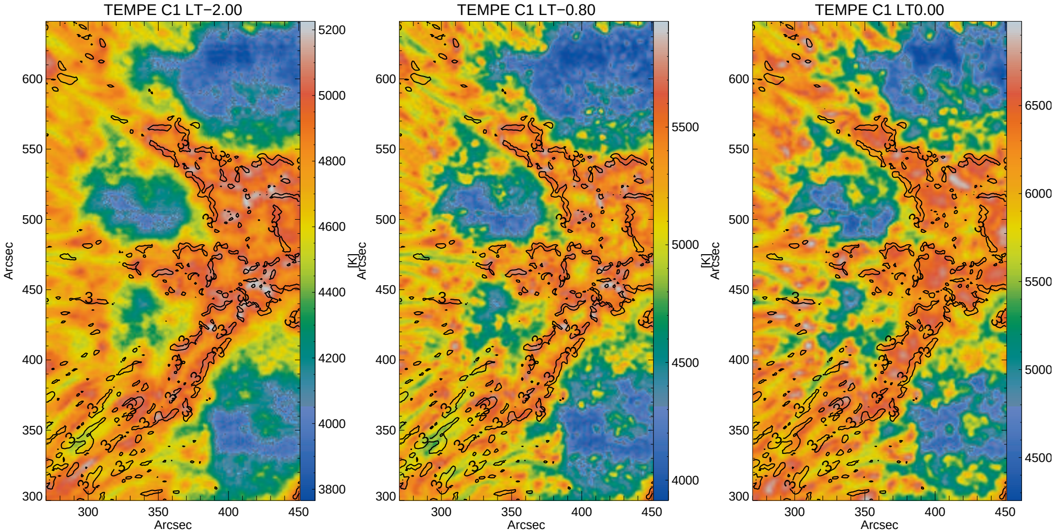
# Magnetic field strength



# Inclination



# Temperature



## Appearance: very similar to granule in quiet Sun

- upflow in center
- surrounded by downflows
- field free / week fields in deep layers
- field concentrations at boundaries

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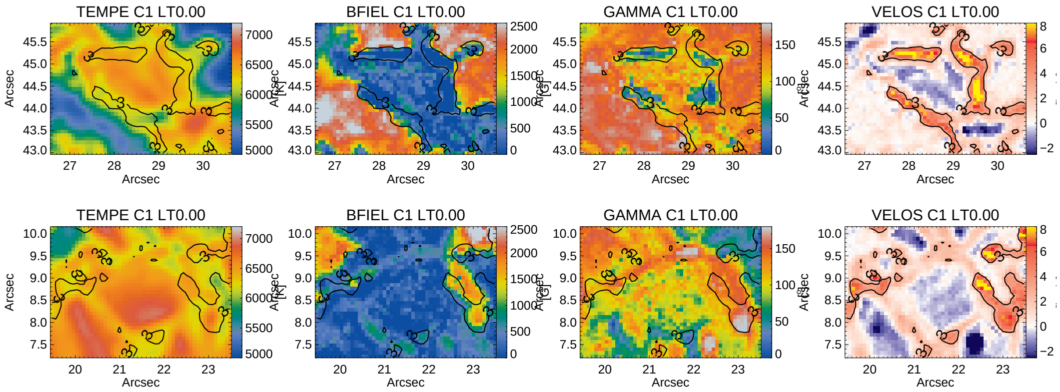
**Are we seeing a ”naked” granule?**

# Comparison LB / QS granule $\log \tau = 0.0$

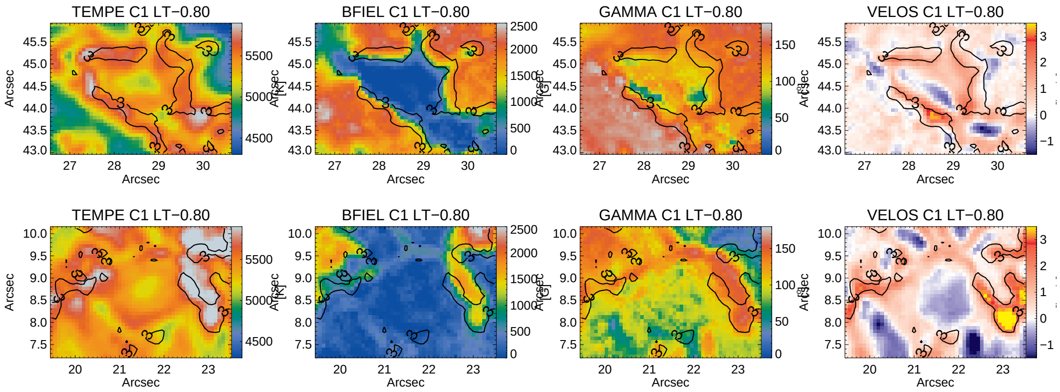
light bridge granule




QS granule

# Comparison LB / QS granule $\log \tau = -0.8$

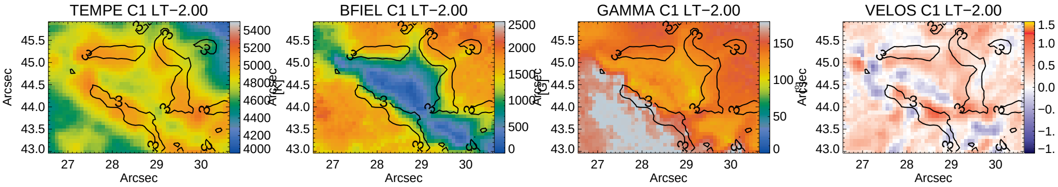
## light bridge granule

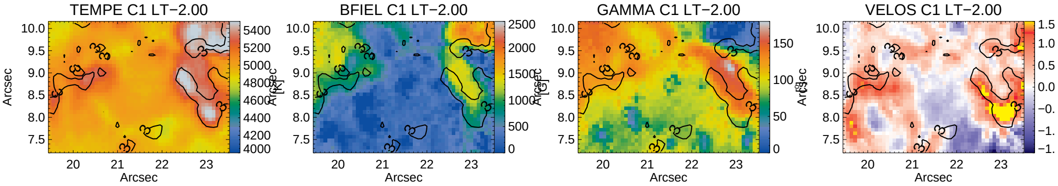



## QS granule

# Comparison LB / QS granule $\log \tau = -2.0$

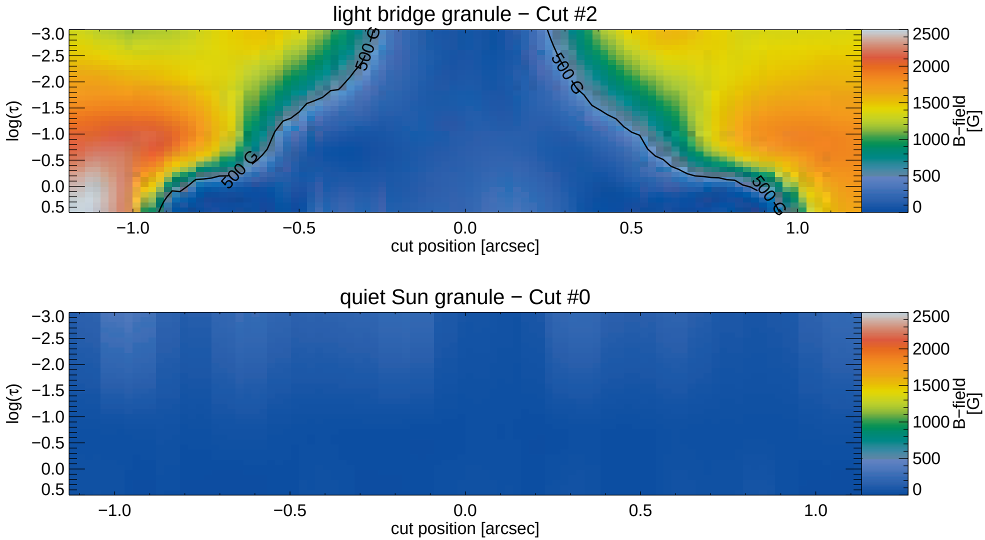
## light bridge granule




## QS granule

# Comparison LB / QS granule mag. field log $\tau$ cuts



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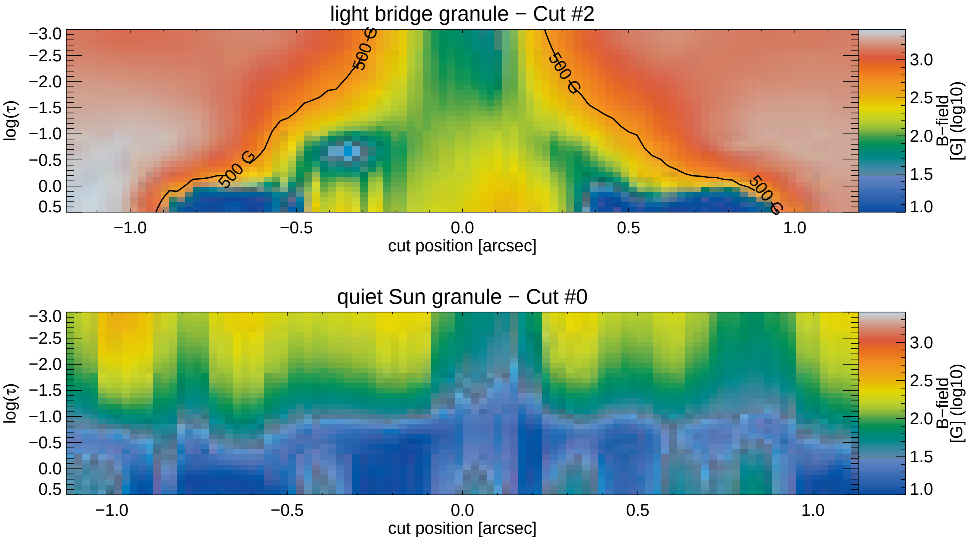
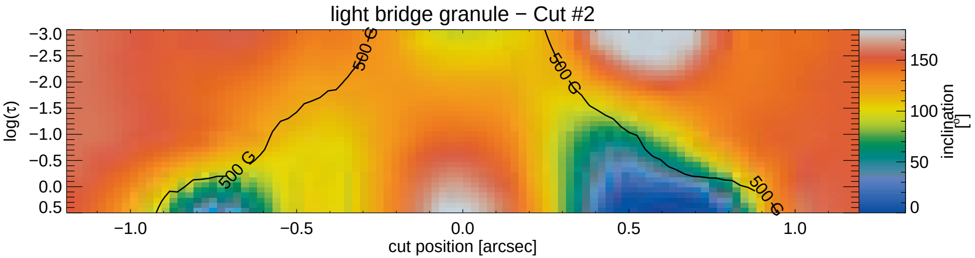
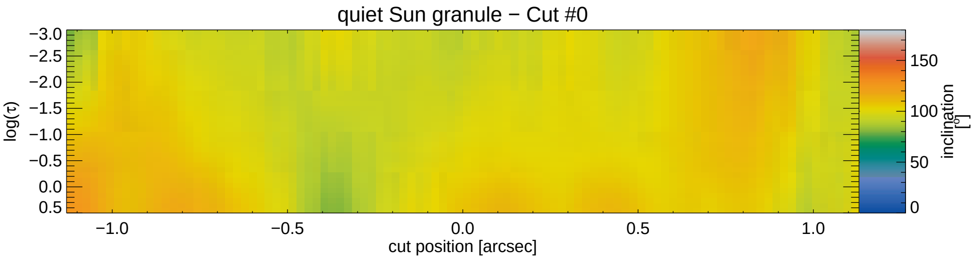
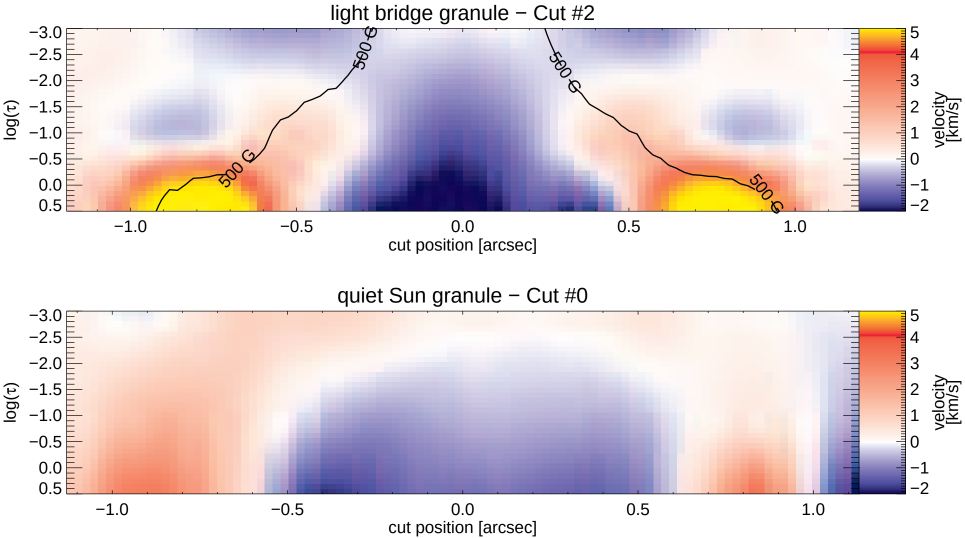


# Comparison LB / QS granule inclination log $\tau$ cuts

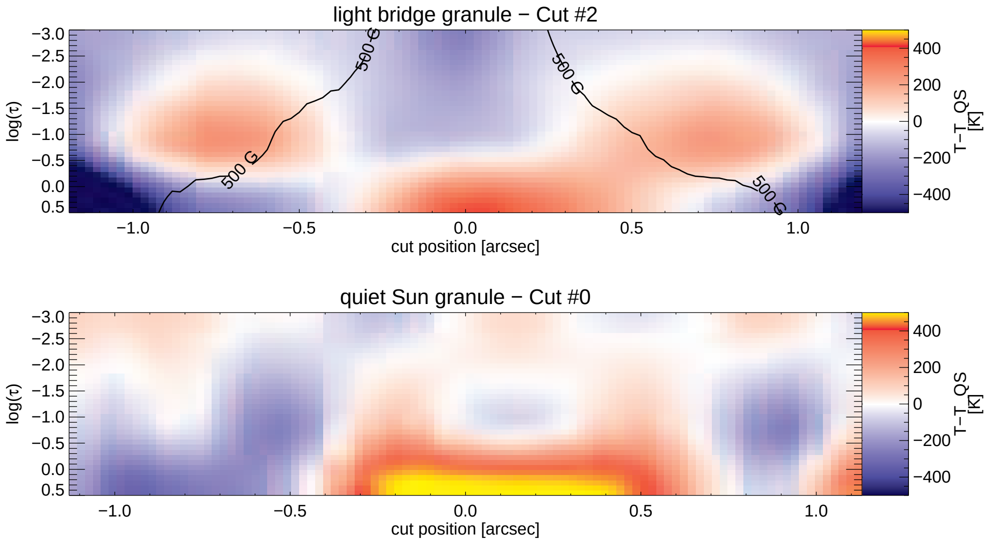


# Comparison LB / QS granule $v_{LOS}$ log $\tau$ cuts



# Comparison LB / QS granule $T - T_{<QS>}$ log $\tau$ cuts



# Light bridge "mountains"

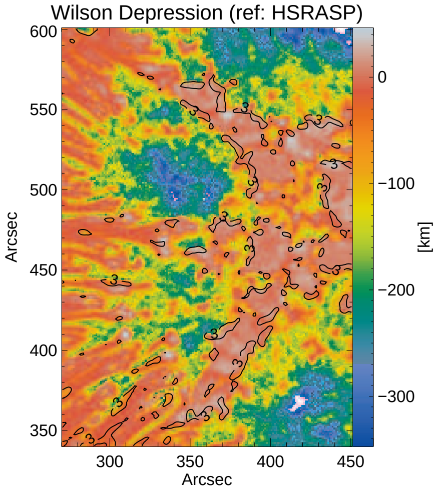
## Height estimate: force balance

$$P_0(z) = P_G(r,z) + B_z^2(r,z)/8\pi + F_c(r,z)/8\pi$$

- LB granule 200 km higher than surrounding umbra
- free fall speed for $\Delta H = 200$ km: $10\ \mathrm{km\,s^{-1}}$

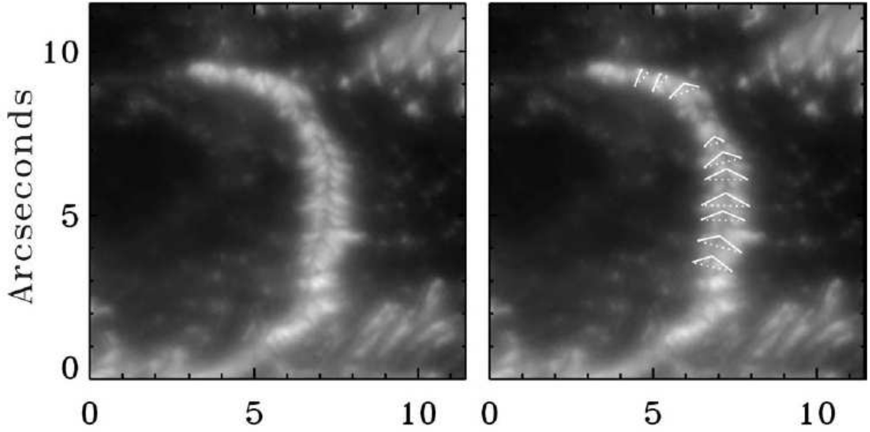
## ToDo:

Estimate $\nabla \cdot B$ and tension forces for more reliable height determination



# Light bridge ”mountains”

Lites et al. (2004) (triangulation): 300±50 km



# Downflows: reconnection?

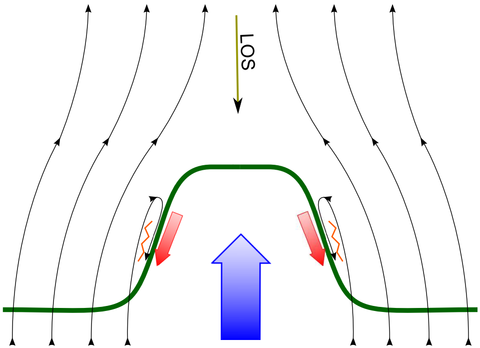
## e.g. Louis et al. (2009)

- strong downflows (up to 10 $\mathrm{km\,s^{-1}}$)
- some correlated with Ca H brightenings

→ signature of reconnection: downflows might represent downward jets

## granular LBs

- strong downflows by gravity
- may drag down field lines and create opposite polarity field
- reconnection could be the result



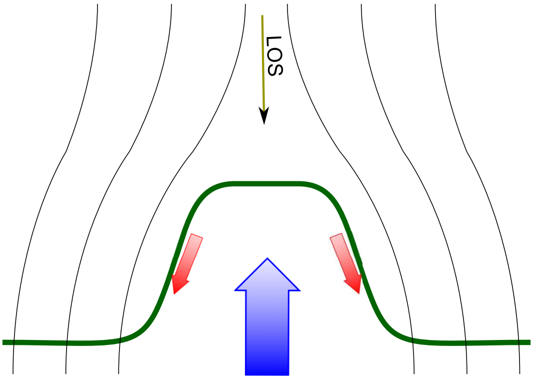
# New insight into convection cells?

## ToDo: Make use of viewing angle

- Wilson depression in umbrae allows to see granular walls at deep layers
- possible to access granular interior

→ investigate granular light bridges under different viewing angles

- compare granular interior with MHD simulations



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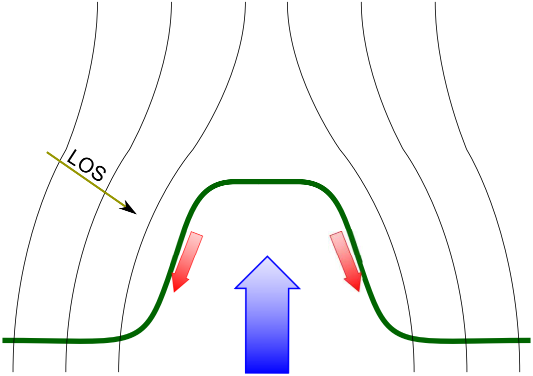

# Summary: LB vs. QS granule

## magnetic field:

- QSG: field free interior
- LBG: field free boundary, few 100 G in center (deepest layer)
- only LBG: hint of opposite polarity (TBC)

## temperature:

- LBG: lower in field free / downflow region
- LBG: enhanced in/above downflow region (middle layer)

## velocity:

- downflows at field-free boundary (all heights)
- LBG higher downflows than QSG
- central upflows (higher for LBG)
- only LBG: upflows above fast downflows

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$\rightarrow$ reconnection?

# ToDo's:

### Force Balance

- more reliable height information

### Mass balance

- $\log \tau$ plots suggest more downflowing than upflowing mass
- proper height scale required

### Viewing angle

- may allow for ”deeper” insight into granule

# Bilbiography


Lites, B. W., Scharmer, G. B., Berger, T. E., & Title, A. M. 2004, Sol. Phys., 221, 65

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