A Granular Light Bridge Observed by Hinode: Evidence for Naked Granules

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Light Bridges

Shimizu (2011)
- separate umbrae in two magnetically similar polarity regions
- source: convective motions
- weak field plasma penetrates from below photosphere
- cusp/canopy configuration at surface
- types: FLBs, SLBs, GLBs
  \[\rightarrow\] different origins?

Light Bridge References
Sobotka & Puschmann (2009); Sobotka et al. (1993); Lites et al. (1991); Sobotka et al. (1993); Rimmele (2008); Rezaei et al. (2012); Vazquez (1973); Lites et al. (1991); Sobotka et al. (1994); Leka (1997); Rouppe van der Voort et al. (2010); Louis et al. (2009); Bharti et al. (2013); Shimizu et al. (2009); Rüedi et al. (1995); Joshi (2013)
AR10926, G-band, temporal evolution
Observations
Hinode SP: 2006-Nov-30

AR10926, SOT/SP scan

AR10926
- several granular light bridges: Nov 26 – Dec 4 2006
- \( \mu = \cos \Theta = 0.96 \)
- SP scan (normal mode) on Nov-30 2006, 2300 UT

Inversions
van Noort (2012)
POSTER: S1 - P - 27

- spatial coupling using PSF → acts as deconvolution
- 3 nodes in T, B, \( \gamma \), \( \phi \), \( v_{\text{LOS}} \), \( v_{\text{micro}} \)
Method: 2D-coupled Inversion

AR10926, selected regions

![Image of a solar granule with selected regions labeled a and b.]

Broad light bridge:
- temporal evolution indicates convective motions
- brightness similar to QS
- Granule
AR10926, selected regions

**Broad light bridge**
- temporal evolution indicates convective motions
- brightness similar to QS granule

**QS Granule**
- not really “quiet” (too close to spot).
- BUT: properties very similar to QS granule
  - selected for comparison
Comparison: LB Granule vs. QS Granule

Atmospheric parameters
- Temp., LOS-velocity, magn. field strength & direction
- at three height nodes
Comparison LB / QS granule

Results Comparison: Granule in LB vs. QS

\[ \log \tau = 0.0 \]

<table>
<thead>
<tr>
<th>Temp.</th>
<th>( v_{\text{LOS}} )</th>
<th>B-field</th>
<th>B-direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>6000</td>
<td>-3</td>
<td>0</td>
</tr>
<tr>
<td>1000</td>
<td>2000</td>
<td>1000</td>
<td>90</td>
</tr>
</tbody>
</table>

\[ \log \tau = 0.0 \]

5000 6000 -3 0 4 8 0 1000 2000 30 90 150

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\[ \log \tau = 0.0 \]
Comparison LB / QS granule

\[ \log \tau = -0.8 \]

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</tr>
<tr>
<td>30</td>
<td>90</td>
<td>150</td>
<td>30</td>
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</tbody>
</table>

\begin{figure}
\centering
\includegraphics[width=\textwidth]{comparison_granule_lb_qs.png}
\end{figure}
Comparison LB / QS granule

\[ \log \tau = -2.0 \]

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![Image showing comparison between LB and QS granules](image-url)
AR10926, selected cuts
Cut through LB / QS granule

Results

Vertical Cuts

Cut position [arcsec]

$\log \tau$

$-3 \rightarrow 0 \rightarrow 3 \rightarrow 6$

$\text{v}_{\text{LOS}}$ [km s$^{-1}$]

$-3 \rightarrow 0 \rightarrow 3 \rightarrow 6$

500 G

$\text{LBG}$

$\text{QSG}$
Results

Vertical Cuts

Cut through LB / QS granule magnetic field

![Graph showing magnetic field cuts through LB/QS granule with log τ and B [G] axes.](image)

- Cut position [arcsec]
- log τ
- B [G]
- Logarithmic scale for τ and B

1000 G
2000 G
Results  Vertical Cuts

Cut through LB / QS granule  

**mag. field inclination**

- Vertical Cuts
  - Cut position [arcsec]
  - $\log \tau$ [G]
  - $\gamma$ [G] (B>70G)

- Cut position [arcsec]
  - $\log \tau$
  - $\gamma$ [G] (B>70G)
Comparison: LB Granule vs. QS Granule

Similarities
- central upflows (≈2 km s$^{-1}$) of hot material
- surrounded by cooler downflows
- typical pattern for convection
- decreasing velocities with height
- field free / weak fields in deep layers
- field concentrations at boundaries
Comparison: LB Granule vs. QS Granule

**Similarities**
- central upflows ($\approx 2 \text{ km s}^{-1}$) of hot material
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**Differences**
- LB: faster downflows (10 vs. 4 km s$^{-1}$)
- LB: narrowing upflows with height
- LB: enhanced temp. at downflows in middle layers, lower in deepest layer $\rightarrow$ small radial gradient at $\tau = 1$
- LB: opposite polarity field at location of downflows
- LB: cusp-like field in highest layer
- QS: canopy field in highest layer
Downflows: reconnection sites?

High speed downflows ($10 \text{ km s}^{-1}$)

Result of Reconnection? (Louis et al. 2009)

- hints of polarity reversal
- above downflows: $T$ enhanced
Downflows: reconnection sites?

Configuration

High speed downflows (10 km s$^{-1}$)

Result of Reconnection? (Louis et al. 2009)

+ hints of polarity reversal
+ above downflows: T enhanced
Downflows: reconnection sites?

High speed downflows ($10 \text{ km s}^{-1}$)

Result of Reconnection? (Louis et al. 2009)

- hints of polarity reversal
- above downflows: $T$ enhanced
  - height: 200–300 km
  - strong downflows by gravity & reduced density
- drag field lines and create opposite polarity field
- reconnection / current sheets (with heating) result of downflows
“Naked” granules

Configuration

Exposed granules (Wilson depression)
- LBG and QSG similar in deep layer
  → points to common origin
  → anchored in deep layers
- different from FLBs or umbral dots
  (“surface” convection)
- probe sub-surface spot structure

Outlook
→ investigate granular light bridges under different viewing angles
  possible to access granular interior
Furukawa Festival (town next to Takayama, every April)

many similarities

- interior: turbulent motions
- boundary: downflow streamlines
- cusp shape
- “granule” exposed to cold environment
- “naked”: not quite (only linecloths)
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Bibliography

Joshi, J. 2013, PhD thesis, Technische Universität Carolo-Wilhelmina zu Braunschweig