On the contrast of solar magnetic elements in the quiet Sun and active region plage

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Abstract

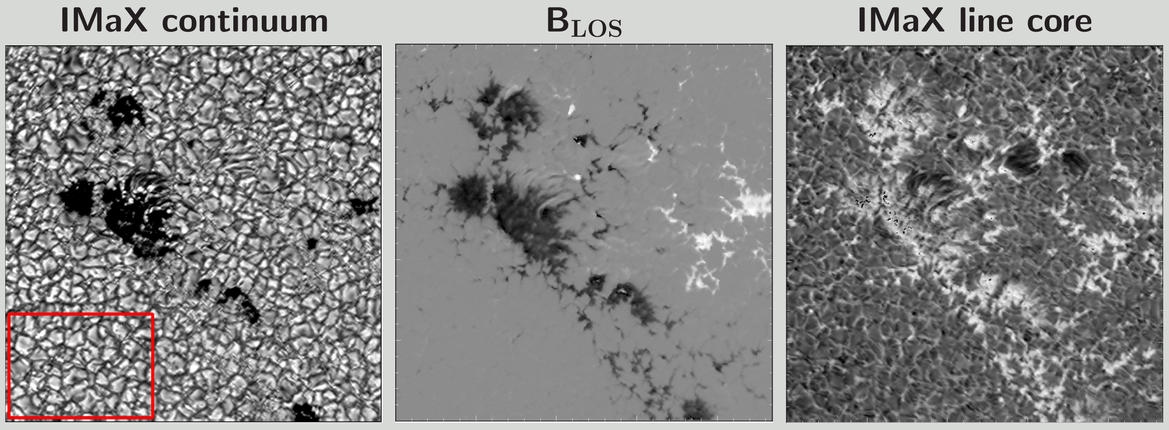
We investigate the relationship between the intensity at different wavelengths in the visible and near UV and the photospheric magnetic field, $\mathbf{B}_{\mathrm{LOS}}$ of small-scale magnetic elements in active region (AR) plage close to disk center. We analyse high resolution time series acquired simultaneously by the **Imaging Magnetograph eXperiment (IMaX)**, and the **Sunrise Filter Imager (SuFI)**, on-board the balloon-borne observatory SUNRISE during its second science flight in June 2013. We compare our results to those obtained from analyzing the quiet-Sun data acquired during the first flight of SUNRISE in June 2009 [1].

Motivation

- Brightness of magnetic elements is the dominant source of the in phase variation of solar irradiance with solar activity over the solar cycle [2].
- They are responsible for structuring the lower chromosphere.
- **How?** $\Longrightarrow$ pixel-by-pixel scatterplots of $\mathbf{I} - \mathbf{B}$ in the visible and UV wavelengths.

AR data: IMaX

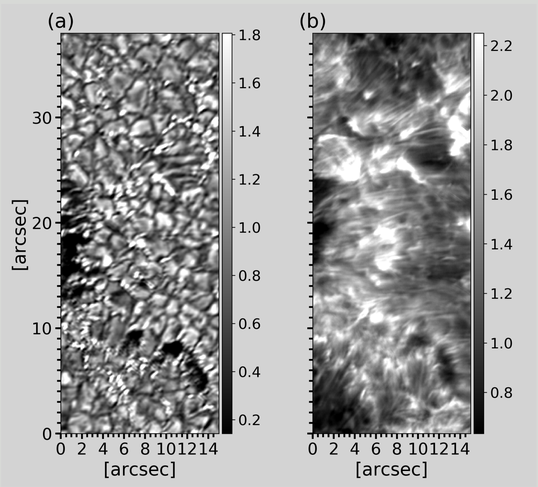
IMaX continuum | $\mathbf{B}_{\mathrm{LOS}}$ | **IMaX line core**



- **IMaX**: Fe I line at $\boldsymbol{\lambda_0} = 5250.2$ Å
- Continuum: at $\boldsymbol{\Delta\lambda} = \mathbf{+227}$ mÅ from $\boldsymbol{\lambda_0}$
- Contrast $= \mathbf{I/I\_qs}$, $\mathbf{I_{qs}}$ is the mean intensity in the red box
- Spatial resolution: 0.15"- 0.18"
- $\mathbf{B}_{\mathrm{LOS}}$ computed from SPINOR Inversions

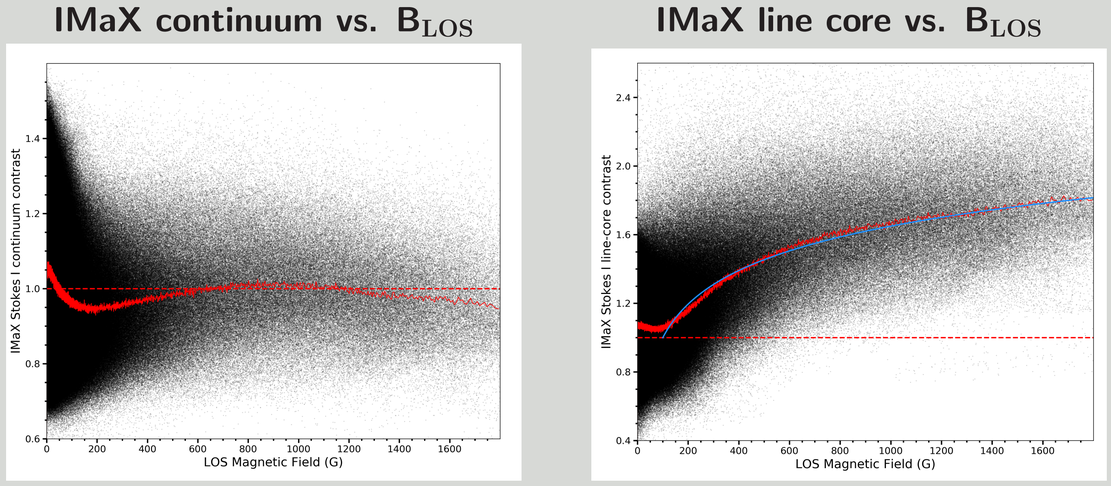
AR data: SuFI

- (a) 300 nm, (b) 397 nm (core of Ca II H line)
- Spatial resolution of 70 km at 397 nm (after spatial reconstructions)
- 397 nm aligned to IMaX line core
- 300 nm aligned to IMaX continuum



Results: Visible wavelengths

IMaX continuum vs. $\mathbf{B}_{\mathrm{LOS}}$ | **IMaX line core vs. $\mathbf{B}_{\mathrm{LOS}}$**



- We show in red the curve composed of the binned contrast values.
- The IMaX continuum contrast peaks at 850 G and decreases below unity at higher $\mathbf{B}_{\mathrm{LOS}}$ values.
- This shape is explained by the effect of finite spatial resolution in observations [3, 6].

References

[1] Kahil, F., Riethmüller, T., L., & Solanki, S., K. 2017, ApJS, 229, 10
[2] Krivova, N. A., Solanki, S. K., & Floyd, L. 2006, A&A, 452, 631
[3] Kobel, P., Solanki, S. K., & Borrero, J. M. 2011, A&A, 531, A112
[4] Topka, K. P., Tarbell, T. D., & Title, A. M. 1992, ApJ, 396, 351
[5] Solanki, S. K. & Brigljevic, V. 1992, A&A, 262, L29
[6] Danilovic, S., Röhrbein, D., Cameron, R. H., & Schüssler, M. 2013, A&A, 550, A118

Results: Morphology of magnetic elements in plage

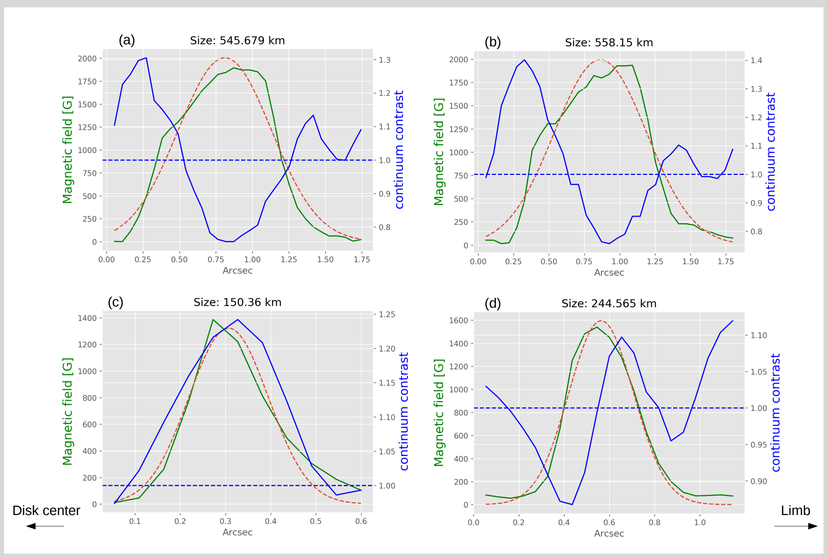
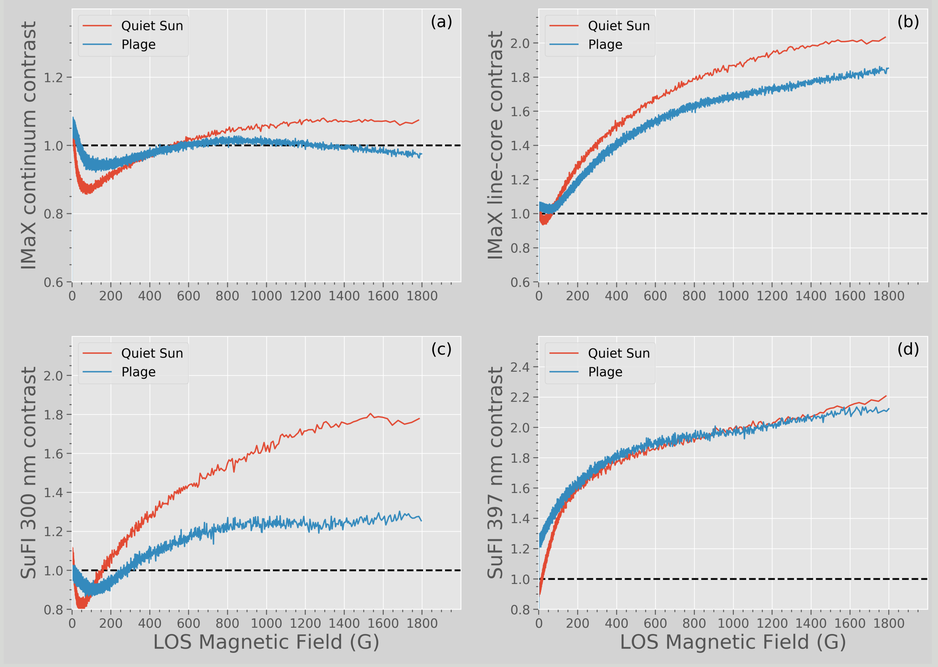


Figure : Profiles of $\mathbf{B}_{\mathrm{LOS}}$ and IMaX continuum contrast across features of different sizes. The cuts are perpendicular to the limb.

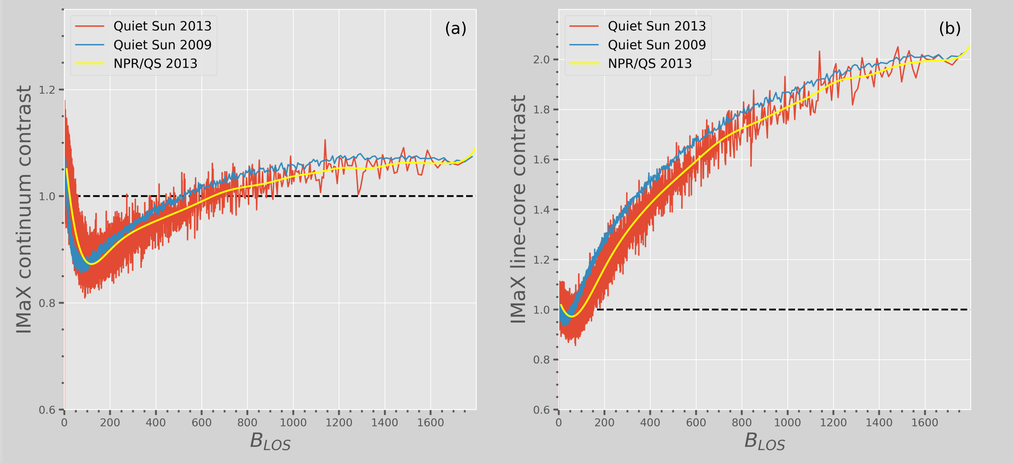
- Large features have a dark core (contrast < 1), small features have a bright core (contrast > 1), intermediate size features are bright in the limb direction and dark towards disc center.
- One plage magnetic element provides pixels in different parts of the IMaX continuum contrast vs. $\mathbf{B}_{\mathrm{LOS}}$ scatterplot $\Longrightarrow$ The scatter is real.

Results: Quiet Sun vs. AR plage



- Quiet Sun contrast is larger than in AR plage at all wavelengths, in accordance with [3, 4].
- The difference in contrast is large in the lower photosphere and decreases with atmospheric height, in accordance with [5].

Quiet Sun 2009 vs. Quiet Sun 2013



- The IMaX continuum and line core contrasts vs. $\mathbf{B}_{\mathrm{LOS}}$ relationship in quiet Sun areas from AR scans ($\boldsymbol{\mu} = \mathbf{0.93}$) agrees qualitatively with the 2009 quiet Sun results ($\boldsymbol{\mu} = \mathbf{0.97}$).

Conclusions

- The turnover of the IMaX continuum contrast at higher $\mathbf{B}_{\mathrm{LOS}}$ values is not an effect of poor spatial resolution, as pointed out in [3, 6].
- Magnetic elements are starting to be resolved with IMaX (saturation of the IMaX continuum contrast at higher $\mathbf{B}_{\mathrm{LOS}}$ in QS-2009 and QS-2013 and internal structure of plage elements are resolved).

Outlook

- To simulate a plage region in which pores are formed ($\bar{\mathbf{B}} = \mathbf{400}$ G), and synthesize Stokes profiles at $\boldsymbol{\mu} = \mathbf{0.93}$ to compare with IMaX observations.

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