Interpretation of SIM measurements through the analysis of MHD simulations

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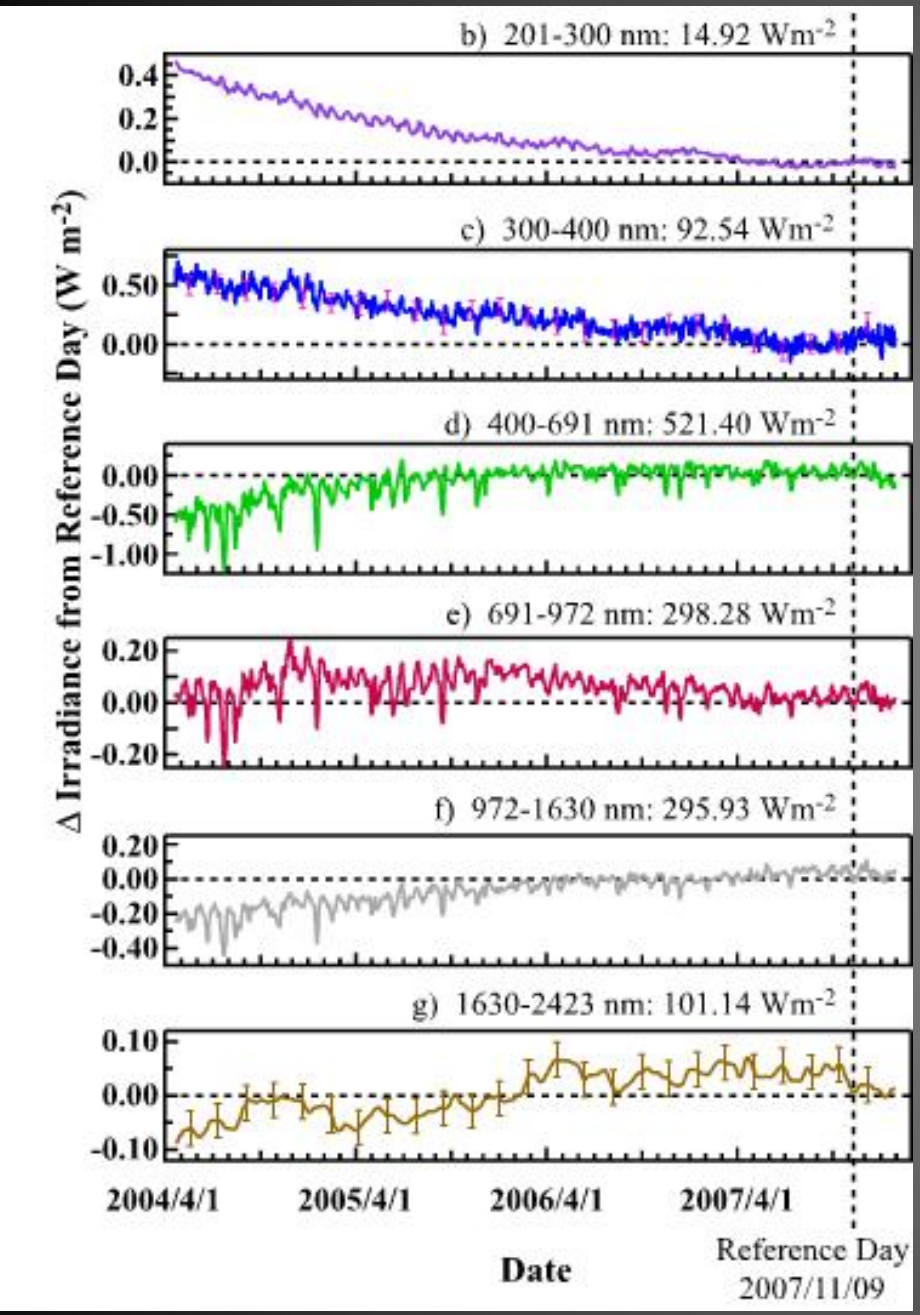
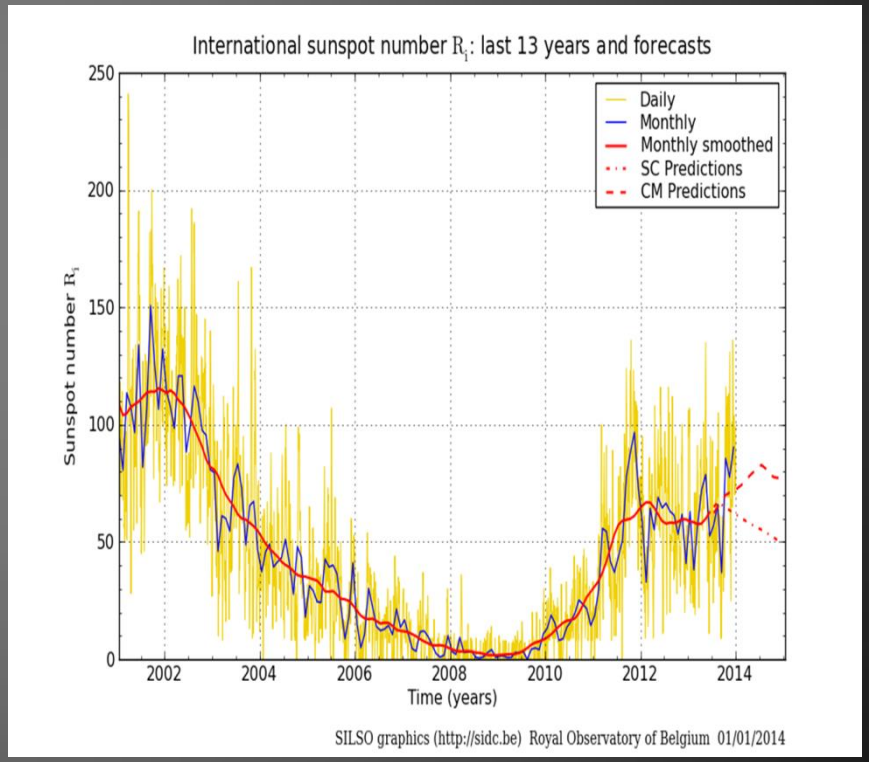


From Harder et al. 2009

SIM measurements in VIS and IR are in counter-phase with the solar magnetic cycle



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SIM results have been largely debated

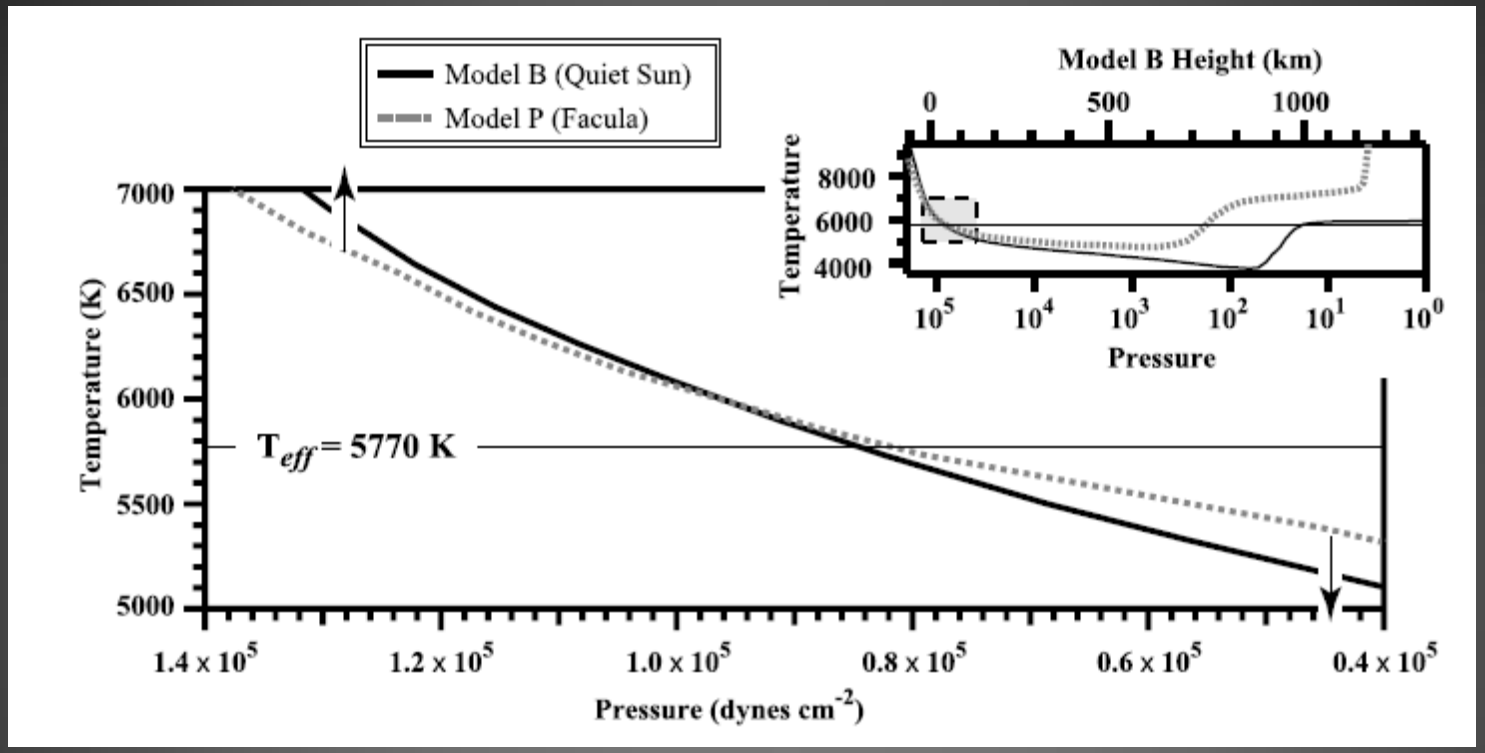
Comparison with other radiometers (e.g. VIRGO):

-- Radiometers are affected by degradation effects which are difficult to remove, so that different corrections lead to different conclusions (see talk by Schmutz)

- Overall, comparison with other instruments seem not to confirm SIM measurements.

Reconstructions

- SATIRE do not reproduce SIM measurements (e.g. Ball et al. 2011)
- SRPM (e.g. Fontenla et al. 2012) and SFO (Preminger et al. 2011) confirm SIM measurements.



According to Harder et al. 2009
SIM measurements suggest that the temperature gradient of magnetic regions changes with the cycle. The arrows indicate the change during the MINIMUM.

Large part of Irradiance reconstructions make use of 1D static atmosphere semi-empirical model, or proxies, which depend on the signals they are trying to reproduce.

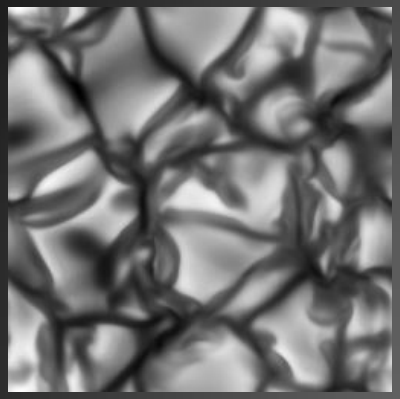
What can we learn from 3D magneto hydrodynamic (MHD) simulation?

Numerical Simulations

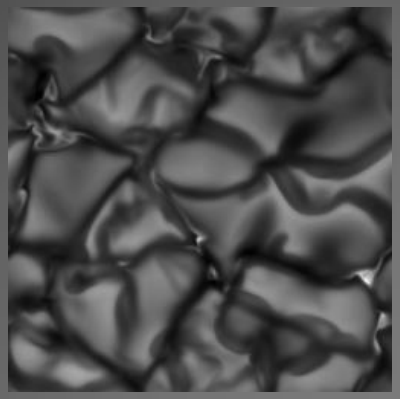
- Copenhagen Stagger Code (Nordlund&Galsgaard 1996)
- 10 snapshots HD; 10 for 50G, 100G, 200G MHD.
- Enough statistics to average over the 5 mins.
- 6 x 6 Mm^2; 24 km hor. res.; 13-19 km vert. res. [-500, 500 km]

Continuum intensity at equally spaced 6 continua within SIM, computed with RH code (Uitenbroek 2002) in LTE.

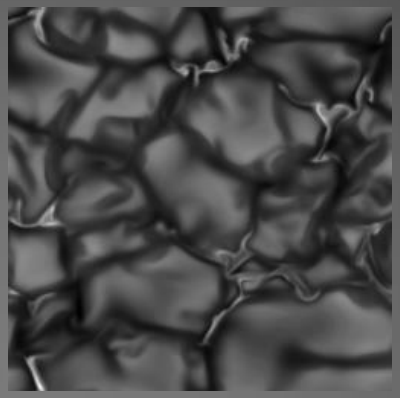
HD



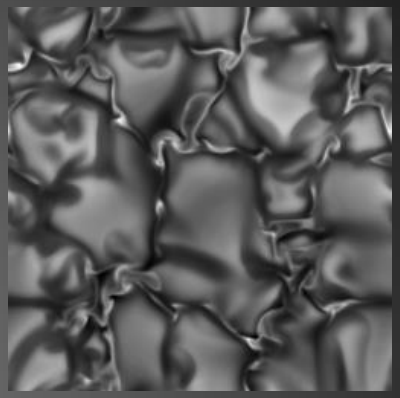
50G



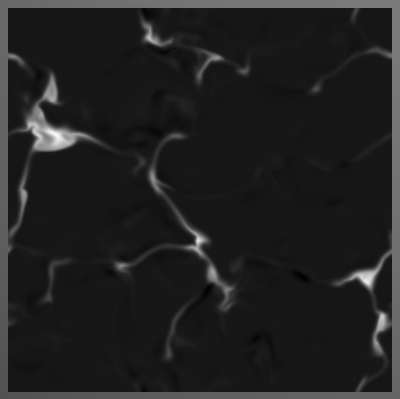
100G

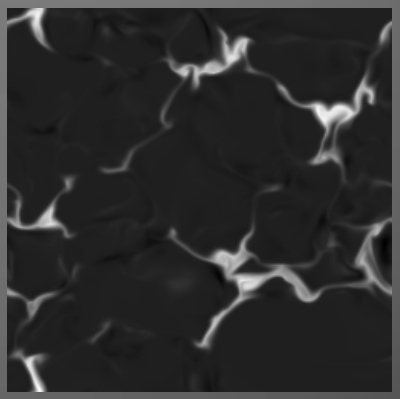


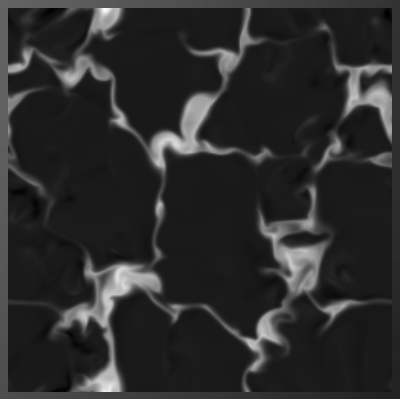
200G



Continuum @ 630 nm

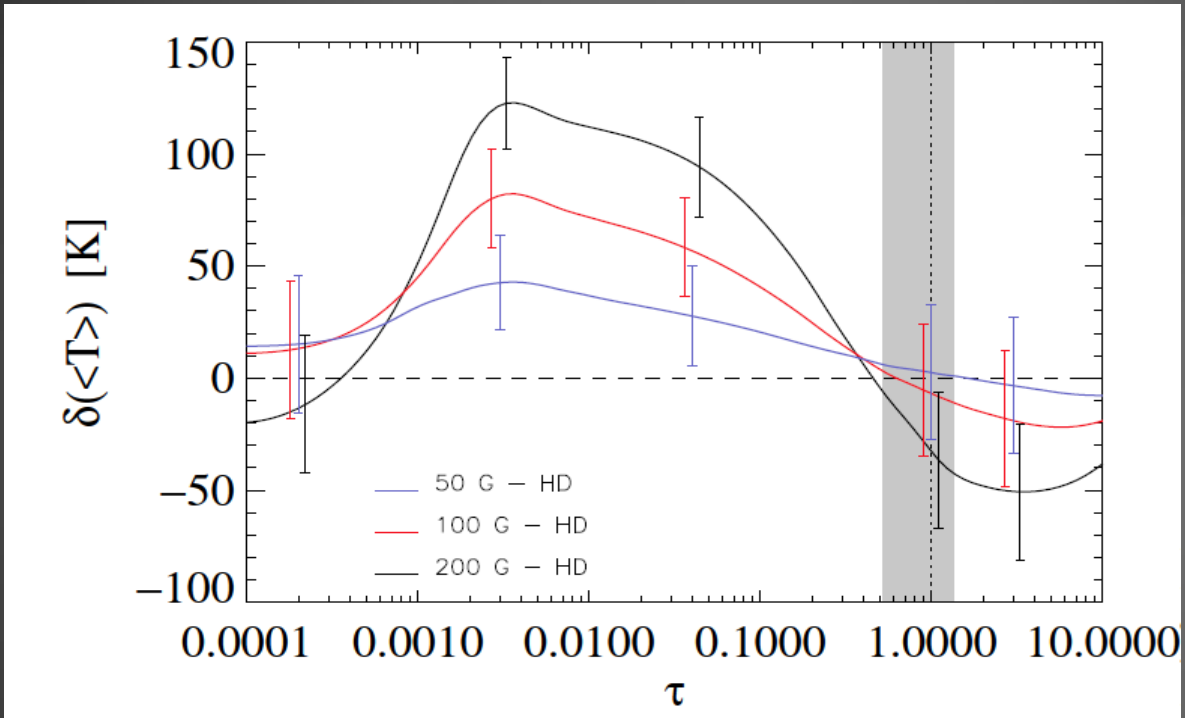






Vertical component of Magnetic Field at τ=1

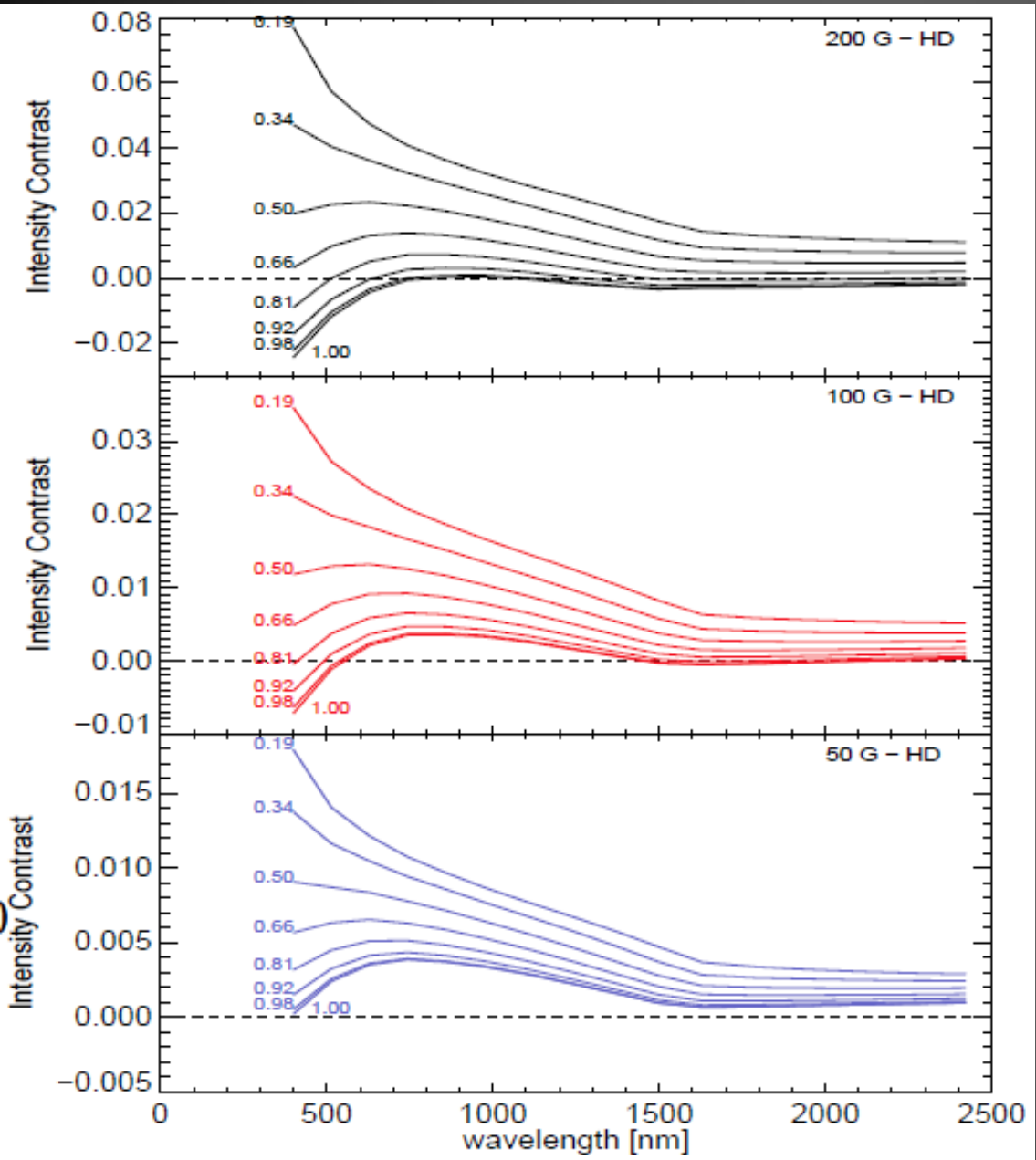
The variation of the average temperature gradient with the magnetic flux is in qualitative agreement with that claimed in Harder et al. 2009!



Gray area: formation height of continua investigated.

The decrease of the temperature in the lower layers with the increase of the magnetic flux is due to the inhibition of convection.
The increase of the temperature in the upper layers with the increase of the magnetic flux is due to the presence of magnetic features.
(Criscuoli, ApJ, 2013)

Average Intensity Contrast



Intensity contrast = $\langle I \rangle_{MHD} / \langle I \rangle_{HD} - 1$

Close to disk center the maximum of contrast is at around 800 nm, which corresponds to the maximum of H^- opacity → higher in the atmosphere

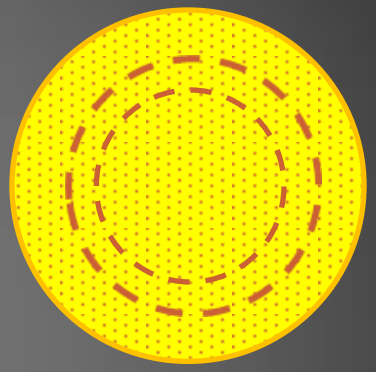
At other λ sample deeper layers, where the difference of T between MHD and HD is lower (negative for 100 and 200 G)

With the increase of Φ(B) the contrast decreases at/close to disk center and increases toward the limb.

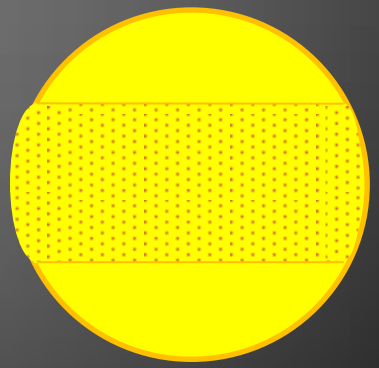
This suggests (confirms) that faculae can have negative contribution

We cannot perform a reconstruction, therefore we consider two cases:

- Faculae uniformly distributed over disks of increasing radius



- Faculae uniformly distributed over the activity belt



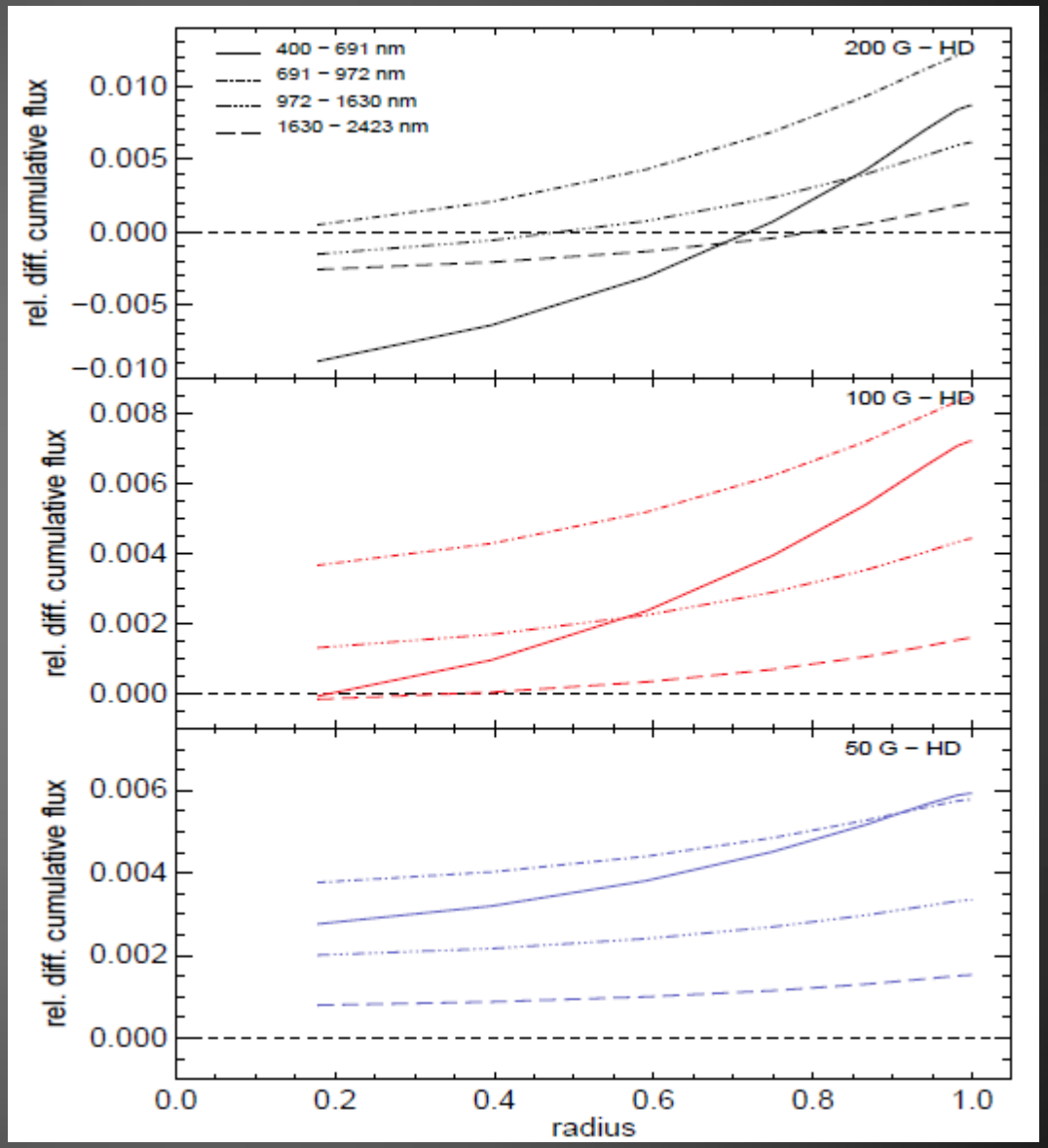
Good approximation for several solar rotations!

Faculae uniformly distributed over disks of increasing radius

The relative contribution of features is strongly dependent on their location over the disk.

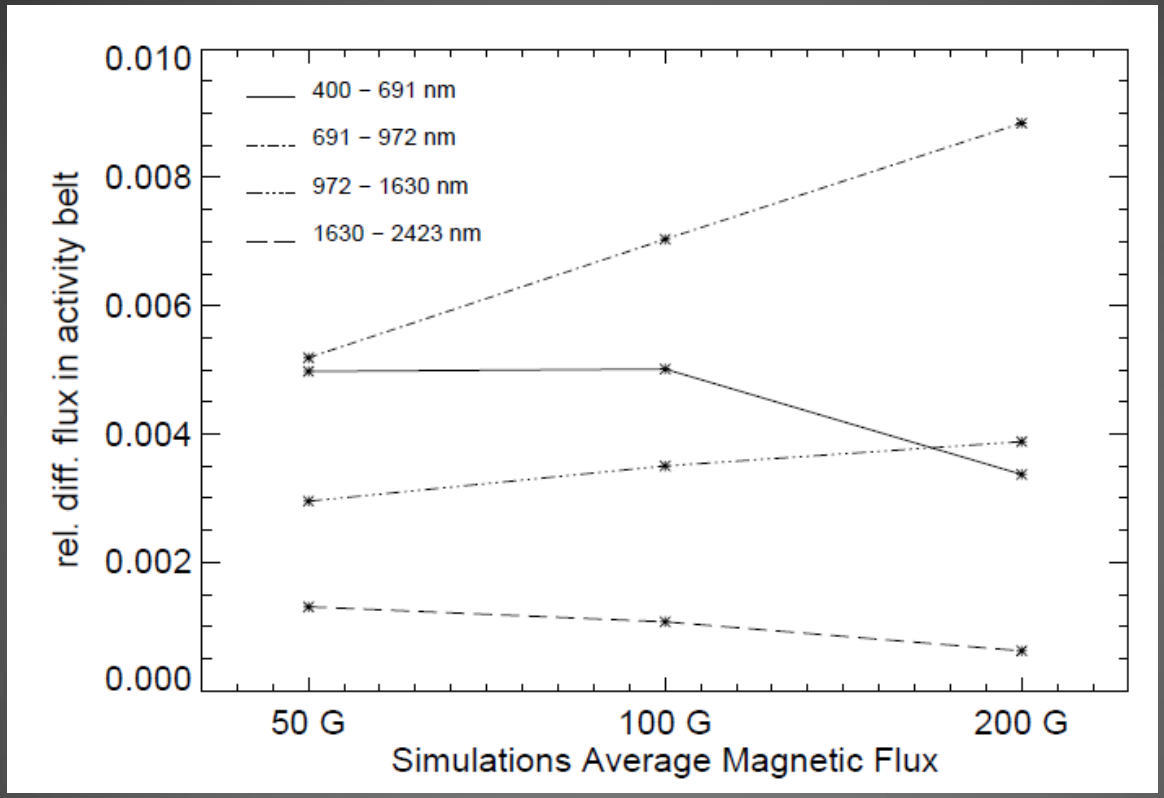
In particular, for the 200 G case the contribution can be negative, especially in the visible and IR bands for which SIM measured the largest decrease with the increase of the magnetic activity.

Nevertheless, when considering the whole disk, the radiative flux increases with $\Phi(B)$.



Relative radiative flux computed at increasing partial radii

Faculae uniformly distributed over the activity belt



Relative radiative flux computed over the activity belt

Radiative flux emerging from MHD snapshots is always larger than the emerging flux from the HD snapshots (the relative difference reported in the plot is always positive), but **it decreases with the increase of the average magnetic flux $\Phi(B)$ in at least two of the SIM bands.**

Discussion

- Assumption #1: LTE

  We consider continua

- Assumption #2: not inclusion of lines

  Most of the irradiance signal is generated by continua. The inclusion of lines shifts the average opacity to higher layers, thus increasing the emission at all wavelengths. Since the temperature gradient becomes more shallow with the increase of $\Phi(B)$, we expect the increase of the opacity to be smaller for the highest magnetic flux, thus steepening the radiative flux – magnetic flux dependence (previous plot).

- Assumption #3: $\Phi(B)$ up to 200 G

  Measurements, as well other MHD simulations indicate that the CLV of continuum contrast steepens with the increase of $\Phi(B)$, while the position at which the contrast becomes positive shifts toward the limb. Therefore we expect the radiative flux – magnetic flux dependence to steepen.

Conclusions

- Our results confirm that the contribution of magnetic features to irradiance strongly depends on their location over the solar disk. A true reconstruction is needed! (see discussion in Fontenla et al. 2012)

- If magnetic features are located mostly in the activity belt, and assuming the HD as the reference, the contribution of magnetic features is always positive, but decreases with the increases of the magnetic flux in some bands (those that form deeper in the atmosphere).

- If we also assume that with the increase of the activity increases the number of features with associated higher magnetic flux, then the SI decreases.

It is therefore plausible to measure a decrease of the irradiance with the increase of the activity at (some of) SIM spectral bands. In particular, if the 50G is taken as reference, the contribution to irradiance can be negative