IRIS-9, MPS | 28 June 2018

Does ALMA help state-of-the-art inversions of the solar atmosphere ?

arXiv.org arXiv:1806.06682

Stockholms universitet

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Contributed Talk

5. Opportunities and challenges

Does ALMA help state-of-the-art inversions of the solar atmosphere ?

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We present a study of the performance of inversions of synthetic optical and UV spectral lines together with ALMA mm-bands computed from a snapshot of a 3D radiation-MHD Bifrost simulation.
Distinctly from photospheric lines, most chromospheric diagnostics such as CaII 854.2 nm and MgII h & k form under non-LTE conditions, therefore they are weakly coupled to the local conditions of the plasma. On the other hand, 1.2 mm and 3 mm continuum emission as probed by ALMA forms in the chromosphere and its source function can be treated in LTE, hence it can be used to estimate chromospheric temperatures. However, proper use of ALMA data requires successful imaging at very high resolution which is a rather challenging endeavor. In fact, ALMA observations will be most useful when combined with other spectral ranges, but the combined diagnostic potential is not yet fully assessed.
We found that coordinated observations from ALMA, SST and IRIS can be used to estimate the full thermodynamical state of the plasma as a function of optical depth. Notably, the addition of ALMA bands to the pre-existing diagnostics should help constraining both chromospheric temperatures and magnetic fields. We found, nonetheless, that multi-line non-LTE inversions already present strong constraints especially when optical and UV lines are used simultaneously, emphasizing the importance of the new CaII K observations with SST/CHROMIS.

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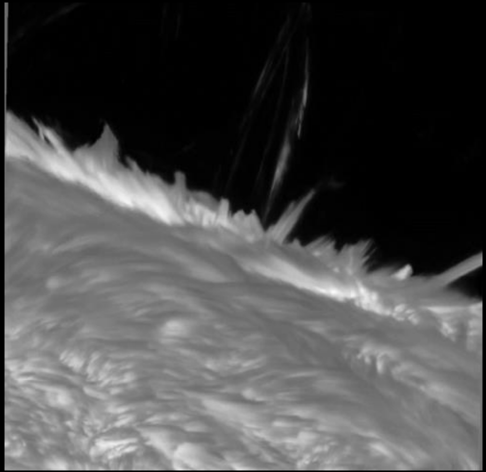
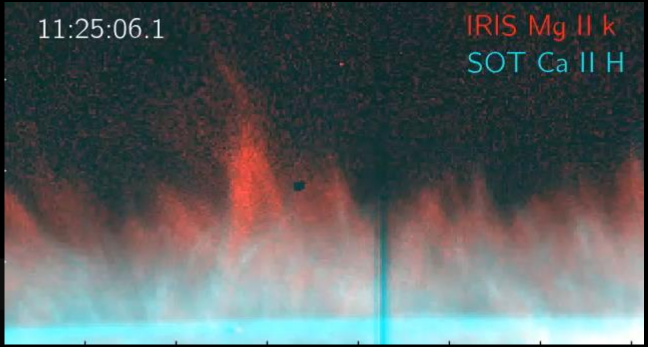


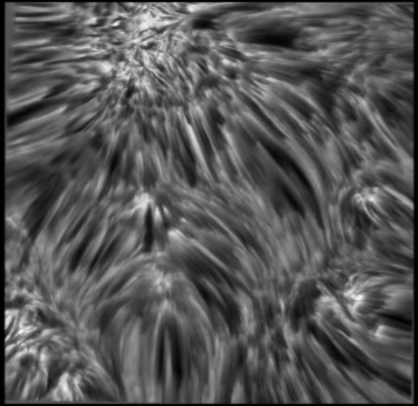
The limb of the Sun in H α (SST)
credit: J. Bjørgen, J. Joshi

Non/LTE,
3D radiative transfer

Solar eclipse 1999
credit: Luc Viatour



The limb of the Sun in Mg II k, CaII H (IRIS/SOT)
credit: Pereira et al. 2014, ApJ, 792, L15



Active region, disk, H α (SST)
credit: S. Kianfar, J. de la Cruz Rodrguez, J. Leenaarts

ALMA

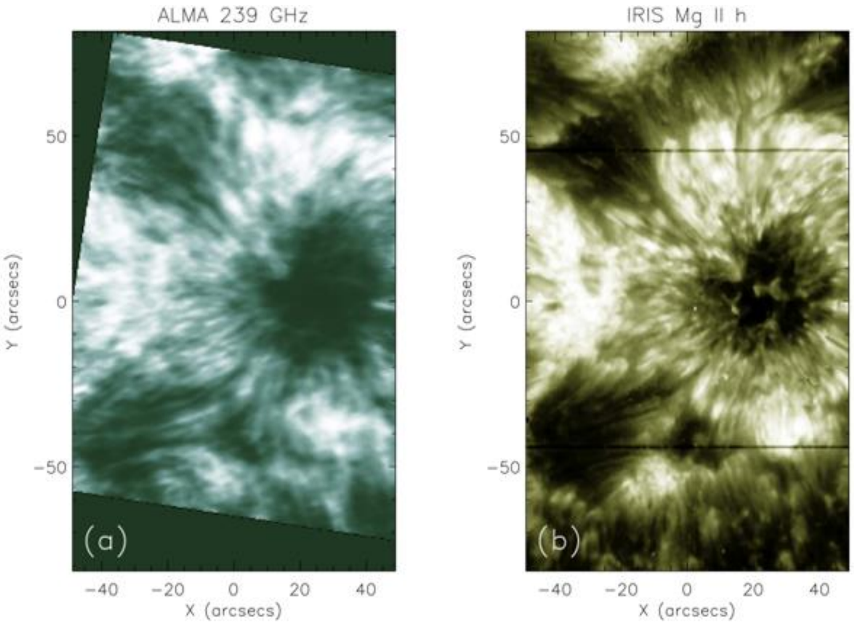
mm-continuum (QS)

thermal free-free, $I_\lambda \propto T/\lambda^4$

(e.g. Kundu 1977; Rutten 2017; Wedemeyer-Böhm et al 2007; White et al 2017)

probing temperatures and magnetic fields

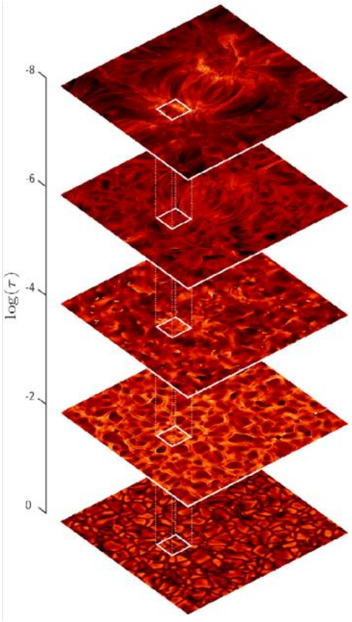
(e.g. Loukitcheva et al 2015, 2017)



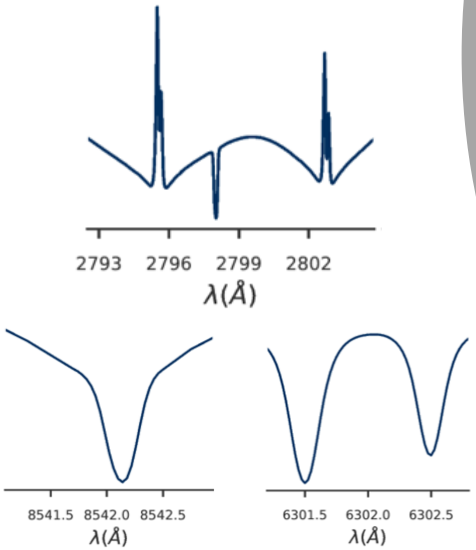
comparison between ALMA T_b at 1.25 mm and MgII h2v (Bastian et al 2017)

Our approach

Calculations



Temperature



Average spectra from a patch of a Bifrost simulation

3D R-MHD simulation:

Bifrost - en024048_hion (385)

(Gudiksen et al 2011; Carlsson et al 2016)

Forward / inverse calculations: STiC

(de la Cruz Rodríguez et al 2016)

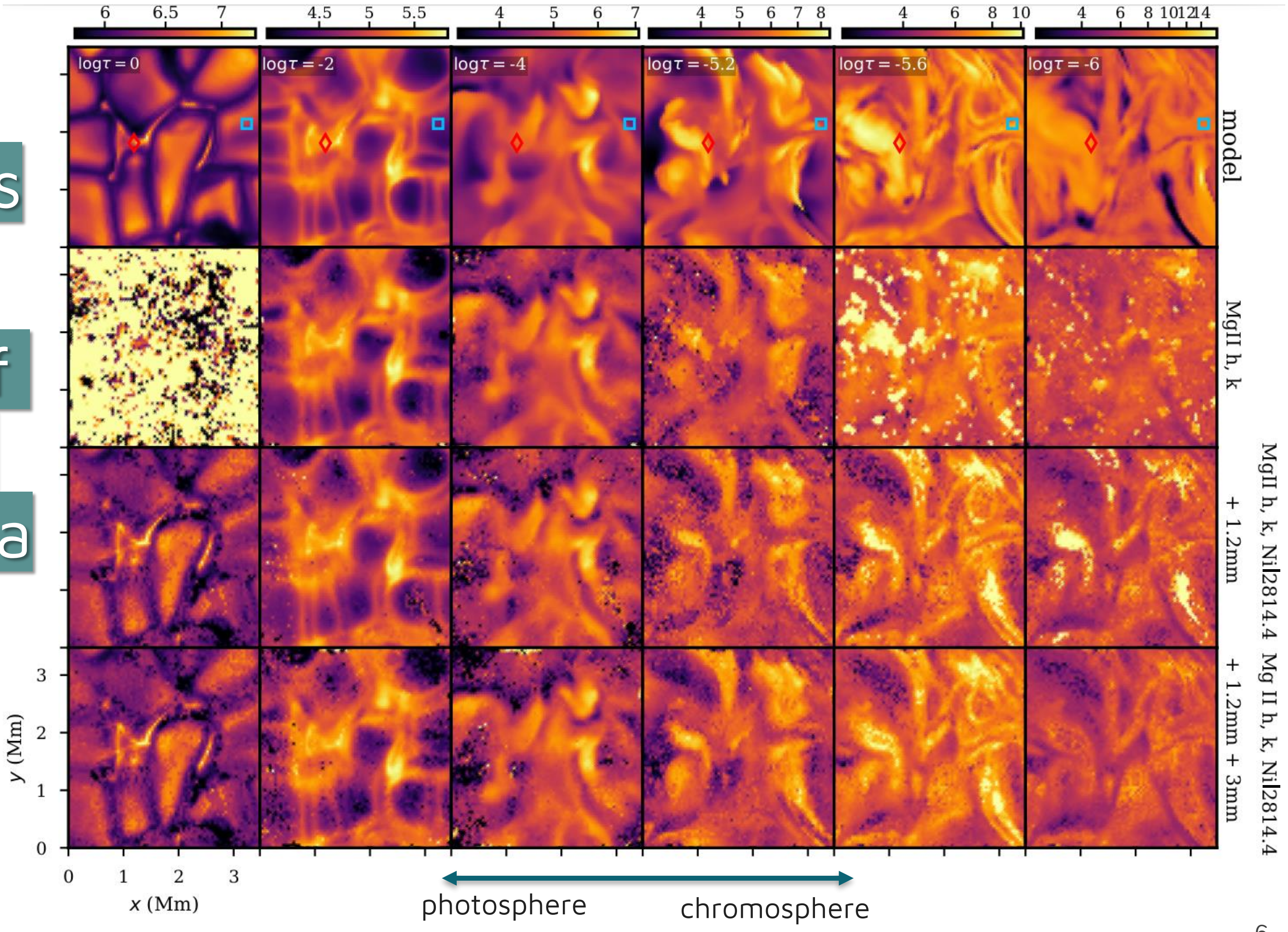
NLTE — 1.5 D — PRD

Hydrostatic Eql.

Results

Inversions of IRIS+ALMA synthetic data

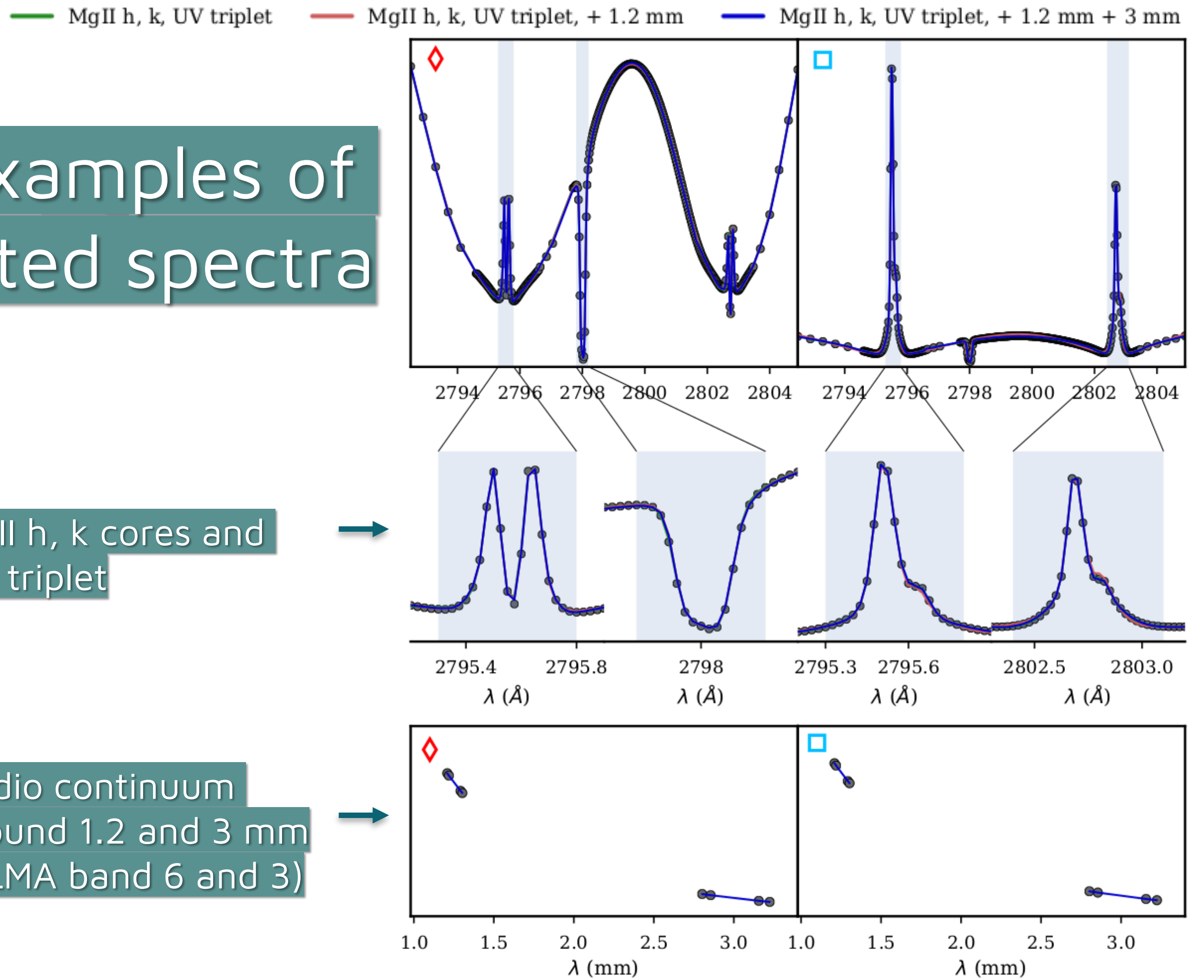
Temperature maps as function of optical depth

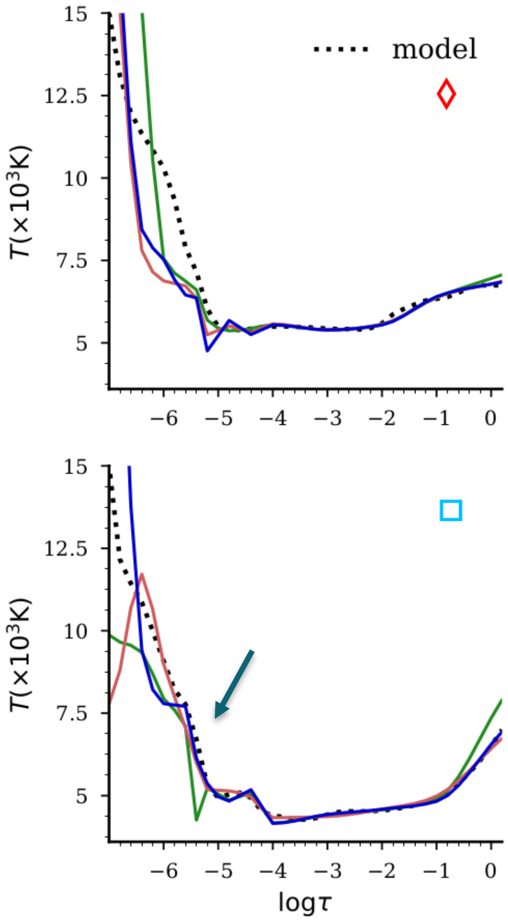


Examples of fitted spectra

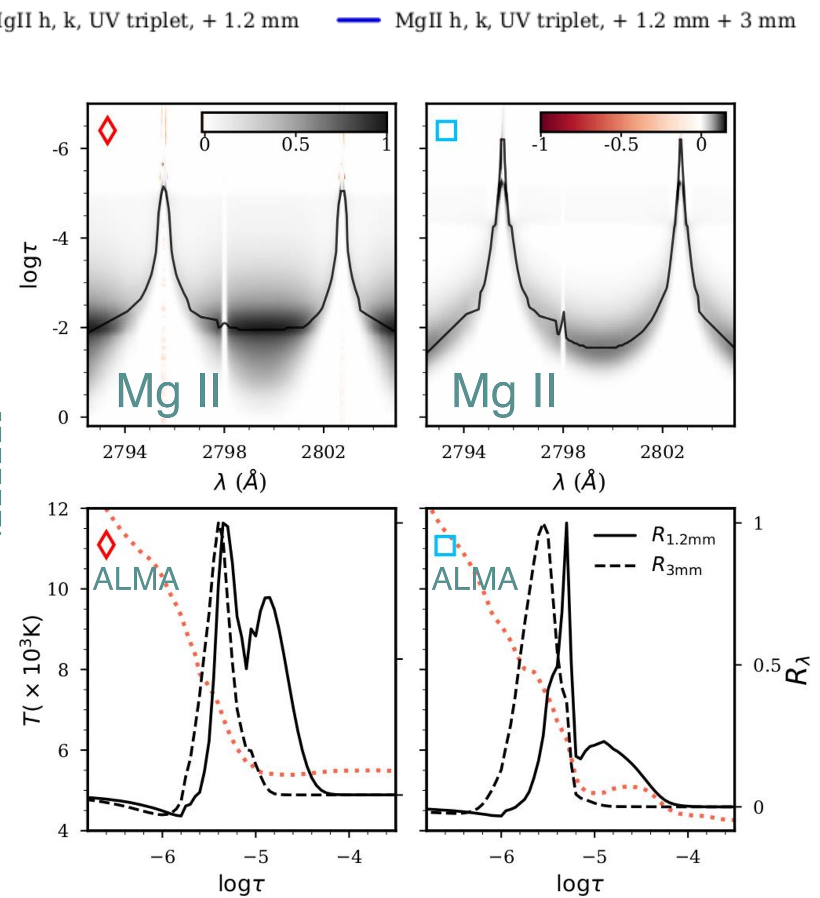
MgII h, k cores and UV triplet

Radio continuum around 1.2 and 3 mm (ALMA band 6 and 3)





Model and inverted temperature profiles for different schemes



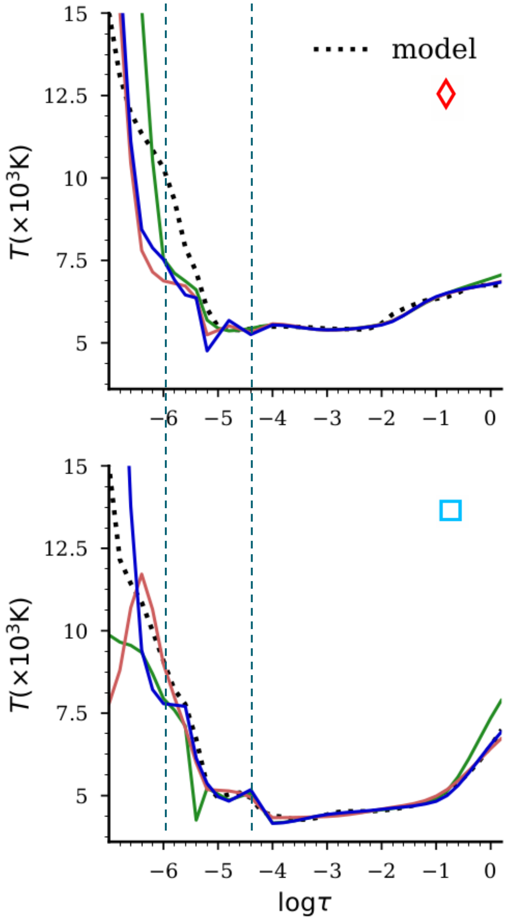
Response functions

$$R_\lambda(T,\tau_k) = \left.\frac{\partial I_\lambda}{\partial T}\right|_{\tau_k}$$

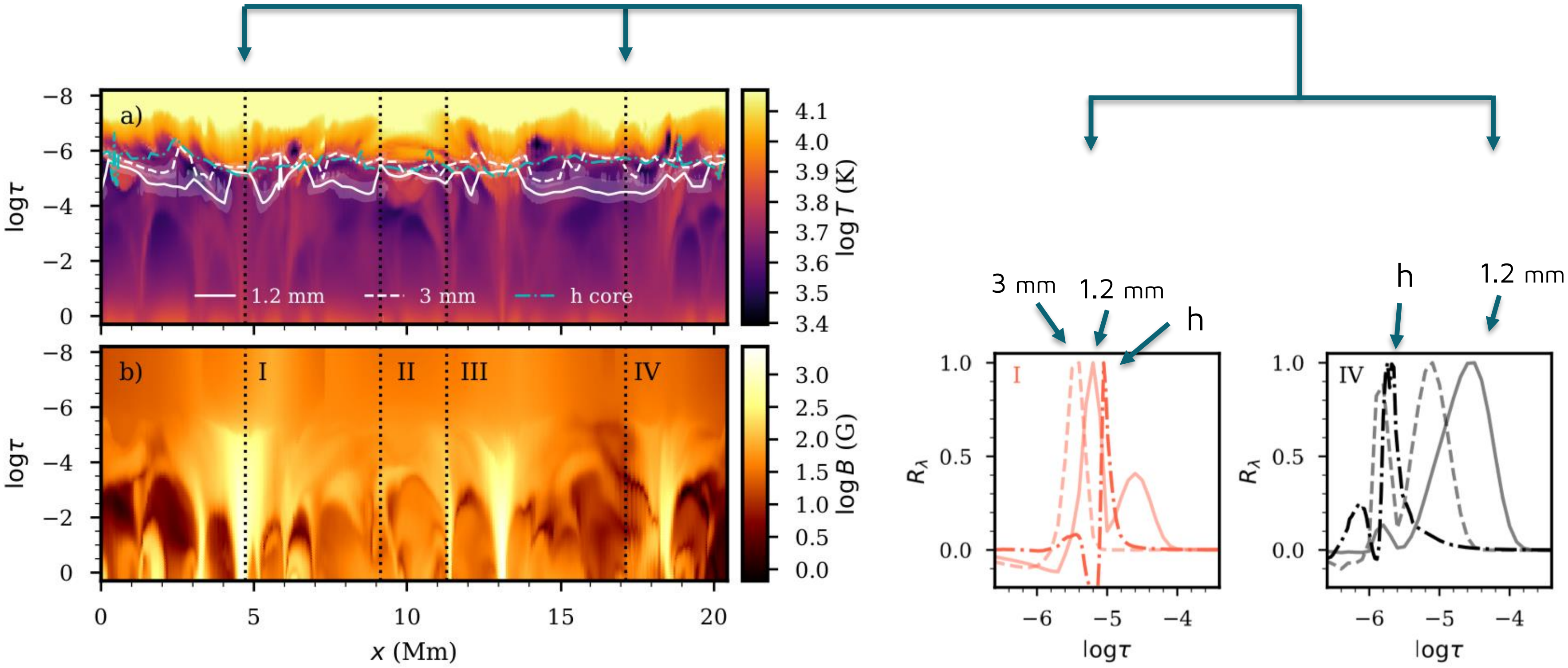
↓

Sensitivity of the diagnostics to temperature perturbations

Normalized $R_\lambda(T,\tau_k)$ of the MgII lines and the mm-continua

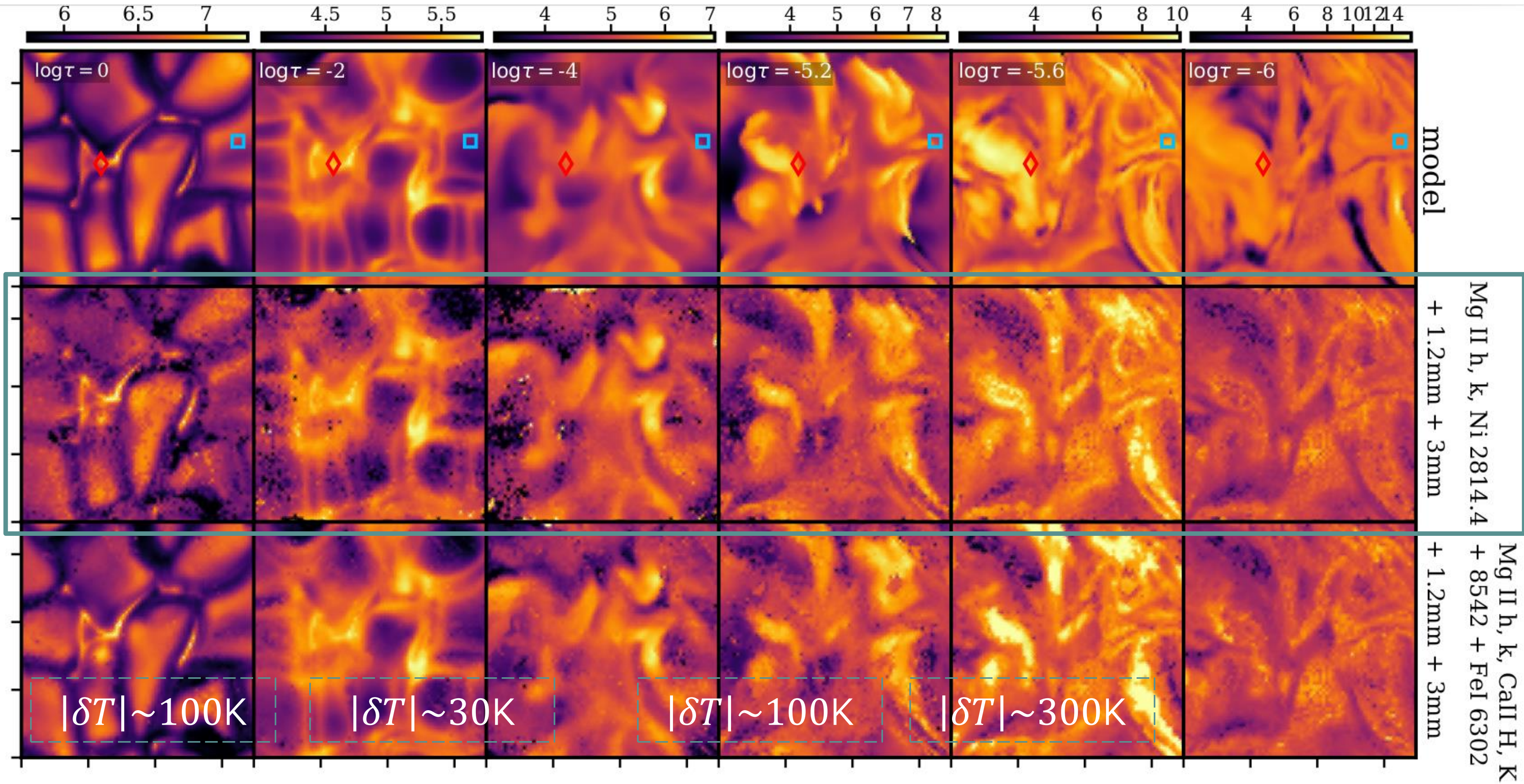


Model and inverted temperature profiles for different schemes



Top: temperature accross a slice of the simulation and peak responses of the mm-continua and MgII h core.
Bottom: magnetic field strength

Normalized $R_\lambda(T, \tau)$ of the mm continua (solid, dashed) and h core (dashed-dot) at two locations marked on the left figure. arXiv:1806.06682



6 6.5 7
4.5 5 5.5
4 5 6 7
4 5 6 7 8
4 6 8 10
4 6 8 10 12 14
logτ = 0
logτ = -2
logτ = -4
logτ = -5.2
logτ = -5.6
logτ = -6
model
Mg II h, k, Ni 2814.4 + 1.2mm + 3mm
Mg II h, k, CaII H, K + 8542 + FeI 6302 + 1.2mm + 3mm
|δT|~100K
|δT|~30K
|δT|~100K
|δT|~300K

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Conclusions

The mm-continnum provides:

- more stringent constraints on chromospheric temperatures;
- more spatial structures in the chromosphere (time evolution?);
- excellent complement to IRIS observations;

but,

- The low chromosphere <u>in the simulation</u> is also relatively well constrained from a combination of UV and optical lines.

extra

Distributions of optical depths at the maximum response