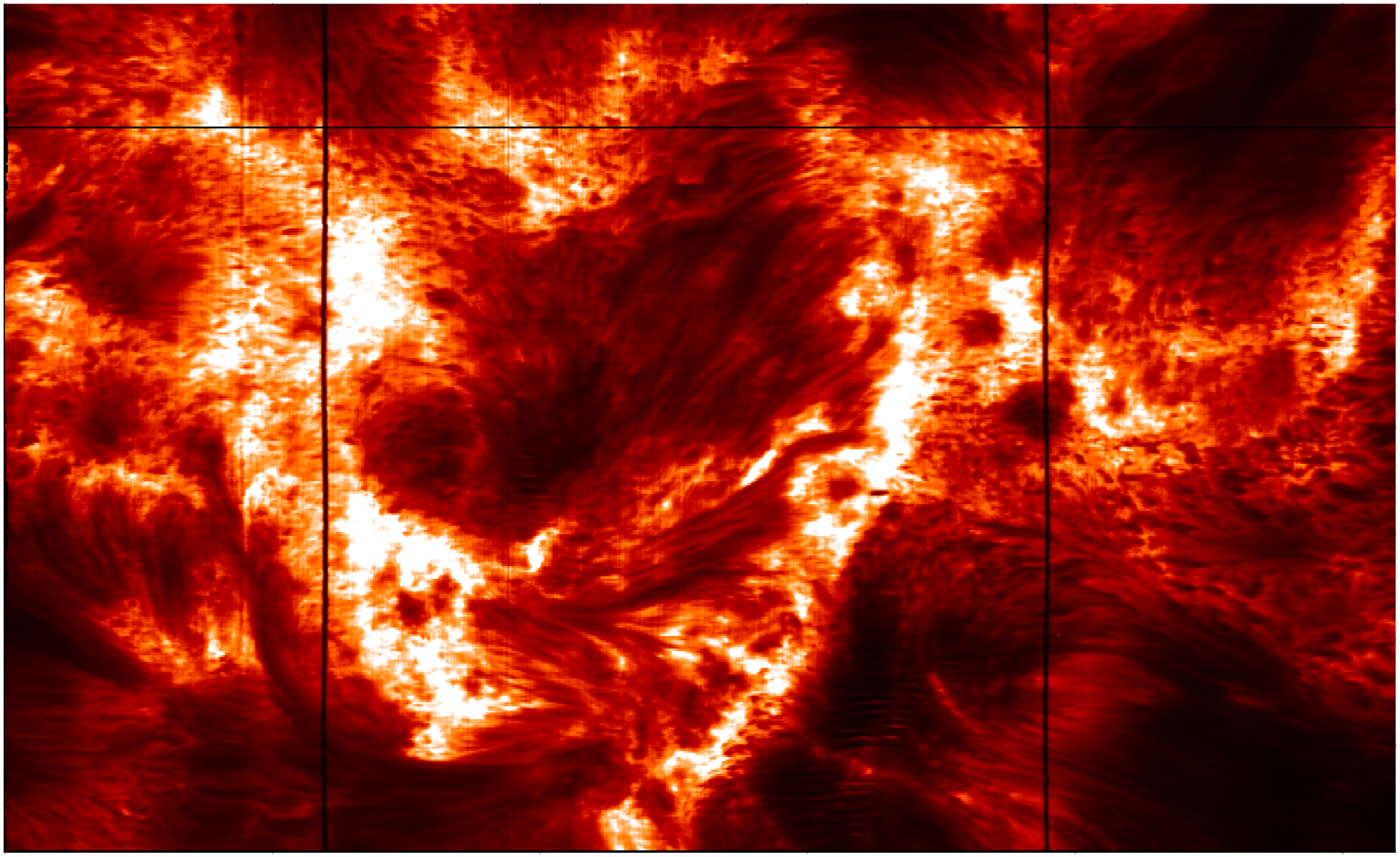
NLTE inversions of Mg II h & k lines including PRD effects



Stockholm University

Jaime de la Cruz Rodríguez

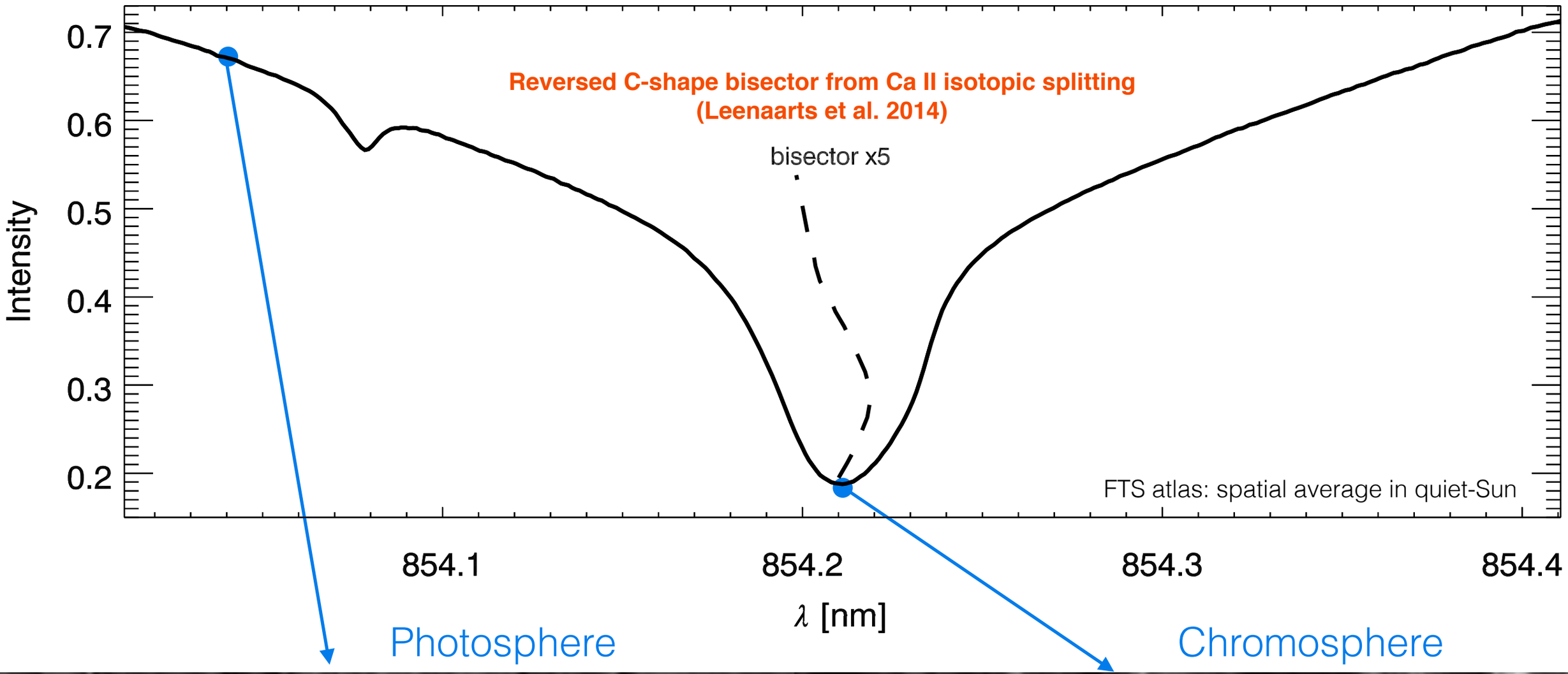
non-LTE inversions: Nicole

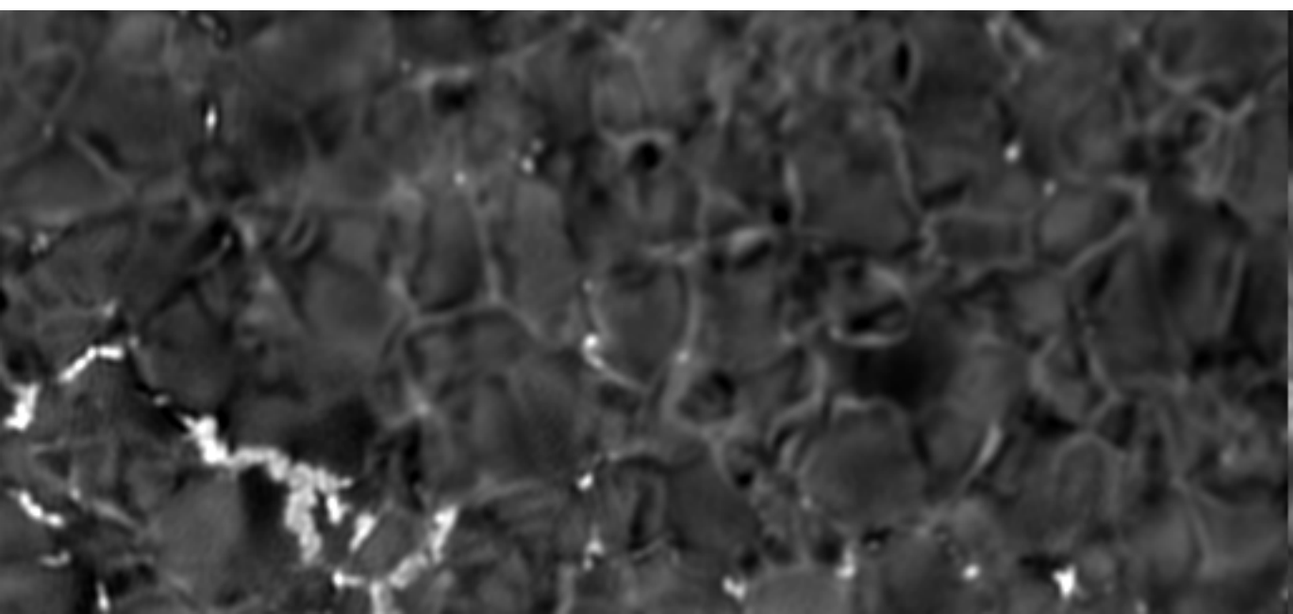
Socas-Navarro et al. (2000, 2015)

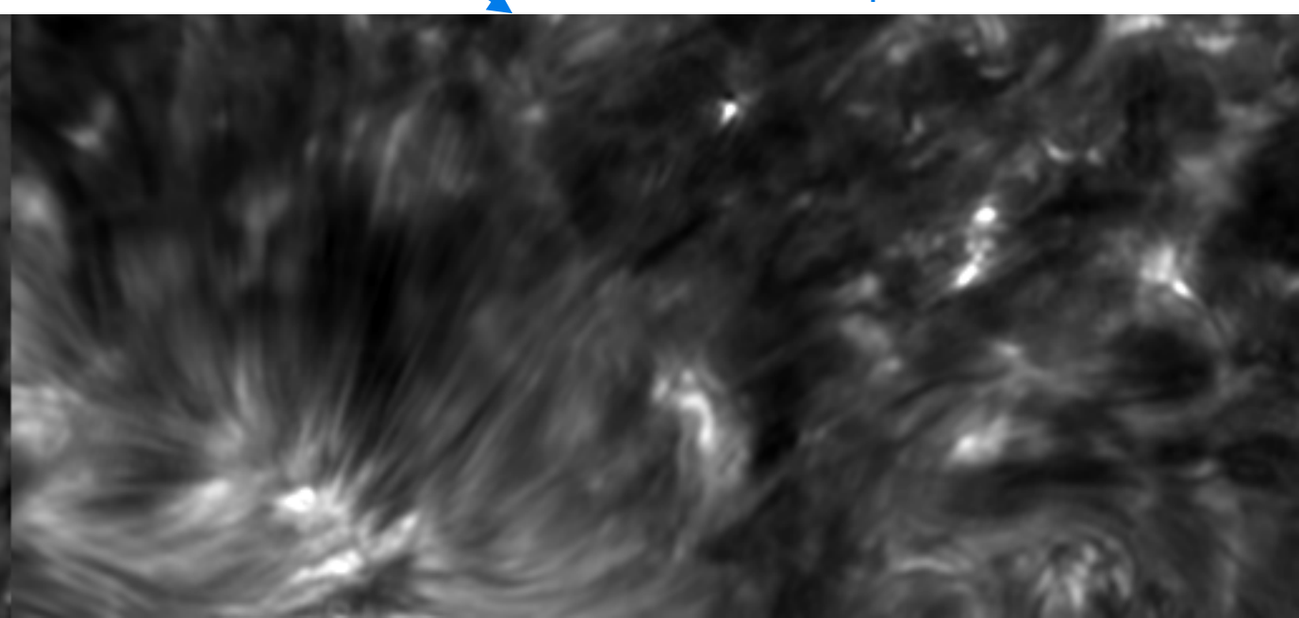
- One atom can be treated in non-LTE (statistical equilibrium).
- 1.5D, each pixel is treated as a plane-parallel atmosphere.
- Hydrostatic equilibrium to derive pressure scales given a tau scale and a temperature profile.
- Complete redistribution of scattered photons (CRD).
- Fortran/MPI.

Line(s)	**Scattered photons**	**Zeeman/Hanle**	**Geometry**	Ionization
Ca II H & K	PRD	Zeeman (AR), Hanle (QS)	1.5D	stat. equilibrium
Hα	CRD	Zeeman (AR), Hanle (QS)	3D	non-equilibrium
Ca II IR triplet	CRD	Zeeman (AR), Hanle (QS)	1.5D	stat. equilibrium
Mg II h & k	PRD	Zeeman, Hanle (k line)	1.5D	stat. equilibrium
He I D_3 & λ10830	CRD (?)	Zeeman + Hanle	3D (?)	non-equilibrium

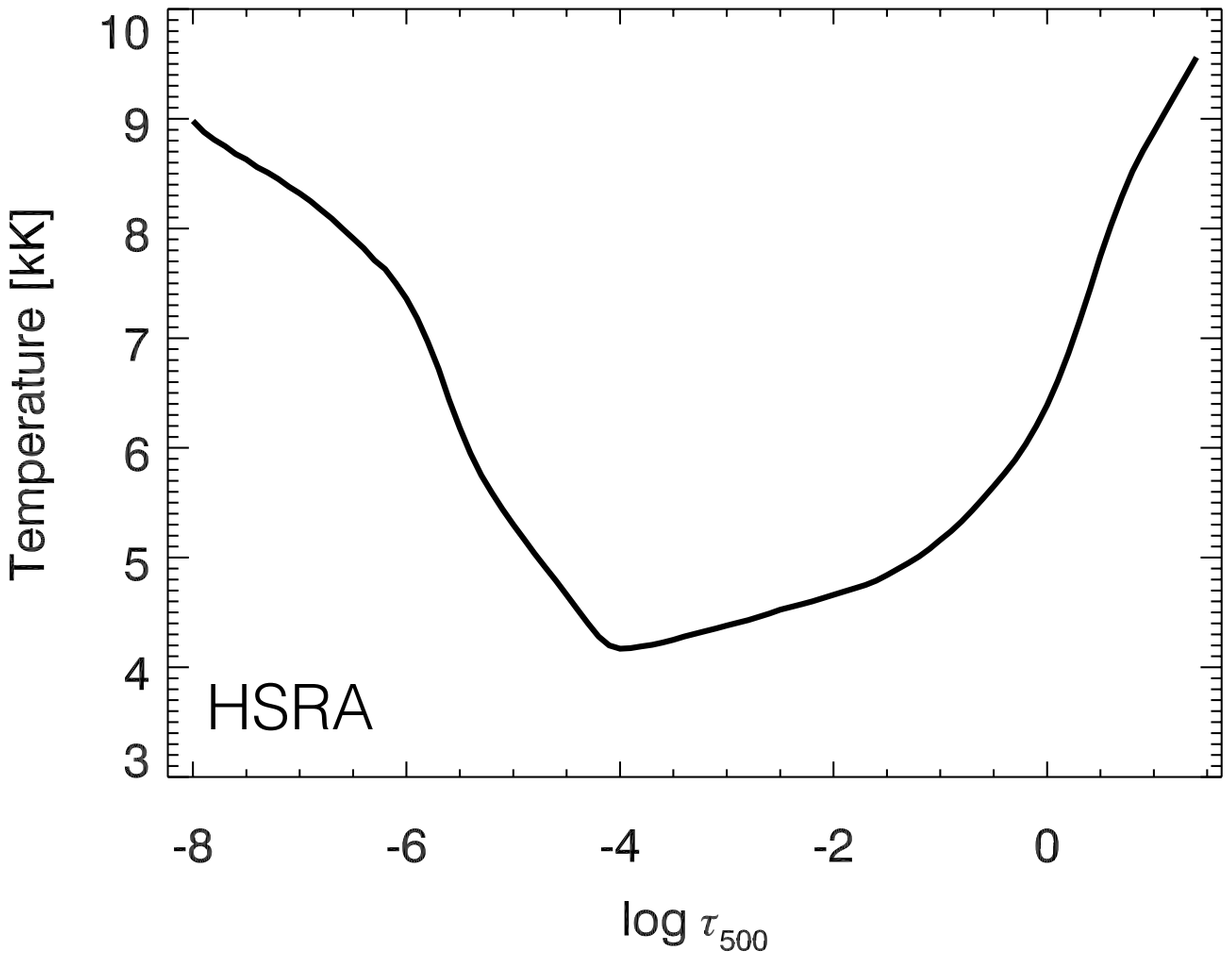
non-LTE inversions in the Ca II 8542 line

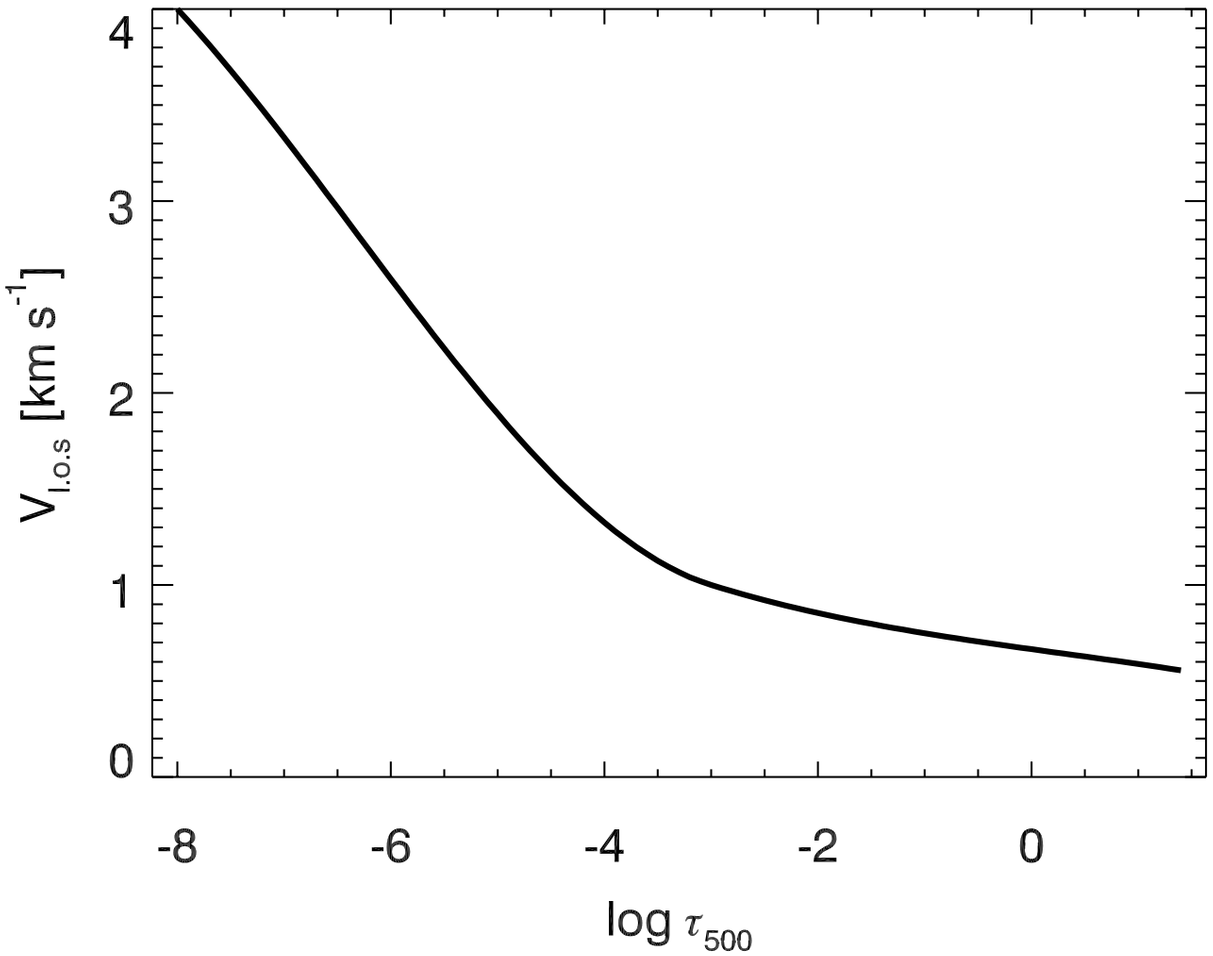






Nodes in depth-stratified atmosphere



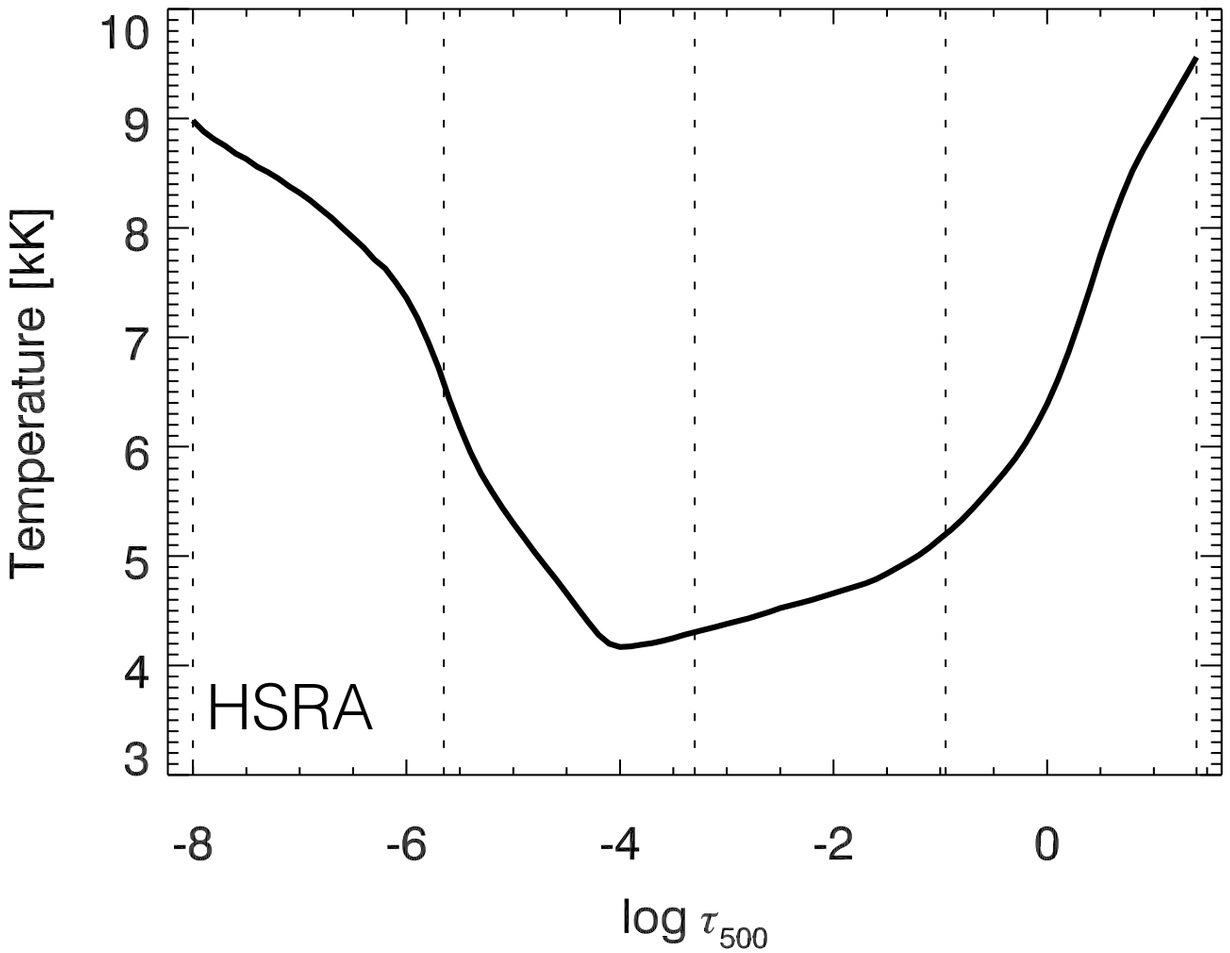


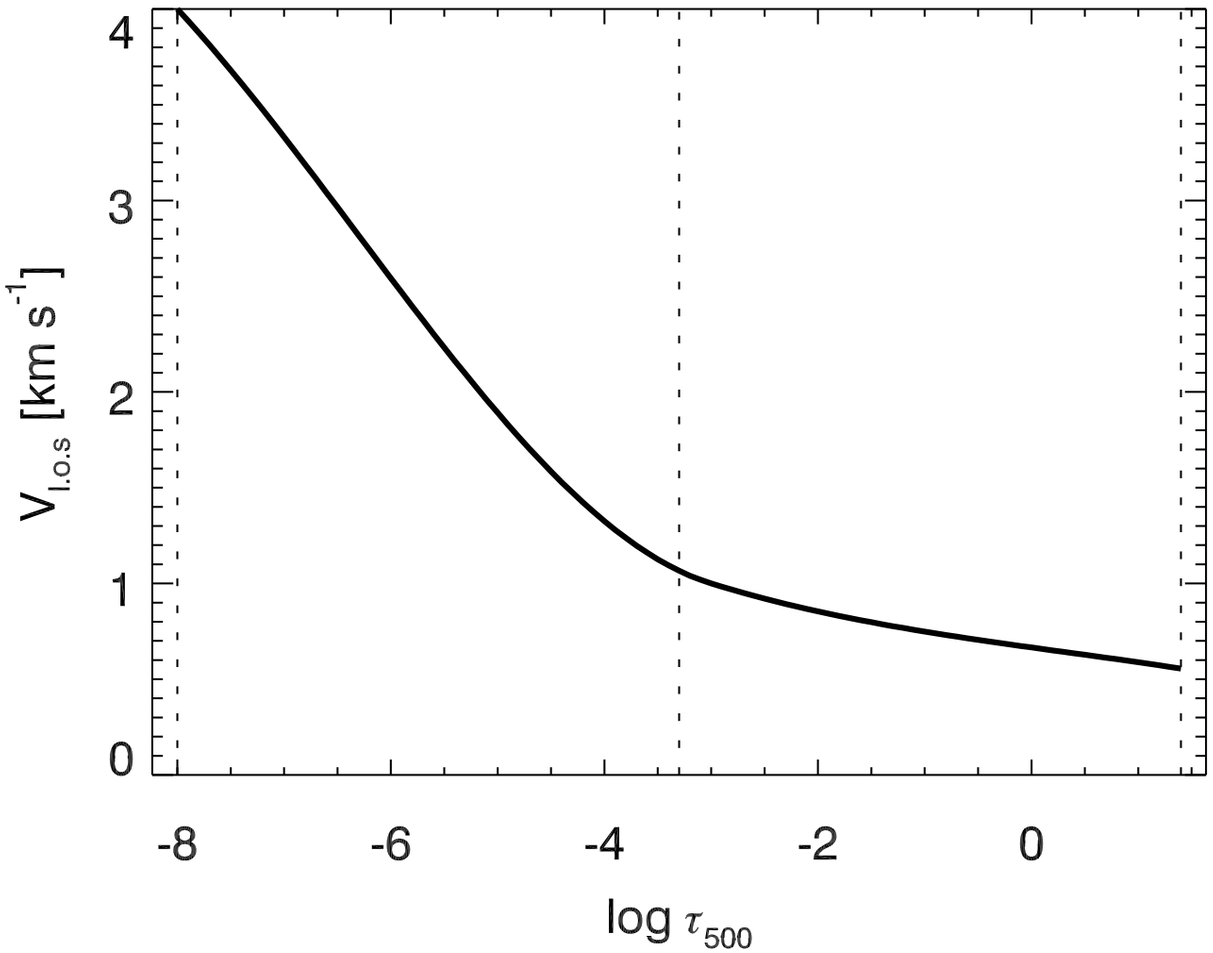
Model: Depth-stratified atmosphere (working in optical-depth at 500 nm).

Parameters: temperature, v_{los}, B_z, B_x, B_y, $v_{turbulent}$, P_{gas}, $P_{el.}$

Inversion : temperature, v_{los}, B_z, B_x, B_y, $v_{turbulent.}$ (hydrostatic eq. for P_{gas}).

Nodes in depth-stratified atmosphere



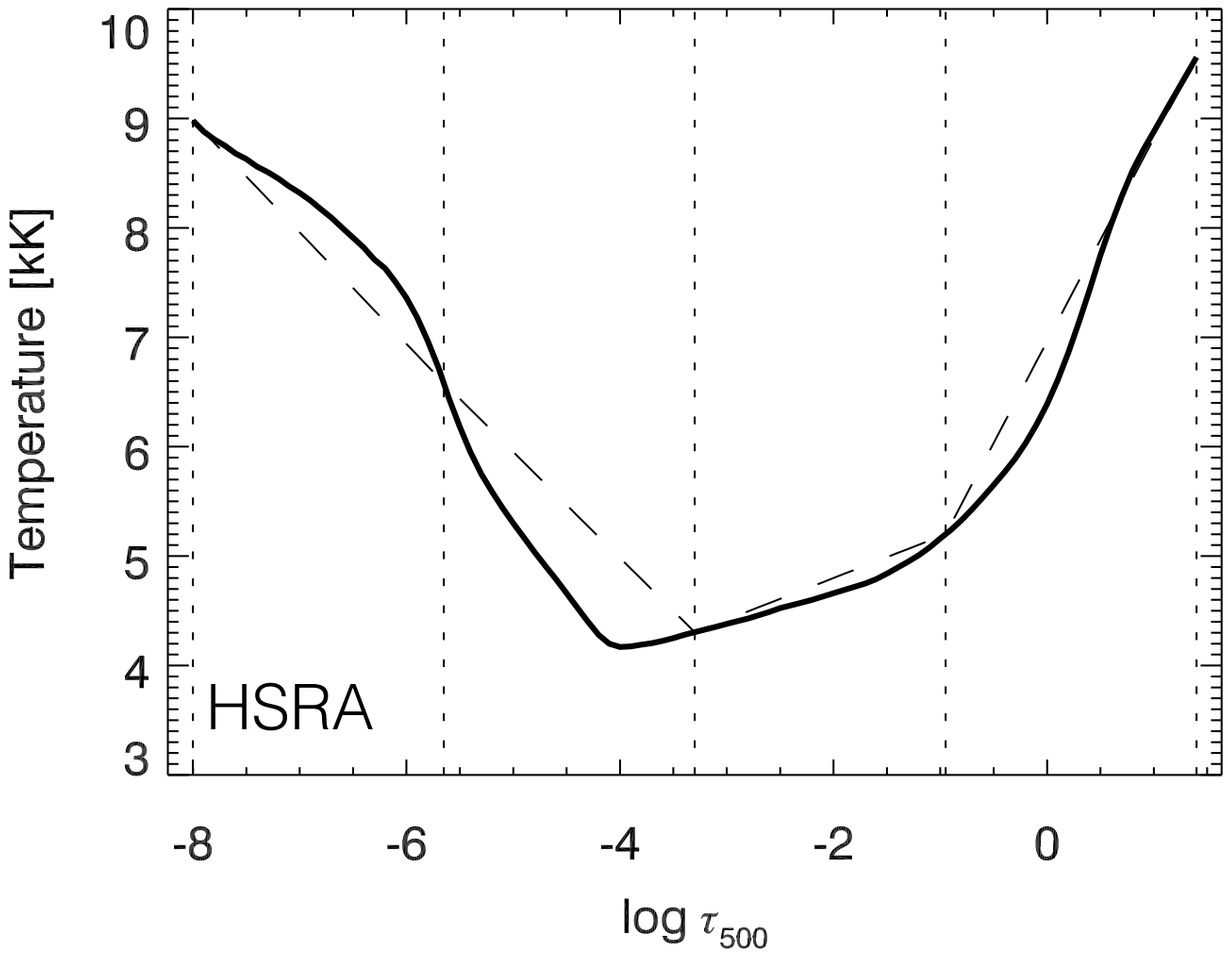


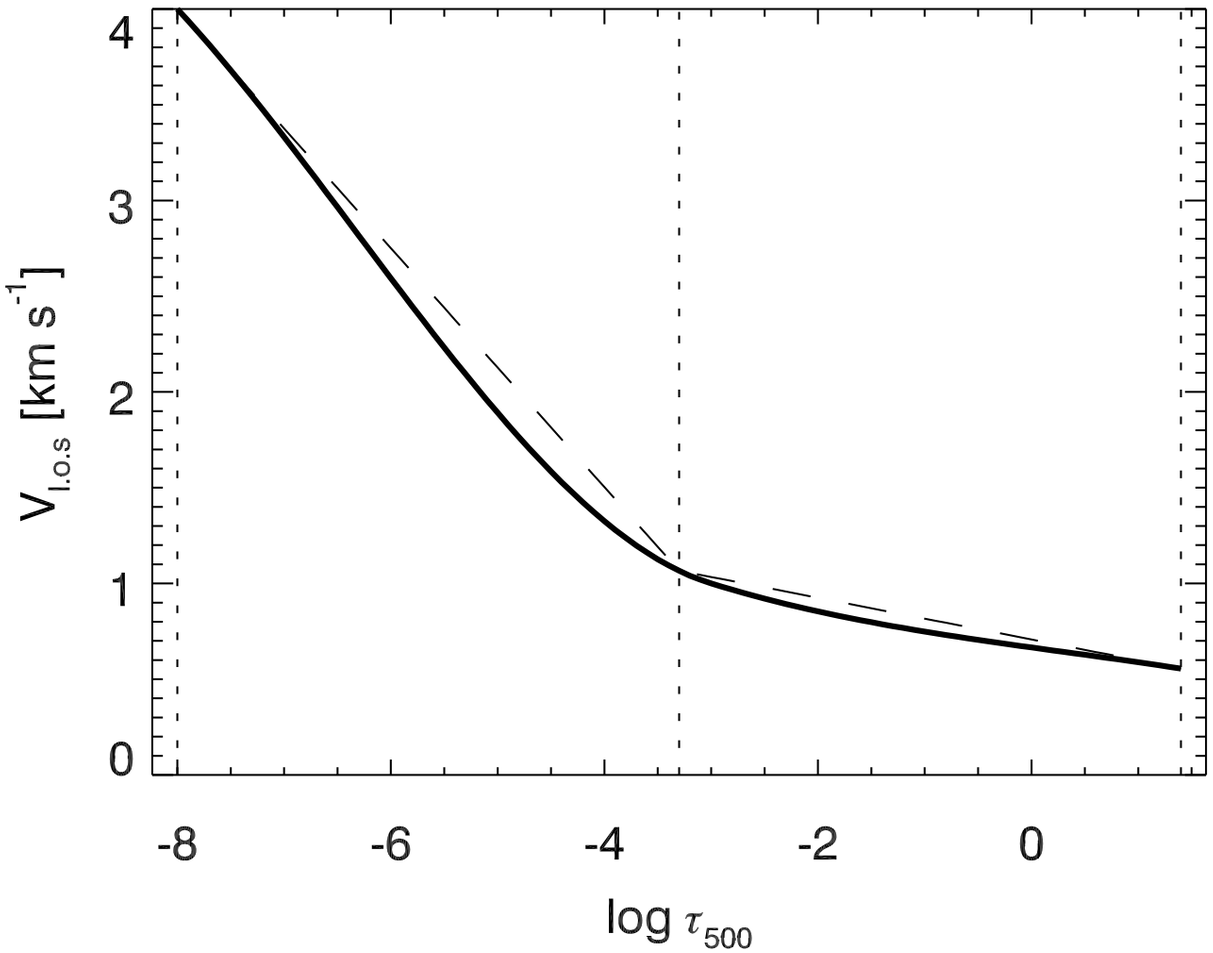
Nodes define the locations where the model is perturbed and modified.

The number of nodes can be different for each parameter.

We need the entire atmosphere to integrate the RT equation.

Nodes in depth-stratified atmosphere





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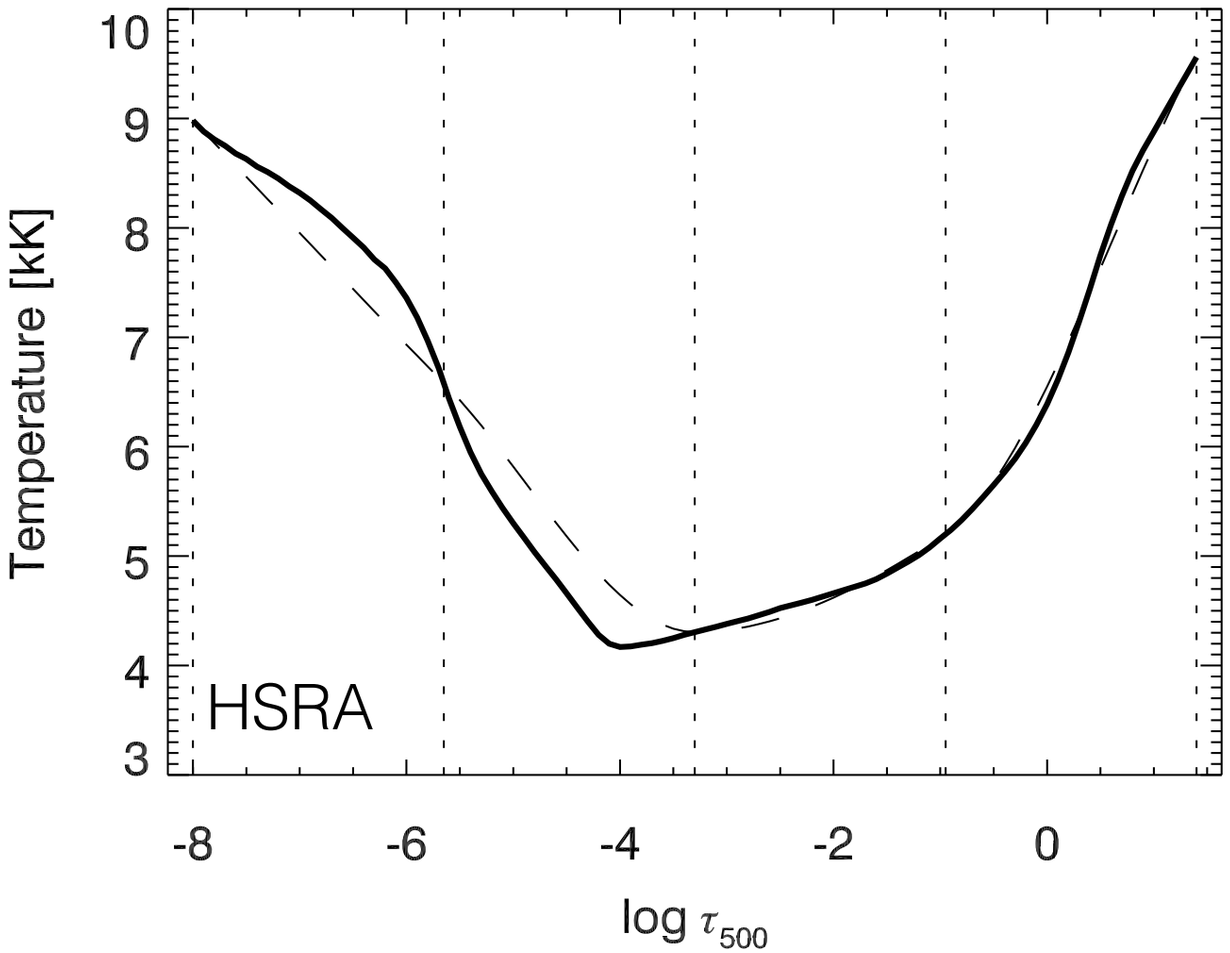
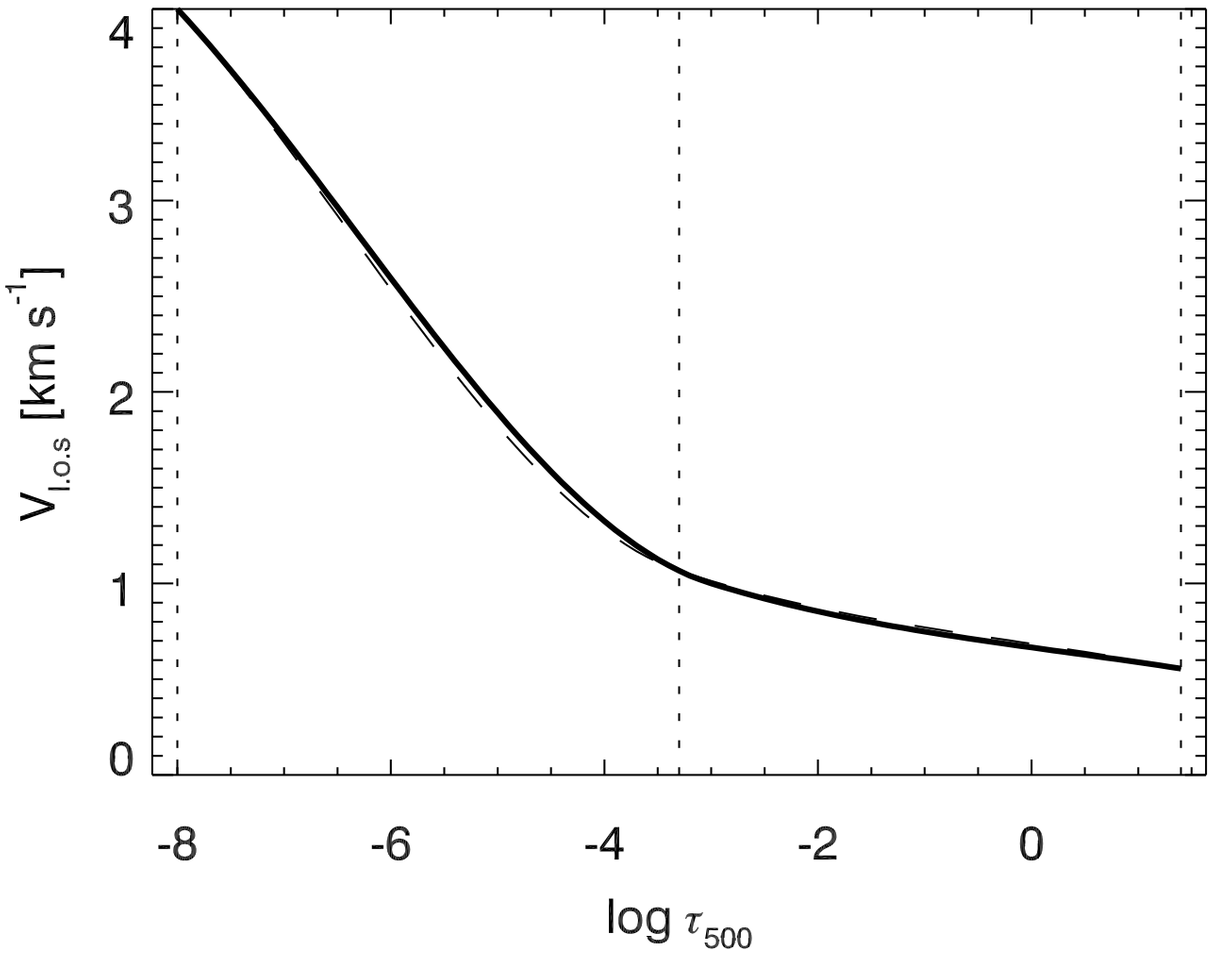
Nodes in depth-stratified atmosphere





Nodes define the locations where the model is perturbed and modified.

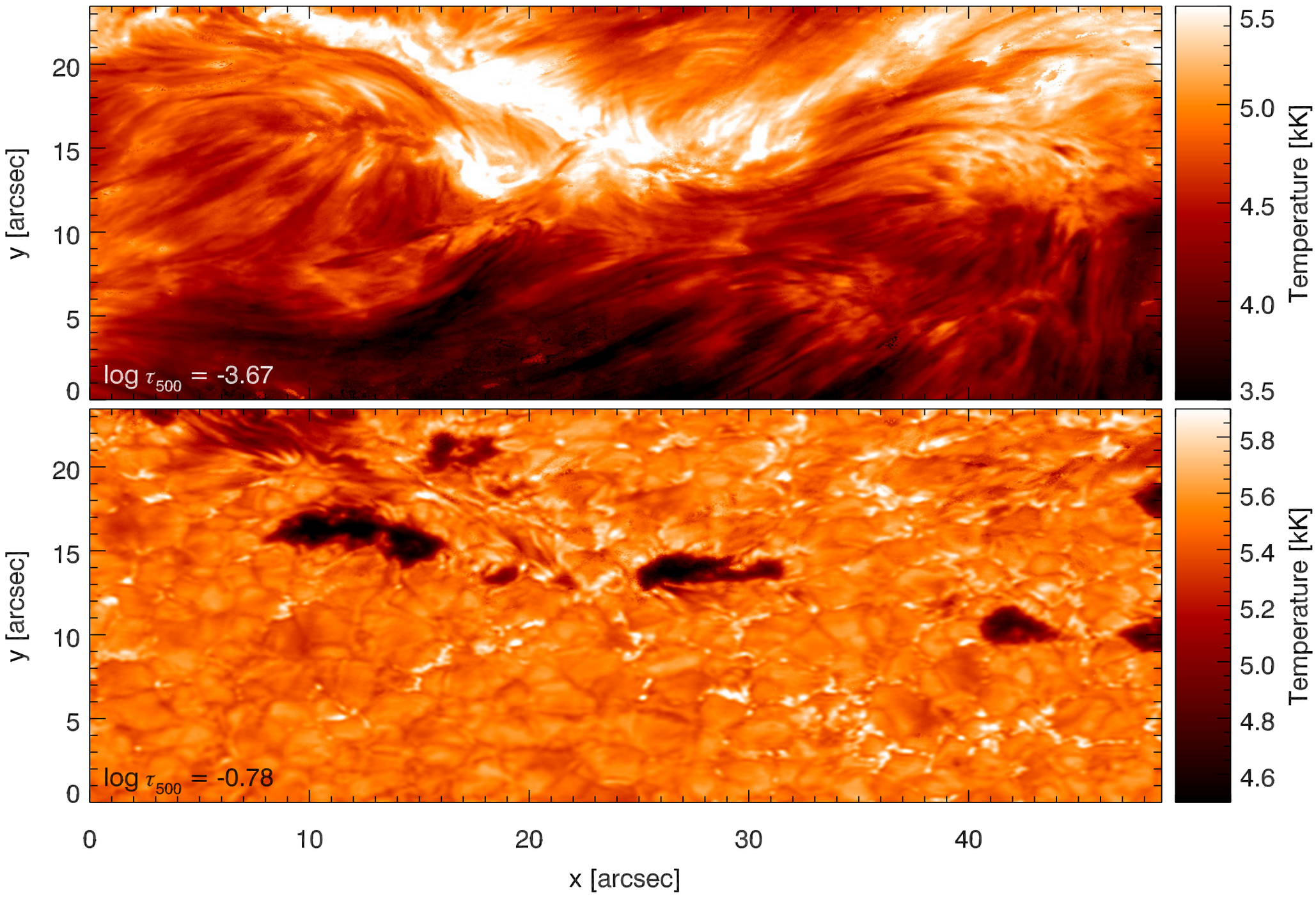
The number of nodes can be different for each parameter.

We need the entire atmosphere to integrate the RT equation.

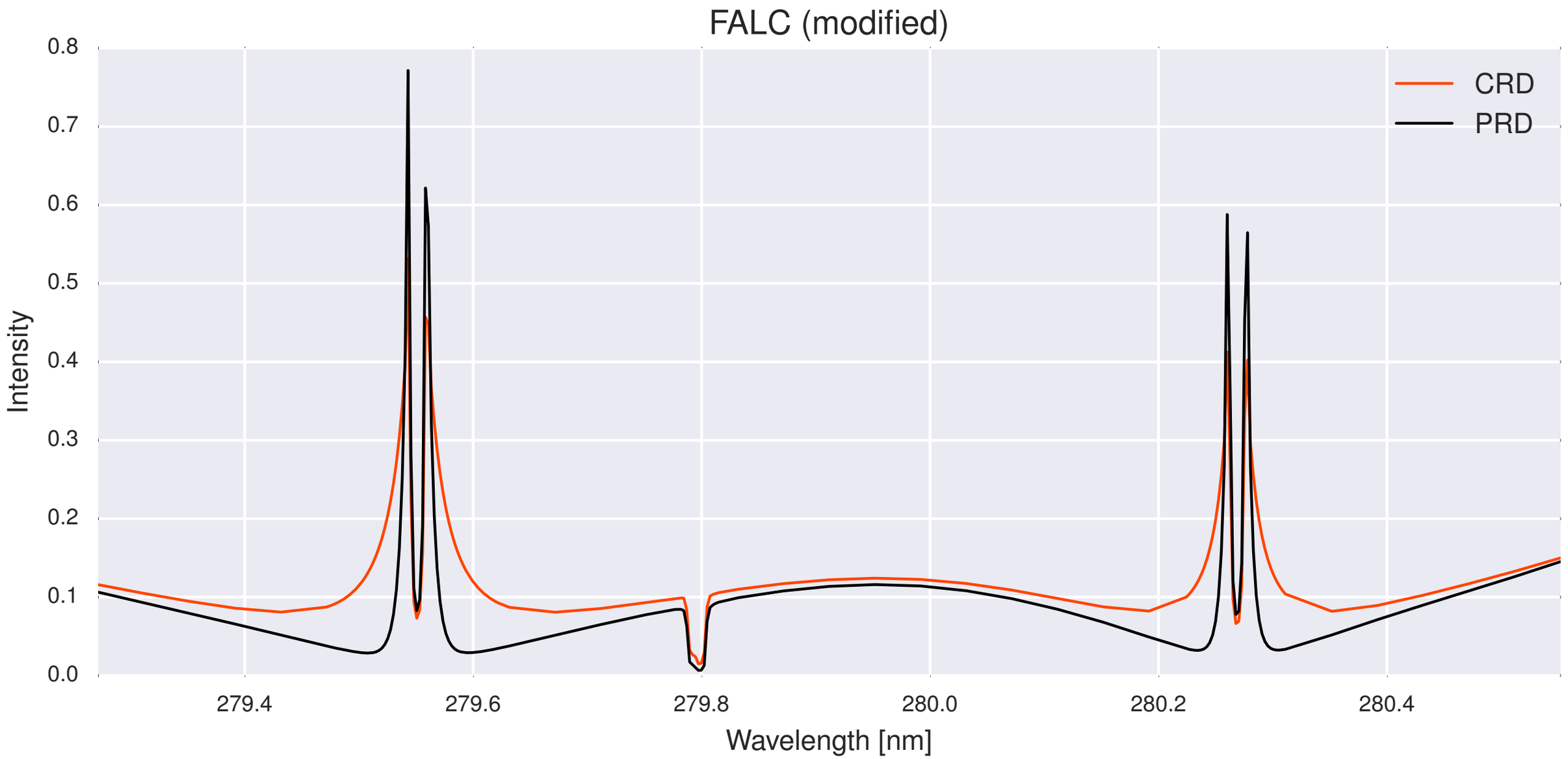
The nodes are connected with a non-overshooting cubic Bezier splines.

non-LTE inversions: Nicole

Temperature maps over an active region



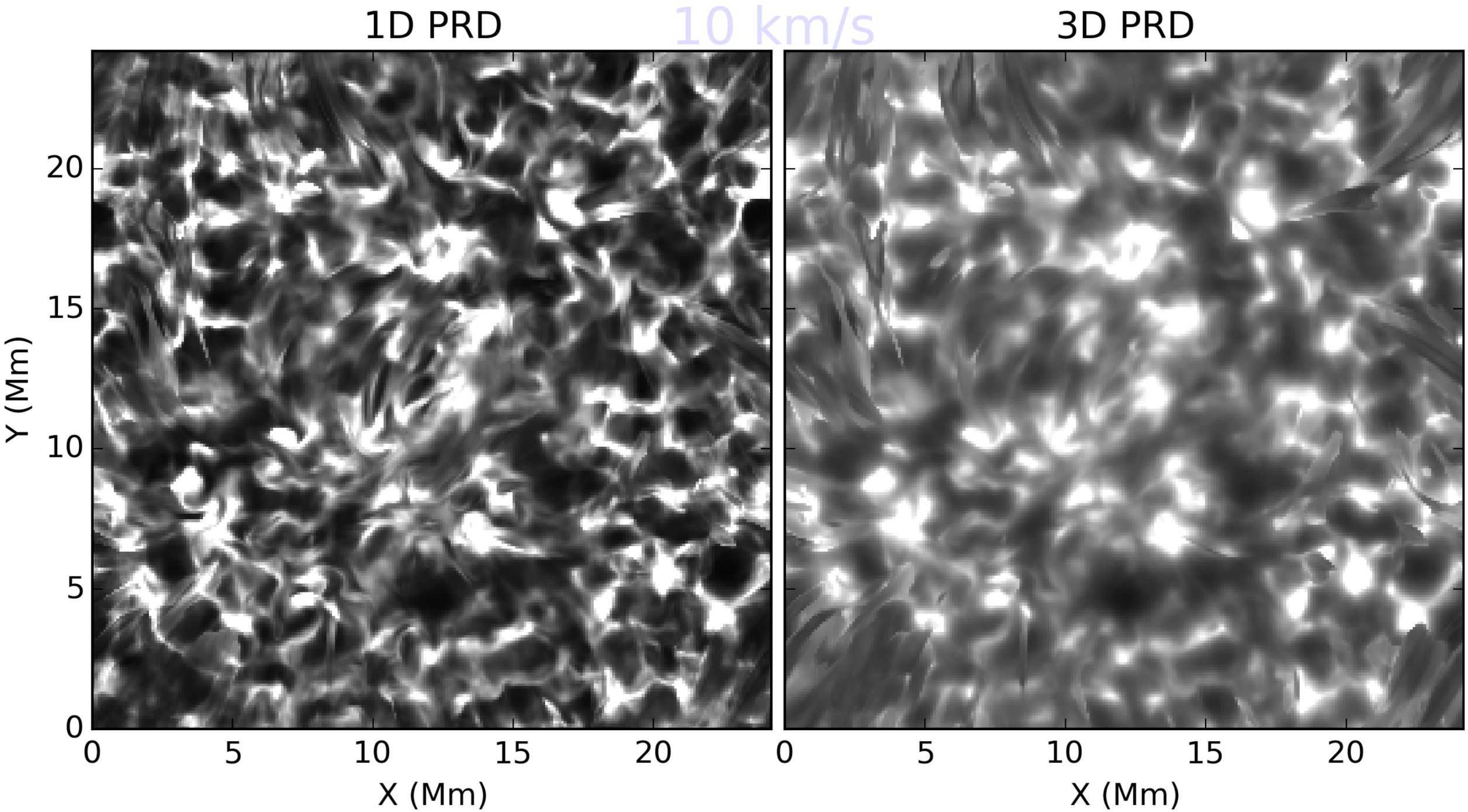
The Mg II h & k lines (PRD vs CRD)



1.5D vs 3D radiative transfer

Mg II k2v

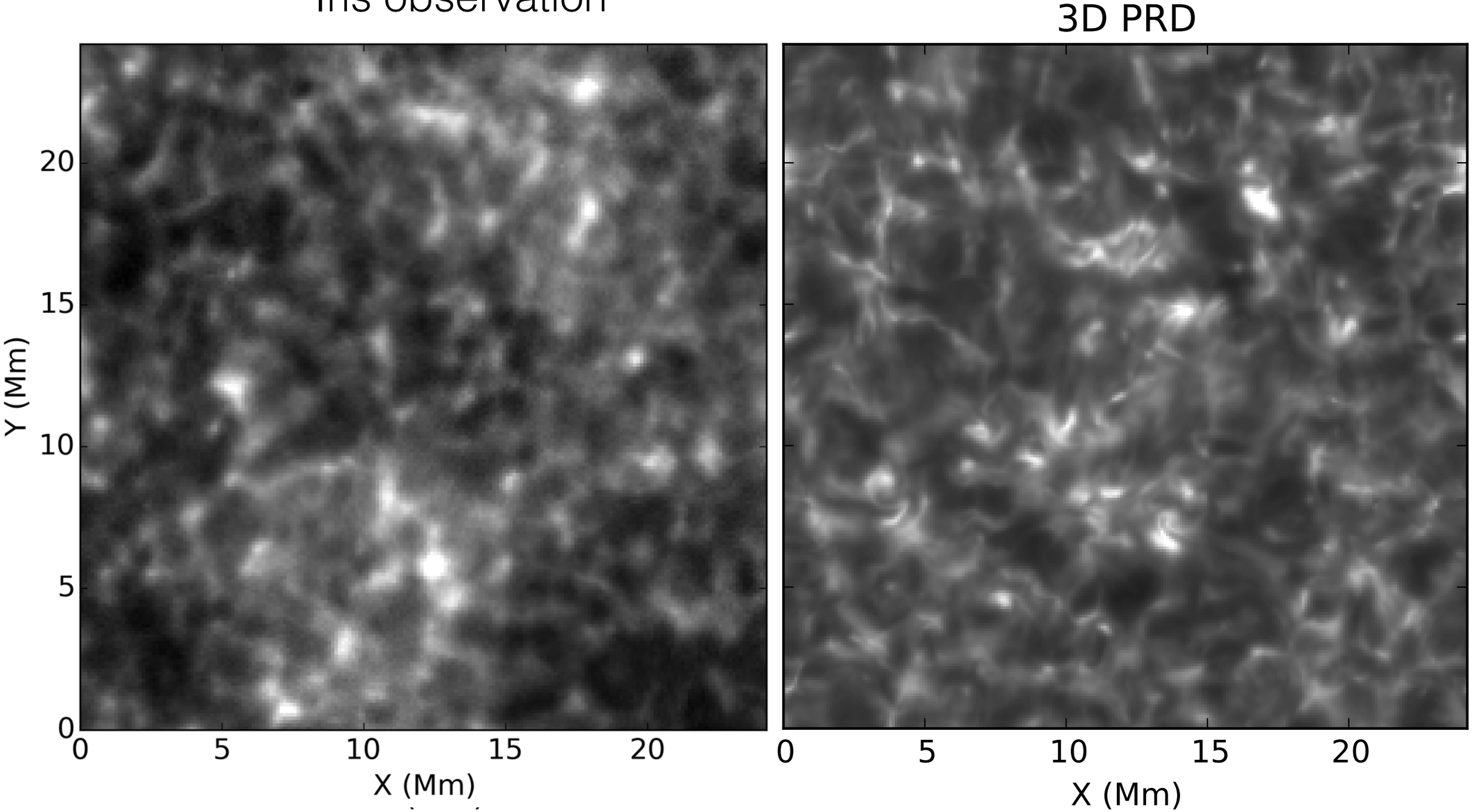
courtesy of Sukhorukov & Leenaarts (in prep.)



1.5D vs 3D radiative transfer

Synthetic slitjaw in Mg II k at disk center

courtesy of Sukhorukov & Leenaarts (in prep.)

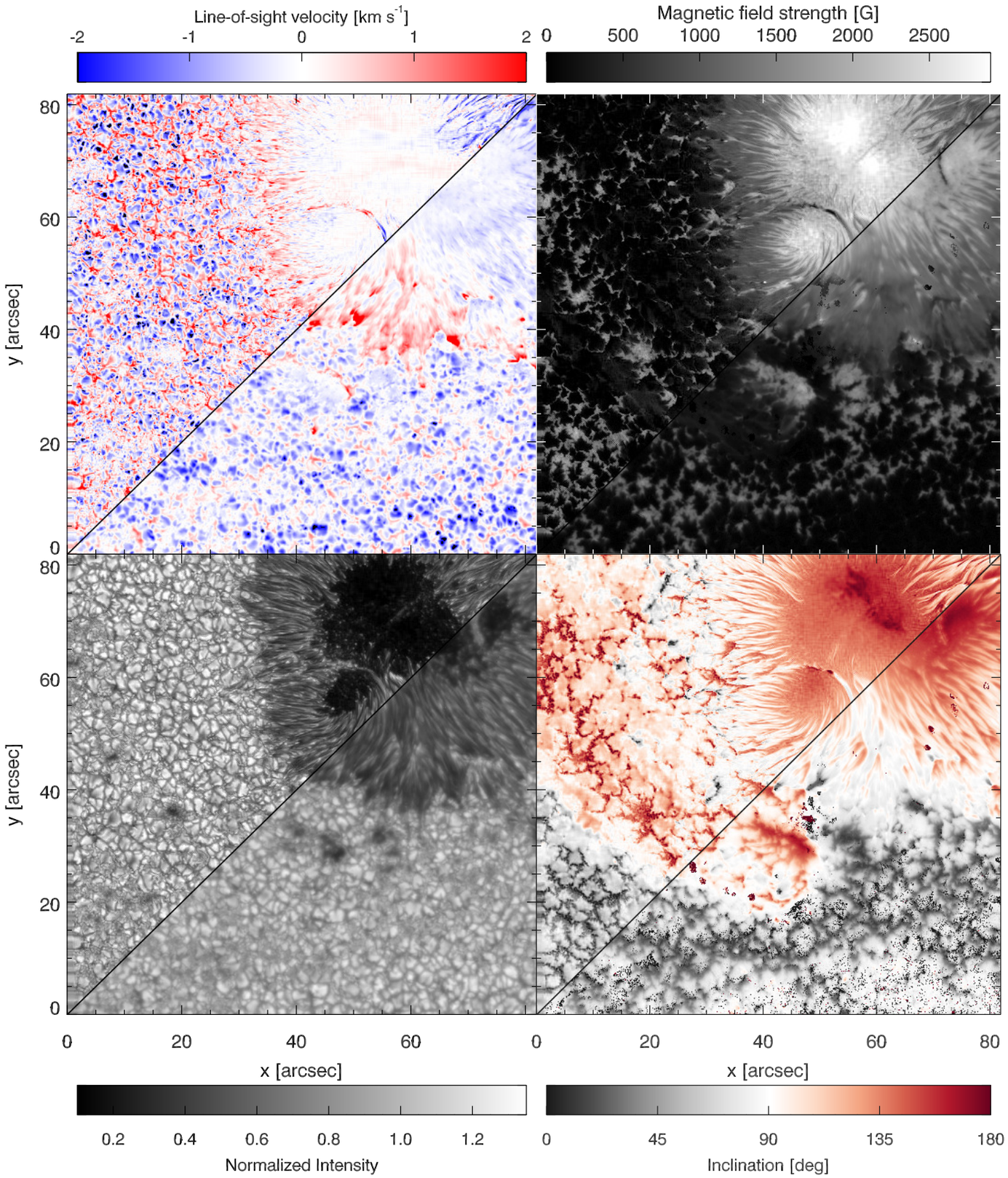


non-LTE inversions: the Stockholm Inversion Code (SIC?)

- In-house Milne-Eddington and LTE implementations.
- NLTE forward module based on RH (Uitenbroek 2001).
- Multiple atoms can be treated in non-LTE (statistical equilibrium).
- 1.5D, each pixel is treated as a plane-parallel atmosphere.
- Hydrostatic equilibrium to derive pressure scales.
- Complete and partial redistribution of scattered photons (CRD, PRD).
- New possibilities with Ca II H & K and Mg II h & k along with Ca II IR lines.
- Written in C/C++ / MPI / netCDF4.

Line(s)	**Scattered photons**	**Zeeman/Hanle**	**Geometry**	Ionization
Ca II H & K	PRD	Zeeman (AR), Hanle (QS)	1.5D	stat. equilibrium
Hα	CRD	Zeeman (AR), Hanle (QS)	3D	non-equilibrium
Ca II IR triplet	CRD	Zeeman (AR), Hanle (QS)	1.5D	stat. equilibrium
Mg II h & k	PRD	Zeeman, Hanle (k line)	1.5D	stat. equilibrium
He I D_3 & λ10830	CRD (?)	Zeeman + Hanle	3D (?)	non-equilibrium

Spatially coupled inversions: PSF or sparsity

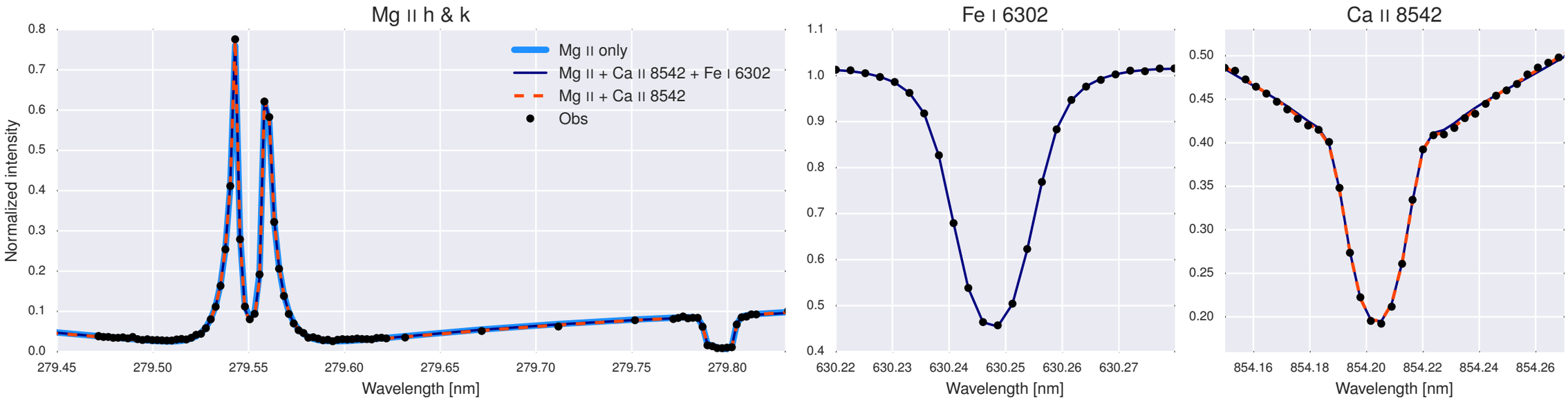


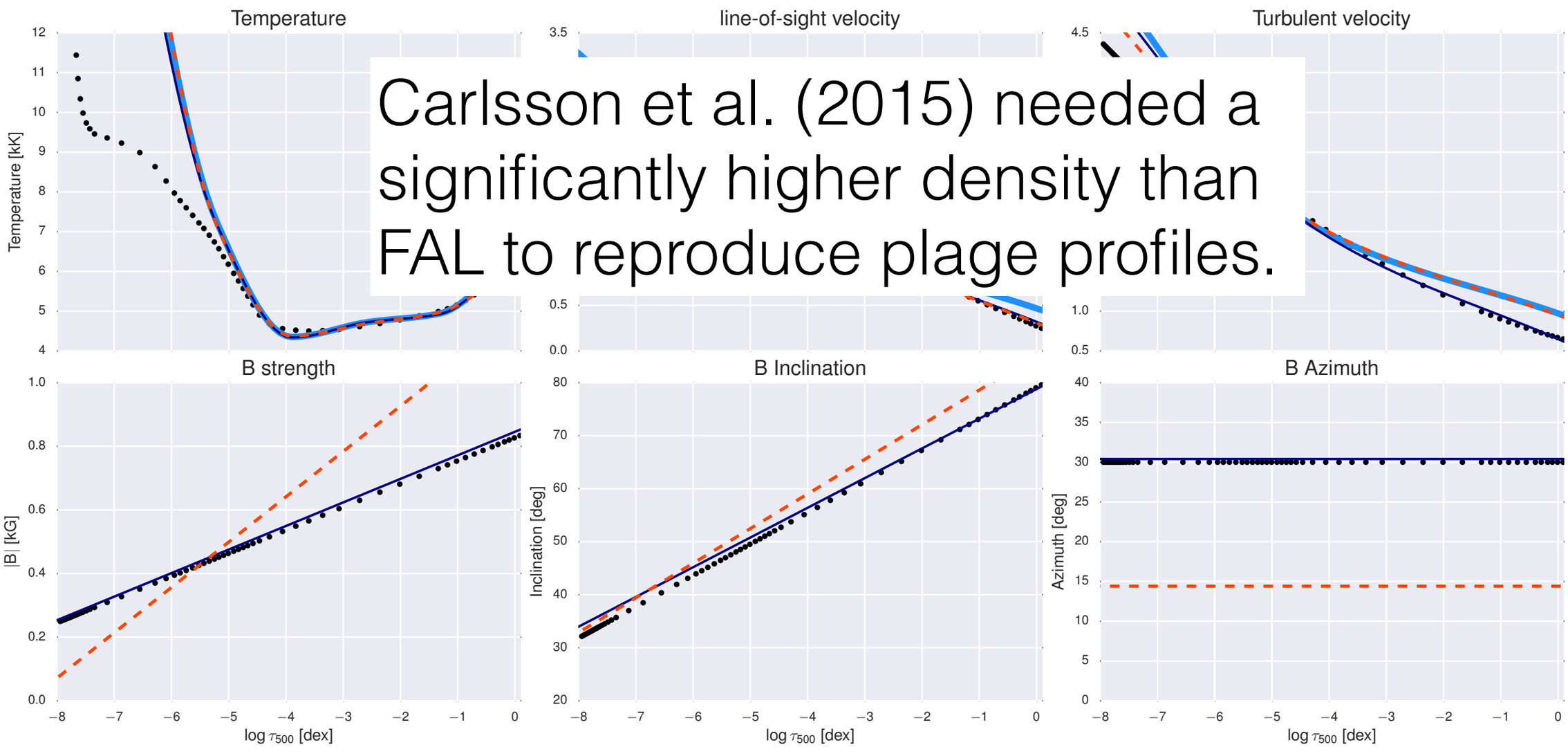
de la Cruz Rodríguez & van Noort (in prep.)

The parameters of the model atmosphere can be coupled using a spatial PSF or by imposing sparsity in a transformed basis (wavelet):

- van Noort (2012)
- Asensio-Ramos & de la Cruz Rodríguez (2015)

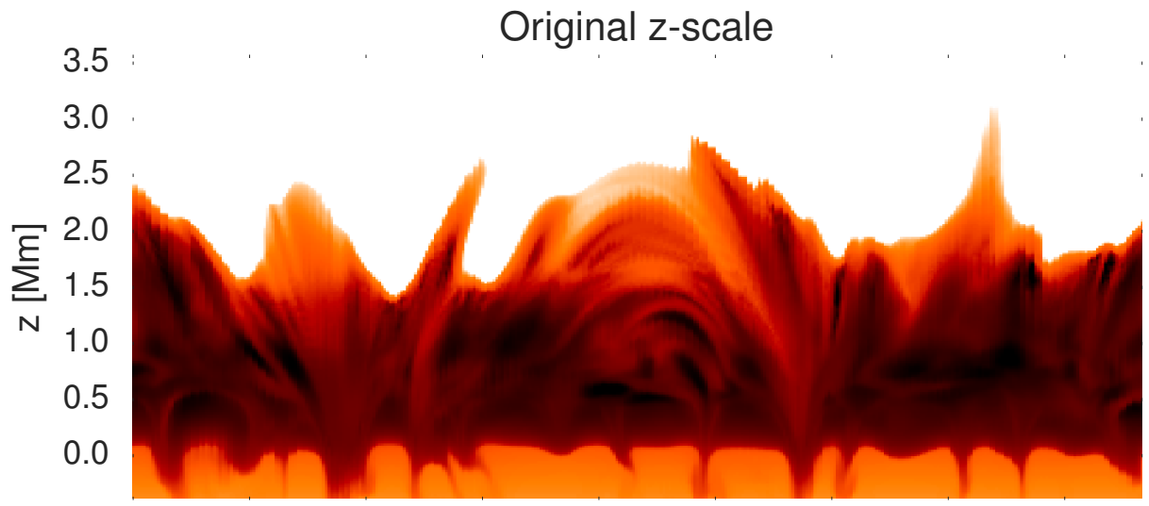
First results with a modified FAL model





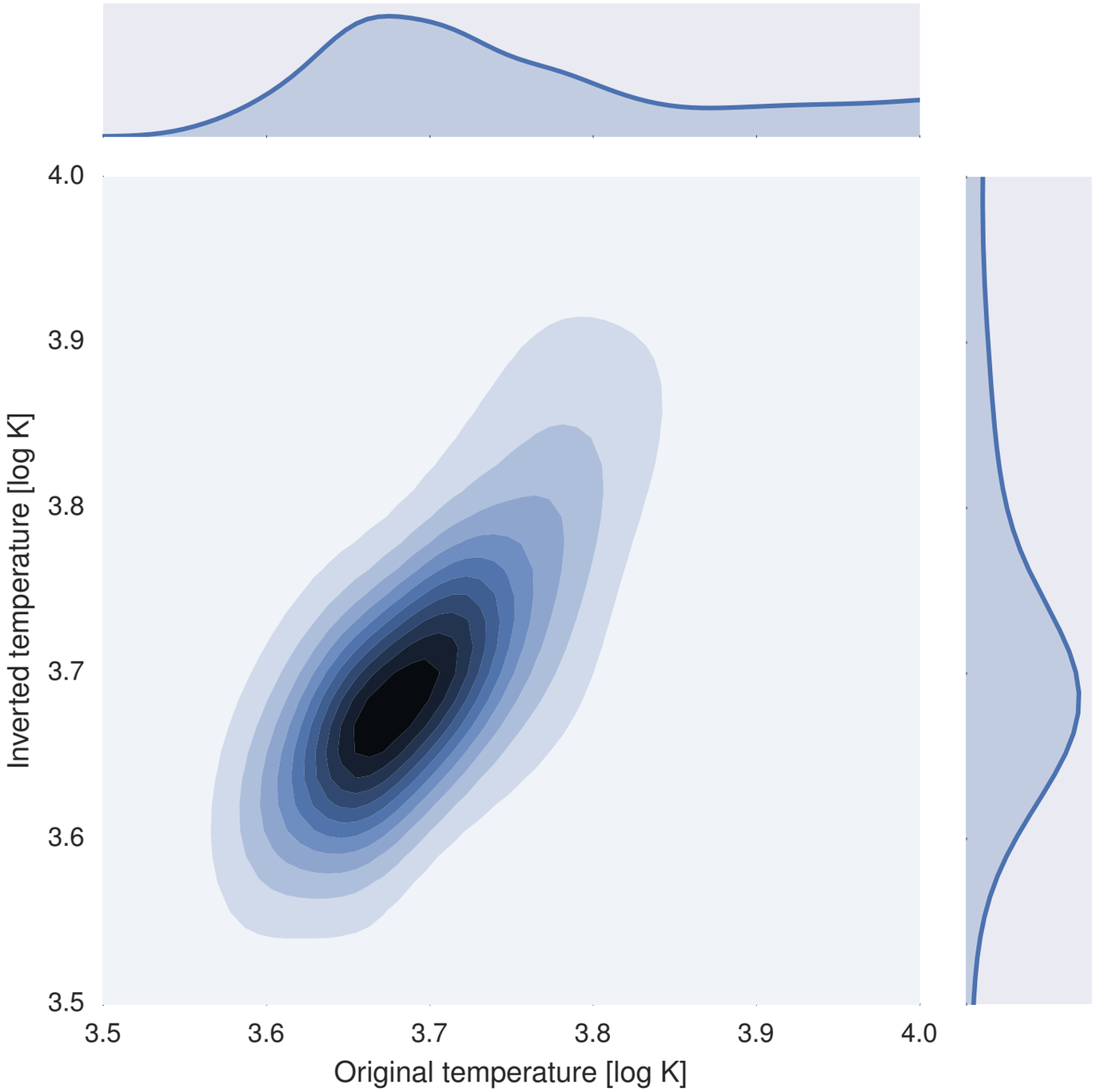
Carlsson et al. (2015) needed a significantly higher density than FAL to reproduce plage profiles.

First results with a *Bifrost* slice



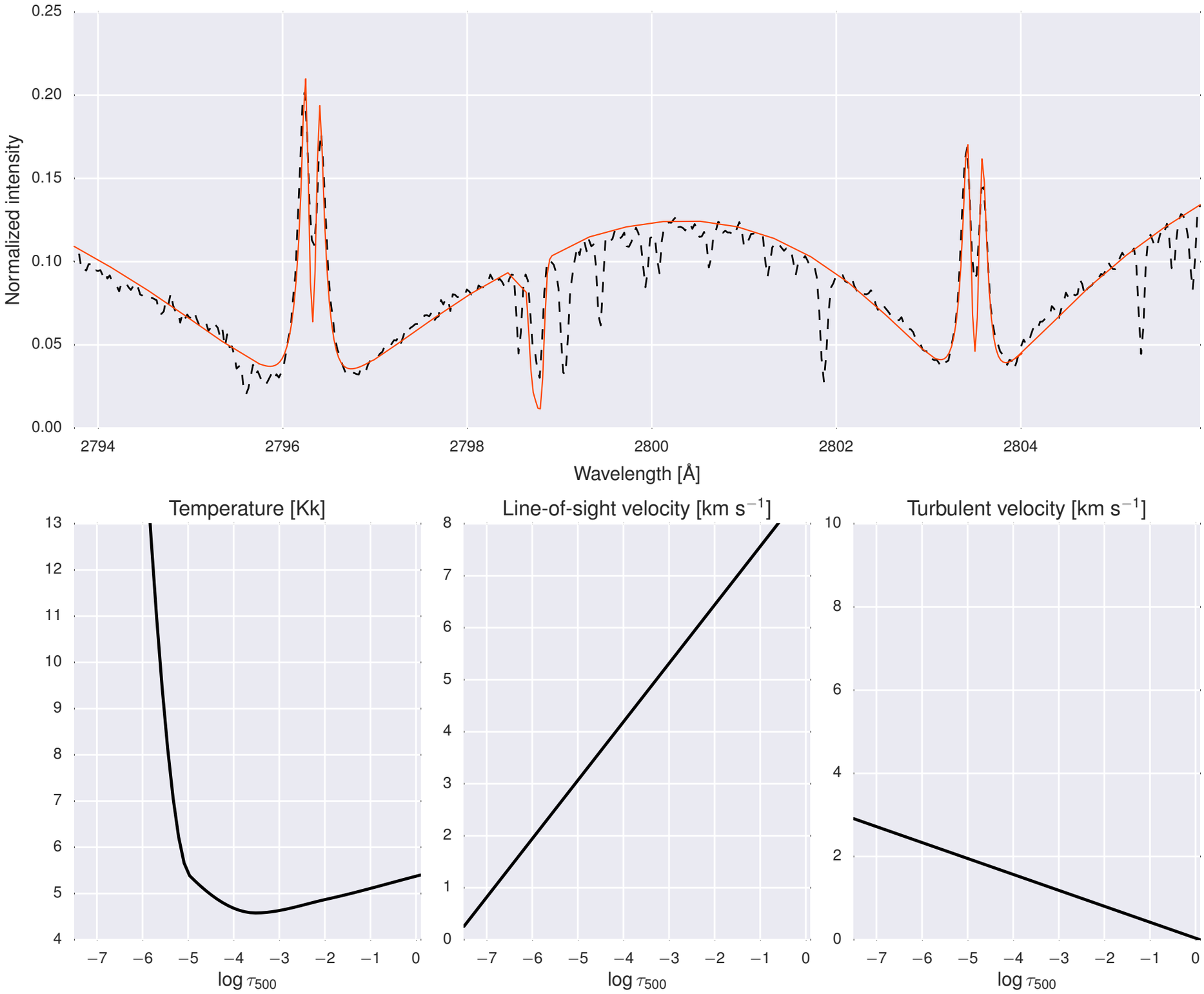
A slice from the enhanced network model, Carlsson et al. (2015)

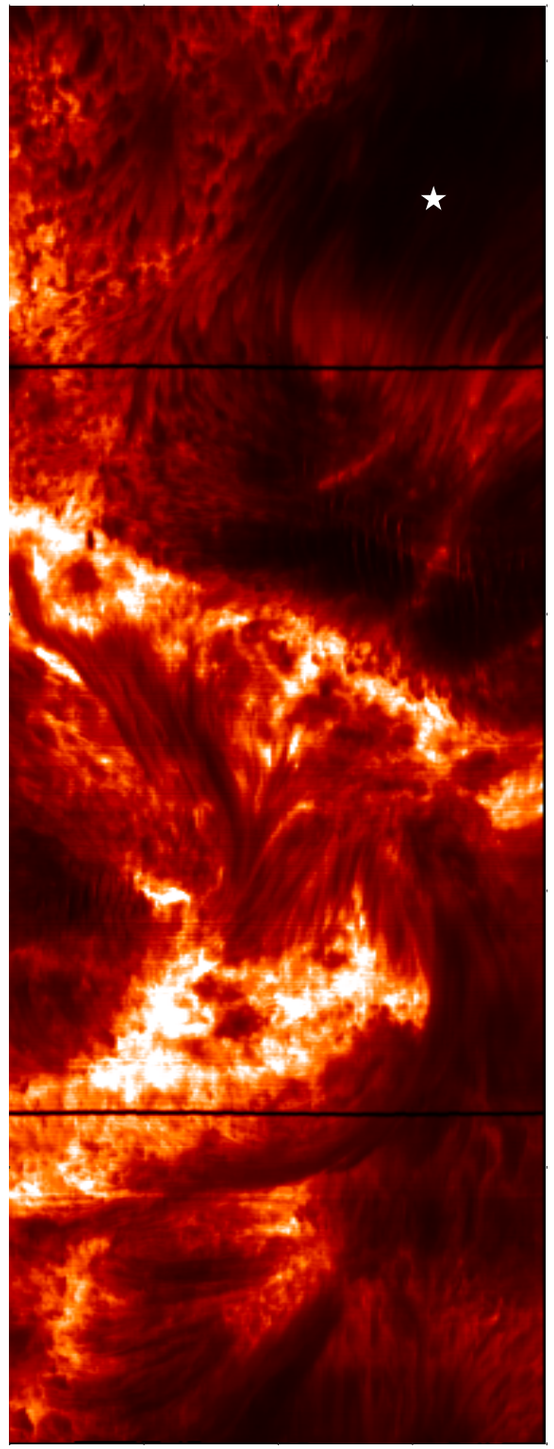
First results with a *Bifrost* slice



A slice from the enhanced network model, Carlsson et al. (2015)

Inversion of IRIS data





Conclusions

- 1.5D (coupled) inversions including PRD effects are now possible: Ca II H & K, Mg II h & k.
- IRIS, CHROMIS (@Swedish 1-m Solar Telescope).
- Hopefully soon we will have the first spatially-coupled inversions of IRIS data!