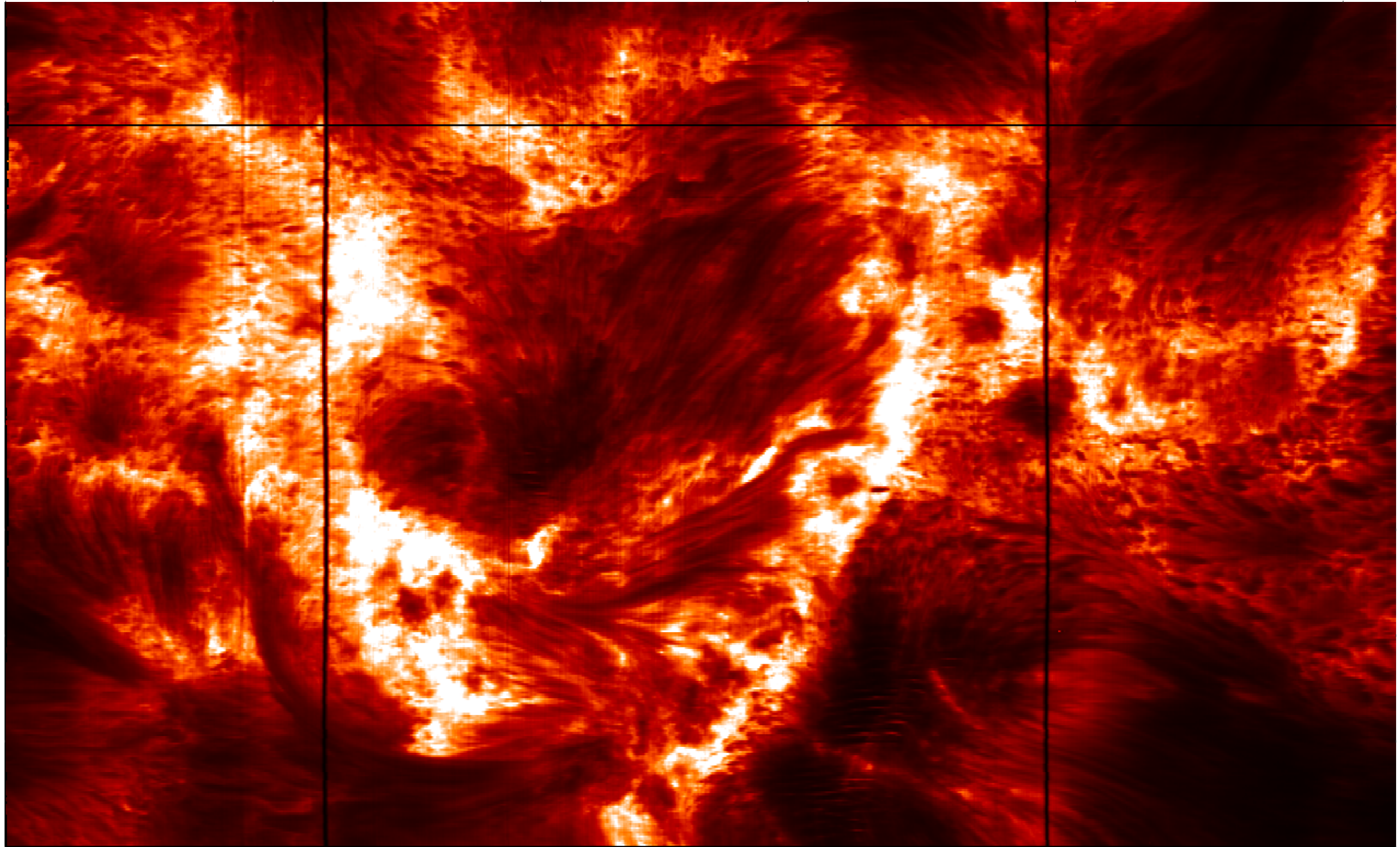


Interface region inversions

and magnetic fields

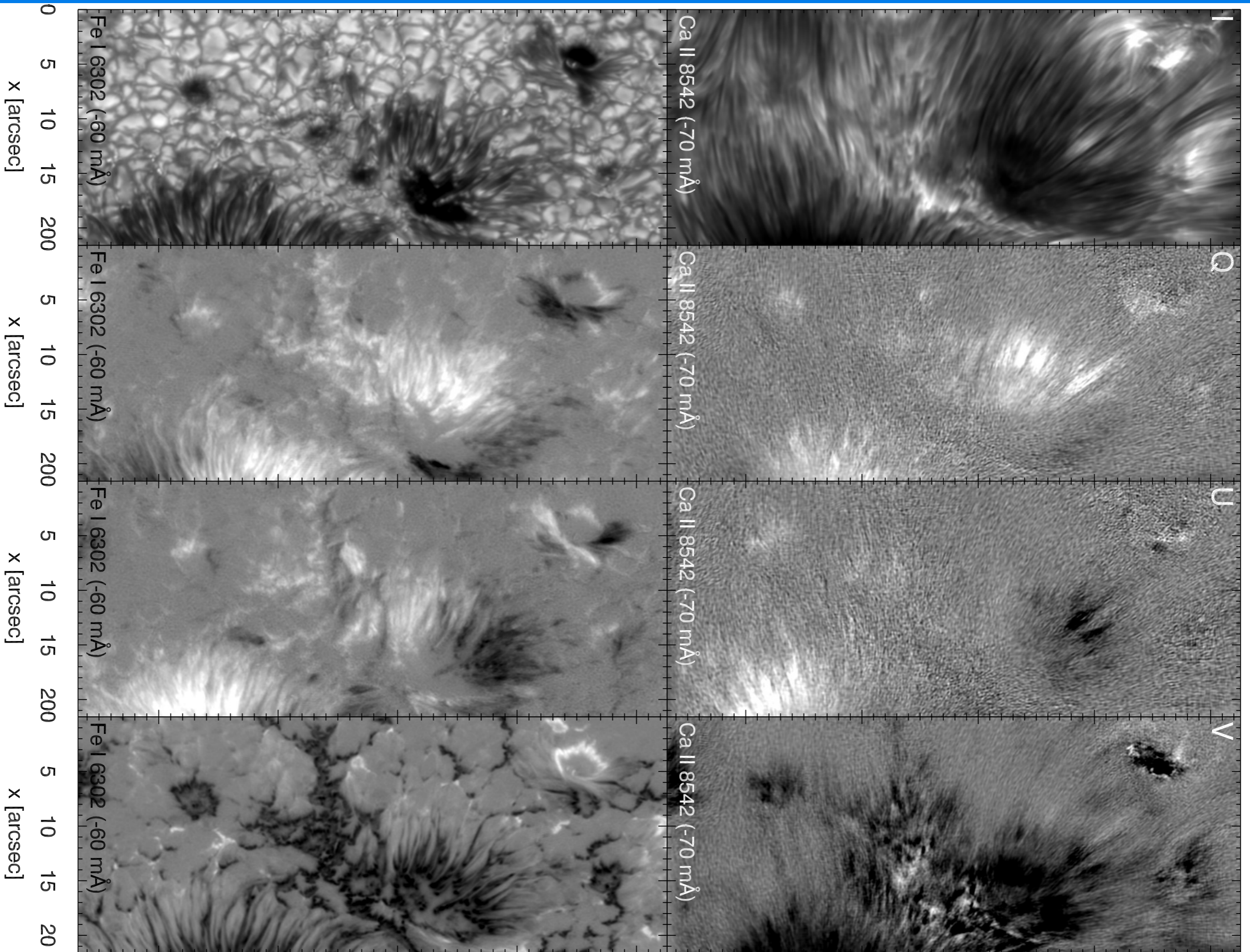


Stockholm
University

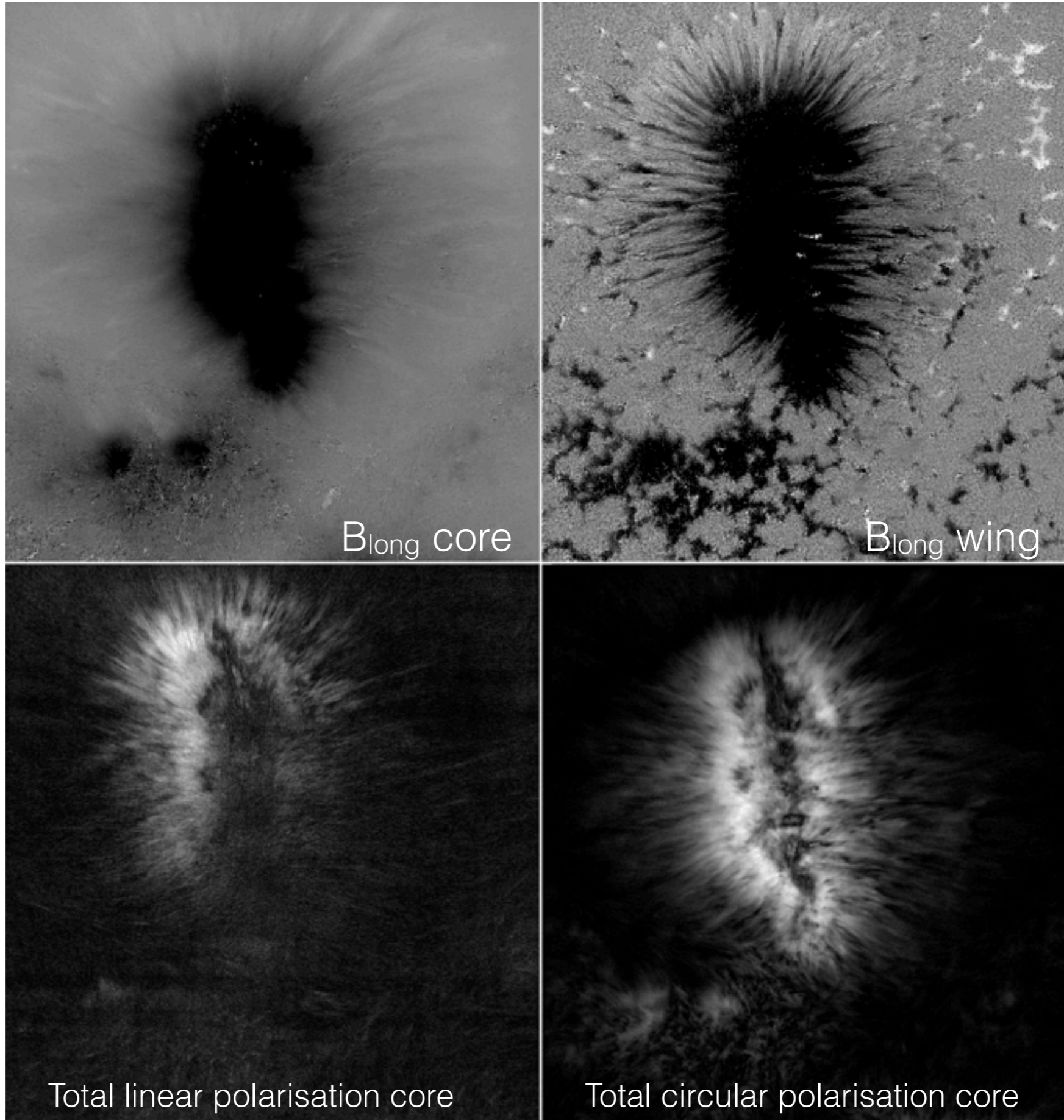
Jaime de la Cruz Rodríguez

Jorrit Leenaarts & Andrés Asensio Ramos

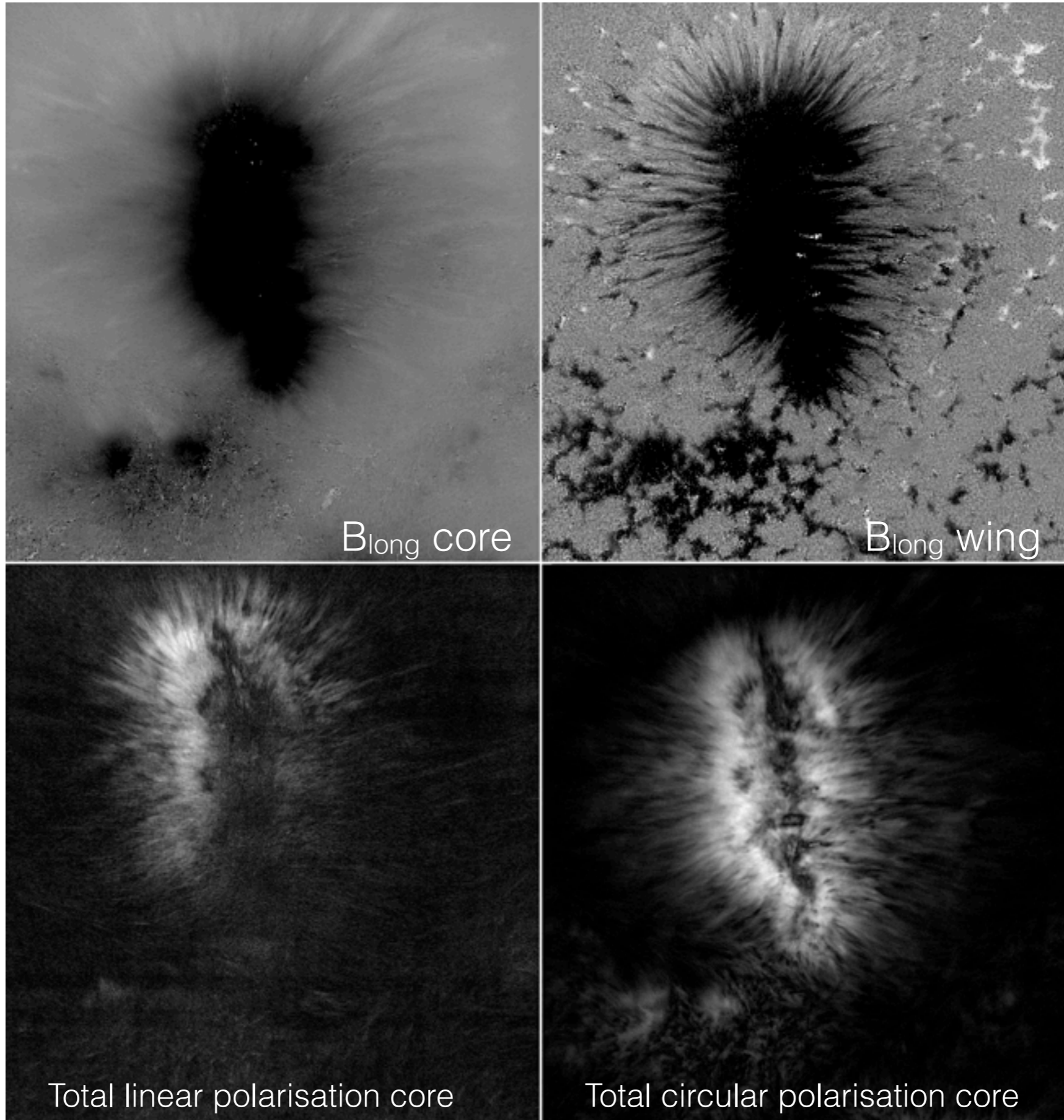
The solar atmosphere: multiple regimes



Polarization signals in the chromosphere



Polarization signals in the chromosphere



non-LTE inversions: NICOLE

- 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.
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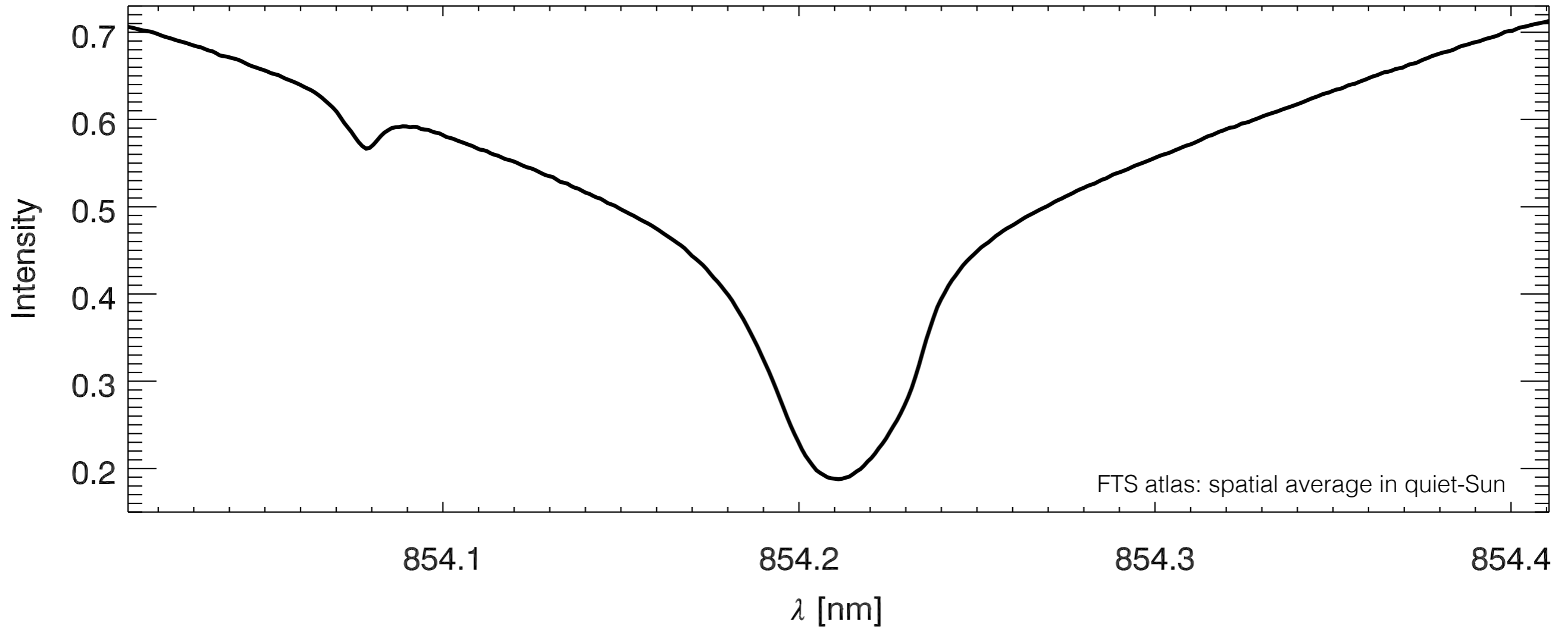
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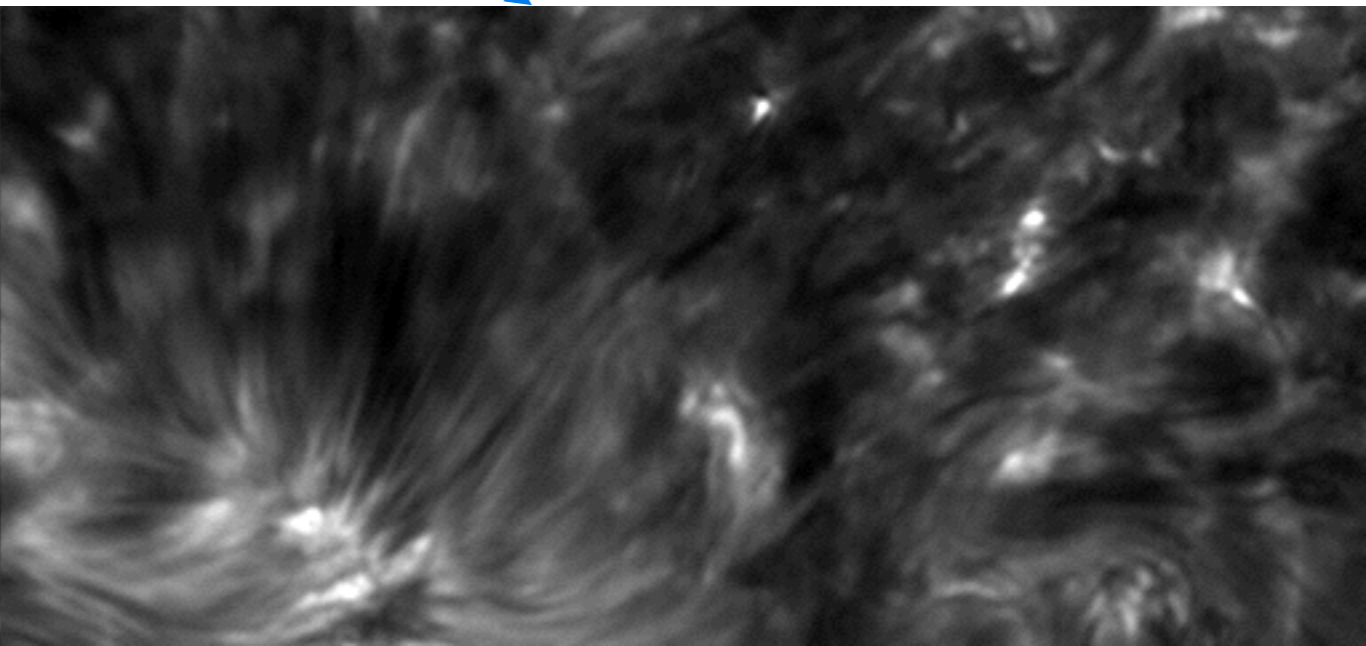
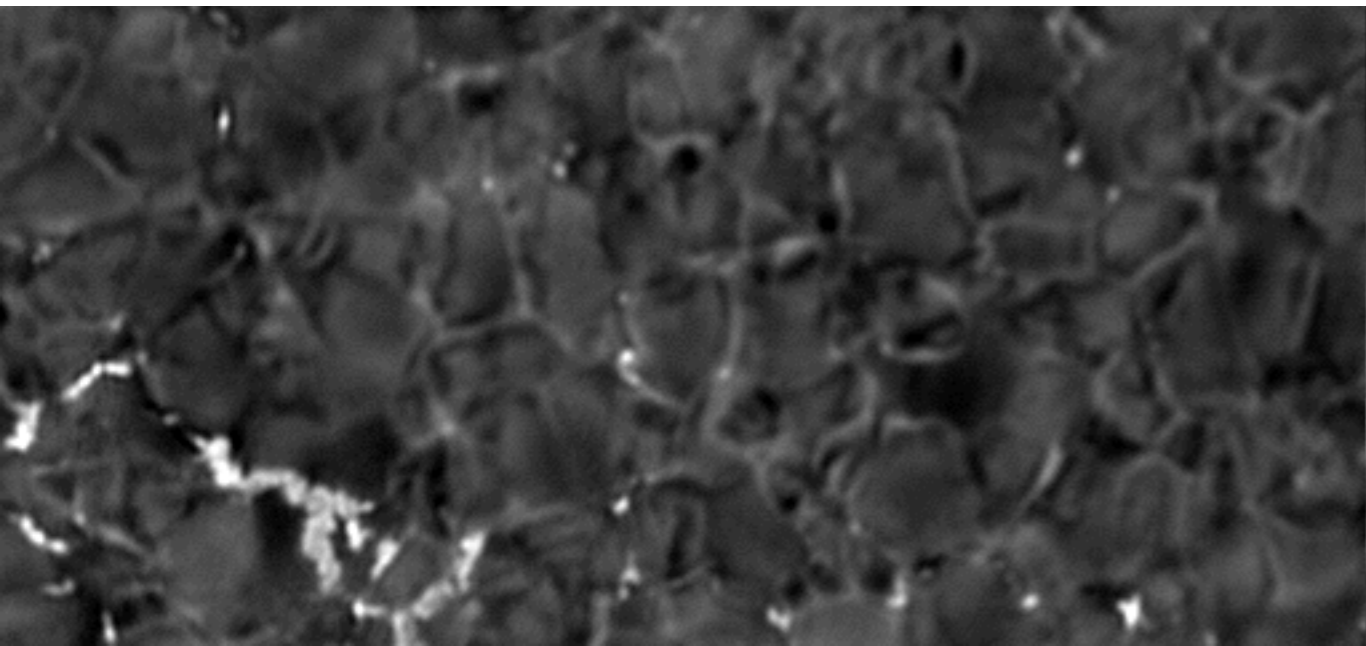
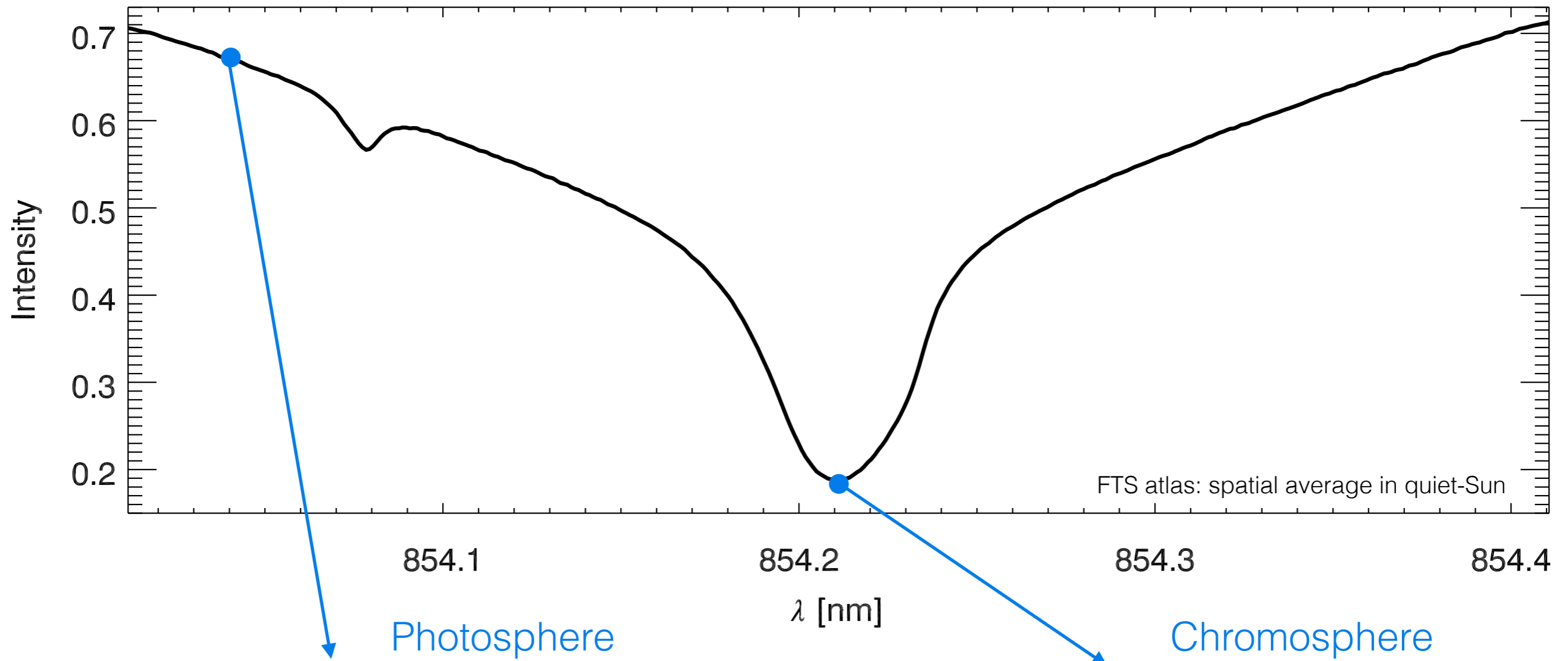
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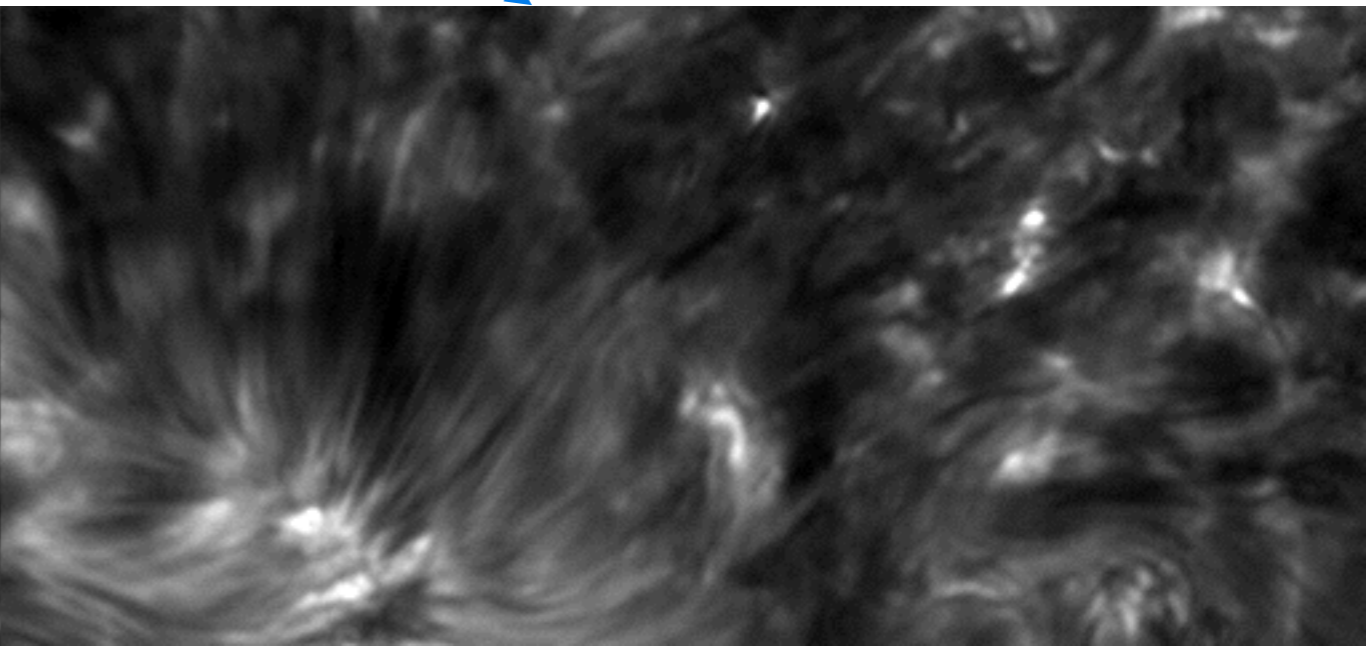
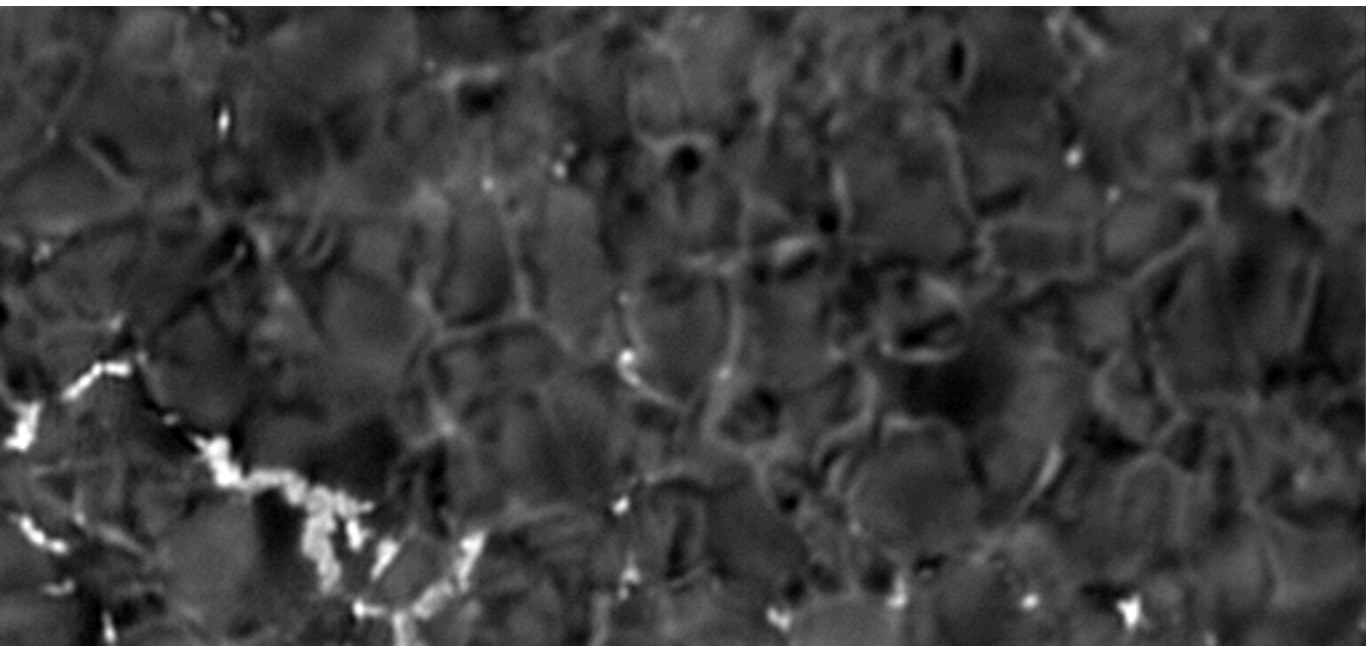
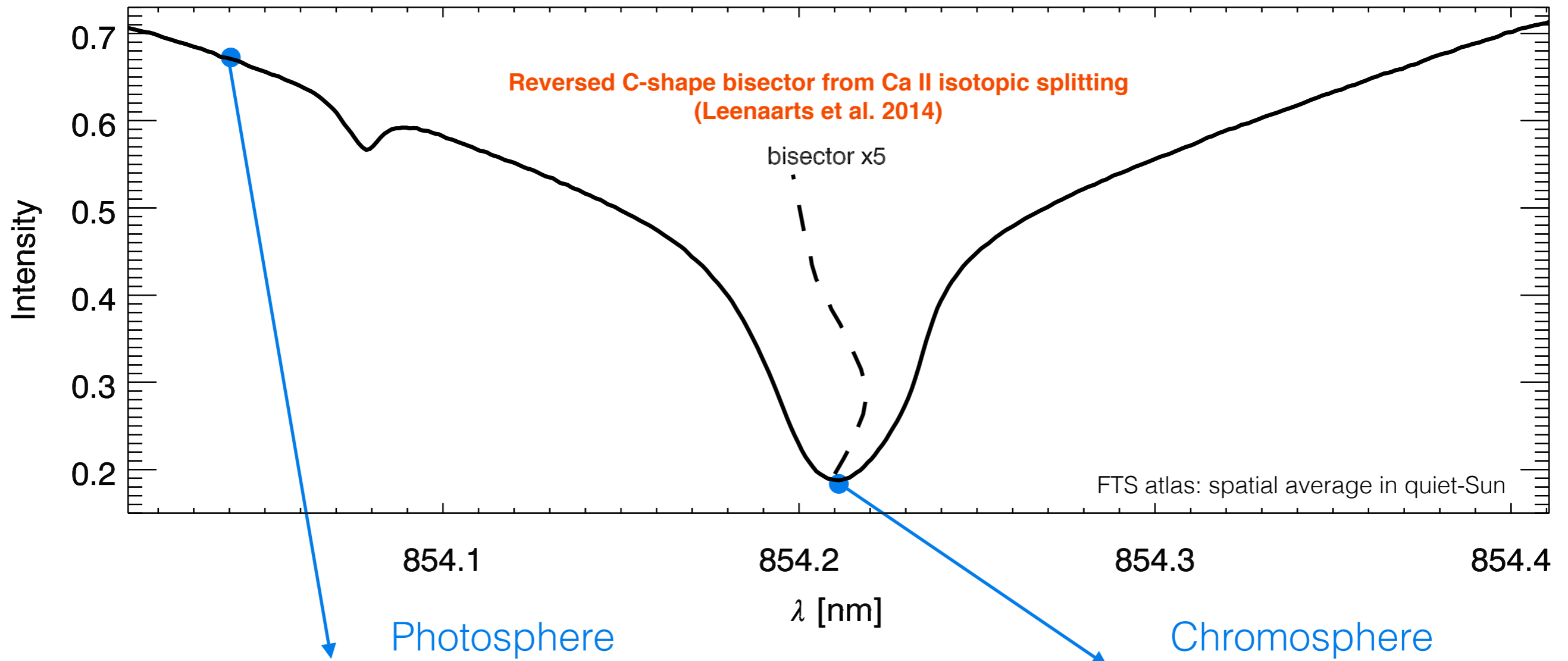
The Ca II 8542 line



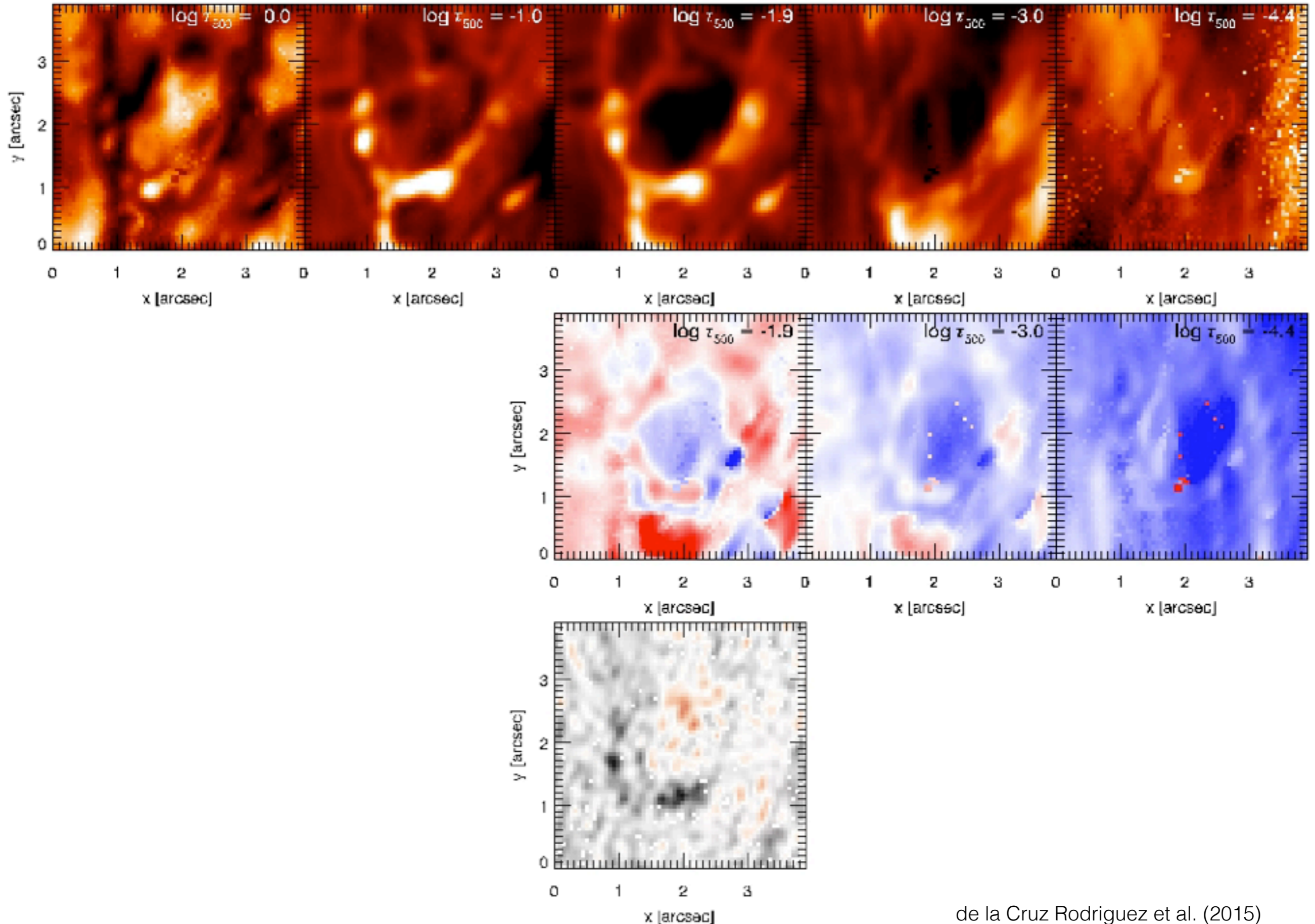
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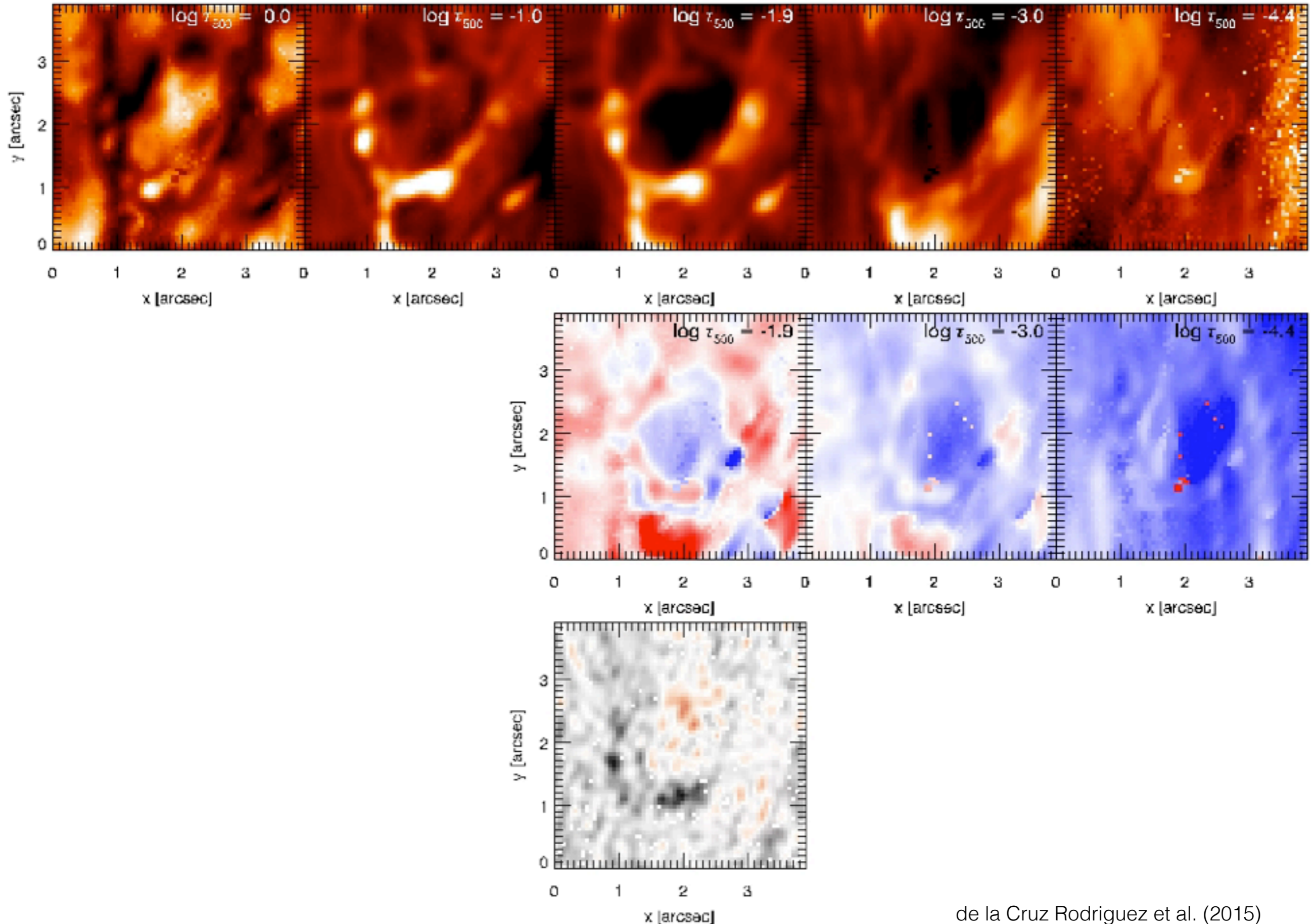
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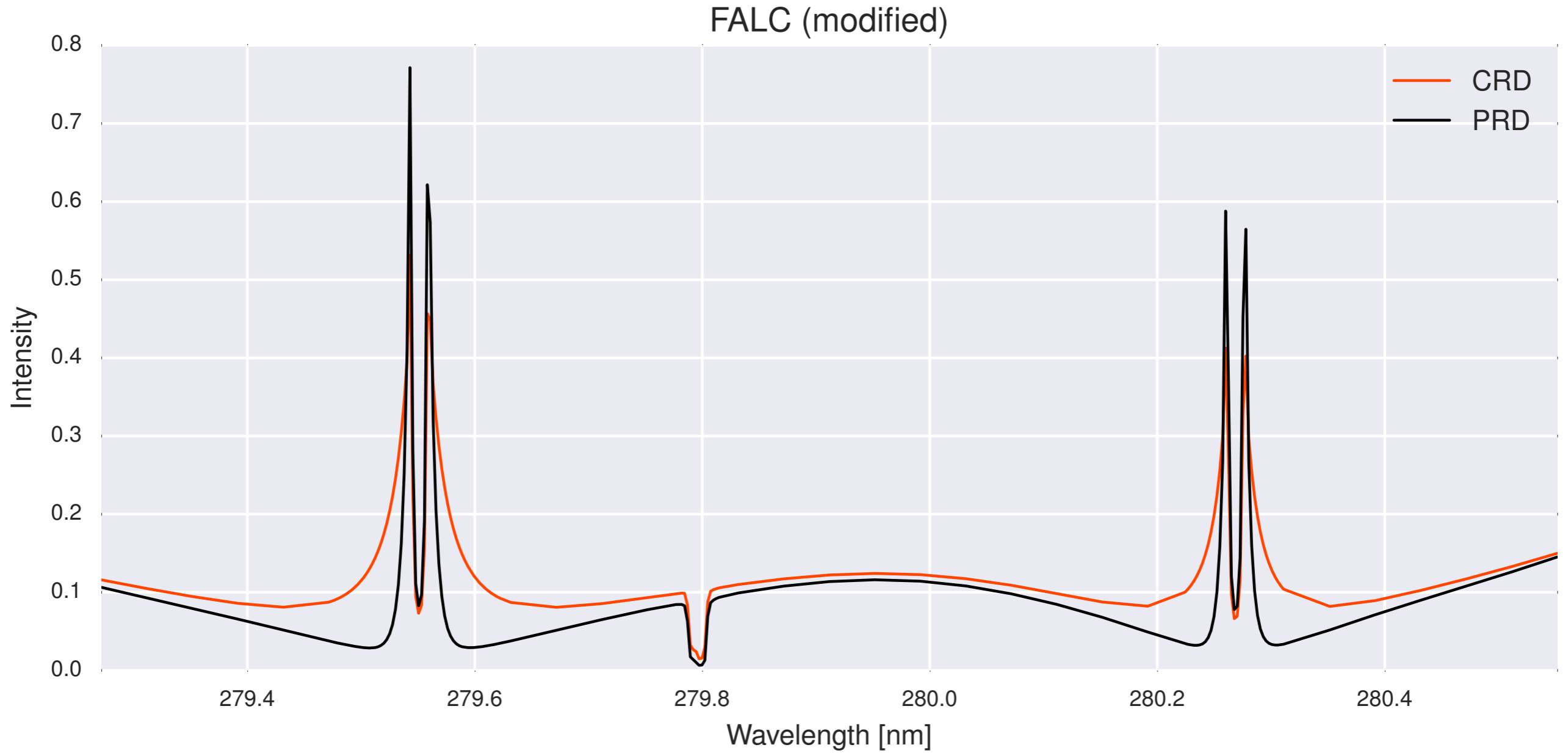


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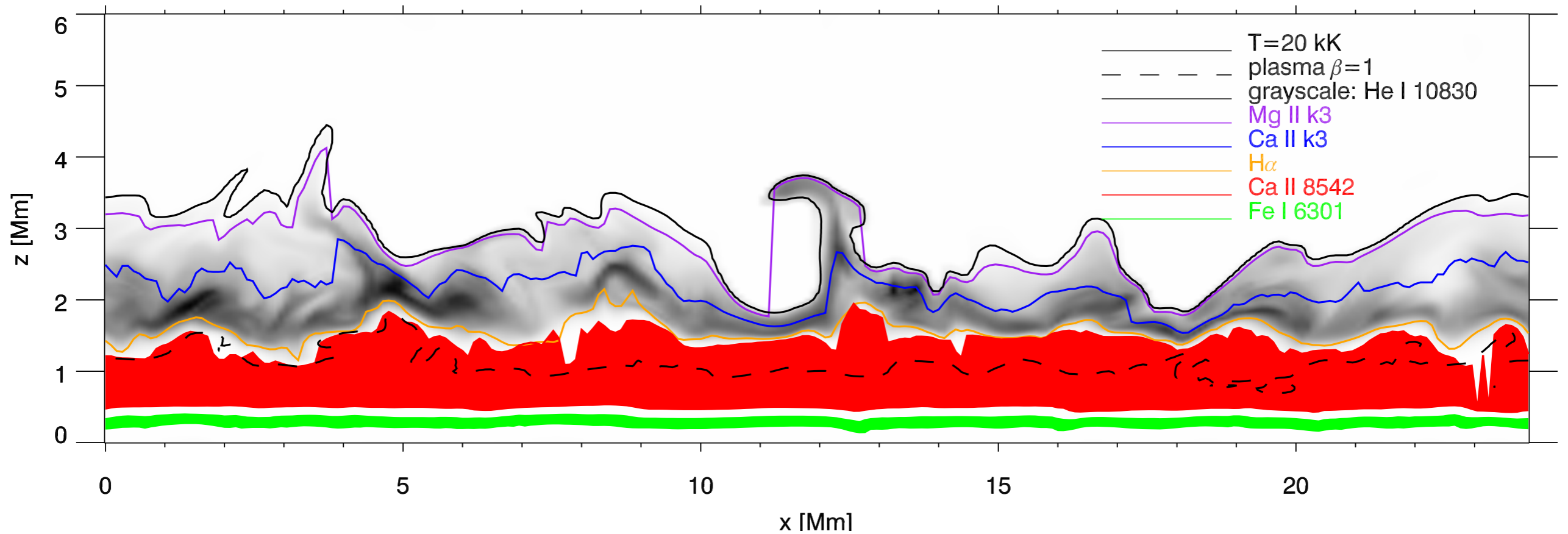


H & K lines (CRD vs PRD)

IRIS and CHROMIS



The solar atmosphere



Courtesy of J. Leenaarts (Stockholm University)

Motivations:

- Multi-line / multi-atom inversions.
- New observations with IRIS and CHROMIS in the H & K lines of Mg II and Ca II.

INterface Region INverSion Code (INTRINSIC)

- 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).
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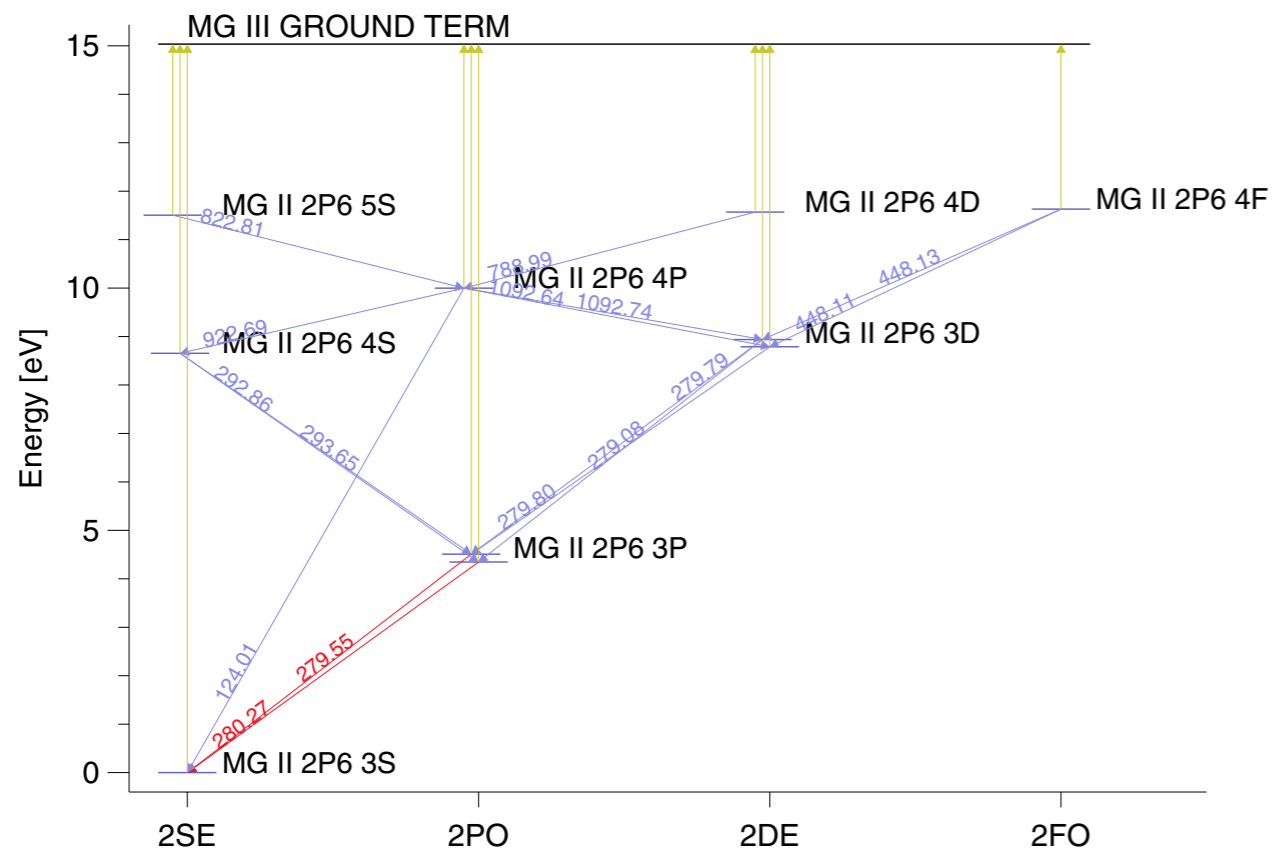
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Basic setup: Mg II h & k + triplet lines

Aim: *Complete coverage from the photosphere to the transition region.*

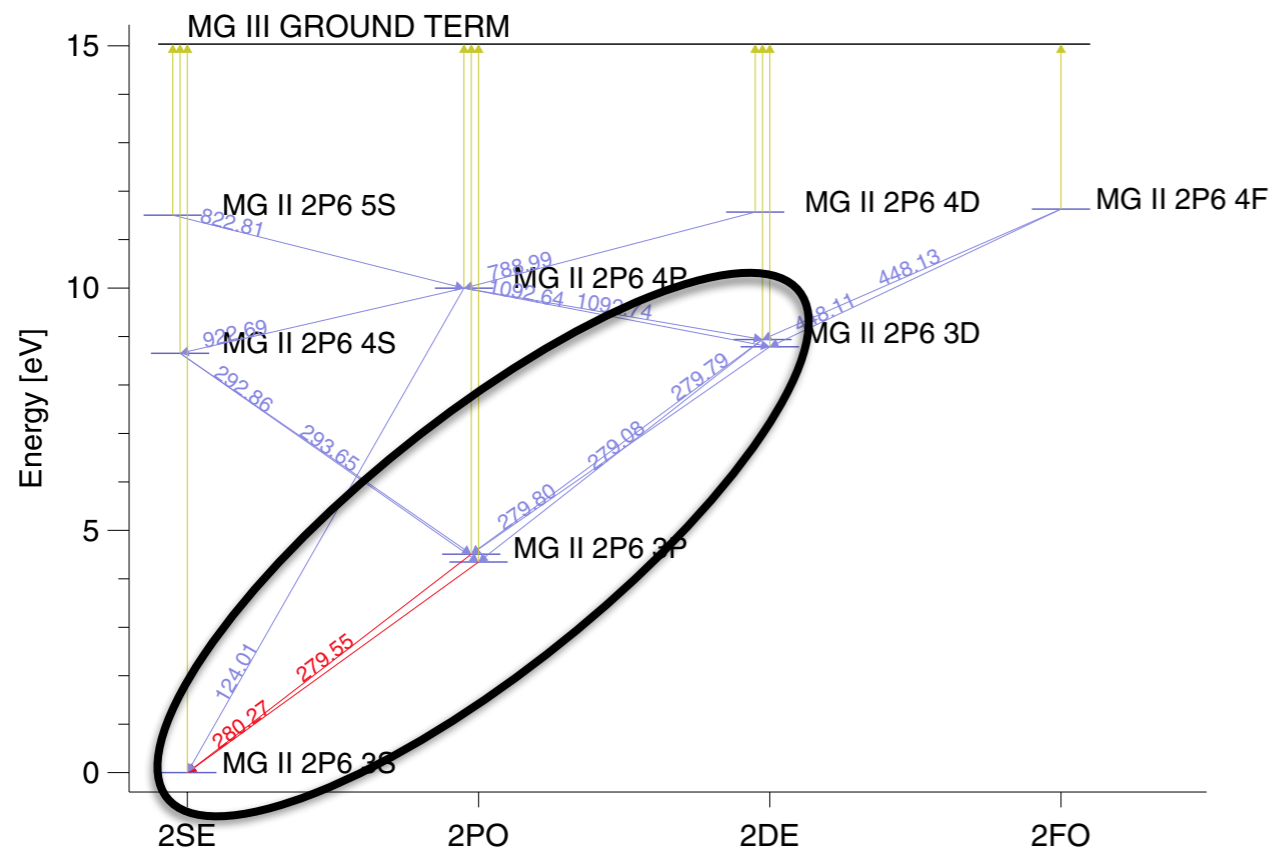
Leenaarts et al. (2013)



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1.5D vs 3D radiative transfer

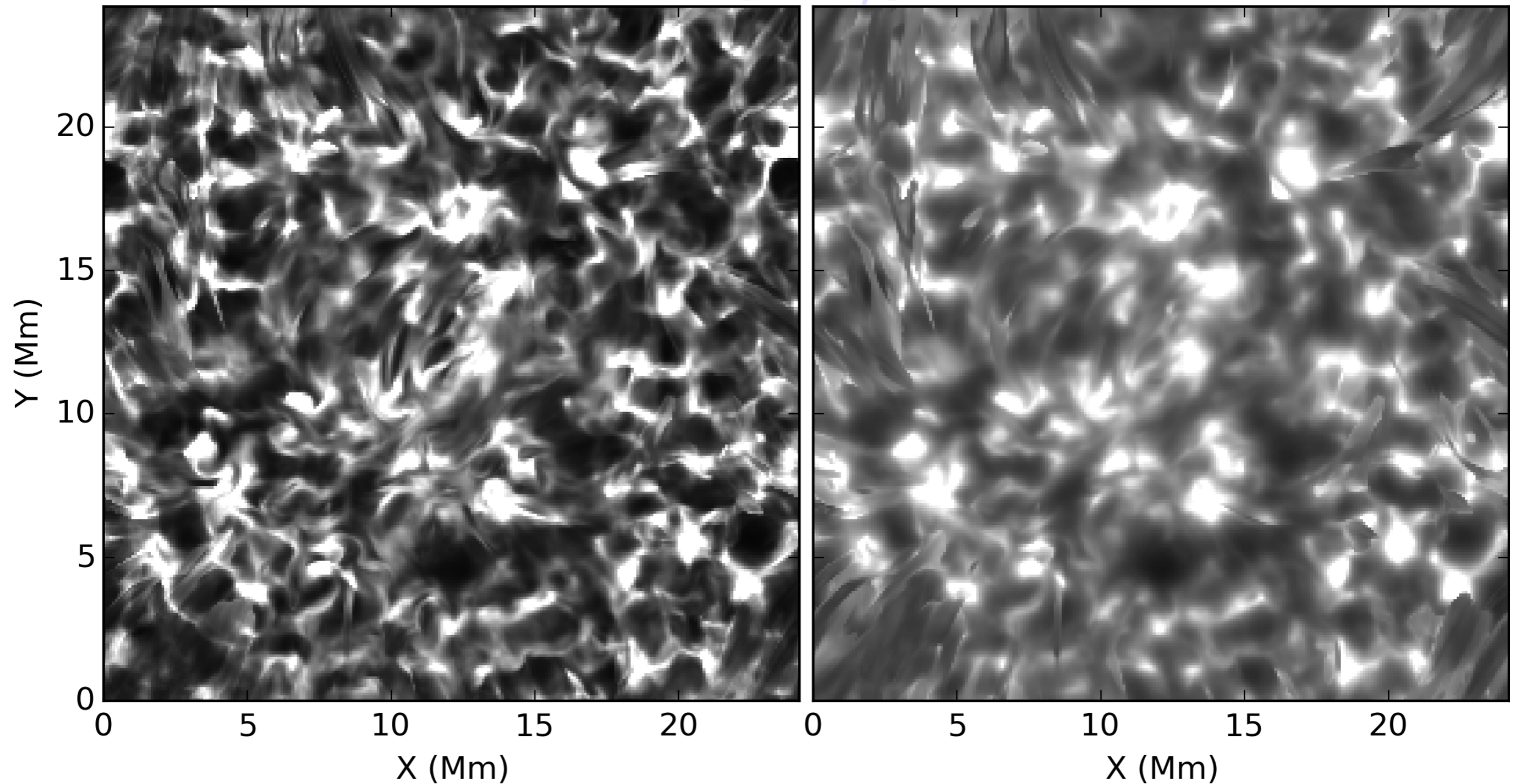
Mg II k2v

courtesy of Sukhorukov & Leenaarts (submitted to A&A)

1D PRD

10 km/s

3D PRD

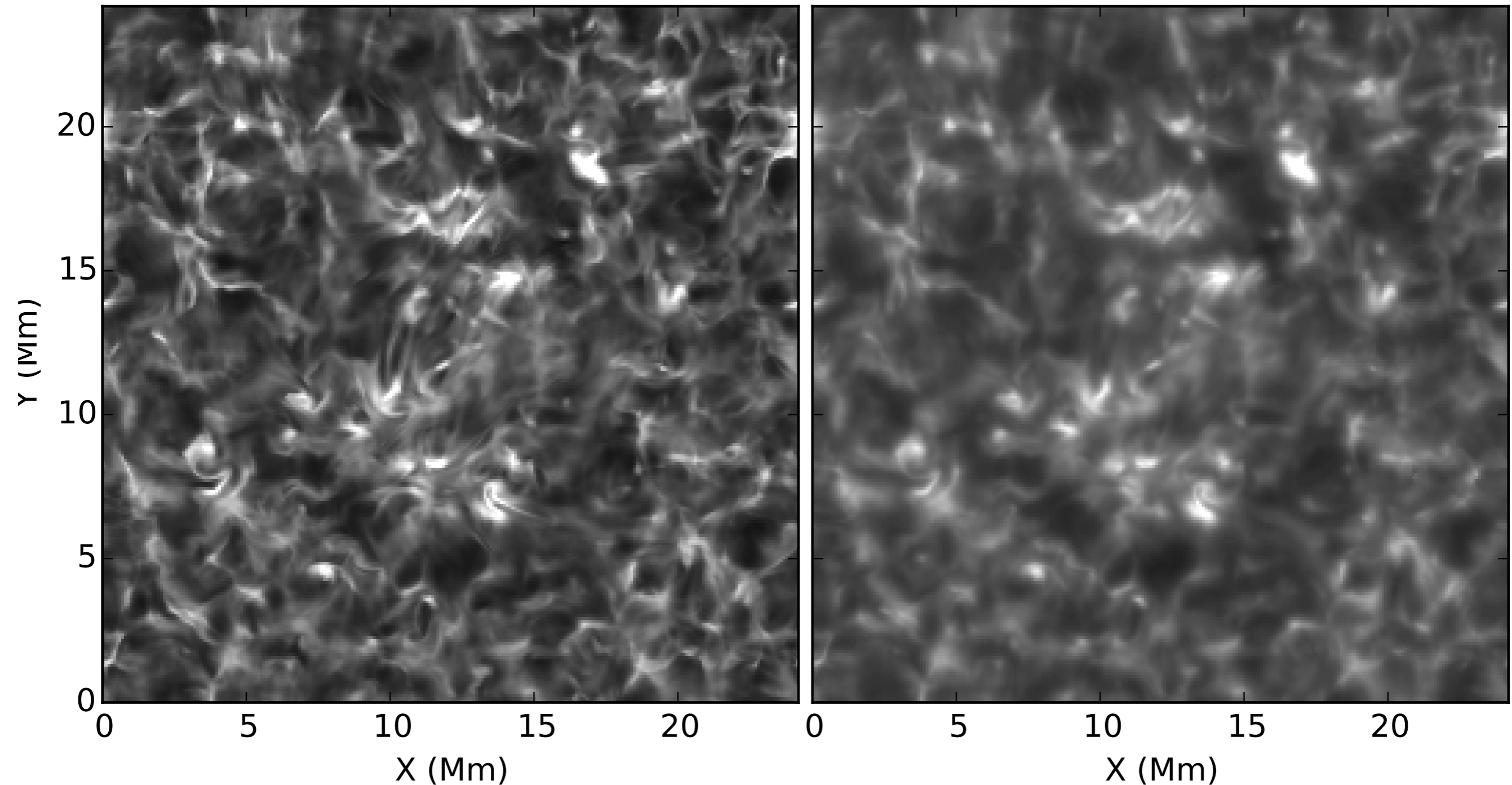


1.5D vs 3D radiative transfer

Synthetic slitjaw in Mg II k at disk center
courtesy of Sukhorukov & Leenaarts (submitted to A&A)

1D PRD

3D PRD

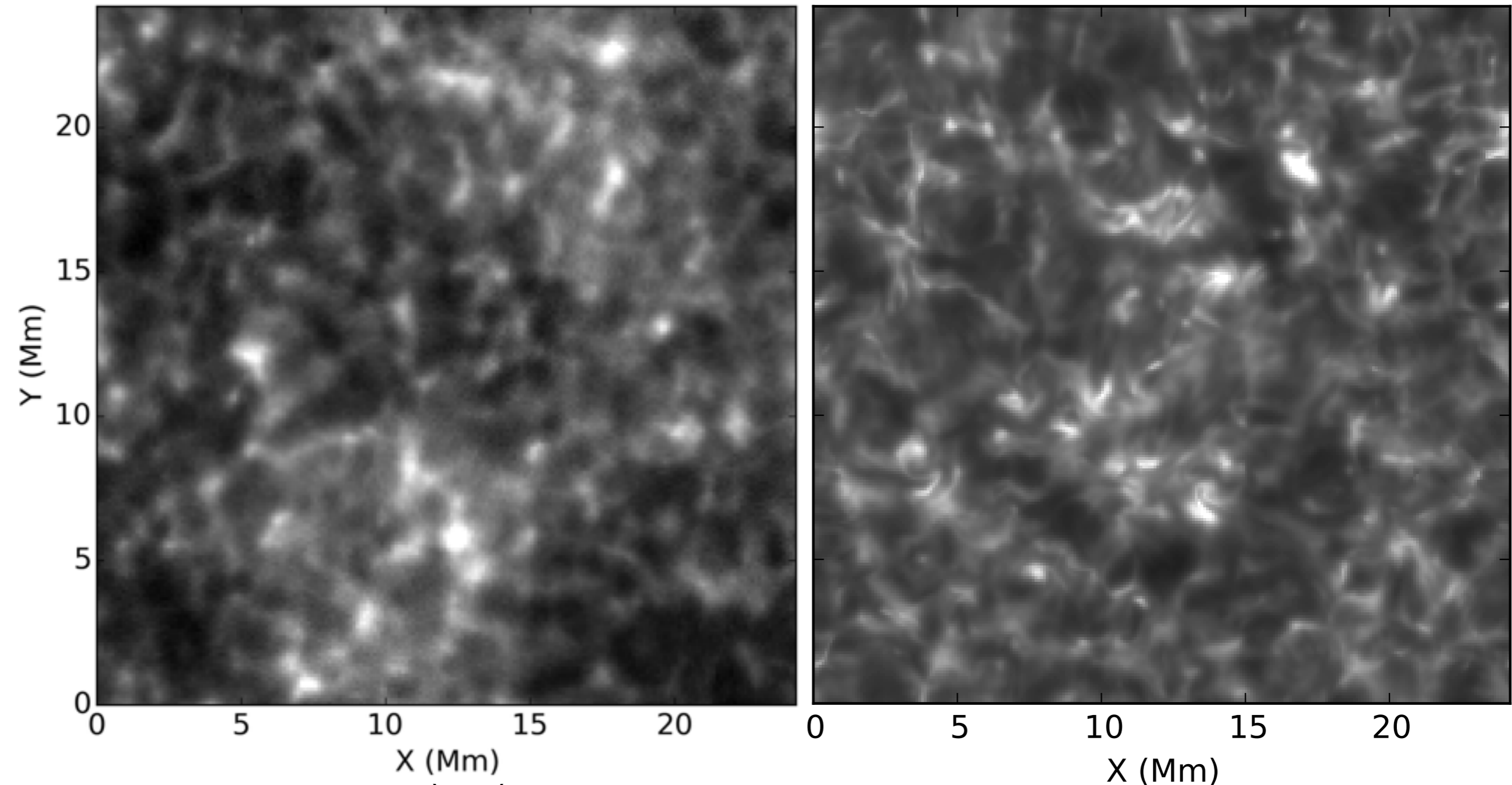


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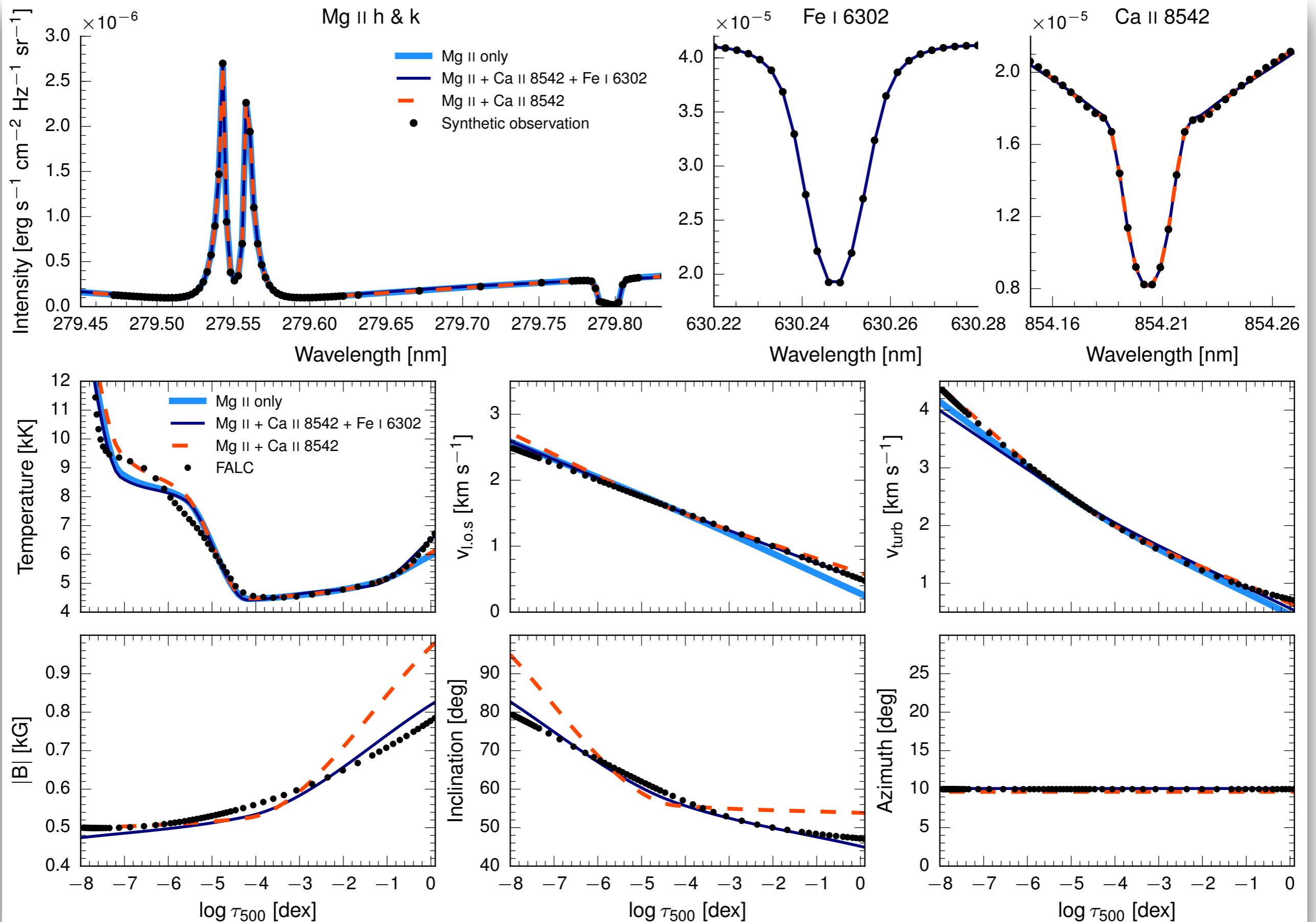
Synthetic slitjaw in Mg II k at disk center
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Iris observation

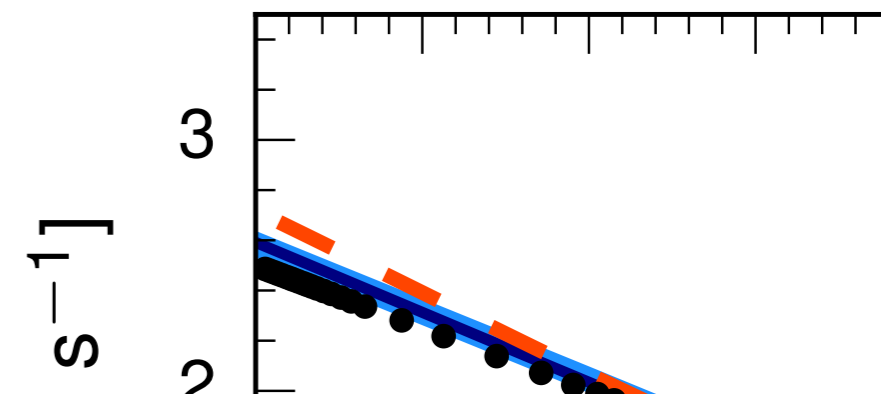
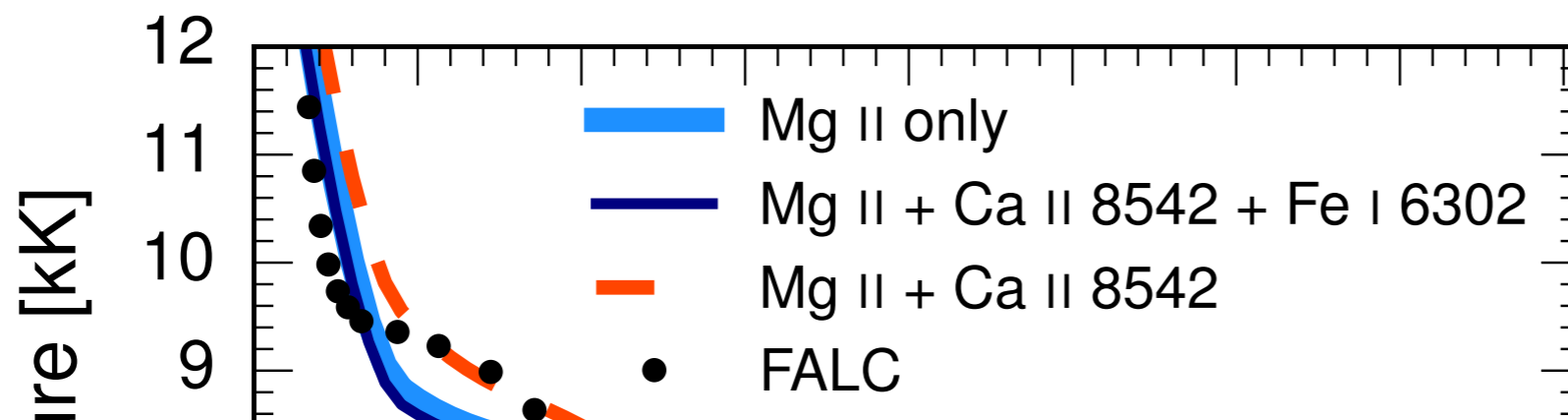
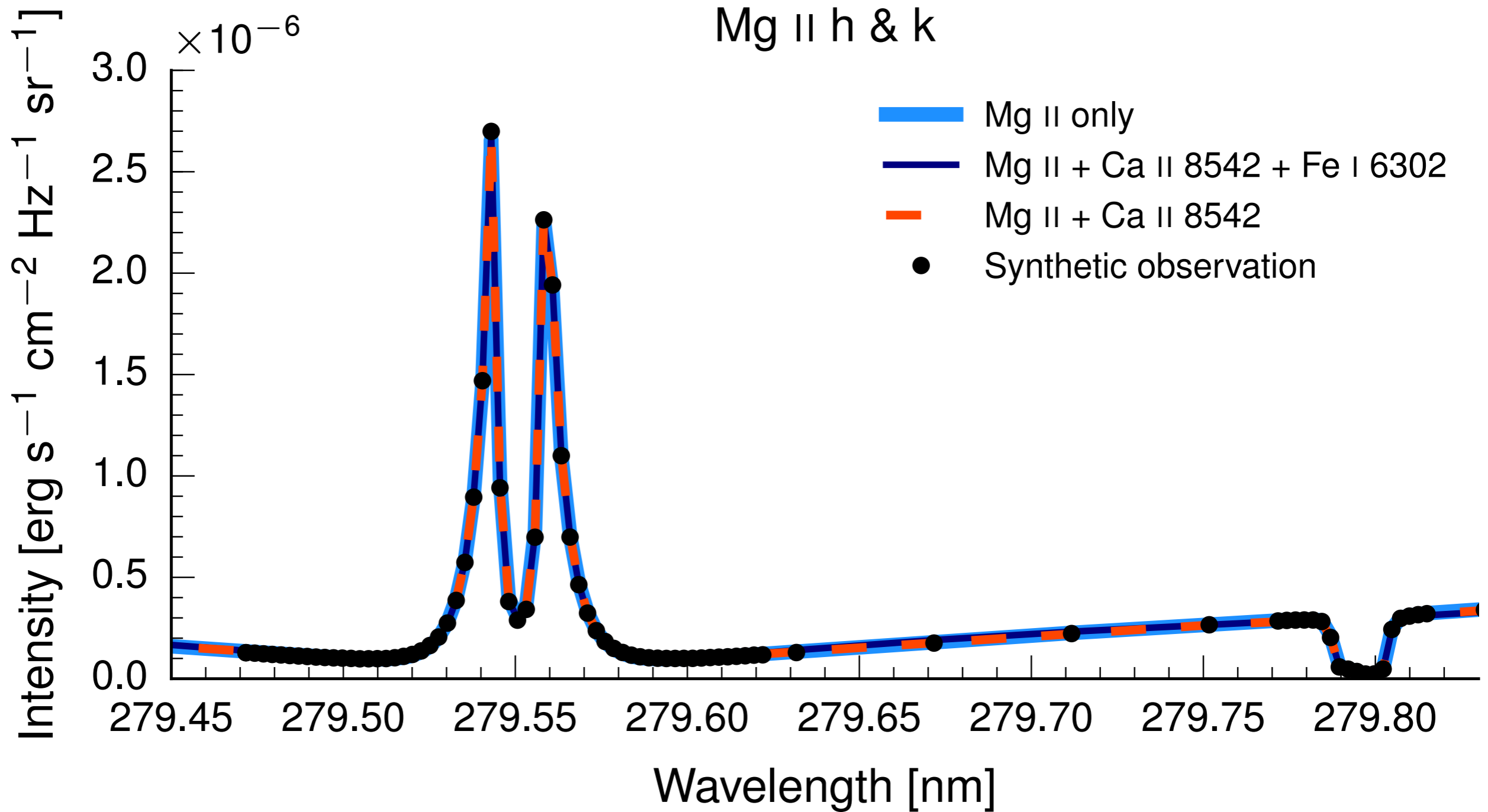
3D PRD



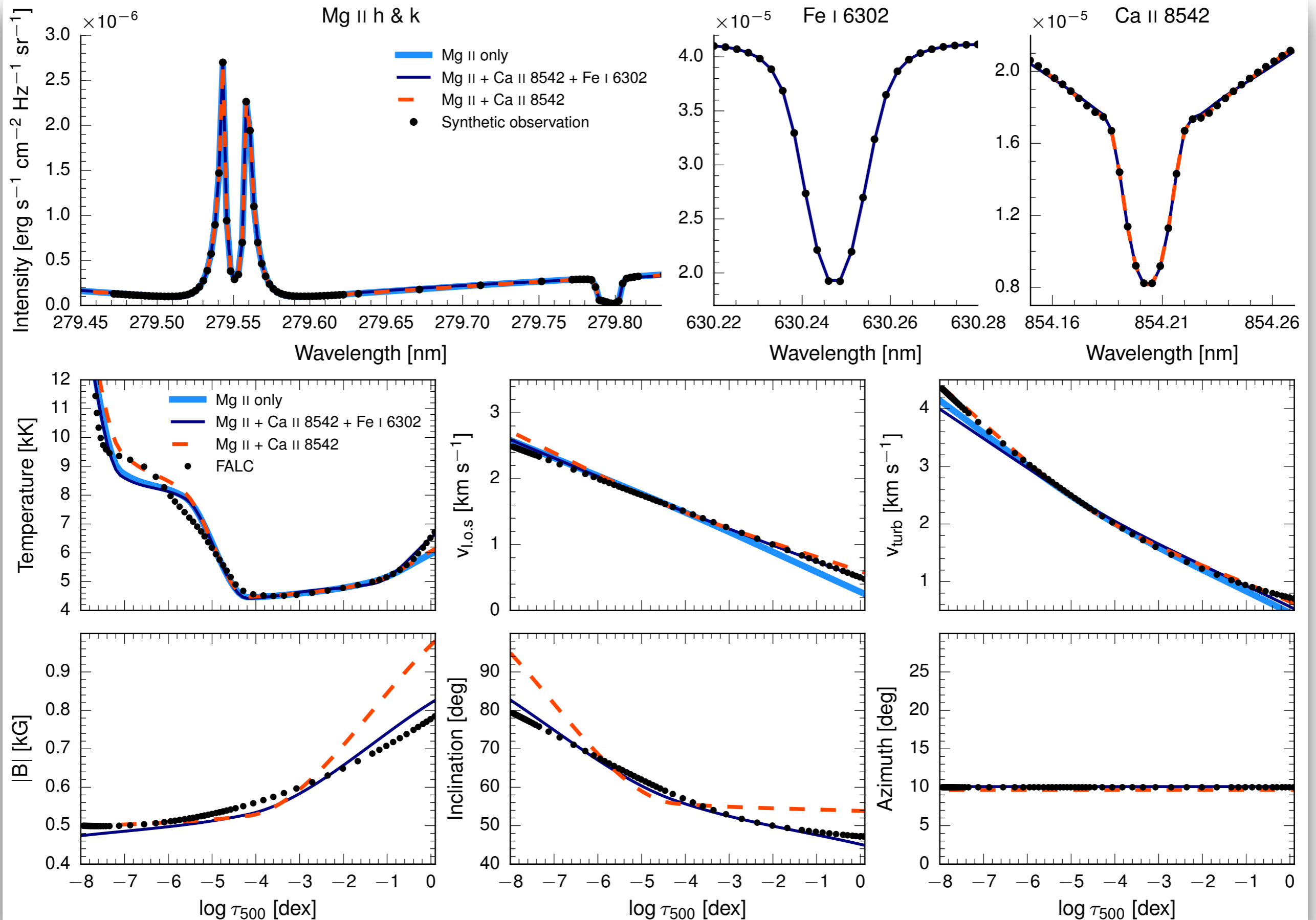
First tests with a modified FALC atmosphere



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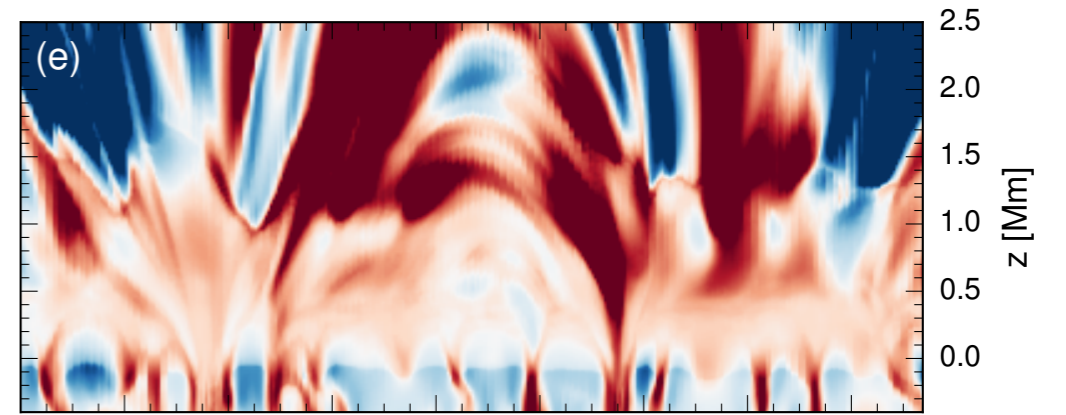
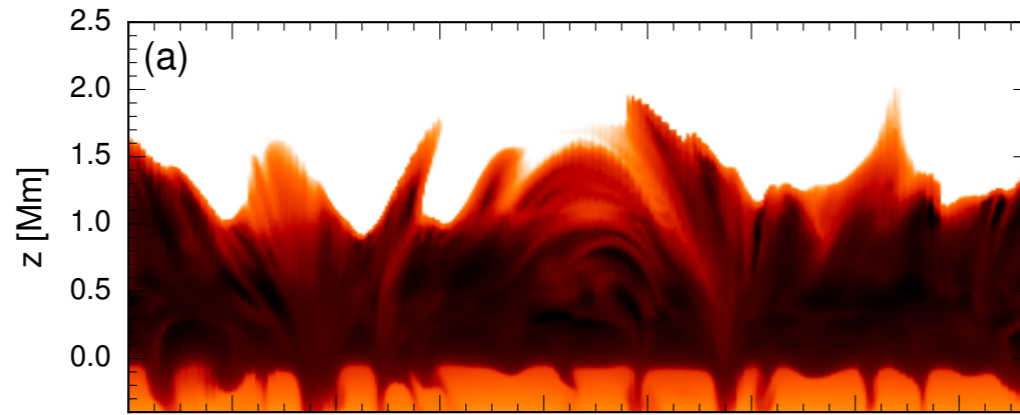


First tests with a modified FALC atmosphere



Bifrost atmosphere

Original



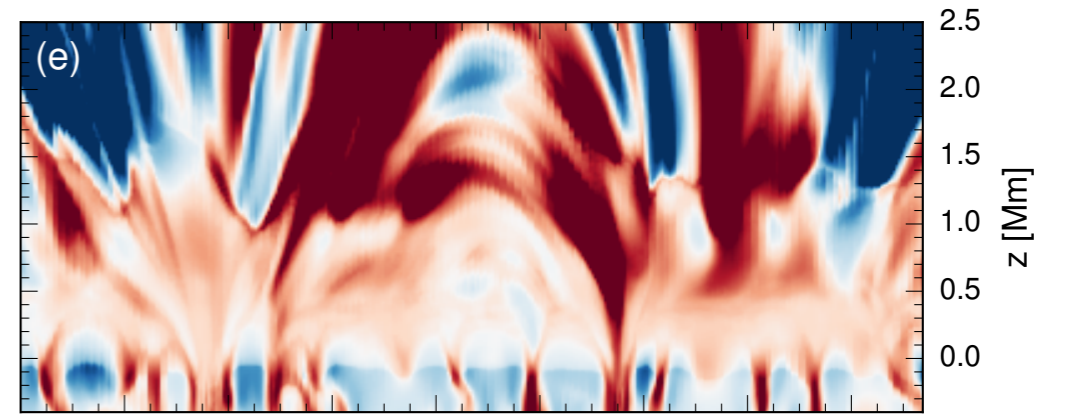
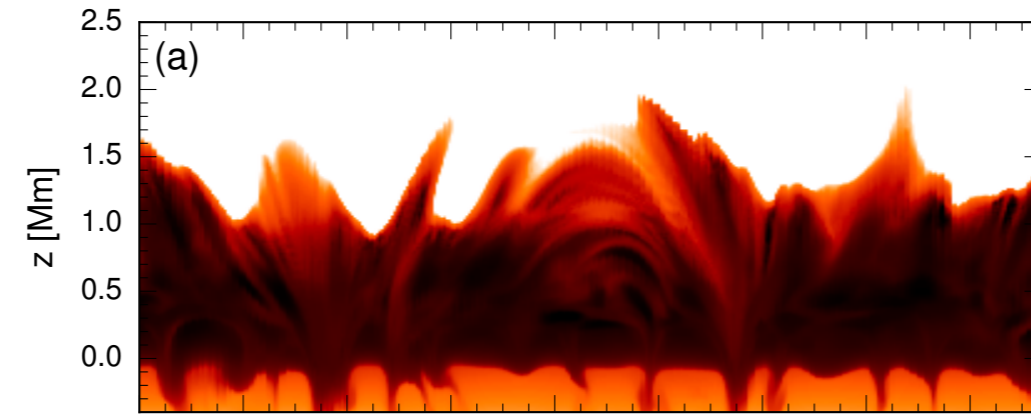
Log tau_500

with nodes

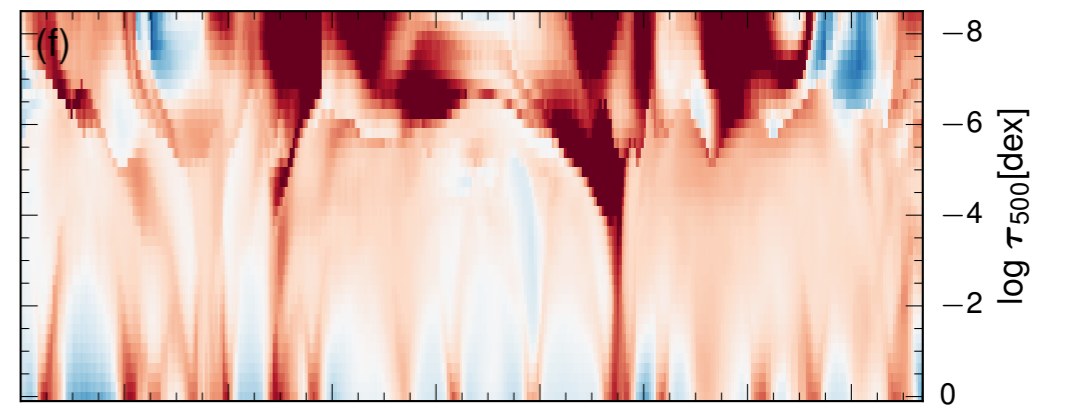
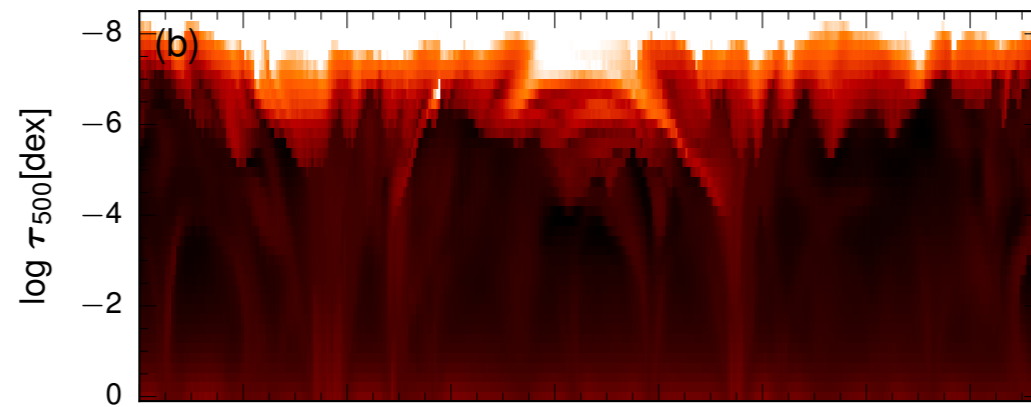
inversion

Bifrost atmosphere

Original



Log tau_500

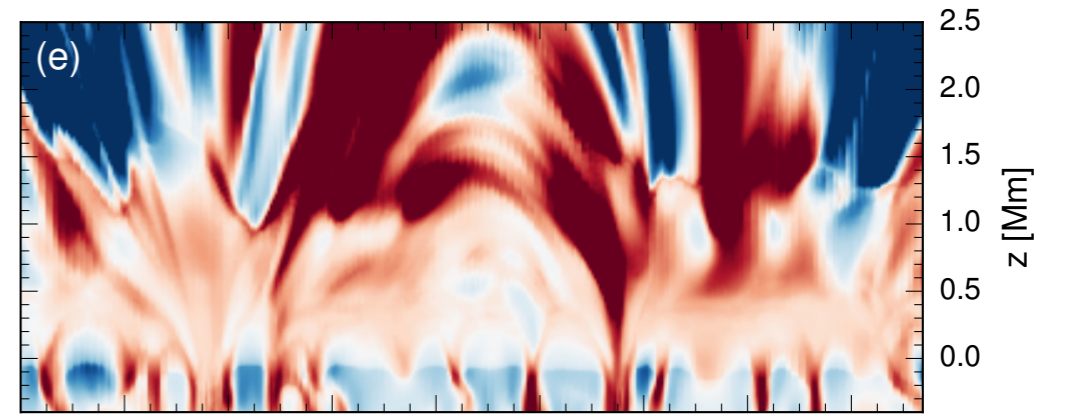
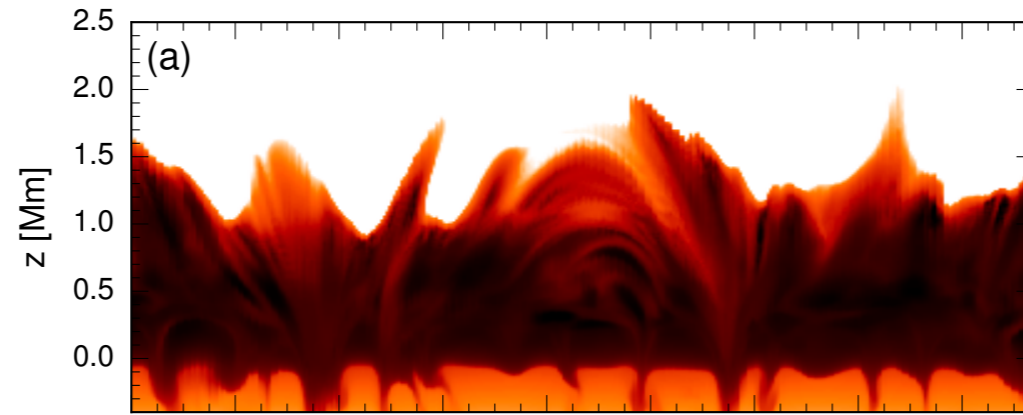


with nodes

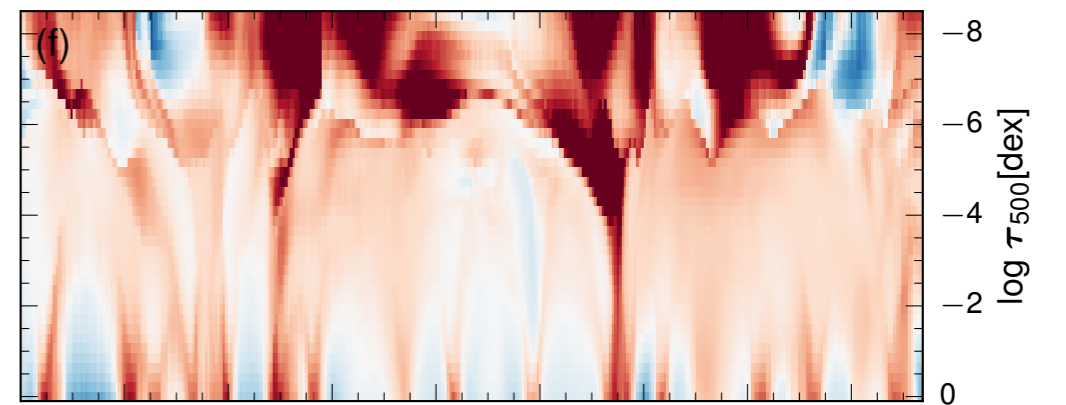
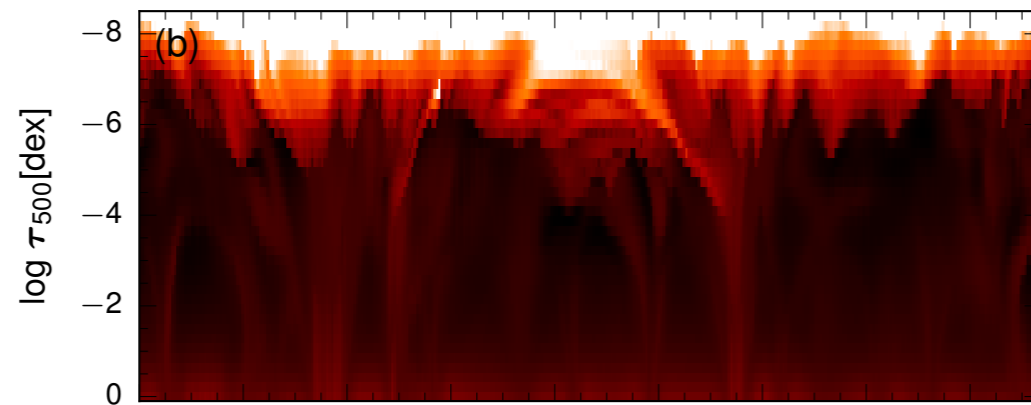
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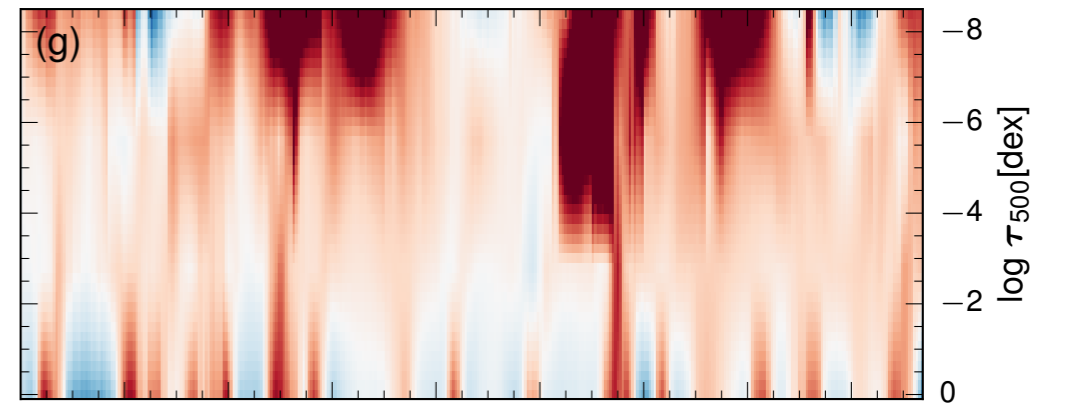
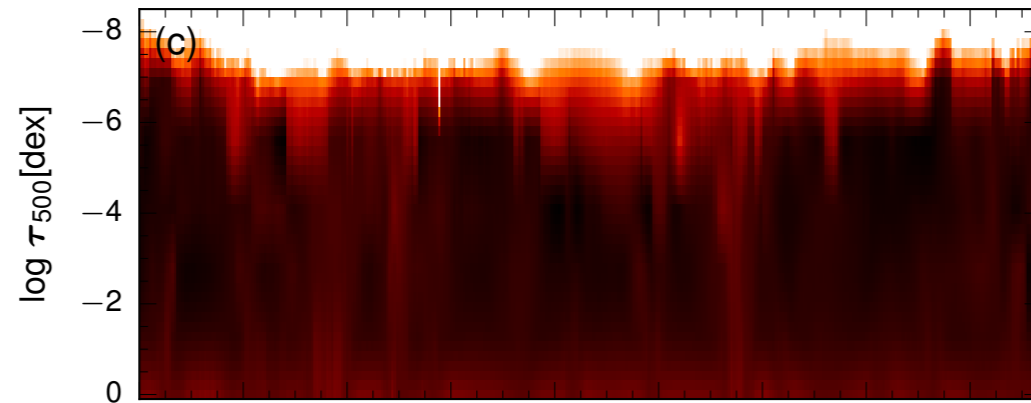
Original



Log tau_500



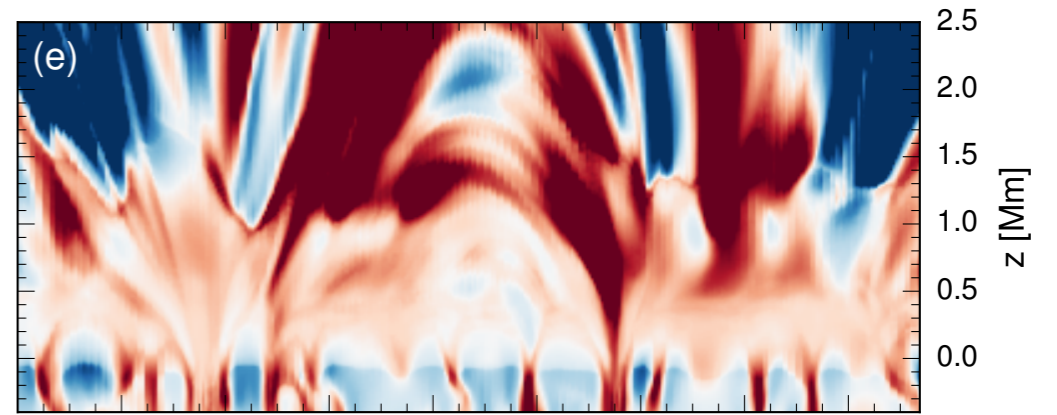
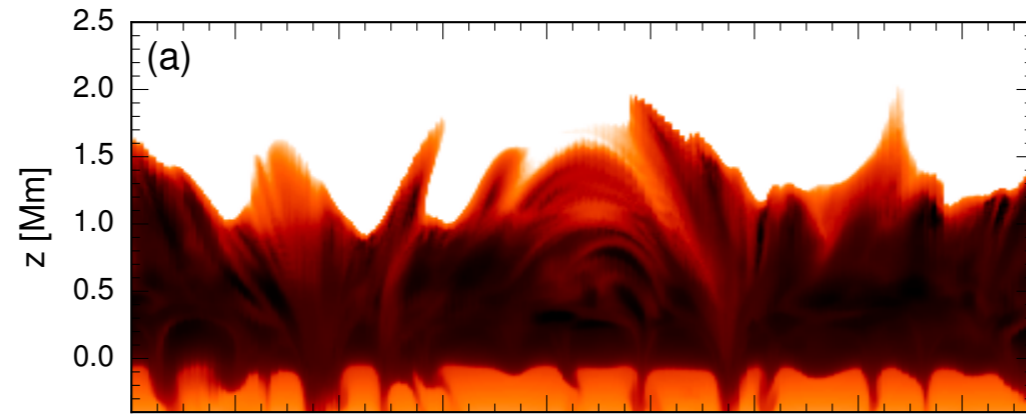
with nodes



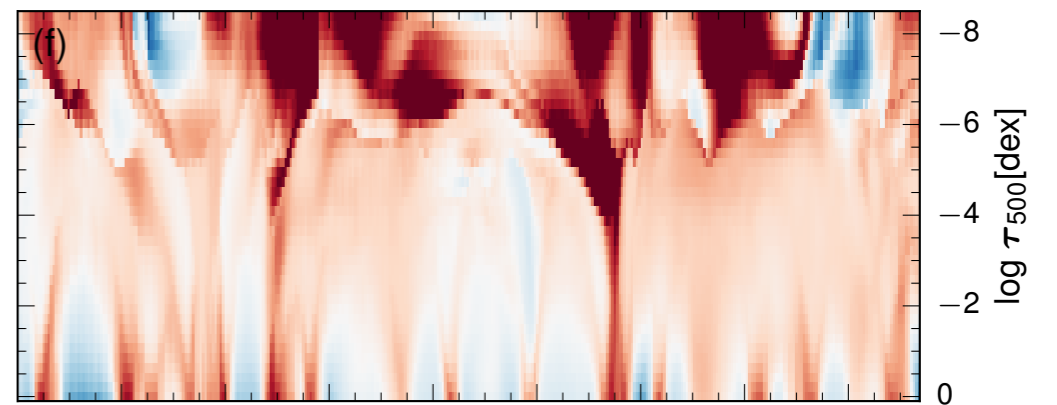
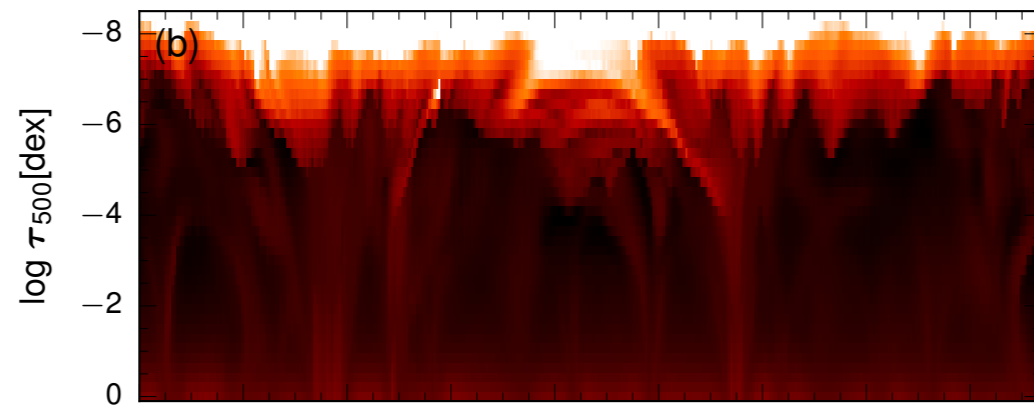
inversion

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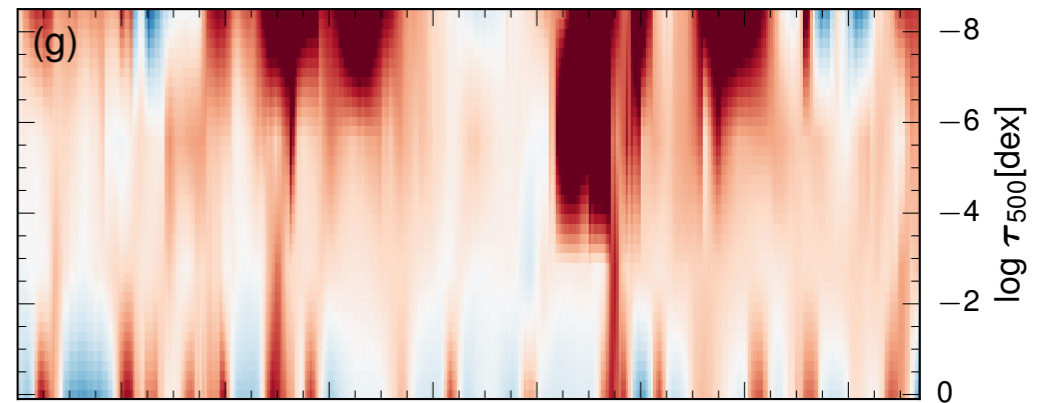
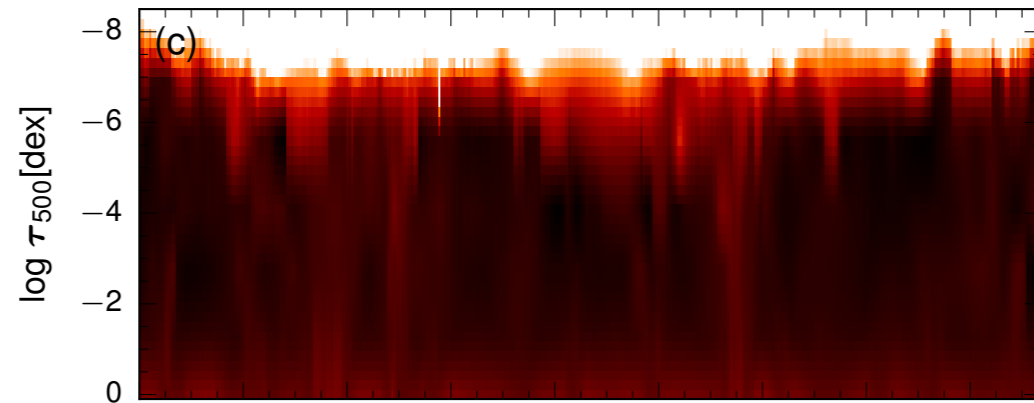
Original



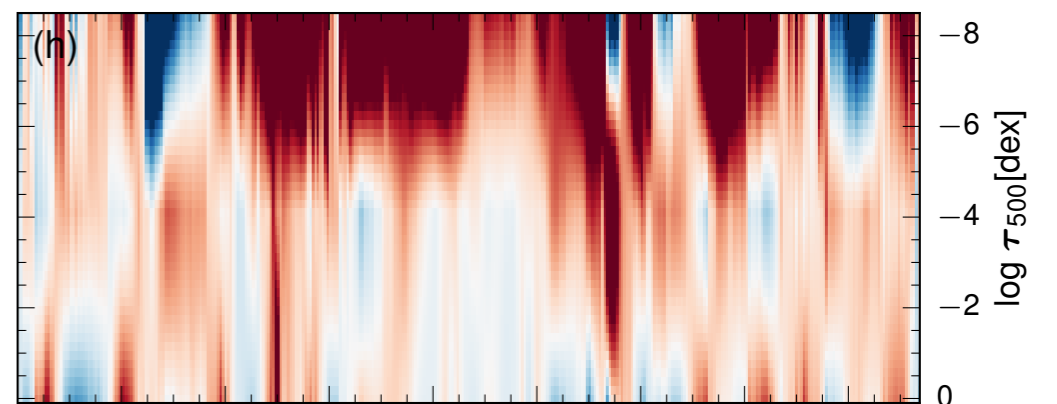
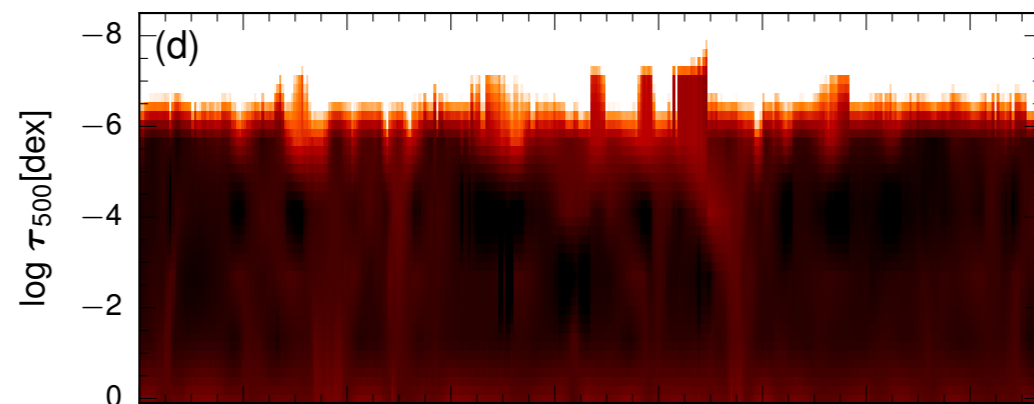
Log tau_500



with nodes



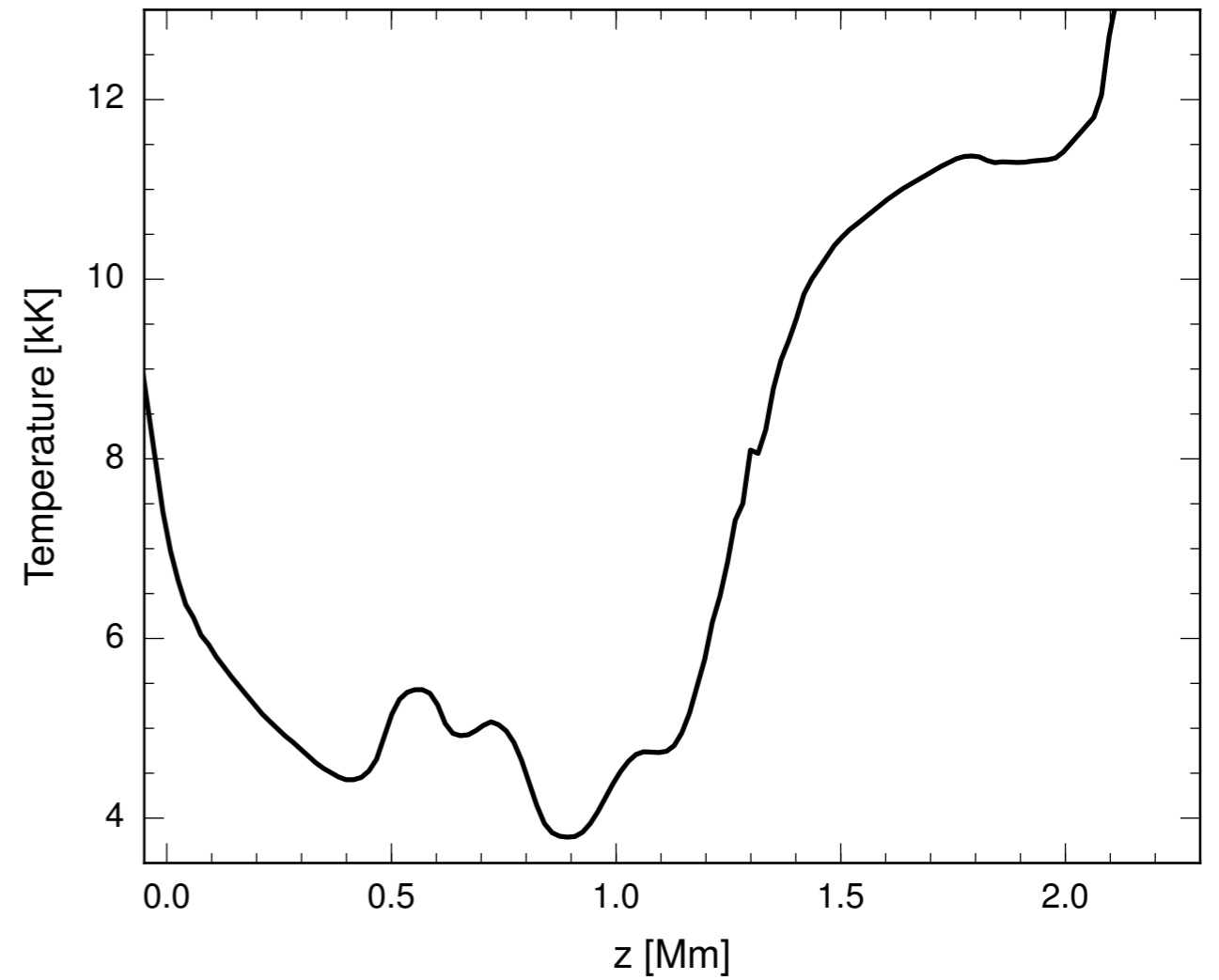
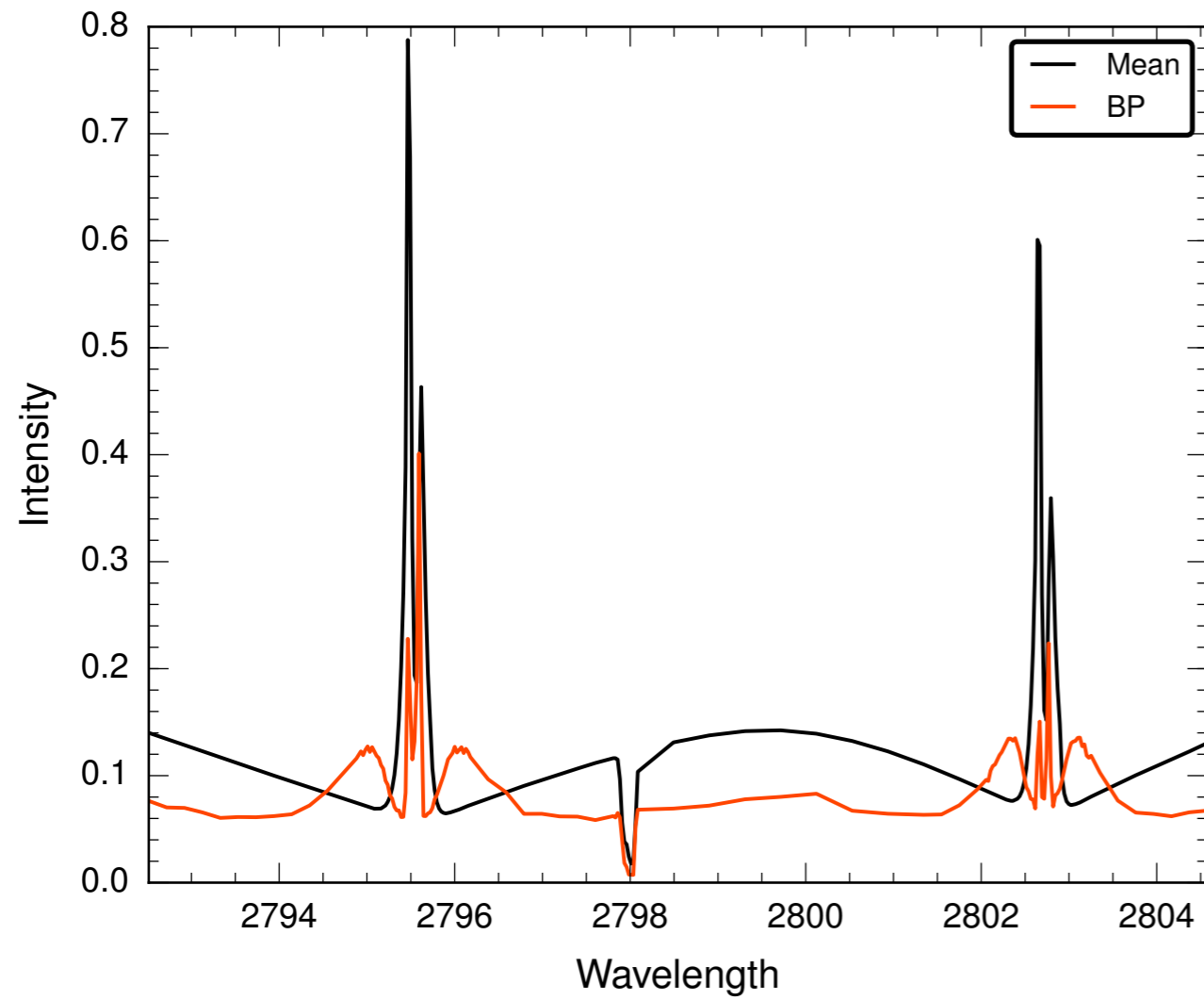
inversion



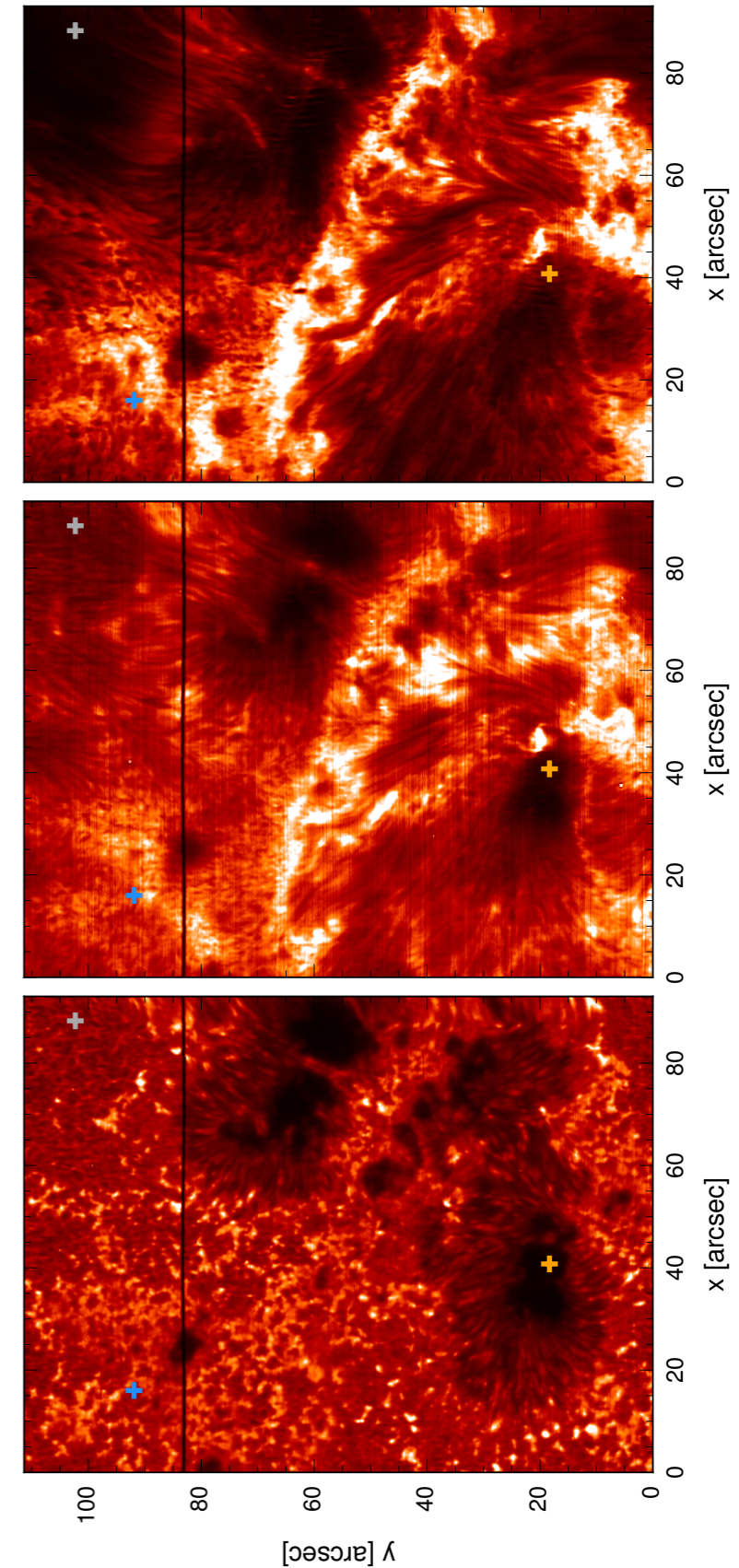
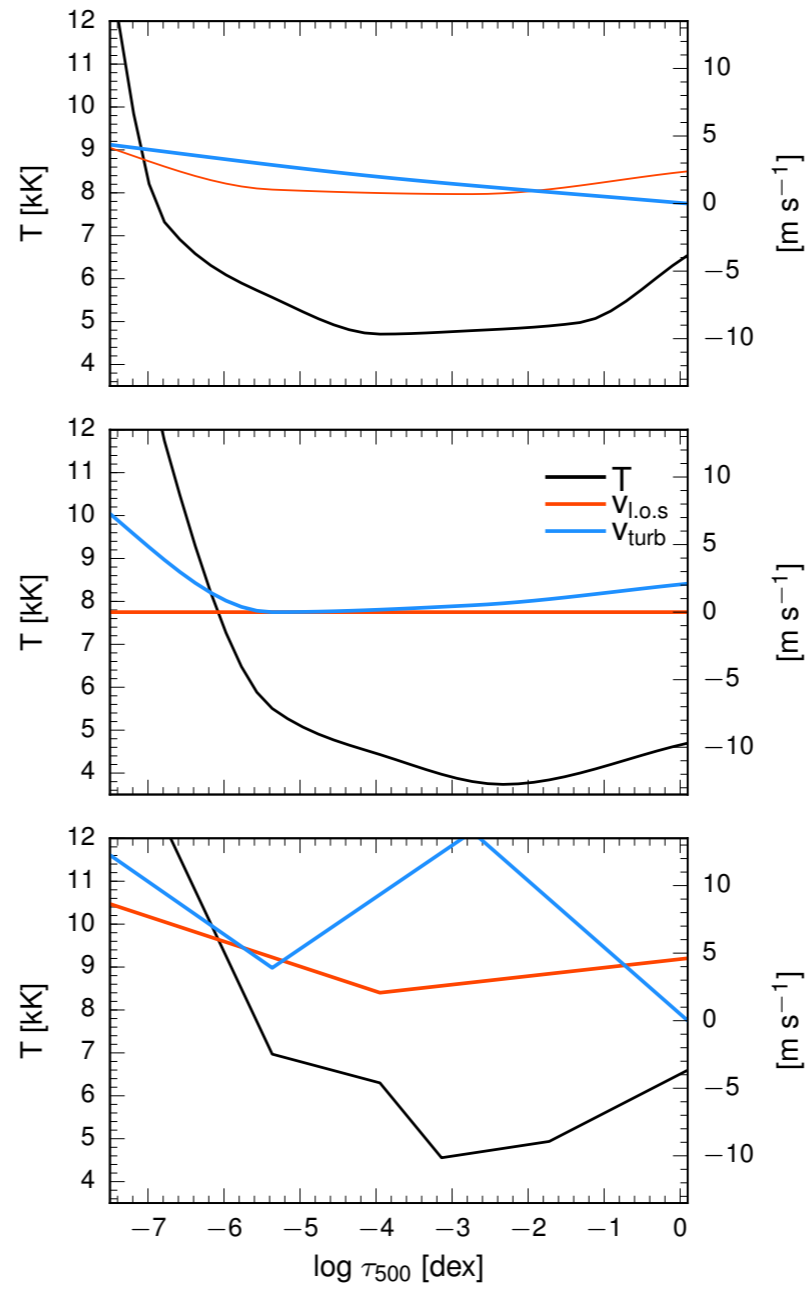
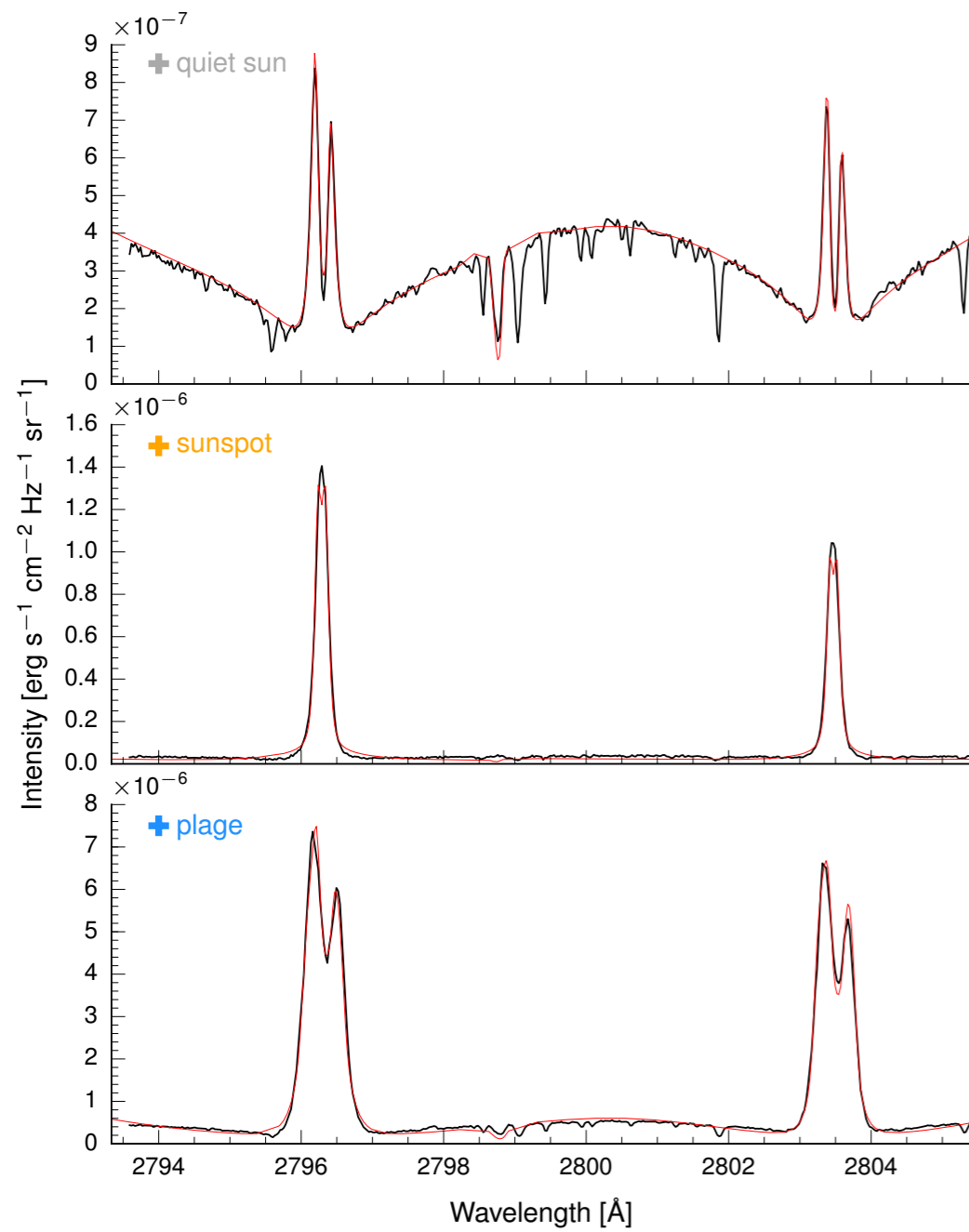
x [Mm]

x [Mm]

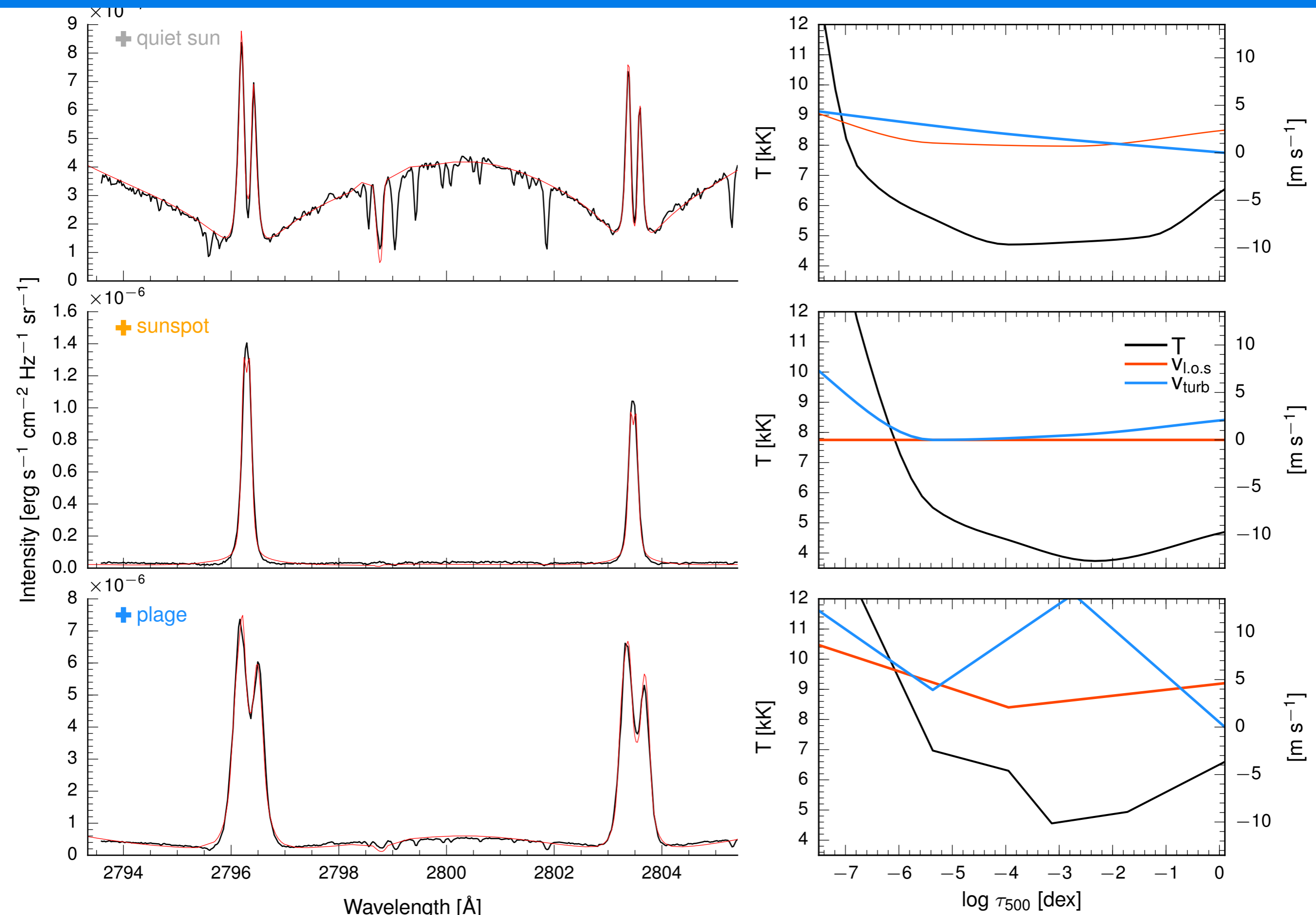
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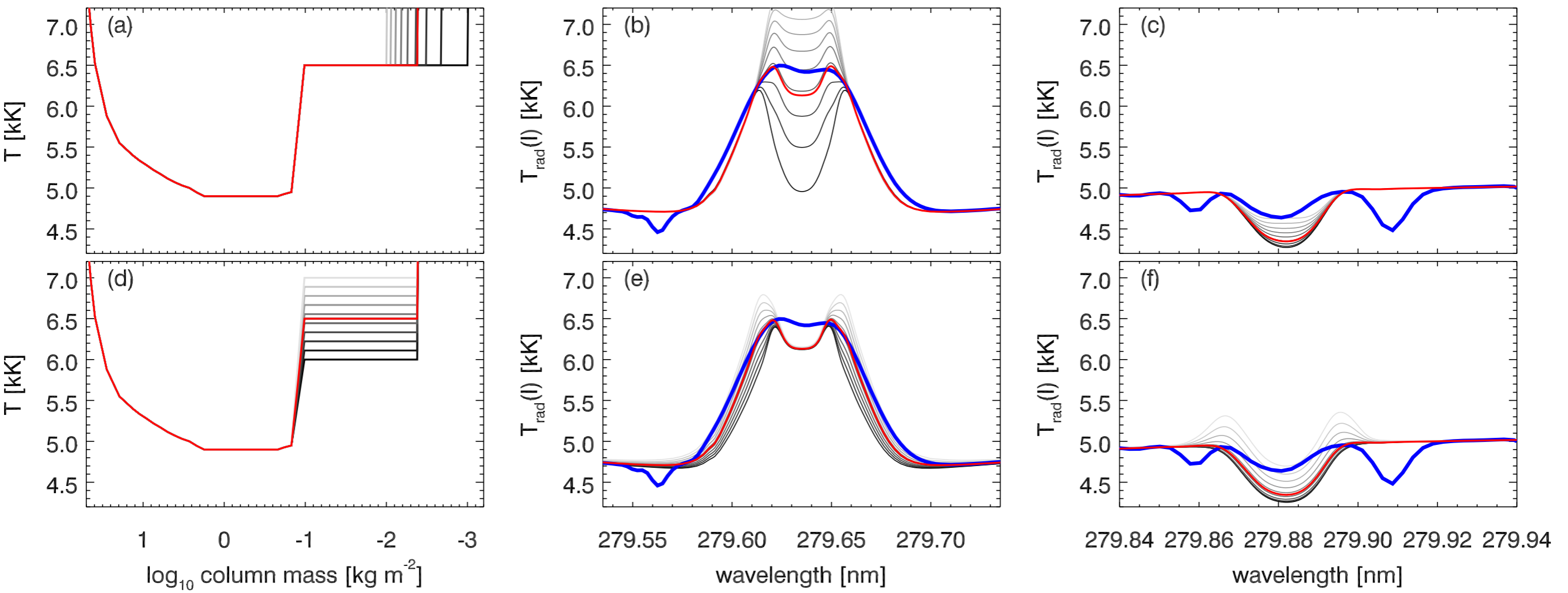
quiet Sun, plage and sunspot profiles from IRIS



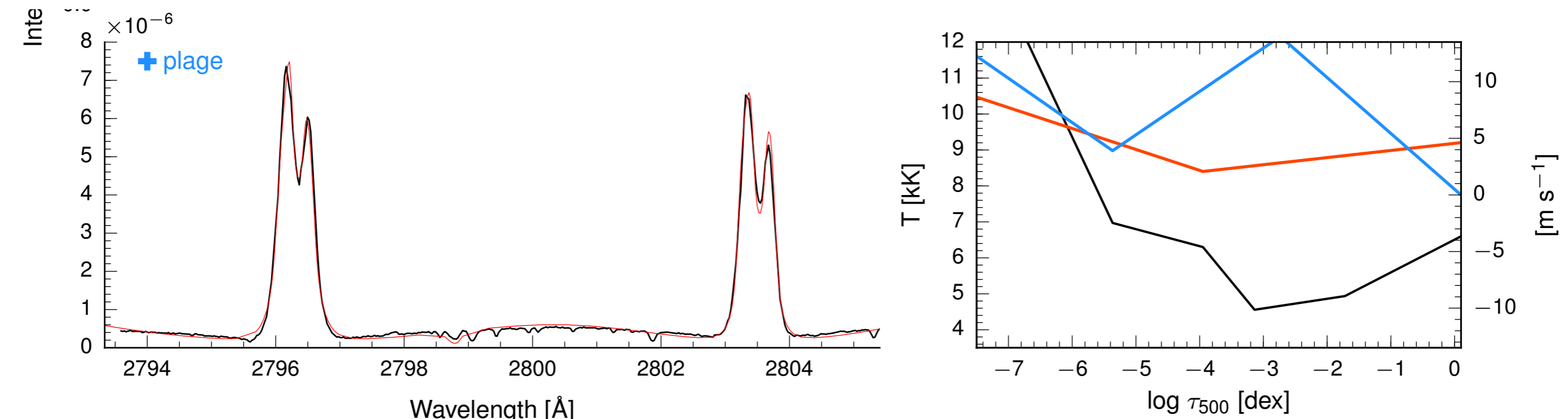
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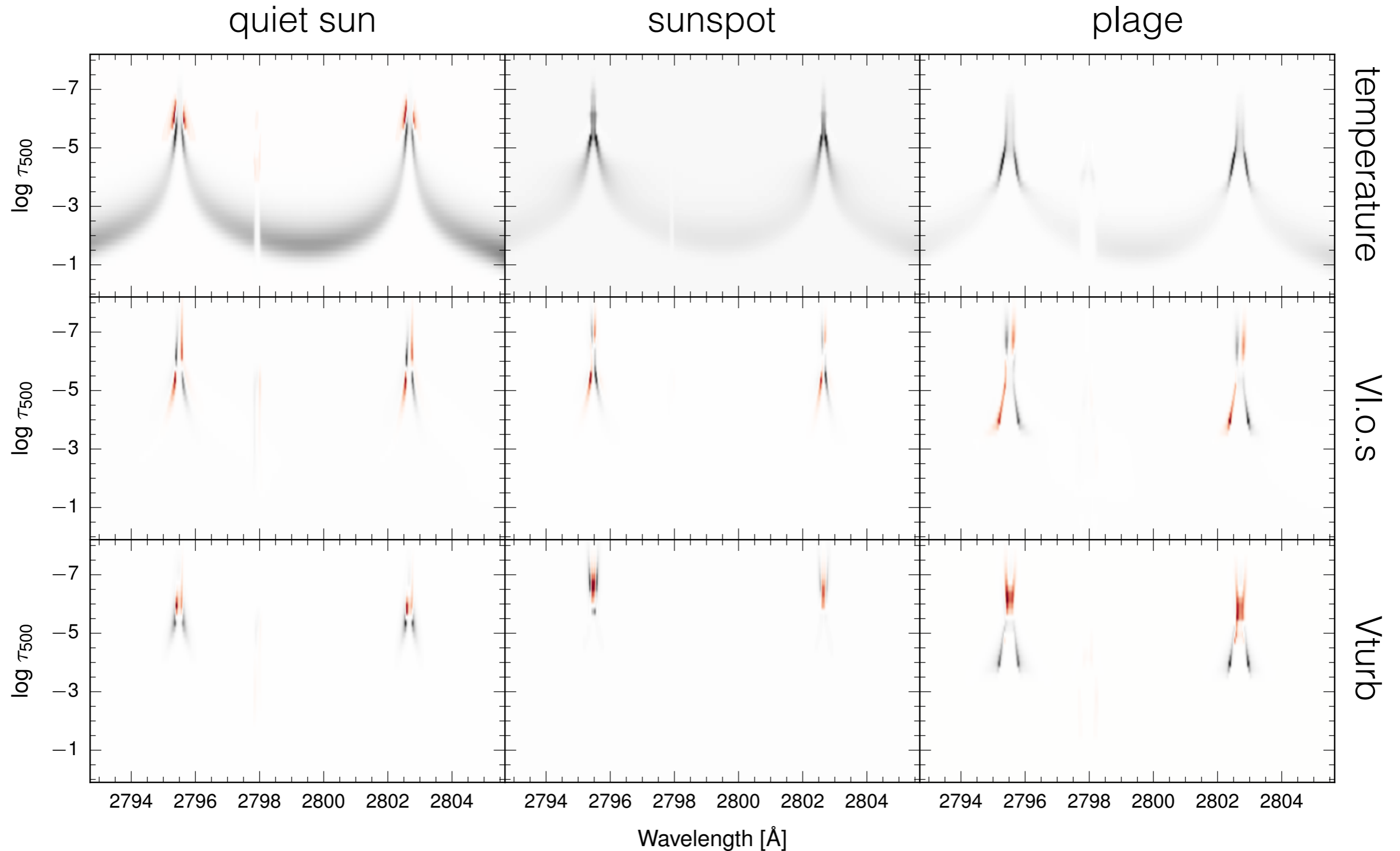


Carlsson et al. (2015)



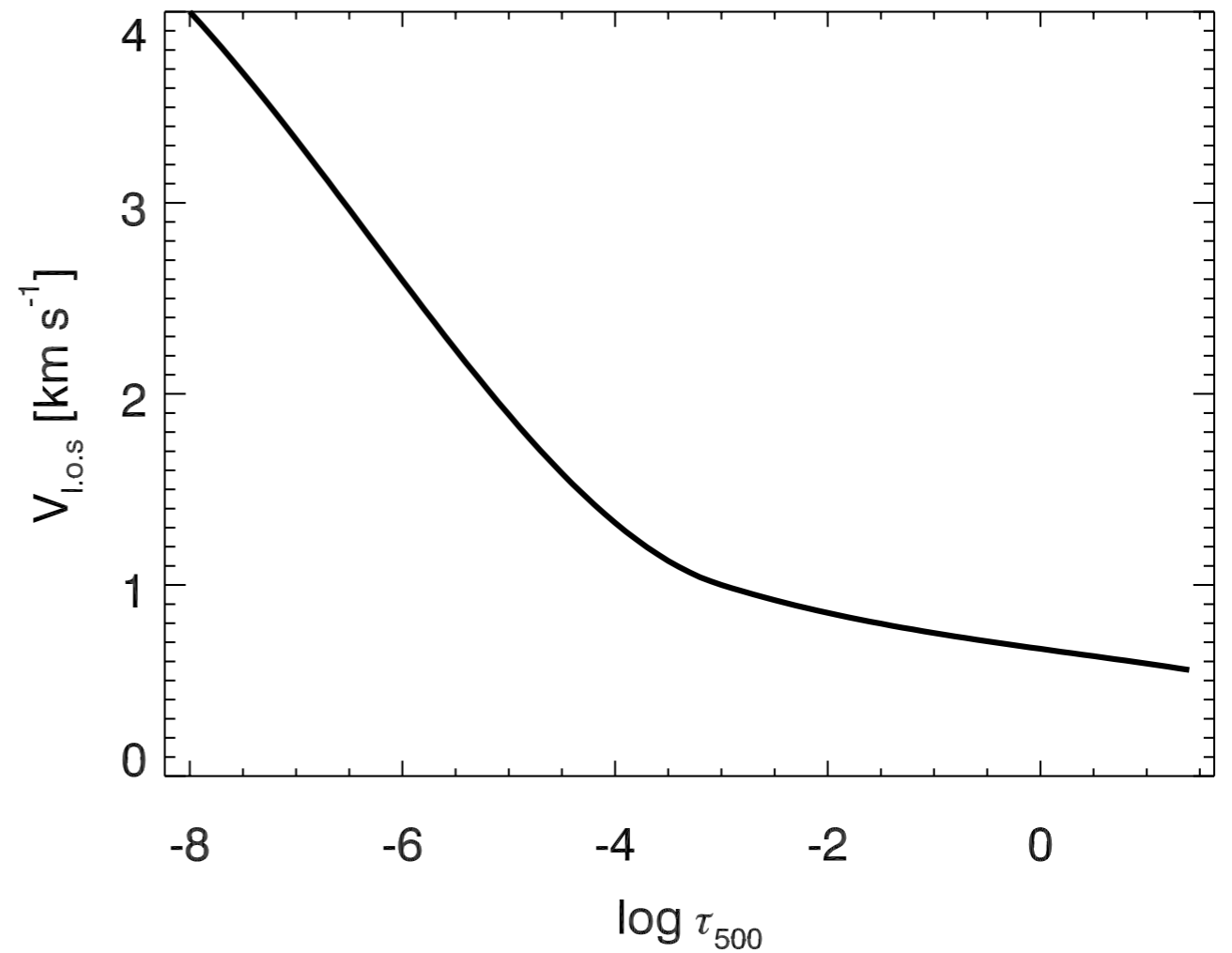
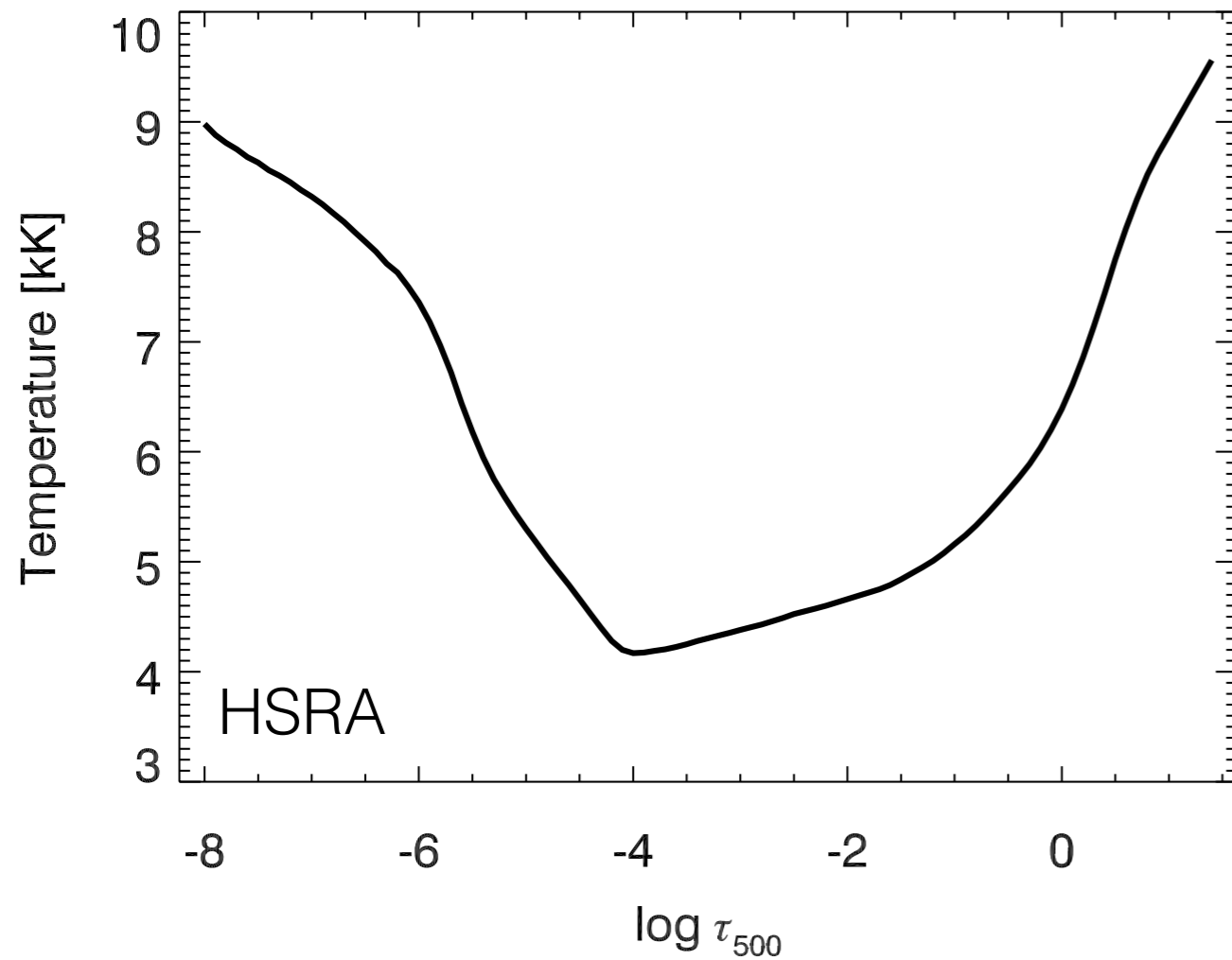
quiet Sun, plage and sunspot profiles from IRIS

Response functions as in Fossum & Carlsson 2005



What comes next?

Nodes inversion

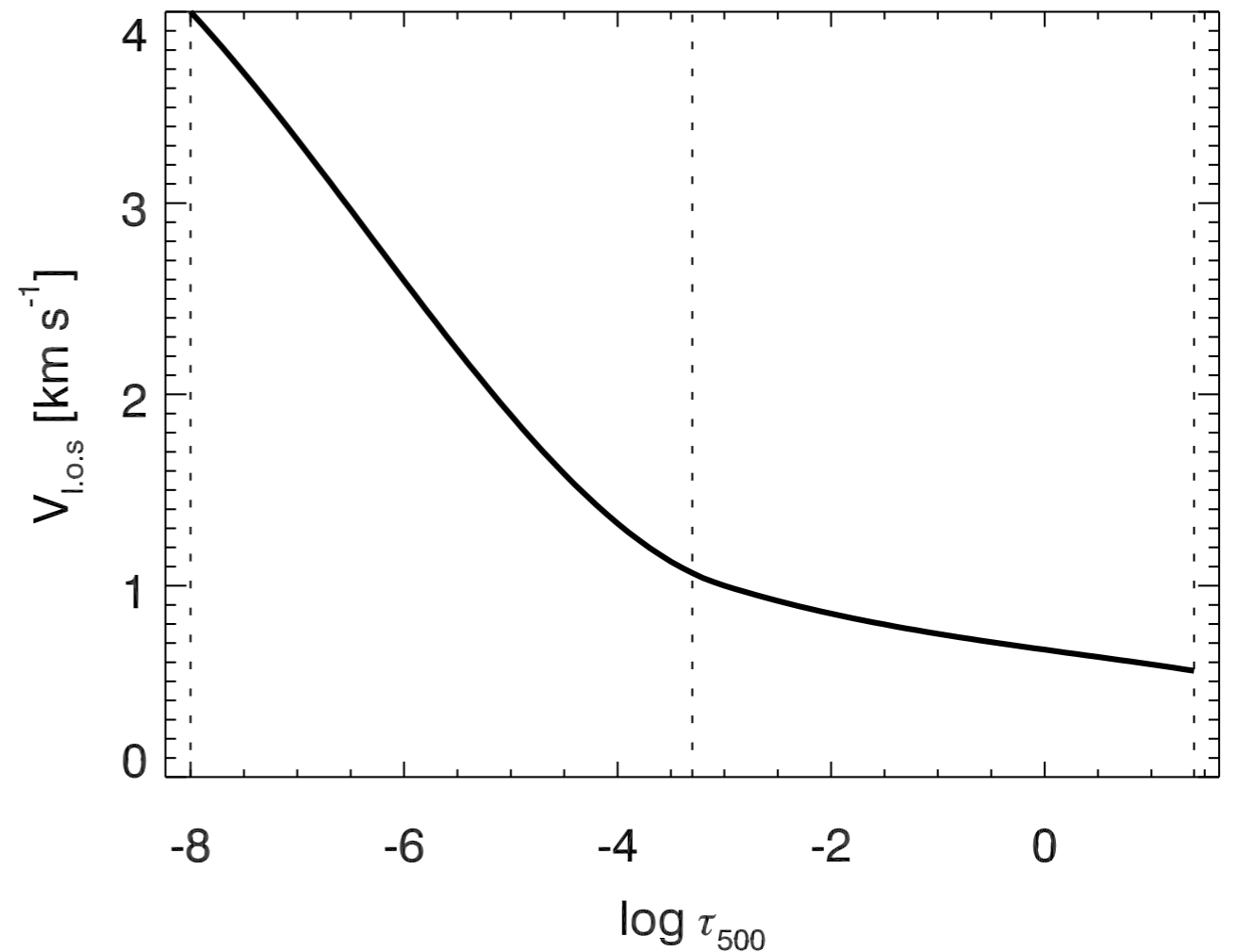
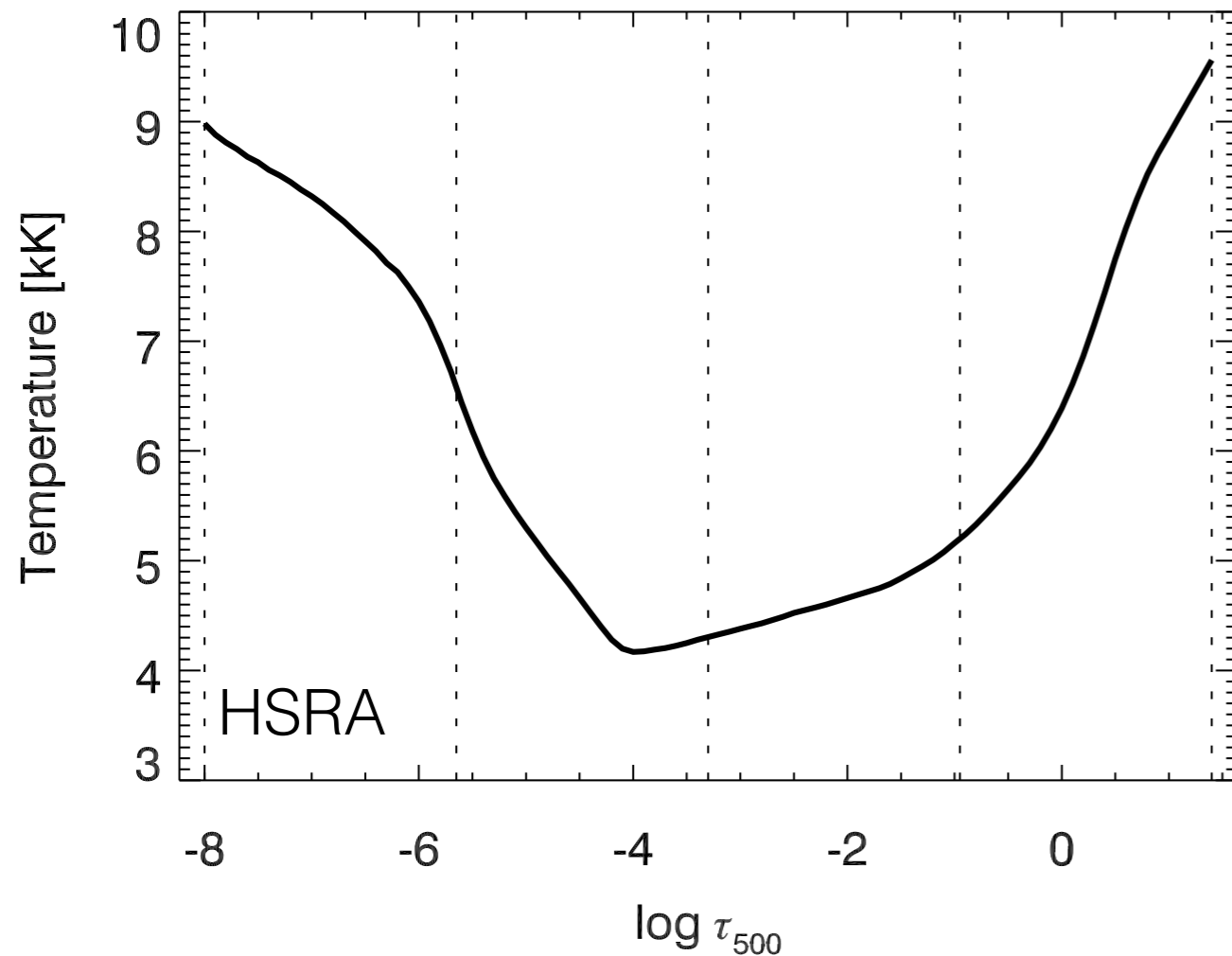


Model: Depth-stratified atmosphere (working in optical-depth at 500 nm).

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}).

Node-less inversion

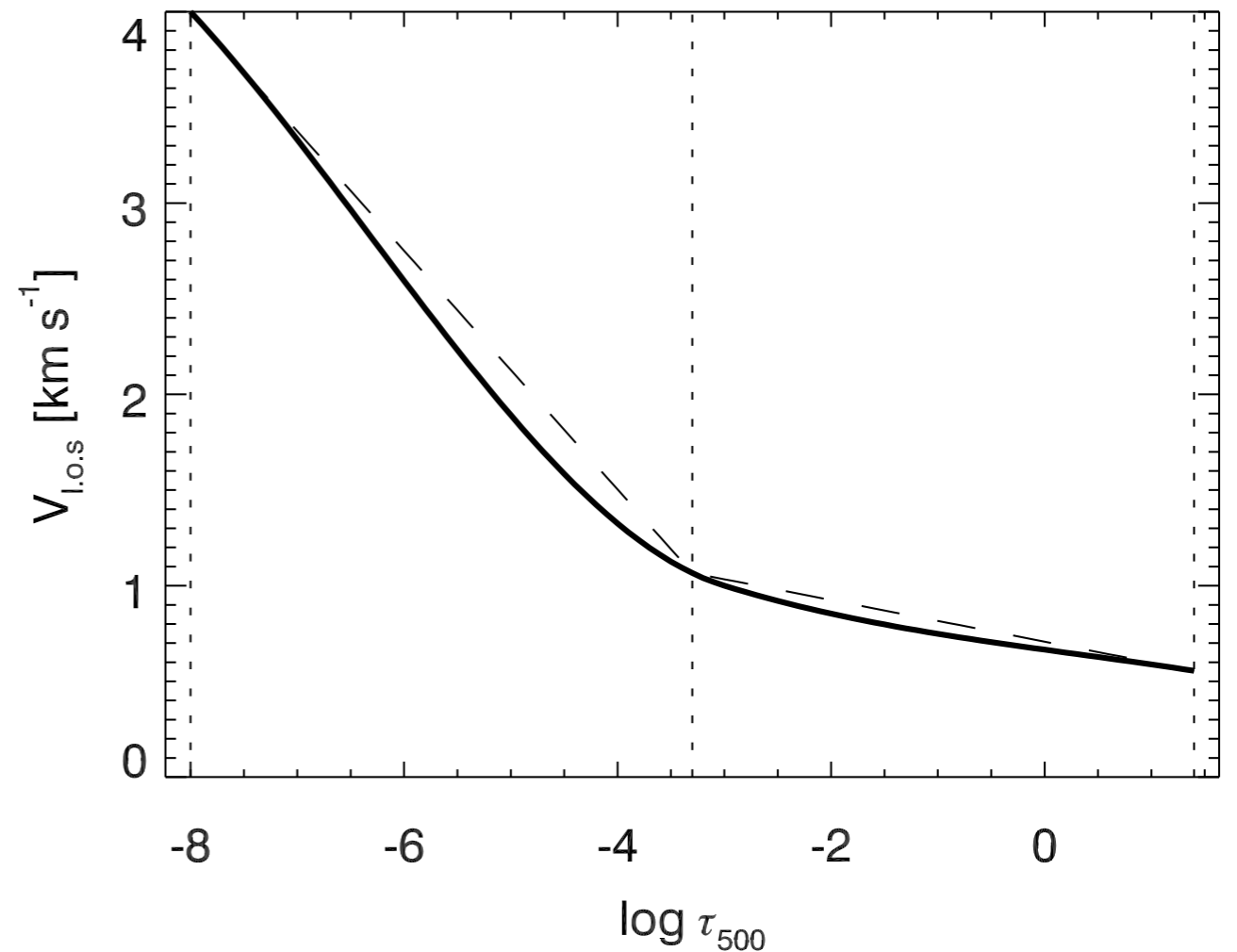
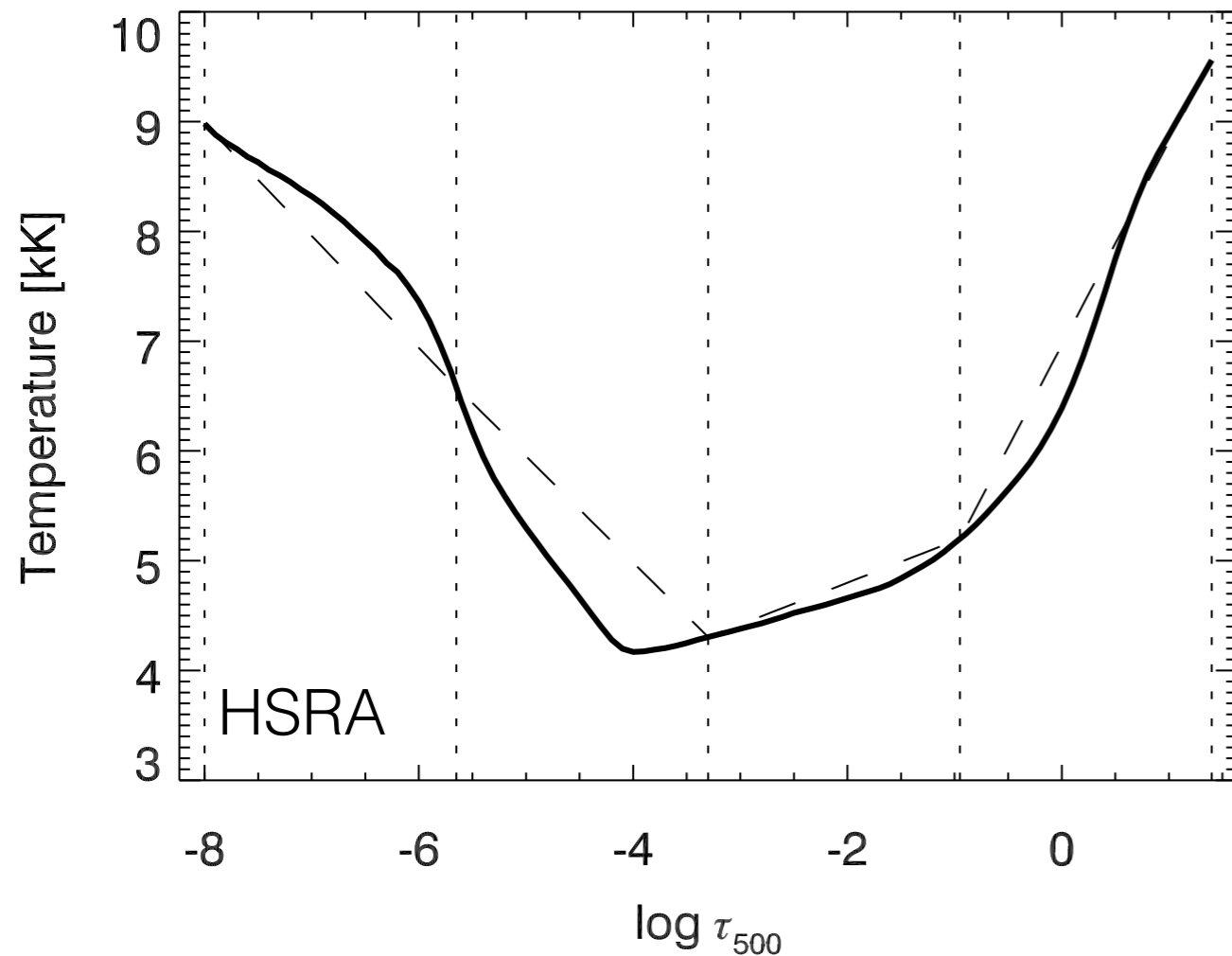


Nodes define the locations where the **model is perturbed and modified**.

The number of nodes can be different for each parameter.

We need the entire atmosphere to integrate the RT equation.

Node-less inversion

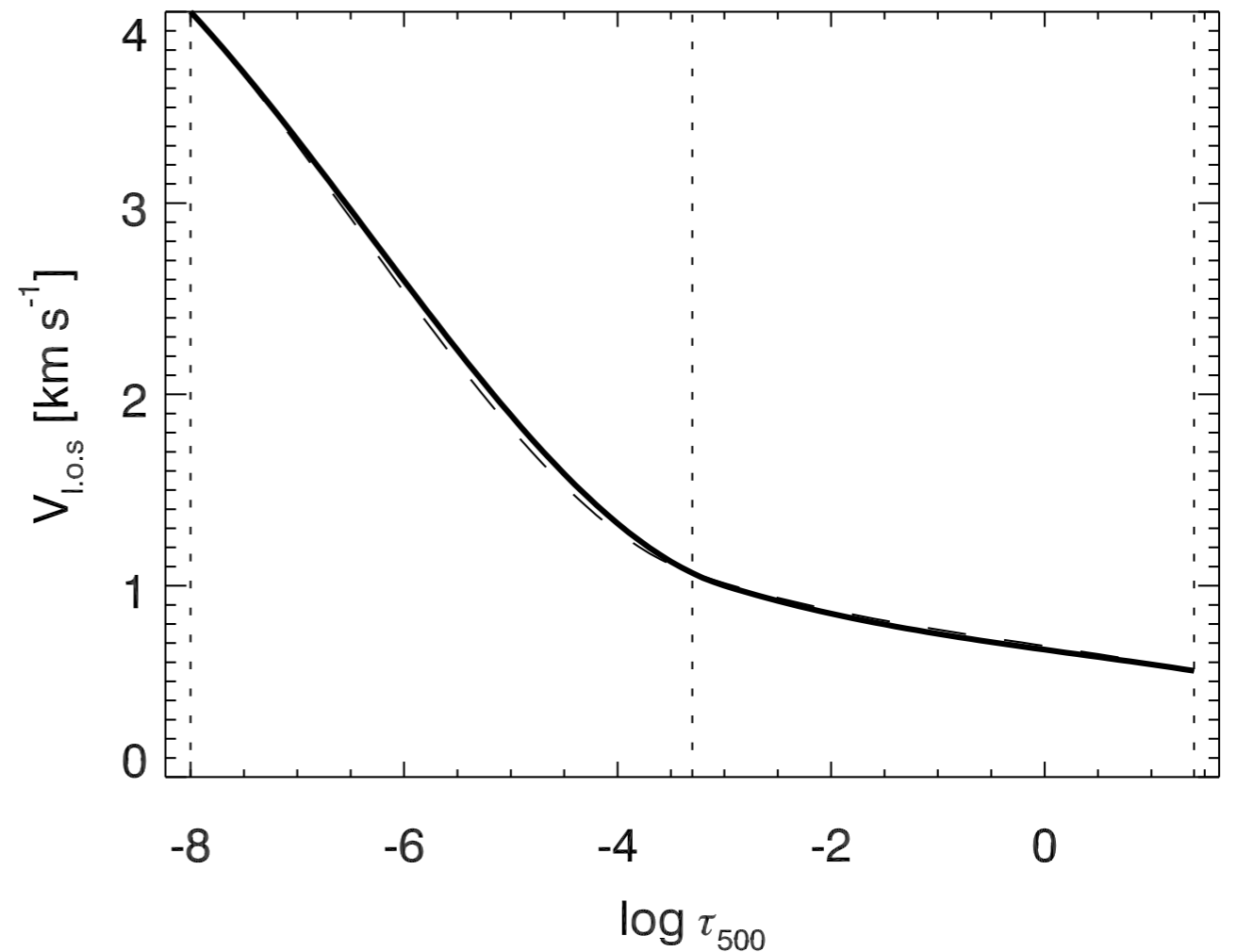
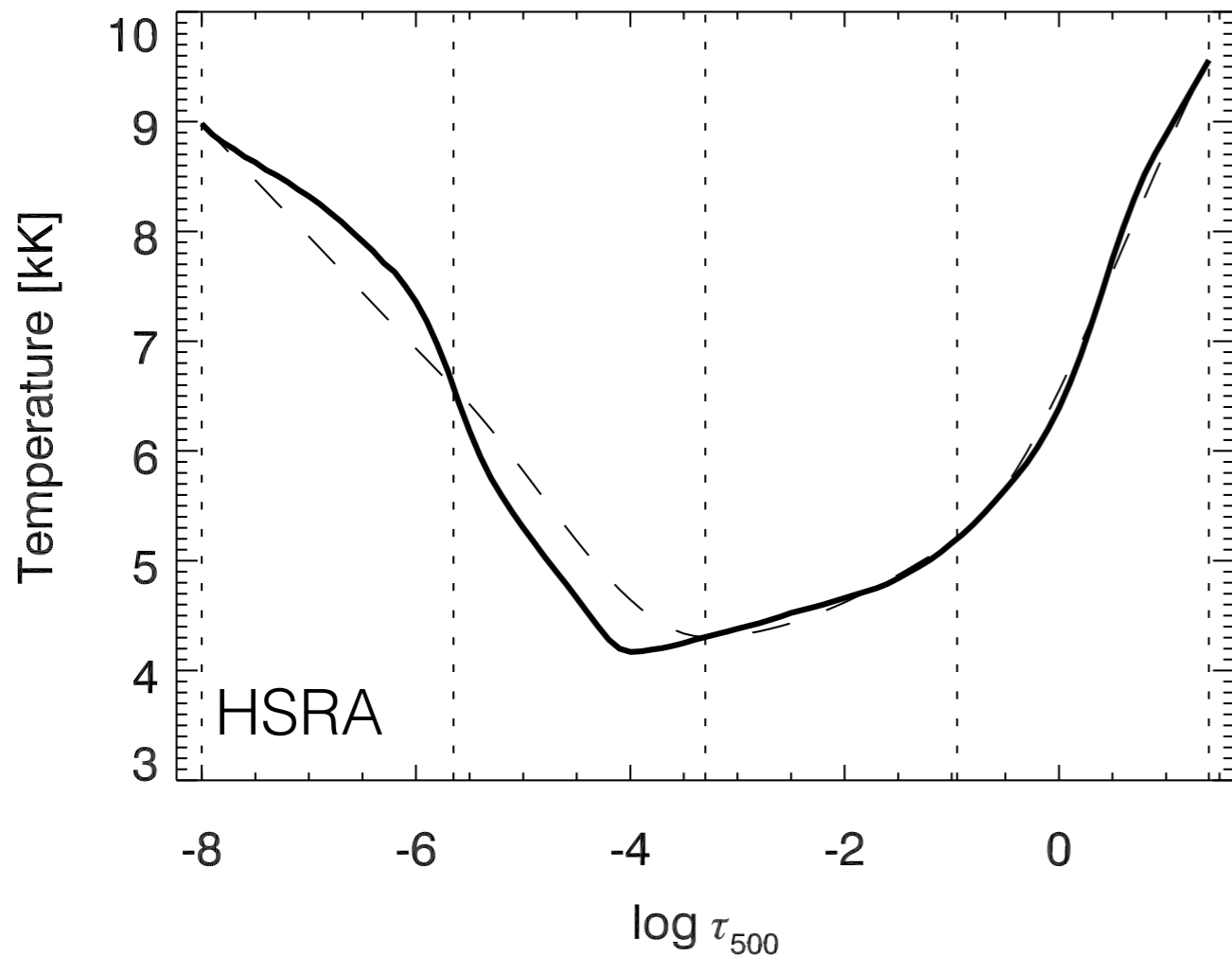


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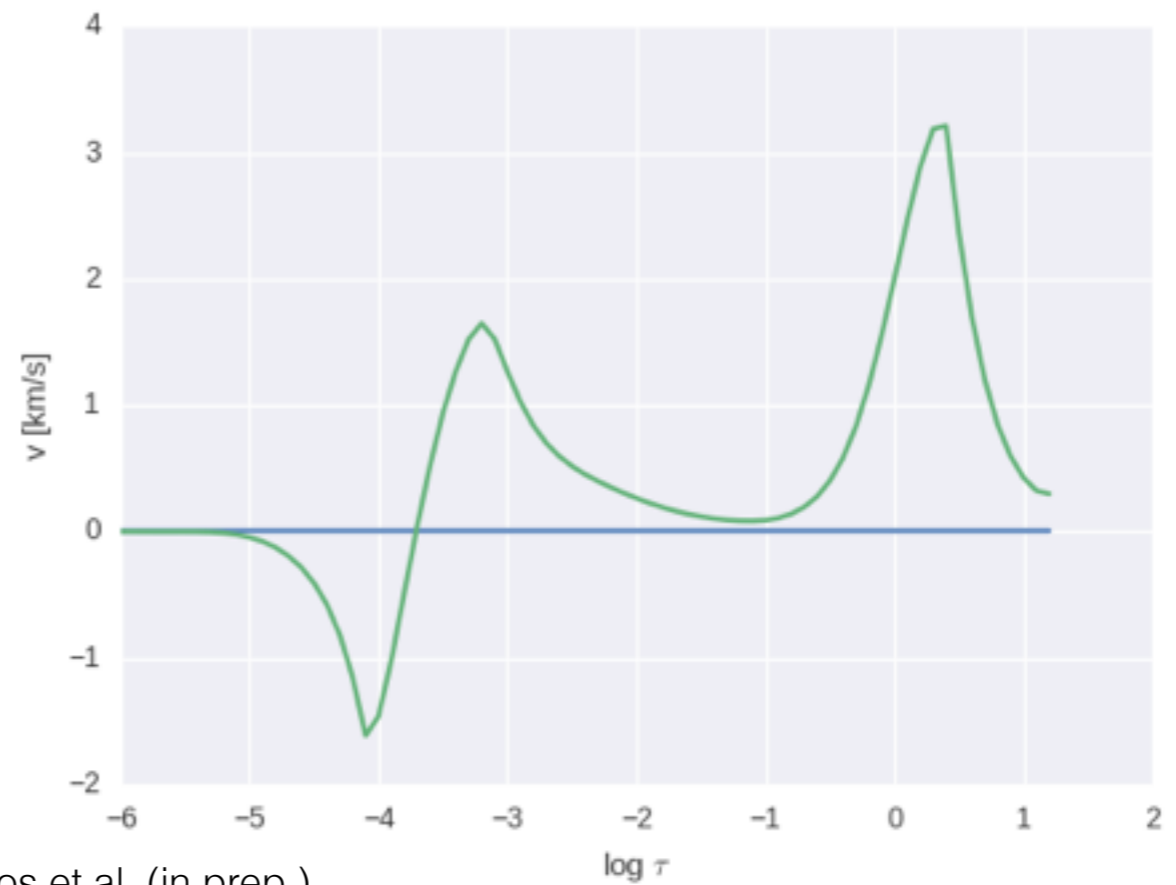
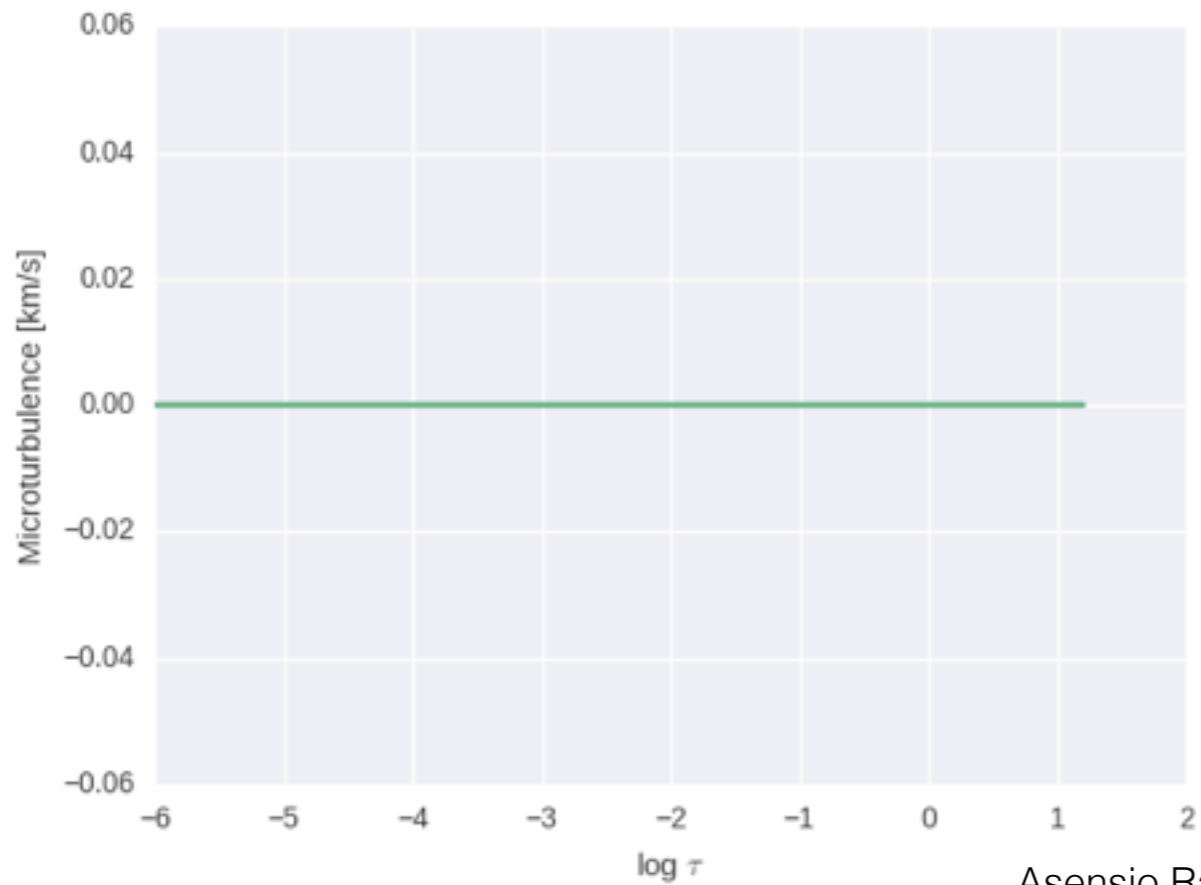
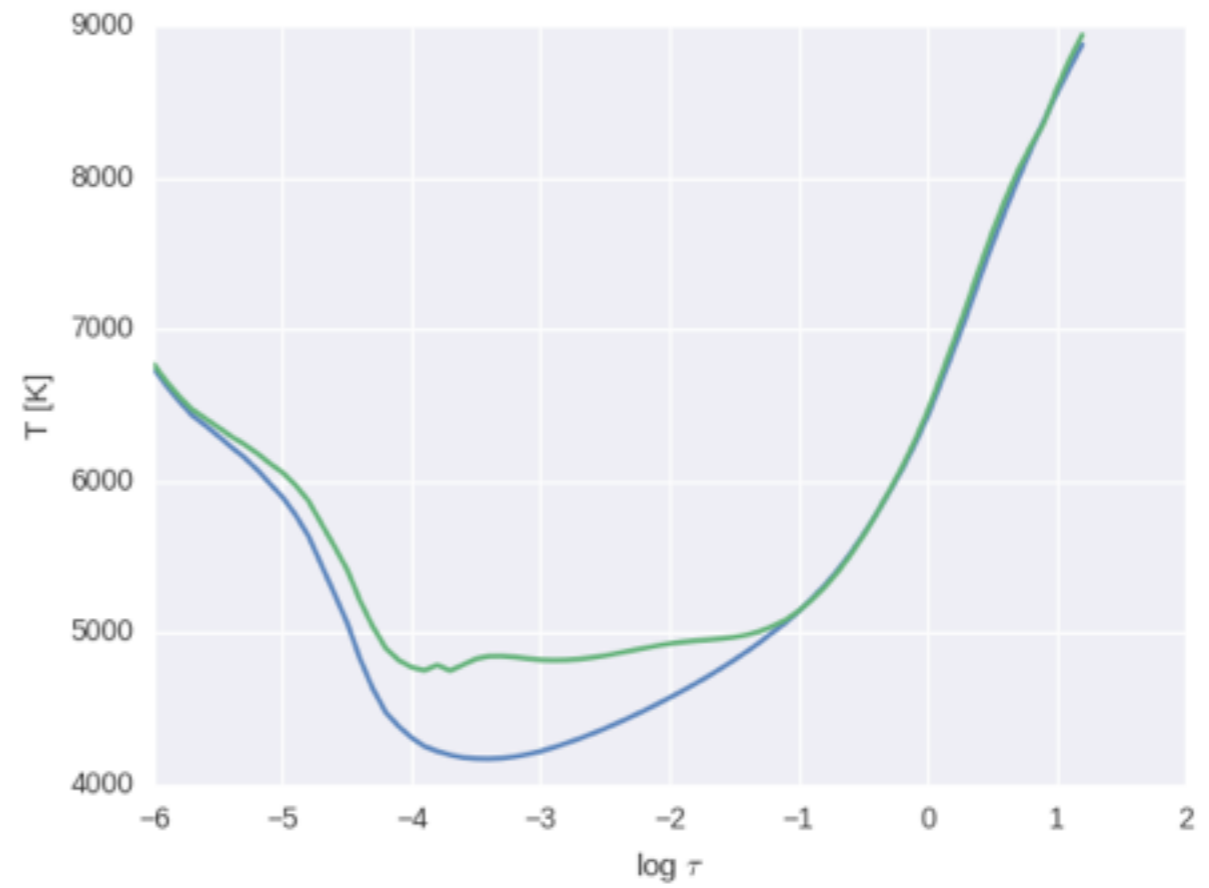
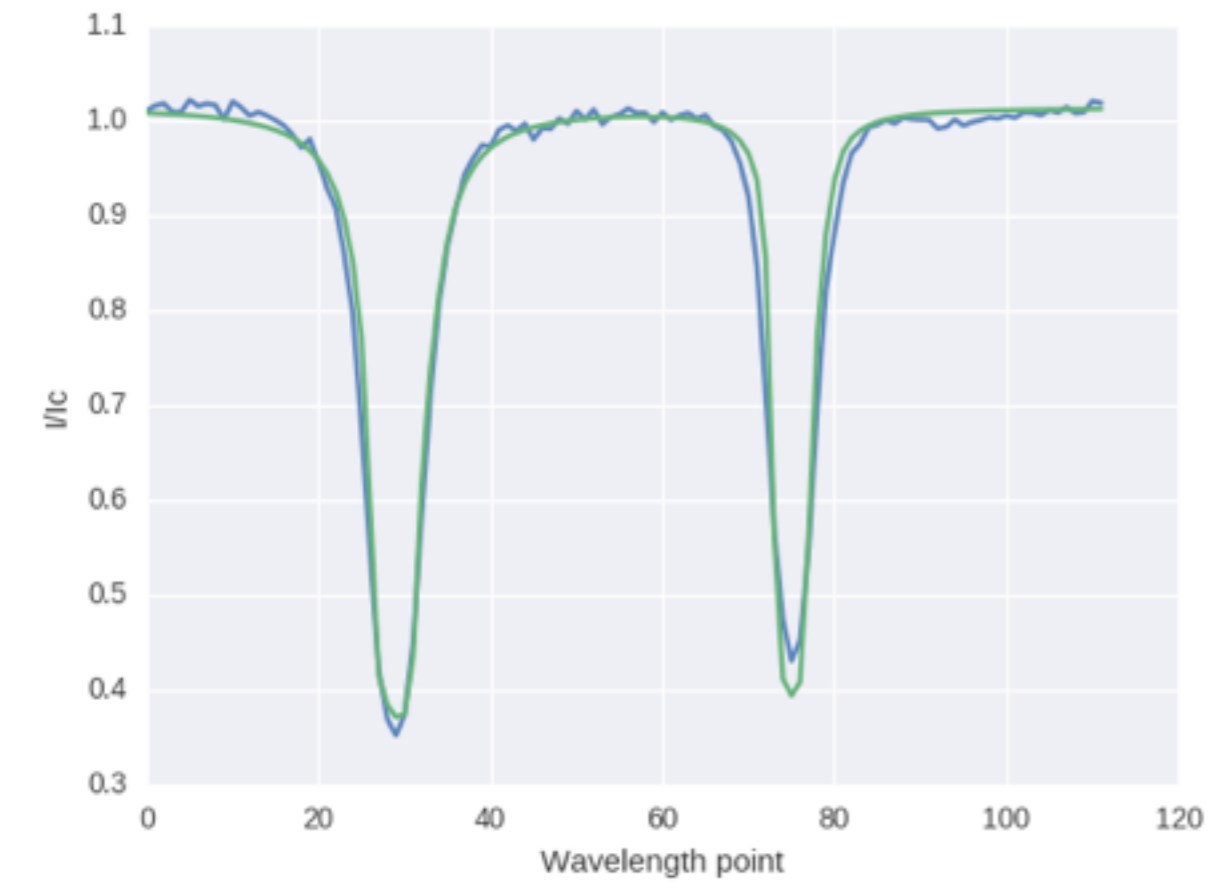
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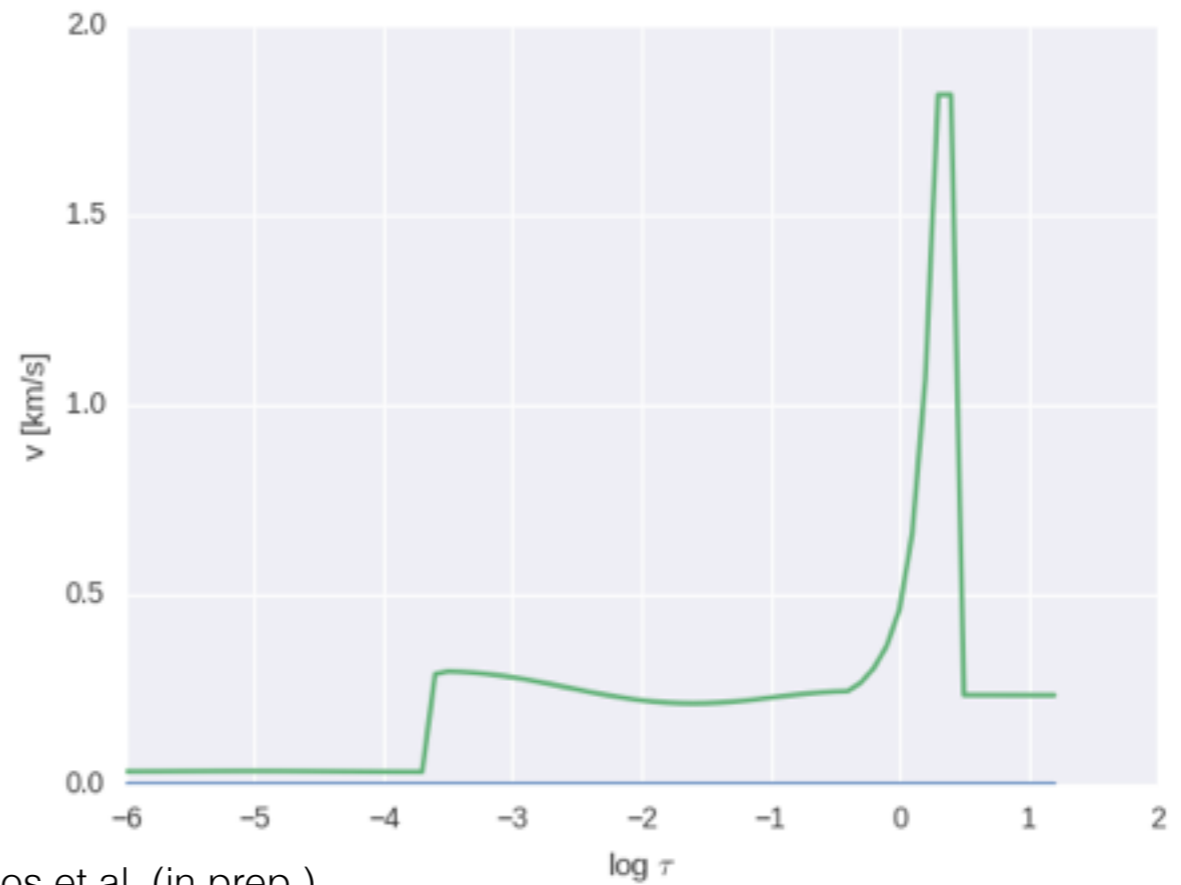
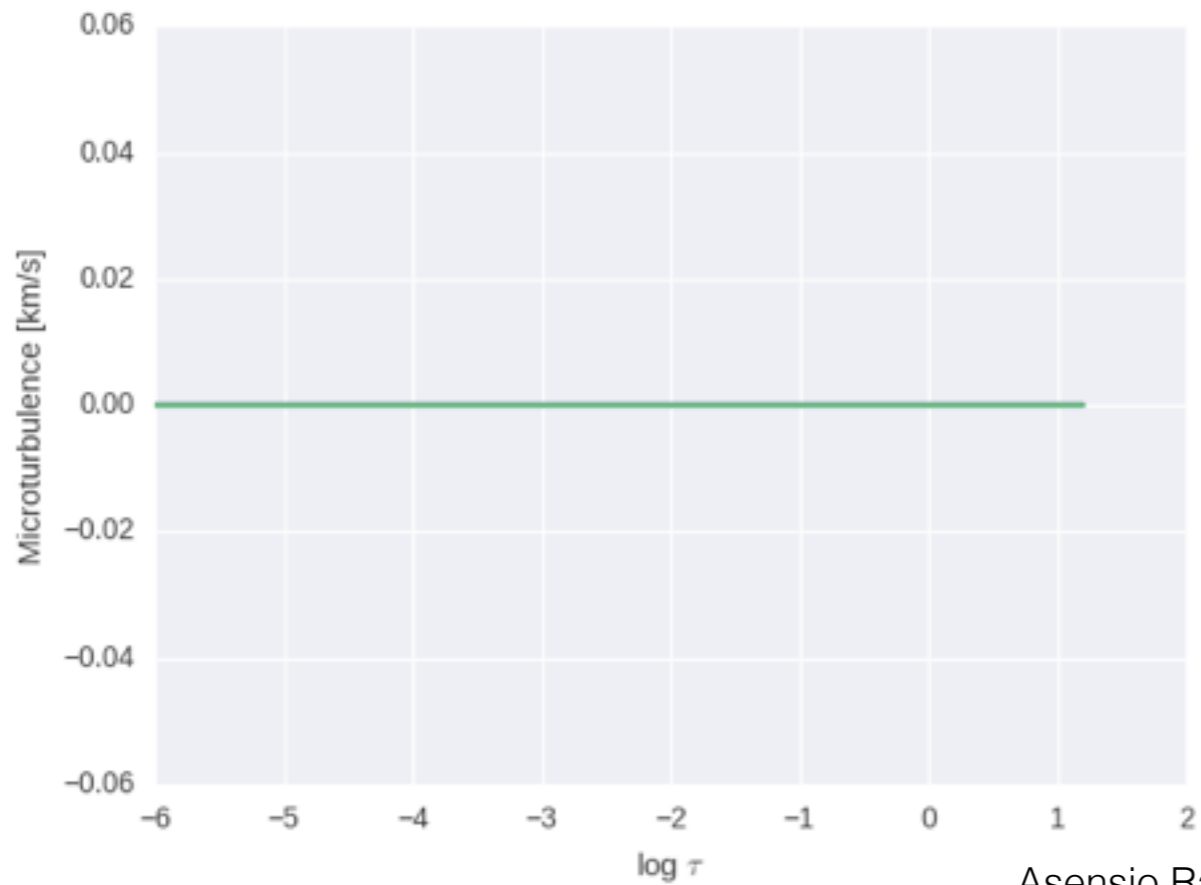
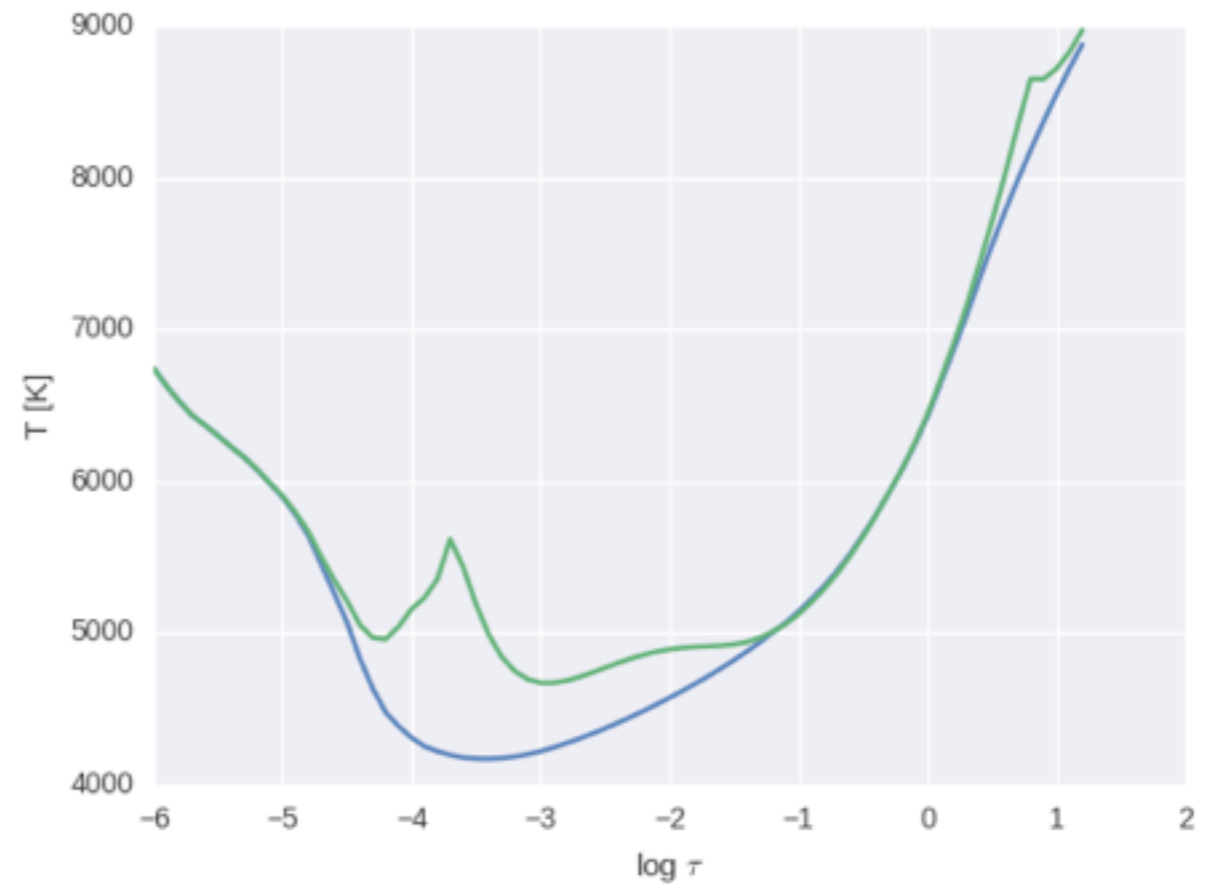
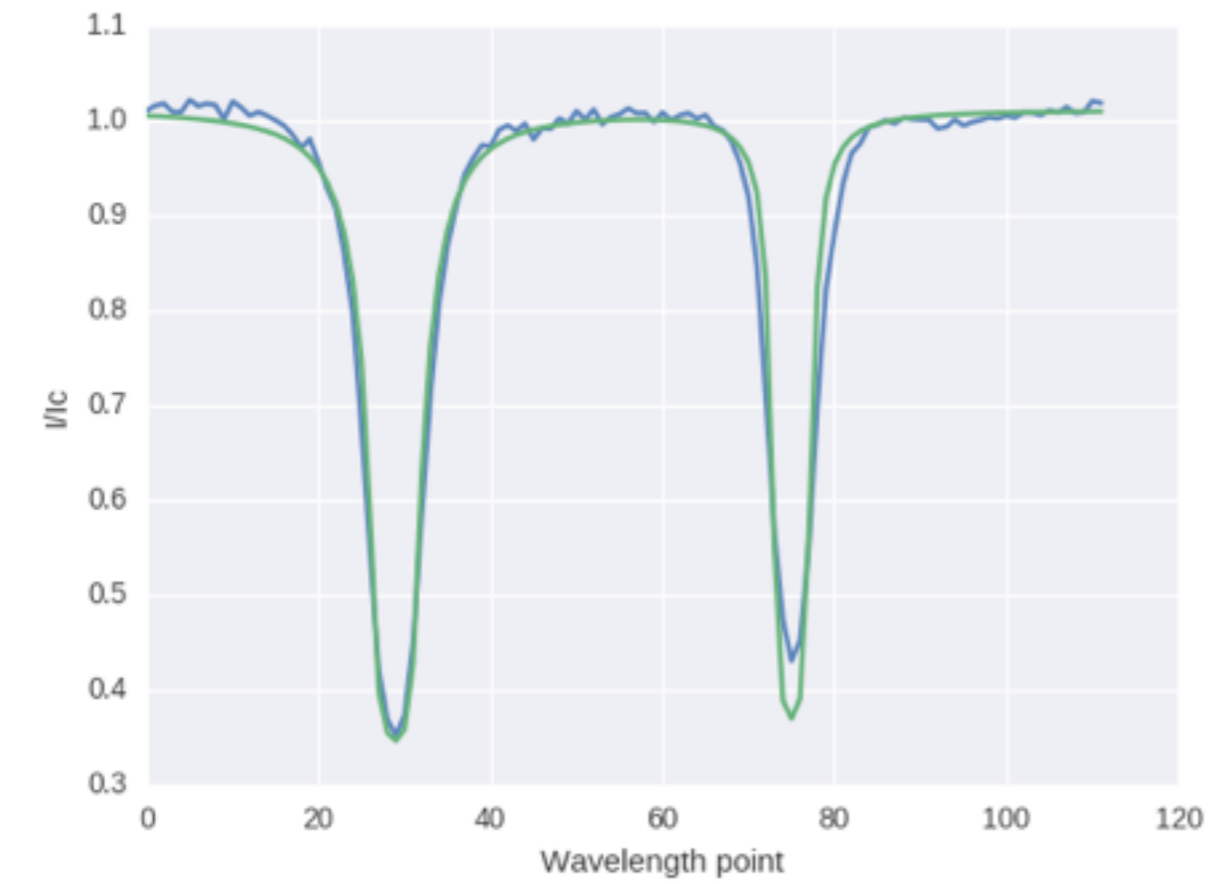
We need the entire atmosphere to integrate the RT equation.

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

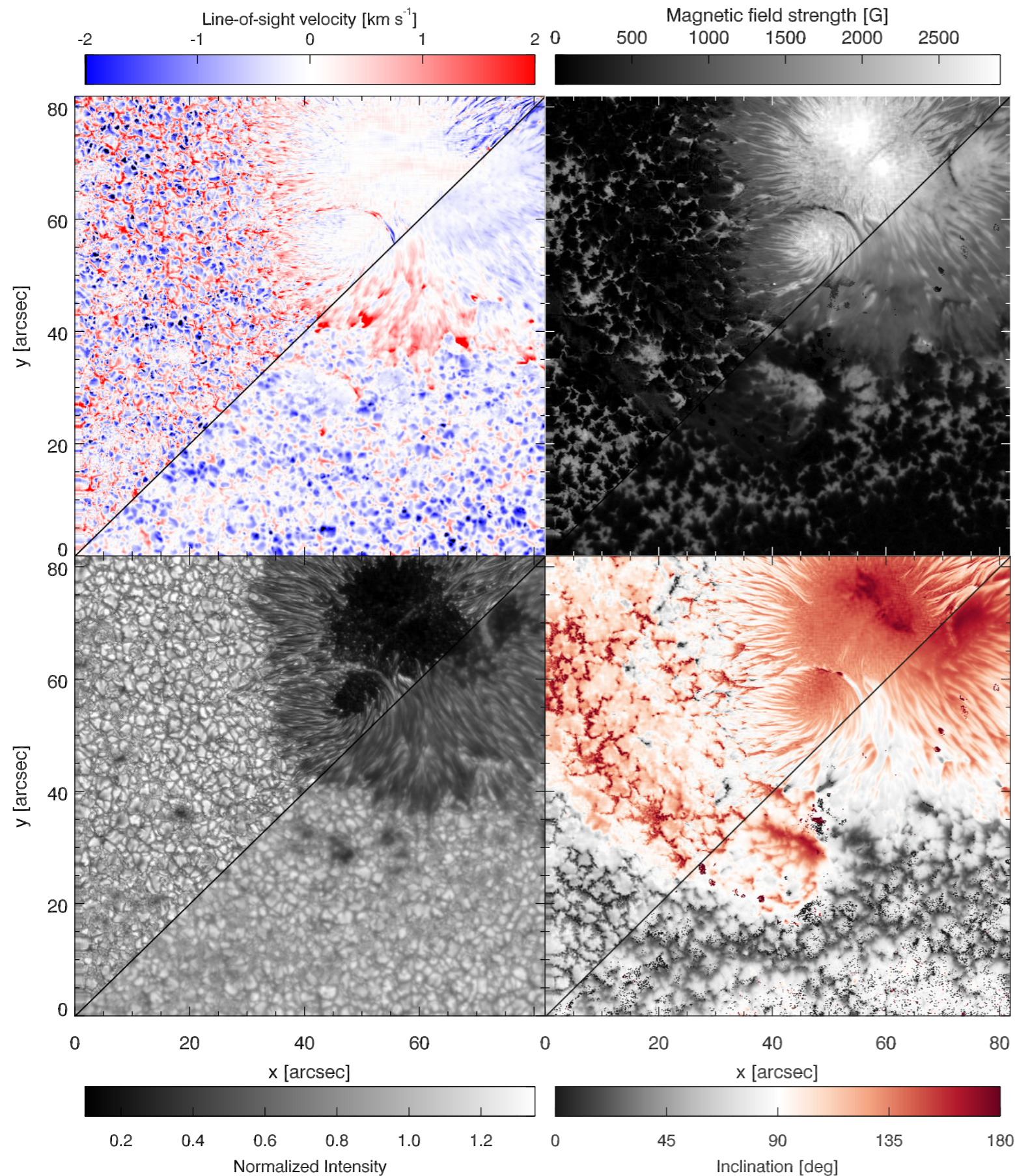
Node-less inversion



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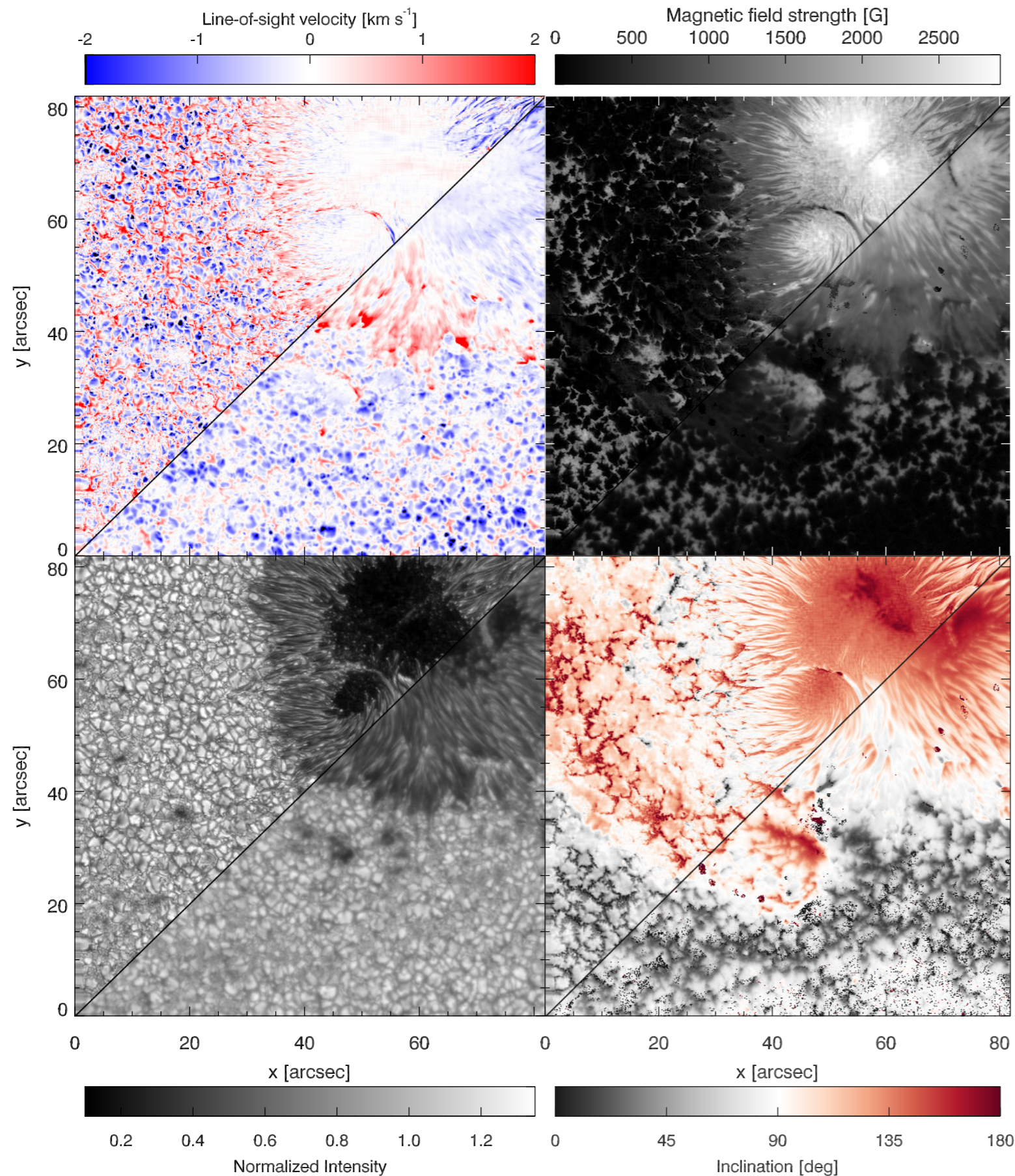
Spatially coupled inversion



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

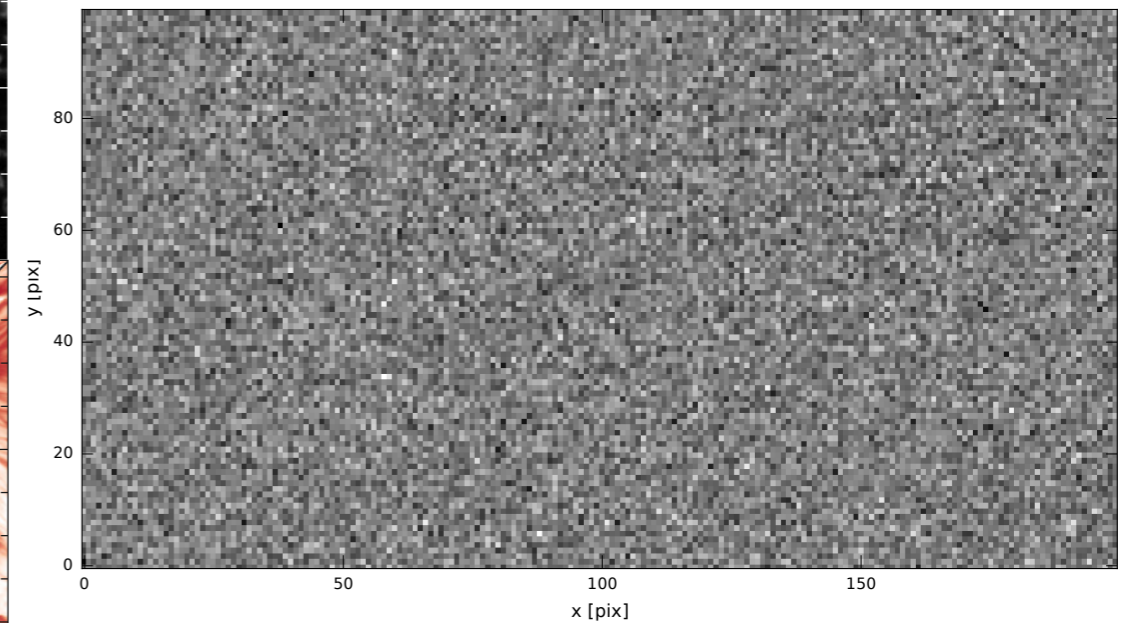
- van Noort (2012)
- Asensio-Ramos & de la Cruz Rodríguez (2015)

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To take home ...

- 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).