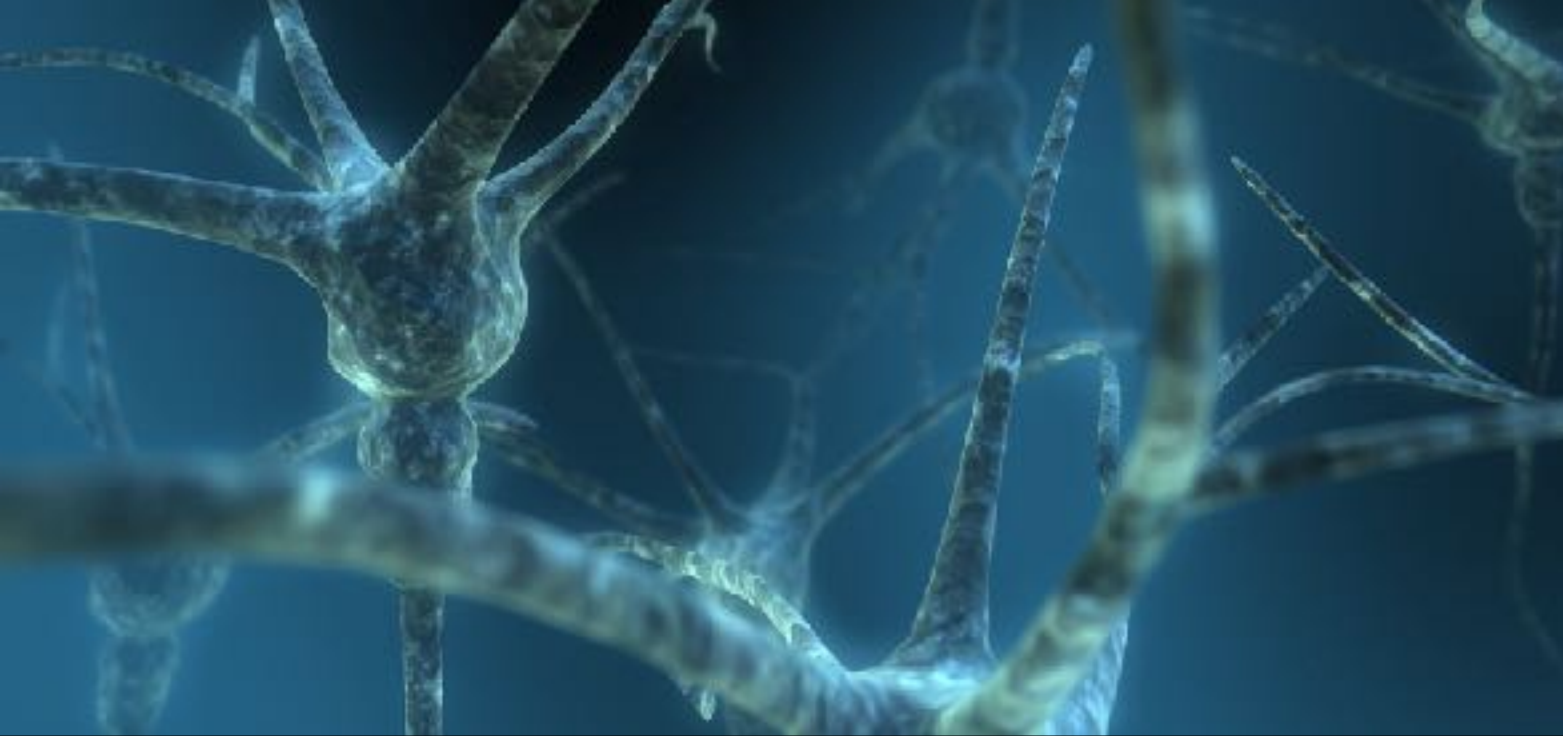
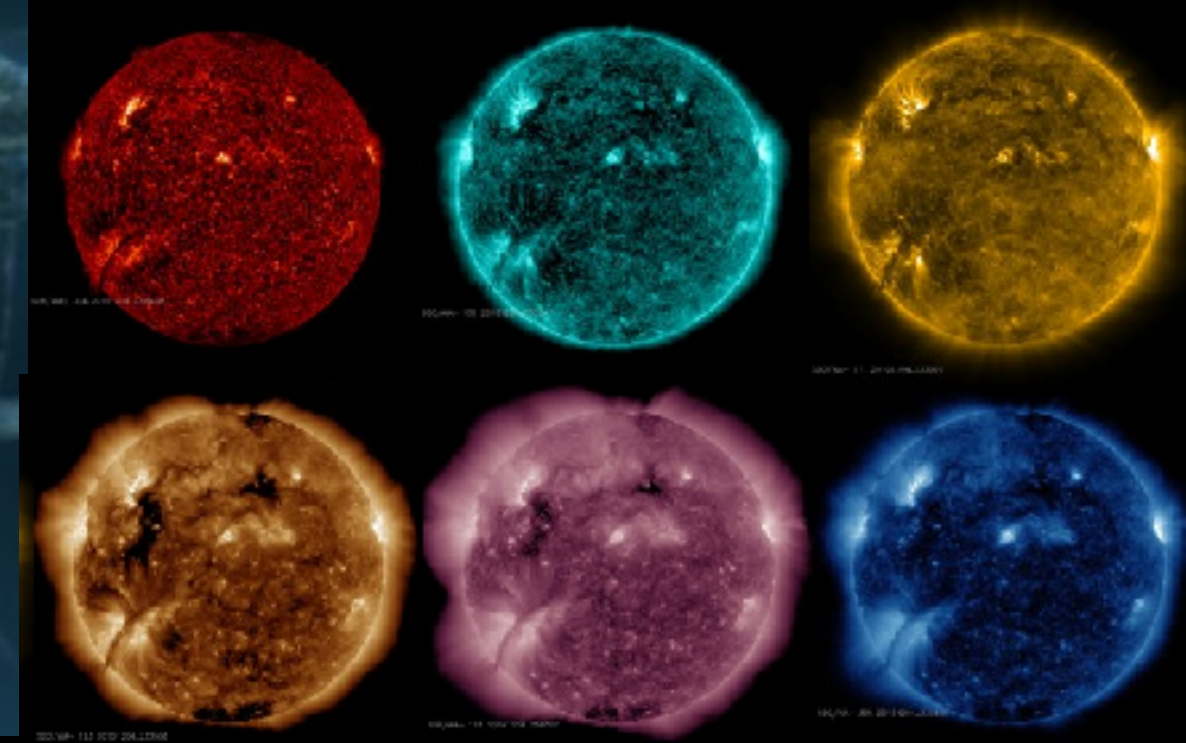




MACHINE LEARNING AND DEEP LEARNING IN SOLAR PHYSICS

a. asensio ramos
@aasensior
github.com/aasensio

Invited Talk

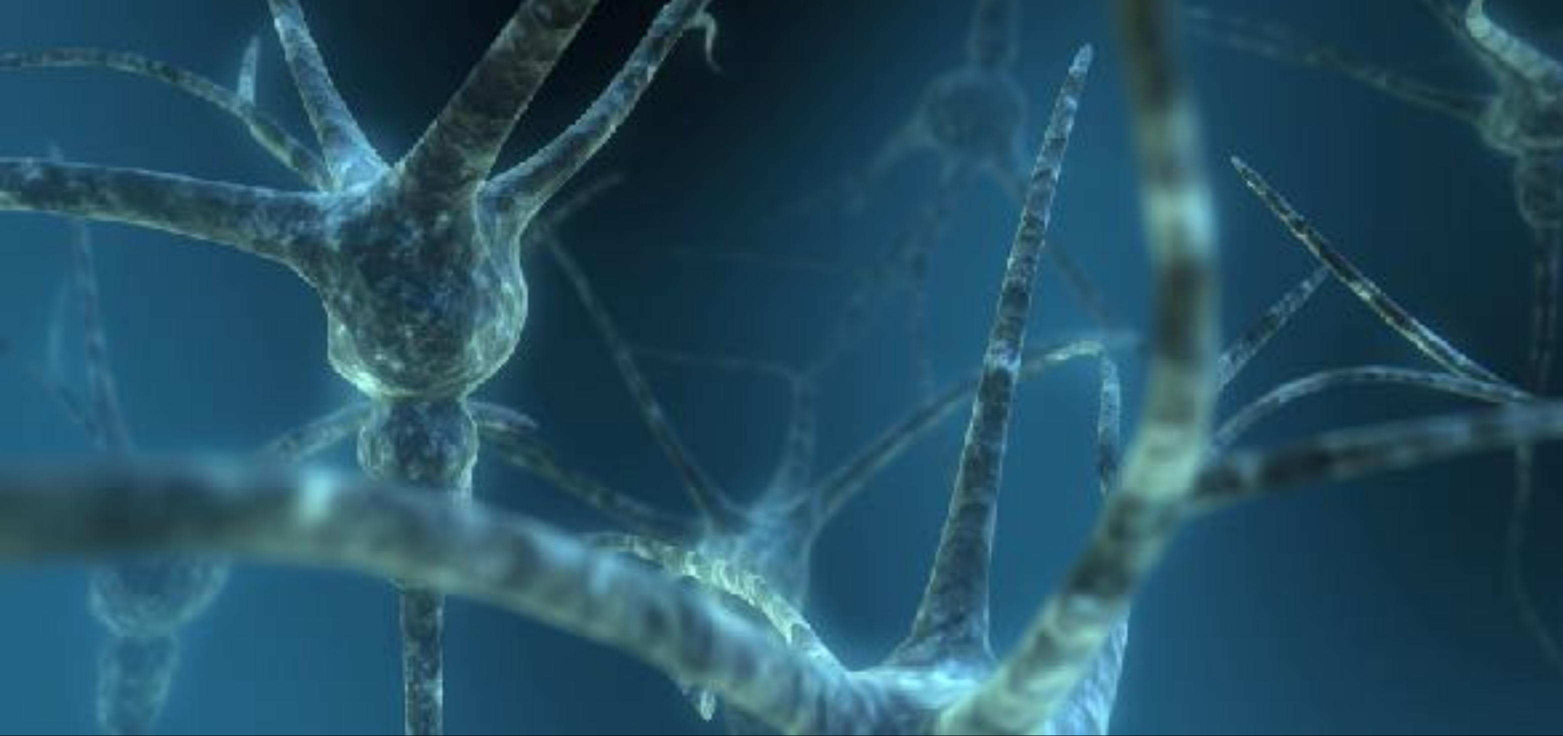
5. Opportunities and challenges

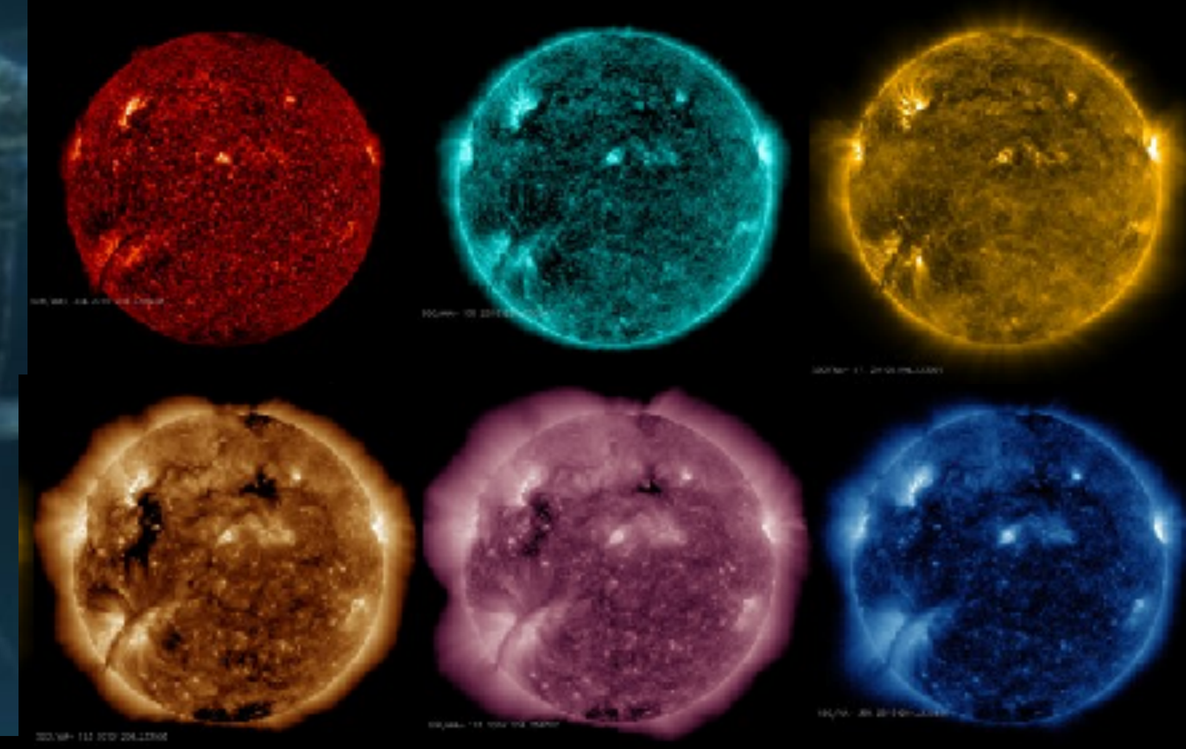
Machine learning to investigate magnetic field and other complex data sets

Andres Asensio-Ramos[1]

[1] *Instituto de Astrofisica de Canarias, IAC, La Laguna, Spain*

In the last decade, machine learning has experienced an enormous advance, thanks to the possibility to train very deep and complex neural networks. In this contribution I show how we are leveraging deep learning to solve difficult problems in Solar Physics. I will focus on how differentiable programming (aka deep learning) is helping us to have access to velocity fields in the solar atmosphere, correct for the atmospheric degradation of spectropolarimetric data and carry out fast 3D inversions of the Stokes parameters.





MACHINE LEARNING AND DEEP LEARNING IN SOLAR PHYSICS

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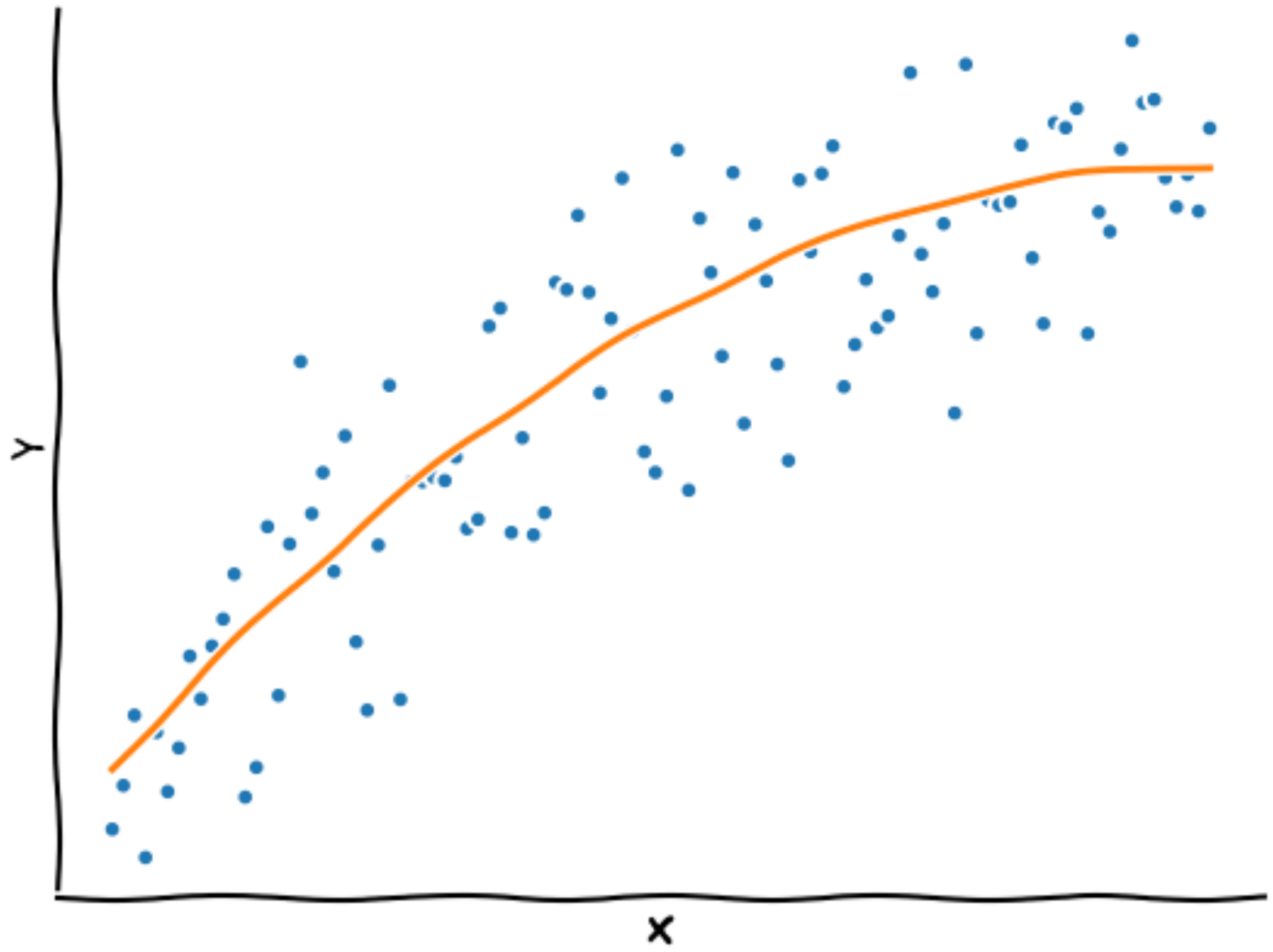
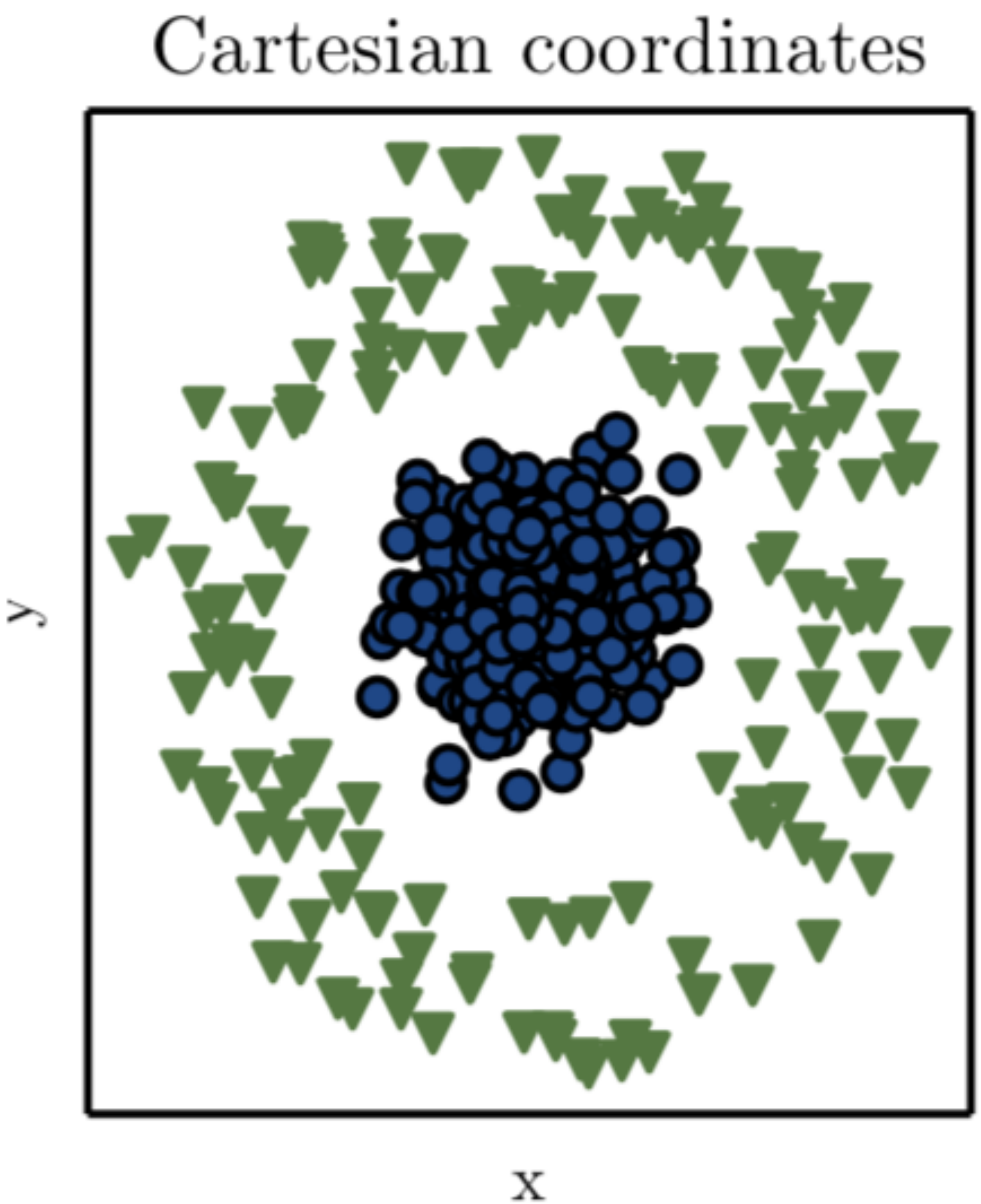
what is machine learning?

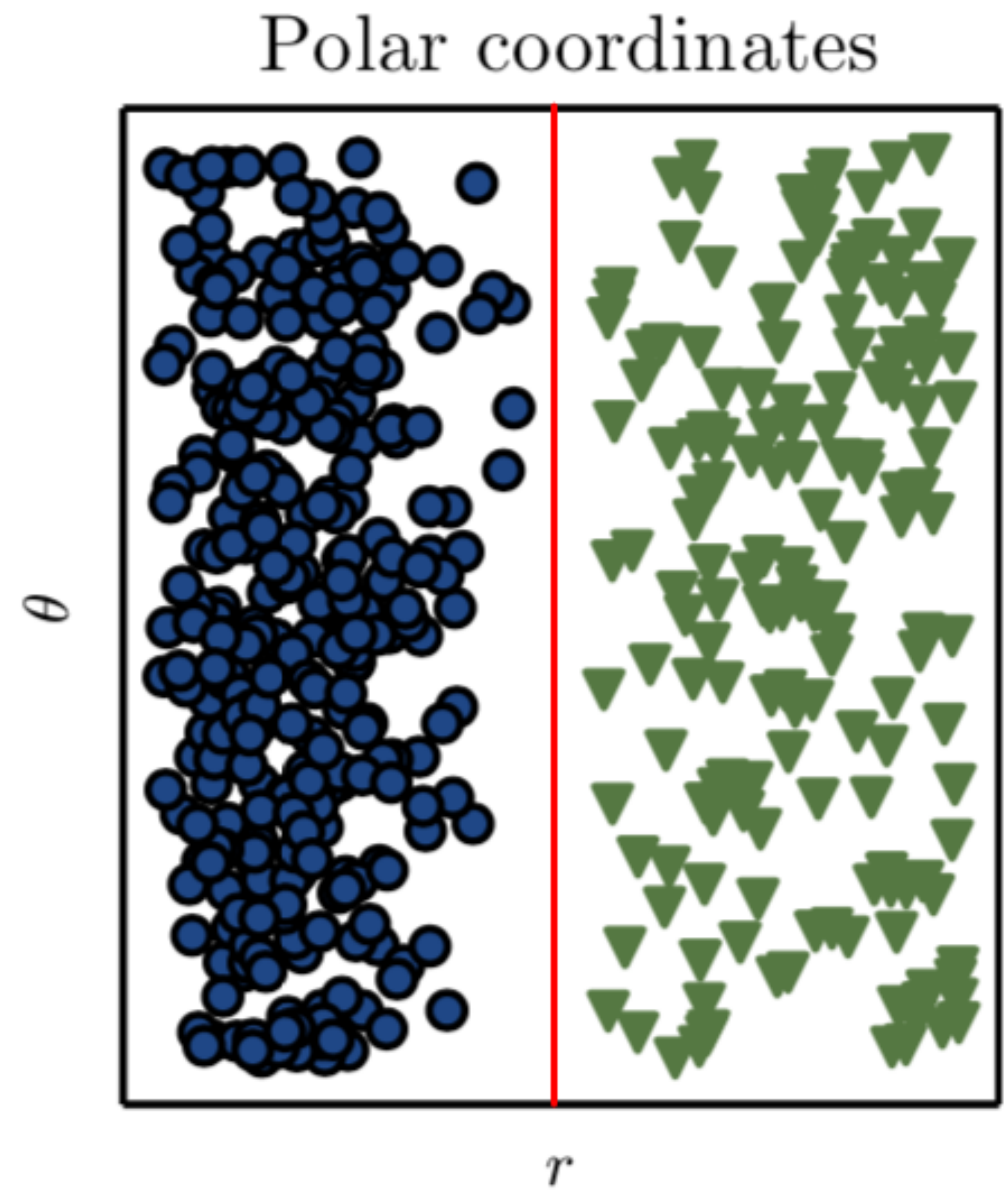
Using statistical techniques to give computers the ability to progressively improve performance on a specific task with data, without being explicitly programmed.

REGRESSION



CLASSIFICATION

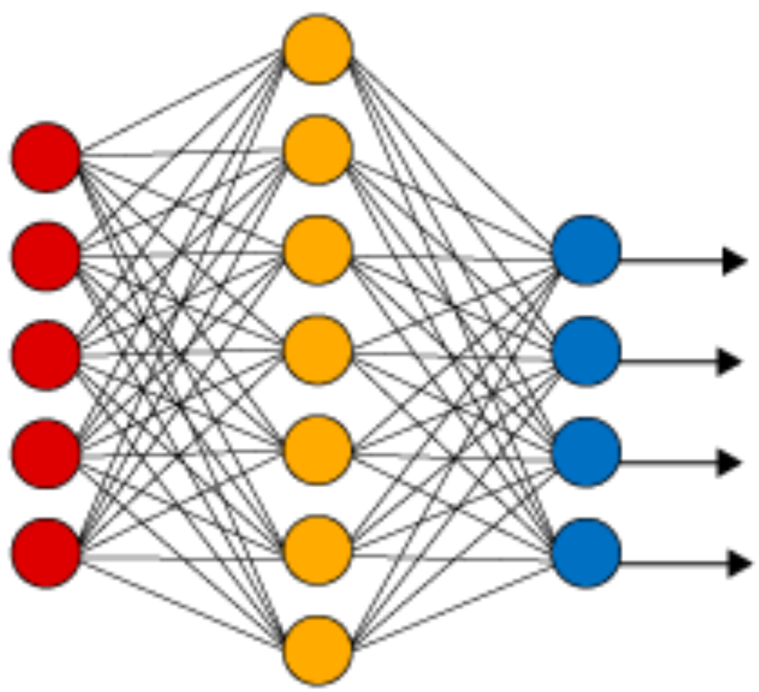




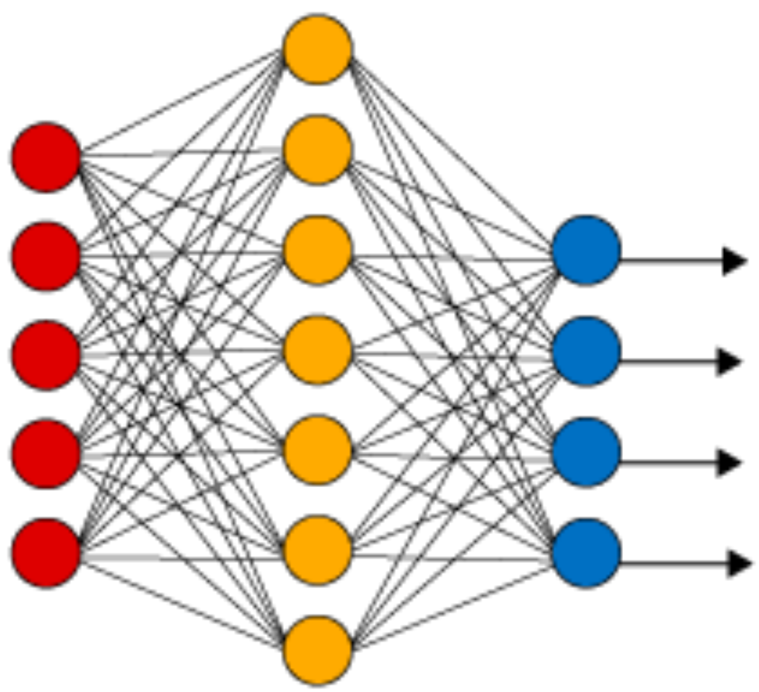
CLASSICAL MACHINE LEARNING

- Principal component analysis (PCA)
- k-nearest neighbors (k-NN)
- Support vector machines (SVM)
- Artificial neural networks (ANN)
- Random forests (RF)
- Gaussian Process (GP)
- …

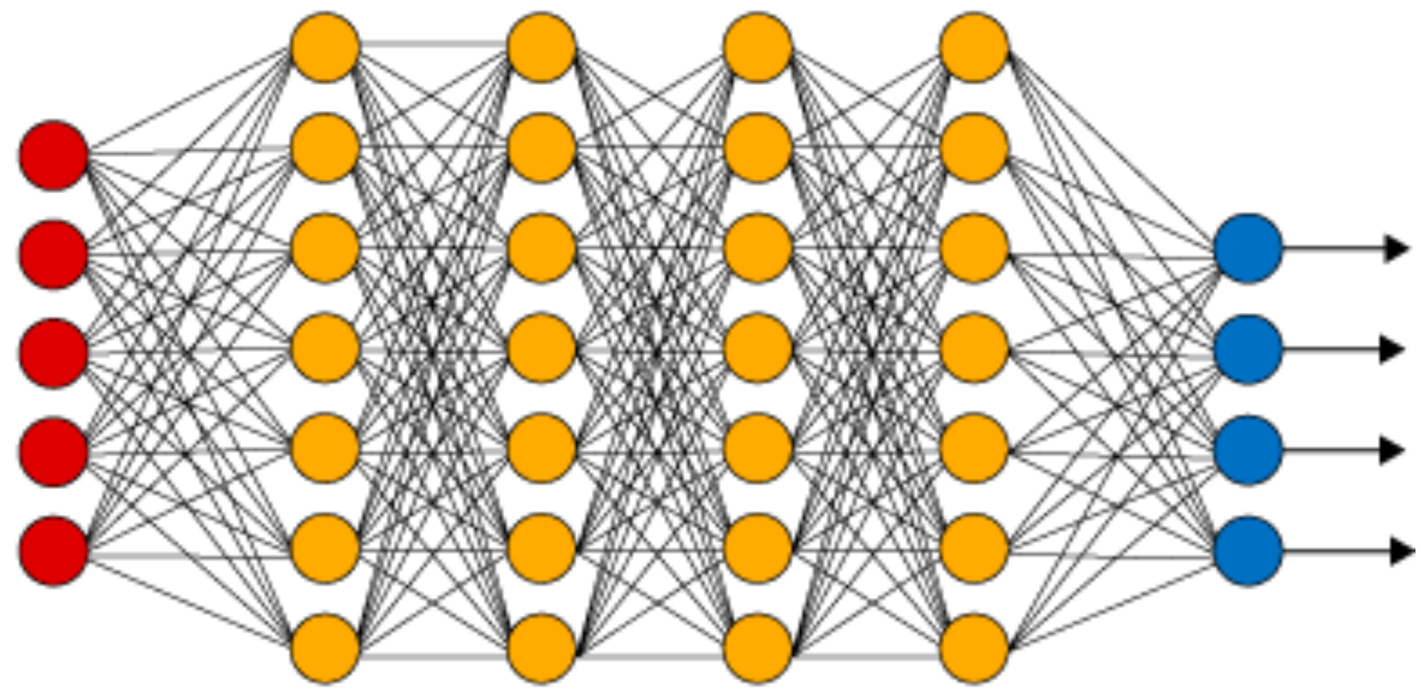
CLASSICAL ML



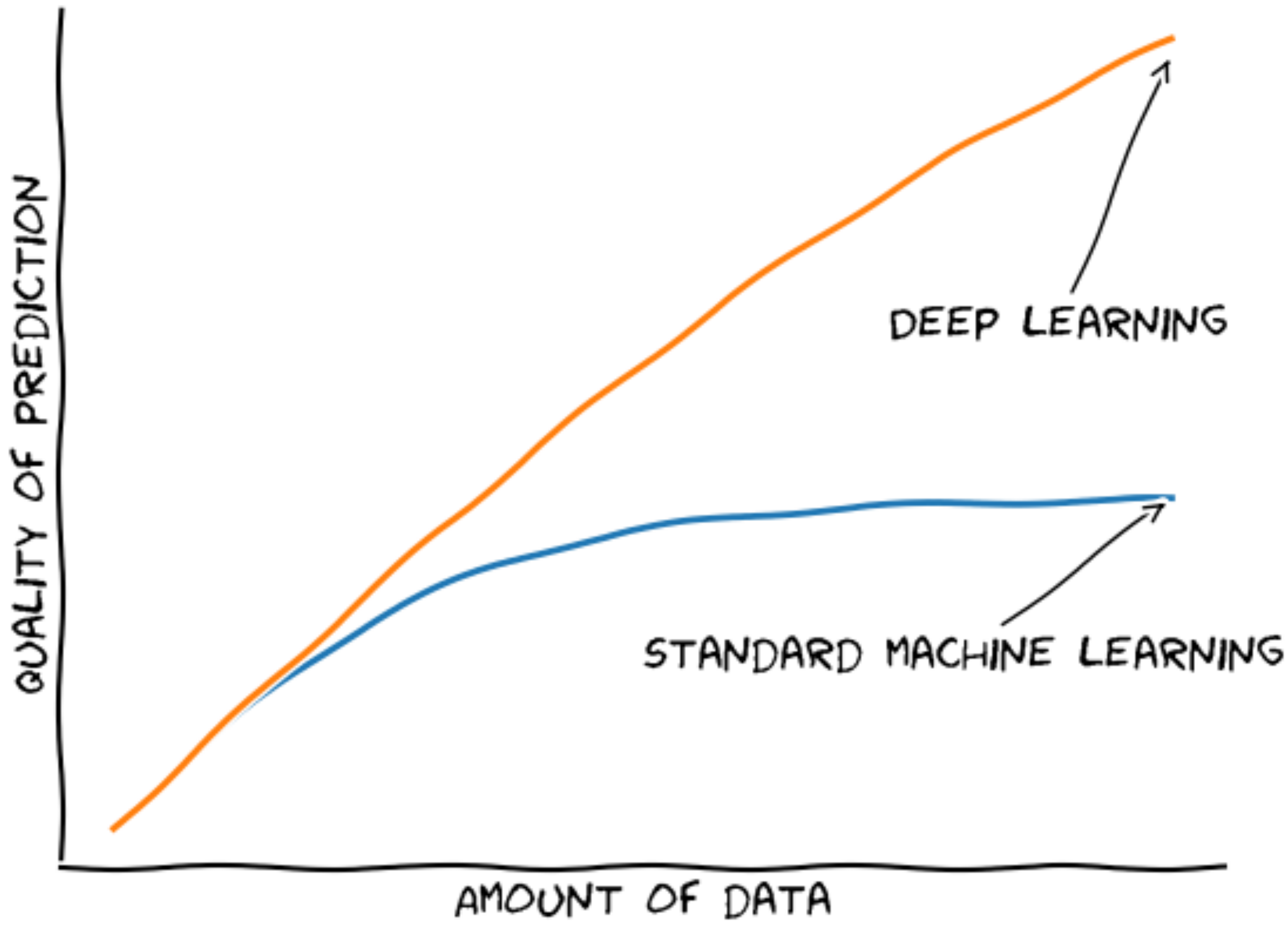
CLASSICAL ML



DEEP LEARNING

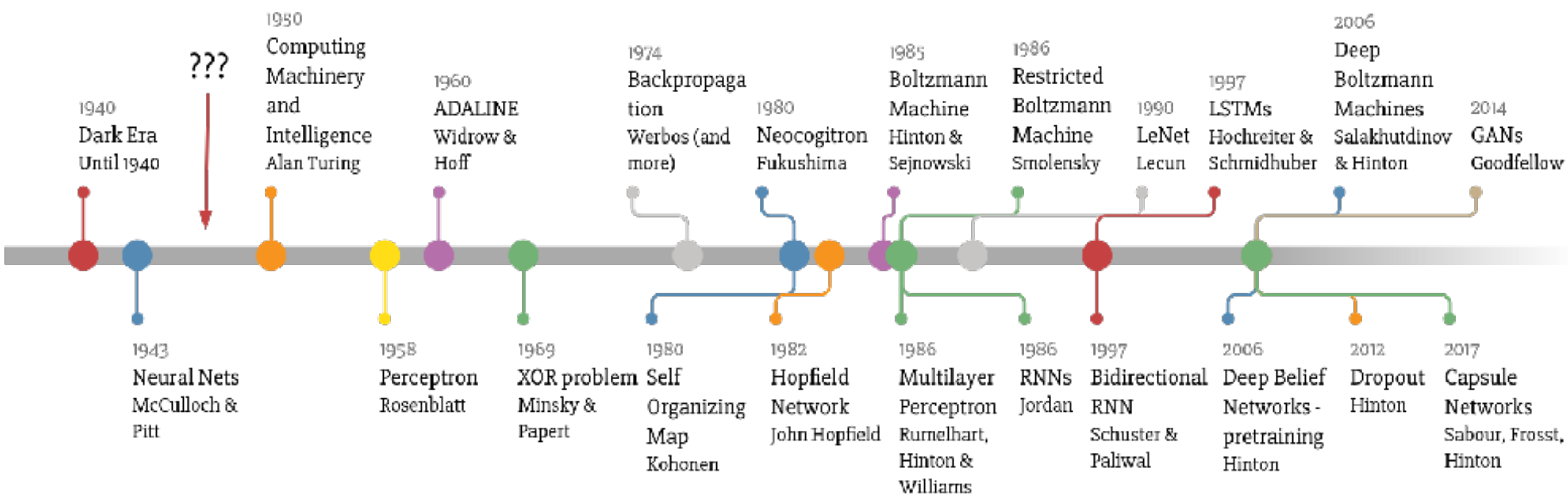


WHY DEEP LEARNING?



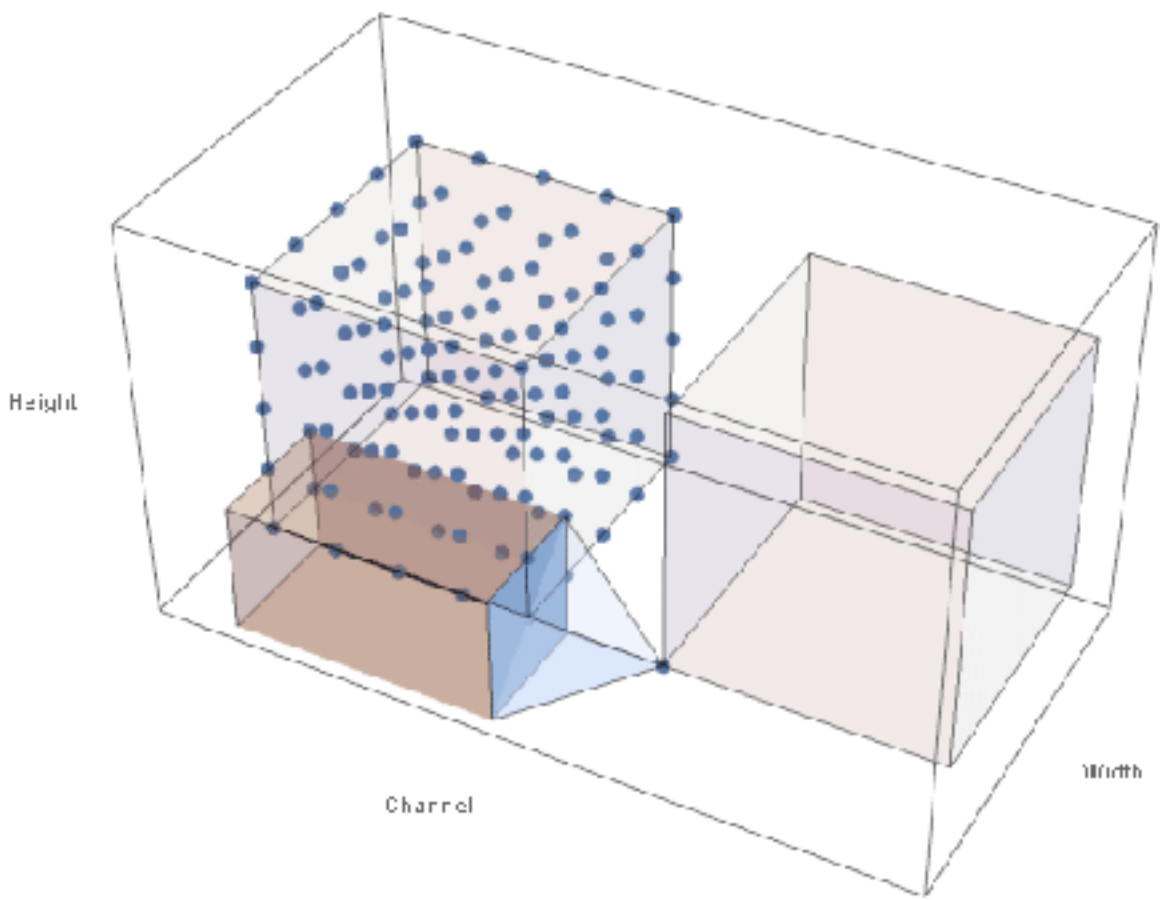
Curse of dimensionality

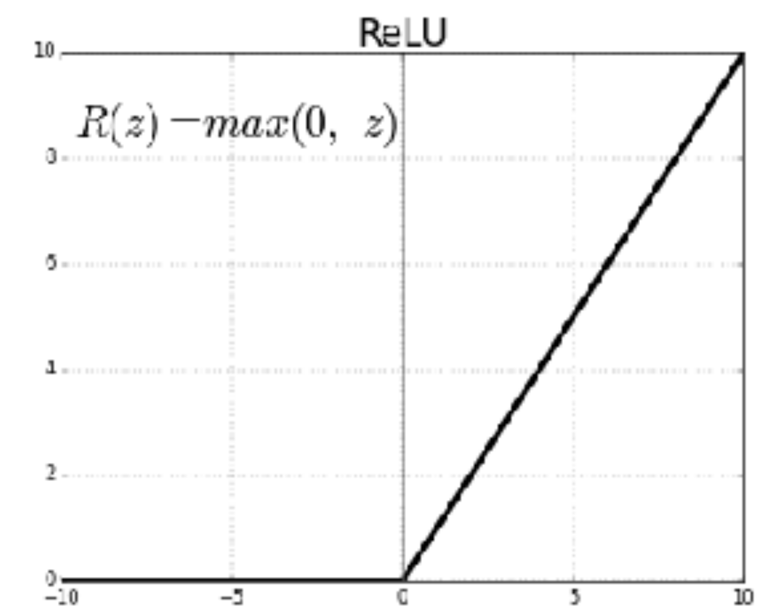
Deep Learning Timeline



Made by Favio Vázquez

BASIC INGREDIENTS





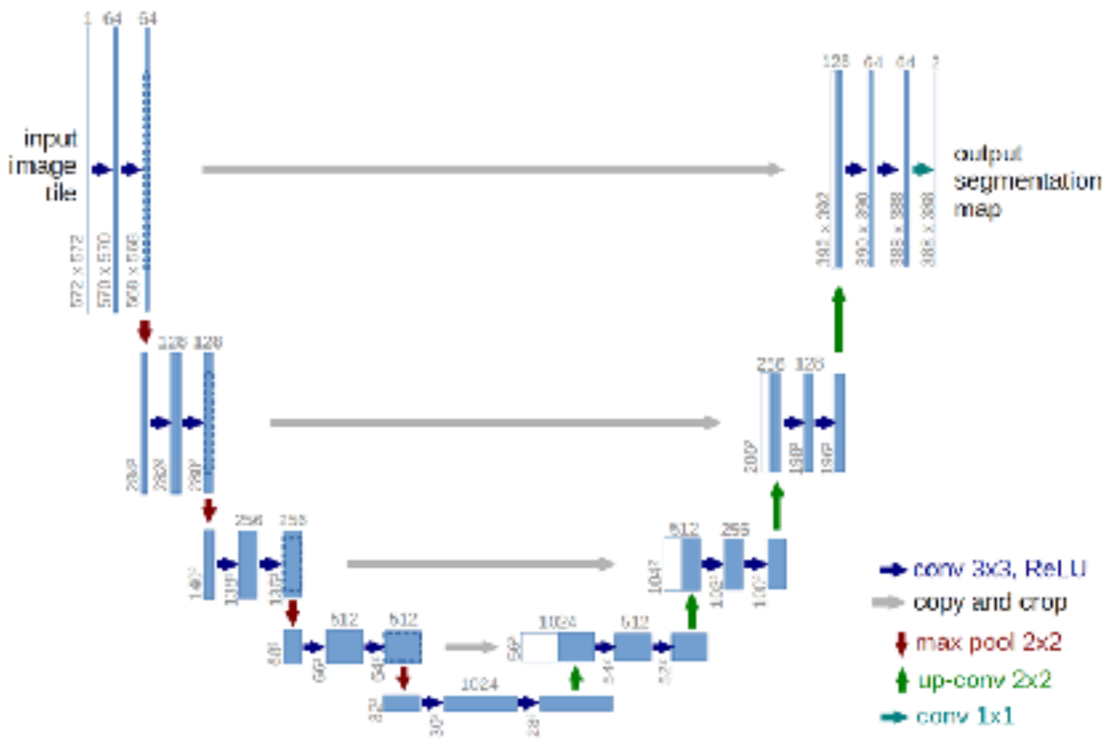
$$f = \|\mathbf{O} - \mathbf{T}\|_2^2$$

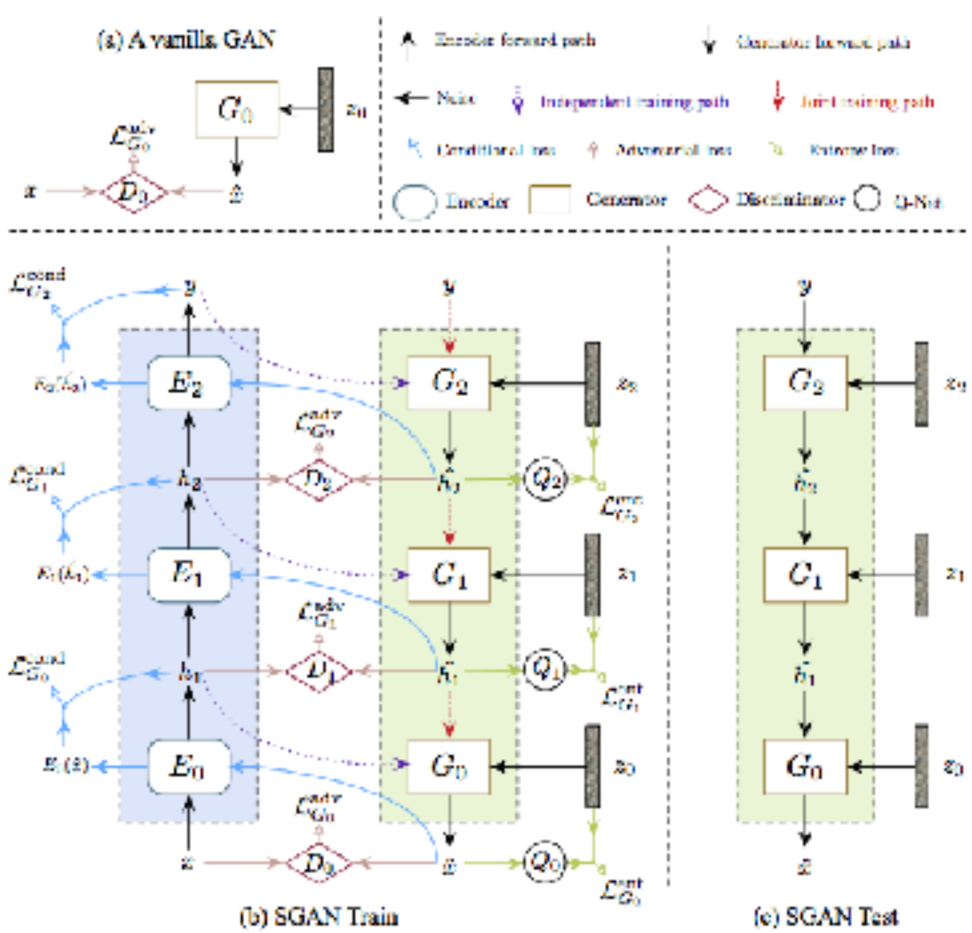
Convolution

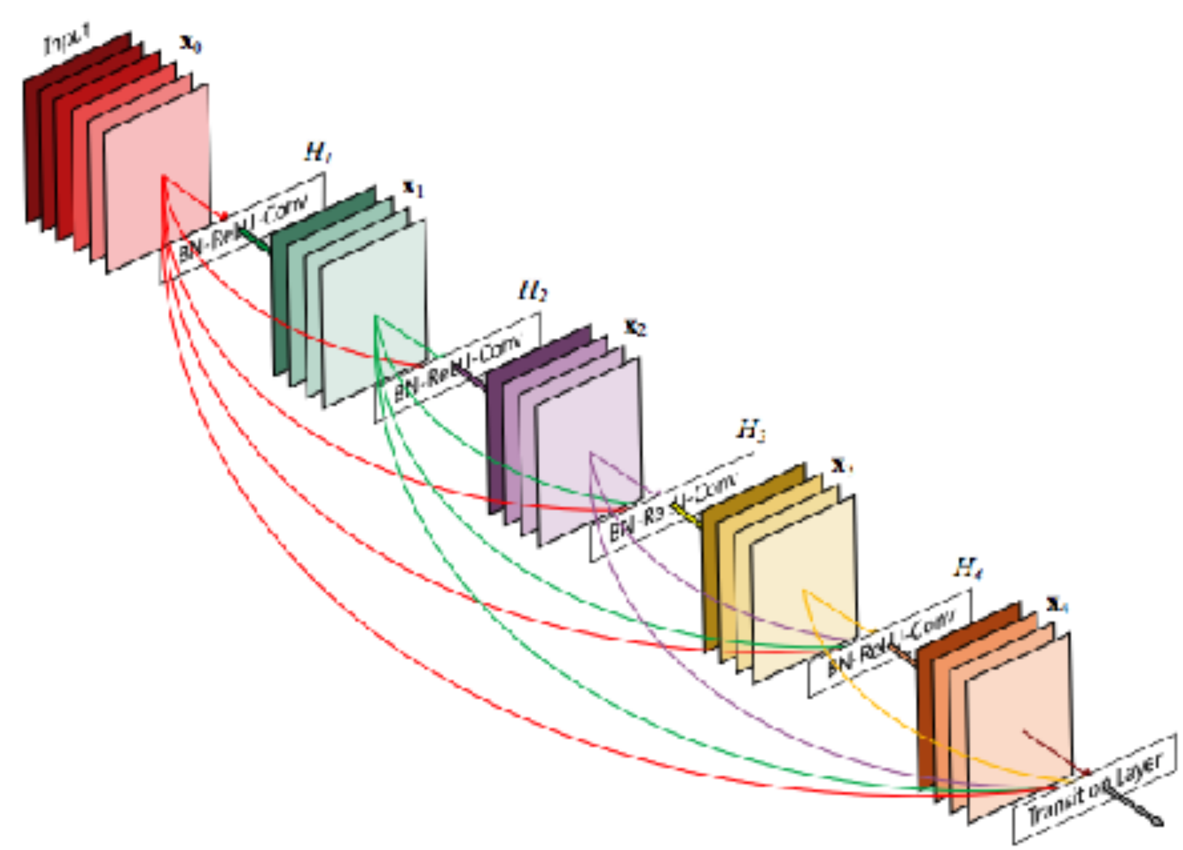
Activation

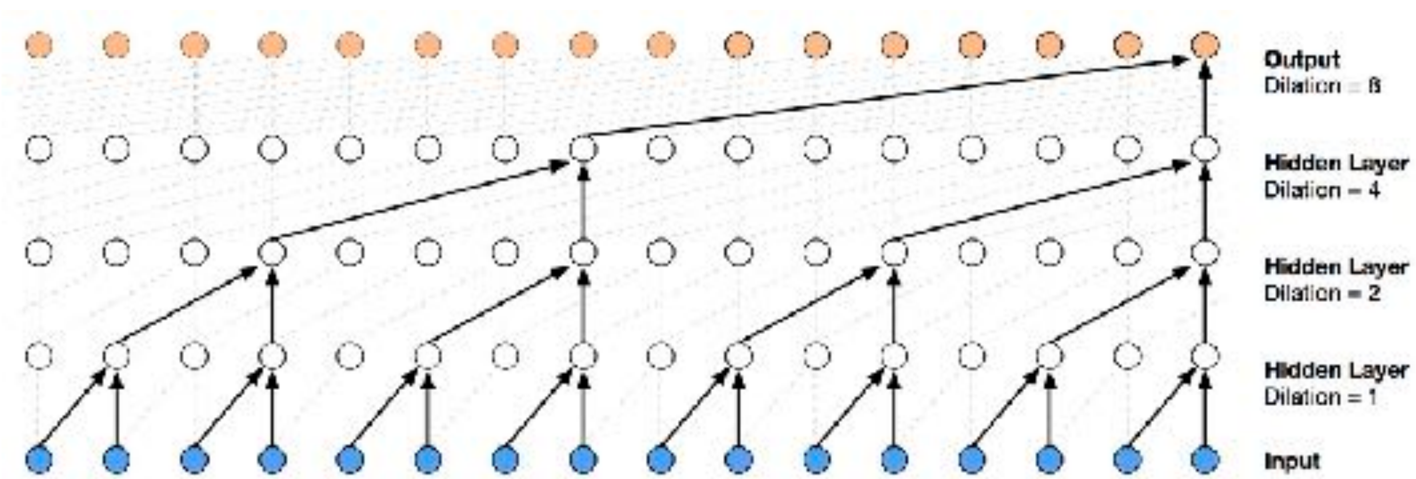
Loss

ENORMOUS LANDSCAPE



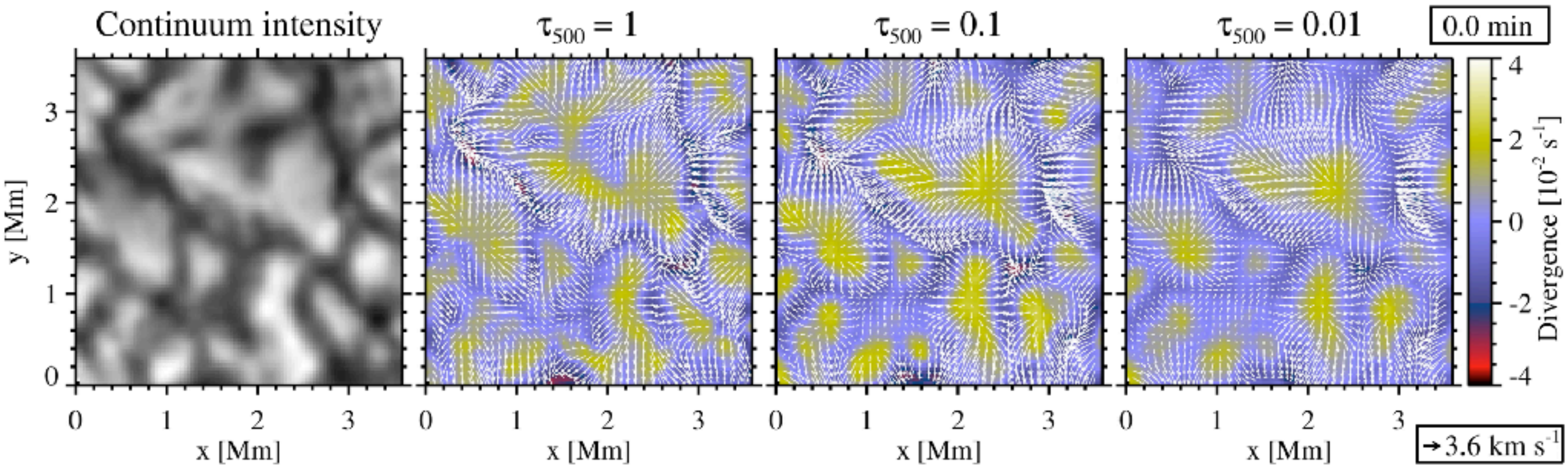






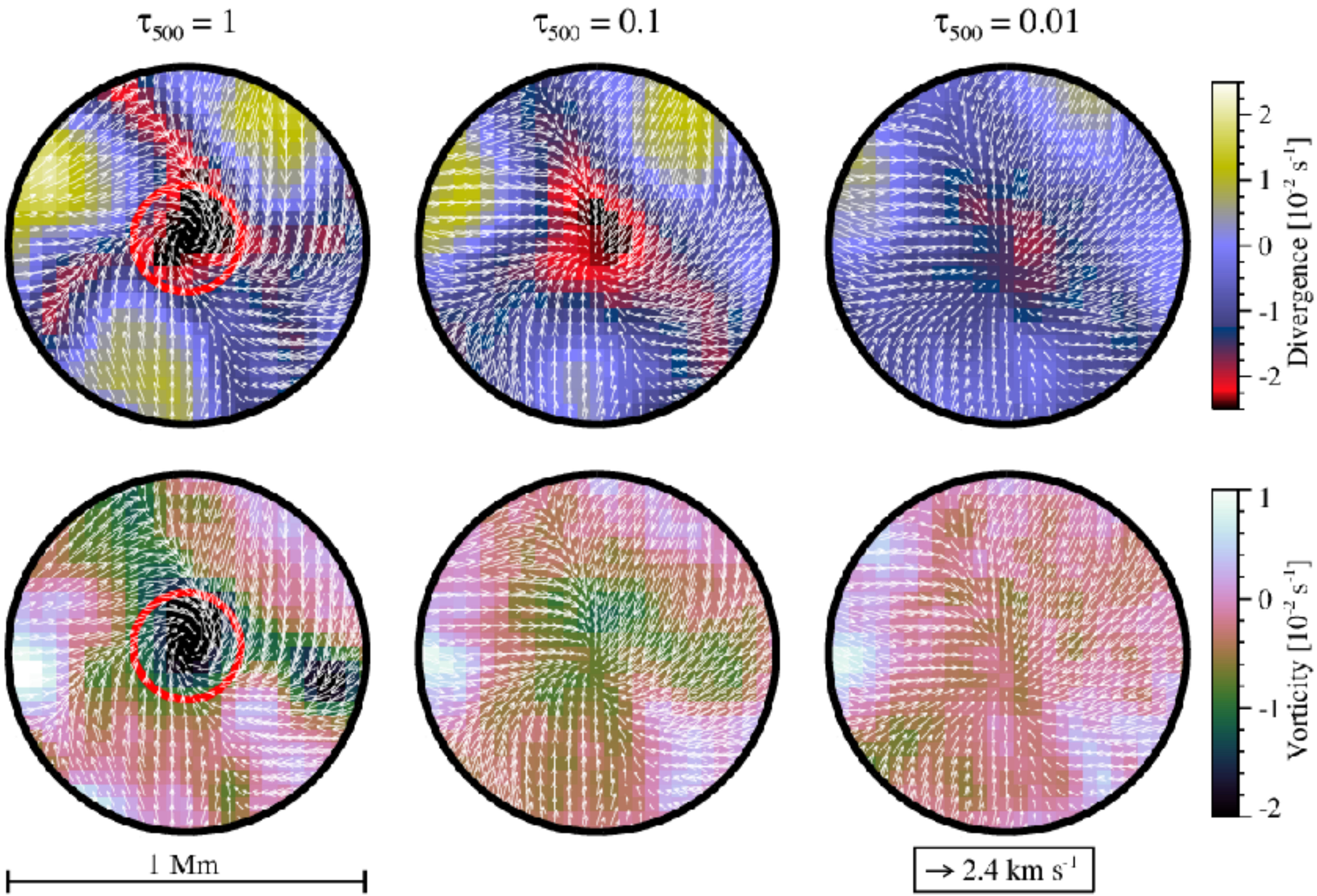
measuring velocities

DEEPVEL https://github.com/aasensio/deepvel

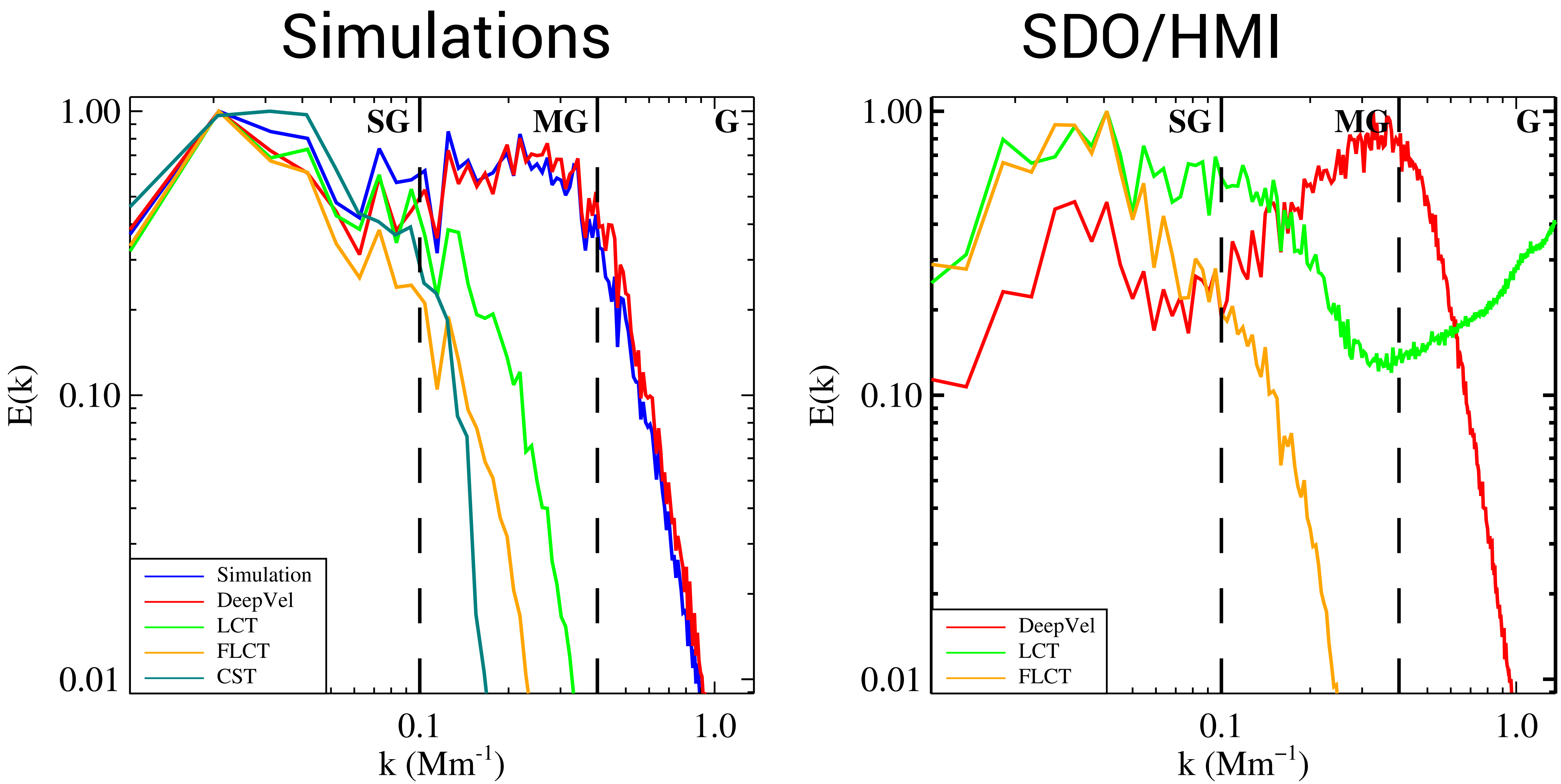


Asensio Ramos, Requerey & Vitas (2017)

SMALL SCALE VORTEX FLOWS

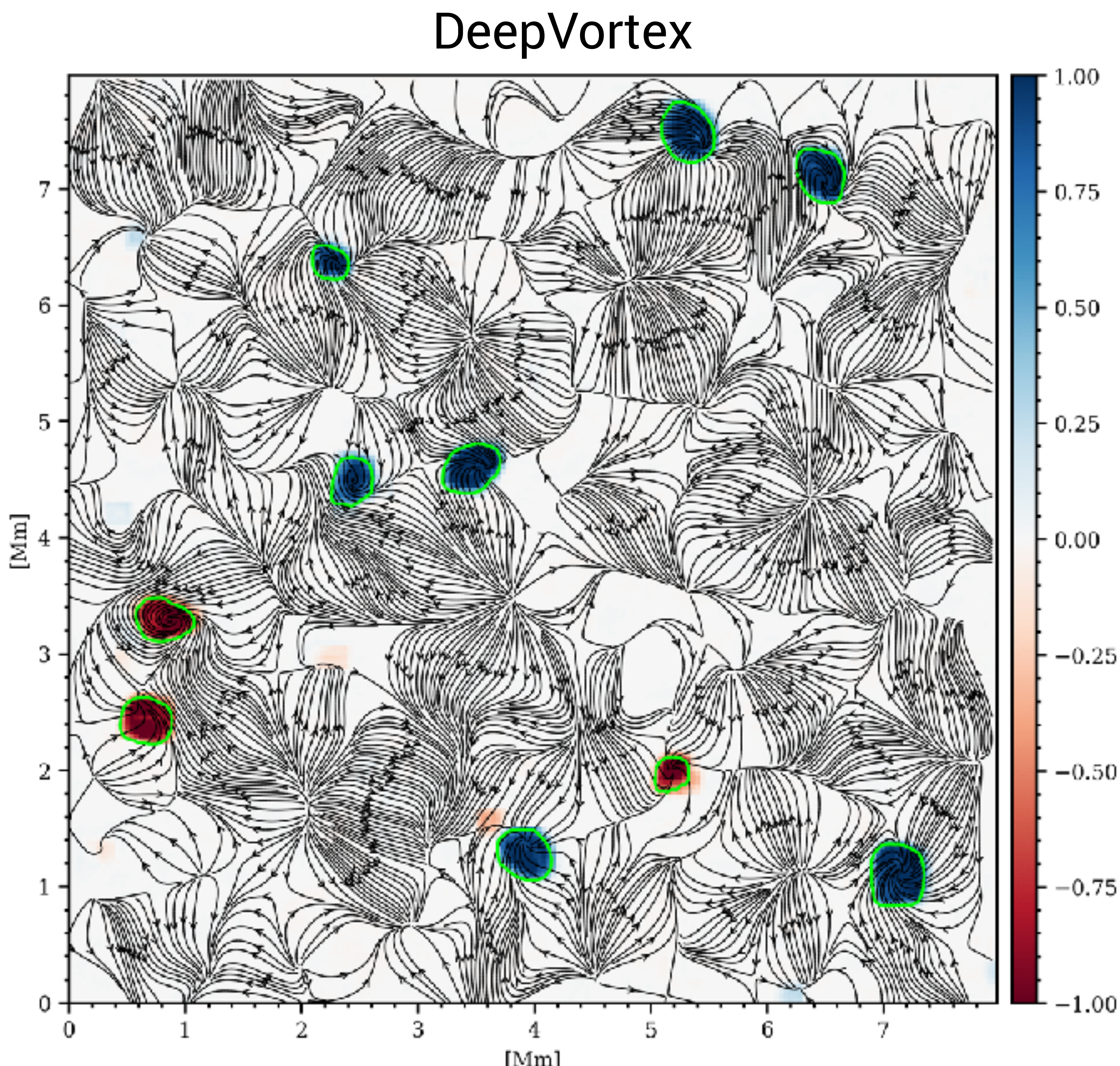


KINETIC ENERGY SPECTRUM



Tremblay et al. (2018)

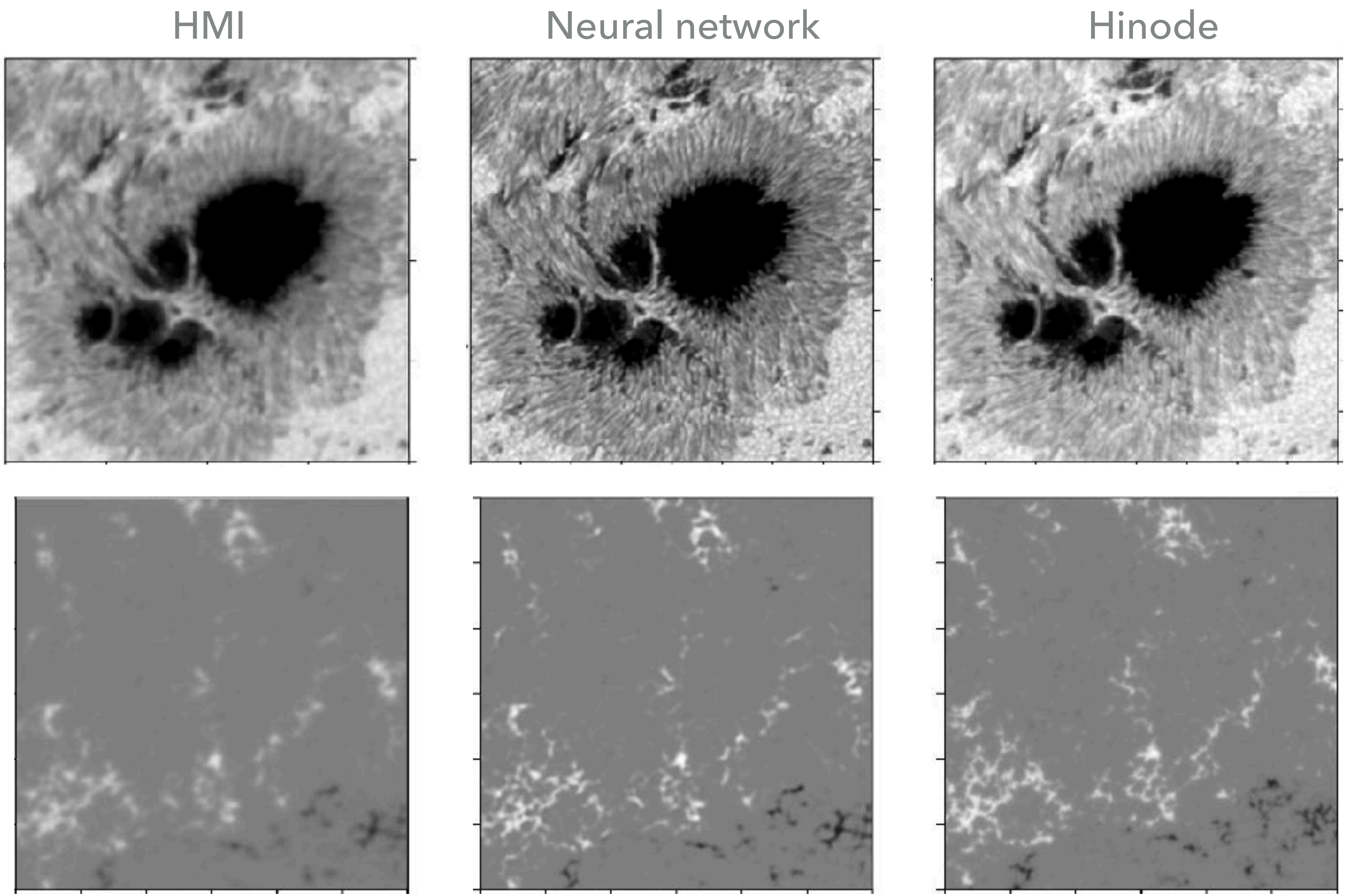
VORTEX DETECTION



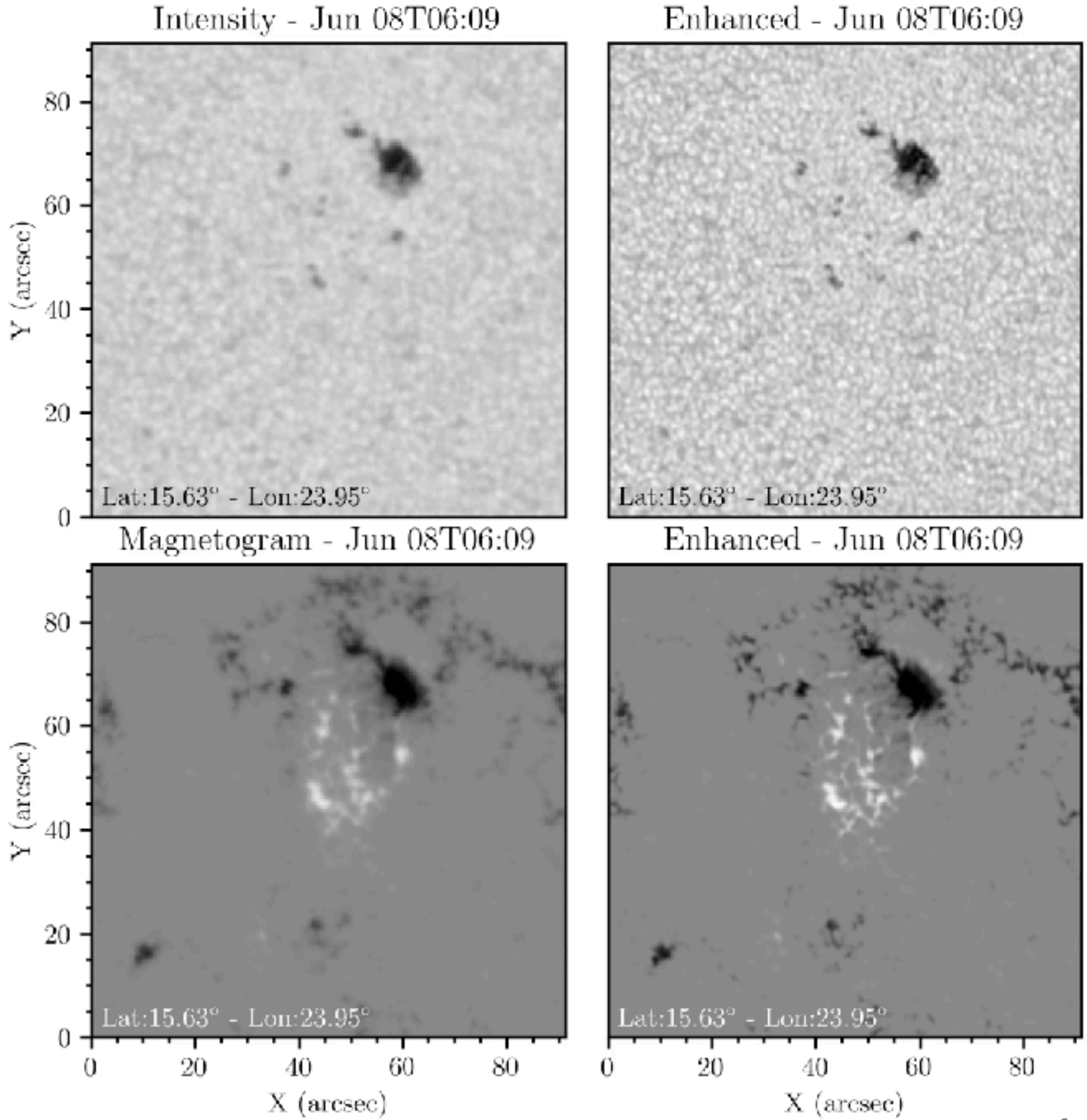
Requerey et al. (in prep)

enhancing HMI images

ENHANCE: SINGLE IMAGE SUPERRESOLUTION



ENHANCE https://github.com/cdiazbas/enhance

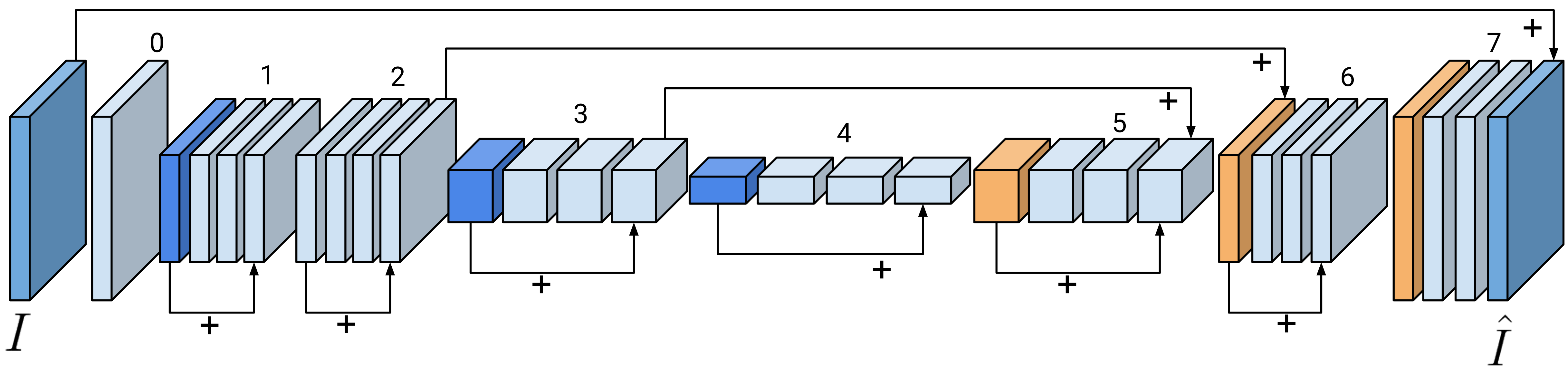


courtesy of S. Castellanos Durán

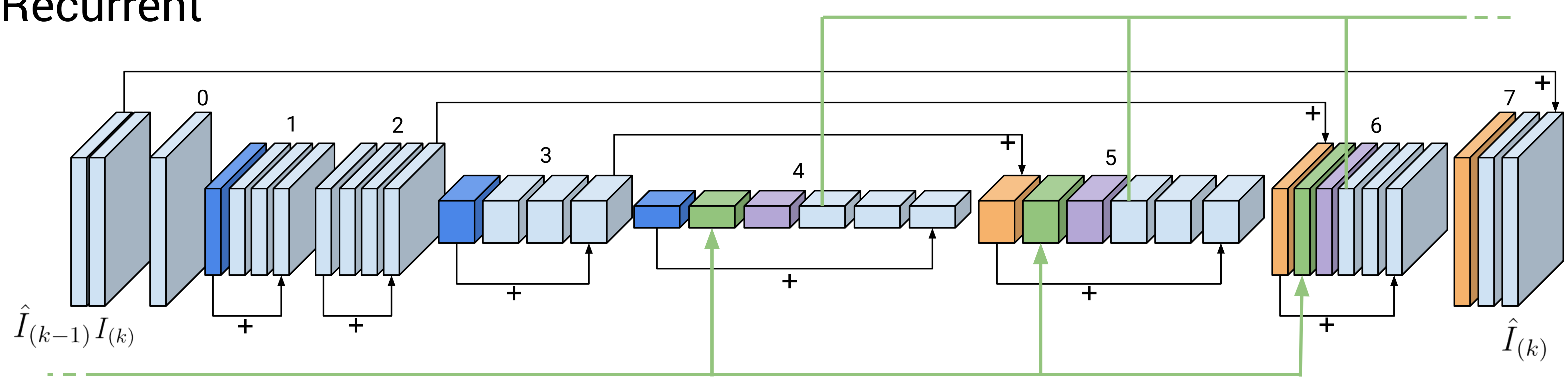
real-time multiframe deconvolution

MULTIFRAME BLIND DECONVOLUTION

Encoder-decoder

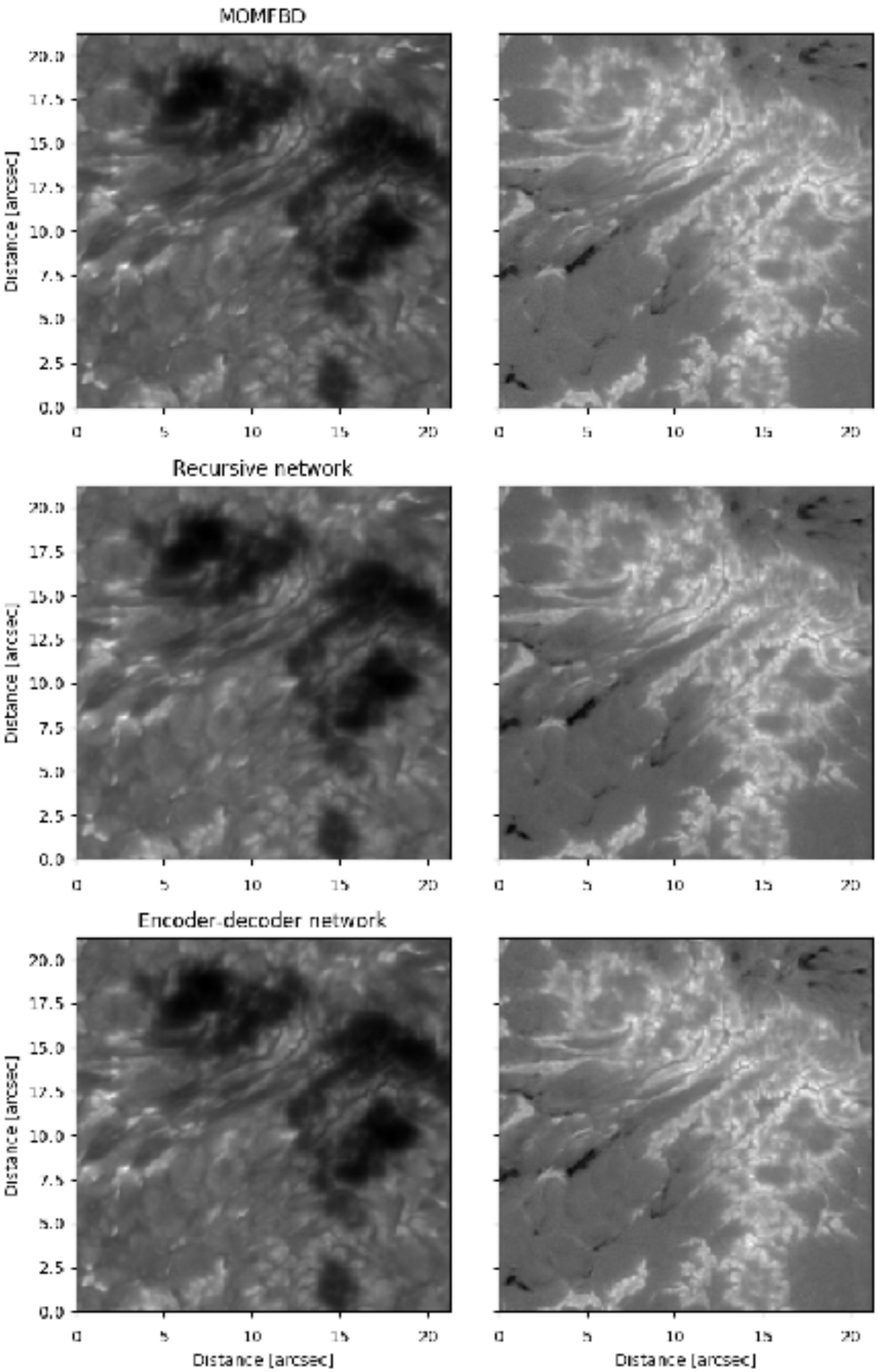


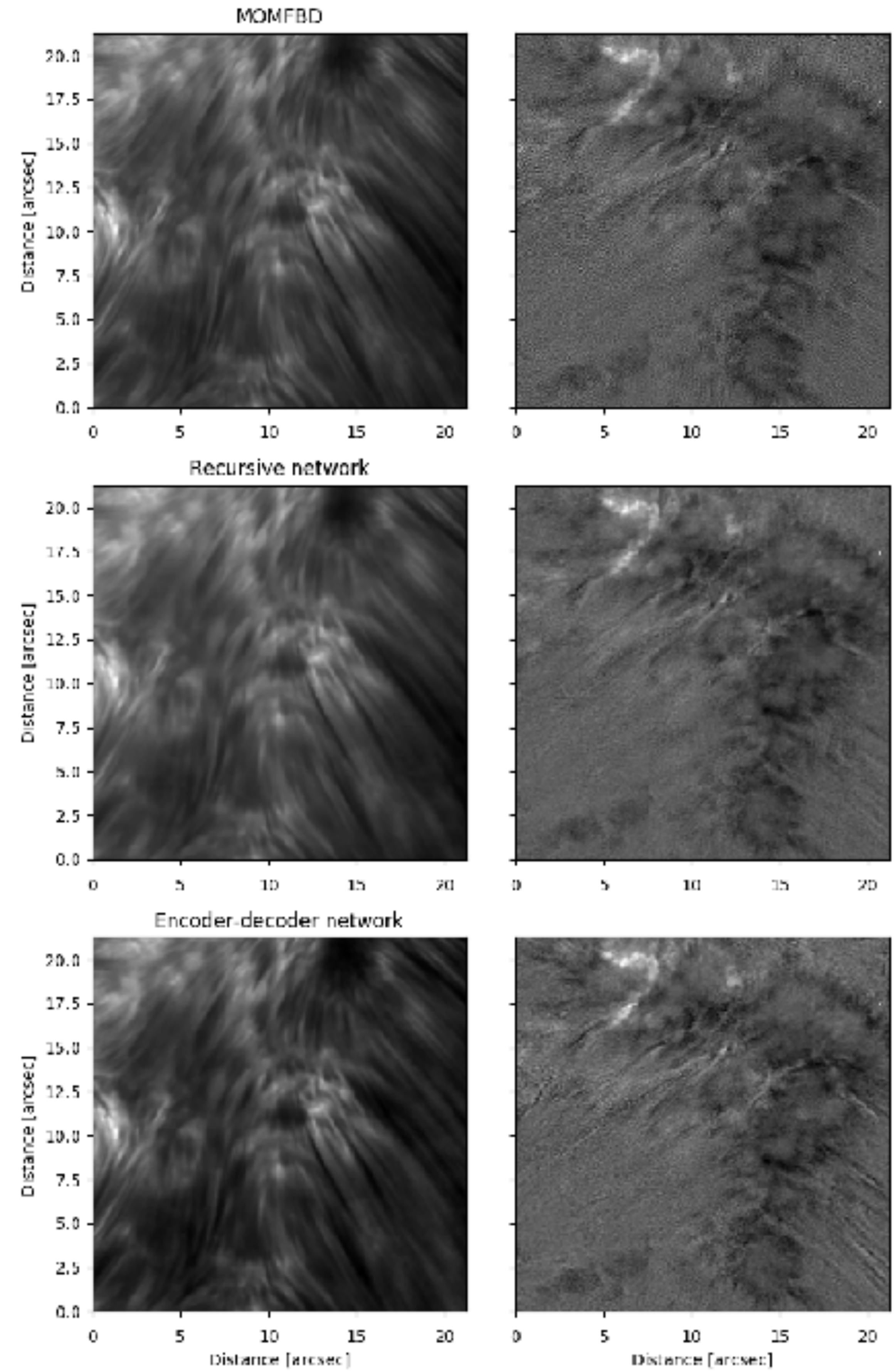
Recurrent



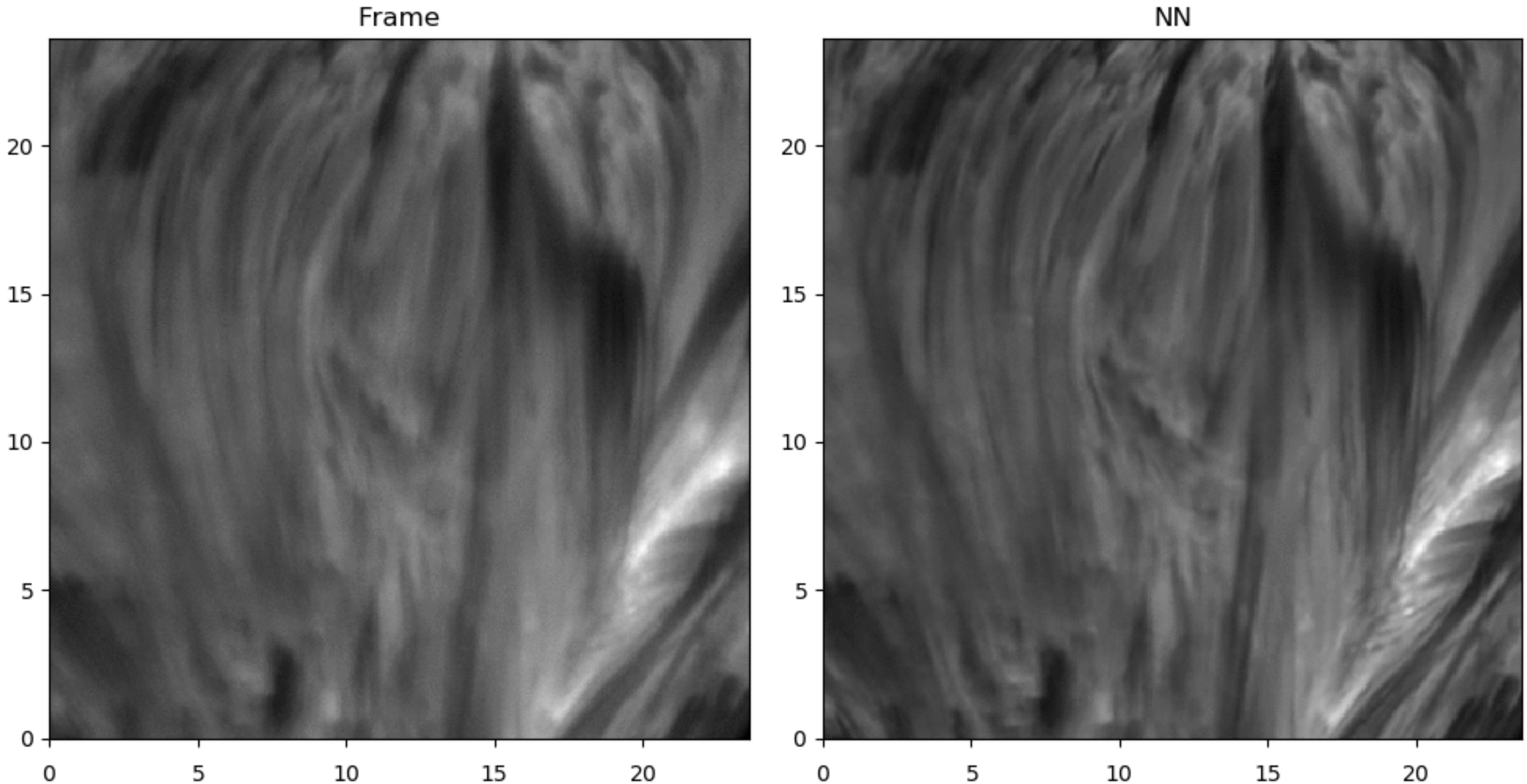
https://github.com/aasensio/learned_mfbd

POLARIMETRY





GENERALIZATION TO UNSEEN DATA

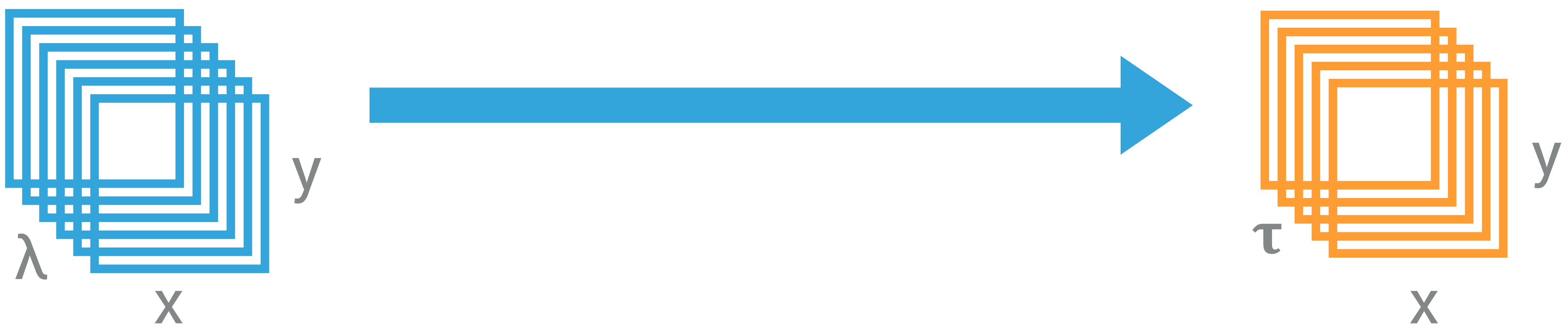


100 images/s

3D inversion of Stokes profiles with height information

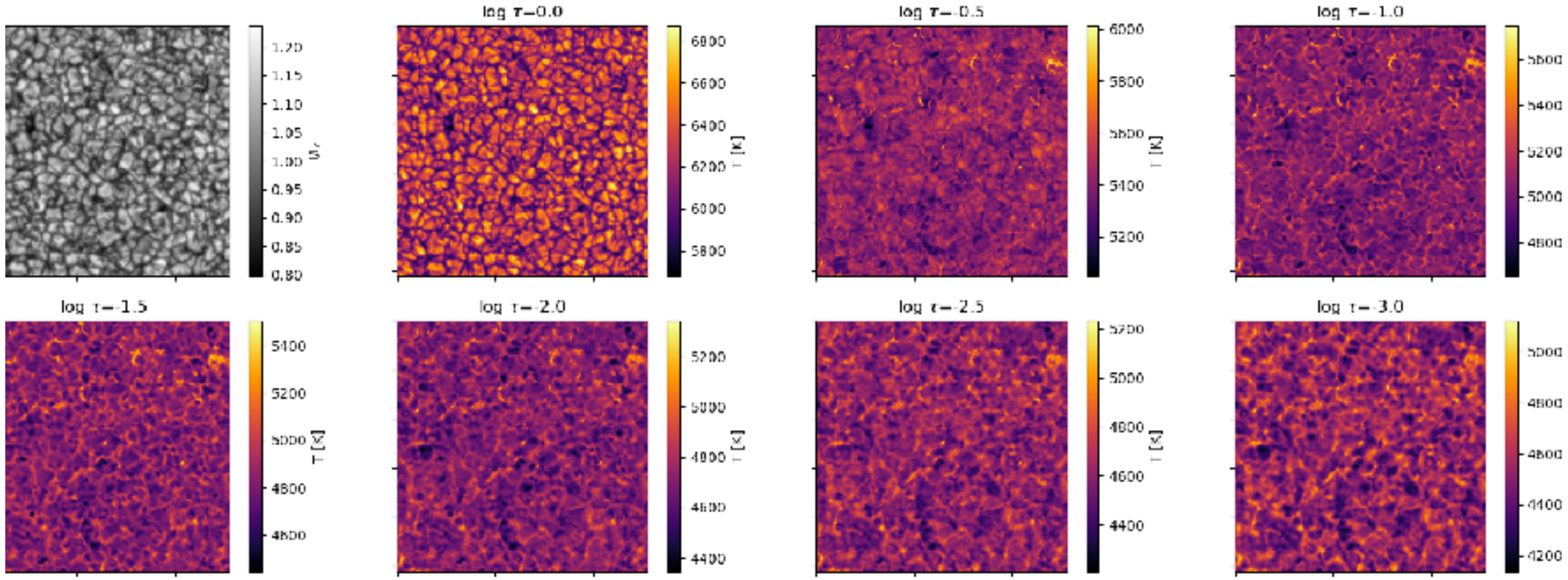
warning: WIP!!

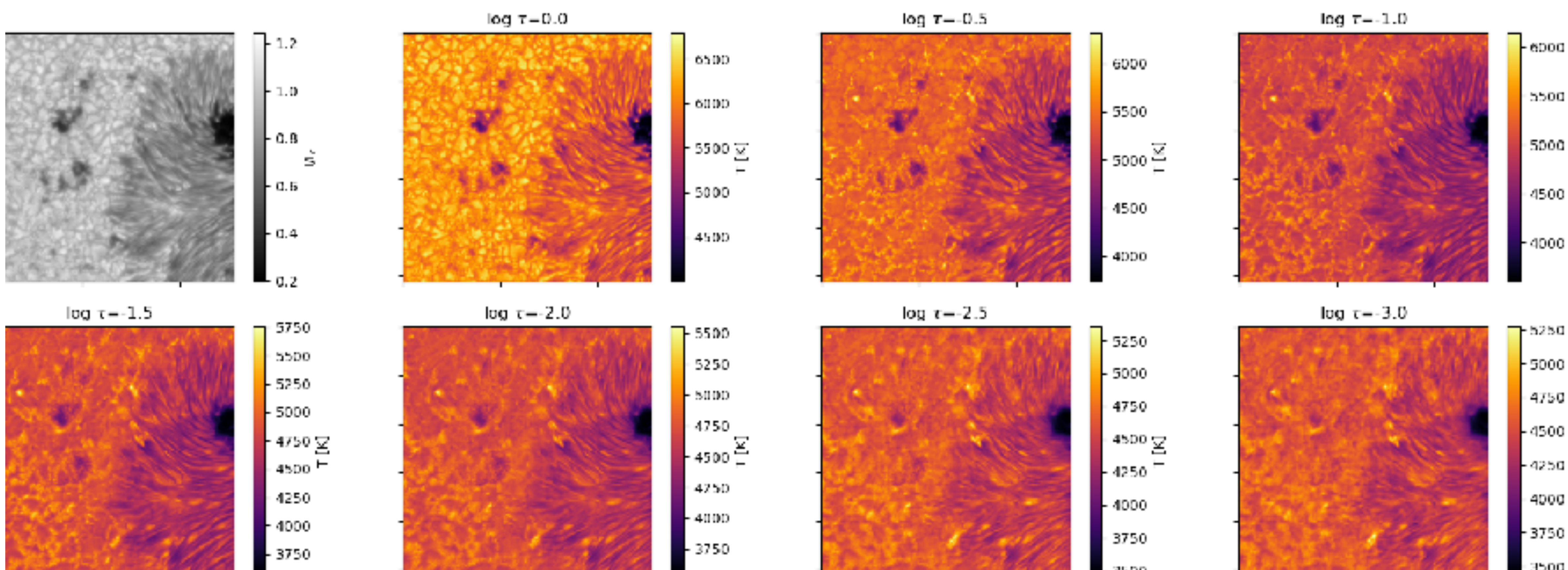
3D INVERSION OF STOKES PROFILES



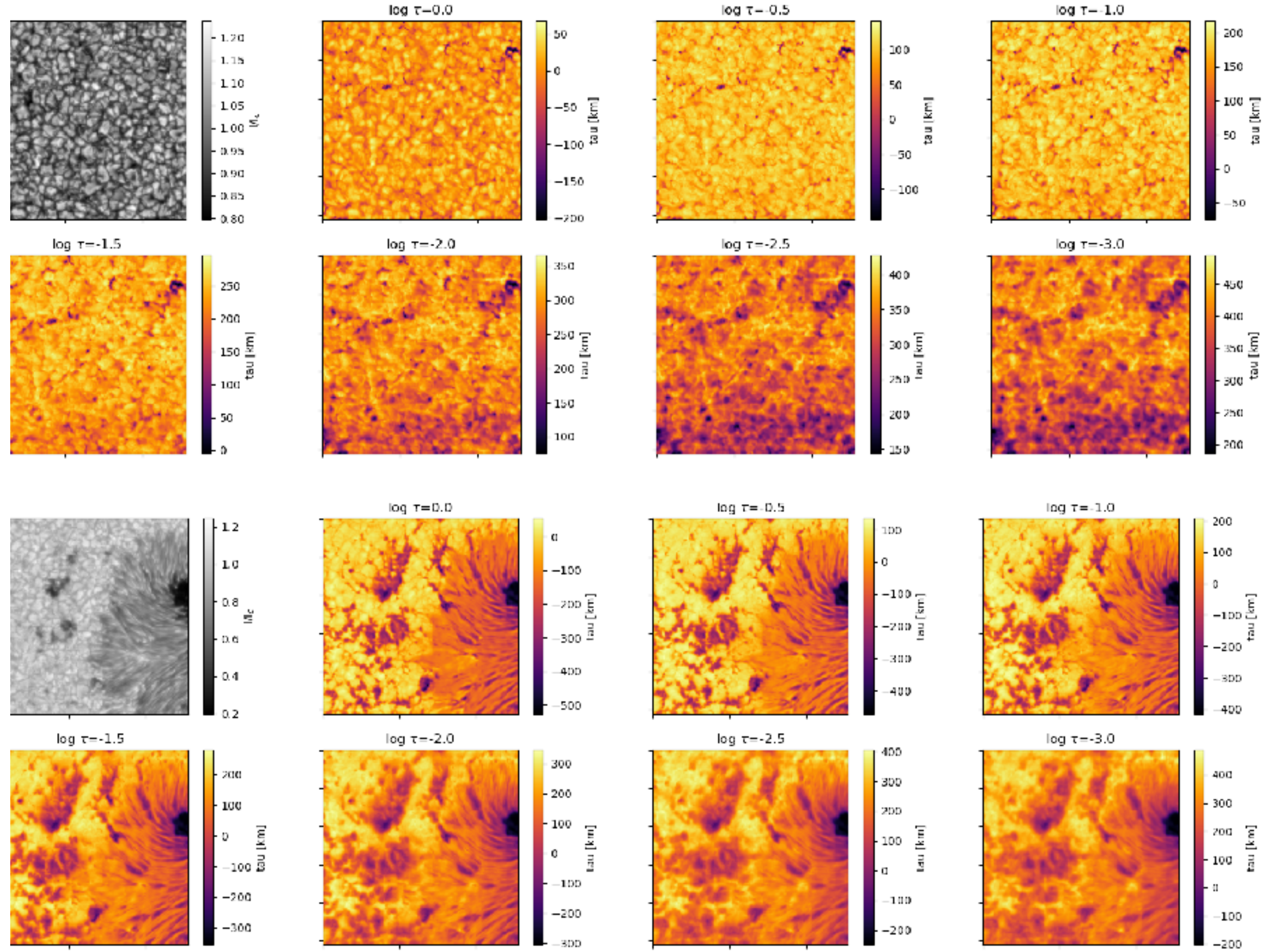
- Trained on Rempel's 3D MHD magnetoconvection snapshot (still too few)
- End-to-end deep neural network
- Severe augmenting during training
- Still without polarimetry

HINODE INVERSION - TEMPERATURE (WIP)

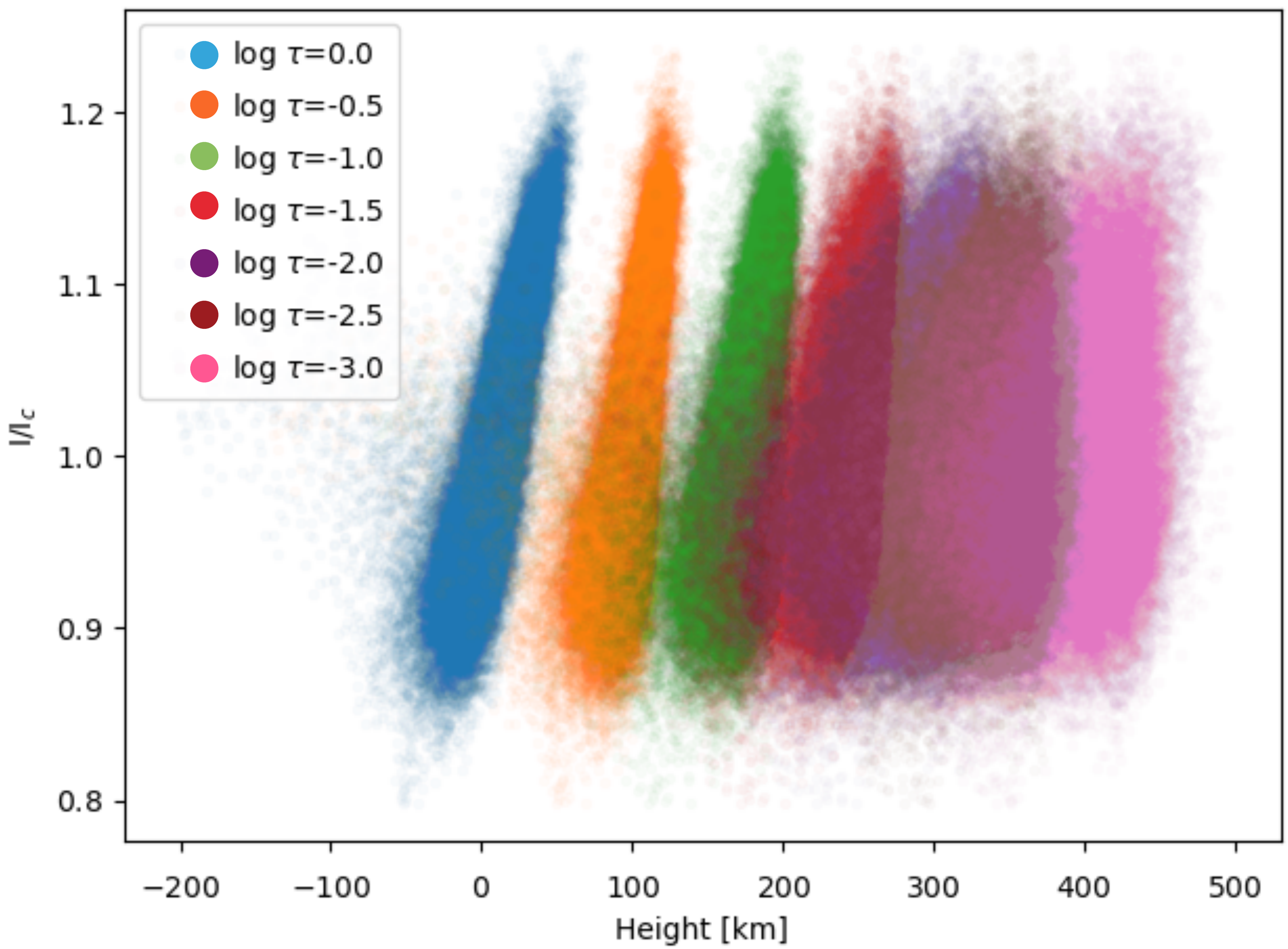




HINODE INVERSION - WILSON DEPRESSION (WIP)



HINODE INVERSION - WILSON DEPRESSION (WIP)



CONCLUSIONS

- very fast image correction
- 3d inversion of Stokes profiles
- more potential applications
  - fast 2d inversion of IRIS spectra
  - inversions without response functions
  - …