

MACHINE LEARNING AND DEEP LEARNING IN SOLAR PHYSICS

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@aasensior

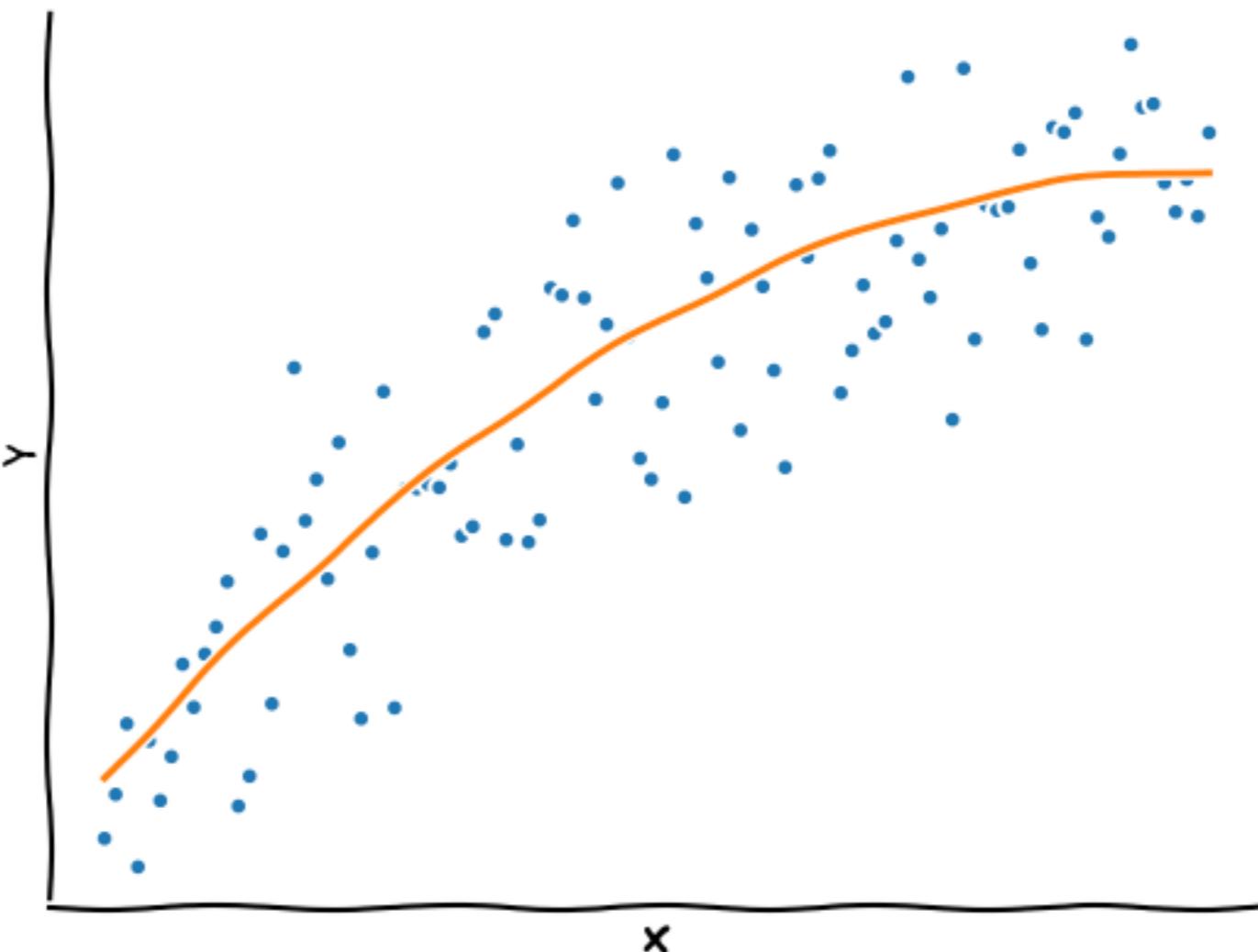
github.com/aasensio



what is machine learning?

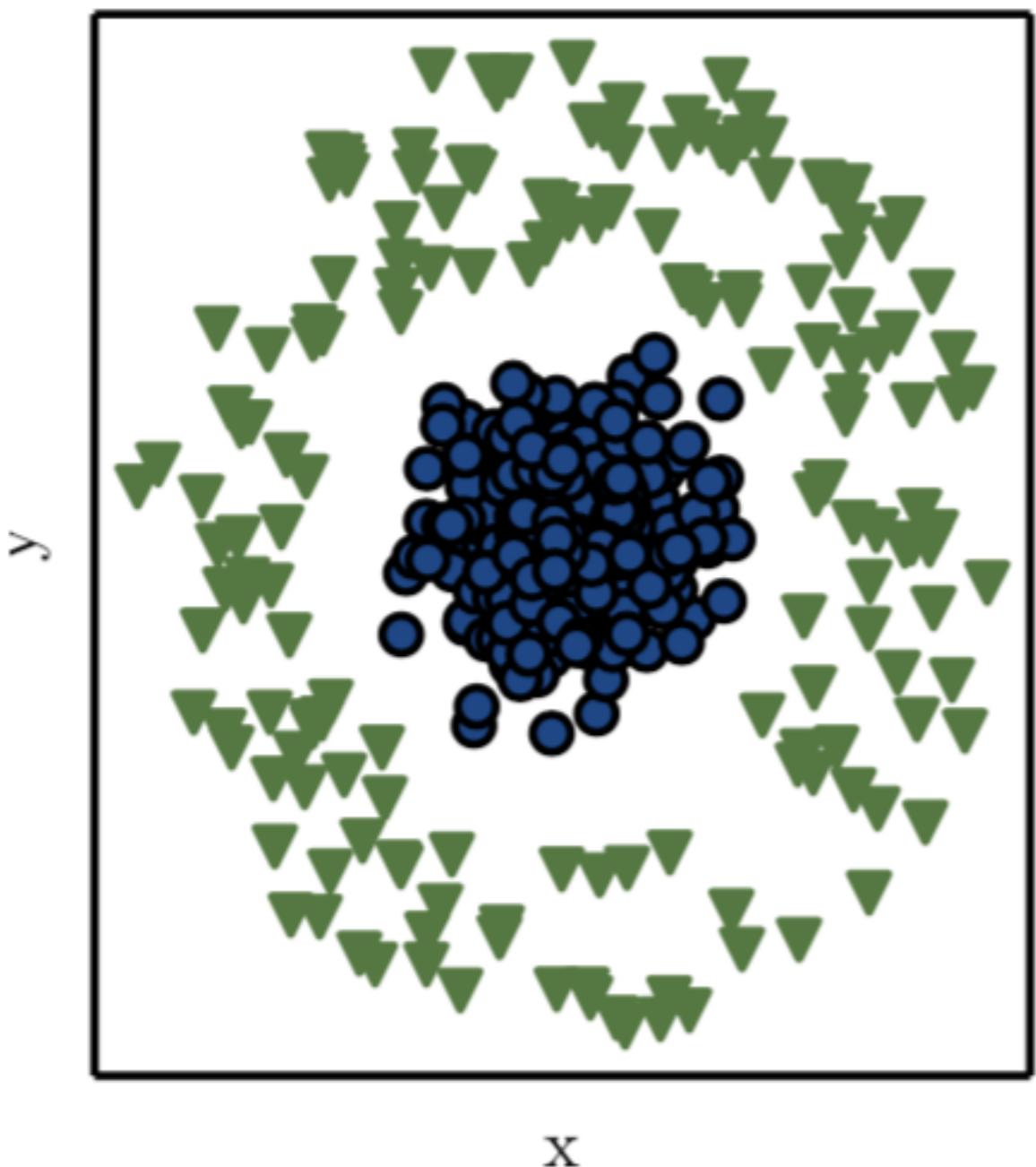
Using statistical techniques to give computers the ability to progressively improve performance on a specific task with data, without being explicitly programmed.

REGRESSION

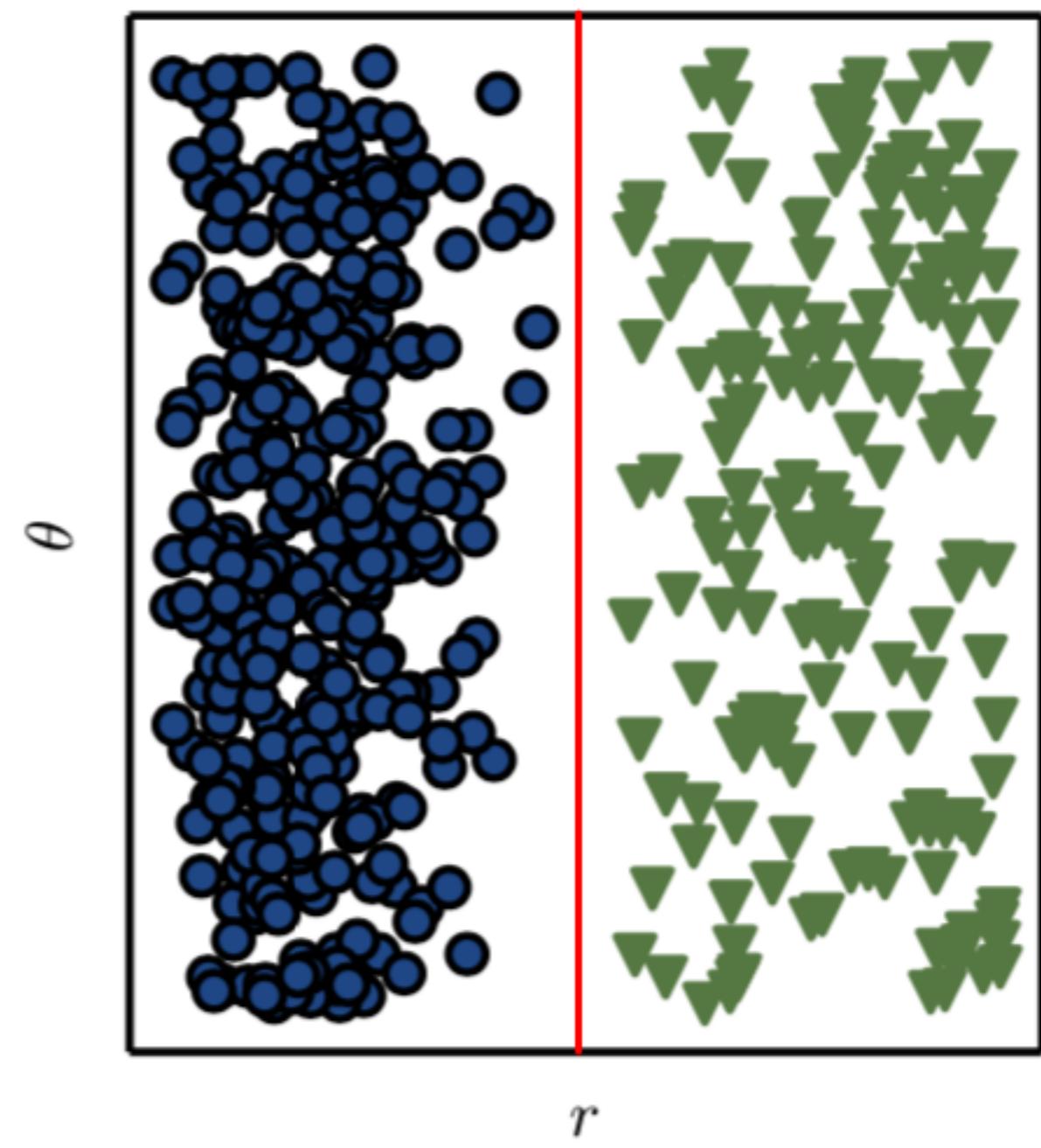


CLASSIFICATION

Cartesian coordinates



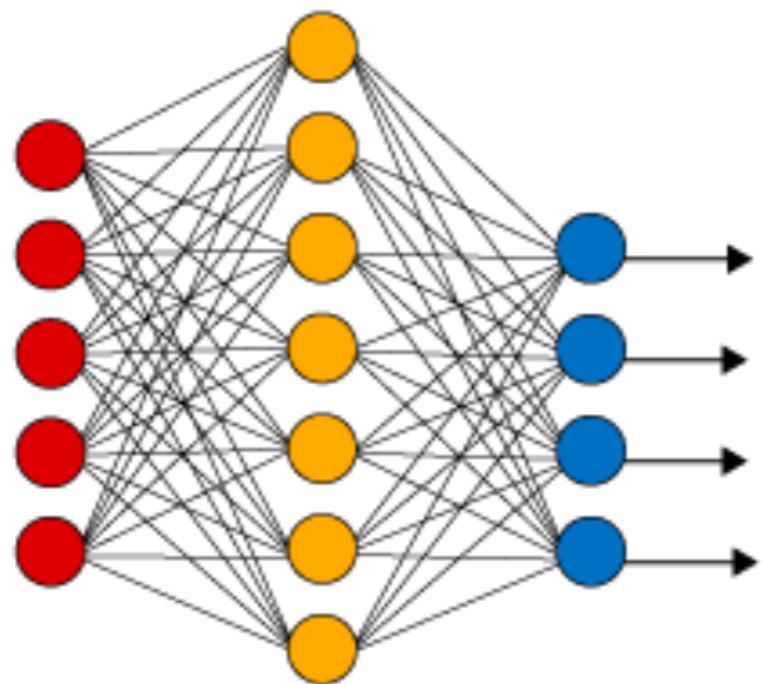
Polar coordinates



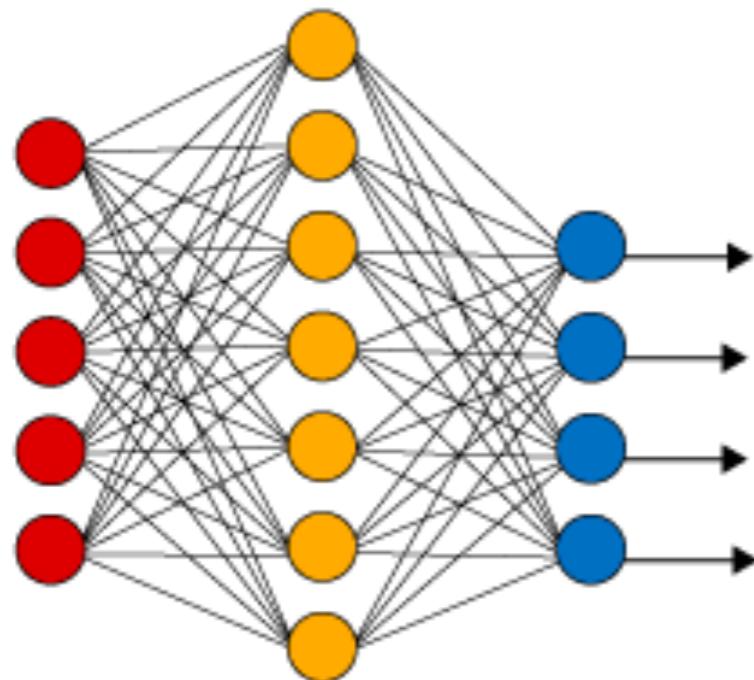
CLASSICAL MACHINE LEARNING

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

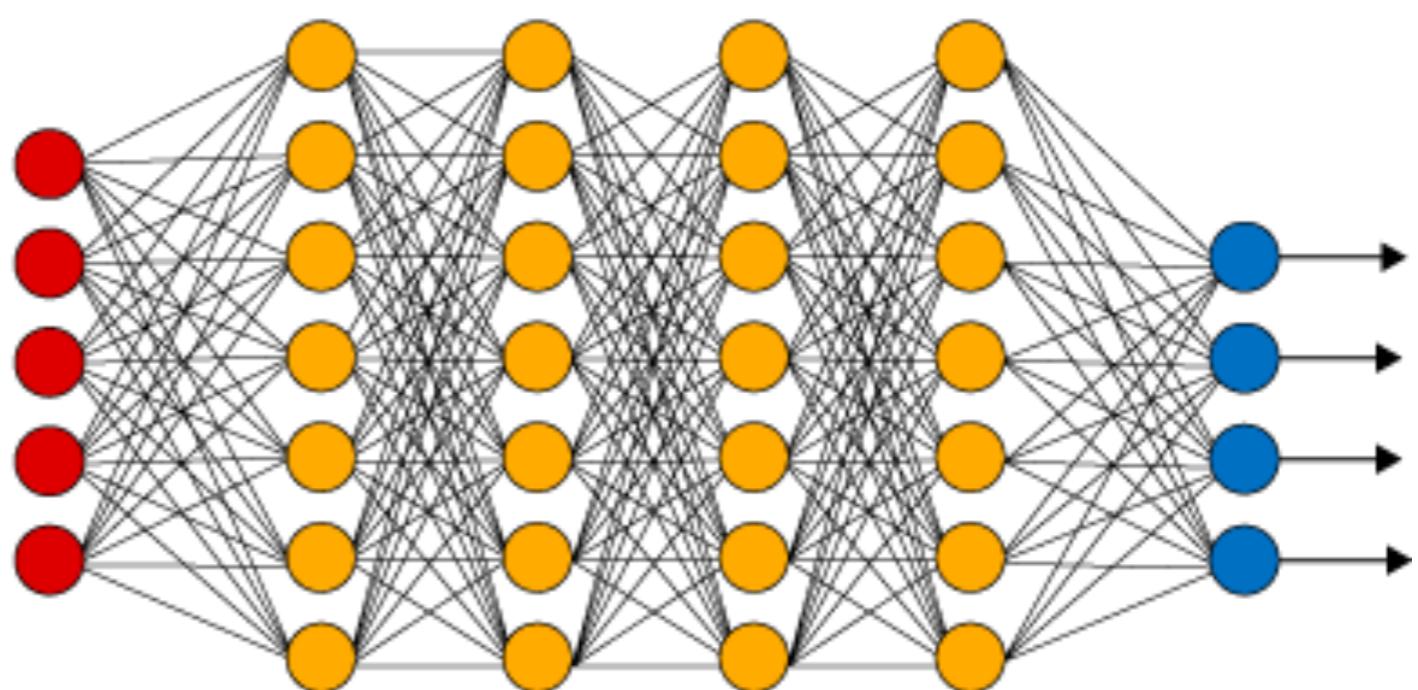
CLASSICAL ML



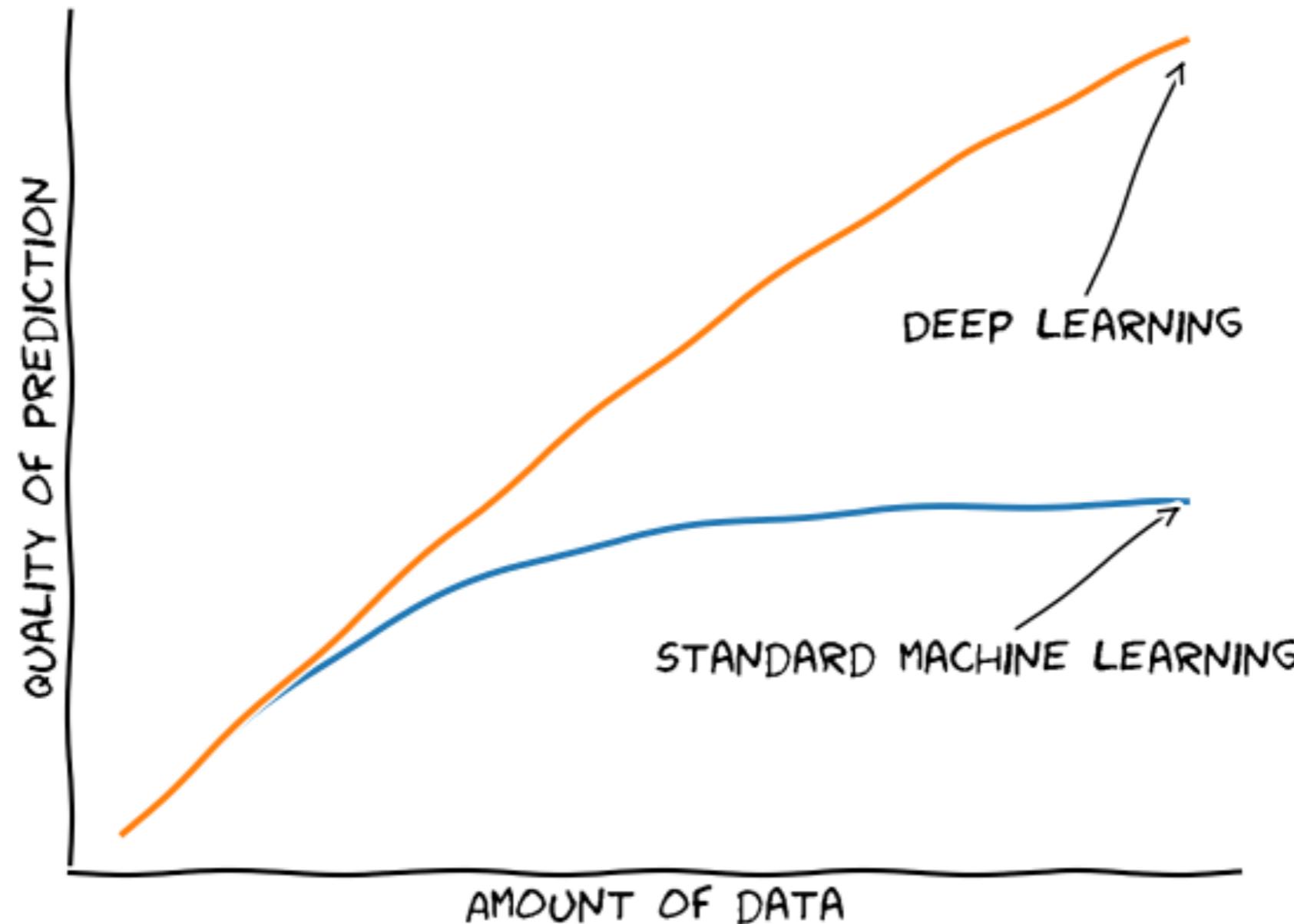
CLASSICAL ML



DEEP LEARNING

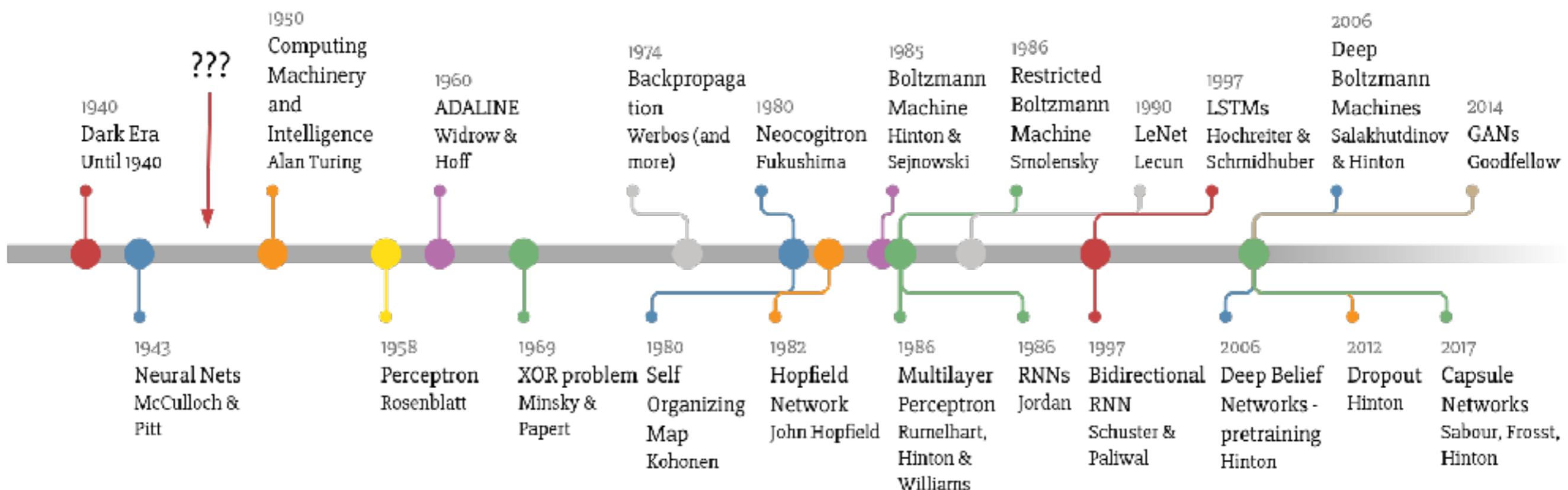


WHY DEEP LEARNING?

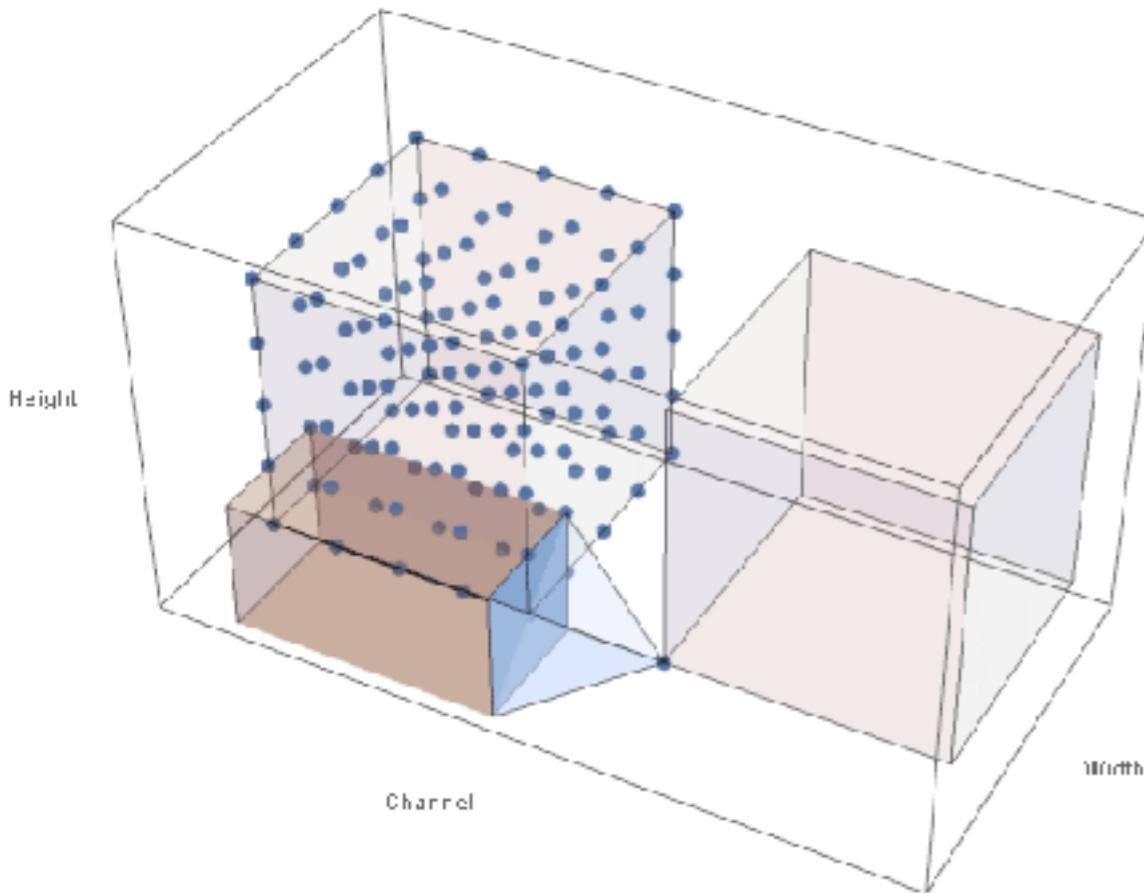


Curse of dimensionality

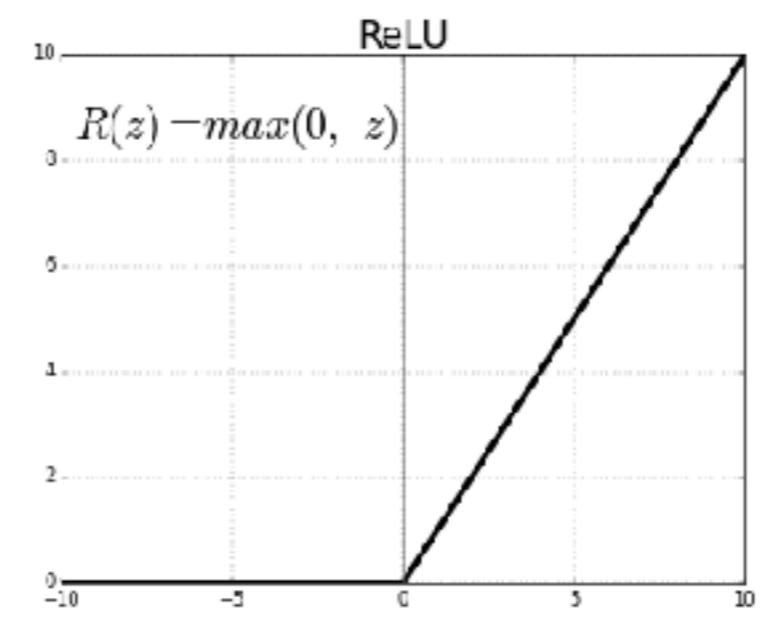
Deep Learning Timeline



BASIC INGREDIENTS



Convolution

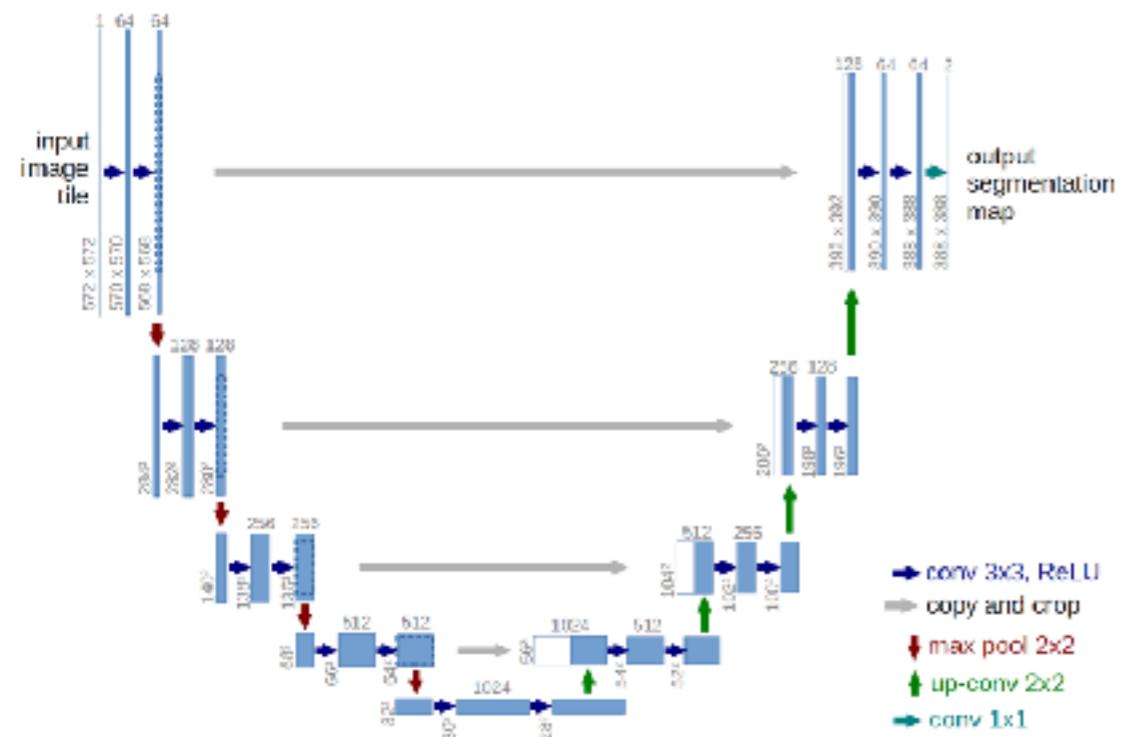


Activation

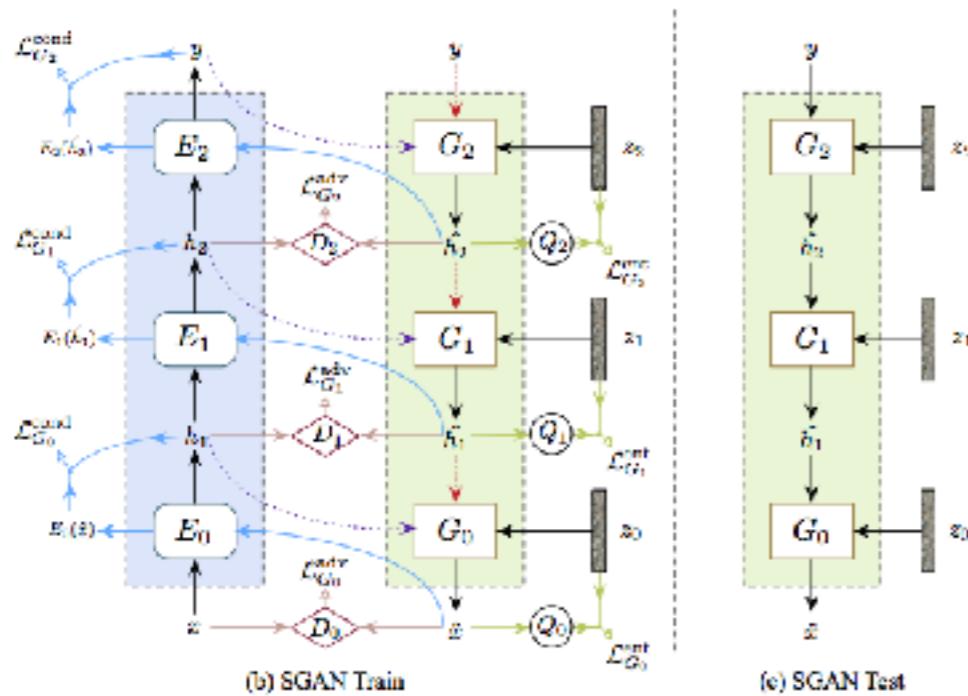
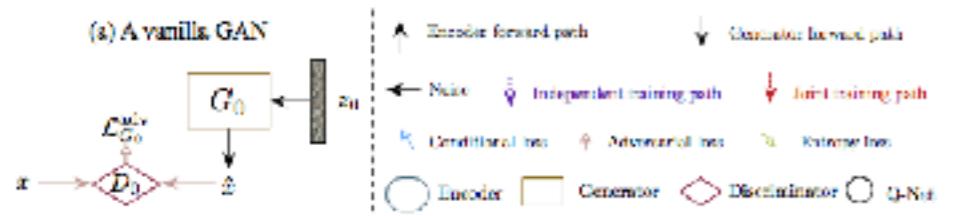
$$f = \|\mathbf{O} - \mathbf{T}\|_2^2$$

Loss

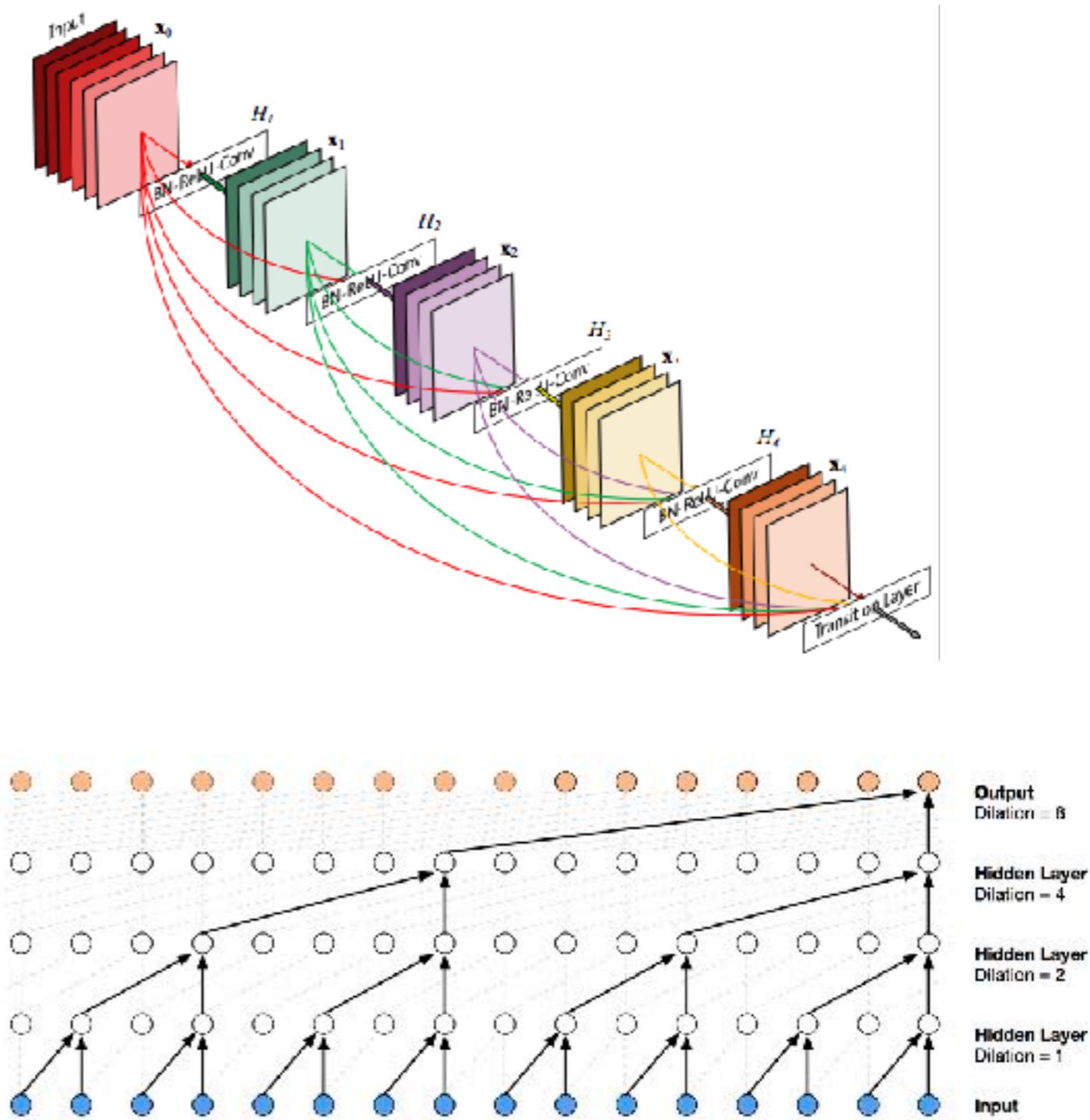
ENORMOUS LANDSCAPE



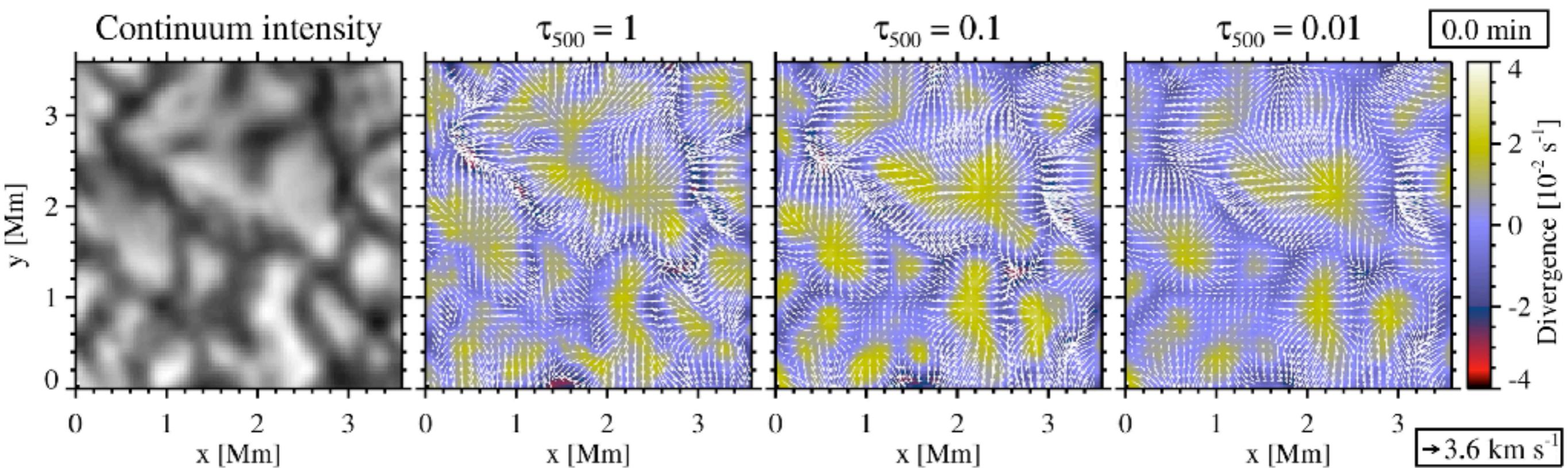
- conv 3x3, ReLU
- copy and crop
- ↓ max pool 2x2
- ↑ up-conv 2x2
- conv 1x1



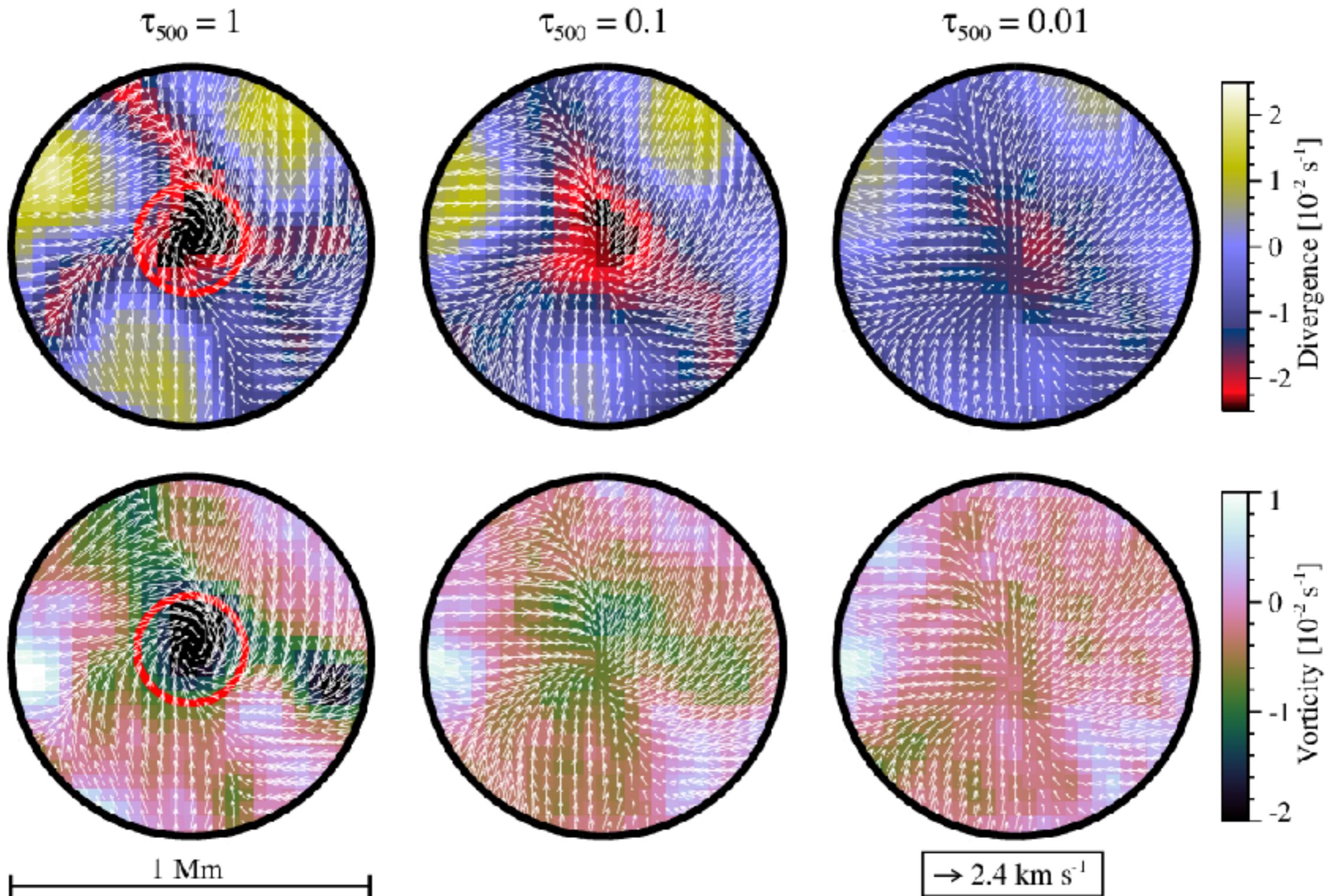
(c) SGAN Test



measuring velocities

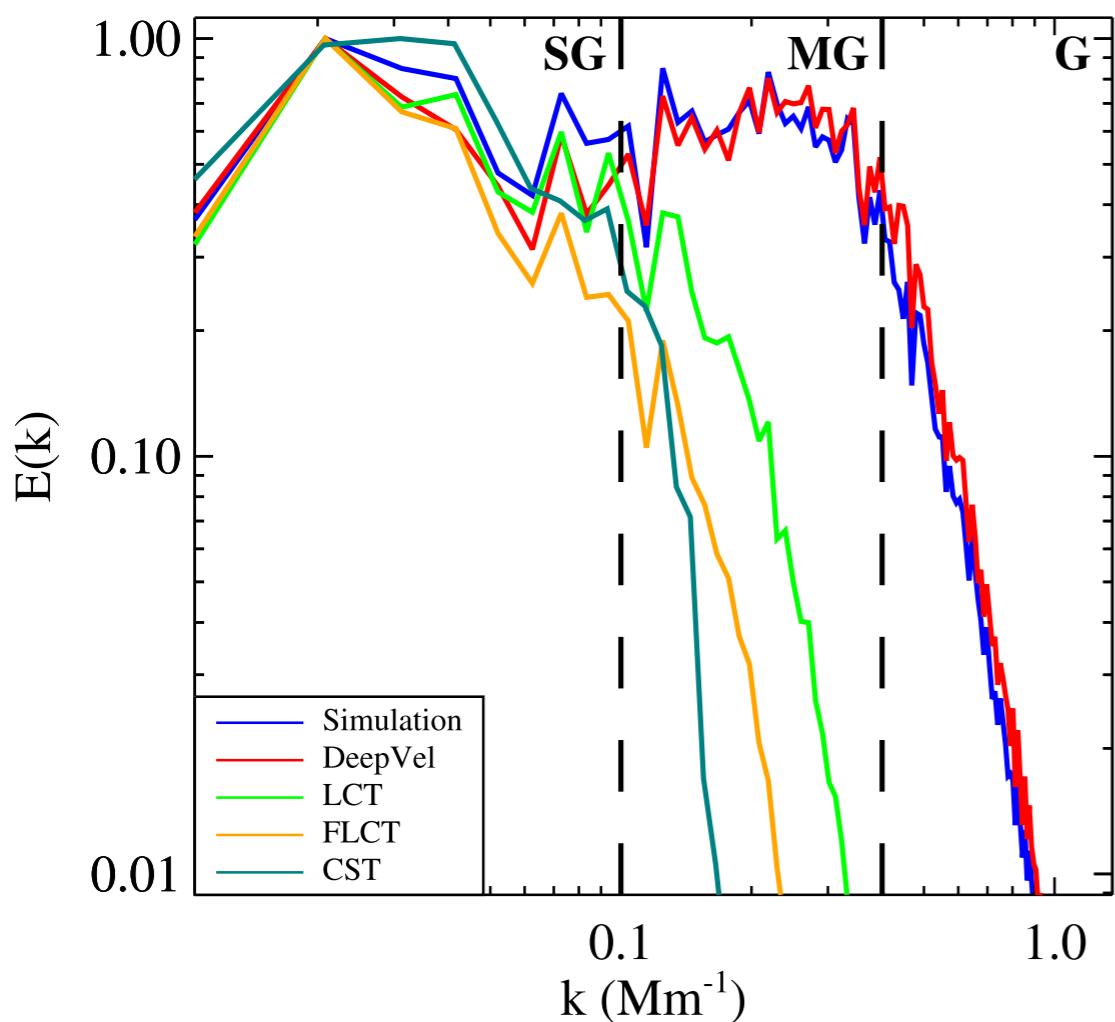


SMALL SCALE VORTEX FLOWS

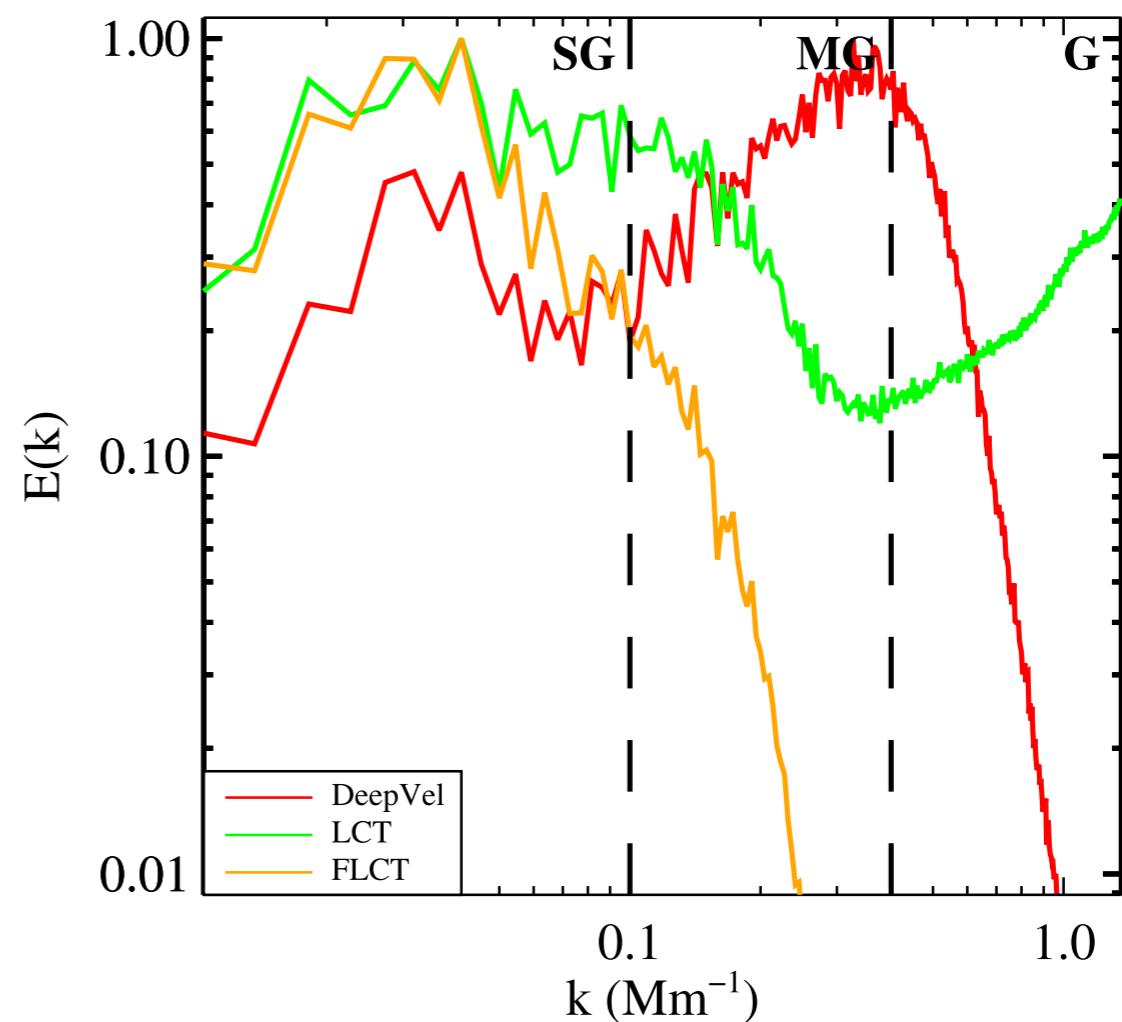


KINETIC ENERGY SPECTRUM

Simulations



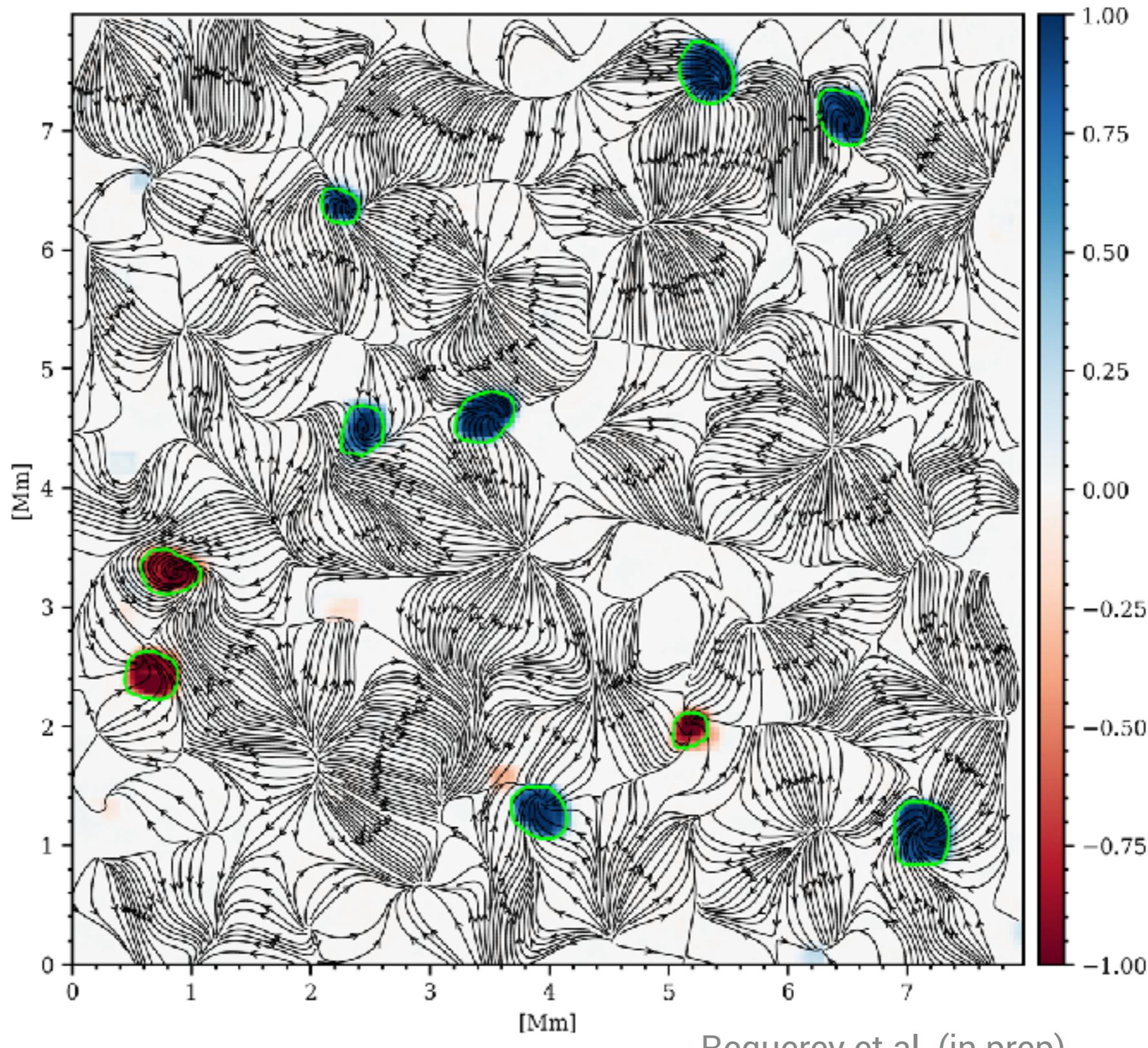
SDO/HMI



Tremblay et al. (2018)

VORTEX DETECTION

DeepVortex

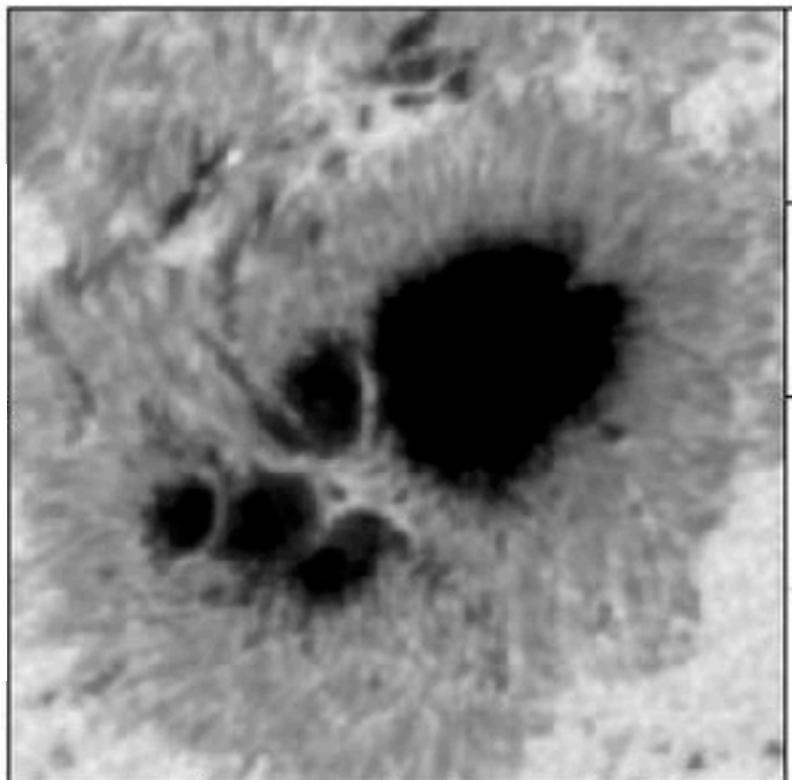


Requerey et al. (in prep)

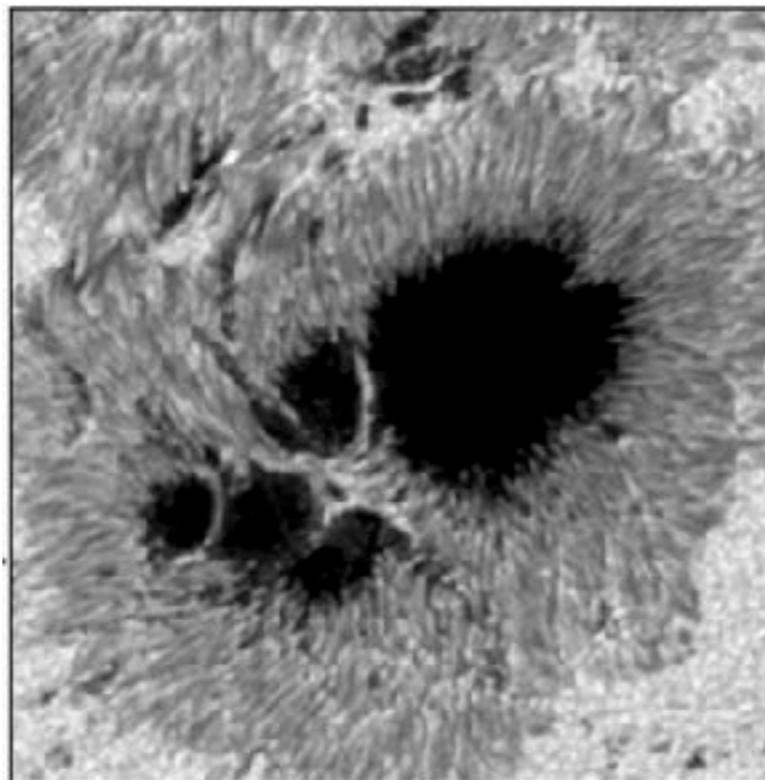
enhancing HMI images

ENHANCE: SINGLE IMAGE SUPERRESOLUTION

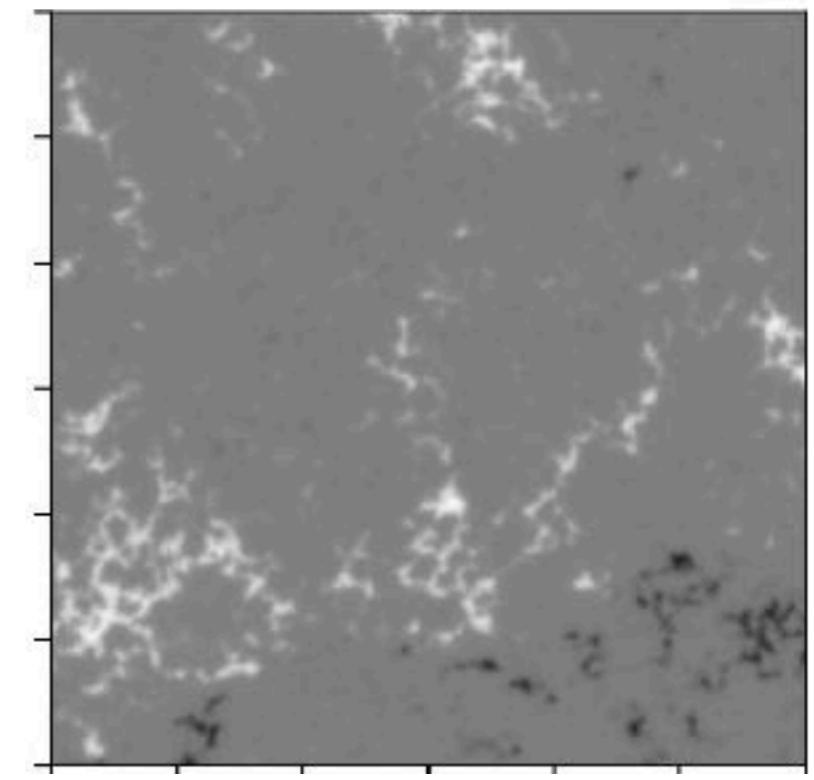
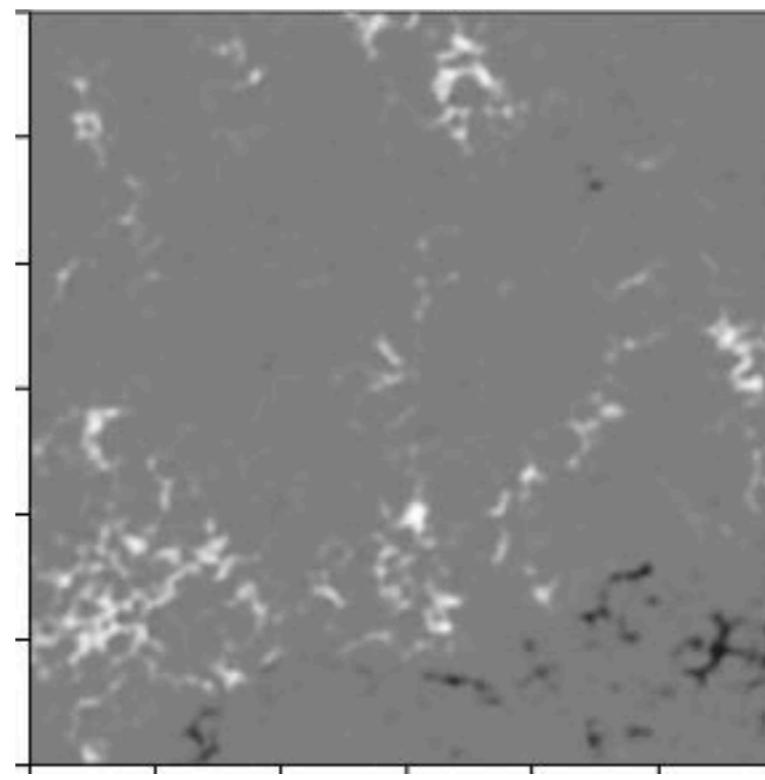
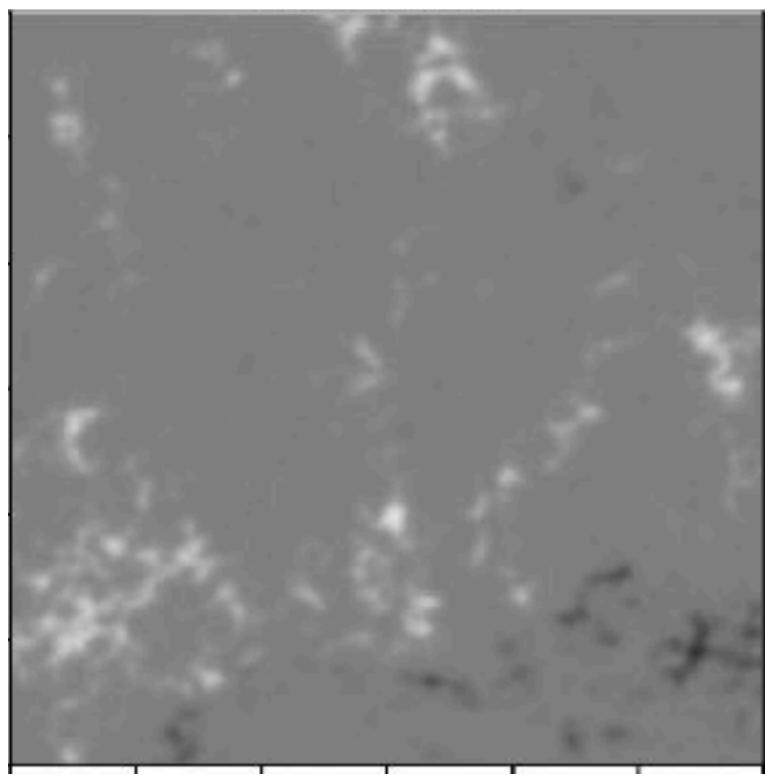
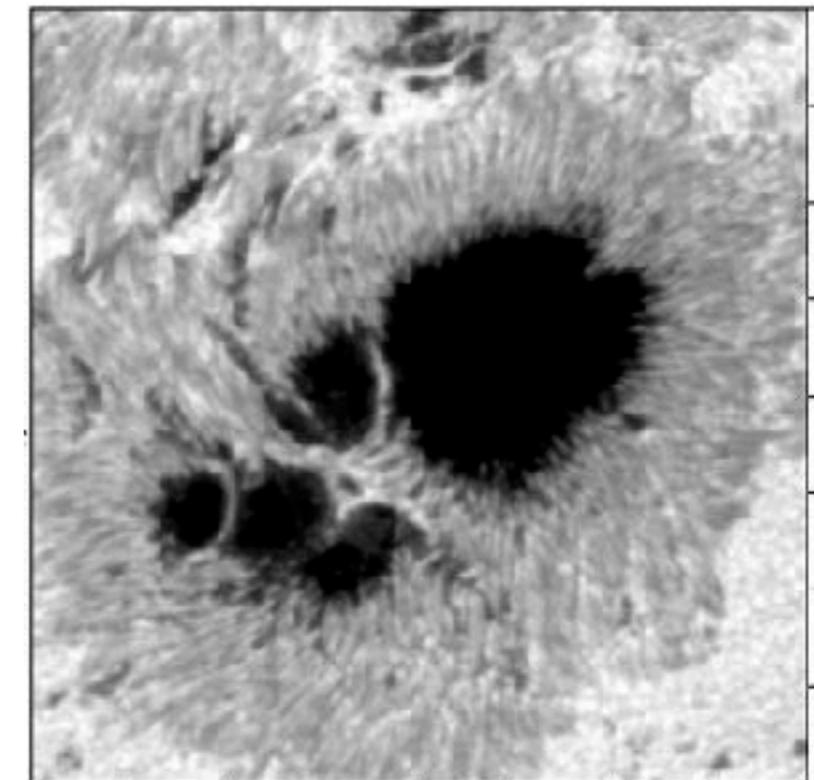
HMI



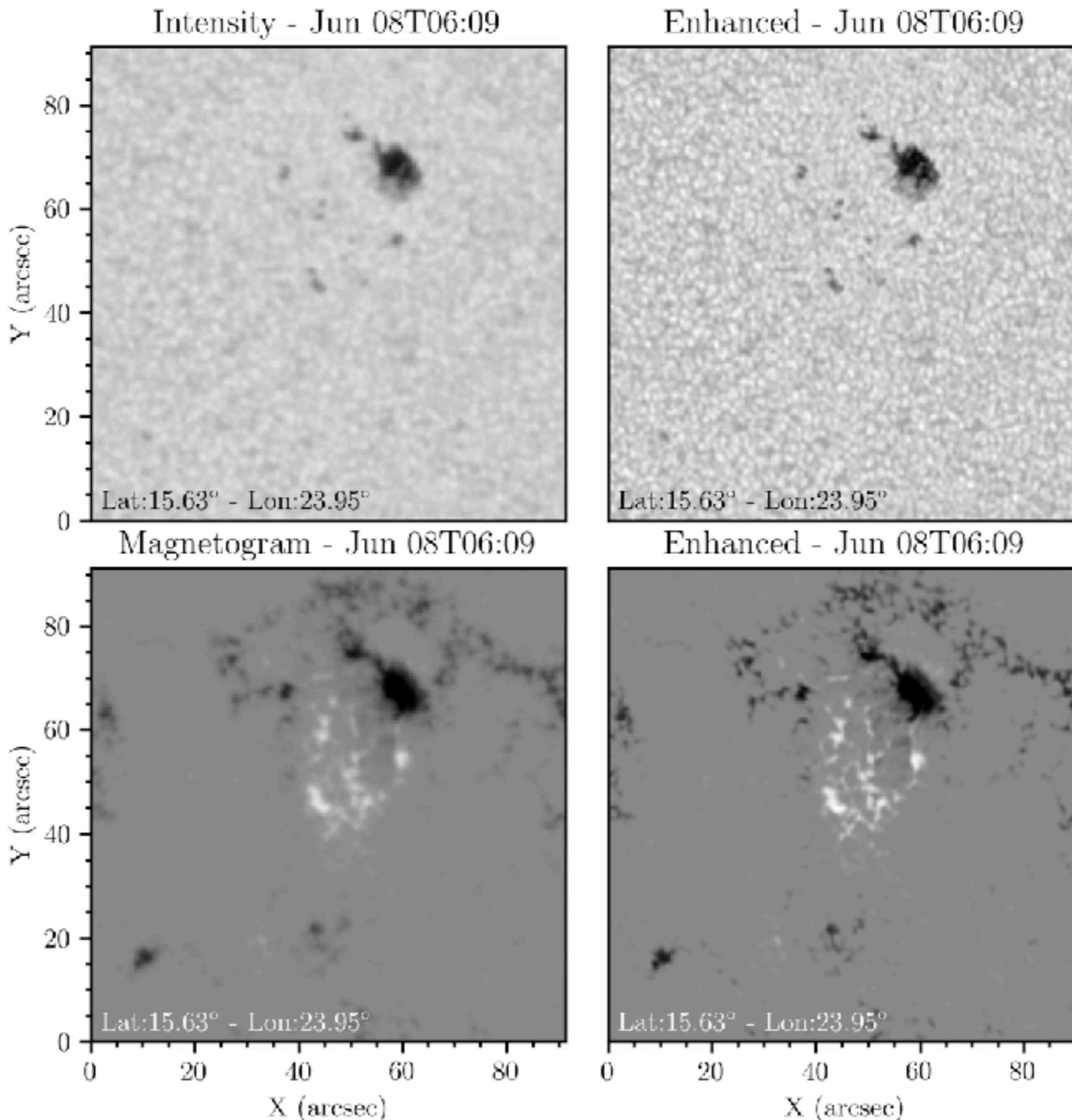
Neural network



Hinode



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

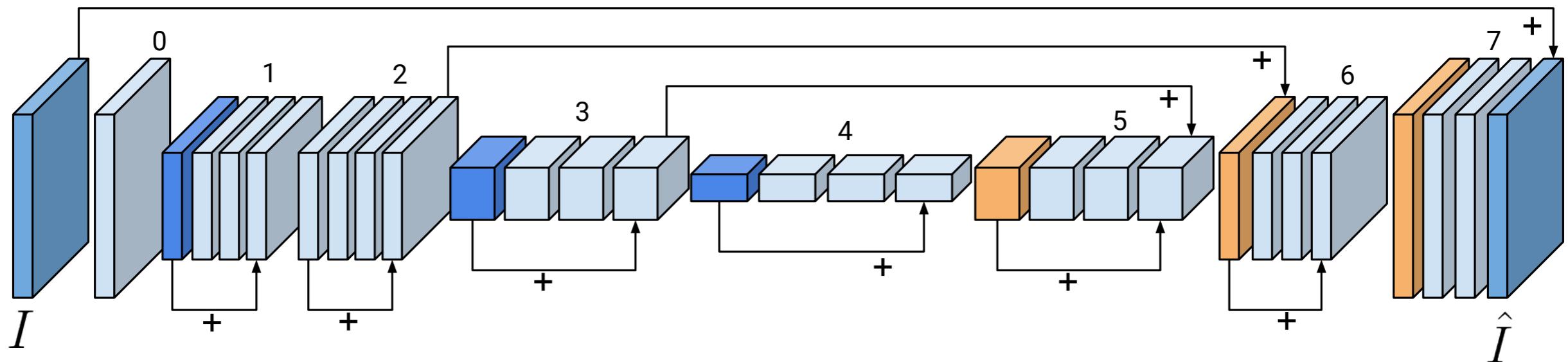


courtesy of S. Castellanos Durán

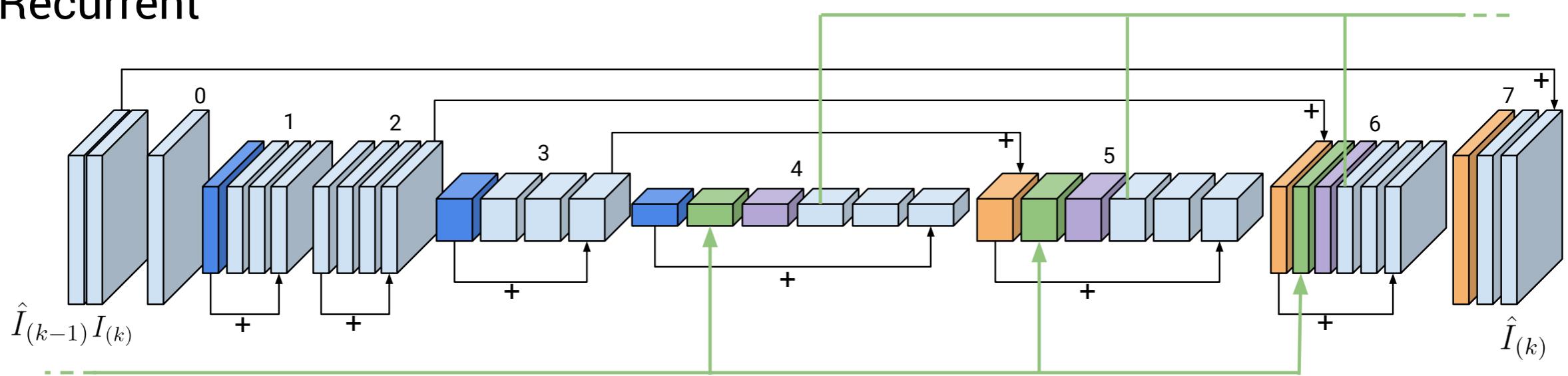
real-time multiframe deconvolution

MULTIFRAME BLIND DECONVOLUTION

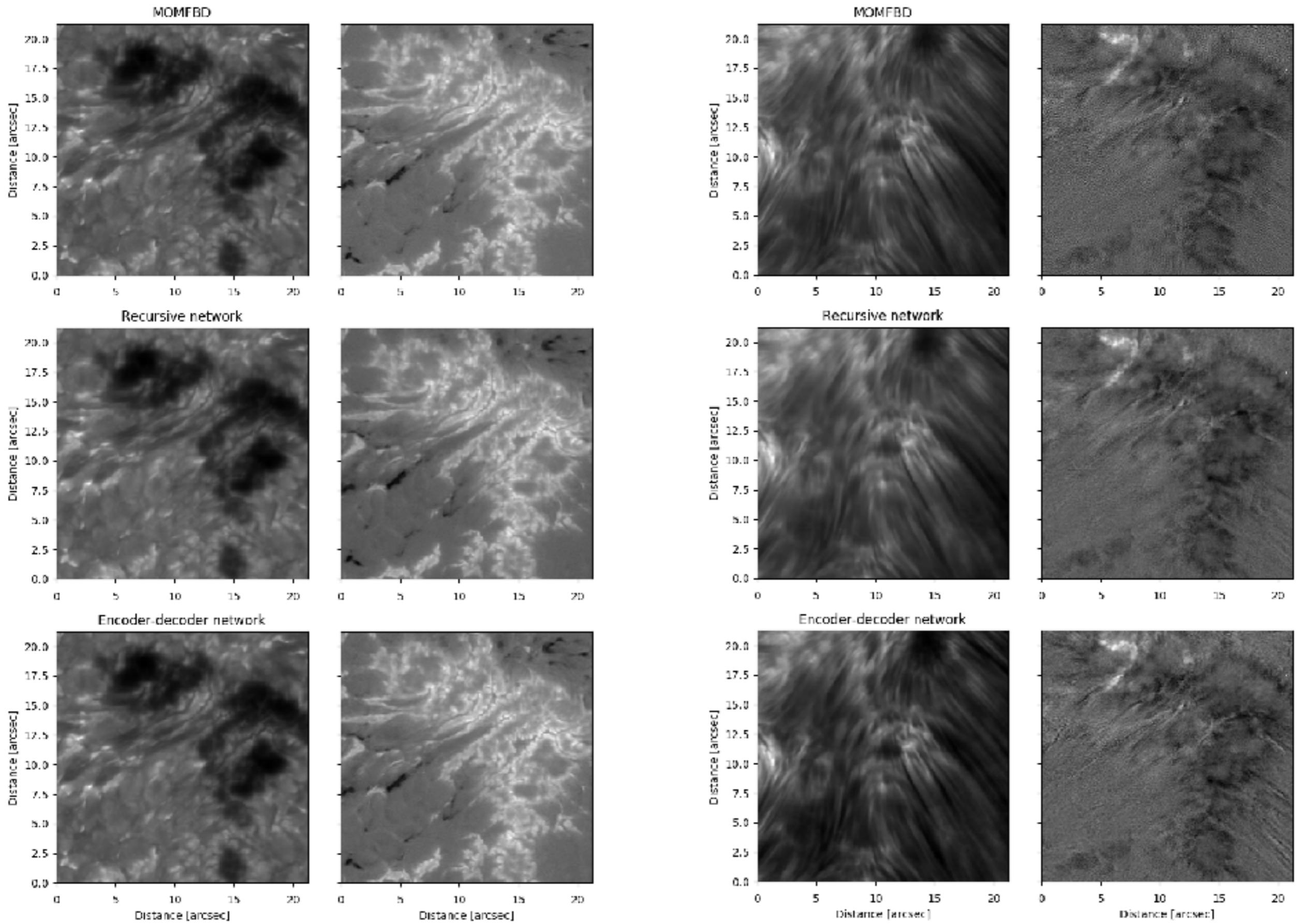
Encoder-decoder



Recurrent

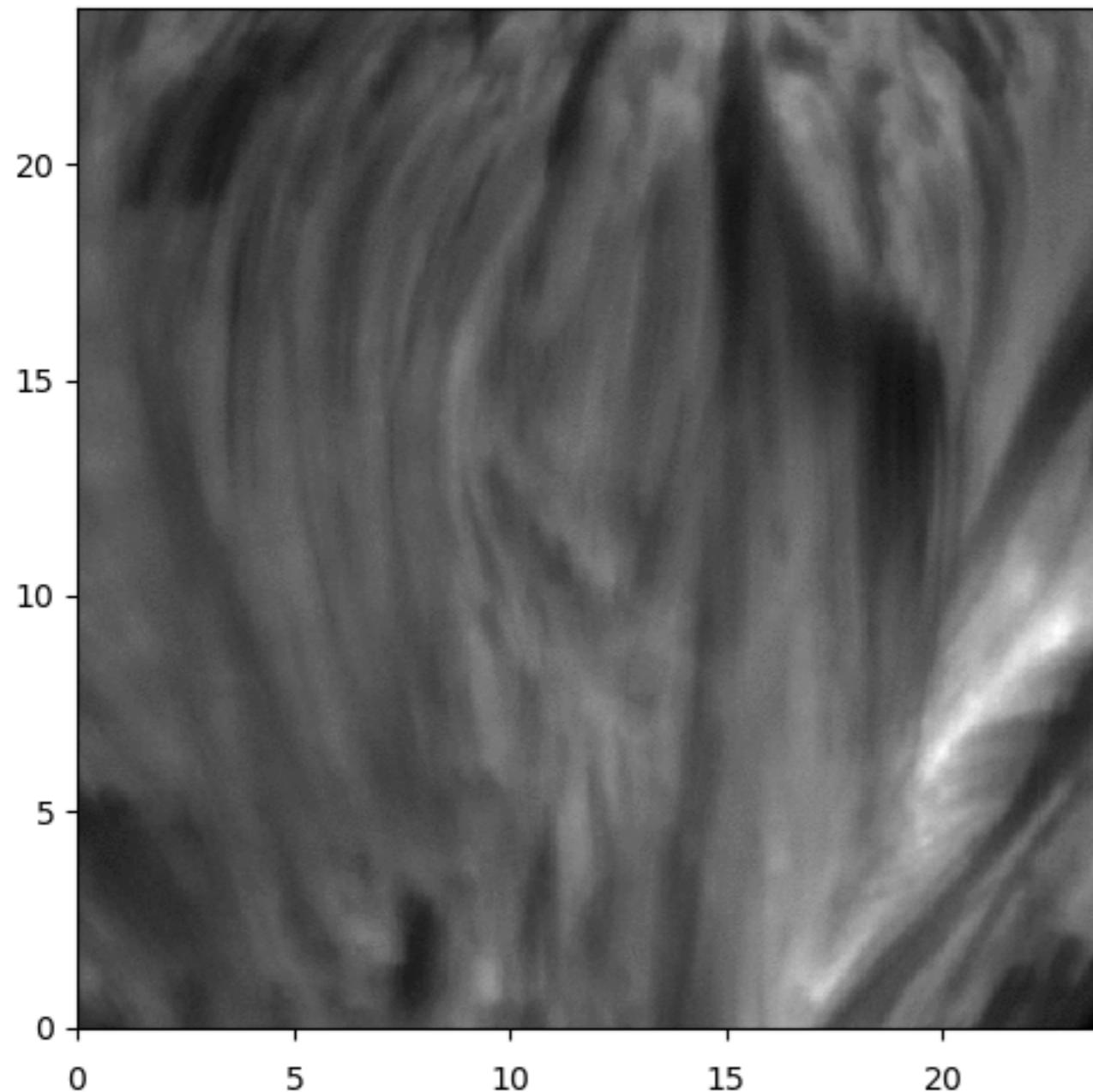


POLARIMETRY

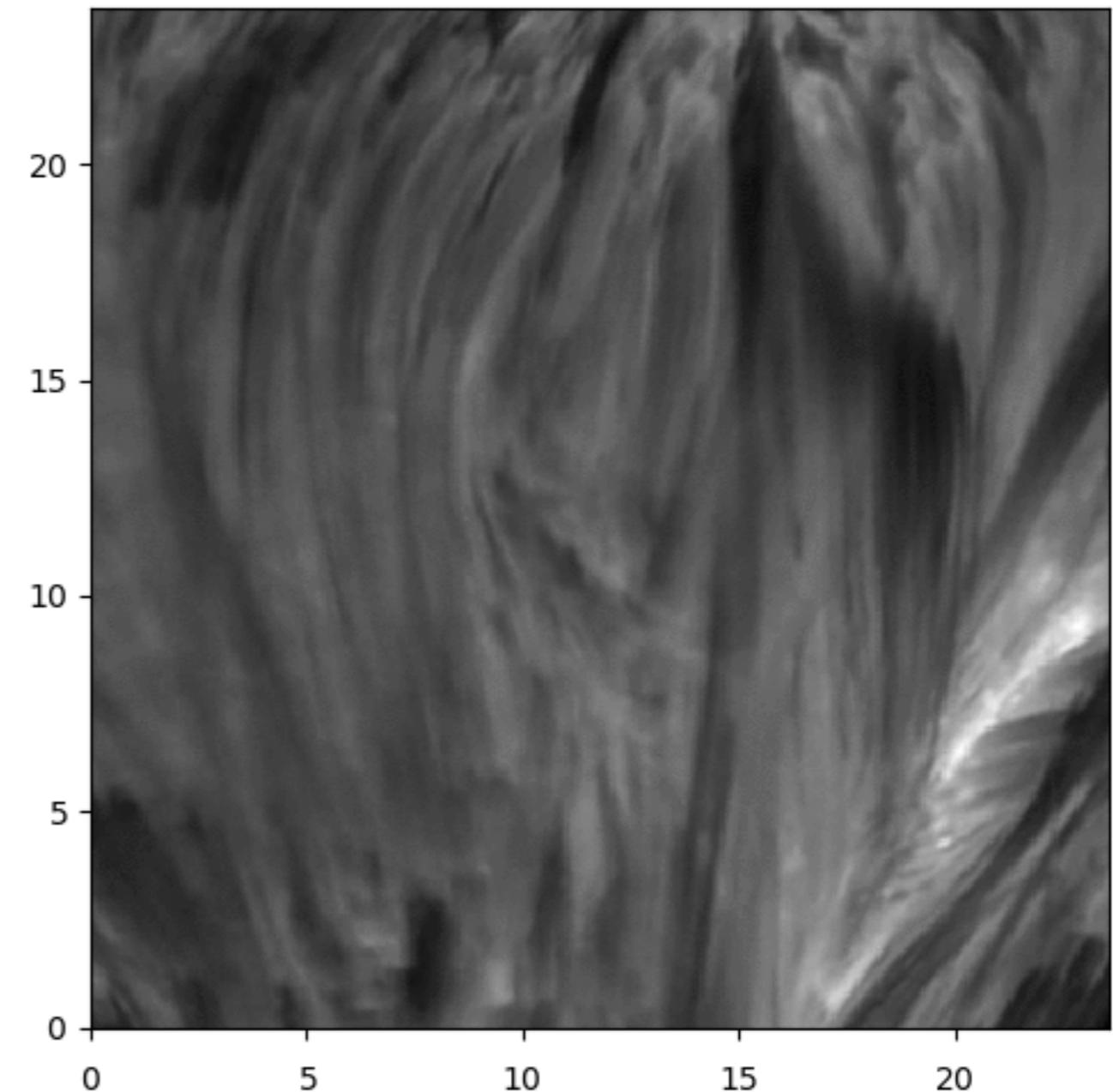


GENERALIZATION TO UNSEEN DATA

Frame



NN



100 images/s

3D inversion of Stokes profiles
with height information

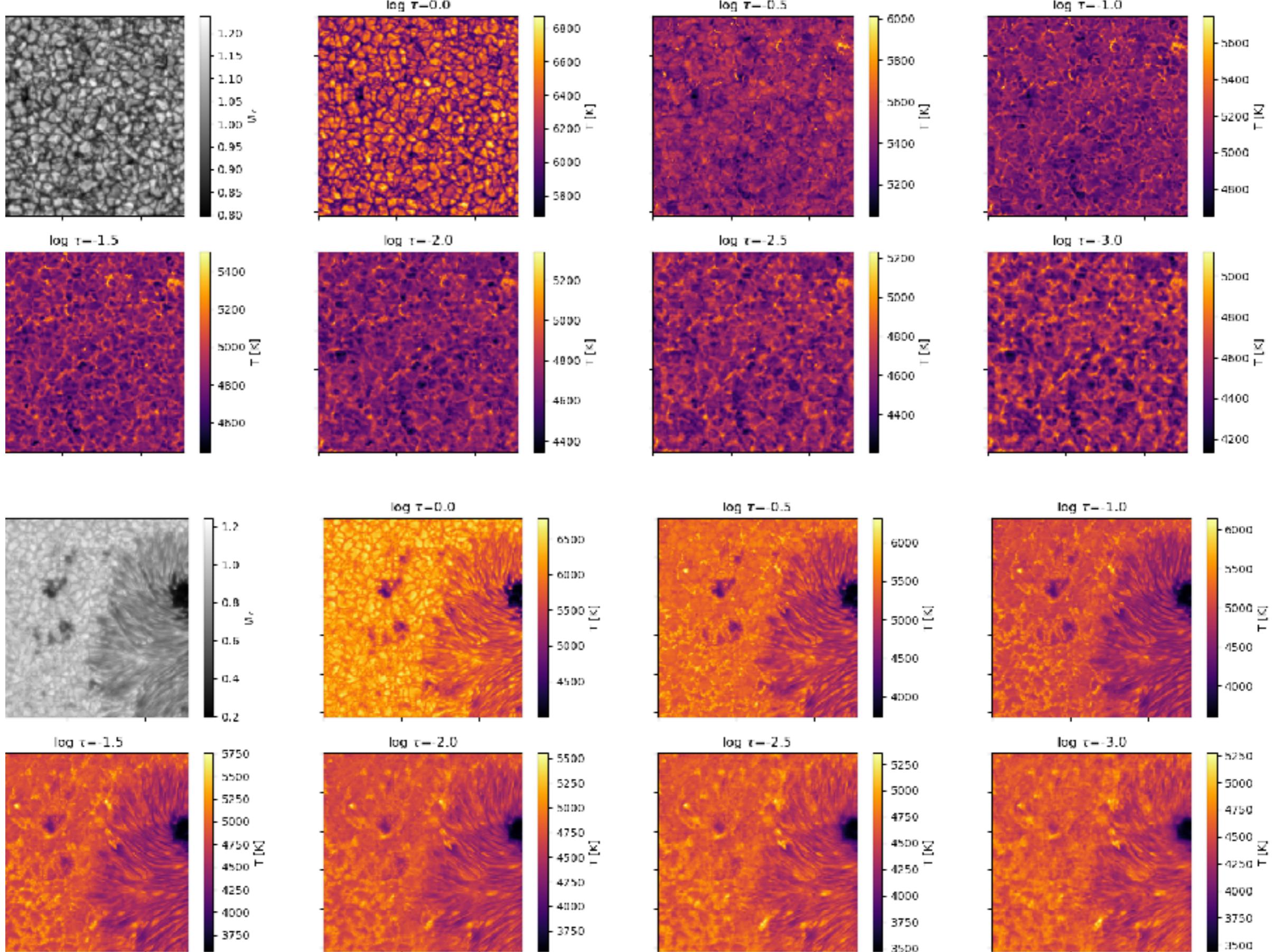
warning: WIP!!

3D INVERSION OF STOKES PROFILES

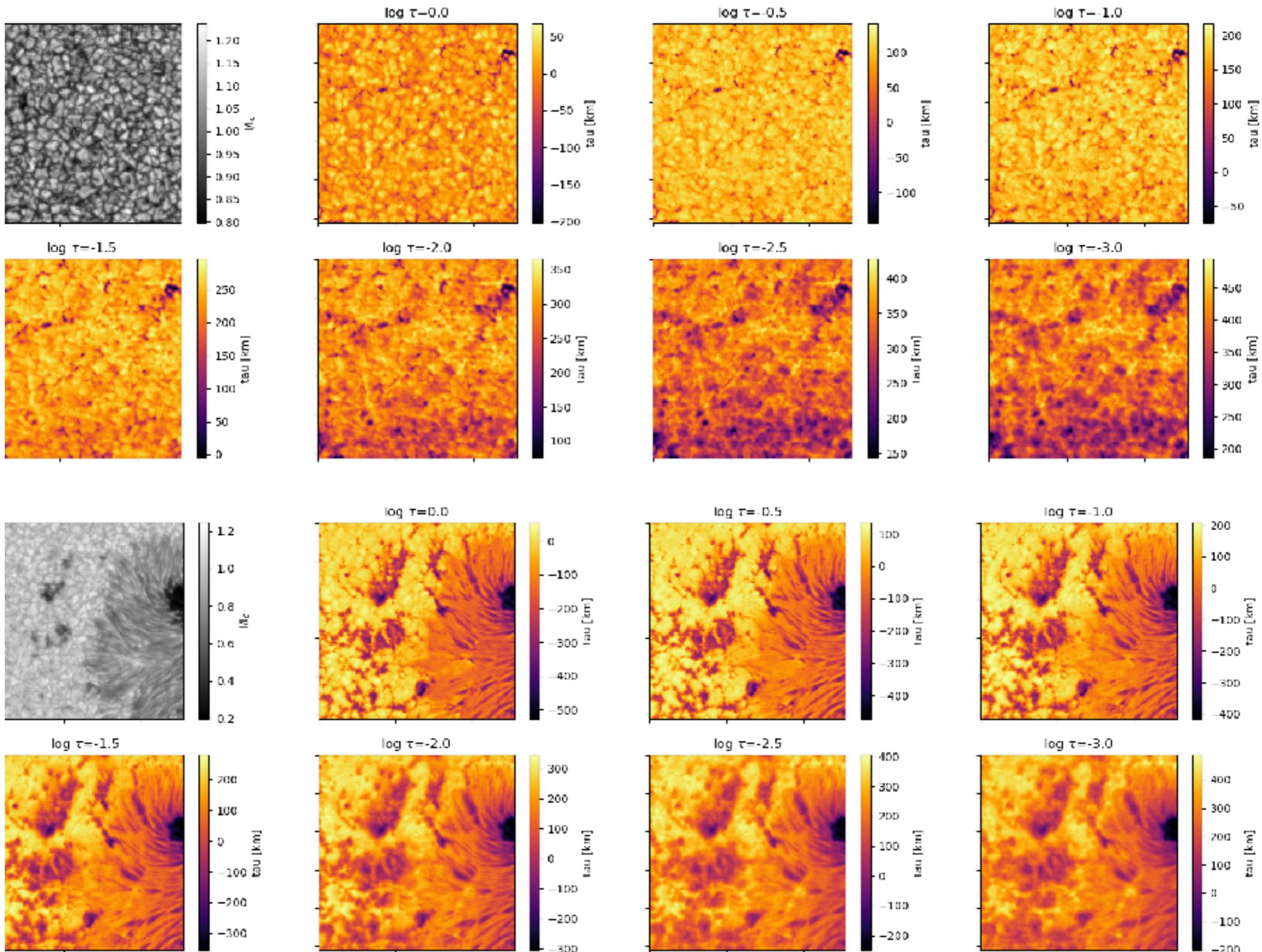


- ▶ Trained on Rempel's 3D MHD magnetoconvection snapshot (still too few)
- ▶ End-to-end deep neural network
- ▶ Severe augmenting during training
- ▶ Still without polarimetry

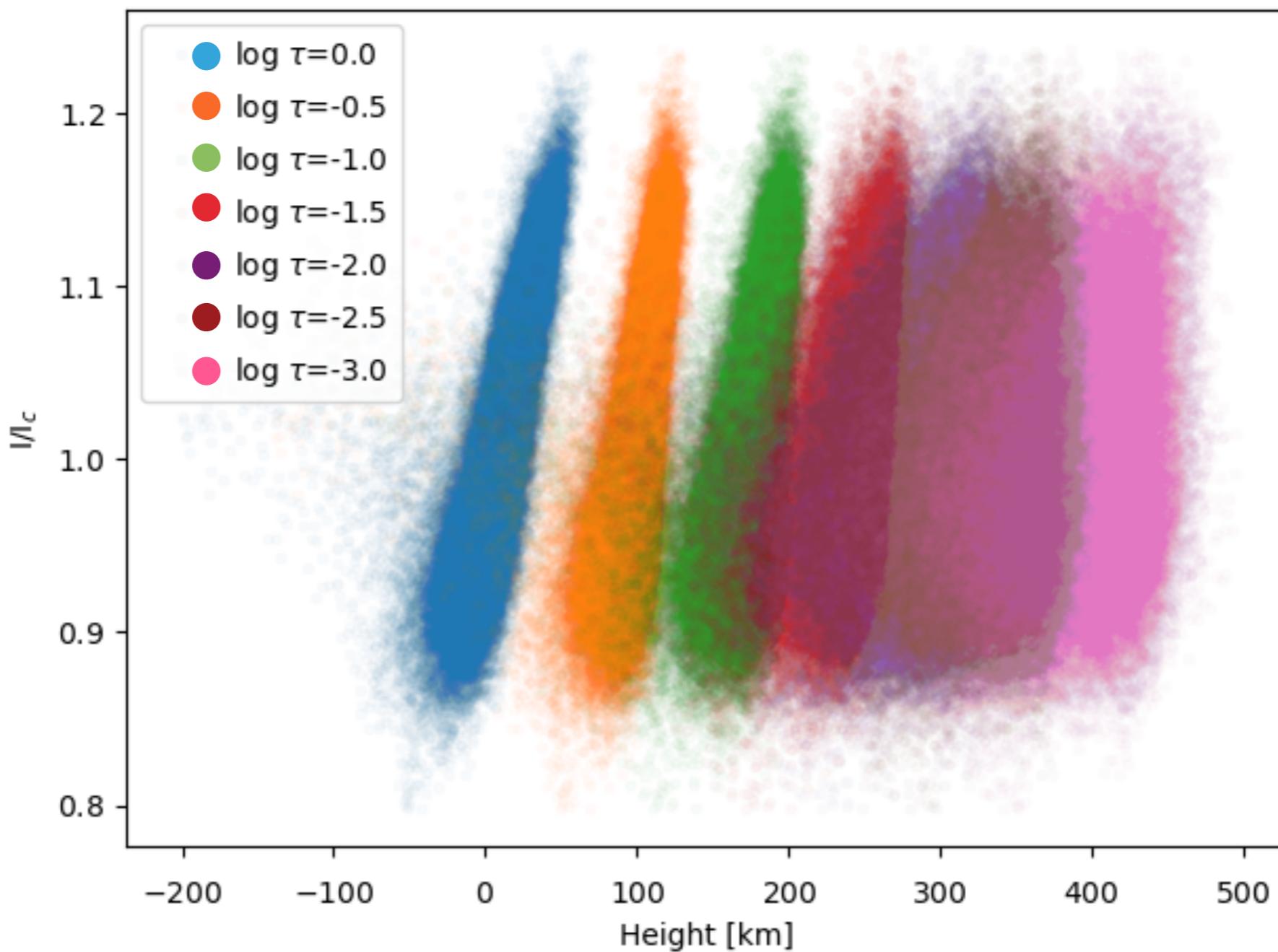
HINODE INVERSION - TEMPERATURE (WIP)



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 IRIIS spectra
 - inversions without response functions
 - ...