An approach using deep learning for tomographic reconstruction in solar observation

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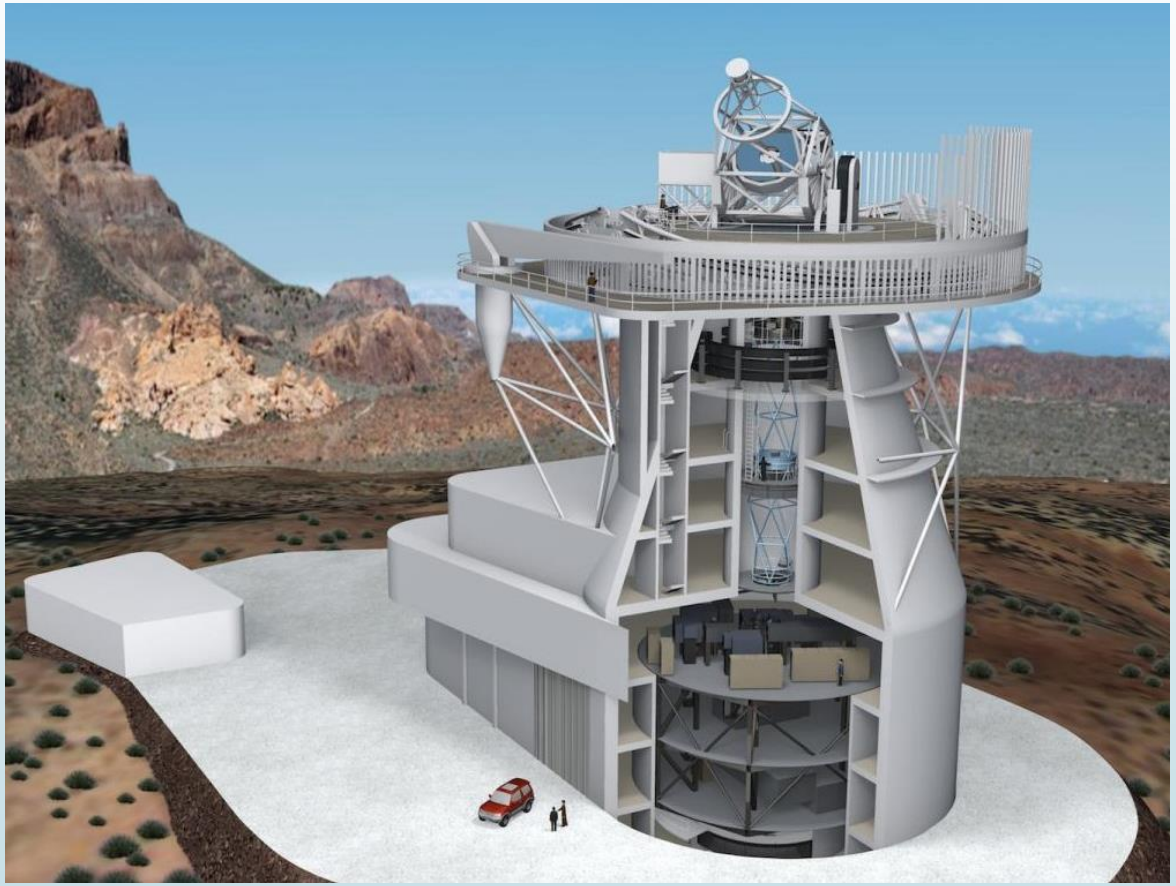
Contents

Solar Adaptive Optics

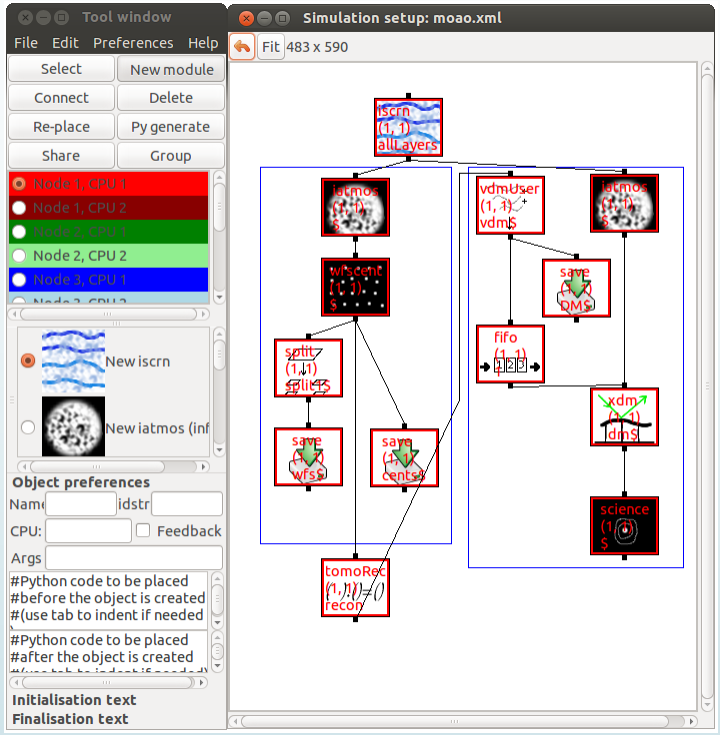
- Some differences with night observation
- Massive object
- Turbulence profile have strong variations during the day

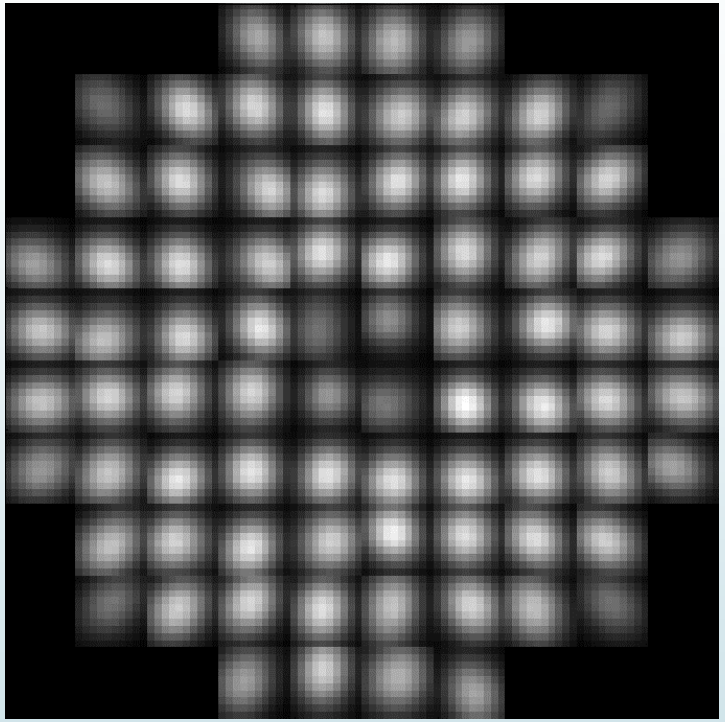


Credit to IAC

Durham AO Simulation Platform (DASP)

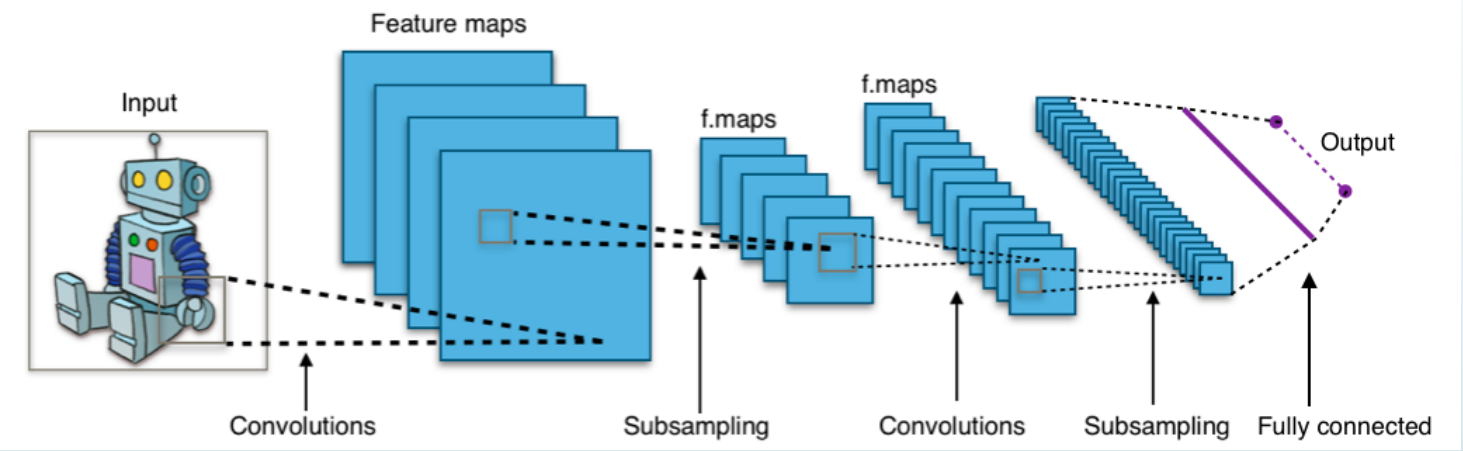
- Open-Source simulator for Adaptive Optics
- Night and Solar modes are available
- Developed in Durham University





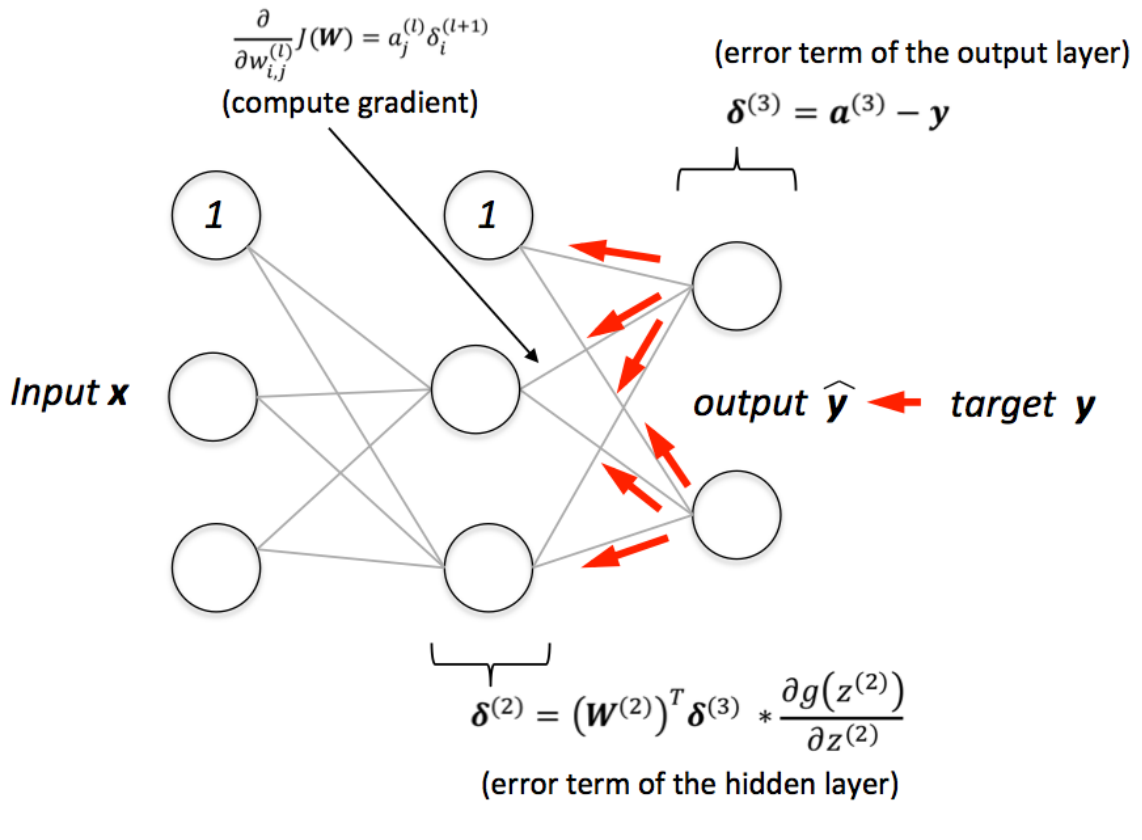
Deep Learning

- Convolutional Neural Networks (CNN)
- Extract features from images, sounds, raw data…
- Usually classifiers, but they can compute any kind of value



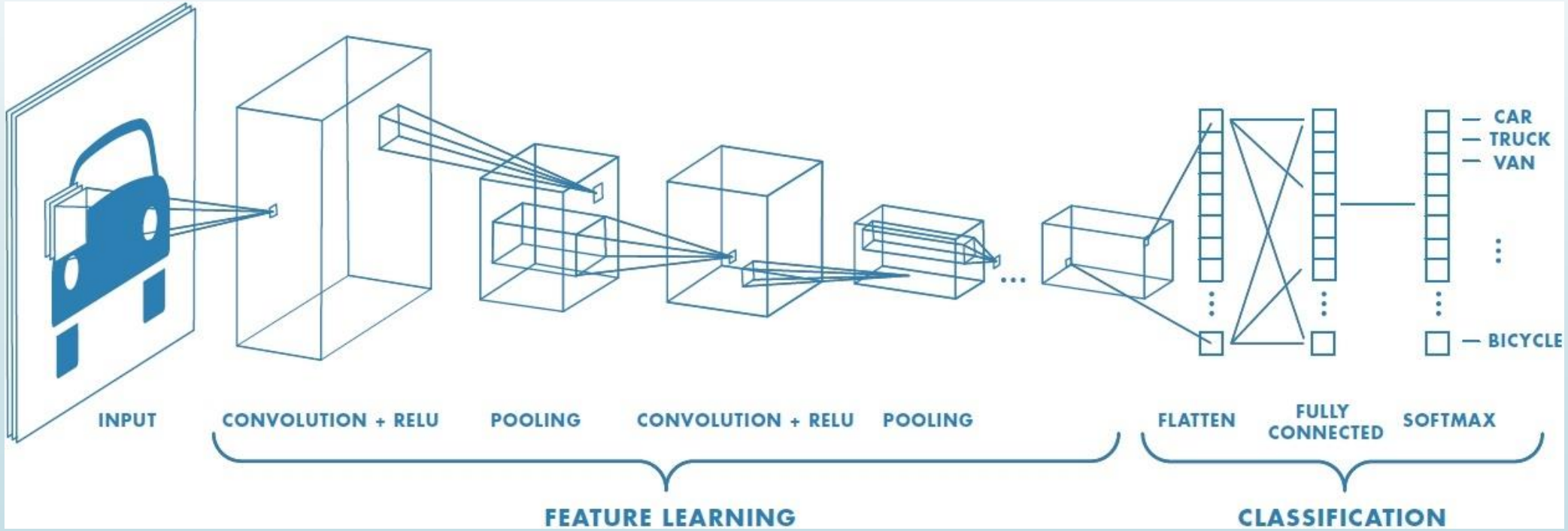
Deep Learning

- Training – Calculate the optim filters and weight values
  - Randomly initialize the values
  - Use known data as input-output to the neural network
  - Compute the output and calculate the error
  - Backpropagate the error through the net
  - Update the weights
  - Repeat!



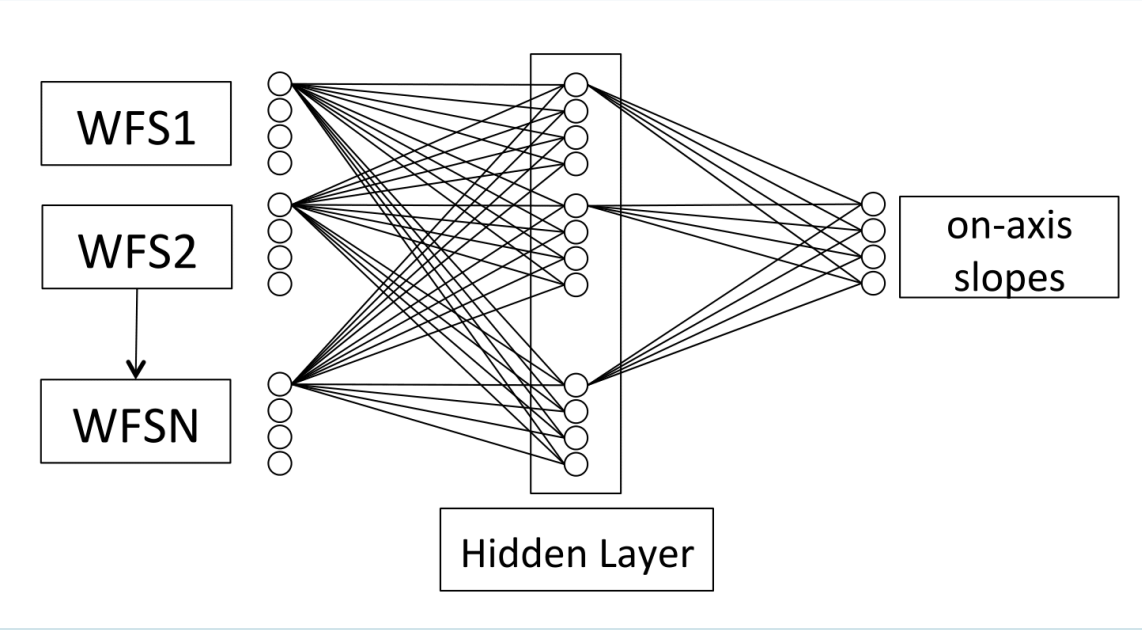
Deep Learning

- Execution – Compute the output
  - Should be really fast – Graphics Processing Units (GPUs)
  - It needs the ability to generalize



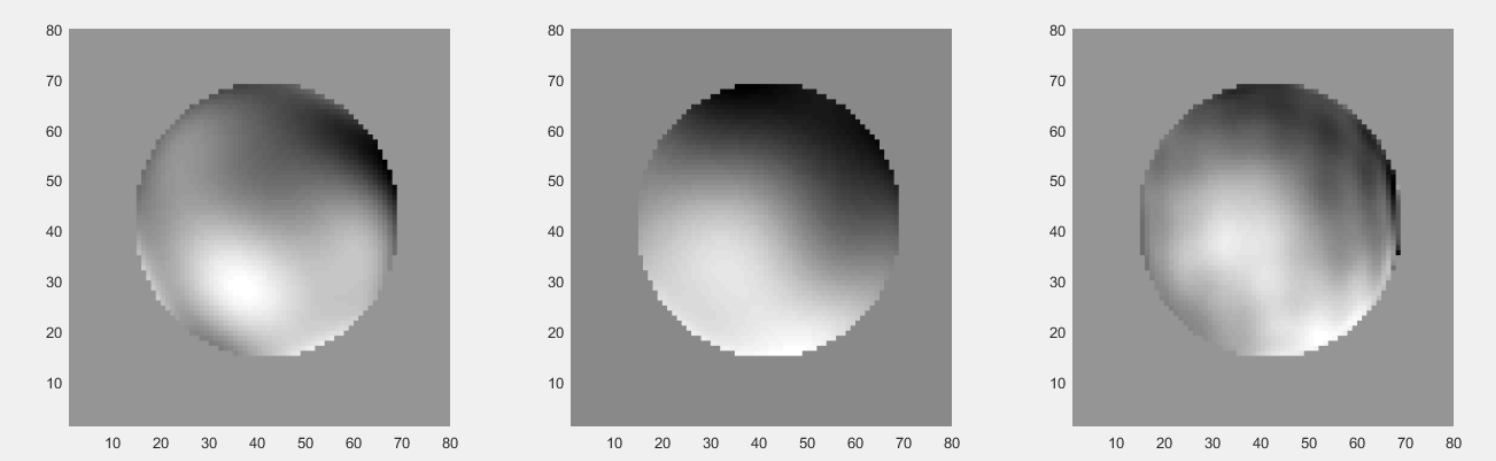
Deep Learning in AO

- Complex Atmospheric Reconstructor based on Machine lEarNing (CARMEN)
- Tomographic reconstructor of atmospheric profiles
- Successfully tested in nocturnal observations
- Osborn J, Guzman D, de Cos Juez FJ, Basden AG, Morris TJ, Gendron E, et al. *Open-loop tomography with artificial neural networks on CANARY: On-sky results*. Mon Not R Astron Soc 2014;441:2508–14.



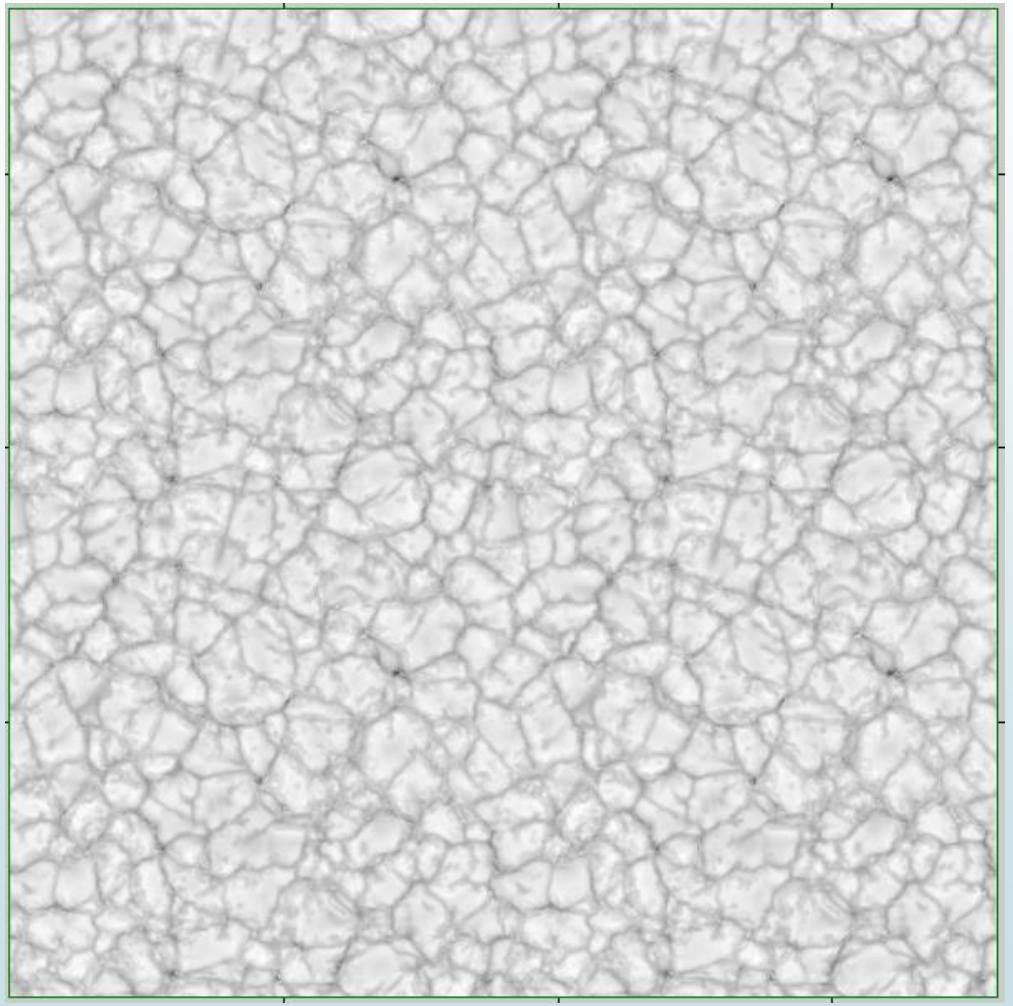
Deep Learning in AO

- Tomographic Pupil Image Wavefront Sensor (TPI-WFS)
- Use images as inputs and calculate Zernike Polynomials
- "New adaptive optics Tomographic Pupil Image reconstructor based on convolutional neural networks" [P3030]



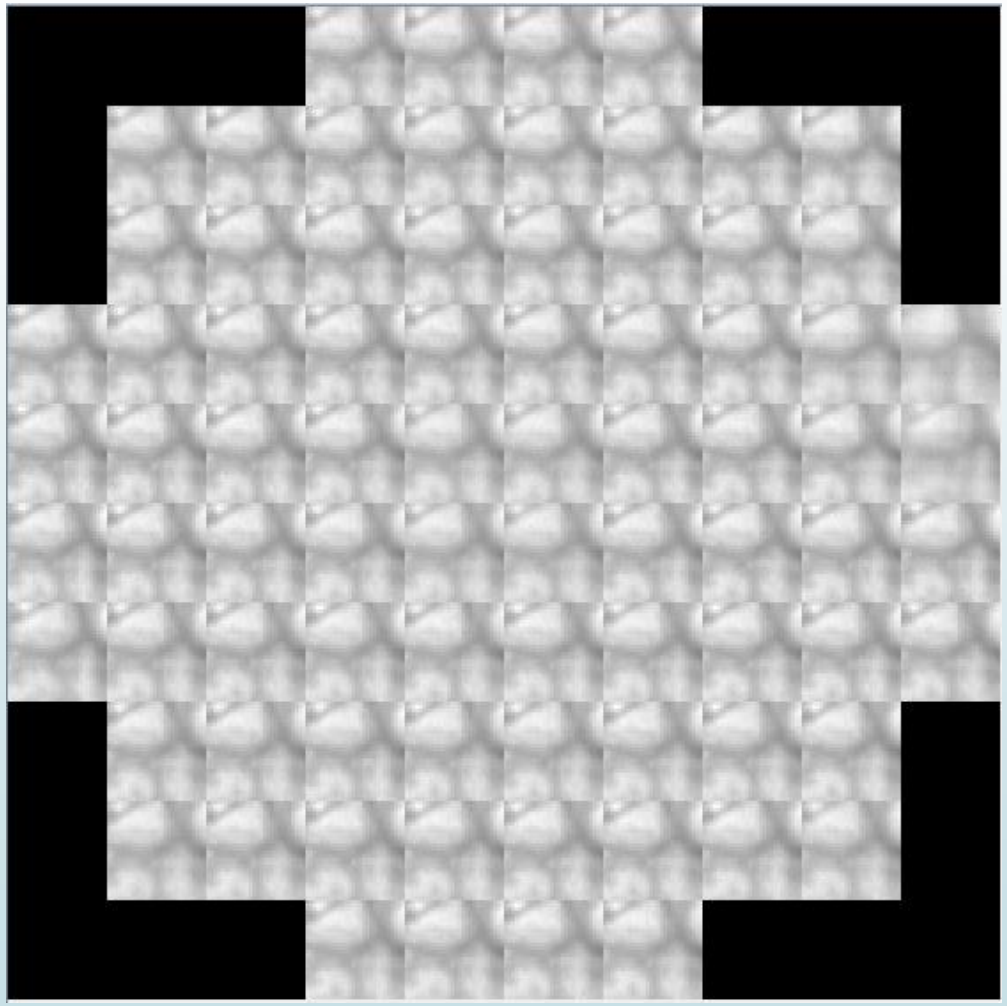
Deep Learning in Solar AO

- "Large" picture of the sun
- Divide the image in small pieces
- Create different turbulence profiles
- Input: Image + Turbulence
- Output:
  - Slopes
  - Deformable mirror actuators



Deep Learning in Solar AO

- First Tests
  - Can not compare with other algorithms (not enough time!)
  - Normalized outputs (-1, 1)
- Shack Hartman images as inputs
- Slopes ~ 25% error
- Deformable mirror actuators ~20% error



Conclusions

- Very early stage of the project
- Promising results
- Deep Learning + Adaptive Optics = Cool combination

Future Lines

- A lot of ideas for testing
- They could be much better
- Recurrent neural networks, on-line training, classifiers…
- Different aplications in astronomy