Reionization Models Classifier using 21cm Maps Deep Learning

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Background credit: M. Alvarez

Adam Lidz view on EoR

Motivations

- Besides the power spectrum, future observations will enable high resolution imaging of the 21cm signal.

- Those images might have more information! than the averaged power spectrum.

- Can we use these images to do model classifications?

Big debate
Galaxies VS AGN

COSMOLOGICAL H II REGIONS AND THE PHOTOIONIZATION OF THE INTERGALACTIC MEDIUM

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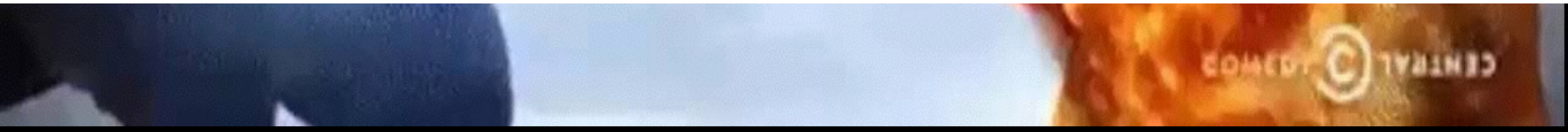
ABSTRACT

The generalization of the classical H II region problem to the case of a point source of ionizing radiation in a cosmologically expanding gas in a Friedmann-Robertson-Walker universe is described. We derive the cosmological generalization of the static Strömgren radius and solve analytically for the time dependence of the radius and peculiar velocity of the ionization front which surrounds each source. An application of this work is described in which is tested the hypothesis that quasars photoionize the IGM to the degree implied by the well-known absence of a Gunn-Peterson effect. Recent studies of faint quasars at high redshift, which suggest a decline in the number density of quasars for $z > 3$, imply that the H II regions of high-redshift quasars cannot overlap early enough to satisfy the Gunn-Peterson test. This suggests that either the observations are failing to detect the true number density of high-redshift quasars or else something else must ionize the IGM at high redshift. An interpretation of the "Lyα forest" in quasar absorption spectra as caused by intergalactic clouds which are highly photoionized by the quasar background radiation leads to a similar conclusion.

Subject headings: cosmology — galaxies: intergalactic medium — nebulae: H II regions — quasars



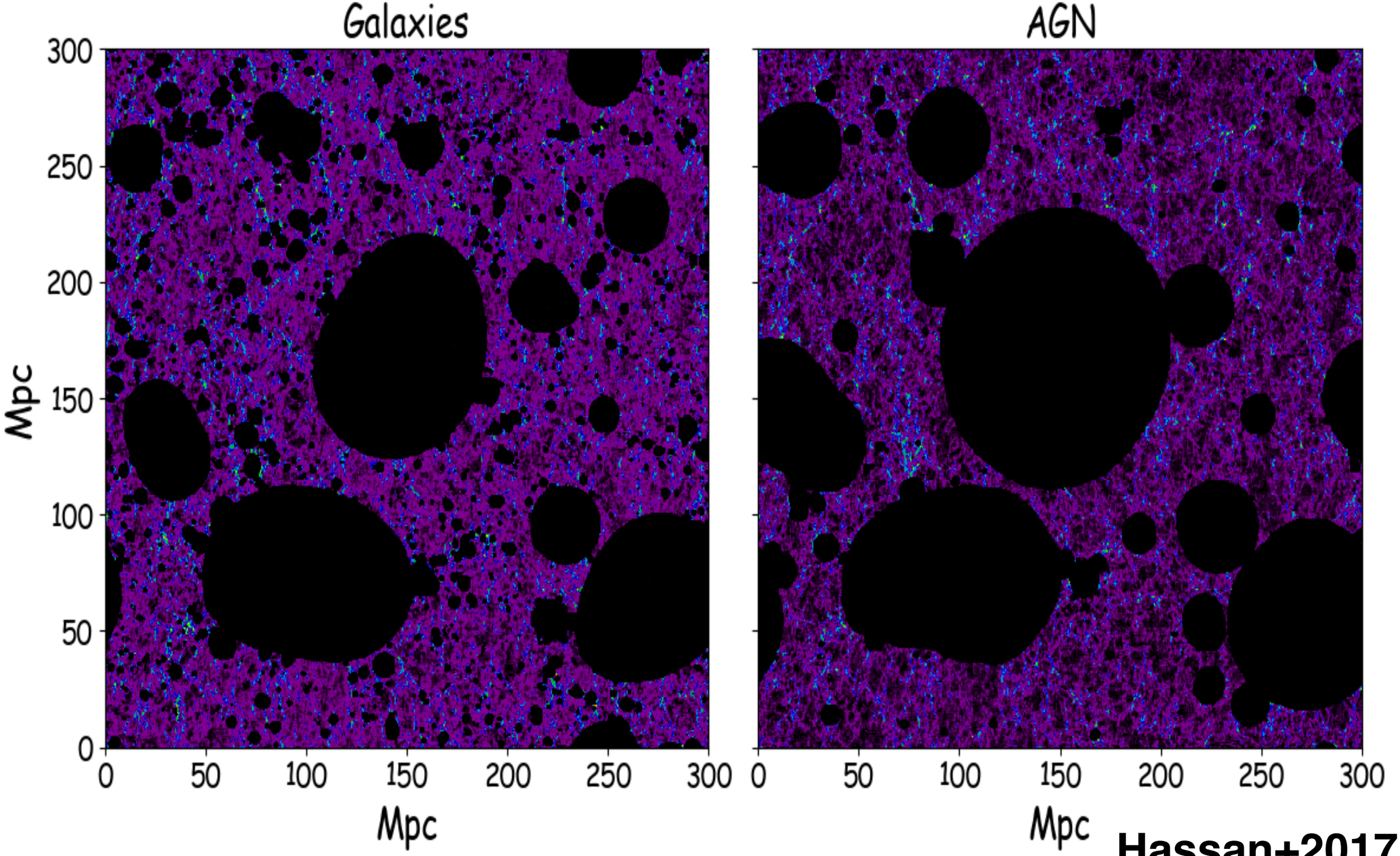
Semi-numerical models (SimFast21, Santos+2010)

- Galaxies: Star formation rate proportional to the halo mass ($M_h \sim SFR \sim L$).
  Parameterized as: $N_{ion} \sim f_{esc,gal}\ A\ M_h^{\ C}$.

- AGN: Black hole mass is strongly correlated to circular velocity of the hosting halo ($Vc \sim M_{BH} \sim L$).
  Parameterized as: $N_{ion} \sim f_{esc,agn}\ A\ M_{BH}^{\ C}$.

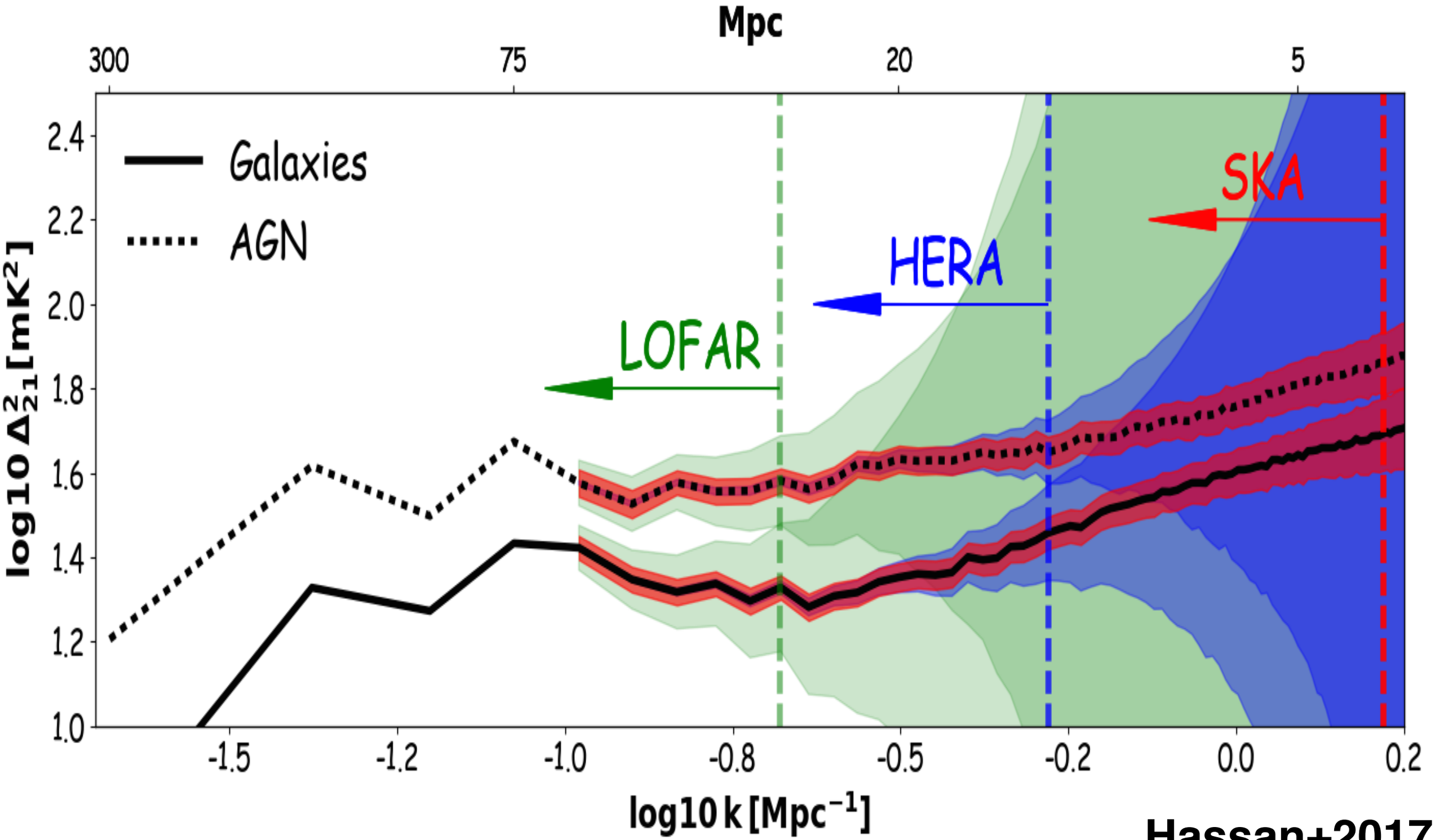
Hassan+2016;2017

21cm maps



Hassan+2017

Mock 21cm observations using 21cmSense (Pober+2013;2014)



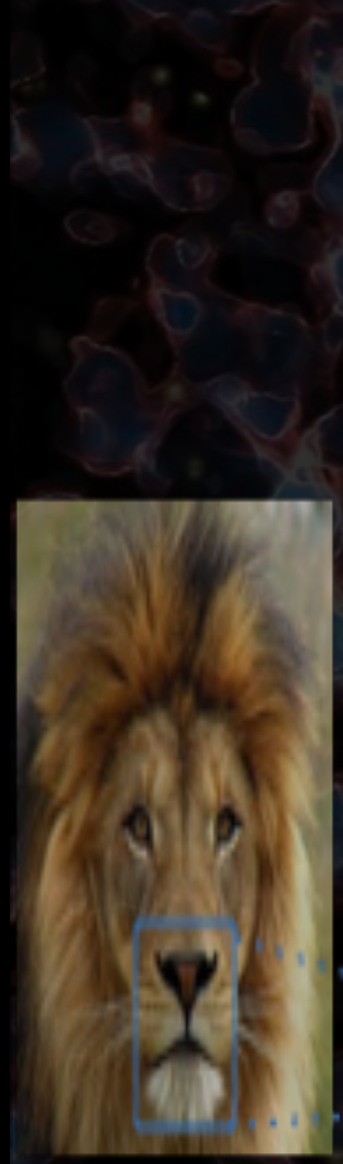
Hassan+2017

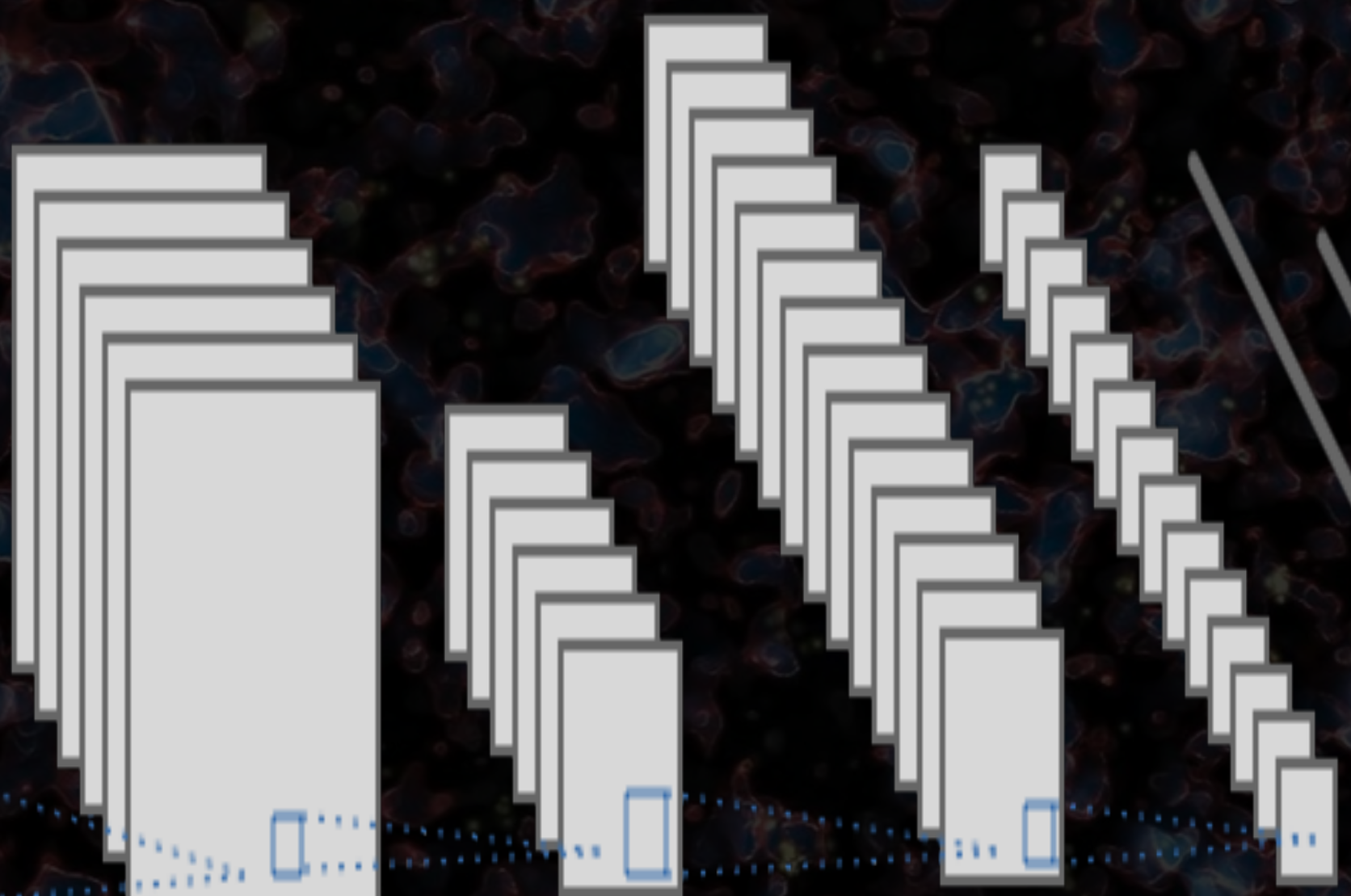
Machine Learning

- Sample: generate ~1000 maps for each model across all redshifts with different neutral fractions (Same density for now!).
- Training with 90% and testing with 10% of the sample.
- Network architecture: Convolutional Neural Network. Layers with 2D batches of neurons.
- Implementation with

Hassan + in prep.

Convolutional Neural Network





Input

Convolution + ReLU

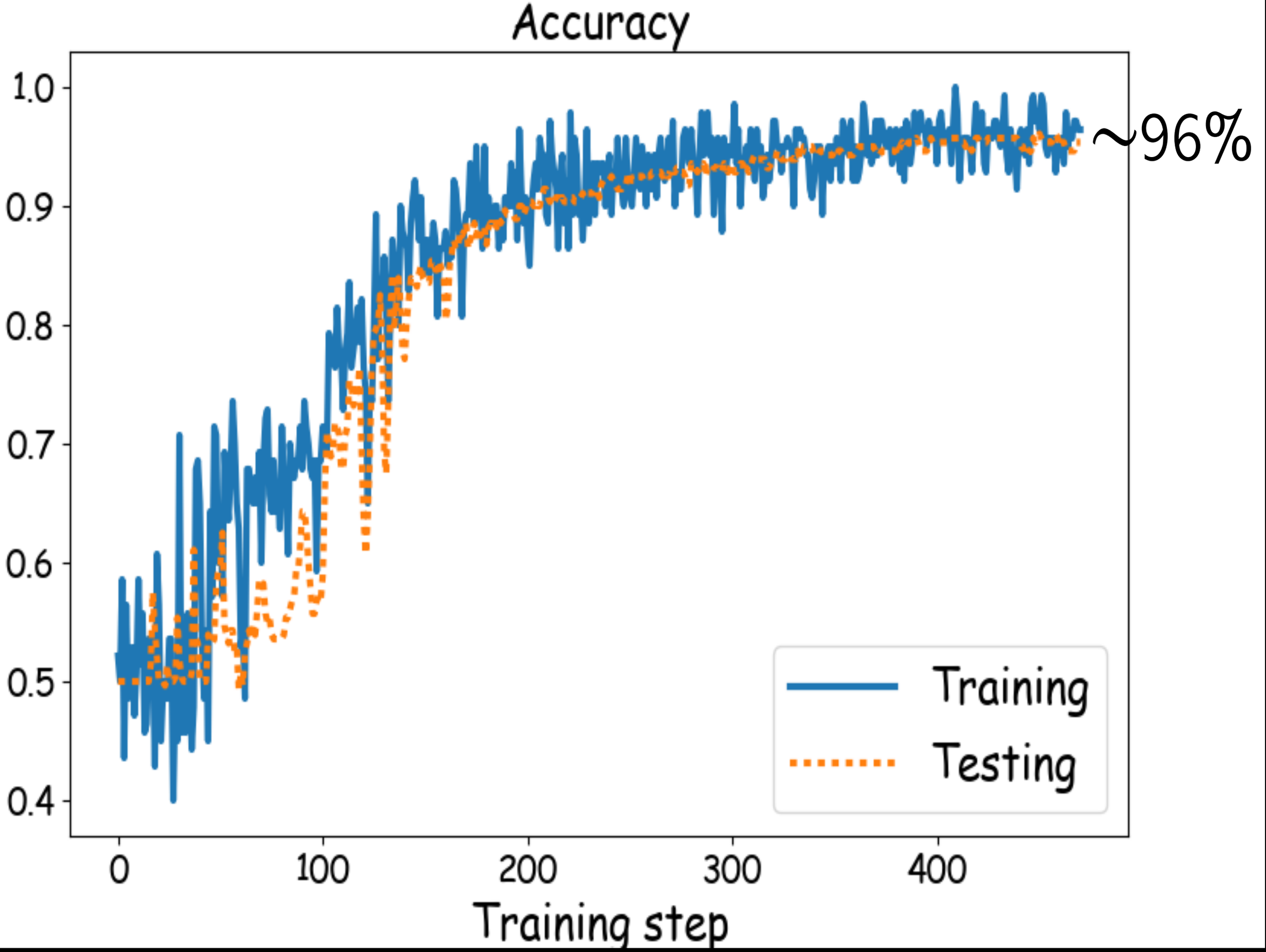
Pooling

Convolution + ReLU

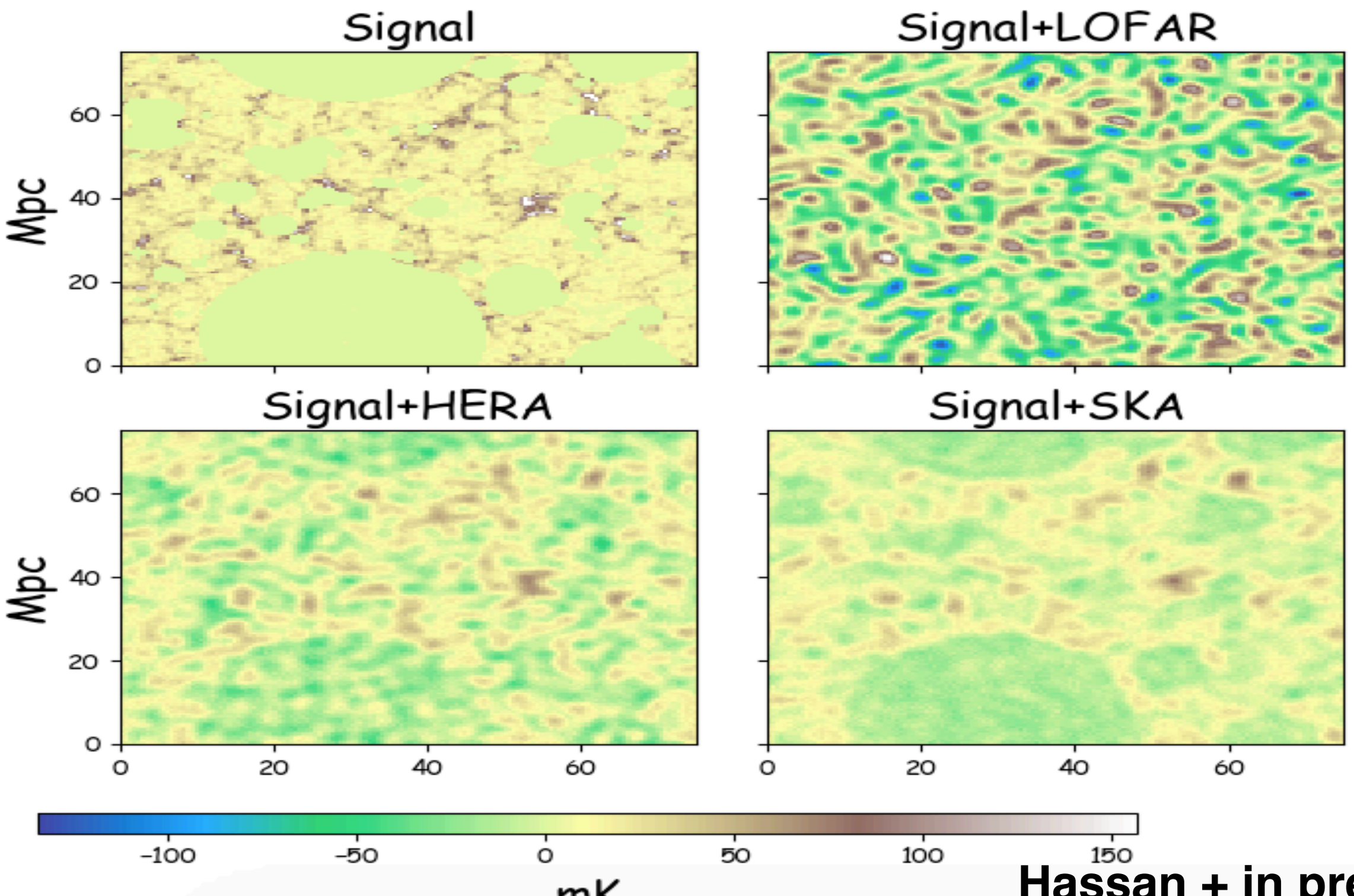
Pooling

Fully Connected

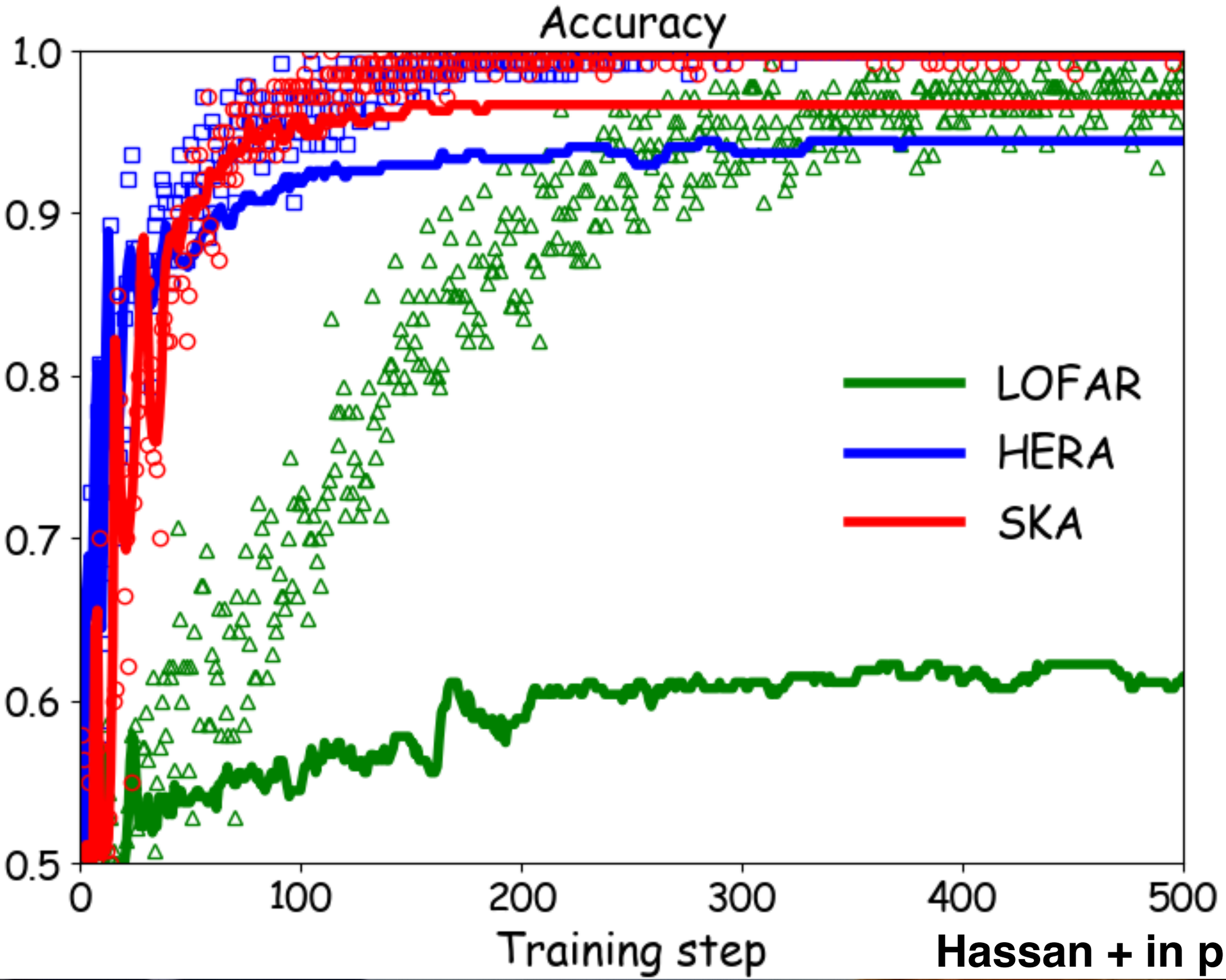
https://shafeentejani.github.io


Accuracy
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0
100
200
300
400
Training step
Training
Testing
~96%

Add noise from experiments using 21cmSense (Pober+2013;2014)

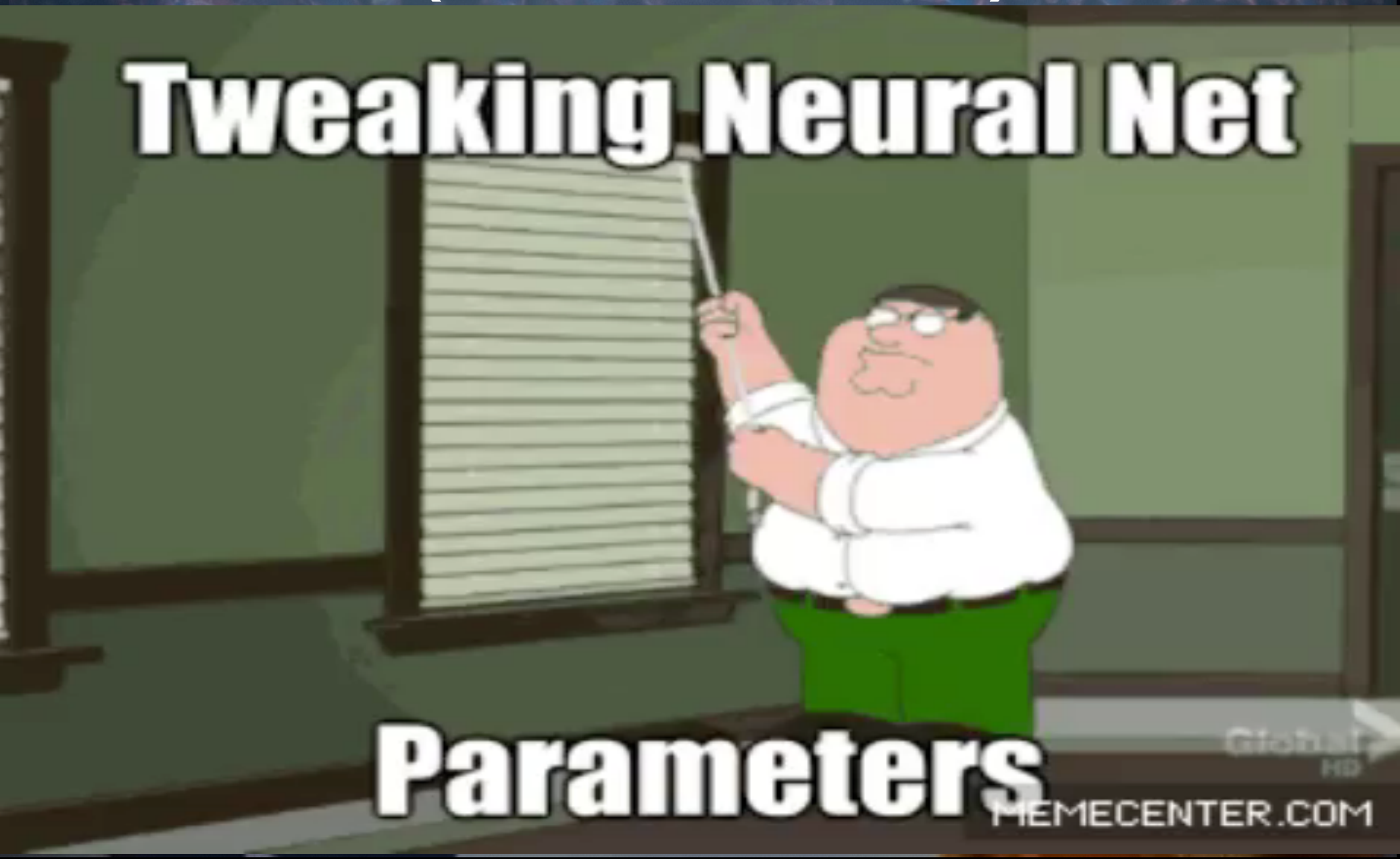


Hassan + in prep.



Hassan + in prep.

For LOFAR and different density (different seed)



Takeaway

- Simple networks can definitely discriminate between different EoR models even with noise added from different experiments.

- SKA and HERA noise don't affect training nor testing accuracy while more complex network is needed to improve classifying with the strong noise from LOFAR (more data, more/less layers, more/less neurons, ..etc).

- Besides power spectra, such a network can be used to constrain the contribution of different ionizing source populations to cosmic reionization using future 21cm maps.