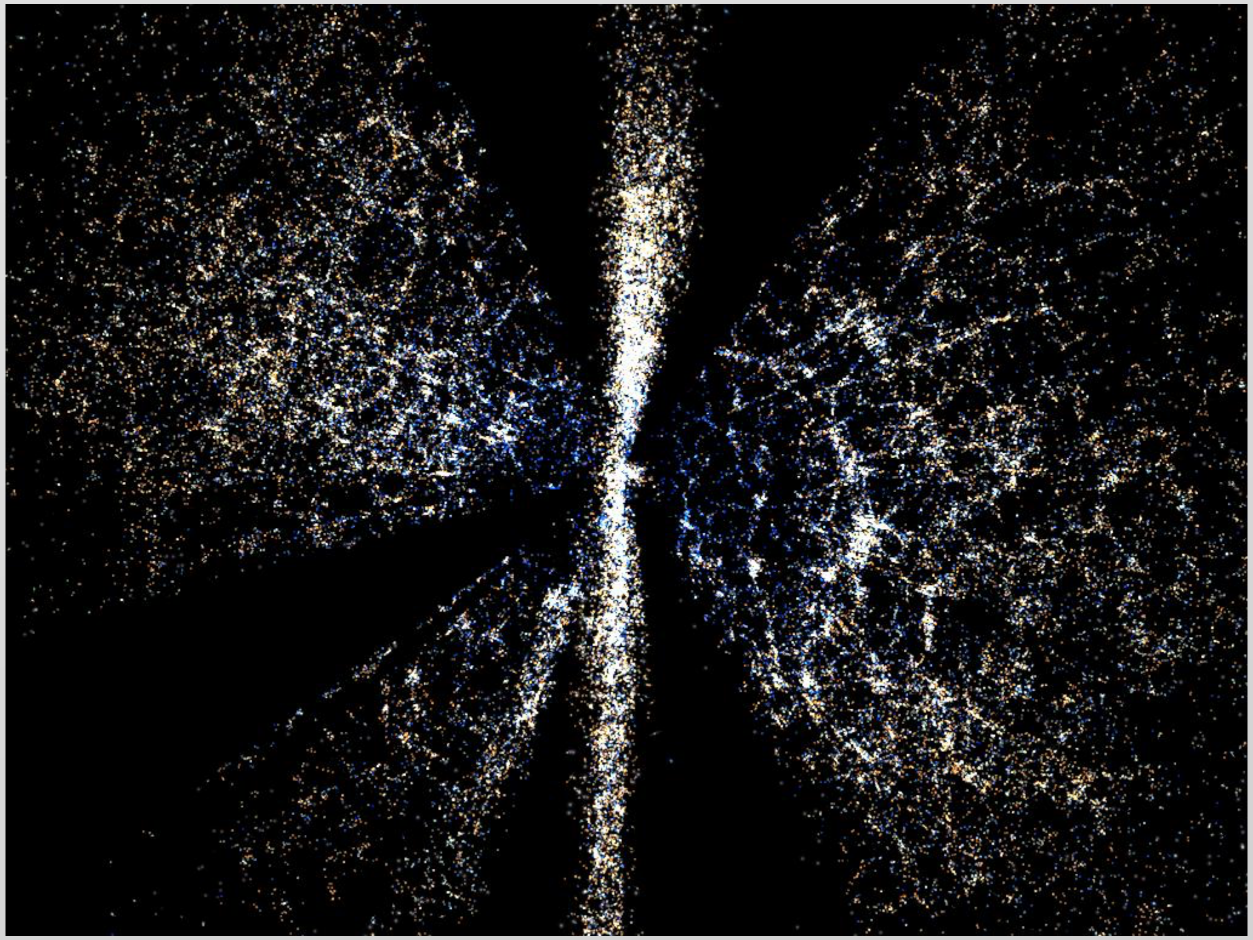
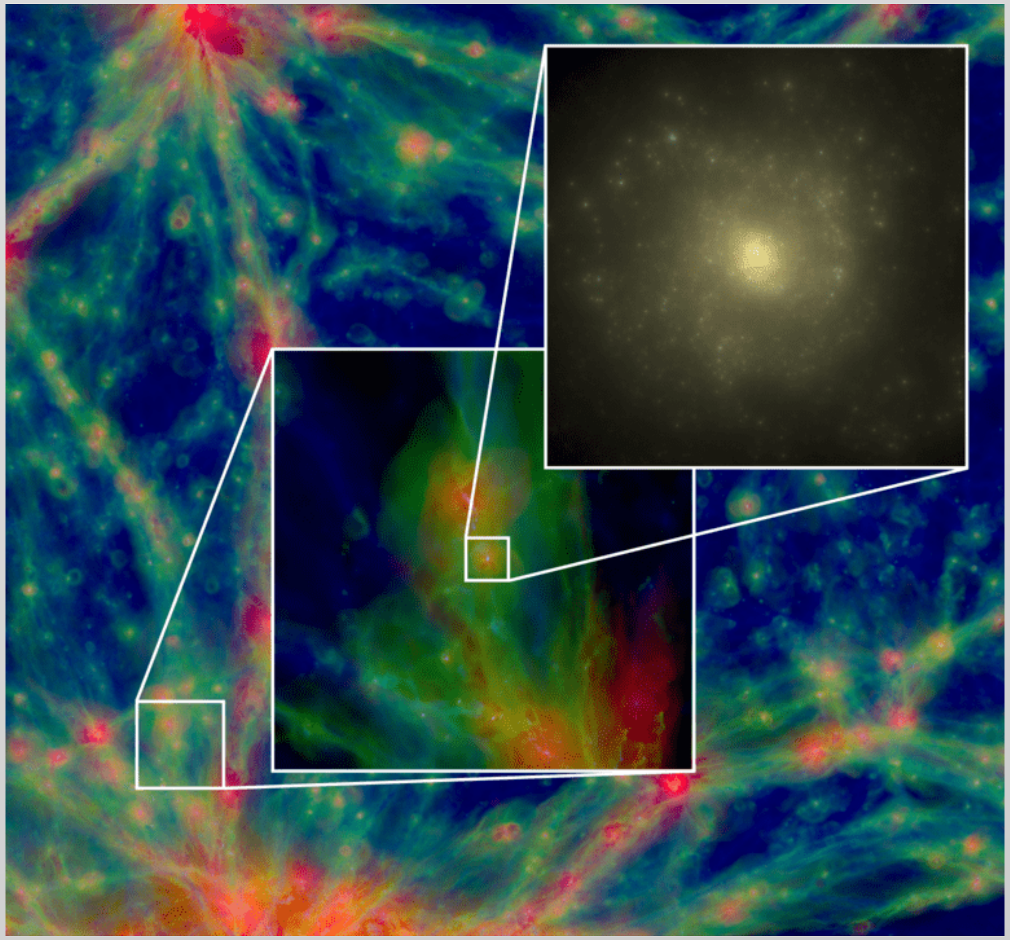
I
AI in the data era

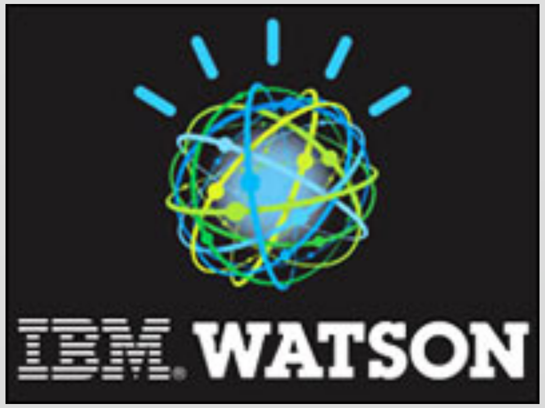
Astronomy in the data era



SDSS



Eagle simulation


IBM. WATSON


Hi, I'm Cortana.


Phone
Mail
What can I help you with?

Radio frequency interference mitigation using deep convolutional neural networks

Joël Akeret[a,*], Chihway Chang[a], Aurelien Lucchi[b], Alexandre Refregier[a]

Measuring photometric redshifts using galaxy images and Deep Neural Networks

Ben Hoyle

Automated Distant Galaxy Merger Classifications from Space Telescope Images using the Illustris Simulation

Gregory F. Snyder[1], Vicente Rodriguez-Gomez[2], Jennifer M. Lotz[1], Paul Torrey[3,4], Amanda C.N. Quirk[1,5], Lars Hernquist[6], Mark Vogelsberger[3], Peter E. Freeman[7]
[1] *Space Telescope Science Institute, 3700 San Martin Dr, Baltimore, MD 21218*
[2] *Department of Physics & Astronomy, Johns Hopkins University, 3400 N Charles St, Baltimore, MD 21218, USA*
[3] *Department of Physics, Kavli Institute for Astrophysics & Space Research, Massachusetts Institute of Technology, Cambridge, MA, 02139, U*
[4] *Department of Astronomy, University of Florida, 211 Bryant Space Science Center, Gainesville, FL, 32611, USA*
[5] *Department of Astronomy & Astrophysics, UC Santa Cruz, 1156 High St, Santa Cruz, CA 95064*
[6] *Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA, 02138, USA*
[7] *Department of Statistics, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA*

Quasar microlensing light curve analysis using deep machine learning

Georgios Vernardos,[1★] and Grigorios Tsagkatakis[2]
[1] *Kapteyn Astronomical Institute, University of Groningen, PO Box 800, NL-9700AV Groningen, the Netherlands*
[2] *Institute of Computer Science - Foundation for Research and Technology (FORTH), GR-71110, Heraklion, Greece*

CLASSIFYING RADIO GALAXIES WITH CONVOLUTIONAL NEURAL NETWORK

A. K. Aniyan
Department of Physics and Electronics, Rhodes University, Grahamstown, South Africa
and
SKA South Africa, 3^{rd} Floor, The Park, Cape Town, South Africa

K.Thorat
Department of Physics and Electronics, Rhodes Unive
and
SKA South Africa, 3^{rd} Floor, The Park, C

Forging new worlds: high-resolution synthetic galaxies with chained generative adversarial networks

Levi Fussell,[1★] Ben Moews,[2]
[1] *Institute of Perception, Action and Behaviour, University of Edinburgh, 10 Crichton St, Edinburgh EH8 9AB, UK*
[2] *Institute for Astronomy, University of Edinburgh, Royal Observatory, Edinburgh EH9 3HJ, UK*

Radio frequency interference mitigation using deep convolutional neural networks

Joël Akeret[a,*], Chihway Chang[a], Aurelien Lucchi[b], Alexandre Refregier[a]

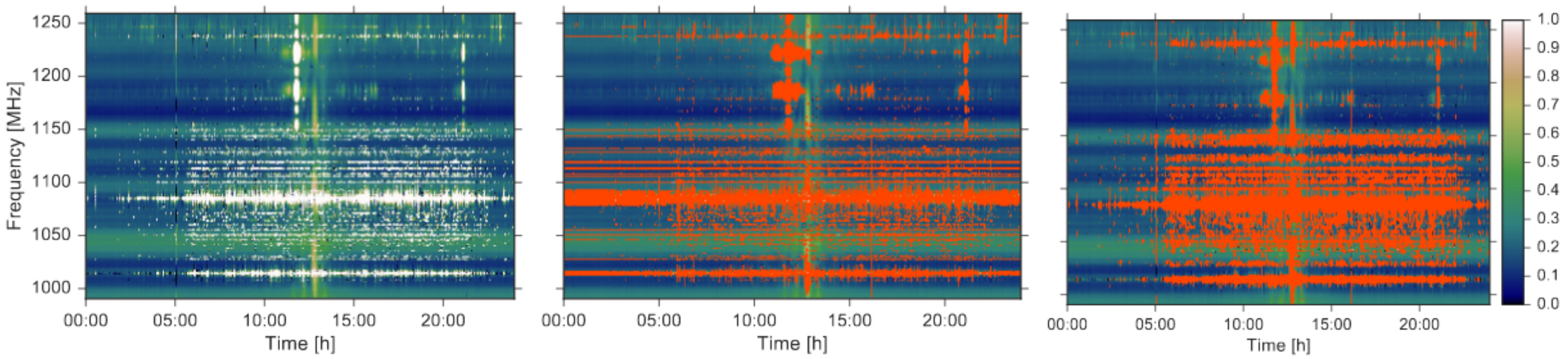
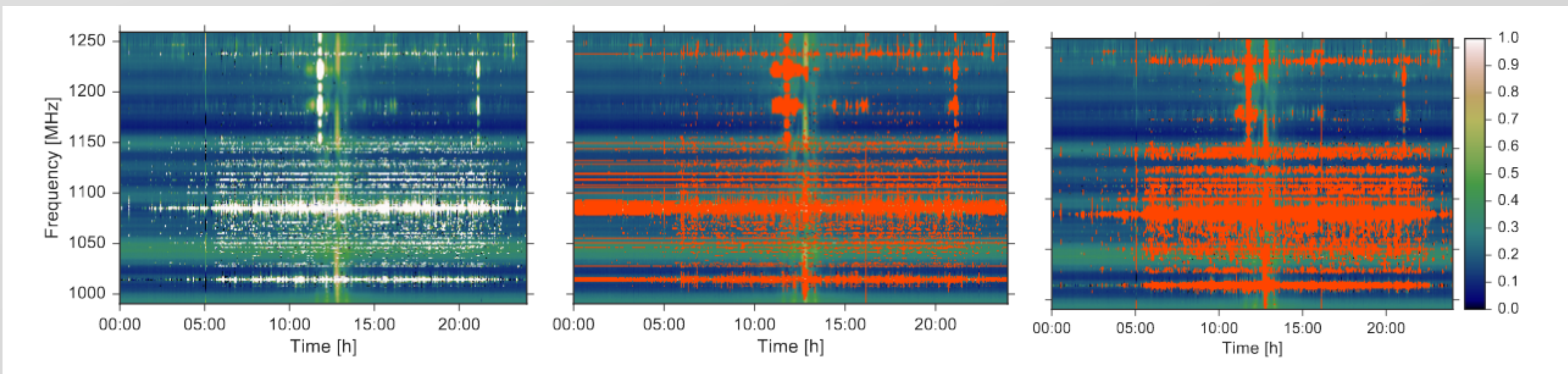


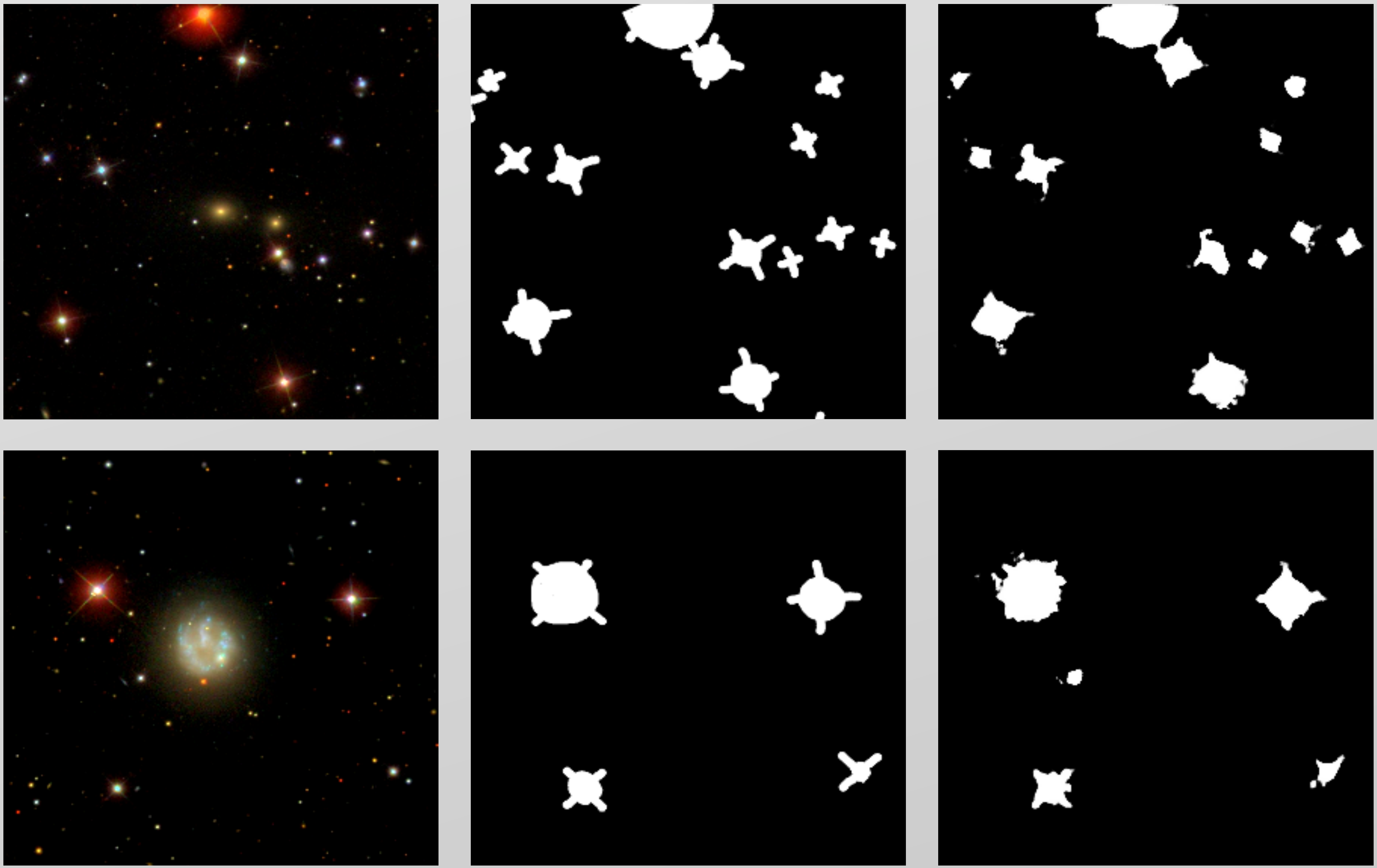
Figure 2: The left panel displays 24 hours of observed TOD from the Bleien Observatory. The broadband RFI contamination mainly comes from the nearby airport and is visible in the 1025–1150 MHz frequency band. The TOD also demonstrates the variation in the RFI level between day and night as the amount of RFI clearly increased at around 6:00 am and decreased at 11:00 pm. The central panel shows the same TOD overlaid (orange) with the RFI mask obtained from `SEEK`'s SumThreshold. The right panel displays the RFI mask from our `U-Net` with 3 layers and 64 features.

Radio frequency interference mitigation using deep convolutional neural networks

Joël Akeret[a,*], Chihway Chang[a], Aurelien Lucchi[b], Alexandre Refregier[a]

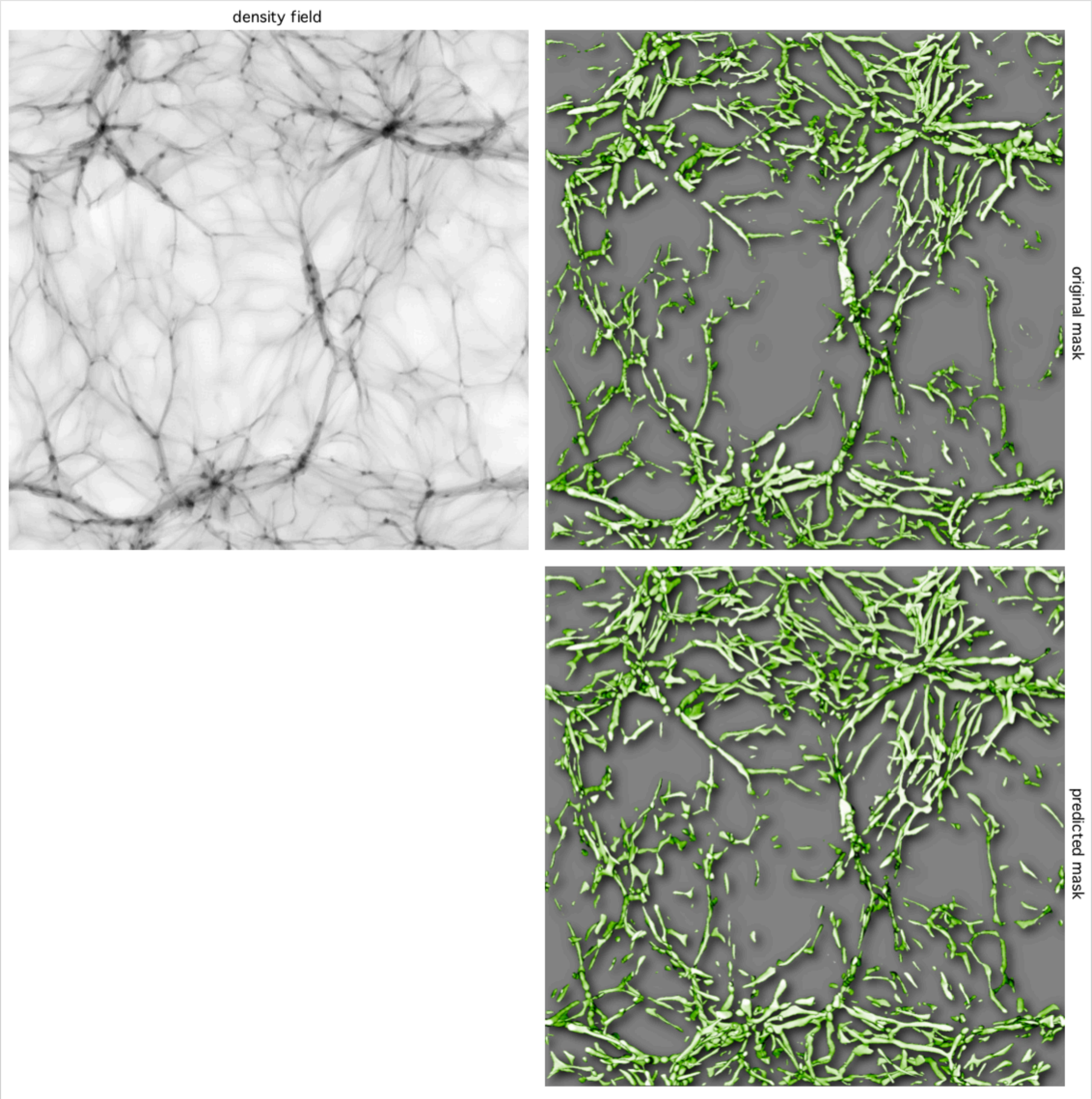


Star masking



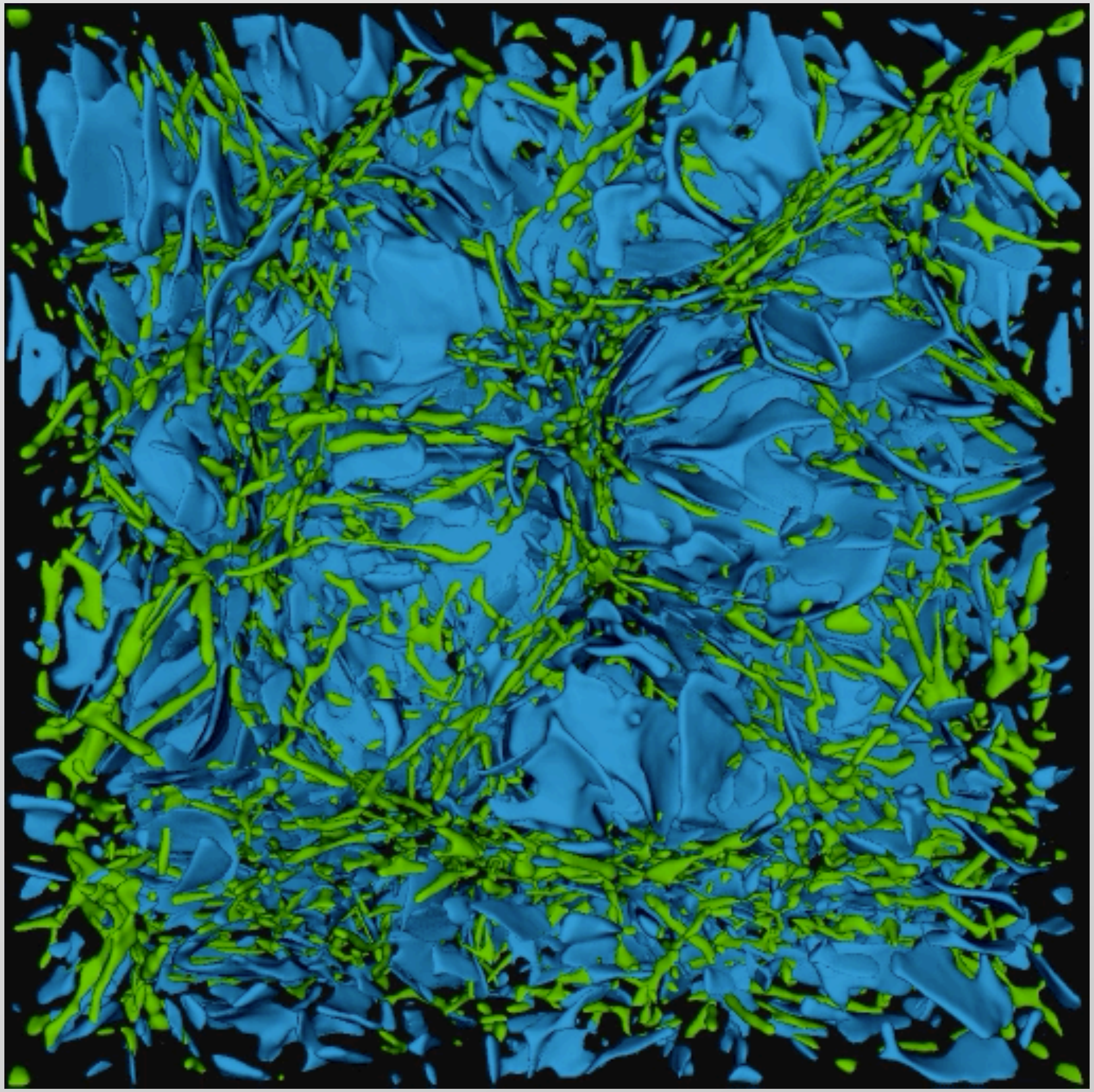
Original Mask Predicted

Automatic cosmic web segmentation



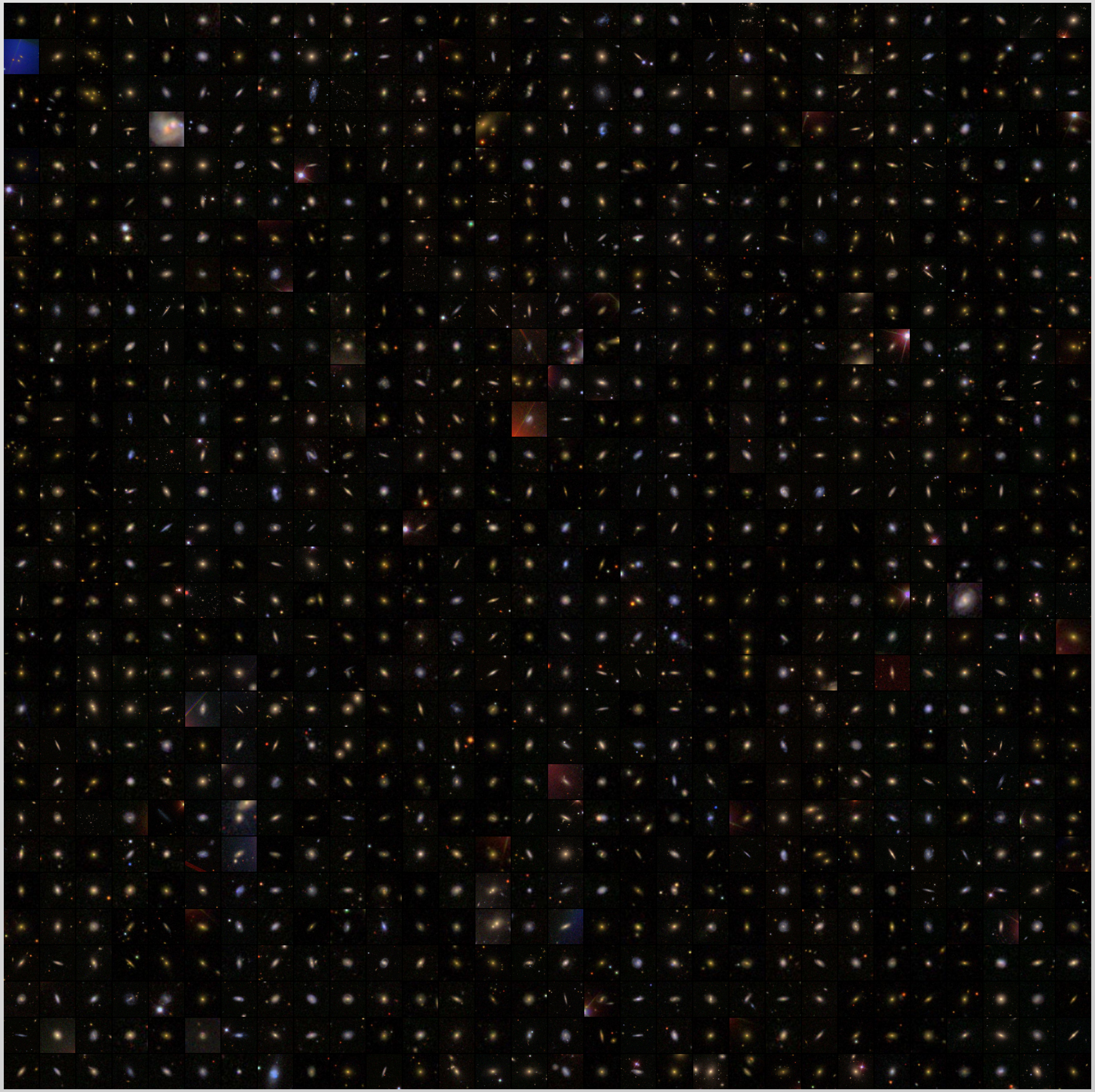
Aragon-Calvo 2019

Automatic cosmic web segmentation

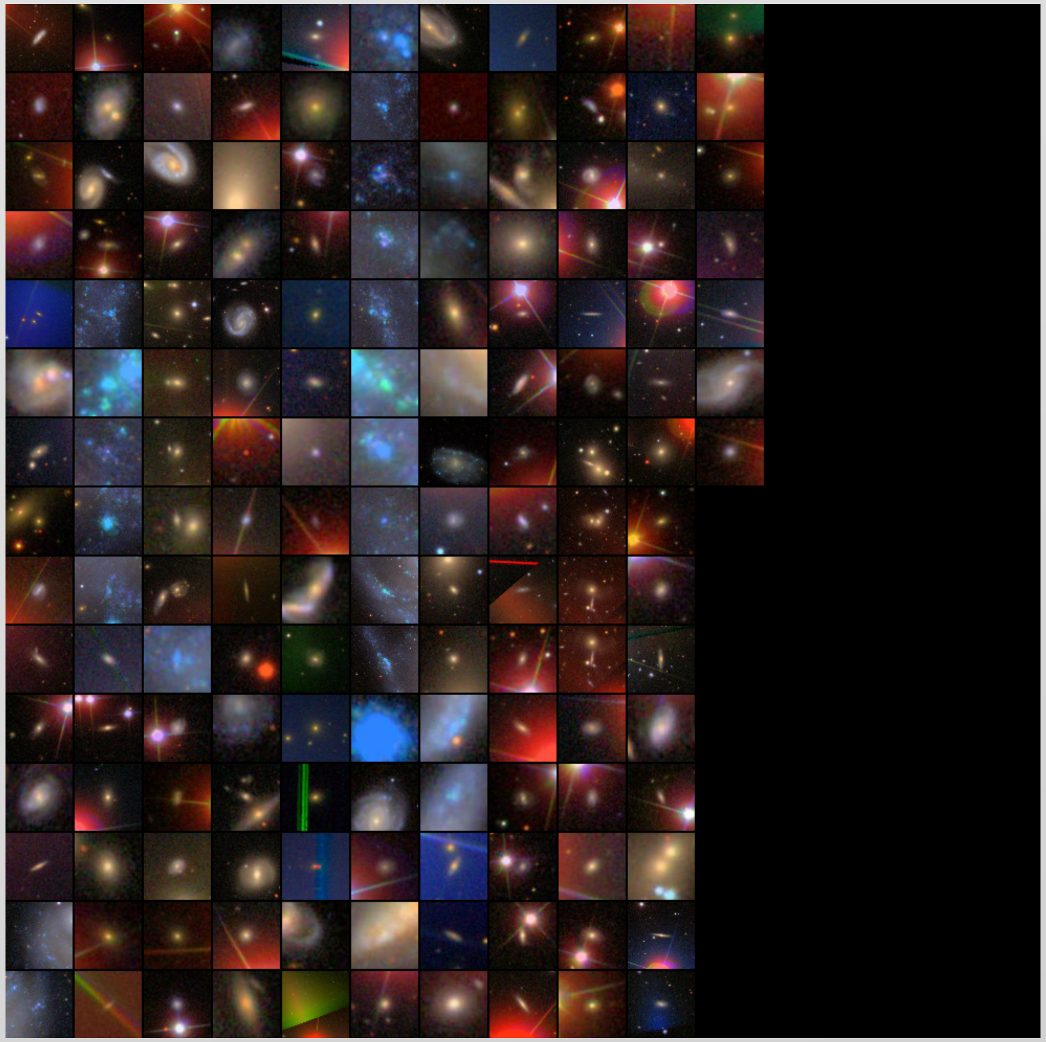


Aragon-Calvo 2019

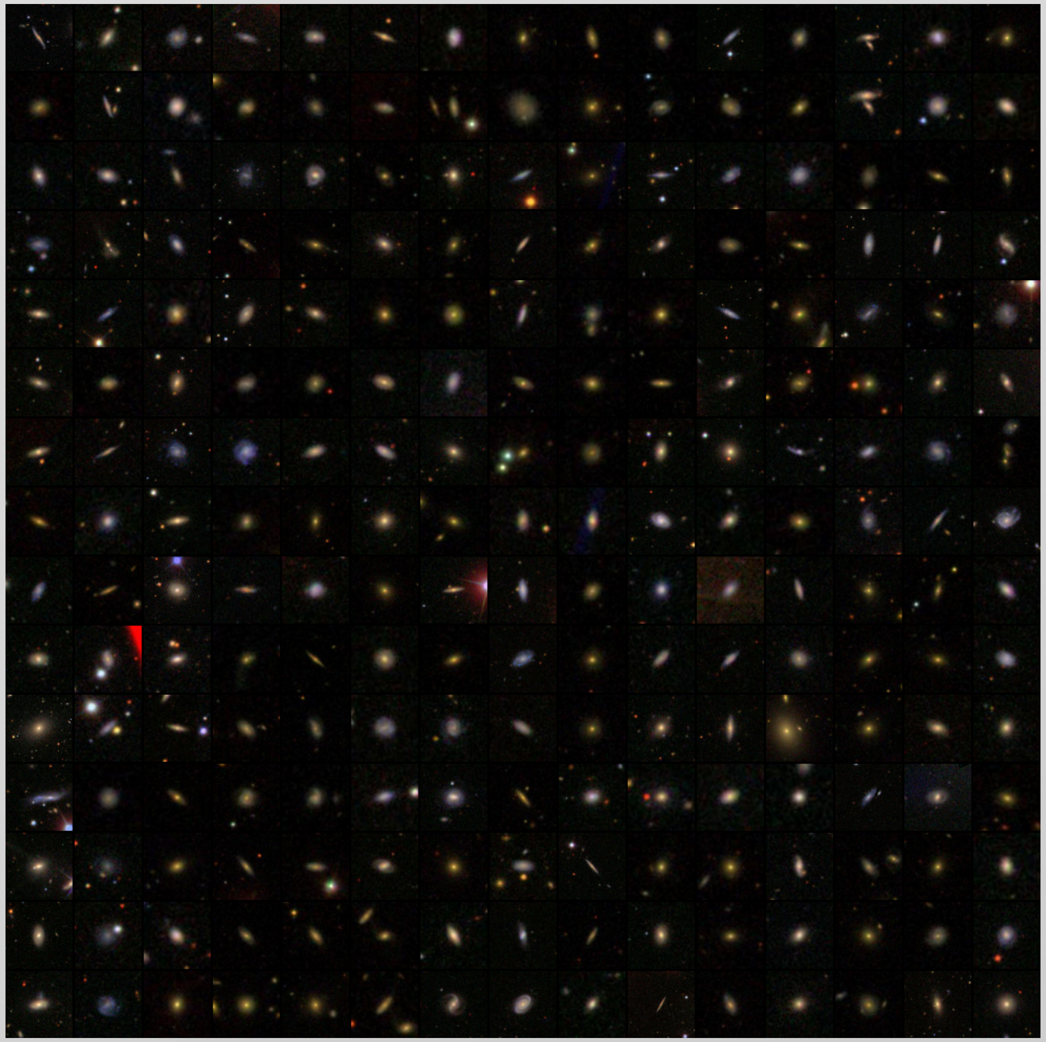
Automatic selection of bad images



Automatic selection of bad images

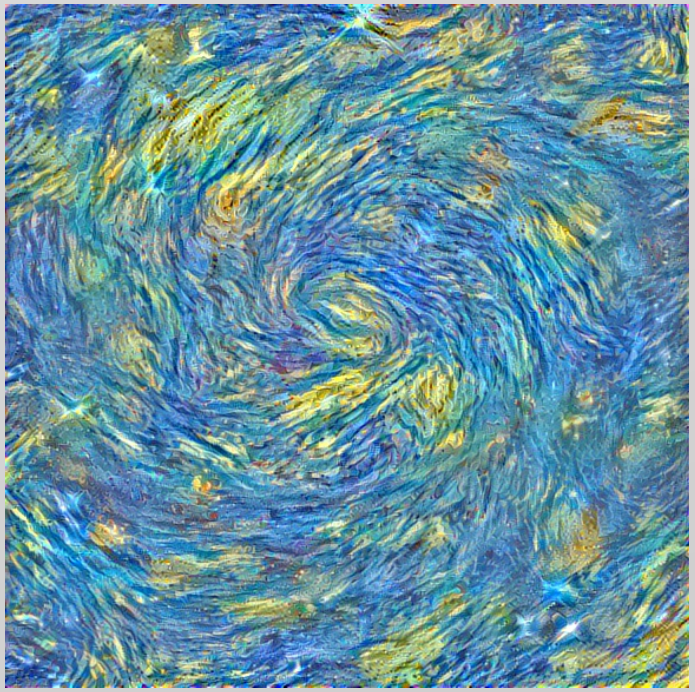


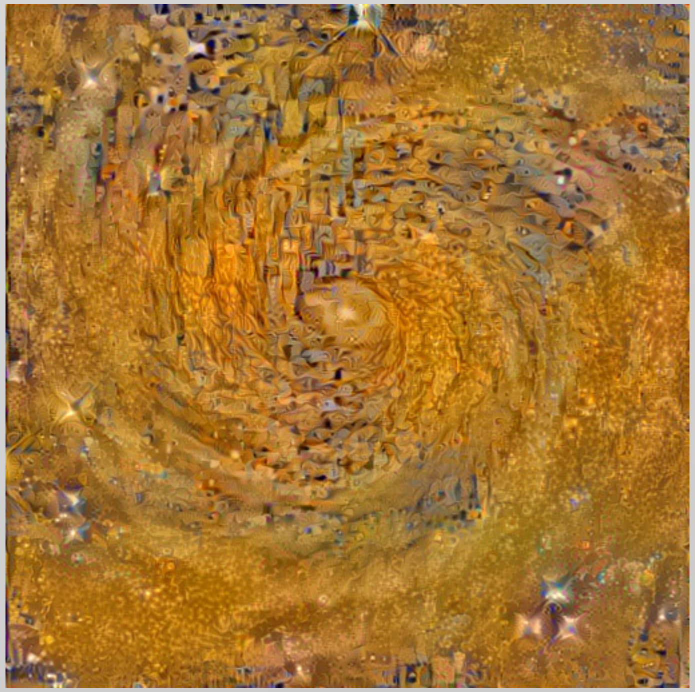
Failed sample



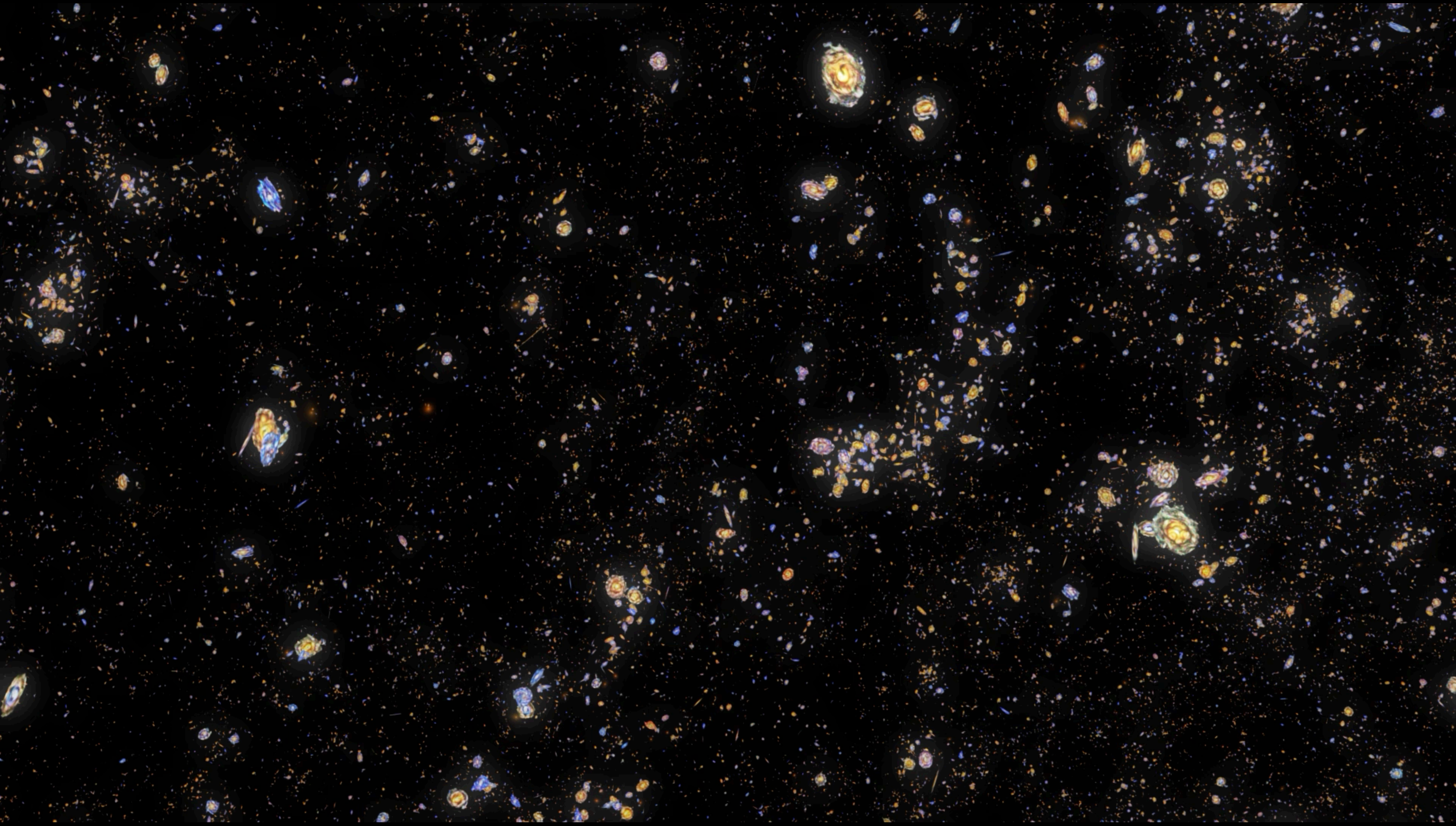
Clean sample

Also not-so serious applications…



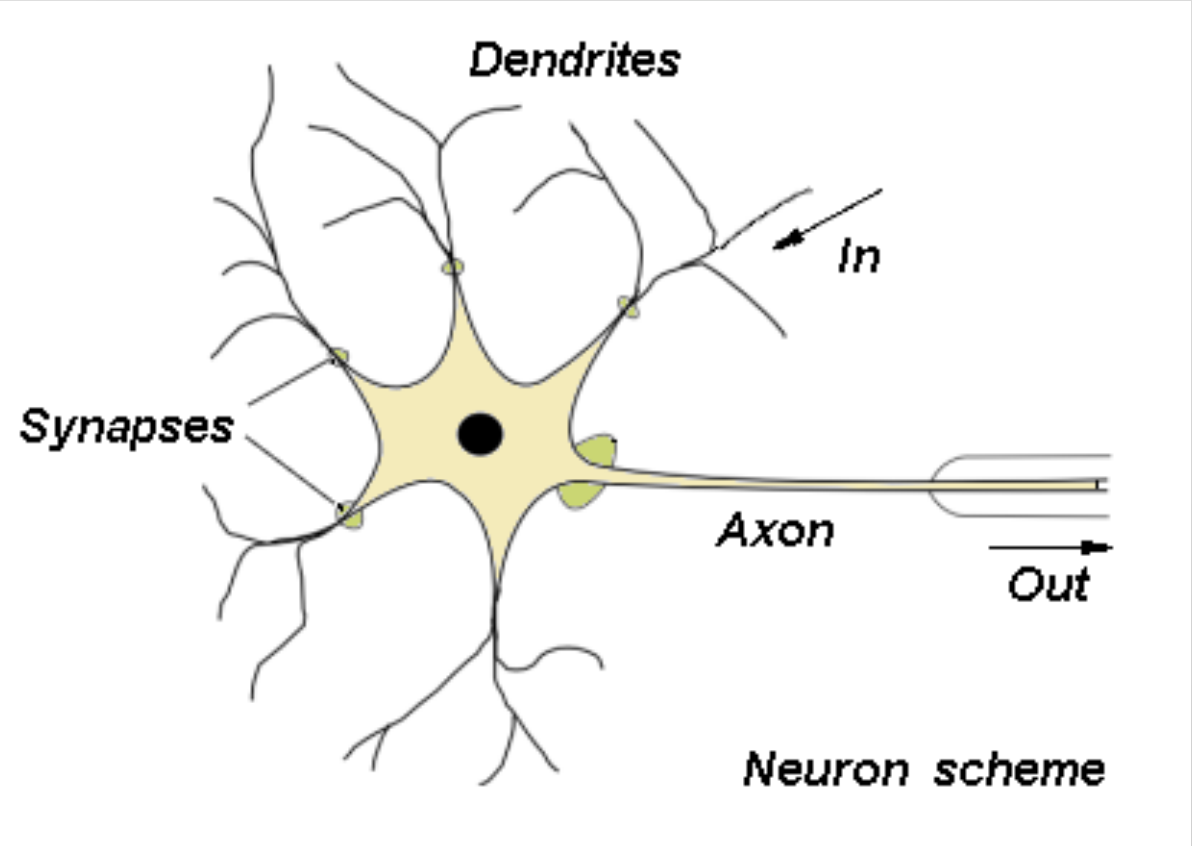


Style transfer



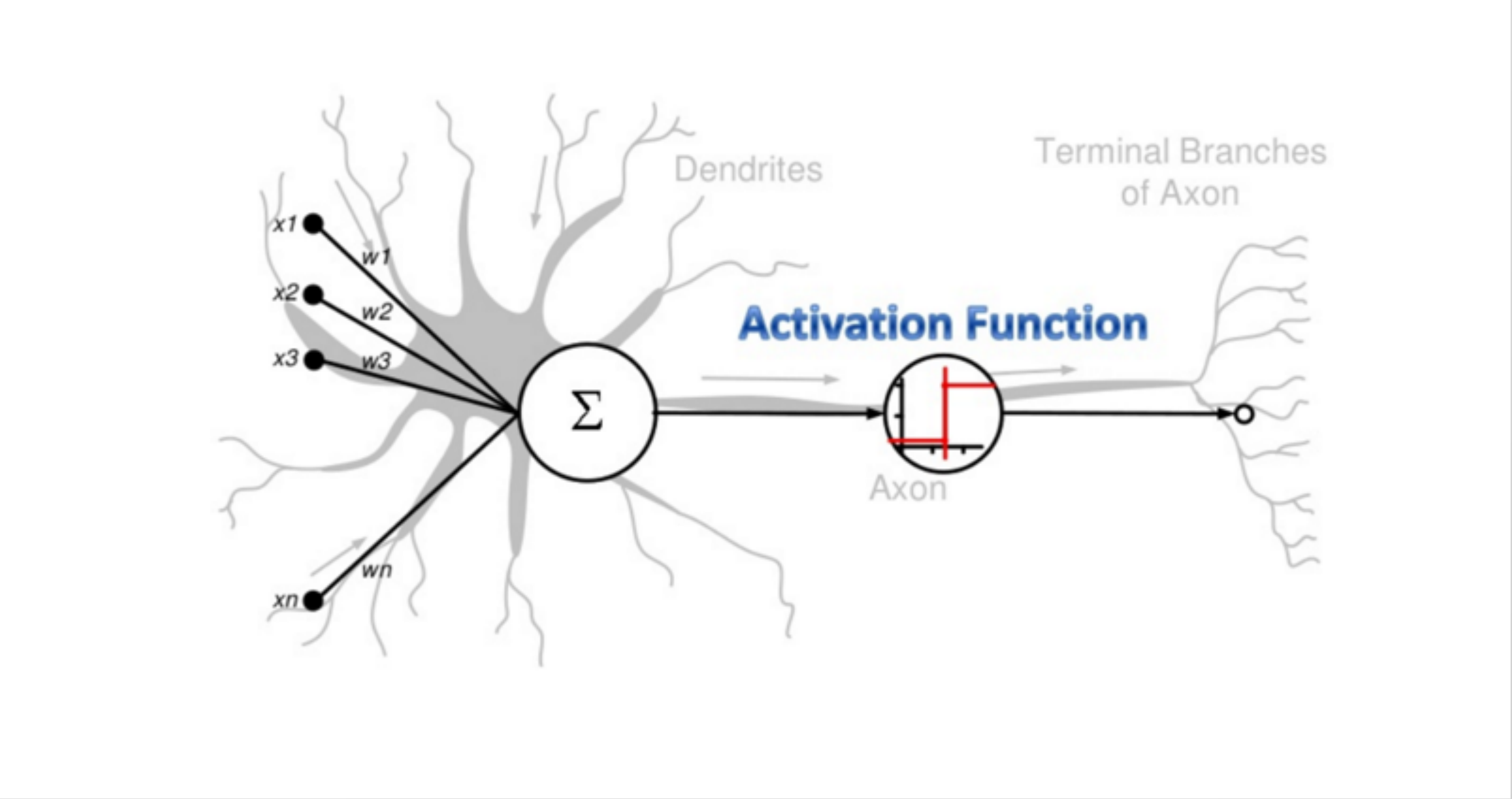
What is an artificial neuron?

2 mins intro…

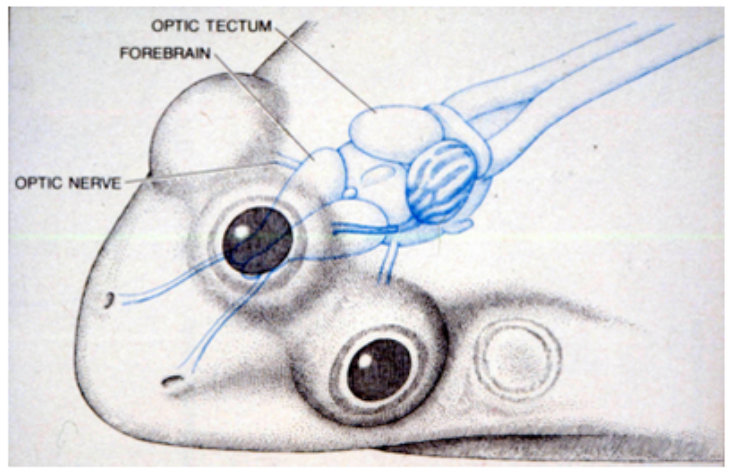


Biological neuron

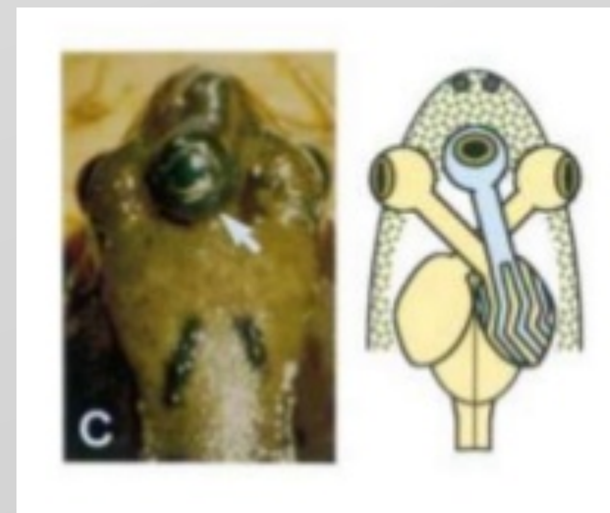
What is an artificial neuron?



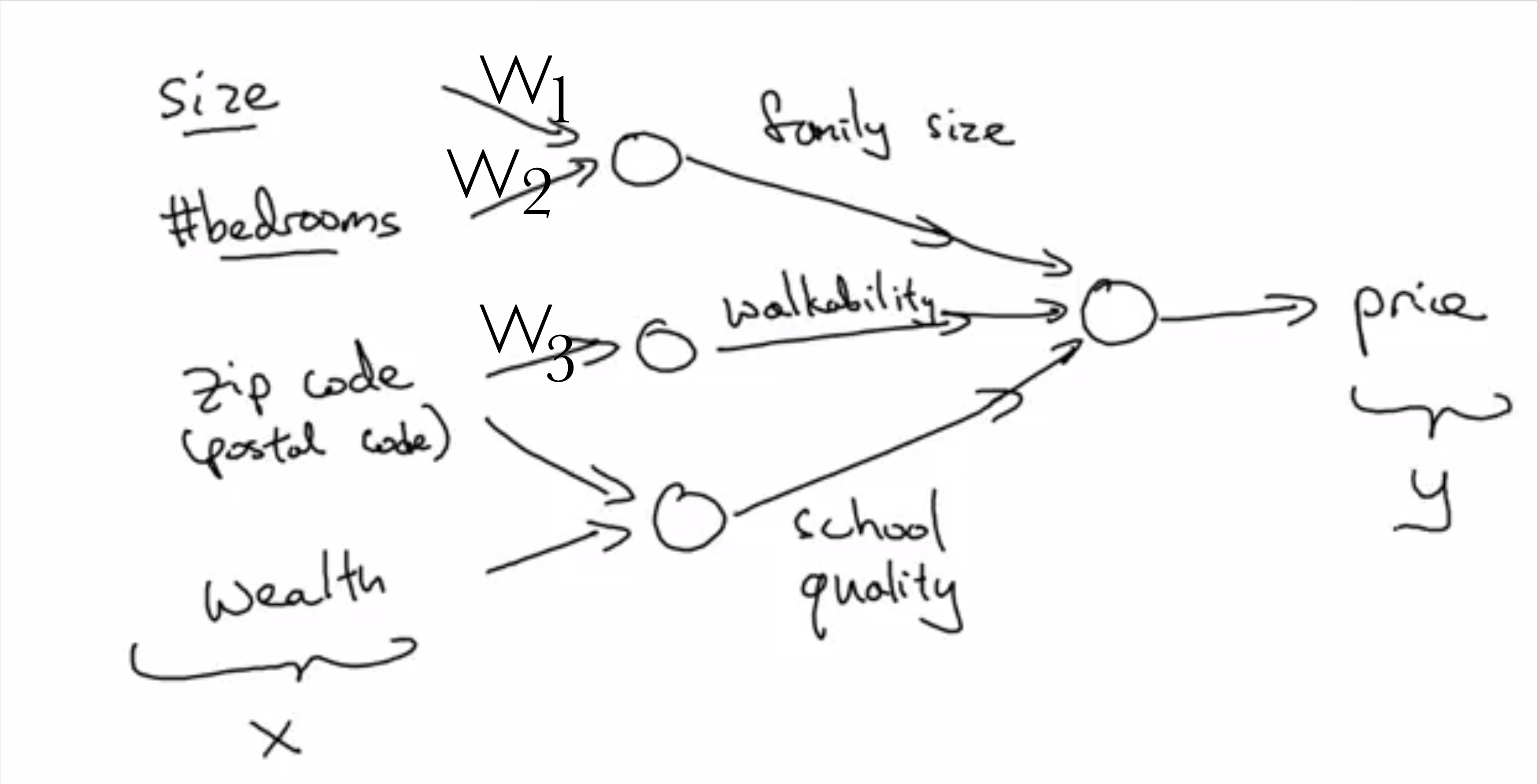
Perceptron



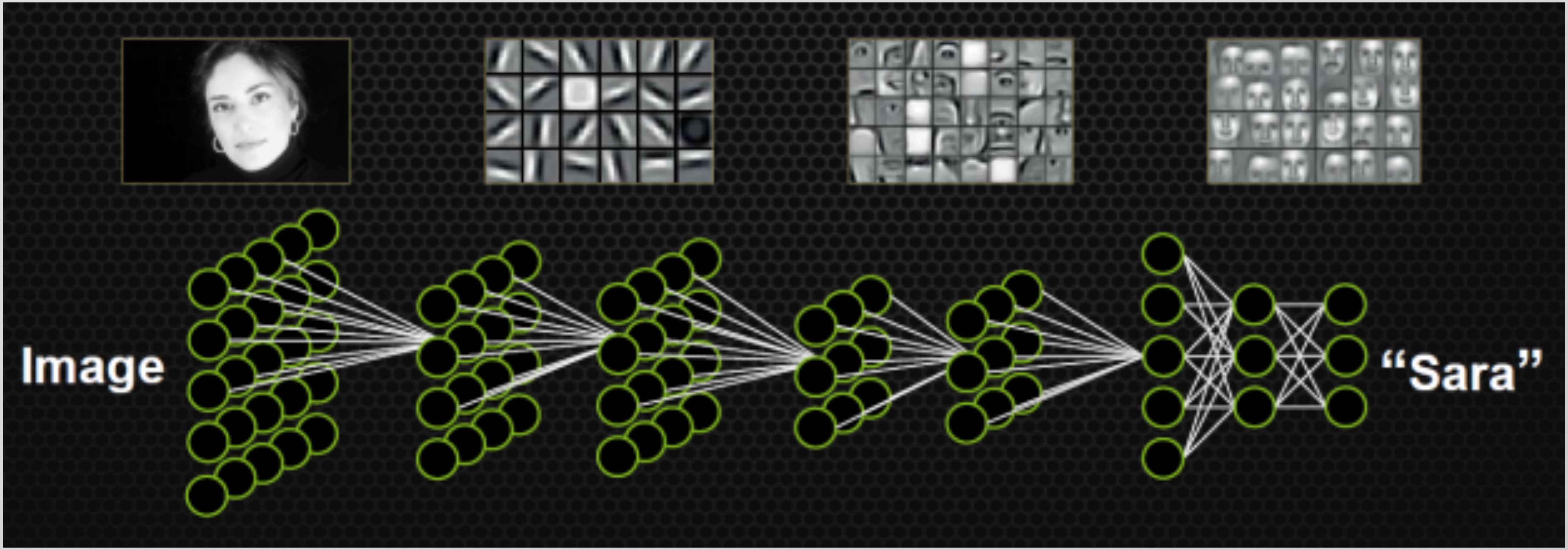
Ocular dominance colums in the optic tectum can be induced in frogs by implantation of a third eye during embryonic development. Normally the retinotectal projection is crossed, but implantation of a third eye results in competition between the third aye and the established eye for tectal target space. Formation of the columns is activity dependent. This experiment supports both the notion that brain wiring is both dependent on molecular cues and on neural activity.



Universal learning algorithm?


size
#bedrooms
zip code
(postal code)
wealth
x
W_1
W_2
W_3
family size
walkability
school
quality
price
y

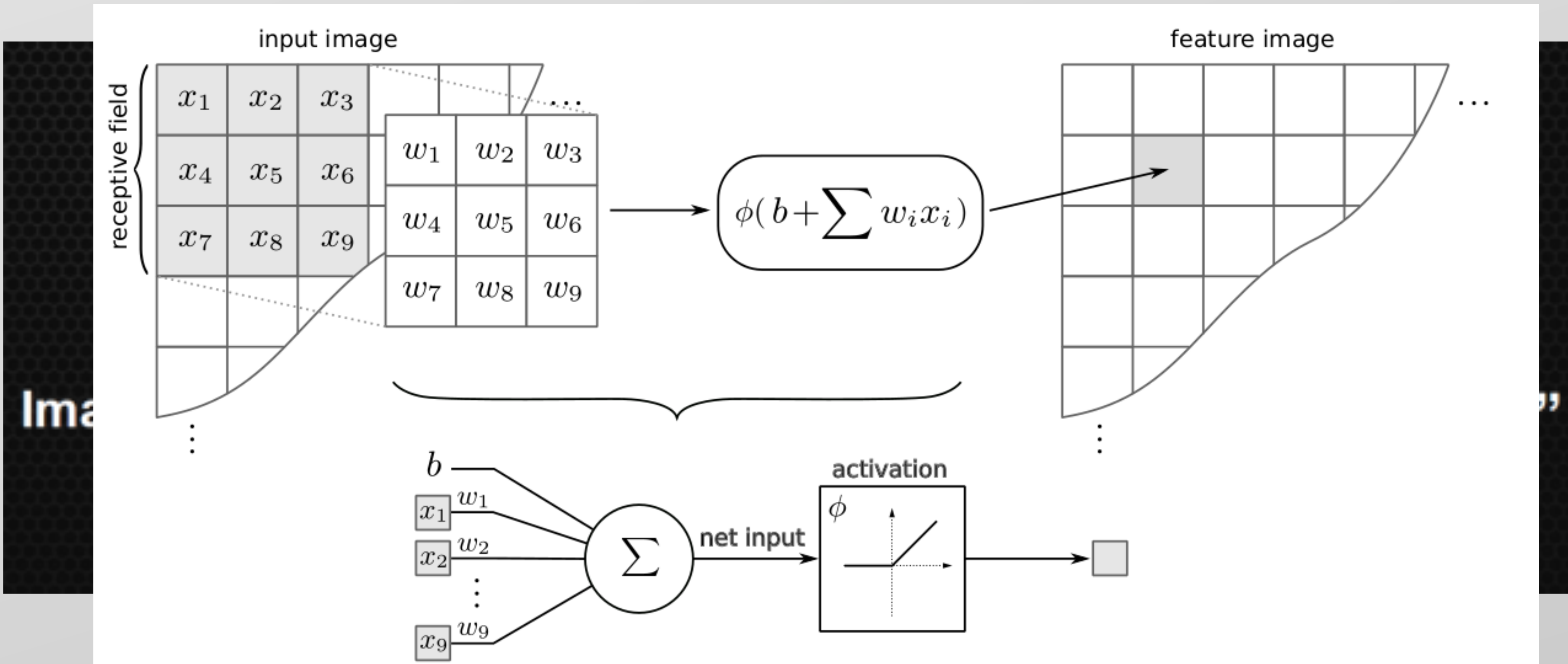
Deep Learning



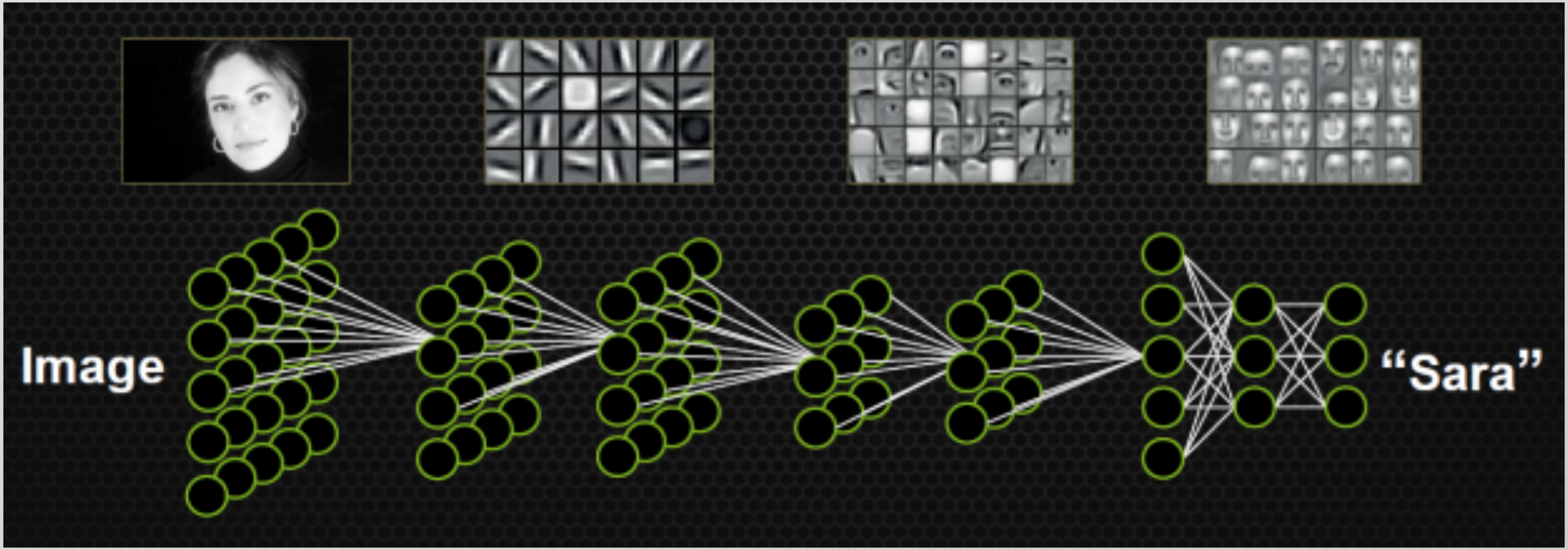
Resolution

Abstraction

Deep Learning

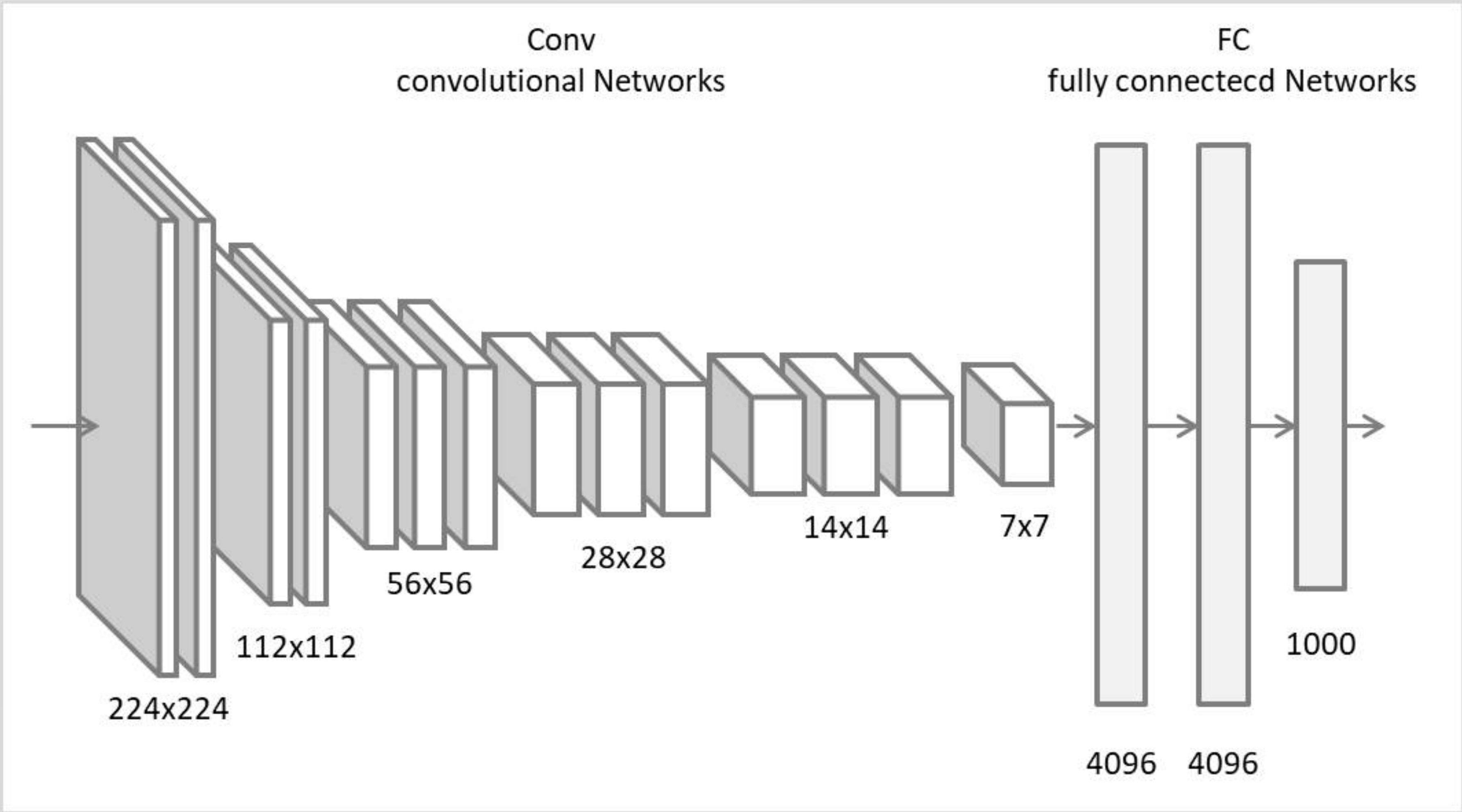


Deep Learning



Feature extractor Aggregator

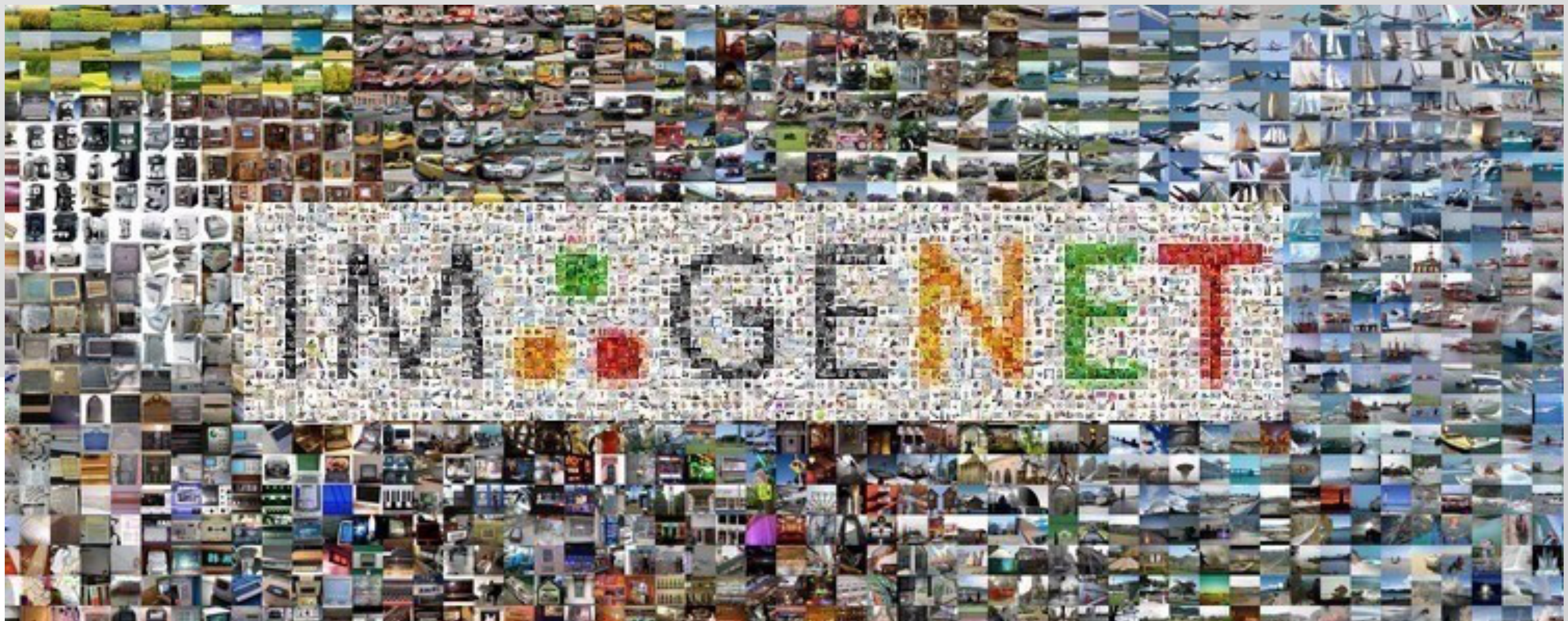
VGG16 (2014)

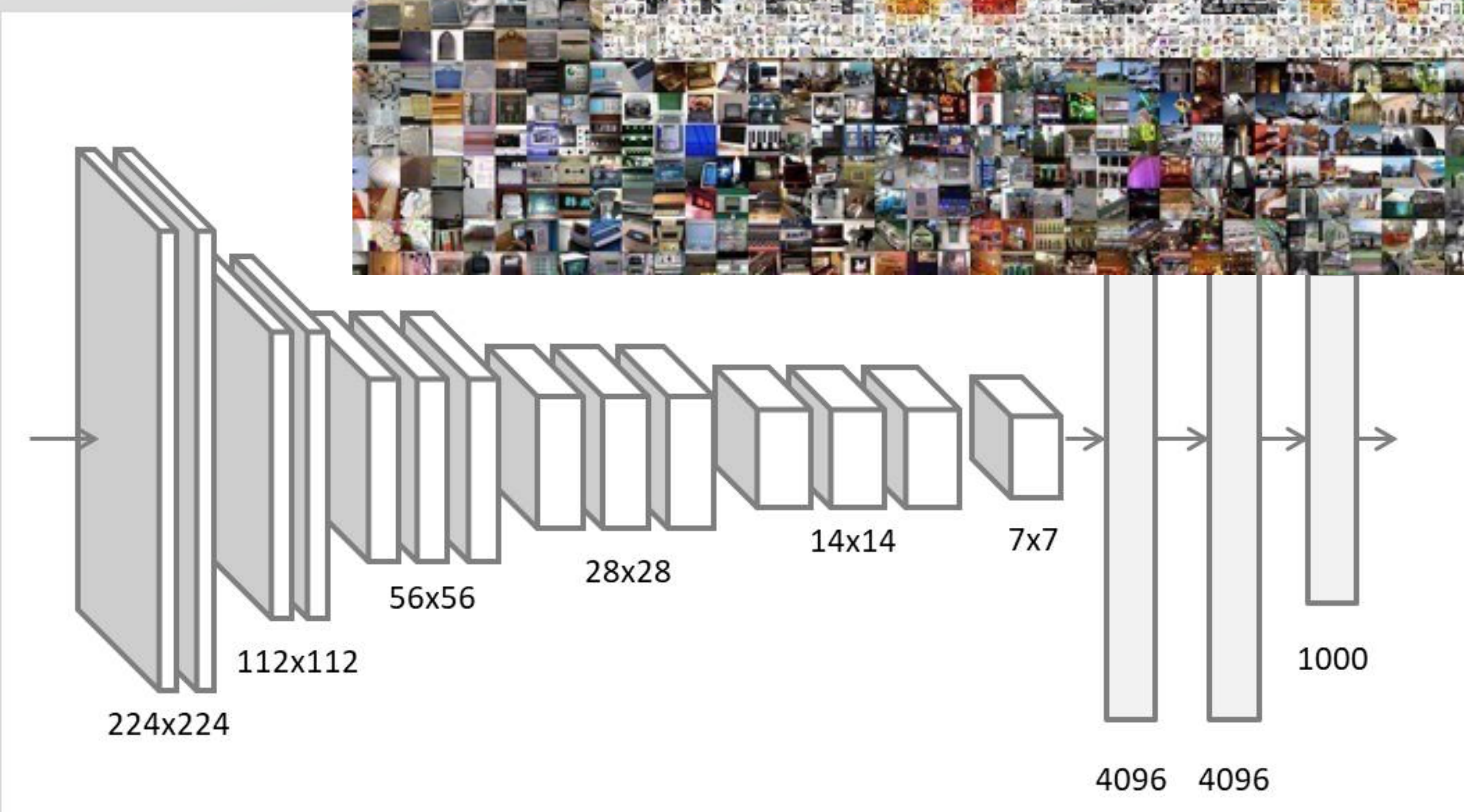


Feature Extractor

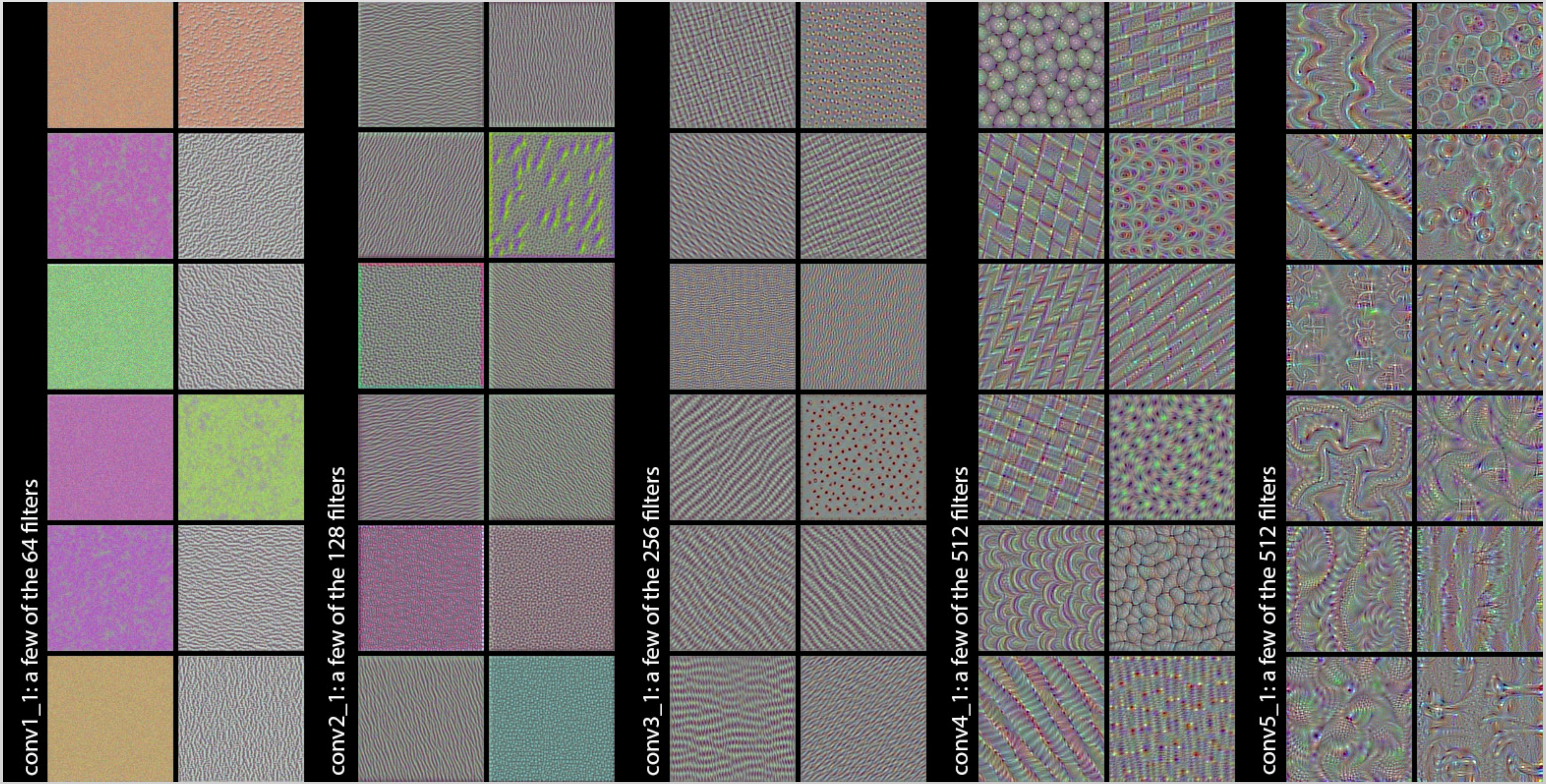
Aggregator

VGG16 (2014)



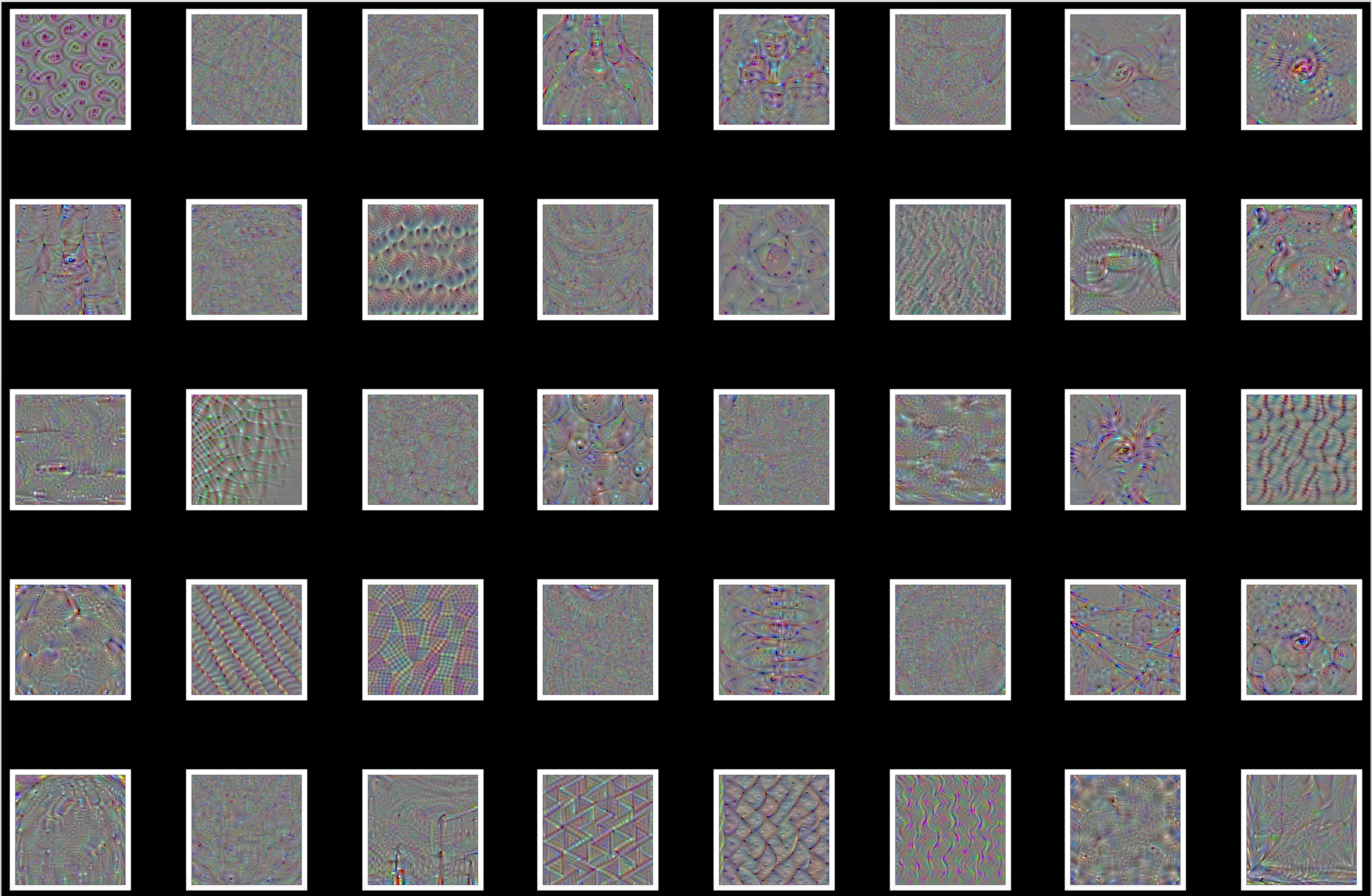


VGG16 filters trained on ImageNet

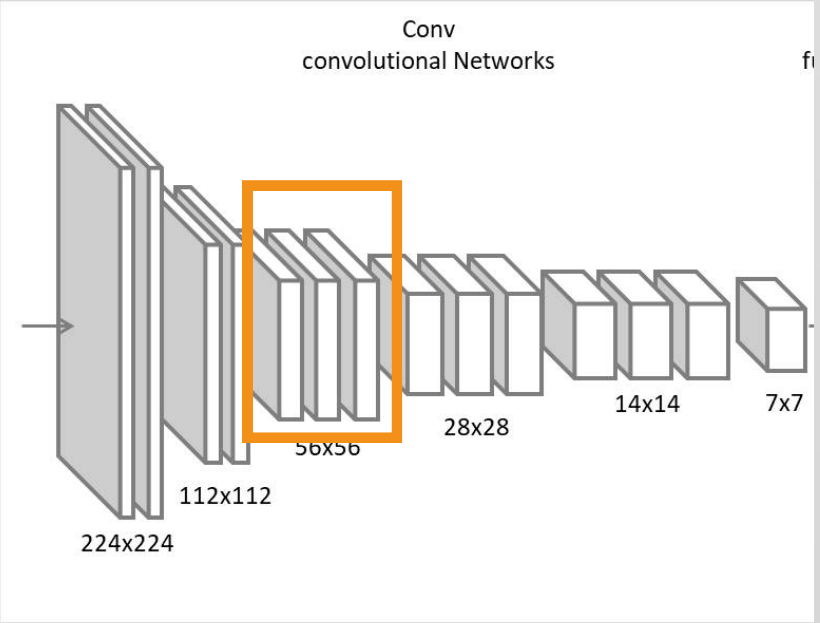


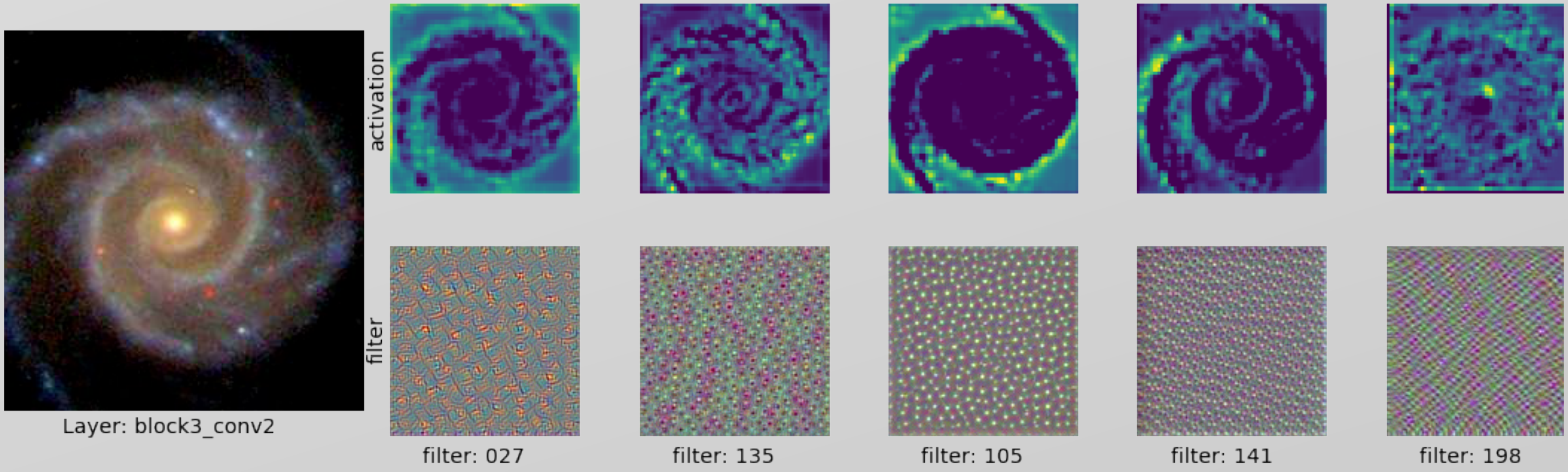
Keras blog

VGG16, some filters in last convolutional layer (512)

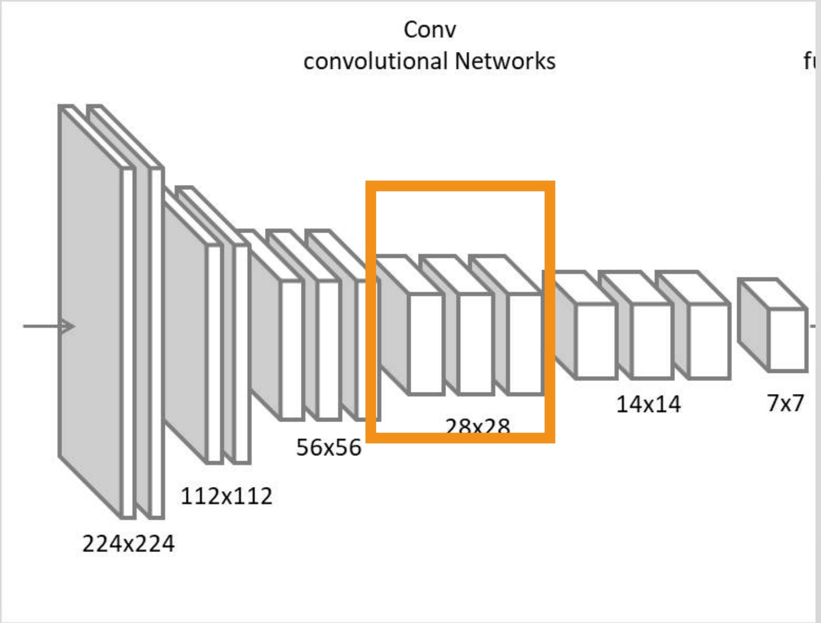


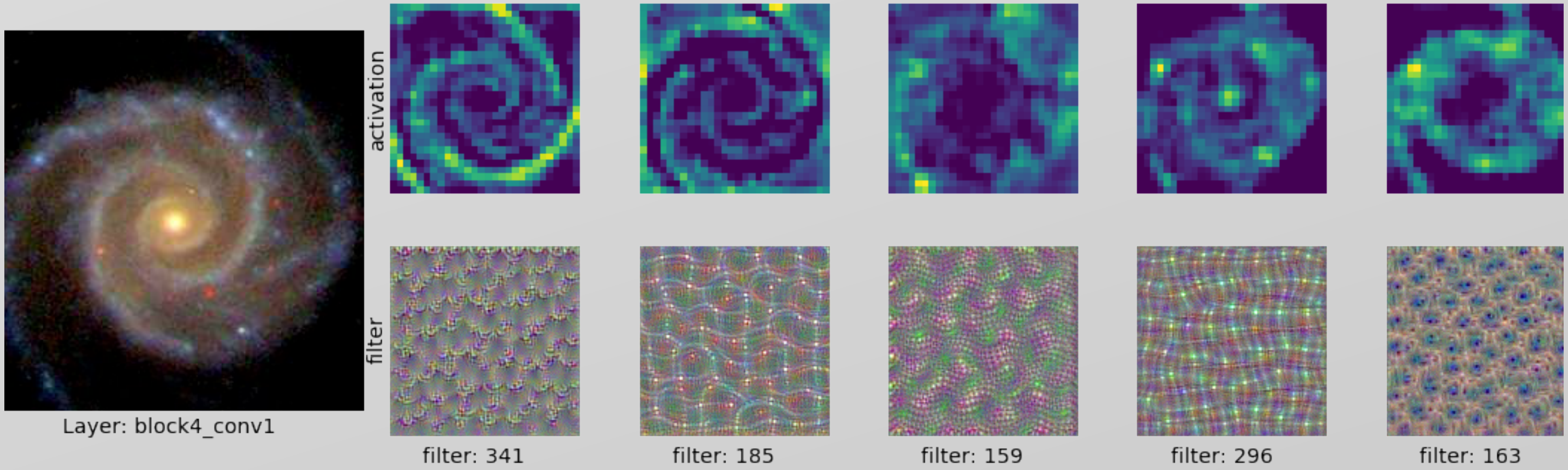
How do neural nets see the world?



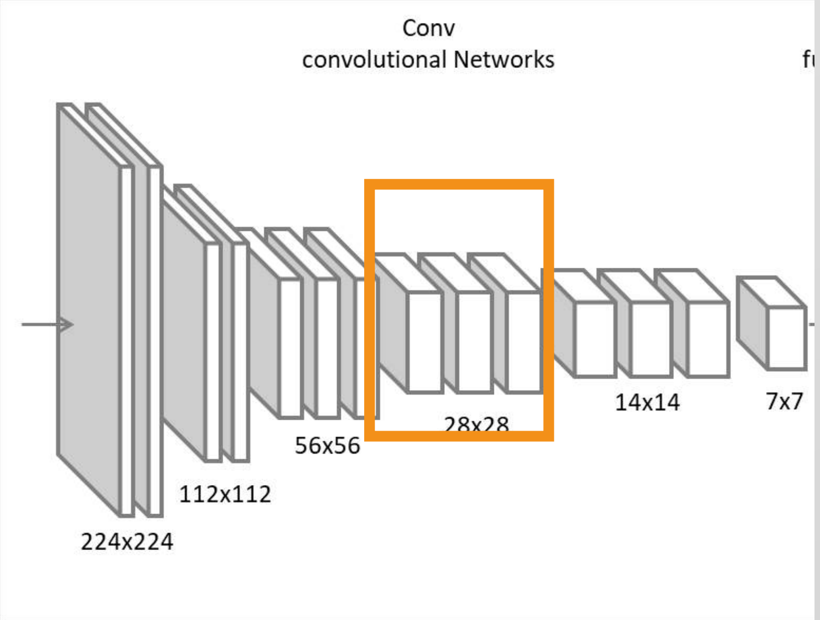


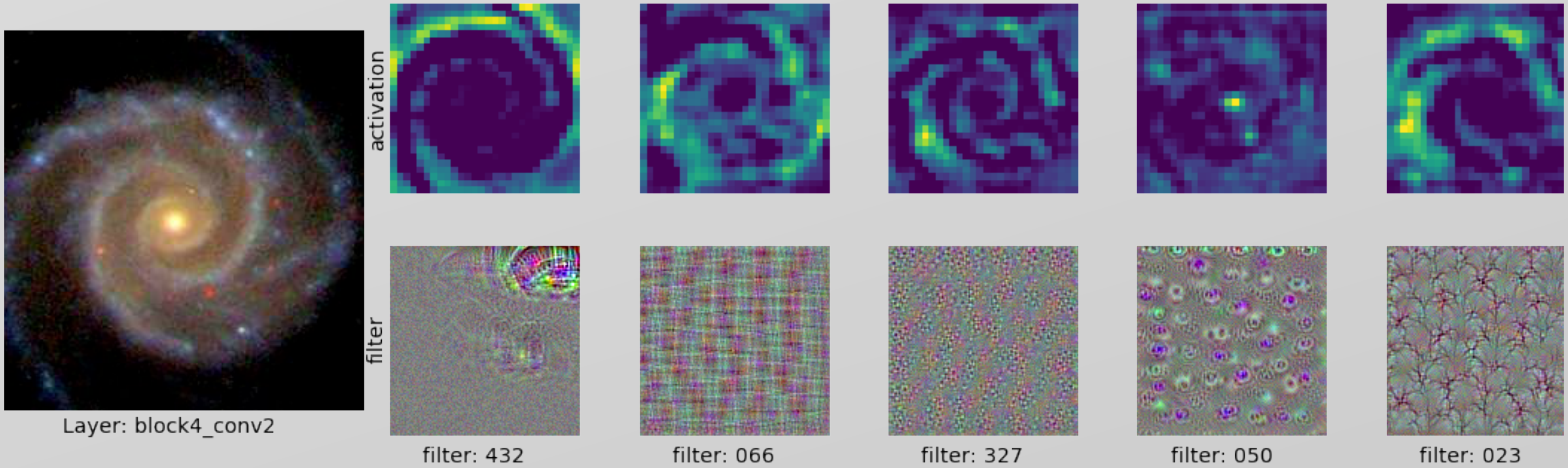
How do neural nets see the world?



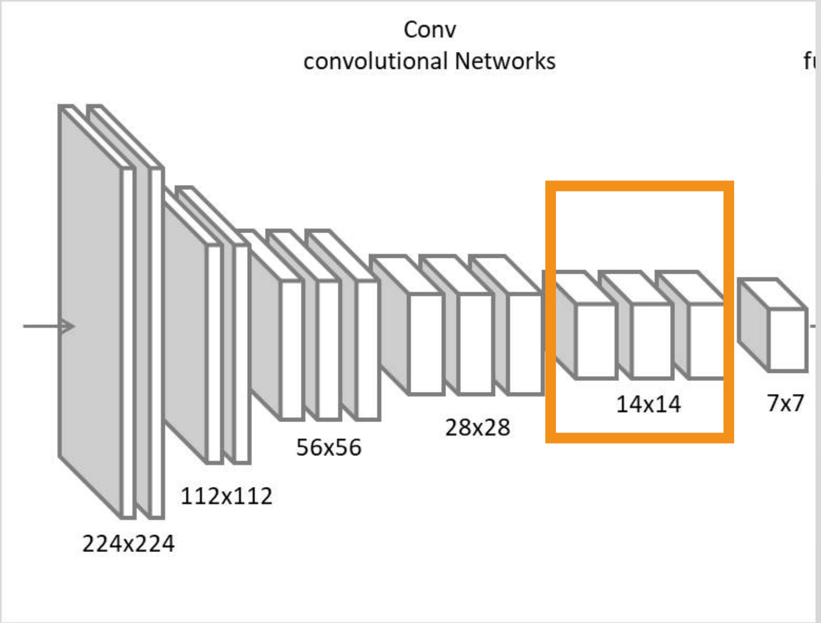


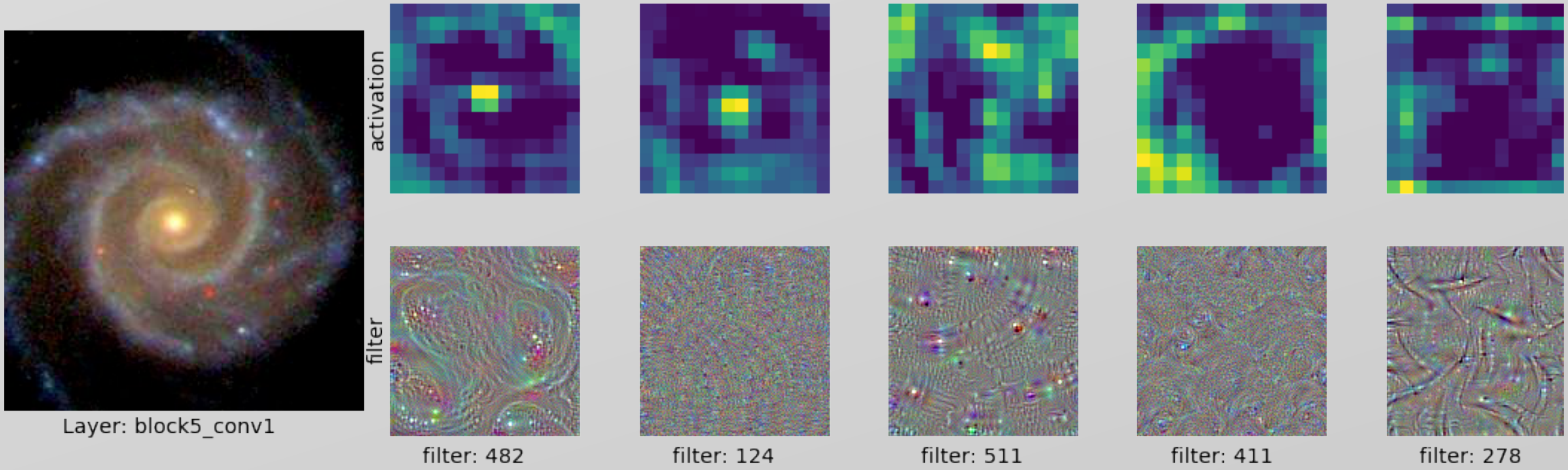
How do neural nets see the world?



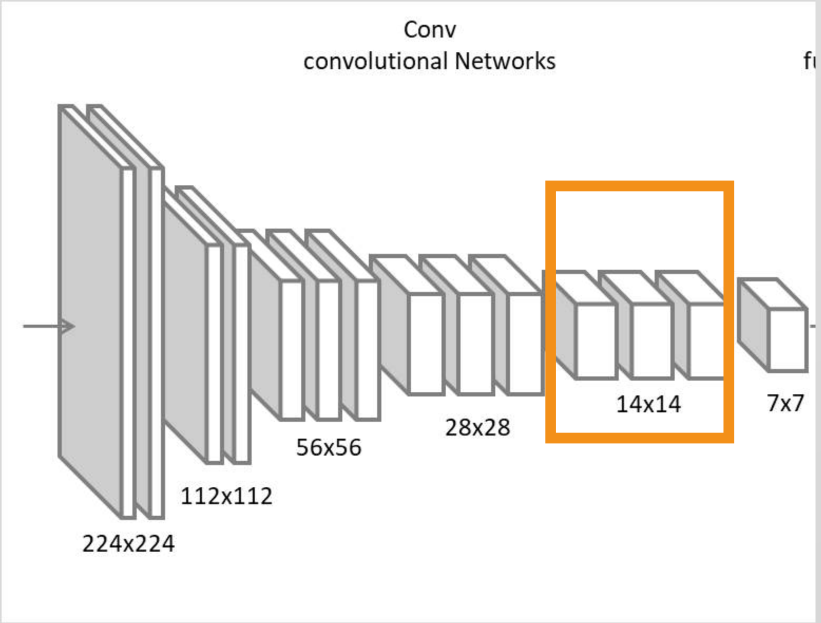


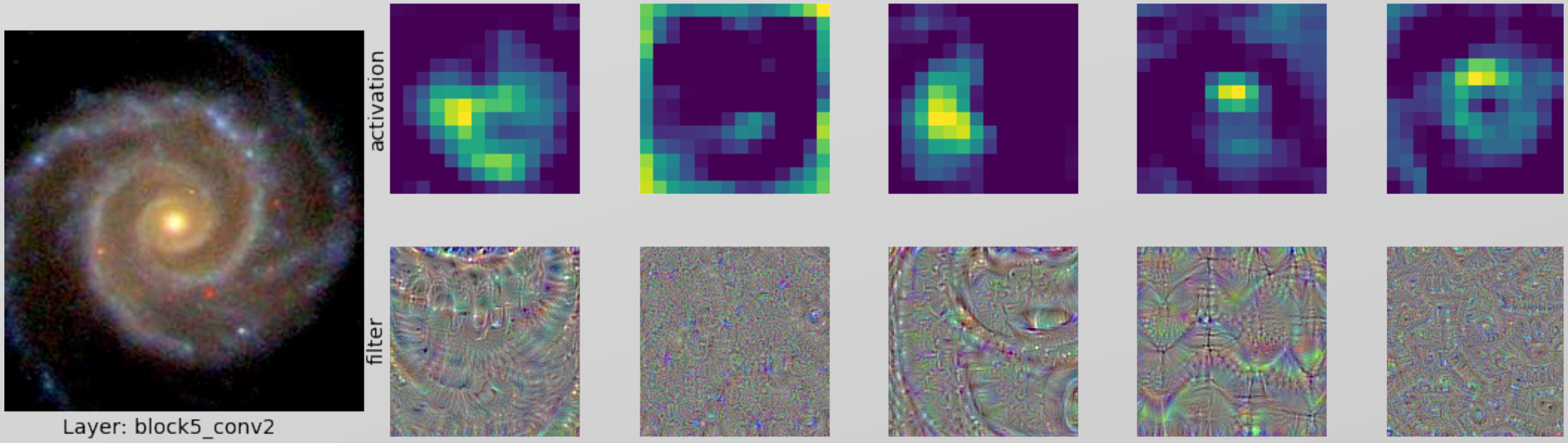
How do neural nets see the world?



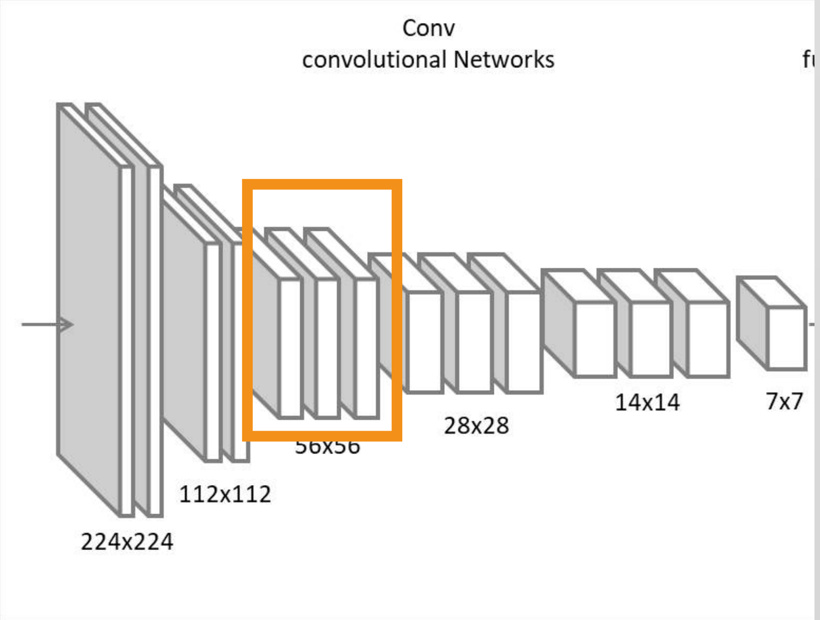


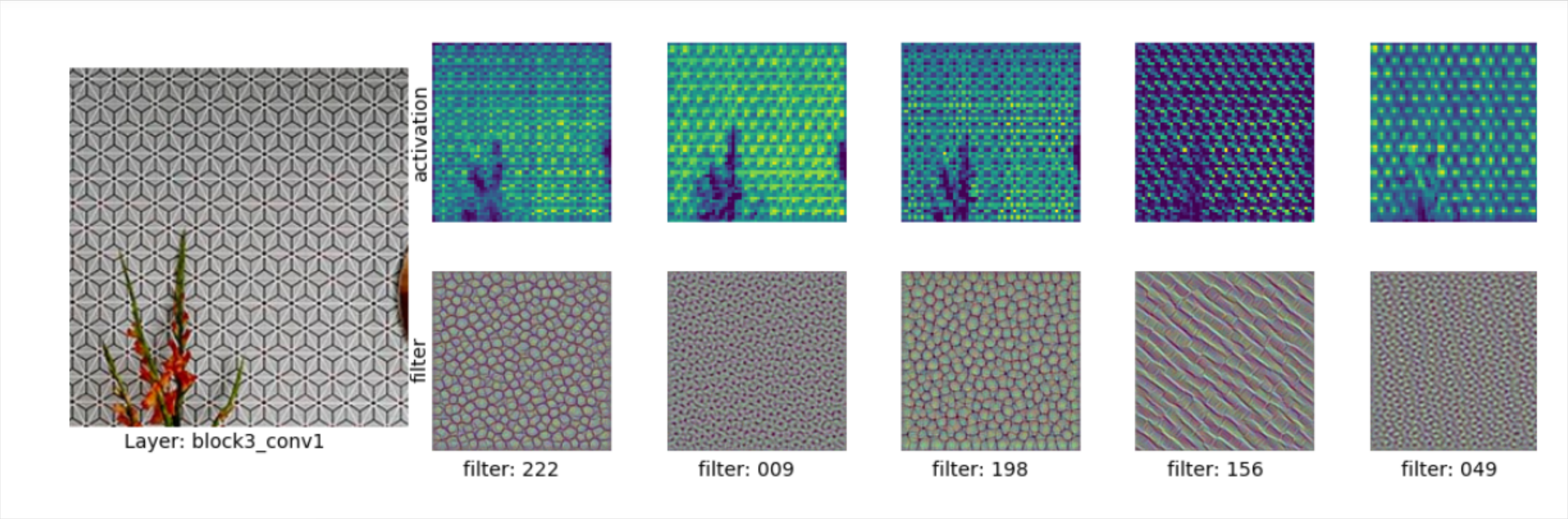
How do neural nets see the world?



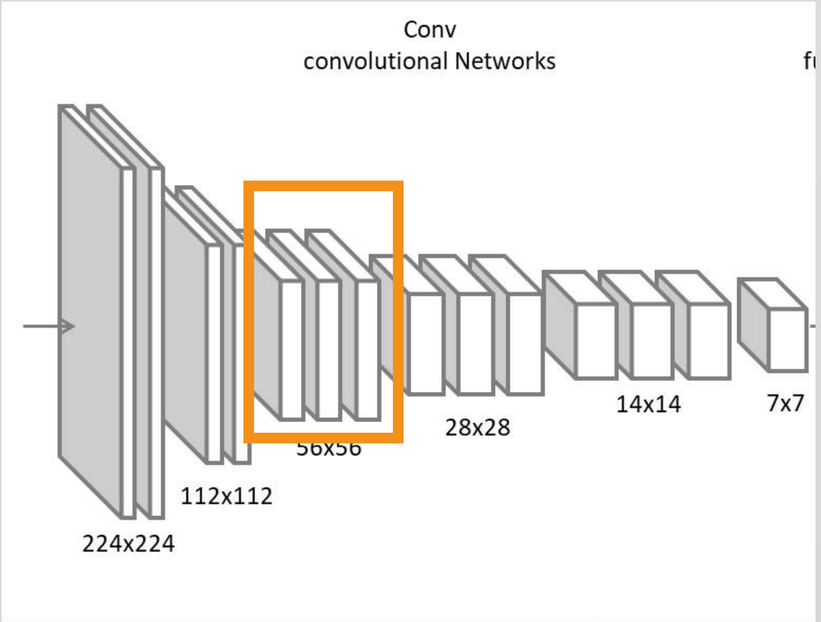


How do neural nets see the world?

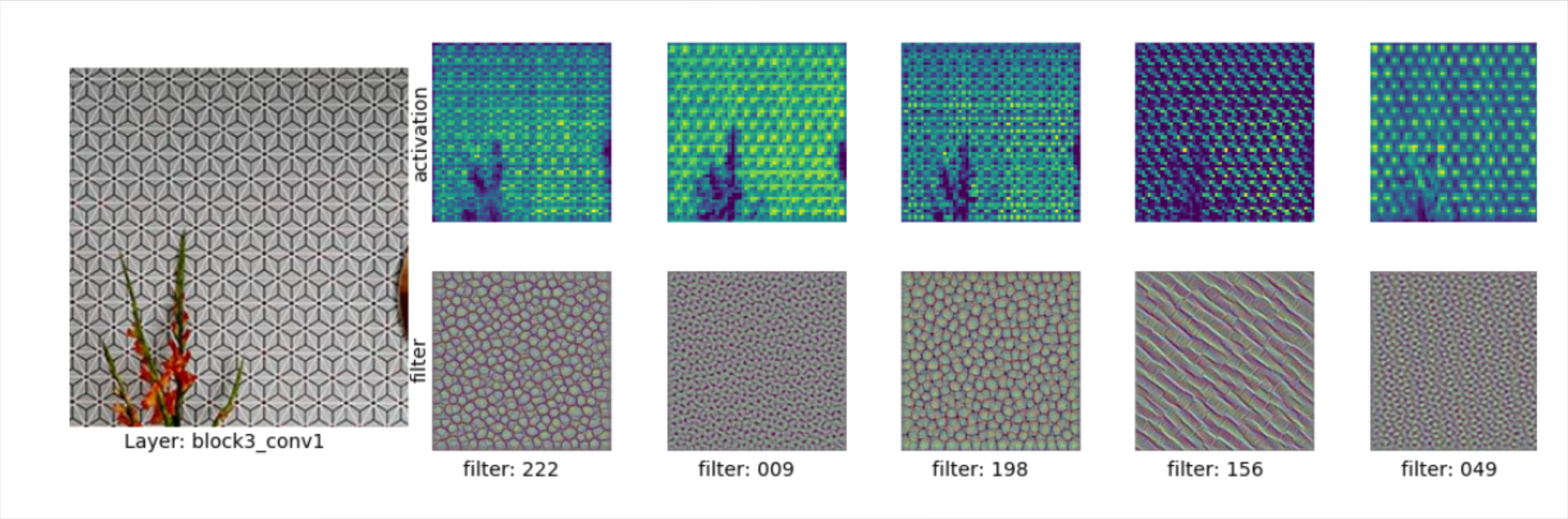




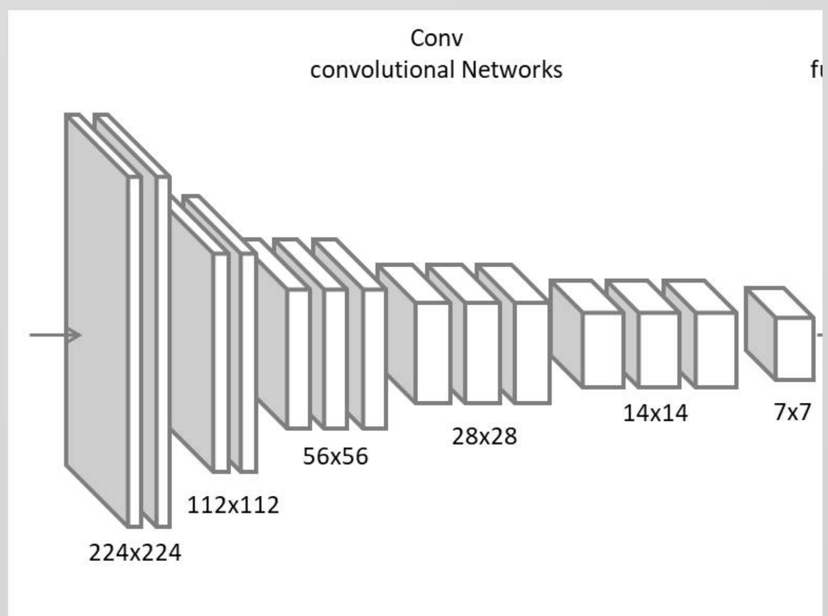
How do neural nets see the world?

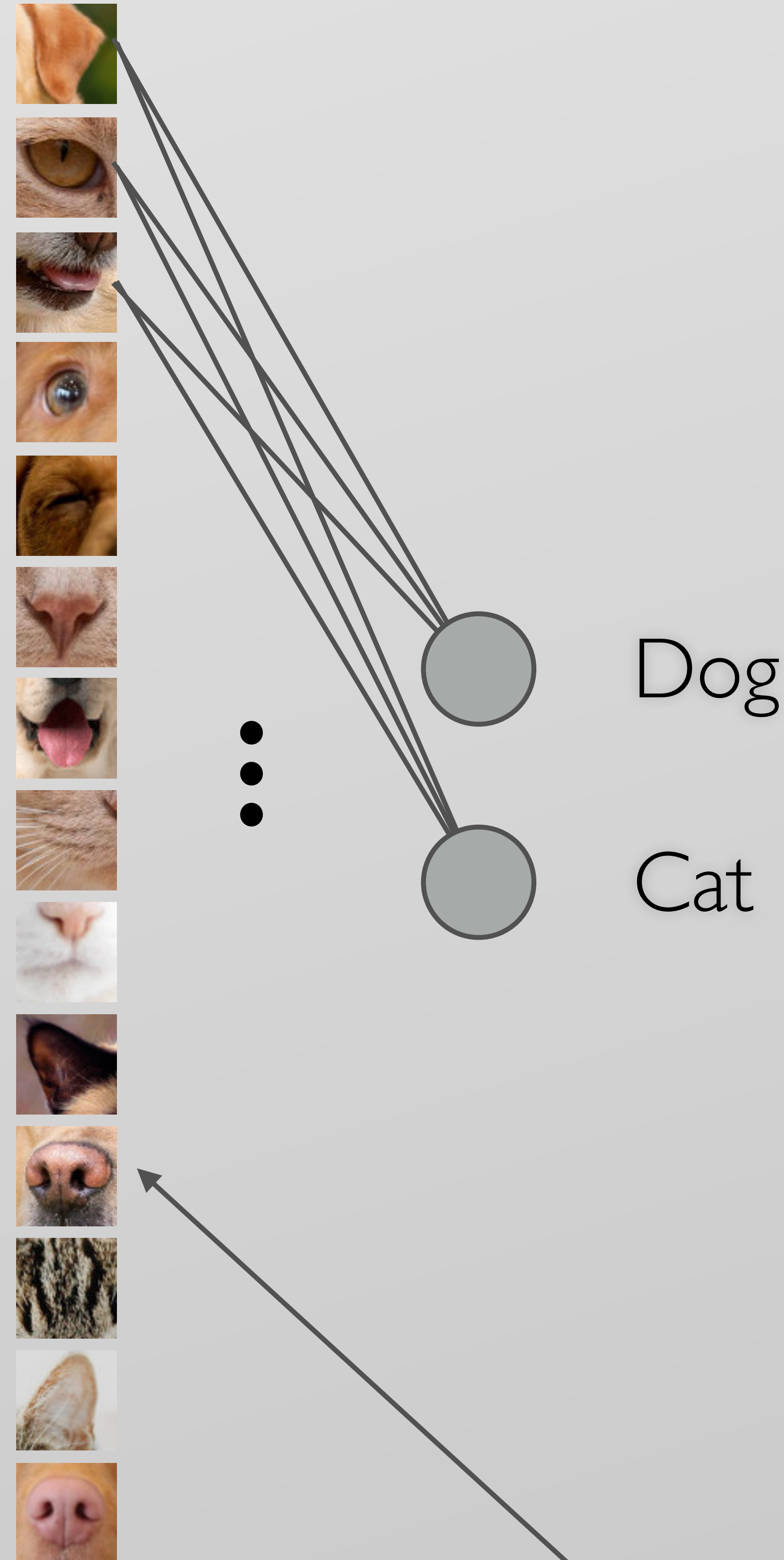


How do they make decisions?



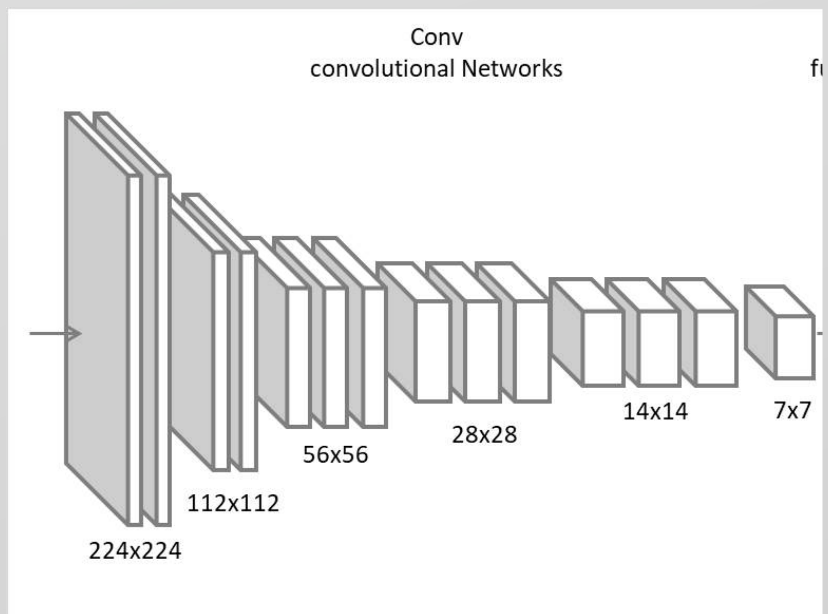
Deen Neural Nets

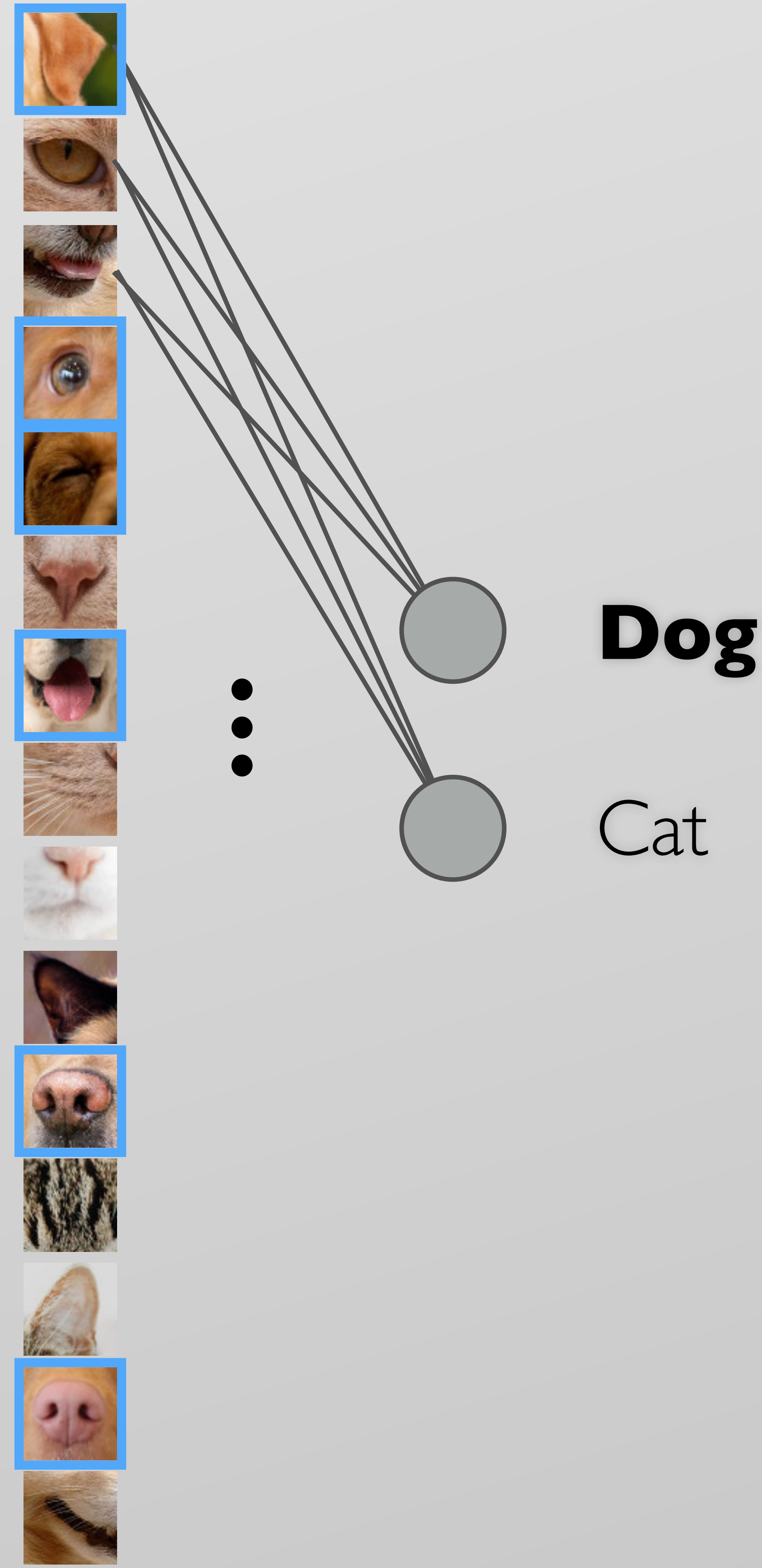




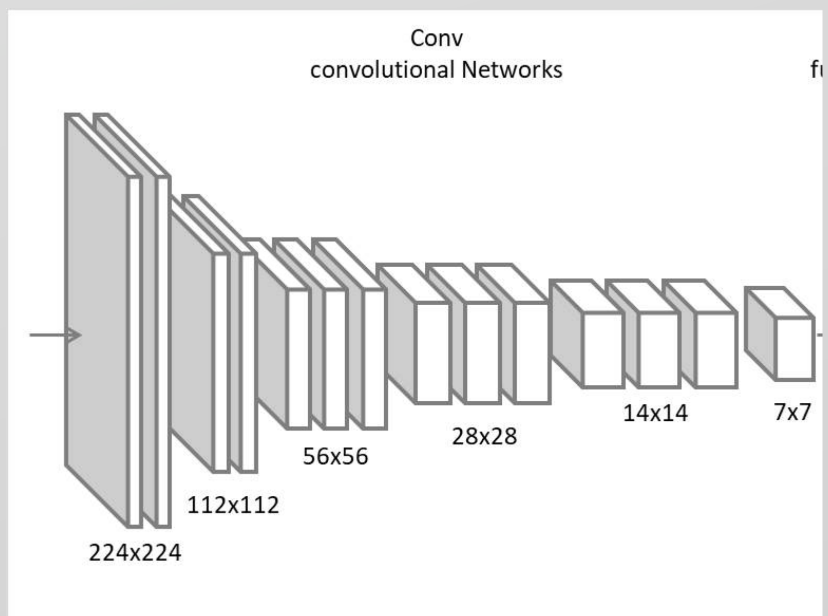
In reality filter responses…

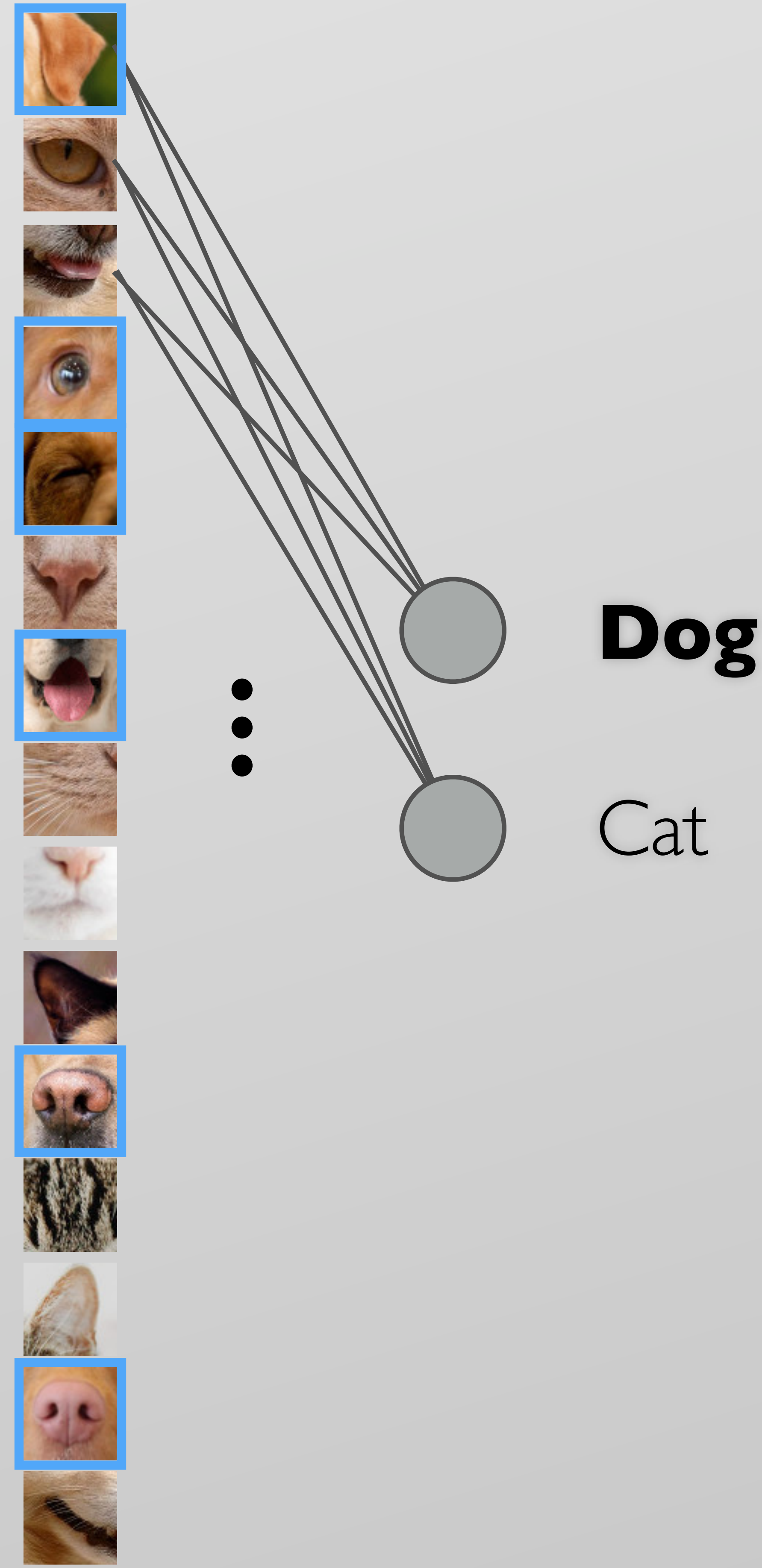
Deen Neural Nets





Deen Neural Nets



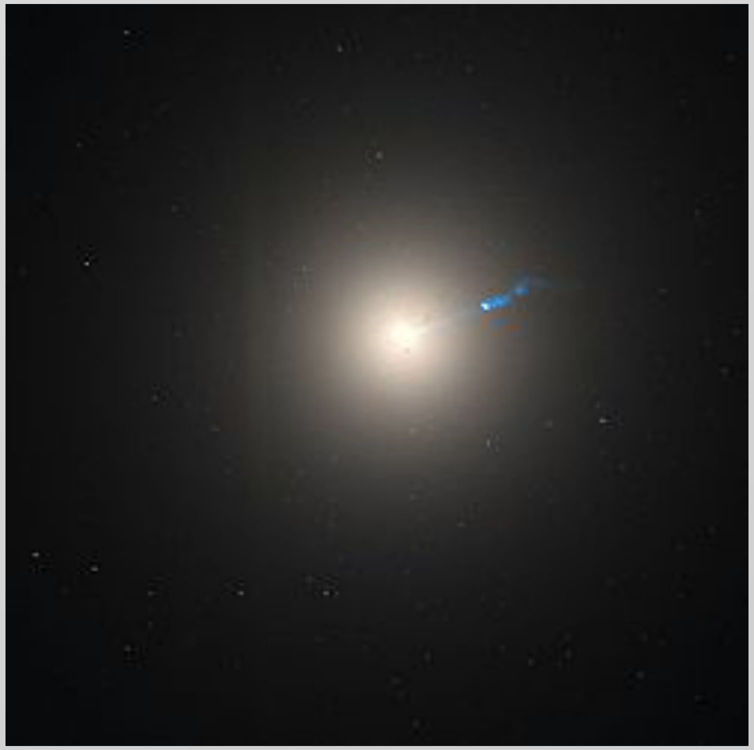


Sparse encoding?

Sparse encoding

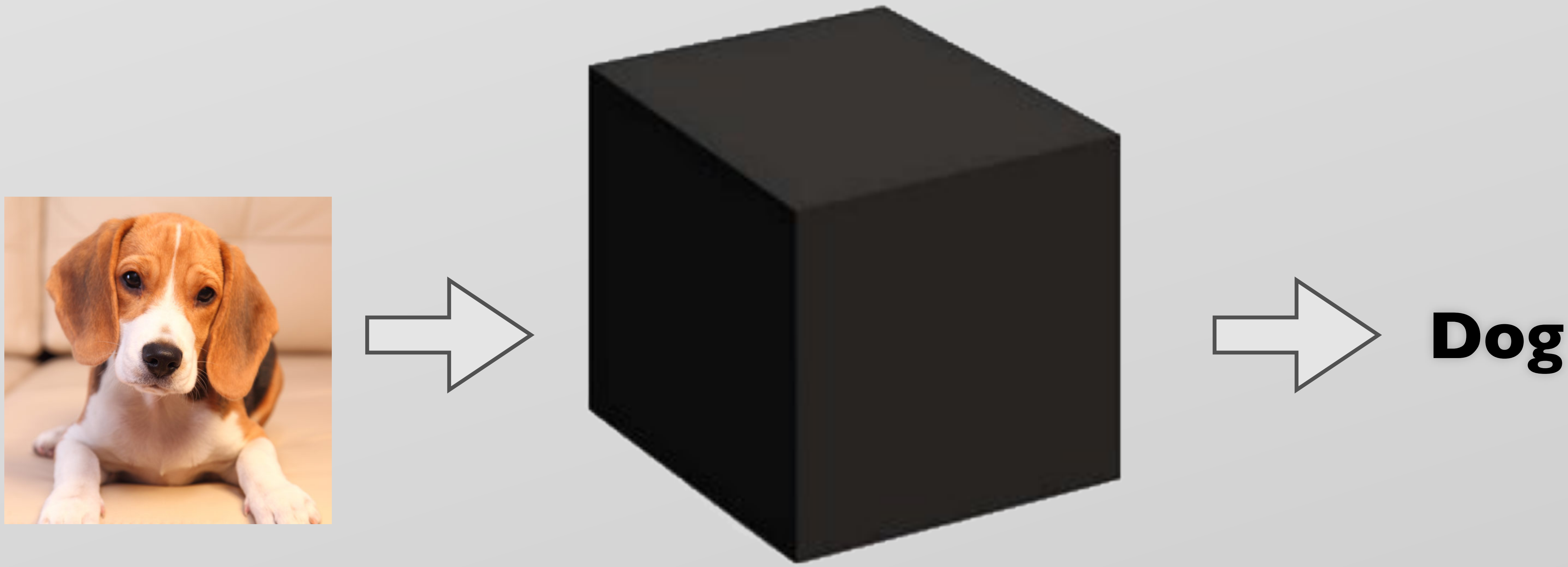
$$I(R) = I_e e^{-7.669\left[\left(\frac{R}{R_e}\right)^{1/4}-1\right]}$$

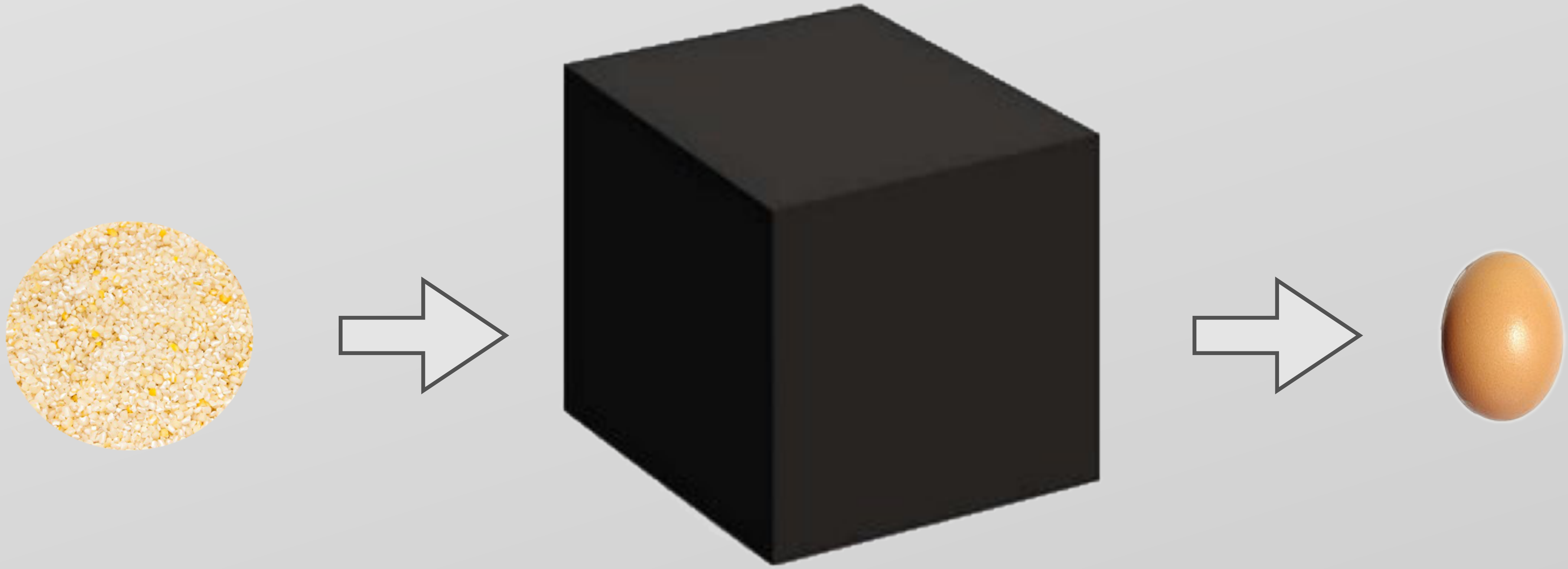
de Vaucouleurs profile



M87

Deen Neural Nets





What is the problem we want to solve?

Accurate, fast, cheap predictions ?

What is the problem we want to solve?

Accurate, fast, cheap predictions ?

New insight, test new ideas ?

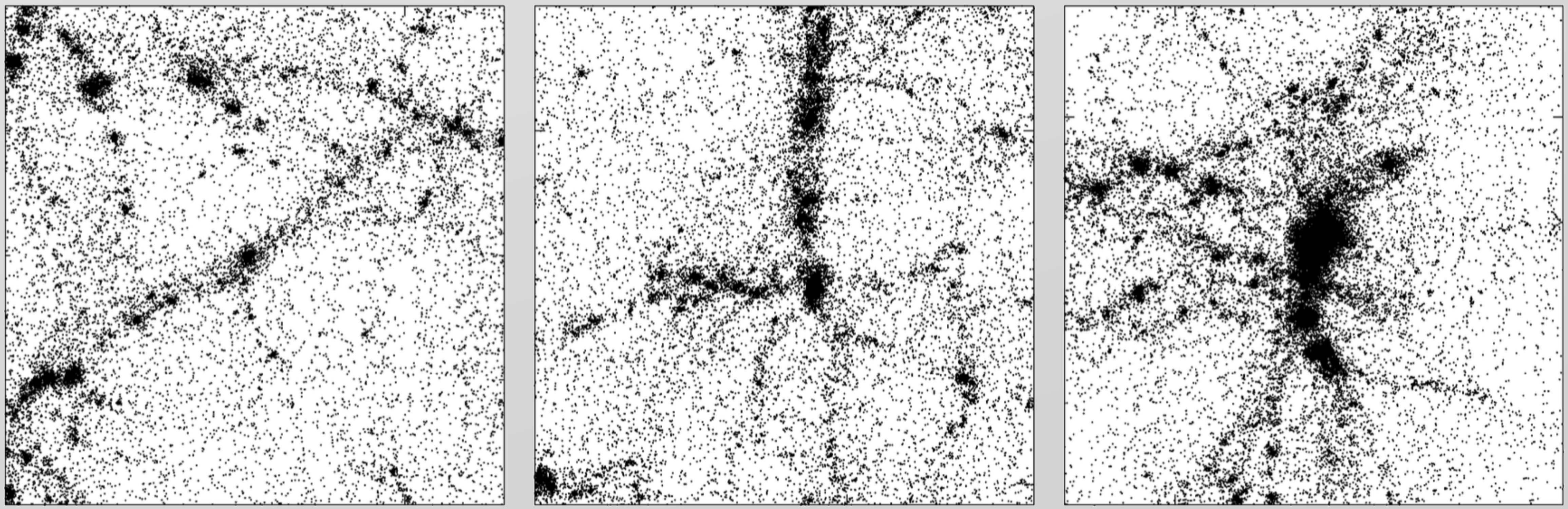
What is the problem we want to solve?

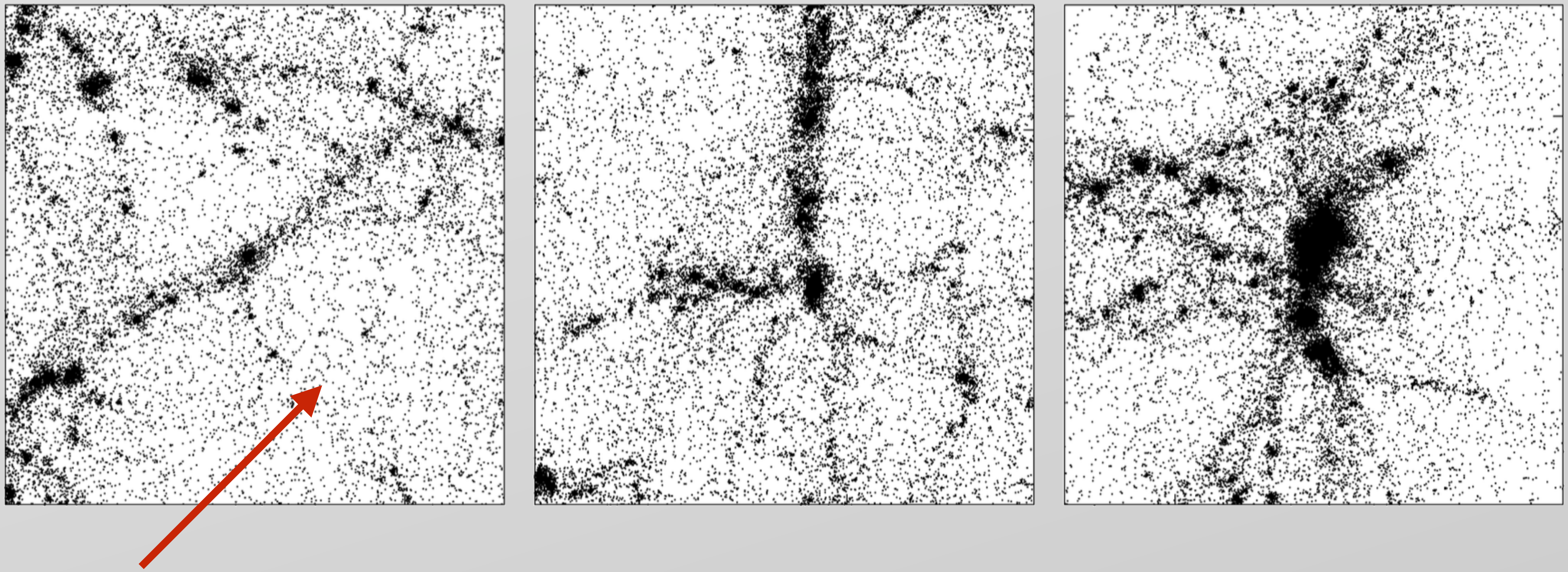
Accurate, fast, cheap predictions ?

New insight, test new ideas ?

II
Geometry and Local Density

(Ana Arcos)



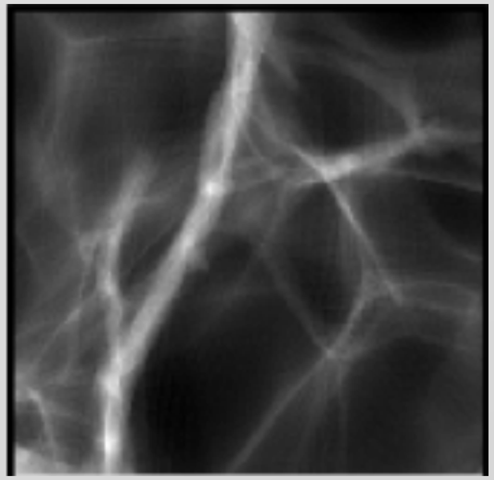


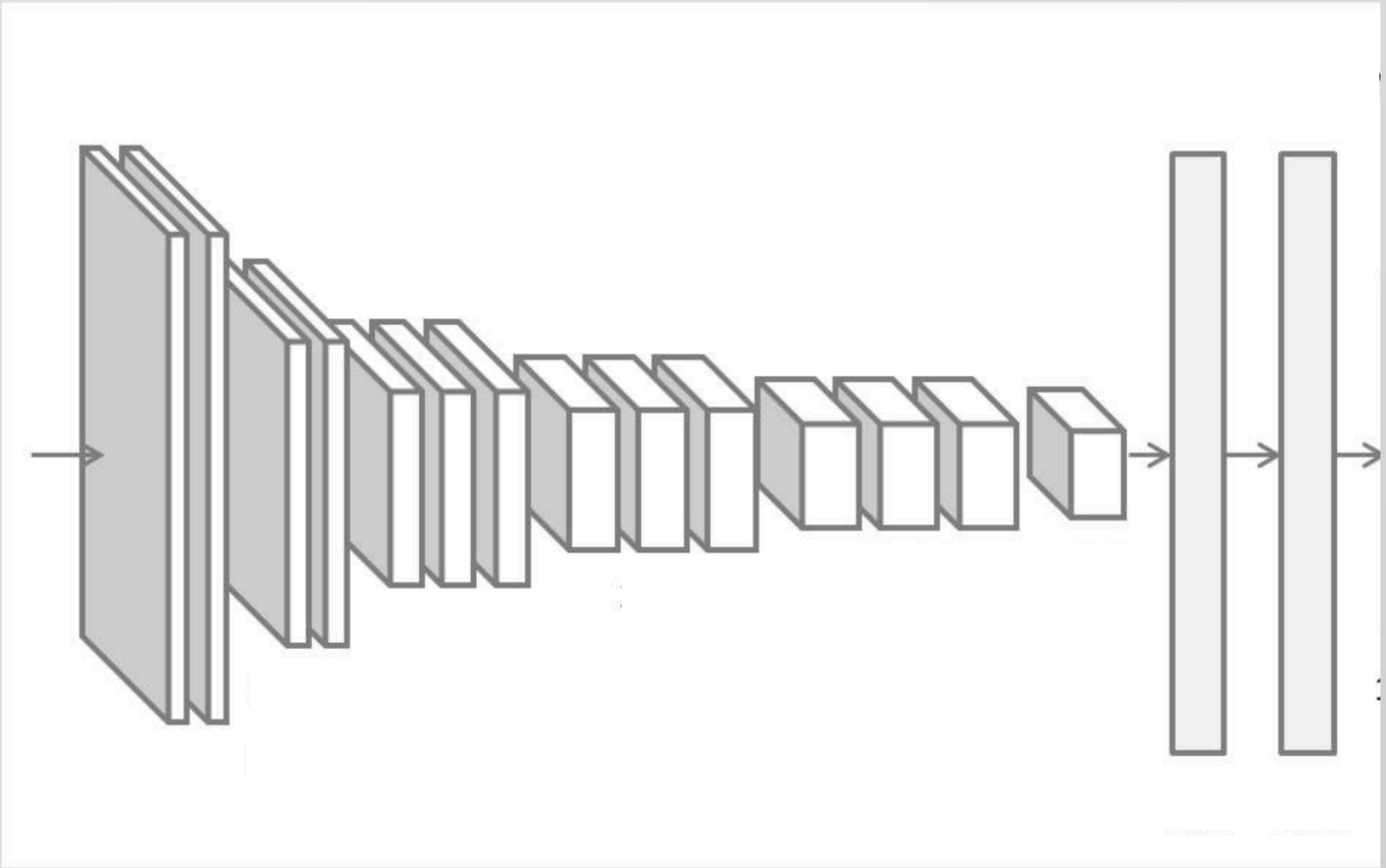
Hypothesis:

The complexity of the cosmic web is related to its local density.

How can we quantify this ?

Ask a Neural Network!

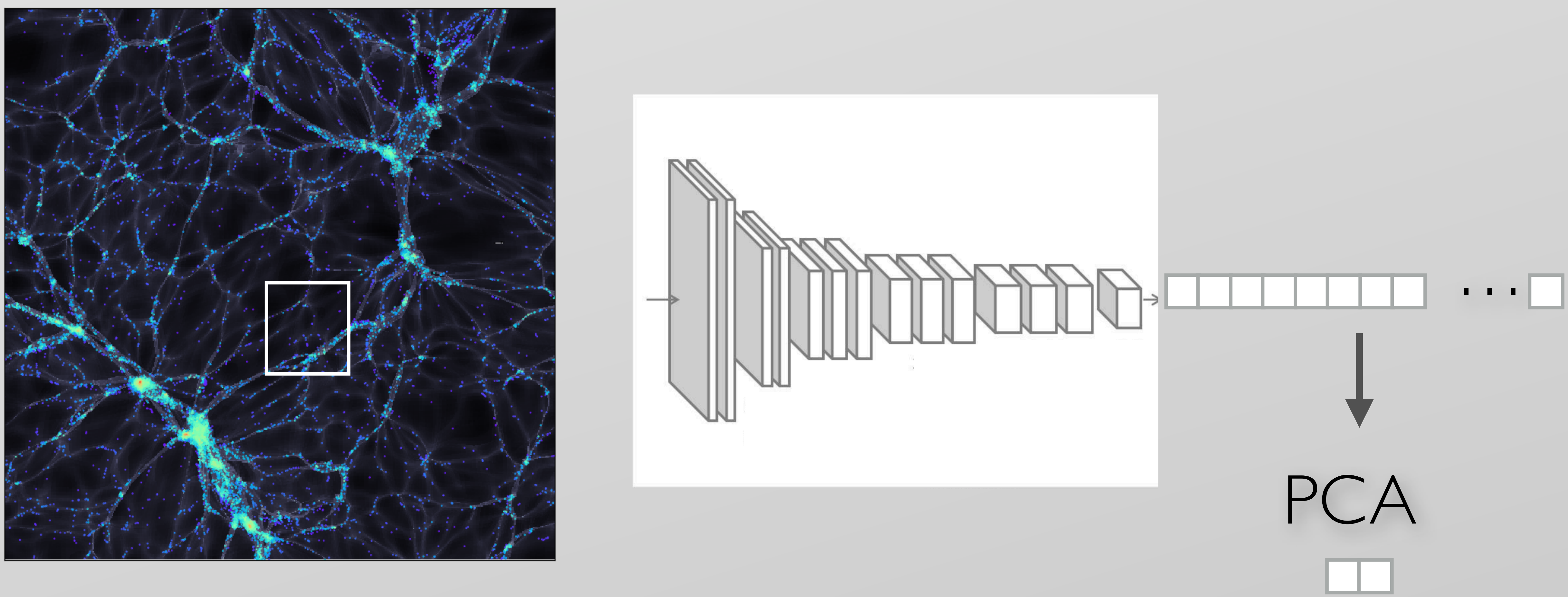




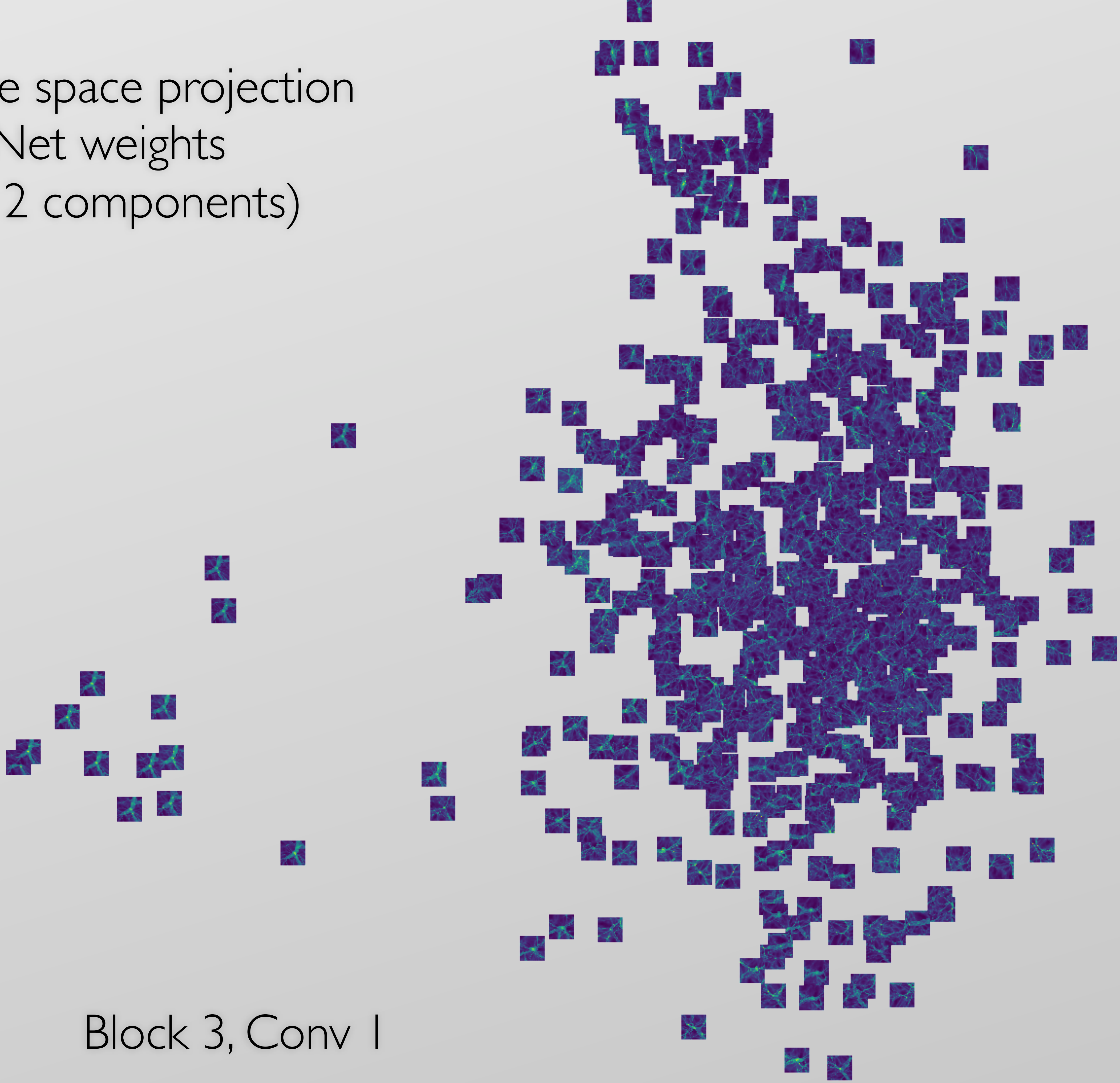
Density

Assumption: if there is a pattern the neural net will find it

First some exploration with feature images …

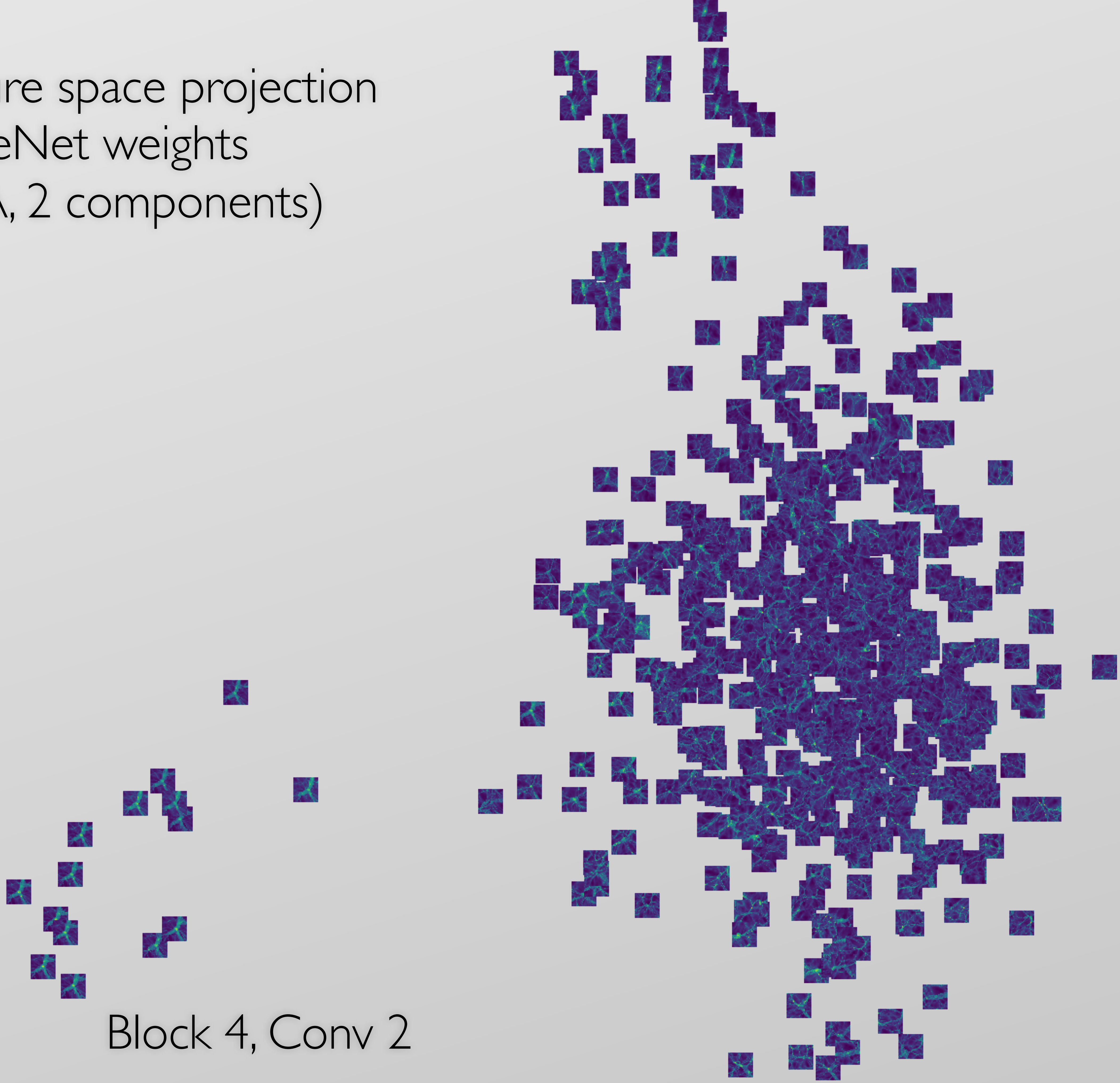


Feature space projection
ImageNet weights
(PCA, 2 components)



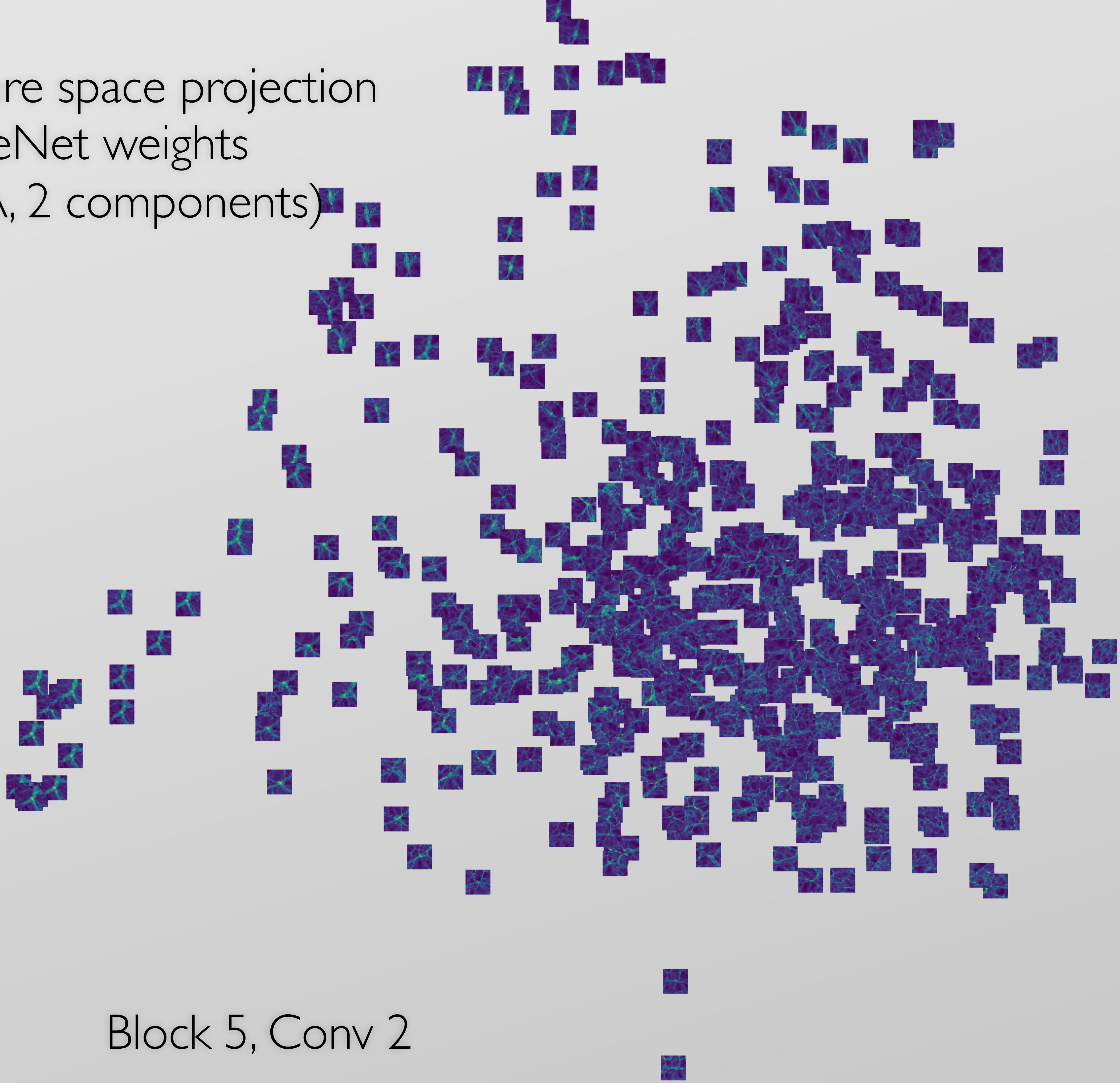
Block 3, Conv 1

Feature space projection
ImageNet weights
(PCA, 2 components)



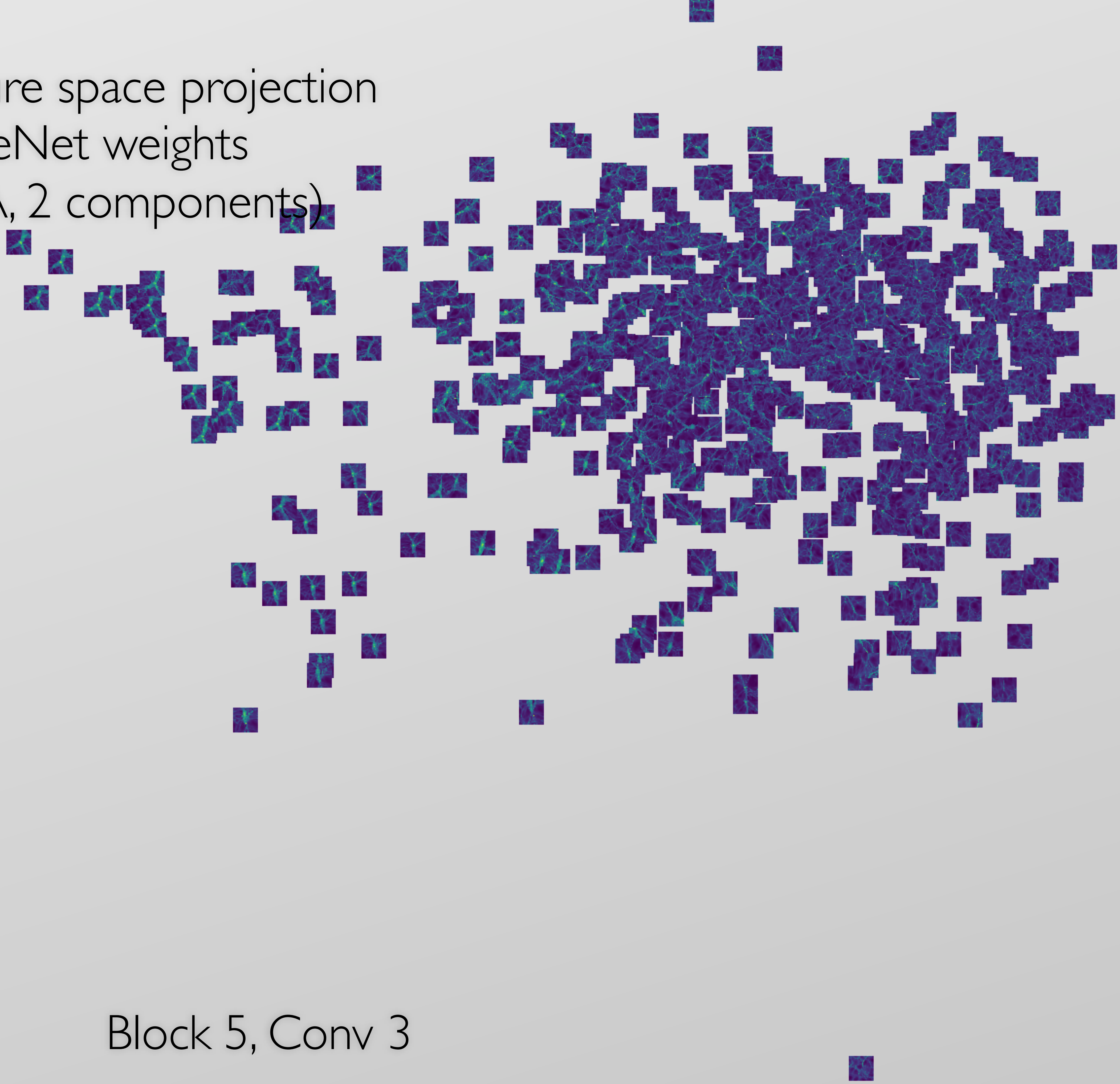
Block 4, Conv 2

Feature space projection
ImageNet weights
(PCA, 2 components)



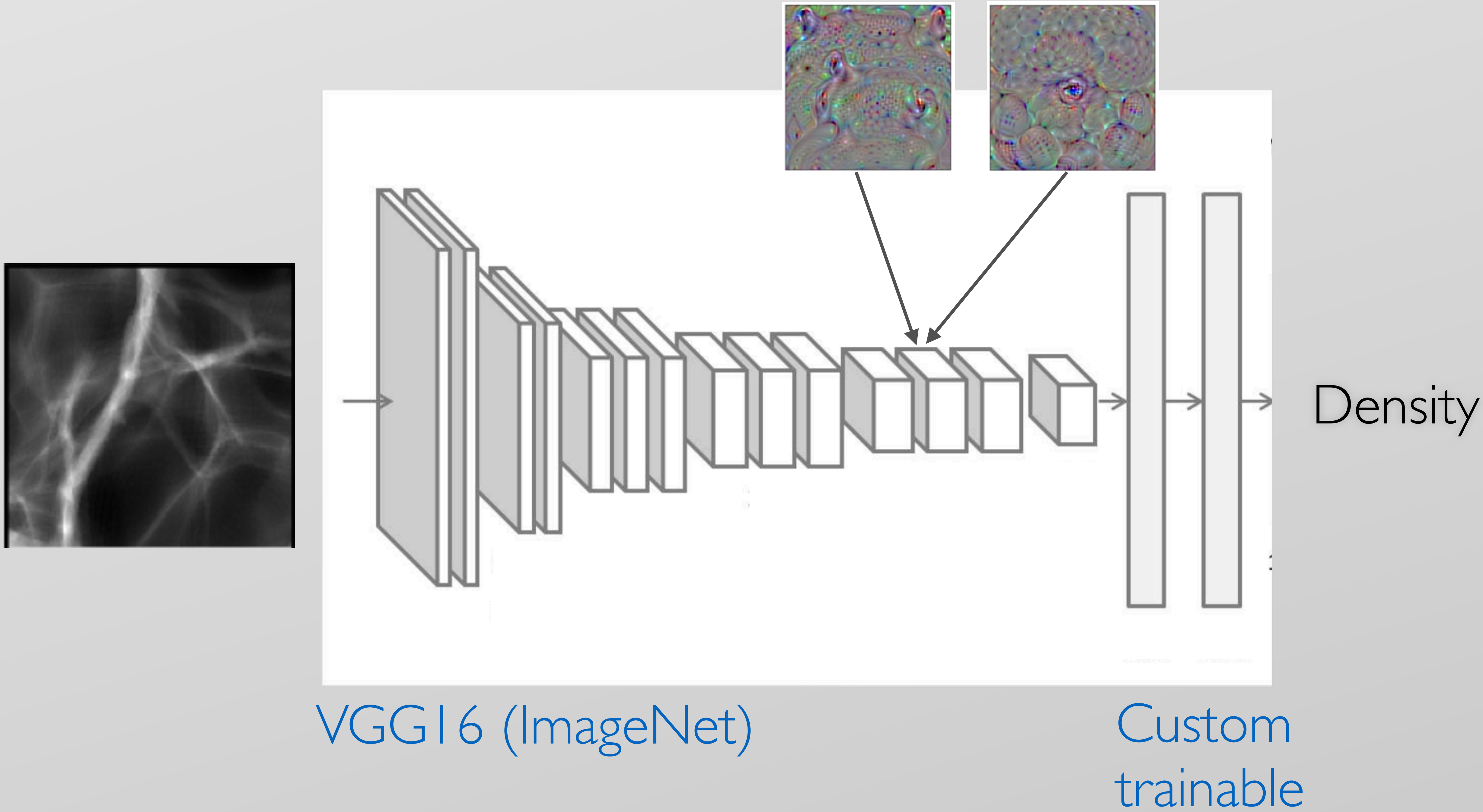
Block 5, Conv 2

Feature space projection
ImageNet weights
(PCA, 2 components)

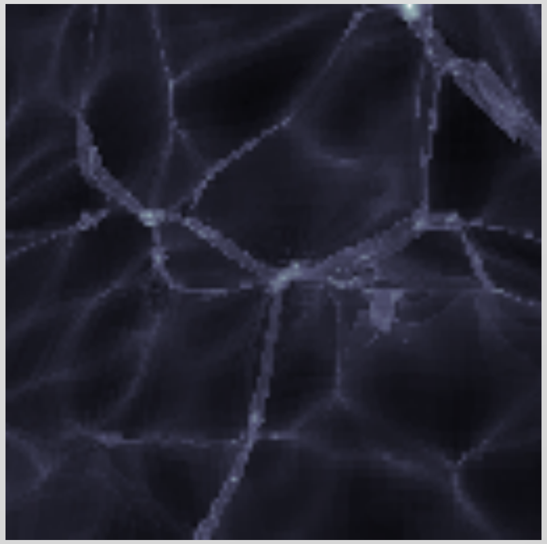


Block 5, Conv 3

Transfer Learning (VGG16 on ImageNet)



Experiment setup



Training data:

X: xy slice (18 Mpc side)

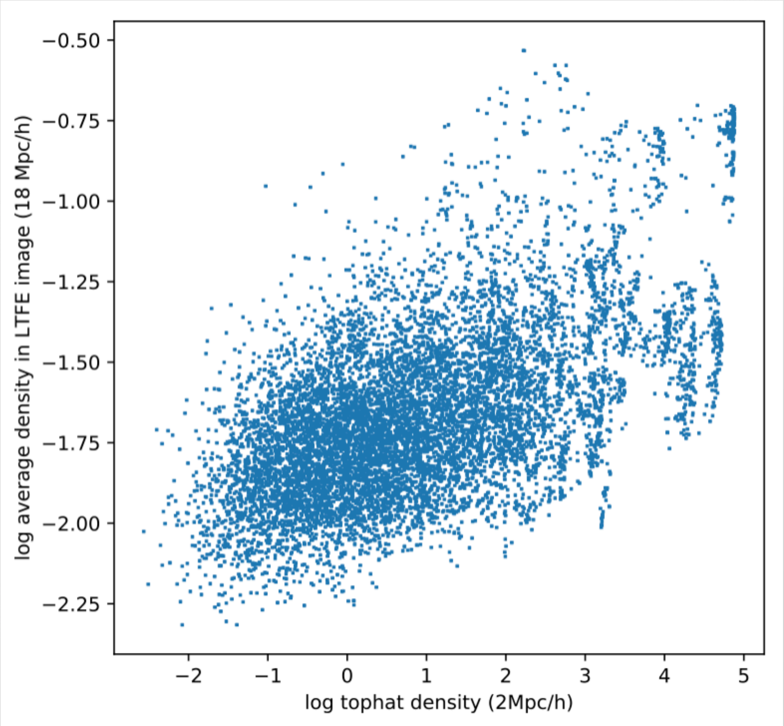
y: tophat density (2 Mpc)

Constraints:

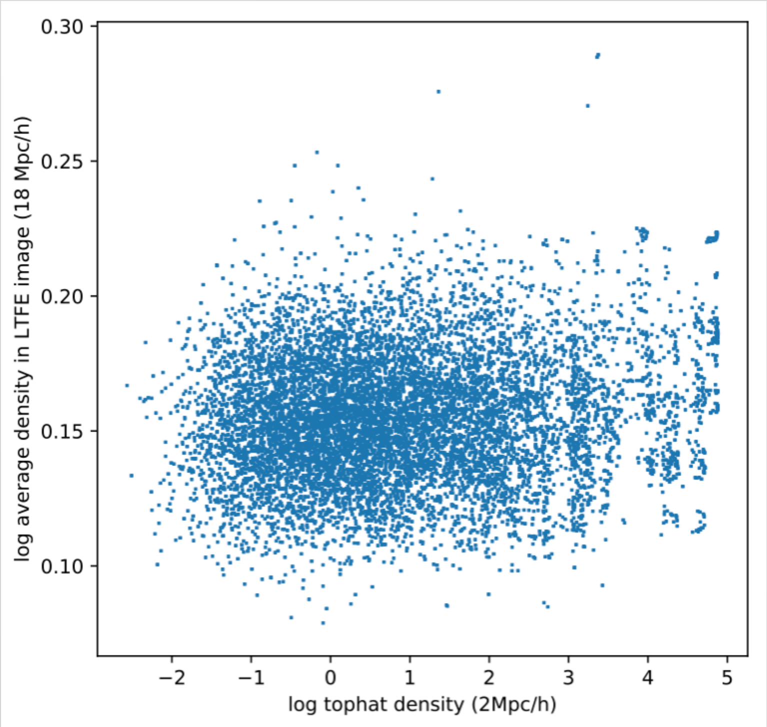
Normalize values in range (0-1)

Constraints:

Normalize values in range (0-1)



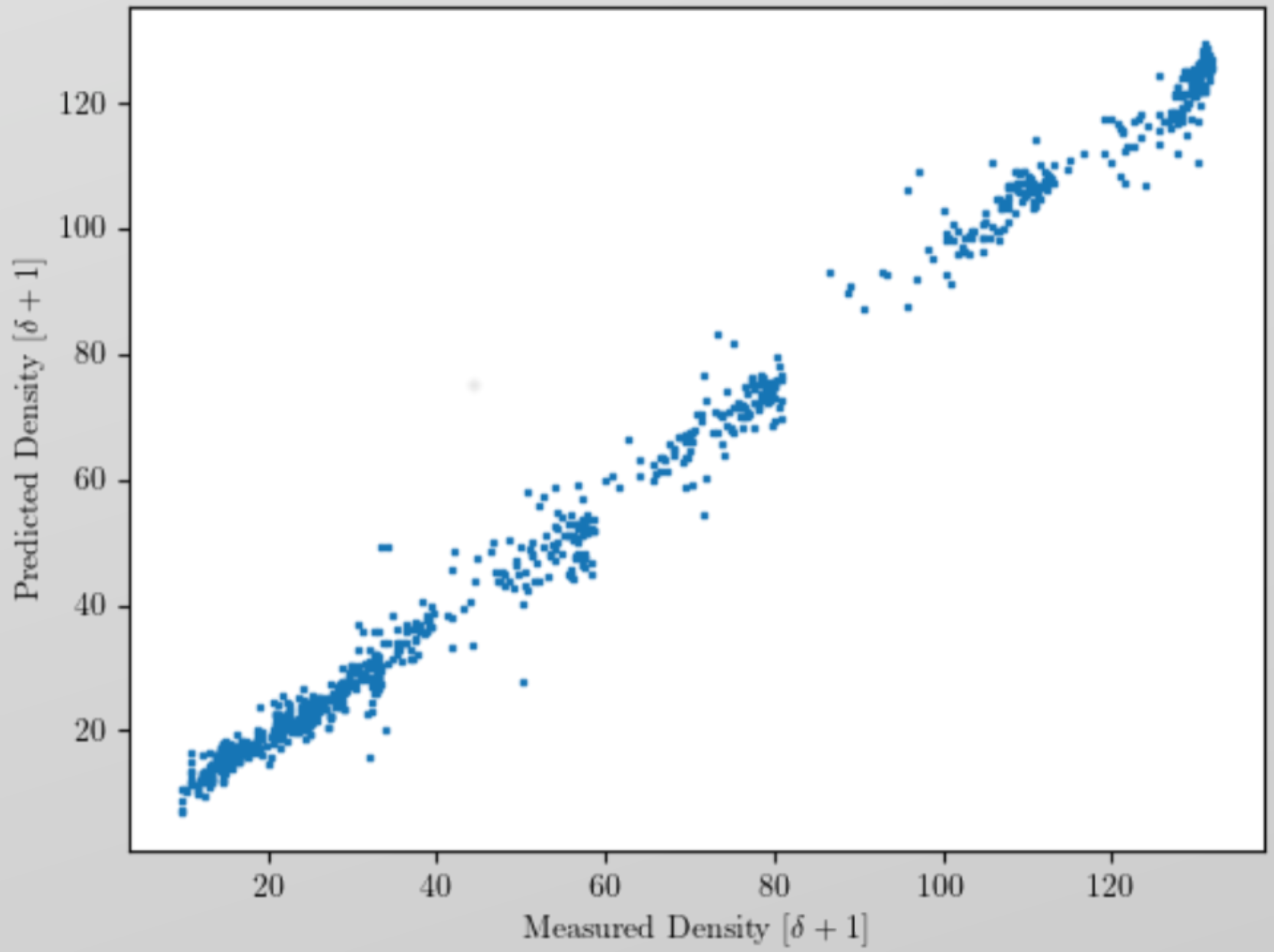
Original



Normalized

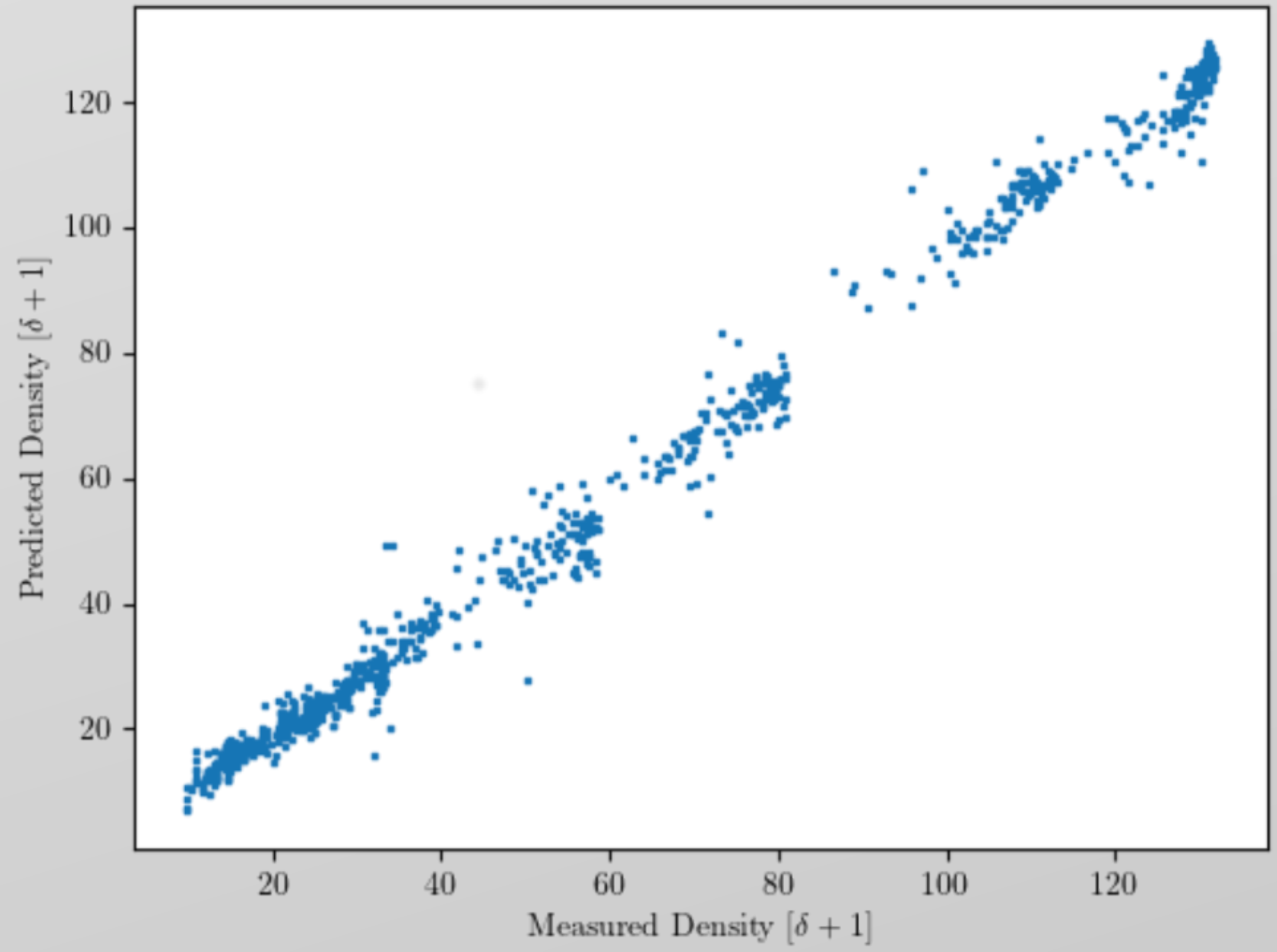
Results

- VGG16 on ImageNet



To do (Ana):

- Use 3D net
- Train from scratch
- Test halo/galaxy properties
- etc.



III
Image-z

(Martin Herrera)

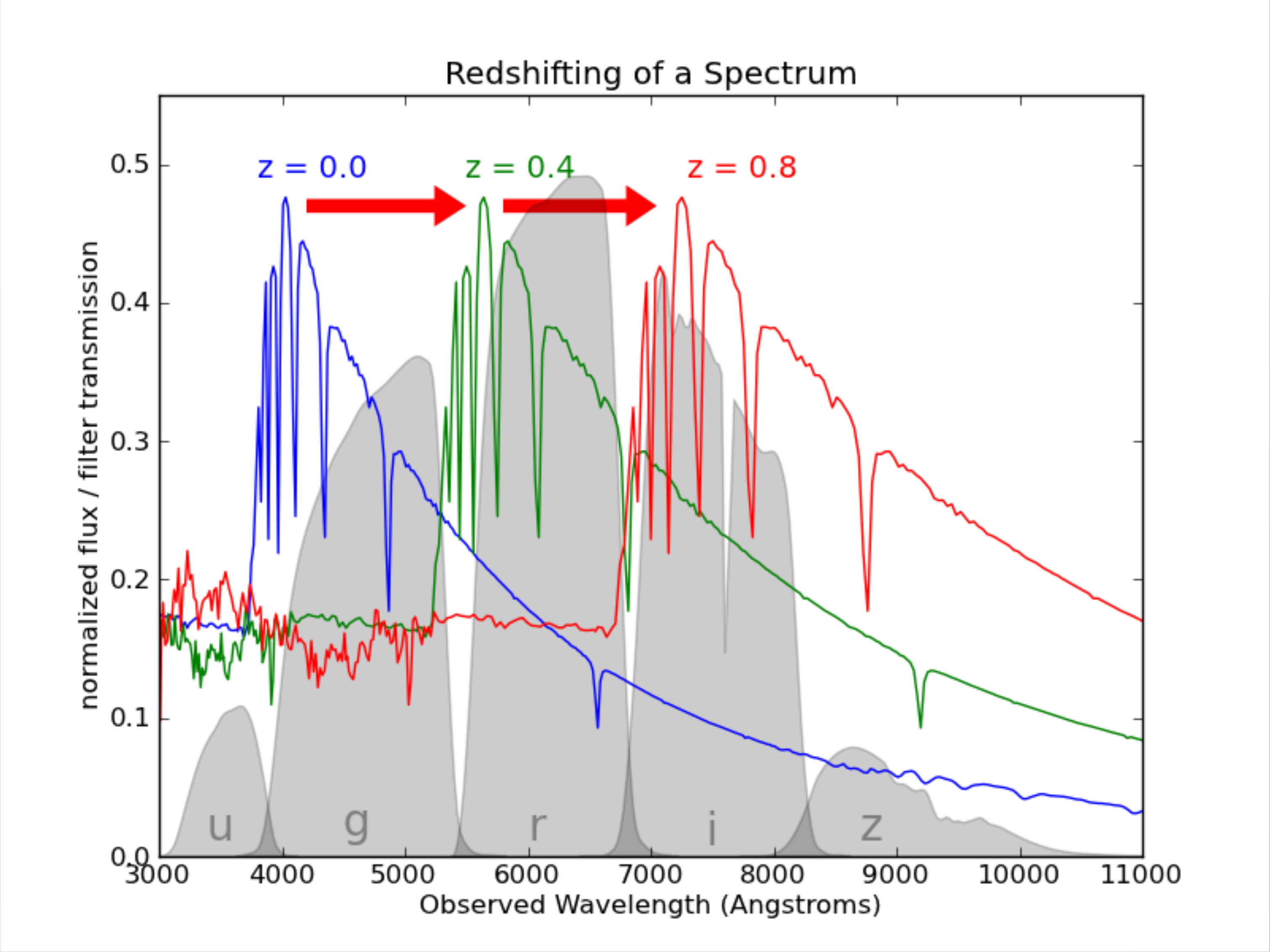

Redshifting of a Spectrum
z = 0.0
z = 0.4
z = 0.8
normalized flux / filter transmission
0.0
0.1
0.2
0.3
0.4
0.5
3000
4000
5000
6000
7000
8000
9000
10000
11000
Observed Wavelength (Angstroms)
u
g
r
i
z

photo-z

Measuring photometric redshifts using galaxy images and Deep Neural Networks

Ben Hoyle

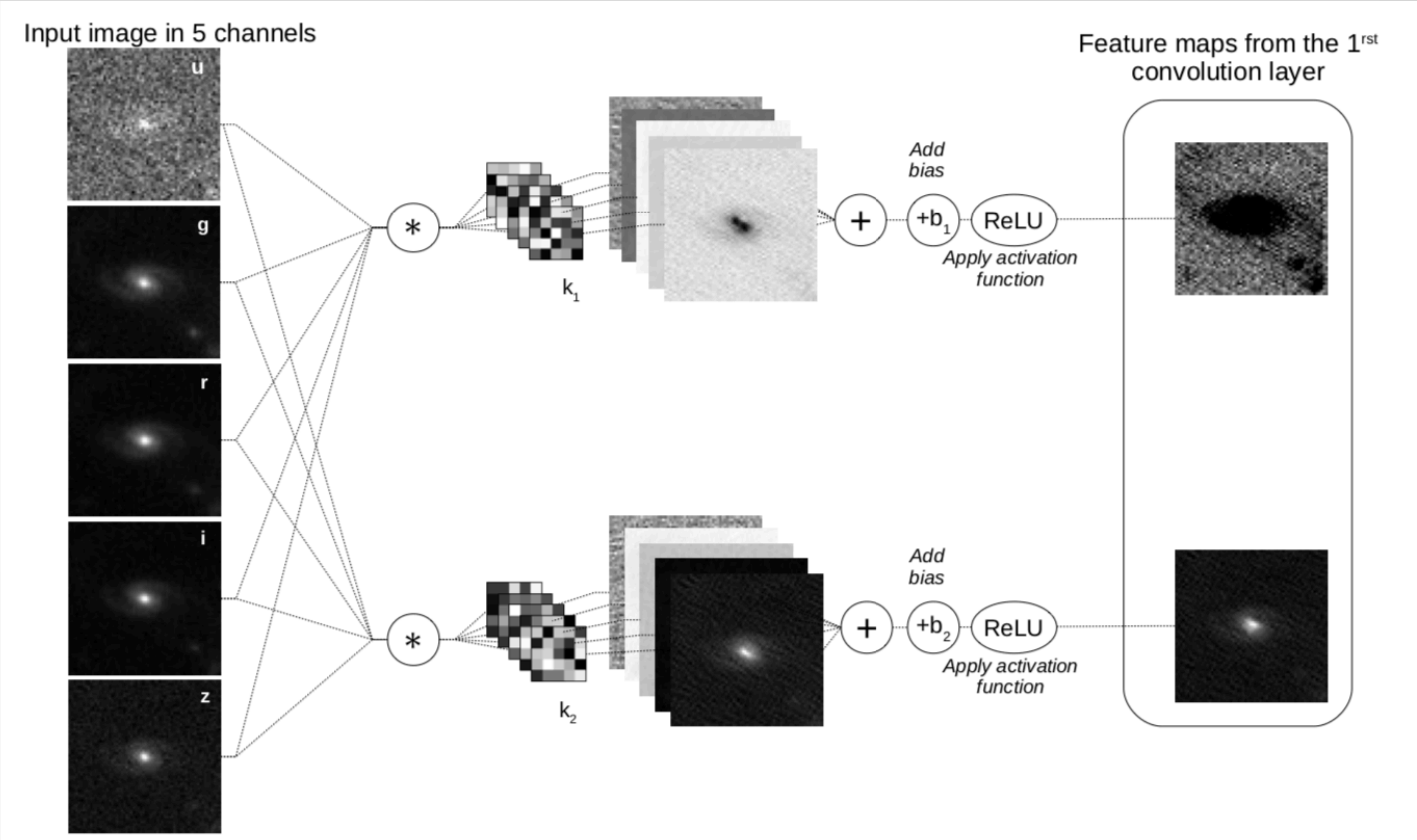
Photometric redshifts from SDSS images using a Convolutional Neural Network

Johanna Pasquet[1], E. Bertin[2], M. Treyer[3], S. Arnouts[3] and D. Fouchez[1]

Photometric redshift estimation via deep learning

Generalized and pre-classification-less, image based, fully probabilistic redshifts

A. D'Isanto and K. L. Polsterer



Pasquet et al. 2018

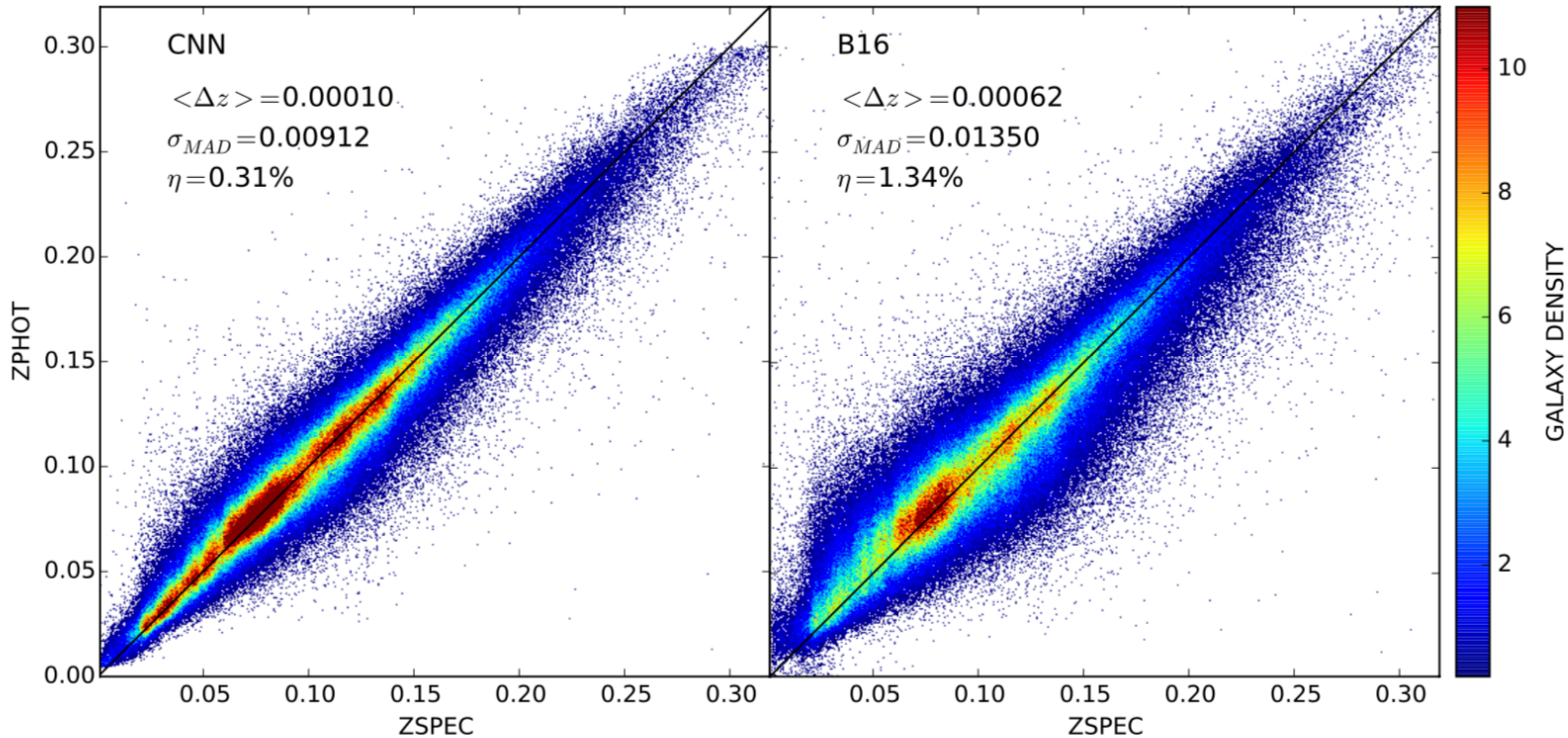
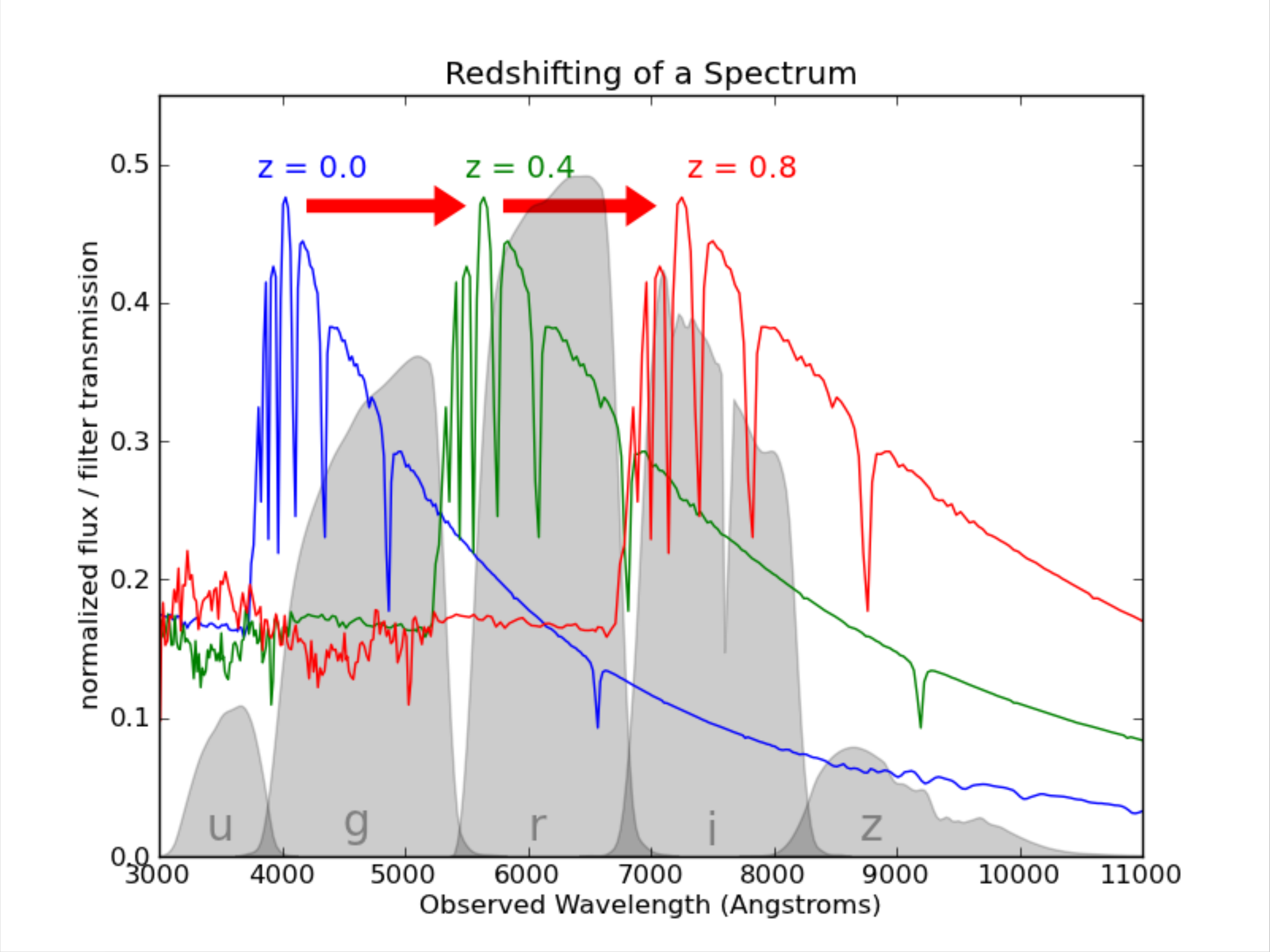


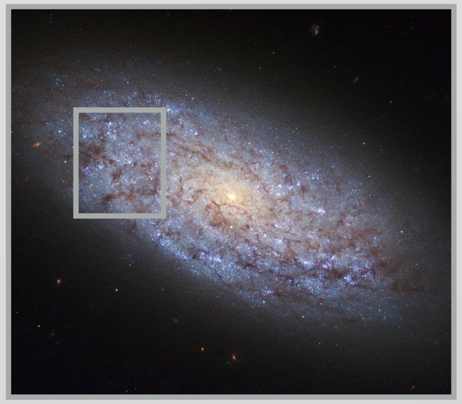
Fig. 7. Comparison between the photometric redshifts predicted by the CNN (left panel) and by B16 (right panel) against the spectroscopic redshifts. The galaxy density and the statistics are averaged over the 5 cross-validation samples.

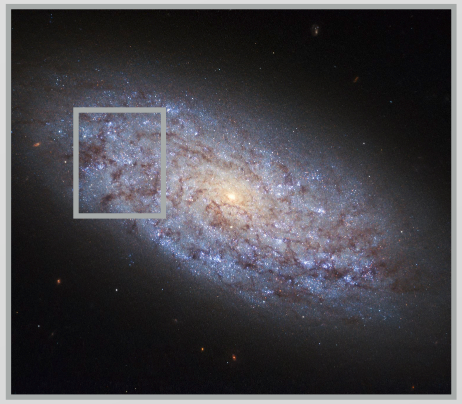
Pasquet et al. 2018

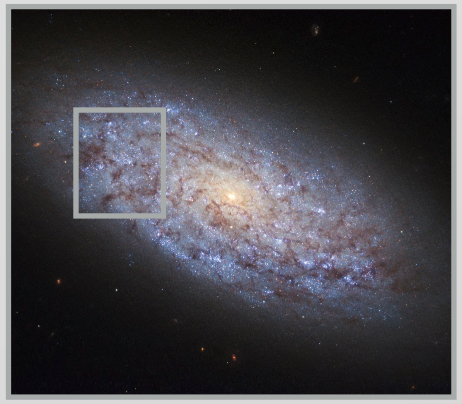


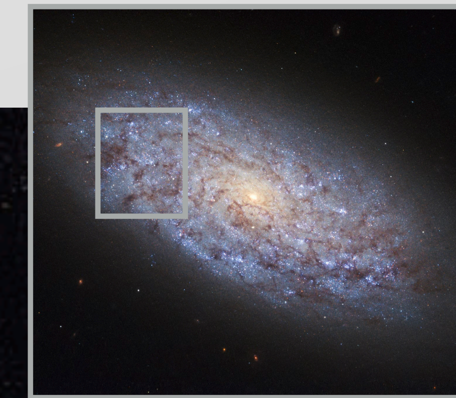
Redshifting of a Spectrum
z = 0.0
z = 0.4
z = 0.8
normalized flux / filter transmission
Observed Wavelength (Angstroms)
0.0
0.1
0.2
0.3
0.4
0.5
3000
4000
5000
6000
7000
8000
9000
10000
11000
u
g
r
i
z

photo-z







NGC 5949 (~5 kpc radius)

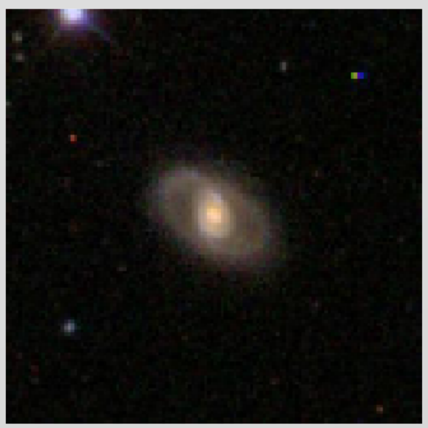
NGC 5457 (~30 kpc radius)

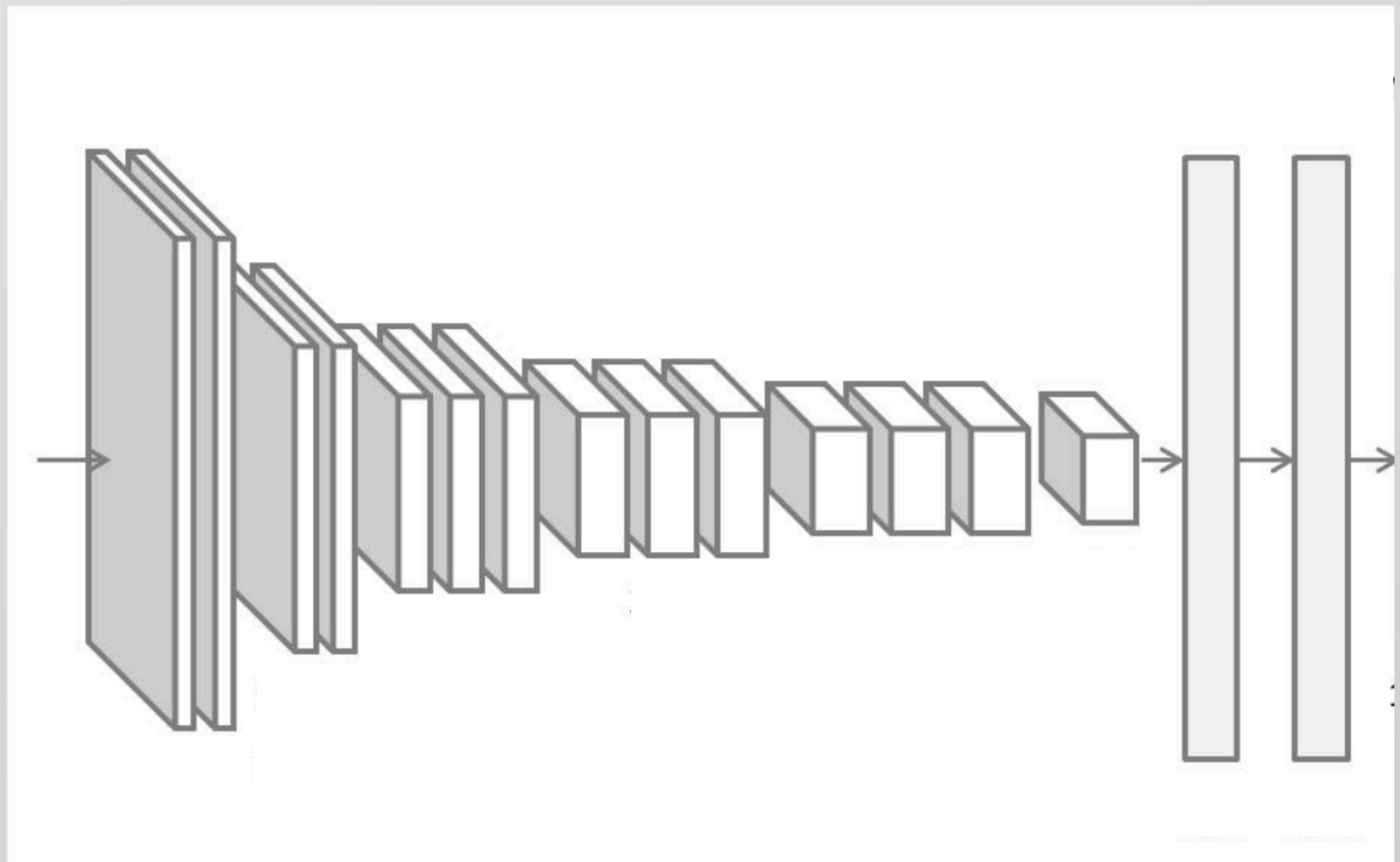
Hypothesis:

There are structural elements in galaxies with constrained physical scales. We can use these elements as standard rulers.

How can we quantify the structure in galaxies ?

Use a neural network !!!



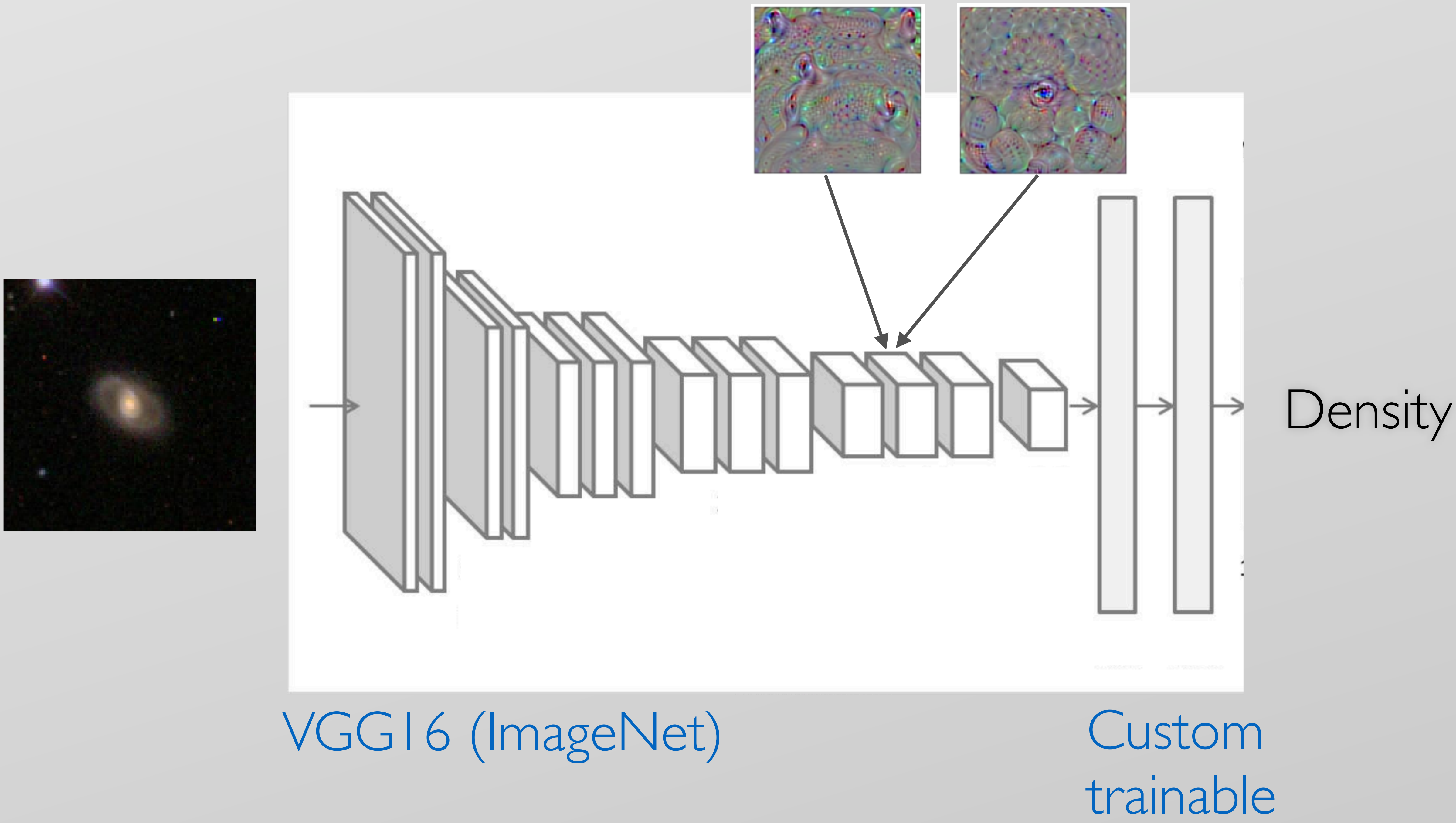


Density

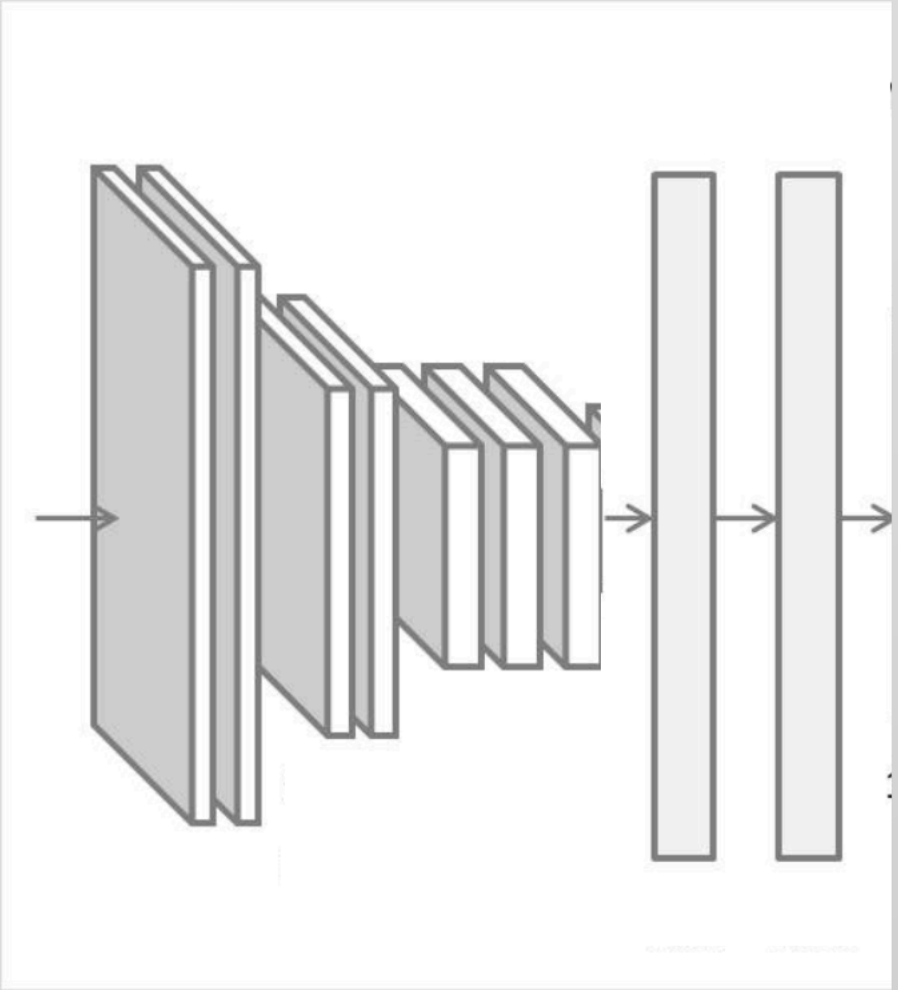
VGG16 (ImageNet)

Custom trainable

Transfer Learning (VGG16 on ImageNet)



Transfer Learning (VGG16 on ImageNet)



redshift

VGG16 (ImageNet)

Custom
trainable

Experiment setup

Training data:

- X: single channel image
- y: redshift

Constraints:

- Large images
- Spirals (galaxy zoo class)
- Face-on (b/a > 0.75)
- Same angular size

Experiment setup

Training data:

X: single channel image

y: redshift

Constraints:

Large images

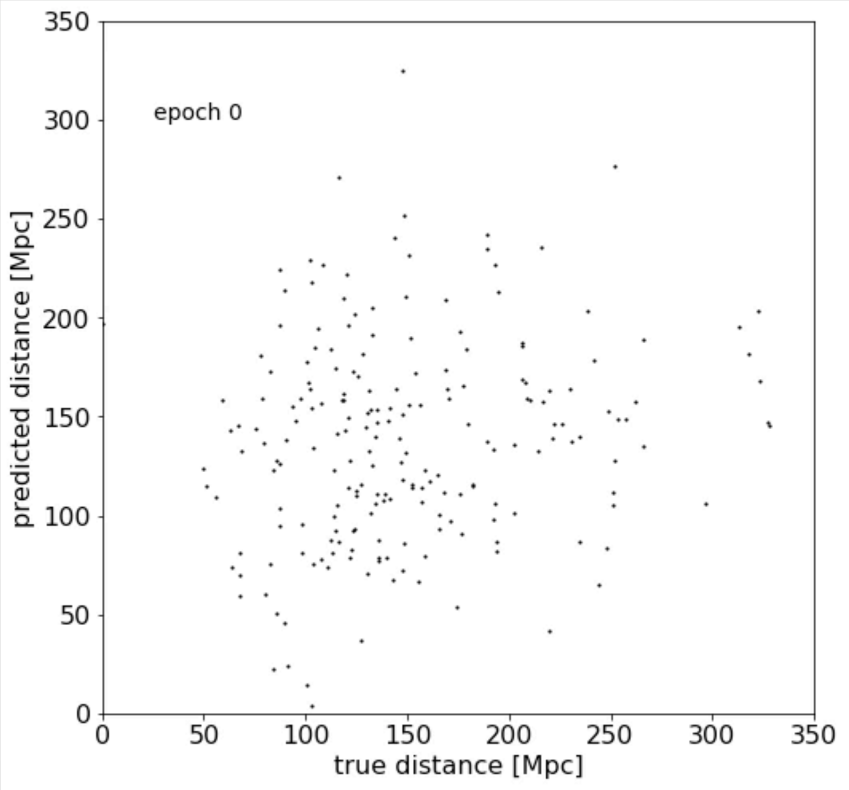
Spirals (galaxy zoo class)

Face-on ($b/a > 0.75$)

Same angular size

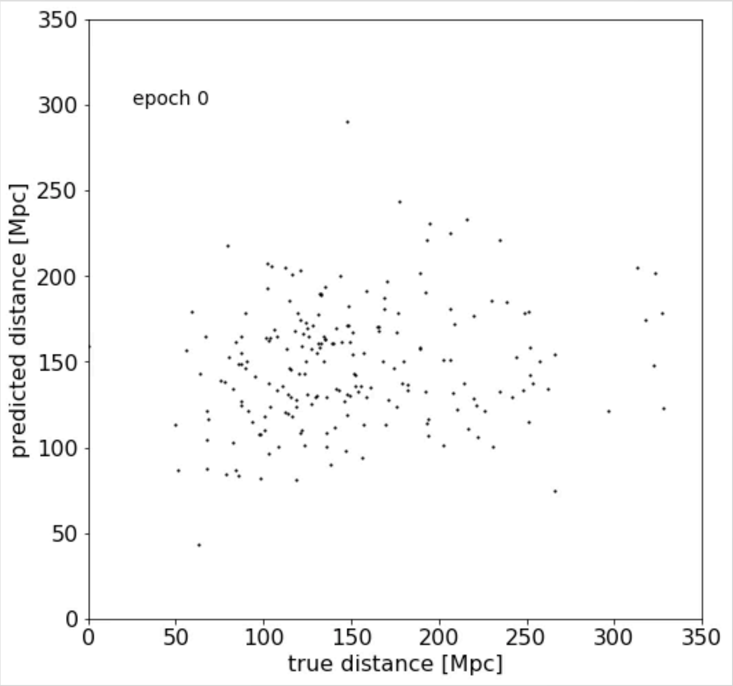
JPG images (!)

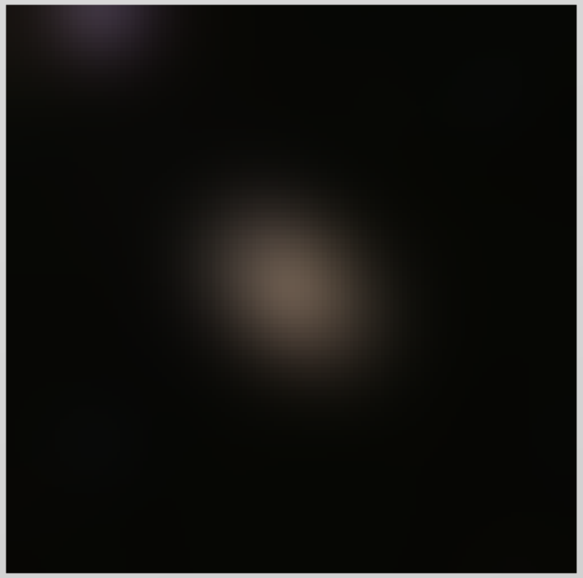
Results (raw images)



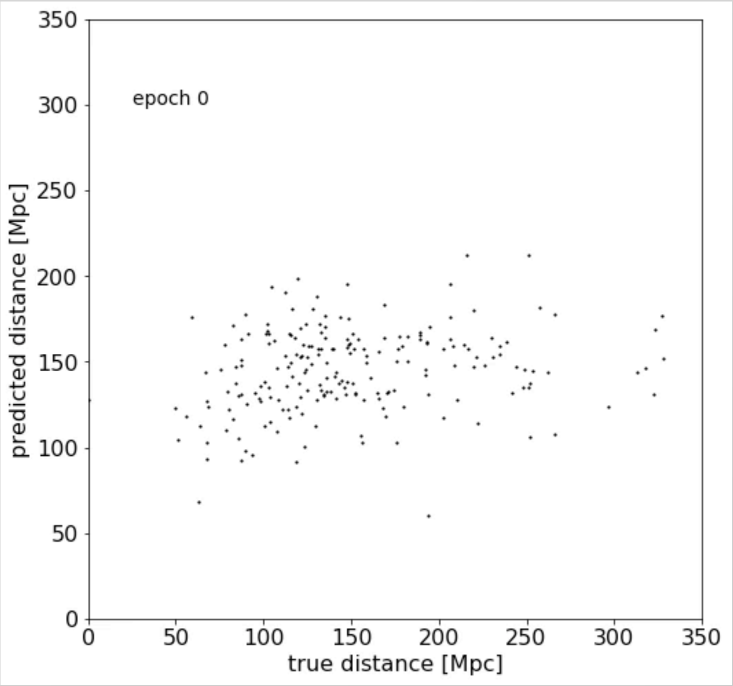
Results (smoothing)

4 pix



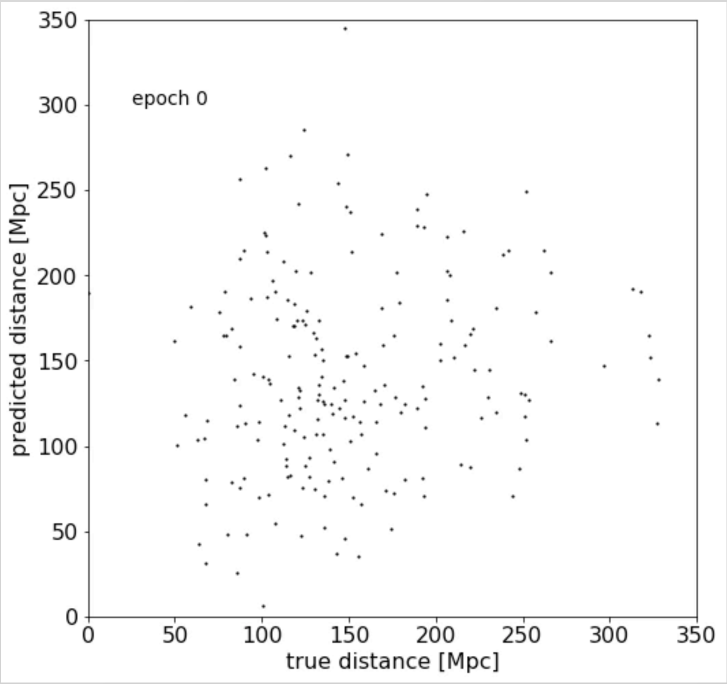


8 pix



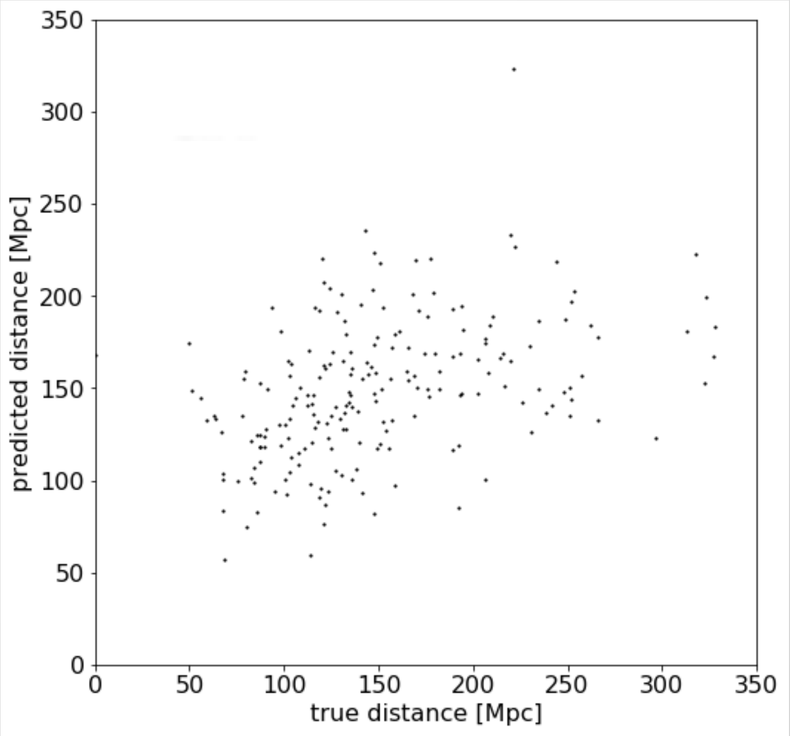
Results (high-pass)

8 pix

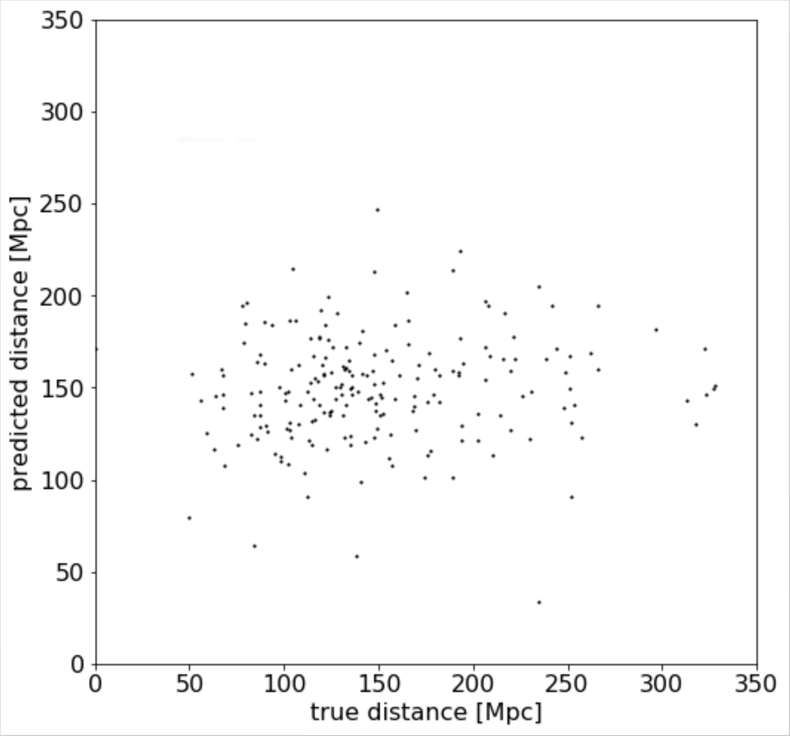


Results (foreground / background)

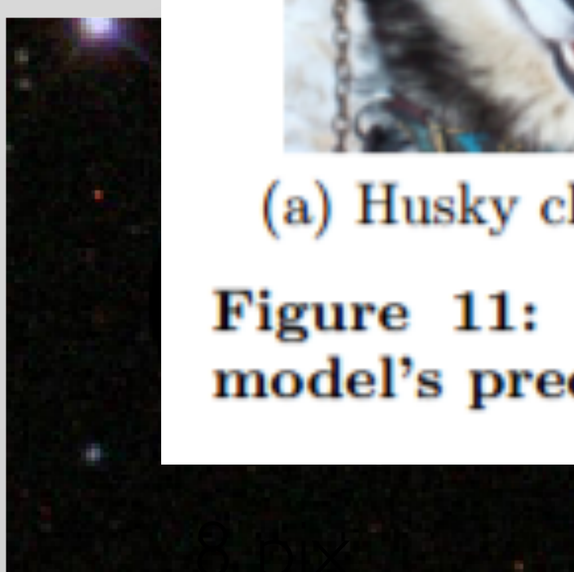
Center



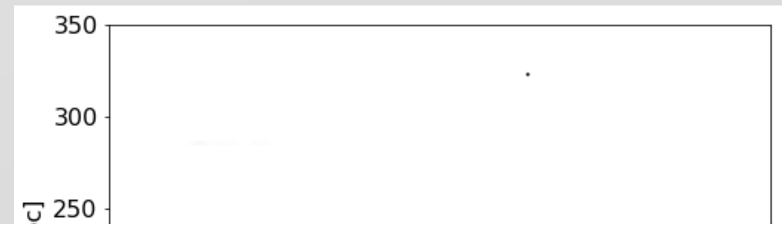
Outskirts



Results (foreground / background)



Outskirts

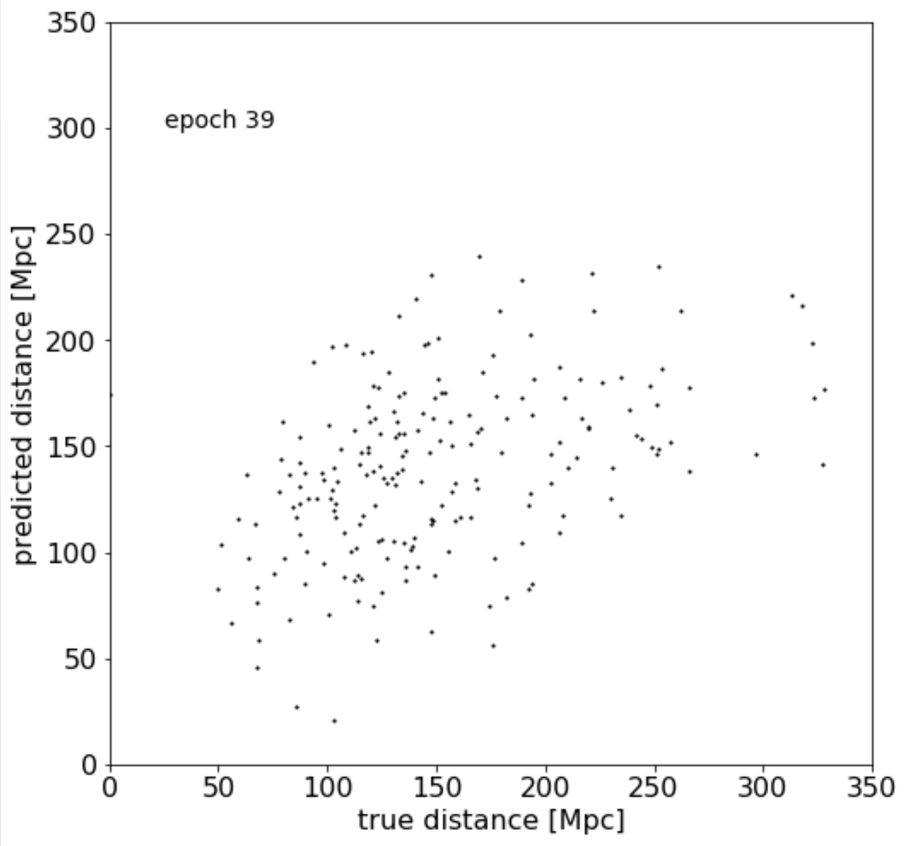


(a) Husky classified as wolf (b) Explanation

Figure 11: Raw data and explanation of a bad model's prediction in the "Husky vs Wolf" task.

To do (Martin)

- Use fits images
- Multiscale analysis
- Explore features
- Add to existing photo-z methods



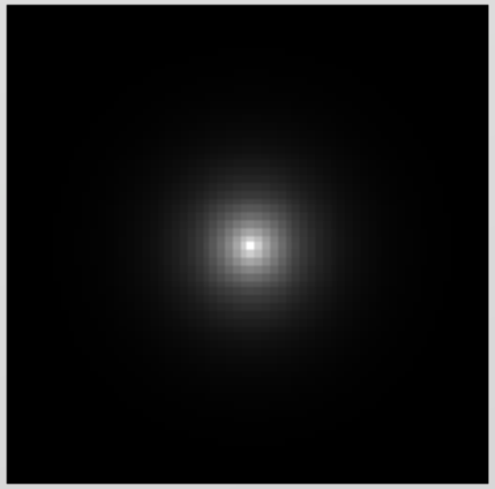
Conclusions

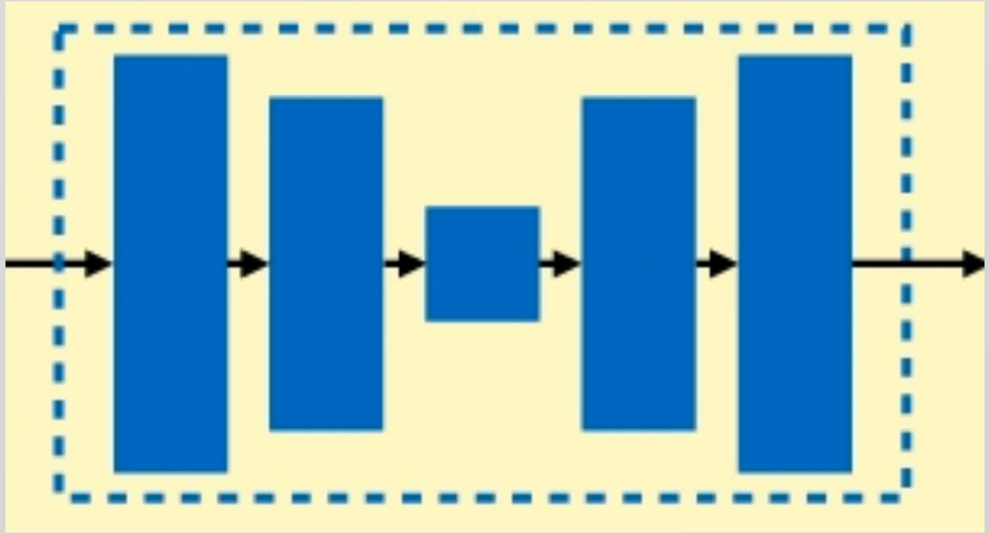
Artificial Intelligence is a black box (so far) but can be used as a powerful hypothesis testing tool

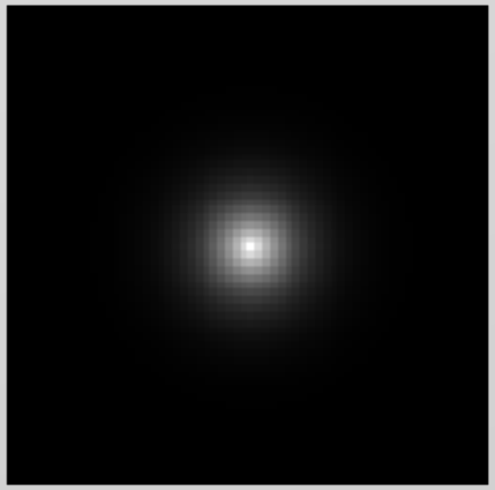
With some constraints on the training process we can also extract insight on the data

Thank you!

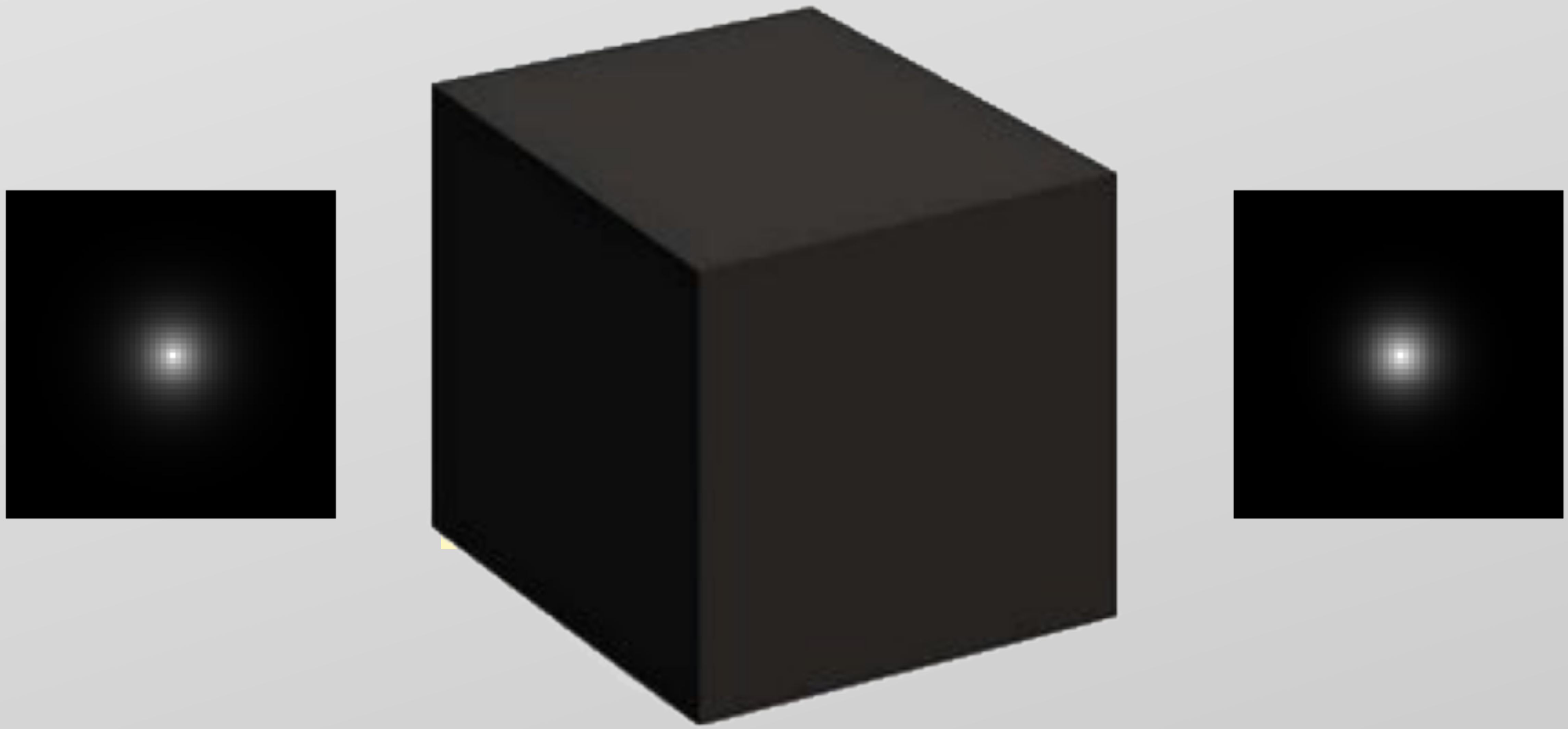
Autoencoder





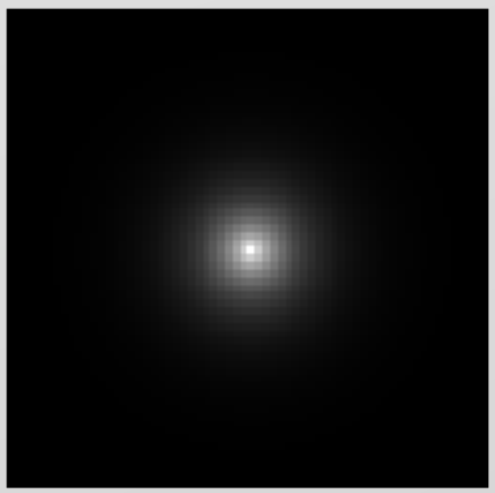


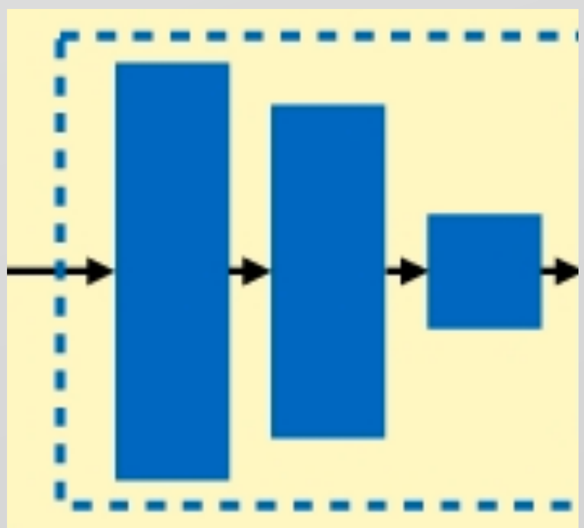
Autoencoder



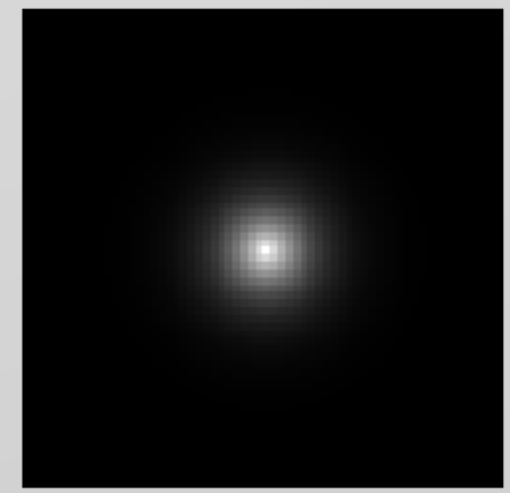
Autoencoder

Differentiable programming



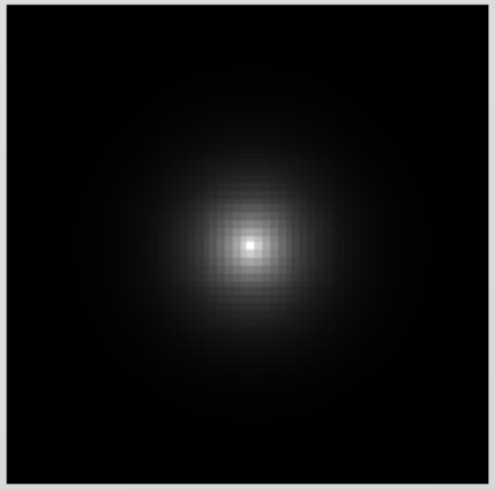


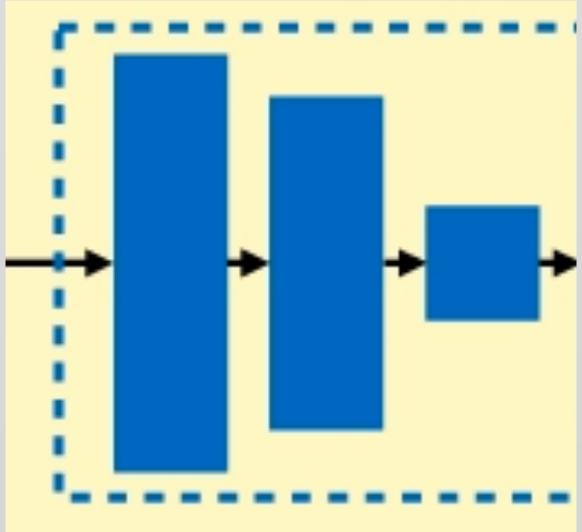
$$I(R) = I_e e^{-7.669\left[\left(\frac{R}{R_e}\right)^{1/4}-1\right]}$$



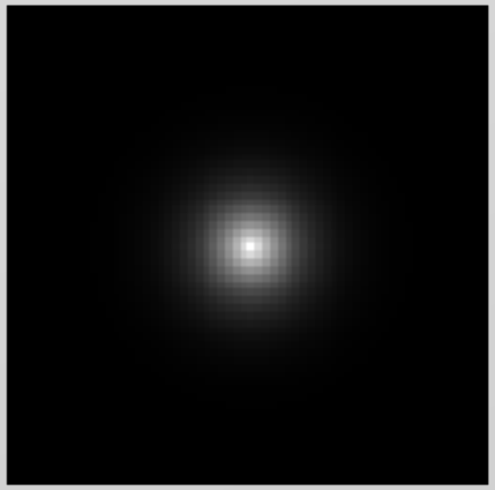
Parametric autoencoder

Physical model



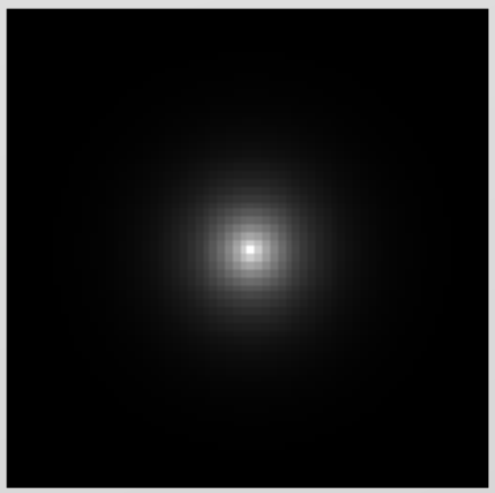


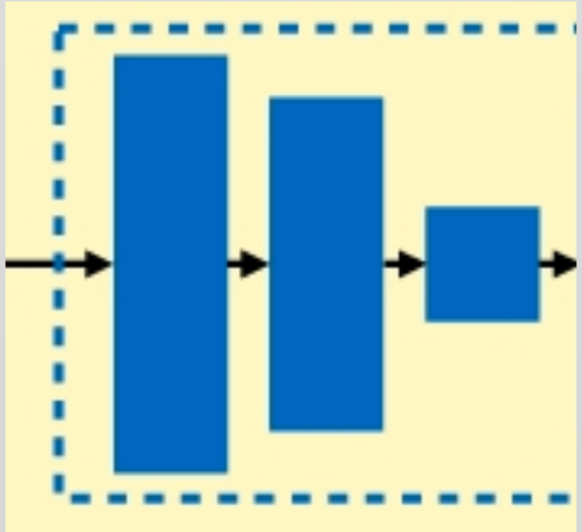
$$I(R) = I_e e^{-7.669\left[\left(\frac{R}{R_e}\right)^{1/4} - 1\right]}$$



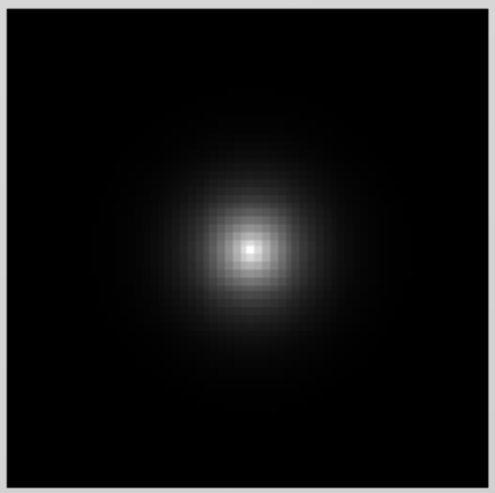
Physical parameters

Parametric autoencoder





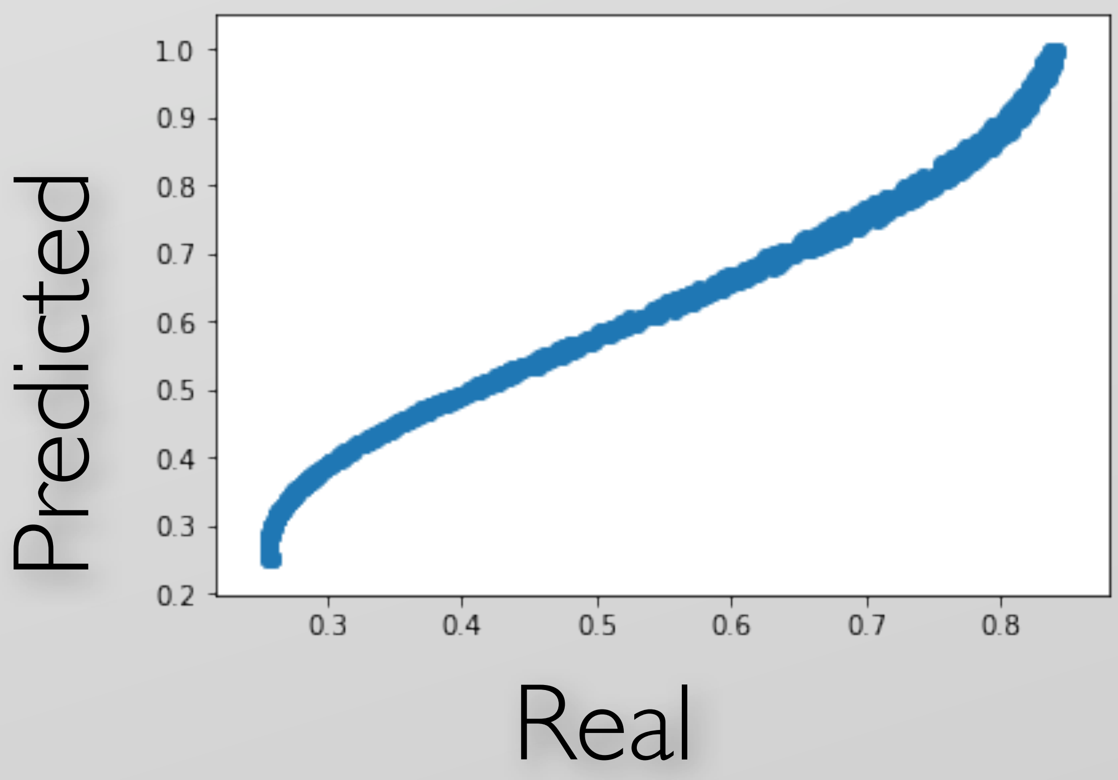
$$I(R) = I_e e^{-7.669\left[\left(\frac{R}{R_e}\right)^{1/4} - 1\right]}$$



Sparse and semantic representation

Unsupervised

Perfect for recovering initial conditions


Predicted
Real
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.3
0.4
0.5
0.6
0.7
0.8