

Application of Convolutional Neural Network for Stellar Spectral Analysis

Kaushal Sharma, Inter University Centre for Astronomy and Astrophysics

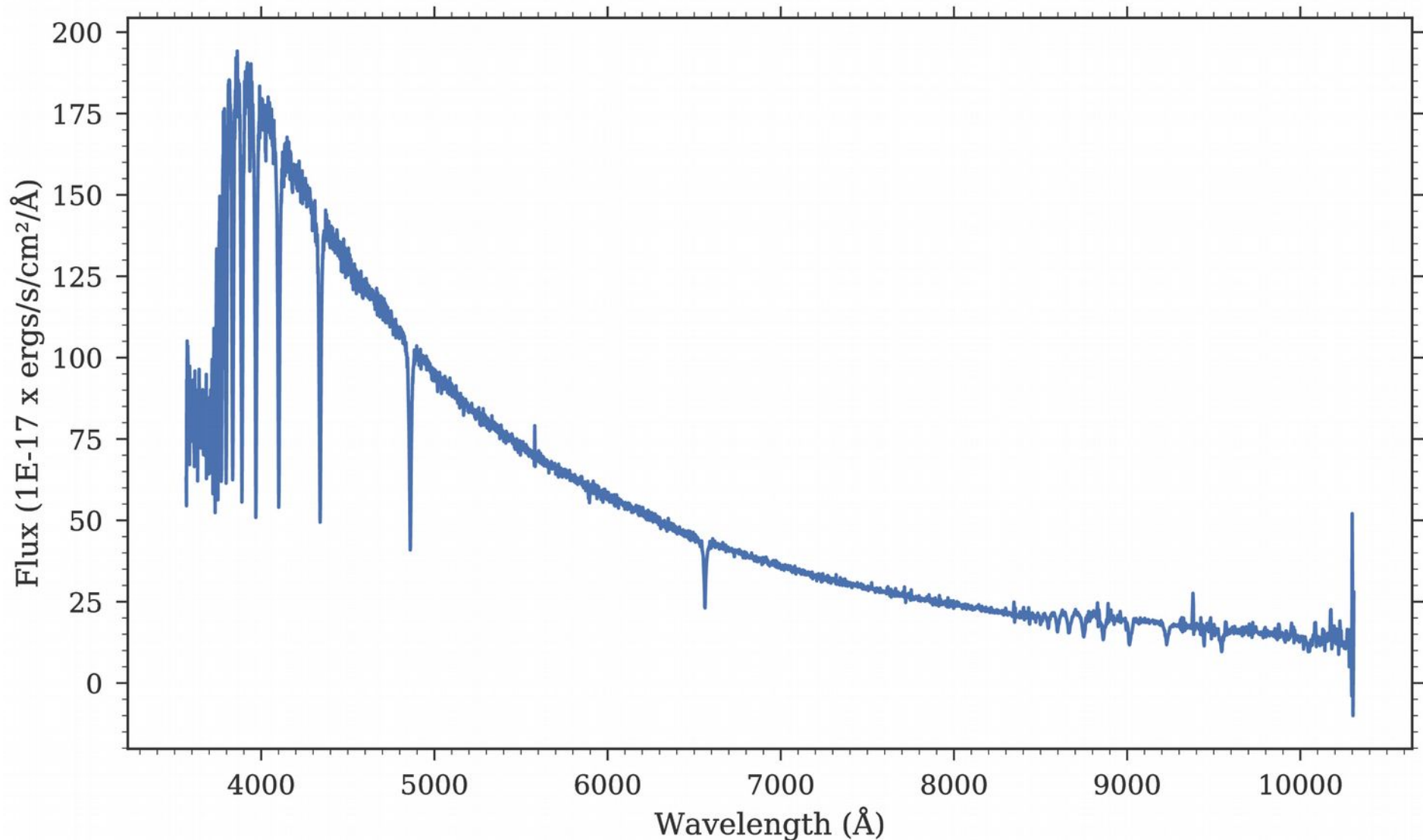
Collaborators: Ajit Kembhavi, Aniruddha Kembhavi, T. Sivarani,
Kaustubh Vaghmare, and Sheelu Abraham



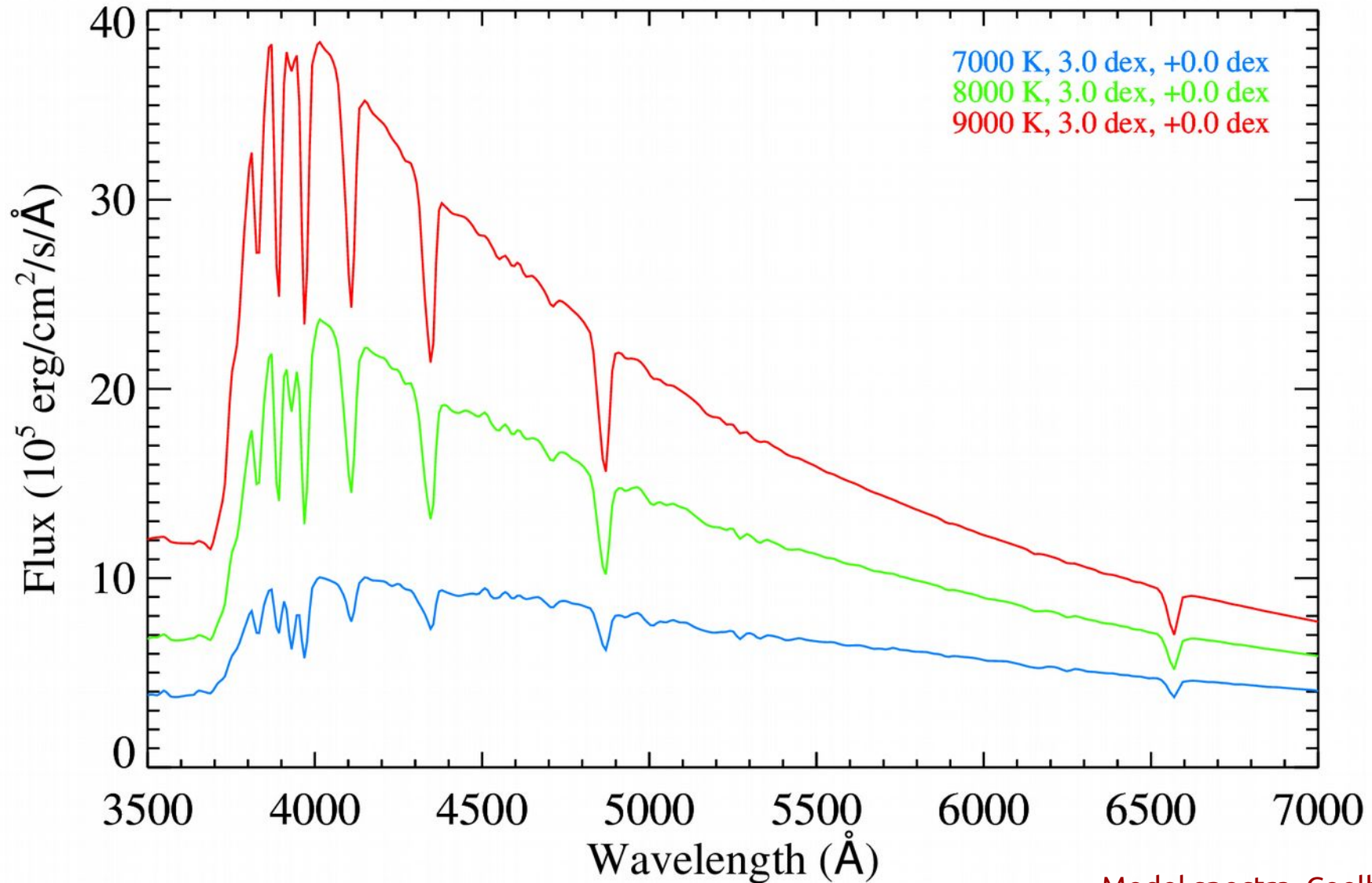
Outline

- Introduction
 - Stellar Spectral Classification
 - Machine Learning/Deep Learning
- Artificial Neural Net
- Convolutional Neural Net
- Autoencoders
- Autoencoders Applications
 - Semi-supervised Classification
 - Outlier Detection
 - Denoising
 - Generative autoencoders

Stellar Spectrum: Distribution of Energy versus wavelength

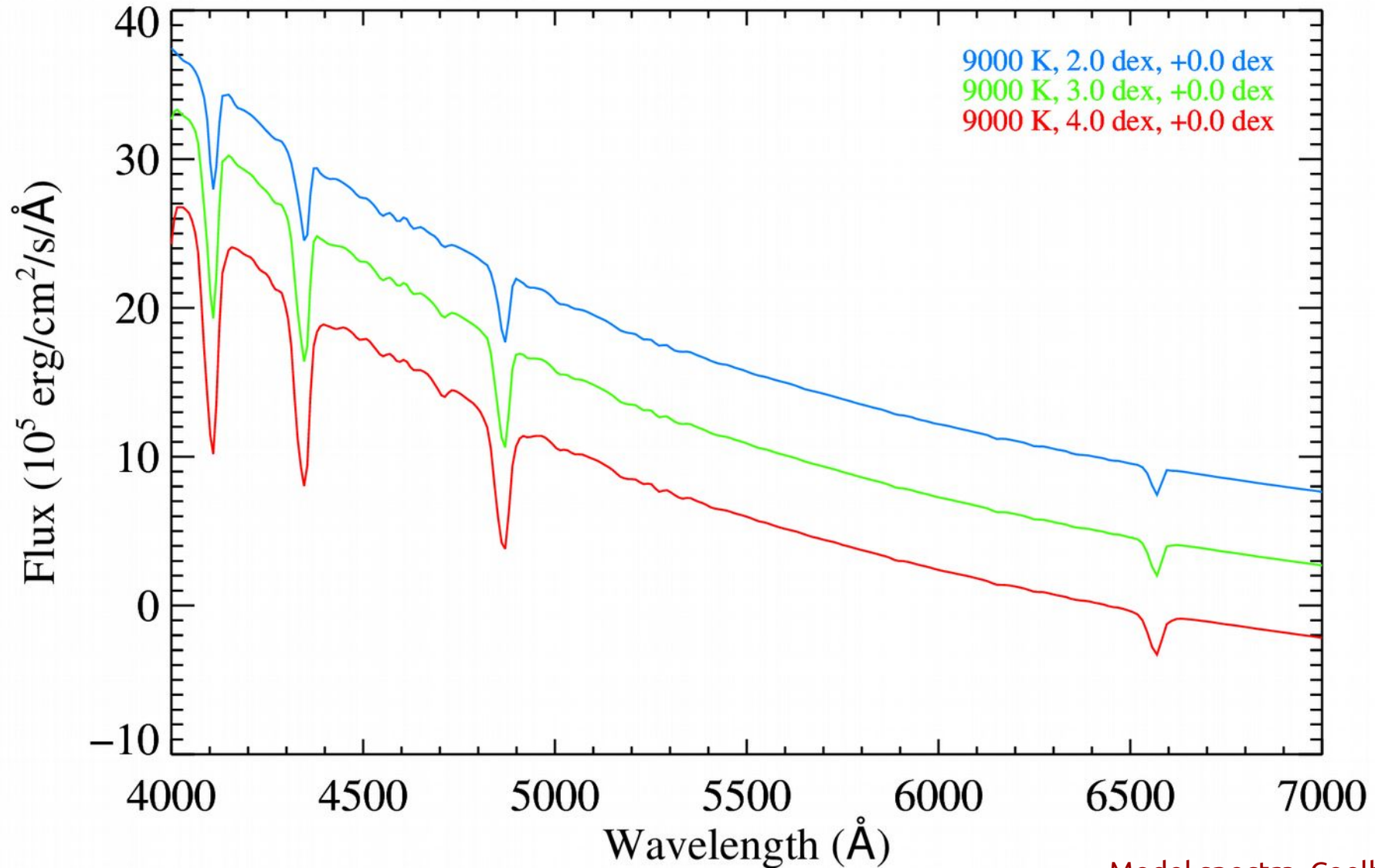


Stellar Spectrum: Influence of Atmospheric parameters



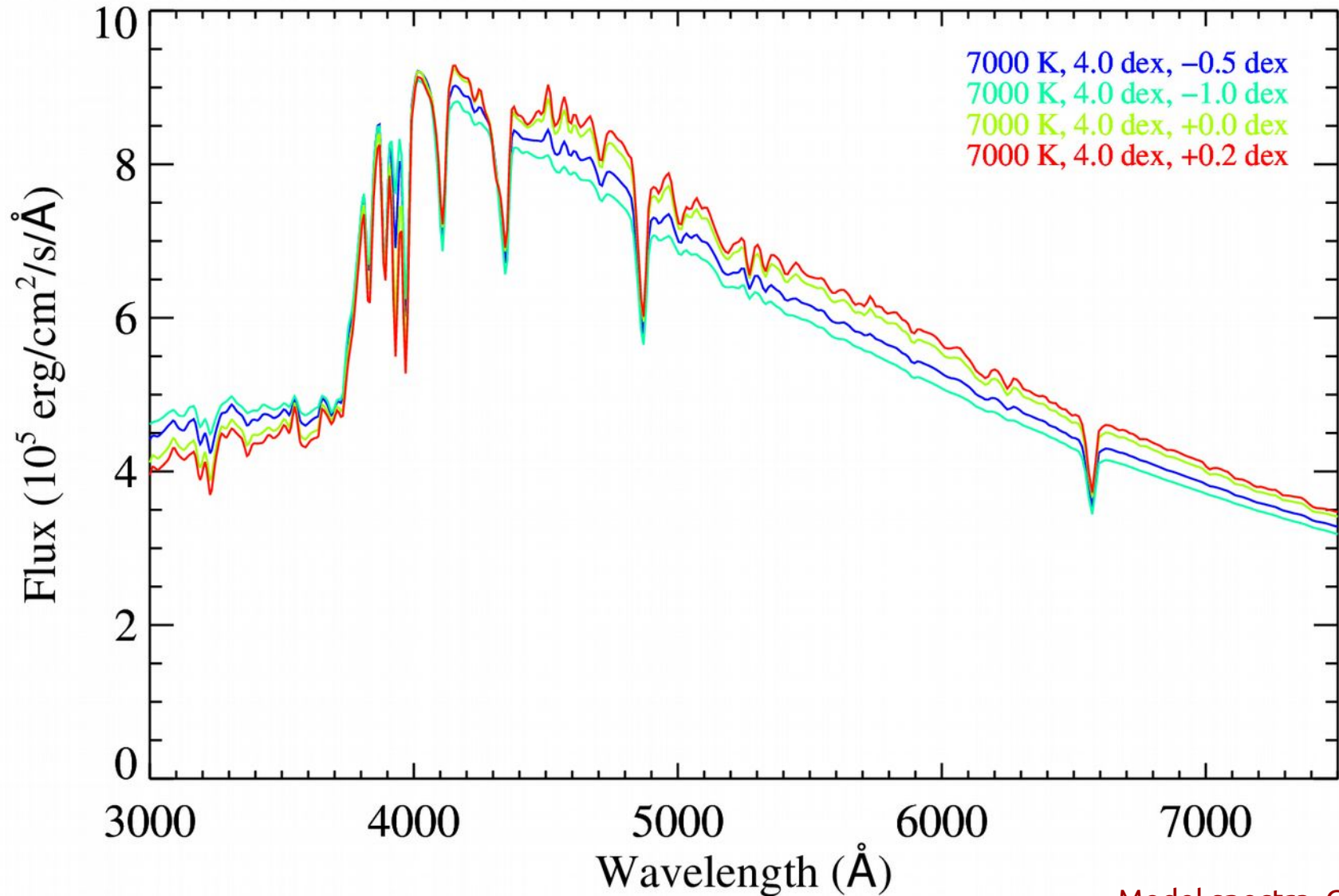
Model spectra, Coelho (2014)

Stellar Spectrum: Influence of Atmospheric parameters



Model spectra, Coelho (2014)

Stellar Spectrum: Influence of Atmospheric parameters

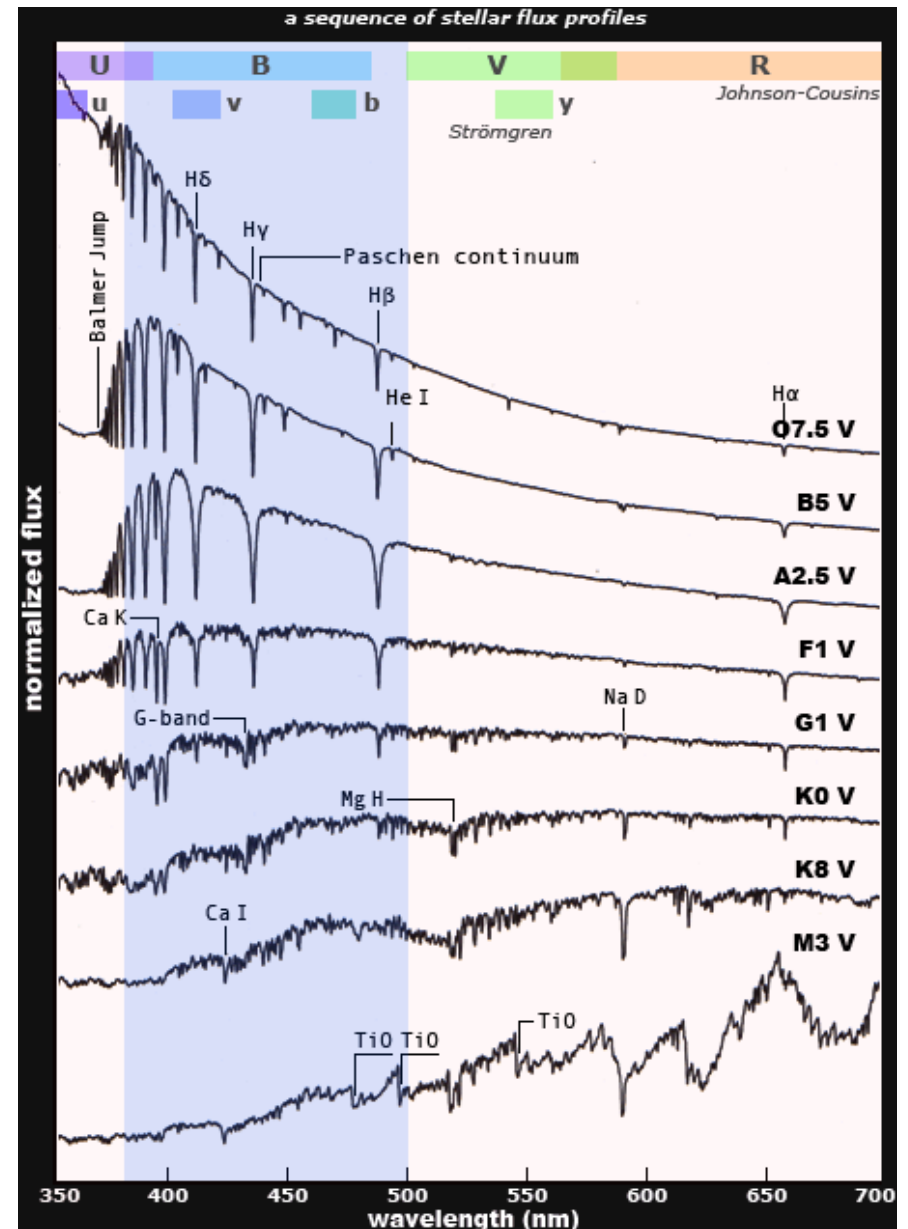


Model spectra, Coelho (2014)

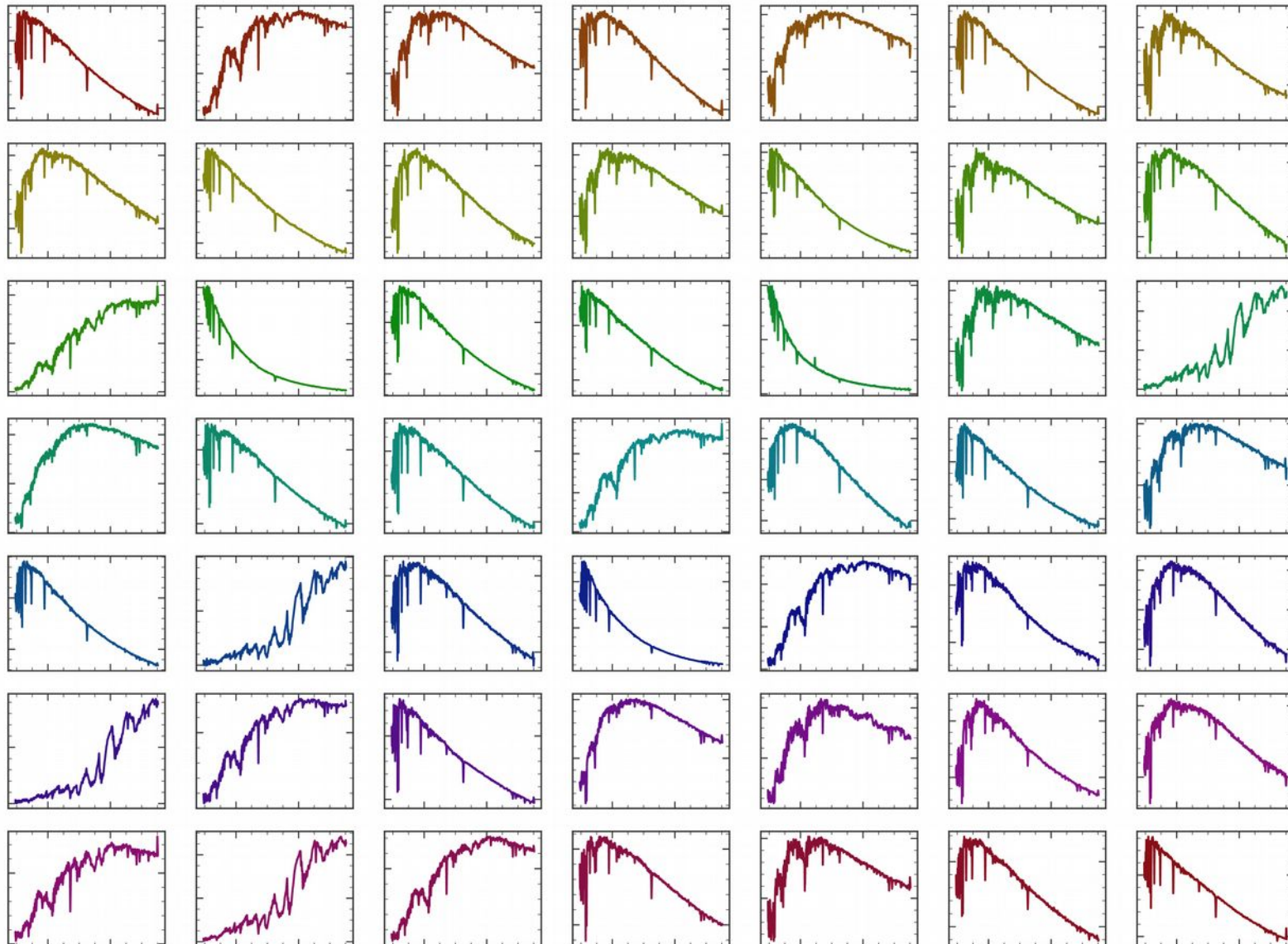
MK Spectral Classification System

- O ($> 30,000$ K),
- B ($10,000 - 30,000$ K),
- A ($7,500 - 10,000$ K),
- F ($6000 - 7500$ K),
- G ($5200 - 6000$ K)
- K ($3700 - 5200$ K) and,
- M ($2200 - 3700$ K)

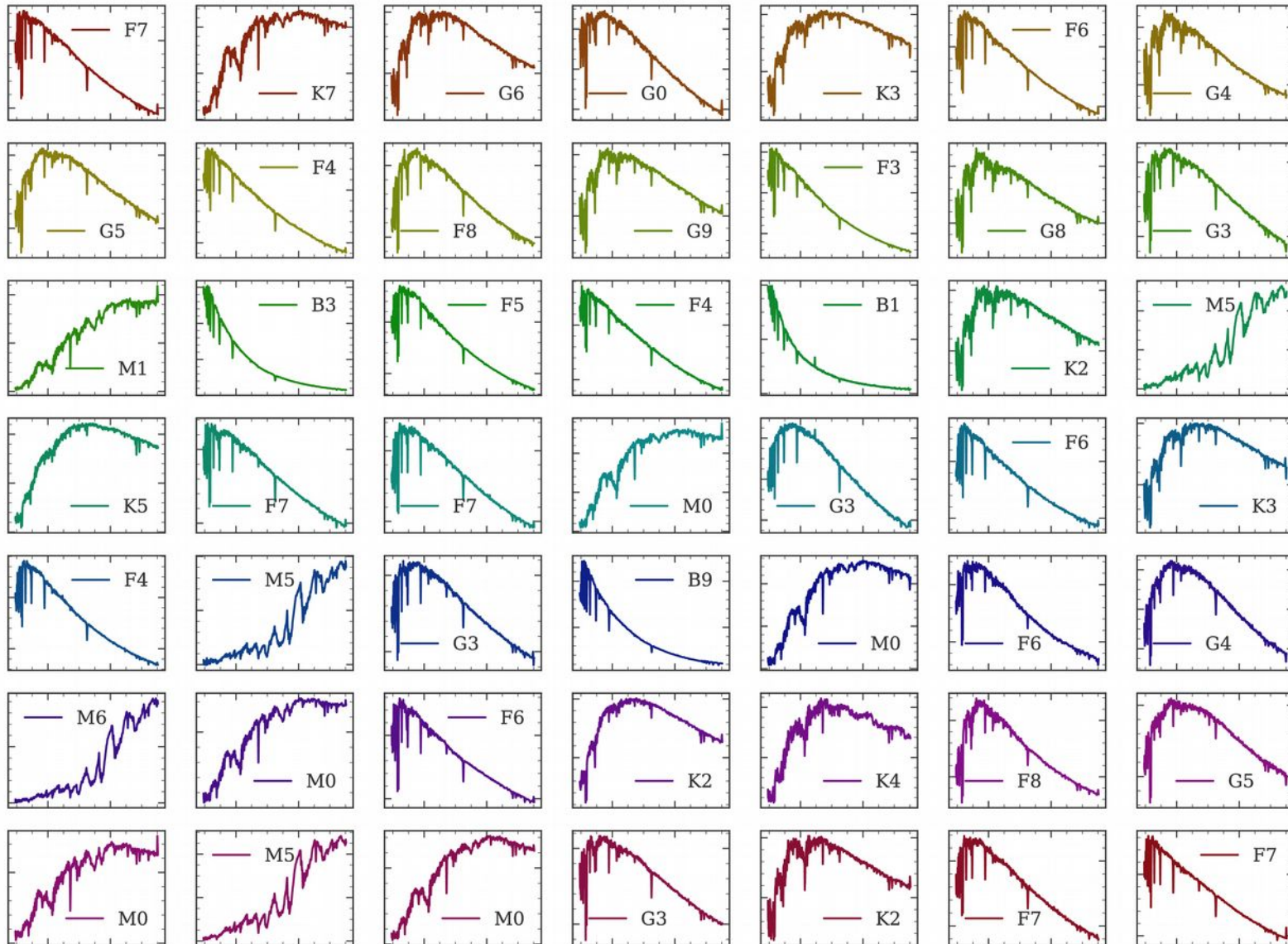
- V: dwarfs, $\log g \sim 4.5$ dex
- IV: subgiants, $\log g \sim 3$ dex
- III: giants, $\log g \sim 1.5$ dex
- II: (bright) giants, $\log g \sim 0.5$ dex
- I: supergiants, $\log g \sim -0.5$ dex



Stellar Spectral Classes



Stellar Spectral Classes



Machine Learning/Deep Learning

Supervised Learning

- Makes machine Learn explicitly
- Data with clearly defined output is given
- Direct feedback is given
- Predicts outcome/future
- Resolves classification and regression problems



Unsupervised Learning

- Machine understands the data (Identifies patterns/structures)
- Evaluation is qualitative or indirect
- Does not predict/find anything specific

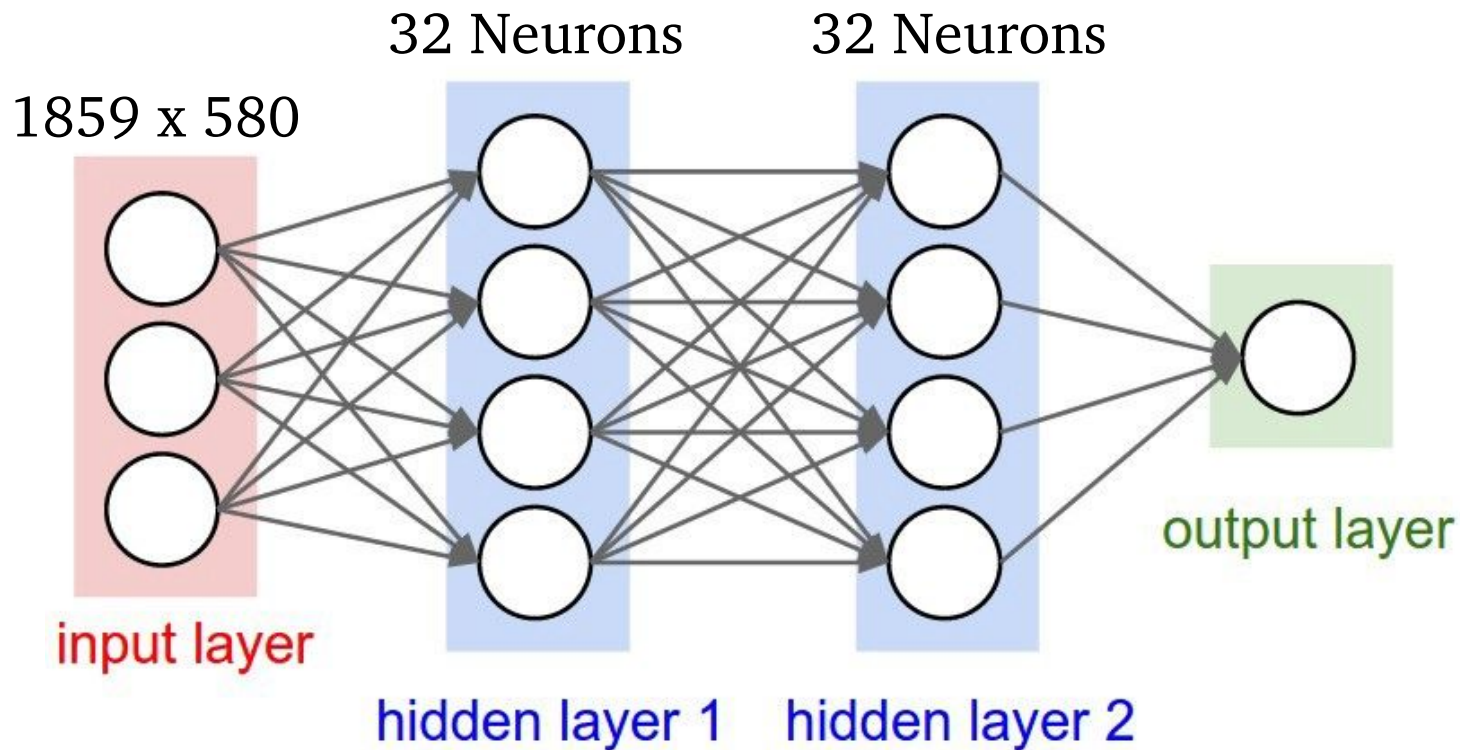
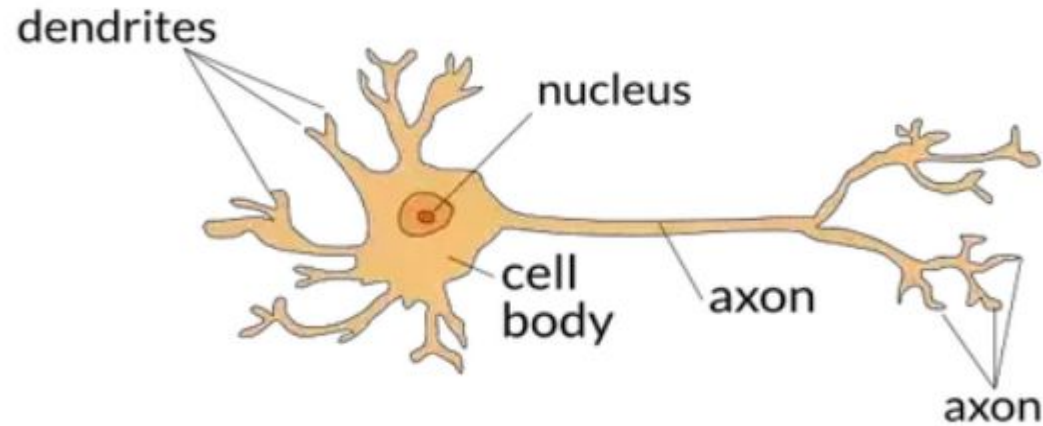


Reinforcement Learning

- An approach to AI
- Reward based learning
- Learning form +ve & +ve reinforcement
- Machine Learns how to act in a certain environment
- To maximize rewards



Classification: Artificial Neural Network



Classification: Convolutional Neural Network

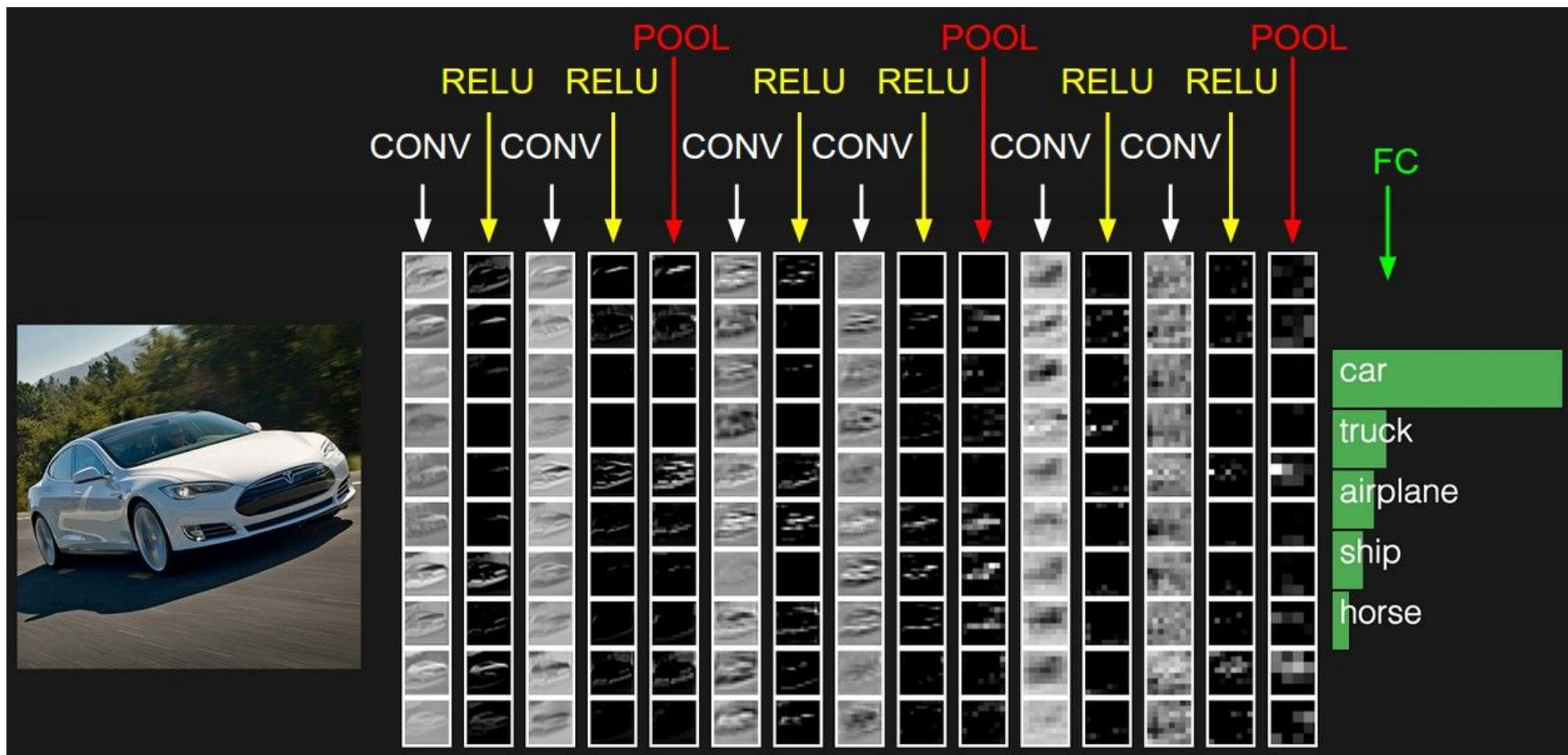
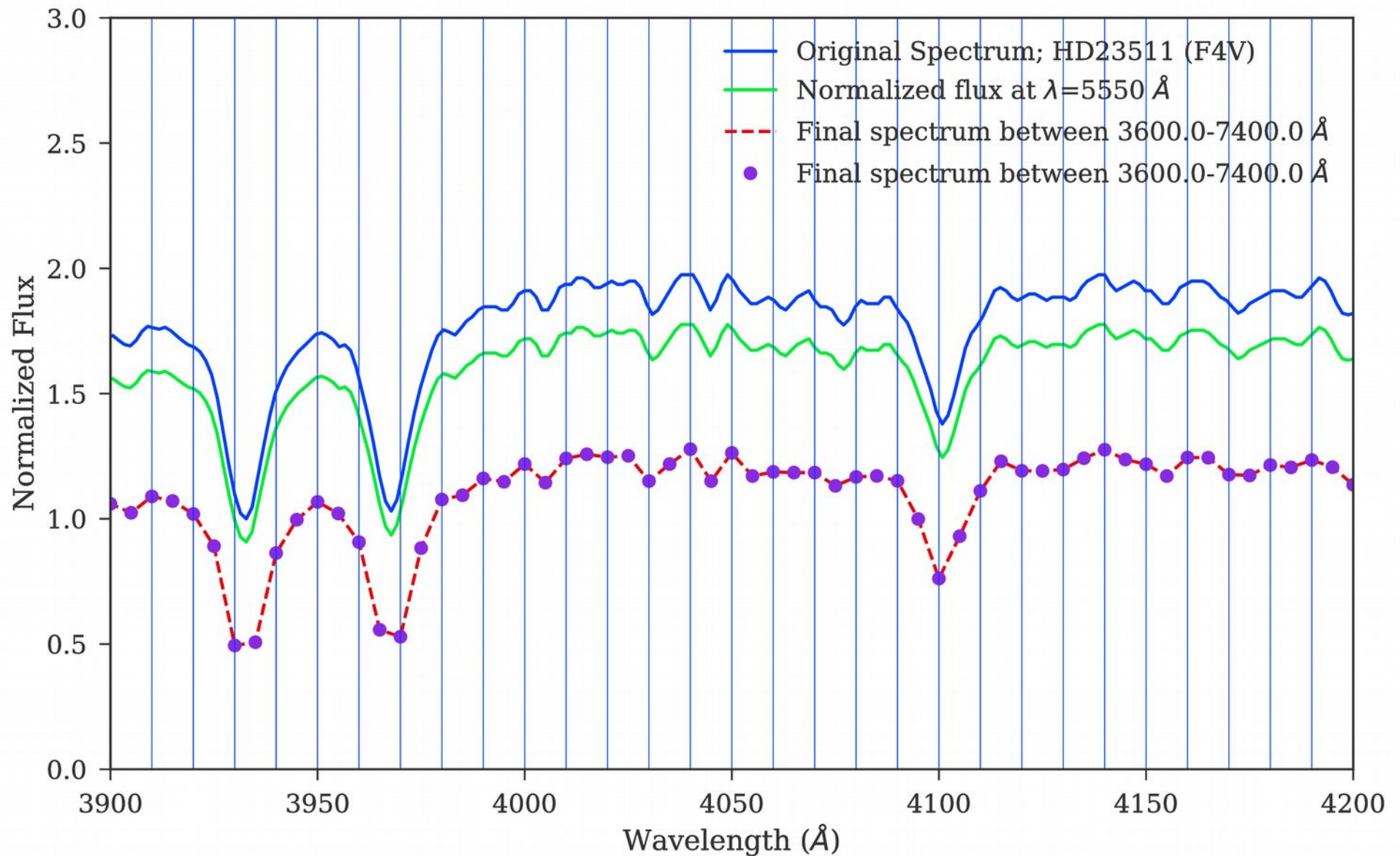
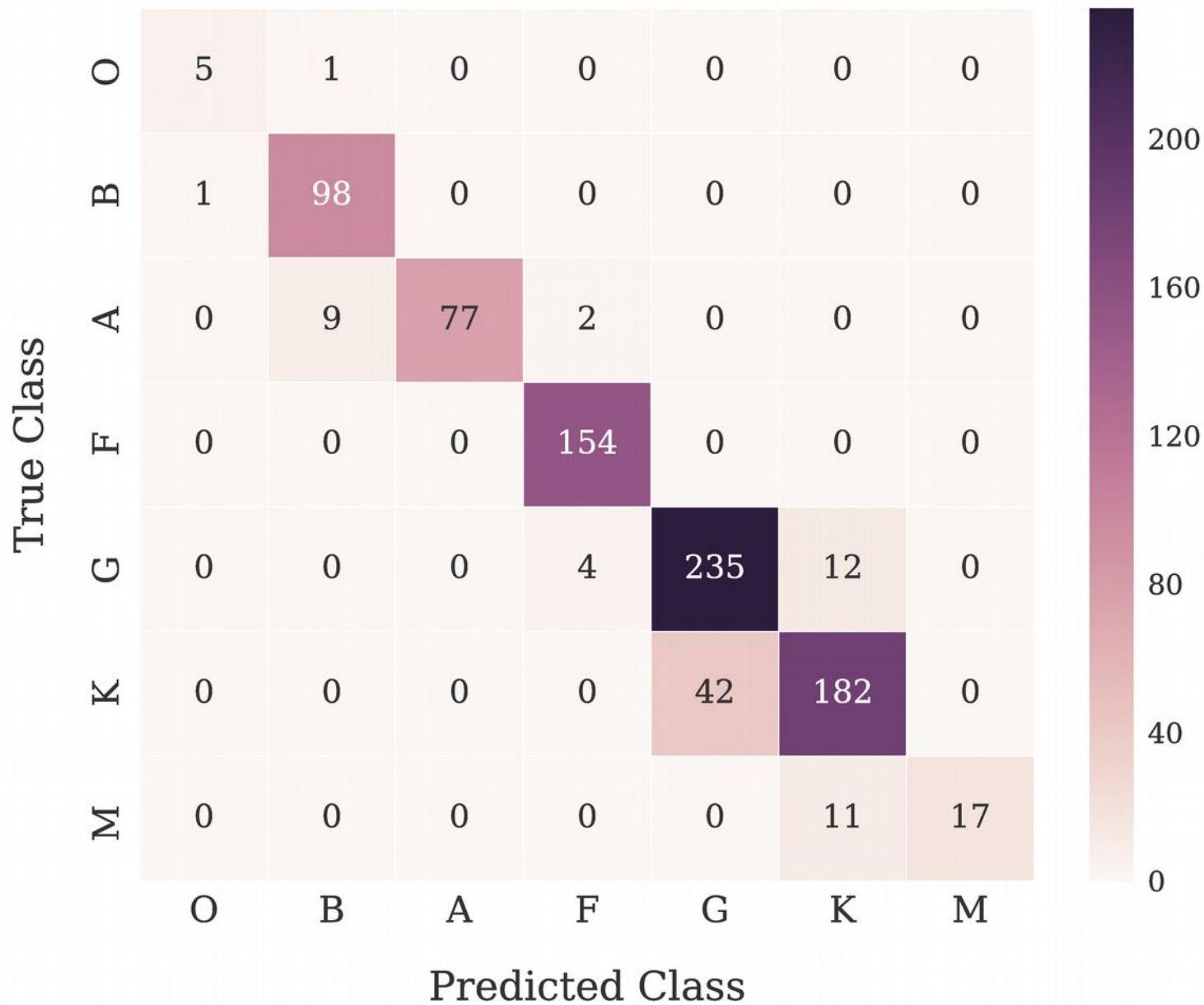


Image Credit: <http://cs231n.github.io/convolutional-networks/>

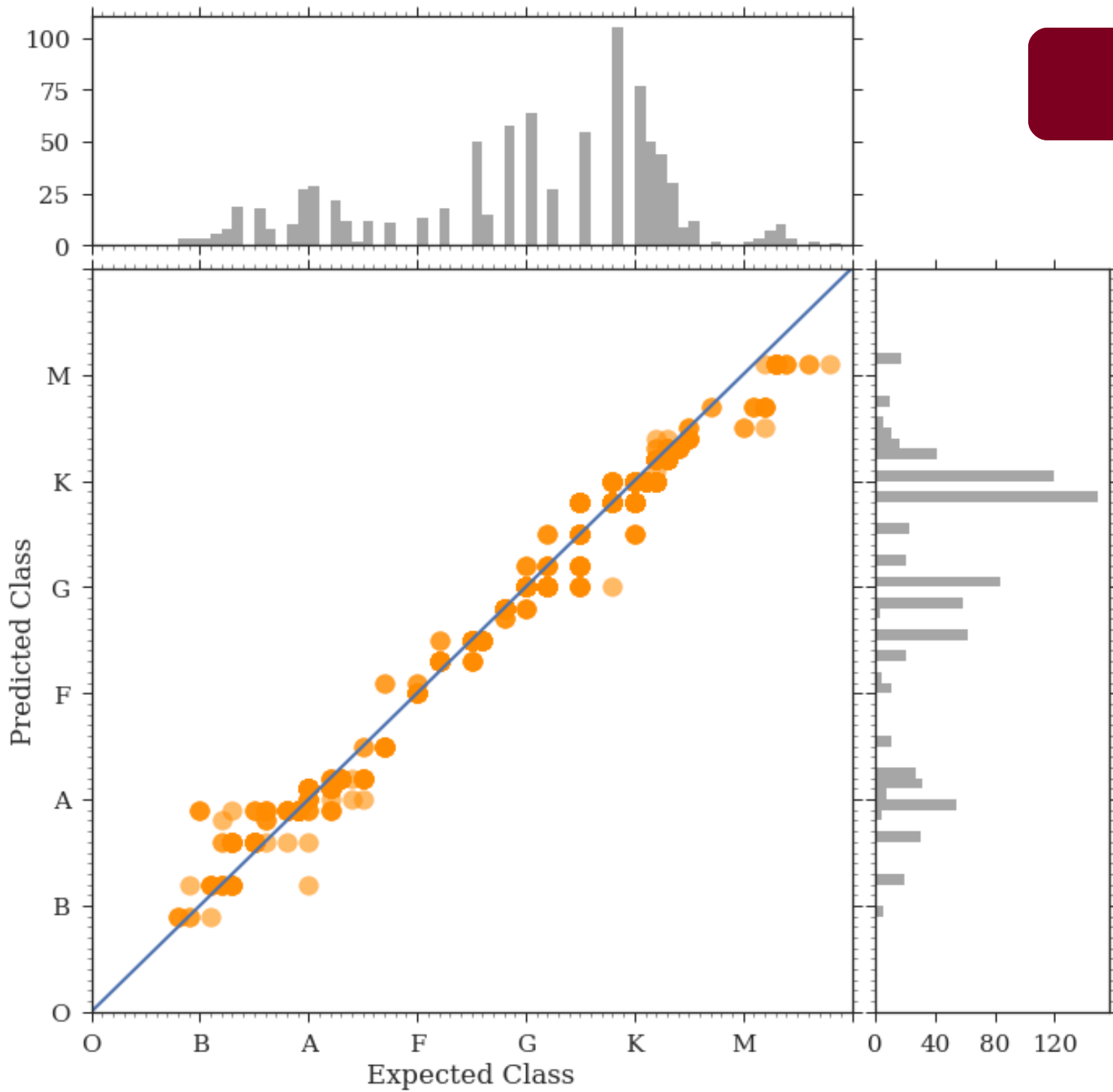
Input features



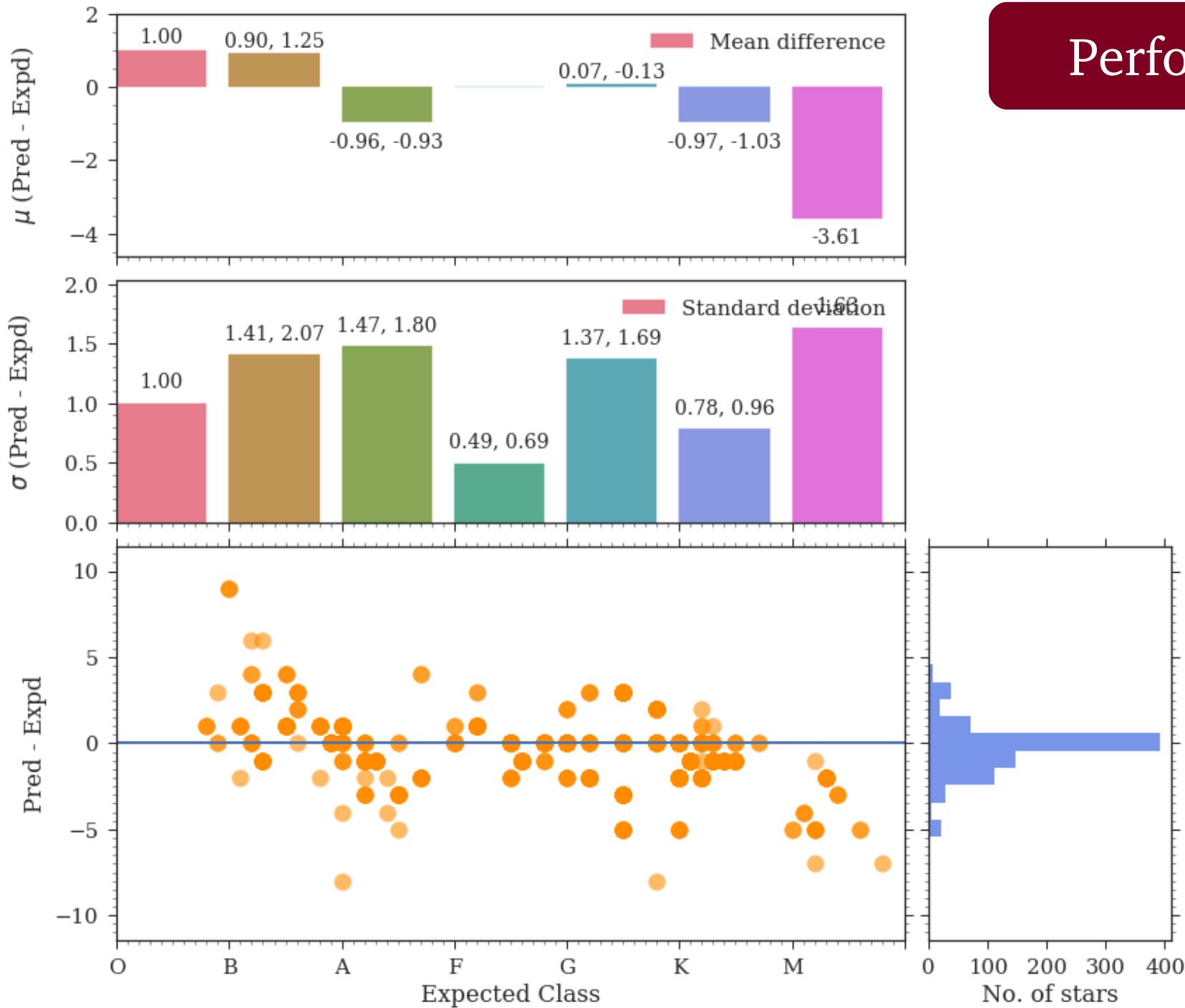
Confusion matrix



Performance

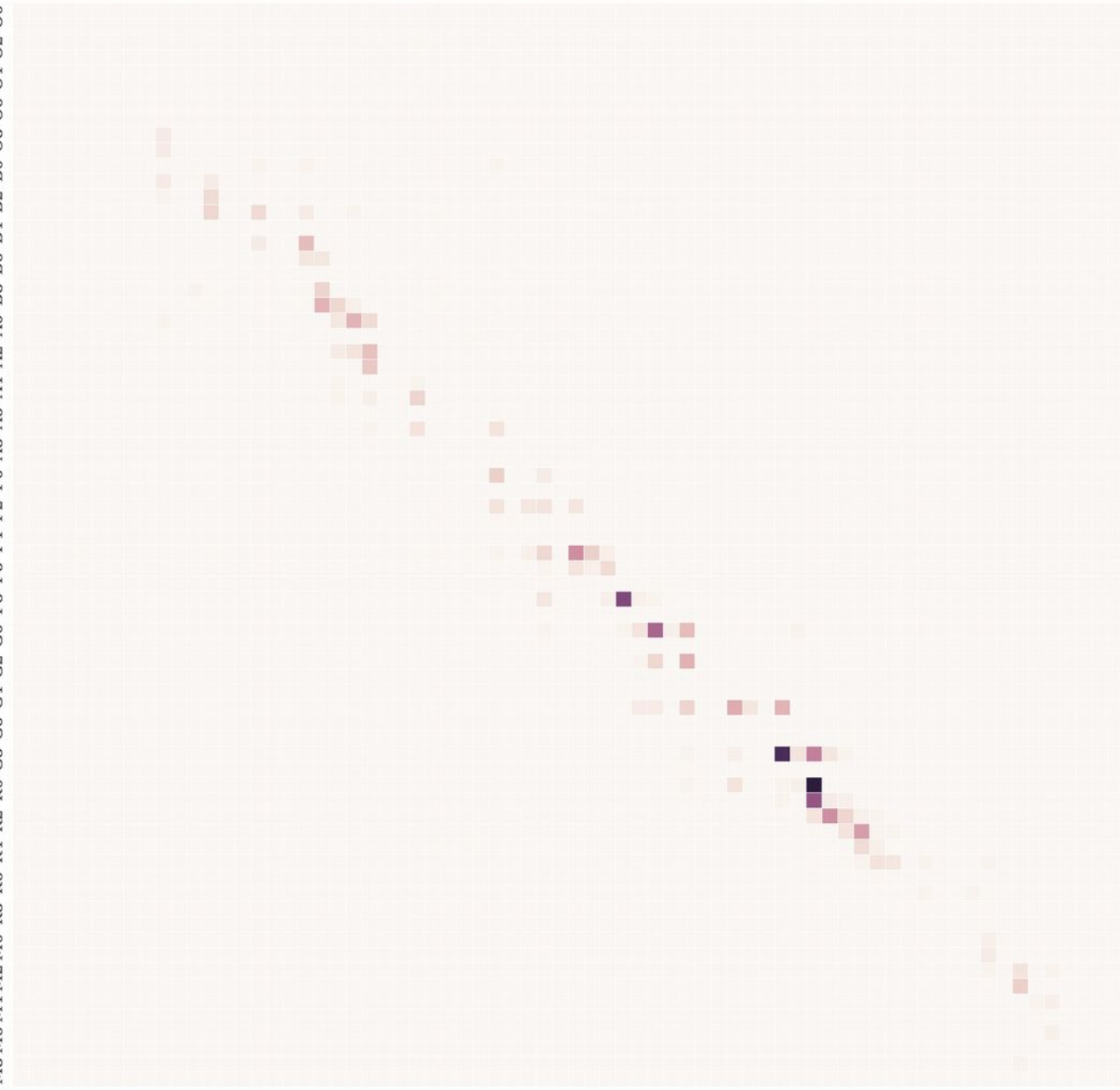


Performance



True Class

M8 M6 M4 M2 M0 K8 K6 K4 K2 K0 G8 G6 G4 G2 G0 F8 F6 F4 F2 F0 A8 A6 A4 A2 A0 B8 B6 B4 B2 B0 O8 O6 O4 O2 O0



00 O2 O4 O6 O8 B0 B2 B4 B6 B8 A0 A2 A4 A6 A8 F0 F2 F4 F6 F8 G0 G2 G4 G6 G8 K0 K2 K4 K6 K8 M0 M2 M4 M6 M8

Predicted Class (ANN)

Statistics: Individual Class

	precision	recall	f1-score	support
A	1.00	0.88	0.93	88
B	0.91	0.99	0.95	99
F	0.96	1.00	0.98	154
G	0.85	0.94	0.89	251
K	0.89	0.81	0.85	224
M	1.00	0.61	0.76	28
O	0.83	0.83	0.83	6
avg / total	0.91	0.90	0.90	850

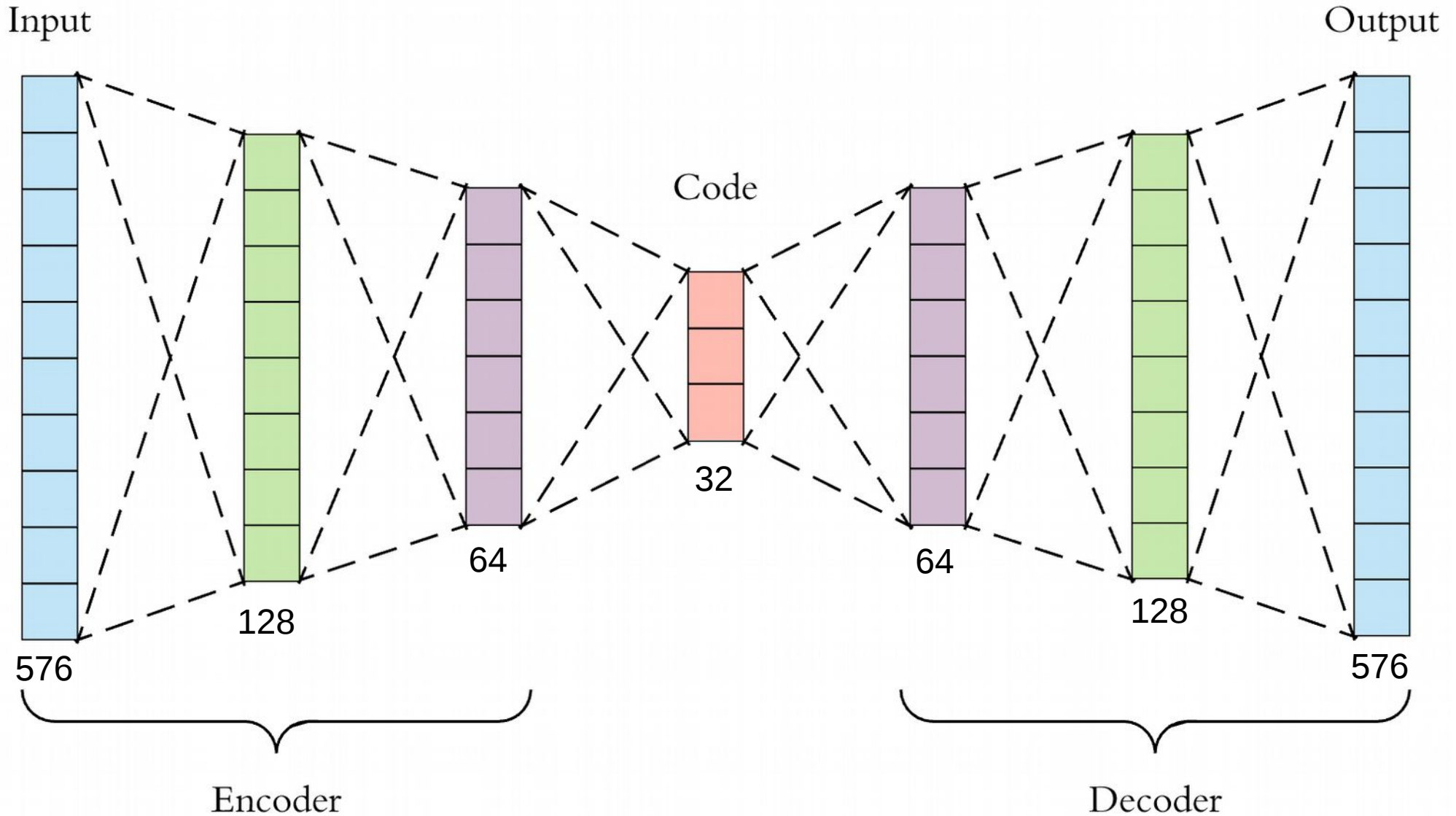
----- Statistics for Test sample (CFLIB)-----

Mean difference between = -0.38

Absolute Std. Deviation = 1.72

Sigma-clipped stats: mean, median, std = -0.26, 0.00, 1.34

Autoencoders



Semi-supervised Classification

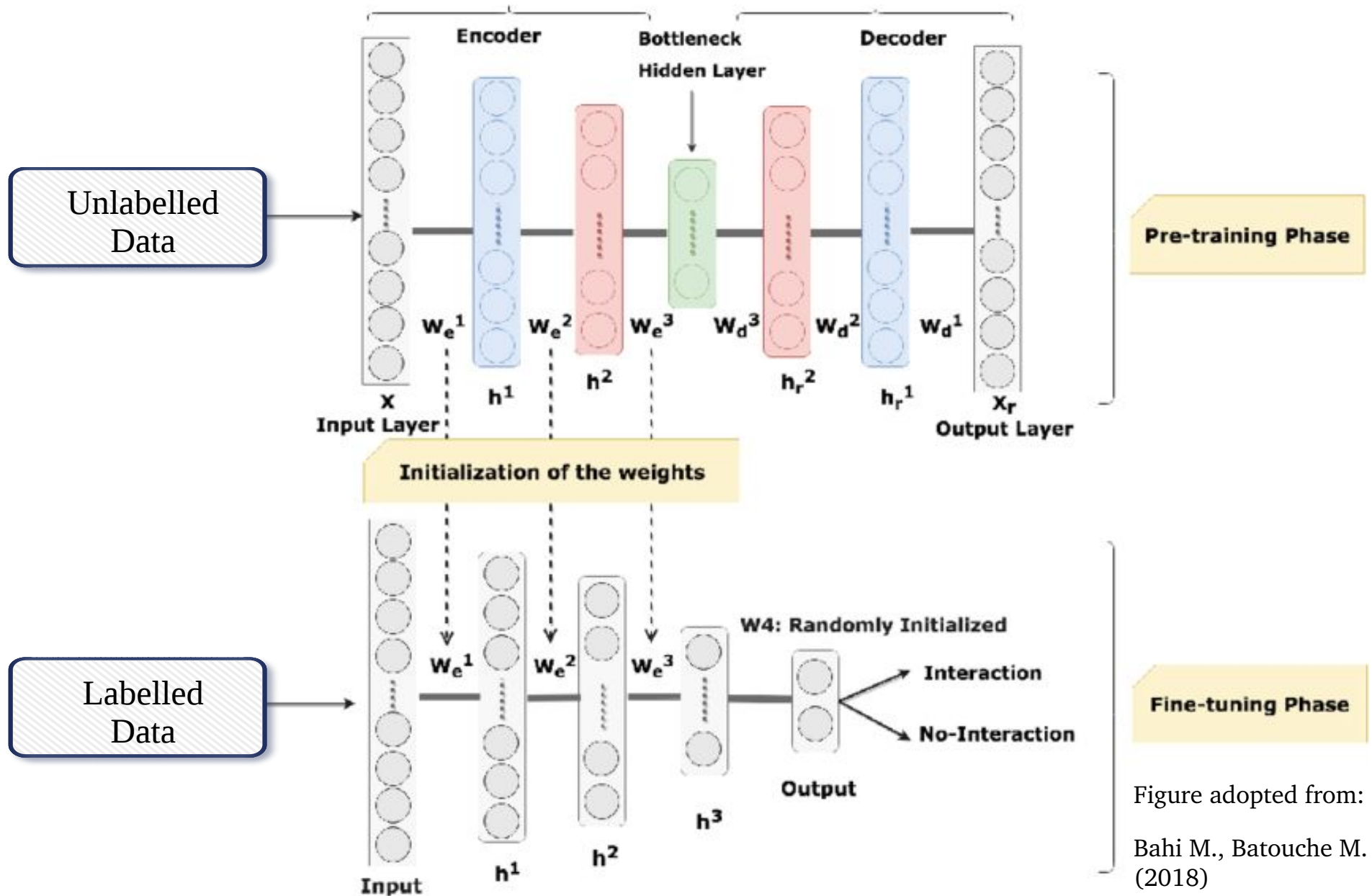
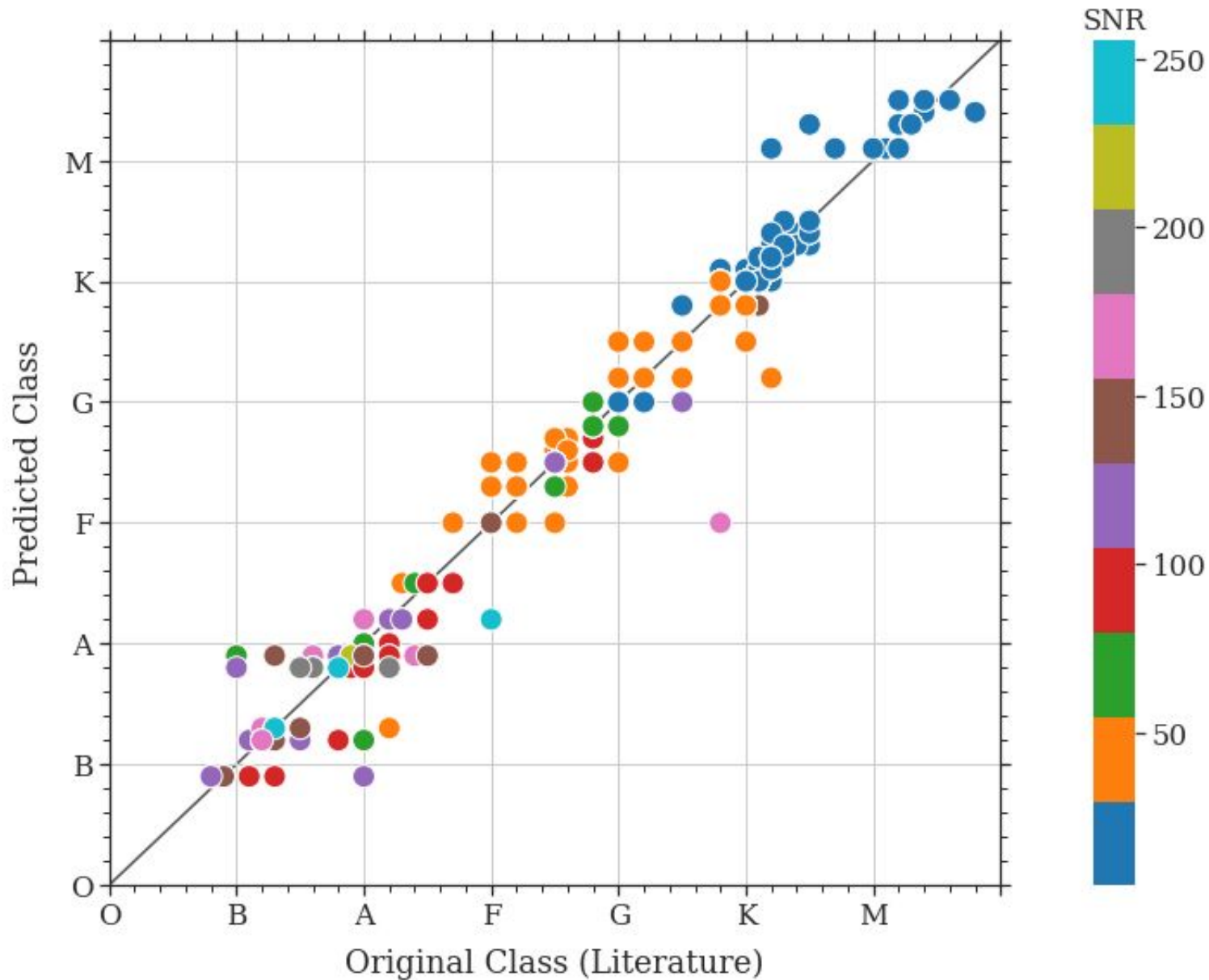
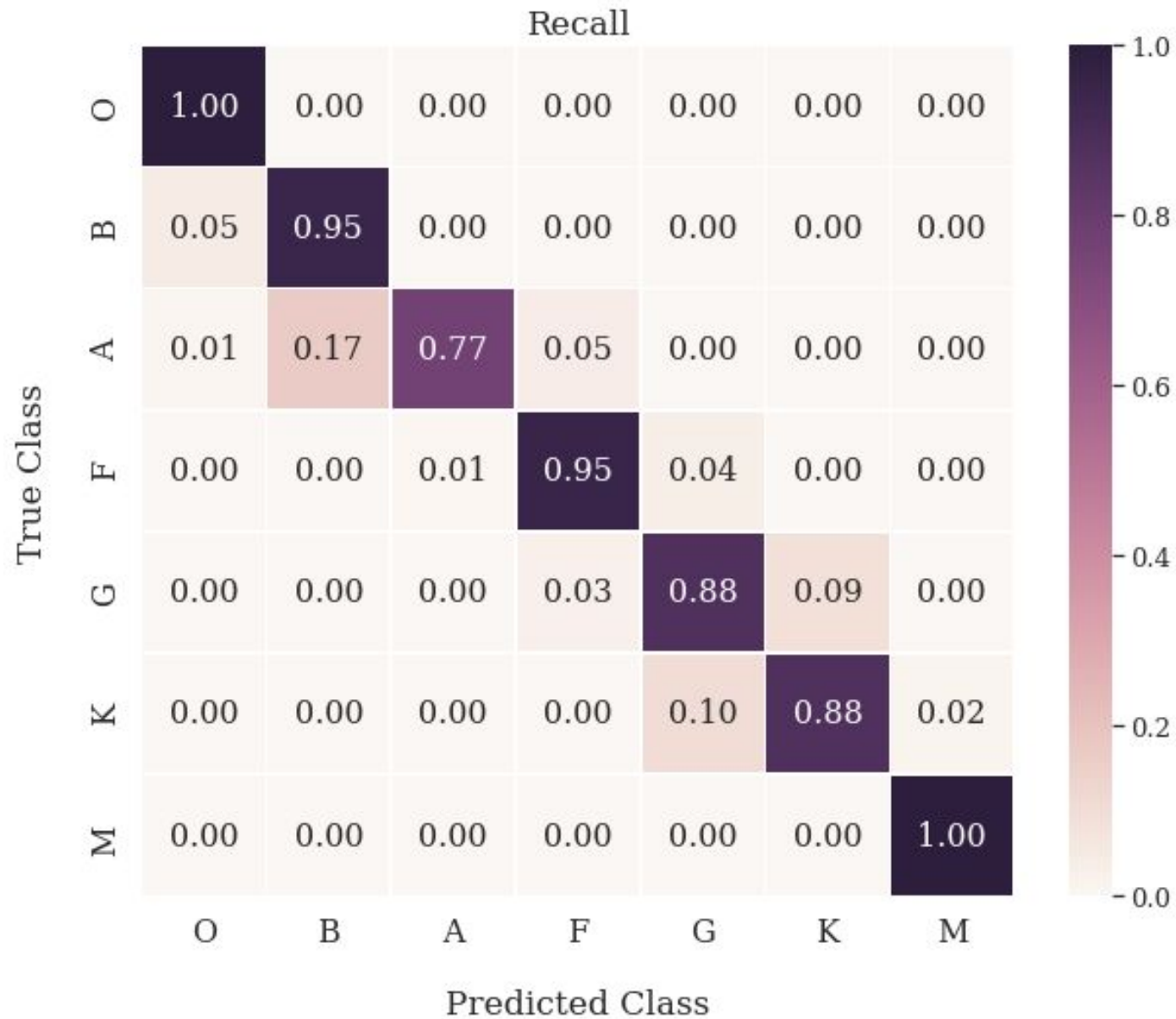


Figure adopted from:
Bahi M., Batouche M.
(2018)

Semi-supervised Classification



Semi-supervised Classification



Statistics: Individual Class

	precision	recall	f1-score	support
A	0.99	0.77	0.87	88
B	0.86	0.95	0.90	99
F	0.93	0.95	0.94	154
G	0.88	0.88	0.88	251
K	0.90	0.88	0.89	224
M	0.88	1.00	0.93	28
O	0.50	1.00	0.67	6
avg / total	0.90	0.90	0.90	850

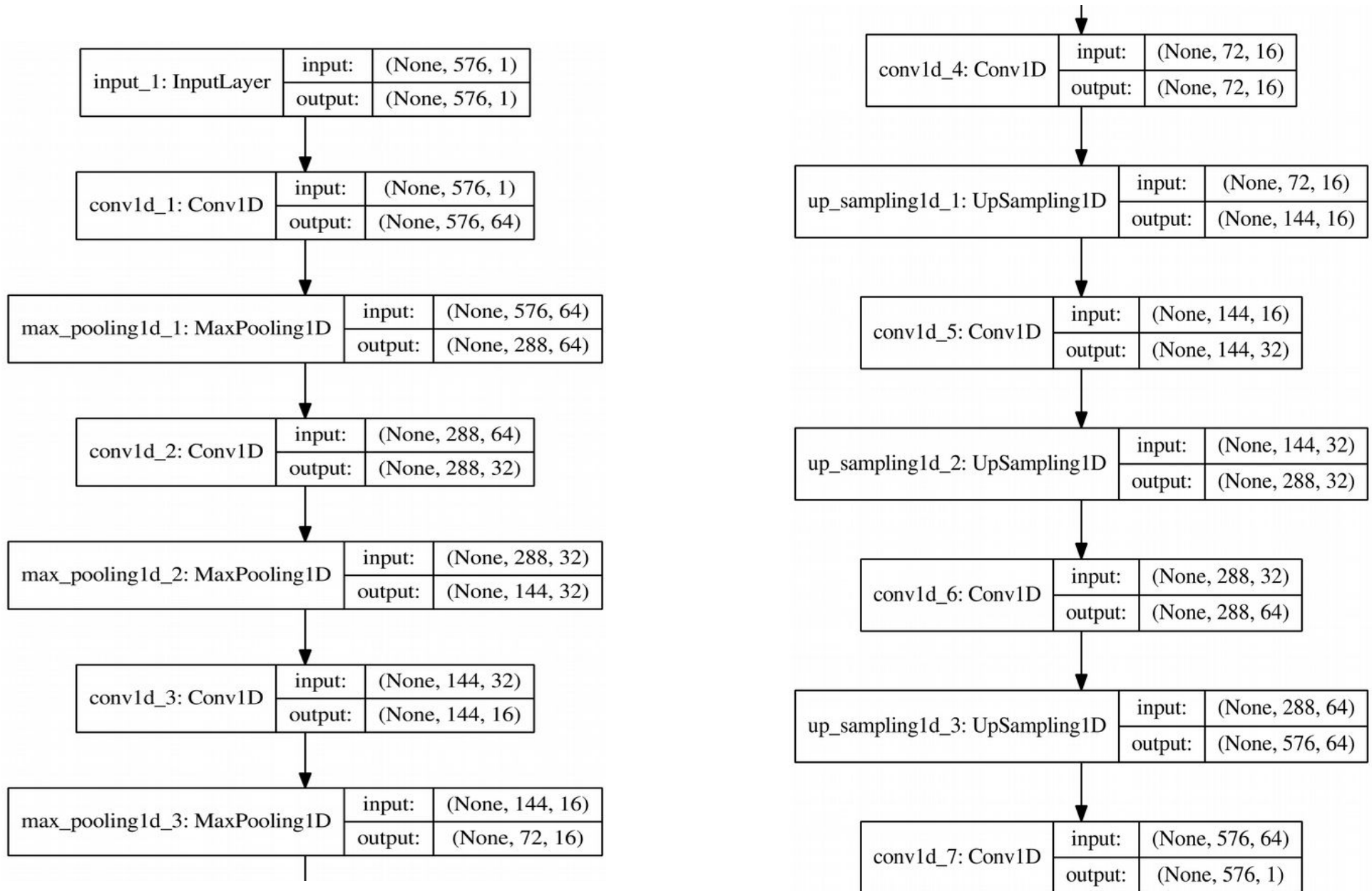
----- Statistics for Test sample (CFLIB)-----

Mean difference = -0.09

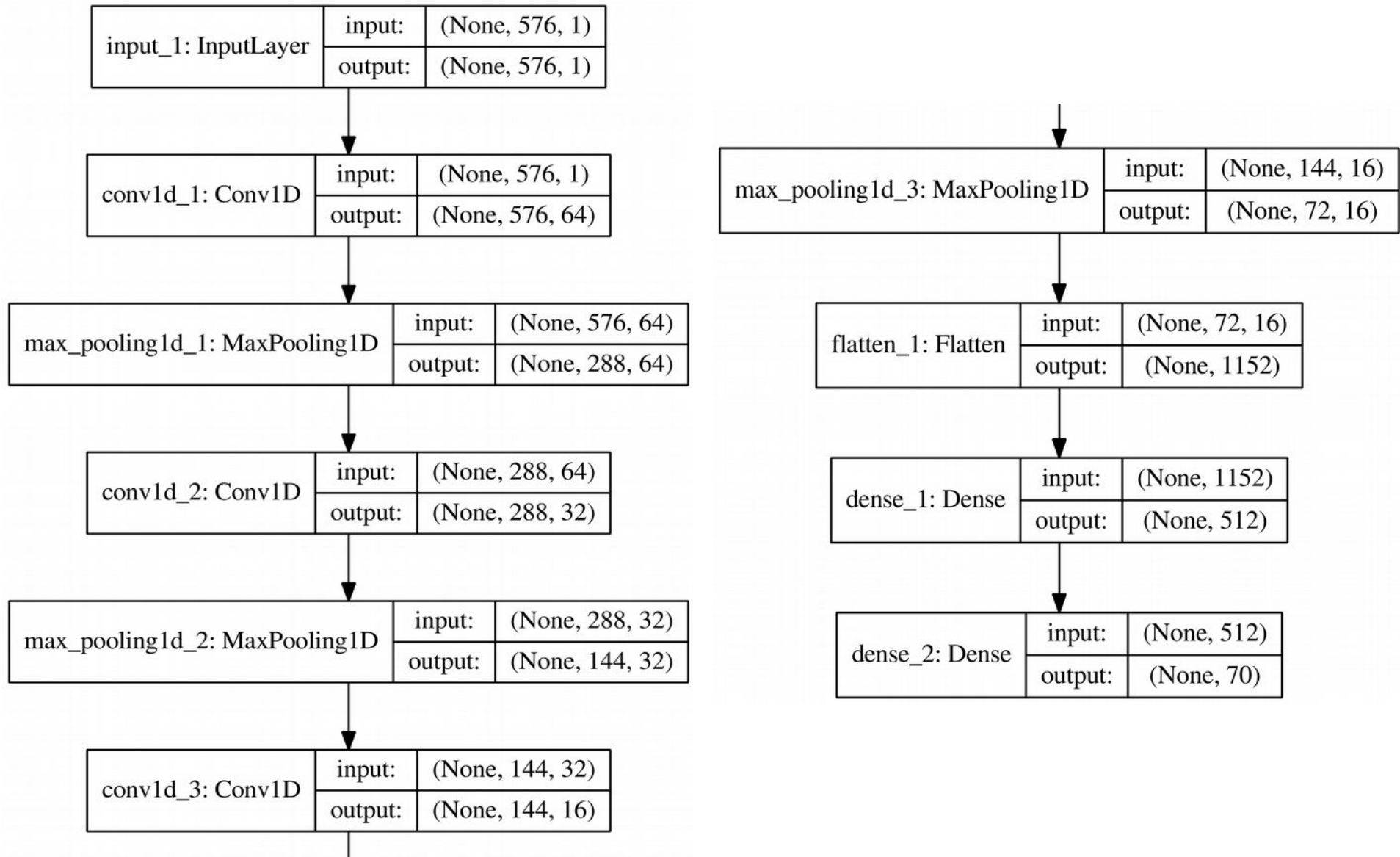
Absolute Std. Deviation = 1.84

Sigma-clipped stats: mean, median, std = -0.01, 0.00, 1.27

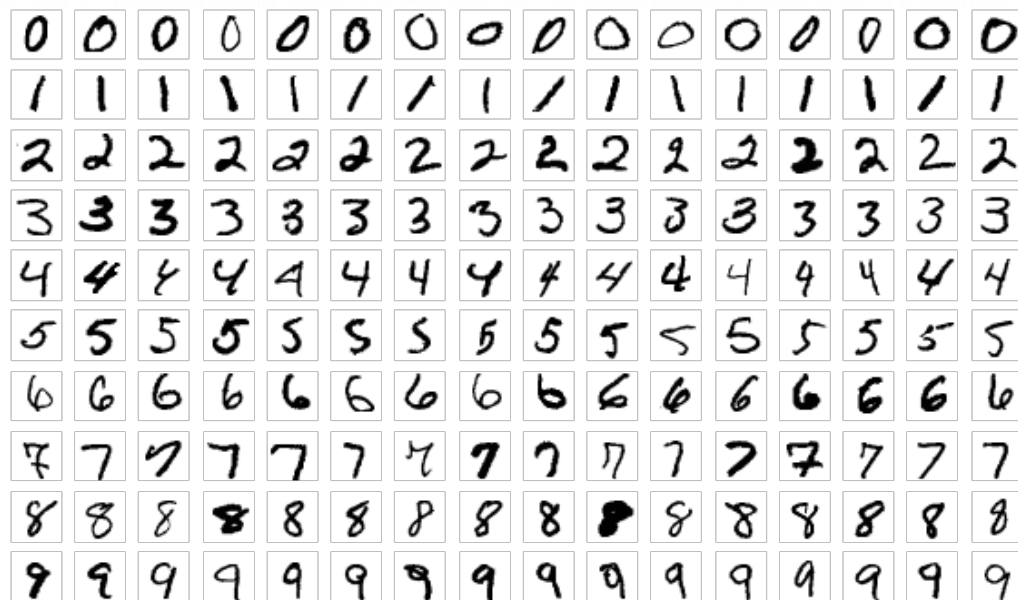
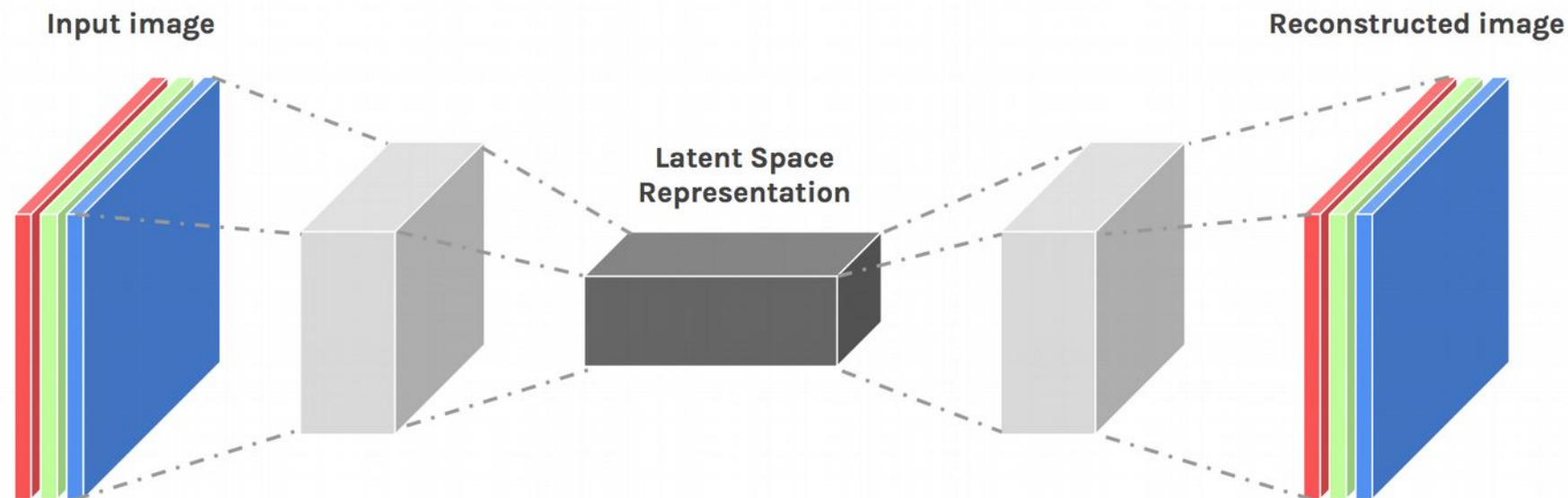
Pre-trained Model: Architecture



Classification Model



Autoencoders



Applications

- Dimensionality reduction
- Denoising
- Data compression
- Outliers Detection/
Fraud Detection

Autoencoders

Clustering:
PCA versus
Autoencoders

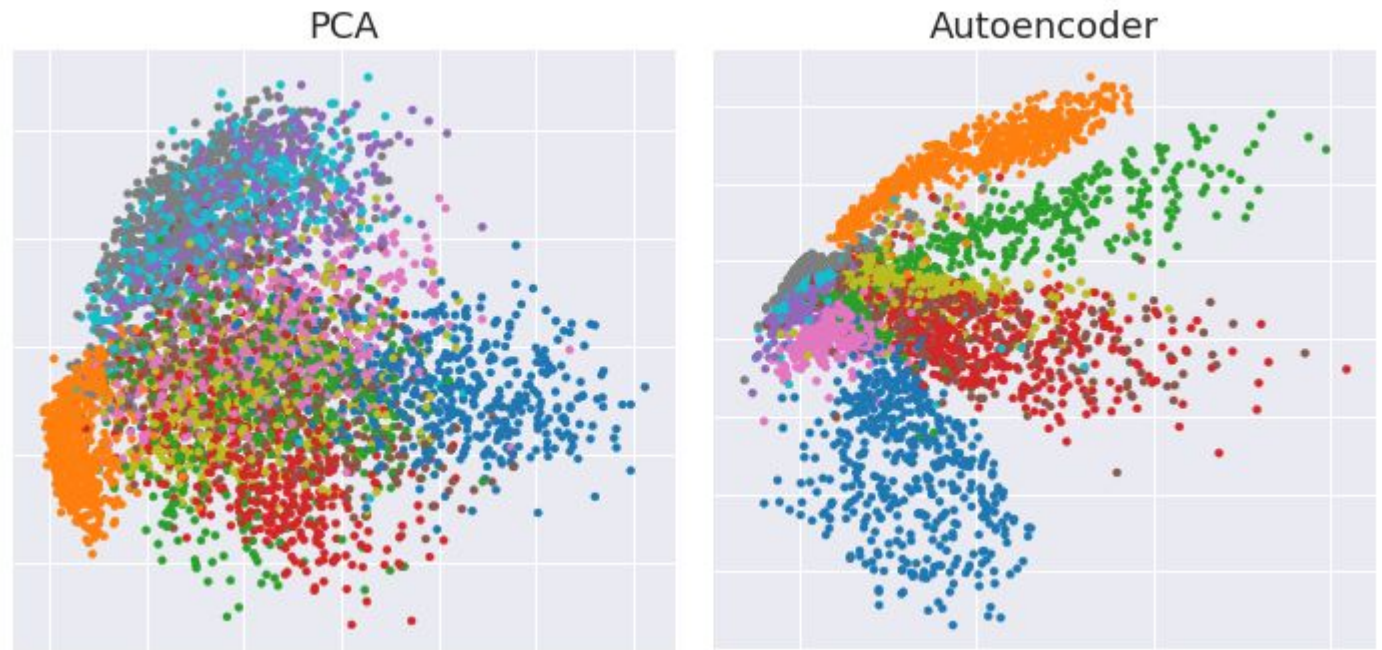
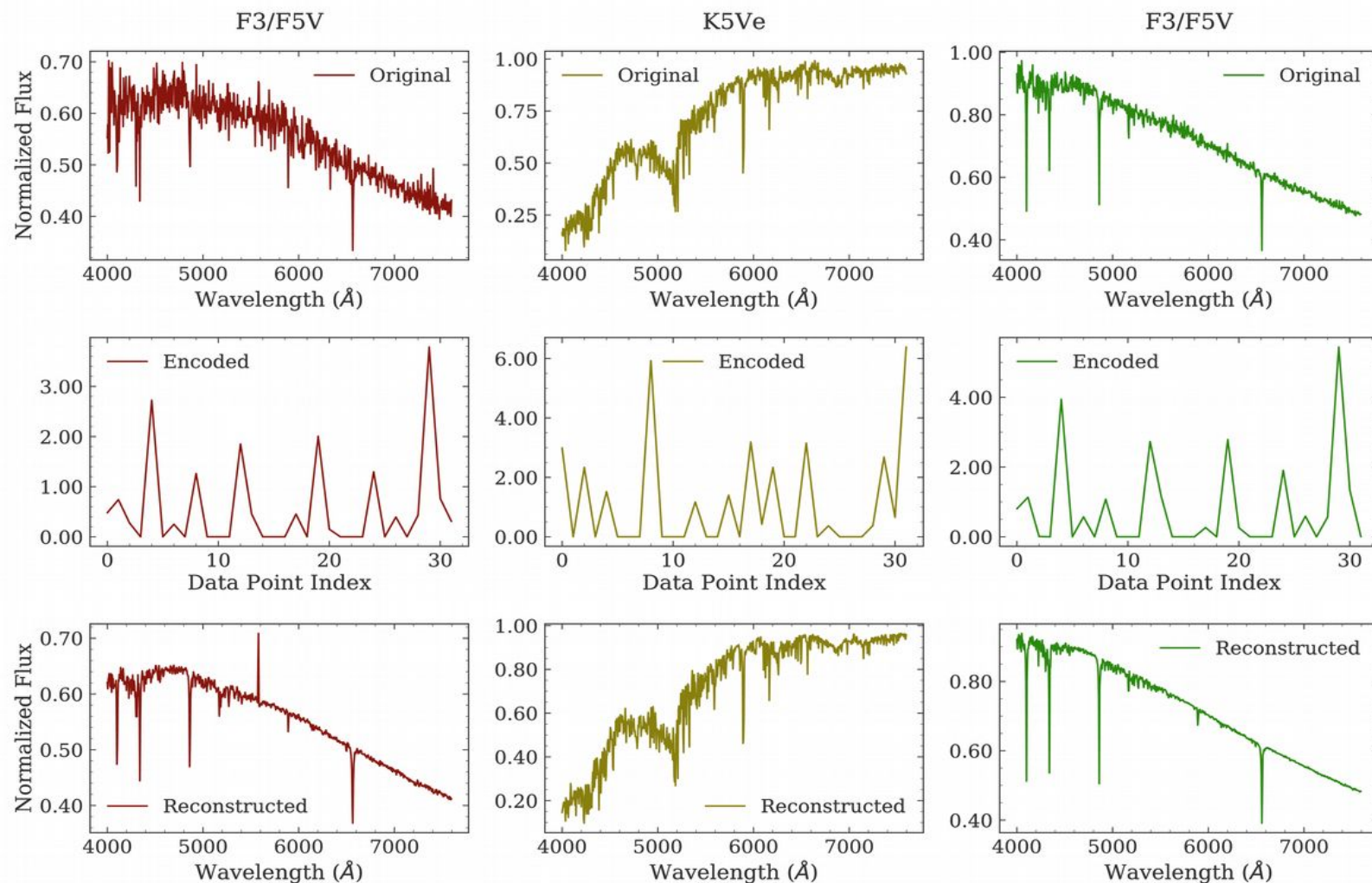


Image reconstruction using only first two components

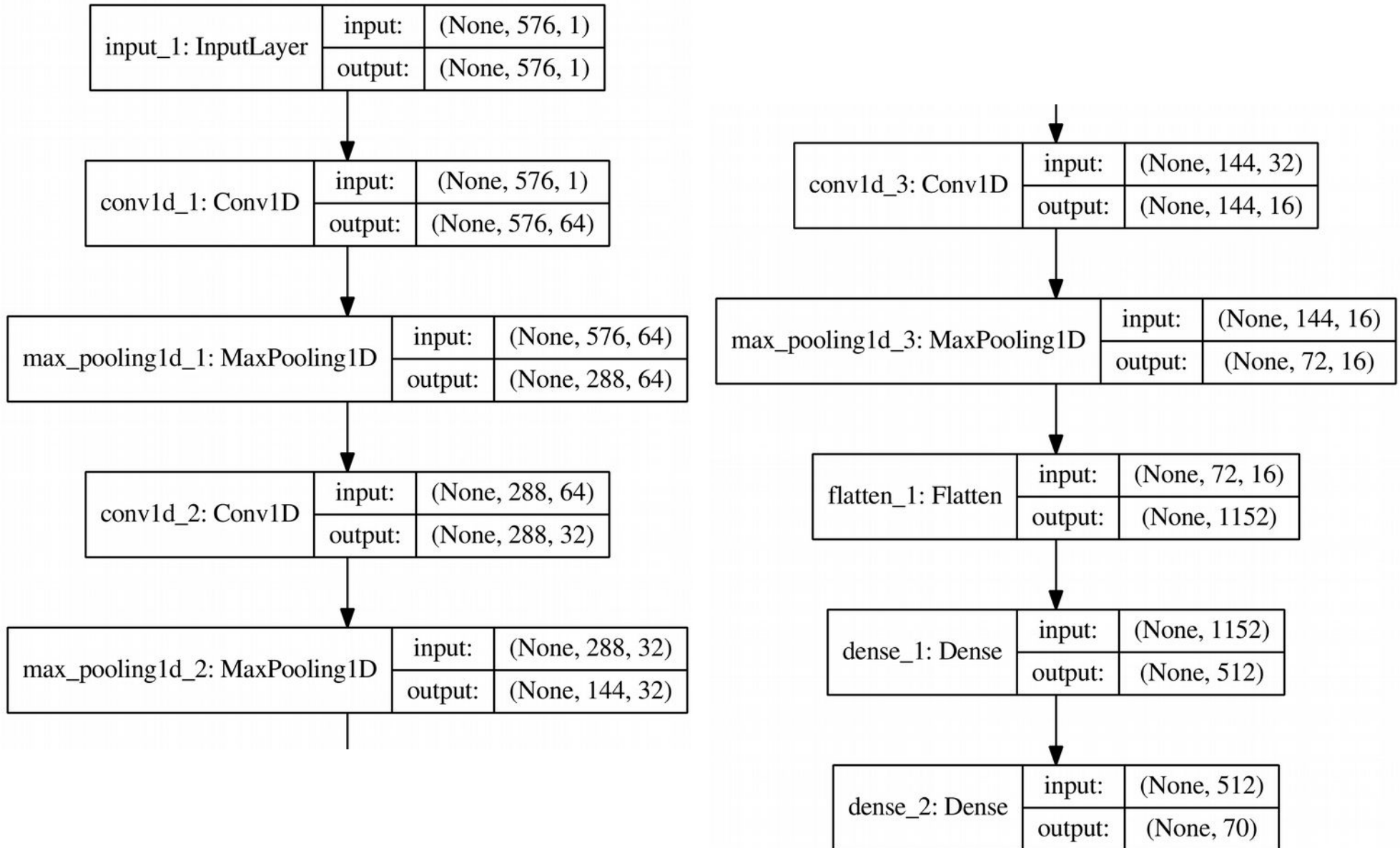


Autoencoders

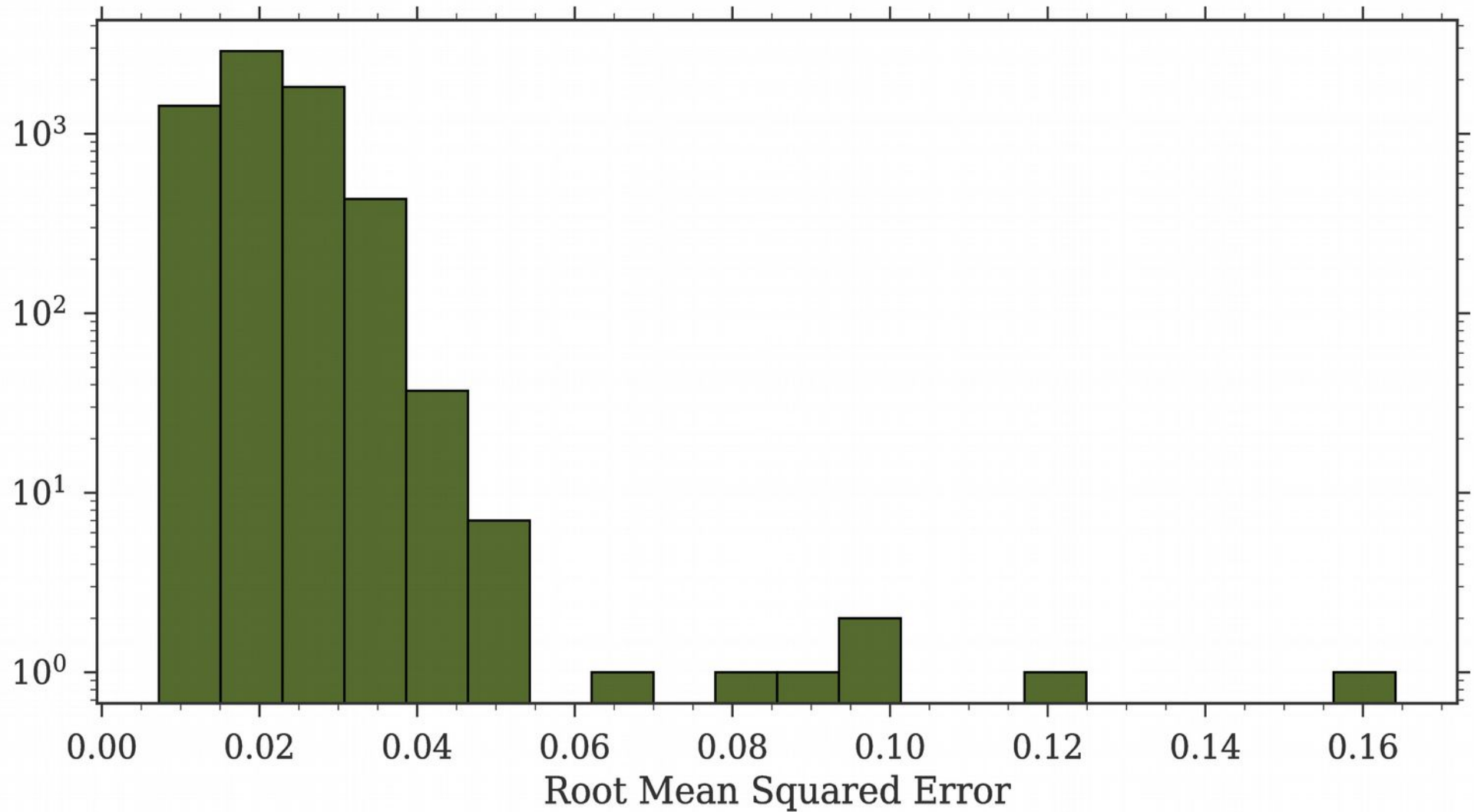


- Signal-to-noise ratio (SNR) greater than 20
- ~60,000 stellar spectra.

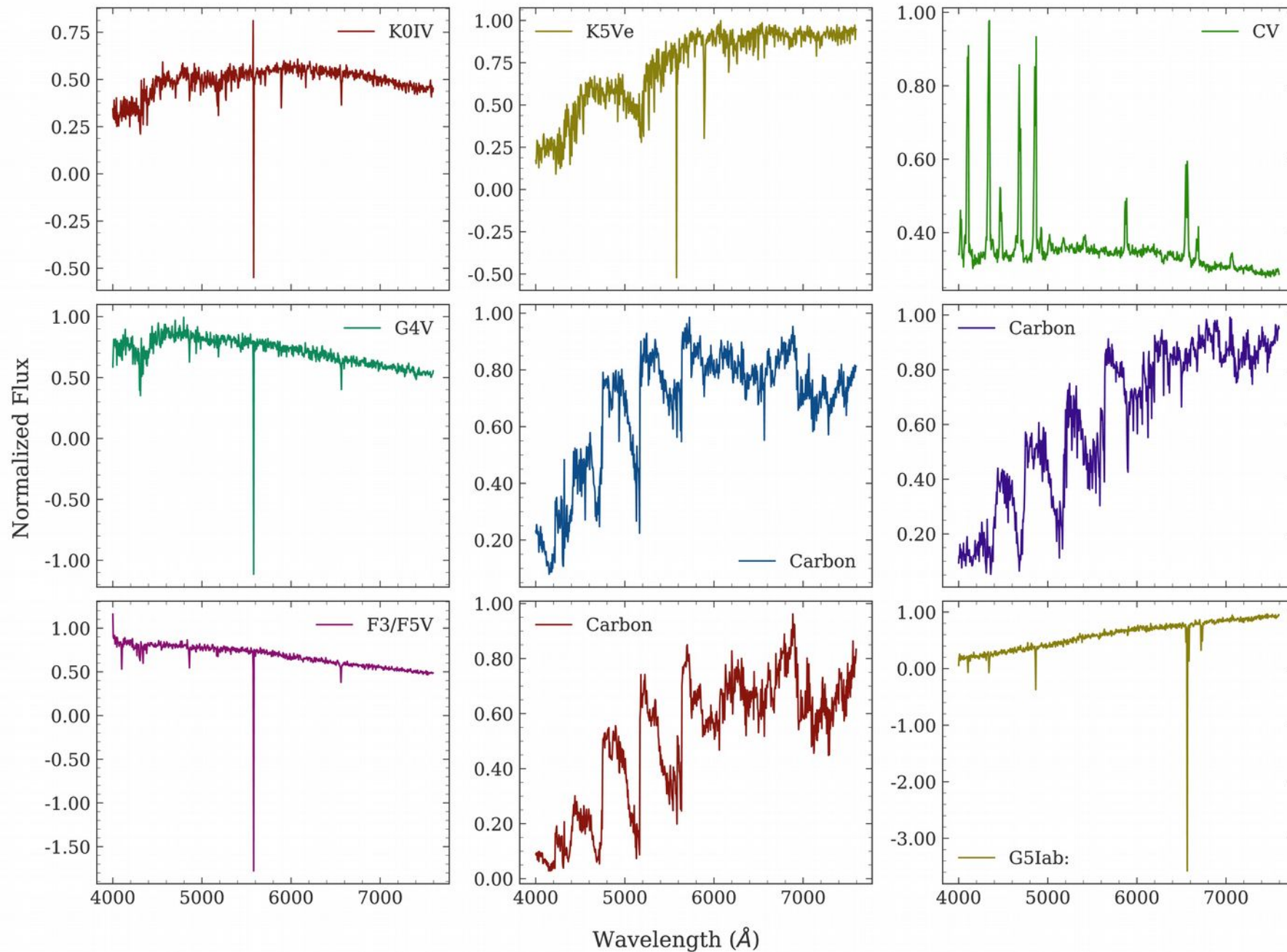
Autoencoders



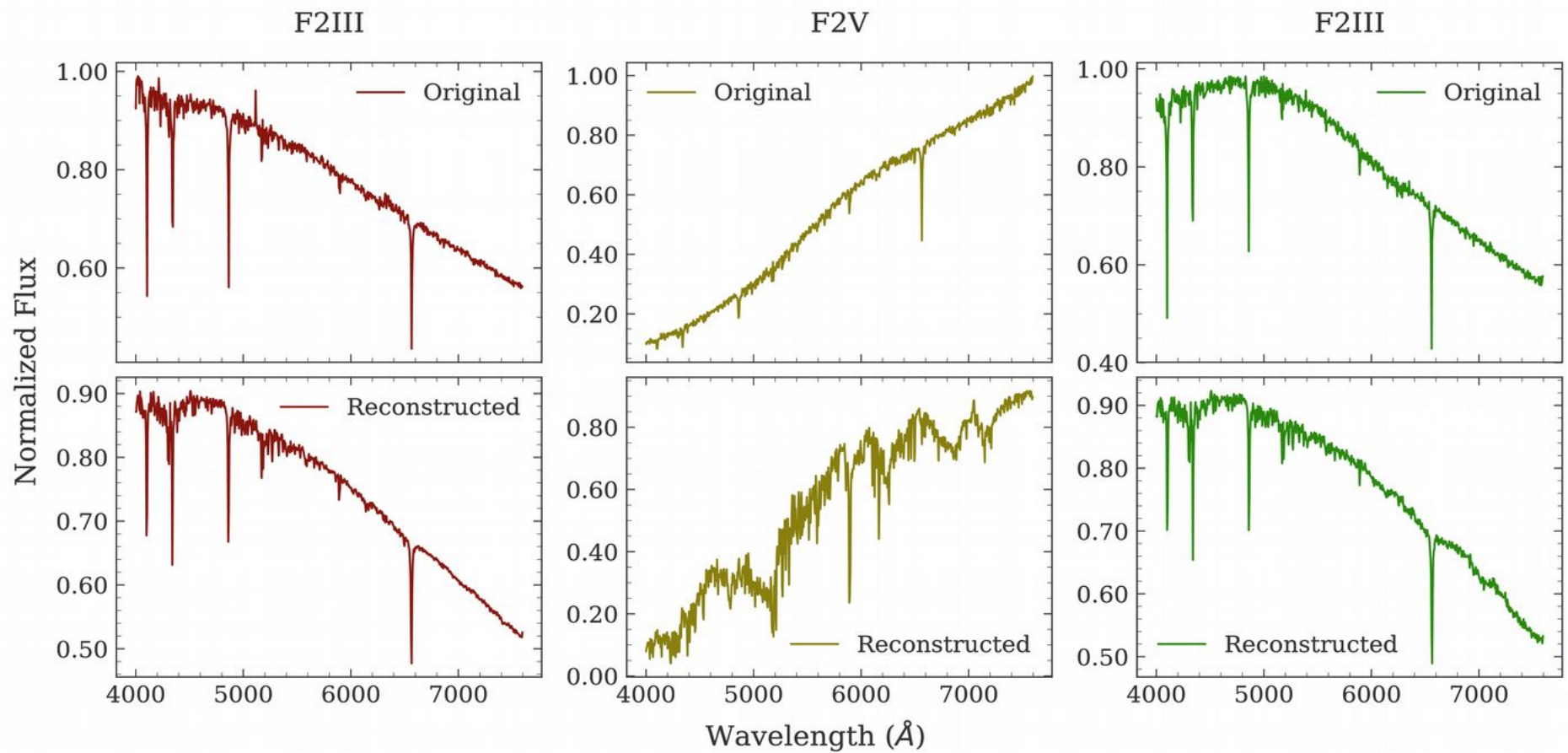
Outlier Detection



Extreme RMSE Outliers



Denoising



Thank you