# Spectral parameterization and Classification with the help of Artificial Neural Networks (ANN)

Group I

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# Our Group


# Overview

# Introduction to Spectral Type

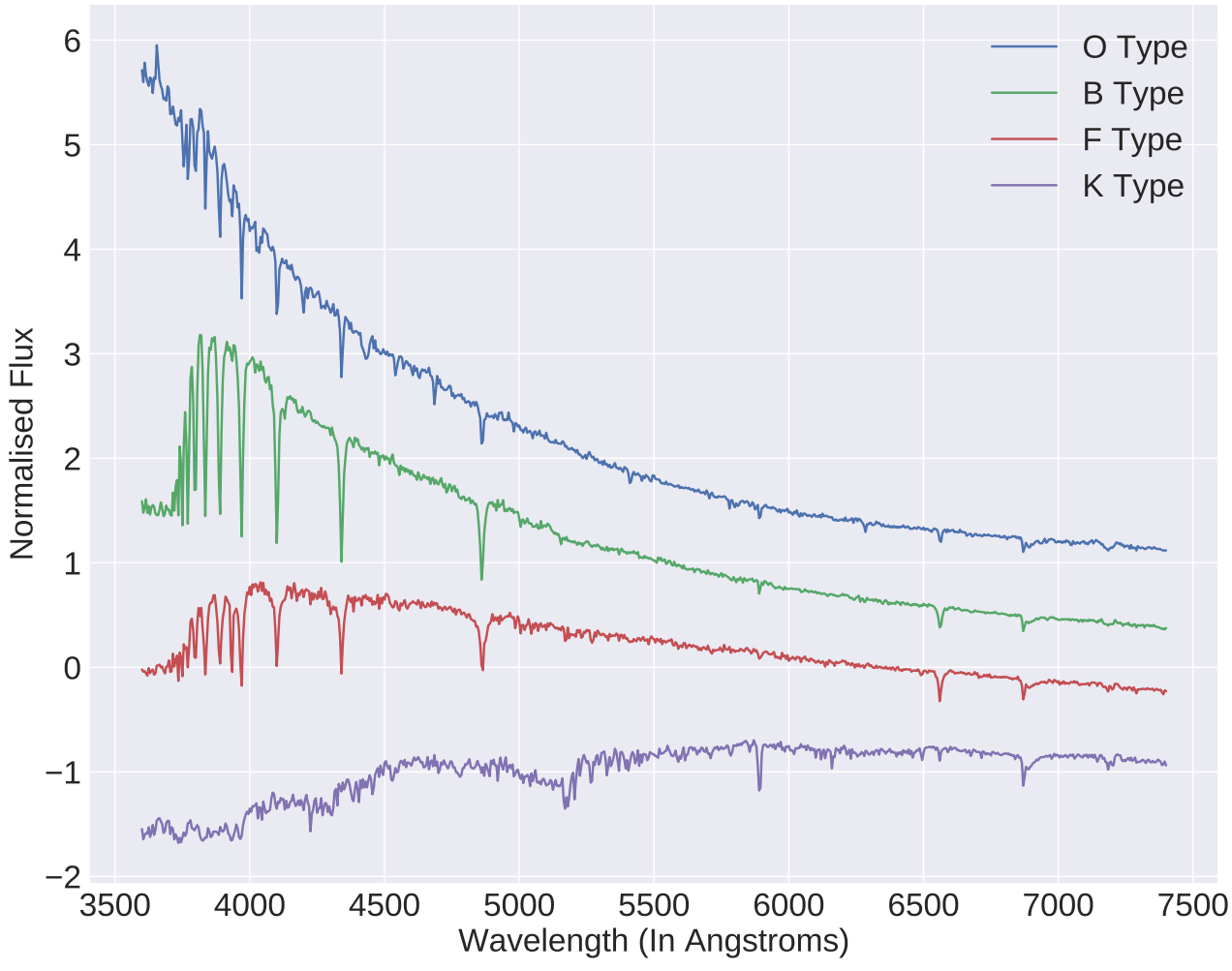
- Each spectral class is characterised by absorption features at few selected wavelengths (based on $T_{eff}$).
- Stars are currently classified under the Morgan - Keenan (MK) system as: O, B, A, F, G, K, and M,
- O type - hottest

  .

  .

  M type - coolest
- Each letter class is then subdivided again using a numeric digit with 0 being hottest and 9 being coolest.
- Luminosity class I stars for supergiants, class II for bright giants, class III for regular giants, class IV for sub-giants, class V for main-sequence stars.

# Different Spectral Types (CFLIB)



# Introduction to Artificial Neural Network

- Computing systems inspired by the biological neural networks.
- They learn (progressively improve performance) to do tasks by considering examples.
- Based on a collection of connected units called artificial neurons, such as:
  1. Perceptrons
  2. Sigmoid Neurons

- Perceptrons:-
  1. Takes several binary inputs and produces a single output i.e. 0 or 1.
  2. Output is based on 'bias' and weights.
- Sigmoid Neurons
  1. Takes several binary inputs and produces a single output-any value between 0 and 1, given by a sigmoid function
  2. Output changes with small changes in 'bias' and weights.

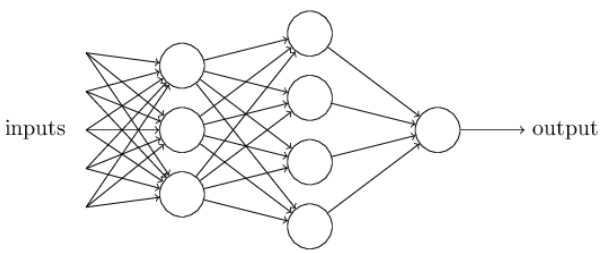



Figure: Layers of Perceptrons
(Source: Internet)

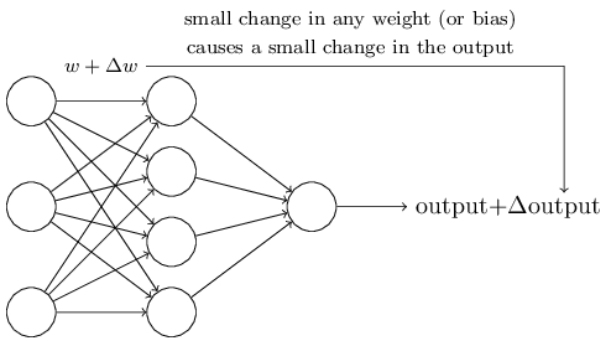



Figure: Sigmoid Neurons
(Source: Internet)

# Data Catalogs

- Jacoby-Hunter-Christian Atlas (Jacoby)[1]:-
  1. Contains 161 stars. 158 selected from classes O to M
  2. Each spectrum covers 3510-7427 Å
  3. Resolution of spectra is $\sim$ 4.5 Å
  4. Training dataset for the ANN classifier
- Indo-US Library of Coudé Feed Stellar Spectra (CFLIB)[2]:-
  1. Contains 1273 stars, 850 excluding the ones with wavelength gaps.
  2. Each spectrum covers 3465-9469 Å with a sampling of 0.4 Å
  3. Resolution of spectra is $\sim$ 0.88 Å
  4. Testing dataset for the ANN classifier & ANN Parameterization.
- Medium Resolution of INT Library of Empirical Spectra (MILES)[3]:-
  1. Contains 985 stars, 220 selected representing the whole parameter space.
  2. Each spectrum covers 3525-7500 Å
  3. Resolution of spectra is $\sim$ 2.50 Å
  4. Training dataset for the ANN Parameterization.

# Pre-Processing

To make the data across catalogs **homogeneous** by:-

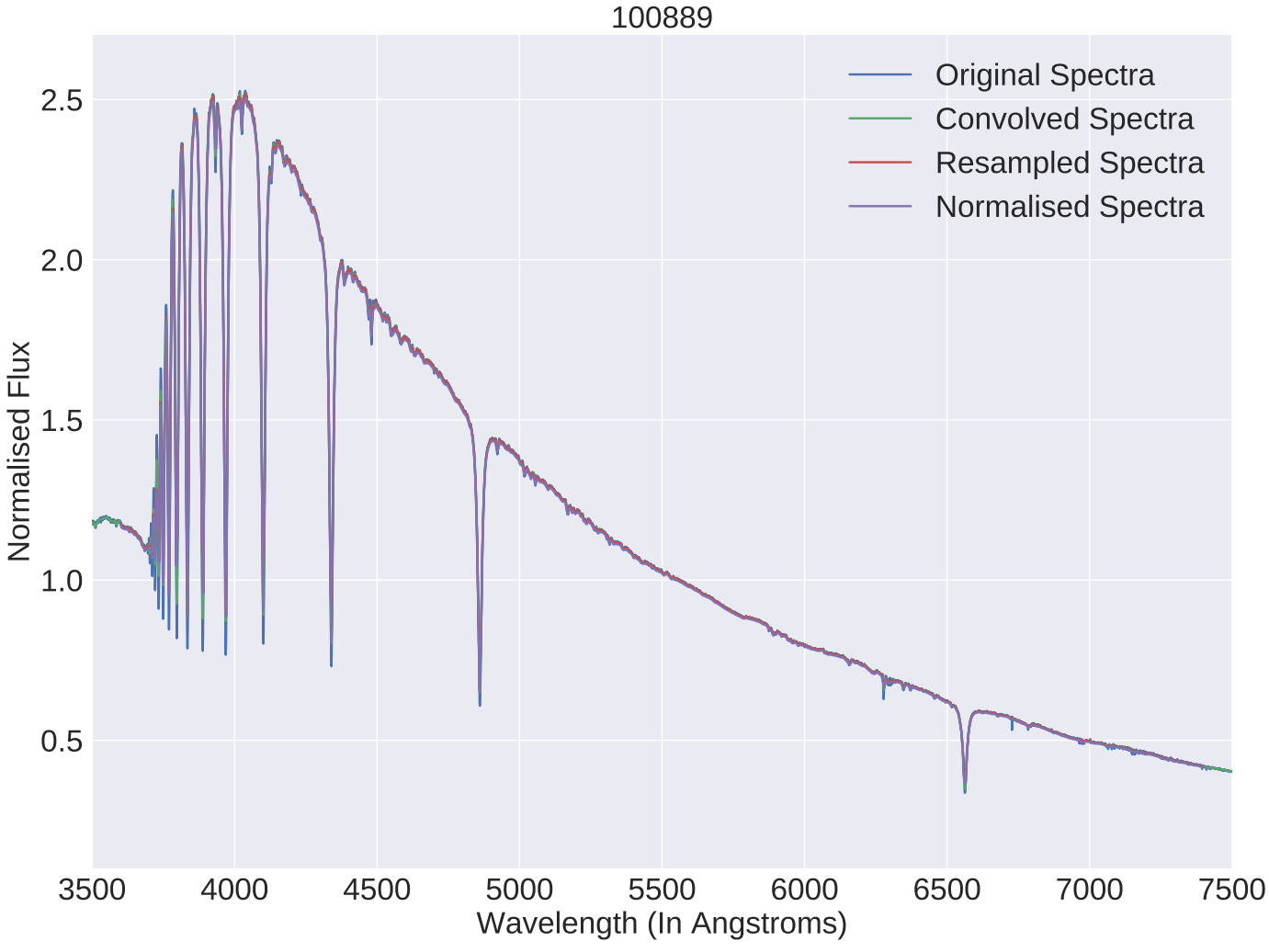
- making the **resolution** of each spectrum across the dataset same.
- **resampling** at specific intervals
- **normalizing** with the flux at a specific wavelength
- **trimming** with the same wavelength limit

# Classification Using ANN

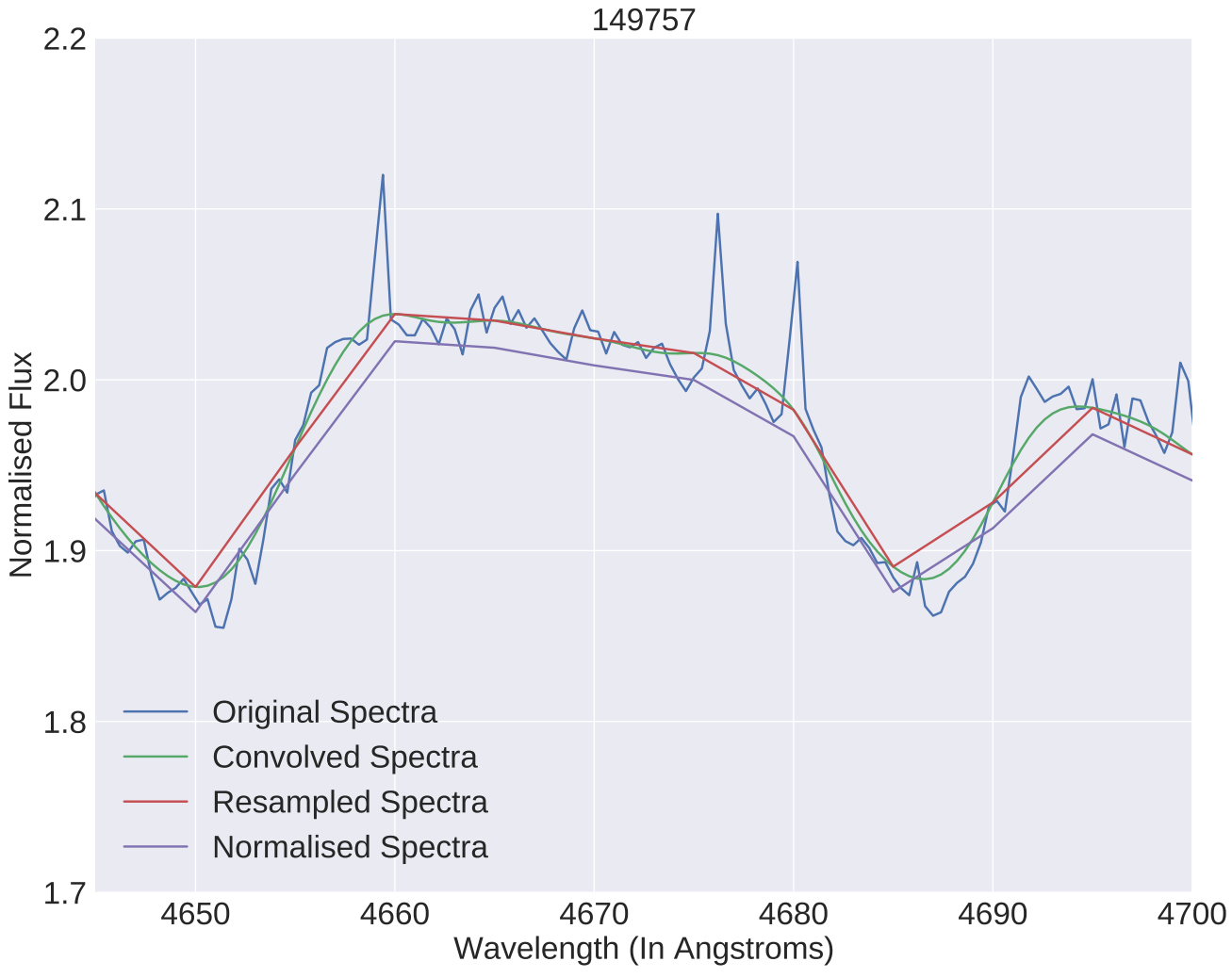
# Pre-Processing for Classification

- Convolved CFLIB data (using Gaussian of $\sigma = \sqrt{(4.5)^2 - (0.88)^2}$)
- Resampled spectra from both the catalogs at 5 Å
- Normalized spectra flux at 5550 Å
- Trimmed spectra in the range 3600-7400 Å

# Pre-Processing of a Hot (B type) Star



# Pre-Processing of a Cool (M type) Star



# Spectral Class Encoding

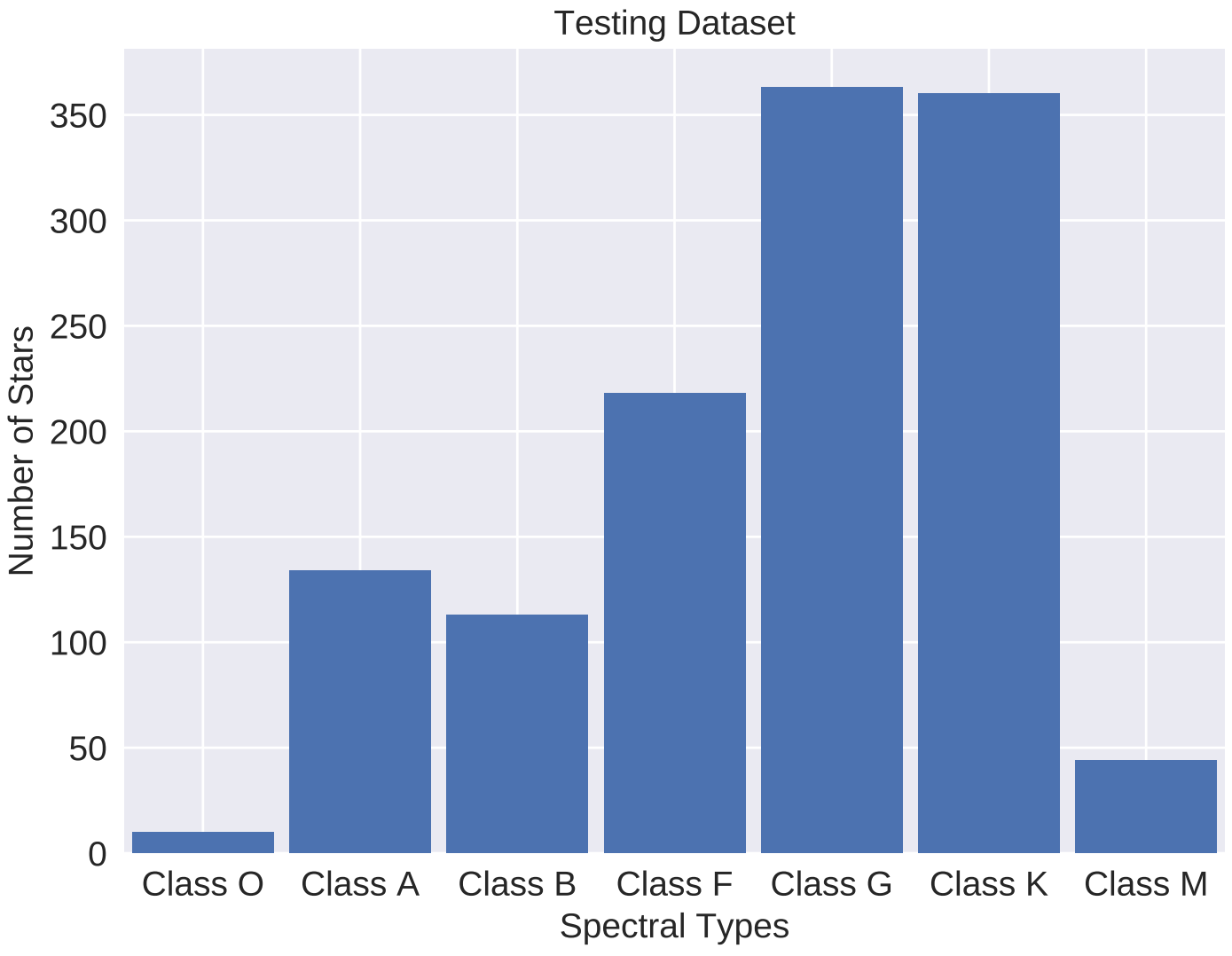
- Spectral type is conventionally named as an alphanumeric
- Converted each spectral type to a unique number as follows:-

$$\text{Coded Number } = 1000 * \text{S} + 100 * \text{SS} + 2 * (\text{L} - 1) \quad (1)$$

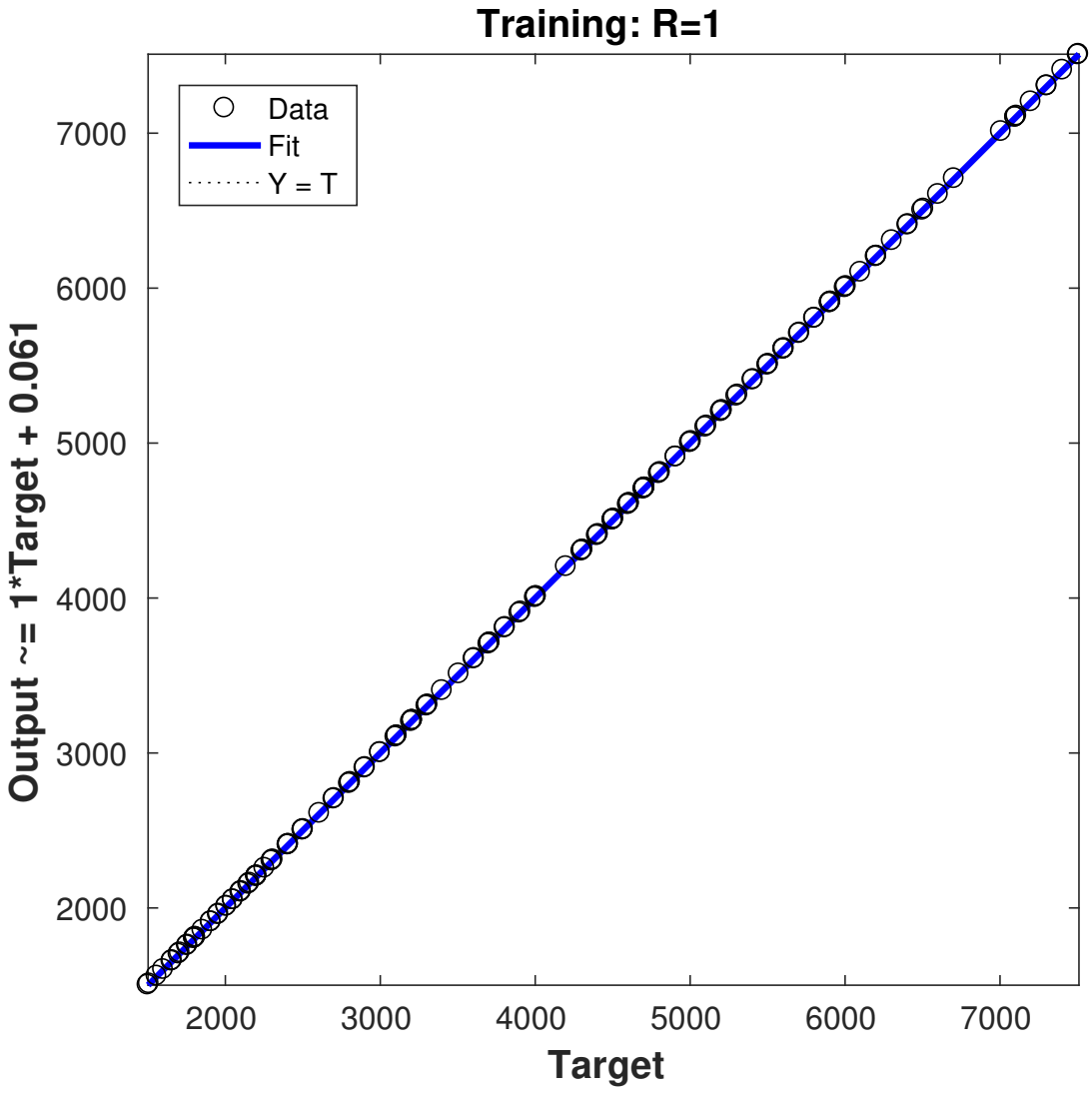
- S = Main spectral type (coded from 1 to 7 for types O to M)
- SS = Sub-spectral type (coded from 0 to 9)
- L = Luminosity class (coded from 0 to 4 for classes I to V)

# Training Dataset (Jacoby)

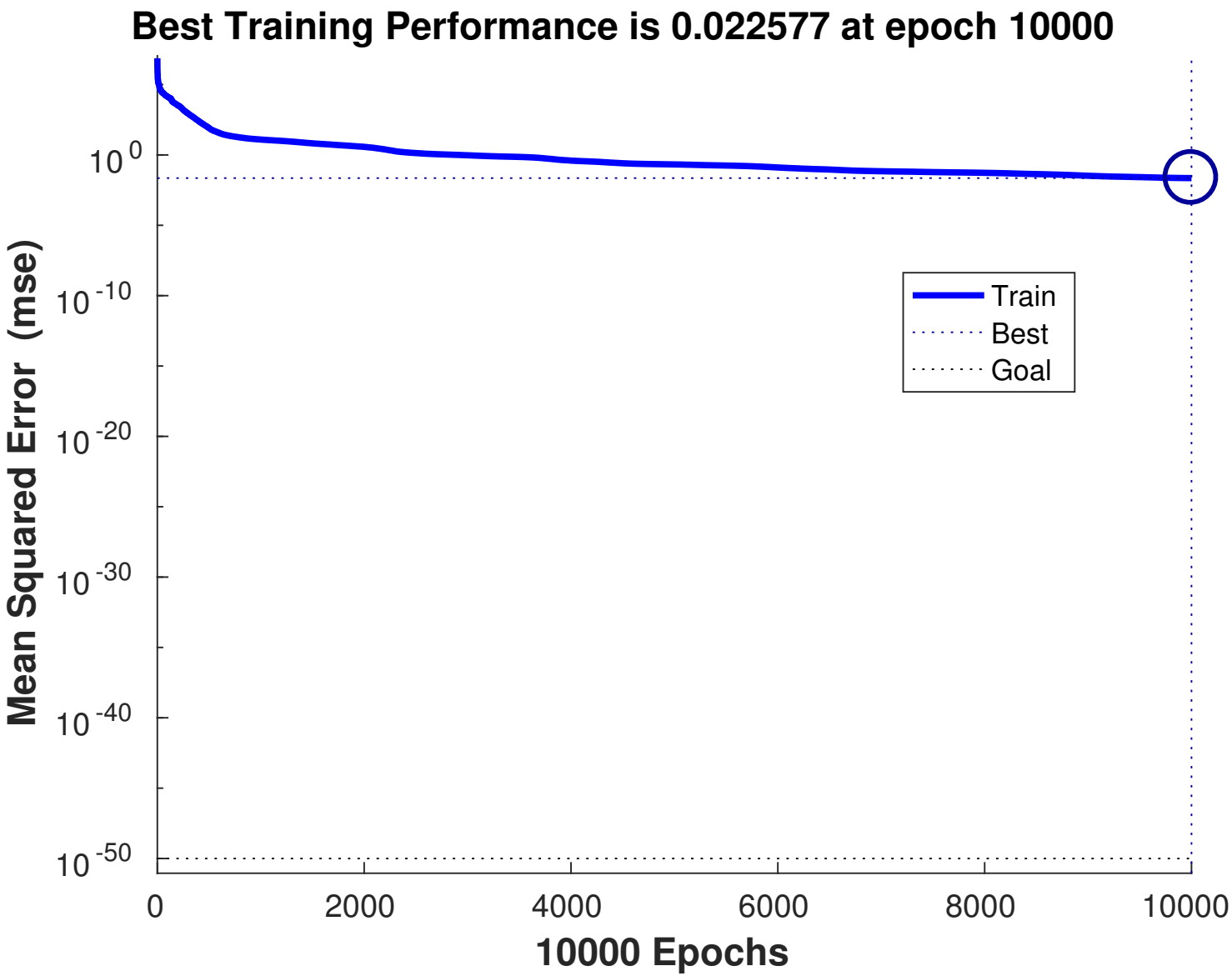
# Testing Dataset (CFLIB)



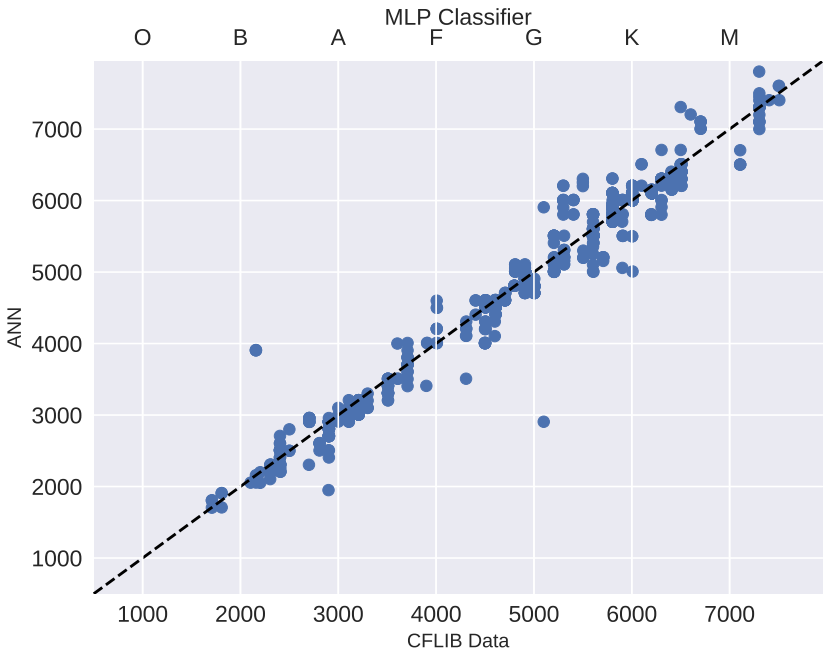
# Training- Regression

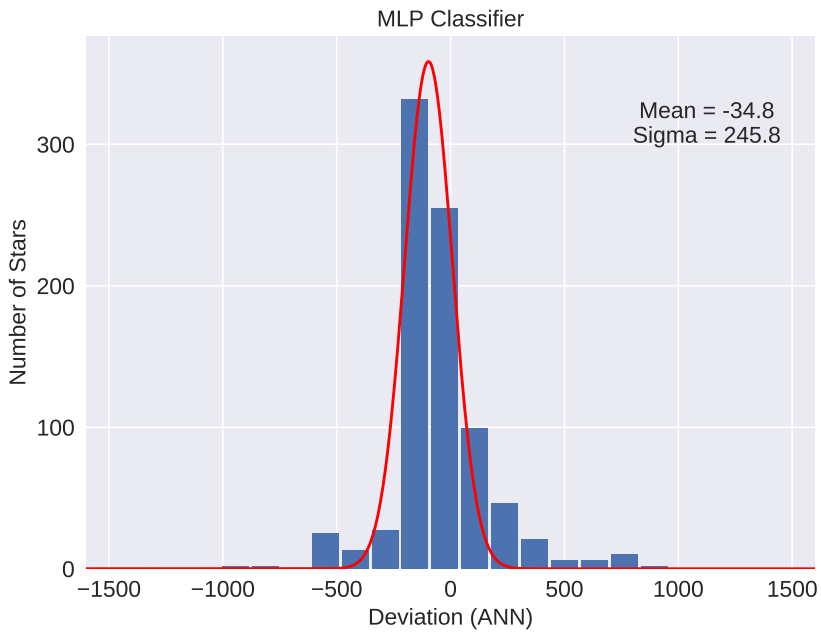


# Training Performance

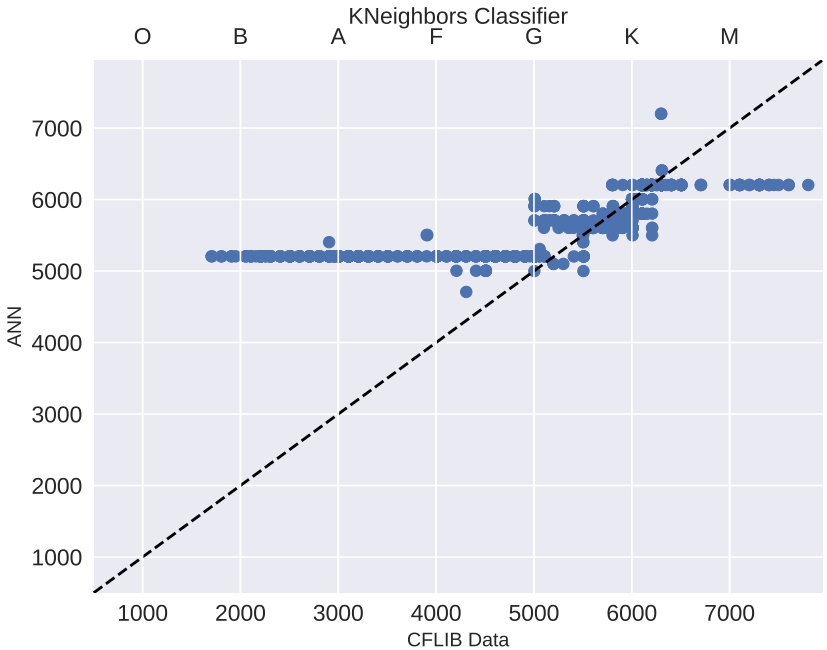


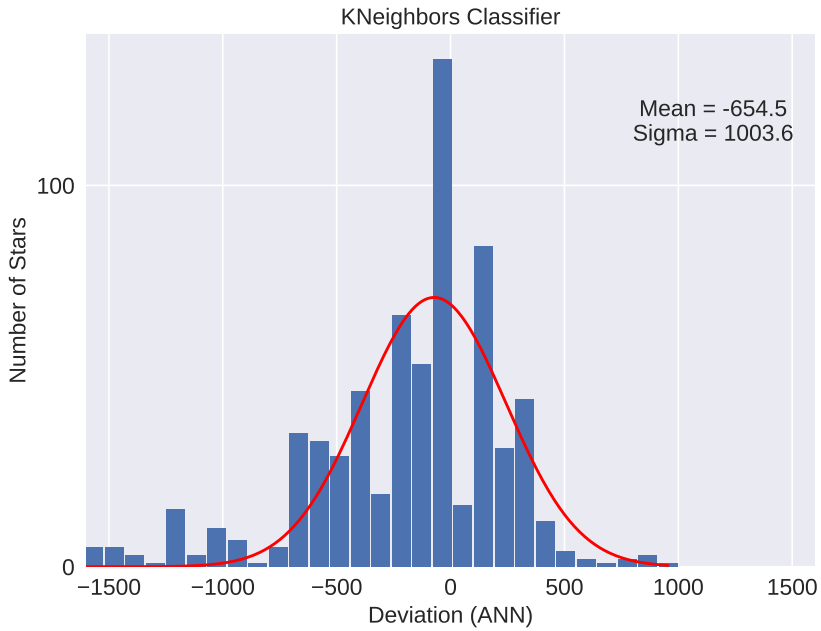
# Classification with MLP



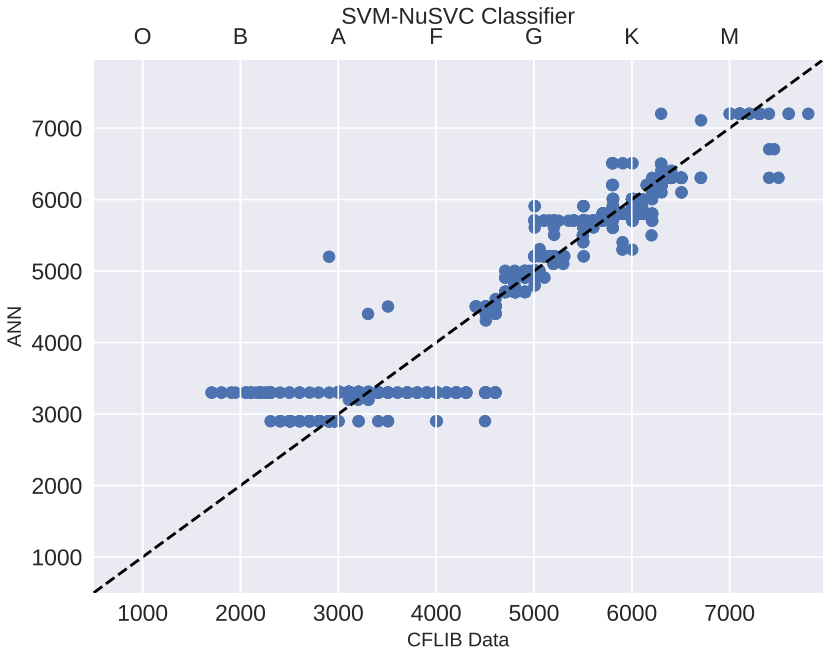



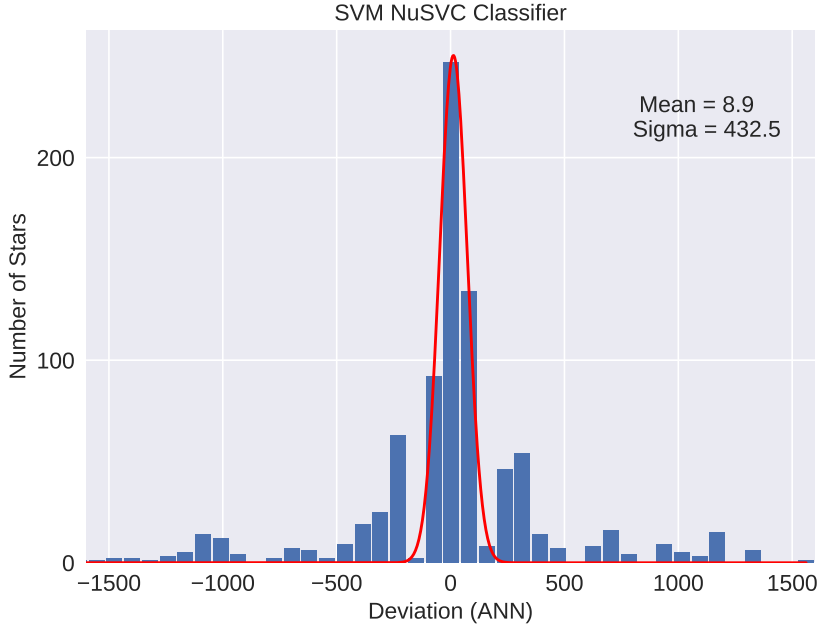
# Classification with KNN



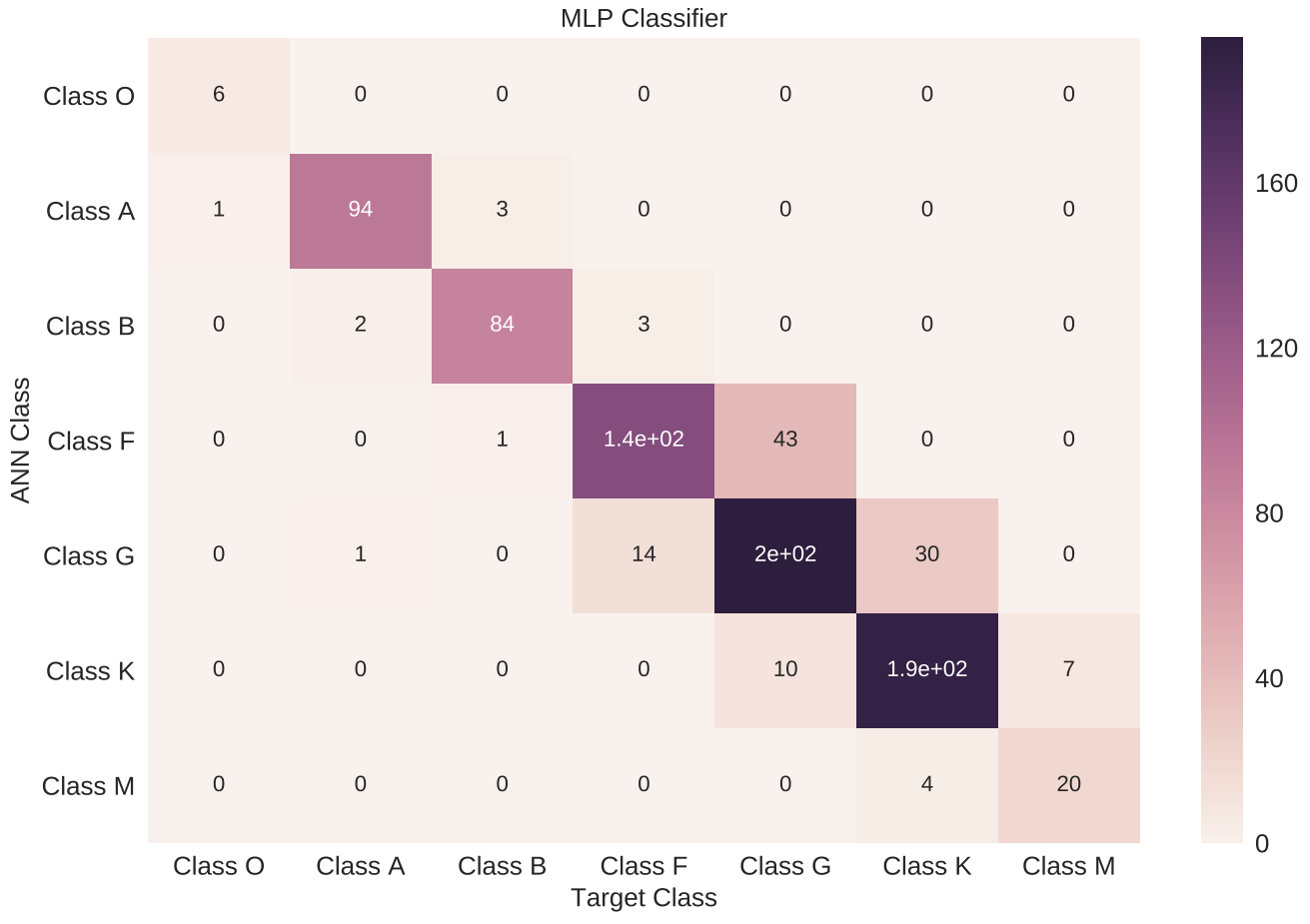



# Classification with SVM

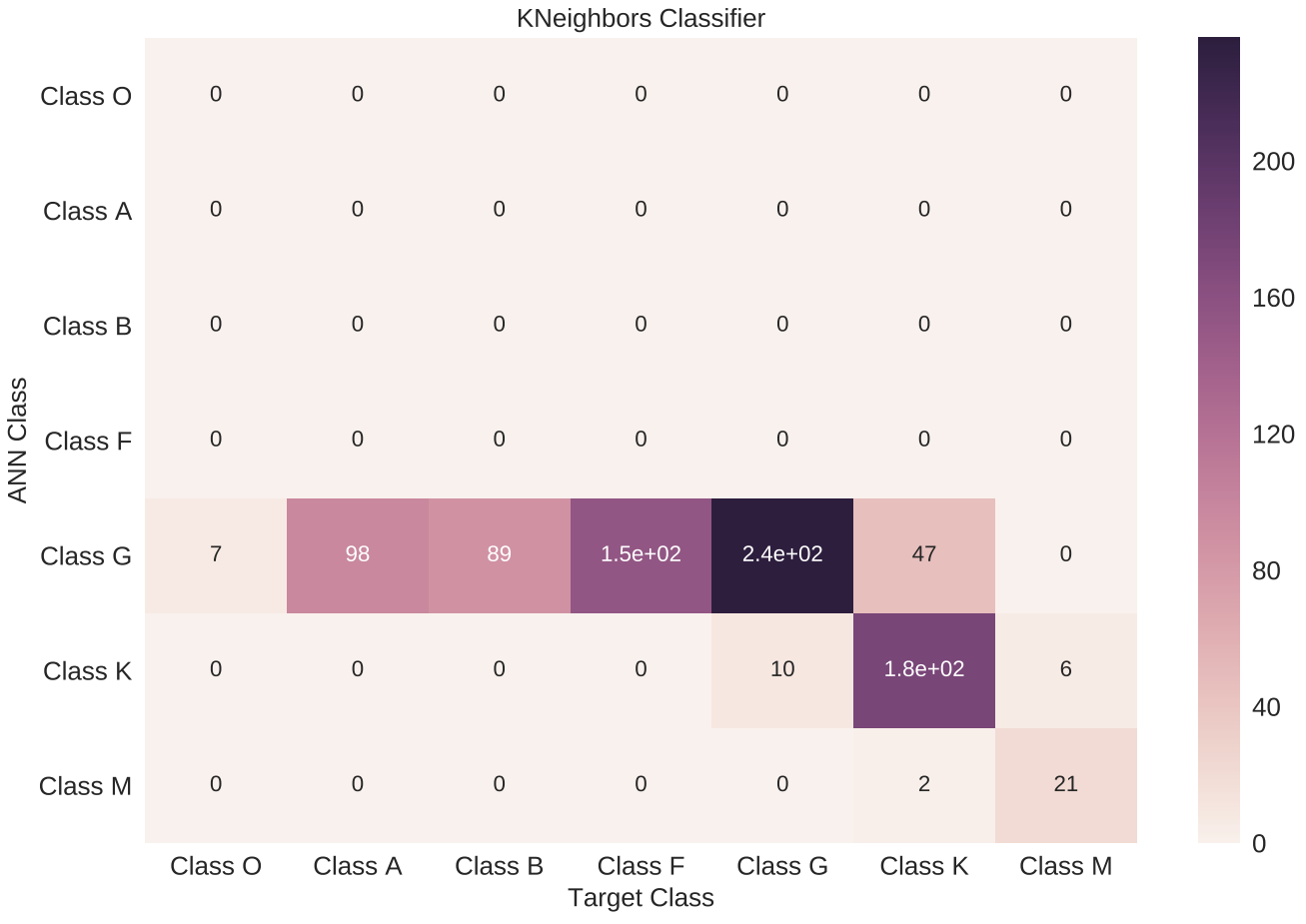


# Confusion Matrix (MLP)



# Confusion Matrix (KNN)

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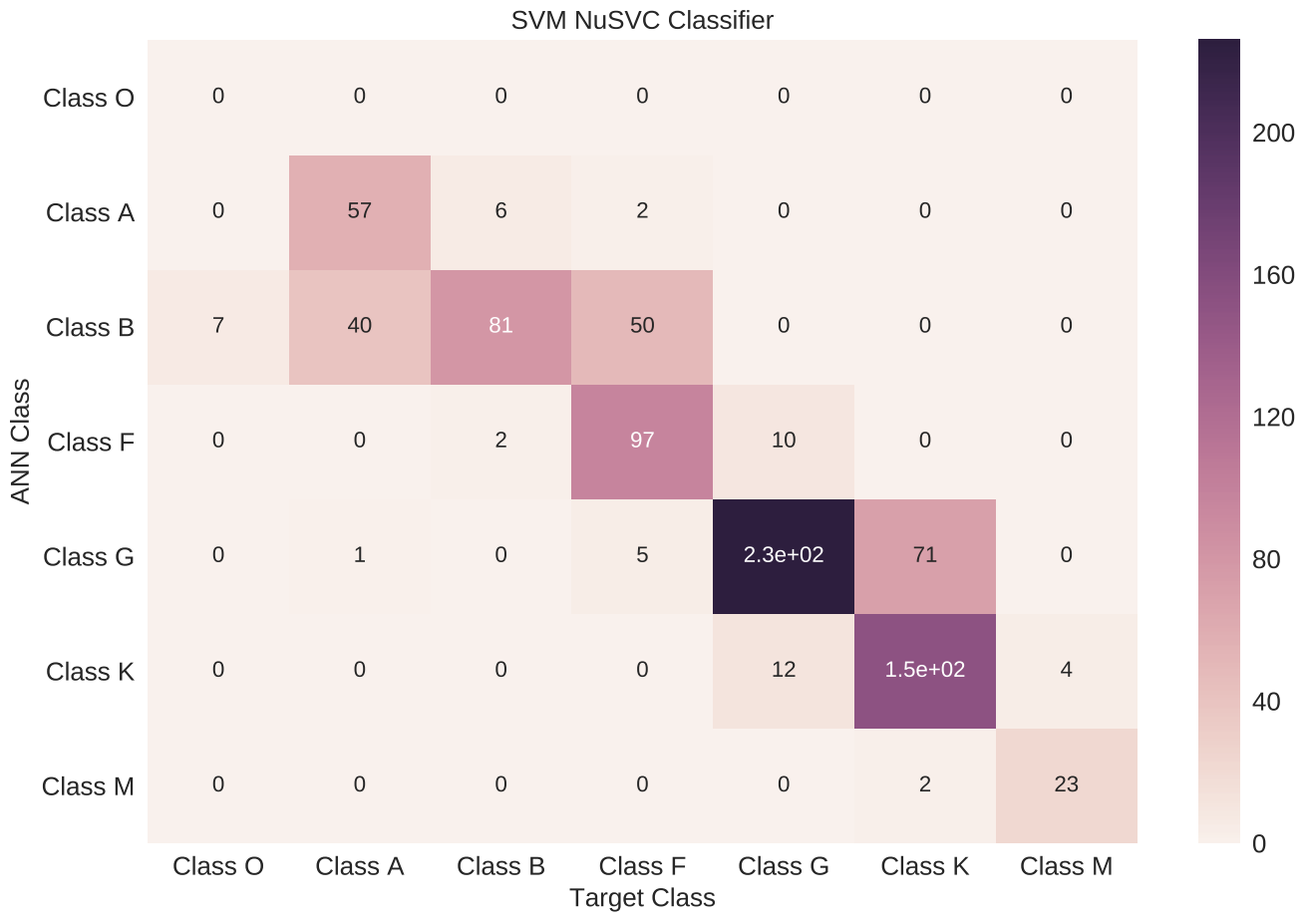
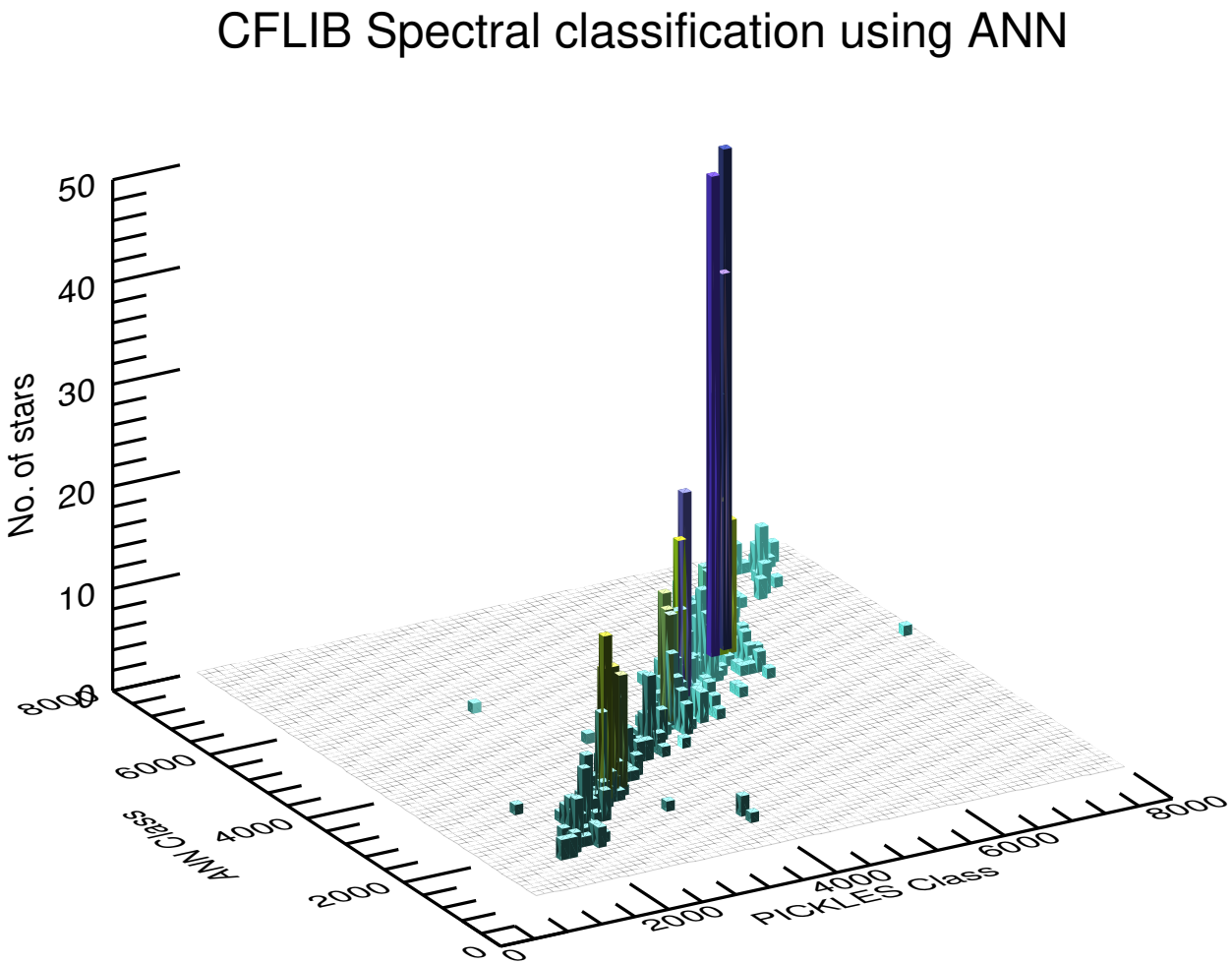
# Confusion Matrix (SVM)



# Histogram Of The MLP Fit



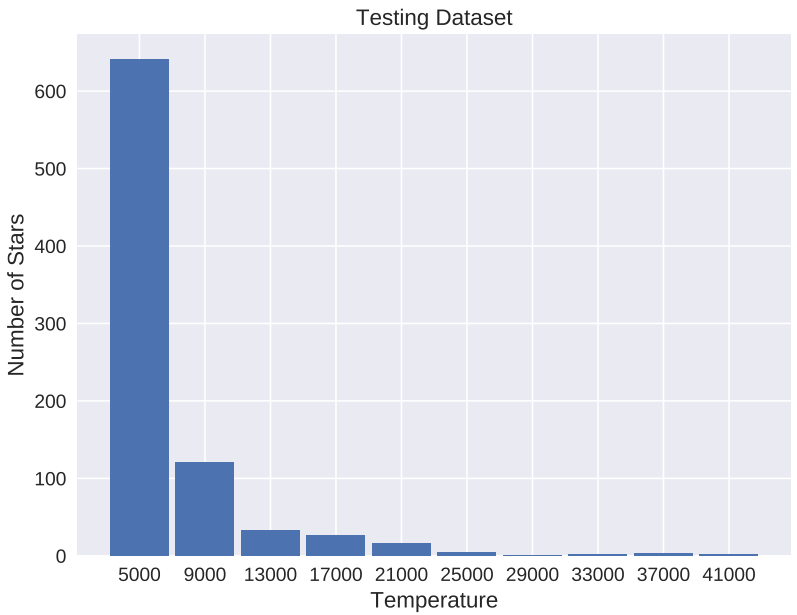
# Comparison Of Different Classifiers

| Classifier | Mean | Sigma |
|---|---|---|
| MLP | -34.8 | 245.8 |
| KNN | - 654 | 1003.6 |
| SVM NuSVC | 8.9 | 432.5 |

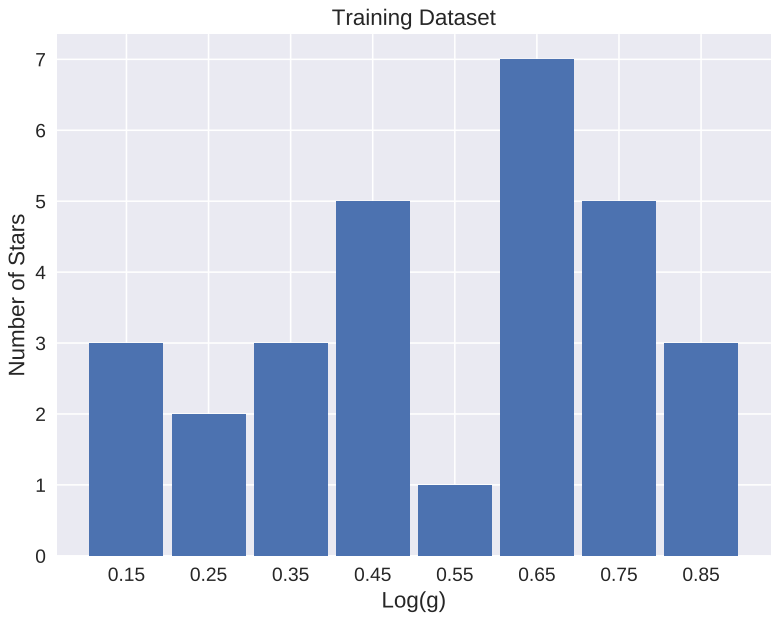
# Pre-Processing for Parameterization

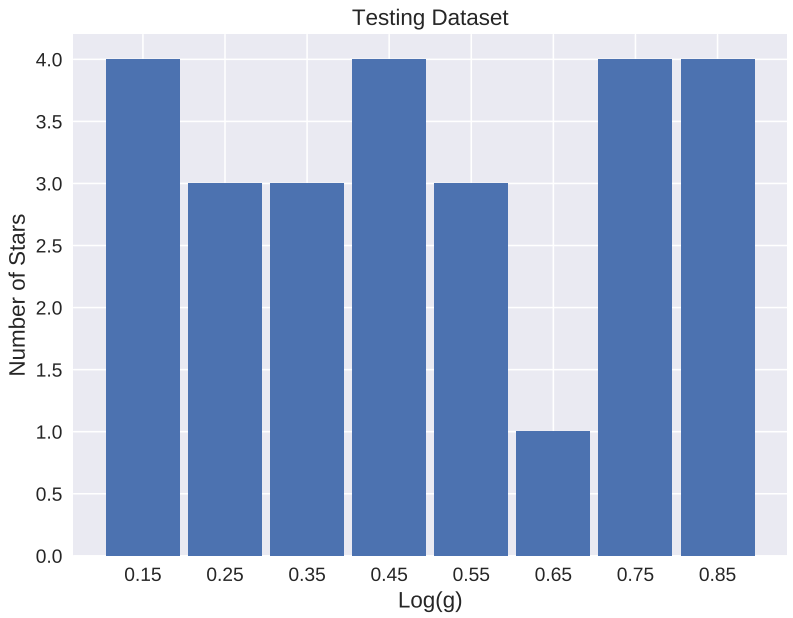
- Convolved CFLIB data (using Gaussian of $\sigma = \sqrt{(2.56)^2 - (0.88)^2}$) to bring it at the resolution of MILES.
- Resampled spectra from both the catalogs at 3 Å
- Normalized spectral flux at 5550 Å
- Trimmed spectra in the range 3600-7400 Å

# Training & Testing Dataset - Teff (MILES & CFLIB)

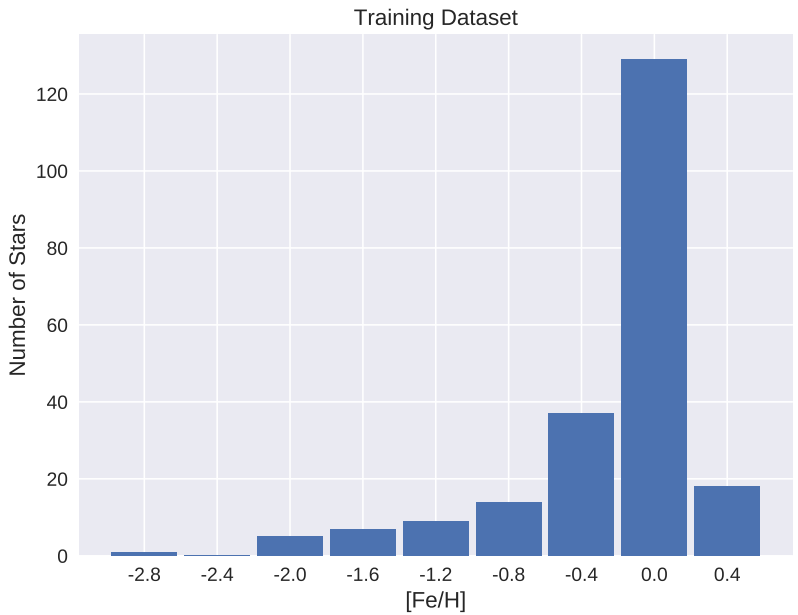



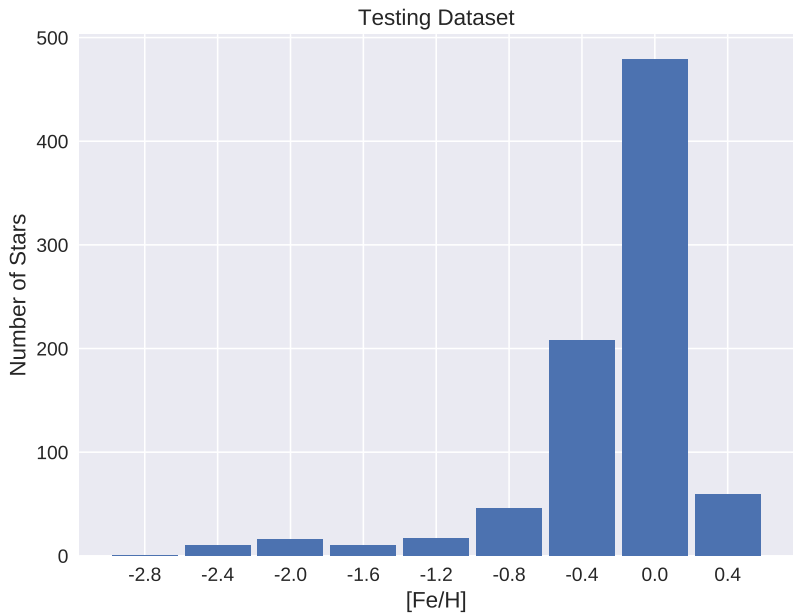
# Training & Testing Dataset - log(g) (MILES & CFLIB)



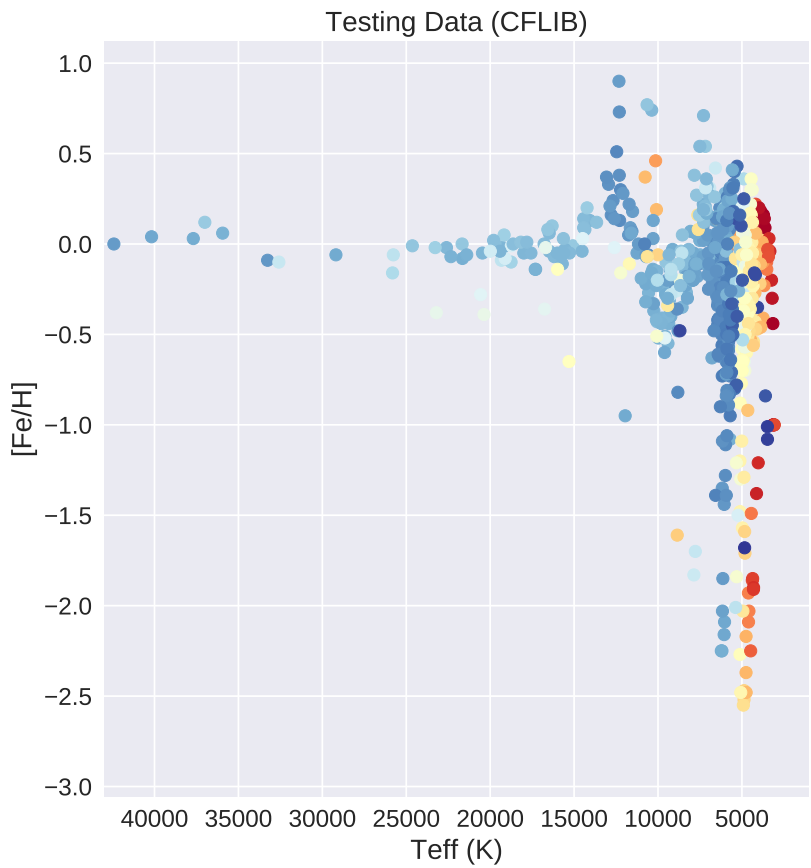



# Training & Testing Dataset - [Fe/H] (MILES & CFLIB)

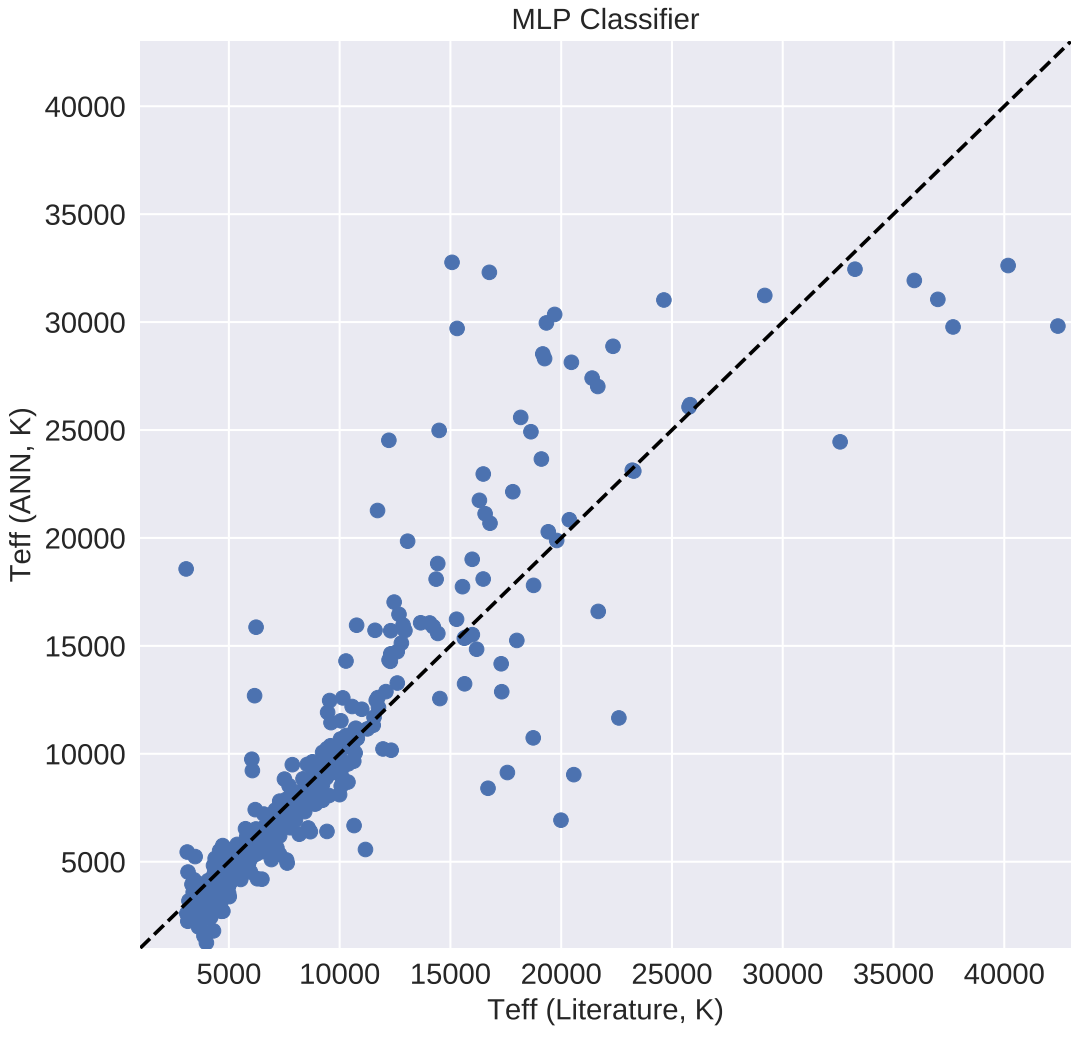


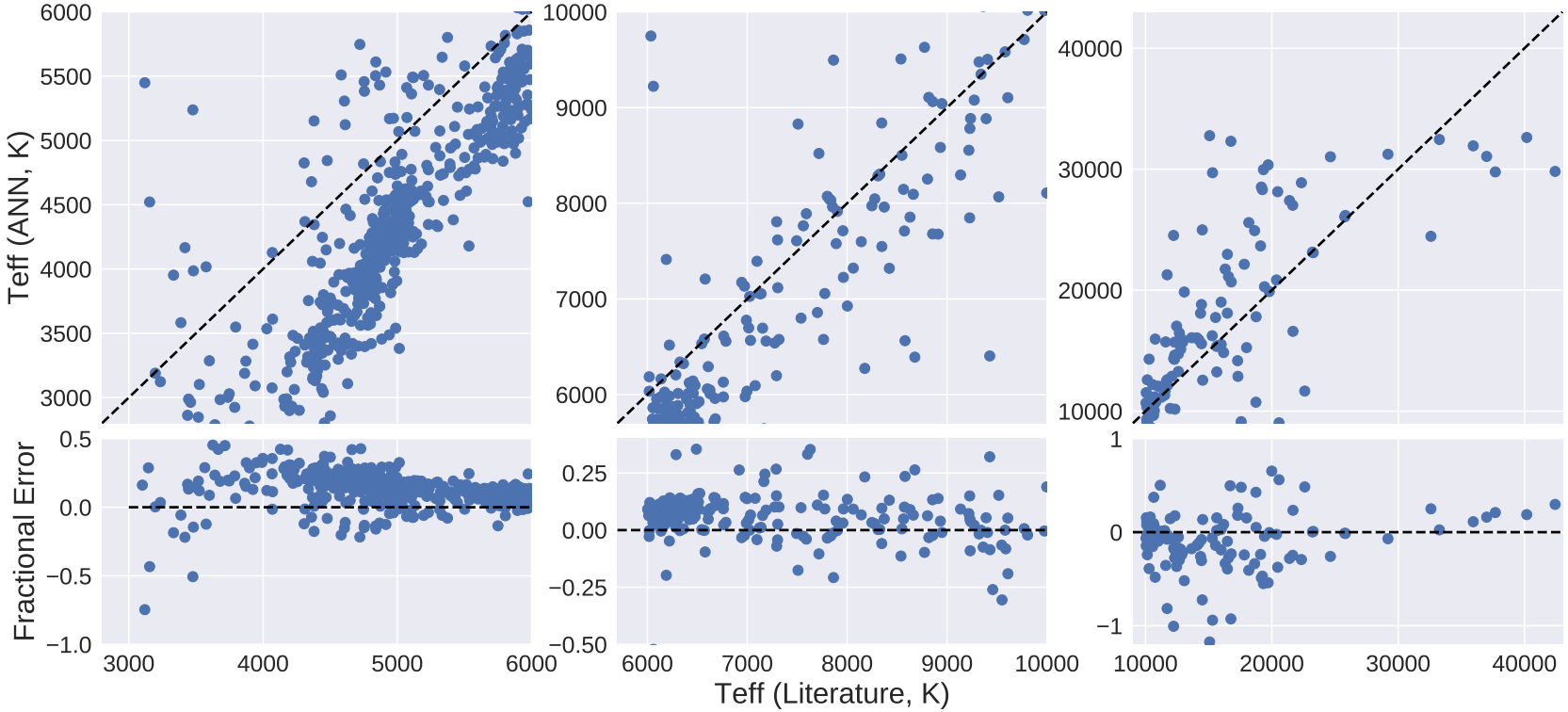
# Training & Testing Data - Parameter Space

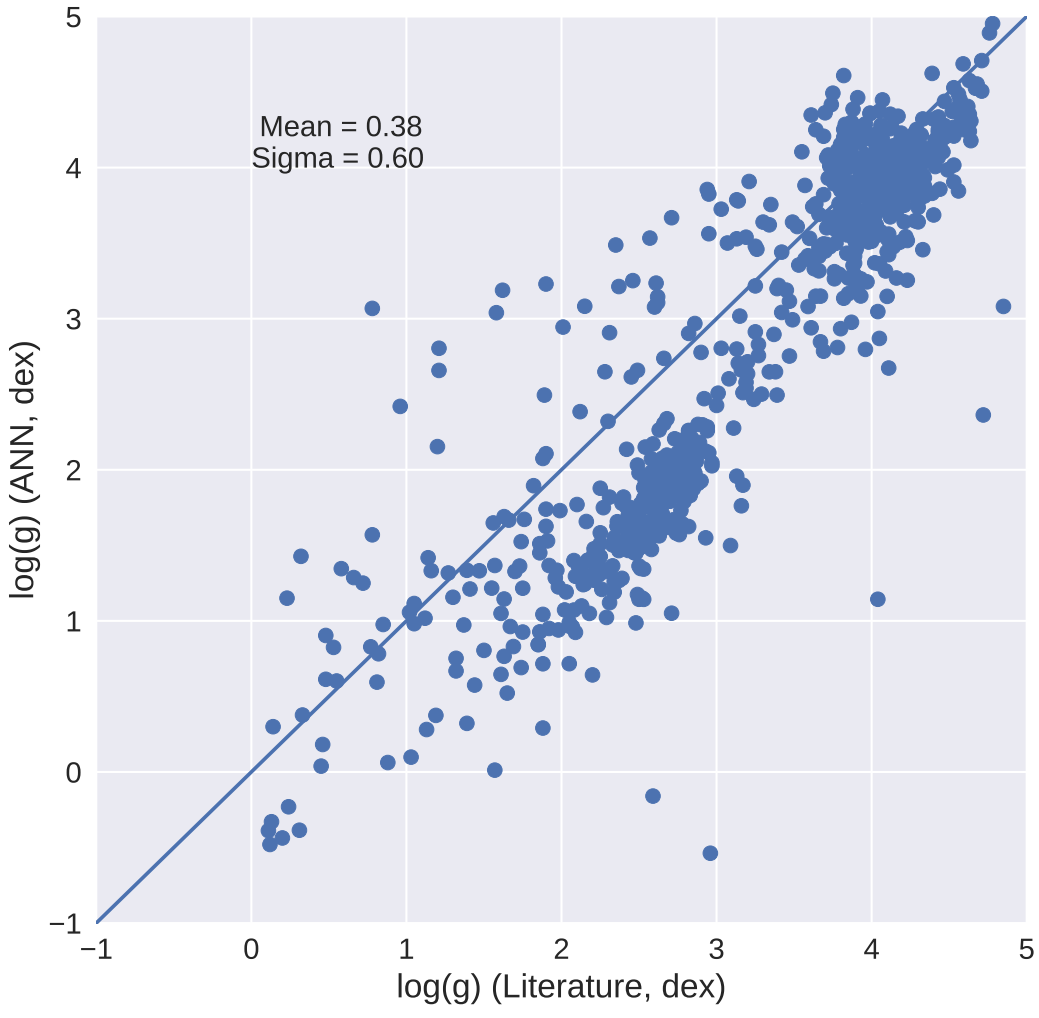
# Teff - Parameterization



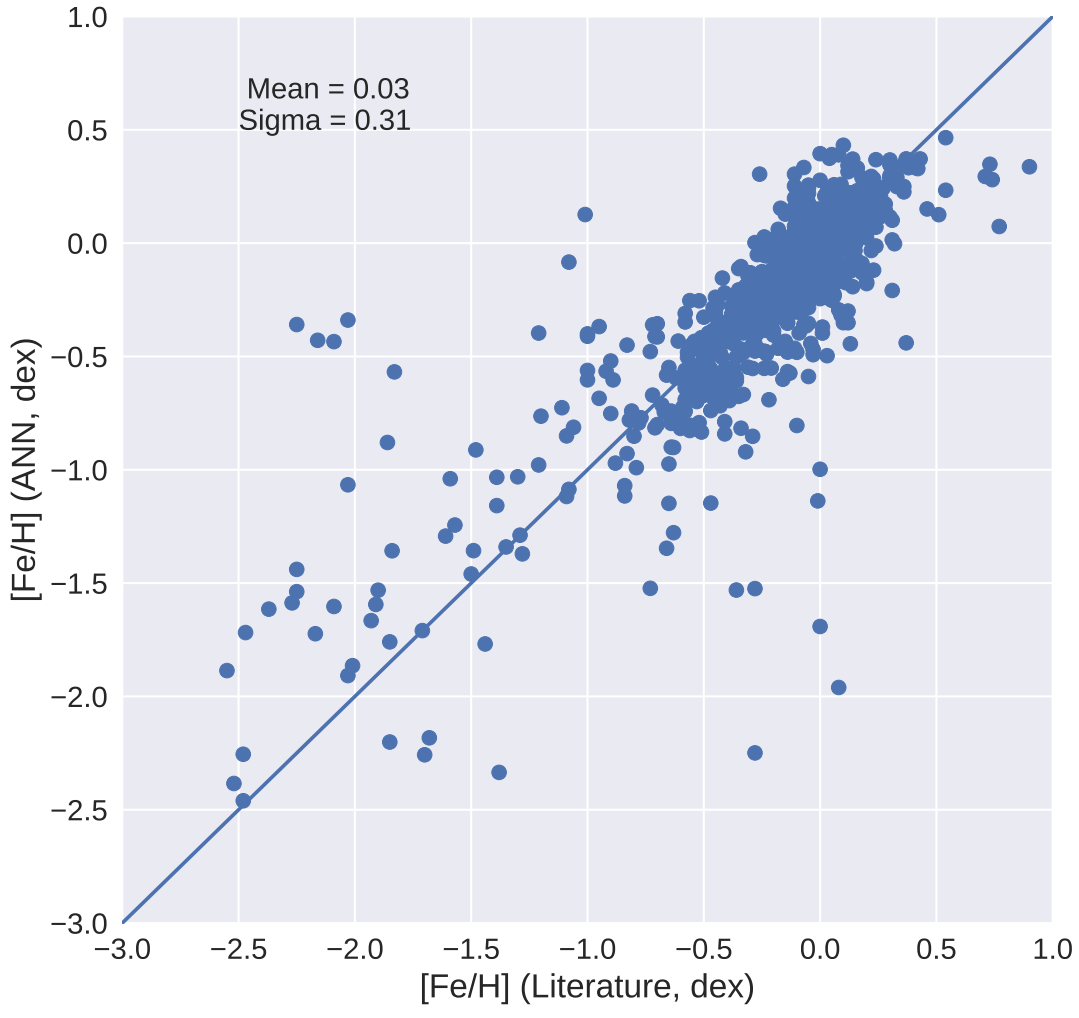
# Teff - Parameterization



# log(g) - Parameterization

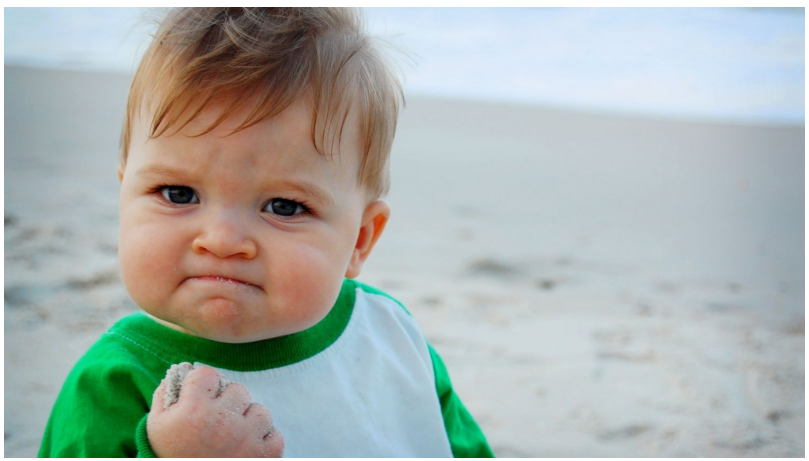


# [Fe/H] - Parameterization



# Summary

- Classification:-
  1. JHC Atlas was used for training and CFLIB for testing the ANN.
  2. The MLP classifier was found to be better than KNN classifier.
  3. We were able to classify the spectra with an accuracy of $\sim$ 245.8, i.e. 3 spectral sub-types
- Parameterization
  1. MILES Spectral Library was used for training and CFLIB for testing the ANN.
  2. Accuracy of the parameters determined could be easily be reflected in the incomplete parameter space of the training library.



# Future Plan

- Inclusion of the external libraries **(ELODIE, SDSS)** to the training set will give a better correlation for the hot stars as there were very few in our training dataset.
- Spectral data with SNR information **(SDSS)** can give us the measure of the classification accuracy that can be achieved using ANN

# References


1. Jacoby Library - ftp://ftp.stsci.edu/cdbs/grid/jacobi/
2. Indo-US Library - https://www.noao.edu/cflib/V1/TEXT/
3. MILES Library - http://miles.iac.es/
4. Prugniel *et al.*, 'The atmospheric parameters and spectral interpolator for the MILES stars', A&A, Vol.531, id.A165 (2011)
5. Wu *et al.*, 'Coudé-feed stellar spectral library - atmospheric parameters' A&A, Vol.525, id.A71 (2011)
6. Prugniel,*et al.*,'New release of the ELODIE library: Version 3.1',ArXiv, 2007
7. Prugniel,*et al.*,'A database of high and medium-resolution stellar spectra', Vol.369, p.1048-1057 (2001)
8. Gulati,*et al.*,'Stellar spectral classification using automated schemes', The Astrophysical Journal, May 1994.


# Thank You