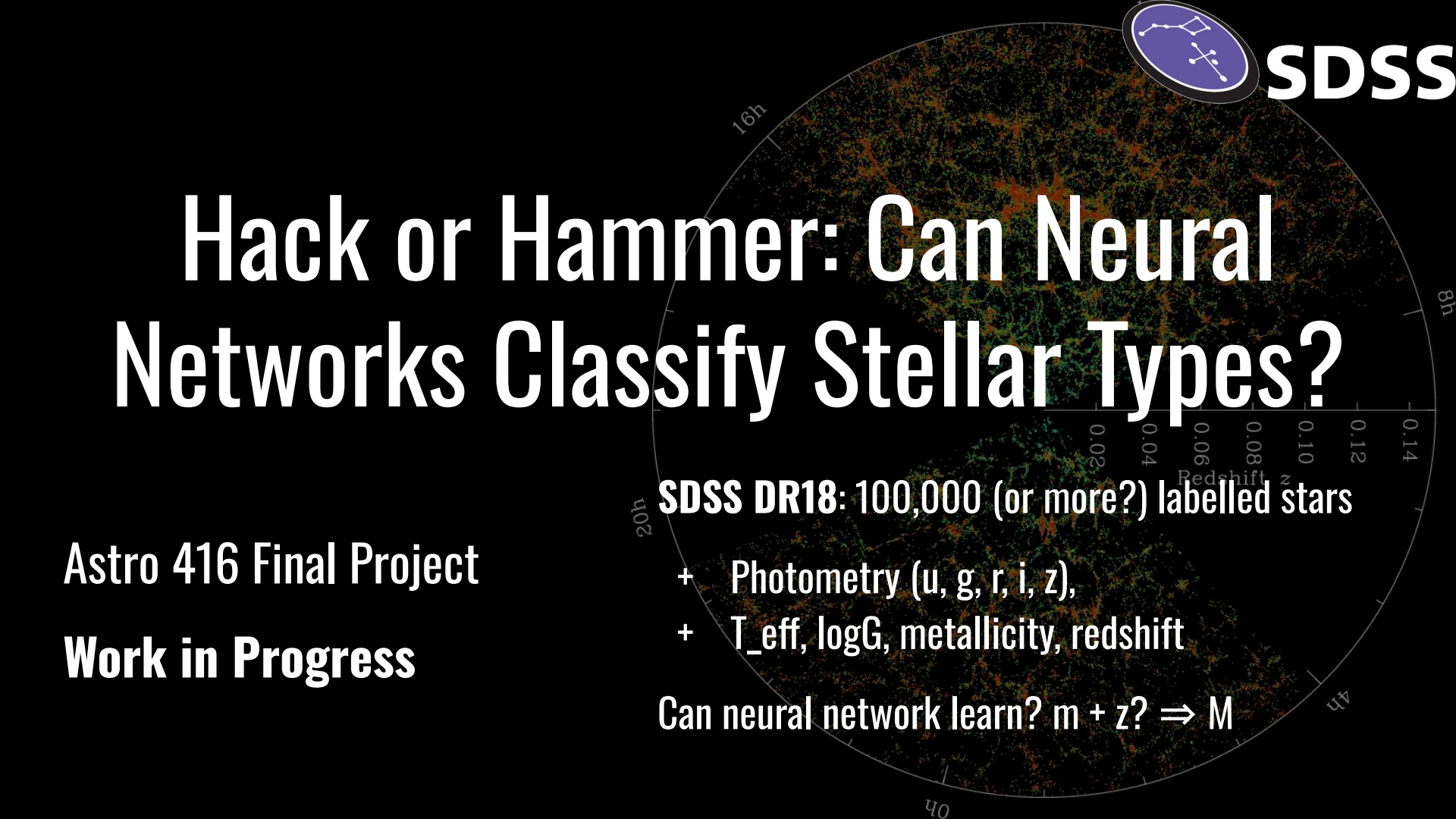


Hack or Hammer: Can Neural Networks Classify Stellar Types?

Astro 416 Final Project

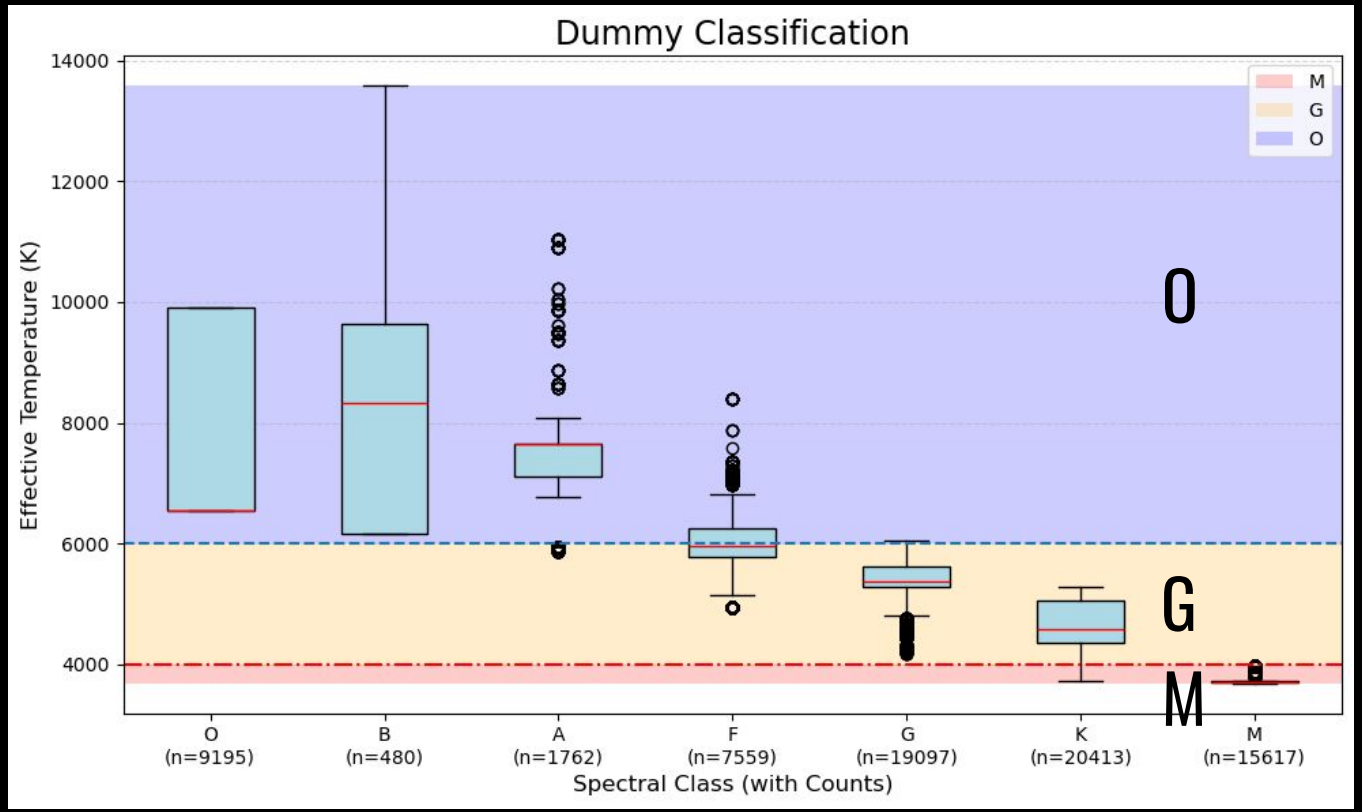
Work in Progress

SDSS DR18: 100,000 (or more?) labelled stars

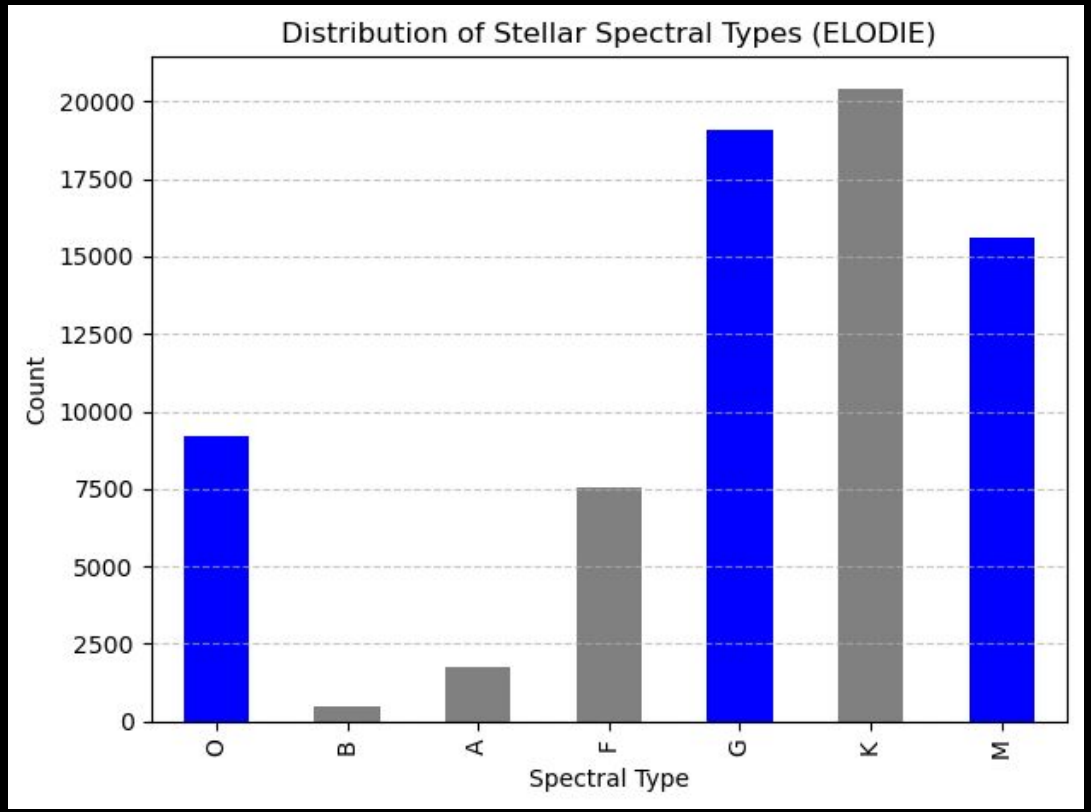
+ Photometry (u, g, r, i, z),
+ T_eff, logG, metallicity, redshift

Can neural network learn? m + z? ⇒ M

Data Exploration & Benchmarking



Dummy Model Benchmarking



Dummy Model Performance

59.2% accuracy

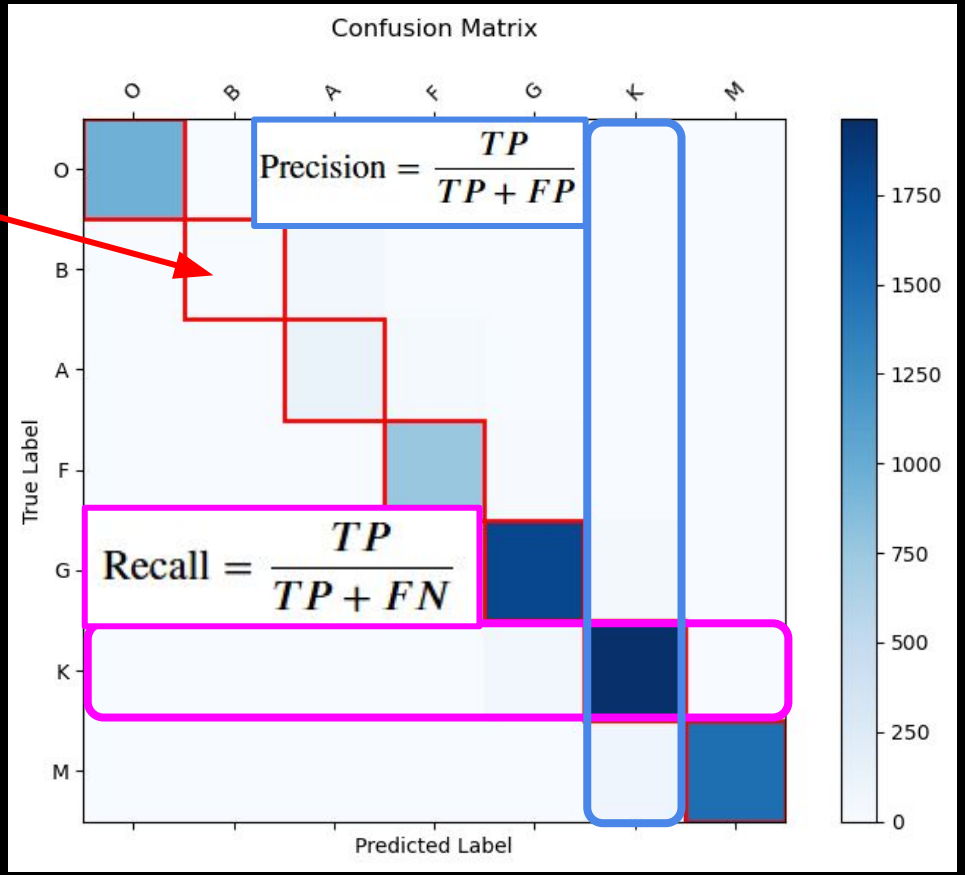
37.2% precision

59.2% recall

Multiclass Classification

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

$$F1 = 2 \cdot \frac{\text{Precision} \cdot \text{Recall}}{\text{Precision} + \text{Recall}}$$



Feedforward Neural Networks

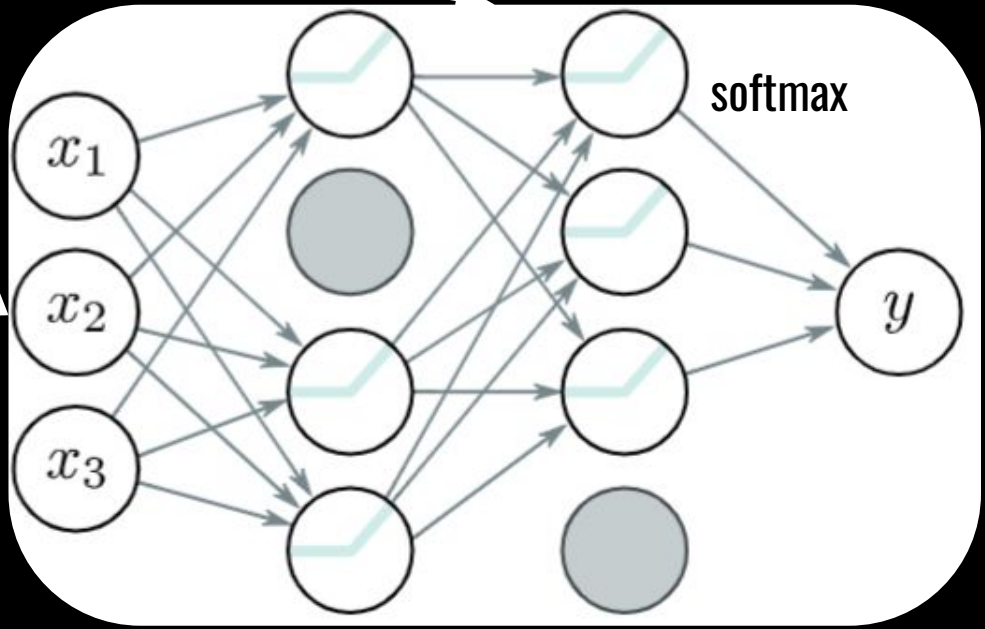
$$\text{softmax}_k[\mathbf{z}] = \frac{\exp(z_k)}{\sum_{k'=1}^{K} \exp(z_{k'})}$$

Hyperparameter Optimization
(Keras tuner)

Stellar Parameters

Data Standardization

One-hot encoding



Stellar Classes:
OBAFGKM

Use accuracy, precision, recall to evaluate

Cross-validate

Spectral Class	One-Hot Encoding
O	[1, 0, 0, 0, 0, 0, 0]
G	[0, 0, 0, 0, 1, 0, 0]
M	[0, 0, 0, 0, 0, 0, 1]

Can Neural Networks Memorize All Data?

Model: "sequential"

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 16)	272
dropout (Dropout)	(None, 16)	0
dense_1 (Dense)	(None, 32)	544
dropout_1 (Dropout)	(None, 32)	0
dense_2 (Dense)	(None, 7)	231

Total params: 1,047 (4.09 KB)

Trainable params: 1,047 (4.09 KB)

Non-trainable params: 0 (0.00 B)

51,886 training data

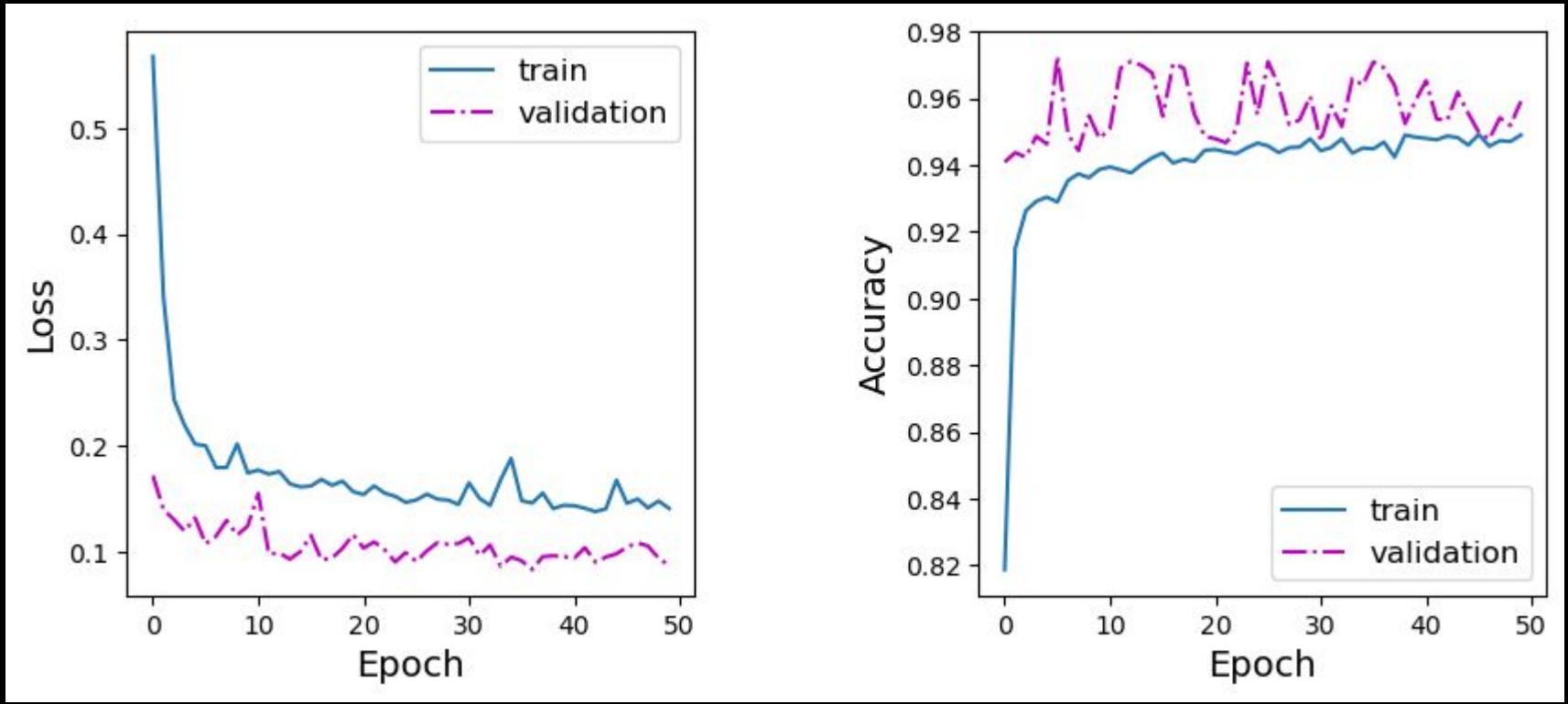
vs 14,824 validation data

7,413 test data

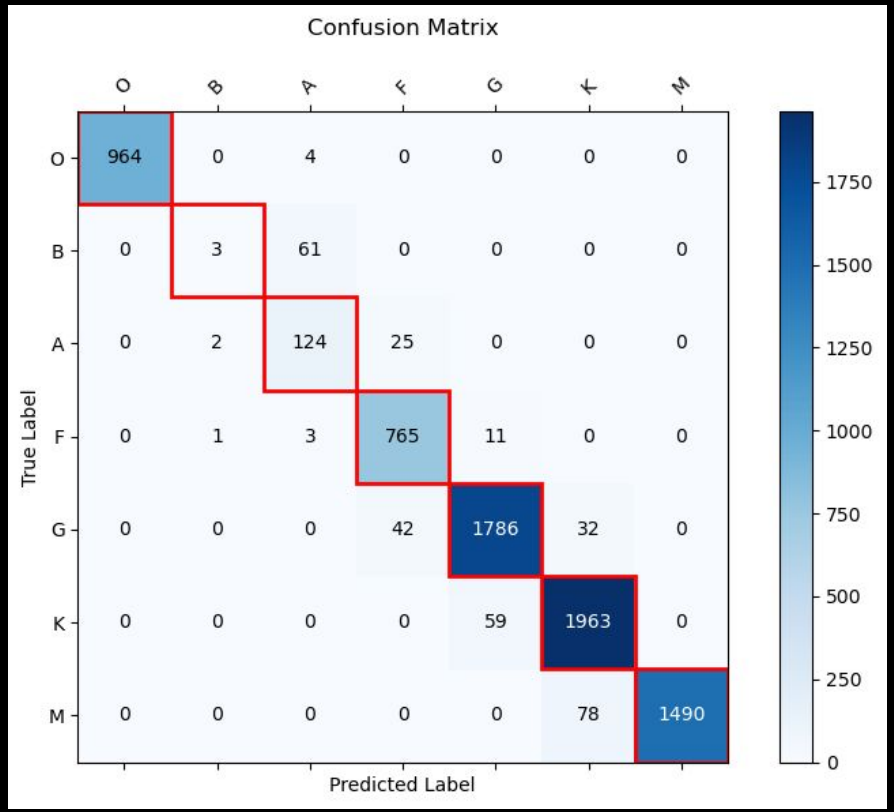
It worked!

$$L[\phi] = -\sum_{i=1}^{I} \log\left(\text{softmax}_{y_i}\left[f(\mathbf{x}_i, \phi)\right]\right)$$

$$L[\phi] = -\sum_{i=1}^{I} f_{y_i}[\mathbf{x}_i, \phi] - \log\left(\sum_{k=1}^{K} \exp[f_k[\mathbf{x}_i, \phi]]\right)$$



It worked!



20 Fold Cross-Validation on the Best Model

96.9 ± 0.9% Accuracy

95.4 ± 1.8% Precision

96.9 ± 0.9% Recall

95.9 ± 1.4% F1-score

What's next?

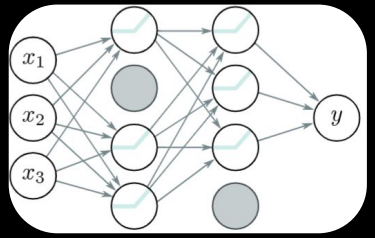
Try more models using keras tuner

Customize metrics: It is not good to classify O as M

Leave some features out and see what happens

Can Neural Nets Classify Stellar Types?

Stellar Parameters



Stellar Classes

Multiclass **Classification** (Cross-entropy loss); **supervised** machine learning

Neural Networks (So many knobs to tune 🎛️)

- Structure (Depth, width, activation function)
- Regularization (Dropout, early stopping, L2 weight decay)
- Gradient descent (Adam, mini-batch, learning rate, epochs)
- Loss function, softmax
- Performance (accuracy, recall, precision, overfitting)
- Cross-validation (70/30 Split)