8-Month Syllabus: Astronomy & Astrophysics with Machine Learning

This syllabus provides a clear and realistic plan to develop skills in astronomy, astrophysics, and machine learning
over 8 months. Each section lists specific, manageable topics for focused learning. The topics are designed to build proficiency
within the available timeframe.

1. Core Foundations

1.1 Python Programming

Topics to Cover:

- Functions: Advanced function arguments, lambda functions, and list comprehensions.
- Classes and OOP: Defining classes, inheritance, and encapsulation.
- Exception Handling: Writing robust code with try-except blocks.
- Modules and Packages: Importing modules, working with Python packages, and structuring projects.

Focus Time: 3 weeks.

1.2 NumPy and Scientific Computing

Topics to Cover:

- Arrays: Array creation, reshaping, and basic operations.
- Indexing and Slicing: Efficient ways to access array elements.
- Broadcasting: Utilize broadcasting rules to handle different-sized arrays.
- Linear Algebra: Matrix operations like dot products, inverses, and eigenvalues.

Focus Time: 2 weeks.

1.3 Astropy for Astronomy

Topics to Cover:

- FITS Files: Read and manipulate FITS files using Astropy.

- Coordinates: Working with celestial coordinate systems.

- Time Series: Handling and analyzing time data in astronomical datasets.

- Cosmology Utilities: Using Astropy for basic cosmological calculations (e.g., redshift, distance).

Focus Time: 3 weeks.

1.4 Probability and Statistics

Topics to Cover:

- Probability Distributions: Focus on normal, binomial, and Poisson distributions.

- Hypothesis Testing: P-values, confidence intervals, and significance.

- Bayesian Statistics: Basics of Bayes' theorem, prior, posterior, and likelihood.

- Markov Chain Monte Carlo (MCMC): Learn MCMC for parameter estimation in astronomy.

Focus Time: 3 weeks.

2. Machine Learning Fundamentals

2.1 Supervised Learning

Topics to Cover:

- Linear Regression: Simple and multiple linear regression.

- Classification: Decision Trees, Logistic Regression, and Support Vector Machines (SVM).

- Model Evaluation: Metrics like accuracy, precision, recall, F1 score, and cross-validation.

Focus Time: 4 weeks.

2.2 Unsupervised Learning

Topics to Cover:

- Clustering: K-Means and DBSCAN for astronomical data.

- Dimensionality Reduction: Principal Component Analysis (PCA) for reducing data dimensions.

- Anomaly Detection: Techniques for identifying outliers in large datasets.

Focus Time: 3 weeks.

2.3 Deep Learning

Topics to Cover:

- Neural Networks: Understand the architecture of basic neural networks and backpropagation.
- Convolutional Neural Networks (CNNs): Focus on CNNs for image classification (e.g., galaxy classification).
- Recurrent Neural Networks (RNNs): Basics of RNNs and their application in time-series data (e.g., light curves).

Focus Time: 4 weeks.

3. Astronomy & Astrophysics Focus

3.1 Data-Driven Astronomy

Topics to Cover:

- Large Datasets: Work with datasets like SDSS or Gaia for classification tasks.
- Time Series Analysis: Analyze light curves for transit detection and variable stars.
- Anomaly Detection: Identify rare or unexpected events in astronomical data.

Focus Time: 4 weeks.

3.2 Simulations and Modeling

Topics to Cover:

- N-body Simulations: Basics of N-body simulations for studying galaxy dynamics.
- Hydrodynamic Simulations: Introduction to hydrodynamics in astrophysical systems.
- Dark Matter: Understand how simulations model dark matter and structure formation.

Focus Time: 4 weeks.

3.3 Gravitational Wave Data Analysis

Topics to Cover:

- Signal Processing: Basics of signal processing for gravitational wave detection.
- Machine Learning: Apply machine learning to detect gravitational waves and classify signals.

Focus Time: 3 weeks.

4. Project-Based Learning

Recommended Projects:

- Galaxy Classification: Use deep learning to classify galaxies from image data.
- Exoplanet Detection: Apply time-series analysis to detect exoplanets from light curve data.
- Cosmological Parameter Estimation: Use machine learning to estimate cosmological parameters using Planck or WMAP data.
- Gravitational Wave Pipeline: Develop a machine learning pipeline for detecting gravitational wave signals.

Focus Time: 4 weeks (ongoing throughout the 8 months).