Seasons of Code Project: Data Driven Astronomy

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GitHub repo: https://github.com/aswinsuresh24/SoC-Data-Driven-Astronomy.git

Week 1:

- Completed Krittika tutorials 1 through 4, which included Introduction to Python, NumPy Basics, Functions in Python and Introduction to Matplotlib.

- Completed Assignment 1 given by project mentor. The assignment included 3 problems.
  - Problem 1: Drawing a probability distribution histogram when 2 dice are tossed using Matplotlib.
  - Problem 2: Highlighting possible challenges that may be faced when analysing datasets.
  - Problem 3: Sorting a given list of strings, in ascending order of their lengths.

Week 2 and 3:

- Completed all graded exercises, assignments and videos from the first 4 weeks of the course “Data-driven Astronomy”, which included:
  - Week 1: Pulsars and detecting pulsars using mean stacking.
  - Week 2: Supermassive blackholes and AGN detection using cross-matching of two catalogs containing optical and radio data.
  - Week 3: Exoplanets and verifying if they could potentially harbour life using SQL database querying.
  - Week 4:Creating databases and querying them using SQL and further using Python to perform calculations which are difficult to carry out using SQL.

- Working on ungraded exercises from the first 2 weeks, involving median stacking, cross-matching using k-d trees. Completed week 3 ungraded exercise involving SQL joins and subqueries. Completed week 4 ungraded exercise involving a mix of Python and SQL to perform calculations on exoplanet data from week 3.

Week 4:

- Completed all graded exercises, assignments and videos from week 5 and 6 of the course, which included:
  - Week 5: Calculating galaxy redshifts using decision trees and regression

- ➢ Week 6: Classifying galaxies as spiral, elliptical or merger using classifiers.
- ❖ Completed ungraded exercise from week 5, involving k-fold validation.

<u>Post completion of the course data driven astronomy:</u>

Week 1:

- ❖ Started the course “The Evolving Universe”. Completed all videos, quizzes and assignments from weeks 1 and 2 covering:
  - ➢ History of astronomy, evolution of models of the solar system, basic laws of the universe, time and distance scales and coordinate systems.
  - ➢ EM spectrum, Kirchoff’s laws, spectra, 21-cm Hydrogen line, Telescopes: Types (Optical, UV, IR, X-ray, gamma-ray), Diffraction and resolution limits, modern telescopes (adaptive optics and CCDs),synchrotron radiation, absolute and apparent magnitudes and flux.

Week 2:

- ❖ Completed all videos, quizzes and assignments from week 3 covering:
  - ➢ Interstellar medium (gas and dust) and their types, namely hot, warm and cold, formation of stars from protostellar clouds via core collapse and formation of planets from protoplanetary discs, absorption of light by ISM leading to extinction and reddening, Jeans mass, cherenkov radiation.
  - ➢ Solar system: Kinds of planets in our solar system, planetesimals (comets and asteroids), kuiper belt and oort cloud, brown dwarfs and atmospheric effects.

Week 3:

- ❖ Completed all videos, quizzes and assignments from week 4 covering:
  - ➢ Extrasolar planets and energy budget, identification and characterisation of exoplanets through techniques such as transits, gravitational lensing, radial velocity method and direct imaging.
  - ➢ Global warming, exoplanet atmospheres and life outside Earth (drake equation and fermi paradox).
  - ➢ Solar astrophysics: stellar structure equations, hydrostatic equilibrium and thermonuclear reactions in the sun. Energy generation (p-p cycle and cno cycle) and energy transport: radiation and convection.
  - ➢ Outer effects in the sun’s photosphere: solar flares and dark spots and the solar neutrino problem.

Week 4:

- ❖ Completed all videos, quizzes and assignments from week 5 covering:

- ➢ Stellar evolution: HR diagrams, color-magnitude diagrams and their correlation with the age of stars and thermonuclear reaction in the stars core.
- ➢ Stellar clusters (open and globular) and their properties such as lifetime and crossing rate. Analysis of HR diagram, main sequence, turnoff, horizontal branch etc.
- ➢ Star death: Endpoint of a star's life depending on its mass, degeneracy pressure, white dwarfs and the Chandrashekhar limit, Roche lobe overflow and accretion.
- ➢ Supernovae, their classification (type 1 and 2), spectra, and how they are formed, core collapse and nebulae.

Week 7 (post endsem):

- ❖ Completed all videos, quizzes and assignments from week 6 and 7 covering:
  - ➢ Neutron star formation, structure and discovery. Pulsars and timing of pulsars.
  - ➢ Black holes: Schwarzschild radius, singularity and event horizon. Indirect evidence of black holes and binary BHs. Hawking radiation, GRBs and their lightcurves and the collapsar model.
  - ➢ Supermassive black hole: Energy production through accretion
  - ➢ Galaxies and the milky way, stellar populations, components of a galaxy, rotation curves and differential rotation, presence of dark matter, density wave theory, galaxy bars and local groups.
  - ➢ Morphological classification of galaxies (elliptical and spiral, barred and unbarred, lenticular), dwarfs, formation of galaxy spheroids and discs, galaxy mergers and dynamic friction.
- ❖ Completed watching Lectures 1 to 3 from PH556 course on basics of astrophysics.
- ❖ Started reading the paper on use of machine learning in astronomy and learnt about types of ML, input data set classification (training, validation and testing), model parameters and hyperparameters, evaluation metrics: ROC, MAE, MSE and confusion matrix.

Week 8:

- ❖ Completed all videos, quizzes and assignments from week 8 covering:
  - ➢ Large scale structure, redshift surveys, local groups and superclusters, correlation functions, power spectrum, peculiar velocities, dark matter and galaxy clusters.
  - ➢ Quasars and AGN, X-ray emissions and luminosity, seyfert galaxies, unification models, synchrotron radiation, CMB.
- ❖ Completed watching Lectures 3 to 6 from PH556
- ❖ Continuing the paper: Learnt about supervised learning models and their use in regression and classification: Support Vector Machine, decision trees and random forests, probabilistic random forest ANNs. Started on unsupervised learning: uses and distance assignment (failure of euclidean metric in some cases).

Week 9 (Final Week):

- Completed all videos, quizzes and assignments from weeks 9 and 10 covering:
  - Cosmology: The cosmological principle, friedmann equation, cosmological models and distance scales, CMB and anisotropy, nucleosynthesis in the very early universe, and inflationary theory.
  - Present value of Hubble's constant, age of the universe, standard candles (supernovae of type 1a and cepheids).
  - Dark matter and dark energy, energy densities, using gravitational lensing to map dark matter distribution forms. Concordance theory.
- Completed watching lecture 7 of PH556.
- Completed the ML paper; learnt more about unsupervised ML algorithms which are mainly used in astronomy for clustering (k-means, hierarchical clustering, dendrograms), dimensionality reduction algorithms (principle component analysis, stochastic embedding, autoencoders, self organising maps) and anomaly detectors.