Prepared by group 10

Project Pitch

F20 DL

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Project Topic

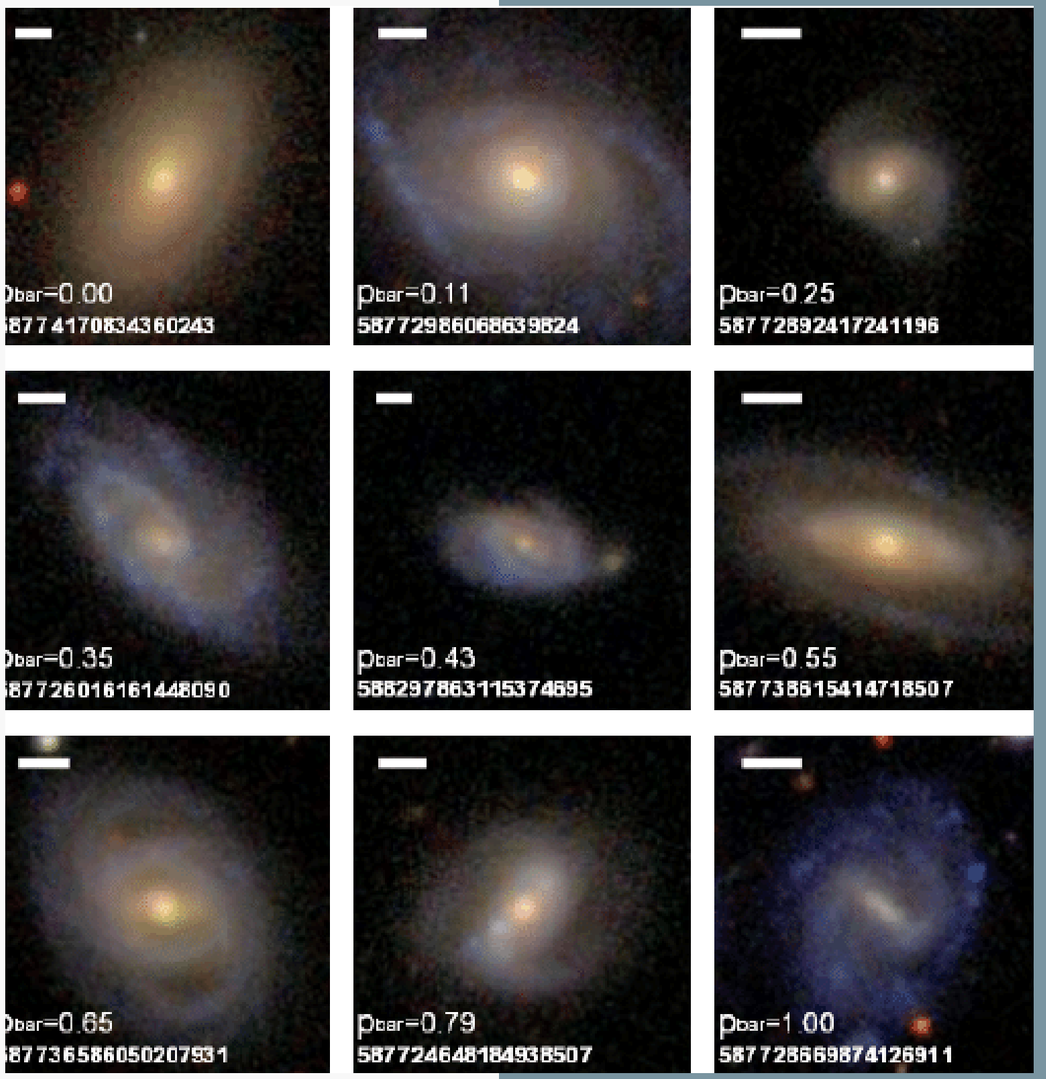
Galaxy Morphology Classification and Quenching State Prediction using ML models

Overview:

- Focus on two astrophysical problems:
  - Galaxy morphological classification (spiral vs elliptical, etc.)
  - Galaxy quenching prediction (whether a galaxy has stopped forming stars)
- Assess and compare predictive performance of:
  - Image-based models
  - Tabular-data models
  - Hybrid approaches (image + tabular)

Why We Picked This Topic:

- Scientific significance – key to understanding galaxy evolution.
- Rich datasets – SDSS & Galaxy Zoo are large, publicly available, and widely used in astronomy + ML research.
- Comparative learning – allows evaluation of image-driven vs tabular-driven ML.



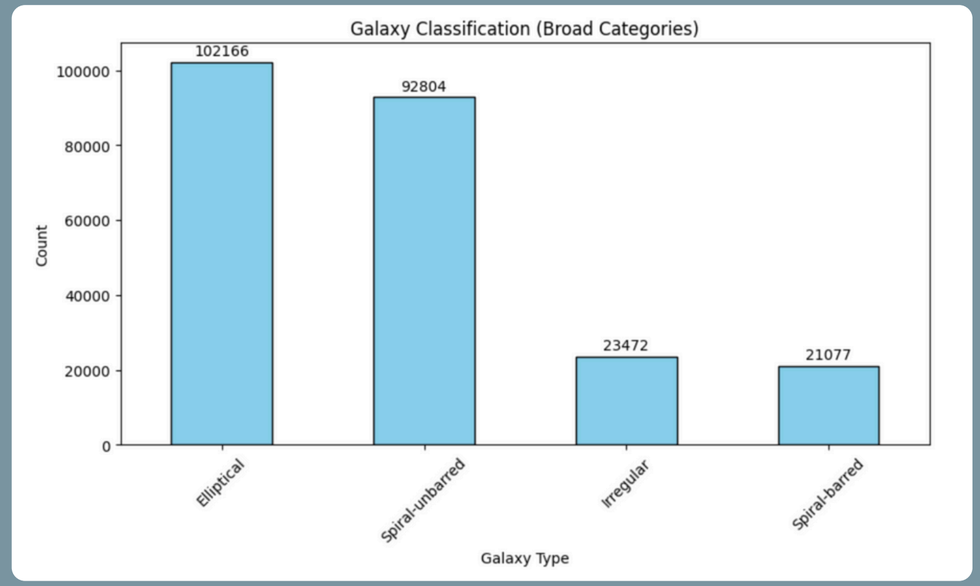
Data Description

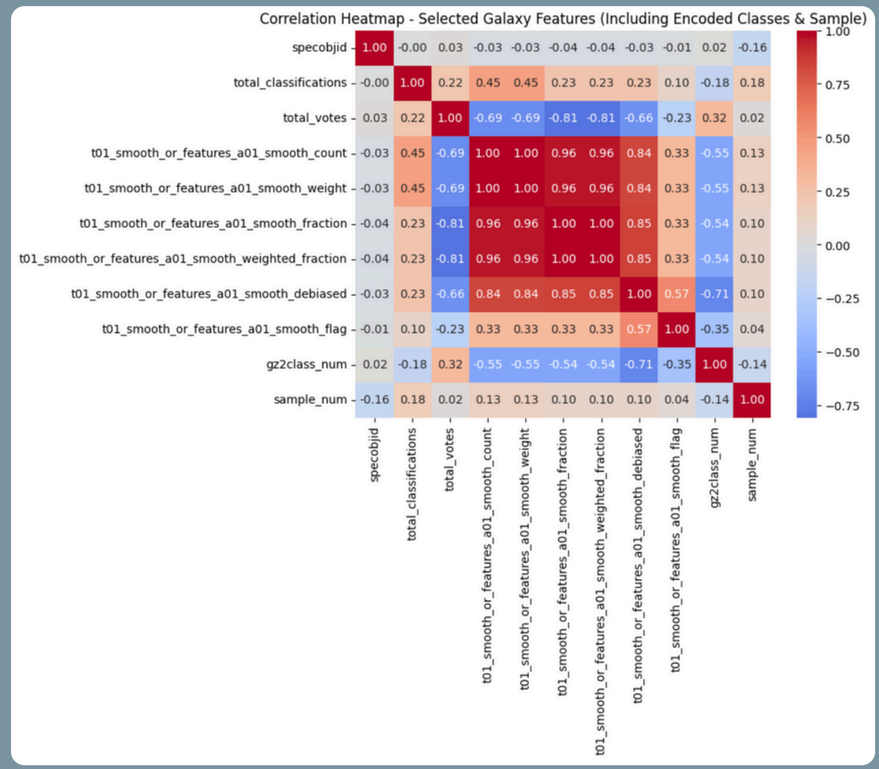
Galaxy Zoo 2 (Tabular, SDSS DR7/DR8):

- Dataset size: 243,500 galaxies.
- Feature scope: The dataset contains 233 features including IDs and coordinates (Nominal/Interval), total classifications and votes (Interval), per-task vote counts, weighted votes, fractions, weighted fractions, debiased fractions (Interval), and binary flags and gz2class, which is a shorthand string representing the most common consensus morphology for each galaxy (Nominal).
- 4 Morphological Classes created on gz2class: Elliptical, Spiral-unbarred, Spiral-barred, and Irregular
- 3 Quenching States Classes created on Morphological classes: Alive (star-forming), Dead (quenched), Intermediate (irregular star formation)
- Galaxy Zoo 2 Tabular Link: Galaxy Zoo Data Release
- Key Reference: Galaxy Zoo 2: Detailed morphological classifications for 304,122 galaxies (Willett et al., 2013, DOI:10.1093/mnras/stt1458)

Preprocessing:

Google Colab
co google.com





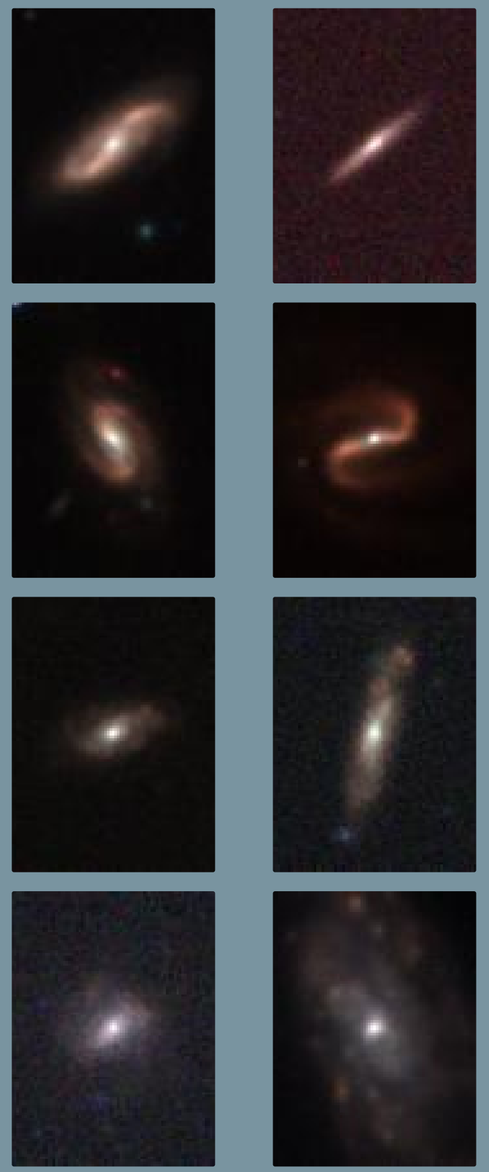
Data Description

SDSS Image Dataset (NERSC SSL release):

- Dataset size: 399,982 images
- Each galaxy in the dataset is provided as an image in the five standard SDSS photometric bands (ugriz). These bands represent different wavelength ranges of light captured from the galaxy:
    - u-band (354 nm) → ultraviolet light
    - g-band (477 nm) → green/blue visible light
    - r-band (623 nm) → red visible light
    - i-band (763 nm) → near-infrared
    - z-band (913 nm) → deep near-infrared

For every galaxy, the dataset gives us five aligned images (one per band), capturing how the galaxy looks across different parts of the spectrum.

- All the images are of the size 107x107 pixels.
- SDSS Images source link: NERSC SDSS Dataset



Preprocessing:

Data Source & Past Applications

Previous ML Applications:

- Hayat et al. (2020): Self-Supervised Representation Learning for Astronomical Images. DOI 10.3847/2041-8213/abf2c7
  - Aim: To show that Self Supervised Learning can pretrain useful galaxy features from raw pixels.
  - Dataset: SDSS Data Release 12
  - Difference: This study only uses image data, tabular data like GZ2 fractions are not compared.
- Dieleman et al. (2015):Rotation-invariant CNNs for galaxy morphology. DOI 10.1093/mnras/stv632
  - Aim: To achieve high accuracy supervised classification of morphology from GZ2 labels.
  - Dataset: Galaxy Zoo 2 images.
  - Difference: Our work will be integrating both image and tabular features, connecting morphology to quenching.
- Domínguez Sánchez et al. (2018): Improving galaxy morphologies for SDSS with Deep Learning. DOI 10.1093/mnras/sty338
  - Aims: Create a sizable, uniform morphology catalog for SDSS
  - Dataset: SDSS Data Release 7
  - Difference: This study only uses image data, tabular data like GZ2 fractions are not compared.
- Smethurst et al. (2017): Galaxy Zoo: the interplay of quenching mechanisms in the group environment. DOI 10.1093/mnras/stx973
  - Aim: To investigate how different quenching pathways correlate with morphology.
  - Dataset: GZ2 vote fractions (morphologies), SDSS/GALEX photometry.
  - Difference: Tabular data only approach, no imaging ML
- Géron et al. (2021): Galaxy Zoo: Stronger bars facilitate quenching in star forming galaxies. DOI 10.1093/mnras/stab2064
  - Aim: To prove that bars play a role in quenching star formation by funneling gas into central regions.
  - Dataset: DECaLS DR8 - https://www.legacysurvey.org/dr8/
  - Difference: Tabular only approach, No Hybrid Model Considered.

Our Contribution:

Unlike prior works that either:

1. use only image data (Dieleman, Hayat, Domínguez Sánchez), or
2. rely purely on tabular/statistical analyses (Smethurst, Géron),

our project directly compares image-only, tabular-only, and combined ML approaches to assess how different data modalities influence galaxy classification and quenching prediction.

Work Plan & Project Requirements

Gantt Chart

PROCESS	WEEKS											
	1	2	3	4	5	6	7	8	9	10	11	12
Datasets & Problem definition	■	■										
Data Preprocessing & EDA			■	■								
Training & Testing Baseline Models					■	■	■					
Training & Testing Neural Network							■	■	■	■		
Project Report & Code				■	■	■	■	■	■	■	■	
Project Presentation											■	■

Task Prioritization

TASK	PRIORITY
Selection of Datasets & Problem definition (R1) – *Mustansir, Vaishnavi, Adam, Janya, Ihsan*	Must
Data Preprocessing & Cleaning (R2) – *Vaishnavi, Adam, Mustansir*	Must
Exploratory Data Analysis (R2) – *Vaishnavi, Adam*	Must
Clustering Algorithm to find similarities (R2) – *N/A*	Wont
Application of at least 3 ML Algorithms (R3) – *Mustansir, Ihsan, Janya*	Must
Implementing Neural Network Models (R4) – *Vaishnavi, Mustansir*	Must
Performance Metrics and Analysis (R4) – *Adam, Janya, Ihsan*	Should
Model Fine-tuning and Optimization (R4) – *Adam, Janya, Ihsan*	Must
Reporting and Evaluation – *Mustansir, Vaishnavi, Adam, Janya, Ihsan*	Must

Thank you