Suggested Final Project Schemas

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1. Exploring Quasars Across Cosmic Time

Background / Motivation:

Due to their extreme luminosities, quasars can be observed from great distances and provide a tool for mapping structure in the early/distant universe. Unfortunately, quasars can be difficult to find in the first place, since in imaging surveys quasars are often hard to distinguish from stars; both quasars and stars appear as point sources and can have similar colors and magnitudes. In regions of color-space where quasar identification is particularly difficult, other indicators, such as optical variability and/or radio emission, can help us to pick them out from the much more numerous stars.

Spectroscopic follow-up is always required in order to definitively identify a quasar and determine its redshift. Quasar spectra are distinguished by their strong and broad emission lines (produced by the energetic accretion disk). At different redshifts, these emission lines fall in different photometric filter ranges, causing quasar colors to be redshift-dependent. This results in color selection of quasars becoming more difficult (and their targeting less efficient) at certain redshifts.

Suggested Project Objectives:

- Explore ways of identifying quasars in color imaging surveys
  - For different ranges in redshift, visualize the colors of known quasars in comparison to stars in the Milky Way.
    - Recommended magnitude range: $14 < r < 19$
    - Recommended color-color axes: (g-r) vs. (u-g)
- Explore the spectra of quasars, and how the appearance of quasar spectra change with increasing redshift, brightness, spectral slope, or radio emission
- Examine the redshift distribution of SDSS quasars, and explore whether the shape may be correlated with the color-dependent target selection.
- Explore where quasars with broad absorption lines, radio emission, or variable brightness are found in color-magnitude space
- Refine a method for selecting quasars from stars in imaging data
- Explore the properties of variable quasars using the eBOSS QSO variability value-added catalog (“qsoVarPTF”)

Resources:

SDSS spectral line table for galaxies and quasars:
http://classic.sdss.org/dr6/algorithms/linestable.html

The SDSS DR7 quasar catalog:
http://www.astroml.org/user_guide/datasets.html#sdss-dr7-quasar-catalog

Comparing the colors of stars and quasars:
http://www.astroml.org/examples/datasets/plot_sdss_galaxy_colors.html

The color-selection of quasars from the SDSS Legacy survey:
http://adsabs.harvard.edu/abs/2002AJ....123.2945R
http://www.sdss.org/dr12/algorithms/legacy_target_selection/#Quasars

Visualizing the SDSS imaging filter curves:
http://ogrisel.github.io/scikit-learn.org/sklearn-tutorial/auto_examples/tutorial/plot_sdss_filters.html

Extreme variability in quasars:
https://astrobites.org/2017/07/11/extreme-variability-quasars/

2. Galaxy Evolution: Looking beyond the SDSS

Background / Motivation:

In the course you have explored some of the fundamental properties and relations of galaxies in the local (i.e., low-redshift universe). You may be interested to explore more about how galaxies looked earlier in time. Thanks to major campaigns using space-based telescopes, large multi-wavelength photometric galaxy catalogs are now available. These datasets enable explorations of trends in galaxy properties and environments at much earlier times, which we can compare to trends in the local universe, as seen in the data from the Sloan Digital Sky Survey.

Suggested Project Objectives:

- Compare measurements made using the low-redshift NYU Value Added Catalog to measurements from higher redshift surveys:
  - Does the color-magnitude distribution of galaxies evolve with redshift?
  - Does the luminosity function of galaxies evolve with redshift?
  - Does the mass function of galaxies evolve with redshift?
  - How do galaxies evolve in terms of their rest-frame colors?

Suggested Resources:

Deep field data, published by the 3D-HST collaboration:
https://3dhst.research.yale.edu/Data.php

The color bimodality of galaxies at higher redshift:
https://arxiv.org/abs/0910.2227

Origins of the galaxy bimodality
http://www.physics.utah.edu/~vdbosch/SC09.pdf

https://astrobites.org/2013/04/12/the-mass-assembly-of-milky-way-like-galaxies/

3. Clustering and the environmental-dependence of galaxy properties

Background / Motivation:

Over the past 13.7 Billion years gravity has shaped the Universe into a vast cosmic web. One of the primary aims of the Sloan Digital Sky Survey was to map out the shape of the nearby cosmic web. The survey also set out to explore the ways in which different types of galaxies cluster on large scales, and whether galaxy properties may be related to their environments.

Suggested Project Objectives:

- Make a "pie-slice" diagram of galaxy clustering in the SDSS, and experiment with other ways of visualizing the large-scale structure of the Universe, using SDSS observations
- Explore various methods of measuring structure in the Universe (e.g., 2-pt correlation functions, nearest neighbor statistics)
- Quantify the clustering of galaxies in the SDSS
- Explore the relationship between galaxy clustering and morphology
- Investigate how a galaxy's environment relates to its other properties (e.g., color, shape, mass, star formation rate, metallicity)
- Investigate now the properties of the nearest neighbors of a galaxy depend on its other characteristics.

Suggested Resources:

An introduction to galaxy clusters, superclusters, and voids in the Universe:
http://skyserver.sdss.org/dr1/en/astro/structures/structures.asp
http://skyserver.sdss.org/dr1/en/astro/cosmology/cosmology.asp
https://astrobites.org/2016/10/04/tying-the-knot-with-galaxy-clustering/

Descriptions and tools for measuring large-scale clustering:
http://voyages.sdss.org/wp-content/uploads/2015/08/BAO_activity-2015.pdf
http://www.astroml.org/book_figures/chapter6/fig_correlation_function.html
http://www.astroml.org/user_guide/correlation_functions.html

Selecting a random subset of the SDSS data:
http://www.sdss.org/dr12/tutorials/random/

Catalogs of galaxies, according to their environment (isolated, paired, clustered):
http://www.aanda.org/articles/aa/full_html/2015/06/aa26016-15/aa26016-15.html

NASA-Sloan Atlas: a catalog of images and parameters of local galaxies, including sersic indices (a measure of the shape of the light profile, and a rough morphology measurement)
http://www.nsatlas.org/

4. Exploring moving, variable, and transient objects

Background / Motivation:

During the second phase of the SDSS, the project repeatedly surveyed a small stripe of sky known as Stripe 82. This yielded an unprecedented set of data in the time domain, which yielded insight into phenomena as wide-ranging as the orbits of asteroids, the variability of certain classes of stars, and the acceleration of the expansion of the universe.

Suggested Project Objectives:

- What are the typical colors, magnitudes, and velocities of asteroids at different orbital distances?
- What are the luminosity functions and number densities for asteroids at different parts of the solar system?
- Can you identify different families of asteroids using color measurements?

Suggested Resources:

"The size distributions of asteroid families in the SDSS moving object catalog 4" - Parker et al. 2008 http://adsabs.harvard.edu/abs/2008Icar..198..138P

SDSS Moving Object Catalog (including measurements of distance, velocity, magnitude, color, etc.,)
http://faculty.washington.edu/ivezic/sdssmoc/sdssmoc3.html

SDSS query to return moving asteroids:
http://skyserver.sdss.org/dr15/en/help/docs/realquery.aspx#movast

Additional ways to query and visualize moving object data from SDSS:
http://www.astroml.org/user_guide/datasets.html#stripe-82-time-domain

5. Active Galactic Nuclei

Background / Motivation:

Active galactic nuclei (AGN) have been suggested to play a major role in shutting down star formation in galaxies through the expulsion and heating of gas. AGN activity in galaxies is generally diagnosed by taking a spectrum and determining the galaxy's location on a BPT diagram, which uses the ratios of a combination of emission lines to separate star-forming and active galaxies. It has been suggested that AGN activity is enhanced in cases where galaxies are undergoing (or recently underwent) a major merger. AGN are also observed to vary stochastically in brightness on short timescales, as the gas accretion onto the central black hole varies with time.

Suggested Project Objectives:

- What are the common characteristics of galaxies with AGN activity? What are their masses, colors, morphologies, and environments?
- What are the characteristics of the nearest neighbors of galaxies with AGN?
- Where do AGN live in the color-magnitude diagram for galaxies?
- Do the types of galaxies hosting AGN change with time (i.e., redshift)?
- Time-variable information is available in a single strip of the sky repeatedly observed by the SDSS ("Stripe 82"). Using this data explore the characteristics of AGN light curves (plots of brightness versus time).

Suggested Resources:

Introduction to the AGN theory:
https://www.noao.edu/education/arbsefolder/files/monsters.pdg.pdf
https://astrobites.org/2012/12/23/active-galactic-nuclei-how-to-stop-star-formation/
https://astrobites.org/2014/02/20/do-major-mergers-trigger-luminous-agn/

BPT Diagrams:
http://www.astroml.org/examples/datasets/plot_sdss_line_ratios.html
https://astrobites.org/2011/10/05/finding-agn-at-higher-redshifts/