Observational Methods for Galaxy Surveys: from pixels to cosmology - Syllabus

Teaching staff: daniel.gruen@lmu.de and luca.tortorelli@lmu.de

Goals:

- You will learn how the data collected by photometric and spectroscopic galaxy surveys is connected to the galaxies present in the universe.
- You will gain an understanding of methods and challenges in modeling and accounting for the observational process.
- You will get an overview of existing and soon-to-exist galaxy survey data and observational facilities that are accessible to LMU researchers.
- You will gain a practical understanding and work with commonly used and self-written code for processing, modeling, interpreting galaxy survey data, including techniques for tracking and testing Python code.

Prerequisites:

- Knowledge of the Essentials of Astrophysics lecture is useful, but the course will be understandable on its own if you are willing to do some background reading
- Basic knowledge of Python and Shell commands is necessary, especially for the exercises.

Format:

- Lectures Monday 14:15-15:45 at USM lecture hall.
- Associated tutorial with a mix of discussion of weekly exercises and tutorials on development/use of codes; likely time 16-17:30 on Mondays, USM lecture hall (but could be changed according to peoples' preferences, or split in multiple groups if there is availability).
- Please bring your laptop (and power supply, if needed) to all sessions.
- Please ensure you can log-on to gitlab.physik.uni-muenchen.de (for accessing / managing code) and workshop.physik.uni-muenchen.de (for accessing data and running code) and contact the teaching staff in case of any problems.

Exam:

- The exam will be a *Hausarbeit* in the form of a proposal (either an observing proposal for applying for time with a telescope of your choice, or a project proposal for a measurement to be made with data from a large galaxy survey of your choice), with topics and abstracts due July 4 and papers due August 15. You are welcome to inquire for advice from your peers or other scientists at USM or elsewhere (listing them as sources / Co-Investigators in an appendix) but all writing and actual research work has to be done by yourself. The grade will be based on the displayed command of concepts covered in the lecture, including the appropriate choice of instrument, exposure time, and observing conditions to reach the intended science goal (40%), the detailed demonstration of feasibility, e.g. exposure time calculation, mock analysis to show the proposed measurement could work (40%), and the scientific merit of the proposed measurement, i.e. the potential of gaining new insights from them (20%). The teaching staff will support authors of outstanding proposals in realizing them for their M.Sc. project.

Approximate lecture plan:

- April 25: Describing the sky
    - topics covered: electromagnetic radiation, coordinate systems, description of galaxy population
- May 2: From the universe to the focal plane
    - topics covered: gravitational lensing, redshift, reddening, point-spread function, telescopes including optics and filters, astrometry, noise
- May 9: Delving too deep
    - topics covered: simulating the transfer function (guest lecturer Dr. Spencer Everett, JPL); relating the measurement to the truth
- May 16: To see the world in a grain of sand
    - topics covered: function of CCDs and interpretation of their data including flat / bias / dark calibration observations, non-linearities
- May 23: Calibration and data reduction in spectroscopic surveys
    - guest lecturer Dr. Michael Walther
- May 30: With great statistical power comes great systematic responsibility
    - topics covered: galaxy shape and photometric redshift measurement and cosmological insights from galaxy data
- June 6: no lecture (Pentecost)
- June 13: Open questions in galaxy survey science
    - topics covered: state of galaxy evolution and cosmology research
- June 20: Overview of observational facilities
    - topics covered: instruments and process of getting observing time at ESO telescopes, NOAO telescopes, Keck, Magellan, Wendelstein, future
- June 27: Writing astronomical proposals
    - topics covered: structure of observing proposals, structure of survey project proposals, criteria for success
- July 4: Present and future photometric surveys
    - topics covered: SDSS, DES, KiDS-VIKING, LSST, Euclid
- July 11: Present and future spectroscopic surveys
    - topics covered: SDSS, DESI, deep spectroscopic surveys
    - proposals and abstracts for your observing proposal are due
- July 18: Not (optical photons)
    - topics covered: high-energy astrophysics, radio astronomy, neutrino astronomy, gravitational waves
- July 25: Review and outlook
    - topics covered: review of the path from a galaxy to pixel data, artificial intelligence as a tool for galaxy surveys