

ASTRONOMY 511: LABORATORY III
OBSERVATIONS WITH THE FAN MOUNTAIN FIBER SPECTROGRAPH

In this lab you will inaugurate student observations with the new Fan Mountain Observatory Bench Spectrograph (FMOBS). You will obtain spectra of three different targets:

- P Cygni: massive, luminous blue variable star, like the Hubble-Sandage variables in M31; related to η Car and S Dor; instabilities have caused a mass outflow, which produces characteristic “P-Cygni” absorption/emission line profiles.
- ρ Cas: a hypergiant G-type variable star; possible pre-supernova; eruption expected soon, comparable to one in 2000.
- Nucleus of NGC 1068: the archetypal Seyfert 2 galaxy, with very strong, broadened nuclear emission lines; an adjacent starburst region.

I. DATA TAKING

Each lab group should take its own data and submit its own lab writeup.

A) Divide each group into subunits responsible for: telescope handling, spectrograph handling, CCD operation. You will have assistance from Peter Frinchaboy and Jeff Crane for using the telescope and instrument.

B) Familiarize yourselves with the 40-in telescope manual and the spectrograph manual. Carefully study the instructions for the part of the operation for which you will be responsible. Also, reread “Hints on Observing.”

C) Get coordinates and other relevant information from standard database sources. Recommended: for the stars, try the AAVSO (<http://www.aavso.org>); for N1068, try NED (<http://nedwww.ipac.caltech.edu/>).

Although these are bright targets, you should make finding charts for all three. The coarse acquisition field of FMOBS is $6' \times 4.4'$, so your charts should be about 15-20' across. Mark orientation and angular scale on the charts.

D) You can take data on nights with moonlight, but it may be hard to locate the galaxy under bright moonlight conditions.

E) Use the standard “primary setup” for the spectrograph as described in the manual. This covers the spectral range 4700–6700 Å with a resolution $\mathfrak{R} \sim 1200$. Among other important spectral features, it includes both $H\alpha$ and $H\beta$.

F) Before attempting observations, let the CCD stabilize at its operating temperature; this will take at least 30 minutes. Check stability by taking “bias”/dark exposures (very short exposures with the shutter closed). You can check spectrograph focus using the internal comparison lamp while waiting.

G) When the CCD is ready, you should take the full set of recommended calibration data (except for the radial velocity and flux standards, not needed here). You should take a bias/dark stack of frames both before and after observing to check for drifts. Take 3 comparison lamp exposures: before, during, and after your target observations.

H) Check your calibration data to see that you have the right number of counts (a few thousand for the “milky flats”; unsaturated data for the quartz and comparison labs).

I) The stars should present no acquisition problems, so observe them first. But before attempting them, be sure the Focal Plane Module and acquisition camera are focussed. Determine the orientation of the acquisition field. Take one or more well-exposed spectra of each star showing the spectral features across the whole accessible range with a good SNR.

J) Finding NGC 1068 should be relatively straightforward, after some practice with the acquisition camera, but placing its nucleus on the input fiber may be tricky. Plan for iterations here. There will be line emission throughout the central part of the galaxy, but the nuclear lines are markedly stronger. Take one or more well-exposed nuclear spectra.

II. DATA REDUCTION AND ANALYSIS

Your writeup should be typeset using TeX or LaTeX in two parts. In part I, write a 1–2 page description of your observing session and procedures. Comment on the general quality of your data. List the data frames you reduced. Store your data in an easily-accessible area on the department disks, and tell me where that is. In part II, describe the analysis of the reduced data; see below for specific items which should be included.

A) Peter Frichaboy will provide a standard IRAF script for FMOBS data reduction. Introductory manuals for IRAF are linked to the ASTR 511 Lab page.

B) Comment on the stability of the system (CCD and spectrograph) based on processing the relevant calibration data.

C) Extract the calibrated spectra and produce a table of wavelength and flux. (The flux will not be on an absolute scale.) Our main goal here is simply to identify the stronger spectral features and obtain wavelengths and FWHM's for them.

D) Identify the stronger emission and absorption line features in each object. (There are a number of spectral atlases in the Library or on the Web which will help.) Produce a plot for each with the features labeled.

E) P Cygni: In the literature, review how a P-Cygni reversed line profile is produced. Which lines show the profile here? Measure the velocity difference between the center of the emission and absorption components. If the outburst producing the profile started in 1900, how far has the edge of the wind traveled?

F) ρ Cas: Identify the stronger lines. Search for any emission components. If you can, compare to other recent spectra in the literature and comment on changes.

G) NGC 1068: Measure the centroids and widths of the $H\beta$, [O III], $H\alpha$, and [N II] features. Convert to redshift and velocity FWHM. How distant is this galaxy if the Hubble Constant is $H_0 = 75 \text{ kms}^{-1}\text{Mpc}^{-1}$ and its motion is not affected by any local departures from the Hubble flow? At this distance, what diameter (in parsecs) did the measuring fiber cover?