

## ASTR 511: PROCEDURES FOR LABORATORY IV

### I. BACKGROUND

**Group Work and Writeups:** The class will work in groups on this project but with specific tasks broken out and assigned to individuals. The group should decide on an equitable division of the workload in advance and should specify in the writeup who was responsible for what.

Your individual grade will be based on the overall writeup, on the individual effort you have contributed to the group project, *and on your individual answer to the question on the last page of these instructions*. The group writeup will be worth a maximum of 150 points. The individual response will be worth a maximum of 40 points.

**Planning and Making Observations:** Each group has already submitted a scientific proposal for an observing project. Each should consult among themselves and with Peter Frinchaboy and David McDavid on exposure time estimates, necessary calibration data, and drawing up an efficient observing plan. If possible, design the program to be finished in a single night of observing. Decide to what extent it will be desirable to share calibration data (e.g. twilight flat-field frames) among groups.

Weather is now the most valuable resource. You should be prepared to take advantage of suitable weather on **any night** from now on. It may be necessary, owing to personal schedules, to observe without your full group present. Strictly photometric conditions may not be necessary: e.g. extra extinction affects only the zero points and not the relative flux ratios between bands in a CMD. Part of designing your program is deciding whether you need photometric weather. Make observations of flux calibration fields even if the night is not strictly photometric. Use your judgement as to the applicability of the flux zero-points obtained.

Follow systematic procedures when making observations. Be sure to obtain appropriate calibration frames and to thoroughly document what you have done (on paper or with electrons).

#### Pipeline Reduction: General

First, review the general outline for CCD reductions described in the on the web page *CCD's in Astronomy*.

Basic data reduction should be done using IRAF. You can find the *Beginner's Guide to Using IRAF* and the *User's Guide to CCD Reductions with IRAF* linked to the *Laboratory* page on the 511 web site. Peter can provide expert advice as needed. Other documentation on IRAF is at:

<http://iraf.noao.edu/docs/docmain.html>.

### II. PIPELINE REDUCTION PROCEDURE

This section describes the standard reduction procedure for CCD frames. It would apply to the two star cluster programs being done this semester. The planetary transit program may require special treatment (e.g. a subset of the following steps followed by a different analysis phase).

1) **Data Management:** Decide on a storage location and arrange for sufficient disk space. Transfer the FITS data files to the storage area. Be sure you have an index which shows the correspondence between the data file names and their contents. (Easiest if this is digital and kept in the same directory.) IRAF will now read FITS files directly, so do not convert to the old IRAF header/data format.

If necessary, fill important identifying and observational information into the image headers using the header editor function in IRAF. Organize subdirectories as appropriate.

To keep track of data processing, it is important to make notes of what you have done in a README.log file. Unfortunately, IRAF does not have a “journal”-like facility comparable to IDL’s.

2) **Inspection:** It may be easier to use IDL/ATV for this step, since all students are now familiar with it. Inspect each bias and flatfield frame for quality. Display & adjust images; sample pixel values/histograms; plot slices, etc. Reject frames with serious problems (e.g. resolved objects on flatfields). You may have to *iterate* after the next few steps. Inspect the data frames. Consider seeing FWHM and typical source-to-sky levels. Decide whether more data are needed.

It would be useful to create a log containing the object ID and at-telescope comments for each frame and a data evaluation comment.

Choose the best frames for complete reduction. Include good versions of all the necessary calibrator frames (bias, flat field, standard stars).

3) **Bias Frames:** Create mean bias frame (“zero” in IRAF lingo) by median-filtering the set of good biases. Inspect the result. Check for bias drifts by comparing the bias frames taken during the observational runs with the mean frame. Create and store sample difference frames. Bias variations during the night can be tracked by using the “overscan” region on the CCD, though this does not help with variations in 2-dimensional bias structure. It is good practice to take single bias frames before and after each target to track variations.

If significant drifts exist, then you will need to create a separate adjusted bias frame for each target by scaling the mean bias frame to the bias level at the time of the observation.

4) **Flat Fields:** Create a mean flatfield frame for each filter by median-filtering all the appropriate twilight flats.

Inspect the resulting mean flats. Estimate the expected photon-statistical uncertainty in the mean flat and compare to the actual pixel-to-pixel scatter. Evaluate large scale nonuniformities—how bad are they? Are they stable for all frames? How much wavelength dependence? Make hard-copies of plots and/or images as appropriate. Color displays and printouts can be useful.

5) **Pipeline Process the Image Frames:**

- Trim away unneeded parts of the image frames.
- Subtract the mean bias frame.
- Divide by the appropriate flat field for the filter used.

The standard IRAF procedure for these steps is “CCDPROC.” You should read through its description before using it. In our case, you will want to set “overscan=yes, trim=yes, zerocor=yes, and zero=[name of (adjusted) bias frame]”.

For most subsequent steps, IDL is preferred.

6) **Image Internal Documentation:** Use the AstUseLib SXADDPAR and SXADDHIST procedures to document all subsequent processing steps in the header records.

7) **Determine the Flux Zero Points.** Reduce the flux calibrator frames. If the frames for a given filter superpose well, you can simply average them together. If not, you could try registering them or, instead, simply analyze them separately and average the results. Measure star brightnesses using DAOPHOT (overkill here) or simple photometry with square apertures and sky subtraction using several sky samples

near each star. If you observed a cluster field, you should measure at least 8 stars with a range in brightness and color. Correct for extinction using a standard extinction curve scaled to Fan's altitude. Determine the conversions between total counts per second in the star image and flux for each filter. Check for consistency between stars and nights (if possible).

Do *not* convert the other image frames to flux units at this point. Flux conversions are best done by simple scaling *after* measurements are taken off the image frames.

8) **Inspect** the results for the target frames. Determine FWHM's of stars to measure seeing; determine the maximum and minimum signals of the combined frames. (Note bad pixels or saturated regions). Make hardcopies, as appropriate.

Select the frames you think are "keepers" for further reduction, but do not discard the other frames. Make written notes on the quality of all frames. Include the notes in your writeups. Add comments to the frame headers as appropriate.

9) **Register** the various keeper frames taken through a given filter on a given object. IRAF has a convenient program for doing this. Sum up all frames for a given filter, and update the header to indicate what the total integration time is.

10) **Measure the Sky Level** on the combined frame in each filter by using the IDL AstUseLib SKY routine or by using boxes with 30-50 pixel sides placed in clear areas around the frames. Using your standard star observations and the known projected size of one pixel on the sky, convert the result to mags per square arcsec in each filter. You could compare these results to those from the SKY routine, which uses a different algorithm. Note the zenith distances and Charlottesville avoidance angle. Report the results in your writeup.

11) **Data Backup:** When the analysis is complete, arrange with Peter to make a backup "tar" tape of **all** your data from the project: raw, processed, supporting data files, ASCII files, and so forth. Give that to me with the writeup.

You are now ready to proceed to a project-specific set of measurements and scientific analysis.

### III. GROUP ANALYSIS AND WRITEUP

The details of your analysis and writeup will obviously depend on the nature of the project you proposed. Writeups should be in the range of 5–10 text pages plus figures and tables as appropriate. At a minimum, you should include the following sections.

1) **Scientific Goal.** Briefly describe the scientific motivation for your project and the intended goal. Include literature citations as appropriate.

2) **Observational Procedures.** Describe what you did.

3) **Observing Conditions.** Evaluate the seeing, sky brightness, transparency, bias drift and other aspects of the observing runs that affected the data quality. Express the sky brightnesses in mags per square arcsec; note zenith distances and the Charlottesville avoidance angle. Comment on any anomalies found in the data. Comment on performance of the instrumentation and software.

4) **Observational Results.** Present the main observational results you obtained. Include image hardcopies, plotted figures and tables as appropriate. Include estimates of observational error in important measured quantities.

5) **Discussion and Conclusion.** Relate the observational results to the scientific goals. Discuss the implications of your data. Make thoughtful comments on what you have learned to do or not to do. Summarize the project.

#### **IV. INDIVIDUAL PROBLEM: EXTENSION OF THE PROJECT**

Each student, in **one** TeX'd page, should describe an extension or elaboration of this same project to any of the larger telescopes to which UVa will have access over the next several years through its association with Steward Observatory. See the Steward web-site (linked from the 511 web links page) for information on their observing equipment. You can propose for any telescope (LBT, MMT, Magellan, 90-in, Vatican Telescope, etc). The project should, however, be appropriate to the telescope selected in both feasibility and scientific importance.

You should explain why the project is of importance to astronomy and what observations will be required. You do not need to justify feasibility in detail as you would for a real observing request. But you should have done rough order of magnitude calculations which demonstrate that it could be successfully done given the time and equipment you request.

You can specify that new hardware (e.g. filters, a focal reducer) be purchased as part of the project, so long as the likely cost does not exceed \$5000 (making a realistic cost estimate is part of the problem).

**BOTH THE GROUP AND INDIVIDUAL WRITEUPS ARE DUE  
MONDAY, DECEMBER 15**