Obtaining and reducing astronomical images

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1 Planning your observations

You must obviously ensure your targets are observable from Nottingham at the date and time you are observing. For convenience, choose objects that are high in the sky (close to the Zenith).

The computer in the telescope dome has Stellarium and Earth Centred Universe (ECU) sky map software installed, which are useful for finding objects during observing, as well as checking observability beforehand. Stellarium is freely available[1] for use on your own Windows, OS X and Linux computer. Various other 'planetarium' software tools are also available online.

The UoN Physics telescope is at (lat, long) = (+52.94166, -1.19201) = (52°56′30″ North, 1°11′31″ West) = (52°56′30″ North, 0h4m46s West), at an altitude of ∼35 m. The nearest Minor Planet Centre observatory code is J06 (Trent Astronomical Observatory, Clifton).

The field of view is roughly half a degree across, corresponding to about half the full moon. (More precisely, 3032x2016 pixels, with a pixel scale of 0.54 arcsec/pixel, so 27x18 arcmin).

Due to normal limitations of the mount, the telescope pointing 'wobbles' back and forth on a timescale of six minutes. Without guiding (active optics) or at least a Periodic Error Correction (PEC), the longest useable exposure time is 30–60 seconds.

2 Observing

You must have already completed the standard telescope training before using the telescope. All guidance and safety requirements in the provided instructions must be adhered to. In particular, you must always observe in a group of at least two.

The "Telescope User Instructions" describes procedures for obtaining bias and flatfield exposures. These are essential for scientific measurements or producing high quality images. If you wish to obtain twilight flats you will need to start taking these shortly after sunset, but you should wait until the sky is reasonably dark before attempting science exposures. You can take some dark images while you are waiting. It is useful to obtain dark and flat exposures each night you observe, otherwise you may not be able to adequately process your data.

Check weather forecasts for advance notice of clear skies. The Met Office has a cloud forecast[2], and there are online sources of satellite images that are useful in assessing local observing conditions and potential for clear skies[3].

It is essential that you keep an accurate observing log, identifying each image number with the target name, exposure time, sky conditions and any other useful information.

3 Data reduction

Before the data can be analysed, the images must be processed to remove instrumental artefacts, combine multiple exposures, and finally make any measurements, or produce a colour image.

There are a variety of packages available to perform the different aspects of this processing. The custom observing software on the dome PC now performs automatic reduction of the images. However, project students it is important that you understand the steps involved and are able to perform a manual data reduction. For this you are recommended to use AstroImageJ.[4] This is a powerful tool with a graphical interface and many convenient features. AstroImageJ is freely

[1] http://www.stellarium.org

[2] https://www.metoffice.gov.uk/public/weather/uk-cloud-cover-forecast/

[3] https://en.sat24.com/

[4] http://www.astro.louisville.edu/software/astroimage/

available for Windows, OS X and Linux, so you can download it for use on your own computer or any University PC. After installing, you should ensure you click *Help* → *UpdateAstroImageJ...* to get the latest version.

3.1 Organisation

It is very important that you keep your data organised and your work documented. You should copy each night's worth of observations into a separate folder, within which you should arrange the images into folders for each type of image (e.g., 'bias', 'flat', 'science, 'other'), by referring to your night log. It is important that you only use good quality calibration images. You should inspect the raw images to check they look as you expect, identify any mistakes or problems, and reject unsuitable images. For bright objects, it is possible to skip many of these steps and proceed directly to obtaining an astrometric solution. However, for faint sources or photometry these steps are essential, and they do not take long once learned.

3.2 Standard steps

The standard reduction steps include bias subtraction, flatfielding, filter demosaicing, image alignment, coaddition, astrometry and photometry.

Once your images are organised, these data reduction steps can be achieved in a fairly straightforward way with AstroImageJ. However, in order to have confidence in your results, it is important that you gain a thorough understanding of the process. You should examine the intermediate and final images produced by AstroImageJ and compare them, qualitatively and quantitatively, with your expectations.

You will be given an introduction to the standard reduction steps and usage of AstroImageJ. You may also like to consult the AstroImageJ manual. Briefly, the key steps are:

- Use the CCD Data Processor (DP button) to perform the bias and flatfield corrections and update the image headers to include the target name and position.
- Load all the calibrated science images for one target in to a 'stack' using *File* → *Import* → *Image Sequence*.
- Demosaic the images to produce separate R, G and B stacks, using *Plugins* → *Debayer Stack*. This requires a custom plugin to be installed, which can be downloaded from the observatory webpage. Note that you may need to establish the appropriate arrangement of the filters.
- Align each stack with *Process* → *Align stack using WCS or apertures* (or click the button), left click several stars, then right click to perform the alignment.
- Combine the images in each stack with *Image* → *Stacks* → *Z Project...*, using the Median projection type.
- Save the images: *File* → *Save image/slice as FITS*.
- Obtain an astrometric calibration for the images. Close and re-open the combined images. Go to *WCS* → *Plate solve using Astrometry.net (with options)* or click the button. This will find bright stars in the images and use an online tool to determine the exact coordinates of the image. Save the image to retain this information: *File* → *Save image*.

Any software which can read fits files and composite them can be used to produce a colour image. DS9 has this facility, although more sophisticated solutions exist.

If required, AstroImageJ can be used to measure the position and brightness of targets in your images. For measurements of large numbers of objects per image, more automated software is available, such as Source Extractor[5], SEP[6] and photutils[7]. To determine uncertainties on measurements you will require the CCD gain, which is 0.4 electrons per ADU.

[5] https://www.astromatic.net/software/sextractor
[6] http://sep.readthedocs.io/
[7] https://photutils.readthedocs.io/