Observing and data reduction with DFOSC/Danish 1.54

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Includes some material from Petr Pravec, Seppo Mattila, and Thomas Dahlen
Outline

- Danish telescope
- Instruments at the Danish telescope
- Brief introduction to the control system
- Basics of reducing imaging data
Installation of Danish 1.54m

- Building finished 1975
- Installation of telescope 1976
Installation of Danish 1.54m

- Building finished 1975
- Installation of telescope 1976
Installation of Danish 1.54m

- Building finished 1975
- Installation of telescope 1976
- Astigmatism of almost 10”!
- Repolish at Grubb Parsons
Take two

- First light Nov 20, 1978
- Main mirror 1.54 meters
- Optical system classical Ritchey-Chrétien
- Focal length ~13 meters
- Equatorial mount
- Build by Grubb Parsons (England)
The Danish 1.54 telescope now

- A dedicated photometric telescope.
- Owner: University of Copenhagen
- Operated jointly by Niels Bohr Institute and research groups in Czech Republic
The Danish 1.54 telescope now

- In 2012 the telescope was refurbished and a new control system was installed.
- The author of the new control system is ProjectSoft from Czech Republic.
- The telescope upgrade was funded by the Academy of Sciences of the Czech Republic.
- As the payment Czech astronomers use the telescope half of the year.
Danish 1.54 instruments: DFOSC

- Danish Faint Object Spectrograph and Camera (DFOSC)
- Focal reducer type camera
- DFOSC consists of a collimator and a camera
- Originally, filter wheel and a grism wheel in between them
- Between the telescope and DFOSC there is a Filter And Shutter Unit (FASU)
- FASU has two filter wheels
- An aperture wheel is situated at the telescope focus. Used to include slits for spectroscopy, but is not in use anymore

Since 2004 scaled down to exclude the spectroscopic capability
DFOSC layout

Danish – Faint Object Spectograph & Camera
DFOSC imaging

2k x 2k thinned Loral CCD:
• Field-of-view: 13.7' x 13.7'
• Plate scale 0.39" / pixel
• Gain: 0.25 e^-/ADU
• Dynamical range 19.4 bit
• Linear to ~600,000 ADU
• Readout noise 4.5 e^- 
• Full CCD readout time: 22 seconds
Danish 1.54 / DFOSC parameters and capabilities

Limiting magnitude (3-min integration):
\[ V_{\text{lim}} = 18.5 \text{ at SNR } = 100 \]
\[ V_{\text{lim}} = 20.0 \text{ at SNR } = 30 \]

Typical seeing: <1” (median 0.8-0.9”).

Fraction of usable nights (during Chilean summer season):
• Only 4% of nights have been totally lost due to bad weather.
• The net time loss has been 10% for weather and 4% for technical and other reasons.

Danish 1.54 first light image from 1978
DFOSC science example

Southworth et al. 2016
Danish 1.54 instruments: TCI

- Two colour imager (TCI): red and visual
- Electron multiplying CCDs (EMCCD)
- Uses Andor iXon +897 cameras
- 512 x 512 pixels
- Field of view 45" x 45"
- High frame-rate: 10Hz
Science with TCI

Braga-Ribas et al. 2014

- Asteroid occultations: Chariklo
- The stellar occultation was observed from eight sites in South America
- Observed dips before and after the stellar event: rings!
- Only the data from TCI at Danish 1.54 show that the ring occultation is resolved into two sub-events, lasting only 0.1 and 0.3 seconds, with a 0.2 second gap.
- The best interpretation of the observations is that Chariklo has two rings: 7km and 3km wide
The Danish 1.54 telescope control

- The telescope and instruments are controlled from a control room, just below the telescope itself
- The telescope can also be fully controlled remotely
Telescope Control System (TCS)

- Highly automated
- Safety systems which take care of the telescope and dome in case of:
  - Bad weather
  - Someone going into the dome during observations
  - Loss of remote connection
- The core is based on industrial components and solutions
Weather station

**METEO DATA**

- **BRIGHTNESS EAST**: 0.0kLux
- **BRIGHTNESS NORTH**: 0.0kLux
- **BRIGHTNESS WEST**: 0.0kLux
- **TWILIGHT**: 0Lux
- **HUMIDITY**: 44%
- **TEMPERATURE**: 14.0°C
- **WIND SPEED**: 3.3m/s
- **PRECIPITATION**: NO
- **ATMOSPHERIC PRESS.**: 768.40mbar
- **PYRGEOMETER**: -99.22W/m²
DFOSC control system

![Software interface for DFOSC control system](image_url)
Data reduction

I love data reduction
The image read from the CCD camera is a ‘raw’ image, i.e. the pixel values do not represent the true light distribution in the sky.
Reducing raw images

A number of different frames are needed in order to get well calibrated images on which the photometry of your science objects can be measured:

• 1: Bias frames
• 2: Flat fields
• 3: Standard stars
• 4: Bad pixel masks
• 5: Super flats
• 6: Dark frames
• 7: Fringe frames
BIAS frame

The bias is an offset of a few hundred counts added to the CCD before start of the exposure

- Reason: to avoid negative counts
- Must be subtracted from all images

How to create a bias frame:

- Take ~11 frames with 0 second exposure time at beginning of the night
- And/or ~11 after the nights observations

Use IRAF task zerocombine to combine the frames to an averaged bias frame.

Use IRAF task ccdproc to correct all other images for the bias
Flat fields

The response/sensitivity of the detector is not uniform:

- varies from pixel to pixel
- wavelength dependent (therefore depends on the filter)

To overcome this, one observes a source with uniform illumination to create a flat field image. This can thereafter be used to correct the images for the variations.
Obtaining flat field for imaging

- Observe the twilight sky at dusk and/or dawn.
- Suitable blank fields to observe are listed at the telescope.
- Make sure you get significant counts, ~60% of saturation
- Get as many images as possible, with at least 4 images in each filters you will use during the night
- Randomly move the telescope a bit between exposures (few 10"), so that you can get rid of any possible bright stars that are seen in the fields
- Ideally rotate the CCD 90 degrees between each exposure so that gradients in the twilight sky can be averaged out
- Remember that the sky brightness changes quickly
- In the evening start with the bluest/narrowest filters and end with the reddest ones (in the morning the other way around)

One can also use ‘dome flats’, but it is more difficult to get uniform illumination
Processing flat fields

Use IRAF package flatcombine to combine the individual flat field images, and normalise them to 1
Make one flat field image for each band and each night.

Original flat image

Normalised & combined flat
Ovs : Subtract overscan
Trim : Cut away the overscan region
Av. : Average frames
Other effects – sky concentration

- For focal reducers instruments, like DFOSC, multiple reflections in the optics will produce a ghost image of the flat field. This is often referred to as sky concentration, as it usually results in a diffuse blob of light centred on the optical axis.

- This means that the flat field will not be an accurate estimate of the spatial detector response.

- This can be corrected by observing a field of stars and studying changes in their magnitudes in different parts of the detector. See Andersen Freyhammer & Storm (1995) for more details.
Some things to remember

• The idea of image reduction is to improve the raw frame.
• Take many calibration frames to reduce noise.
• At each reduction step, check that the result is reasonable (noise not increased significantly, no negative values, ...).

• If you are observing extragalactic objects, you need to correct for galactic extinction.
• Have a 'Back up' program
• Scale images to 1s (keep track of total exposure time)
• Take notes during night (weather, seeing etc.)

• Don't forget the standard stars, even if I didn't talk about them