Observing and data reduction with DFOSC/Danish 1.54

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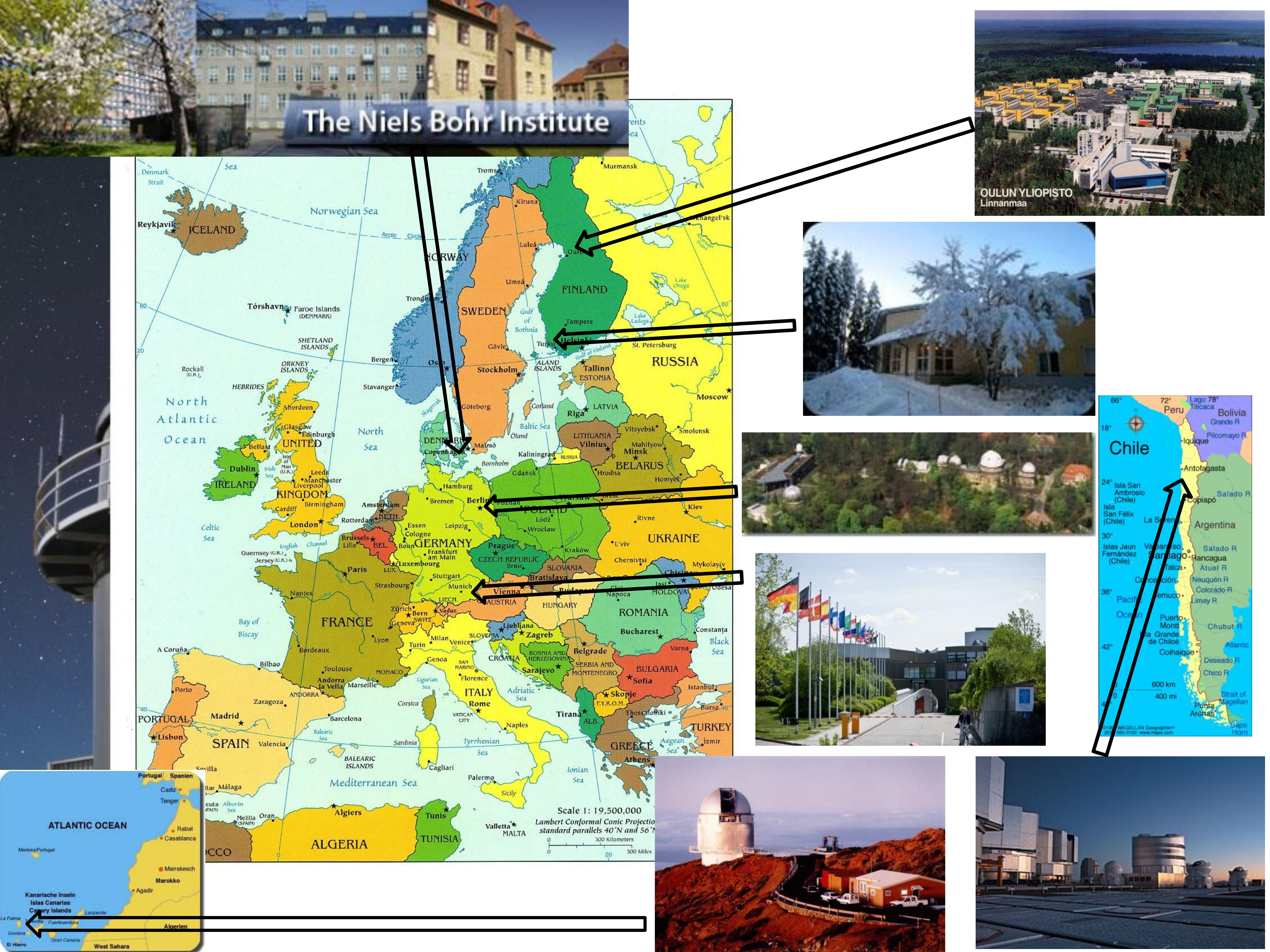
ESO Chile

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



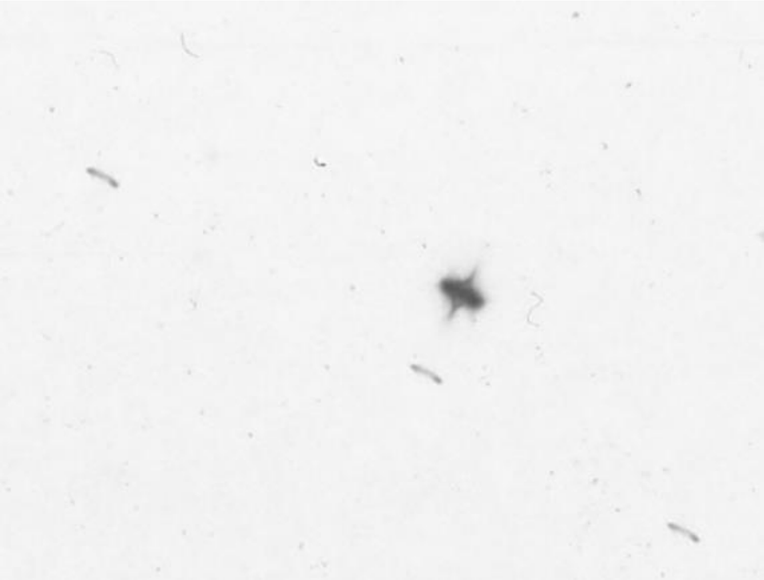
The Niels Bohr Institute
OULUN YLIOPISTO
Linnanmaa
Norwegian Sea
North Atlantic Ocean
North Sea
ICELAND
NORWAY
SWEDEN
FINLAND
RUSSIA
ESTONIA
LATVIA
LITHUANIA
BELARUS
UKRAINE
DENMARK
UNITED KINGDOM
IRELAND
GERMANY
POLAND
CZECH REPUBLIC
SLOVAKIA
AUSTRIA
HUNGARY
ROMANIA
FRANCE
SPAIN
PORTUGAL
ITALY
CROATIA
BULGARIA
GREECE
TURKEY
ALGERIA
TUNISIA
Mediterranean Sea
Black Sea
Bay of Biscay
Scale 1: 19,500,000
Lambert Conformal Conic Projection
ATLANTIC OCEAN
Kanarische Inseln
Islas Canarias
Canary Islands
Marokko
West Sahara
Chile
Peru
Bolivia
Argentina
Antofagasta
Santiago

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

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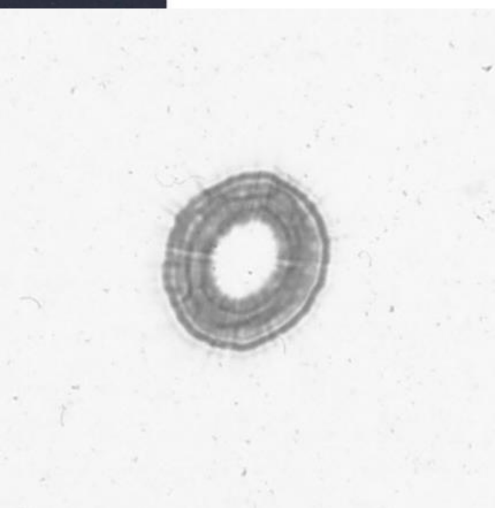

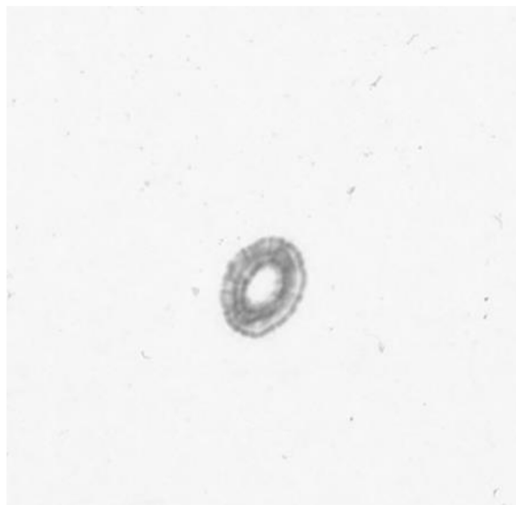

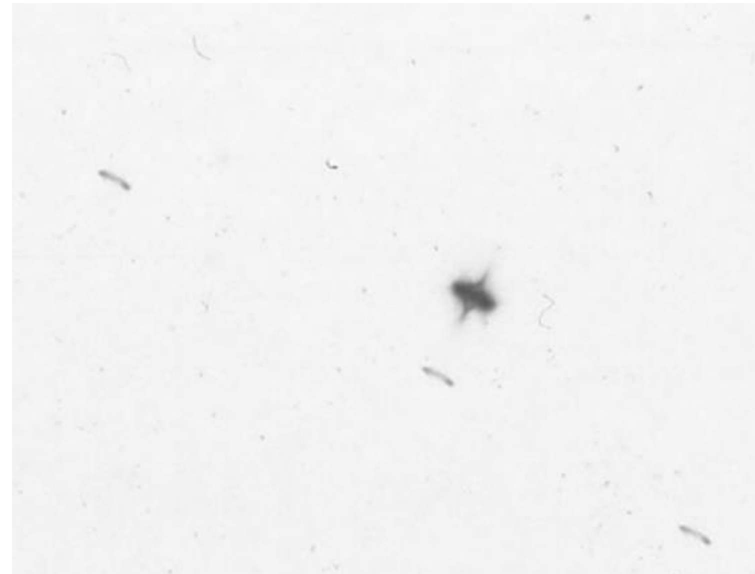

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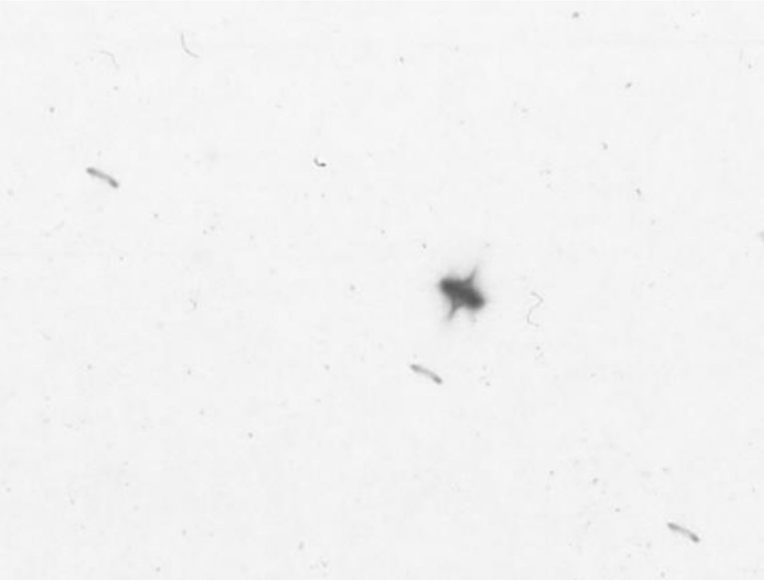
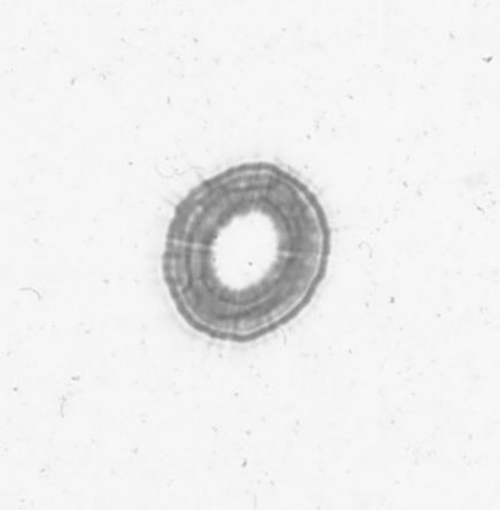


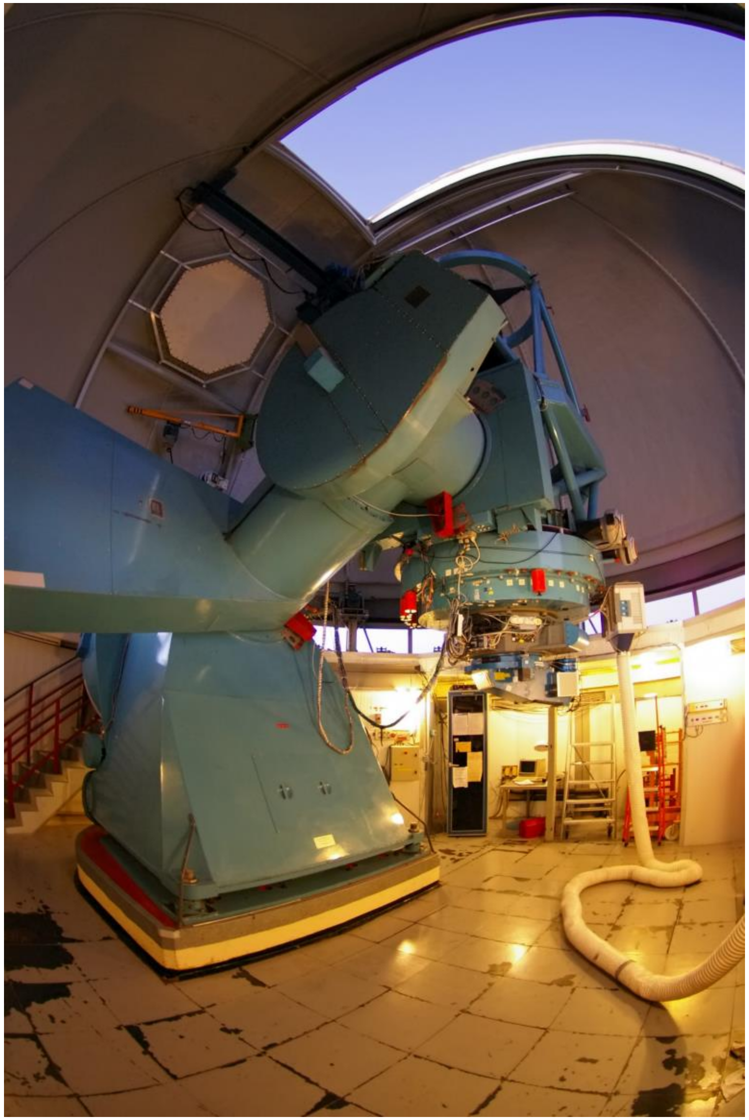


- Astigmatism of almost 10”!
- Repolish at Grubb Parsons

Take two

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

The Danish 1.54 telescope now



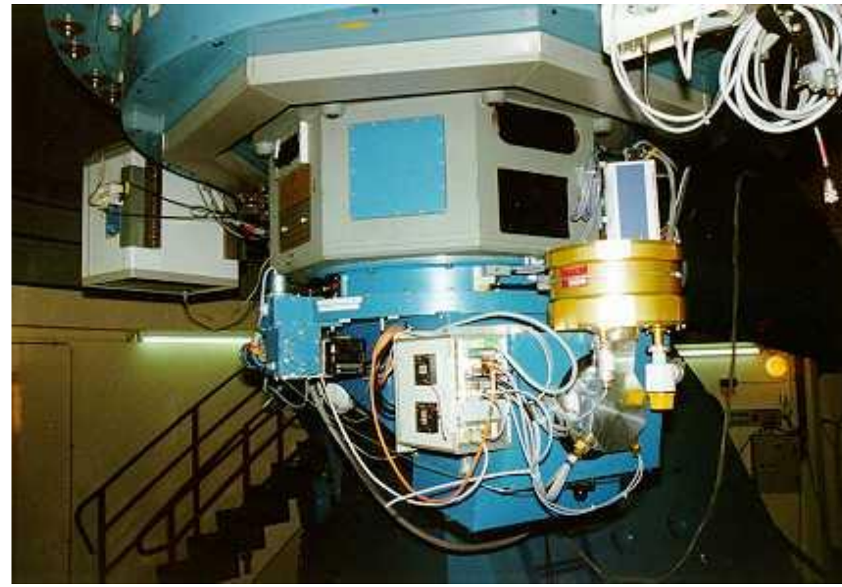
- A dedicated photometric telescope.
- Owner: University of Copenhagen
- Operated jointly by Niels Bohr Institute and research groups in Czech Republic

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.

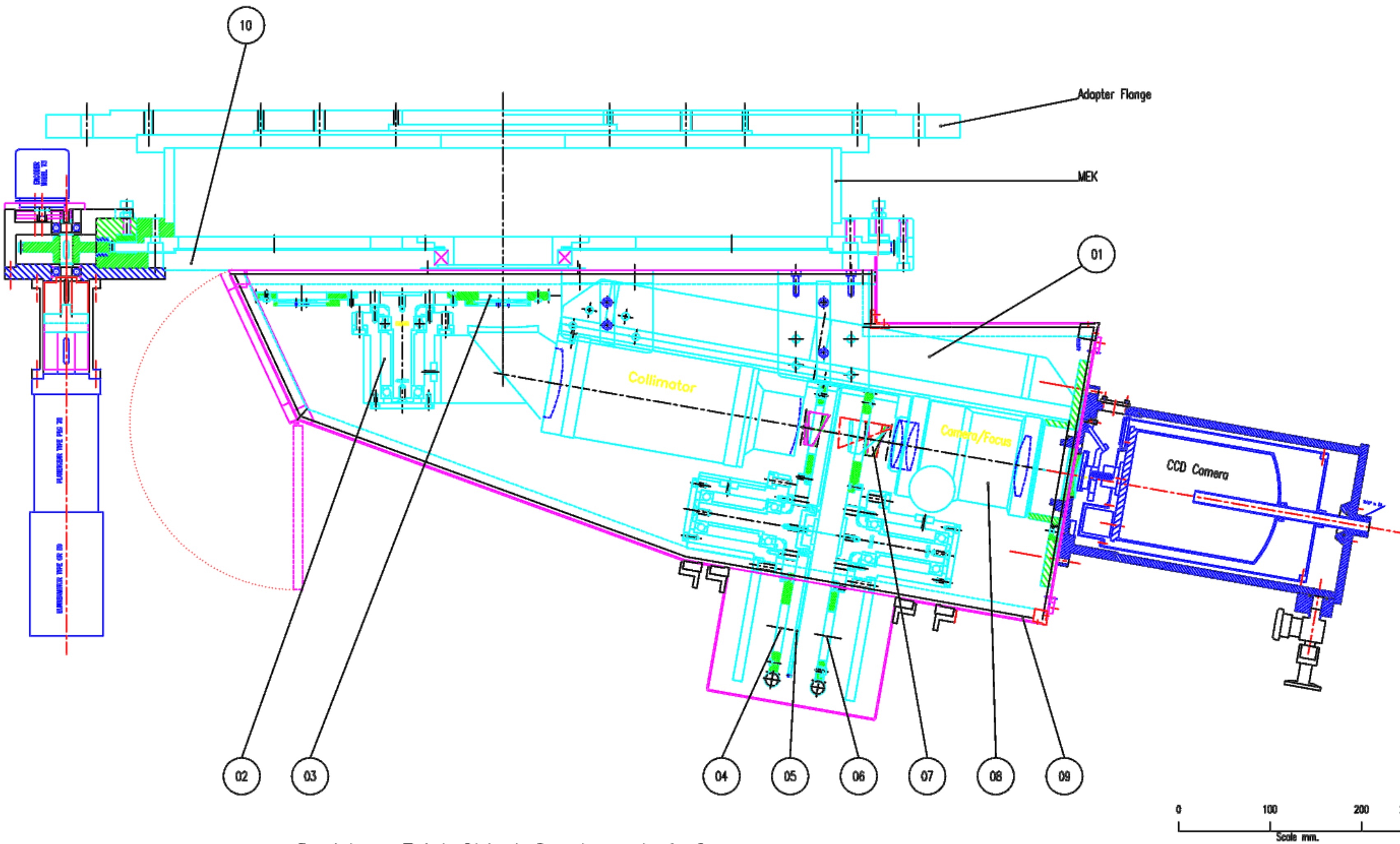
Danish 1.54 instruments: DFOSC

- 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 spectrocopy, but is not in use anymore



Since 2004 scaled down to exclude the spectroscopic capability

DFOSC layout

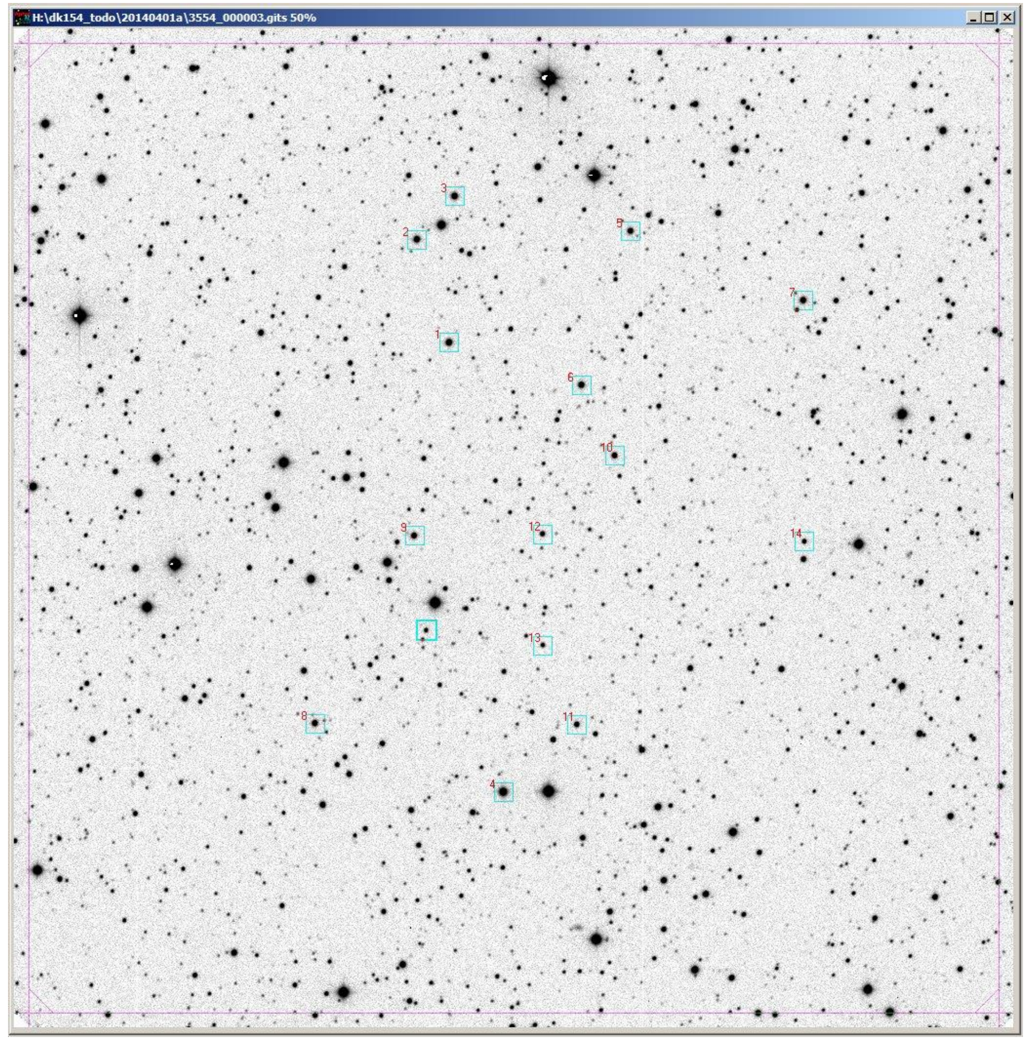


Danish – Faint Object Spectograph & Camera

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_{lim} = 18.5 at SNR =100
V_{lim} = 20.0 at SNR =30

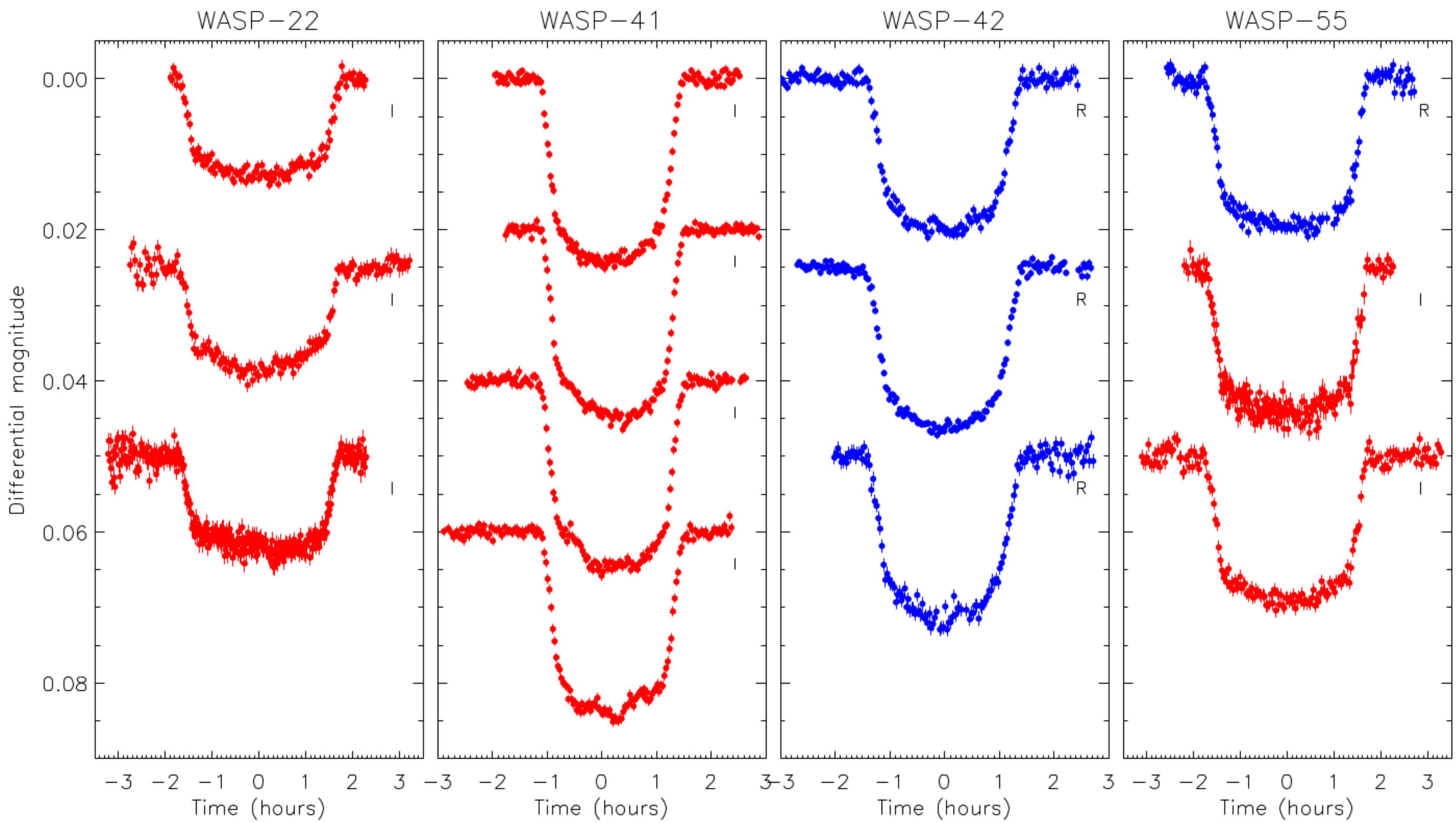
Typical seeing: <1” (median 0.8-0.9”).

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

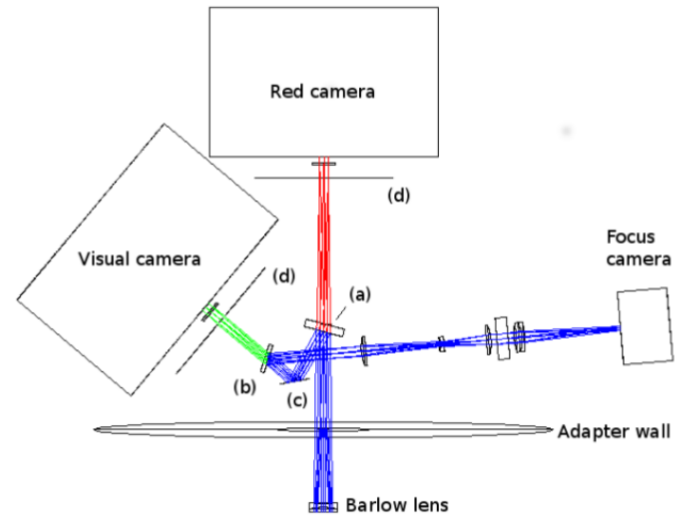
DFOSC science example

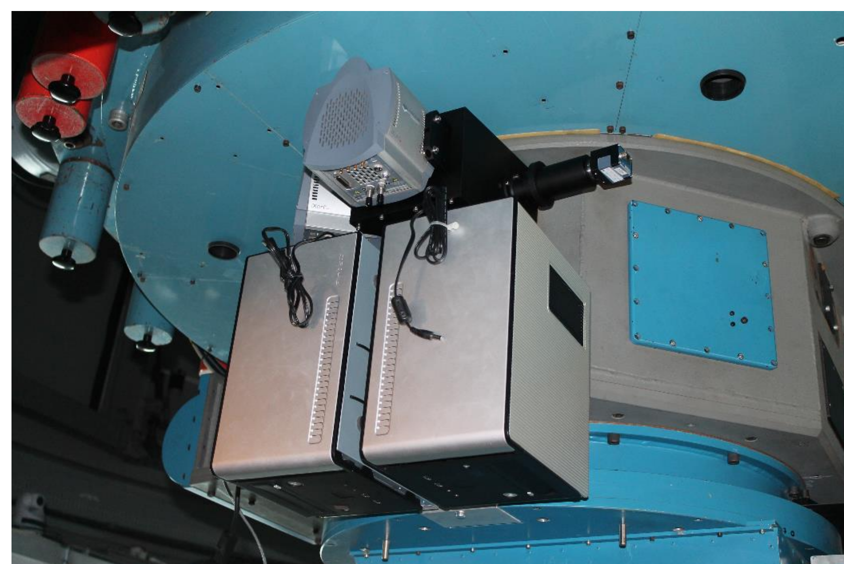


Southworth et al. 2016

Danish 1.54 instruments: TCI

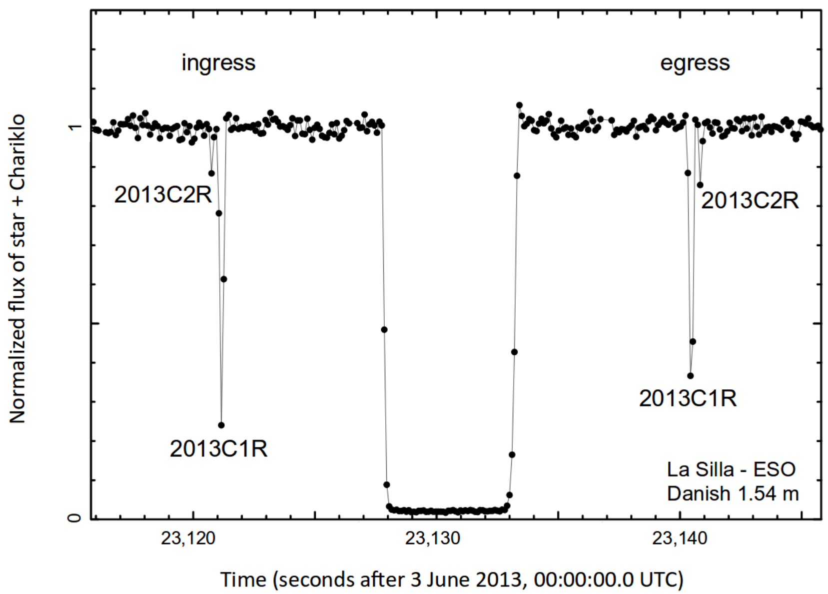
- Two colour imager (TCI): red and visual
- Electron multiplying CCDs (EMCCD)
- Uses Andor iXon +897 cameras
- 512 x 512 pixels
- Field of view 45" x 45"
- High frame-rate: 10Hz





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

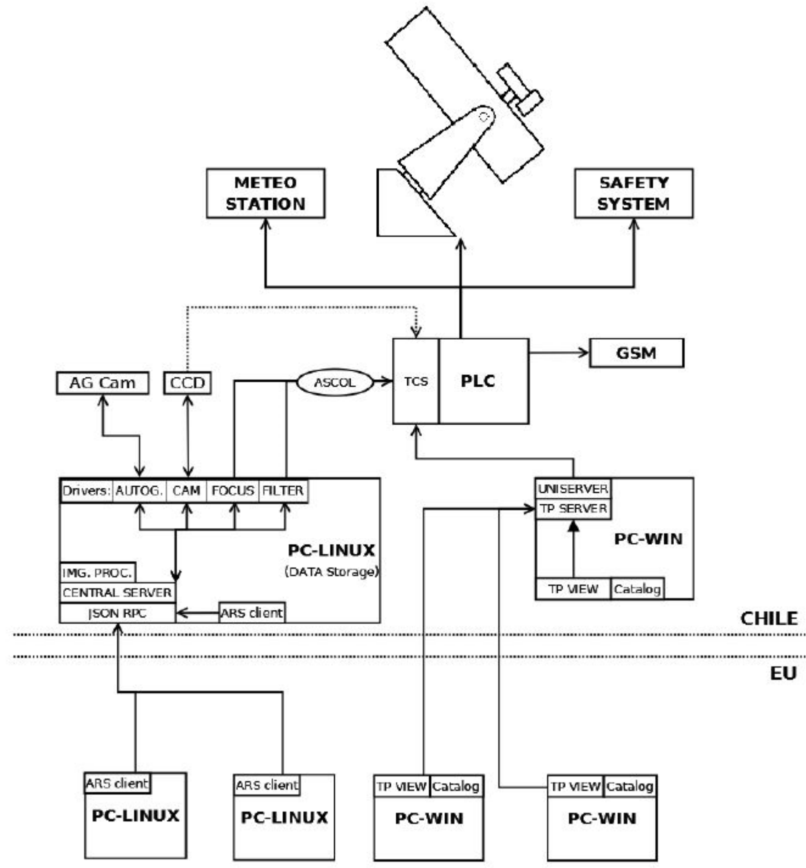
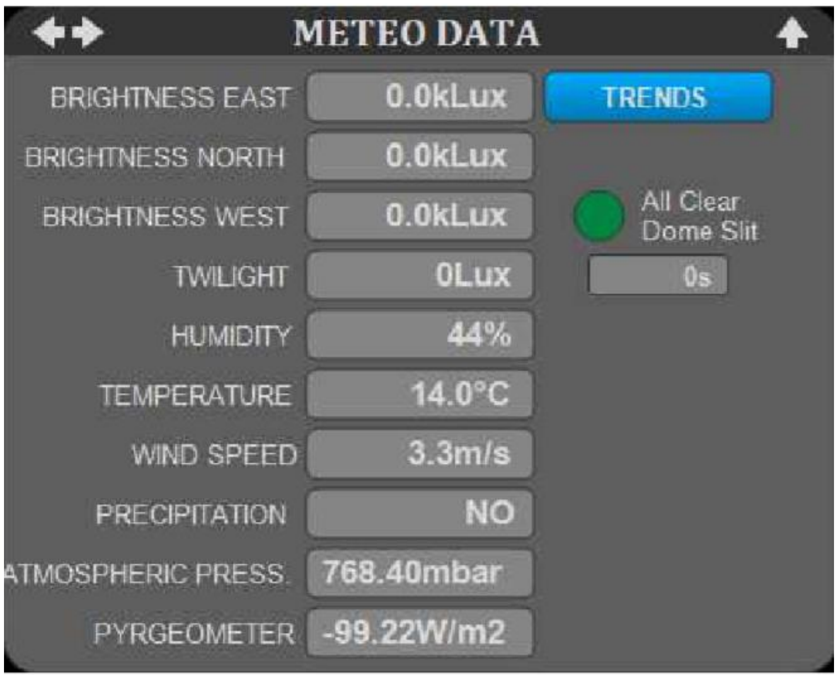
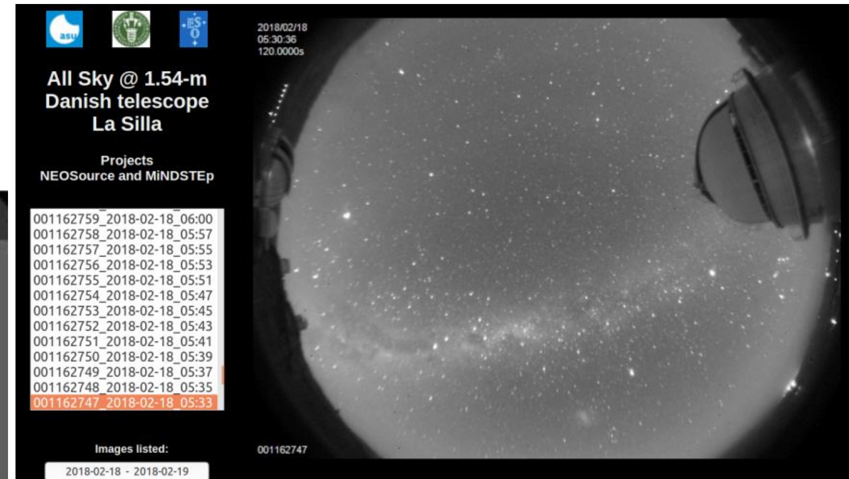


Fig.1: Structure of control and visualization system

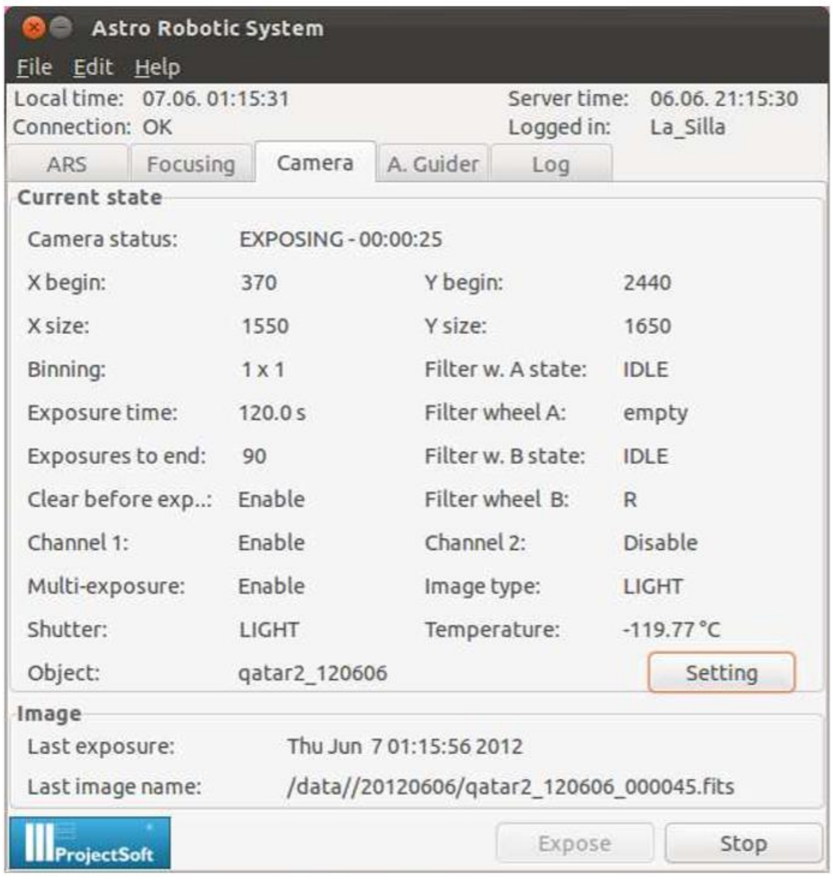

ProjectSoft
Server time (UTC) 14.01.2013 10:45:37
Client time 14.01.2013 10:45:37
CONTROLS
LOCAL CONTROL
La Silla LS_Operator
05.10.2012 13:40:08 + GENE AL 1, control voltage is off
100
SKY COORDINATES
RA 11h 02m 56.81s
DEC -29° 12' 10.0"
HA 0h 01m 06.41s
EPO 2000-000
RA 5h 02m 40.80s
DEC -68° 24' 21.0"
POS MAIN REV
EPO 2000-000
ALT 26.94° SLEW OBJS SEL
TIME
LAST 11h 04m 03s
UTC 14h 48m 16s
AZIMUTH / ALTITUDE
TEL. AZ 192.14°
DOME AZ 90.00°
TEL. ALT 90.00°
DOME ALT 69.37°
MANUAL CONTROL
ADD TO OFFSETS
ON OFF
DEC+ DA+
RA+/HA-
RA-/HA+
DEC- DA-
T1 T2 T3
3500"/s 240"/s 15"/s
ADDITIONAL TRACKING / OFFSETS
RA-/HA+ 0.000"/min ON
DEC+ 0.000"/min OFF
Use AG
/MIN TS 0.000"/min ON ON
/SEC PA 0.0000° OFF OFF
RA+/HA- 0.0" RESET
DEC- 0.0"
RA+/HA- 0.0" RESET
DEC- 0.0"
CORRECTIONS
ON OFF
POINTING MODEL left2 SEL
DOME ANIMATION
N S
N
W
E
S
FILTER WHEELS / CAMERA SHUTTER
WHL A empty
POS STOP - +
WHL B empty
POS STOP - +
SHUT CLOSED INIT
MAIN FOCUS
STOPPED 0.000mm
POS 39.004mm STOP COR
ABS 39.013mm POSIT SLOW FAST
REL 0.080mm POSIT - +
POINTING RESTRICTIONS
DIST SAFE
ACT. POS
LEFT RIGHT
MAIN
REV
TELESCOPE
LOCAL VOLTAGE ON
SWITCHED OFF
ON OFF STOP PARK
INIT INIT MAIN FLIP
CLOSE ALL INIT AG PARK AG
DOME ROTATION
STOPPED
POS 179.76° STOP
POS 270.00° SLEW
AUTO PARK
DOME SLIT
CLOSED
OPEN CLOSE STOP
CASSEGRAIN FLAP
CLOSED
OPEN CLOSE STOP
MIRROR FLAP
CLOSED
OPEN CLOSE STOP
CONTROLS
TECHNOLOGIES
TEXT

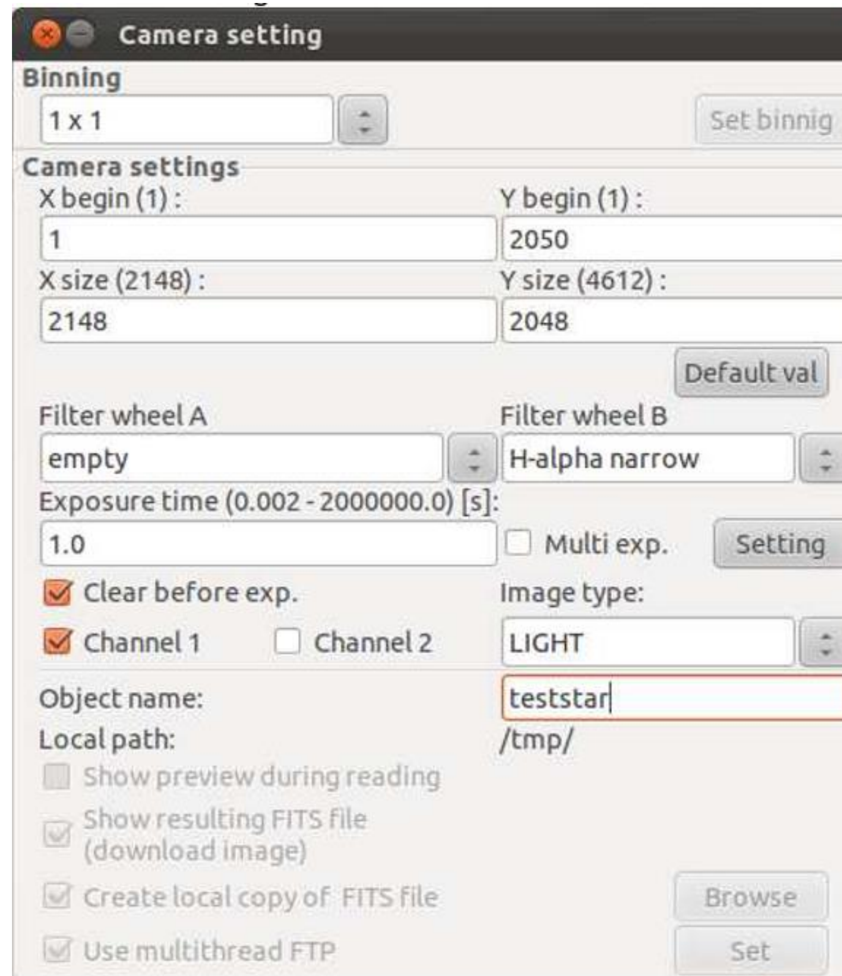
Weather station





DFOSC control system

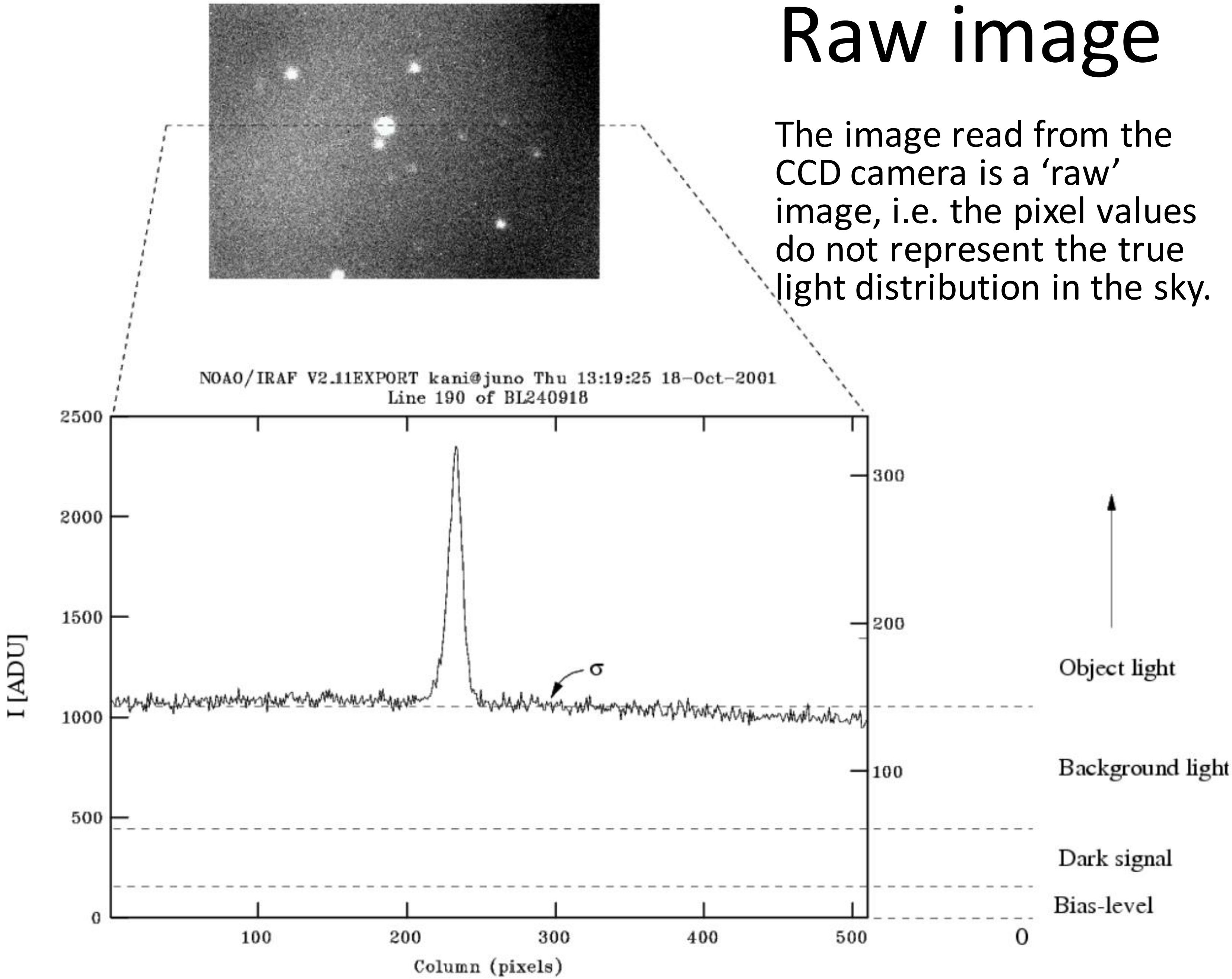




Data reduction

Raw image

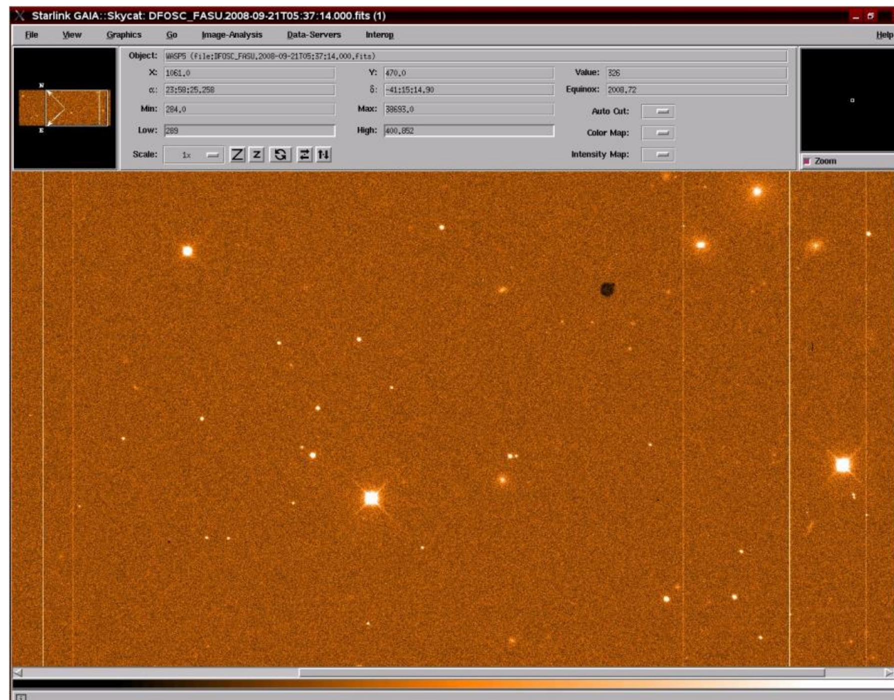
The image read from the CCD camera is a 'raw' image, i.e. the pixel values do not represent the true light distribution in the sky.



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

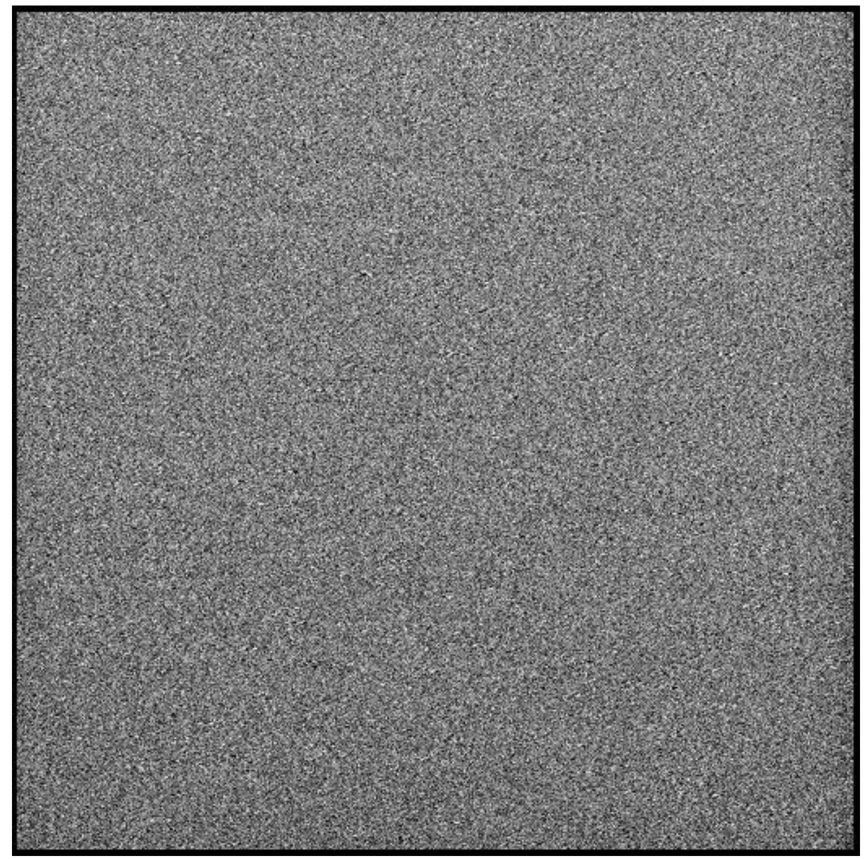
- Reason: to avoid negative counts
- Must be subtracted from all images

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

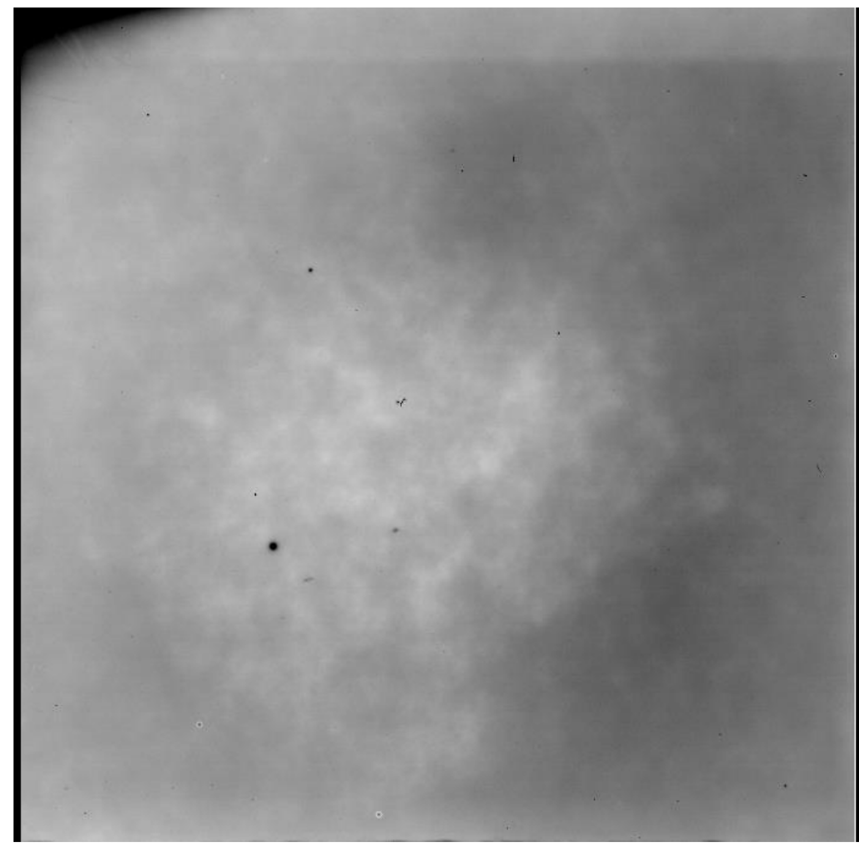


Flat fields

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

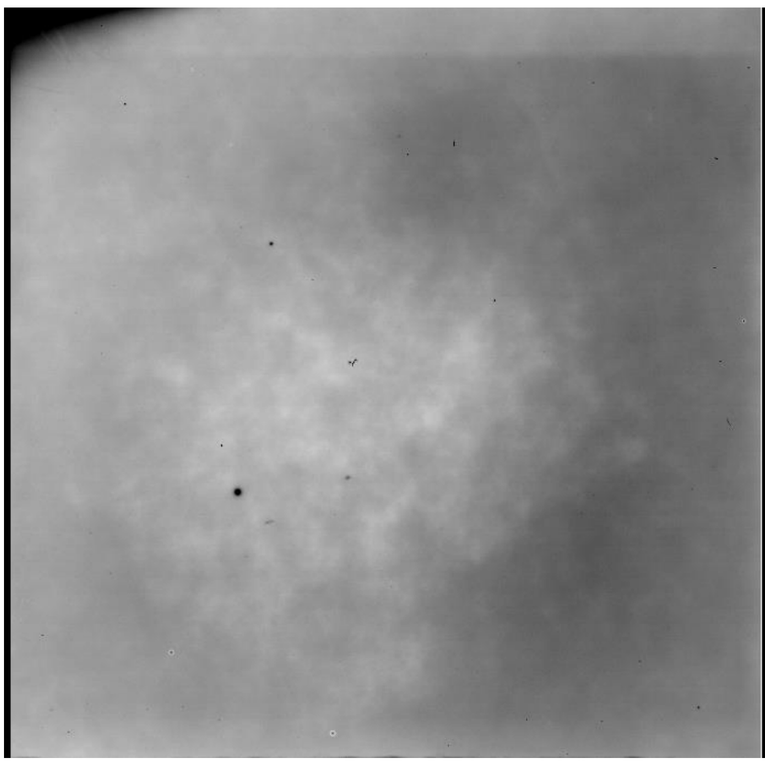
- Observe the twilight sky at dusk and/or dawn.
- Suitable blank fields to observe are listed at the telescope.
- Make sure you get significant counts, ~60% of saturation
- Get as many images as possible, with at least 4 images in each filters you will use during the night
- Randomly move the telescope 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

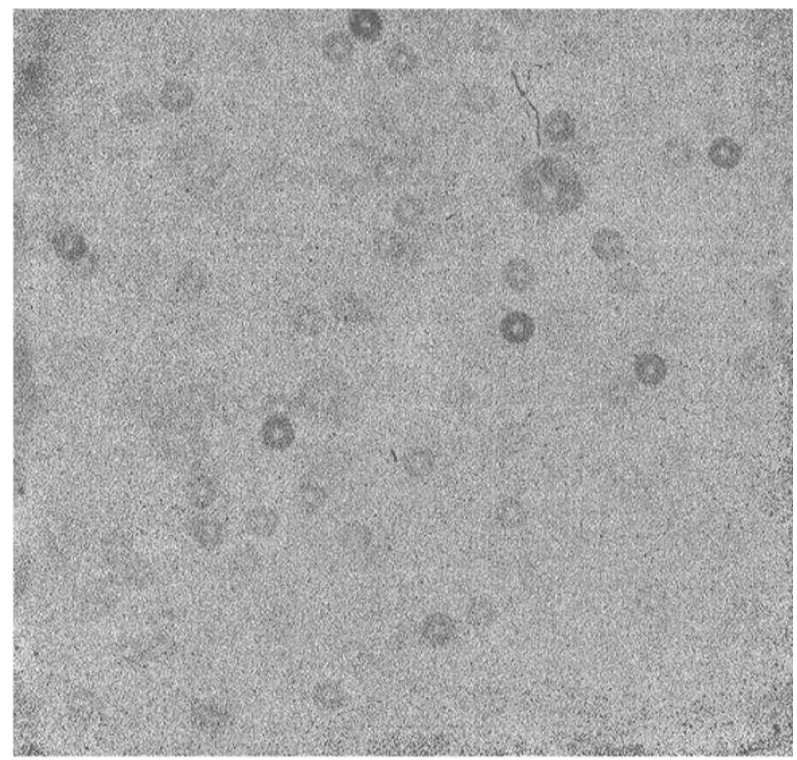
Processing flat fields

Use IRAF package flatcombine to combine the individual flat field images, and normalise them to 1

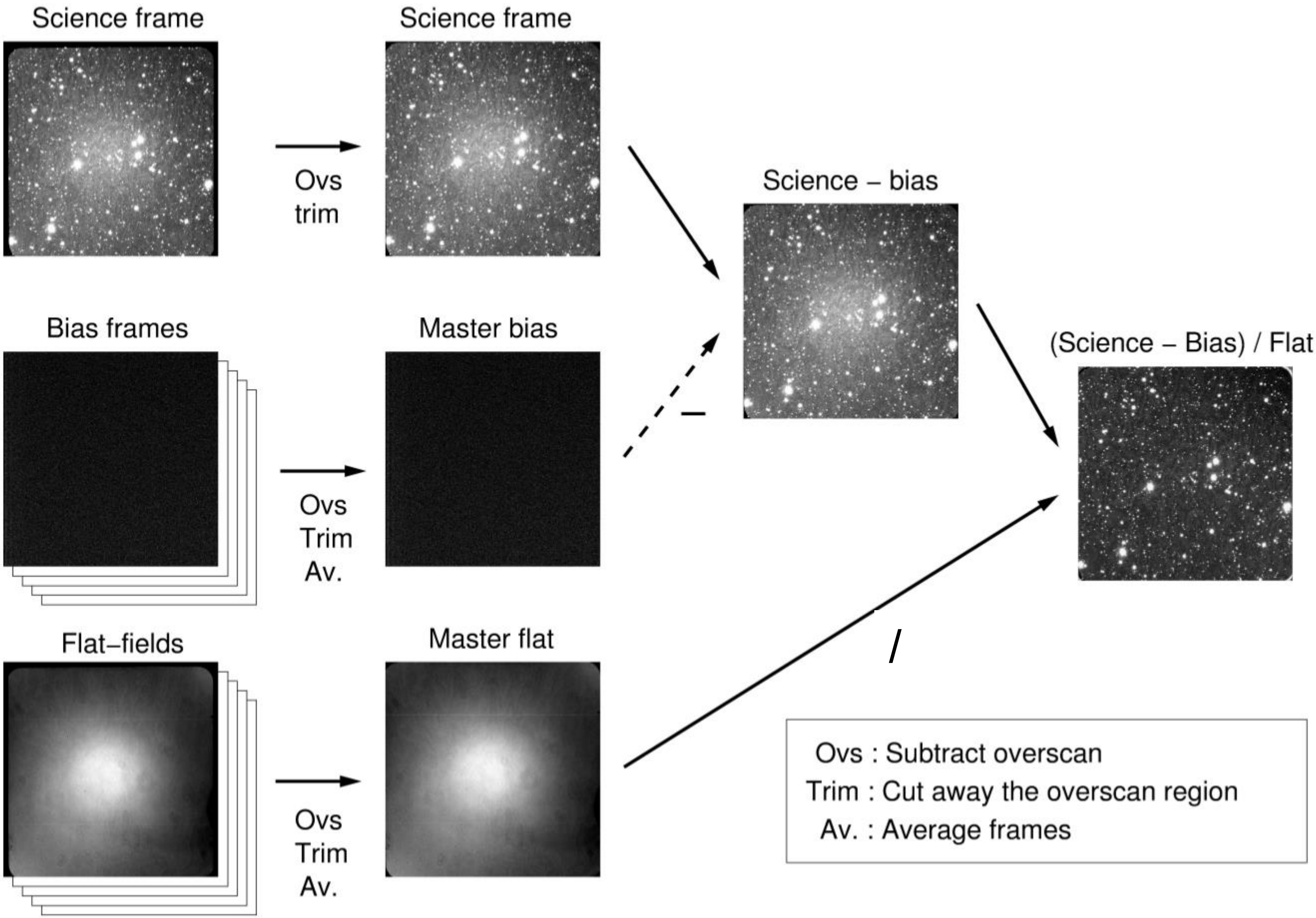
Make one flat field image for each band and each night.



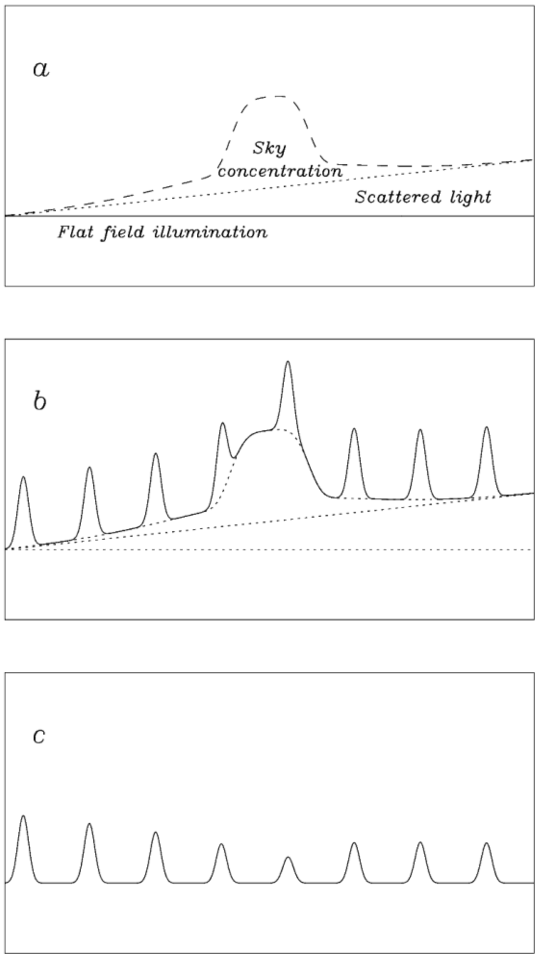
Original flat image



Normalised & combined flat


Science frame
Ovs
trim
Science frame
Science – bias
Bias frames
Ovs
Trim
Av.
Master bias
–
(Science – Bias) / Flat
Flat–fields
Ovs
Trim
Av.
Master 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