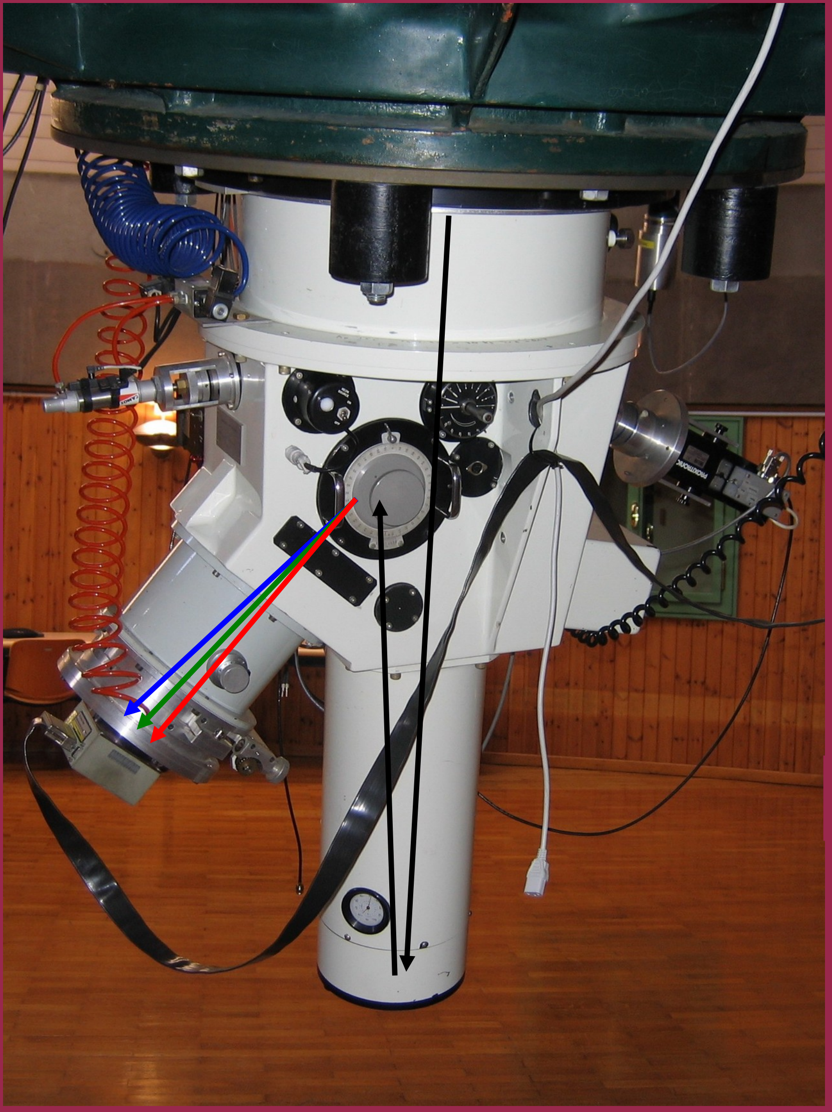
Reduction procedure of long-slit optical spectra

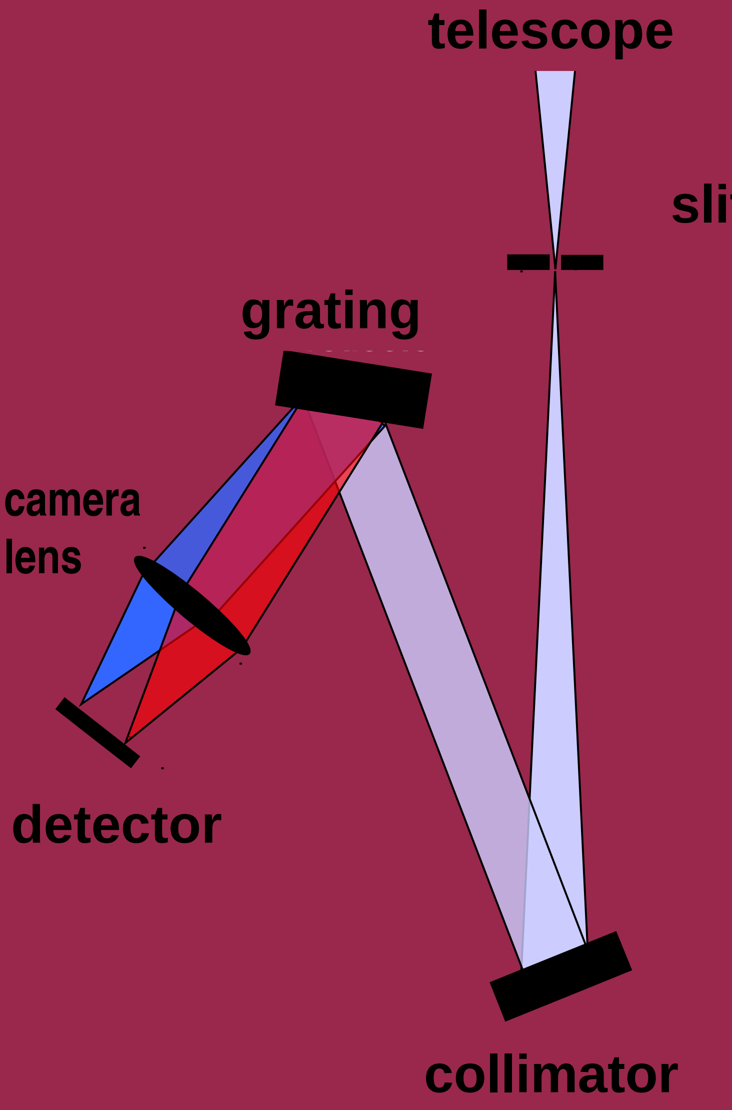
Astrophysical observatory of Asiago

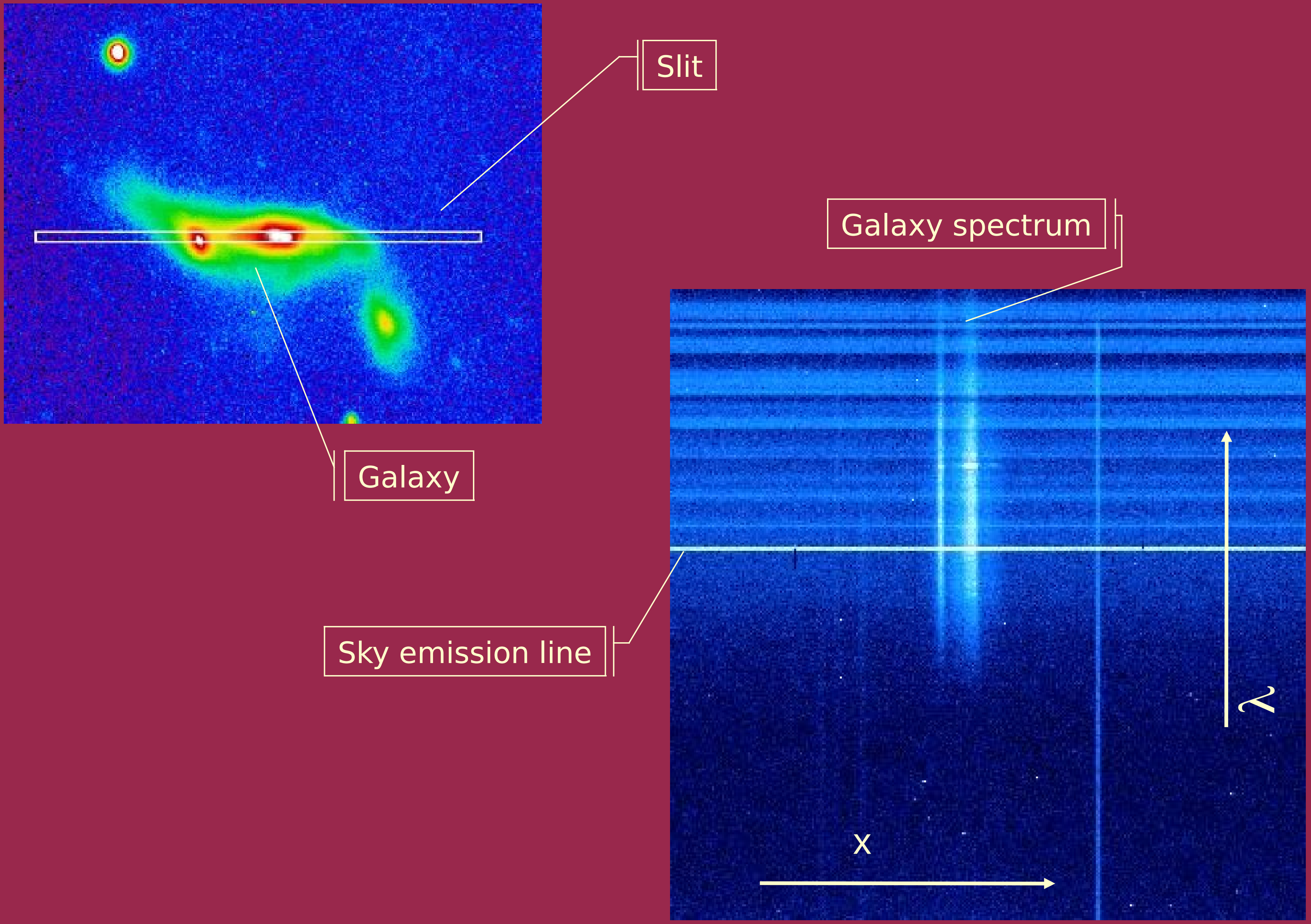
Spectrograph: slit + dispersion grating + detector (CCD)

It produces two-dimension data:

- Spatial direction (x) along the slit
- Spectral dispersion (λ= radiation wavelength)






Slit
Galaxy
Galaxy spectrum
Sky emission line
x
λ

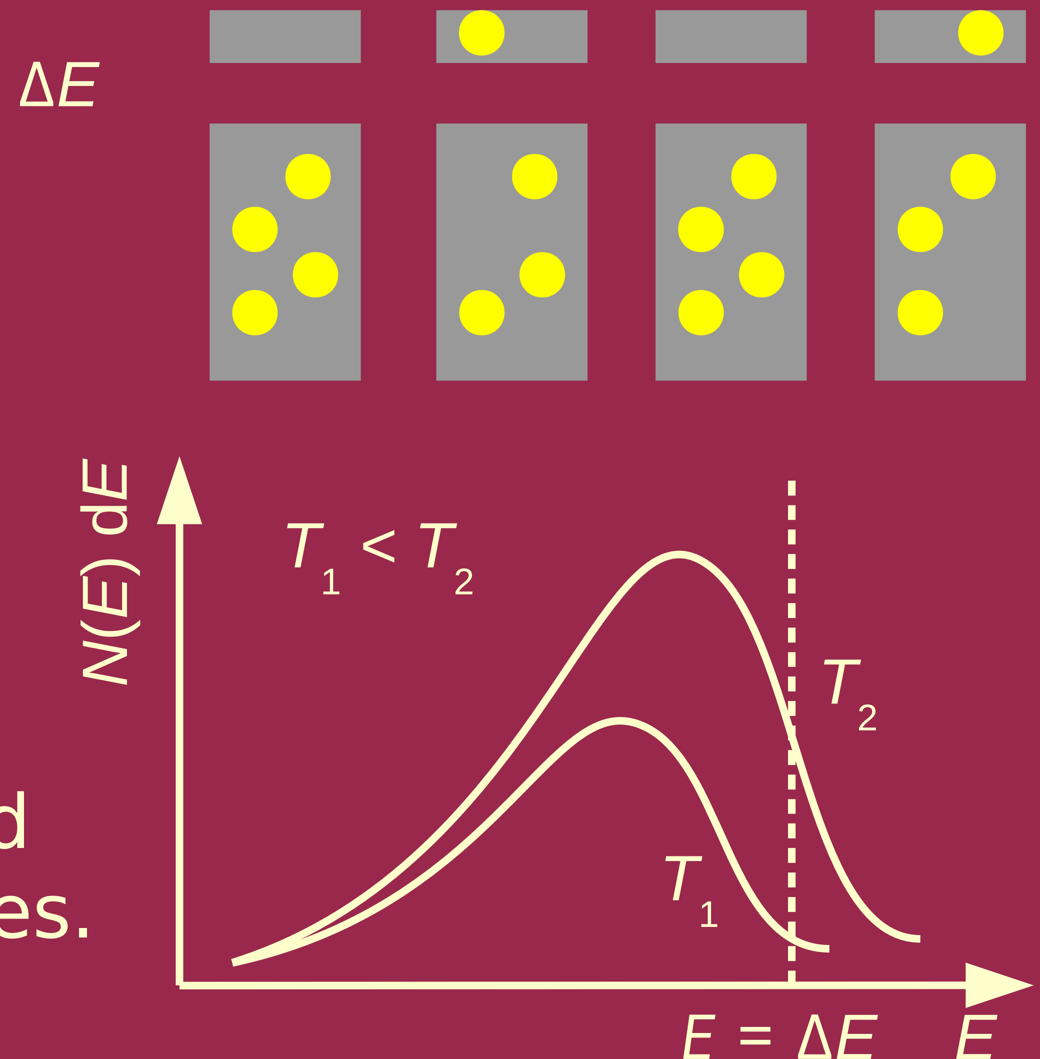
Reduction:
the process to turn raw observational data into scientific measurable quantities

Sequence:
- Bias subtraction
- Flat-Field correction
- Cosmic ray removal
- Wavelength calibration
- Flux calibration
- Sky subtraction

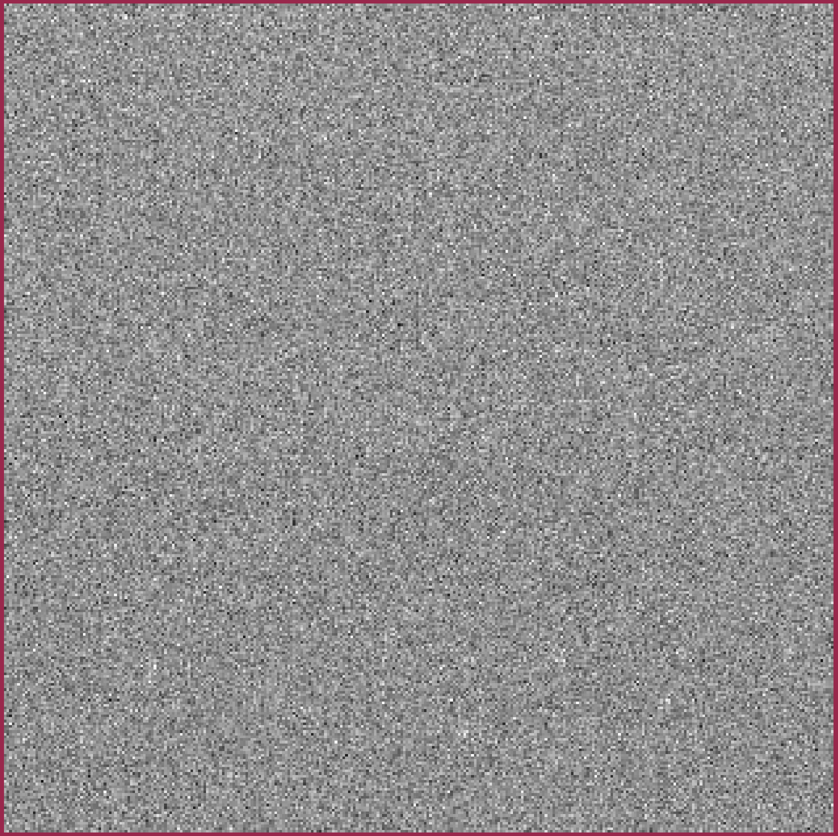
Thermal noise

Because of thermal energy distribution, some electrons can be energetic enough to jump in the read-out circuit.

In order to reduce the effect of thermal noise, the detector is operated at very low temperatures.



Bias subtraction



Bias:
electronic noise of the CCD

It can be obtained by reading the unexposed detector with closed shutter

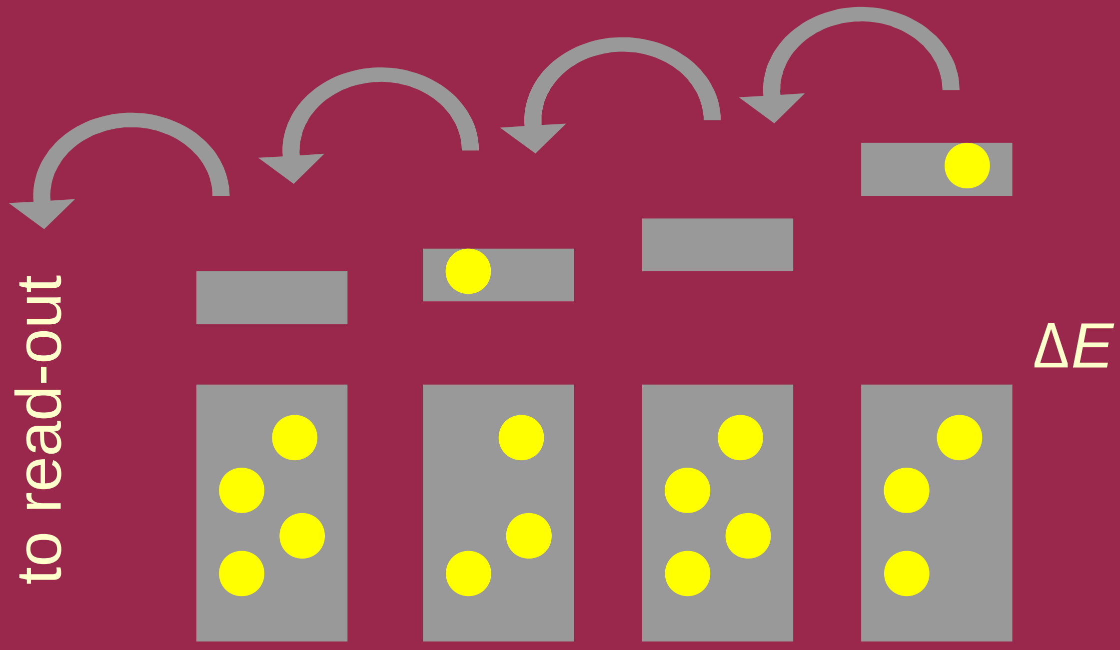
average value = 197.6 ± 0.8
(detector cooling on)

(*) Ima=image

ImaB = Ima(*) - bias

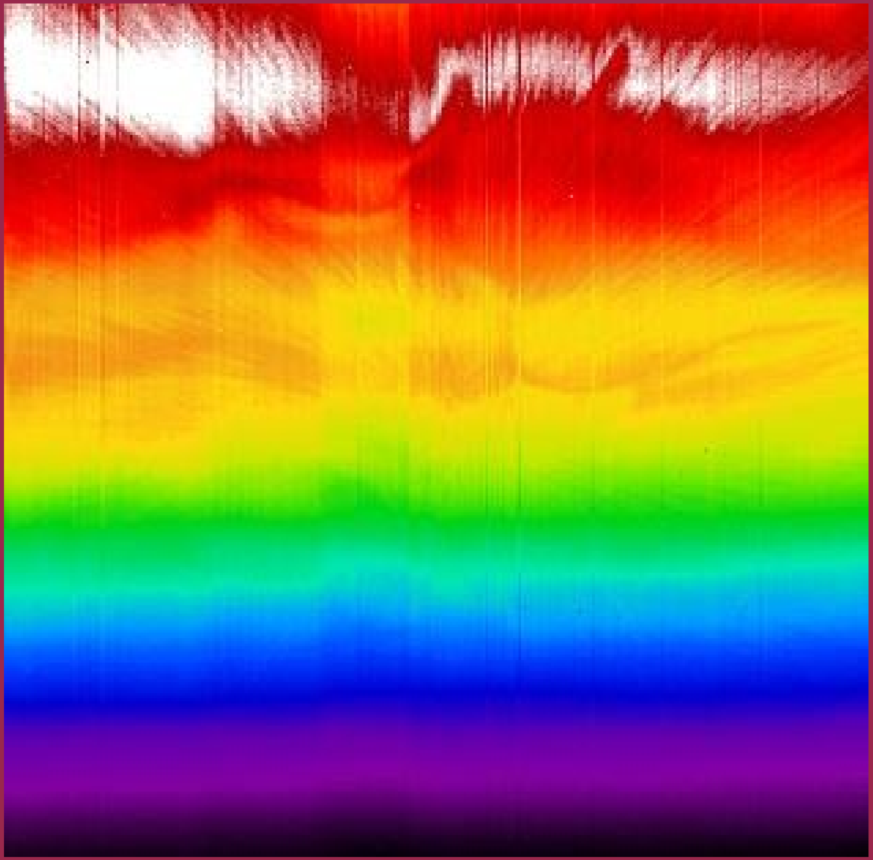
Flat field correction

The surface of the detector does not respond uniformly to incoming light.



This is due both to the fact that charge has to be carried all the way to the read-out circuit, leading to charge losses along the way, as well as to intrinsic differences between the pixels. Rigorously speaking, even the amount of charge stored in one cell plays a role, because it will be harder to bring new electrons where there are already many.

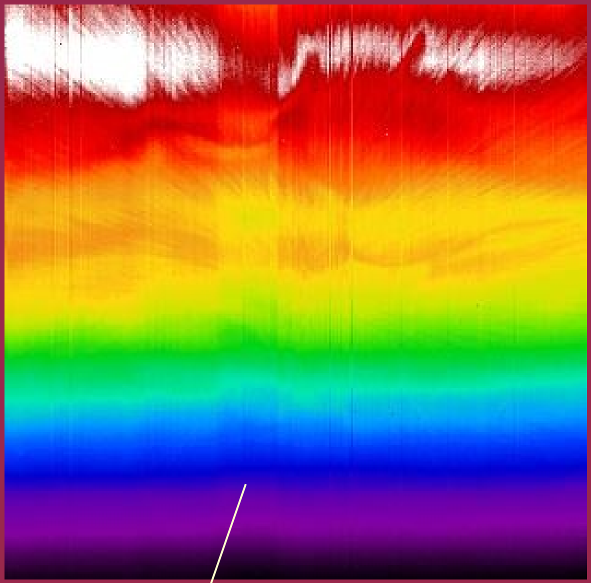
Flat-Field correction

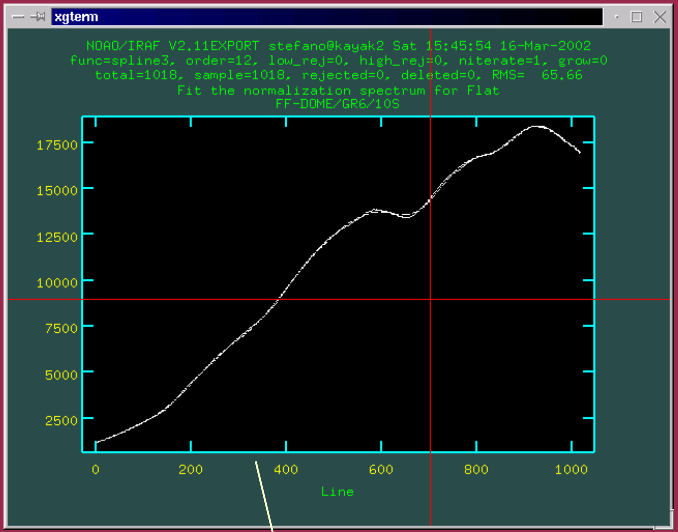


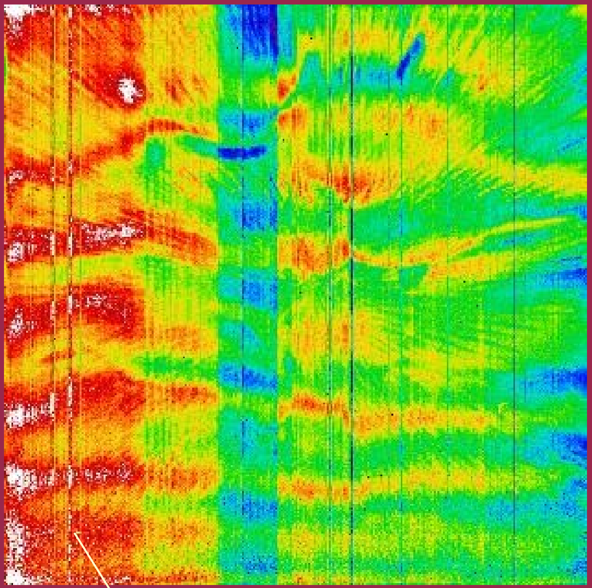
Flat-Field:
spectrum obtained by shading the spectrograph with a uniform light beam

It is needed to correct for the non-uniform response of the detector pixels to incoming light

In order to remove the wavelength dependence, it must be normalized, so that its average intensity is 1







Flat

Normalized flat

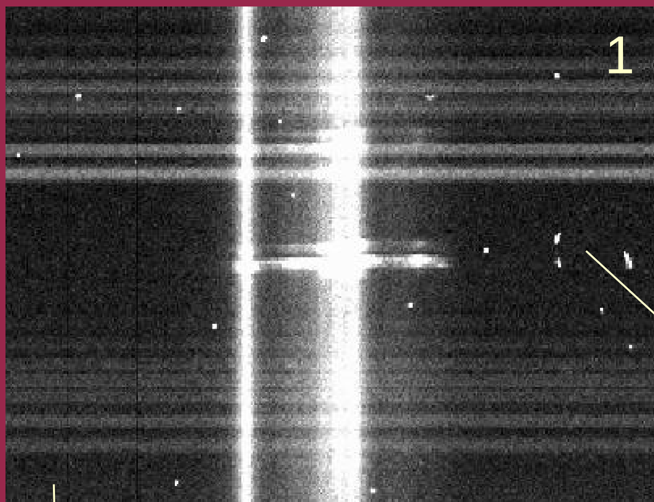
Average of flat columns

We can average together the flat-field columns and the function which fits resulting profile can be used to normalize the image.

Average=1.00 ± 0.03

$$\boxed{\text{ImaBF} = \text{ImaB / flatN}}$$

Cosmic ray subtraction



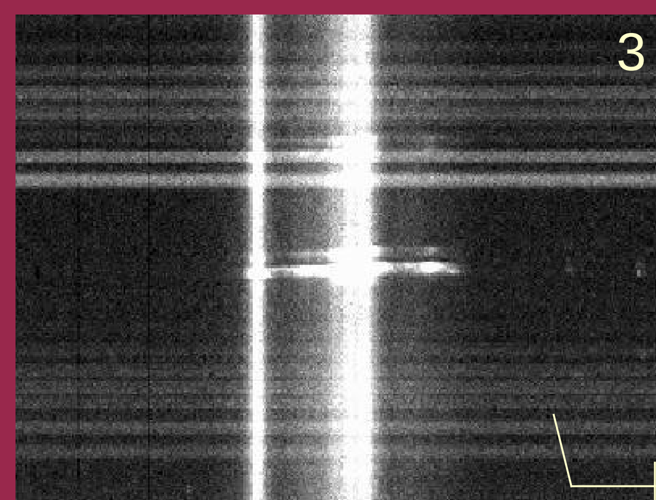
Cosmic rays

Section of spectrum

Cosmic rays:
energetic particles that hit the detector during an exposure with a random pattern

We see them as very bright pixels or groups of pixels

Mask



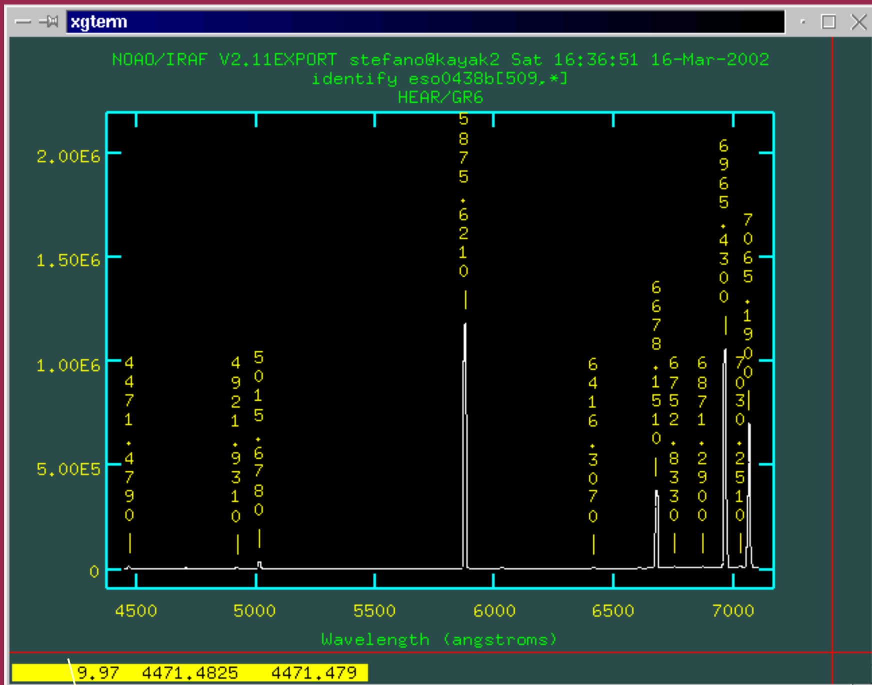
Cleaned spectrum

Wavelength calibration

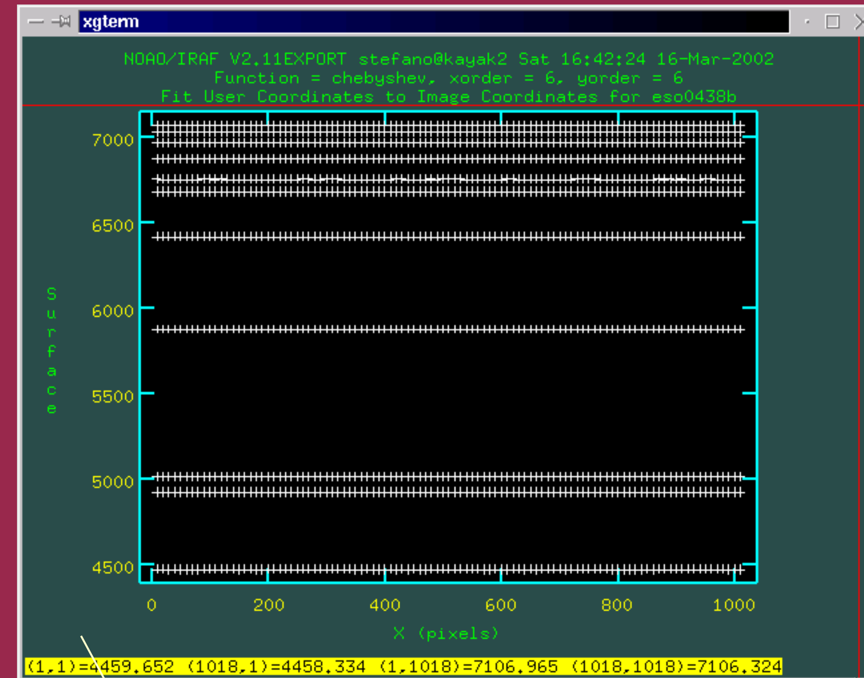
We need the (known) emission line spectrum of a lamp powered by a gas or gas mixture

The position of every emission line on the frame (in pixel) can be thus related with its corresponding λ (in Å)

The function which converts from Pixels to Å is called dispersion solution



Emission line identification

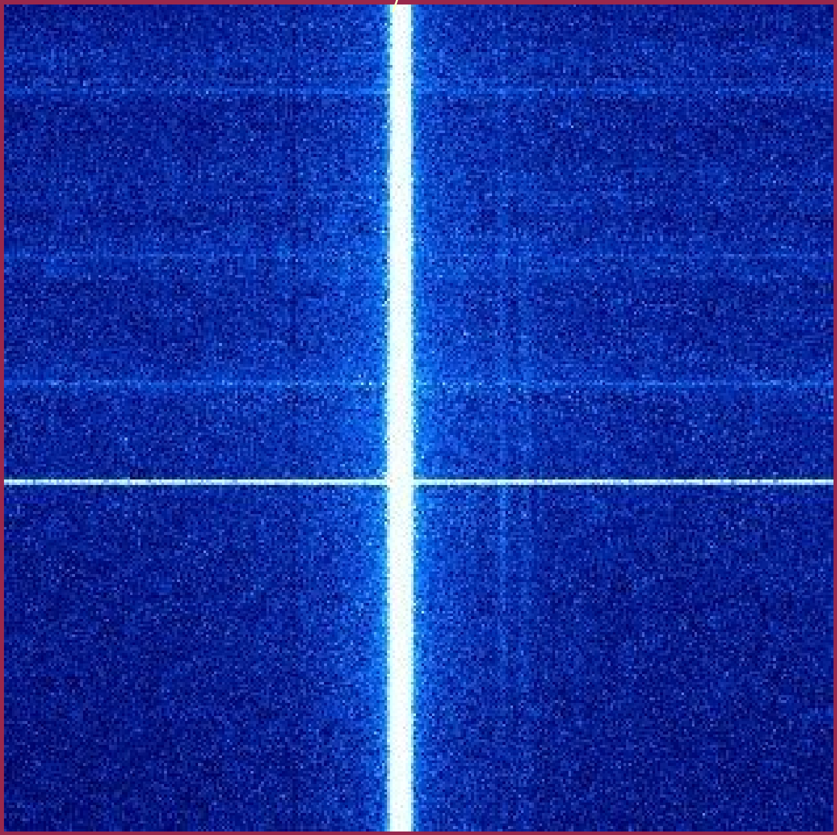


Dispersion grid solution

With a polynomial function of appropriate degree we can fit the dispersion solution, determining the initial wavelength and the dispersion per pixel, which of course depend on the spectrograph setup.

Flux calibration

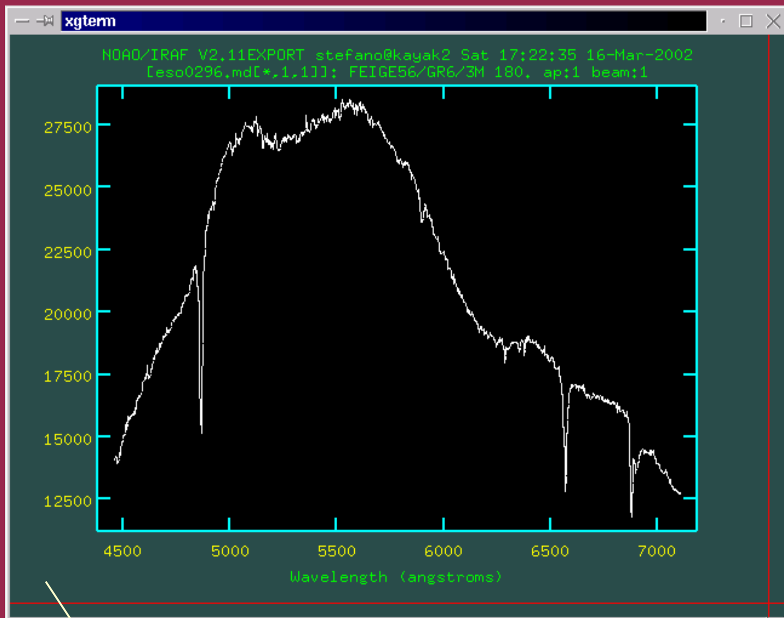
Standard star spectrum



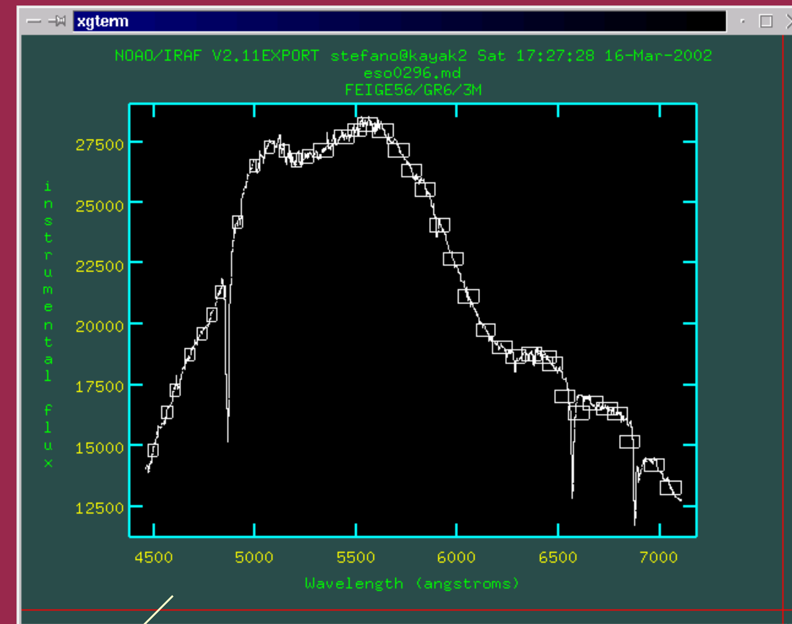
We use the spectrum of a spectro-photometric standard star for which we know the flux as a function of λ

We extrac the mono-dimensional Spectrum and we measure the flux (in units of photon counts) as a function of λ

We are thus able to provide the calibration function, which converts our flux from photon counts into erg cm^{-2} sec^{-1} $Å^{-1}$

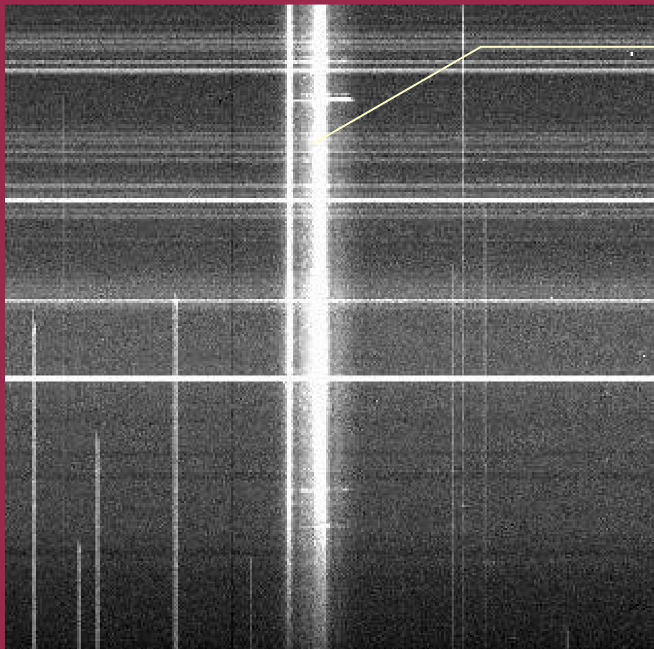


1D spectrum of star

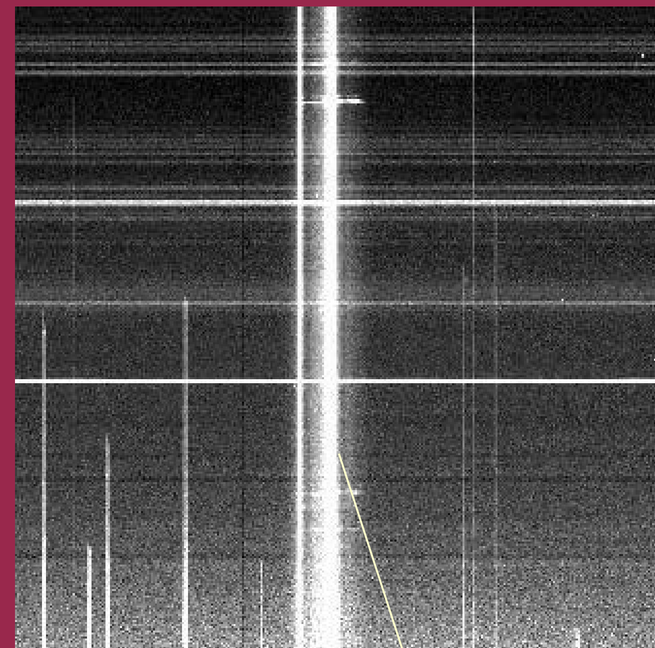


Flux measurement bands

Calibration function



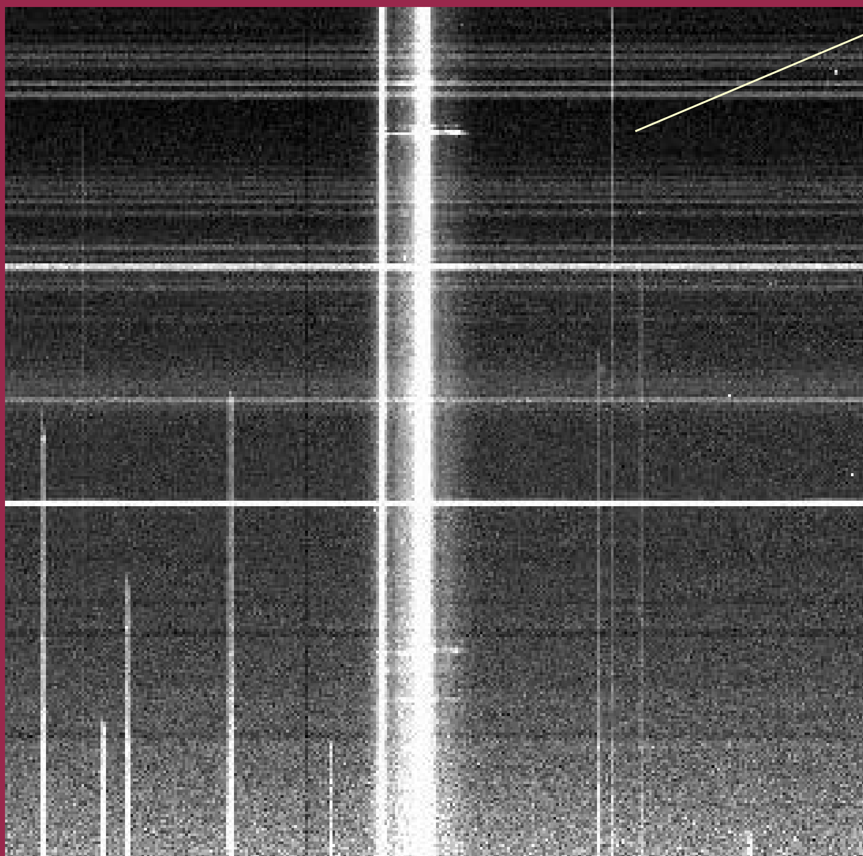
Spectrum before the
the flux calibration

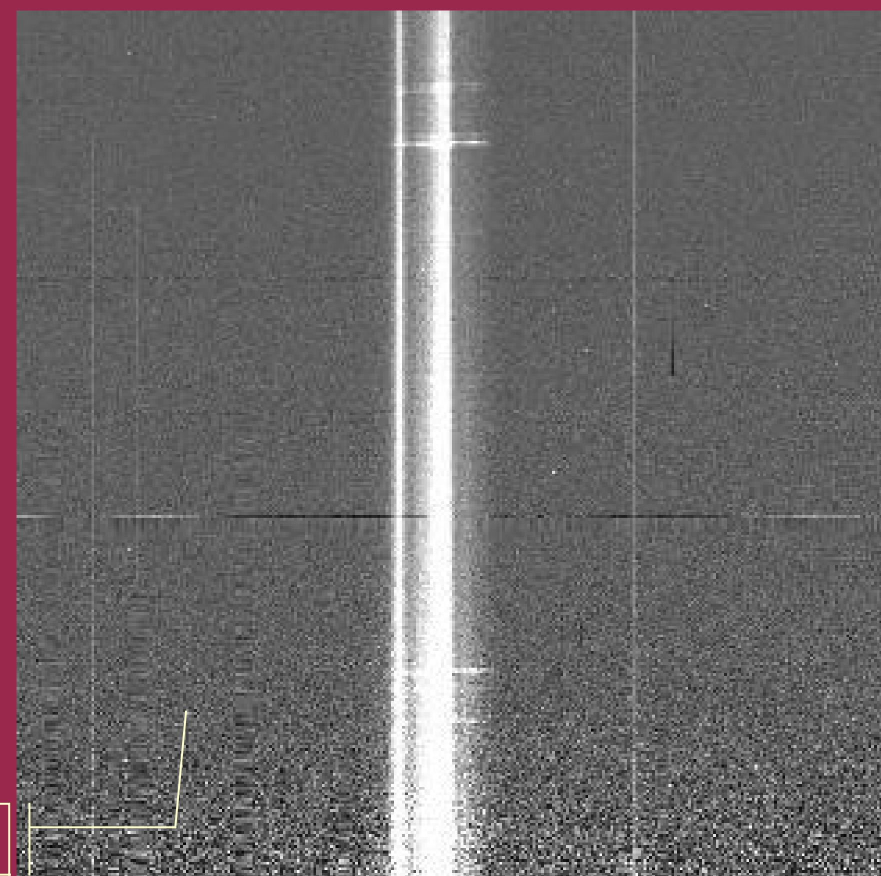


Spectrum after the
flux calibration

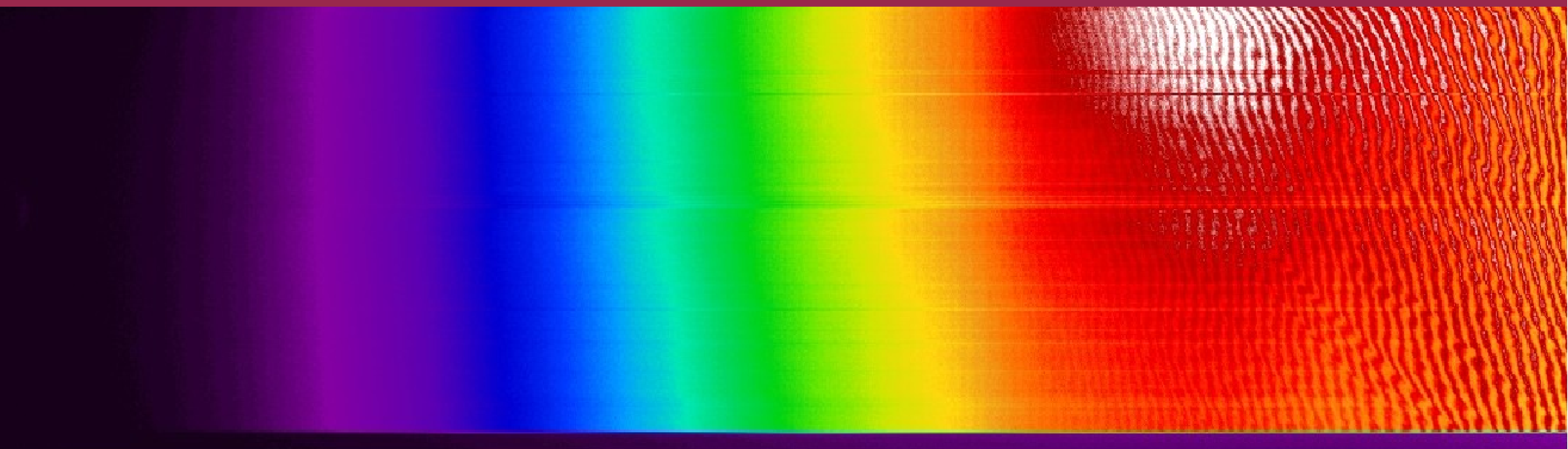
With the flux calibration we correct for the non-uniform sensitivity of a detector at various wavelengths

Sky emission subtraction



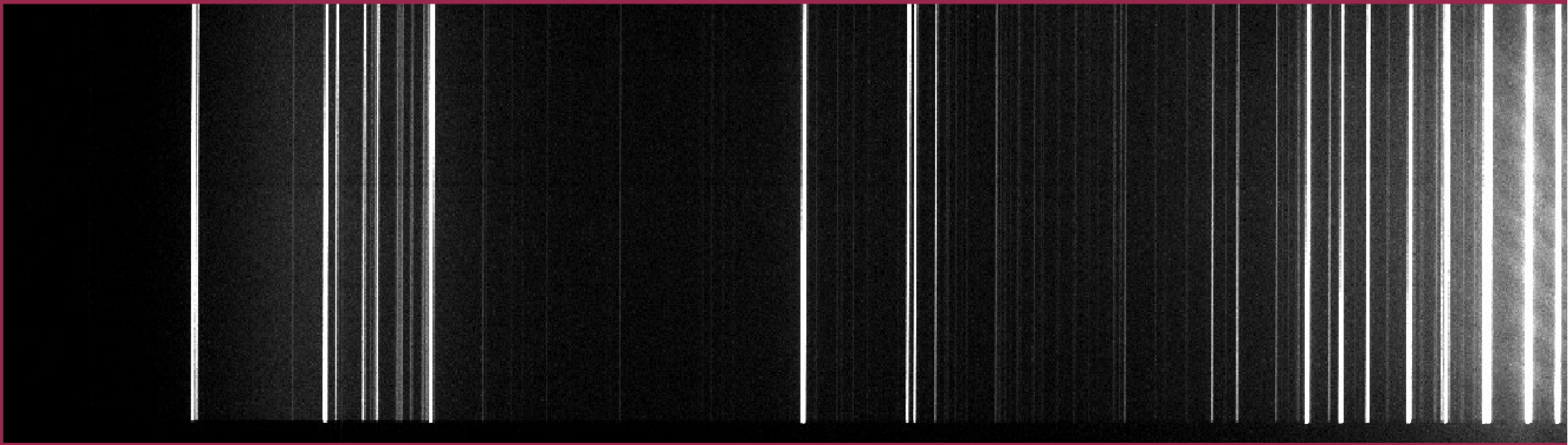


1.22 Telescope example spectra



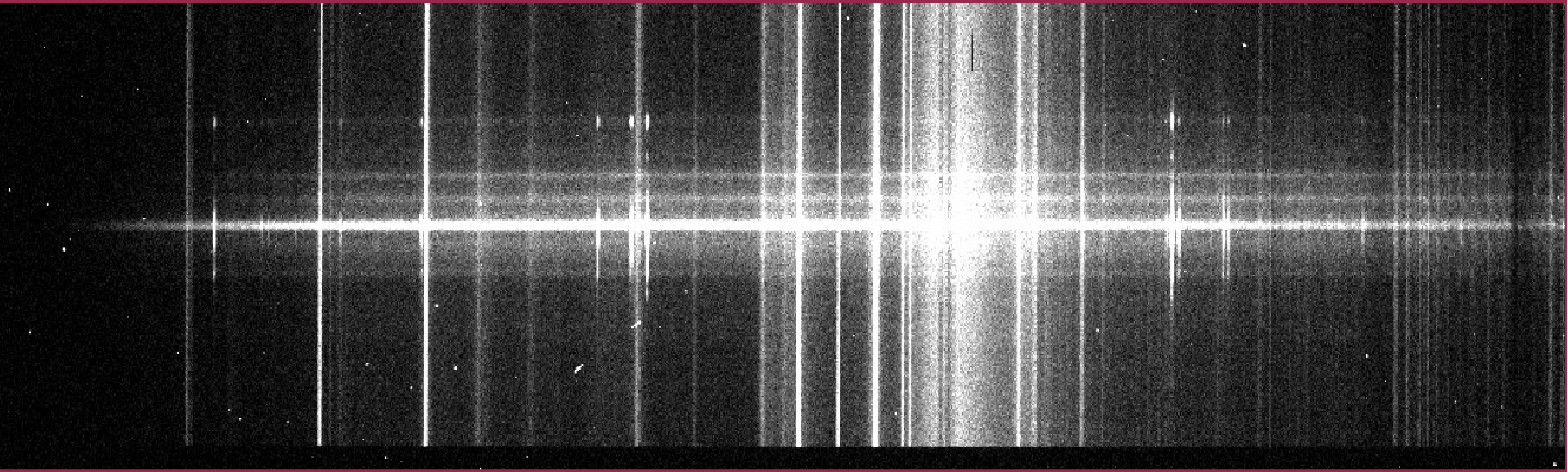
λ

Hg-Ne-Ar Lamp



λ

Object spectrum



λ

The ASGRED data reduction package

IRAF window

```
        apropos     fitsutil.   images.     nmisc.      rvsao.      taxe16.
        color.      fuzzy.      language.   noao.       softools.   utilities.
        ctio.       gemini.     lists.      obsolete.   stsdas.     vol.
        dataio.     gmisc.      mscred.     plot.       system.
        dbms.       guiapps.    nlocal.     proto.      tables.

ecl> asgred


        +-------------------------------------------------------------+
        |                          ASGRED                             |
        |                                                             |
        |           Asiago 120cm + B&C  Reduction Package             |
        |                                                             |
        |                 Version February, 2009                      |
        |                                                             |
        +-------------------------------------------------------------+


        cosmics     newsethdr   prered2     skysub      wlcal2
        fcal        prered      sethdr      wlcal

asgred>
```

ASGRED tasks and their role

IRAF window

```
     |              Asiago 120cm + B&C  Reduction Package             |
     |                                                                 |
     |                   Version February, 2009                        |
     |                                                                 |
     +-----------------------------------------------------------------+


     cosmics     newsethdr   prered2     skysub      wlcal2
     fcal        prered      sethdr      wlcal

asgred> help


       cosmics - Remove cosmic rays
          fcal - Flux calibration procedure
        prered - Pre-reduction procedure (bias, flat)
       prered2 - New pre-reduction procedure (overscan, flat)
     newsethdr - Correct header (new version)
        sethdr - Correct header
        skysub - Remove night sky emission
         wlcal - Wavelength calibration procedure
        wlcal2 - Wavelength calibration and distortion correction

asgred>
```

Setting up ASGRED