Image and Spectrum Reduction with IRAF

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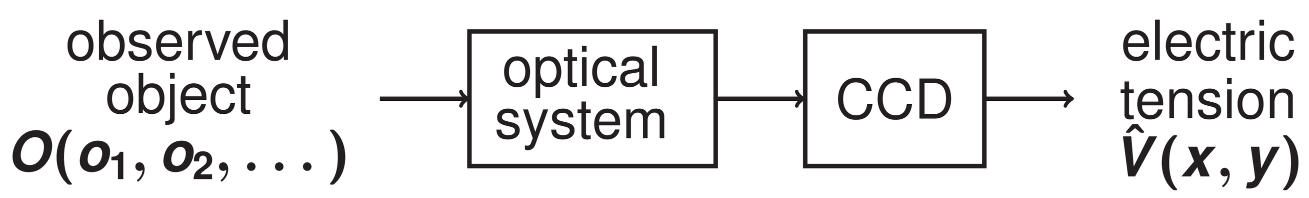
Images in astrophysics

- Astrophysics has **two particularities**:
  - it sees **experiments replaced by observations**
    - No way to change parameters
    - Results are generally a superposition of multiple effects
  - **Information is transmitted only by photons**
    - Images, spectra, light-curves, polarisation...

Main detectors in astronomy

- **Photographic plates**
  - ☺ high quality, durability
  - ☹ needs digitalization for processing, non linearity
- **CCD Camera**
  - ☺ linearity, sensitivity, digital quantities
  - ☹ reading speed, small FOV (so far)
- Infrared Camera
- Without spatial resolution: bolometers, photomultiplicators...

Raw CCD Observation & Image processing



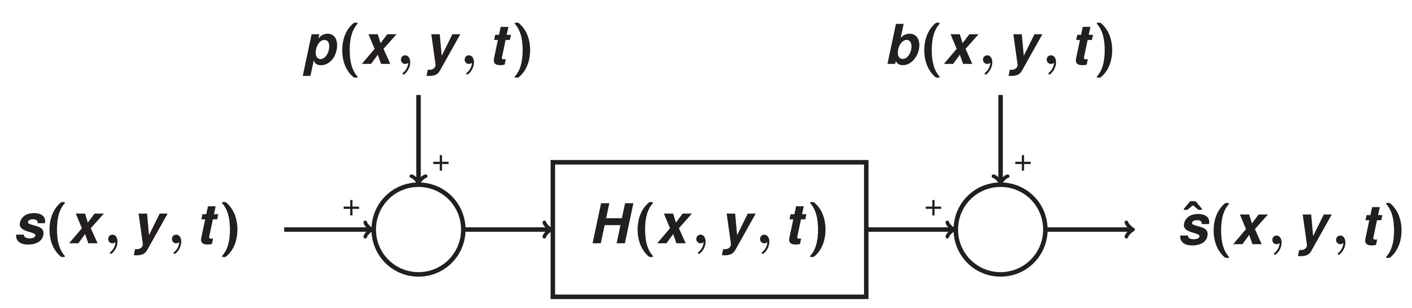
- Measure $\hat{V}$ comes from multiple sources:
  - photons from the source itself and the sky background
  - **read-out noise**
  - **dark current**, electric and thermal noise (while reading)

- $\{x_i\}$, instrument parameters (position on the detector, signal dynamic...)
- $\{y_i\}$, astrophysical quantities (wavelength, sky position, ...)
- $\hat{M}$ estimated quantity such as a calibrated flux, a polarisation...

Data Reduction: 3 Major Steps

1. **Reduction**: Corrects artifacts and instrumental defects
2. **Calibration**: Transforms instrumental values into calibrated data
3. **Measurements**: Extracts physical quantities

CCD Reduction Principle



$$\tilde{s}(x, y, t) = H^{-1}(x, y, t) \times (\hat{s}(x, y, t) - b(x, y, t))$$

Generally applied as:

$$\tilde{s}(x, y) = \tilde{H}^{-1}(x, y) \times \left(\hat{s}(x, y) - \tilde{b}(x, y)\right)$$

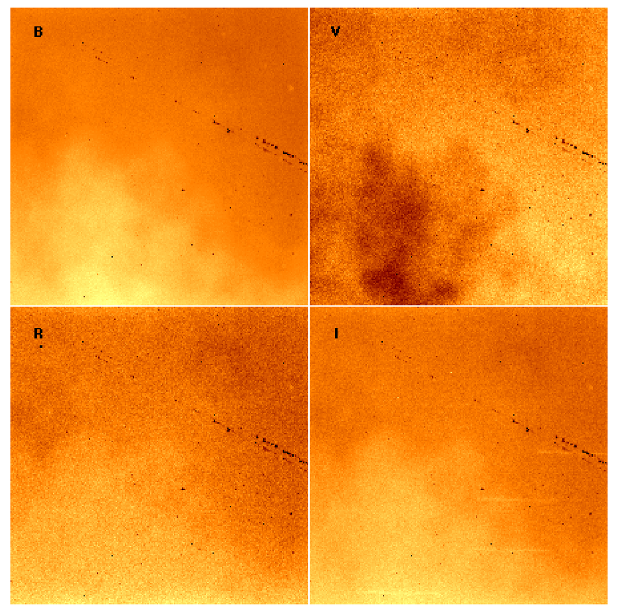
$$Image_{red.} = (Image_{raw} - bias) / flat_{norm.}$$

- p sums all the perturbation sources between the object and the observer (e.g. atmosphere,...)
- modified quantity Q is written $\hat{Q}$
- estimated quantities Q is written $\tilde{Q}$

Flat-Field: $\hat{H}(x, y)$ *Instrument Response, white balance*

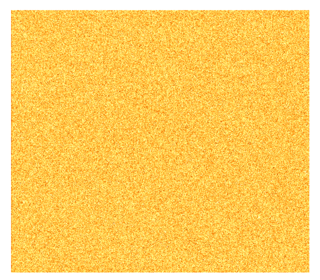
Wavelength dependent!

- Corrects from non-equal CCD pixel responses
- Valid within the tension fluctuations limit
- Quality criteria: light uniformity, mean value $\approx \frac{1}{2}$ detector's dynamic.
- 'Master–Flat' median of multiple normalized flat images.

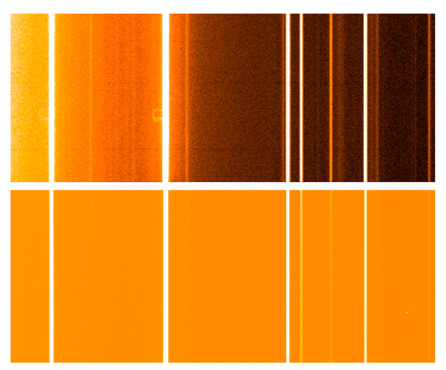


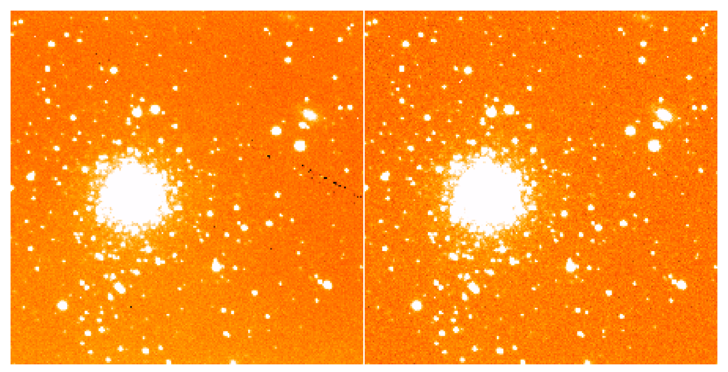
Bias: $\hat{b}(x, y)$ *Instrument Offset*

- Corrects from residual detector tension.
- **Image with a "null" exposure time**
- 'Master–Bias' median of multiple bias images.



Reduced Images Examples





Starting with IRAF

- Profil creation: `$ mkiraf` (originally one profile per project)
- Change default profile: `$ vi loginuser.cl`

```
# LOGINUSER.CL -- IRAF User login file
    set stdimage=imt1024
    set imtype = 'fits'
    keep #Very important to have this
```

- Use IRAF **in the `login.cl` (profile) directory**.
- Run within an **xgterm** in compound with `ds9`: `$ xgterm -e cl &`

Frequently Used Commands

http://w1.ira.cnr.it/Computing/manuals/stsdas/UserQR.ps

- Get help about commands: **`help <command>`**
- Display an image: `display dev$pix 1 xrange- xscale- z1=0 z2=900`
- Display a sub-image: `display dev$pix[20:200,120:400] 2`
- Plot an image (line or column): `implot dev$pix 18`
- Image arithmetic: `imarith im1 / im2 output`
- Combine images: `imcombine im* output combine='median'`
- Plot spectrum: `splot image`

Image Reduction

- **Master–Bias**: `cl> imcombine offset/* master_bias combine='median'`
- **Master–Flat**:
  1. `cl> imarith flats/* - master_bias flats/*//tmp`
  2. `cl> imarith flats/kr930044tmp / 32427. flats /kr930044n` for each flat
  3. `cl> imcombine flats/*n master_flat combine='median'` **same λ!!**
- **Image Reduction**:
  1. `cl> imarith ngc7006/* - master_bias ngc7006/*//tmp`
  2. `cl> imarith ngc7006/*tmp / master_flat ngc7006/*//red`

Spectrum Calibration:get a (geometric) relation $\lambda(x, y)$, generally from *He* lamp

- identify significant lines: `cl> identify master_he`
  - `m` affect λ to peaks
  - `:func cheby` change interpolation function
  - `:order 3` change interpolation order
  - `f` fit spectrum
- **1D** Fit calibration: `calib`
- **2D** Extend identification `reidentify`
- **2D** Fit calibration: `fitcoords`
  - `y` modify y axis signification
  - `r` replot after modifications
  - `d / y` delete current point/line
  - `f` fit 2D spectrum
- Affect calibration to spectrum: `cl> transform image ref out`

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