OBSERVATIONAL ASTROPHYSICS AND DATA ANALYSIS

Lecture 10

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Methods of Observations

- Imaging
- Photometry
- Spectroscopy
- Polarimetry
- Interferometry

The Primary Tools of Astronomy

Light is the only thing we can work with. What can we do with it?

- Imaging – we can take "pictures" of the things we see. But pictures alone tend to lack the "quantitative" aspect that is needed for most serious scientific studies.
- Photometry – the technique that measures the relative *amounts* of light in different wavelength ranges.
  But these ranges are too wide to provide detailed information on the light's spectral distribution.
- Spectroscopy (spectrophotometry) – the most informative technique of light analysis, that measures how much light an object produces at various wavelengths of light.

Imaging

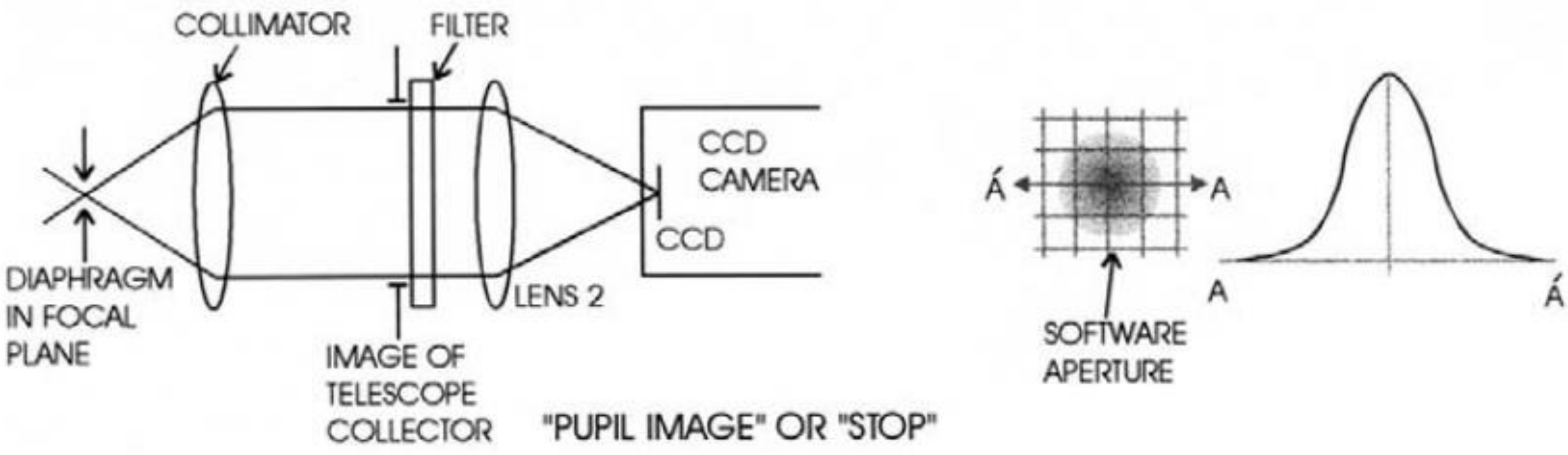
- Mapping the distribution of celestial sources on the sky in order to locate the position of source precisely – astrometry.
- Getting information on the source's form and that of its local environment.

Imaging

Pixel sampling and matching to the plate scale.

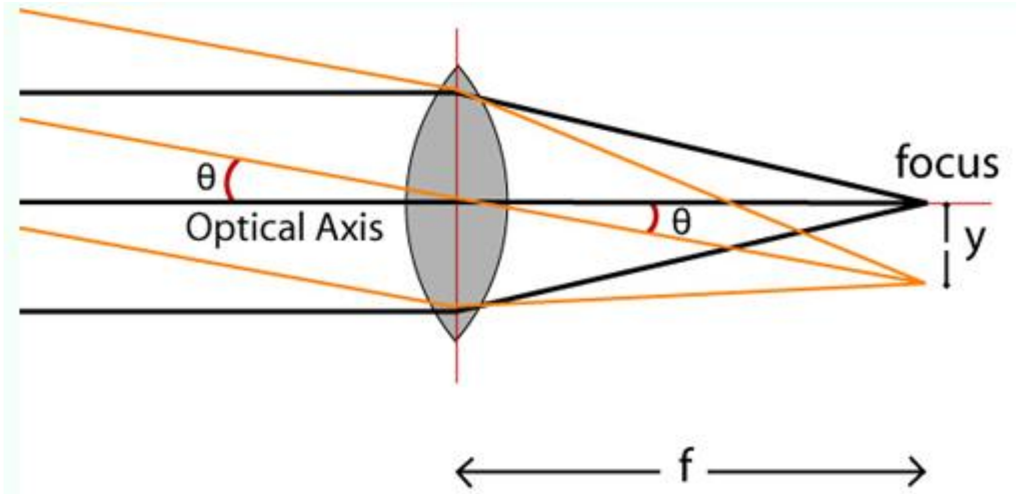
Two issues:

1. Maximizing observing efficiency → more light onto a pixel → less integration time
2. No compromise to the ability to obtain accurate brightness measurements



Imaging

- The plate scale of the telescope: $ps = \frac{206265}{f}$ [“/mm]



- For direct imaging, the angle on the sky subtended by the detector pixel is $\theta = ps\ d_{pix}$
  where d_{pix} is the physical pixel size in mm

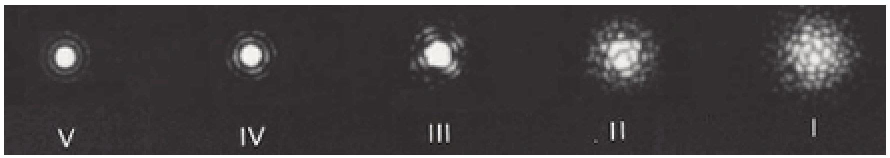
Imaging

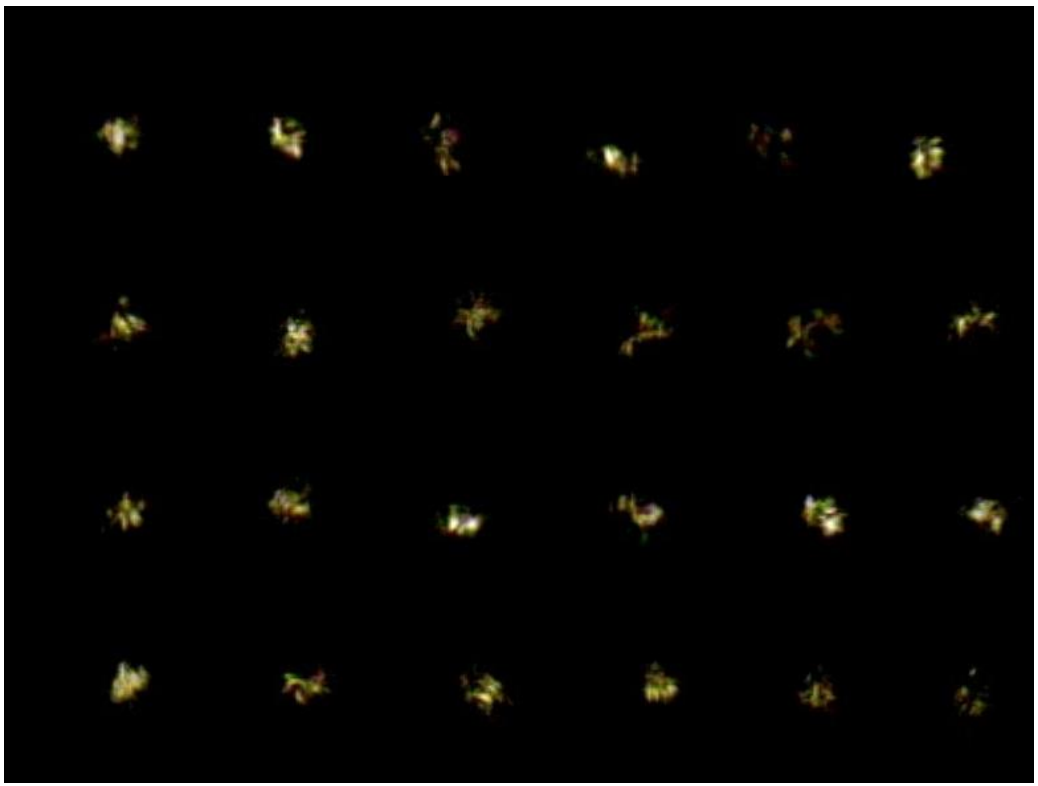
The spatial resolution element may be determined by seeing conditions or by optical constrains.

- In general, the image is critically sampled if there are about 2 pixels (the Nyquist limit) across the resolution element
- Or the image is oversampled if there are a few pixels (~4-5) across the resolution element

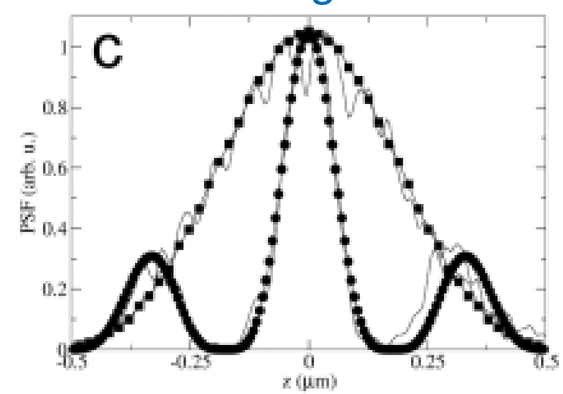
The resolution element: diffraction limit and seeing!

Imaging and Seeing





Ground-based telescope resolution is determined by the atmosphere, rather than aperture size. The central maxima of a Point Spread Function (PSF) expanded by turbulence is called *seeing disc*, and its FWHM is *seeing*.

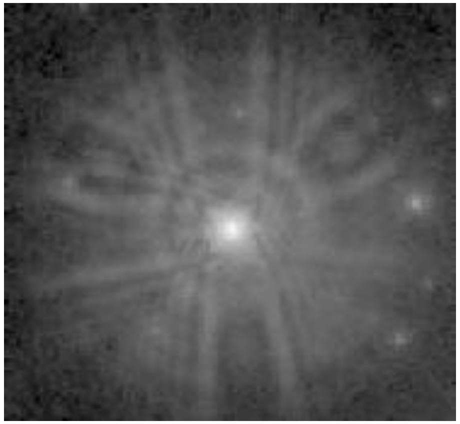


Imaging: PSF, convolution & deconvolution

- The **Point Spread Function** (PSF) is the main brick that builds up the whole acquired image.

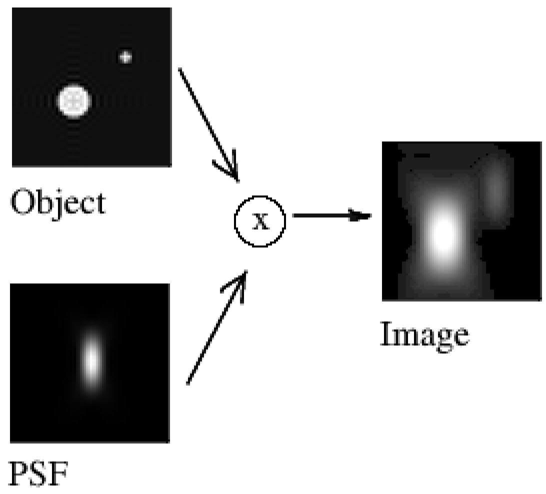
- The PSF is the image of a single point object (rescaled to make its integral all over the space equal 1). The degree of spreading (blurring) in the image of this point object is a measure for the quality of an image.

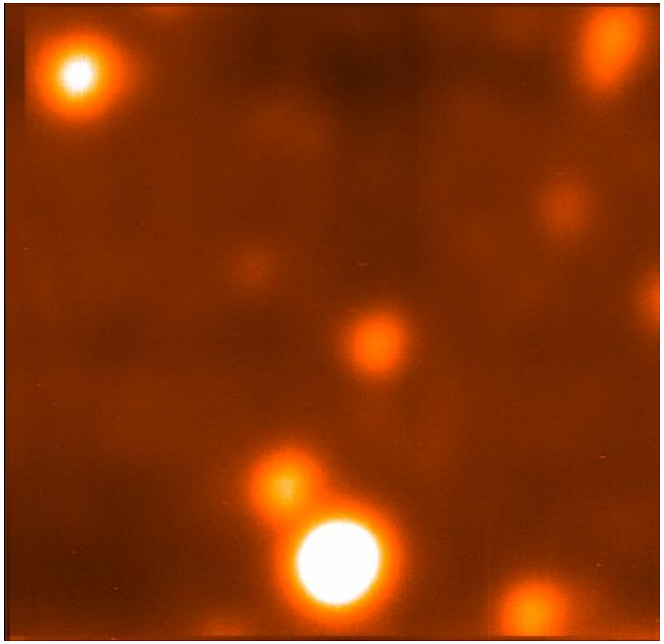
- The point spread function of Hubble Space Telescope's WFPC camera before corrections were applied to its optical system.



Imaging: PSF, convolution & deconvolution

- **Convolution:** The process is mathematically described by a convolution equation of the form $g = h * f$, where the image *g* arises from the convolution of the real light sources *f* (the object) and the PSF *h*.
- You can imagine that an image is formed in your telescope by *replacing* every original Sub Resolution light source by its Point Spread Function (multiplied by the correspondent intensity).





Imaging: PSF, convolution & deconvolution

- **Deconvolution (Image restoration)** is the recovery of images from raw data. Deconvolution is an "inverse" problem: the object of deconvolution is to find the solution of a convolution equation of the form

$$h * f + \varepsilon = g,$$

where h is PSF, g is some recorded image, ε is noise that has entered our recorded signal, and f is the real light source that should be recovered.

- The algorithms and methods are:
  - **Richardson – Lucy** deconvolution
  - **Maximum Entropy Method**

Lucky Imaging

- Lucky Imaging is an effective technique for delivering near-diffraction-limited imaging on ground-based telescopes.
- The basic principle is that the atmospheric turbulence that normally limits the resolution of ground-based observations is a statistical process. If images are taken fast enough to freeze the motion caused by the turbulence we find that a significant number of frames are very sharp indeed where the statistical fluctuations are minimal.
- By combining these sharp images we can produce a much better one than is normally possible from the ground.