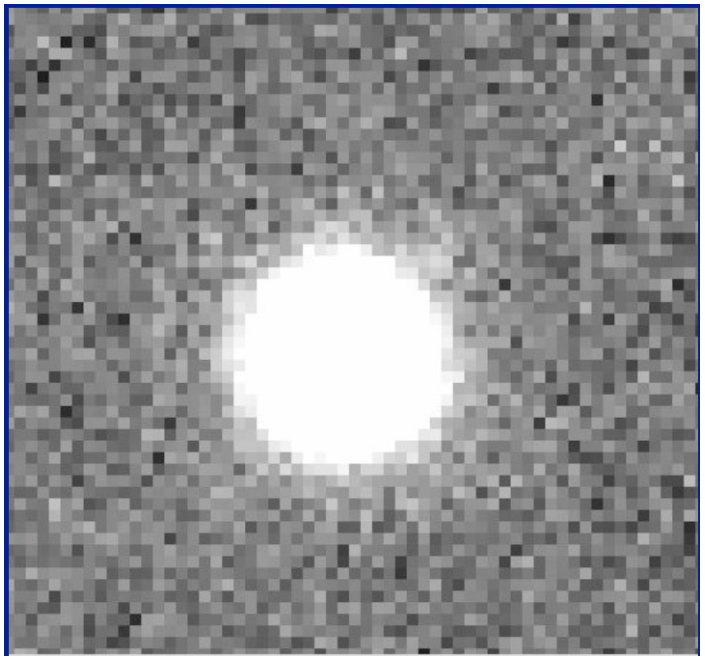
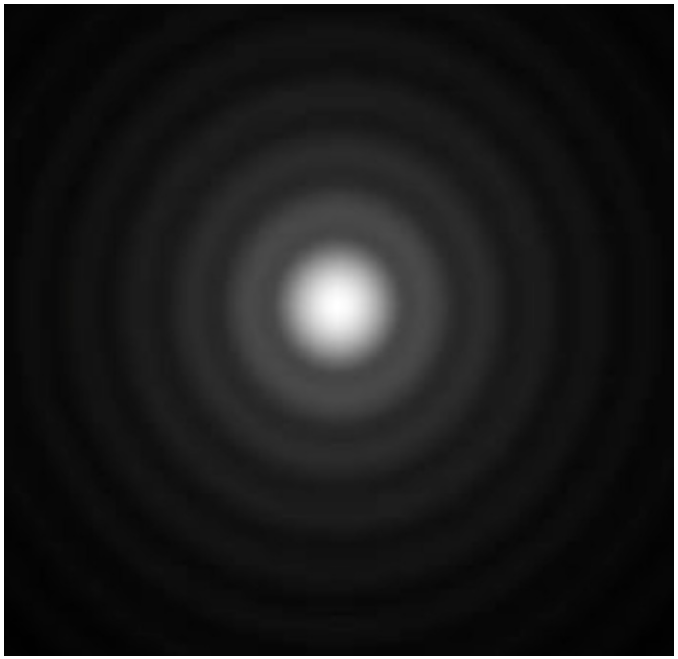
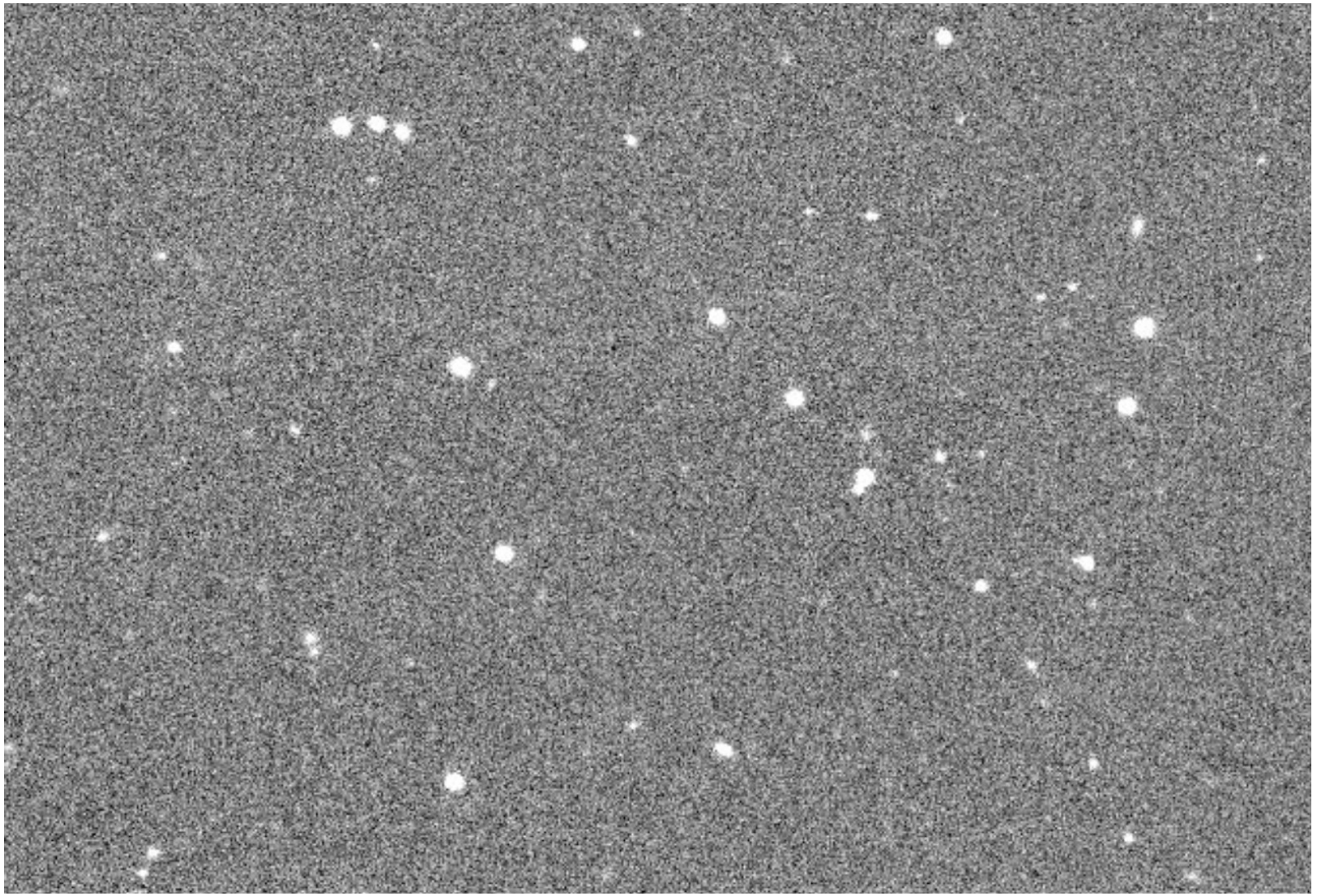
Astronomical Photometry

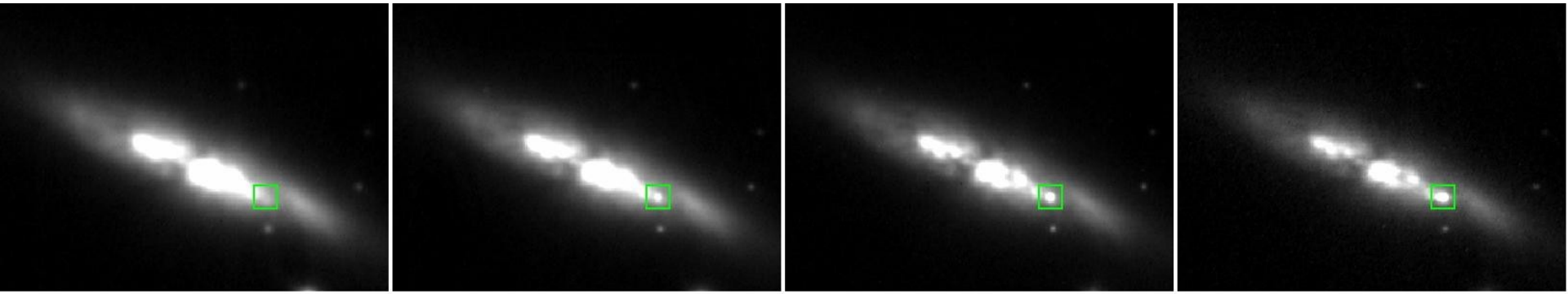
- Identify objects in your image
- Measure the flux from an object
- Estimate the uncertainties of the flux





Defining an Object

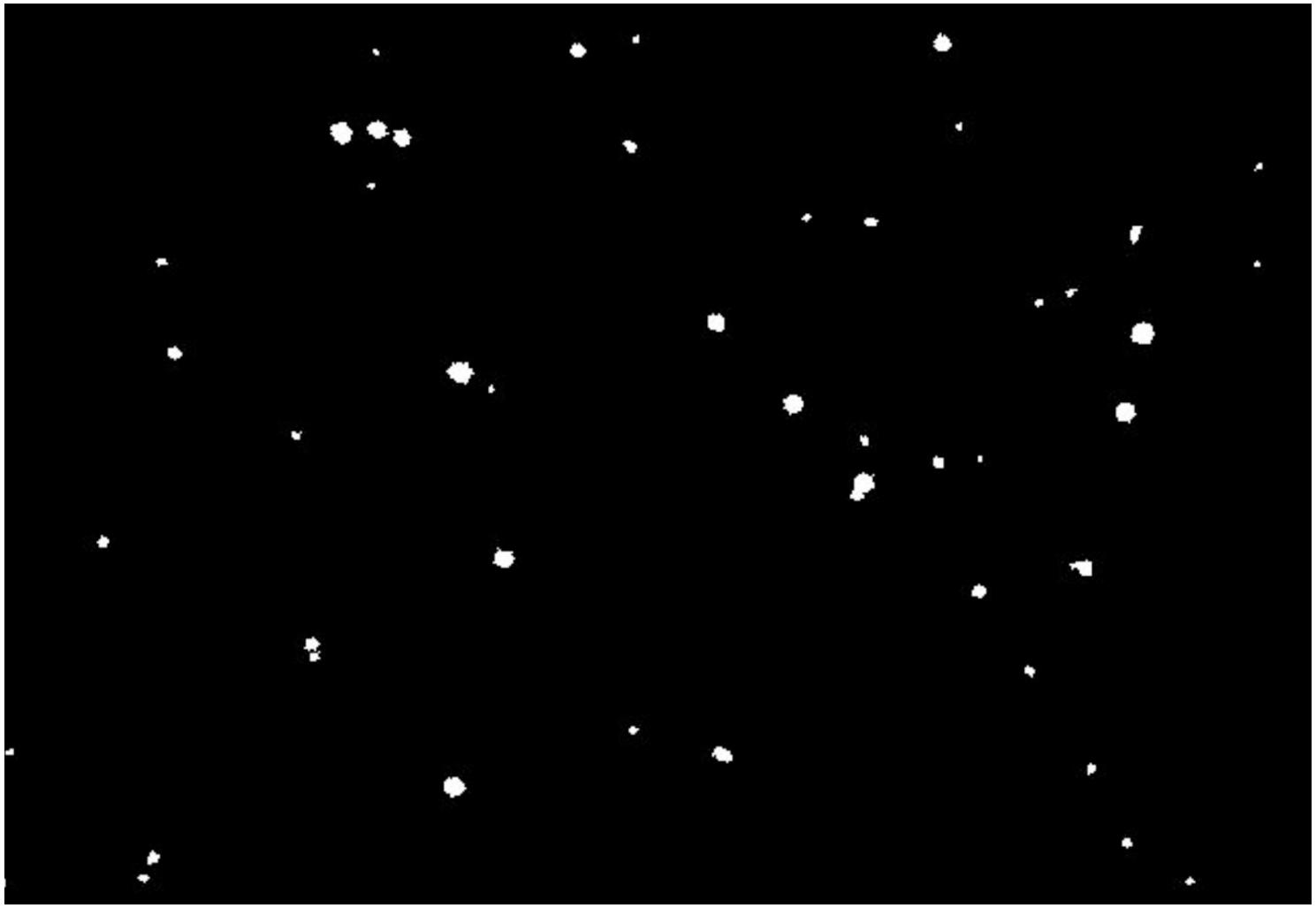




Jan 11 Jan 15 Jan 17 Jan 19

Detection

- Define a *detection threshold* and *detection area.* An object is detected only if it has N pixels above the threshold.
- A simple algorithm:
  - Generate a segmentation image that includes only pixels above the threshold
  - Identify each group of contiguous pixels, and call it an object if there are more than N contiguous pixels

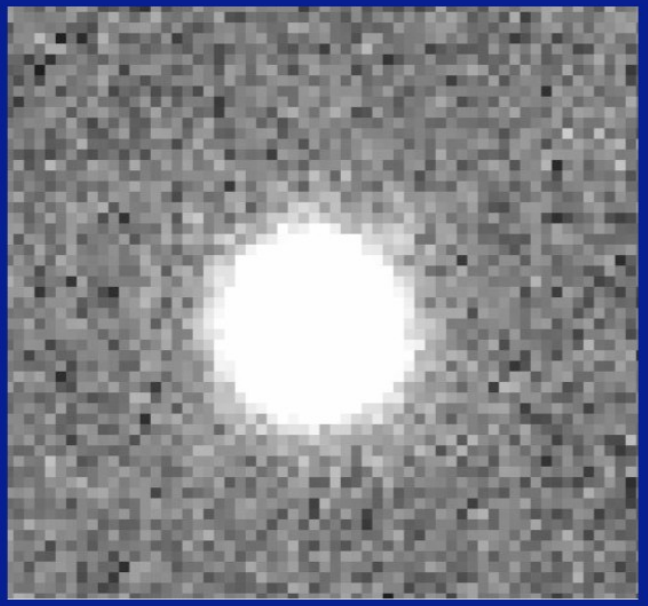


Background (Sky) Flux

- Background
  - The total flux that you measure (*F*) is the sum of the flux from the object (I) and the sky (S).

$$F = I + S = \sum I_{ij} + n_{pix} \cdot sky / pixel$$

  - Must accurately determine the level of the background to obtaining meaningful photometry (We'll return to this a bit later.)



Photometric Errors

Issues impacting the photometric uncertainties:

- Poisson Error
  - Recall that the statistical uncertainty is Poisson in electrons rather than ADU. In ADU, the uncertainty is

$$\sigma_{ADU} = \sqrt{ADU / Gain}$$

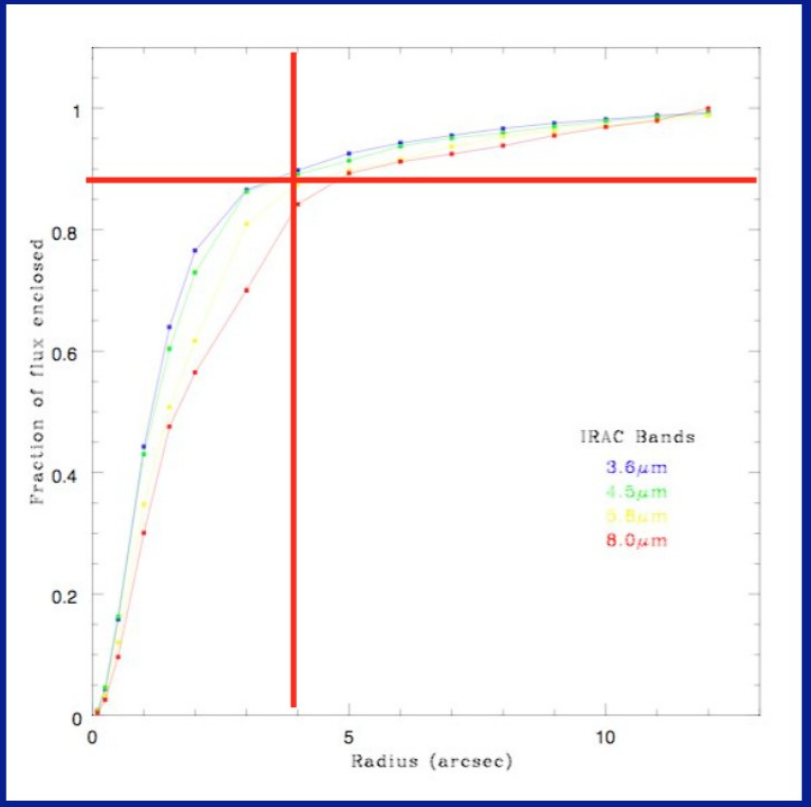
- Crowded field contamination
  - Flux from nearby objects can lead to errors in either background or source flux

- Correlated pixel statistics
  - Interpolation when combining images leads the uncertainties to be non-Poisson because the pixels are correlated.

II. Stellar Photometry

- Stars are unresolved point sources
  - Distribution of light determined purely by point spread function (PSF)
  - How do you measure the light?

- "Curve of Growth"
  - Radial profile showing the fraction of total light within a given radius



http://www.cfht.hawaii.edu/~morrison/home/GOODS/curve_of_growth.html

- PSF fitting:
  - Determine the form of the PSF and then fit the amplitude to all the stars in the image.
  - Typical parameterizations of PSF
    - Gaussian

      $I(r) = \exp(-0.5 * (r/\sigma)^2)$

      $F(r) = 1 - \exp(-0.5 * (r/\sigma)^2)$

      $FWHM = 2\sigma * \sqrt{(2 * \ln(2))}$
    - Moffatt

      $I(r) = (1 + (r/\alpha)^2)^{-\beta}$

      $F(r) = 1 - (1 + (r/\alpha)^2)^{(1-\beta)}$

      $FWHM = 2\alpha * \sqrt{(2^{1/\beta} - 1)}$

    where I(r) is the intensity profile and F(r) is the enclosed flux profile. F(r) is typically what is fit to determine the best parameters. The FWHM formulae correspond to what you would see in IRAF using imexam.

- PSF fitting:
  - Determine the form of the PSF and then fit the amplitude to all the stars in the image.
  - Typical parameterizations of PSF

Gaussian

$$I(r) = e^{-r^2/2\sigma^2}$$

$$F(r) = 1 - e^{-r^2/2\sigma^2}$$

$$FWHM = 2\sigma\sqrt{2\ln 2}$$

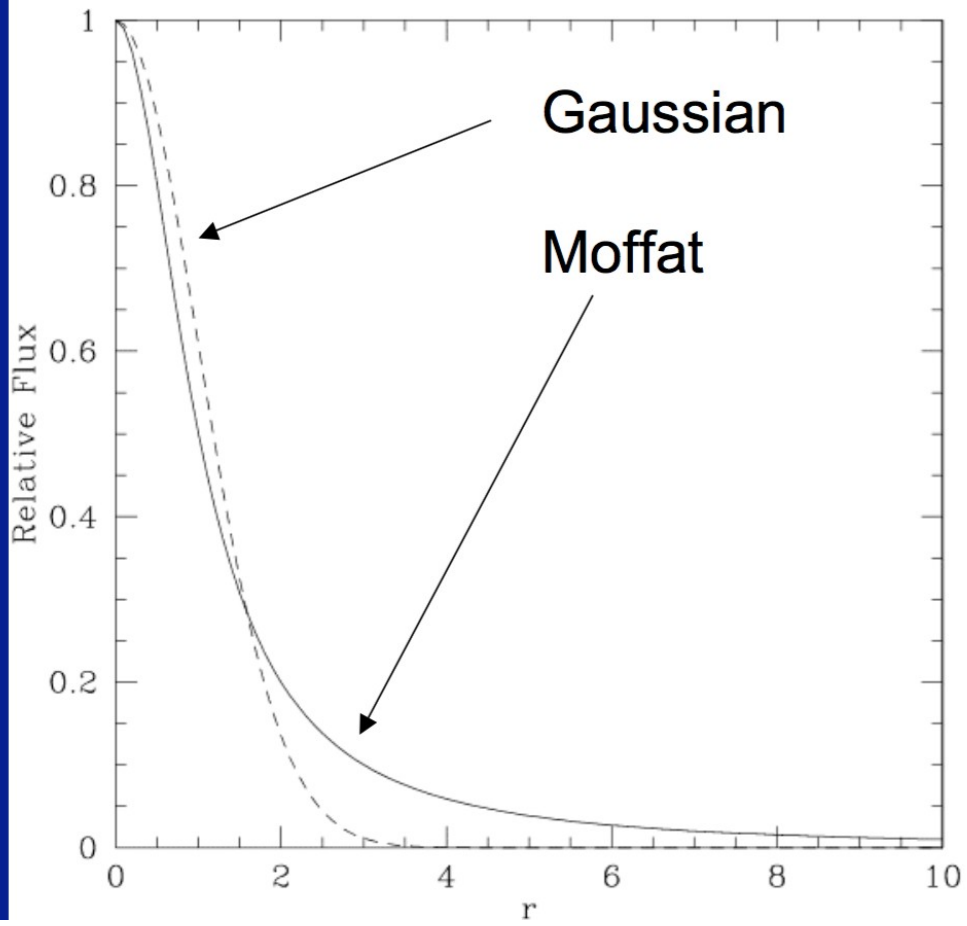
Moffat

$$I(r) = \left(1 + \left(r/\alpha\right)^2\right)^{-\beta}$$

$$F(r) = 1 - \left(1 + \left(r/\alpha\right)^2\right)^{1-\beta}$$

$$FWHM = 2\sigma\sqrt{2^{1/\beta} - 1}$$

where I(r) is the intensity profile and F(r) is the enclosed flux profile. F(r) is typically what is fit to determine the best parameters. The FWHM formulae correspond to what you would see in IRAF using imexam.



Gaussian: $\sigma=1$

Moffat: $\alpha=1$

$\beta=1$

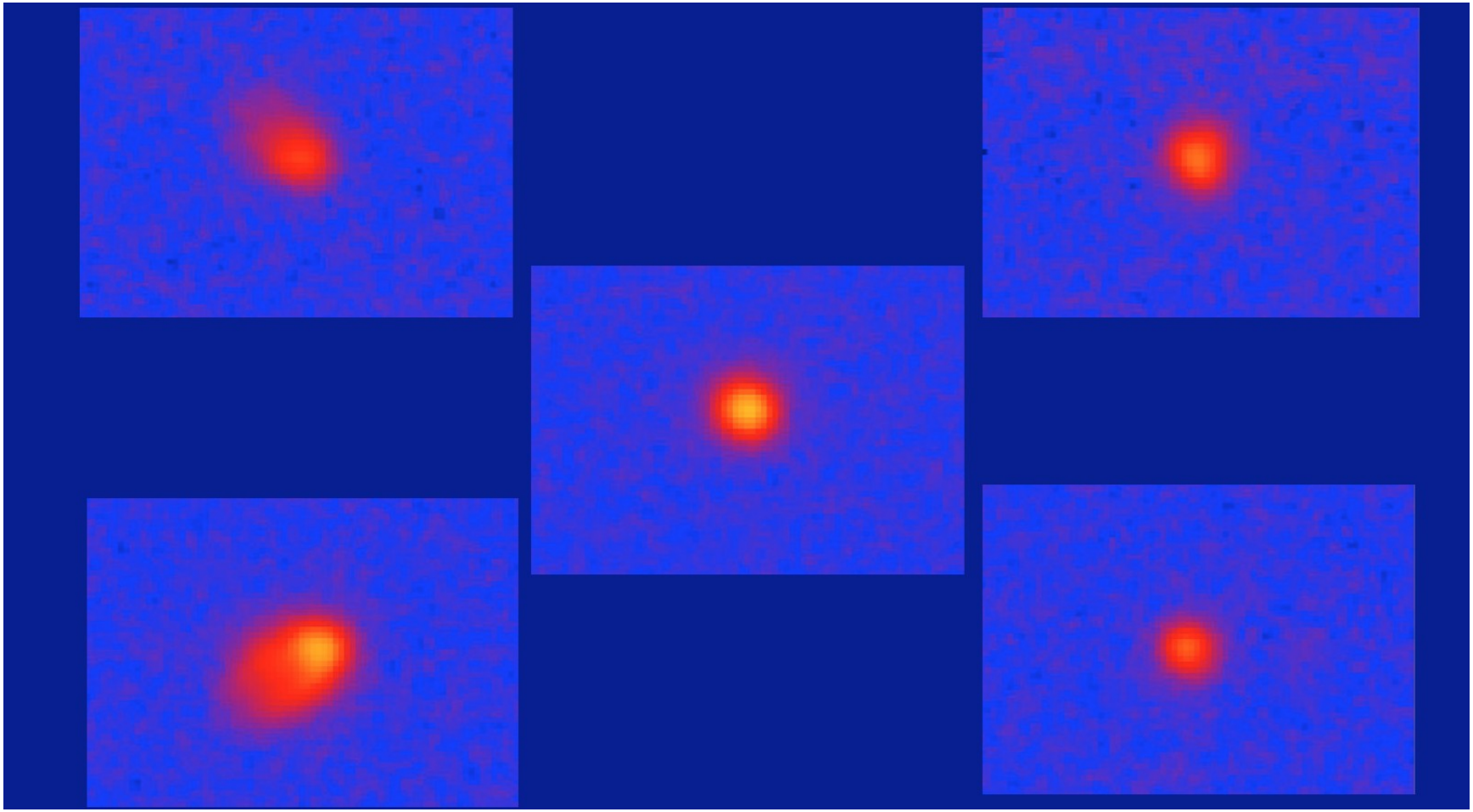
fitting:

Advantages:

- Still works in crowded fields (can fit the center)
- Regions with highest S/N have most weight in determining fit
- Background is included as one additional parameter (constant in the fit)

Potential problems:

- The PSF is not well described by the parametric profiles.
- The PSF varies across the detector.



- Determining Photometric Errors
  - Best approach: Artificial Star Tests
    - Basic idea - Insert a large number of fake stars into image and then obtain photometry for these objects.
    - Provides a direct measure of the scatter between true and observed magnitudes
    - Caveat: Requires that you have a good model for the PSF

Stellar Photometry: Codes

- DAOPHOT
  - Written by Peter Stetson
  - The standard in the field for several decades
  - Can be run standalone or as part of IRAF
  - Handles PSF variations and aberrations
  - Can perform artificial star tests to get uncertainties
  - Steep learning curve
- Starfinder (www.bo.astro.it/~giangi/StarFinder/index.html)
  - IDL routines, relatively new
  - Straightforward interface
  - Not currently designed to handle PSF variations

Optimal Extraction

http://mnras.oxfordjournals.org/content/296/2/339.full.pdf

http://www.beverlyhillsastronomer.org/photproc_x/