Image analysis

Andrew Hopkins
Australian Astronomical Observatory

With thanks to Naomi McClure-Griffiths
Any errors are all mine

Australian Government
Department of Industry
Innovation, Science, Research
and Tertiary Education

Outline

- Non-imaging analysis
- Parameter estimation
- Source-finding and statistics
- Radio source counts
- Visualisation

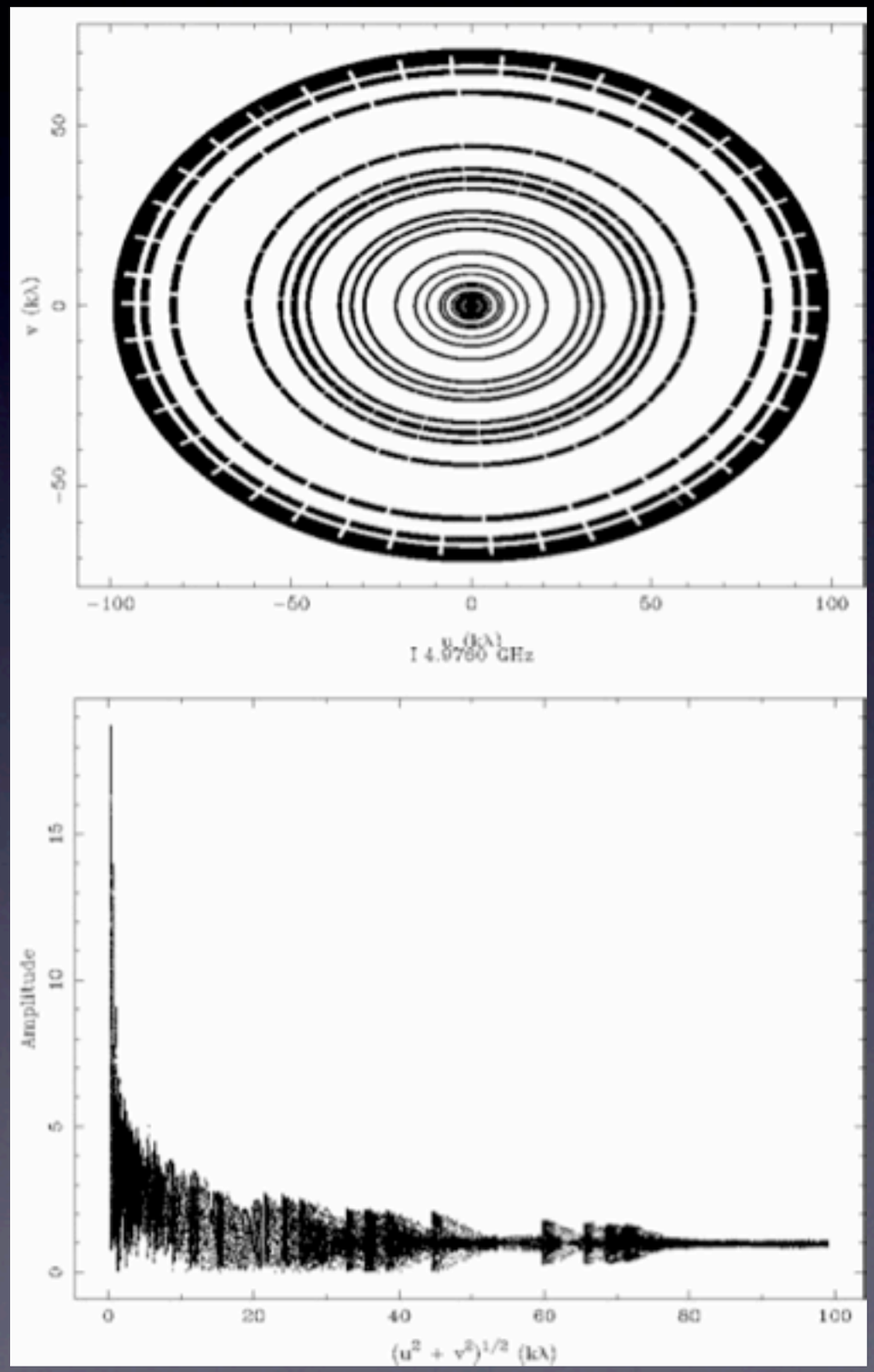
What do you want?

- Variability?
  - u-v amplitude vs time
  - flux vs time
- Measuring source positions, fluxes, sizes?
  - Gaussian fits
  - extended source fits
- Measuring source morphology?
  - visualisation
- Spectral line velocity, intensity, width?
  - Gaussian fits
  - moment analysis
- Emission mechanism (synchrotron/ thermal)?
  - spectral index
- Magnetic field properties?
  - polarisation angle and intensity
  - rotation measure, RM synthesis

Look at UV-data

- You can tell a lot without even making an image:
  - Amplitude vs time
  - Amplitude vs uv distance

- At times this may be the only way to get something from your data, particularly if:
  - You have poor uv coverage
  - You are only interested in the variability



Model fitting to UV-data

- Works best for targets that can be represented by a simple model with few parameters
  - Finding positions and fluxes for a few point sources
  - Modelling and subtracting a bright point source, especially if it is far from the pointing centre, before imaging and deconvolution can give a better deconvolution
- Some tools that do model fitting are:
  - miriad *uvflux*: fits a simple point source
  - miriad *uvfit*: fits point sources, Gaussians, disks, etc.

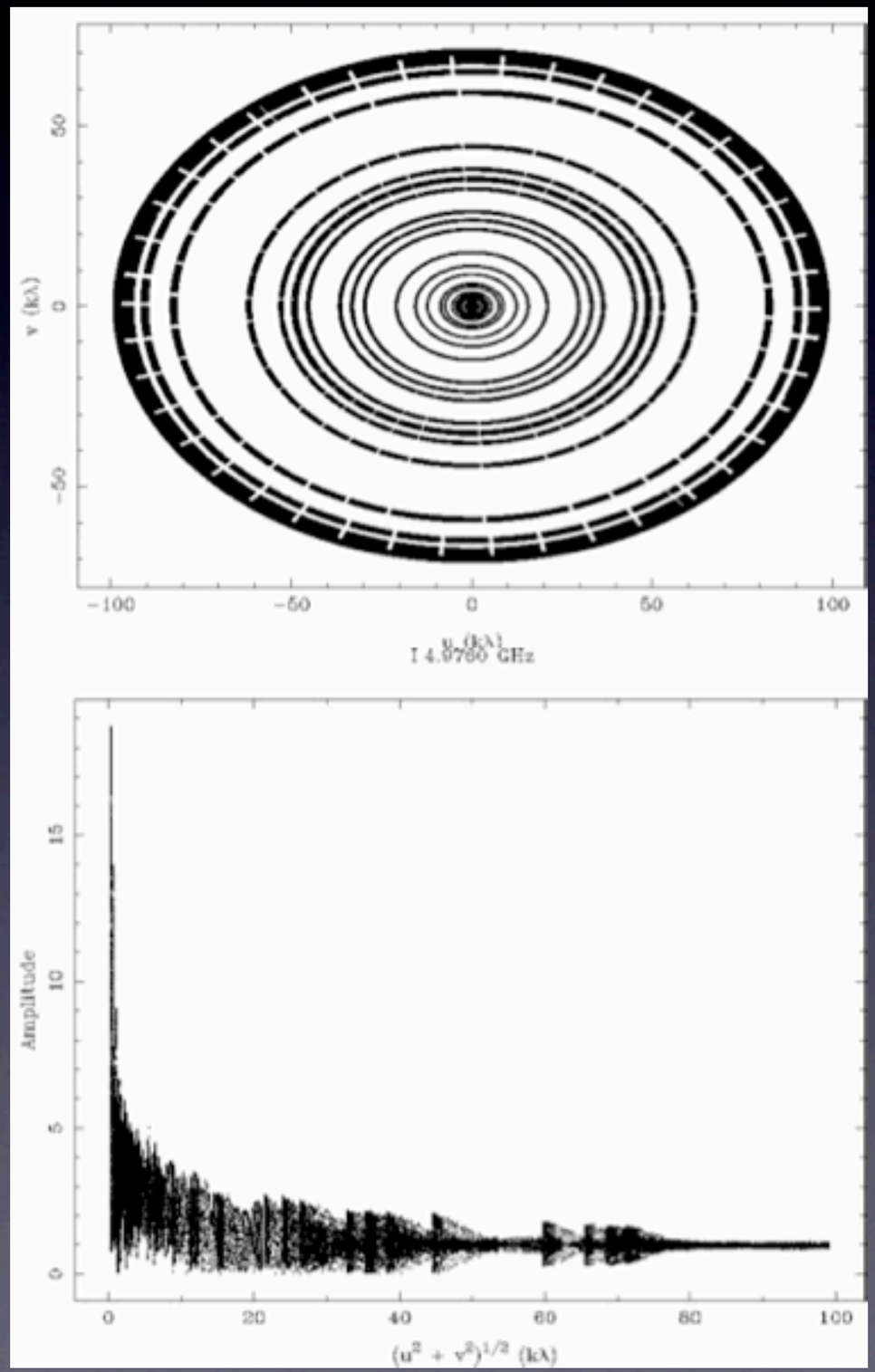
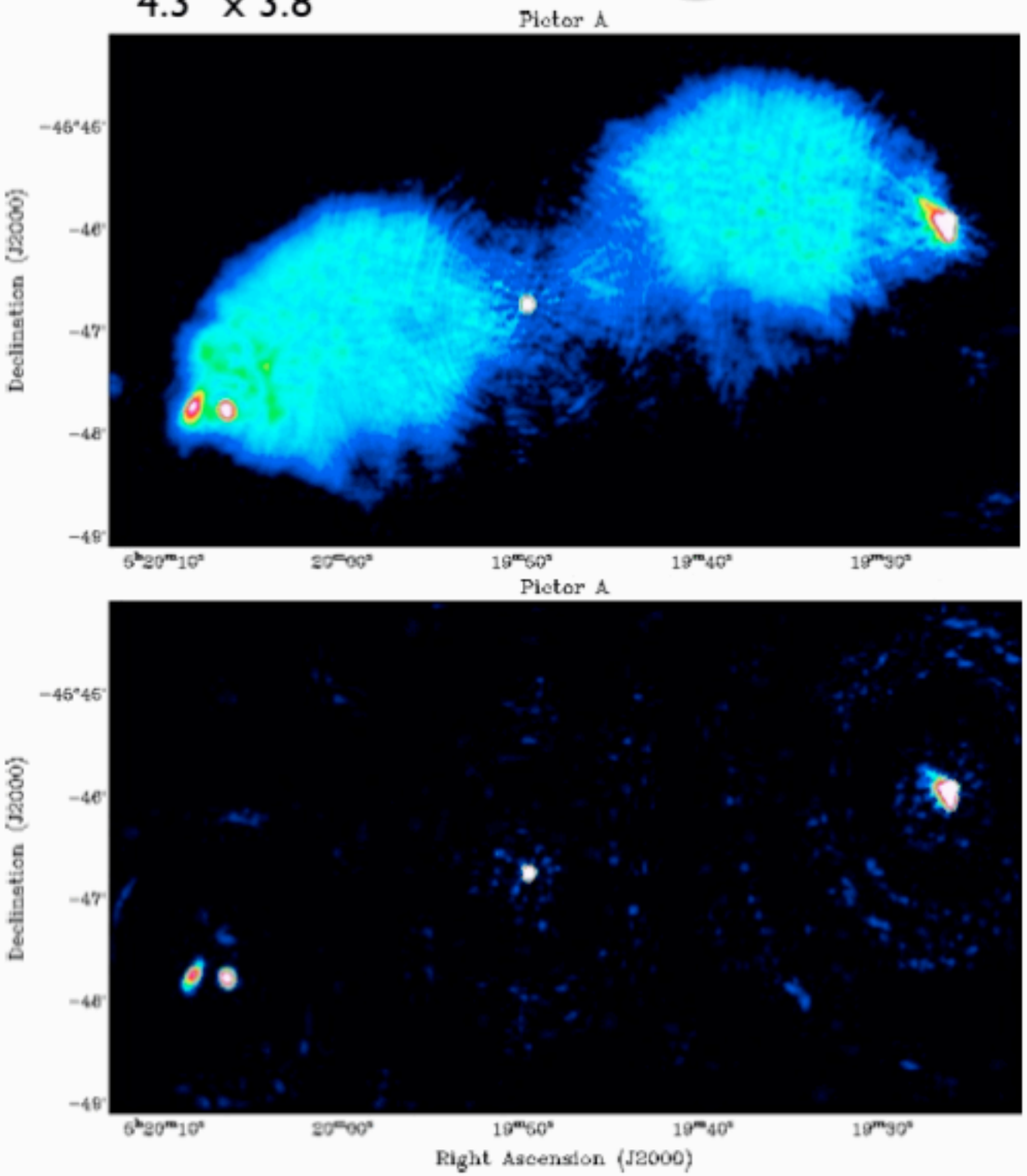


Image your data appropriately

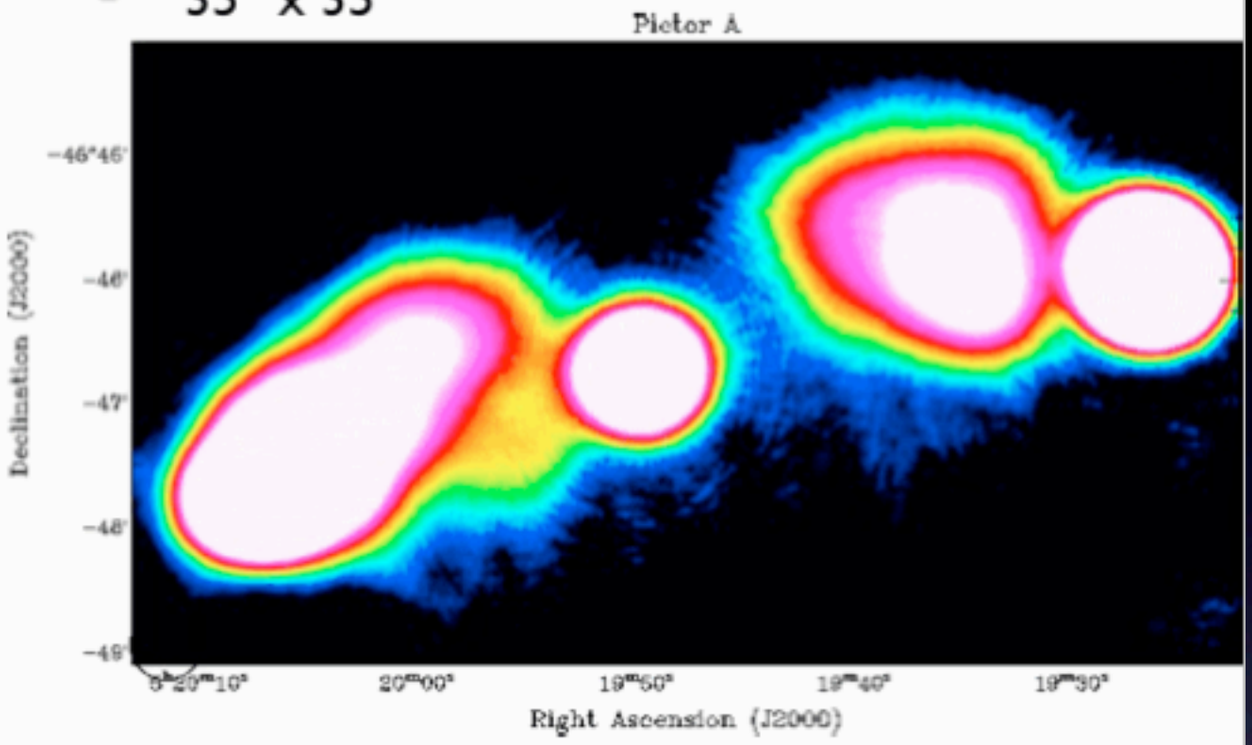
- Do you want to know source positions?
  - Image with as small a beam as possible
- Do you want to know the total flux?
  - Image with as large a beam as possible
- Do you want to look for low-level emission?
  - Smooth the image

Image Manipulation

4.3" x 3.8"



35" x 35"



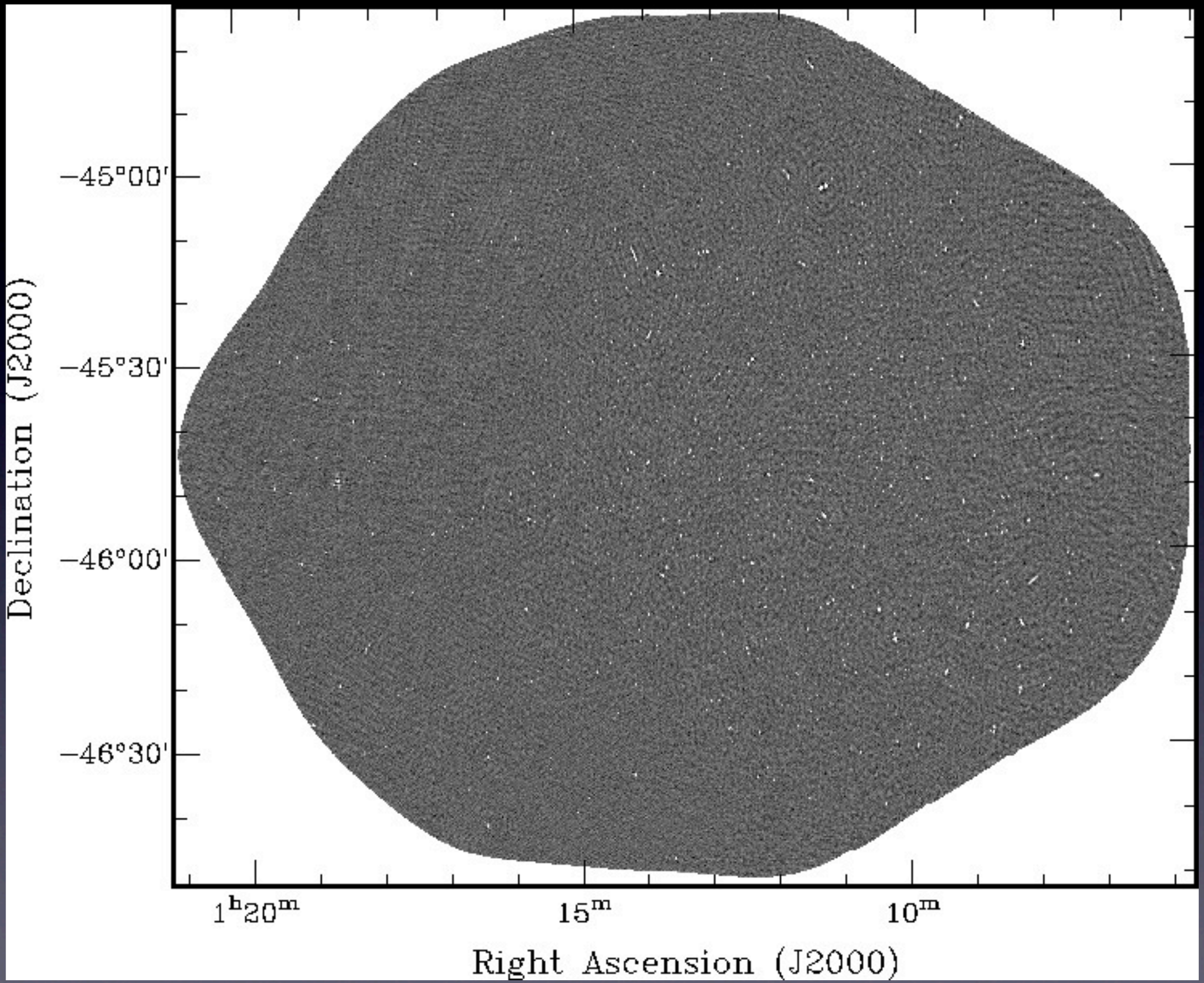
Each image emphasises a different aspect of the data:

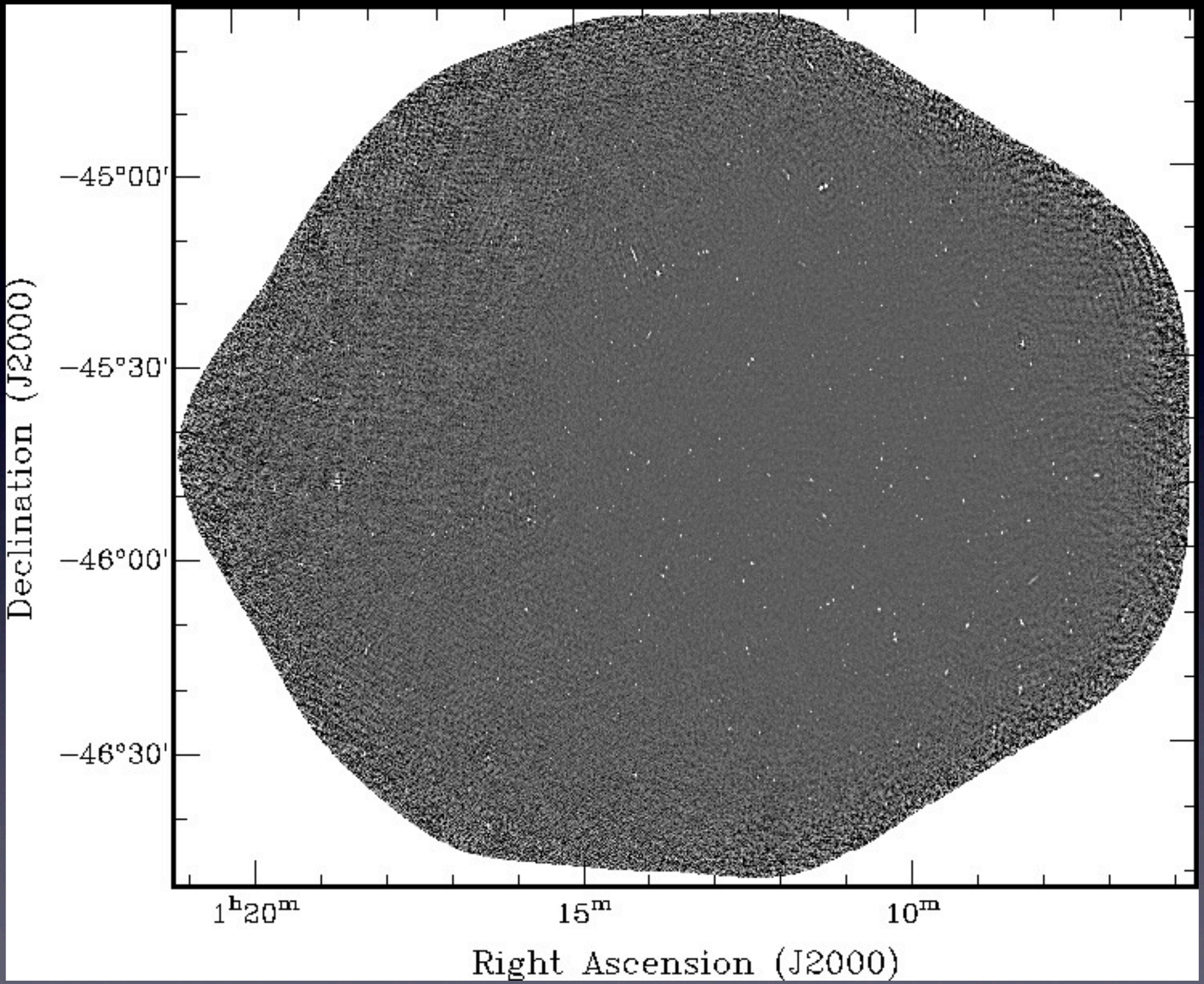
- Hot spots plus large scale emission
- Total flux
- Peak intensities

4.3" x 3.8" high-pass filter

Primary beam correction

- Beware the limitations of your image
  - Your image is weighted by the primary beam sensitivity.
  - Divide by the primary beam response to ensure sources have the correct flux density. Note that this highlights the increased noise at the edges of the image.


−45°00'
−45°30'
−46°00'
−46°30'
Declination (J2000)
1h20m
15m
10m
Right Ascension (J2000)


−45°00'
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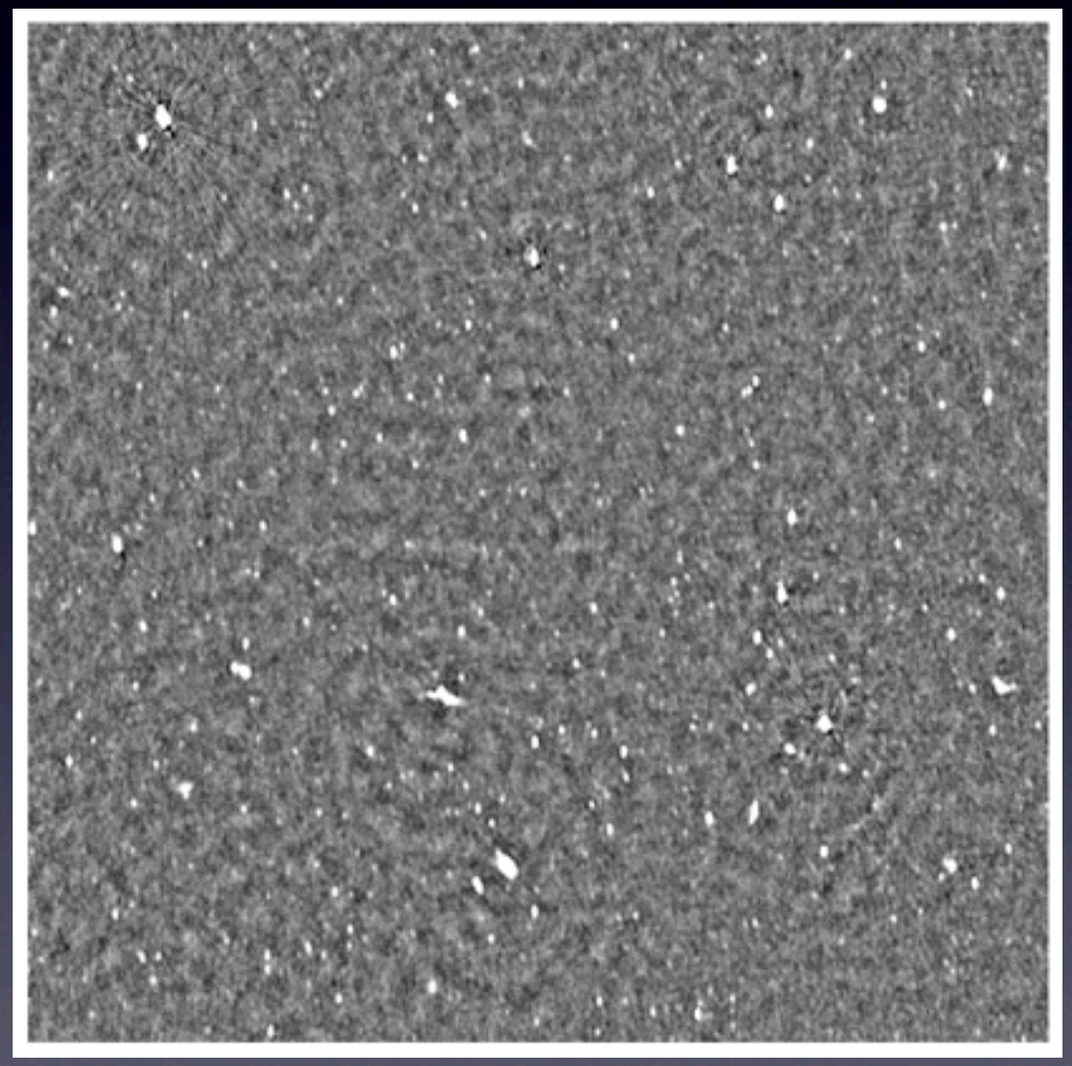
Source finding and measurement

- There are many tools for automated source finding and measurement:
  - miriad: *imsad, sfind, imfit*
  - CASA: *findsources, fitsky*
  - Duchamp/Selavy
  - SExtractor
- Limitations in the presence of artefacts, extended/complex emission
- New tools being developed



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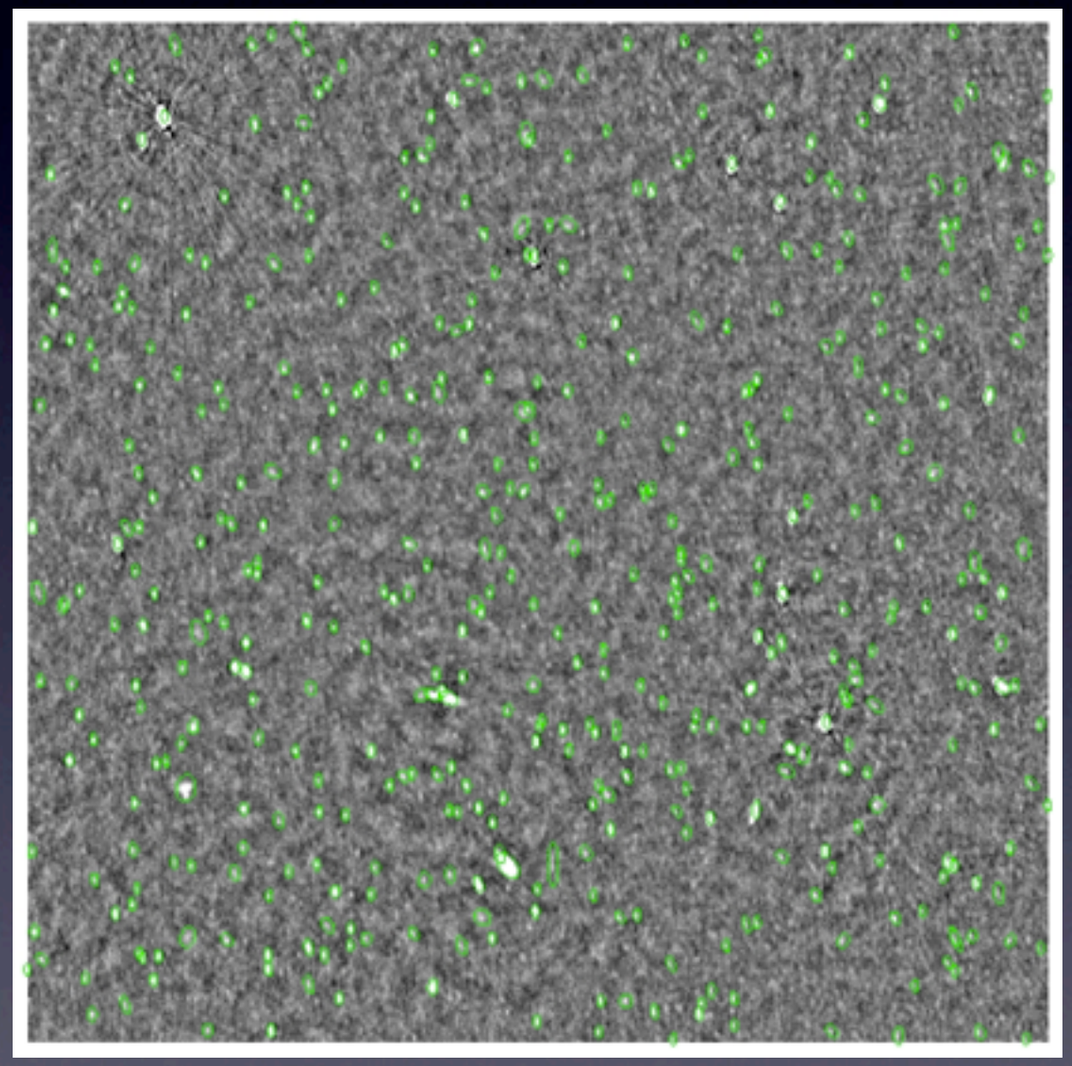
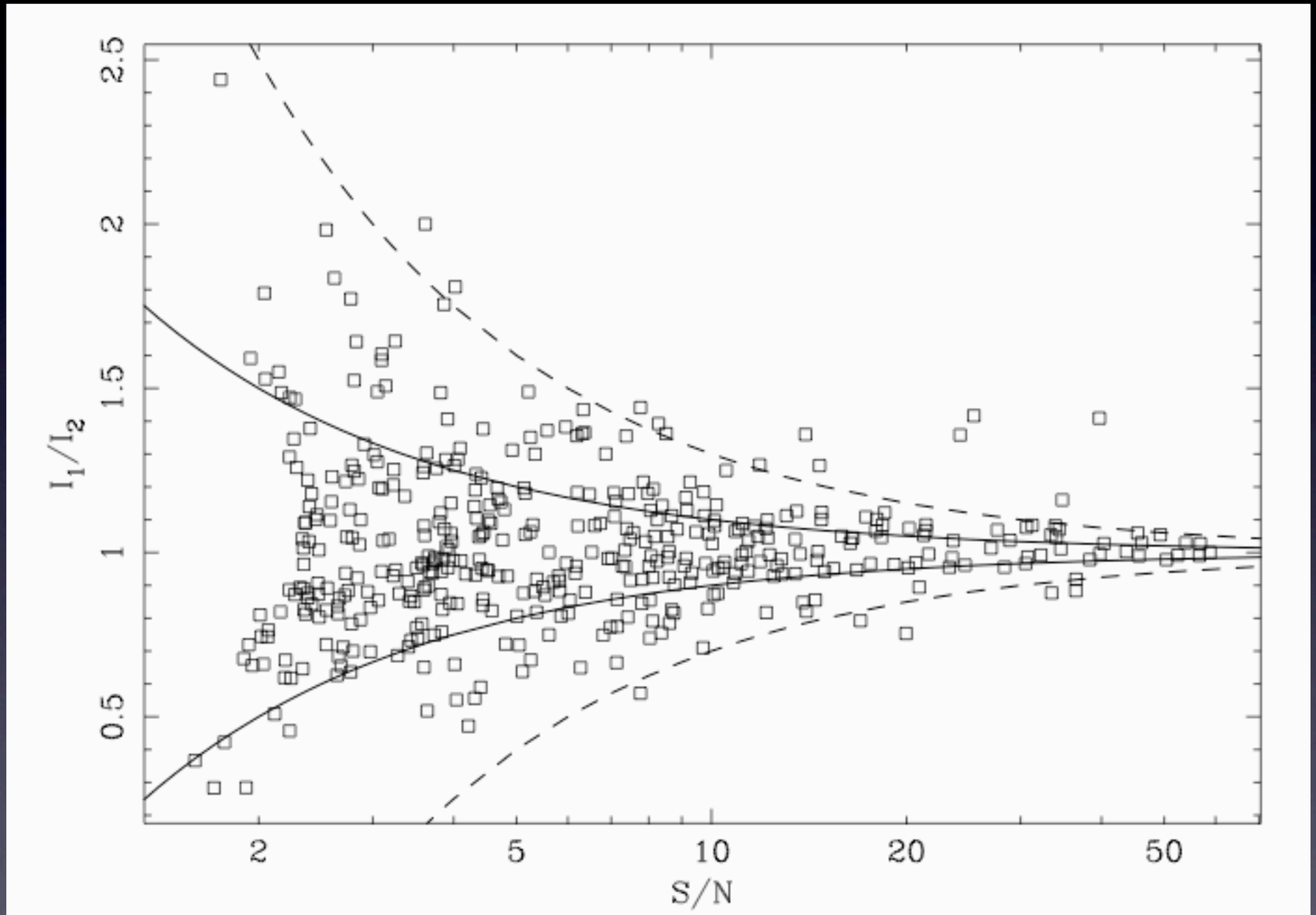


Flux error estimates



Hopkins et al., 2003, AJ, 125, 465

Source finding issues

- Background estimation
- Threshold definitions (3σ, 5σ, varying?) A 5σ threshold is a 6×10^{-7} chance of randomly occuring(but in a 10000×10000 pixel image, that is 6 pixels).
- Gaussian fitting (multiple component), isophotal contours, curve-of-growth, floodfill, etc.
- Deblending
- Complex or extended sources
- Dynamic range

Error types

- False-positives, Type I: Incorrectly identifying a background fluctuation as a source (i.e., false sources, false detections)
- False-negatives, Type II: Incorrectly identifying a source as a background fluctuation (i.e., missing true sources)
- Unless the background distribution and the source distribution are well-separated, there is always a trade-off between these two types of error.

Error types

- False-positives, Type
background fluctuati
sources, false detect
- False-negatives, Type
source as a backgrou
true sources)
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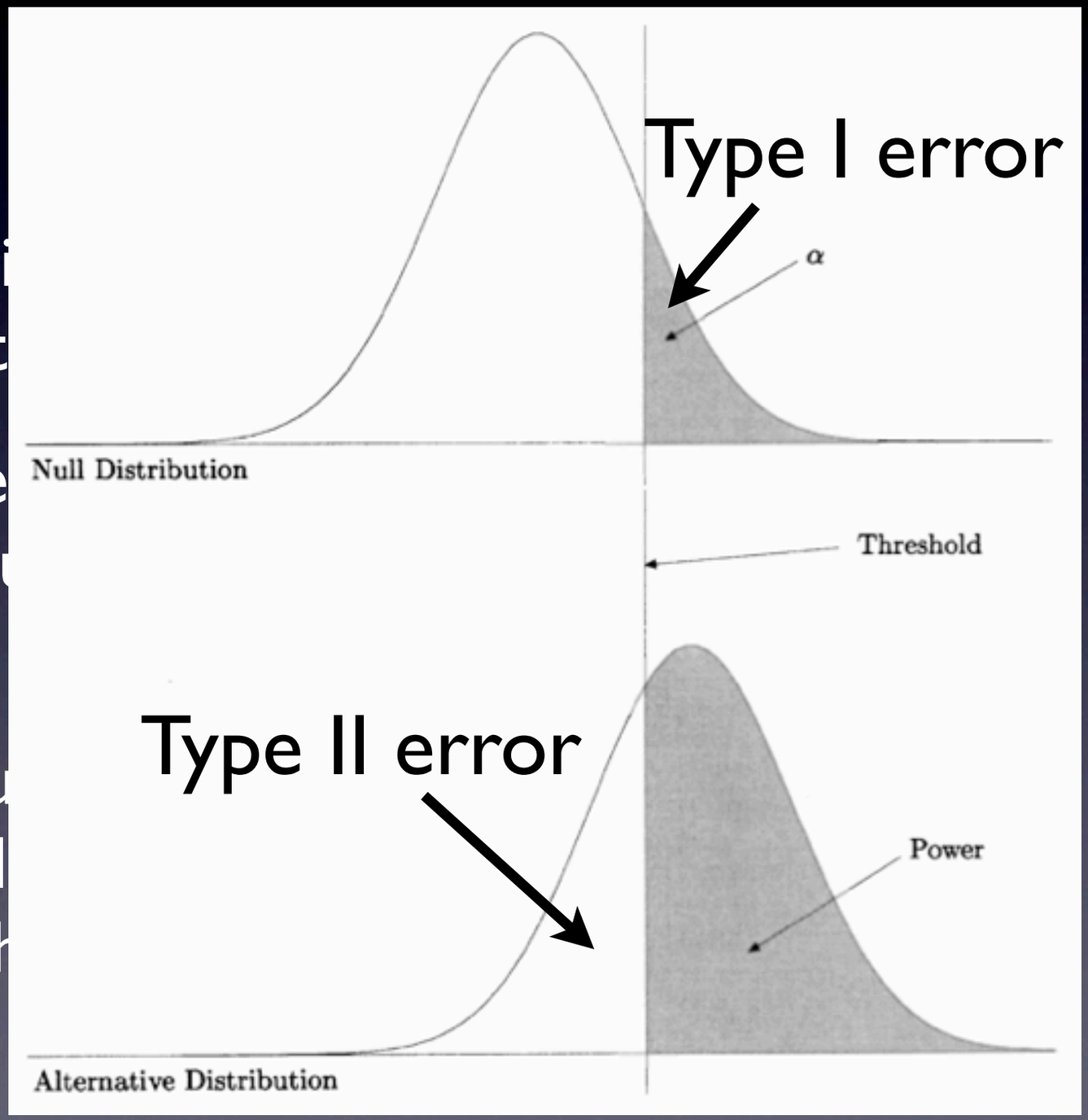
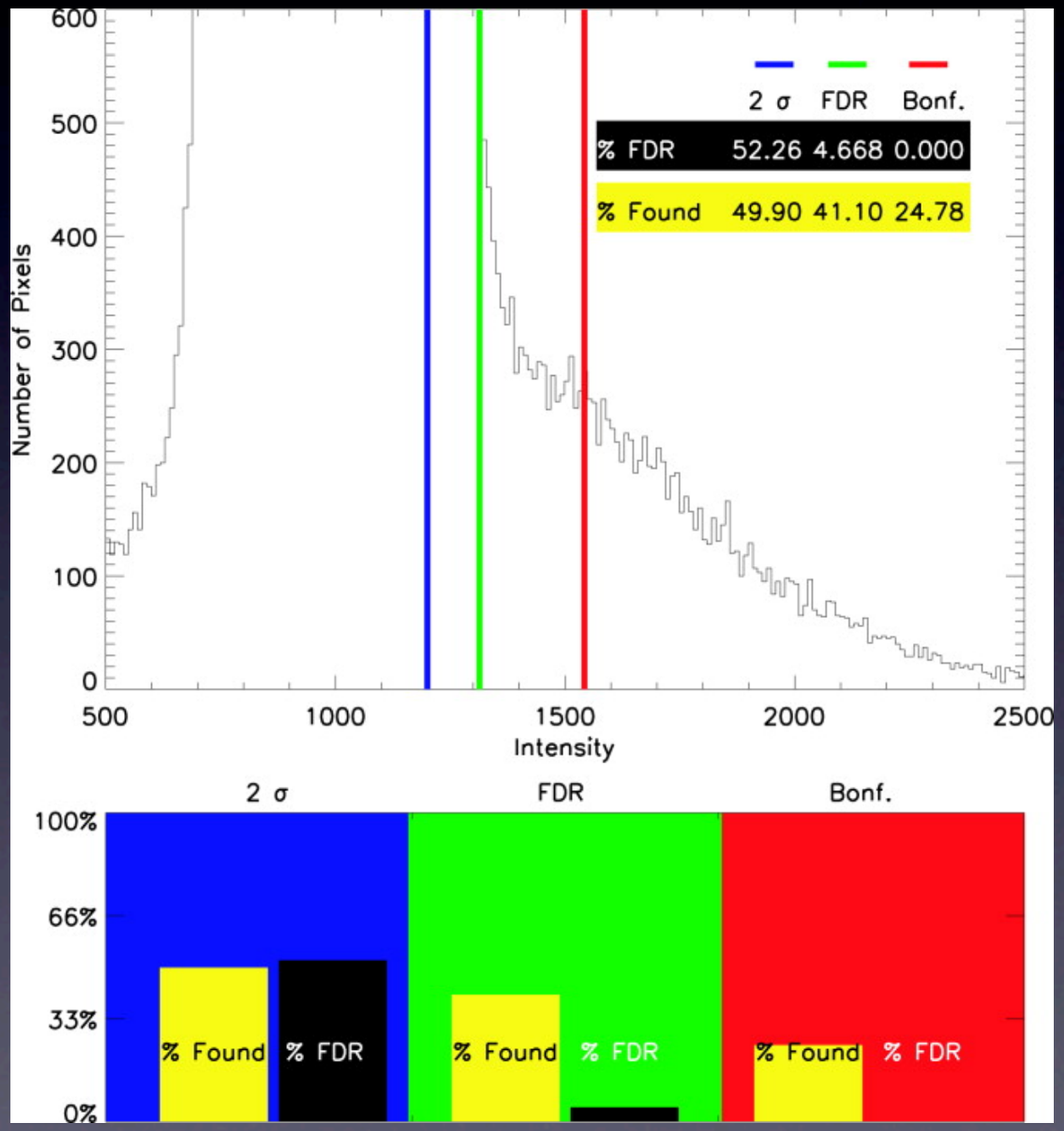


Miller et al., 2001, AJ, 122, 3492

False Discovery Rate



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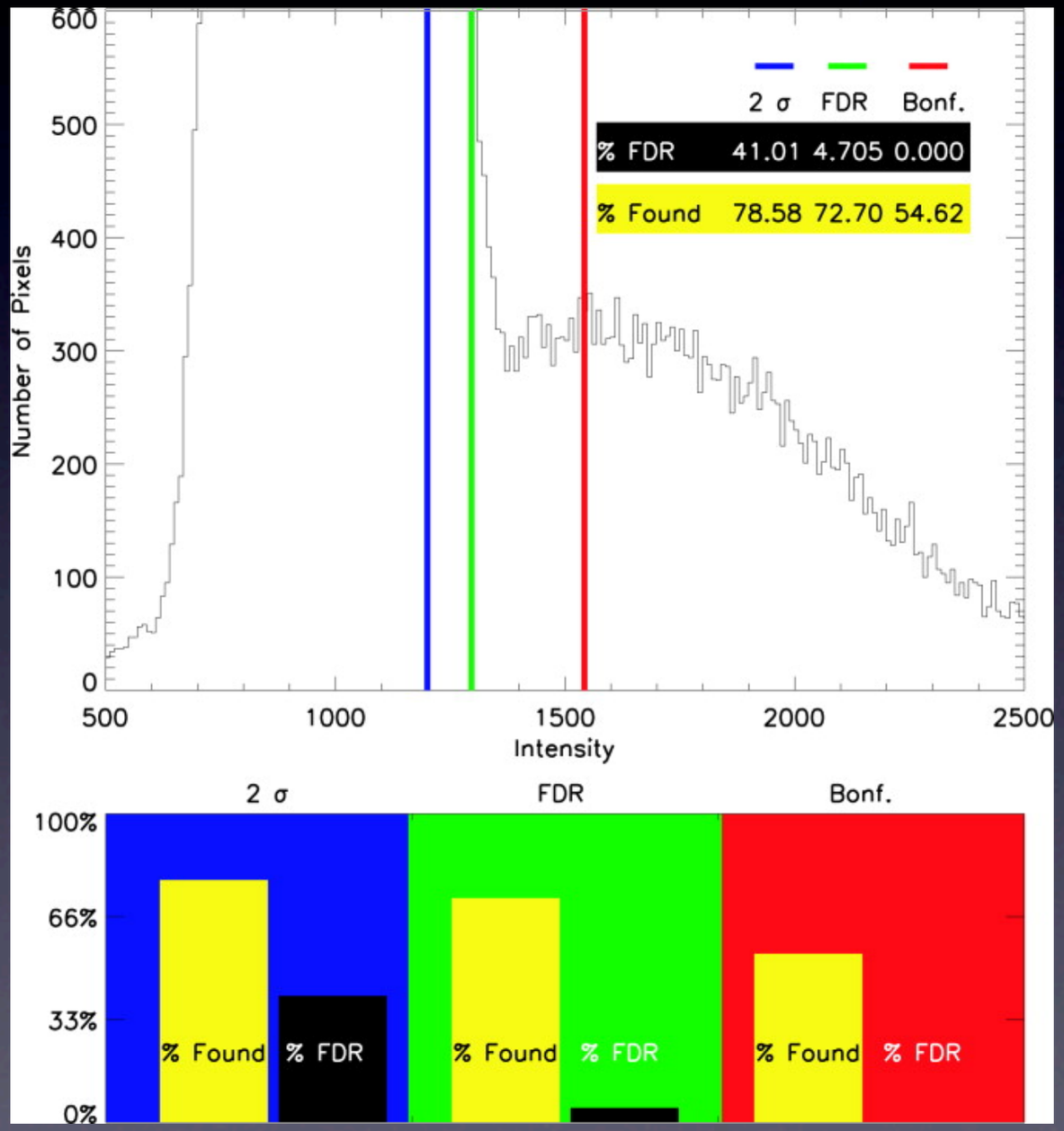
Hopkins et al., 2002, AJ, 123, 1086

False Discovery Rate



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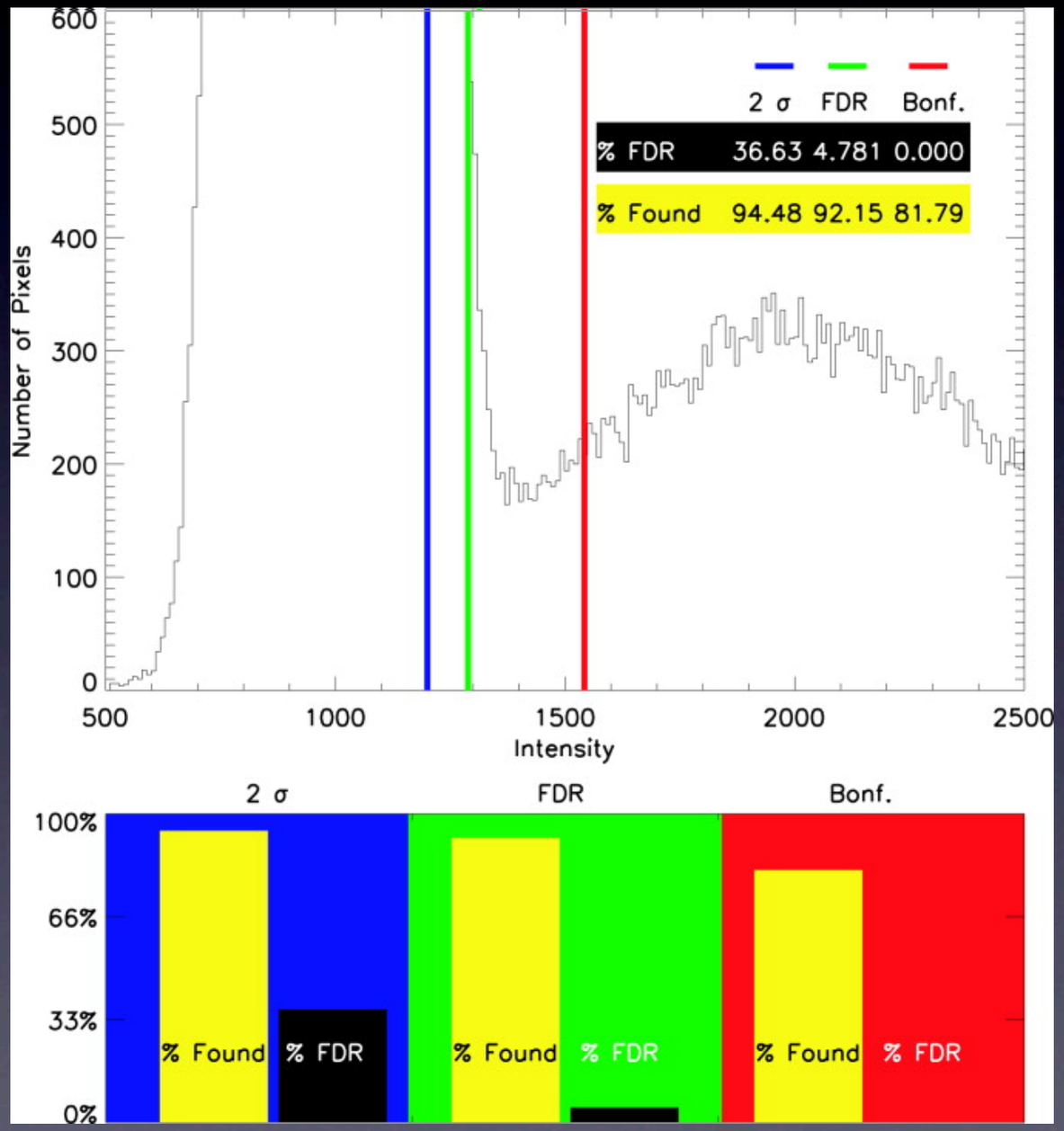

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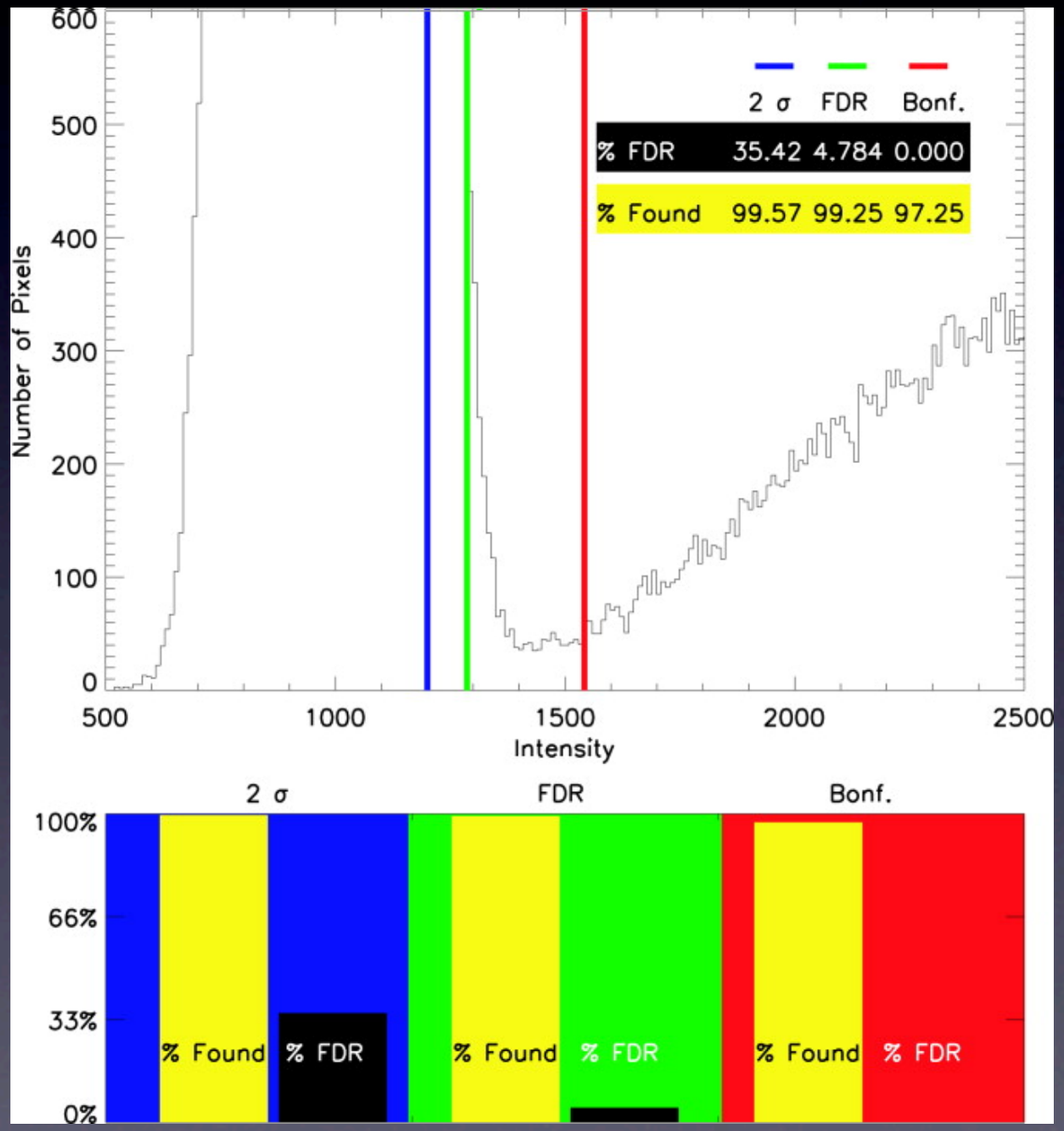
False Discovery Rate



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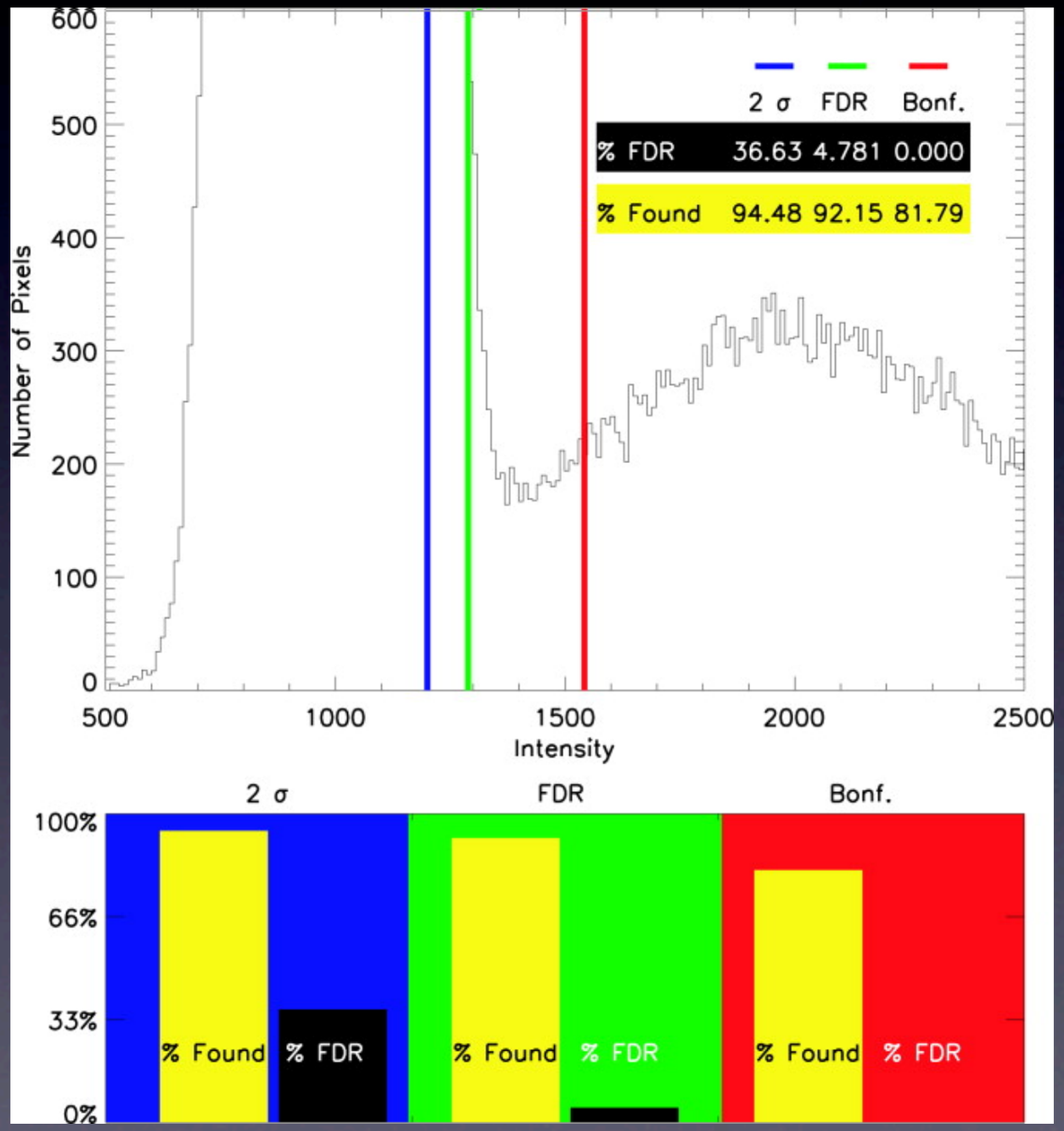

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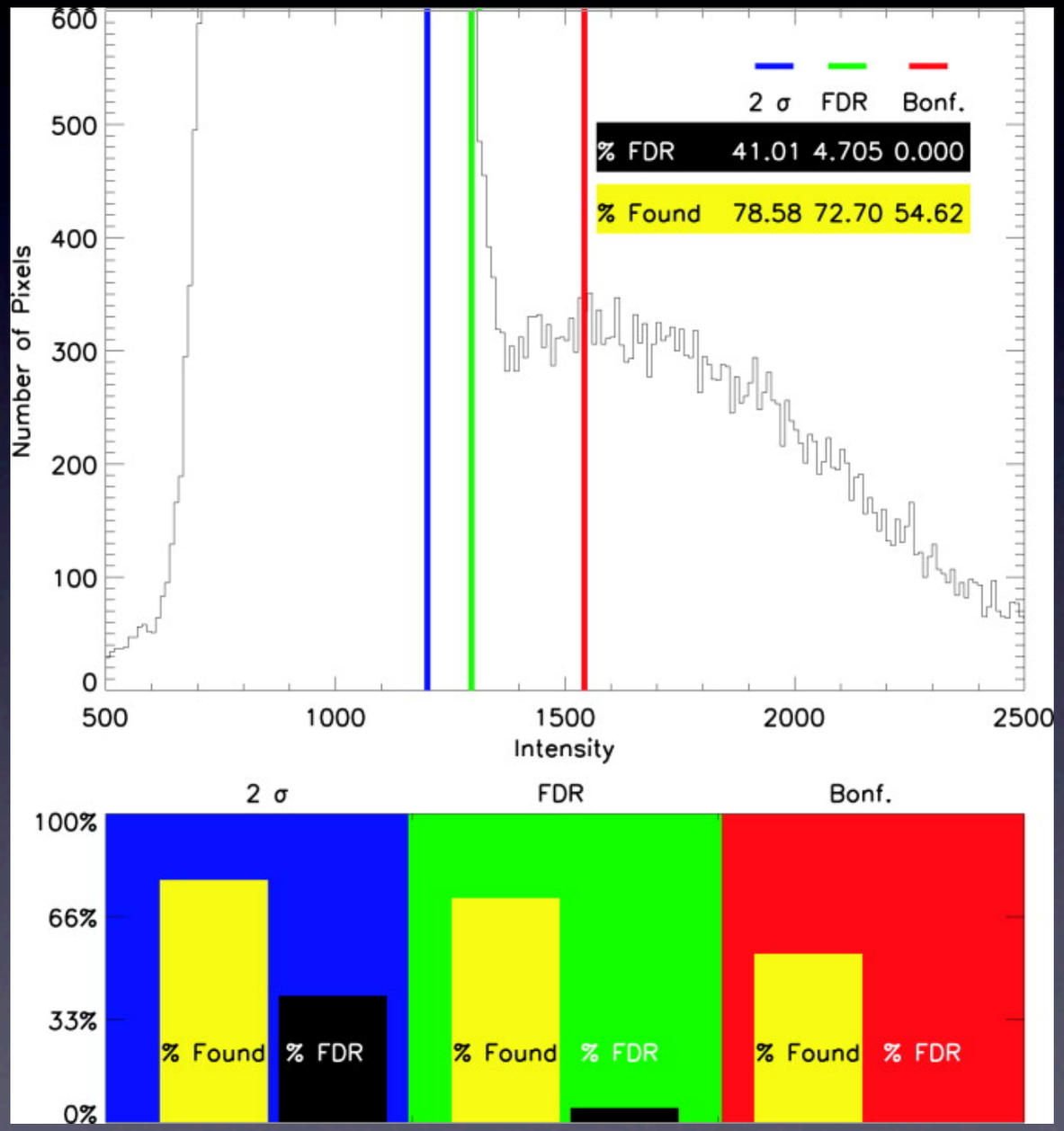

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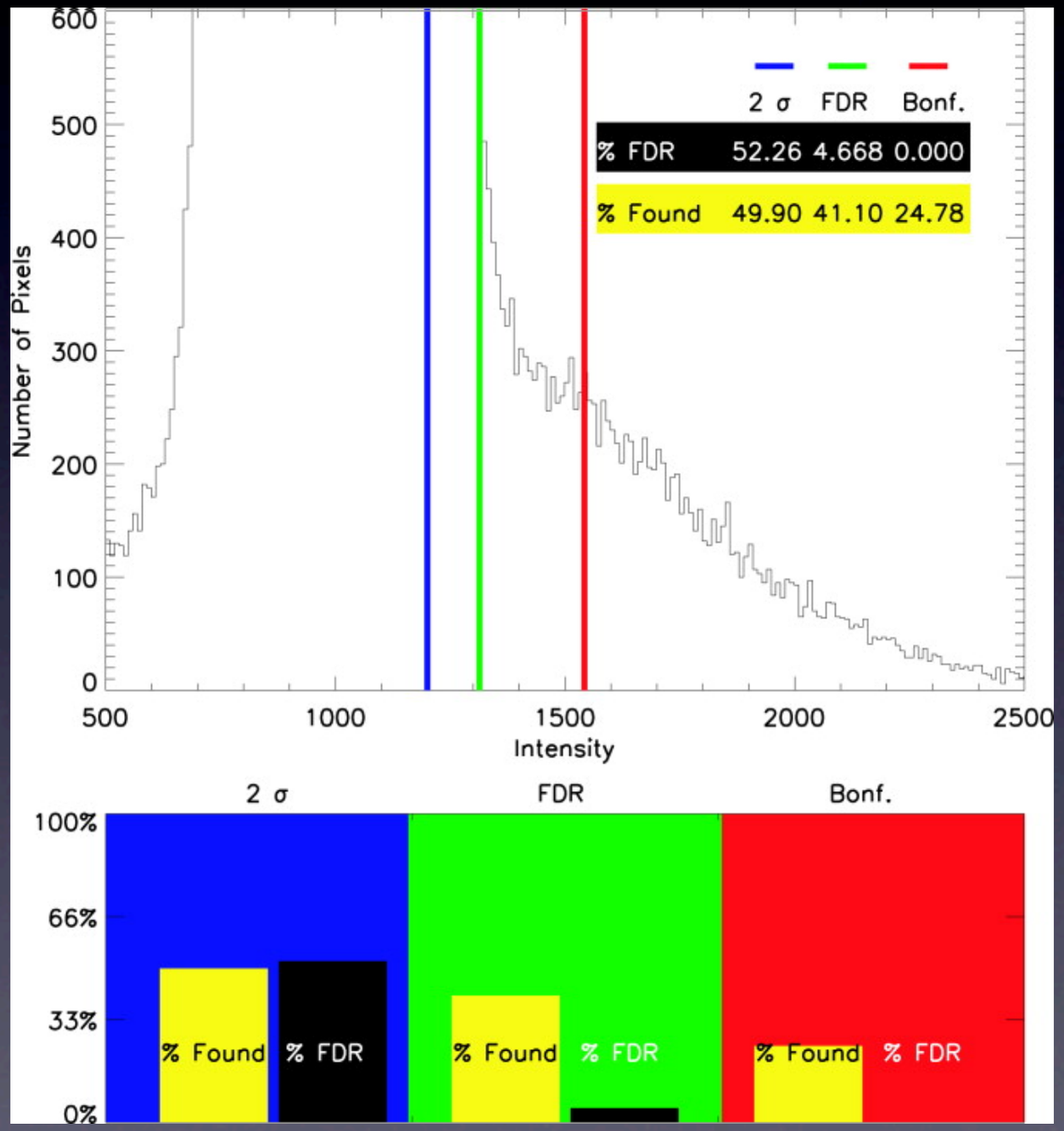

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Visualisation

- ***Aladin***: aimed originally at optical images, very flexible, very generic and VO-aware, can search/find/download catalogues, instrument sky-footprints, etc., multicolour images, overlays, and more. Incredibly powerful, but not very intuitive interface. Worth spending the time to learn.
- Miriad *cgdisp*: produces good publication quality plots, scriptable, but clunky.
- ***Kvis***: excellent for two-dimensional images, three-colour images, contour/annotation overlays. Some good analysis tools. Harder to script, has limitations with large sky areas.
- *CASA viewer*: very good for coordinate systems, and some nice analysis tools, not very intuitive.
- ***DS9***: aimed mainly at optical images, very flexible, handles coordinate systems well, overlays contours/annotations well.

−45°40′
−41′
−42′
−43′
Declination (J2000)
1h11m50s
45s
40s
35s
Right Ascension (J2000)

Summary

- Decide what you want to know before you do anything.
  - Do you need to image your data? How do you image/restore your data? Do you need to manipulate your images?
- Look at your uv data.
- Consider tools appropriate for your source-measurements (point source vs extended, blended sources).
- Use visualisation tools to provide you with more information.
- Understand your errors.
  - Estimate the rms noise level in images with miriad's *imstat* or the "s" key in kvis.
  - The S/N in the image determines the accuracy to which your source measurements can be made.
- There are many techniques available, so don't limit yourself to just one. Independent tests are a good measure of reliability.