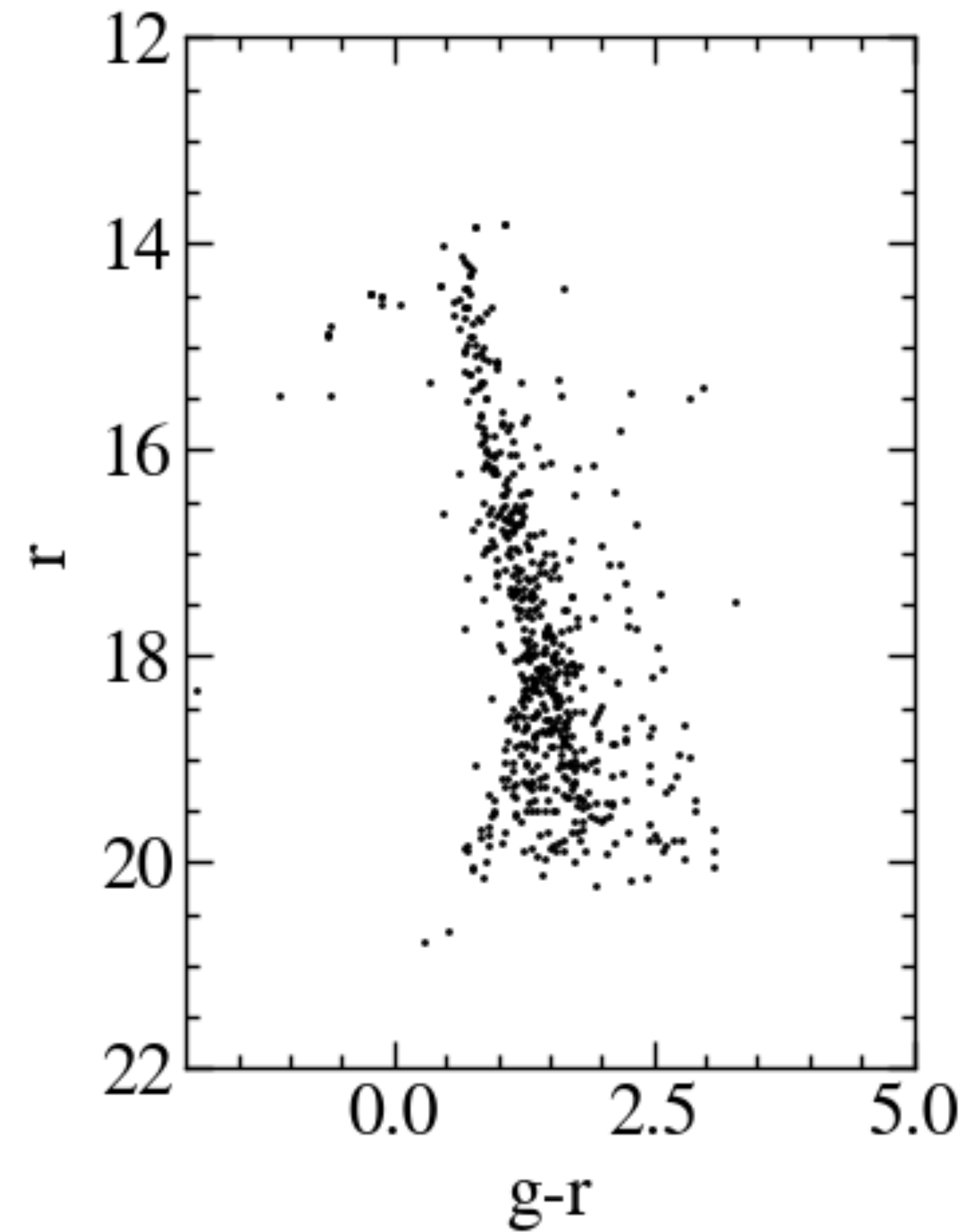
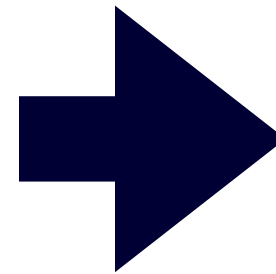
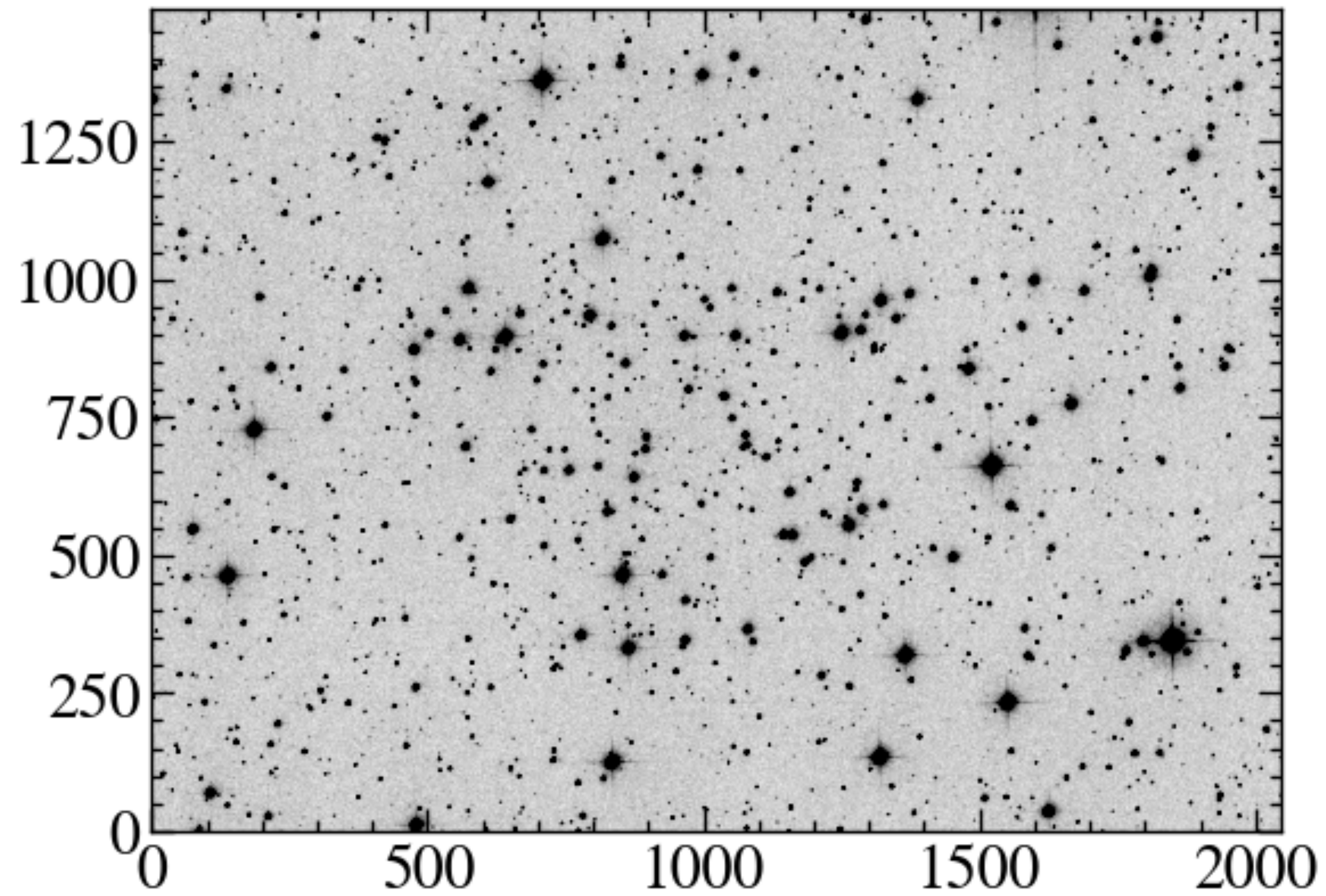

Aperture photometry

Goal



Color-magnitude diagram (CMD)

- The diagram plotting the relation between magnitudes and colors of target objects.
- For stellar objects, x-axis usually indicates a color and y-axis usually indicates a magnitudes (for galaxies, it's flipped).

From the CMD, we see

- Stars disributes on color-magnitude plan with patterns.
- Most stars are on the thine lines.
- and,,,



From the CMD, we know

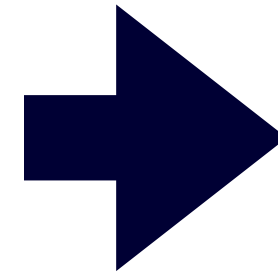
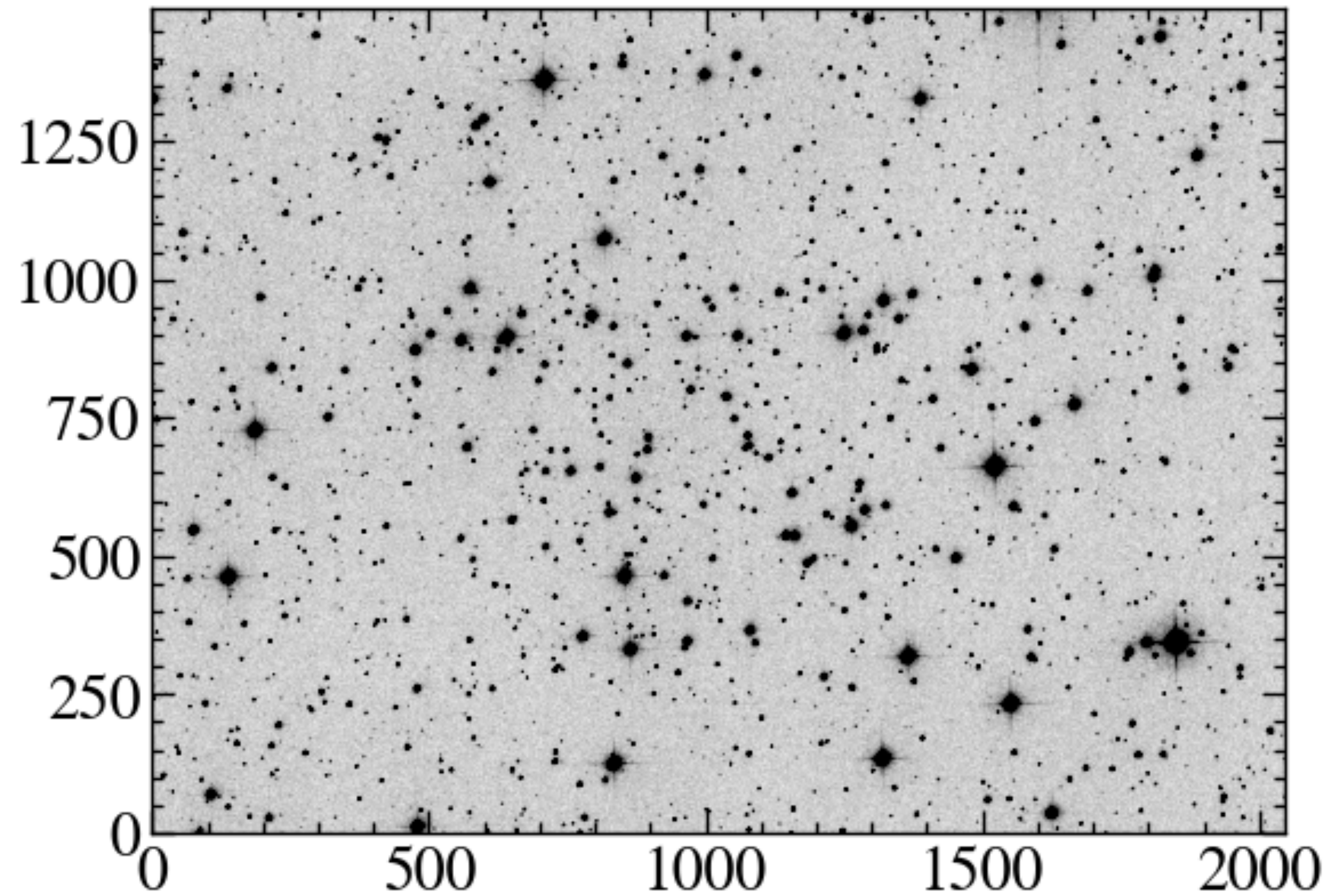
- (add)
 - Compare with a Hertzsprung-Russel diagram.
 - In observation, which one is easier to be obtained?
 - Is it okay to use an apparent magnitude instead of a luminosity or an absolute magnitude?
 - More details in the astronomy classes.
-

To construct a CMD, we should measure

- x-axis: color, which is the difference of magnitudes between two bands.
- y-axis: magnitude
- We should measure **magnitudes!**



(real) Goal



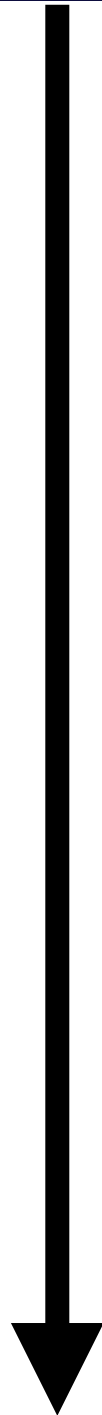
ra_r	dec_r	ra_g	dec_g	mag_r	mag_g
84.097787	31.193101	84.097786	31.193098	18.156043	19.582877
84.138697	31.138529	84.138698	31.138541	19.040868	20.932445
84.178309	31.085561	84.178288	31.085562	18.328615	16.426038
84.109727	31.177515	84.109743	31.177521	18.697421	19.973394
84.069409	31.233780	84.069398	31.233782	19.996716	20.878002
...
84.244876	31.294286	84.244873	31.294286	19.110202	20.262591
84.335969	31.172562	84.335958	31.172582	18.862541	20.144324
84.236671	31.305838	84.236660	31.305840	16.232652	17.185152
84.216391	31.333031	84.216389	31.333030	16.783001	17.530967
84.253575	31.284087	84.253580	31.284090	15.357524	16.182001

Reference

- Setson 1987 section 3: <https://ui.adsabs.harvard.edu/abs/1987PASP...99..191S/abstract>
 - Da Costa 1992 section 2: <https://ui.adsabs.harvard.edu/abs/1992ASPC...23...90D/abstract>
 - Romanishin 2002 section 17.2: <https://www1.phys.vt.edu/~jhs/phys3154/CCDPhotometryBook.pdf>
 - Photutils doc.: <https://photutils.readthedocs.io/en/stable/aperture.html>
 - AO class material by YS.Bach: https://ysbach.github.io/SNU_AOpython/chaps/03-aperture.html
-

From an image to a magnitude

IMAGE



MAGTNIDUE OF THE STAR

- Q. What is a magnitude?
A. a measure of brightness
- Q. Can we measure a 'standard' brightness only from an image?
A. No.

From an image to magnitudes

IMAGE



**(RELATIVE) BRIGHTNESS OF
THE STAR**



MAGNITUDE OF THE STAR

- Q. How can we define the brightness of a star?

Hint. pixel value \propto # of photons

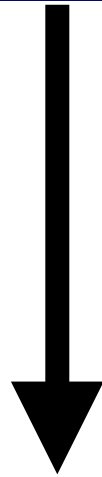
- Do CCD pixels detect only photons from the star?

A. No, there are many sources of photons

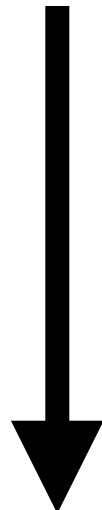
- target star
- sky background
- other stars
- unresolved objects

From an image to magnitudes

IMAGE



**(RELATIVE) BRIGHTNESS OF
THE STAR**

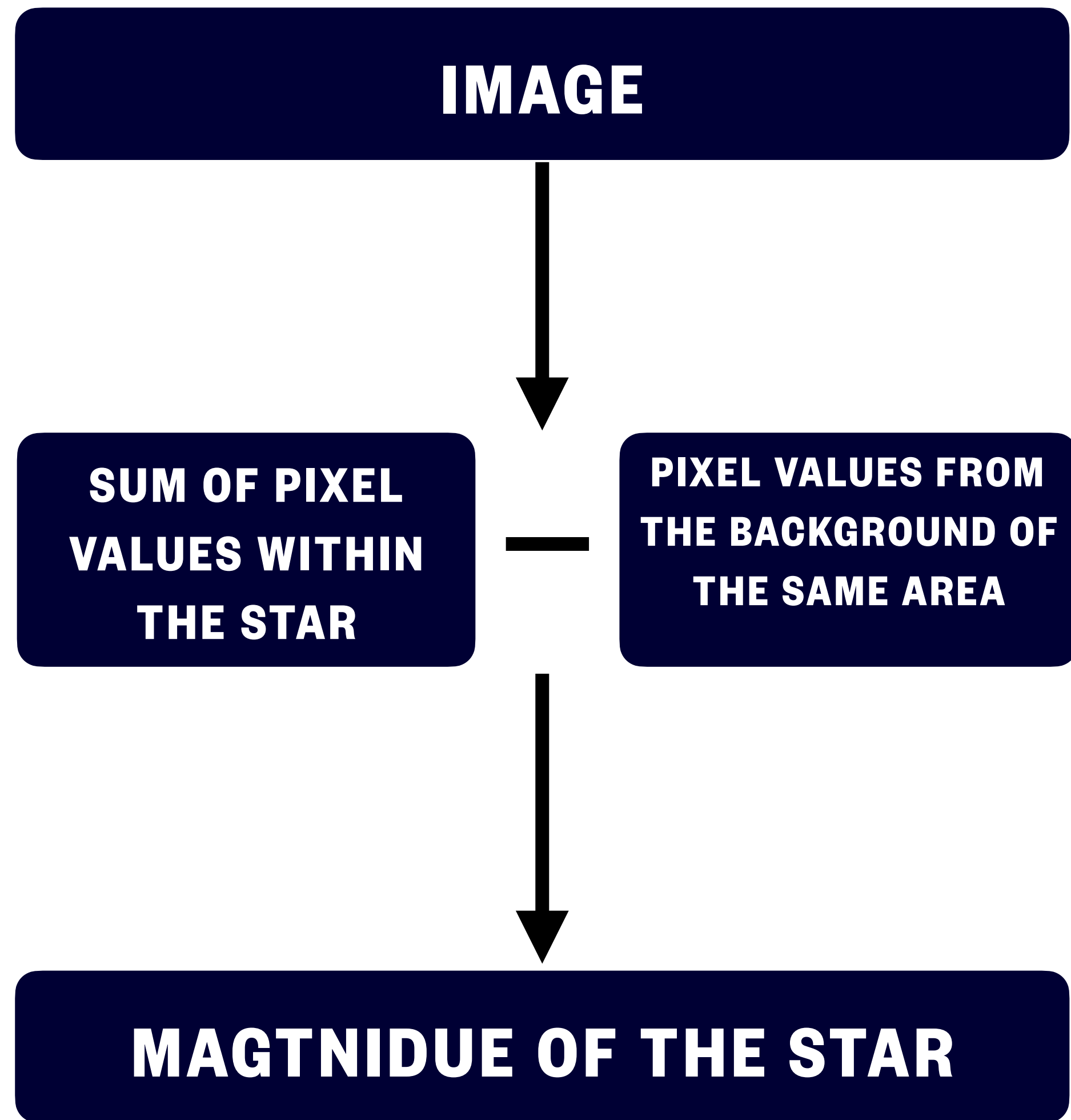


MAGNITUDE OF THE STAR

- Q. How can we count only the photons from the star?

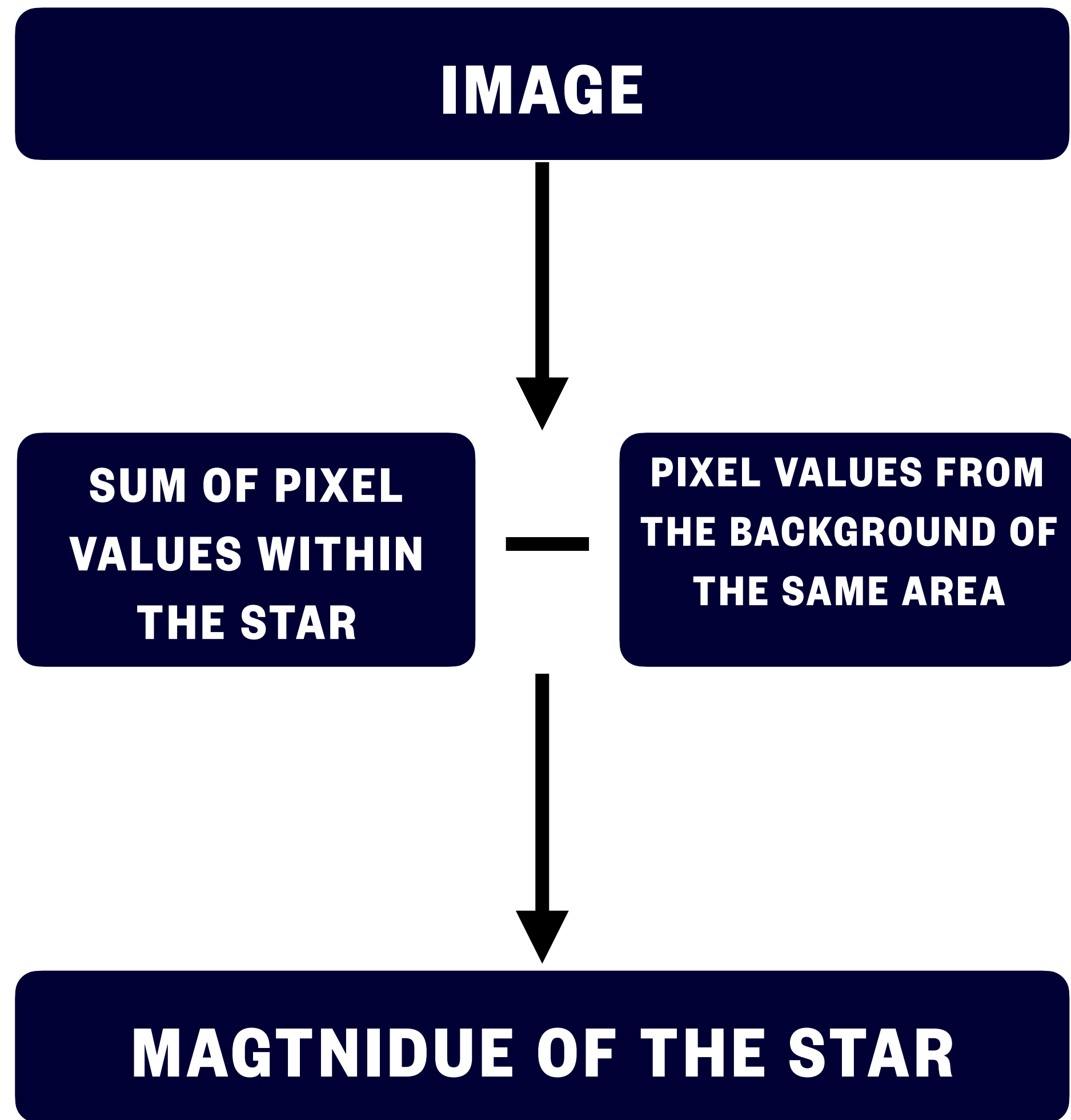
A. Subtract the photons from the background

From an image to magnitudes



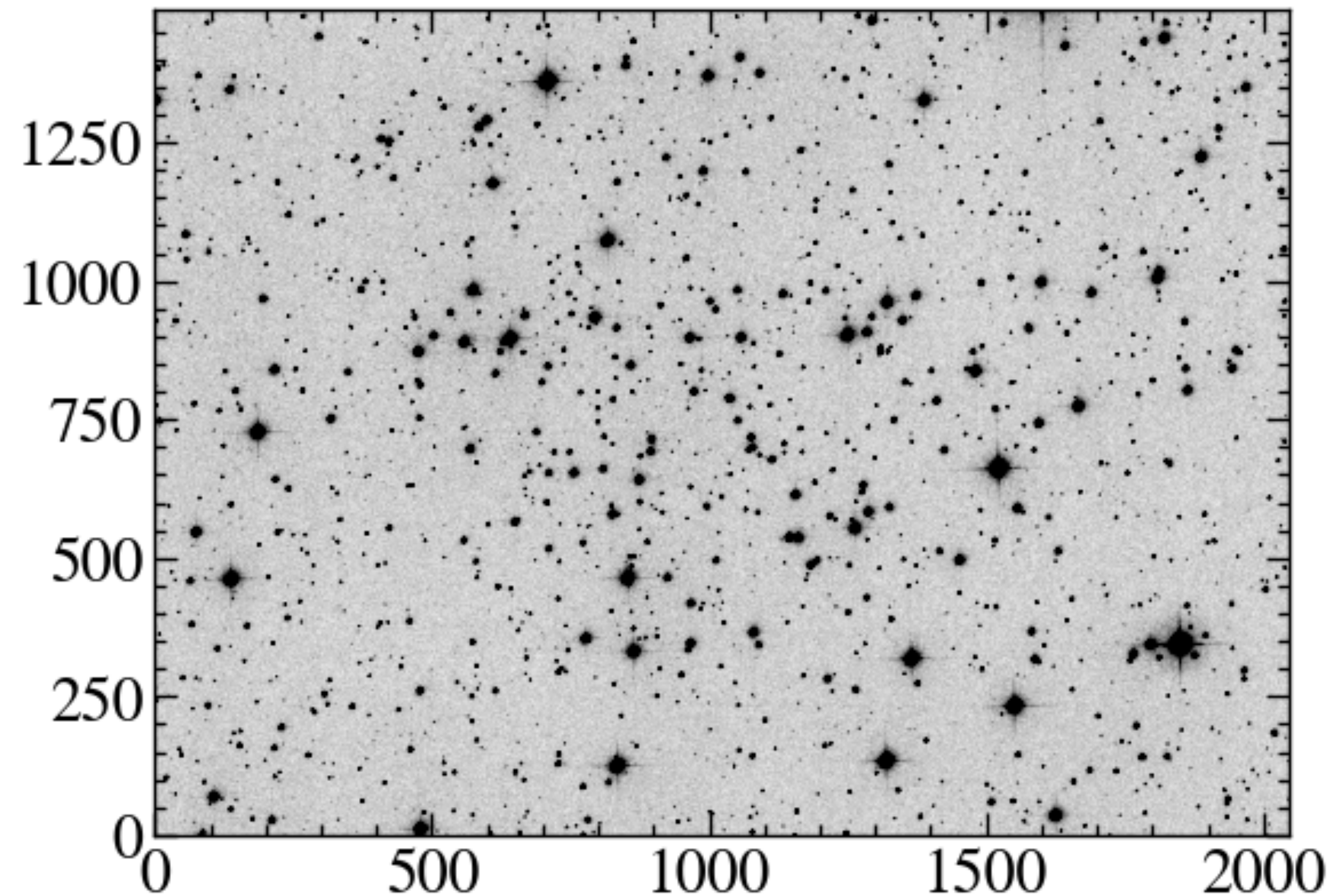
- Q. What is the range of the sum?
A. are the star occupies, surely.
- Q. How can we define the 'region' of the star?
A. Little vague...

From an image to magnitudes



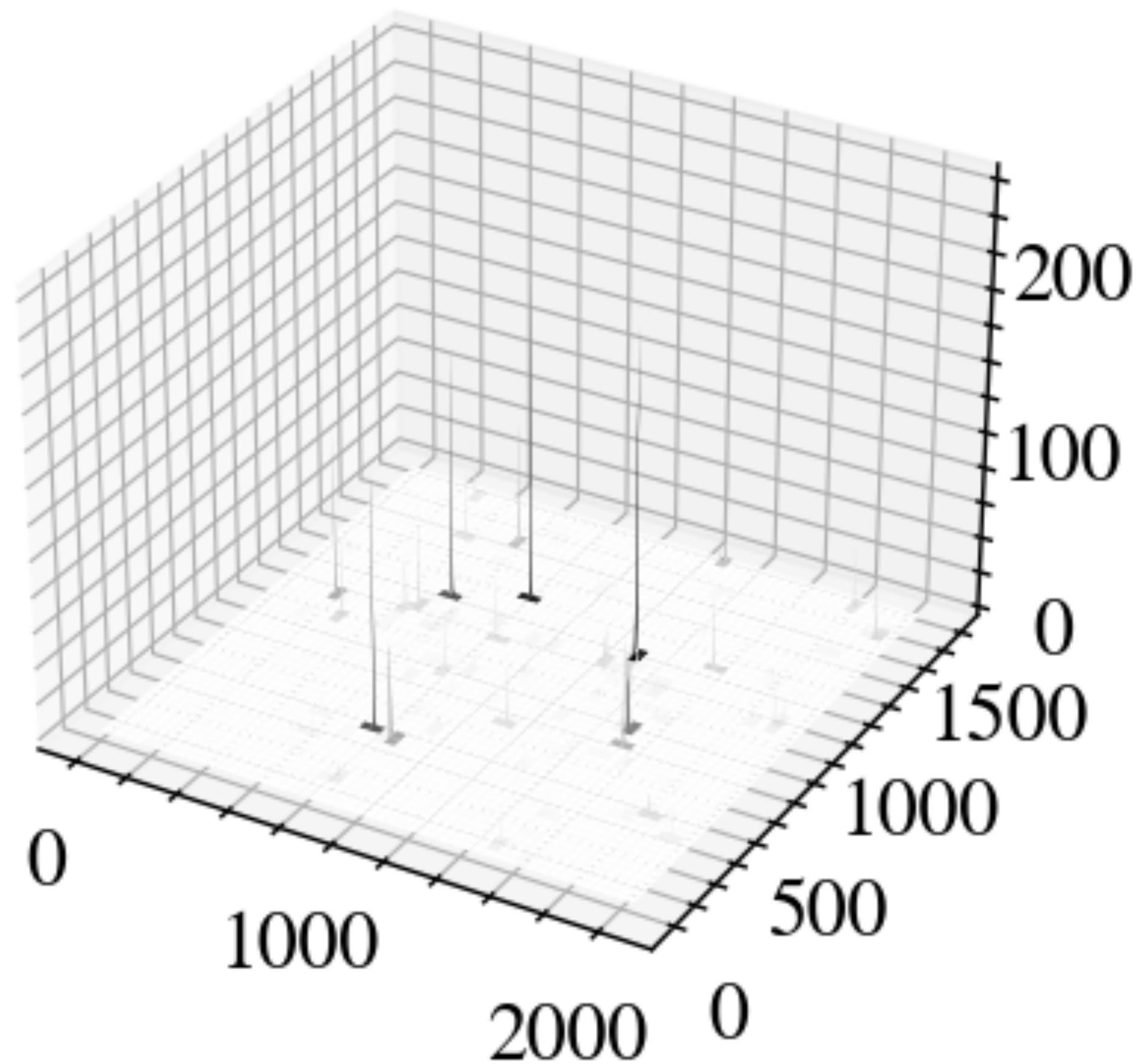
- Detection of the star?
- Ceter of the star?
- Boundary of the star?

From an image to magnitudes



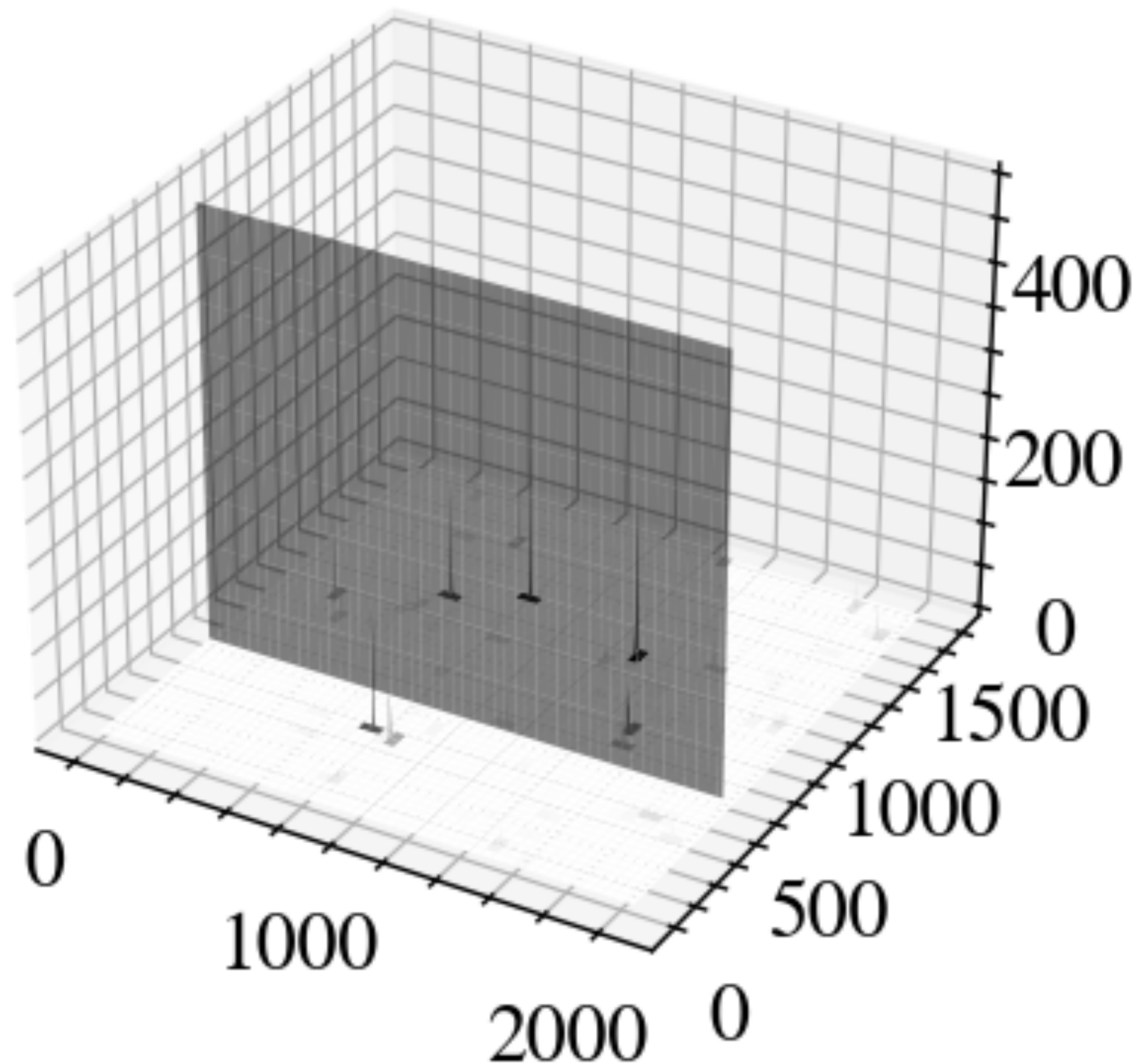
- Detection of the star?
 - Find a local maximum
 - profile width $> (\text{FWHM})_{\text{thres}} \sim \text{seeing}$
- Center of the star?
- Boundary of the star?

From an image to magnitudes



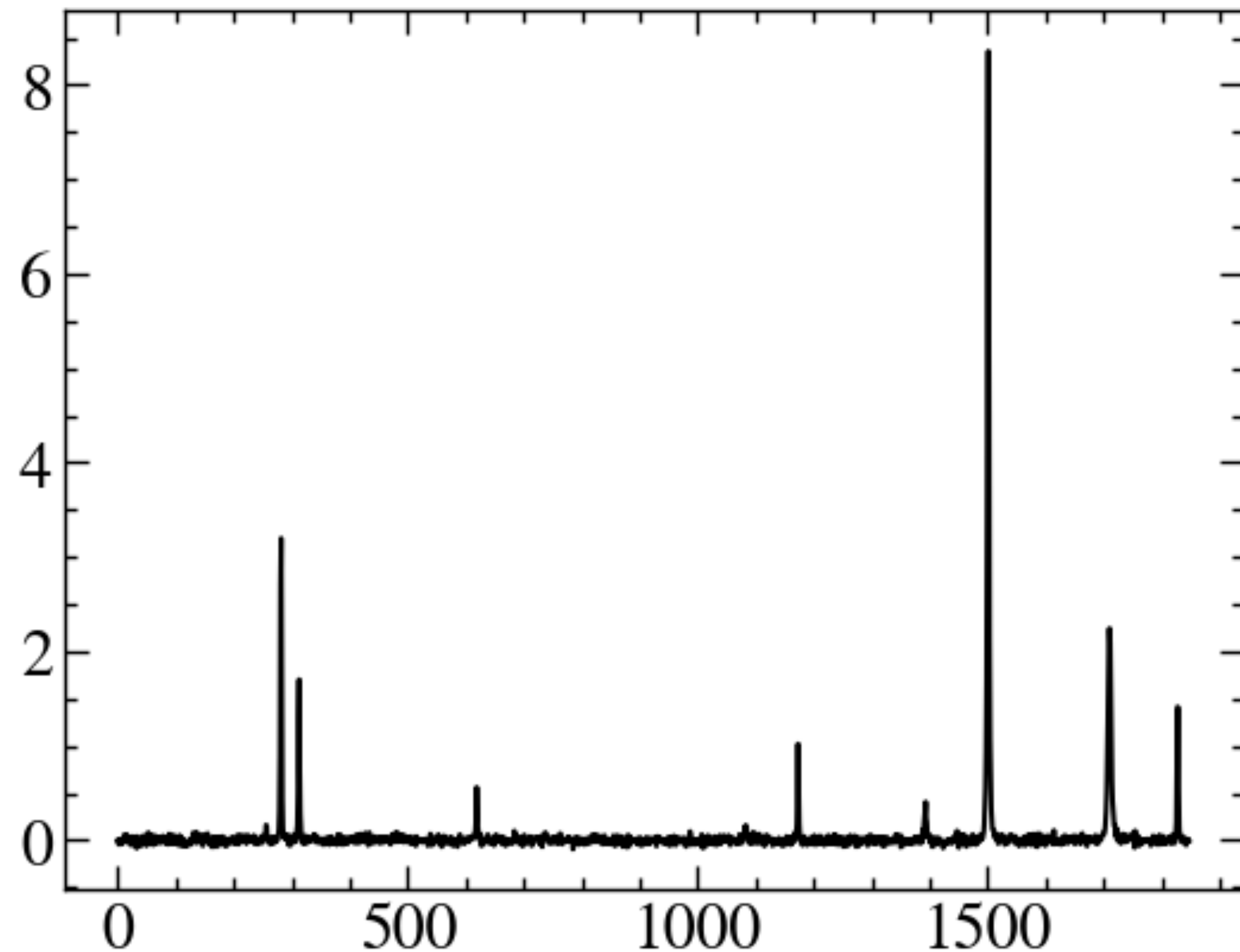
- Detection of the star?
 - Find a local maximum
 - profile width $> (\text{FWHM})_{\text{thres}} \sim \text{seeing}$
- Center of the star?
- Boundary of the star?

From an image to magnitudes



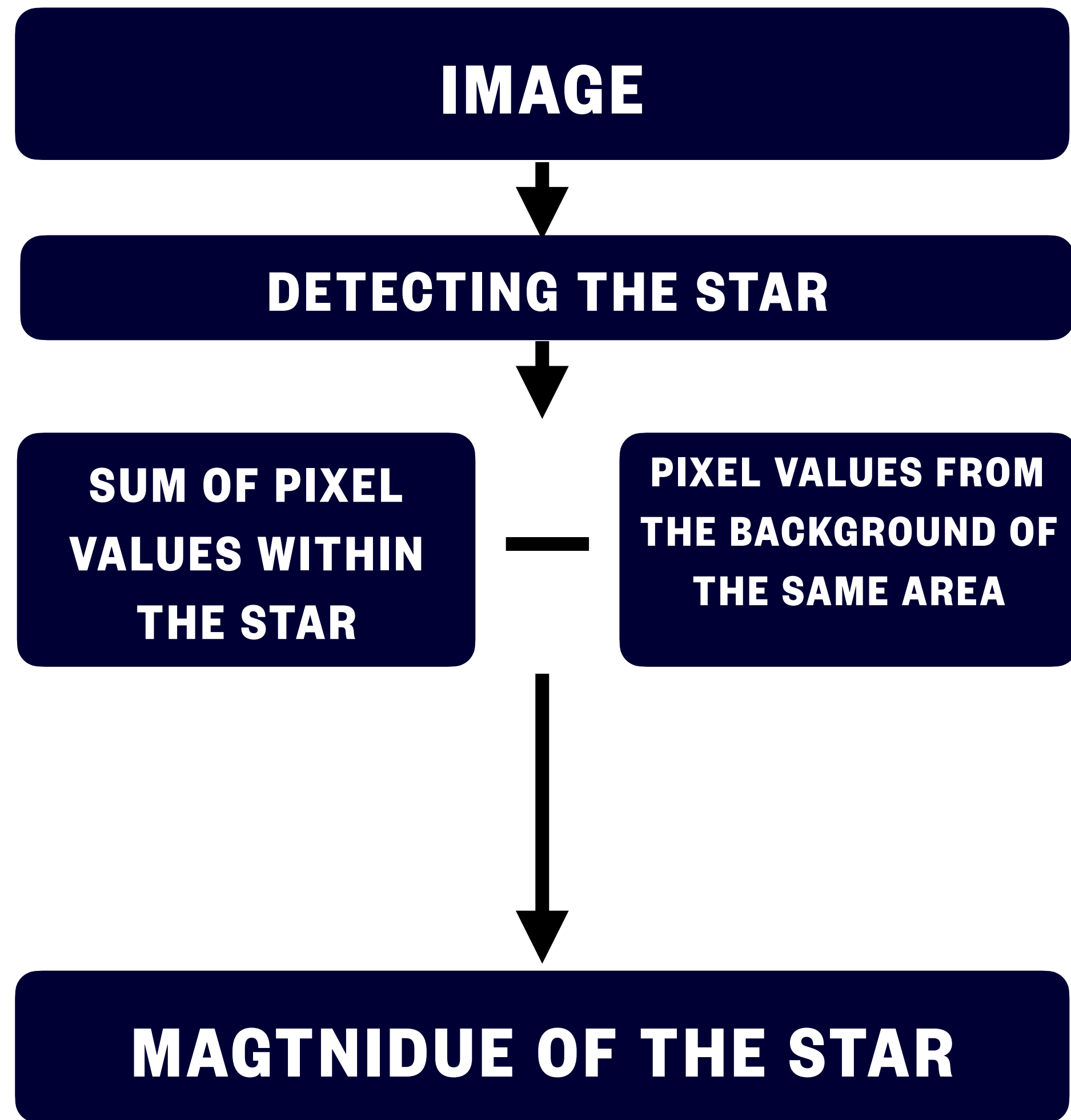
- Detection of the star?
 - Find a local maximum
 - profile width $> (\text{FWHM})_{\text{thres}} \sim \text{seeing}$
- Center of the star?
- Boundary of the star?

From an image to magnitudes



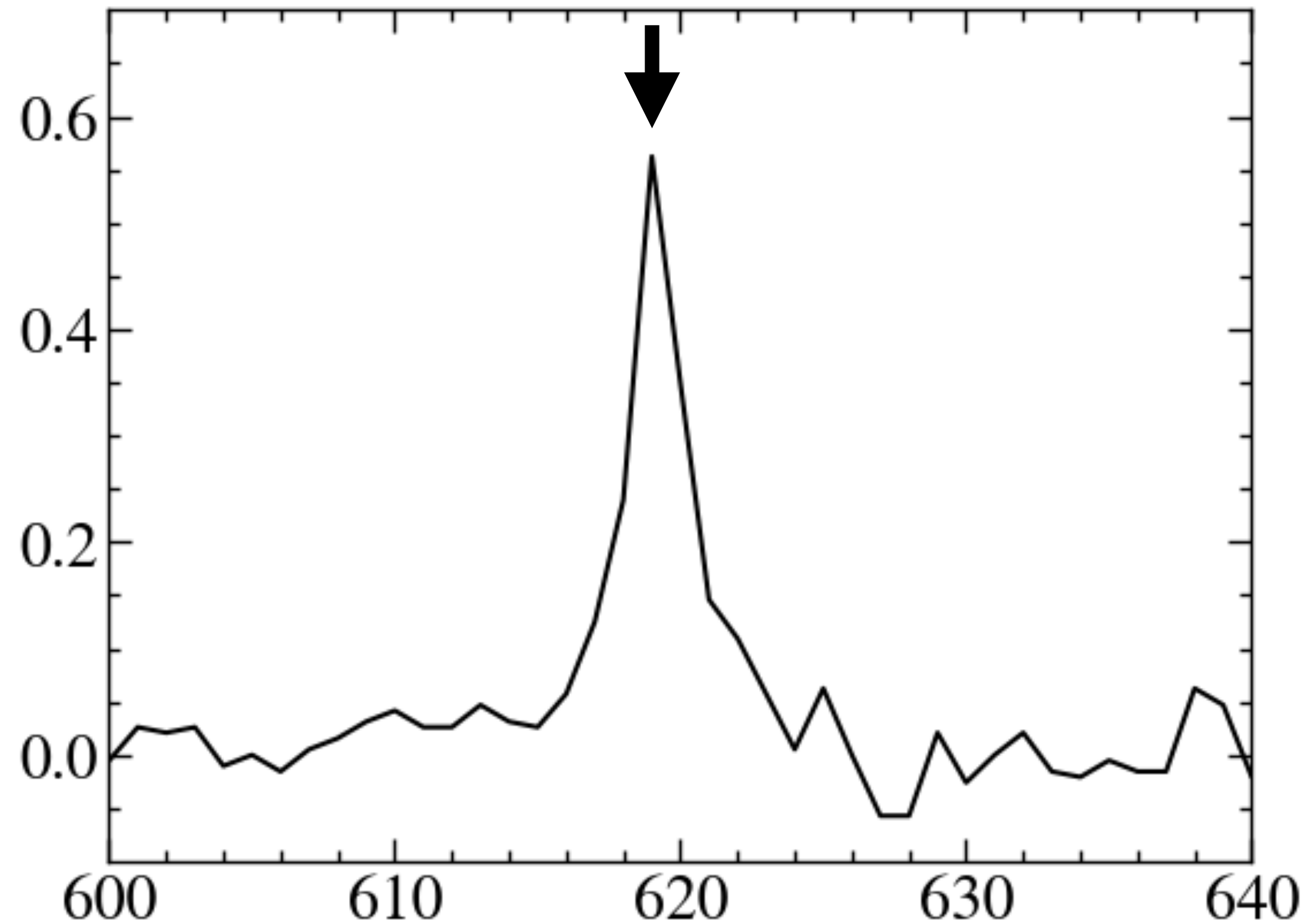
- Detection of the star?
 - Find a local maximum
 - profile width $> (\text{FWHM})_{\text{thres}} \sim \text{seeing}$
- Center of the star?
- Boundary of the star?

From an image to magnitudes



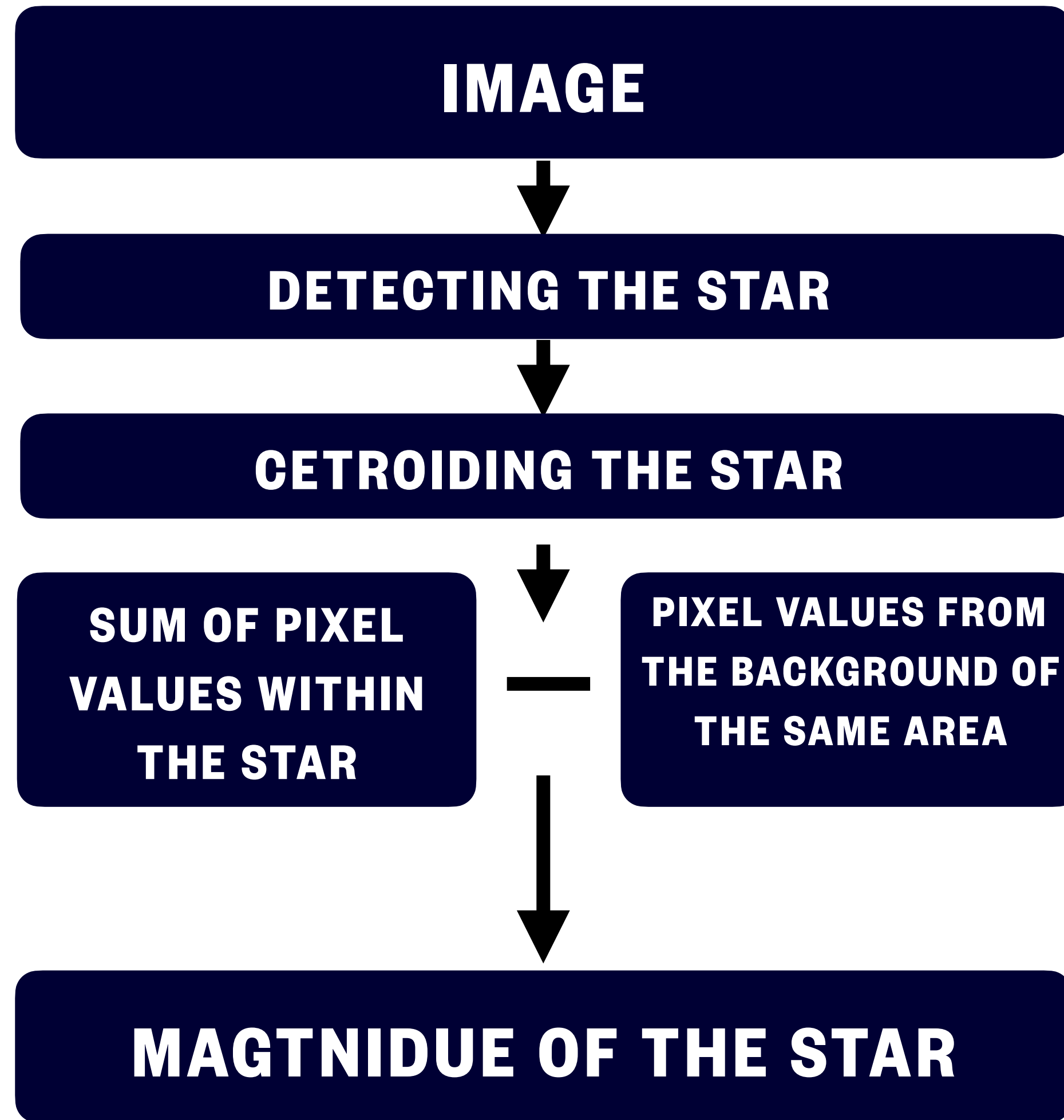
- Detection of the star?
 - Find a local maximum
 - profile width $> (\text{FWHM})_{\text{thres}} \sim \text{seeing}$
- Ceter of the star?
- Boundary of the star?

From an image to magnitudes



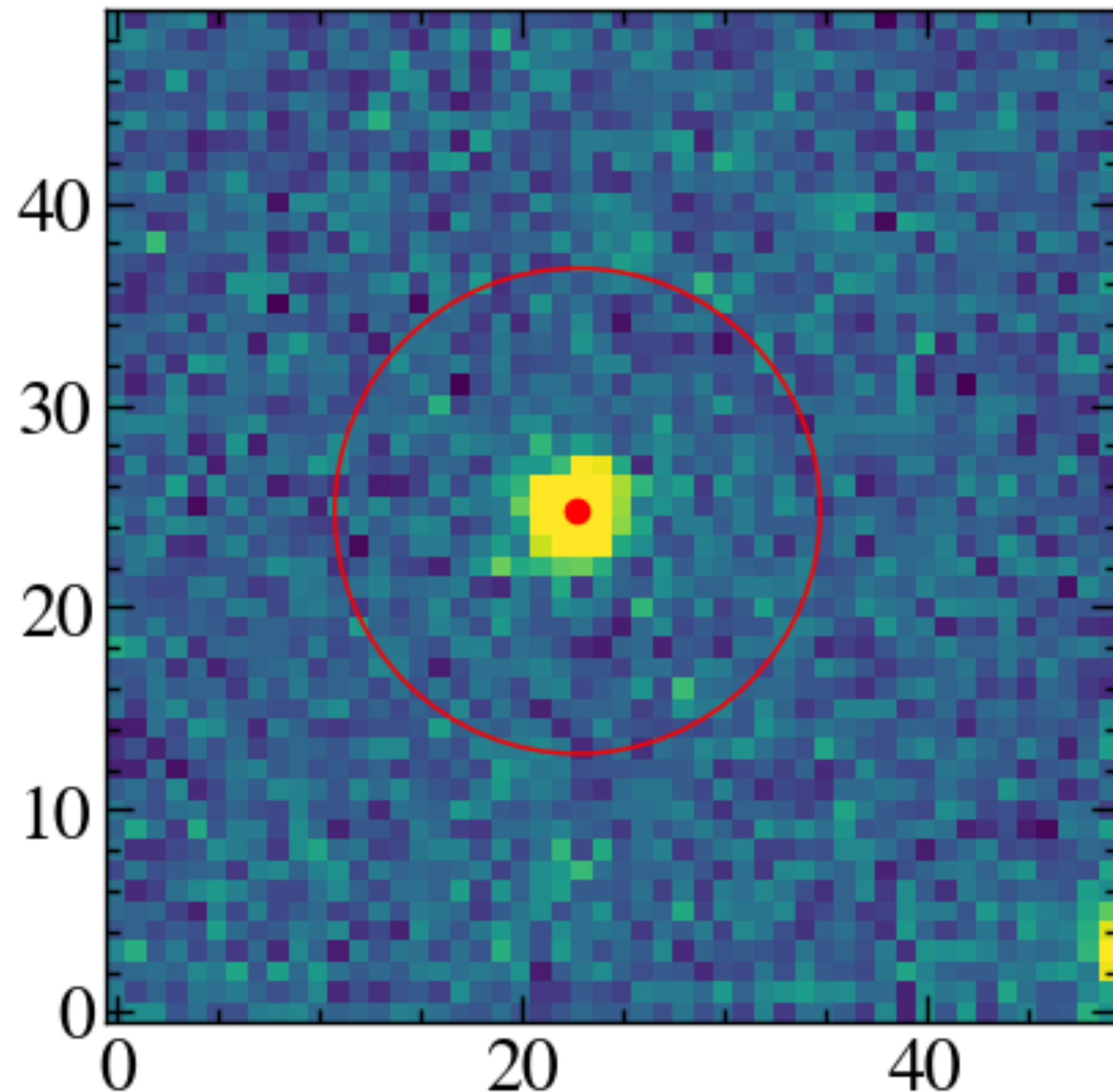
- Detection of the star?
- Ceter of the star?
 - center of mass/Gaussian fitting
- Boundary of the star?

From an image to magnitudes



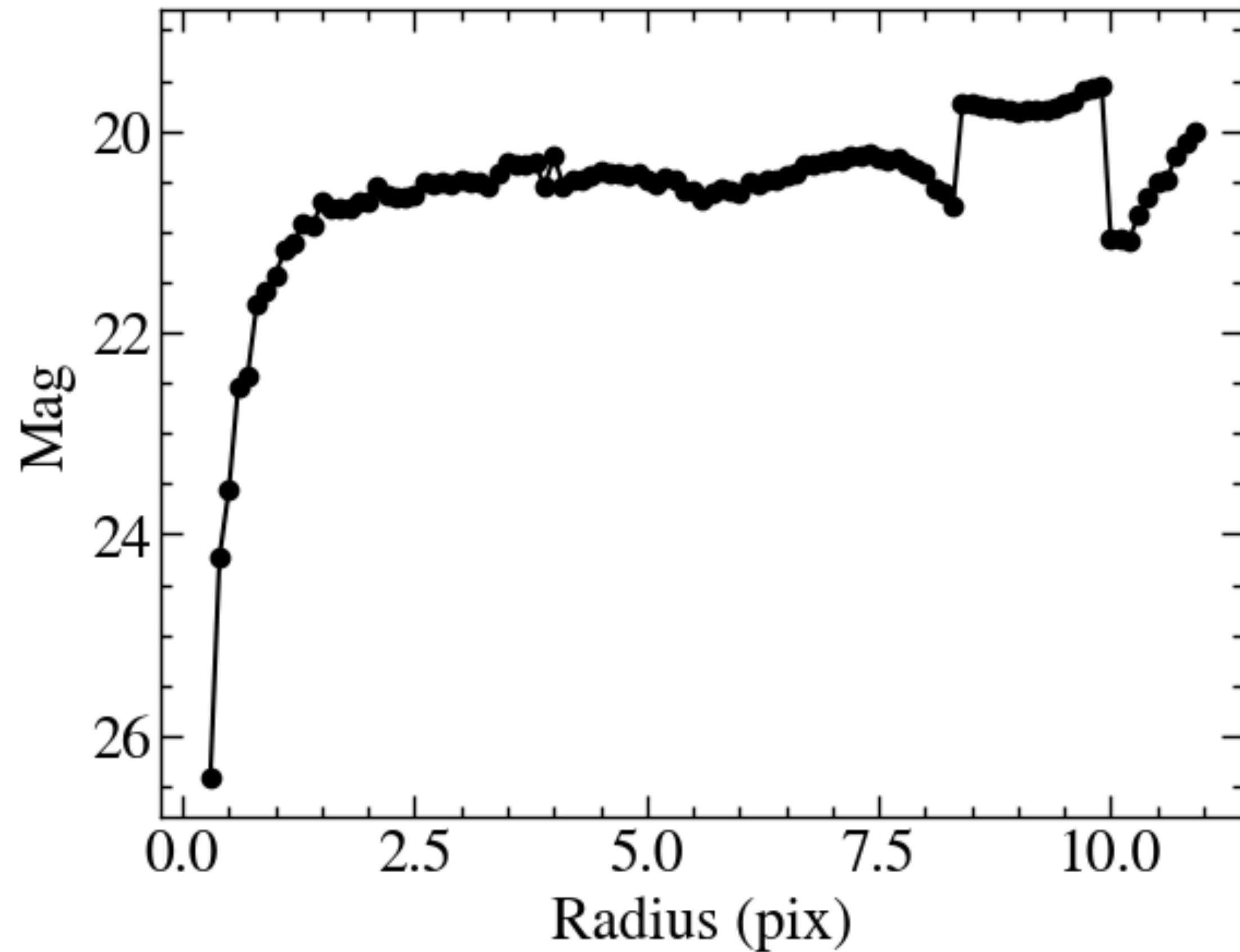
- Detection of the star?
- Ceter of the star?
 - center of mass/Gaussian fitting
- Boundary of the star?

From an image to magnitudes



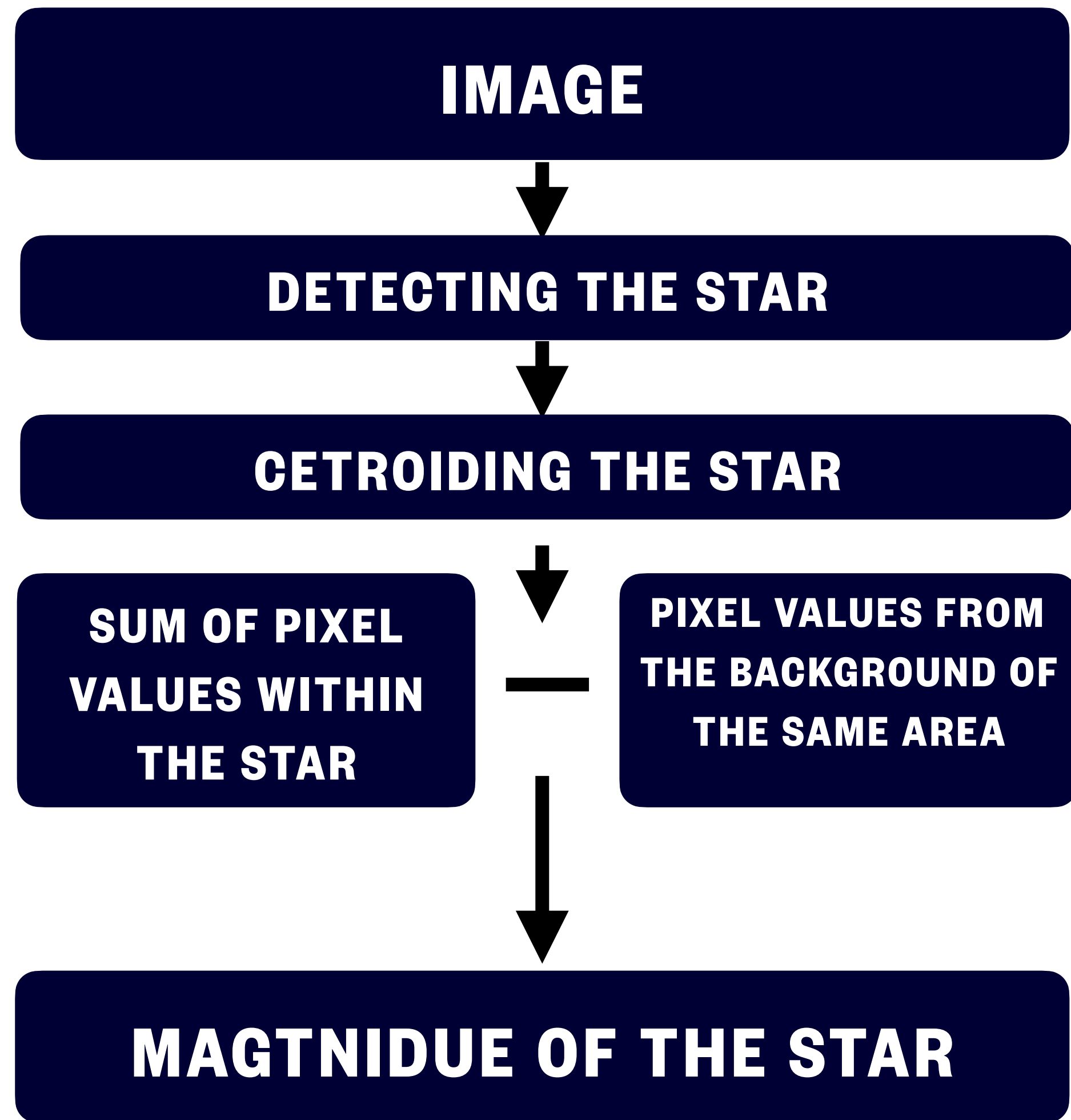
- Detection of the star?
- Center of the star?
- Boundary of the star?
 - In principle, the star extends infinitely
 - In practice,
 - ✓ small enough not to be contaminated from other sources
 - ✓ large enough to include the 'most' of the star

From an image to magnitudes



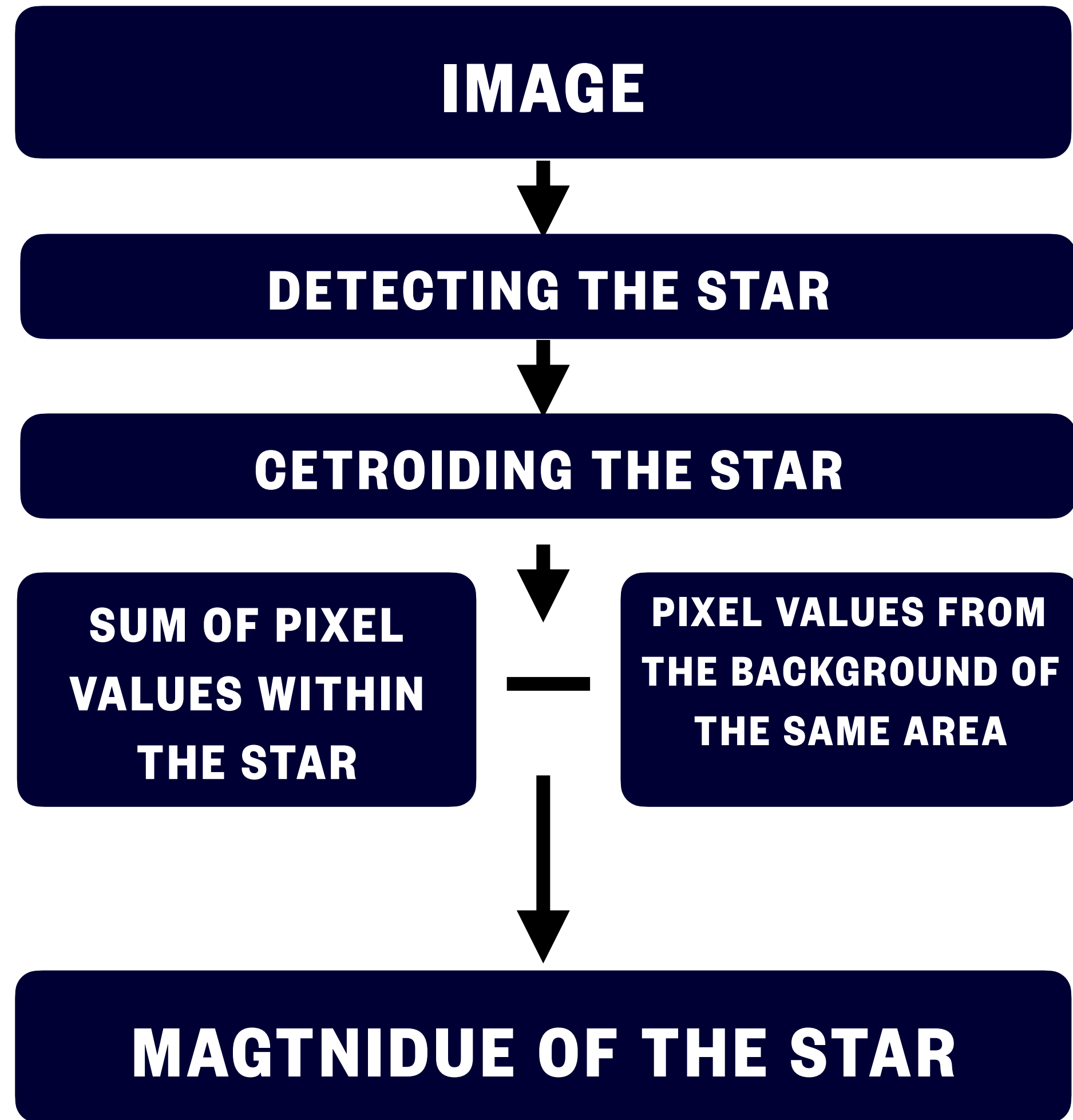
- Determining the aperture size e.g.)

From an image to magnitudes



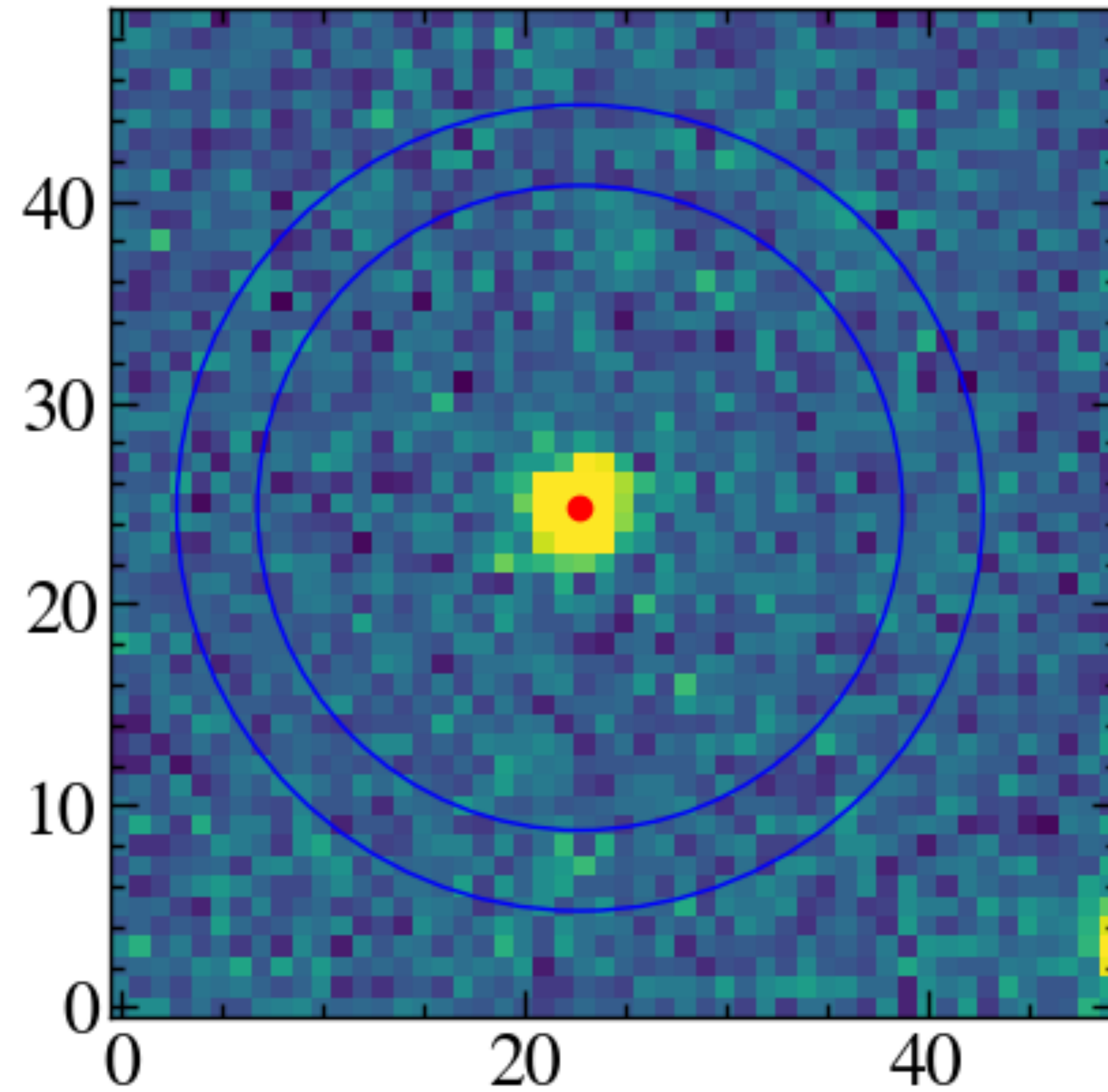
- Detection of the star?
- Center of the star?
- Boundary of the star?
 - In principle, the star extends infinitely
 - In practice,
 - ✓ small enough not to be contaminated from other sources
 - ✓ large enough to include the 'most' of the star

From an image to magnitudes

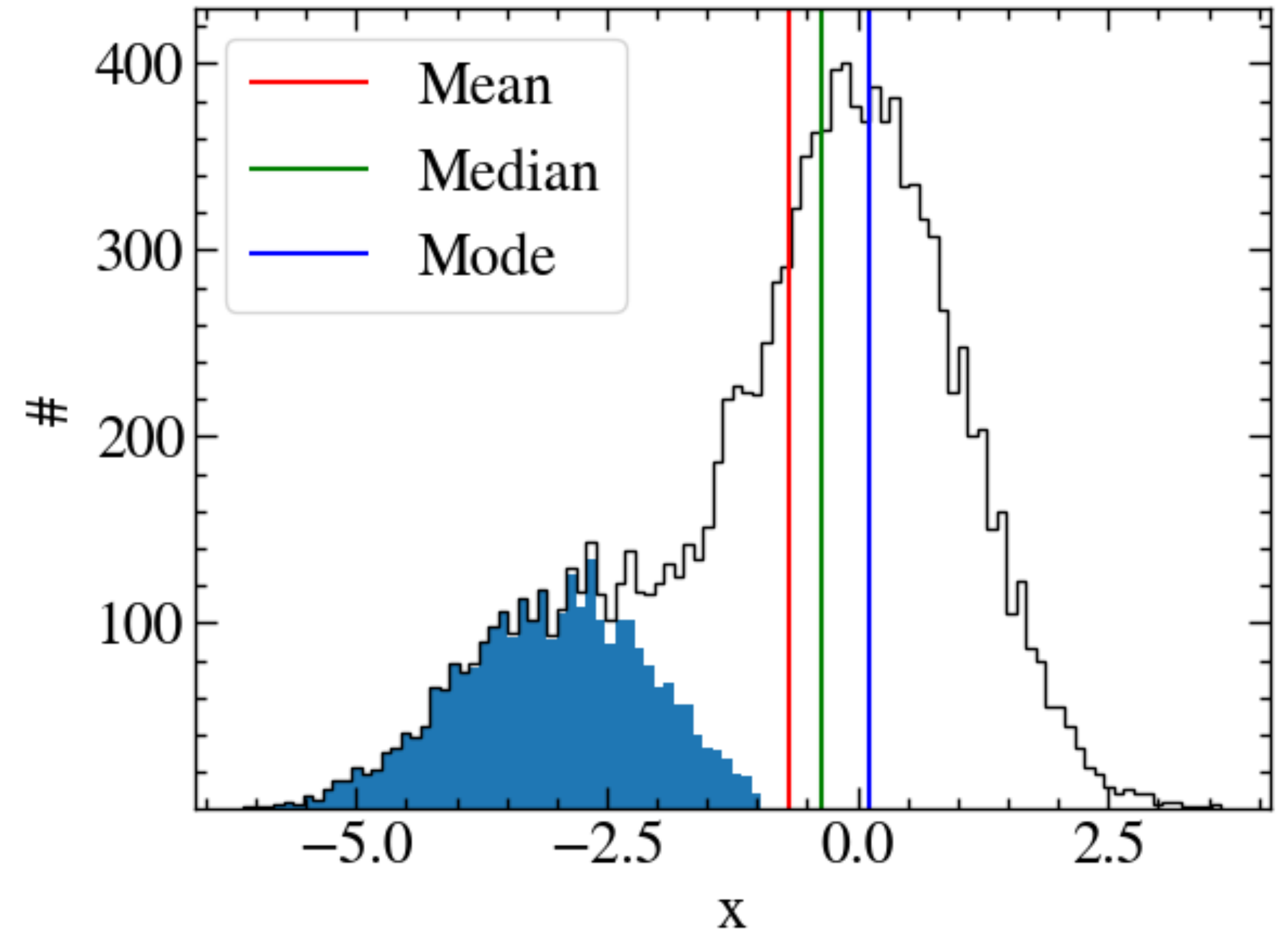
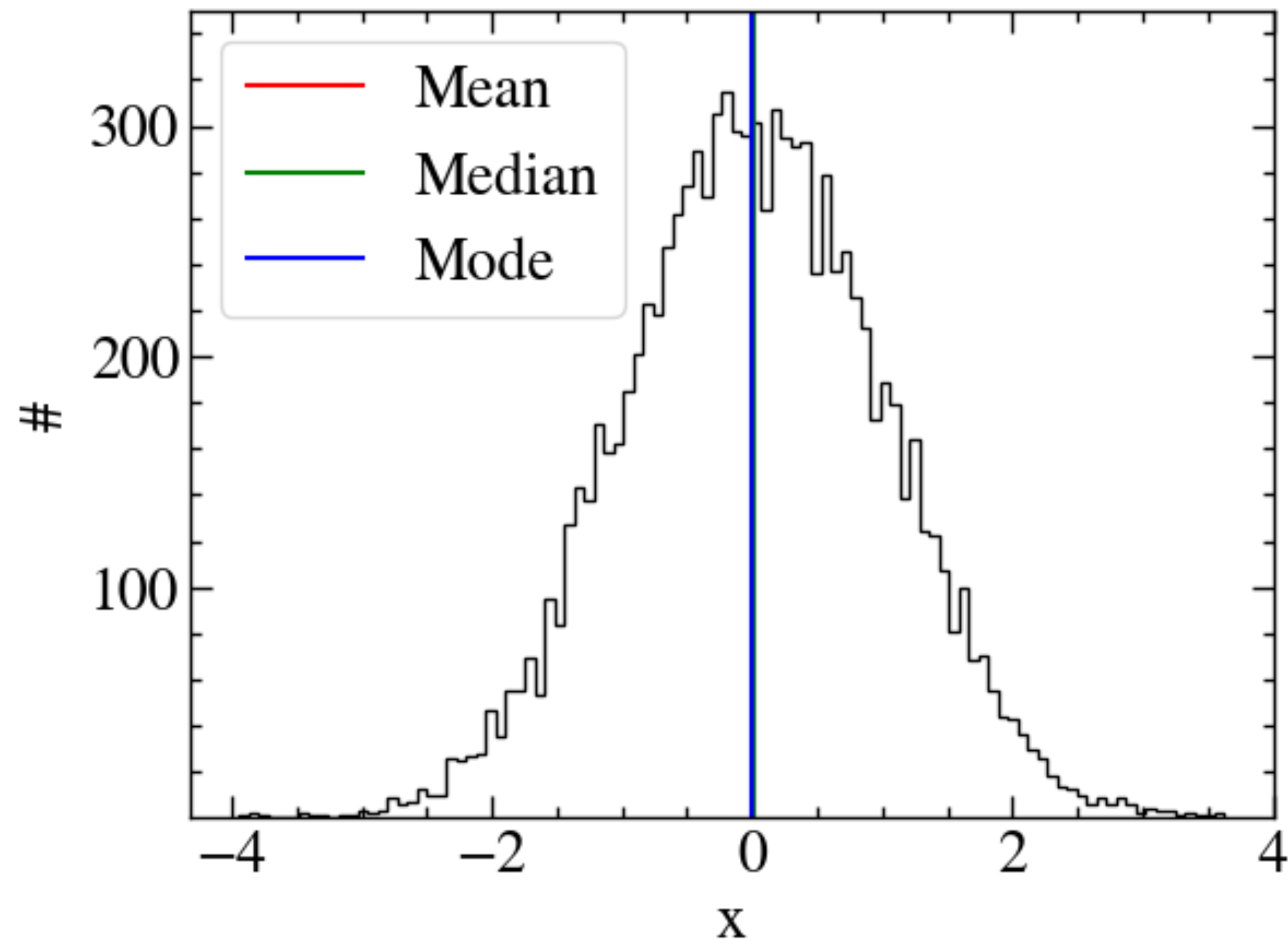


-
- Which background?
 - ~~The star area~~
 - The most exact. But we can't.
 - ~~Mean of all background in the image~~
 - the background varies over the image.
 - Nearby area
 - approximately correct. Actually, in general, correct enough.
-

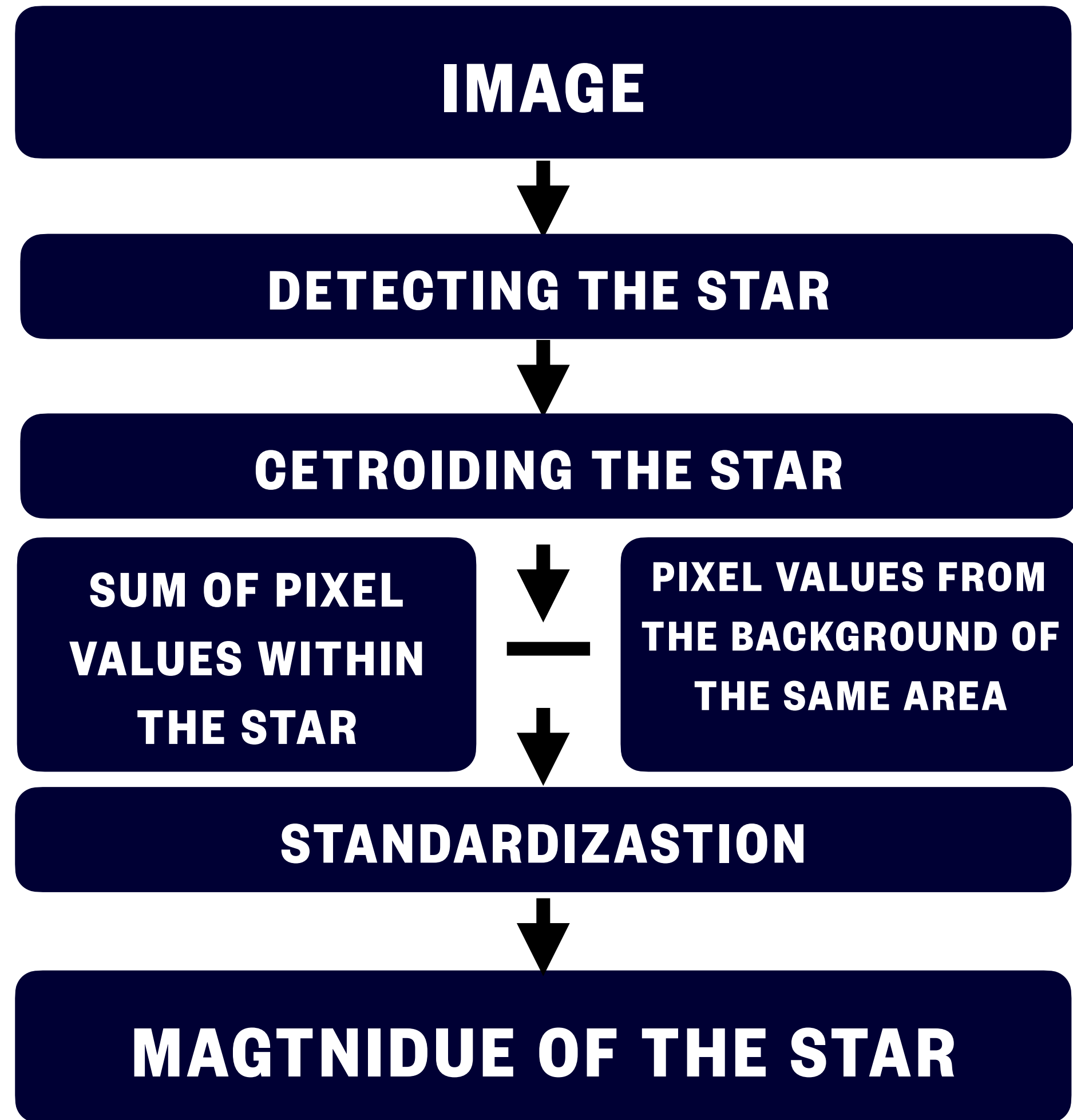
- Annulus



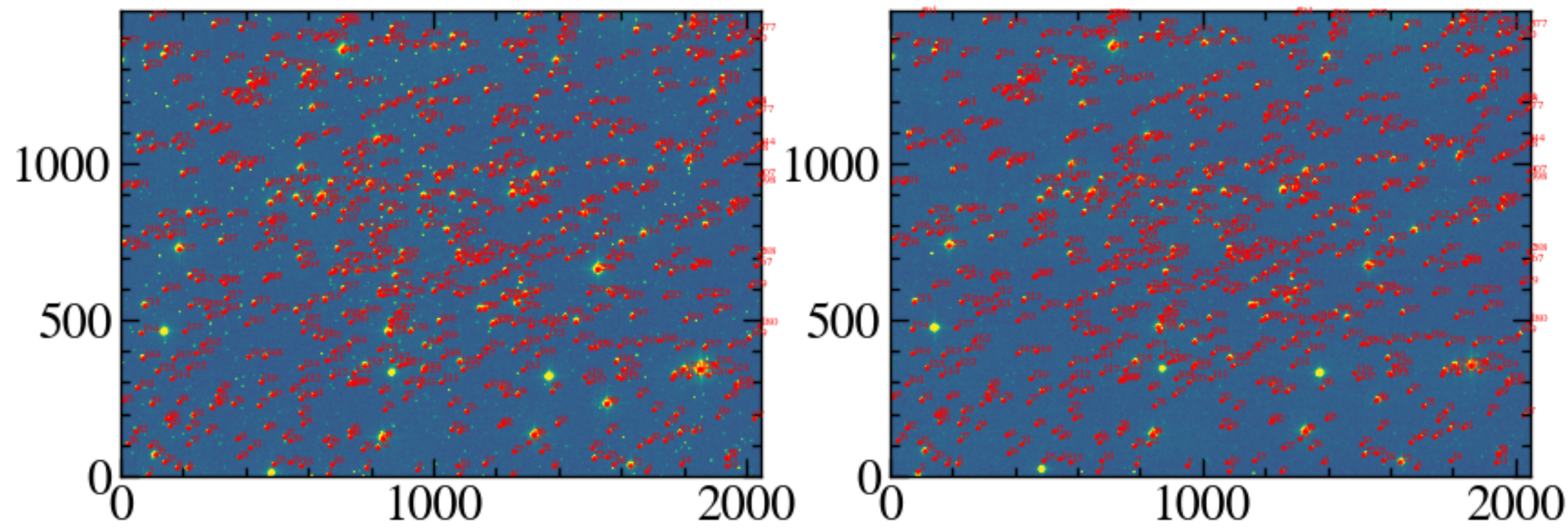
- Mean vs Median vs Mode



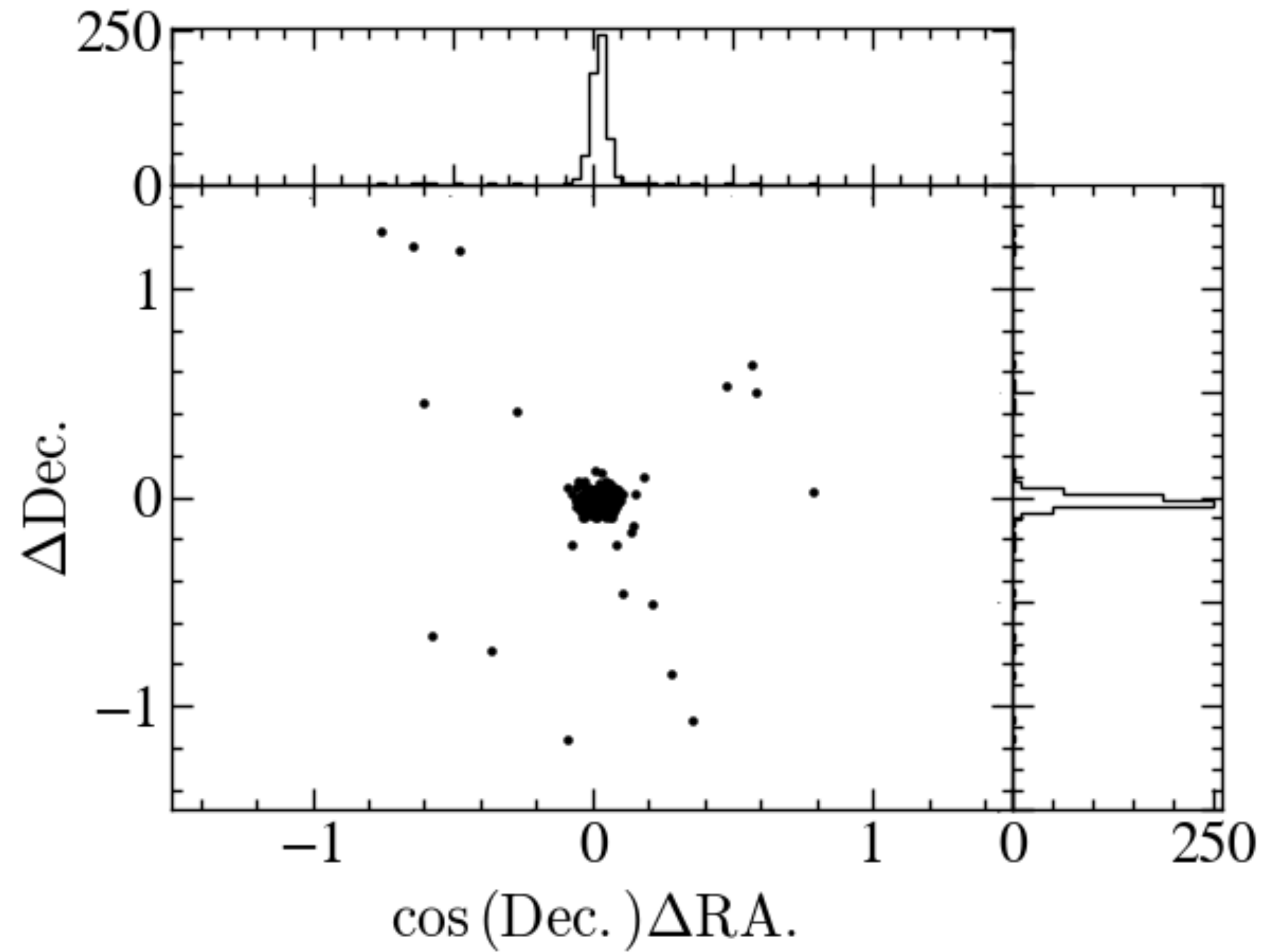
From an image to magnitudes



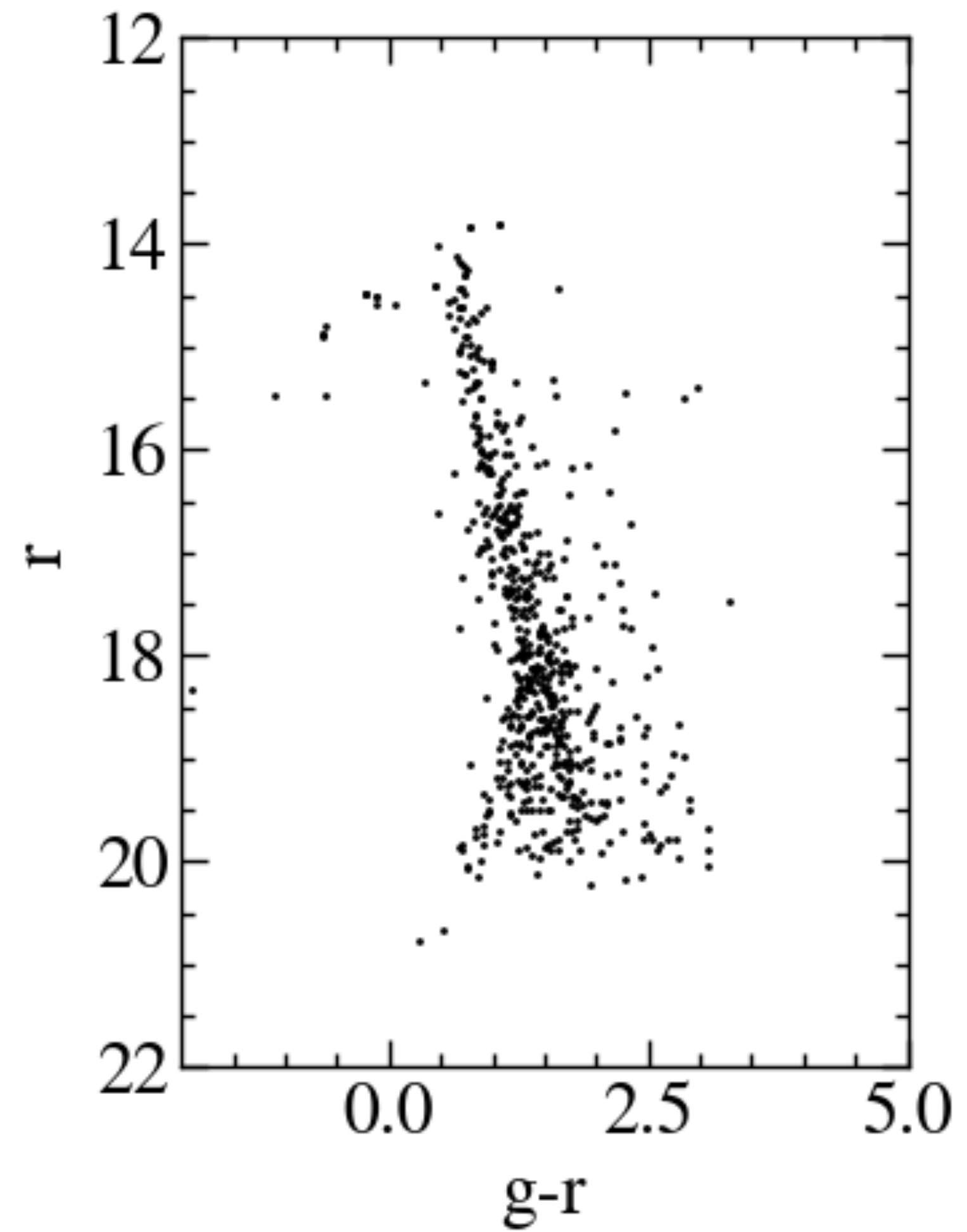
Matching and CMD



Matching and CMD



Matching and CMD



Advanced aperture photometry

- distinguish star and contaminat
- Adjustable aperture radius
- aperture corrections
- Uncertainties of the fluxes



(Simple) Aperture radius

- Here, we use a single radius for apertures.

HW: Draw a CMD from a JWST image
