Determining Optical Distortion

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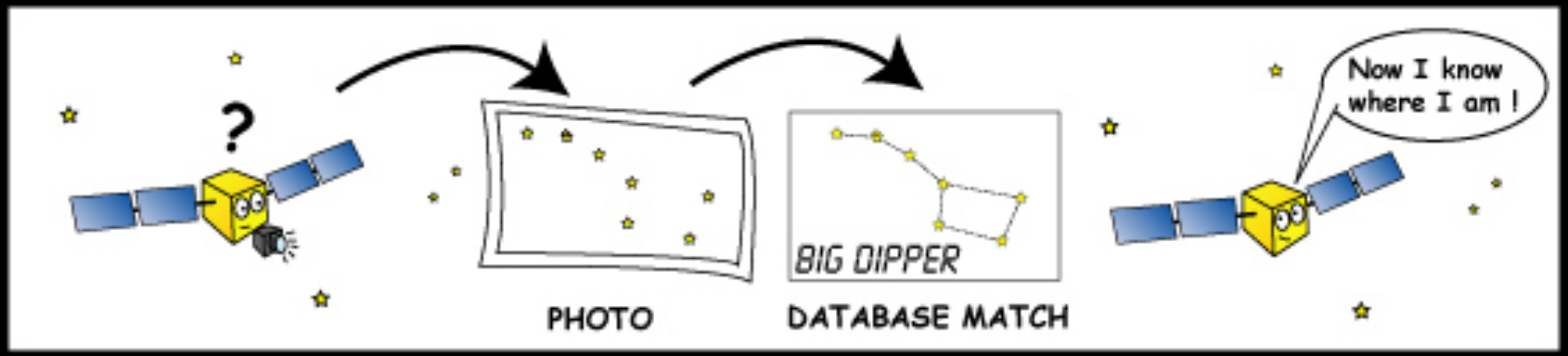
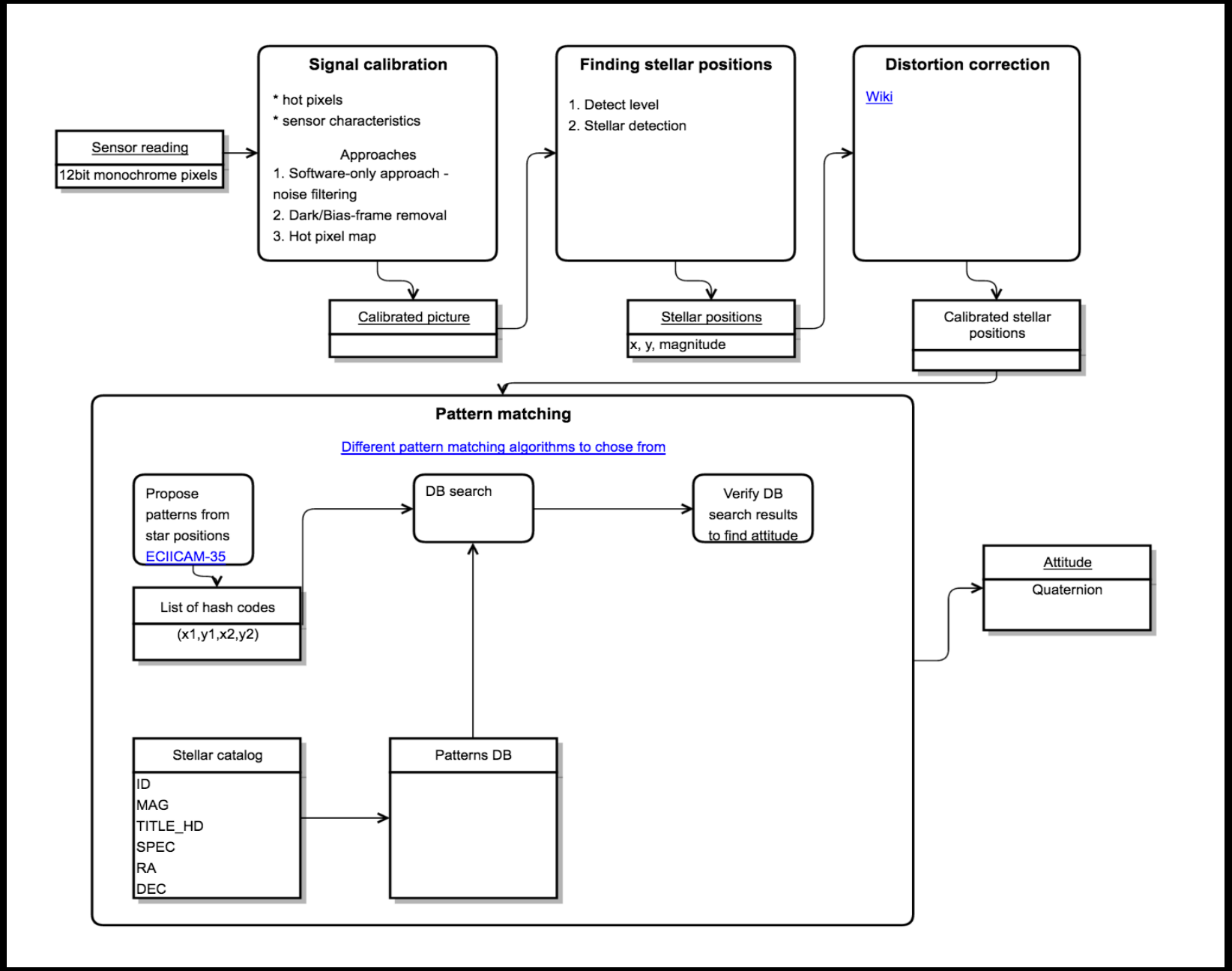
Star Tracker



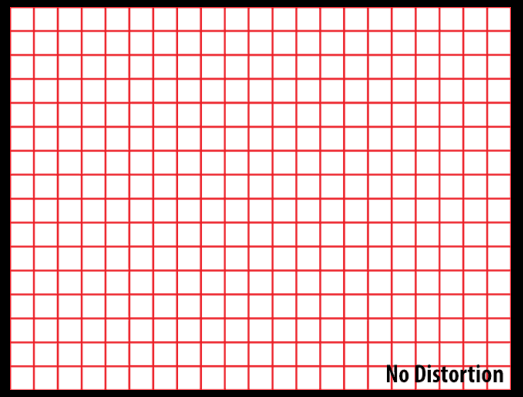

Signal calibration
* hot pixels
* sensor characteristics
Approaches
1. Software-only approach - noise filtering
2. Dark/Bias-frame removal
3. Hot pixel map
Finding stellar positions
1. Detect level
2. Stellar detection
Distortion correction
Wiki
Sensor reading
12bit monochrome pixels
Calibrated picture
Stellar positions
x, y, magnitude
Calibrated stellar positions
Pattern matching
Different pattern matching algorithms to chose from
Propose patterns from star positions
ECIICAM-35
List of hash codes
(x1,y1,x2,y2)
DB search
Verify DB search results to find attitude
Attitude
Quaternion
Stellar catalog
ID
MAG
TITLE_HD
SPEC
RA
DEC
Patterns DB

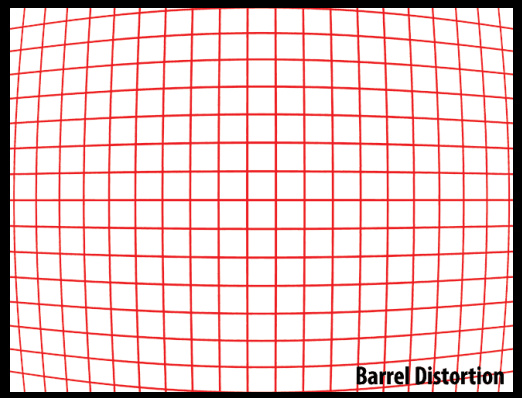
Optical Distortion

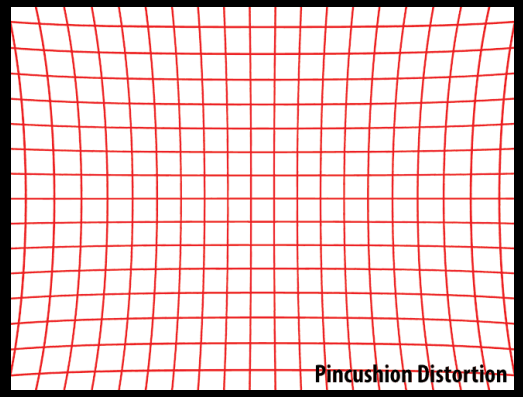
- Distortion is generally referred to an optical aberration that deforms and bends physically straight lines and makes them curvy in images

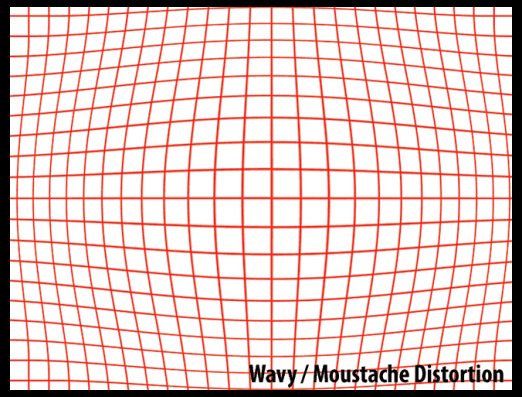
Optical Distortion

- Optical distortion occurs as a result of optical design, when lens elements are used to reduce aberrations (a lens error)
- There are 3 known types of optical distortion - BARREL, pincushion, mustache



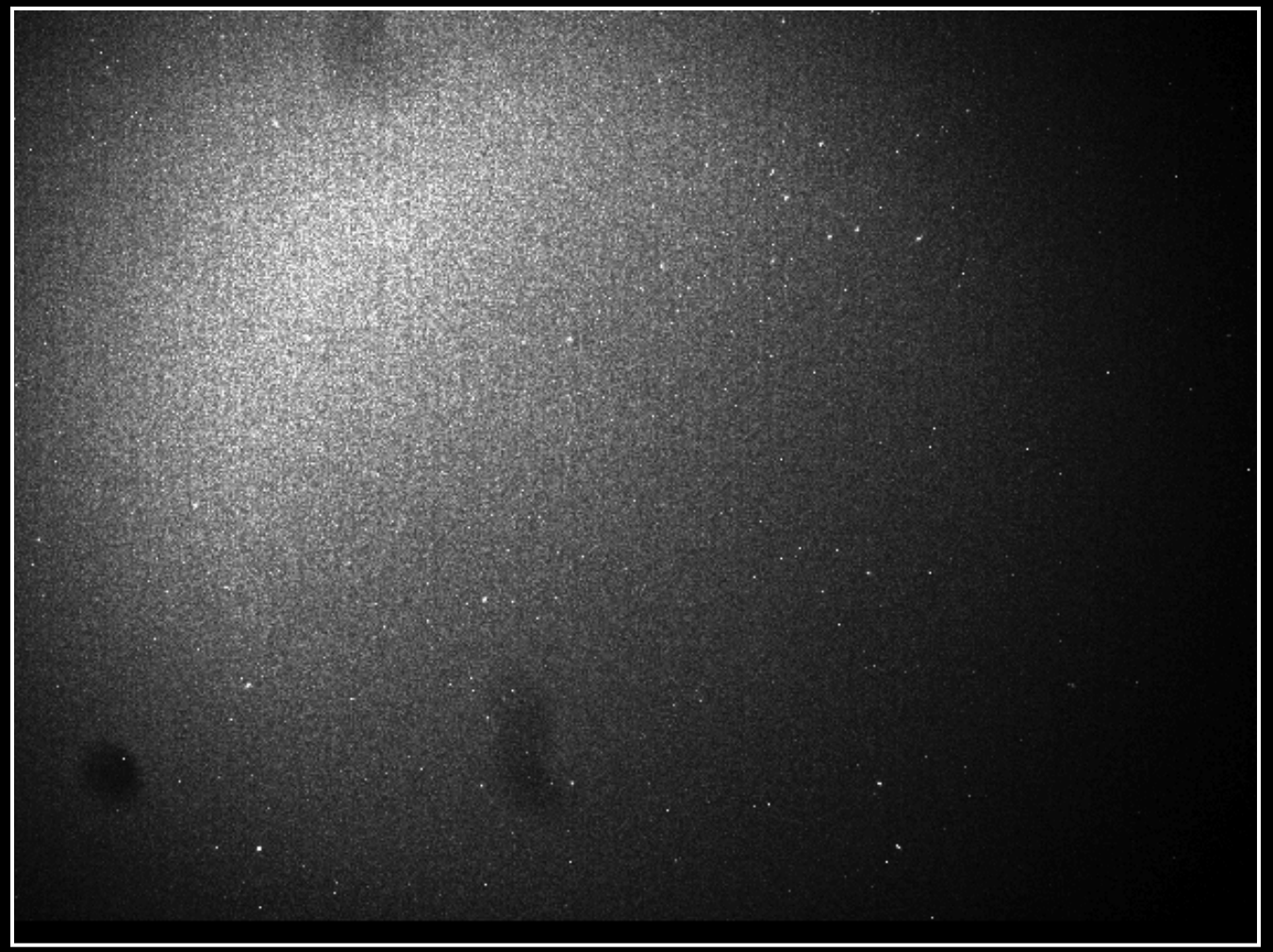


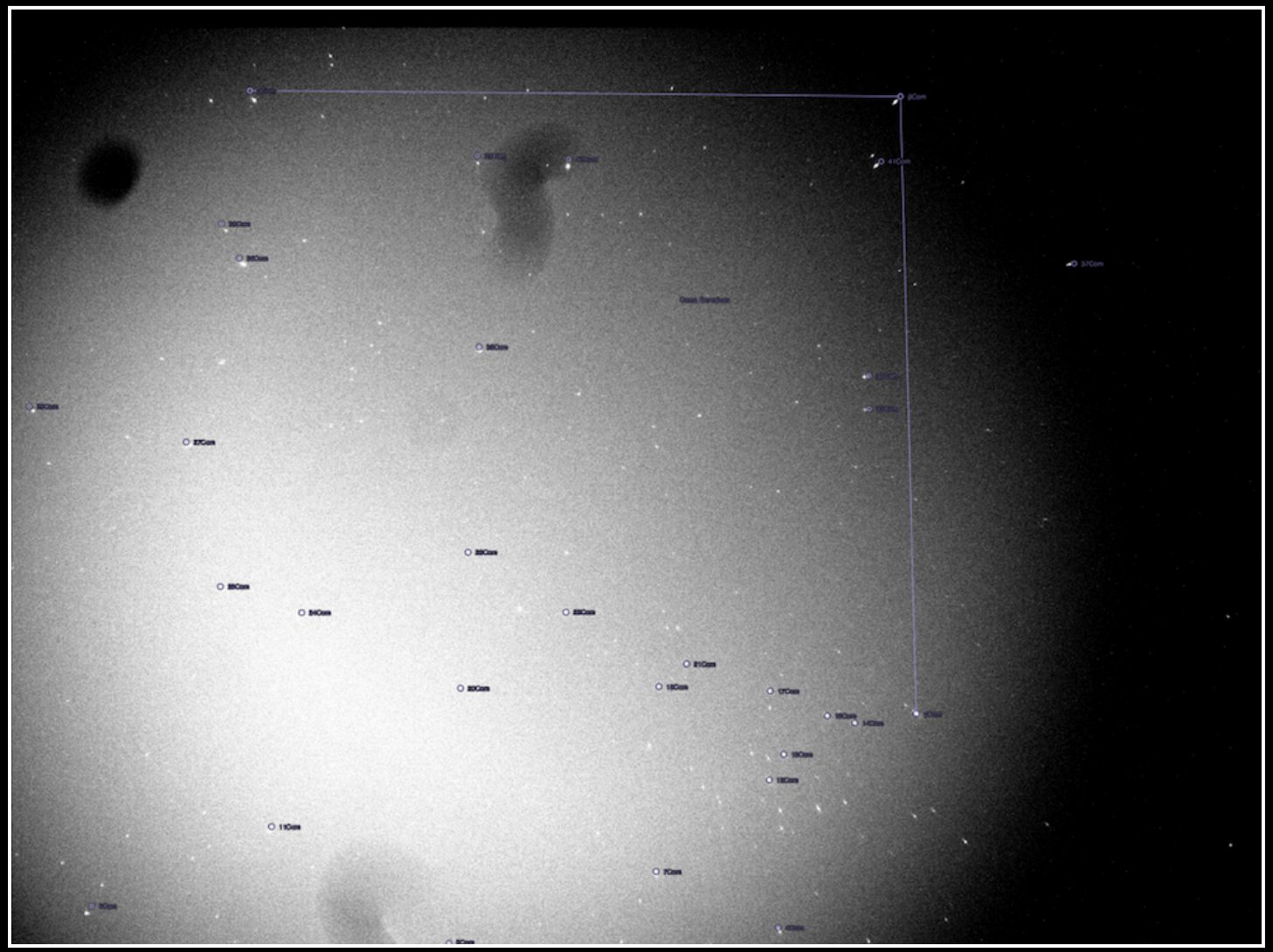




Determining Star Coordinates

Determining Star Coordinates





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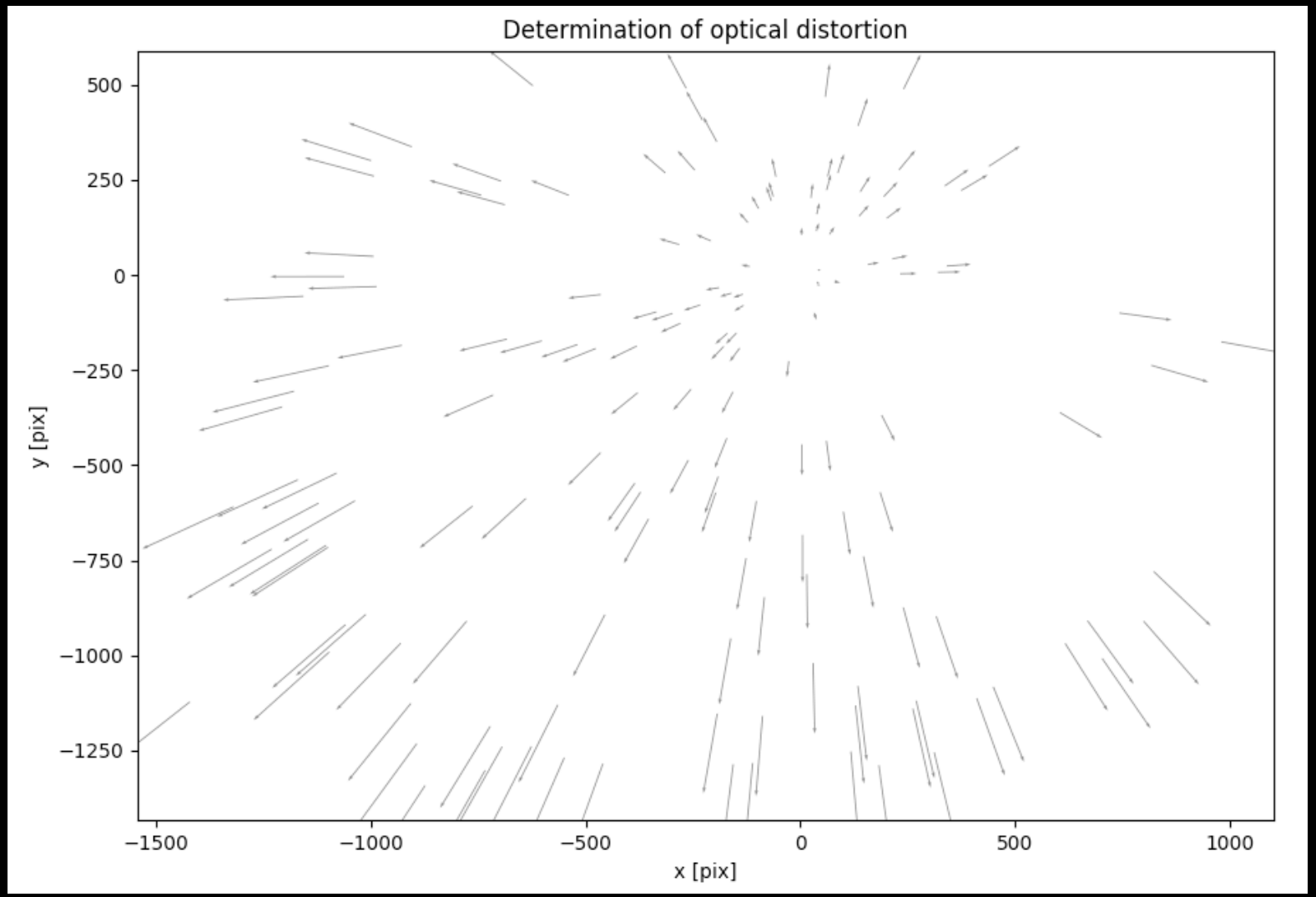
Determining Star Coordinates

- Coordinates of all the stars (.axy file)
- Matched it with Tycho-2 star catalogue in TopCat (2.5 mil stars)

- Converted RA/DEC coordinates into PIX (using 2 headers – LIN & SIP)
- Created 2 sets of data – distorted and undistorted pixel coordinates



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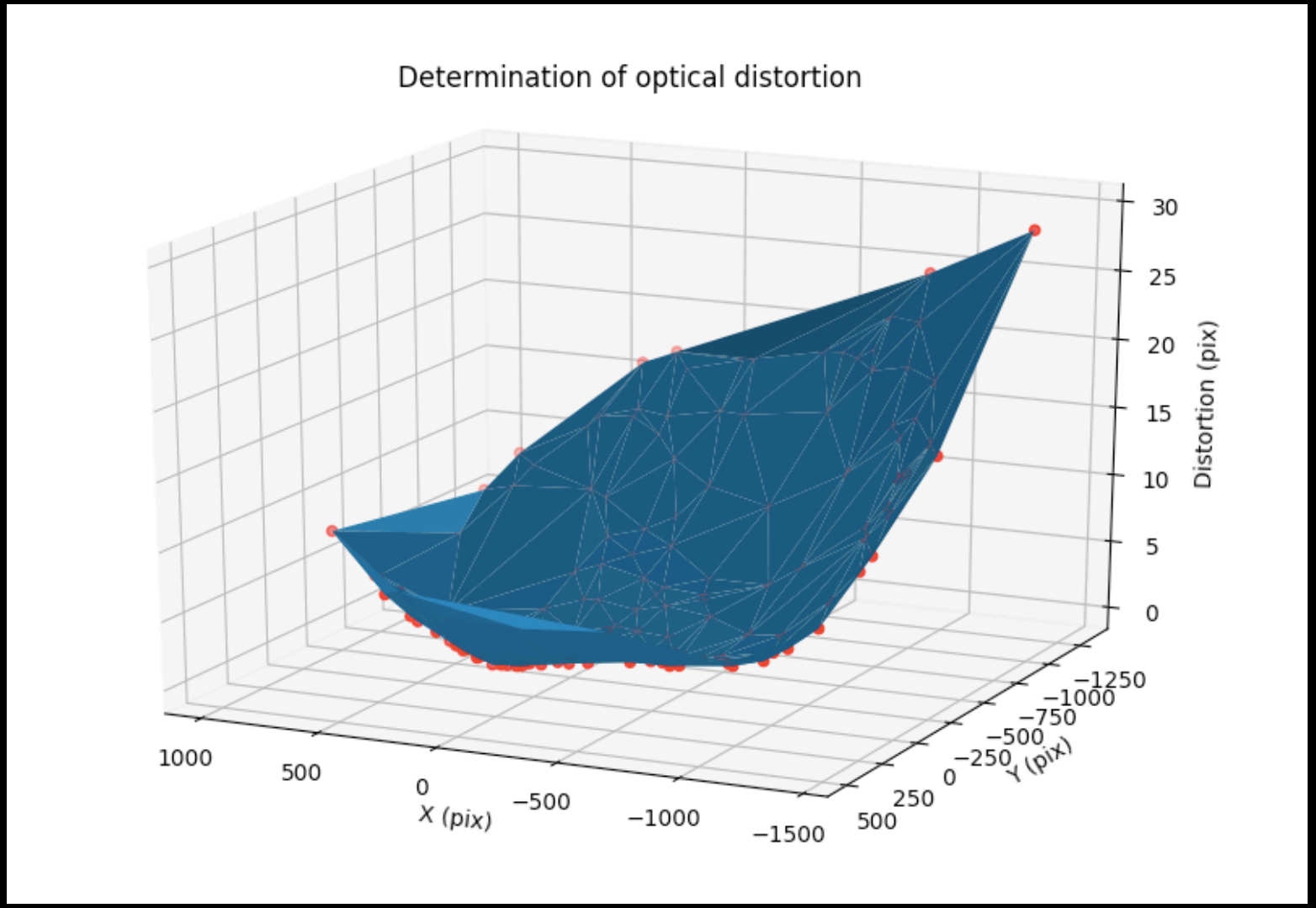

Determination of optical distortion
Distortion (pix)
30
25
20
15
10
5
0
1000
500
0
−500
−1000
−1500
X (pix)
500
250
0
−250
−500
−750
−1000
−1250
Y (pix)

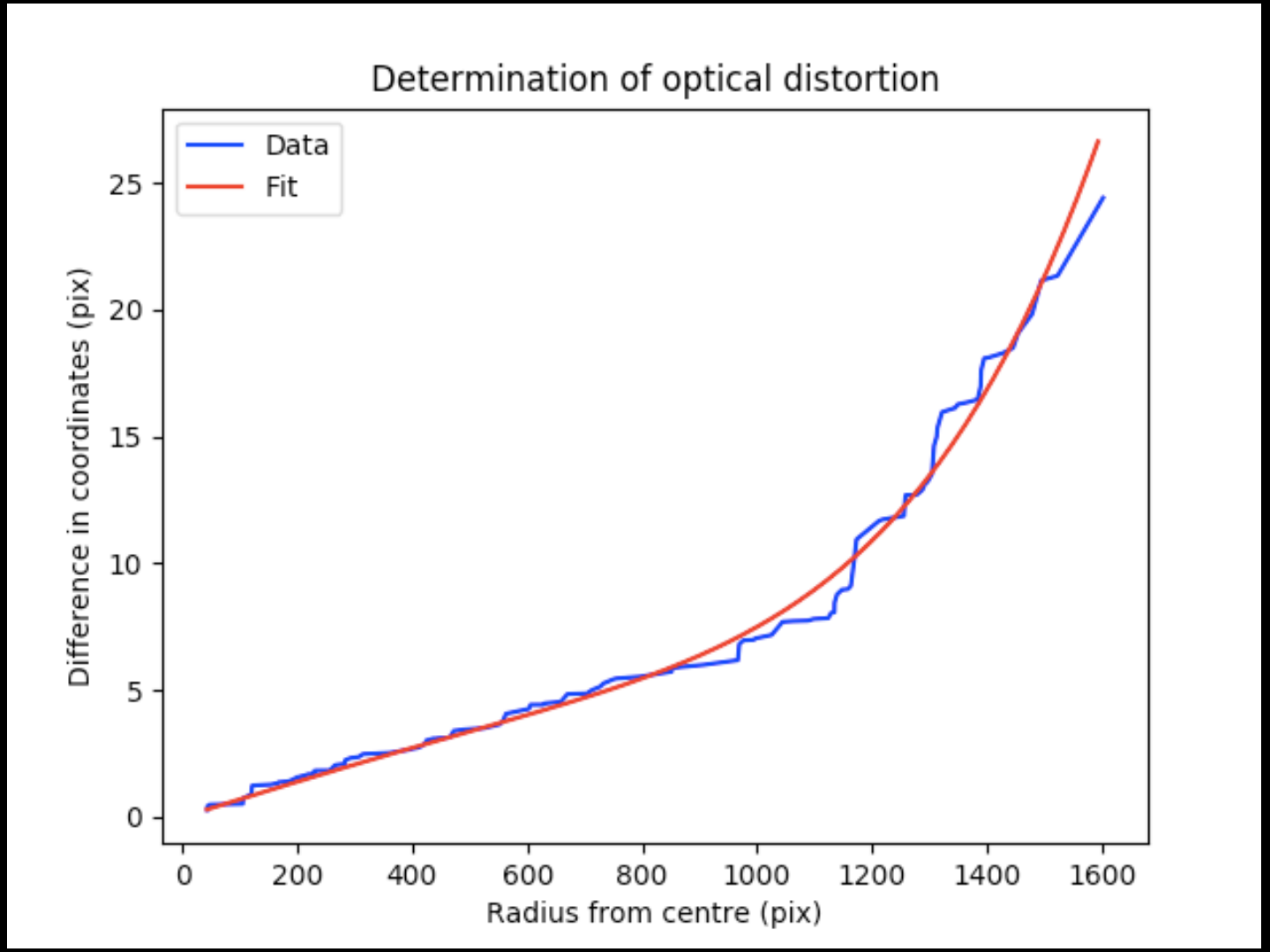
Determining Optical distortion

- Used the simplest case for lens distortion correction formula

$$r_u = r(1 + K_1 r^2 + K_2 r^4)$$

- Where r_u – undistorted coordinates, r – distorted coordinates
- K_1 & K_2 – constants we want to find

- Used scipy.optimize (least squares function)



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Results

- K_1 = 2.72783066e-16
- K_2 = 3.19674373e-09
- Very small!

Further Analysis

- Determine the constants from all images (16)
- Take more images (bigger portion of sky – more stars)
- Repeat

Conclusion

- Lens error
- Determining distorted and undistorted coordinates
- Fitting the polynomial

- K_1 = 2.72783066e-16
- K_2 = 3.19674373e-09