Two-Step Position Detection for NIF Automatic Alignment

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Outline

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- Introduction
- Problem Statement
- Background
- Two step algorithm examples: simple to complex
- Results
- Challenges

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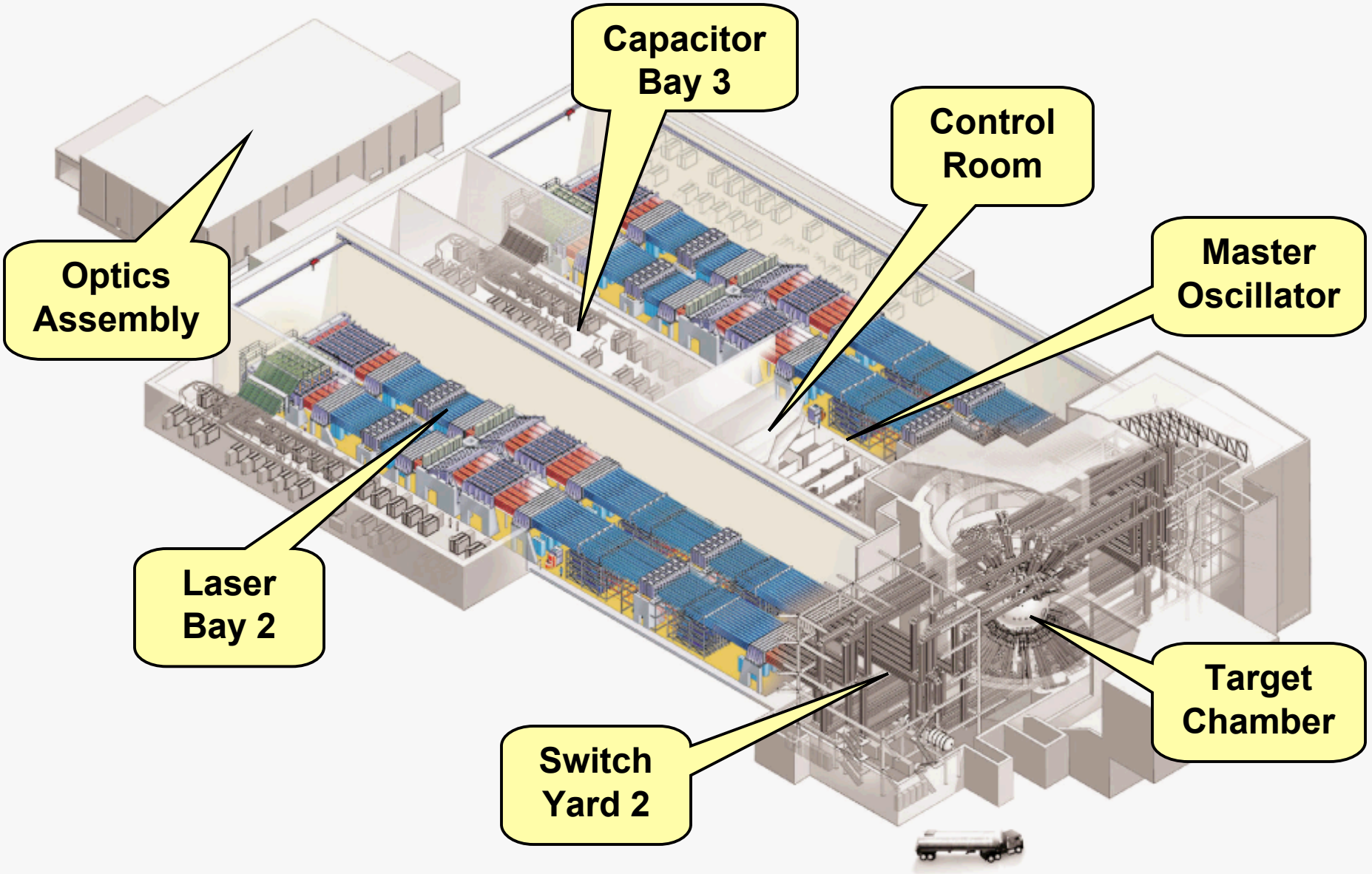

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Automatic alignments need automated detection of beam position and automatic mirror adjustments

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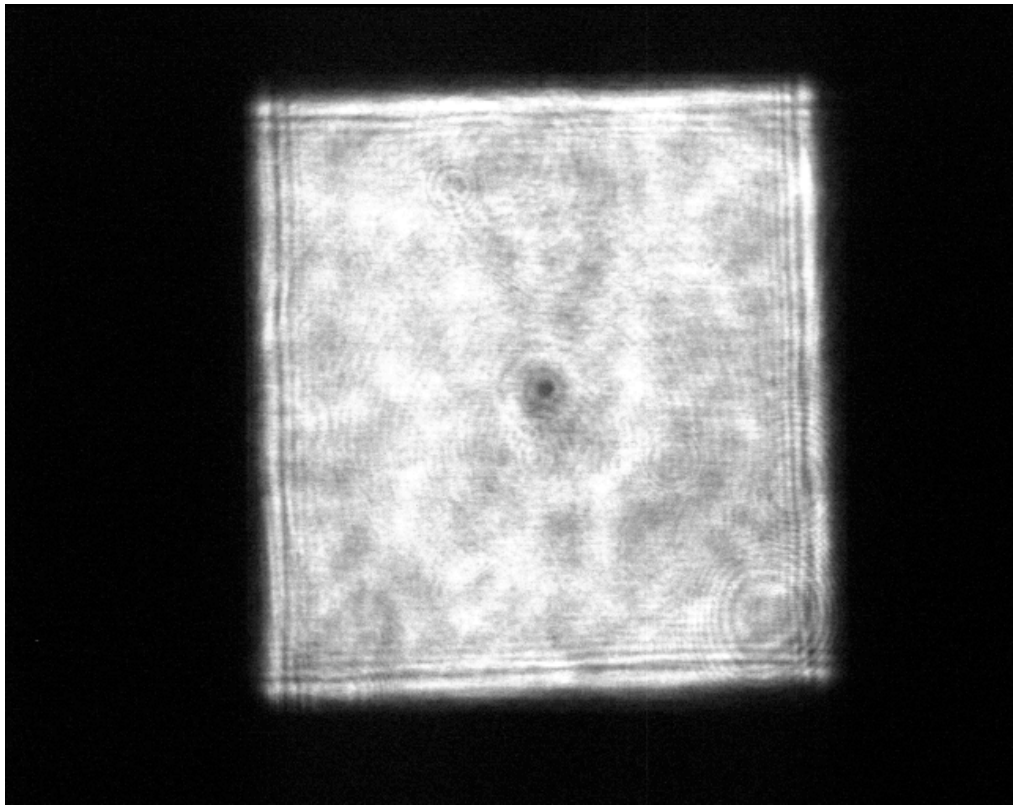
- **Automatic alignment uses video images of fiducials to find positions of laser beam**



Problem: How do we detect positions when the fiducials vary in shape and size?

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- Automatic alignment needs to detect position of beam
  - Challenges
    - Beams with different markers
    - Same marker, but sizes vary due to defocus
    - Circles of different sizes
    - Variations relatively large

Alignment image contains circles and squares

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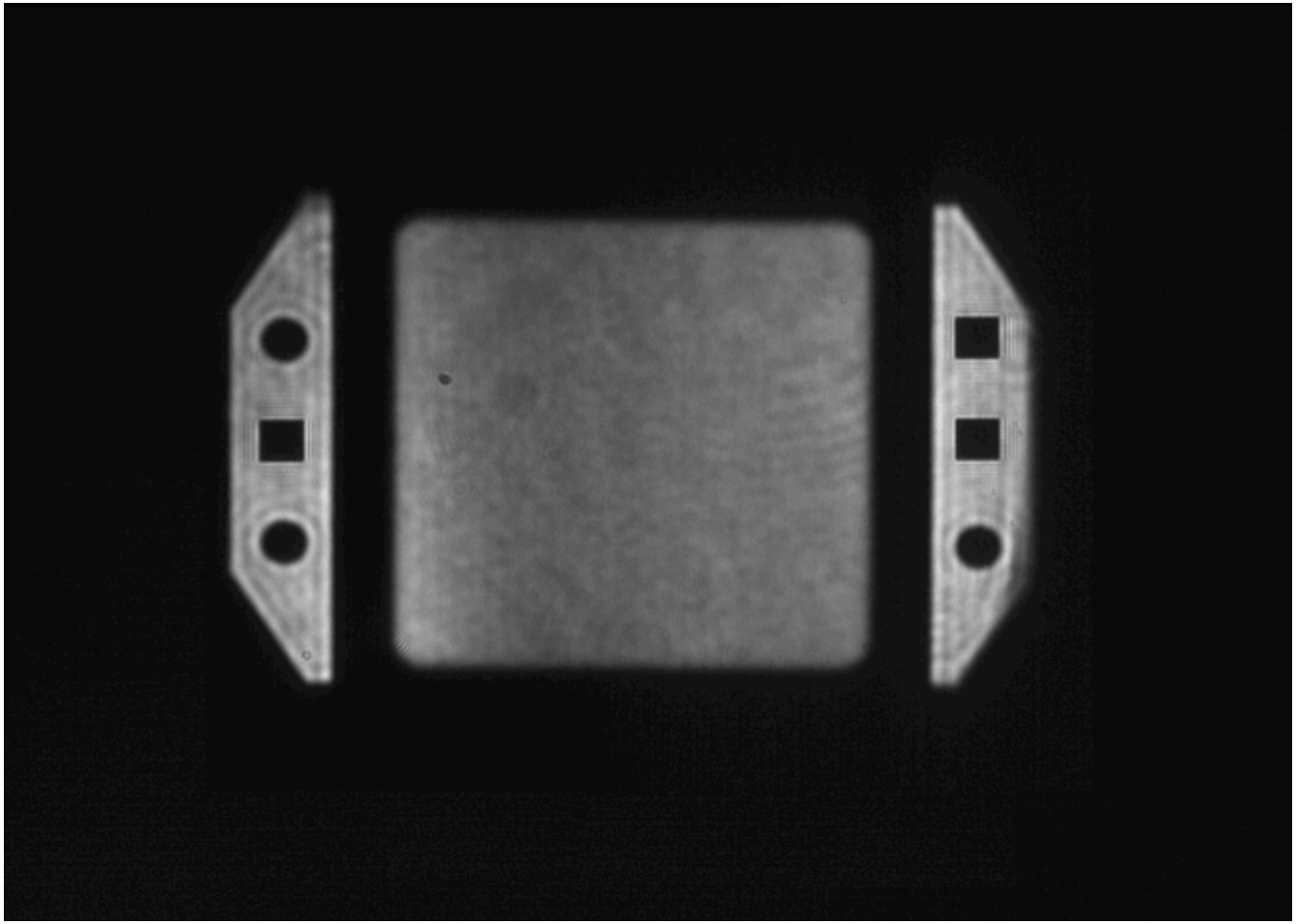

Defocused spots exhibit wide variation in size and quality

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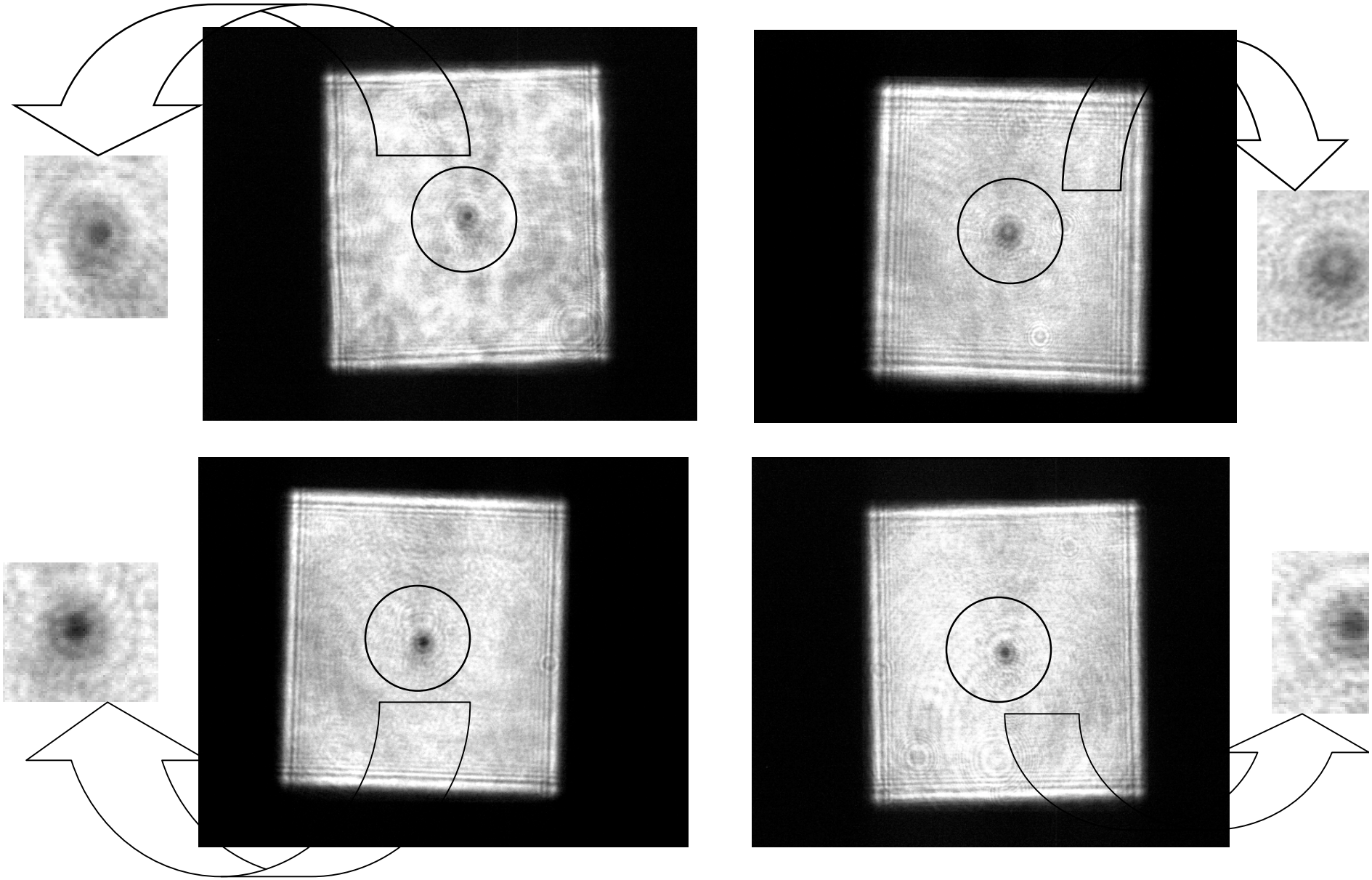

Different markers identify different beams

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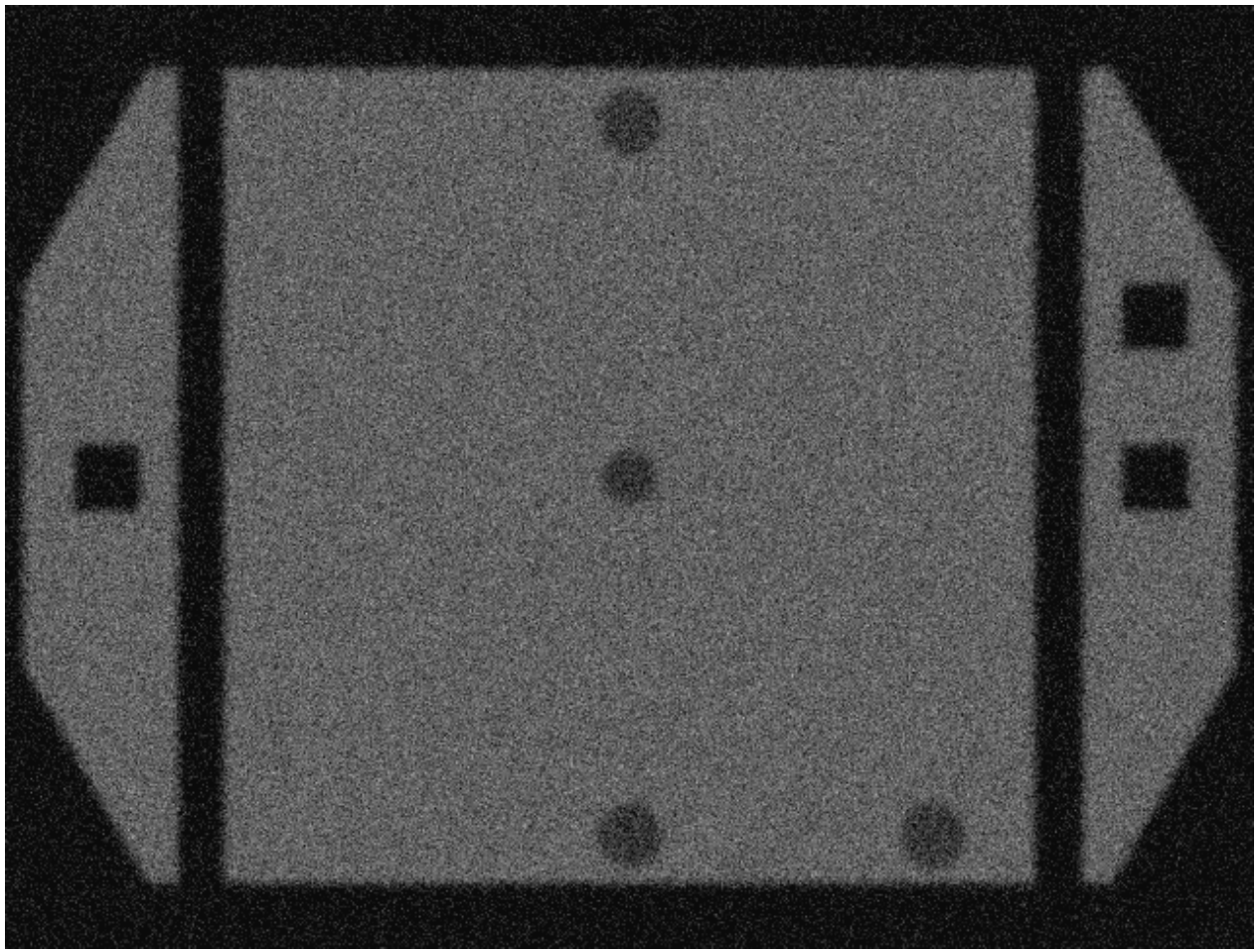

Some alignment images vary from 35 pixels to 200 pixels

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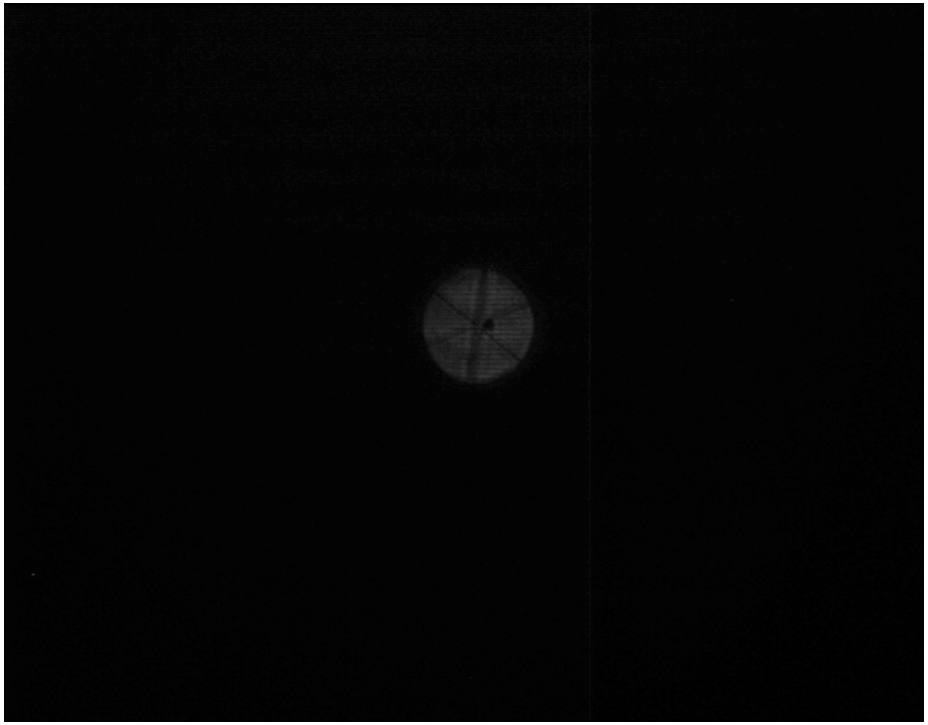

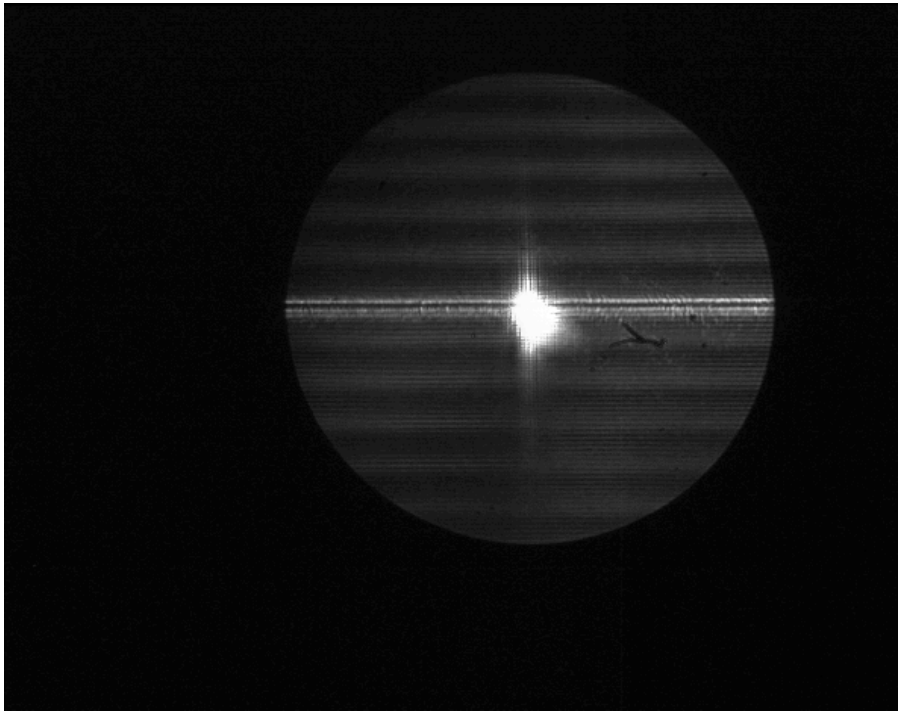

Possible solutions

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- **Centroid**
- **Template**

How to choose the template?

Algorithm background

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CMF

$$H_{CMF}(U_x,U_y) = F^*(U_x,U_y) = \left|F(U_x,U_y)\right| \exp(-j\phi(U_x,U_y))$$

POF

$$H_{POF}(U_x,U_y) = \exp(-j\phi(U_x,U_y))$$

AMPOF

$$H_{AMPOF}(U_x,U_y) = \frac{aF^*(U_x,U_y)}{\left[\, b + c\left|F(U_x,U_y)\right| + d\left|F(U_x,U_y)\right|^2 \,\right]^m}$$

Position is obtained from cross and auto-correlation and the original template location

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$$x_{pos} = x_{cross} \square x_{auto} + x_c$$

$$y_{pos} = y_{cross} \square y_{auto} + y_c$$

CMF output shows cross-correlation location

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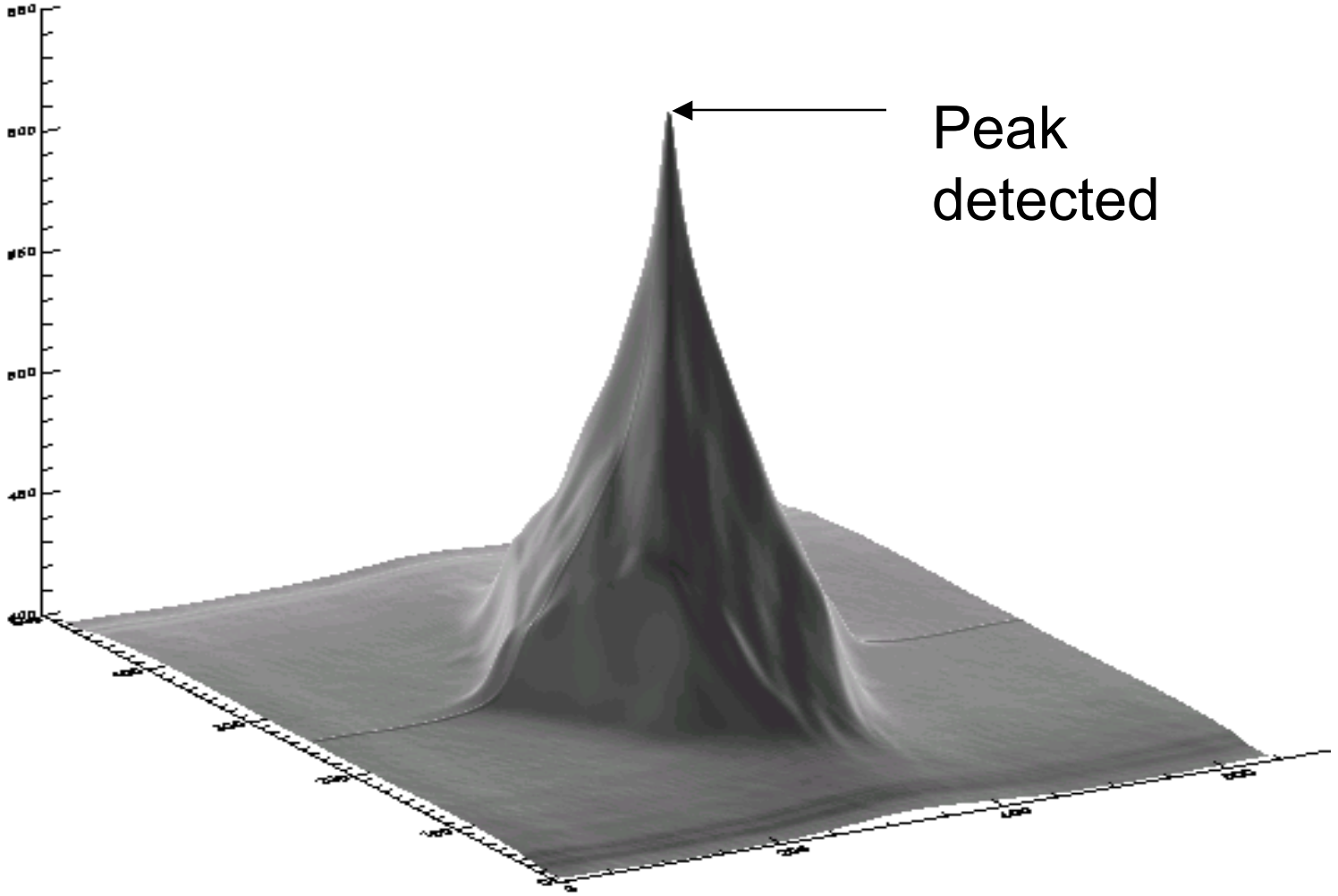

Problem

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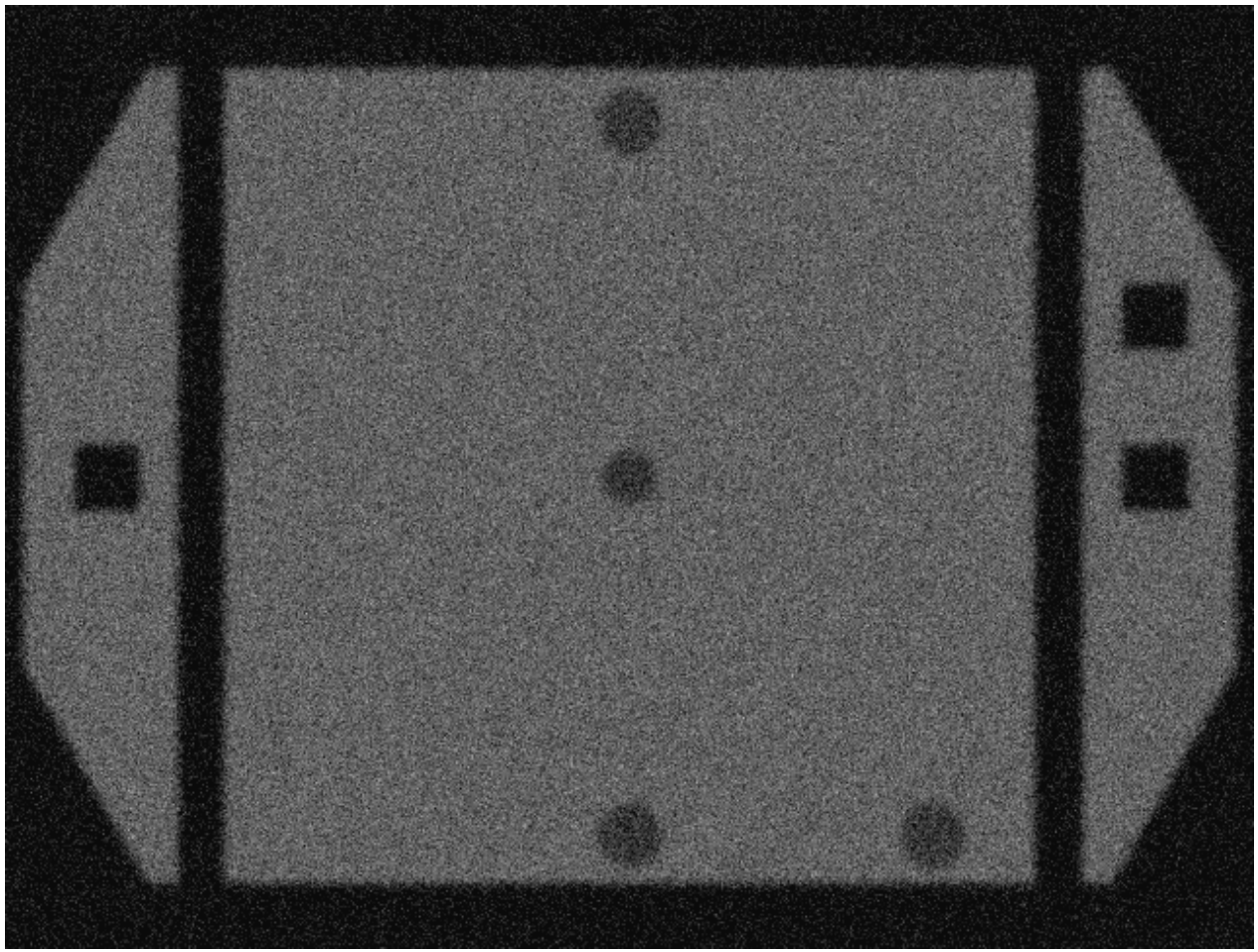

Problem

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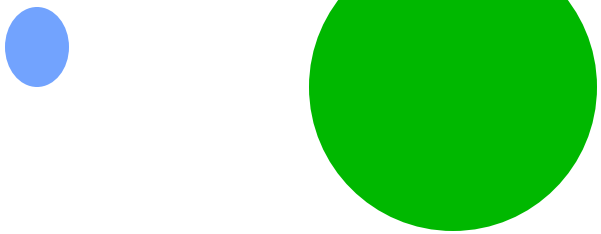
- Two circles, r1 < r < r2 and r3 < r < r4
- Square, d1 < d < d2



- Why ?
- By design
- Due to optics

Two step approach

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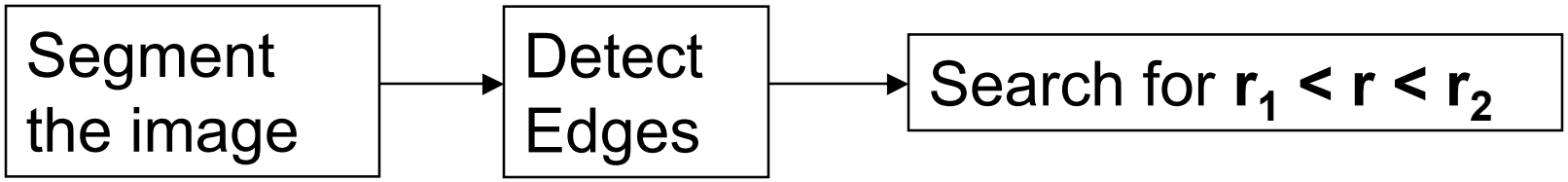
- **Step 1: Search for right radius**



- **Segment based on blob size**
  - **Segment 1, less than 800**
  - **Segment 2, between 900 and 1100**
  - **Segment 3, between 1200 and 1400**

- **Change to square, repeat step 1**

Two step process

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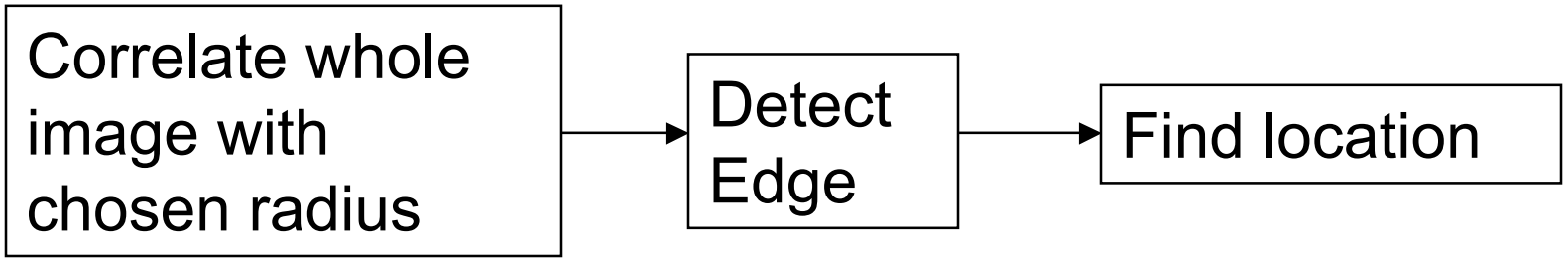
- **Step 2: Find the position**



- **Change to square, repeat step 2**

Segmentation is performed based on pixel size

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- **Feature sizes of interest (area in pixels)**

  (1086, 1074, 1086, 836, 832, 836)

- **Searching for squares (589.0, 158.5)**
- **Searching for circles at (52.0,158.0)**

Movie of the circle match in the correlation plane shows correlation becomes a point at right radius

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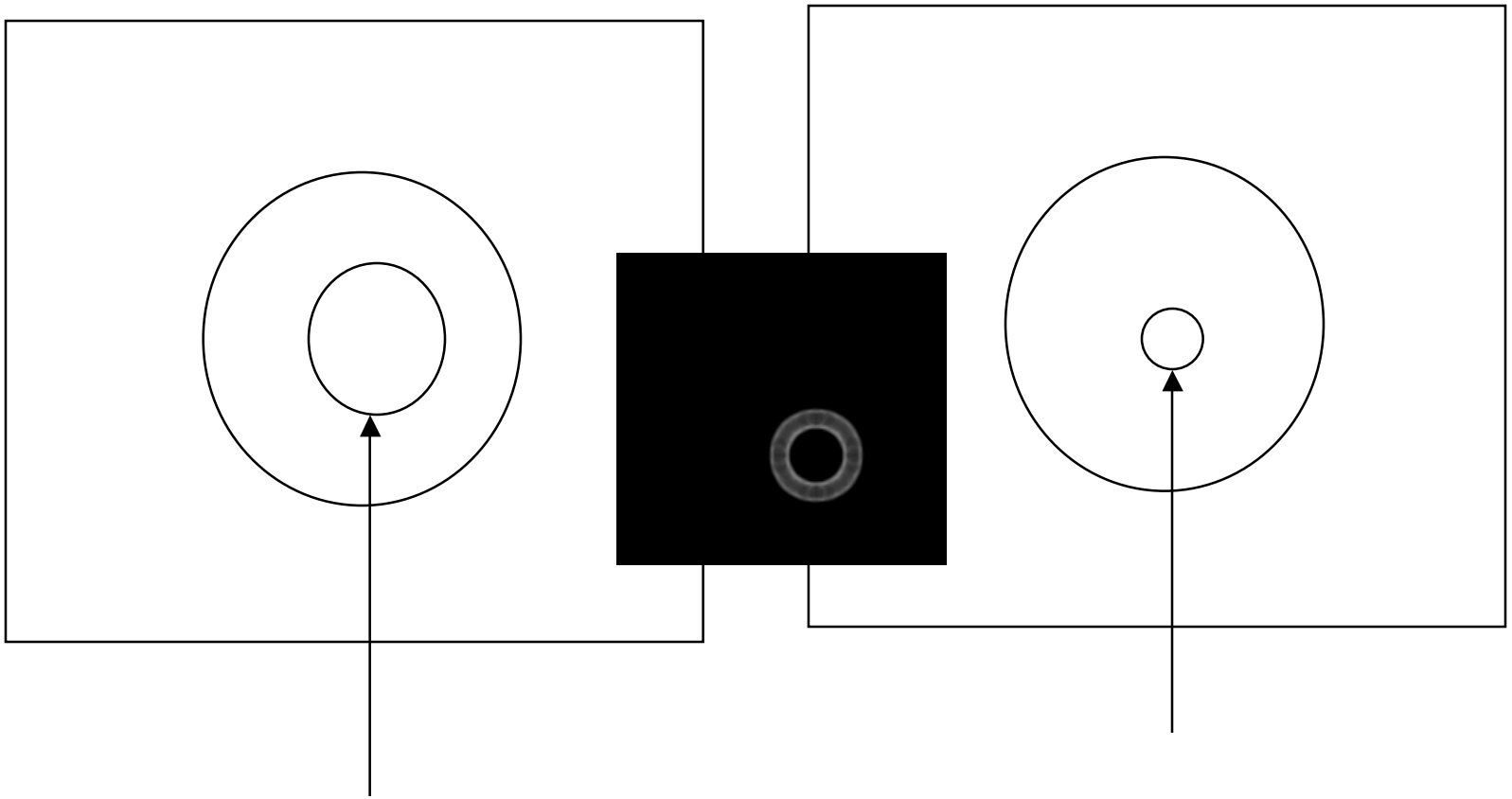

Correlation is also a circle

Circle becomes smaller as it nears the right radius

Search selected 16.5 pixels for circle radius

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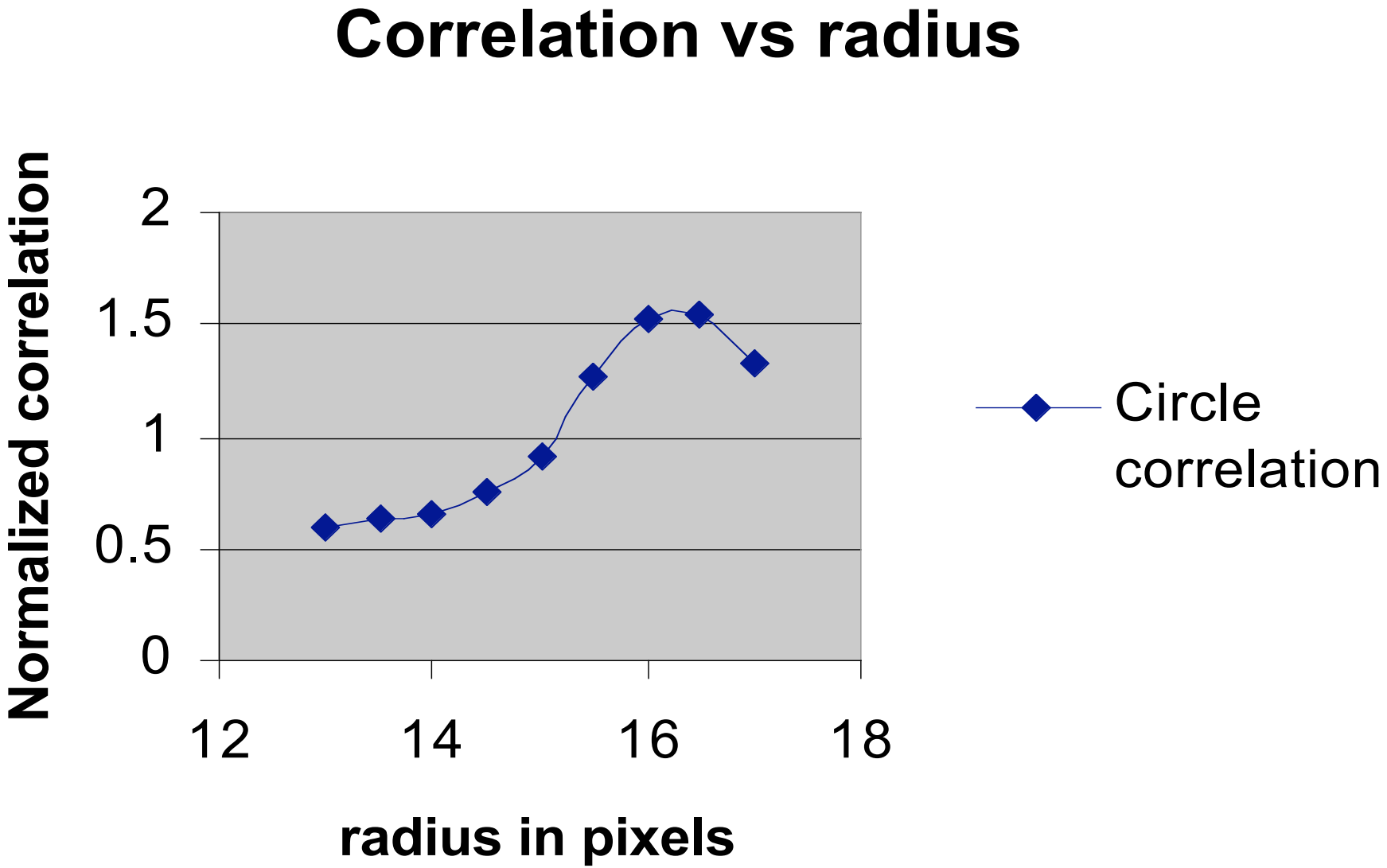

Search selected square with dimension of 15.5 pixels

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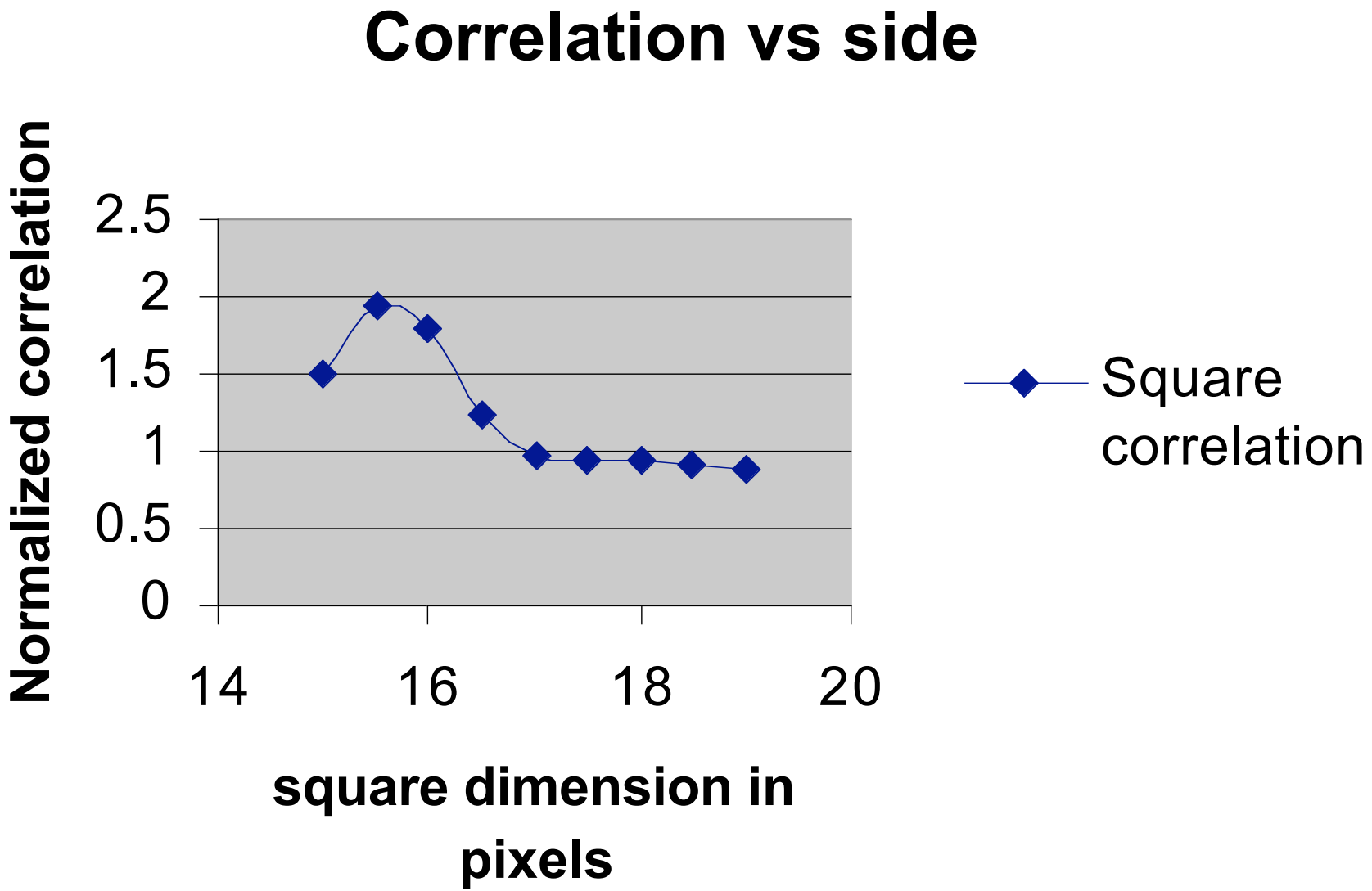

Circles of two sizes and squares of a single size detected (after 3 searches and 3 correlations)

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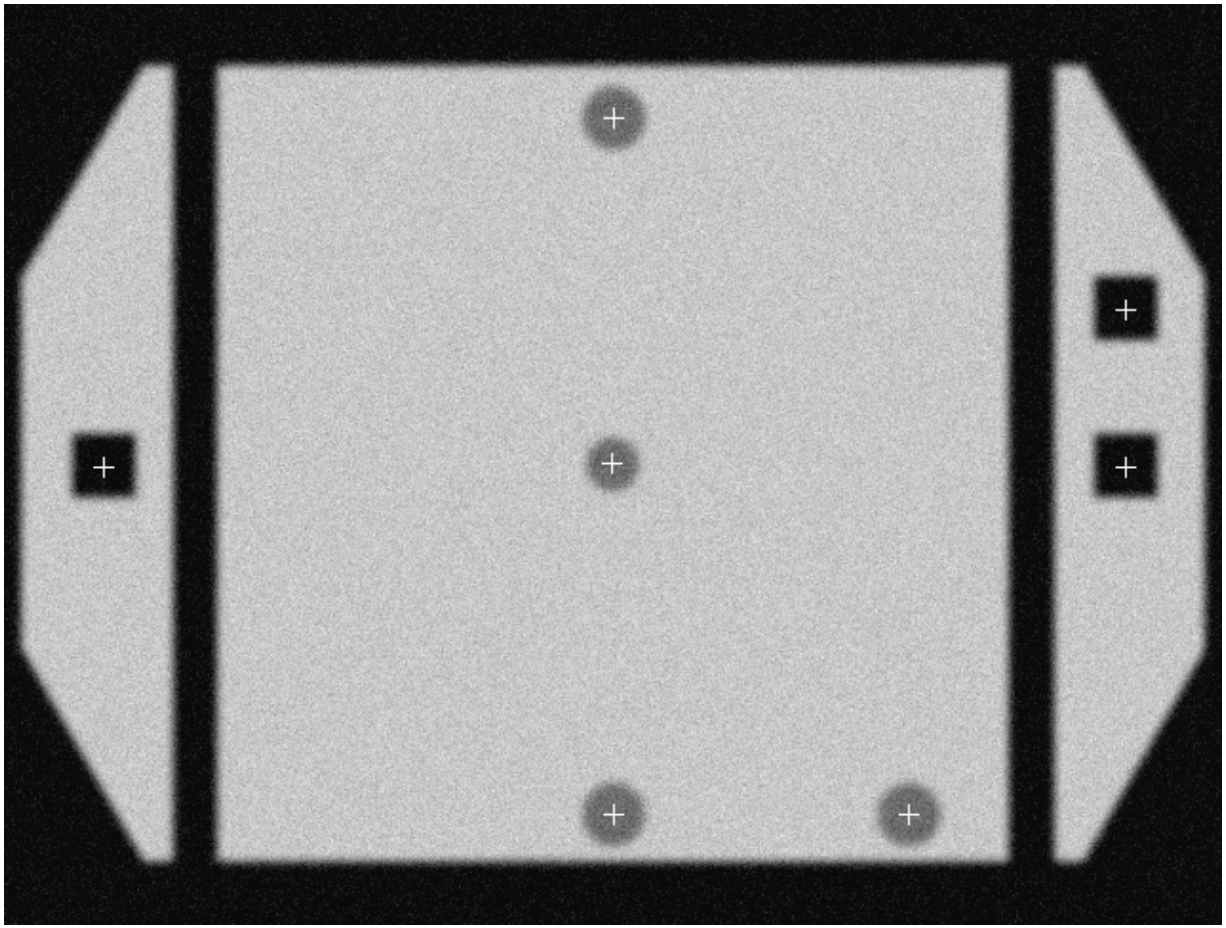

Example 2

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- 5 circles, $r_1 < r < r_2$
  - Where $r_1 = 35$ and $r_2 = 260$

Pinhole images could vary from 35 pixels to 200 pixels (radius)

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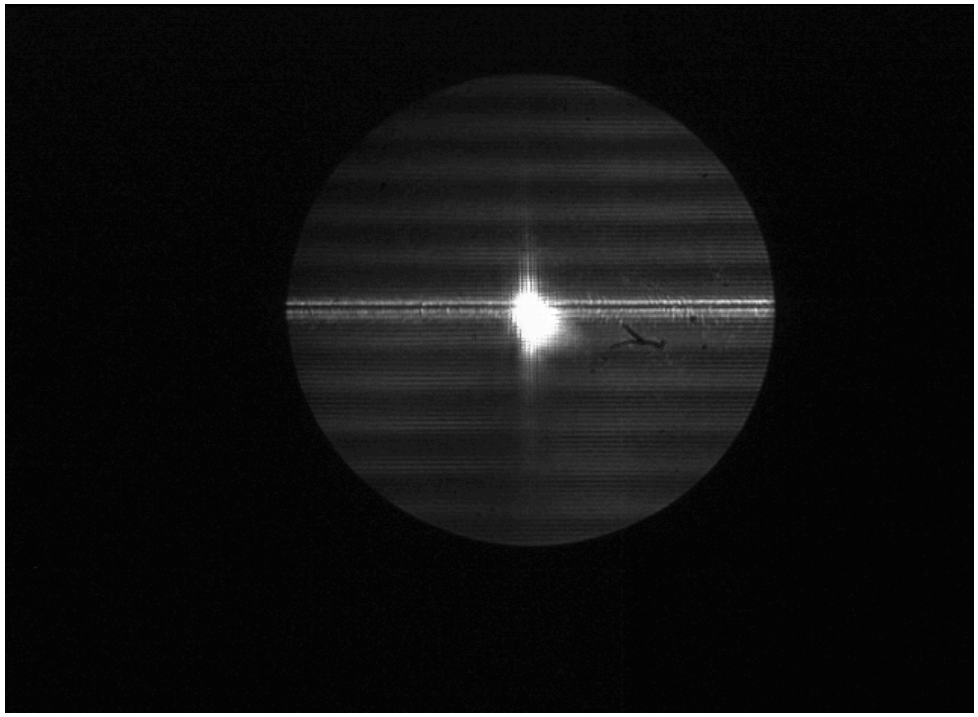

Solution to complex problem: Example 2

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- **Successive approximation**

Centroid

Section the image at centroid → Estimate $r_1 < r < r_2$

- **Search by matching**

Correlate whole edge image with radius range → Find location

Cross-section of images could provide an initial estimate of the radius such as 37 and 204 pixels

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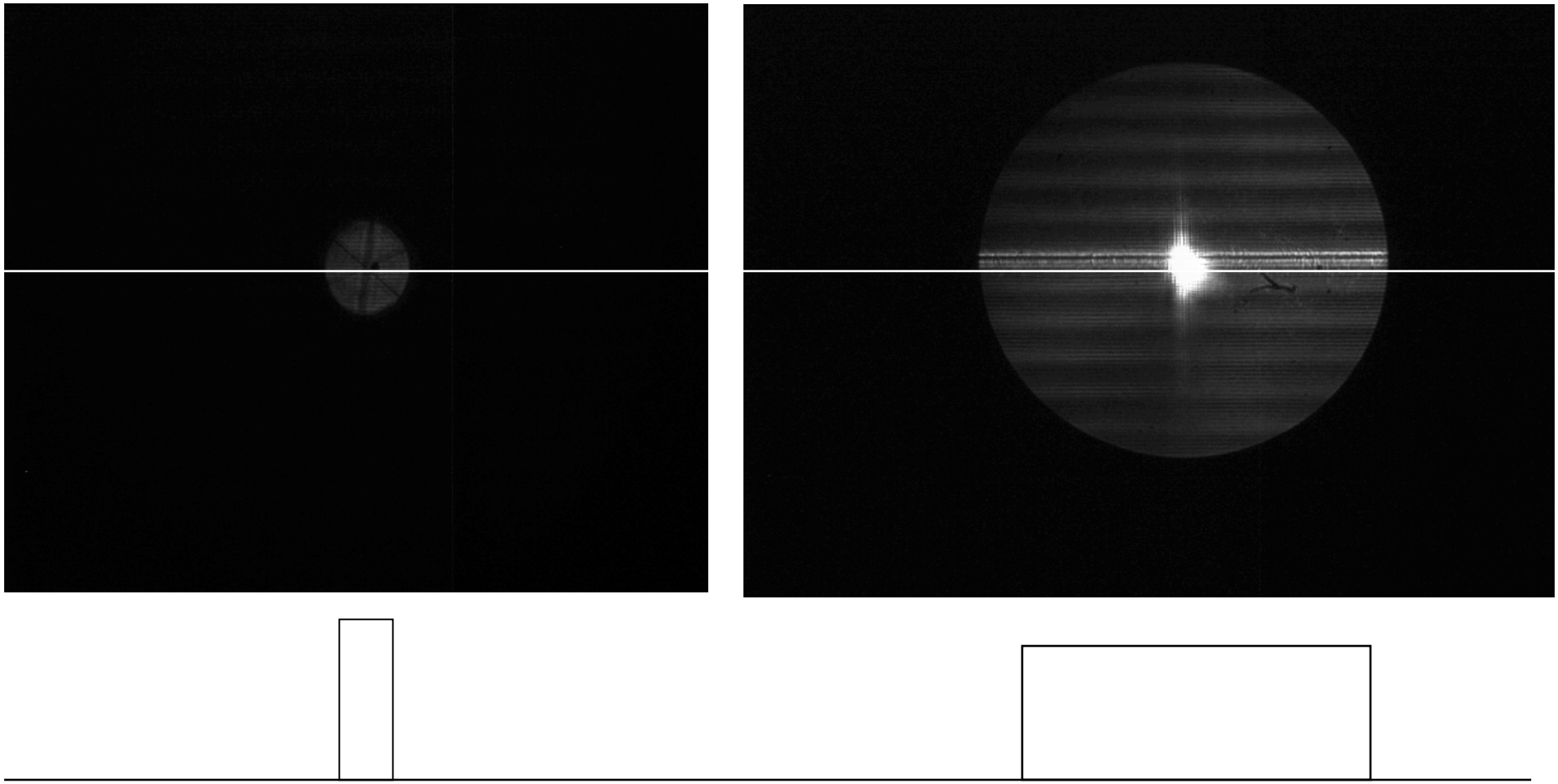

Edge detected image

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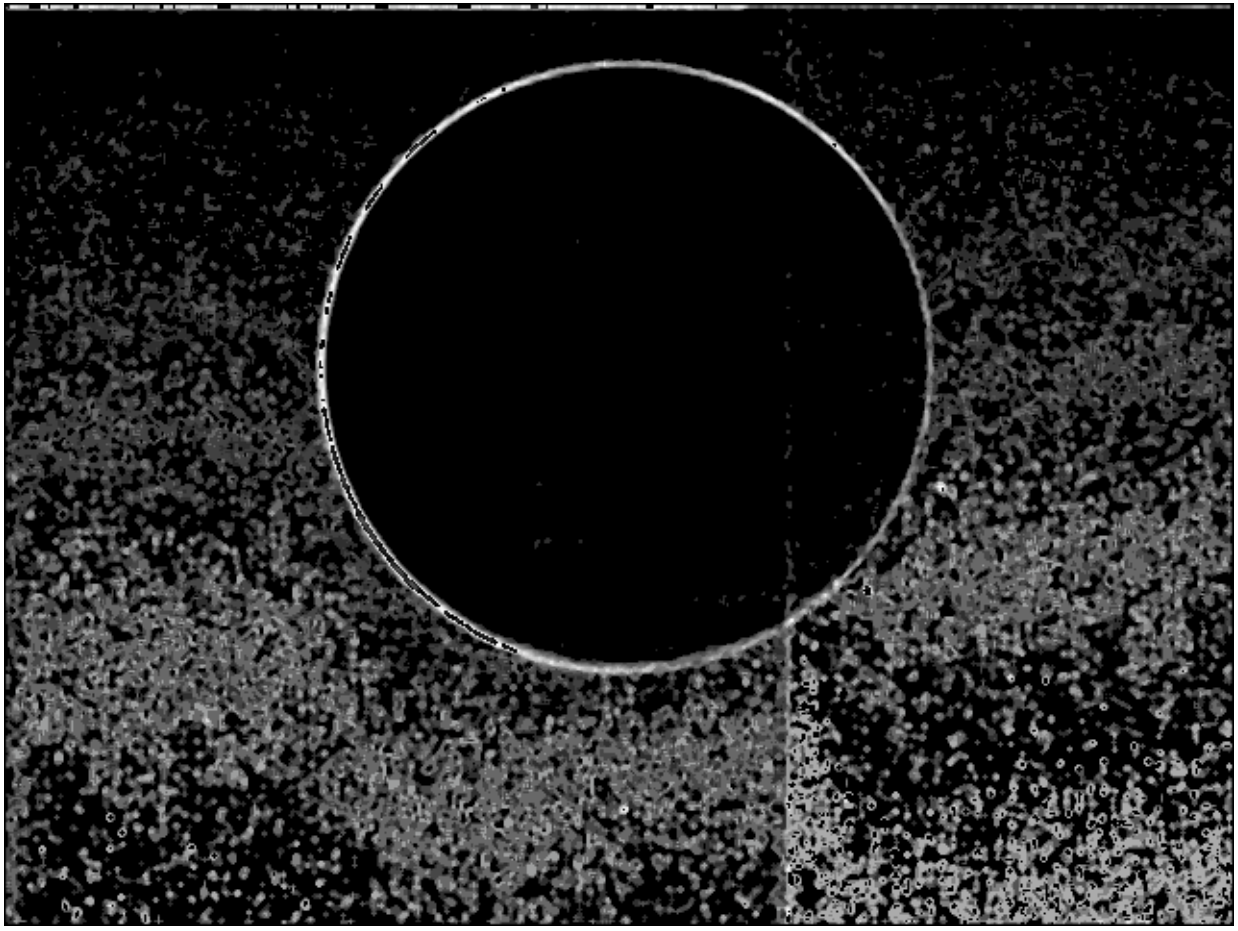

Two typical final results show the edge and center of the circular images

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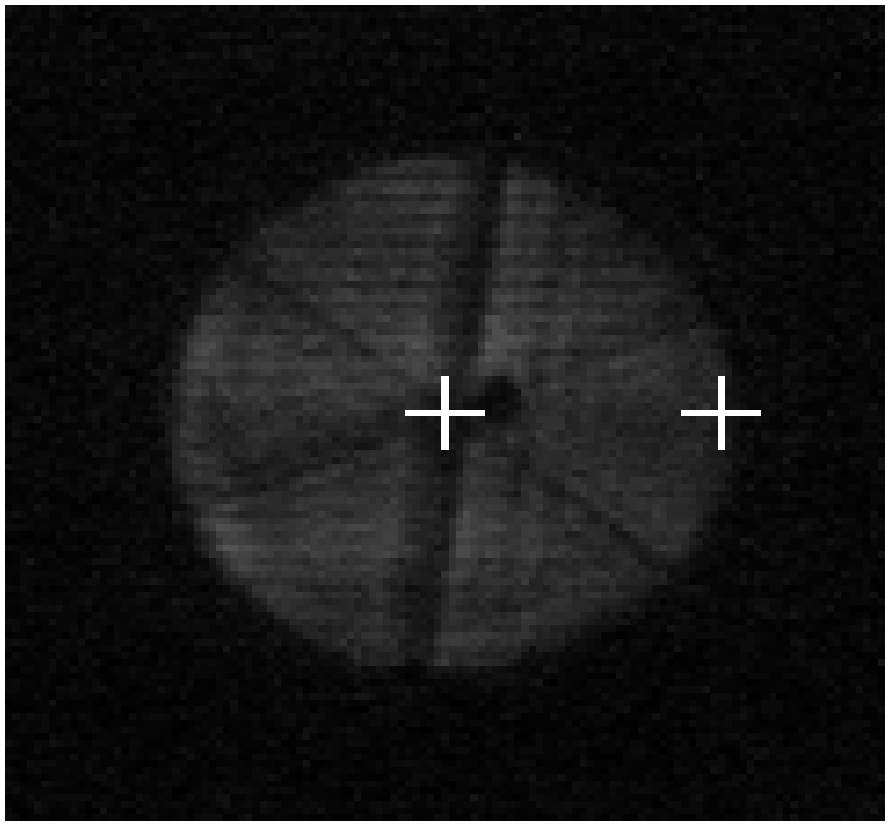

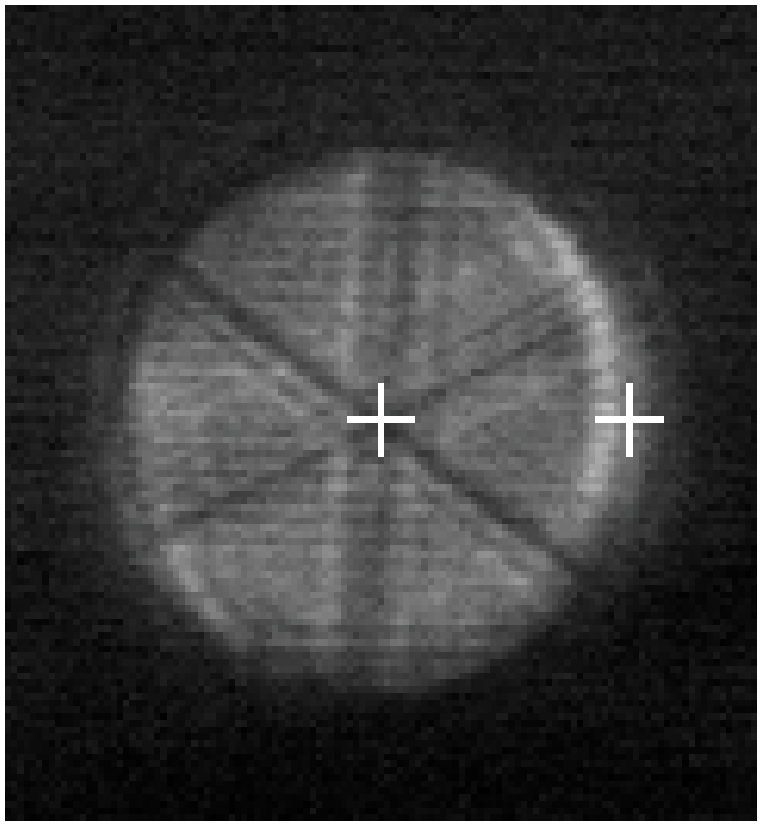

Refined algorithm

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- **Successive approximation**

Segment the image find ROI

Measure the pedestal → Estimate $r_1 < r < r_2$

- **Search by matching**

Correlate segmented image with range of radius → Find location

More detailed in paper no. 5556-30

Box classifier

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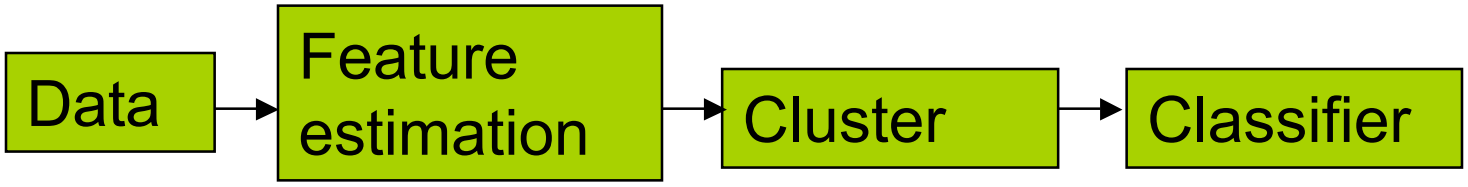

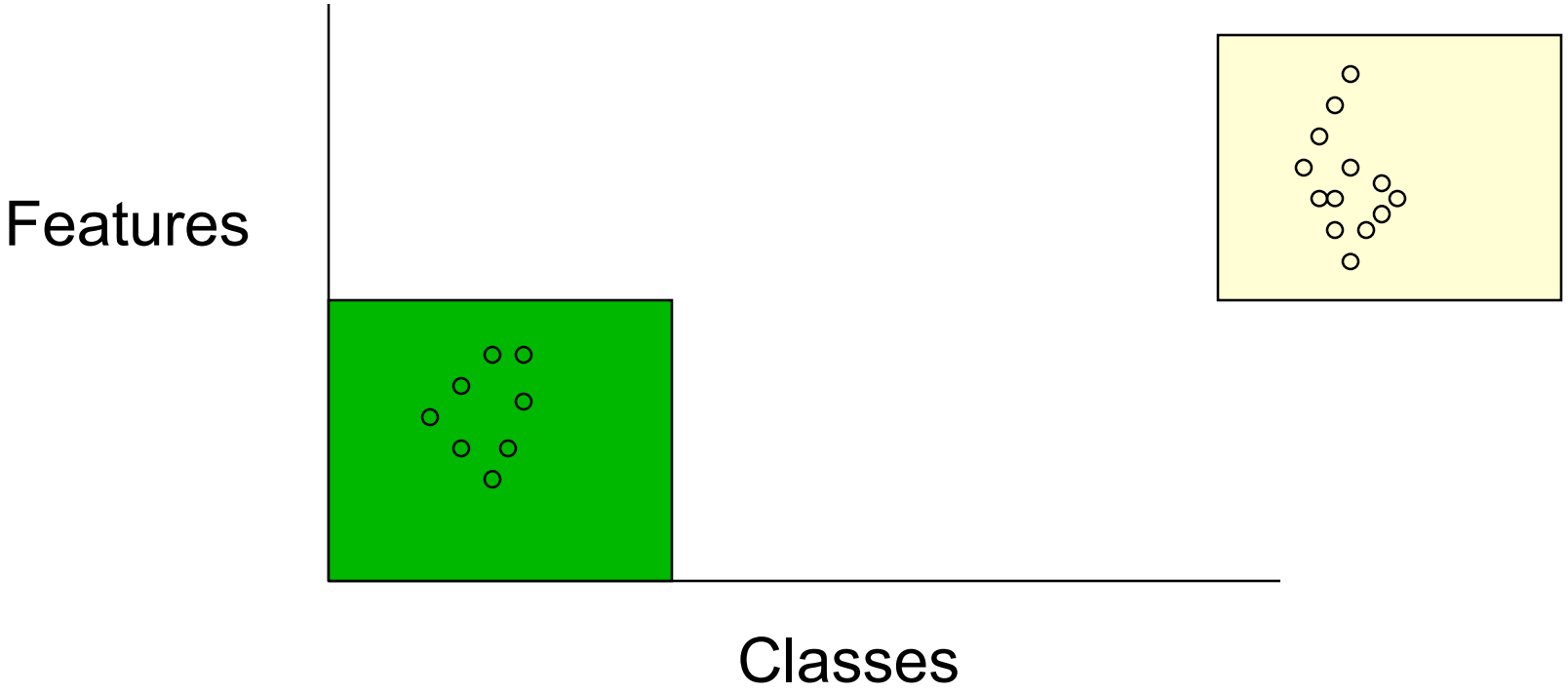

Search space shows 3 classes, range is chosen to bound the class- box classifier

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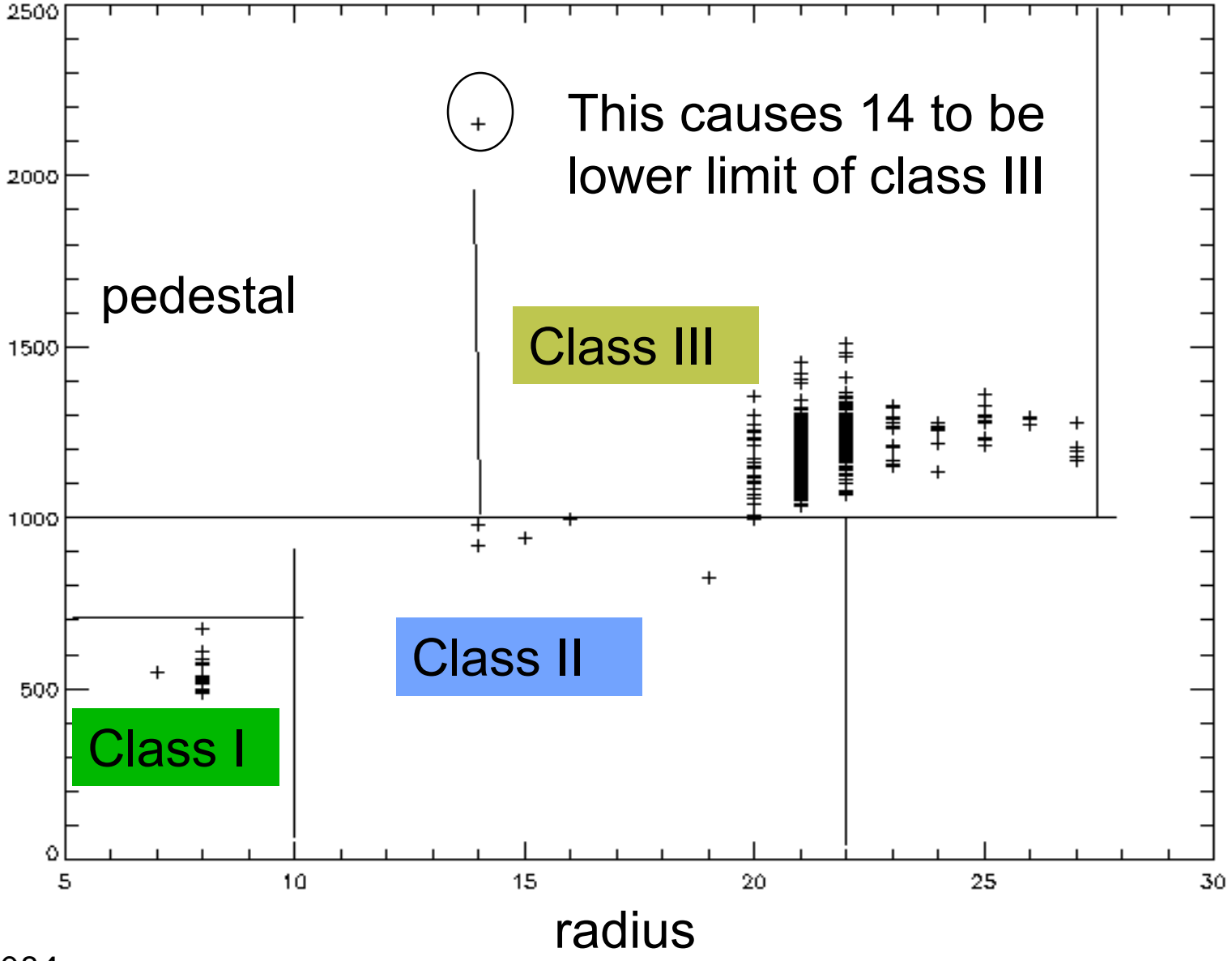

Box classifier

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Measure the pedestal area → Estimate $r_1 < r < r_2$

```
if (pedestal lt 700) then
                minRad=5
                maxRad=10
 elseif (pedestal lt 1000) then
                minRad=11;
                maxRad=22
            else
                minRad=14 ;
                maxRad=27
            end
```

Detection of four defocused spots

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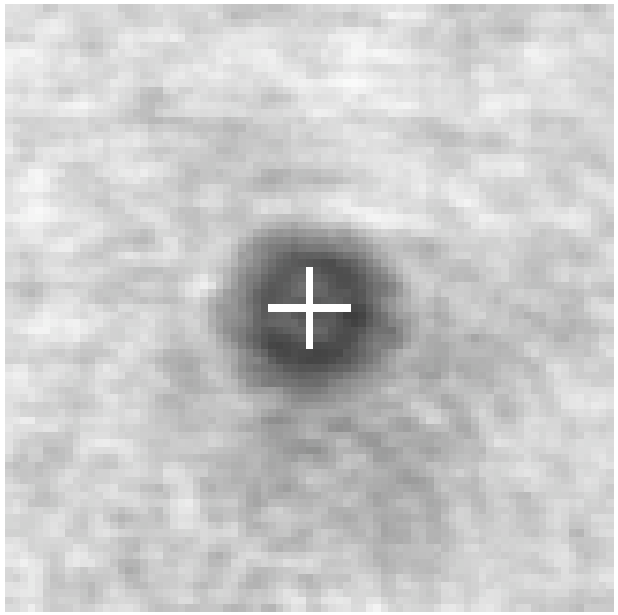

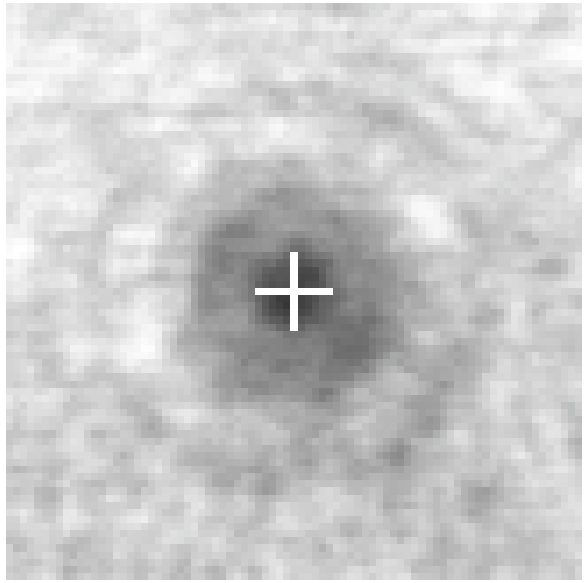

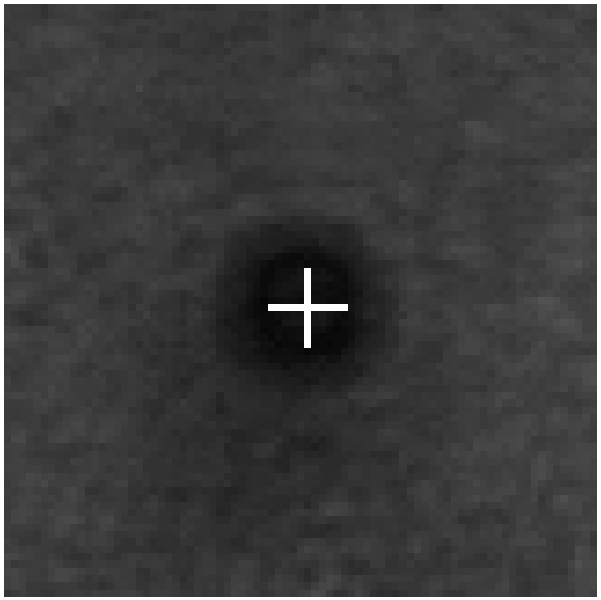

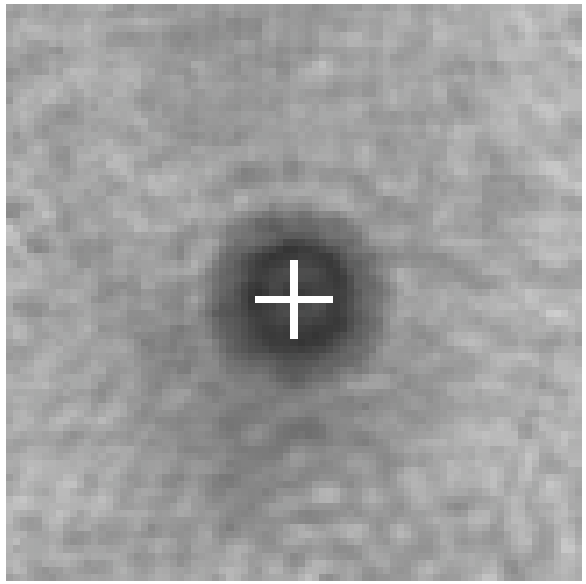

Challenges

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- **Partially missing**
- **Blobs may be divided into two**
- **Successive approximation may fail if initial guess is incorrect**
  - **automated guess correction by counting the right and wrong moves**

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