Measurement Uncertainty for Automatic Alignment Algorithm

Presentation to
LLNL CASIS Workshop

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Outline

- Review of earlier works
- Motivation
- Normal pointing uncertainty
- Pinhole image uncertainty
- Comparison of noise-based and new uncertainty

What causes the measurement uncertainty?

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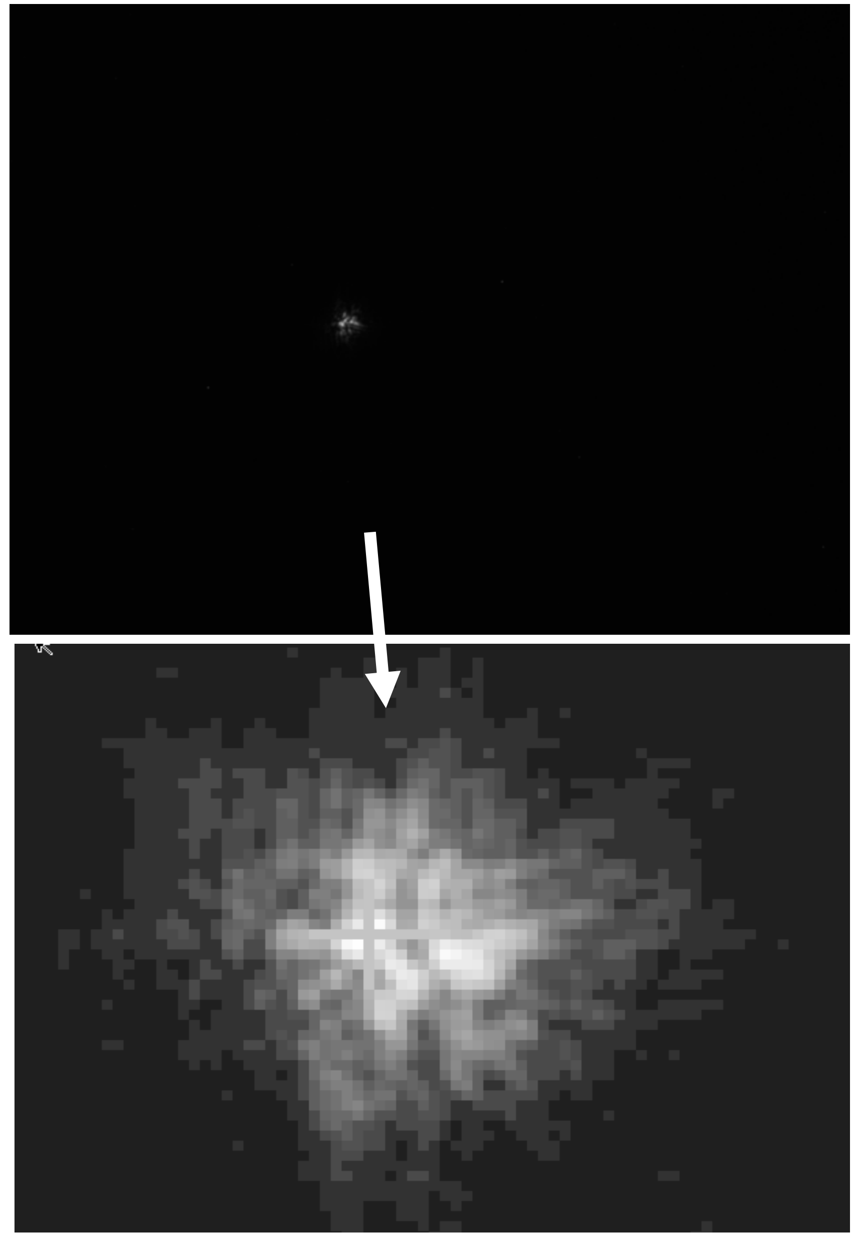
- Tolerances in the lenses
- Phase and amplitude aberrations of wavefront
- Detector noises
- Noise introduced by optical defects
- Algorithm - Parameter variation



Uncertainty is an attempt to quantify these variations

Noise-based model uses Monte-Carlo simulation to estimate variations in position measurement

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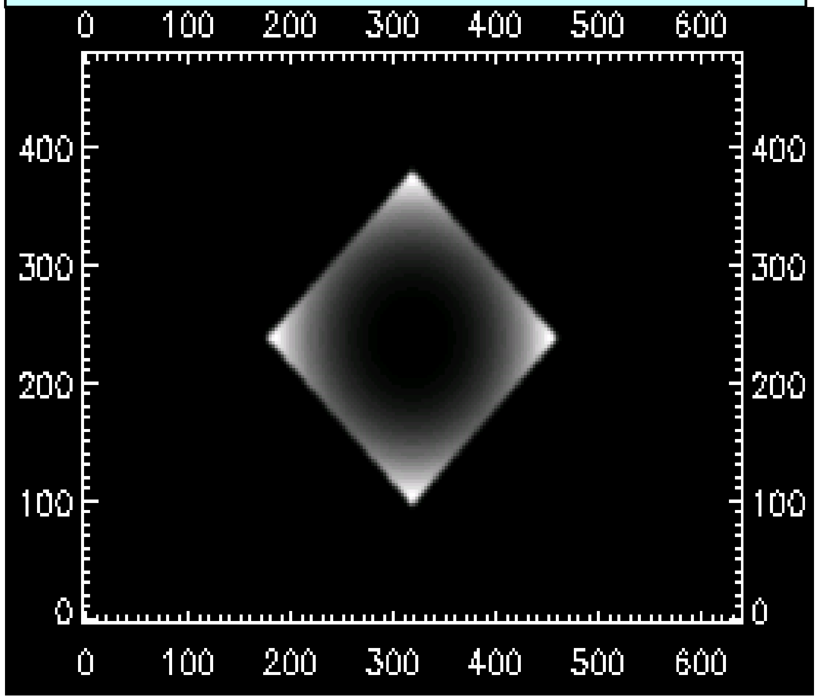
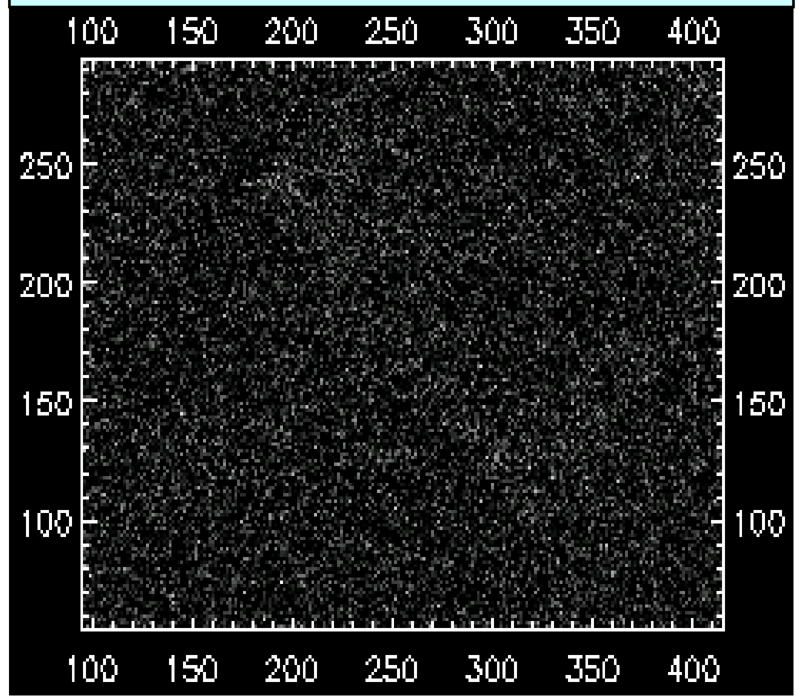
Original image



Amplitude 50, noise 50



100 image sets are created for each noise level, the deviation of the position estimate is a measure of uncertainty

Position estimates from one set of 100 images

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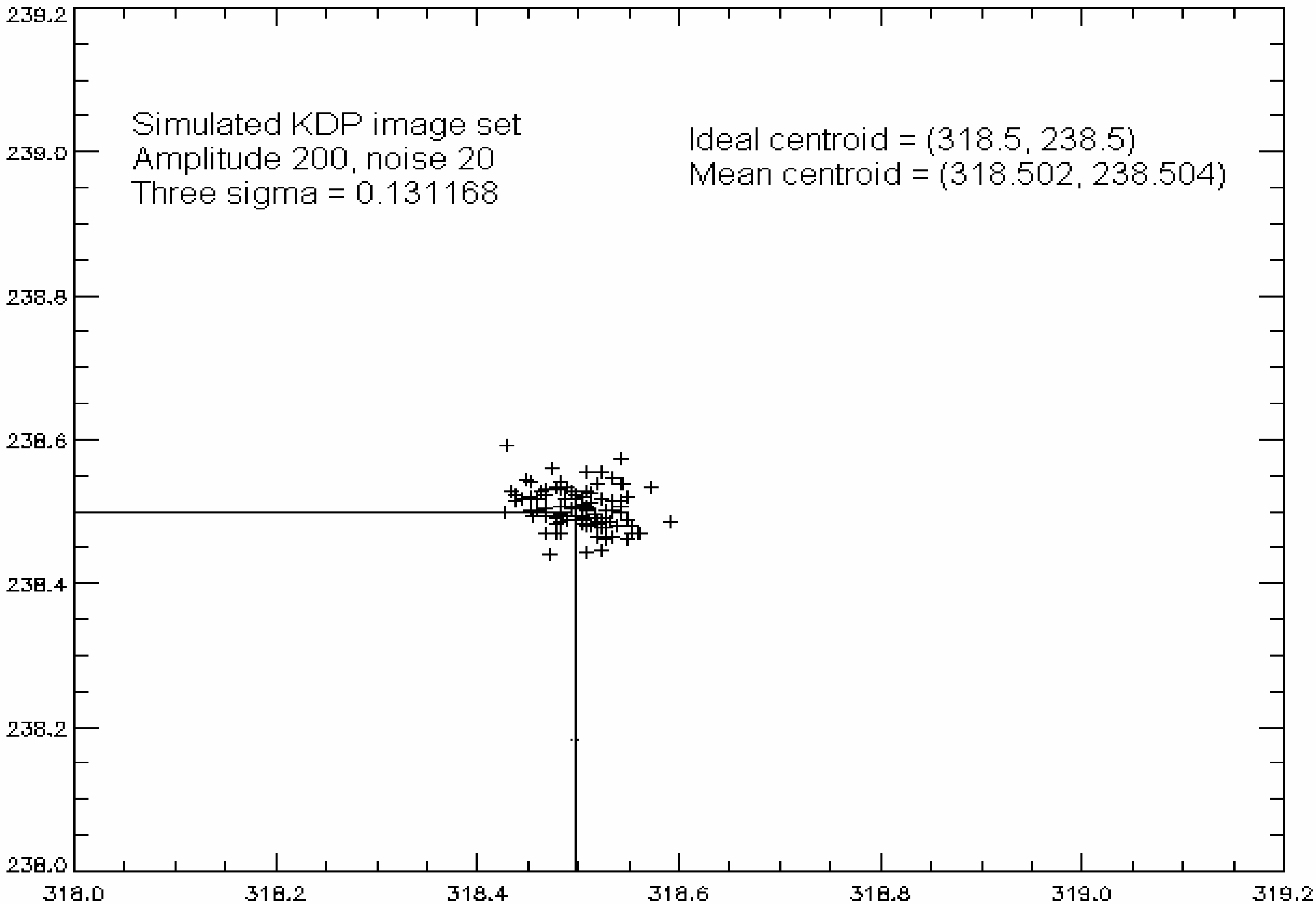

3 x the radial standard deviation is the measure of uncertainty

Uncertainty vs. noise curve generated from 800 images with varying amplitude and noise

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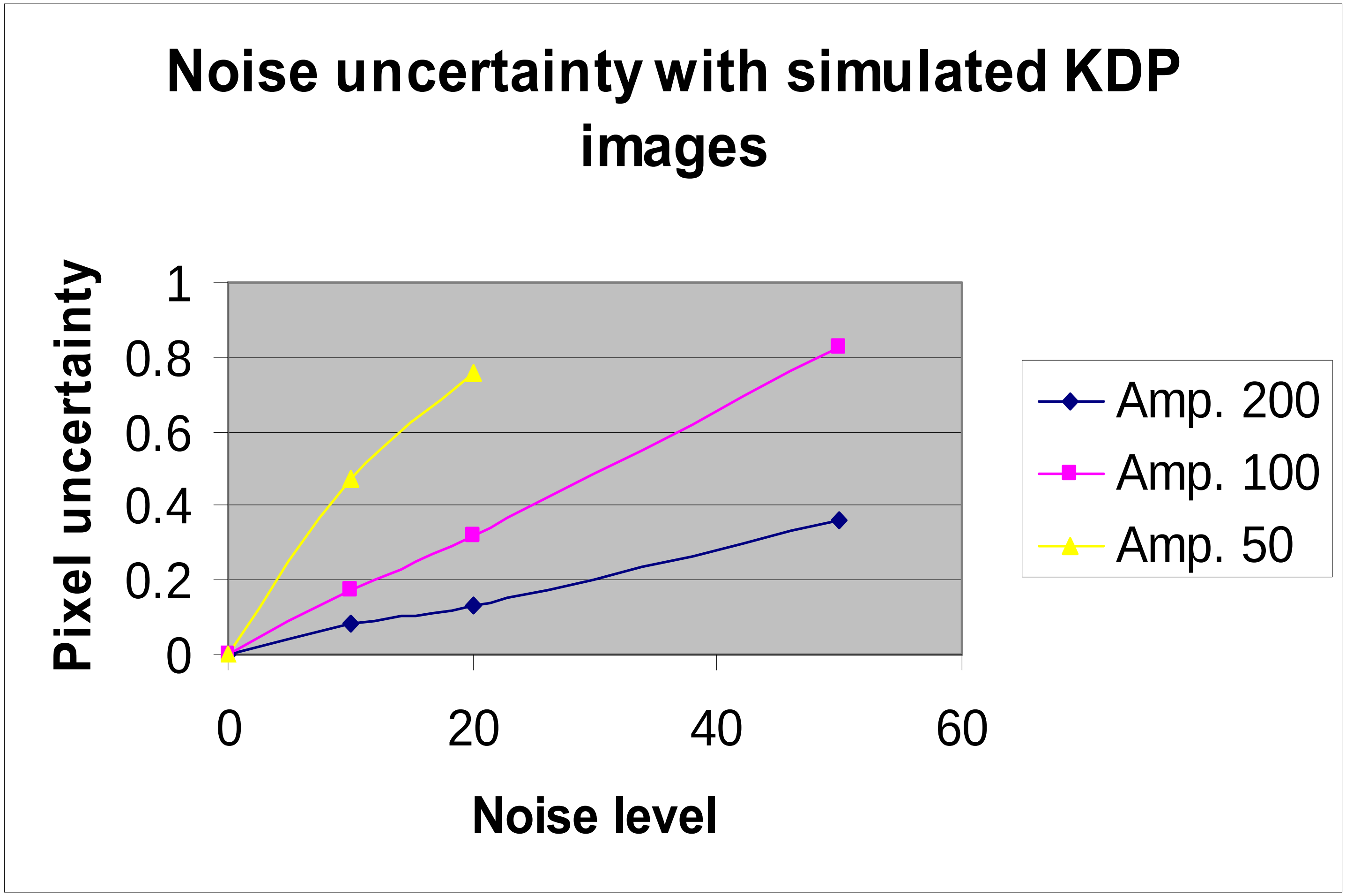
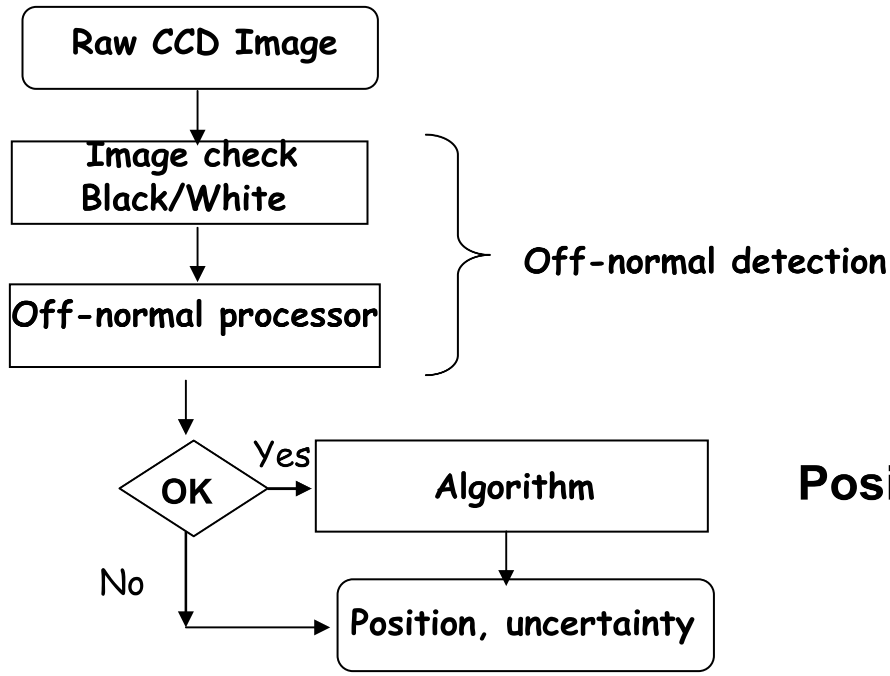


These curves are part of a truth table associated with each algorithm. The truth table is looked up to find the uncertainty. The input to the table is an estimate of noise.

A generic algorithm is applied to all Automatic Alignment processing loops



Position = f (x1,x2,x3..)

Position is a function of various parameters that are used by the algorithm, which are quantified by the uncertainty measurement

Various ROI lead to different position estimates

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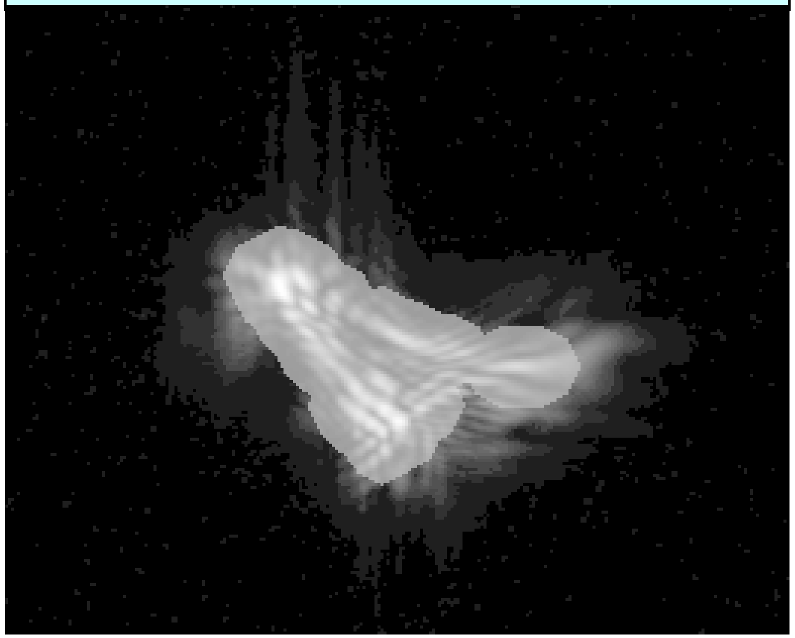
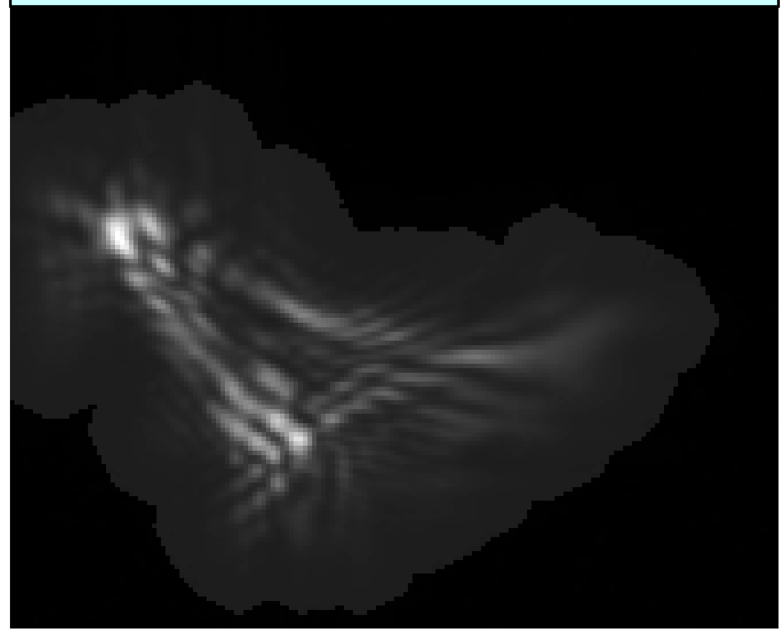
Centroid Positions from NPNT Algorithm
383.688 208.505 1.50000



Centroid Positions from NPNT Algorithm
387.107 207.555 1.50000



Expanding or shrinking the ROI affects the position estimate (4 pixels variation shown)

Dynamic Thresholding example shows centroid location moves with different values

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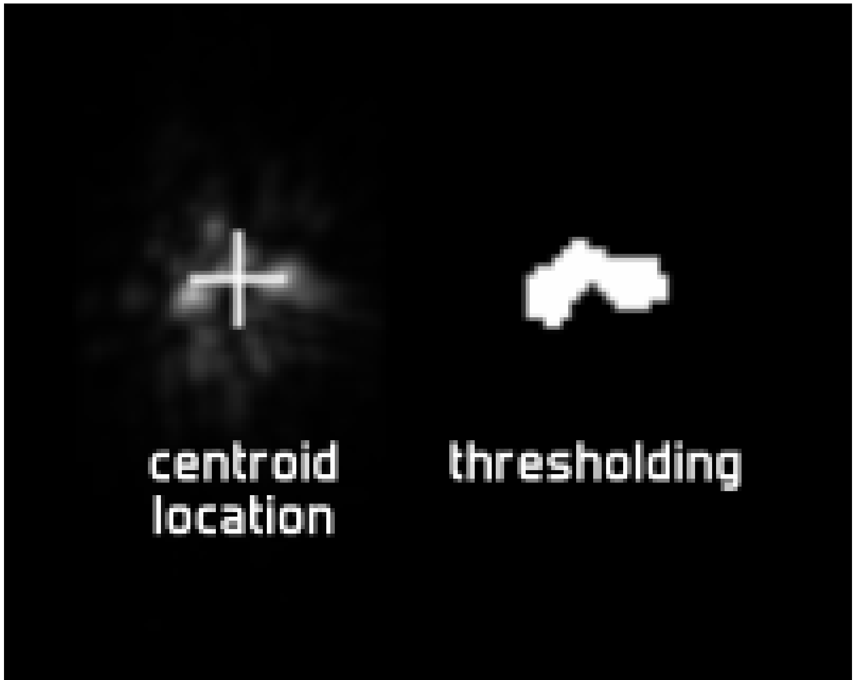
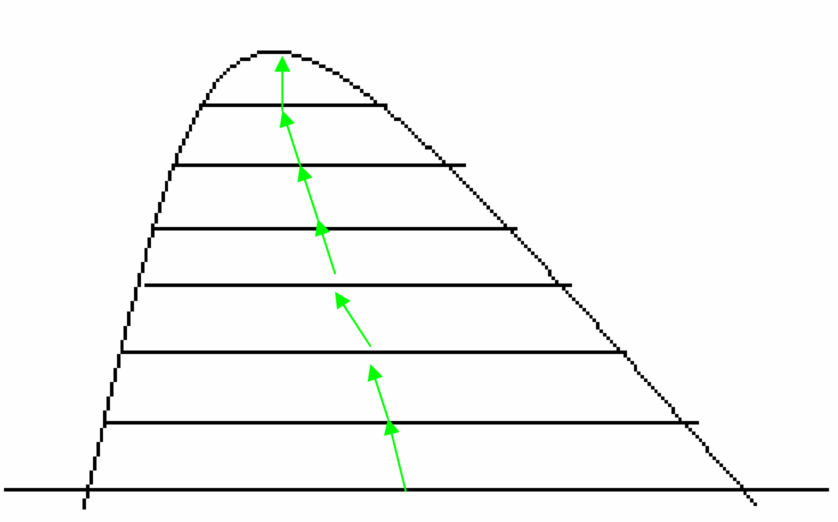


thresholding.avi

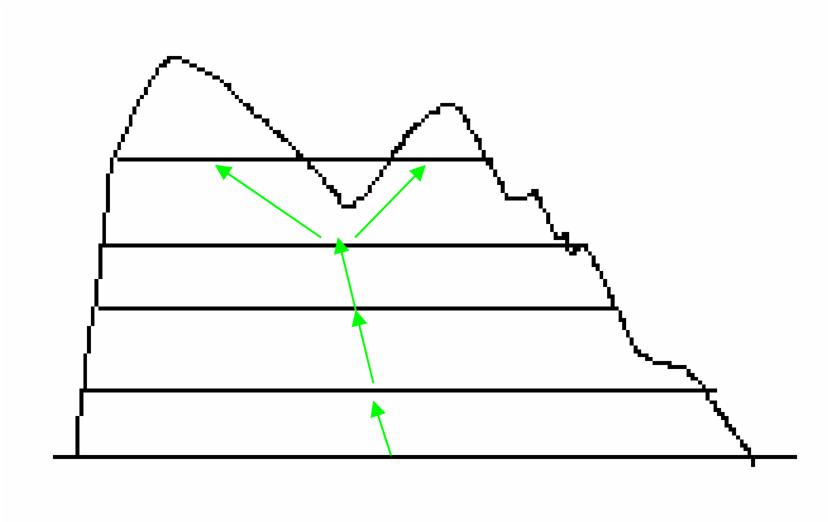
In the weighted centroid only the largest blob is chosen; a multimodal distribution could significantly vary the estimate

Distorted or asymmetric position variation

Somewhat Symmetric



Asymmetric



As the profile changes between symmetric and unsymmetric, there is greater chance of position variability

Uncertainty is the range of centroid positions as threshold varies from minimum to ½ max (intensity)

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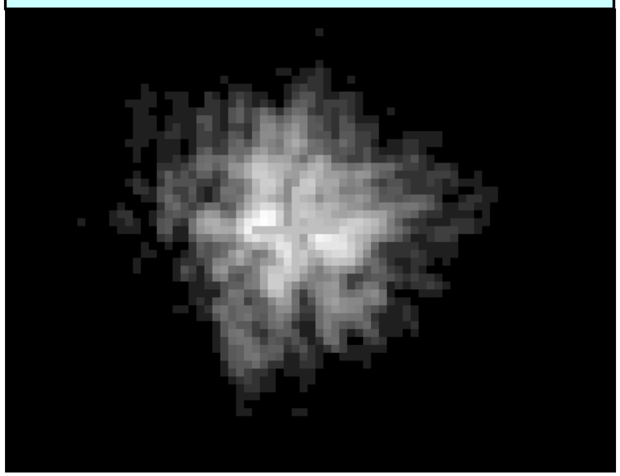
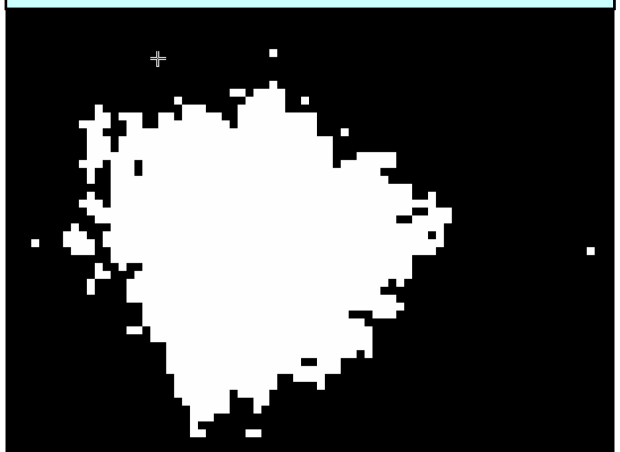
Original image



minTh = bkg + 3 * σ



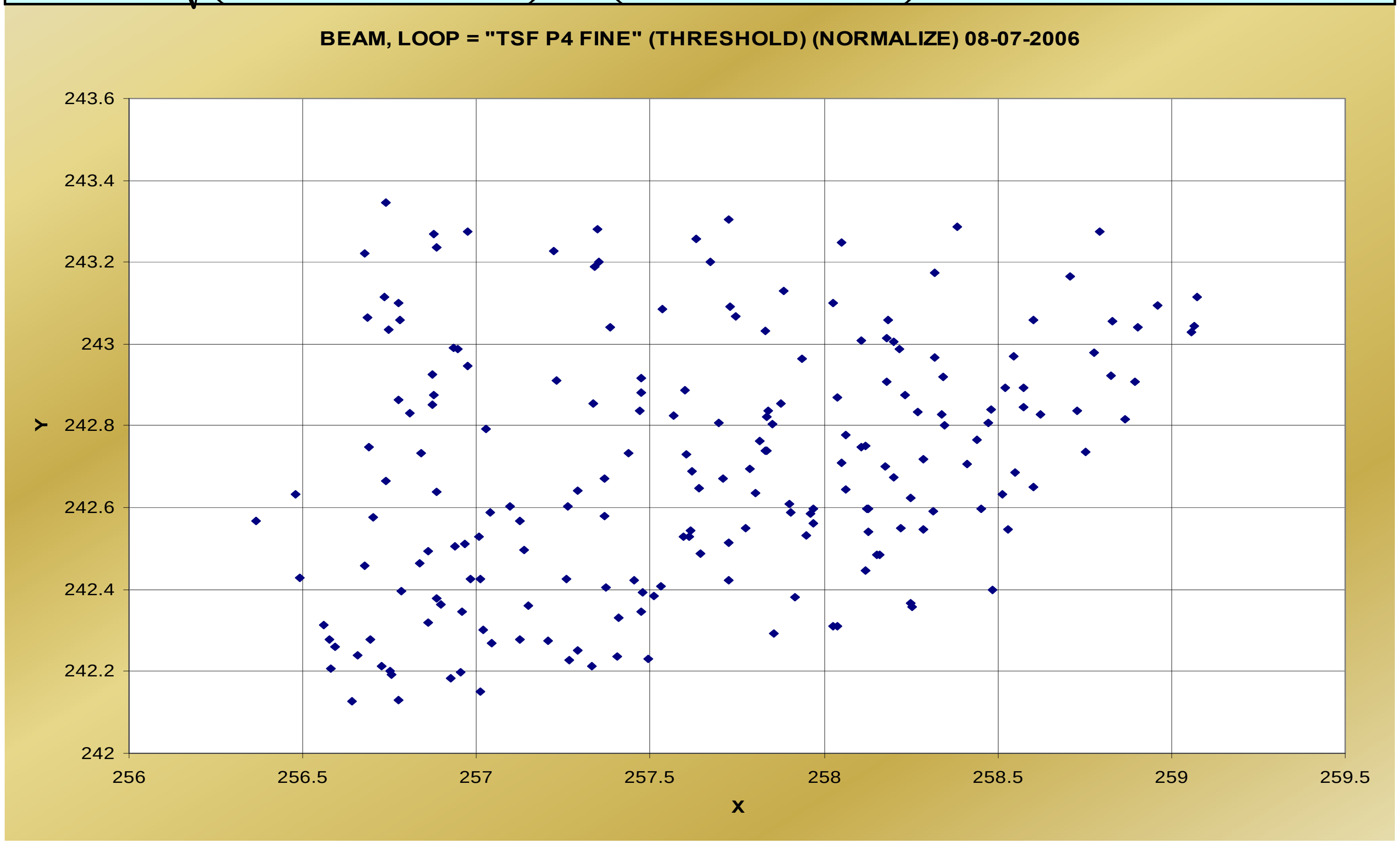
Larger portion remains after low threshold

maxTh = ½ max(int)

Smaller portion remains after high threshold

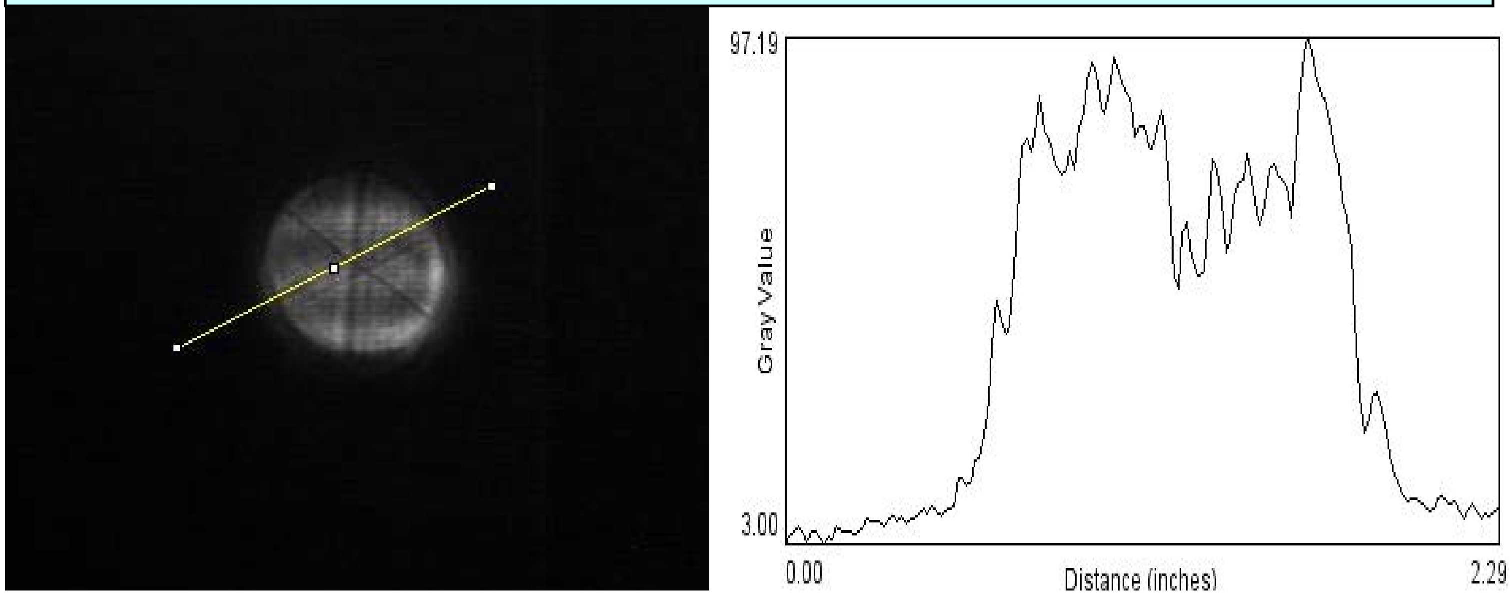
Uncertainty is the range of centroid positions obtained by adjusting the threshold

Range = $\sqrt{(\max X - \min X)^2 + (\max Y - \min Y)^2}$



Lineout shows possible threshold range

Pinhole Image with Lineout



Threshold chosen to preserve shape of the object

Position estimate varies as threshold changes

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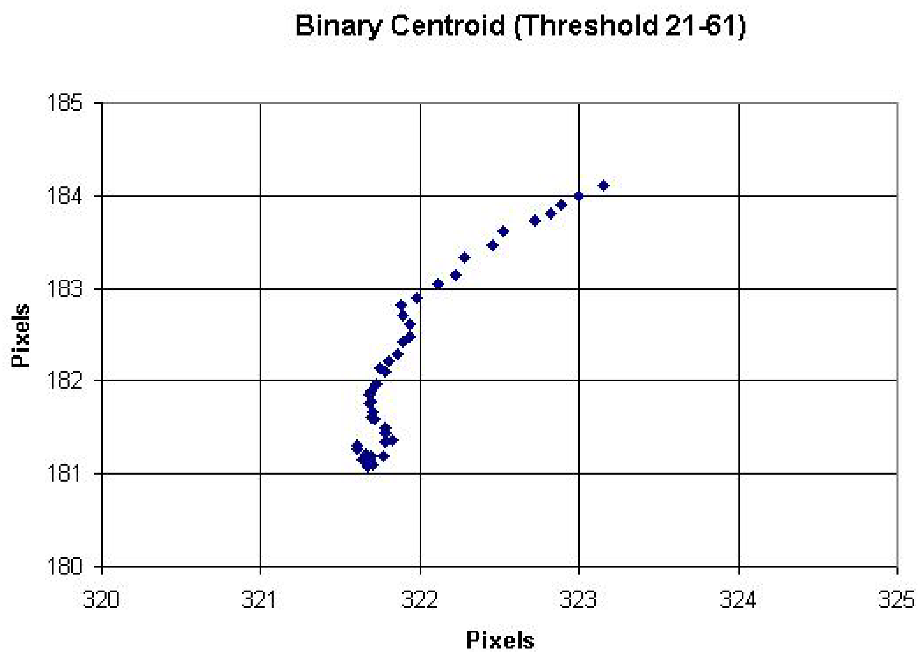
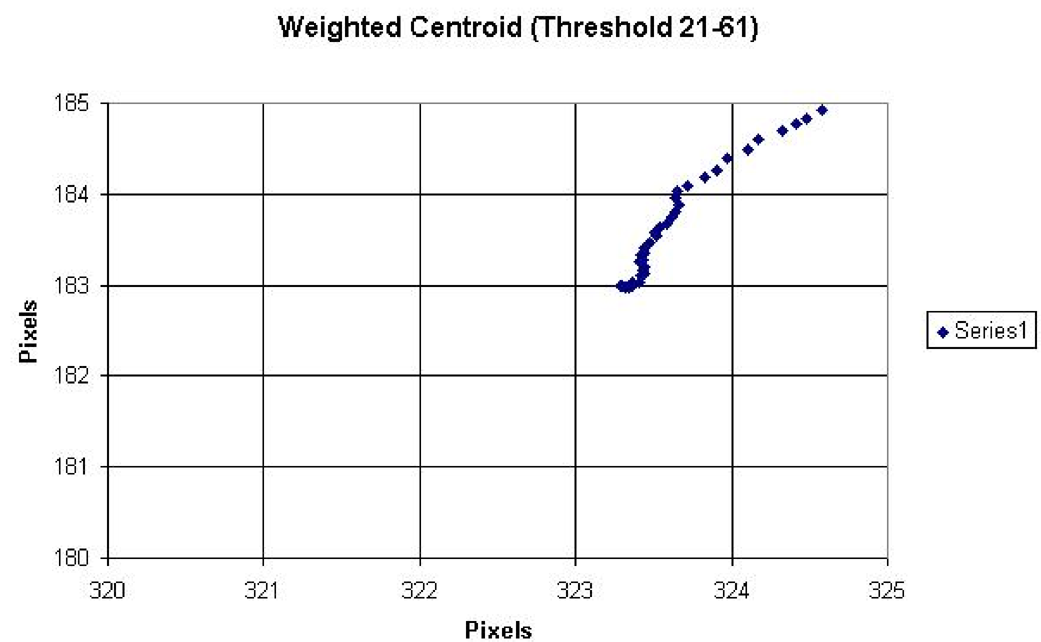
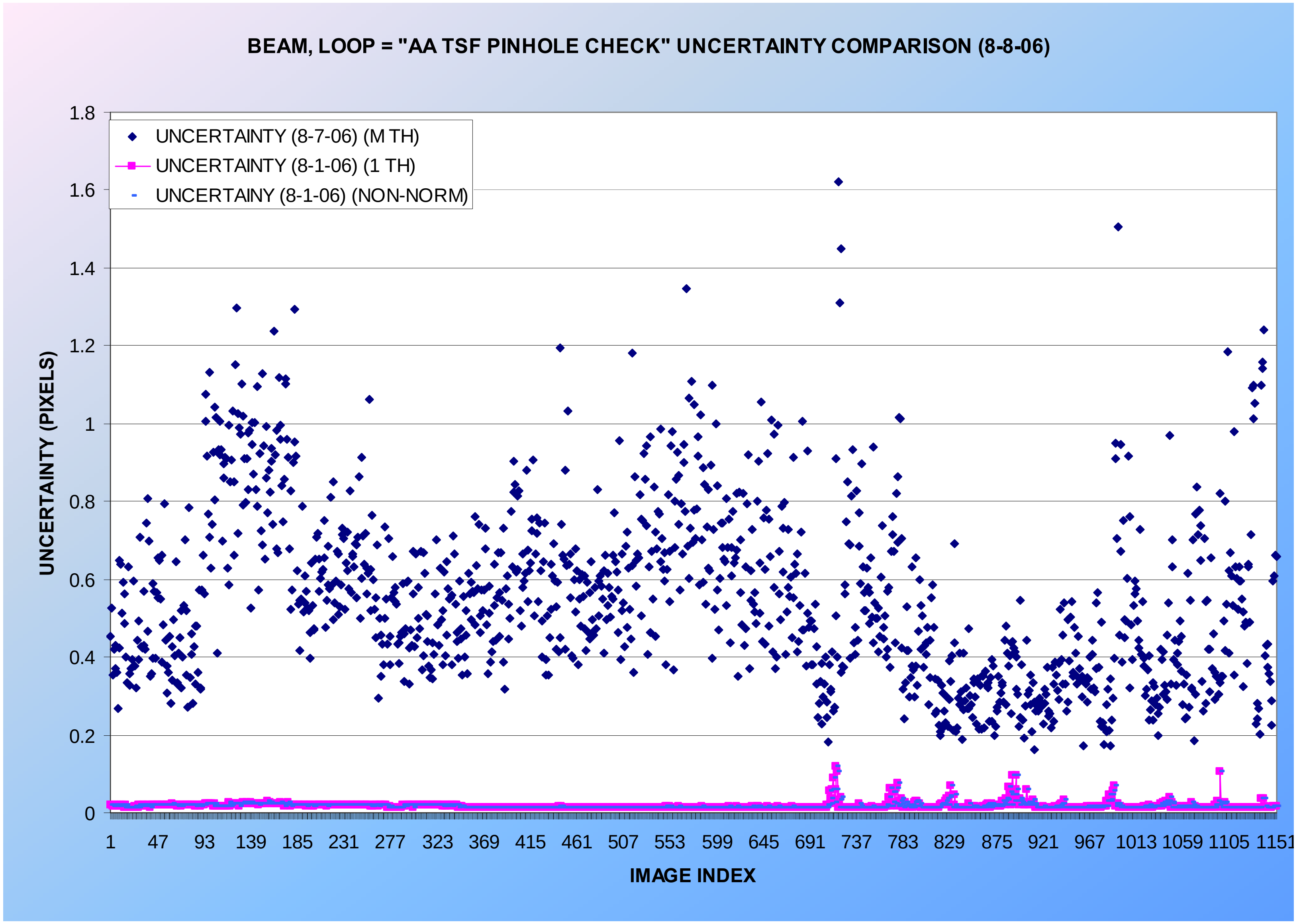


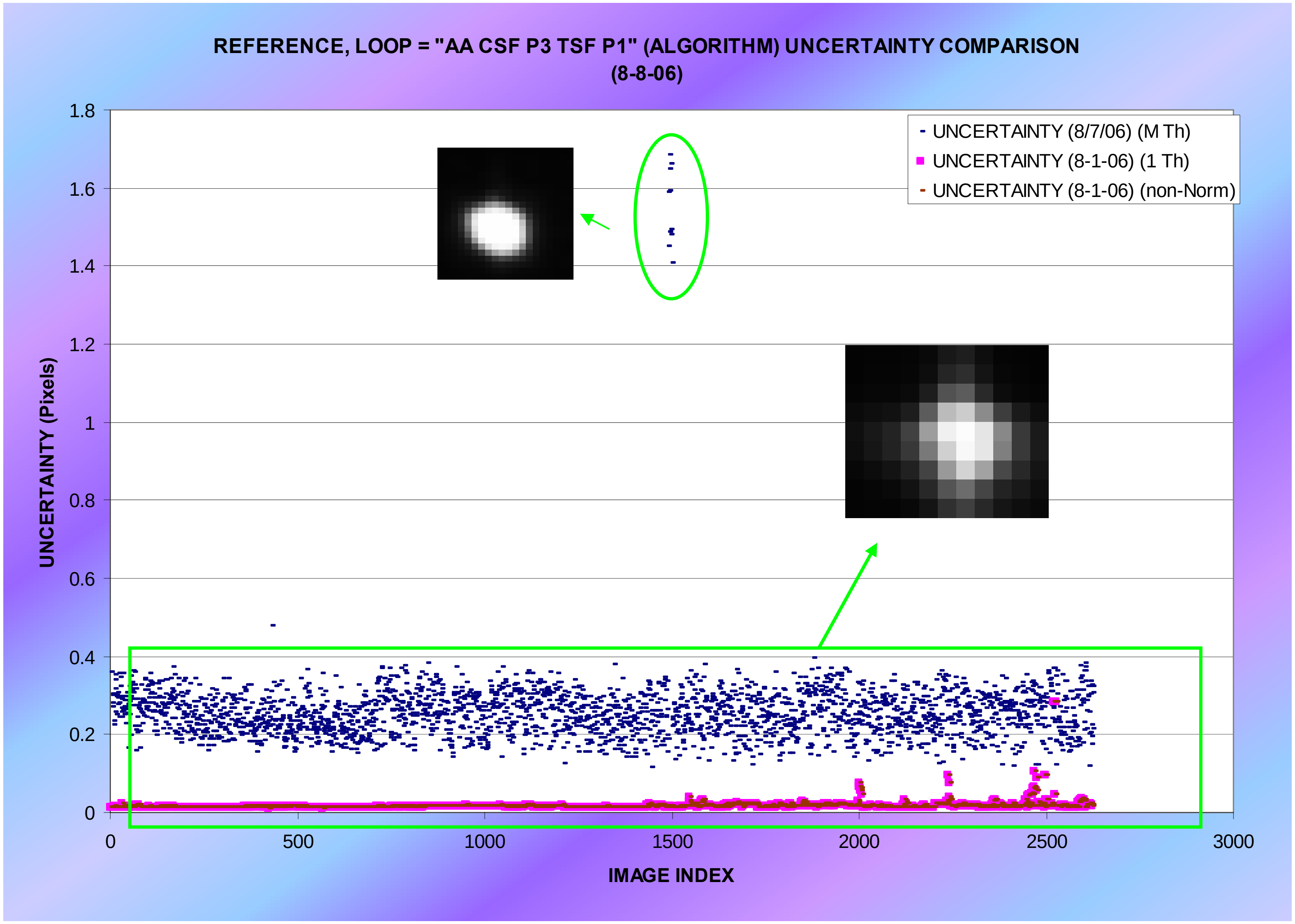


Comparison of old and proposed method of uncertainty measurement



This measurement results in higher uncertainty estimates

Comparison of old and proposed method of uncertainty measurement



This measurement correlates well with image quality

Comparison of old and proposed method of uncertainty measurement

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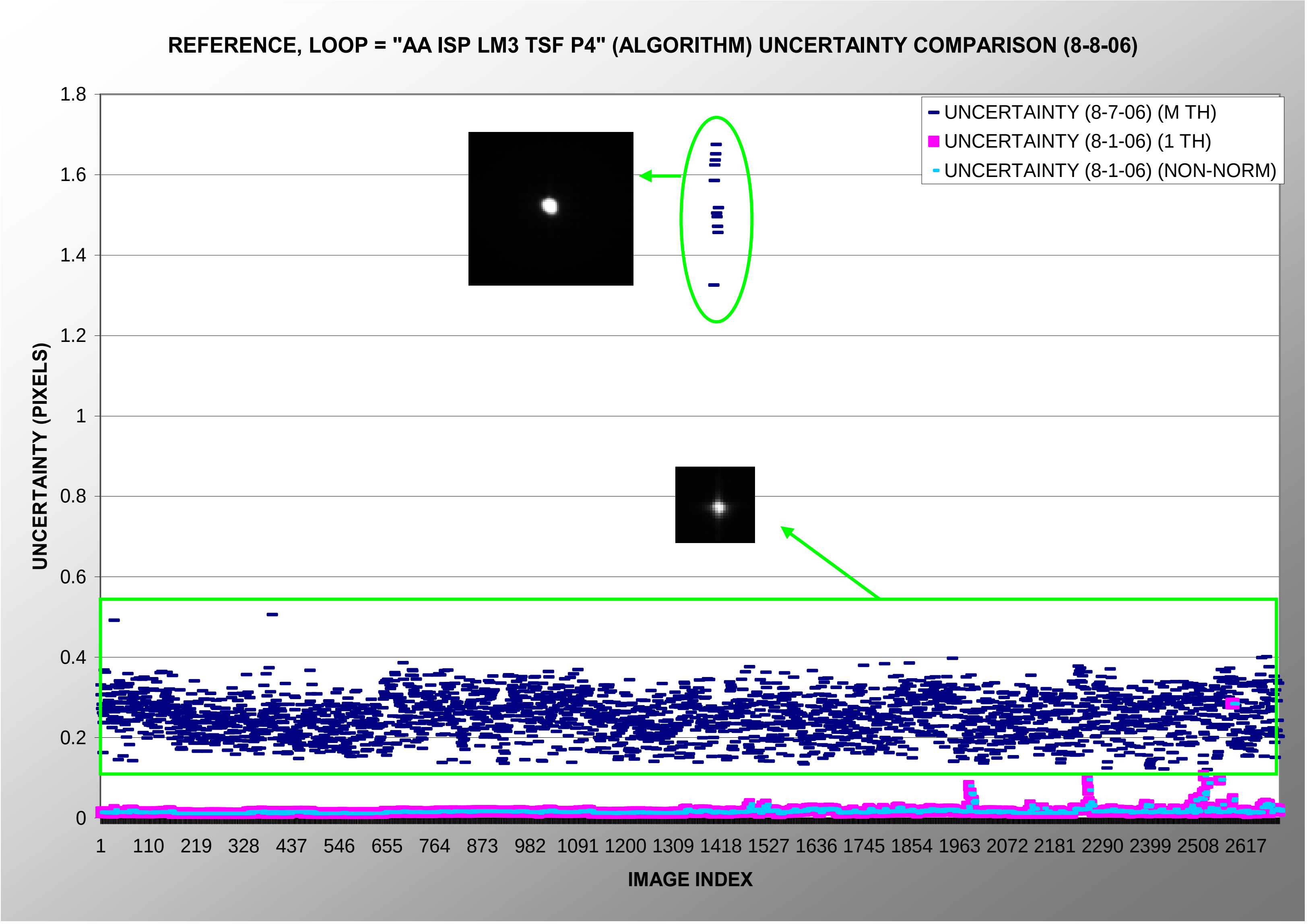

Normal Pointing Uncertainty Algorithm

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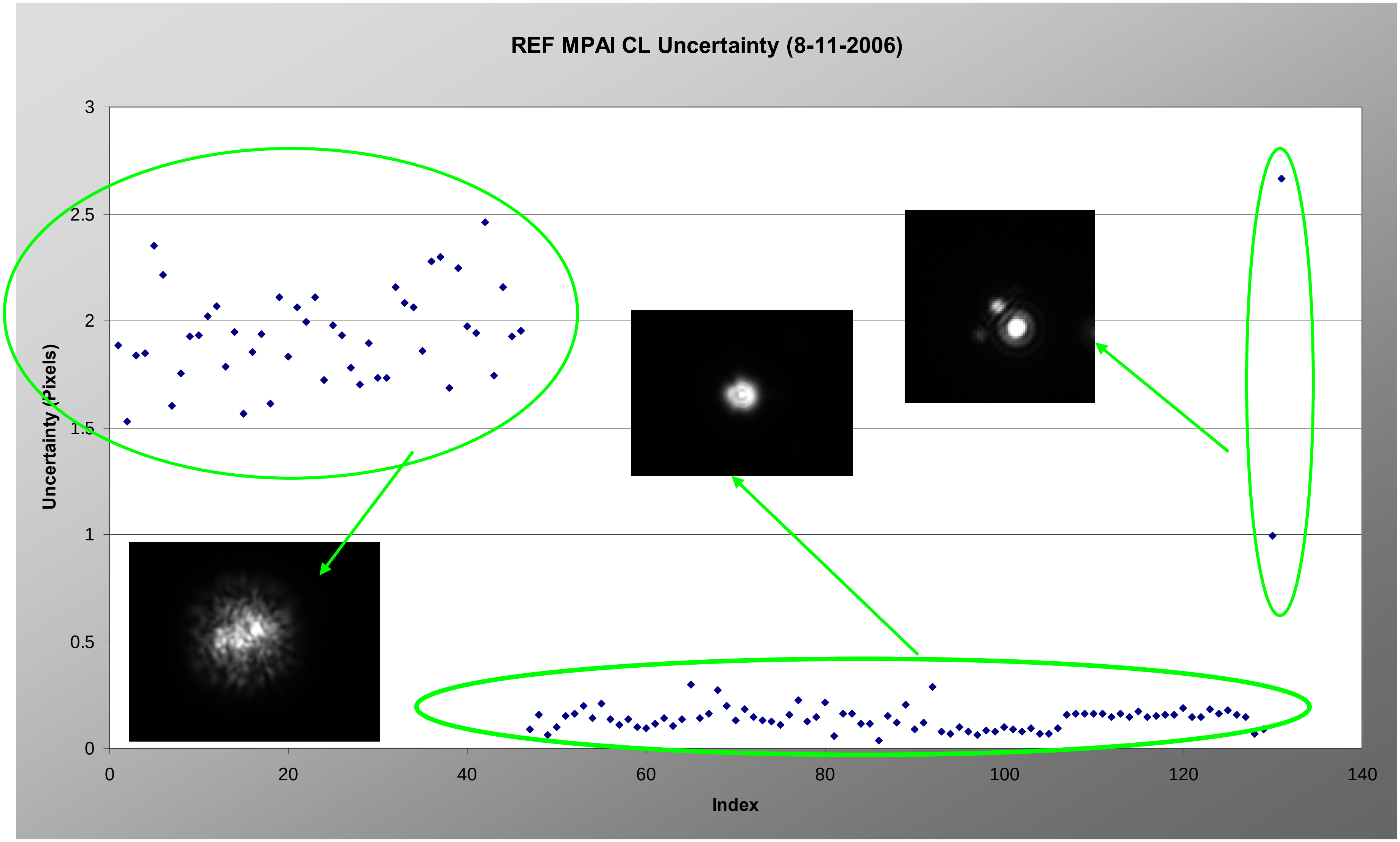

Distribution shows how the uncertainty relates to the beam quality

When Normal Pointing Spot has multiple blobs

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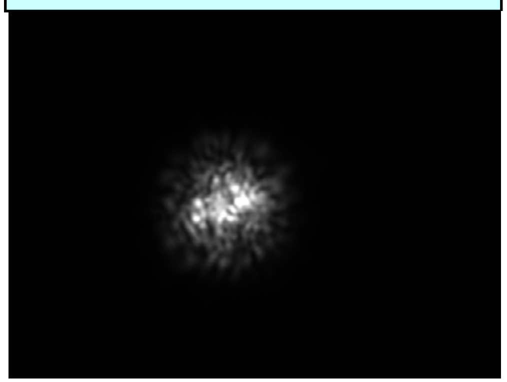
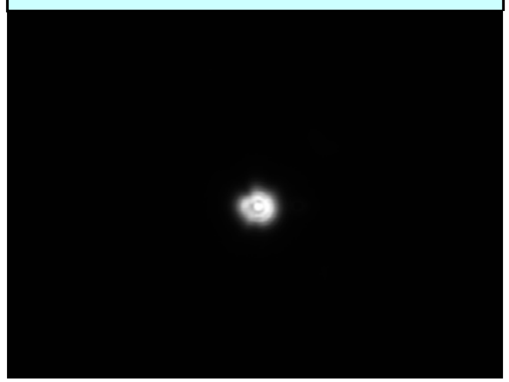
- Use a mask
- Calculate the weighted or binary centroid inside mask

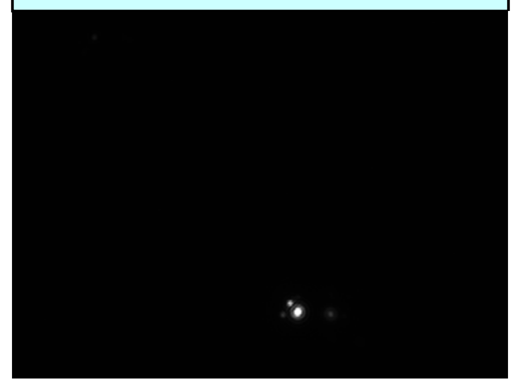
Multimodal spot



Multimodal spot



Multimodal spot



Pinhole uncertainty with +/-2 pixel rad variation

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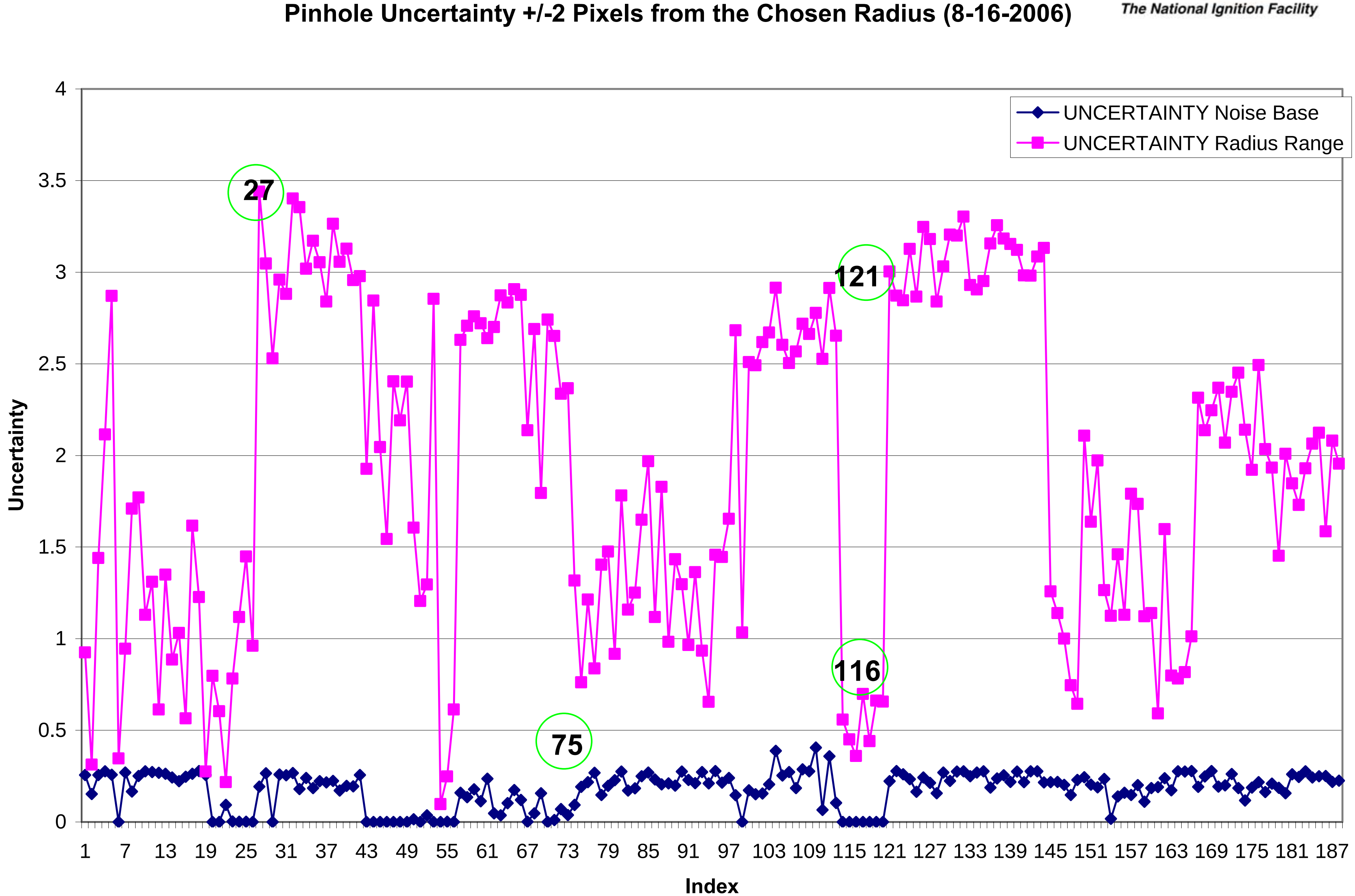
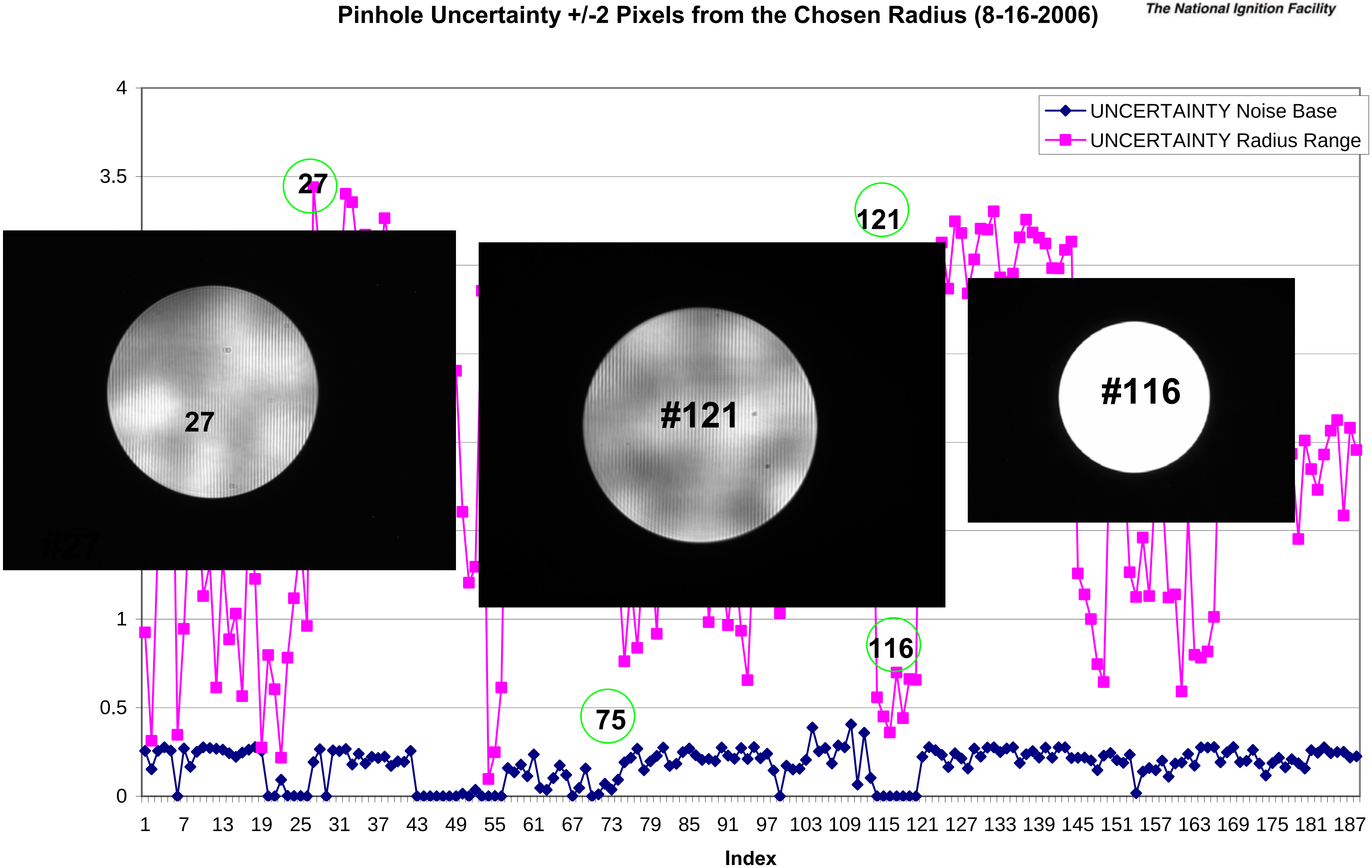


Pinhole uncertainty with +/-2 pixel rad variation



Uncertainty measurement correlates well with image quality

Conclusion

- New algorithm shows more realistic uncertainty compared to noise-based value.
- Reference Images uncertainties are bounded between 0.2 and 0.4.
- Asymmetric or distorted beam caused by bad wave front have multiple blobs after segmentation and therefore higher uncertainty

Challenges

- Increase in processing time. Since the algorithm has to be executed multiple times (0.7 secs)

- Increase in uncertainty since it captures the position variations due to algorithm parameters