Image Calibration and Deconvolution for Space Object Imaging

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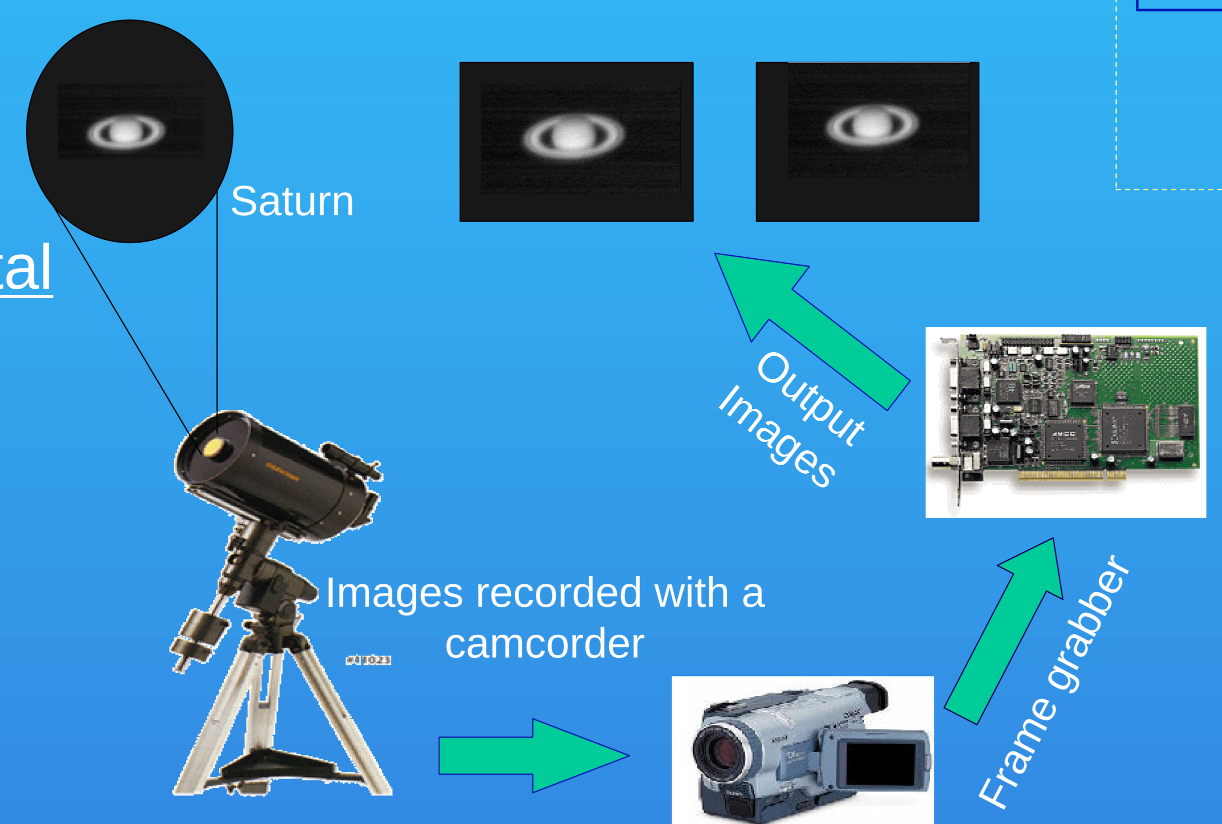
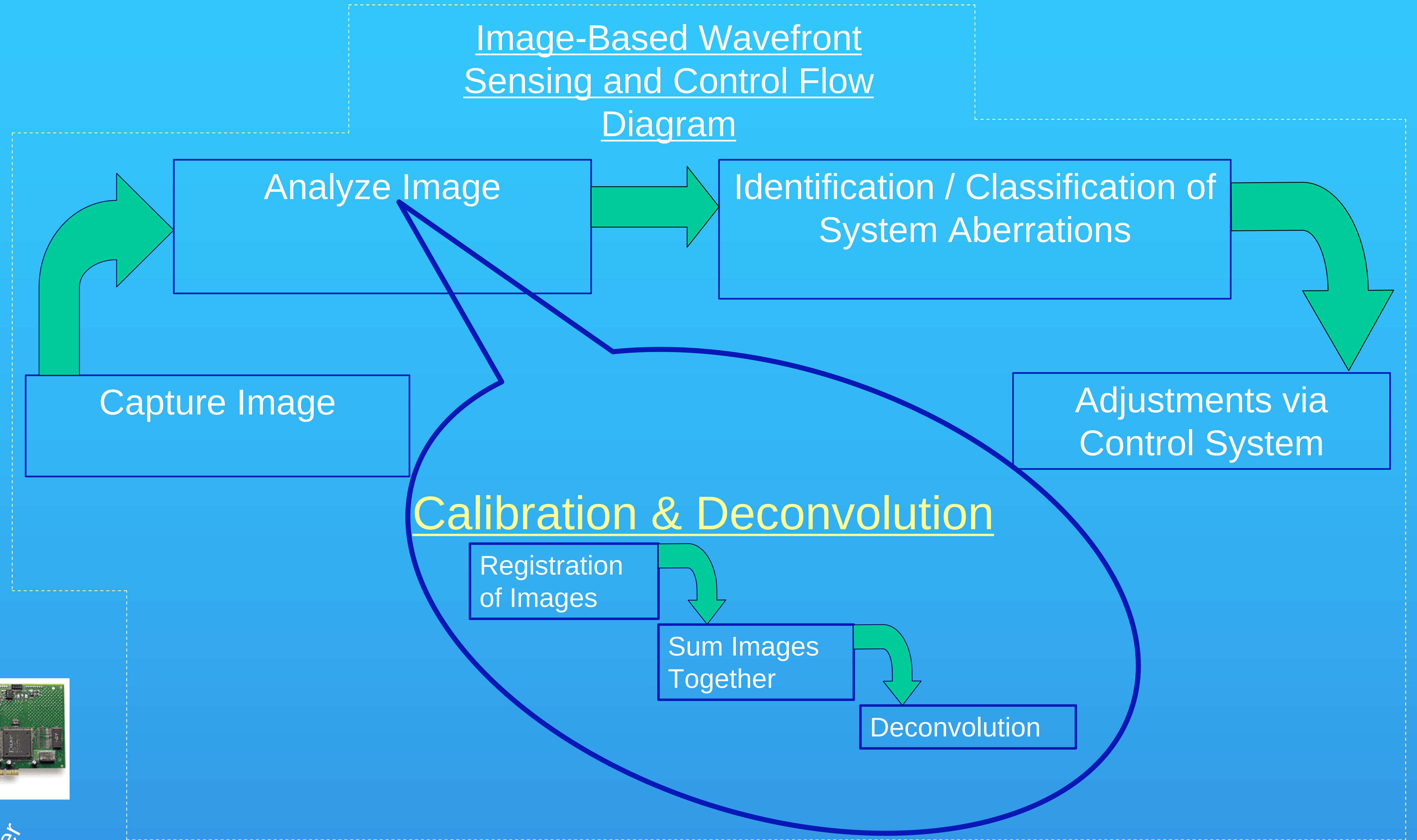
1 Introduction

Testing the optical system can be achieved via analysis and repair of resultant images by means of calibration and deconvolution algorithms/filters. This can be used as one approach to Image-based wavefront sensing and control.

2 Experimental Setup





Abstract:

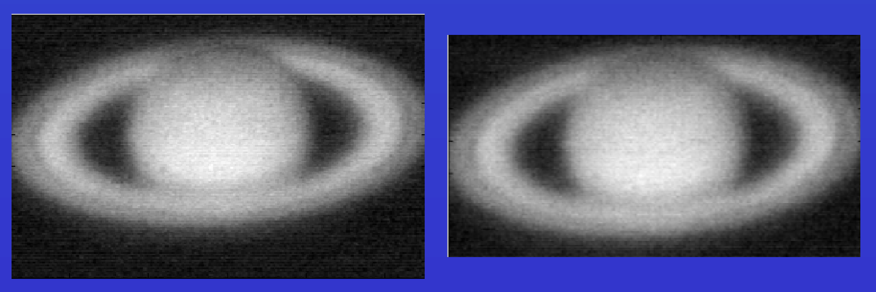
Data was collected using a 12" Schmidt-Cassegrain telescope with off-the-shelf imaging equipment. The data was then recorded using a home video recorder and the individual frames were captured from mini-DV tape. Video and CCD imaging systems can produce short-exposure images that contain little or no information due to poor SNR (signal-noise-ratio), blurring due to object motion, atmospheric turbulence, or optical system mis-alignments. Each of the listed aberrations can be corrected to some degree and faults within the optical system can be estimated using image calibration and deconvolution techniques.

3 Analysis Methods and Tools

MATLAB Development Environment

$$f(E)=\int_{-\infty}^{\infty} g(x)h(E-x)\,dx$$

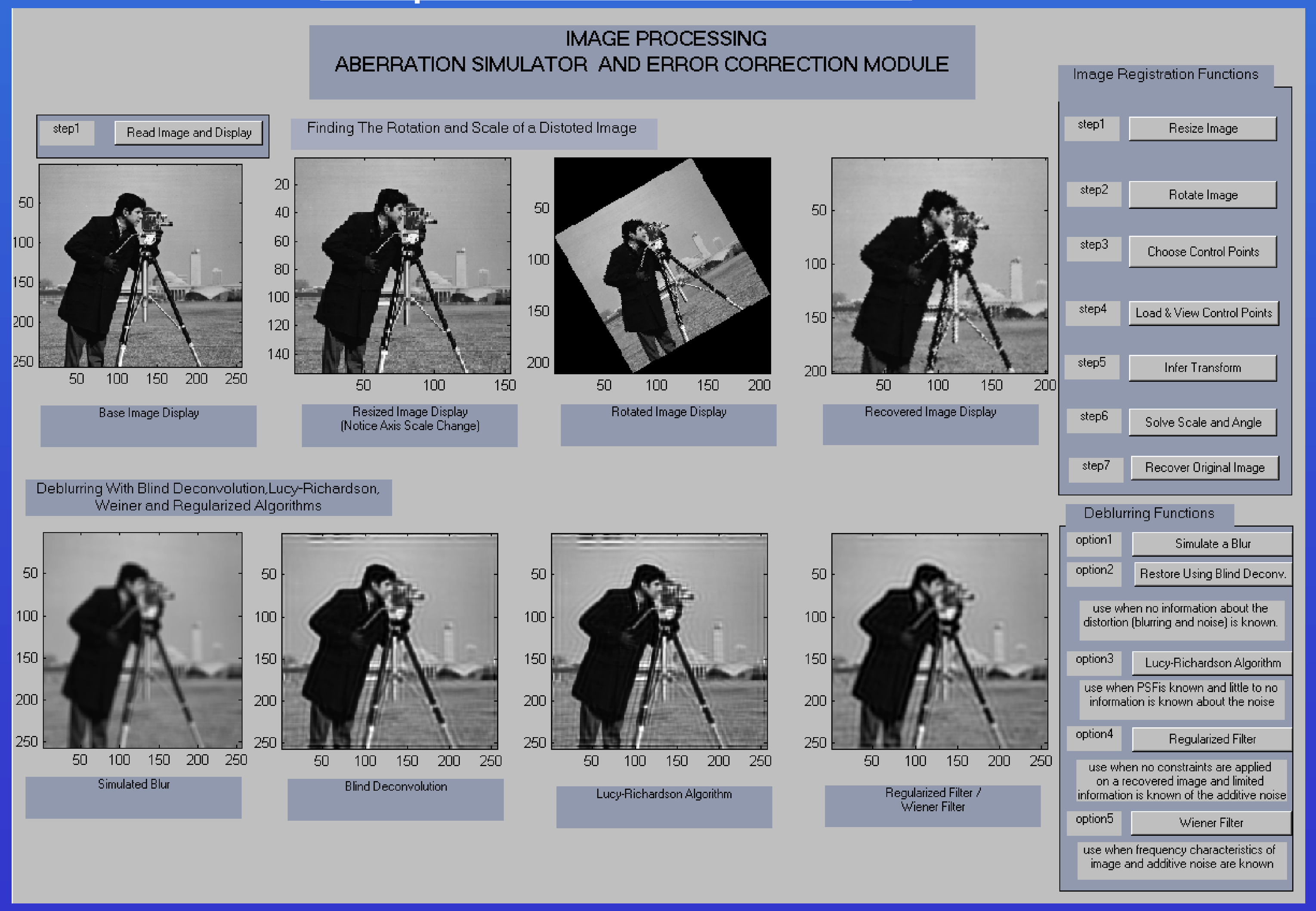
4 Sample Data Frames



5 Personal Contribution

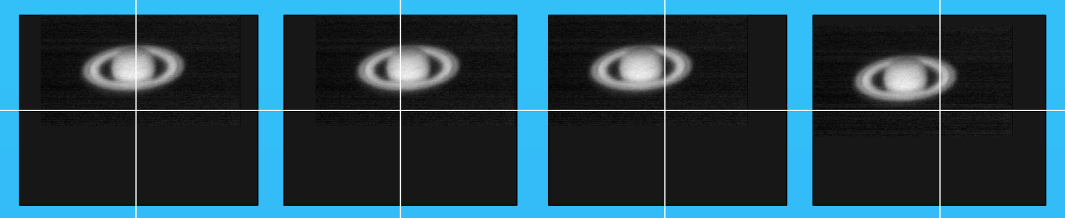
- Development/Testing of Calibration and Deconvolution Techniques
- Development of a Graphical User Interface for Image Processing

Graphical User Interface

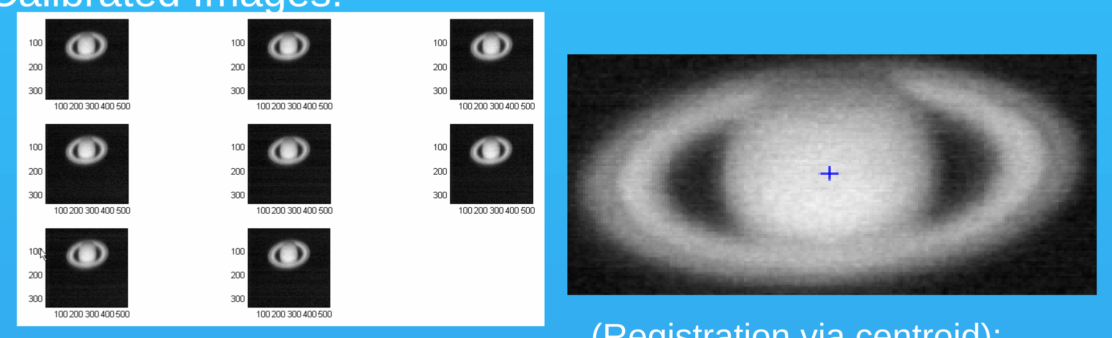


7 Results and Conclusions

Sample Raw Data From Frame Grabber:

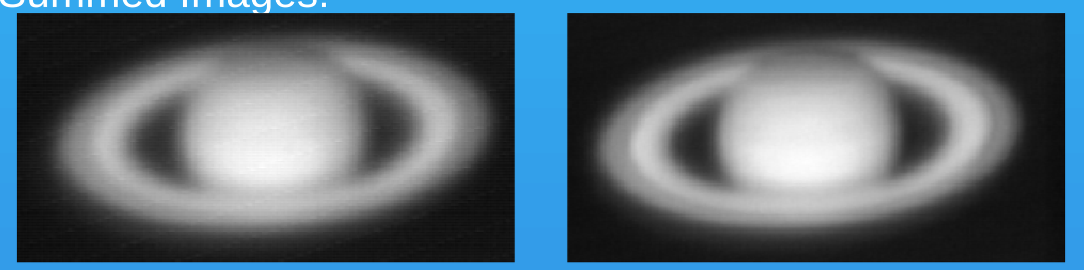


Calibrated Images:



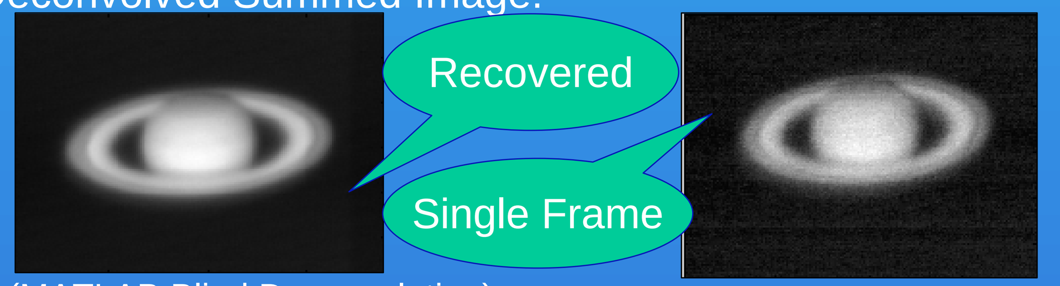
(Registration by hand) (Registration via centroid):

Summed Images:



(No Centroiding) (Centroid (0.05 pixels) + Sum)

Deconvolved Summed Image:



(MATLAB Blind Deconvolution)

Alternative Approaches:

Assumed SNR = 3 Assumed SNR = .85

- Register, Deconvolve and Sum (1&2): Custom Ayers-Dainty Algorithm
- MATLAB: Deconvolve, Register and Sum (3)

In conclusion, calibration and deconvolution techniques can greatly improve image quality. In addition, resulting information can be used to characterize the optical system.

6 General Filter Derivation

$$i_d = psf_A \otimes i_o + n, \qquad \Im(i_d) = I_d = PSF \cdot I_o + N, \qquad I_o' = Y \cdot I_d$$

$$\text{minimize: } e^2 = \left\langle \left| I_o - I_o' \right|^2 \right\rangle, \quad \frac{\partial}{\partial \bar{Y}}(e^2) = 0, \Rightarrow Y = \frac{PSF}{PSF^2 + (S_N / S_O)}$$

$$\text{Case1: } \frac{S_N}{S_O} \square\ 1, Y = \frac{I_d}{PSF} \qquad \text{Case2: } \frac{S_N}{S_O} \square\ 1, \ Y \to 0$$