Solar Irradiance, Image Restoration and Structure Identification

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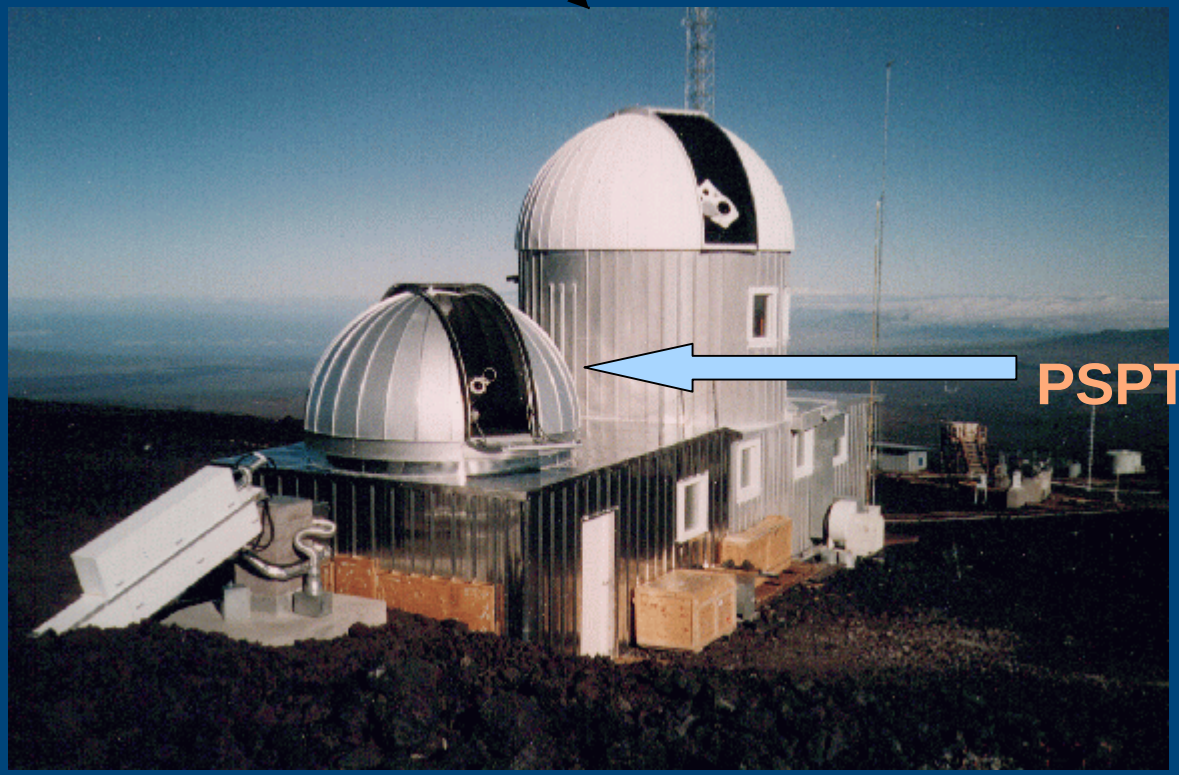
Introduction

- Solar Irradiance
  - Average incoming solar radiation
- How can this be modeled?
  - Varying Magnetic Features on the surface of the Sun will change how much radiation is observed
  - The 'quality' of an image could also change how solar features are quantified.
- In order to develop a rich model for solar irradiance, it is necessary to understand how solar images can be corrected fo defects and how that correction will affect the way the solar features are identified.

Introduction:Scope of Presentation

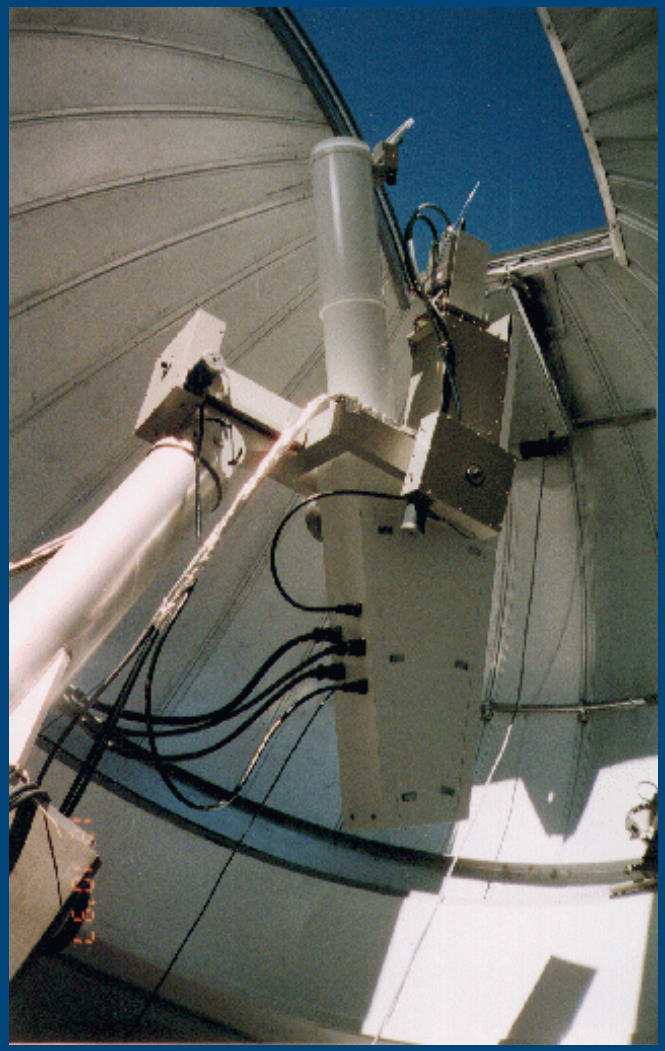
- PSPT
  - Specifications
  - Image Gathering
- Magnetic Feature Identification
  - Identifying different features on surface
  - Use total feature area to better quantify irradiance
- Image Defects and Restoration
- Image Control
- Restoration and Identification Results

Precision Solar Photometric Telescope (PSPT)



- Hawaii, Southeast of Honolulu
- Mauna Loa Solar Observatory (MLSO)
  - http://www.mlo.noaa.gov/livecam/livecam.html

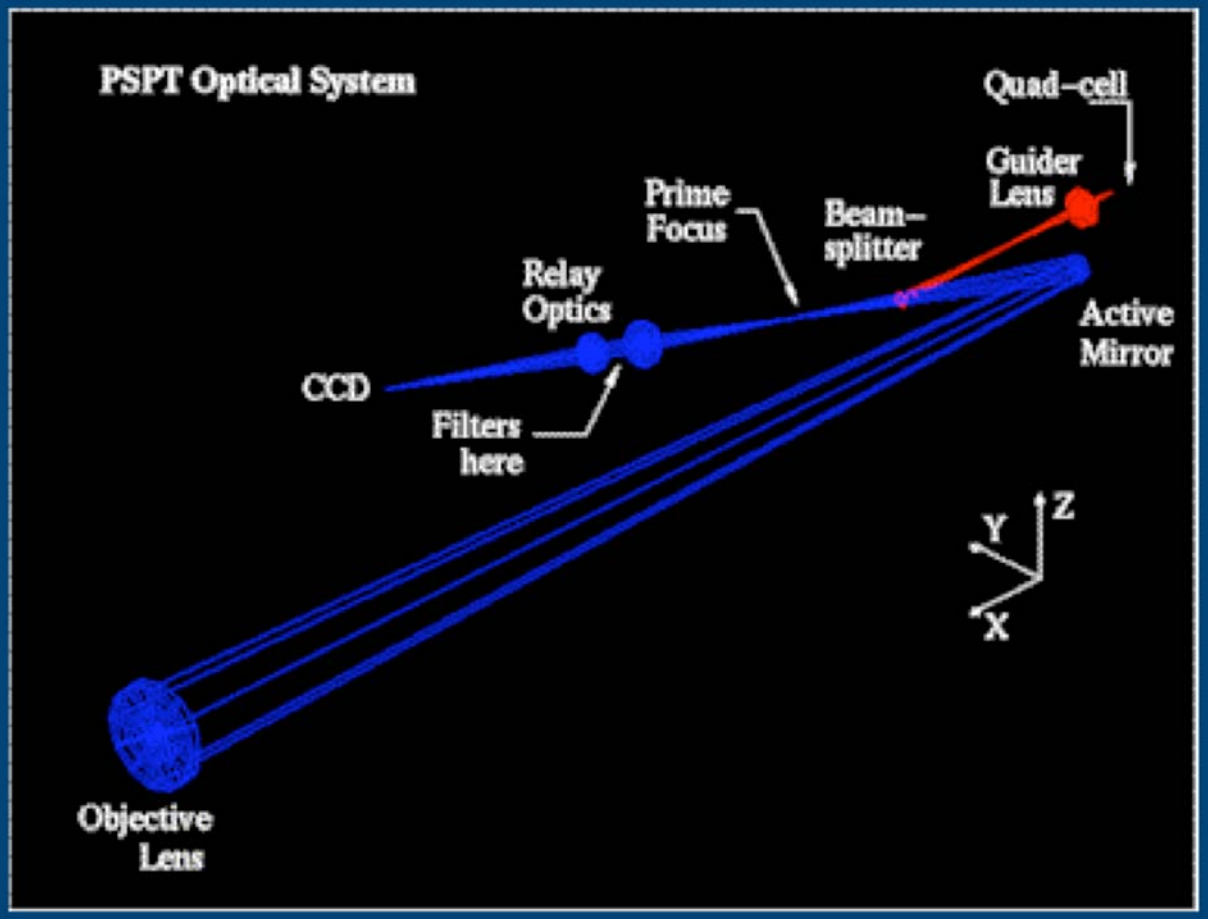
Precision Solar Photometric Telescope (PSPT)



- 15 cm Refracting
- Observed Wavelength
  - CaIIK (393.4nm)
  - blue continuum (409.4nm)
  - red continuum (607.1nm)
- 1TB of data per year
  ~2.7 GB a day

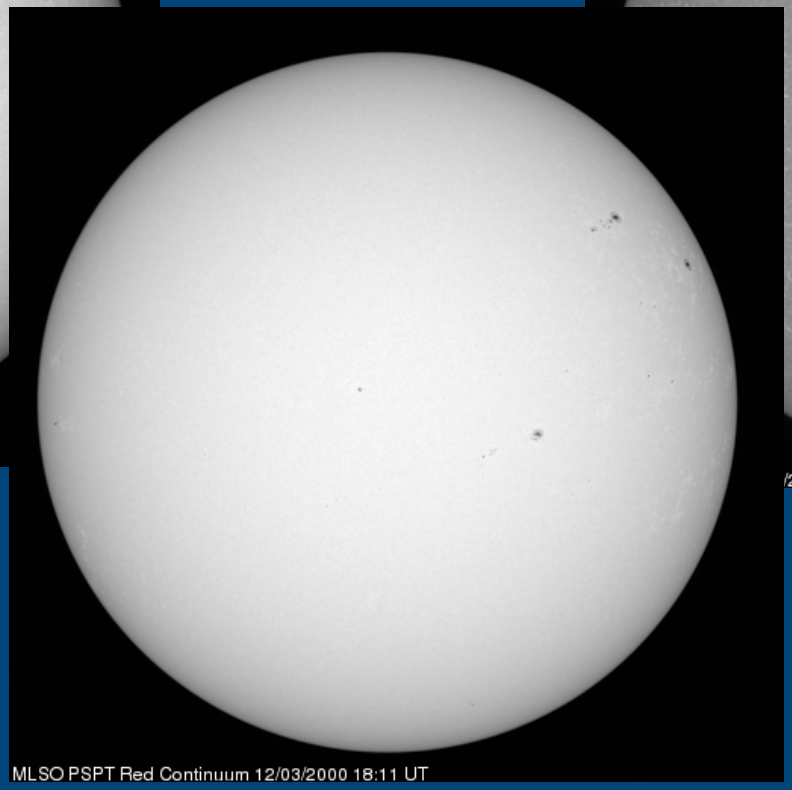
Precision Solar Photometric Telescope (PSPT)

Image Gathering

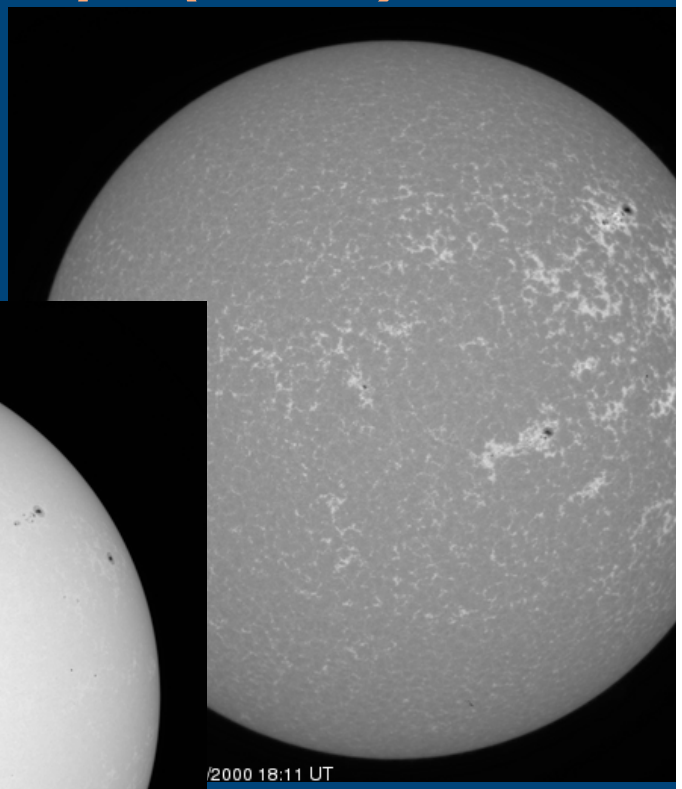


Precision Solar Photometric Telescope (PSPT)

Blue Continuum



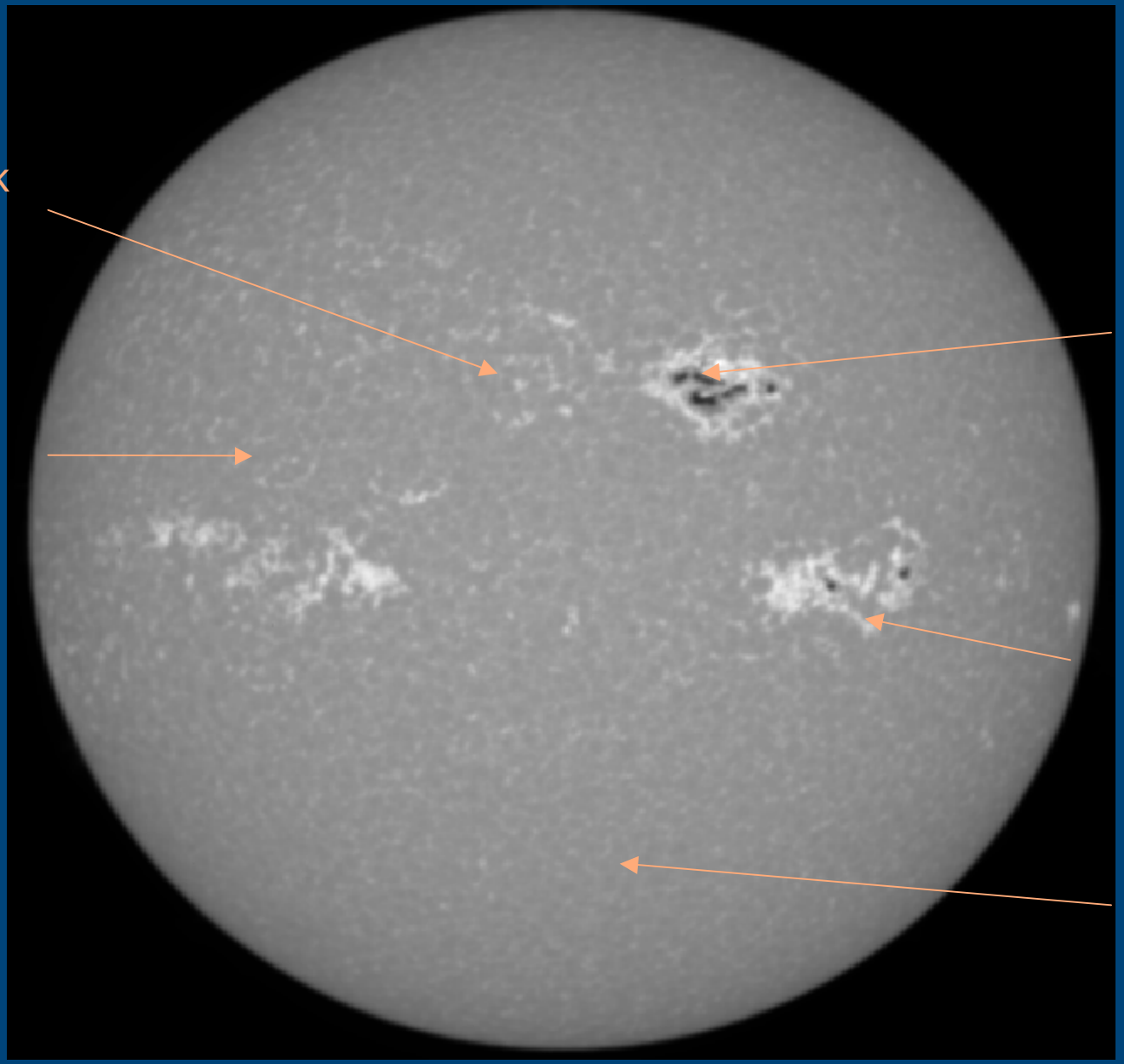
Red Continuum



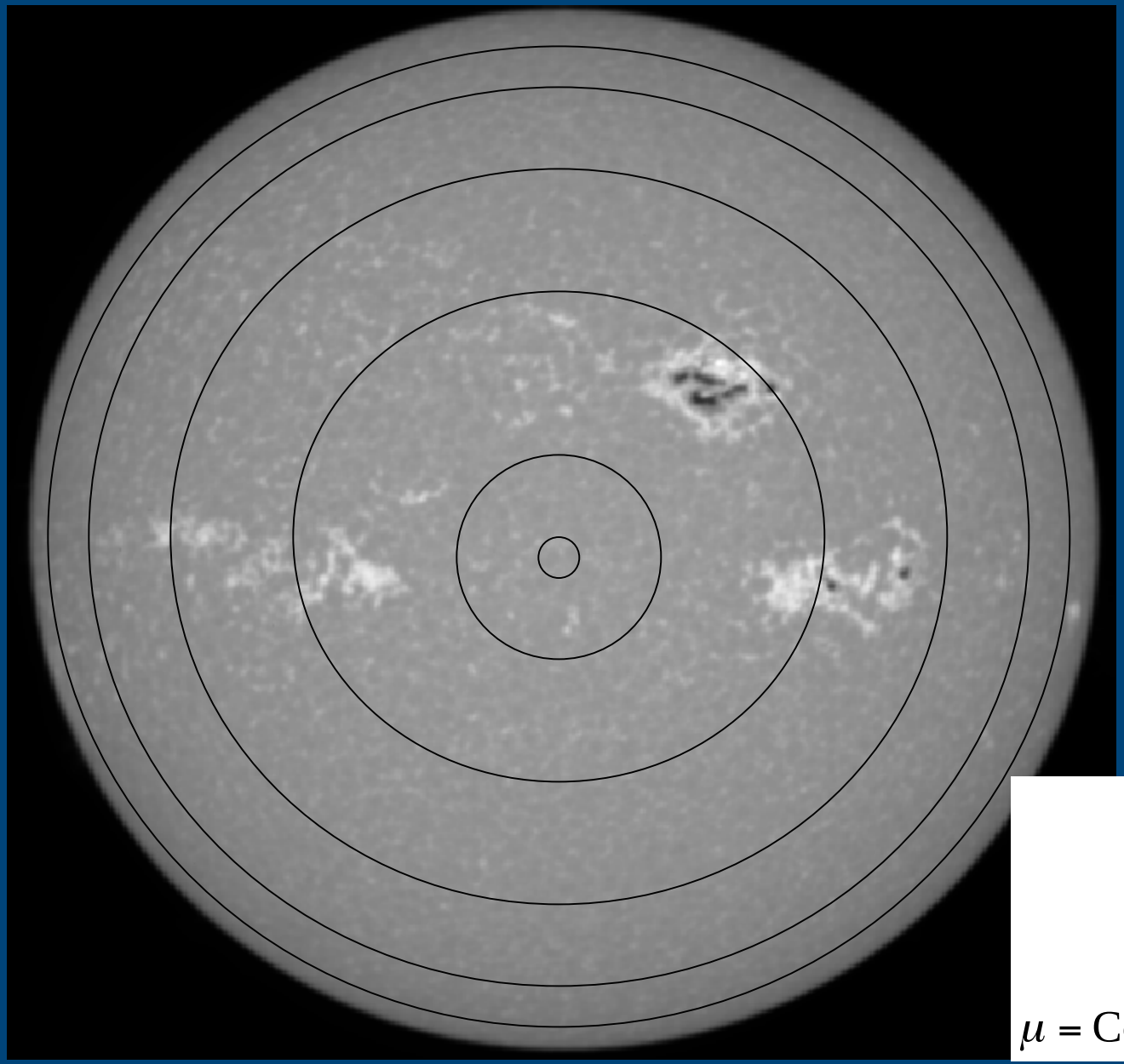
CaIIK

images: http://rise.hao.ucar.edu/links/mlso_hourly_images.html

Solar Feature Extraction: What features are there?



Solar Feature Extraction: Annuli and Averages



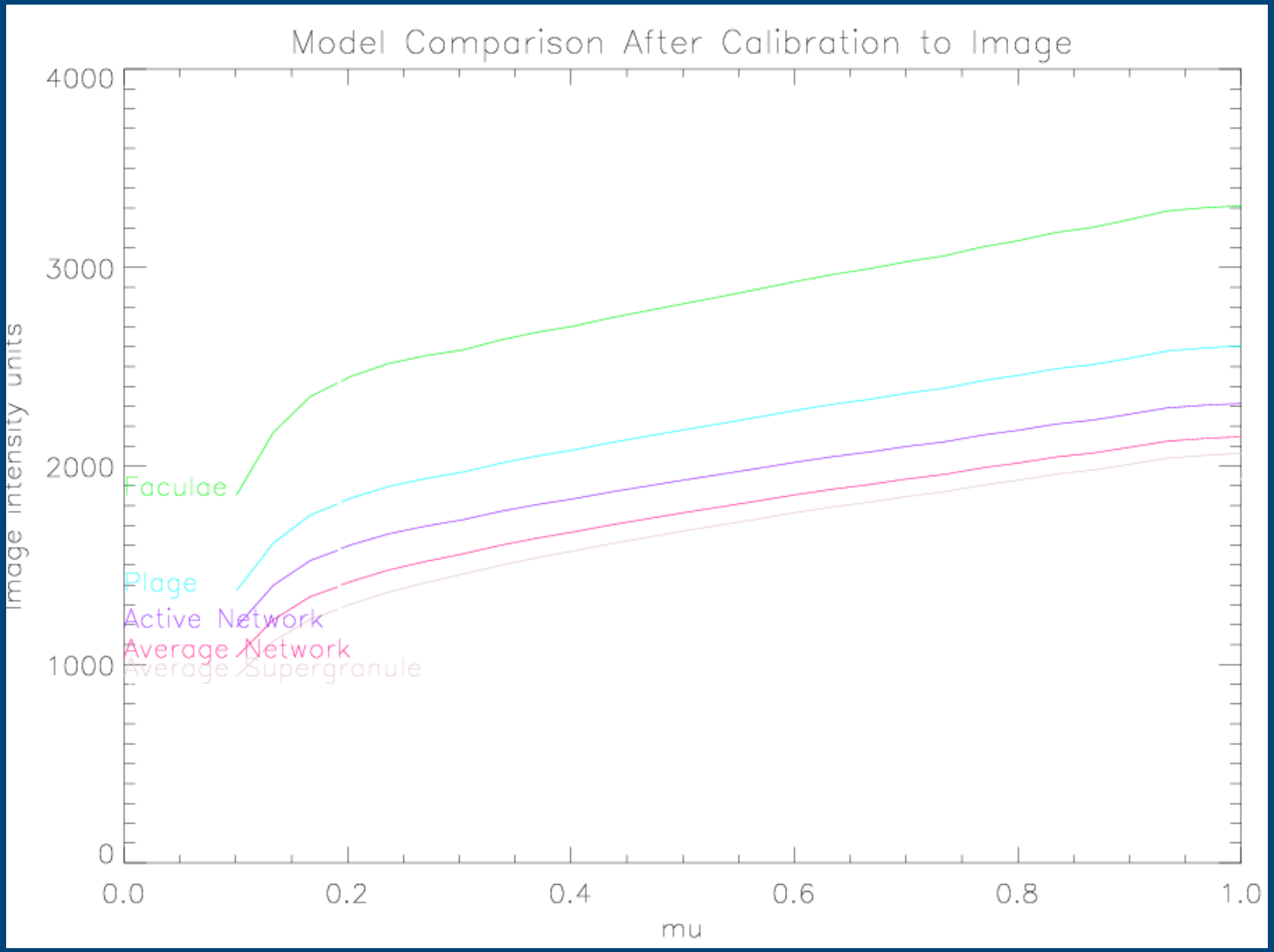
$$r_a = r_s\sqrt{1-\mu^2}$$

r_a = annulus radius

r_s = solar radius

μ = Cosine of Heliocentri

Solar Feature Extraction: Calibrated Models



Solar Feature Extraction: Original vs Identified

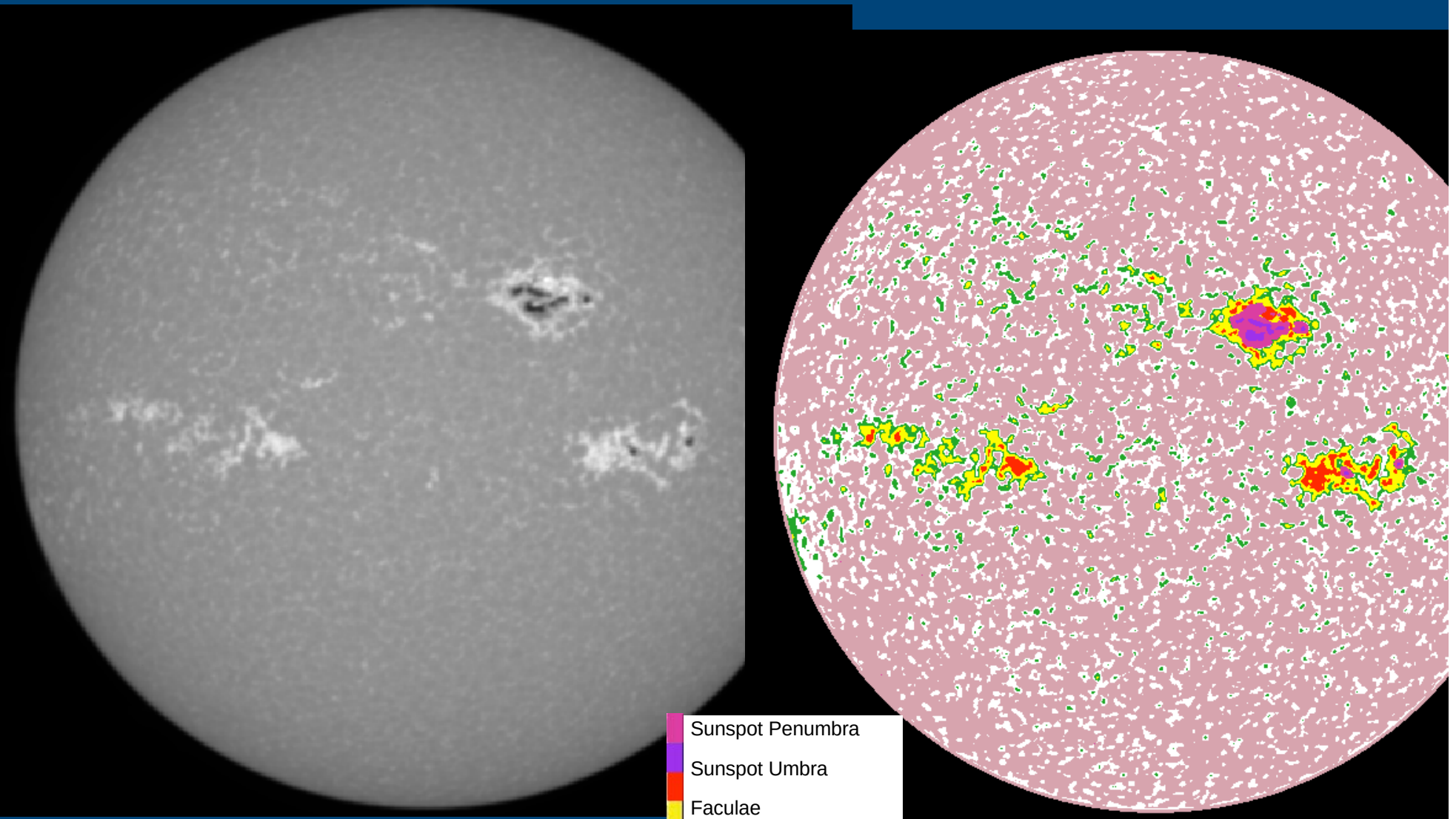


Image Defects and Restoration

- Instrument Effects
  - Quadrant Defects
    - Artifact of how images are gathered (old CCD)
  - Flat Field Defects
    - Artifacts left in during the flat field process
- Natural Effects
  - Solar Limb-Darkening
    - Result of increased optical depth of cooler atmosphere
  - Stray Light
    - Scattering and blurring by the Earth's atmosphere and the PSPT
    - Solar features (sunspots, faculae, etc.) are degraded

Image Defects and Restoration: Quadrant and Flat-Field Defects

Histogram equalization: intensity in the image is propo
to the number of pixels in a given original intensity

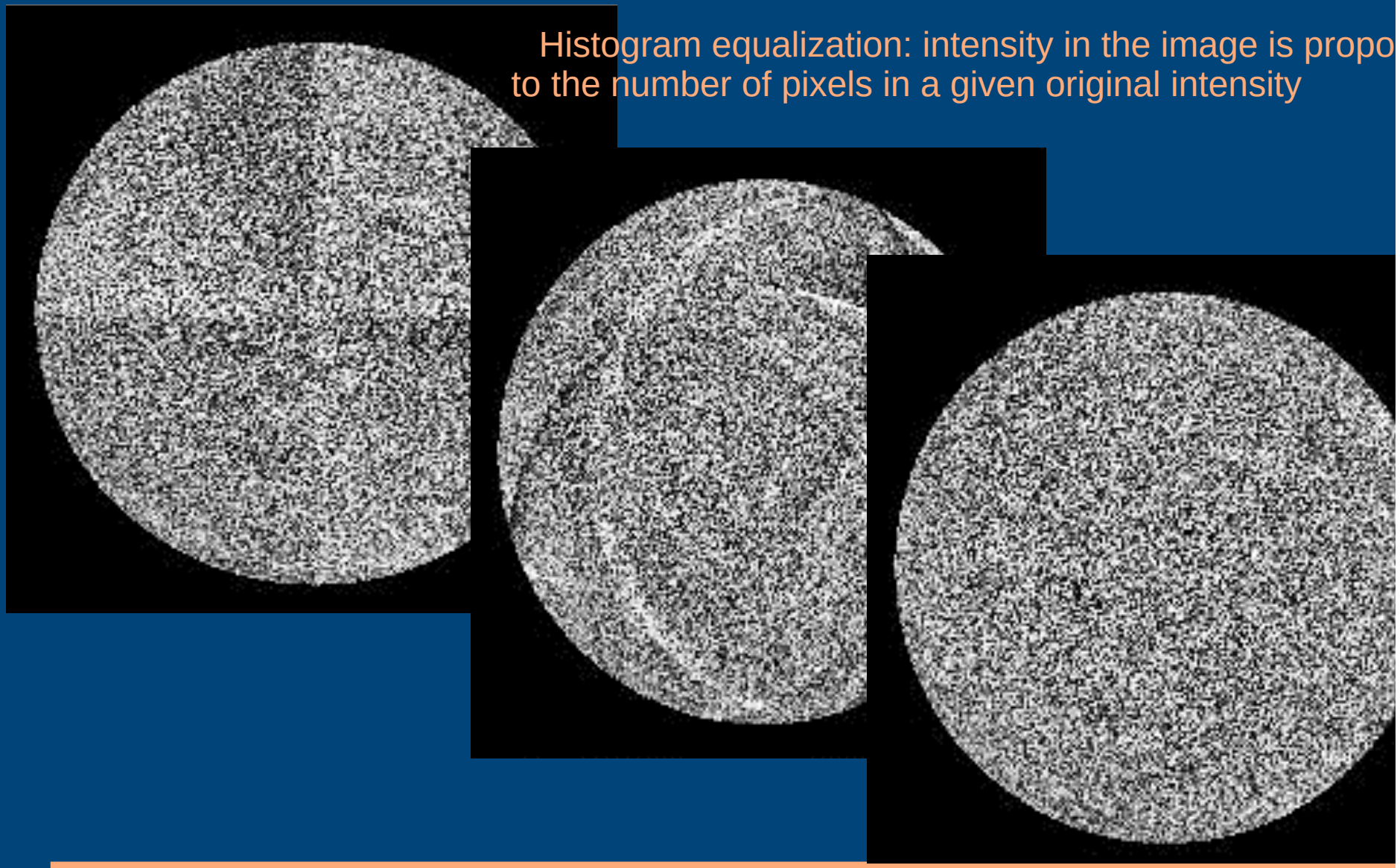
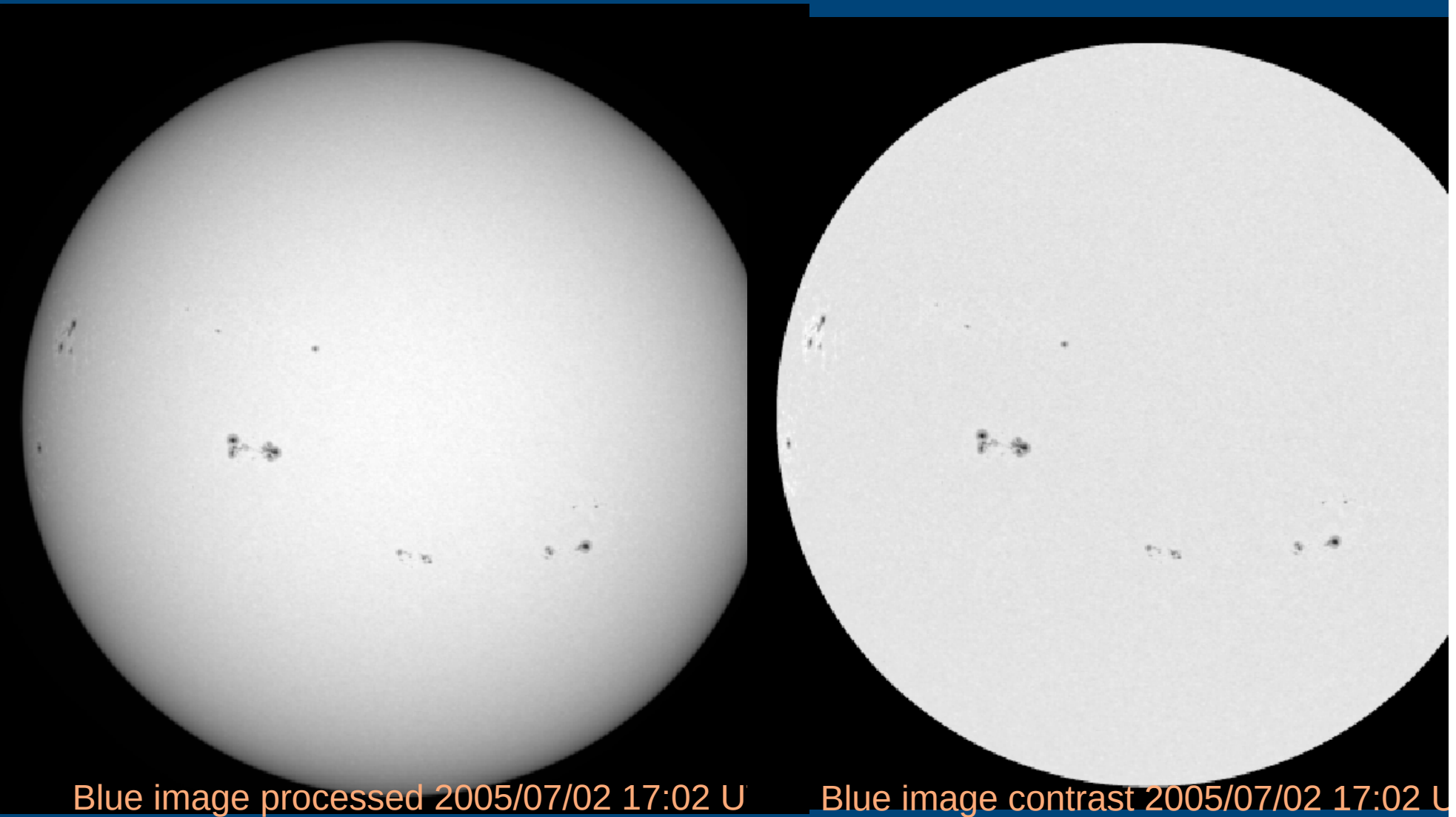


Image Defects and Restoration: Center to Limb Variation

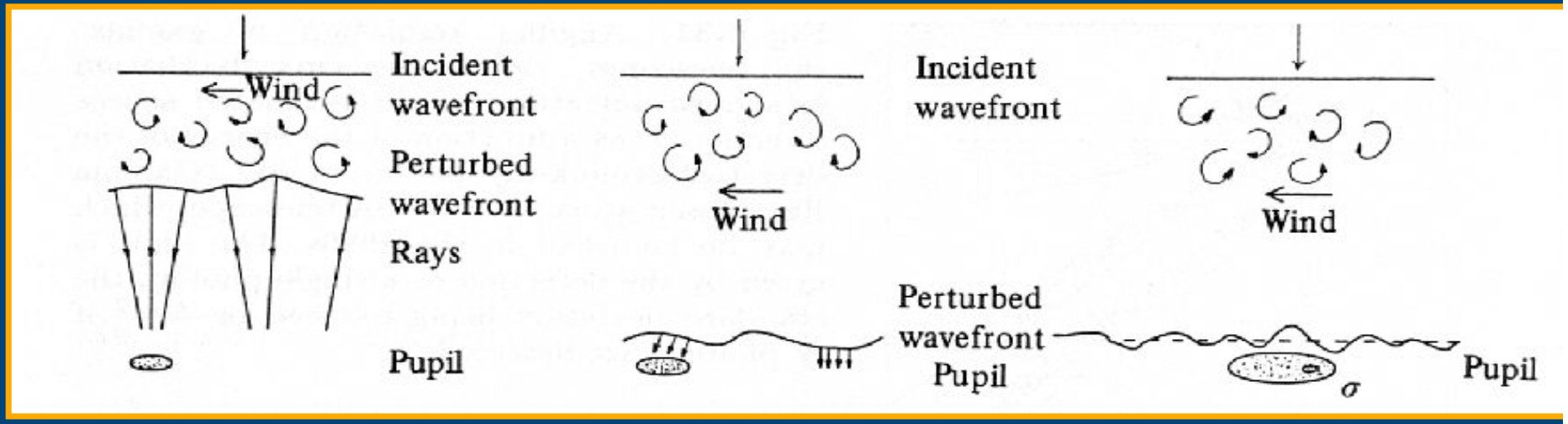


Blue image processed 2005/07/02 17:02 U

Blue image contrast 2005/07/02 17:02 U

Image Defects and Restoration: Main Defect Cause

- Turbulence in Earth's atmosphere bends wavefront
  - Scintillation
  - Agitation
  - Smearing



Scintillation: Not Addressed in restoration

Agitation

Smearing

Image Defects and Restoration: How is distortion observed?

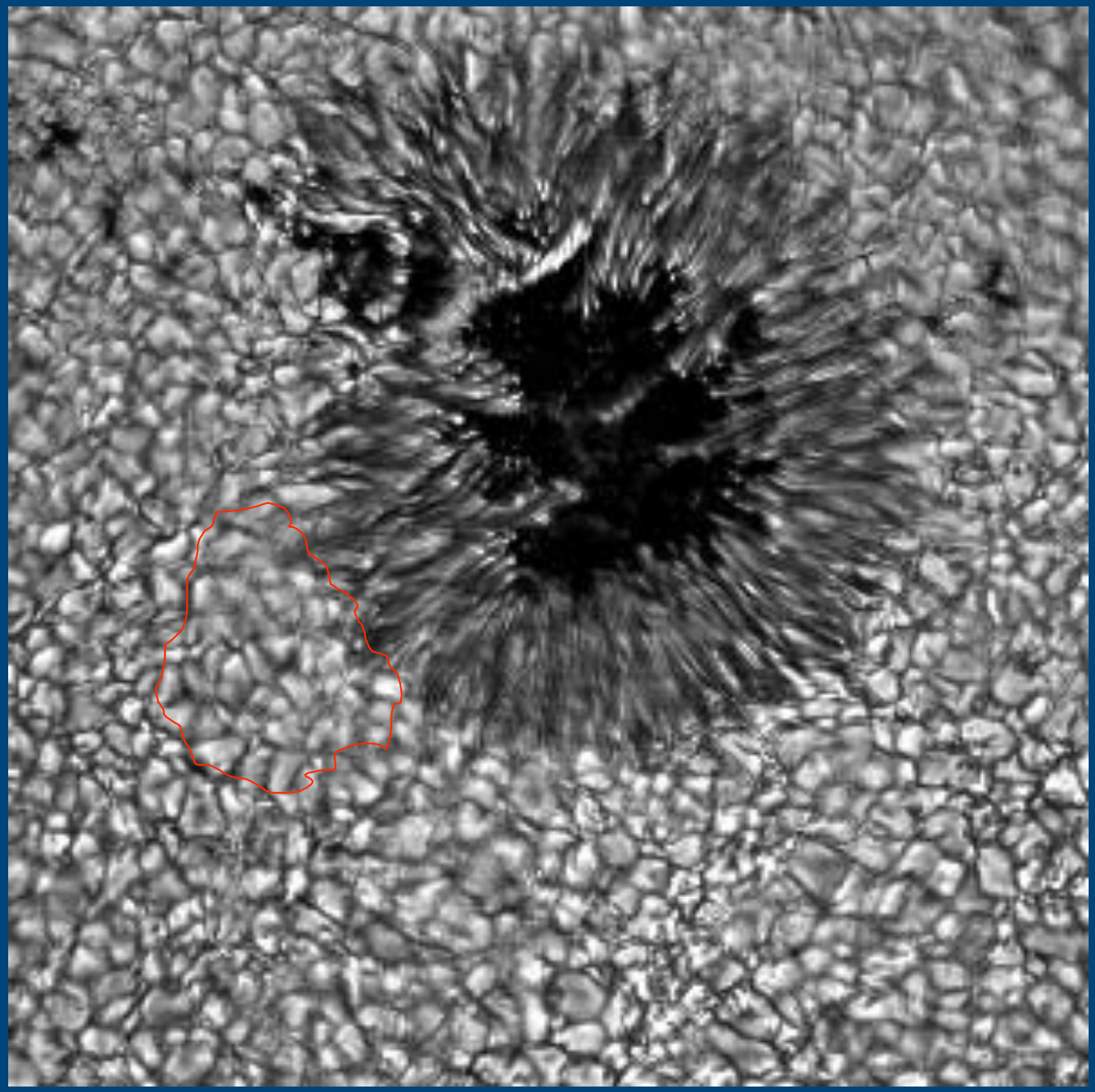
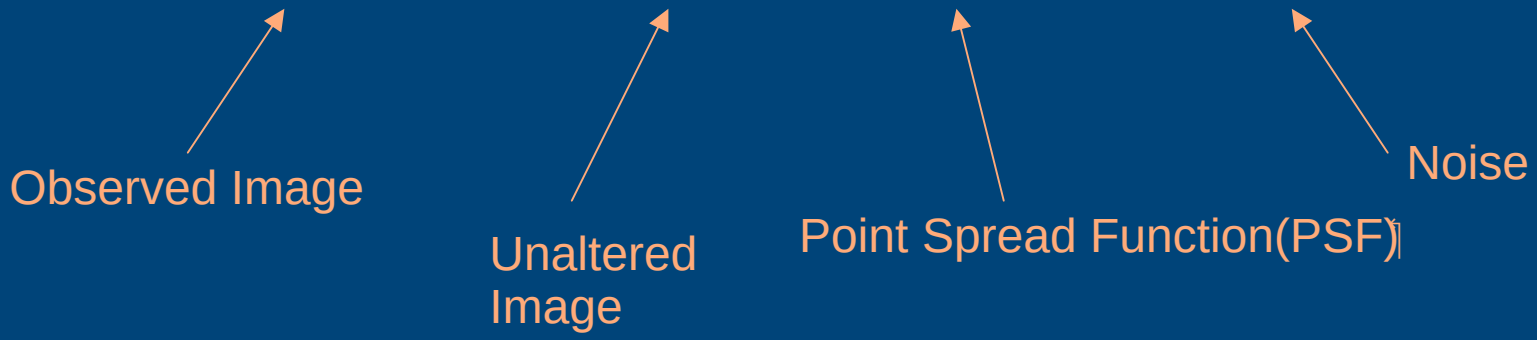


Image Defects and Restoration: Correction Procedure

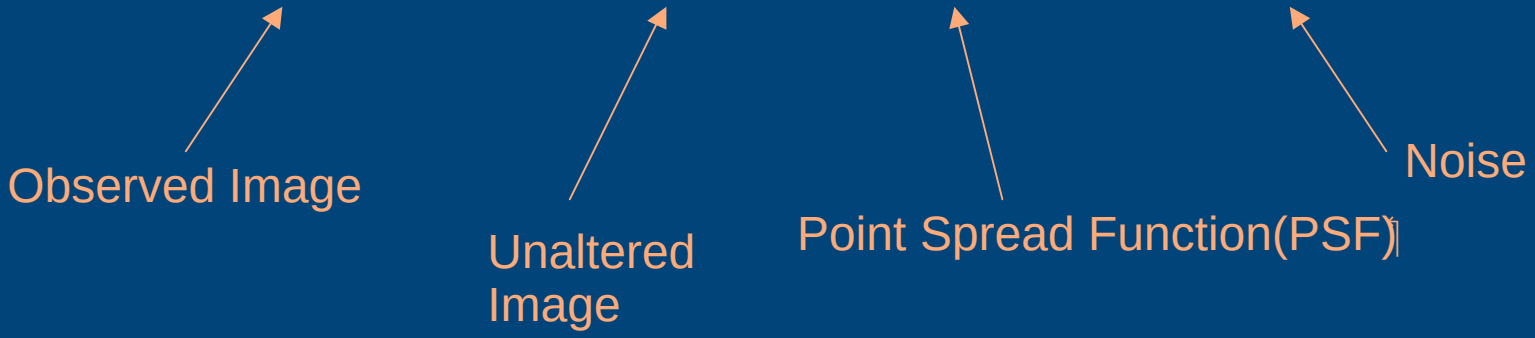
$$i(x,y) = i_0(x,y) * s(x,y) + n(x,y)$$



- Unaltered image: Image if viewed without any distortion.
- PSF: Describes both Atmospheric distortions.
- Noise: Noise due to unpredictable actions.

Image Defects and Restoration: Correction Procedure

$$i(x,y) = i_0(x,y) * s(x,y) + n(x,y)$$



- Unaltered Image estimated through Inverse Fourier Transform.
- Noise is generated randomly
- The real aim of the procedure is to properly describe the PSF.

Image Defects and Restoration: Correction Procedure

$$i(x,y) = i_0(x,y) * s(x,y) + n(x,y)$$

Observed Image

Unaltered Image

Point Spread Function(PSF)

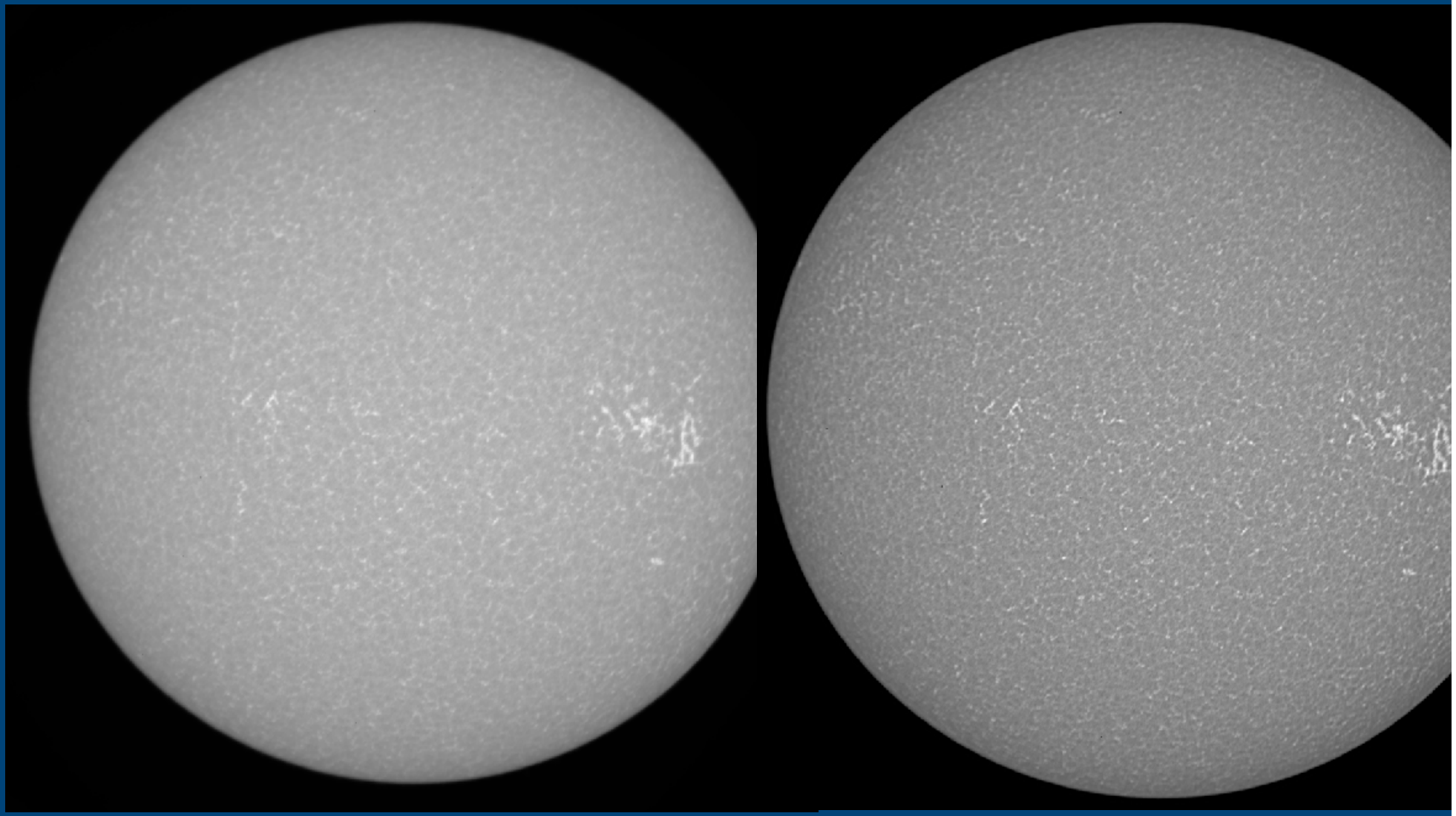
Noise

After several assumptions about the distribution of the image distortions:

$$s(r) = C_1\{C_2 e^{-(r/b_1)^2} + C_3 e^{-(r/b_2)^2} + C_4 e^{-(r/b_3)^2}\} + \frac{a_1}{A(r^2 + b_4^2)}$$

$$C_1 = (1-a_1); C_2 = (1-a_2)(1-a_3); C_3 = a_2(1-a_3); C_4 = a_3$$

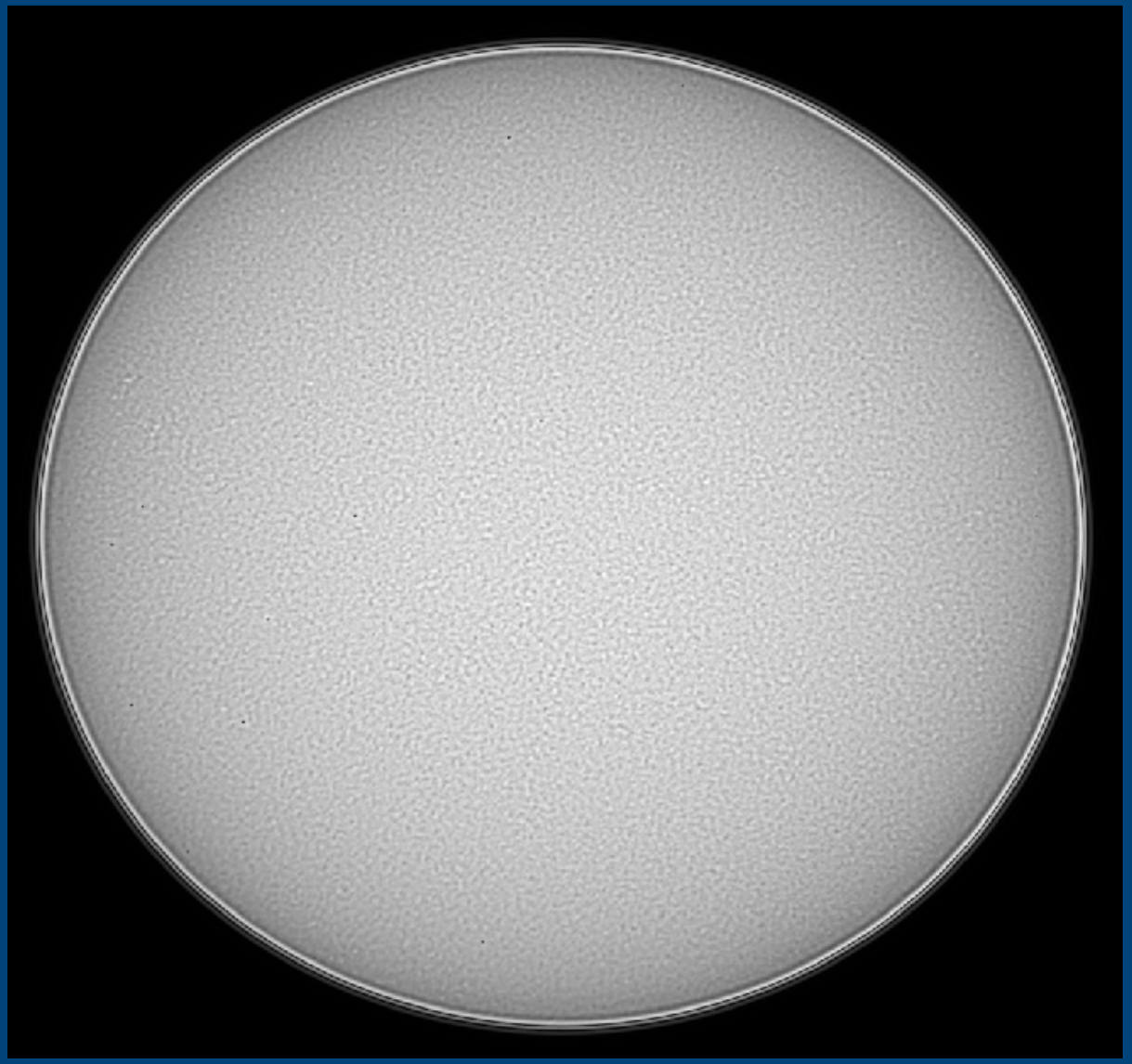
Image Defects and Restoration: Original vs Restored



Original Image: 20070405.1740

Restored Image: 20070405.1740

Image Defects and Restoration: Poor Restoration



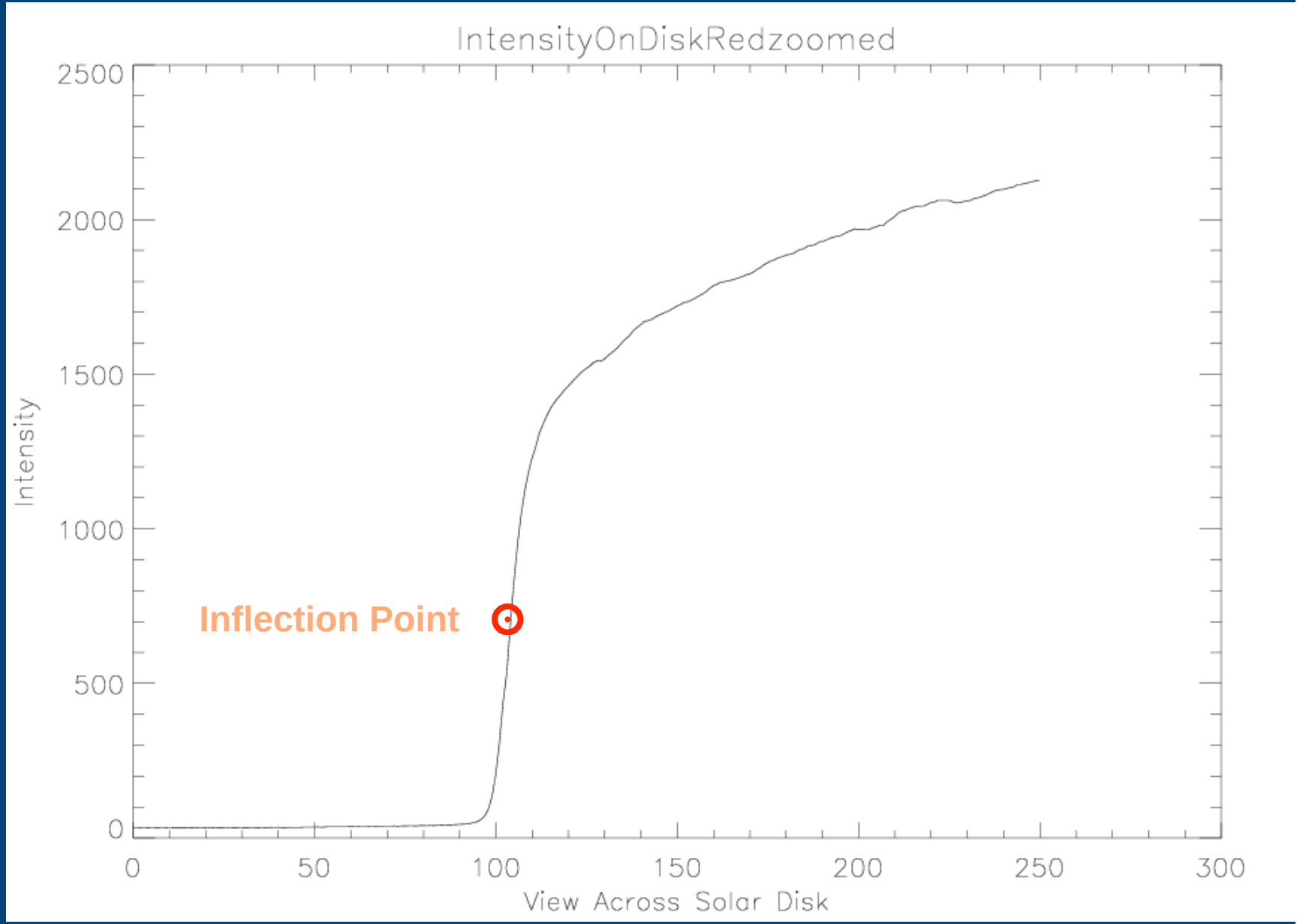
Poor Restoration: 20070317.1730

Image Control Preparation

To test restoration and identification methods you must have a control!

- Control requirements
  - High “quality” images
  - Large data set
  - Detailed images
- Selection process
  - Choose observation days that have many images
  - Find quality data and create histogram to divide image into three groups; good, bad and ugly.

Image Control Preparation: Defining Quality



Control Image Preparation: Defining Quality

- Quality is average of width for each limb
- The sharper the image, the narrower the width

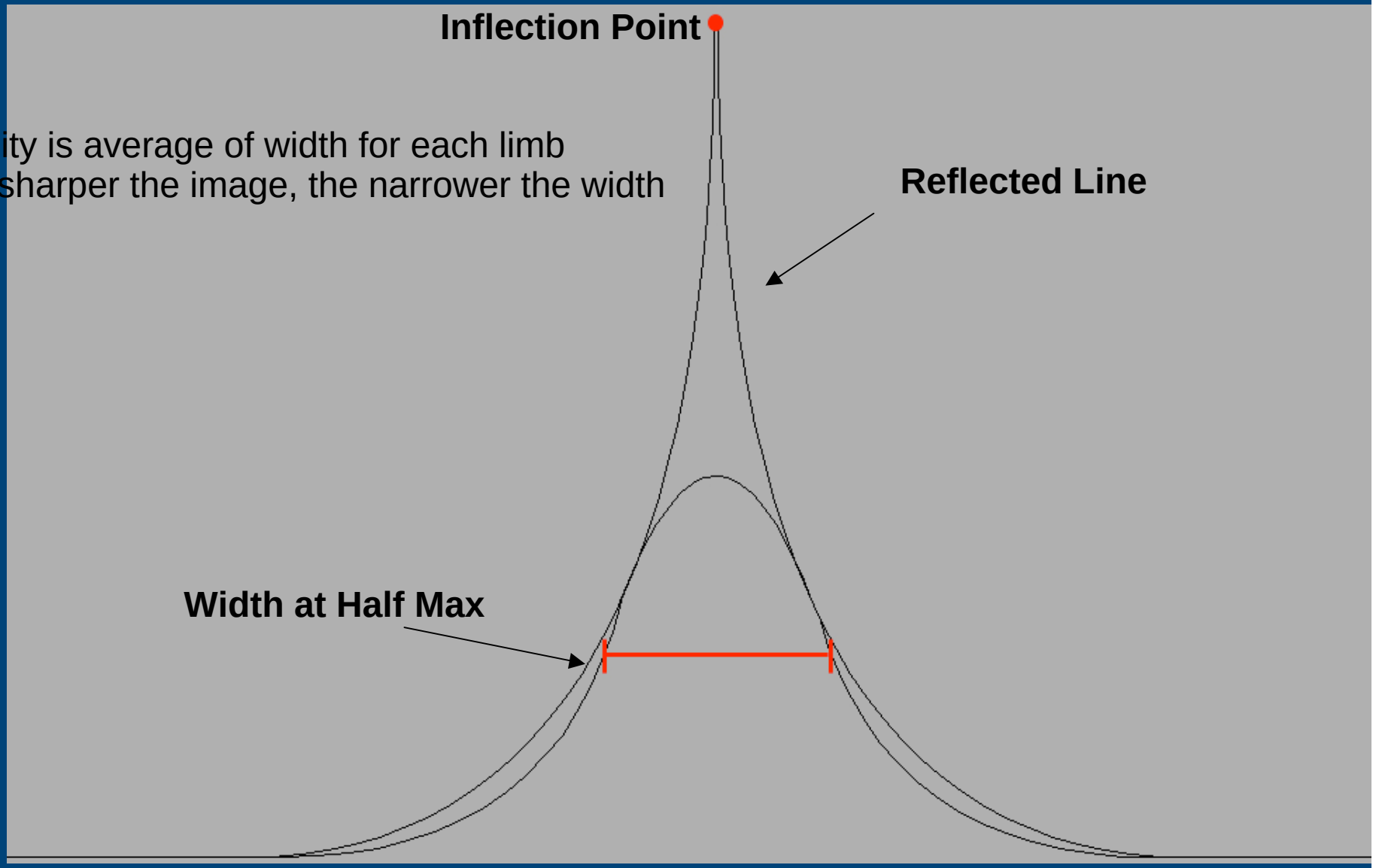


Image Control Preparation: Comparison of Qualities

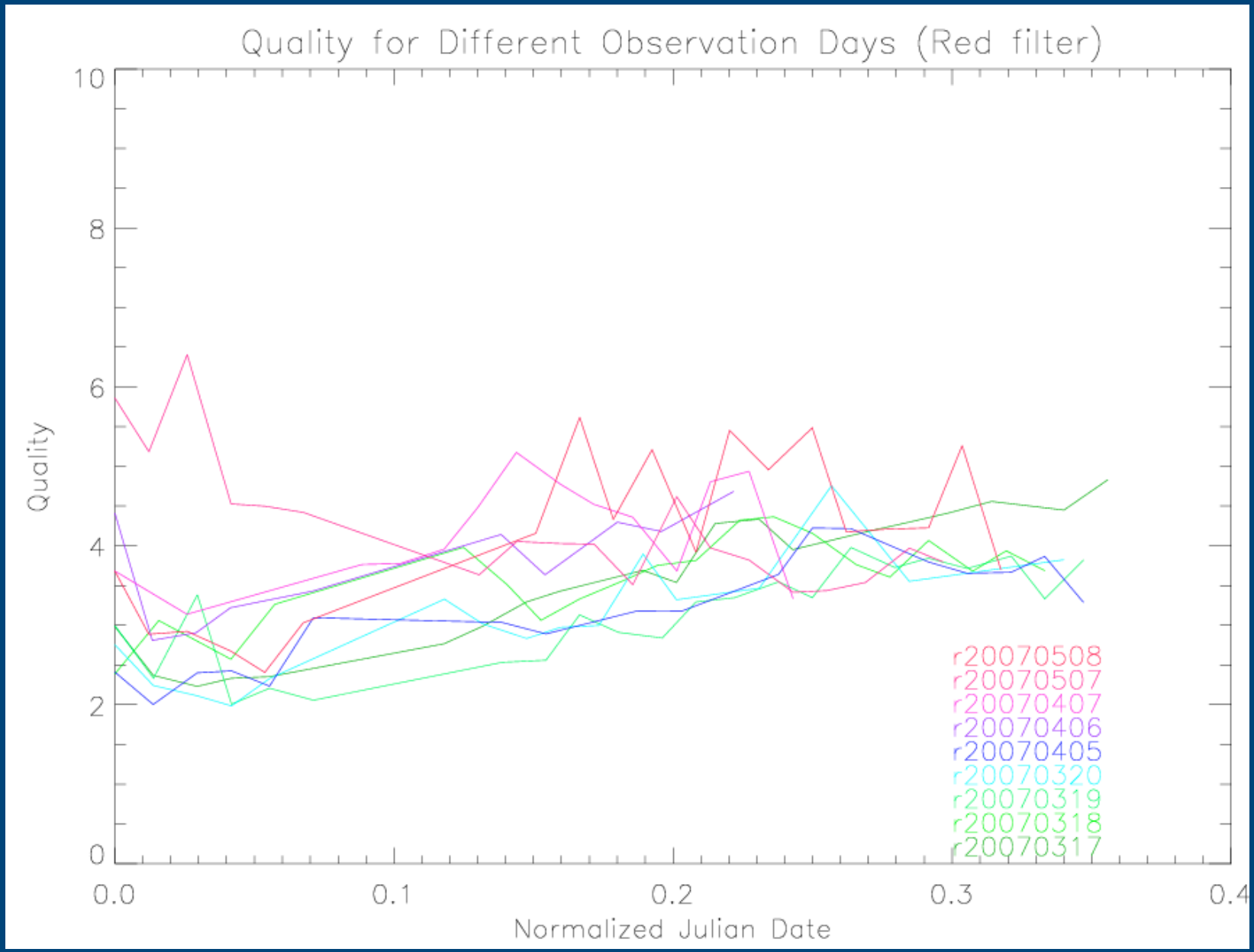
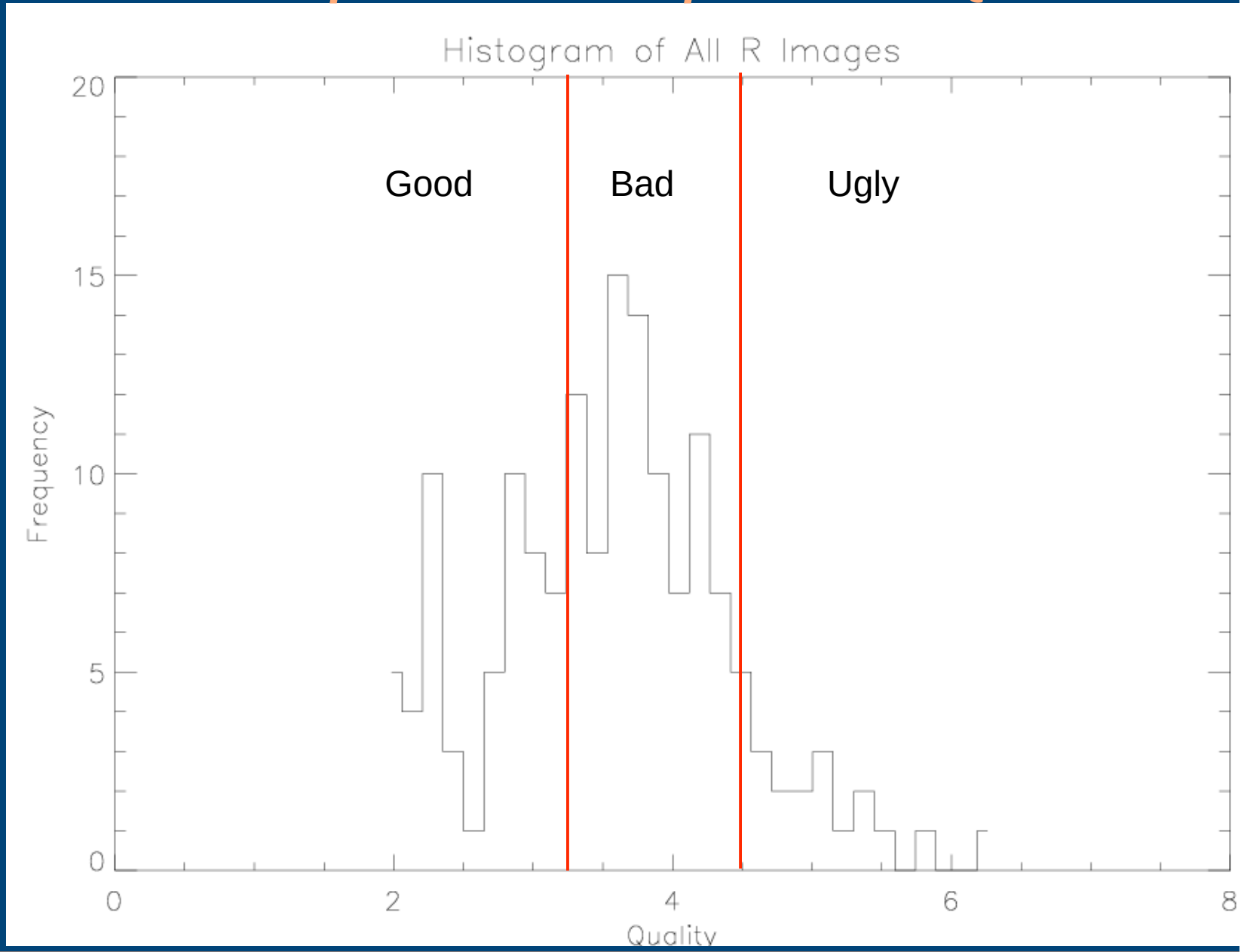
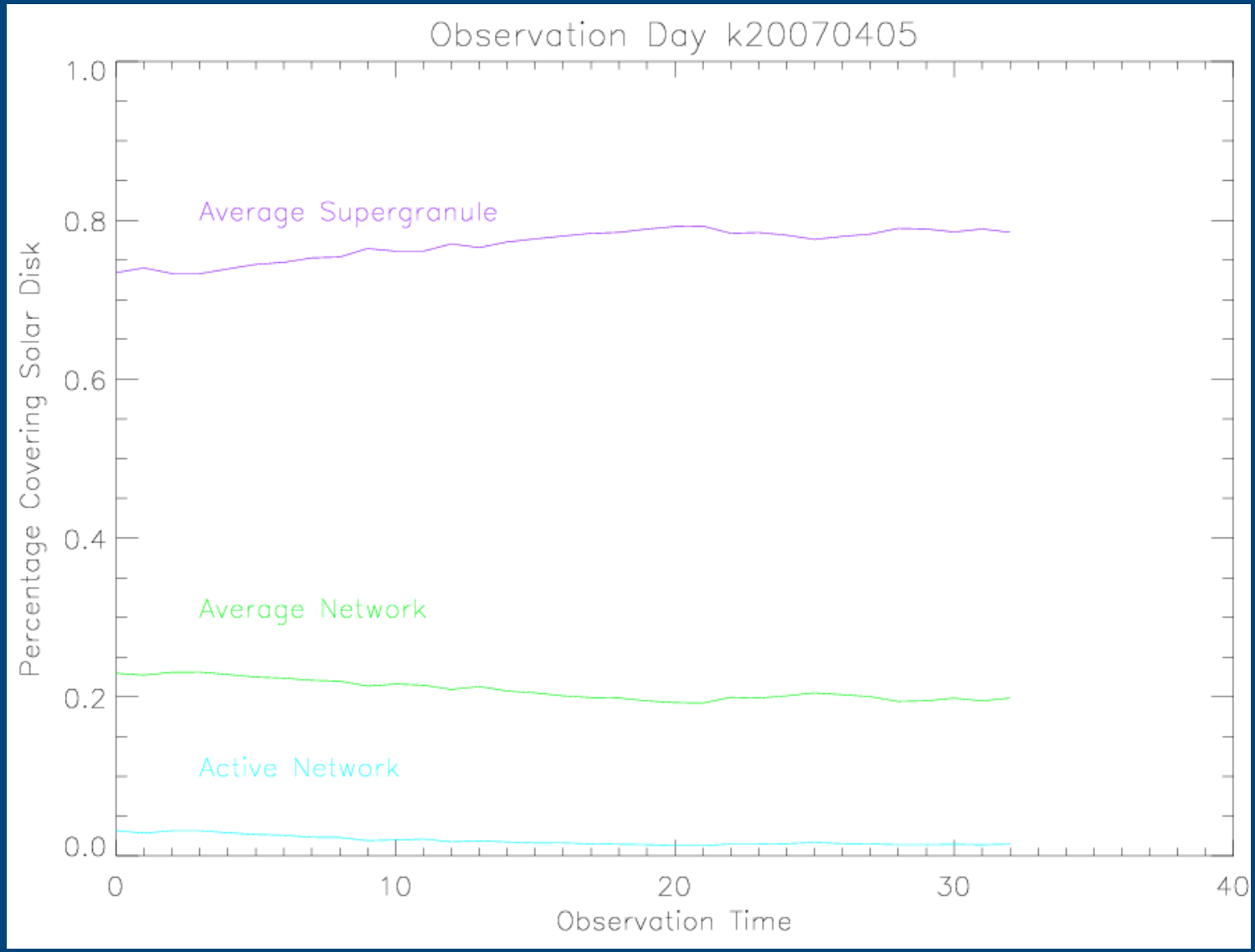


Image Control Preparation: Comparison of Qualities



Restoration and Extraction Results: Area over a Day



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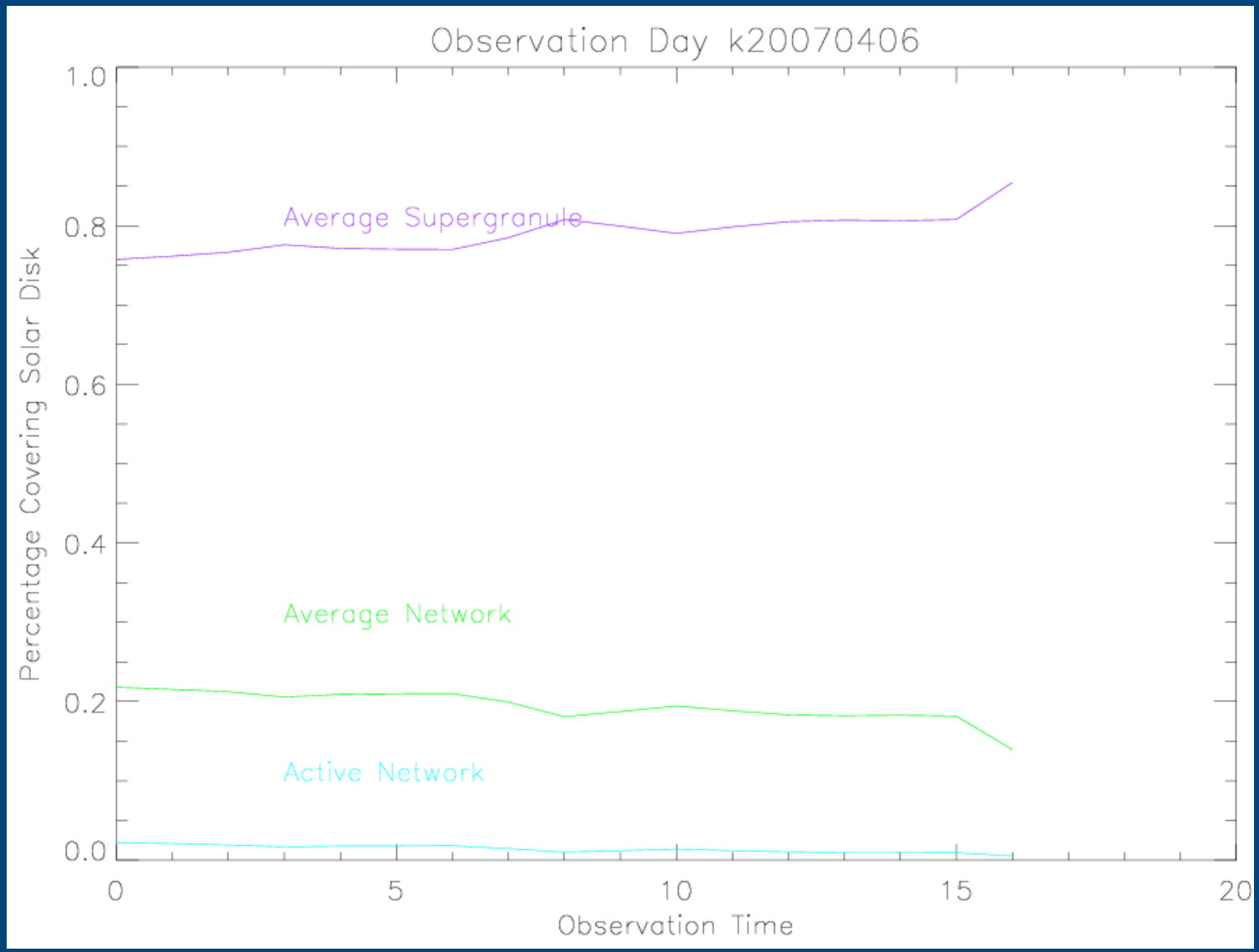

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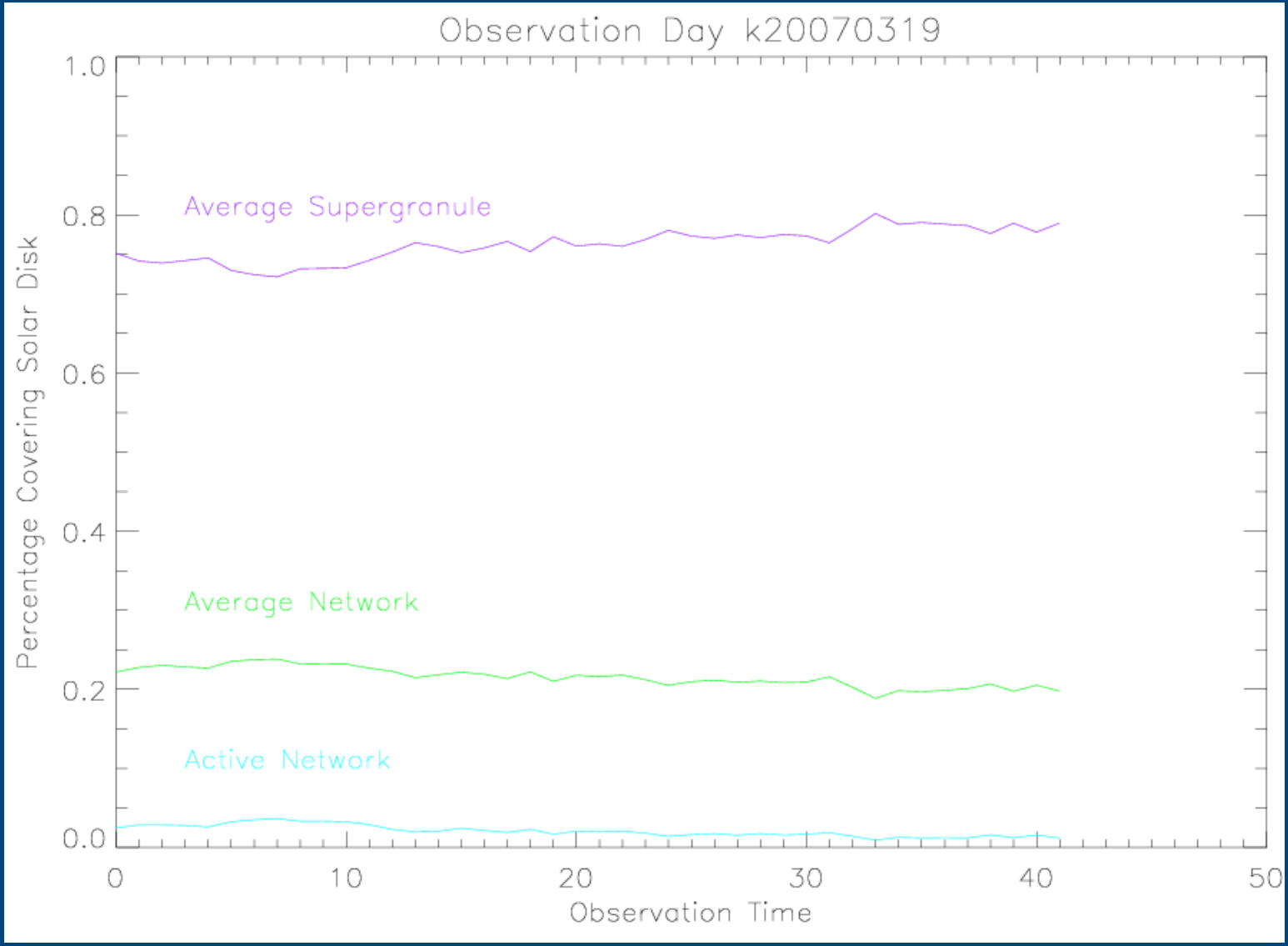

Restoration and Extraction Results: Good and Bad

Summary and Conclusions

- Quality of an image decreases over an observation day
  - Sun heats the atmosphere creating turbulence
- Active and average network increases with the restoration of a image
- Superganulation decreases with restoration of image
- Change in area between restored and non-restored images is s large that restoration gives an images that has better quality th the highest quality image gathered for that day

Future Plans

- Perform restoration on all images over a single observation day. how identified areas change. If restored correctly, images would same identified features
  - Compare the restoration of the worst quality image in a single with the best unrestored image of that day
- Structure Identification
  - Structure models are normalized to annulus mean. Restoration changes the distribution of intensity, leaving the mean moderate unchanged. An improvement would normalize to something that is not constant with restoration
- Image Restoration
  - Improve restoration algorithm to not over restore an image
  - Restoring no further than the best quality images of that day or highest quality images of the PSPT
    - Prevents restoration beyond the quality the PSPT will allow

References

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