Bias Frame

- Total darkness and zero integration time.
- Constant bias plus random readout noise.
- Pixels have nearly same value (usually 100).
- Check camera by examining bias frame.
- Will be used to establish camera zero point.

Dark Frame

- Total darkness and same integration as images.
- Bias plus dark current that increases with time.
- Most pixels low value but with a few “hot” pixels.
- Needed to remove dark current from images.
- Will be used to subtract dark current.
- Average many to make Master Dark Frame.

Raw Flat Frame

- Uniform light and short integration time.
- Bias plus dark plus uniform QE and illumination.
- Pixels cluster around average level of frame.
- Needed to fix non-uniform QE and illumination.
- No good without flat-dark to fix dark current.
- Average many to get high signal-to-noise ratio.

Flat-Dark Frame

- No light and short integration time.
- Bias plus dark current (same as flat-field).
- Pixels at bias plus short-time dark current.
- Used to remove dark current from flat-field.
- Average many to get high signal-to-noise ratio.

Flat-Field Frame

- Pixel values proportional to light detected.
- Computed from: (Raw Flat) – (Flat Dark)
- Bias has been removed.
- Dark current has been subtracted.
- Pixel values cluster around average light level.
- Will be use to correct raw image.

Raw Image

- Integrate long time to collect lots of light.
- Bias plus dark current plus image electrons.
- Image has nonuniform QE and illumination.
- Maximum number of pixels have sky level.
- Shoot multiple images to collect good signal.
- Must be on target, in focus, well tracked.

Basic Calibration Math

Step 1: Make the Master Flat-Field

Flat-Field = (Raw Flat) – (Flat Dark)

Step 2: Subtract the Master Dark Frame

Dark-Subtracted Image = (Raw Image) – (Dark Frame)

Step 3: Divide by the Master Flat-Field

Calibrated Image = (Dark-Subtracted Image) / (Flat-Field)

Calibrated Image

- Pixel values linearly proportional to light.
- Bias has been removed.
- Dark current has been subtracted.
- QE nonuniformity has been corrected.
- Nonuniform illumination has been corrected.
- *But* must be on target, in focus, well tracked.

Images are Numbers

Pixel Value = The numerical value of a pixel.

Pixel Statistics = The lowest, highest, averge, etc.

Histogram = Number of pixels *versus* pixel value.

Black Point = Pixel value that is black on screen.

White Point = Pixel value that is white on screen.

Brightness Scaling / Enhancement

- Brightness enhancement is subjective, mostly.
- Ideal: Important features shown as gray tones.
- Ideal: Nothing lost in black; nothing lost in white.
- Transfer curve controls pixel value distribution.
- Old pixel values —> New pixel values.

Transfer Curves

- **Linear** = Equal stretch from black to white.
  Good for lunar and planetary images.
- **Gamma** = Gray tones made lighter or darker.
  Good for bright deep-sky objects.
- **GammaLog** = Brightens dark parts of image.
  For faint deep-sky objects.

Histogram Shaping

- Histogram used to create special transfer curve.
- Special transfer curve —> desired histogram.
- “Normal Scenic” histogram: Gaussian shape.
- “Geological” histogram: Cosine shape.
- “Deep-Sky” histogram: Exponential shape.

Image Detail

24	24	24	30	36
24	24	30	36	42
24	30	36	42	48
30	36	42	48	48
36	42	48	48	48

16	16	16	18	36
16	16	18	36	56
16	18	36	54	56
18	36	54	56	56
36	54	56	56	56

Q: Which pixel array is sharper?

A: The one with rapid change in pixel value.

Image Sharpening

- **Filter & Add** technique…
- Duplicate image.
- Erase large features (detail stays).
- Add small scale detail to original.
- **Blur & Subtract** technique…
  1) Duplicate image.
  2) Erase small-scale detail (i.e., blur).
  3) Subtract blur from original.

Unsharp Masking

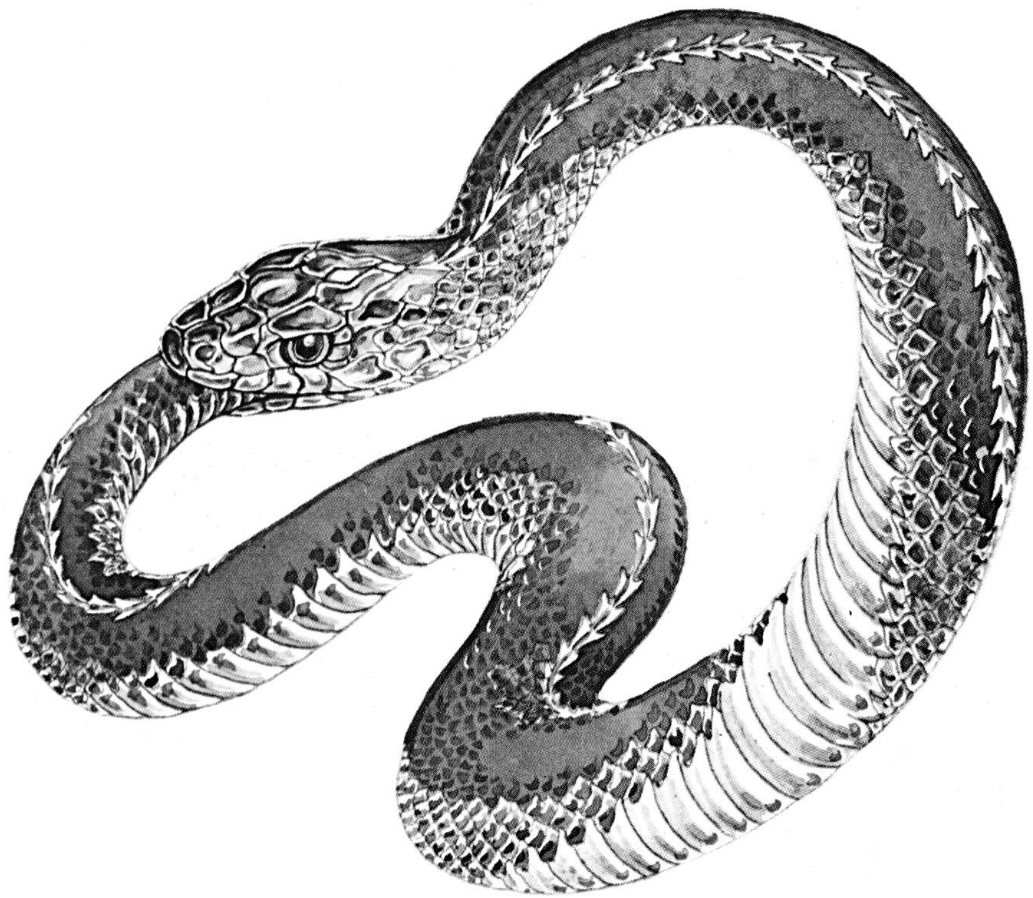
If small-scale detail is present in the original…

- Detail becomes more visible.
- Random noise becomes more visible.
- On balance, the image looks better.

If small-scale detail is **NOT** present…

- Detail is not created from nothing.
- Random noise becomes more visible.
- Image looks ugly…or worse.

Deconvolution



Doing Deconvolution

- Need good Signal-to-Noise ratio in original.
- If the original image is undersampled or critically sampled, upsample before deconvolving.
- Match the instrumental Point-Spread Function.
    1) Too small = nothing happens.
    2) Too large = ugly dark circles on stars.
- Stop before artifacts become annoying.

True-Color Imaging

Imaging with RGB

- Expose to get good signal-to-noise.
- White balance using G2V stars.

Imaging with CMY

- Similar to RGB, except different filters.
- R = M+Y−C; G = C+Y−M; B = C+M−Y

Imaging with Luminance

- Build very high signal-to-noise image.