Statistics, Source Detection, and Noise in the Optical / Infrared

ASTR 288C: Lecture 4
Sources of Detected Signal

Astrophysical Sources

Atmosphere transmits most light at optical wavelengths and within "windows" in the infrared

Earth’s Atmosphere
Sources of Detected Signal

Astrophysical Sources

Atmosphere transmits most light at optical wavelengths and within “windows” in the infrared.

Earth’s Atmosphere

Optical

J

H

K

Total Absorption and Scattering

Wavelength (µm)
Sources of Detected Signal

Atmosphere transmits most light at optical wavelengths and within “windows” in the infrared

BUT... it emits its own light, especially in the infrared where this emission is significantly greater than from astrophysical sources
Sources of Detected Signal

**Astrophysical Sources**

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BACKGROUND ("SKY")
Sources of Detected Signal

Astrophysical Sources

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BUT… it emits its own light, especially in the infrared where this emission is significantly greater than from astrophysical sources.

BACKGROUND ("SKY")

Telescope and detector may be source of light reflections.
Sources of Detected Signal

Astrophysical Sources

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Sources of Detected Signal

- Astrophysical Sources
- Earth’s Atmosphere
- Telescope
- Detector

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BACKGROUND ("SKY")

Telescope and detector may be source of light reflections.

Thermal emission of detector itself.
Sources of Detected Signal

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Thermal emission of detector itself (cool the detector)
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Background

Astrophysical Sources
Sources of Detected Signal

- Astrophysical Sources
- Background
Sources of Detected Signal

Background ~ 0 ADU since these are REDUCED (not RAW) images.

REDUCED images have had the background level subtracted.

The RAW images have backgrounds of ~1000 ADU, significantly greater than the astrophysical sources identified below.
Sources of Detected Signal
Sources of Detected Signal

Gaussian

\[ N = N_{\text{peak}} e^{-\frac{1}{2} \left( \frac{x - x_0}{\sigma} \right)^2} \]

\[ \sigma = \frac{\text{FWHM}}{2 \sqrt{2 \ln 2}} \]
Sources of Detected Signal

Gaussian

$$N = N_{\text{peak}} e^{-\frac{1}{2} \left[ \frac{x - x_0}{\sigma} \right]^2}$$

$$\sigma = \frac{\text{FWHM}}{2 \sqrt{2 \ln 2}}$$

Background

FWHM = 0.56

$$\sigma = 0.24$$

Astrophysical Sources
Sources of Detected Signal

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What is the “TYPICAL” background level?

- MEAN intensity = 0.88 ADU
- MEDIAN intensity = 0.02 ADU
- MODE intensity = 0.00 ADU

Background

FWHM = 0.56
\( \sigma = 0.24 \)
Sources of Detected Signal

**Gaussian**

\[ N = N_{\text{peak}} e^{-\frac{1}{2} \left(\frac{x - x_0}{\sigma}\right)^2} \]

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**Background**

- FWHM = 0.56
- \( \sigma = 0.24 \)

**Astrophysical Sources**

- What is the “TYPICAL” background level?
  - MEAN intensity = 0.88 ADU
  - MEDIAN intensity = 0.02 ADU
  - MODE intensity = 0.00 ADU
What is meant by “TYPICAL”?  
What is the typical weight of the pets in the neighborhood?
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What is the typical weight of the pets in the neighborhood?

MEAN = 9.9 lbs
MEDIAN = 10.0 lbs
MODE = 10.0 lbs

<table>
<thead>
<tr>
<th>Pet</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buz</td>
<td>11 lbs</td>
</tr>
<tr>
<td>Dizzy</td>
<td>9 lbs</td>
</tr>
<tr>
<td>Tiger</td>
<td>10 lbs</td>
</tr>
<tr>
<td>Lanky</td>
<td>8 lbs</td>
</tr>
<tr>
<td>Dash</td>
<td>10 lbs</td>
</tr>
<tr>
<td>Fido</td>
<td>12 lbs</td>
</tr>
<tr>
<td>Teddy</td>
<td>10 lbs</td>
</tr>
</tbody>
</table>
What is meant by “TYPICAL”?

What is the typical weight of the pets in the neighborhood?

**MEAN = 9.9 lbs 1008.6 lbs**
**MEDIAN = 10.0 lbs**
**MODE = 10.0 lbs**

- Buz: 11 lbs
- Dizzy: 9 lbs
- Tiger: 10 lbs
- Lanky: 8 lbs
- Dash: 10 lbs
- Fido: 12 lbs
- Teddy: 10 lbs
- Elsa: 8000 lbs
Source Detection

Identification of a real signal from an astrophysical source
Source Detection

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Identification of a real signal from an astrophysical source

By eye, 31-36 sources in 1.0’ x 0.6’
Source Detection

Identification of a real signal from an astrophysical source

ANY VOLUNTEERS ?!

Suggests ~43-50k sources in 28.8' x 28.8' !

By eye, 31-36 sources in 1.0' x 0.6'
Source Detection

Identification of a real signal from an astrophysical source

ANY VOLUNTEERS ?!

Clearly, we need an automated source detection method.

By eye, 31-36 sources in 1.0’ x 0.6’

Suggests ~43-50k sources in 28.8’ x 28.8’!
Source Detection

Identification of a real signal from an astrophysical source

Automated source detection procedures:

- IRAF *daofind*
- IDL *daofind*
- SExtractor