Astronomical Techniques I

Lecture 9

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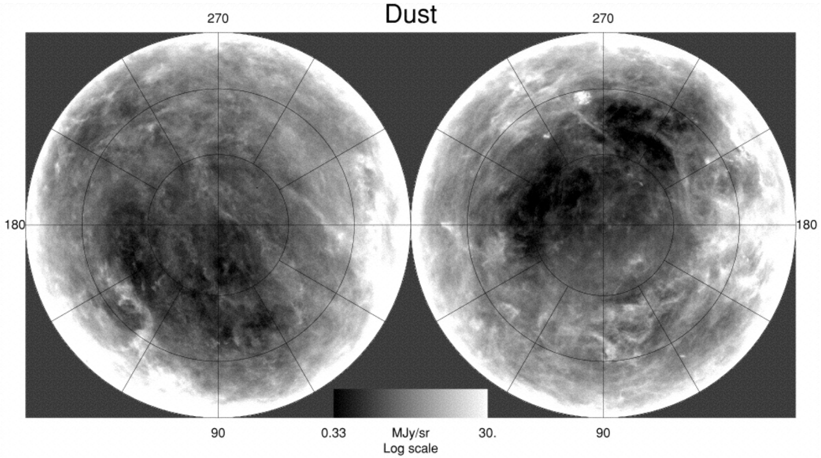
Jan-Feb 2015

Infrared Cirrus

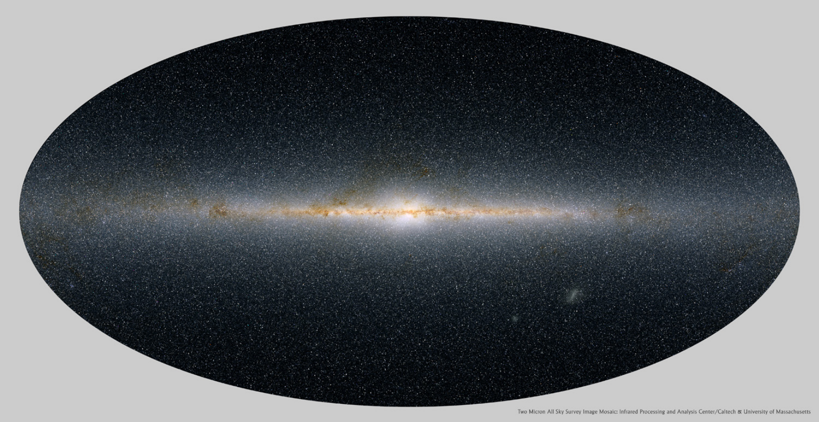


Sources of cirrus

Cirrus emission is produced by warm interstellar dust grains at typical distances of 100-3000 pc within the Galaxy. Far-IR observations can be severely affected by this strongly non-uniform background. Must use Schlegel et al. 1998 maps to account for cirrus.

What is signal? What is noise?

In crude terms, signal is the quantity we are interested in and noise is all the quantities we are not interested in, one person's signal is another person's noise.



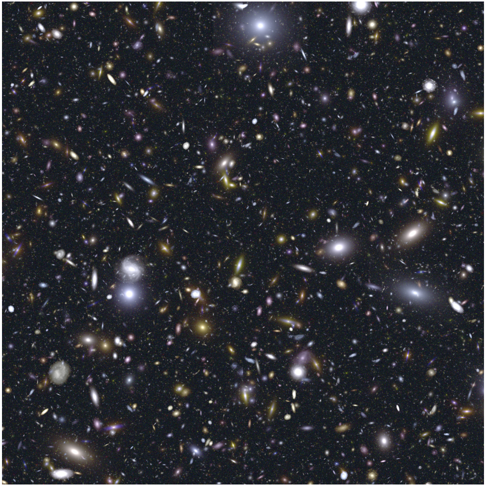
Discrete Cosmic Sources: Field stars

Star light scattered, refracted, or diffracted by the atmosphere and by telescope optics and structures can produce effects at large distances from a star. King (1971) showed that the PSF has a Gaussian core, but then an exponential shoulder and a power law at $r > 30$ arcsec.

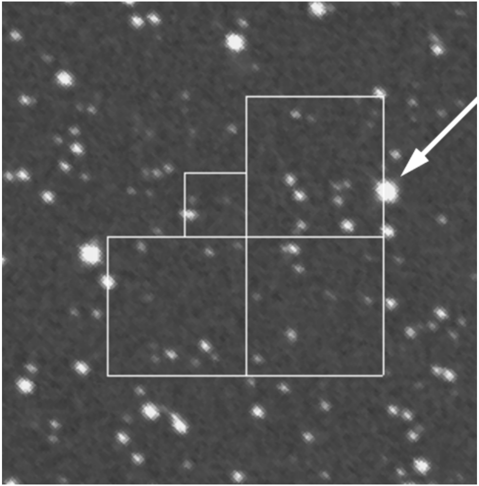
Extended envelopes from nearby galaxies

Faint distant galaxies

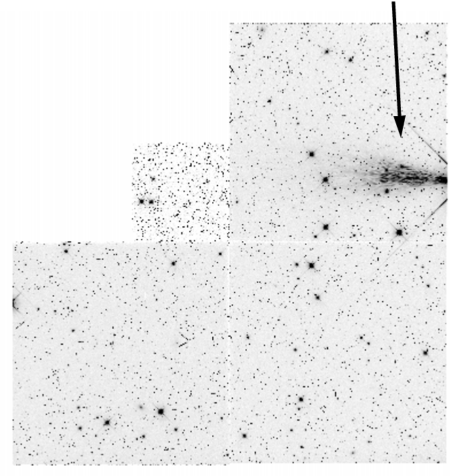
cause confusion related effects (serious problem at faint levels since are thousands per square degree)



Telescope artifacts e.g. Dragon's breath

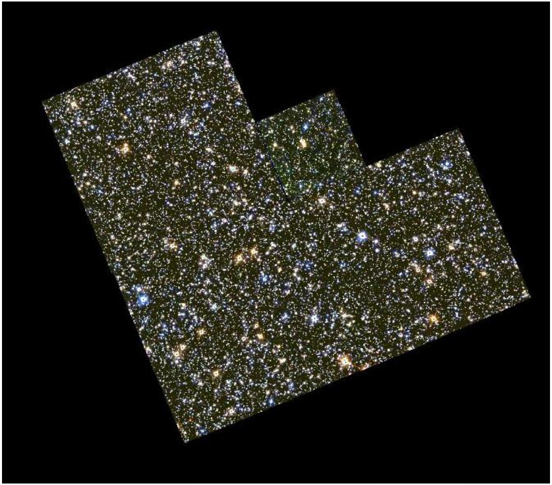


Dragon's breath

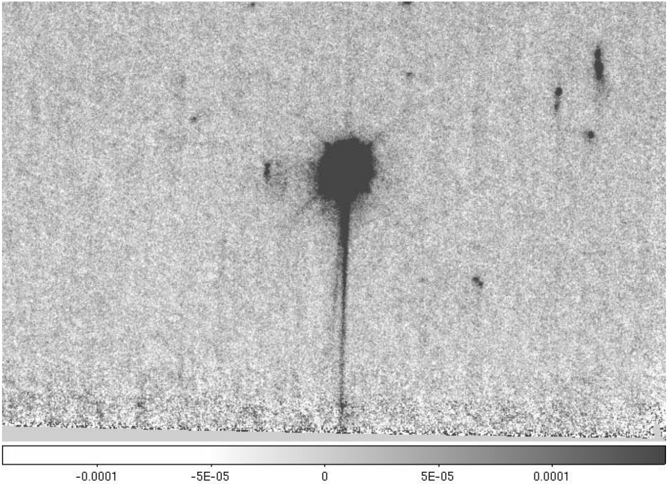


Confusion

Confusion caused by source blending within spatial resolution cell.



Charge transfer efficiency



Telescope backgrounds

- IR: emission ($T \sim 280$ K) of optics and other structures visible to detector ($\lambda > 1.5\mu$m)
- Diffraction & scattering (e.g. from dust on optics) contributes to background at all wavelengths

Advantage of 2D detector arrays

- provide a large number of background samples surrounding a source of interest.
- The samples are also usually obtained (in imaging, for instance) *simultaneously* with the source observations, which is very important in the case of large & variable backgrounds.
- As long as the background contains only low spatial frequencies, it can be well modeled and removed, greatly improving the detection of faint sources.
- The 2-D advantage is especially important in the near-IR, where the sky, telescope, and detector backgrounds can be fierce.

Miscellaneous "noise" sources

- Variations in atmospheric turbulence/seeing
- Strong and/or variable absorption in atmosphere (general extinction; clouds; bands of H2O, O2, O3)
- Cosmic rays: tracks easily detected in CCD, other devices; produce serious, though localized, effects, SAA anamoly.
- Interference (e.g. light leaks)
- Radioactive decay glow in filters/windows
- Guiding errors
- Mechanical flexure in telescope or instrument; focus shifts

Moments of Parent Distribution

The parent distribution is characterized by its moments:

- Parent probability distribution: $p(x)$
- First moment $\mu = \int x\, p(x) dx$
- Variance: second moment $Var(x) = \int (x - \mu)^2 p(x) dx$
- $\sigma = \sqrt{Var(x)}$ is the standard deviation, but is also known as the *dispersion* or *rms dispersion*
- μ measures the *center* and σ measures the *width* of the parent distribution.

Variance and Standard deviation of discrete variables

$Variance(X) = E[(X-\mu)^2]$

Standard deviation $\sigma_X = \sqrt{Variance(X)} = \sqrt{E[(X-\mu)^2]}$

If X is discrete random variable having probability function $f(x)$, then the variance is given by,
$\sigma_X^2 = E[(X-\mu)^2] = \sum_{i=1}^{n}(x_i-\mu)^2 f(x_i)$

If the probability function $f(x)$ is flat, then the variance is simply $[\sum_{i=1}^{n}(x_i-\mu)^2]/n$

Poisson distribution

Poisson distribution is a *discrete* probability distribution that expresses the probability of a (integral, non-negative) number of events (≥ 0, integral values) occurring in a fixed period of time if these events occur with a known average rate and independently of the time since the last event.

It essentially describes processes for which the single trial probability of success is very small but in which the number of trials is so large that there is nevertheless a reasonable rate of events. e.g. radioactive decay.

Poisson distribution

Let X be a discrete random variable which can take on the values 0,1,2,... such that the probability of X is given by:

$f(x) = P(X = x) = \frac{\lambda^x e^{-\lambda}}{x!}$

where λ is a given positive constant. Unlike a Gaussian, it is a one parameter distribution, specifying λ specifies everything.

Properties of Poisson distribution

- mean λ
- Variance λ
- Standard deviation $\sqrt{\lambda}$

Note that the distribution is not symmetric about the mean, although at high λ, it may *appear* to be symmetric. As $\lambda \to \infty$, poisson becomes Gaussian. For large number of trails n and small success probability p, binomial distribution becomes Poisson.

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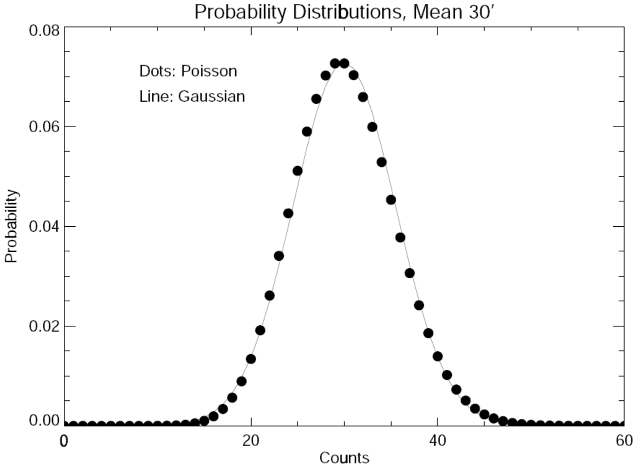
Poisson nearly Gaussian at $\lambda = 30$



Question

You have set up an experiment such that a *mean* current I passes through a section of a circuit. You also have a super accurate ammeter connected so that you can record the *instantaneous* current flowing through that section. Explain how you can determine the charge of an electron with this setup.

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$I = eN/t$, $\sigma_I = e\sqrt{N/t} \Rightarrow e = \sigma_I^2/I$

Gaussian properties

The *central limit theorem* of Gauss demonstrates that a Gaussian distribution applies to any situation where a large number of *independent random processes* contribute to the result. This means it is a valid statistical description of an enormous range of real-life situations. Much of the error analysis of data measurement is based on the assumption of Gaussian distributions.

Gaussian properties

$$g(x) = \frac{1}{\sqrt{2\pi\sigma}} \cdot e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

- mean μ
- Variance σ^2
- Standard deviation σ
- Full Width Half Maximum = 2.355σ

Fundamental rule of astronomical error

For discrete number statistics use Poisson, for continuous number statistics or where mean > 30 use Gaussian.