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Diffuse Emission and Map Making

(1)

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Def 1: Map – a set of pixels $\{p_i\}$ (small patches of sky) and a value $\{f_i\}$ (counts, flux, etc) for each pixel.

convenient: grid. equal area.

Eg.

1	0	1
2	4	3
4	7	2
1	1	0

grid of numbers
grayscale image

$f(1,1) = 7$
0-indexed.

Def 2: Map – a discrete sampling $f(\vec{x}_i)$ of a continuous function $f(\vec{x})$ with dense "enough" sample points.

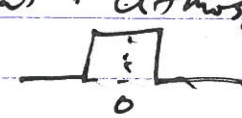
Enough? Nyquist – Shannon
Fourier
$\rangle$ sampling theorem

"If a function $f(t)$ contains no frequencies higher than B Hertz, it is completely determined by giving its ordinates (values) at a series of points spaced $1/2B$ seconds apart." Shannon '49

"Bandlimited" function can be perfectly reconstructed from these samples. True in 2-D also.

So, are these definitions the same?

Let $S(\vec{x})$ be the "sky"
$k(\vec{x})$ be psf (instrument + atmosphere etc.)
$p(\vec{x})$ be pixel function

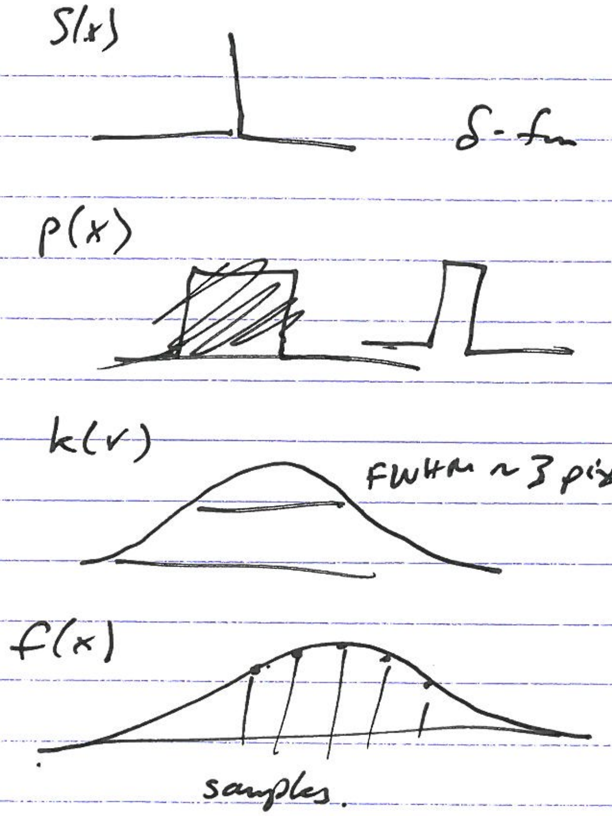


Let $f(\vec{x}) =$ ~~S*k*p~~ $S * k * p$ ← convolution.

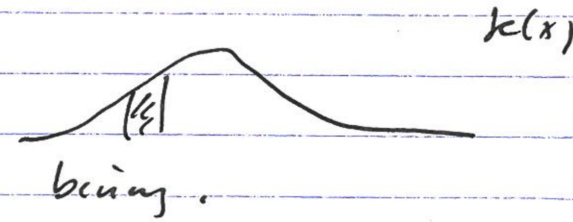
→ same.

②

Eg. a star



Exactly the same as



But wait!
What if you have additional information about each photon?
PSF, bandpass (energy ⅋ pdf)
Binning loses this information
In optical astr the instrument bins for you.
Fermi does not. → binning ⇒ bad.

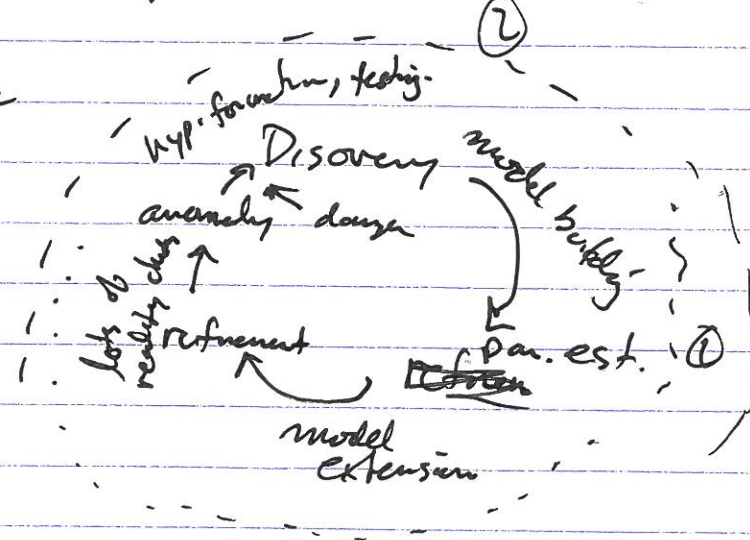
To Bin or not to bin:

Do you have everything important in your model?

2 ~~a~~. A correct model, just need parameter estimates and errors - formal $\mathcal{L}$ analysis no binning.

1 ~~b~~. Uncertain model, don't know what we're looking for. bin and play.

Non trivial difference



The anomaly - discovery leg is exciting, dangerous

→ find ways to use your neural net, *see things.

→ most things you see will be wrong. Must iterate fast, get on to next thing.

Now for map making.

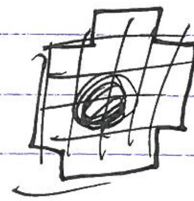
Diffuse emission: What are we making a map of?

Unlike a flux $^{(F)}$ (erg/s/cm^2) from an object, diffuse emission $^{(I)}$ is flux per solid angle

erg/s/cm^2/sr.

obviously related by $F = \int I \, d\Omega$

e.g. Aperture photometry



$$F = \sum_j p_j \cdot A_{pix}$$

p_j: flux in pixel / A_{pix}

$$= \sum f_j$$

Always keep track of whether you are talking about counts or counts per sr.

May be familiar with the "specific intensity", I_ν

$$[I_\nu] = \text{Jy/sr} \sim \text{J/s/m}^2\text{/Hz/sr} \sim \text{erg/s/cm}^2\text{/Hz/sr}$$

$$[F_\nu] \sim \text{Jy}$$

In gammas, we think of binning counts in energy and talk about

$$\frac{dN}{dE} = \text{counts per energy}$$

i.e. counts/GeV.

Could bin in ln E

$$\frac{dN}{d\ln E} = E\frac{dN}{dE}$$ counts per log E

or mult by E

$$E\frac{dN}{d\ln E} = E^2\frac{dN}{dE}$$ energy per log E

~~Recall I_ν is erg/s/cm²/~~

These can all be per cm² per sec, per sr.

E.g.

I_ν = erg/s/cm²/s/~~Hz~~/sr (energy per log energy)

$E^2 dN/dE \sim I_\nu$.

$\cancel{E^2 d}$ $\frac{dN}{dE}$ $\cancel{\frac{\text{counts}}{\text{GeV cm}^2}}$ $\frac{\text{counts}}{\text{s}\cdot\text{cm}^2\cdot\text{GeV}\cdot\text{sr}}$

$$I_\nu \sim E^2\frac{dN}{dE} \sim \frac{\text{GeV}}{\text{s}\cdot\text{cm}^2\cdot\text{sr}}$$

How to make a map of diffuse emissn.

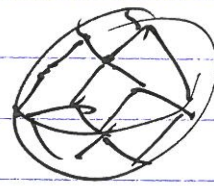
Want $\frac{dN}{dE}$ $\quad \frac{\text{counts}}{\text{GeV-s} \cdot \text{cm}^2 \cdot \text{sr}}$

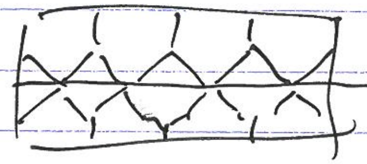
Have exposure (cm^2-s) from Fermi tools

so
need counts in a ΔE bin in $d\Omega$ pixel.

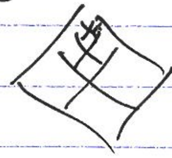
Any pixelization is fine, but equal-area pixelizations are nice.

Eg. Healpix





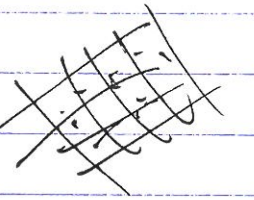
each square



Hierarchical
Equal-area
Iso-lAtitude pixelization

— Anyway...

Event list
(ra, dec)
(time)
(energy)
...
zenith angle
data quality cuts.



bin, space + E
count,

$\frac{\text{counts}}{\Delta E \cdot A_{pix}} \quad \frac{1}{\text{expos.}}$

Easy, right?

Some issues:

- psf different for front/back converting evts.
- point sources. mask? subtract?
- bad time intervals?
- Sun/Moon?
- Smoothing to some target psf?

So in more detail
- make front and back exp map, (mask bad times, Z<105)
- subtract sources (for wings also). (1873 in 2FGL)
- mask 400 brightest & most variable (mask means remove counts, set exposure to zero). (mask some by hand)
- make front, back map & combine.

$$I = \frac{N_f + N_B}{exp_f + exp_b}$$

- in general, smooth lay $I = \frac{\mathrm{Smooth}(N_f)}{\mathrm{Smooth}(E_f)} + \ldots$

pretend psf is Gaussian.
σ_T = target
$\sigma_F = \sigma_F$ fermi $\qquad \sigma = \sqrt{\sigma_T^2 - \sigma_F^2}$

write fits file (map + exp in 1st ext.)
Also f, b sep, different FWHM.
Usually use f only at E < 1 GeV.

→ Show examples on computer

5–10 GeV
minus 0.5–1 GeV