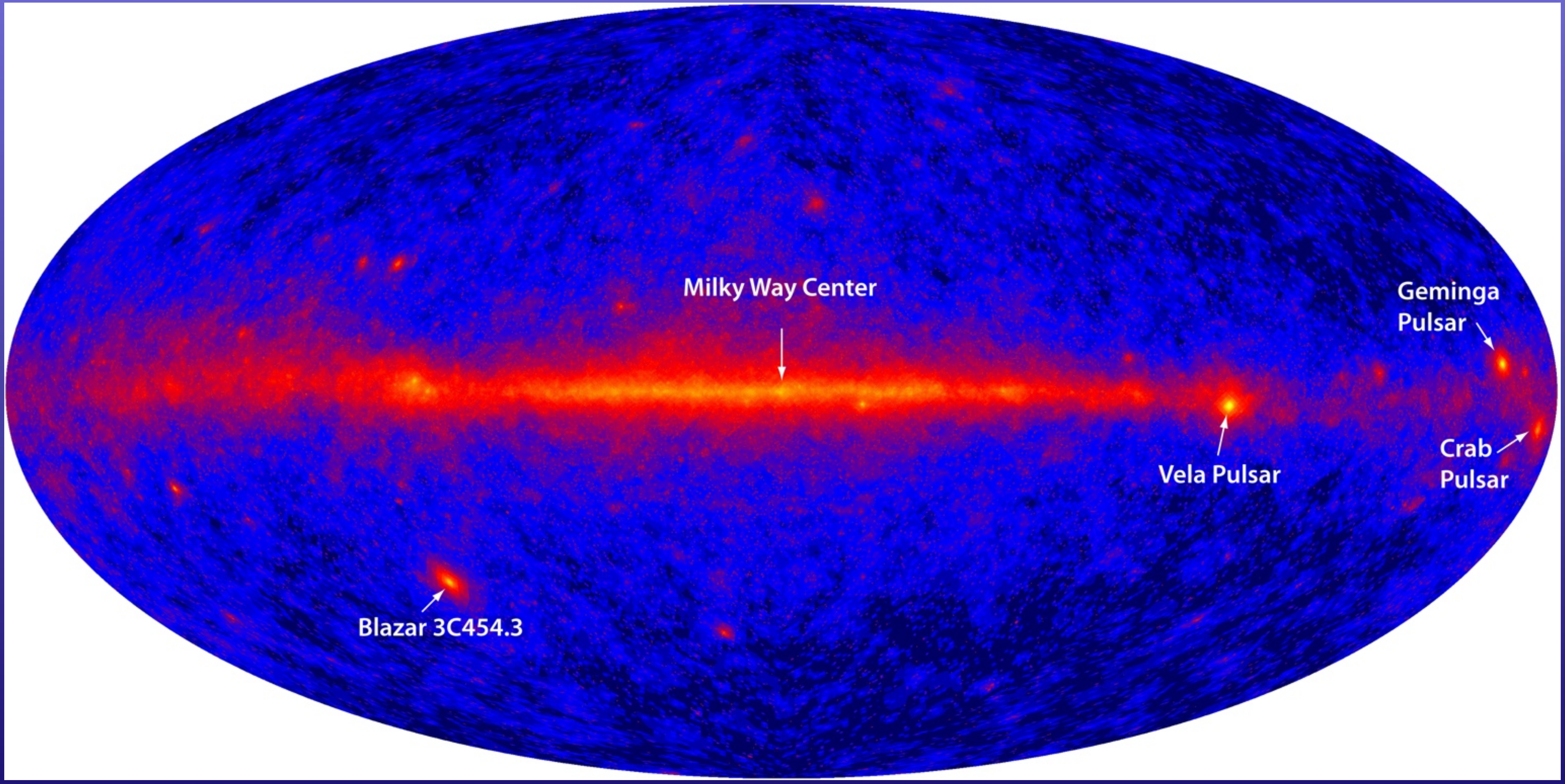
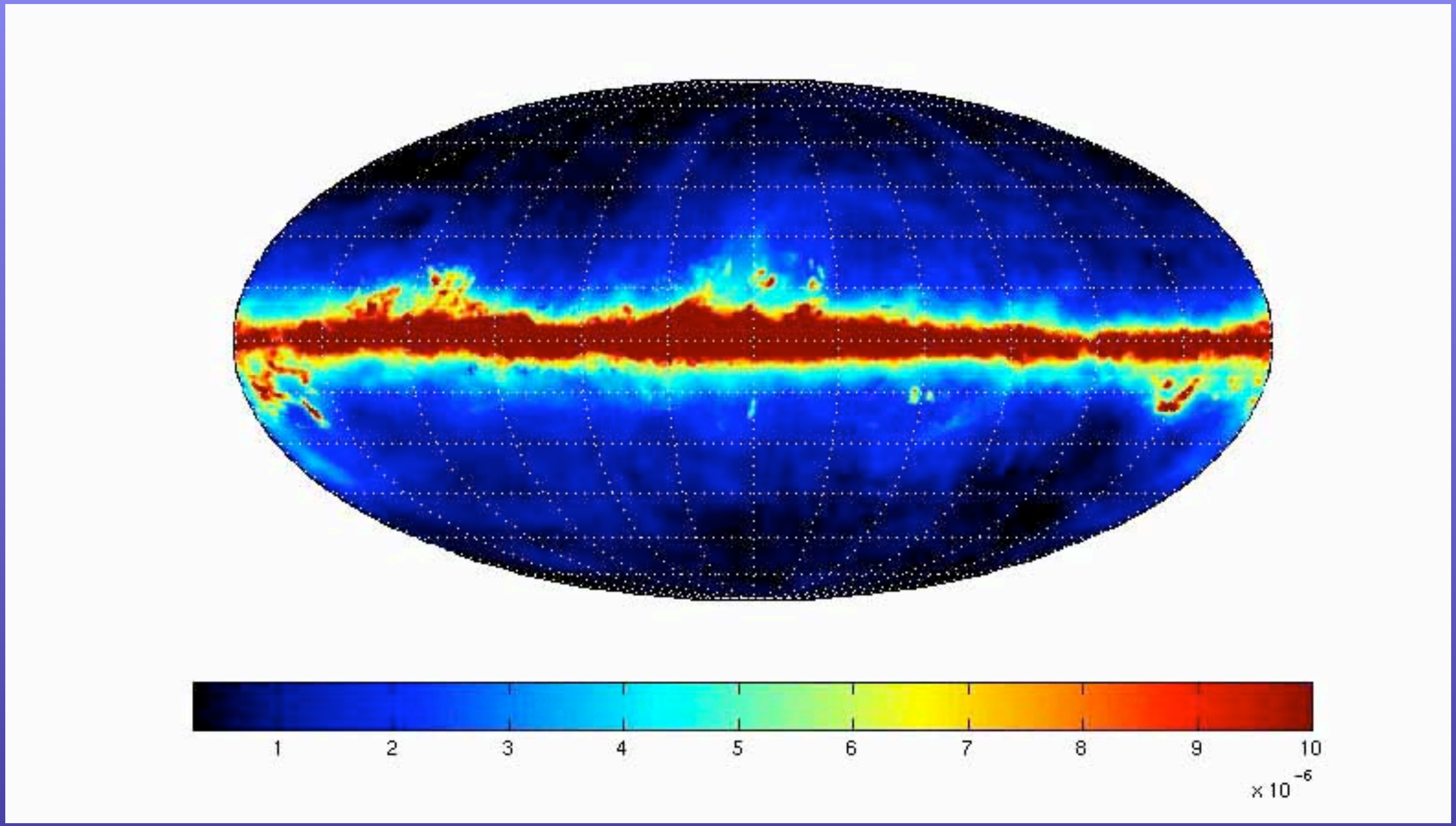
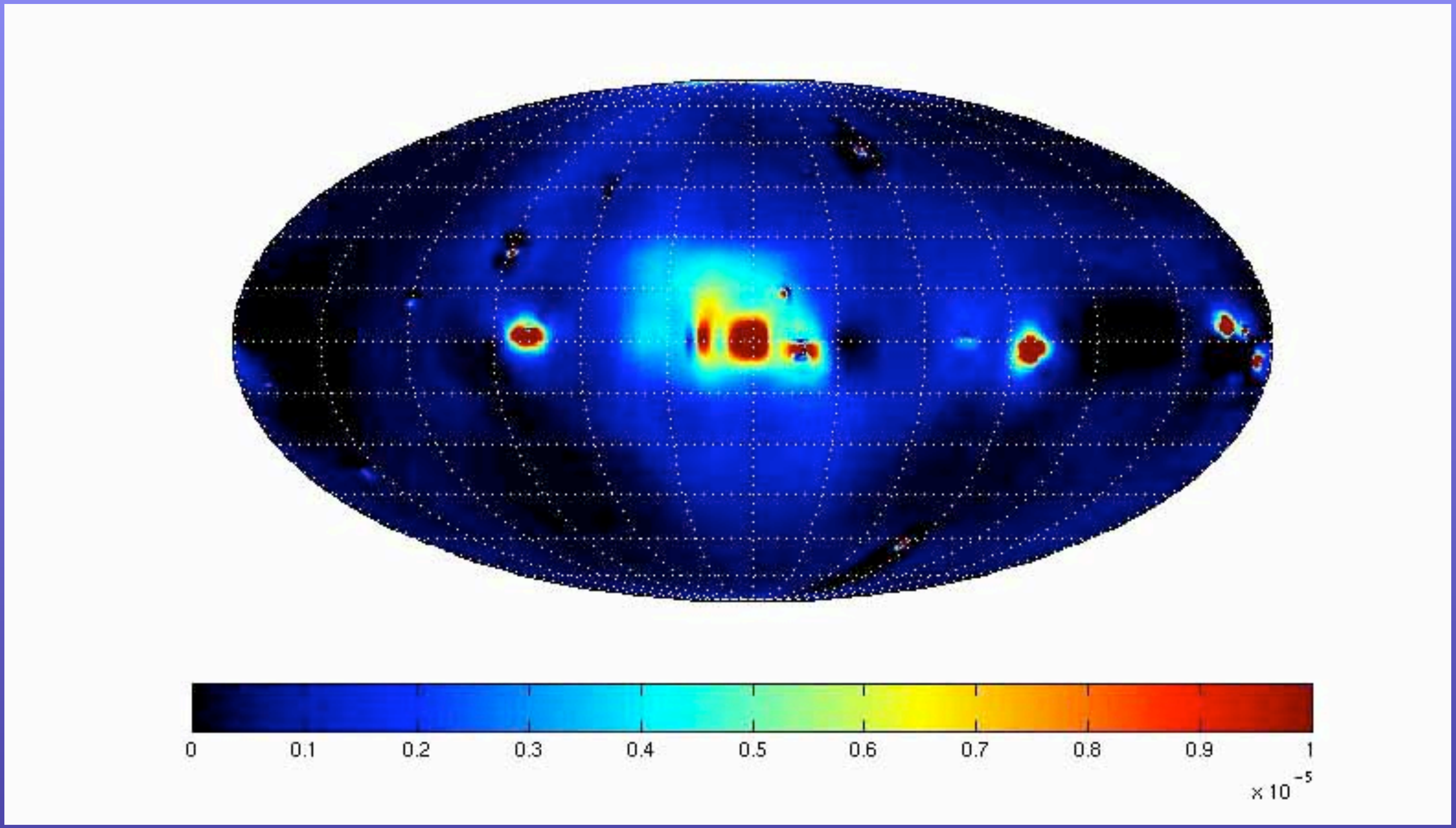
QUANTIFYING, SUMMARIZING, AND REPRESENTING 'TOTAL' UNCERTAINTIES IN IMAGE (AND SPECTRAL) 'DECONVOLUTION'

A. Connors for 'CHASC' or CBASC





`The immediate question arises as to the statistical significance of this feature... quantification of object-wise significance (e.g., "this blob is significant at the n-sigma level") are difficult.' (Dixon et al. 1998 New Astronomy 3, 539)



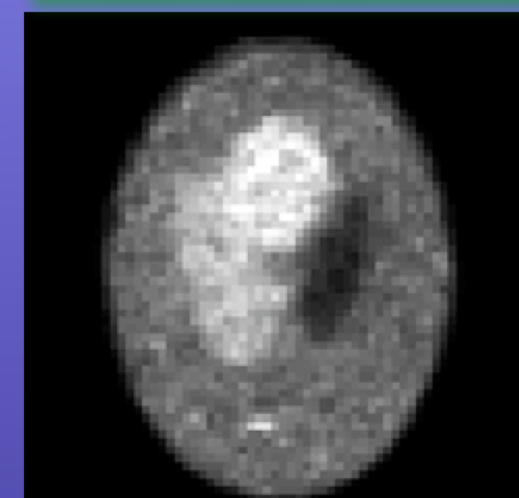
`The immediate question arises as to the statistical significance of this feature... quantification of object-wise significance (e.g., "this blob is significant at the n-sigma level") are difficult.' (Dixon et al. 1998 New Astronomy 3, 539)

Tomographic Reconstruction: Comparing Examples (from Willett et al.)

True image

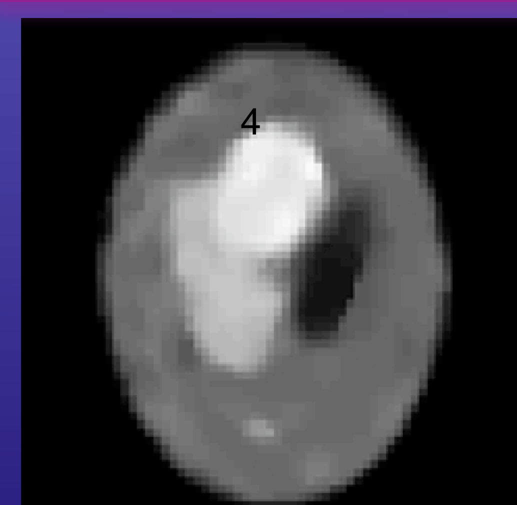
Filtered back projection

MLE reconstruction



Fessler's PWLS

Wedgelet reconstruction



What's the significance of / uncertainty on features?

Talk Outline (Parallel pieces):

0. What/Why: Demos, Definitions

1. What/Why: Problem Definition:
   - 1.1 Goodness-of-fit and feature-detection
   - 1.2 Mismatch significance, shape error bars
   - 1.3 All uncertainties: instrument, physics

2. How/Why: History/Methods
   - 2.1 Frequentist Multiscale, Bayesian Structure
   - 2.2 DA/MCMC
   - 2.3 Comparisons of Null (simulations) vs Data

3. Current Examples
   - Varying signal to noise: “E” and Gamma-ray sky

4. Current Challenges

How/Why: History/Methods

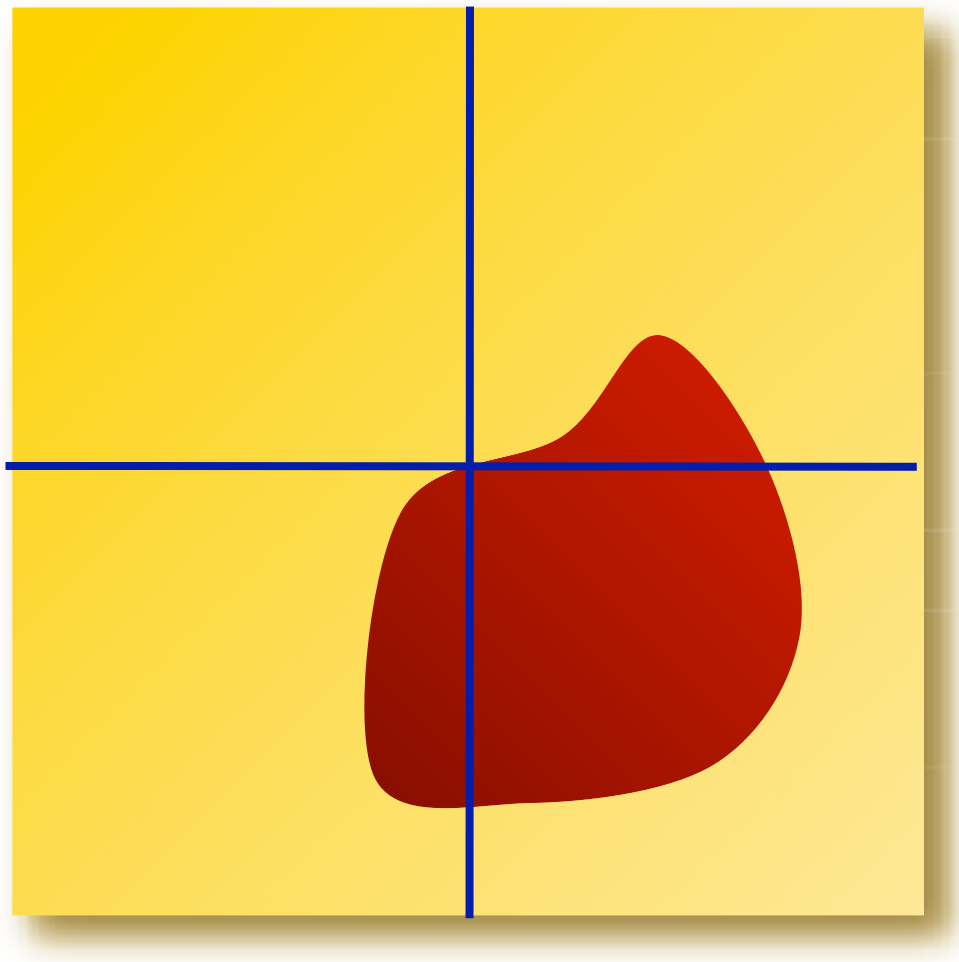
* Putting Flexible/Multiscale 'NP' models
* Together with parametrized physics-based models
* Full Bayesian Posterior framework

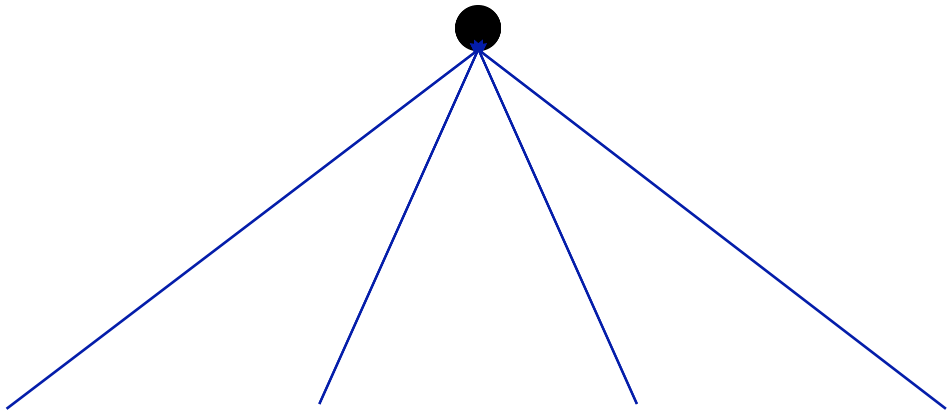
* 'Likelihoodist' (Tanner); Priors ~ Complexity Penalty
* Bayes allows Modularity: Data Augmentation,
* Bayes allows complex, high-dimensions: MCMC

Multiplicative Multiscale Innovation Models

Timmermann & Nowak, 1999
Kolaczyk, 1999

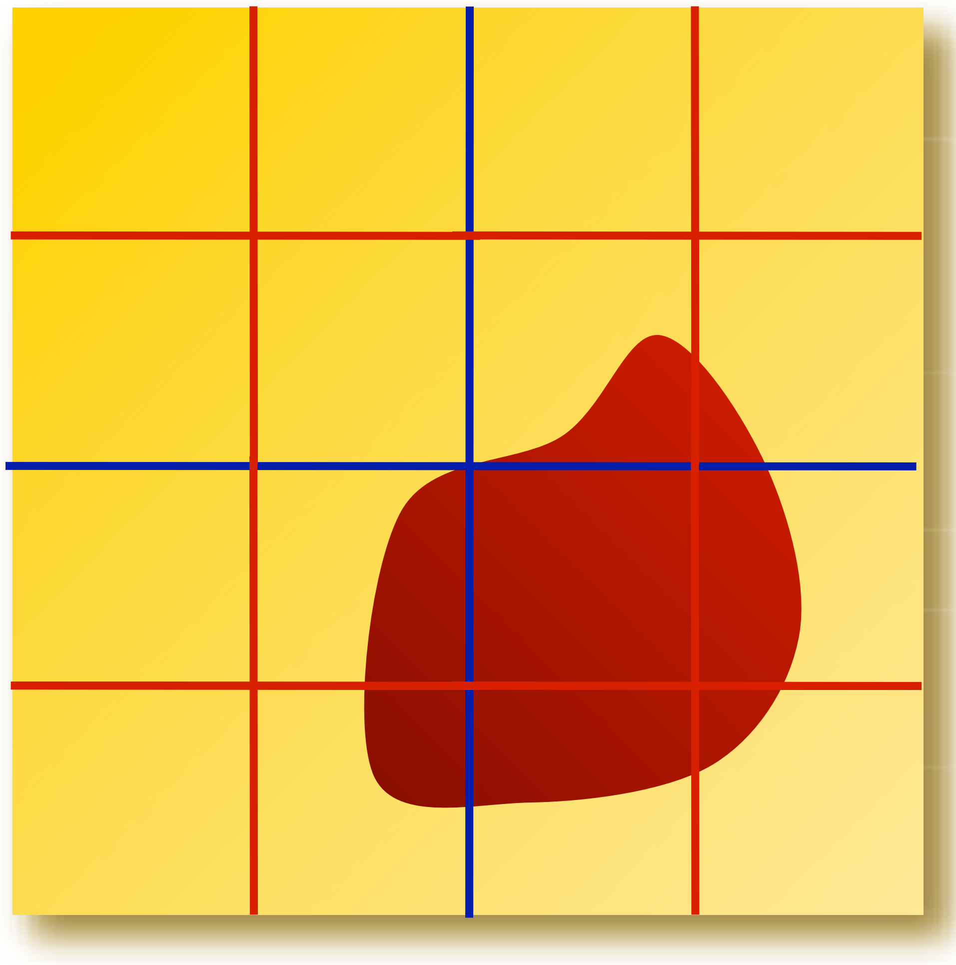
Multiplicative Multiscale Innovation Models

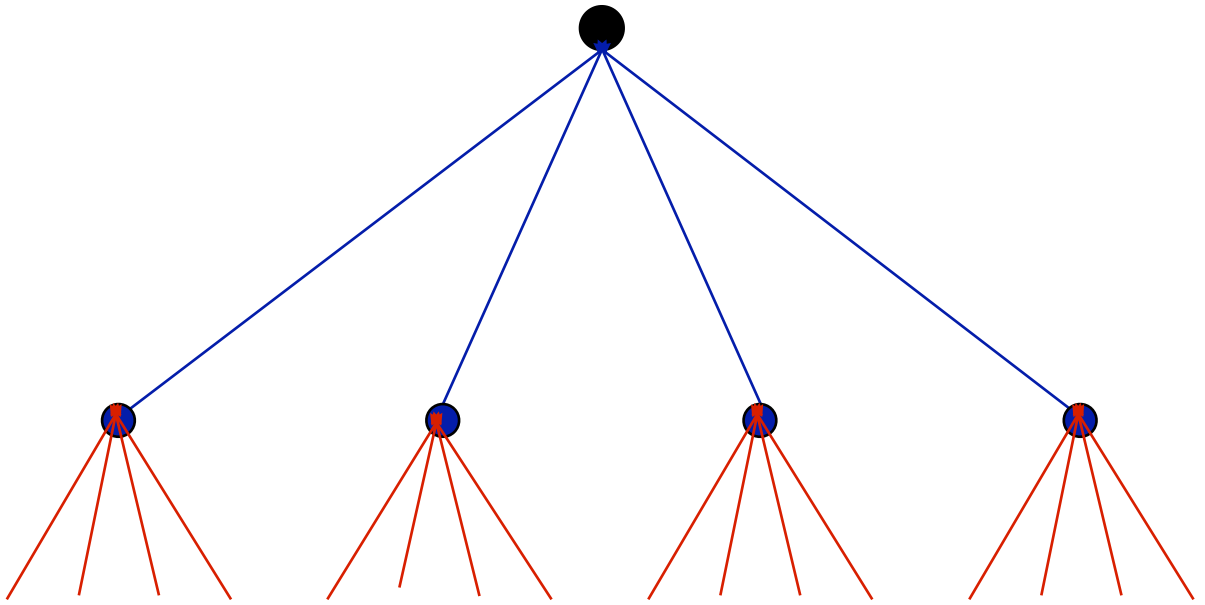




Timmermann & Nowak, 1999
Kolaczyk, 1999

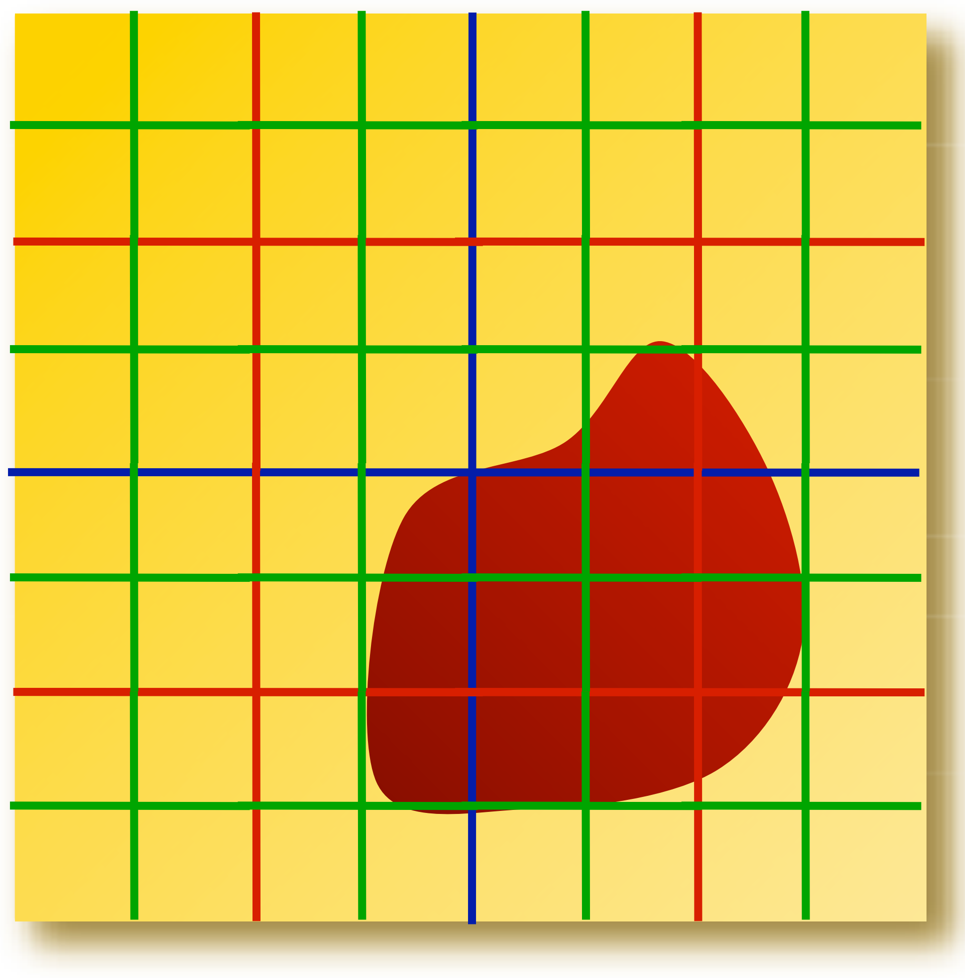
Multiplicative Multiscale Innovation Models

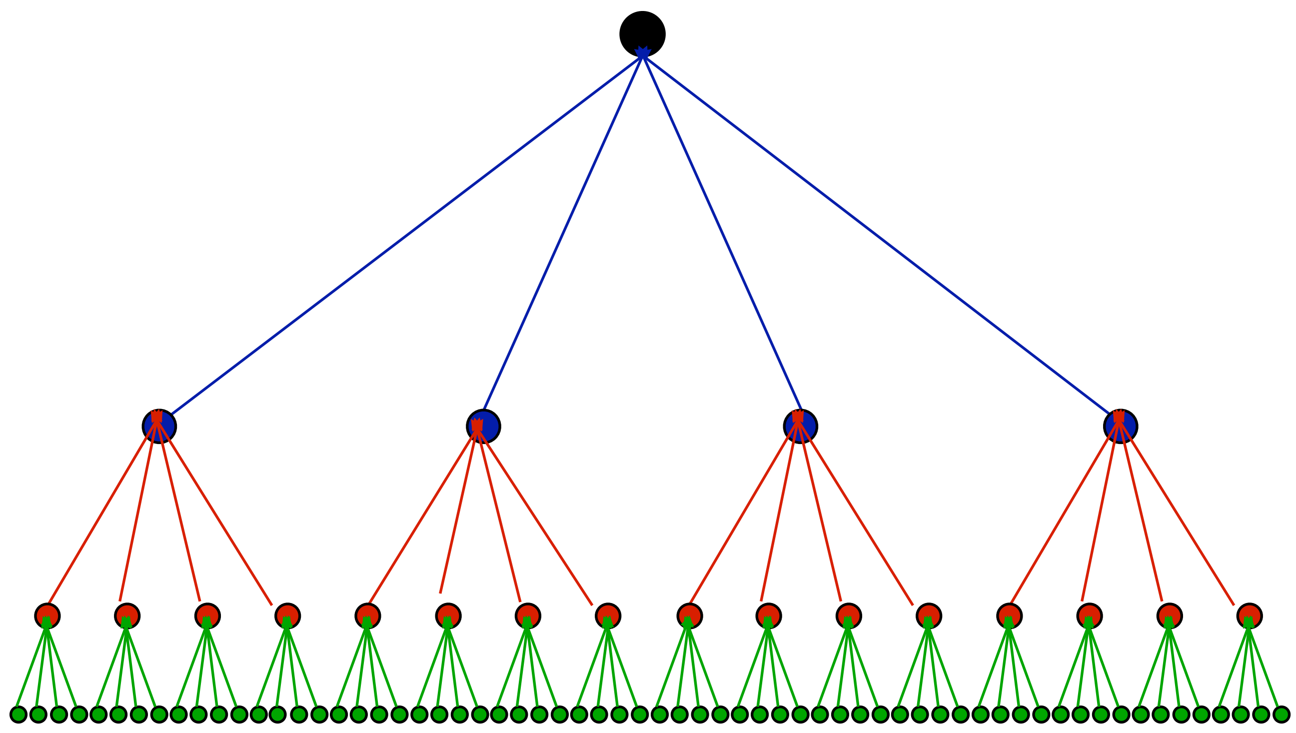




Timmermann & Nowak, 1999
Kolaczyk, 1999

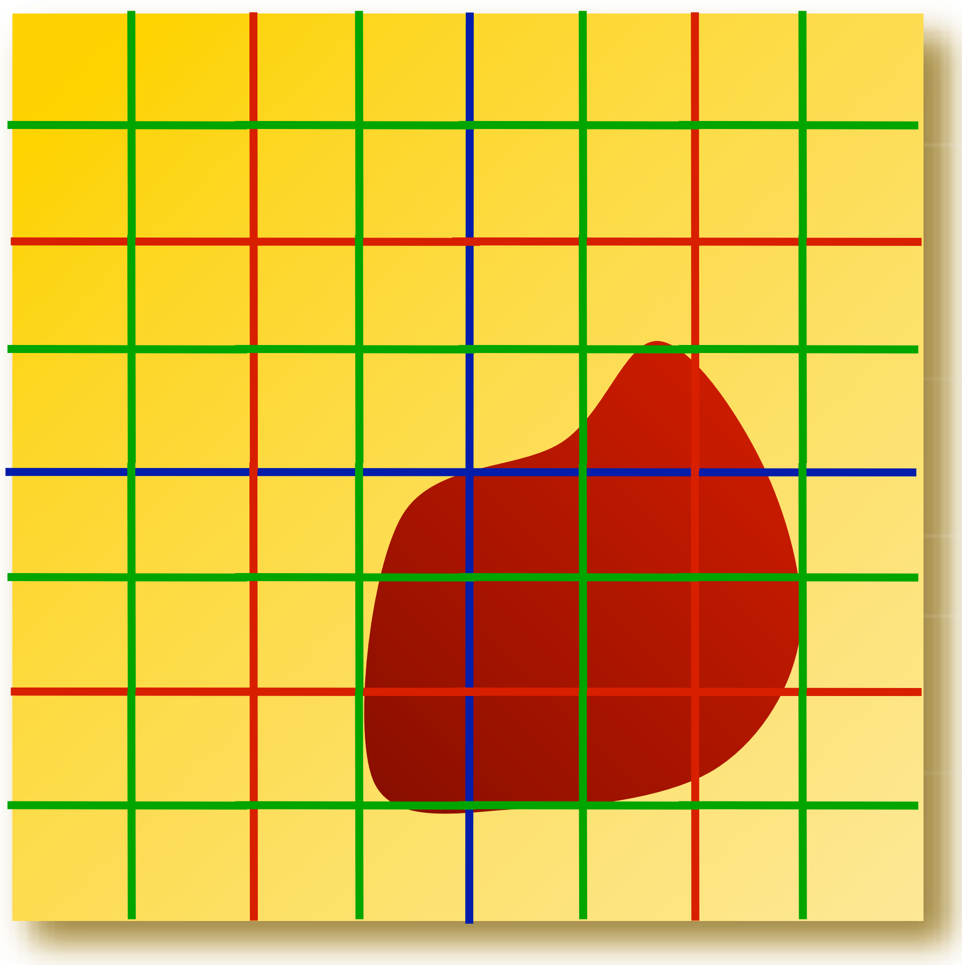
Multiplicative Multiscale Innovation Models

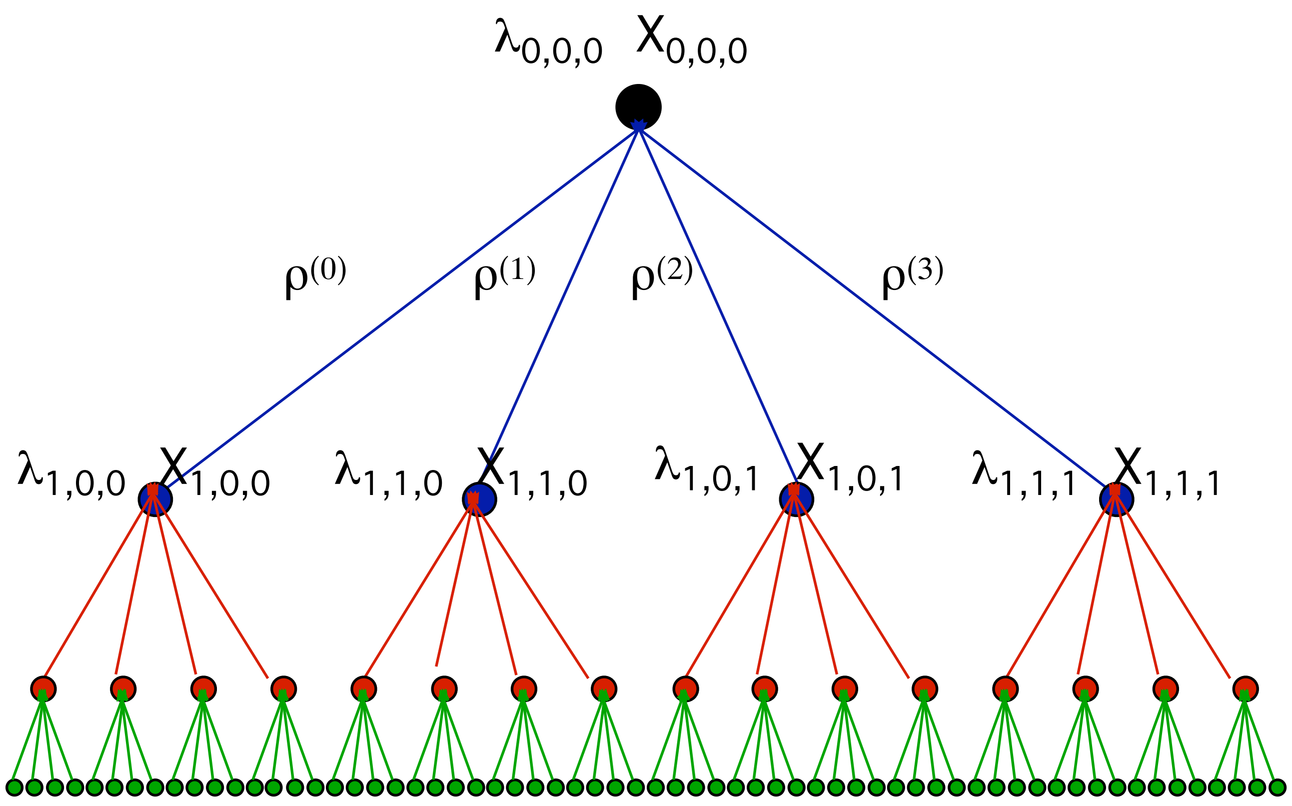




Timmermann & Nowak, 1999
Kolaczyk, 1999

Multiplicative Multiscale Innovation Models





- Recursively subdivide image into squares
- Let $\{\rho\}$ denote the ratio between child and parent intensities
- Knowing $\{\rho\}$ $\Leftrightarrow$ Knowing $\{\lambda\}$
- Estimate $\{\rho\}$ from empirical estimates based on counts in each partition square

Timmermann & Nowak, 1999
Kolaczyk, 1999

Usual Equations for 'True' Intensity, Instrument, Data:

$S(l,b,e,t,\theta)$ = Expected 'True' Source Intensity

$E(l,b,e,t,\varphi)$ = 'True' Effective Area

$PSF(x,y \mid l,b,e,t,\xi)$ = 'True' instrument smearing

$\Lambda(x,y,e,t,\theta,\varphi,\xi)$ = 'True' Expected counts in detector

$D(x,y,e,t,\theta,\varphi,\xi)$ = measured counts in detector

$$\Lambda(x,y,e,t,\theta,\varphi,\xi) = PSF(x,y|l,b,e,t,\xi) @ E(l,b,e,t,\varphi) * S(l,b,e,t,\theta)$$

$$D(x,y,e,t,\theta,\varphi,\xi) \sim \text{Poisson}(\Lambda(x,y,e,t,\theta,\varphi,\xi))$$

Usual Equations for 'Model' Intensity, Instrument, Data:

$s(l,b,e,t,\theta)$ = Expected 'Model' Source Intensity

$\epsilon(l,b,e,t,\varphi)$ = 'Model' Effective Area

$psf(x,y \mid l,b,e,t,\xi)$ = 'Model' instrument smearing

$\lambda(x,y,e,t,\theta,\varphi,\xi)$ = 'Model' Expected counts in detector

$D(x,y,e,t,\theta,\varphi,\xi)$ = measured counts in detector

$$\lambda(x,y,e,t,\theta,\varphi,\xi) = psf(x,y|l,b,e,t,\xi) @ \epsilon(l,b,e,t) * s(l,b,e,t,\theta)$$

$$D(x,y,e,t,\theta,\varphi,\xi) \sim \text{Poisson}(\lambda(x,y,e,t,\theta,\varphi,\xi))$$

Our Equations for 'Model' Intensity, Instrument, Data:

$s(l,b,e,t,\theta)$ = Expected 'Physics Model' Source Intensity

→ $m(l,b,e,t,\alpha,\kappa)$ = Expected Multiscale Source Counts

α = Smoothing Parameters for each scale

κ = 'Range' parameter for Hyper-priors on α

→ β = 'Scale Factor' for Physics Model

$\epsilon(l,b,e,t,\varphi)$ = 'Model' Effective Area

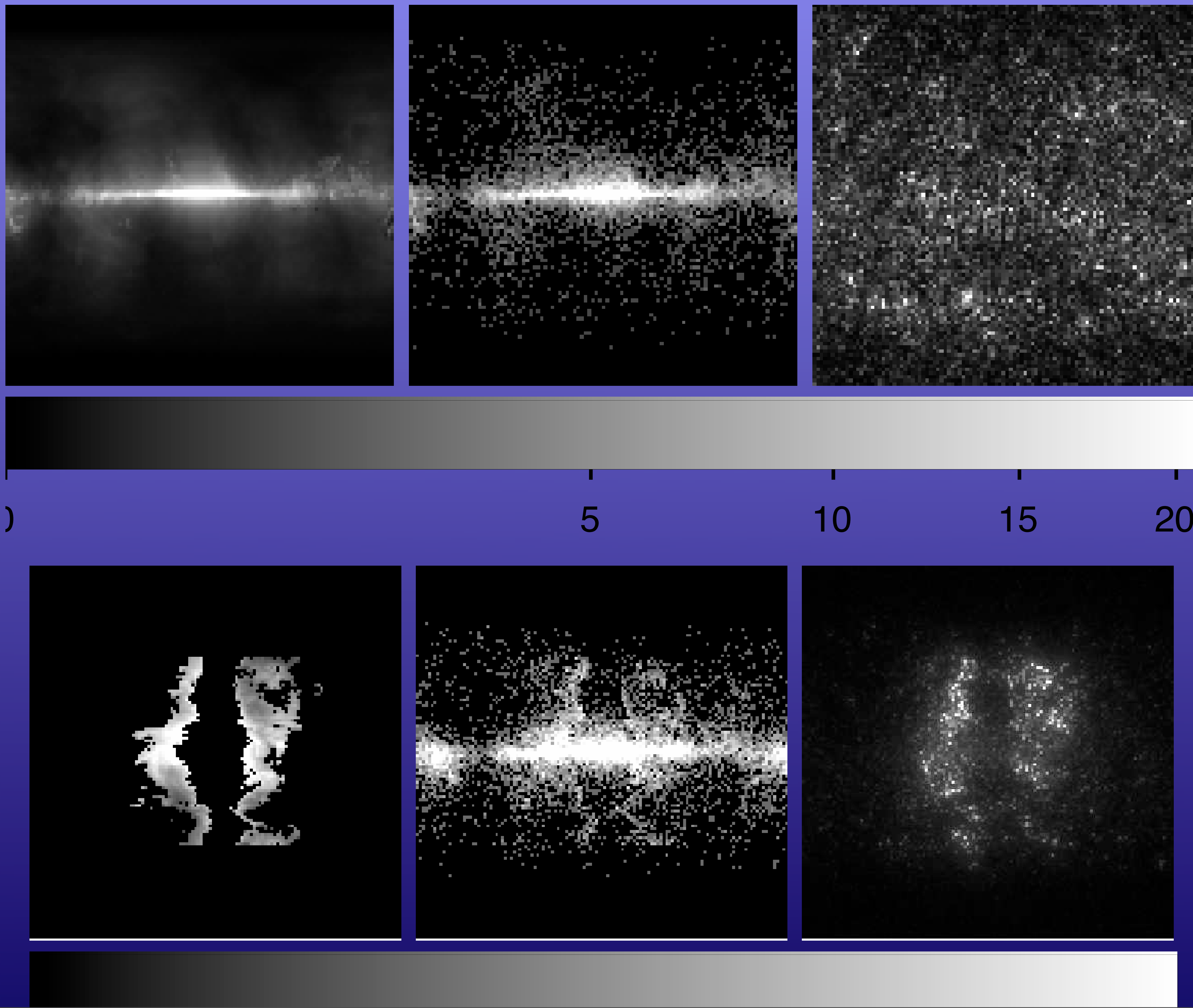
$psf(x,y \mid l,b,e,t,\xi)$ = 'Model' instrument smearing

$\lambda(x,y,e,t,\theta,\varphi,\xi)$ = 'Model' Expected counts in detector

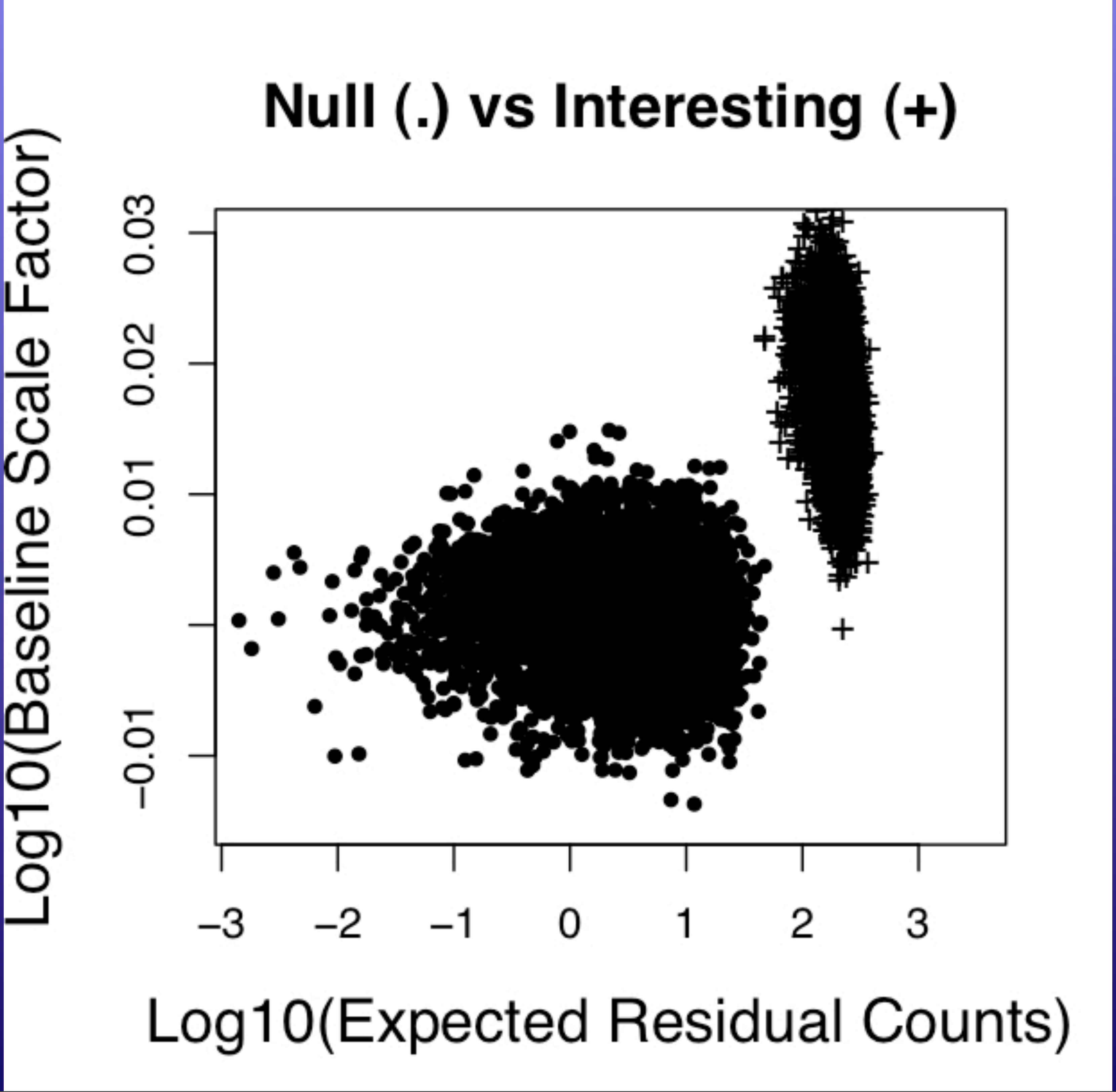
$D(x,y,e,t,\theta,\varphi,\xi)$ = measured counts in detector

$$\lambda(x,y,e,t,\theta,\varphi,\xi) = psf(x,y|l,b,e,t,\xi)@$$
$$(\ \beta*\epsilon(l,b,e,t)*s(l,b,e,t,\theta) + m\ (l,b,e,t,\alpha,\kappa)\ )$$

3. Moderate Signal-To-Noise Examples:Gamma-Ray Sky:



3. Moderate Signal-To-Noise Examples:Gamma-Ray Sky:



3. Moderate Signal-To-Noise Examples:Gamma-Ray Sky: