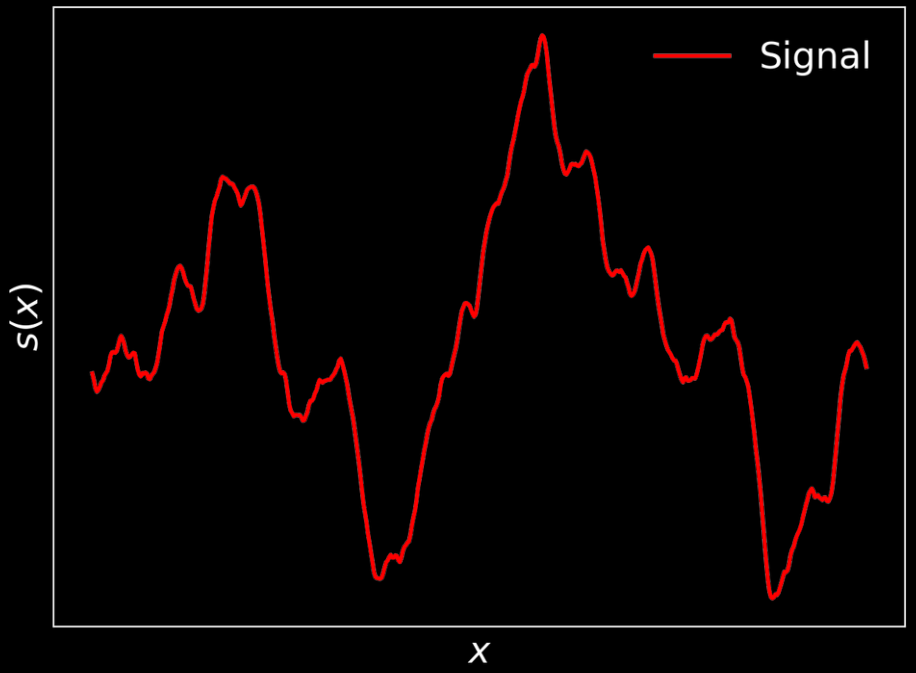
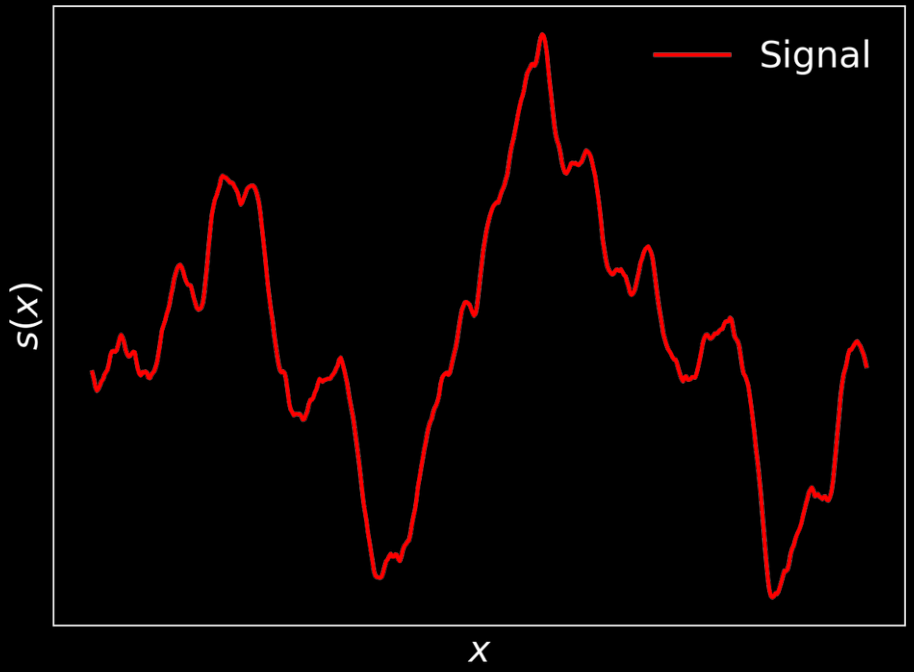
X-UBIK

The Universal Bayesian Imaging Kit Applied to X-ray data

M. Westerkamp, V. Eberle, M. Guardiani, P. Frank, T. Enßlin

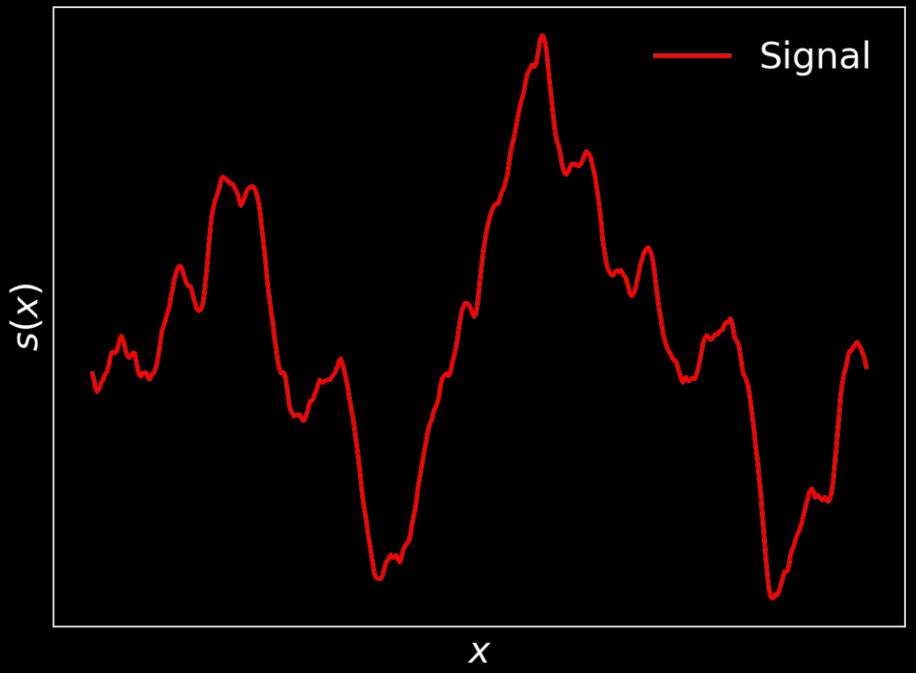
Sep. 19, 2024 Garching
First Results from the SRG/eROSITA All-Sky Survey
From Stars to Cosmology


Signal
s(x)
x



Signal 1 … Signal N

Signal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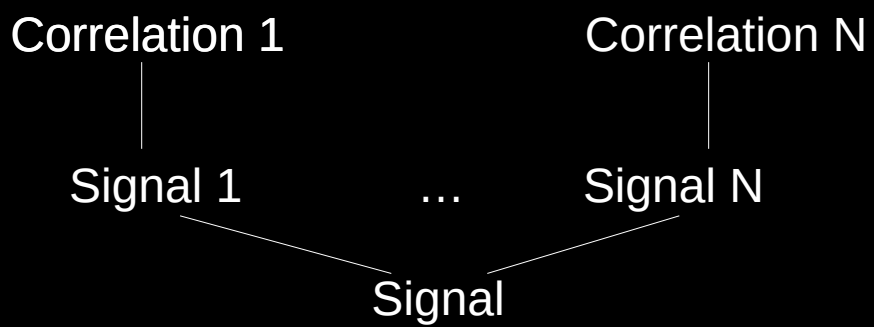
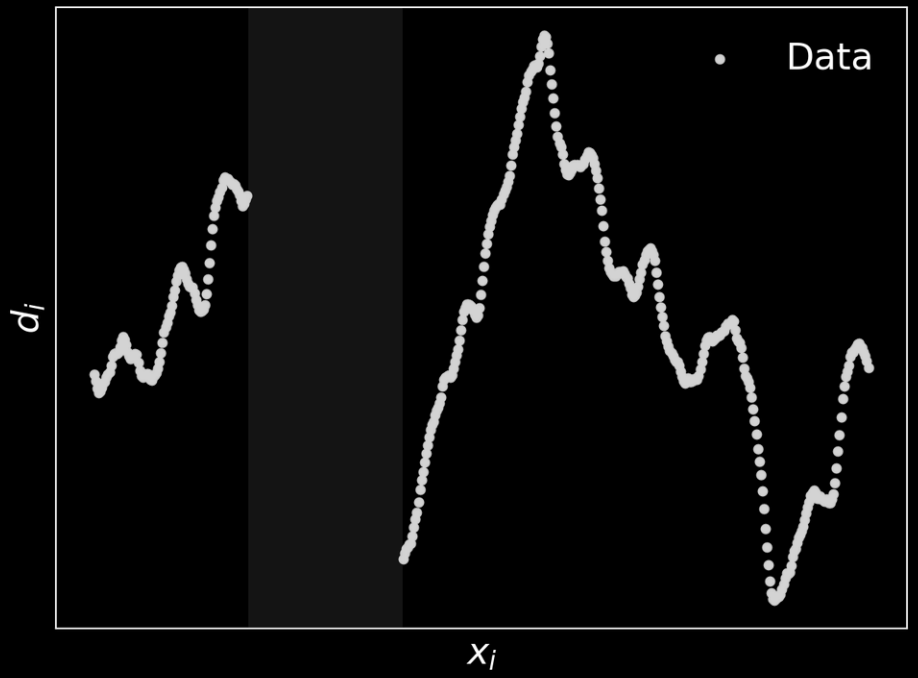
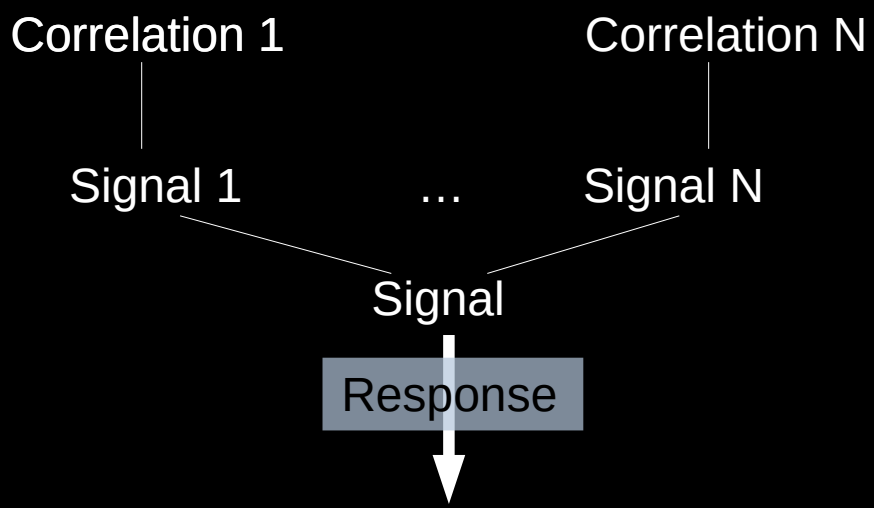
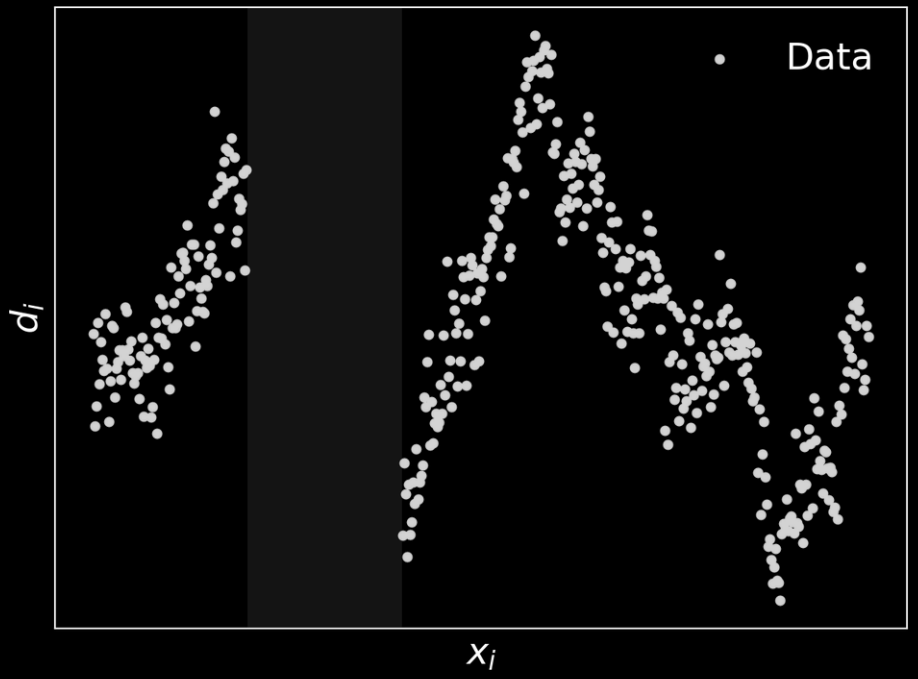
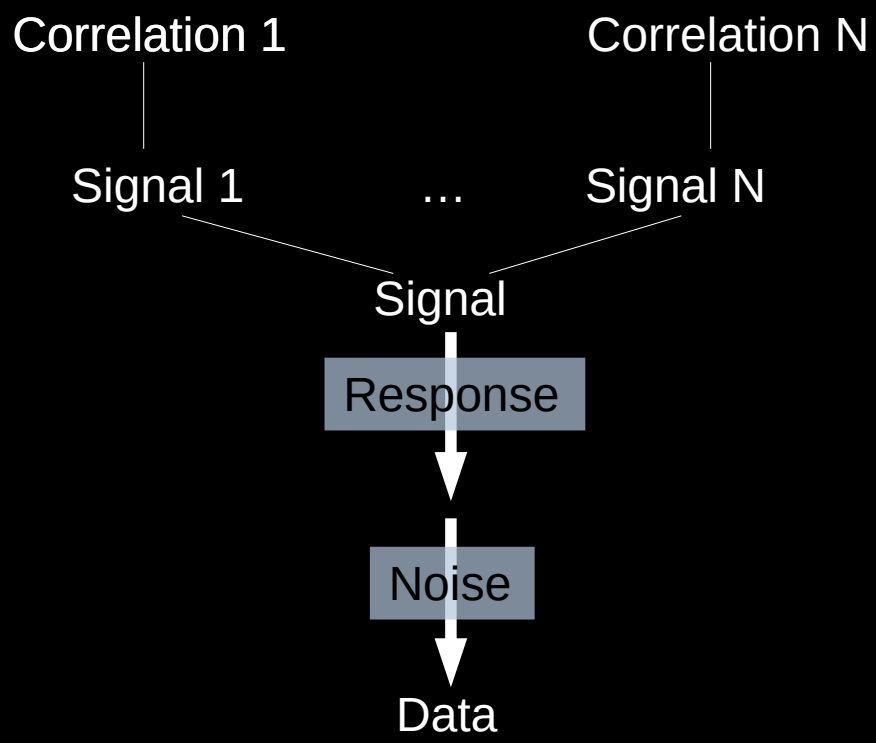
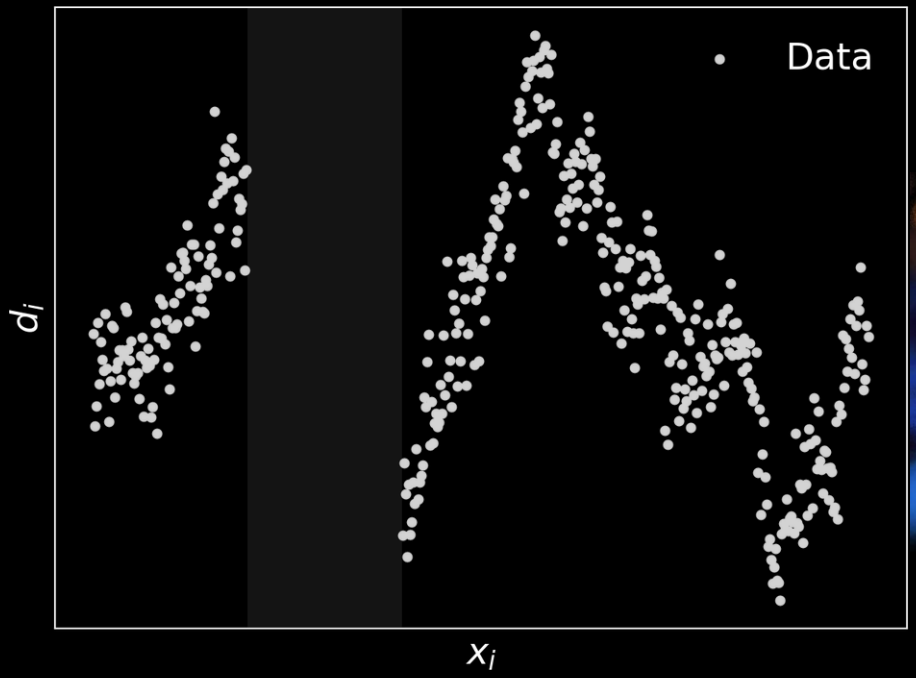

Correlation 1
Correlation N
Signal 1
…
Signal N
Signal


Data
d_i
x_i


Correlation 1
Correlation N
Signal 1
…
Signal N
Signal
Response


Data
d_i
x_i


Correlation 1
Correlation N
Signal 1
…
Signal N
Signal
Response
Noise
Data



Correlation 1 Correlation N

Signal 1 … Signal N

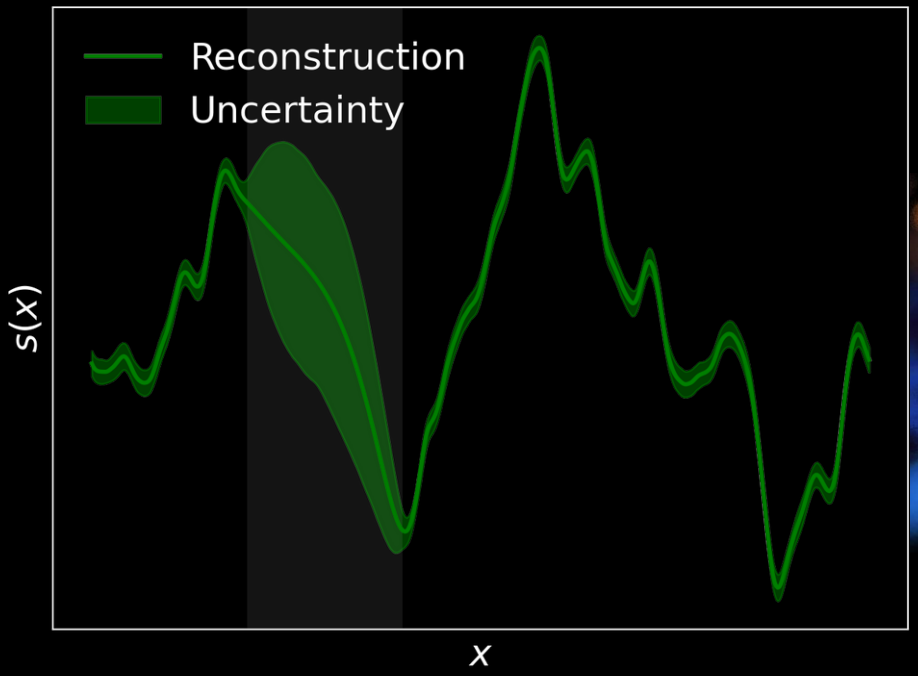
Signal

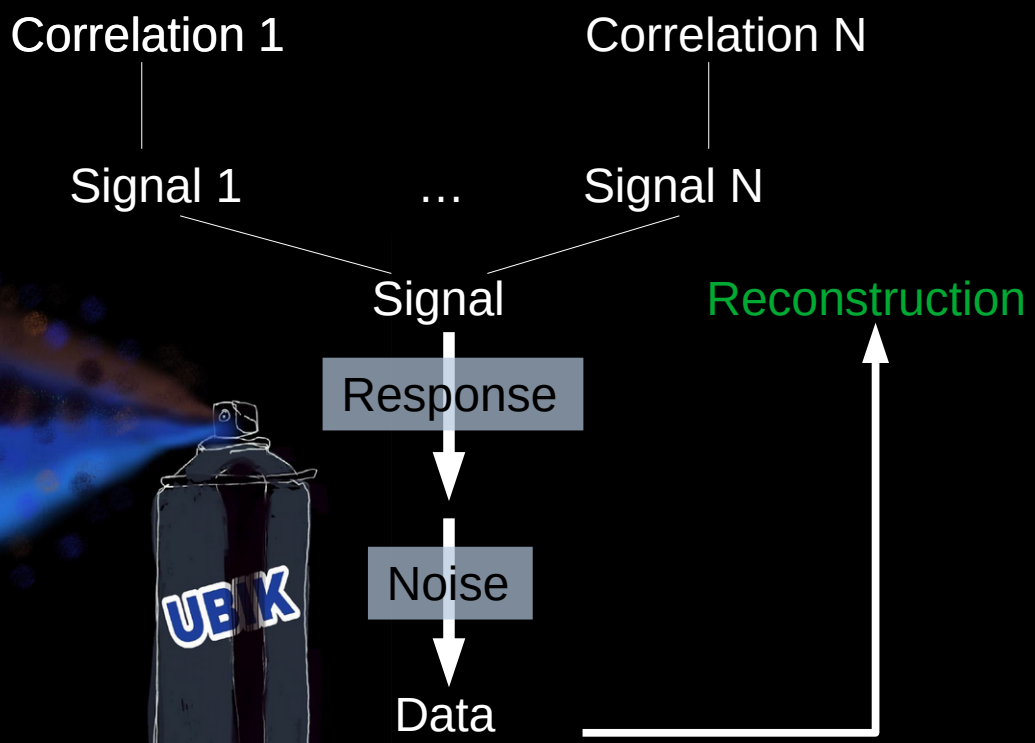
Response

Noise

Data

Reconstruction


Reconstruction
Uncertainty
s(x)
x


Correlation 1
Correlation N
Signal 1
…
Signal N
Signal
Response
Noise
Data
Reconstruction

Challenges

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- Non-trivial correlation structures
- Mixture of several components

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Information Field Theory

$$P(s|d) = \frac{P(d|s)\,P(s)}{P(d)}$$

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Variational inference:

$$min\, D_{KL}(Q(s|d)|P(s|d))$$

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$$m = \langle s \rangle_Q$$
$$\sigma^2 = \langle (s-m)^2 \rangle_Q$$

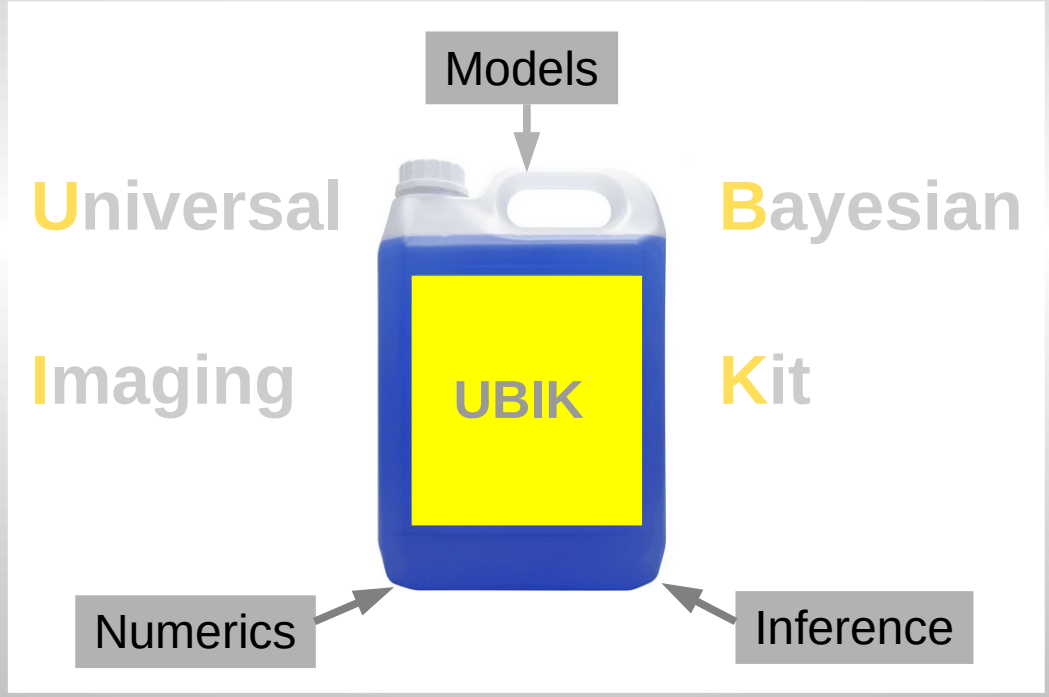
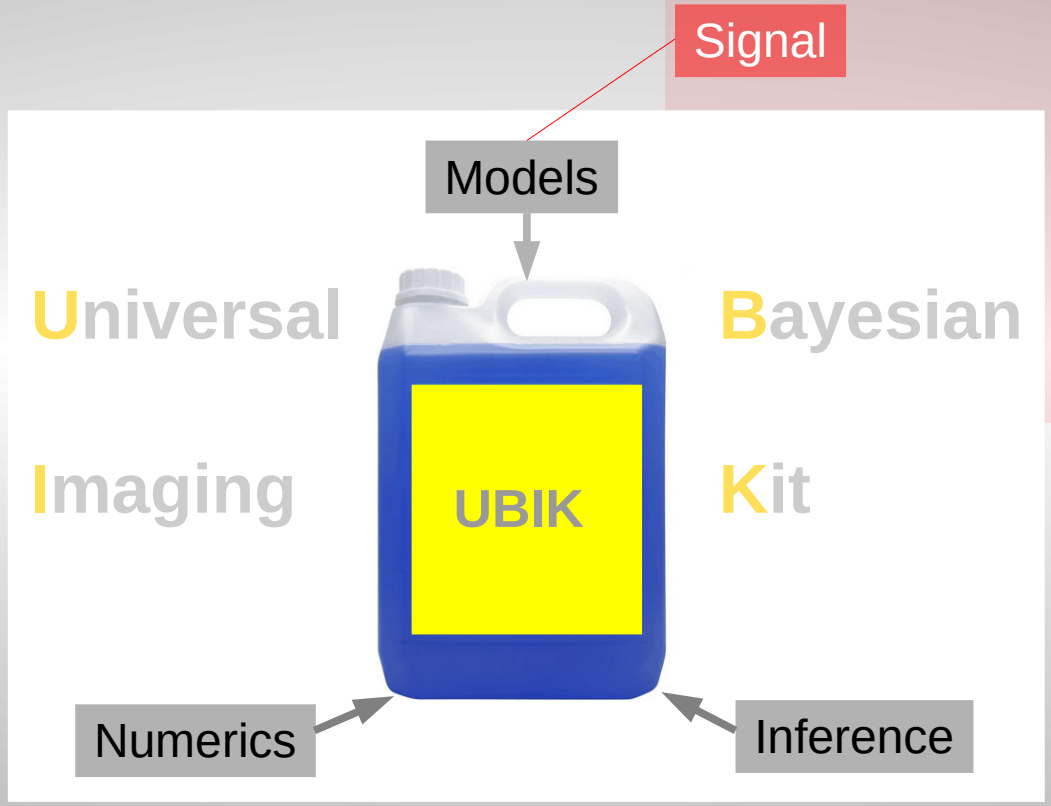


Image: https://www.pollards.co.uk/products/ubik-2000

PRIOR MODEL



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PRIOR MODEL

Dimensions

- Space
- Time
- Energy
- Polarization
- ...

Signal

Models

Universal

Bayesian

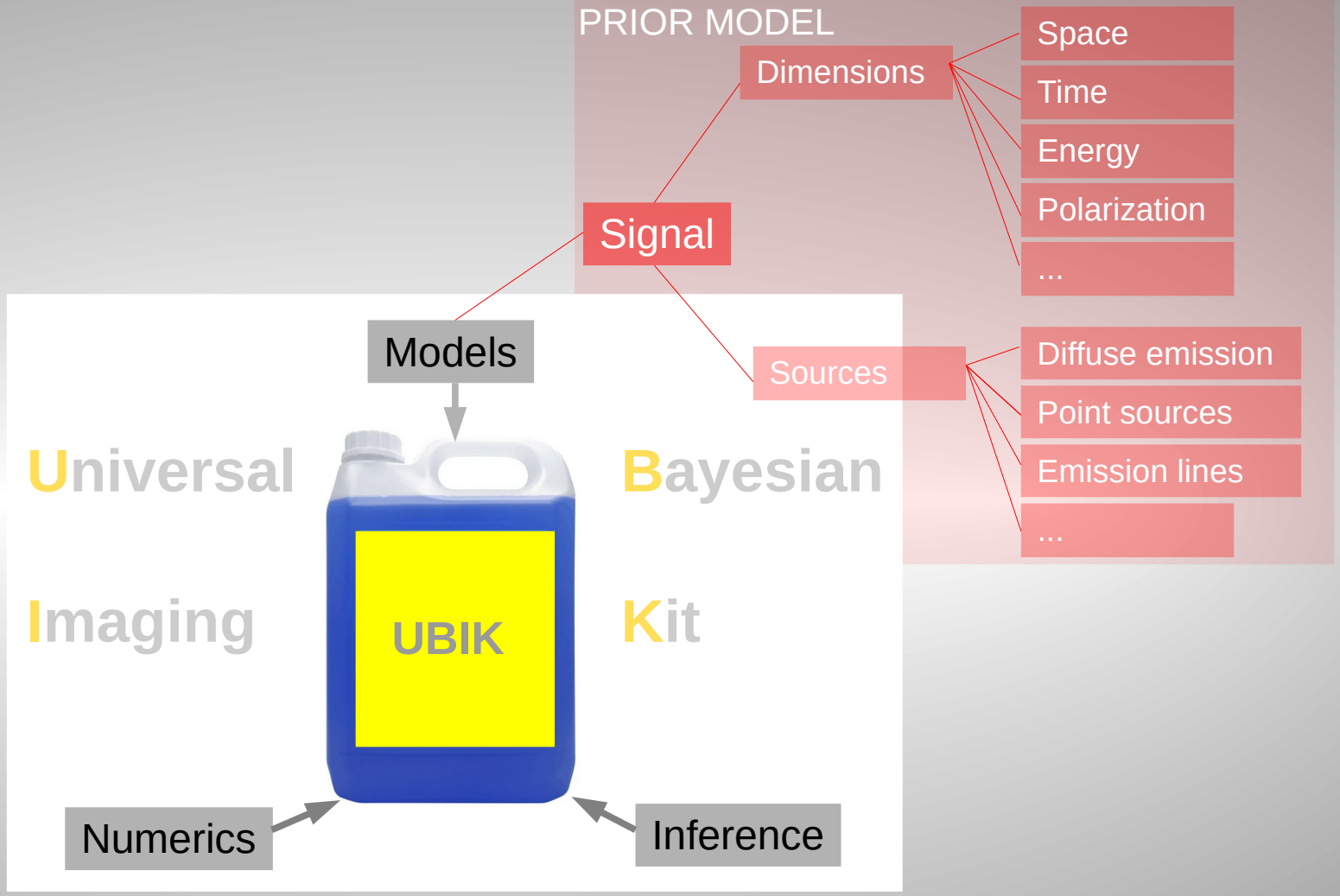
Imaging

Kit

Numerics

Inference

Image: https://www.pollards.co.uk/products/ubik-2000



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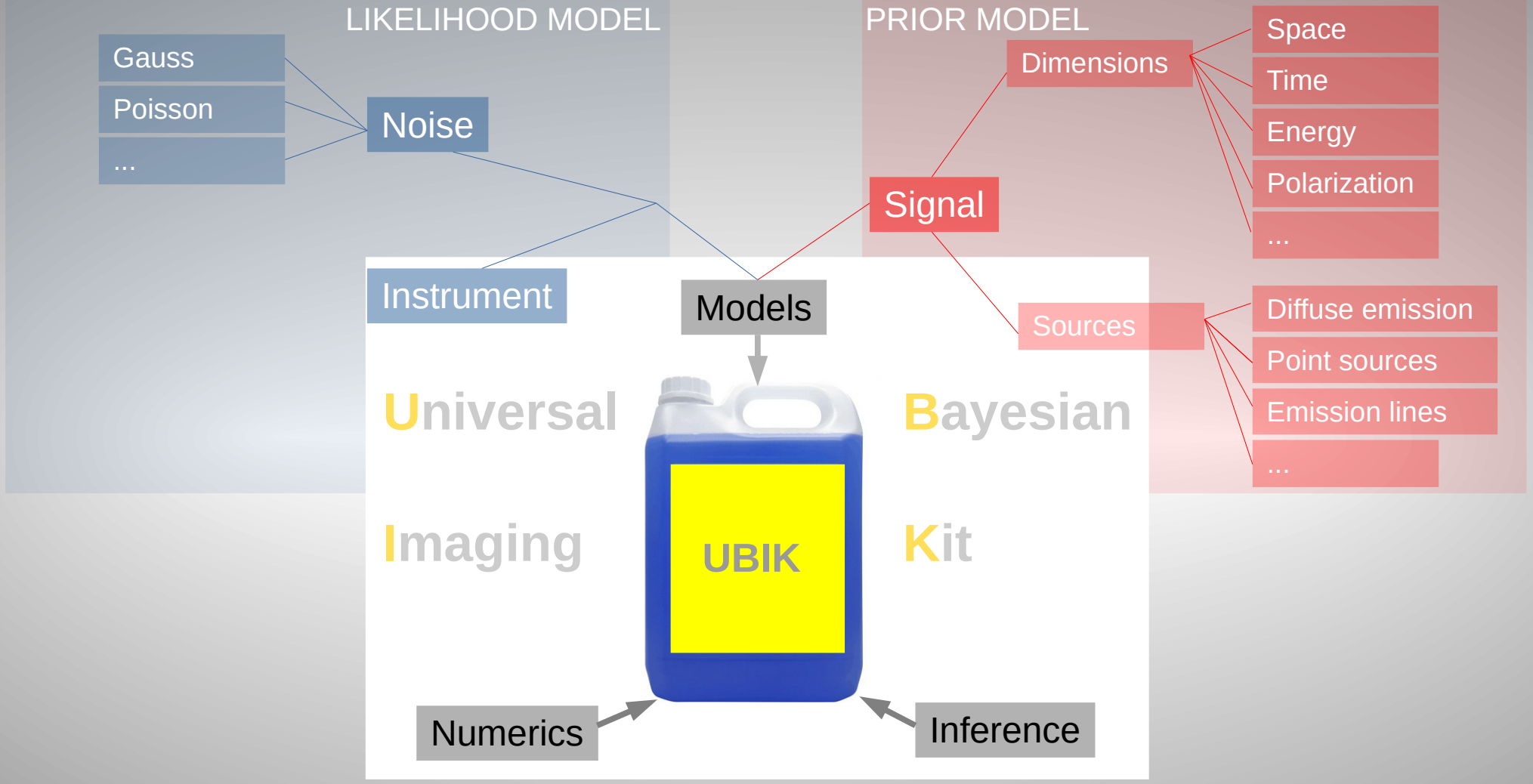

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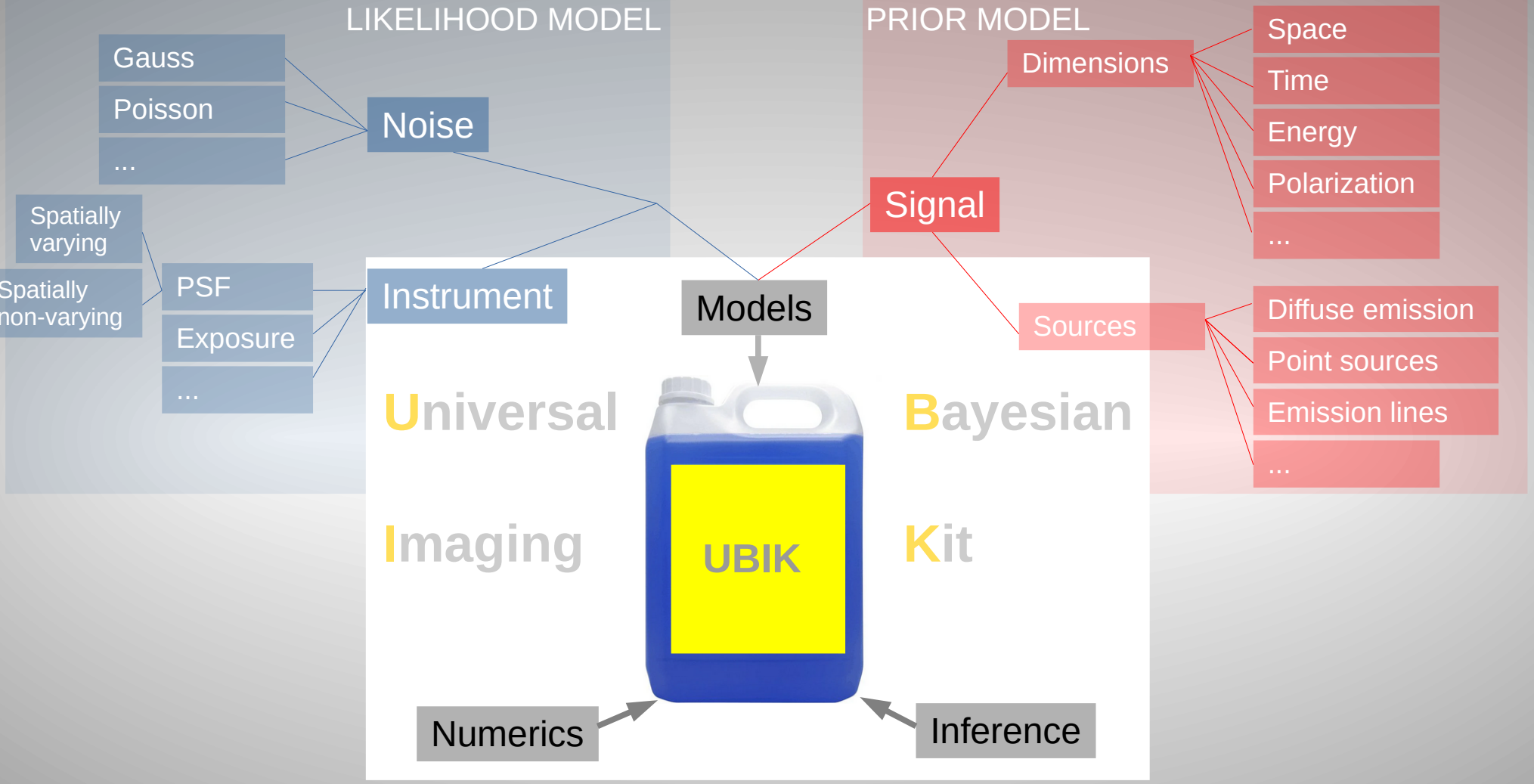

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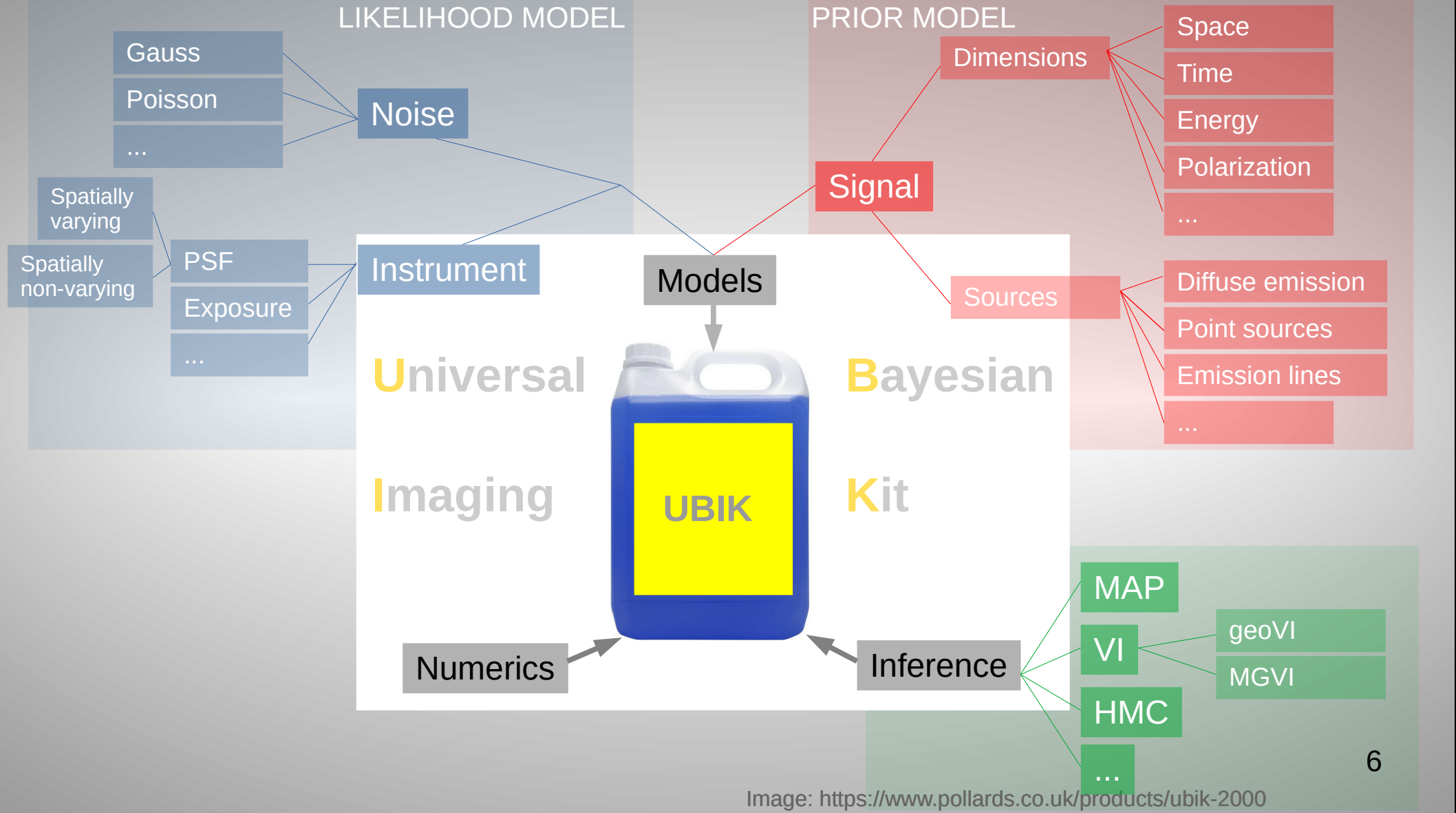

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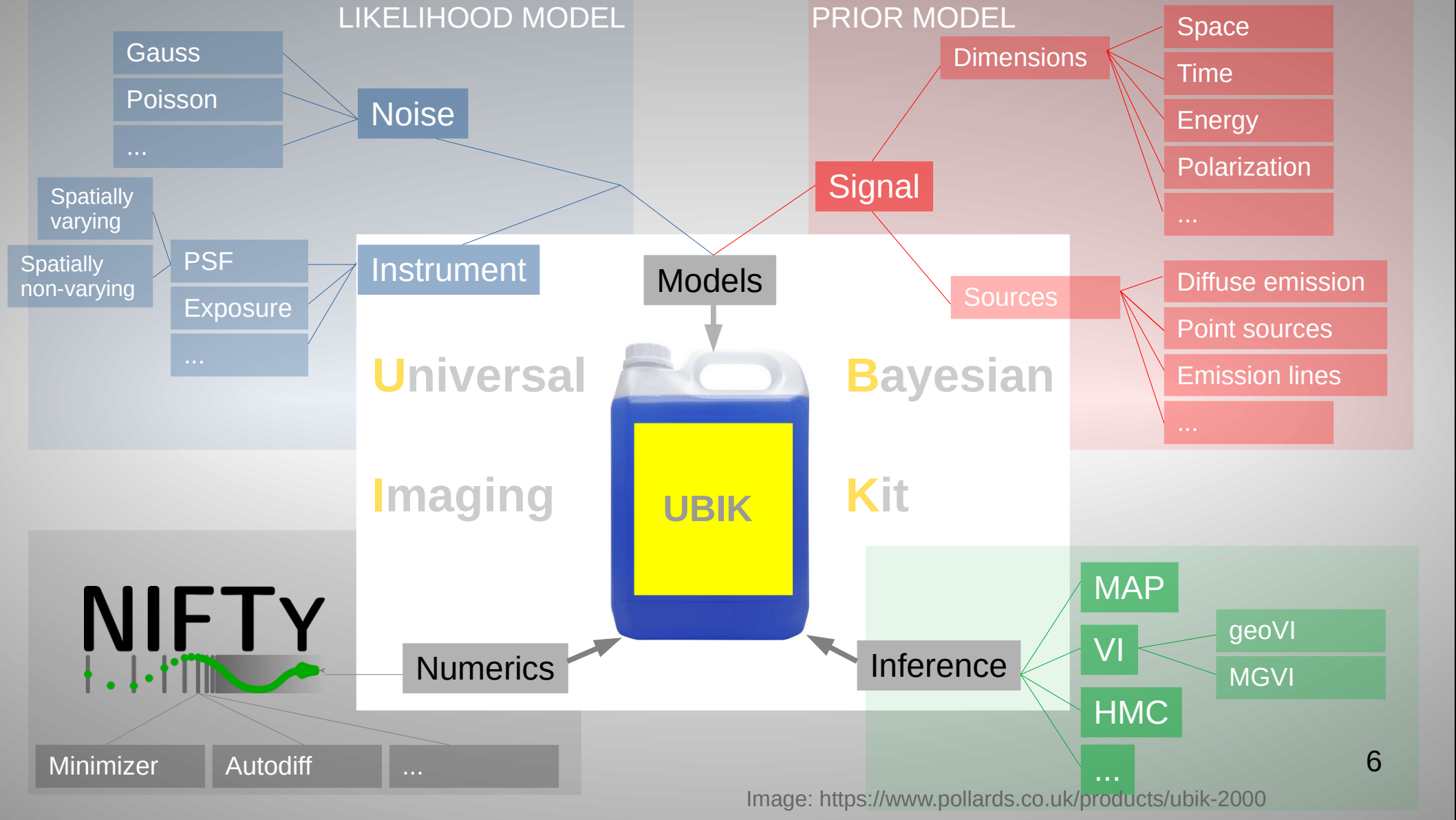

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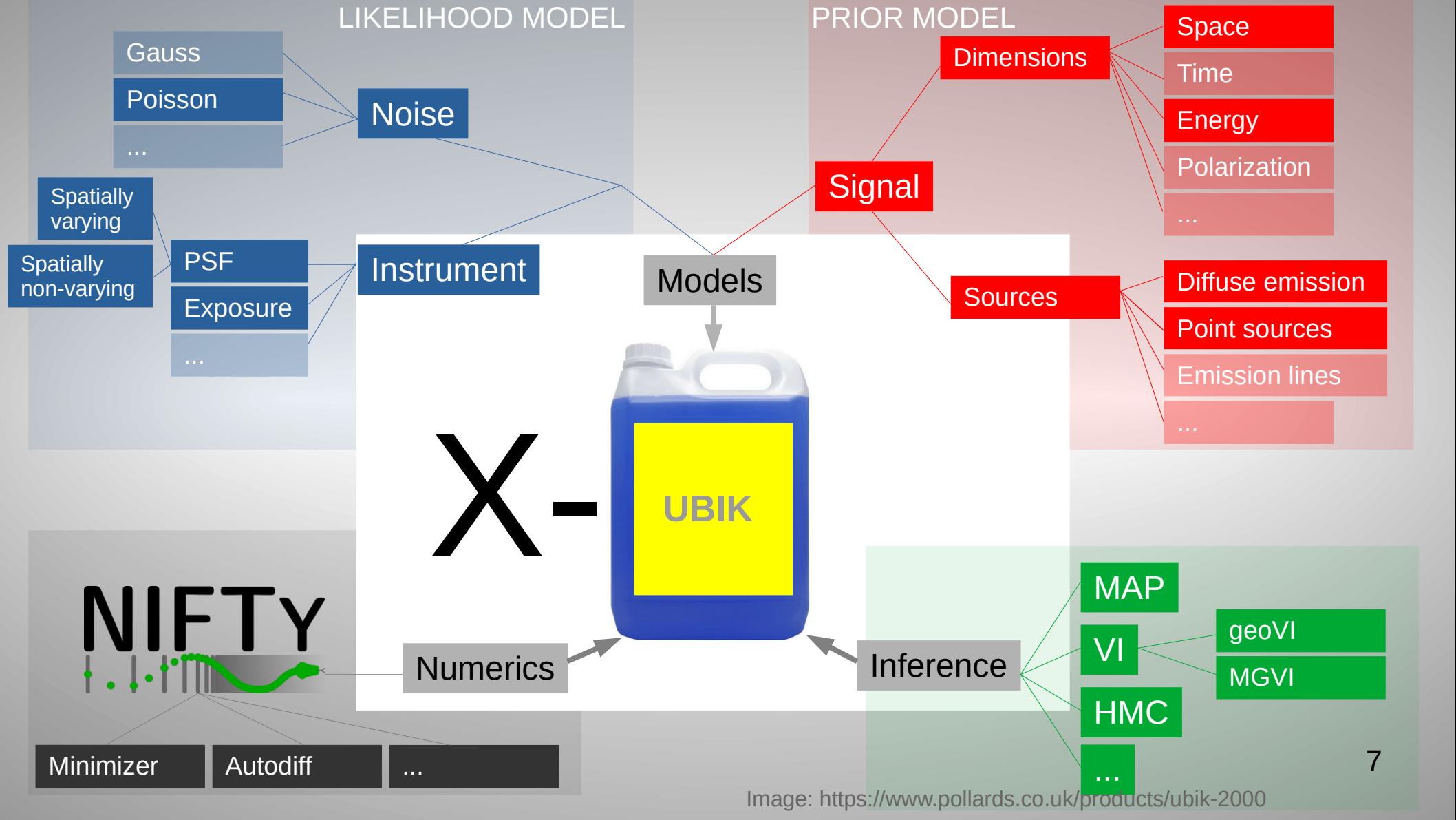

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Likelihood Model

Poissonian log-likelihood for observation k:

$$-\ln P\left(d_k|\lambda_k\right)= \quad -\sum_{i=1}^{N}\left[\lambda_k^i - d_k^i \ln \lambda_k^i + \ln\left(d_k^i!\right)\right]$$

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average counts $\lambda_k = R_k s$

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exposure k

psf k

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Prior Generative Models

$$s = s(\xi), \qquad P(\xi) = N(\xi, 1)$$

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diffuse emission **point sources**

$s(\xi) =$ + + ...

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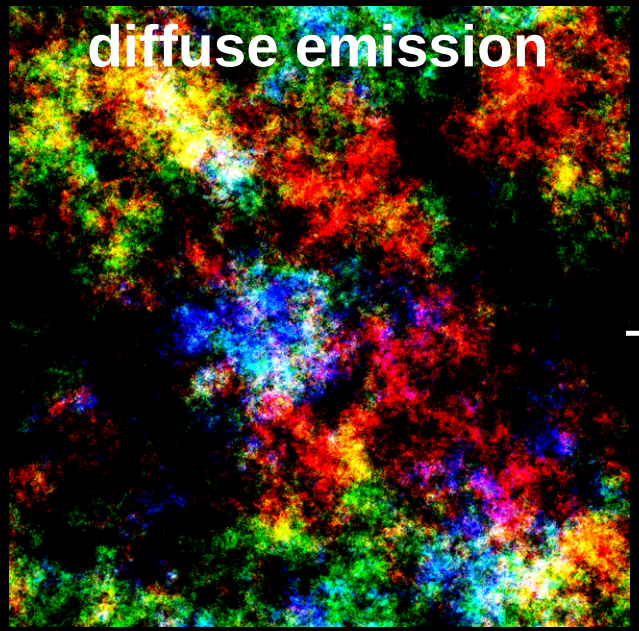

$s(\xi) =$ + + ...

point sources

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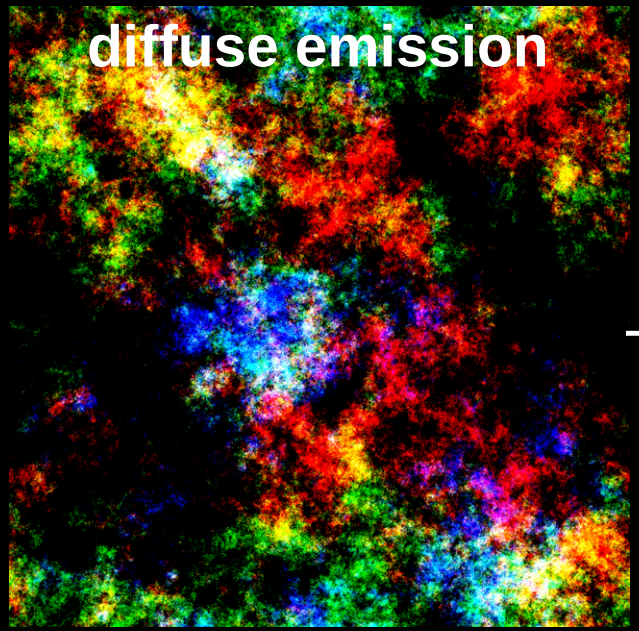
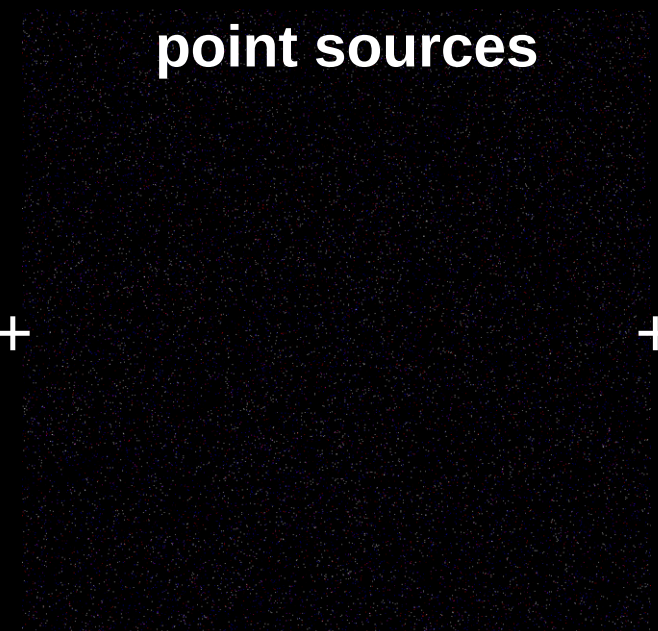
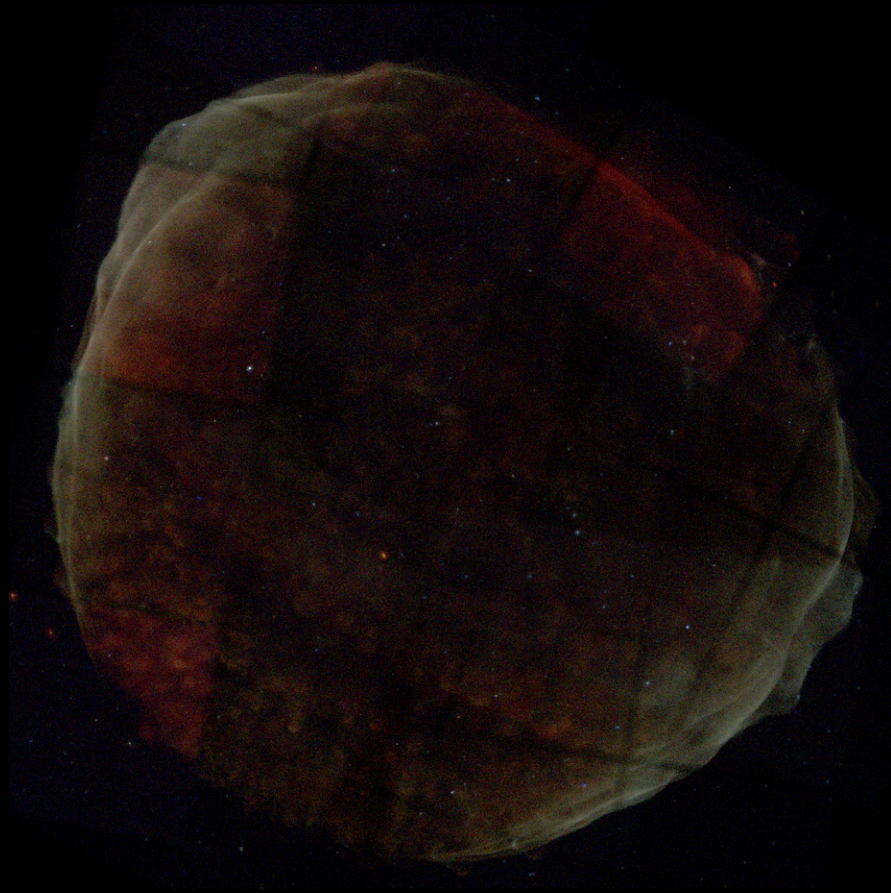
$s(\xi) =$ 

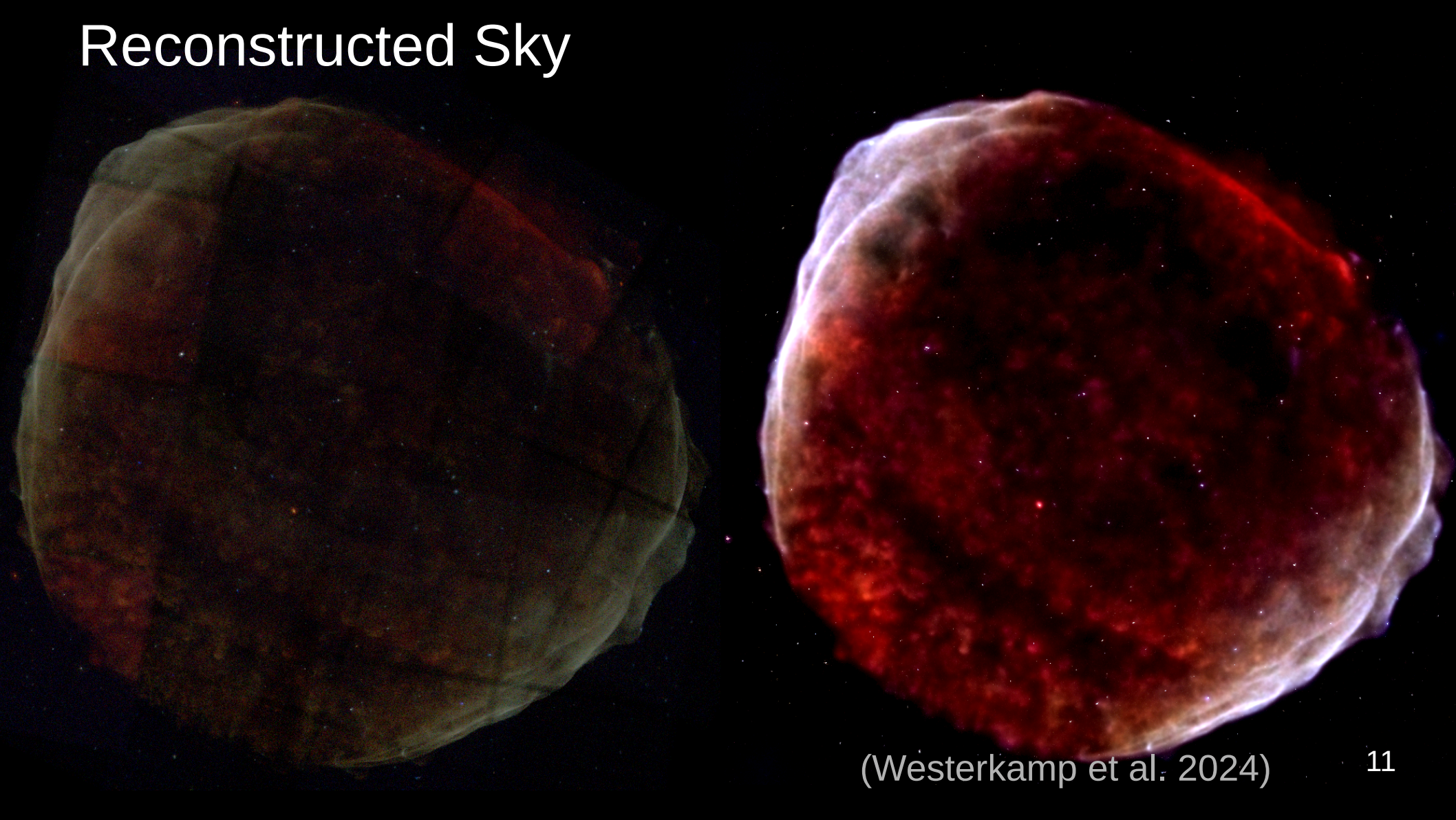
+ 

+ ...

Chandra - SN1006

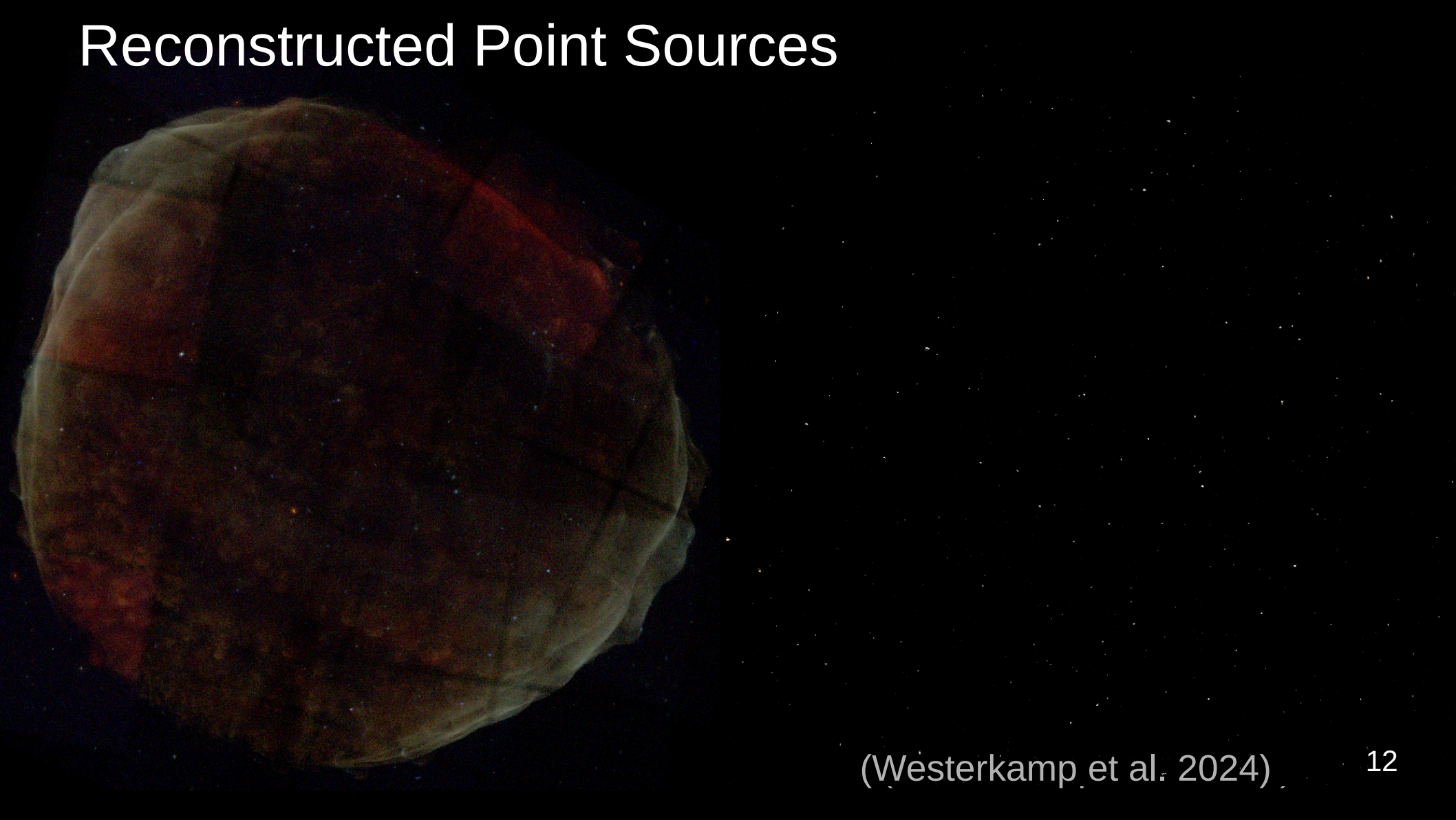


Reconstructed Sky



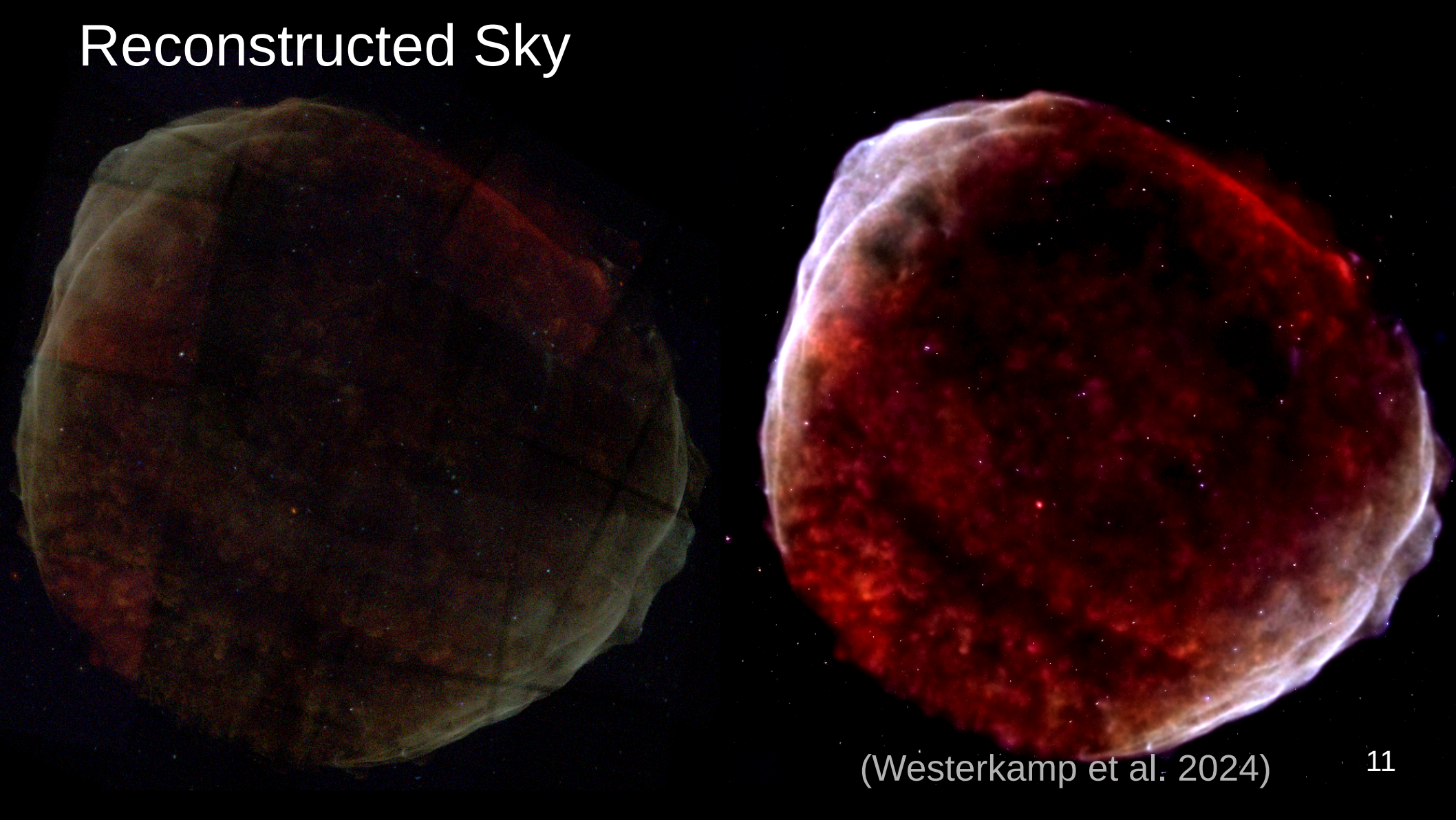
(Westerkamp et al. 2024)

Reconstructed Point Sources



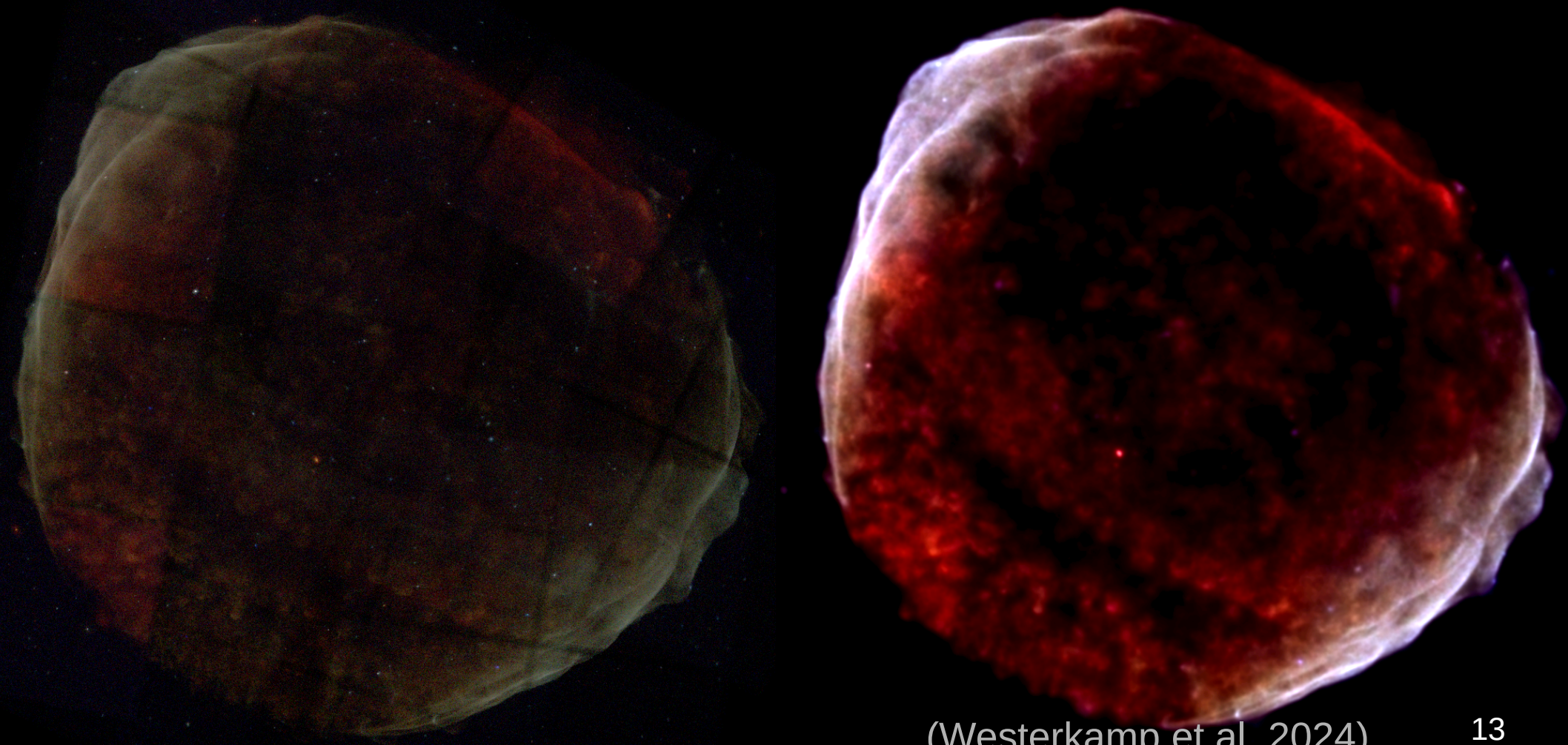
(Westerkamp et al. 2024)

Reconstructed Sky



(Westerkamp et al. 2024)

Reconstructed Diffuse Emission



(Westerkamp et al. 2024)

… and more

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eROSITA:

Eberle, Guardiani, Westerkamp
et. al in prep.

… and more

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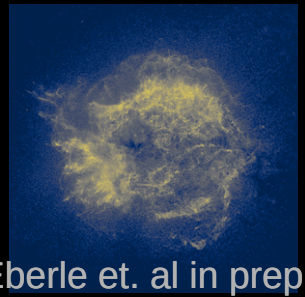
Chandra:



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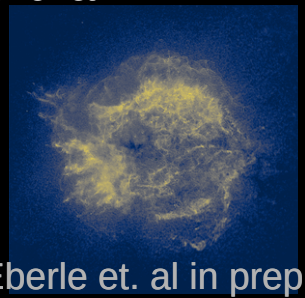

Eberle et. al in prep.

XMM-Newton:

Credit: ESA/ XMM-Newton

… and more

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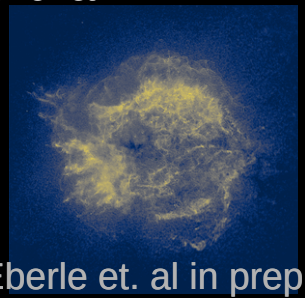

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Rüstig et. al 2023

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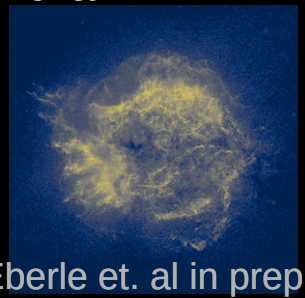

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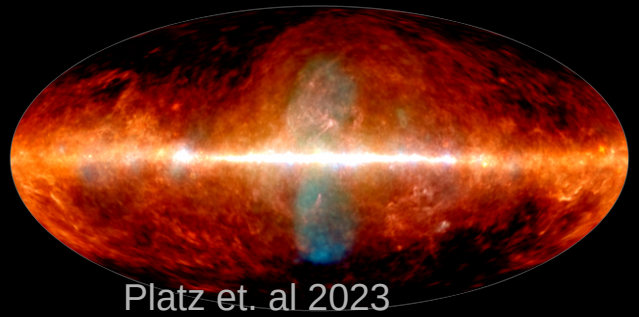

Platz et. al 2023

… and more

eROSITA:

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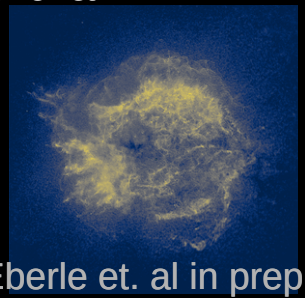
Chandra:



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J-UBIK

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