MAX-PLANCK-GESELLSCHAFT

Max-Planck-Institut
für Astrophysik

# Towards Reconstructing the Galactic Electron Density from Pulsar Dispersion Measurements

an IFT application

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**with**

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*http://www.mpa-garching.mpg.de/ift/*

# Outline:

1. **The Physics**
   pulsar dispersion and electron density

2. **The IFT Approach**
   response, prior and the Wiener Filter

3. **Application**
   first 2D images from mock data

4. **Conclusion and Outlook**
   what needs to be done...

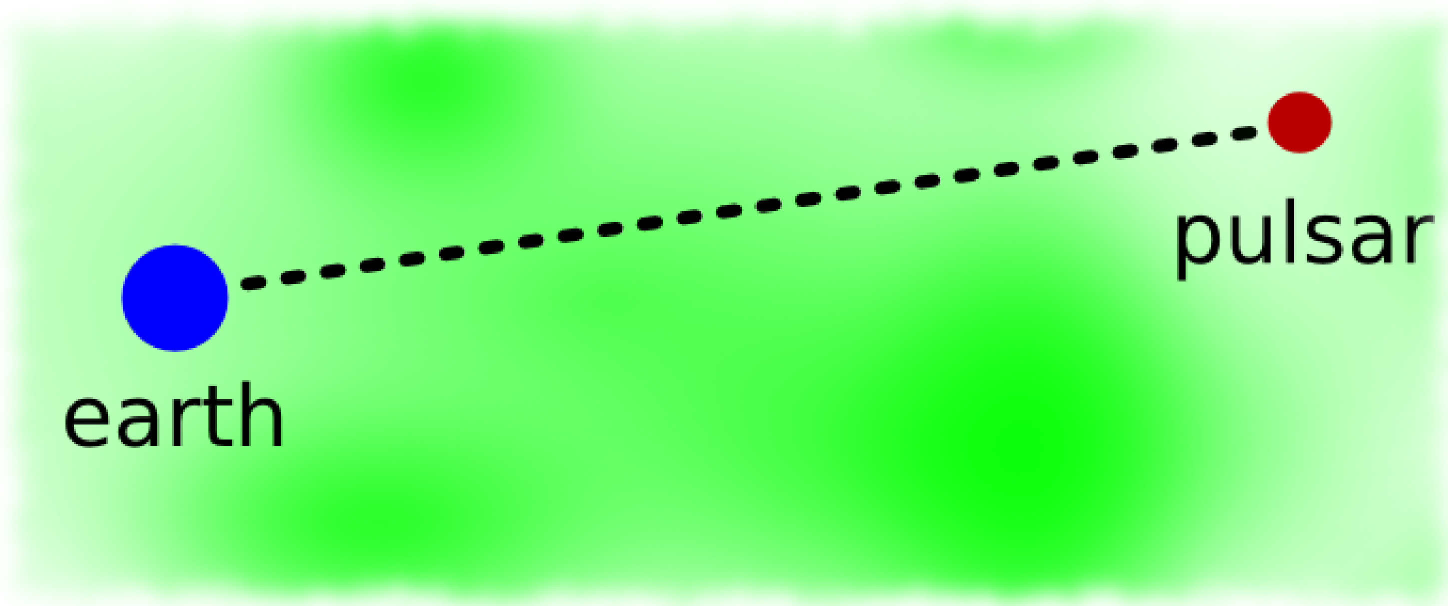
# The Physics

the radiation dispersion time

$$t = k_{\mathrm{DM}} \times \frac{\mathrm{DM}}{\nu^2}$$

is proportional to the line integral over the electron density

$$\mathrm{DM} = \int_0^d n_e \, \mathrm{d}r$$



# The IFT Approach

- data are split up into response and noise:

$$s = n_e$$
$$d = Rs + n$$

$$(Rs)_i = \int_{earth}^{pulsar\ i} s \, \mathrm{d}r$$

- the noise is assumed to be Gaussian with zero mean:

$$P(n) = \mathcal{G}(n, N) := | \, 2\pi N \, |^{-\frac{1}{2}} \exp\left(-\frac{1}{2} n^\dagger N^{-1} n\right)$$

$$P(d \mid s) = \mathcal{G}(d - Rs, N)$$

- we are looking for the posterior $P(s \mid d)$

- Bayes theorem:

$$P(s \mid d) = \frac{P(d \mid s) P(s)}{P(d)}$$

# The Wiener Filter

- we assume that the signal follows Gaussian statistics:

$$P(s) = \mathcal{G}(s, S)$$

with known covariance $\left\langle s s^\dagger \right\rangle_{\mathcal{G}(s,S)} = S$

- then the posterior is

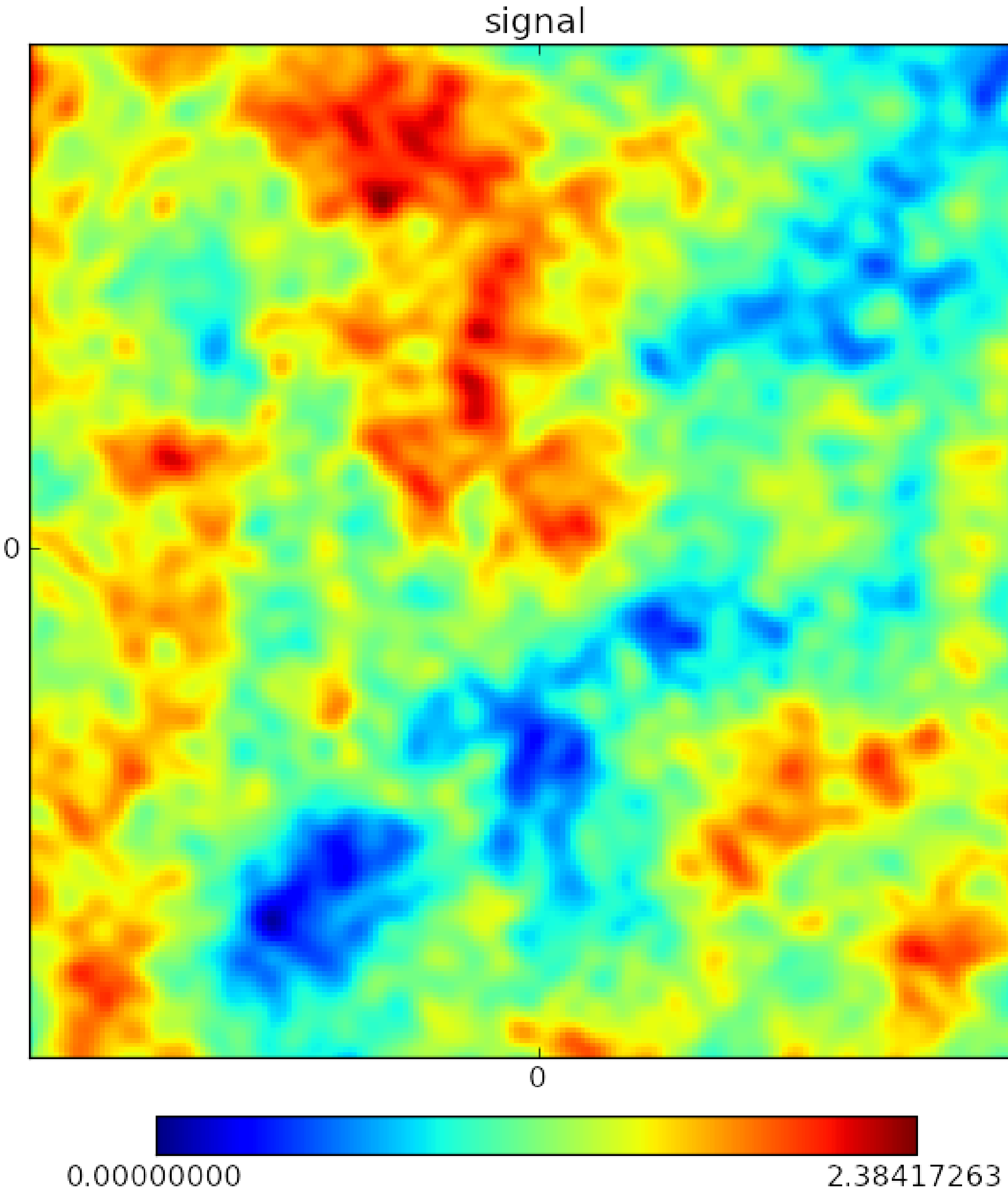
$$P(s \mid d) = \mathcal{G}(s - m, D)$$

with $m = Dj \qquad j = R^\dagger N^{-1} d$

$$D = \left(R^\dagger N^{-1} R + S^{-1}\right)^{-1}$$

- $m$ is our reconstructed signal

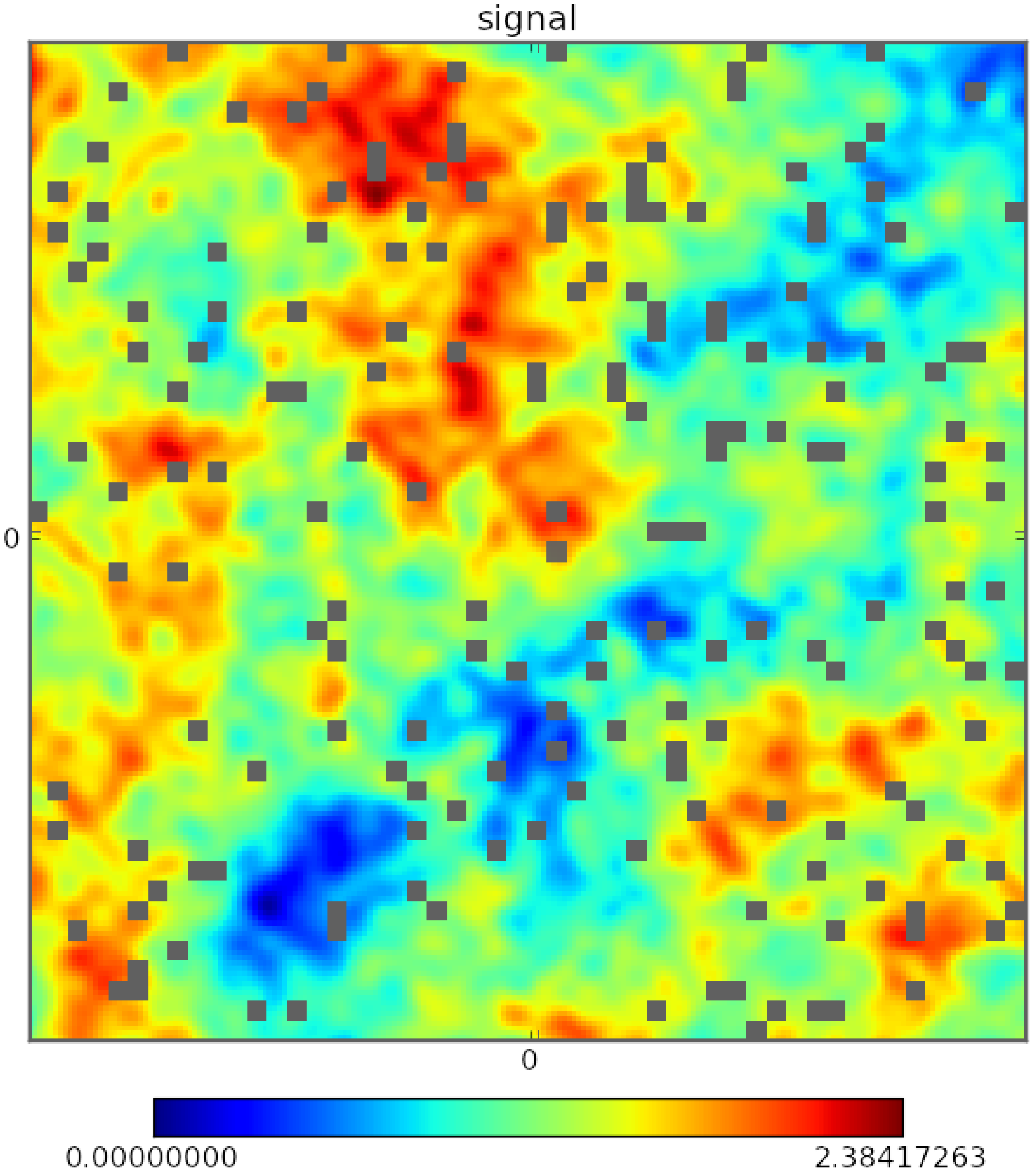
# Application




mock signal from known power spectrum

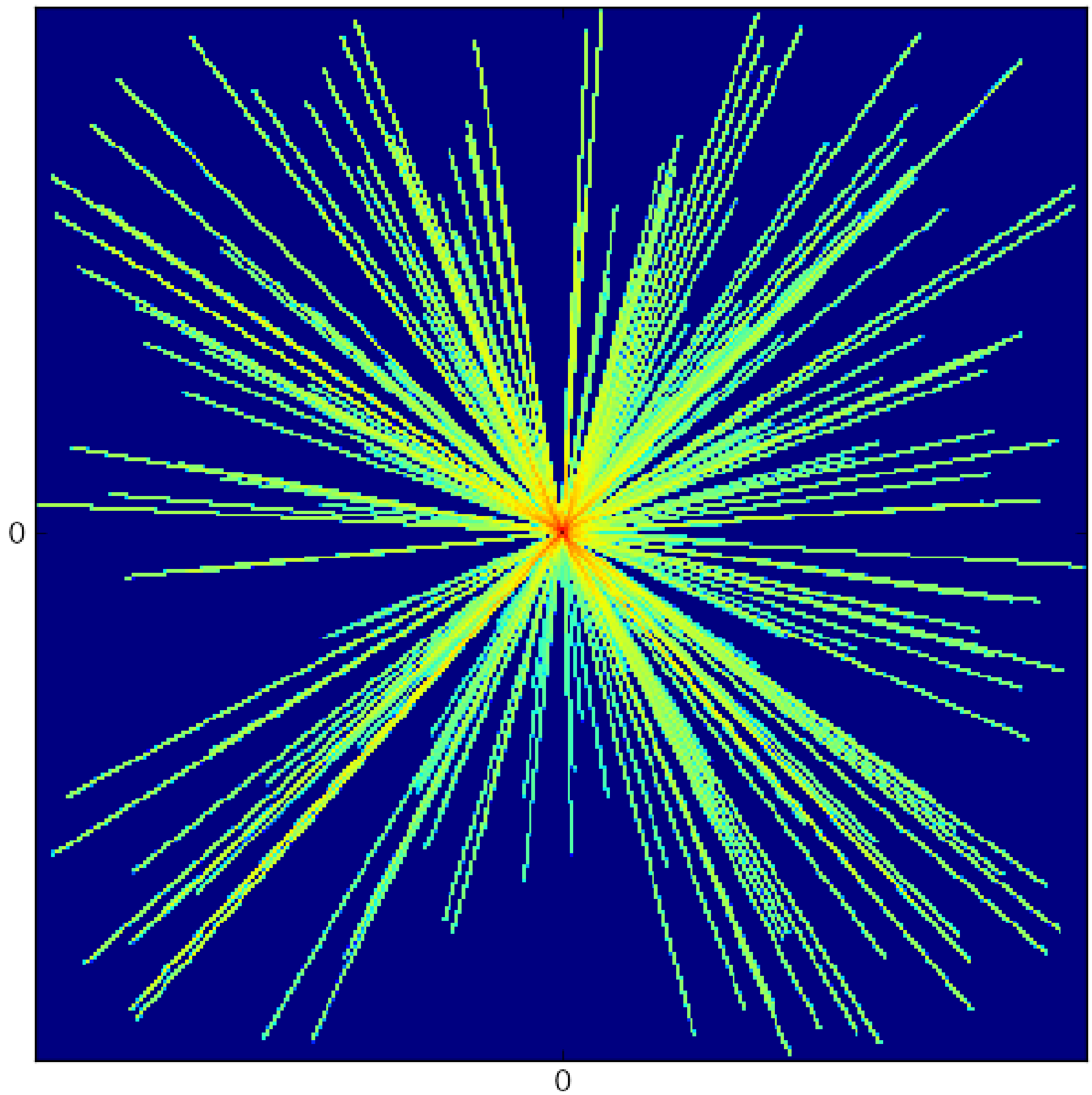
$$p \propto \left(1 + (k/k_0)^2\right)^{-4/3}$$

# Application




200 random pulsar positions

# The Wiener Filter reconstruction




$j$

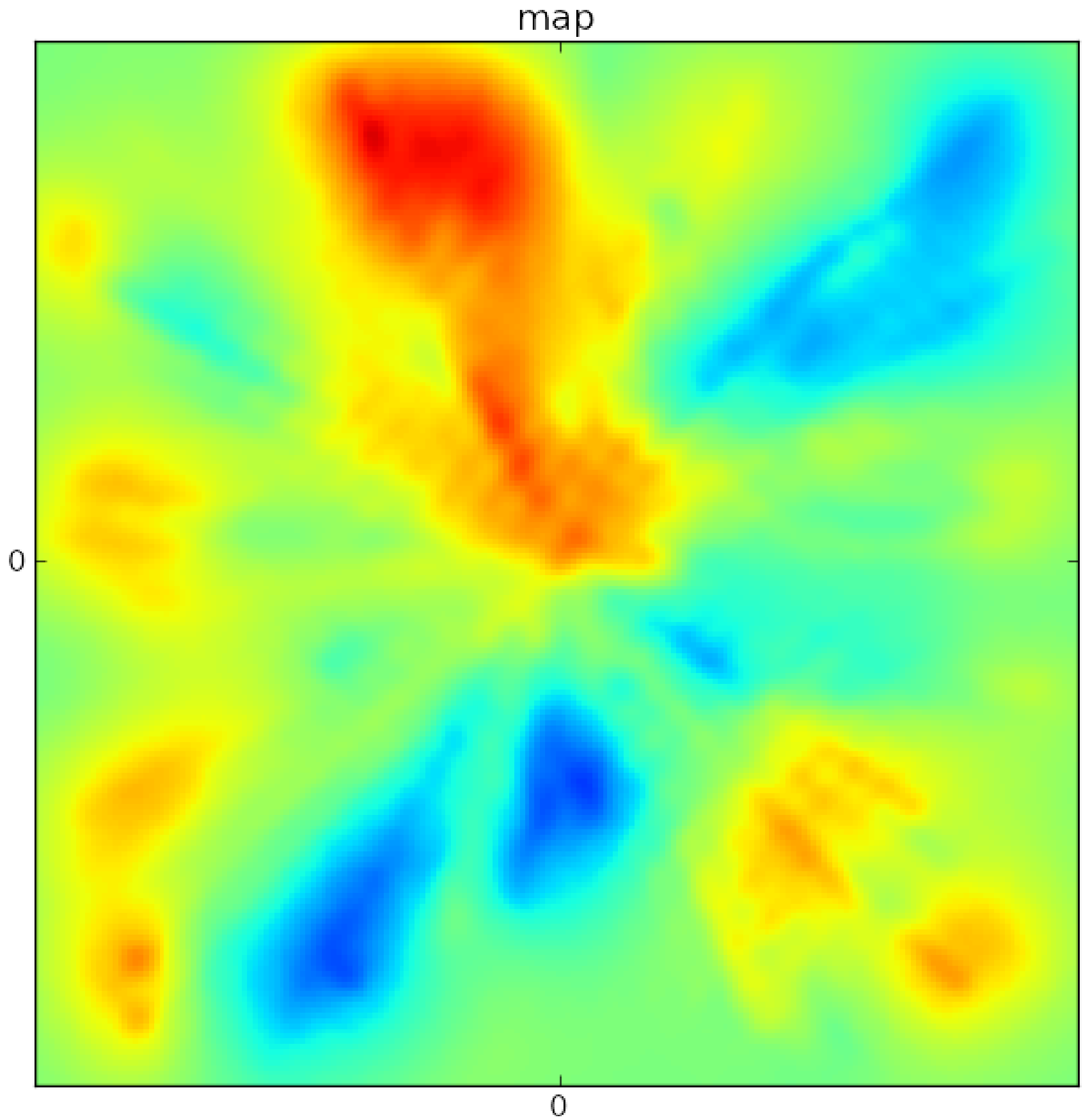
$$d = Rs + n$$

$$(Rs)_i = \int_{earth}^{pulsar\ i} s \ \mathrm{d}r$$

$$j = R^{\dagger} N^{-1} d$$

$$m = Dj$$

# The Wiener Filter reconstruction




$m$

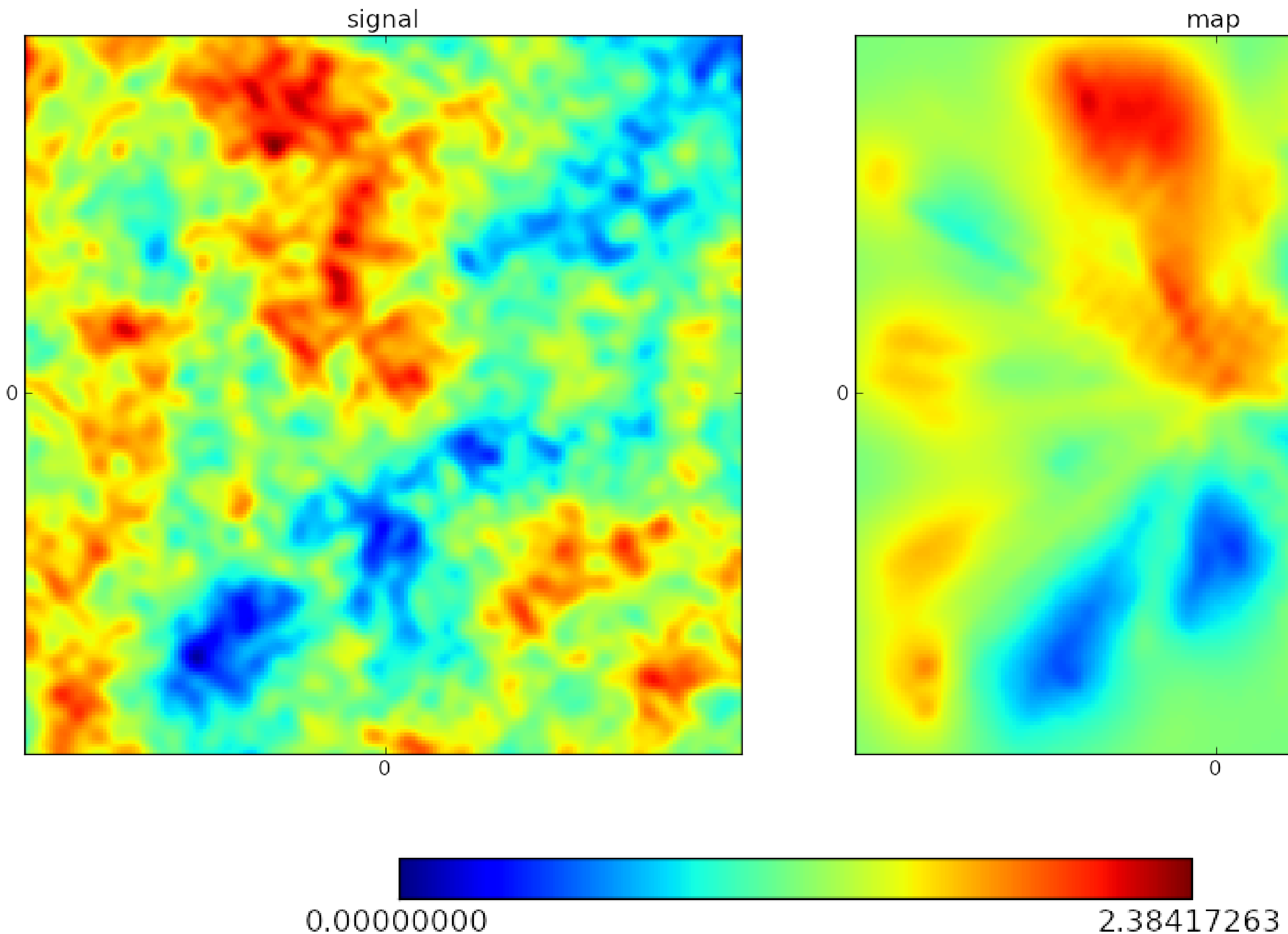
$$d = Rs + n$$

$$(Rs)_i = \int_{earth}^{pulsar\ i} s \, \mathrm{d}r$$

$$j = R^\dagger N^{-1} d$$

$$m = Dj$$

# The Wiener Filter reconstruction



# Conclusion

- sparse DM-measurements from pulsars

- Wiener Filter reconstruction
  - power spectrum known
    → deconvolution & extrapolation

- map resembles true electron density

# Outlook

- Critical Filter
  - without knowledge of power spectrum

- application to real data in 3D

- incorporation of errors in pulsar distances

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