Robust source deconvolution and the estimation of primaries by sparse inversion

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EPSI Model

Estimation of Primaries by Sparse Inversion (van Groenestijn and Verschuur, 2009)

recorded data predicted data from primary IR

$$\mathbf{P} = \mathbf{G}(\mathbf{Q} + \mathbf{R}\mathbf{P})$$

$\mathbf{P}$	total recorded up-going wavefield
$\mathbf{Q}$	source signature (incl. src ghosts)
$\mathbf{R}$	reflectivity of free surface (assume -1)
$\mathbf{G}$	primary impulse response
	(all monochromatic data matrix, implicit ω)

EPSI Inversion

Estimation of Primaries by Sparse Inversion (van Groenestijn and Verschuur, 2009)

recorded data predicted data from primary IR

$$\mathbf{P} = \mathbf{G}(\mathbf{Q} + \mathbf{RP})$$

Inversion objective:

$$f(\mathbf{G}, \mathbf{Q}) = \frac{1}{2}\|\mathbf{P} - \mathbf{G}(\mathbf{Q} + \mathbf{RP})\|_2^2$$

+ *Sparse* inversion

Convolution model

Convolution Model

$$\text{Up-going Primary} = \mathbf{GQ}$$

EPSI Model

$$\text{Up-going Primary} + \text{Multiples} = \mathbf{GQ} + \mathbf{GRP}$$

$\mathbf{P}$	total recorded up-going wavefield
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Convolution model

Convolution Model

$$\text{Up-going Primary} = \mathbf{GQ}$$

EPSI Model

$$\text{Up-going Primary} + \text{Multiples} = \mathbf{GQ} + \mathbf{GRP}$$

additional info on G

$\mathbf{P}$ total recorded up-going wavefield

$\mathbf{Q}$ source signature (incl. src ghosts)

$\mathbf{R}$ reflectivity of free surface (assume -1)

$\mathbf{G}$ primary impulse response

(all monochromatic data matrix, implicit ω)

EPSI Inversion Procedure

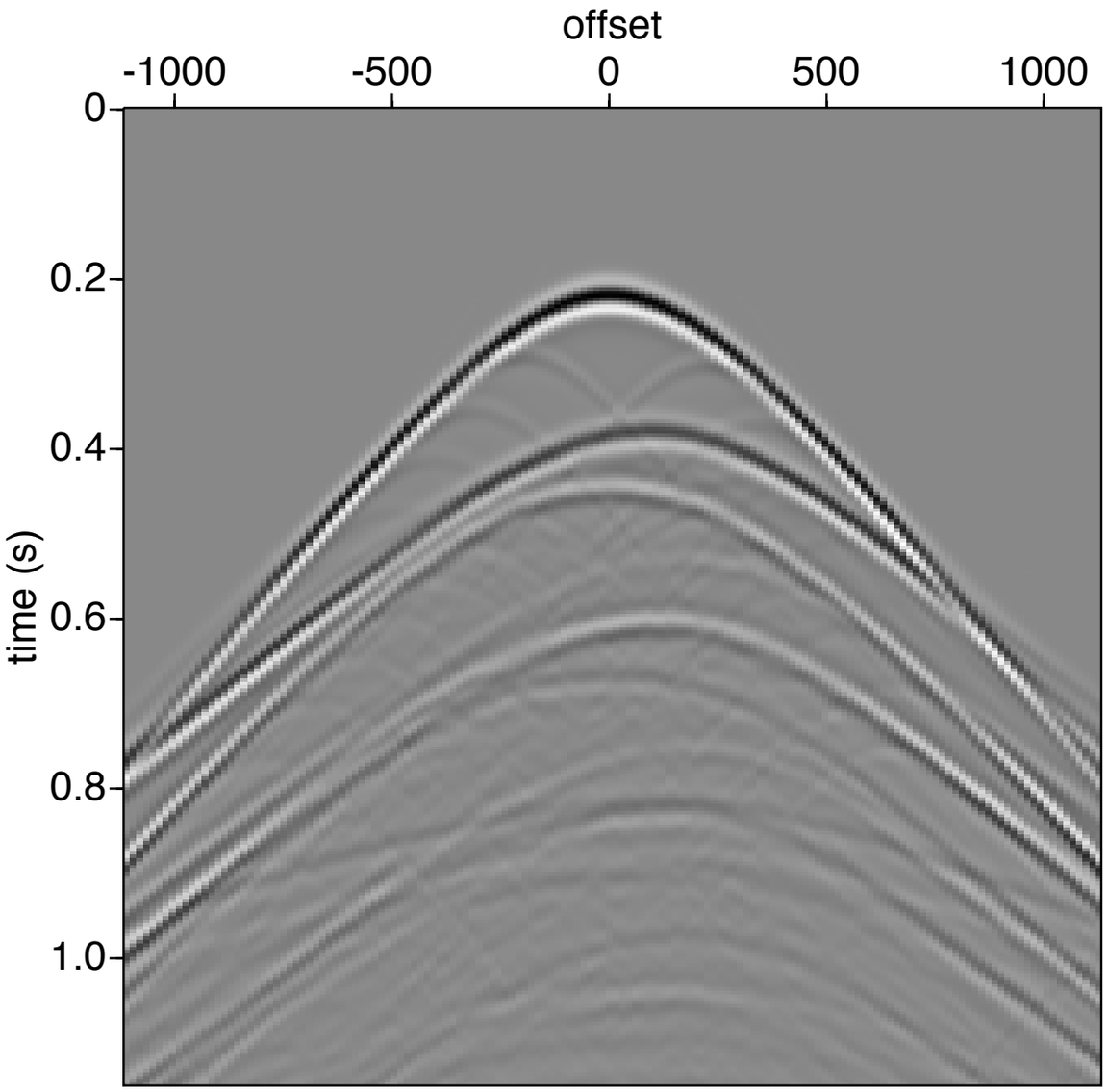
Do:

$$\mathbf{g}_{k+1} = \mathbf{g}_k + \alpha \mathcal{S}(\nabla f_{q_k}(\mathbf{g}_k))$$

$$\mathbf{q}_{k+1} = \mathbf{q}_k + \beta \nabla f_{g_{k+1}}(\mathbf{q}_k)$$

Gradient sparsity

$\mathcal{S}$: pick largest ρ elements per trace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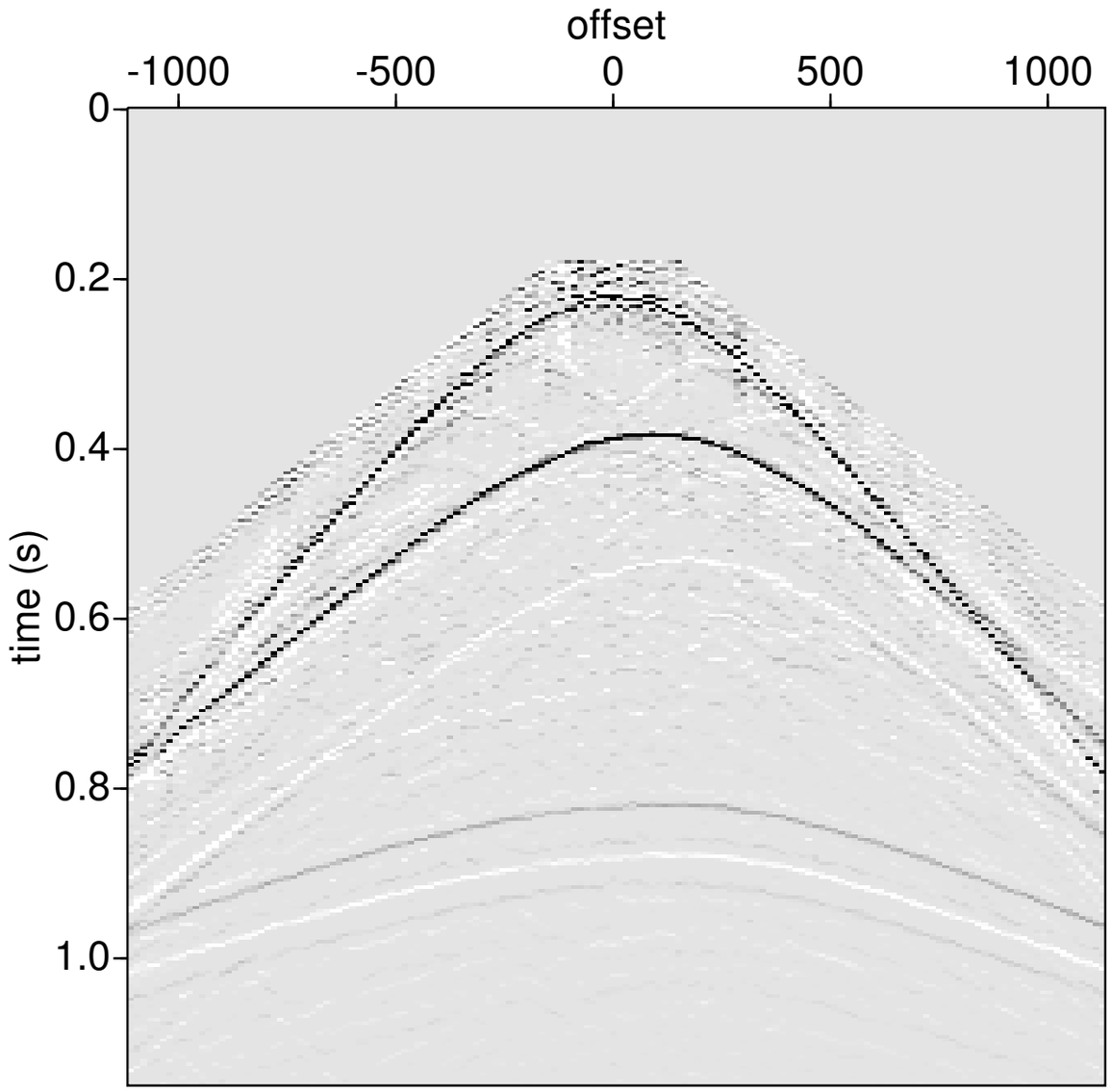
500
1000
0
0.2
0.4
0.6
0.8
1.0
time (s)

Data


offset
-1000
-500
0
500
1000
0
0.2
0.4
0.6
0.8
1.0
time (s)

EPSI IR

Robust EPSI procedure

While $\|\mathbf{p} - \mathcal{M}(\mathbf{g}_k, \mathbf{q}_k)\|_2 > \sigma$

determine new τ_k

$$\mathbf{g}_{k+1} = \arg\min_{\mathbf{g}} \|\mathbf{p} - \mathbf{M}_{q_k}\mathbf{g}\|_2 \text{ s.t. } \|\mathbf{g}\|_1 \leq \tau_k$$

(Solve with SPGL1)

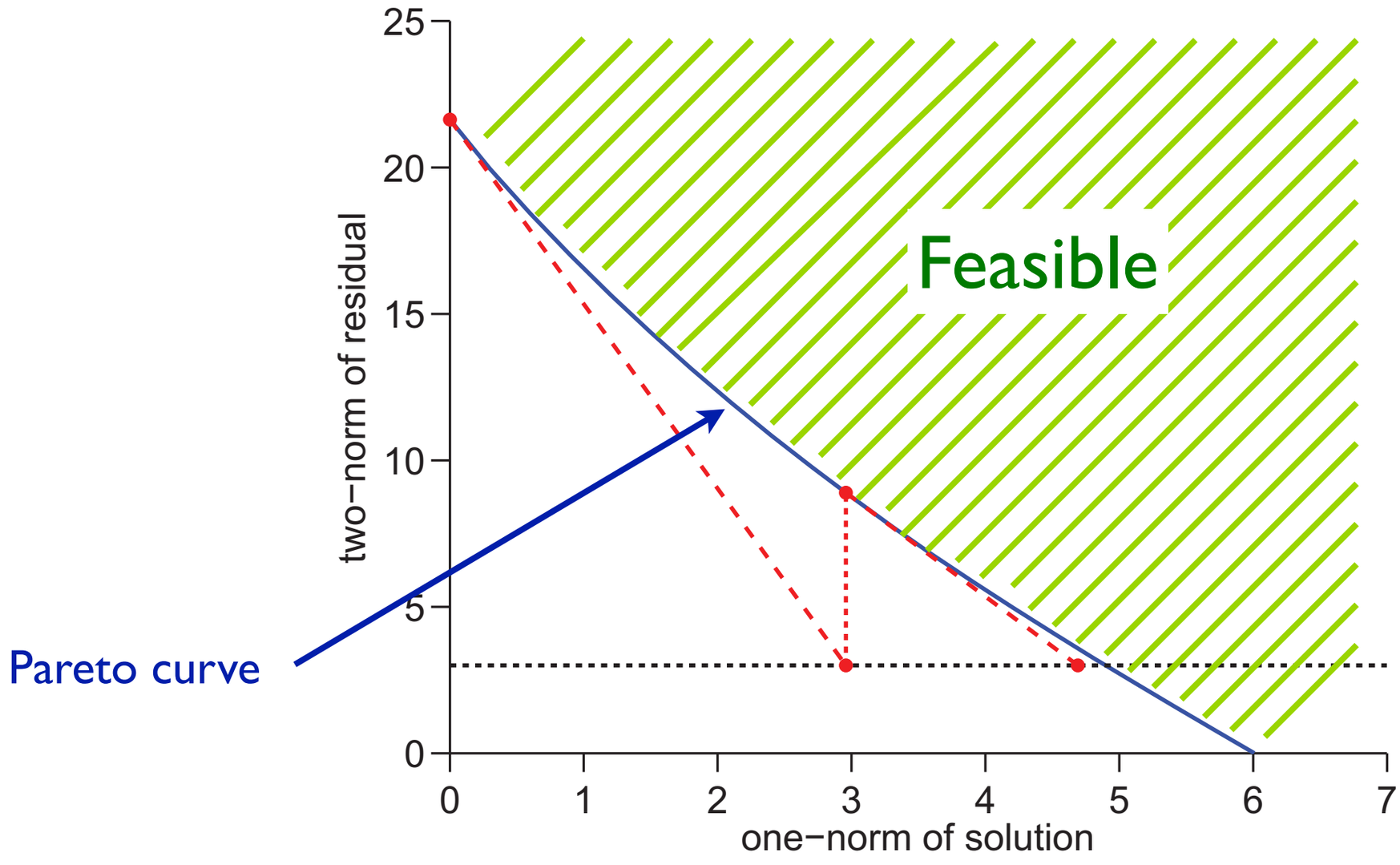
$$\mathbf{q}_{k+1} = \arg\min_{\mathbf{q}} \|\mathbf{p} - \mathbf{M}_{g_{k+1}}\mathbf{q}\|_2$$

(Solve with LSQR)

Pareto curve

$$\begin{aligned} \text{minimize} \quad & \|Ax - b\|_2 \\ \text{subject to} \quad & \|x\|_1 \leq \tau \end{aligned}$$

Look at the solution space and the line of optimal solutions (Pareto curve)



(van den Berg, Friedlander, 2008)

Pareto curve

$$\begin{aligned} \text{minimize} \quad & \|x\|_1 \\ \text{subject to} \quad & \|Ax - b\|_2 \leq \sigma \end{aligned}$$

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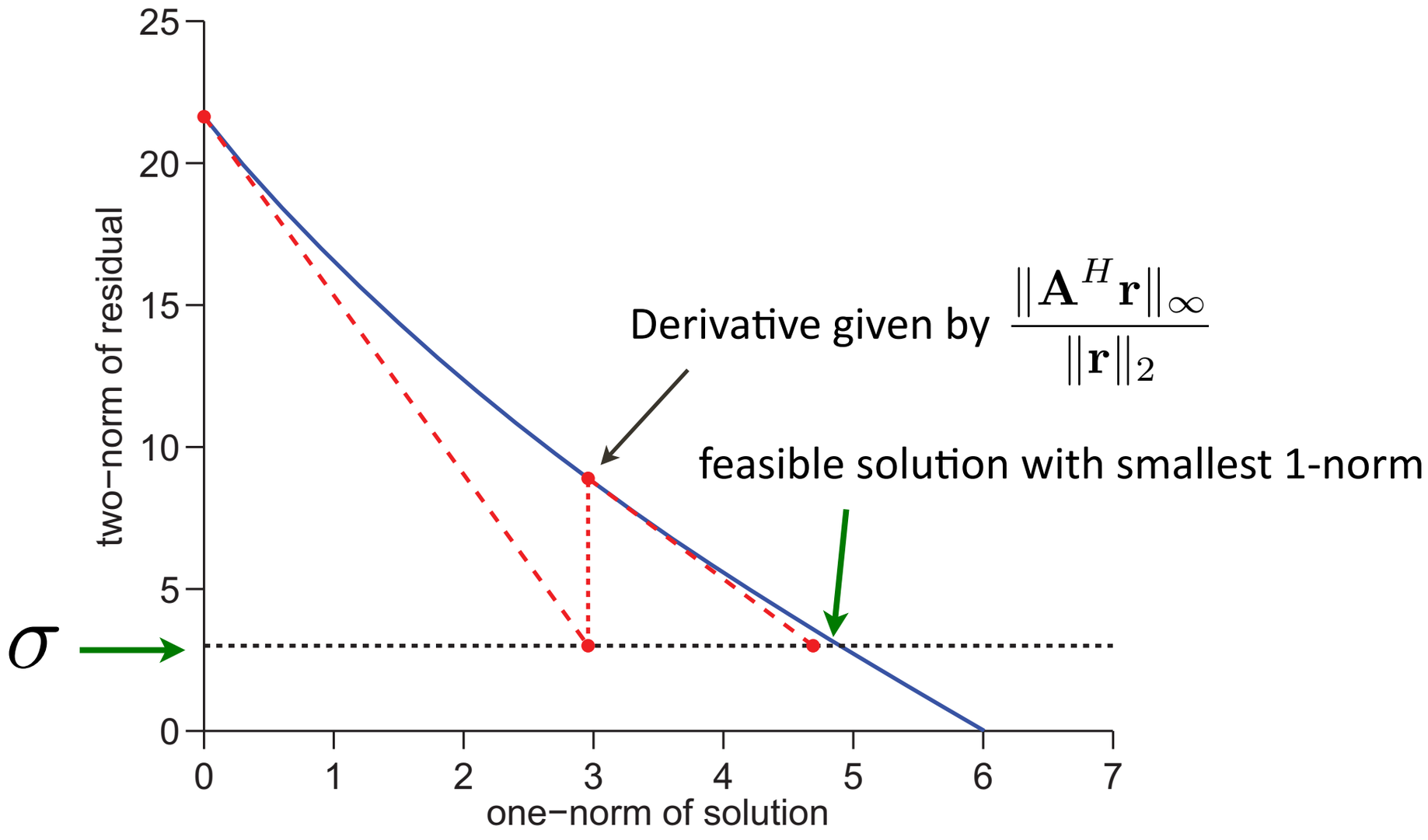
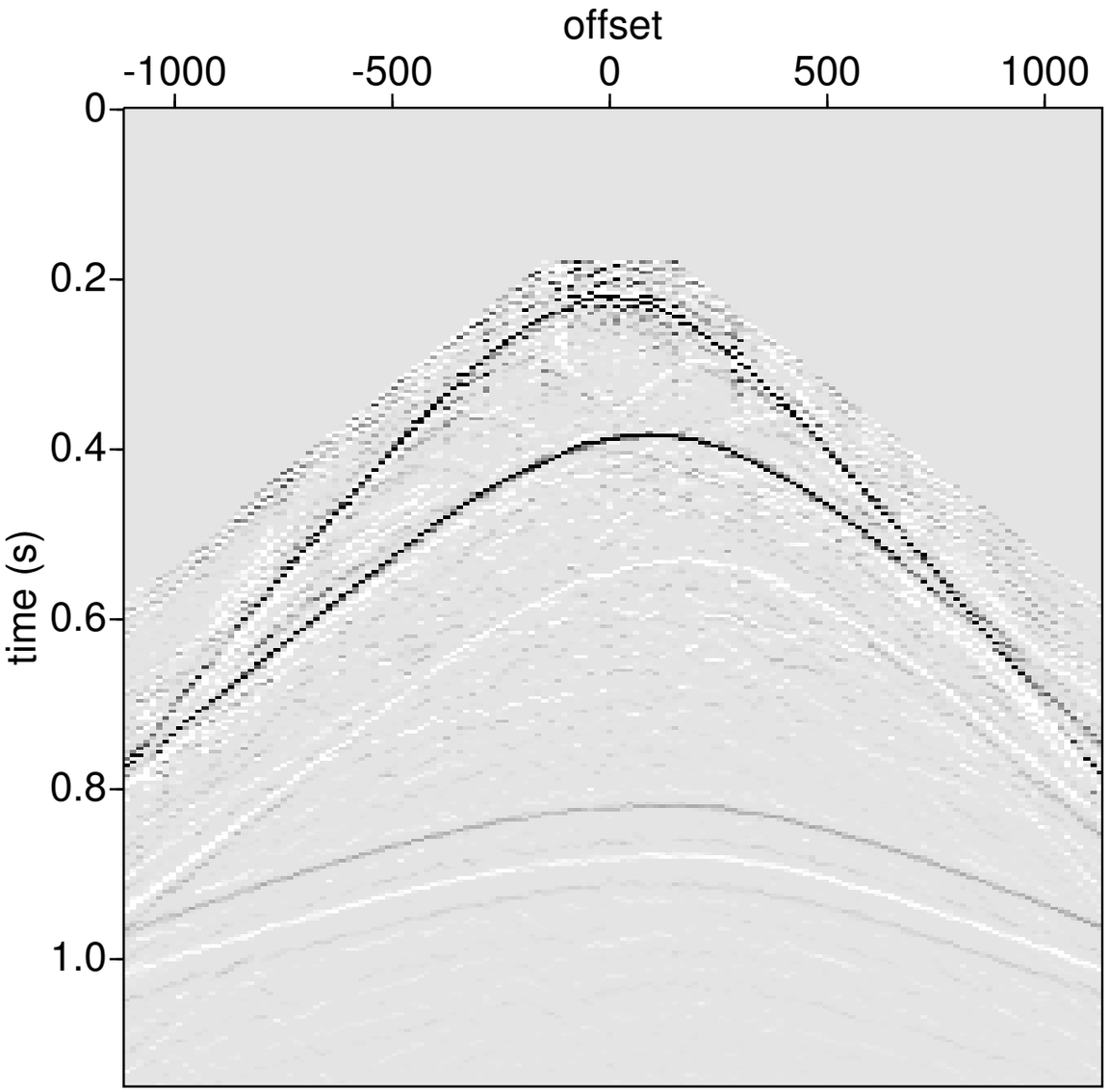
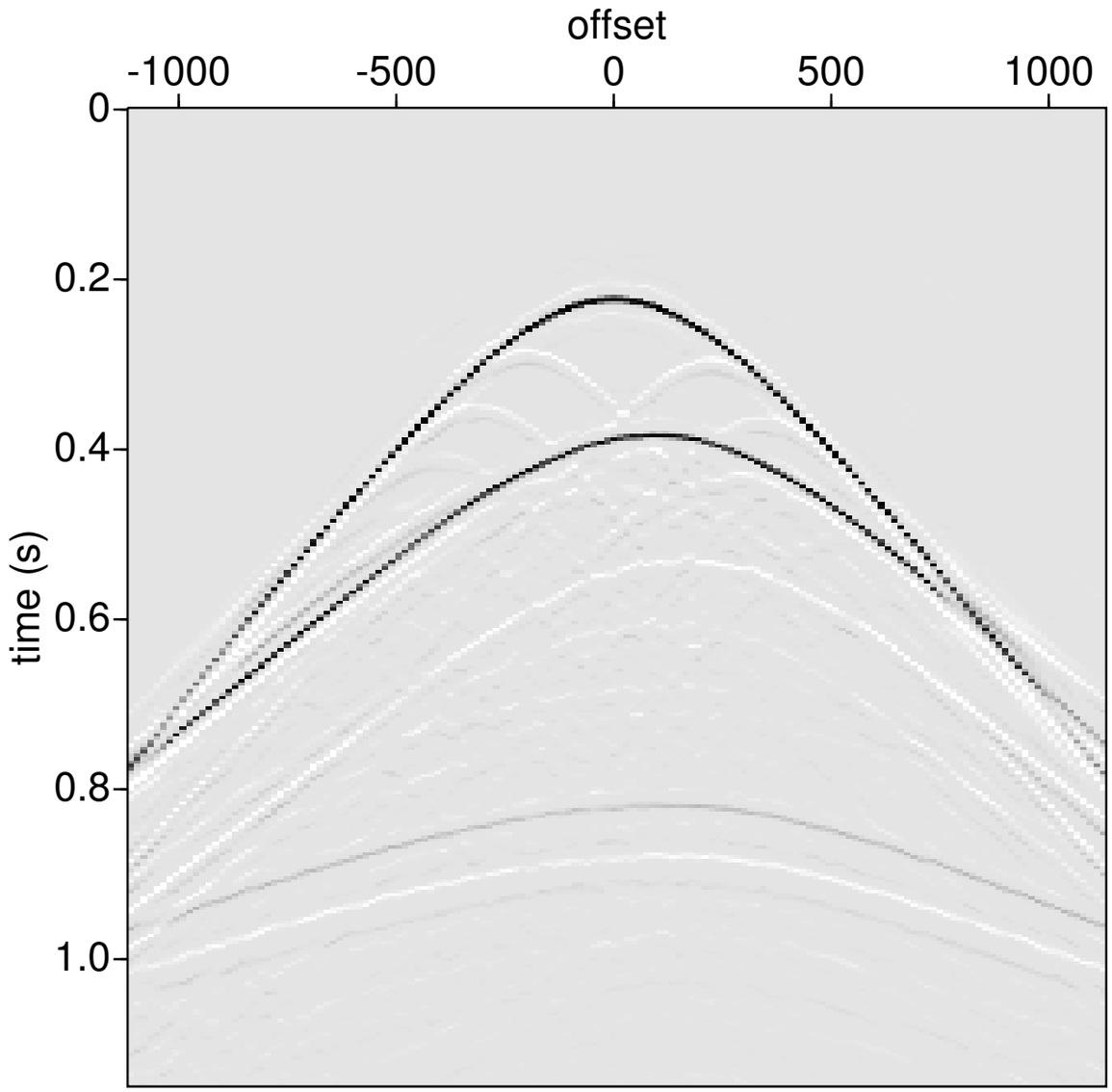
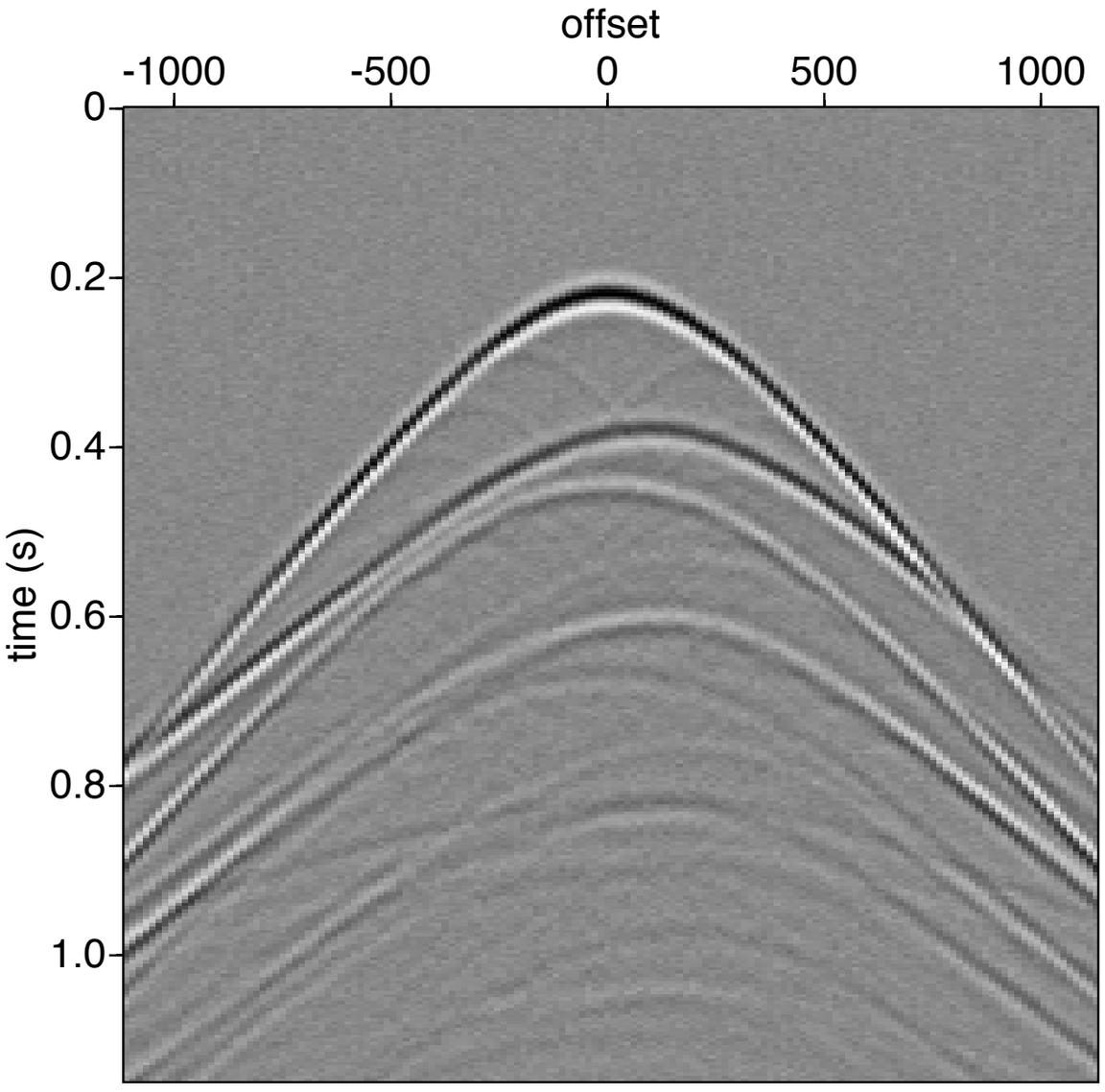




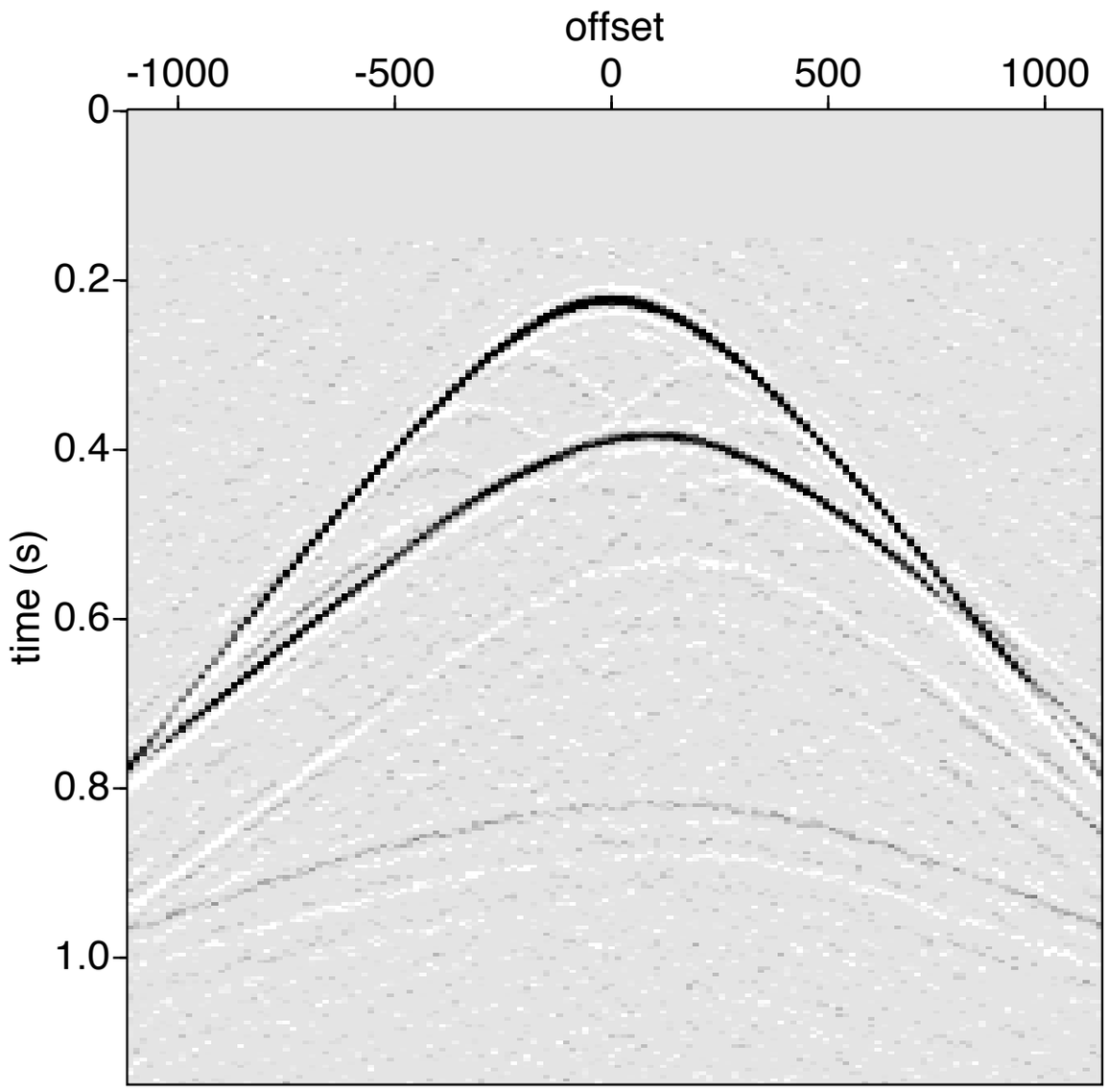
EPSI IR



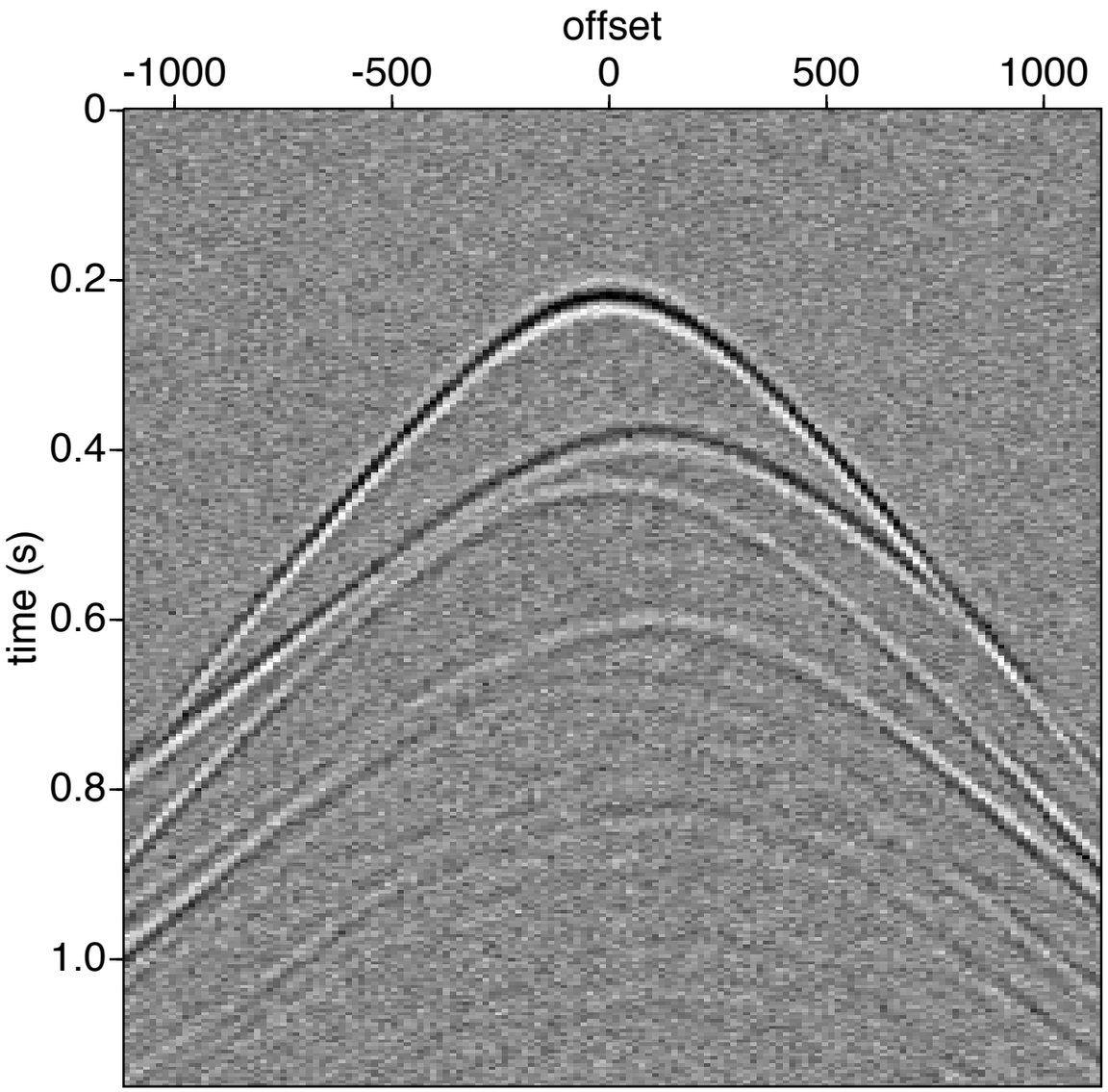
Robust EPSI IR



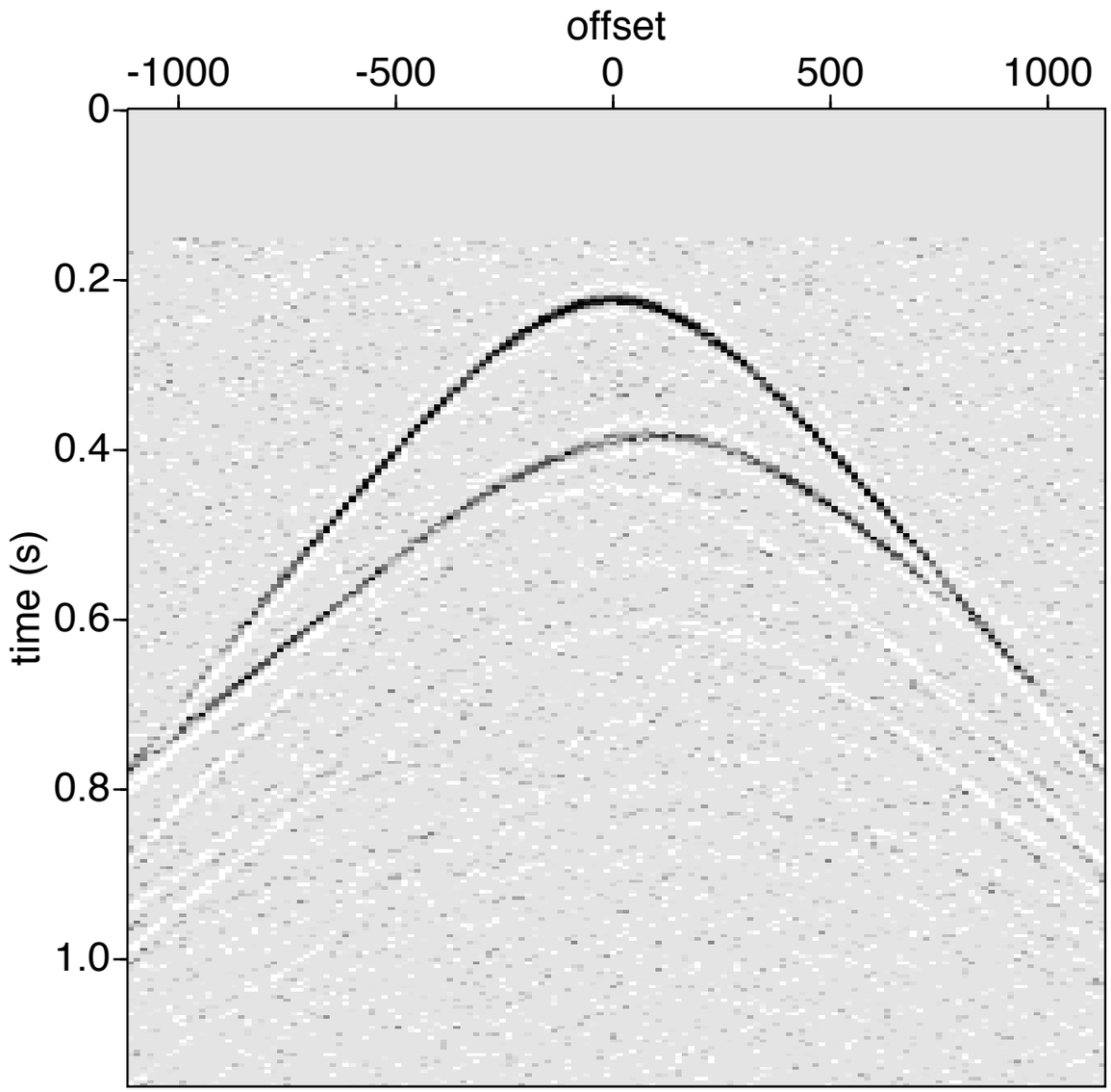
Data + 40% noise (SNR 7)



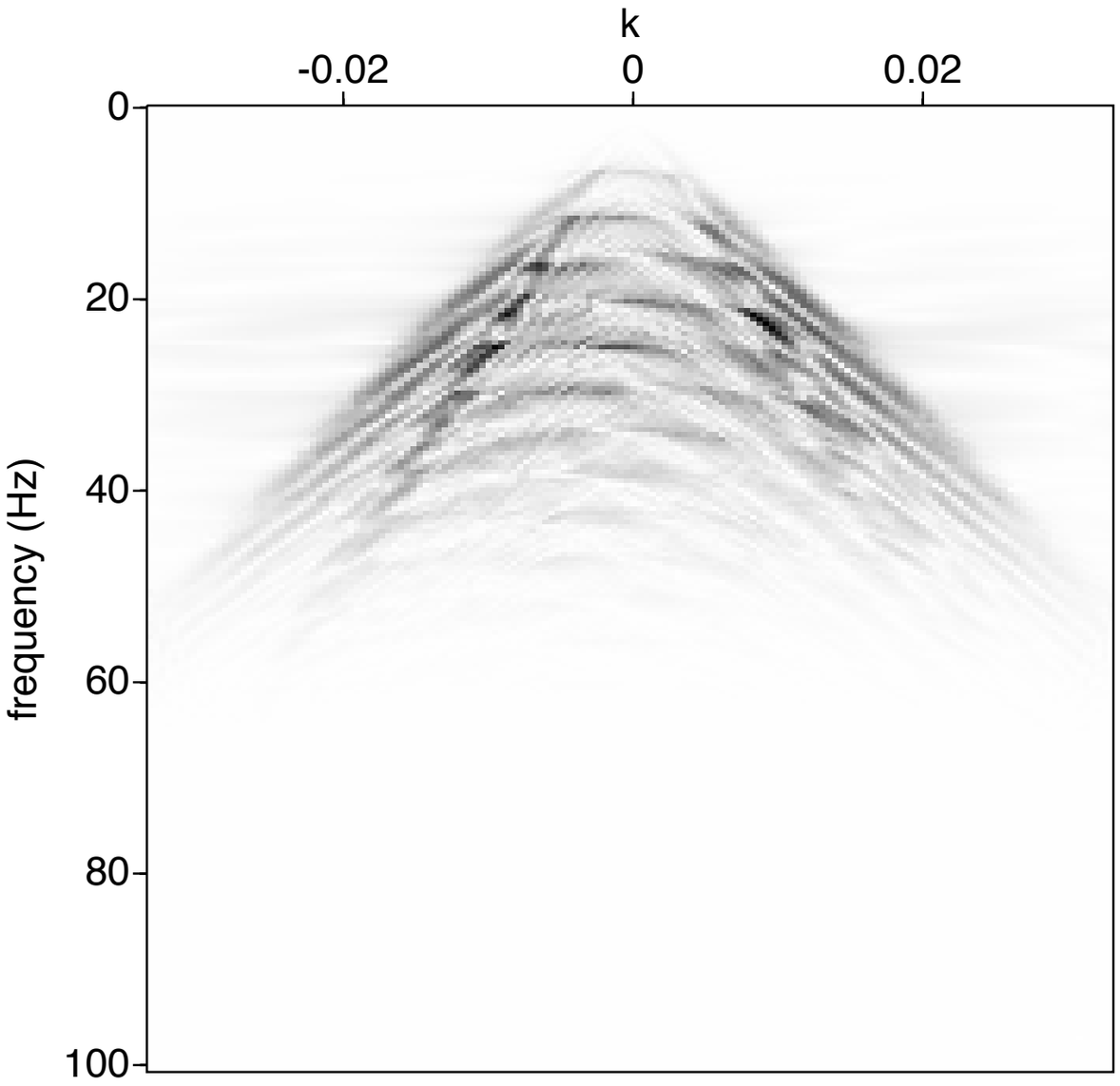
Robust EPSI IR



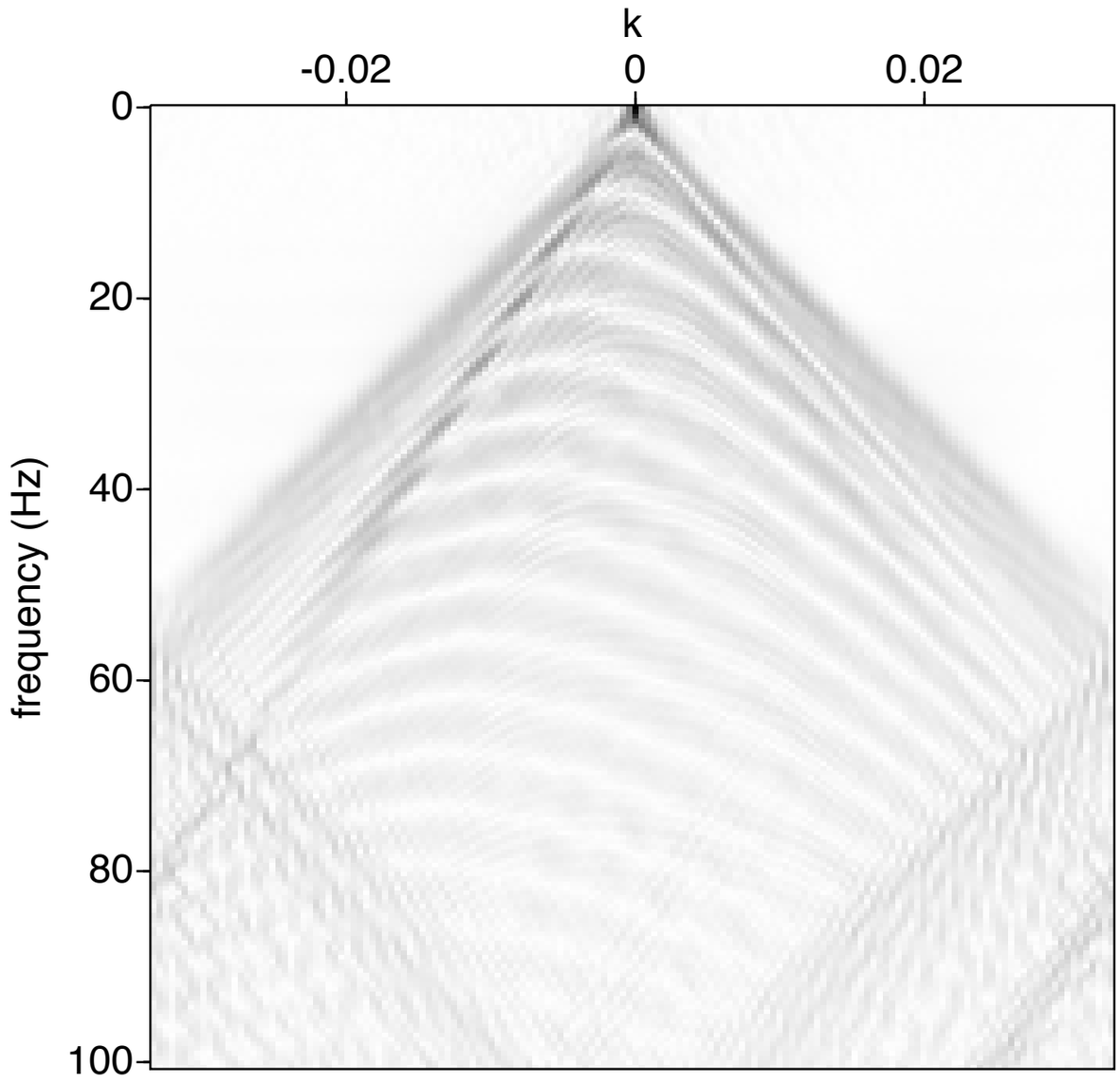
Data + 100% noise (SNR 0)



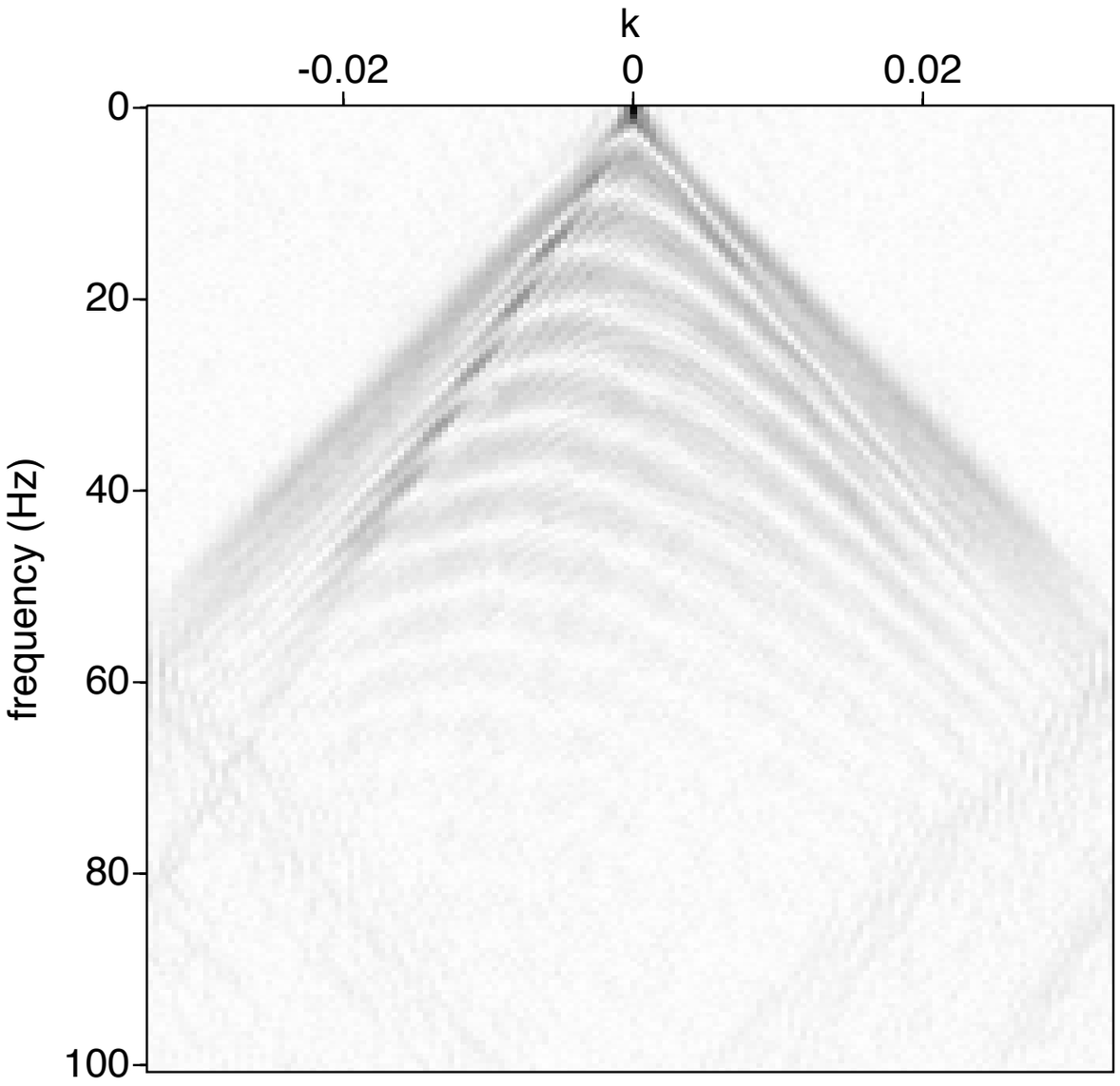
Robust EPSI IR



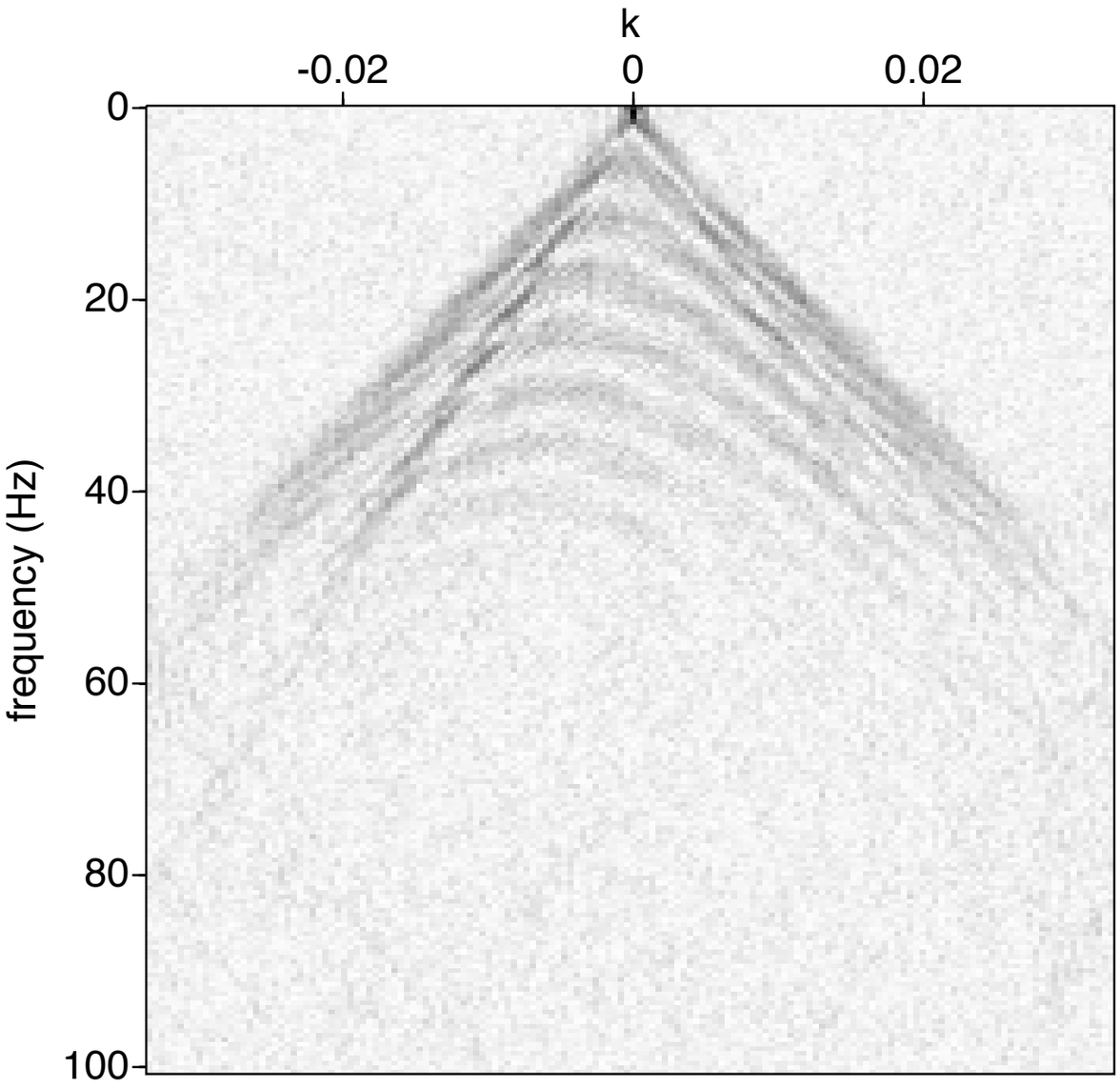
Data FK



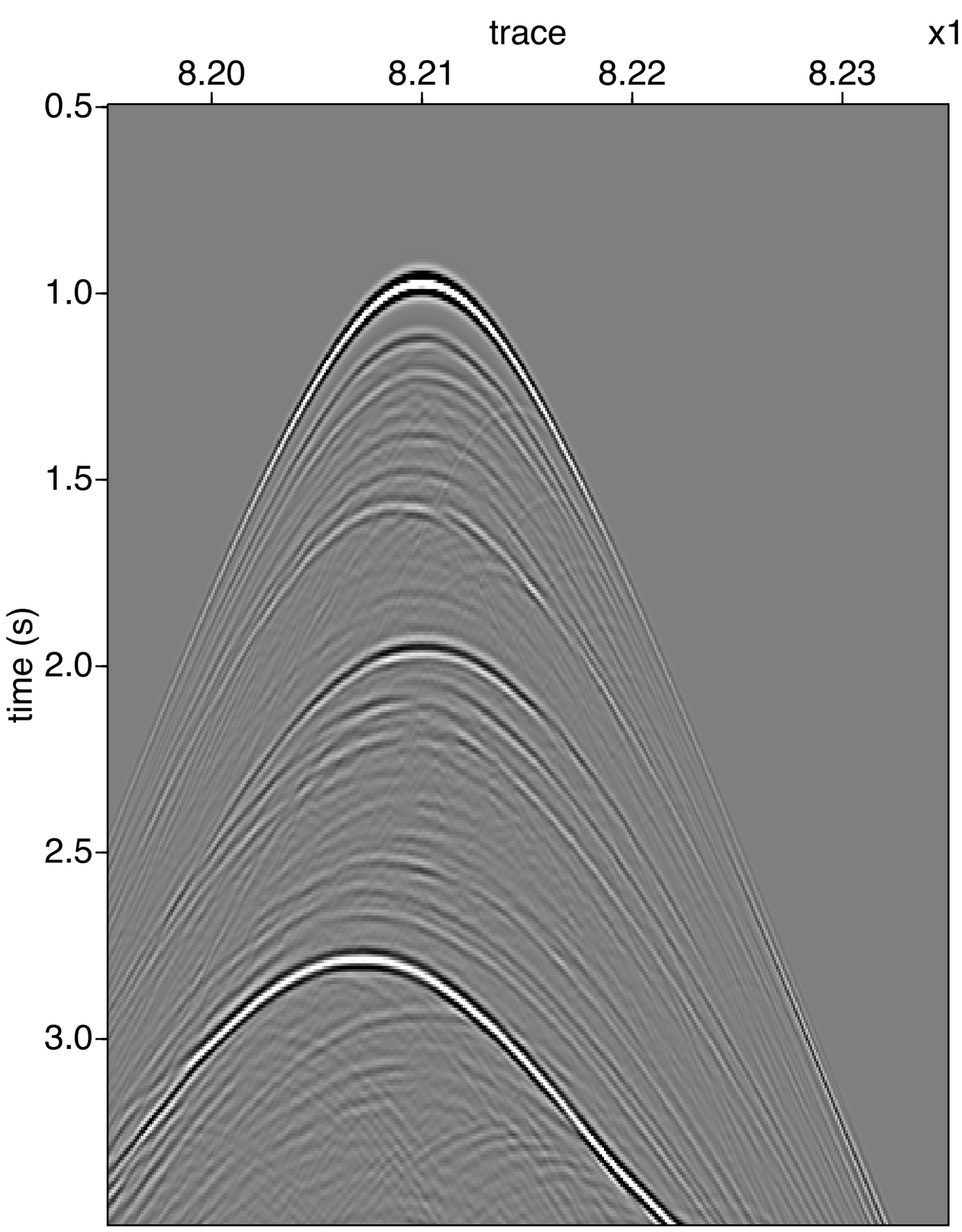
Robust EPSI IR FK



+40% noise Robust EPSI IR FK



+100% noise Robust EPSI IR FK



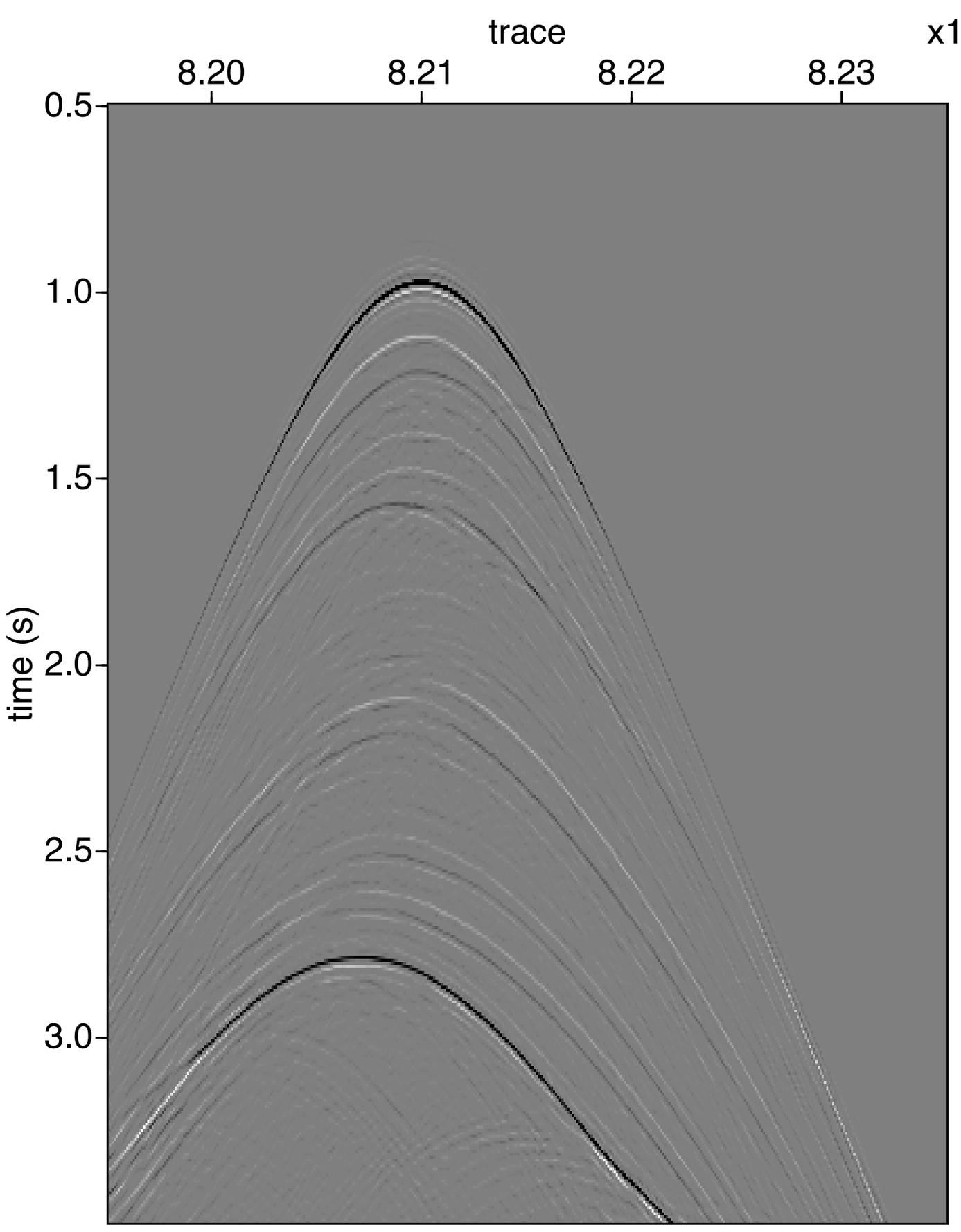
Pluto15

data

Elastic FD Modeling

muted

no deghosting



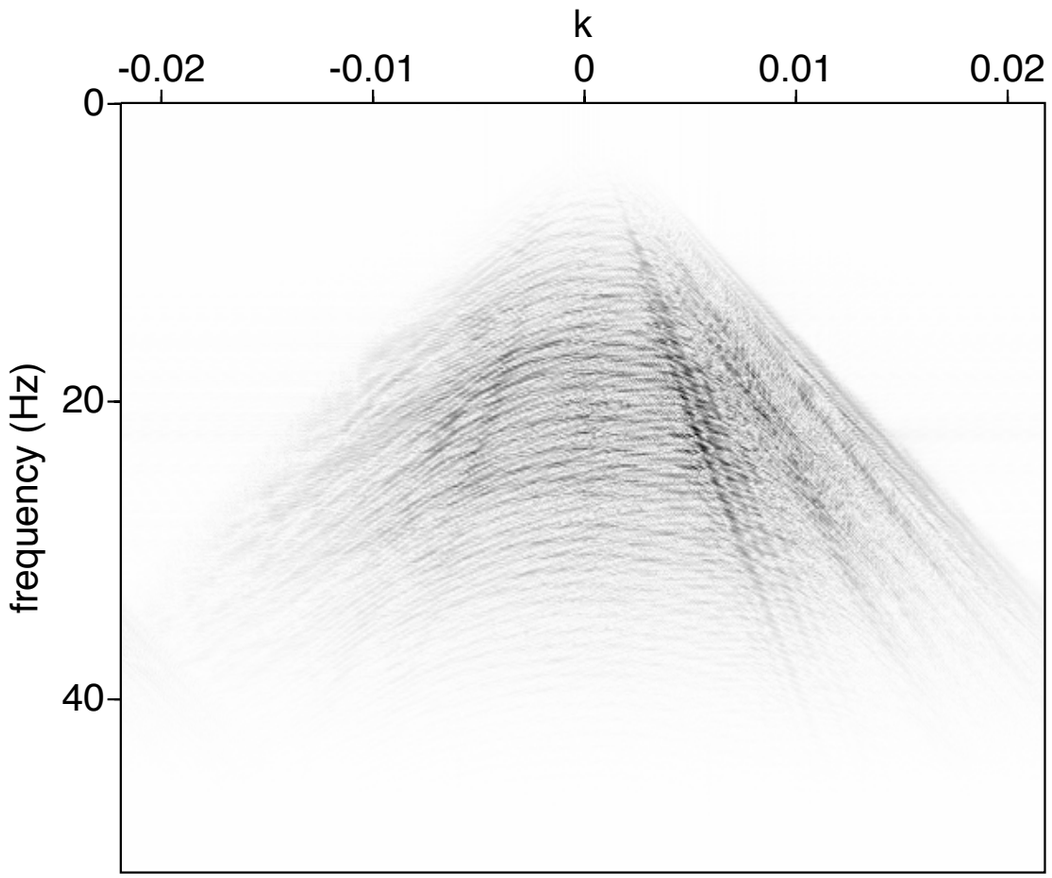
Pluto15

REPSI

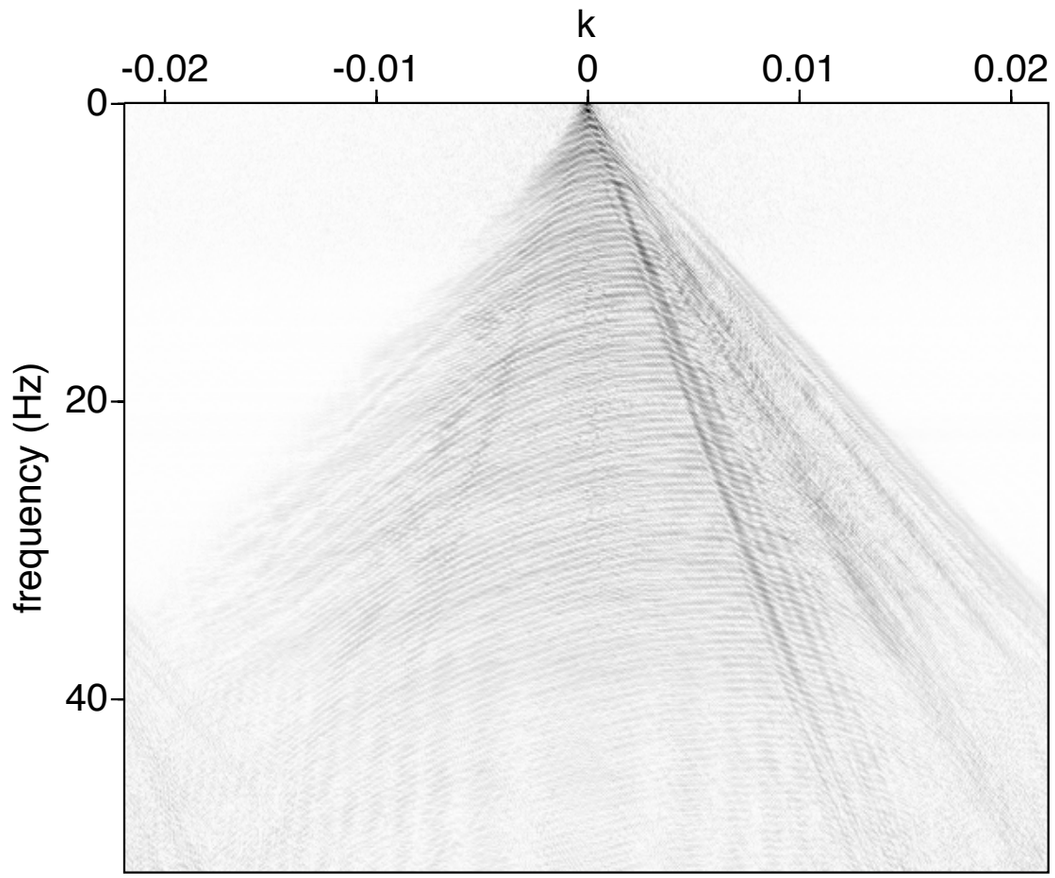
Primary IR (G)

no transform used

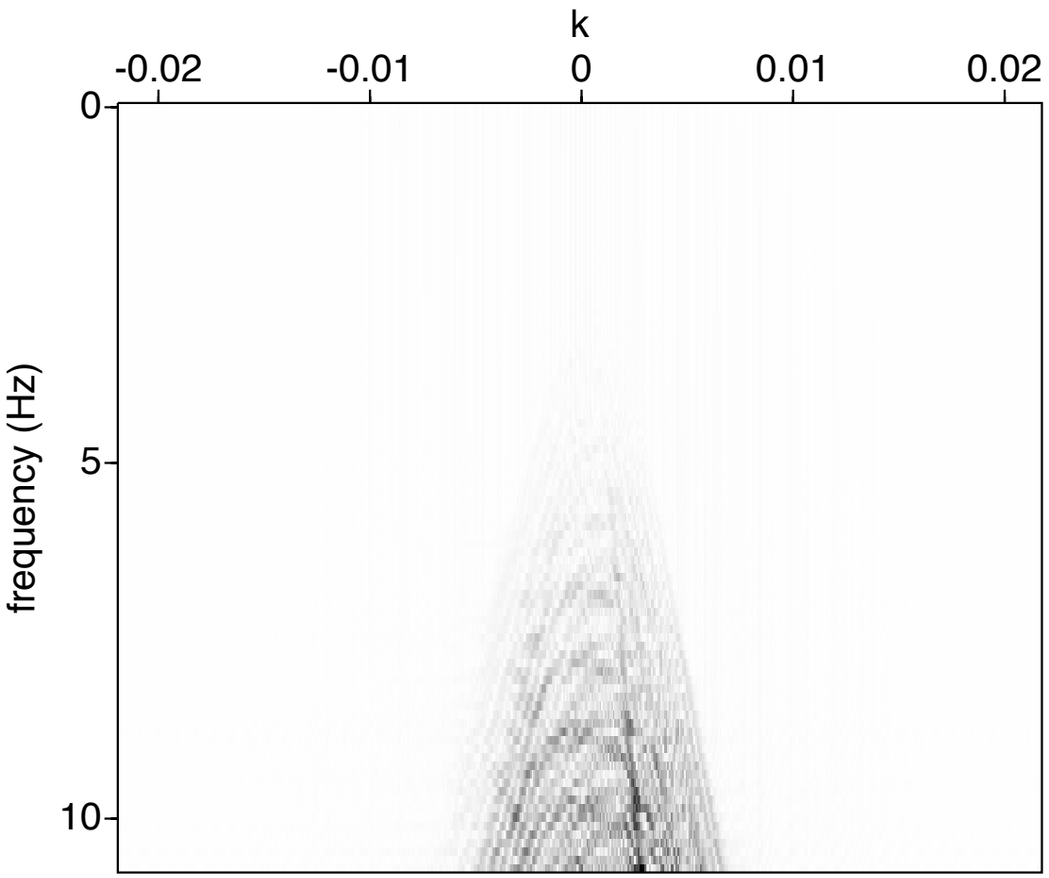
80 iters



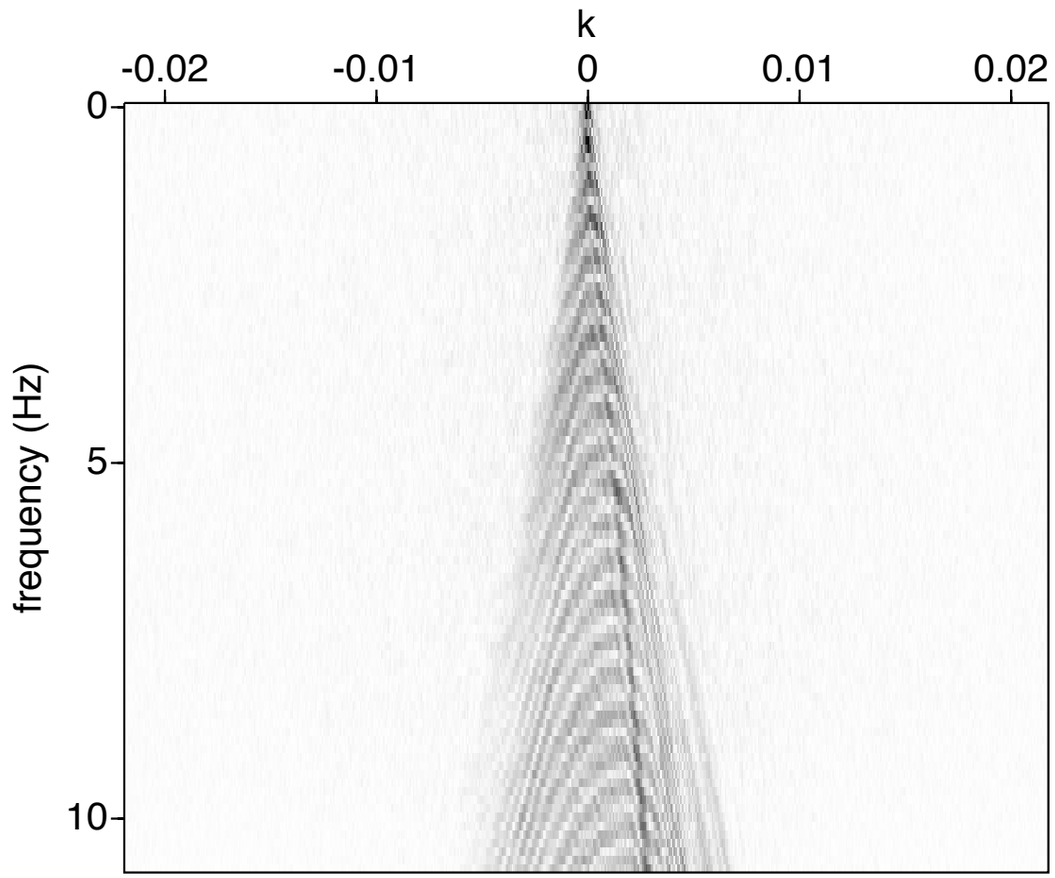
F-K Spectrum of data



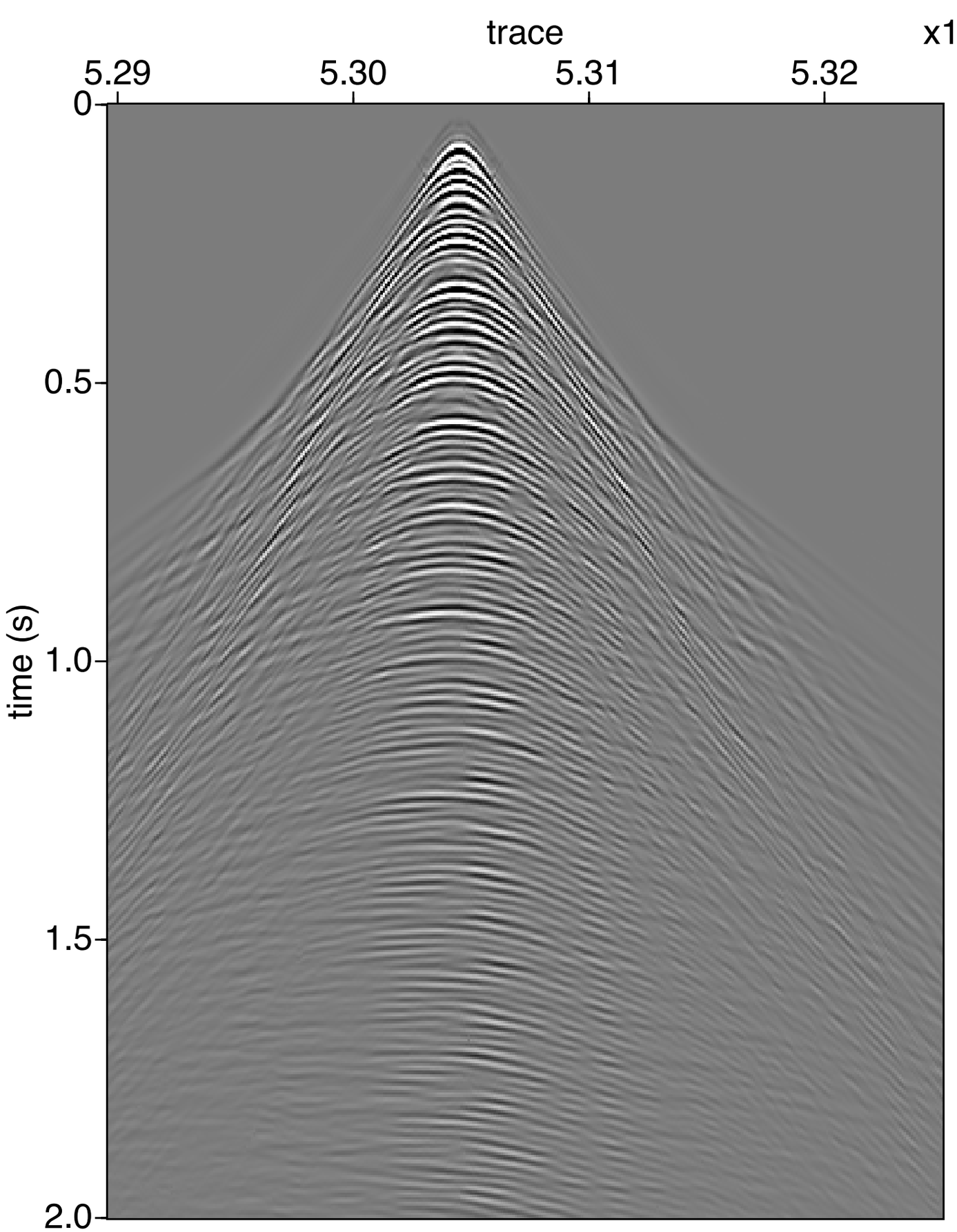
F-K Spectrum of REPSI Primary IR



F-K Spectrum of data



F-K Spectrum of REPSI Primary IR



Gulf of Suez

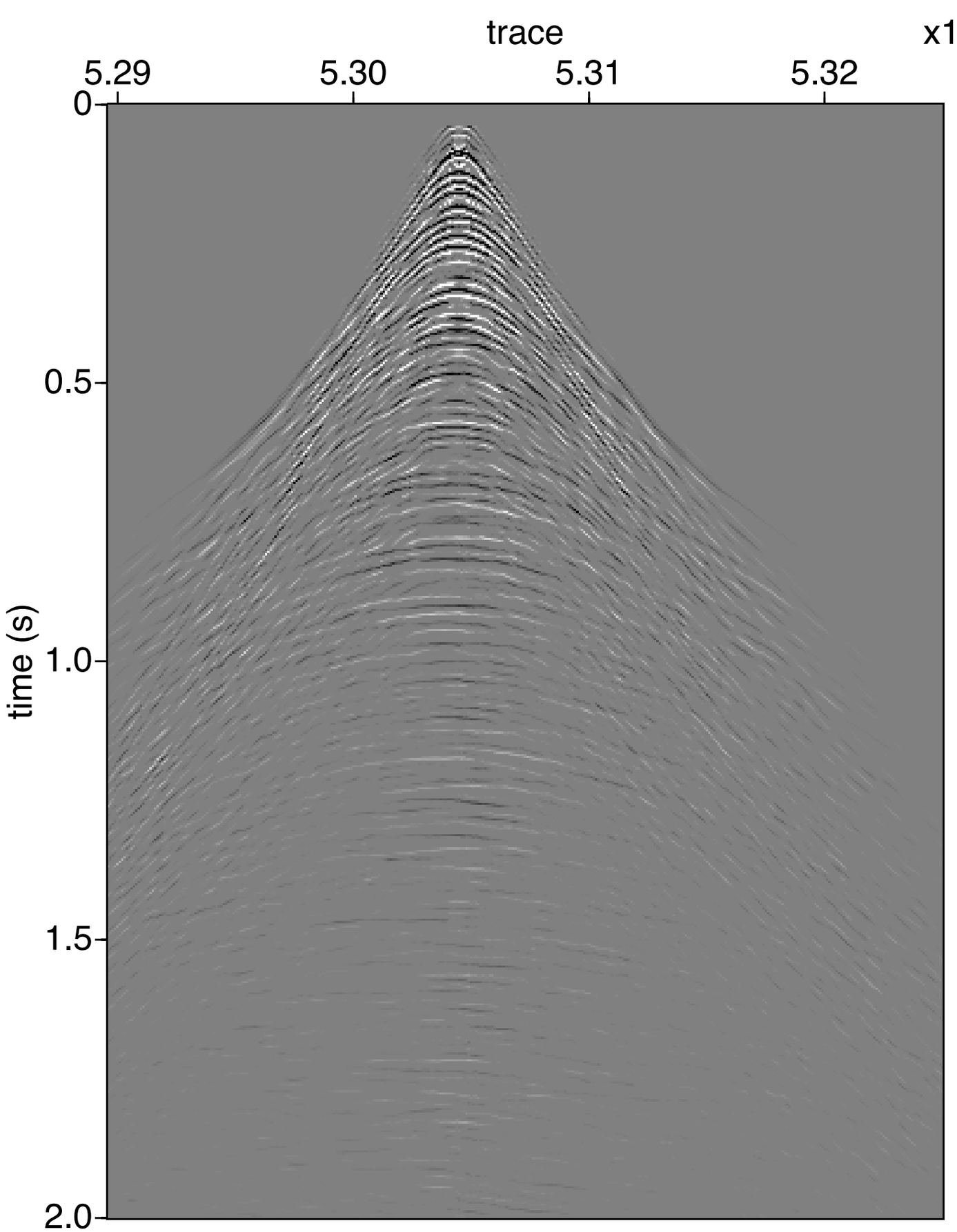
data

shot gather

interpolated, muted

reciprocity

no deghosting



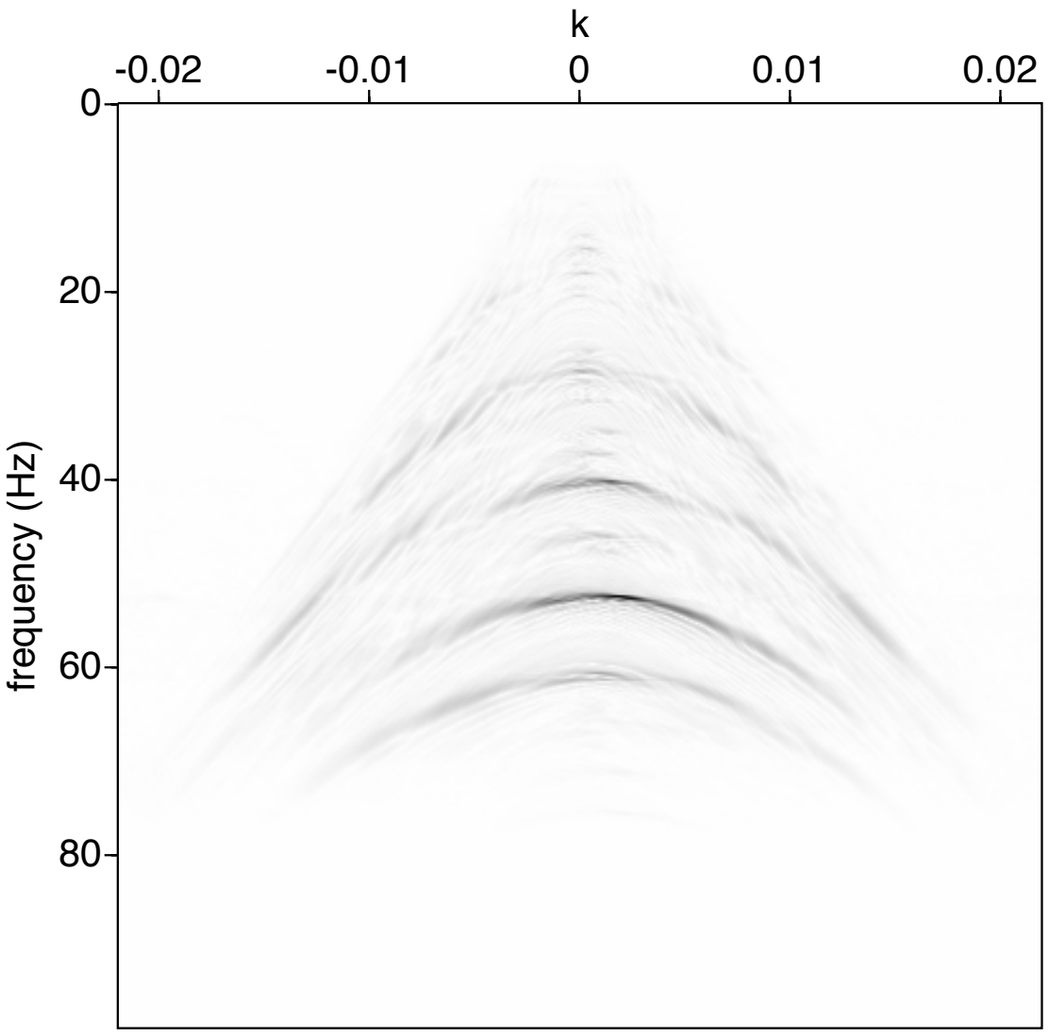
Gulf of Suez

REPSI

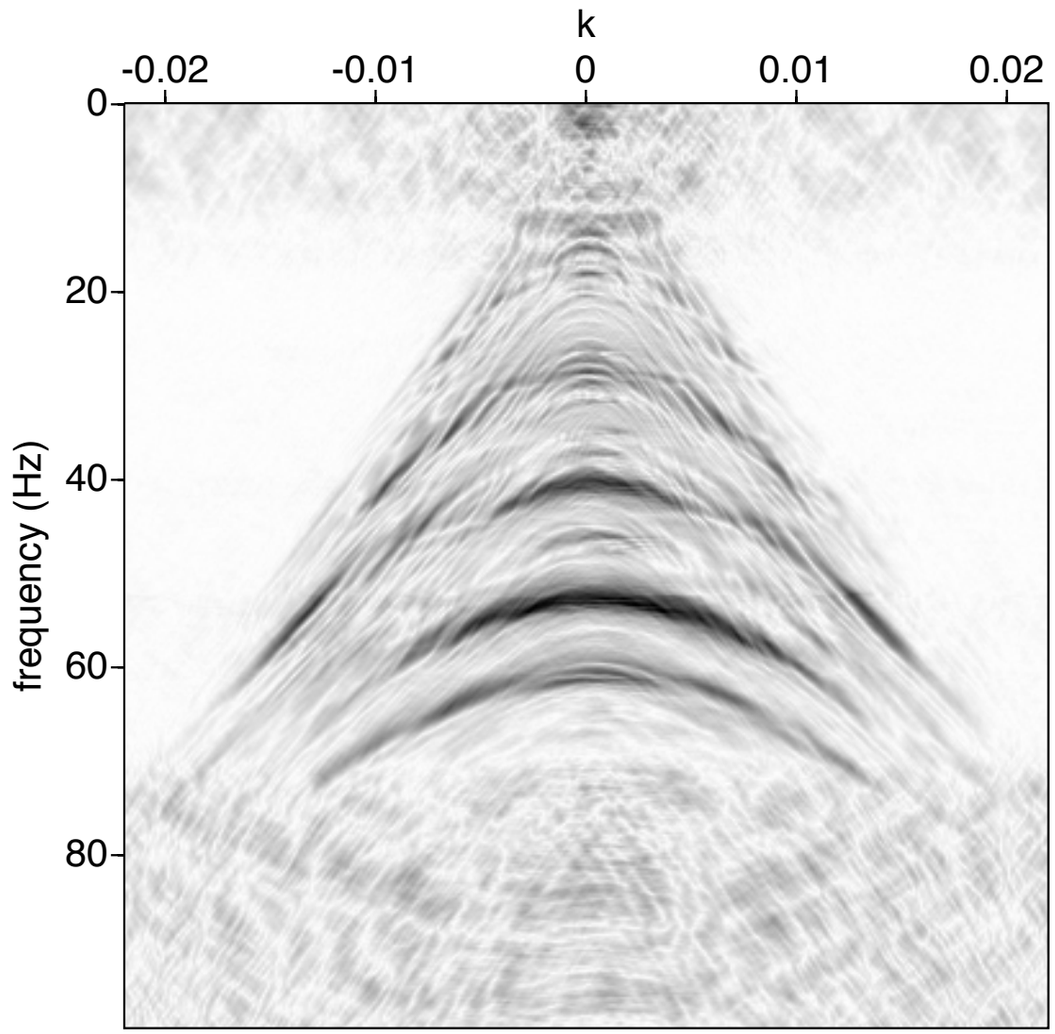
Primary IR (G)

shot gather

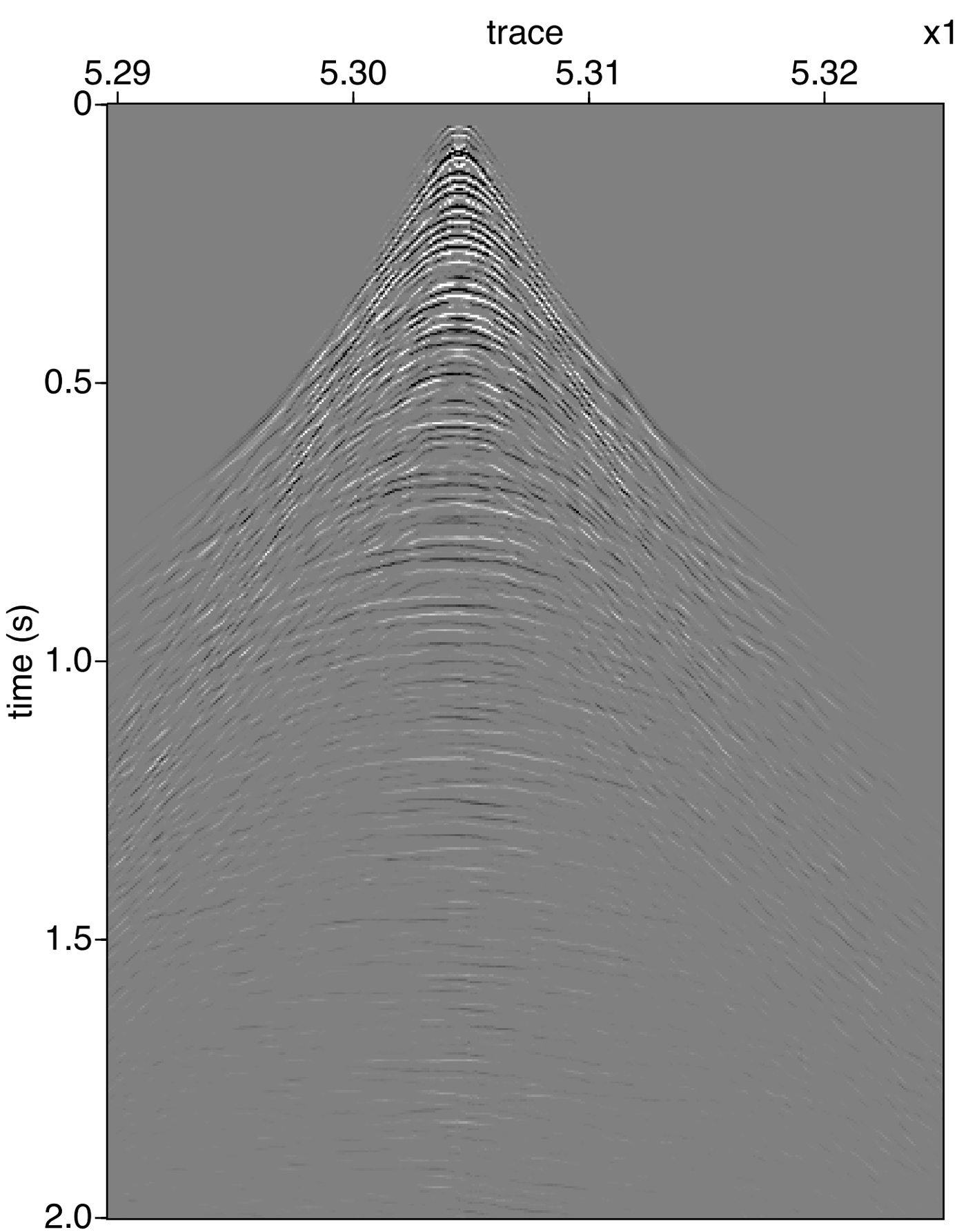
80 SPG grad. iterations



F-K Spectrum of data



F-K Spectrum of REPSI+Transform Primary IR



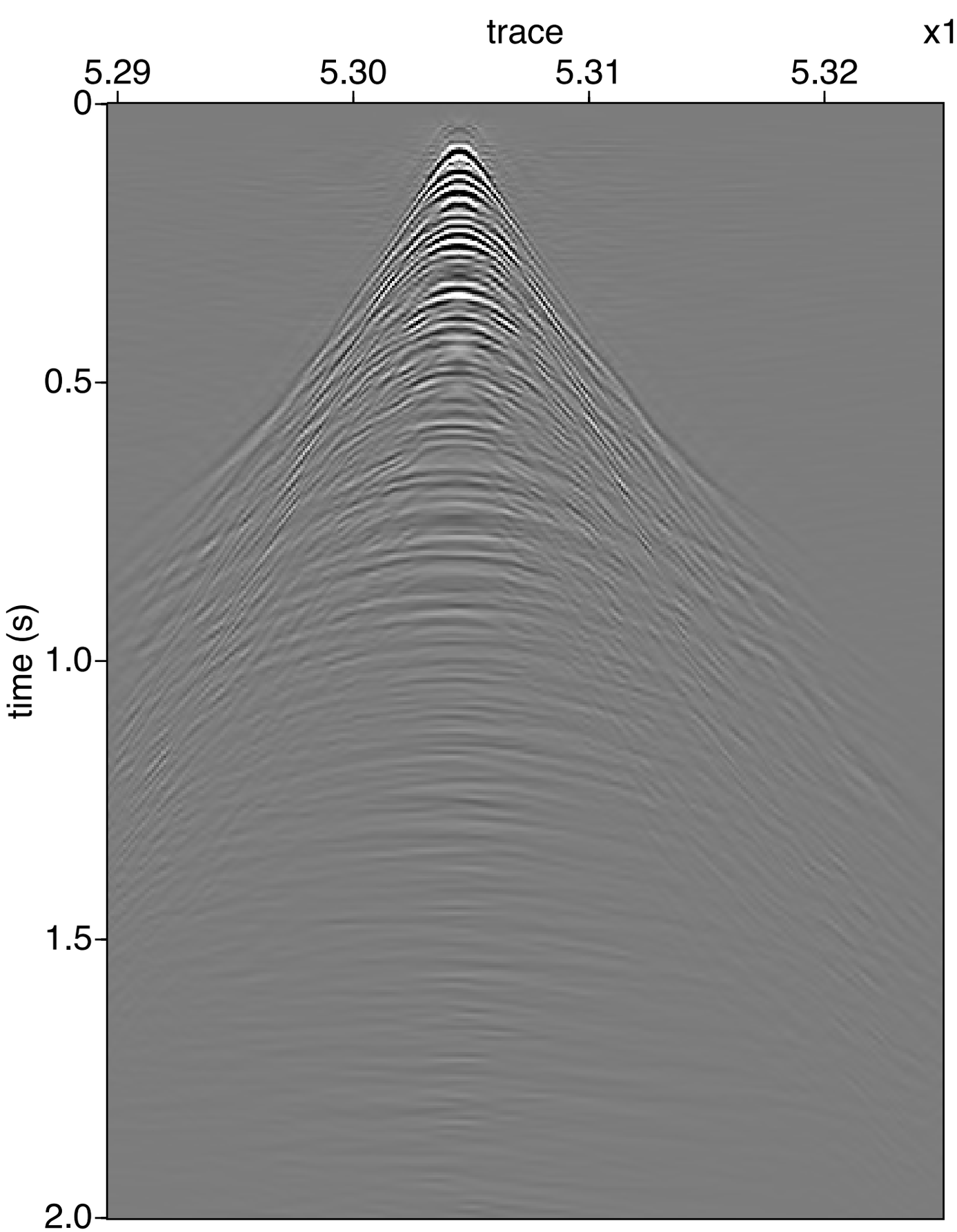
Gulf of Suez

REPSI

Primary IR (G)

shot gather

80 SPG grad. iterations



Gulf of Suez

REPSI + Transform

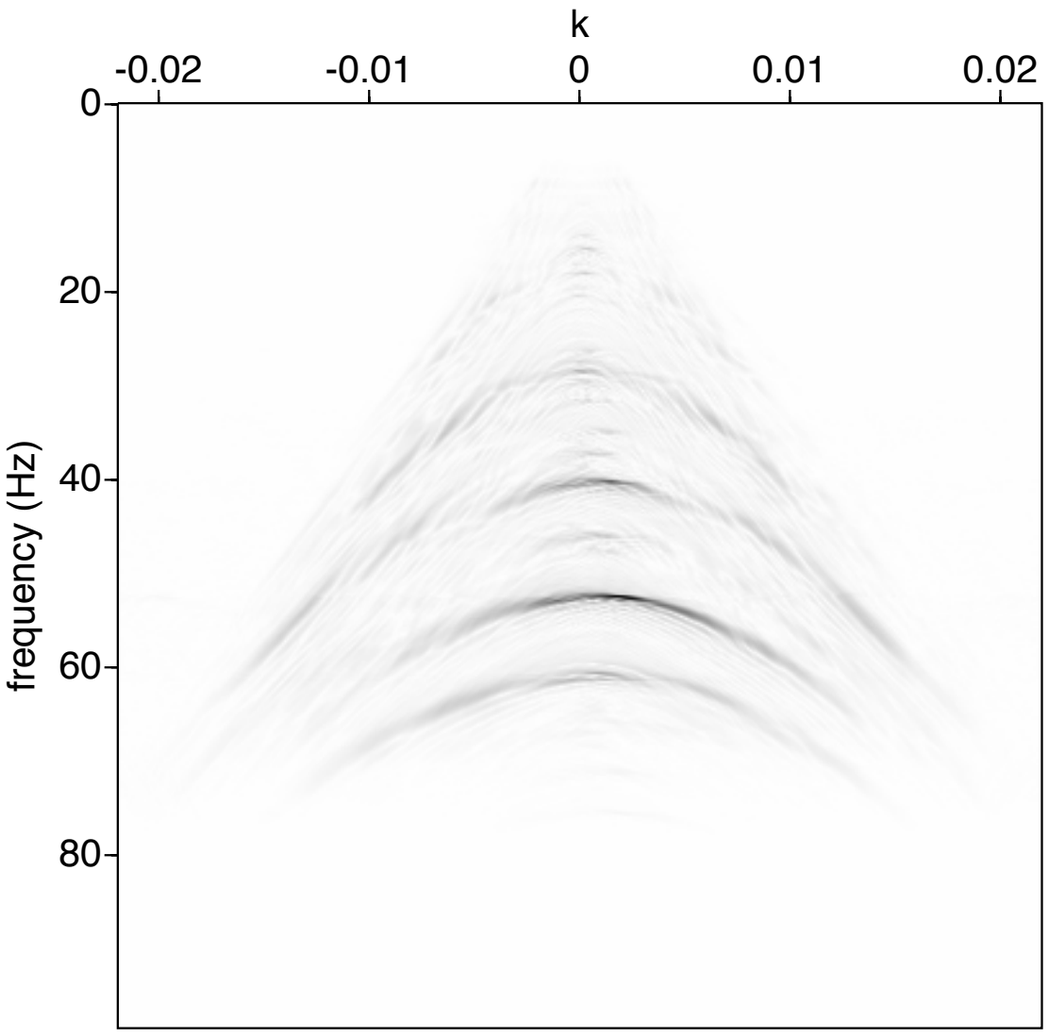
Primary IR (G)

shot gather

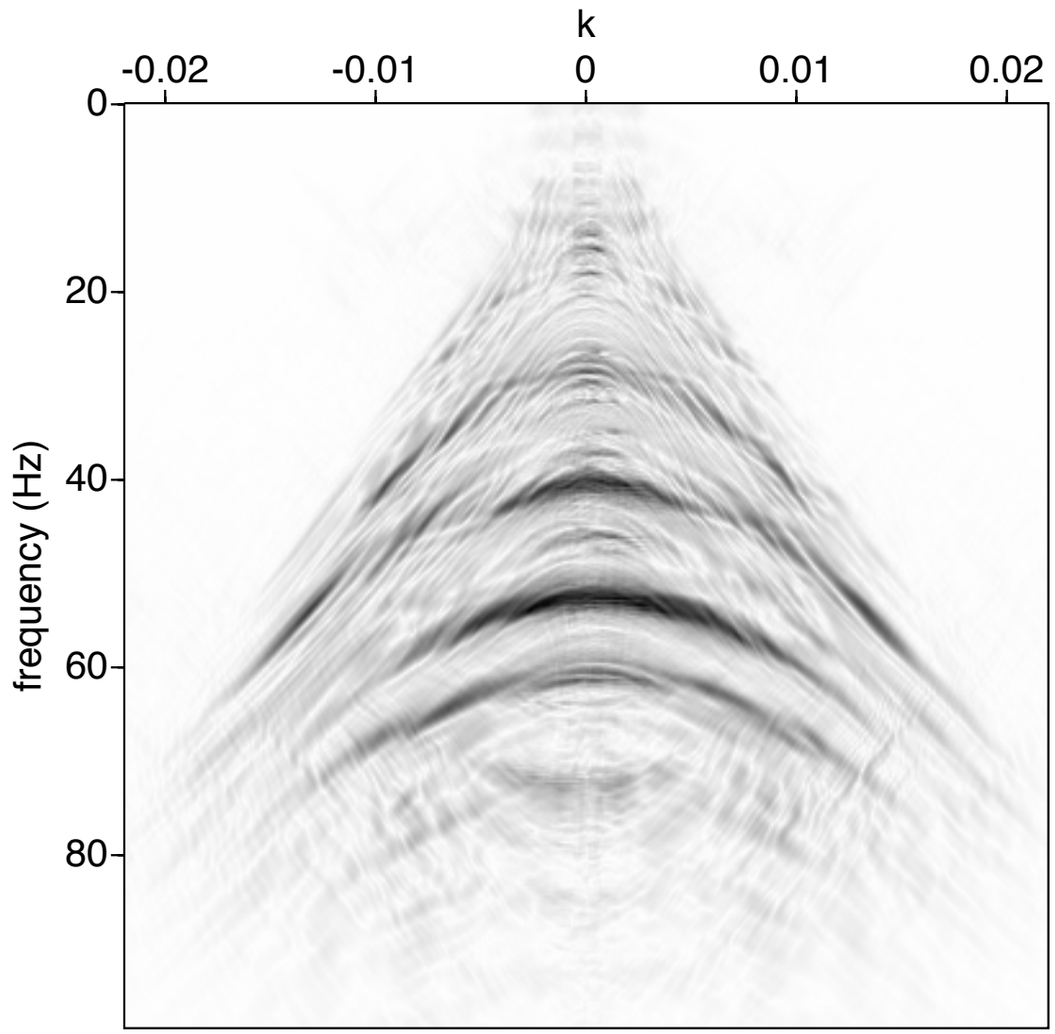
2D Curvelet (Src-Rcv)

Spline a=3.0 DWT (Time)

90 SPG grad. iterations



F-K Spectrum of data



F-K Spectrum of REPSI+Transform Primary IR

Discussion topics

- EPSI's place in the processing flow: are we there yet? Compatibility with existing inversion framework?
- Multiples here differentiates between seismic events and noise. Thus we should collect and preserve multiples as much as possible?
- What is the right representation basis/frame in which to reconstruct seismic impulse responses?

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- authors of SPGL1 + Pareto curve probing
- SMAART JV for Pluto1.5 model

SINBAD

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