Parameterization, stacking, and inversion of locally coherent events with the Common-Reflection-Surface Stack method

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Overview

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- assumption of 1-D model, $v_{\mathrm{RMS}} \stackrel{def}{=} v_{\mathrm{stack}}$ or $v_{\mathrm{RMS}} \stackrel{def}{=} v_{\mathrm{DMO}}$

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- fails for significant dip/curvature

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Final model beyond second-order approximation:

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$$t^2(\Delta\mathbf{x},\mathbf{h}) = (t_0 + 2\,\mathbf{p}\cdot\Delta\mathbf{x})^2 + 2t_0\left(\Delta\mathbf{x}^T\mathbf{M}_x\,\Delta\mathbf{x} + \mathbf{h}^T\mathbf{M}_h\,\mathbf{h}\right)$$

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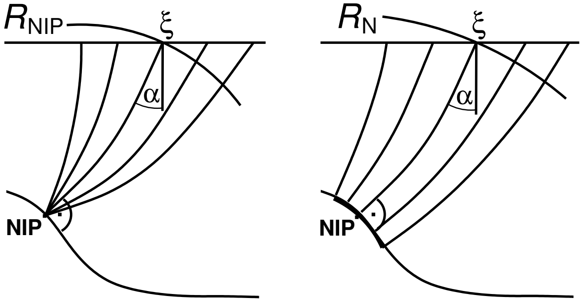
  ☞ geometrical interpretation

CRS wavefield attributes in 2-D

Geometrical interpretation of stacking parameters:



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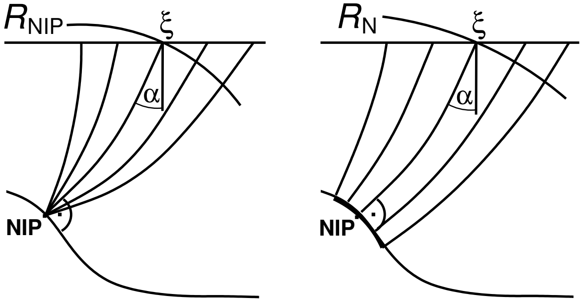

Emergence direction and curvatures of hypothetical wavefronts:

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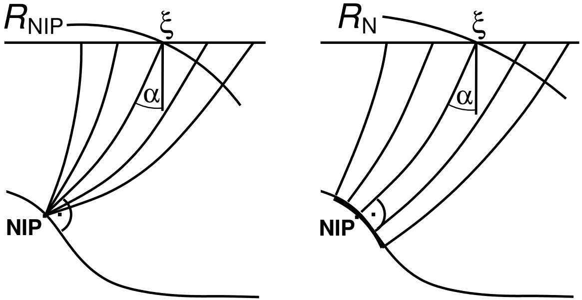

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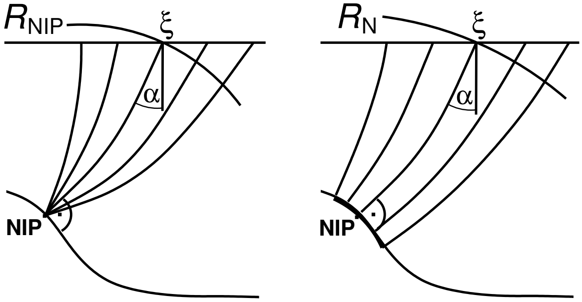

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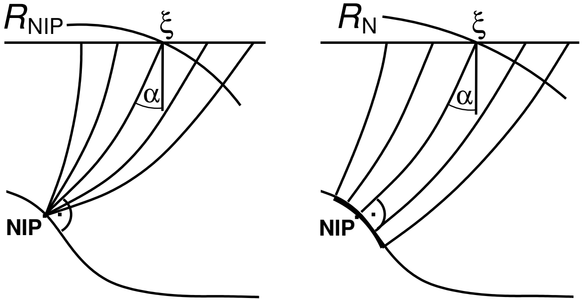

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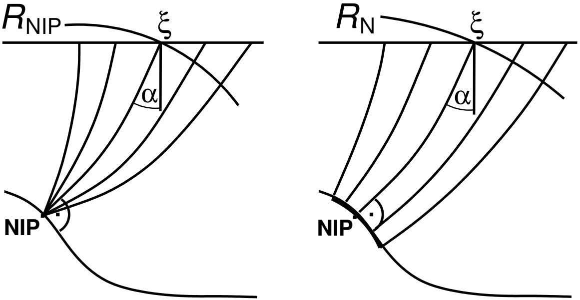

Emergence direction and curvatures of hypothetical wavefronts:

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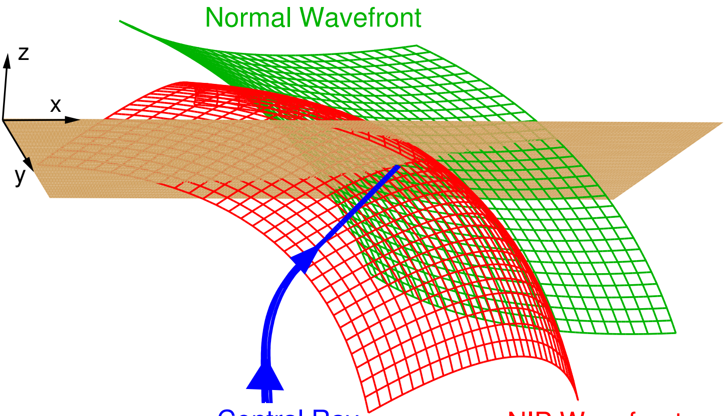
CRS wavefield attributes in 3-D



☞ slowness vector and curvature matrices!

(Höcht, 2002)

Reformulation of traveltime formula

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In terms of traveltime derivatives:

$$t^2(\Delta\mathbf{x},\mathbf{h}) = (t_0 + 2\,\mathbf{p}\cdot\Delta\mathbf{x})^2 + 2t_0\left(\Delta\mathbf{x}^T\mathbf{M}_x\,\Delta\mathbf{x} + \mathbf{h}^T\mathbf{M}_h\,\mathbf{h}\right)$$

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α, ψ	azimuth & emergence angle of normal ray
$\mathbf{D}$	transformation ray-centered/global coordinates
$\mathbf{K}_{\mathrm{NIP}}, \mathbf{K}_{\mathrm{N}}$	curvature matrix of NIP/normal wavefront
v_0	near-surface velocity

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  - Drop analytic approximation, switch to model-based diffraction traveltimes

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➥ analytic description

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$$(x, z, \Theta_0)_i \quad ; \quad v(x, z)$$

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- inversion of analytic diffraction traveltimes plus normal rays

Inversion with analytic diffraction traveltime

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$$\left(x_0, t_0, \left.\frac{\partial t}{\partial x}\right|_{(x_0,h=0)}, \left.\frac{\partial^2 t}{\partial h^2}\right|_{(x_0,h=0)} \right)_i$$

- model space

$$(x, z, \Theta_0)_i \quad ; \quad v(x, z)$$

- inversion of analytic diffraction traveltimes plus normal rays
- geometric interpretation: normal-incidence-point (NIP) wave

Inversion with analytic diffraction traveltime

NIP-wave tomography (2D)

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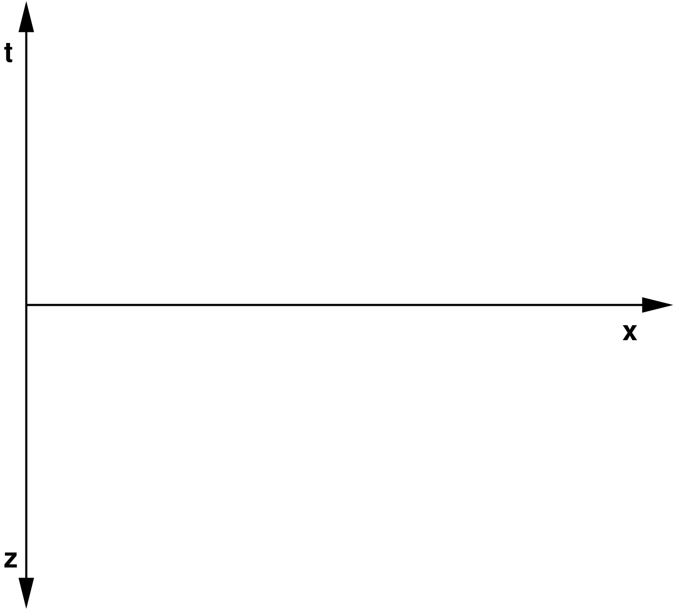
- inversion of analytic diffraction traveltimes plus normal rays
- geometric interpretation:
  normal-incidence-point (NIP) wave
- straightforward extension to 3-D

Principle of NIP-wave tomography



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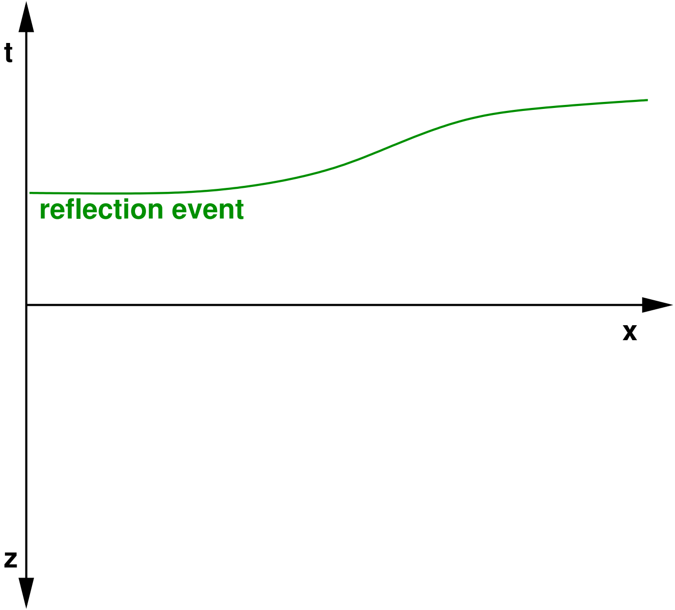

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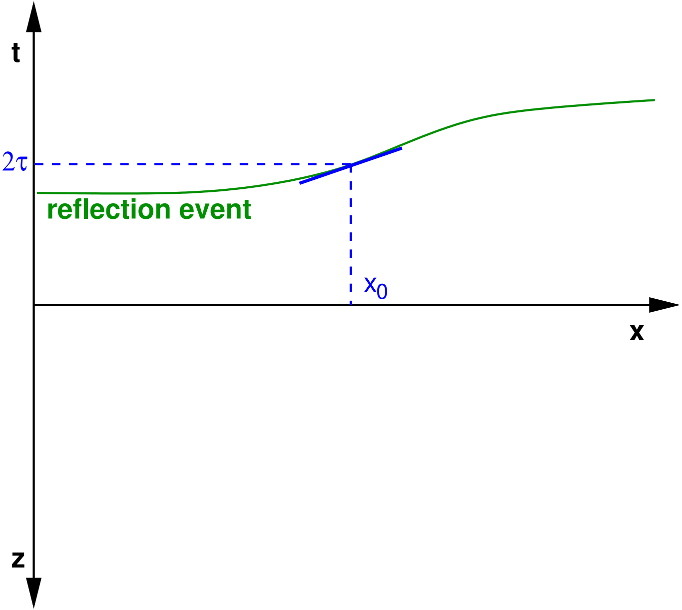

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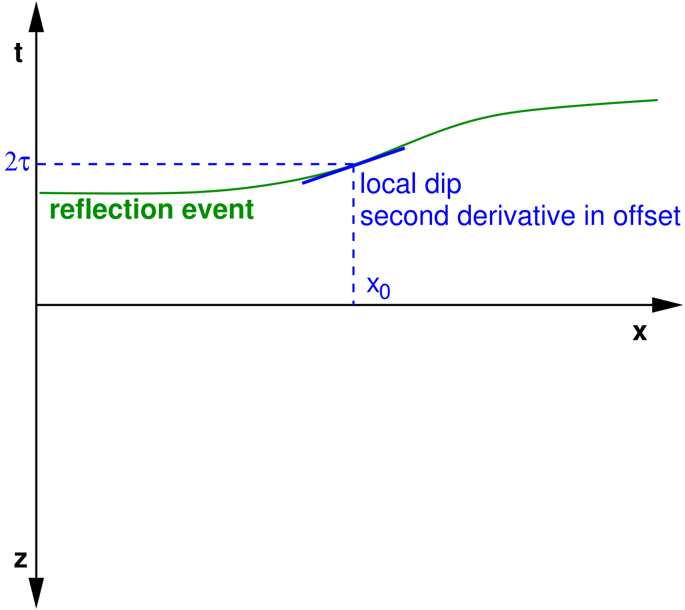

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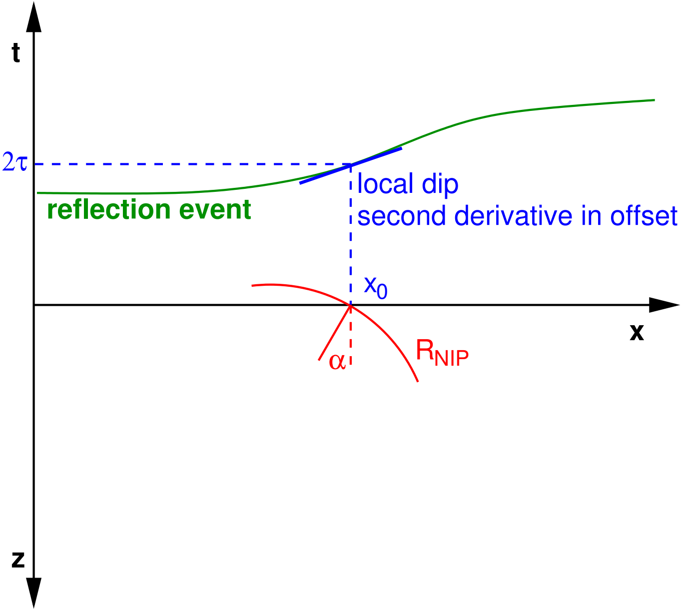

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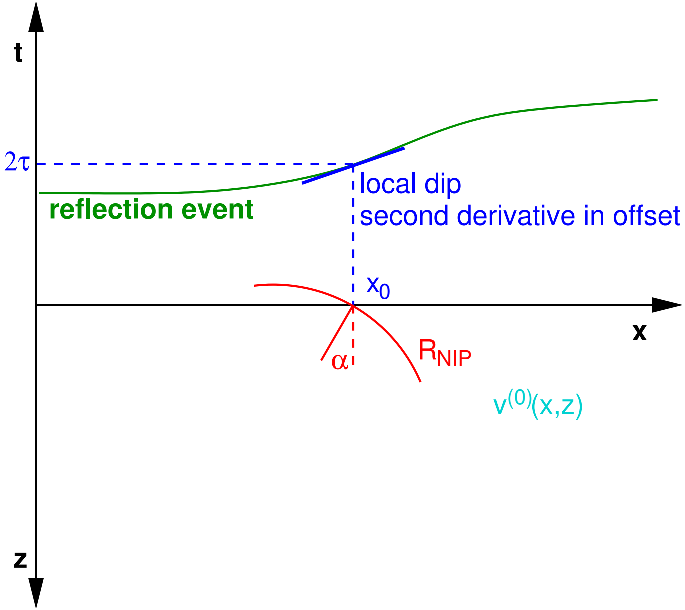

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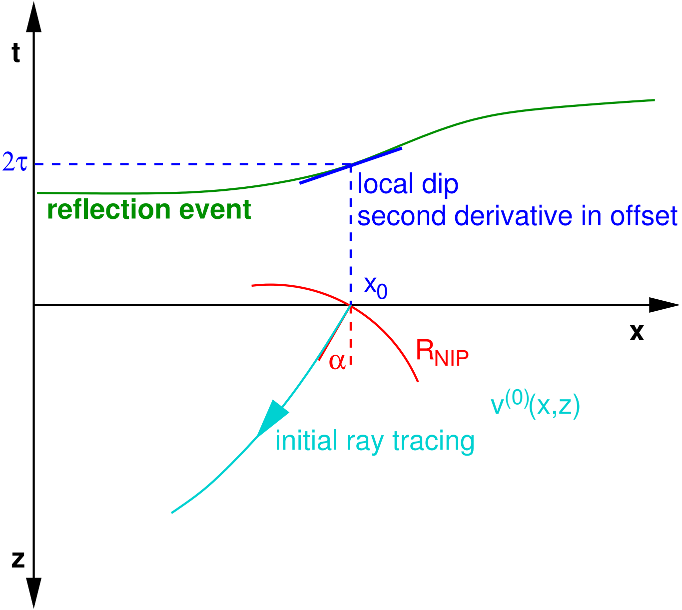

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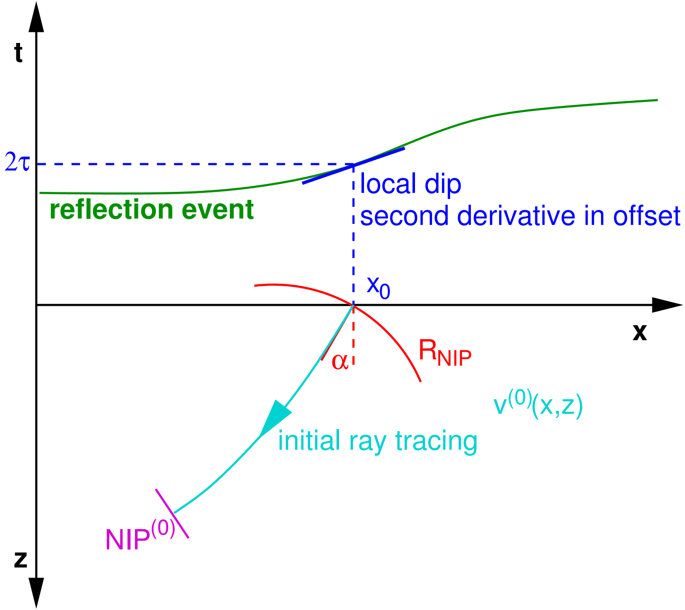

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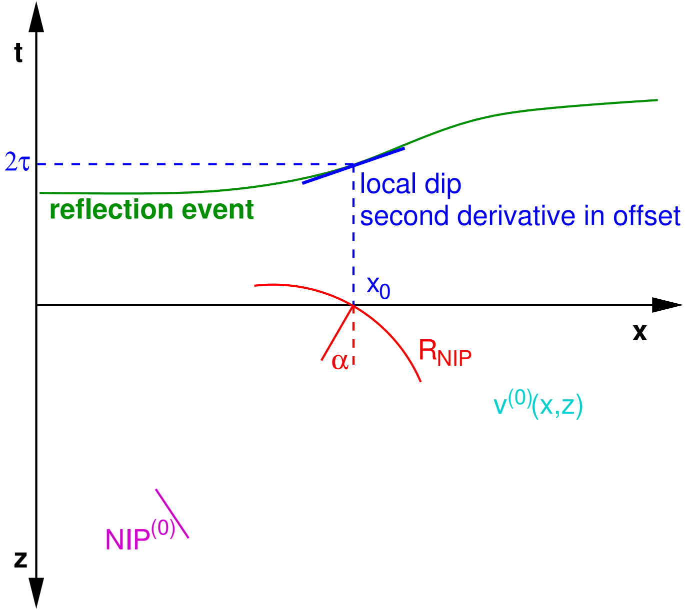

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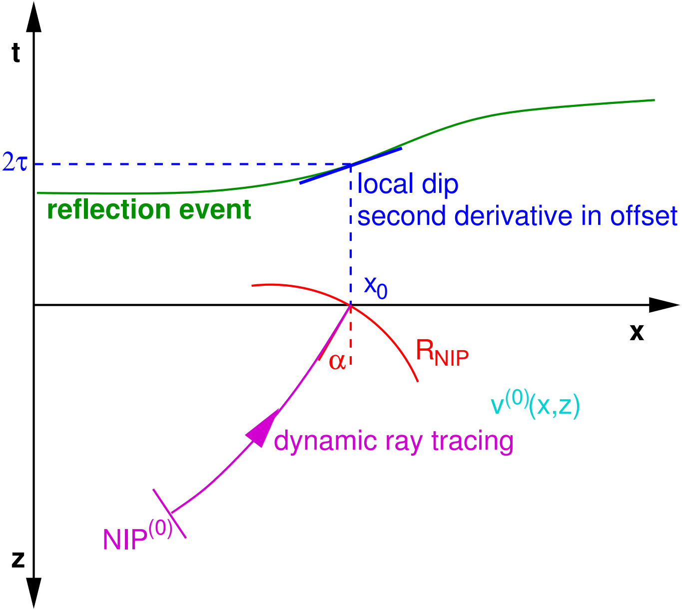

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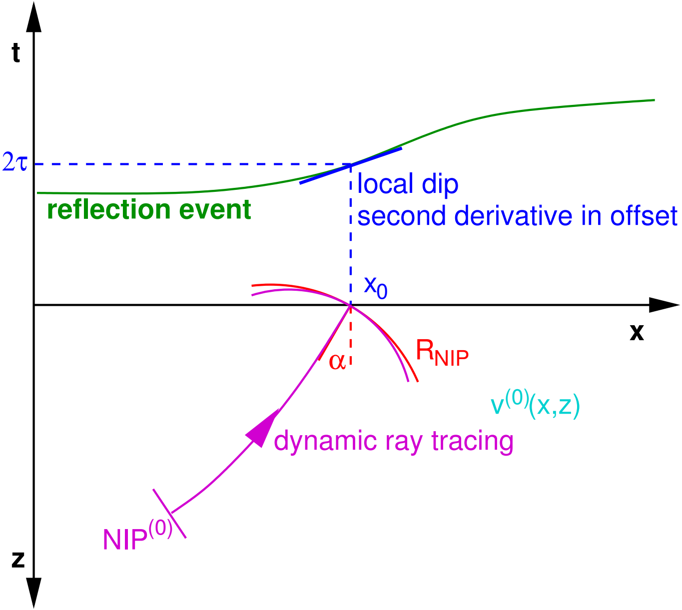

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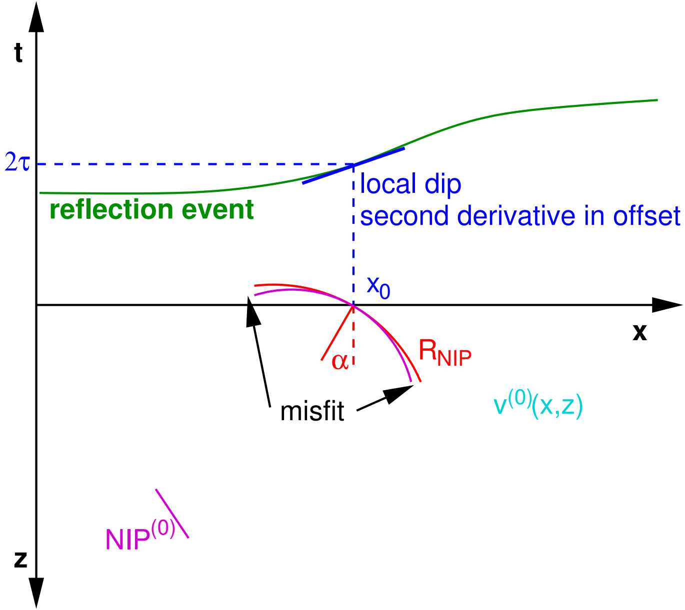

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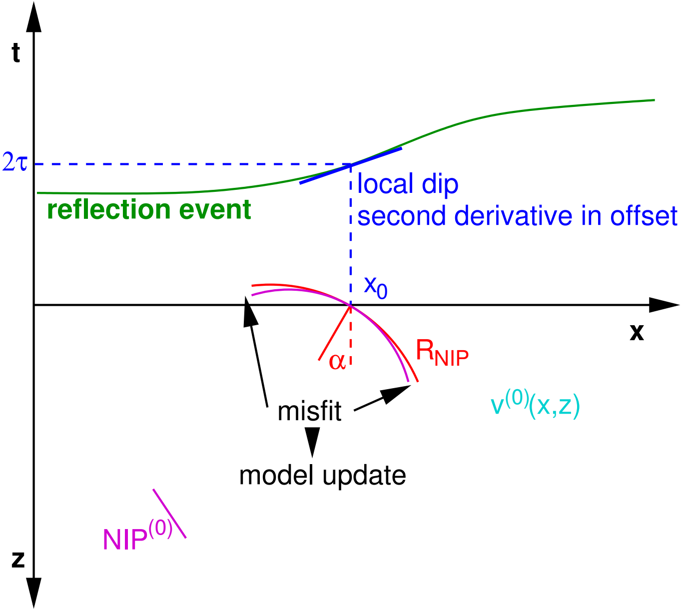

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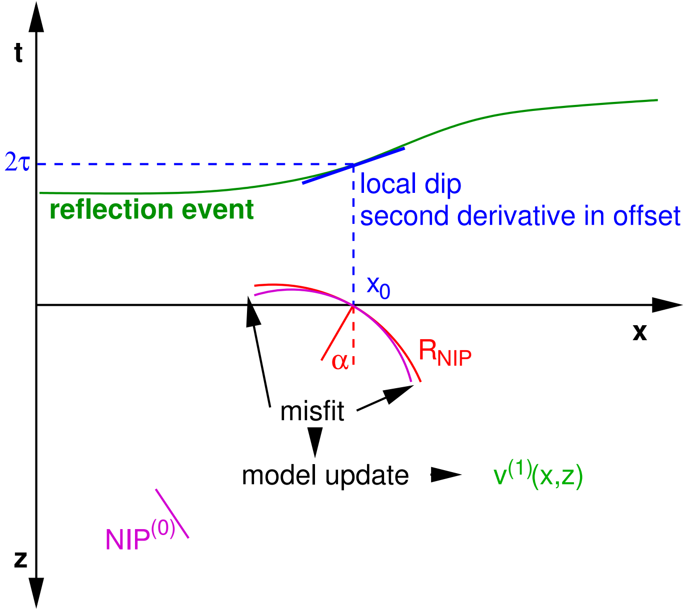

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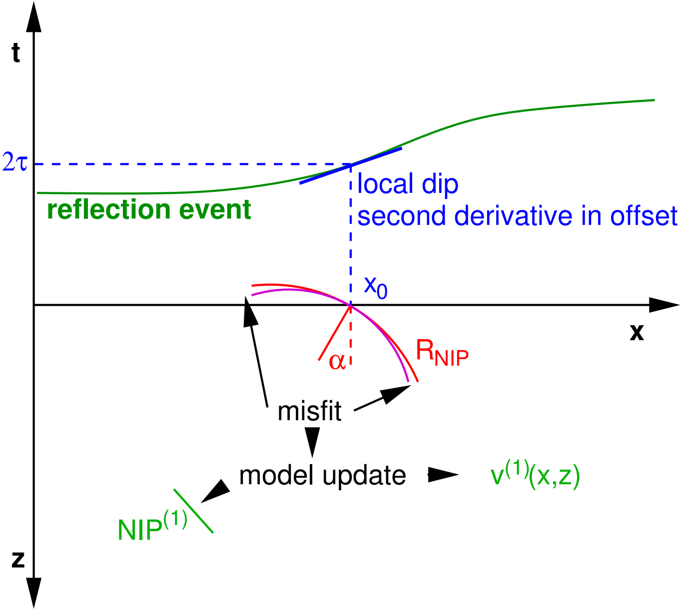

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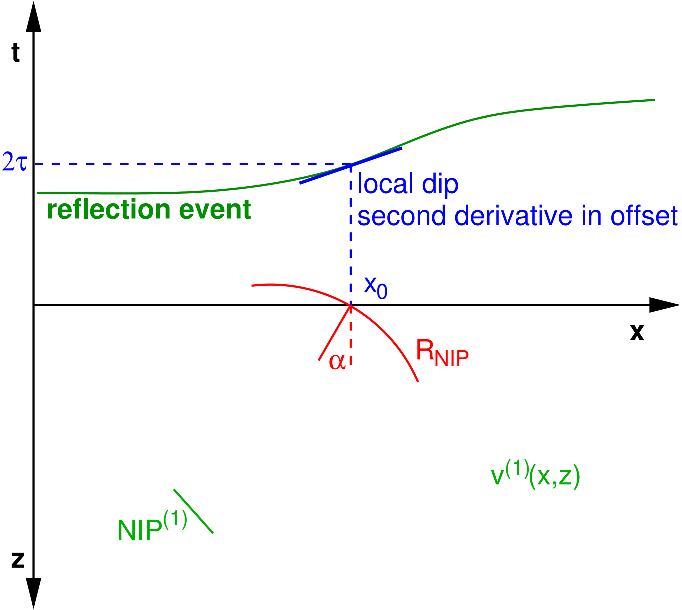

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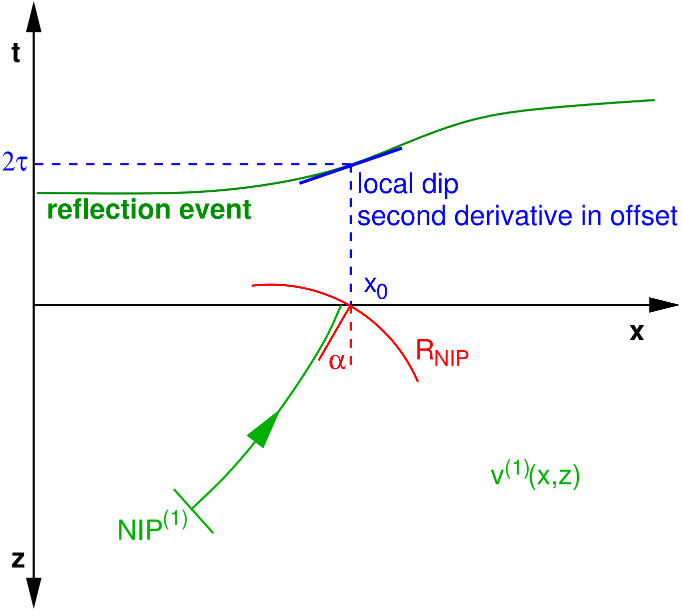

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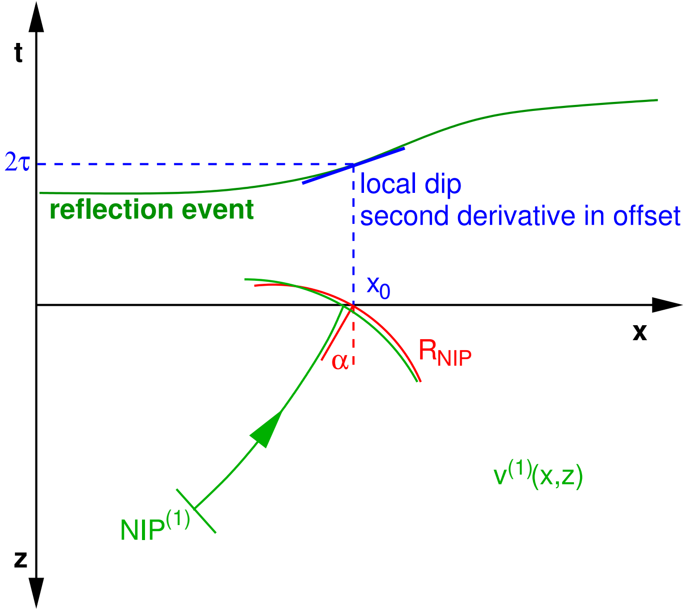

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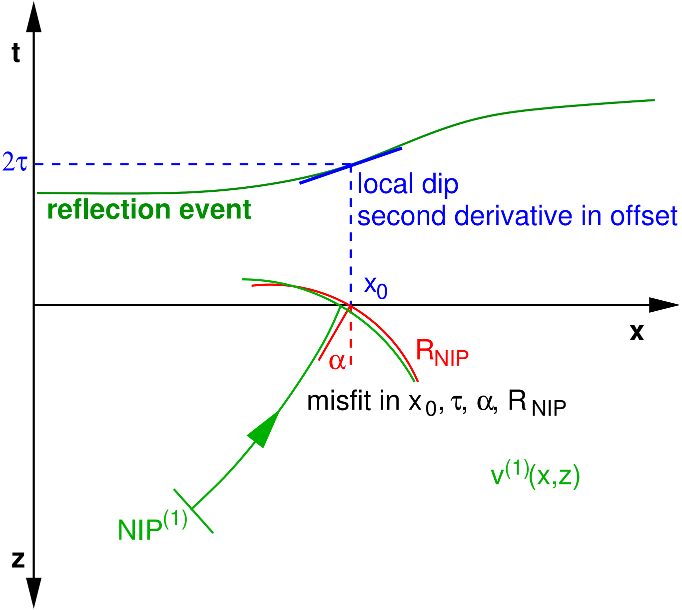

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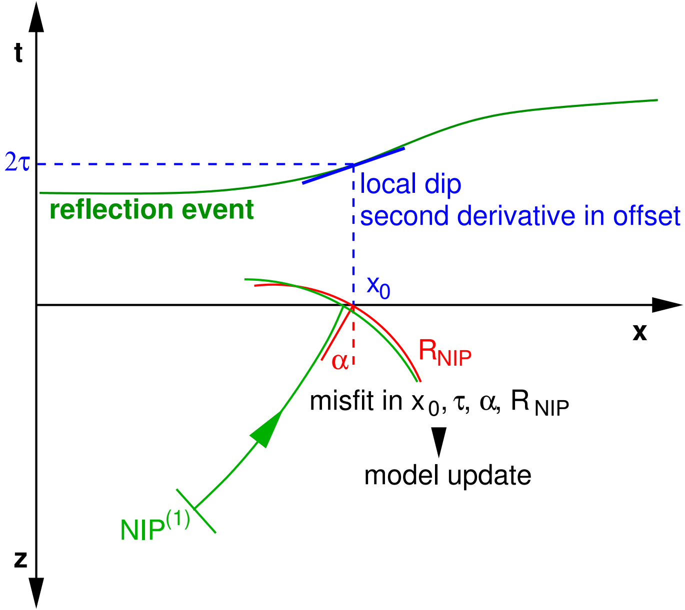

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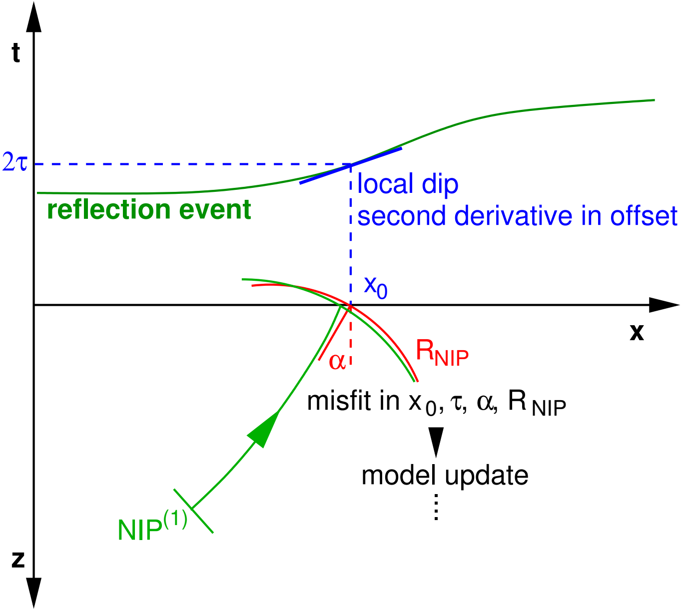

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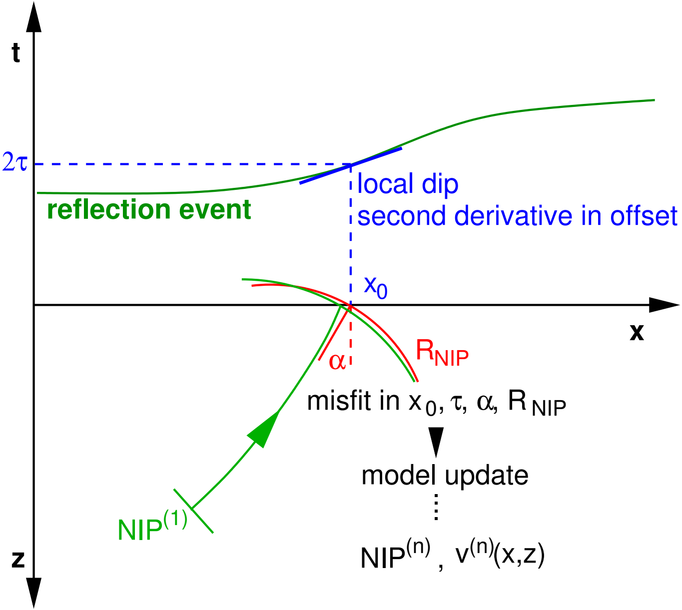

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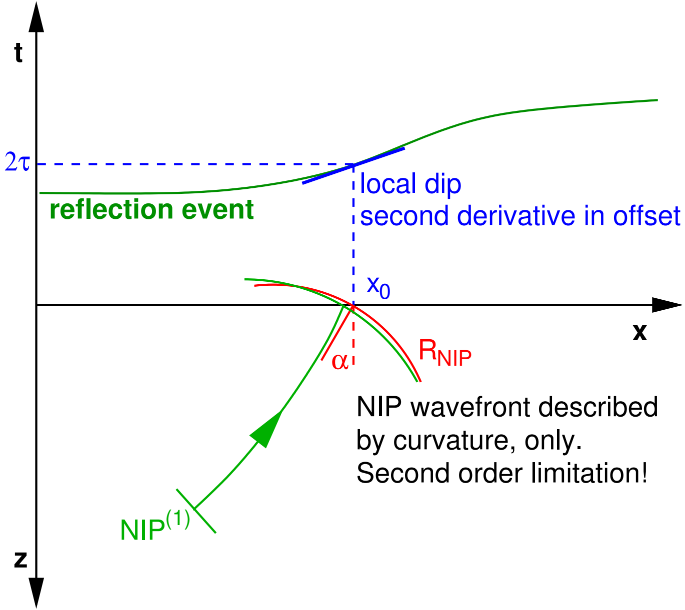
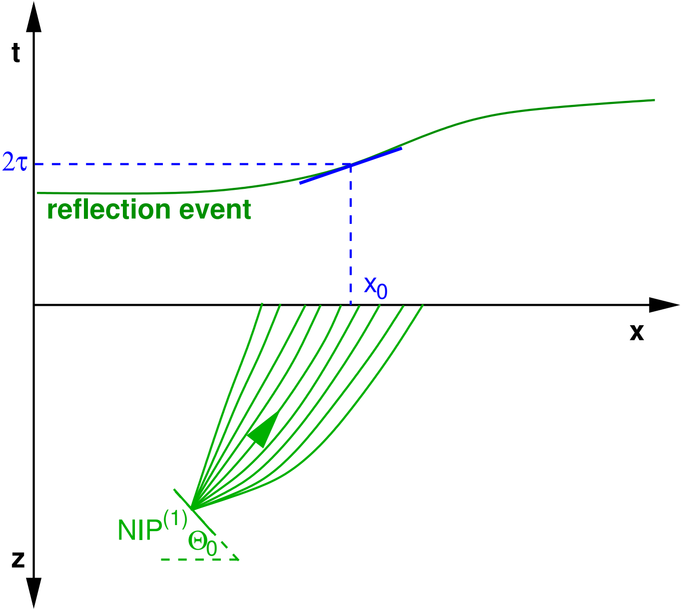


NIP wavefront described by curvature, only.
Second order limitation!

Principle of NIP-wave tomography



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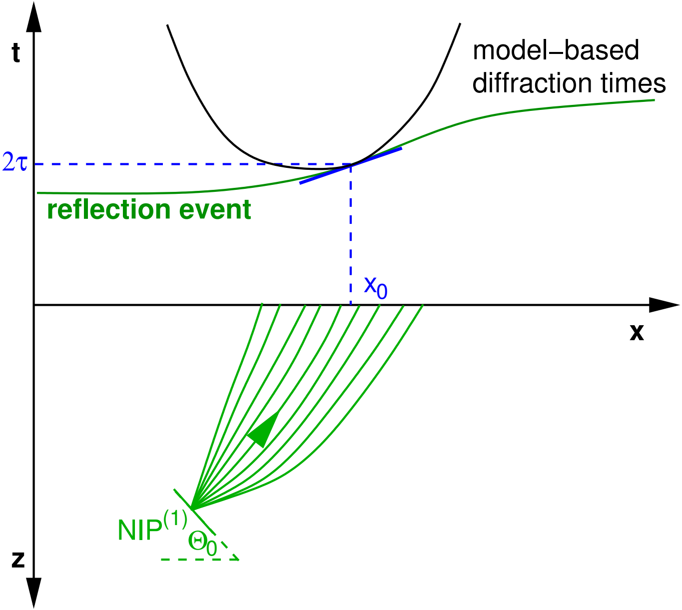

Inversion with model-based diffraction traveltimes

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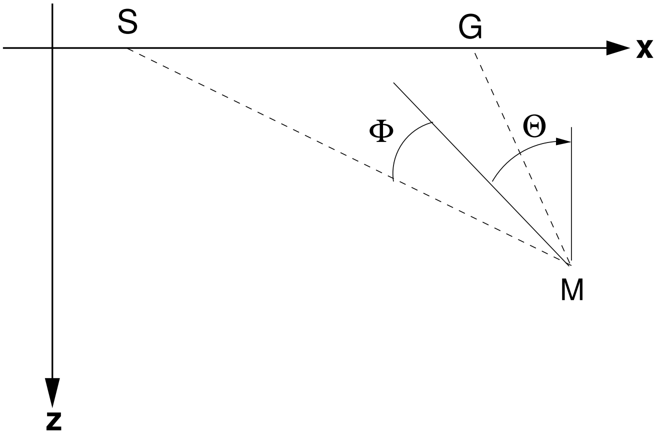
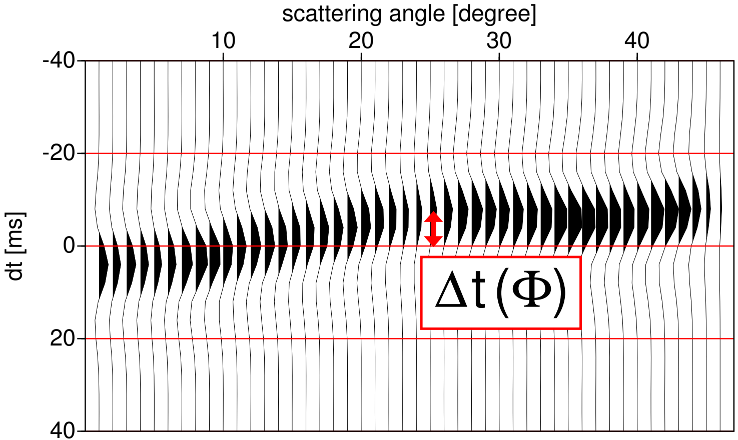
Scattering angle Φ and illumination angle Θ



Common-illumination-angle gather in residual time



(Klüver, 2007)

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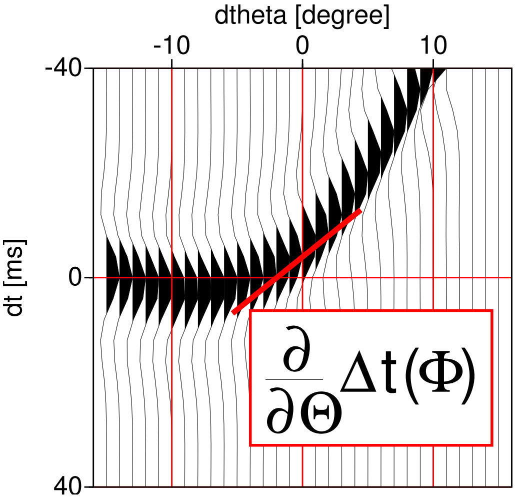
- Determination of $\Delta t\,(\Phi)$ by cross-correlation with subset of pilot trace

Common-scattering-angle gather in residual time

$\Delta\Theta = \Theta - \Theta_0$

(Klüver, 2007)



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Fermat's principle of stationary traveltime

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  Fermat's principle of stationary traveltime

- Determination of this dip by coherence analysis along plane operator

Inversion concept

Iteratively

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Conclusions

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Acknowledgments

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- Federal Ministry of Education and Research, Germany, program **GEO**TECHNOLOGIEN
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