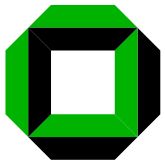
# CRS stacking: a simplified explanation

Jürgen Mann[1], Jörg Schleicher[2],
and Thomas Hertweck[3]

[1]Geophysical Institute, University of Karlsruhe (TH), Germany

[2]Dept. Applied. Math., IMEEC/UNICAMP, Brazil

[3]Fugro Seismic Imaging Ltd., Swanley, UK



June 14, 2007





# Overview

## Motivation

## CRS stack

## CRS stacking parameters

## What about 3D?

## Practical aspects

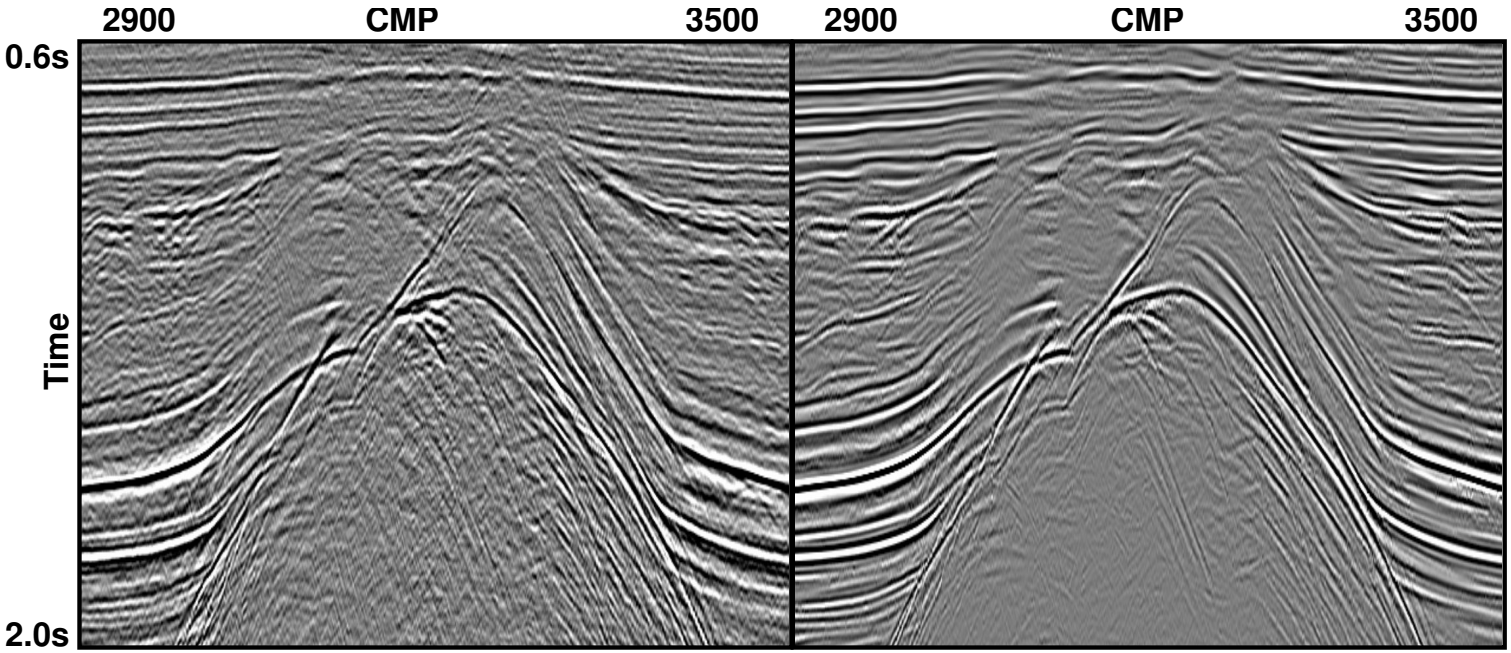
## Conclusion

## Acknowledgments





# Data example




conventional stack
(no postprocessing)

CRS stack

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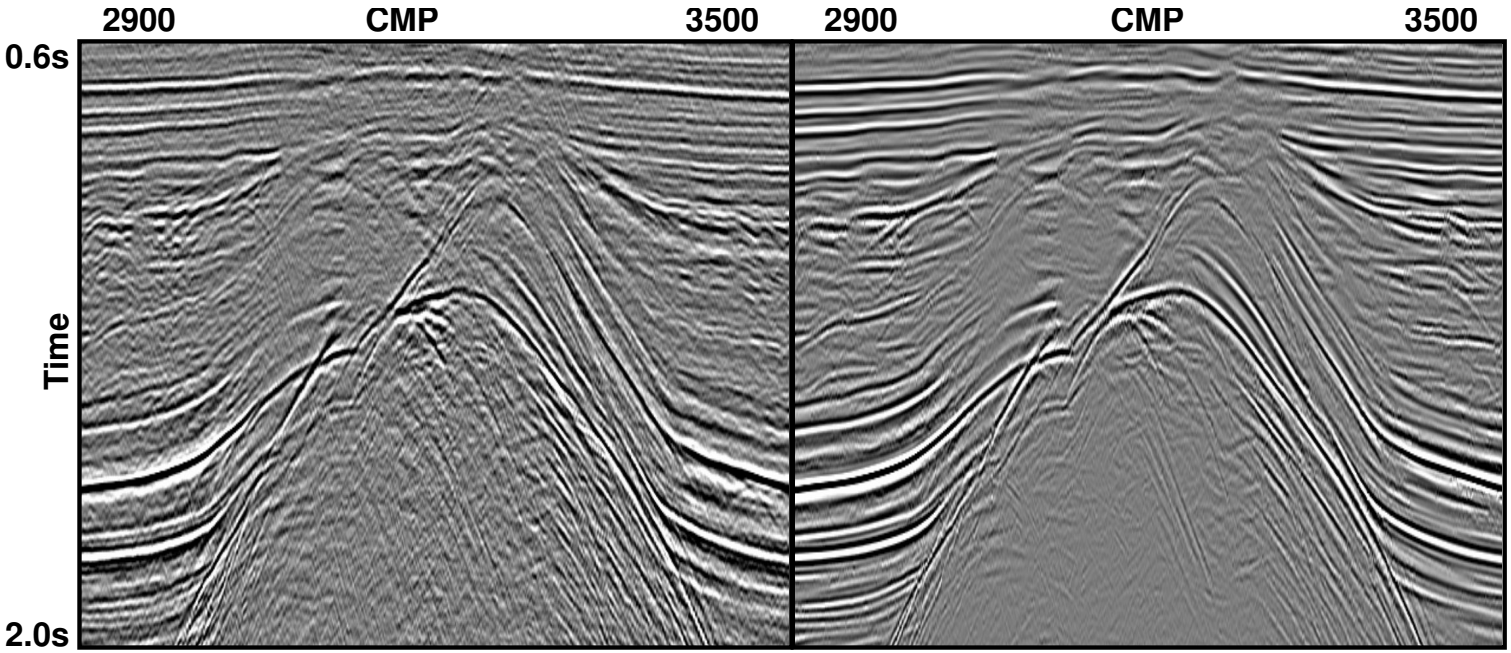


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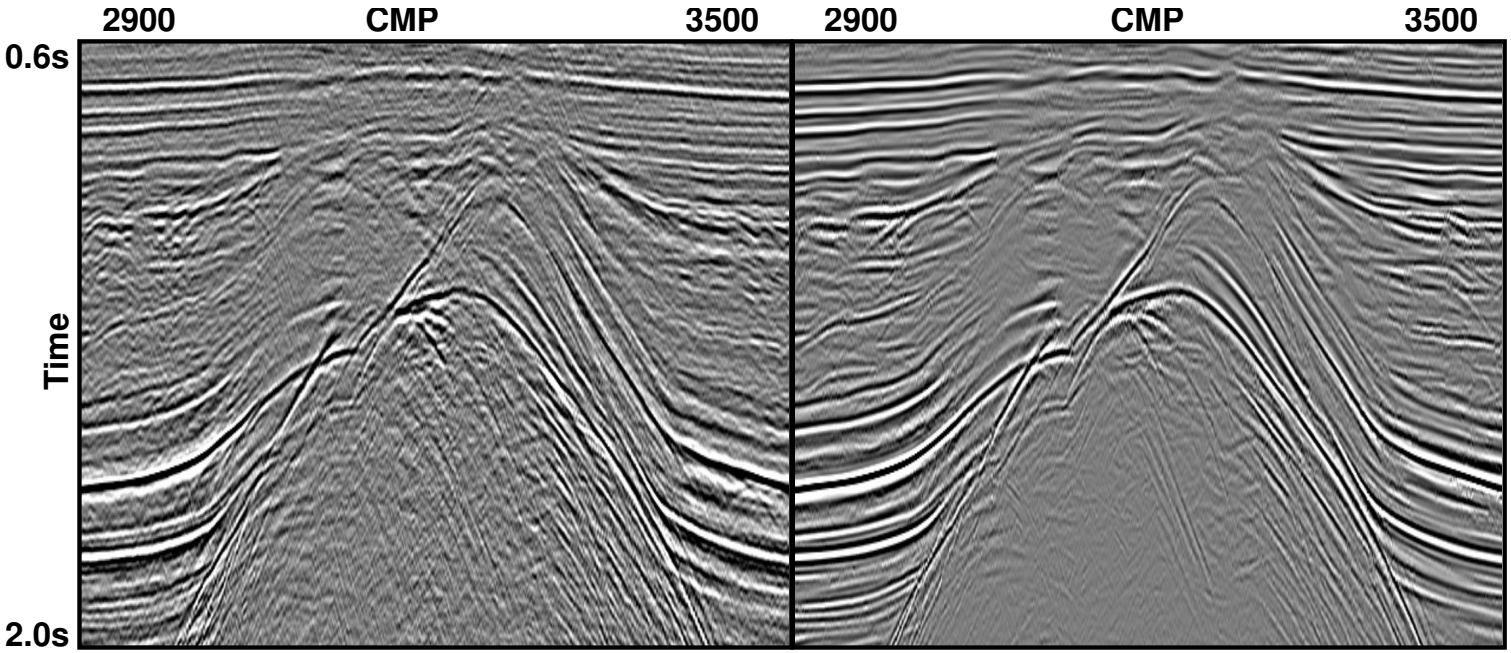


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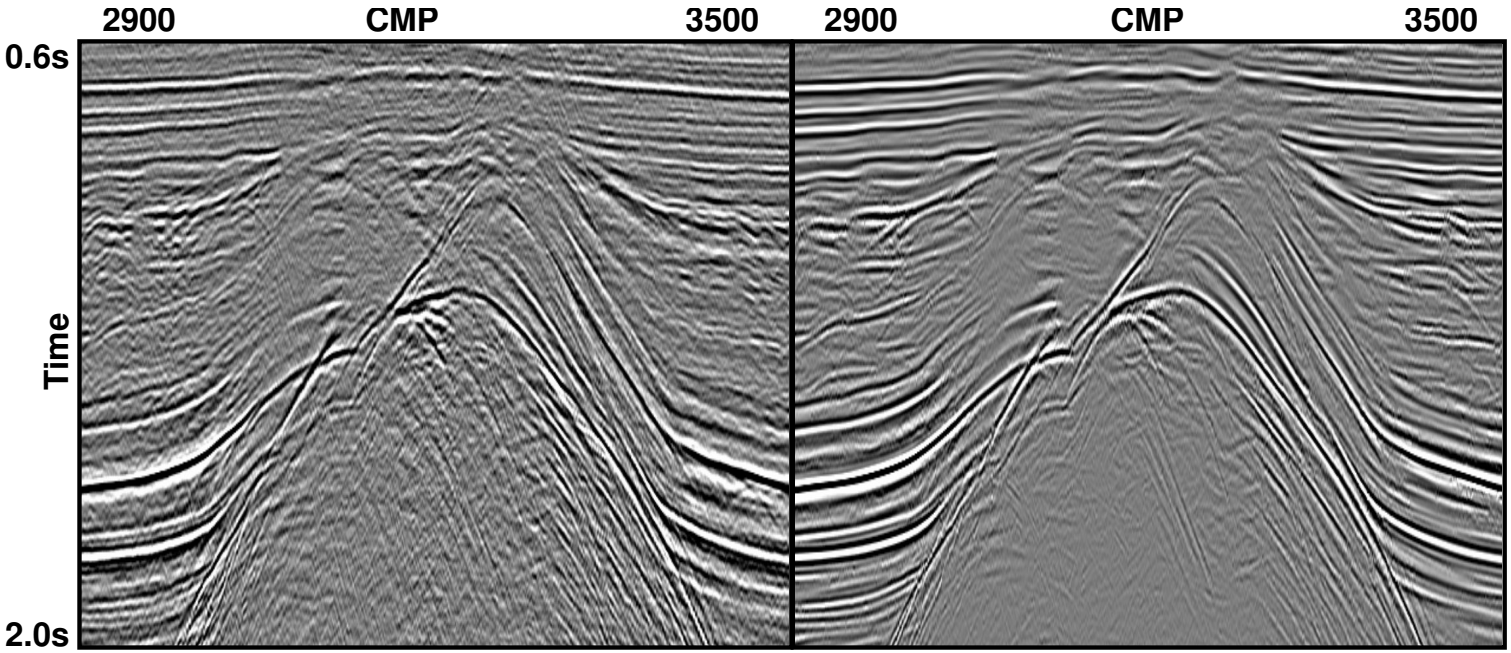


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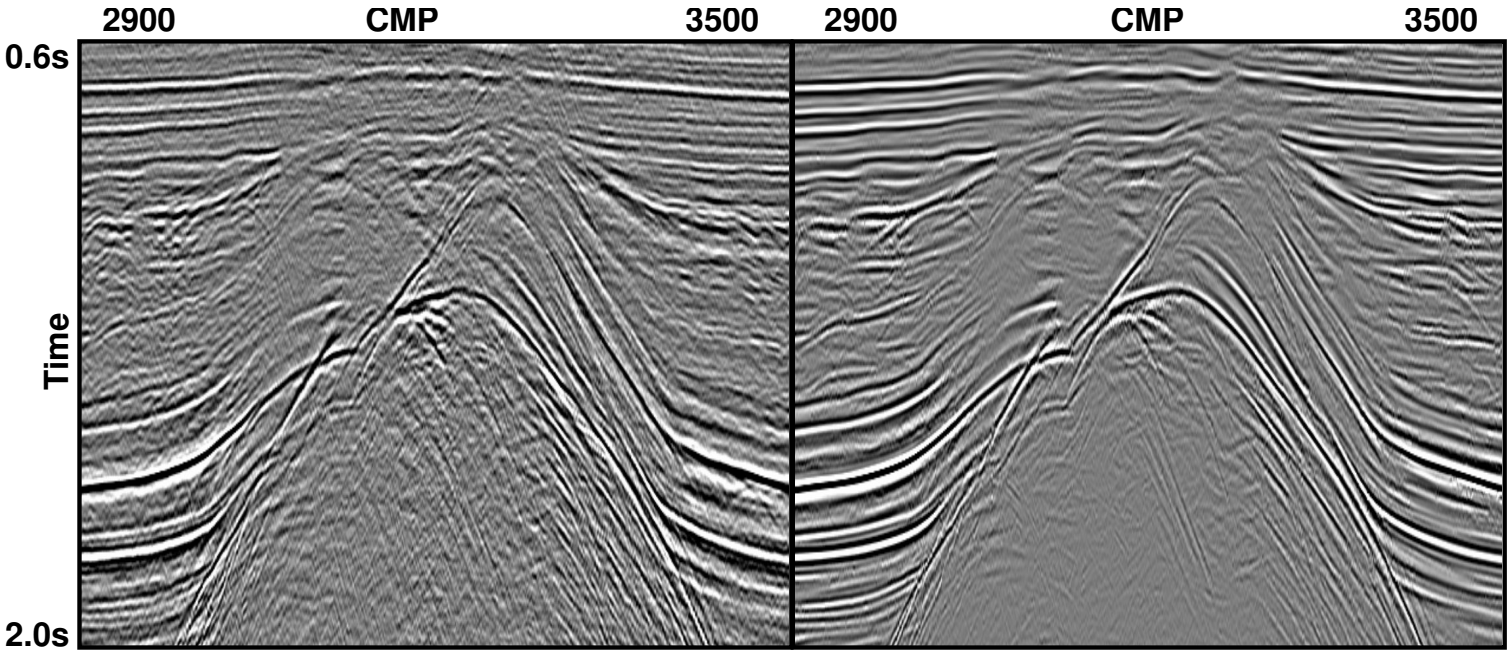


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- additional stacking parameters
  - ➥ inversion, projected Fresnel zone, geometrical spreading, . . .

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Stacking velocity analysis and CMP stack





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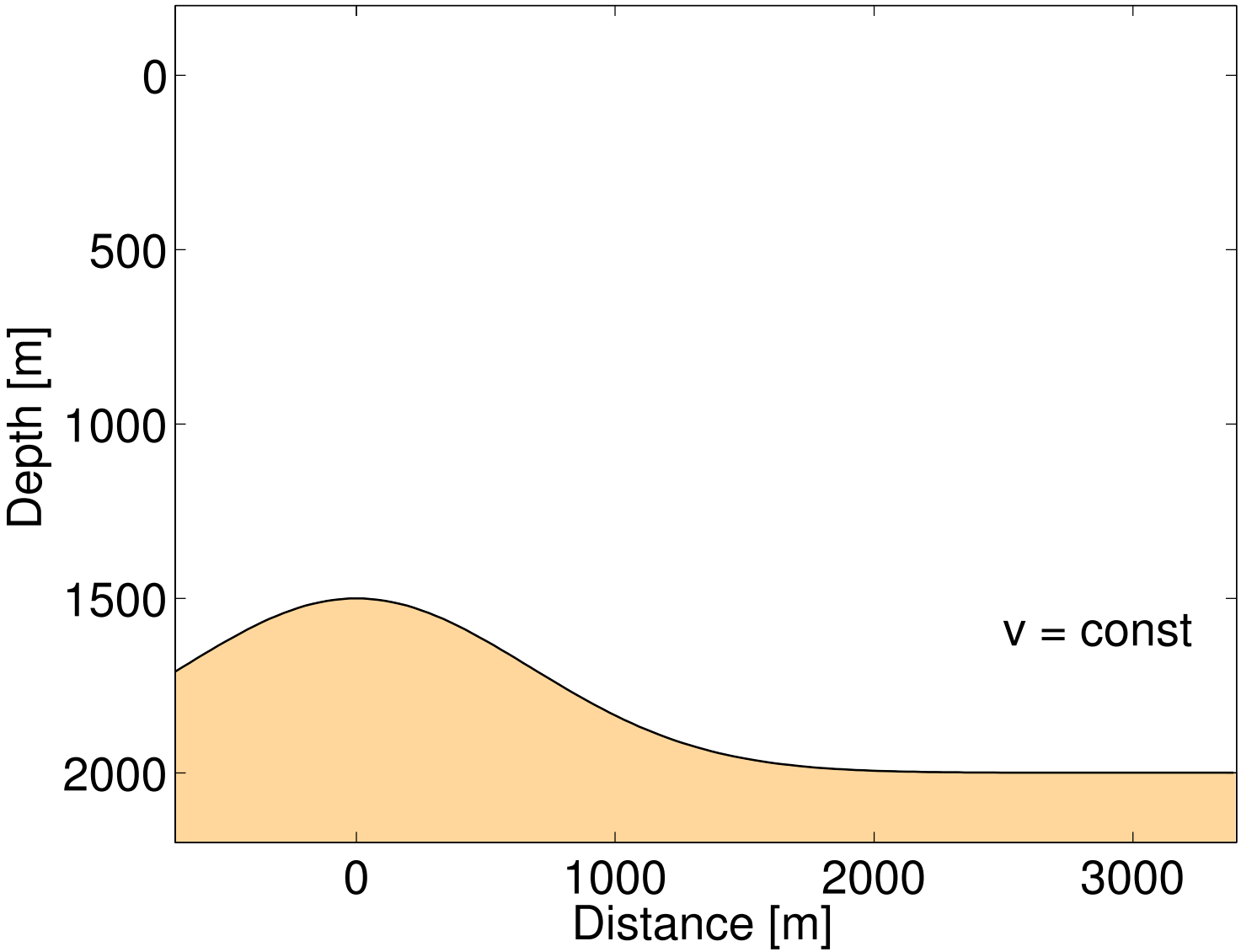
Further implicit assumptions?





# Overlap of CMP illuminations



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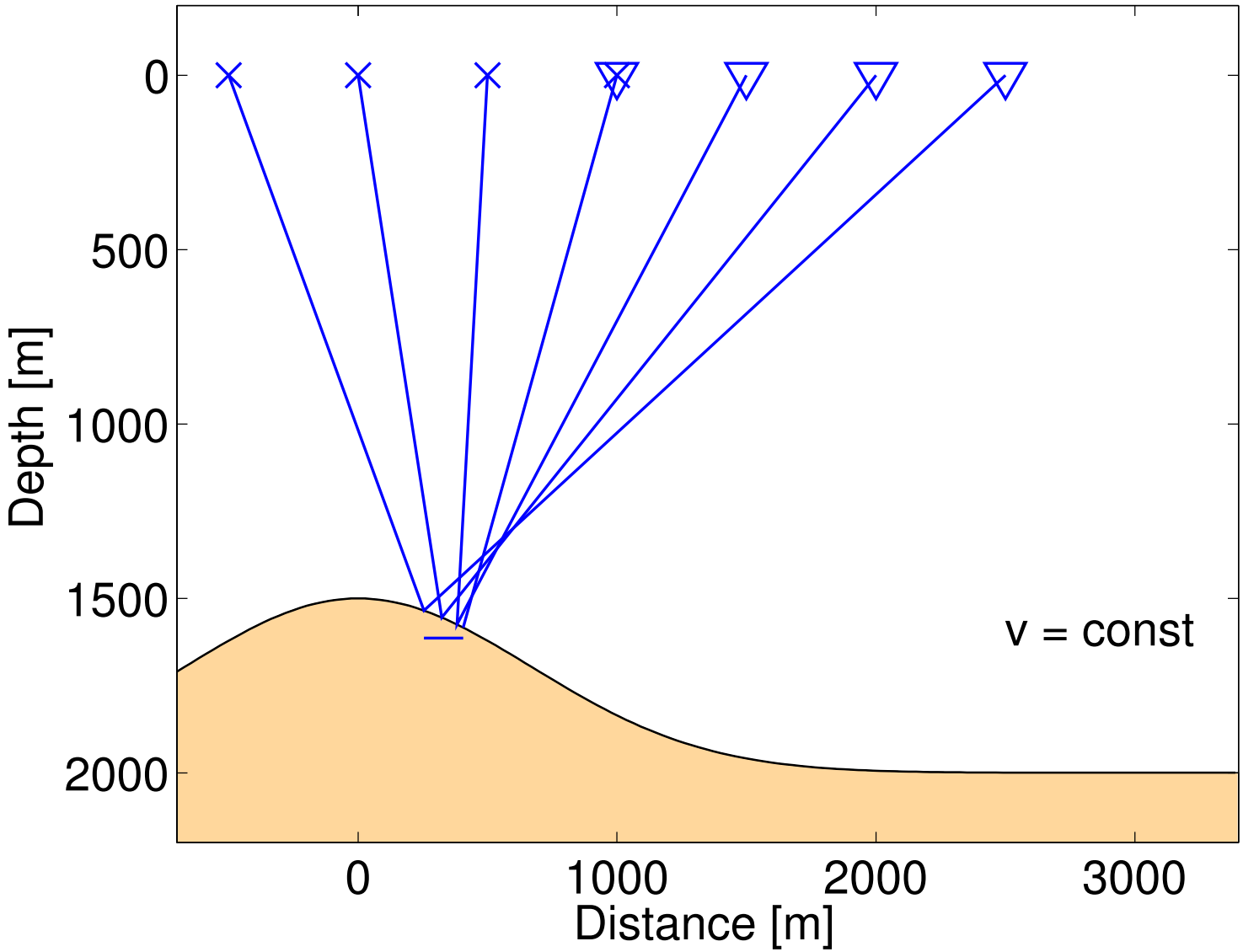

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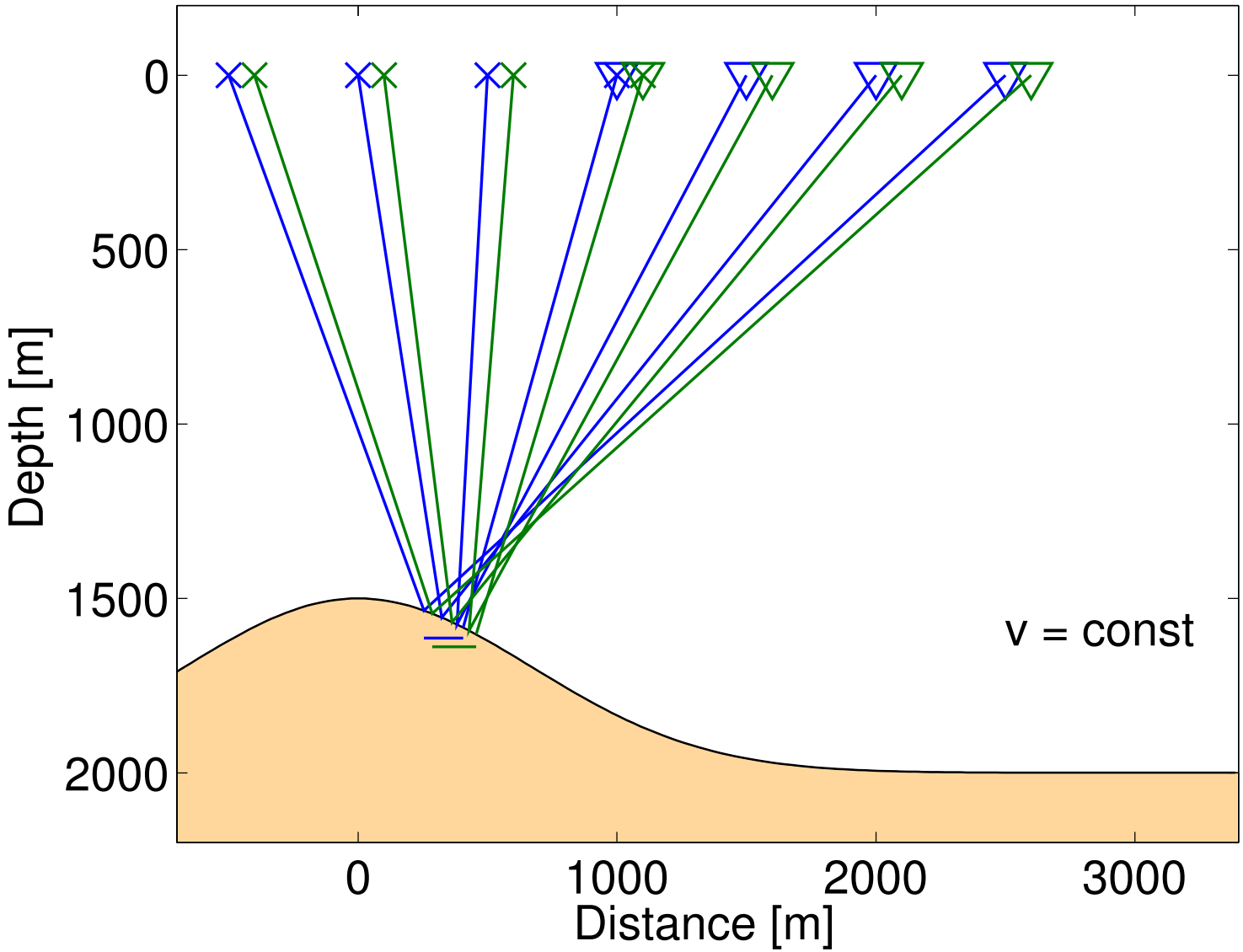

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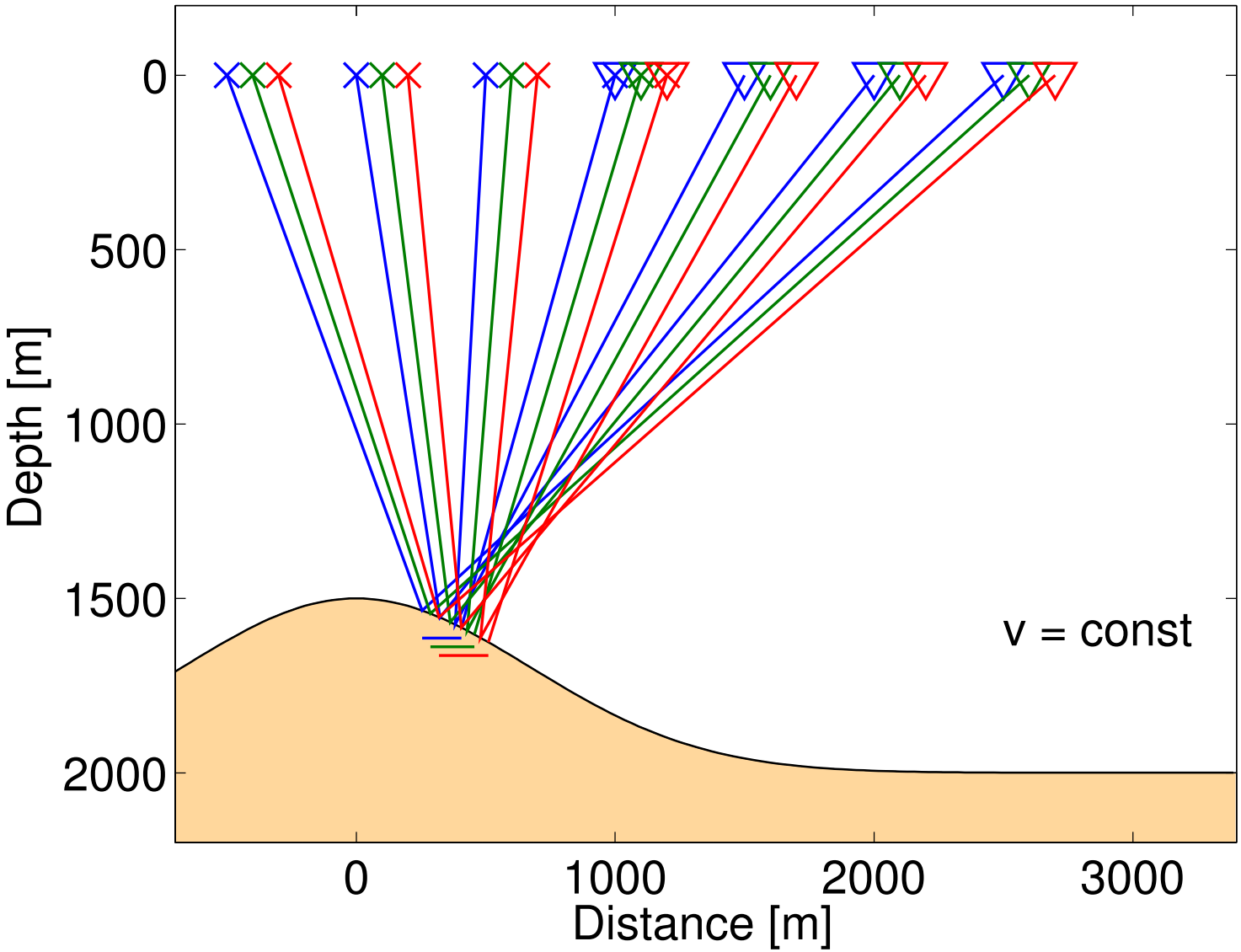

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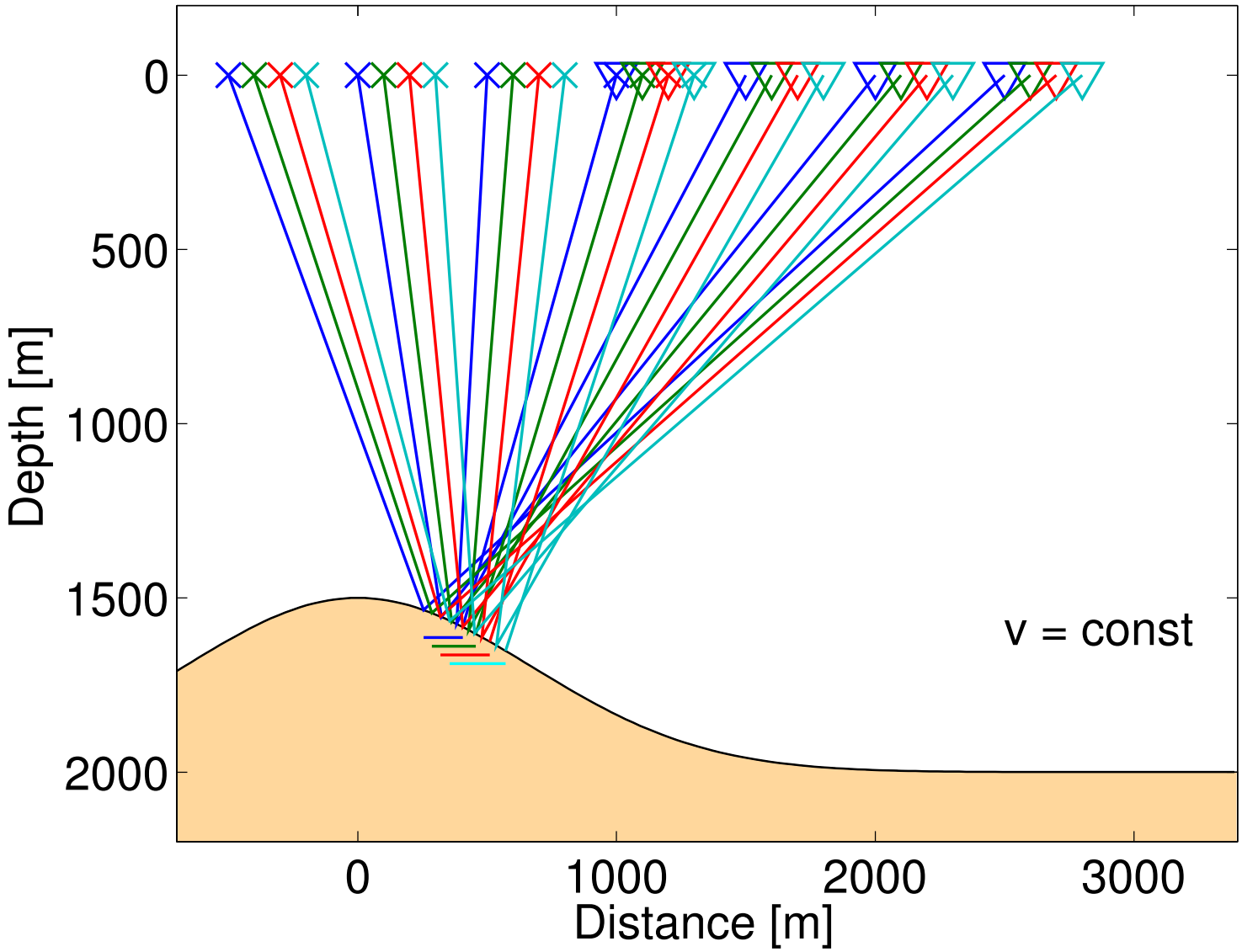

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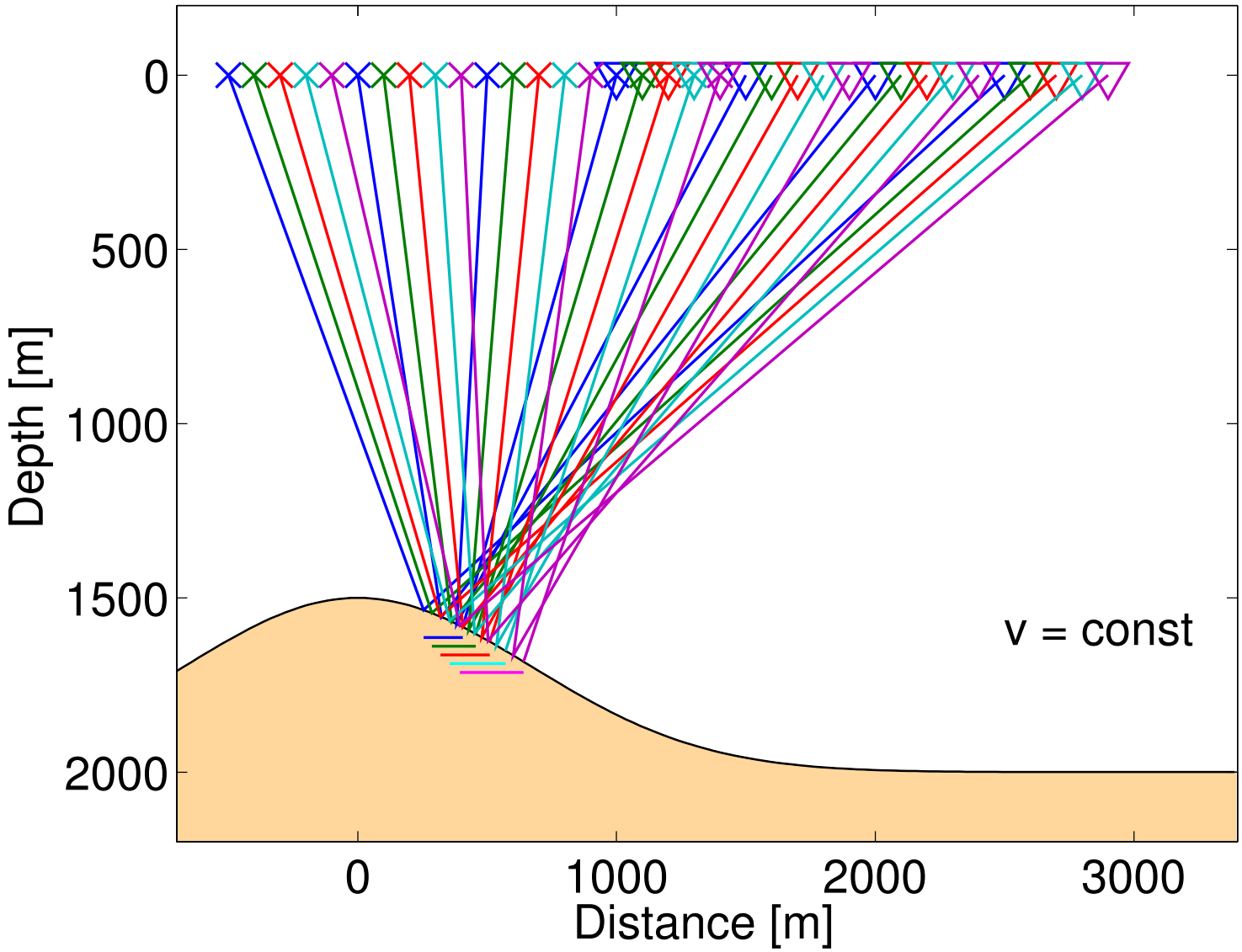

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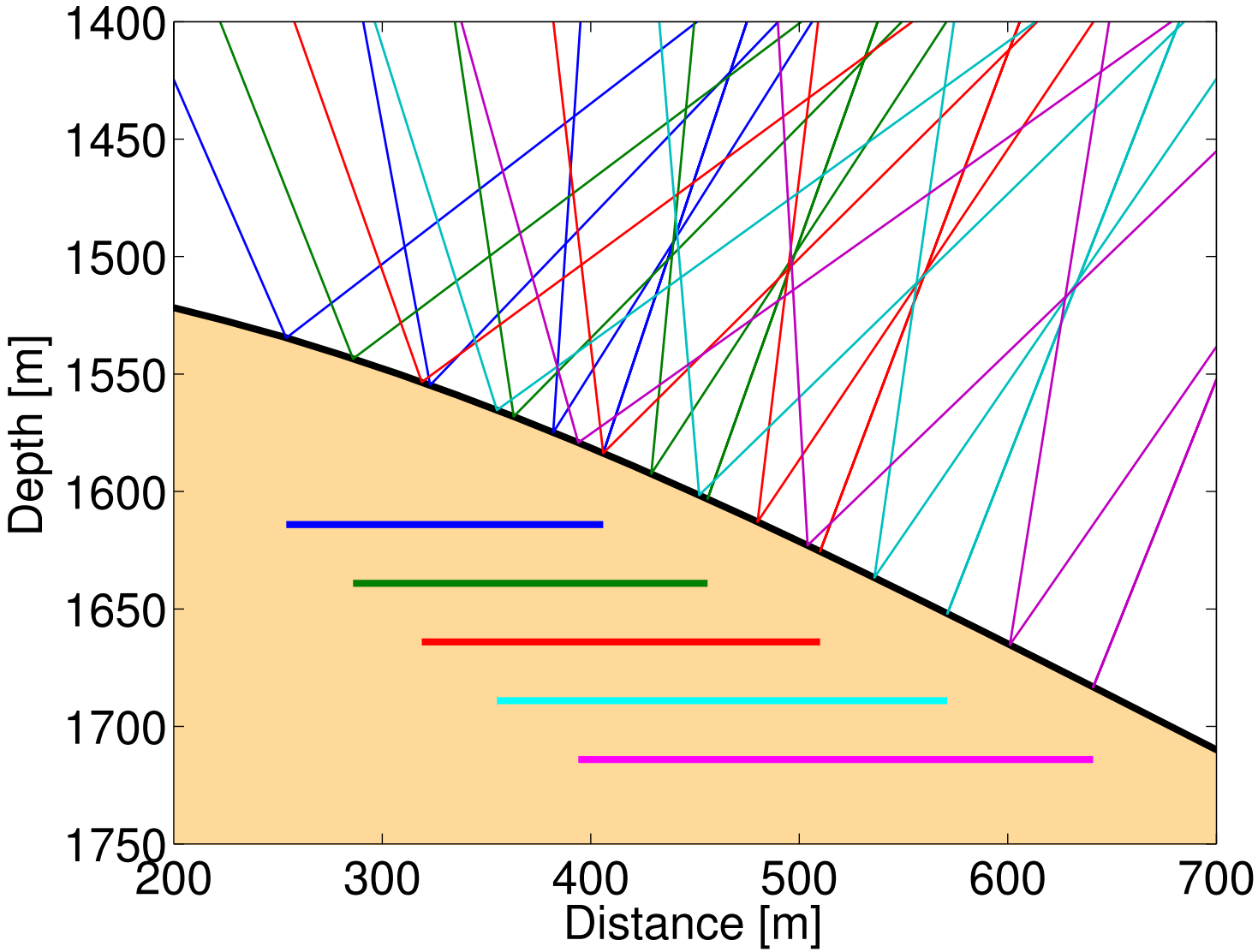

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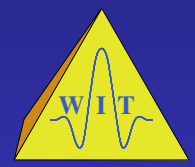
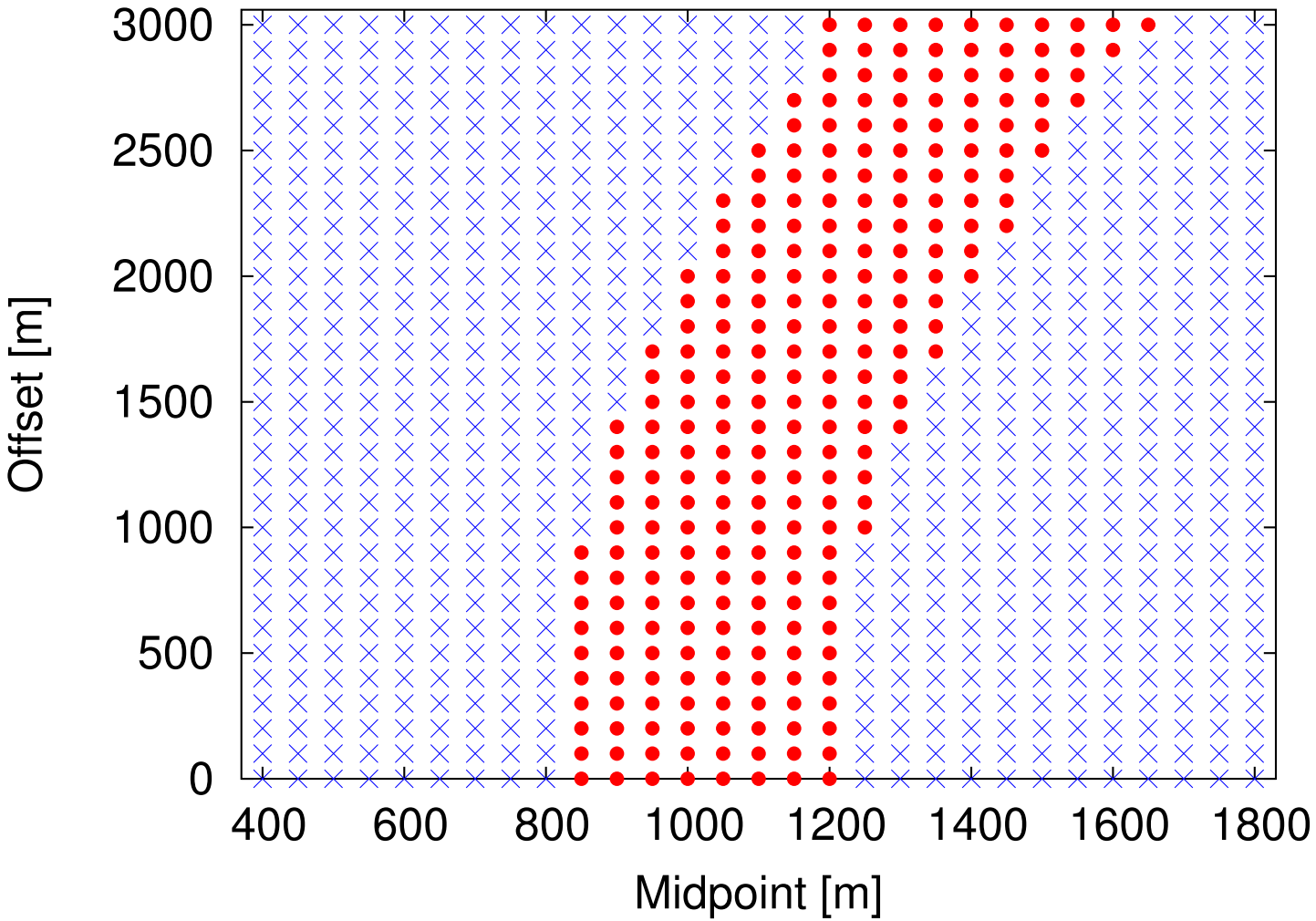
Why shouldn't we incorporate these neighboring reflection points?



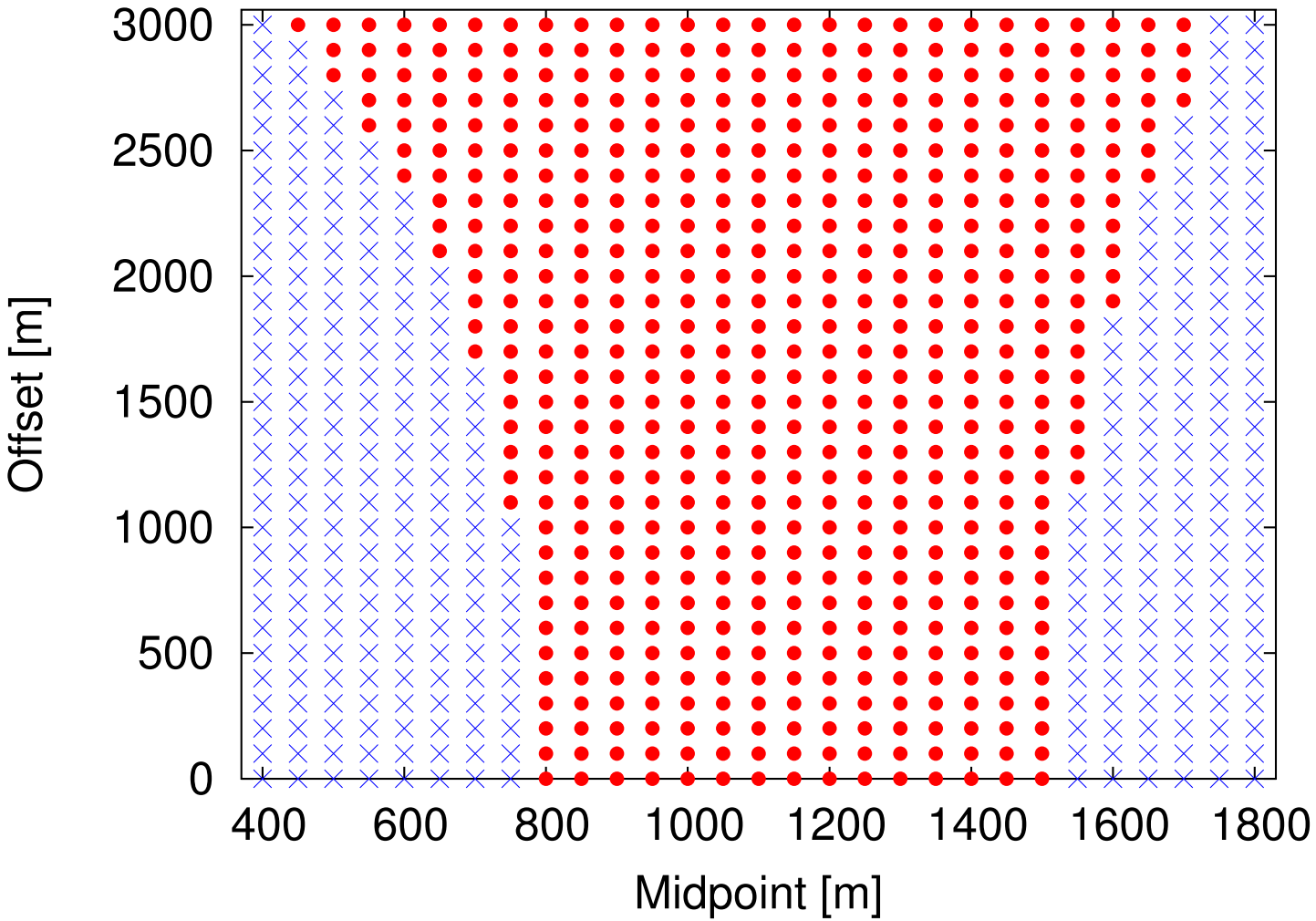


# Coverage of one CMP ray family




Traces with reflection points on reflector area illuminated by one CMP ray family

# Projected Fresnel zone




Projected Fresnel zone of the reflector area illuminated by one CMP ray family

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Additional features:

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- yields additional stacking parameters
- increases the coverage
- improves reflector continuity and S/N ratio





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Aims in the following:

- operator expressed in more familiar terms
- demonstrate relation between these parameters
- clear distinction between model and data space





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Hyperbolic representation:

$$t^2(\Delta m, x) = [t_0 + 2p\Delta m]^2 + \frac{x^2}{v^2_{\mathrm{NMO}}} + \frac{\Delta m^2}{v^2_{\mathrm{CMO}}}$$





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| $p$ | horizontal slowness |
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$$= \underbrace{t_0^2 + \frac{x^2}{v_{\mathrm{NMO}}^2}}_{\text{conventional stack}} + \underbrace{4\,t_0\,p\,\Delta m + 4\Delta m^2 p^2}_{\text{dip dependent}}$$

$$+ \underbrace{\frac{\Delta m^2}{v_{\mathrm{CMO}}}}_{\text{curvature dependent}}$$

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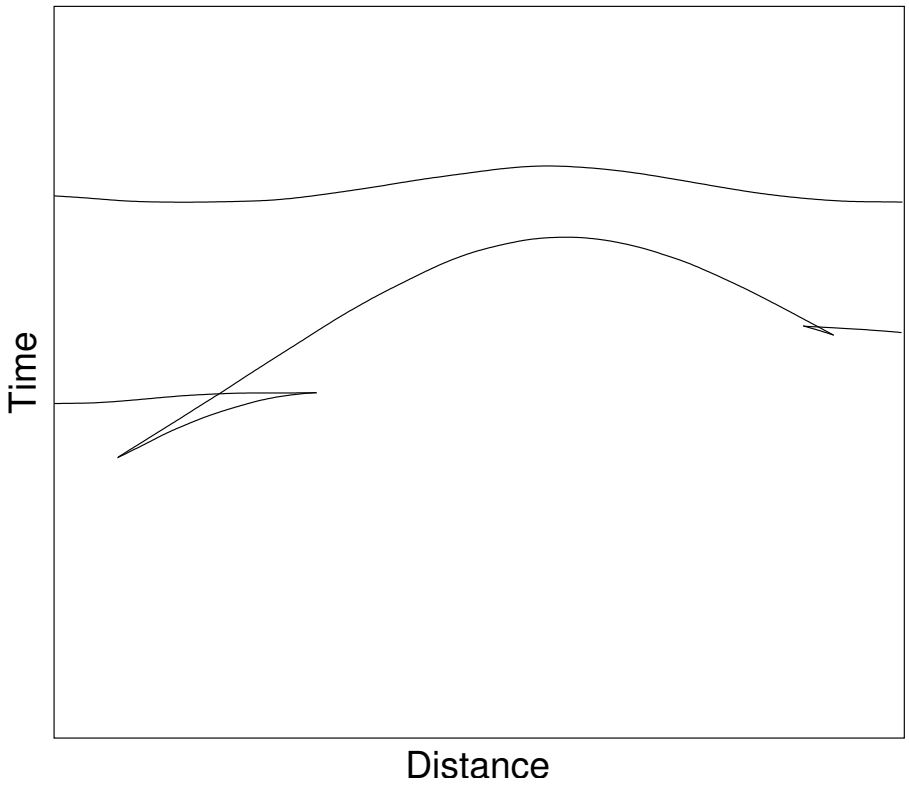

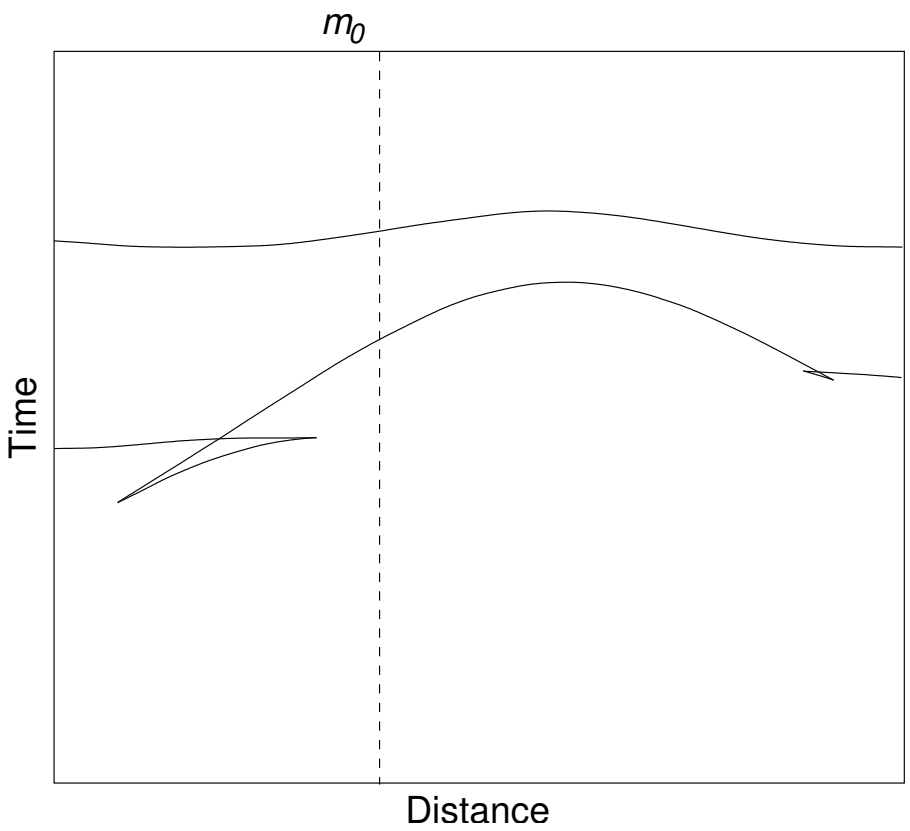

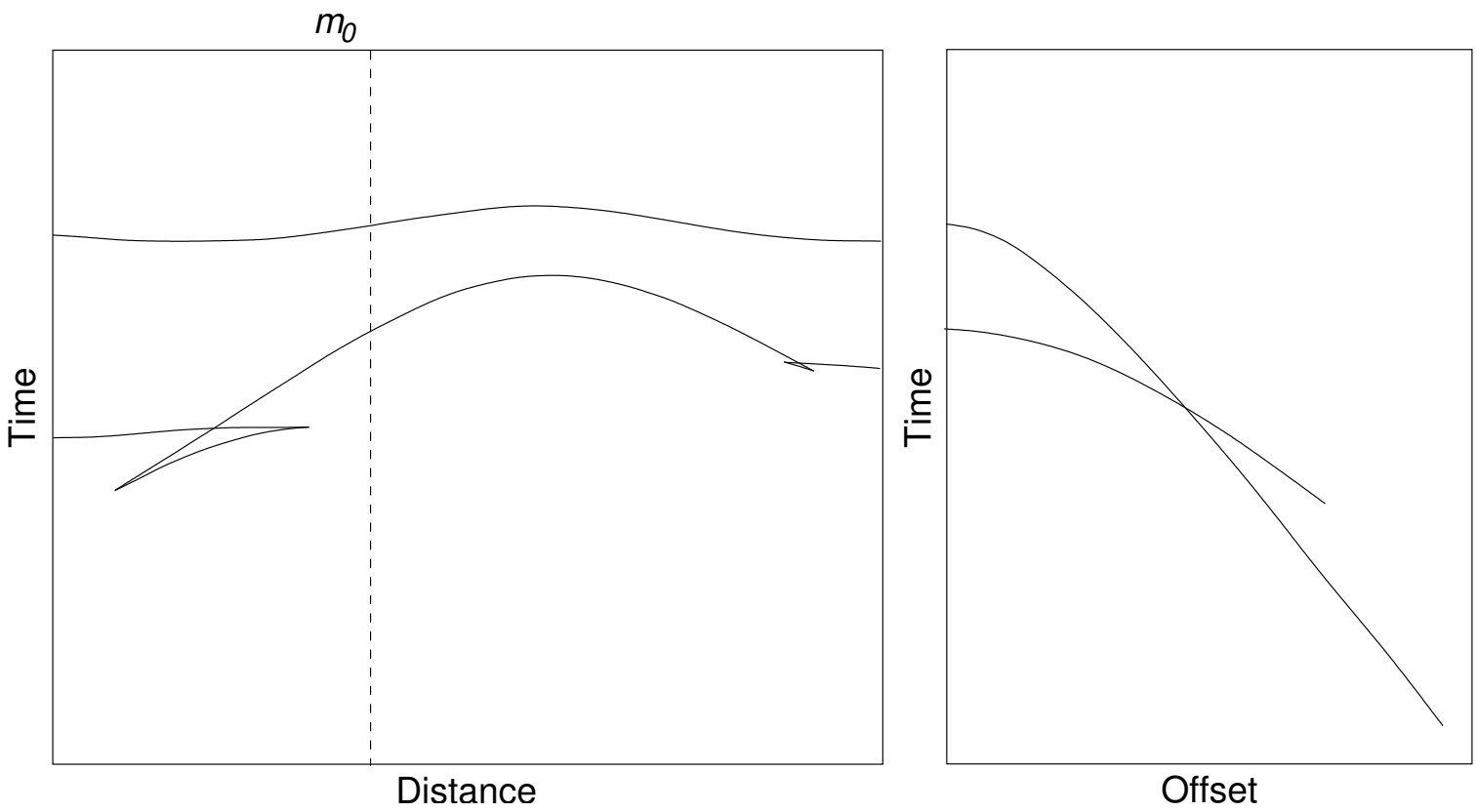
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Time
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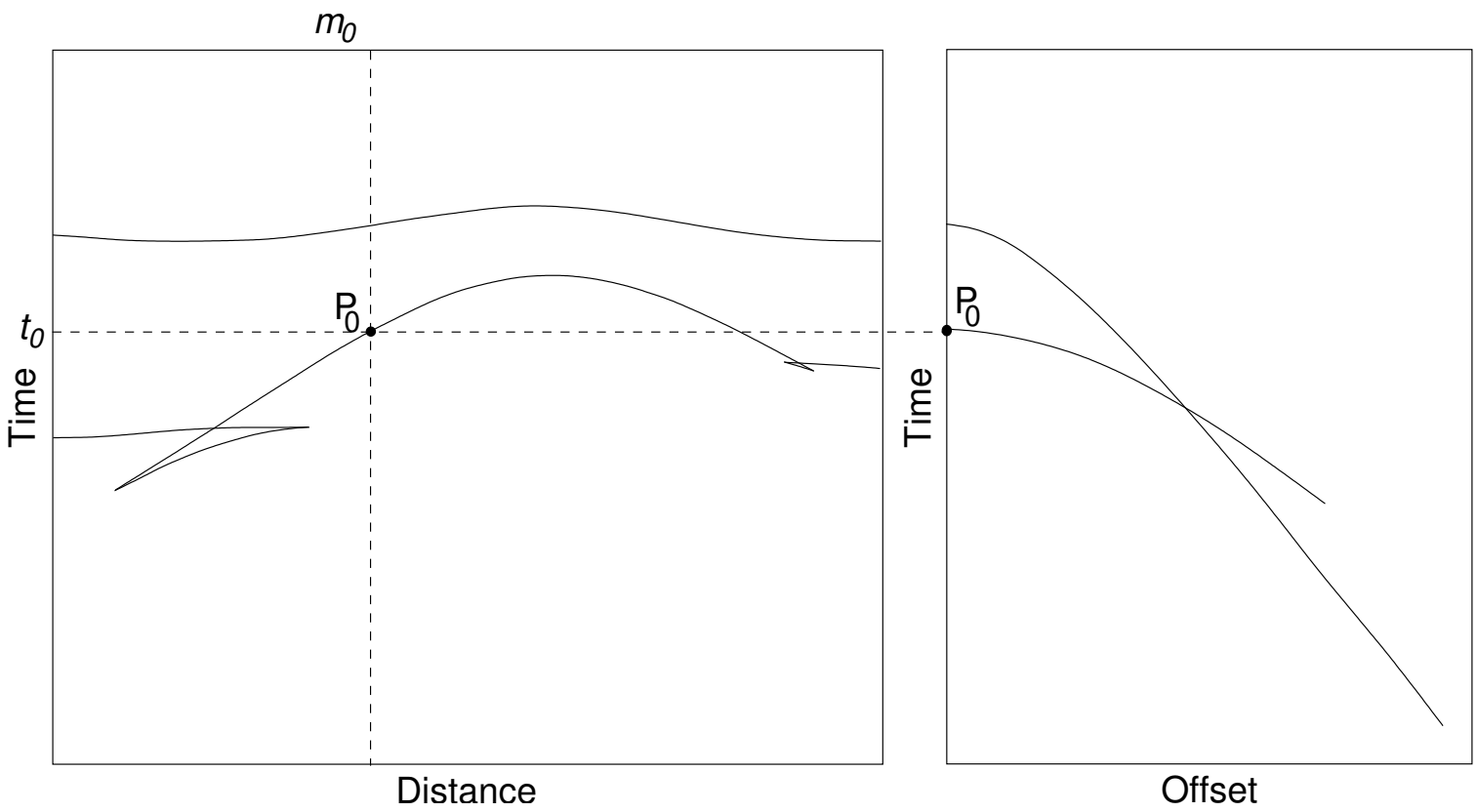
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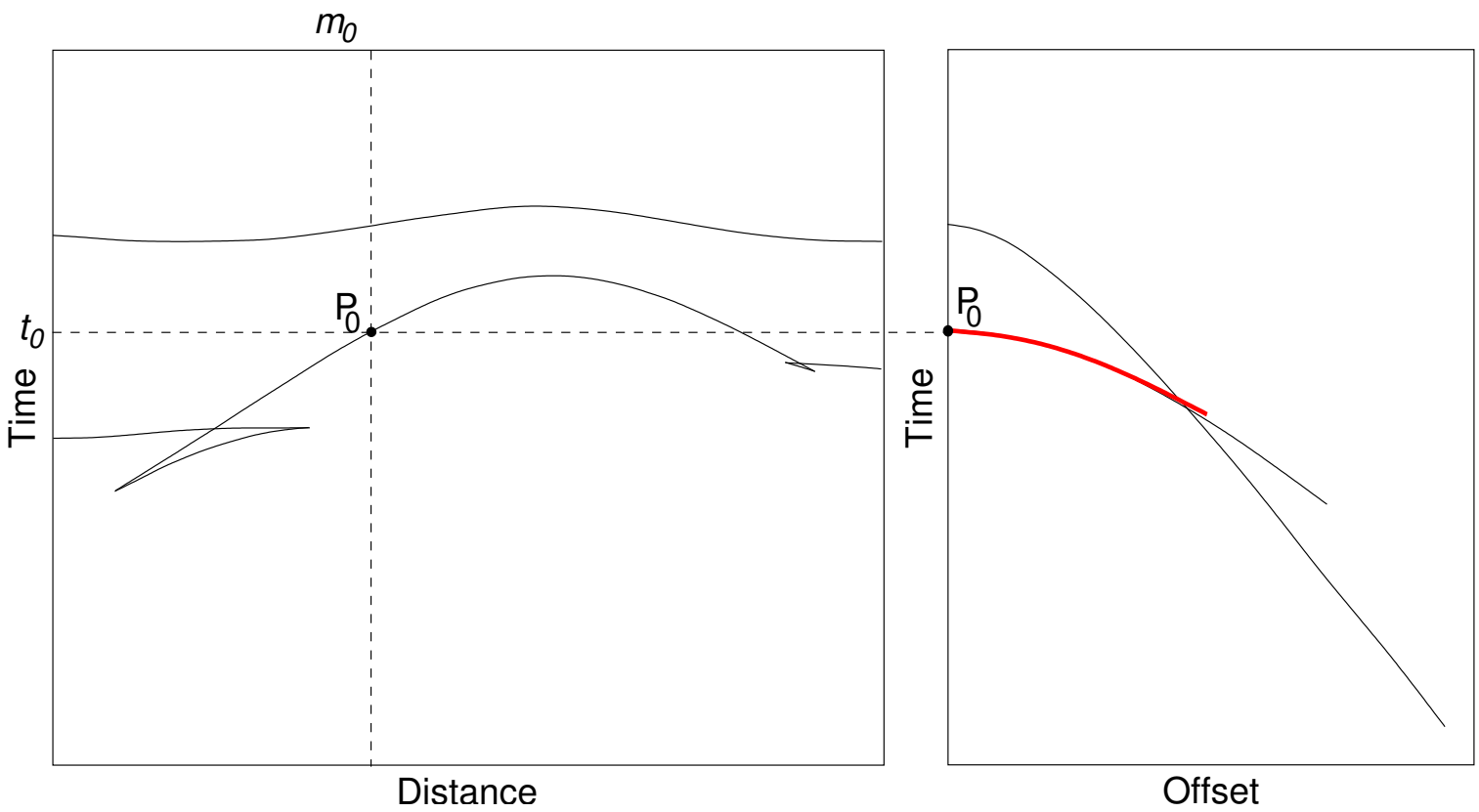

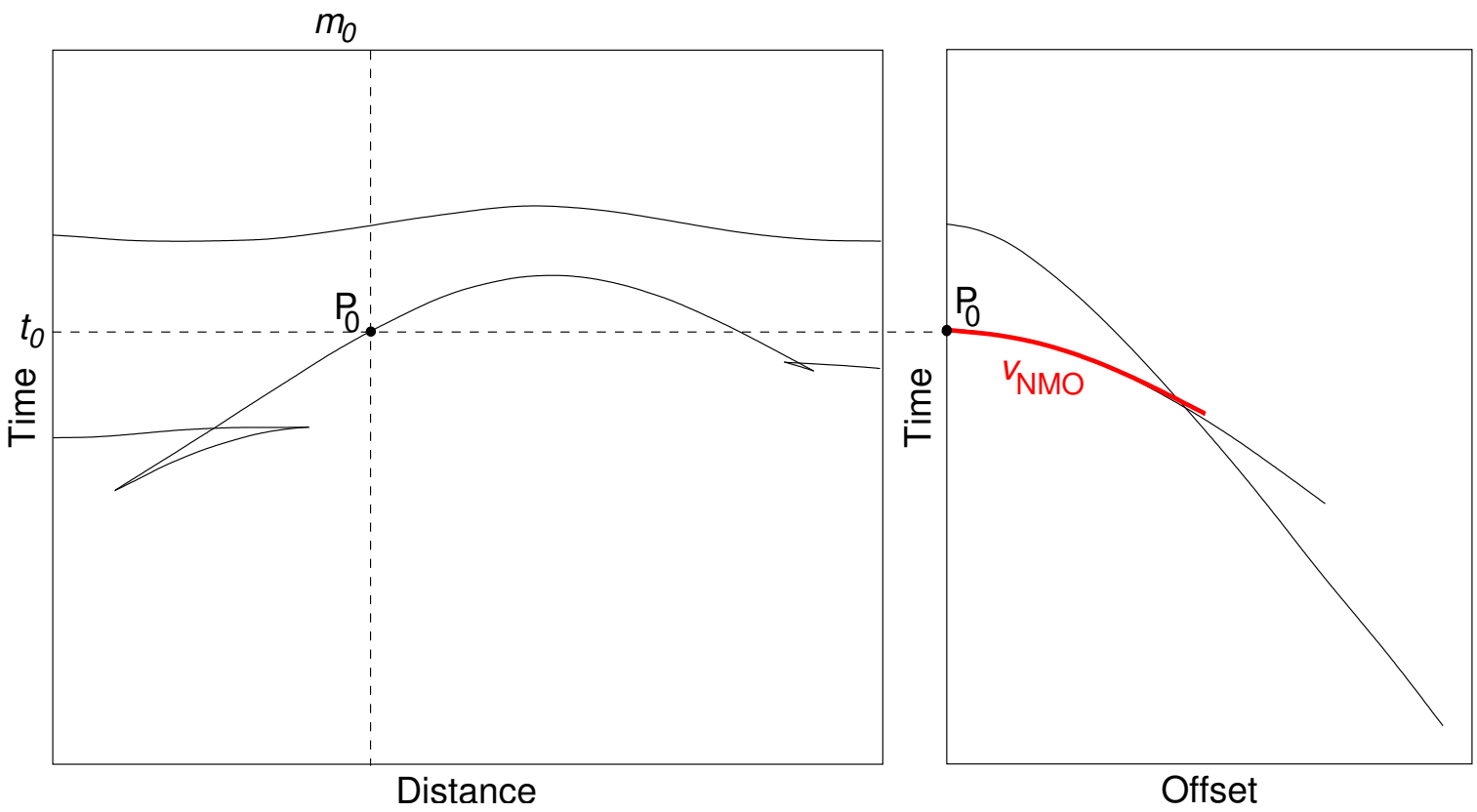
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Time
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$v_{NMO}$
Time
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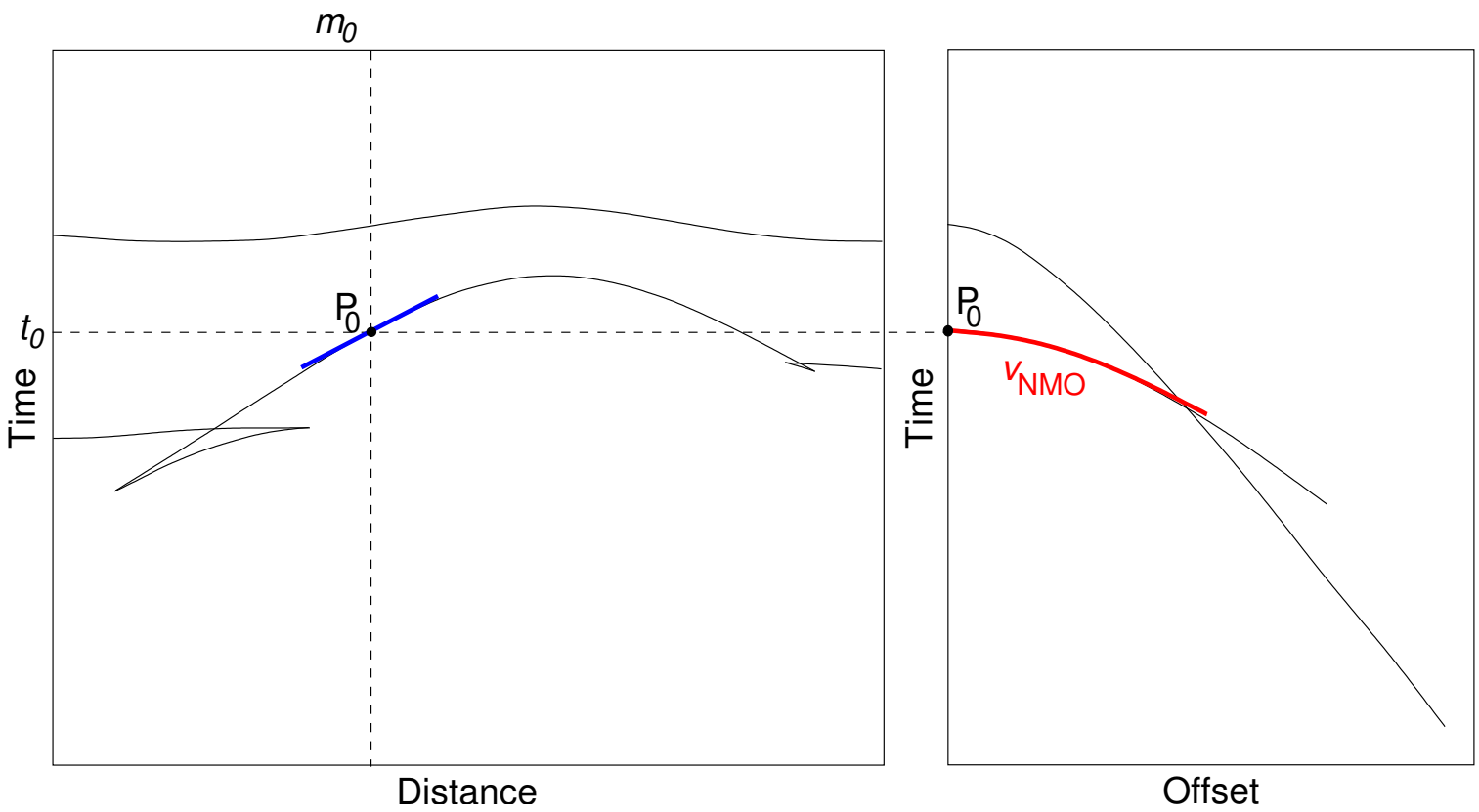
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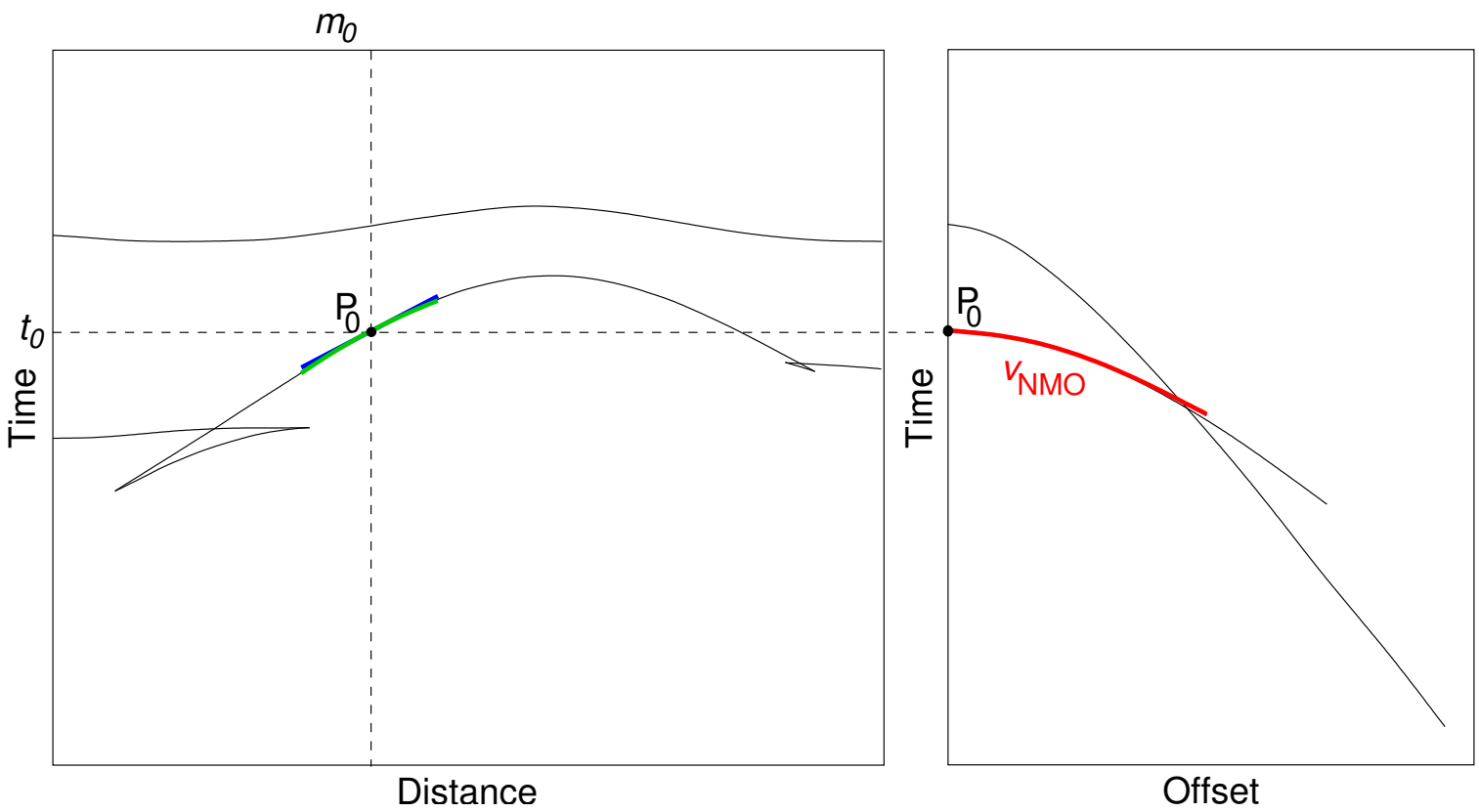
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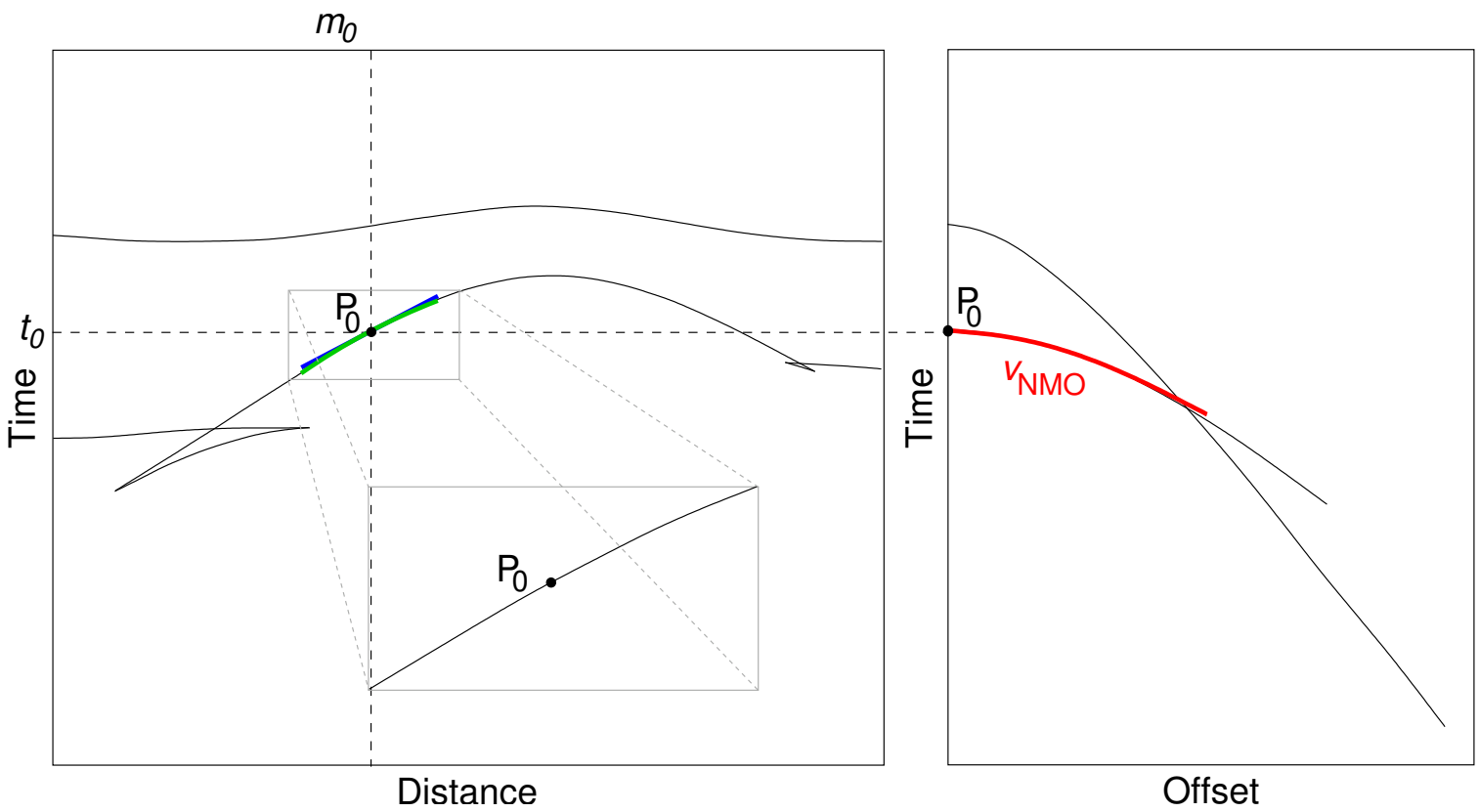

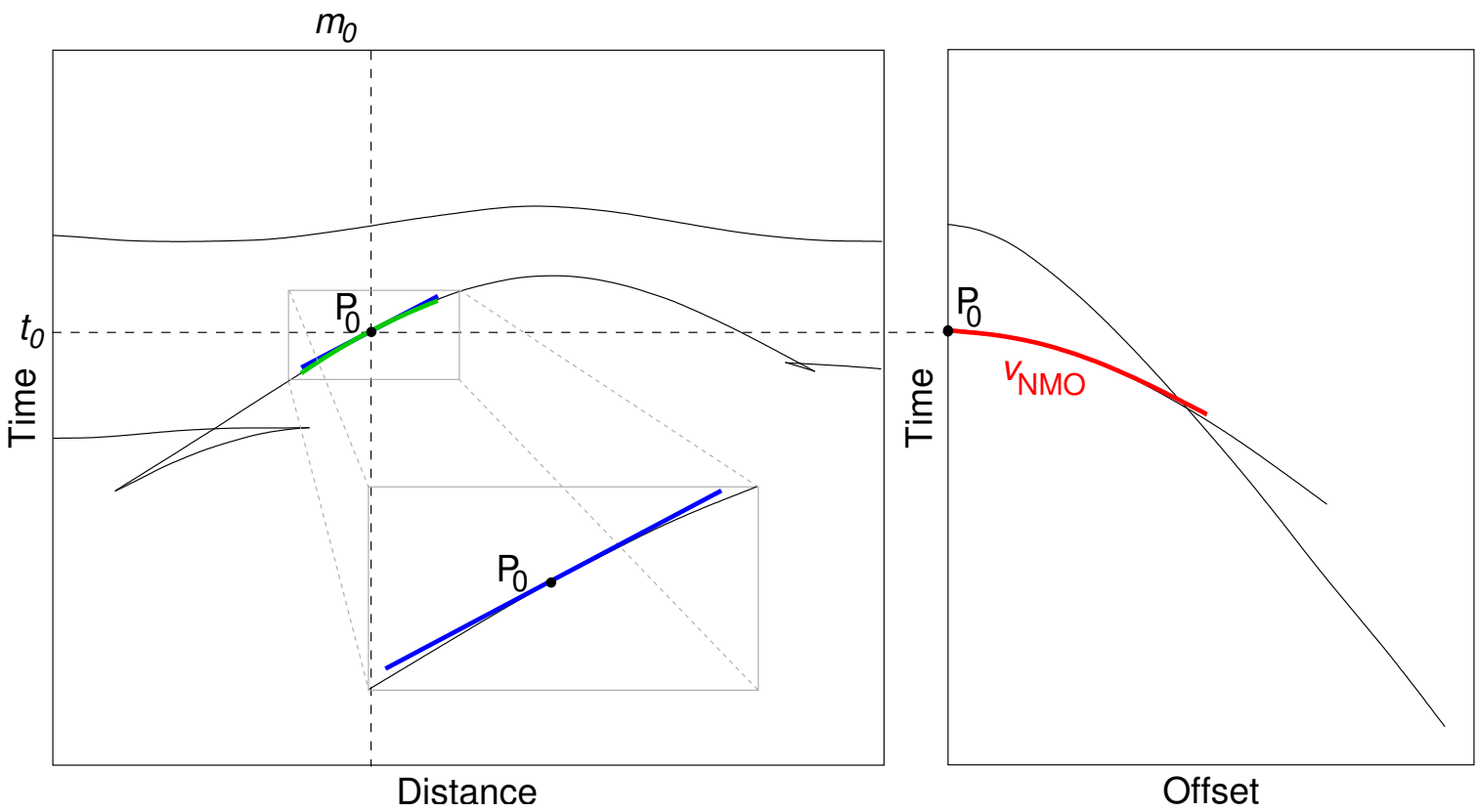
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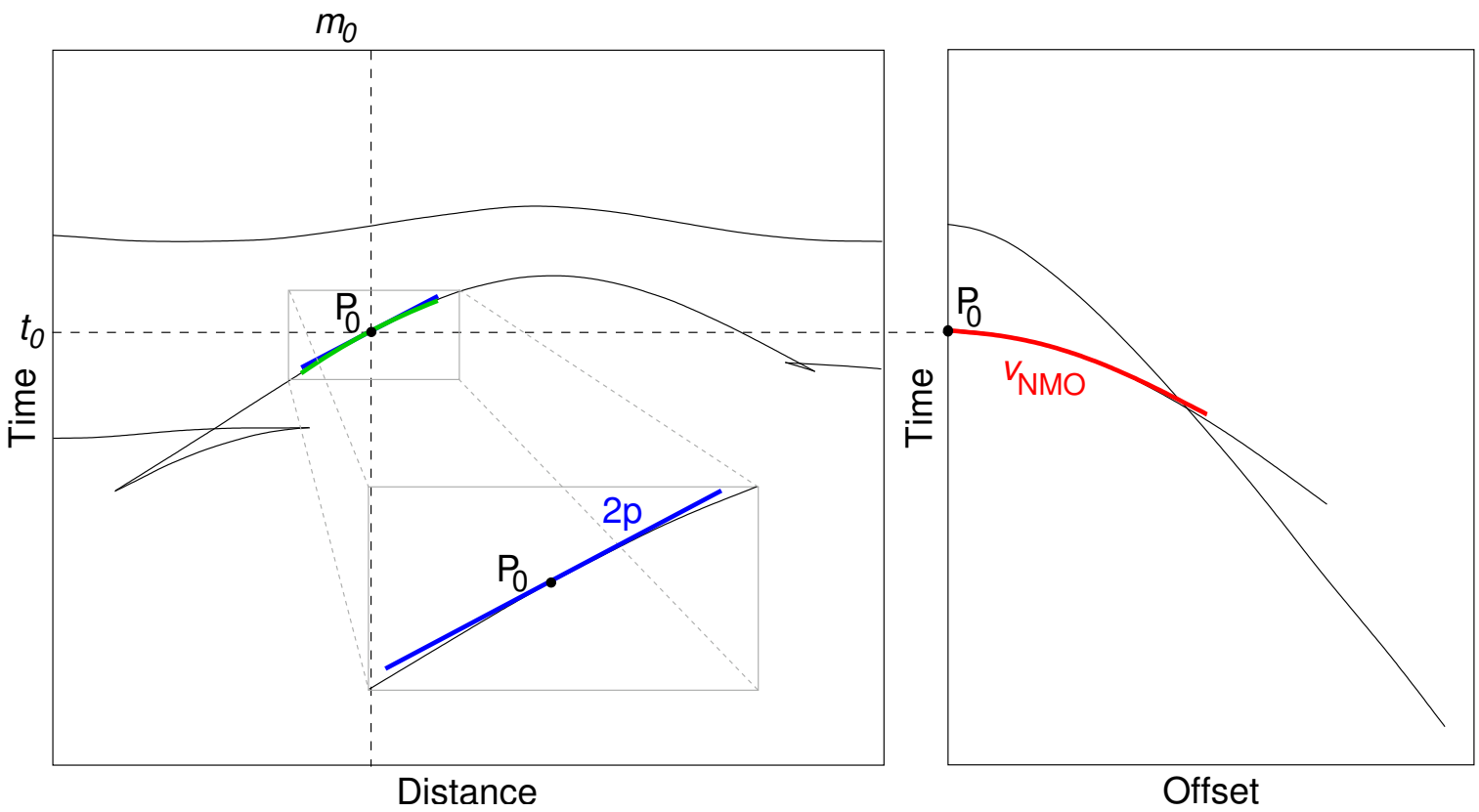

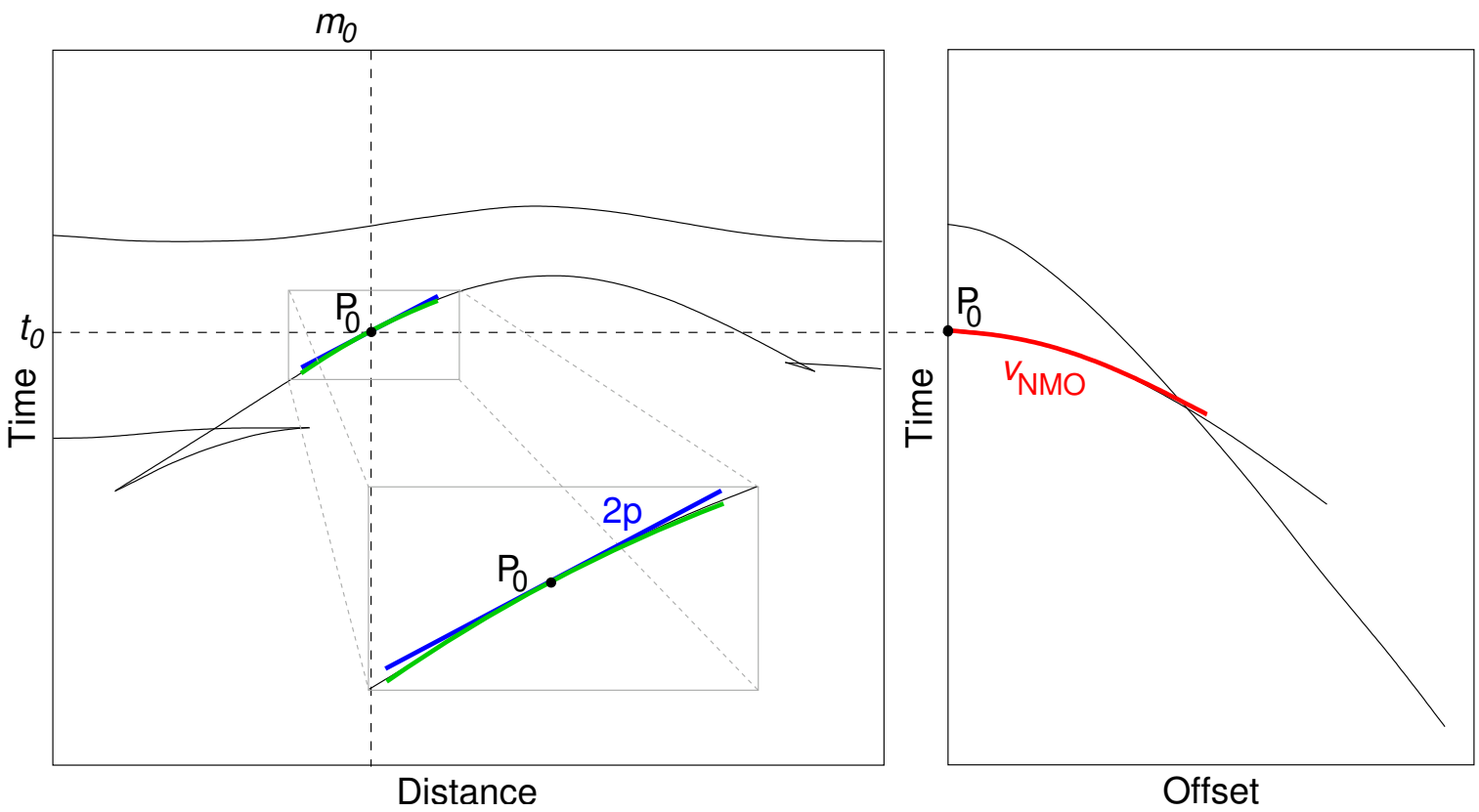
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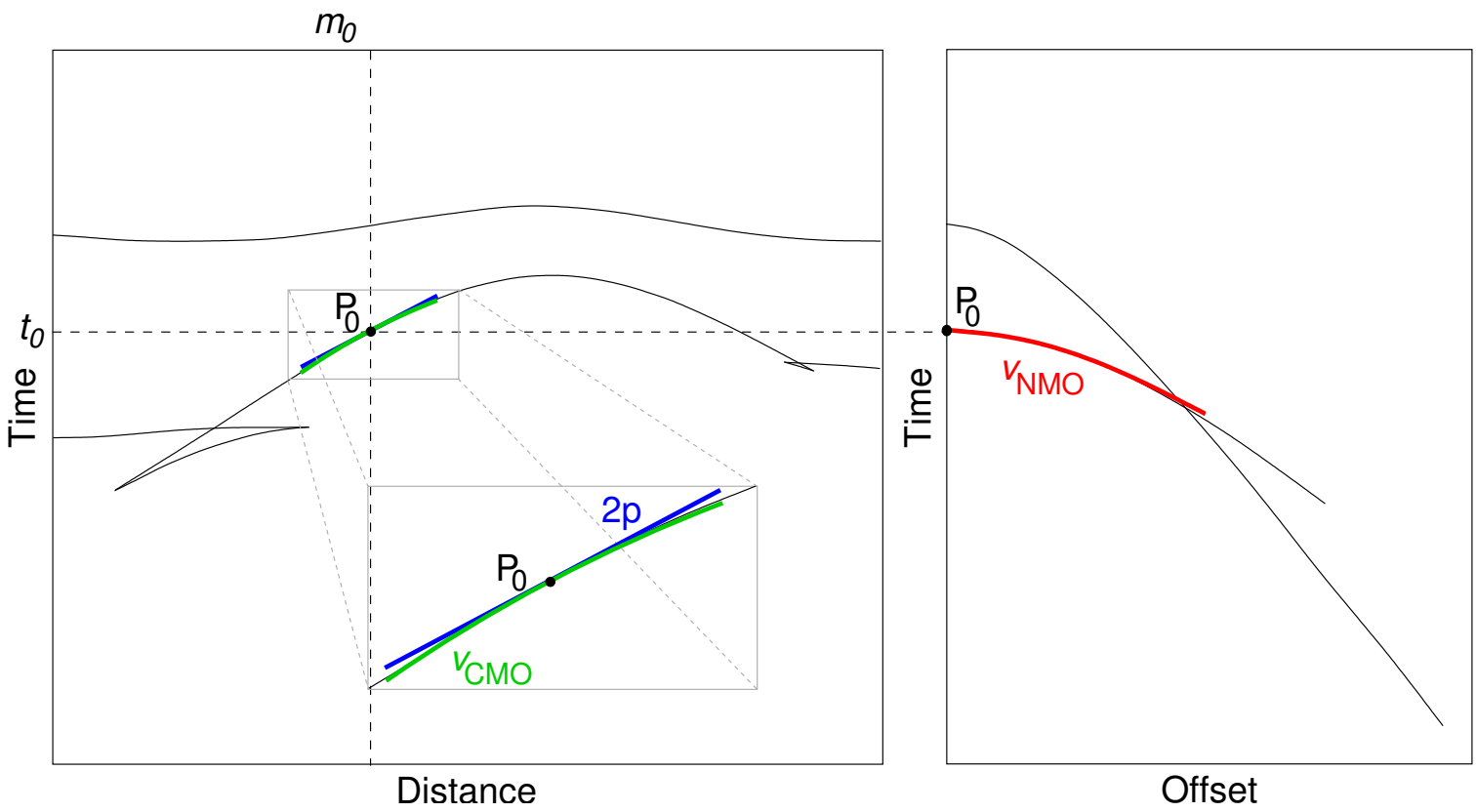
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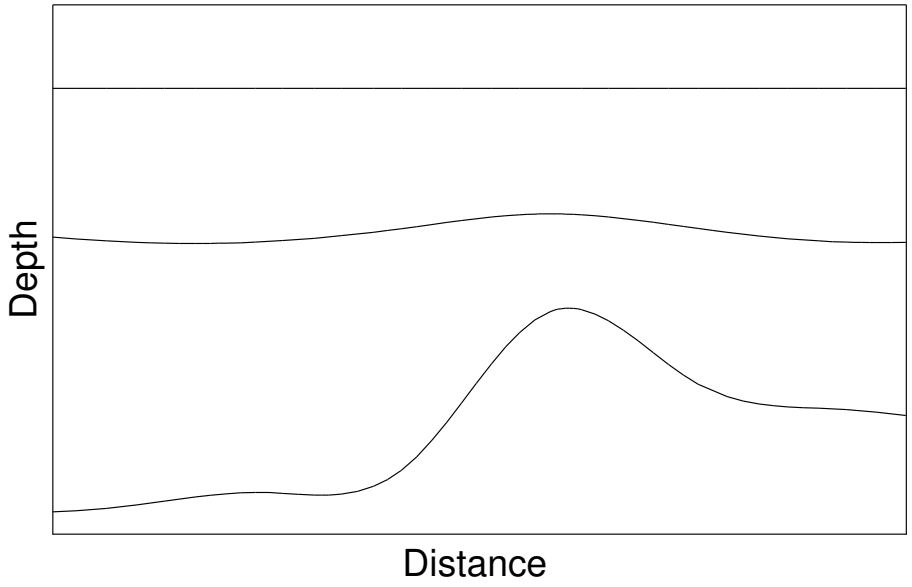


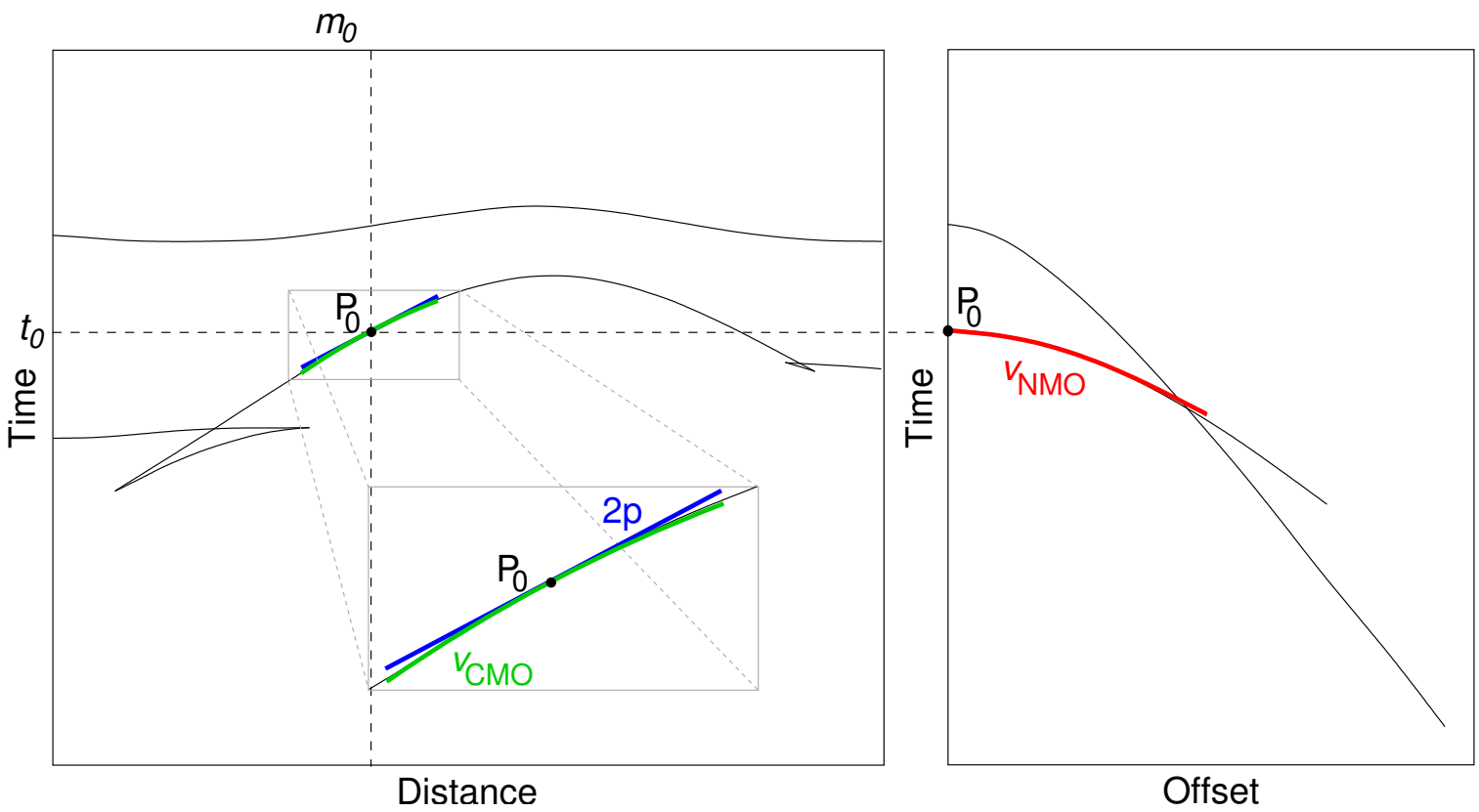

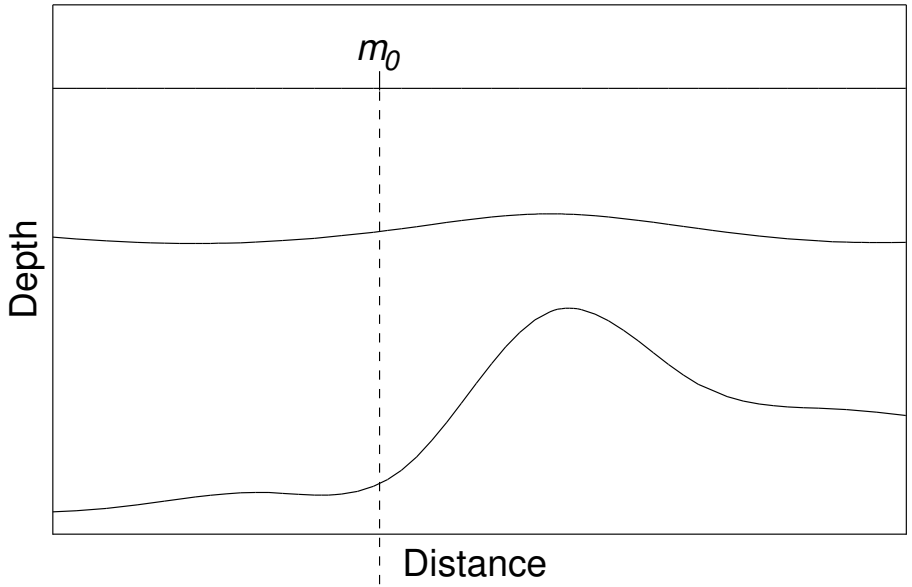
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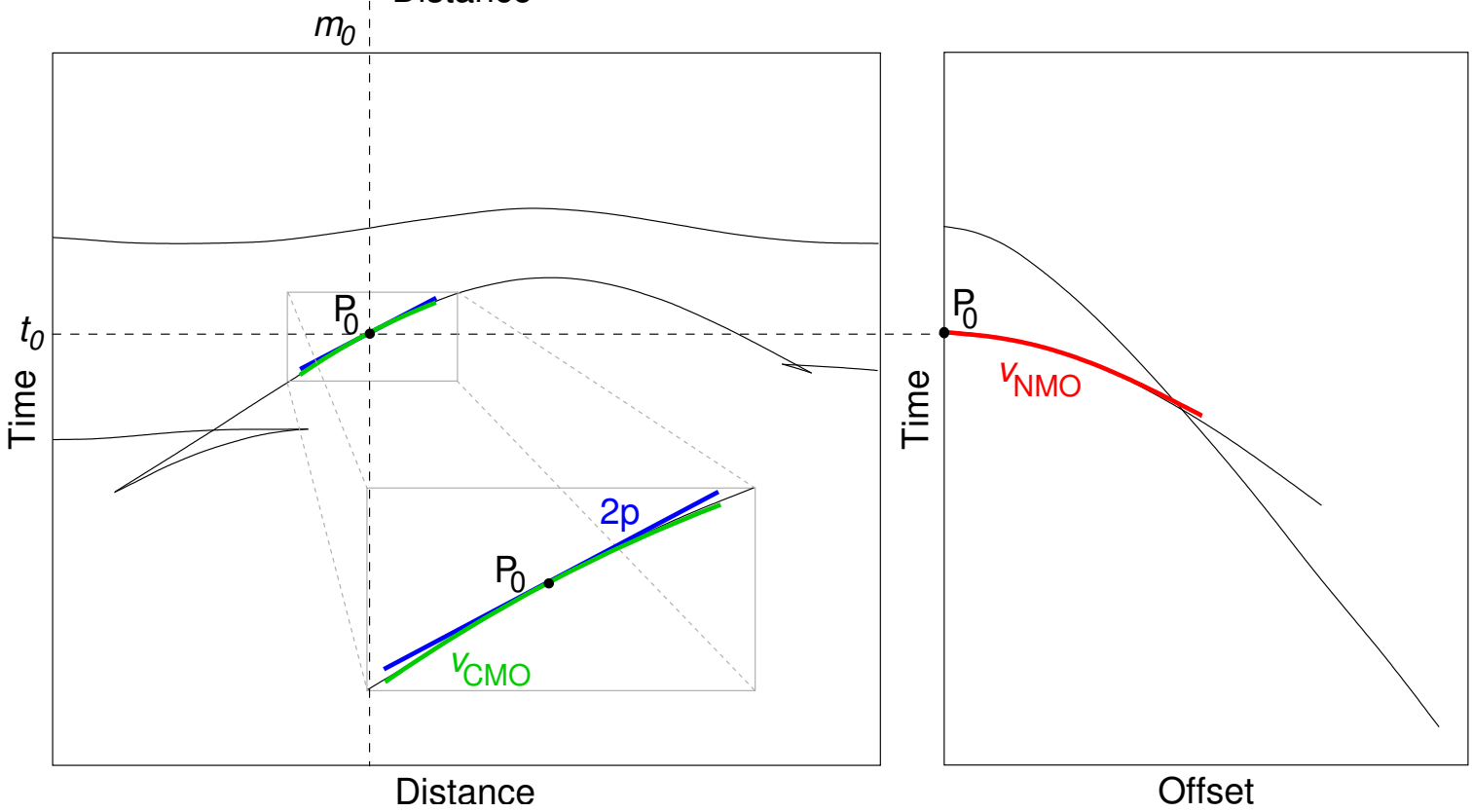
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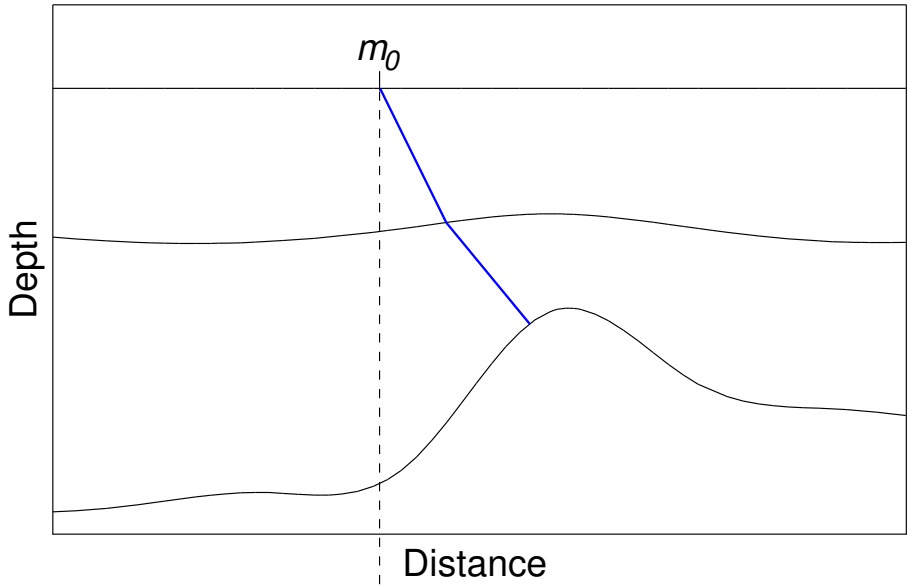
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Depth
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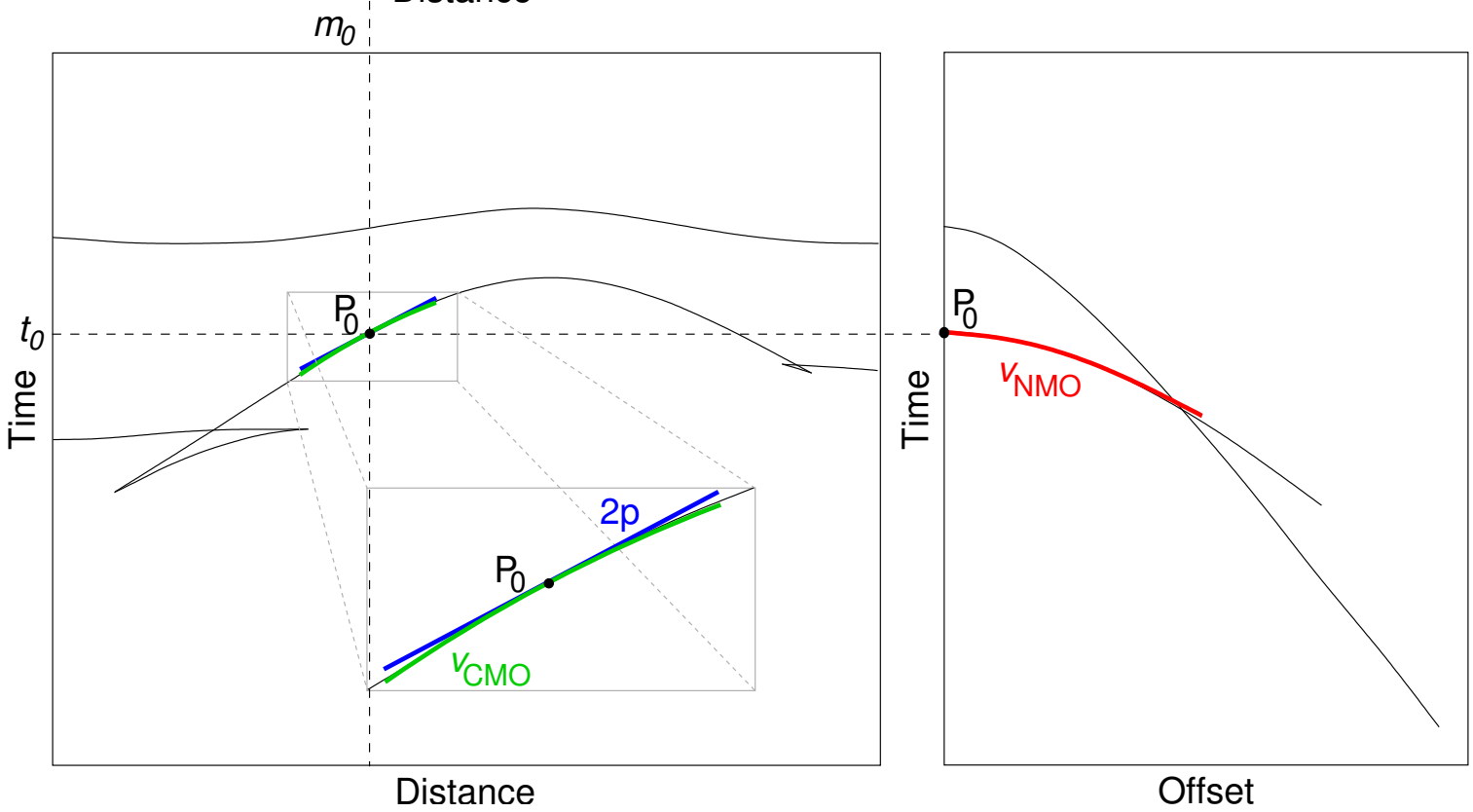
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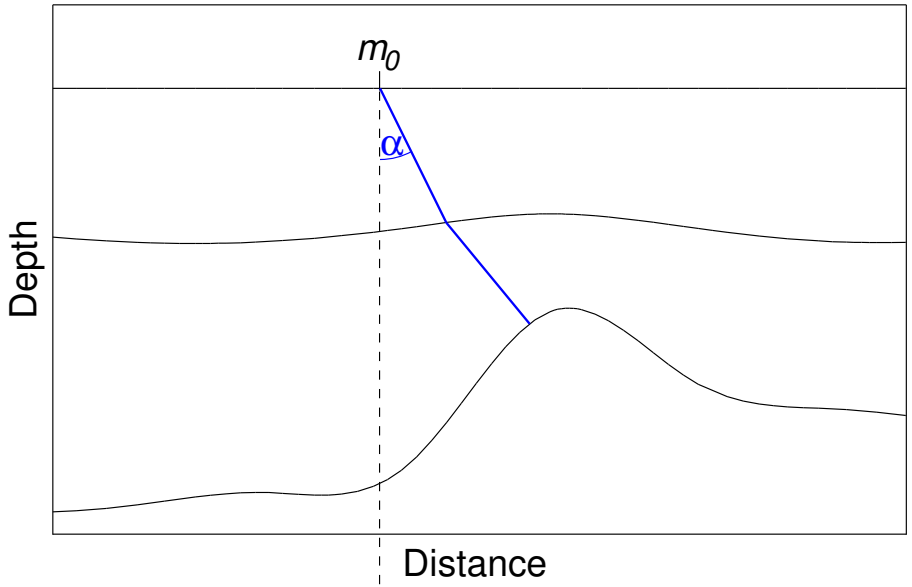
$P_0$
2p
$P_0$
$v_{CMO}$
Distance
$P_0$
$v_{NMO}$
Time
Offset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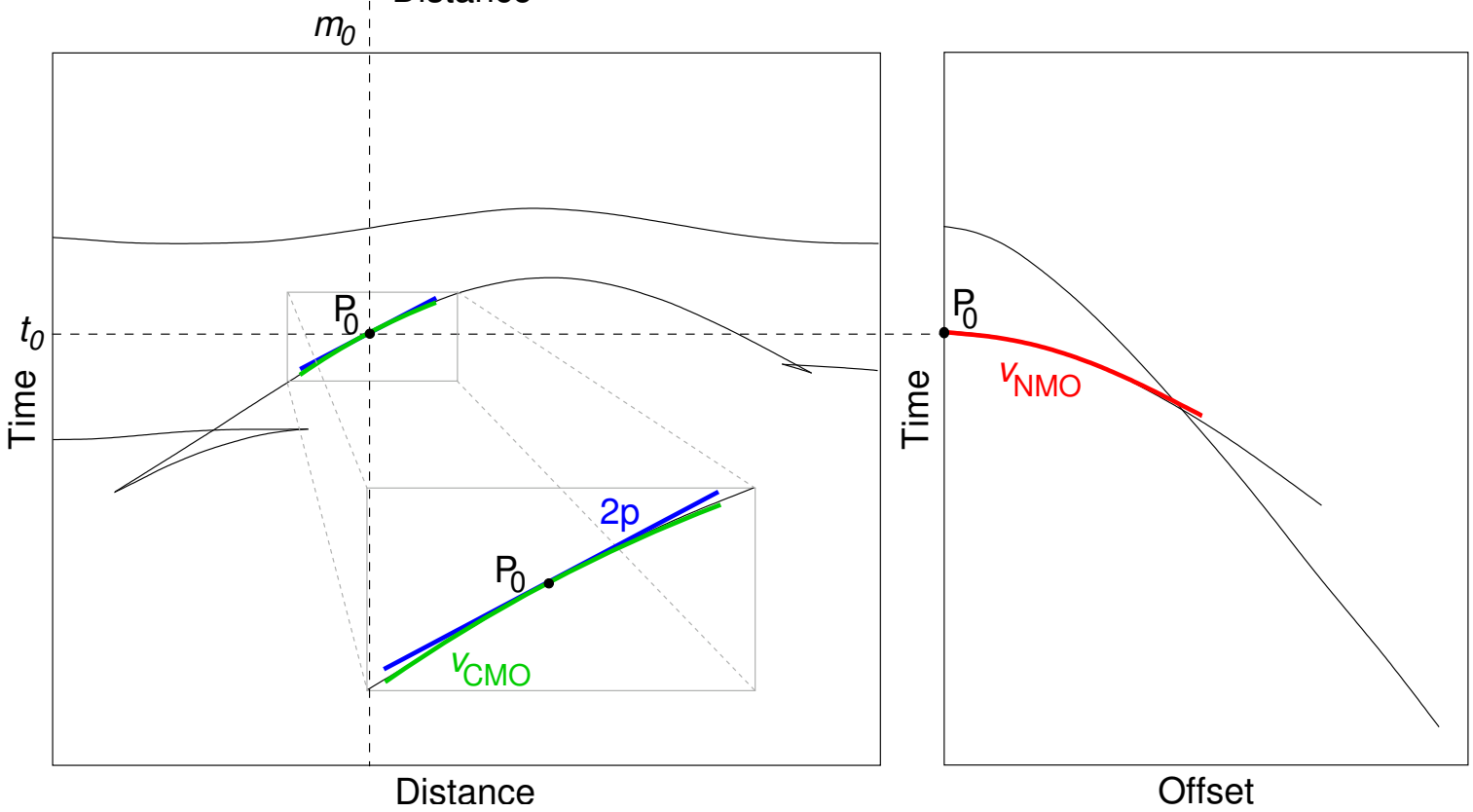
Distance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$P_0$
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$v_{CMO}$
Distance
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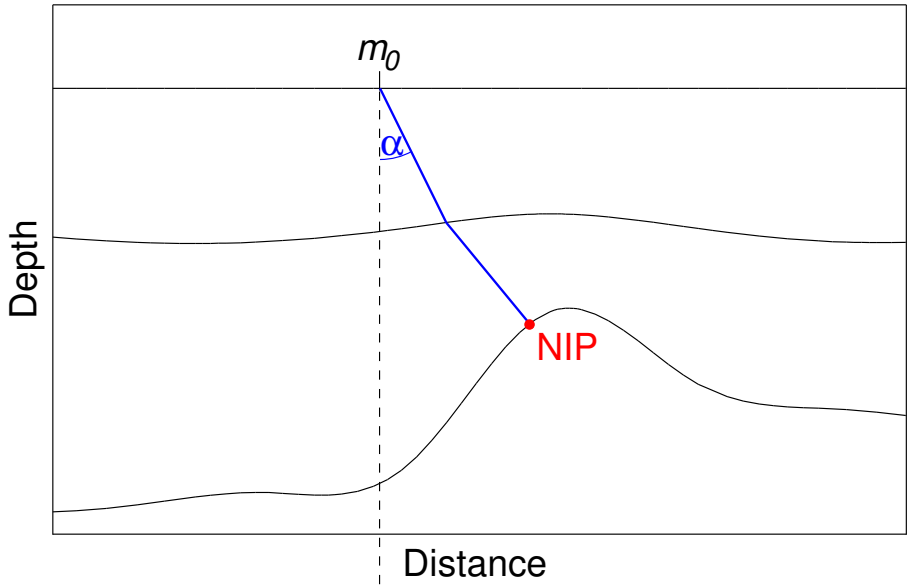
$v_{NMO}$
Time
Offset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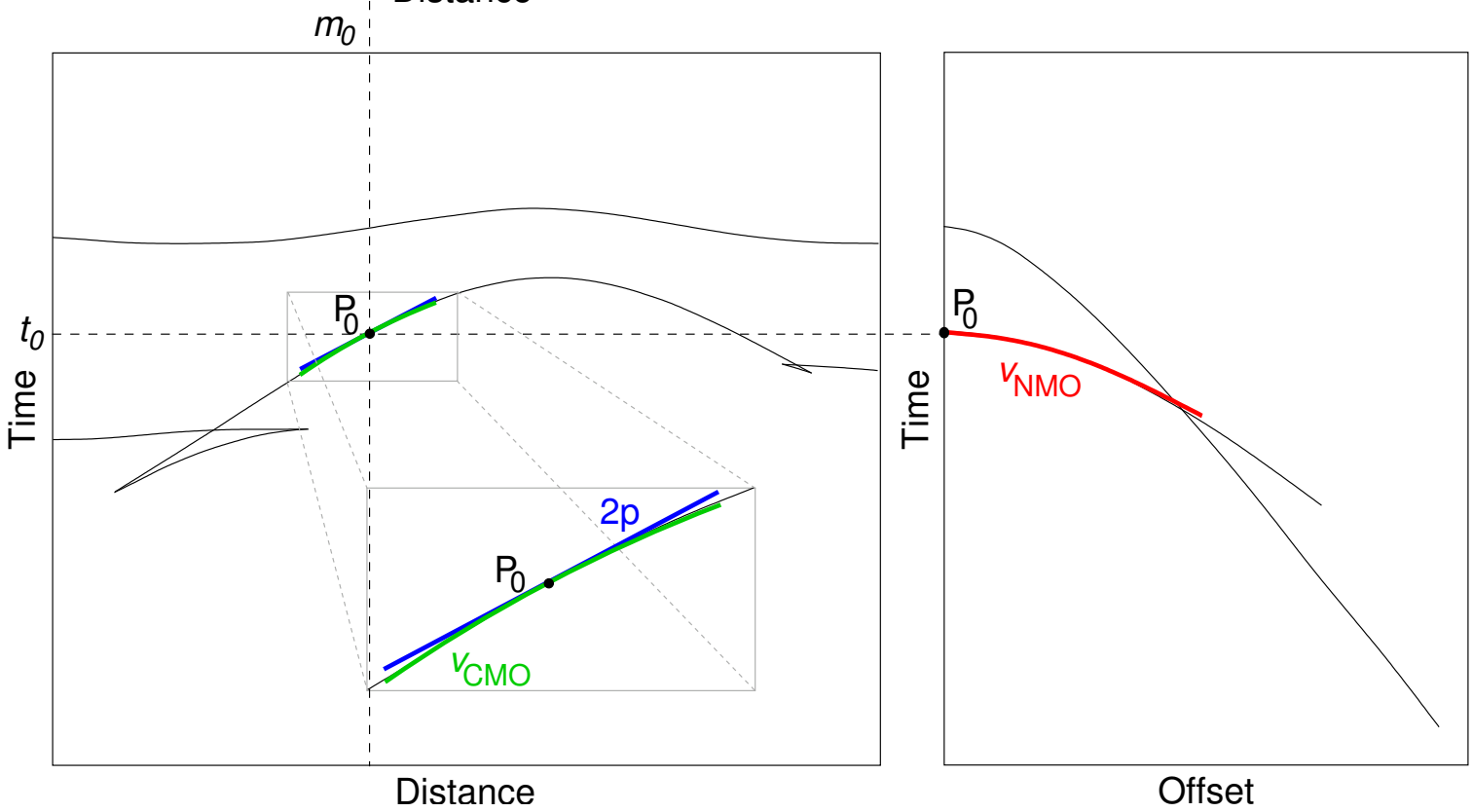
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Distance
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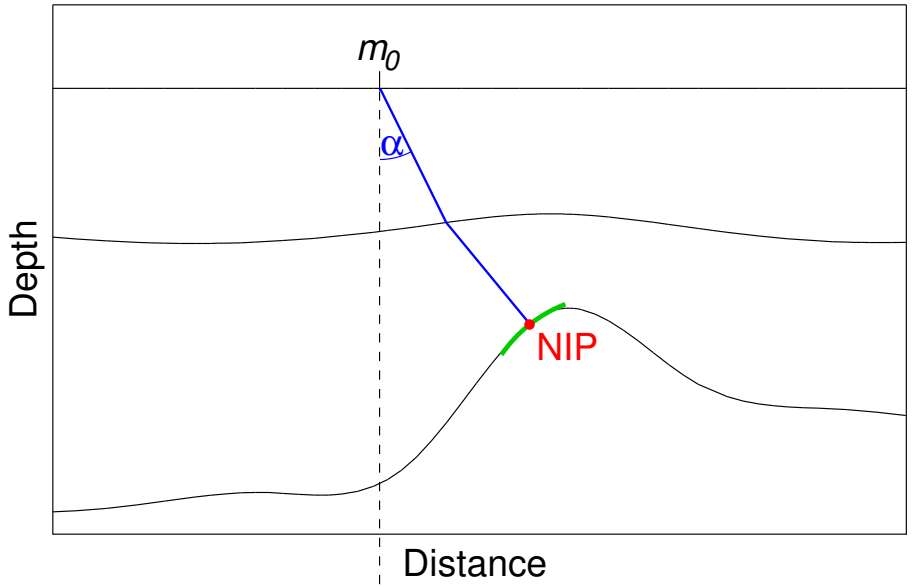
P0
$v_{NMO}$
Offset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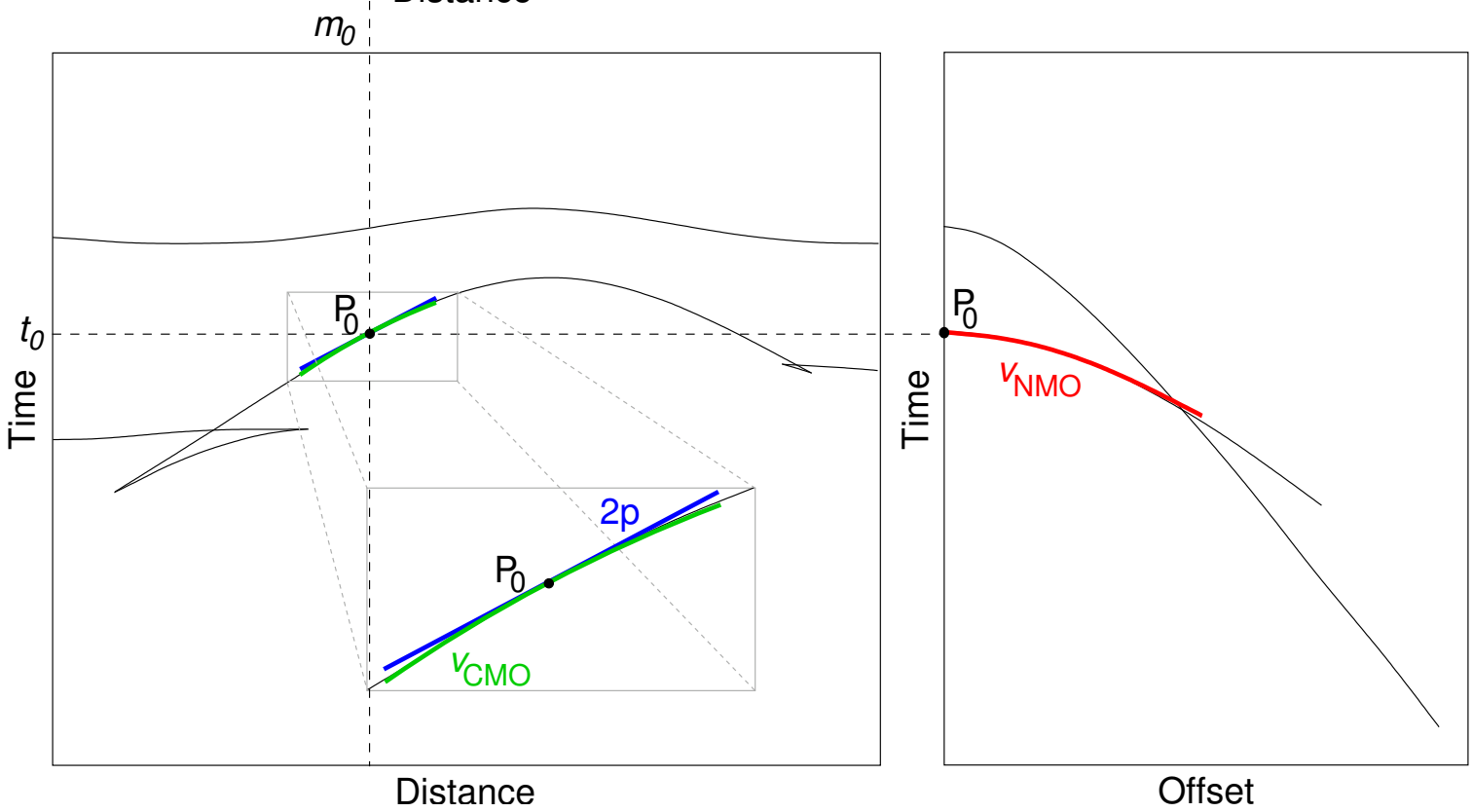
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Distance
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$v_{NMO}$
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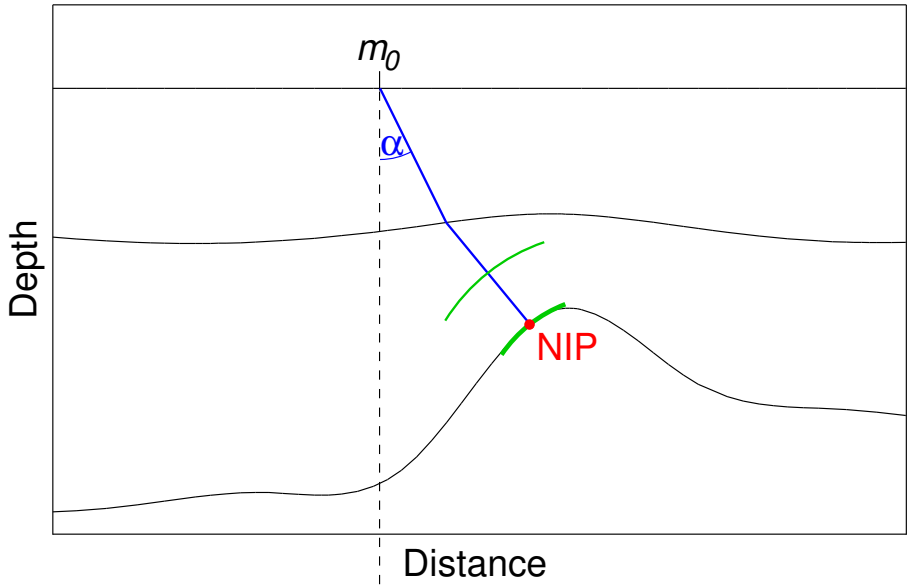
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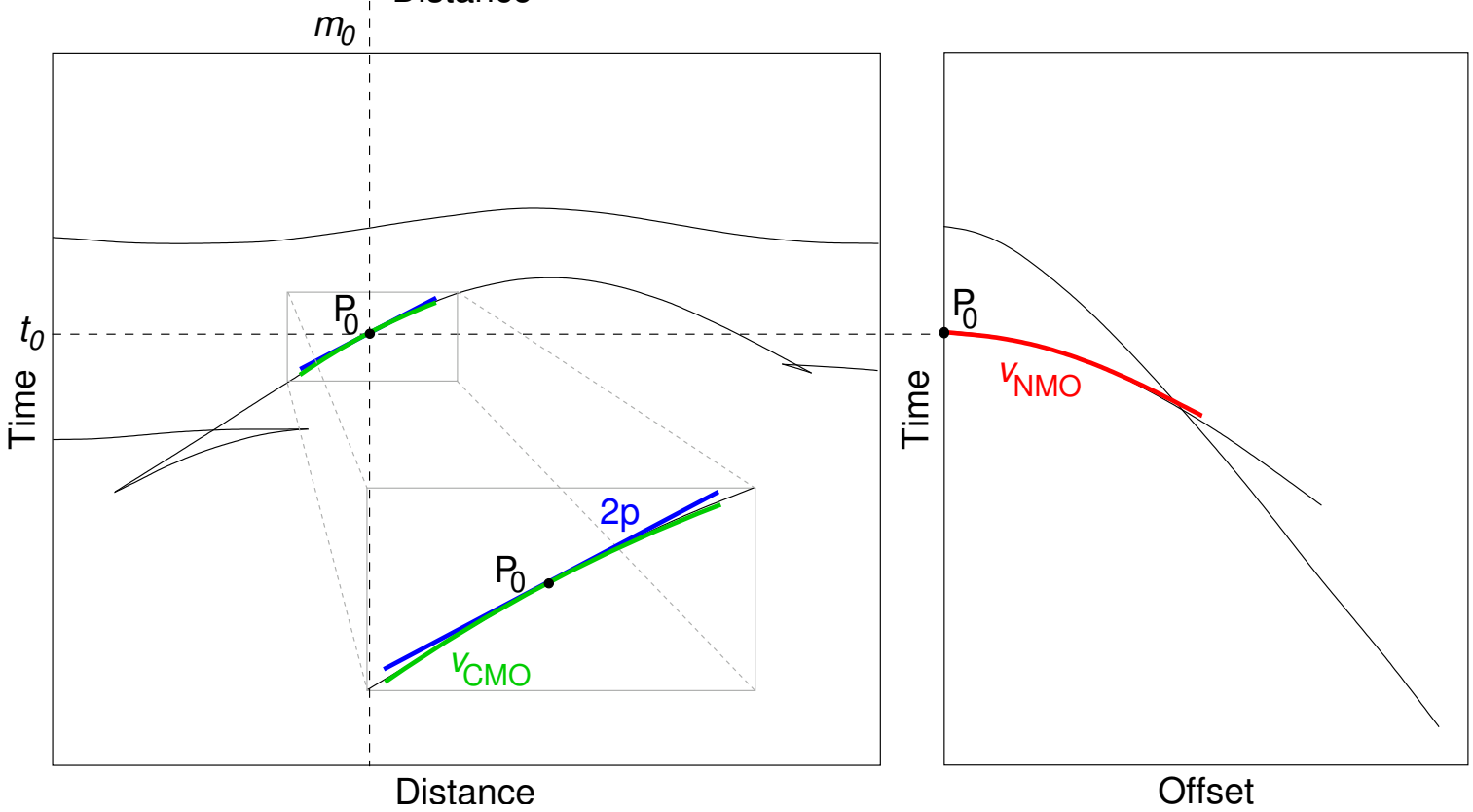
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Distance
Time
$P_0$
$v_{NMO}$
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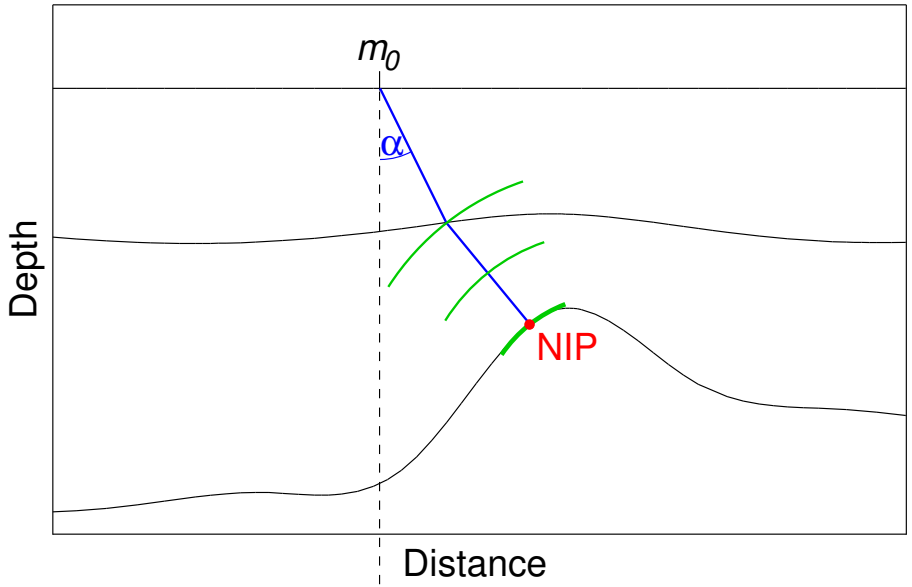
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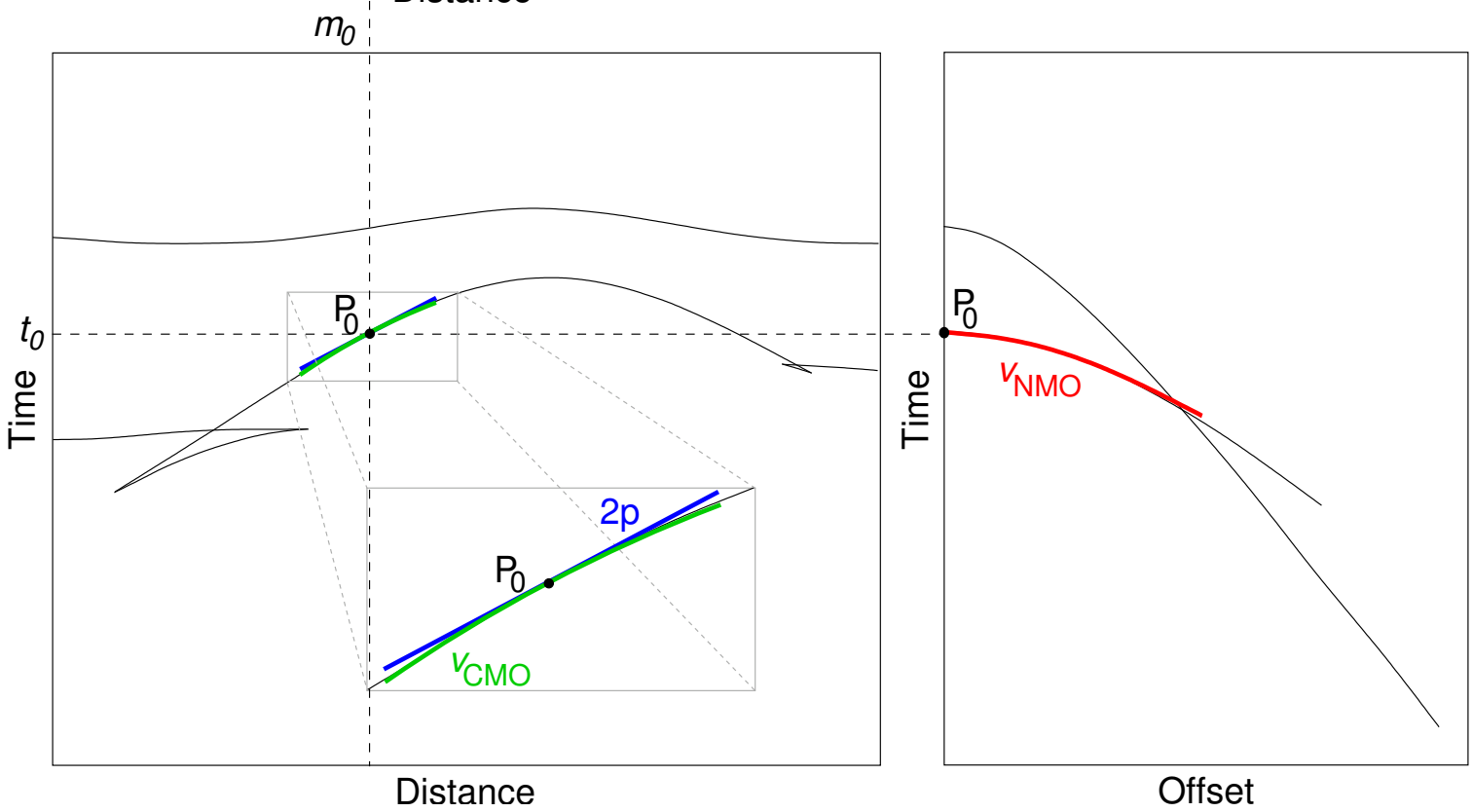
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P0
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P0
$v_{CMO}$
Distance
Time
P0
$v_{NMO}$
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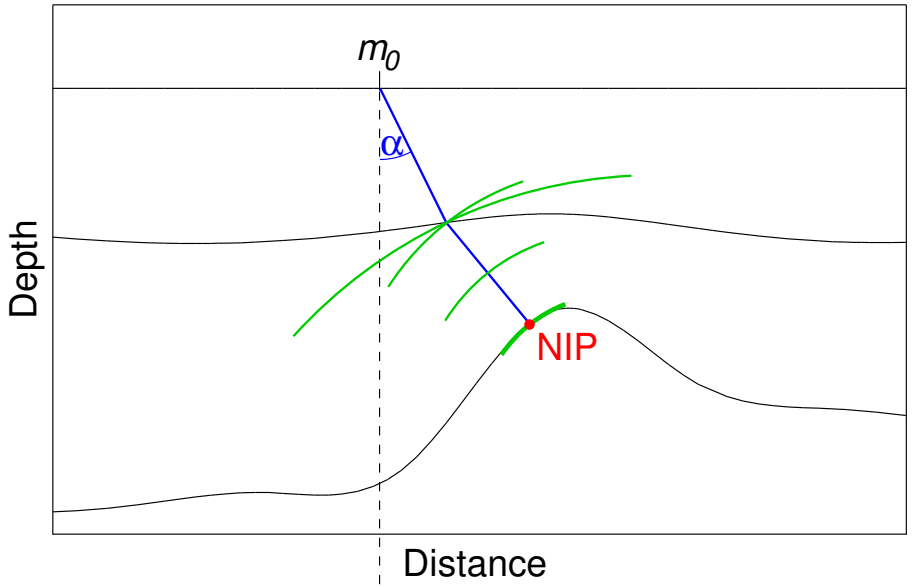
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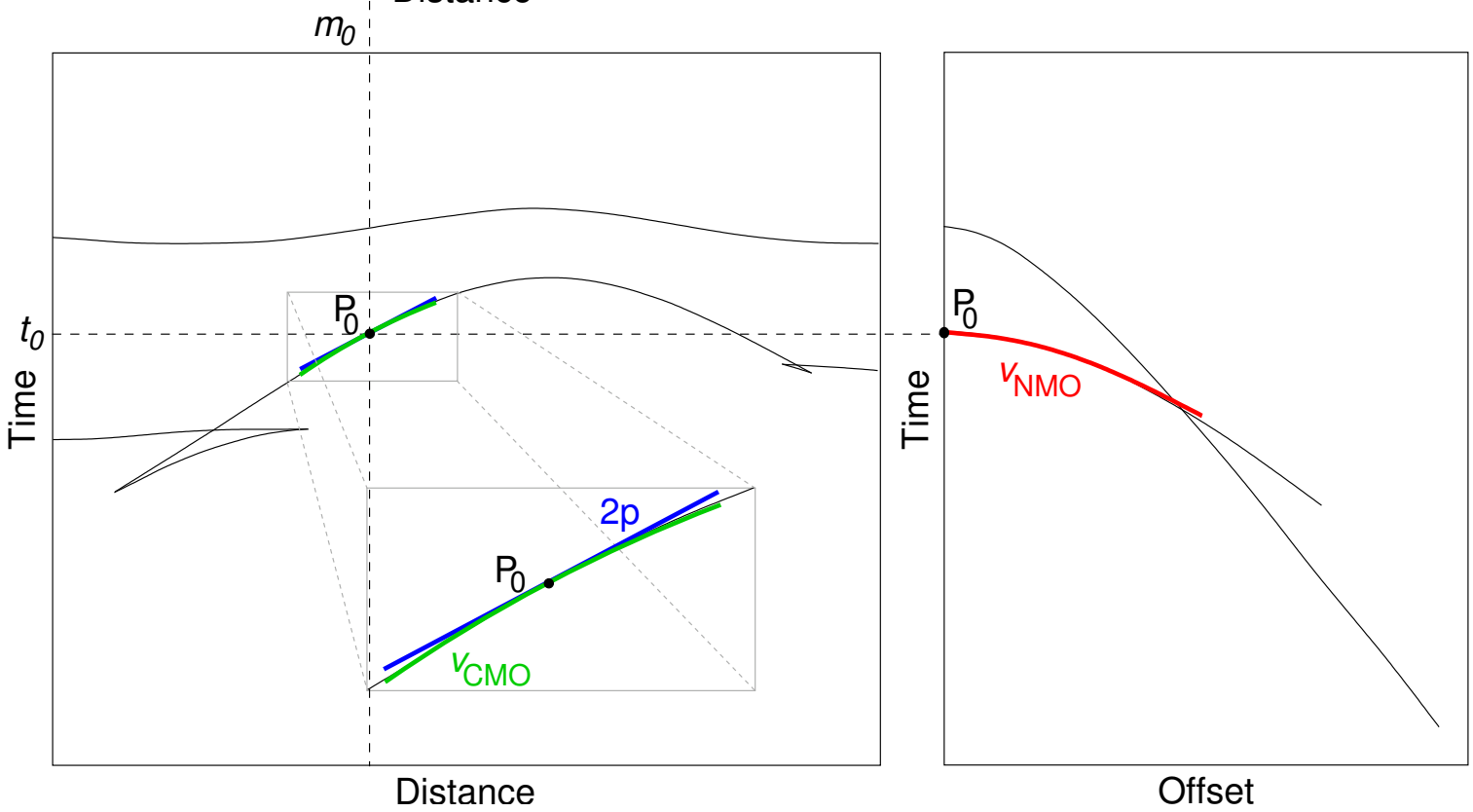
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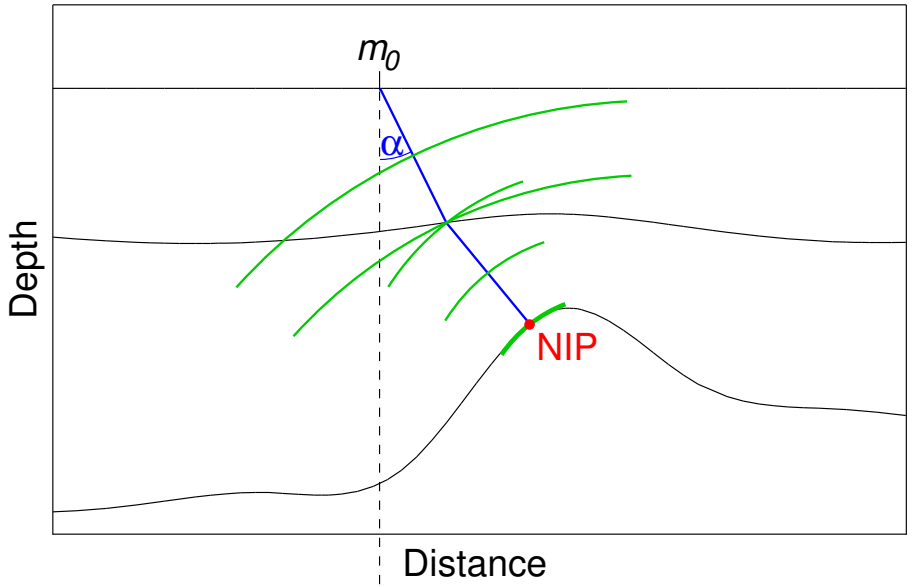
Time
P0
2p
P0
$v_{CMO}$
Distance
Time
P0
$v_{NMO}$
Offset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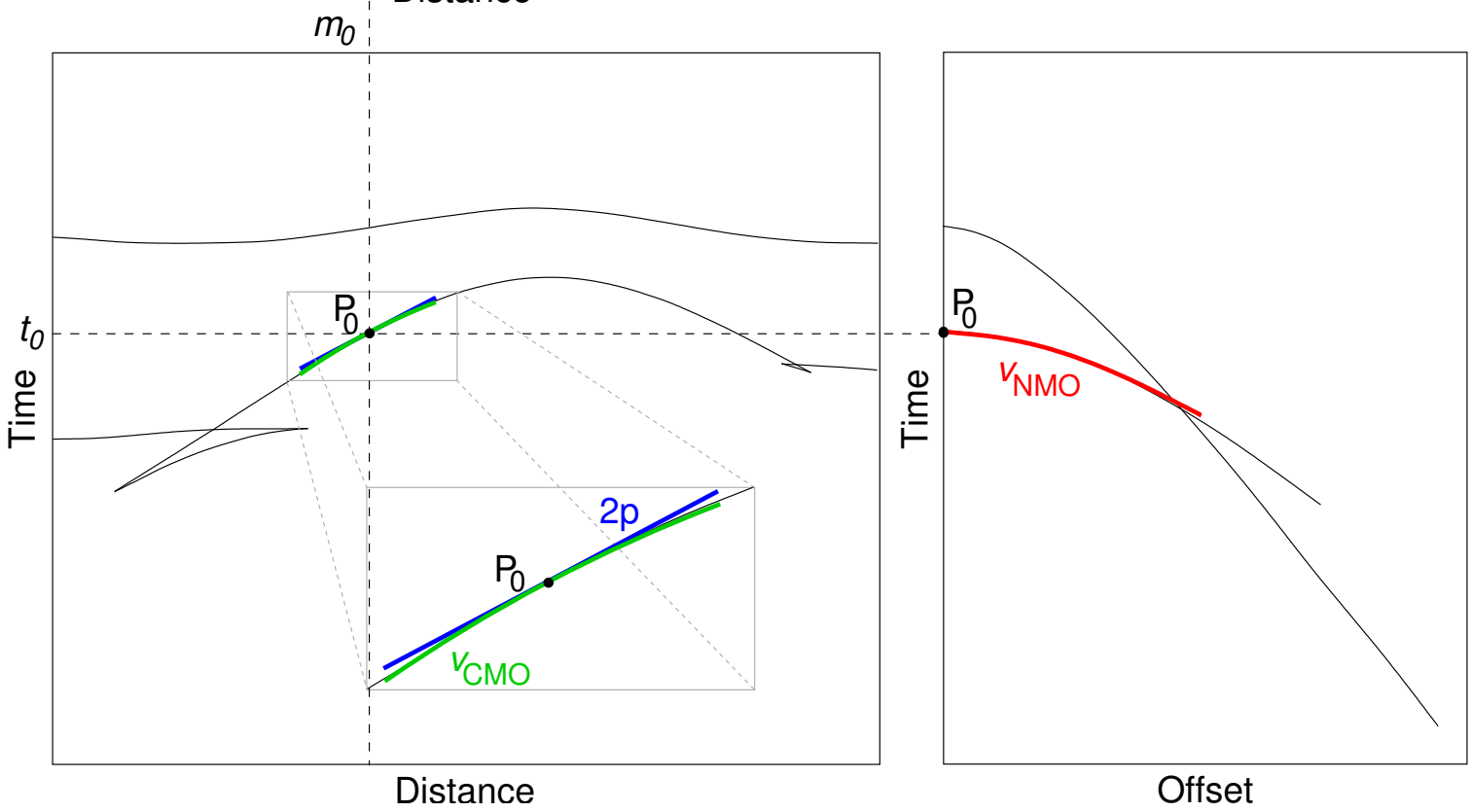
α
Depth
NIP
Distance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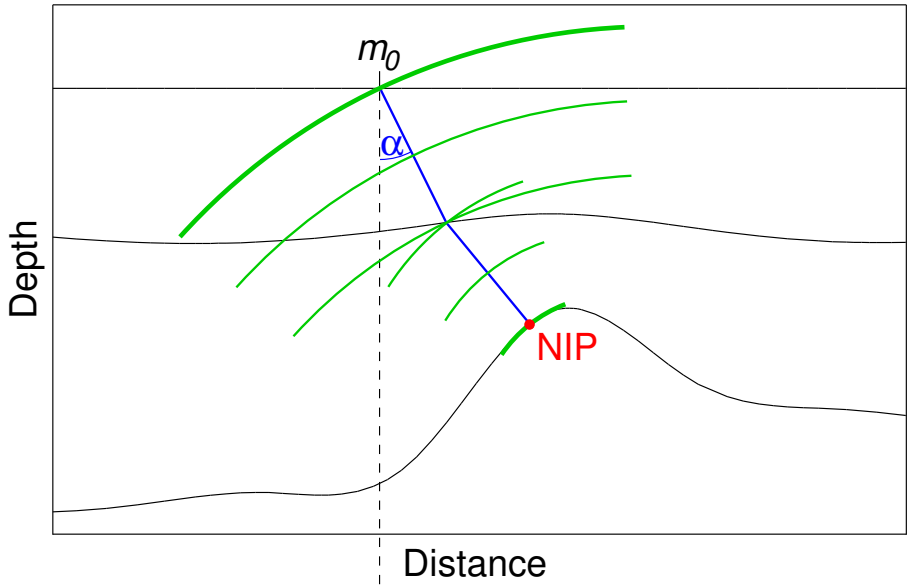
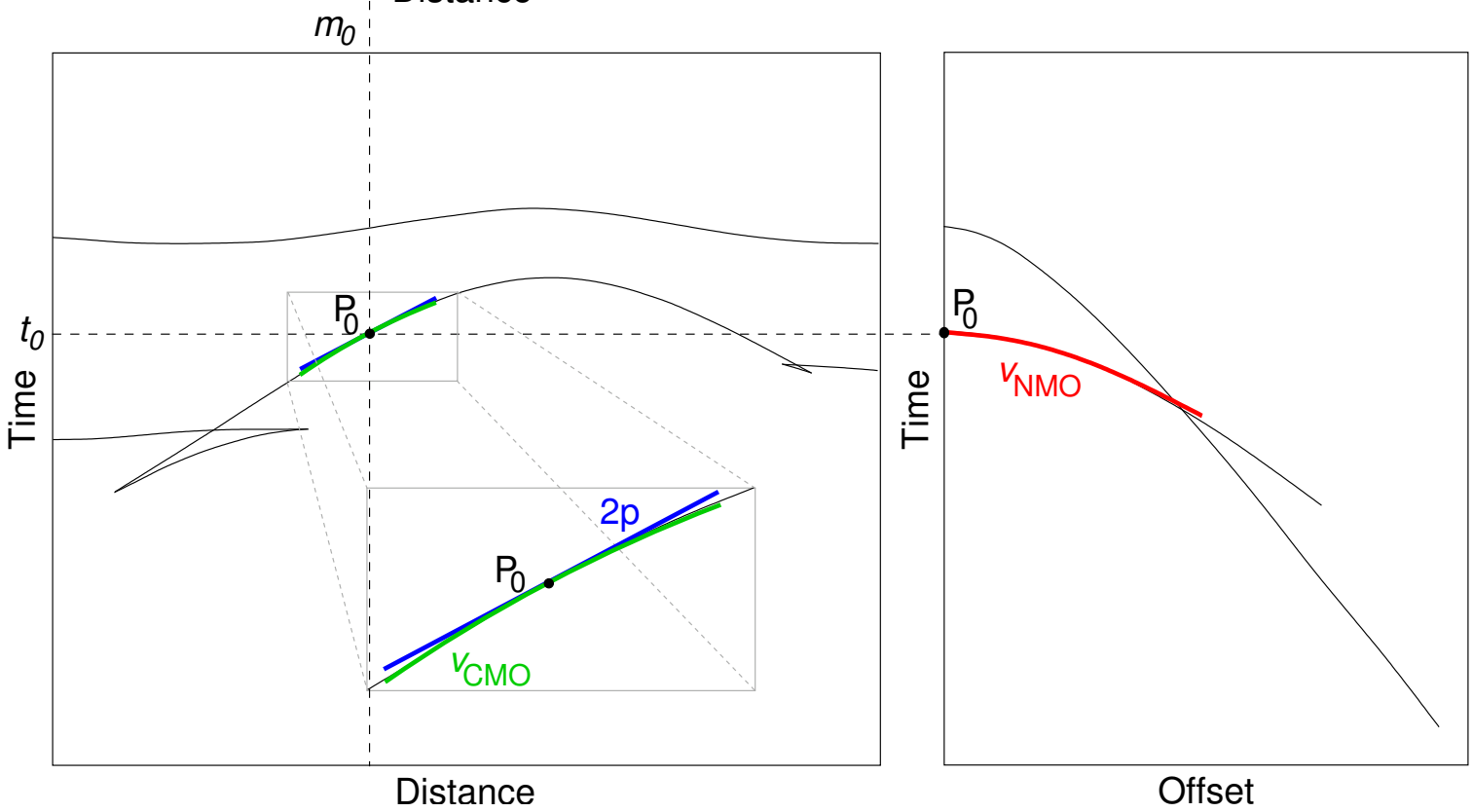
2p
$P_0$
$v_{CMO}$
Distance
Time
$P_0$
$v_{NMO}$
Offset


$m_0$
α
Depth
NIP
Distance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$t_0$
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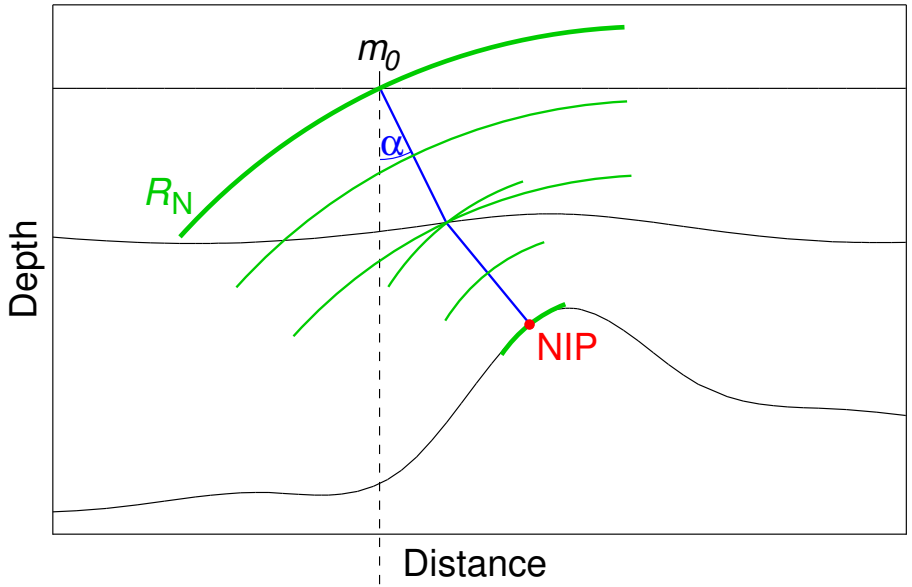
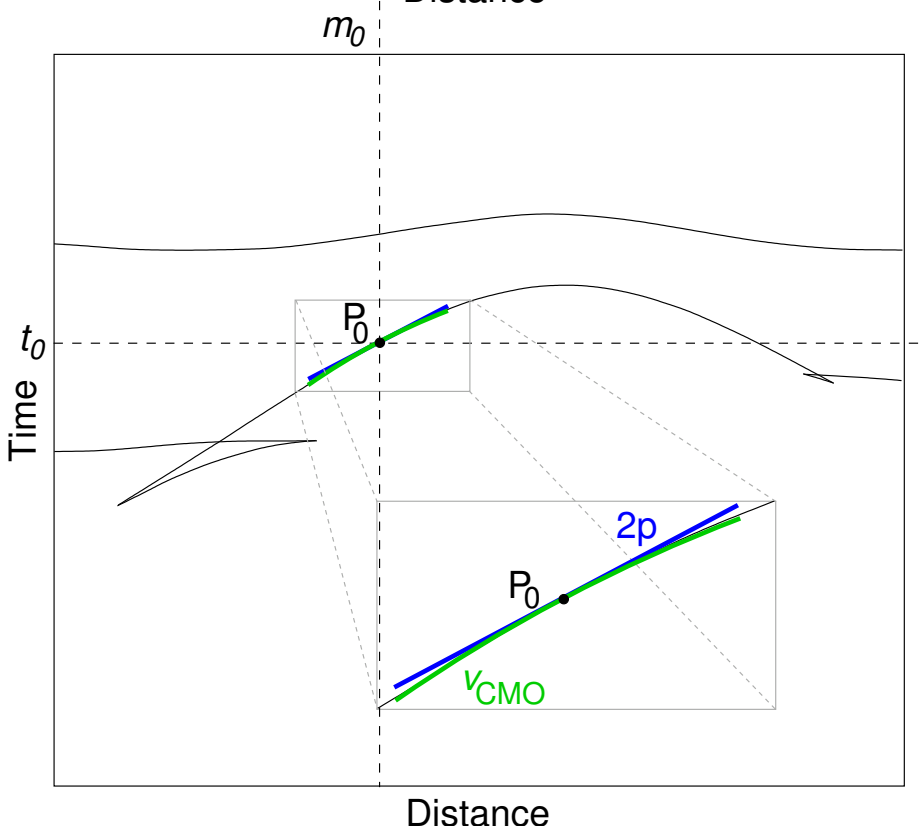
$P_0$
2p
$P_0$
$v_{CMO}$
Distance
Time
$P_0$
$v_{NMO}$
Offset


$m_0$
α
$R_N$
Depth
NIP
Distance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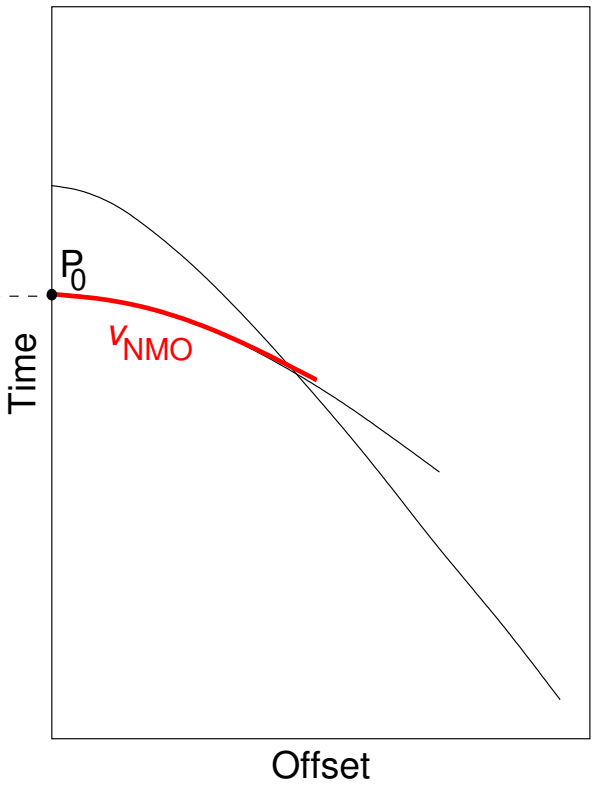
$t_0$
Time
$P_0$
2p
$P_0$
$v_{CMO}$
Distance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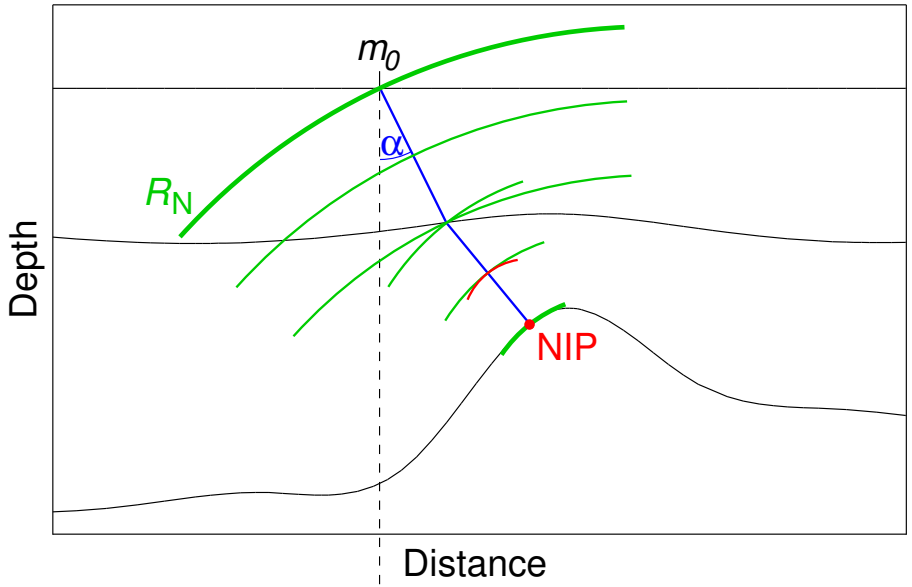
$v_{NMO}$
Time
Offset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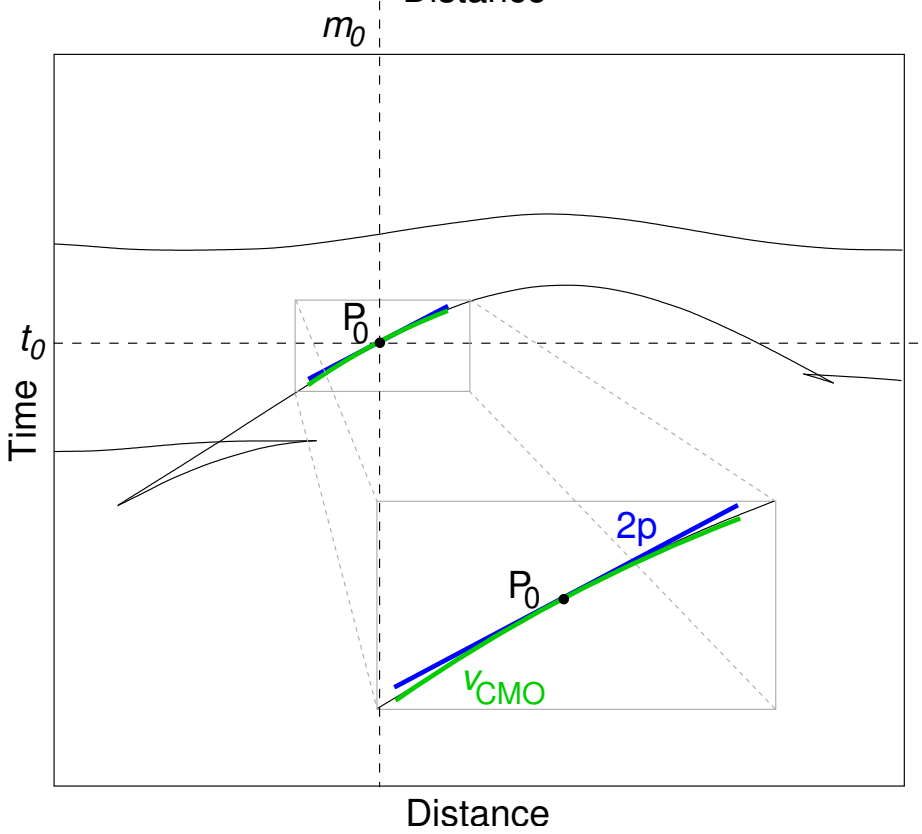
α
$R_N$
Depth
NIP
Distance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Time
$P_0$
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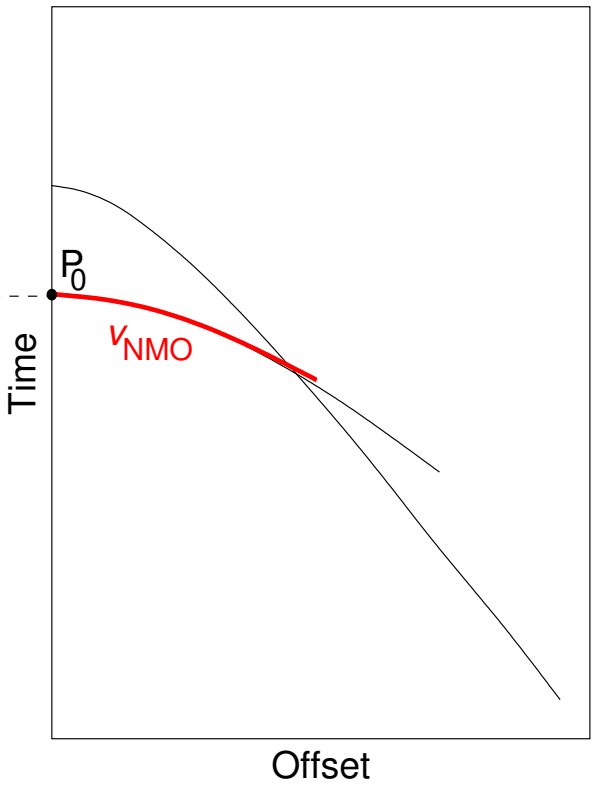
$v_{CMO}$
Distance


Time
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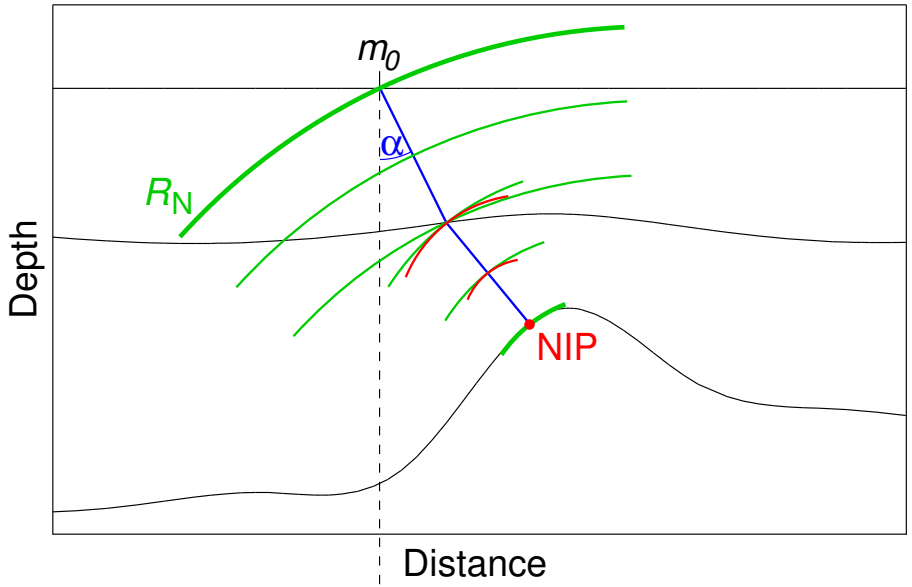
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α
$R_N$
NIP
Depth
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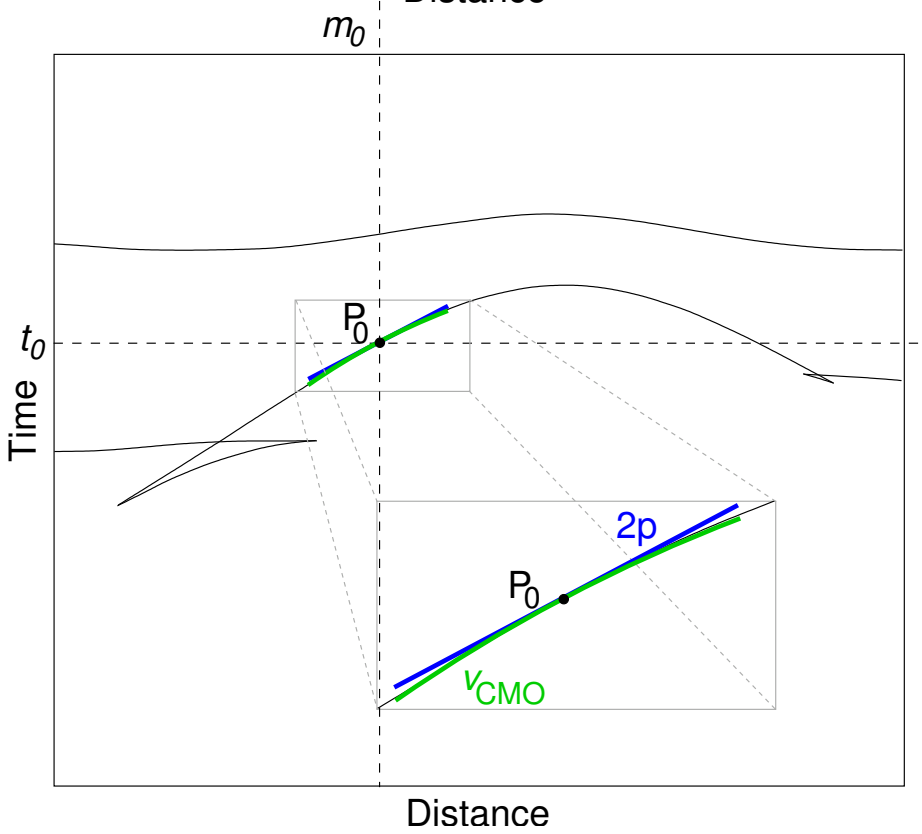
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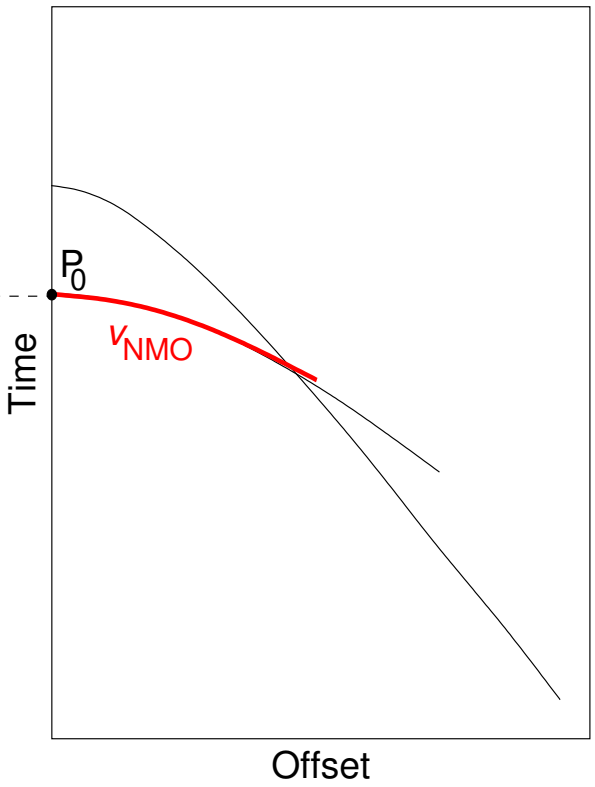
Time
Distance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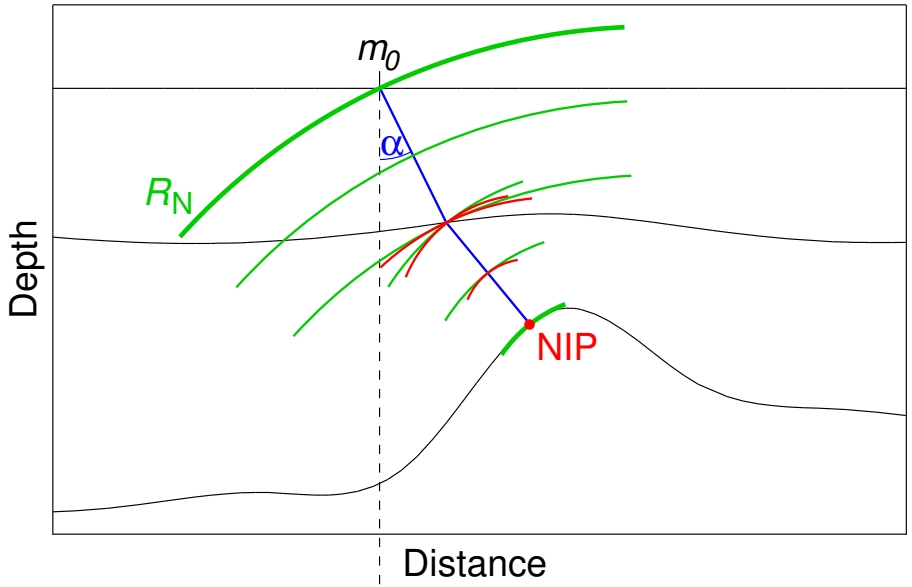
Time
Offset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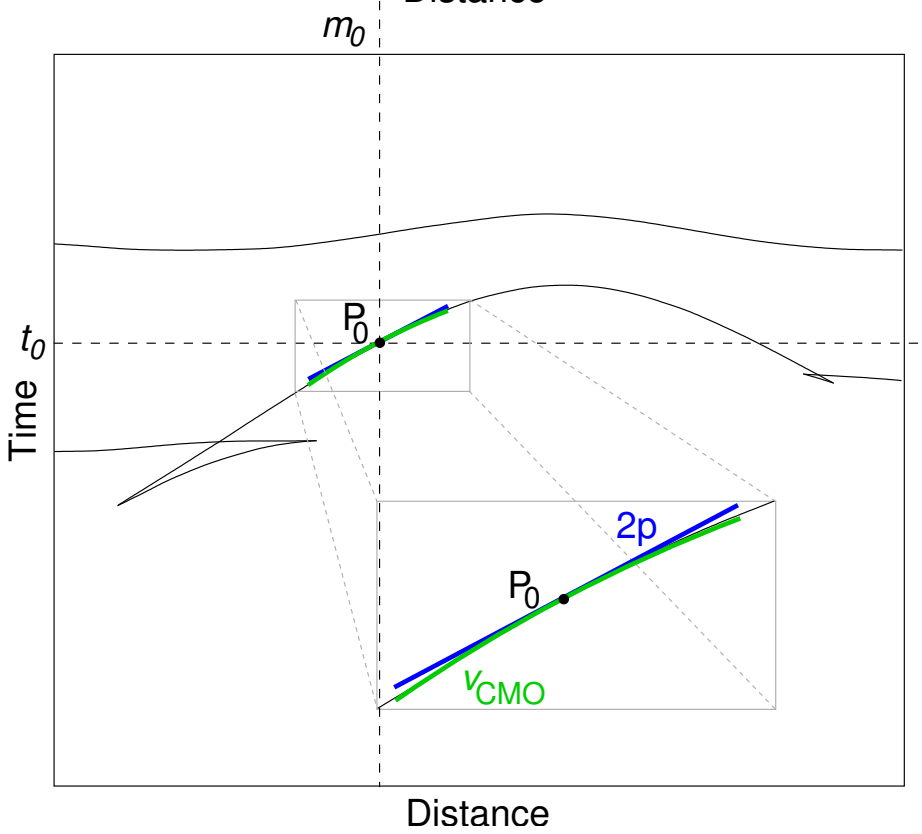
α
$R_N$
NIP
Depth
Distance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$P_0$
2p
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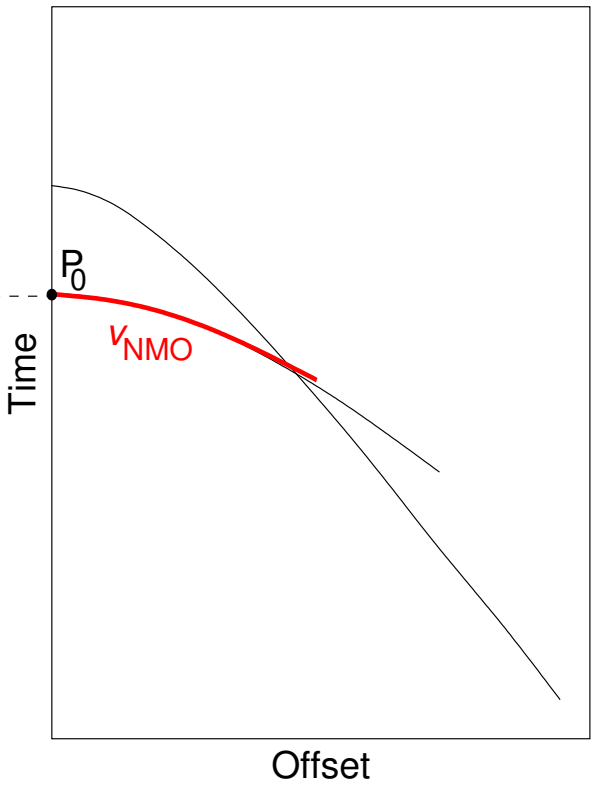
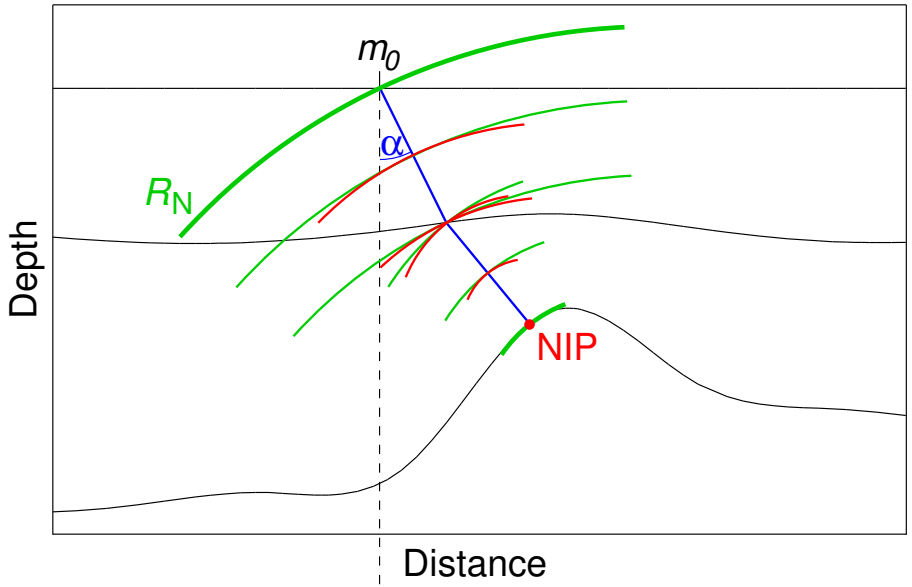
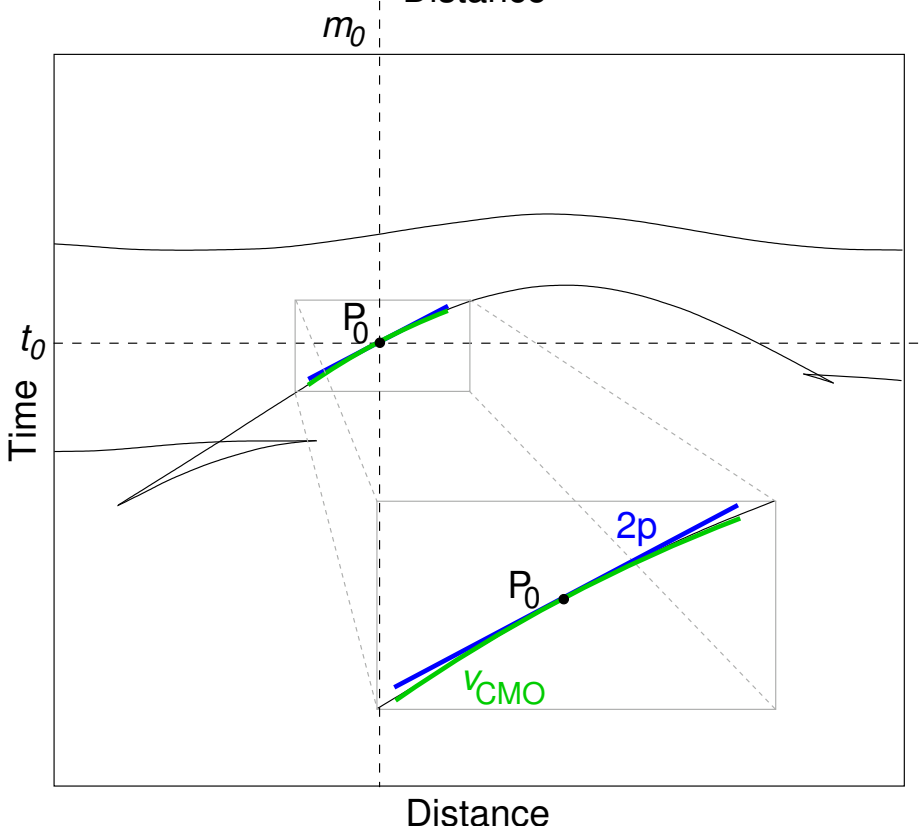
$v_{CMO}$
Time
Distance


$P_0$
$v_{NMO}$
Time
Offset




W I T


$m_0$
α
$R_N$
NIP
Depth
Distance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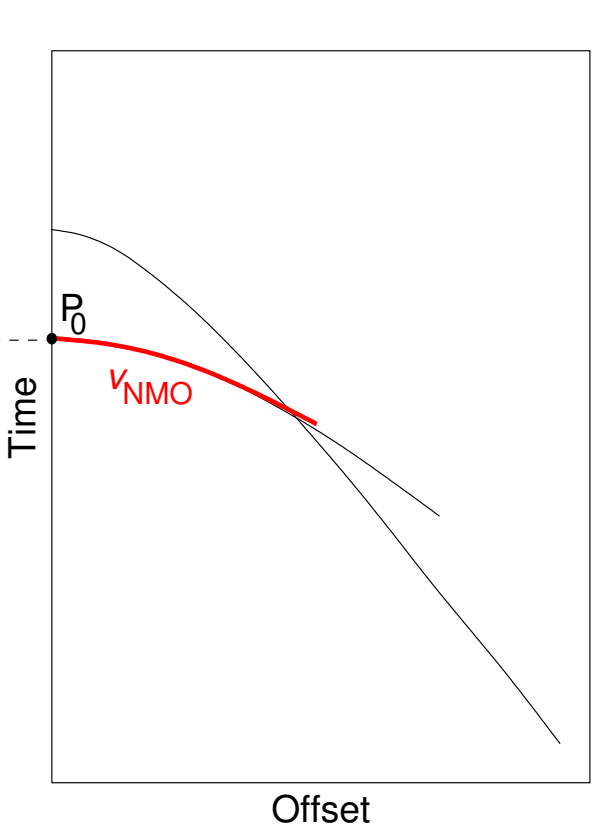
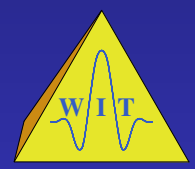
$P_0$
2p
$P_0$
$v_{CMO}$
Time
Distance


$P_0$
$v_{NMO}$
Time
Offset

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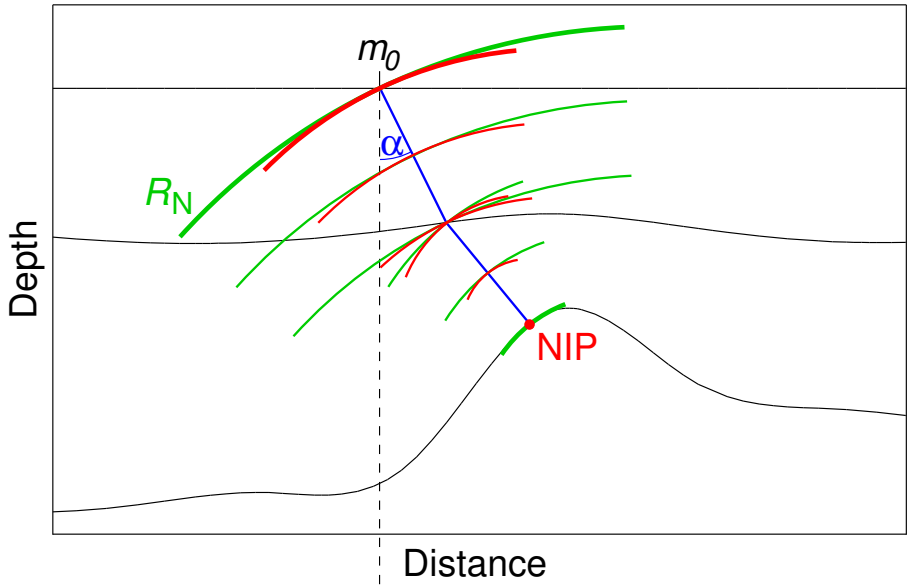
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α
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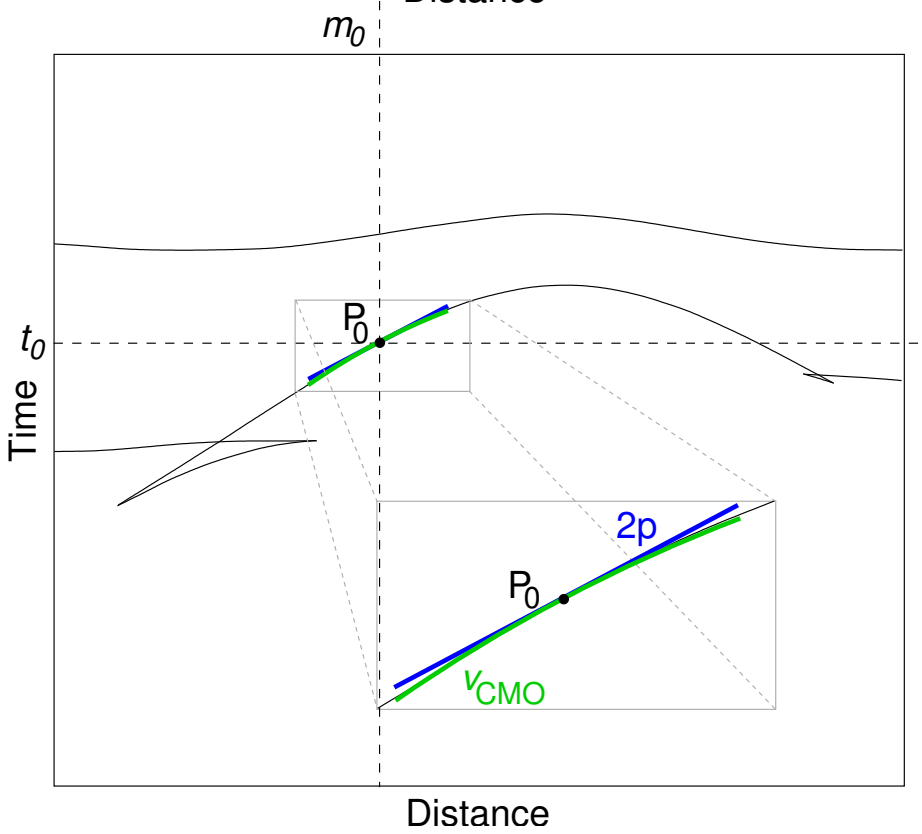
Depth
Distance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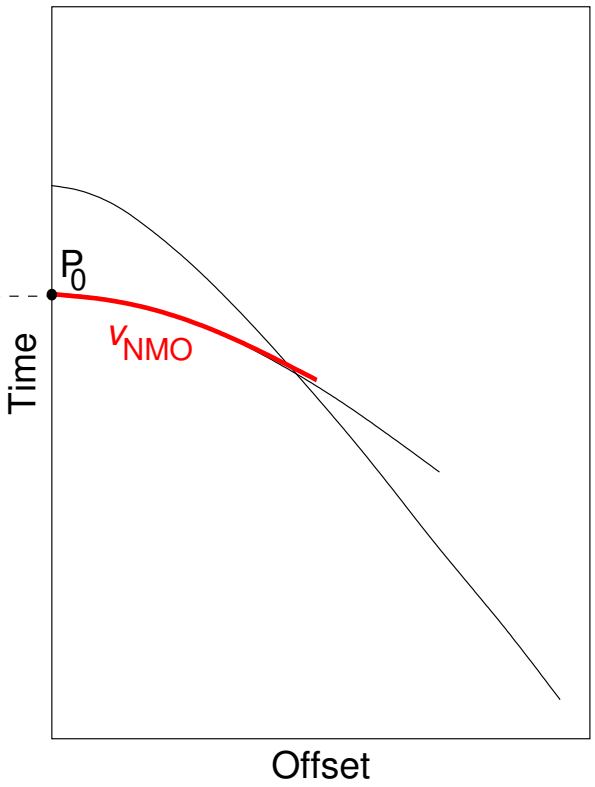
Time
Distance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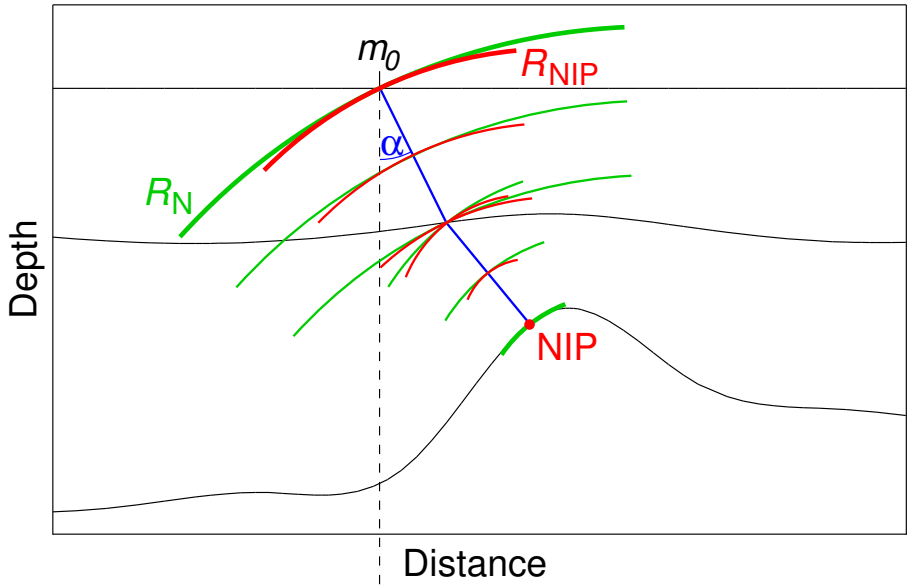
Time
Offset




W I T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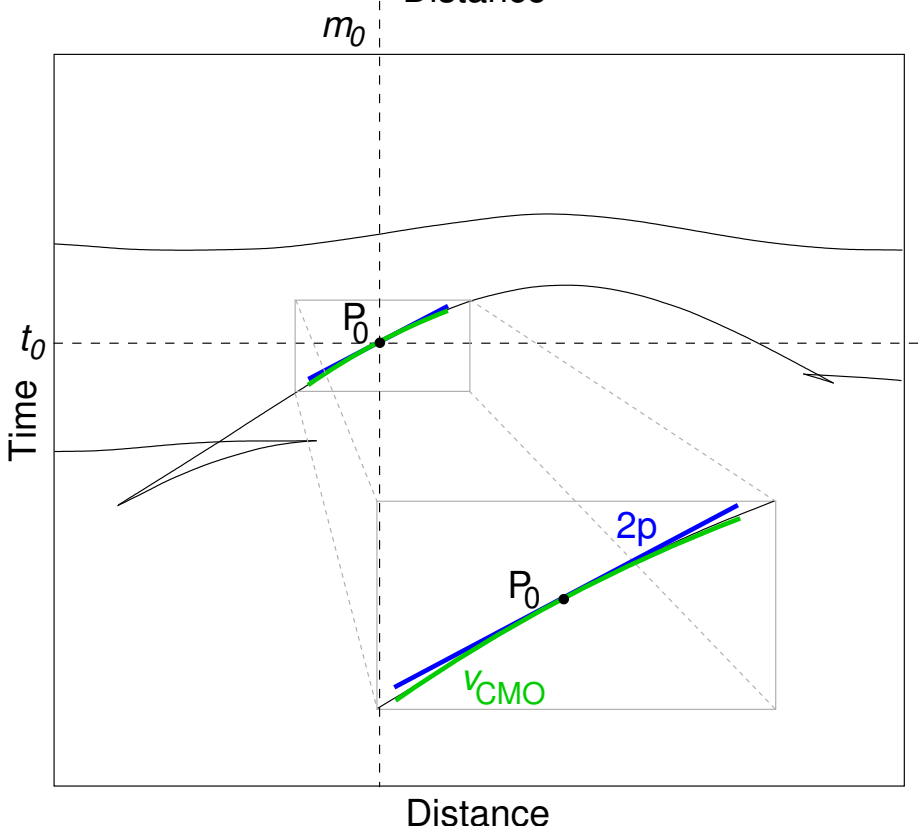
$R_{NIP}$
$R_N$
α
NIP
Depth
Distance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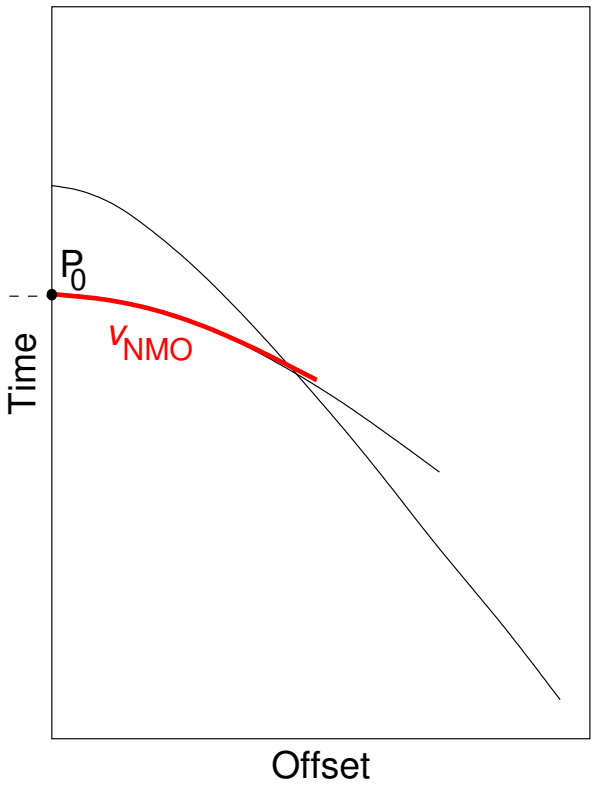
Time
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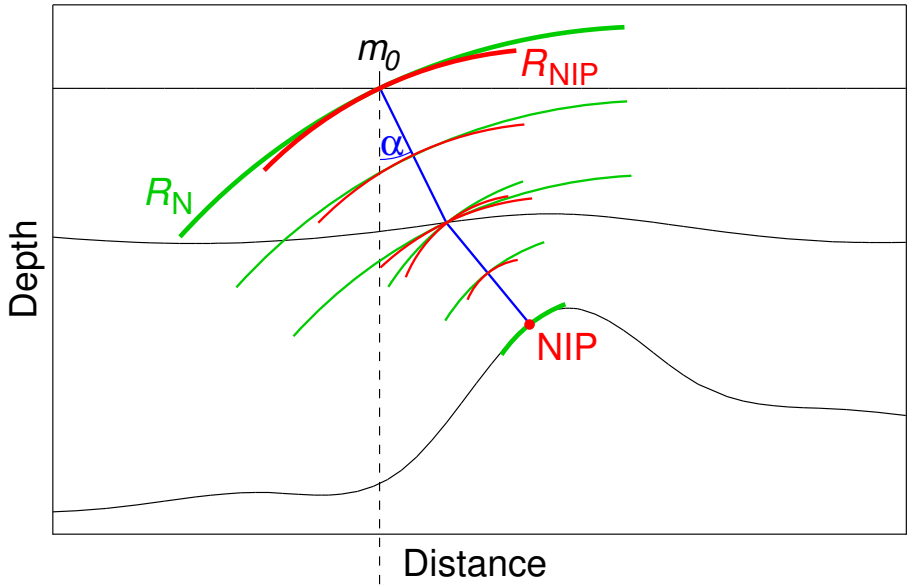
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$R_{NIP}$
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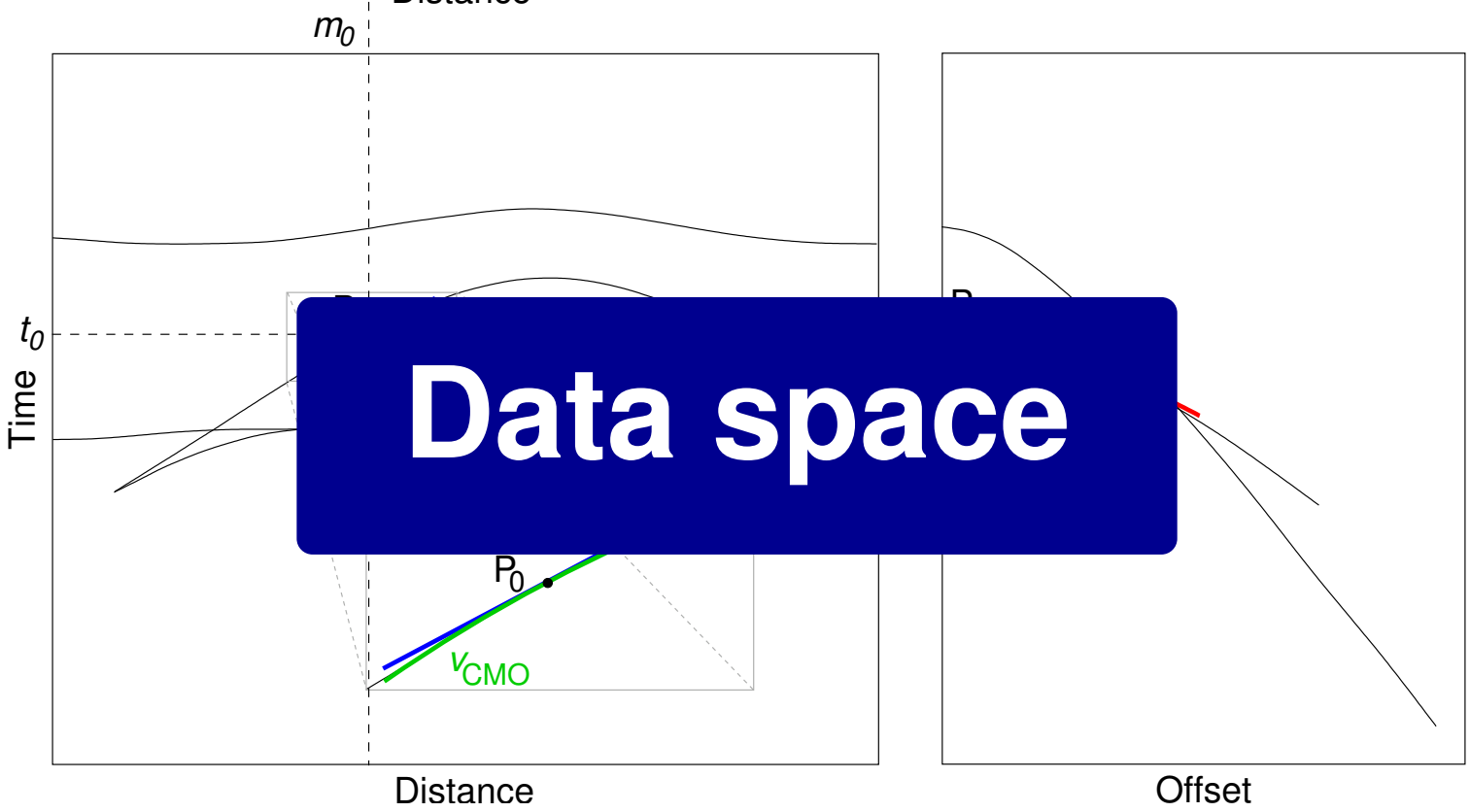
α
NIP
Depth
Distance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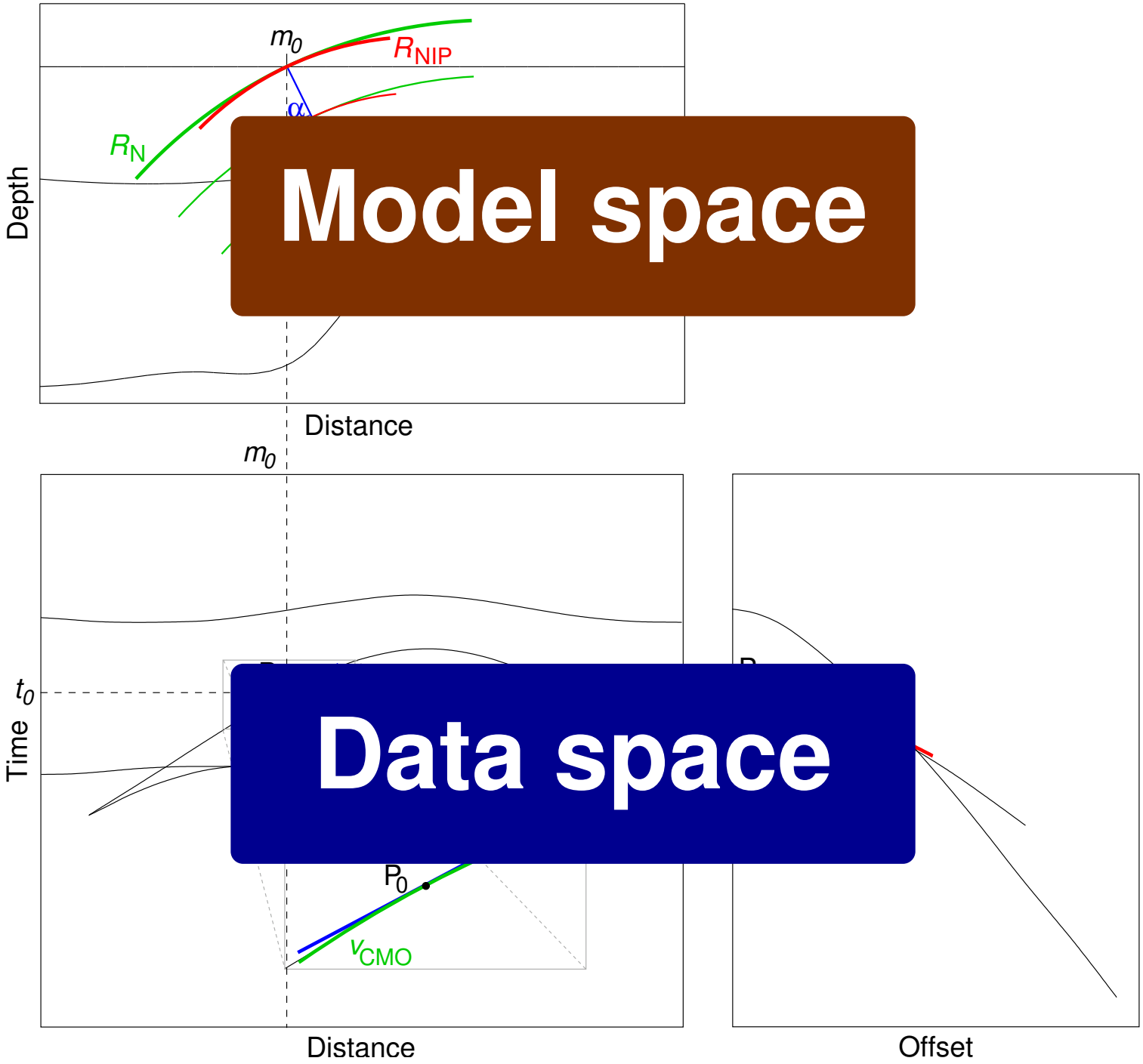
Time
$P_0$
$v_{CMO}$
Distance
Offset

# Data space


$m_0$
$R_{NIP}$
$\alpha$
$R_N$
Depth
Distance
Model space
$m_0$
$t_0$
Time
Data space
$P_0$
$v_{CMO}$
Distance
Offset

# Relations between parameters





# Relations between parameters

| Parameterization in terms of… | | |
|---|---|---|
| traveltime derivatives | wavefront properties | slowness and velocities |
| | | |
| | | |
| | | |



# Relations between parameters

| Parameterization in terms of... | | |
|---|---|---|
| traveltime derivatives | wavefront properties | slowness and velocities |
| $\left.\frac{\partial t}{\partial m}\right\|_{m=m_0, x=0}$ | $\frac{\sin\alpha}{v_0}$ | $p$ |
| | | |
| | | |

$v_0$: near surface velocity



# Relations between parameters

| Parameterization in terms of... | | |
|---|---|---|
| traveltime derivatives | wavefront properties | slowness and velocities |
| $\left.\frac{\partial t}{\partial m}\right\|_{m=m_0, x=0}$ | $\frac{\sin\alpha}{v_0}$ | $p$ |
| $\left.\frac{\partial t}{\partial m}, \frac{\partial^2 t}{\partial m^2}\right\|_{m=m_0, x=0}$ | $\frac{\cos^2\alpha}{v_0 R_N}$ | $v_{CMO}$ |
| | | |

$v_0$: near surface velocity



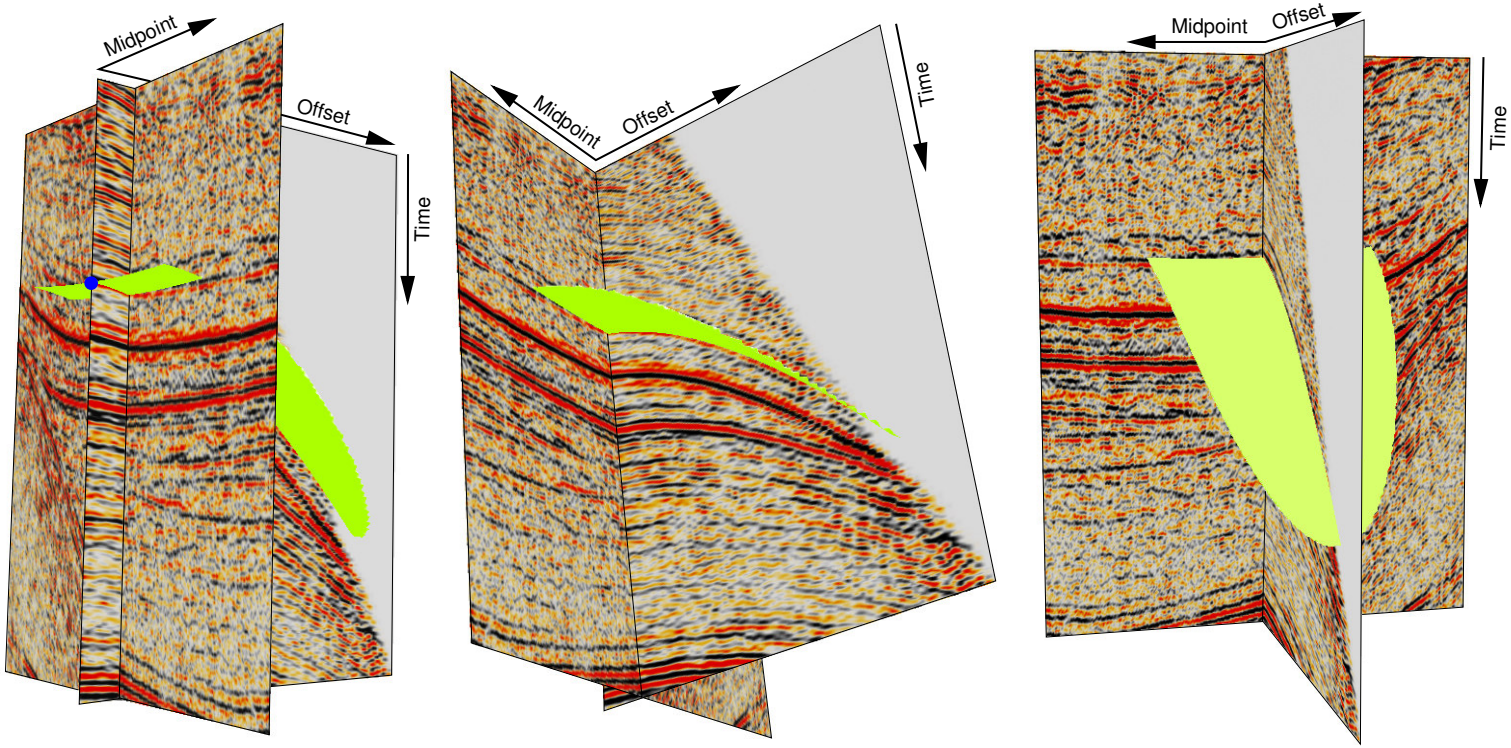
# Relations between parameters

| Parameterization in terms of... | | |
|---|---|---|
| traveltime derivatives | wavefront properties | slowness and velocities |
| $\left.\frac{\partial t}{\partial m}\right\|_{m=m_0, x=0}$ | $\frac{\sin\alpha}{v_0}$ | $p$ |
| $\left.\frac{\partial t}{\partial m}, \frac{\partial^2 t}{\partial m^2}\right\|_{m=m_0, x=0}$ | $\frac{\cos^2\alpha}{v_0 R_N}$ | $v_{CMO}$ |
| $\left.\frac{\partial t}{\partial m}, \frac{\partial^2 t}{\partial x^2}\right\|_{m=m_0, x=0}$ | $\frac{\cos^2\alpha}{v_0 R_{NIP}}$ | $v_{NMO}$ |

$v_0$: near surface velocity

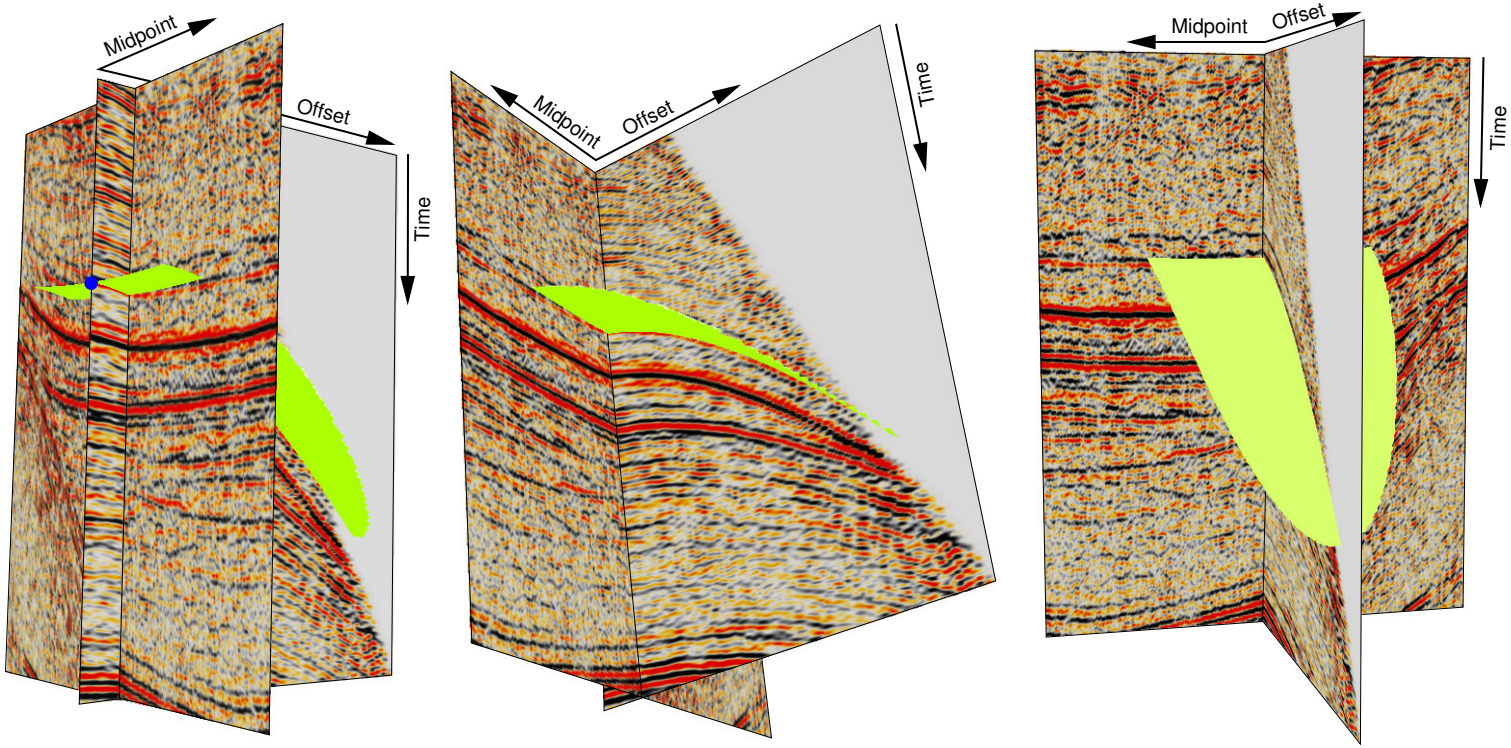


# CRS operator




CMP gather and section at offset 500 m

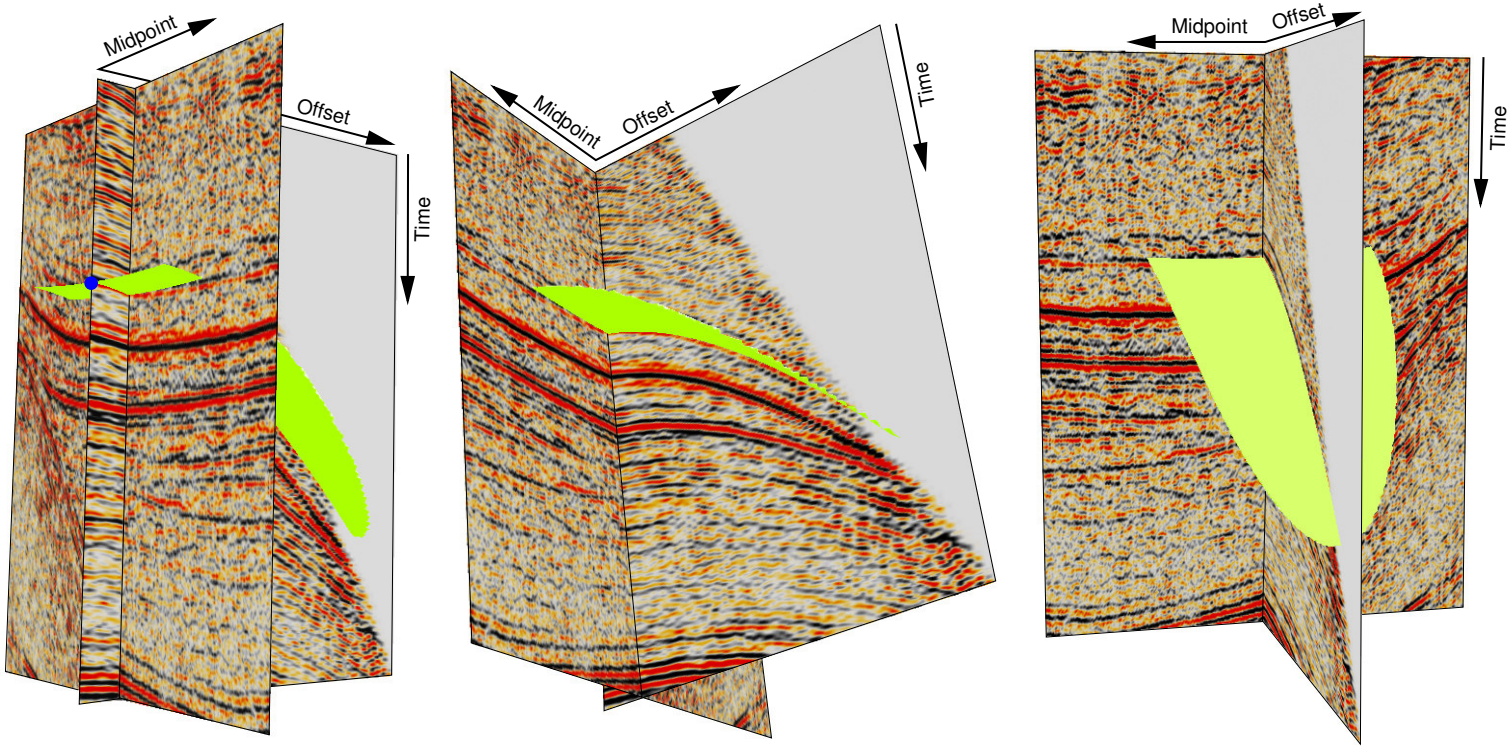
# CRS operator




CMP gather and section at offset 500 m

Displayed ranges: offset up to 3.5 km, midpoint $\pm 5$ km

# CRS operator

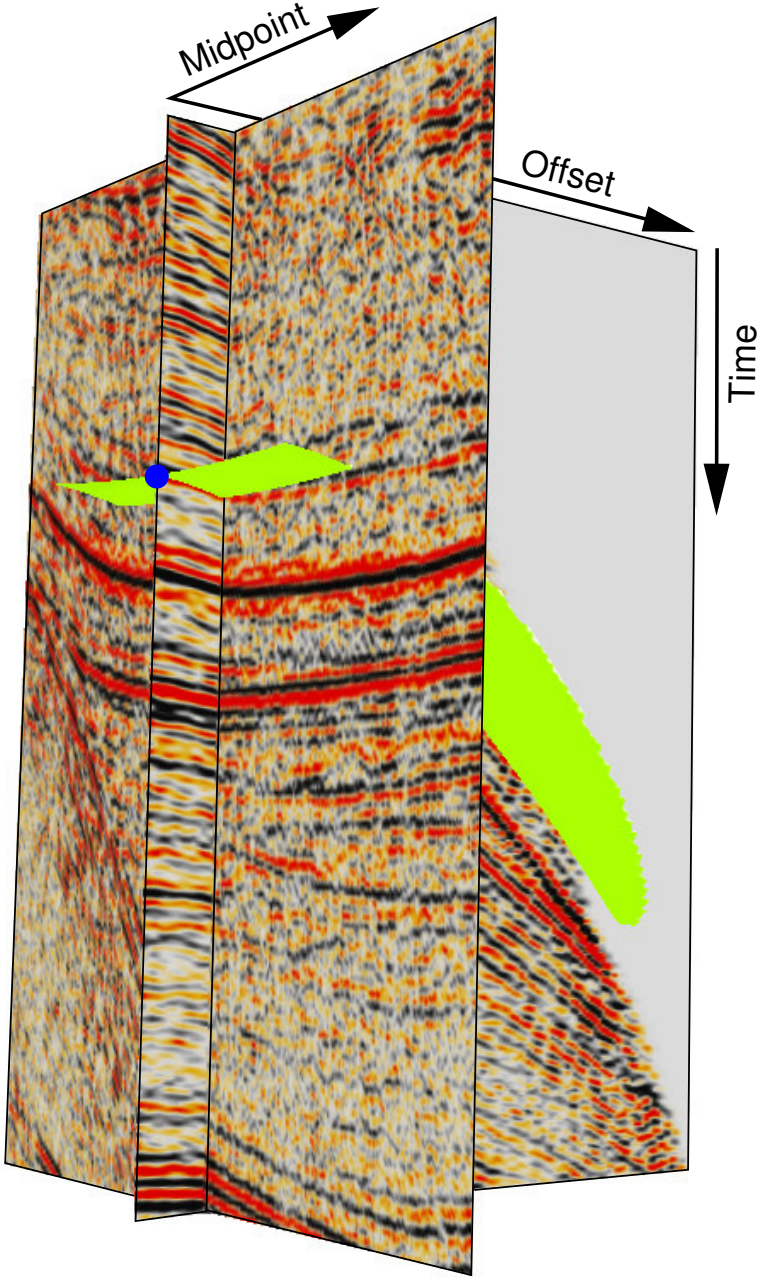


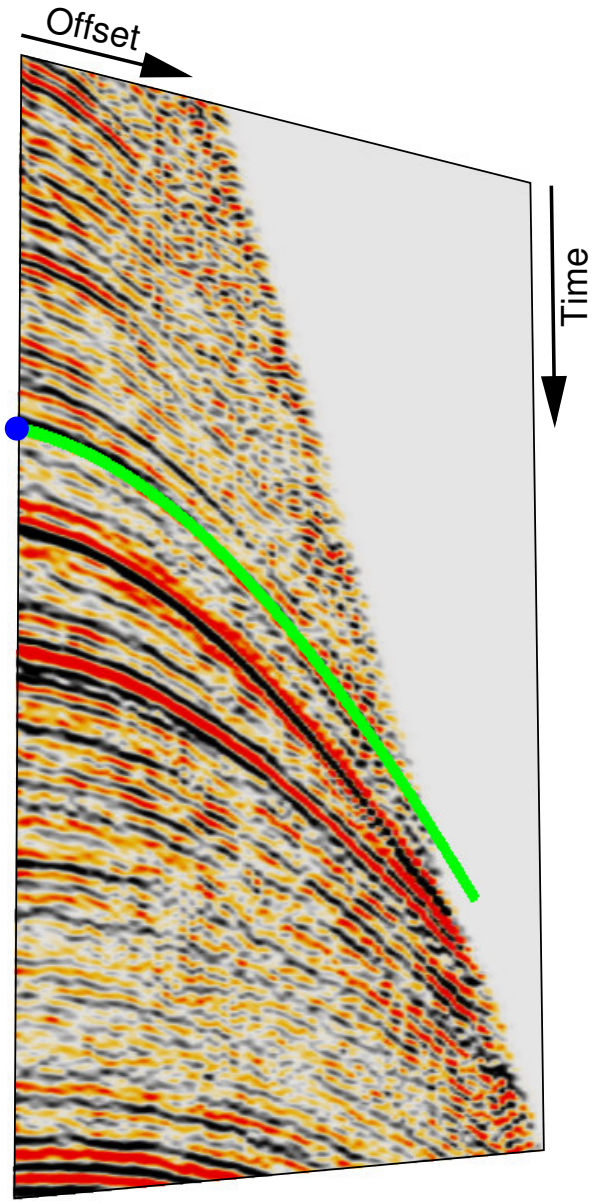

CMP gather and section at offset 500 m

Displayed ranges: offset up to 3.5 km, midpoint $\pm 5$ km

$$t_0 = 1.5\,\text{s},\ p = 1.5 \times 10^{-5}\,\text{s/m},$$
$$v_{\text{NMO}} = 2015\,\text{m/s},\ v_{\text{CMO}} = i \times 9812\,\text{m/s}$$

# CRS vs. CMP operator



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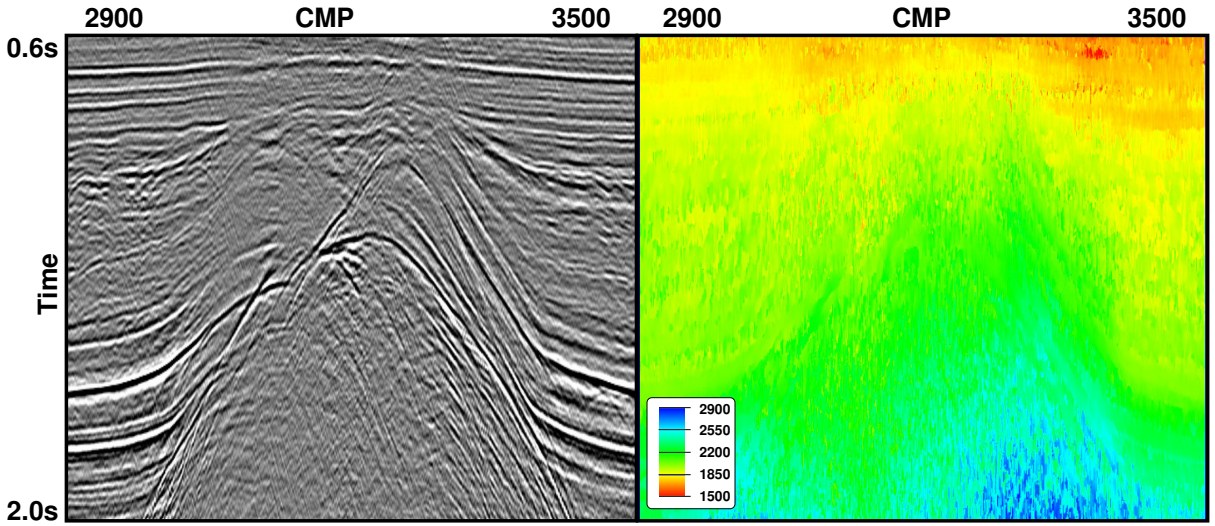
- general idea remains just the same





# High density velocity analysis




intermediate stack stacking velocity

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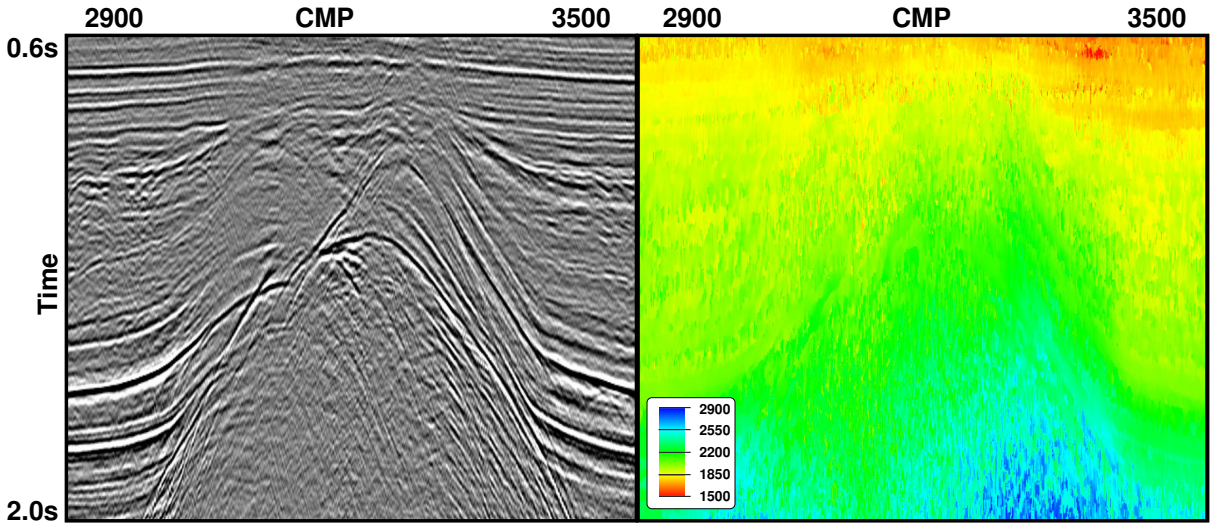


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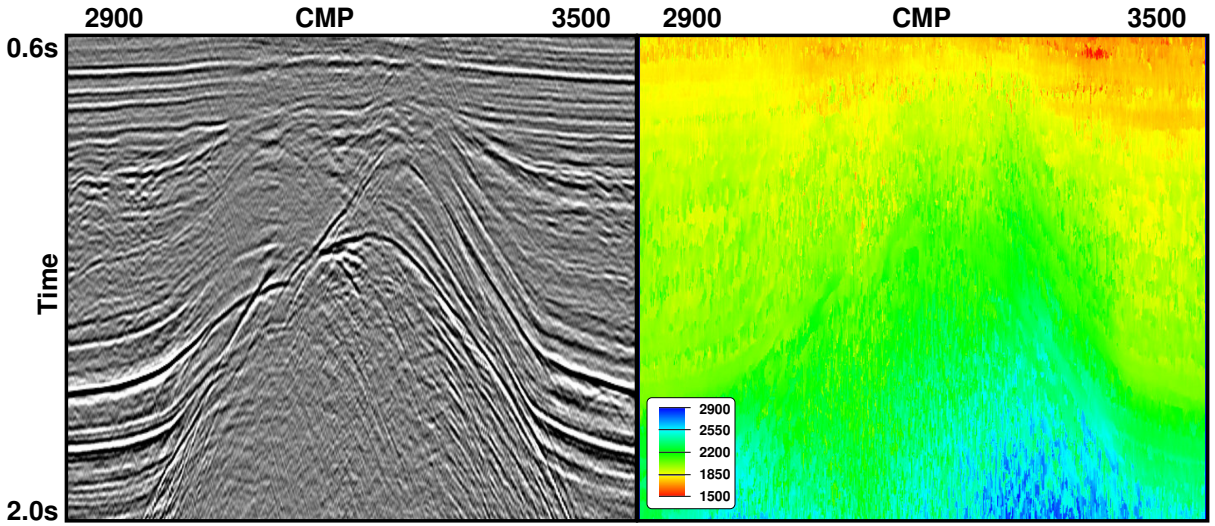


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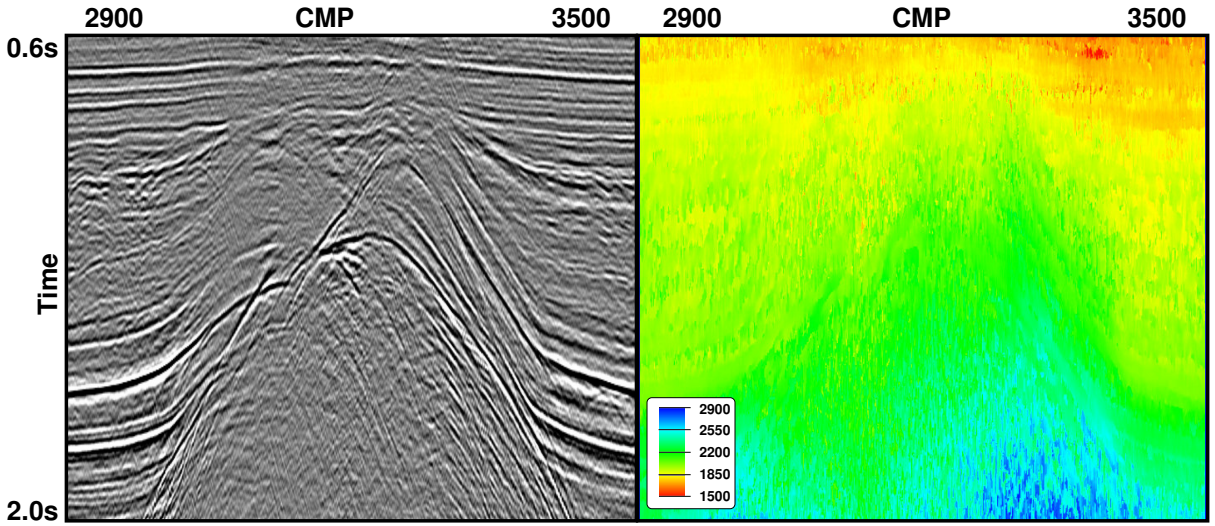


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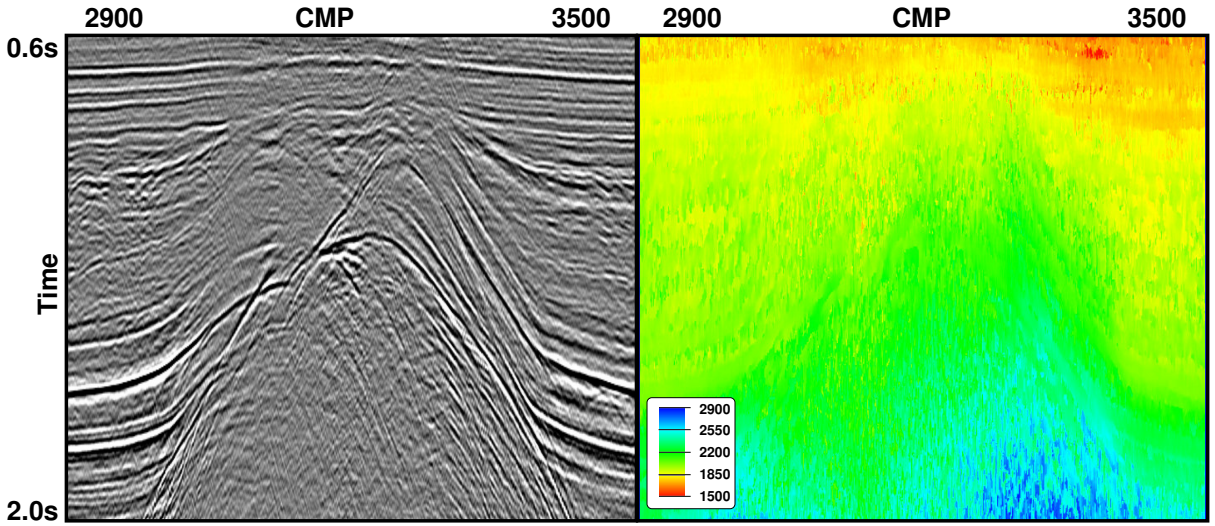


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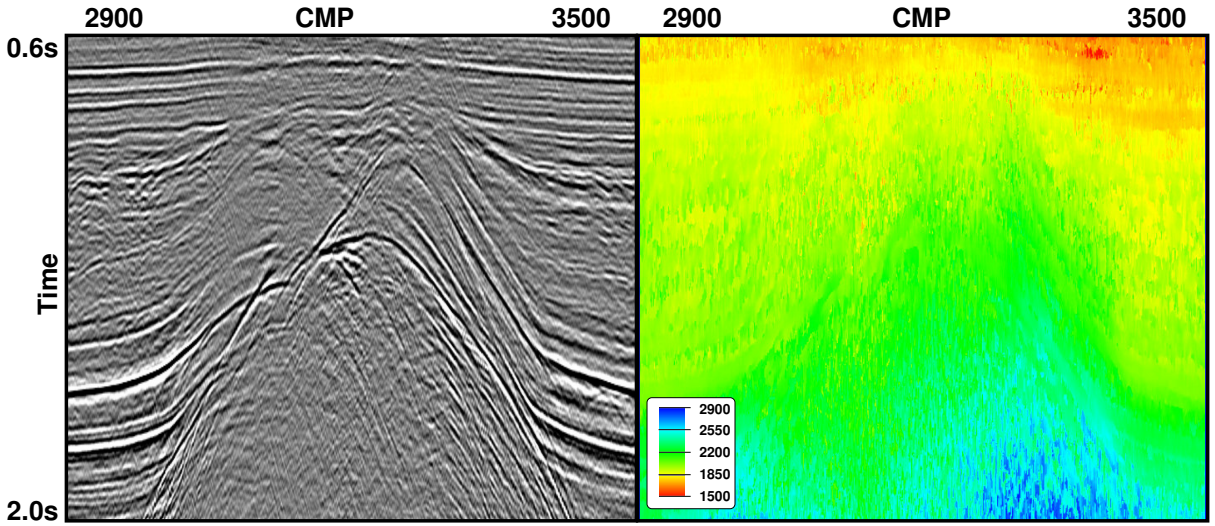


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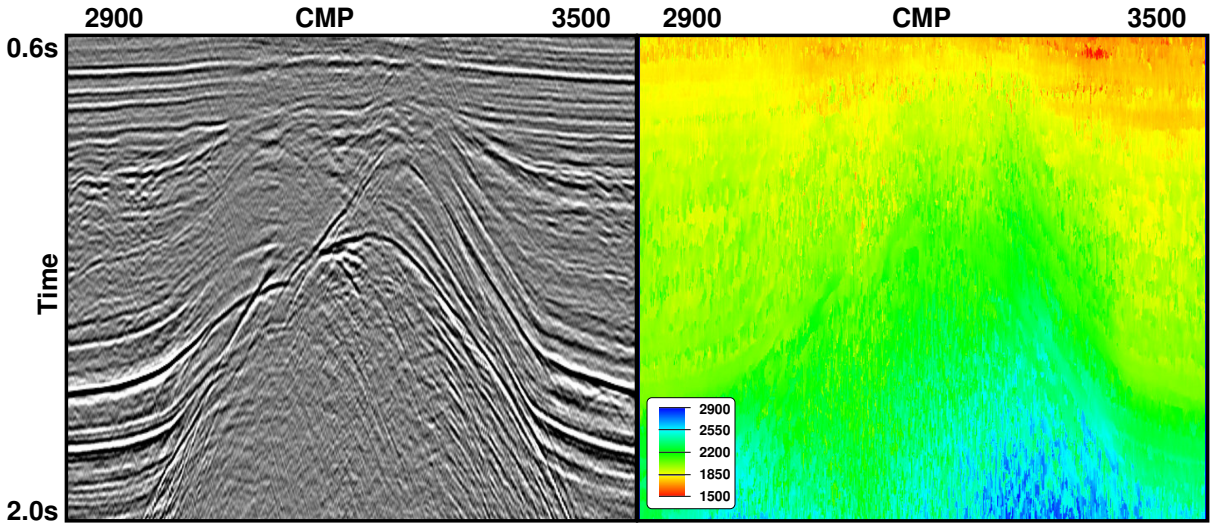


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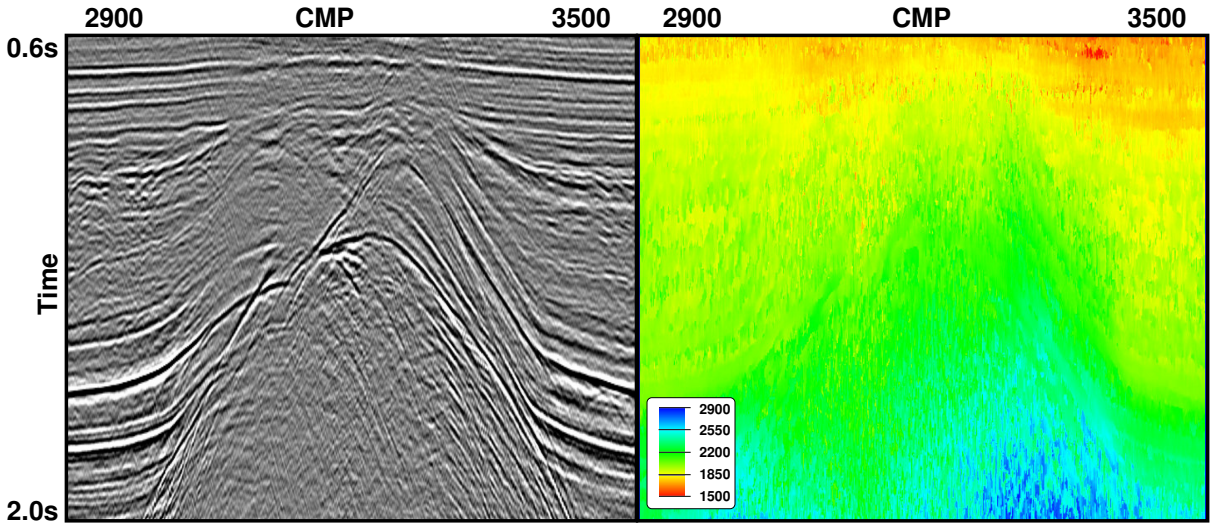


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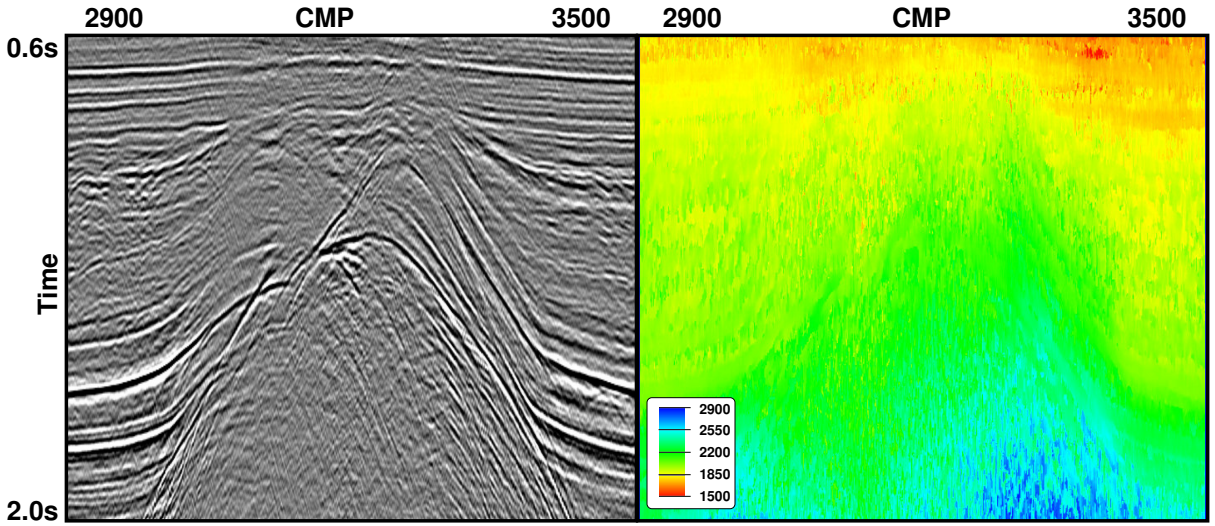


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  ➥ event-consistent smoothing
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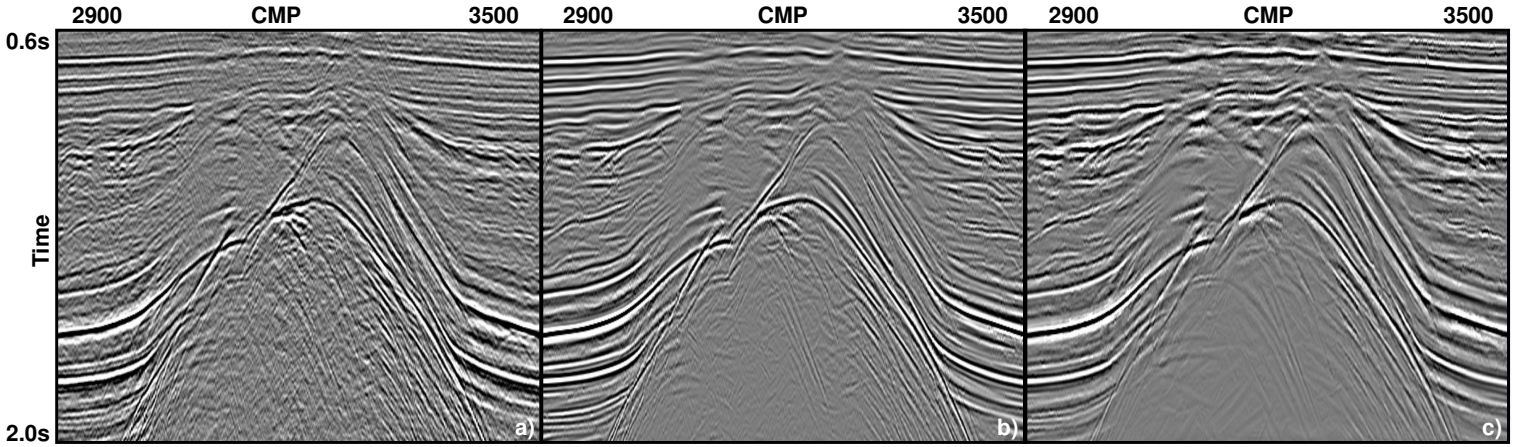
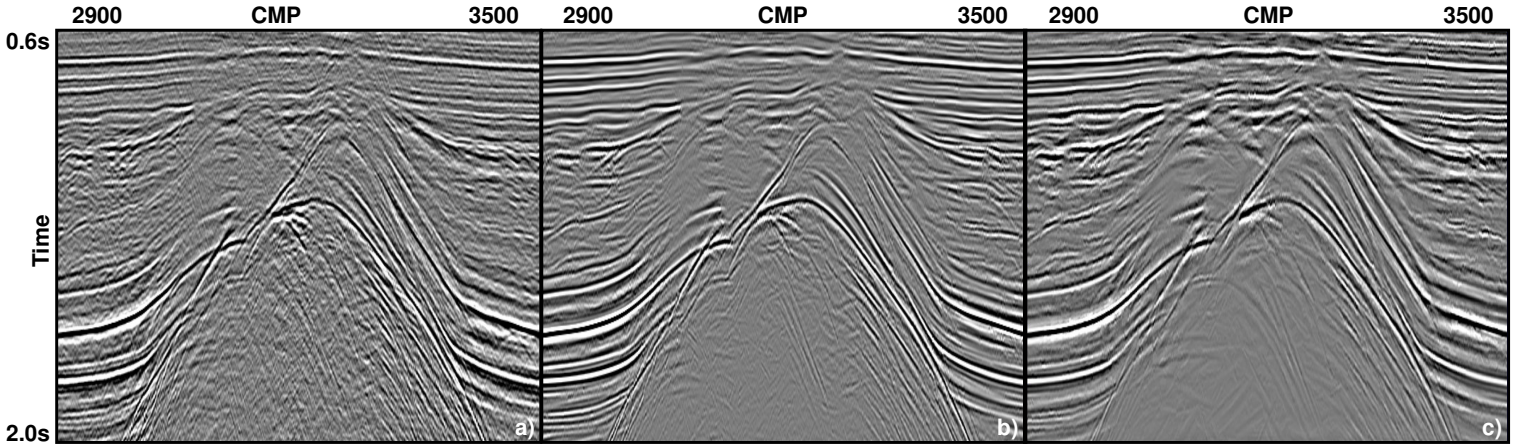
  ➥ smooth reference model plus variation

# Midpoint aperture




Detail of a stacked section with

# Midpoint aperture

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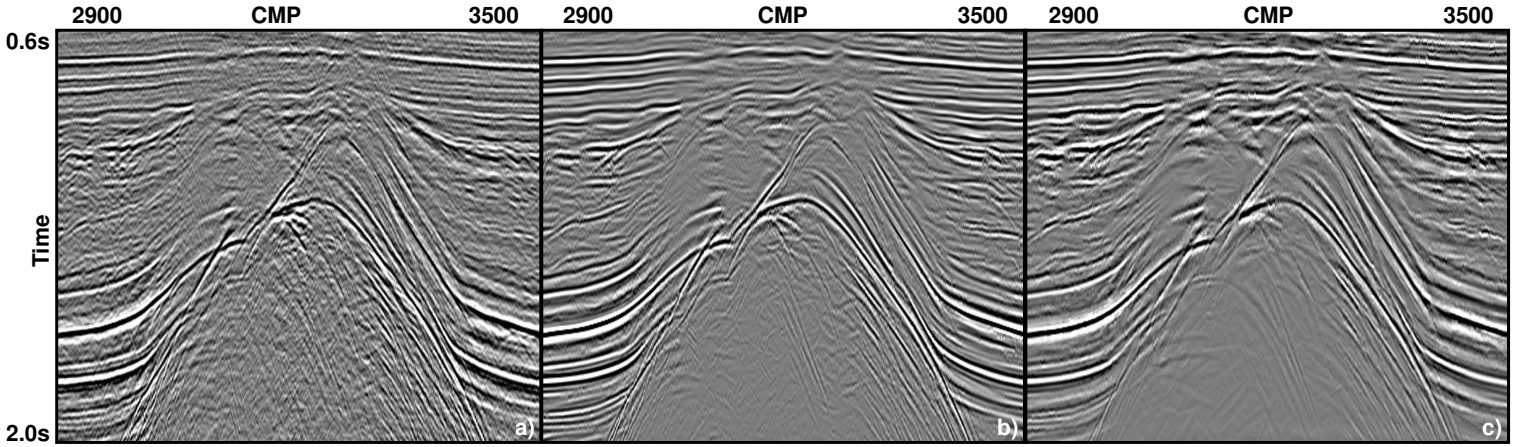


Detail of a stacked section with

a) zero midpoint aperture (conventional stack)

b) estimated size of the projected Fresnel zone

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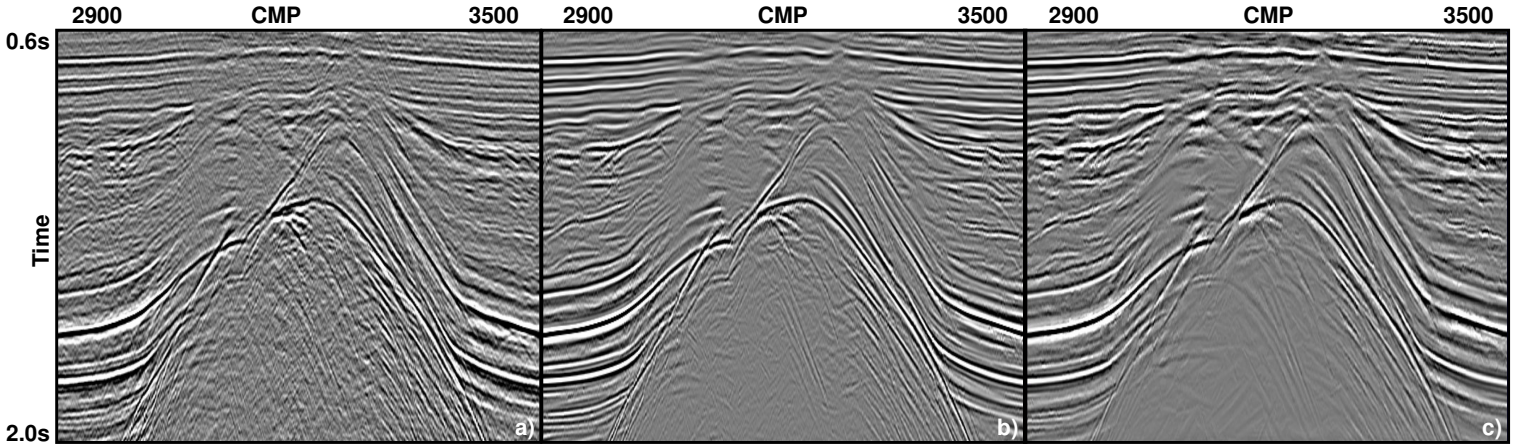


Detail of a stacked section with

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c) five times larger than in b)

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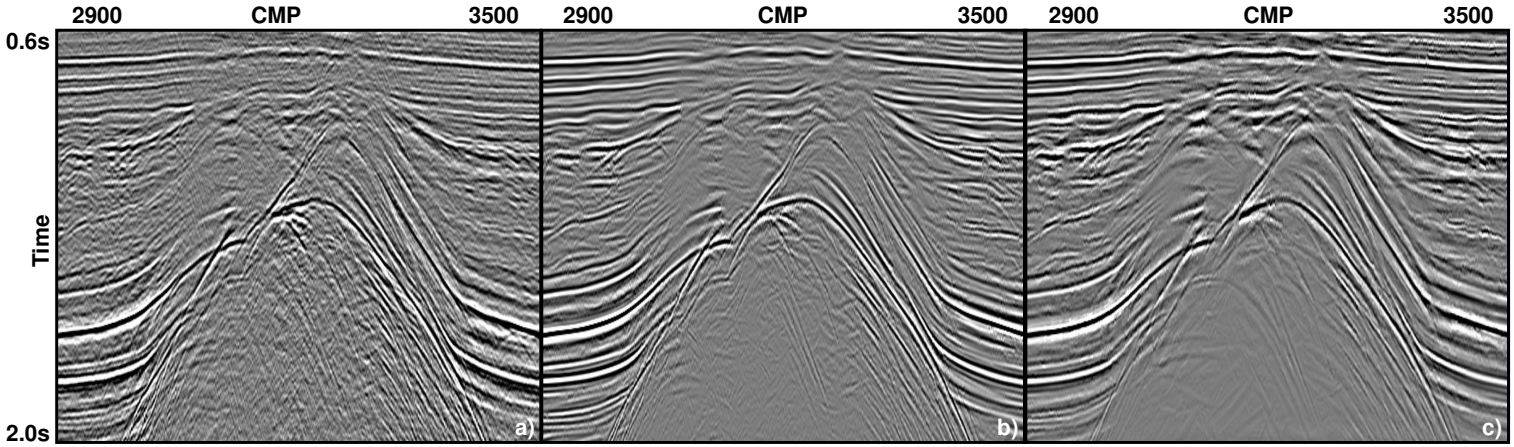


Detail of a stacked section with

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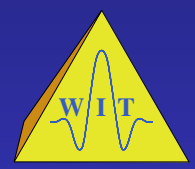
c) five times larger than in b)

➥ b) is a balance between high S/N ratio, reflector continuity, and resolution

# Conclusions







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  - ...





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