12. Seismic Migration

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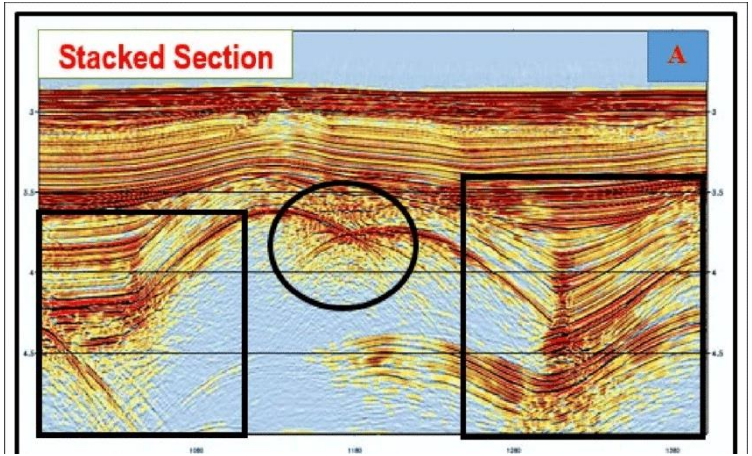
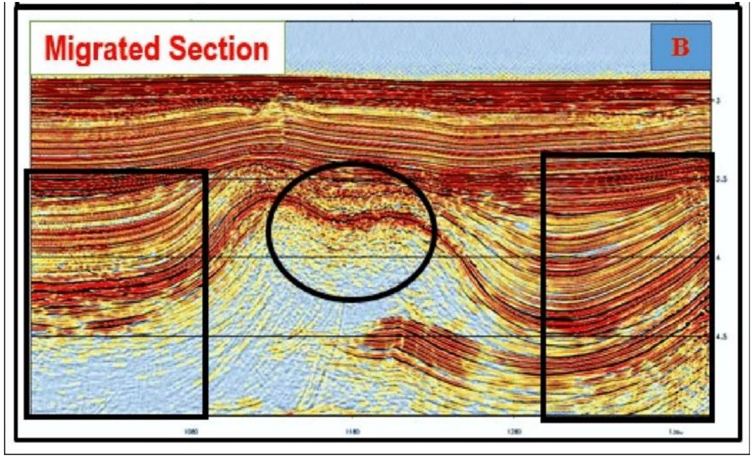
ERSE 210 Seismology

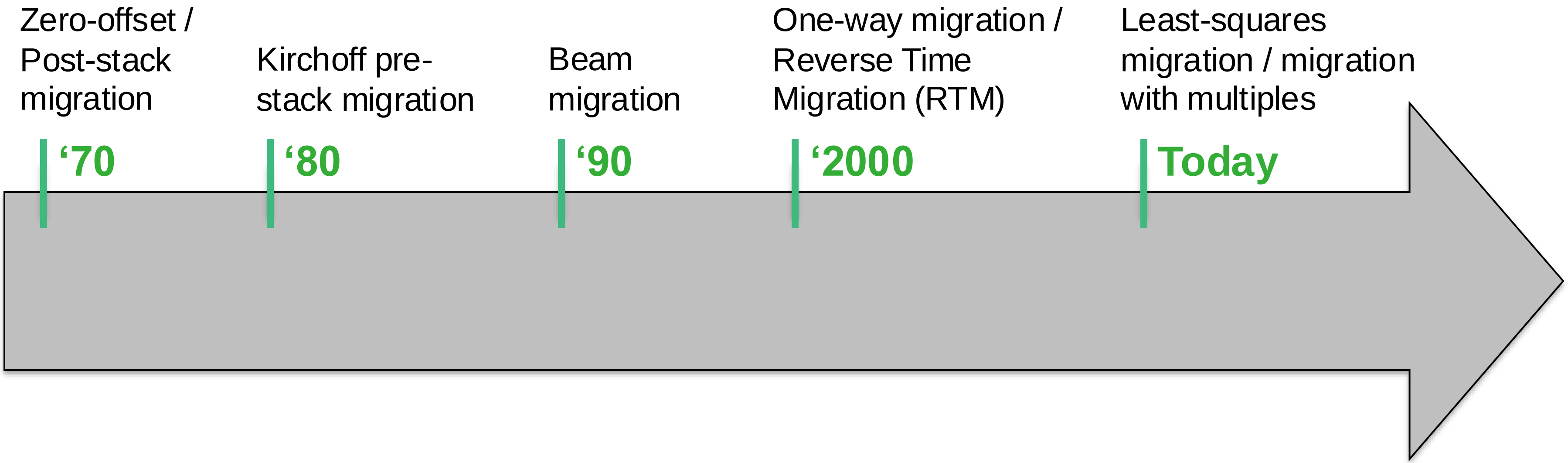
Seismic Migration (or Imaging)

As the name implies, **migration** is the process of migrating/repositioning seismic events to the (horizontal) location at which a scattering or reflection has occurred.





Seismic Migration - history



Zero-offset / Post-stack migration

‘70

Kirchoff pre-stack migration

‘80

Beam migration

‘90

One-way migration / Reverse Time Migration (RTM)

‘2000

Least-squares migration / migration with multiples

Today

* This is a timeline of industry adoption (most theories have been developed some 20 years before the method becomes practical for real applications

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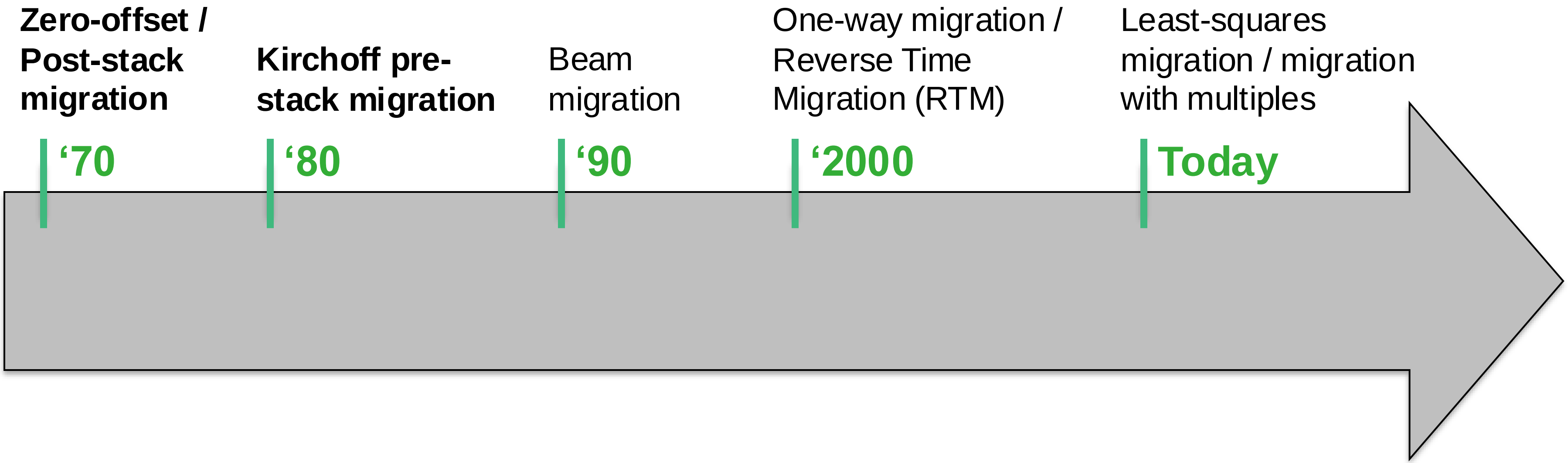

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Seismic Migration - nomenclature

Migration algorithms can be divided into 4 classes:

Domain\Vertical axis	Time	Depth
Post-stack	…	…
Pre-stack	…	…

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After NMO&
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Acts directly on data
in CSG/CRG/COG

Seismic Migration - nomenclature

Migration algorithms can be divided into 4 classes:

After NMO& stacking, directly on ZO sections

From $d(x_R, x_S, t)$/ $d(x_{mid}, t_0)$ to $\mathrm{i}(x, t_0)$

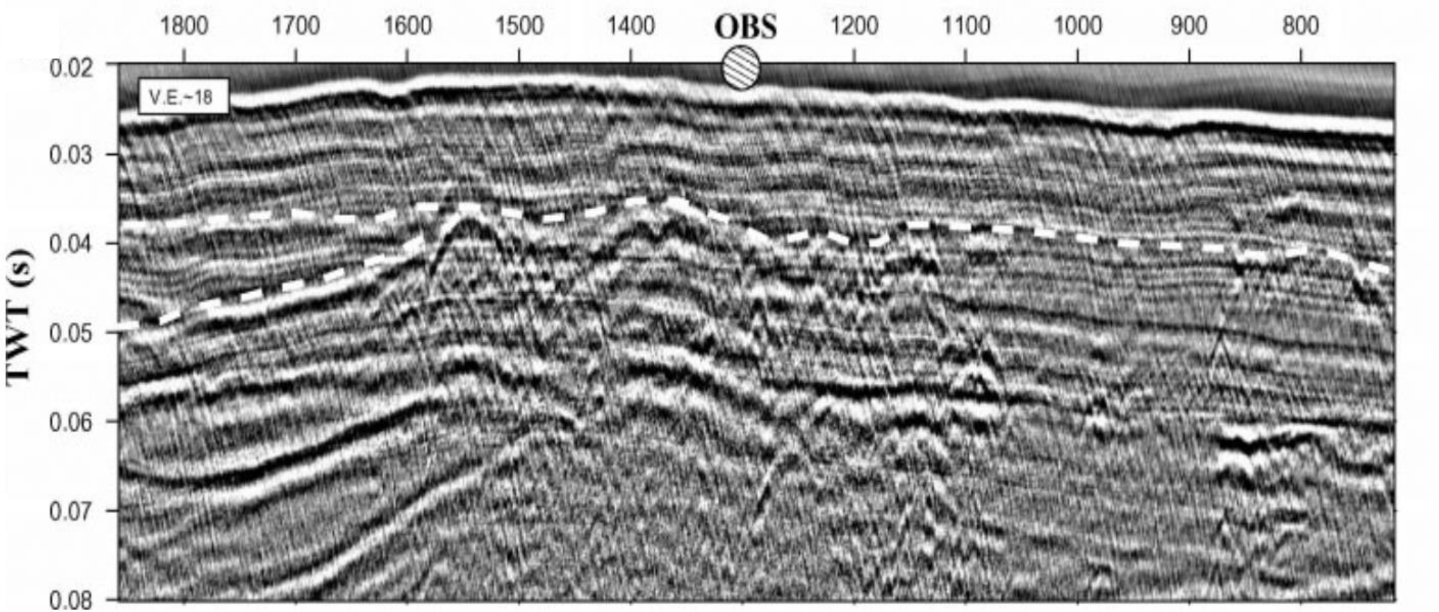
From $d(x_R, x_S, t)$ to $\mathrm{i}(x, z)$

Domain\Vertical axis	Time	Depth
Post-stack	…	…
Pre-stack	…	…

Acts directly on data in CSG/CRG/COG

Post-stack migration

Zero-offset (pre-migration) section



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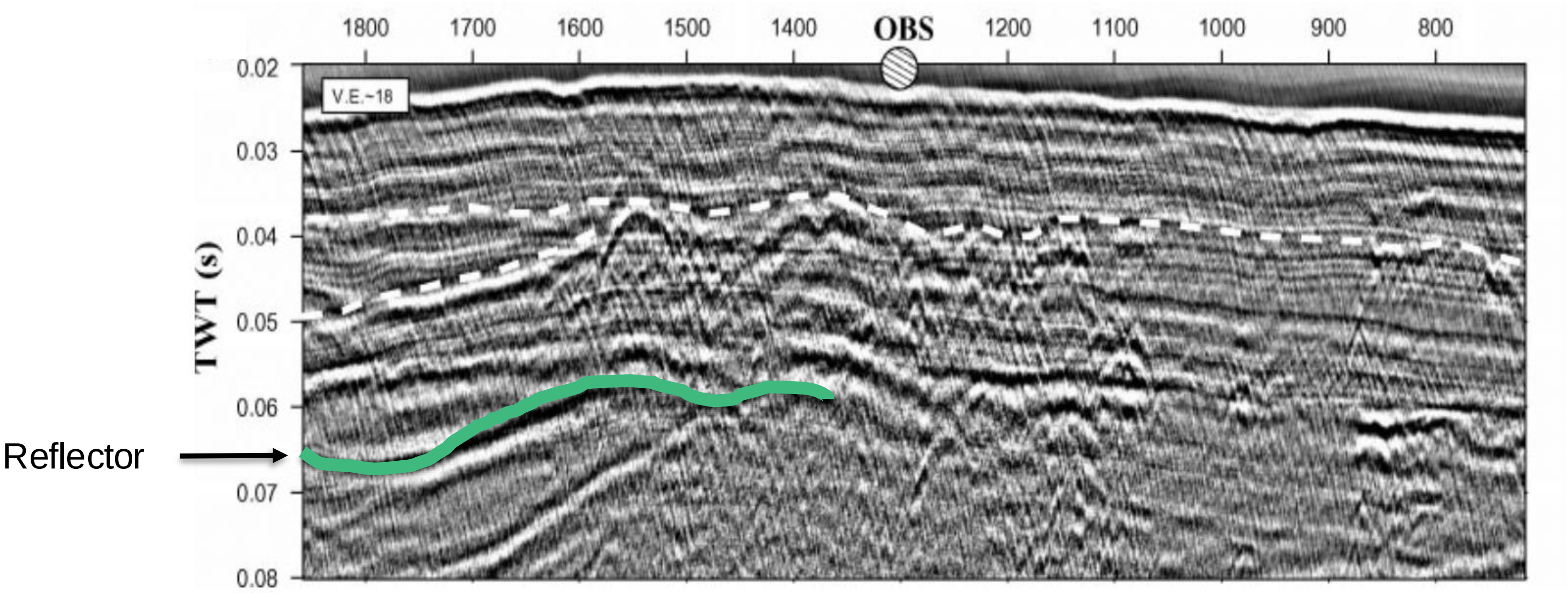

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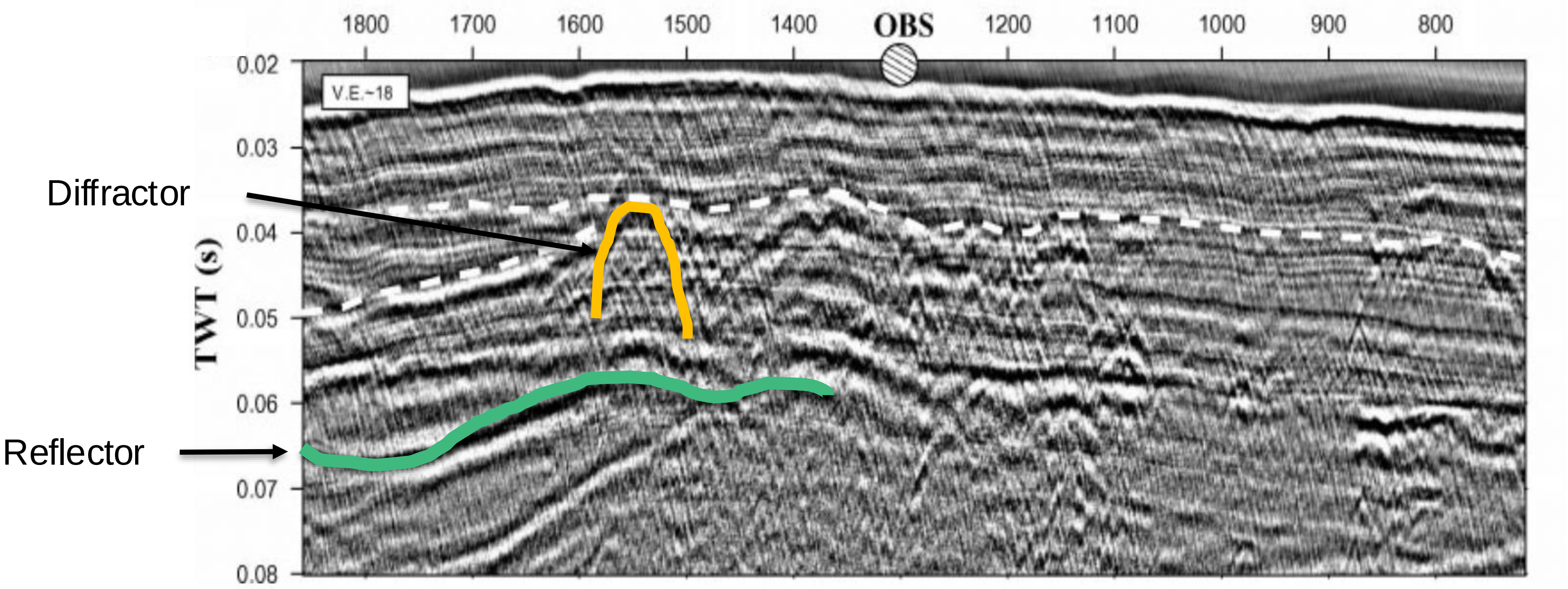

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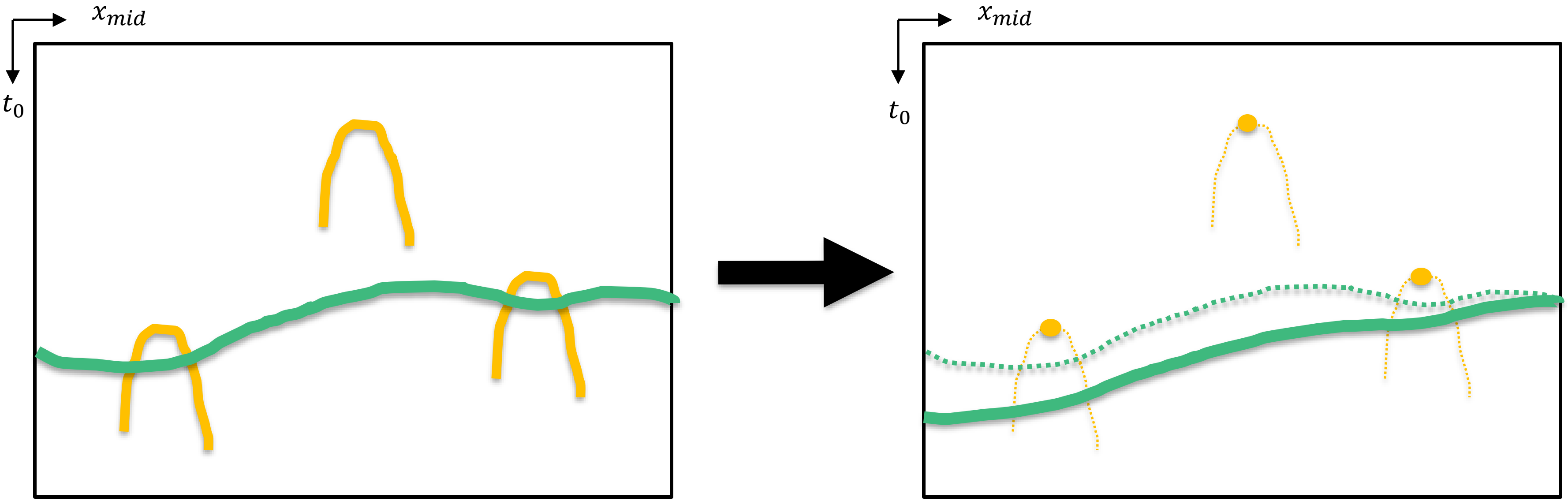
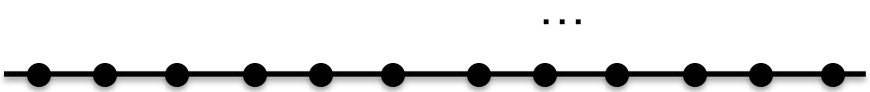


Huygens principle

A simple physical principle can be used to explain this drawing. Developed in ’1600 in the context of **light wave propagation**

It explains how, given a wavefront at time t, the wavefront at time $t + dt$ looks like – based on **constructive interference of secondary sources**



wavefront at time t

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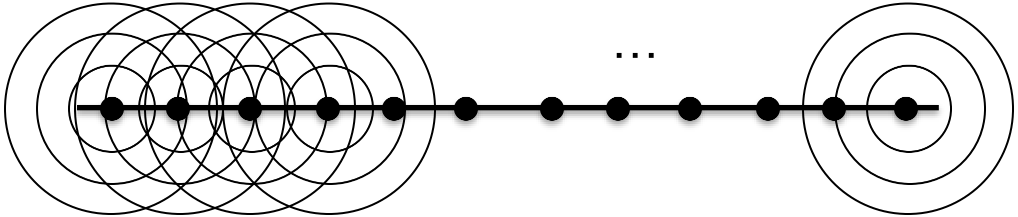

wavefront at time $t + dt$

wavefront at time t

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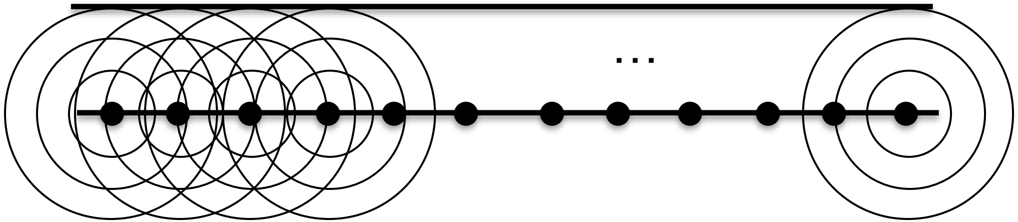
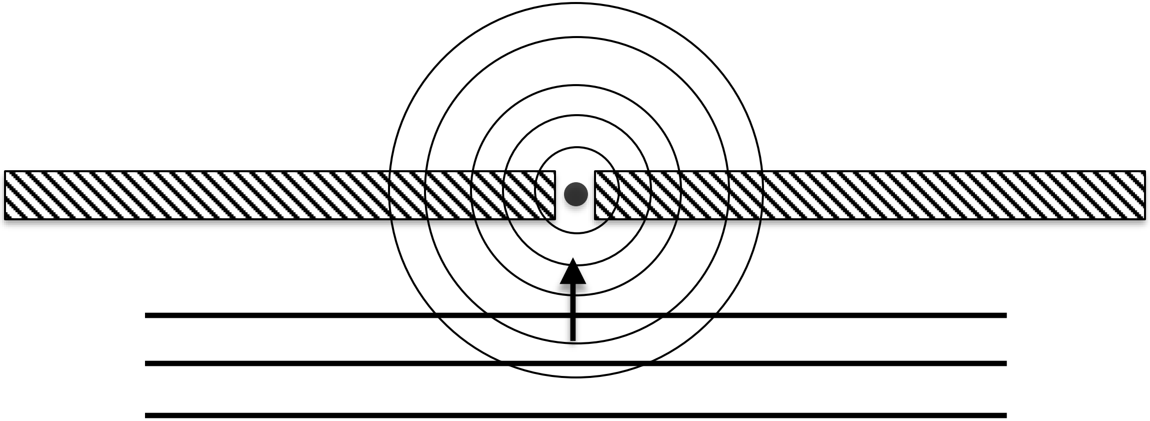


wavefront at time $t + dt$

wavefront at time t

Huygens principle

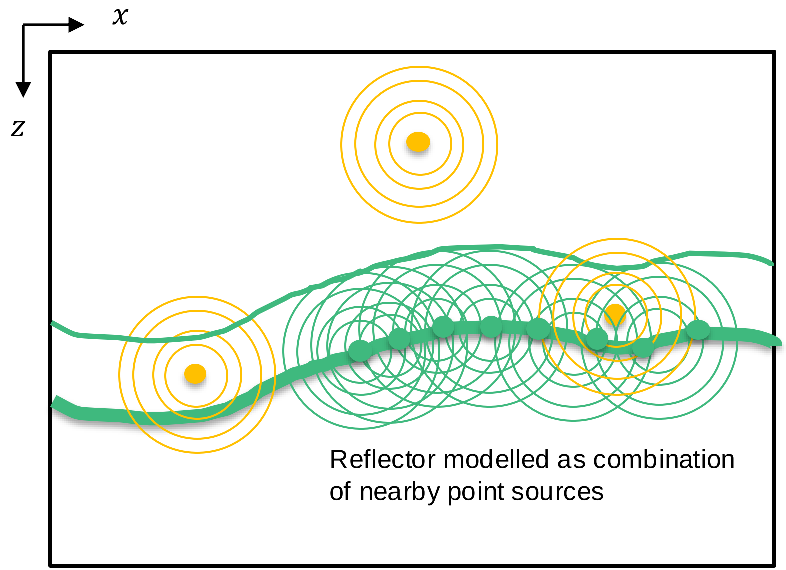
For a plane wave hitting on a wall with a small opening (aka a diffractor):



Plane wave → spherical wavear

Huygens principle

Applying the same principle to seismic reflectors and diffractors:

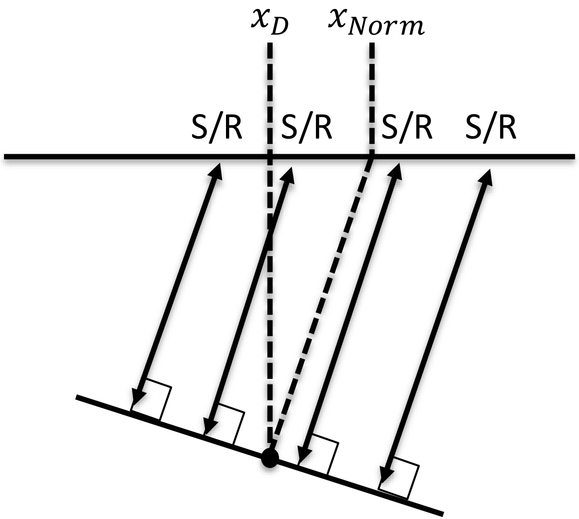


Reflector modelled as combination of nearby point sources

Exploding reflector model

Post-stack time migration - reflectors

Reflectors are laterally migrated – change dips



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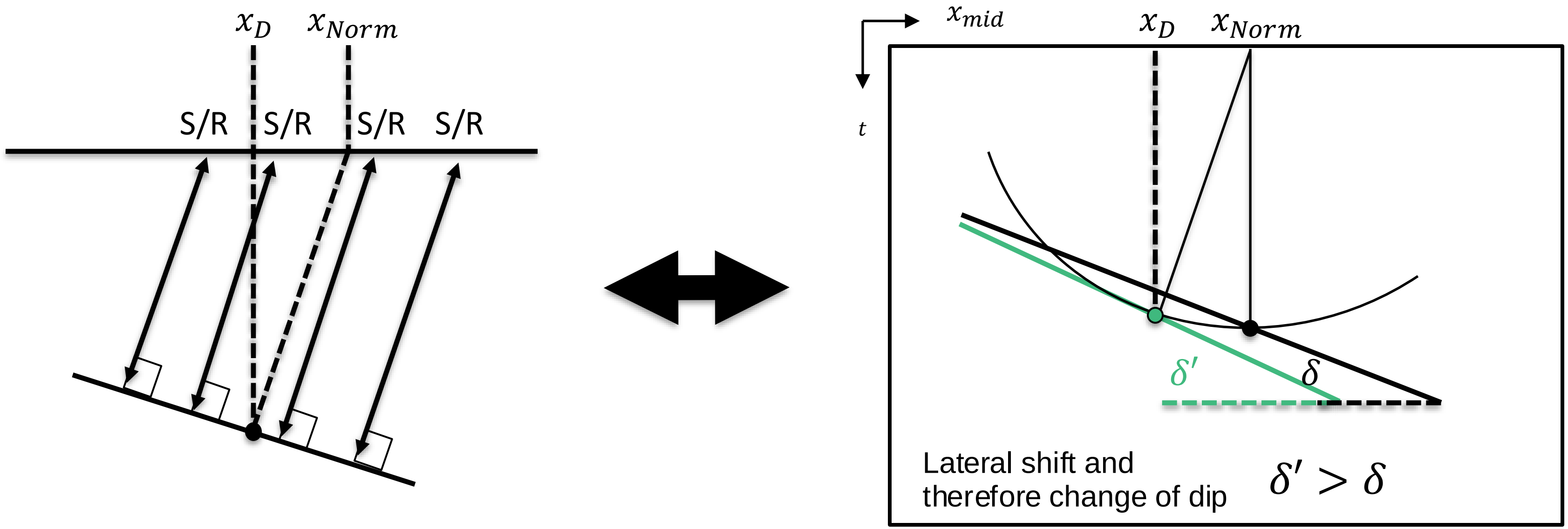
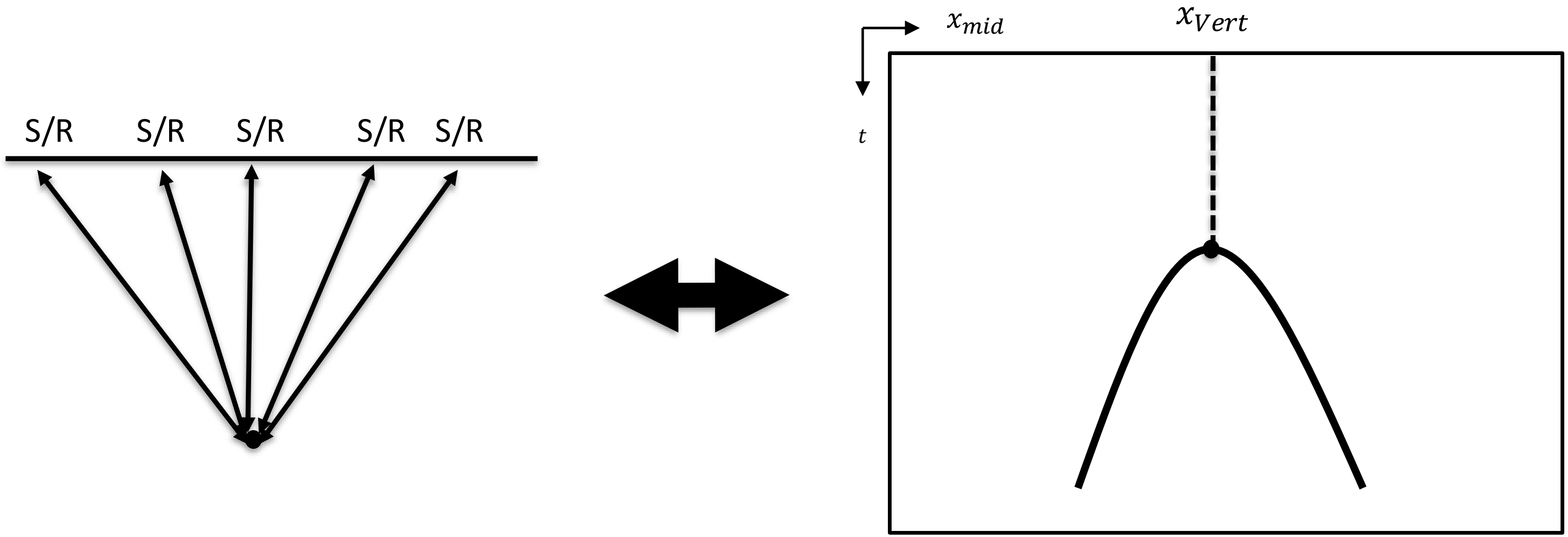


Lateral shift and therefore change of dip

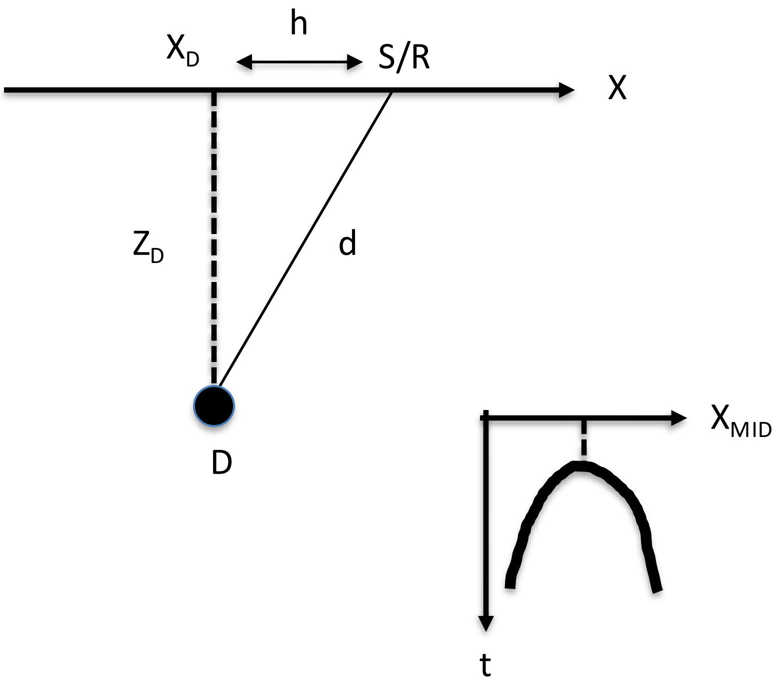
$\delta' > \delta$

Post-stack time migration - diffractors

Diffractors collapse from a hyperbola to a point



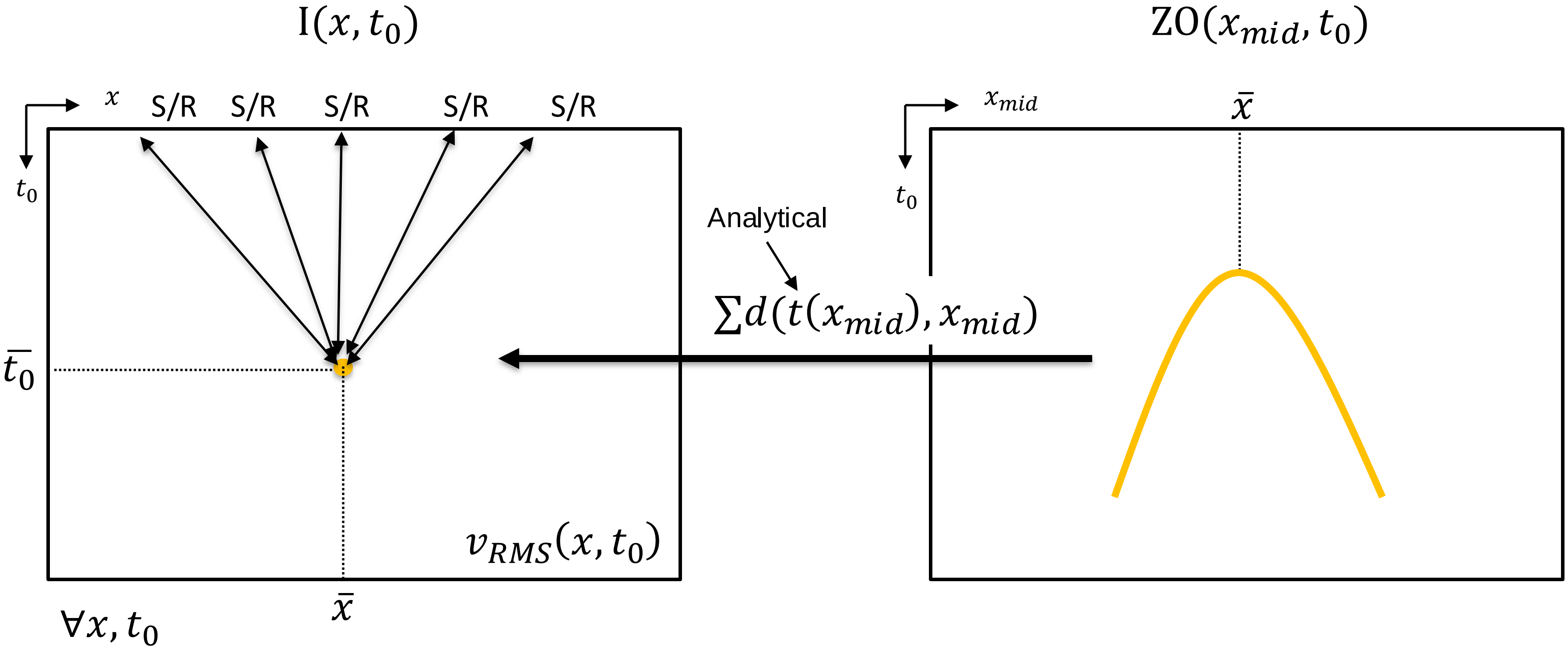
Post-stack time migration - diffractors



$$t(x_{MID}; D) = \sqrt{t_0^2 + \frac{4h^2}{v^2}}$$

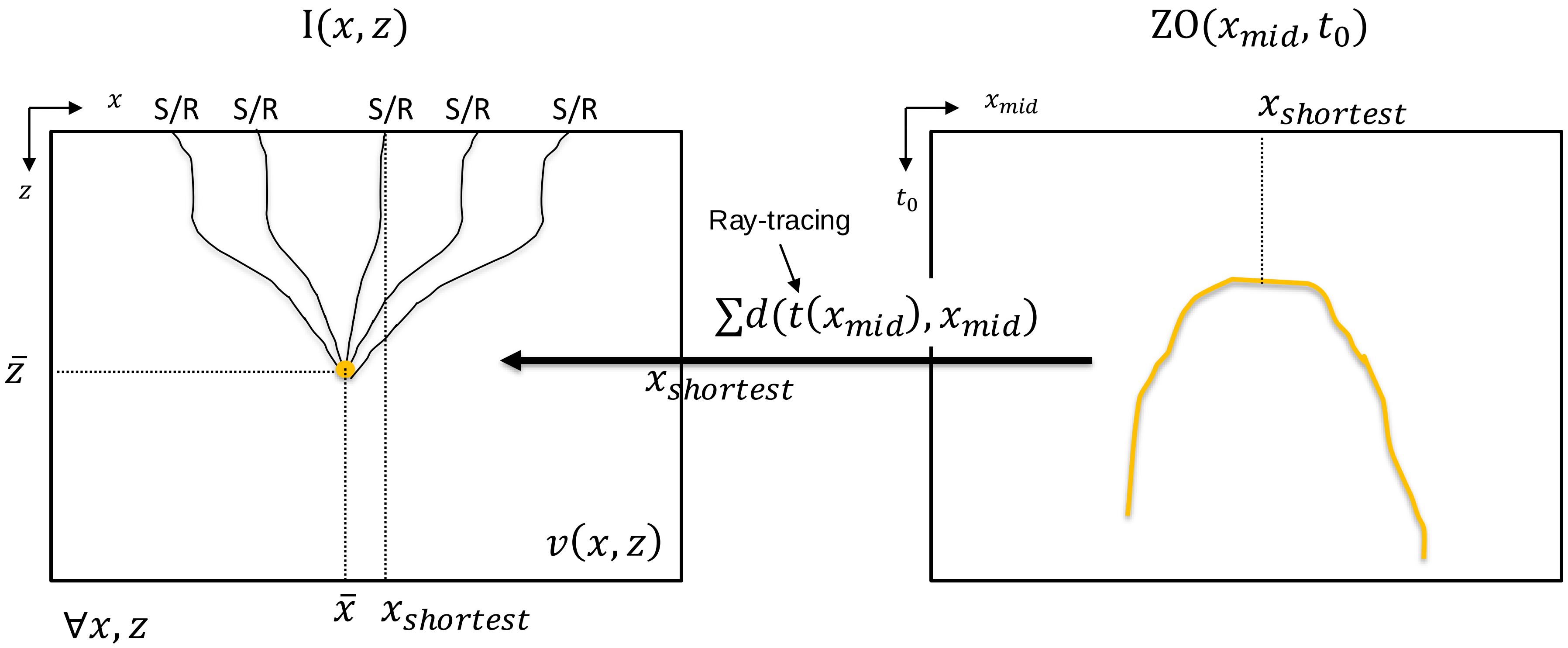
$$t_0 = \frac{2z_D}{v}$$

Post-stack time migration - algorithm



Kirchhoff summation / hyperbola stacking

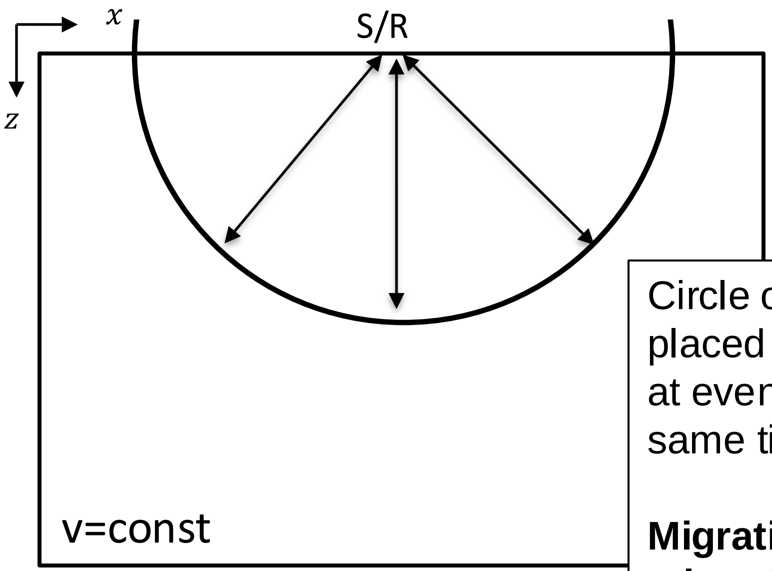
Post-stack depth migration - algorithm



Kirchhoff summation / ‘hyperbola’ stacking

Post-stack migration – algorithm 2

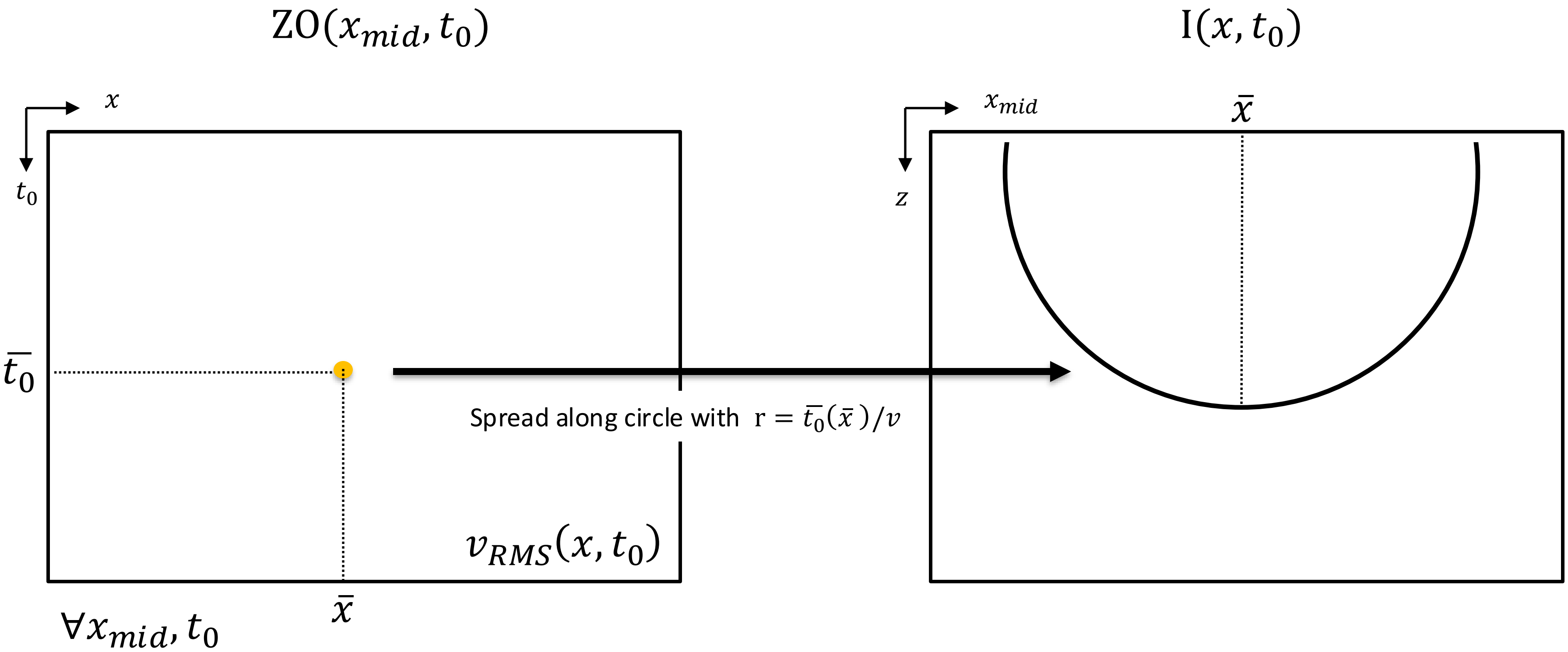
Let us at the modelling of one event from the S/R perspective:



Circle of radius r: any diffractor placed along this circly will create at event in the S/R trace at the same time (r/v)

Migration impulse response / migration smile

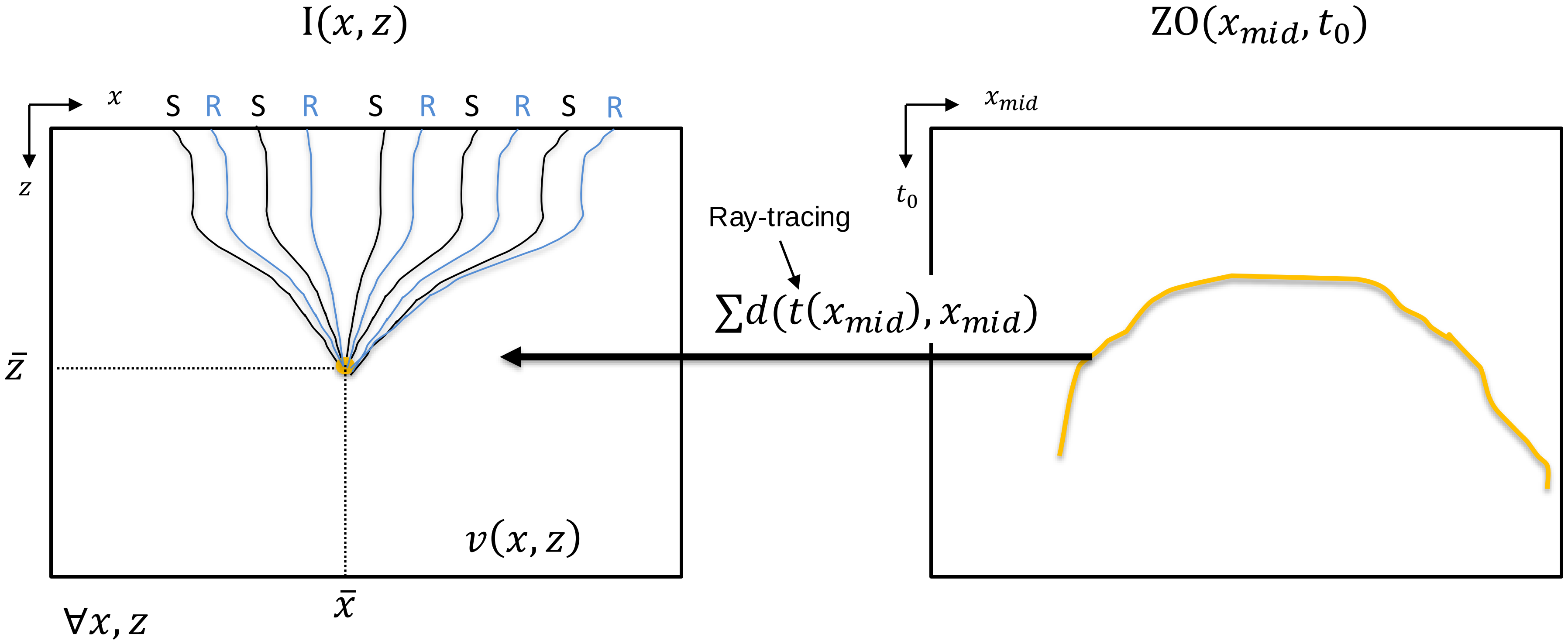
Post-stack migration – algorithm 2



Spread along circle with $\mathrm{r} = \bar{t_0}(\bar{x}\,)/v$

Kirchhoff (circle) spreading

Pre-stack migration – algorithm



$\mathrm{I}(x,z)$

$\mathrm{ZO}(x_{mid},t_0)$

x S R S R S R S R S R

z

$\bar{z}$

$\bar{x}$

$v(x,z)$

$\forall x,z$

x_{mid}

t_0

Ray-tracing

$\sum d(t(x_{mid}),x_{mid})$

Pre-stack Kirchhoff summation (repeated for all offset classes)

Stacking vs spreading

In summary:

Stacking → image-oriented approach (easier to implement, as each output is completely independent from the other, but requires getting back to the same data over and over again)

Spreading → data-oriented approach (more efficient with modern, very large data as image is much smaller than data, so we can loop over traces in the data and just spread each sample; once a trace is used, we do not need it again)