Finite-frequency sensitivity of body waves to anisotropy based upon adjoint methods

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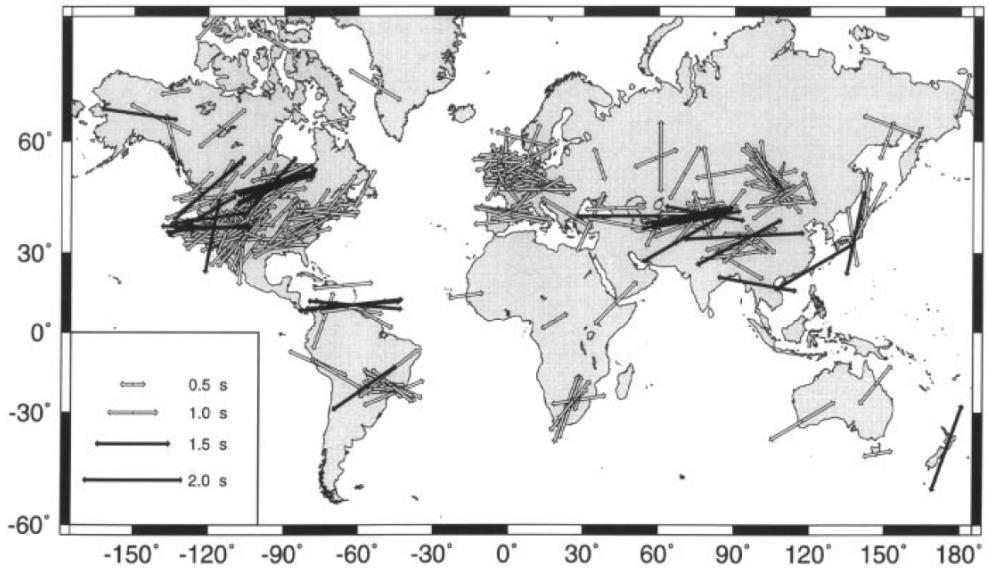
Introduction

- SKS splitting is popular to map mantle anisotropy



Splitting parameters
(fast direction and time shift)
Silver (1996)

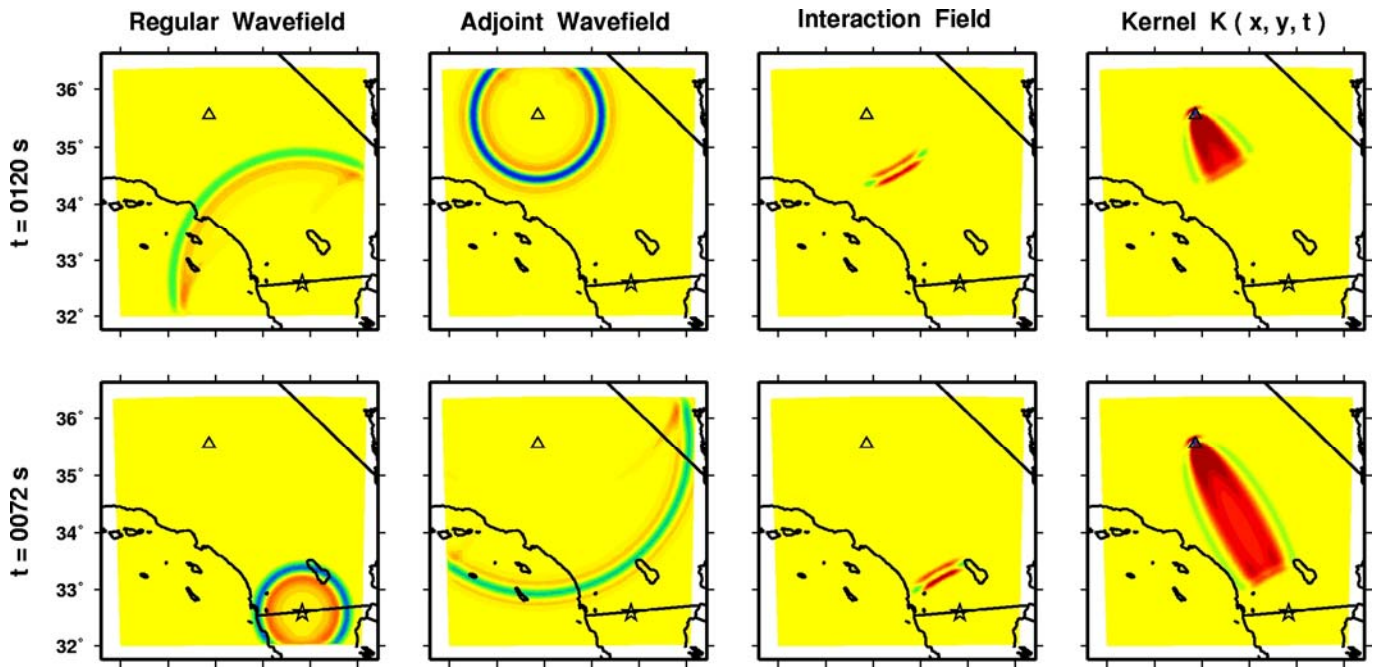
- But what is the sampled region ?

$\Rightarrow$ A general tool: Adjoint Spectral Element Method

Tromp et al. (2005) Liu & Tromp (2006) Sieminski et al. (2007)

Sensitivity computation

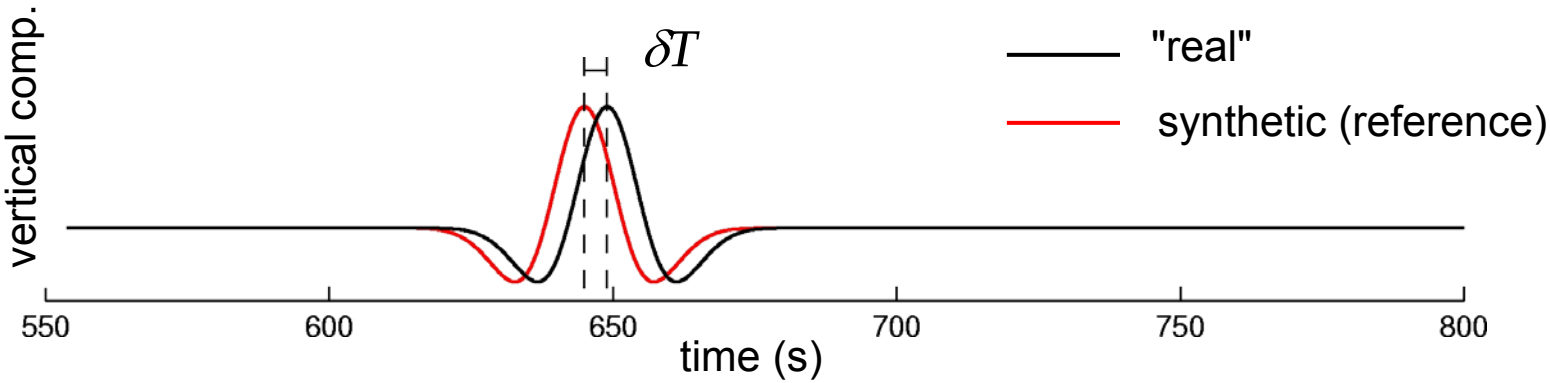
- Sensitivity kernel: $\delta d = \iiint K_{\delta m}^{\delta d}(x)\delta m(x)dx^3$
- Construction:



Tape et al. (2007)

Observable

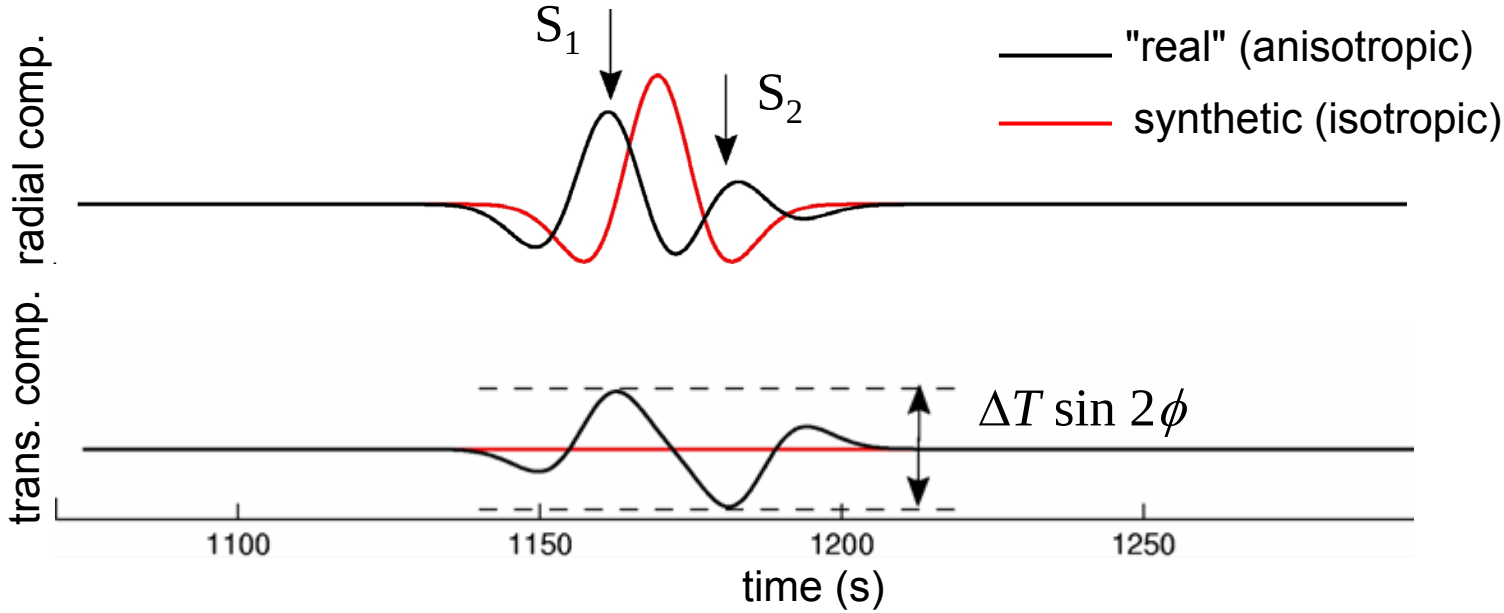
- Isotropic case:



$\rightarrow$ "traveltime anomaly" $\delta T \leftrightarrow \max \{ s_V(t) \stackrel{*}{-} d_V(t) \}$

Observable

- Anisotropic case with SV waves:



→ "splitting intensity" $\Delta T \sin 2\phi$ Chevrot (2000)

$$\leftrightarrow \max \{ s_R(t) \overset{*}{-} [s_R(t) + d_T(t)] \}$$

Anisotropic parameters

- Asymptotic propagation is controlled by

0ξ $\boxed{A \;\; C \;\; F \;\; L \;\; N}$ vertically transverse isotropy

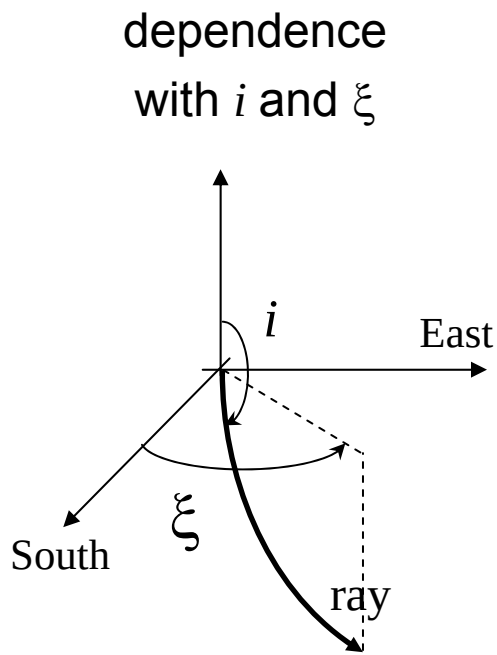
1ξ $Jc \;\; Js \;\; Kc \;\; Ks \;\; Mc \;\; Ms$

2ξ $Bc \;\; Bs \;\; Hc \;\; Hs \;\; Gc \;\; Gs$

3ξ $Dc \;\; Ds$

4ξ $Ec \;\; Es$

- Each parameter is $\sum a_{IJ} C_{IJ}$



Smith & Dahlen (1973) Montagner & Nataf (1986)
Jech & Psencik (1989) Larson et al. (1998) Chen & Tromp (2007) …

Anisotropic parameters

- Asymptotic propagation is controlled by

0ξ A C F L N

1ξ Jc Js Kc Ks Mc Ms

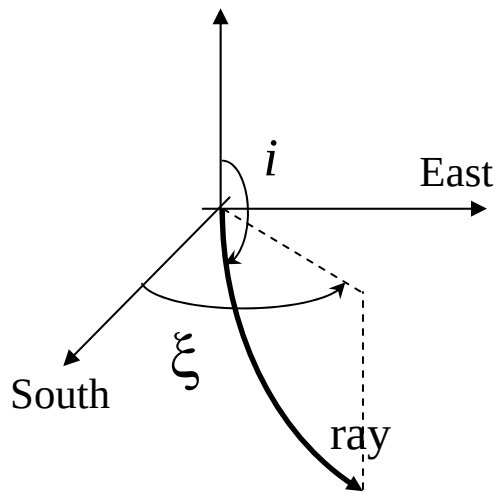
2ξ Bc Bs Hc Hs Gc Gs

3ξ Dc Ds

4ξ Ec Es

azimuthal anisotropy

dependence with i and ξ



- Each parameter is $\sum a_{IJ} C_{IJ}$

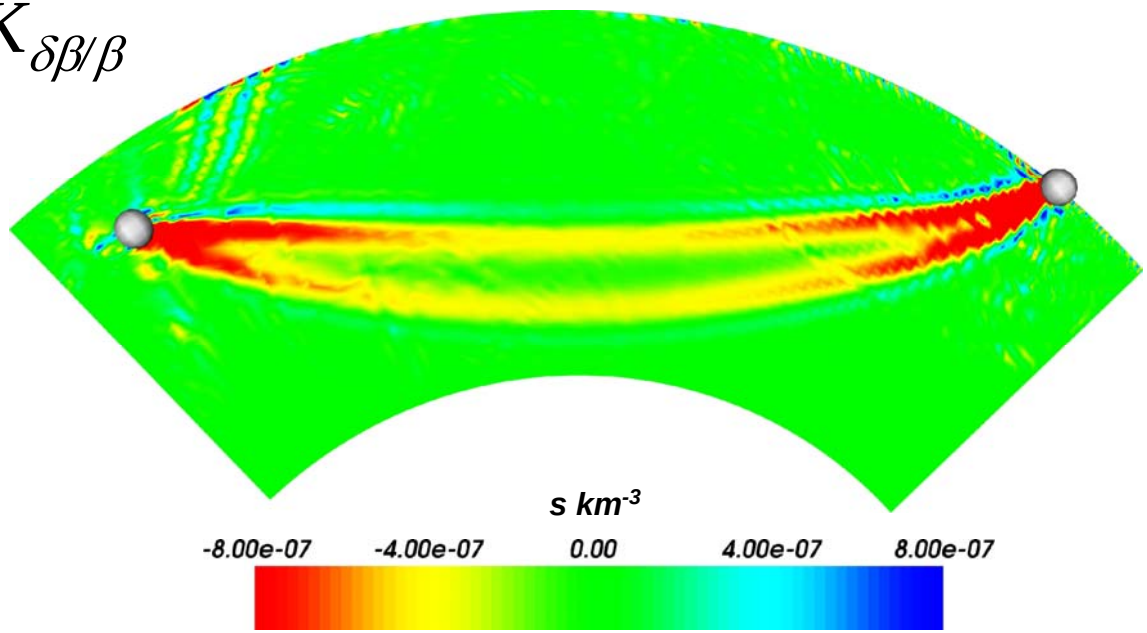
Smith & Dahlen (1973) Montagner & Nataf (1986)

Jech & Psencik (1989) Larson et al. (1998) Chen & Tromp (2007) …

SV wave

- A banana-doughnut for δT and $\delta\beta/\beta$

$K_{\delta\beta/\beta}$

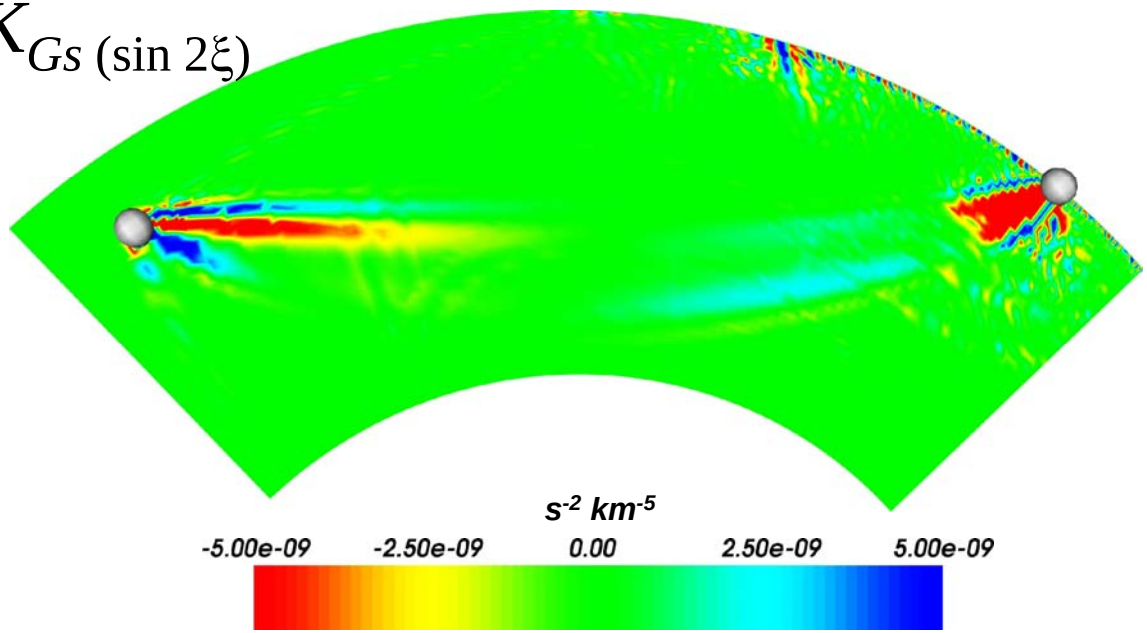


along the source-receiver plane (T = 15s ; Δ = 75°)

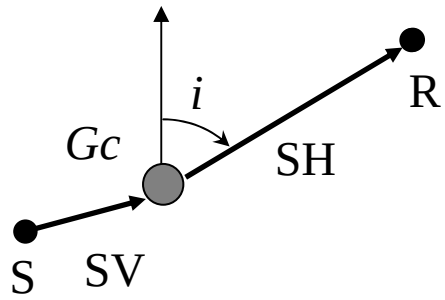
SV wave

- A "perturbed" banana-doughnut for $\Delta T \sin 2\phi$ and Gs

$K_{Gs}(\sin 2\xi)$



Interpretation

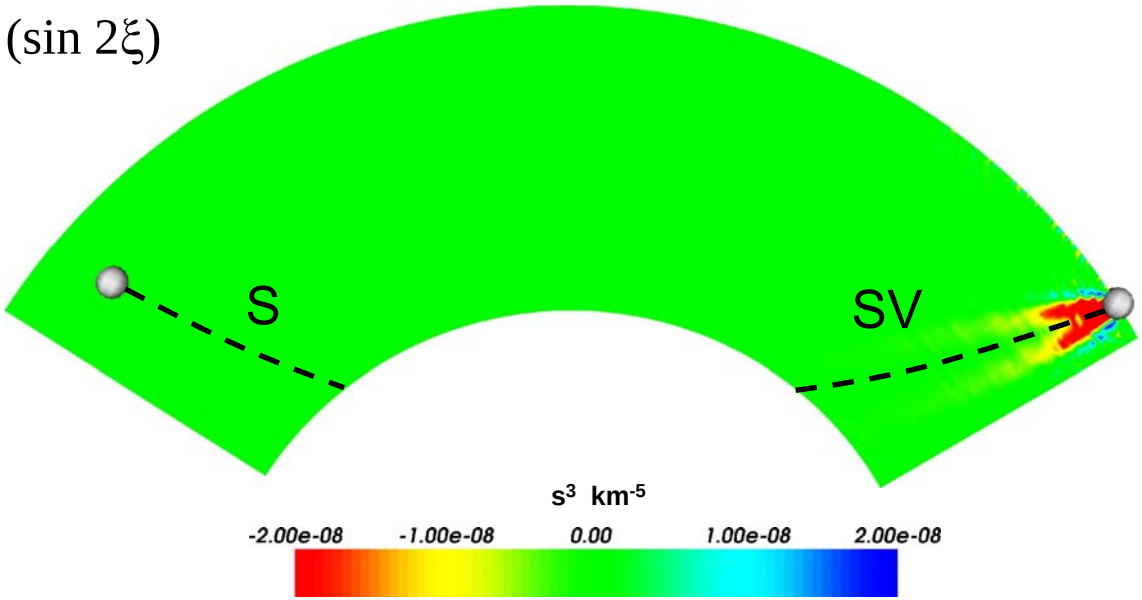


along the source-receiver plane (T = 15s ; Δ = 105º)

SKS wave

- No sensitivity before the core

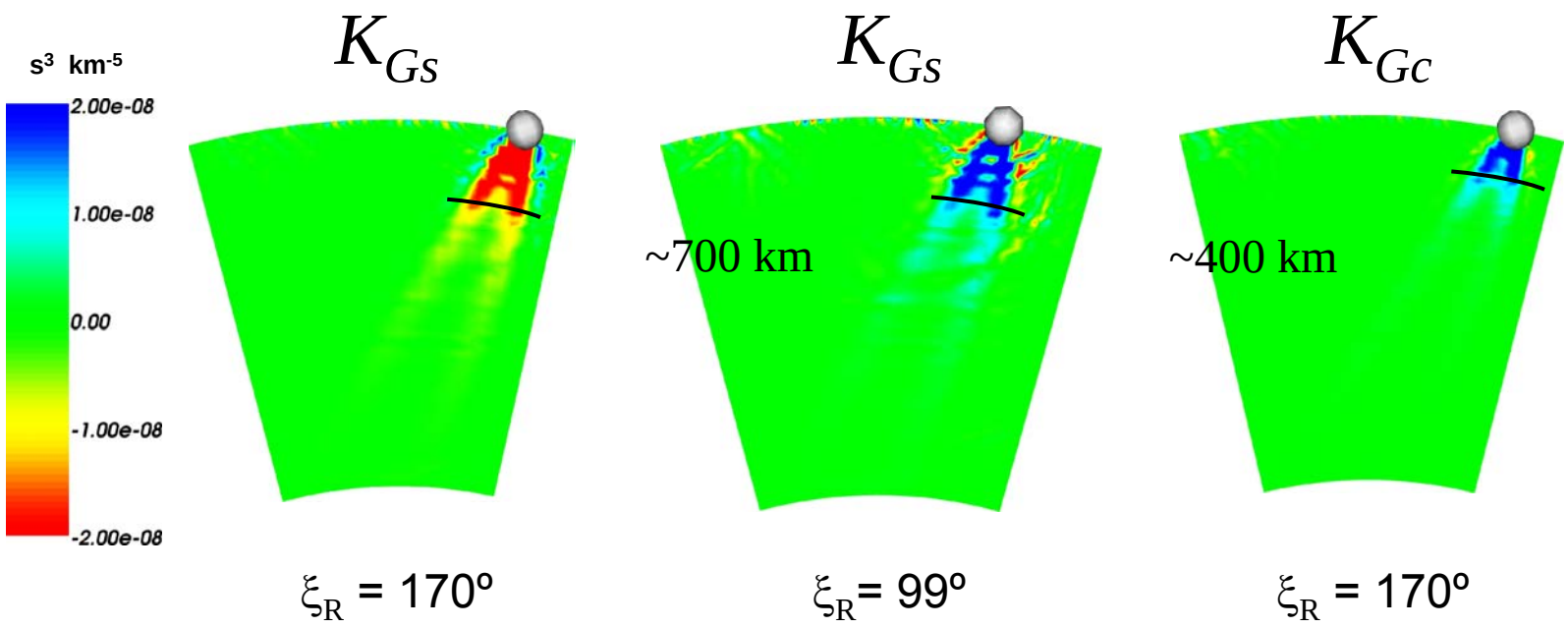
$K_{Gs}(\sin 2\xi)$



along the source-receiver plane (T = 15s ; Δ = 105º)

SKS wave

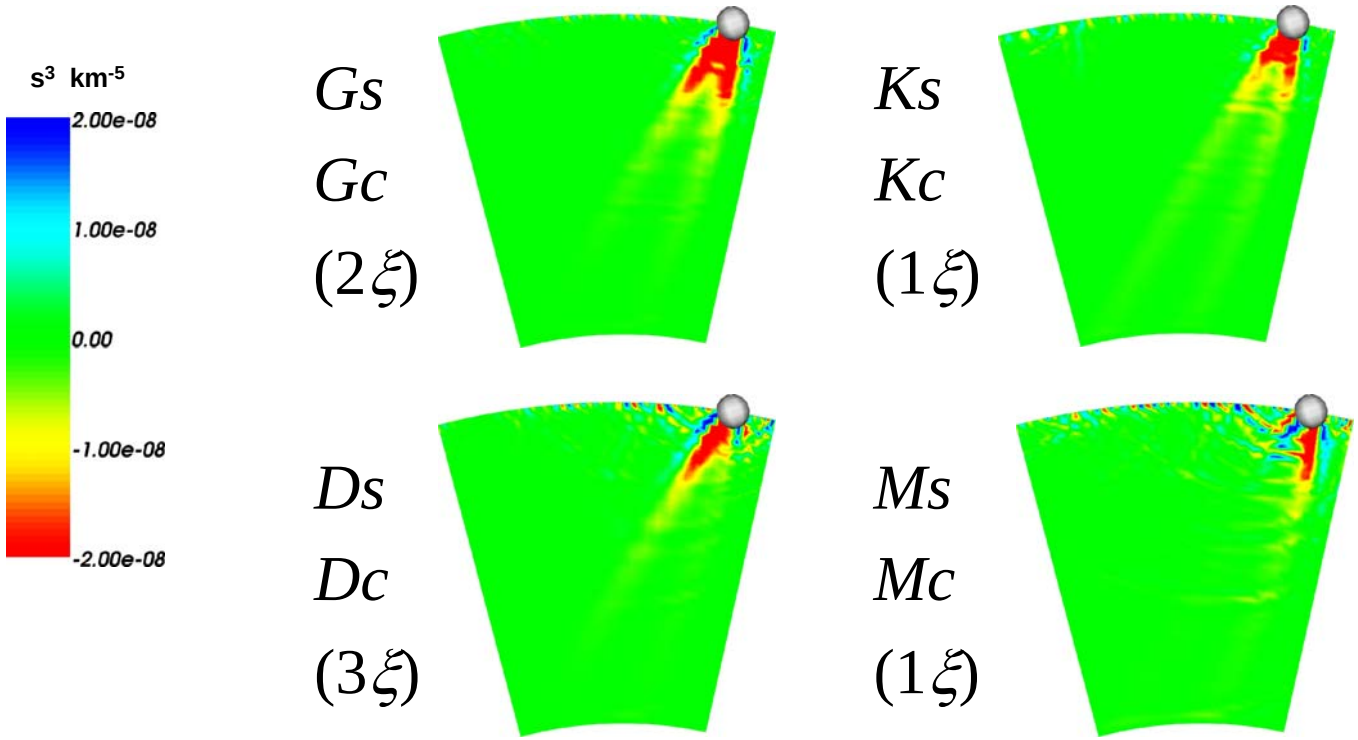
- Dependence on i and ξ $\Rightarrow$ path-dependence



zoom along the source-receiver plane (T = 15s ; Δ = 105°)

SKS wave

- Main anisotropic parameters



zoom along the source-receiver plane (T = 15s ; Δ = 105º)

Conclusion

• The sensitivity to anisotropy is characterized by a dependence with the propagation direction
($\rightarrow$ complexity and path-dependence)

• SKS-splitting intensity is well adapted for imaging ("small" sensitivity zone and "few" parameters)

• To reduce the number of parameters, we may look for which $\sum a_{IJ} C_{IJ}$ the dataset is the most sensitive to