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# Numerical modelling of the electrical activity of the atria and the pulmonary veins.

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## INTRODUCTION : NUMERICAL MODELLING FRAMEWORK

**Pre-processing**  
Parameters setting

**Numerical model**

**Post-processing**  
Medical or biological insight

**Monodomain :**

$$\underbrace{\alpha(C_m \partial_t V + I_{ion}(V))}_{\text{electrophy.}} + \underbrace{\text{div} D \nabla V}_{\text{coupling}} = \underbrace{I_{app}}_{\text{stim}}$$

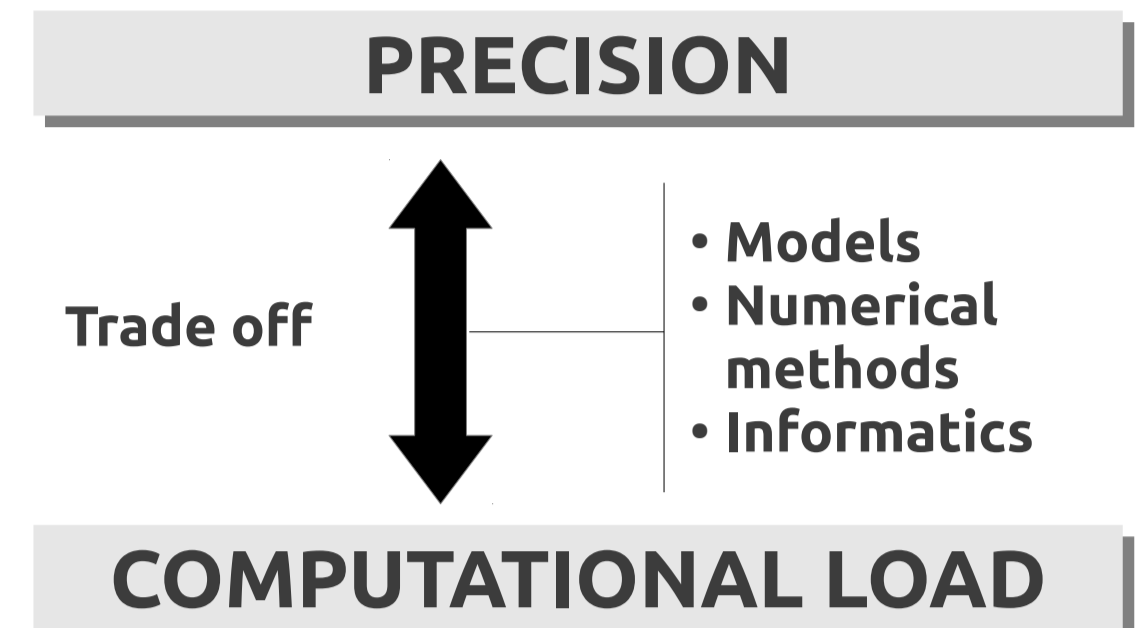
### INPUTS

- Electrophysiology : ionic models
- Tissue anisotropy and coupling
- Anatomy : IRM, fibres.
- Stimulation : SAN, trigger, electrode...

### OUTPUTS

- Potential maps :  $V_m, \Phi_i, \Phi_e$ .
- Electrophysiological insights : EGM / ECG PA,  $\partial V / \partial t_{max}$  Ionic currents
- ...

### TRADE OFF

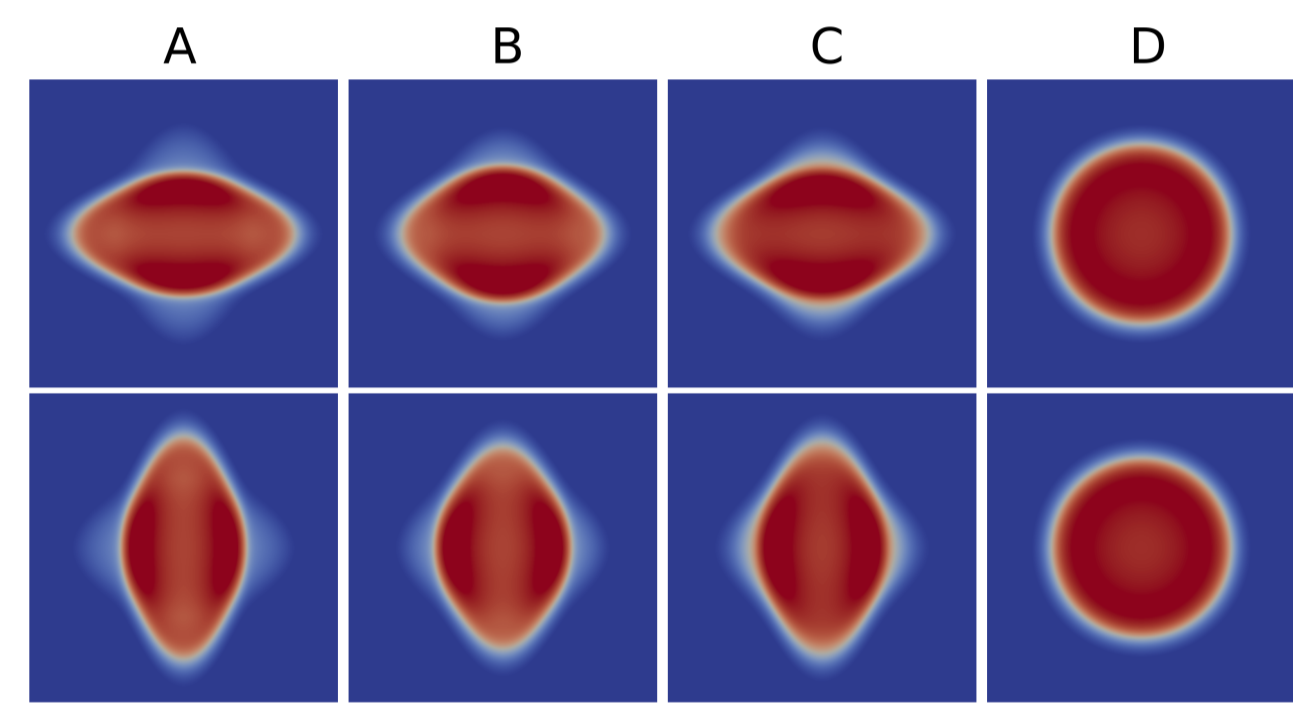
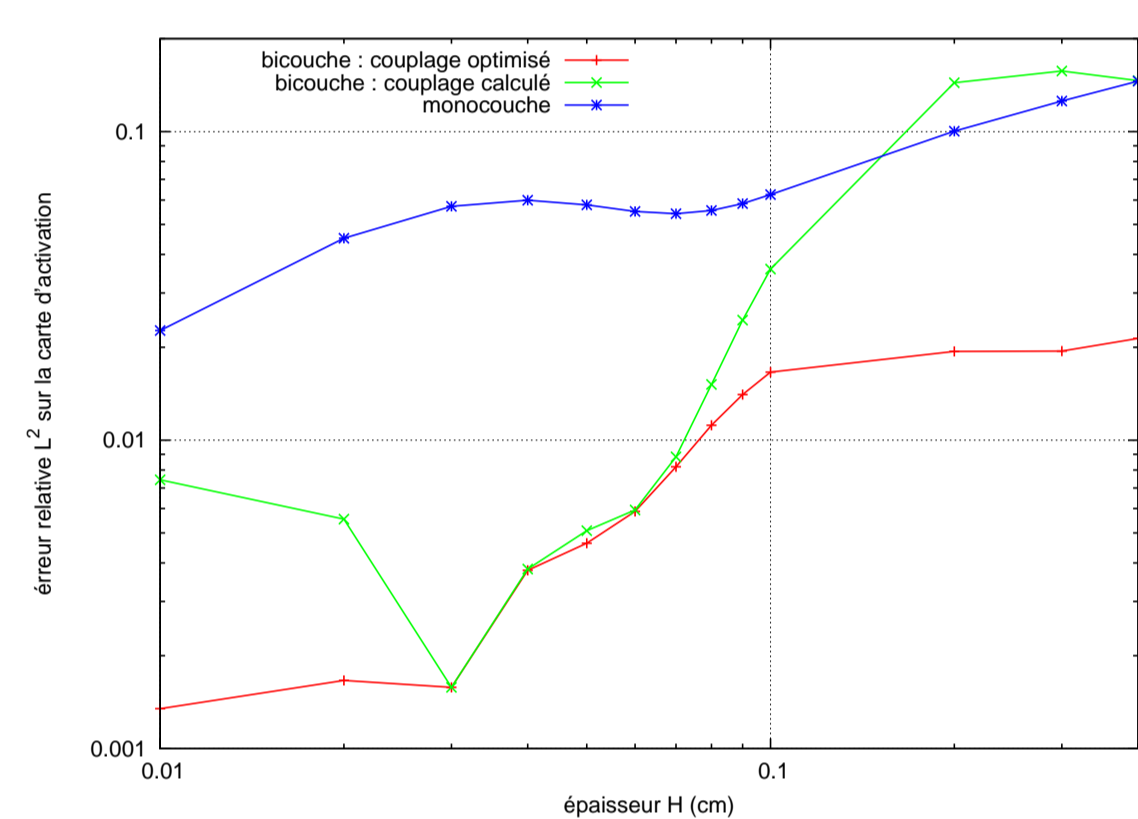


## DERIVATION OF MATHEMATICAL MODELS

### BILAYER SURFACE MODEL

- Three-dimensional behaviours for 2D computational load.
- Asymptotic analysis  $\Rightarrow$  Second order convergence.

$$\underbrace{\alpha(C_m \partial_t V_k + I_{ion}(V_k))}_{\text{electrophy.}} - \underbrace{\text{div} D \nabla V_k}_{\text{coupling}} + \underbrace{(-1)^k \tilde{\sigma} \frac{V_2 - V_1}{h^2}}_{\text{coupling}} = \underbrace{I_{app}}_{\text{stim}}$$



### HOMOGENIZATION WITH GAP JUNCTIONS NON LINEAR DYNAMICS

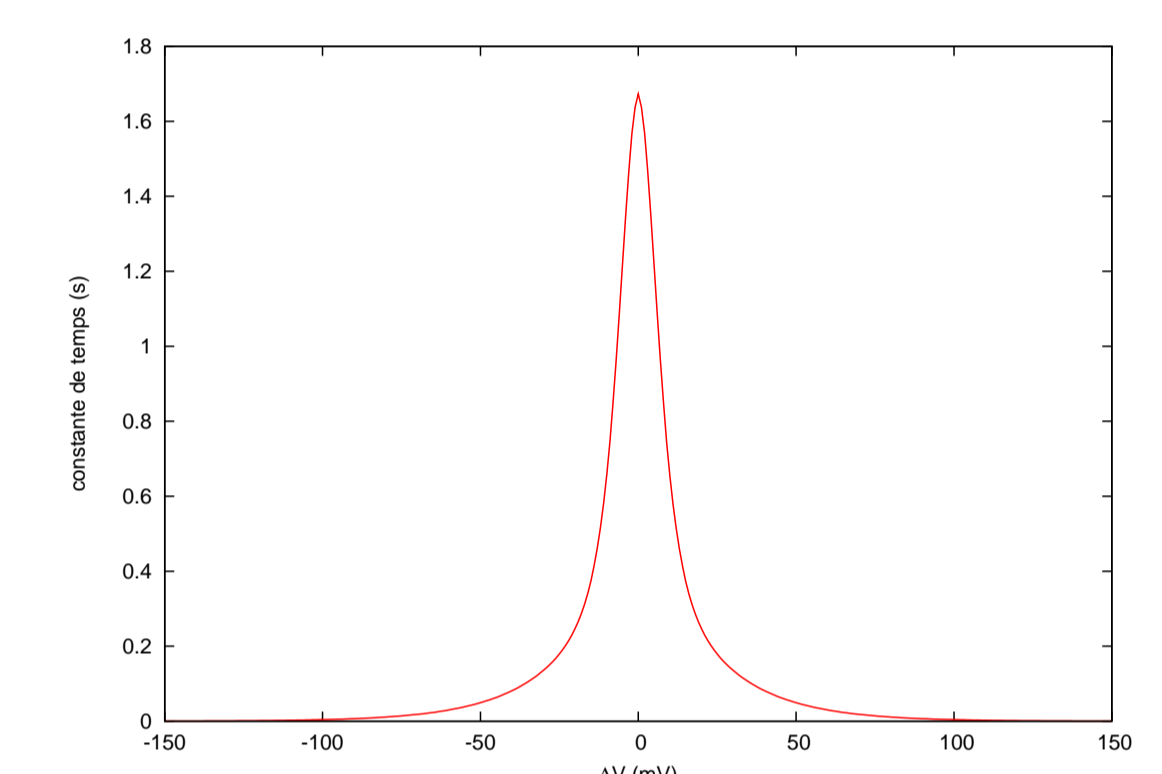
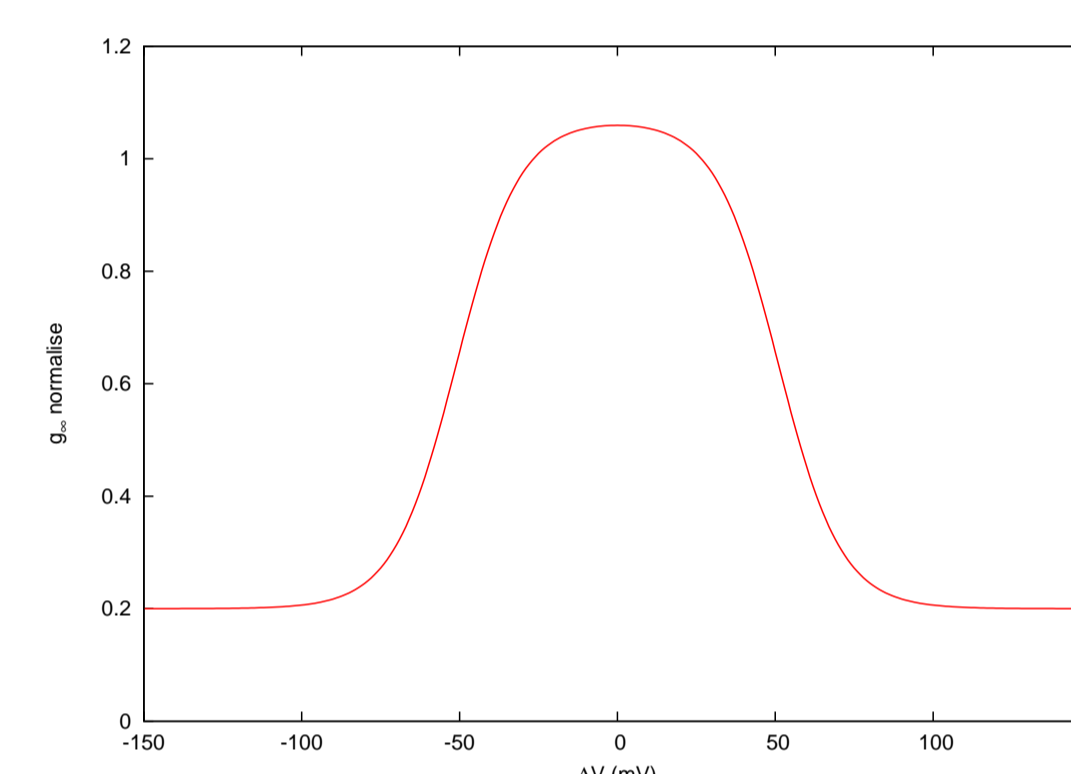
- GJ conductance:

$$G_{GJ} = G_{max} w_0$$

$$\partial_t w_0 = \frac{w_\infty(V) - w_0}{\tau(V)}$$

$$\beta(C_m \partial_t \phi_0 + I_{ion}(\phi_0)) - \partial_x(\tilde{\sigma}(w_0) \partial_x \phi_0) = 0$$

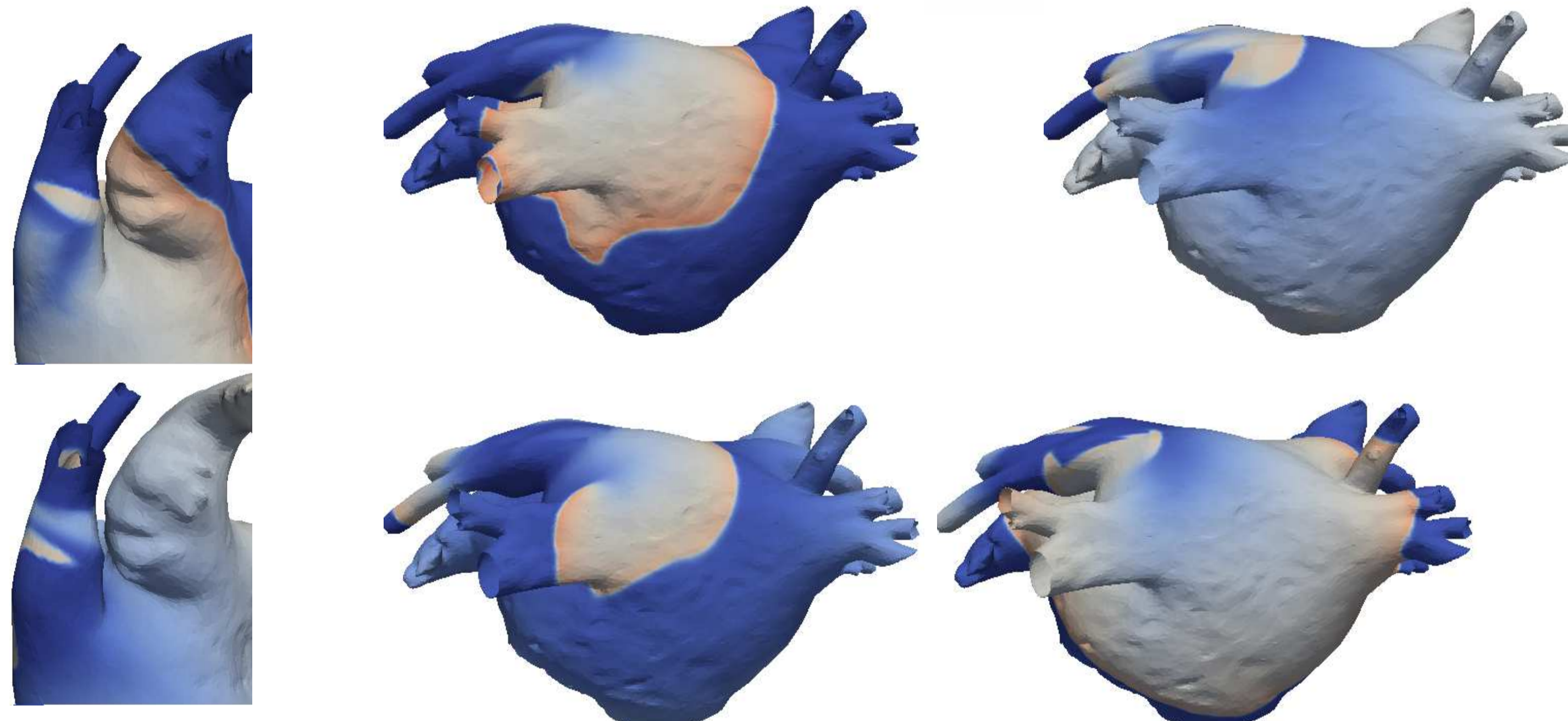
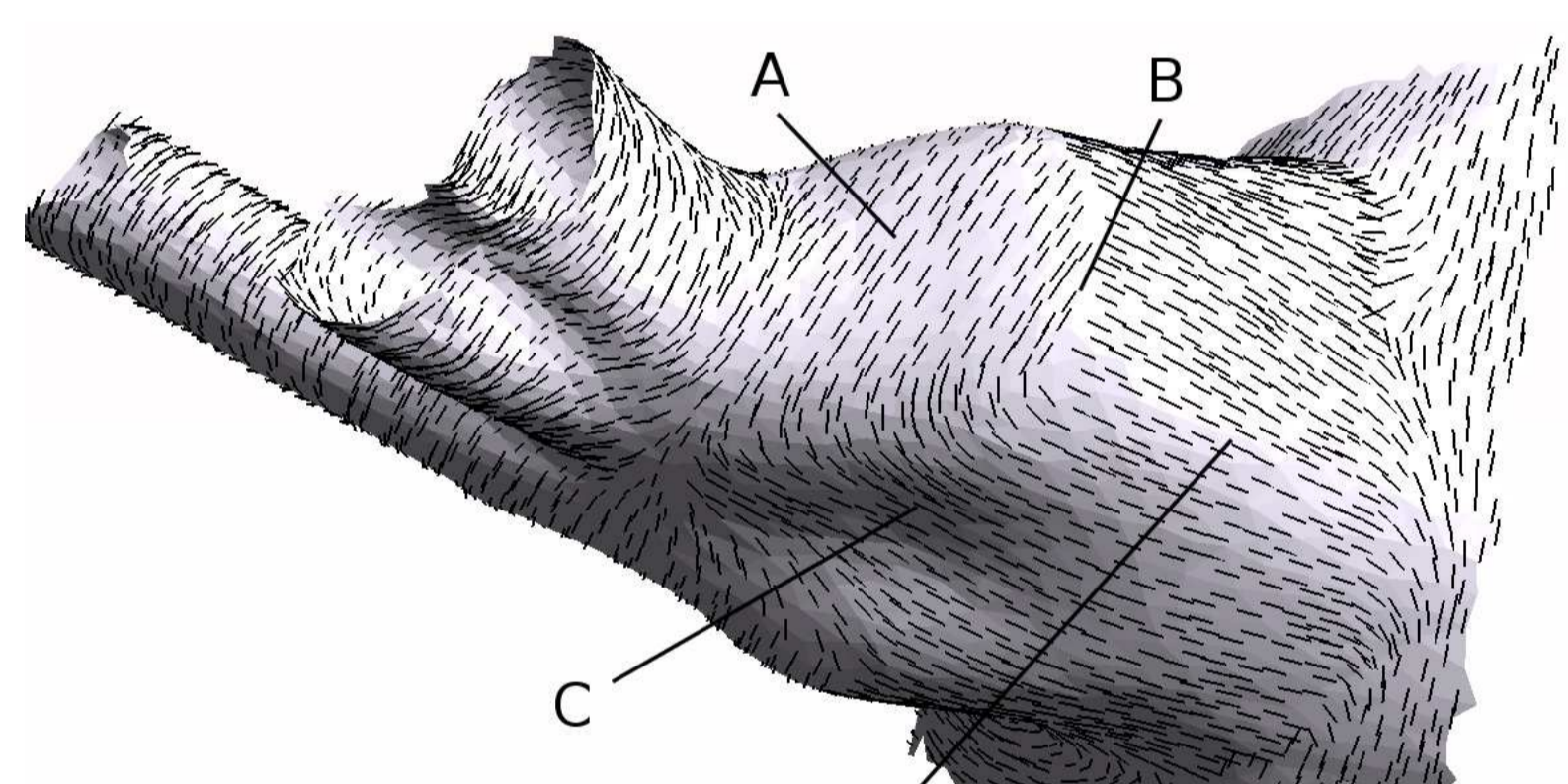
$$\partial_t w_0 + H(\mu(1 - \tilde{\sigma}(w_0)) \partial_x \phi_0, w_0) = 0$$



## ARRHYTHMIA TRIGGERS IN THE PV

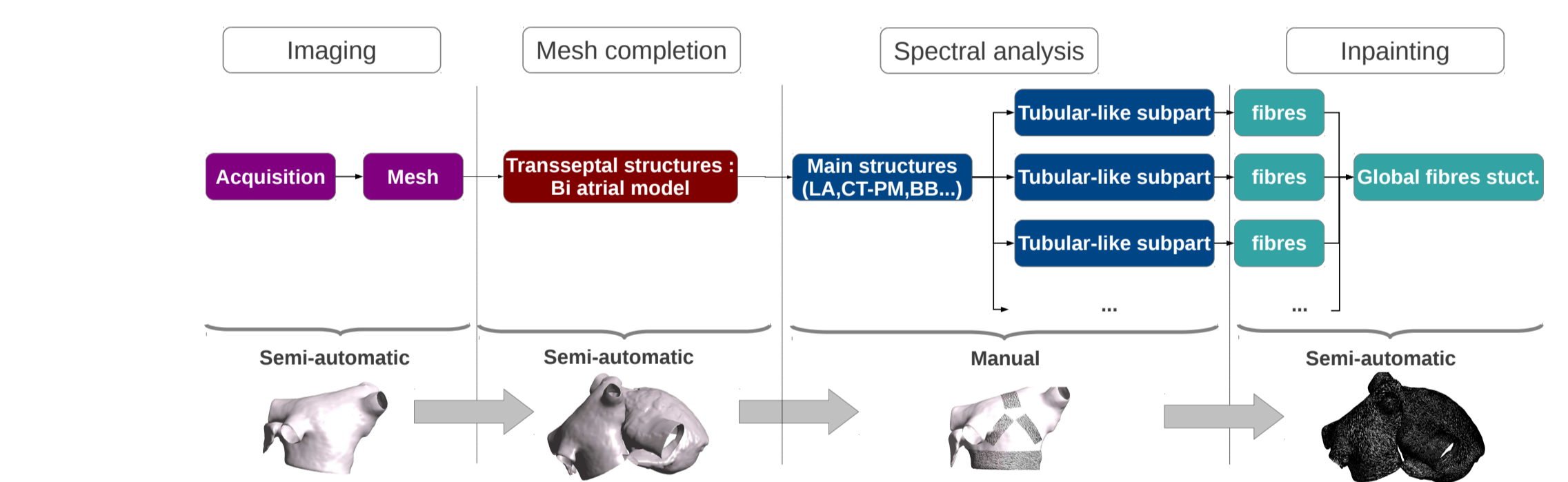
### FIBRES DISCONTINUITY

- Bloc in LSPV
- Micro reentry in LSPV  $\Rightarrow$  Macro reentry in LA.

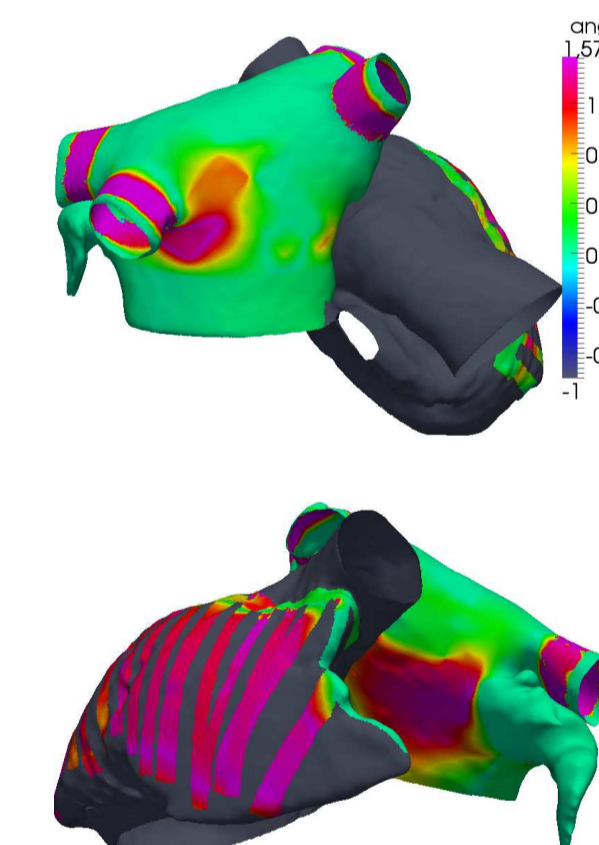


## ARRHYTHMIA PERPETUATION IN THE ATRIA

### BIATRIAL BILAYER MODEL OF HUMAN ATRIA



Angle differences

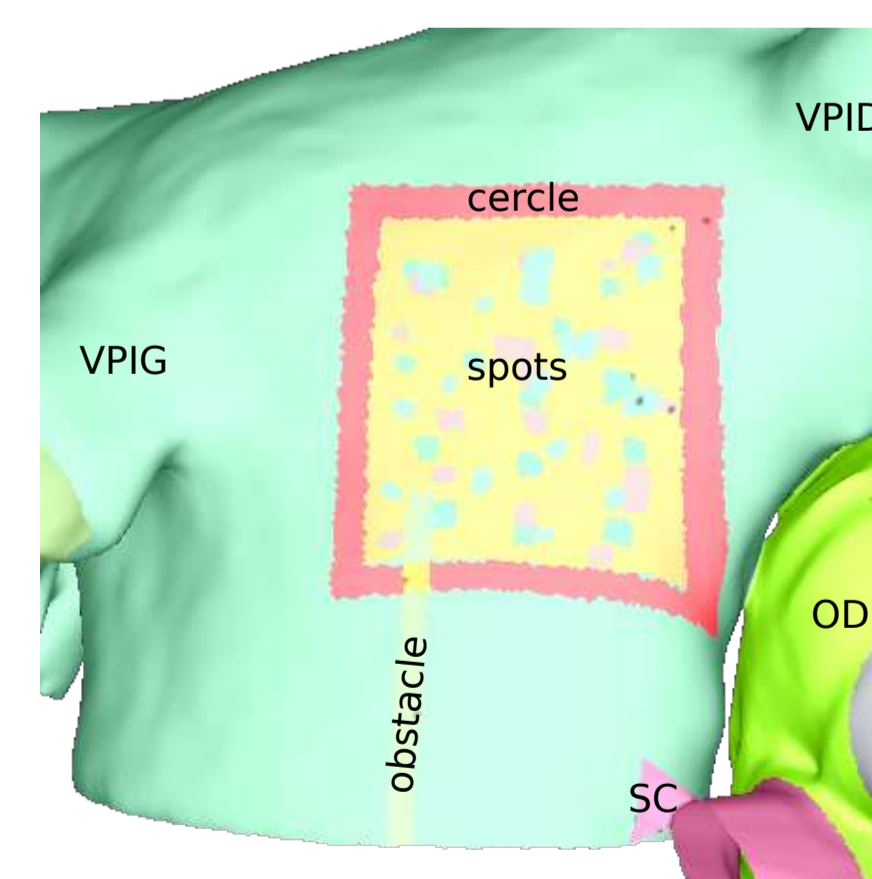


Activation times differences



Mono. vs. bilayer Endo vs epi

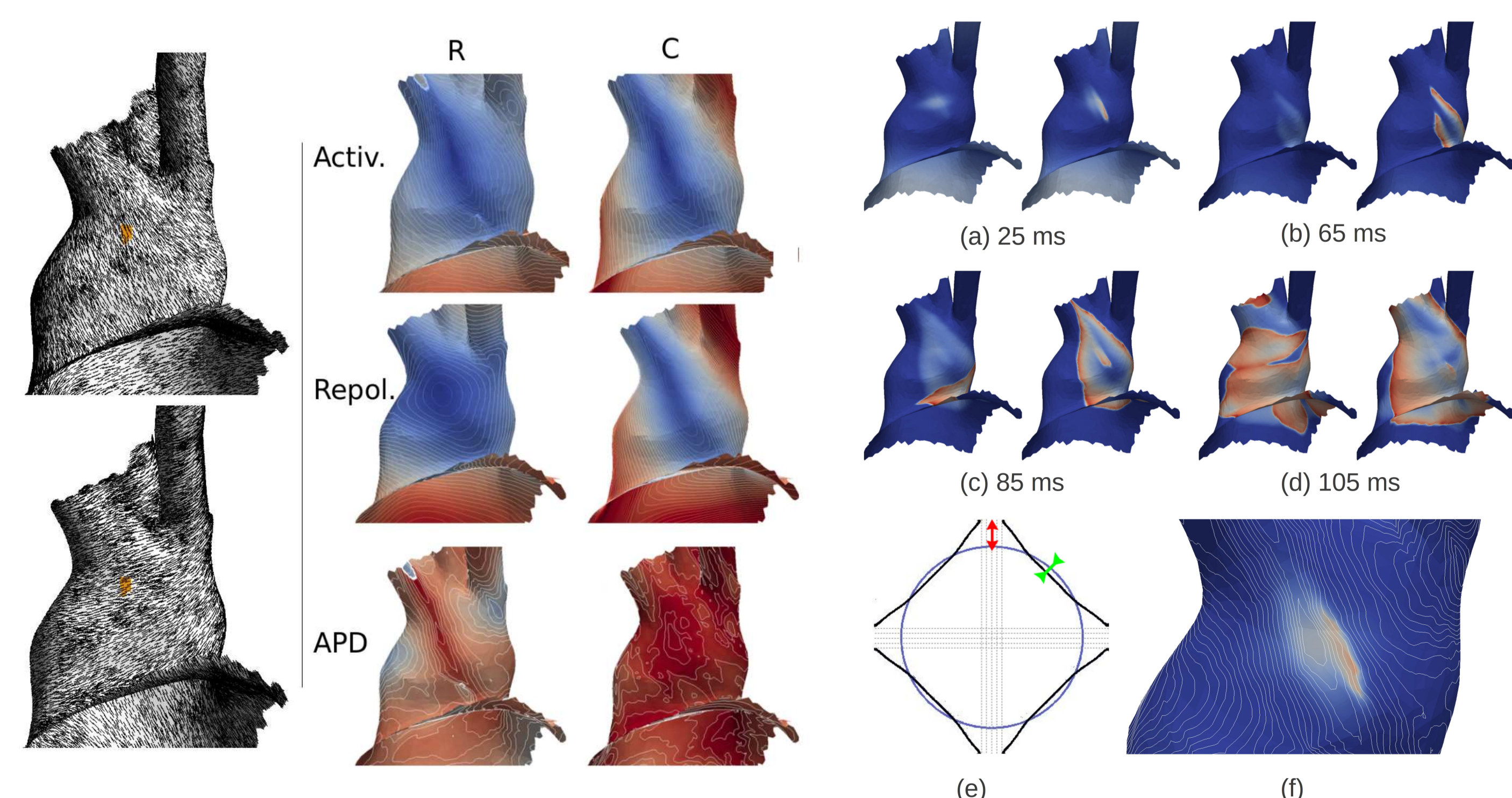
### EFFECT OF TRANSMURAL FIBROSIS AND ABLATION.



- Transmural fibrosis  $\Rightarrow$  Stabilization effect on a macro-reentry.
- Ablation protocol. Most efficient: surrounding line or line bloc to the closest natural obstacle. Less efficient: ablation spots.
- Non transmural ablation are still efficient.

### TRANSMURAL FIBRES DISCONTINUITY

Different dynamics during depolarization and repolarization  $\Rightarrow$  APD gradient  $\Rightarrow$  functional substrate of arrhythmia.



### PERSONALIZATION

