



**HAL**  
open science

# Numerical modeling of the electrical activity of the atria and the pulmonary veins

Simon Labarthe, Yves Coudière, Jacques Henry

► **To cite this version:**

Simon Labarthe, Yves Coudière, Jacques Henry. Numerical modeling of the electrical activity of the atria and the pulmonary veins. Workshop IHU Liryc, Oct 2013, Pessac, France. <hal-00926441>

**HAL Id: hal-00926441**

**<https://inria.hal.science/hal-00926441v1>**

Submitted on 9 Jan 2014

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

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

SIMON LABARTHE, YVES COUDIÈRE, JACQUES HENRY  
simon.labarthe@u-bordeaux2.fr, yves.coudiere@inria.fr, jacques.henry@inria.fr

## INTRODUCTION : NUMERICAL MODELLING FRAMEWORK

**Pre-processing**  
Parameters setting

**Numerical model**

**Post-processing**  
Medical or biological insight

**Monodomain :**

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

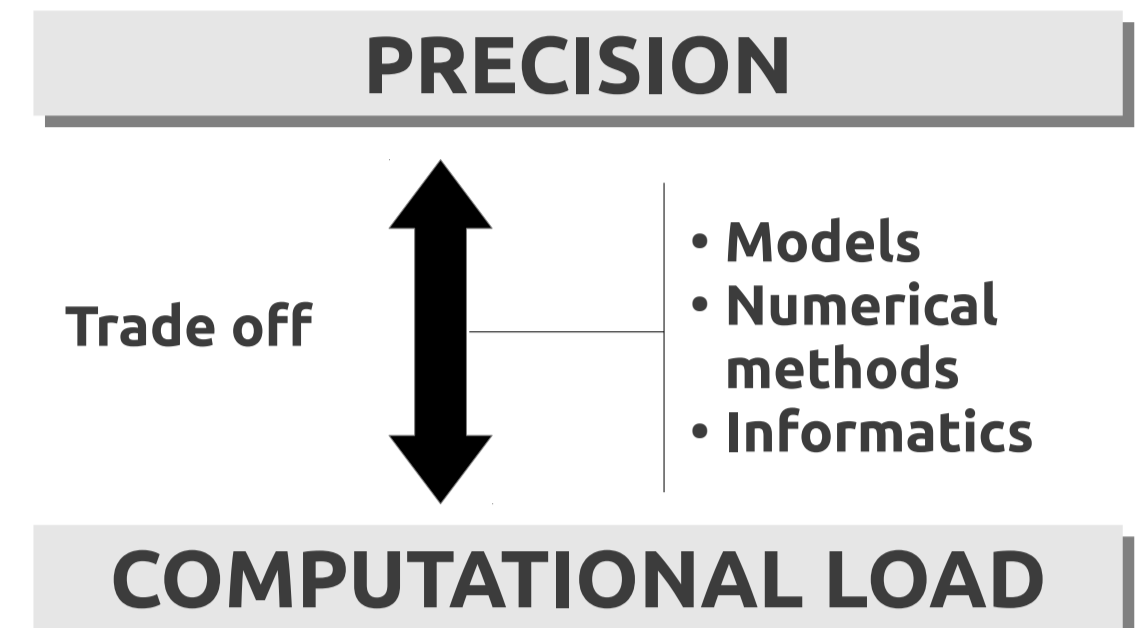
### INPUTS

- 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

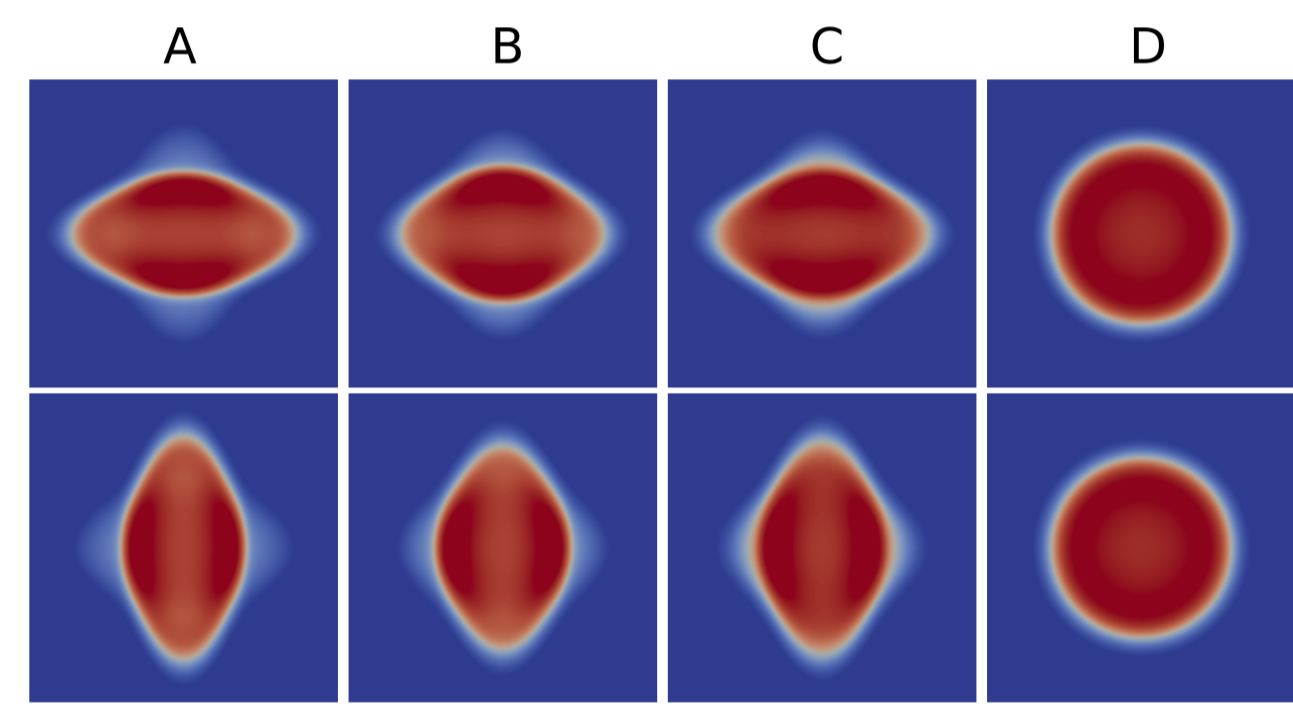
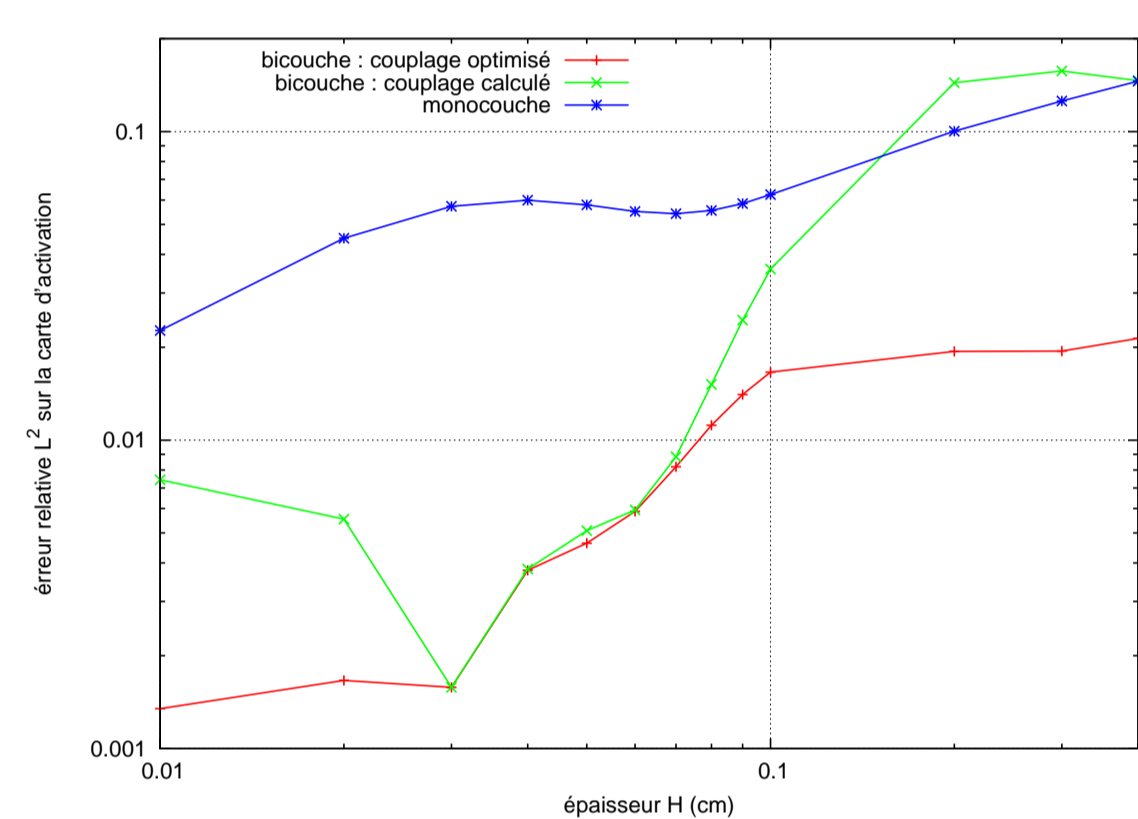


## DERIVATION OF MATHEMATICAL MODELS

### 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

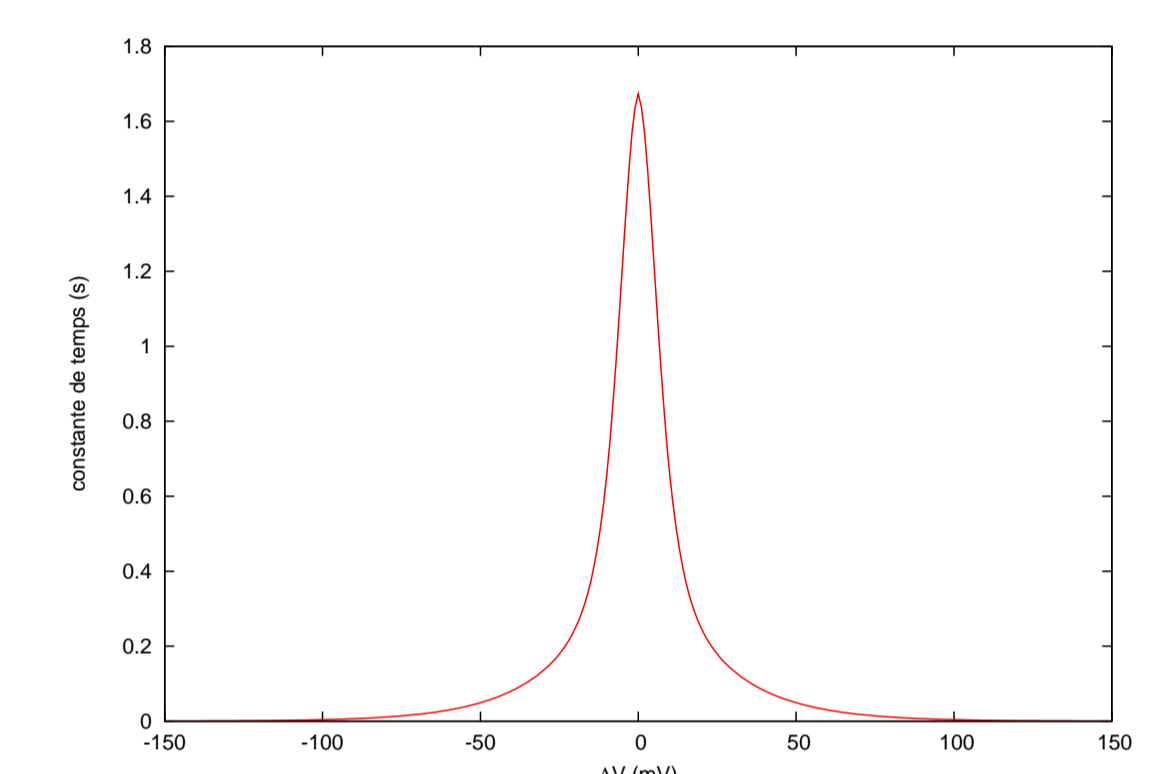
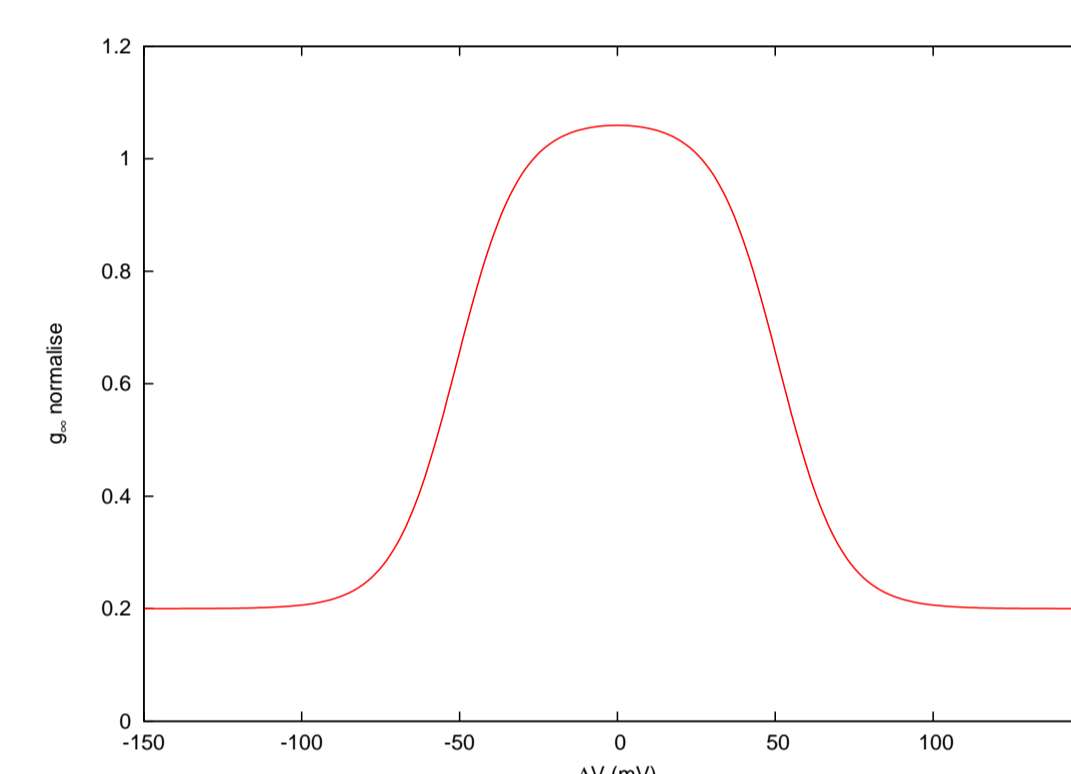
- GJ conductance:

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

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

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

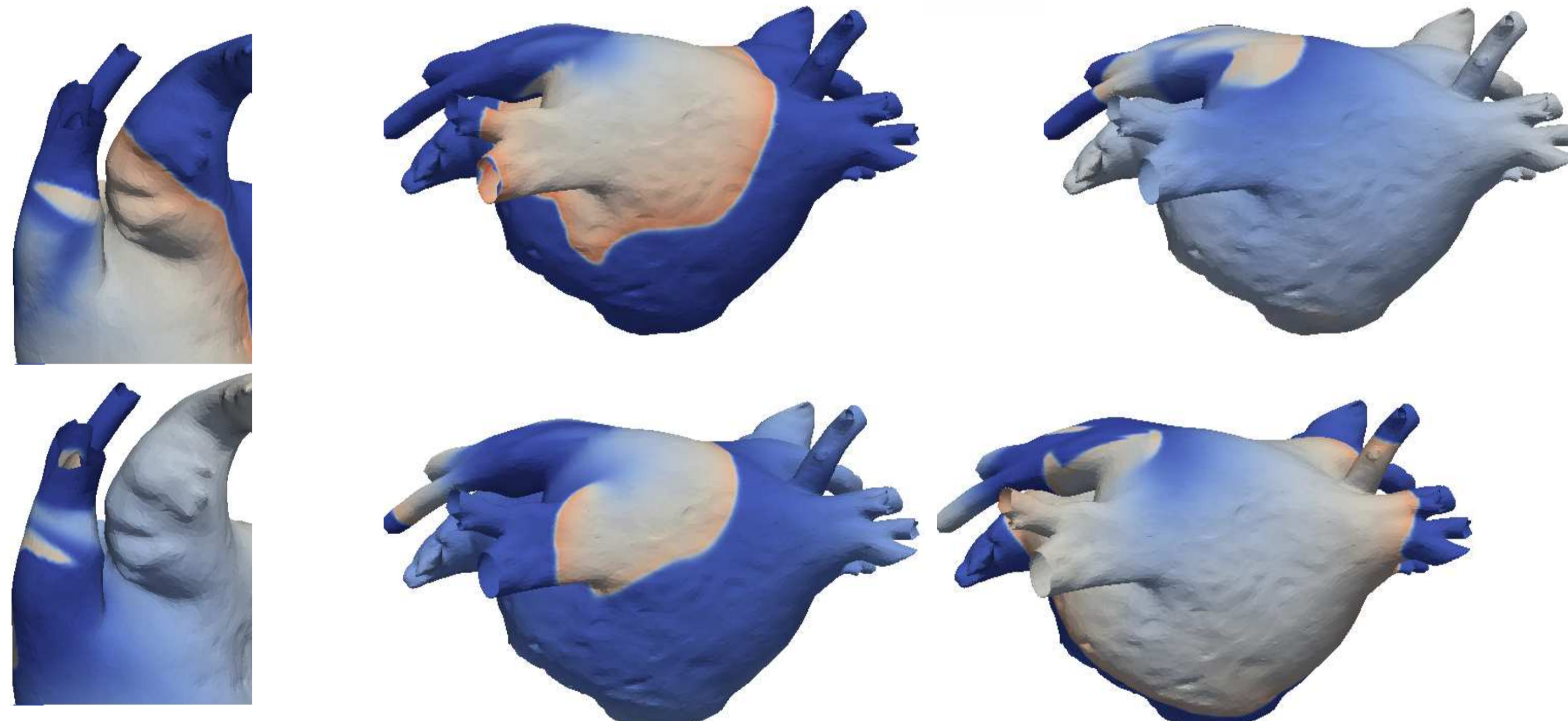
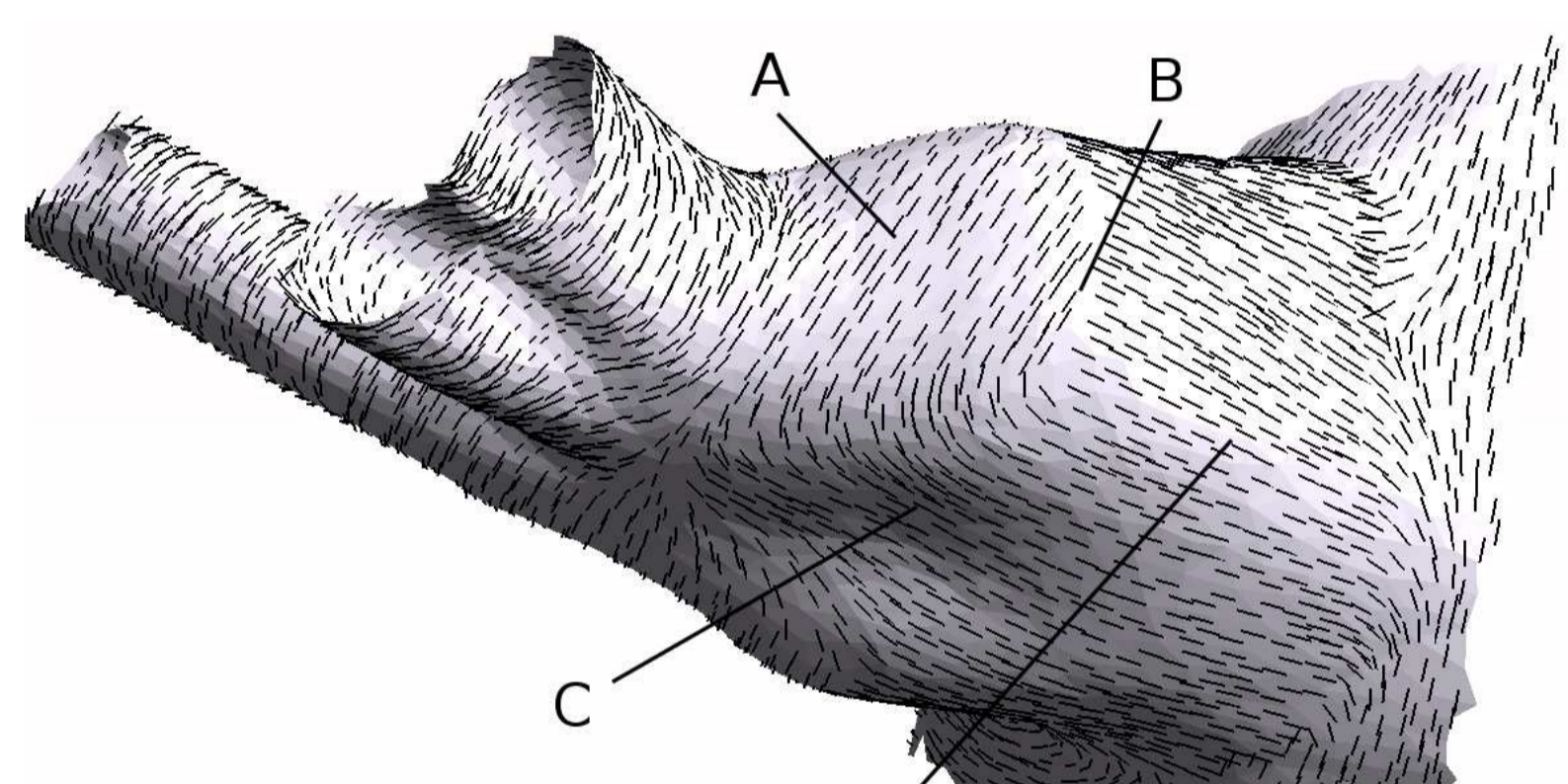
$$\partial_t w_0 + H(\mu(1 - \tilde{\sigma}(w_0)) \partial_x \phi_0, w_0) = 0$$



## ARRHYTHMIA TRIGGERS IN THE PV

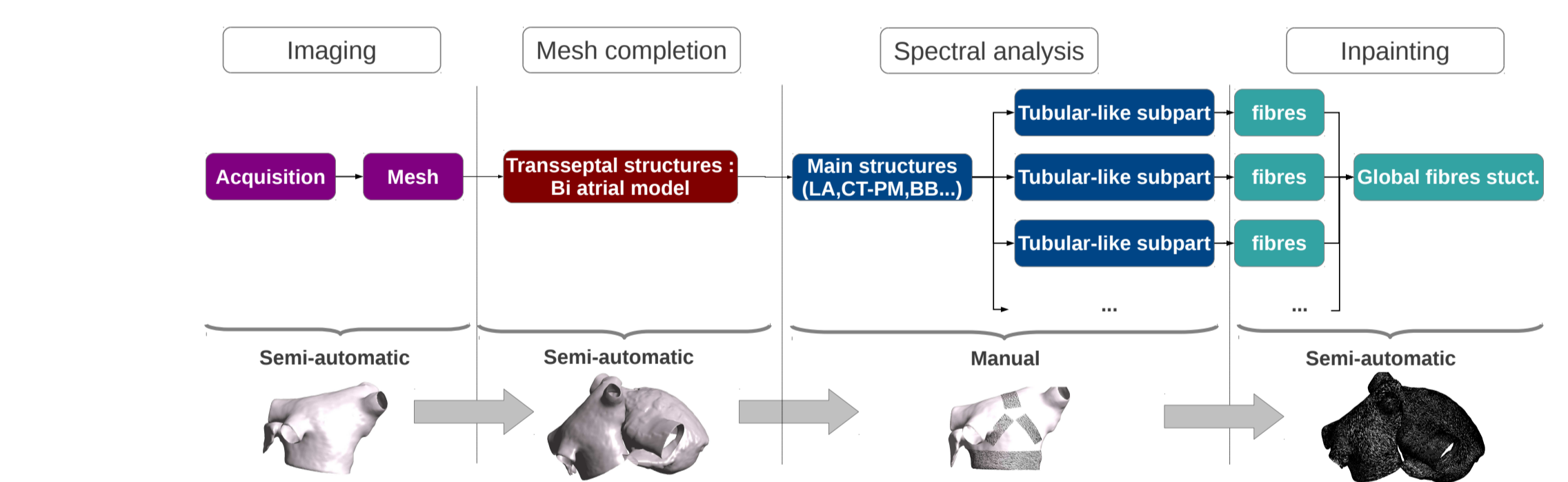
### FIBRES DISCONTINUITY

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

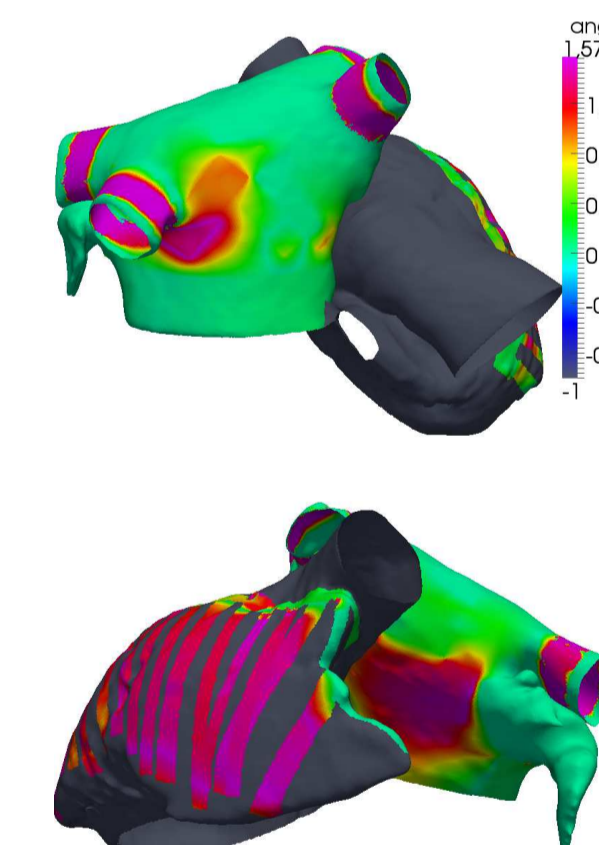


## ARRHYTHMIA PERPETUATION IN THE ATRIA

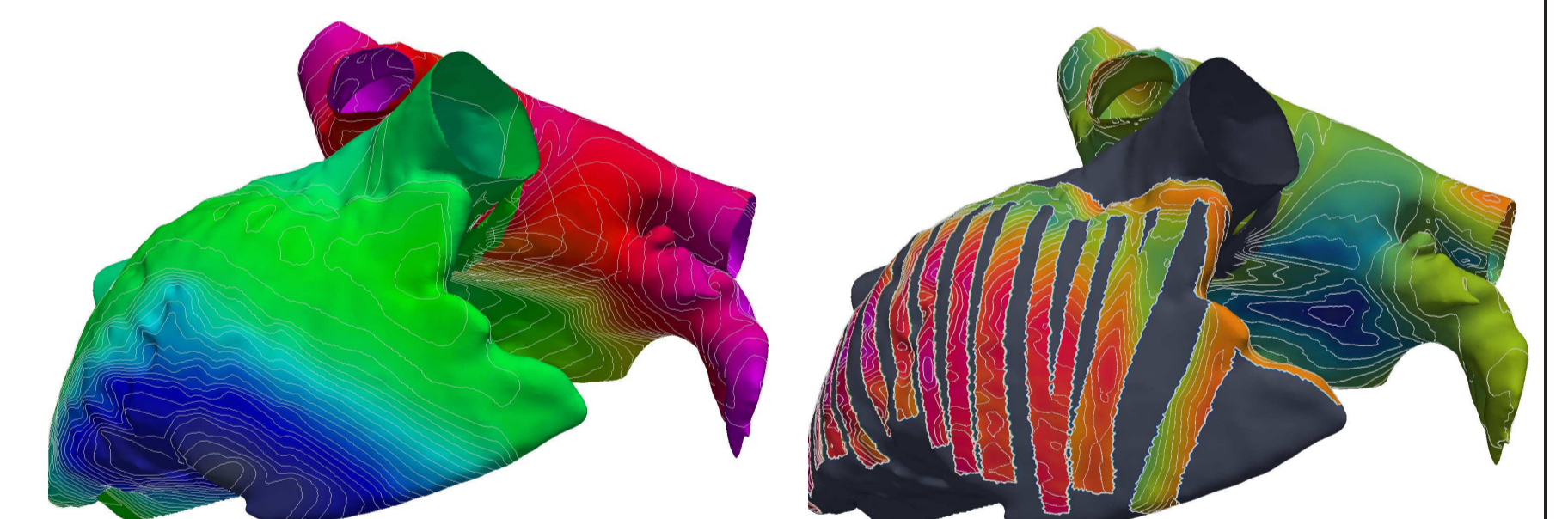
### BIATRIAL BILAYER MODEL OF HUMAN ATRIA



Angle differences

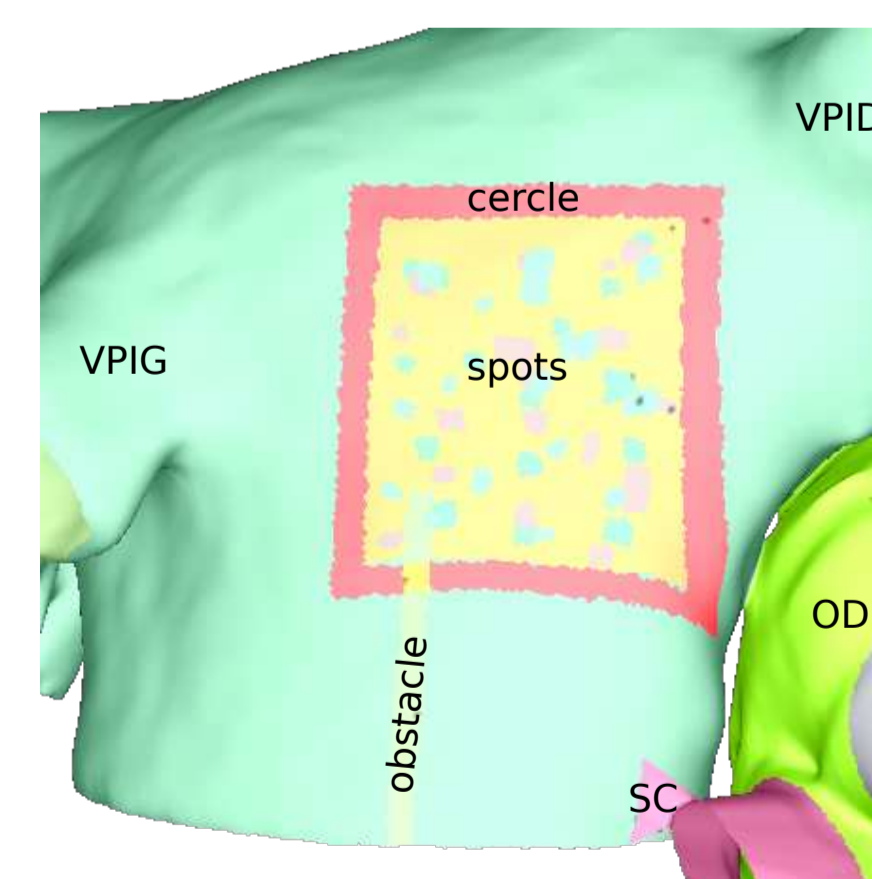


Activation times differences



Mono. vs. bilayer Endo vs epi

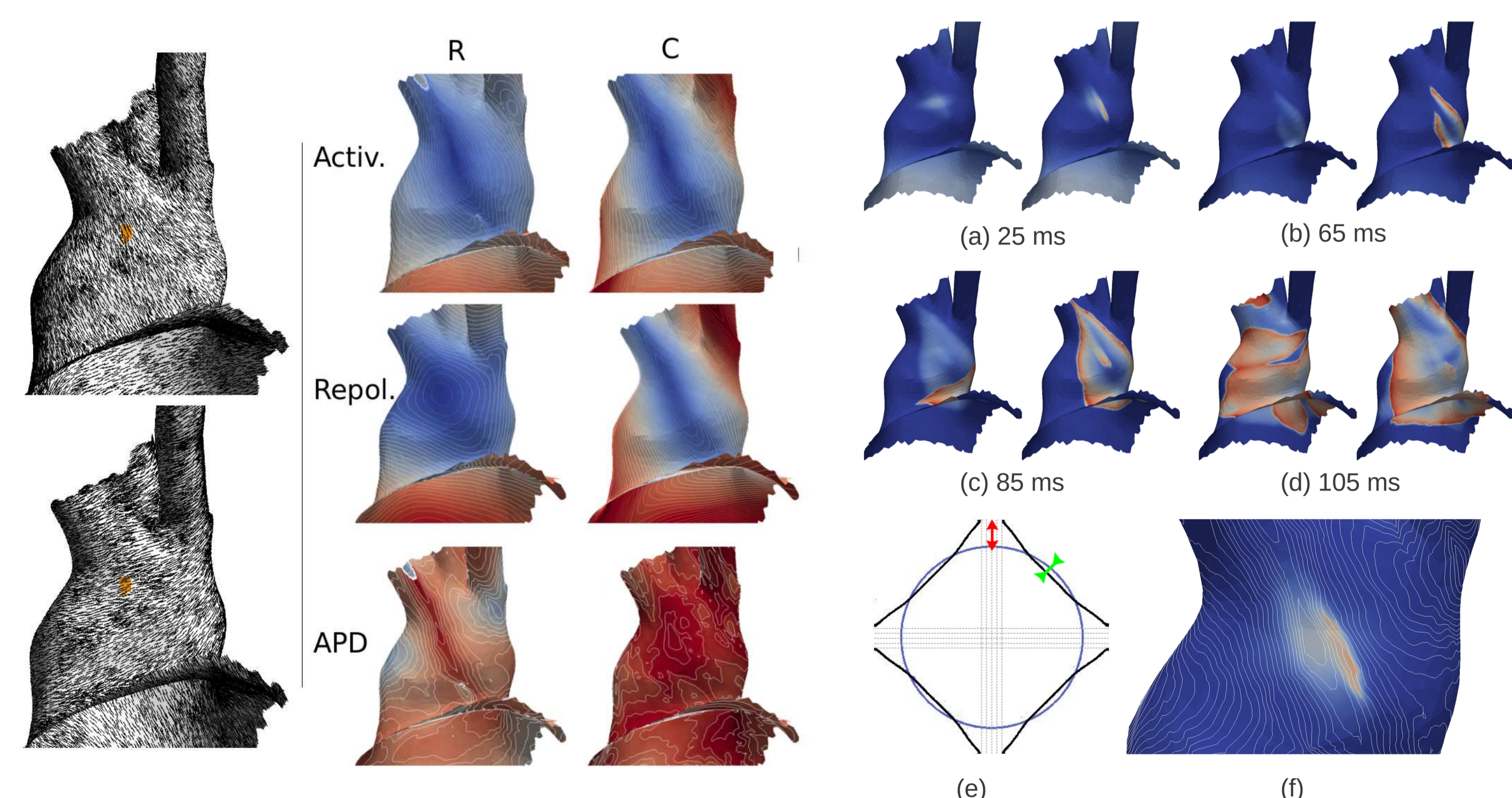
### EFFECT OF TRANSMURAL FIBROSIS AND ABLATION.



- Transmurular 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 transmurular ablation are still efficient.

### TRANSMURAL FIBRES DISCONTINUITY

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



### PERSONALIZATION

