

# Fabric-Elasticity Relationships in Cortical Bone

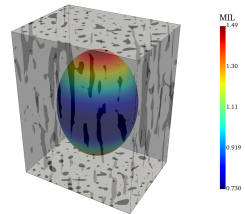
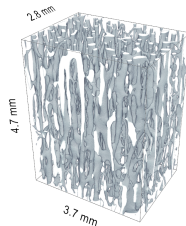
Mathieu Simon

February, 2025

# Material

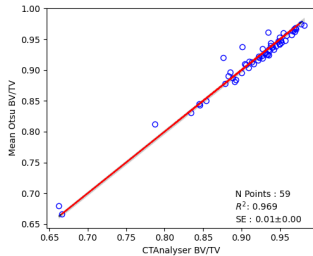
## Data

- 59 scans
- 6.5  $\mu\text{m}$  voxel size
- RUS measurements
- CTAnalyser

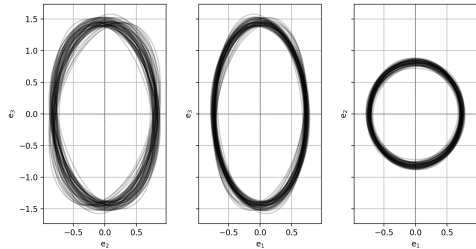


# Segmentation

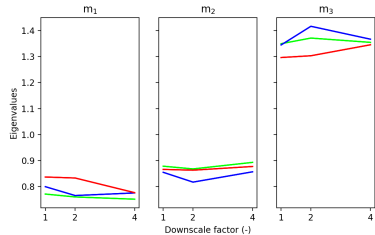
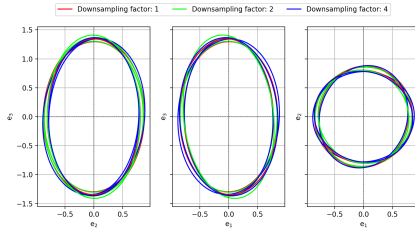
## Mean Otsu threshold



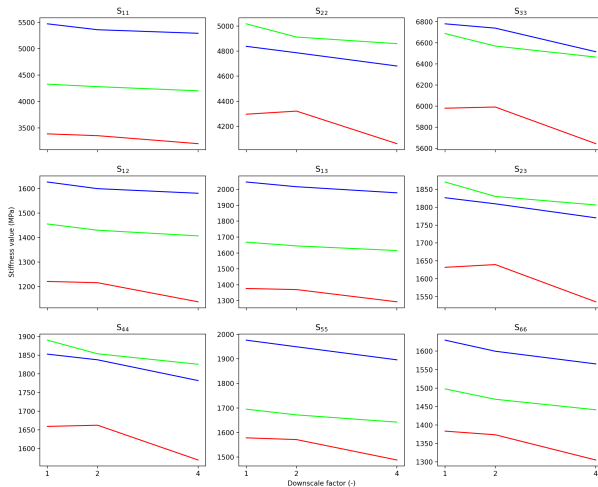
## Fabric distribution



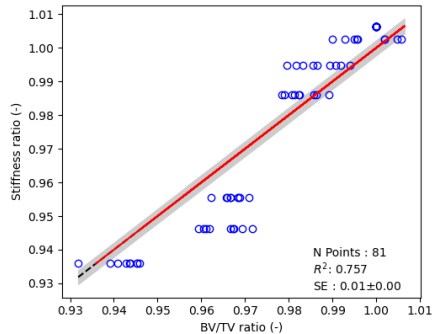
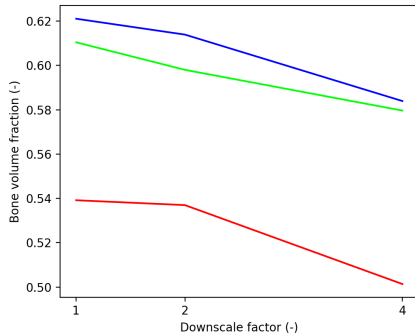
# Resolution Effect - Fabric



# Resolution Effect - Elasticity



# Resolution Effect - Elasticity II

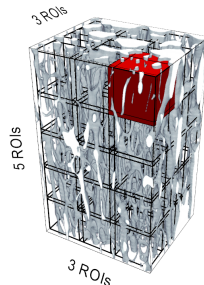


# Convergence Study

## Setup

- 1 mm ROI side length
- 3x3x5 ROIs
- 65  $\mu\text{m}$  margin
- Groups of 1, 2, ..., 45 ROIs

→  $\sim 2^{45}$  possibilities

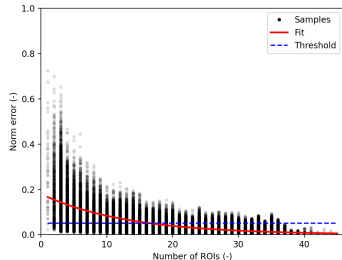


# Convergence Study

## Sampling

- Balanced clustering
  - Linear sum assignment
  - $216 \cdot 10^6$  possibilities
- N samples = 1000
- Norm Error
- Threshold = 0.05

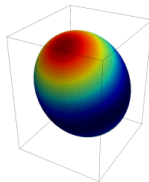
→ 15-16 ROIs





# Material Effect

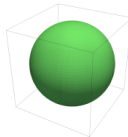
## Structure



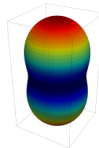
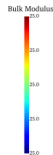
Fabric



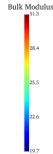
## Material



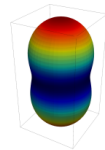
Isotropic



Transverse Isotropic



## Mechanics



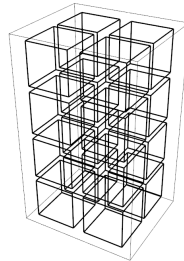
Transverse Isotropic



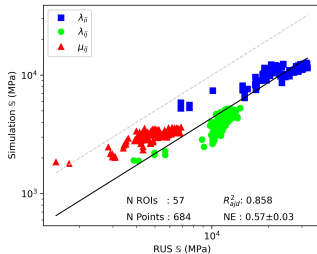
# Homogenization

## Setup

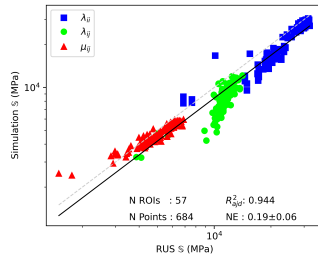
- Downsampling factor: 2
- $16 \times 1 \text{ mm}^3$  ROIs
- Isotropic vs transverse
- Mean  $\bar{S}$  / Sample



# Simulations vs RUS

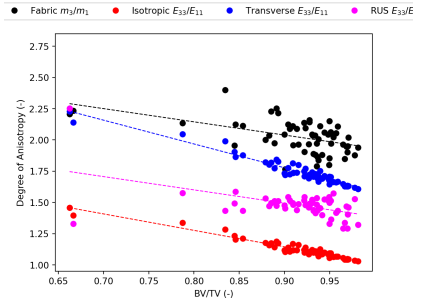
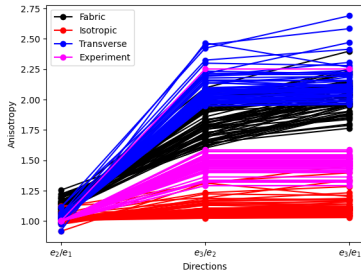


Isotropic Material

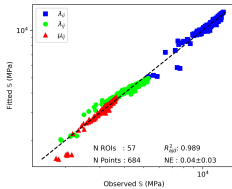


Transverse Isotropic Material

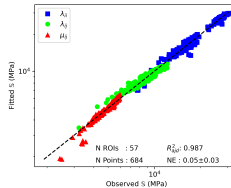
# Anisotropy



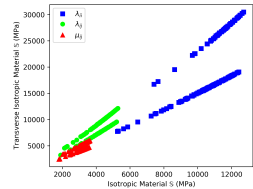
# Homogenization



Isotropic



Transverse



Comparison

# Comparison with Trabecular Bone

$$\mathbb{S}_{Ts} = \mathbb{S}_T / \|\mathbb{S}_T\| * \|\mathbb{S}_I\|$$

Study	Bone type	Resolution	$\lambda_0$	$\lambda_0'$	$\mu_0$	k	l	DA
Gross et al.	Trab.	18	4609	3692	3738	1.60	0.99	1.67
Panyasantisuk et al.	Trab.	36	3841	3076	3115	1.60	0.99	1.54
Simon et al	Trab.	61	2738	1662	2187	1.60	0.99	1.99
Present study	Cort. ( $\mathbb{S}_I$ )	13	5389	5307	4023	1.60	0.99	2.02
Present study	Cort. ( $\mathbb{S}_{Ts}$ )	13	5838	5768	3224	1.60	0.99	2.02

# Comparison $l$ Exponent

Reference: Transverse isotropic

- $S_{Is} = S_I / ||S_I|| * ||S_T||$
- $\lambda_0 = 11138$
- $\lambda_0' = 11006$
- $\mu_0 = 6152$
- $k = 2.21$

Matrix	Isotropic	Transverse
$l$	-0.02	0.31
95% CI Low	-0.09	0.24
95% CI High	0.05	0.38