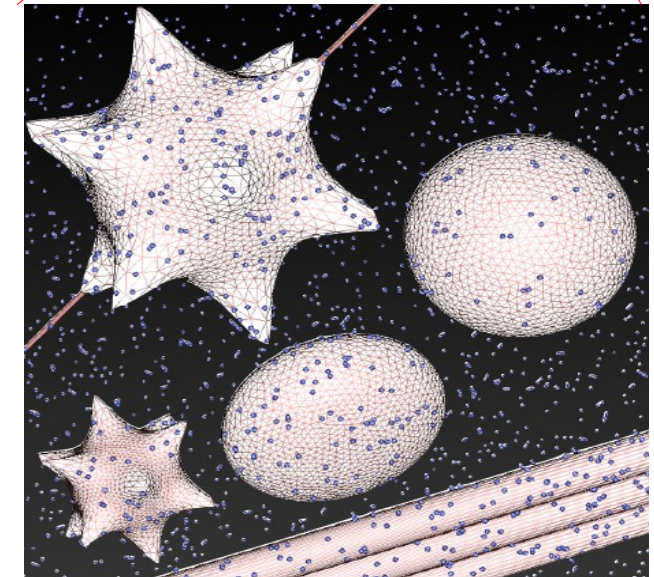
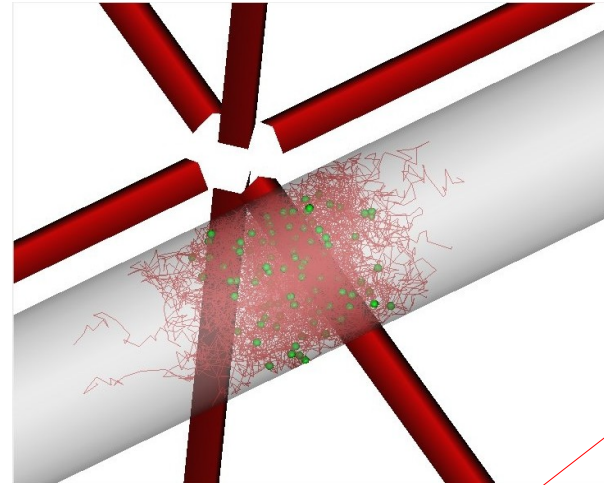
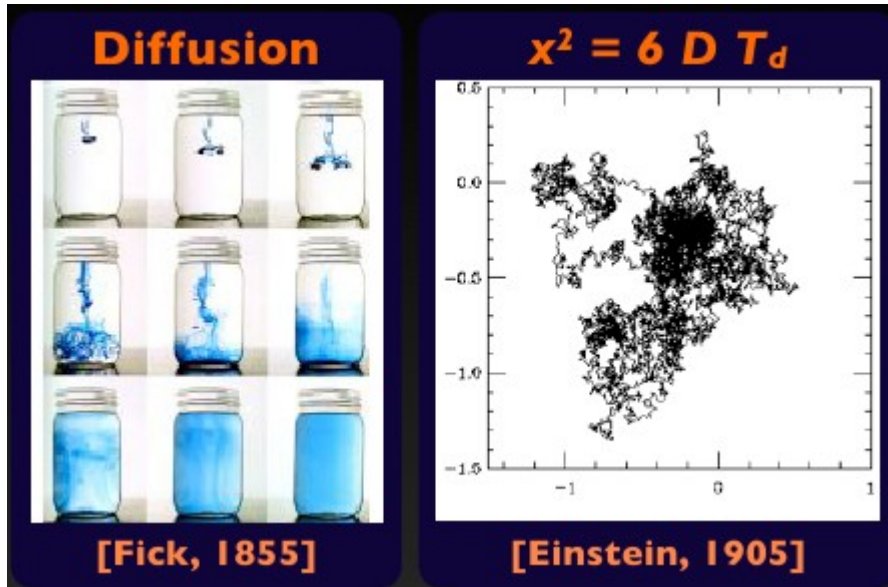


ANR COSINUS meeting
Project SIMUDMRI

Task 3 : development of a Monte-Carlo simulator
BrainVISA/Microscopist-1.0

Benoit Schmitt, Chun-Hung Yeh, Alice Lebois, Cyril Poupon
CEA I²BM NeuroSpin partner

Diffusion of water molecules in brain tissues

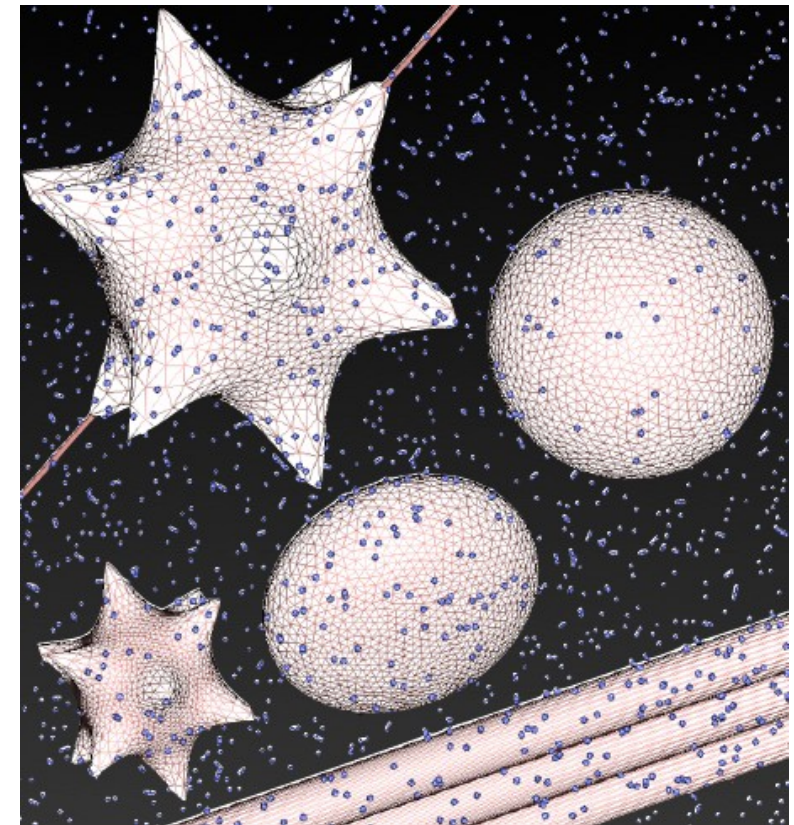
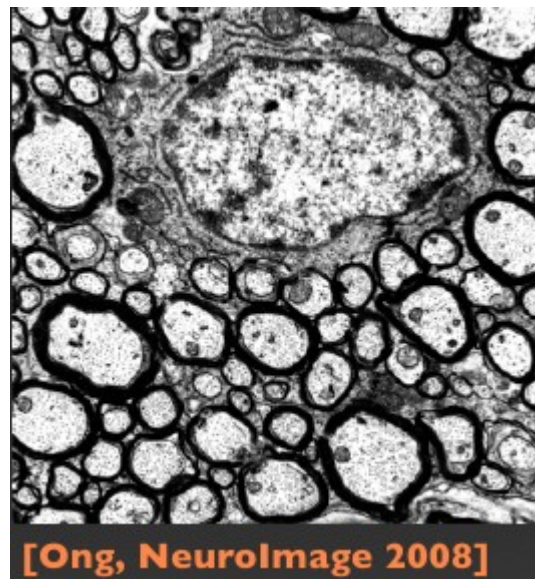
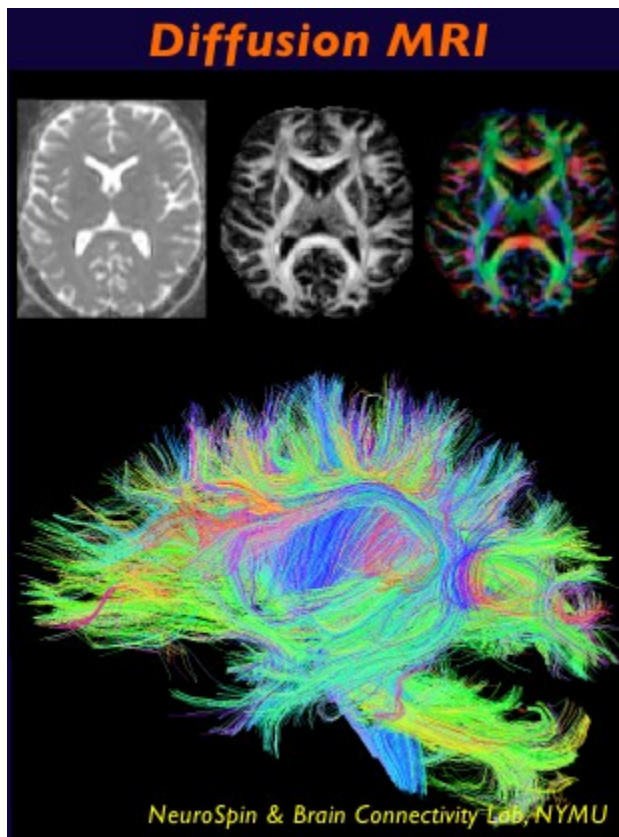


Water molecules in the brain move randomly and meet membranes that restrict and hinder their displacement.

Diffusion-weighted MRI is an imaging technique that probe this motion using magnetic resonance imaging.

The MRI signal “contains” the information about the geometry of membranes of cells at microscopic scales, and can be used reciprocally to “decode” the microscopic cytoarchitecture

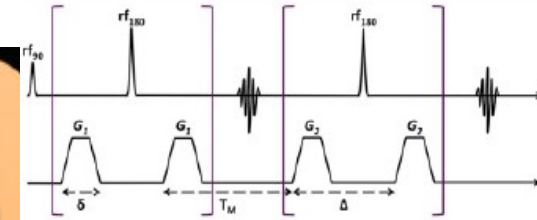
Task 3: Developing a large scale Monte-Carlo simulator of the diffusion process of water in brain



Yeh, ISMRM, 2010

Overview of the design of the simulator

[Shemesh, JMR 2009] **Double PGSE**

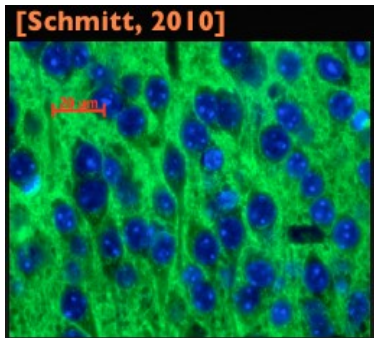


MRI physics
of pulse sequences

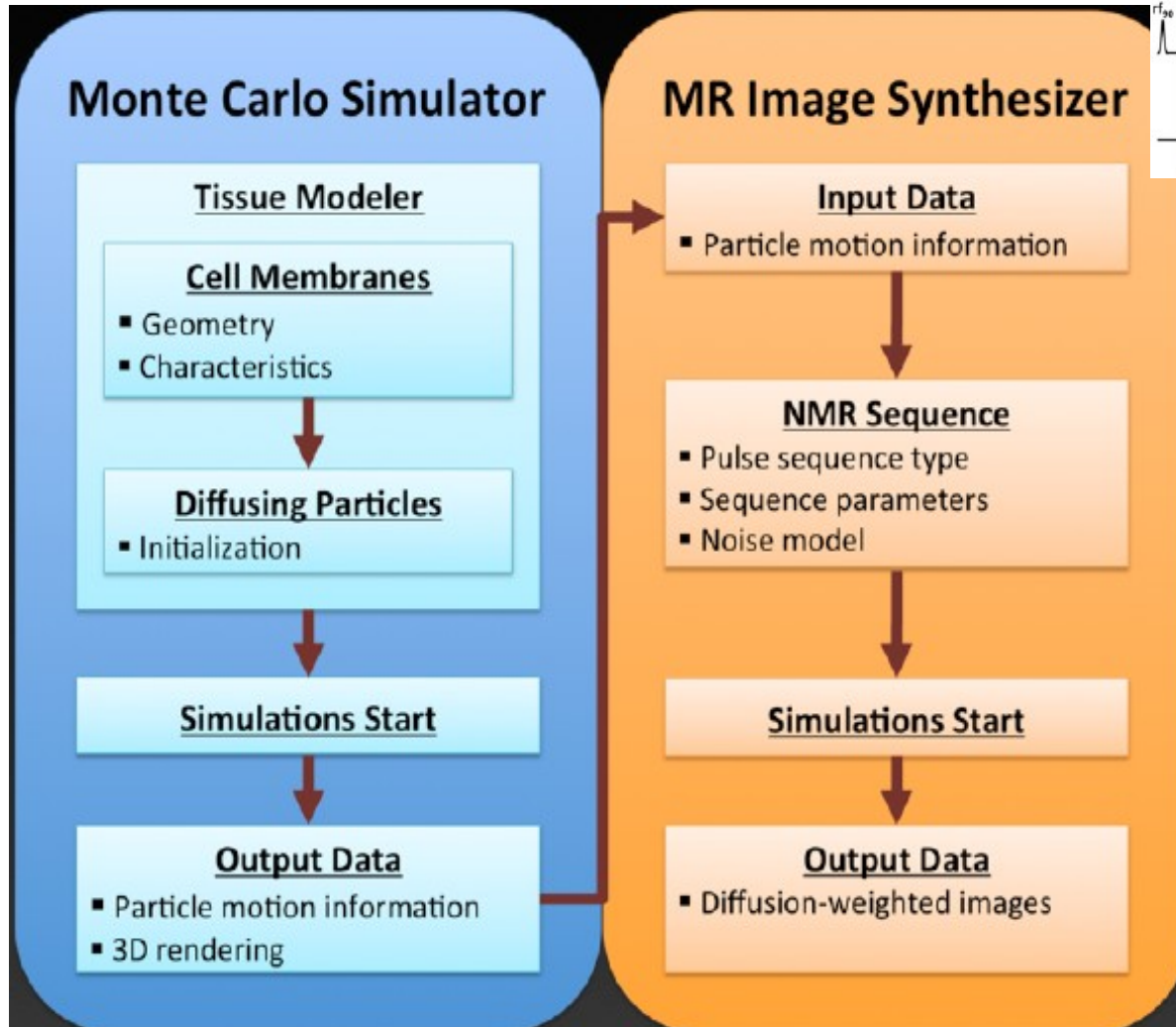
Clinical applications:
- cognitive neuroscience
- novel biomarkers of brain diseases



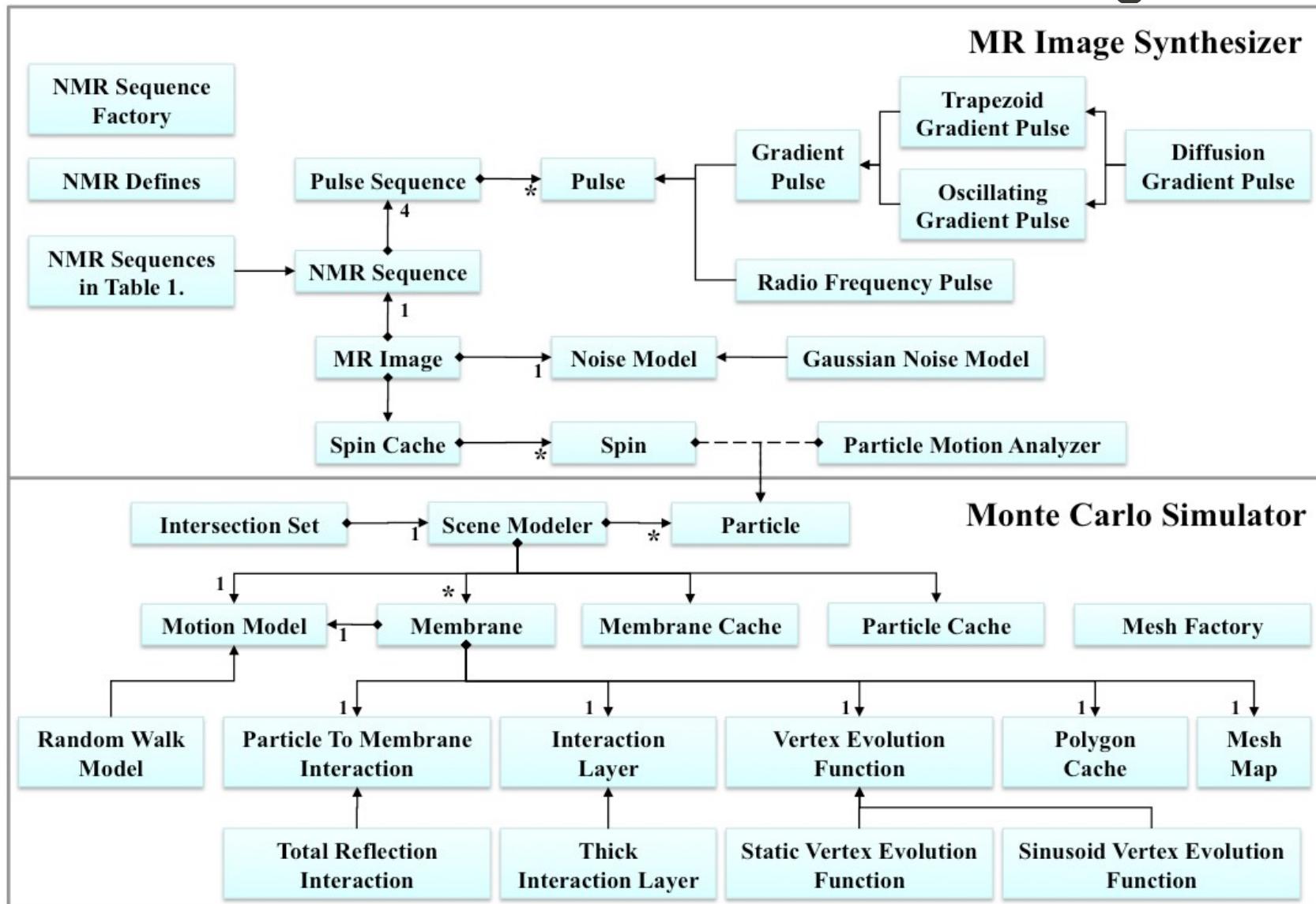
High performance
computing



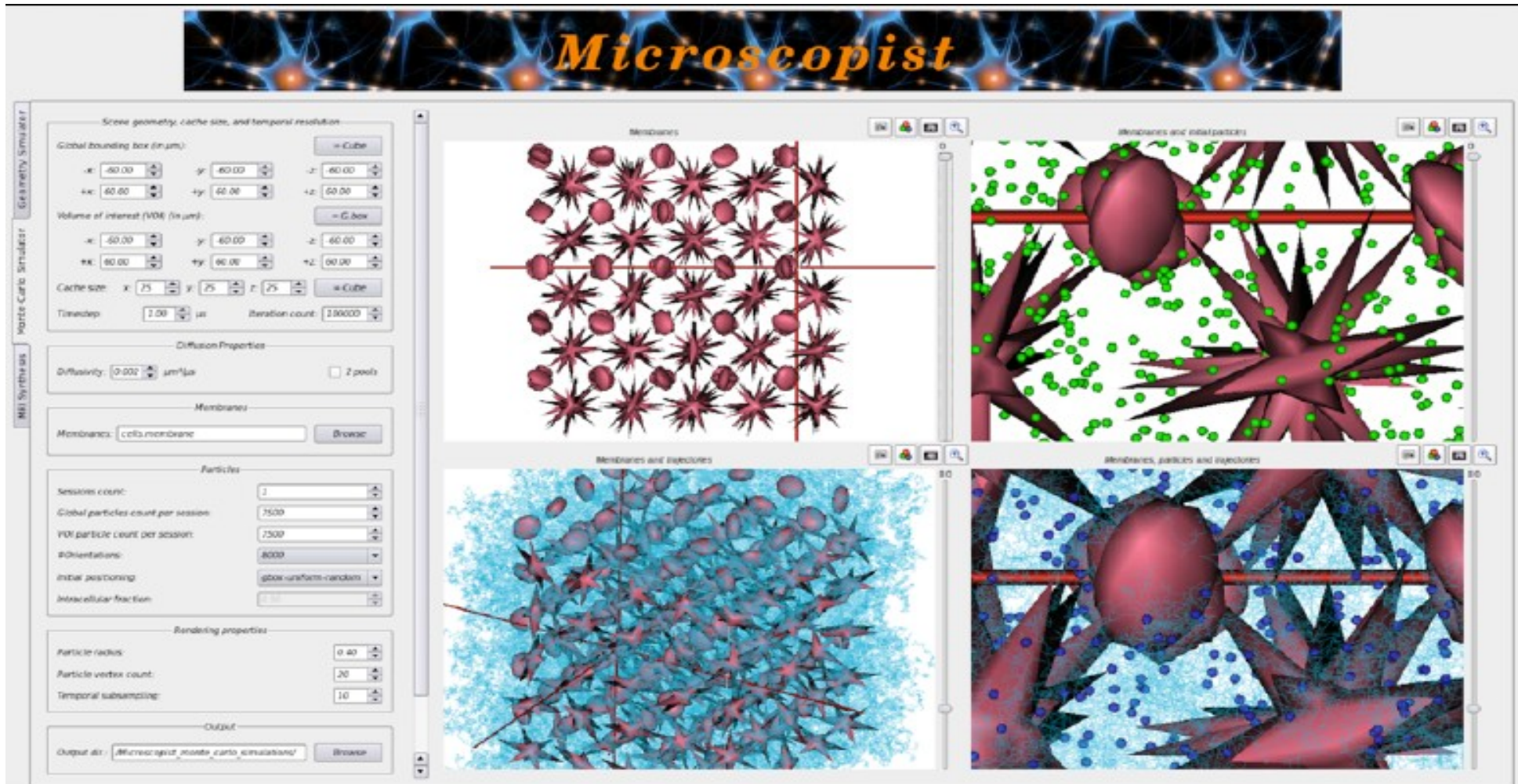
Biology of
brain tissues



Overview of the software design



BrainVISA/Microscopist-1.0 (released in january 2012)

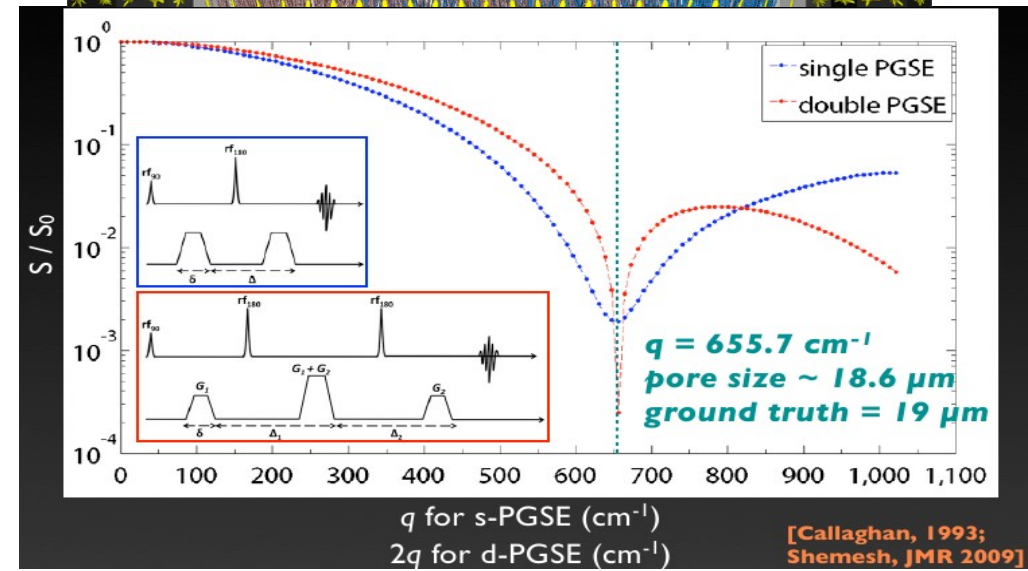
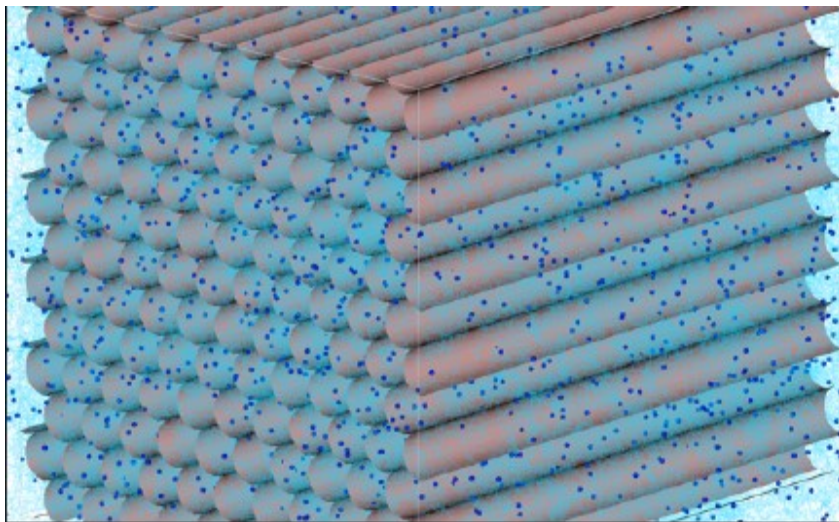
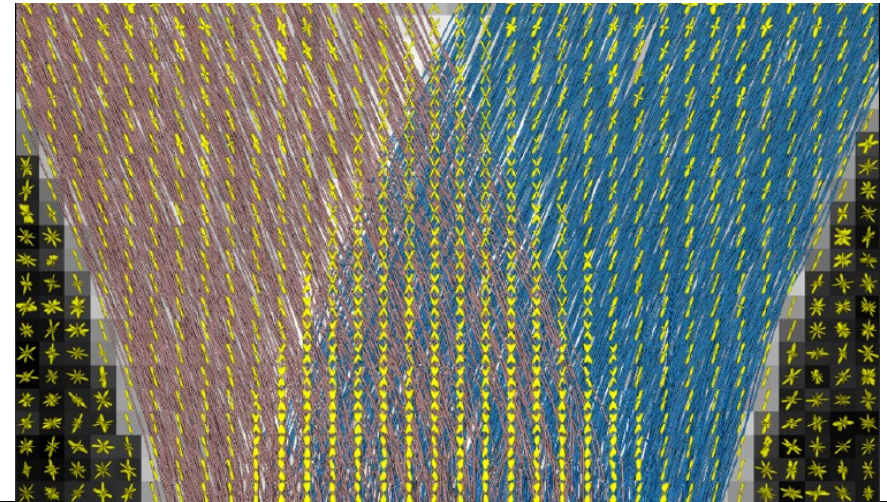
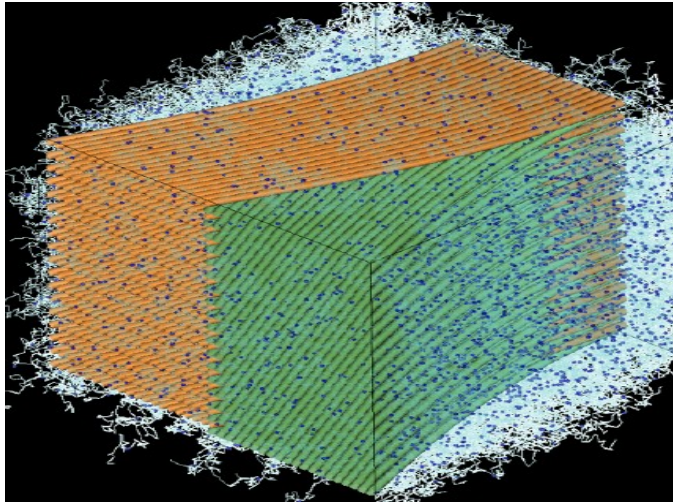
BrainVISA (brainvisa.info)

[Schmitt, 2010; Yeh, ISMRM 2010]

Can mimic any tissue environment and synthesise diffusion MRI data in accordance

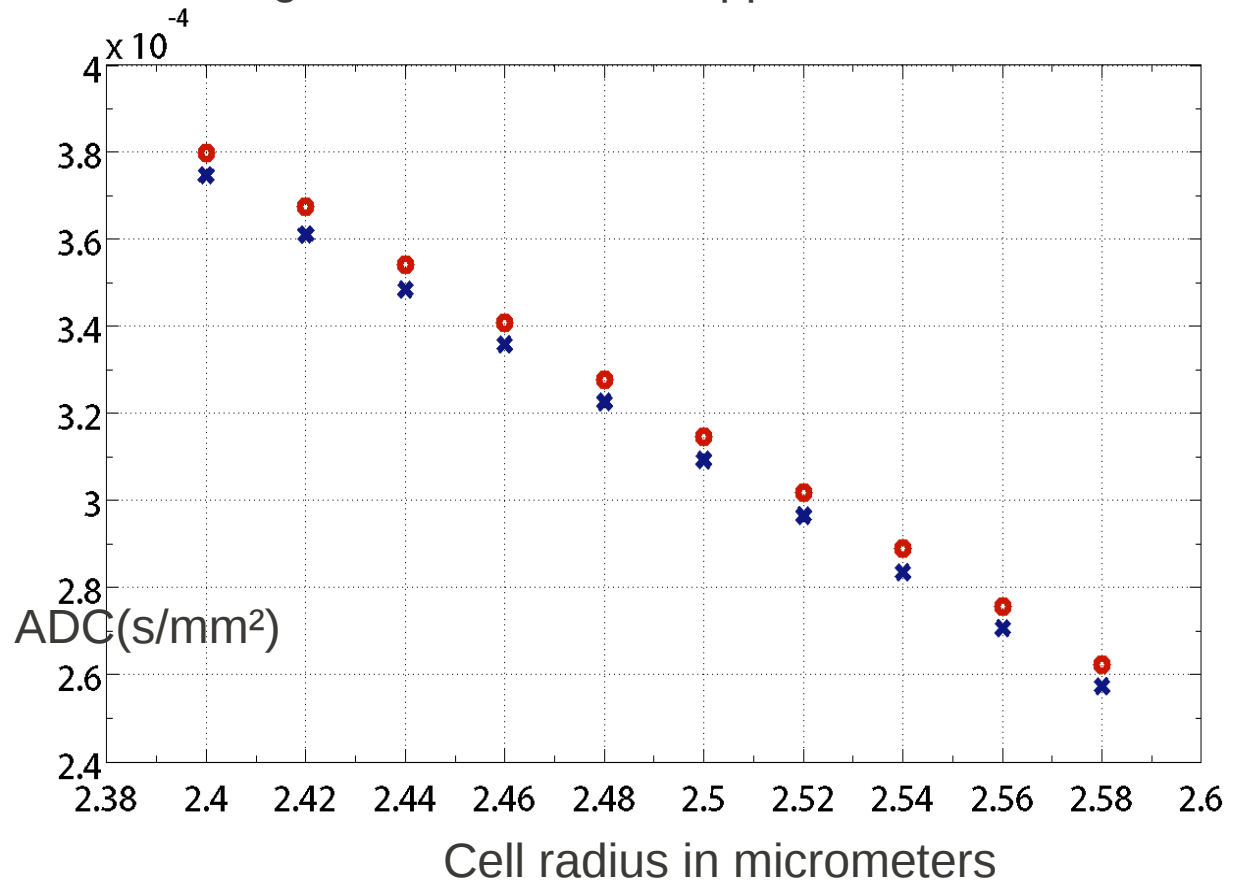
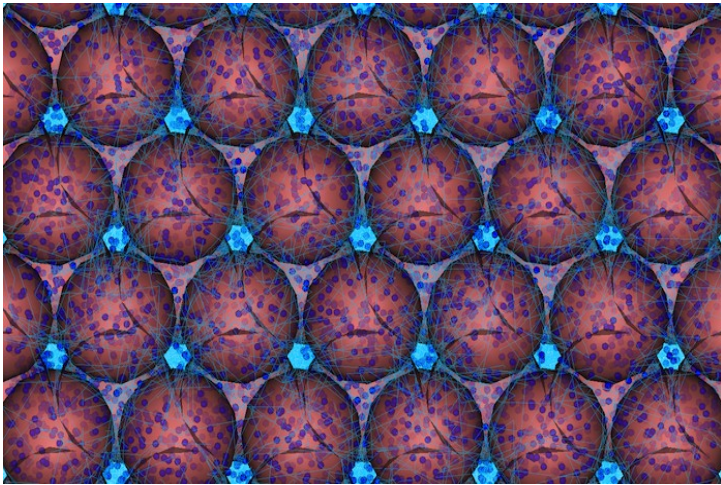
Applications of the BrainVISA/Microscopist

- Validation of benchmark experiments (multiple scattering, tractography, ...)



Applications of the BrainVISA/Microscopist

- Demonstration of cell swelling effects leading to increase of the apparent diffusion coefficient (ADC)



Swelling of cells causes a decrease of the apparent diffusion coefficient.

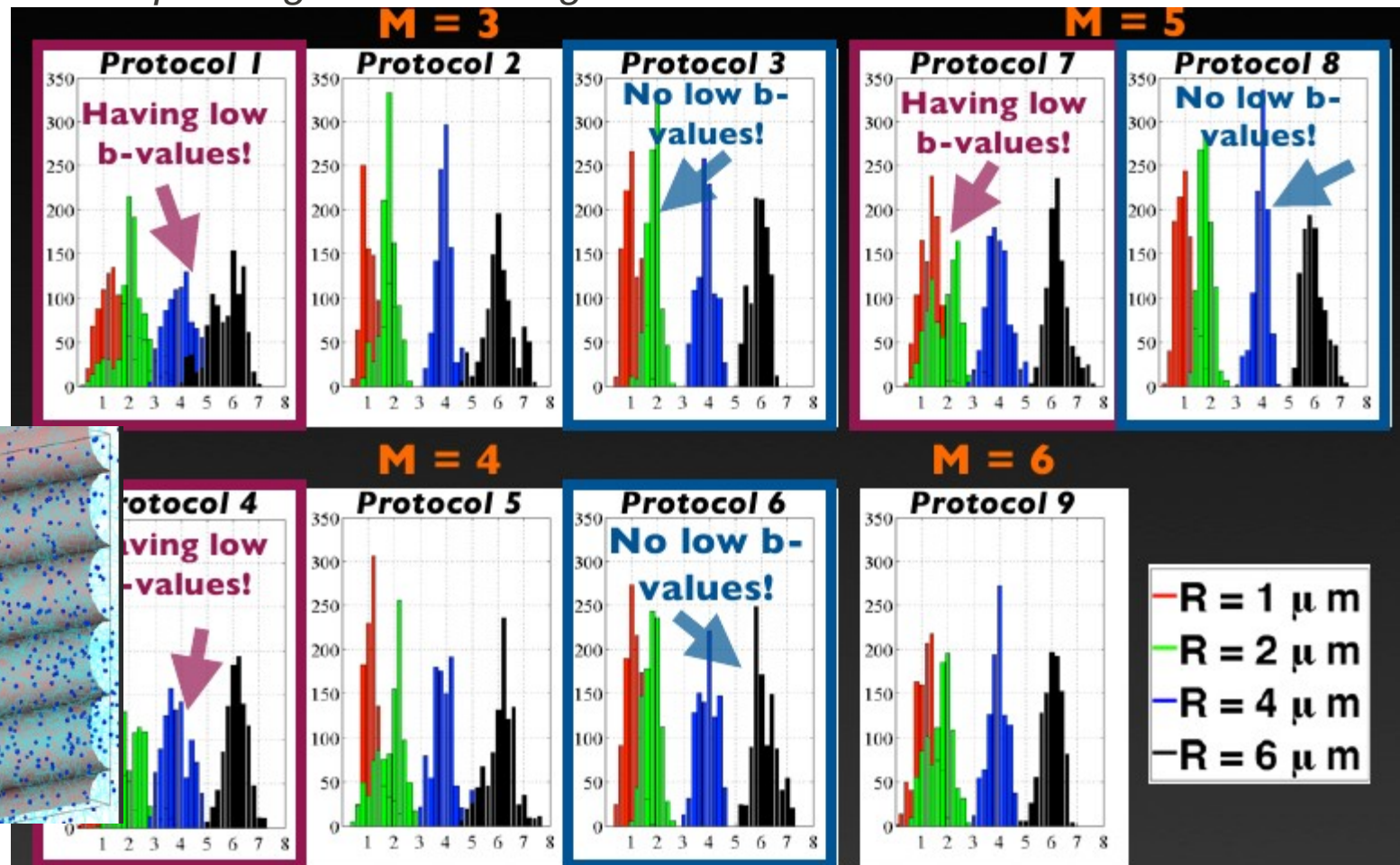
That is counter-intuitive, but was effectively observed in ischemia.

This result suggest that the decrease is linked to an increase of the slow pool of water molecules within a layer close to cell membranes.

Applications of the BrainVISA/Microscopist

- Optimization of MRI protocols for fiber radii estimates using Active Imaging

simulation of a white matter tissue made up of a distribution of axons of radius 1/2/4/6 μm and simulation of the corresponding diffusion-weighted MRI data



Publications

Full papers :

- Yeh CH, Le Bihan D., Li J.-R., Mangin J.-F., Lin C.-P., Poupon C., Monte-Carlo simulation software dedicated to diffusion-weighted MR experiments in neural media. (submitted to NeuroImage)
- Yeh CH, Kezele I., Schmitt B., Li J.-R., Le Bihan D., Lin C.-P., Poupon C., Evaluation of fiber radius mapping using diffusion MRI under clinical system constraints. (submitted to Magnetic Resonance Imaging)

Conference abstracts:

- Yeh CH, Tournier J.-D., Cho K.-H., Poupon C., Lin C.-P., Evaluation of angular uncertainties of q-space diffusion MRI under finite gradient pulse widths : a phantom study. Proc ISMRM 2009, p. 3550.
- Yeh CH, Le Bihan D, Li JR, Mangin JF, Lin CP, Poupon C. Monte-Carlo simulation software dedicated to diffusion weighted MR experiments in neural media. In proceedings 16th HBM, 2010 (Barcelone, Espagne)
- Yeh CH, Le Bihan D, Li JR, Mangin JF, Lin CP, Poupon C. Monte-Carlo simulation software dedicated to diffusion weighted MR experiments in neural media. In Proceedings ISMRM 2010 (Stockholm, Suede), abstract number 5762.
- Yeh CH, Kezele I, Alexander D, Schmitt B, Li JR, Le Bihan D, Lin CP, Poupon C. Evaluation of fiber radius mapping using diffusion MRI under clinical system constraints". In 19th ISMRM, Montreal, Canada, 2011, abstract number 2017

Work in progress and future work

- Incorporating the novel models of Task 1&2 into BrainVISA/Microscopist to create a faster hybrid large scale simulator = Task 4 to be started in the coming weeks
 - Development of a novel Arbitrary-shaped gradient Spin Echo (ASE) pulse sequence @7T (thesis of Alice Lebois)
 - sequence development achieved (2012/T1)
 - preliminary tests using hardware white matter phantoms to be started (2012/T2)
 - grey matter modeling under ASE sequence assumption in progress (2012/T3)
 - validation on human subjects scheduled in 2012/T3
 - Extraction of true membrane geometries from brain samples using optical microscopy in progress (thesis of Benoît Schmitt) in order to incorporate true membrane geometry in BrainVISA/Microscopist
 - Ancillar project not part of SIMUDMRI : undergoing discussions with the Synchrotron Soleil facility to perform direct 3D imaging of brain tissue samples
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