Alexandra Vallet

Postdoctoral researcher
Four years of postdoctoral research experience
Three years of semi-industrial experience
33 years old
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I am a multi-disciplinary researcher with a deep background in fluid dynamics, solid mechanics and neuroscience. I believe that fundamental laws of physics and mathematical models will provide breakthroughs in our understanding and management of dementia in the same way as it transformed other fields, such as meteorology or aerospace, decades ago.

I studied fluid and solid mechanics in a graduate engineering school and obtained a PhD in radiative-hydrodynamics [2-6]. I worked in a semi industrial context as the principal investigator for experimental campaigns on the Megajoule Laser facility (permanent position at the CEA - France). I coordinated work from several teams and used complex multi-physics, multi-code simulations to both design and interpret experiments reproducing 'mini stars' in the laboratory.

A fruitful encounter with neurosurgeon Eric Schmidt convinced me that current mathematical modelling capabilities, combined with existing neuroimaging technologies, provide an unprecedented opportunity to better understand brain ageing. Since 2018, I have developed several modelling tools to predict fluid dynamics, porous medium deformation, fluid-poroelastic structure interaction and transport in the brain. I demonstrated the potential of my transdisciplinary approach [7-8] and I am now building a research project about the mechanical determinants of brain ageing.

Field of expertise

Biomechanics, fluid and solid mechanics, fluid-poroelastic structure interaction, particle transport, computational modelling, mathematical modelling, clinical/experimental data processing, data science, brain ageing

Education - Diploma

20/11/2014 **PhD, CELIA UMR 5107, University of Bordeaux**
"Hydrodynamic modelling of the shock ignition scheme for inertial confinement fusion"
Inertial confinement fusion is a way to reproduce fusion reactions (the origin of the energy unleashed by the sun and stars) in a laboratory. A pellet target is compressed and heated with high-energy beams of laser light until the needed extreme conditions of stellar interiors are reached. This PhD study investigates theoretically and experimentally how to get ignition with a converging shock wave. [2-5]
Advisors: V. Tikhonchuk, X. Ribeyre

27/10/2011 **Master of Science in Mechanics and Engineering with a speciality in fluid mechanics, University of Lille – First rank.** My grade score was 16.622/20 which is equivalent to grade A in US system *.

28/09/2011 **Diploma in Engineering, École des Mines de Douai with a speciality in solid mechanics– First rank.** My average grade over the four years was 16.22/20 which is equivalent to grade A in US system*.

* *WES Grade Conversion Guide". World Education Services. Retrieved 2012-09-03*

Professional experience

01/09/2022-present	**Department of mathematics, University of Oslo** *Researcher - short contract*, Oslo (Norway). Analysis of dispersion effect in the brain.
01/09/2020 – 31/08/2022	**Department of mathematics, University of Oslo** *RCN-funded post-doctoral fellowship (PI K. A. Mardal)*, Oslo (Norway). Modelling of fluid flow and mass transport in the brain seen as a poroelastic medium (1D and 3D modelling, fluid-poroelastic structure interaction). Computational modelling using FEniCS (finite elements) and OpenFOAM (finite volumes). Analysis of in-vivo data from patients and mice **[10]**.
25/02/2019 – 24/02/2020	**CNRS UMR 5502 IMFT** *ERC-funded post-doctoral fellowship (PI S. Lorthois)*, Toulouse (France). Analysis of the coupling between the vascular system and the cerebrospinal fluid at the mesoscale level with a network modelling approach (finite volumes).
13/12/2017 – 12/12/2018	**INSERM UMR 1214 ToNIC** *Post-doctoral research funded by the region Occitanie*, Toulouse (France). An exploratory study about the altered biomechanical properties of the central nervous system in pathological brain ageing **[7-9]**.
10/12/2014 – 12/12/2017	**CEA** *Research engineer - semi-industrial*, Paris (France). Radiative-hydrodynamics theory and simulation, design and interpretation of high energy density physics experiments on the Megajoule Laser facility. *Confidential work*
20/02/2013 – 20/05/2013	**LLE** *Long term mission*, Rochester (New-York State, USA). Study of strong spherical shock pressure generation, design and interpretation of experiments on the OMEGA laser facility **[3 - 5].**
01/05/2011 – 30/09/2011	**CEA** *Internship*, Paris (France). Instabilities seeded by surface roughness in self-similar ablation flow in inertial confinement fusion **[6].**
14/06/2010 – 25/03/2011	**INSERM U703 / École Centrale de Lille LML-UMR 8107** *Project in parallel with my studies*, Lille (France). Finite elements quasi-static model of pelvic mobility using ABAQUS **[1].**

Supervising and mentoring activities

20/06/2021 – 31/07/2021	**Supervising Anders Bredesen Hatlelid, MSc student.** Short master internship about time series analysis, measuring the Granger causality between arterial pressure and intracranial pressure.
01/09/2020 – present	**Co-supervising Sophie Guillotin, PhD student.** PhD in pharmaceutical sector : analysis of the biological processes involved in frailty **[9].**
01/03/2021 – 05/08/2021	**Supervising Alice Hamon, MSc student.** Master internship about the "Heart rate variability associated to the coupling between blood pressure and intracranial cerebrospinal fluid pressure"
04/03/2019 – 03/08/2019	**Supervising Jose Ramon Camacho Bosca, MSc student**. Master internship about the "Transport in deformation porous medium : application cerebral perivascular spaces"
01/09/2019 – present	**Mentoring activities** as part of the action of the "Femmes & Sciences" association aiming at promoting sciences for women

Committees

Doctoral progress committee – *Doctoral school « ASTRONOMIE & ASTROPHYSIQUE D'ILE-DE-FRANCE » PhD student L. Van Box Som, (LERMA - CEA)* – 2017

Funding of my research

- **Alzheimer's physics project Fellowship,** Funded by the Norwegian Research Council (NRC grant agreement, FRIPRO, 12 MNOK), PI K.A. Mardal, Norway, September 2020-August 2022
- **BrainMicroFlow Fellowship,** Funded by the European Research Council (ERC grant agreement n°615102), PI S. Lorthois, France, February 2019 - February 2020
- **FluidBrain Fellowship,** Funded by the Occitania Region (RPBIO 2015 n°14054344), PI E. Schmidt, France, December 2017 – December 2018
- **CEA PhD grant**, CEA - CELIA – Université de Bordeaux, France, October 2011 – October 2014

Prizes and Awards

2014 European Physical Society best poster award
2013 Fusion Science Center Award for Excellence in Poster Presentation
2011 Oscar Waquet award 2500 euros (First rank student at EMD school)
2010 Merit award (4000 euros) for my study in biomechanics (INSERM, EC Lille)

Referee for

- Fluids and Barriers of the CNS journal
- Brain Multiphysics journal
- Biomechanics and Modelling in Mechanobiology (BMMB)

Outreach activities

Project leader for the European Researchers' Night 2019, Quai des Savoirs, Toulouse : "The mysterious crime of Mr. Brain". Game activity about the physical approach of neurodegenerative diseases.
See blog article: http://alexandra-vallet.eu/index.php/2019/09/24/researcher-night-2019/

Organisation of conferences and symposia

Organisation

Teaching Experiences (>80h)

2019 -2022 **ISAE-SUPAERO (FR)**, Biomechanics, Lecture.
The main objective of the module is to show the link between engineering science methodologies and living organisms. My course focuses on mechanics of biological tissues, fluid dynamics of blood, coupled problems, transport by advection-diffusion. (level: master)

2015 **The University of Oxford (UK)**, Spherical shock wave - self-similar solutions, Lecture.
In this course, I demonstrate the analysis of converging shock waves in an ideal compressible gas via Lie group theory. I introduce the general framework of Lie group of transformations used to determine the whole range of self-similar solutions to a problem involving spherical strong converging shocks. I show how this method provides useful scaling laws to interpret experiments and numerical simulations. (level: PhD)

2013 **The University of Bordeaux**, Fluid mechanics, Practical works.
Those practical works were aimed at first-year biology undergraduates. They introduce the fundamental notions of fluid mechanics and mass transport essential to tackle a biology course

at the undergraduate level. In particular, the experiments dealt with the following concepts: rheology, concentration, diffusion, hydrostatics. (level: bachelor)

2012 - 2013 **The University of Technology of Bordeaux**, Fluid mechanics, Tutorials/Practical works
The module provides the knowledge and technical skills necessary to carry out measurements in various sectors: automotive, aeronautics, space, electronics, optic, research. My tutorials and practical works focused on the notion of pressure, hydrostatics, Archimedes principle, Bernoulli equation, viscosity, laminar and turbulent flows and vacuum techniques. (level : bachelor)

Peer-reviewed journal publications

[9] Homocysteinemia is Associated with Frailty and Biomechanical Response of the CNS in NPH-suspected Patients, S. Guillotin, **A. Vallet**, S. Lorthois, P. Cestac, E. Schmidt, N. Delcourt, - Journal of Gerontology: Biological Sciences glac074- 2022

[8] Assessment of Pressure-Volume Index During Lumbar Infusion Study: What Is the Optimal Method? **A. Vallet**, L. Gergelé, E. Jouanneau, E. A Schmidt, R. Manet. Acta neurochirurgica. Supplement, Vol 131, P 335-338. 2021

[7] Biomechanical response of the CNS is associated with frailty in NPH-suspected patients. **A Vallet**, N Del Campo, E Hoogendijk, A Lokossou, O Baledent, Z Czosnyka, L Balardy, P Payoux, P Swider, S Lorthois, and E Schmidt. Journal of Neurology – 2020

Between 2015 – 2017 : confidential reports at the CEA, please contact Emeric Falize as reference

[6] Transient effects in unstable ablation fronts and mixing layers in HEDP. J-M Clarisse, S Gauthier, L Dastugue, **A Vallet** and N Schneider. Physica Scripta – Volume 91 – Issue 7 – Pages 074005. 2016

[5] Physics of laser-plasma interaction for shock ignition of fusion reactions. VT Tikhonchuk, A Colaïtis, **A Vallet**, E Llor Aisa, G Duchateau, Ph Nicolaï, X Ribeyre. Plasma Physics and Controlled Fusion – Volume 59 – Issue 1 – Pages 014018 . 2015

[4] Spherical strong-shock generation for shock-ignition inertial fusion. W Theobald, R Nora, W Seka, M Lafon, KS Anderson, M Hohenberger, FJ Marshall, DT Michel, AA Solodov, C Stoeckl, DH Edgell, B Yaakobi, A Casner, C Reverdin, X Ribeyre, A Shvydky, **A Vallet**, J Peebles, FN Beg, MS Wei, R Betti. Physics of Plasmas – Volume 22 – Issue 5 – Pages 056310 . 2015

[3] Gigabar spherical shock generation on the OMEGA laser. R Nora, W Theobald, R Betti, FJ Marshall, DT Michel, W Seka, B Yaakobi, M Lafon, C Stoeckl, J Delettrez, AA Solodov, A Casner, C Reverdin, X Ribeyre, **A Vallet**, J Peebles, FN Beg, MS Wei. Physical review letters – Volume 114 – Issue 4 – Pages 045001, 2013

[2] Finite Mach number spherical shock wave, application to shock ignition. **A Vallet**, X Ribeyre, V Tikhonchuk. Physics of Plasmas – Vol 20 – Issue 8 – Pages 082702 . 2013

[1] Simulation of normal pelvic mobilities in building an MRI-validated biomechanical model. Michel Cosson, C Rubod, **A Vallet**, JF Witz, P Dubois, M Brieu. International urogynecology journal – Volume 24 – Issue 1 – Pages 105-112 . 2013

Publications under review

[10] Sleep cycle-dependent vascular dynamics enhance perivascular cerebrospinal fluid flow and solute transport - L. Bojarskaite*, **A. Vallet***, D. Bjørnstad*, K.M.G. Binder, C. Cunen, K. Heuser, M. Kuchta, K. Mardal, R. Enger– *under revision for* Nature Communication. ** equally contributed first authors.*

preprint : *https://doi.org/10.1101/2022.07.14.500017*

Publications in preparation

[11] Can sleep architecture affect brain clearance ? A fluid-poroelastic modelling analysis. **A. Vallet,** M. Kuchta, L. Bojarskaite, D. Bjørnstad, R. Enger, K. Mardal **–** *Submission planned by November2022.*

[12] Reduced model of advection-diffusion transport in a pulsating flow through a network of deformable channels. **A. Vallet**, T. Koch, K. Mardal – *Submission planned by December 2022*

[13] Biological and mechanical signature of CSF outflow impairment. **A. Vallet,** S. Guillotin, N. Delcourt S. Lorthois E. Schmidt – *Submission planned by December 2022.*

[14] Brain compliance : clarification of theory and clinical applications –**A. Vallet**, A. Kazimierska, A. Ziolkowski, E. Schmidt, M. Kasprowicz, R. Manet- *Review paper. Submission planned by November 2022.*

Communications for international congresses

[c-7] Can sleep architecture affect brain clearance? **A. Vallet**, L. Bojarskaite, D. Bjornstad, M. Kuchta, R. Enger, K. Mardal, Journal of Cerebral Blood Flow and Metabolism 42, 287-288. 2022

[c-6] Intracranial fluids dynamics alterations and cortical thickness. **A Vallet**, N Del Campo, E Hoogendijk, A Lokossou, O Baledent, Z Czosnyka, L Balardy, P Payoux, P Swider, S Lorthois, and E Schmidt. Journal of Cerebral Blood Flow and Metabolism 39, 507-507, 2019

[c-5] Hot-Electron and Strong-Shock Generation at Shock-Ignition-Relevant Laser Intensities. W Theobald, R Betti, R Nora, W Seka, M Lafon, DT Michel, C Stoeckl, A Casner, J Peebles, FN Beg, X Ribeyre, **A Vallet**, MS Wei. APS Meeting Abstracts . 2015

[c-4] Shock Ignition Theoretical Studies: From Hot Electrons Pressure Generation To Converging Amplification Effects. X. Ribeyre, E. Llor, **A. Vallet**, P. Nicolai, V. Tikhonchuk. APS Meeting Abstracts – 2014

[c-3] Demonstration of 200-Mbar ablation pressure for shock ignition. W Theobald, R Nora, M Lafon, KS Anderson, JR Davies, M Hohenberger, TC Sangster, W Seka, AA Solodov, C Stoeckl, B Yaakobi, R Betti, A Casner, C Reverdin, X Ribeyre, **A Vallet**. Bulletin of the American Physical Society – Volume 58 – Pages 16 . 2013

[c-2] Analytical criterion for shock ignition of fusion reaction in hot spot. X Ribeyre, VT Tikhonchuk, J Breil, M Lafon, **A Vallet**, E Le Bel. EPJ Web of Conferences – Volume 59 – Pages 03005

[c-1] Simulation of pelvic mobility: topology optimisation of ligamentous system. **A Vallet**, C Rubod, JF Witz, M Brieu, M Cosson. Computer Methods in Biomechanics and Biomedical Engineering – Vol 14 – sup1 – Pages 161-162 . 2011

Invited talk at conferences

[i-2] Flow and Transport in Permeable Media (GRS) Gordon Research Seminar - France, Oral - invited speaker. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal. *Transport around a pulsating cerebral vessel.* July 2022

[i-1] 9th World Congress of Biomechanics - Taipei, Taiwan. Oral - invited speaker. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal . Oral, *Can sleep architecture affect brain clearance ?* July 2022

Invited seminars (40 - 60 minutes)

[s-2] SAINBIOSE - Saint-Etienne, France. **A. Vallet**, *Biomechanics of the pulsating brain : toward a new understanding and management of dementia ?* Mai 2022

[s-1] OxMBM Seminar - Oxford, United Kingdom. **A. Vallet**, *Brain biomechanics and brain ageing.* October 2020

International conference presentations

[p-14] Flow and Transport in Permeable Media (GRC) Gordon Research Seminar - France, Poster. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal. *Fluid-poroelastic coupling and solute transport in an oscillatory squeezed flow.* July 2022

[p-13] Brain - BrainPET - Glasgow (UK) , Poster. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal . Oral, *Can sleep architecture affect brain clearance ?* May 2022

[p-12] Oslo glymphatics symposium - Oslo, Norway - Oral. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal . *How does sleep architecture affect brain clearance ?*, December 2021

[p-11] IESC – Cargese, France - Poster. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal . *Modeling of perivascular flow during sleep using a fluid-poroelastic structure interaction approach*, July 2021

[p-10] Coupled 2021, Online - Oral. **A. Vallet** , M. Kuchta, L. Bojarskaite , D. M. Bjørnstad, R. Enger and K. A. Mardal . *Modeling of perivascular flow during sleep using a fluid-poroelastic structure interaction approach*, June 2021

[p-9] 6th Oxford International Neuron and Brain Mechanics Workshop - Oxford, United Kingdom, Oral. **A. Vallet**, M. Kuchta, L. Bojarskaite, D. M. Bjørnstad, R. Enger and K. A. Mardal. *Investigation of the intracranial pulsatile behaviour and effect of dispersion*, June 2021

[p-8] BRAIN & BRAIN PET 2019 - Yokohama, Japan - Poster. **A Vallet**, S Lorthois, N Chauveau, P Swider, Z Czosnyka, N Del Campo, L Balardy, P Peran, A Lokossou, O Baledent, P Payoux, E Schmidt. *Intracranial fluids dynamics alterations and cortical thickness*. July 2019

[p-7] Neuroscience 2018 - San Diego, USA - Poster. **A Vallet,** A Lokossou, S Lorthois, P Swider, P Assemat, L Risser, Z Czosnyka, M Czosnyka, N Del Campo, L Balardy, P Peran, O Balédent, P Payoux, E Schmidt. *Biomechanical approach of brain aging, neurodegenerative diseases and frailty*. November 2018

[p-6] Hydrocephalus 2018 - Bologna, Italy - Oral. **A Vallet**, A Lokossou, S Lorthois, P Swider, P Assemat, L Risser, Z Czosnyka, M Czosnyka, N Del Campo, L Balardy, P Peran, O Balédent, P Payoux, E Schmidt. *Biomechanical approach of brain ageing, neurodegenerative diseases and frailty*. October 2018

[p-5] International conference on inertial fusion sciences and applications - Saint Malo , France - Poster. **A Vallet**, F Girard, E Falize, B Villette, R Rosch, G Oudot, G Soullie, J Fariaut, F Durut, F Seguineau, M Klein and D Raffestin. *Laser Mégajoule experiments of X-ray driven heat waves in sub-sonic diffusive* regime. September 2017

[p-4] International congress on plasma physics - Lisbon, Portugal - Oral. **A Vallet**, X. Ribeyre, V. Tikhonchuk, *Hydrodynamic modelling of shock ignition*. September 2014

[p-3] EPS conference on plasma physics - Berlin, Germany - Poster. **A Vallet**, X. Ribeyre, V. Tikhonchuk, *Semi-analytic modelling of shock ignition*. June 2014

[p-2] HEDP summer school - Columbus, Ohio state, USA - Poster. **A Vallet**, X. Ribeyre, V. Tikhonchuk. *Finite Mach number spherical shock wave - analytical criterion for shock ignition*. July 2013

[p-1] SPIE - Laser energy workshop - Prague , Czech Republic - Poster. **A Vallet**, X. Ribeyre, V. Tikhonchuk. *Study of converging spherical shock wave with a finite Mach number in the context of shock ignition*. April 2013

References

Pr Kent Mardal, Postdoc mentor - University of Oslo, Norway, +47 22855828, kent-and@math.uio.no

Pr Sylvie Lorthois, Postdoc mentor - IMFT Toulouse, France, +33 534322874, sylvie.lorthois@imft.fr

Pr Emeric Falize, CEA, manager of the laboratory I worked for, +33 169264000, emeric.falize@cea.fr

Dr Xavier Ribeyre, PhD advisor - CELIA, France, +33 54003366 , xavier.ribeyre@u-bordeaux.fr

Arteriole active oscillations during NREM sleep enhance solute transport in the brain

Recent studies showed that waste clearance from the brain is more efficient during sleep than wakefulness. Sleep stages are associated with specific oscillatory vasomotion patterns that subsequently affect the flow of cerebrospinal fluid (CSF). These oscillations are believed to affect the so-called 'glymphatic system' where brain metabolic wastes are transported by CSF in perivascular spaces (PVSs). We aimed to quantify how different stages in sleep affect brain clearance through the mechanical coupling between the cerebral vascular system and the CSF.

I collaborated with a team of biologists who perform two-photon imaging of naturally sleeping mice. I post-processed the measured time series to characterise the arterioles oscillations during awake and sleeping states. **We demonstrated sleep cycle-dependent PVS dynamics** – slow, large-amplitude oscillations in NREM, a reduction in REM and an enlargement upon awakening at the end of a sleep cycle. I developed a finite element modelling tool to assess fluid flow and solute transport in the PVS around an oscillating vessel wall. We demonstrated that **these sleep cycle-dependent PVS dynamics enhance solute transport by dispersion effect**.

Sleep architecture may therefore play an important role in brain clearance during sleep.

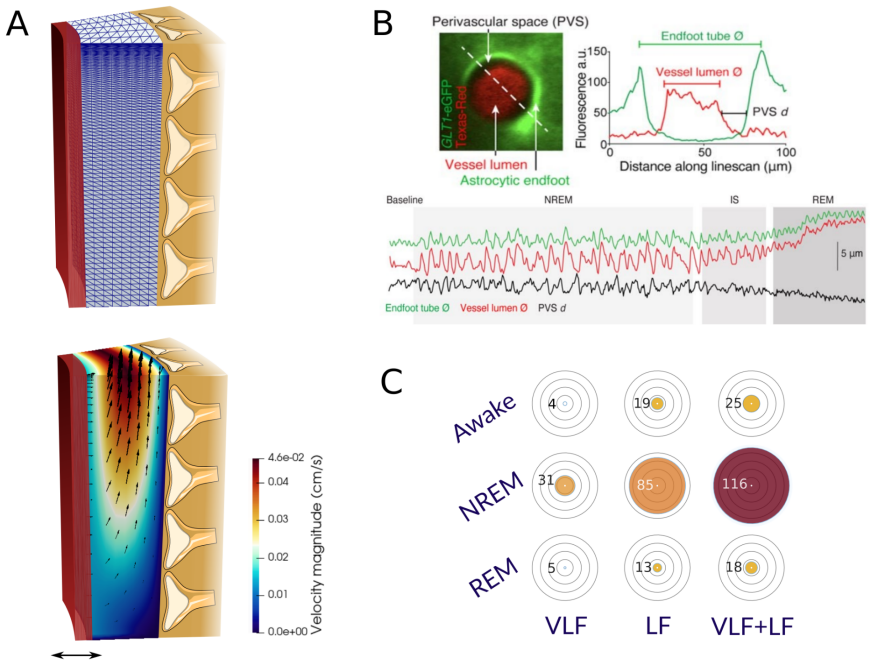

Figure 1: Simulation of fluid flow and tracer transport around a vessel during sleep in mice. A – Geometry and typical velocity field. B – Two-photon imaging of PVS deformation. C- Diffusion transport enhancement by dispersion effect (in pourcentage).

Work valued in [10]

Relevance of a biomechanical approach to the brain pathological ageing

I used a multimodal approach and a simple biomechanical model to analyse a cohort of 100 patients suspected of normal pressure hydrocephalus (NPH). **I demonstrated that brain vulnerability to mechanical stressors**, measured through a biomechanical marker called the CNS elastance coefficient, **is associated with frailty, a syndrome of general health deficits making an individual at risk for negative health outcomes, including dementia.**

The CNS elastance coefficient was measured by combining intracranial pressure data (from lumbar infusion test, see Fig.1 A and B) and intracranial blood flux data (from PCMRI, see Fig. 1 C and D). Frailty was measured as an index based on 40 variables of health deficits.

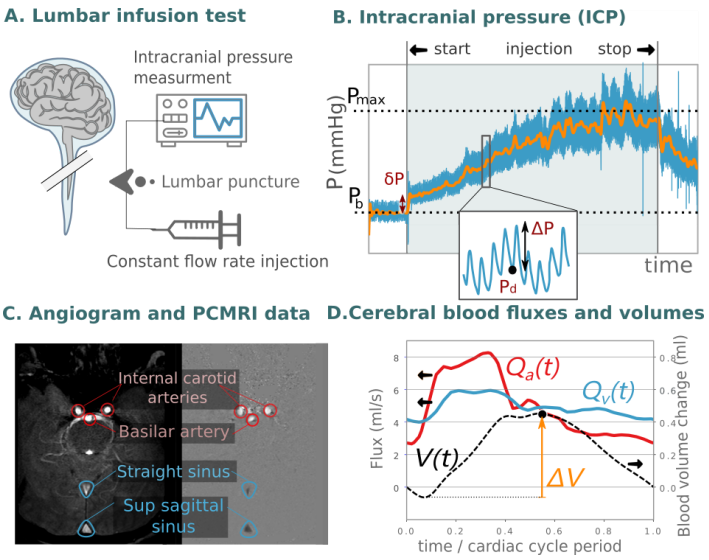

Figure 1: A - Scheme of the lumbar infusion test where the intracranial pressure (ICP) is measured while saline is injected at a constant rate. B. Typical ICP curve from the infusion test. C. Angiogram and phase contrast magnetic resonance imaging. D. Typical cerebral blood fluxes and volume changes deduced from PCMRI data.

I showed that the observations were **not specific to a particular neurological condition** since the patients of the cohort exhibited neurobiological markers of several neurodegenerative diseases: NPH, Alzheimer's diseases, Parkinsonian syndrome and vascular dementia. Hence, the data reinforced the concept that pathological brain ageing is an accumulation of various pathologies.

These findings are relevant because they **provide a novel framework to investigate *in vivo* the mechanisms underlying brain pathological ageing** that I think would be relevant for an objective characterization of the preclinical stage of dementia and therefore be valuable for preventive strategies. This work was possible thanks to a **transdisciplinary collaboration between clinical neuroscientists, imaging experts and physicists** leading to a novel and promising approach to brain ageing.

Work valued in [7]

Design of a successful campaign of experiments on the Laser Megajoule facility

I designed and interpreted a campaign of experiments on the Laser Mégajoule (LMJ) facility (see Fig. 2), dedicated to the propagation of a subsonic radiation heatwave in a diffusive regime. **The experiments aimed to better understand the complex multidimensional dynamics** behind a subsonic radiative Marshak wave. They were designed in such a way that the energy flux was dominated by **photon transport**. This is similar to astrophysical plasmas when a compact object (young stellar object, white dwarf or neutron star) irradiates the surrounding clumpy and cloudy interstellar medium.

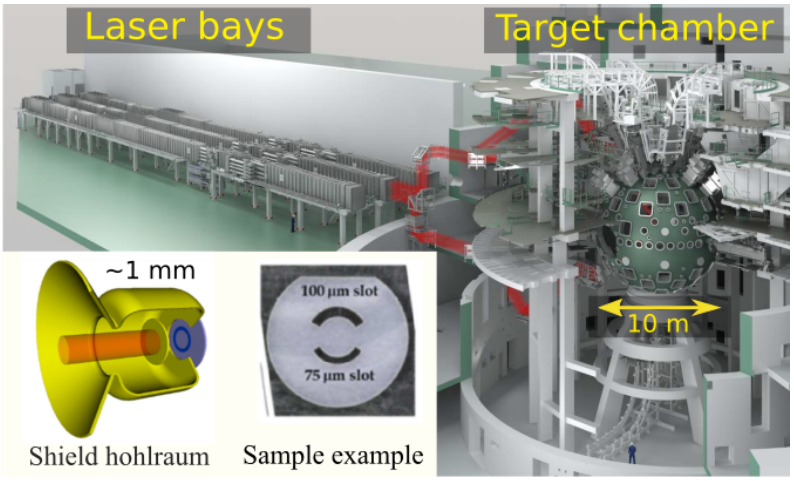

Figure 2: Laser Mégajoule facility and target

I coordinated and integrated multi-disciplinary activities from several teams. One LMJ quadruplet with a pulse duration of 4 ns and total energy of 11 kJ irradiated a shield hohlraum to create, behind the shield, a Planckian X-ray radiation source of 110 eV without photons in the AU M-band energy range. An aluminium sample with annular slots covered the opposite side of the hohlraum (see Fig. 2). Two Broad-band X-ray Spectrometers, DMX and miniDMX, measured the X-ray flux coming from the Laser Entrance Hole and the sample respectively.

After one year of preparation, the eight experiments, planned on a time window of eight days, were successful. They provided the data needed to select the modelling technique (multi-code, multi-physics approach) that best describes the photon transport in the regime of interest.

Confidential work: only internal reports.
Partially presented in conference : [p-5]

Please contact my reference Emeric Falize

Key processes in the shock ignition scheme for inertial confinement fusion

Mankind has a continuously increasing demand for energy. Fossil energy leads to carbon dioxide emission, which contributes to global warming, while nuclear energy produces dangerous radioactive waste and has a risk of reactor accident and renewable energy are predicted to not be enough. Therefore, a new source of energy is needed. The **energy from fusion reactions,** the origin of the energy unleashed by the sun and stars, seems promising as it would have **plenty of resources on earth, a low climate impact, a low level of radioactive wastes** and a very low risk of accidents. However, fusion reactions are not yet controlled on earth. **Inertial confinement fusion** is one of the research avenues toward controlled fusion reactions in a laboratory. A pellet target is compressed and heated with high-energy beams of laser light until the needed extreme conditions of stellar interiors are reached. The shock ignition scheme uses an intense power spike at the end of the target compression to ignite the fusion reactions.

The modelling of multi-physics processes was required to highlight phenomena that are hard or even impossible to assess experimentally (see figure 3). I developed a **new semi-analytical hydrodynamic model** to describe a spherical converging shock wave in a pre-heated hotspot. I demonstrated that a minimal shock pressure of 20 Gbar is needed when it enters the hotspot. I analysed the shock dynamics in the imploding shell, *i.e.* the **shock propagation into a non-inertial medium** with a high radial pressure gradient and a shock collision with a returning shock coming from the compression phase. An **analytical theory** allowed me to describe the shock pressure and strength evolution in a typical shock ignition implosion. I demonstrated that a generated shock pressure of the order of 300-400 Mbar is needed in order to reach a shock pressure of 20 Gbar in the hot spot. Finally, I helped in the **design/interpretation of experiments** performed on the OMEGA laser facility dedicated to strong shock generation. These experiments demonstrated that a shock pressure close to 300 Mbar is reached with an absorbed laser intensity up to 2×10^{15} W.cm^{-2} and a laser wavelength of 351 nm. This value is two times higher than the one expected from collisional laser energy absorption. I developed a simple model that explained the significant pressure enhancement by the contribution of hot electrons which are generated by non-linear laser/plasma interaction in the plasma corona.

Work valued in [2-6].

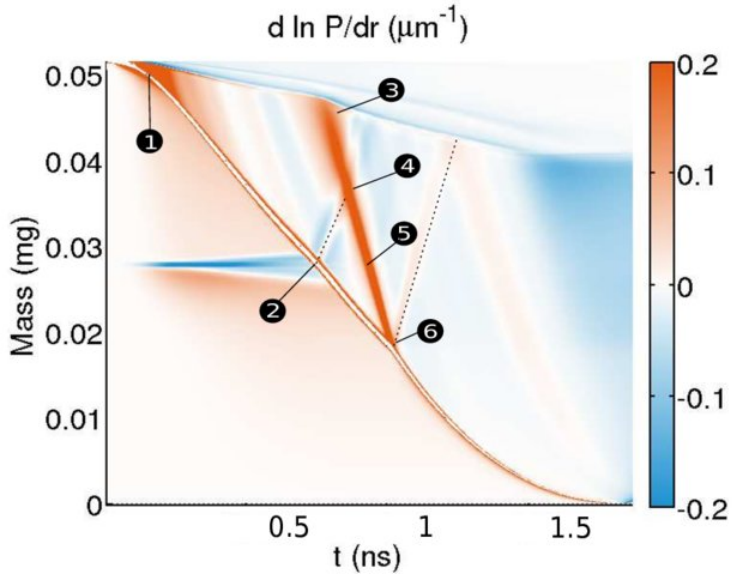

Figure 3 : Typical 1D simulation of shock and rarefaction waves occurring during the pellet implosion in inertial confinement fusion experiment.