

PHD PROPOSAL FOR THE DOCTORAL SCHOOL « Ecologie, Géosciences, Agronomie, ALimentation »

GENERAL INFORMATION

Thesis title: Fate of primordial organic matter in the icy moons of the outer planets: experimental approach
Acronym: EMOI
Disciplinary field 1: Geosciences
Disciplinary field 2: Select an element
Three keywords: Planets and Moons, Organics, Experiments
Research unit : Laboratoire de Planétologie et Géodynamique
Name of the thesis director HDR (Habilitation thesis to supervise research) required: Sotin, Christophe
Email address of the thesis director: Christophe.Sotin@univ-nantes.fr
Name of the thesis co-director (if applicable): HDR (Habilitation thesis to supervise research) required: Bujoli, Bruno
Email address of the thesis co-director (if applicable): Bruno.Bujoli@univ-nantes.fr
Name of the thesis co-supervisor 1 (if applicable):
Email address of the thesis co-supervisor 1 (if applicable):
Name of the thesis co-supervisor 2 (if applicable):
Email address of the thesis co-supervisor 2 (if applicable):
Thesis grant (funding origin and amount): CNRS, (3-year salary at 2135€ per month (76860 € for the duration of the thesis) plus 20 k€ grant for the first year with a similar forthcoming request for the second year)
Contact(s) (mailing address and E-mail): Christophe Sotin, Laboratoire de Planétologie et Géodynamique, Bâtiment 4, Faculté des Sciences, 2 rue de la Houssinière, 44072 Nantes Cedex 03. Christophe.Sotin@univ-nantes.fr
Recruitment process: Recruitment process depends on thesis funding. To select the corresponding recruitment process, please visit the EGAAL website here . This information is needed for proposal publication. <input type="checkbox"/> Doctoral school contest <input checked="" type="checkbox"/> Interview <input type="checkbox"/> Other (indicate) :

All sections must be filled. Once filled, please save the proposal form in pdf format using the following naming: Supervisor Name_Unit_Subject Acronym_EN.pdf

ED EGAAL

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SCIENTIFIC DESCRIPTION OF THE PhD PROJECT

Socio-economic and scientific context : (10 lines)

This interdisciplinary project between Chemistry and Planetary Science was triggered by the recent discovery that large amount of insoluble organic matter (IOM) was present in comets and in the large icy moons of Jupiter and Saturn. These planetary bodies are composed of silicates, ices and IOM. However, there is a dearth of experimental data on the reactions between IOM, silicates, and water ice at the relevant (P,T) conditions. The present work will simulate such reactions using analog IOM (heavy nitrogen rich polyaromatic molecules identified in comets and meteorites) and silicates brought at the relevant (P,T) conditions in high-pressure cells. This work is critical to the understanding of future observations by space missions (ESA JUICE mission to the Jovian environment and the NASA Europa Clipper mission) for which a number of research scientists at the Laboratoire de Planétologie et Géodynamique (LPG) are Co-Investigators.

Assumptions and questions (8 lines)

This work assumes that Insoluble Organic Matter (IOM) was accreted during the formation of outer solar system bodies. Two main science questions will be addressed by this work: (1) Can the pyrolysis of IOM explain the origin of Titan's atmosphere (N_2 and CH_4) and can it explain the late replenishment in CH_4 , a molecule that has a life time of only a few tens of Myr in Titan's atmosphere?, and (2) can molecules considered as biosignatures be formed by the pyrolysis of that IOM, an abiotic process that would challenge the biogenic origin of those molecules?

The main steps of the thesis and scientific procedure (10-12 lines)

The work will have the following milestones: (1) synthesis and characterisation of the analog IOM, (2) experiments in a diamond anvil cell of mixtures of IOM / water / hydrated silicates (antigorite) – different sets of experiments will be performed from mixtures without silicates to mixtures without water, the water being provided by the hydrated silicates. (3) same as (2) with the addition of iron sulfides that are present up to 10% in the primordial bodies. (4) some experiments in a piston-cylinder vessel that can handle larger volumes but does not allow the observation of the sample during the experiment. (5) inclusion of the laboratory data in the thermo-chemical evolution models of Ganymede and Titan. Each task (2), (3), (4) will be followed by the characterisation of the different components by the different techniques available at the laboratory CEISAM. The work also includes the writing and submission of papers in international peer-reviewed journals. The work mainly involves laboratory experiments. The LPG has already developed the numerical thermo-chemical evolution models of the large icy moons. These models provide values for observables that will be acquired by the future space missions.

Methodological and technical approaches considered (4-6 lines)

The experimental work will use the high-pressure and medium temperature instruments available at LPG: (1) a diamond anvil cell with Raman and infrared in-situ observations and (2) a piston-cylinder vessel. Both of them can reach (P,T) conditions in the large icy moons of Jupiter and Saturn (50 MPa to 5 GPa, 0 to 800 C). Starting material and material after reactions will be characterized using a diversity of instruments available at CEISAM: ICP-OES, RMN MAS, IR/FT, gas chromatography (GC) with embedded thermal conductivity detectors, GC-MS, and RMN 1H. If required, we will use the national equipment FT-ICR-MS managed by FR CNRS 3624.

Scientific and technical skills required by the candidate

The successful applicant must have a Master degree in Earth Science and/or Astrophysics and/or Chemistry. The candidate should have previous experience in laboratory experiments and experience in interpreting data from some of the instruments listed above.

THESIS SUPERVISION¹

Unit name: Laboratoire de Planétologie et Géodynamique, UMR-CNRS 6112	Team name: Diversité des mondes glacés
Unit director name: Antoine Mocquet	Team director name: Gabriel Tobie
Mailing address of the unit director: Pr. Antoine Mocquet, Laboratoire de Planétologie et Géodynamique, UMR-CNRS 6112, UFR Sciences et Techniques, 2 rue de la Houssinière, BP 92208, 44322 Nantes Cedex 3, France tel: +33 (0)2 51 12 54 68, fax : +33 (0)2 51 12 52 68, email : dir.umr6112@univ-nantes.fr	Mailing address of the team director: Dr. Gabriel Tobie, Laboratoire de Planétologie et Géodynamique, UMR-CNRS 6112, UFR Sciences et Techniques, 2 rue de la Houssinière, BP 92208, 44322 Nantes Cedex 3, France, (+33)2 76 64 51 61, e-mail: gabriel.tobie@univ-nantes.fr
Thesis director Surname, first name: Sotin, Christophe Position: Professor Obtained date of the HDR (Habilitation thesis to supervise research): 1986 Employer: University of Nantes Doctoral school affiliation: EGAAL Rate of thesis supervision in the present project (%): 50 Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 0 Number of current thesis supervisions/co-supervisions: 0	
Thesis co-director Surname, first name: Bujoli, Bruno Position: DR1 CNRS Obtained date of the HDR (Habilitation thesis to supervise research): 1992 Employer: CNRS Doctoral school affiliation: 3M Rate of thesis supervision in the present project (%): 50 Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 120 Number of current thesis supervisions/co-supervisions: 3	
Thesis co-supervisor 1 (if applicable)	

¹ In EGAAL Doctoral School, if only one scientist in thesis supervision = 100% of supervision rate; if 2 people involved in thesis supervision = from 50% to 70% of supervision rate for the director; if 3 people involved in thesis supervision = 40% / 30% / 30% of supervision rate distribution among supervisors.

Surname, first name:

Position:

Habilitation thesis to supervise research yes no If yes, date diploma received:

Employer:

Doctoral school affiliation:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

Thesis co-supervisor 2 (if applicable)

Surname, first name:

Position:

Habilitation thesis to supervise research yes no If yes, date diploma received:

Employer:

Doctoral school affiliation:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

Private partner (if CIFRE funding, private funding,...)

Surname, first name:

Position:

Employer:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

International partner (if Cotutelle thesis)

Surname, first name:

Position:

Employer:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

Professional status of previous PhD students supervised by both director and co-supervisors (from 5 years)

Please provide the following information for each PhD students supervised

Surname, first name:

Date of PhD beginning and PhD defence:

Thesis supervision:

Professional status and location:

Contract profile (post-doc, fixed-term, permanent):

List of publications from the thesis work:

Christophe Sotin: No PhD students in the last five years

Bruno BUJOLI

Thèse CIFRE Graftys (Pierre Leuret) - [Co-direction: J.M. Bouler 50%, B Bujoli 50%]: soutenue le 29 Mars 2016. **Devenir** : CDI public (professeur de sciences physiques - Académie de Nantes). Durée de la thèse : 37 mois
Développement de biomatériaux de remplacement osseux pour applications spécifiques en chirurgie du rachis.
Pas de publication, ni brevet pour l'instant. Résultats confidentiels

Thèse cotutelle University of Puerto Rico – bourse Chateaubriand (Barbara Casanas-Montes) - [Co-direction: J Colon 50%, B Bujoli 20% et co-encadrante C Queffelec 30%]: soutenue le 19 Mai 2017. **Devenir** : CDI privé (Bristol-Myers Squibb). Durée de la thèse : 43 mois

Layered inorganic nanomaterials for potential cancer therapy.

Molybdocene dichloride intercalation into zirconium phosphate nanoparticles

Casanas-Montes, B; Diaz, A; Barbosa, C; Ramos, C; Collazo, C; Melendez, E; Queffelec, C; Fayon, F; Clearfield, A; Bujoli, B; Colon, JL JOURNAL OF ORGANOMETALLIC CHEMISTRY, 2015, (791), 34-40, doi, ImpFact⁵: 2.336

Thèse MESR (Florian Forato) - [Direction: B Bujoli 40% et co-encadrante C Queffelec 60%]: soutenue le 12 Octobre 2017. **Devenir** : CDI privé (Oléa innovation). Durée de la thèse : 36 mois

Applications de la chimie des acides phosphoniques dans le domaine de la catalyse et des biotechnologies.

Comparison of Zirconium Phosphonate-Modified Surfaces for Immobilizing Phosphopeptides and Phosphate-Tagged Proteins

Forato, Florian; Liu, Hao; Benoit, Roland; Fayon, Franck; Charlier, Cathy; Fateh, Amina; Defontaine, Alain; Tellier, Charles; Talham, Daniel R.; Queffelec, Clemence; Bujoli, Bruno LANGMUIR, 2016, 32 (22), 5480-5490, doi, ImpFact⁵: 3.993

Core-Shell Ag@TiO₂ Nanocomposites for Low-Power Blue Laser Enhanced Copper(I) Catalyzed Ullmann Coupling

Forato, Florian; Talebzadeh, Somayeh; Bujoli, Bruno; Queffelec, Clemence; Trammell, Scott A.; Knight, D. Andrew CHEMISTRYSELECT, 2017, 2 (2), 769-773, doi, ImpFact⁵: 1.716

Phosphonate-Mediated Immobilization of Rhodium/Bipyridine Hydrogenation Catalysts

Forato, Florian; Belhboub, Anouar; Monot, Julien; Petit, Marc; Benoit, Roland; Sarou-Kamian, Vincent; Fayon, Franck; Jacquemin, Denis; Queffelec, Clemence; Bujoli, Bruno CHEMISTRY-A EUROPEAN JOURNAL, 2018, 24 (10), 2457-2465, doi, ImpFact⁵: 5.16

Non-photochemical catalytic hydrolysis of methylparathion using core-shell Ag@TiO₂ nanoparticles

Somayeh Talebzadeh, Florian Forato, Bruno Bujoli, Scott A. Trammell, Stephane Grolleau, Hemant Pal, Clemence Queffelec and D. Andrew Knight RSC ADVANCES, 2018, 8, 42346-42352, doi, ImpFact⁵: 3.29

Functionalized core-shell Ag@TiO₂ nanoparticles for enhanced Raman spectroscopy: a sensitive detection method for Cu(II) ions

Forato, Florian; Talebzadeh, Somayeh; Rousseau, Nicolas; Mevellec, Jean-Yves; Bujoli, Bruno; Knight, D. Andrew; Queffelec, Clémence; Humbert, Bernard PHYSICAL CHEMISTRY CHEMICAL PHYSICS, 2019, 21 (6), 3066-3072, doi, ImpFact⁵: 3.567

Investigation of copper oxidation states in plasmonic nanomaterials by XAS and Raman spectroscopy

Queffelec, C.; Forato F.; Bujoli, B.; Knight, D.A.; Fonda, E.; Humbert, B. PHYS. CHEM. CHEM. PHYS., 2020, 22, 2193-2199, doi, ImpFact⁵: 3.567

Five main recent publications of the supervisors on thesis subject:

Christophe Sotin

Sotin C., Kalousova K., & Tobie G. (2021), Titan's Interior Structure and Dynamics After the Cassini-Huygens Mission, Annu. Rev. Earth Planet. Sci., 49.

Hand K.P., Sotin C., Hayes A., and Coustenis A. (2020) On the Habitability and Future Exploration of Ocean Worlds; Space Science Reviews, 216, 5, 95, DOI: 10.1007/s11214-020-00713-7

Kalousova, K., & Sotin, C. (2020). The insulating effect of methane clathrate crust on Titan's thermal evolution, *Geophysical Research Letters*, 47, e2020GL087481. <https://doi.org/10.1029/2020GL087481>

Vu T.H., Choukroun M., Sotin C., Munoz-Iglesias V., Maynard-Casely H.E. (2020) Rapid Formation of Clathrate Hydrate from Liquid Ethane and Water Ice on Titan; *Geophys. Res. Lett.*, 47, e2019GL086265.

Neri A , Guyot F., Reynard B. and Sotin C. (2020) A carbonaceous chondrite and cometary origin for icy moons of Jupiter and Saturn; *Earth Planet. Sci. Lett.*, 530, 11592.

Bruno BUJOLI

Audo, M.; Paraschiv, M.; Queffelec, C.; Louvet, I.; Hemez, J.; Fayon, F.; Lepine, O.; Legrand, J.; Tazerout, M.; Chailleux, E.; Bujoli, B. Subcritical Hydrothermal Liquefaction of Microalgae Residues as a Green Route to Alternative Road Binders *Acs Sustainable Chemistry & Engineering* **2015**, 3, 583

Borghol, I.; Queffelec, C.; Bolle, P.; Descamps, J.; Lombard, C.; Lepine, O.; Kucma, D.; Lorentz, C.; Laurenti, D.; Montouillout, V.; Chailleux, E.; Bujoli, B. Biosourced analogs of elastomer-containing bitumen through hydrothermal liquefaction of *Spirulina* sp microalgae residues *Green Chemistry* **2018**, 20, 2337.

THESIS FUNDING

Origin(s) of the thesis funding: CNRS

Gross monthly salary: 2135 Euros

Thesis funding state : Acquired

Funding beginning date/Funding ending date: September 1, 2021

Date: April 26, 2021

Name, signature of unit director: Antoine Mocquet



Name, signature of team director: Gabriel Tobie



Name, signature of thesis project director: Christophe Sotin

