

Theory Group

Scientific Council

Cristina Volpe

APC Laboratory

Activity during 2013-17

Theory group members

- **15 permanent researchers :**

Enseignants-chercheurs : Eric Huguet (MdC), Jihad Mourad (Pr), Francesco Nitti (MdC), Jacques Renaud (Pr), Julien Serreau (MdC), Danièle Steer (Pr), Jean-Pierre Gazeau (émérite)

Chercheurs CNRS (section 02) : Chiara Caprini (CR), Nathalie Deruelle (DR), Elias Kiritsis (DR), Marc Lachièze-Rey (émérite), David Langlois (DR), Dimitry Semikoz (DR), Vincent Vennin (CR), Cristina Volpe (DR)

- **7 postdocs :**

Sajad Abbar (IN2P3), Davide (ERC), Andrei Belokogne, Marcela Cardenas (Chile), Nelson Merino (Chile), Lukas Witkowski (ERC)

Theory group members

- 10 PhD students :

Amélie Chatelain (2015-18, C. Volpe, ENS)

Jewel Ghosh (2016-19, F. Nitti- E. Kiritsis, ERC)

Felix Julié (2015-18, STEP-UP, N. Deruelle)

Frédéric Lamy (2015-18, STEP-UP, P. Binetrui-D. Langlois)

Gabriel Moreau (2016-2019, Polytechnique, J. Serreau)

Jaen Maelger (2016-19, co-direction J. Serreau, Polytechnique)

Tanguy Marchand (2015-18, co-direction D. Langlois, IAP)

Andrea Gallo Rosso (2015-18, co-direction C. Volpe, GSSI L'Aquila U.)

Leandro Silva Pimenta (2015-18, E. Kiritsis-F. Nitti, STEP-UP)

Hongoung Li (2016-19, K. Noui-délégation CNRS, U. Tours)

Recent evolution (5 last years)

- **Permanent :**

Arrivals : - Vincent Vennin (CR), CNRS section 02, arrived in 2017
- Chiara Caprini (CR), from IPhT Saclay, arrived in 2016
- Cristina Volpe (DR), from IPN Orsay, arrived in 2012

Departures : - Pierre Binetruy (DR), died in 2017
- J.P. Gazeau (Pr) et M. Lachièze-Rey (DR), retired

- **16 PhD Thesis supervised during 2012-2017 :**

A. Chatelain (Neutrinos), J. Ben Achour (Gravitation), F. Julié (Gravitation), F. Gautier (TQC), J. Ghosh (Holographie), M. Guilleux (Cosmologie), A. Helou (Gravitation), J. Maelger (TQC), F. Lamy (Gravitation), W. Li (Holographie), T. Marchand (Gravitation), M. P. Pieroni (Cosmologie), L. Silva Pimenta (Holographie), A. Gallo Rosso (Neutrinos), D. Väänänen (Neutrinos), A. Tresmontant (TQC).

- **HDR :** 11 permanents over 13 have HDR
- C. Caprini in 2018, V. Vennin.

Organisation

Theory group leader during 2014-17

C. Volpe (head of the group), D. Steer (adjoint)

D. Semikoz since 1/11/2017 and E. Huguet (ajoint), D. Langlois in 2013 with Steer (ajoint)

Several meetings per year , depending on the information to give (budget, changes at the laboratory/IN2P3 or CNRS, calls, arrivals....), decisions to take collectively (CNRS candidats, invited professors, positions at CNRS/University, organisation, ...)

Common lunches on Tuesdays (hall de convivialité)

Group scientific life :

- ❖ Seminars every Tuesday at 14:00 - organizer : J. Serreau
planning sur le site web du groupe et du labo, café, cookies
- ❖ Theory Journal Club every Friday between 12:30 and 13:30,
organized by N. Deruelle and the postdocs

Research activities

As theoreticians our research is focussed on

- ❖ fundamental questions
- ❖ development of computational tools
- ❖ model building
- ❖ understanding experimental observations
- ❖ up to proposing new experiments...

Research activities

We work at the forefront of research in

- ❑ fundamental interactions : gravity, strong and weak interactions
- ❑ cosmology
- ❑ quantum field theory and string theory
- ❑ astro-particles : cosmic rays, photons and neutrinos

Tight links with the experimental groups of high energy astrophysics, neutrino, cosmology and gravitation groups. Strong implication of some of the members in/for experiments (Planck, LSST, EUCLID, LISA, CTA, JEM-EUSO, Virgo, JUNO).

Highlights : Gravitation

We develop extended theories of gravity, mathematically consistent (ex. without instabilities) and in agreement with tests of General Relativity. They aim at explaining the current acceleration of the Univers expansion.

□ General Relativity and modified gravity

- Deruelle, Kiritsis, Langlois, Mourad, Steer

- gravity models with higher order derivatives :

$f(R)$, «Galileon» and «generalised Galileon » models

- «massive gravity »

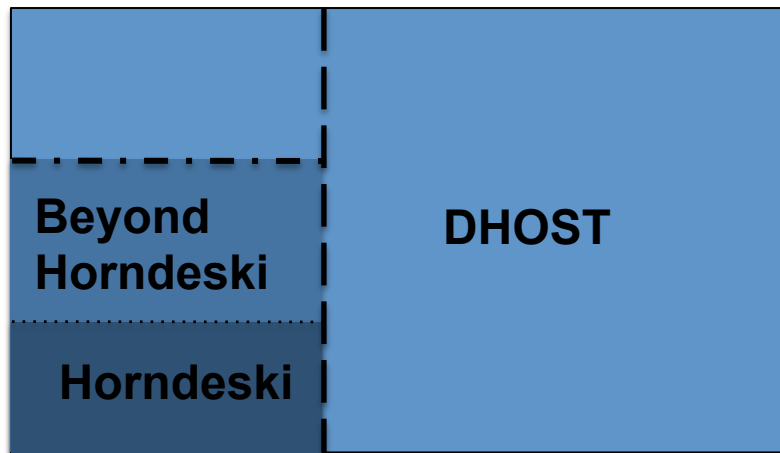
- black holes and gravitational waves

« Two-body problem in scalar-tensor theories as a deformation of General Relativity : an effective two-body problem. »

- Felix Julié et Nathalie Deruelle, arXiv :1703.05360

Highlights : Gravitation

“We have introduced a new class of scalar-tensor theories, whose Lagrangian depends on second order derivatives of a scalar field. These theories, called DHOST (Degenerate Higher-Order Scalar-Tensor) theories, include and extend Horndeski and "Beyond Horndeski" theories. They avoid the Ostrogradsky instability and contain only one scalar degree of freedom. We have classified all theories of this type with a quadratic dependence on second derivatives (and later with a cubic dependence).”



Langlois et Noui, JCAP 1602
(2016) 034, [1510.06930](https://arxiv.org/abs/1510.06930)

see also C.Deffayet, G.Esposito-Farese, D. Steer, Phys.Rev. D92
(2015) 084013.

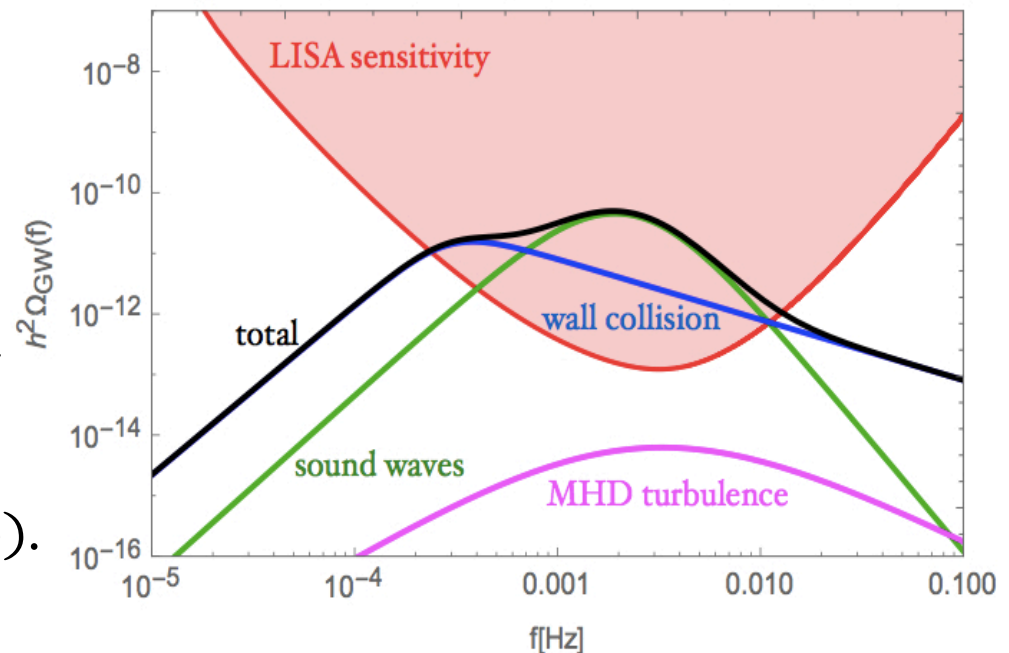
Highlights : Gravitation

□ **Gravitational waves**, with LIGO/VIRGO, LISA.

We investigate how gravitational waves can be used to test cosmology :
Primordial Univers (phase transitions) and late time Univers (cosmological parameters).

«Physics potential of LISA interferometer to detect the signal from a first-order phase transition in the early Universe and to test beyond the Standard Model physics.»

- Caprini et al, JCAP 1604 (2016).



Highlights : Cosmology

□ Inflation and cosmological perturbations

- Caprini, Kiritsis, Langlois, Steer, Vennin

□ Dark energy

New approach to dark energy, that includes the majority of existing models and allows to explore systematically new regions of the parameters' space describing models of dark energy.

Gleyzes, Langlois, Piazza, Vernizzi, JCAP 1308 (2013) 025

Highlights : Quantum Field Theory

We work on different aspects of quantum field theory in curved space time.

- Gazeau, Huguet, Kiritsis, Mourad, Renaud, Serreau

« We propose a new quantization method in analogy with molecular physics. It generates a repulsive potential that resolves the classical singularity. »

-- Bergeron, Czuchry, Gazeau, Małkiewicz, Piechocki, PRD,92, (2006)

□ Strong interaction and confinement

« Perturbative description of the phase diagram of QCD with heavy quarks a nonzero temperature and chemical potential in the context of a massive gluon approach. We obtain a qualitative (and, for some quantities, even quantitative) agreement with known lattice results for the deconfinement phase transition. »

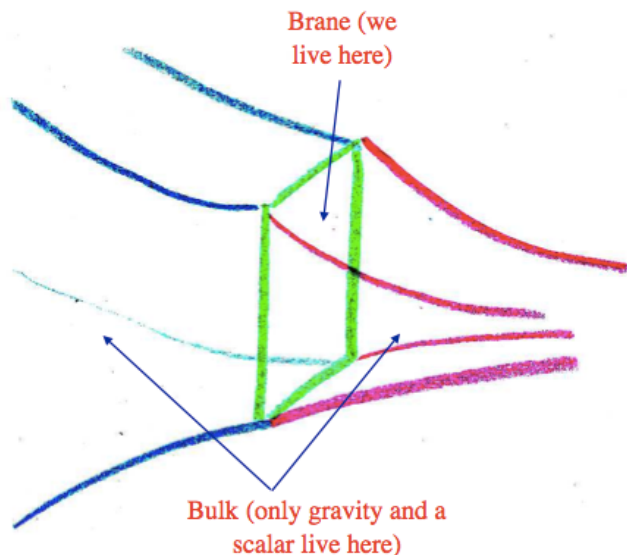
Reinosa, Serreau, Tissier, PRD92 (2015) 0250.

Highlights : Quantum Field Theory

Holography: The conjecture of an equivalence between a quantum field theory (QFT) on one hand and a gravity theory in more than 4 dimensions on the other.

It furnishes a computational method to replace a strongly coupled QFT with a classical theory of gravity.

We work on theoretical aspects as well as applications : QCD, condensed matter and cosmology.



« A mechanism is proposed that can hide the cosmological constant in the holographic/braneworld context. »

- Charmousis, Kiritsis,
Nitti, 1704.05075 .

Highlights : Astroparticle physics

- Semikoz

□ Cosmic rays

We develop theoretical models to explain the spectra, the composition and the cosmic ray sources, as well as their propagation in the intergalactic medium.

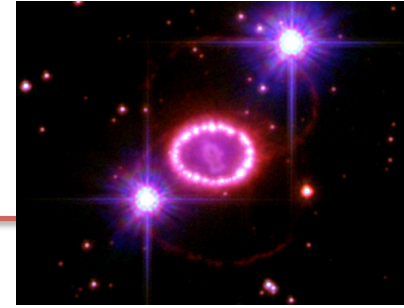
«A two million year old supernova can explain the spectra of cosmic ray protons, antiprotons and positrons as well as the dipole asymmetry in the cosmic rays spectra, unexplained since the '80s.»

Kachelriess, Neronov and Semikoz, PRL 115, 181103 (2015).

□ Ultra high energy neutrinos

We work to explain the origin of the UHE neutrinos observed in ICECUBE.

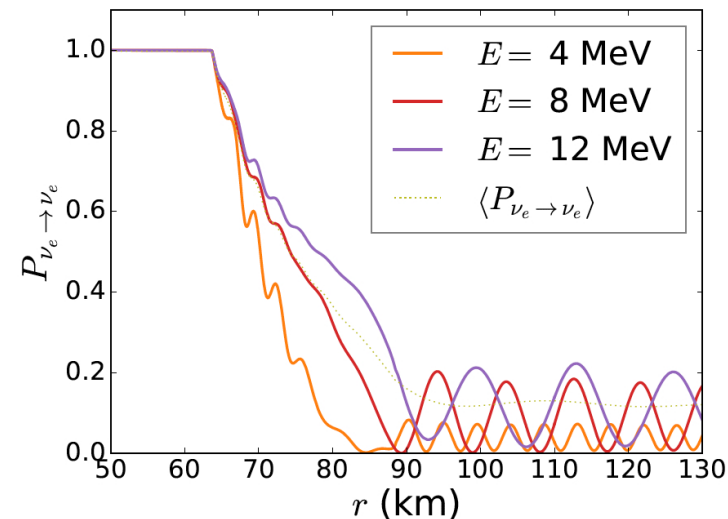
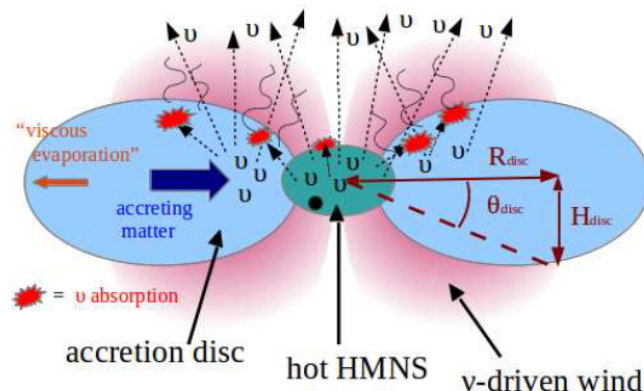
Highlights : Astroparticle physics



- Volpe

We work along different directions

- ❖ to push forward **our understanding of flavor mechanisms in astrophysical environments**, i.e. core-collapse supernovae, BNS.
 - > **explosion dynamics, nucleosynthesis of heavy elements**
- ❖ to unravel key unknown neutrino properties
- ❖ to establish the link with other domains, such as atomic nuclei and condensed matter



Chatelain, Volpe, PRD(2017) 1611.01862

Publications (2013-17)

- **Number of publications in refereed journals : 169**
- **Proceedings : 39**
- **Books : 3**

N. Deruelle et J.P. Uzan, “Théories de la Relativité”, Belin (2014)

S.T. Ali, J.P. Antoine and J.P. Gazeau, "Coherent states, wavelets and their generalizations", Springer (2013)

D. Langlois, “Relativité générale: des fondements géométriques aux applications astrophysiques”, Vuibert (2013)

- **Lecture notes : 11**
- **Editors of Proceedings' books : 2**
- **Editors of Focus Issues : 2** - Journ. of Phys. G (2014), (2017)

International visibility

- **Invited talks at international conferences and workshops: 123**
- **Organisations de conférences, workshops : 22**
8 at APC, 5 in Greece, 1 in Italy, 1 in Iceland, 1 in Japan, 1 in Korea, 1 in Cyprus, 1 in Belgium, 1 in the US and 2 EPS conferences.
- **Distinctions :**
International committee of the Marcel Grossmann meetings,
'nominating committee' of the Scie GRG, chairman (2008-2014)
and Honorary member (2015-) of the Standing Committee of the
International Colloquium on Group Theoretical Methods in Physics
(ICGTMP)

Scientific responsibilities

- **Boards, convenerships**

Conveners du GDR «Neutrinos», Président du «Ondes gravitationnelles»

Committees : GRAM National Program, Labex P2IO, CNRS section 02 (2011-2012), CNU (2012-).

International committee: European Physical Society High Energy Physics Board (since 2011). Deputy Chair of EPS HEPP (2015-2017), coordinator of the LISA cosmology working group

Sociétés savantes : International committee of the Marcel Grossmann meetings, 'nominating committee' of the Scie GRG, chairman (2008-2014) and Honorary member (2015-) of the Standing Committee of the International Colloquium on Group Theoretical Methods in Physics(ICGTMP)

- **Grants**

CT IN2P3 (2012-2016), PICS Paris-Kyoto (2013-2016), PEPS Physique Théorique et Interface (2013), Défi InPhyNiTi (2014), GPhys (2014-2016), PICS France-Brésil (2017-2020), ERC Advanced Grant (2016-2020).

Scientific responsibilities

- **Referees for funding agencies and grants:** Italian Ministry for Education University and Research (2012, 2013, 2014) and Roumanian Ministry (2012), FNRS (2012-2017), COFUND Marie Curie Fellowships (2012-2014), Marie Curie pannels (2012-2017), ERC grants (2014, 2016), Fondo Nacional de Desarrollo Científico y Tecnológico (Fondecyt, Chili, since 2009), European Science Foundation College of Expert Reviewers, Natural Sciences and Engineering Research Council of Canada (NSERC), Austrian Science Fund, Czech Science Foundation, ERC committee "Sciences de l'Univers" for the ERC Consolidator Grants (2012, 2014, 2016), INFN Theory committee for Astroparticle (CSN4, 2013), National Science Foundation (NSF, USA), Department Of Energy (DOE, USA), Research Foundation Flanders (FWO), Research Council of KU Leuven (Leuven U.), Russian Science Foundation, Russian Foundation for Research, Netherlands Organisation for Scientific Research, Royal Society (UK), STFC (UK), COST (EU), Cyprus Institute, Polish National Science Center, Levehume trust (UK), American-Israeli binational Foundation, Institut Universitaire de France, Israel Science Foundation.
- **Editorial Boards :** JCAP (since 2009), EPL (since 2016), Journ. Phys. G (2008-2017), Journal of Physics A: Math. and Theoretical, Classical and Quantum Gravity (since 2011), International Journal of Modern Physics (since 2010), European Physical Journal C (since 2014).

Communication

Actions

- ✓ MOOC Gravity and MOOC "Histoire des sciences »
- ✓ **Articles : 21, Conferences : 14**
- ✓ **Multimedia lectures** : Lectures in Astroparticle physics for Master-2 students with APC virtual Institute of Astroparticle Physics (2015, 2016)
- ✓ **Primary schools** :
«*Comment "meurent" les supernovae ?*», (CM2, 2017); «*Comment vivent les étoiles ?*», (CM1, 2016) ; «*La petite énigme des ν solaires*», (CE2, 2015).
- ✓ **Radio** : "100 years of General Relativity".
Interviews at RFI, France Culture, France Inter.

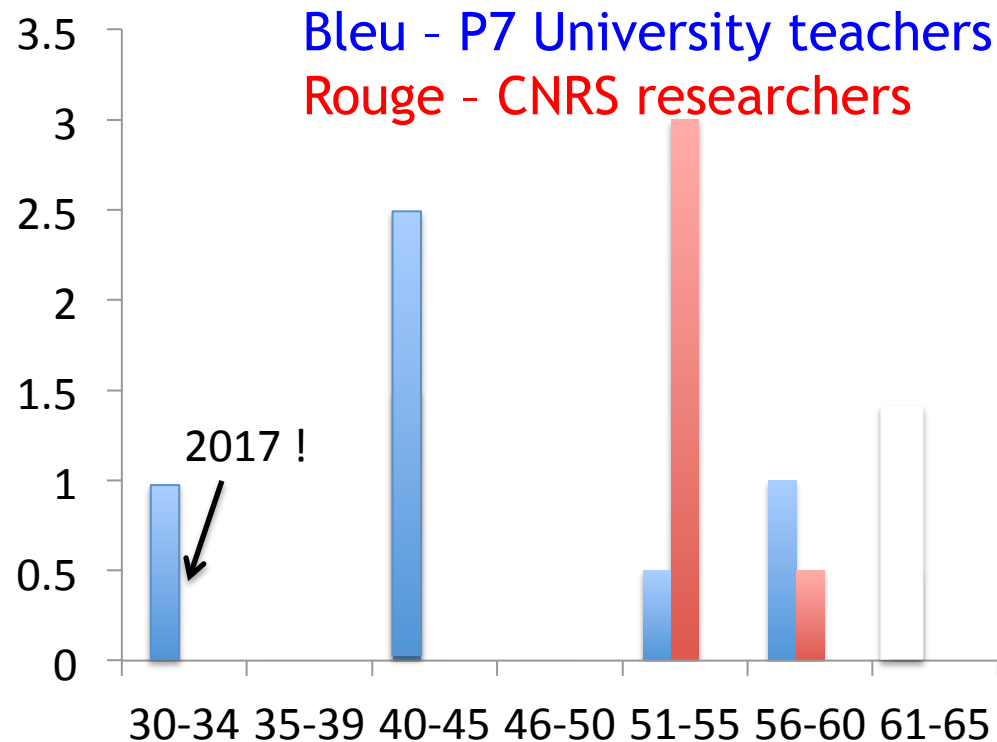
Future

In the coming years we will follow axis that we have been identifying or that have emerged from our works, or stimulated by observations.

- ➡ **Astro-particle** : galactic/extra-galactic transition, cosmic rays anisotropies, origin(s) of neutrinos seen in IceCube
- ➡ **Neutrino (astro)physics** : ν in supernovae and binary neutron star mergers, flavor evolution mechanisms, impact on observations
- ➡ **Cosmology** : effective theories for dark energy, inflation
- ➡ **Gravitation** : Horndeski et beyond, quantum gravity, Gravitational waves
- ➡ **Quantum field theory** : renormalisation in de Sitter space, confinement
- ➡ **Gauge/gravity duality** : strong interactions

Forseen evolution (personnel)

- Departures for retirement: N. Deruelle (DR, 2018), J. Renaud (Pr)



Todayi : Ratio around «40 »/ »over 47» = 0.54 .

In 3 years, the group will consist of 2.5 University teachers (50% ETP) and 6 CNRS researchers.

Future of the group

There is a real need to hire new people to keep the critical size of the theory group and maintain its international visibility, its role at different levels, i.e. research, teaching, supervision, and committees.

Our priorities for the near future :

Côté CNRS :

- ❑ CR section 01 : «Aspects théoriques des astroparticules
- rayons cosmiques, neutrinos, ondes gravitationnelles »

Côté Université :

- ❑ Ouverture d'un poste de Professeur section 29-34 en 2018 :
«Théorie des interactions fondamentales et des astroparticules»

AFOM analysis

(aka SWOT = Strengths, Weaknesses, Opportunities, Threats)

- **Strengths**

- ❖ internationally renown experts in these fields and has high international visibility
- ❖ heavily involved in teaching and the supervision of students at all levels of the LMD, of PhD students and postdocs
- ❖ strong connections with the 4 experimental groups in the laboratory

AFOM analysis

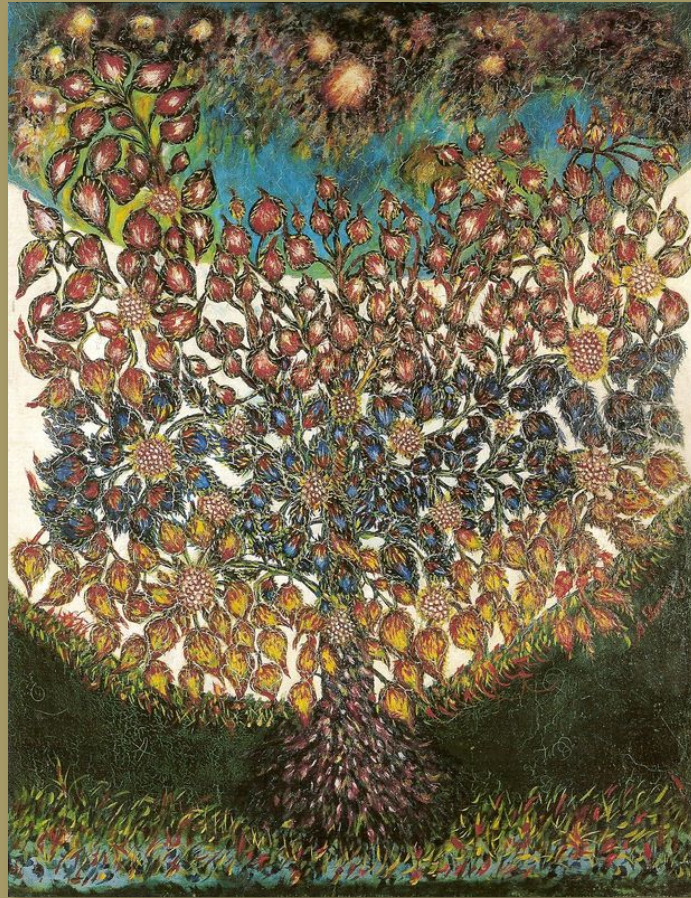
(aka SWOT = Strengths, Weaknesses, Opportunities, Threats)

- **Weaknesses**

- ❖ the very small number of young researchers (1 is less than 40 years old !)

- **Threats**

- ❖ The age pyramid :
Researchers around 40/Researchers above 47 = 0.38.
- ❖ The allocated budget (SBNA) for about 30 researchers
40850 euros (2014), 43300 euros (2015), 41250 (2016), 40850 (2017)
About 1000-1500 euros per person/year is too low !
- ❖ Too much administrative tasks, including the filling in of data basis,
procedure to hire too heavy - stages, postdocs, fundings.
--> too much time consuming.
More administrative support, simplification/automatic of procedures.



Life tree