Institut national de physique nucléaire et de physique des particules

in2p3.cnrs.fr

Theory

APC, Paris

Composition de l'équipe de recherche

- Responsable scientifique de l'équipe :
- Head of group Dmitri Semikoz, vice-head Eric Huguet
- Budget annuel soutien équipe (hors budget projets) : **38 000**

Liste des chercheurs de l'équipe :

- X permanents [prénom, nom, qualité (émérite, PR, DR, MCF, CR, IR-chercheur), HDR]
- **11+4 permanents [Name, Status (Emeritus, PR, DR, MCF, CR, IR-Chercheur), (HDR)**
- **CNRS**

- Kiritsis Elias DR
- Langlois David DR
- Semikoz Dmitri DR
- Vennin Vincent CR /HDR
- Volpe Cristina DR

- **University Paris 7**

- Huguet Eric MCF/ ***HDR***
- Mourad Jihad PR
- Neronov Andrii PR
- Nitti Francesco PR
- Serreau Julien MCF/ ***HDR***
- Steer Danièle PR

- **Emeritus**

- Deruelle Nathalie DR
- Gazeau Jean-Piere PR
- Lachièze-Rey Marc. DR
- Renaud Jacques PR

Before Sept 2021

Caprini Chiara DR

Composition de l'équipe de recherche

- 3 post-doctorants [prénom, nom, indiquer projet, origine financement, date de début, date de fin]
  - Alberto Mangiagli IN2P3 1/2021-1/2023
  - Alberto Roper Pol ANR 10/2020-10/2022
  - Marius Ramsoy ANR 11/2020-11/2022

- 7 doctorants [prénom, nom, indiquer sujet, origine financement, directeur, codirection, cotutelle, date de début, date de fin]
  - Korochkin Alexander Gamma-ray astronomy Vernadskii D. Semikoz Oct 2018 Sept 2022
  - ROUSSILLE, Hugo Modified gravity models ENS Ulm D.Langlois Oct 2019 June 2022
  - Jani Kastikainen Holography otutelle Helsinki F.Nitti June 2020 June 2022
  - Edwan Préau Holography E.Kiritsis Oct 2020 Oct 2023
  - Valentin Nourry Holography. F.Nitti Oct 2020 Oct 2023
  - Thomas Colas Cosmology co-tutelle with Orsay. V.Vennin Oct 2020 Oct 2023
  - Konstantin Leyde Cosmology D.Steer Oct 2020 Oct 2023
  - Julien Froustey Neutrino co-encadrement IAP M.C. Volpe Janvier-September 2020

Activités de l'équipe de recherche

- Coopérations/collaborations principales avec l'extérieur (avec équipes locales, nationales, internationales)

- Associated scientists:

- K.Noui (Orsay) 2 days/week
- F. Vernizzi (Saclay) 1 day/week
- U.Reinosa (Polytechnique) 1 day/week
- Julien Grain (IAS) 1 day/week
- Brando Bellacini (Saclay)
- Christos Charmousis (Orsay)
- Blaise Gouteraux (Ecole Polytechnique)
- Monica Guica (Saclay)
- Herve Bergeron (Orsay)
- Chiara Caprini (Geneva) 1 week/month

Activités de l'équipe de recherche

- Coopérations/collaborations principales avec l'extérieur (avec équipes locales, nationales, internationales)

- Visiteurs de longue durée (>3 mois) depuis 3 ans (sabbatiques, cofinancés, ...)

- M.Takook 1 year PAUSE

- Before covid we had 3-6 1-3 months visitors and 30+ short term visitors per year

M.Kachelriess (Trondheim U) Nov-Dec 2021

Restarted Sept 2021.

Activités de l'équipe de recherche

- Coopérations/collaborations principales avec l'extérieur (avec équipes locales, nationales, internationales)
  - **Collaboration with following institutes:**

1) Albert Einstein Institute Potsdam
2) Aquila University, Italy
3) ASU, Phoenix, Arizona, USA
4) Brookhaven National Lab
5) Carnegie Mellon University, USA
6) CERN
7) CPHT-X
8) Dept Histoire and Philosophy of Sciences, Univers. Paris Diderot
9) Dept de mathématiques, Univ Paris Diderot
10) DESY Hamburg
11) Ecole Normale Superieure
12) Geneva Observatory and physics department
13) GSSI, Italy
14) Institut d'Astrophysique de Paris
15) Institute d'Astrophysique Spatiale
16) Institute of Cosmology and Gravitation, University of Portsmouth (Angleterre)
17) IFFI, Montevideo, Uruguay
18) ICTP Trieste
19) INFN Florence
19) INFN Milan and Milano University
20) INR, Moscow
21) IPMU Tokyo
22) IPHC (Strasbourg)
23) IPM Tehran, Iran

Activités de l'équipe de recherche

- Coopérations/collaborations principales avec l'extérieur (avec équipes locales, nationales, internationales)
  - **Collaboration with following institutes:**

- Stockholm University
- 25) L2C (Montpellier)
- 26) LPTMC, Sorbonne Université
- 27) Leiden Univ.
- 28) Max Planck Institute fur Physik, Munich
- 29) Novosibirk University

30) Osaka University
31) Perimeter Institute, Canada
32) RIKEN, Japon
33) Stanford University
34) Simon Fraser, Vancouver
35) Trondheim University, Norway
36) UCL, Louvain La Neuve, Belgique
37) Université Libre de Bruxelles, Belgique
38)) University of Barcelona
39) University of Crete
40) University of Heildelberg
41) University of Helsinki
42) University of Lanzhou, China
43)) University of McGill
44) University of Milano
45) University of Nottingham
46) Universte d'Orsay

Activités de l'équipe de recherche

- Coopérations/collaborations principales avec l'extérieur (avec équipes locales, nationales, internationales)
  - **Collaboration with following institutes:**

- 47) University of Padova
- 48) University of Roma II
- 49) University of Stavanger (Norway)
- 50) University of Sussex
- 51) University of Trieste
- 52) University of Taiwan
- 53) University of Vienna
- 54) University of Utrecht
- 55) University of Winskonsin
- 56) Warsaw University, Pologne
- 57) Waseda University
- 58) Yukawa Institute for Theoretical Physics, Kyoto, Japon

- **PhD defended in period (2017-2021)**
- **Name, PhD subject, financial source, PhD advisor, starting date, final date…**

Chatelain Amélie	Novel neutrino flavour conversion phenomena in media	ENS	Cristina Volpe	Sept 2016 Sept 2018
Ghosh Jewel Kumar	Aspects of holographic RG flows on curved manifolds	ERC	Elias Kiritsis/F.Nitti	Sept 2016 Sept 2019
Liu Hong Guang	Modified Gravity	CPT Marseille	Karim Noui /A.Perez	Sept 2016 Sept 2019
Pimenta Leandro,	Holography	Paris 7,	Kiritsis+Nitti,	9/2015-8/2018
Félix-Louis Julié,	the problem of motion in, modified theories of gravity	bourse de thèse	N.Deruelle	9/2015-9/2018
Maelger Jan	Transitions de Phases en QCD	Paris7	Julien Serreau	Oct 2016 Oct 2019
Andrea Gallo Rosso	"Supernova neutrinos and observations »	GSSI	Cristina Volpe/F. Vissani	Sept 2016 Avr 2019
Moreau Gabriel	Champs quantiques en espace-temps courbe	Paris 7	Julien Serreau	Oct 2017 Oct 2020
Auclair Pierre	Cosmology with Gravitational Waves	EPolytechnique	D.Steer/ Ch. Caprini	Oct 2018 Jul 2021
Bouyahiaoui Makarim	Models of multi-messenger sources of cosmic-rays, gamma-rays and neutrinos	Paris7	D. Semikoz	Oct 2018 Dec 2021
Papanikolaou Theodoros	Constraining the early Universe with Primordial BH	Paris7	V. Vennin	Oct 2018 Oct 2021

Projet #1 String theory and Holography

Scientist responsible for project : E.Kiritsis,F.Nitti

List of researchers in the project:

•**2 permanent [Name, %ETPT in projet, (status)]**

•Elias Kiritsis 100% (responsable)

•Francesco Nitti 50% (co-responsable)

•**2 postdocs [Name, %ETPT in projet, (status)]**

•Panagiotis Betzioa 100% research

•Yuta Hamada 100% research

• **3 PhD students: [Name, %ETPT in projet, (status)]**

• Valentin Nourry 50% research

• Edwan Préau 100% research

•Jani Kastikainen 100% research

•**Important scientific results in project (2020-2021)**

•Non-perturbative study of holographic field theories on de Sitter spacetime

•Models with the self-tuning of the cosmological constant and holographic relaxion mechanism

•Holographic RG flows on products of spheres

•Study of AdS vacuum decay by Coleman-de Luccia instantons

•Study of holographic F-theorems in flavored ABJM model

•Baryons in phenomenological holographic models for QCD (in progress)

•Computation of weak processes in dense strongly coupled media (like neutron stars) using semi-holography(in progress)

•**Important publications (2020-2021)(3 max) :**

•Revisiting Coleman-de Luccia transitions in the AdS regime using holography, J.K. Ghosh (ICTS, Bangaloreand Independent U., Dhaka), E. Kiritsis (APC), F. Nitti (APC) L. Witkowski (IAP), Feb 23, 2021, ***JHEP*09 (2021) 065**

•Back-reaction in massless de Sitter QFTs: holography, gravitational DBI action and f(R) gravity J.K. GhoshICTS, Bangalore and Independent U., Dhaka), E. Kiritsis (APC), F. Nitti (APC) L. Witkowski (IAP), May 18, 2020, ***JCAP* 07 (2020) 040**

•The Self-Tuning of the Cosmological Constant and the Holographic Relaxion Y. Hamada (APC), E. Kiritsis(APC), F. Nitti (APC) L. Witkowski (IAP), Jan 15, 2020 , ***Fortsch.Phys.* 69 (2021) 2, 2000098**

•

5 papers in journals published

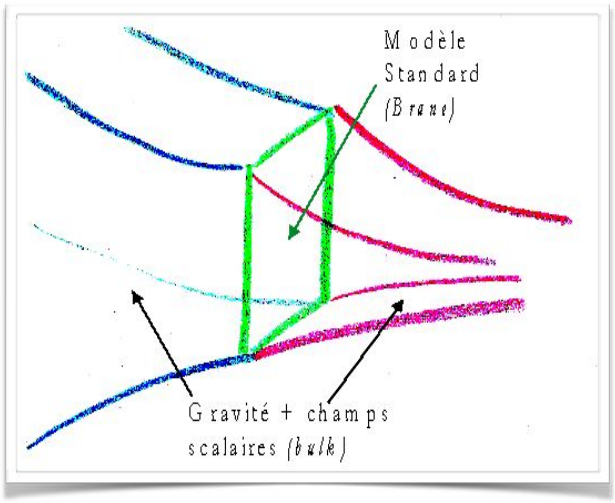
Projet #1 String theory and Holography

Holographie, constante cosmologique et gravité modifié

Problème de la constante cosmologique:
pourquoi l'énergie de vide quantique du Modèle Standard TQC ne semble pas contribuer à la courbure de l'espace-temps ?

Universe Branaire holographique à 5d

C. Charmousis, E. Kiritsis, F. Nitti, JHEP 1709 (2017) 031



- Le modèle standard (localisé en 4d) intéragit avec un *bulk* courbé à 5d;
- Mécanisme d'annulation automatique de la constante cosmologique à 4d (*self-tuning*);
- Modifications de la gravité à grande et/ou courte distance (duale: *gravité émergente*)

Projet #2 Quantum field theory

LList of researchers in the project:

•**5 permanents [Name, %ETPT in projet, (status)]**
•E.Huguet 50%
•J.Mourad 50%
•J-P. Gaseau 100%
• J. Renaud 100%
•M.Lachieze-Rey 100%

•**Important scientific results in project (2020-2021)**
•Covariant integral quantization of various classical systems.
•Restriction of “massless” to “massive” scalars from Conformal to Sitter space
•Study of breaking of Supersymmetry: New vacua with broken supersymmetry with (p+1) dimensionnal space-timePoincar\'esymmetry are found with supersymmetric and tachyon-free non-supersymmetric 10D string theories.

•**Important publications (2020-2021)(3 max) :**

Massive scalar field on (A)dS space from a massless conformal field in R6,
E. Huguet, J. Queva and J. Renaud, J.~Math.~Phys. 61, 053506 (2020).

On boundaries, charges and Fermi fields
Mourad, J. and Sagnotti, A., hep-th 2002.05372, **Phys. Lett. B 804 (2020) 135368.**

String (In)Stability Issues with Broken Supersymmetry
Mourad, J. and Sagnotti, A., hep-th 2107.04064", JHEP 2021 (2021)

Projet #2 Quantum field theory

G.P.Gazeau

«Quantum Field Theory - Quantizations - Cosmology - Foundations of Physics» the following ones selected from a list of 29 articles published in international journals with referees:

J.-P. Gazeau
From classical to quantum models: the regularising rôle of integrals, symmetry and probabilities,
Foundations of Physics 48 1648-1667 (2018); https://doi.org/10.1007/s10701-0180219-3; arXiv: 1801.02604 [quant-ph]

H. Bergeron, E. Czuchry, J.-P. Gazeau, and P. Małkiewicz,
Integrable Toda system as a novel approximation to the anisotropy of Mixmaster,
Phys. Rev. D 98 083512 (2018); https://doi.org/10.1103/PhysRevD.98.083512

H. Bergeron, J.-P. Gazeau, and P. Małkiewicz,
Primordial gravitational waves in a quantum model of big bounce,
JCAP, 05 057 (2018); doi.org/10.1088/1475-7516/2018/05/057 arXiv:1709.05851v1 [gr-qc]

J.-P. Gazeau, H. Pejhan, M. Enayati, and A. Wang,
Gupta-Bleuler quantization for linearized gravity in de Sitter spacetime,
Phys Rev. D 100 066012 (2019); https://doi.org/10.1103/PhysRevD.100.066012; arXiv:1906.06644v1 [gr-qc]

J.-P. Gazeau, H. Pejhan, M. Enayati, and A. Wang,
“Massive" Rarita-Schwinger field in de Sitter space,
Phys Rev. D 100 125022 (2019); DOI: 10.1103/PhysRevD.100.125022; arXiv:1909.13450v1 [gr-qc]

J.-P. Gazeau and G. Cohen-Tannoudji.
Cold dark matter: a gluonic Bose-Einstein condensate in Anti-de Sitter space time,
Universe 2021, 7(11), 402; https://doi.org/10.3390/universe7110402 arXiv:2111.01130 [gr-qc]

J.-P. Gazeau and M. Takook
Quantum Yang-Mills theory in de Sitter ambient space formalism
Nuclear Physics B 980 (2022) 115811; arXiv:2112.02651 [hep-th]; https://doi.org/10.1016/j.nuclphysb.2022.115811

There is also the book in print :

J.-P. Gazeau, H. Pejhan, M. Enayati, and A. Wang,
The de Sitter group (dS) and its representations:
An Introduction to Elementary Systems and Modeling the Dark Energy Universe
to appear in Synthesis Lectures on Mathematics & Statistics, Springer (2022); arXiv:2201.11457 [math-ph]

Projet #3 QFT in curved spacetime and QCD

Scientist responsible for project : J. Serreau

List of researchers in the project:

•**1 permanents [Prénom, Nom, %ETPT dans le projet, (responsabilité)]**

Julien Serreau 50% (responsable)

•**1 PhD student: [Prénom, Nom, sujet, %ETPT dans le projet, (responsabilité)]**

Moreau Gabriel Champs quantiques en espace-temps courbe %100

•**Important scientific results in project (2020-2021)**

-nonperturbative QFT techniques to compute the effect of gravitationally enhanced quantum fluctuations during inflation.

-modified perturbative approach for the infrared regime of QCD. Calculation of the phase diagram of the quark-gluon plasma. Semi-analytical computation of dynamical breaking of chiral symmetry.

•**Publications emblématiques de l'équipe dans revues à comité de lecture (2020-2021)(3 max) :**

A novel background field approach to the confinement-deconfinement transition D. M. van Egmond, U. Reinosa (Ecole Polytechnique, CPHT), J. Serreau (APC, Paris), M. Tissier (Sorbonne Univ. LPTMC). SciPost (2021), to appear

The 1/N expansion for stochastic fields in de Sitter spacetime G. Moreau, J. Serreau (APC, Paris). PhysicalReview D 102 (2020) 125015

A window on infrared QCD with small parameters M. Pelaez (Republica Univ. Montevideo), U. Reinosa (Ecole Polytechnique, CPHT), J. Serreau (APC, Paris), M. Tissier (Sorbonne Univ. LPTMC). Reports on Progress in Physics(2021)

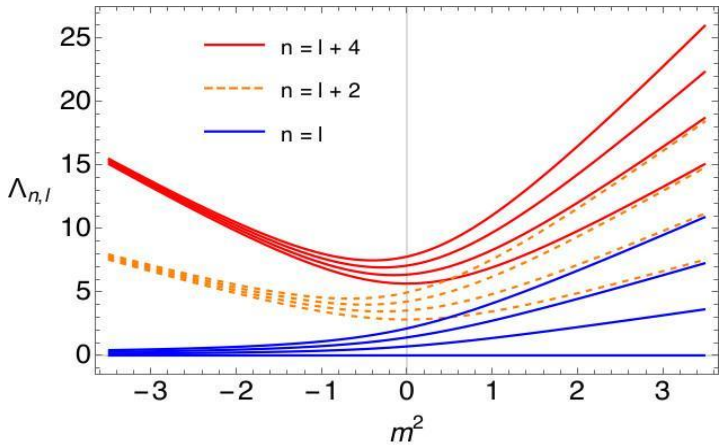
7 papers in journals published + 1 conference proceedings

QFT in curved spacetime and QCD

J. Serreau, G. Moreau

Quantum field theory in curved spacetime

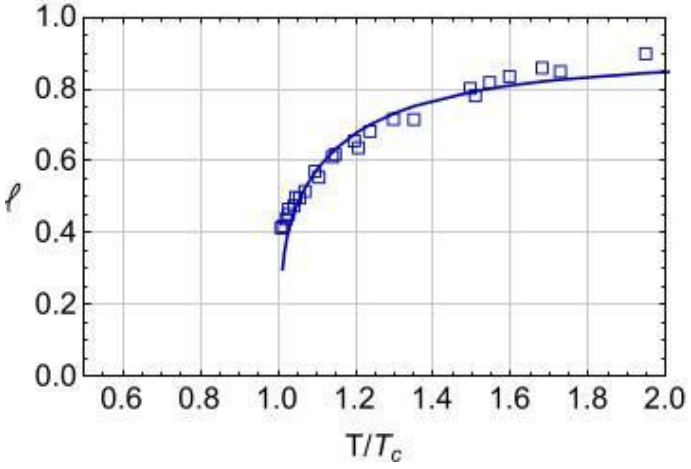
- development of nonperturbative QFT techniques to compute the effect of gravitationally enhanced quantum fluctuations during inflation
- analytical expressions of correlation lengths/times relevant for inflationary physics



Exact eigenvalues of the Fokker-Planck operator in the large-N limit as a function of the self coupling [PRD 102 (2020) 125015]

Infrared regime of Quantum Chromodynamics

- analytical computation of the phase diagram of QCD with modified perturbative approach (massive extension of Landau gauge = Curci-Ferrari model)
- semi-analytical computation of dynamical breaking of chiral symmetry with the CF model



The order parameter of the confinement-deconfinement transition in SU(3) Yang-Mills theory as a function of temperature (one-loop calculation vs. lattice results) [SciPost (2021), to appear]

Projet #4 Modified Gravity

Scientist responsible for project : D.Langlois

List of researchers in the project:

- **2 permanents+1 associé [Name, %ETPT in projet, (status)]**
- David Langlois 100% (responsable)
- Karim Noui 50%
- Danièle Steer 10%

- **1 Doctorant: [Name, %ETPT in projet, (status)]**
- Hugo Roussille 100%
- Konstantin Leyde 10%

- **Important scientific results in project (2020-2021)**

  - geometric reformulation of quadratic DHOST (Degenerate Higher-Order Scalar-Tensor) theories
  - perturbations and quasi-normal modes of black holes in DHOST theories
  - tests of different modified gravity theories with GWs

- **Important publications (2020-2021)(3 max) :**

Quadratic degenerate higher-order scalar-tensor theories revisited David Langlois(APC, Paris), Karim Noui(IDP, Tours and APC, Paris), Hugo Roussille(APC, Paris and IDP, Tours), Published in: *Phys.Rev.D* 103 (2021) 8, 084022

Asymptotics of linear differential systems and application to quasi-normal modes of nonrotating black holes David Langlois(APC, Paris), Karim Noui(IDP, Tours and APC, Paris), Hugo Roussille(APC, Paris and IDP, Tours), To appear in: *Phys.Rev.D*

Current and future constraints on cosmology and modified gravitational wave friction from binary black holes K.Leyde, S.Mastrogiovanni, D.A.Steer, E.Chassande-Mottin et ali , *2022.00025 [gr-qc]*

Projet #5 Equivalent formulations of General Relativity

E. Huguet

Scientist responsible for project : E. Huguet

List of researchers in the project:

- **1 permanents [Name, %ETPT in projet, (status)]**
  - E. Huguet 50% (responsible)

- **Important scientific results in project (20-2021)**
  - Critical analysis of the Teleparallel Equivalent of General Relativity (TEGR) as a gauge theory of the translation group
  - Reformulation of the Teleparallel Equivalent of General Relativity (TEGR) using a Cartan connection.
- **Important publications (2020-2021)(3 max):**
- **``Teleparallel gravity as a gauge theory: coupling to matter with Cartan connection.''**
  E.~Huguet, M.~Le~Delliou, M.~Fontanini and Z.- C.~Lin,, Phys. Rev. D {\bf 103}, 044061 (2021).

- **``Cartan approach to Teleparallel Equivalent to General Relativity: a review.'',**
  E.~Huguet, M.~Le~Delliou and M.~Fontanini, Int. Jou. Geom. Meth. Math. Phys., 18 supp01, 21400041 (2021).

- **``Teleparallel theory as a gauge theory of translations: Remarks and issues.'',**
  M.~Le~Delliou, E.~Huguet and M.~Fontanini, Phys. Rev. D 101, 024059 (2020).

3 papers in journals published

Projet #6 Cosmology and GW

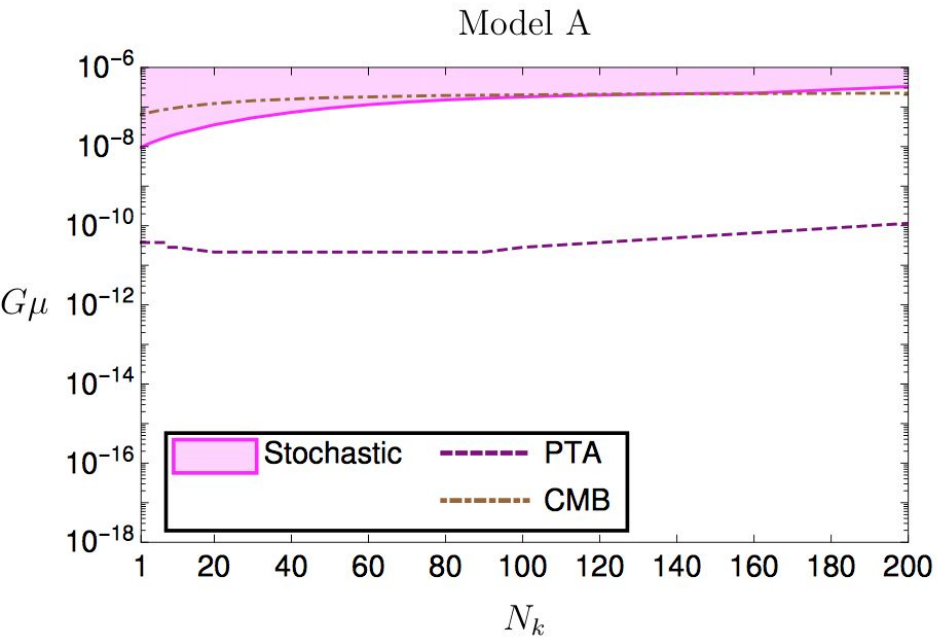
Scientist responsible for project: D.A.Steer

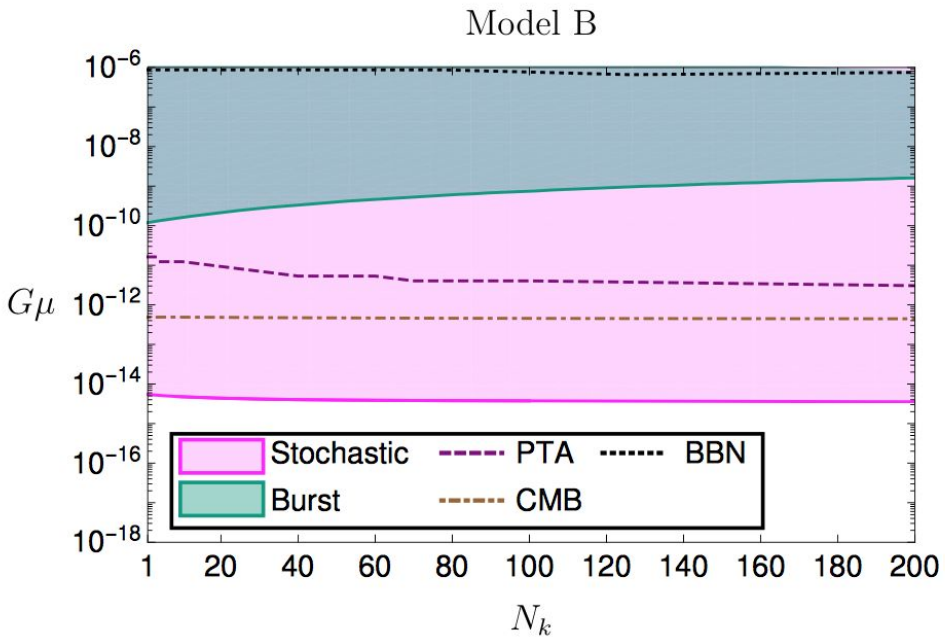
List of researchers in the project:

- **1 permanents [Name, %ETPT in projet, (status)]**
  - Danièle Steer 80% (responsible)
  - Chiara Caprini
- **2 Doctorants: [Name, %ETPT in projet, (status)]**
  - Pierre Auclair 100%, *Primordial cosmology and gravitational waves:from phase transitions to cosmic strings and primordial black holes* ED STEPPUP, Septembre 2018→ Septembre 2021
  - Konstantin Leyde 90%, Testing General Relativity and Cosmology with Third Generation Gravitational Wave Detectors, ED STEPPUP, co-tutelle avec Eric Chassande-Mottin depuis Septembre 2020
- **Important scientific results in project (2020-2021)**
  - Cosmic string model development
  - LIGO-Virgo O3 constraints on cosmic strings
  - Generation of gravitational waves from freely decaying turbulence, and applications to LISA
  - Cosmology and tests of GR with dark GW standard sirens (black hole binaries)
- **Important publications (2020-2021)(3 max) :**
  - **Constraints on cosmic strings using LIGO-Virgo O3 data** *Phys.Rev.Lett.* 126 (2021) 24, 241102,
  - **Generation of gravitational waves from freely decaying turbulence, P.**Auclair, C.Caprini, D.Steer et al, to appear in JCAP, 2022
  - **Current and future constraints on cosmology and modified gravitational wave friction from binary black holes** K.Leyde, S.Mastrogiovanni, D.A.Steer, E.Chassande-Mottin et ali , *2022.00025 [gr-qc]*

Projet #6 Cosmology and GW

- **Constraints on cosmic strings using LIGO-Virgo O3 data.**





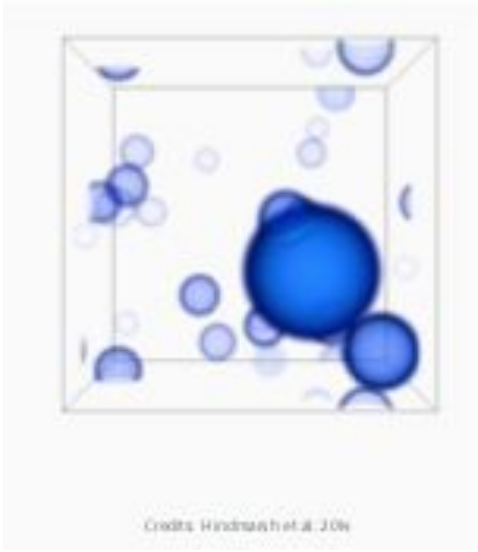
Exclusion plots for 2 models of cosmic strings. y-axis = string tension Gmu; x-axis = number of kinks of strings

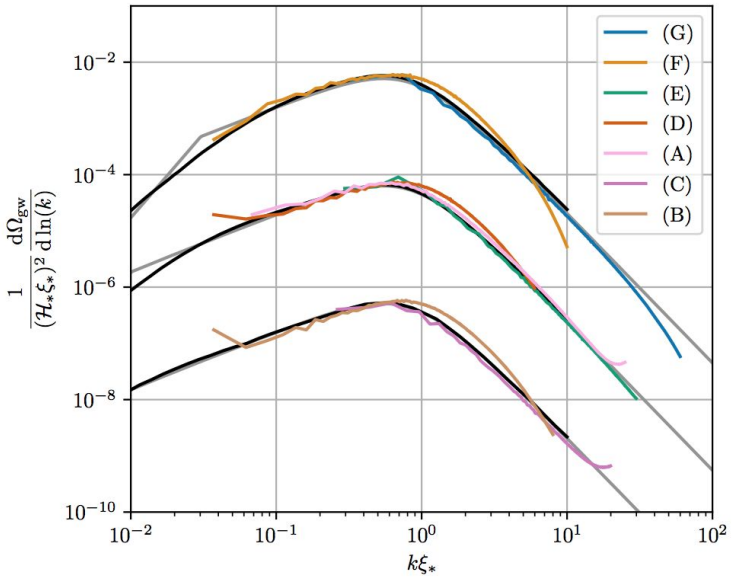
Phys.Rev.Lett. 126 (2021) 24, 241102

Projet #6 Cosmology and GW

- **Generation of gravitational waves from freely decaying turbulence, P.**Auclair, C.Caprini, D.Steer et al, 2022

  - In strong phase transitions, shocks may convert the acoustic phase into a turbulent one
  - main result: provide templates for the future LISA GW detector.
  - we have modeled decaying turbulence semi-analytically and validated with massively parallel numerical simulations





- gray: our analytical approximation based on a constant source lasting a few eddy turnover times. Colours = numerical simulations

Projet #7 Early-Universe Cosmology

Scientist responsible for project: V.Vennin

List of researchers in the project:

- **1 permanents [Name, %ETPT in projet, (status)]**
  - Vincent Vennin 100% (responsible)

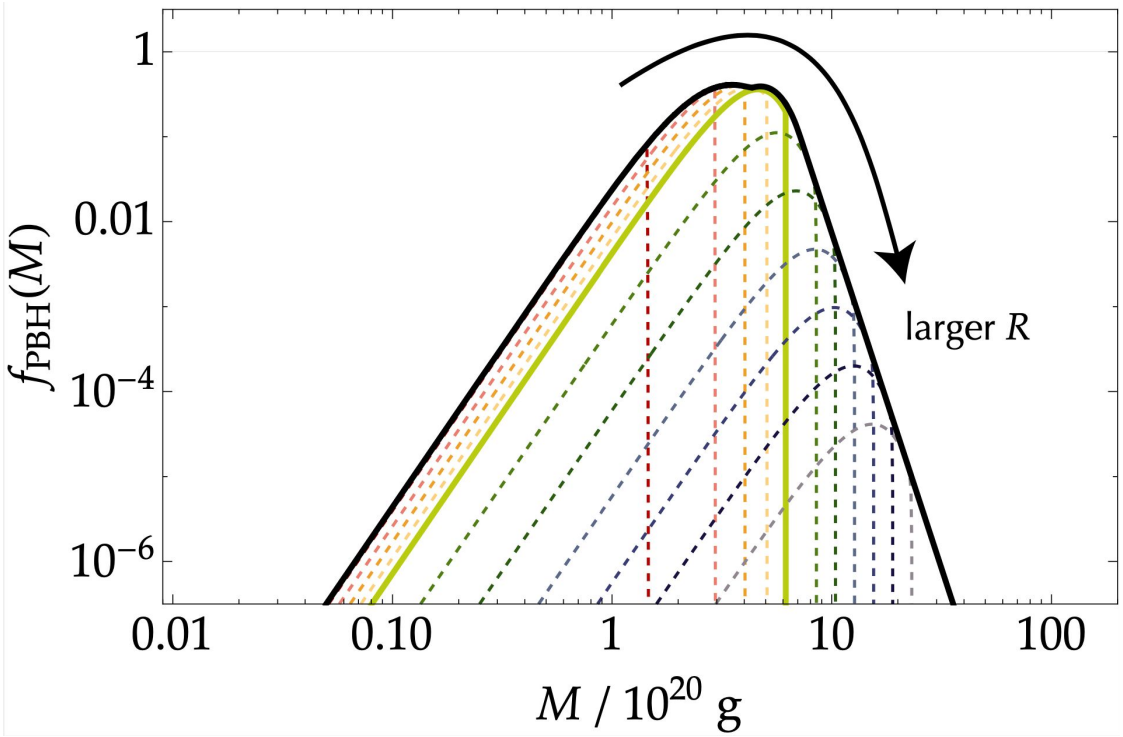
- **2 Doctorants: [Name, %ETPT in projet, (status)]**
  - Theodoros Papanikolaou 100%, *Primordial Black Holes*, ED STEPPUP, Septembre 2018→ Septembre 2021
  - Thomas Colas 100%, *Quantum aspects of primordial fluctuations*, ED PIF, co-tutelle avec Julien Grain (IAS), depuis Septembre 2020

- **Important scientific results in project (2020-2021)**
  - Quantum backreaction in stochastic inflation: statistics of cosmological fields and consequences for primordial black holes
  - Primordial black holes from metric preheating
  - Induced gravitational waves from a primordial-black-hole dominated era
  - Observational signatures of the quantum origin of cosmological perturbations: real-space quantum discord, generalised Bell inequalities
  - Dynamical collapse models of the wavefunction in cosmology

- **Important publications (2020-2021)(3 max) :**
  - Gravitational waves from a universe filled with primordial black holes (Theodoros Papanikolaou, Vincent Vennin, David Langlois), JCAP 03 (2021) 053
  - Ultra slow roll with quantum diffusion (Chris Pattison, Vincent Vennin, Hooshyar Assadullahi, David Wands), JCAP 04 (2021) 080
  - Bipartite temporal Bell inequalities for two-mode squeezed states (Kenta Ando, Vincent Vennin), Phys. Rev. A 102 (2020) 5, 052213

2020-2021: 11 papers in journals published + 4 preprints + 1 HDR

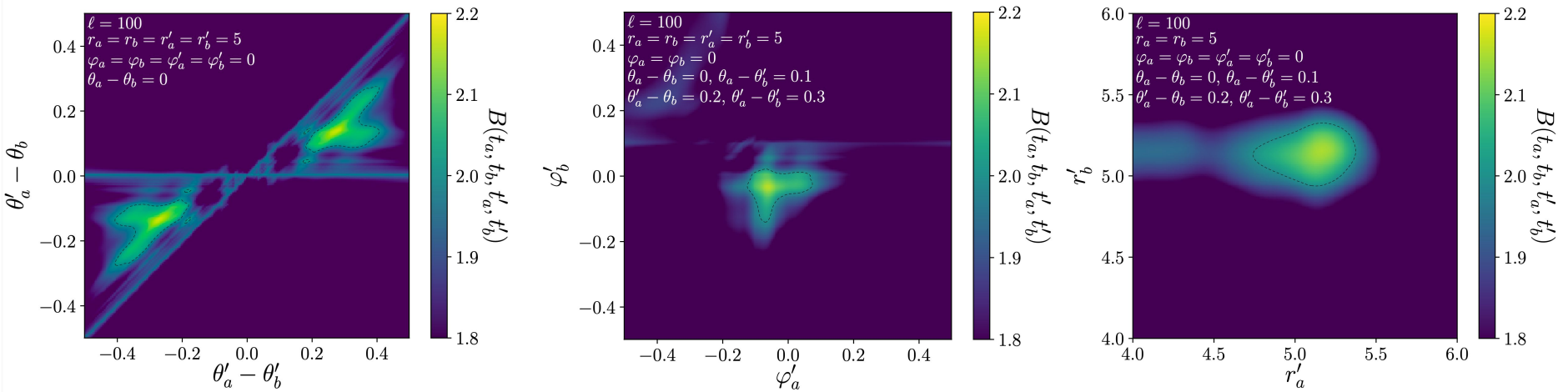
- **Highlight 1: mass fraction of primordial black holes in the presence of quantum diffusion**



Statistics of coarse-grained cosmological fields in stochastic inflation, Yuichiro Tada, Vincent Vennin (2021)

Quantum kicks in the stochastic motion of the inflation yield large cosmological fluctuations that may later collapse into primordial black holes. The figure shows the mass distribution of such black holes, in a model where the inflaton's potential features an exactly flat region

- **Highlight 2: Violation of temporal Bell inequalities by primordial fluctuations**



Bipartite temporal Bell inequalities for two-mode squeezed states, Kenta Ando, Vincent Vennin (2020)

In the parameter space describing the quantum state in which primordial fluctuations are placed, the figure shows regions where temporal Bell inequalities are violated, denoting the presence of genuine quantum effects.

Projet #8 Neutrino physics et Astrophysics

Scientist responsible for the project : M.C.Volpe

List of researchers in the project:

- **1 permanent [Name, %ETPT in projet, (status)]**
  - Maria Cristina Volpe 100% (responsable)
- **1 postdocs [Name, %ETPT in projet, (status)]**
  - Sajad Abbar 100% research (2019), now at MPI Münich
- **2 PhD students : [Name, %ETPT in projet, (status)]**
  - Andrea Gallo Rosso, (2019) 100% research "Observational aspects of supernova neutrinos", supervisors : M.C.Volpe/ F. Vissani, Aquila U. et GSSI,(financement GSSI). Postdoc à Laurentian, Stockholm U.
  - Julien Froustey (en 2020), 100% research, (IAP), co-encadrement avec C. Pitrou.
  - Pilar Hernandez-Pallesteros, Master 2-PHE and ETH Zürich, "The diffuse supernova neutrino background and its potential", 2022 (4 mois)

Important scientific results in project (2019-2022)

- Effets de décohérence dans la propagation des neutrinos, dues à la gravitation, près d'objets compacts
- Première mise en évidence de modes "fast" (modes de très courte échelle) dans les simulations multi-dimensionnelles des supernovae
- Premier calcul des nombre des degrés de liberté effectif des neutrinos à l'époque de la nucléosynthèse primordial incluant le terme complet de collision des neutrinos

Important publications (2019-2022)(3 max):

« Neutrino decoherence in presence of strong gravitational fields », Chatelain and Volpe, *Phys. Lett. B 801 (2020) 135150.*

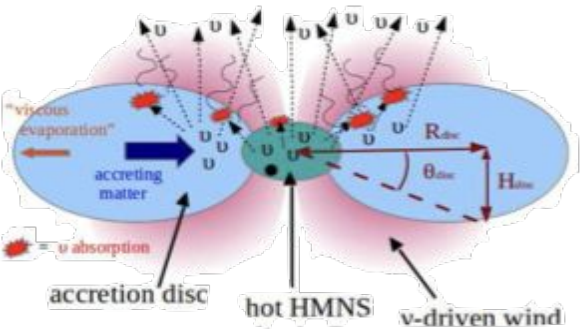
« Neutrino decoupling including flavor oscillations and primordial nucleosynthesis », Froustey, Pitrou, Volpe, *JCAP* 12 (2020) 015.

« On fast neutrino flavor conversion modes in the non linear regime », Abbar, Volpe, 790 (2019) 545.

5 published papers in refereed journals, 3 proceedings + 1 preparation, 1 invited review (in preparation), 11 articles (JUNO)

Neutrino physics and astrophysics

M.C.Volpe, A. Abbar, A.Chatelain, J. Froustey, A. Gallo Rosso

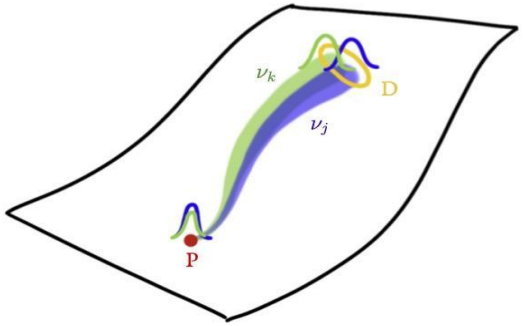


neutron star mergers

- Neutrinos modify their flavor while travelling. In dense environments new flavor mechanisms are being uncovered.
- Flavor evolution can impact the neutron richness and nucleosynthesis of heavy elements - r-process - in core-collapse supernovae and binary neutron star merger remnants.

Supernovae

Core-collapse supernova neutrinos



Decoherence of the neutrino wave packets during propagation, due to the presence of strong gravitational fields nearby compact objects.

Chatelain, Volpe,Phys.Lett. B 801(2020)135150.

Cosmological neutrinos

Precise calculation of the effective number of degrees of freedom at the epoch of Big-bang nucleosynthesis,
including for the first time the full neutrino collision term, giving
Neff = 3.0440 .

Froustey, Pitrou,Volpe,JCAP 12 (2020) 015.

> Predictions for future observations of supernova neutrinos in neutrino detectors such as Super-Kamiokande, Hyper-K, JUNO, DUNE, …

Projet #9 Cosmic rays

Scientist responsible for project : D.Semikoz

List of researchers in the project:

- **2 permanents [Name, %ETPT in projet, (status)]**
-
  - Dmitri Semikoz 30% (responsible)
  - Andrei Neronov 15% (co-responsible)
- **1 Doctorants[Name, %ETPT in projet, (status)]**
  - M.Bouvahiaoui, 100% Cosmic ray models

- **Important scientific results in project (2020-2021)**
- Detailed model on cosmic ray propagation in local 1 kpc was constructed
- Cosmic ray spectrum in outer galaxy was studied with Tibet data
- New secondary production model in A-A collisions AAfrag was developed

- **Important publications (2020-2021)(3 max) :**

Pion decay model of the Tibet ASgamma PeV gamma-ray signal

S. Koldobsky (Moscow Phys. Eng. Inst.), A.Neronov (APC, Paris), D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.). . Published in **Phys Rev D 104 (2021) 4, 043010**

Energy spectra of secondaries in proton-proton interactions

S. Koldobsky (Moscow Phys. Eng. Inst.), M. Kachelriess (Norwegian U. Sci. Tech.), A. Lskavyan (Moscow Phys. Eng. Inst.), A.Neronov (APC, Paris), S.Ostapchenko (Hamburg U. and SINP, Moscow), D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.)., 2110.00496 [astro-ph.HE], accepted PRD

High-energy neutrinos from cosmic ray interactions in the Local Bubble

M. Bouyahiaoui (APC, Paris), M. Kachelriess (Norwegian U. Sci. Tech.), D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.). Jun 22, 2020. 10 pp. Published in **Phys ReV D 101 (2020)** 12, 123023

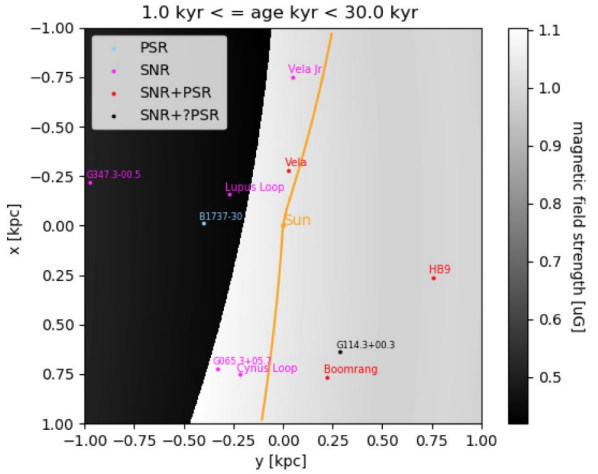
3 papers in journals + 2 archive preprints under consideration + JEM-EUSO

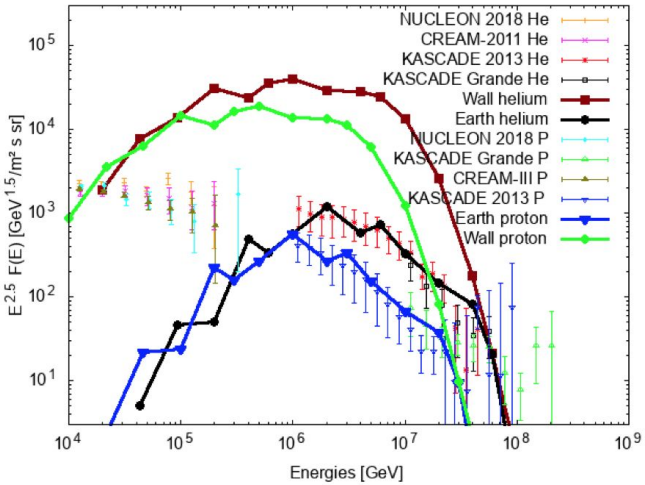
Cosmic rays

Knee is sharp feature in CR known from 1957. Nature is unknown. We explore possibility it is dominated by nearby SN Vela in framework of anisotropic diffusion scenario, taking into account Local Bubble and other local matter detected by Gaia. This Model explain knee in cosmic rays, IceCube neutrino excess in 1-100 TeV energies.

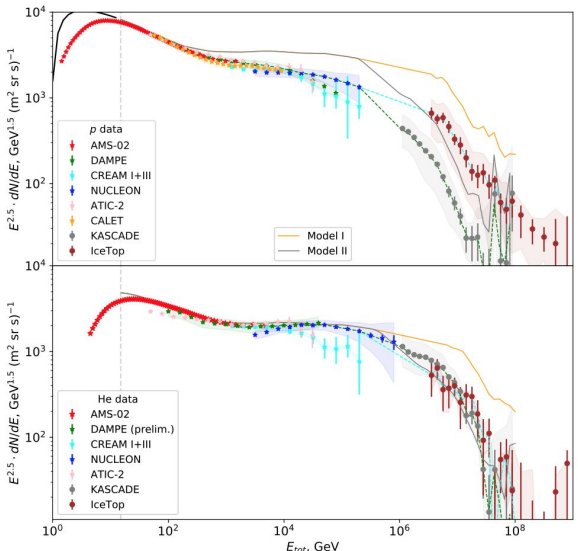
PhD Thesis of M.Bouvahiaoui 3 papers in journals + 2 conference proceedings

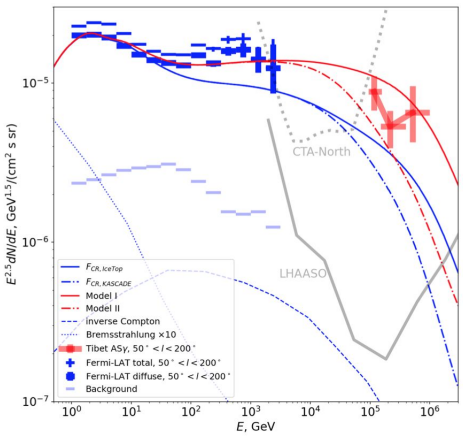
We are organizing writing new code for anisotropic cosmic ray diffusion at CR knee with 10 scientists from 5 countries





Phys ReV D 101 (2020) 12, 123023





Phys Rev D 104 (2021) 4, 043010

Multimessenger physics with high energy gamma-rays and neutrinos

Scientist responsible for project : A.Neronov

List of researchers in the project:

- **2 permanents [Name, %ETPT in projet, (status)]**
  - Andrei Neronov 35% (responsible)
  - Dmitri Semikoz 20% (co-responsible)
- **1 Doctorants [Name, %ETPT in projet, (status)]**
  - A.Korochkin, 50% gamma-ray astronomy

- **Important scientific results in project (2020-2021)**
- Tibet high galactic latitude data allowed to establish new limit on PeV gamma-rays which is order of magnitude better compared to old KASCADE limit and close to predictions of several models, restrict heavy DM
- We predicted neutrino flux for Galactic sources which have high 100 TeV flux
- Icecube data coincide with active radio loud blazars (like famous TXS), we constructed model which explain radio-neutrino connection
- LHAASO sensitivity to diffuse galactic gamma-rays was studied
- **Important publications (2020-2021)(3 max):**

New limit on high Galactic latitude PeV γ-ray flux from Tibet ASγ
A. Neronov (APC, Paris),D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.), Ye.Vovk (Tokyo U.) . Jul 14, 2021 10 pp. Published in ***Astron.Astrophys.* 653 (2021) L4**

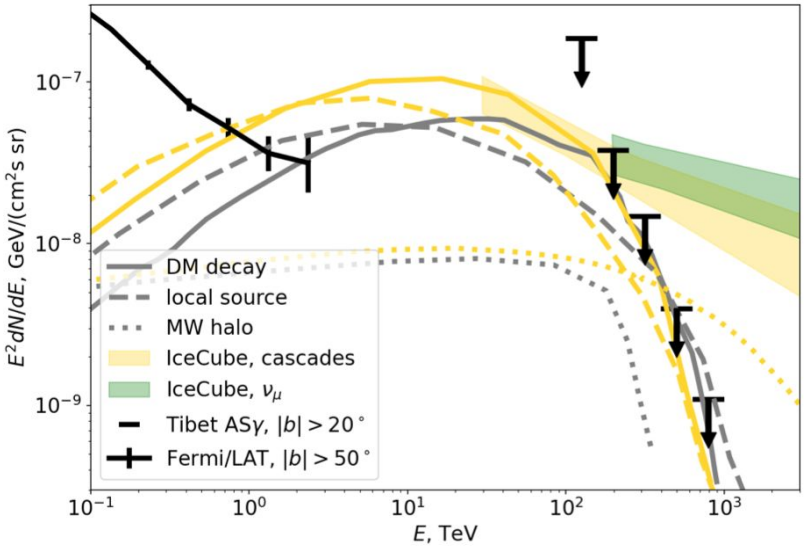
Neutrinos from the gamma-ray source eHWC J1825-134: Predictions for Km3 detectors
V. Niro(APC, Paris), L. Fusco(APC, Paris), A.Neronov (APC, Paris) S. Gabici(APC, Paris), D. Semikoz(APC, Paris)
Published in: *Phys.Rev.D* 104 (2021) 2, 023017

LHAASO telescope sensitivity to diffuse gamma-ray signals from the Galaxy
A. Neronov (APC, Paris & ISDC, Versoix), D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.). *Phys.Rev.D* 102 (2020) 4, 043025

4 papers in journals + 1 preprint + several experimental papers ANTARES,FACT,CTA

Multimessenger physics with high energy gamma-rays and neutrinos

A.Neronov, D.Semikoz

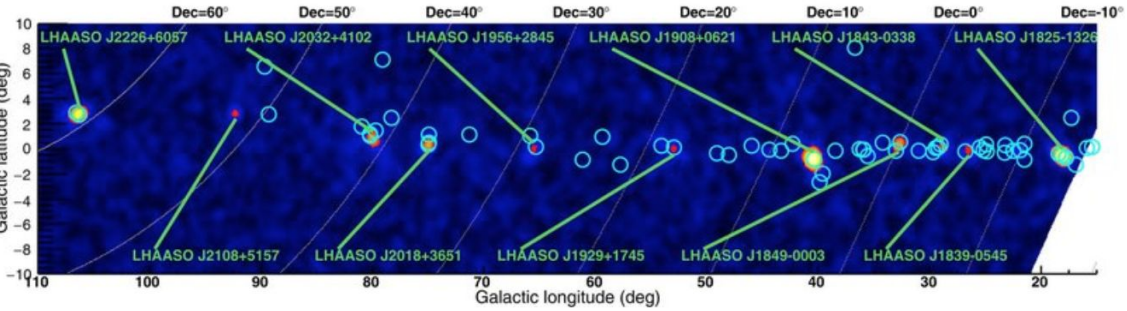


Tibet **ASγ** gamma-ray limit at high galactic latitude confirm extragalactic nature of high energy neutrinos above 300 TeV. It constrain parameter space heavy DM model and Local Bubble models

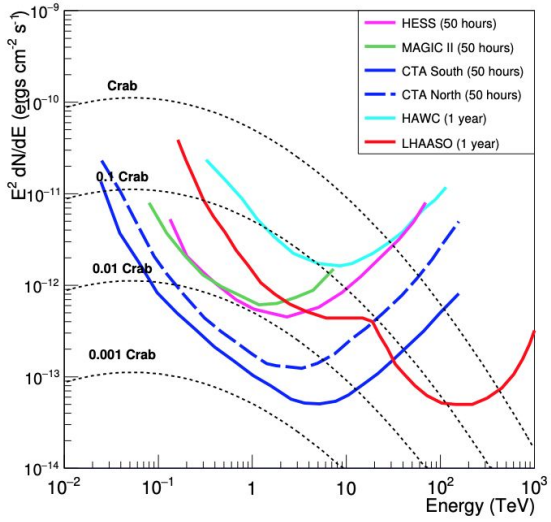
New limit on high Galactic latitude PeV γ-ray flux from Tibet ASγ
A. Neronov (APC, Paris),D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.), Ye.Vovk (Tokyo U.) . Jul 14, 2021
10 pp. Published in ***Astron.Astrophys.*** **653 (2021) L4**

Multimessenger physics with high energy gamma-rays and neutrinos

LHAASO - best to date cosmic ray / gamma-ray experiment in E=100TeV energy range



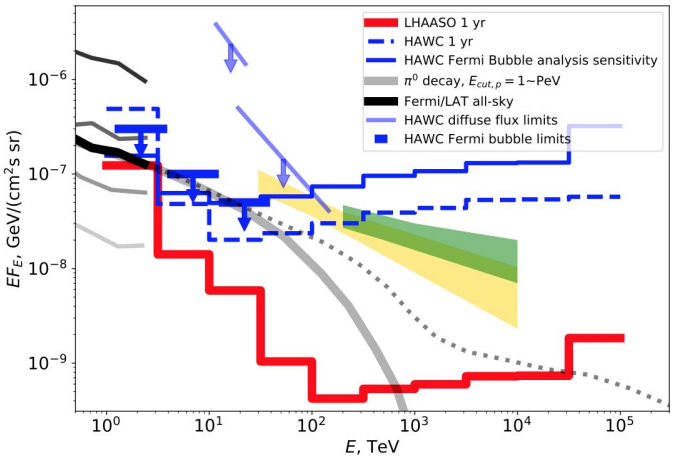
LHAASO Nature, May 2021



A.Neronov and D.Semikoz associated members of LHAASO since Nov 2021 for diffuse gamma-rays from Galaxy analysis

APC was invited as member Institute to LHAASO for data analysis/interpretation

Need approval from IN2P3



A.Neronov and D.Semikoz
Phys. Rev. D 102, 043025 (2020)

Primordial black holes from cosmological inflation

Jan 2020- Dec 2021

V.Vennin

Title: Primordial black holes from cosmological inflation

with Portsmouth U.

Description:

Since the first detection of gravitational waves associated to black-hole mergers by the LIGO collaboration in 2015, the interest in the physics of primordial black holes (PBHs) has kept increasing. They may indeed explain the existence of progenitors for these events, and possibly play a role in the dark matter.

PBHs are expected to form from large density perturbations produced during inflation. We propose to include the back reaction of these inhomogeneities during inflation, with the formalism of stochastic inflation.

Preliminary works have indeed shown that the inclusion of stochastic effects can completely change the range of masses and abundances expected for PBHs. We plan to address realistic models where multi-field effects and deviations from slow roll are expected.

The production of PBHs from instabilities during preheating, and the associated production of gravitational waves, will also be studied in the light of the prospects offered by future missions such as LISA.

Projet ANR New windows in Early Universe with multimessenger astrophysics (ANR 2020-2023)

cosmology, gravitational waves and gamma-ray astronomy

Scientist responsible for project : D.Semikoz PI, include APC and IAP, Paris

List of researchers in the project:

- **2 permanents [Name, %ETPT in projet, (status)]**
  - Chiara Caprini 20% (co-responsible)
  - Andrei Neronov 20% (co-responsible)
  - Dmitri Semikoz 40% (responsible)
- **2 Postdocs[Name, %ETPT in projet, (status)]**
  - Alberto Roper Pol, 100% production of GW and magnetic fields in cosmological models of phase transitions
  - Marius Ramsoy 100% 3-dimentional constraint similations of magnetic field in local Universe
- **1 Doctorants [Name, %ETPT in projet, (status)]**
  - A.Korochkin, 100% gamma-ray astronomy
- **Important scientific results in project (2020-2021)**
- NANOGrav signal explained by production from primordial MF. Same field needed or H0.
- New way to detect inflation MF by set of blazars in nearby Universe similar to set of pulsars in GW
- CTA can test strong MF
- **Important publications (2020-2021)(3 max):**

NANOGrav signal from magnetohydrodynamic turbulence at the QCD phase transition in the early Universe
A. Neronov (APC, Paris), Ch. Caprini (APC, Paris), A. Roper Pol (APC, Paris), D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.). **(Sep 29, 2020) *Phys.Rev.D* 103 (2021) 4, 041302**

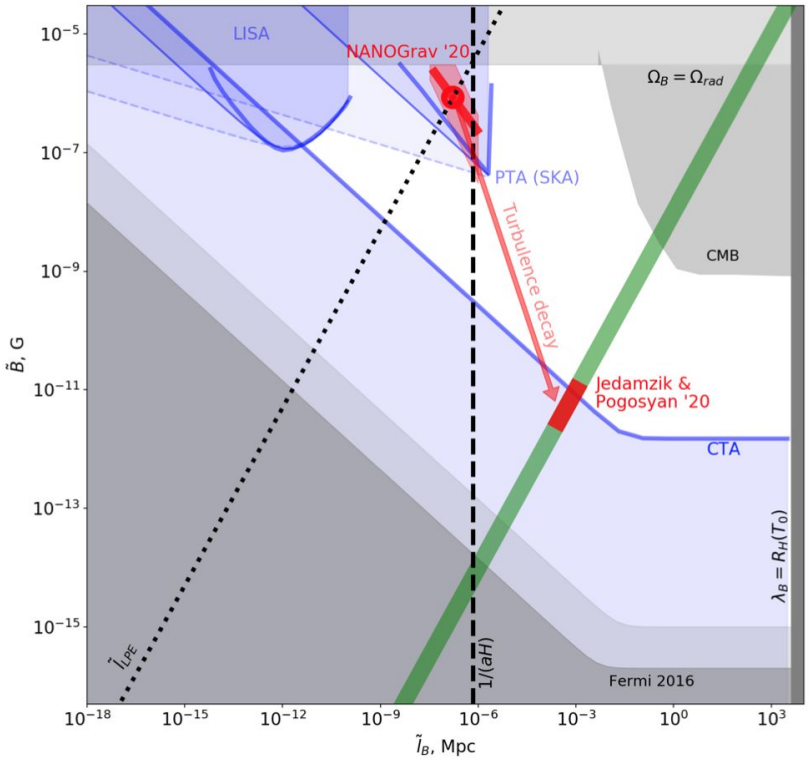
Detectability of large correlation length inflationary magnetic field with Cherenkov telesopes
Alexander Korochkin (APC, Paris and Moscow, INR), Andrii Neronov(APC, Paris and Ecole Polytechnique, Lausanne), Guilhem Lavaux (Paris, Inst. Astrophys. Marius Ramsoy (APC, Paris and Paris, Inst. Astrophys). Dmitri Semikoz (APC, Paris and Moscow Phys. Eng. Inst.) (Nov 19, 2021) 2111.10311 [astro-ph.HE] accepted JETP

Sensitivity reach of gamma-ray measurements for strong cosmological magnetic fields
Alexander Korochkin (APC, Paris and Moscow, INR), Andrii Neronov(APC, Paris and Ecole Polytechnique, Lausanne) Dmitri Semikoz (APC, Paris and Moscow Phys. Eng. Inst.) (Jul 28, 2020) Published in: *Astrophys.J.* 906 (2021) 2, 116

5 papers in journals + 2 preprints

New windows in Early Universe

Ch. Caprini, A. Neronov, D. Semikoz



Primordial MF can help to solve H0 problem, can be responsible for NANOGrav, can be detected by CTA in future.

Baryonic feedback from AGN is important for observations of large IGMF, connection to LSS studies

NANOGrav signal from magnetohydrodynamic turbulence at the QCD phase transition in the early Universe

A. Neronov (APC, Paris), Ch. Caprini (APC, Paris), A. Roper Pol (APC, Paris), D.V. Semikoz (APC, Paris & Moscow Phys. Eng. Inst.). **(Sep 29, 2020) *Phys.Rev.D* 103 (2021) 4, 041302**

Now we use local LSS data up to 200 Mpc. Next step we use LSS from SDDS in known directions, in future Euclid and LSST

- **Evolution de la composition de l'équipe (départs/arrivées permanents)**

Retirements University:
Jean-Pierre Gazeau (2018)
Jacques Renaud (2021)

Promotion University Paris:
F.Nitti MDC -> Prof. 2020

Retirement CNRS
Nathalie Deruelle (2020)
On leave to CERN Chiara Caprini

We plan to push for opening MdC on Paris U. and hire young CNRS researchers on activities of group

IN2P3 postdocs 4 propositions

Is any possibility to have 'theory' postdocs?

Demande de postdoc IN2P3 M.C.Volpe :

"Neutrinos and the discovery of the diffuse supernova neutrino background"

A new observational window is about to be opened with the much awaited discovery of the diffuse supernova neutrino background (DSNB) by the Super-Kamiokande+Gd experiment, currently taking data, the JUNO and Hyper-Kamiokande experiments (under construction). The DSNB will bring key information on the star formation rate, on failed supernovae and on fundamental neutrino and non-standard properties.

The work will focus both on the the investigation of fundamental physics that we will learn from the upcoming discovery of the diffuse supernova neutrino background, on non-standard neutrino properties and on novel flavor mechanisms, in relation with future supernova observations, r-process nucleosynthesis and kilonovae.

Description holographique de la matière dense de la QCD avec applications aux étoiles à neutrons

Demande de postdoc IN2P3 : E.Kiritsis and F.Nitti

La correspondance holographique est une approche qui permet de décrire une théorie de jauge fortement couplée en terme d'une théorie gravitationnelle dans un espace ayant des dimensions supplémentaires. Dans ce contexte, on peut obtenir des informations sur la théorie de jauge par un calcul relativement simple de relativité générale dans le modèle dual gravitationnel.

Le but de ce projet est d'utiliser la correspondance holographique pour modéliser la matière de la QCD à une très haute densité, où d'autres méthodes perturbatifs et nonperturbatifs (comme la QCD sur les réseaux) ne sont pas applicables. Les modèles développés seront connectés aux observations provenant, d' un côté, des expériences de collisions relativistes de ions lourdes et, de l'autre côté, de l'astrophysique.

En particulier, nous allons utiliser les modèles de QCD holographique pour décrire des états à très hautes densité baryonique comme ceux qui on trouve dans les étoiles à neutrons. À partir du modèle dual holographique, nous calculerons l'équation d'état ainsi que les coefficients de transport qui gouvernent les états hors équilibre, ce qui permettra de contraindre le modèle à travers le diagramme de phase masse-rayon et de connecter les résultats aux observations des signaux d'ondes gravitationnelles provenant de la fusion de système binaires d'étoiles à neutrons. Il sera souhaitable que le chercheur recruté ait une expérience dans le contexte de la correspondance holographie, ainsi qu'une bonne connaissance de la QCD. Ce projet permettra d'établir une collaboration entre le groupe théorie et le groupe gravitation de l'APC, et impliquera aussi des experts de l'équation d'état des étoiles à neutrons du LUTH.

Demande de postdoc IN2P3 A.Neronov and D.Semikoz (with V. Van Elewyck (neutrino)):

"Multi-messenger astronomy at PeV energy frontier"

We propose postdoc project between theory group and neutrino group on "astronomy at the PeV energy frontier", aimed at the study of Galactic multi-messenger sources, understanding of the origin of Galactic cosmic rays and clarification of the nature of the knee of cosmic ray spectrum. Within this project we plan to model and observe sources of the highest energy multi-PeV Galactic cosmic rays, model and observe diffuse multi-messenger emission generated by interactions of multi-PeV cosmic rays during their propagation through the interstellar medium, model and observe or constrain the signal from decaying super-heavy dark matter particles in the Galactic halo.

Demande de postdoc IN2P3 D.Langlois:

``Black hole perturbations in modified gravity”

Binary black hole mergers provide a novel and powerful probe to **test gravity** in the strong field regime. Of particular interest is the **ringdown phase**, during which the newly-formed black hole emits gravitational waves at specific frequencies corresponding to the so-called **quasinormal modes**. These modes strongly depend on the underlying theory of gravity and can thus be exploited to test GR and put constraints on modified gravity theories. Quasinormal modes are obtained from the equations of motion of the linear perturbations about the black hole solution, equations which can become quite involved in theories of modified gravity. We have thus developed a **systematic approach that extracts the asymptotic behaviour of perturbations at spatial infinity and near the horizon** directly from the equations of motion. The asymptotic behaviour gives physical insight about the modes and enables us to compute their frequencies numerically, as we have shown for particular non-rotating black hole solutions in the context of DHOST theories.

References:

D.Langlois, K. Noui and H. Roussille, ``Asymptotics of linear differential systems and application to quasi-normal modes of nonrotating black holes'', Phys. Rev. D 104, no.12, 124043 (2021); ``Black hole perturbations in modified gravity'', Phys. Rev. D 104, no.12, 124044 (2021); ``Linear perturbations of Einstein-Gauss-Bonnet black holes,''arXiv:2204.04107 [gr-qc],submitted to JCAP; ``On the effective metric of axial black hole perturbations in DHOST gravity'', arXiv:2205.07746 [gr-qc], submitted to JCAP.

- **Responsable scientifique de l'équipe : XXX**

- **Budget annuel soutien équipe (hors budget projets) : XXX**

Liste des chercheurs de l'équipe :

- **X permanents [prénom, nom, qualité (émérite, PR, DR, MCF, CR, IR-chercheur), HDR]**
  - Nom 1
  - Nom 2

- **X post-doctorants [prénom, nom, indiquer projet, origine financement, date de début, date de fin]**
  - Nom 1
  - Nom 2

- **X doctorants [prénom, nom, indiquer sujet, origine financement, directeur, codirection, cotutelle, date de début, date de fin]**
  - Nom 1
  - Nom 2