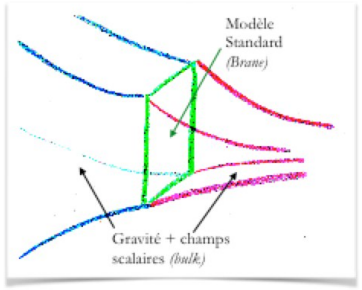
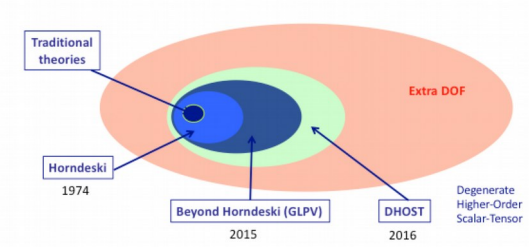
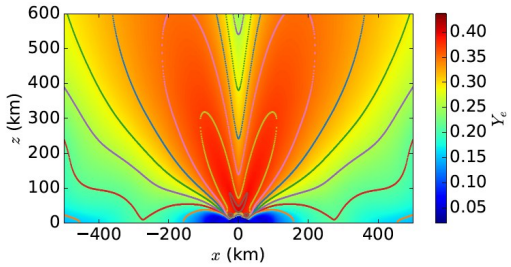
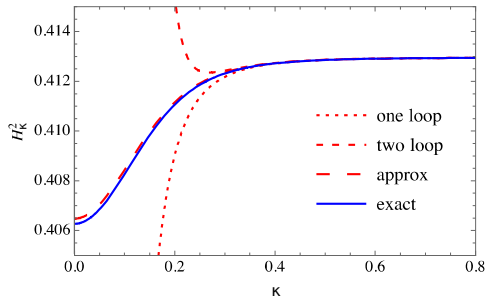
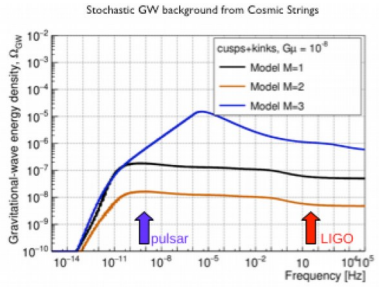


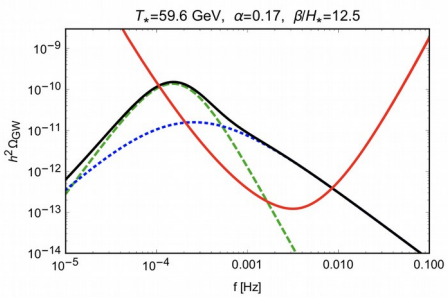




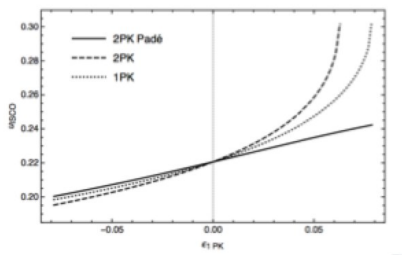
APC Theory Group

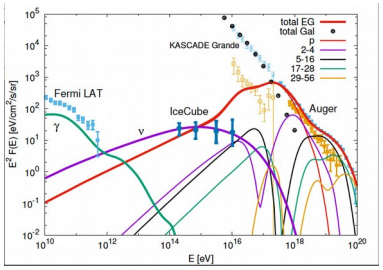


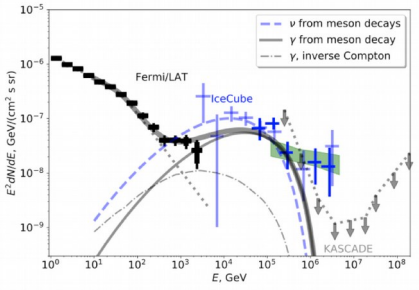




Dmitri Semikoz







Composition de l'équipe de recherche

- Responsable scientifique de l'équipe :
- Head of group Dmitri Semikoz, vice-head Eric Huguet

Liste des chercheurs de l'équipe :

- **12+3 permanents [Name, Status (Emeritus, PR, DR, MCF, CR, IR-Chercheur), (HDR)**
- **CNRS**

- Gwenael Giacinti DR
- Kiritsis Elias DR
- Langlois David DR
- Lemoine Martin DR
- Luca Santoni CR
- Semikoz Dmitri DR
- Volpe Cristina DR

- **University Paris 7**

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

- **Emeritus**

- Gazeau Jean-Pierre PR
- Lachièze-Rey Marc. DR
- Renaud Jacques PR

Composition de l’équipe de recherche

4 postdocs [prénom, nom, indiquer sujet, origine financement, directeur, codirection, cotutelle, date de début, date de fin]

416A

Christoph Toennis	ANR LACTEL	A.Neronov	Feb 2024 –April 2026
Sophie Aerdker	German grant	M.Lemoine	Oct 2025 – April 2026+ ext
Alessandro Longo	ANR Gravity	L.Santoni	Oct 2025-Oct 2028
A.Korochkin.	ANR COSMAG.	D.Semikoz	Sept 2026-Sept 2028

473A

Andrea Olzi	ANR XtremDyn	F.Nitti	Jan 2026 – Jan 2028

----- no room ---

+ 4 postdocs next year

NN	LabEx UnivEarthS, HERMES	A.Neronov	Sept 2026-Sept 2028
NN	LabEx UnivEarthS, HERMES	D.Langlois	Sept 2026-Sept 2028

Composition de l’équipe de recherche

- 8 doctorants [prénom, nom, indiquer sujet, origine financement, directeur, codirection, cotutelle, date de début, date de fin]

- Apostolides Thomas Holography E.Kiritsis Sept 2024-Sept 2027
- Betrand Theodore Holography F.Nitti Oct 2024-Oct 2027
- Blunier Jeffrey Cosmological magnetic fields A.Neronov Dec 2024-Dec 2027
- Combaluzier-Szteinsznaider Oscar Gravity L.Santoni Oct 2024-Oct 2027
- Fourquet Philippe Quantum Field Theory E.Huguet Sep 2022 – June 2028
- Ligout Etienne Cosmology D.Langlois Sept 2024-Sept 2027
- Raymond Jean-Loup Holography F.Nitti Sept 2025-Sept 2028
- Zhu Zanfeng Diffuse emission Galaxy D. Semikoz May 2025 – May 2028

Accociated scientists

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

- Associated scientists:

- K.Noui (Orsay) 1 day/week
- F. Vernizzi (Saclay) 1 day/week
- D.Steer (ENS) 1 day/week
- U.Reinosa (Polytechnique) 1 day/week
- Julien Grain (IAS) 1 day/week
- Pierre Cristofari (Obs. Paris)
- Pierrick Martin (IRAP, Toulouse)
- Brando Bellacini (Saclay)
- Christos Charmousis (Orsay)
- Blaise Gouteraux (Ecole Polytechnique)
- Monica Guica (Saclay)
- Herve Bergeron (Orsay)
- Chiara Caprini (ENS)

Long term visitors

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

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

Prof. Morgan Le Delliou (China) July 1 2026 to the end of October 2026.

- 1-3 months visitors and 30+ short term visitors per year

Prof. M.Kachelriess (Trondheim U) Nov 26 -Dec 24 2026

Prof. Foteini Oikonomou (NTNU, Norway) June 15 2026 – July 15 2026

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)

•**1 postdoc [Name, %ETPT in projet, (status)]**

• Andrea Olz 100% research

•

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

• Theodore Betrand 100% research

• Thomas Apostolides 100% research

•**Important scientific results in project (2020-2025)**

•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 (2020-2025)(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

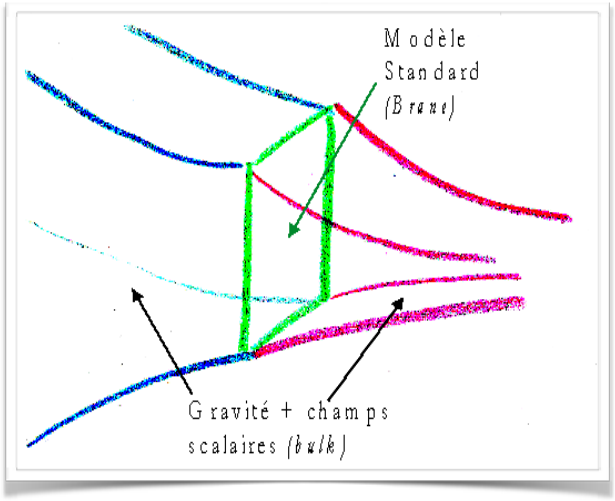
Projet #1 String theory and Holography

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)]**
•Eric Huguet 50%
•Jihad Mourad 50%
•Jean-Pierre Gazeau 100%
• Jacques Renaud 100%
•Marc Lachieze-Rey 100%

•**PhD Students**
P. Fourquet

•**Important scientific results in project (2022-2023)**
•Covariant integral quantization of various classical systems.
•Restriction of Laplace operators on one-forms..
•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 (2022-2023)(3 max) :**

Restriction of Laplace operators on one-forms : From Rn+1, Rn+2 ambiant spaces to embedded (A)dSn submanifolds.,
E. Huguet, J. Queva and J. Renaud, J.~Math.~Phys. 63, 07230 (2022).

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 #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)

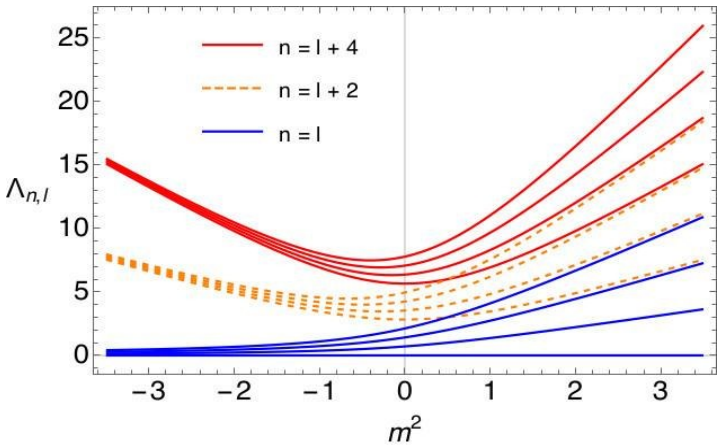
7 papers in journals published + 1 conference proceedings

QFT in curved spacetime and QCD

J. Serreau, G. Moreau

Quantum field theory in curved spacetime

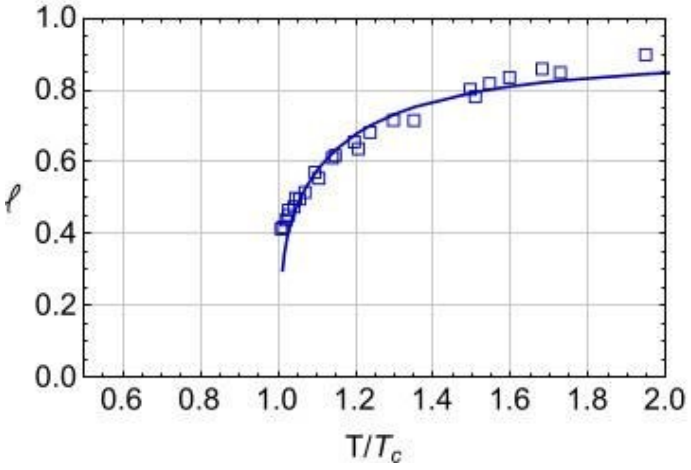
- development of nonperturbative QFT techniques to compute the effect of gravitationally enhanced quantum fluctuations during inflation
- analytical expressions of correlation lengths/times relevant for inflationary physics



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

David Langlois & Karim Noui (associé)

Doctorant: Etienne Ligout

Topics

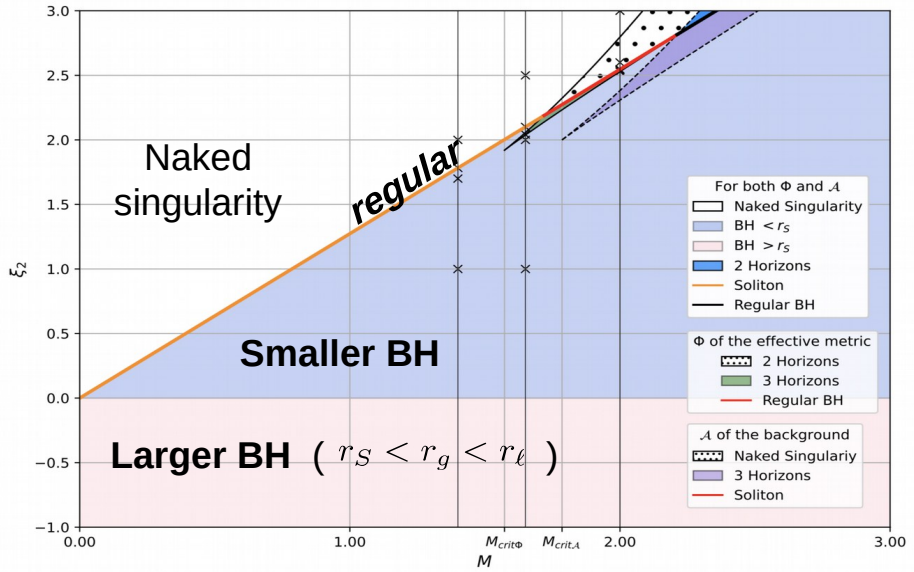
- perturbations and quasi-normal modes of black holes in DHOST theories
- tests of modified gravity theories with gravitational waves

Recent publications :

Black hole perturbations in modified gravity
David Langlois, Karim Noui, Hugo Roussille ,
Phys.Rev.D 104 (2021) 12, 124044

On the effective metric of axial black hole perturbations in DHOST gravity
David Langlois, Karim Noui, Hugo Roussille ,
JCAP (2022) 08, 040

Axial perturbations of black hole with primary scalar hair
Christos Charmousis, Simon Iteanu, David Langlois, Karim Noui,
JCAP (2025) 05,102



Deformation of Schwarzschild

$$\mathcal{A}(r) = 1 - \frac{2M}{r} + \xi_2 \left(\frac{\pi/2 - \arctan r}{r} + \frac{1}{1+r^2} \right)$$

« Phase diagram »
of the background and effective metrics

Projet #5 Equivalent formulations of General Relativity

Eric 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 (2022-2023)**
  - Reformulation of the Teleparallel Equivalent of General Relativity (TEGR) using a Cartan connection.
- **Important publications :**
- **``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).

2 papers in journals published

Projet #7 Gravity and Cosmology

Scientist responsible for project : Luca Santoni

List of researchers in the project:

- **1 permanent** **[ANR JCJC grant (3 years) "*TydalSymm*"]**
- Luca Santoni 100% (responsable)

- **1 postdocs**
- Alessandro Longo 100% research, starting in October 2025 until October 2028

- **1 PhD student:** **[CNRS grant - Campagne PhD joint program, with D. Langlois (APC) and A. Joyce (UChicago)]**
- Oscar Combaluzier-Szteinsznaider 100% research, from October 2024 to September 2027

Important scientific results in project (2023-2025)

- Study of nonlinear tidal deformability of compact objects
- Symmetries of black hole perturbations
- Model of dissipative dynamics and particle production in cosmic inflation
- Generalization of no-hair theorem for rotating black holes in scalar-tensor theories
- Analysis of the connection between nonzero density and spontaneous symmetry breaking in interacting scalar theories

Important publications (2023-2025) (3 max) :

- Oscar Combaluzier-Szteinsznaider, Lam Hui, Luca Santoni, Adam R. Solomon, Sam S.C. Wong, "*Symmetries of Vanishing Nonlinear Love Numbers of Schwarzschild Black Holes*", JHEP 03 (2025) 124, e-Print: 2410.10952 [gr-qc]
- Simon Iteanu, Massimiliano Maria Riva, Luca Santoni, Nikola Savic and Filippo Vernizzi, "*Vanishing of Quadratic Love Numbers of Schwarzschild Black Holes*", JHEP 02 (2025) 174, e-Print: 2410.03542 [gr-qc]
- Paolo Creminelli, Soubhik Kumar, Borna Salehian and Luca Santoni, "*Dissipative inflation via scalar production*", JCAP 08 (2023) 076 • e-Print: 2305.07695 [hep-th]

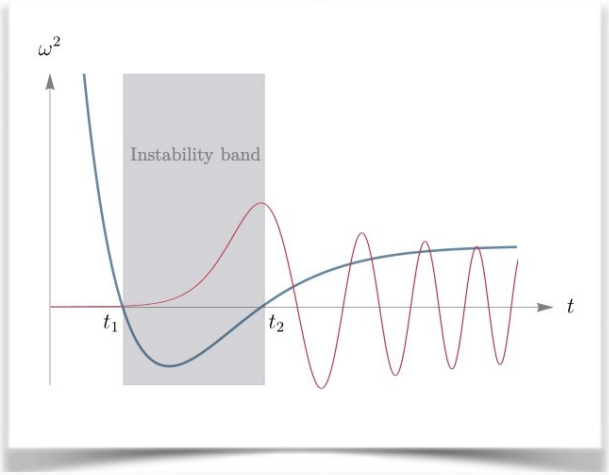
Dissipative Inflation via Scalar Production

with Paolo Creminelli, Soubhik Kumar and Borna Salehian

The model. The inflaton ϕ couples to a complex scalar field χ charged under a (softly-broken) global U(1) symmetry:

$$S = \int \mathrm{d}^4x\sqrt{-g}\left[\frac{1}{2}M_{\rm Pl}^2R - \frac{1}{2}(\partial\phi)^2 - V(\phi) - |\partial\chi|^2 + M^2|\chi|^2 - i\frac{\partial_\mu\phi}{f}\left(\chi\partial^\mu\chi^* - \chi^*\partial^\mu\chi\right) - \frac{1}{2}m^2(\chi^2+\chi^{*2})\right]$$

The coupling to ϕ is responsible for triggering an instability in the χ sector for a finite range of momenta. The copious production of χ modes extracts energy from the inflaton sector and induces an extra friction in the background and inflaton dynamics.

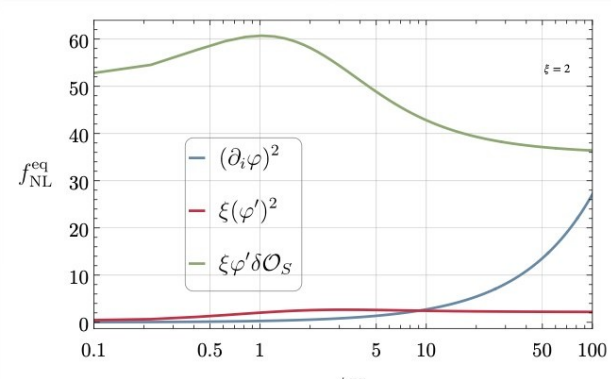


If $H \ll m \ll M \ll f$, dissipation takes place on parametrically small scales, allowing for an analytical description of the dynamics.

The model is the first *robust* explicit example of dissipative inflation which admits a local description.

By virtue of the central limit theorem and the large occupation on short scales, the statistics of the perturbations is naturally close to Gaussian.

The size of $f_{\rm NL}^{\rm eq}$ is always large provided that cosmological perturbations are sourced by χ; the size is indeed at reach of current and upcoming non-Gaussianity searches.



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% (responsible)
  - **1 PhD student : [Name, %ETPT in projet, (status)]**
- Pilar Ivanez-Ballesteros, Master 2-PHE and ETH Zürich, "The diffuse supernova neutrino background and its potential¨,

  PhD Thesis (2022-2025)
- **2 Master students:** Noah Roux (7 months) et Clément Erhardt (6 months), Master 2-PHE and ETH Zürich (2025)

Important scientific results in project (2022-2025)

- We showed that if neutrinos can decay non-radiatively, this can challenge the interpretation of the upcoming diffuse supernova neutrino background (DSNB) observations by the Super-Kamiokande+Gd, DUNE, JUNO and Hyper-Kamiokande detectors.
- We provided a unique review on neutrinos from dense environments and future observations of core-collapse supernovae, the DSNB and **kilonovae.**
- We obtained a competitive limit on neutrino non-radiative decay and on neutrino-Majoron couplings using the 24 antinue events detected in Kamiokande, IMB and Baksan from SN1987A.

Important publications (2022-2025)(3 max):

P. Ivanez-Ballesteros and M. C. Volpe, "SN1987A and neutrino non-radiative decay » *Phys.Lett.B* 847 (2023) 13825, e-Print: 2307.03549

S. Abbar and M.C. Volpe, »

Using Bayesian inference to distinguish neutrino flavor conversion scenarios via a prospective supernova neutrino signal

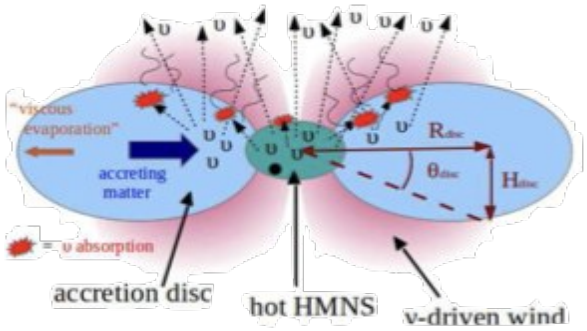
», *Phys.Rev.D* 111 (2025) 8, 083005, e-Print: 2401.10851 [astro-ph.HE]

M. C. Volpe, «Neutrinos from dense: flavor mechanisms, theoretical approaches, observations, new directions», Review of Modern Physics, e-Print: 2301.11814 [hep-ph].

M. C. Volpe (period 2020-2025), 7 published articles, 2 articles in preparation, 1 article submitted, 1 (invited) Review

Neutrino physics and astrophysics

M.C.Volpe, P. Ivanez-Ballesteros, N. Roux, C. Erhadht



neutron star mergers

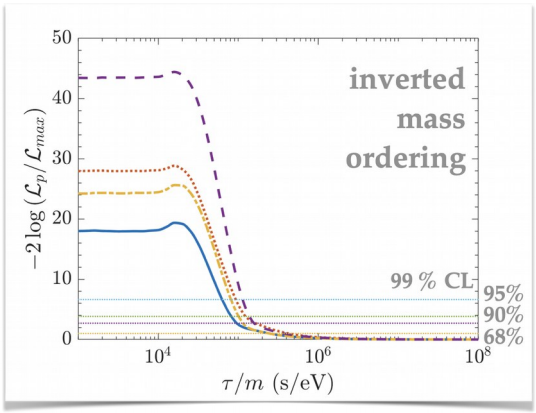
- Neutrinos modify their flavor while travelling. In dense environments new flavor mechanisms are being uncovered.
- Flavor evolution can impact the neutron richness and nucleosynthesis of heavy elements - r-process - in core-collapse supernovae and binary neutron star merger remnants.

Supernova e

M. C. Volpe, *Rev.Mod.Phys.* 96 (2024) 2, 025004, e-Print: 2301.11814

Neutrino non-radiative decay and SN1987A

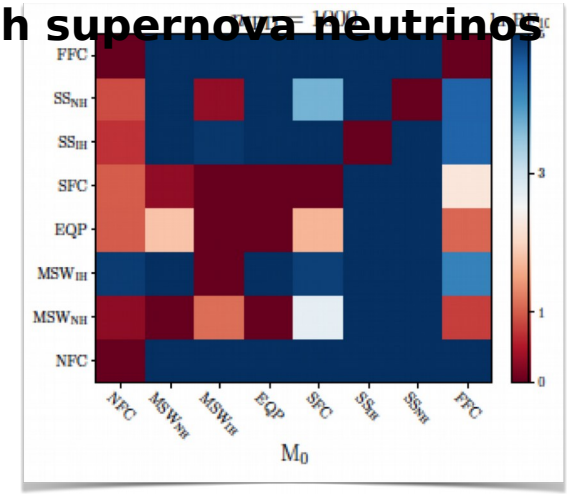
A likelihood analysis (7D) of the 24 SN1987 neutrino events in Kamiokande, IMB and Baksan, with non-radiative decay yields



Ivanez-Ballesteros, Volpe, PLB 2023, 2307.03549

$\tau/m > 1.2 \times 10^5$ (90 % C . L.) for ν_1 and ν_2 (IO)

Discriminating flavor mechanisms with supernova neutrinos



Abbar and Volpe, 2401.10851

> Predictions for future observations of supernova neutrinos and the diffuse supernova neutrino background 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)
    - Martin Lemoine 30% (co-responsible)
    - Gwenael Giacinti 30% (co-responsable)
    - Andrei Neronov 10% (co-responsible)

- **Important scientific results in project (2023-2025)**
- New model of cosmic ray propagation in Galaxy was developed
- Local cosmic ray spectrum compared to averaged one in the Galaxy: knee is the local feature
- Developed an effective theory of stochastic acceleration (“generalized Fermi”)

- **Important publications (2023-2025)(3 max) :**

Model of Cosmic Ray Propagation in the Milky Way at the Knee
G.Giacinti (Shanhai U.) and D.Semikoz (APC, Paris), [arXiv:2305.10251 [astro-ph.HE]].

Energy dependence of the knee in the cosmic-ray spectrum across the Milky Way
C. Prevotat, M. Kachelriess, S. Koldobskiy, A. Neronov, D. Semikoz
Phys.Rev.D 110 (2024) 10, 103035

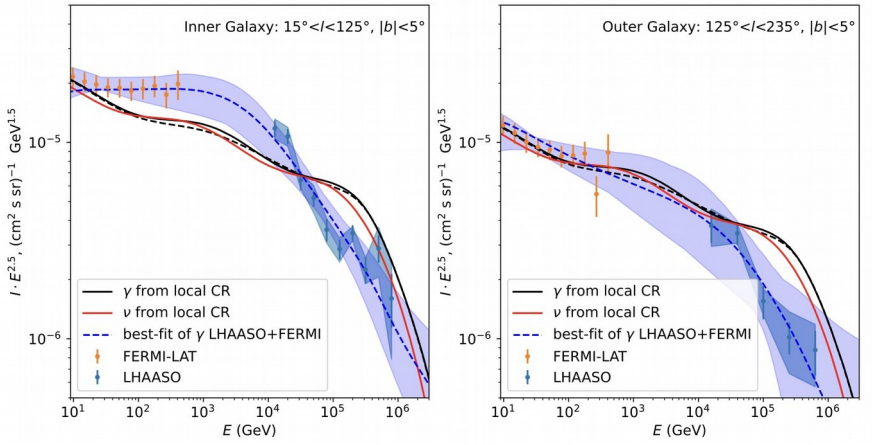
Effective theory for stochastic particle acceleration, with application to magnetized turbulence

M. Lemoine [Phys. Rev. E, in press (2025), arXiv:2501.19136]

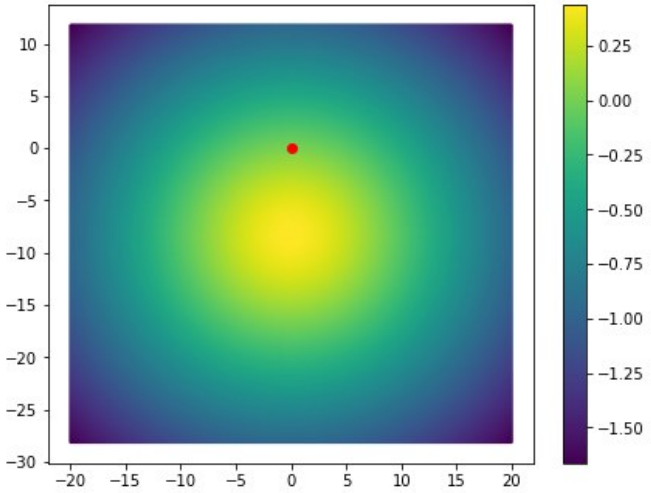
Cosmic rays

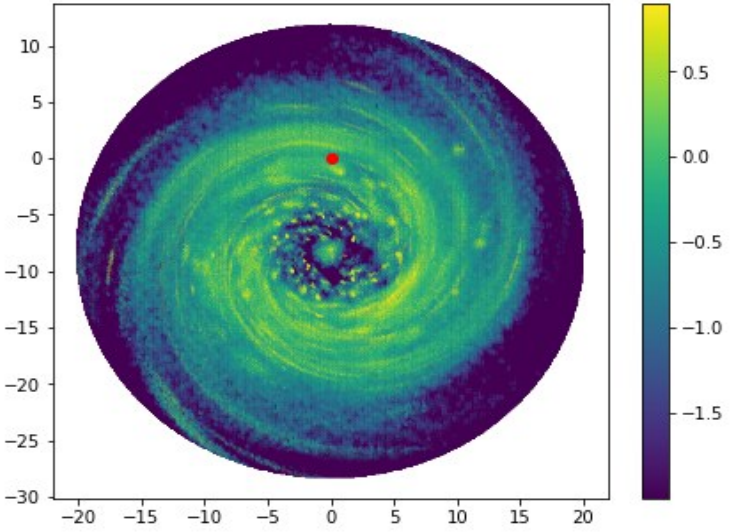
We are organizing writing new code for anisotropic cosmic ray diffusion at CR knee with 10 scientists from 5 countries involved

First results very promissing to explain gamma-ray data at E> 1 TeV



C. Prevotat, M. Kachelriess, S. Koldobskiy, A. Neronov, D. Semikoz
Phys.Rev.D 110 (2024) 10, 103035
• e-Print: 2407.11911





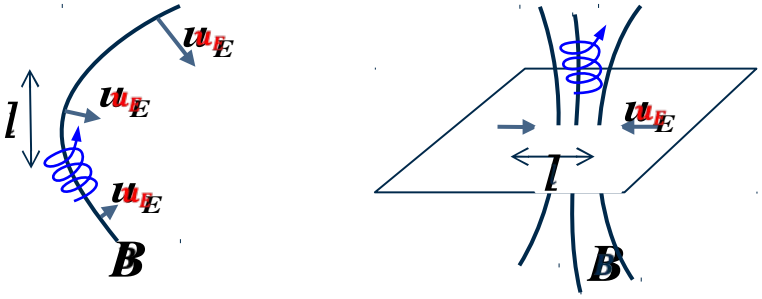
G.Giacinti & D.Semikoz, arXiv:2305.10251

Recent research activity: M. Lemoine

Theory of particle acceleration in extreme environments:

→ an effective theory of stochastic acceleration (“generalized Fermi”) combining GR tools and turbulence physics

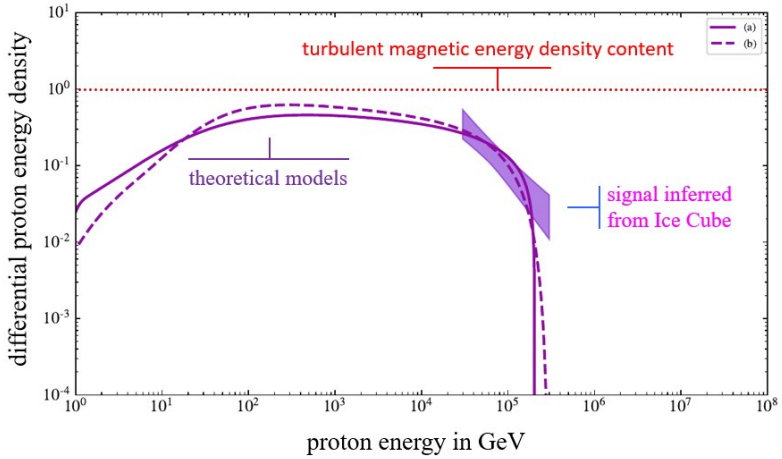
M. Lemoine [Phys. Rev. **E**, in press (2025), arXiv:2501.19136]



Multimessenger astrophysics:

→ a theoretical model of proton acceleration to VHE in the turbulent corona of AGN black holes, connection to neutrinos from NGC1068

M. Lemoine, F. Rieger [A&A **697**, A124 (2025)]



ANR proposal (2025): HENBoS (High Energy Neutrinos from massive Black hOle Systems)

PRME: single team at APC (groups: Théorie, AHE and Particules) – D. Allard, J. Aublin, B. Baret, F. Casse, M. Cerutti, S. Gabici, M. Lemoine (PI), A. Neronov, E. Parizot, D. Semikoz, R. Terrier, P. Varnière

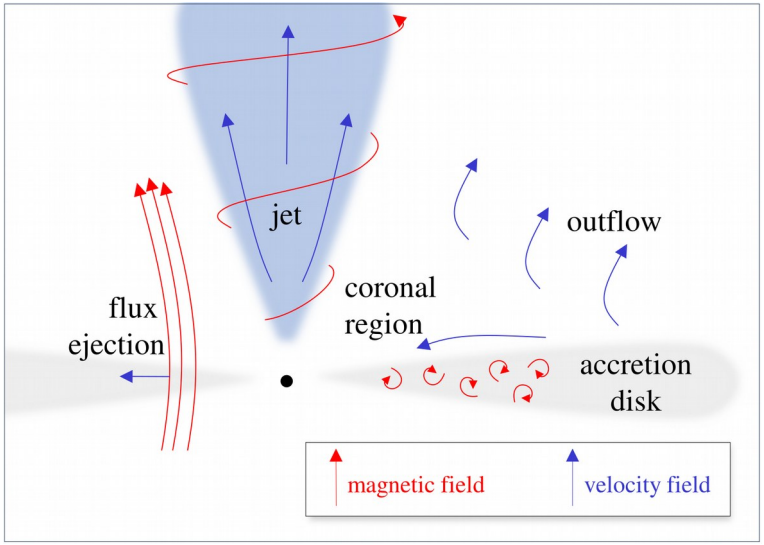
Funded personnel: 1 post-doc (3yrs) + 1 PhD

Rationale: develop a self-consistent, first-principles view of massive black hole environments as sources of VHE particles (cosmic rays, photons and neutrinos), by combining:

1. theoretical expertise in particle acceleration

2. numerical simulations (GRMHD, GRMHD-PIC, PIC)

3. expertise in phenomenology and detection of VHE multi-messengers.



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)
  - Gwenael Giacinti 20% (co-responsable)
- **1 Doctorants [Name, %ETPT in projet, (status)]**
  - T.Boyer, 100% cosmological magnetic field models
  - J.Blunnier 100% cosmological magnetic field observations from gamma-ray astronomy
  - Z.Zhu 50 % multi-messenger signal from Galaxy
- **Stagers[Name, %ETPT in projet, (status)]**
  - M.Kleymanov 4 months stage M1 Model of Micro-quasar V4641

- **Important scientific results in project (2021-2025)**
- We found 5 sigma signal from Seyfert galaxies in IceCube 10 years data: first class of sources in neutrinos
- First complete at the flux limit 1.3e-12 erg/cm2s catalog of gamma-ray sources in VHE band from Fermi LAT
  Un addition to 71 known sources 204 new: 53 - 5 sigma , 57 -4 sigma 94 - 3 sigma. CTA work for 5 years
- We put constraint from GRB 221009A on cosmological magnetic field. This is first constraint on cosmological magnetic field from GRB

- **Important publications (2021-2025)(3 max):**

Neutrino signal from Seyfert galaxies
A.~Neronov, D.~Savchenko and D.~V.~Semikoz, [arXiv:2306.09018 [astro-ph.HE]].

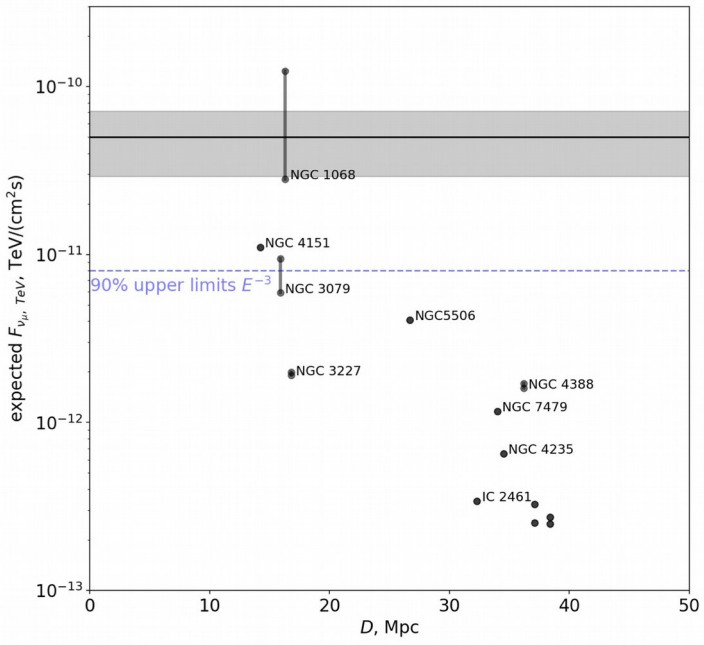
Catalog of very-high-energy emitting active galactic nuclei at high Galactic latitudes
Neronov, A. and Semikoz, D. [arXiv:2506.08496 [astro-ph.HE]].

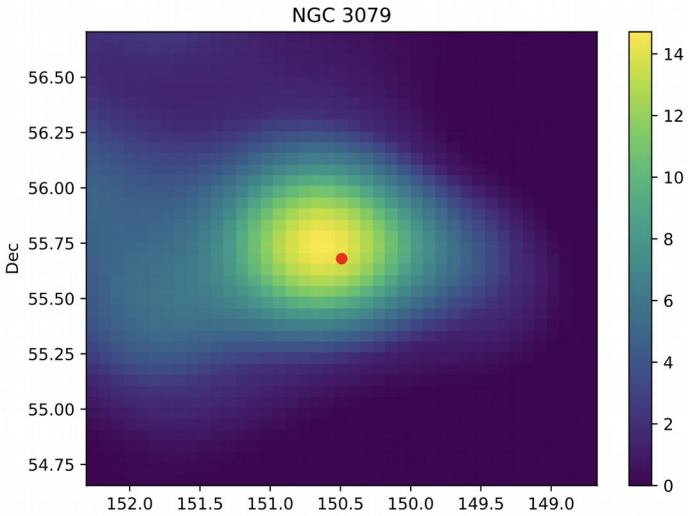
Energy dependence of the knee in the cosmic-ray spectrum across the Milky Way

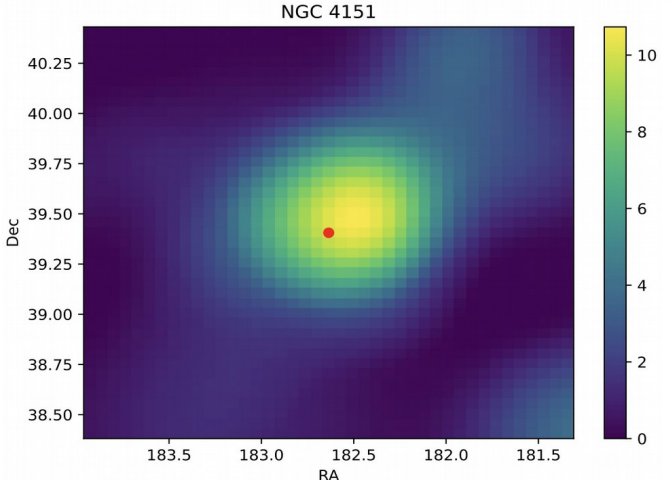
Multimessenger physics with high energy gamma-rays and neutrinos

Discovery of first population of astrophysical neutrino sources

A.Neronov, D.Savchenko and D.Semikoz (APC, Paris)







NGC 3079 and NGC 4151 are only Sources except NGC 1068 should be visible In 10 years of IceCube. BOTH are detected above 3 sigma.

Probability that both are by chance is 3e-7

- ***Phys.Rev.Lett.* 132 (2024) 10, 101002 [arXiv:2306.09018 [astro-ph.HE]].**