Marco CIRELLI

Date of Birth: June 20th, 1975
Place of Birth: Milano, Italy
Citizenship: Italian

Curriculum Vitae

Present position(s) and address:

from 10.2009 **CERN Fellow** at CERN Theory Division

PH-TH, Case C01600, CERN
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and

from 10.2007 **CNRS Researcher** (CR2) in Theoretical Physics
at the Institut de Physique Théorique of **CEA-Saclay**
Gif-sur-Yvette, France

Research Interests:

Astroparticle - Physics beyond the Standard Model - Cosmology
Dark Matter (models, direct and indirect searches, colliders)
Neutrinos (phenomenology, sterile neutrinos, neutrino cosmology, supernova)

Education and Past Employment:

10.2006 – 10.2007 **Post-Doc**, Institut de Physique Théorique at **CEA-Saclay**, France
awarded INFN postdoc fellowship, *first place - 97.5/100*

09.2003 – 09.2006 **Post-Doc**, Physics Dept., **Yale University**, New Haven, CT, USA
Particle Theory group (Prof. Thomas Appelquist)

17.04.2004 **Ph.D. in Physics** from **Scuola Normale Superiore**:
70/70 magna cum laude
Thesis: "Sterile neutrinos in 4D and 5D in supernovæ and the cosmo"
Advisors: R. Barbieri (Scuola Normale Superiore, Pisa),
A. Romanino (Scuola Normale Superiore, Pisa and CERN)
Board of external referees: A.Yu. Smirnov (ICTP, Trieste) and
A. Dolgov (INFN, Ferrara).

06 – 07.2003 Short Term Visitor at CERN Theory Division, Geneva, Switzerland
supported by Scuola Normale studentship

2001 – 2003 Ph.D. Student at Scuola Normale Superiore, Pisa, Italy
Research Interest: High Energy Physics, Extra dimensions, Neutrino Physics
Key courses: Elementary Particle Theory (R. Barbieri) - Cosmology (A. Riotto) - Critical Phenomena (S. Caracciolo) - Monopoles (V. Zakharov) - Non Perturbative aspects in Quantum Field Theory (F. Strocchi) - String Theory (M. Porrati) - High Energy Astrophysics (M. Vietri)

11.07.2000 **Laurea in Physics** from **Milano University**:
110/110 magna cum laude
Thesis: "Soft Gluon Resummation in Drell-Yan processes in QCD"
Advisors: G. Marchesini (now Milano-Bicocca University, Italy)
P. Nason (now INFN, Milano-Bicocca, Italy)

1994 – 1999 Undergraduate studies in Physics, Milano University
Exams average: *29.8/30*

Professional Activities:

▷ Grants and Grant Administration:
- one postdoctoral recruitment funded by *Physique des 2 Infinis* Consortium (100 K€), 2008–2010, with IAP
- 'scientist in charge' of the Saclay node of the European RTN Network *UniverseNet*, from 2008 (main coordinator S. Sarkar)

▷ Supervision of Students and Post-docs:
- post-doctoral appointment of Fabio Iocco (with IAP), from 2008
- PhD of Paolo Panci (jointly with L'Aquila University), from 2009
- 'mentoring' of Andrzej Hryczuk, within the *UniverseNet* network, from 2009
- Master research stage of Carolin Bräuninger (Tübingen University), 2008–2009
- PhD research project of Yi-Zen Chu (Yale University), 2005–2006
- (member of PhD committee: Gilles Vertongen at ULB Bruxelles, September 2009)

▷ Conference Organization:
- ICHEP 2010 "International Conference on High Energy Physics",
  Paris, July 2010 – member of the scientific and local committees
- PONT d'Avignon 2008 "Progress on Old and New Themes in cosmology",
  Avignon, April 2008 – with G. Servant and Ph. Brax

▷ Meeting Series Organization:
- french GDR Neutrino
  from 2008 – theory coordinator with S. Lavignac
- Rencontres IPhT/SPP, regular tri-annual meetings theorists ↔ experimentalists in particle physics and cosmology at Saclay
  2008–2009 – organizer with E. Mazzucato
- mini-workshops at IPhT on the Physics of ElectroWeak Symmetry Breaking and LHC
  2008–2009 – local organization

▷ Seminar Organization:
- Particle and Cosmology seminar series, IPhT CEA/Saclay, 2007–2009
- High Energy Theory seminar series, Yale University, 2004–2005

▷ Grant Reviewer:
- for the ERC (European Research Council), 2009
- for the NSERC (Natural Science and Engineering Research Council) of Canada, 2008

▷ Journal Referee:
- Physical Review Letters, Nuclear Physics B, Physics Letters B, JHEP, JCAP, Physical Review D, Progress of Theoretical Physics (since 2004)

▷ Membership in research networks:
- *UniverseNet* European Research and Training Network (coordinator S. Sarkar)
- *UniLHC* European Research and Training Network (coordinator I. Antoniadis)
- *Phys@Col&Cos* Agence Nationale de la Recherche (ANR) grant (coordinators C. Savoy)
- *DarkPhys* ANR grant (coordinators G. Servant et P. Brax)
- French *Groupement de Recherche* (GDR) Neutrinos

▷ Memberships:
- Société Française de Physique
- American Physical Society
- Associazione Alunni Scuola Normale Superiore

Languages:

Italian (native), English, French.

List of Publications:

The list includes Conference Proceedings, only if published and containing original material.
Other non-published (refereed and non-refereed) works can be found on my personal webpage.

22. M. Cirelli, F. Iocco, P. Panci
"Constraints on Dark Matter annihilations from reionization and heating of the intergalactic gas"
arXiv:0907.0719 [astro-ph.CO], in press on JCAP.

21. M. Cirelli, P. Panci
"Inverse Compton constraints on the Dark Matter e+e- excesses"
Nucl. Phys. B **821** (2009) 399-416, arXiv:0904.3830 [astro-ph.CO].

20. C. B. Braeuninger, M. Cirelli
"Anti-deuterons from heavy Dark Matter"
Phys. Lett. B **678** (2009) 20-31, arXiv:0904.1165 [hep-ph].

19. M. Cirelli, A. Strumia
"Minimal Dark Matter: Model and results"
arXiv:0903.3381 [hep-ph], invited review for the New Journal of Physics.

18. G. Bertone, M. Cirelli, A. Strumia, M. Taoso
"Gamma-ray and radio tests of the e+e- excess from DM annihilations"
JCAP 03 (2009) 009, arXiv:0811.3744 [hep-ph].

17. M. Cirelli, M. Kadastik, M. Raidal, A. Strumia
"Model-independent implications of the $e^{\pm}, \bar{p}$ cosmic ray spectra on properties of Dark Matter"
Nucl. Phys. B **813** (2009) 1-21, arXiv:0809.2409 [hep-ph].

16. M. Cirelli, A. Strumia
"Minimal Dark Matter predictions and the PAMELA positron excess"
arXiv:0808.3867[astro-ph].

15. M. Cirelli, R. Franceschini, A. Strumia
"Minimal Dark Matter predictions for galactic positrons, anti-protons, photons"
Nucl. Phys. B **800** (2008) 204-220, arXiv:0802.3378[hep-ph].

14. M. Cirelli, A. Strumia, M. Tamburini
"Cosmology and Astrophysics of Minimal Dark Matter"
Nucl. Phys. B **787** (2007) 152-175, arXiv:0706.4071[hep-ph].

13. M. Cirelli, Y.-Z. Chu
"Sterile neutrinos, lepton asymmetries, primordial light elements: how much of each?"
Phys. Rev. D **74** (2006) 085015, arXiv:astro-ph/0608206.

12. M. Cirelli, A. Strumia
"Cosmology of neutrinos and extra light particles after WMAP3"
JCAP 12 (2006) 013, arXiv:astro-ph/0607086.

11. M. Cirelli, N. Fornengo, A. Strumia
"Minimal Dark Matter"
Nucl. Phys B **753** (2006) 178, arXiv:hep-ph/0512090.

10. M. Cirelli, N. Fornengo, T. Montaruli, I. Sokalski, A. Strumia and F. Vissani
"Spectra of neutrinos from dark matter annihilations"
Nucl. Phys. B **727** (2005) 99, arXiv:hep-ph/0506298.

9. M. Cirelli, M.C. Gonzalez-Garcia, C. Peña-Garay
"Mass varying neutrinos in the Sun"
Nucl. Phys. B **719** (2005) 219, arXiv:hep-ph/0503028.

8. M. Cirelli,
"Sterile Neutrinos in Astrophysical and Cosmological Sauce",
Proceedings of Pascos 2004 – 10th international symposium on Particles, Strings and Cosmology and of IFAE 2004, arXiv:astro-ph/0410122.

7. M. Cirelli, G. Marandella, A. Strumia. F. Vissani
"Probing Oscillations into Sterile Neutrinos with astrophysics, cosmology and experiments"
Nucl. Phys. B **708** (2005) 215-267, arXiv:hep-ph/0403158.

6. M. Cirelli
"Neutrinos in Extra Dimensions and Supernovae"
Proceedings of the 38th Rencontres de Moriond – Electroweak Interactions and unified theories, ed. J. Trân Thanh Vân, World Publishers, arXiv:hep-ph/0305141.

5. G. Cacciapaglia, M. Cirelli, A. Romanino
"Signatures of Supernova Neutrino Oscillations into Extra Dimensions"
Phys. Rev. D **68** (2003) 033013, arXiv:hep-ph/0302246.

4. G. Cacciapaglia, M. Cirelli, Y. Lin, A. Romanino
"Bulk neutrinos and core collapse supernovae"
Phys. Rev. D **67** (2003) 053001, arXiv:hep-ph/0209063.

3. M. Cirelli
"Muon g-2 in a model with one extra dimension"
Proceedings of the 37th Rencontres de Moriond – Electroweak Interactions and unified theories, ed. J. Trân Thanh Vân, World Publishers, arXiv:hep-ph/0205140.

2. G. Cacciapaglia, M. Cirelli, G. Cristadoro
"Muon anomalous magnetic moment in a calculable model with one extra dimension"
Nucl. Phys. B **634** (2002) 230-246, arXiv:hep-ph/0111288.

1. G. Cacciapaglia, M. Cirelli, G. Cristadoro
"Gluon fusion production of the Higgs boson in a calculable model with one extra dimension"
Phys. Lett. B **531** (2002) 105-111, arXiv:hep-ph/0111287.

Popular Articles and other publications:

+ M. Cirelli, C. Bonvin
"Theory of Dark Matter"
Clefs du CEA, October 2009

+ M. Cirelli, F. Zamponi
"On the academic recruitment system in Italy",
La Stampa (italian daily newspaper), October 2007

+ interviews with Nature (UK), Scientific American (USA), ScienceNews (USA), Cosmos Magazine (Australia), The Australian (Australia), The Times Online (UK)...

Main invited plenary talks at Conferences

- PASCOS 2009 - 6-10 Jul 2009, Hamburg, Germany
- Moriond EW 2009 - 7-13 Mar 2009, La Thuile, Italy
- NUFACT 06 - 24-30 Aug 2006, Irvine CA, Usa

Lectures

- *invited lectures* – "Dark Matter", UniverseNet School and Meeting - 28 Sep - 2 Oct 2009, Autonoma Barcelona, Spain
- *invited lectures* – "Dark Matter in cosmic rays", Ecole de Physique des Astroparticules - 7-12 Sep 2009, OHP, Saint Michel l'Observatoire, France
- *invited lectures* – "Dark Matter", Roma 2 Tor Vergata - 5-6 Feb 2009, Roma, Italy

Conference responsabilities

- *convener* – COSMO 2009 - 7-11 September 2009, CERN, Geneva, Switzerland
- *organizer* – PONT d'Avignon 2008 - 21-25 Apr 2008, Palais des Papes, Avignon, France
- *convener* – ENTApP DM Visitor's Program DESY - 25-29 Feb 2008, Hamburg, Germany

Other conferences

- *invited talk* – CCAPP Symposium - 12-14 Oct 2009, Columbus, OH
- *invited talk* – 12th Marcel Grossmann Meeting on GR - 12-18 Jul 2009, Unesco, Paris, France
- *invited talk* – Joint ICTP-INFN-SISSA conference on LHC - 29 Jun - 2 Jul 2009, Trieste, Italy
- *invited talk* – New Lights on Dark Matter - 11-13 Jun 2009, Perimeter Institute, Waterloo, Canada
- *invited talk* – Rencontre at the Colegio de España - 4-5 Jun 2009, Paris, France
- *invited talk* – TANGO workshop - 4-6 May 2009, IAP, Paris, France
- *invited talk* – GDR TeraScale - 30 Mar - 1 Apr 2009, Grenoble, France
- *invited talk* – Rencontre Physique Particules - 23-25 Mar 2009, Ecole Polytechnique, France
- *invited review talk* – Dutch Astroparticle Meeting, 20 Mar 2009, Leiden, The Netherlands
- *invited talk* – Frontiers in Neutrino Physics - 16-18 Mar 2009, APC, Paris, France
- *invited talk* – Neutrino Telescopes Venice 2009 - 10-13 Mar 2009, Venice, Italy
- *invited talk* – IPhT Departmental Meeting - 15-17 Oct 2008, Batz-sur-Mer, France
- *invited talk* – UniverseNET school and meeting - 22-26 Sep 2008, Oxford, UK

- *talk* – NOW 2008, Neutrino Oscillation Workshop - 6-13 Sep 2008, Conca Specchiulla, Italy
- *talk* – iDM2008, Identification of Dark Matter - 18-22 Aug 2008, Stockholm, Sweden
- 12th Paris Cosmology Colloquium 2008 Ecole Chalonge - 17-19 Jul 2008, Paris, France
- PLANCK 2008, From the Planck scale to the EW scale - 19-23 May 2008, Barcelona, Spain
- GDR Neutrino - 10-11 Apr 2008, Saclay, France
- Dark Matter at Small Scales - 13-15 Feb 2008, APC, Paris, France
- *invited talk* – GDR SuSy - 12-14 Nov 2007, Bruxelles, Belgium
- *invited talk* – The Path to Neutrino Masses - 3-6 Sep 2007, Aarhus, Denmark
- *invited talk* – TeV Particle AstroPhysics - 27-31 Aug 2007, Venice, Italy
- *invited talk* – LHC-Cosmology Interplay CERN Theory Institute - 9-20 Jul 2007, CERN
- *invited talk* – GDR Neutrinos Plenary Meeting - 21-22 Jun 2007, APC, Paris, France
- *invited review talk* – Rencontre at the Colegio de España - 17-18 May 2007, Paris, France
- *invited talk* – GDR Neutrinos Plenary Meeting - 13-14 Mar 2007, LAPP, Annecy, France
- *invited short talk* – CERN Dark Matter Visitor Program - 5-9 Mar 2007, CERN
- *talk* – Rencontres de Physique de Particules 2007 - 28 Feb - 2 Mar 2007, Grenoble, France
- *invited talk* – Aspen Conference on Neutrinos Astrophysics - 28 Jan - 3 Feb 2007, Aspen
- Nobel Conference, Ecole d'Astrophysique D. Chalonge - 16 Dec 2006, Paris, France
- *talk* – ENTApP Annual Meeting (Theoretical Astroparticle) - 12-14 Dec 2006, Paris, France
- High Energy Physics in the LHC Era - 13-17 Nov 2006, LPNHE Jussieu, Paris, France
- Astroparticle Workshop - 23 Oct - 4 Nov 2006, Galileo Galilei Institute, Firenze, Italy
- *talk* – IFAE (Incontri sulla Fisica delle Alte Energie) - 19-21 April 2006, Pavia, Italy
- XI IFT-UAM/CSIC Christmas Workshop - 14 -16 Dec 2005, UAM, Madrid, Spain
- *talk* – QUEST Meeting 2005 - 12-13 Dec 2005, UAM, Madrid, Spain
- Tribute to John Bahcall - 29 Oct 2005, IAS, Princeton NJ
- *talk* – INFO 05, Implications of Neutrino Flavor Oscillations - 11-15 Jul 2005, Santa Fe NM
- Cosmic Connections – 17-23 Apr 2005, Quarrata, Italy
- COSMO 2004 - 17-21 Sep 2004, Toronto, Canada
- *talk* – PASCOS 2004 - 16-22 Aug 2004, Northeastern University, Boston MA, Usa
- IFAE (Incontri sulla Fisica delle Alte Energie) - 14-16 Apr 2004, Torino, Italy
- CAPP 2003, Cosmology And Particle Physics - 12-17 June 2003, CERN
- PLANCK 2003 – 26-31 May 2003, Madrid, Spain

- Pisa Week on Astro-Particle Physics and Cosmology: LSS and CMB, 5-9 May 2003
- *talk* – IFAE (Incontri sulla Fisica delle Alte Energie) - Lecce, Italy, 23-26 April 2003
- *talk* – Moriond 2003, EW Interactions & Unified Theories - 15-22 Mar 2003, Les Arcs, France
- PLANCK 2002 - Kazimierz, Poland, 25-29 May 2002
- *short talk* – Moriond 2002, EW Interactions & Unified Theories - 9-16 Mar 2002, France
- Corfu 2001, Summer Institute on Elementary Particles - 31 Aug-21 Sep 2001, Corfu, Greece
- PLANCK 2001 - 11-16 May 2001, La Londe les Maures, France
- IX National Seminar of Theoretical Physics - 4-15 Sep 2000, Parma, Italy

Invited Colloquia

- Heidelberg University Physics Department, Germany (May 2009)
- Federal University of Rio de Janeiro, Brazil (December 2008)
- IFT Saõ Paulo & University of Saõ Paulo, Brazil (November-December 2008)
- CERN-TH Colloquium, CERN Theory Division (October 2008)

Invited Seminars and other short term visits

- LPSC Grenoble, France (Dec 2009)
- IFT Granada, Spain (Nov 2009)
- Milano-Bicocca University, Italy (Oct 2009)
- ITP Warsaw, Poland (Oct 2009)
- IPHC Strasbourg, France (Sep 2009)
- LAPP, Annecy, France (Jun 2009)
- Imperial College, London, UK (May 2009)
- AstroParticle Theory group, Bielefeld, Germany (May 2009)
- ETH Zürich, Switzerland (April 2009)
- Max Planck Institute Heidelberg, Germany (January 2009)
- APC, Paris, France (December 2008)
- Autonoma University Barcelona, Spain (December 2008)
- LPT Paris XI Orsay, France (November 2008)
- Colloquium IPhT, Saclay, France (March 2008)

- CPT, Ecole Polytechnique, Palaiseau, France (March 2008)
- LPT, Paris XI Orsay, France (February 2008)
- LUTH, Observatoire de Paris, Meudon, France (November 2007)
- ULB Brussels, Belgium (October 2007)
- CPT Marseille, France (May 2007)
- IPN Lyon, France (April 2007)
- University of Wisconsin-Madison WI, Usa (February 2007)
- Fermilab, Batavia IL, Usa (February 2007)
- SPhT CEA/Saclay, France (April 2006)
- University of Washington, Seattle WA, Usa (February 2006)
- Harvard University, Cambridge MA, Usa (February 2006)
- New York University, New York NY, Usa (February 2006)
- EPFL, Lausanne, Switzerland (January 2006)
- Torino University, Italy (January 2006)
- ICTP, Trieste, Italy (January 2006)
- SPhT CEA/Saclay, France (December 2005)
- Institute for Advanced Study, Princeton NJ (October 2005)
- Zürich University, Switzerland (June 2005)
- Brookhaven National Lab, Upton NY (April 2005)
- SUNY Stony Brook NY, Usa (April 2005)
- UC Riverside CA, Usa (April 2005)
- UC Los Angeles CA (April 2005)
- UC Berkeley CA (April 2005)
- Harvard University, Cambridge MA, Usa (March 2005)
- Los Alamos National Lab, NM, Usa (March 2005)
- Cornell University, Ithaca NY, Usa (April 2004)
- Milano-Bicocca University, Italy (2003, 2004, 2006)
- Department of Physics at Pisa University (2002-2003)

Research Description:

My current research activity focuses on the intersections among

- Particle Theory Beyond the Standard Model,
- Neutrino Physics,
- Astrophysics and
- Cosmology.

In particular, my main current interests lie in Neutrino Cosmology and in exploring the phenomenology of Dark Matter models, with a special attention to our recent proposal of Minimal Dark Matter.

In the following, I briefly review my past research activity in some detail, and give an outlook of the open projects and directions.

I began my work in Particle Theory Beyond the SM by computing some relevant observables in the framework of the *theory proposed by R. Barbieri, L. Hall and Y. Nomura* (Phys. Rev. D63, 105007, 2001), an extension of the Standard Model to five dimensions endowed with a supersymmetric structure. The theory is successful in providing a description of the mechanism of electroweak symmetry breaking thanks to the extra dimension, while ensuring calculability for several quantities, a property that is not so common among extra dimensional models.

In [1] cited above we found that the *production rate of the Higgs boson via gluon fusion* (which is the main channel at a hadron collider) is significantly suppressed, due to cancellations among the additional (Kaluza-Klein) states of the theory.
In [2] we showed that the theory is compatible with the precision measurements of *muon anomalous magnetic moment*, by explicitly computing all the relevant additional contributions to such a quantity and finding them small.

In [4], I shifted to a more general class of models, characterized by *large flat extra dimensions* accessible to a *sterile neutrino*. We analyzed the effects in the context of *supernova physics*, where resonant oscillations between the Standard Model electron neutrino and the additional sterile states provide an unconventional escape channel. We showed (via numerical and analytical work) how previous bounds can be largely overcome, thanks to a feedback mechanism that self-limits the energy loss, and we discussed positive effects towards supernova explosion.

In [5] we completed the previous analysis including the effects of muon and tau neutrinos escape, showing how a feedback prevents an unacceptable energy loss also in this case. For all the different scenarios, we discussed the signatures in the neutrino signal on Earth.

In [7] we performed a thorough analysis of oscillation signals generated by *one extra sterile neutrino*, extending previous analyses done in simple limiting cases and including the effects of established oscillations among active neutrinos. Many New Physics candidates act effectively as sterile neutrinos, so that we include them all. We consider as probes the solar, atmospheric, reactor and beam neutrinos, Big-Bang Nucleosynthesis (^{4}He, D), the Cosmic Microwave Background, Large Scale Structure, supernovæ and neutrinos from other astrophysical sources. We found no evidence for a sterile neutrino in present data, we identified the still allowed regions, and studied which future experiments can best probe them: sub-MeV solar experiments, more precise studies of CMB or BBN, future supernova explosions... I particularly was involved in the SN and cosmological studies.

In [9], we addressed the implications on *solar neutrino oscillations* of the recent proposal that the mass of the neutrinos and the field responsible for *dark energy* may be connected, leading to the effect of *mass varying neutrinos* depending on environment. We stressed the model independent consequences, finding in particular that a connection between the effective Δm^2 in the Sun and the absolute neutrino

mass scale is established in these scenarios. This leads to the possibility of explicitly testing the model and to other interesting consequences both for the neutrinos and for the mechanism of dark energy.

In [10] we presented results on neutrino fluxes from the *annihilation of Dark Matter particles* (neutralinos, KK dark matter, strongly interacting dark matter, GUT scale dark matter ...) accumulated in the center of the Earth and the Sun. They will be hopefully detected in the Neutrino Telescopes (Antares, IceCube, a large Cerenkov detector...). The neutrino fluxes carry precious information on the main properties of DM (its abundance, its mass and its annihilation branching ratios), opening unique windows on its nature and on the theory that encompasses it. We computed precisely the expected neutrino yield and, especially, the neutrino spectra, which are more free from astrophysical uncertainties. We developed the appropriate formalism to follow the neutrino production, the evolution of the fluxes in the matter of the Earth and the Sun (determined by flavor oscillations, absorptions/scatterings and tau regeneration) and in the vacuum and finally the detection signatures.

In [11] we explored a new approach to the Dark Matter problem: while Beyond-the-SM theories often provide DM candidates with a complex phenomenology and an ad-hoc method for stabilization (such as R-parity in SuSy), we looked for a viable candidate just adding to the SM a multiplet in some representation of $SU_L(2) \otimes U_Y(1)$. We find that a quintuplet with zero hypercharge provides a *new minimal candidate for Dark Matter* that is fully successful: weakly interacting, electrically neutral and (most importantly) automatically stable on cosmological time scales. We computed its distinctive phenomenology at colliders (the LHC) and in experiments of direct and indirect DM detection, finding that the particle can be detected in the next generation of experiments.

In [12] we investigate the *cosmology of ordinary neutrinos and of possible extra light particles*. We make use of the most recent *data from Cosmic Microwave Background, Supernovæ type Ia, Large Scale Structure, Lyman-α forest, Baryon Acoustic Oscillation peaks* etc. We obtain stringent constraints on the neutrino mass, the effective neutrino density and the properties of proposed new interacting light particles that diminish the neutrino free-streaming. It should be noted that we performed all the analysis making use of numerical codes and tools written and developed by ourselves instead of the commonly used CMBfast-derived tools.

With [13] we investigated how unconventional cosmologies can relax the stringent bounds on sterile neutrinos. We open the way to a possible *primordial leptonic asymmetry*, that has the effect of suppressing the production of sterile neutrinos in the Early Universe, therefore modifying the constraints from BBN and from LSS. We identify the portions of the parameter space that can be reopened by introducing a given asymmetry. In the case of the LSND sterile neutrino, we find that a primordial asymmetry of the order of 10^{-4} is needed in order to lift the conflicts with cosmology.

With [14] we revisited the computation of the cosmological relic abundance in the Minimal Dark Matter proposal introduced in [11], including *non-perturbative 'Sommerfeld' corrections*. These were found to have a very relevant effect in enhancing the DM annihilations. We also study the peculiar behavior of the DM particles while crossing the Earth at Ultra High Energies, in order to assess the possible detectability in future cosmic ray and neutrino telescopes (e.g. Icecube, Auger, Antares).

In [15] we precisely calculated the *indirect detection* signatures of the Minimal Dark Matter model of [11]. We computed the fluxes of positrons, antiprotons and gamma rays from the annihilations of DM particles in the galactic halo and their propagation in the galaxy (designing our own computational tools). We found distinctive and univocal predictions (the model has no free parameters). The enhancement in the annihilation cross section discussed in [14] put the foreseen fluxes within the reach of those that were upcoming experiments, PAMELA in particular.

When the PAMELA satellite announced preliminary data on the positron flux, showing confirmation for an excess over the expected background that previous experiments had already exposed, we compared in [16] the fluxes from Minimal DM annihilations predicted in [15] with such data. We found a remarkably good agreement, and we were able to determine the set of astrophysical parameters that gives the best

fit. Later, we summarized in [19] the status of the model.

In a subsequent paper [17], we performed a model independent analysis of the PAMELA preliminary data on positrons and anti-protons, together with less known (before our analysis) but relevant data from cosmic ray balloon experiments: ATIC and PPB-BETS. We looked for which DM models can explain the signals that appear in the data while remaining compatible with the searches in all other channels. We find that the PAMELA results alone, if due to DM annihilations, individuate a quite unusual DM particle: either very heavy (above 10 TeV) or lighter but annihilating mainly into leptonic channels such as DM DM $\to e^+e^-$. Adding the balloon datasets, only the second possibility is favored.

In [18] we pursued the model independent analysis of *multi-messenger indirect signatures* extending to gamma rays and synchrotron radiation from the galactic center and dwarf satellite galaxies. We found that these observations impose stringent constraints: a tension is present with the explanation of the PAMELA and ATIC data in terms of DM annihilations, unless the DM halo profile is significantly more smooth than expected from numerical simulations.

In [20] we considered another interesting possible signal of DM indirect detection: *fluxes of anti-deuterium* synthetized in galactic annihilations. We focussed on the 'very heavy Dark Matter' scenarios individuated by the recent data, and we found promising perspectives especially for primary annihilation channels into quarks.

Another relevant test of the Dark Matter invoked to explain the positron excess in PAMELA is the flux of *gamma rays produced by inverse Compton scattering* of such energetic positrons on low energy ambient photons in the galactic halo. This signal has the advantage of being less sensitive to astrophysical details than the gamma rays from the Galactic Center discussed above. We computed this flux for several cases and for a range of DM models in [21], finding again stringent constraints.

In [22] we looked once again at the implications of Dark Matter annihilations, this time on the cosmological evolution of the universe. Indeed, the annihilations of Dark Matter during the epoch of galaxy formation inject charged particles and energy, producing *reionization and heating of the primordial gas*. Comparing with the observed optical depth (from CMB) and the measured temperature of the intergalactic gas we found relevant constraints on DM properties, in the particular for the PAMELA-motivated models. We also found general constraints for more 'ordinary' Dark Matter.

During my laurea thesis work I also dealt with the physics of Strong Interactions and *Quantum Chromodynamics*. We derived a formula for a particular regime in Drell-Yan processes (the production of a lepton–antilepton pair in proton–antiproton collisions). Namely, the intersection of threshold production and small transverse momentum regimes. I had the opportunity of studying in a certain detail the resummation of soft gluon emissions.

In the upcoming future, I plan to further explore the indirect detection signatures of Dark Matter and to investigate the effect of *non-standard neutrino interactions in the core of Supernovae*. On this latter topic, preliminary results obtained in collaboration with Renata Zukanovich-Funchal (Saõ Paulo) show that even a tiny amount of non-standard neutrino interactions that convert an electron neutrino into a muon or tau neutrino (as predicted by many extensions of the SM) drastically modify the transport of energy outside of the core of the collapsing star, since electron and muon/tau neutrinos have very different transport properties. So we expect that SN physics will impose stringent bounds on such interactions, currently poorly constrained by experiments. Concerning Dark Matter, the concrete goal is to develop the tools to assess which DM models can explain possible signals that might appear in the data (e.g. the current PAMELA excess in positron fluxes, or future possible results from the Fermi telescope in gamma rays...) while remaining compatible with the searches in other channels, or producing predictions for other channels. This multi-messenger approach will be further enriched and complemented by the information on Dark Matter (and on new particle physics in general) to be gathered at the LHC. Hopefully, the next few years will see us gaining a precise insight on the properties of Dark Matter and the theory encompassing it, finally getting to identify its nature.

Referees:

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