Curriculum Vitae

Name: *Riotto Antonio Walter*.

Homepage: http://fiteoweb.unige.ch/riotto/

Google Scholar ID: Google Scholar

Recent academic career stages

July 2016-present: Director of the Theoretical Physics Department, University of Geneva, Switzerland.

January 2012-: Full Professor, University of Geneva, Switzerland.

March 2019 - August 2019: On leave of absence from the University of Geneva at the CERN Theory Department, Geneva, Switzerland as Scientific Associate.

September 2007 - December 2011: Staff Member the CERN Theory Division, Geneva, Switzerland.

February 2005- December 2011: Full-time tenured position as "Direttore di Ricerca" (Research Director) at Istituto Nazionale di Fisica Nucleare (INFN) in Padua, Italy.

Main current institutional responsibilities

– *Director* of the Theoretical Physics Department, University of Geneva.

– *Full Professor* at the Theoretical Physics Department, University of Geneva.

– *Member* of the 2016 ERC Starting Grant panel *Fundamental Constituents of Matter*.

– Member of the EuCAPT Steering Committee.

– Coordinator of the Division 3 (Population Studies) of the Observational Science Board of the Einstein Telescope.

– Editor of the EuCapt White Paper "Opportunities and Challenges for Theoretical Astroparticle Physics in the Next Decade".

– *Member* of the LISA collaboration.

– *Member* of the EUCLID collaboration.

– Member of the SKA collaboration.

– *Referee* for: UK Royal Society, Estonian Research Council, Centre of Excellence Programme in 2018-2025 of

the Academy of Finland, STFC Review panel, National Science Center, Poland, FONDECYT Chilean National Science and Technology Commission, German Israeli Foundation for Scientific Research and Development, European Research Council (ERC) Advanced Grants, Israeli Science Foundation (ISF), Shota Rustaveli National Science Foundation (SRNSF) Georgia, the Italian Research and University Evaluation Agency (ANVUR).

– *Member* of the Planning Committee of the Physics Section of the University of Geneva.

– *Member* of the Planning Committee of the Mathematics Section of the University of Geneva.

– *Member* of the Committee des Locaux of the Physics Section of the University of Geneva.

– *Member* of the LHC Dark Matter Working Group.

– *Member* of the U.S. Department of Energy Office (DOE) of High Energy Physics Review Panel.

Organization of Conferences and Lecturing: last two years

June 2020: Lecturer at the "Second Joint ICTP-Trieste/ICTP-SAIFR School on Particle Physics", Sao Paolo, Brazil. Title of the lectures: "Early Universe and Particle Physics".

February 2021: Organizer of the "Primordial Black Holes confront GW data", University La Sapienza, Roma, Italy.

Invited Talks: last two years

November 2020: Invited plenary speaker at the *Less Travelled Path for Dark Matter* conference, ICTS, Bangalore, India.

April 2021: Invited speaker at the *MIT/Tufts cosmology seminar*, Boston, USA.

April 2021: Invited speaker at the *Sharif University of Technology Cosmology Group Weekly Seminars*, Teheran, Iran.

April 2021: Invited speaker at the *LMU*, Munich, Germany.

April 2021: Invited speaker at the *Meeting of the National Research Group* conference, Paris, France.

May 2021: Invited speaker at the *Gravitational-Wave Primordial Cosmology* conference, Paris, France.

June 2021: Invited speaker at the *2021 CERN-CKC Theory Workshop*, CERN, Switzerland.

June 2021: Invited speaker at the *2021 Quarks* conference, Moscow, Russia.

August 2021: Invited speaker at the *2021 PAX VII* workshop, Lisbon, Portogual.

November 2021: Invited speaker at the *Zurich University*, Zurich, Switzerland.

Prizes

January 2019: 2018 Buchalter Cosmology Prize.

Grants: last five Years

September 2015-September 2018: Grant n. 20002 159223 from the Fonds National Suisse (FNS). Amount: 388.087 CHF for the project ' 'Investigating the nature of dark matter".

June 2016: Grant from the COMAD (Commission administrative de l'UniGe). Amount: 5500 CHF for organization of the conference "TeV Particle Astrophysics 2016" held at CERN, 12-16 September 2016.

September 2018- August 2022: Grant n. 200020 178787 from the Fonds National Suisse (FNS). Amount: 780.000 CHF for the project "The Non-Gaussian Universe and Cosmological Symmetries".

September 2018-September 2020: Grant from the Fondation Ernest Boninchi. Amount: 100.000 CHF for the project "The Non-Gaussian Universe and Cosmological Symmetries".

Supervision of Master students: last five years

September 2016: Supervisor of the Master thesis of Goran Jelic-Cizmek, University of Geneva, "The instability of the Standard Model in the presence of black holes". Final vote: 6/6.

March 2017: Supervisor of the Master thesis of Romain Chessex, ETH Zurich, "Inflation and dS/CFT". Final vote: 6/6.

September 2018: Supervisor of the Master thesis of Ameek Molhatra, University of Geneva, "The black holes". Final vote: 6/6.

Supervision of Ph.D. Students: last two years

November 2017-present : Supervisor of the Ph. D. student Gabriele Franciolini.

September 2018-present : Supervisor of the Ph. D. student Valerio de Luca.

Supervision of Post-docs: last two years

January 2018-present: Supervisor of the Post-Doc Azadeh Moradinezhad Dizgah.

Teaching at the University of Geneva: last two years

September 2020 -June 2021: Course of Mathematical Methods for Physicists II (12P015, 6 credits).

September 2020 -June 2021: Course of Laboratoire IV Theorique (14P951, 15 credits).

Major general scientific achievements: last five years

Citation according to Google Scholar. Total n. of citations: 49130, h-index=107.

[1] N. Bartolo, V. De Luca, G. Franciolini, M. Peloso, D. Racco and A. Riotto, "Testing primordial black holes as dark matter with LISA," Phys. Rev. D **99** (2019) no.10, 103521 [arXiv:1810.12224 [astro-ph.CO]].

Cited 150 times. The idea that primordial black holes (PBHs) can comprise most of the dark matter of the Universe has recently reacquired a lot of momentum. Observational constraints, however, rule out this possibility for most of the PBH masses, with a notable exception around $10^{-12}M_\odot$. These light PBHs may be originated when a sizable comoving curvature perturbation generated during inflation reenters the horizon during the radiation phase. During such a stage, it is unavoidable that gravitational waves (GWs) are generated. Since their source is quadratic in the curvature perturbations, these GWs are generated fully non-Gaussian. Their frequency today is about a millihertz, which is exactly the range where the LISA mission has the maximum of its sensitivity. This is certainly an impressive coincidence. We show that this scenario of PBHs as dark matter can be tested by LISA by measuring the GW two-point correlator. On the other hand, we show that the short observation time (as compared to the age of the Universe) and propagation effects of the GWs across the perturbed Universe from the production point to the LISA detector suppress the bispectrum to an unobservable level. This suppression is completely general and not specific to our model.

[2] N. Bartolo, V. De Luca, G. Franciolini, A. Lewis, M. Peloso and A. Riotto, "Primordial Black Hole Dark Matter: LISA Serendipity," Phys. Rev. Lett. **122** (2019) no.21, 211301 [arXiv:1810.12218 [astro-ph.CO]].

Cited 153 times. There has recently been renewed interest in the possibility that the dark matter in the Universe consists of primordial black holes (PBHs). Current observational constraints leave only a few PBH mass ranges for this possibility. One of them is around $10^{-12}M_\odot$. If PBHs with this mass are formed due to an enhanced scalar-perturbation amplitude, their formation is inevitably accompanied by the generation of gravitational waves (GWs) with frequency peaked in the mHz range, precisely around the maximum sensitivity of the LISA mission. We show that, if these primordial black holes are the dark matter, LISA will be able to detect the associated GW power spectrum. Although the GW source signal is intrinsically non-Gaussian, the signal measured by LISA is a sum of the signal from a large number of independent sources suppressing the non-Gaussianity at detection to an unobservable level. We also discuss the effect of the GW propagation in the perturbed Universe. PBH dark matter generically leads to a detectable, purely isotropic, Gaussian and unpolarized GW signal, a prediction that is testable with LISA.

[3] G. Franciolini, A. Kehagias, S. Matarrese and A. Riotto, "Primordial Black Holes from Inflation and non-Gaussianity," JCAP **03** (2018), 016 [arXiv:1801.09415 [astro-ph.CO]].

Cited 144 times. Primordial black holes may owe their origin to the small-scale enhancement of the comoving curvature perturbation generated during inflation. Their mass fraction at formation is markedly sensitive to possible non-Gaussianities in such large, but rare fluctuations. We discuss a path-integral formulation which provides the exact mass fraction of primordial black holes at formation in the presence of non-Gaussianity. Through a couple of classes of models, one based on single-field inflation and the other on spectator fields, we show that restricting to a Gaussian statistics may lead to severe inaccuracies in the estimate of the mass fraction as well as on the clustering properties of the primordial black holes.

[4] J. R. Espinosa, D. Racco and A. Riotto, "Cosmological Signature of the Standard Model Higgs Vacuum Instability: Primordial Black Holes as Dark Matter," Phys. Rev. Lett. **120** (2018) no.12, 121301 [arXiv:1710.11196 [hep-ph]].

Cited 80 times. For the current central values of the Higgs boson and top quark masses, the standard model Higgs potential develops an instability at a scale of the order of 10^{11} GeV. We show that a cosmological signature of such instability could be dark matter in the form of primordial black holes seeded by Higgs fluctuations during inflation. The existence of dark matter might not require physics beyond the standard model.

[5] V. De Luca, G. Franciolini and A. Riotto, "NANOGrav Data Hints at Primordial Black Holes as Dark Matter," Phys. Rev. Lett. **126** (2021) no.4, 041303 [arXiv:2009.08268 [astro-ph.CO]].

Cited 149 times. References [1]-[5] represent significant recent contributions to the physics of the primordial black holes from the theoretical point of view and also in relation to experiments. They are relevant references in connection to the project. In particular, the NANOGrav Collaboration has recently published strong evidence for a stochastic common-spectrum process that may be interpreted as a stochastic gravitational wave background. We show that such a signal can be explained by second-order gravitational waves produced during the formation of primordial black holes from the collapse of sizeable scalar perturbations generated during inflation. This possibility has two predictions: (i) the primordial black holes may comprise the totality of the dark matter with the dominant contribution to their mass function falling in the range $(10^{-15} \div 10^{-11})M_\odot$ and (ii) the gravitational wave stochastic background will be seen as well by the Laser Interferometer Space Antenna experiment.

[6] G. Franciolini, V. Baibhav, V. De Luca, K. K. Y. Ng, K. W. K. Wong, E. Berti, P. Pani, A. Riotto and S. Vitale, "Quantifying the evidence for primordial black holes in LIGO/Virgo gravitational-wave data," [arXiv:2105.03349 [gr-qc]].

Cited 33 times. In this paper we have performed the first hierarchical Bayesian analysis on the GWTC-2 catalog by combining several astrophysical formation models with a population of primordial black holes. We have found that the evidence for primordial black holes against an astrophysical-only multichannel model is decisively favoured in some scenarios, but it is significantly reduced in the presence of a dominant stable-mass-transfer isolated formation channel. The tantalizing possibility that LIGO/Virgo may have already detected black holes formed after inflation should be verified by reducing uncertainties in astrophysical and primordial formation models, and it may ultimately be confirmed by third-generation interferometers. This paper is relevant in connection to the project.

[7] V. De Luca, V. Desjacques, G. Franciolini, P. Pani and A. Riotto, Phys. Rev. Lett. **126** (2021) no.5, 051101 [arXiv:2009.01728 [astro-ph.CO]].

Cited 54 times. The LIGO/Virgo Collaboration has recently observed GW190521, the first binary black hole merger with at least the primary component mass in the mass gap predicted by the pair-instability supernova theory. This observation disfavors the standard stellar-origin formation scenario for the heavier black hole, motivating alternative hypotheses. We show that GW190521 cannot be explained within the primordial black hole (PBH) scenario if PBHs do not accrete during their cosmological evolution, since this would require an abundance which is already in tension with current constraints. On the other hand, GW190521 may have a primordial origin if PBHs accrete efficiently before the reionization epoch.

[8] V. De Luca, G. Franciolini, P. Pani and A. Riotto, JCAP **06** (2020), 044 [arXiv:2005.05641 [astro-ph.CO]].

Cited 61 times. The LIGO and Virgo Interferometers have so far provided 11 gravitational-wave (GW) observations of black-hole binaries. Similar detections are bound to become very frequent in the near future. With the current and upcoming wealth of data, it is possible to confront specific formation models with observations. We investigate here whether current data are compatible with the hypothesis that LIGO/Virgo black holes are of primordial origin. We compute in detail the mass and spin distributions of primordial black holes (PBHs), their merger rates, the stochastic background of unresolved coalescences, and confront them with current data from the first two observational runs, also including the recently discovered GW190412. We compute the best-fit values for the parameters of the PBH mass distribution at formation that are compatible with current GW data. In all cases, the maximum fraction of PBHs in dark matter is constrained by these observations to be about 10^{-3}. We discuss the predictions of the PBH scenario that can be directly tested as new data become available. In the most likely formation scenarios where PBHs are born with negligible spin, the fact that at least one of the components of GW190412 is moderately spinning is incompatible with a primordial origin for this event, unless accretion or hierarchical mergers are significant. In the absence of accretion, current non-GW constraints already exclude that LIGO/Virgo events are all of primordial origin, whereas in the presence of accretion the GW bounds on the PBH abundance are the most stringent ones in the relevant mass range. A strong phase of accretion during the cosmic history would favour mass ratios close to unity, and a redshift-dependent correlation between high masses, high spins and nearly-equal mass binaries, with the secondary component spinning faster than the primary. Finally, we highlight that accretion can play an important role to relax current constraints on the PBH abundance, which calls for a better modelling of the mass and angular momentum accretion rates at redshift $0 < z < 3$.

[9] D. Abercrombie, N. Akchurin, E. Akilli, J. Alcaraz Maestre, B. Allen, B. Alvarez Gonzalez, J. Andrea, A. Arbey, G. Azuelos and P. Azzi, *et al.* Phys. Dark Univ. **27** (2020), 100371 [arXiv:1507.00966 [hep-ex]].

*Cited 644 times.*This document is the final report of the ATLAS-CMS Dark Matter Forum, a forum organized by the ATLAS and CMS collaborations with the participation of experts on theories of Dark Matter, to select a minimal basis set of dark matter simplified models that should support the design of the early LHC Run-2 searches. A prioritized, compact set of benchmark models is proposed, accompanied by studies of the parameter space of these models and a repository of generator implementations. This report also addresses how to apply the Effective Field Theory formalism for collider searches and present the results of such interpretations.

[10] A. Boveia, O. Buchmueller, G. Busoni, F. D'Eramo, A. De Roeck, A. De Simone, C. Doglioni, M. J. Dolan, M. H. Genest and K. Hahn, *et al.* Phys. Dark Univ. **27** (2020), 100365 [arXiv:1603.04156 [hep-ex]].

Cited 330 times. This document summarises the proposal of the LHC Dark Matter Working Group on how to present LHC results on s -channel simplified dark matter models and to compare them to direct (indirect) detection experiments.

[11] A. Albert, M. Backović, A. Boveia, O. Buchmueller, G. Busoni, A. De Roeck, C. Doglioni, T. DuPree, M. Fairbairn and M. H. Genest, *et al.* Phys. Dark Univ. **26** (2019), 100377 [arXiv:1703.05703 [hep-ex]].

Cited 121 times: References [9]-[11] represent documents obtained in participation with theoretical and experimental experts on theories and search of dark matter and summarise the engagement of the PI as theorist within the ATLAS Dark Matter Working Group. Weakly-coupled TeV-scale particles may mediate the interactions between normal matter and dark matter. If so, the LHC would produce dark matter through these mediators, leading to the familiar "mono- X" search signatures, but the mediators would also produce signals without missing momentum via the same vertices involved in their production. This document from the LHC Dark Matter Working Group suggests how to compare searches for these two types of signals in case of vector and axial-vector mediators, based on a workshop that took place on September 19/20, 2016 and subsequent discussions. These suggestions include how to extend the spin-1 mediated simplified models already in widespread use to include lepton couplings. This document also provides analytic calculations of the relic density in the simplified models and reports an issue that arose when ATLAS and CMS first began to use preliminary numerical calculations of the dark matter relic density in these models.

[12] J. R. Espinosa, D. Racco and A. Riotto, JCAP **09** (2018), 012 [arXiv:1804.07732 [hep-ph]].

Cited 104 times: A fundamental property of the Standard Model is that the Higgs potential becomes unstable at large values of the Higgs field. For the current central values of the Higgs and top masses, the instability scale is about 1011 GeV and therefore not accessible by colliders. We show that a possible signature of the Standard Model Higgs instability is the production of gravitational waves sourced by Higgs fluctuations generated during inflation. We fully characterise the two-point correlator of such gravitational waves by computing its amplitude, the frequency at peak, the spectral index, as well as their three-point correlators for various polarisations.