UMONS Université de Mons activities

Andrea Campoleoni

Physique de l'Univers, Champs et Gravitation

11th CosPa meeting, *Brussels, 29/10/2021*

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Physics of fundamental interactions @ UMONS

- Three groups working on theoretical physics of fundamental interactions

Physics of the Universe, Fields and Gravitation	• Nicolas Boulanger • Andrea Campoleoni • Evgeny Skvortsov
Atomic Physics and Astrophysics	• Pascal Quinet • Patrick Palmeri
Nuclear and Subnuclear Physics	• Claude Semay

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Physics of the Universe, Fields and Gravitation

Staff

- Nicolas Boulanger (head)
- Andrea Campoleoni (CQ FNRS)
- Evgeny Skvortsov (CQ FNRS)

Postdocs

- Ivano Basile
- Chrysoula Markou
- Tung Tran
- Thomas Basile

PhD students

- Arnaud Delfante
- Yegor Goncharov
- Simon Pekar
- Shailesh Dhasmana
- Akshay Bedhotiya
- Mattia Serrani
- Victor Dehouck
- Josh O'Connor
- Richard van Dongen
- Kamil Cwiklinski
- Noemie Parrini

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Key research themes

- Modified theories of gravity (higher-spin theories and massive gravity)
- Asymptotic symmetries & conserved charges in gauge theories
- Conformal field theories & AdS/CFT

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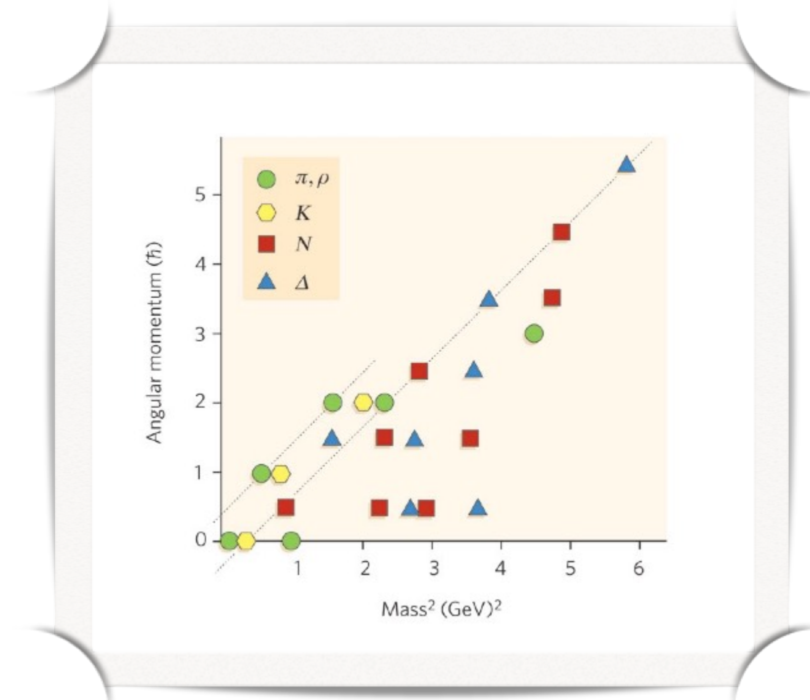
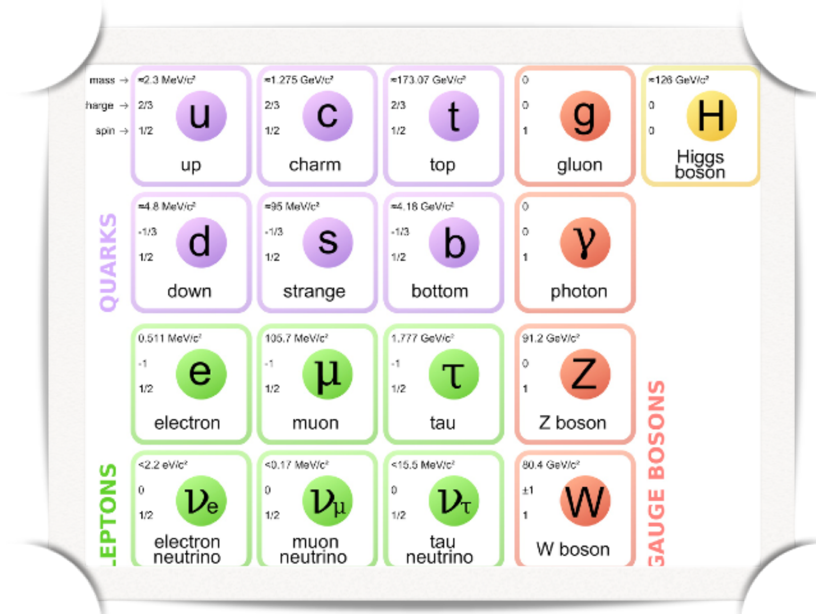
Constraints on gravitational waves

A common leitmotiv: higher-spin particles (s > 2)

- Plenty of higher-spin *resonances* in hadronic interactions…
- …but fields in the standard model have at most spin 1
- Gravity and supergravity push the limit to spin 2 (*but they aren't renormalisable*)





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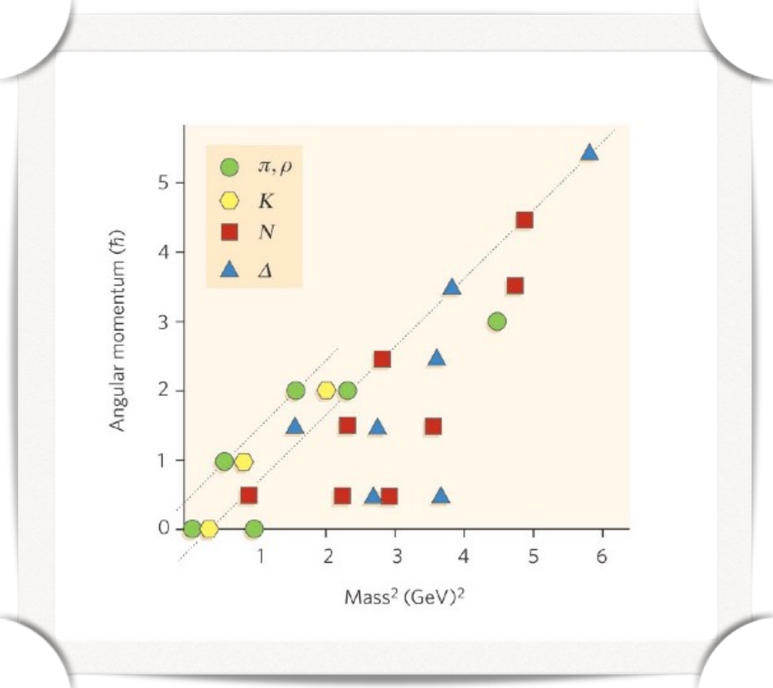
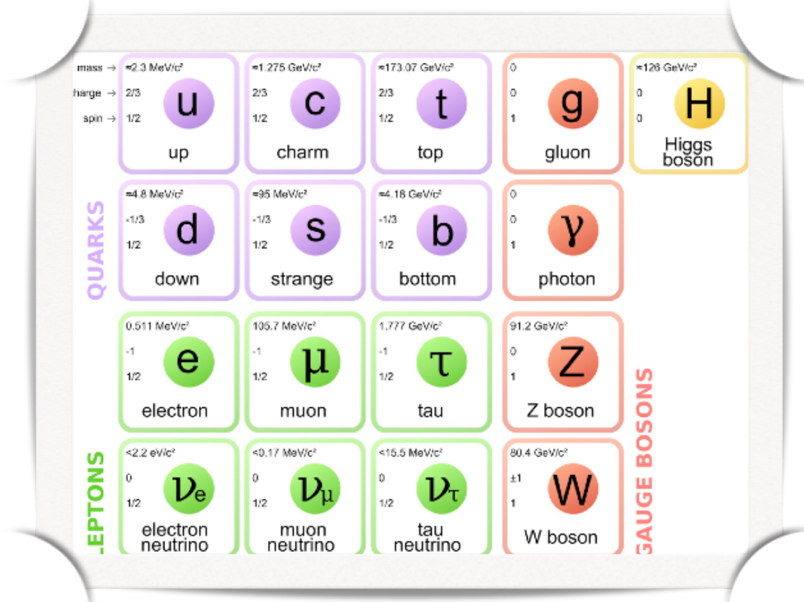
Higher is the spin, more constrained are the interactions





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apply only to massless particles

are not valid in (A)dS!

does not exclude non-minimal couplings

many counter-examples already known: massive gravity bi-gravity, etc.

Examples (and yes-go results)

- Some examples of higher-spin models
  - String theory (massive excitations, quantum complete, nice but complicated; *not easy to get dS*)
  - Vasiliev theories (massless fields in (A)dS, non-localities and quantum properties under investigation; <u>*good for cosmology: defined on dS!*</u>)
  - Low-dimensional models (simple model with higher-spin fields exist in $D \leq 3$; *toy models for higher-spin cosmology*)
  - Conformal higher-spin gravity (extension of conformal gravity)
  - Chiral higher-spin gravity (quantum finite, but non-unitary model in flat space; *useful effective field theory?*)

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Examples (and yes-go res

X. Bekaert, N. Boulanger and P. Sundell, *How higher-spin gravity surpasses the spin two barrier: no-go theorems versus yes-go examples*, Rev. Mod. Phys. 84 (2012), 987-1009 [arXiv:1007.0435 [hep-th]].

V. E. Didenko and E. D. Skvortsov, *Elements of Vasiliev theory*, arXiv:1401.2975 [hep-th].

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Applications (*I*): cosmology

- Could the <u>*inflationary era*</u> be described by a higher-spin theory? What would the observational imprints for such a scenario be?
  - D. Anninos, V. De Luca, G. Franciolini, A. Kehagias and A. Riotto, *Cosmological Shapes of Higher-Spin Gravity*, JCAP 04 (2019), 045 [arXiv:1902.01251 [hep-th]].
  - Analysis of the tensor non-Gaussianities for the graviton field induced by higher-spin interactions (Einstein gravity + higher-derivative corrections fixed by HS symmetry).

- Could <u>dark-matter</u> be composed by weakly-interacting *massive higher-spin particles*?
  - S. Alexander, L. Jenks and E. McDonough, *Higher spin dark matter*, Phys. Lett. B 819 (2021), 136436 [arXiv:2010.15125 [hep-ph]].
  - Models for gravitational production of superheavy bosonic higher spin fields during inflation and proposals for characteristic signatures of bosonic higher spin dark matter in directional direct detection.

Applications (*II*): post-Minkowskian, post-Newtonian approx

- Emission of gravitational waves by two compact spinning objects from quantum massive higher-spin amplitudes?
    - A. Guevara, A. Ochirov and J. Vines, *Black-hole scattering with general spin directions from minimal-coupling amplitudes*, Phys. Rev. D 100 (2019) no.10, 104024 [arXiv:1906.10071 [hep-th]].
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- N. Boulanger, C. Deffayet, S. Garcia-Saenz and L. Traina, *Theory for multiple partially massless spin-2 fields*, Phys. Rev. D 100 (2019) no.10, 101701 [arXiv:1906.03868 [hep-th]].

Group Members

- Pascal Quinet

  Head of Unit, Research Director of the F.R.S.-FNRS, Part-time Professor

- Patrick Palmeri

  Research Associate of the F.R.S.-FNRS

- Jérôme Deprince

  Postdoctoral Researcher

- Sébastien Gamrath

  PhD Researcher, Teaching Assistant

- Helena Carvajal Gallego

  PhD Researcher, FRIA Fellow

Main fields of research

- Modeling of atomic structures and processes

  Determination of fundamental parameters for radiative and non-radiative processes in complex atomic systems (from neutrals to highly ionized).

- Applications in Astrophysics

  Chemical abundances in peculiar stars and compact object atmospheres.
  High-density effects on emission spectra from black hole accretion disks.
  Opacities in kilonova spectra observed following neutron star mergers.

- Applications in Laboratory Plasma Physics

  Spectral analysis and diagnostics of plasmas confined in fusion reactors.

- Applications in Nuclear Physics

  Atomic structure of short-lived isotopes.
  Hyperfine structures, isotope shifts.

Key expertise

- Computational methods in atomic physics

  Pseudo-relativistic and fully-relativistic theoretical approaches.
  Semi-empirical methods.

- Multiplatform approaches

  Uncertainty estimates in atomic calculations.
  Complete and unique expertise within the atomic physics community.

- Experimental atomic physics

  Laser-induced spectroscopy measurements in collaboration with different laboratories (Lund Laser Center, Sweden; Jilin University, China).

- Computing resources

  Powerful local workstation + Access to High-Performance CECI Clusters

Some recent studies

- High-density effects on X-ray K lines of iron

  [Collaboration with NASA GSFC, Caltech, Western Michigan University]

  Highlighting the main effects due to the plasma environment on the K lines of iron ions in the context of accretion disks around black holes (Ionization potentials, K thresholds, radiative and Auger rates) [still to be done : plasma effects on ionization and recombination processes].

- Highly-excited states in heavy ions

  [Collaboration with Lund Laser Center and Jilin University]

  Semi-empirical determination of radiative parameters for higly-excited states in lowly ionized heavy atoms of interest for NLTE astrophysical models and stellar nucleosynthesis investigations (recent works on Nb, Nb+, Rh+, Ba, La, Re, Ir).

- Spectral analysis of hot white dwarfs

  [Collaboration with Tübingen University]

  Calculations of new atomic data in moderately charged ions observed in high-resolution UV spectra of hot white dwarfs, highlighting large overabundances of heavy elements ($Z > 30$).

- Atomic data for cosmochronology

  [Collaboration with Université Libre de Bruxelles]

  Spectral line list of cosmochronological interest deduced from new calculations of radiative parameters in Th+ and U+.