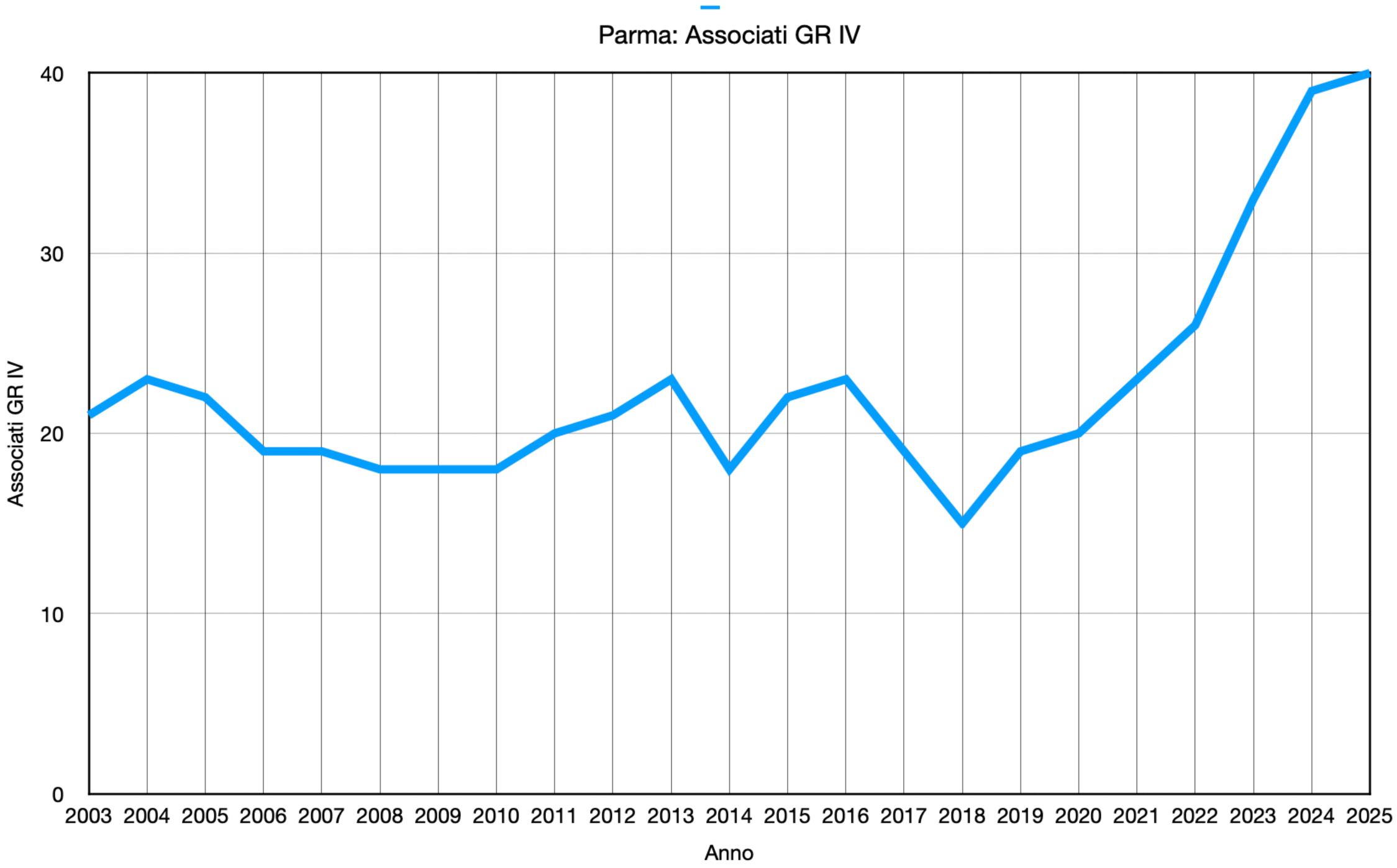
Il Gruppo Collegato INFN di Parma

Massimo Pietroni 10/7/2025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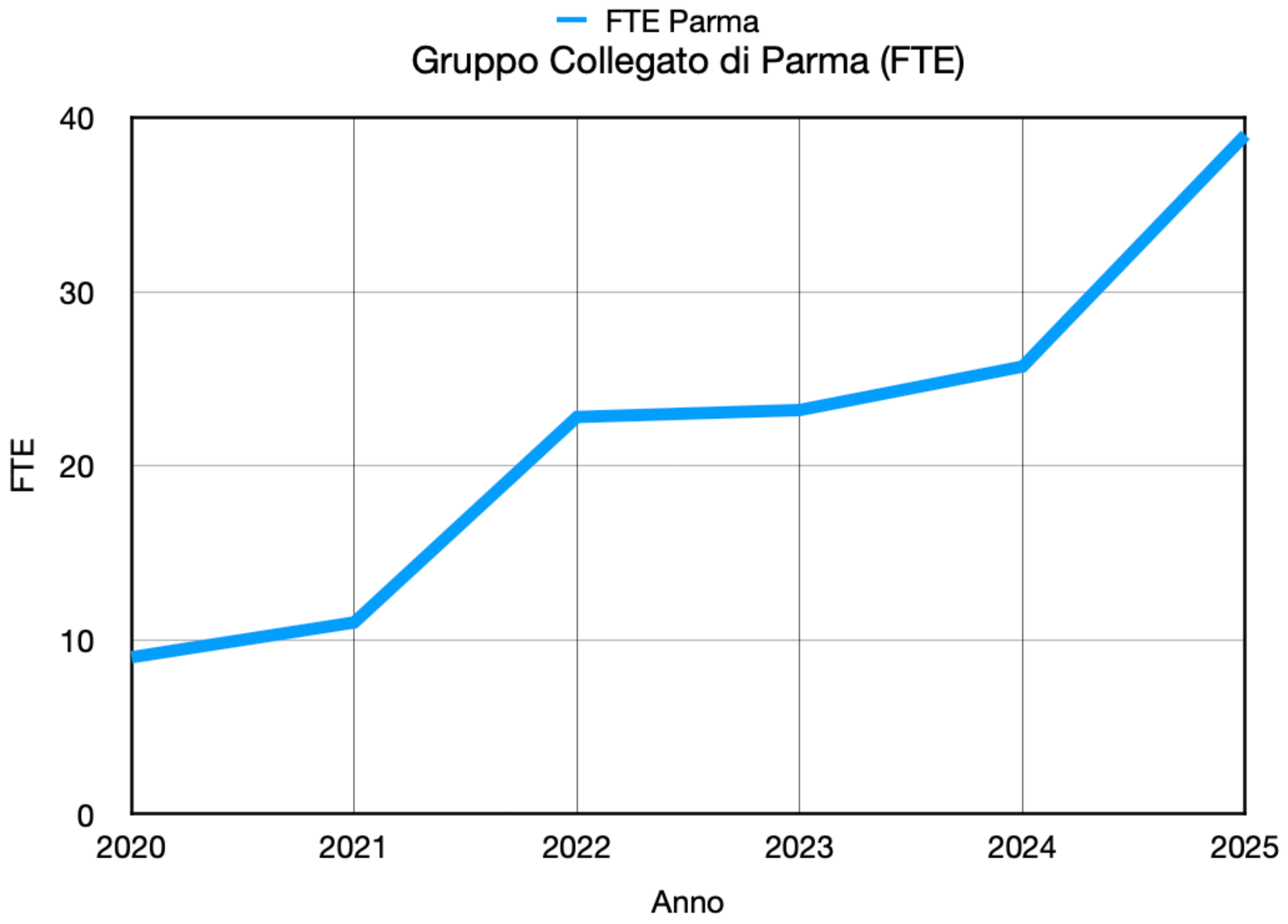
FTE Parma
Gruppo Collegato di Parma (FTE)
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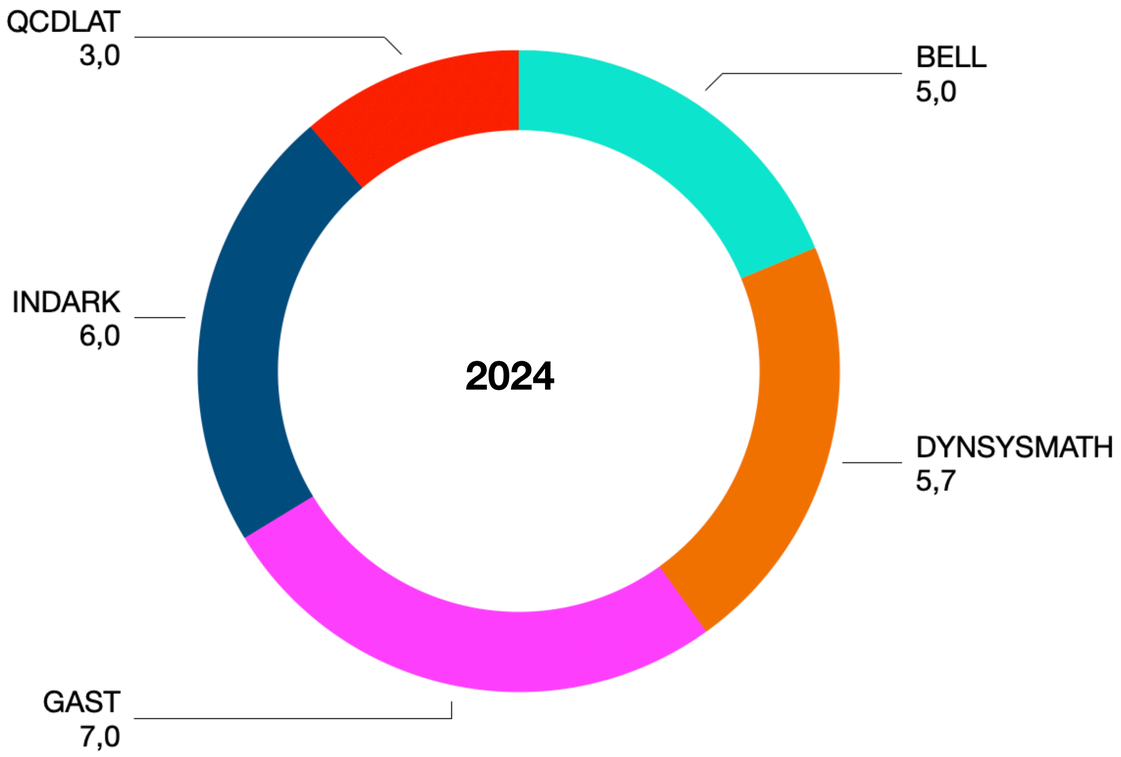
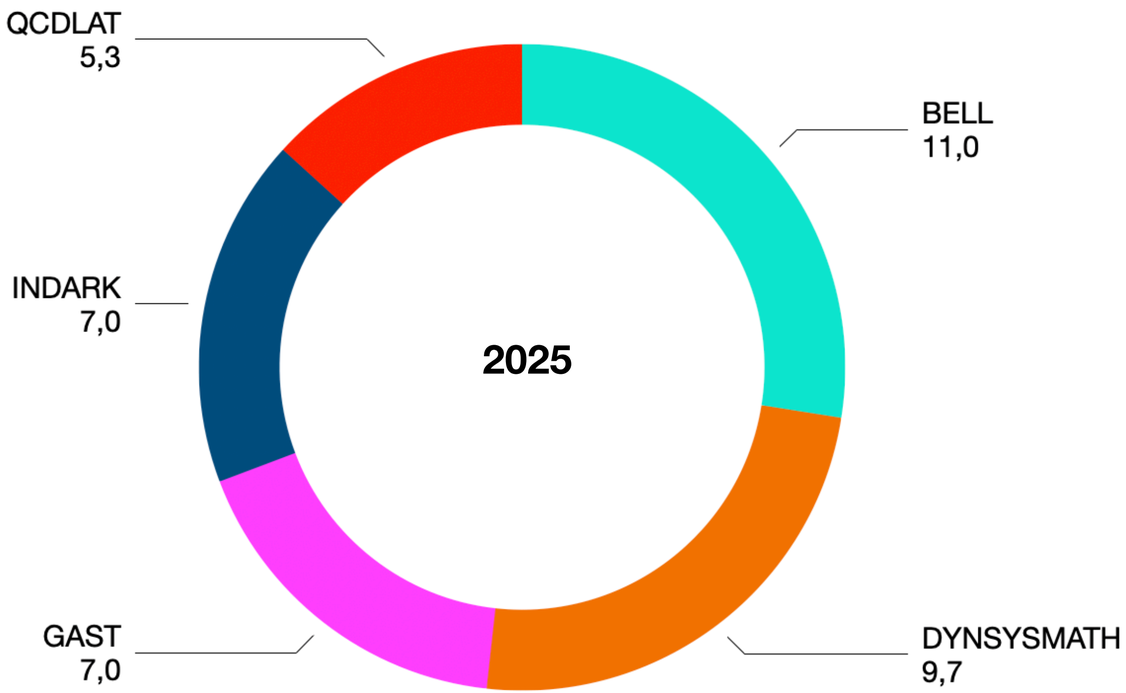
FTE per iniziativa specifica





GAST: Teoria di campi e stringhe
DYNSYSMATH: Sistemi complessi
BELL: Quantum
QCDLAT: Teoria dei campi nonperturbativa
INDARK: Cosmologia e astroparticelle

- 12 universitari staff (11 CSN4 + 1 CSN2 (Virgo))
- 6 incarichi di ricerca
- 4 RTD/RTT
- 1 dipendente CNR
- 18 dottorandi (di cui 3 su borsa INFN)
- 3 borsisti post doc INFN
- 1 tecnologica borse E.P.

Convenzione INFN-UNIPR

- rinnovata a gennaio 2024
- durata 7 anni
- contributo INFN per servizi e utenze, 1 borsa di dottorato all’anno, (co)finanziamento post-doc…
- modifiche minori rispetto alla precedente

Le iniziative specifiche

★ GAST-Gauge and String Theory

★ GAST-Gauge and String Theory

Andrea Appel: Staff
Marisa Bonini: Staff
Luca Griguolo: Staff
Carlo Meneghelli: Staff
Sophie Mueller: Post-Doc (su PRIN 2022)
Rudolph Triels: Post-Doc (su grant universitario cofinanziato INFN al 50%)
Daniele Artico: Post-Doc-da Settembre 2025 (su PRIN 2022)

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Dottorandi: Leonardo Bossi, Michele Savi, Alex Tarana (borsa INFN), Alessandro Testa

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Collaborazioni principali

Firenze University, Torino University, Ghent University, Southampton University, Humboldt University Berlin, Iceland University, Desy-Hamburg University, Warsawa University, Stony Brook University, Simons Center for Physics&Geometry, Oxford University, Murcia University, Ohio State University, Northeastern University, Beijing Institute for Mathematical Sciences and Applications

★ GAST-Gauge and String Theory

Principali expertise del gruppo: Aspetti perturbativi e
non-perturbativi in QFT, Teorie Supersimmetriche e Superconformi,
Teorie di Stringa, Gravità quantistica in basse dimensioni, Corrispondenza AdS/CFT
Integrabilità, Strutture matematiche in QFT

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Teorie di Stringa, Gravità quantistica in basse dimensioni, Corrispondenza AdS/CFT
Integrabilità, Strutture matematiche in QFT

Highlights recenti:

Andrea Appel: Yangiani e teoria delle rappresentazioni, aspetti matematici di sistemi integrabili

Carlo Meneghelli: Bootstrap in teorie superconformi, funzioni di correlazione a molti punti in N=4 SYM, algebra di operatori di vertice in N=2 SYM

Luca Griguolo: Localizzazione supersimmetrica in teorie non-conformi, Difetti e linee di Wilson in diverse dimensioni, Gravità bidimensionale e i suoi aspetti olografici, Potenziale Quark-anti Quark in N=4 SYM

DYNSYSMATH

DYNamics and non equilibrium states of complex SYStems: MATHematical methods and physical concepts

Nodi:

- Parma (national coordinator: R. Burioni)
- Roma Sapienza
- Milano Statale (+ Brescia and Como)
- Catania
- Firenze

Parma: R. Burioni, D. Cassi, S. Wimberger,

M. Bellingeri, P. Rotondo (RTDA)

A. Vezzani (CNR) **Post Doc INFN!!**

P. Baglioni (Post-doc PRIN INFN), C. Keup (Post-doc INFN)

\+ A Bassanoni, L. Guglielmi, V. Zimbardo (Ph.D. Students)

\+ 2 studenti in tesi magistrale

Principali expertise del gruppo di Parma:

Equilibrium and out of equilibrium statistical physics,

Statistical Physics and dynamical models on graphs and networks, neural networks

Classical and quantum transport, quantum control

Research Topics

- Sincronizzazione e transizioni di fase dinamiche su networks: applicazioni a neural networks, a processi epidemici e di trasporto e a misure di resilienza delle reti

- Inferenza statistica da dati neural, Statistical Physics of Machine Learning, Bayesian Inference. Analisi di grandi fluttuazioni e large deviations

- Trasporto coerente e effetti quantistici, quantum walks, quantum control, classical to quantum parallels in Synchronization and Entanglement

Collaborazioni principali

Parigi IV, ENS Paris, Friburgo, Zurigo, Boston Northeastern, Bar Ilan University, Vietnam National University, Erlangen-Norimberga, Heidelberg, Oklahoma State University, Granada University , Leiden, Cardiff, Sapienza Roma, Roma Tor Vergata, CNRS Marsiglia, Los Alamos, Washington, Università di Bologna, Università di Firenze, Università di Pisa, Istituto dei Sistemi Complessi CNR-ISC Roma e Firenze, Università di Salerno

Highlights

- Presenti in 2 partenariati Estesi e 2 Centri Nazionali PNRR, 1 progetto internazionale, 2 progetti regionali, 2 PRIN (di cui uno su INFN Mib)
- Borsa Post Doc per Stranieri INFN nel 2024 (Christian Keup) per DYNSYSMATH
- 11 tesi di dottorato svolte all'interno del gruppo negli ultimi 5 anni, di cui 3 in cotutela con Università Straniere
- 1 tesi di Dottorato premiata con Menzione Speciale del Premio Fubini 2023 (Marco Mancastroppa)
- 1 tesi di Dottorato premiata con il Premio "Giovanni Paladin" della Società Italiana di Fisica Statistica per la miglior tesi di dottorato in Fisica Statistica 2022 (Marco Mancastroppa).

- Organizzazione di 3 conferenze internazionali e 3 sessioni APS March Meeting

- Gruppo coinvolto nell'organizzazione di Statphys29 (Firenze 2025)

Group

BELL : Fundamental Problems in Quantum Physics (Commissione IV, Linea 4)

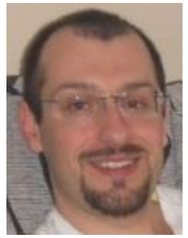
S. CARRETTA

P. SANTINI

- Stefano Carretta (PO)
- Paolo Santini (PO)

A. CHIESA

E. GARLATTI



L. LEPORI

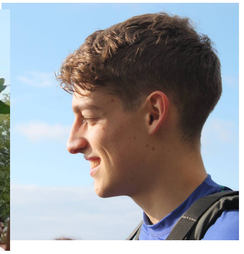
L. RATINI

- Alessandro Chiesa (RTD)
- Elena Garlatti (RTD)
- Luca Lepori (RTD)
- Leonardo Ratini (assegnista)

A. CANTARELLA

S. MACEDONIO

M. MEZZADRI



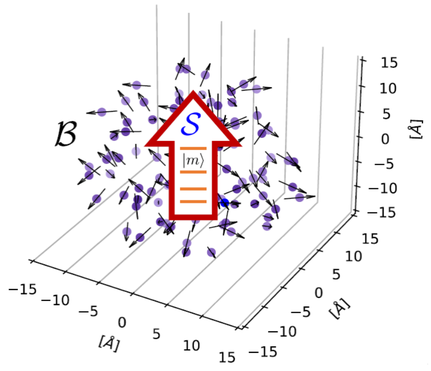
G. SANSONE

- Arianna Cantarella (phD student)
- Silvia Macedonio (phD student)
- Matteo Mezzadri (phD student)
- Giacomo Sansone (phD student

Research Lines

Theoretical modelling, schemes and algorithms for Quantum Information Processing

- Modelling of decoherence in molecular qubits and qu**D**its



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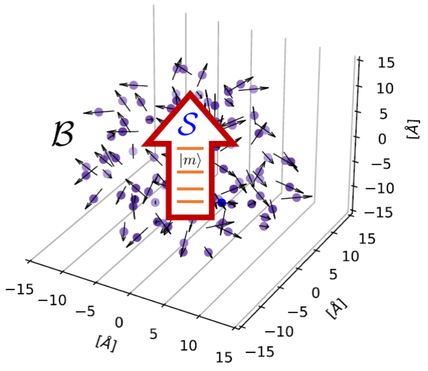

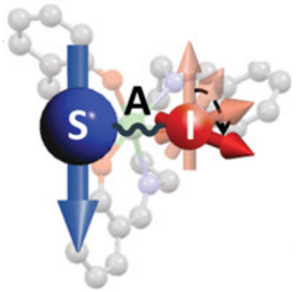

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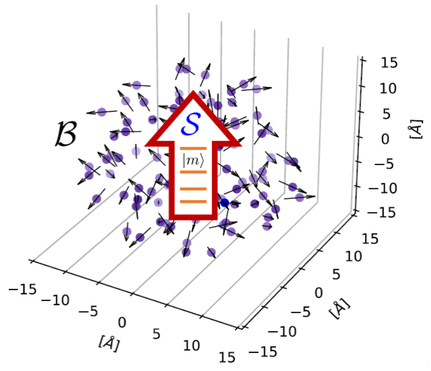

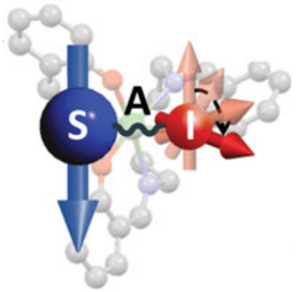

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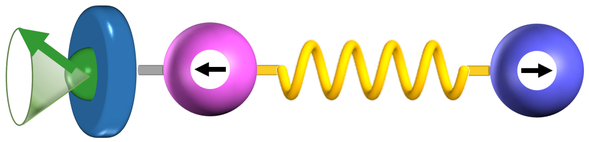
- Chirality-Induced Spin Selectivity: a tool for quantum technologies in molecular spins



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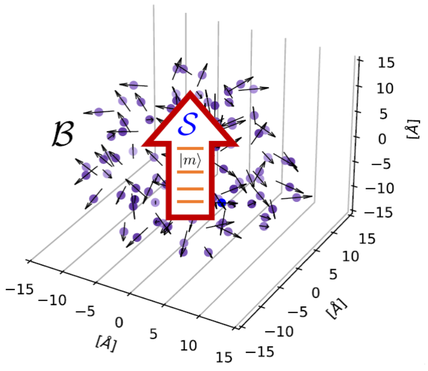

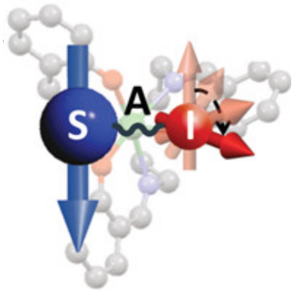

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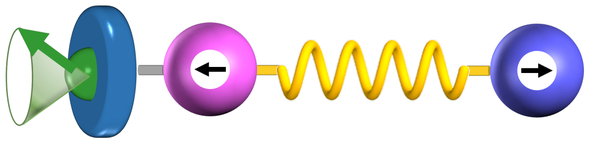
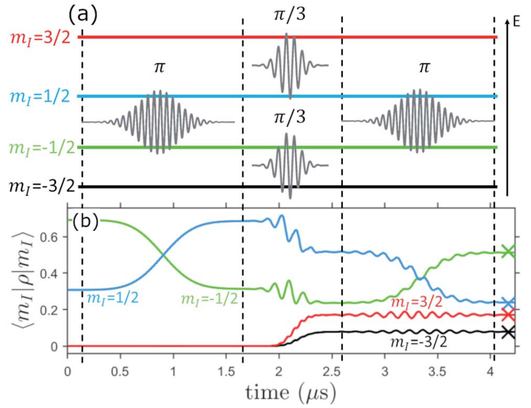


- Design of pulse sequences to implement quantum algorithms



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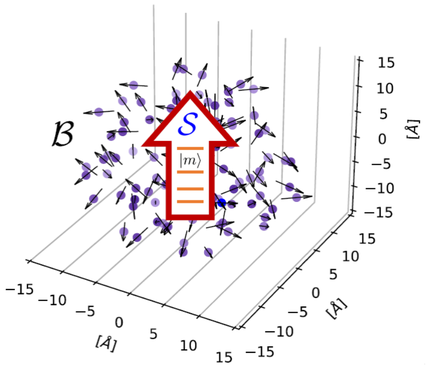

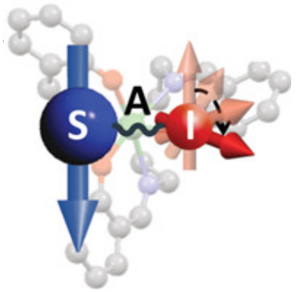

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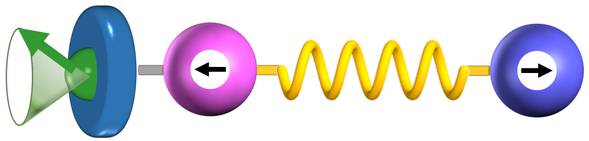
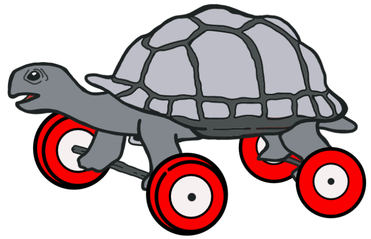


- Preparation of quantum states with optimized adiabatic techniques



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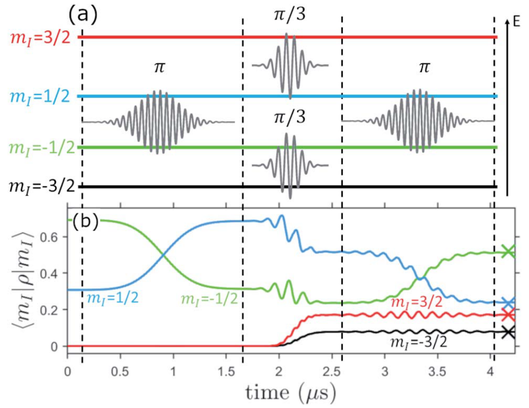

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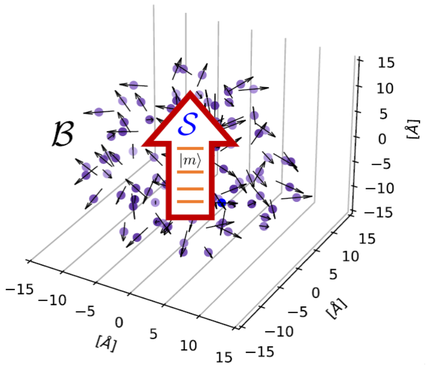

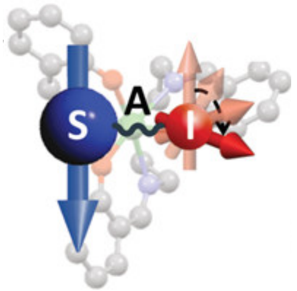

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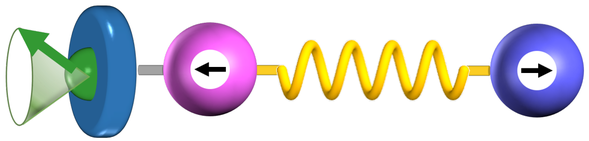

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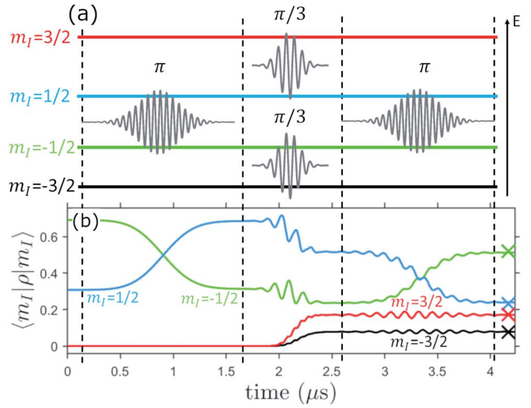

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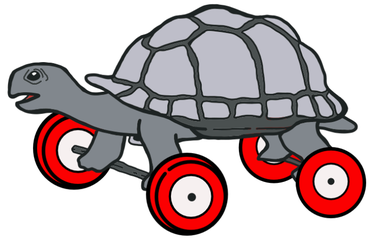
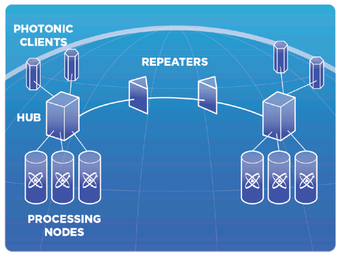


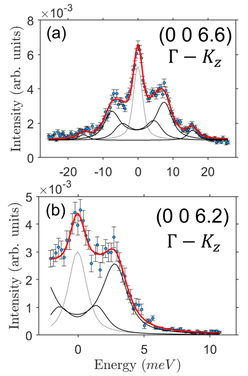


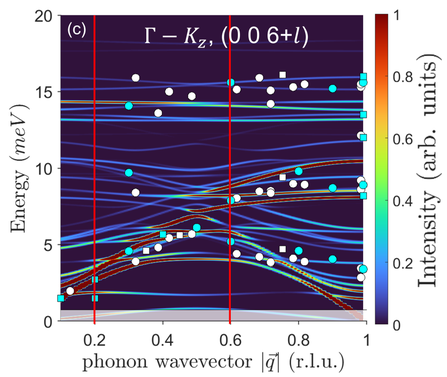
- Quantum internet

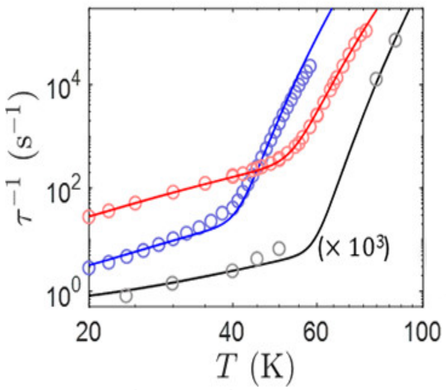
Highlights

Highlights

- Investigation of phonon-induced relaxation in molecular qubits by modelling the first INS and IXS experiments







Nature Commun. **14**, 1653 (2023)

J. Phys. Chem. Lett. **12**, 8826–8832 (2021)

Highlights

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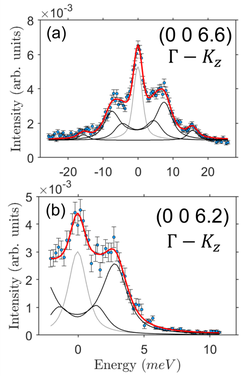

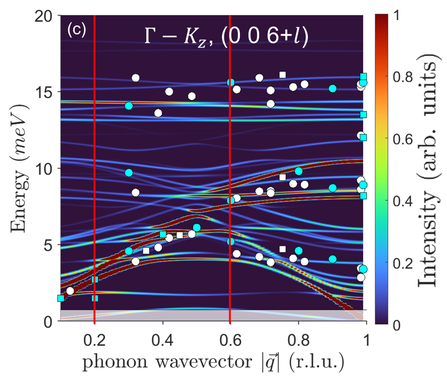

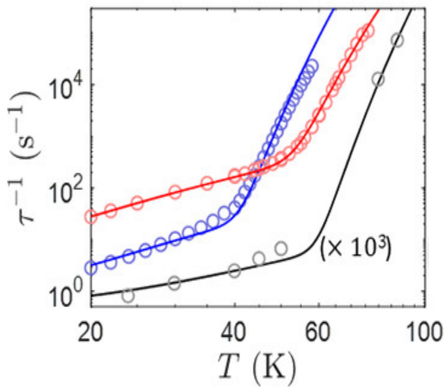

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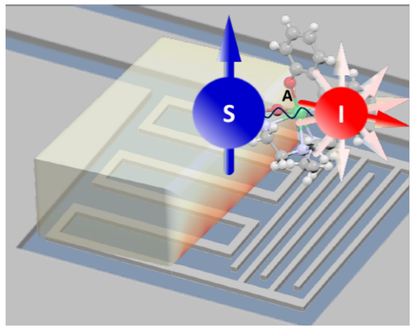
- Design of qudit-based QC schemes based on multi-level logic to enhance computing power and **embed quantum error correction**

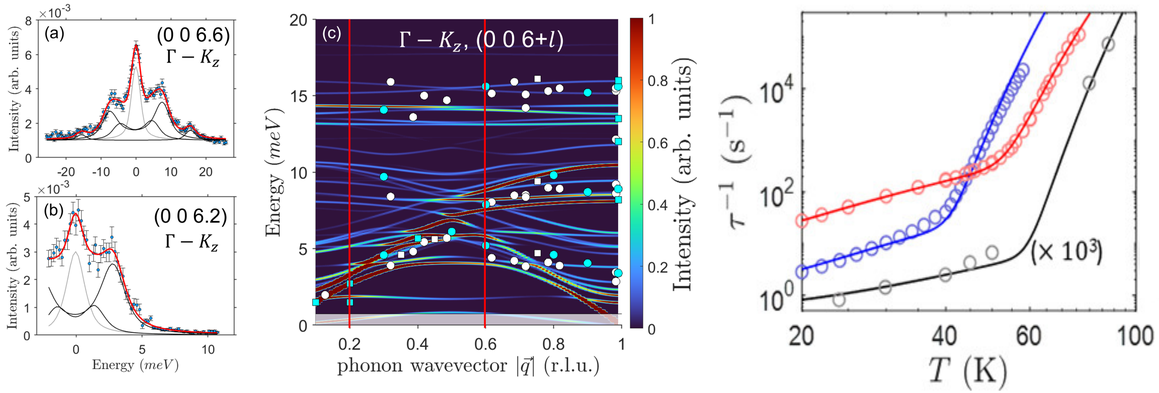


Rep. Prog. Phys. **87** 034501 (2024)

NPJ Quantum Inf. **7**, 133 (2021)
J. Phys. Chem. Lett. **13**, 6468 (2022)
Phys. Rev. A **110**, 062602 (2024)
Mater. Horiz. **11**, 4961-4969 (2024)

Highlights

- Investigation of phonon-induced relaxation in molecular qubits by modelling the first INS and IXS experiments



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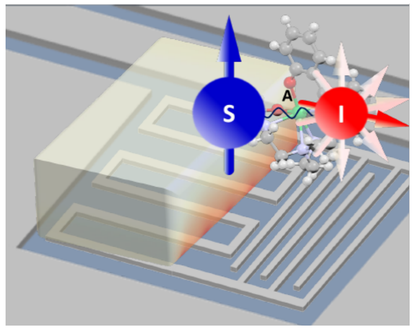

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Phys. Rev. A **110**, 062602 (2024)
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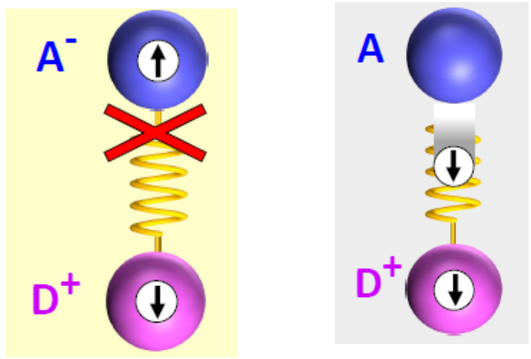
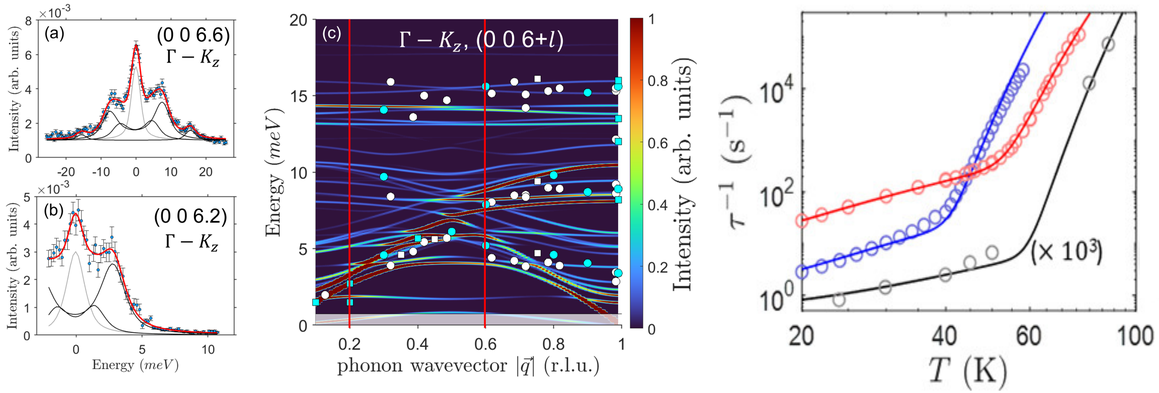
- Schemes for **spin to charge conversion** based on chirality induced spin selectivity



Adv. Mater **35**, 2300472 (2023)
Nano Lett. **24**, 12133-12139 (2024)

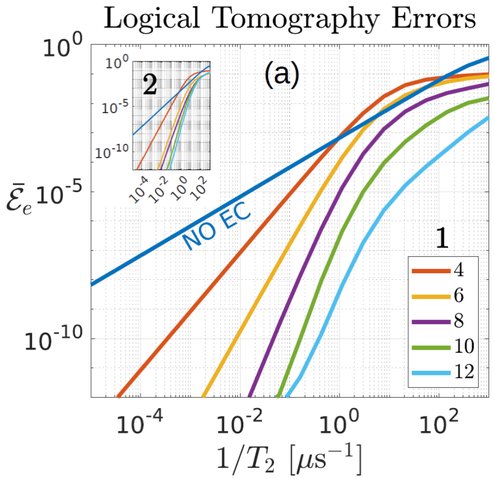
Highlights

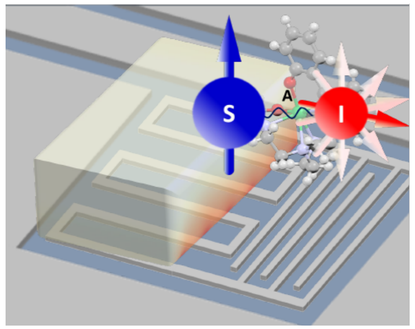
- Investigation of phonon-induced relaxation in molecular qubits by modelling the first INS and IXS experiments



Nature Commun. **14**, 1653 (2023)
J. Phys. Chem. Lett. **12**, 8826–8832 (2021)

- Design of qudit-based QC schemes based on multi-level logic to enhance computing power and **embed quantum error correction**

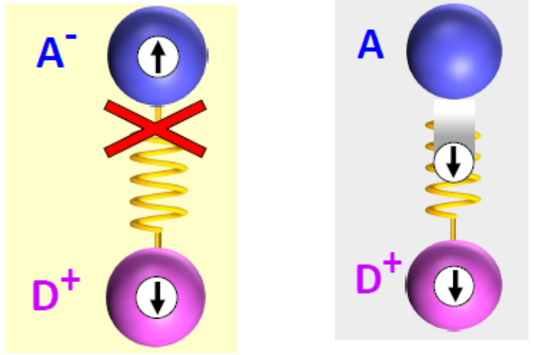




Rep. Prog. Phys. **87** 034501 (2024)

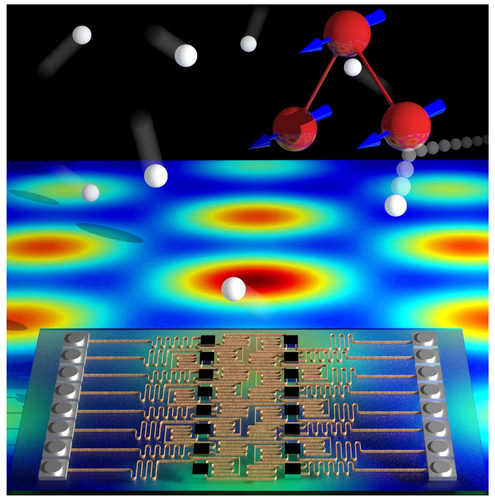
NPJ Quantum Inf. **7**, 133 (2021)
J. Phys. Chem. Lett. **13**, 6468 (2022)
Phys. Rev. A **110**, 062602 (2024)
Mater. Horiz. **11**, 4961-4969 (2024)

- Schemes for **spin to charge conversion** based on chirality induced spin selectivity



Adv. Mater **35**, 2300472 (2023)
Nano Lett. **24**, 12133-12139 (2024)

- **Quantum simulations** on prototype quantum chips



Nat. Phys. **15**, 455-459 (2019)

Projects

CASTLe

project n. 101071533

European Research Council
Established by the European Commission

PNRR MUR project PE0000023-NQSTI
National Quantum Science and Technology Institute

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

QST

MUR
Ministero dell'Università e della Ricerca

PRIN 2022 "CROQUET"

QIA
QUANTUM INTERNET ALLIANCE

novo nordisk foundation

Coherent addressing of isotopically pure lanthanide complexes by photons and efficient quantum error correction for Quantum Information Technologies

QCDLAT@Parma

Linea scientifica 2 (*Phenomenology of elementary particles*)

"The main objective of this project is to search for new fundamental phenomena in Nature by advancing the theoretical knowledge on strongly interacting theories in the Standard Model (SM) and beyond."

LAT stands for **LATTICE**

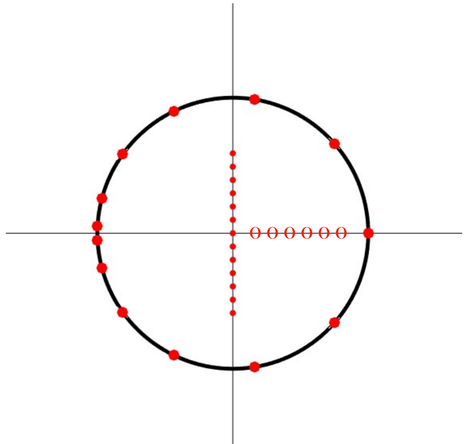
A Parma

- **QCD a TEMPERATURA e DENSITÀ FINITE** (cercando di ricostruire il *diagramma di fase della QCD*)

Problema del segno! ci si deve confinare a valori immaginari del potenziale chimico barioni!

Uno sviluppo recente:

CONTINUAZIONE ANALITICA per mezzo di un PROBLEMA INVERSO a partire dalla *FORMULA INTEGRALE DI CAUCHY [*]*



si calcola la funzione sull'asse immaginario;
la si ricostruisce sul contorno di integrazione di una formula di Cauchy (problema inverso!);
si calcola la funzione sull'asse reale per mezzo della stessa formula di Cauchy…

QCDLAT@Parma

A Parma

- **QCD a TEMPERATURA e DENSITÀ FINITE** (cercando di ricostruire il *diagramma di fase della QCD*)
- **Sviluppi teorici** (*regolarizzazione di teorie di campo su Lefschetz thimbles*; *alti ordini perturbativi, rinormaloni, resurgence theory*)
- **Sviluppo di strategie computazionali** (*Numerical Stochastic Perturbation Theory*; *implementazione algoritmica della regolarizzazione su L. Thimbles*; approssimanti di Padè multi-point per lo studio della struttura di singolarità del diagramma di fase della QCD; *PROBLEMI INVERSI in formulazione integrale - cfr [*]; applicazioni di Intelligenza Artificiale*)

Membri del gruppo

PhD INFN!!

Francesco DI RENZO (coordinatore locale) Marco ALIBERTI E LEONARDO PIOVAN (dottorandI XXXIX ciclo) Petros DIMOPOULOS (tecnologo T.D. UNIPR… purtroppo ancora per poco) Demetrianos GAVRIEL (PostDoc INFN)

Post Doc INFN!!

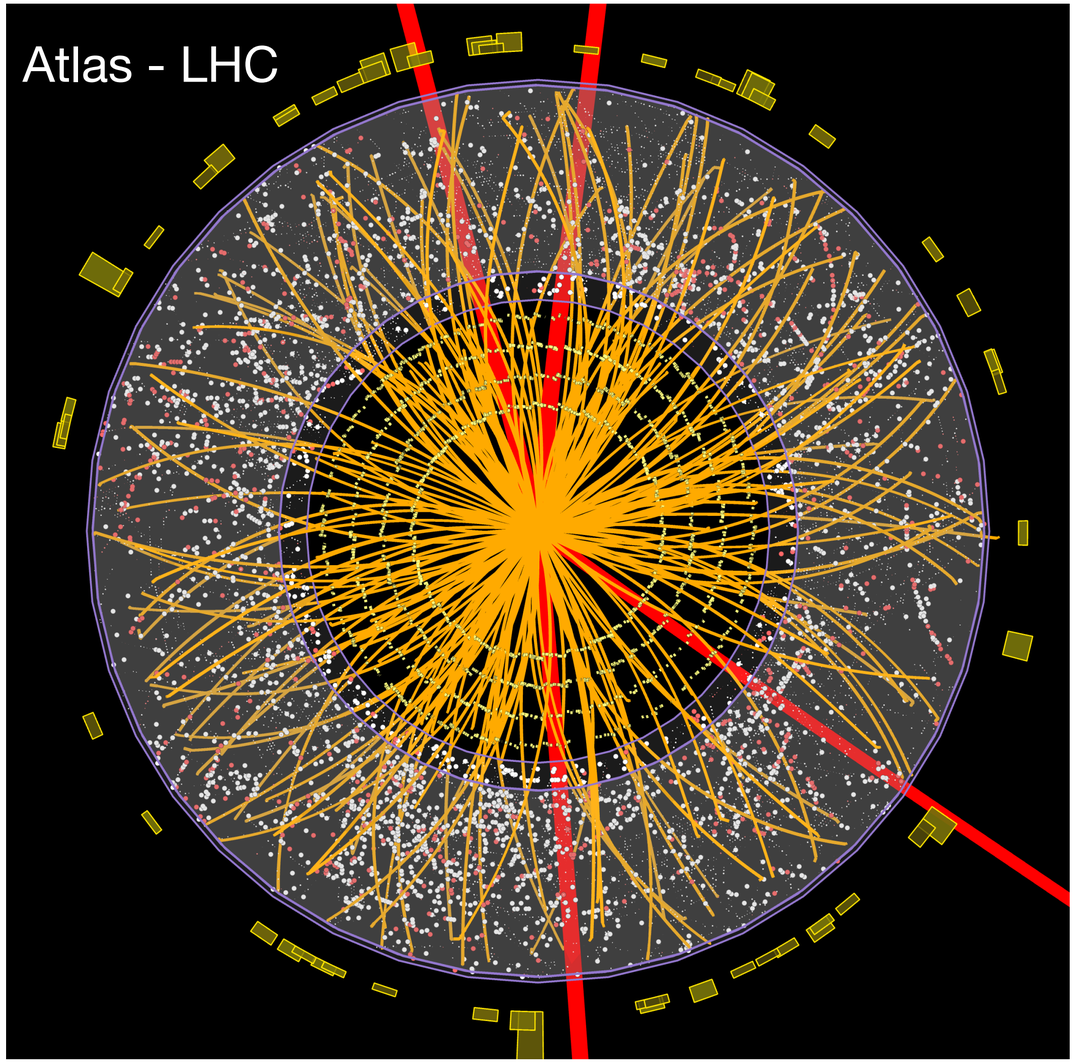
Principali collaborazioni scientifiche

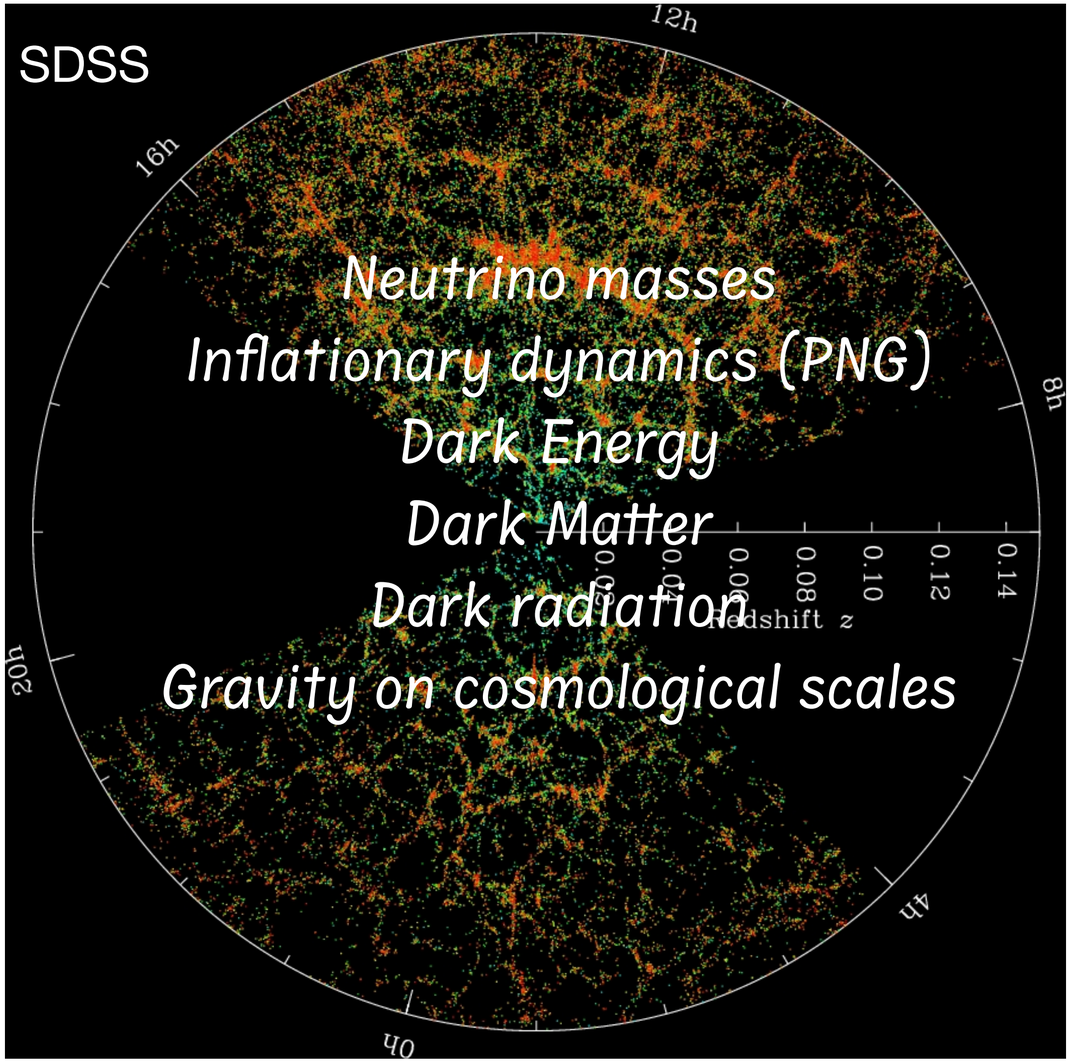
- Bielefeld (*C. Schmidt*)
- ETMC, FLAG (*via P. Dimopoulos*)

- **Grant di calcolo** (*PRACE, ISCRA B, EuroHPC, …*)

INDARK

Extract information on Fundamental Physics from Cosmological Observations

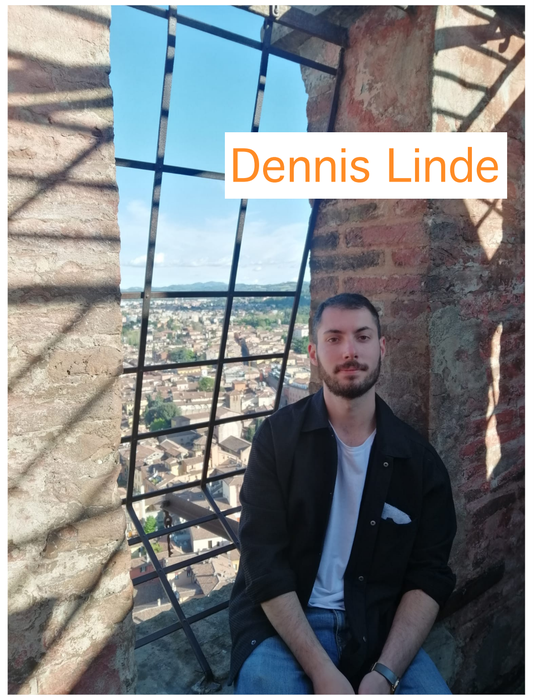




Neutrino masses
Inflationary dynamics (PNG)
Dark Energy
Dark Matter
Dark radiation
Gravity on cosmological scales

INDARK a Parma

UNIPR Staff: G. D'Amico e M. Pietroni
Post doc INFN: Kevin Pardede
Post Doc (PRIN): Pietro Conzinu
PhD:
Matteo Peron (INFN), Dennis Linde, Giorgia Biselli



Euclid Consortium (ESA)

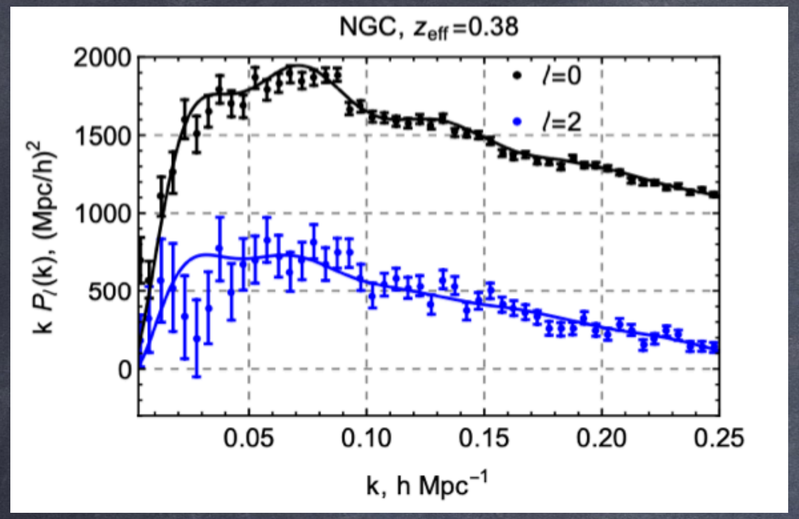
Scientific goals:
Dark Energy
Dark Matter
Testing Gravity on cosmological Scales
Measuring neutrino masses

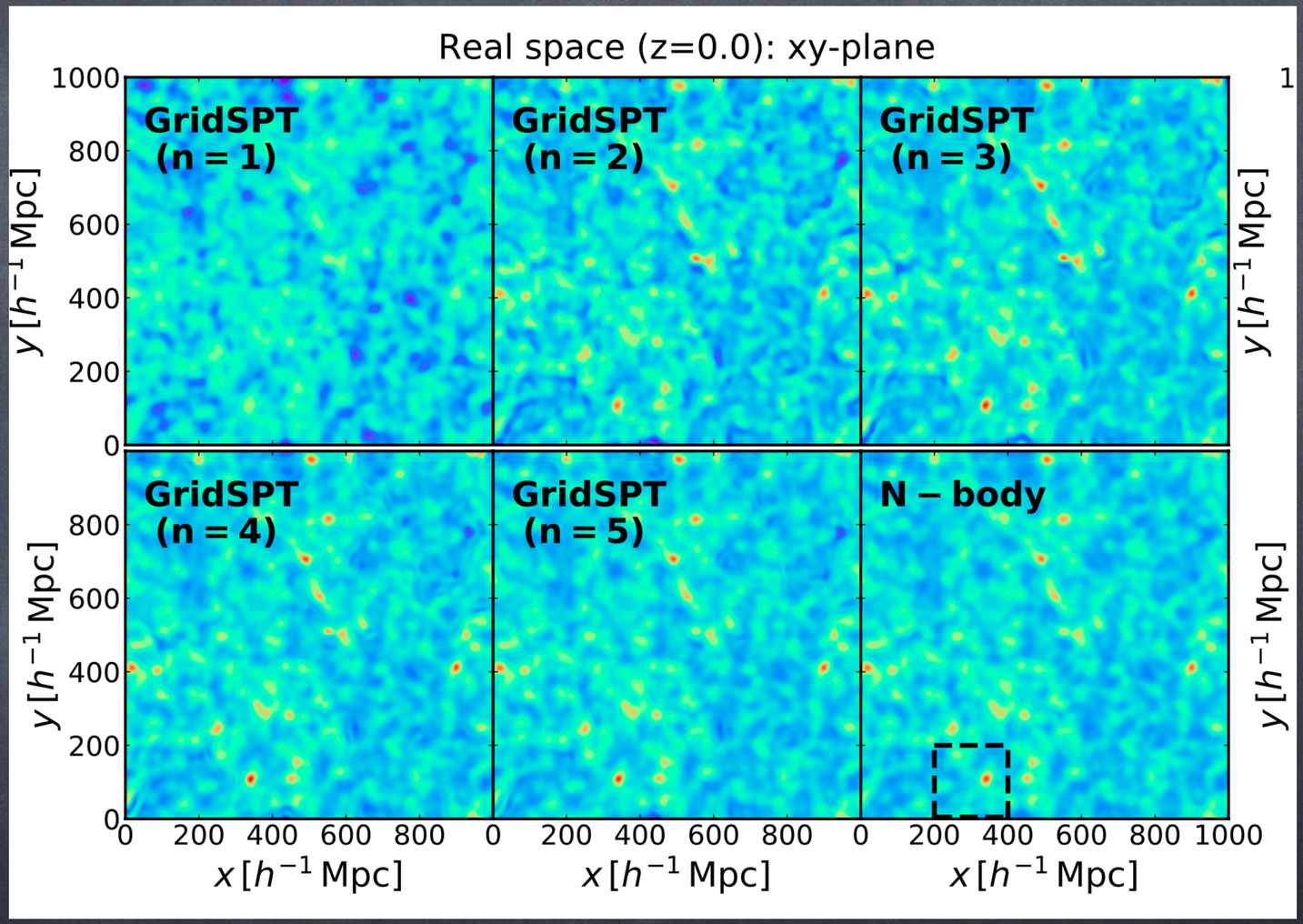
First data release in ~ 1 year from now

Parma Cosmology Group:
Galaxy clustering data analysis, extraction of cosmological parameters and tests of new physics beyond standard models of cosmology and particle physics

contact: massimo.pietroni@unipr.it

From field correlators to the field itself





F. Schmidt++ 1808.02002, 2004.06702, 2403.03220, 2504.15351 ...

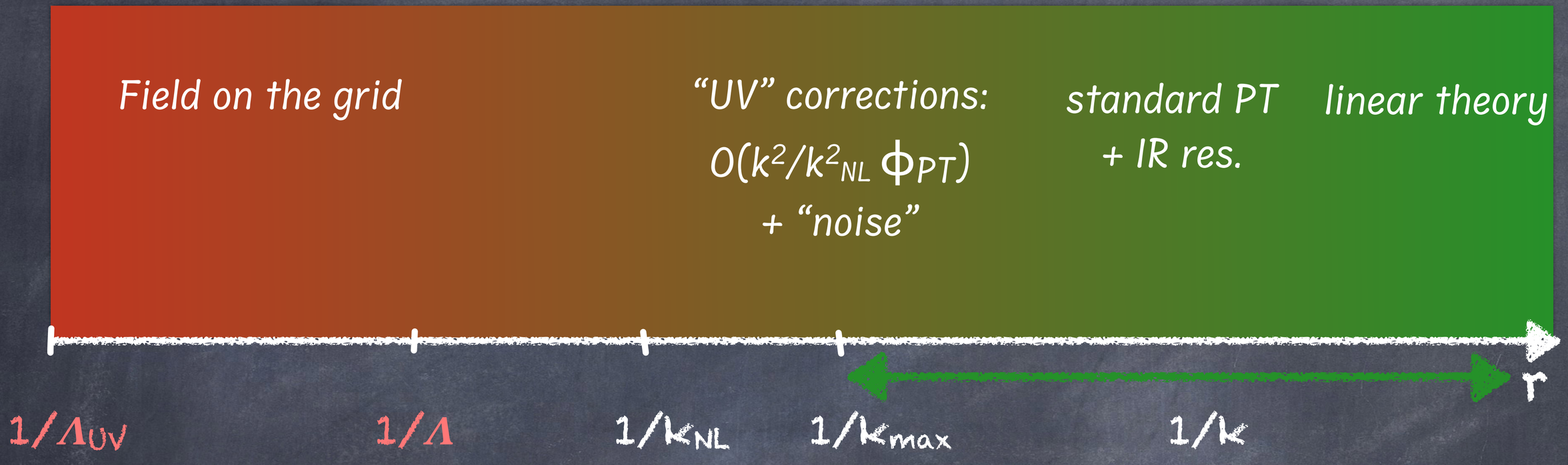
G. Cabass++ 2307.04706

A.Obuljen++ 2207.12398

N. Kokron++ 2112.00012

Taruya, Nishimichi, Jeong, 2109.06734

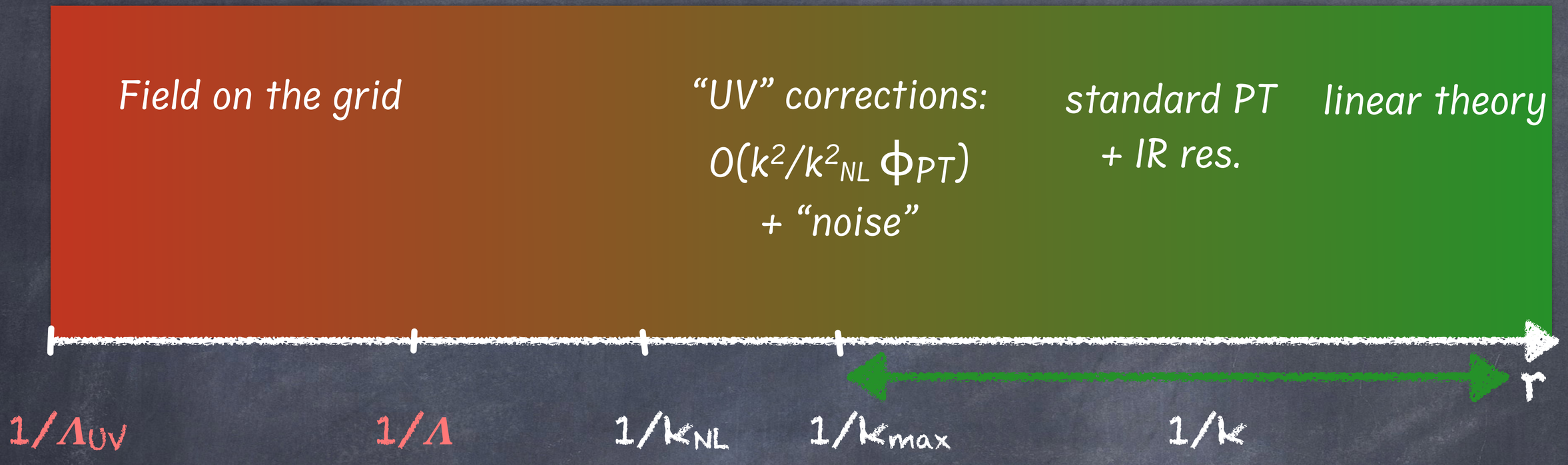
Field on a grid needs field theory



Physical observables must be Λ-independent

$$\delta_{\Lambda}^{[N],\mathrm{PT}}(\mathbf{k}) + \Delta\delta_{\Lambda}^{[N]}(\mathbf{k}) = \delta_{\Lambda_{\mathrm{uv}}}^{[N],\mathrm{PT}}(\mathbf{k}) + \Delta\delta_{\Lambda_{\mathrm{uv}}}^{[N]}(\mathbf{k}) = \delta^{[N]}(\mathbf{k})$$

Field on a grid needs field theory



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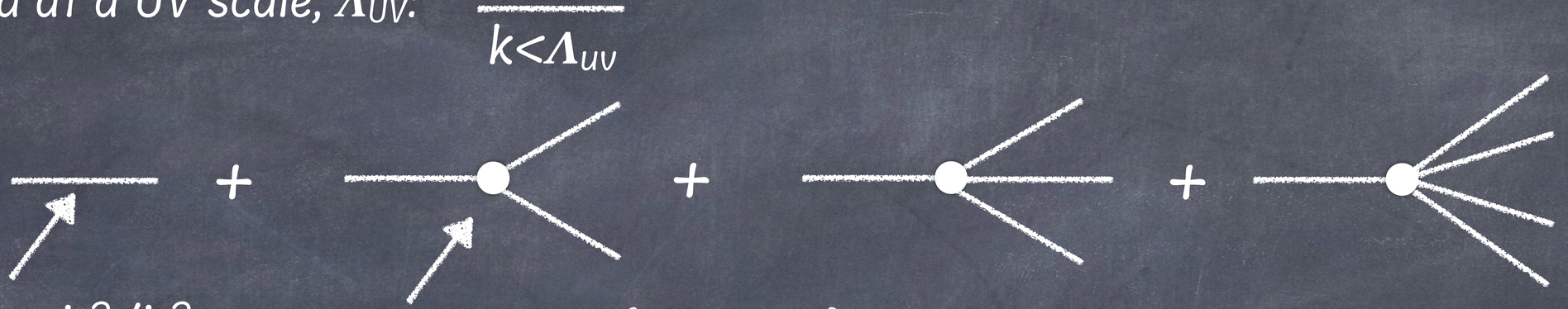
To achieve accuracy, the renormalization of the model must be accurately checked!

Wilsonian approach to LSS field theory

Theory defined at a UV scale, Λ_{UV}:

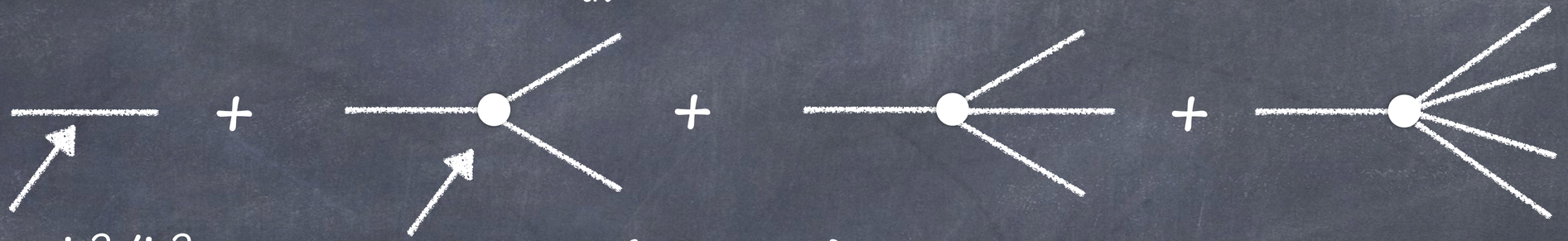


"1"+ $c^2_{\Lambda uv}\, k^2/k^2_{nl}$ ... $+a_{\gamma,\Lambda uv} + O(k^2/k^2_{nl})$

See also:
Carroll, Leichenauer, Pollack 1310.2920
Rubira, Schmidt 2307.15031
Nikolis, Rubira, Schmid 2405.21002

Wilsonian approach to LSS field theory

Theory defined at a UV scale, Λ_{UV}: $\overline{k<\Lambda_{uv}}$



"1"+ $c^2_{\Lambda uv}\, k^2/k^2_{nl}$ ... +$a_{\gamma,\Lambda uv}$ + $O(k^2/k^2_{nl})$

Theory defined at a lower scale, $\Lambda < \Lambda_{UV}$: $\overline{k<\Lambda}$

"1"+ $c^2_{\Lambda}\, k^2/k^2_{nl}$ ... +$a_{\gamma,\Lambda}$ + $O(k^2/k^2_{nl})$

See also:
Carroll, Leichenauer, Pollack 1310.2920
Rubira, Schmidt 2307.15031
Nikolis, Rubira, Schmid 2405.21002

The two models describe the same physics at $k \ll k_{nl}$

$$\overline{k<\Lambda_{uv}} = \overline{k<\Lambda} + \overline{\Lambda<k<\Lambda_{uv}}$$

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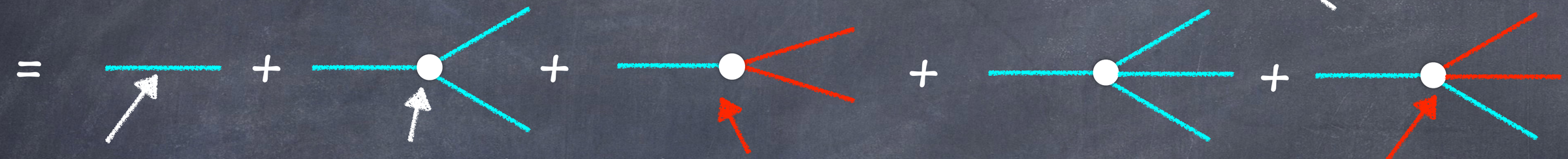
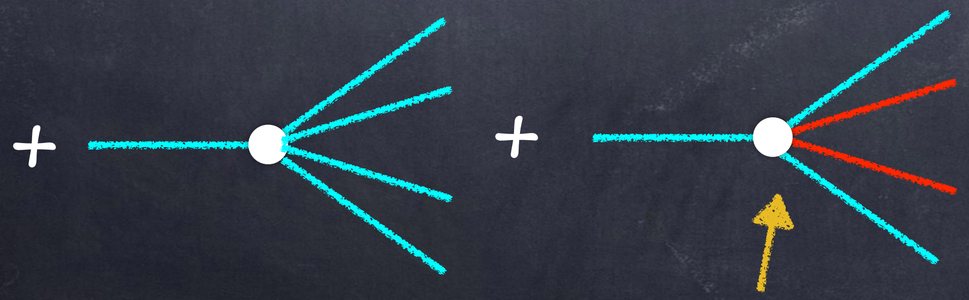
$\overline{k<\Lambda_{uv}} = \overline{k<\Lambda} + \overline{\Lambda<k<\Lambda_{uv}}$



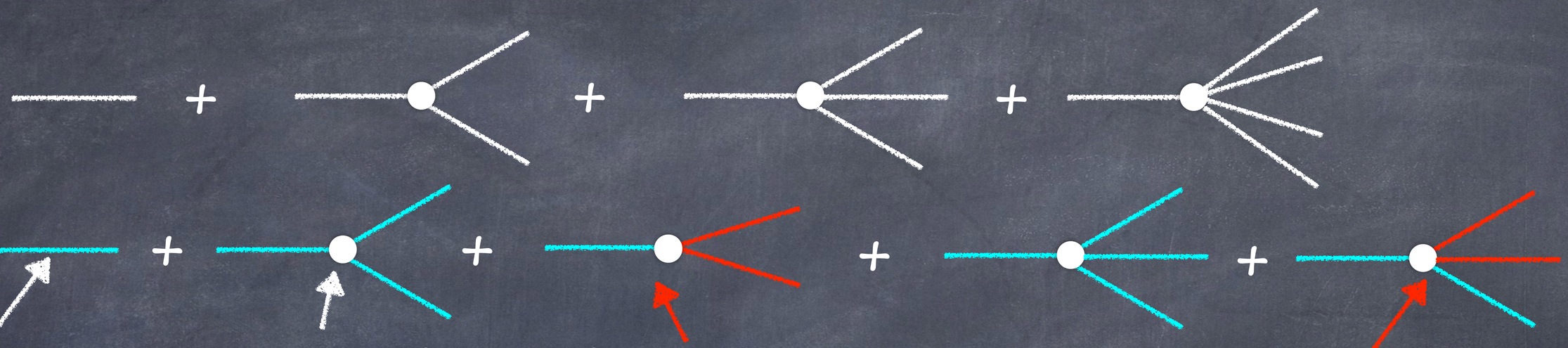
"1"+ $c^2_{\Lambda uv}\, k^2/k^2_{nl}$ $a_{\gamma,\Lambda uv} + O(k^2/k^2_{nl})$ $\varepsilon_{\Lambda,\Lambda uv}\, k^2/k^2_{nl}$ $\delta c^2_{\Lambda,\Lambda uv}\, k^2/k^2_{nl}$



$O(k^2/\Lambda^2)$ $a_{\gamma,\Lambda uv}$ $+O(k^2/\Lambda^2)$

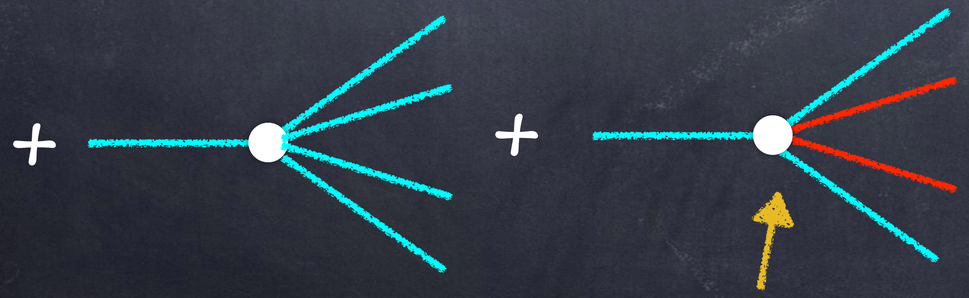
The two models describe the same physics at $k \ll k_{nl}$

$\overline{k<\Lambda_{uv}} = \overline{k<\Lambda} + \overline{\Lambda<k<\Lambda_{uv}}$



$= \quad$ "1" $+ c^2_{\Lambda uv}\, k^2/k^2_{nl} \quad a_{\gamma,\Lambda uv} + O(k^2/k^2_{nl}) \quad \varepsilon_{\Lambda,\Lambda uv}\, k^2/k^2_{nl} \quad \delta c^2_{\Lambda,\Lambda uv}\, k^2/k^2_{nl}$

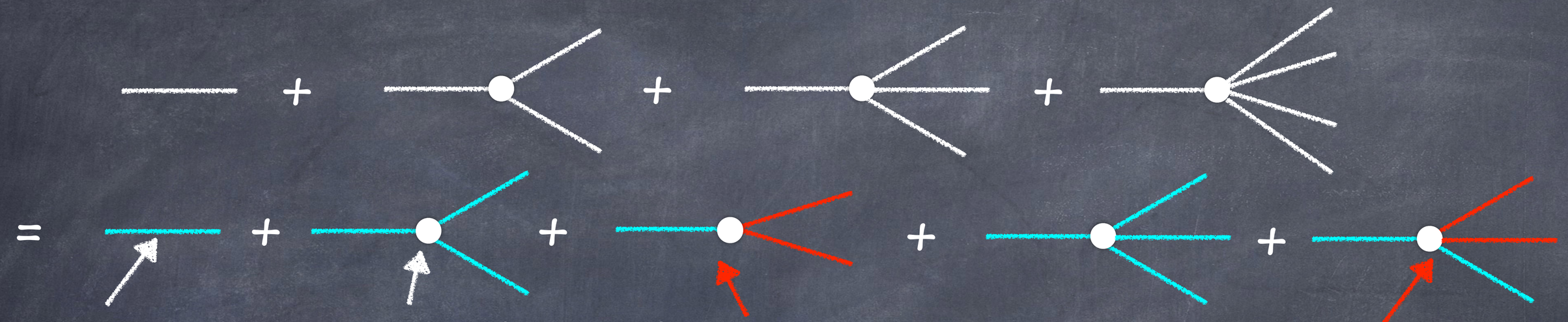
$c^2_{\Lambda uv} + \delta c^2_{\Lambda,\Lambda uv} = c^2_{\Lambda}$



$O(k^2/\Lambda^2)\; a_{\gamma,\Lambda uv} + O(k^2/\Lambda^2)$

The two models describe the same physics at $k \ll k_{nl}$

$\overline{k<\Lambda_{uv}} = \overline{k<\Lambda} + \overline{\Lambda<k<\Lambda_{uv}}$



"1"+ $c^2_{\Lambda uv}\, k^2/k^2_{nl}$ $a_{\gamma,\Lambda uv} + O(k^2/k^2_{nl})$ $\varepsilon_{\Lambda,\Lambda uv}\, k^2/k^2_{nl}$ $\delta c^2_{\Lambda,\Lambda uv}\, k^2/k^2_{nl}$

$c^2_{\Lambda uv} + \delta c^2_{\Lambda,\Lambda uv} = c^2_{\Lambda}$

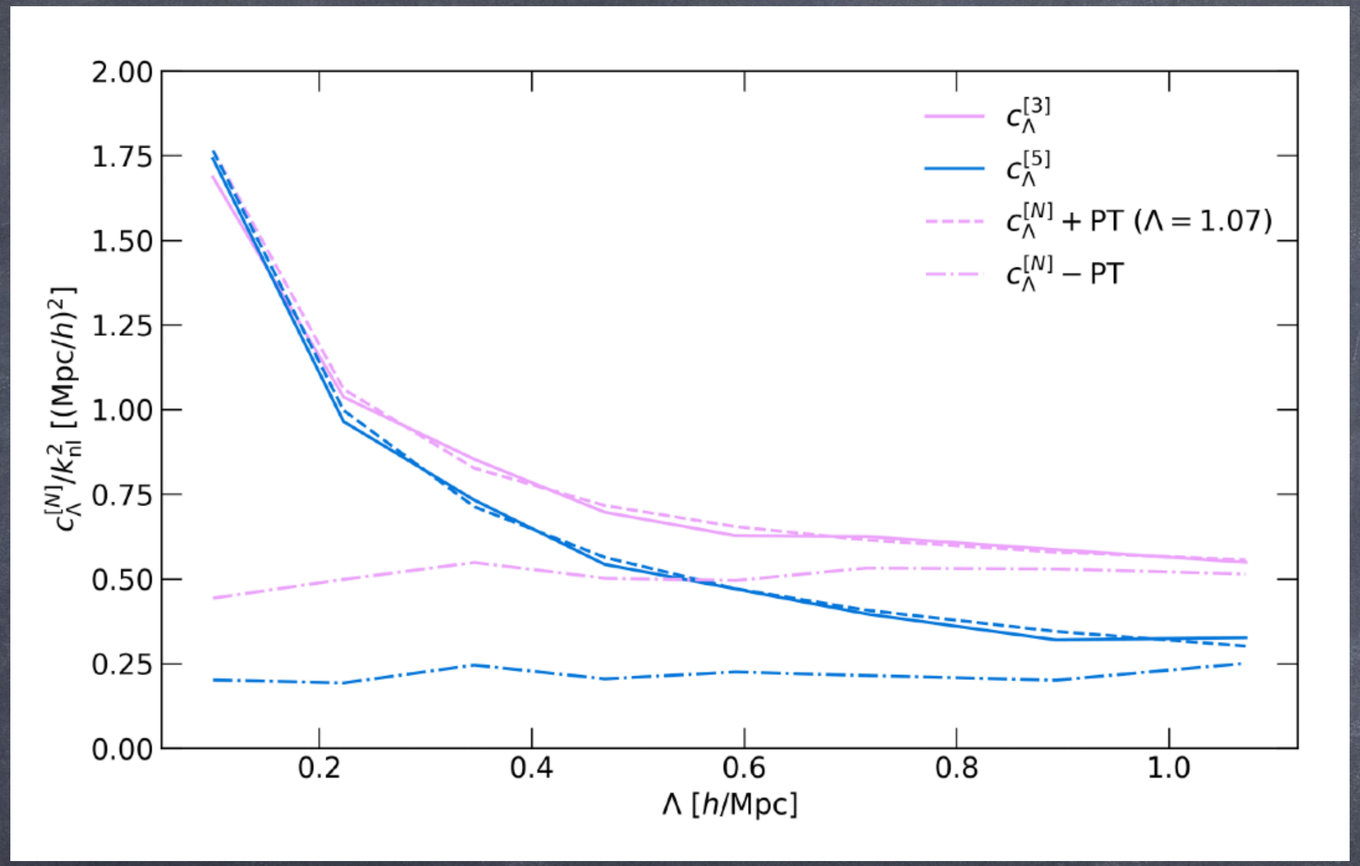
correction to the higher der. quadratic term

$O(k^2/\Lambda^2)$ $a_{\gamma,\Lambda uv}$ $+O(k^2/\Lambda^2)$

$a_{\gamma,\Lambda} = a_{\gamma,\Lambda uv}$:non-renormalization th. of galileon operators

Asassi, Baumann, Green, Zaldarriaga, 2014

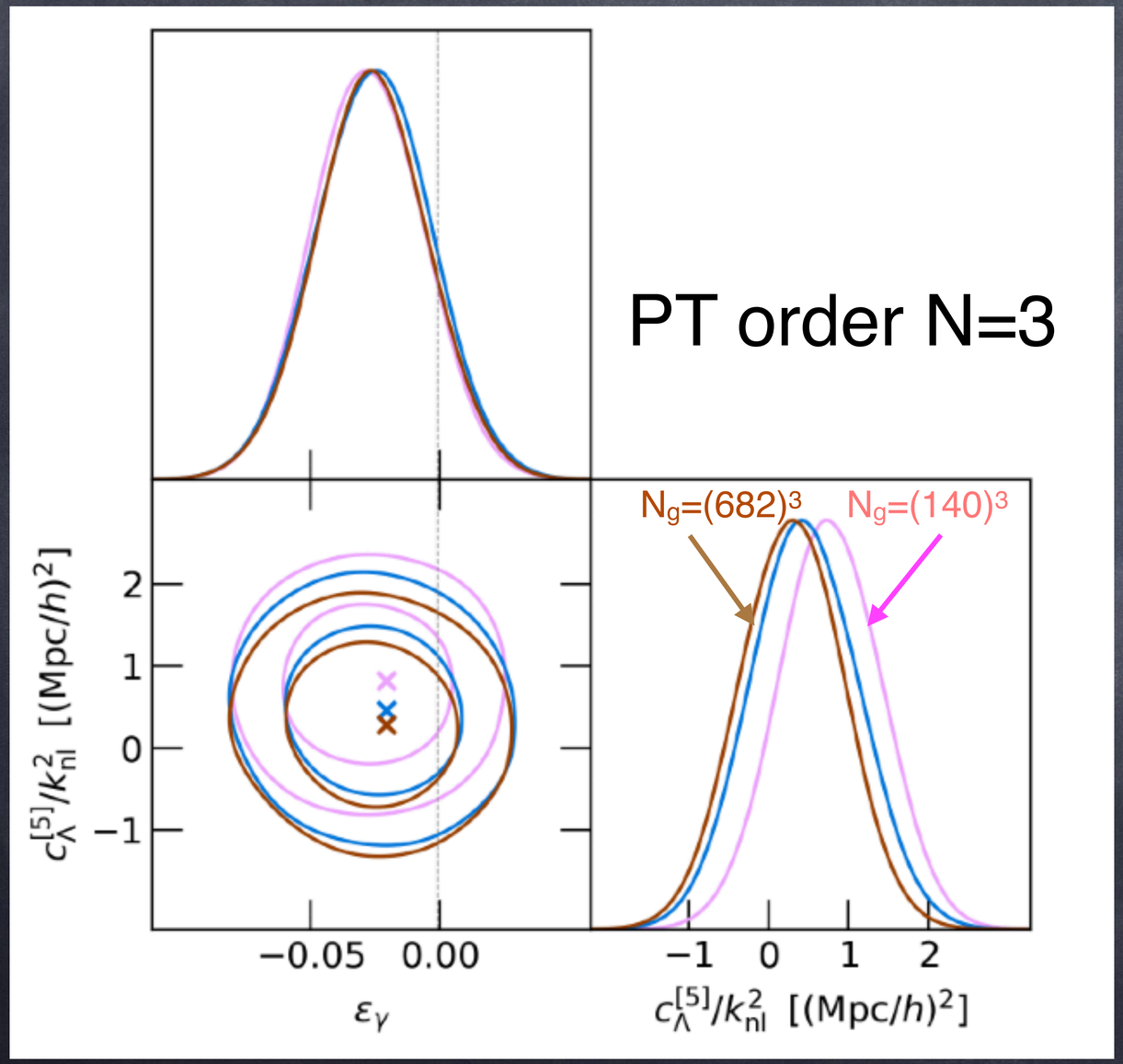
Running of the Wilson coefficients

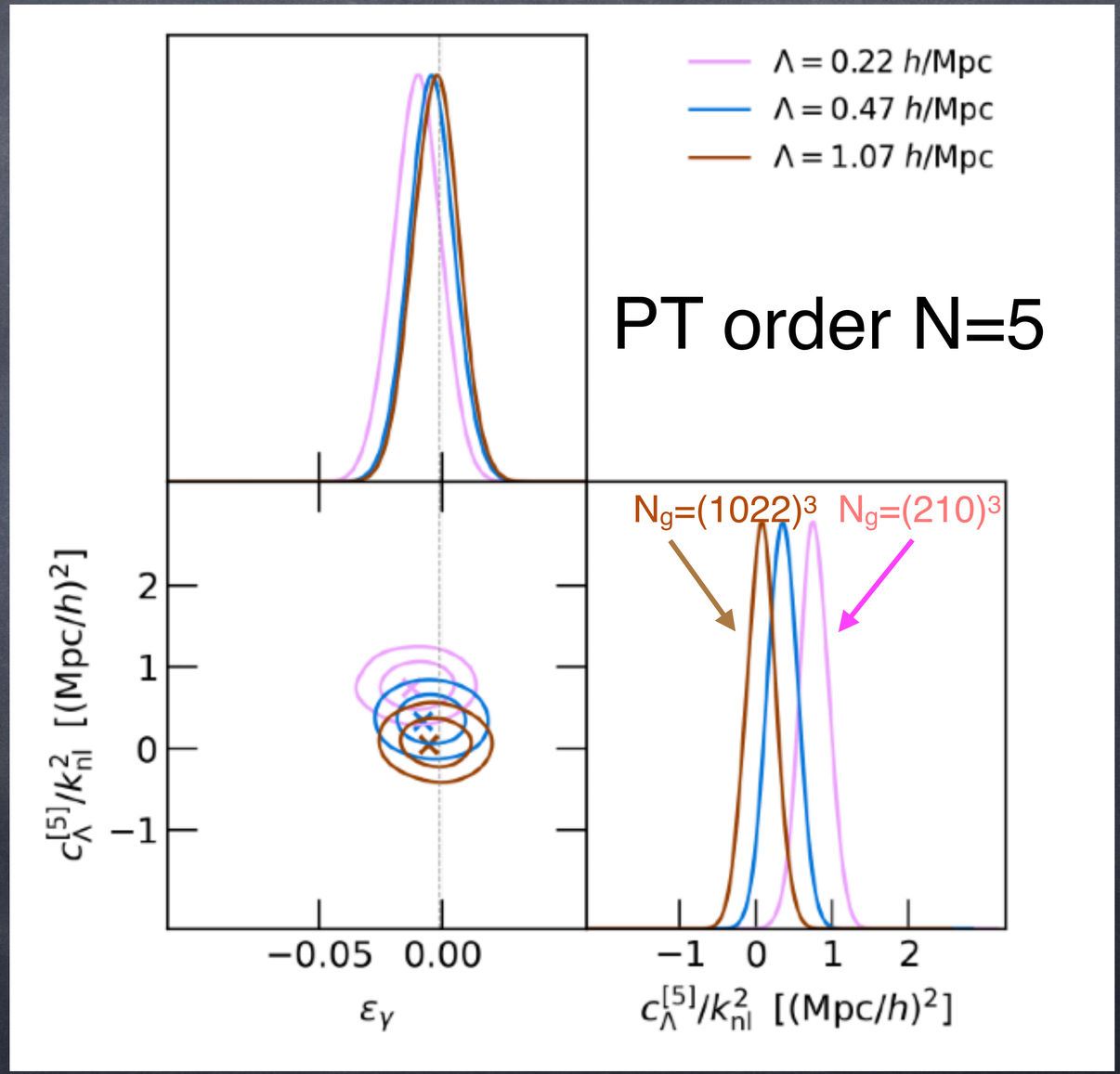


Peron, Nishimichi, MP, Taruya 2506.07105

From Λ-dependent parameters...

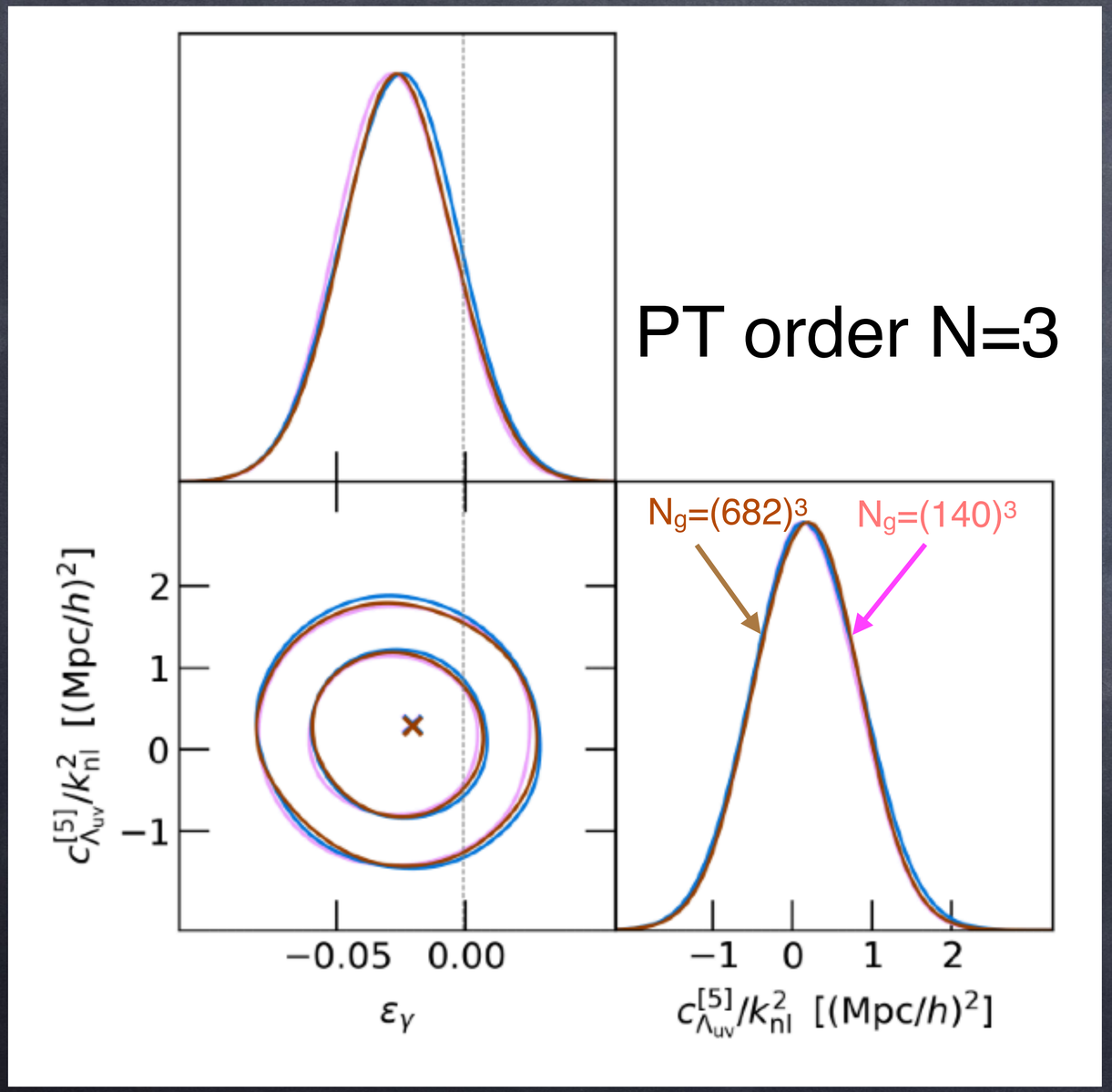
Peron, Nishimichi, MP, Taruya 2506.07105

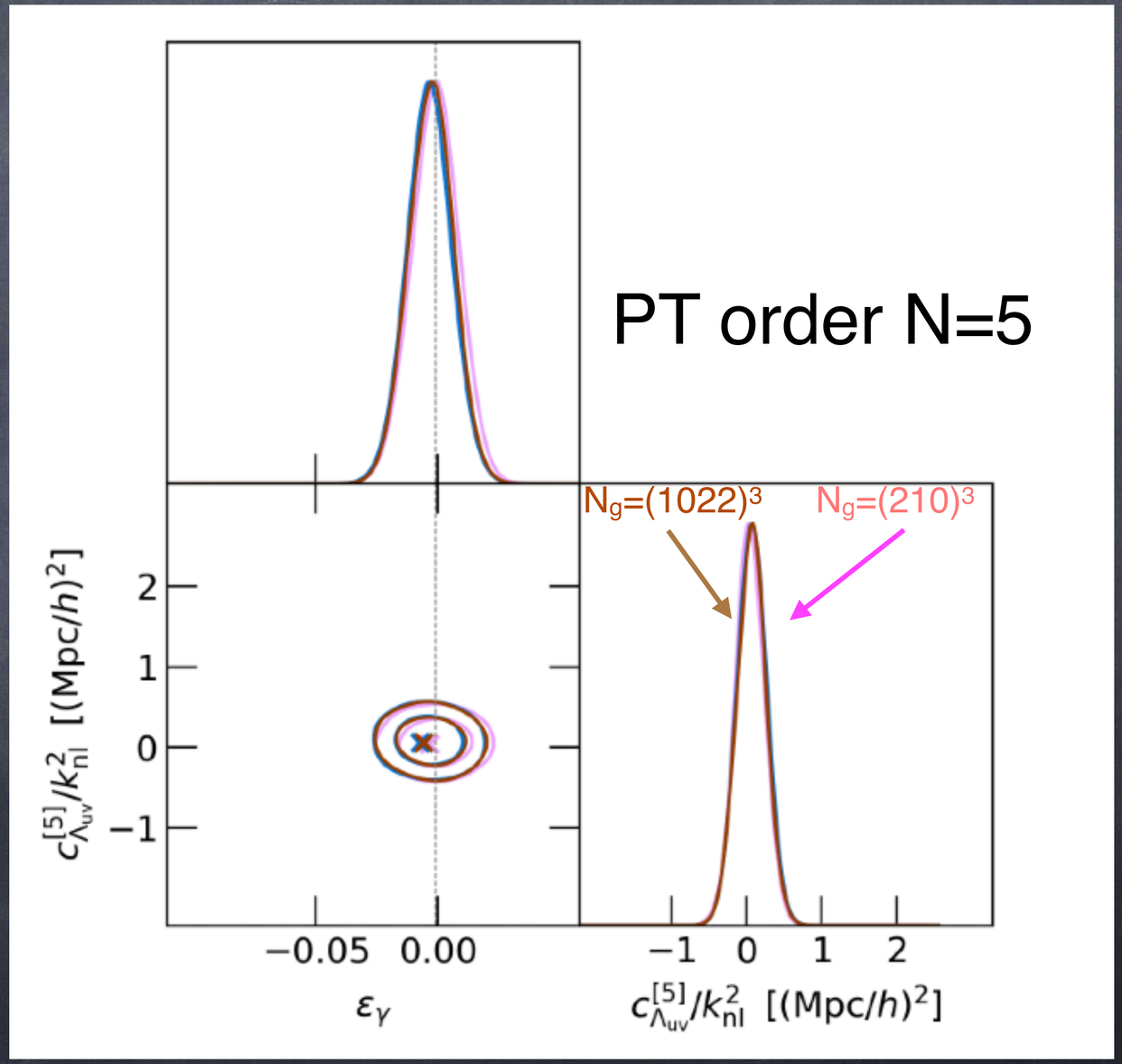




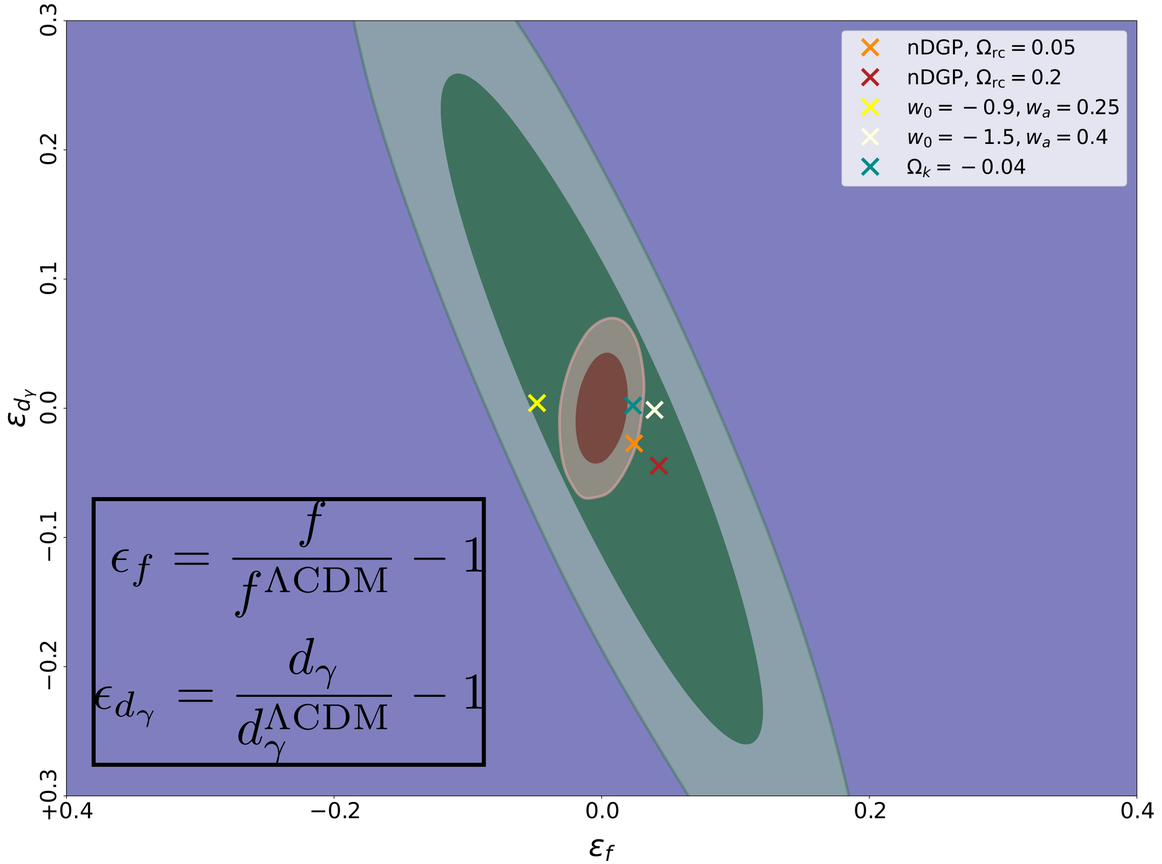
… to renormalized ones

Peron, Nishimichi, MP, Taruya 2506.07105





- The Universe as a laboratory for Fundamental Physics
- Neutrino Masses and properties
- Dynamics of Inflation
- Precision tests of the Standard Cosmological Model
- Tools from our (INFN) common background: Effective Field Theory, Resummations, Symmetries, Bootstrap, radiative corrections…



ex: Precision tests of new physics beyond ΛCDM

- The Universe as a Fundamental Phys
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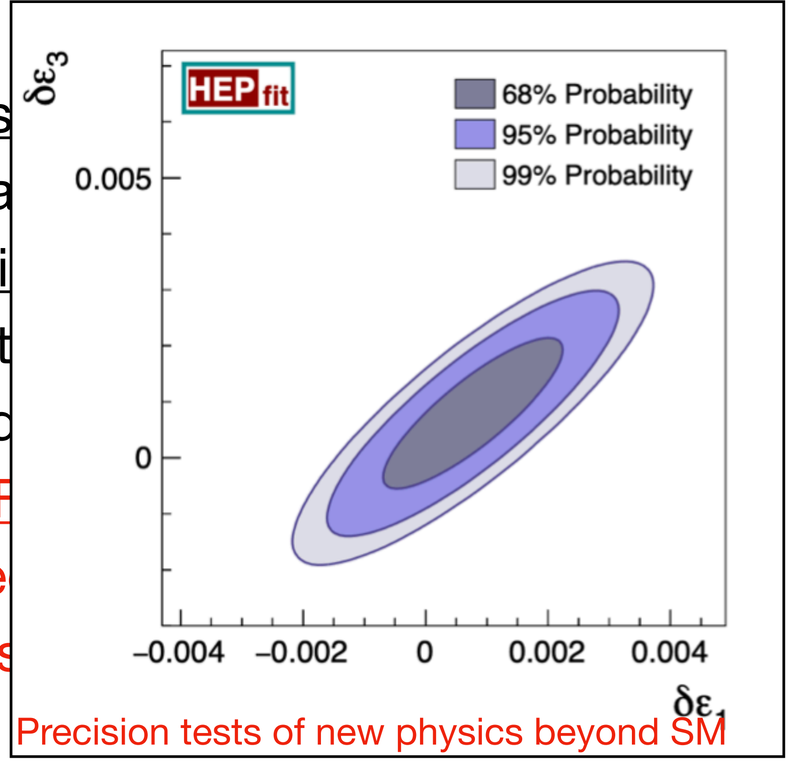
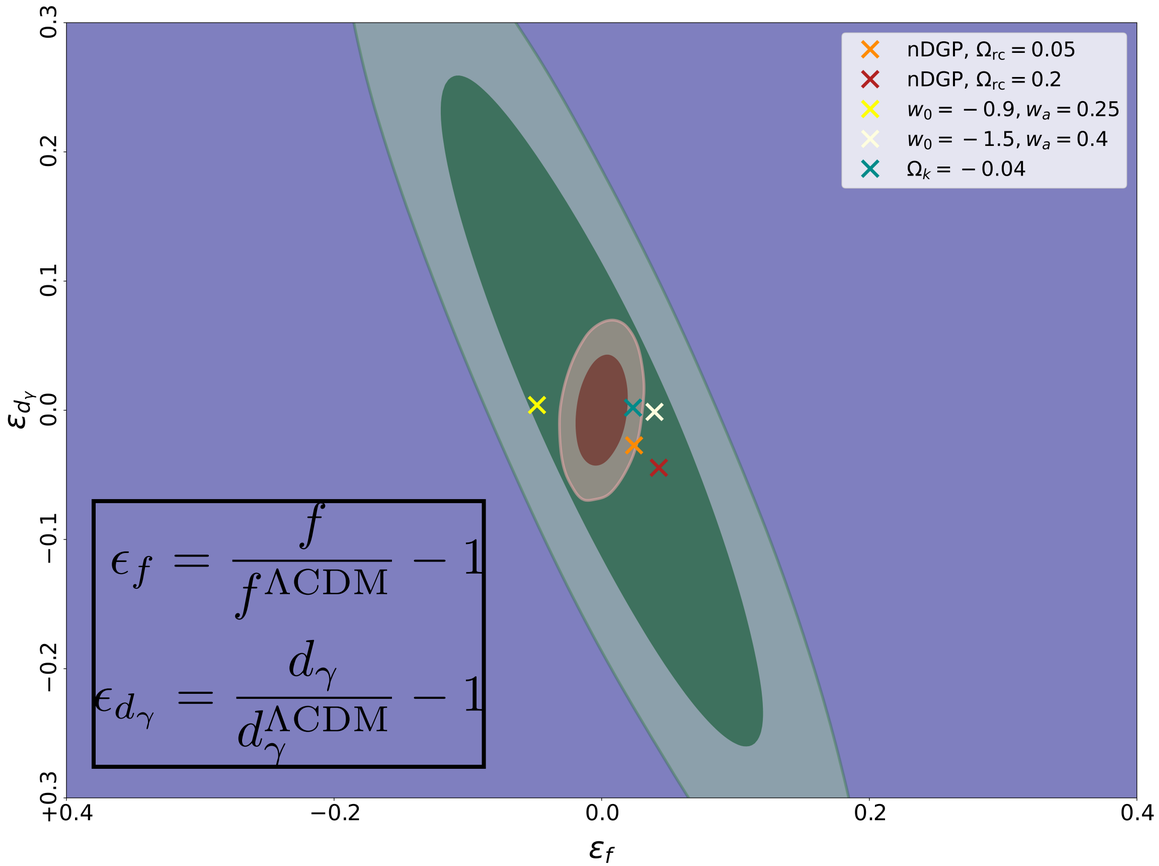


Precision tests of new physics beyond SM



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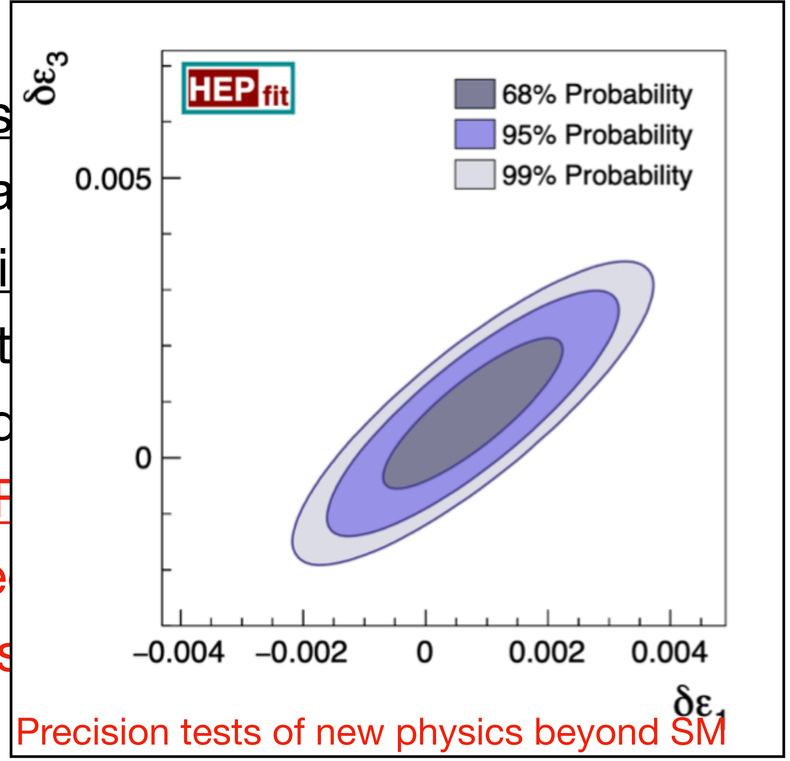
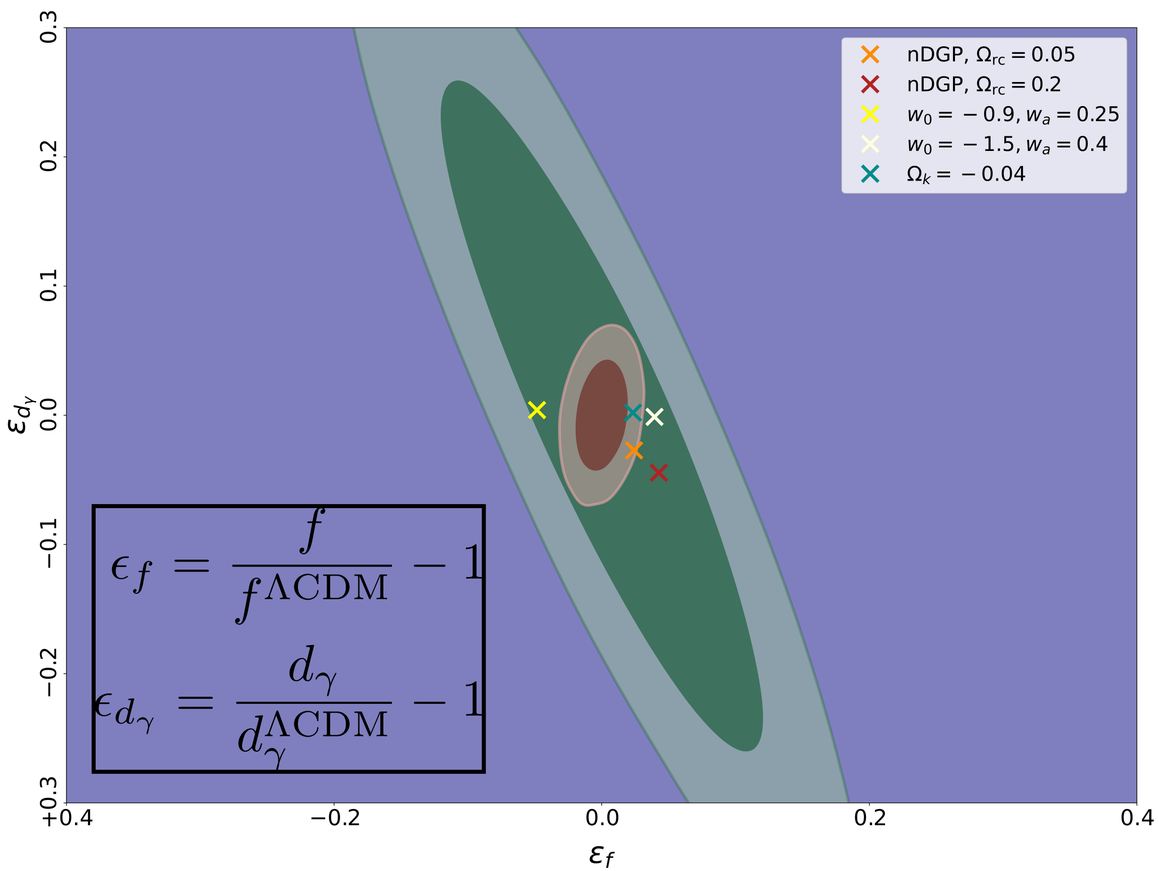


Precision tests of new physics beyond SM

In Euclid:
MP: Co-lead of Work Package on *"Analytical Approaches to Non-Linearities"*

GdA: Lead of Key Project Paper on: "Cosmological constraints on non-standard cosmologies"



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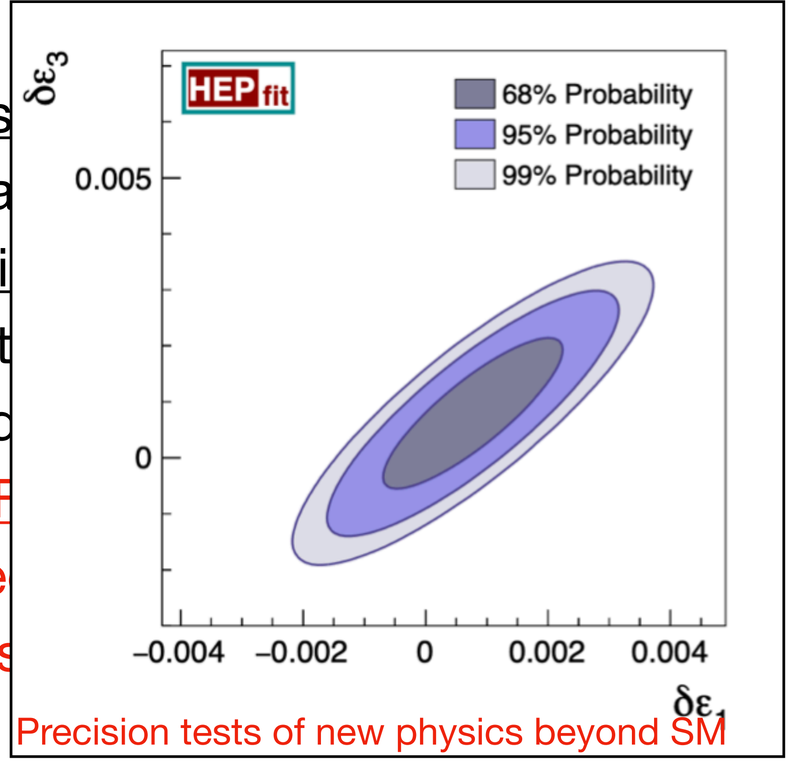
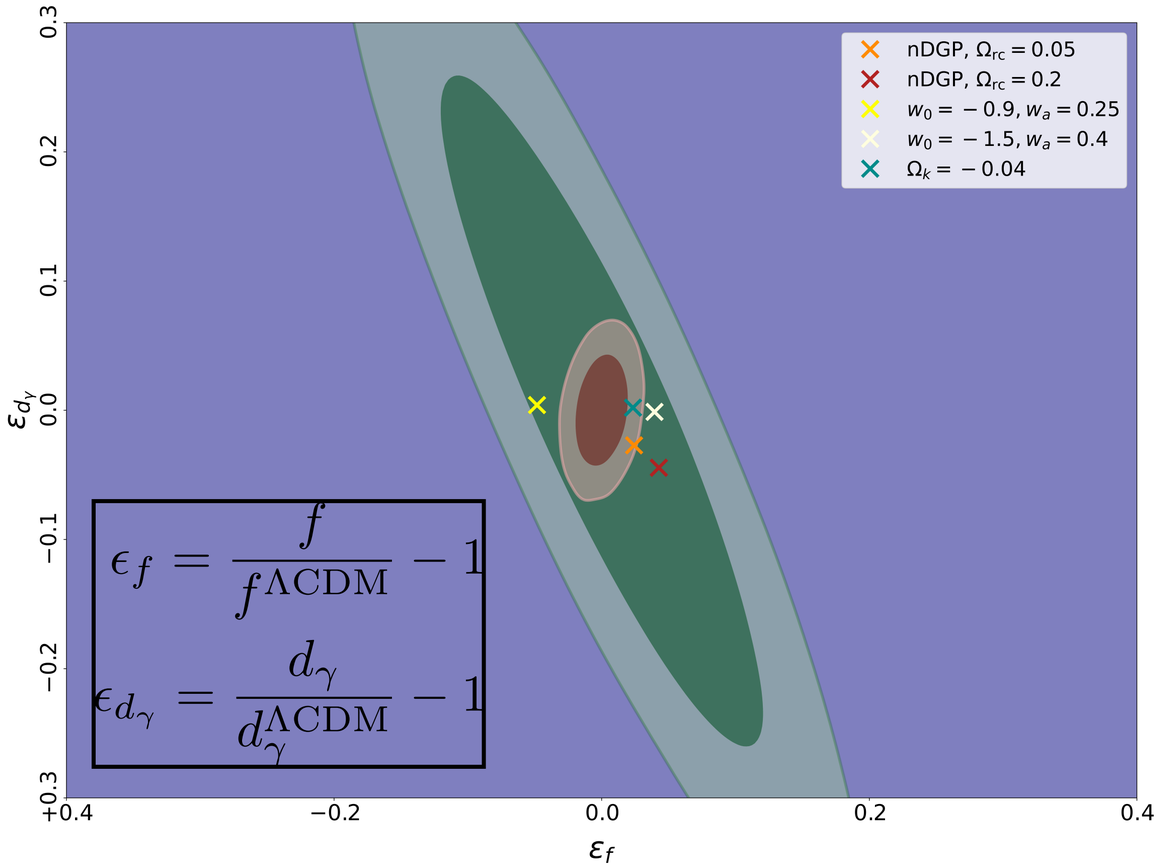


Precision tests of new physics beyond SM



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PRIN 2022 PD-PR (M.Pietroni) "Learning Early Universe Physics with Galaxy Survey and Gravitational Wave Data"
1 Assegno di Ricerca finanziato MUR + 1 PhD cofinanziato UniPR

- The Universe as a
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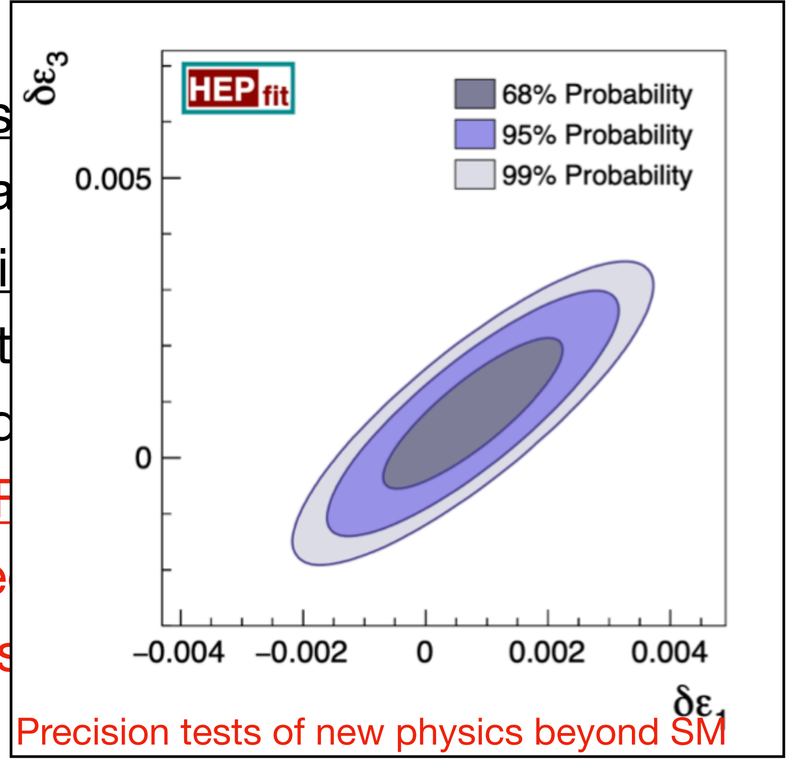
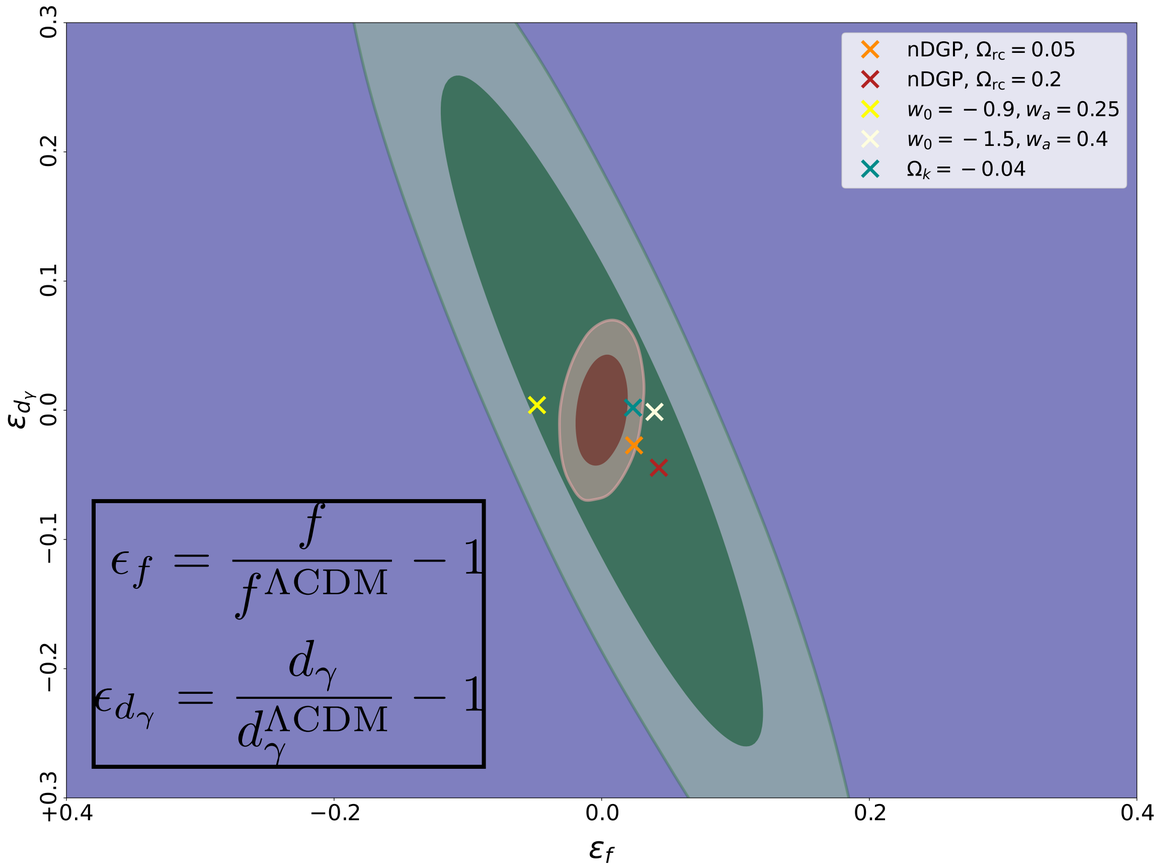


Precision tests of new physics beyond SM



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CONTRIBUTO INFN:
1 post DOC, Kevin Pardede, in partenza per JPL NASA (nov 2025)
1 PhD: Matteo Peron 38° ciclo

Richieste 2026

CAPITOLO	Assegnazioni 2025	Richieste 2026
Dotazioni GR IV	26 K€	32 K€ (missioni: 10, inviti: 8, consumo: 4, inventario: 10)
BELL	14 K€	18 K€
DYNSYSMATH	13 K€	15 K€
GAST	11.5 K€	12 K€
INDARK	11 K€	12 K€
QCDLAT	5.5 K€	7 K€