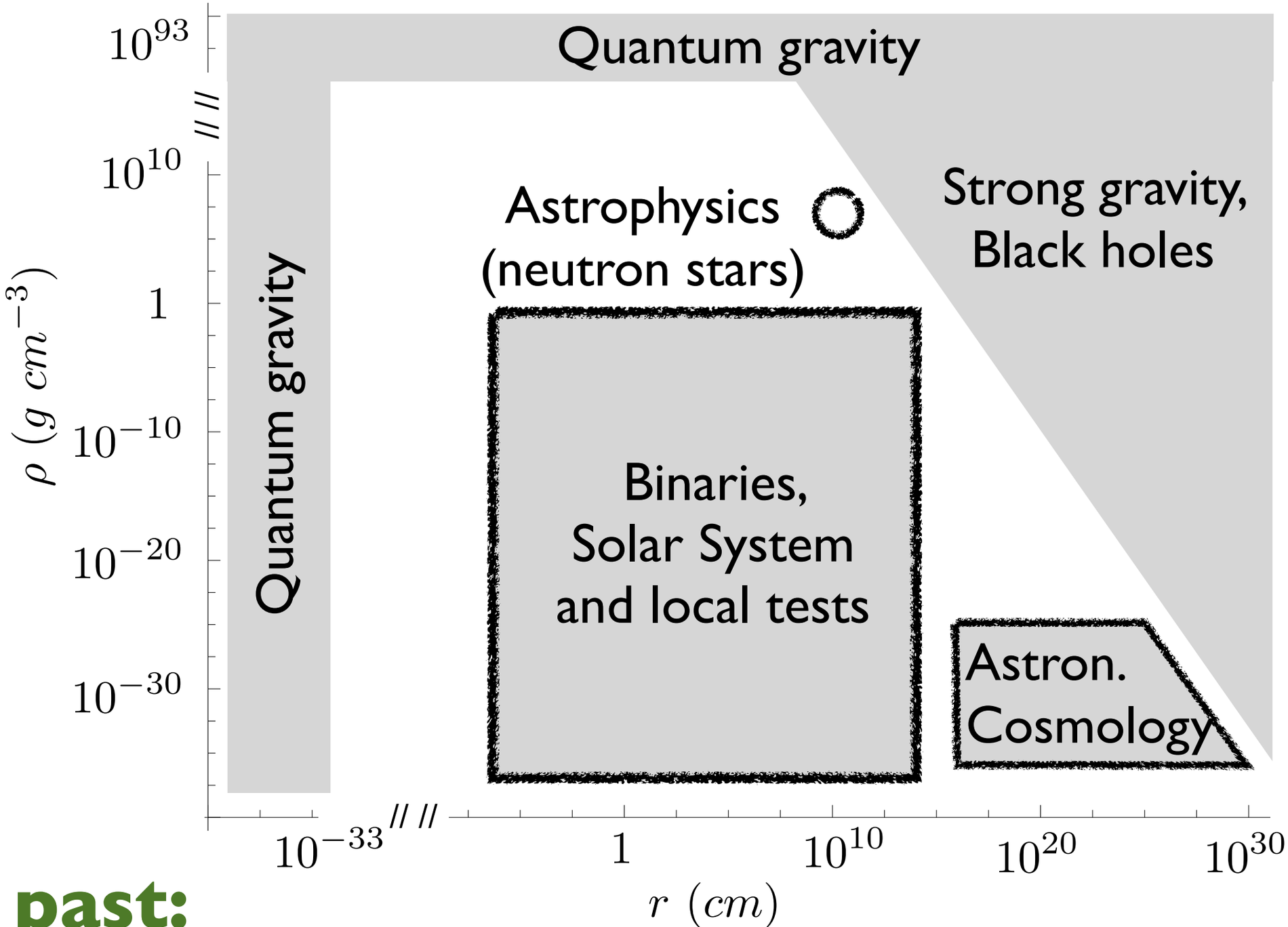
Playing with gravity at different scales

Diego Blas Temiño



My past:

post-Newtonian physics, black holes, gravity waves from binaries,
dark matter, dark energy, next to leading order ΛCDM,
massive gravity, unimodular gravity, scale invariant alternatives to GR,
quantum gravity (Hořava),

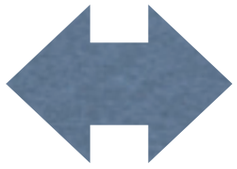
Flavours of Lorentz violation

- Beyond power counting **Hořava gravity**

  pQFT for gravity without Lorentz invariance

Power counting

$$G \sim \frac{1}{\omega^2 - k^2\left(\left(1 + \left(\frac{k}{M_\star}\right)^4\right)\right.}$$



One-loop/amplitudes

???

- Lorentz invariance **emergence**

  IR fixed points of RG flow tend to make LI emergent!
  Use **analogue-circuits** to show it non-perturbatively!

- **Entanglement entropy** in non-relativistic field theories

Tests of gravity

- Motivation: alternatives to GR are important for
  - > quantum gravity and cosmology (Λ?)
  - > understanding GR 'unique' features
- Where to look?
  - > theoretical constraints (stability of Minkowski,...)
  - > experiments. They span many regimes.

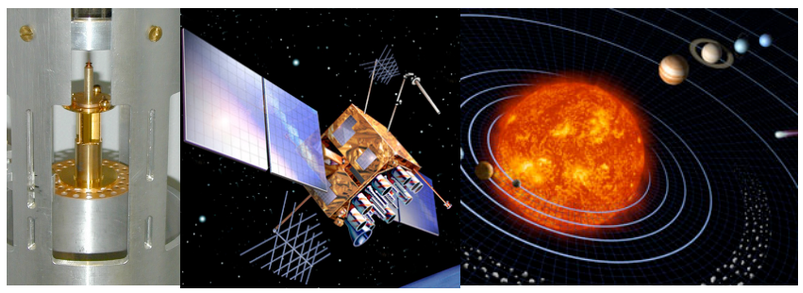
I) slow motions, small ϕ
(post) Newtonian

Solar System

PPN

$$\phi = -G\frac{M}{r}\left(1 + a\, e^{-M_* r}\right)$$

$$M_* > 0.1 \text{ eV}$$



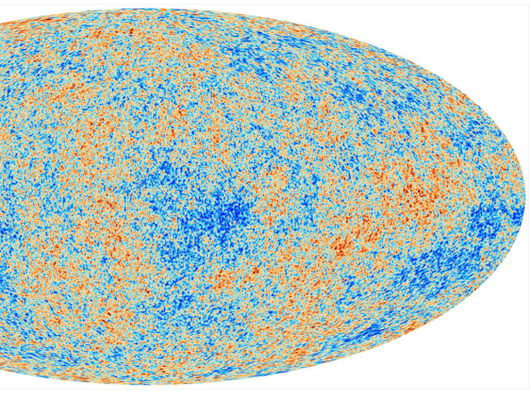
$$\phi = -G_N \frac{M}{r}\left(1 - \frac{(\alpha_1^{PPN} - \alpha_2^{PPN})v^2}{2} + ...\right)$$

$$\alpha_1^{PPN} \lesssim 10^{-4}$$

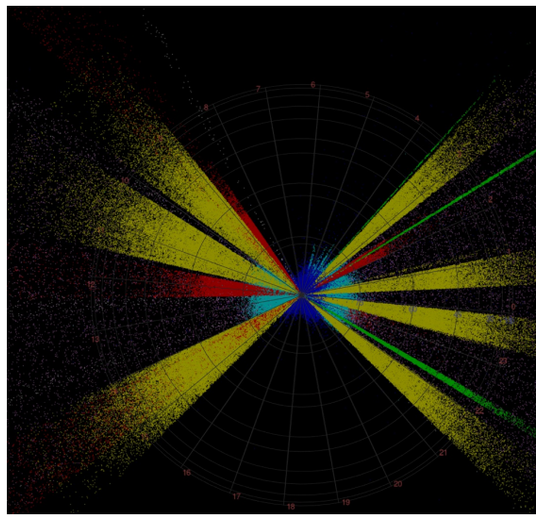
$$\alpha_2^{PPN} \lesssim 10^{-7}$$

Tests of gravity II: cosmology

w/ Audren, Lesgourgues, Sibiryakov

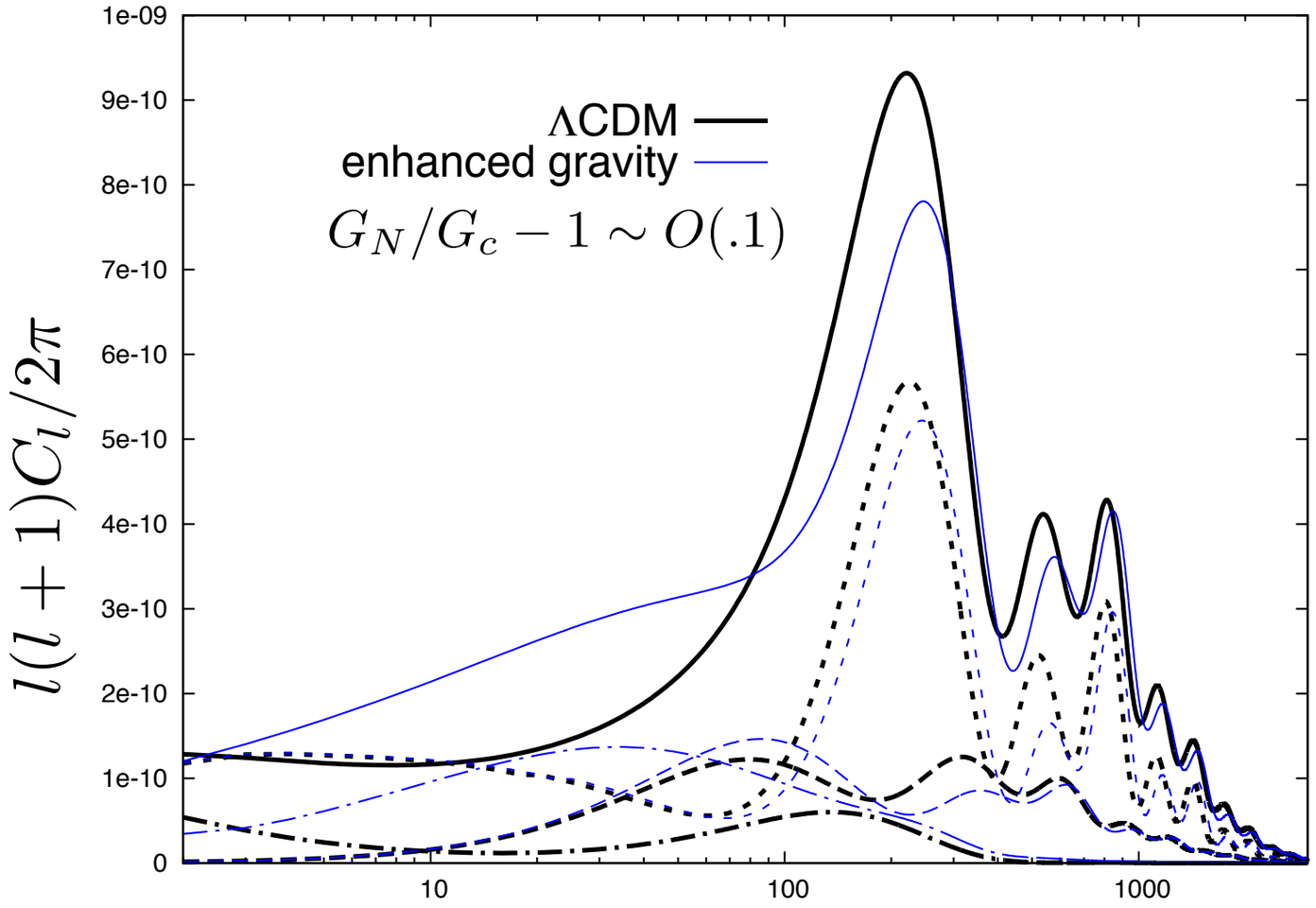


relativistic, small ϕ



CMB, matter power spectrum

$\langle \delta\gamma\delta\gamma \rangle \equiv \delta_{ll'} C_l$ http://class-code.net



$$\phi = -G_N \frac{M}{r}$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi}{3} G_c \sum \rho_i$$

$G_N \neq G_c$

generic beyond GR

\+ http://montepython.net $|G_N/G_c - 1| < 0.02$

Tests of gravity III: binary pulsars

w/ Barausse, Yagi, Yunes

small v, moderate $\phi \sim .1$

$$\dot{v}^i_A = -\frac{\mathcal{G} m_B r^i_{AB}}{r^3}$$

for circular orbits

Binary pulsars

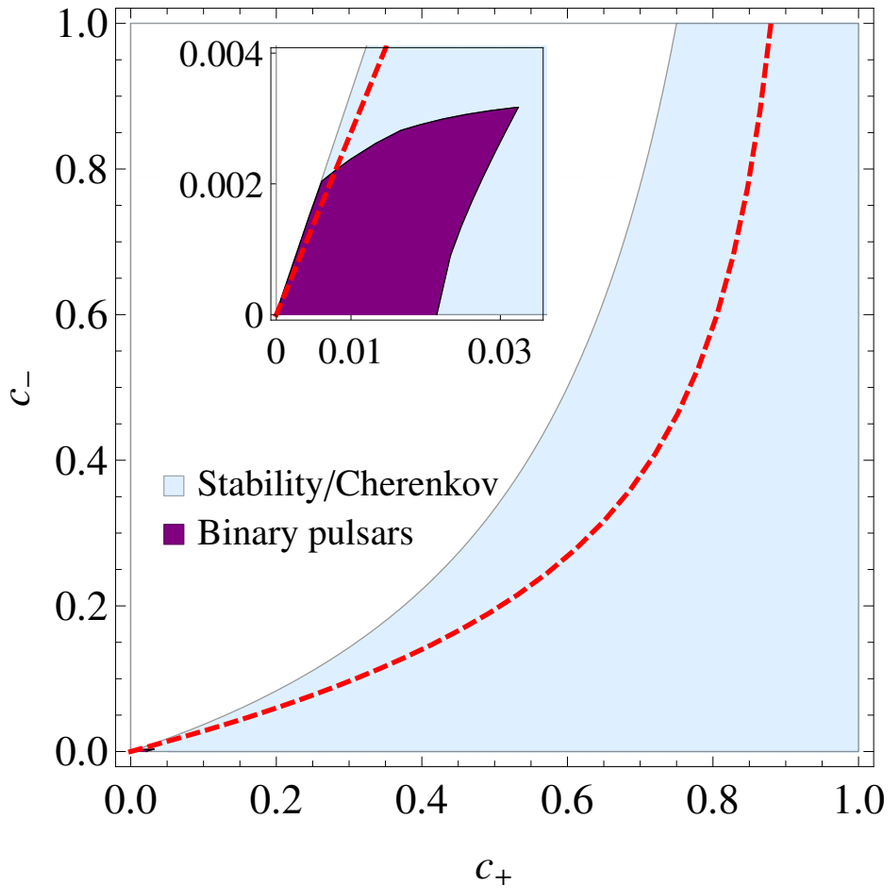
$$\frac{\dot{P}}{P} \approx -3\frac{\mathcal{G}Ga\mu M}{r^4}\left\langle \frac{96}{15}Av^2 + C \right\rangle$$

quadrupole (also in GR) dipole

A, *C*,...: Star structure + modified GR

$$M \equiv m_1 + m_2$$

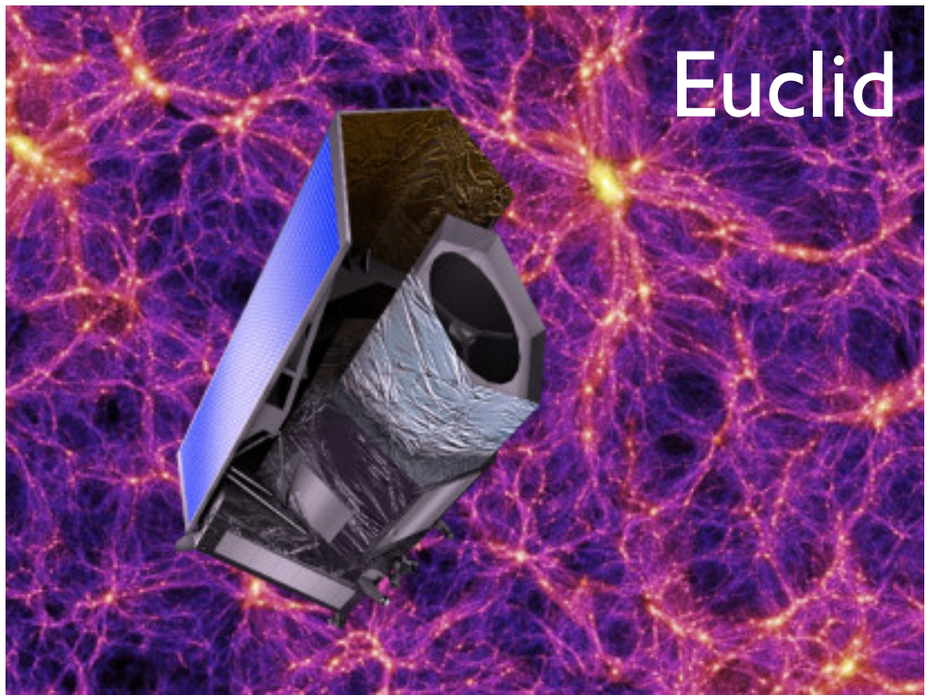
$$\mu \equiv \frac{m_1 m_2}{M}$$



c_-, c_+ parameters of Lorentz violating gravity

WD-NS and NS-NS systems
PSR J1141-6545, PSR J0348+0432,
PSR J0737-3039)

Precision (standard) cosmology



WiggleZ, BOSS, PAU, WFIRST, HETDEX, JWST, SKA,...
A lot of data on cosmic expansion and structure formation

Precision (per cent) cosmology!

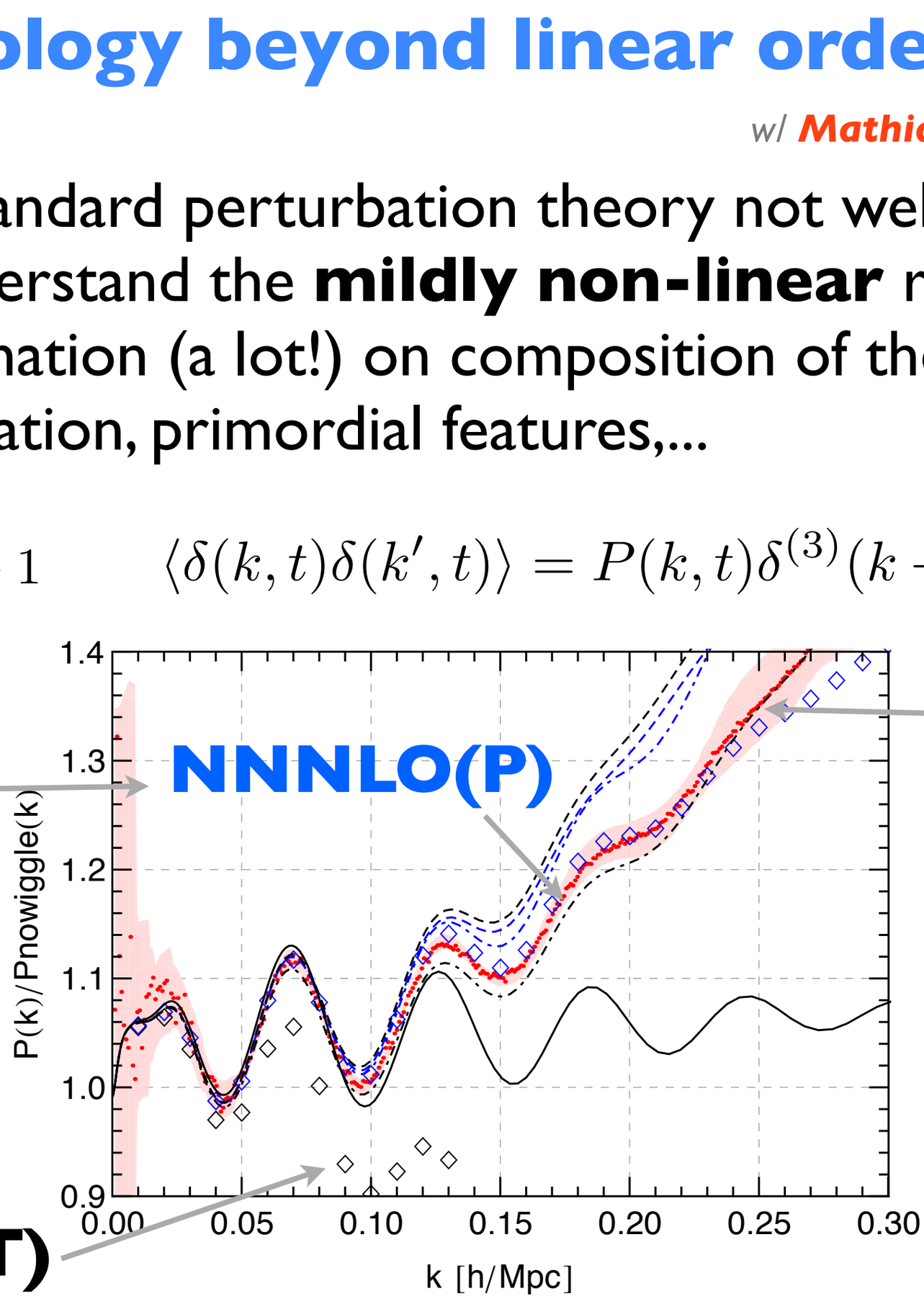
Cosmology beyond linear order

w/ ***Mathias Garny,*** *Konstandin*

- Motivation: standard perturbation theory not well-behaved, can we understand the **mildly non-linear** regime?
- To win: information (a lot!) on composition of the Universe, gravitation, primordial features,...

$$\delta_n \equiv \frac{\rho_n(x,t)}{\bar{\rho}_n(t)} - 1 \qquad \langle \delta(k,t)\delta(k',t)\rangle = P(k,t)\delta^{(3)}(k+k')$$

PT based on a Padé resummation



z=0.375

N-body

Horizon Run 2, Kim et al. 11