Dark Gravity confronted with SN, BAO and the CMB

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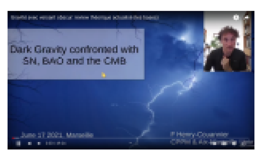
Dark Gravity

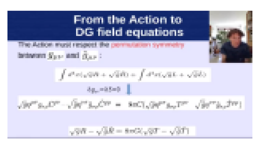
Regularly updated review not on arXiv (too many versions !) but here :
www.darksideofgravity.com/DG.pdf

DG : Gravity with its Dark side

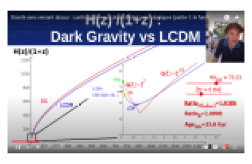
- DG : Theoretical review (part 1)
  https://www.youtube.com/watch?v=FkehW60m9fc



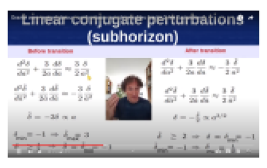
- DG : Theoretical review (part 2)
  https://www.youtube.com/watch?v=VYqkXl1UyEo



- DG : Confrontation with cosmological observables (part 1: background)
  https://www.youtube.com/watch?v=IkbWTctPDkU



- DG : Confrontation with cosmological observables (part 2: fluctuations)
  https://www.youtube.com/watch?v=_cLSm4tA7SU



From background dependence to Dark Gravity (DG)

How far can we go ?

GR : $g_{\mu\nu}$

DG : $g_{\mu\nu}$ and $\eta_{\mu\nu}$

$Riem(\eta_{\mu\nu})=0$

$\Rightarrow$ $g_{\mu\nu}$ has a twin, « the inverse metric » $\tilde{g}_{\mu\nu}$

$$\tilde{g}_{\mu\nu} = \eta_{\mu\rho}\eta_{\nu\sigma}\left[g^{-1}\right]^{\rho\sigma}$$

$\Rightarrow$ $(g_{\mu\nu}, \tilde{g}_{\mu\nu})$ is a Janus field

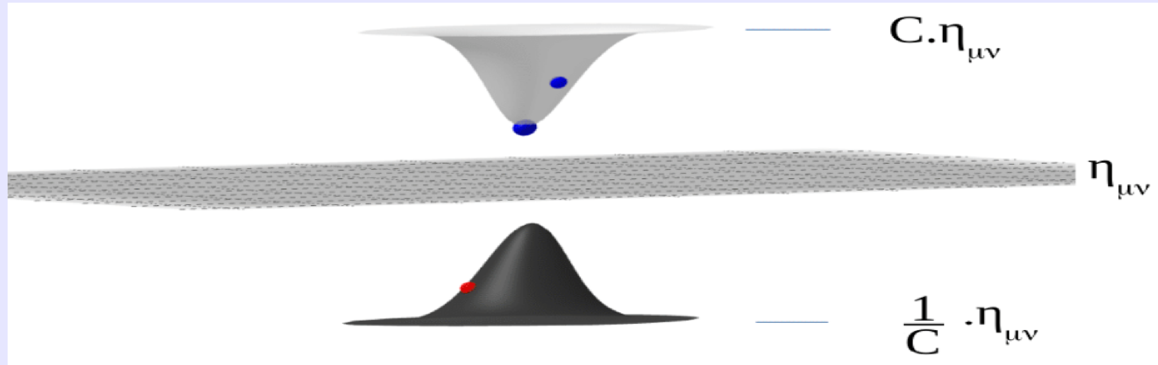
The Action must respect the permutation symmetry between $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$:

$$\int d^4x(\sqrt{g}R + \sqrt{\tilde{g}}\tilde{R}) + \int d^4x(\sqrt{g}L + \sqrt{\tilde{g}}\tilde{L})$$

$$\delta g_{\mu\nu} \Rightarrow \delta S = 0$$

$$\sqrt{g}\eta^{\mu\sigma}g_{\sigma\rho}G^{\rho\nu} - \sqrt{\tilde{g}}\eta^{\nu\sigma}\tilde{g}_{\sigma\rho}\tilde{G}^{\rho\mu} = -8\pi G(\sqrt{g}\eta^{\mu\sigma}g_{\sigma\rho}T^{\rho\nu} - \sqrt{\tilde{g}}\eta^{\nu\sigma}\tilde{g}_{\sigma\rho}\tilde{T}^{\rho\mu})$$

The static isotropic solution



- Antigravity without run away !
- Asymptotic C matters : GR corresponds to C infinite

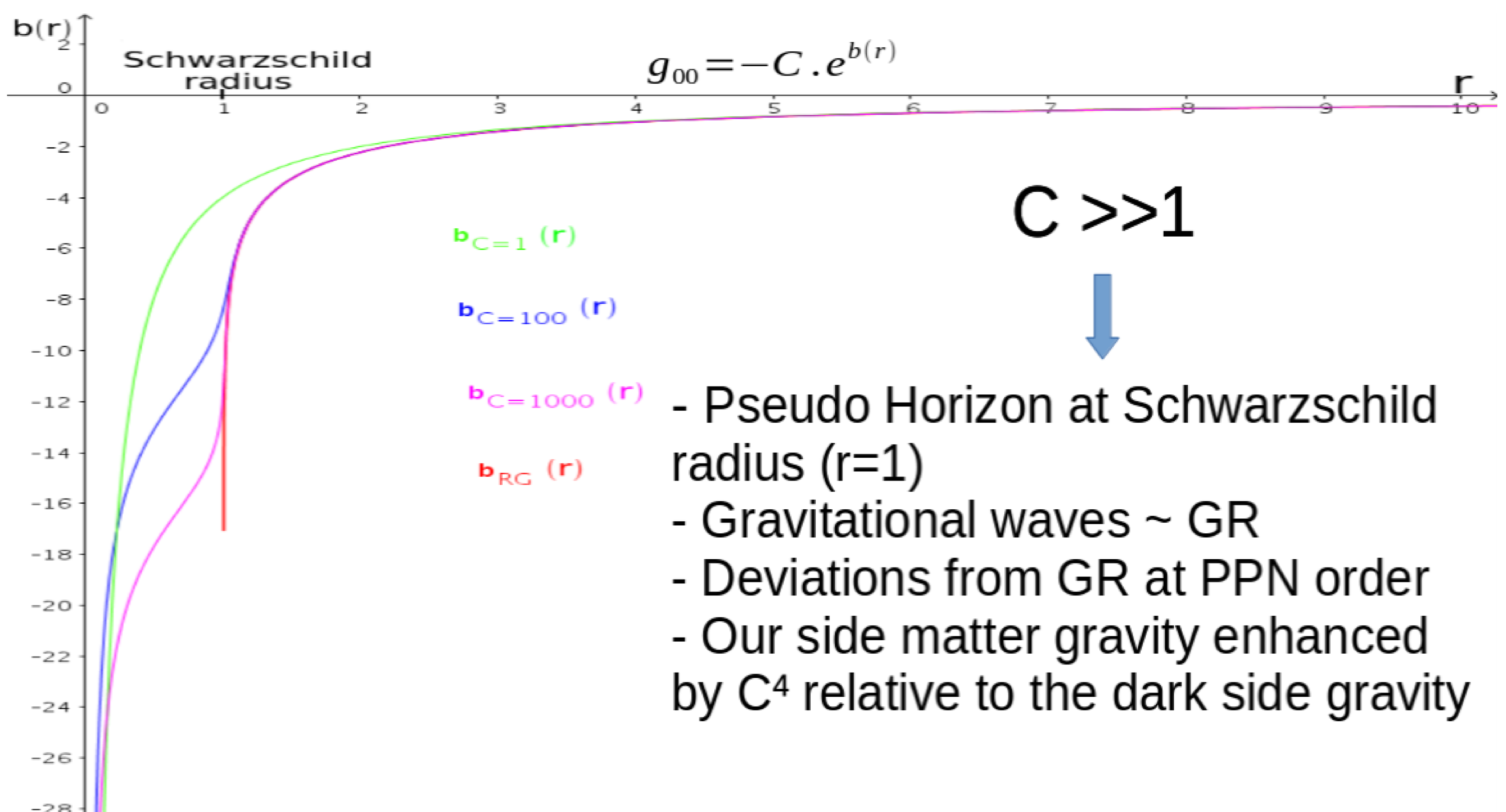
C=1 DG:	C=∞ RG (Schwarzschild) :
$g_{ii}(r) = A = e^{2MG/r} \approx 1 + 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2}$	$g_{ii}(r) = \left(1+\frac{MG}{2r}\right)^4 \approx 1 + 2\frac{MG}{r} + \frac{3}{2}\frac{M^2G^2}{r^2}$
$-g_{00}(r) = \frac{1}{A} = e^{-2MG/r} \approx 1 - 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2} - \frac{4}{3}\frac{M^3G^3}{r^3}$	$-g_{00}(r) = \frac{\left(1-\frac{MG}{2r}\right)^2}{\left(1+\frac{MG}{2r}\right)^2} \approx 1 - 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2} - \frac{3}{2}\frac{M^3G^3}{r^3}$

- No Horizon
- Zero Gravitational Waves $\tilde{h}_{\mu\nu} = -h_{\mu\nu} + O(h^2)$

$$2(R^{(1)}_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}R^{(1)\lambda}_{\lambda}) = -8\pi G(T_{\mu\nu} - \tilde{T}_{\mu\nu} + (t_{\mu\nu} - \tilde{t}_{\mu\nu}))$$

$\to 0$

- Deviations from GR at PPN order only



C >>1

- Pseudo Horizon at Schwarzschild radius (r=1)
- Gravitational waves ~ GR
- Deviations from GR at PPN order
- Our side matter gravity enhanced by C^4 relative to the dark side gravity

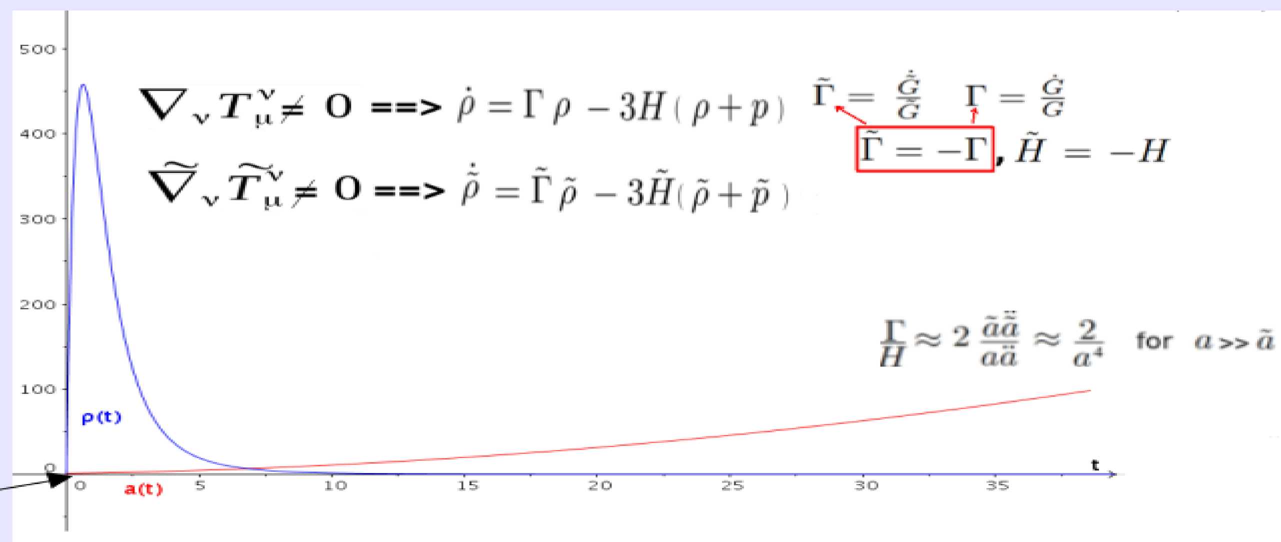
DG Cosmology

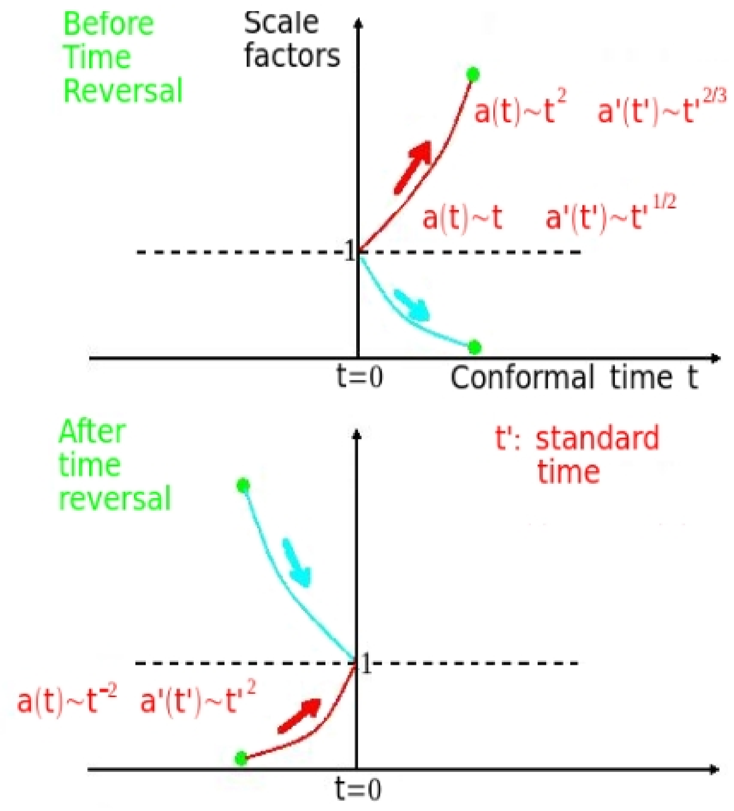
$g_{\mu\nu} = a^2(t)\eta_{\mu\nu}$ $\quad \tilde{a}(t) = \frac{1}{a(t)}$ $\quad \tilde{g}_{\mu\nu} = a^{-2}(t)\eta_{\mu\nu}$

- Problem : Homogeneous & isotropic Janus solution is flat but static !

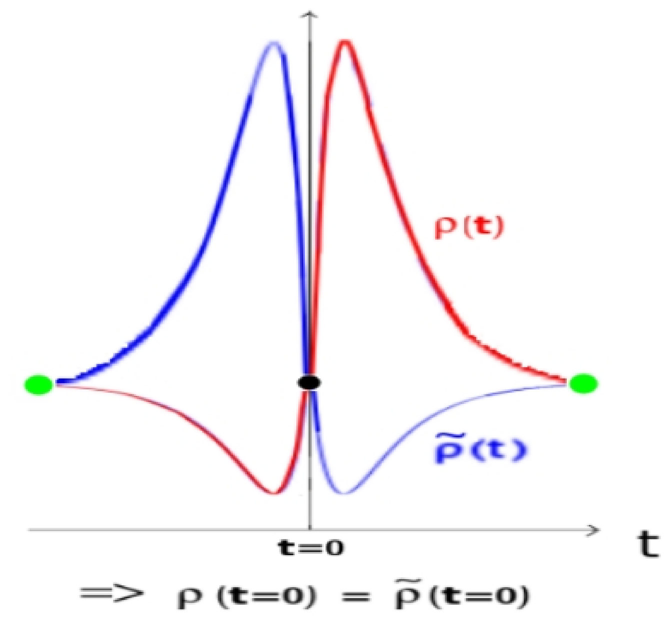
$$a^2H^2 - \tilde{a}^2\tilde{H}^2 = \frac{8\pi G}{3}(a^4\rho - \tilde{a}^4\tilde{\rho})$$
$$a^2(2\dot{H} + H^2) - \tilde{a}^2(2\dot{\tilde{H}} + \tilde{H}^2) = -8\pi G(a^4p - \tilde{a}^4\tilde{p})$$

- Solution : Introduce offshell mechanism Γ(t) : variable $\tilde{G}(t) = \frac{1}{G(t)}$
- **Differential equations can be solved numerically :**





Γ(t) allows to:
- interpret permutation symmetry as a time reversal symmetry
- get a cyclic universe



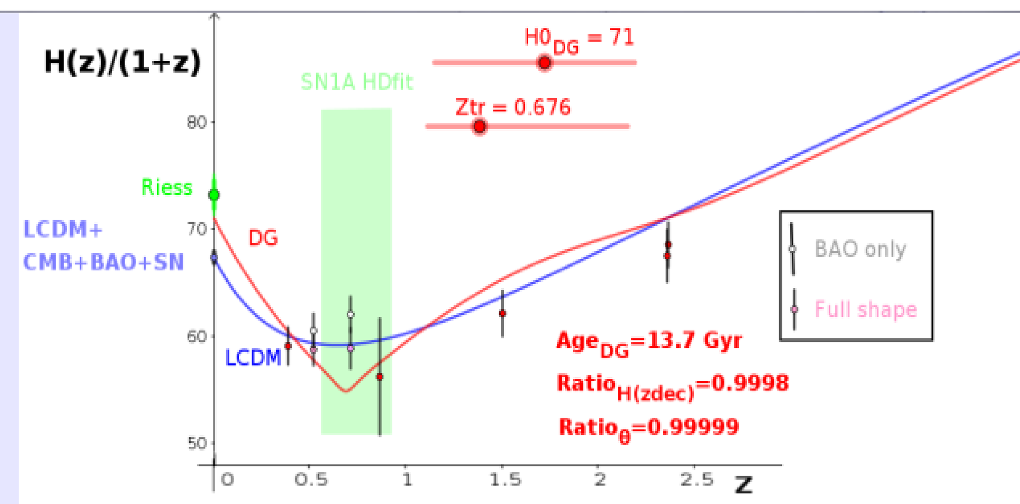
- Hyp : $\rho = \tilde{\rho}$ occured at transition redshift triggering T ⇒ a'(t')~ t'²
- With H'(t') continuous at the transition from $t'^{2/3}$ to t'^{α} and assuming same rough universe age as within LCDM (≈ 1 / H'$_0$)

$$z_{tr} = \left(\frac{2/3 - \alpha}{1-\alpha}\right)^{\alpha} - 1$$

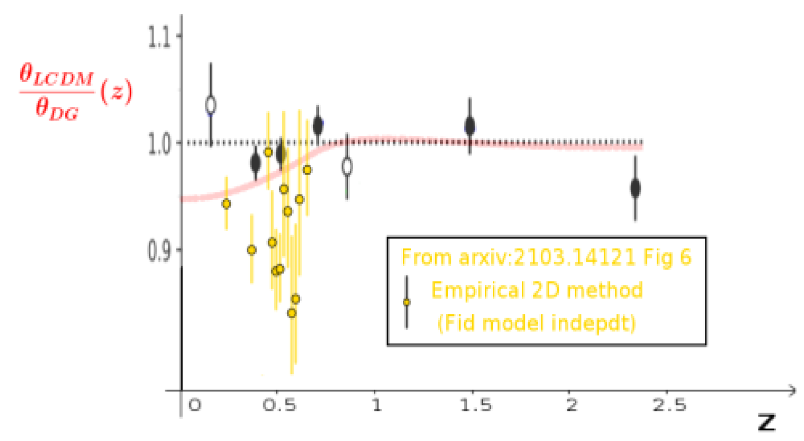
⇒ z_{tr} = 0.78 vs observed LCDM z_{tr} =0.67+- 0.1

- Close to LCDM scale factor evolution
- Without DE
- Inflation not needed to get k=0
- Without Big Bang singularity
- Cosmological DM still needed
- Dark side effects only since t_{tr} or near t=0

- Good agreement with BAO transverse, CMB and SN data !



- Tension in BAO LoS for BAO only method
  But BAO only is Fid Model Biased according arxiv 1811.12312 (Anselmi et al.)



Planck and matter power spectra

Planck arxiv:1807.06209
Class software arxiv:1104.2933

- Planck TT+TE+EE

$\chi^2_{DG} = 6701.9$
$\chi^2_{DG} - \chi^2_{LCDM} = +4.4$