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Gravitational Waves in Bouncing Cosmology

(1604.xxxxx)
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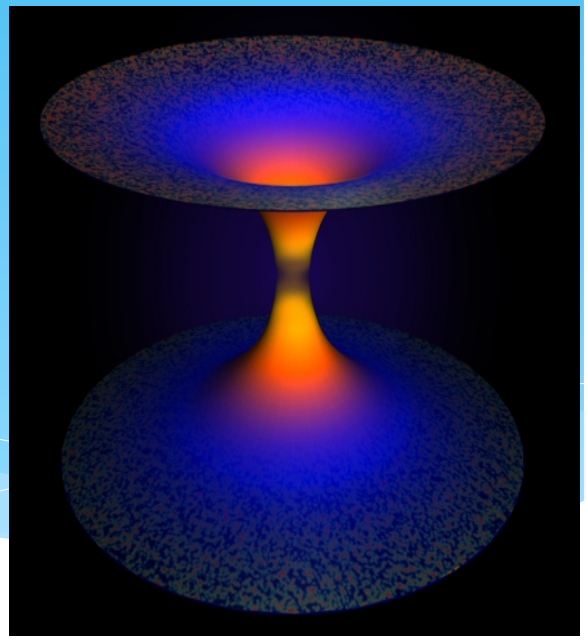


Motivation I:

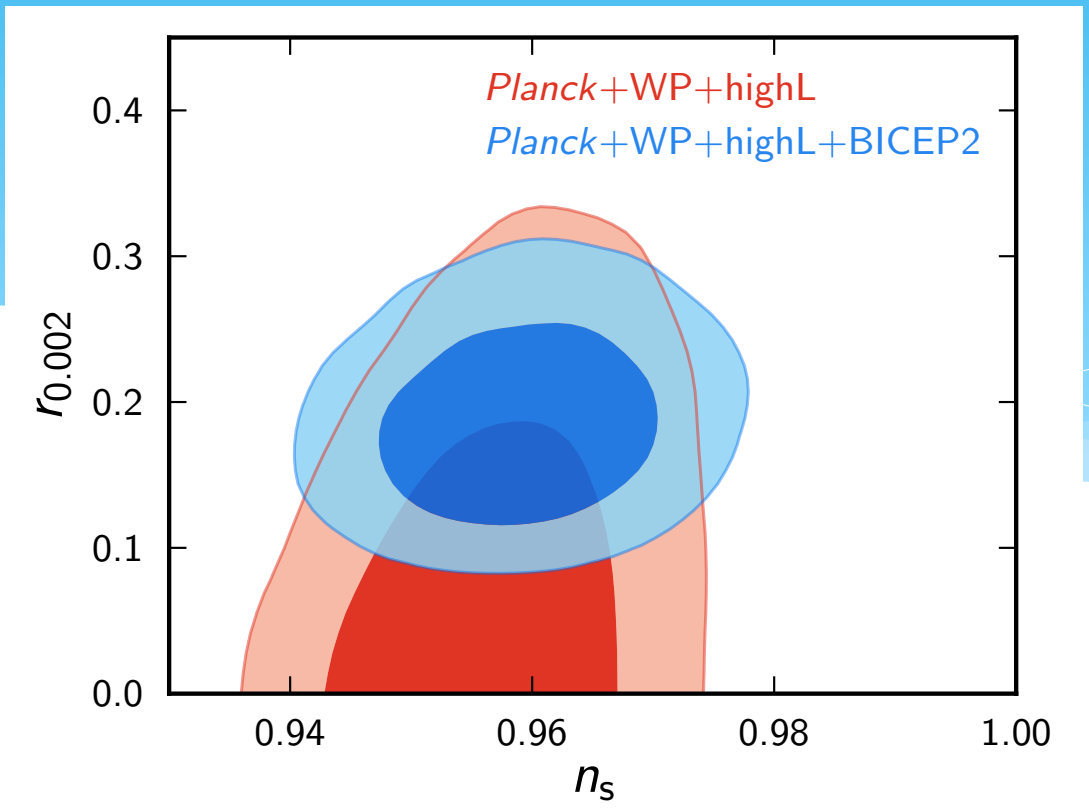
Inflation is geodesically past incomplete!

New Physics is necessary!

Some NP discards inflation

=>Bouncing Cosmology

Motivation II: Moriond 2014



Aim:

Can We Get Observable Gavitational Waves on CMB Scales in a Bouncing Cosmology?

Idea:

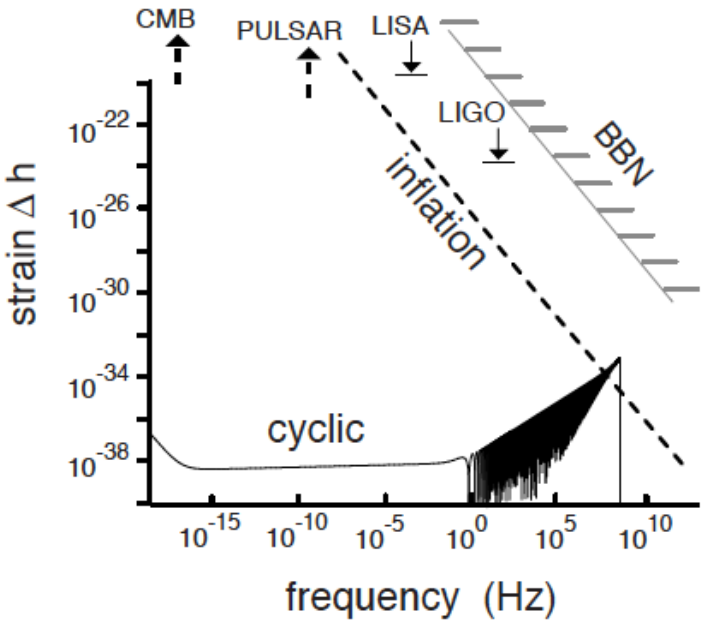
Coupling to Gauge Fields

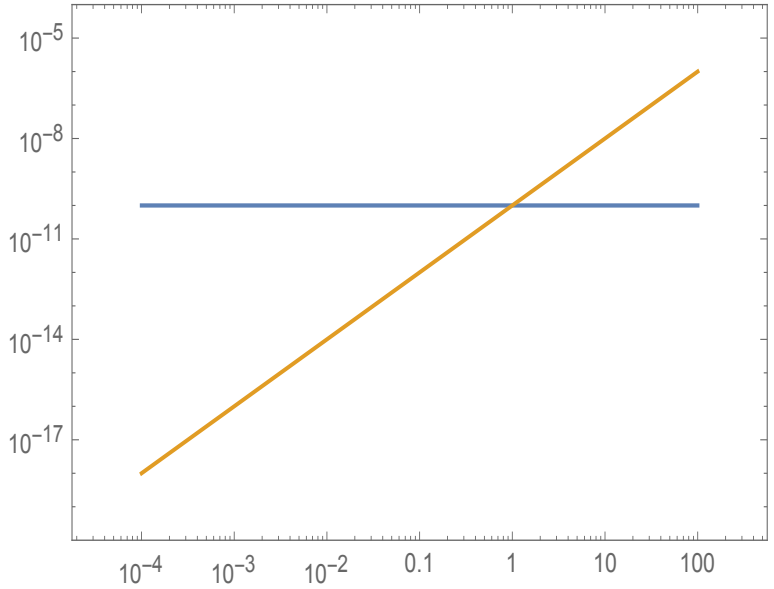
Problem: Blue Spectrum

$$a = a_0(-\tau)^b \Rightarrow \mathcal{P}_{vac.} \sim k^{2+2b}$$

$$Inf. : b = -1, \quad Bounce : 0 < b \ll 1$$

* Present Day Strain: ~$P^{1/2}$
* Primordial





Updated Constraints: Meerburg et al. 2015

Early Universe Cosmology

Inflation

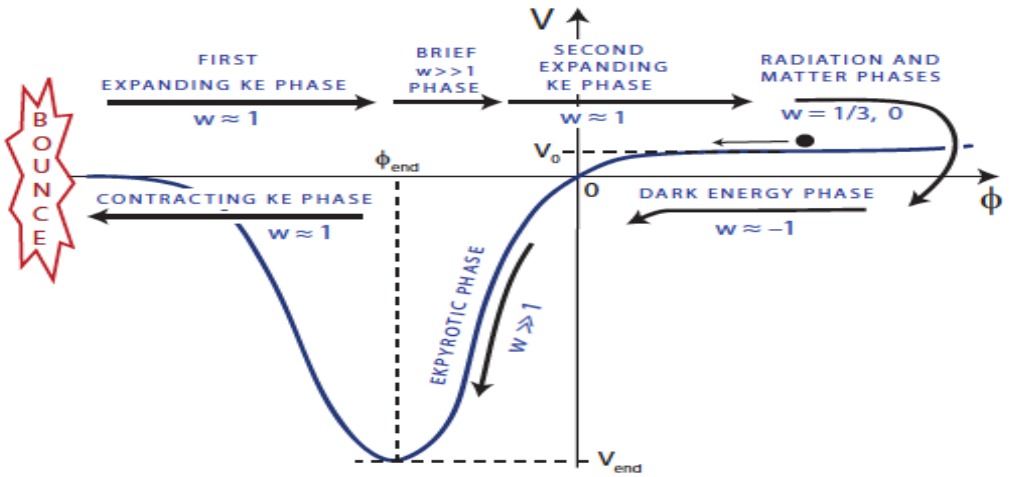
* Universe expands exponentially ~dS space
* Isotropy & Homogeneity
* Vacuum fluctuations generate spectra
* Nearly scale inv. scalar spectrum
* Nearly scale inv. GW spectrum
* Geodesically Incomplete

Bounce

* Universe slowly contracts towards Minkowski space
* Isotropy & Homogeneity
* Vacuum fluctuations generate spectra
* Nearly scale inv. scalar spectrum* (2-fields).
* Blue GW spectrum
* Violates Null Energy Condition

Brief History of Time

* **Universe slowly contracts. b<<1.** Isotropizes and flattens! Vacuum fluctuations generate spectra
* **Kinetic Energy Dominated Contraction. (b=1/2)**
* **BOUNCE!** (H flips sign), No Big Bang singularity
* **Kinetic Energy Dominated Expansion. (b=1/2, tau>0)**
* **Standard Hot Big Bang.**



$$a = a_0(-\tau)^b$$

Coupling to Gauge Fields

* Controlled Backreaction.
* Inflation (Barnaby, Peloso, Sorbo, Silverstein…) – GW regardless of the energy scale of inflation. (See V. Domcke's talk)
* Exponential enhancement of gauge quanta - inflaton/ ekpyrosis generate additional spectra via inverse decays!
* Uncorrelated with vaccum fluc.

$$\mathcal{S}_1 = \int d^4x\sqrt{-g}\left[\frac{M_p^2}{2}R - \frac{1}{2}(\partial\varphi_1)^2 - V(\varphi_1) - \frac{1}{4}F^{\mu\nu}F_{\mu\nu} - \frac{\alpha}{4f}\varphi_1\,\tilde{F}^{\mu\nu}\,F_{\mu\nu}\right]$$

$$\mathcal{S}_2 = \int d^4x\sqrt{-g}\left[\frac{M_p^2}{2}R - \frac{1}{2}(\partial\varphi_1)^2 - V(\varphi_1) - (-\tau)^{-2n}\left\{\frac{1}{4}F^{\mu\nu}F_{\mu\nu} - \frac{\gamma}{4}\,\tilde{F}^{\mu\nu}\,F_{\mu\nu}\right\}\right]$$

Solutions for GW with a Source

* Valid for all FLRW cosmologies (Inflation (b=-1), matter(b=2), ekpyrotic (b<<1) …)
* Various "magnetic field" tilt!
* h- GW pert., J – source, A- gauge fluc.

SOURCE TERM

$$\left[\partial_\tau^2 + \left(k^2 - \frac{a''}{a}\right)\right] \frac{h_\lambda}{a}\left(\tau, \vec{k}\right) = J_\lambda\left(\tau, \vec{k}\right)$$

$$J_\lambda \sim \tilde{A}^2$$

Model 2: constant xi

$$\tilde{A}_\sigma(k, \tau) \simeq \sqrt{-\frac{\tau}{2\,\pi}}\, e^{\pi\xi}\, \Gamma\left(|2n+1|\right)\, |2\,\xi\, k\,\tau|^{-|n+1/2|}$$

Enhancement of fluctuations

* The gauge quanta and hence the GW are exponentially enhanced
* Non-gaussian.
* Only the + helicity is enhanced.
* No dependence on the tilt of the gauge fields! n drops out!

$$h \sim A^2 \sim e^{2\pi\xi}$$

$$P_T^{total} \equiv \frac{k^3}{2\pi^2}\left\langle \hat{h}_\lambda(\vec{k})\hat{h}_{\lambda'}(\vec{k}')\right\rangle = \frac{4k^{2+2b}}{\pi^2 M_{pl}^2 k_0^{2b}}\left[1 + 4.1\times 10^{-7}\,\frac{e^{4\pi\xi}}{\xi^2}\,\frac{k^{1+2b}H_{ek.-end}}{M_{pl}^2 k_0^{2b}}\right]$$

$$\xi > 3 \Rightarrow P_T \sim k^{3+4b} H_{end}$$