A Unique and Observable Imprint: Inflation and Gravitational Leptogenesis

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New: Toy Model of Inflation

$$\mathcal{L} = \frac{1}{2}M_P^2 R - \frac{1}{2}(\partial\chi)^2 - V(\chi) - \frac{1}{4}F^a_{\mu\nu}F_a^{\mu\nu} + \frac{\chi}{M}F^a_{\mu\nu}\widetilde{F}_a^{\mu\nu}$$

SU(2) *vev* assists inflation, and leaves a distinct imprint on spectra

Devulder & RC 2017

$$V = \frac{1}{n}m^4(\chi/m)^n$$

$$m,\, M \ll M_P$$

$$g \ll 1$$

$$A_i^a = \phi\delta_i^a$$

Also, see: Dimastrogiovanni, Fasiello, Fujita 2017; Adshead, Martinec, Sfakianakis, Wyman 2016; Maleknejad 2016; Agrawal, Fujita, Komatsu 2017

New: Toy Model of Inflation

Scalar Fluctuations: $\delta\chi$, δA

three dynamical modes, three constraints

Dominant mode sound speed: $c_s^2 = 1 - 2/\gamma$

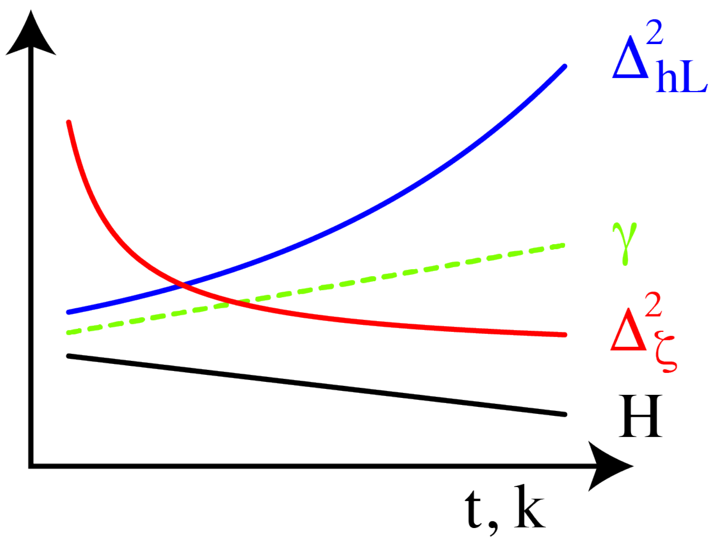
Tensor modes: h, δA

four dynamical modes (2L, 2R)

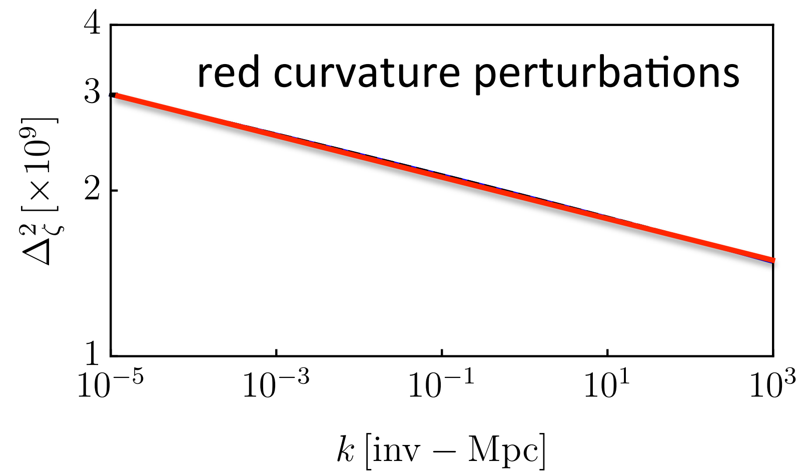
Dispersion: $\omega_{LR}^2 = k^2 \mp \gamma k \mathcal{H}$

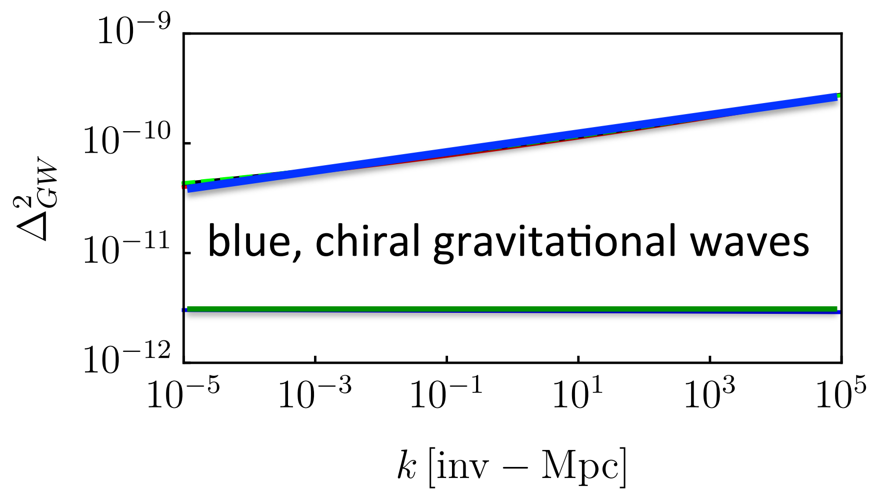
Extra: generalization from SU(2) to SU(N)

New: Toy Model of Inflation



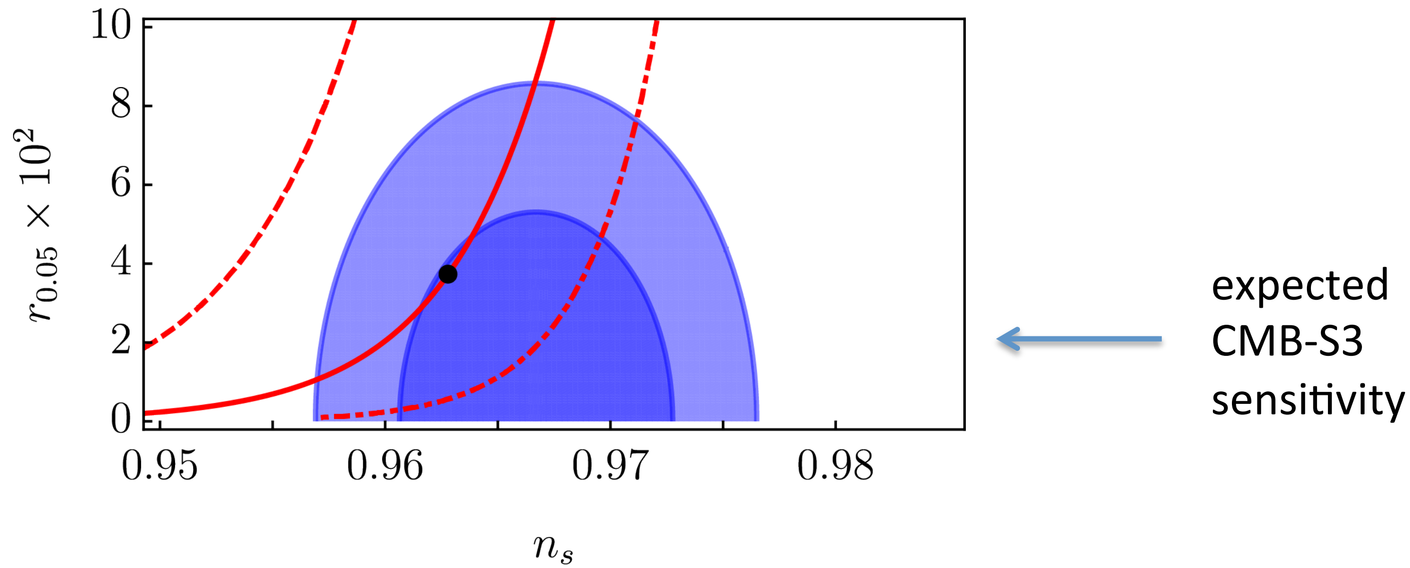
"accelerating track" picture





New: Toy Model of Inflation

Red curves: family of potential models (n)
Location along curve: vary func(m, M, g) with fixed $\Delta_{\zeta,}$



Constraints:

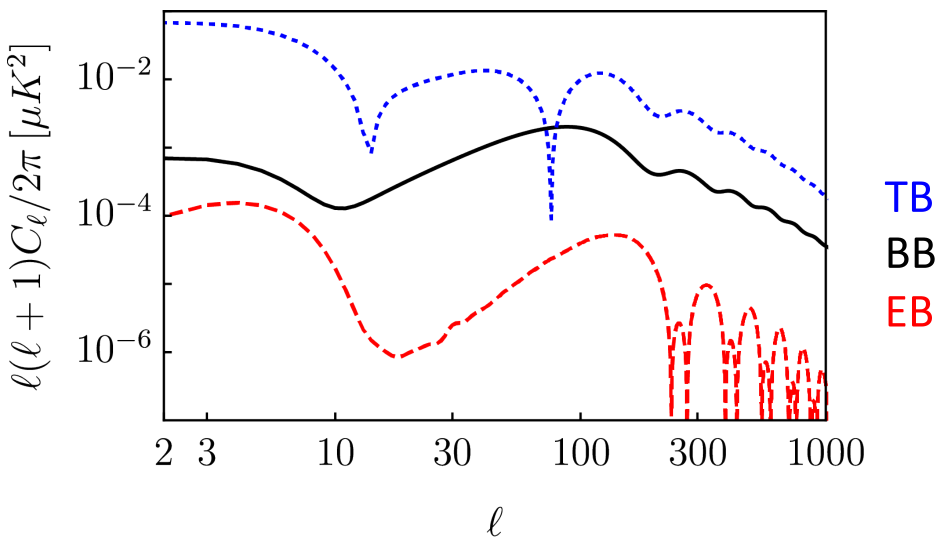
$$n_s = 0.9667 \pm 0.0040\,(1\sigma)$$ Planck 2016

$$r < 0.07\,(95\%\,C.L.)$$ BKP 2016

New: Toy Model of Inflation

- Model does not obey standard slow roll relations
- Gauge field dominates at end of inflation: w=1/3
- Scalar spectrum amplitude fixes H_{end}, N-efolds
- Perturbations under control: $|\delta A| \ll A$
- No instability backreaction: $\Omega_{GW}, \Omega_{\delta A} \ll 1$

Chiral Gravitational Waves



This model predicts

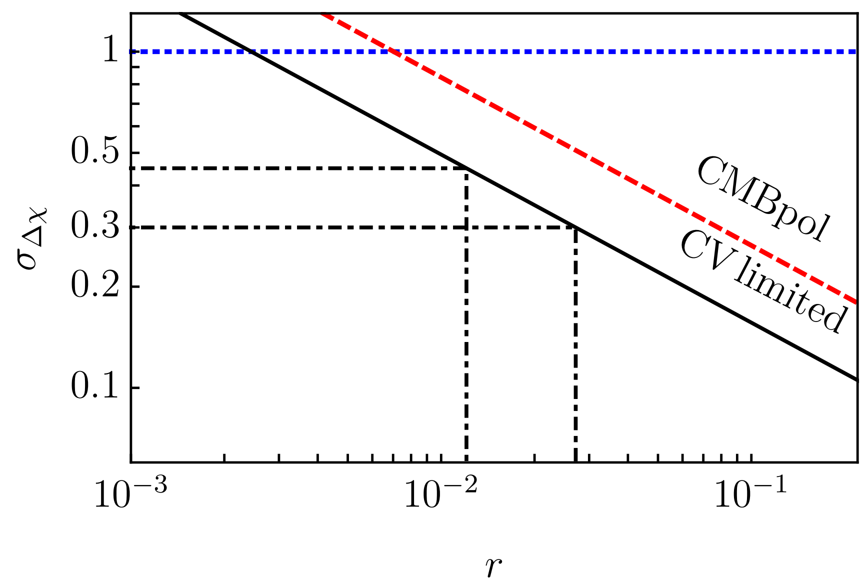
$$\Delta\chi = (P_L - P_R)/(P_L + P_R)$$

$$\Delta\chi \simeq 0.9$$

$$r_{0.05} = 0.035$$

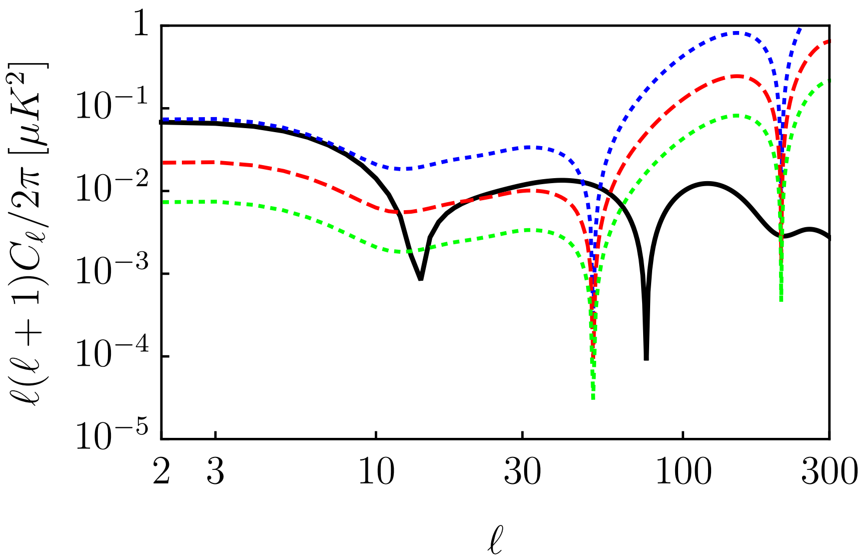
An additional, unique observable!

adapted from
Gluscevic & Kamionkowski 2010



other probes:
Jeong et al 2012, Masui et al 2017

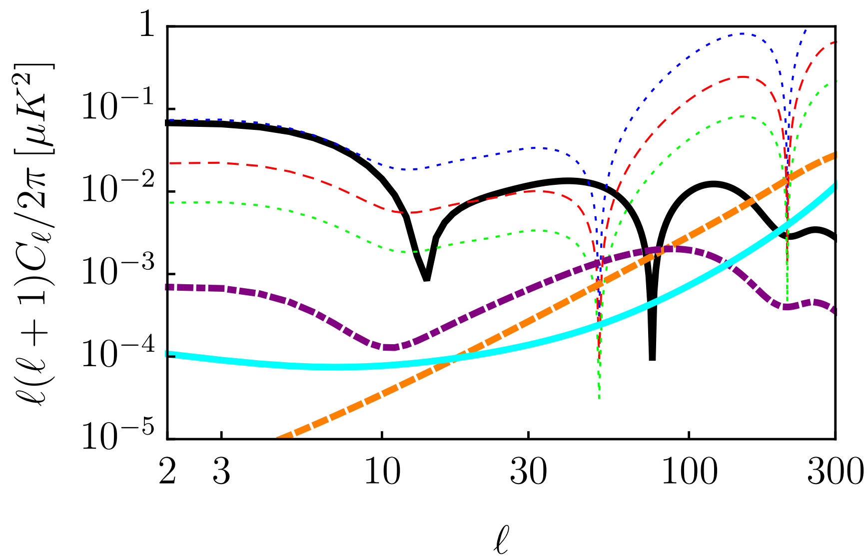
Chiral Gravitational Waves



1°
0.3°
0.1°
TB

Contamination from TE due to uncertainty in absolute polarization

TB
BB Lensing
BB
Noise*



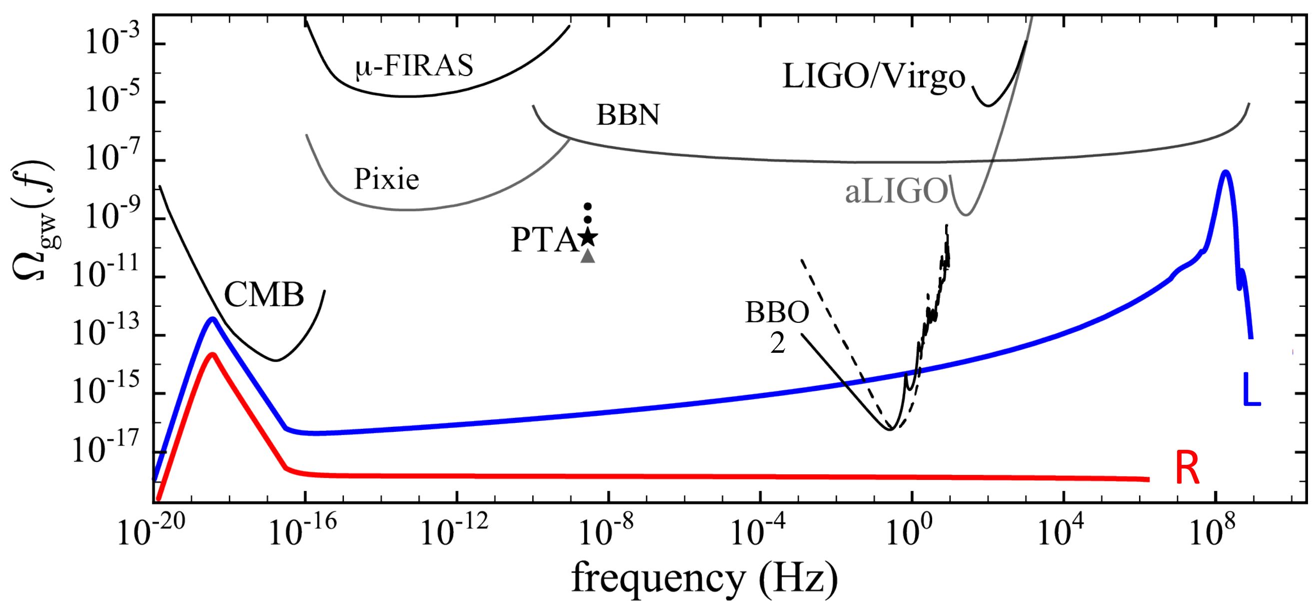
* Instrument noise, residual foregrounds

See Thorne et al, 2017; Shiraishi et al, 2016.

Is the curl pattern correlated
with hot or cold spots?

If so, then the gravitational waves
have a preferred handedness.

Chiral Gravitational Waves

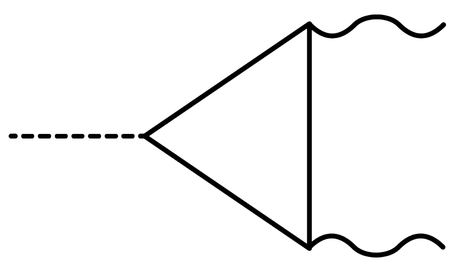


Lasky et al 2016
RC & Devulder 2017
In preparation: Smith & RC 2017

Leptogenesis

$$\nabla_\mu J^\mu_A = \frac{N_{R-L}}{24(16\pi^2)} R\widetilde{R}$$

Gravitational Anomaly



Kimura 1969
Delbourgo & Salam 1972
Eguchi & Freund 1976
Alvarez-Gaume & Witten 1984

$$R\widetilde{R} \propto (\Delta_R^2 - \Delta_L^2)$$

Leptogenesis

$$N_{\ell ep} = \frac{N_{R-L}}{24(16\pi^2)} \int d^4x \sqrt{-g} R\widetilde{R}$$

leptons created,
with asymmetry

$$j_{\ell ep} = \sum_i \left(j_{e^i_L} + j_{\nu^i_L} + j_{e^i_R} \right)$$

Standard Model particles;
chiral biased particle production

Gravitational Leptogenesis: Alexander, Peskin, Sheikh-Jabbari 2006

+ Reheating: Adshead, Long, Sfakianakis 2017

Create the matter-antimatter asymmetry
from chiral gravitational waves

Leptogenesis

Sakharov Conditions

- Violation of baryon number
- CP violation
- Out of equilibrium

… satisfied

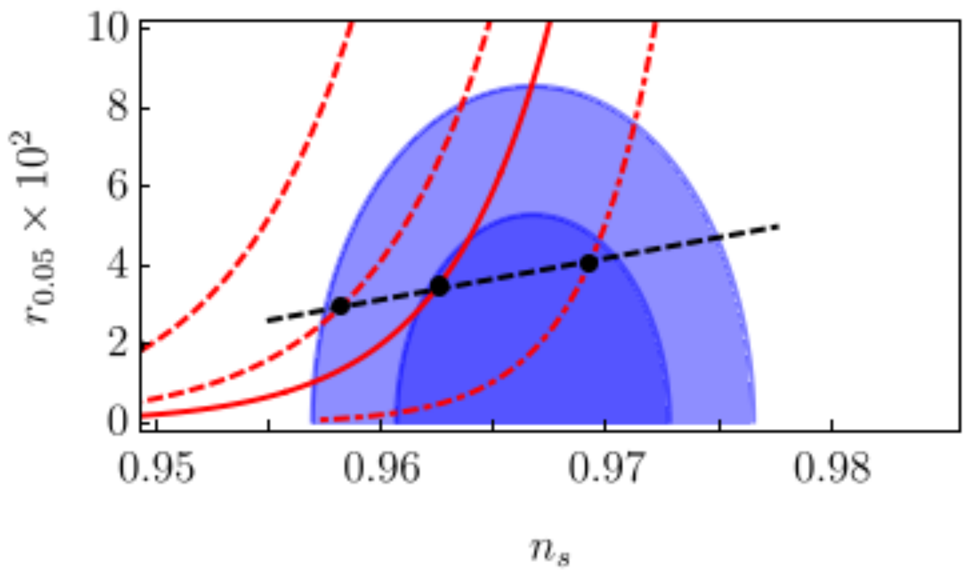
- Lepton number violated
- Inflaton/gauge field are parity-odd
- Inflation is far out of equilibrium

Leptogenesis

$$\eta \equiv \frac{n_B}{n_\gamma}$$
$$\simeq \frac{1}{7} \times \frac{28}{79} \times \frac{\langle n_\ell \rangle}{s}$$

Convert to baryon asymmetry by SM electroweak processes

Klebnikov & Shaposhnikov 1988



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Planck 2016

$$\eta \simeq 6.1(\pm 0.04) \times 10^{-10}$$

← CMB-S3 (3σ)

An observable within reach!

Leptogenesis

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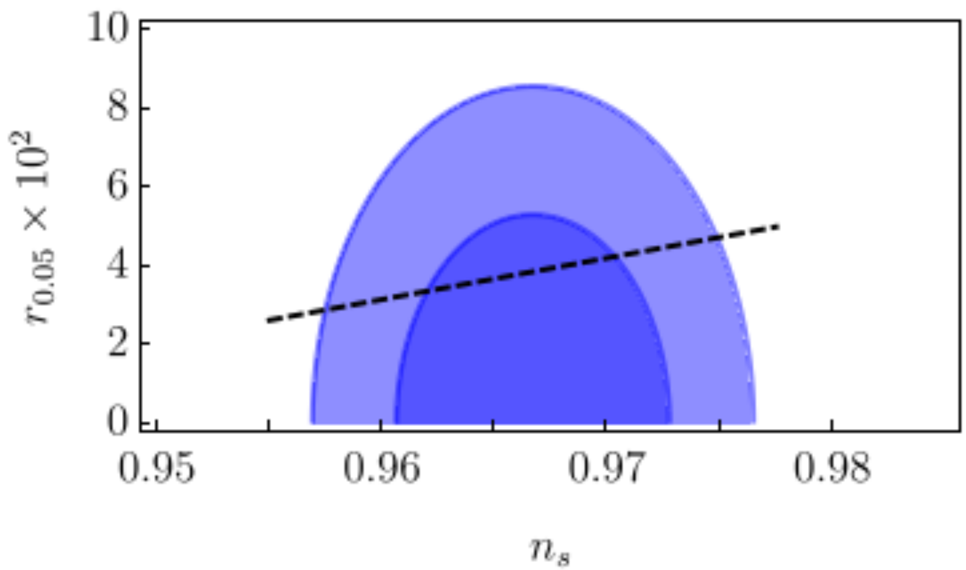

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An observable within reach!

Baryogenesis: Chiral gravitational waves create lepton asymmetry via gravitational anomaly

To match the observed baryon asymmetry, require tensor-to-scalar ratio r ~ 0.03-0.04

Claim: If reheating thermalization is delayed, more particle species added, or asymmetry erased, then larger r required to match η

Viable scalar spectrum, Observable tensor spectrum

Unique imprint: circular polarized GW background

Leptogenesis implies a lower bound for B modes

Measurement of TB/EB is an important goal!