Primordial Gravitation Waves: A Signal of Inflation?

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- Q: If we see a flat spectrum of gravitational waves with wavelengths extending to the horizon size (i.e. quadrupole in CMB), is that an unambigious signal of inflation

- A: probably not.

- An existence proof: LMK, PLB 284 (1992)
- Consider any global (i.e. non gauged) phase transtion (second order)

$$L = (1/2)(\delta\phi)^2 - V(\phi)$$

- minimum at ϕ_0
- Energy Density: $\frac{1}{2}(\partial_0\phi_0)^2 + \frac{1}{2}(\nabla\phi_0)^2$

- If spatially uniform and time invariant, zero energy density
- but, correlation length equals horizon size
- standard mechanism for generation of topological defects, stored energy density
- BUT, even if no defects, relaxation of fields over horizon-sized regions should involve generation of gravitational waves.
- No reason to expect <T> to be spherically symmetric for fields just entering horizon.

- Note: if pre-symmetry breaking universe was isotropic, excess energy associated with gradients must be compensated by variations in density of other matter and radiation..
- But.. effects scalar and vector metric perturbations.. tensor modes not compensated.
- if energy density gradients small, scalar field evolution independent of perturbations in other (uncoupled) fields.
- Assume spatial and time derivations order H^{-1}
- Energy density is v^2H^2, where v is VEV

- Total energy $M = \rho H^{-3}$
- grav wave generation related to relaxation of non-spherically symmetrical components of $T_{\mu\nu}$
- Use quadrupole approx. (not valid since scale of source is comparable to wavelength.. but to first order in R/Lambda..)
- For non-spherical mass distribution M, scale of quadrupole is

$$Q = fH^{-2}M \approx fv^2H^{-3}, \ \ where \ \ f < 1$$

- If distribution relaxes on order of the horizon time, quadrupole approx gives luminosity in grav waves, and thus energy liberated as:

$$\Delta E = H^{-1} G (d^3 Q/dt^3)^2 \approx g H^{-1} (f v^2 H^3 / H^3)^2 = g f^2 v^4 / H$$

- Energy density is:

$$\rho^{H^{-1}} = H^3 \Delta E = g f^2 v^4 H^2$$

- rewrite as dimensionless RMS wave amplitude h using

$$h \approx H^{-1}(G\rho)^{1/2}$$

- Thus

$$h_{H^{-1}} \approx H^{-1}(G^2 f^2 v^4 H^2)^{1/2} = G f v^2 \approx f(v/M_{pl})^2$$

- As should be expected on dim. analysis grounds.

- Thus, central result:
  - due to continual relaxation of order parameter on horizon scales, background of grav. waves generated at each time with dim. amplitude on horizon scale, independent of time (i.e. scale invariant) with mag of order $(v/M_{pl})^2$
- identical in form to inflationary universe?

Issues

- only good for global, not local
- note that these energy density fluctuations would also lead to direct deltaT/T in CMB
- Q: will polarization signal in CMB differ from inflation signal, which also involves "superhorizon" modes? Not clear...
- Dim analysis suggests any horizon-sized rearrangments.. similar effects..