Title: 21cm gravity wave fossils

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Abstract: TBA

Gravity Wave Fossils

signatures of tensor modes in pre-reionization 21 cm structure

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Testing Inflation

- most tests are qualitative postdictions: slightly red HZP spectrum, adiabatic fluctuations, flatness.
- tensor modes: generic, no amplitude prediction
- consistency relation: $n_T = r/8$. Requires measuring tensor power spectrum to 1% accuracy on two scales!
- 3-PCF: very small, also hard to measure

Background

- Majority of cosmological information encoded in pre-reionization 21cm structures at $z \sim 15$
- universe transparent in 21cm along most lines of sight
- $\sim 10^{18}$ modes: $(k_{\mathrm{Jeans}}/k_{\mathrm{Hubble}})^3$
- $k_{\mathrm{Jeans}} \propto 1/(1+z)$ for $z \gg 10$
- Several experiments under way (GMRT, LOFAR, MWA, PAPER)
- Suitable for Arecibo, FAST, next generation cylinders.
- $r \sim 10^{-8}, f_{NL} \sim 10^{-4}$?

Motivation

- Primordial tensors (gravity waves) are hard to detect: current constraint is $r < 0.24$ (WMAP), near future $r \sim 0.01$ (B-modes).
- Inflation generically makes quantitative prediction for the tensor power spectrum, $n_T = r/8$.
- How would you look for tensors? Lensing? (Dodelson, Rozo, Stebbins)

Gravity Wave Fossils

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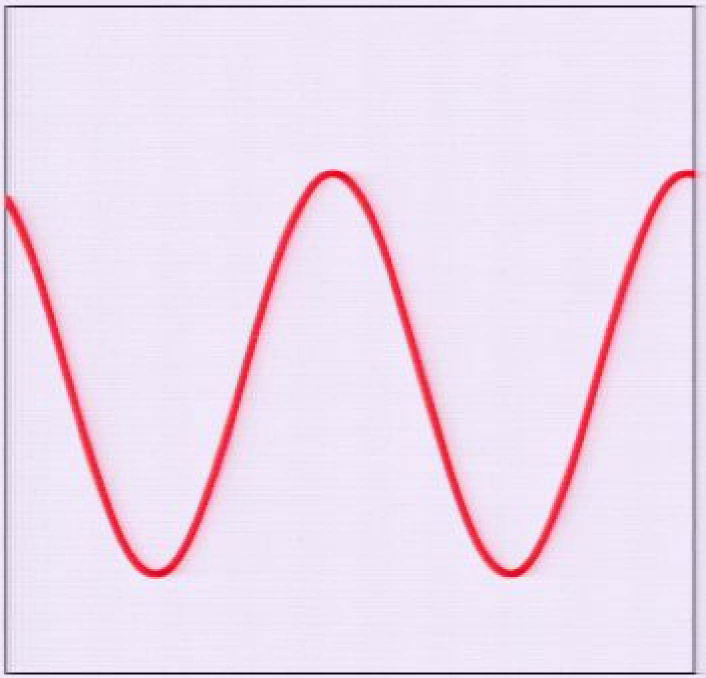

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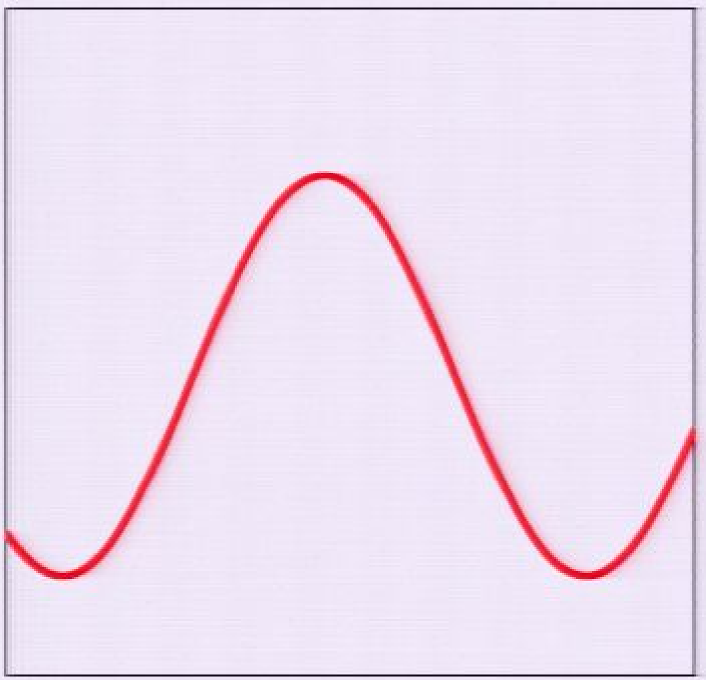

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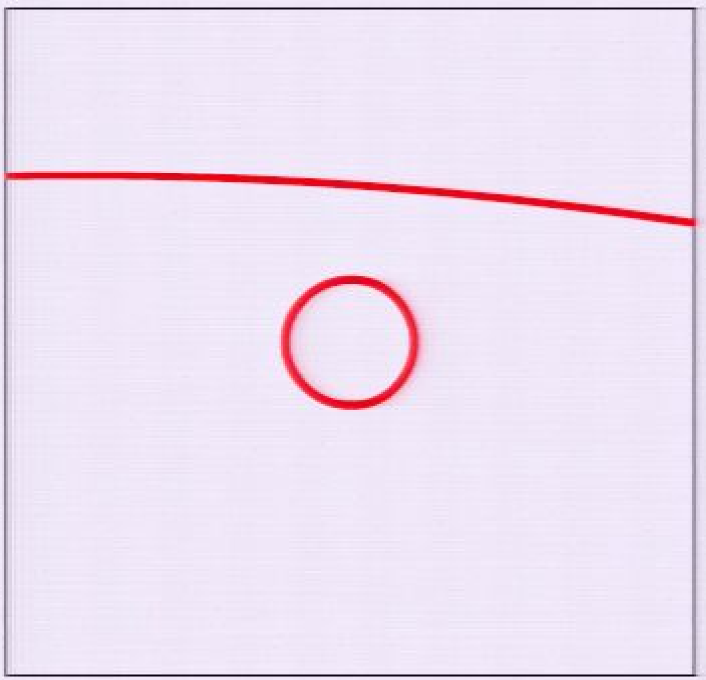

- $ds^2 = a(\eta)^2 \left[-d\eta^2 + (h_{ij} + \delta_{ij}) dx^i dx^j \right]$
- $k_T \ll aH$
- $\tilde{x}^\alpha = (x^\alpha - \frac{1}{2} h_{\alpha\beta} x^\beta)$

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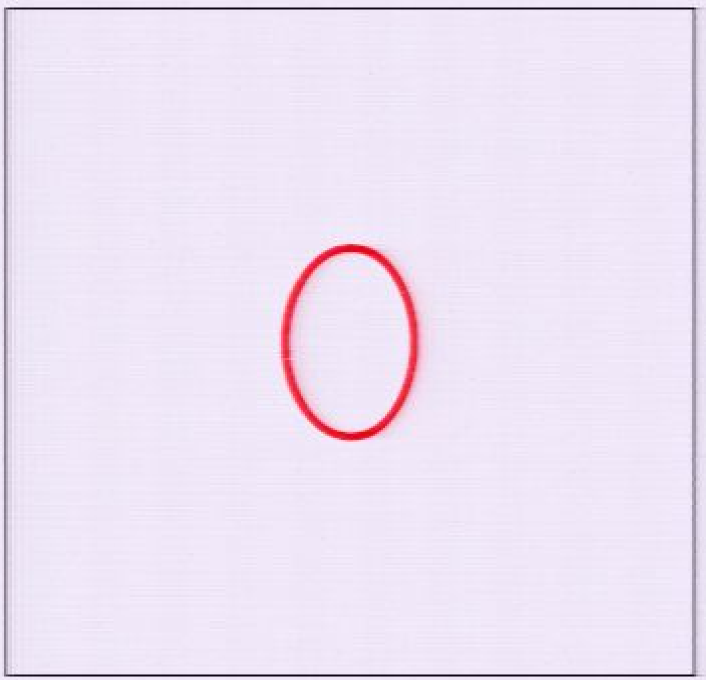

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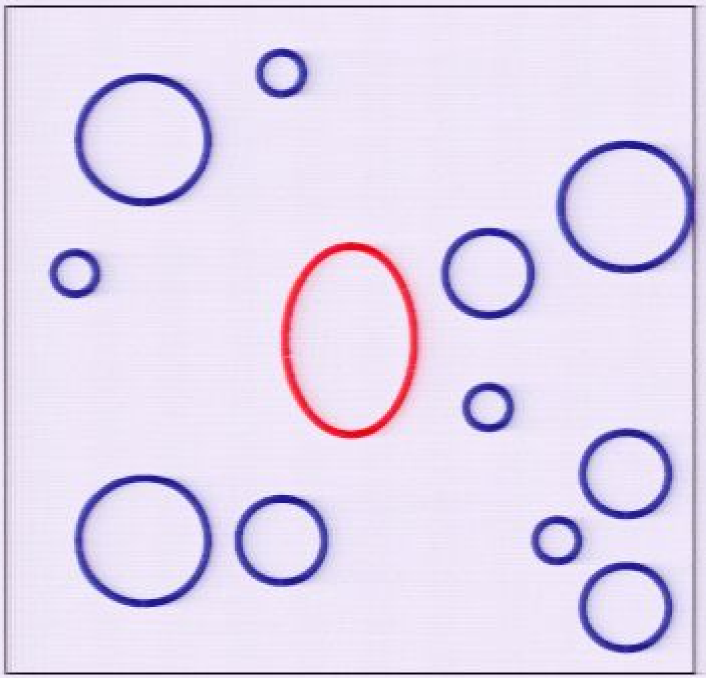

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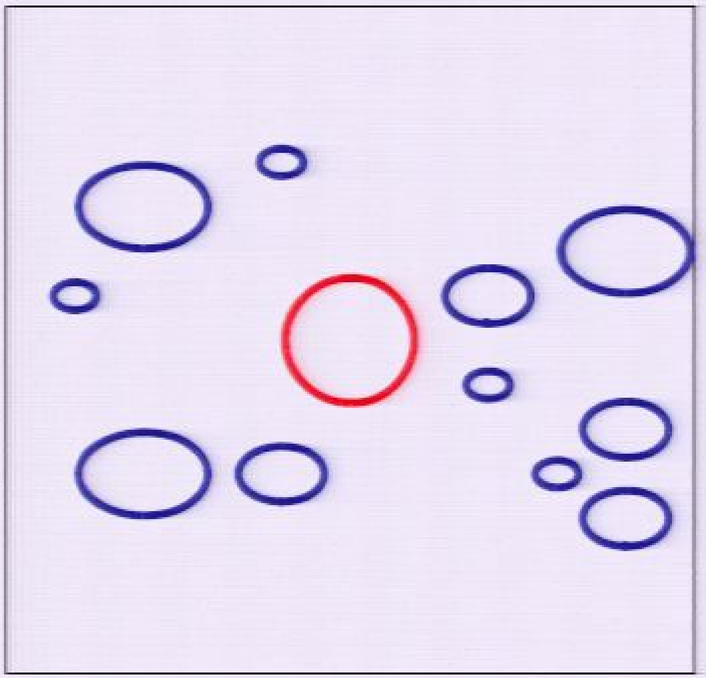

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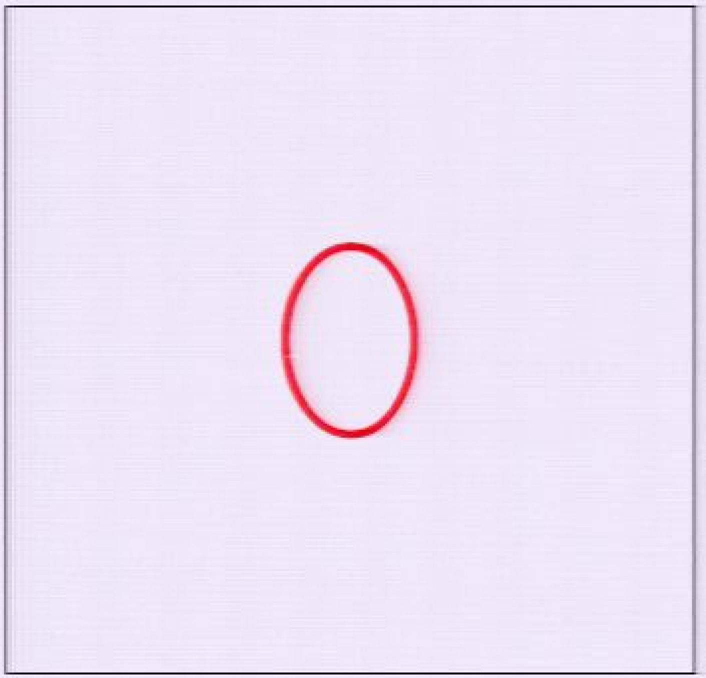

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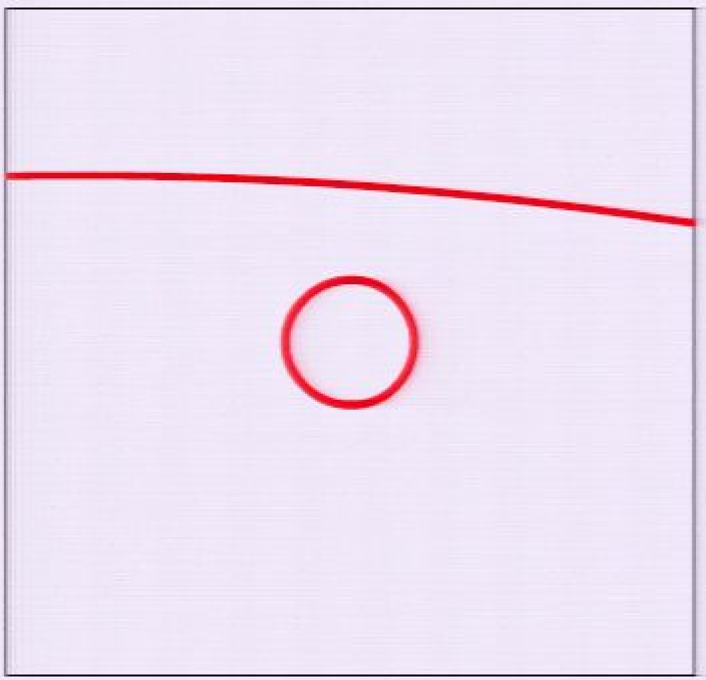

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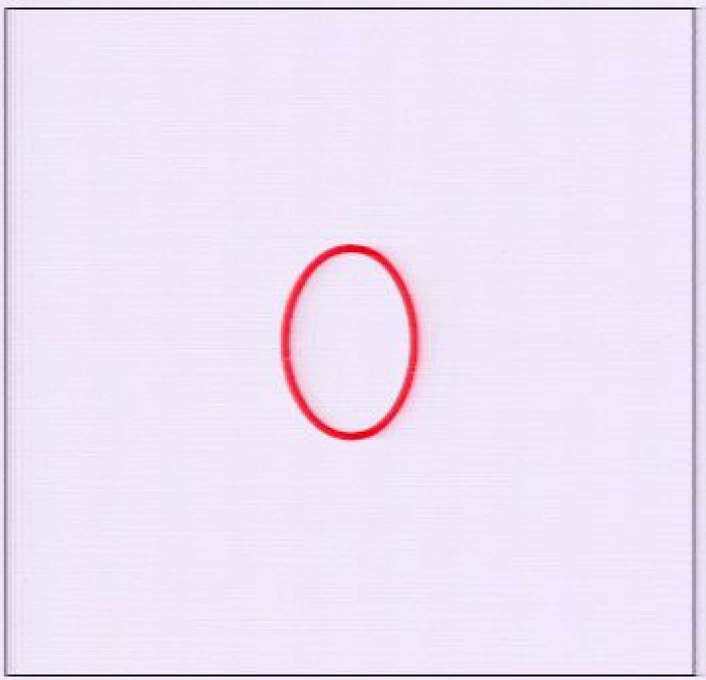

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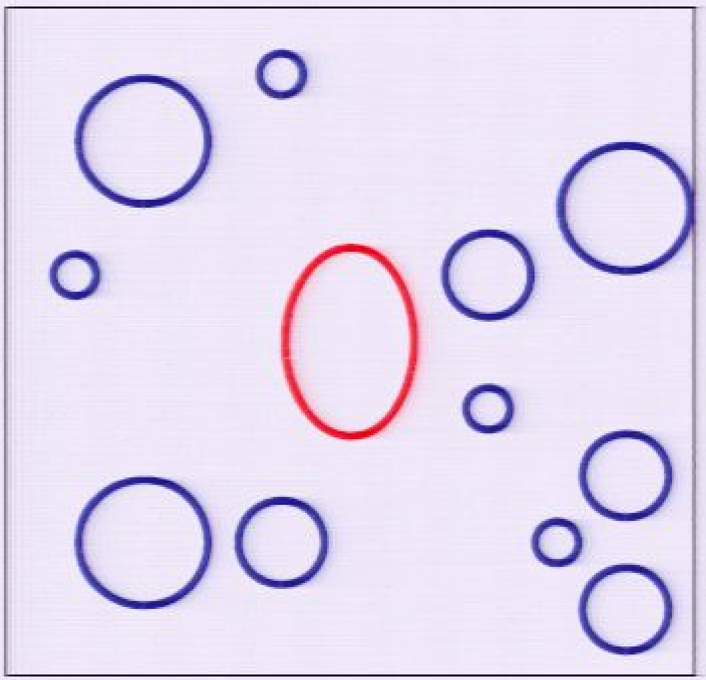

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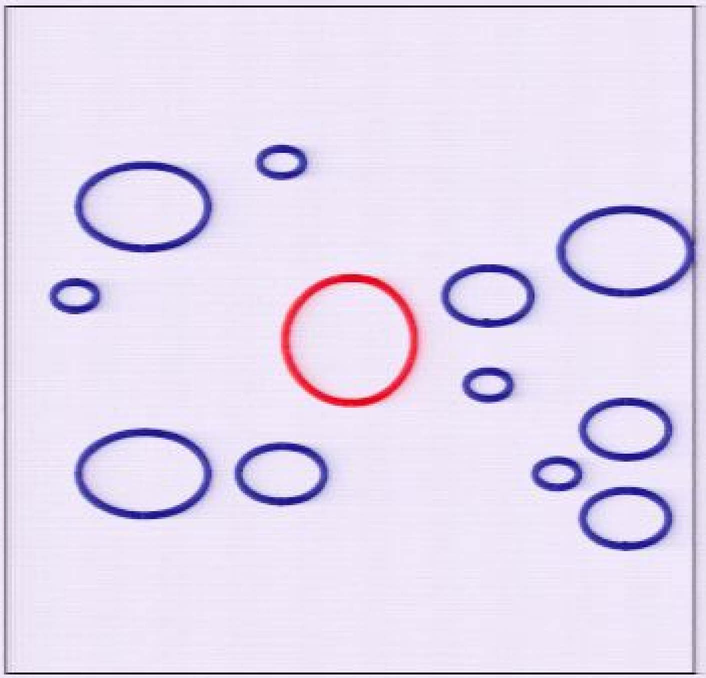

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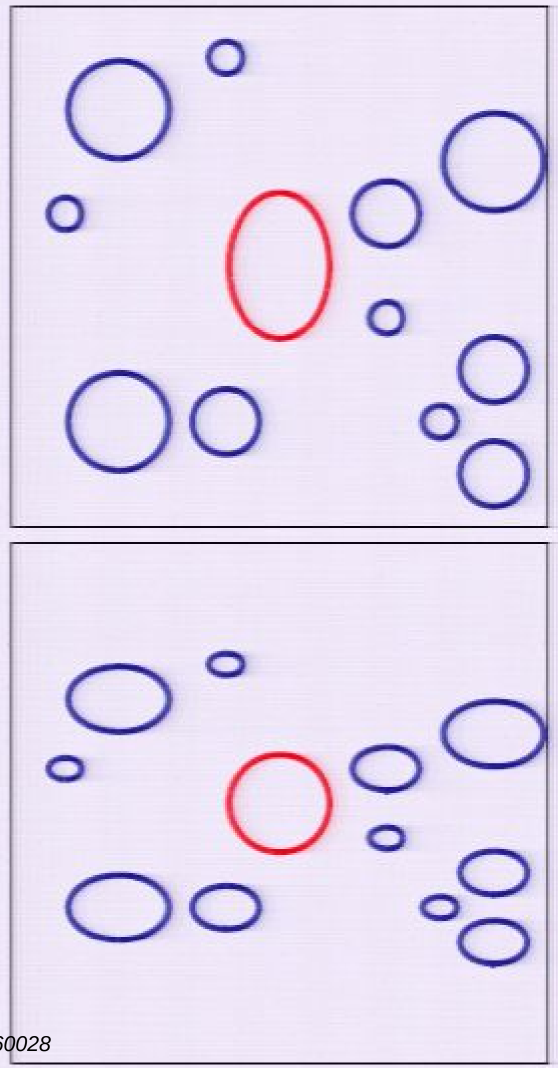

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- Gravity wave decays.
- Geodesic equation is trivial original coordinates.
- Anisotropy becomes observable.

Gravity Wave Fossils

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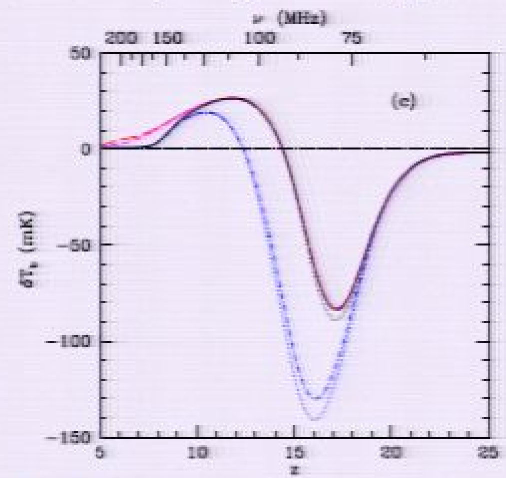
- Looking for a local anisotropy in the *scalar* power spectrum.
- Tensor modes can be reconstructed by measuring scalar power spectrum patch by patch $h_{ij} \sim \langle \delta_{,i} \delta_{,j} \rangle$.
- Can then verify that h_{ij} is transverse and traceless.
- However, effect is minute, so you need many scalar modes.

Why is this bigger than other effects

- Normally tensor modes decay rapidly once they enter the horizon.
- The fossils are permanent.
- Simultaneously probe a range of scales for the tensor power spectrum.
- not contaminated by lensing: TT
- May allow the measurement of the tensor spectral tilt n_T.
- Test the inflation consistency relation.

Forecasts

Furlanetto, Peng and Briggs, 2006



SKA will try to detect the 21 cm line at redshift 15 with 10 km baselines.

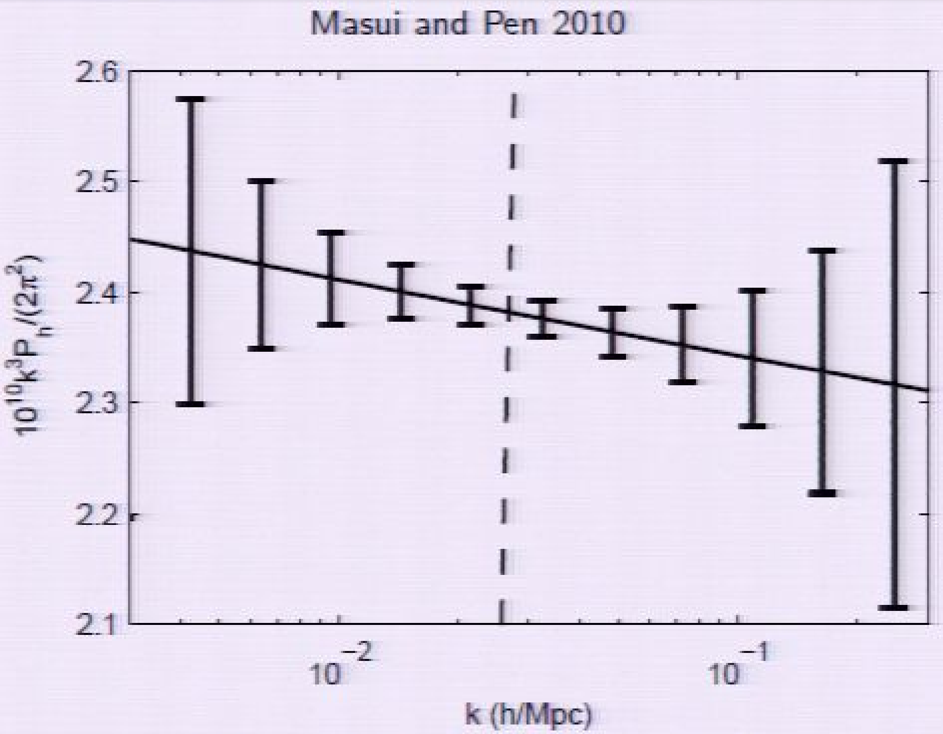
$$r_{min} = \frac{32\pi^2}{A_s k_{max}^3} \left(\frac{6}{V V_H} \right)^{1/2}$$

$$r_{min} = 7.3 \left(\frac{1.2\, h/\mathrm{Mpc}}{k_{max}} \right)^3 \left[\frac{200\, (\mathrm{Gpc}/h)^3}{V} \frac{3.3\, (\mathrm{Gpc}/h)^3}{V_H} \right]^{1/2}$$

To test the consistency relation:

$$\Delta n_t = F \left[\left(\frac{2\pi}{k_{max}} \right)^3 \frac{1}{r A_s V} \right]^{1/2}$$

Power Spectrum

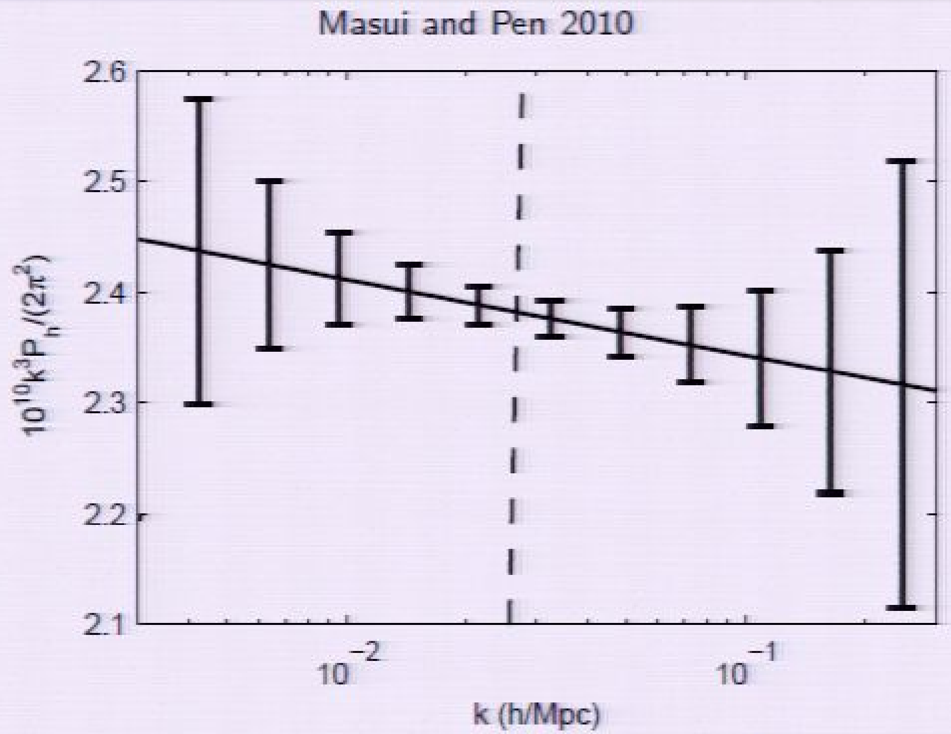


Primordial tensor power spectrum obeying the consistency relation for $r = 0.1$. The solid line is the tensor power spectrum. Error bars are for a perfect experiment surveying $200\,(\mathrm{Gpc}/h)^3$ and resolving scalar modes down to $k_{max} = 168h/Mpc$. The dashed, nearly vertical, line is the reconstruction noise power. The non-zero slope of the solid line is the deviation from scale-free

Conclusions

- New linear memory effect for detecting primordial tensor modes.
- Measures metric at source – tensors unaffected by lensing.
- Potentially powerful for measuring r with ground based low frequency telescopes ($z \sim 15$).
- Opportunity to measure n_T, but r needs to cooperate.

Power Spectrum



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