

(Re)Connecting General Relativity with Cosmology

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in transition to: Max Planck Institute for Gravitational Physics, Hannover

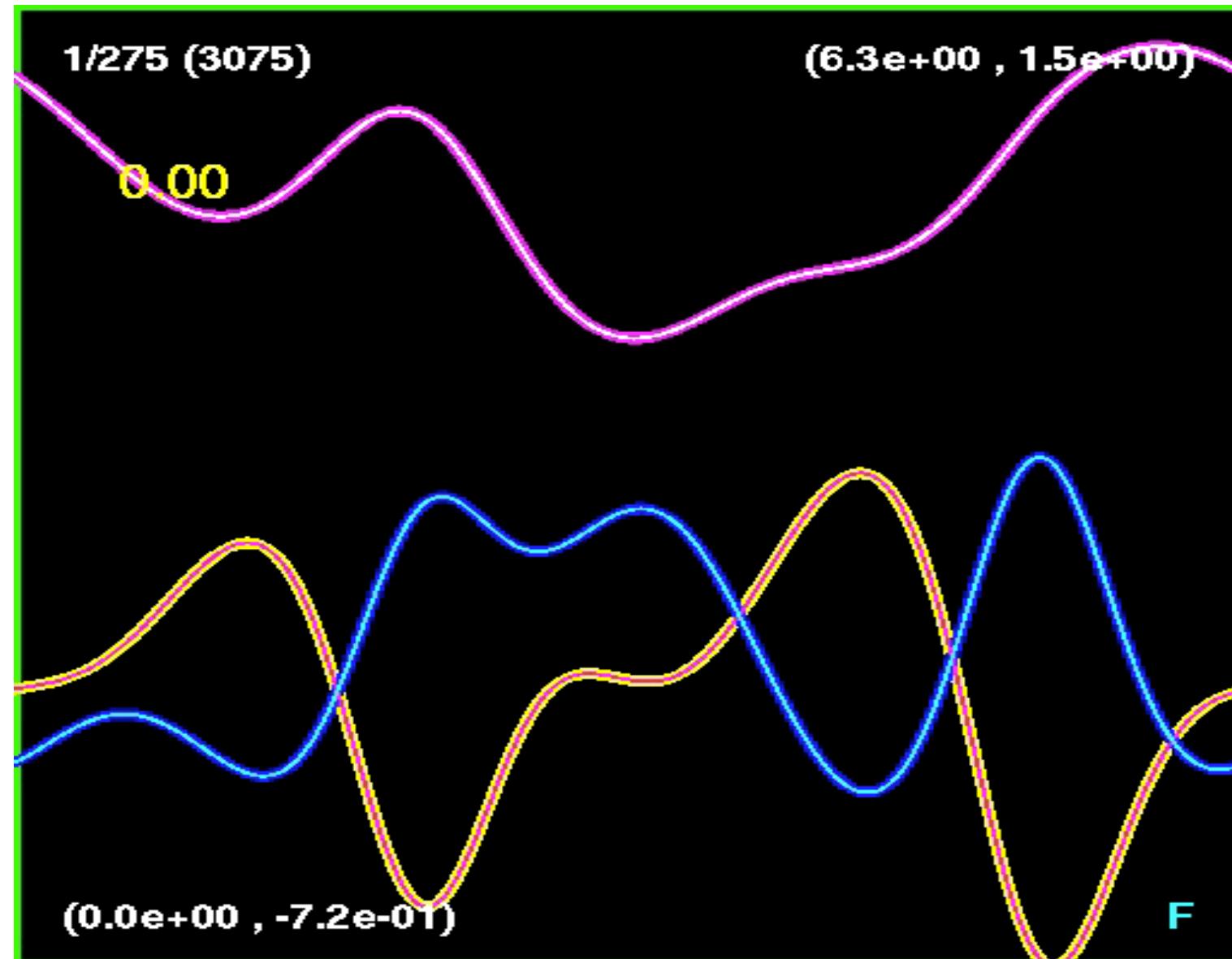
Smoothing through slow contraction

$$ds^2 = -dt^2 + a(t)^2 dx_i dx^i$$

$$H^2 = \left(\frac{\dot{a}}{a} \right)^2 = \frac{1}{3} \left(\frac{\rho_m^0}{a^3} + \frac{\rho_r^0}{a^4} \right) - \frac{k}{a^2} + \frac{\sigma^2}{a^6} + \frac{1}{3} \left(\frac{\rho_\phi^0}{a^{2\epsilon}} \right)$$

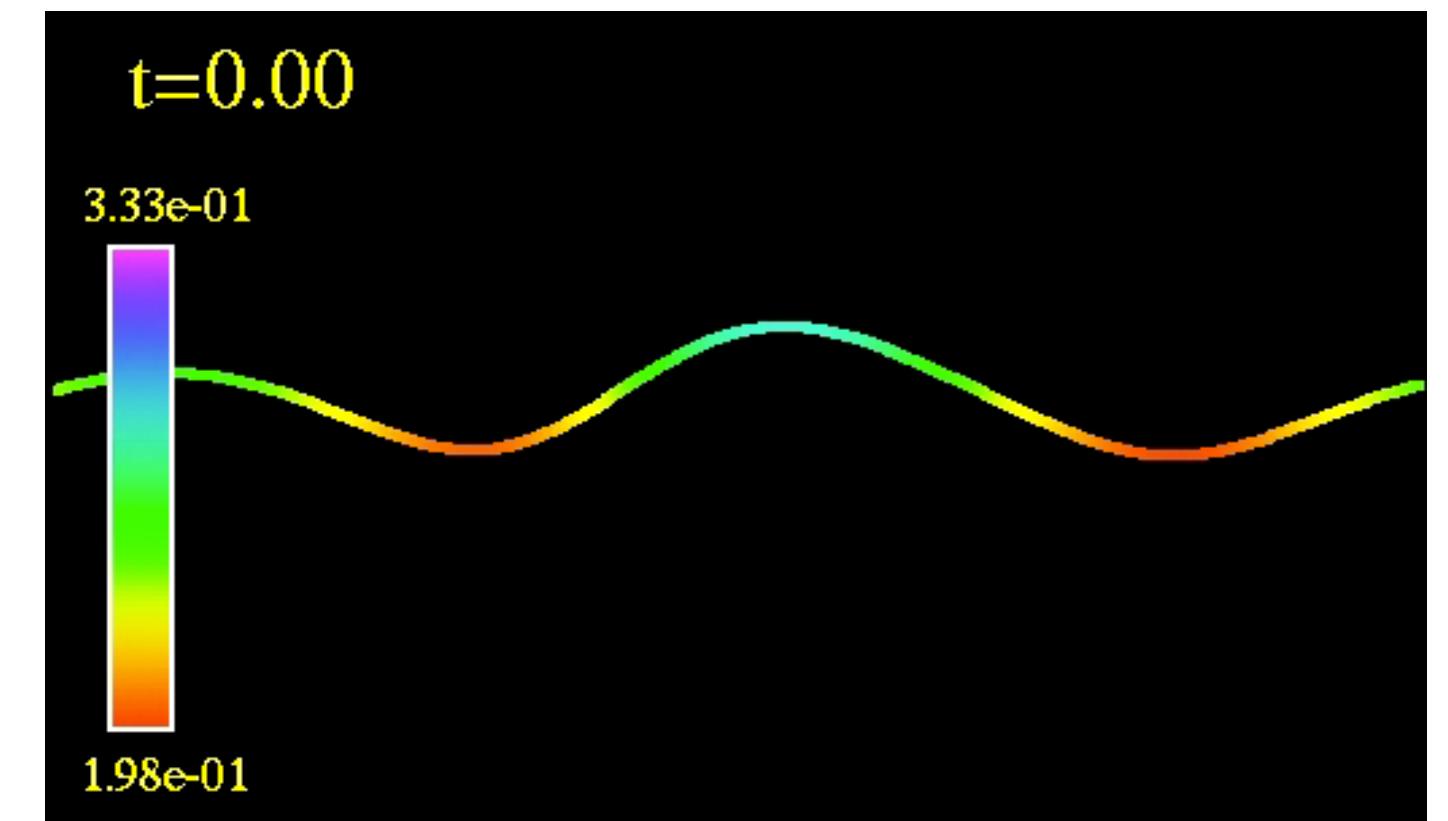
where $\epsilon = \frac{3}{2} \left(1 + \frac{p}{\rho} \right) = 3 \left(\frac{\frac{1}{2} \dot{\phi}^2}{\frac{1}{2} \dot{\phi}^2 + V(\phi)} \right)$

Smoothing through slow contraction



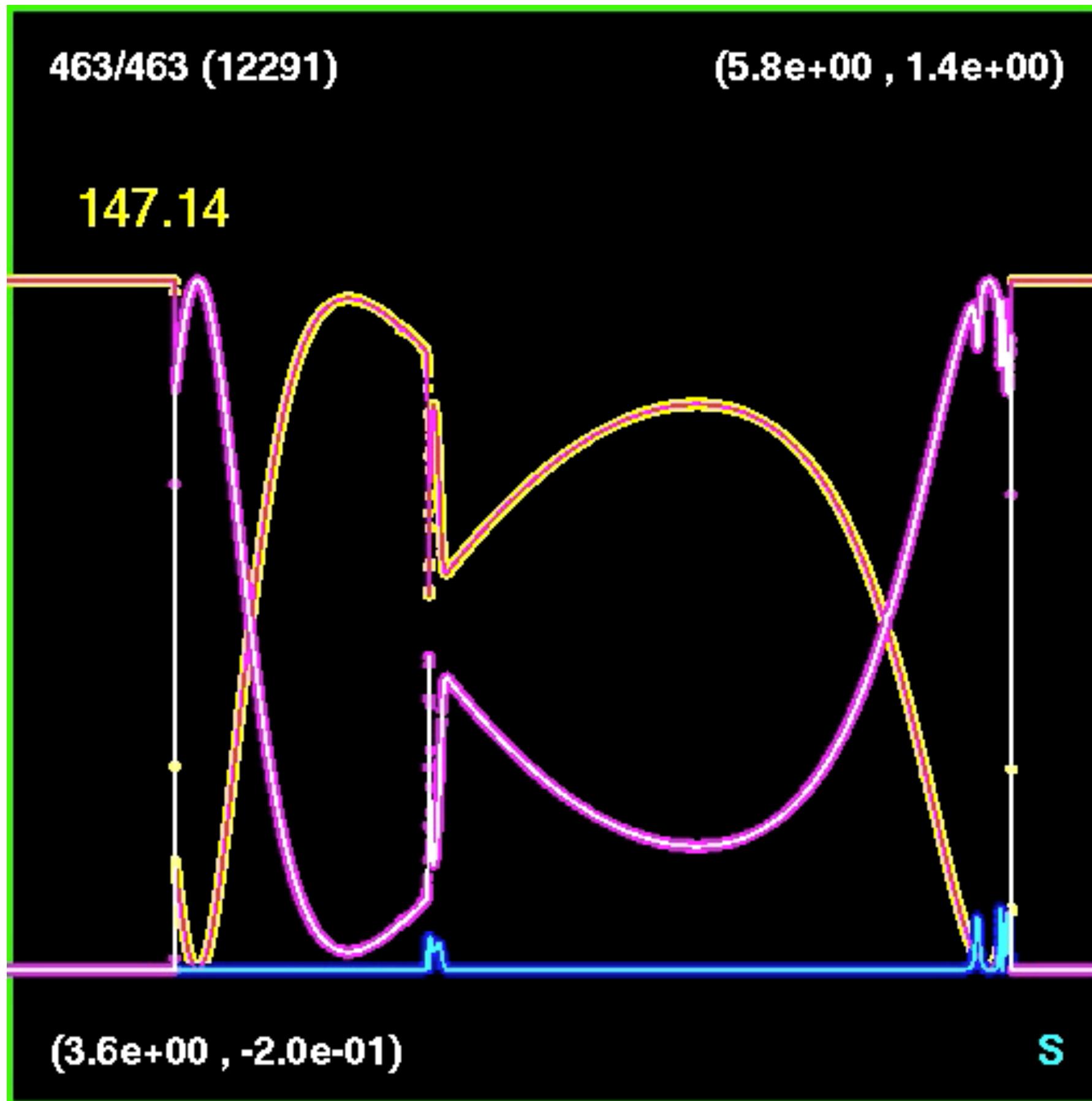
matter – yellow
curvature – blue
shear – pink

small volume



proper (spatial) volume of scalar-field matter, curvature, and shear

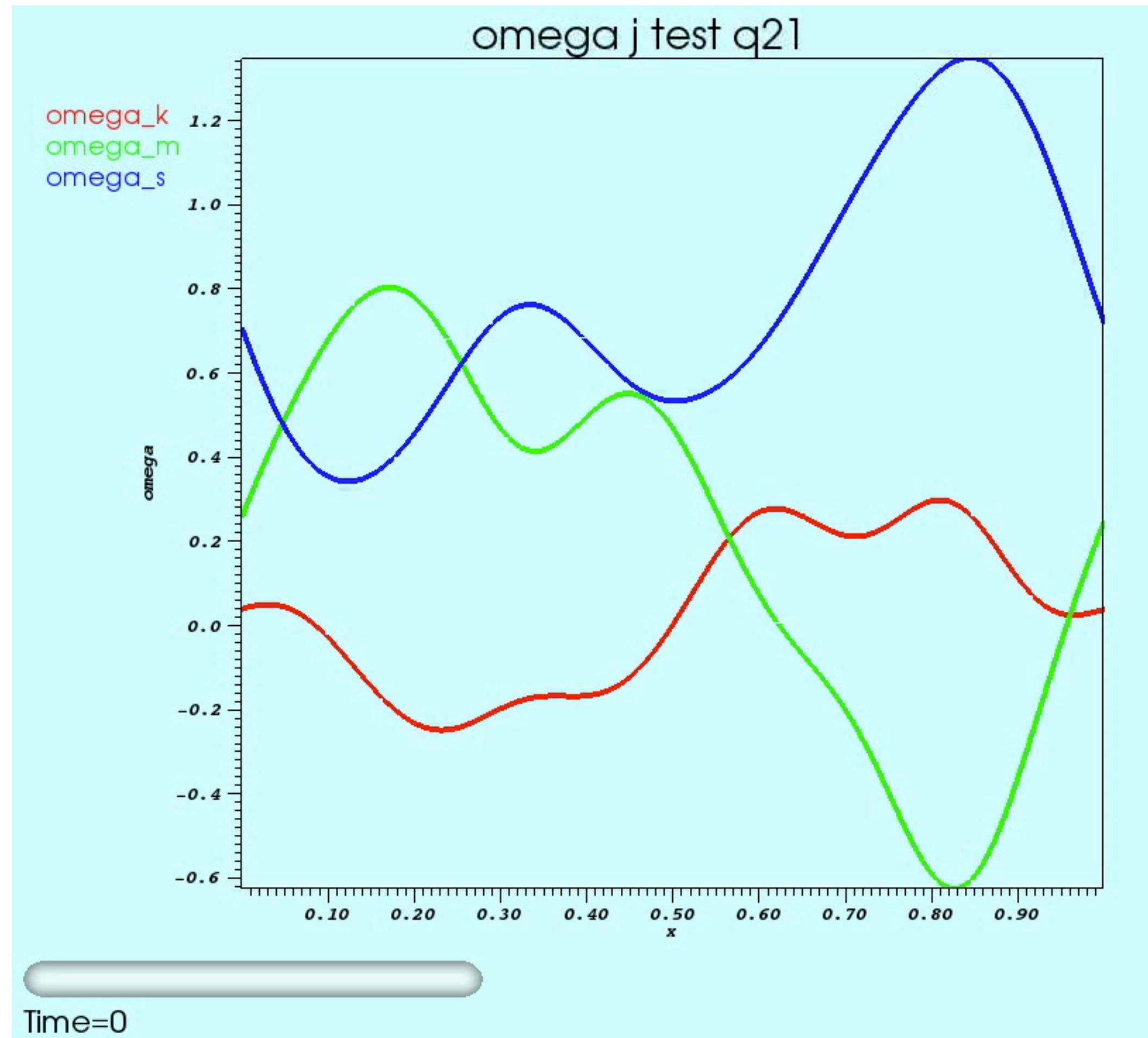
Mixmaster spikes



chaotic behavior at every space-time
point

Super-Smoothing through slow contraction

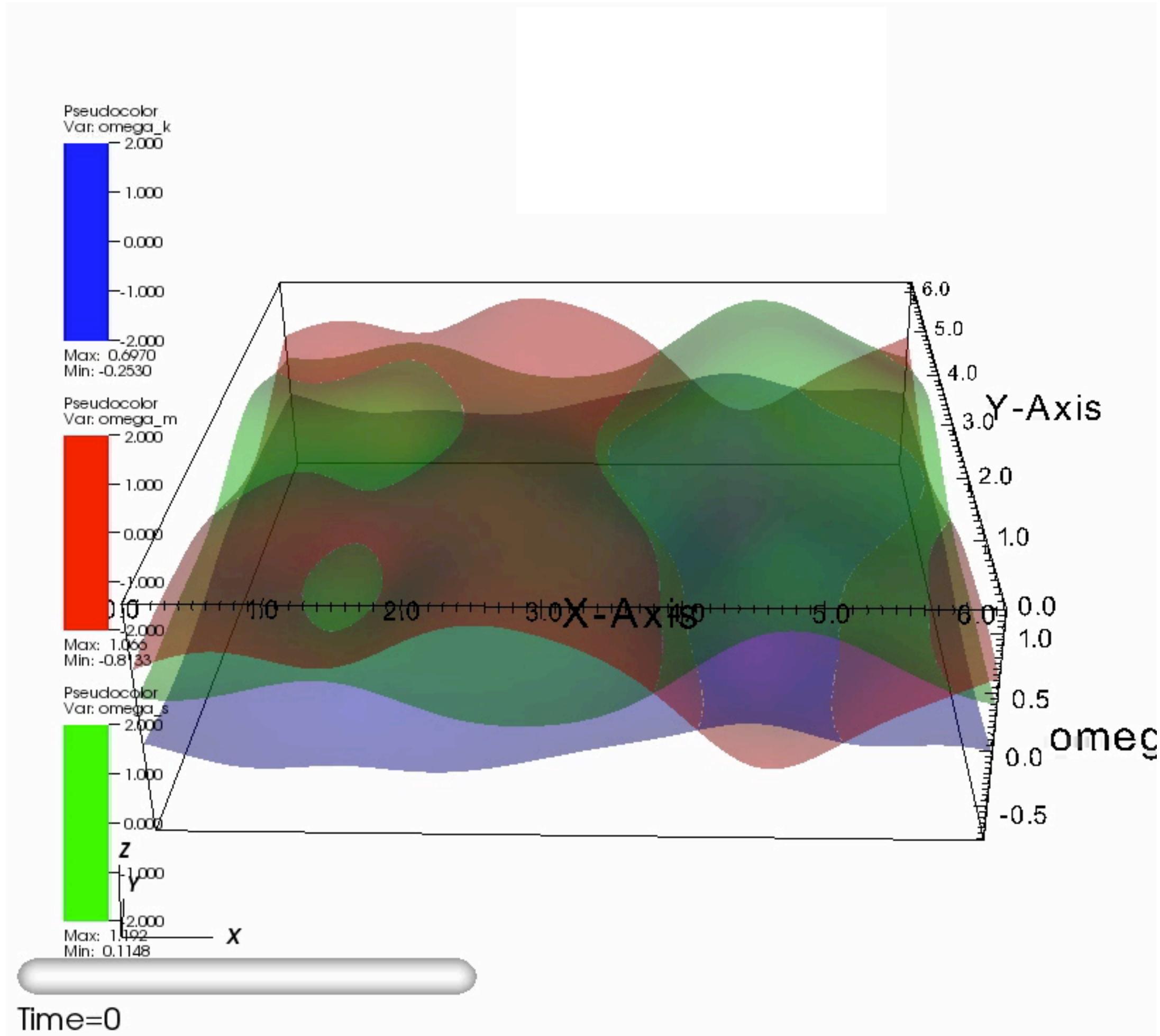
curvature – red
matter – green
shear – blue



time evolution of the fractional energy densities
scalar-field matter, curvature, and shear

Super-Smoothing through slow contraction

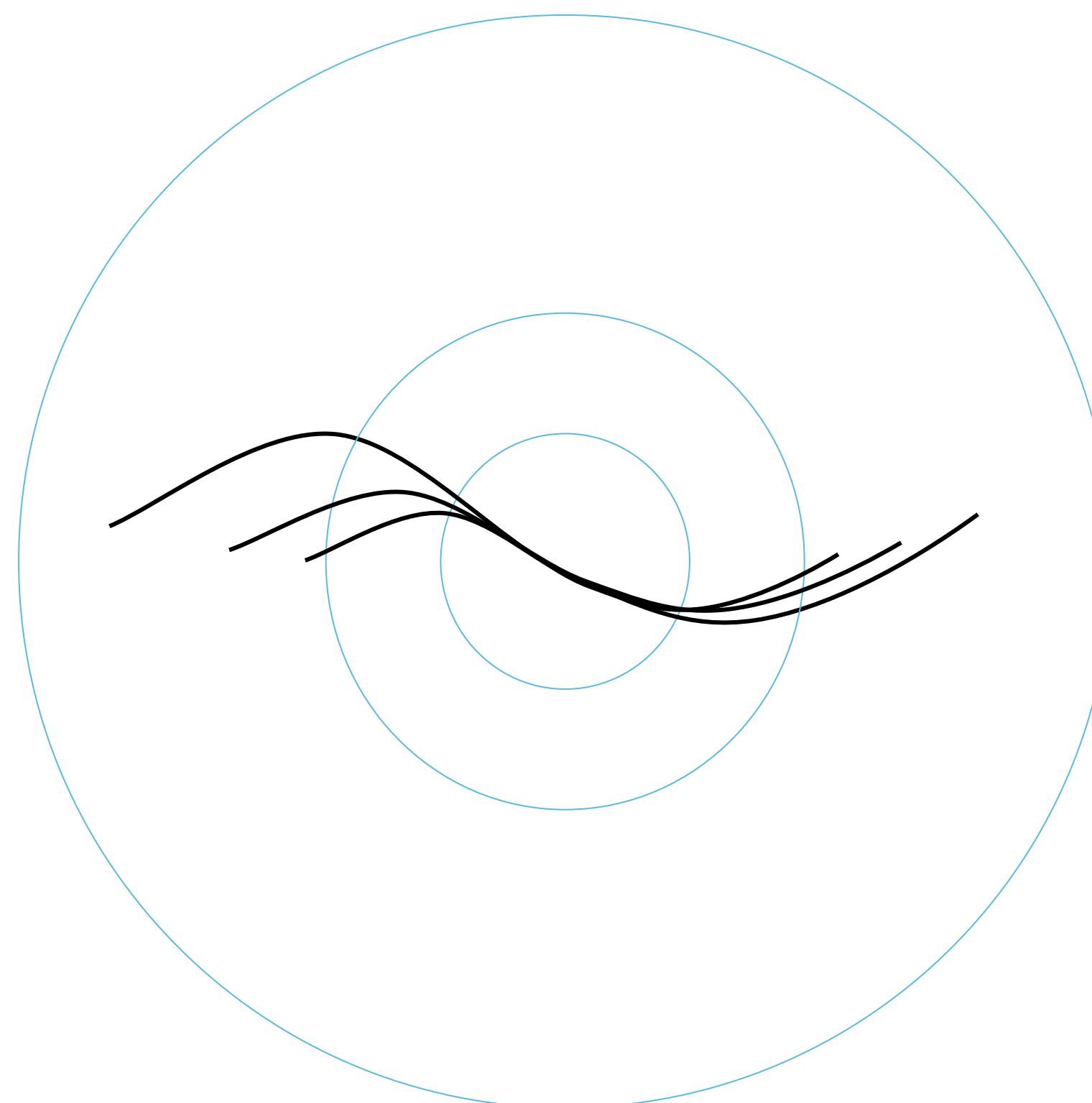
curvature – blue
matter – red
shear – green



time evolution of the fractional energy densities scalar-field
matter, curvature, and shear

Super-horizon modes through slow contraction

7



Generation of primordial perturbations

$$\mathcal{S} = \int d^4x \sqrt{-g} \left(\frac{1}{2}R - \frac{1}{2}(\partial_\mu\phi)^2 + V_0 \exp(-\sqrt{2\epsilon}\phi) - \frac{1}{2}\Omega^2(\phi)(\partial_\mu\chi)^2 \right)$$

DENSITY PERTURBATIONS:

- stable background solution;
- least tuned;
- (near) scale invariance
- local non-gaussianity: $f_{NL} = 0$

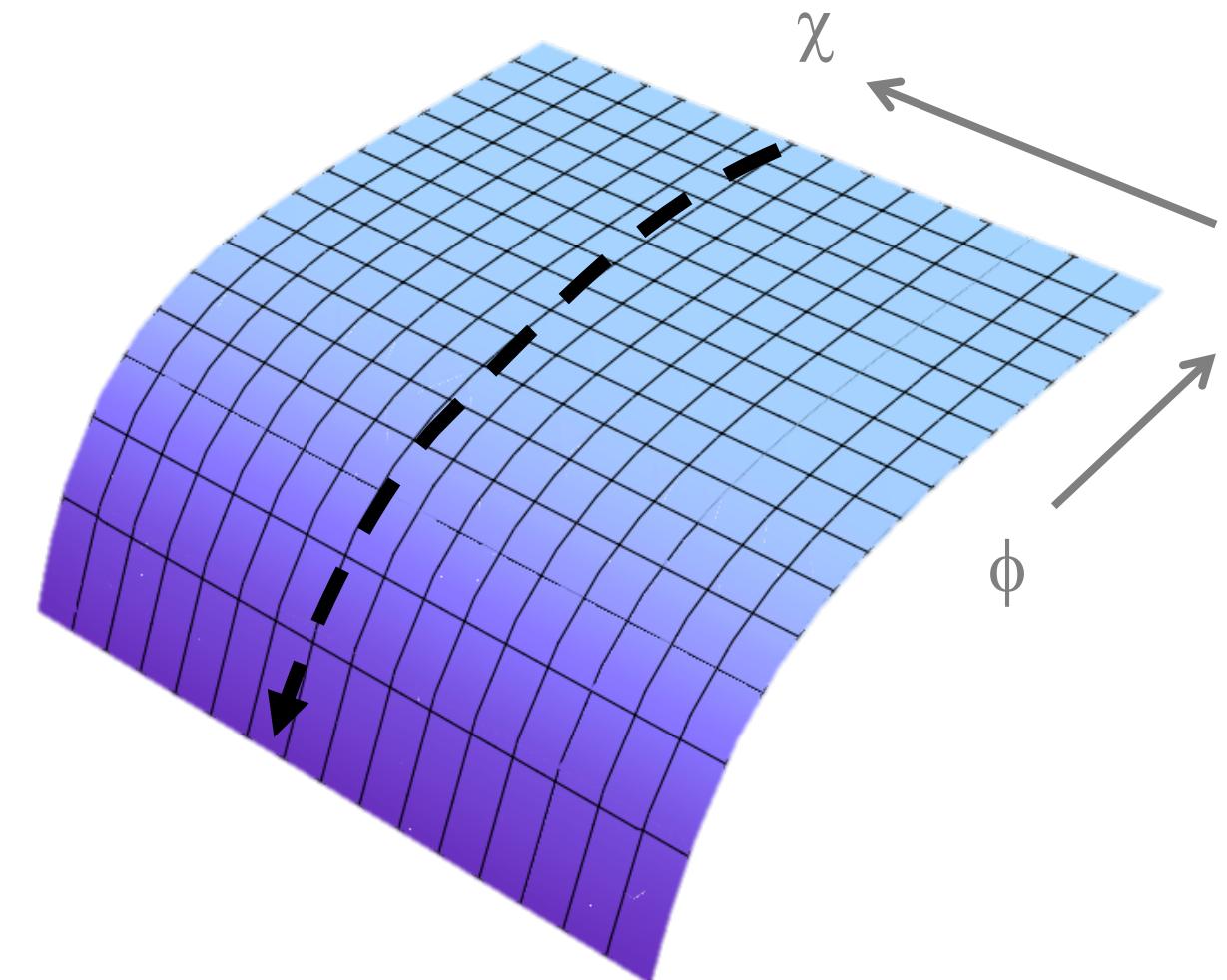
CONVERSION!

$f_{NL} \sim O(1)$ possible

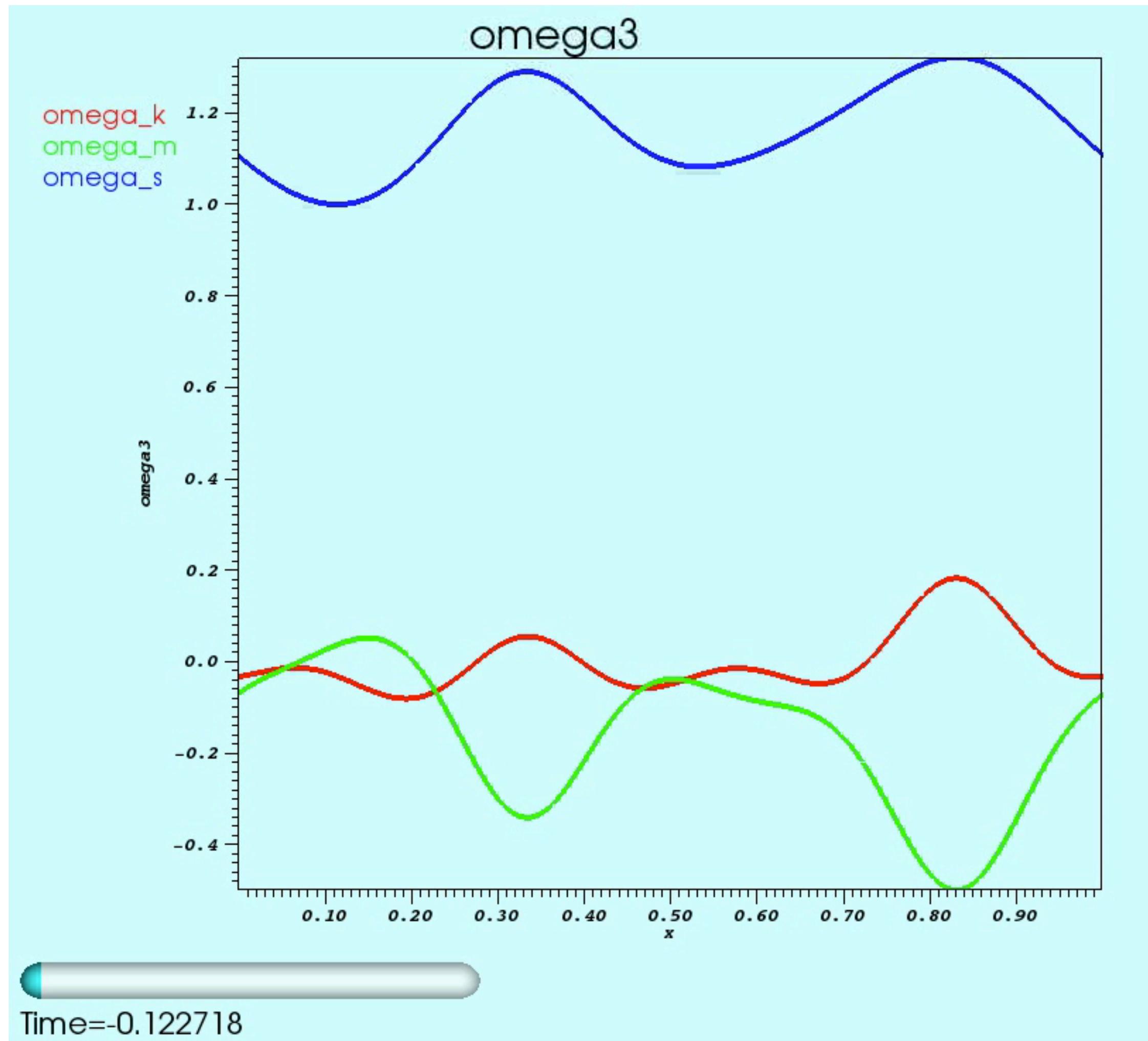
NO PRIMARY TENSOR PERTURBATIONS!

... but

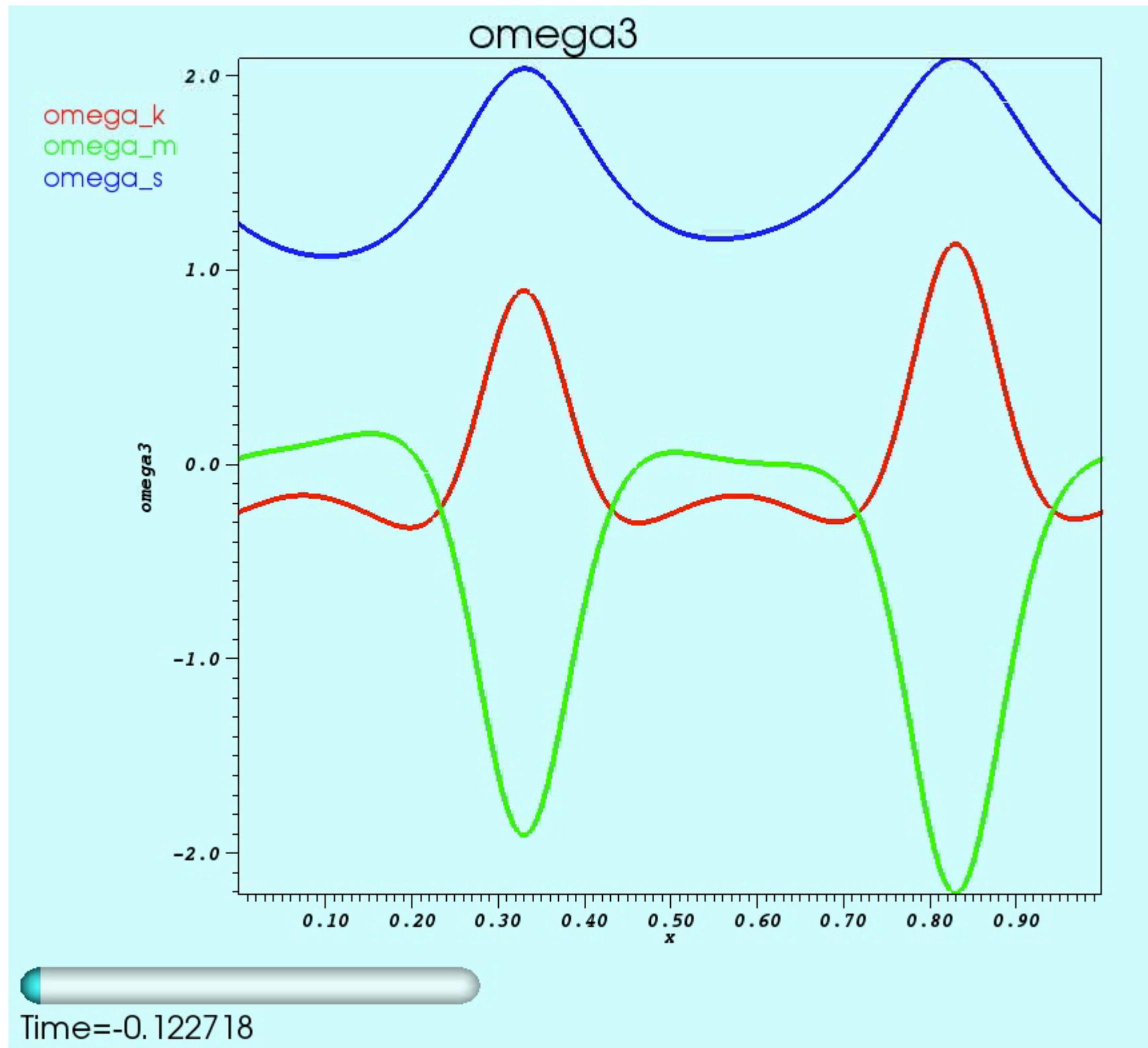
- secondary tensors ($r \sim 10^{-6}$);
- B-modes from defects possible (typically, non-Gaussian)



Surprises from non-perturbative analysis



You better break that symmetry ...

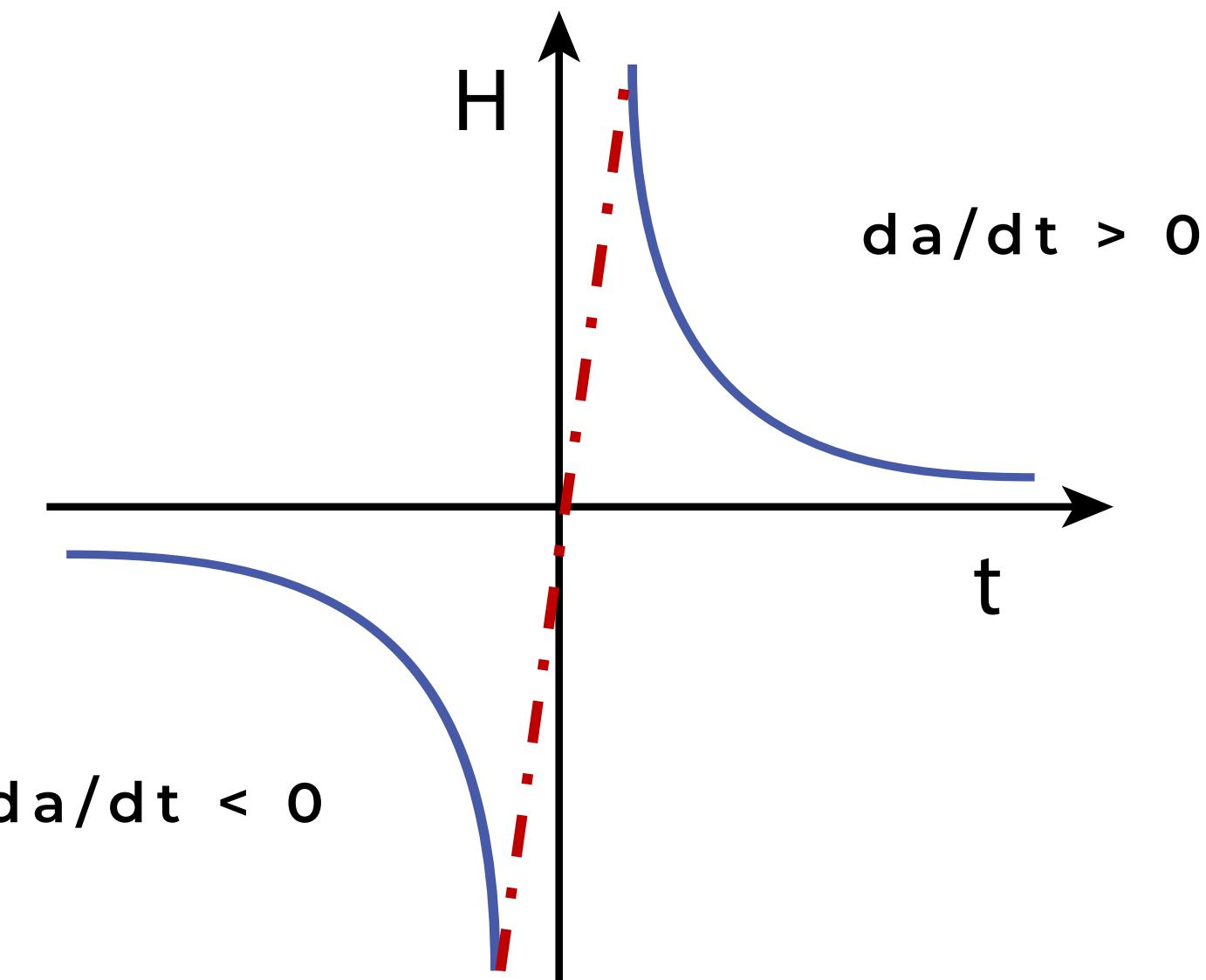


COSMOLOGY AS A TEST OF EINSTEIN GRAVITY WITH NON-STANDARD SOURCE AND/OR MODIFIED GRAVITY

well-posedness, physical and numerical
stability, and gauge issues

VIOLATE NULL CONVERGENCE CONDITION:

$$R_{\alpha\beta} n^\alpha n^\beta \cancel{\geq} 0$$



What constitutes a ‘good’ dynamical theory?