From elastic continua to space-time

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The universe: a dualistic description

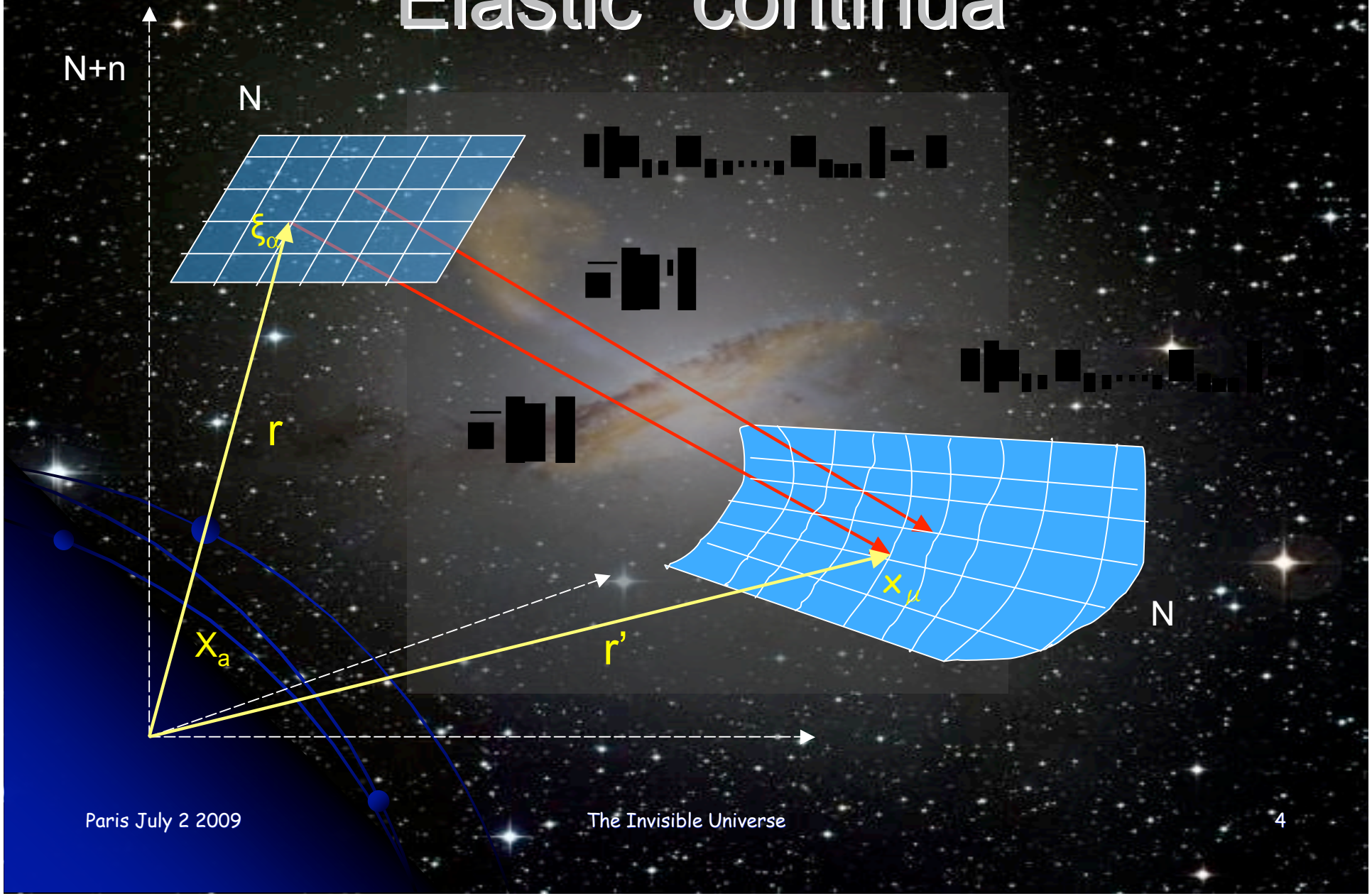
Space-time/Matter-energy

What is this?

What is space-time?

- Is it a mathematical artifact to describe the gravitational field and the global properties of the universe?
- Is it something real endowed with physical properties?

“Elastic” continua



Geometry and elasticity

In a strained medium each point is in one to one correspondence with points in the unstrained state

u, r and r′ are (N+n)-vectors in the flat embedding space

The strain is described by the differential change of u

[redacted]

[redacted]

[redacted]

Metricity

[redacted]

[redacted]

[redacted]

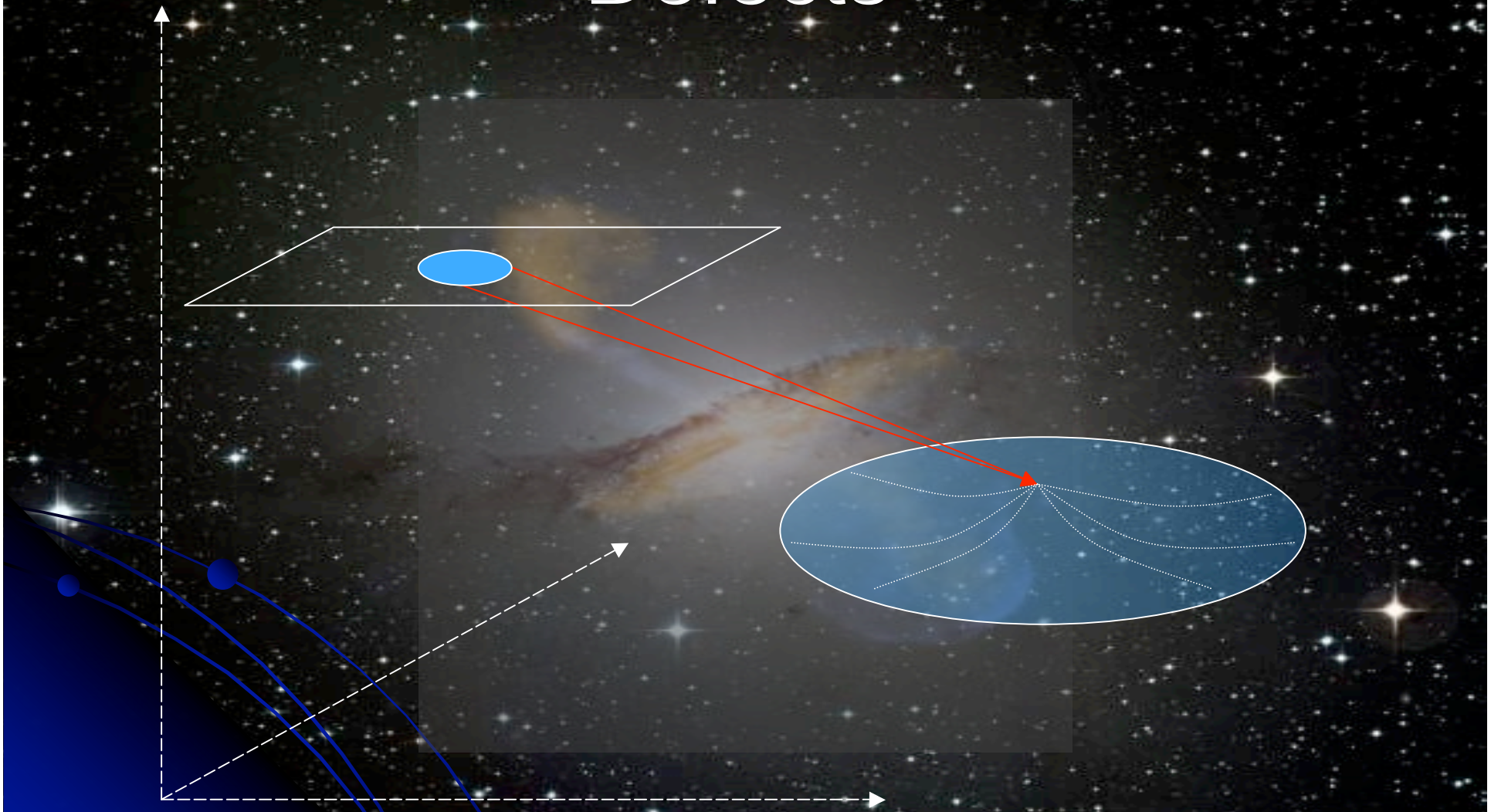
Strain tensor

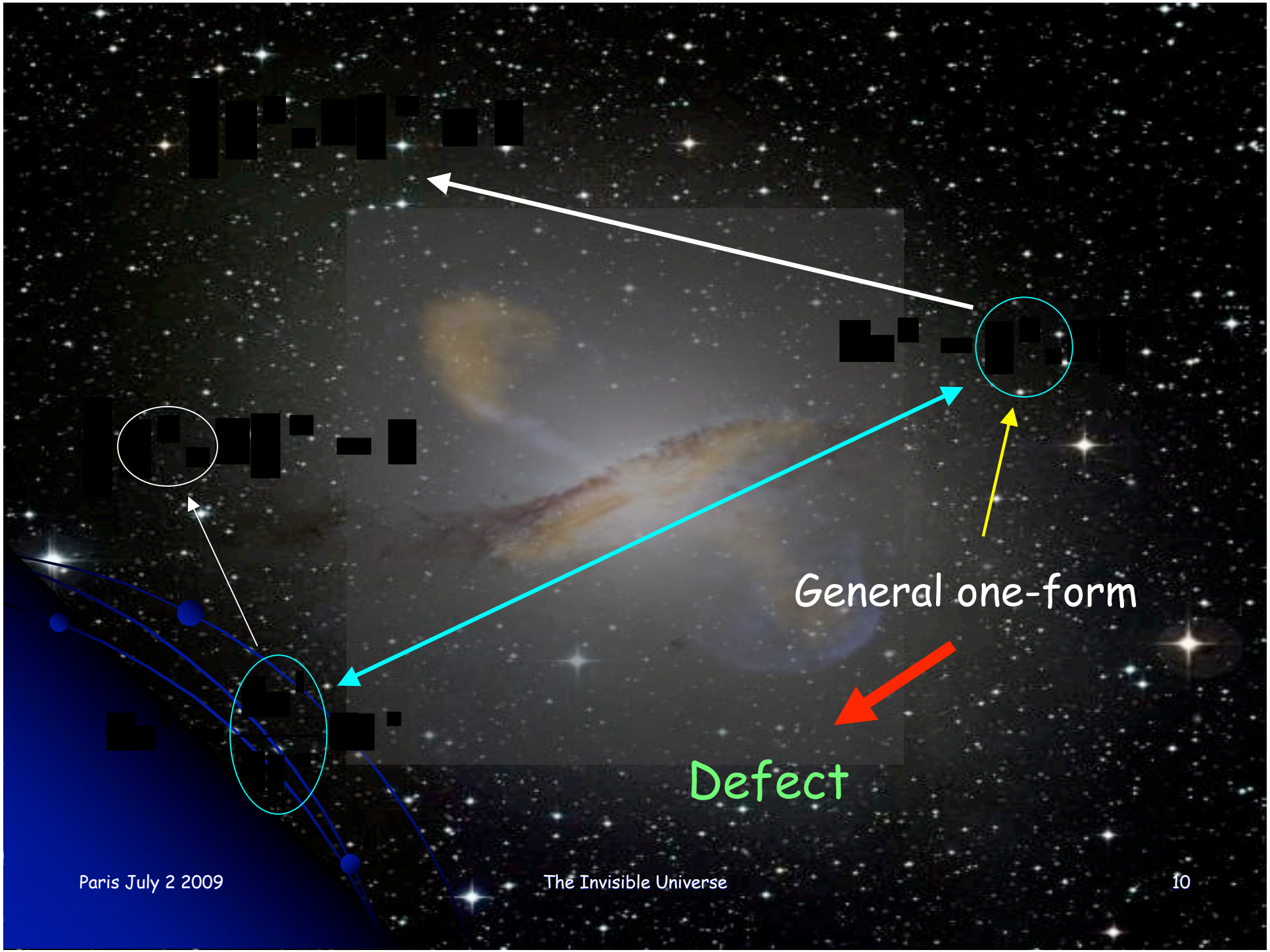
[redacted]

De Saint Venant integrability condition

Pure elasticity

Defects




General one-form
Defect

What consequences for a defect?

- The global symmetry is fixed by the defect
- A spontaneous strain tensor $\xi_{\mu\nu}$ (or displacement vector field u^a) appears
- All this must show up in the Lagrangian of the strained manifold (space-time)

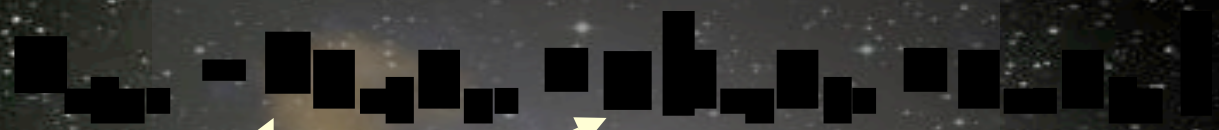
The "elastic" approach

Stress tensor

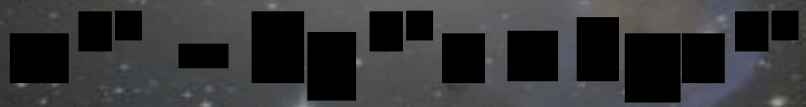
Hooke's law

Elastic modulus tensor

Isotropic medium

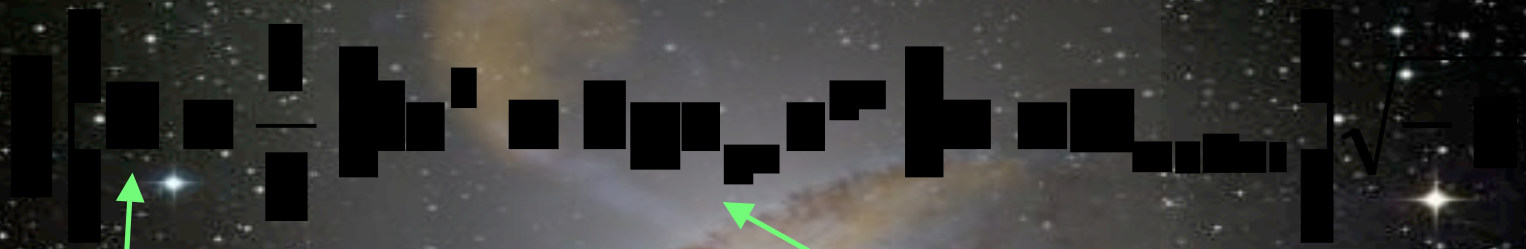


Lamé coefficients



Lorentz signature notation

Correspondence with the usual way of thinking

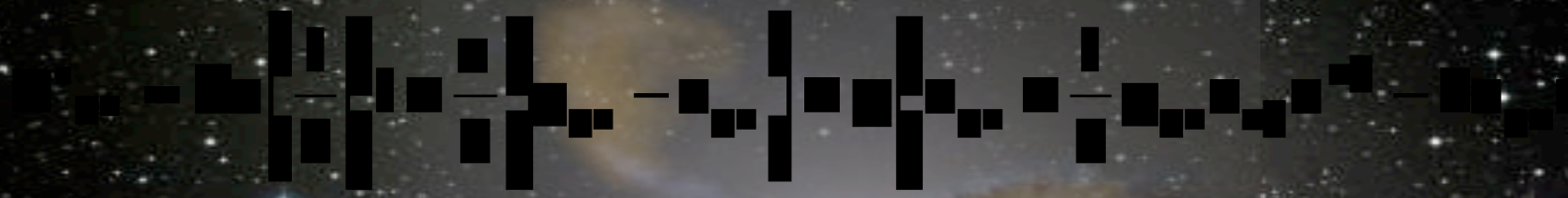


"Kinetic" term

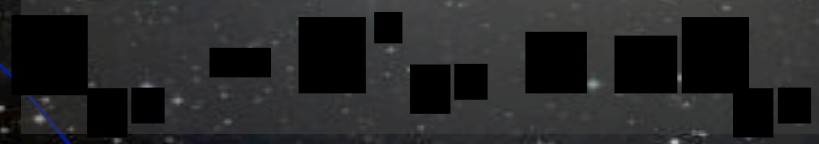
Potential term

Geometry

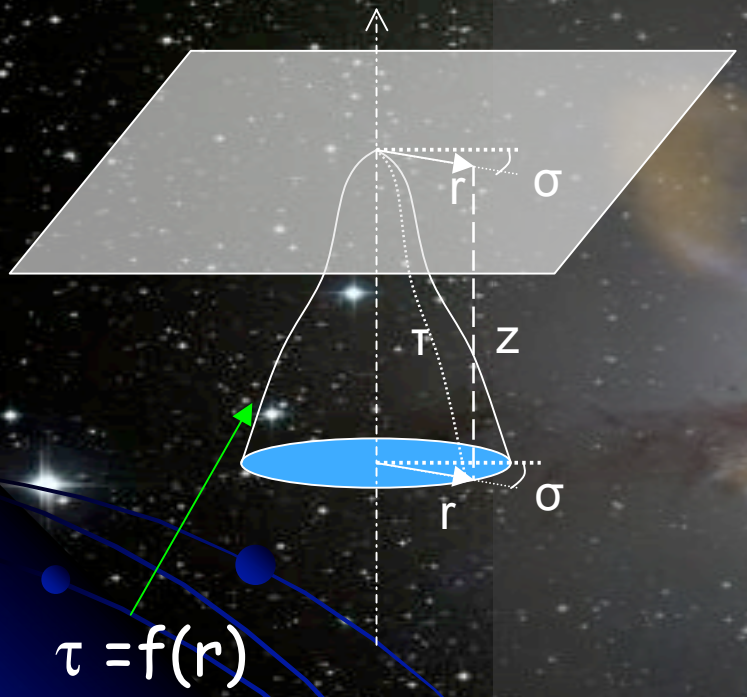
Elastic energy/momentum tensor



Generalized Einstein equations



Robertson-Walker symmetry, closed space: the strain



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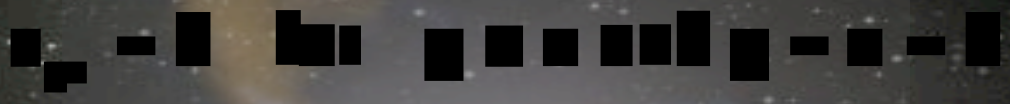
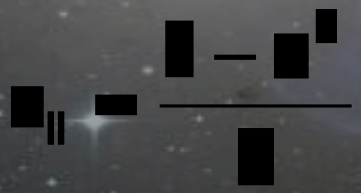
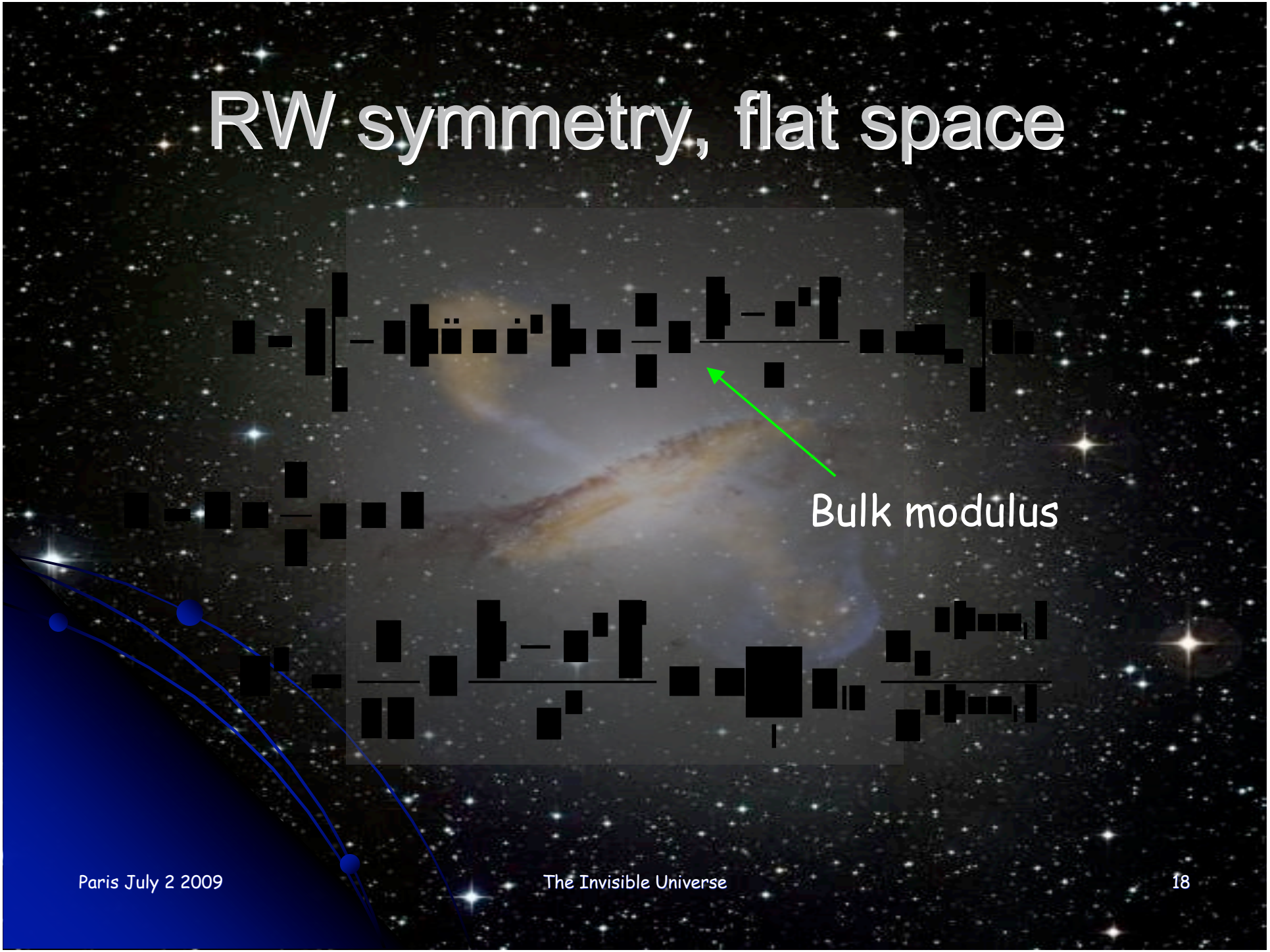
RW, flat space





RW symmetry, flat space



The distance modulus of bright objects

$$m - M = 5 \log \frac{H_0 d}{c} - 5$$

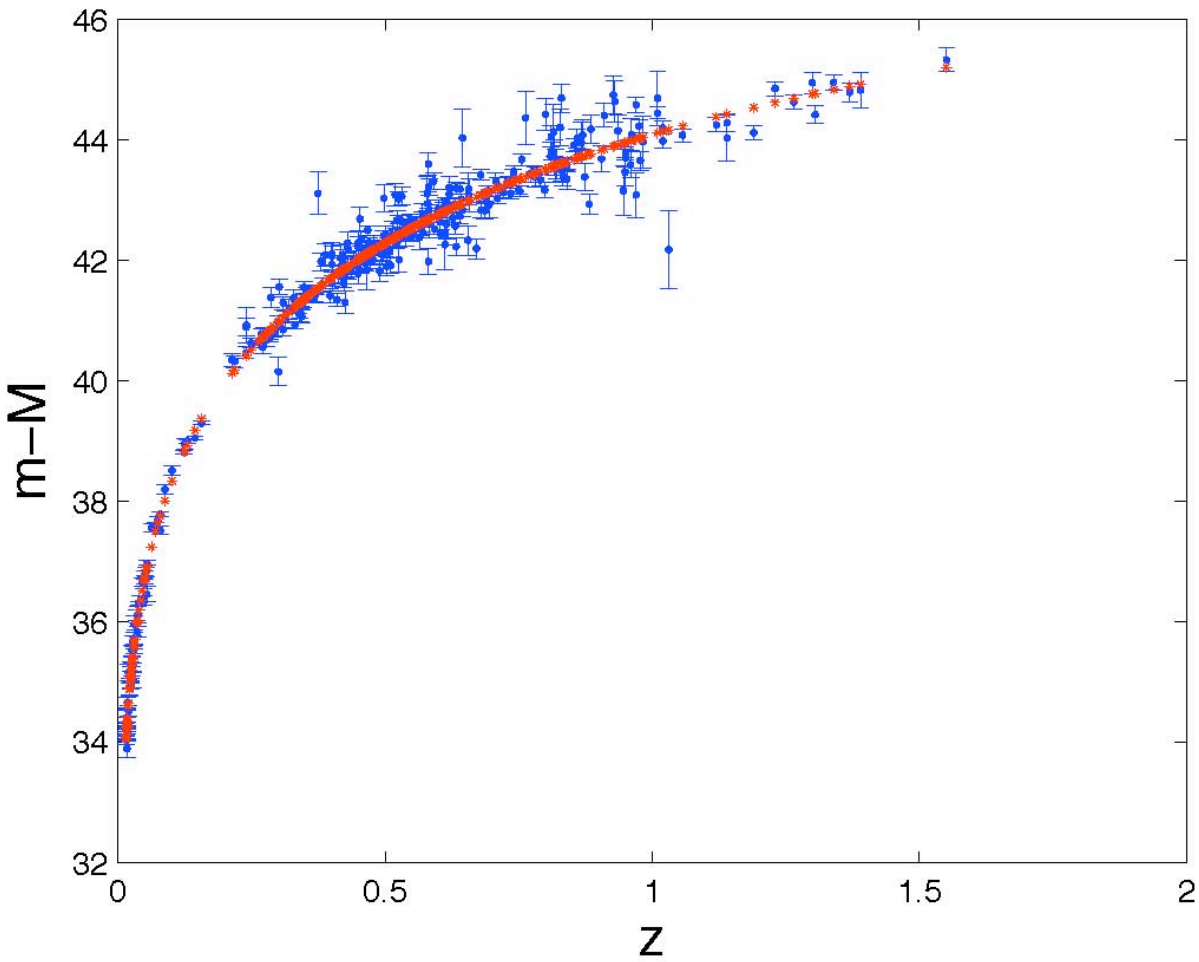
Observed magnitude

Absolute magnitude

Hubble parameter

Distances in Mpc

Fitting the data (307 SnIa)



Reduced χ^2 of the fits (2 parameters)

CD $\chi^2 = 1.017$

ΛCDM $\chi^2 = 1.019$

$B = (3 \pm 2) \times 10^{-7}\ \mathrm{Mpc}^{-2} = (3 \pm 2) \times 10^{-52}\ \mathrm{m}^{-2}$

Conclusion

The CD theory is a theory of space-time preserving all general features of GR.

CD introduces the idea of a global symmetry fixing defect.

Local effects coincide with GR effects

The nature of space-time shows up only at the cosmic scale, where CD performs at least as well as other theories, however providing a compact and consistent picture

The weak field approximation of the theory and the corresponding gravitational waves will be presented tomorrow by Ninfa Radicella

Space time and the ether

…. according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether. ……. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. ……

Albert Einstein, Leiden, 192

A. Tartaglia, N. Radicella, Phys. Rev. D, 76, 083501 (2007)

A. Tartaglia, M. Capone, Int. Jour. Mod. Phys. D, **17, 275-**299 (2008)

A. Tartaglia, M. Capone, V. Cardone, N. Radicella, Int. Jour. Mod. Phys. D, **18**, n. 3, 1-12 (2009)

A. Tartaglia, *Geometry, Integrability and Quantization X.*, Varna, Bulgaria, 6-11 June 2008, Publisher SOFIA: Avangard Prima, p. 248-264, 2009

A. Tartaglia, N. Radicella, arXiv:0903.4096