Title: Dynamics of the cosmological constant and Newtonâ€™s constant

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Abstract:

The cosmological constant as a dynamical variable

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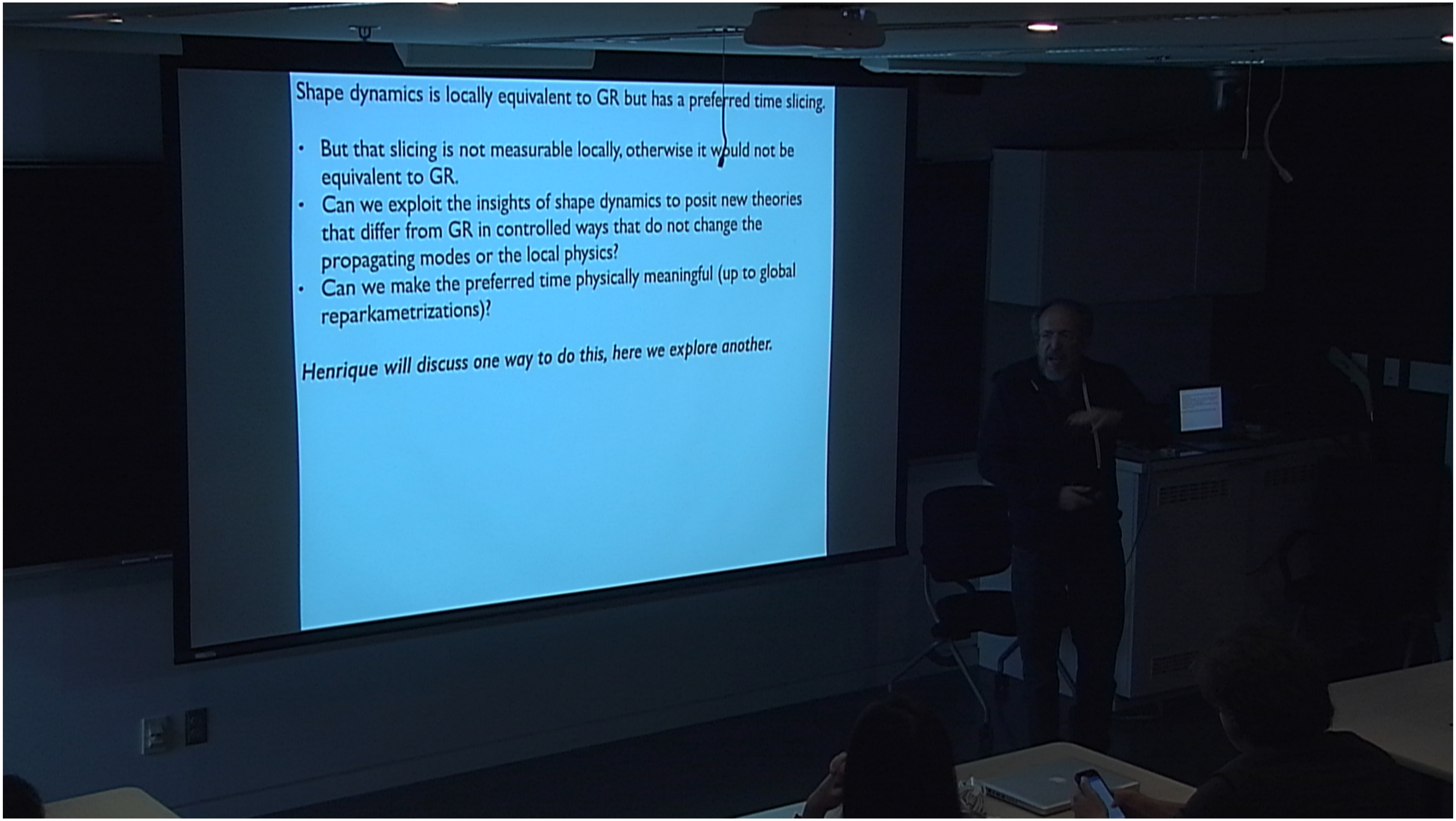
WORK IN PROGRESS

Thanks to Marina Cortes, Laurent Freidel, Henrique, Niayesh,….


Shape dynamics is locally equivalent to GR but has a preferred time slicing.
But that slicing is not measurable locally, otherwise it would not be equivalent to GR.
Can we exploit the insights of shape dynamics to posit new theories that differ from GR in controlled ways that do not change the propagating modes or the local physics?
Can we make the preferred time physically meaningful (up to global reparkametrizations)?
Henrique will discuss one way to do this, here we explore another.

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What can we do with a preferred time?

- Quantization.
- Have laws and/or their parameters evolve, to explain fine tuning issues, hierarchies etc.
- Explain the arrows of time by positing a fundamental arrow of time.
- Address cosmological issues re modified gravity, ie dark energy, dark matter, specialness of initial conditions, inflation or whatever replaces it.

Shape dynamics has two complementary scalar constraints, based on the ADM phase space: $\{g_{ab}(x), \pi^{cd}(y)\} = \delta(x,y)\delta^{(ab)}_{(cd)}$

$$\mathcal{H}^{GR} = \sqrt{g}(R - 2\Lambda) + \frac{1}{\sqrt{g}}(\pi^{ab}\pi_{ab} - \frac{1}{2}\pi^2) = 0$$

$$\mathcal{S} = \pi - \sqrt{g} < \pi >= 0$$

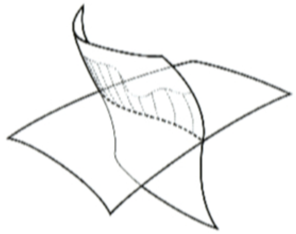
$$\pi = g_{ab}\pi^{ab}$$

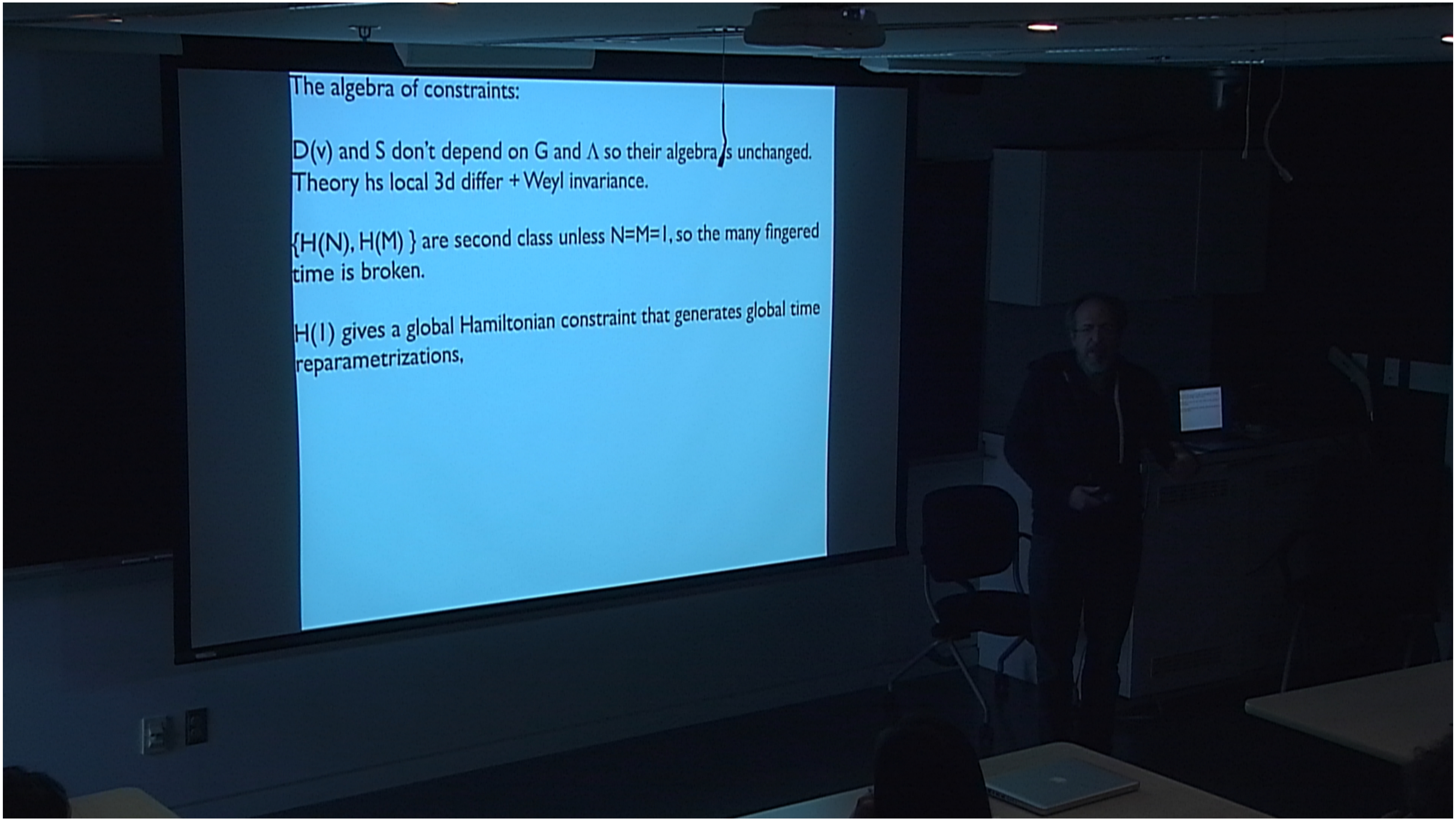
$$< \pi >= \frac{\int_\Sigma \pi}{\int_\Sigma \sqrt{g}}$$

- They generate refoliations and local conformal transformations, respectively.
- Each is first class with the spatial diffeo constraint, H_a.

$$H_a(x) = \nabla_b \pi^b{}_a(x) = 0$$

- They gauge fix each other.
- S implements CMC gauge and generates volume preserving conformal transformations.




The algebra of constraints:
D(v) and S don't depend on G and Λ so their algebra is unchanged.
Theory hs local 3d differ + Weyl invariance.
{H(N), H(M) } are second class unless N=M=1, so the many fingered time is broken.
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FRW cosmology:

$$S = \int dt \left[\Lambda \frac{\dot{G}}{G_0} \mu + v_0 \left(\pi \dot{a} - N\mathcal{C} \right) \right]$$

$$\mathcal{C} = \frac{G_0}{2a} \pi^2 - a^3 U(a)$$

$$U = \frac{\Lambda}{6G_0} - \frac{k}{2G_0 a^2} + \frac{4\pi G \rho_0}{3G_0 a^3}$$

$$g_{ab} = a^2(t) q^0_{ab}$$

$$\tilde{\pi}^{ab} = \frac{1}{3a} \sqrt{q^0} q_0^{ab} \pi(t)$$

$$v_0 = \int_\Sigma \sqrt{q^0}$$

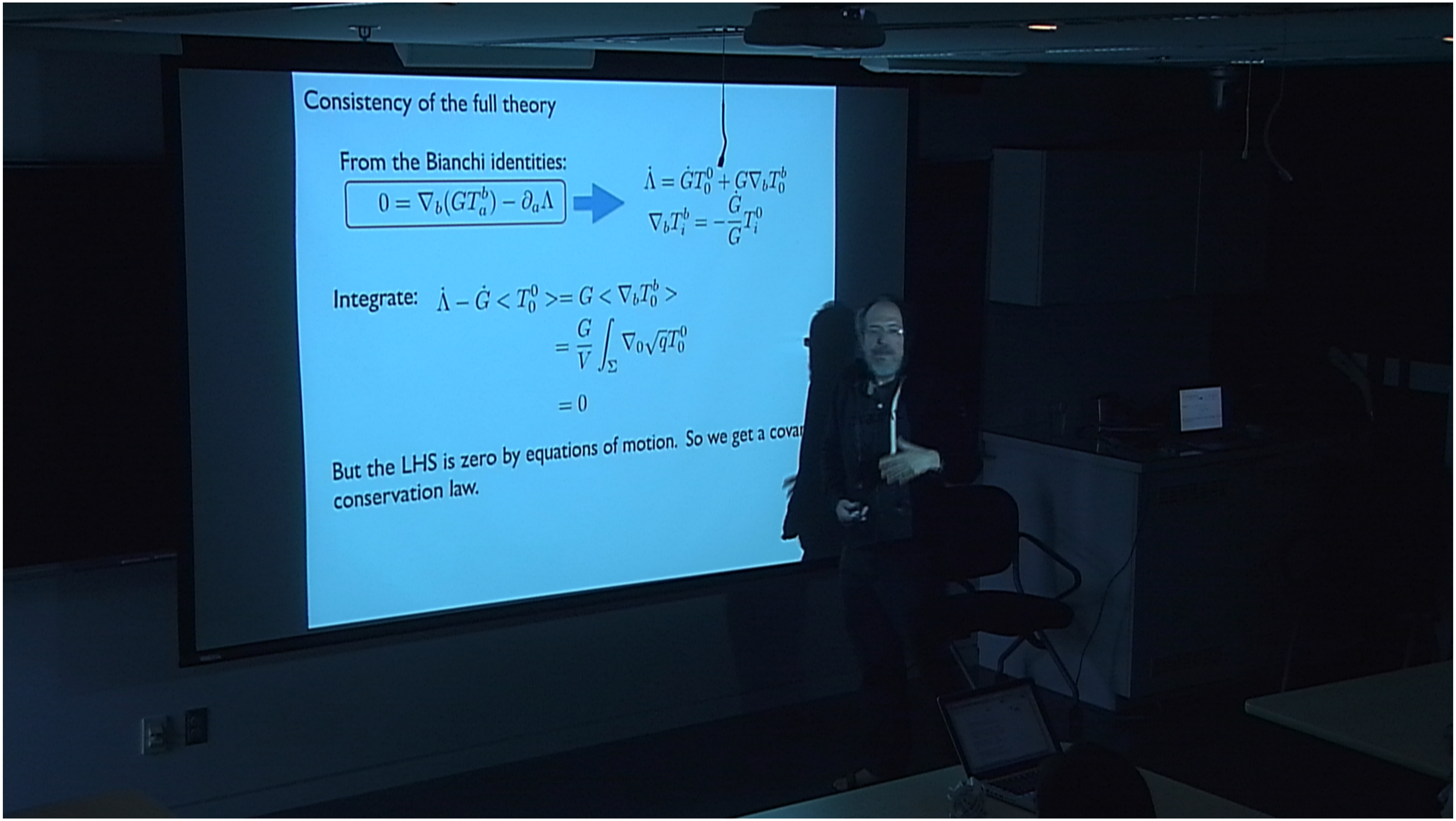
$$V = v_0 a^3$$

$$H = \frac{\dot{a}}{a}$$

Equations of motion:

$$\dot{G} = -\frac{NV}{6\mu} \qquad \pi = \frac{a^2}{NG_0} H$$

$$\dot{\Lambda} = \frac{4\pi}{3} \frac{N v_0 \rho_0}{\mu} \qquad \frac{1}{N} \dot{\pi} = \frac{G_0 \pi^2}{2a^2} + 3a^2 V - a^3 V'$$


Consistency of the full theory
From the Bianchi identities:
$0 = \nabla_b(GT^b_a) - \partial_a\Lambda$
$\dot\Lambda = \dot G T^0_0 + G\nabla_b T^b_0$
$\nabla_b T^b_i = -\frac{\dot G}{G} T^0_i$
Integrate: $\dot\Lambda - \dot G < T^0_0 >= G < \nabla_b T^b_0 >$
$= \frac{G}{V}\int_\Sigma \nabla_0\sqrt{q}T^0_0$
$= 0$
But the LHS is zero by equations of motion. So we get a covar
conservation law.

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- We can make use of that preferred time slicing to explore modified gravity theories that differ from GR and are non-local and dependent on the preferred slicing or time in ways that don't change the local physical degrees of freedom, or Newtonian or linearized limits.
- One way to do this makes G and Λ into a conjugate pair of global dynamical variables. This implies relations between them which are testable.
- Henrique will describe another way to do this.
- Both modified gravity theories break time reversal invariance, (defined because of the preferred time slicing). This gives a second way SD can offer new ideas about the arrows of time problem (complementary to Julian, Tim and Flavio's.)

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