Title: Shape Dynamics - 2

Date: Jul 22, 2013 04:40 PM

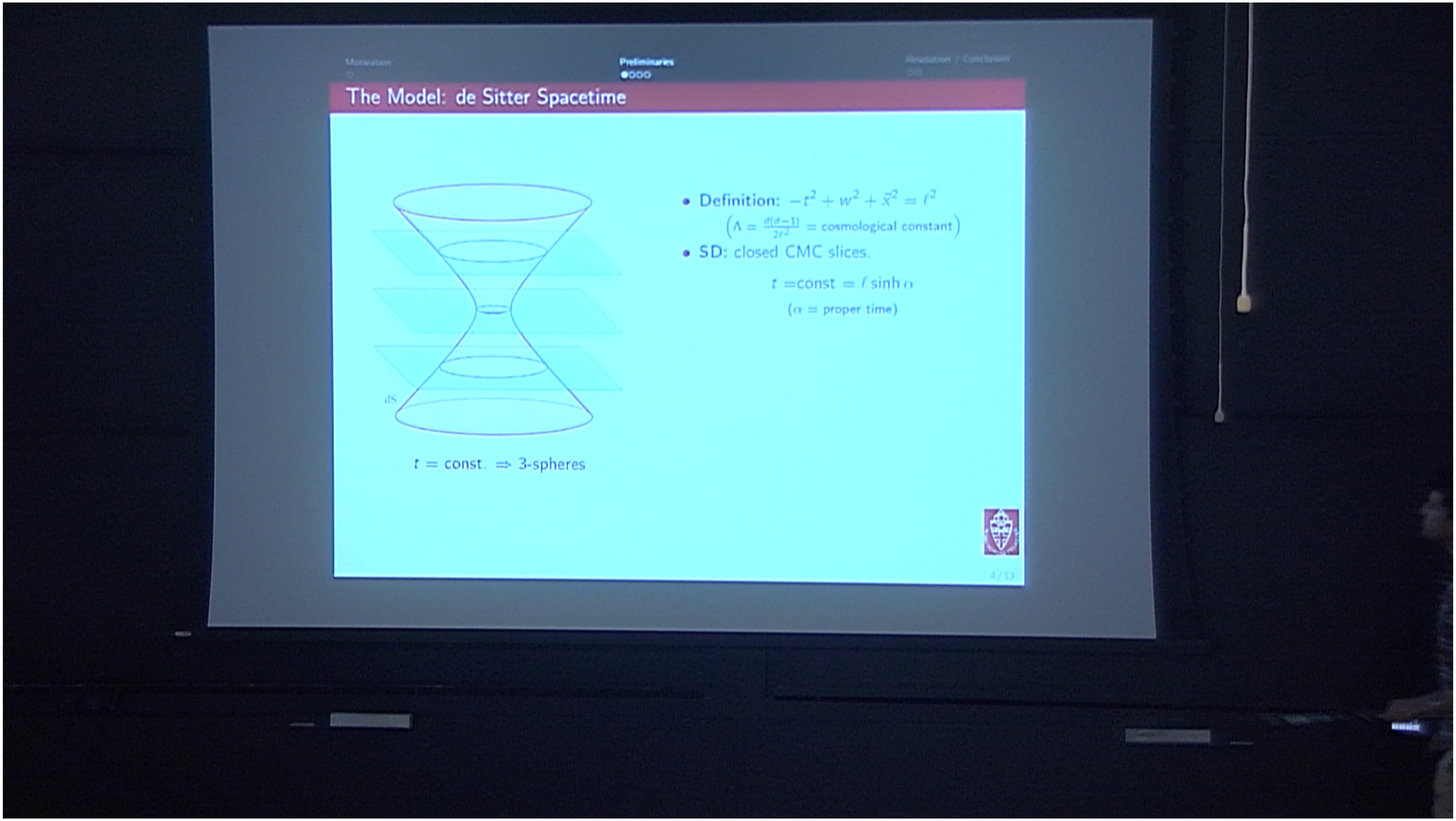
URL: http://pirsa.org/13070044

Abstract:

Motivation

Using a toy model of cosmology

- Give explicit scheme for global symmetry trading in SD.
- Study "shape observers" in de Sitter (dS) and clock synchronization.
- Compute explicit holographic model.


Motivation
Preliminaries
Resolution / Conclusion
The Model: de Sitter Spacetime
dS
t = const. ⇒ 3-spheres
• Definition: $-t^2 + w^2 + \vec{x}^2 = \ell^2$
$\left(\Lambda = \frac{d(d-1)}{2\ell^2} = \text{cosmological constant}\right)$
• SD: closed CMC slices.
t =const $= \ell \sinh \alpha$
(α = proper time)
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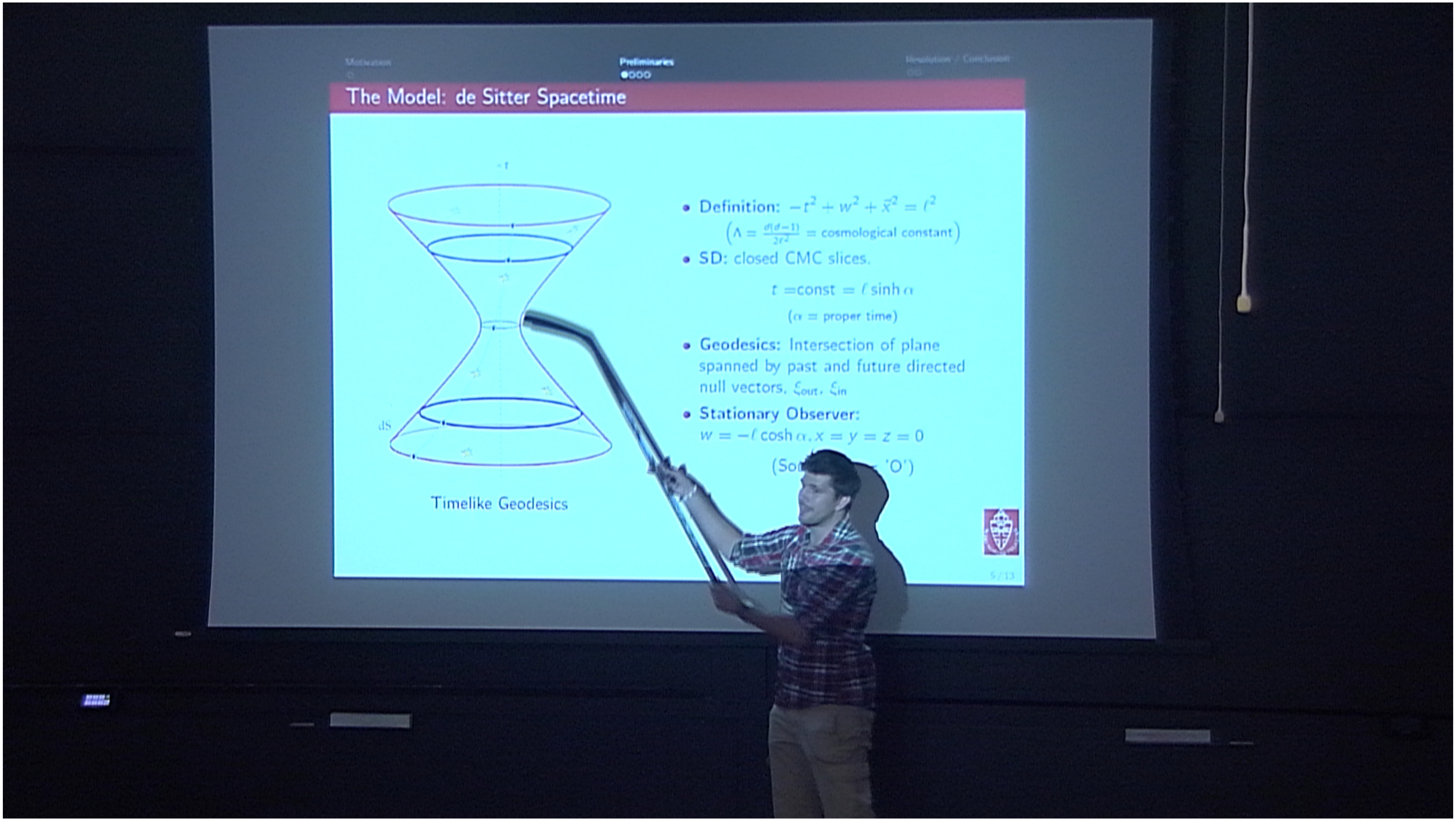
Preliminaries
The Model: de Sitter Spacetime
Timelike Geodesics
Definition: $-t^2 + w^2 + \vec{x}^2 = \ell^2$
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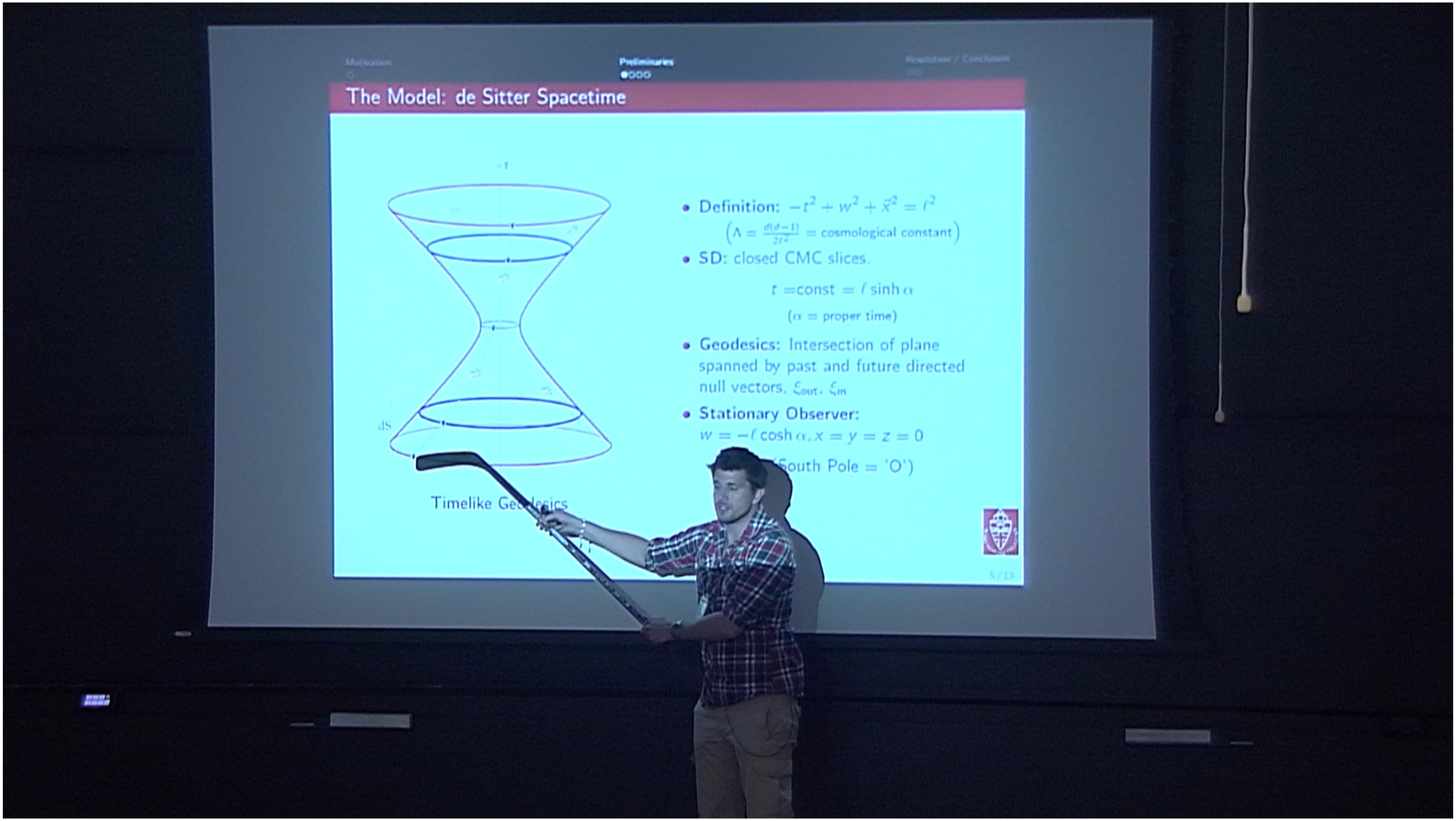
SD: closed CMC slices.
$t = \text{const} = \ell \sinh \alpha$
(α = proper time)
Geodesics: Intersection of plane spanned by past and future directed null vectors, ξ_{out}, ξ_{in}
Stationary Observer:
$w = -\ell \cosh \alpha, x = y = z = 0$
'O')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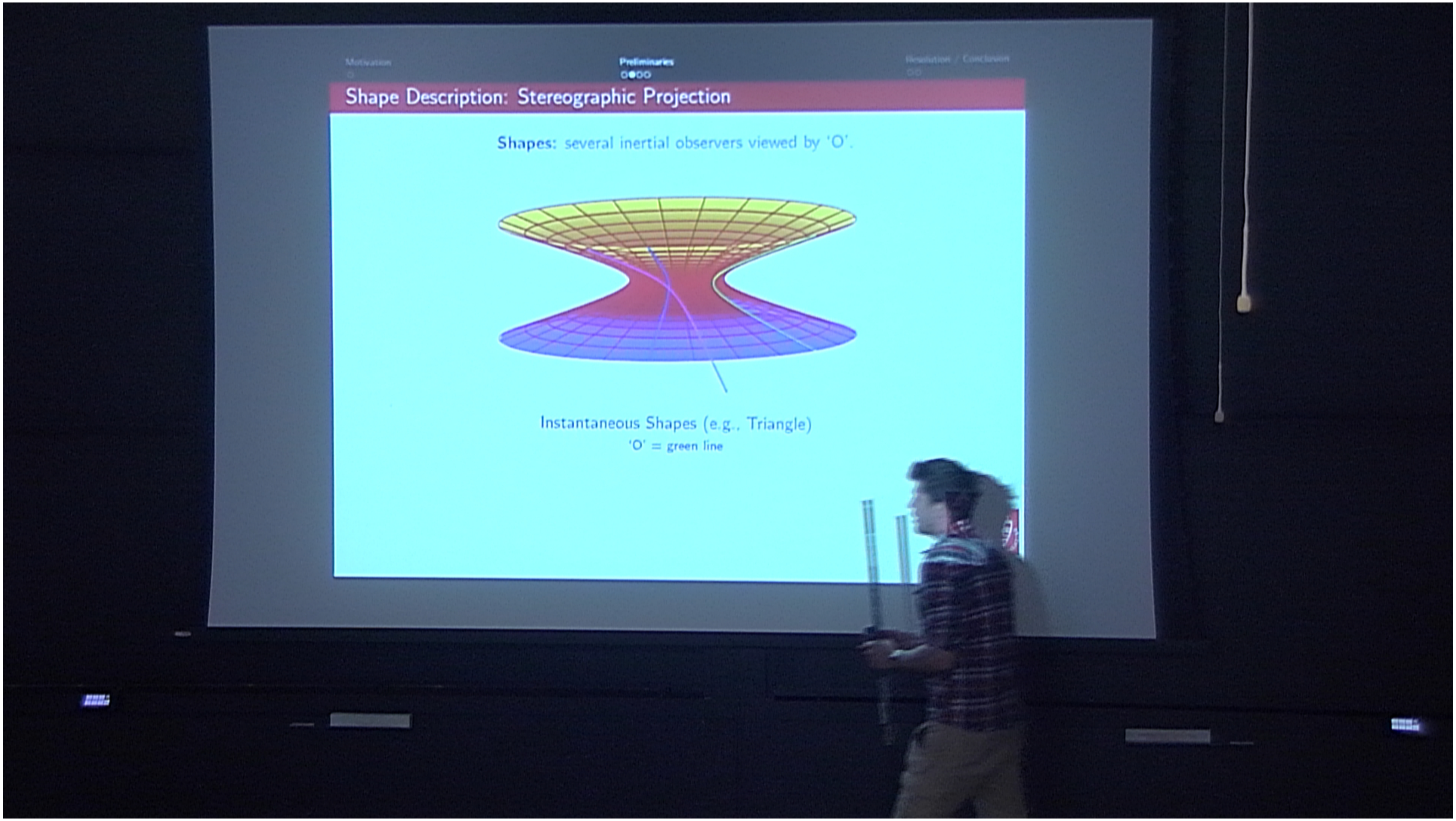
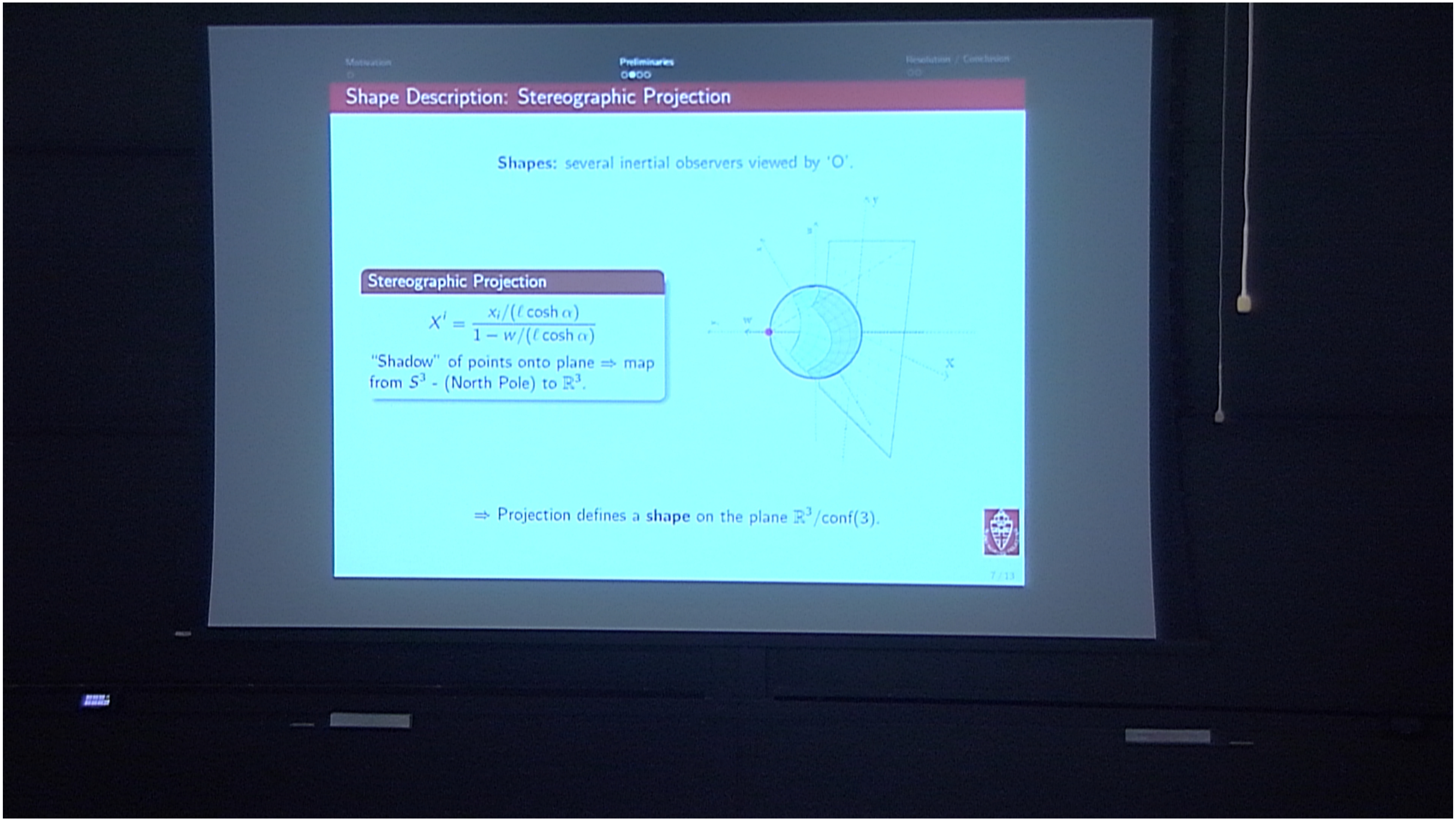
South Pole = 'O')
5 / 13


Preliminaries
Shape Description: Stereographic Projection
Shapes: several inertial observers viewed by 'O'.
Instantaneous Shapes (e.g., Triangle)
'O' = green line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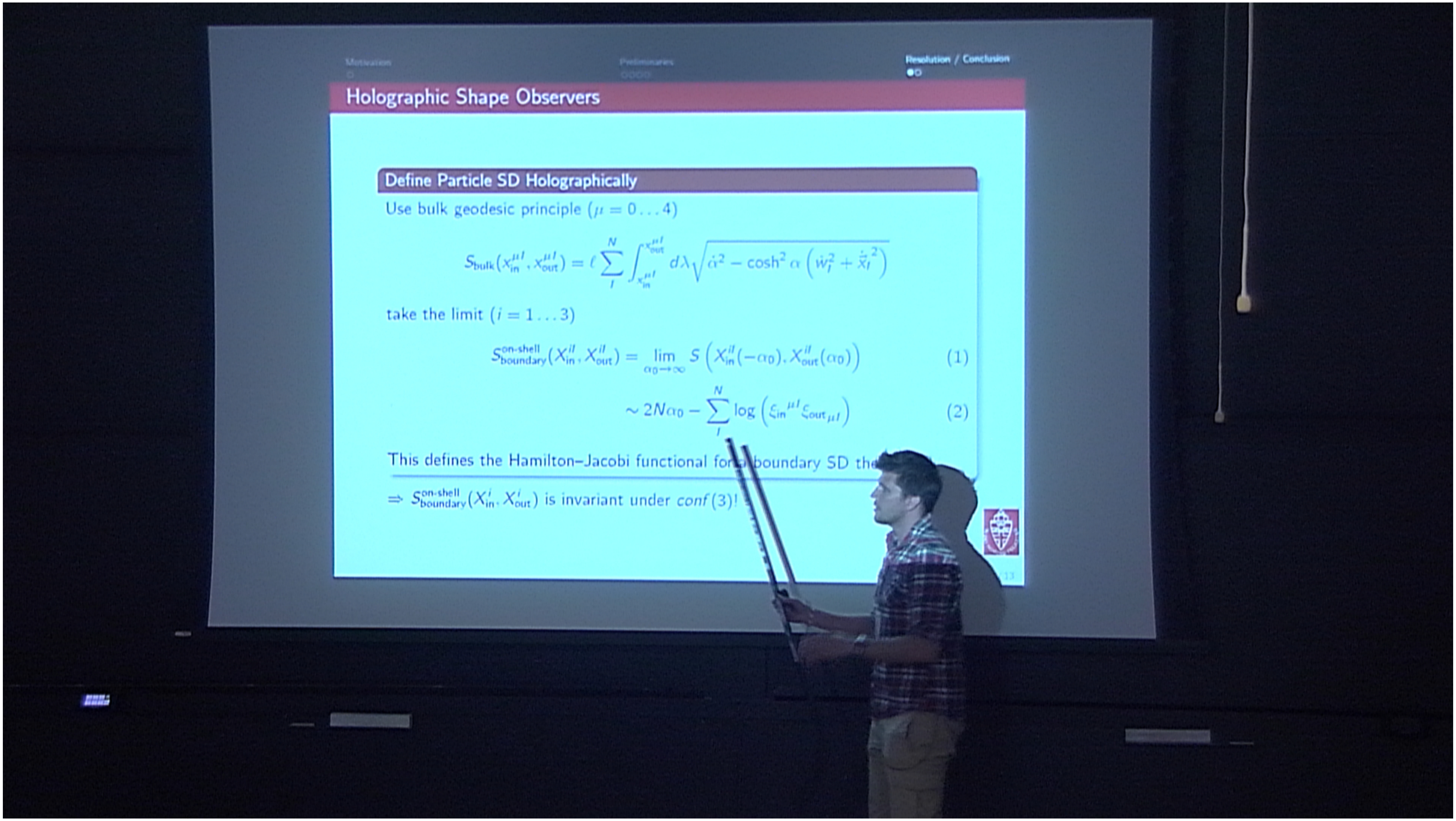
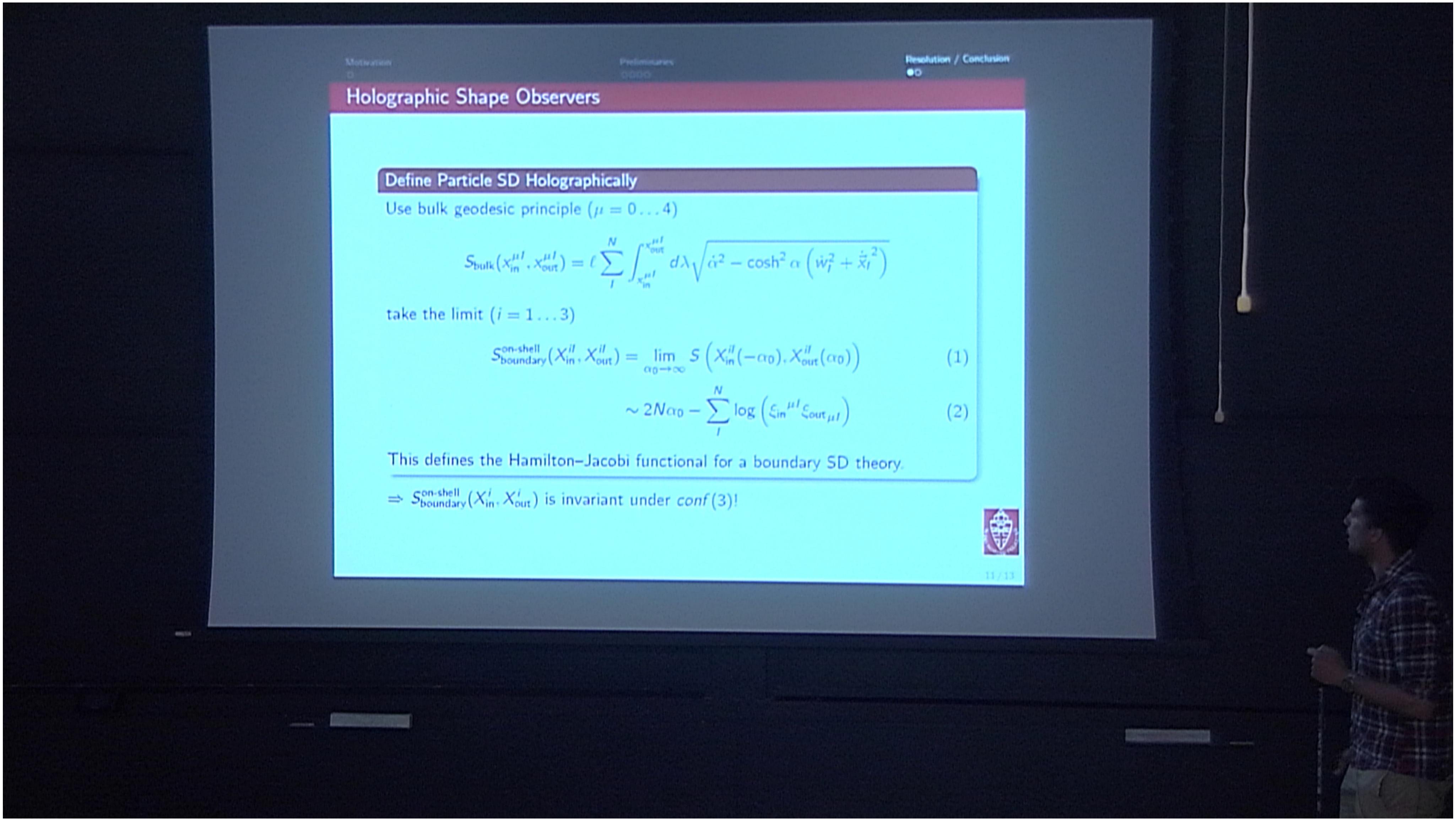
Stereographic Projection
$X^i = \frac{x_i/(\ell \cosh \alpha)}{1 - w/(\ell \cosh \alpha)}$
"Shadow" of points onto plane ⇒ map from S^3 - (North Pole) to $\mathbb{R}^3$.
⇒ Projection defines a shape on the plane $\mathbb{R}^3/\text{conf}(3)$.



Resolution / Conclusion
Holographic Shape Observers
Define Particle SD Holographically
Use bulk geodesic principle ($\mu = 0 \ldots 4$)
$S_{\text{bulk}}(x_{\text{in}}^{\mu I}, x_{\text{out}}^{\mu I}) = \ell \sum_{I}^{N} \int_{x_{\text{in}}^{\mu I}}^{x_{\text{out}}^{\mu I}} d\lambda \sqrt{\dot{\alpha}^2 - \cosh^2\alpha \left(\dot{w}_I^2 + \dot{\vec{x}}_I^{\,2}\right)}$
take the limit ($i = 1 \ldots 3$)
$S_{\text{boundary}}^{\text{on-shell}}(X_{\text{in}}^{iI}, X_{\text{out}}^{iI}) = \lim_{\alpha_0 \to \infty} S\left(X_{\text{in}}^{iI}(-\alpha_0), X_{\text{out}}^{iI}(\alpha_0)\right)$ (1)
$\sim 2N\alpha_0 - \sum_{I}^{N} \log\left(\xi_{\text{in}}{}^{\mu I} \xi_{\text{out}}{}_{\mu I}\right)$ (2)
This defines the Hamilton–Jacobi functional fo boundary SD th
$\Rightarrow S_{\text{boundary}}^{\text{on-shell}}(X_{\text{in}}^{i}, X_{\text{out}}^{i})$ is invariant under $conf(3)$!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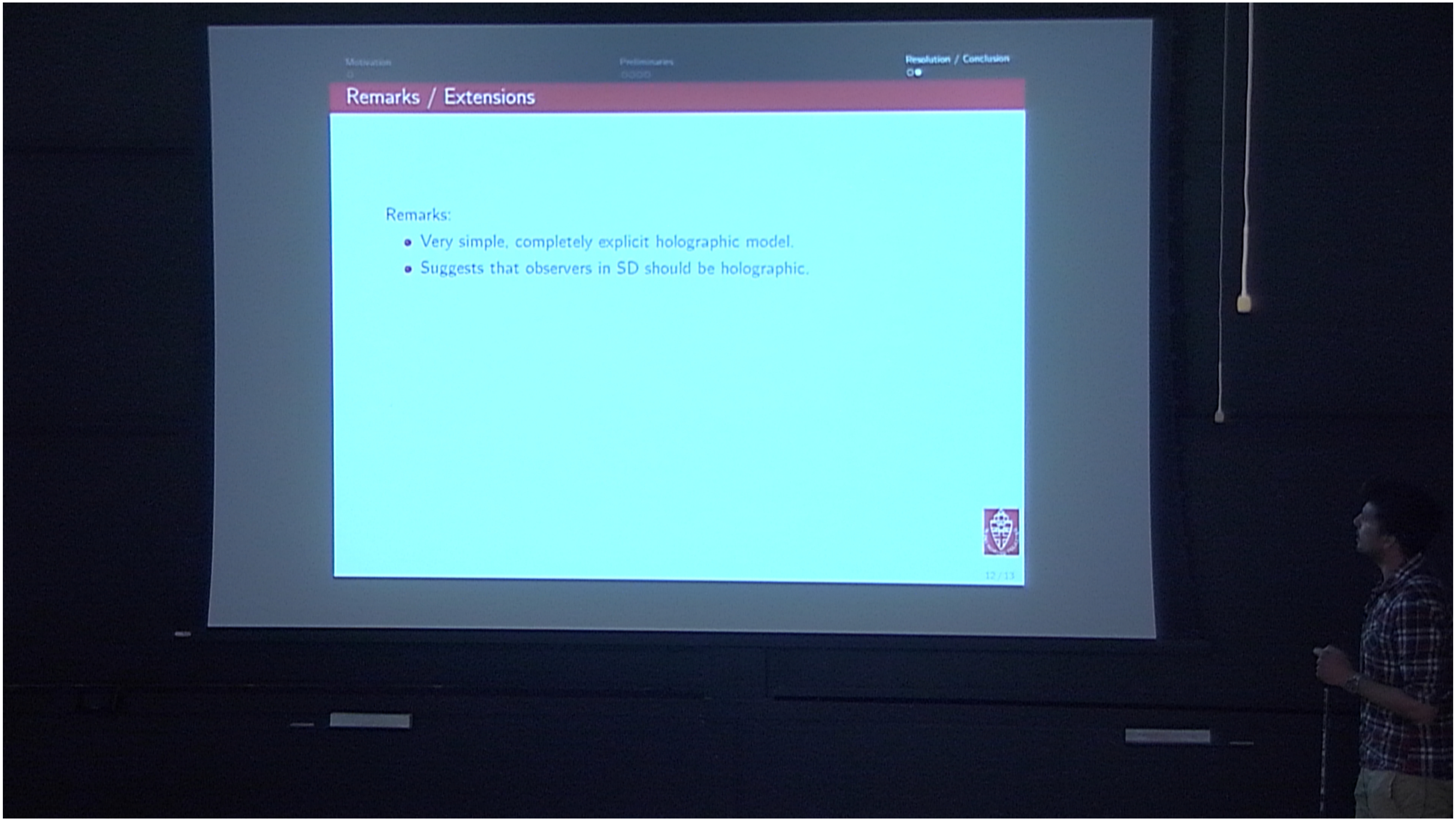
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Remarks / Extensions
Remarks:
• Very simple, completely explicit holographic model.
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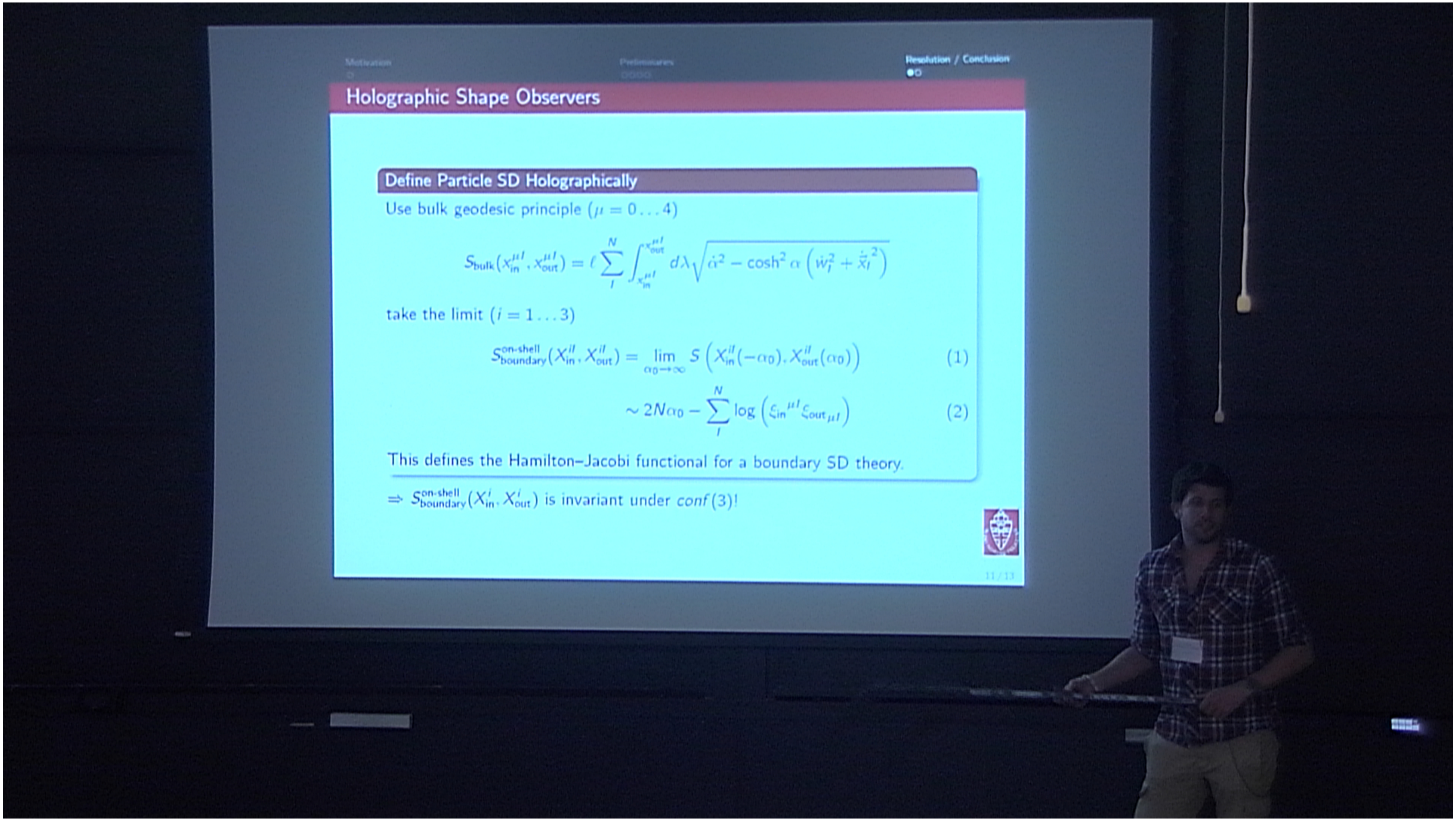
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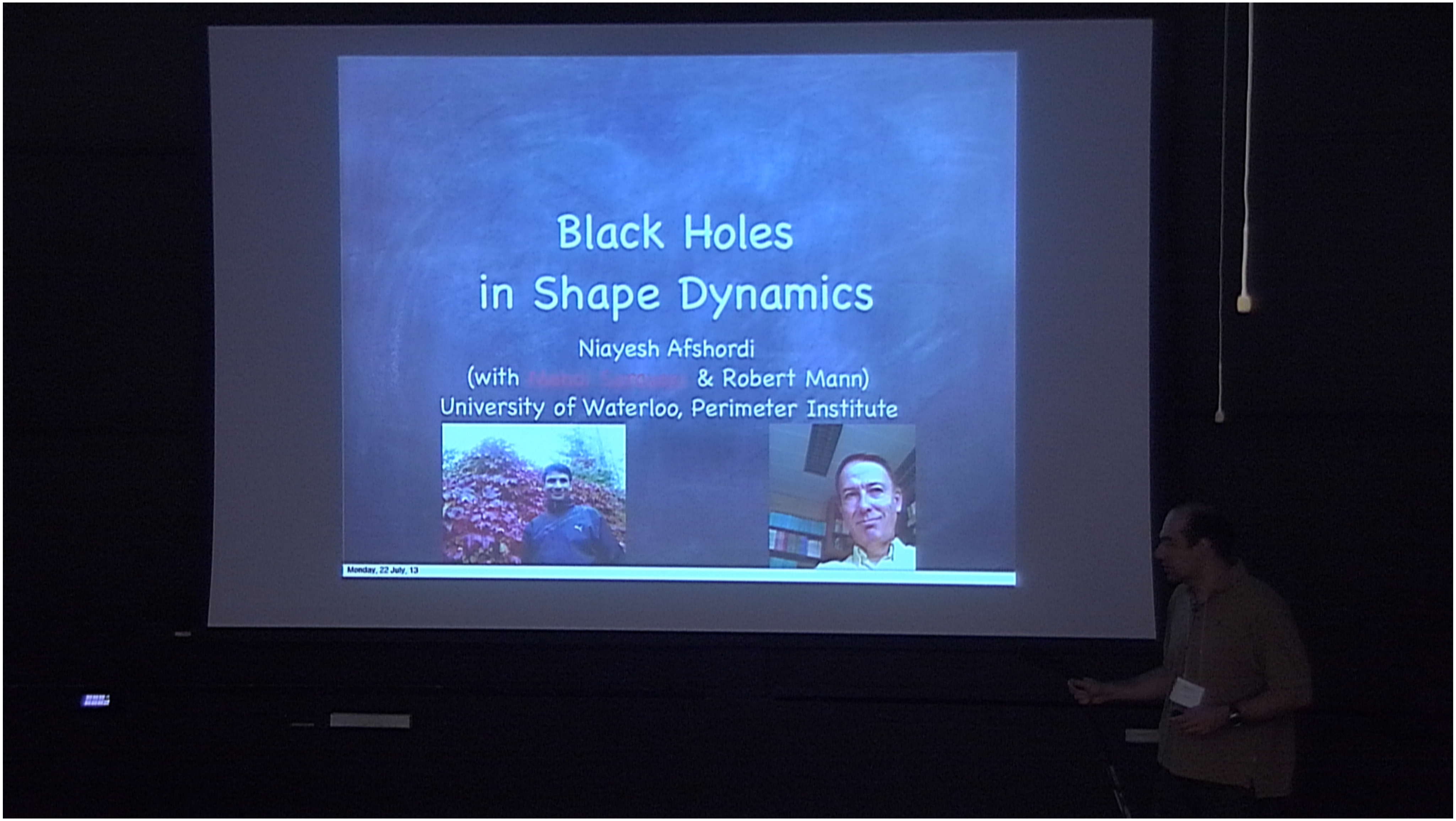
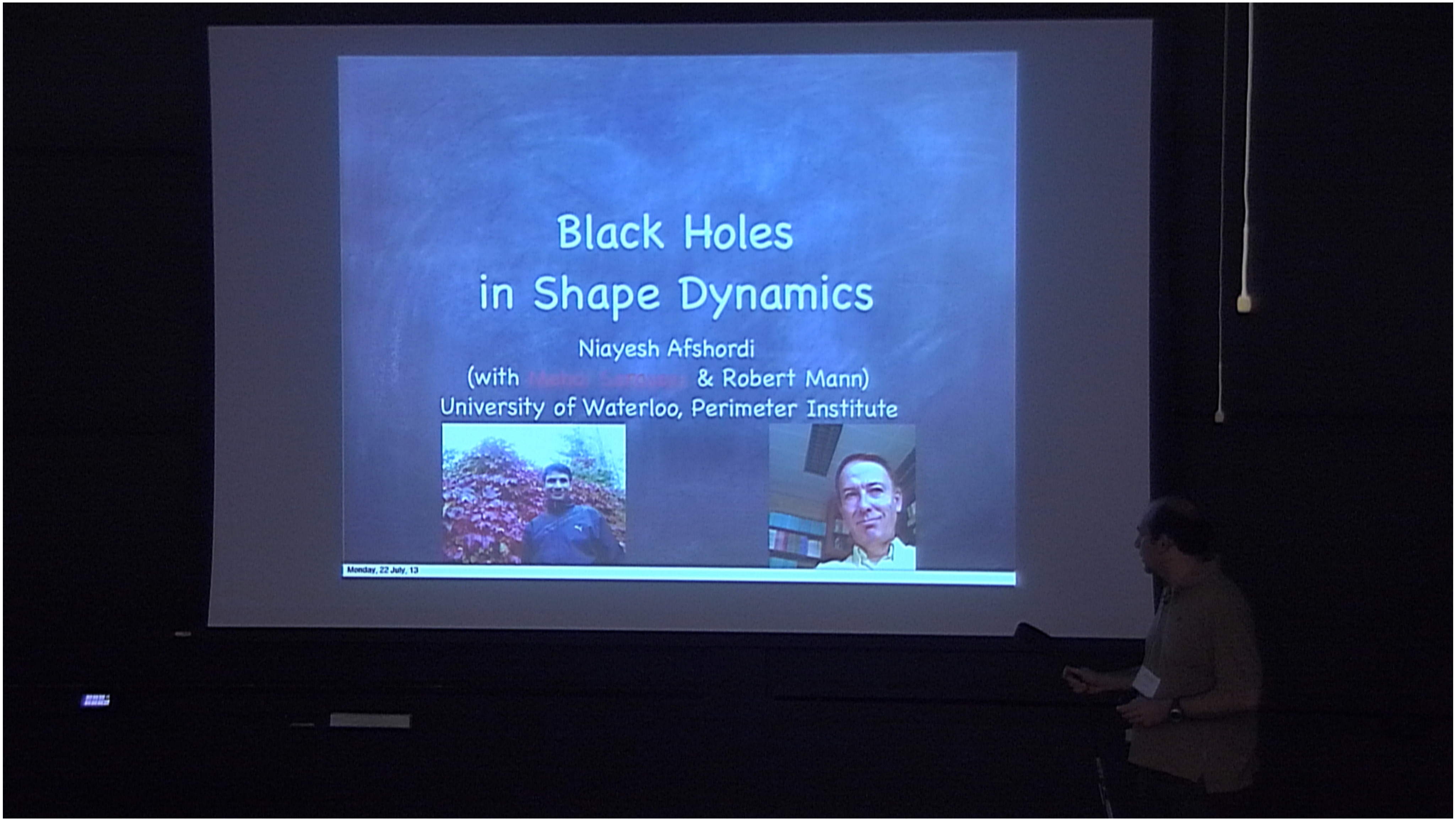

Black Holes
in Shape Dynamics
Niayesh Afshordi
(with & Robert Mann)
University of Waterloo, Perimeter Institute
Monday, 22 July, 13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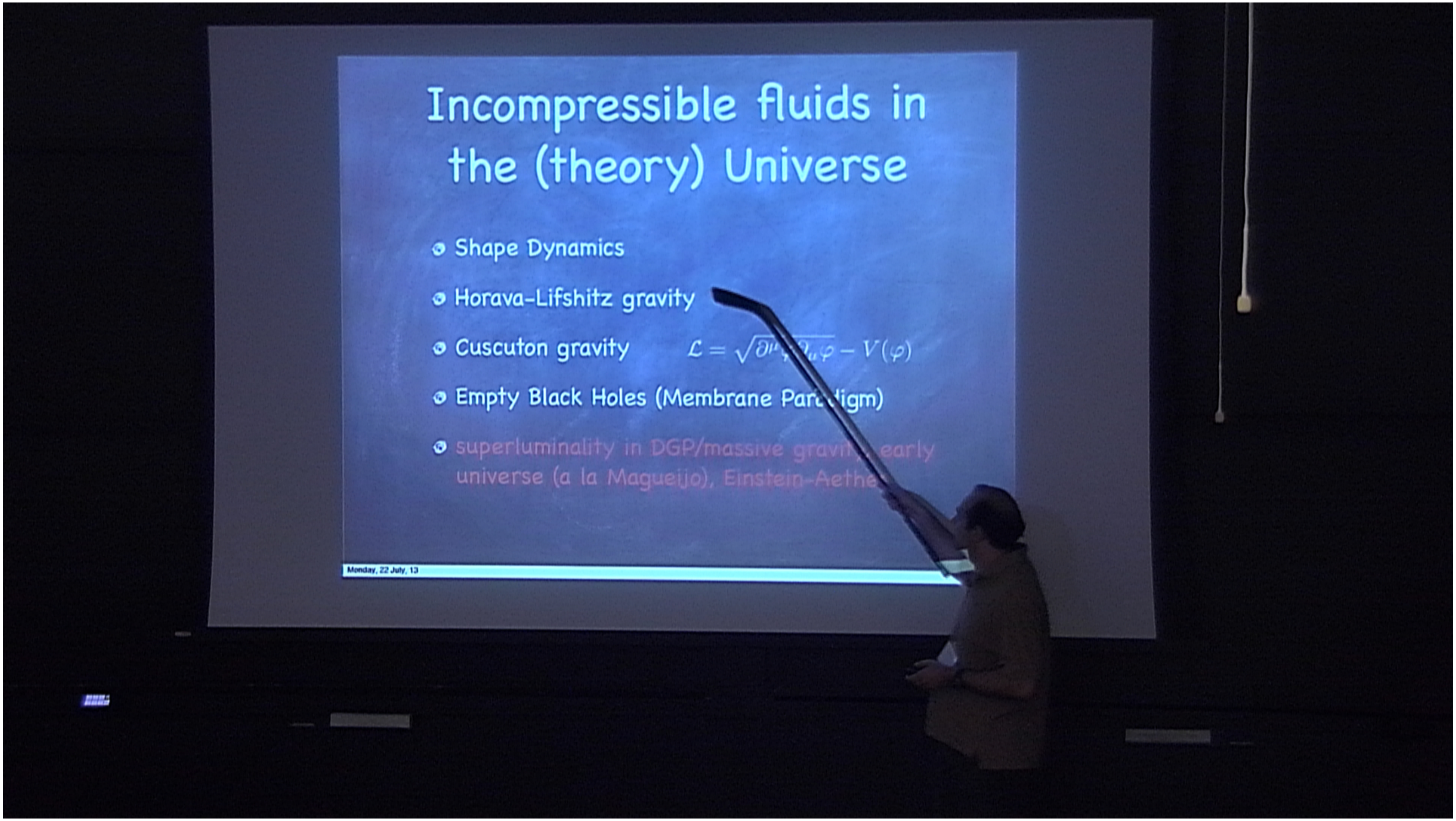
Incompressible fluids in the (theory) Universe
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Horava-Lifshitz gravity
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Empty Black Holes (Membrane Par
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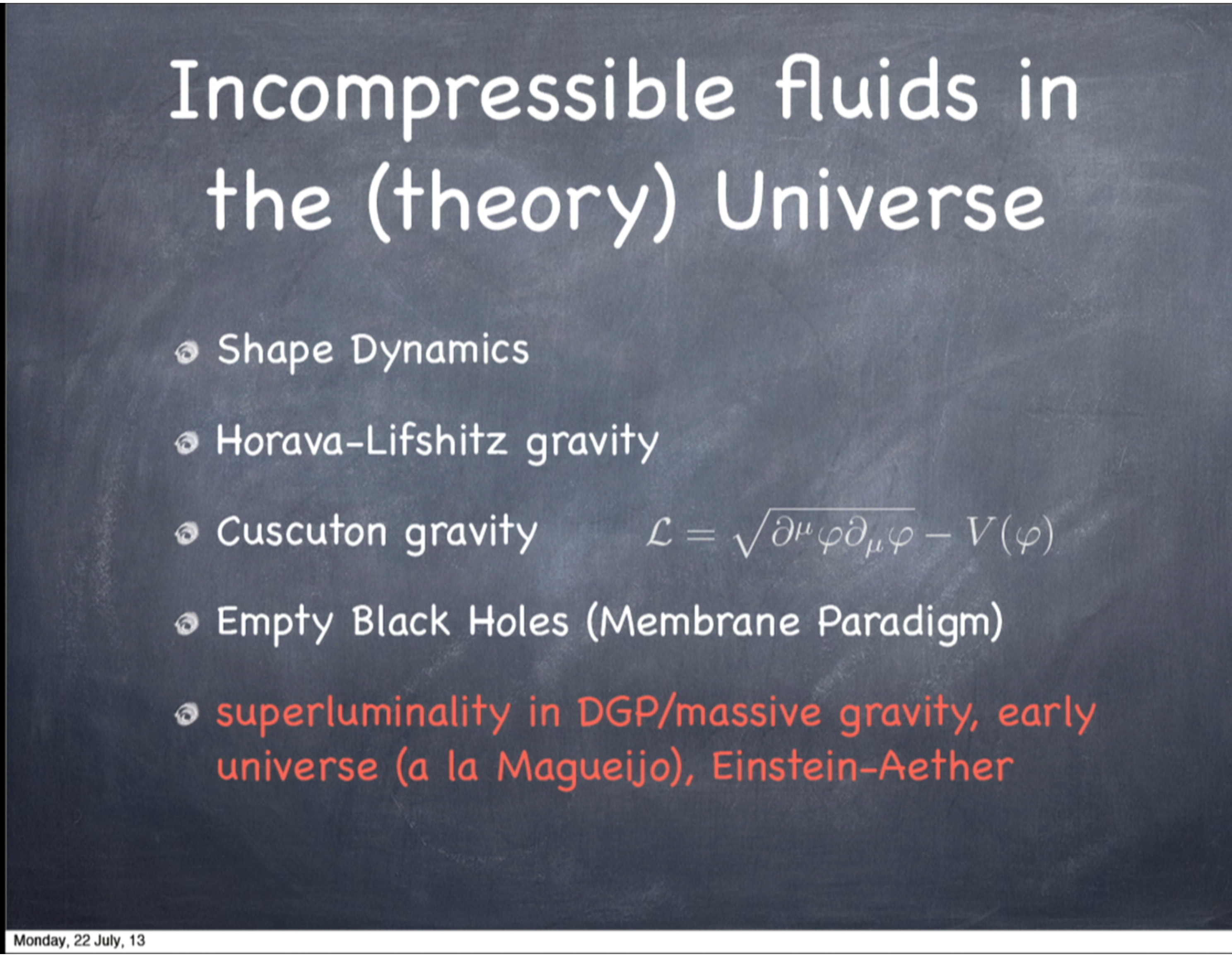
Incompressible fluids in the (theory) Universe
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$\mathcal{L} = \sqrt{\partial^\mu \varphi \partial_\mu \varphi} - V(\varphi)$
Empty Black Holes (Membrane Paradigm)
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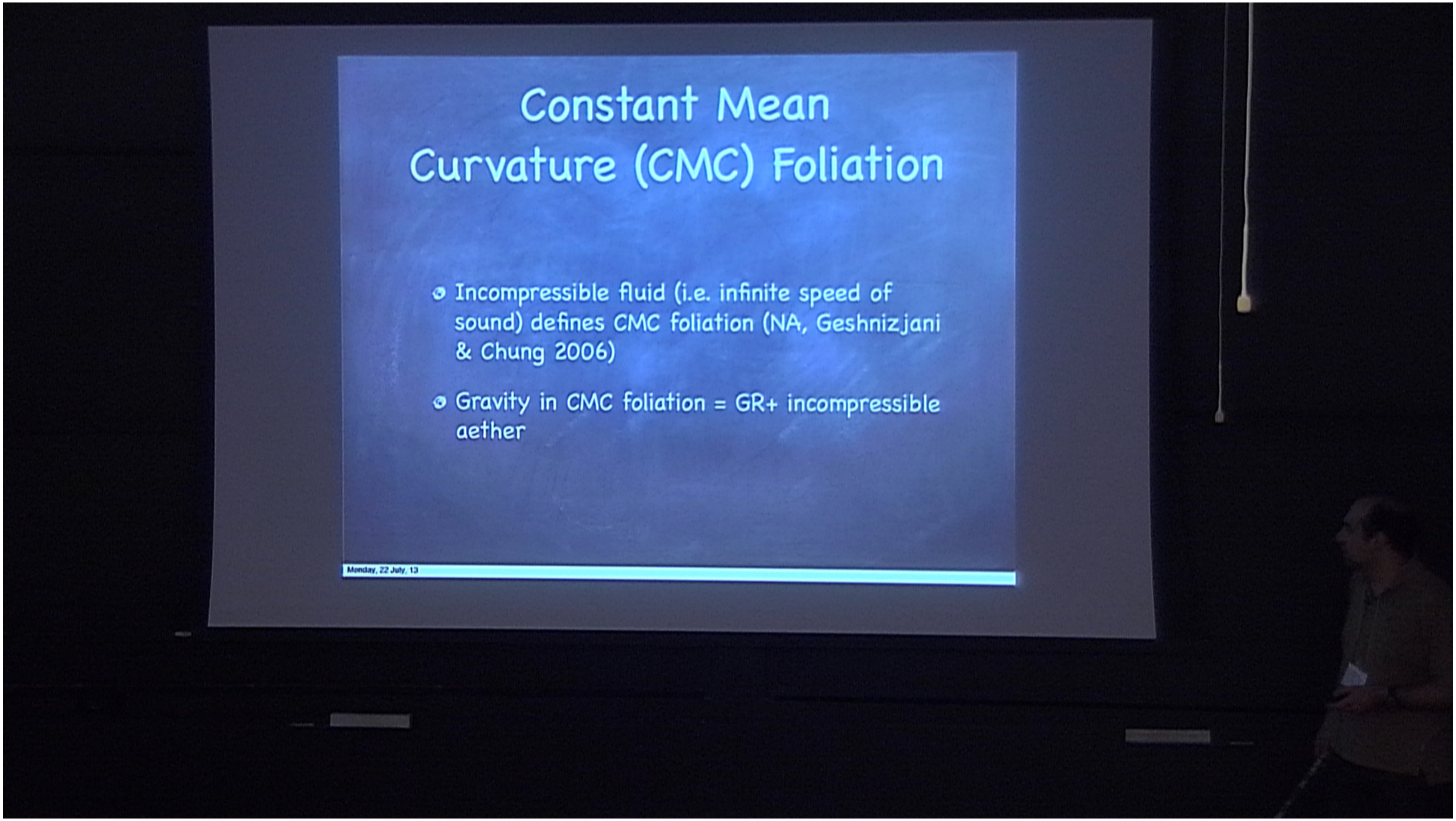
Constant Mean
Curvature (CMC) Foliation
Incompressible fluid (i.e. infinite speed of sound) defines CMC foliation (NA, Geshnizjani & Chung 2006)
Gravity in CMC foliation = GR+ incompressible aether
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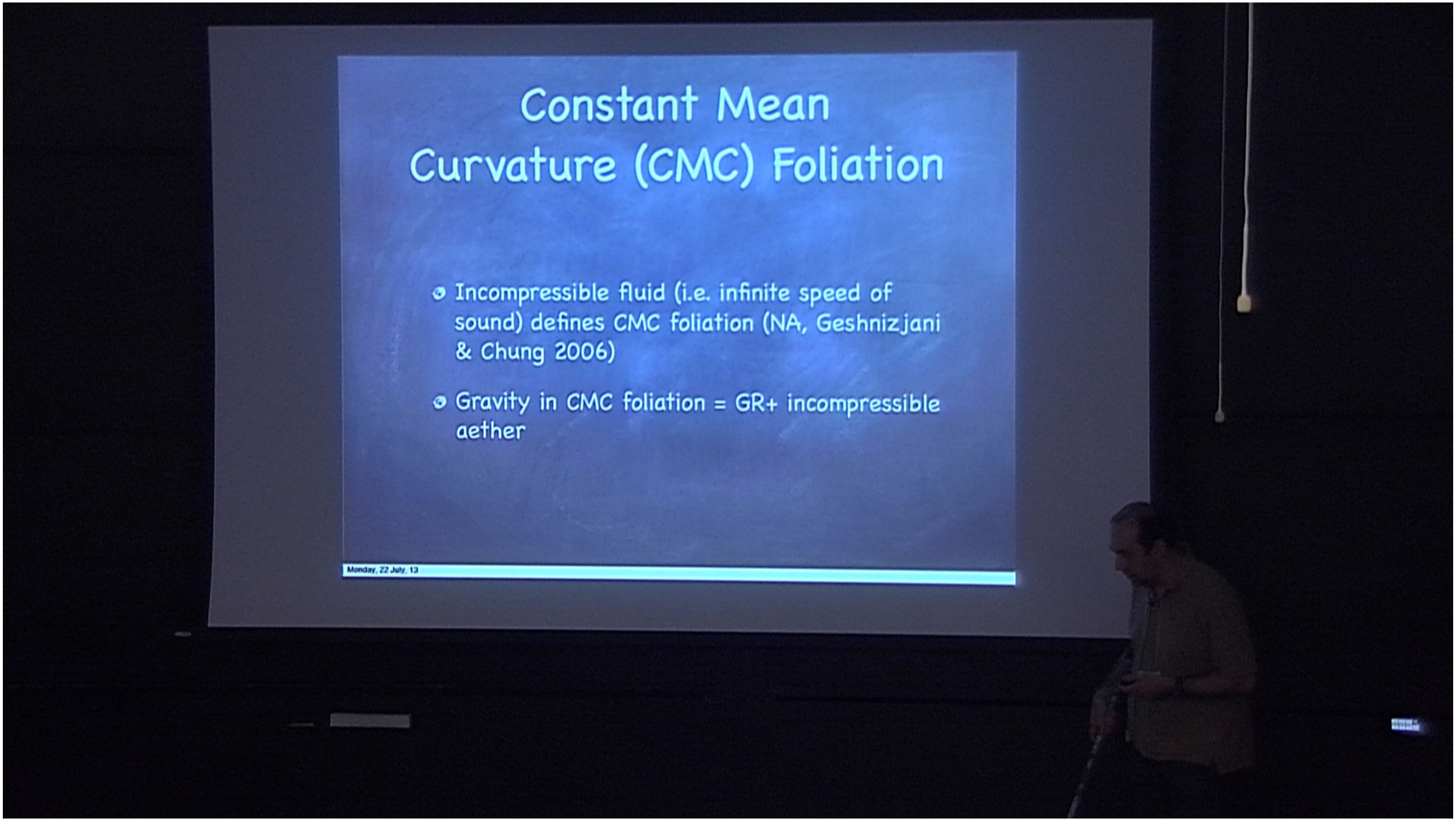
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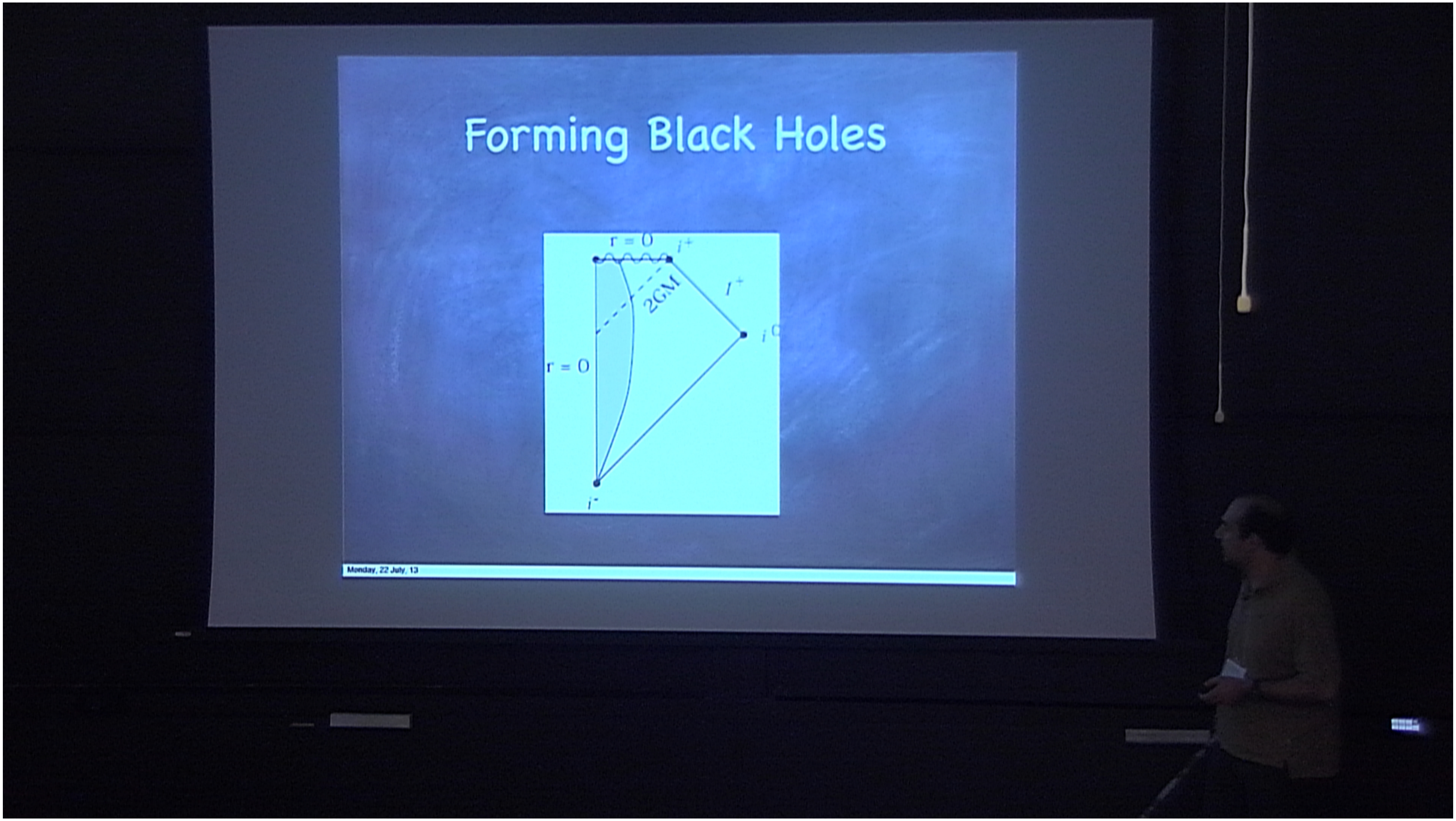
Forming Black Holes
r = 0
i^+
2GM
I^+
i^0
r = 0
i^-
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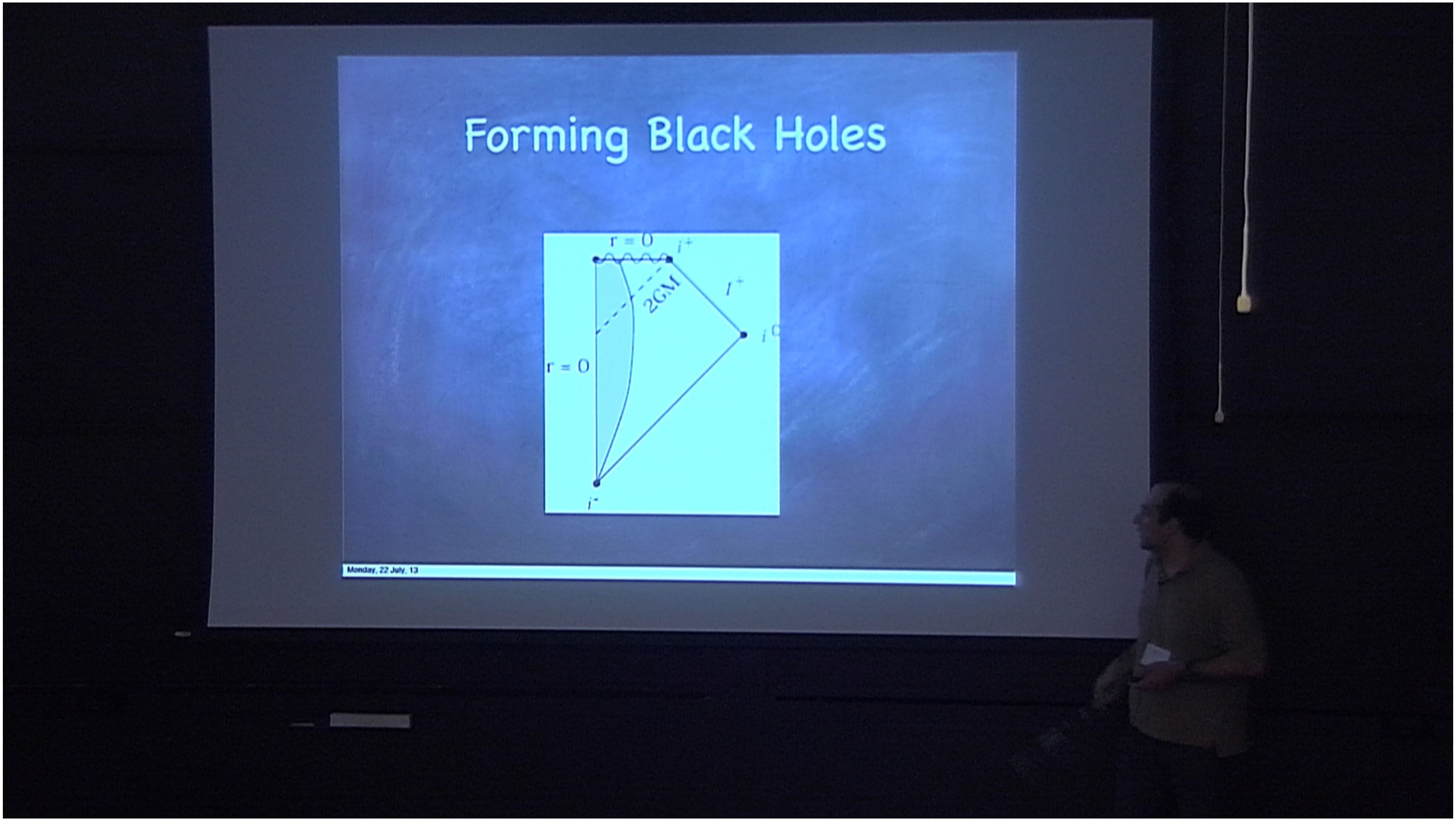

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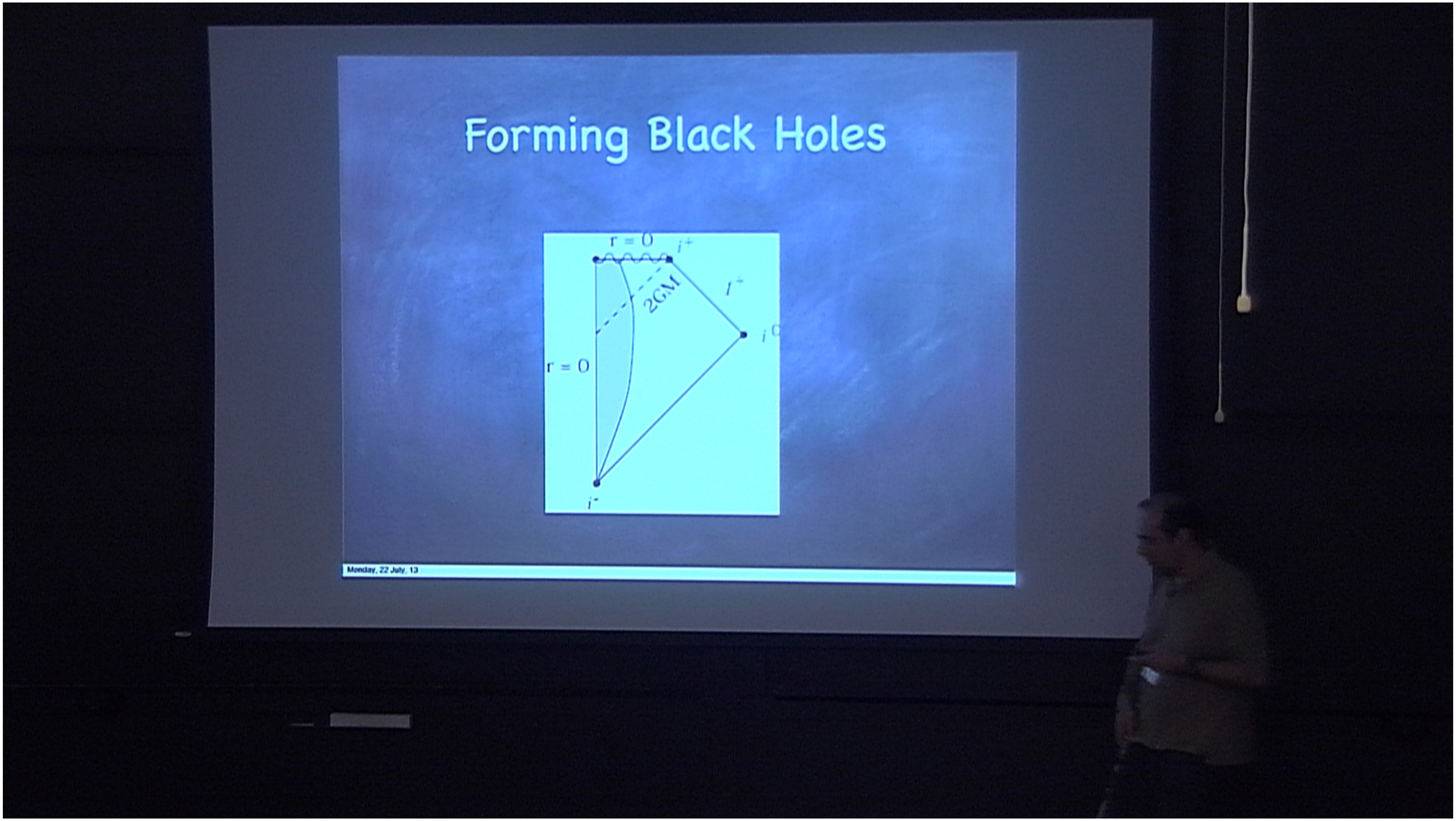
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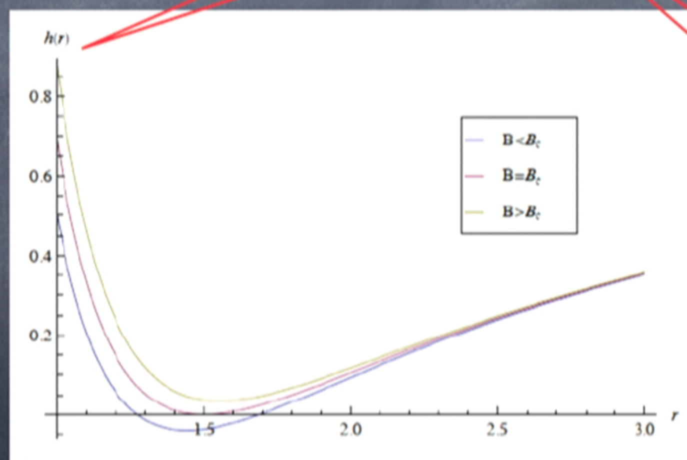
The boundary of Shape Dynamics "Space-Time"!

$$t_{CMC}(r) = t_{shell}(R) + \int_R^r \mathrm{d}x \frac{\frac{K}{3}x - \frac{B}{x^2}}{f(x)\sqrt{f(x) + \left(\frac{K}{3}x - \frac{B}{x^2}\right)^2}}, \quad r > R$$

$$f(r) = 1 - \frac{2M}{r}$$



Aether Flux: fixed by matching conditions @ the shell:
Israel+continuity

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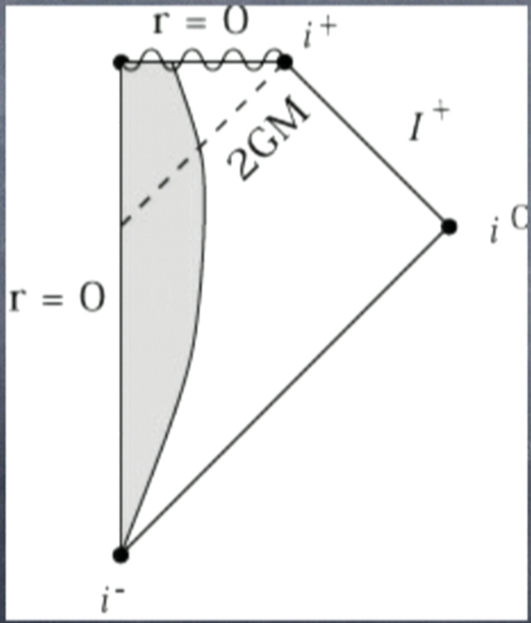

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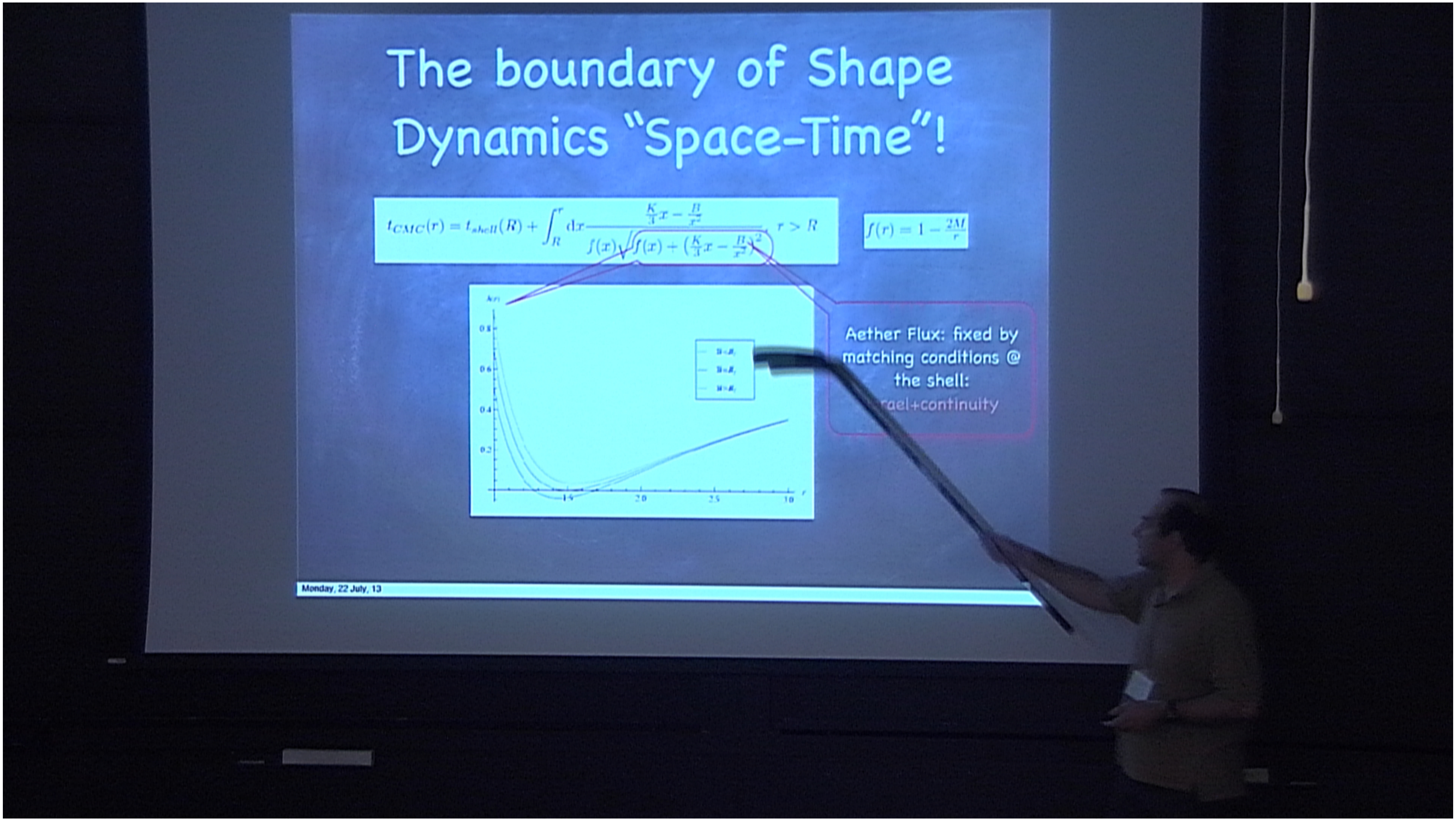
The boundary of Shape Dynamics "Space-Time"!
$t_{CMC}(r) = t_{shell}(R) + \int_R^r dx \frac{\frac{K}{3}x - \frac{B}{x^2}}{f(x)\sqrt{f(x) + (\frac{K}{3}x - \frac{B}{x^2})^2}}, \; r > R$
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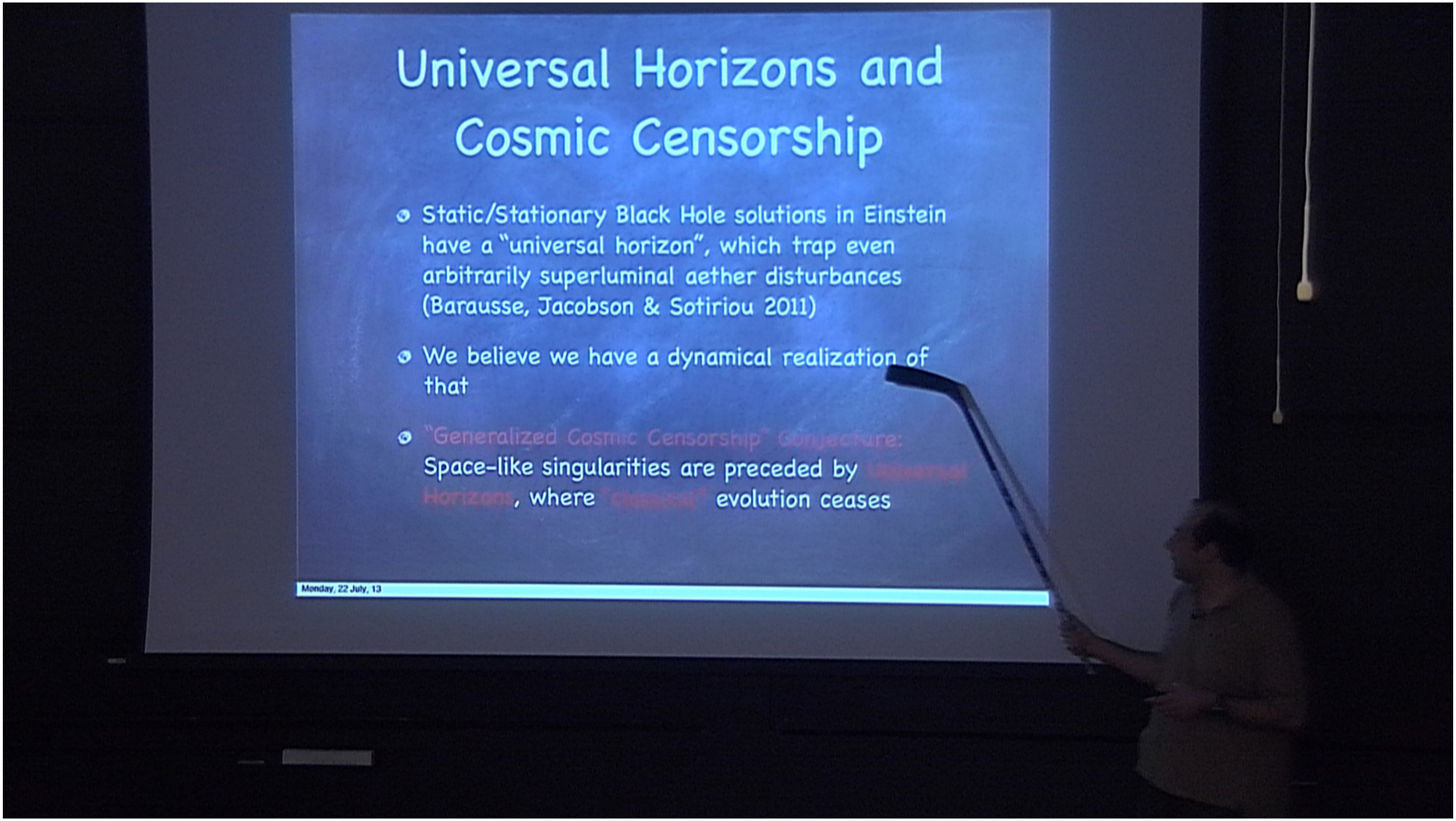
Universal Horizons and Cosmic Censorship
Static/Stationary Black Hole solutions in Einstein have a "universal horizon", which trap even arbitrarily superluminal aether disturbances (Barausse, Jacobson & Sotiriou 2011)
We believe we have a dynamical realization of that
"Generalized Cosmic Censorship" Conjecture:
Space-like singularities are preceded by
Horizons, where
evolution ceases
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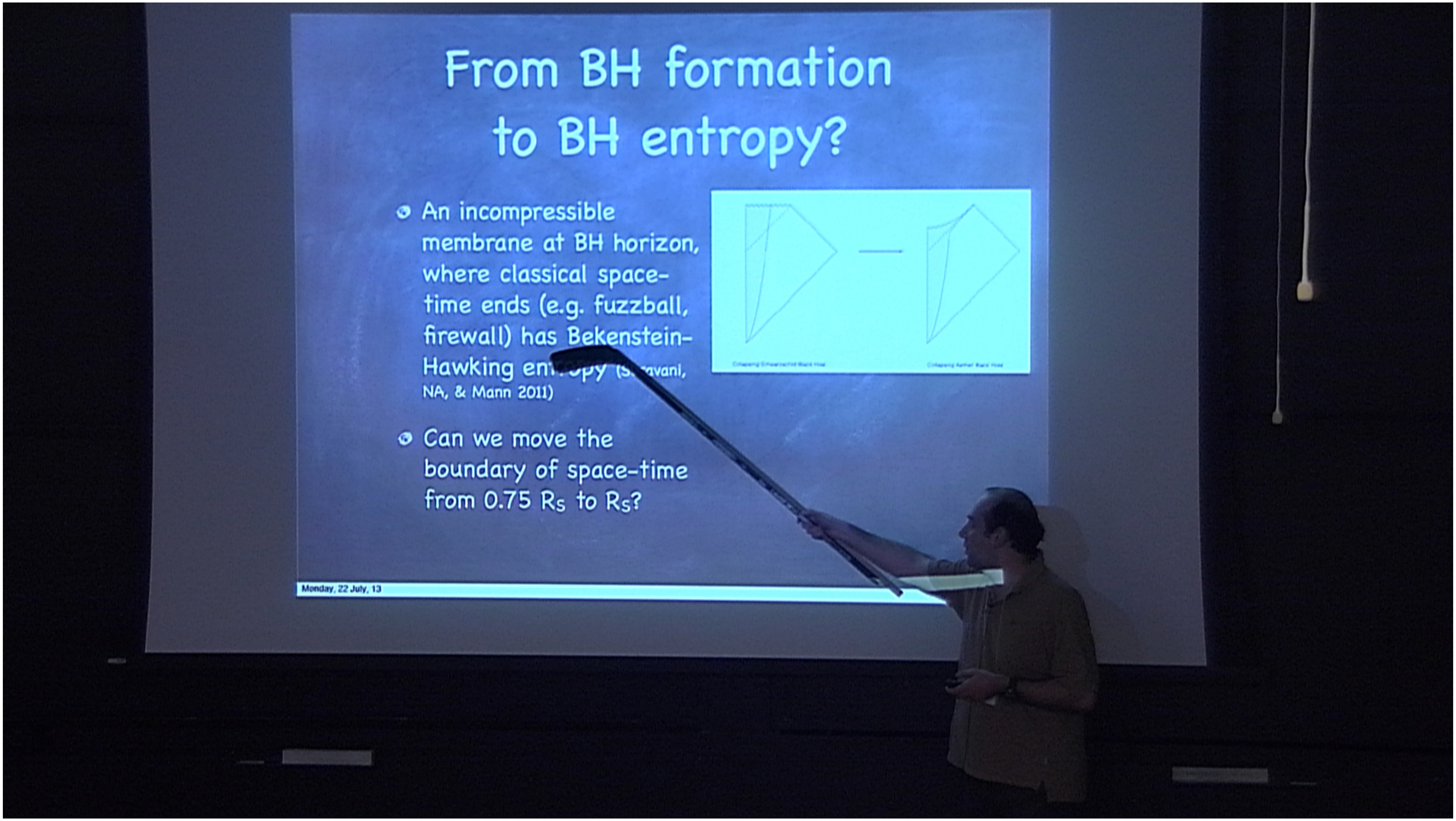
From BH formation
to BH entropy?
An incompressible membrane at BH horizon, where classical space-time ends (e.g. fuzzball, firewall) has Bekenstein-Hawking en
NA, & Mann 2011)
Can we move the boundary of space-time from 0.75 Rs to Rs?
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Collapsing Schwarzschild Black Hole
Collapsing Aether Black Hole

Final Thoughts

- Many motivations for preferred-frame, superluminal theories of gravity
- Maximal Superluminality = Incompressibility = CMC foliation
- Black Hole Space-times seems to end @ a Universal Horizon = 0.75 R_S
- Quantum Evolution? Microstates of Black Holes? Observables? Censorships?!


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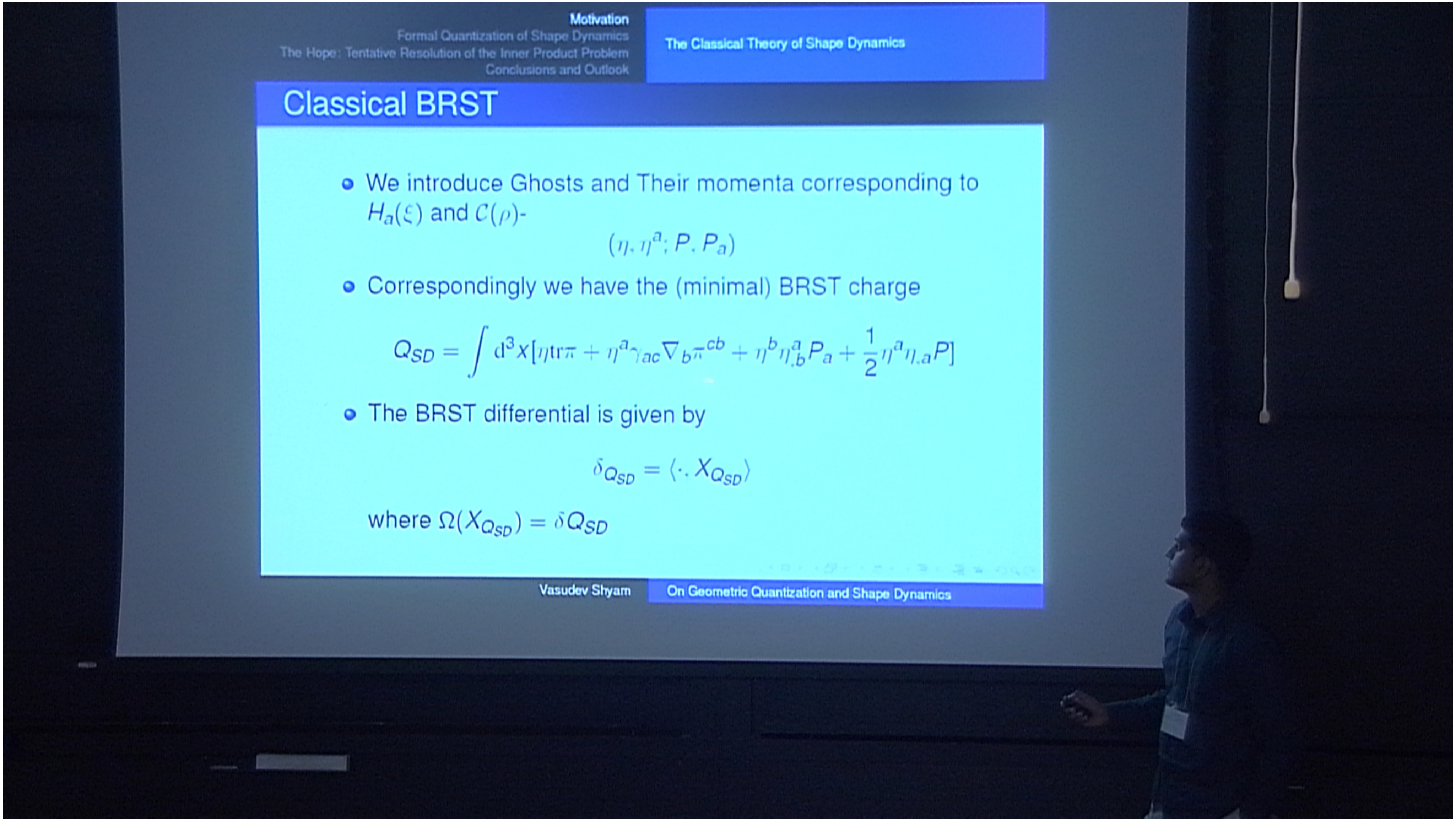
Motivation
Formal Quantization of Shape Dynamics
The Hope: Tentative Resolution of the Inner Product Problem
Conclusions and Outlook
The Classical Theory of Shape Dynamics
Classical BRST
We introduce Ghosts and Their momenta corresponding to $H_a(\xi)$ and $\mathcal{C}(\rho)$-
$(\eta, \eta^a; P, P_a)$
Correspondingly we have the (minimal) BRST charge
$Q_{SD} = \int d^3x[\eta \mathrm{tr}\pi + \eta^a \gamma_{ac} \nabla_b \pi^{cb} + \eta^b \eta^a_{,b} P_a + \frac{1}{2}\eta^a \eta_{,a} P]$
The BRST differential is given by
$\delta_{Q_{SD}} = \langle \cdot, X_{Q_{SD}} \rangle$
where $\Omega(X_{Q_{SD}}) = \delta Q_{SD}$
Vasudev Shyam
On Geometric Quantization and Shape Dynamics

Classical BRST

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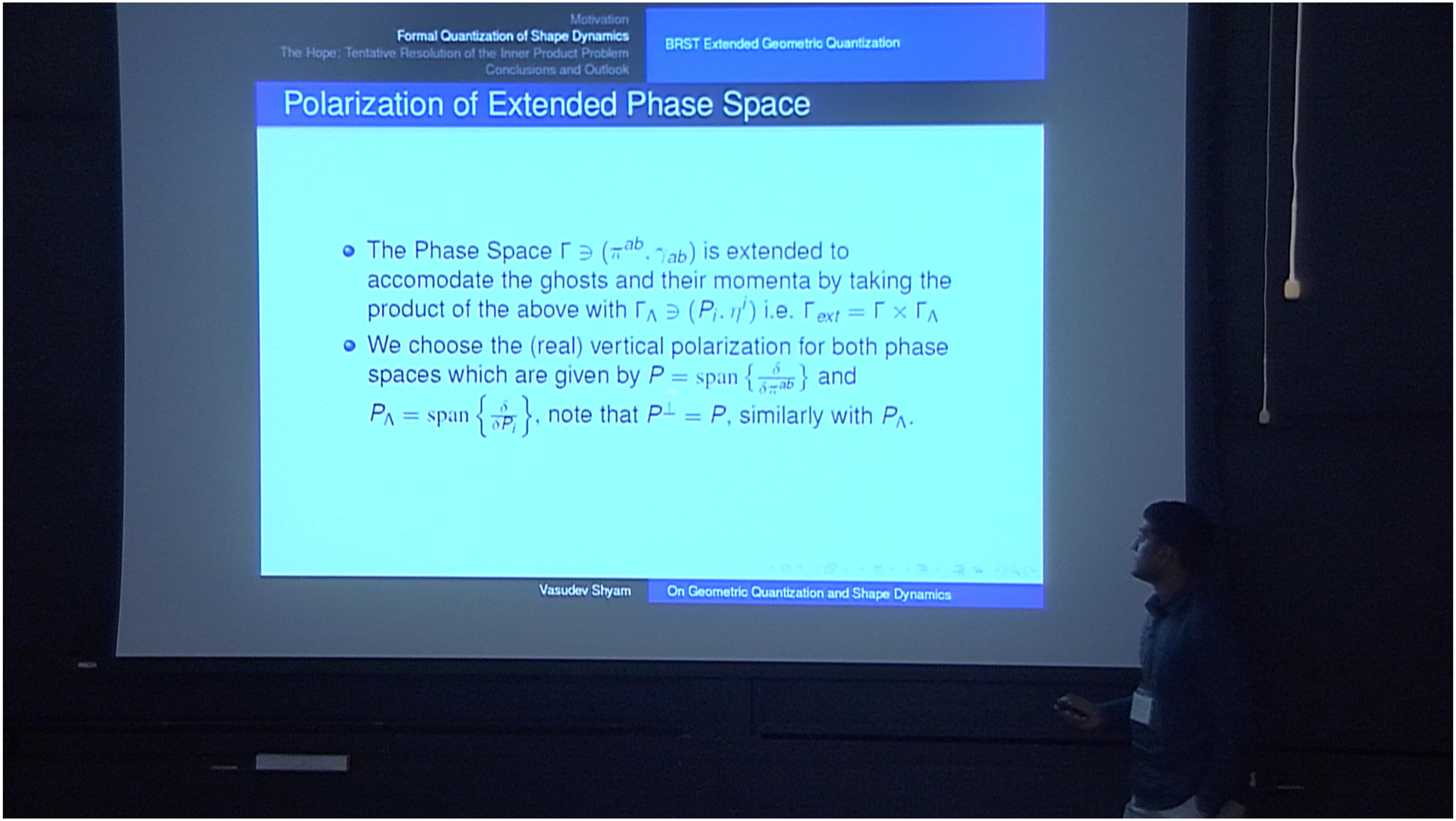
Classical BRST (contd.)

- By construction

$$\delta_{Q_{SD}} Q_{SD} = 0$$

- The Observables all belong to:

$$H^0(\delta_{Q_{SD}}) = \left(\frac{\mathrm{Ker}\delta_{Q_{SD}}}{\mathrm{Im}\delta_{Q_{SD}}}\right)^0$$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BRST Extended Geometric Quantization
Polarization of Extended Phase Space
The Phase Space $\Gamma \ni (\pi^{ab}, \gamma_{ab})$ is extended to accomodate the ghosts and their momenta by taking the product of the above with $\Gamma_\Lambda \ni (P_i, \eta^i)$ i.e. $\Gamma_{ext} = \Gamma \times \Gamma_\Lambda$
We choose the (real) vertical polarization for both phase spaces which are given by $P = \mathrm{span}\left\{\frac{\delta}{\delta \pi^{ab}}\right\}$ and $P_\Lambda = \mathrm{span}\left\{\frac{\delta}{\delta P_i}\right\}$, note that $P^\perp = P$, similarly with P_Λ.
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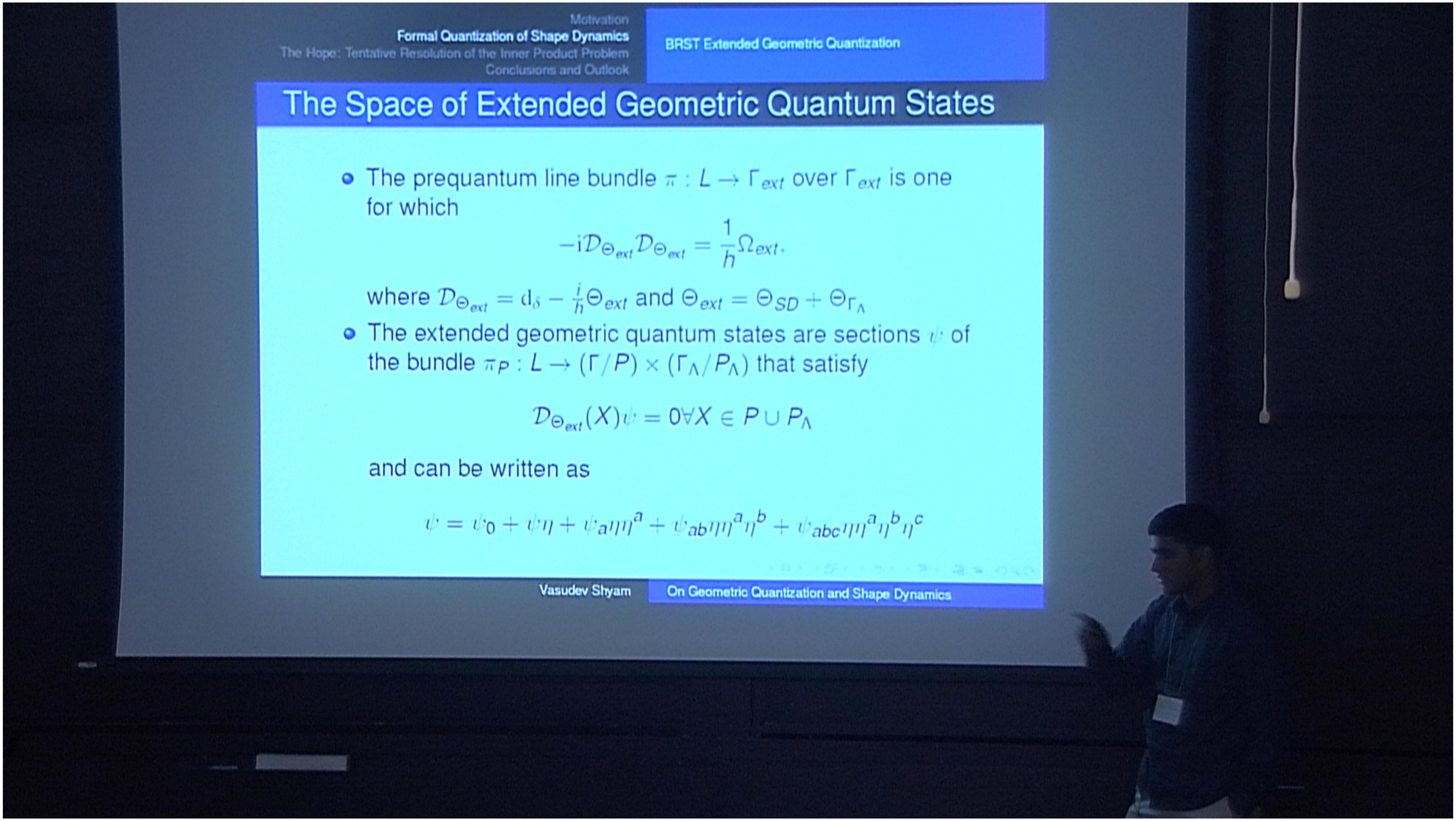
On Geometric Quantization and Shape Dynamics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BRST Extended Geometric Quantization
The Space of Extended Geometric Quantum States
The prequantum line bundle $\pi : L \to \Gamma_{ext}$ over Γ_{ext} is one for which
$-i\mathcal{D}_{\Theta_{ext}}\mathcal{D}_{\Theta_{ext}} = \frac{1}{\hbar}\Omega_{ext}.$
where $\mathcal{D}_{\Theta_{ext}} = d_\delta - \frac{i}{\hbar}\Theta_{ext}$ and $\Theta_{ext} = \Theta_{SD} + \Theta_{\Gamma_\Lambda}$
The extended geometric quantum states are sections ψ of the bundle $\pi_P : L \to (\Gamma/P) \times (\Gamma_\Lambda/P_\Lambda)$ that satisfy
$\mathcal{D}_{\Theta_{ext}}(X)\psi = 0 \forall X \in P \cup P_\Lambda$
and can be written as
$\psi = \psi_0 + \psi\eta + \psi_a\eta\eta^a + \psi_{ab}\eta\eta^a\eta^b + \psi_{abc}\eta\eta^a\eta^b\eta^c$
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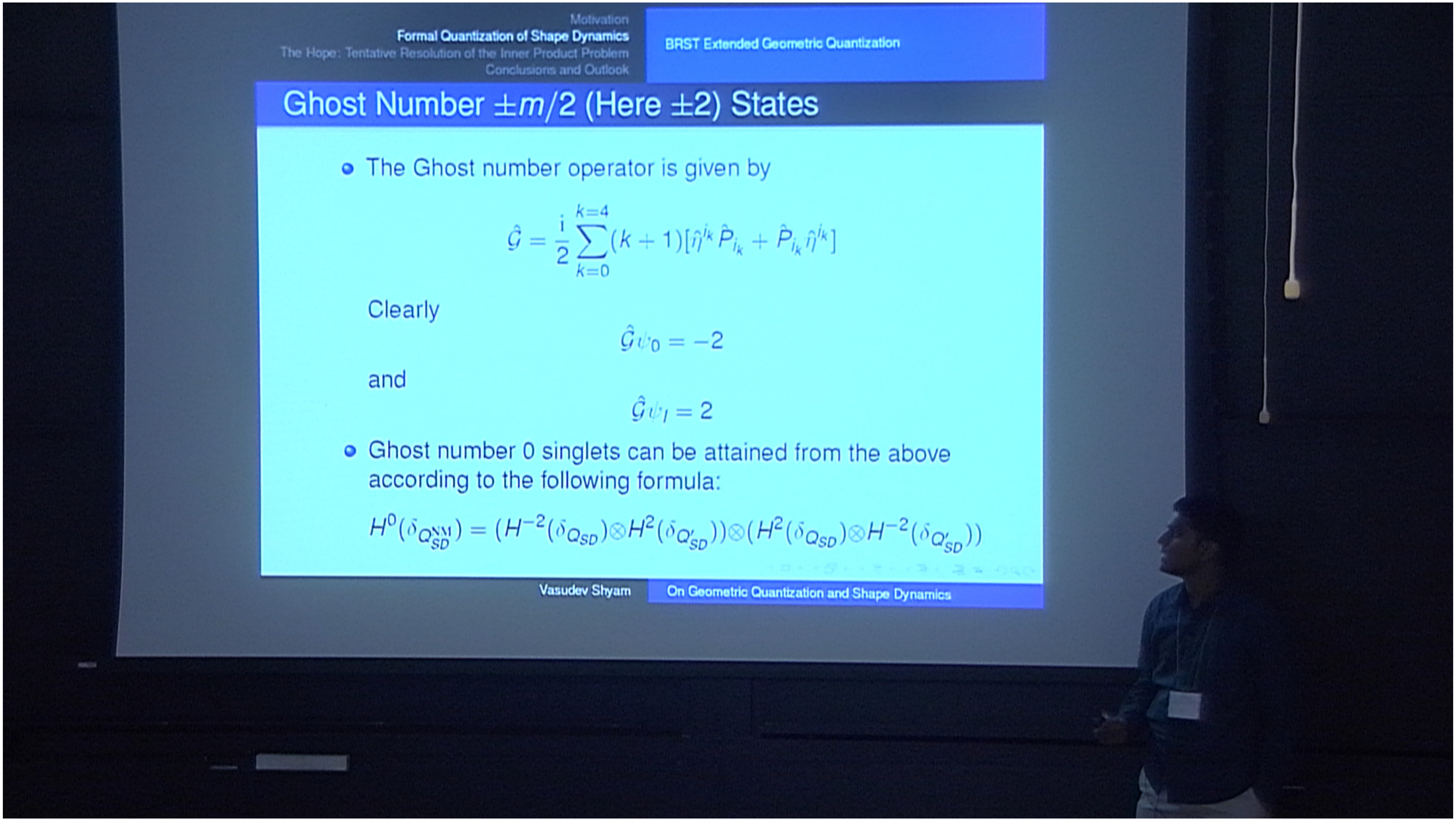
On Geometric Quantization and Shape Dynamics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BRST Extended Geometric Quantization
Ghost Number $\pm m/2$ (Here ± 2) States
The Ghost number operator is given by
$$\hat{\mathcal{G}} = \frac{i}{2}\sum_{k=0}^{k=4}(k+1)[\hat{\eta}^{i_k}\hat{P}_{i_k} + \hat{P}_{i_k}\hat{\eta}^{i_k}]$$
Clearly
$$\hat{\mathcal{G}}\psi_0 = -2$$
and
$$\hat{\mathcal{G}}\psi_I = 2$$
Ghost number 0 singlets can be attained from the above according to the following formula:
$$H^0(\delta_{Q^{NM}_{SD}}) = (H^{-2}(\delta_{Q_{SD}})\otimes H^2(\delta_{Q'_{SD}}))\otimes(H^2(\delta_{Q_{SD}})\otimes H^{-2}(\delta_{Q'_{SD}}))$$
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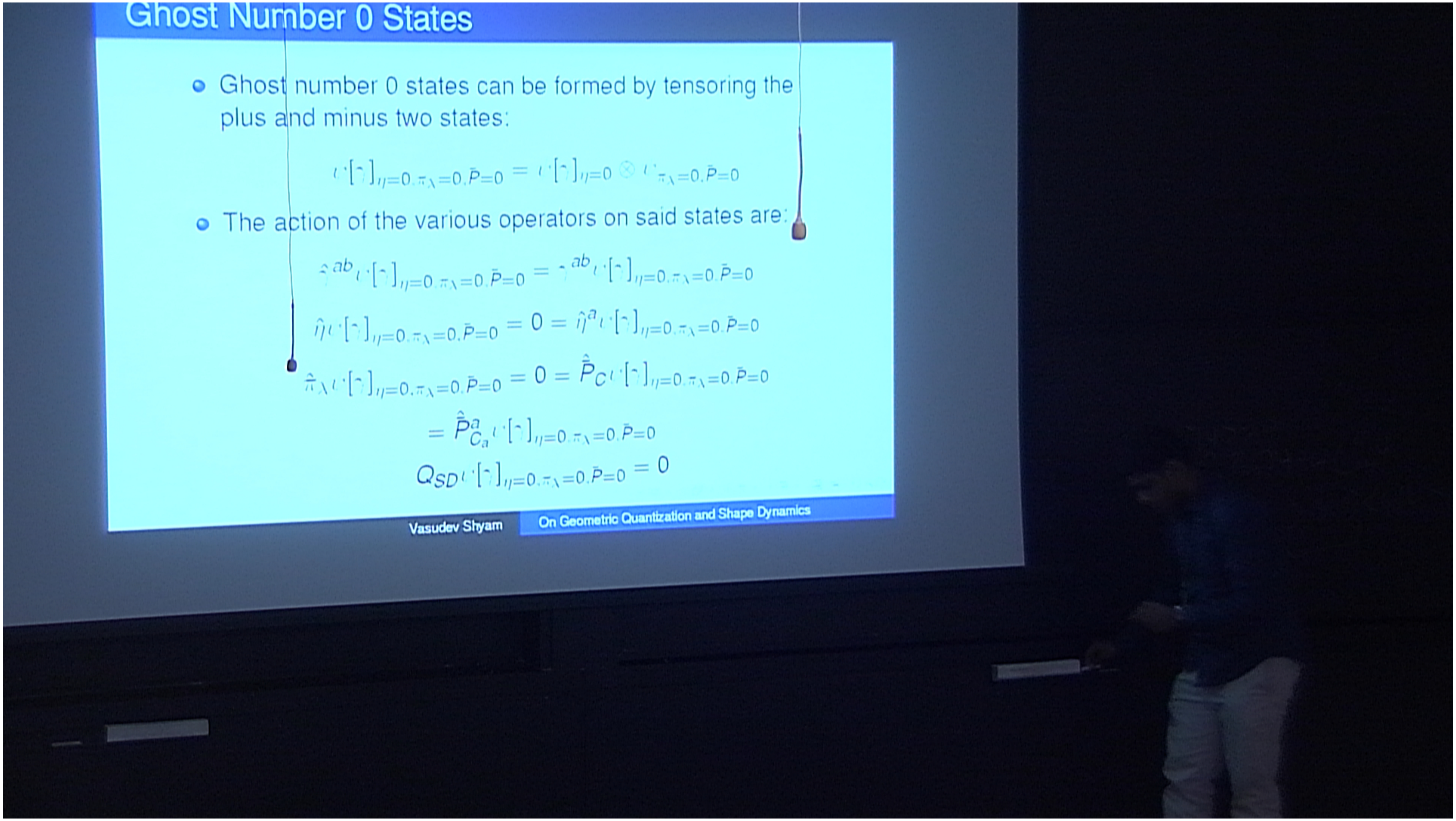
Ghost Number 0 States
Ghost number 0 states can be formed by tensoring the plus and minus two states:
The action of the various operators on said states are:
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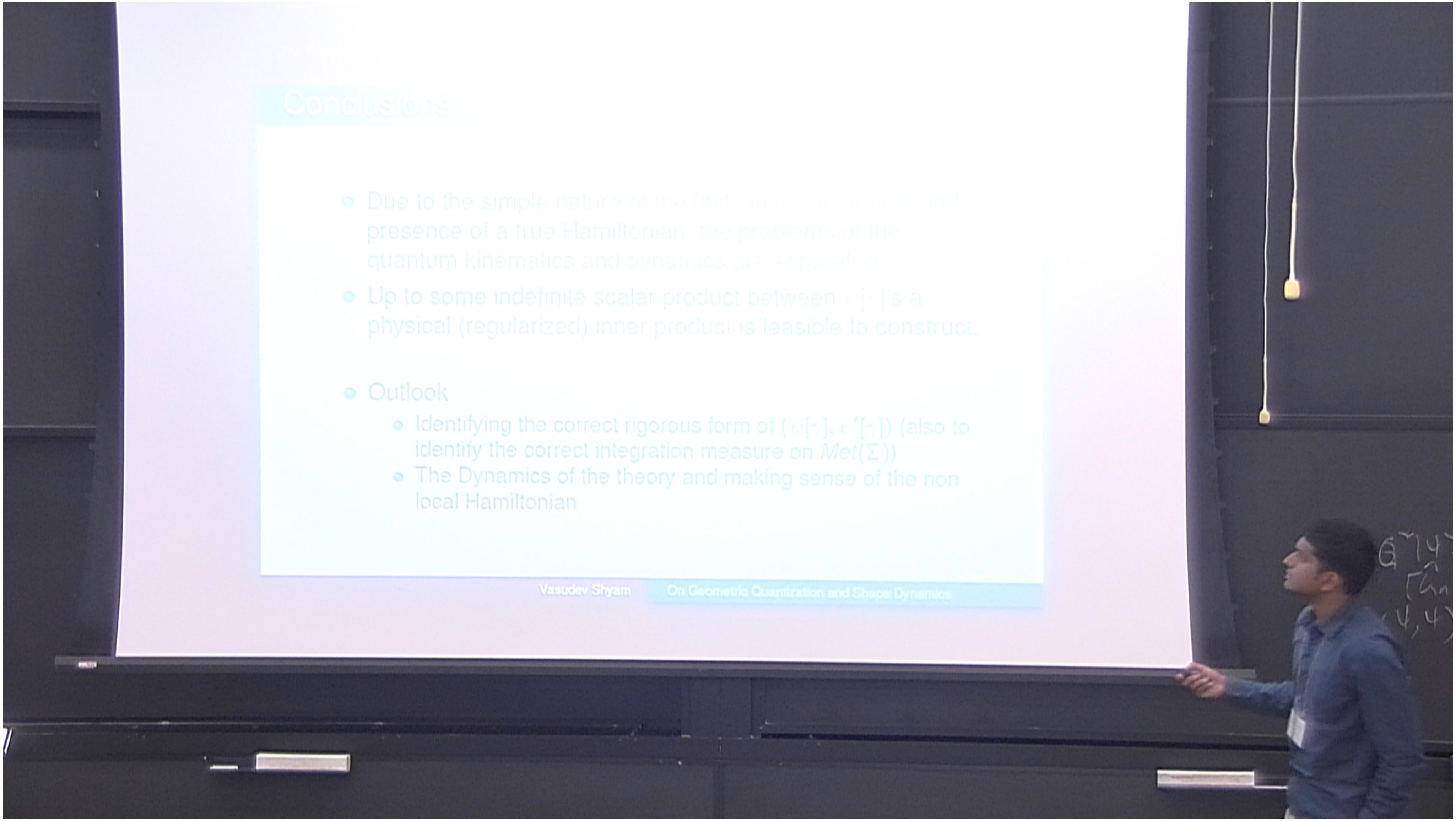
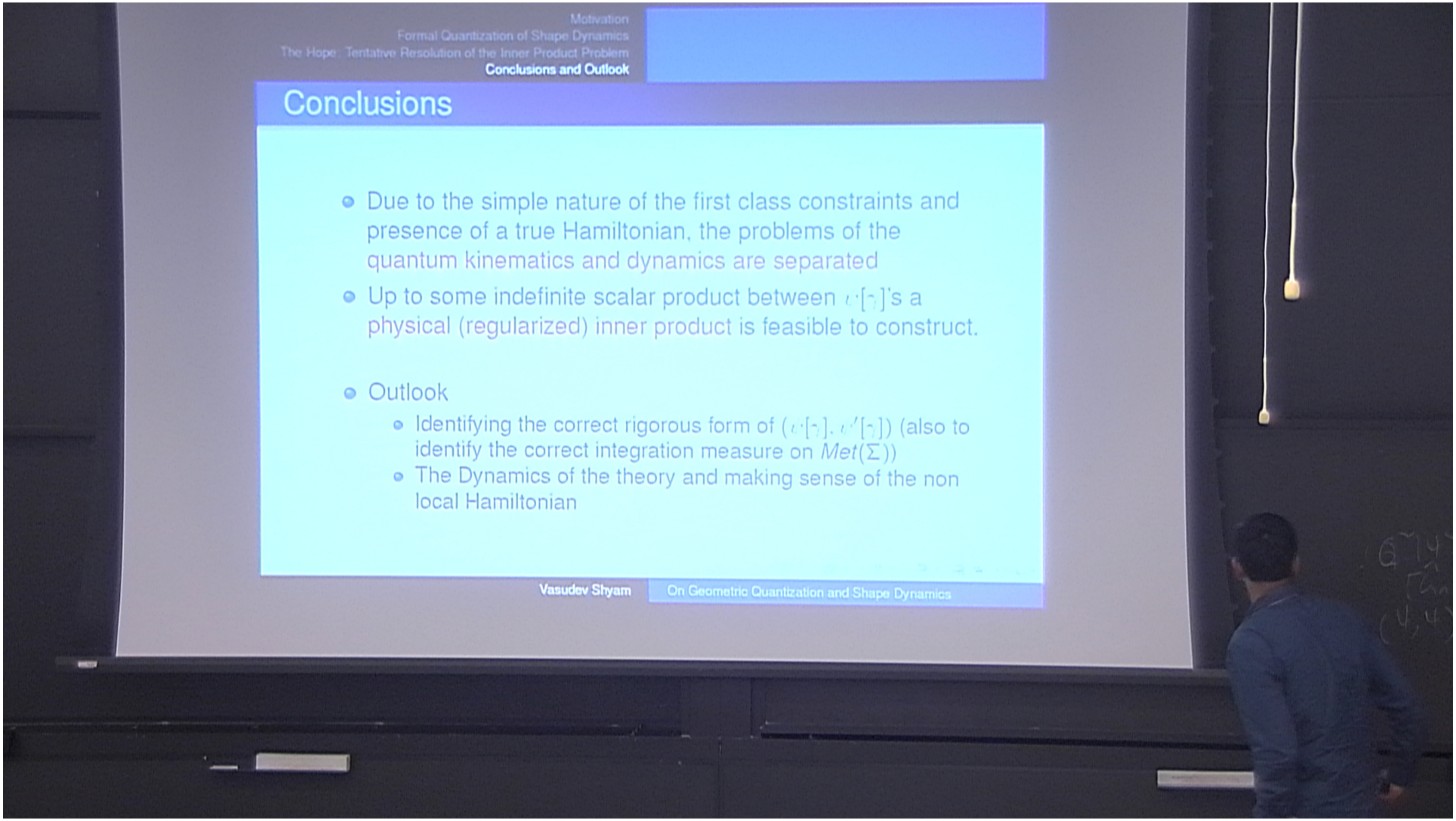
On Geometric Quantization and Shape Dynamics


Conclusions
Due to the simple nature of the first class constraints and presence of a true Hamiltonian the problems of the quantum kinematics and dynamics are separated
Up to some indefinite scalar product between 's a physical (regularized) inner product is feasible to construct.
Outlook
Identifying the correct rigorous form of (also to identify the correct integration measure on Met(Σ))
The Dynamics of the theory and making sense of the non local Hamiltonian
Vasudev Shyam
On Geometric Quantization and Shape Dynamics

Conclusions

- Due to the simple nature of the first class constraints and presence of a true Hamiltonian, the problems of the quantum kinematics and dynamics are separated
- Up to some indefinite scalar product between $\psi[\gamma]$'s a physical (regularized) inner product is feasible to construct.

- Outlook
  - Identifying the correct rigorous form of $(\psi[\gamma], \psi'[\gamma])$ (also to identify the correct integration measure on $Met(\Sigma)$)
  - The Dynamics of the theory and making sense of the non local Hamiltonian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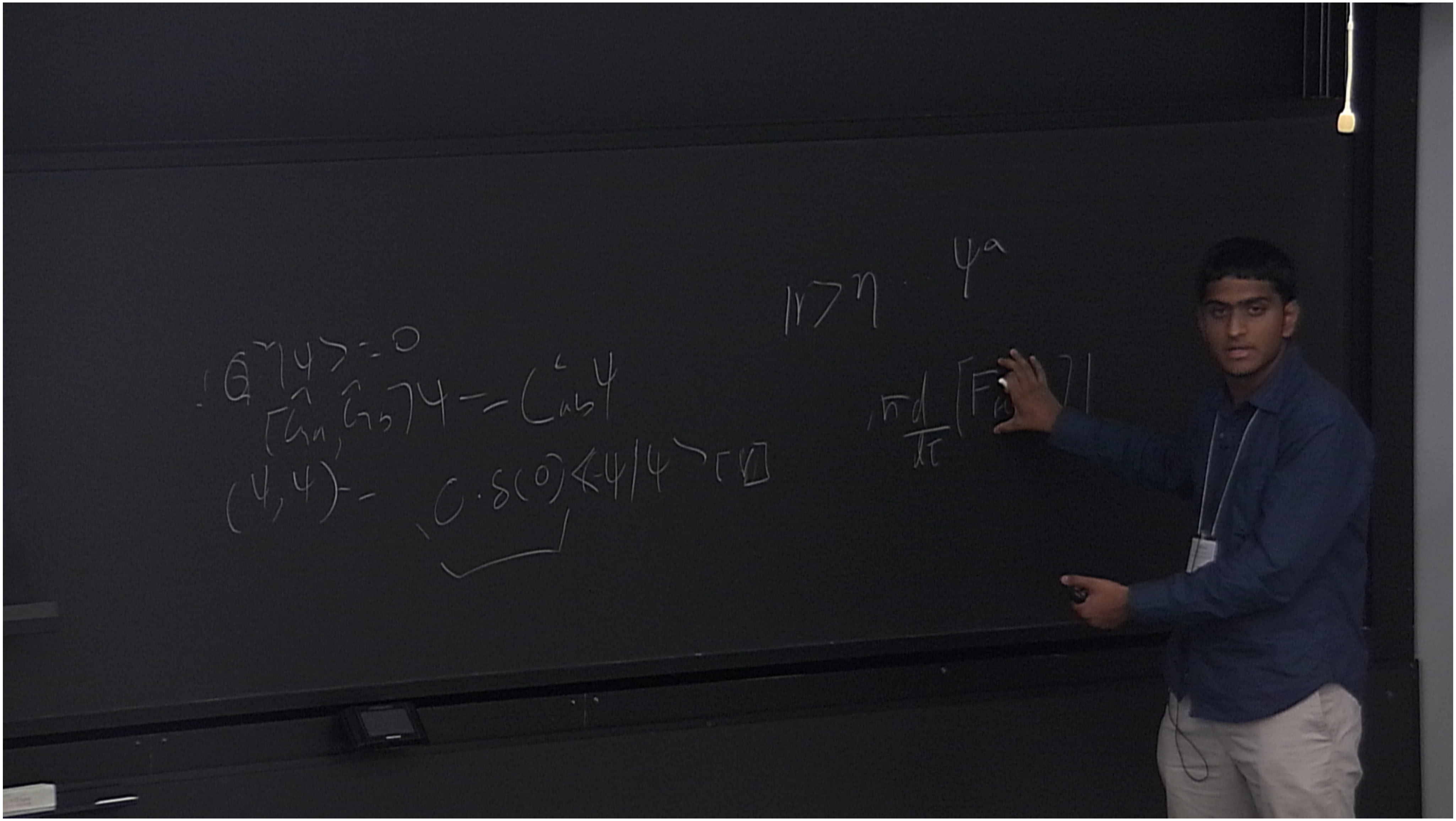
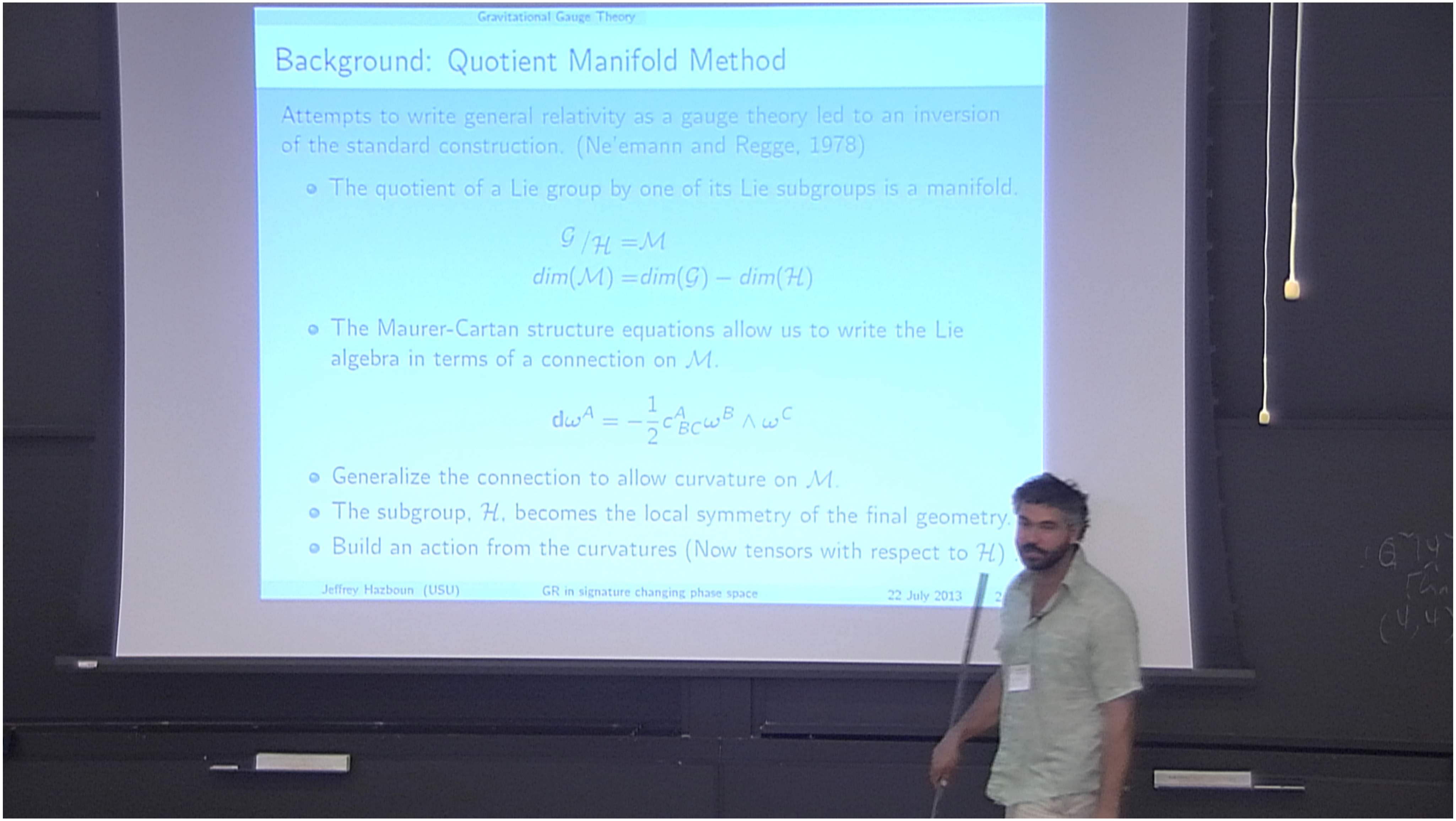
On Geometric Quantization and Shape Dynamics




Gravitational Gauge Theory
Background: Quotient Manifold Method
Attempts to write general relativity as a gauge theory led to an inversion of the standard construction. (Ne'emann and Regge, 1978)
The quotient of a Lie group by one of its Lie subgroups is a manifold.
$\mathcal{G}/\mathcal{H} = \mathcal{M}$
$dim(\mathcal{M}) = dim(\mathcal{G}) - dim(\mathcal{H})$
The Maurer-Cartan structure equations allow us to write the Lie algebra in terms of a connection on $\mathcal{M}$.
$\mathbf{d}\omega^A = -\frac{1}{2} c^A_{\ BC} \omega^B \wedge \omega^C$
Generalize the connection to allow curvature on $\mathcal{M}$.
The subgroup, $\mathcal{H}$, becomes the local symmetry of the final geometry.
Build an action from the curvatures (Now tensors with respect to $\mathcal{H}$)
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22 July 2013

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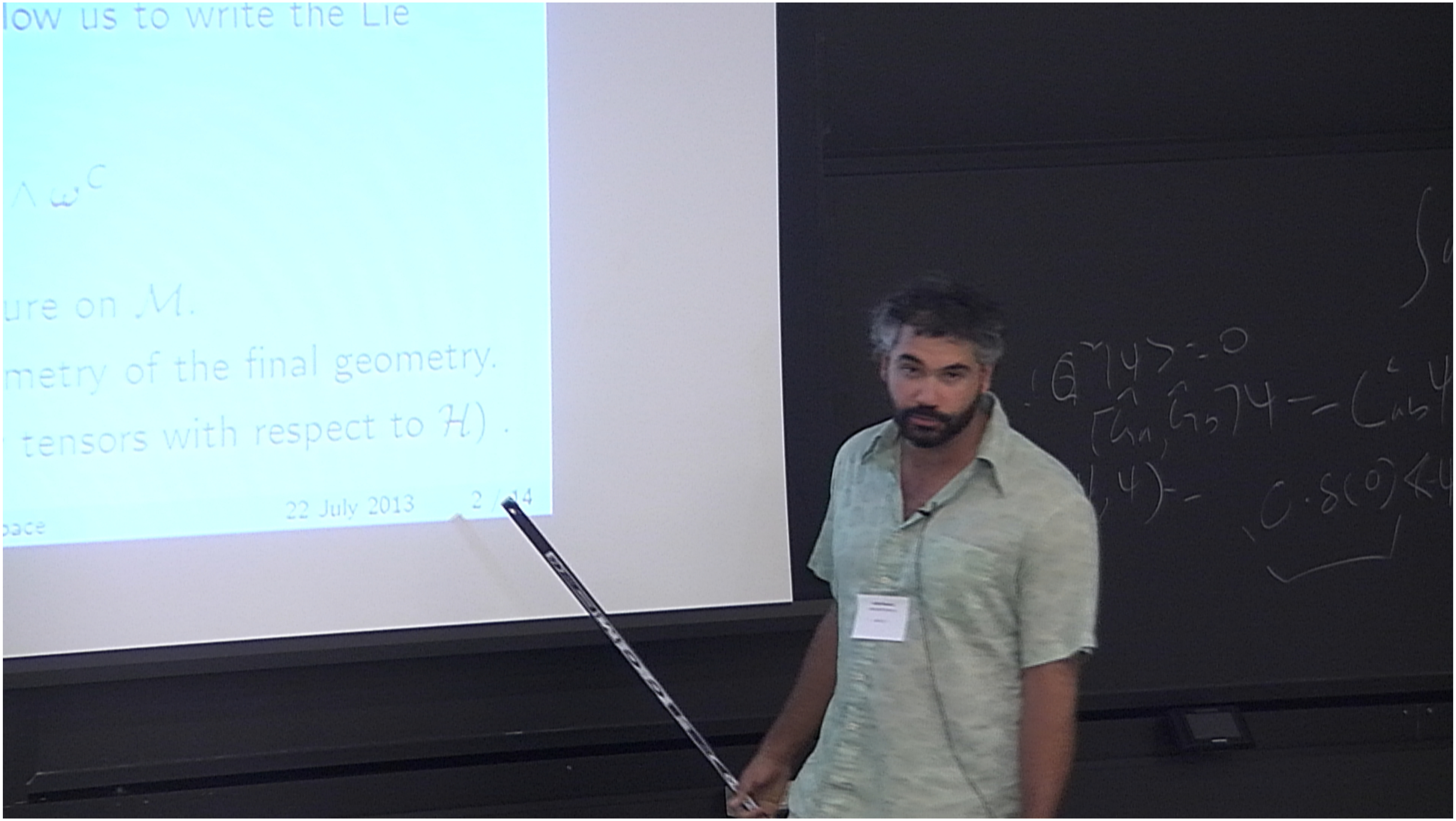
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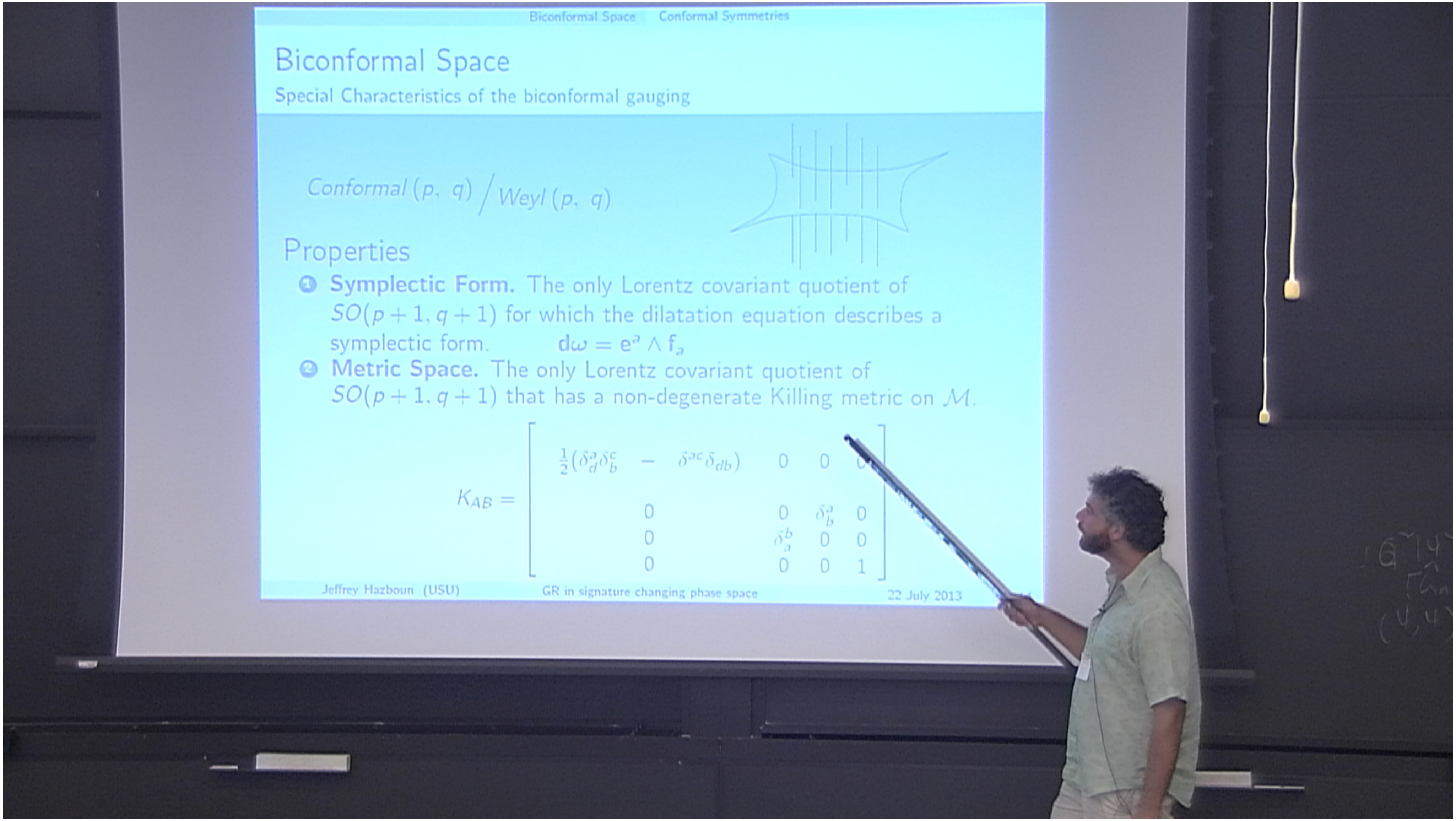
Biconformal Space Conformal Symmetries
Biconformal Space
Special Characteristics of the biconformal gauging
Conformal (p, q) / Weyl (p, q)
Properties
Symplectic Form. The only Lorentz covariant quotient of SO(p + 1, q + 1) for which the dilatation equation describes a symplectic form. dω = e^a ∧ f_a
Metric Space. The only Lorentz covariant quotient of SO(p + 1, q + 1) that has a non-degenerate Killing metric on M.
K_AB =
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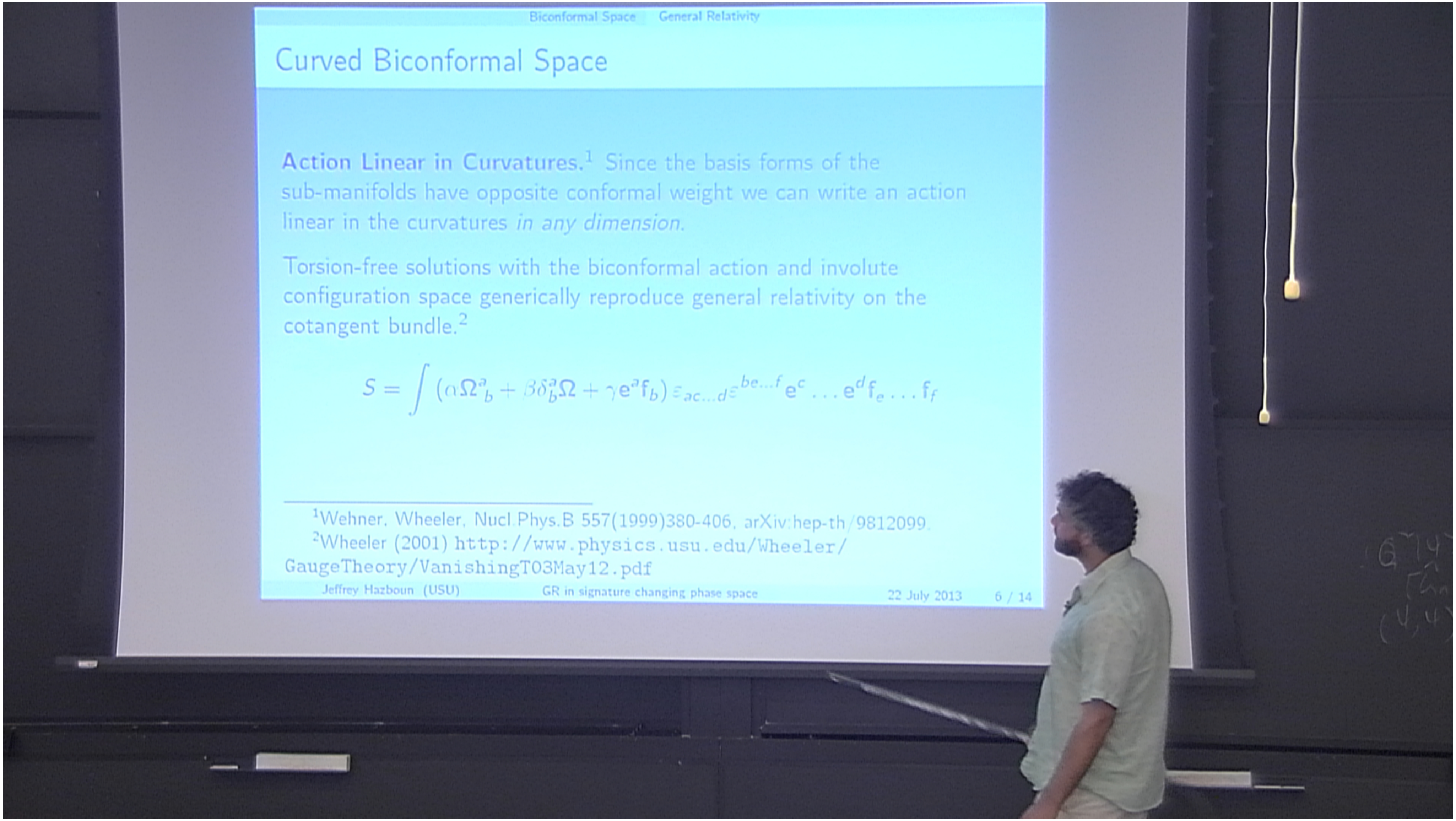
Biconformal Space General Relativity
Curved Biconformal Space
Action Linear in Curvatures.1 Since the basis forms of the sub-manifolds have opposite conformal weight we can write an action linear in the curvatures in any dimension.
Torsion-free solutions with the biconformal action and involute configuration space generically reproduce general relativity on the cotangent bundle.2
$S = \int (\alpha \Omega^a_{\ b} + \beta \delta^a_b \Omega + \gamma e^a f_b)\, \varepsilon_{ac \dots d} \varepsilon^{be \dots f} e^c \dots e^d f_e \dots f_f$
1Wehner, Wheeler, Nucl.Phys.B 557(1999)380-406, arXiv:hep-th/9812099.
2Wheeler (2001) http://www.physics.usu.edu/Wheeler/GaugeTheory/VanishingT03May12.pdf
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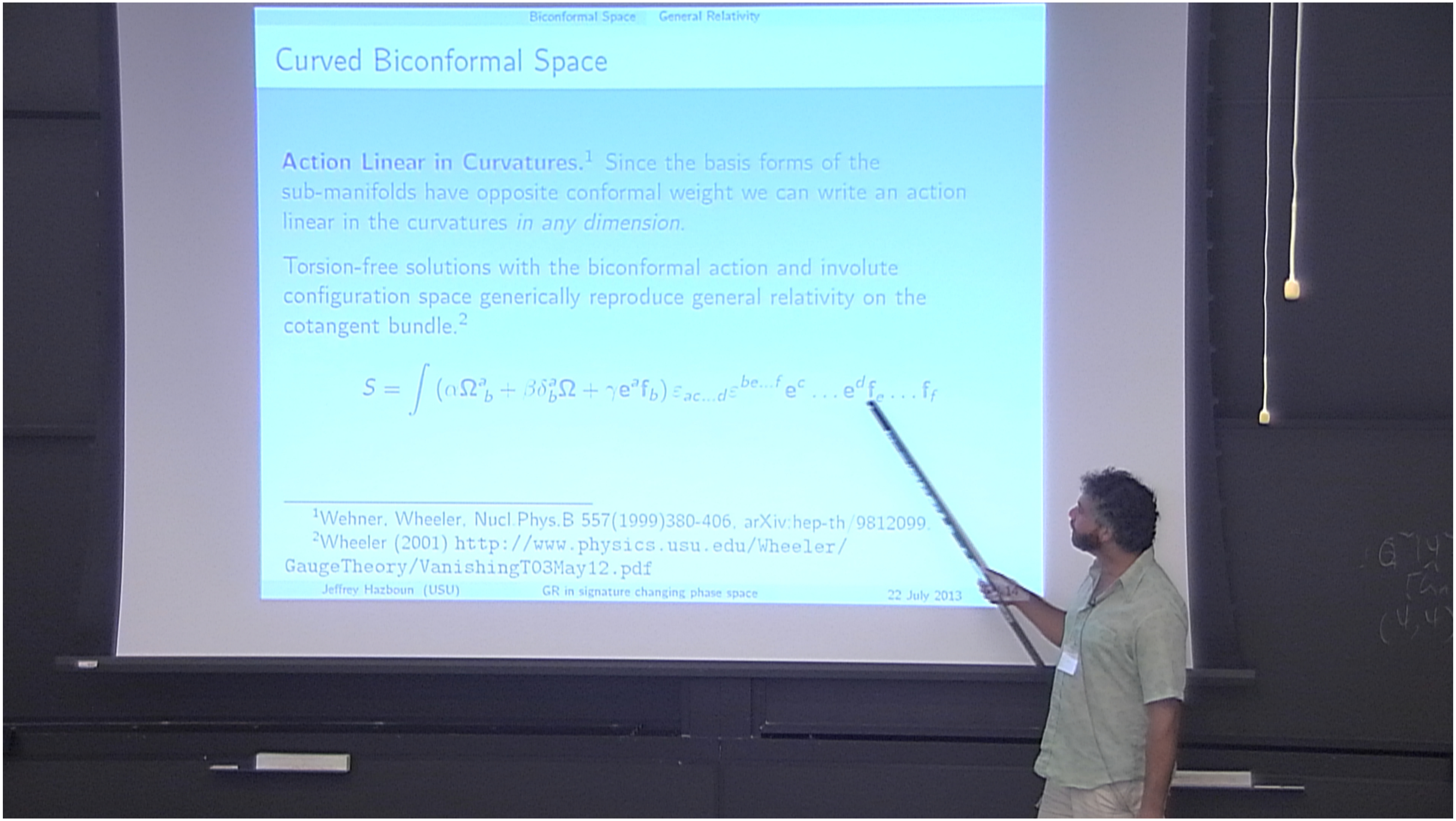
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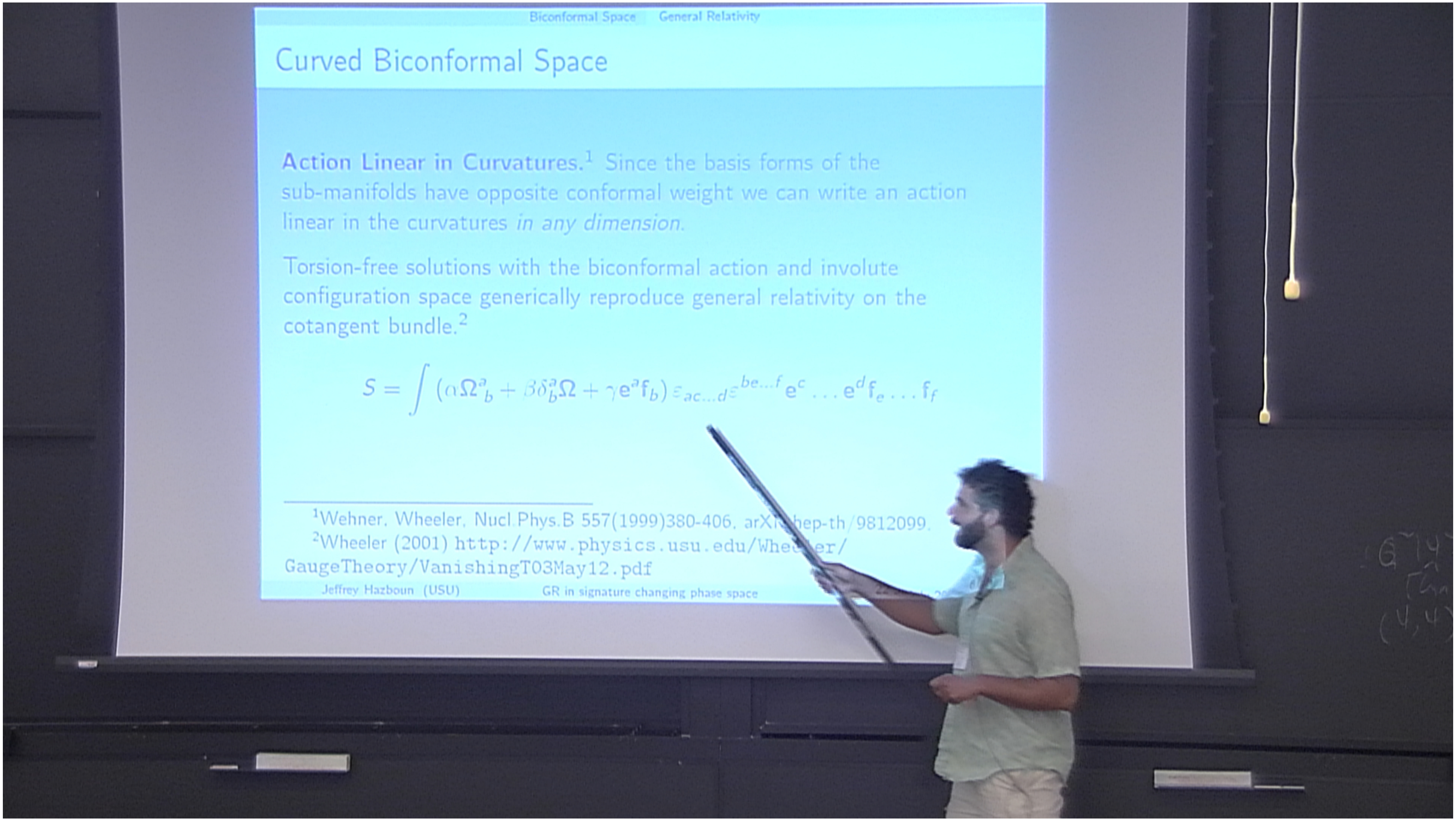
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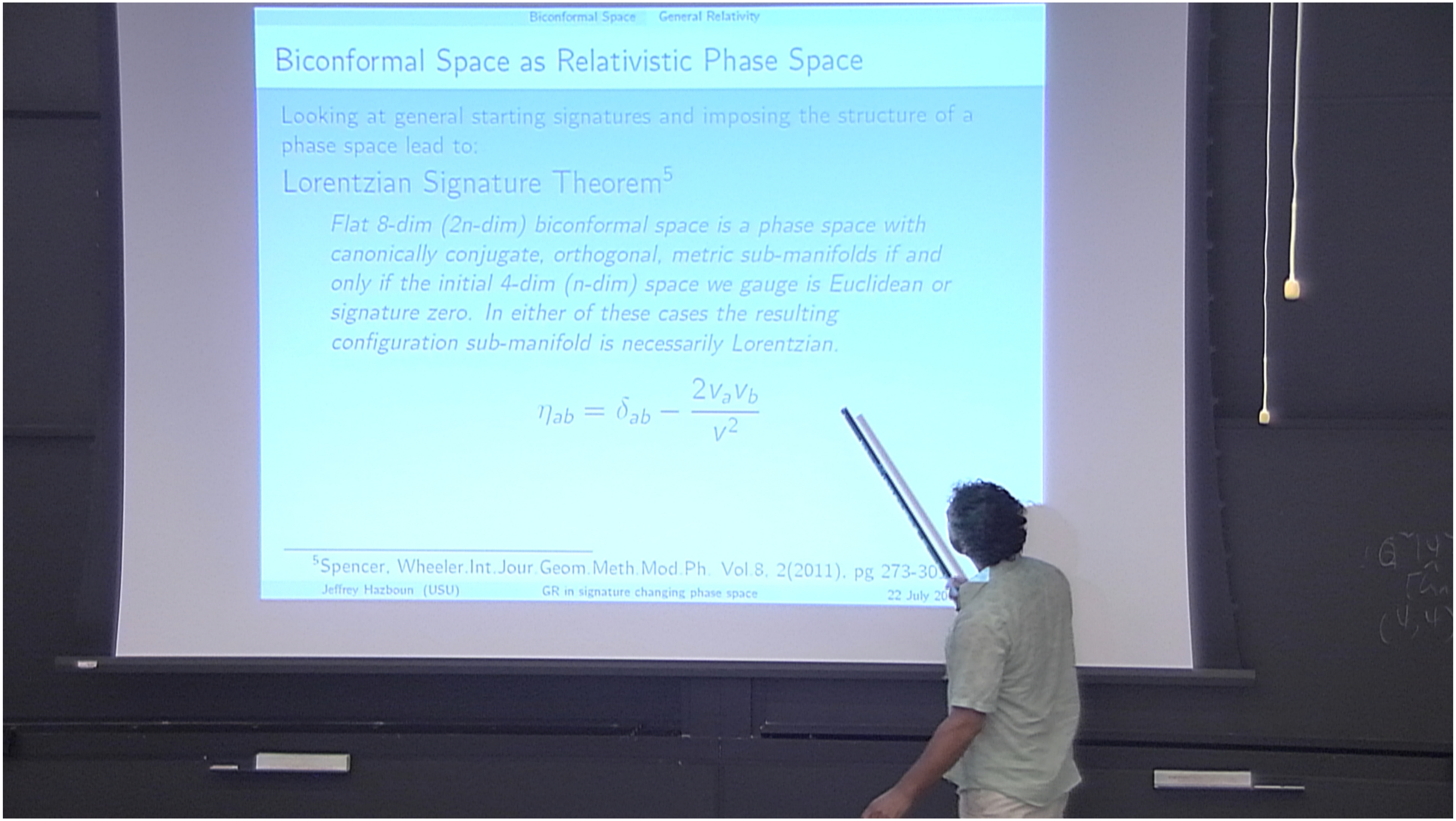
Biconformal Space General Relativity
Biconformal Space as Relativistic Phase Space
Looking at general starting signatures and imposing the structure of a phase space lead to:
Lorentzian Signature Theorem5
Flat 8-dim (2n-dim) biconformal space is a phase space with canonically conjugate, orthogonal, metric sub-manifolds if and only if the initial 4-dim (n-dim) space we gauge is Euclidean or signature zero. In either of these cases the resulting configuration sub-manifold is necessarily Lorentzian.
$\eta_{ab} = \delta_{ab} - \frac{2v_a v_b}{v^2}$
5Spencer, Wheeler.Int.Jour.Geom.Meth.Mod.Ph. Vol.8, 2(2011), pg 273-30
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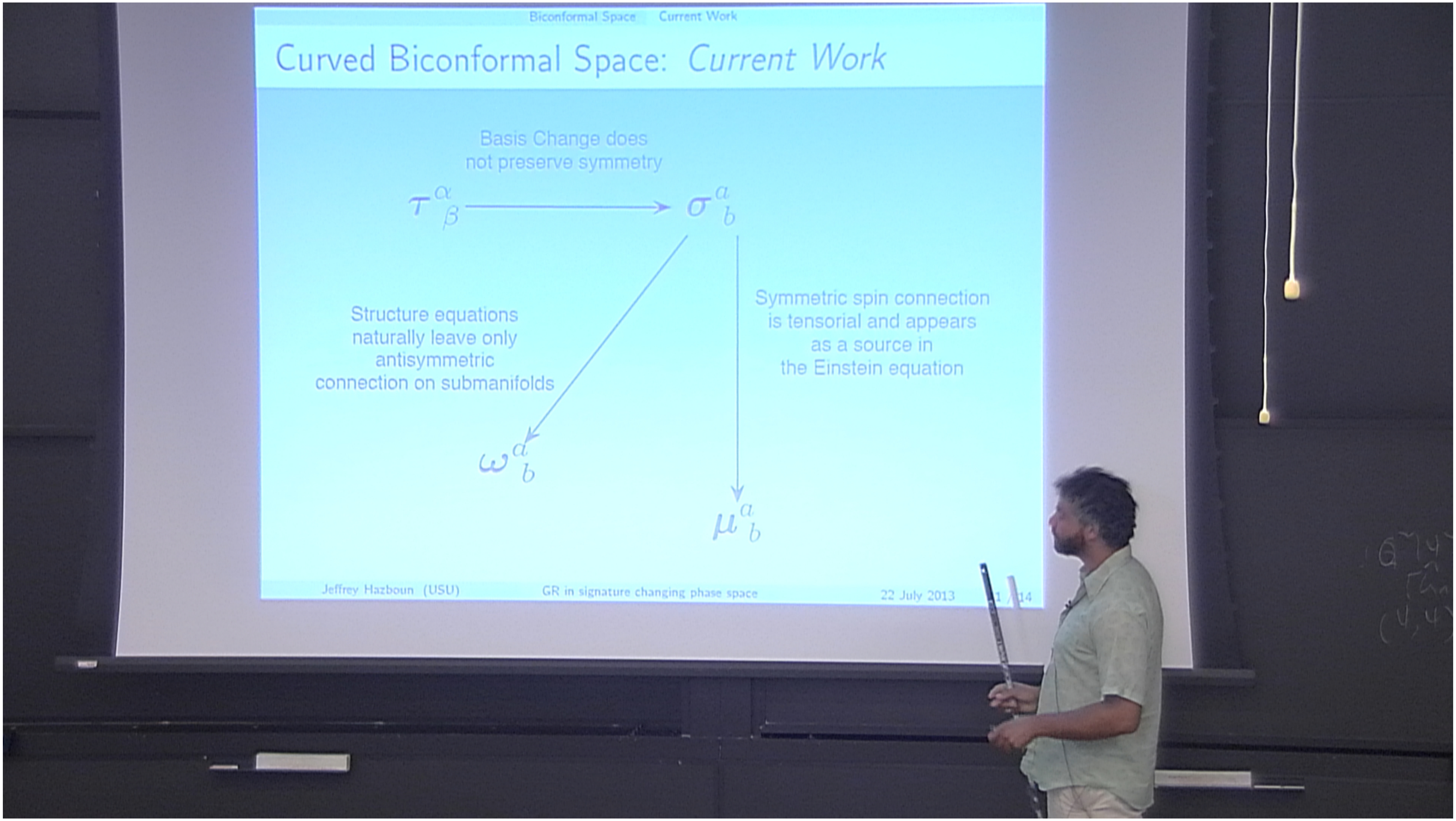
Biconformal Space Current Work
Curved Biconformal Space: Current Work
Basis Change does not preserve symmetry
$\tau^\alpha_{\ \beta}$
$\sigma^a_{\ b}$
Structure equations naturally leave only antisymmetric connection on submanifolds
Symmetric spin connection is tensorial and appears as a source in the Einstein equation
$\omega^a_{\ b}$
$\mu^a_{\ b}$
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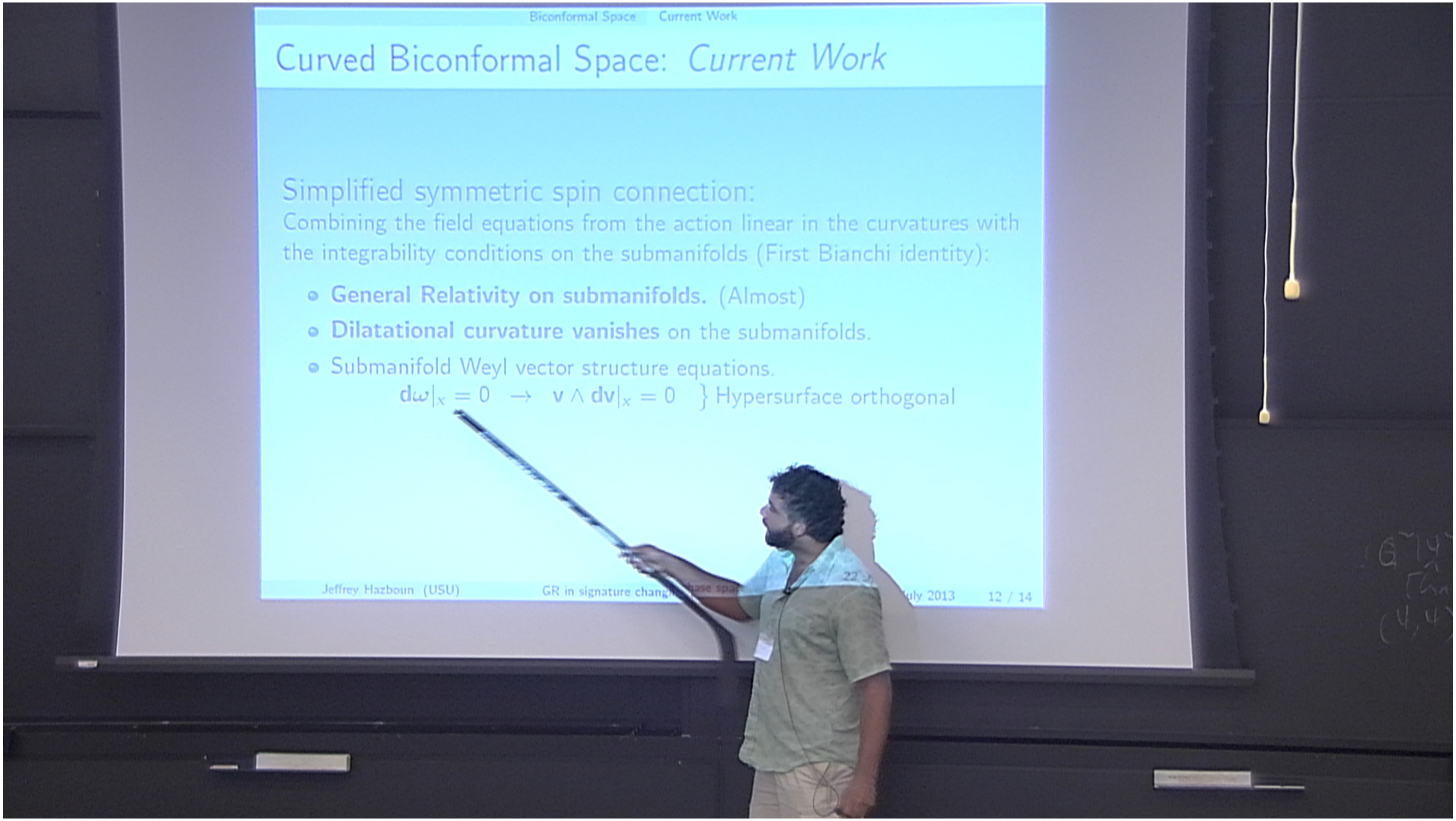
Biconformal Space Current Work
Curved Biconformal Space: *Current Work*
Simplified symmetric spin connection:
Combining the field equations from the action linear in the curvatures with the integrability conditions on the submanifolds (First Bianchi identity):
General Relativity on submanifolds. (Almost)
Dilatational curvature vanishes on the submanifolds.
Submanifold Weyl vector structure equations.
$\mathbf{d}\omega|_x = 0 \quad \rightarrow \quad \mathbf{v} \wedge \mathbf{dv}|_x = 0 \quad \}$ Hypersurface orthogonal
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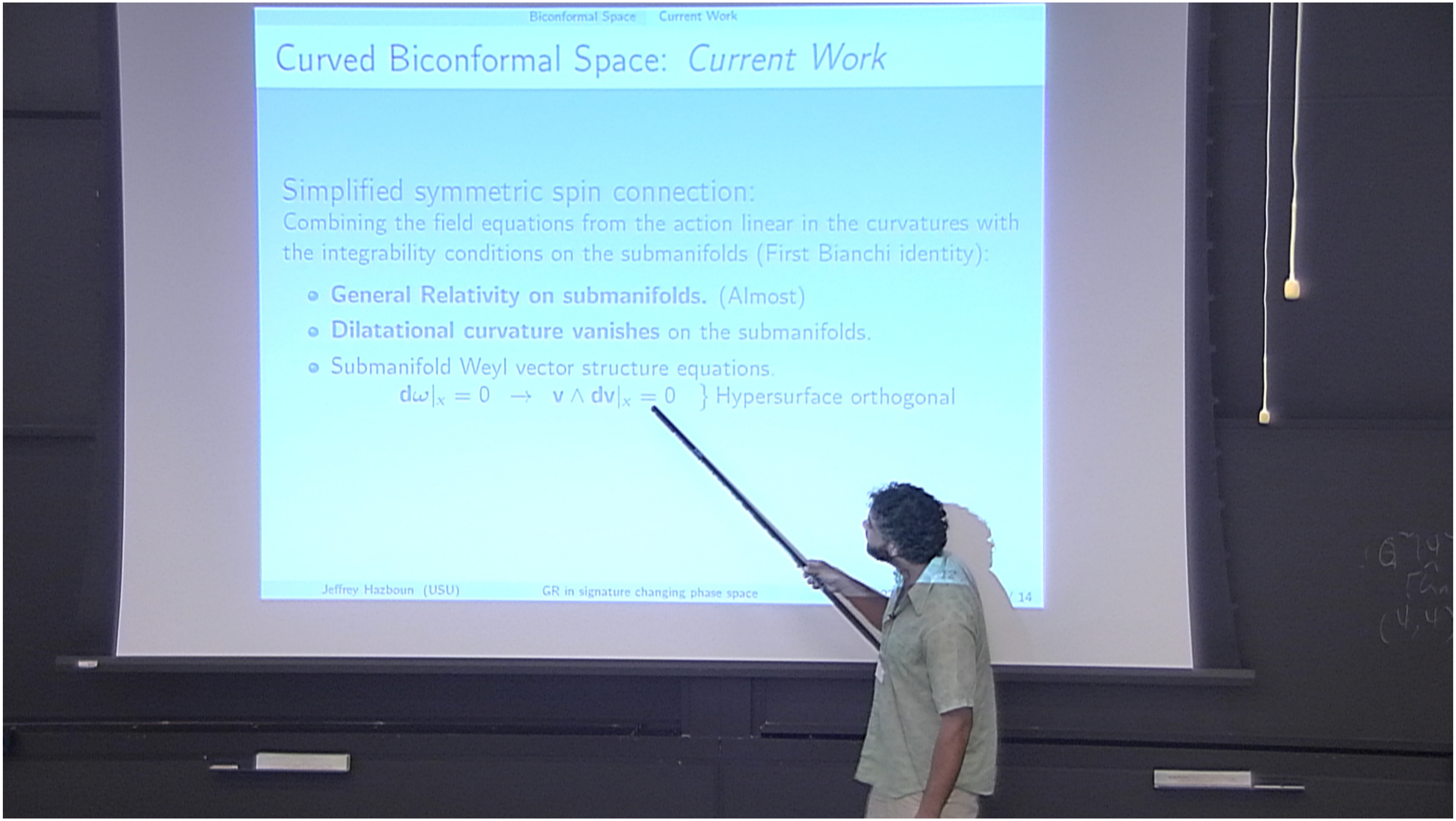
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Biconformal Space Current Work
Biconformal Space and Shape Dynamics
Like Shape Dynamics
Based on ideas about what can be measured.
Scale Invariant theory
The scale invariance is connected to the "flow of time".
Time is an emergent phenomenon.
Time is connected with dynamics.
Agrees with "time-foliated" GR . (Also in CMC gauge)
Extra
Full conformal symmetry
Reference matter.
Gravity in n dimensions
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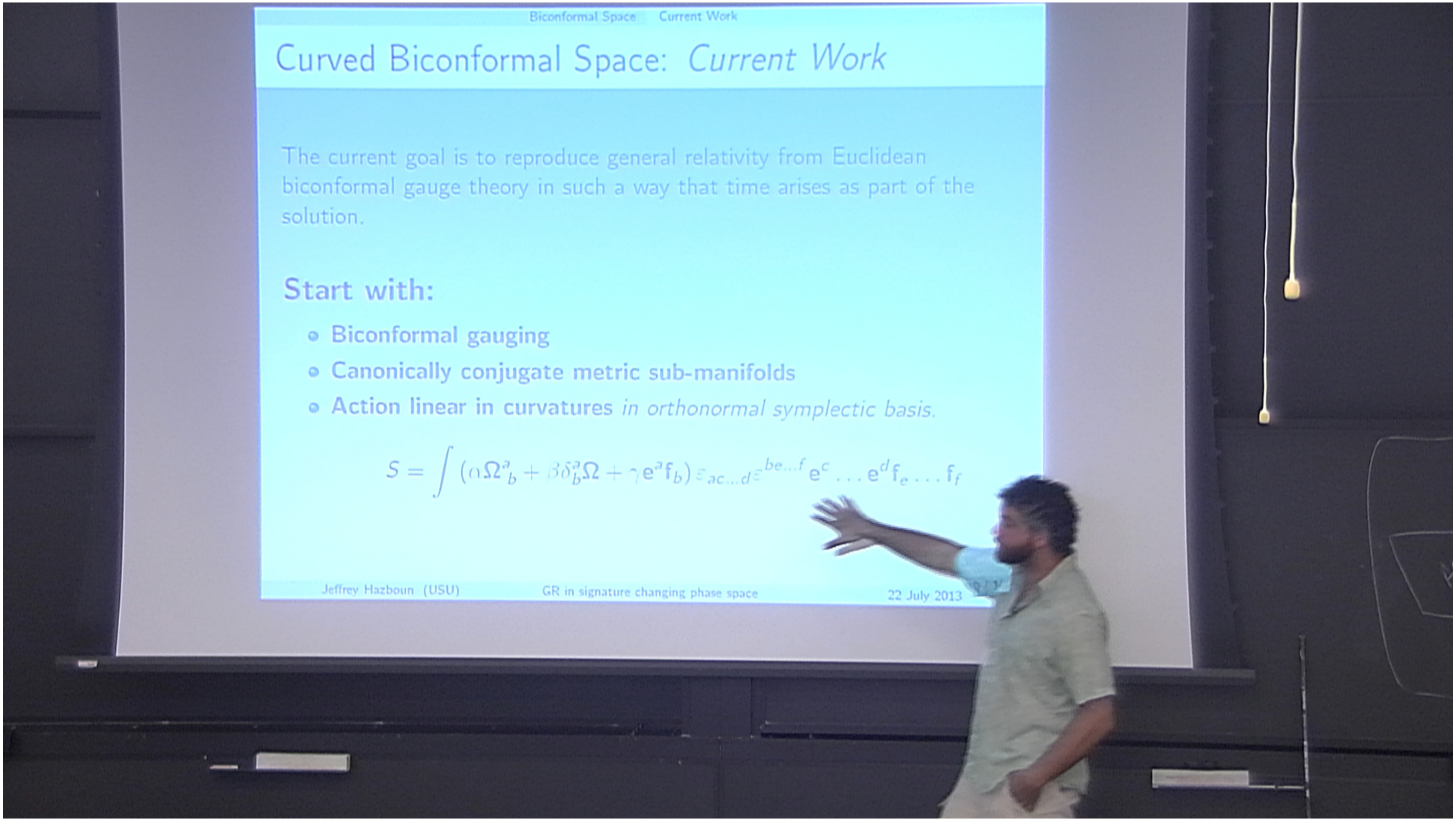
Biconformal Space Current Work
Curved Biconformal Space: Current Work
The current goal is to reproduce general relativity from Euclidean biconformal gauge theory in such a way that time arises as part of the solution.
Start with:
Biconformal gauging
Canonically conjugate metric sub-manifolds
Action linear in curvatures in orthonormal symplectic basis.
$S = \int \left(\alpha \Omega^a{}_b + \beta \delta^a_b \Omega + \gamma e^a f_b \right) \varepsilon_{ac \ldots d} \varepsilon^{be \ldots f} e^c \ldots e^d f_e \ldots f_f$
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