Title: Reconstructing quantum theory from diagrammatic postulates

Date: May 23, 2018 03:30 PM

URL: http://pirsa.org/18050059

Abstract: <p>There has been a dissatisfaction with the postulates of quantum mechanics essentially since the moment that those postulates were first written down. Over the years since there have therefore been many attempts (some successful and some less so) to reconstruct quantum theory from various sets of postulates. The aim being to gain a deeper understanding of the theory by providing a conceptually clear underpinning from which the standard formalism can be derived. In this talk I present recent work with Carlo Maria Scandolo and Bob Coecke (arXiv:1802.00367) in which we reconstruct quantum theory from purely diagrammatic postulates within the process theory framework, showing that the conceptual bare-bones of quantum theory concerns the manner in which systems and processes compose.</p>

Phases of Gravitational Collapse in AdS

Andrew R. Frey

University of Winnipeg

arXiv:1711.00454 with B. Cownden and N. Deppe

also other works with Deppe, Hoult, Kolly, Kunstatter

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Outline

1. Motivation
2. Orientation and Background
3. Phases for a Massive Scalar
4. Connections
5. Ongoing and Future Work

Motivation

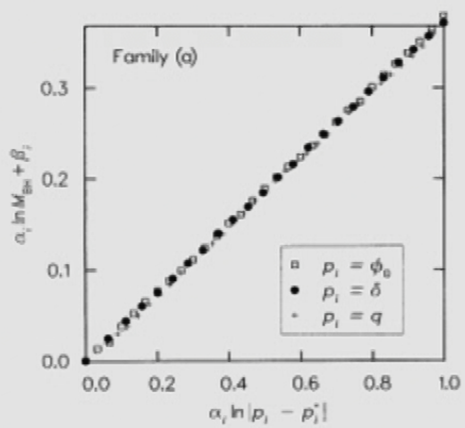
A question for several fields

1. **Motivation**
   - Numerical Relativity
   - Mathematical Physics
   - AdS/CFT Correspondence
2. **Orientation and Background**
3. **Phases for a Massive Scalar**
4. **Connections**
5. **Ongoing and Future Work**

Motivation

Numerical Relativity

Nonlinear test case for dynamics



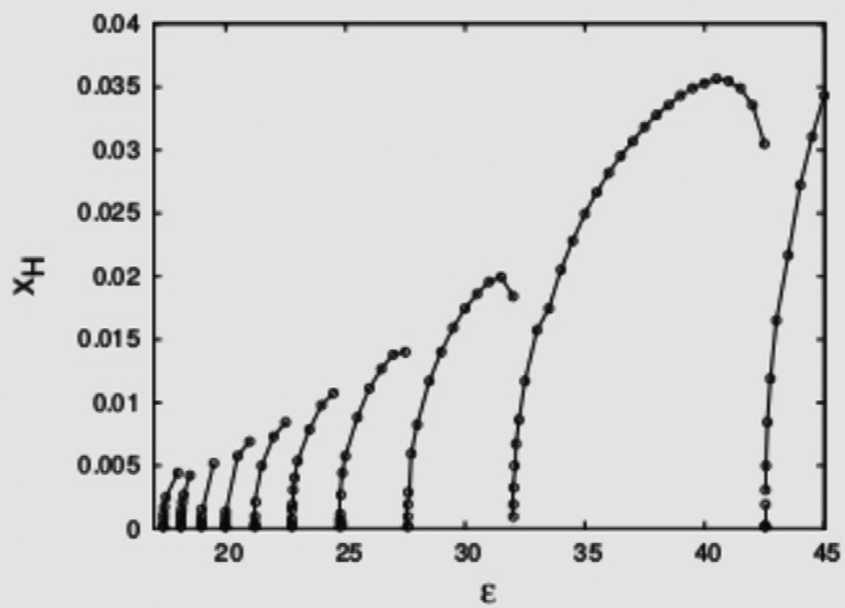
(*Choptuik, PRL70, 9 (1993)*)

Asymptotically flat spacetime

- Initial matter falls in:
  - May form horizon
  - OR disperse
- Critical behavior near transition
  - Initial horizon size follows power law (massless matter)
  - Mass gap for some initial data (massive matter)

Motivation
Numerical Relativity

What about another maximally symmetric spacetime?

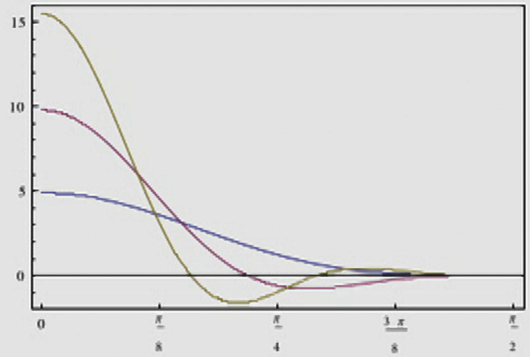


(Bizoń & Rostworowski, arXiv:1104.3702, PRL107, 031102 (2011))

Why aren't more initial data stable against horizons?

Motivation
Mathematical Physics

Evolution of PDE on bounded domain



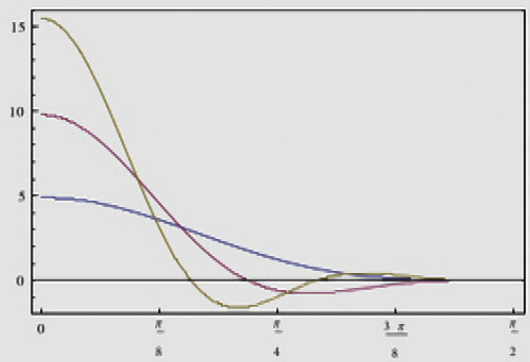
Decompose into AdS eigenmodes

- Resonance, secular growth
- *Weak turbulence:* Flow to higher modes, smaller scales
- BUT high symmetry: quasiperiodic solutions
- What initial data is stable?

Motivation

Mathematical Physics

Evolution of PDE on bounded domain



Decompose into AdS eigenmodes

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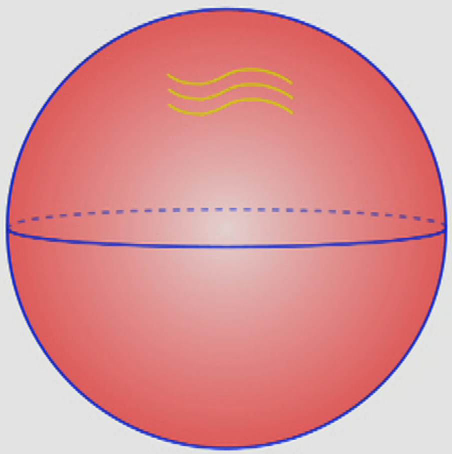
Applicable to other systems, eg, Gross-Pitaevski equation (*Biasi et al*)

Motivation
AdS/CFT Correspondence

Thermalization of CFT on sphere



Gravity/strings on global AdS

- CFT on spherical boundary
- Black hole = thermal state

Quench a thermal state:

- How long to thermalize?
- Perturbations of the black hole
- Related to hydrodynamics
  Qualitatively like ion collisions

Motivation
AdS/CFT Correspondence

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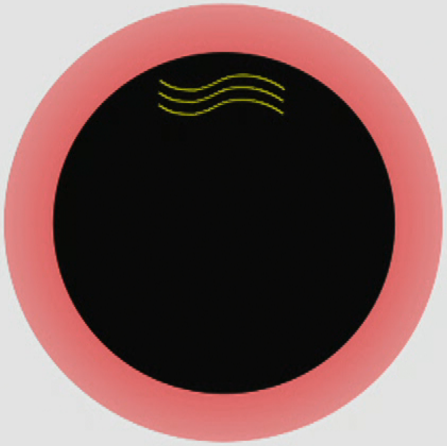

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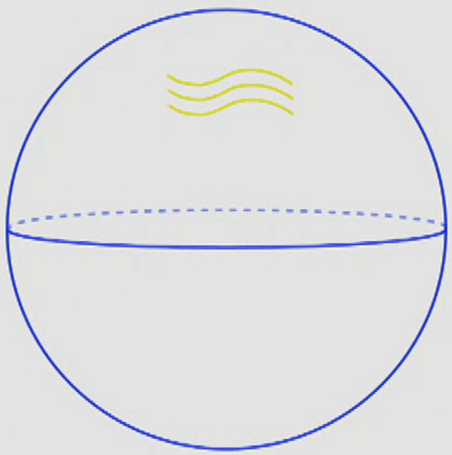
Analogy: stirring tea, then watching slight temperature increase
Close to equilibrium

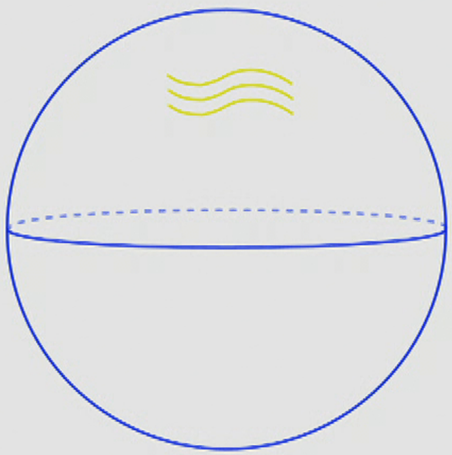
Motivation
AdS/CFT Correspondence



Putting matter in empty AdS:

- How long to horizon formation?
- Heating vacuum state
- What distributions thermalize? How long does it take?
- Far from equilibrium dynamics

Motivation
AdS/CFT Correspondence



Putting matter in empty AdS:

- How long to horizon formation?
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- What distributions thermalize? How long does it take?
- Far from equilibrium dynamics

Heating from absolute zero

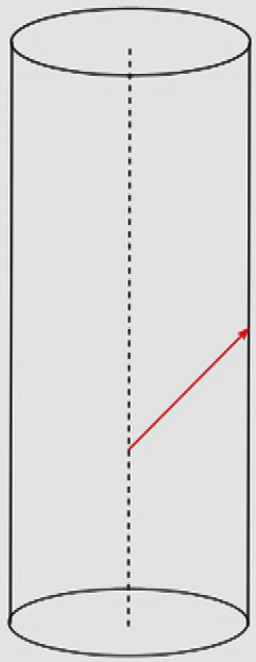
(April in Winnipeg)

Orientation and Background

Refresher and primer

Orientation and Background
AdS Geometry

$$ds^2 = \sec^2(x)\left(-Ae^{-2\delta}dt^2 + A^{-1}dx^2 + \sin^2(x)\,d\Omega^2\right)$$



AdS has a boundary

- Massless waves to $r = \tan x = \infty$ in $t = \pi/2$
- Bounce back to origin, no dispersion
- Massive fields have gravity well

Schwarzschild-like coordinates

- Horizon at $A = 0$
- $\delta =$ time dilation
- $M' =$ mass in shell at x
- Original studies in AdS_4; here AdS_5

Orientation and Background
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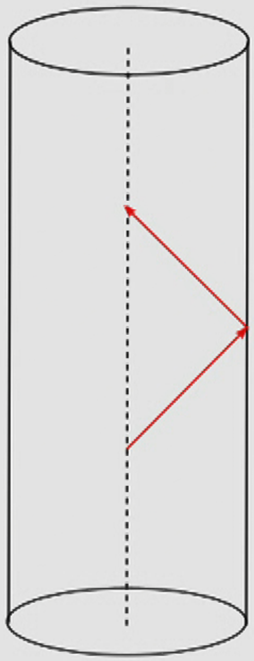

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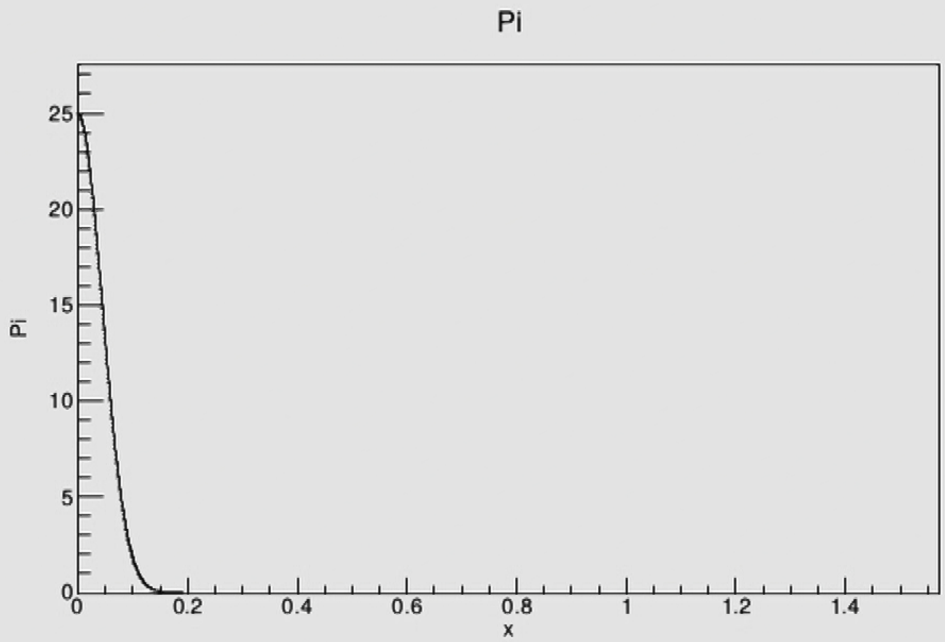
Orientation and Background
Wave Motion in AdS

Numerical evolution of Einstein & Klein-Gordon

Massless: ‣ Field Evolution ‣ Mass Evolution ‣ Horizon Function

Massive: ‣ Mass Evolution



Orientation and Background

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Massless: ▸ Field Evolution ▸ Mass Evolution ▸ Horizon Function

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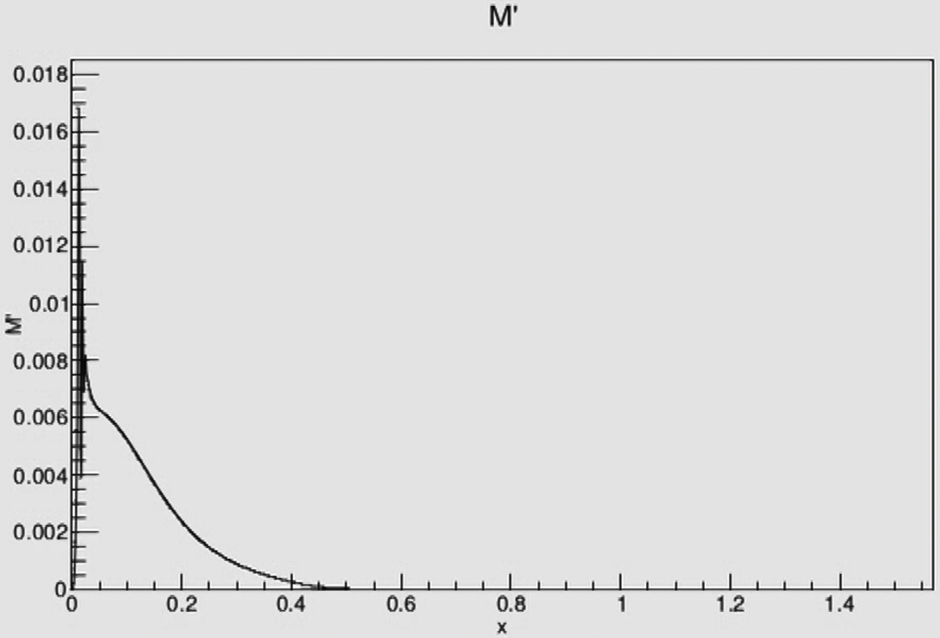
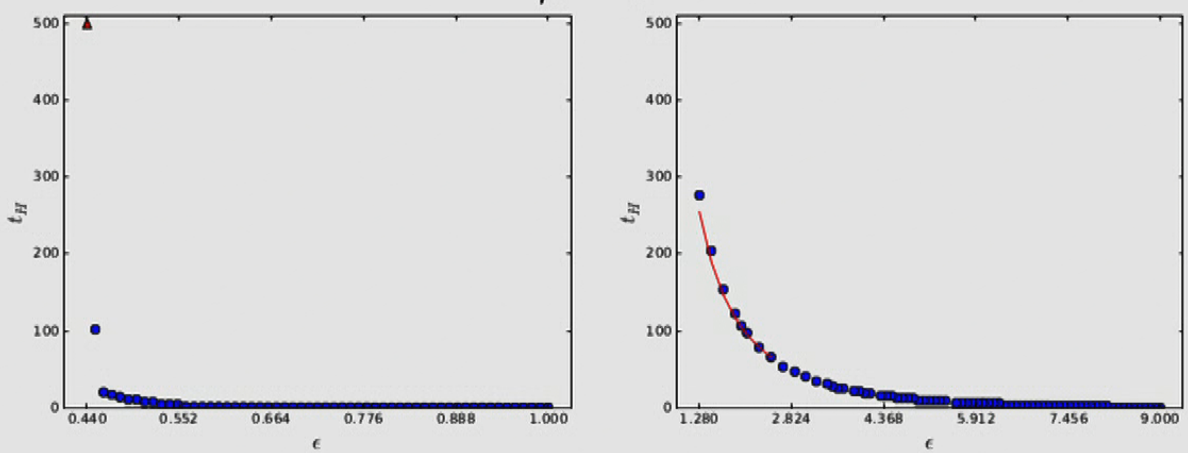


Orientation and Background
Stability vs Instability

Want behavior at arbitrarily small amplitude

$\mu = 0$



$\sigma = 1.5$ $\sigma = 0.25$

- Gaussian initial data in Π, width σ
- $t_H \approx a\epsilon^{-2} + b$ for ϵ small

Phases for a Massive Scalar

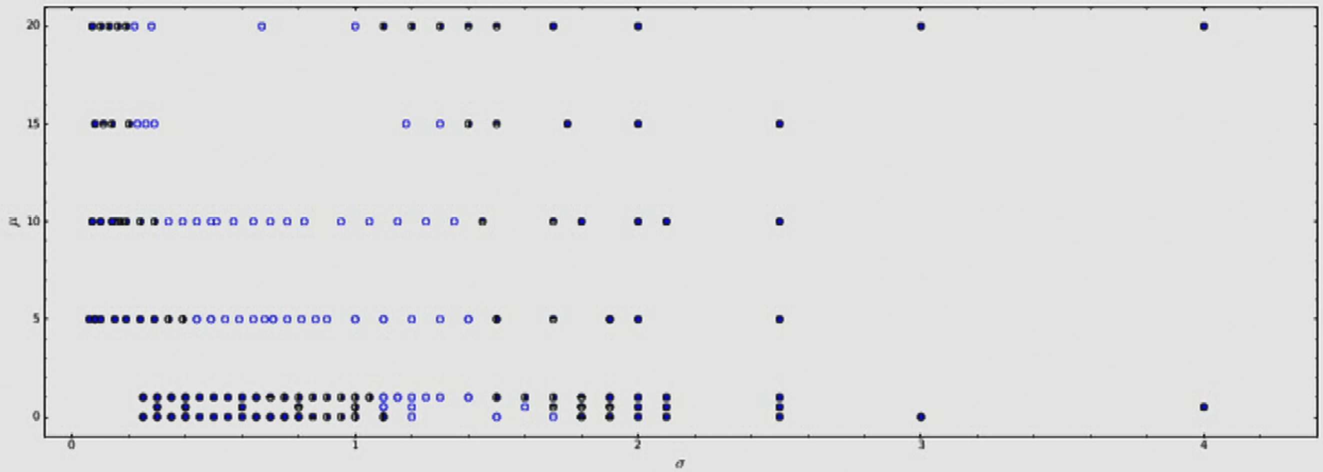
Tune field mass and initial width

1. **Motivation**
2. **Orientation and Background**
3. **Phases for a Massive Scalar**
   - Phase Diagram
   - Unstable Phase
   - Metastable Phase
   - Irregular Phase
4. **Connections**
5. **Ongoing and Future Work**

Phases for a Massive Scalar

Phase Diagram

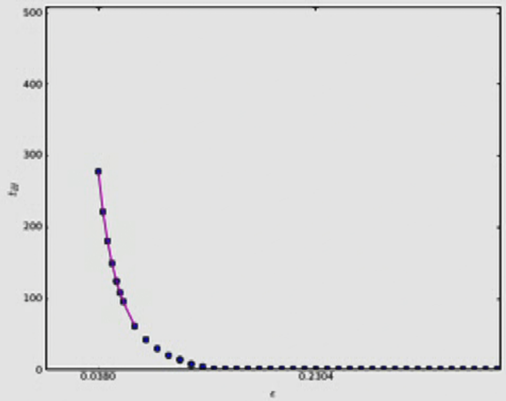
Island of stability



- Stable region larger but at smaller σ for larger μ
- Nonperturbative phases appear

Phases for a Massive Scalar
Unstable Phase

Horizon formation extends to perturbative regime



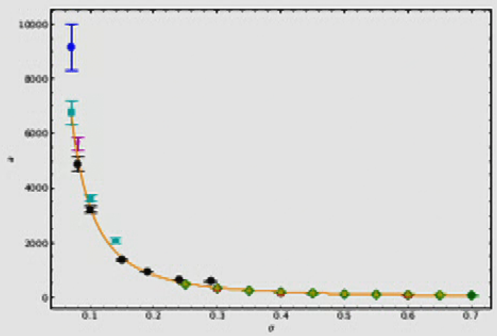
$$t_H = a\epsilon^{-p} + b$$

- Fit for large t_H
- Unstable if $p \approx 2$

Parameters vs μ, σ

- At small σ

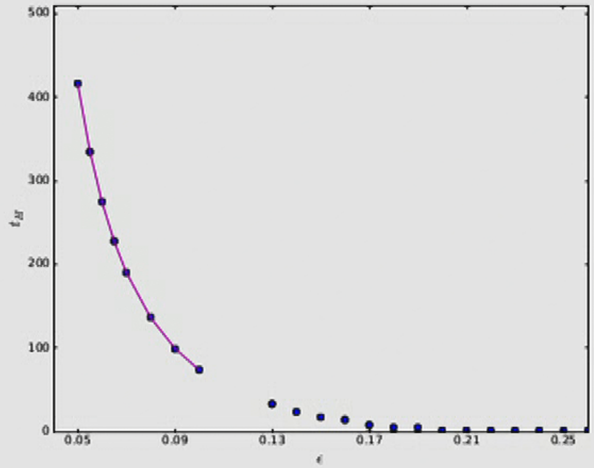
$$a \propto \sigma^{-2}$$



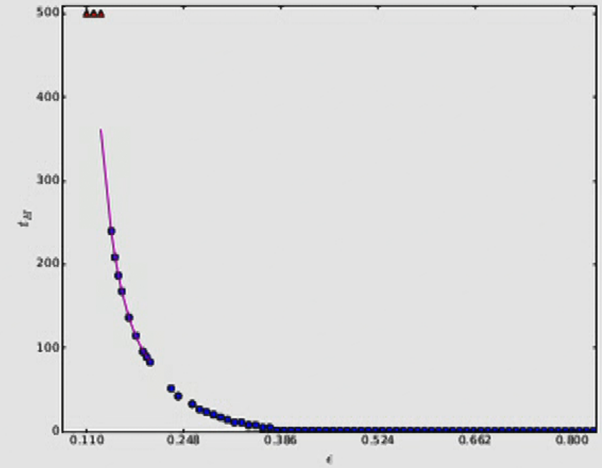
- Independent of μ
- Quality of fit?

Phases for a Massive Scalar
Metastable Phase

Horizon forms later



$\mu = 5, \sigma = 1.7$



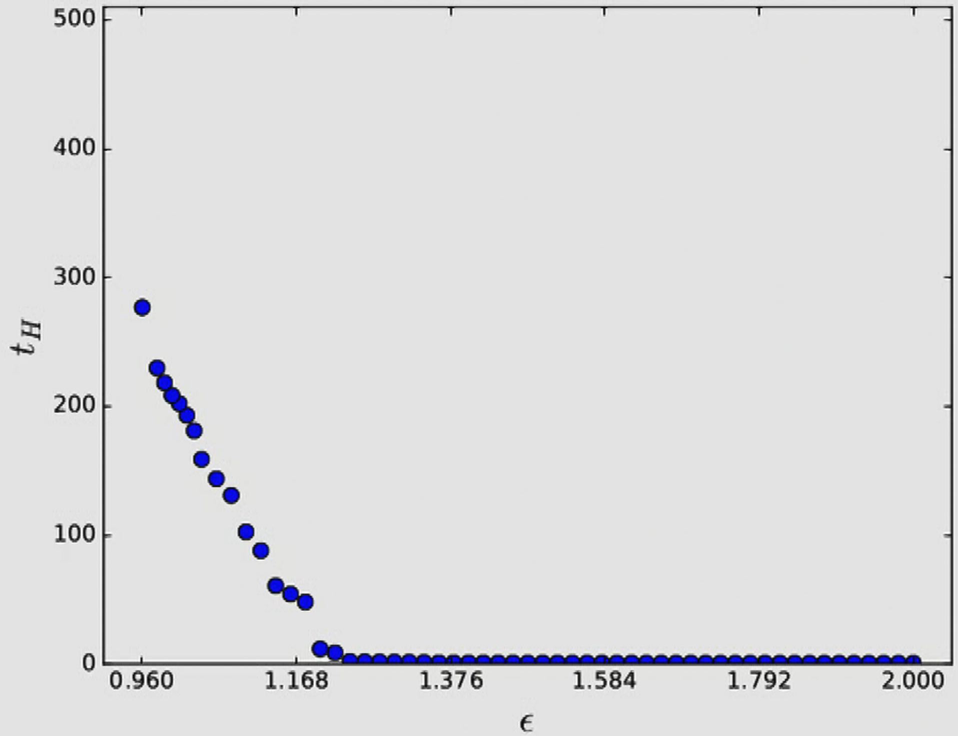
$\mu = 0, \sigma = 1.8$

- Stable or unstable at small amplitude?

Phases for a Massive Scalar

Irregular Phase

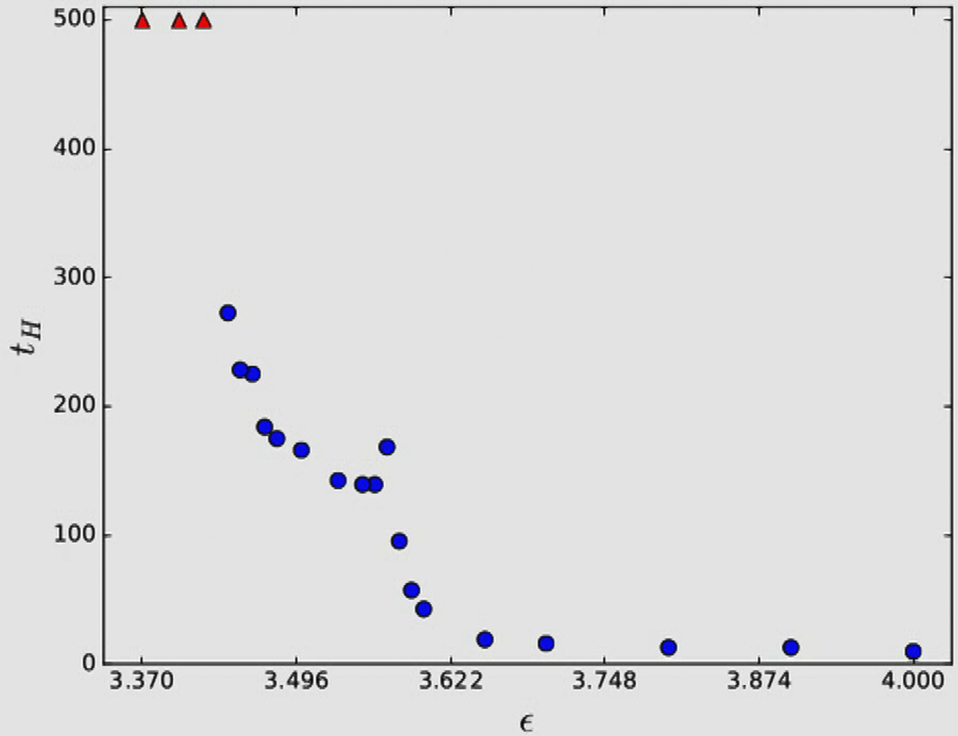
Variety of behaviors



$\mu = 0.5, \sigma = 1$

Phases for a Massive Scalar
Irregular Phase

Variety of behaviors

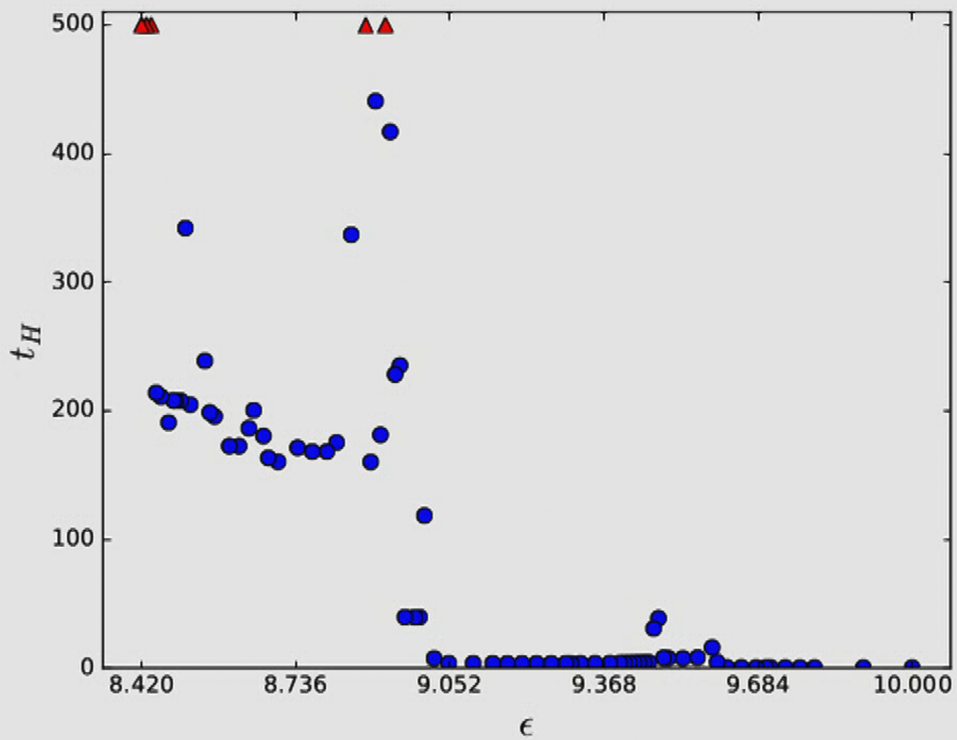


$\mu = 5, \sigma = 0.34$

Phases for a Massive Scalar

Irregular Phase

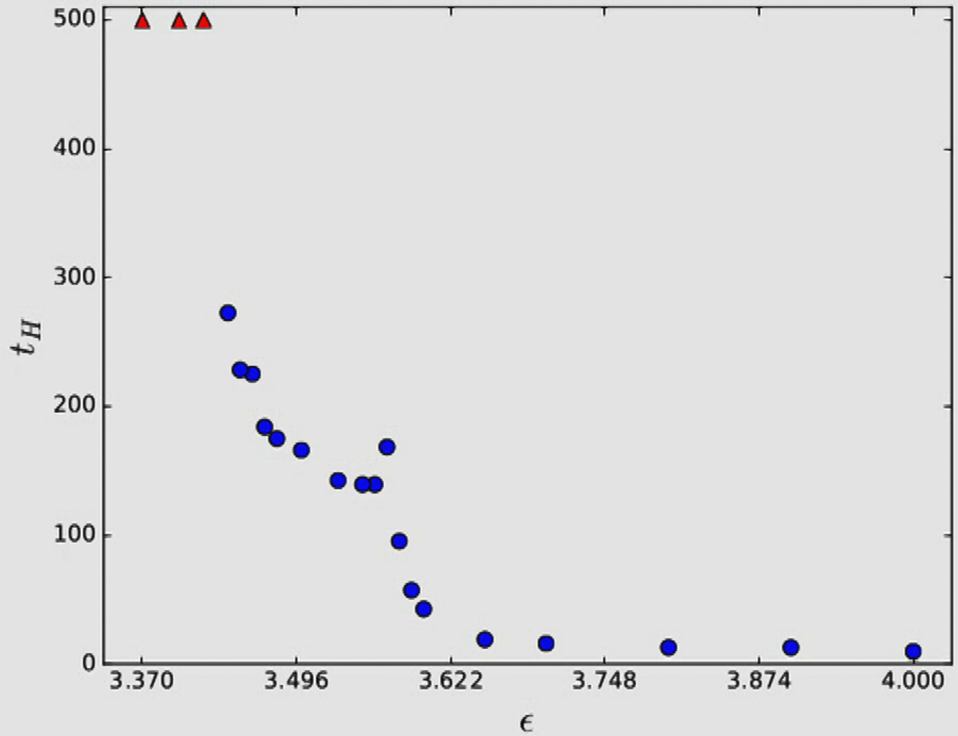
Variety of behaviors



$\mu = 20, \sigma = 0.16$

Phases for a Massive Scalar
Irregular Phase

Variety of behaviors

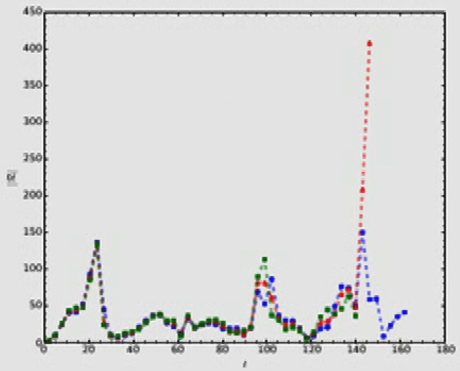


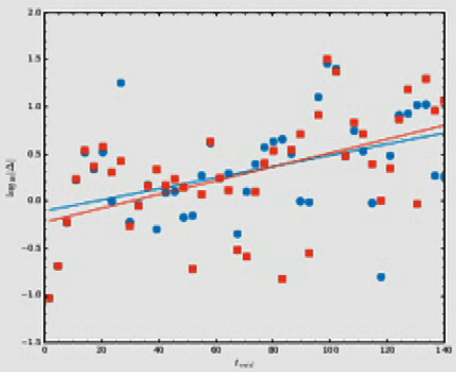
$\mu = 5, \sigma = 0.34$

Phases for a Massive Scalar

Irregular Phase

Chaotic behavior





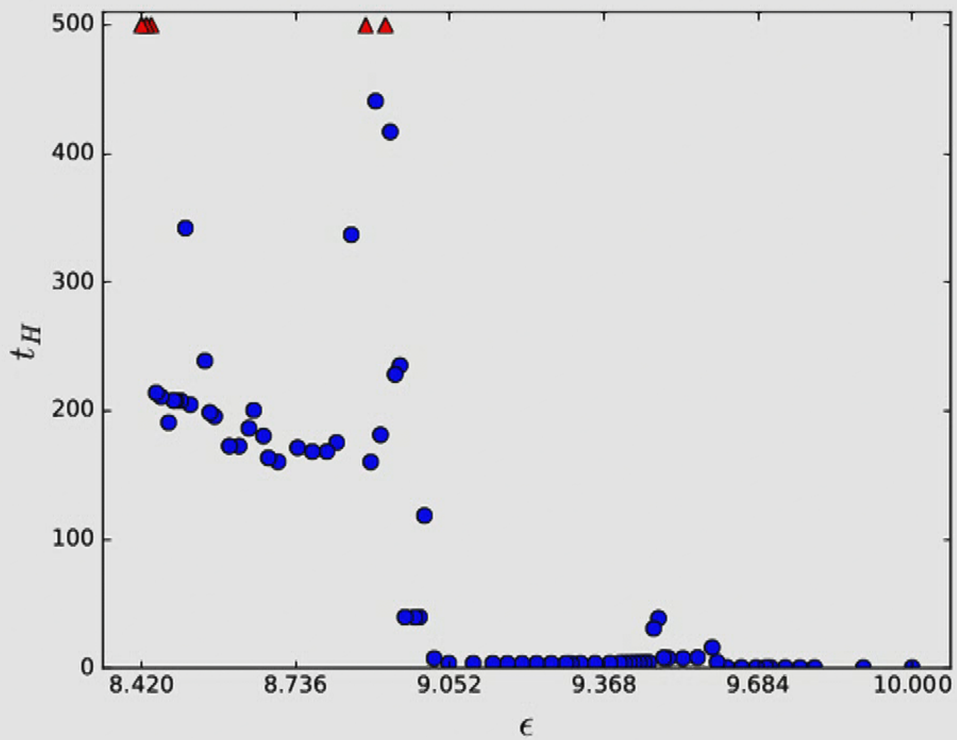
3 similar amplitudes in chaotic region

- Find Ricci scalar at origin
- Difference as function of time
- Exponential growth:
  nonzero Lyapunov coefficient
- Even for “non-monotonic” case
- Evidence for massless scalar

Phases for a Massive Scalar

Irregular Phase

Variety of behaviors



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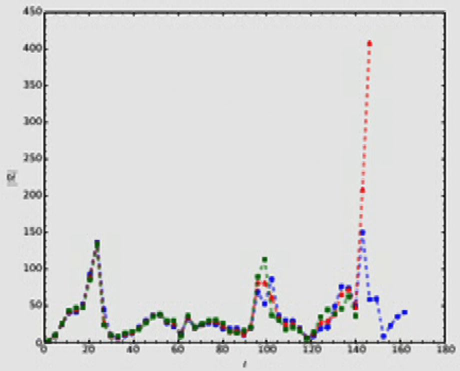
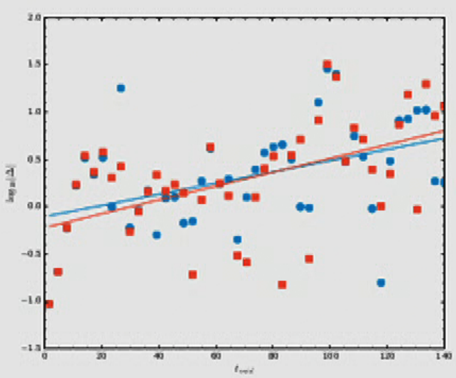
Phases for a Massive Scalar
Irregular Phase

Chaotic behavior





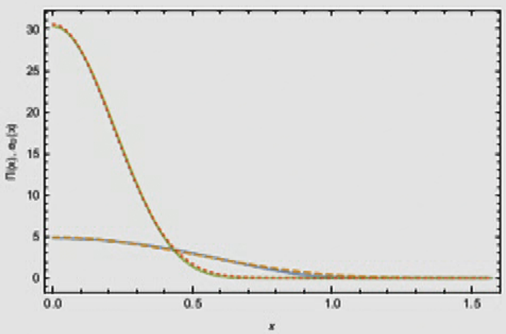
3 similar amplitudes in chaotic region

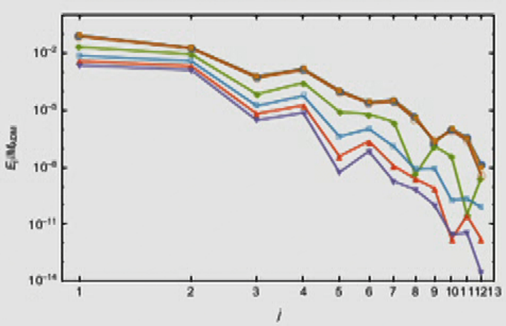
- Find Ricci scalar at origin
- Difference as function of time
- Exponential growth: nonzero Lyapunov coefficient
- Even for "non-monotonic" case
- Evidence for massless scalar

Connections

Oscillons, Boson Stars, & Geons, Oh My!

Stable solutions based on single eigenmodes





- Known nonlinear stability
- More general perturbative extension

Behavior of island of stability

- Fit Gaussian to lowest eigenmode
- Fit improves at larger μ
- Spectrum more concentrated as $\mu \uparrow$
- Stable region larger for large μ
  Moves to smaller σ

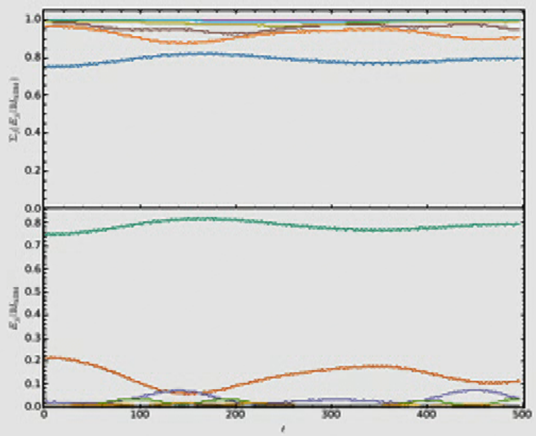
Connections
Cascades and Inverse Cascades

Energy cannot all flow to smaller scales

Perturbative conservation laws require inverse cascades

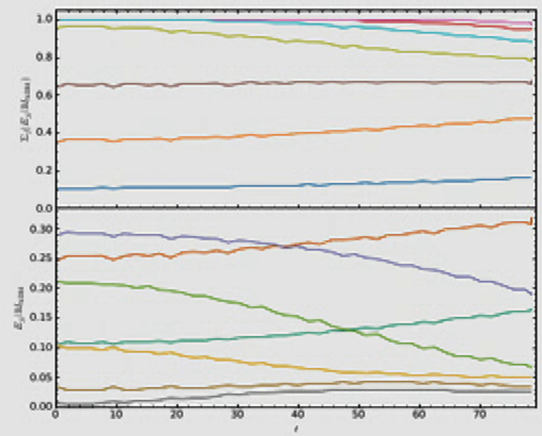
(*Buchel et al, Craps et al*)

Stable



$\mu = 0, \sigma = 1.8, \epsilon = 0.13$

Unstable



$\mu = 0, \sigma = 0.25, \epsilon = 2.28$

Connections
Cascades and Inverse Cascades

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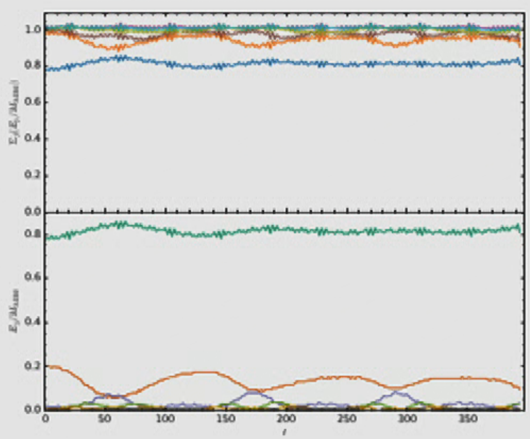
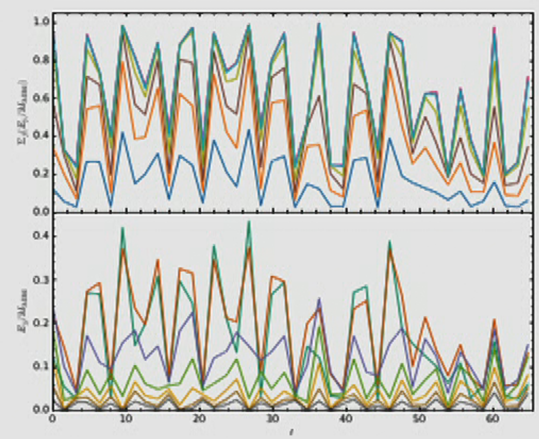
(*Buchel et al*, *Craps et al*)

Metastable



$\mu = 0.5, \sigma = 1.7, \epsilon = 0.216$

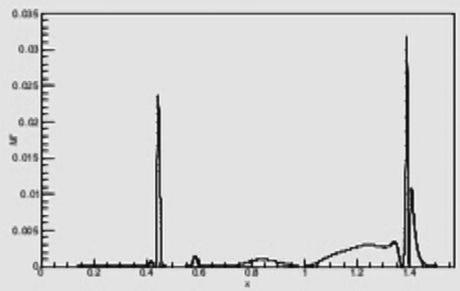
Irregular



$\mu = 20, \sigma = 0.19, \epsilon = 6.95$

Connections
Chaos in Collapse

Mechanism responsible for chaos?



Two-shell model

- Actual interacting shells

  (*Brito et al*)
- Pulse fragmentation with GB term

  (*Deppe, Kolly, AF, Kunstatter*)
- Sufficient energy in one shell

Secondary wave?

- Pulse does not fragment
- Need constructive interference?

Connections
Chaos in Collapse

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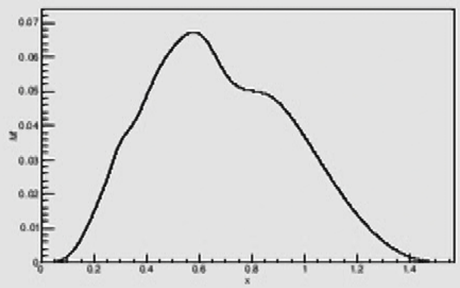

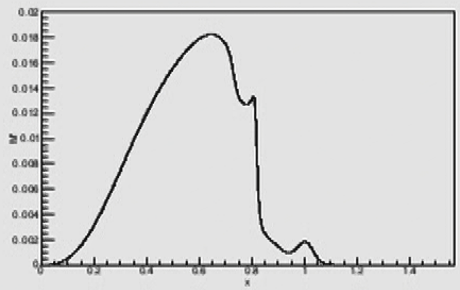

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Ongoing and Future Work

Ongoing and Future Work

- Understand quasiperiodic perturbative solutions (*w/Cownden, Deppe*)
- Perturbative description of massive scalars (*Cownden*)
- Stability of forced boundary conditions (*w/Deppe, Hoult*)
  Related to other work (*Bhattacharya & Minwalla, Awad et al, Carracedo et al*)
- Moving beyond spherical symmetry (*w/Hoult*)

Summary

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THANK YOU