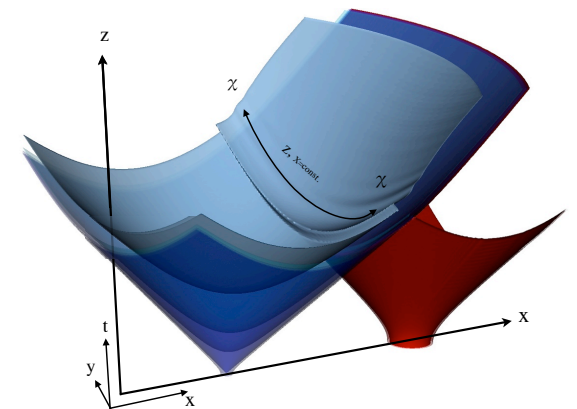
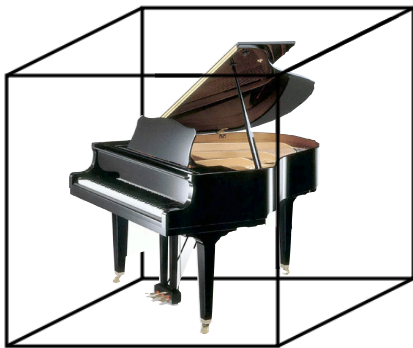


Testing Theories of the High-z and Super-Early Universe

Anthony Aguirre



On the front burners

- **Me:**
 - **Arrived 2003** (Postdoc IAS Princeton, PhD Astronomy Harvard.)
 - Cosmology, broadly construed.
- **Group(s):**
 - Scipp theory (Michael, Tom, Howie, Stefano)
 - Astronomy (Piero Madau and others)
- **Current students & postdocs:**
 - Jonathan Kozaczuk (with Stefano)
 - Max Wainwright (with Stefano)

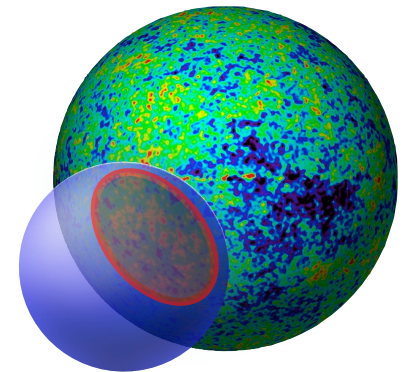
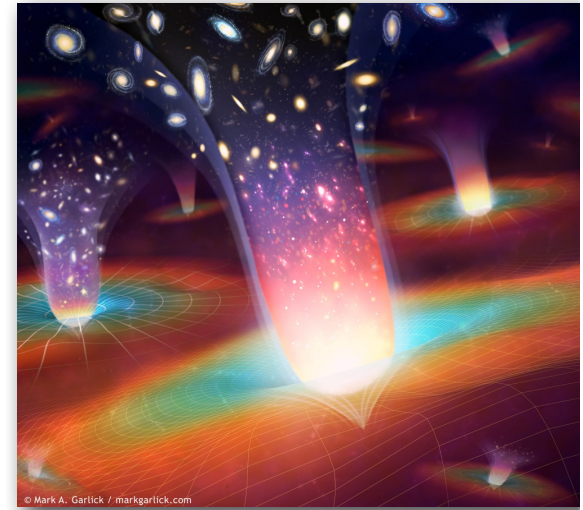
On the front burners

- **Inflation and eternal inflation**

- When and how does ‘eternal inflation’ occur?
- What is the large-scale structure of an eternal inflating universe?
- Given inflation, need there be an initial singularity?
- How do transitions between inflationary ‘vacua’ occur?
- What is the inflationary “multiverse” and how can we test it?
- Might there be observable signatures of eternal inflation?

- **Fundamental Physics**

- How do we interpret quantum theory in an infinite universe?
- How do we think about time in eternal systems?



On the back burners

- **Black holes:**

- What fun things can happen in the interior of a realistic Kerr black hole?
- What to make of black hole complementarity and ‘firewalls’.

- **Enrichment of the intergalactic medium (IGM)**

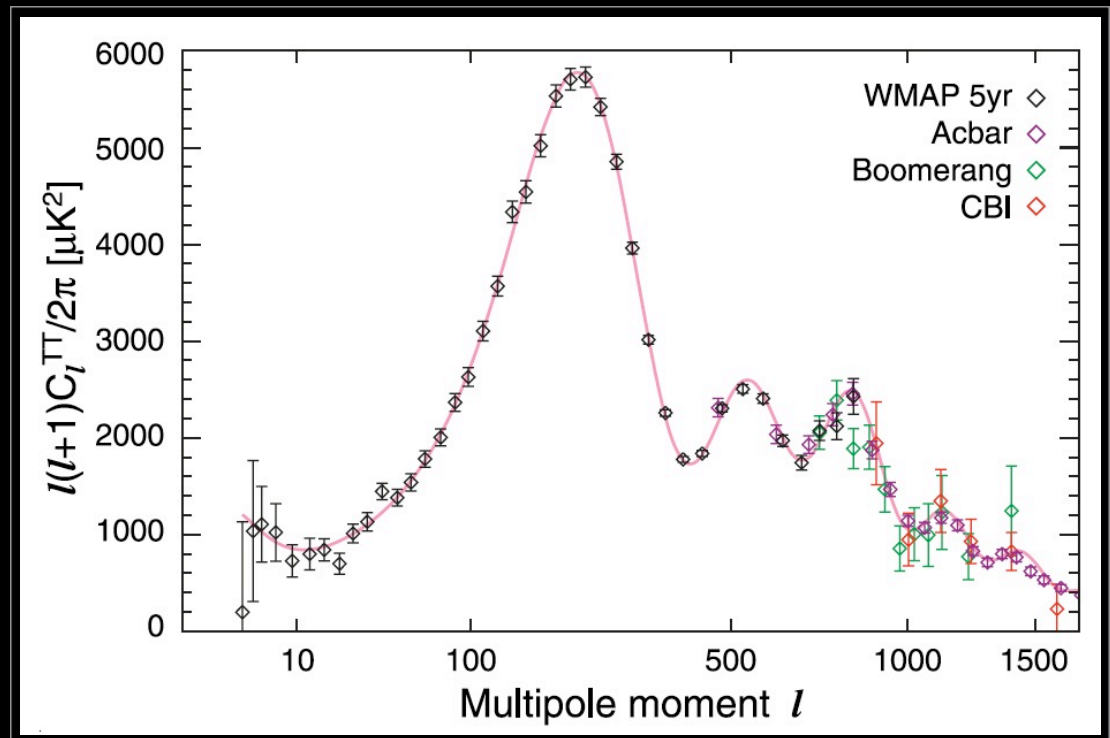
- How did the IGM get enriched with the heavy elements?
- What does this tell us about feedback in galaxy formation?
- What does this tell us about Pop. III? About reionization?

- **Dark matter:**

- Dark matter annihilations and the first stars.
- Modified gravity and dark matter.

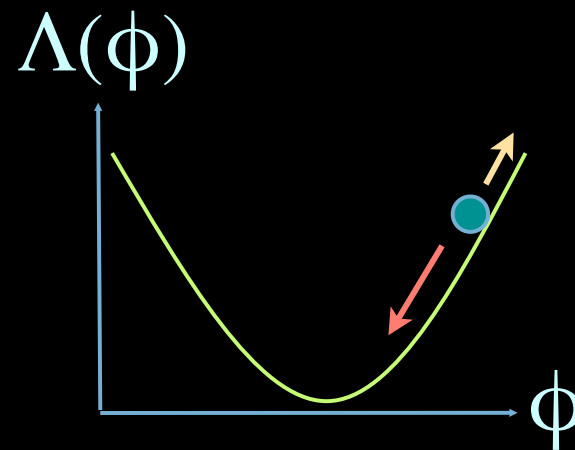
Inflation

- ◆ Basic idea: **exponential** expansion at very early times.
- ◆ Provides:
 - ◆ Expansion
 - ◆ Flatness
 - ◆ Uniformity
 - ◆ Fluctuations



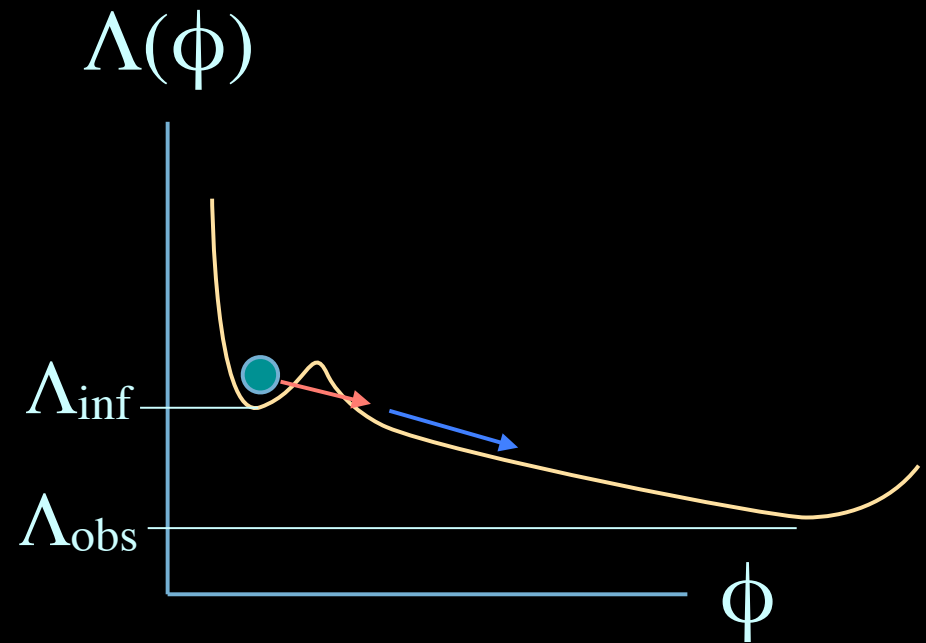
Ending Inflation

- ◆ Driven by vacuum energy, but *dynamical*.
- ◆ Leads to 'field ϕ ', with 'potential' $\Lambda(\phi)$.
- ◆ Handy: description is just like a ball on a slope: **gravity** and friction.
- ◆ Field evolves toward Λ_{obs} , where inflation ends.



Failing to end inflation: Is inflation everlasting?

- ◆ The “double-well”:
 - ◆ **Tunneling** nucleations bubble of new phase.
 - ◆ **Inflation** inside.
 - ◆ but new phase *fails to take over*.

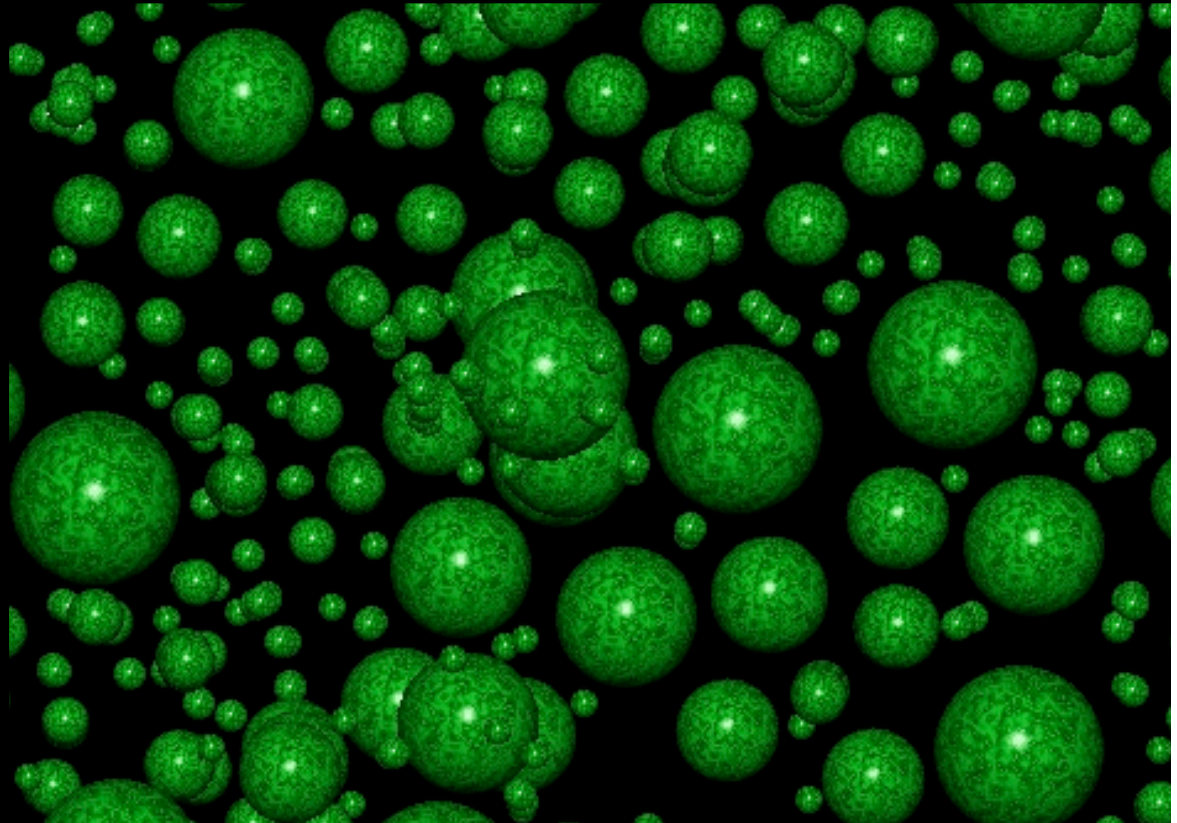


Λ_{inf}



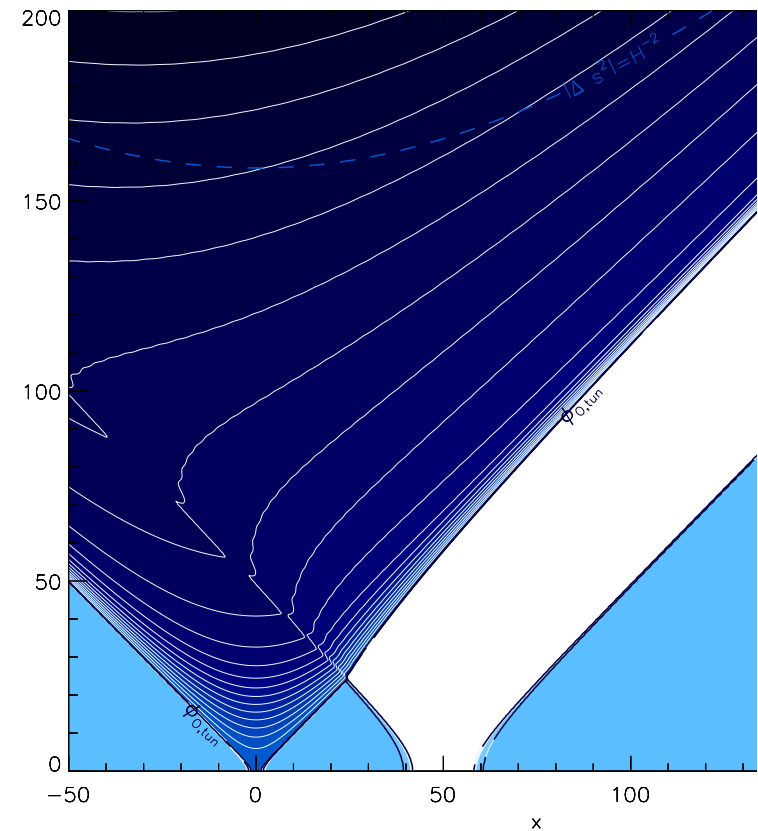
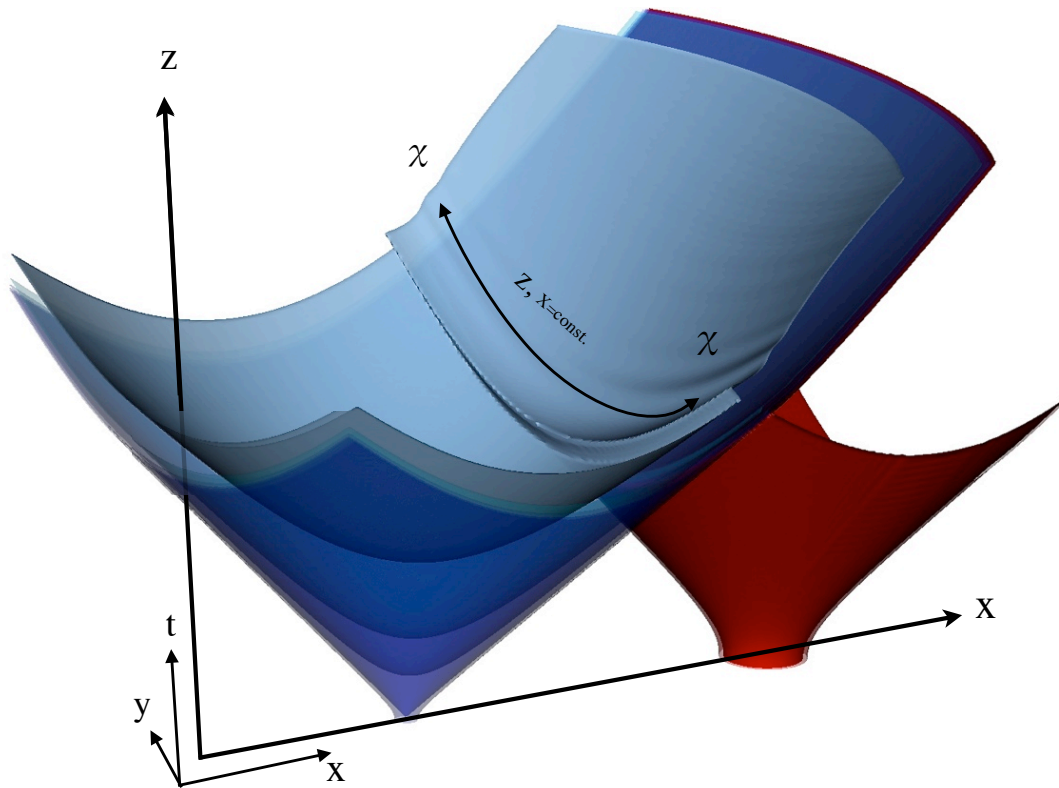
Everlasting bubbly inflation

- ◆ Expanding sea of inflation.
- ◆ Pocket universes fill in interstices, grow.



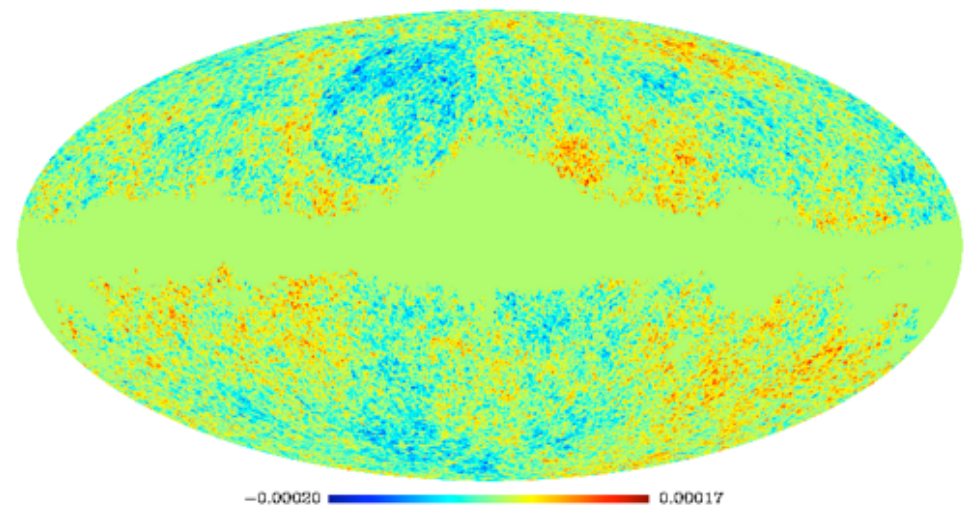
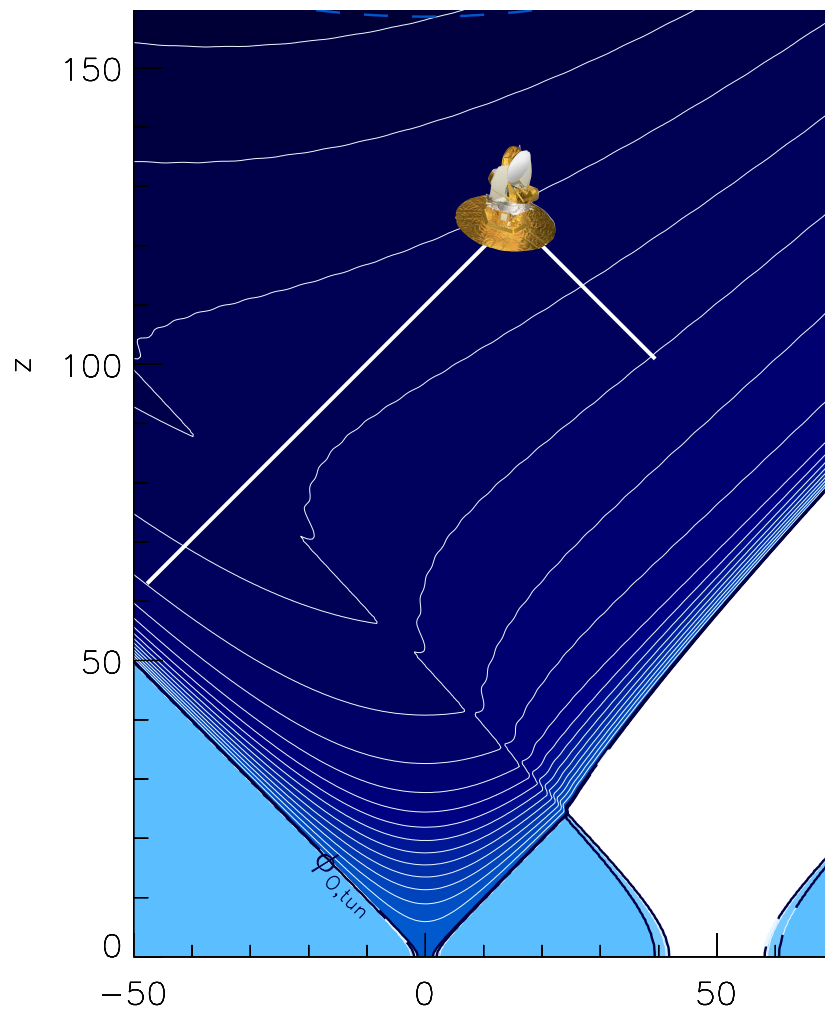
Can we observe other bubble “universes”?

Bubbles collide!



Can we observe other bubble “universes”?

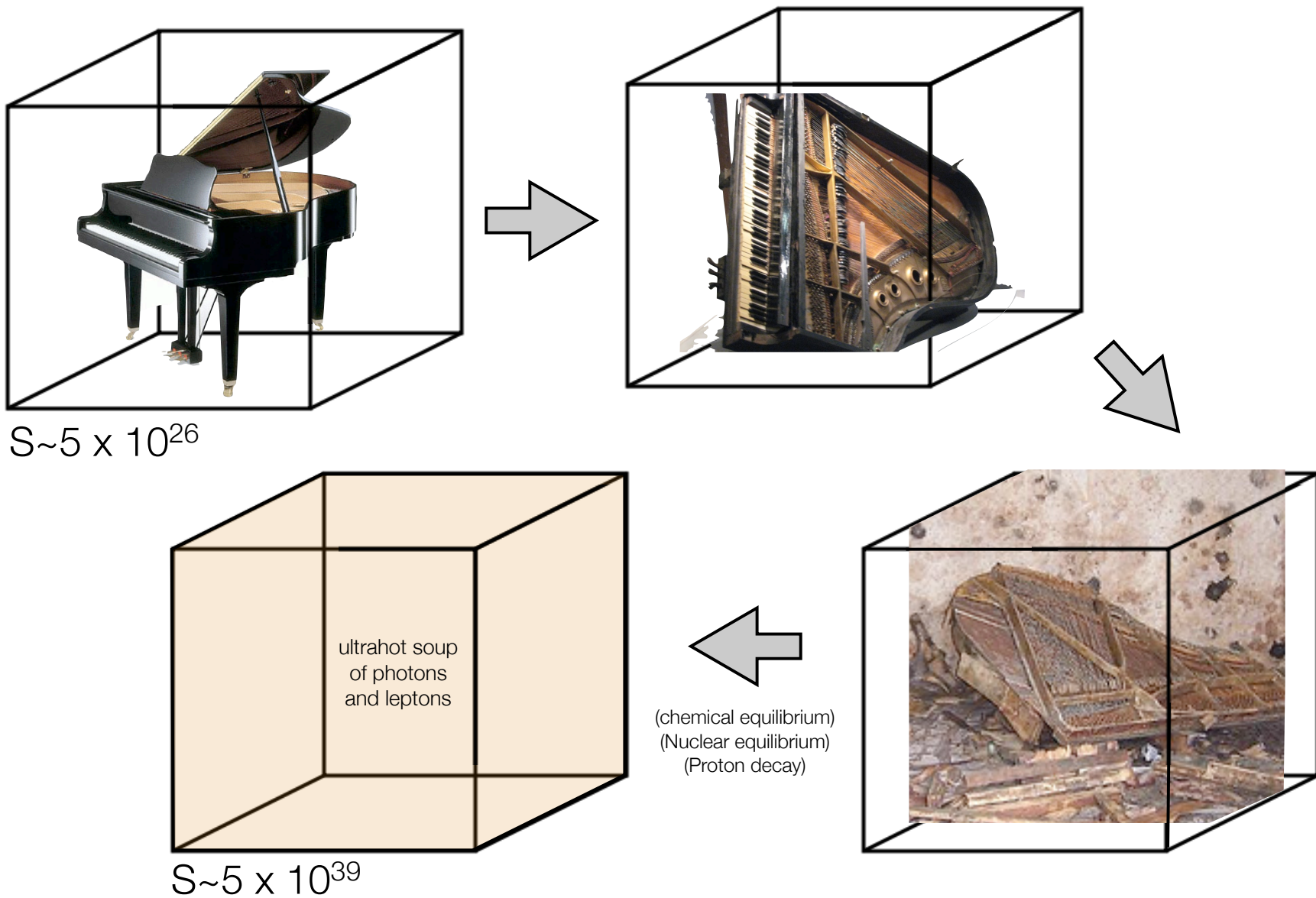
What could we see?



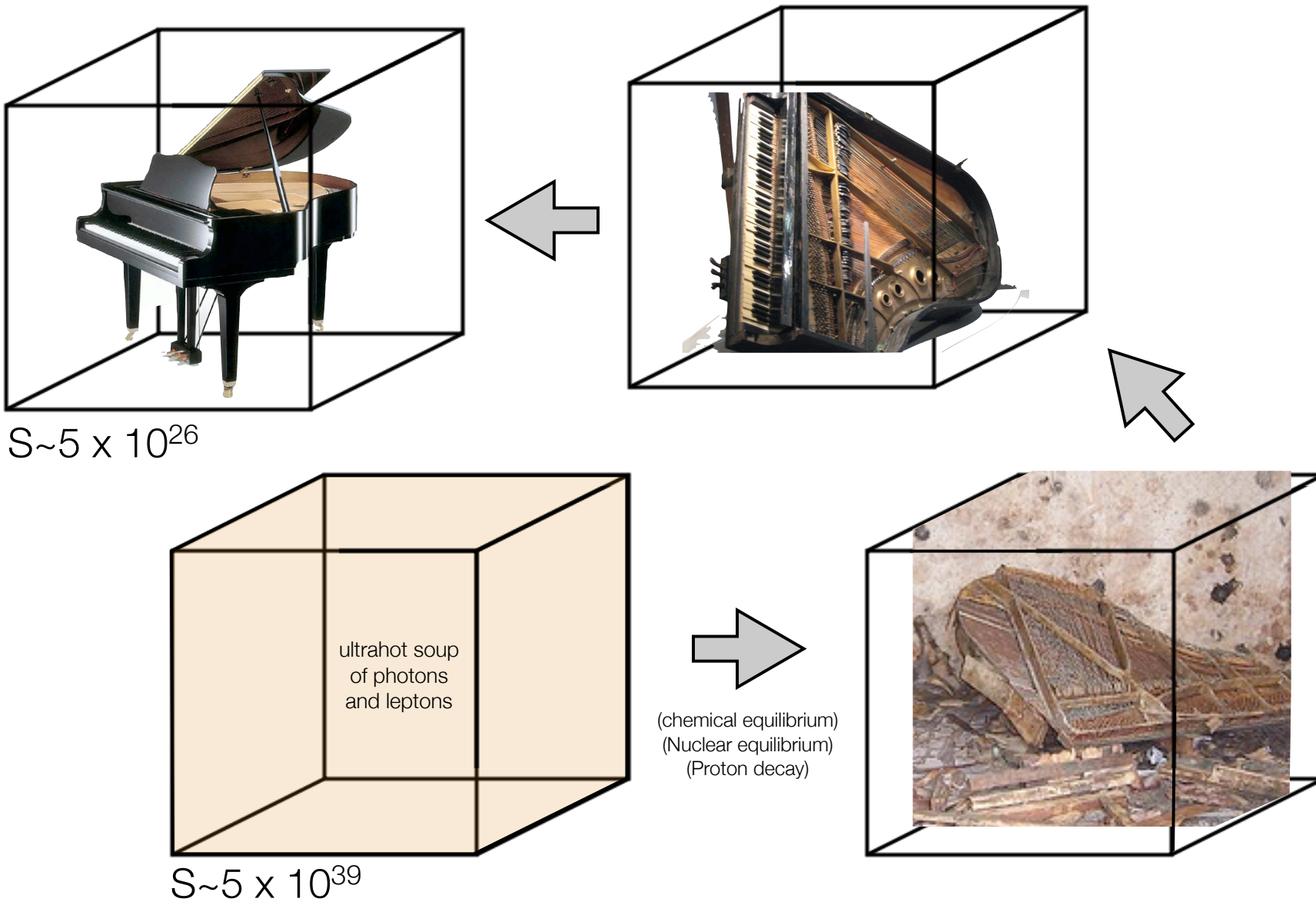
Some current/possible/pondered projects:

- Bubble Collisions:
 - Deeper analysis of link between collisions and cosmological observables:
 - Multiple collisions (Jon K.)
 - 1+1D GR simulations of bubble collisions (Max W.)
 - Analysis of Planck data (Matt Johnson, Hiranya Peiris and UCL collaborators; Max W.)
 - Other processes like decompactifications; collisions between different #s of large dimensions; collisions between bubbles with uncoupled fields.

Entropy decrease in closed systems

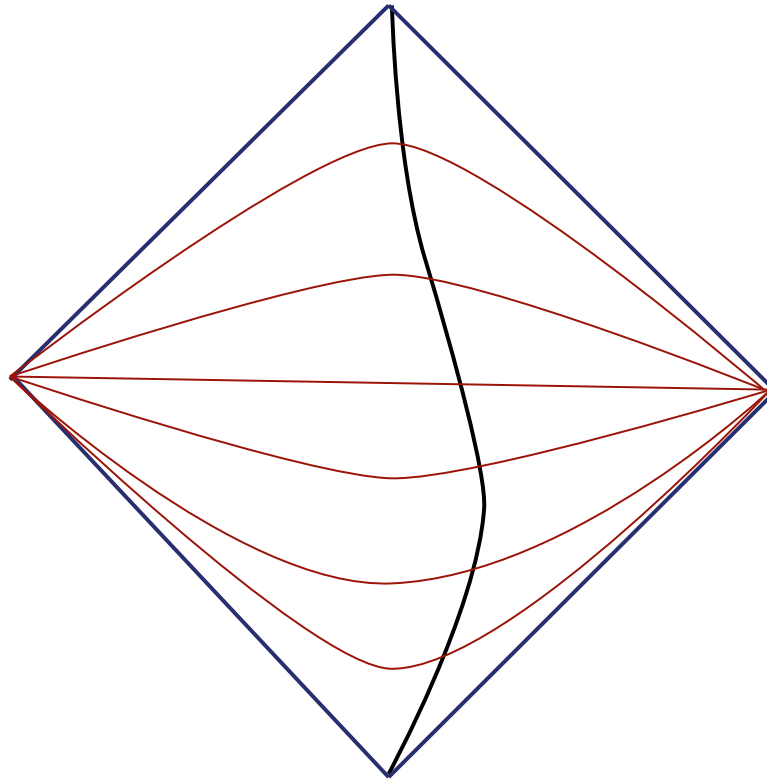


Entropy decrease in closed systems



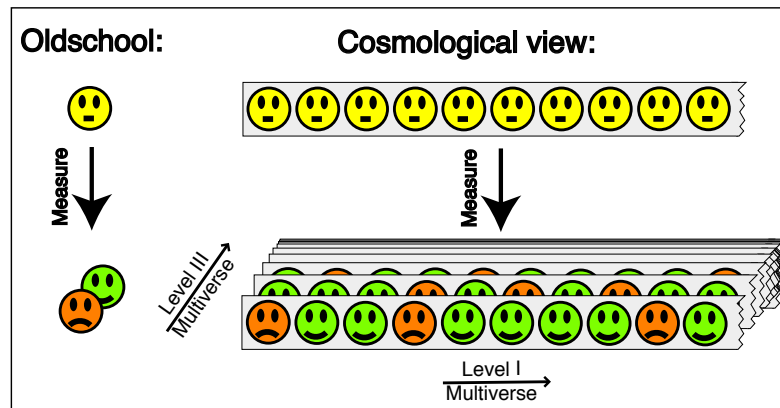
Some current/possible/pondered projects:

- Relativistic closed systems in general (Jon K.)

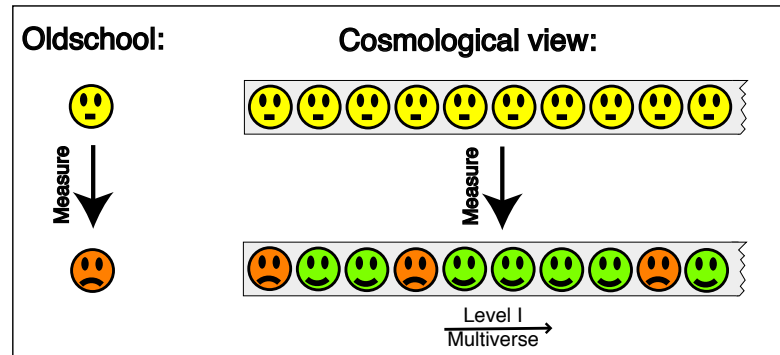


Strange issues in infinite universes

EVERETT (NO WAVEFUNCTION COLLAPSE)



COPENHAGEN (WAVEFUNCTION COLLAPSES)

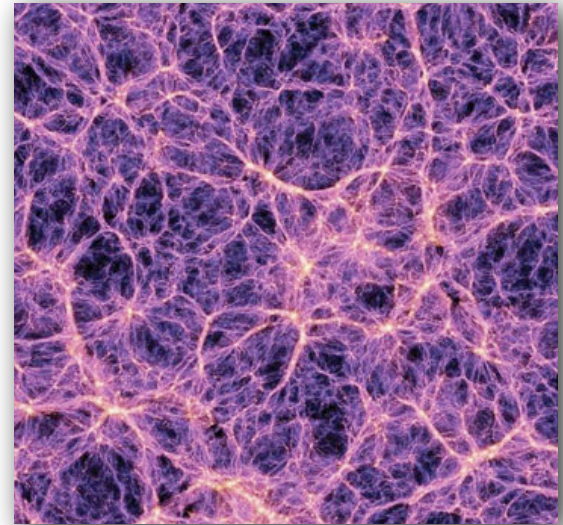
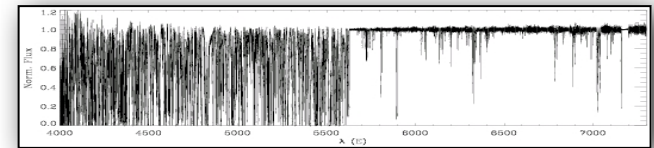


Some current/possible/pondered projects:

- Cosmological interpretation of quantum mechanics vs. 'multiverse interpretation' of quantum mechanics.
- Past-eternal cosmologies: which are possible and which are not? (Emergent universe with John K@IPMU)
- A 'double standard' in the eternal inflationary arrow of time.

Some current/possible/pondered projects:

- Dark stars, Pop. II, and the IGM.



Some current/possible/pondered projects:

- Baby universes inside black holes. (Tegmark and Hamilton)



<http://jila.colorado.edu/~ajsh/insidebh/realistic.html>