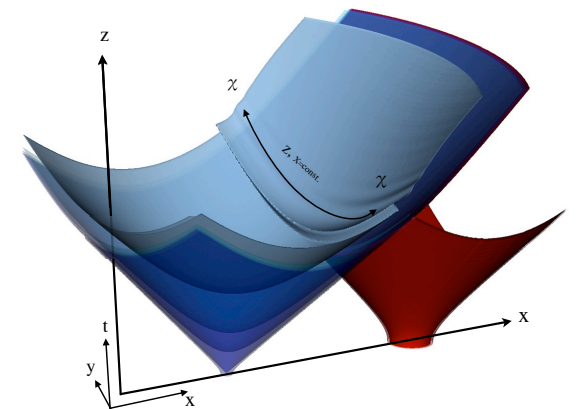
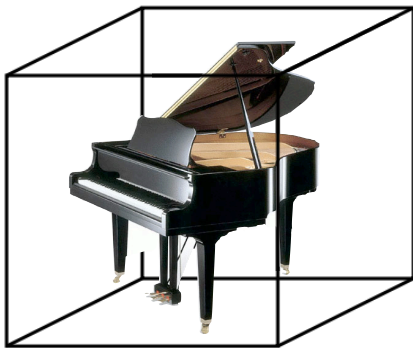


# Testing Theories of the High-z and Super-Early Universe

Anthony Aguirre

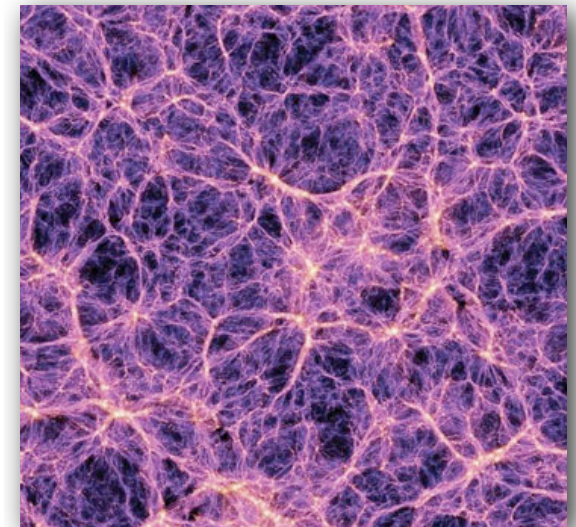
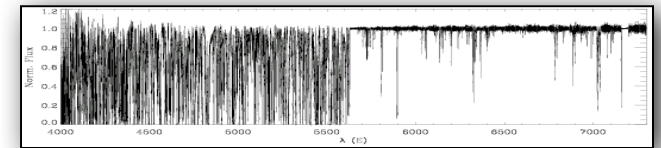


# Anthony Aguirre's *current* research:

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- **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?



**Local Group:** Shen (postdoc), Madau, Prochaska & IMPS

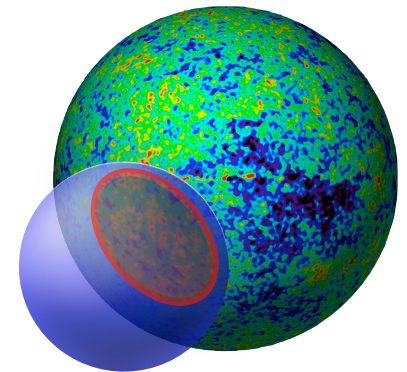
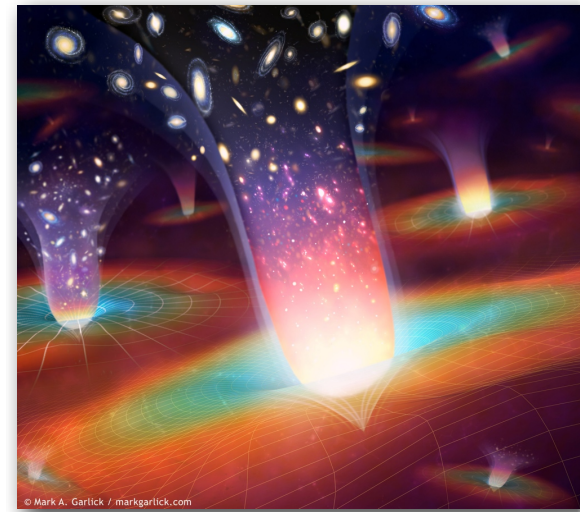
**Strong nonlocal Interactions:** J. Schaye (Leiden), L. Hernquist (Harvard)

# Anthony Aguirre's *current* research:

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- **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?



**Local Group:** Kozakzuk, Tysanner (Grads); Dine, Banks, Profumo

**Strong nonlocal interactions:** S. Gratton (Cambridge); M. Tegmark (MIT); M. Johnson (ex-student, now PI postdoc)

# Anthony Aguirre's recent-past and current research:

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- **Other**

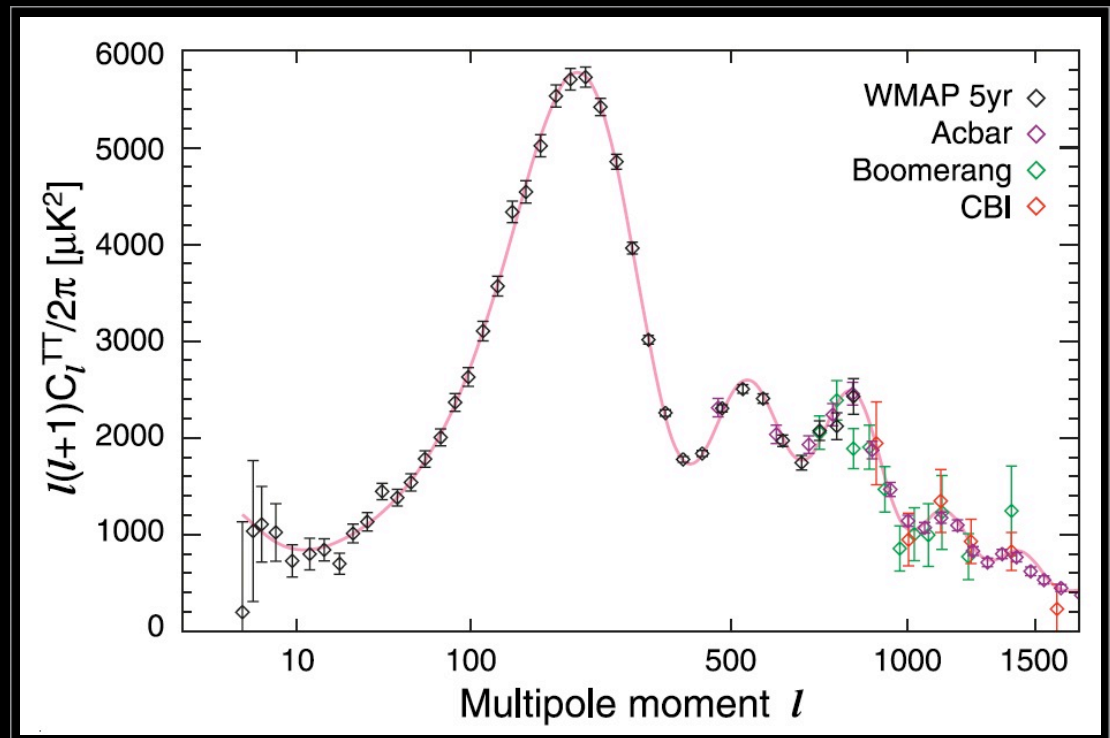
- Could annihilation of dark matter be important in the formation and evolution of the first stars (yes, it could!)
- How do we interpret quantum mechanics in a context where every quantum system has exact duplicates elsewhere? (count!)
- What does it look like when entropy *decreases*? (reverse the film!)

## **Local Group:**

**Strong nonlocal interactions:** D. Spolyar (Fermilab); M. Tegmark (MIT); Sean Carroll (Caltech); M. Johnson (ex-student, now Caltech postdoc)

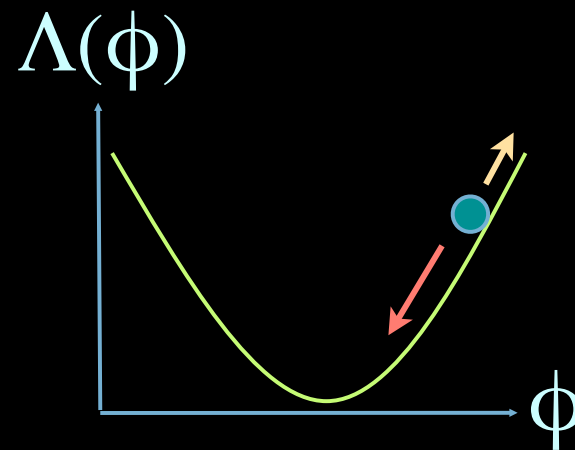
# Inflation

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



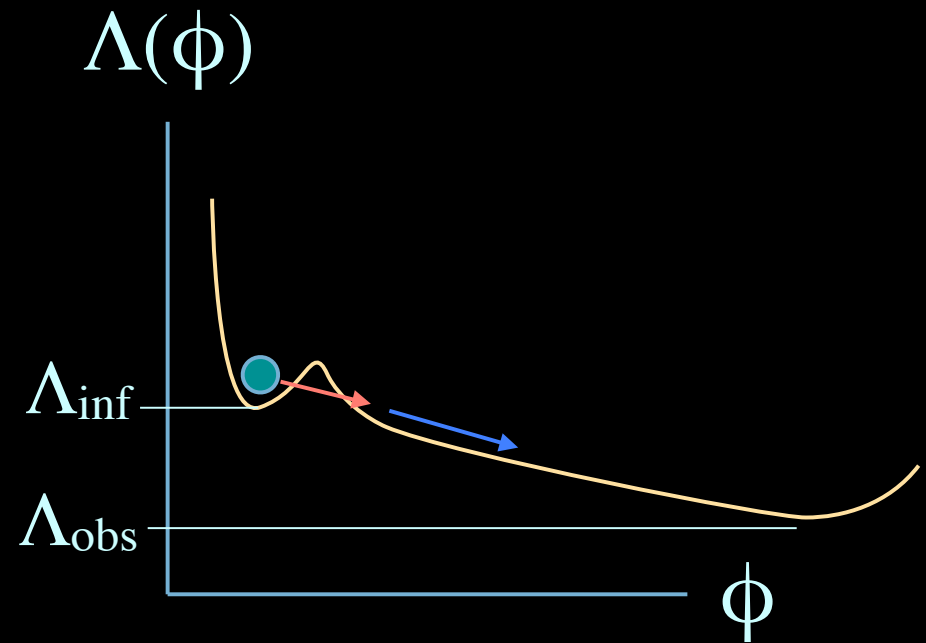
# Ending Inflation

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



$\Lambda_{\text{inf}}$



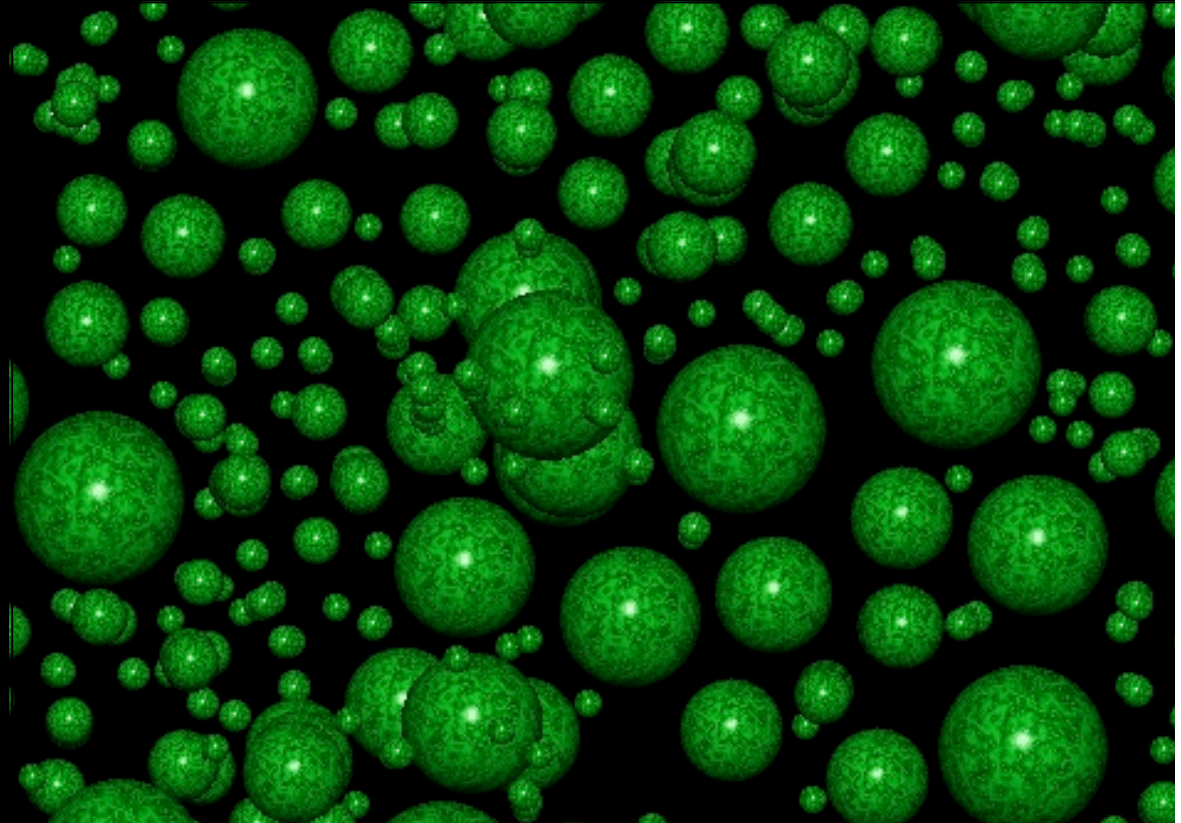
$\Lambda_{\text{obs}}$



$\Lambda_{\text{obs}}$

# Everlasting bubbly inflation

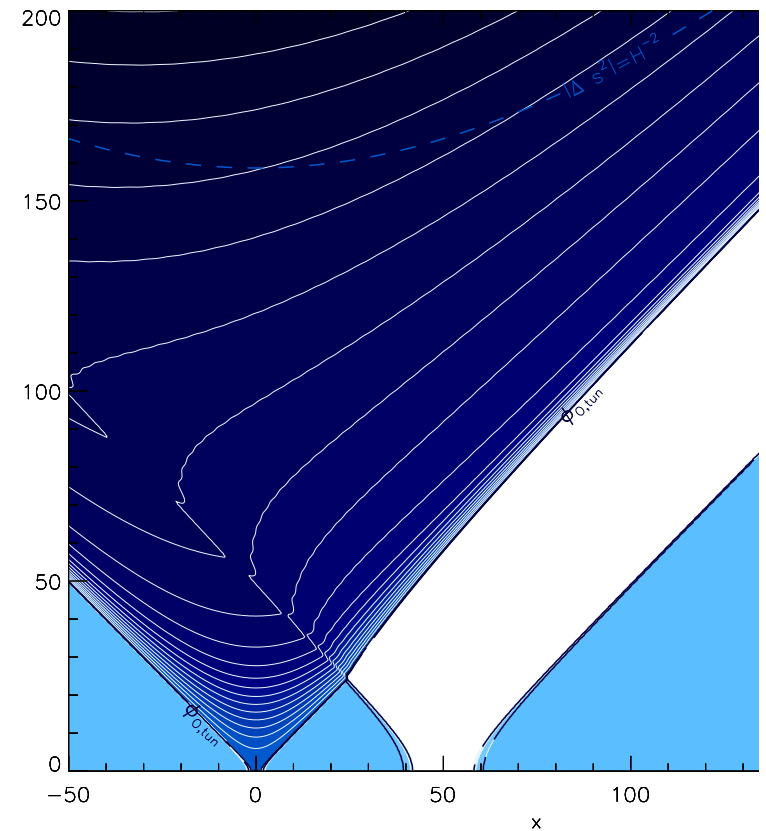
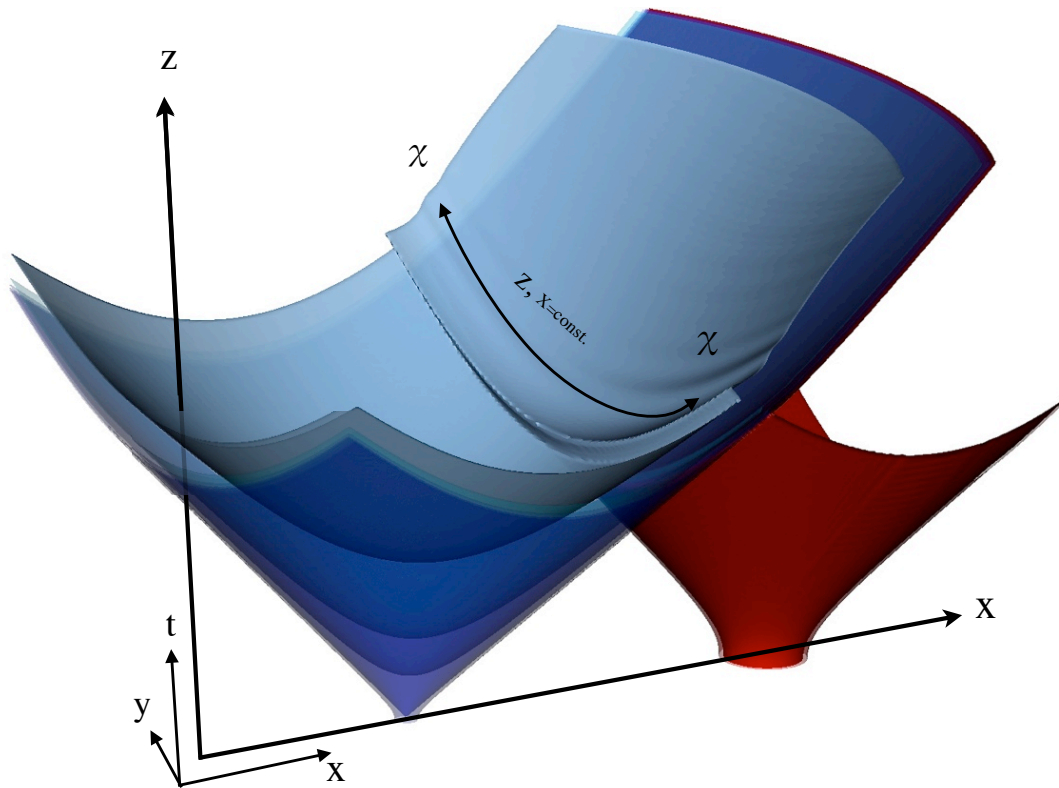
- ◆ Expanding sea of inflation.
- ◆ Pocket universes fill in interstices, grow.





# Can we observe other bubble “universes”?

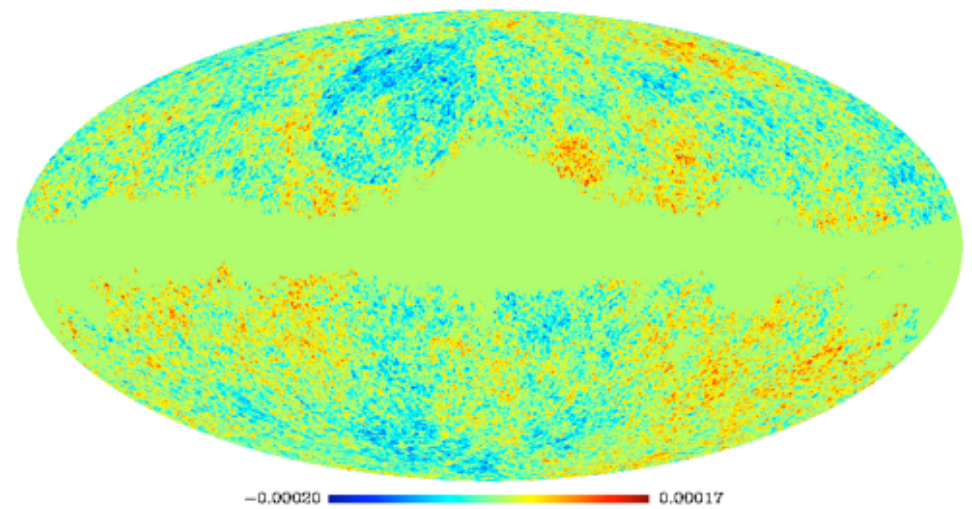
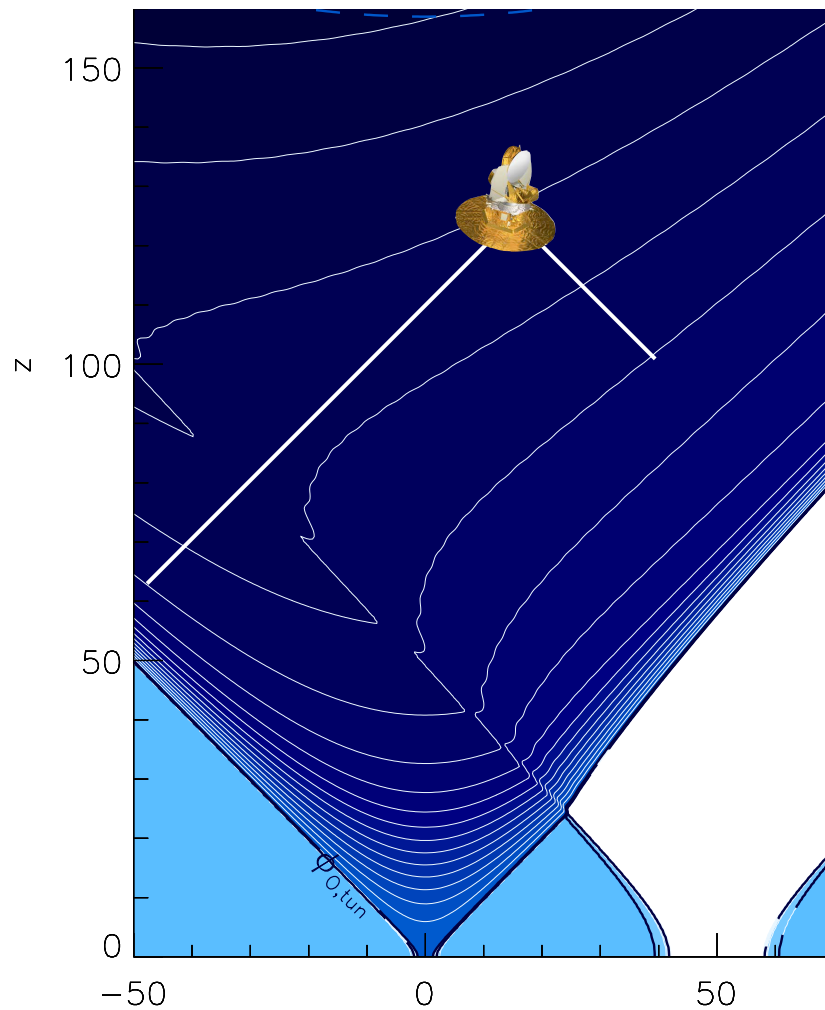
Bubbles collide!



# Can we observe other bubble “universes”?

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What could we see?



# Bubble collisions: what could we see?

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## First evidence of other universes that exist alongside our own after scientists spot 'cosmic bruises'

By NIALL FIRTH

Last updated at 8:29 AM on 17th December 2010

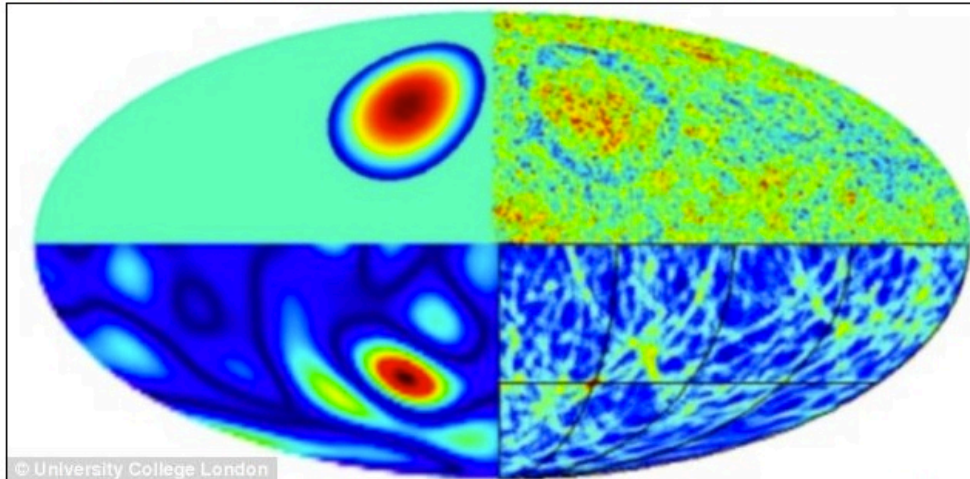
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Scientists say that they have found evidence that our universe was 'jostled' by other parallel universes in the distant past.

The incredible claim emerged after they studied patterns in the cosmic microwave background radiation (CMB) – the after-effects of the Big Bang.

They say they may have found evidence that four circular patterns found in the CMB are 'cosmic bruises' where our universe has crashed into other universes at least four times.



© University College London

The different signatures of a bubble collision. A collision (top left) induces a temperature change in the CMB temperature map (top right). The 'blob' associated with the collision is identified by a large needlet response (bottom left), and the presence of an edge is determined by a large response from the edge detection algorithm (bottom right)

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# Can we observe other bubble “universes”?

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## **Some current/possible projects:**

- Deeper analysis of link between collisions and cosmological observables. (In progress: many collisions at once).
- Involvement in data analysis?
- Other processes like decompactifications; collisions between different #s of large dimensions; collisions between bubbles with uncoupled fields.

# Currently being pondered

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## **Some current/possible projects:**

- Cosmological interpretation of quantum mechanics vs. 'multiverse interpretation' of quantum mechanics.
- Inflation from/as spacetime emergence.
- A 'double' standard in the eternal inflationary arrow of time.

# On the back burner

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## **Some current/possible projects:**

- Dark stars, Pop. III, and the IGM.
- Very interesting things that happen inside Kerr black holes
- Do 'baby universes' actually form?
- The 'emergent' universe.