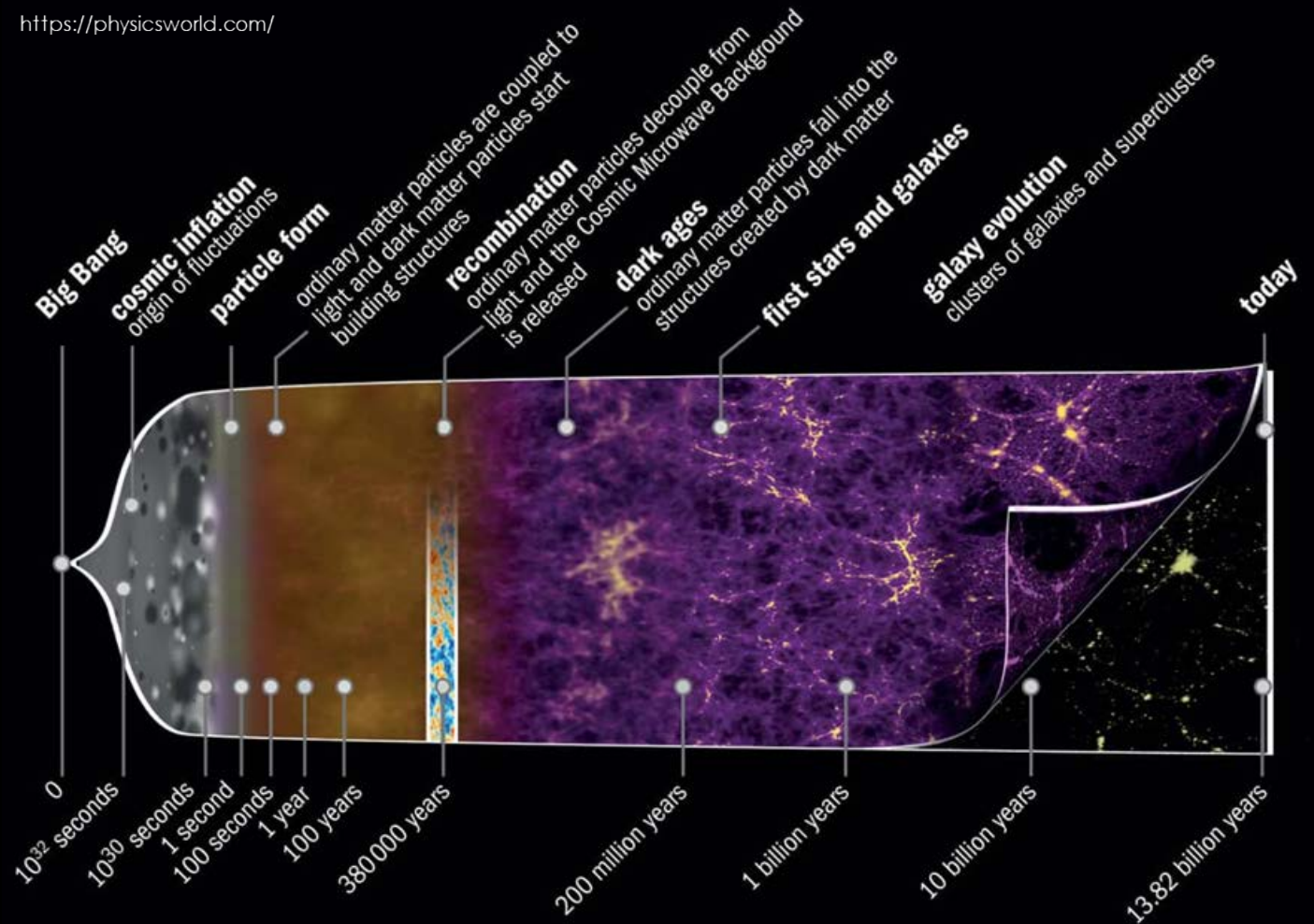
Ways the Universe Could End

Dan Hancock

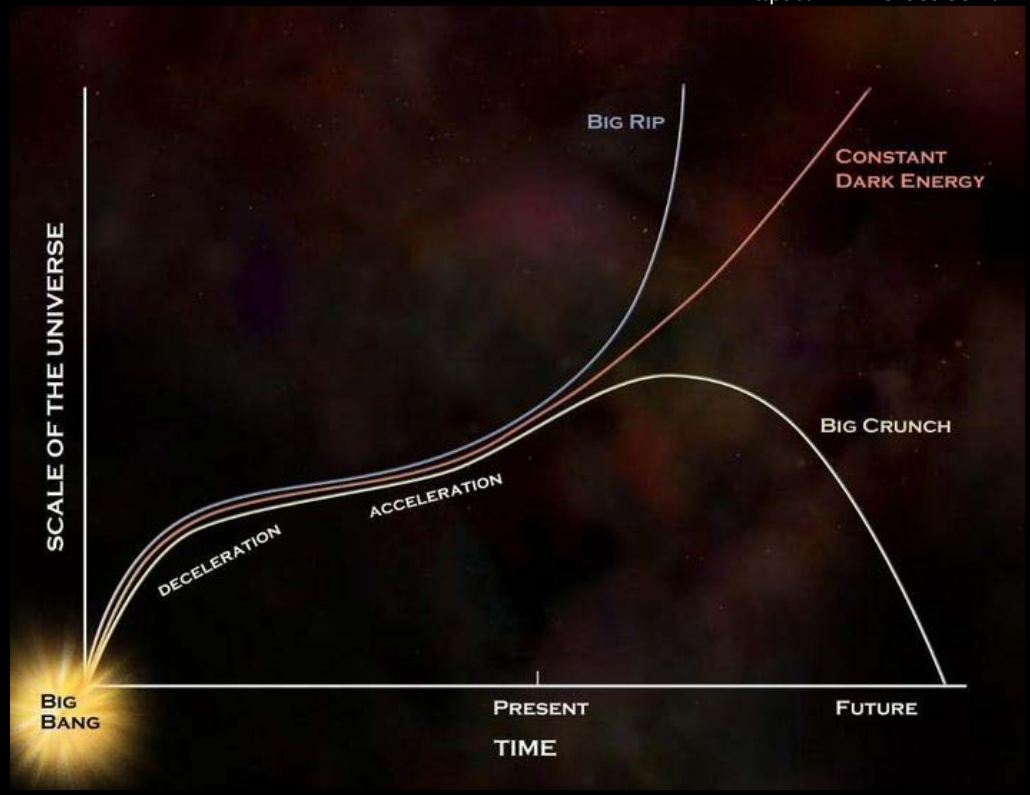
Evolution of the Universe



Main Possibilities

- The Universe Accelerates Quickly
  - Big Rip
- The Universe Begins Accelerating in a Negative Direction
  - Big Crunch
- The Universe Accelerates, but not as Quickly
- The Universe is Expanding Continuously
  - Big Freeze

https://www.forbes.com/



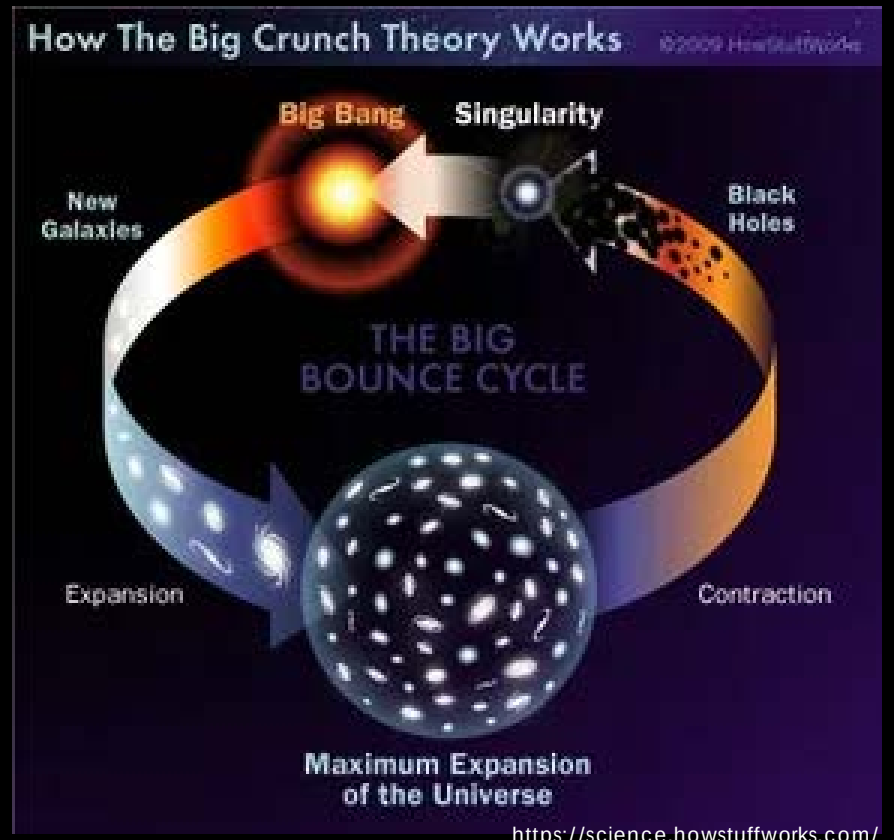
The Big Crunch

- Gravity is Dominant

- The Universe Becomes a Singularity
  - Just like Big Bang Proposes

The Big Crunch

- From this Singularity, a New Big Bang Happens
  - Cyclic process
  - Big Bounce



https://science.howstuffworks.com/

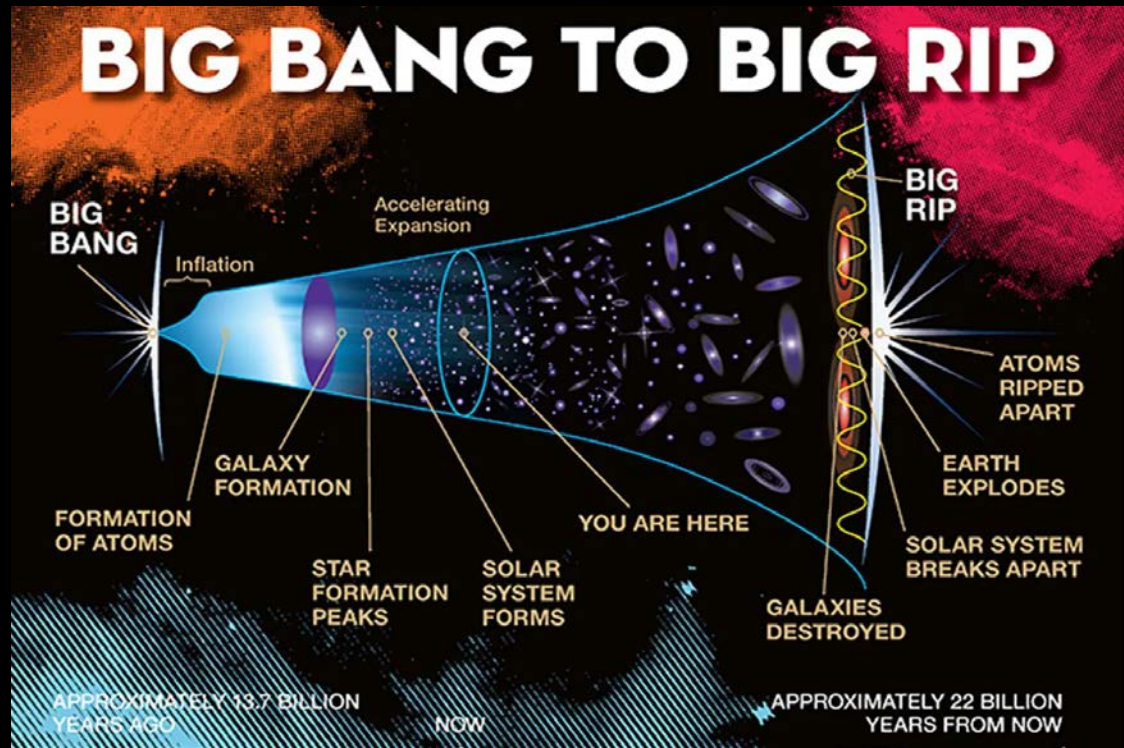
The Big Rip

- Dark Energy Becomes Dominant
  - Overcomes forces
- Expansion Accelerates Quickly

The Big Rip

- Time Approaches a Finite Value
  - Dark energy's effect becomes more dominant
  - Hubble constant approaches infinity
  - Everything gets torn apart

https://www.wired.co.uk/



The Big Freeze

- The Universe is Either Accelerating Slowly or Expanding Constantly
  - Either way, the outcome is similar
- The Universe Progresses as Normal
  - Entropy wins

The Big Freeze

- Galaxies Become Further and Further Apart
  - No visible galaxies outside of our own
- Star Formation Ceases
  - Not enough gas to create new stars
- Black Holes Become Dominant
  - Eventually Hawking radiation disperses all material

Which is Likely?

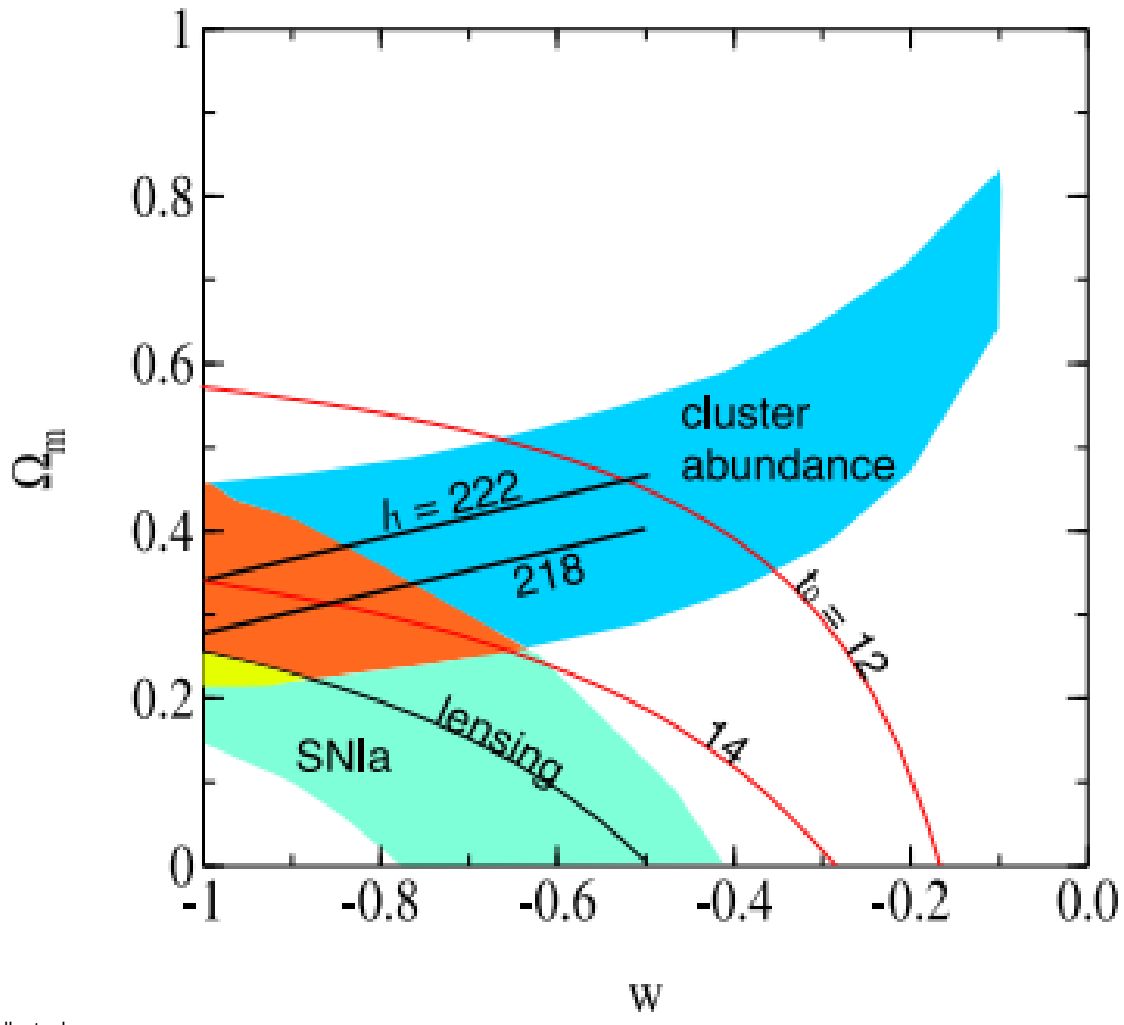
- Little evidence for Big Crunch

- Discovery of Dark Energy
  - Type 1a supernovae
  - Considers both the Big Freeze and Big Rip

Dark Energy

- Seen as a Reverse-Gravitational Effect
- Pushes Apart Matter
- Constitutes 71% of Matter and Energy Distribution
- Equation of State Parameter, *w*
  - Pressure divided by energy density

Dark Energy Parameter *w*



Caldwell et al.

Why is $w = -1$ Important?

- If $w > -1$
  - Universe expands
  - Dark energy does not overcome fundamental forces

- If $w < -1$
  - Dark energy density increases
  - Overcoming fundamental forces
  - Hubble constant approaches infinity

Current Parameterization

- $w = -0.991 \pm 0.045\ (\text{stat}) \pm 0.040\ (\text{sys})$
- Either Situation is Entirely Possible…. HOWEVER

Hypothesis Assumptions

- Assume *w* to be Constant
- Assume Flat Universal Geometry

Conclusions

- There are Several Ways the Universe Could End
  - Big Crunch
  - Big Rip
  - Big Freeze
- Further Parameterizing Dark Energy is the Key
- Currently it Seems that the Big Freeze is the Forefront Hypothesis

Sources

- https://arxiv.org/pdf/1611.01899.pdf#:~:text=The%20condition%20for%20late%20time,be%20a%20function%20of%20time.
- https://web.archive.org/web/20141028023702/https://www.preposterousuniverse.com/blog/2004/09/13/phantom-energy/
- https://arxiv.org/pdf/astro-ph/9908168.pdf
- https://arxiv.org/pdf/astro-ph/0302506.pdf
- https://arxiv.org/pdf/0812.2720.pdf
- https://web.archive.org/web/20210517014117/https://cds.cern.ch/record/318436/files/9701131.pdf
- https://arxiv.org/pdf/astro-ph/0409264.pdf
- https://wmap.gsfc.nasa.gov/news/
- https://www.physicsoftheuniverse.com/topics_bigbang_bigcrunch.html