



A Century of Cosmic Surprises "

BREWSTER ROCKIT: SPACE GUY!

BY TIM RICKARD

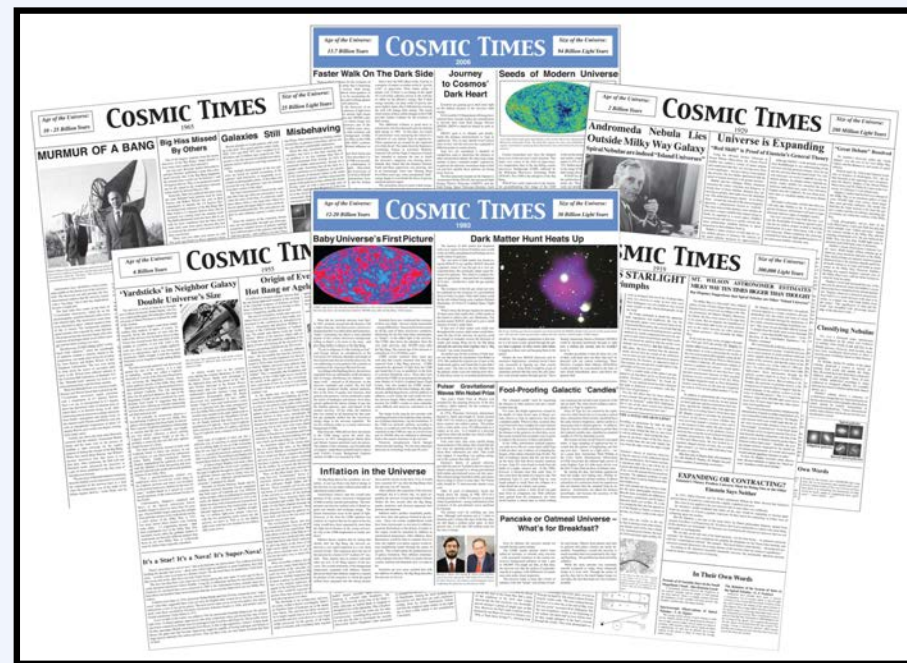


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- I. Questions and Tools
- II. The “State” of the Universe
- III. Determining the Fate of the Universe
- IV. Dark Energy and Beyond

Materials Drawn from
Cosmic Times)
(More on that later ...)





Section I)

Questions and Tools)



Understanding the Nature of the " Universe "



Our understanding of the nature of the Universe has changed as our questions and technology have changed.)

What are some questions we might ask?)



Understanding the Nature of the " Universe "



Our understanding of the nature of the Universe has changed as our questions and technology have changed.)

What are some questions we might ask?)

What are the tools we might use?)



How Far Away are "Spiral Nebulae"?

-) In 1920, astronomers pondered the distance to the "spiral nebulae."



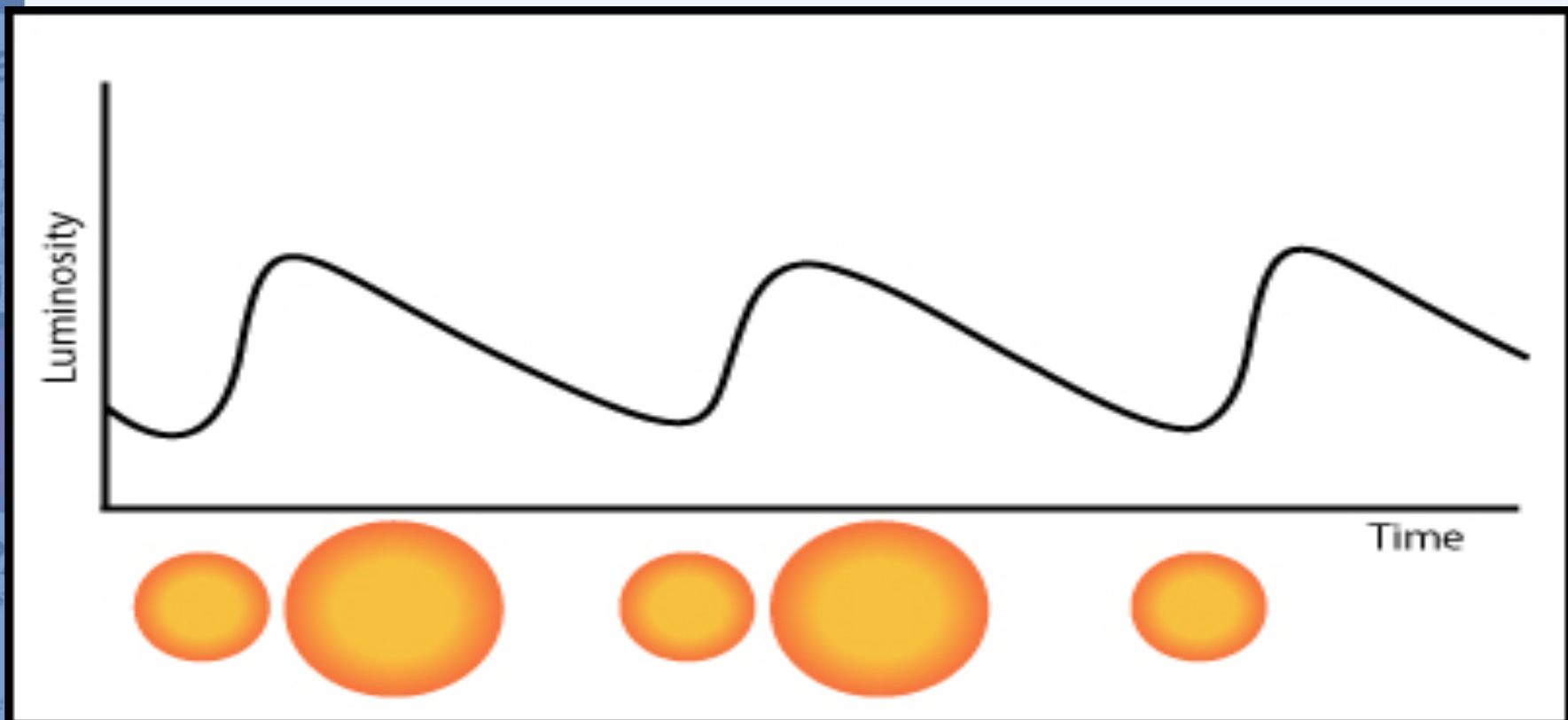
- Harlow Shapley and Heber Curtis debated whether they were within our own Galaxy or outside our Galaxy.
- The question was settled when Edwin Hubble) determined the distance to Andromeda Galaxy.)



Tools for answering “How Far Away are Spiral Nebulae?”

Cepheid Variables

- These stars vary in brightness due to pulsations.



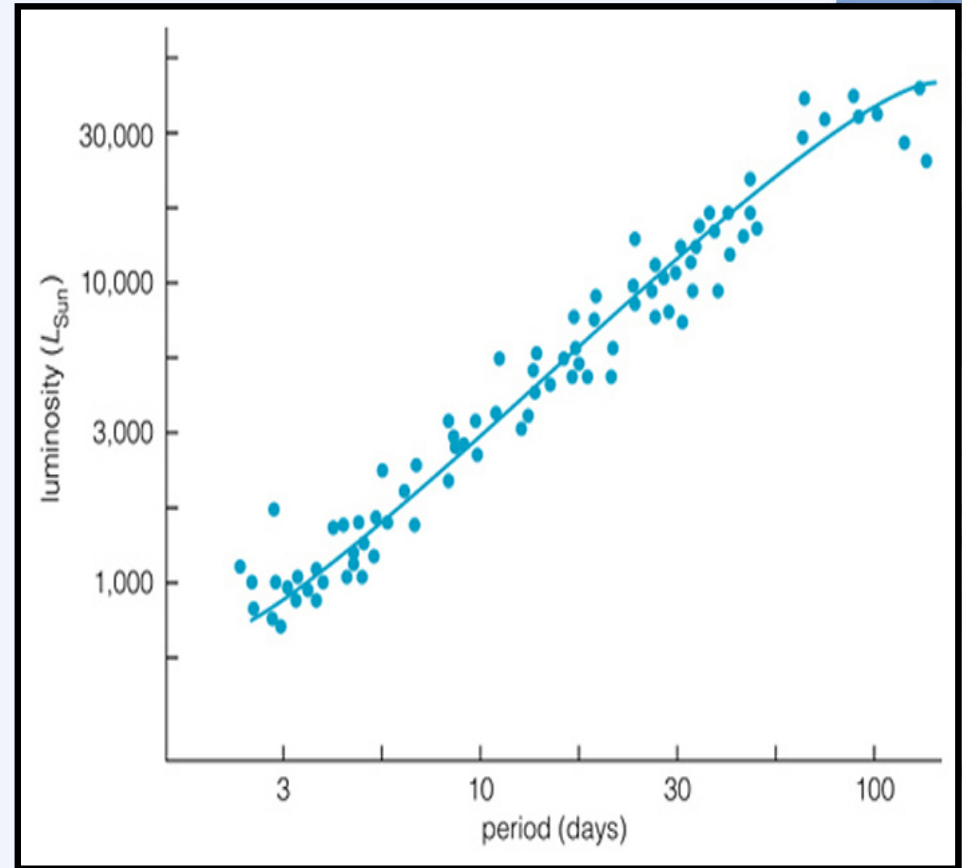


Tools for answering “How Far Away are Spiral Nebulae?”

Cepheid Variables

- The period of brightness variation is related to star's intrinsic luminosity.
- By measuring the observed luminosity, and knowing intrinsic luminosity we can determine distance

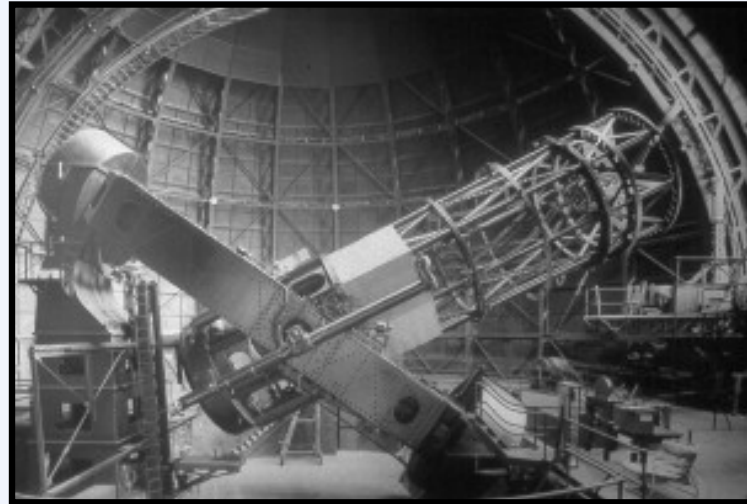
$$L_o \mu L_i / r^2$$





Tools for answering “How Far Away are Spiral Nebulae?”

- 100” Telescope at Mt Wilson, CA (1917)
 - provided the added aperture and resolution to resolve the stars.



Hubble determined distance to Andromeda to be 800,000 LY
(actual distance is 2.8 million LY)

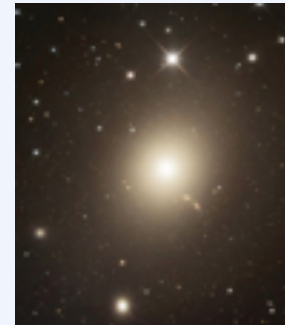


Trivia Question: Which of the following Galaxies is moving toward us?

A. Pinwheel Galaxy



B. M87 (Giant Elliptical)



C. Andromeda Galaxy





Consequence of asking “How Far Away are Spiral Nebulae?”

- Early observations showed the “nebulae” were red-shifted.
 - I.e. moving very fast away from us.
- Hubble put together the redshifts with their distances.

Universe is expanding !





Lets Pause for Questions





Section II

The 'State' of the Universe



Is Universe a “Steady State” or Did it originate from a “Big Bang?”

- Steady State Theory: As universe expands, matter is created.
 - Creation rate - a few hundred atoms per year per galaxy
- Big Bang: running expansion backwards leads us to a point of high density and high temperature from which universe originated.
 - Create everything all at once



Steady State Universe

- Fred Hoyle, Hermann Bondi and Thomas Gold see the movie *The Dead of Night*, in which the end of the story circles back to its beginning.
 - Unchanging situations need not be static
 - New matter can be created spontaneously as the universe expands (a few hundred atoms per year per galaxy)
 - Expansion of universe and creation of new matter balanced via a negative energy.
 - The universe is constant in its overall density





Evolutionary Universe

- Starting from earlier work, George Gamow & Ralph Alpher worked out the conditions in the early universe
 - Universe is expanding from a state of high density and pressure.
 - Hydrogen & Helium were formed as universe cooled.
 - There should be left over a background radiation with a temperature of ~ 5 Kelvin
 - Hoyle scoffed at this theory and coined the term “Big Bang”



Inference vs. Observation

- How would you define an observation?
- How would you define an inference?



What is the Evidence?

Bowl of Evidence

Scientists sort through theories by
examining Evidence and making
Inferences



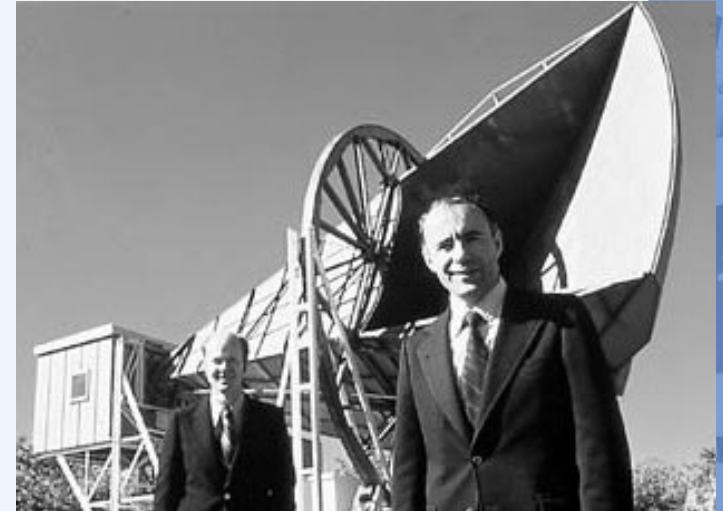
Steady State vs. Big Bang

- As a competing theory, the Steady State provides the impetus to make observations to test the theories.
- Note that this lesson can be adapted for **any** science topic where there are two (or more) competing theories



Tool for Determining “Steady State” vs. “Big Bang”

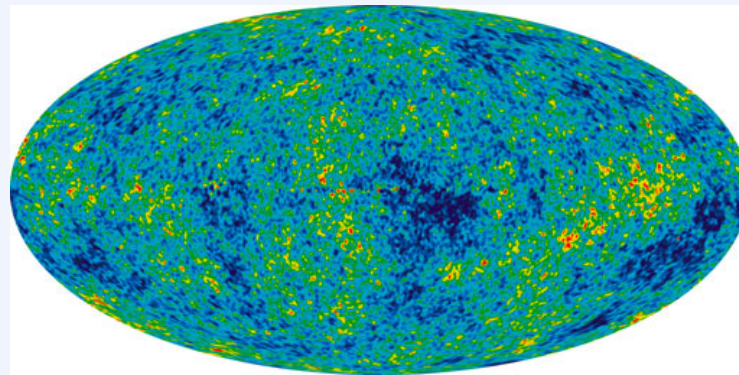
- Penzias and Wilson were using a 20-foot horn detector to make radio observations of the Milky Way.
- Effort to reduce noise in the detector left them with a 3 K residual. But they didn't know its origin.





Tool for Determining “Steady State” vs. “Big Bang”

- Peebles and Dicke (Princeton) had just calculated an estimate for the temperature of the residual background temperature, and found it was detectable in the microwave region.
- P & D were convinced P & W had found it.
This solved the Steady State vs Big Bang question.





Let's Pause for Questions





Section III

Determining the Fate of the Universe



Cosmology's End?

- By the mid-90s, cosmologists thought that they had only to “fill in the details”.
- Remaining questions:
 - Will the expansion continue forever, or will Universe eventually collapse back on itself?
 - What is the mass-density of the Universe (which would answer the above)?



Cosmology's End?

- Things may not be what they seem.
- When we see odd behavior, we look more carefully at what's going on.



How Fast is the Expansion Slowing Down?

- Saul Perlmutter (UC Berkeley) wanted to determine the deceleration rate of the expansion.
- Amount of deceleration depends on average mass density.
 - So we'd be “weighing the universe”
- This would lead to determining the fate of the universe - expand forever, or contract.



Tools for Determining “How Fast is the Expansion Slowing Down?”

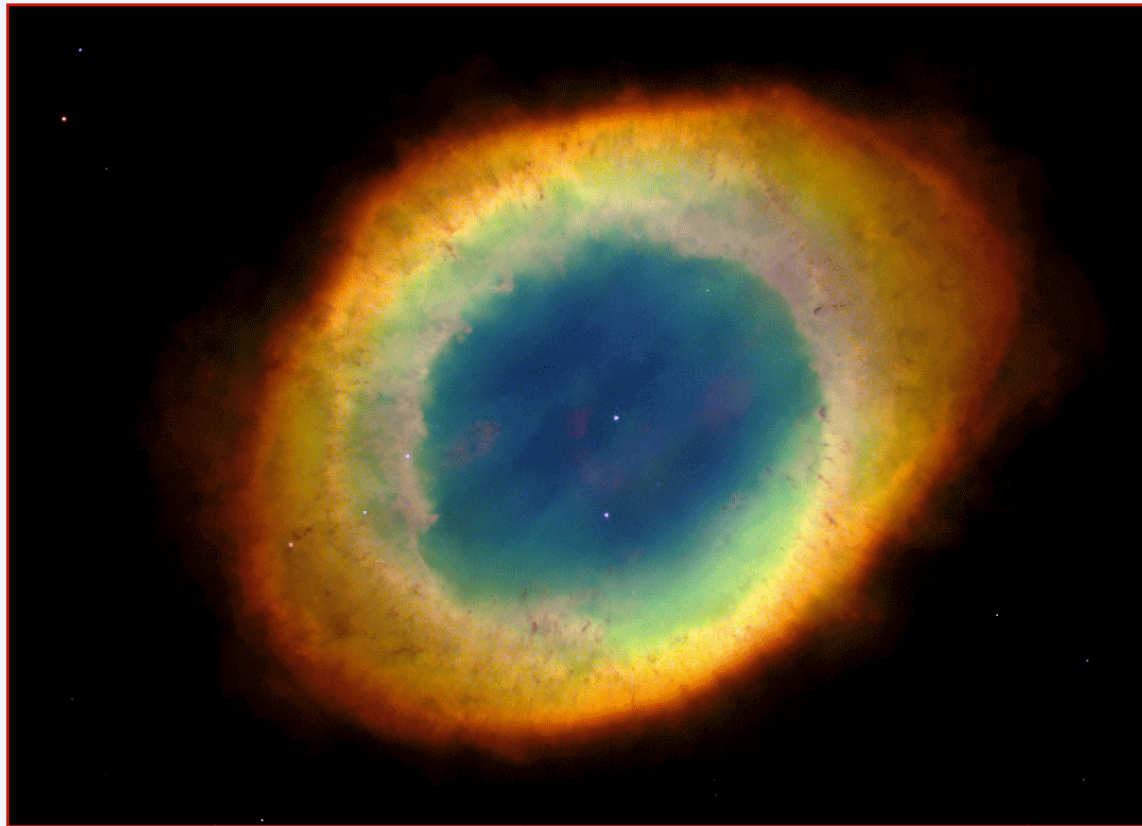
- Compare a galaxy's measured distance with its redshift.
- Get distance by comparing observed and intrinsic luminosity of an object in the galaxy.

Enter Supernovae!

(But we need a special kind of supernova)



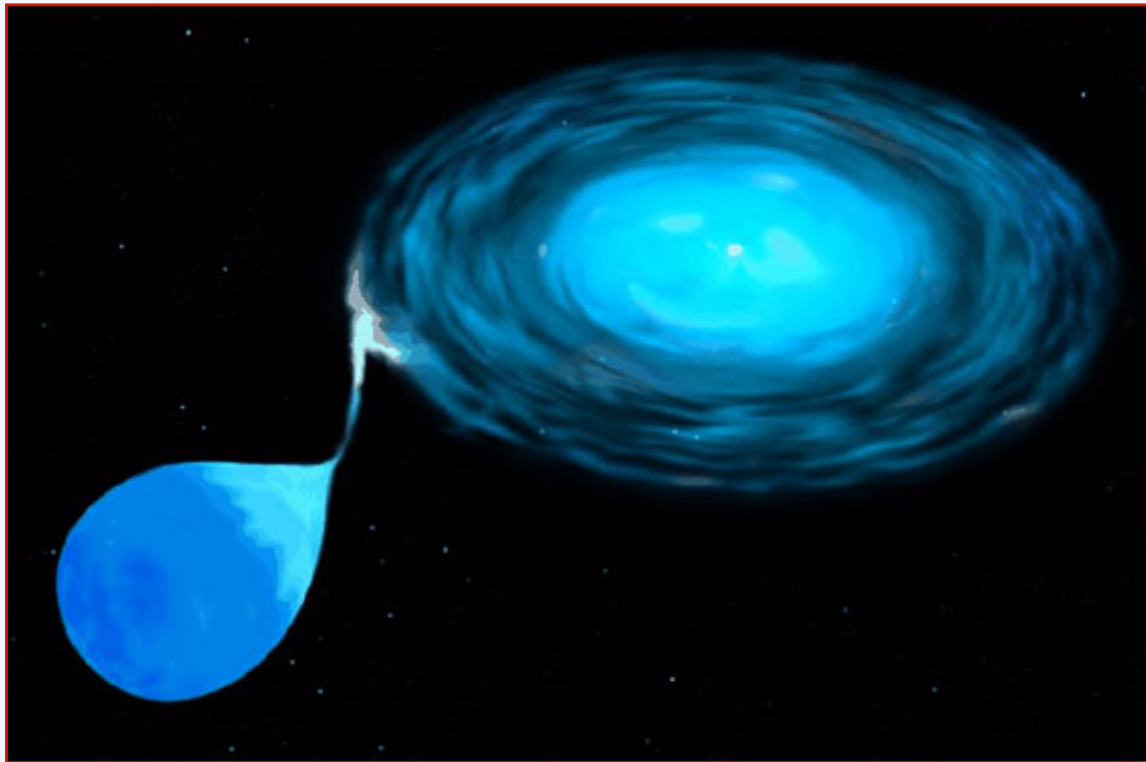
1. Create a White Dwarf



A dying star becomes a white dwarf.



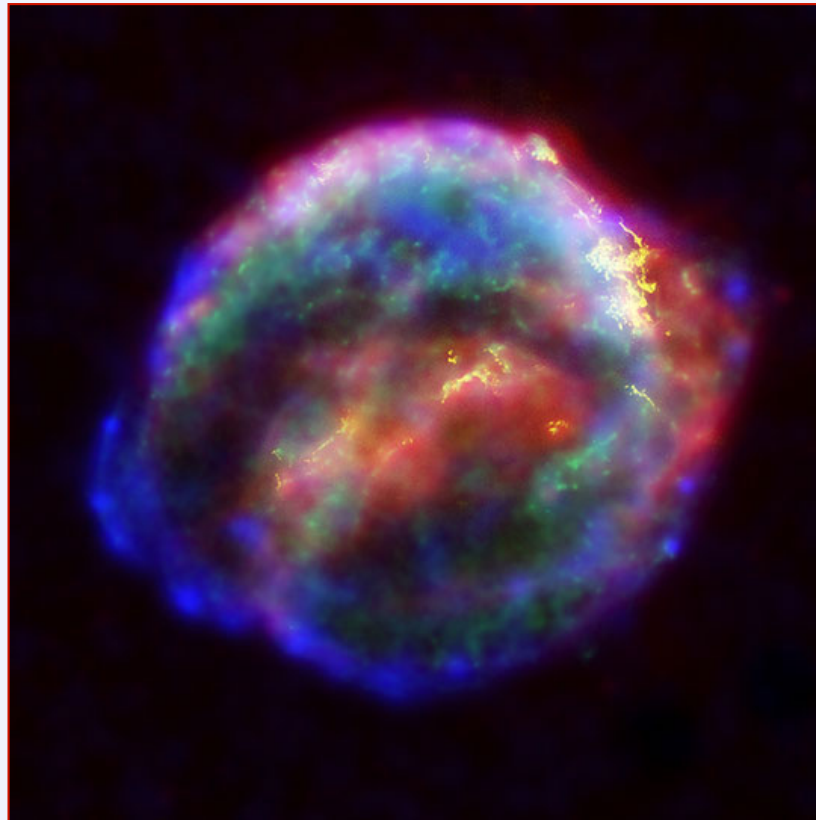
2. *Dump more mass onto it*



The white dwarf strips gas from its stellar companion....



3. *Until it explodes*



....and uses it to become a hydrogen bomb.
Bang!



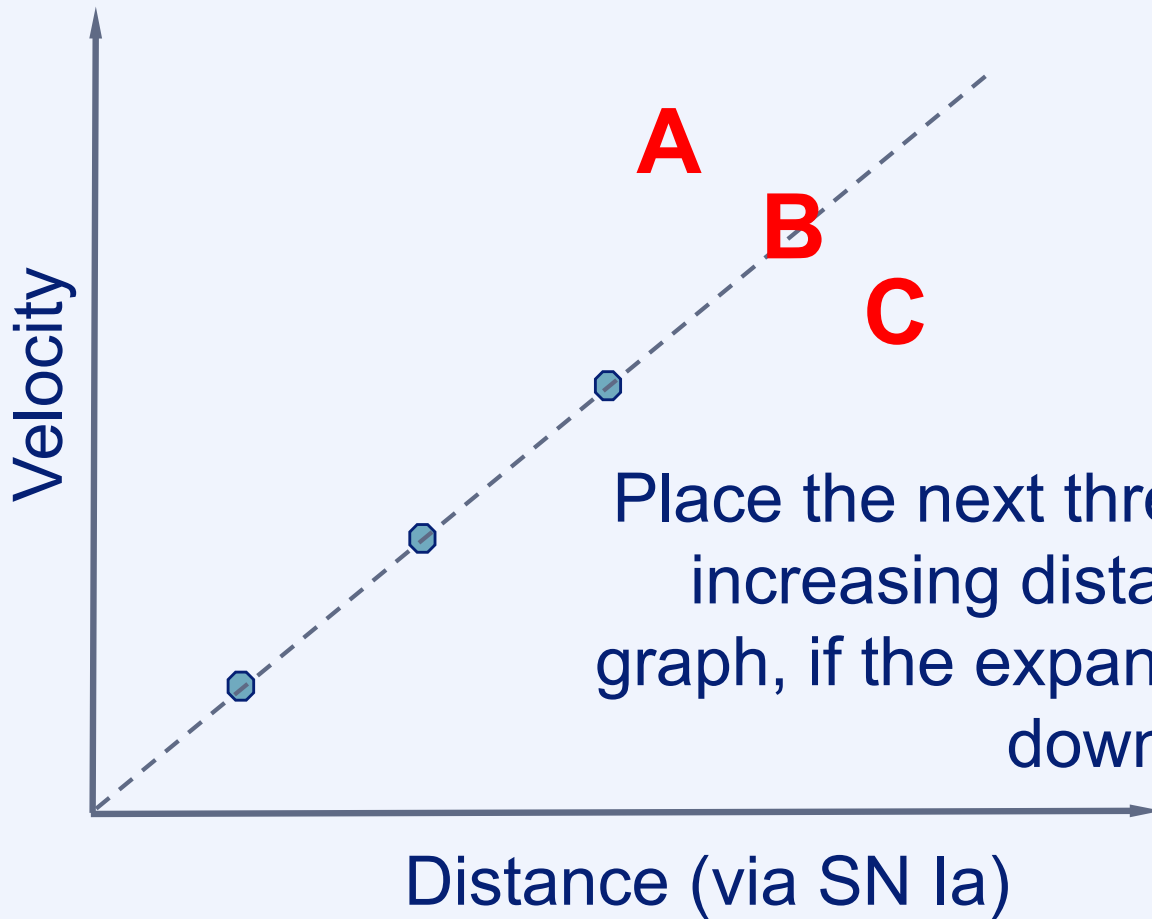
4. Observe it in a distant galaxy



The explosion is as bright as an entire galaxy of stars....
.....and can be seen in galaxies across the universe.



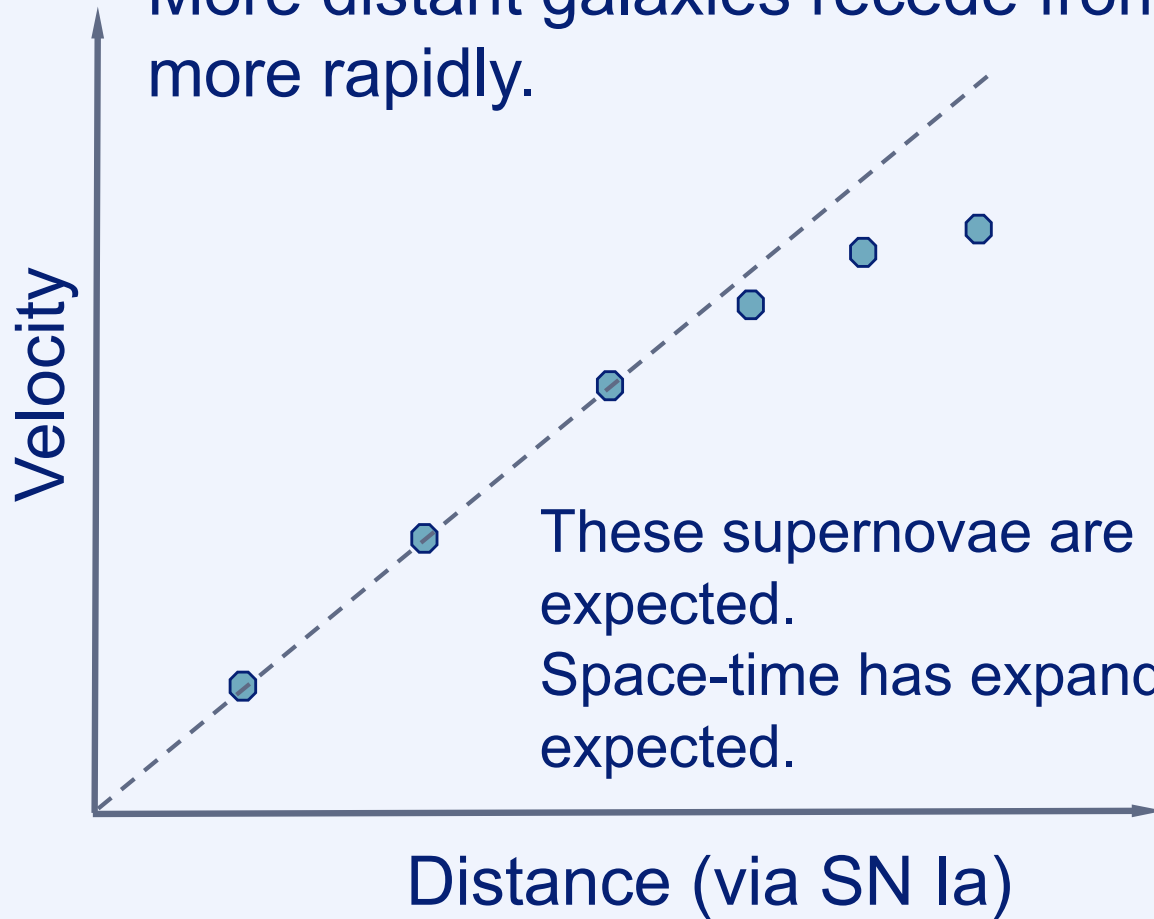
5. Compare its distance to its velocity





5. Compare its distance to its velocity

More distant galaxies recede from us more rapidly.



These supernovae are more distant than expected.
Space-time has expanded more than expected.

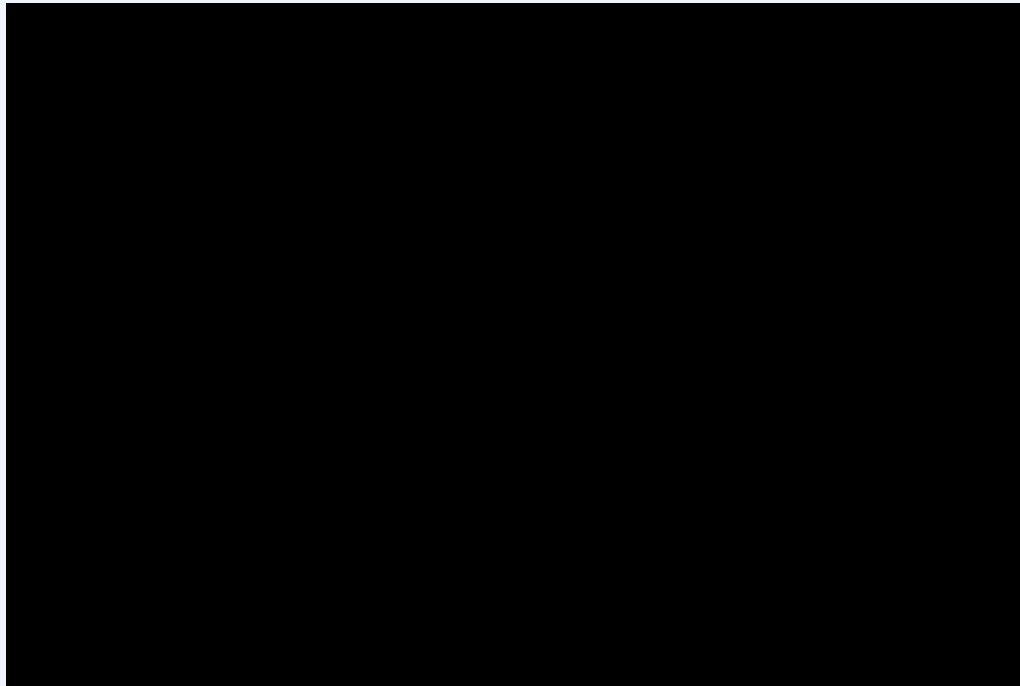


Let's Pause for Questions





History of the Universe's Expansion



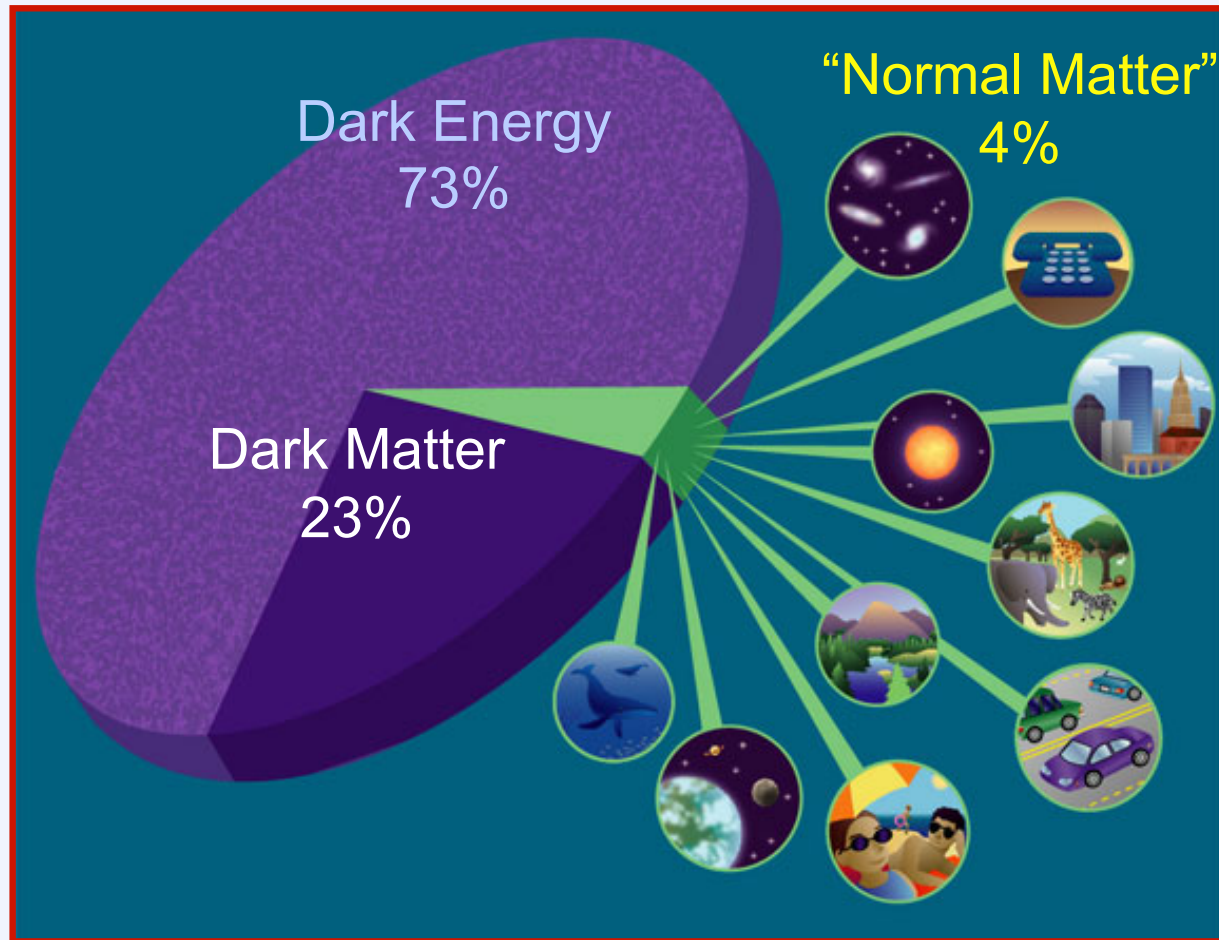


Section IV

Dark Energy and Beyond



Dark Energy Comprises 73% of Universe





Dark Energy is an Unfinished Story

WE DON'T KNOW WHAT IT IS!

But this story of our understanding of the nature of the universe illustrates the process of science.

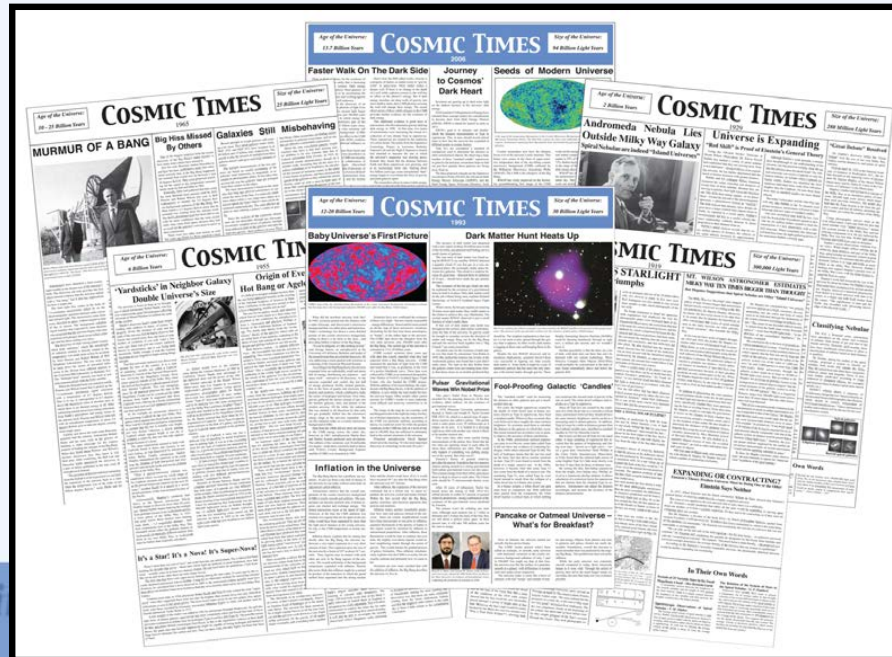
- Science is alive and on-going.
- Our ideas change as the data changes.
- Scientific debate differs from social/political debate.
- Progress in science results from both individual and group efforts.



Cosmic Times

Curriculum support materials that trace our changing understanding of the Universe over the past century.

From Einstein's Theory of Gravity to Dark Energy





Other Themes in Cosmic Times

- Our understanding of the Expansion of the Universe
- Nature of Supernovae
- The size and scale of the Universe

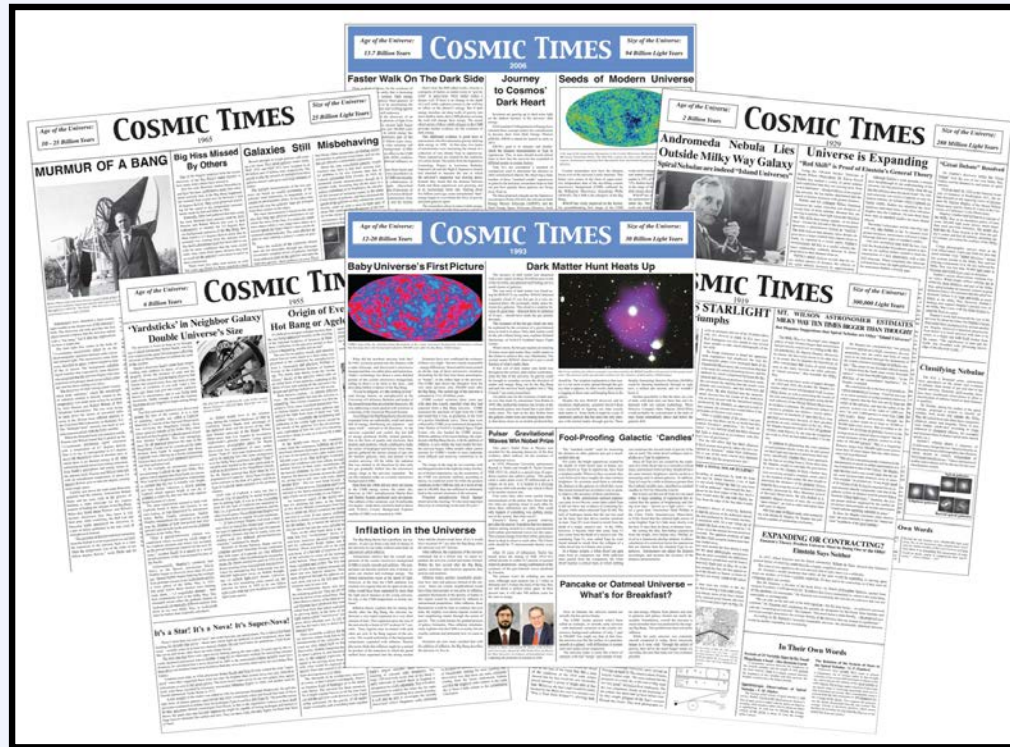
A number of other themes also appear.

- Lesser known astronomers.
- Impact of improved technology.



Cosmic Times

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