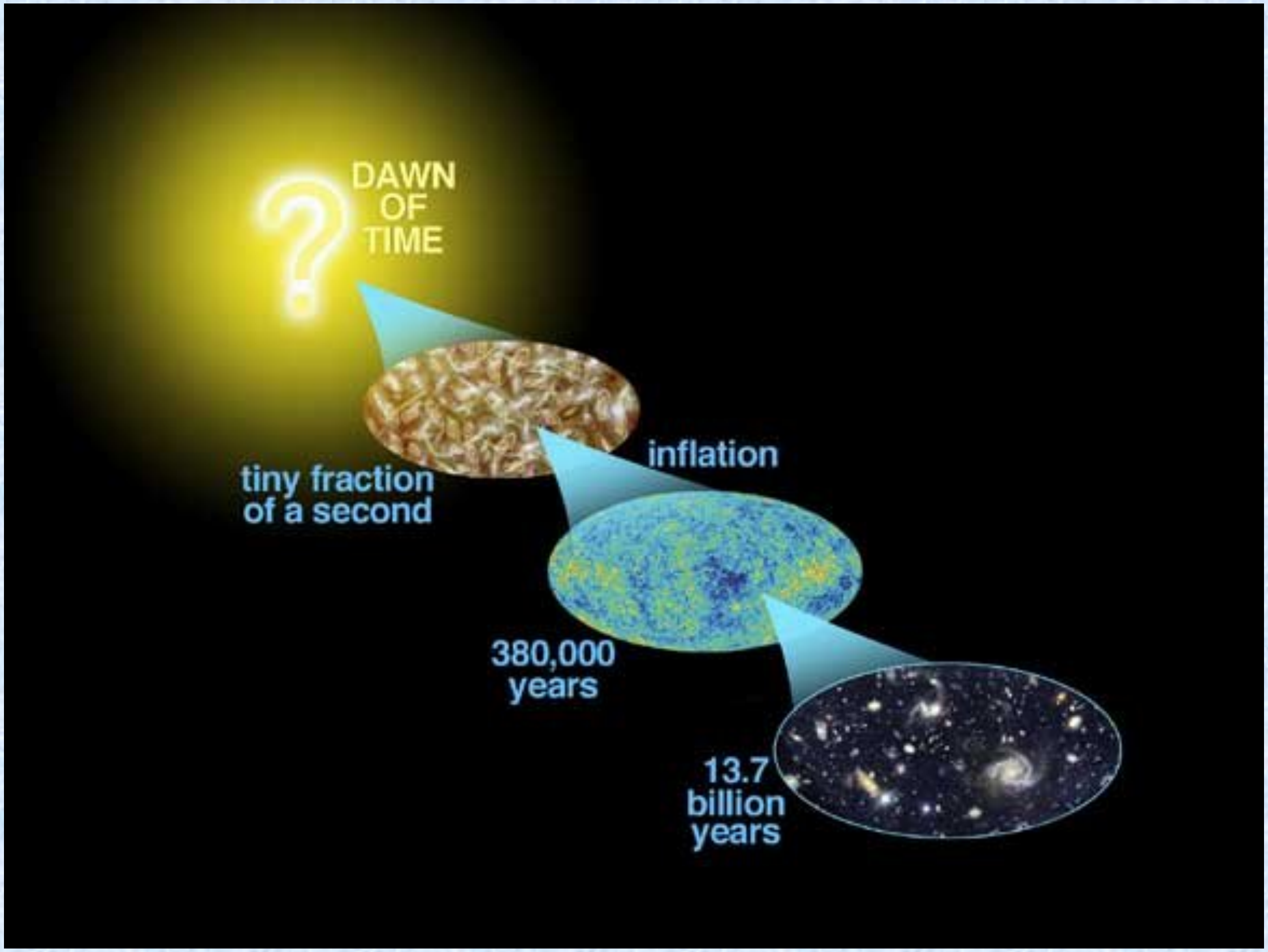
Physics 133: Extragalactic Astronomy and Cosmology



Lecture 16; March 12 2014

Previously:

- Inspite of its great successes the classic Big Bang model has three major problems:
  - It's too flat
  - It's too isotropic
  - There are no magnetic monopoles
- The currently favored solution is called "inflation"

Outline:

- The inflation solution
  - Qualitative description of inflation
  - A toy model of inflation

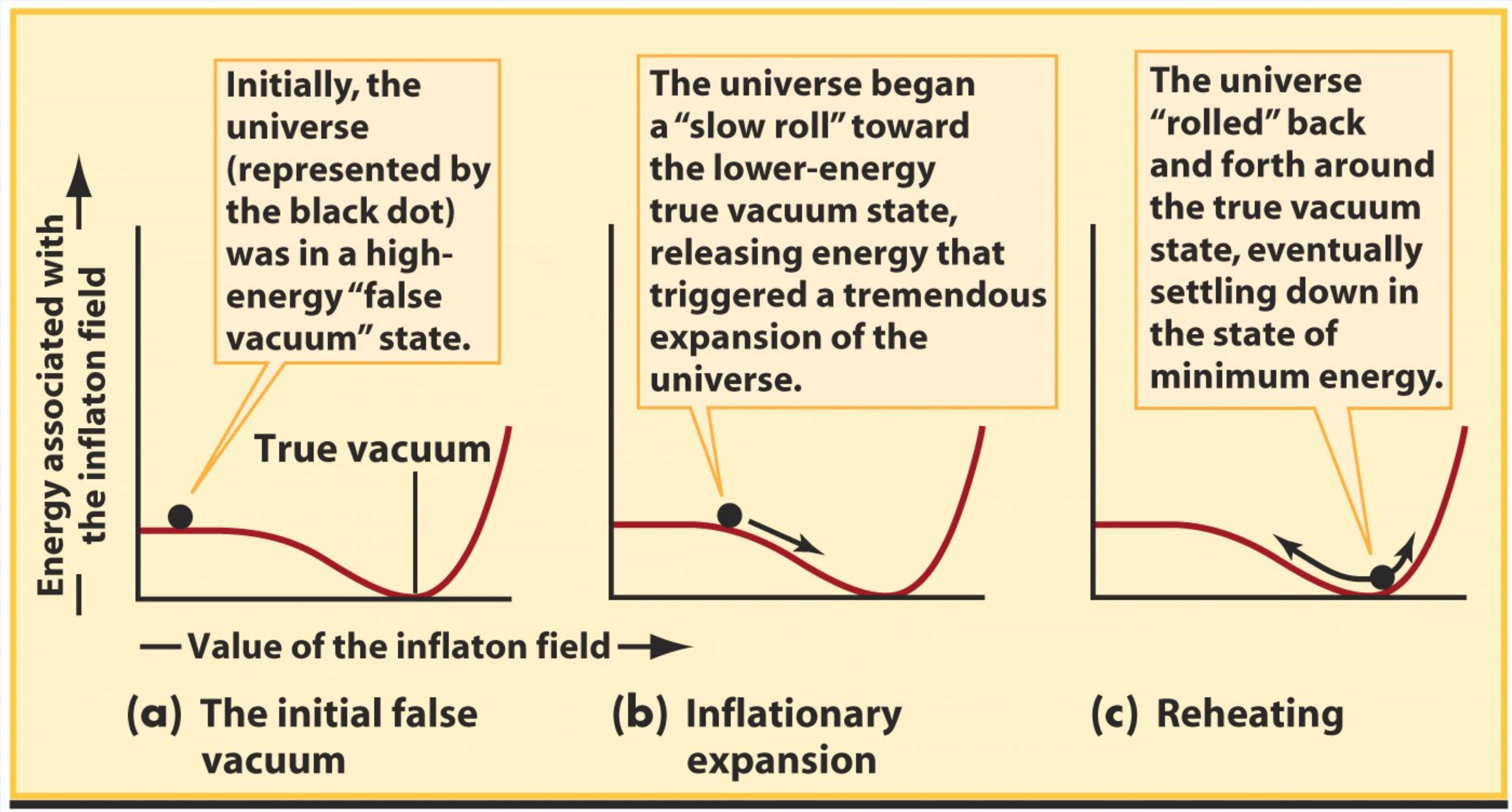
Inflation. True and false vacua

- At about ~10^{-36} s after the Big Bang symmetry broke and strong and electroweak forces separated.
- A quantity called the inflaton field (similar to the Earth's magnetic field in some sense) found itself in a position of false vacuum, i.e. in a state that looked like a minimum but was not a minimum of energy

Inflation. The inflaton rolls down

- The inflaton wants to roll down to its true vacuum, i.e. the energy minimum
- While you roll down you release energy (the guy in the ball is speeding up!) by transforming potential energy into kinetic energy

Inflation. The inflaton rolls down

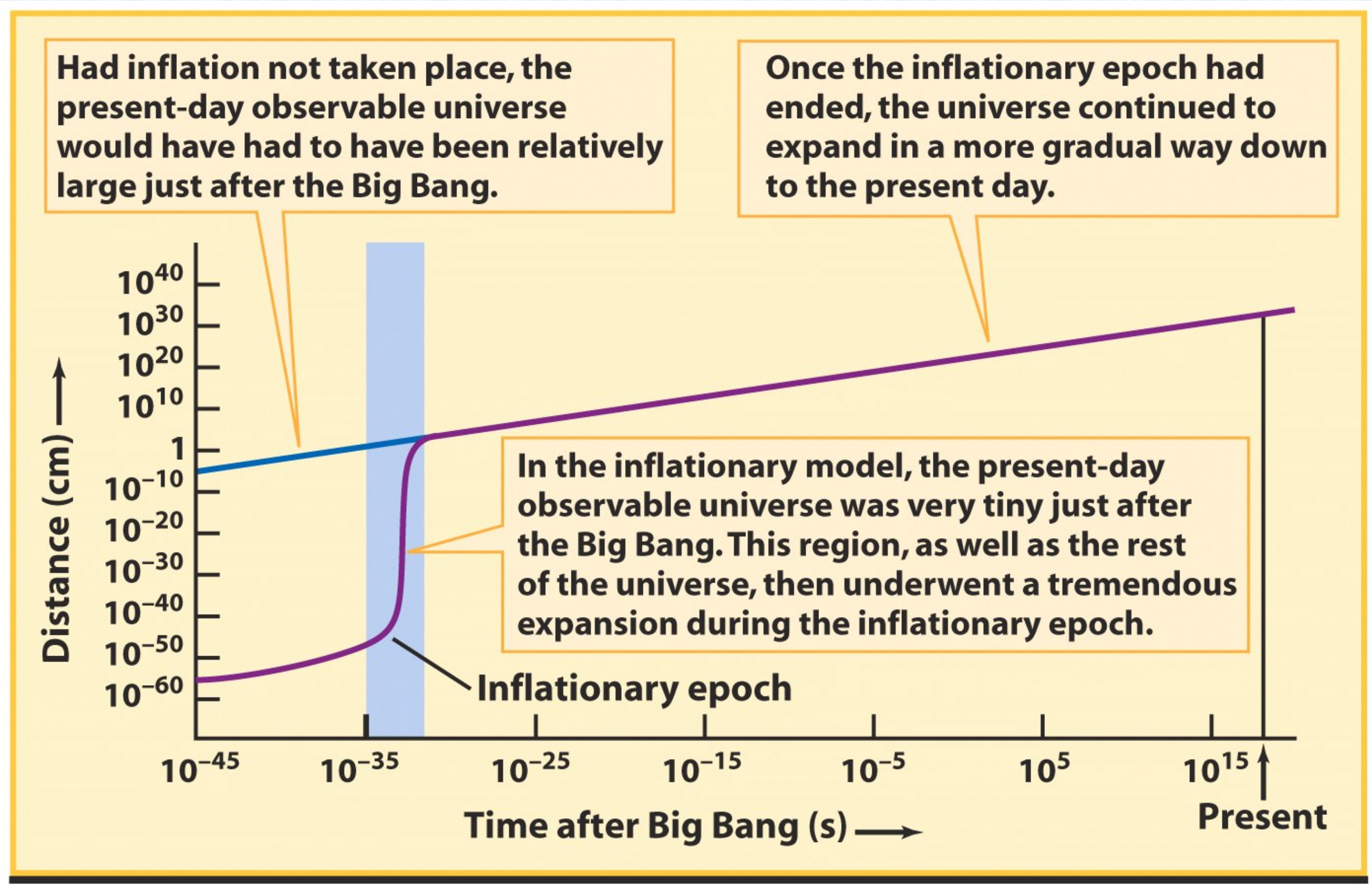


The same thing happens for the inflaton!

As the inflaton rolls down the universe expands very fast (inflates)!

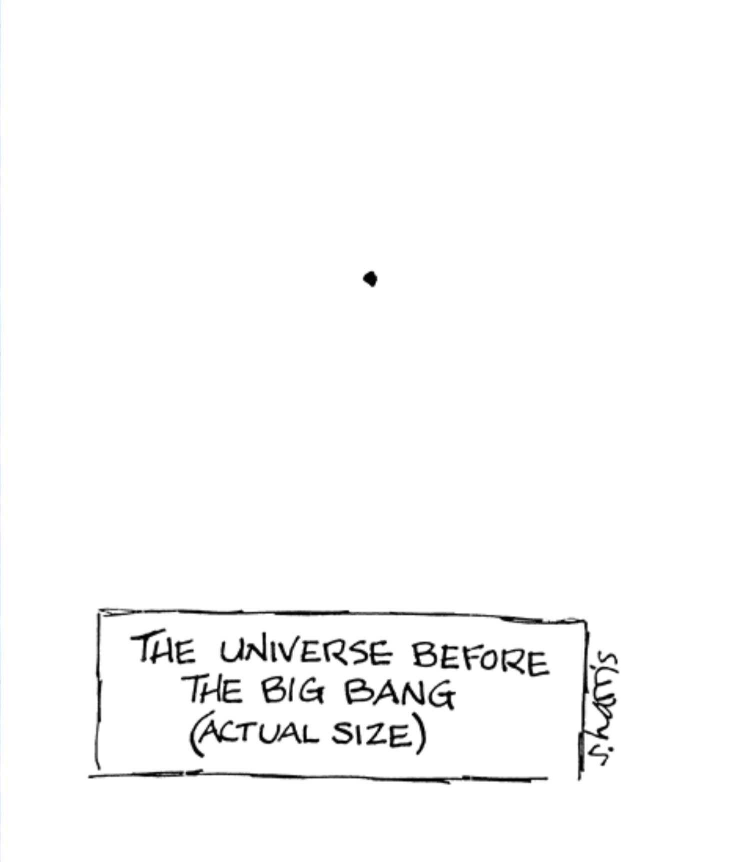
- As the universe rolls down it releases huge amounts of energy that make it expand dramatically
- This period is called inflation
- The size of the universe grows exponentially as a ~ e^{Ht} where H is the "Hubble constant" at that time.
- In just 10^{-32} s the universe expands by a factor of 10^{50}

Inflation. The universe expands fast!



The period of ultra-rapid expansion means that our present day horizon was tiny before inflation. There could be a lot of "bubbles"!

Faster than the horizons!

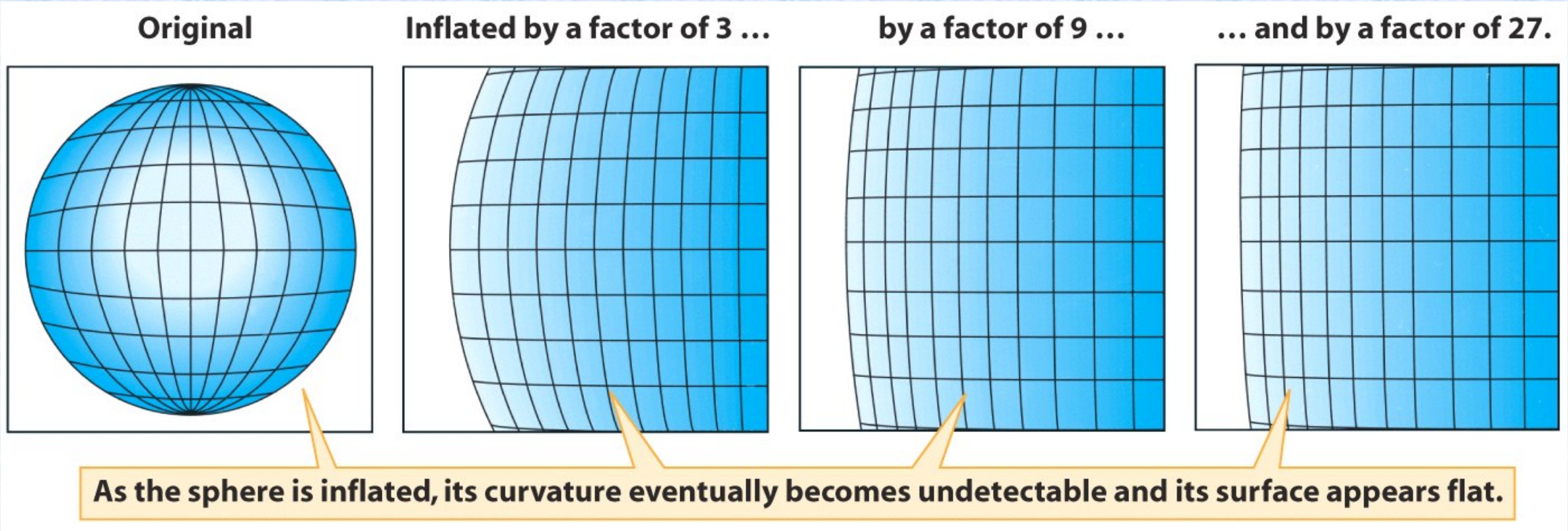


Before inflation the universe was small enough to have been in causal contact. This solves the horizon problem of classic Big Bang!

Inflation. What happens to the temperature?

- Inflation expands space so much that the temperature of the universe cools down to about $e^{-N} T_{GUT}$ at the end of inflation (too cold)
- But at the end of this phase transition there is a bunch of latent heat released by the inflaton field that heats it back to the right temperature, about 10^{27} K
- It's similar to boiling water that you need to heat it to do the phase transition and it releases heat when it condenses back

Inflation and flatness



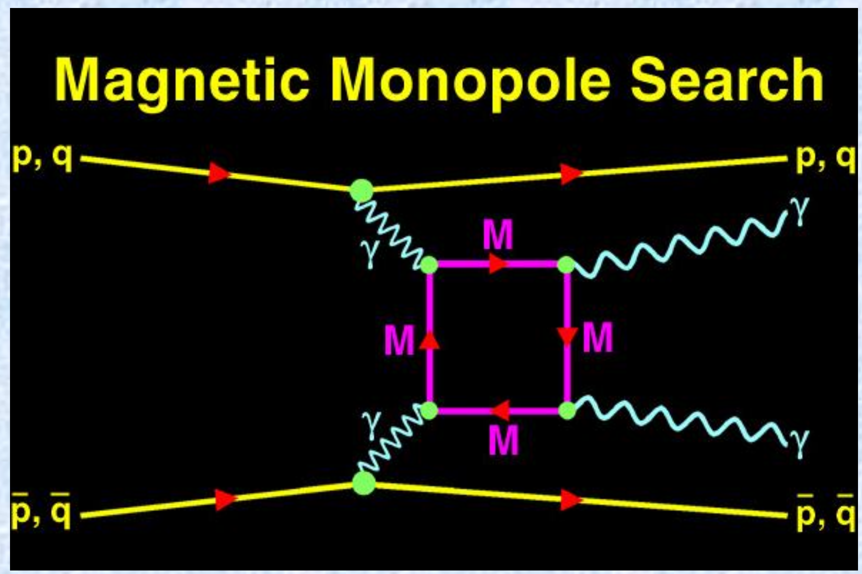
As space inflates the universe becomes flatter.
Inflation solves the flatness problem

Inflation and flatness

Pretty much like a basketball court… the players don't realize it is curved because the radius of curvature of the Earth is so big!!

Inflation solves the monopole Problem

- Inflation dilutes monopoles so that there is of order one or less left for horizon, today (depending on the number of e-foldings)
- So there are monopoles, they are just not observable!



Inflation solved three known problems. How about predictions?

- Inflationary models can predict the amount of polarization of the CMB
- Inflationary models predict fossil gravitational waves, like the CMB but for gravitons.
- Precision measurements of polarization in the CMB and of gravitational wave background can test the theory.
- Polarization measurements of the CMB are currently starting to become interesting (ESA mission Planck launched in 2009)
- For fossil gravitational waves… we'll have to wait..

Review for the final:

- Final exam wednesday 3/19 8AM
- Worth 40% of final grade
- Open book (Ryden) Open notes
- Bring calculator
- Cumulative final: Ryden Chapters 1 thru 11.3

Final exam:

- Five questions, each worth 20%, including:
  - A brief essay on fundamental concepts
  - Four problems on:
    - cosmological models
    - nucleosynthesis
    - gravitational lensing
    - Recombination
- Any questions?

The End