



# EARTH AND SPACE SCIENCE

UNIT 1 LECTURE 1: THE BIG BANG



# EDWIN HUBBLE

AND THE BIG BANG

# EDWIN HUBBLE

- IN 1920'S DISCOVERED THAT DISTANT, FAINT CLOUDS OF LIGHT WERE IN FACT GALAXIES LIKE OUR OWN MILKY WAY GALAXY. THIS CHANGED THE WAY WE VIEWED THE STARS
- IN 1929 HE DISCOVERED THAT THESE OTHER GALAXIES WERE RECEDING FROM OUR OWN AT A RATE OF SPEED THAT WAS PROPORTIONAL TO THE DISTANCE.



# WHY WAS HUBBLE'S DISCOVERY IMPORTANT?

- TWO REASONS:
  - IT SHOWED THAT THE UNIVERSE WAS EXPANDING
  - BUT MORE IMPORTANTLY, BECAUSE THE GALAXIES ARE RECEDING FROM ONE ANOTHER, IT SUGGESTS THAT AT SOME TIME THEY WERE MUCH CLOSER TO ONE ANOTHER – MOVING FAR ENOUGH INTO THE PAST TO WHICH THEY WERE SO CLOSE AND COMPACT THAT THEY OCCUPIED A SPACE OF ROUGHLY ZERO VOLUME!
- THUS THE “BIG BANG THEORY” WAS BORN

# HOW DID HUBBLE PROVE THIS?

- WHEN LOOKING AT A GALAXY THAT IS MOVING AWAY, ONE WOULD EXPECT TO SEE SPECIFIC LIGHT GIVEN OFF BY STARS BECAUSE OF THE TYPES OF ATOMS WITHIN THOSE STARS — MUCH LIKE THE LIGHT THAT WE SEE FROM OUR SUN TODAY
- BUT HUBBLE DISCOVERED THAT THOSE STARS TENDED TO HAVE LIGHT THAT WAS “SHIFTED” TO THE RED SPECTRUM

# RED SHIFTING



- THIS SHIFT IN THE COLOR OF LIGHT IS ATTRIBUTED TO THE DOPPLER EFFECT, WHEREBY THE LENGTH OF A WAVE IS INCREASED AS THE SOURCE OF THE WAVE AND THE REFERENCE POINT MOVE FARTHER FROM ONE ANOTHER
- AS WE INCREASE THE WAVE LENGTH OF VISIBLE LIGHT, IT WILL “SHIFT” TOWARD THE LONGER WAVE LENGTHS (I.E. RED) – THIS IS WHY WE CALL THIS PHENOMENA **RED SHIFTING**



# THE NAYSAYERS

AND STEADY STATE THEORY

# SIR JAMES JEANS

- NOT ALL SCIENTISTS AT THE TIME WERE SATISFIED WITH HUBBLE'S DISCOVERY, SEVERAL CHALLENGED HIS THEORY
- A LEADING THEORY PUT FORTH AT THE TIME TO EXPLAIN HUBBLE'S OBSERVATIONS BUT CONTEST THE BIG BANG THEORY WAS CALLED THE STEADY-STATE THEORY
- THIS WAS FIRST PUT FORTH BY SIR JAMES JEANS





# THE COUNTER ARGUMENT

- TWO OF THE MAIN POINTS AGAINST THE BIG BANG WAS (1) THAT YOU COULD NOT COMPLETELY RULE OUT THAT AT SOME POINT IN THE PAST THE UNIVERSE WAS NOT EXPANDING AND (2) THAT HUBBLE'S IDEAS ASSUMED THE SPEED OF THE EXPANDING UNIVERSE HAS NEVER CHANGED

# STEADY-STATE THEORY

- STEADY-STATE THEORY SAYS THAT INSTEAD OF THE UNIVERSE EXPANDING, THE UNIVERSE HAS A FIXED DENSITY, WHEREBY MATTER BEING CONTINUOUSLY CREATED TO FORM NEW STARS AND GALAXIES IS AT THE SAME RATE THAT OLD ONES BECOME UNOBSERVABLE AS A CONSEQUENCE OF THEIR INCREASING DISTANCE AND VELOCITY OF RECESSION

# HUH? WHAT DOES THAT MEAN?

- A STEADY-STATE UNIVERSE HAS NO BEGINNING AND NO END
- AS STARS AND GALAXIES DIE OFF, THEY ARE BEING REPLACED BY NEW STARS AND NEW GALAXIES
- SO FROM THE MACRO POINT OF VIEW (I.E. VIEWING THE UNIVERSE ON A GRAND SCALE) — FROM ANY POINT WITHIN THE UNIVERSE, THE AVERAGE DENSITY AND ARRANGEMENT OF GALAXIES IS THE SAME

A visualization of the Cosmic Microwave Background (CMB) radiation. The image shows a dark blue background with a prominent, bright blue, swirling pattern in the upper left quadrant, representing the CMB's temperature fluctuations. The rest of the image is filled with a field of small, multi-colored stars (red, blue, yellow, purple) scattered across the dark space.

# COSMIC BACKGROUND RADIATION

AT GATEWAY TO THE PAST

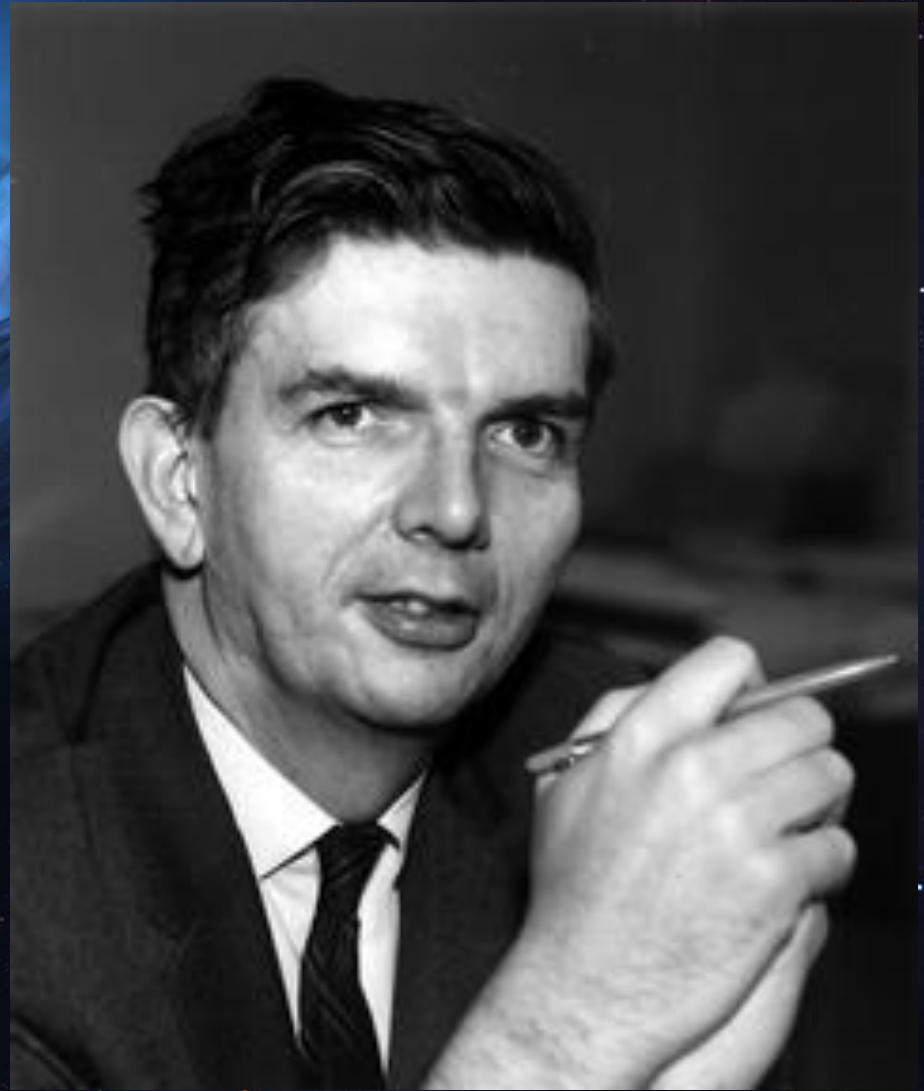
# ARNO PENZIAS AND ROBERT WILSON

- IN 1962 A PAIR OF SCIENTISTS WERE FINALLY ABLE TO USE A SPECIFIC ANTENNA THAT HAD BEEN FREED UP FOR USE.
- WHEN BEGAN USING THE TELESCOPE, THEY DISCOVERED THAT THEY WAS BACKGROUND INTERFERENCE IN THE RADIO WAVE RANGE (SPECIFICALLY THE MICROWAVE RANGE).
- THIS WAS NOT UNUSUAL FOR INSTRUMENTS AT THE TIME, BUT UPON FURTHER INVESTIGATION THEY FOUND THAT THE SOURCE OF THE STATIC WAS EXTRATERRESTRIAL RADIATION
- BECAUSE THEY HAD NO EXPLANATION FOR THIS THEY BEGAN SEARCHING FOR THEORETICAL EXPLANATIONS



# ROBERT DICKE

- A PRINCETON PROFESSOR PURSUING THEORIES ABOUT THE BIG BANG
- HAD ELABORATED ON EXISTING THEORIES TO SUGGEST THAT IF THERE HAD BEEN A BIG BANG, THE RESIDUE OF THE EXPLOSION SHOULD BY NOW TAKE THE FORM OF A LOW-LEVEL BACKGROUND RADIATION THROUGHOUT THE UNIVERSE.
- HE WAS SEEKING EVIDENCE OF THIS THOUGH, WHICH LEAD PENZIAS AND WILSON TO HIM



# COSMIC BACKGROUND RADIATION (CBR)

- SO PENZIAS AND WILSON PUBLISHED THEIR FINDINGS ABOUT CBR WHICH LATER LEAD TO THEM RECEIVING THE NOBLE PRIZE FOR PHYSICS IN 1978.
- CBR IS THE AFTERGLOW OF THE BIG BANG, COOLED TO A FAINT WHISPER WITHIN THE MICROWAVE SPECTRUM BECAUSE OF THE EXPANSION OF THE UNIVERSE FOR ALMOST 14 BILLION YEARS
- SIMPLY PUT, IT IS THE RELIC RADIATION LEFT OVER FROM THE HOT, VERY DENSE YOUNG UNIVERSE DURING THE EARLY YEARS AFTER THE BIG BANG

# SO WHY IS CBR IMPORTANT?

- THE DISCOVERY OF COSMIC BACKGROUND RADIATION (AND LATER THE EXTENSIVE MEASUREMENT OF CBR) HAS VALIDATED THE BIG BANG THEORY OVER THE STEADY-STATE THEORY
- THIS IS INTERESTING BECAUSE ROBERT WILSON WAS TRAINED IN STEADY-STATE THEORY AND FELT UNCOMFORTABLE WITH THE BIG BANG EXPLANATION OF THEIR RADIO NOISE.
- THIS IS WHY WILSON ONLY WANTED TO PUBLISH THE FACTS ABOUT THEIR RECORDED OBSERVATIONS.
- IT IS ALSO IRONICAL THAT MANY RESEARCHERS – BOTH THEORETICAL AND EXPERIMENTAL – HAD STUMBLED UPON THIS PHENOMENON BEFORE, BUT EITHER DISCOUNTED IT OR NEVER PUT IT ALL TOGETHER.





# THE HISTORY OF THE UNIVERSE

A BIG BANG TIMELINE

# THE BIG BANG THEORY

TIME BEGINS

ONE SECOND

PRESENT DAY

Time	$10^{-43}$ sec.	$10^{-32}$ sec.	$10^{-6}$ sec.	3 min.	300,000 yrs.	1 billion yrs.	15 billion yrs.
Temperature		$10^{27}$ °C	$10^{13}$ °C	$10^8$ °C	$10,000$ °C	-200° C	-270° C

**1** The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fraction of a second

**2** Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles

**3** A rapidly cooling cosmos permits quarks to clump into protons and neutrons

**4** Still too hot to form into atoms, charged electrons and protons prevent light from shining; the universe is a superhot fog

**5** Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally shine

**6** Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies; smaller clumps of gas collapse to form the first stars

**7** As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; these will eventually form into new stars and planets

NOTE: The numbers in cosmology are so great and the numbers in subatomic physics are so small that it is often necessary to express them in exponential form. Ten multiplied by itself, or 100, is written as  $10^2$ . One thousand is written as  $10^3$ . Similarly, one-tenth is  $10^{-1}$ , and one-hundredth is  $10^{-2}$ .