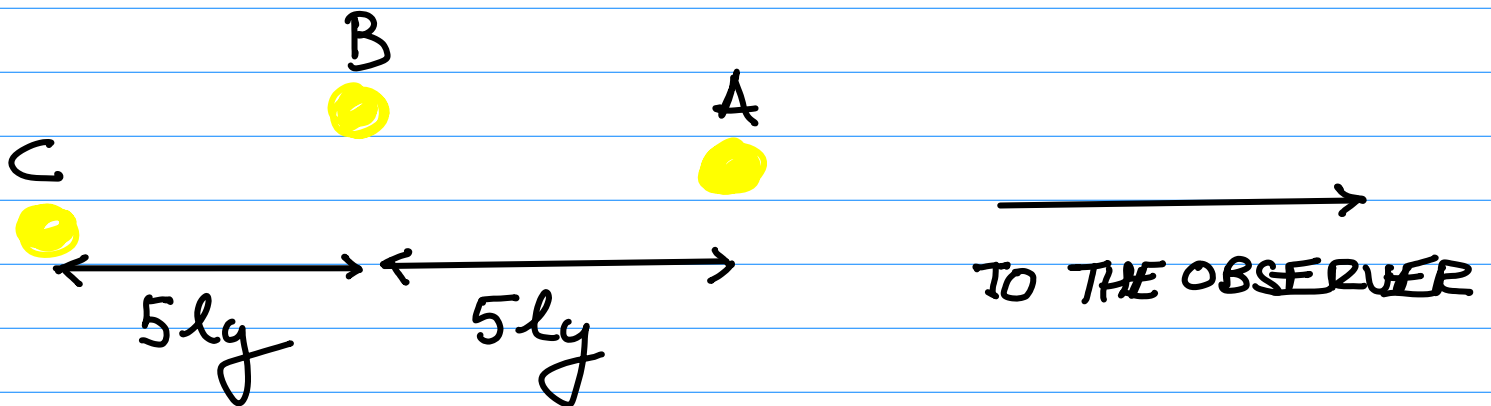


Why is THE TIME OVER WHICH THE INTENSITY OF A SOURCE VARIES RELATED TO ITS MAXIMUM SIZE?

EXAMPLE: THREE SOURCES SEPARATED BY 5 ly



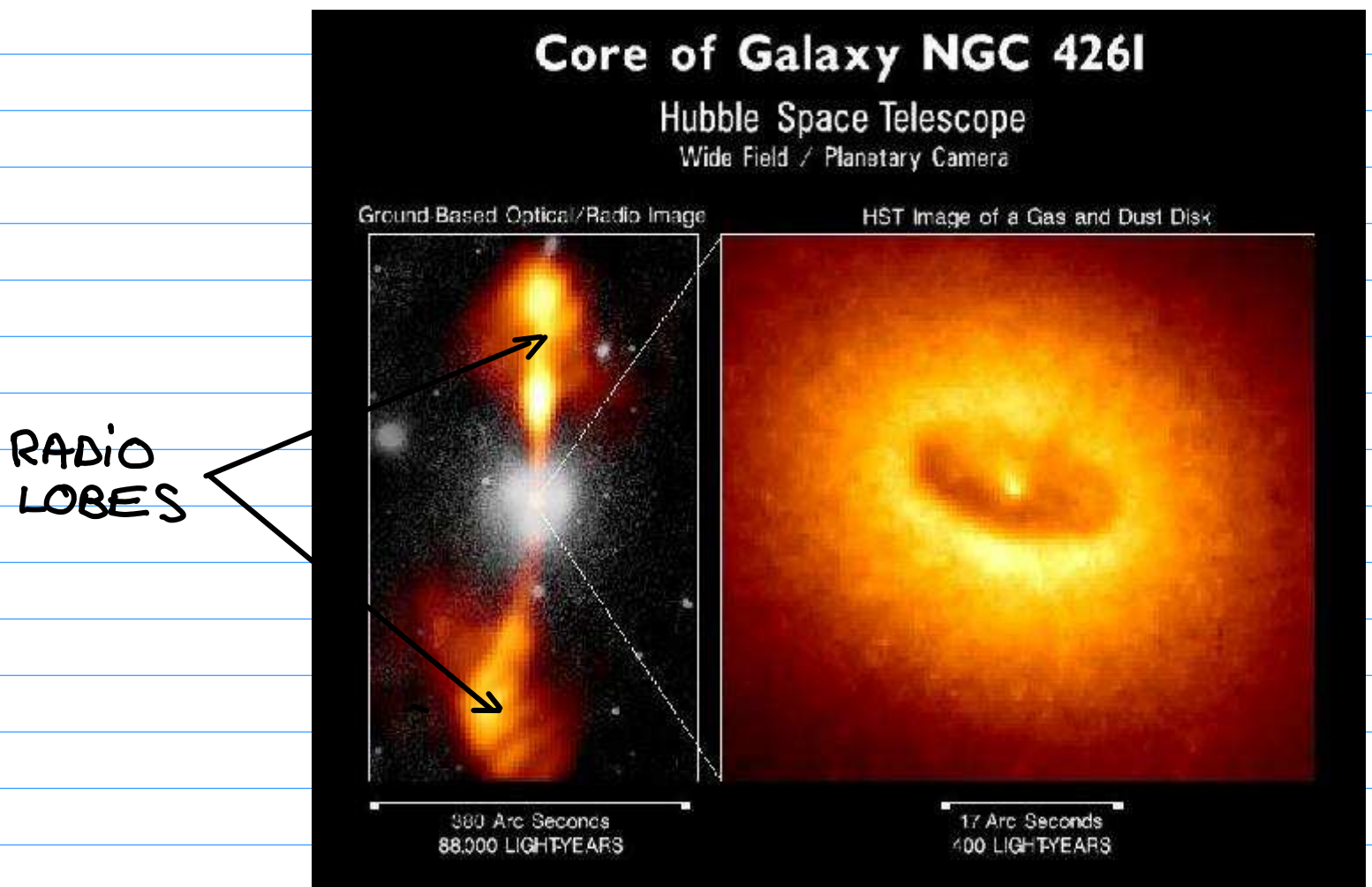
THE THREE SOURCES ARE TURNED ON AT THE SAME TIME:

- WE FIRST SEE A.
- 5 YEARS LATER WE SEE A & B (BUT NOT C).
- 10 YEARS LATER WE SEE ALL THREE SOURCES.

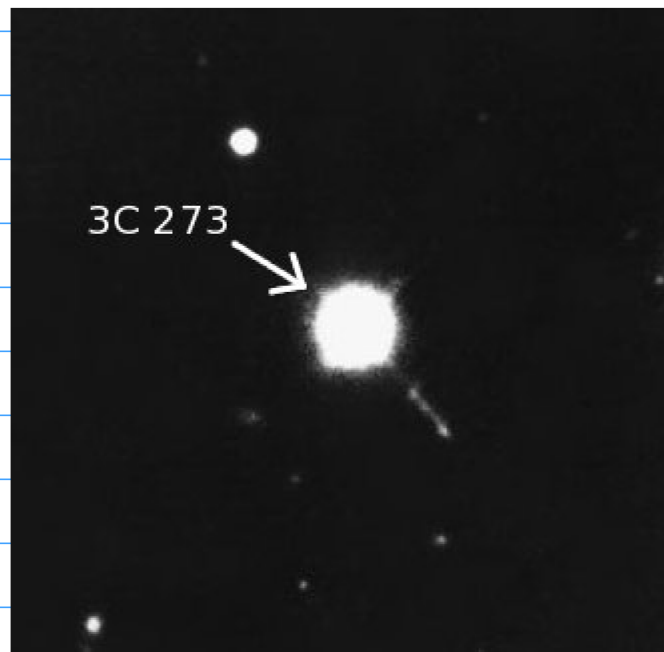
THE LIGHT INTENSITY HAS GONE

FROM 0 TO THE MAXIMUM VALUE IN 10 YEARS BECAUSE THE SIZE OF THE SOURCE (A+B+C) IS 10 ly.

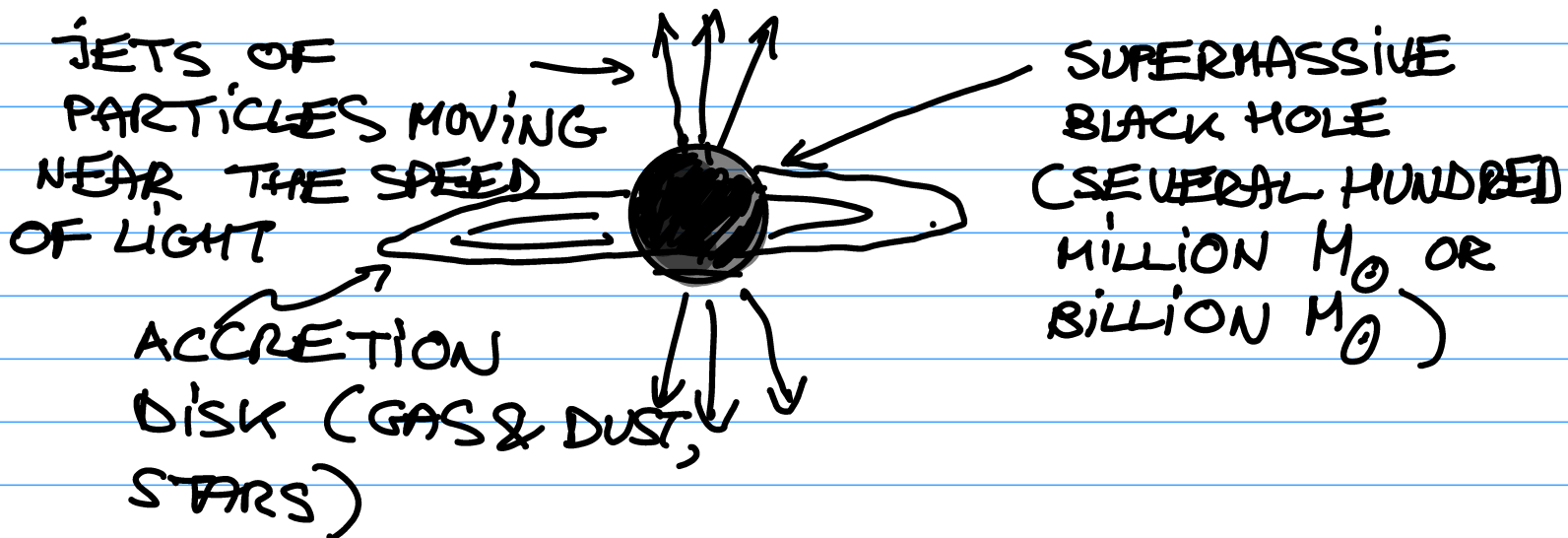
2) RADIO GALAXIES : ELLIPTICAL GALAXIES WHICH EMIT INTENSE RADIO WAVES FROM THEIR CORES AND FROM REGIONS OUTSIDE THE GALAXY (RADIO LOBES).



3) QUASARS (QUASISTELLAR RADIO SOURCES) - "STARS" WHICH ARE ALSO SOURCES OF INTENSE RADIO WAVES (NORMALLY, STARS DO NOT EMIT MUCH ENERGY AT RADIO WAVELENGTHS).



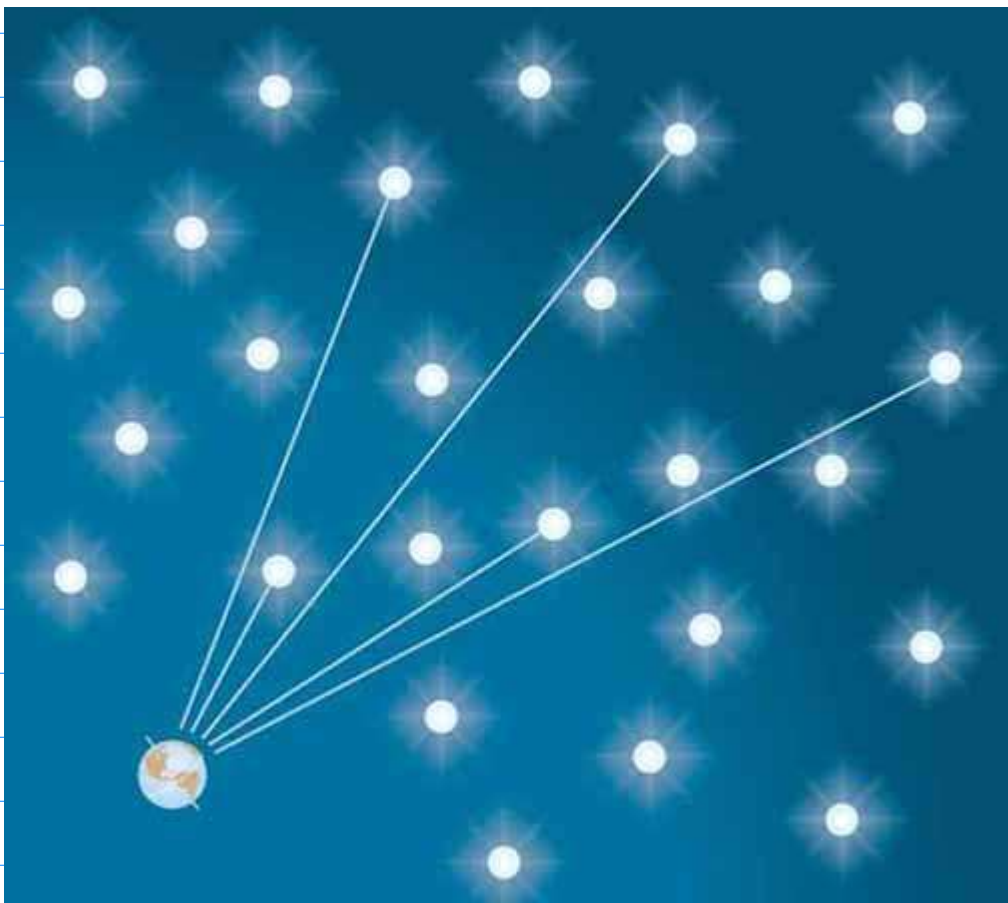
A MODEL FOR GALAXIES WITH ACTIVE GALACTIC NUCLEI:



COSMOLOGY

THE UNIVERSE HAS A FINITE AGE.

OLBERS' PARADOX (1826): IF THE UNIVERSE EXISTED FOR EVER, IS INFINITE, AND IS UNIFORMLY FILLED WITH STARS THEN THE NIGHT SKY SHOULD NOT BE DARK:

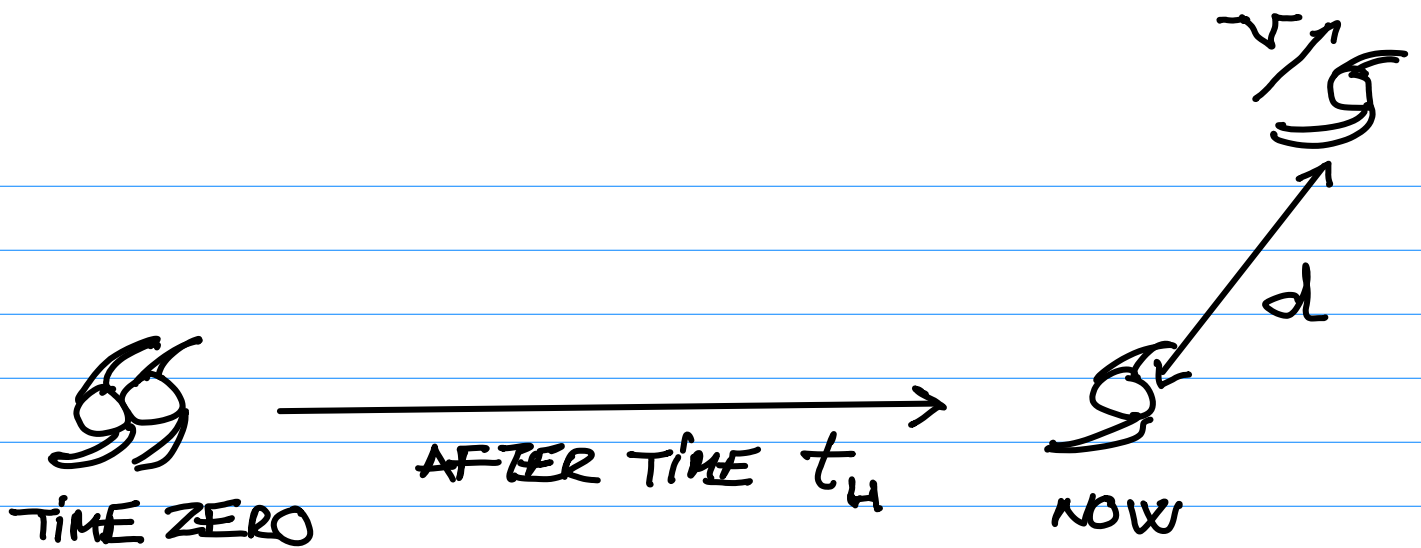


ANALOGY: A VIEW FROM DEEP WITHIN
A FOREST



PLAUSIBLE RESOLUTION (EDGAR ALLAN POE, 1849):
THE UNIVERSE IS NOT INFINITELY OLD AND THE
LIGHT FROM DISTANT STARS DIDN'T HAVE
TIME TO REACH US YET.

BIG BANG THEORY: THE UNIVERSE
(INCLUDING SPACE & TIME) WAS CREATED
IN A GIANT EXPLOSION AND HAS BEEN
EXPANDING EVER SINCE. THE HUBBLE'S
LAW IS CONSISTENT WITH THIS SCENARIO.
HOW OLD IS THE UNIVERSE BASED
ON HUBBLE'S LAW (SO-CALLED HUBBLE'S
TIME)?



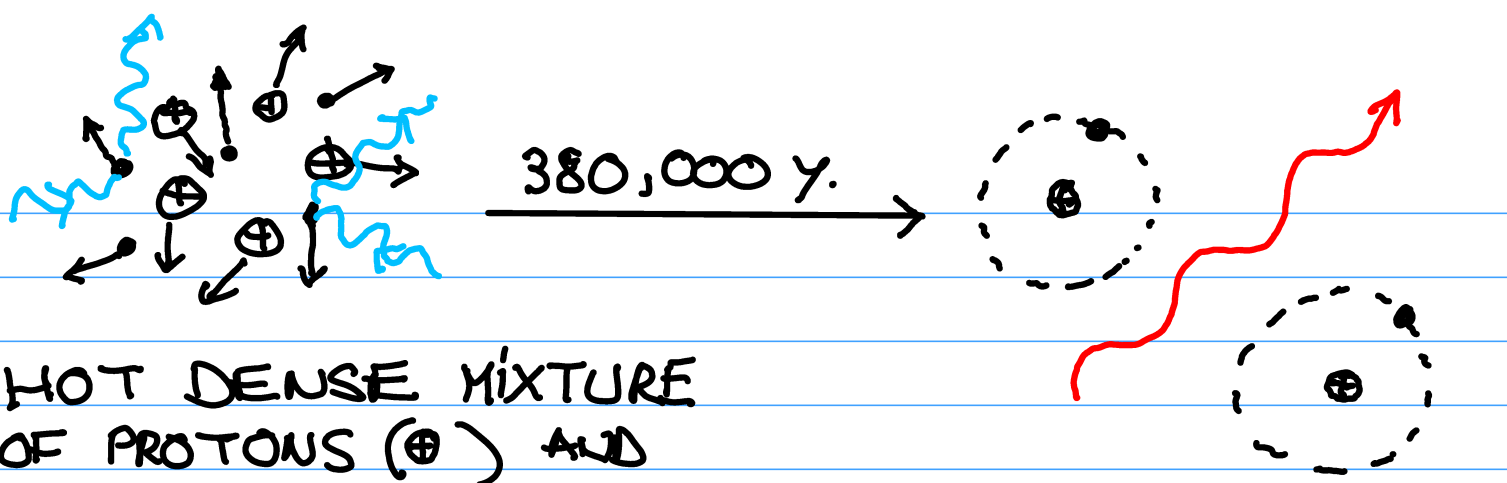
$$\begin{aligned}
 d &= V t_H \\
 V &= H d
 \end{aligned}
 \left. \vphantom{\begin{aligned} d &= V t_H \\ V &= H d \end{aligned}} \right\} \Rightarrow d = H d t_H$$


HUBBLE'S TIME $\rightarrow t_H = \frac{1}{H} \approx 13.7$ BILLION YEARS

WHAT IS THE EVIDENCE FOR THE BIG BANG?

RIGHT AFTER THE EXPLOSION THE UNIVERSE HAD TO BE VERY HOT AND DENSE, BUT IT COOLED AS IT EXPANDED.

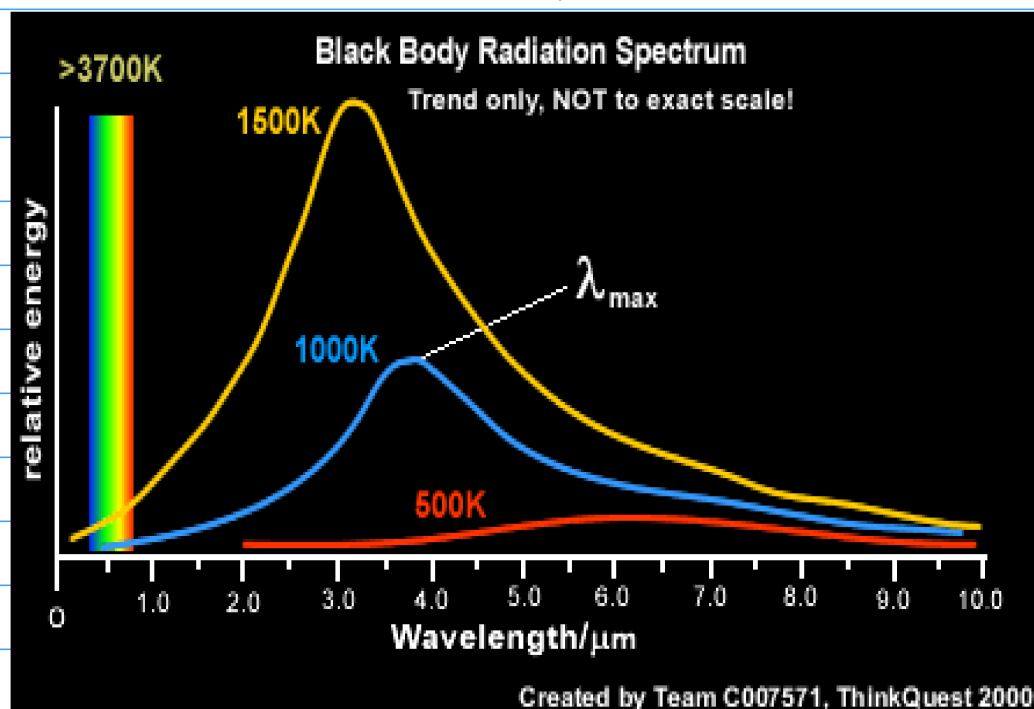
WHEN THE TEMPERATURE DROPPED TO ABOUT 3000 K, ABOUT 380,000 YEARS AFTER THE BIG BANG, IT WAS POSSIBLE FOR PROTONS TO CAPTURE ELECTRONS AND FORM NEUTRAL HYDROGEN ATOMS:



HOT DENSE MIXTURE
OF PROTONS (⊕) AND
ELECTRONS (⊙) AND
SCATTERED PHOTONS
()

NEUTRAL HYDROGEN
ATOMS AND
FREELY PROPAGATING
PHOTONS

THE UNIVERSE BECAME TRANSPARENT TO
LIGHT. THE RADIATION WAS IN EQUILIBRIUM
WITH MATTER AT 3,000 K AND THUS
SATISFIED THE WIEN'S LAW (BLACK
BODY RADIATION LAW):



$$\lambda_{max} = \frac{3 \times 10^6}{T} \quad \text{OR} \quad T = \frac{3 \times 10^6}{\lambda_{max}}$$

For $T = 3,000 \text{ K}$ $\lambda_{\text{max}} = 1,000 \text{ nm}$

SINCE THEN THE UNIVERSE EXPANDED IN SIZE 1000 TIMES AND THE COSMOLOGICAL REDSHIFT INCREASED λ_{max} TO $10^6 \text{ nm} = 10^{-3} \text{ m} = 1 \text{ mm}$ WHICH
 10^{-9} m

IS IN THE MICROWAVE RANGE AND THE CORRESPONDING TEMPERATURE IS ABOUT $3000 \text{ K} / 1000 = 3 \text{ K}$. THIS RELIC RADIATION, SO-CALLED MICROWAVE BACKGROUND RADIATION, SHOULD BE OBSERVABLE IN ALL DIRECTIONS, DAY AND NIGHT.

IT WAS FIRST OBSERVED IN 1964 BY ARNO PENZIAS AND ROBERT WILSON OF BELL LABS. SINCE THEN, SEVERAL SATELLITE MISSIONS WERE PERFORMED TO EXAMINE THE DETAILS OF THE MICROWAVE BACKGROUND RADIATION

