Astro215hf
CMB Experiments, Surveys and Analysis
Lecture 1

Clem Pryke

Feb 9 2016

Modern cosmology in a nutshell:

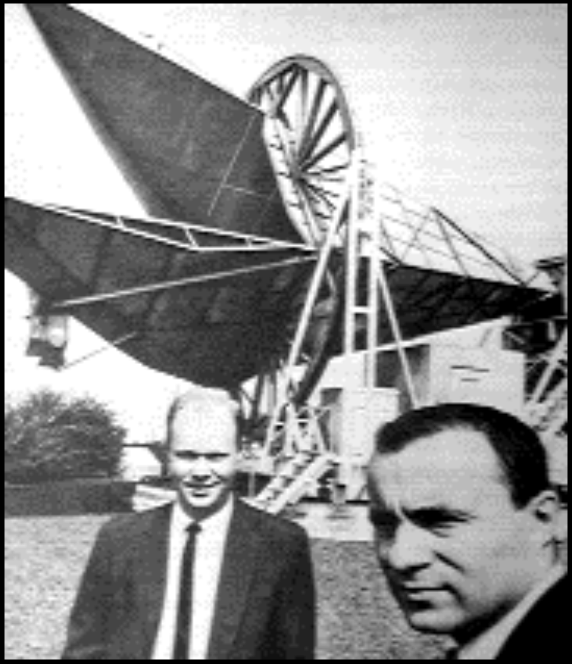
Edwin Hubble

1) The universe is expanding.

(Hubble, 1920s)

2) It was once hot and dense, like the inside of the Sun.

(Alpher, Gamow, Herman, 1940s)



Bob Wilson & Arno Penzias
1978 Nobel Prize

3) You can still see the glow!
The *Cosmic Microwave Background*
(Penzias & Wilson, 1964)

⇒ acceptance of the "HOT BIG BANG"

Hubble and the expanding Universe

- In the 1920's discovery that Universe is expanding

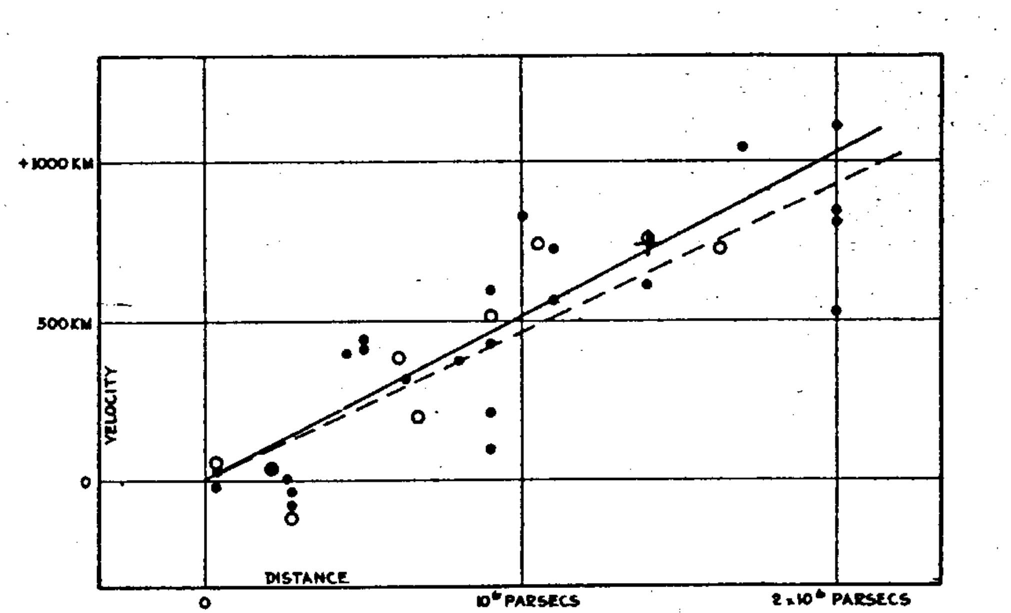
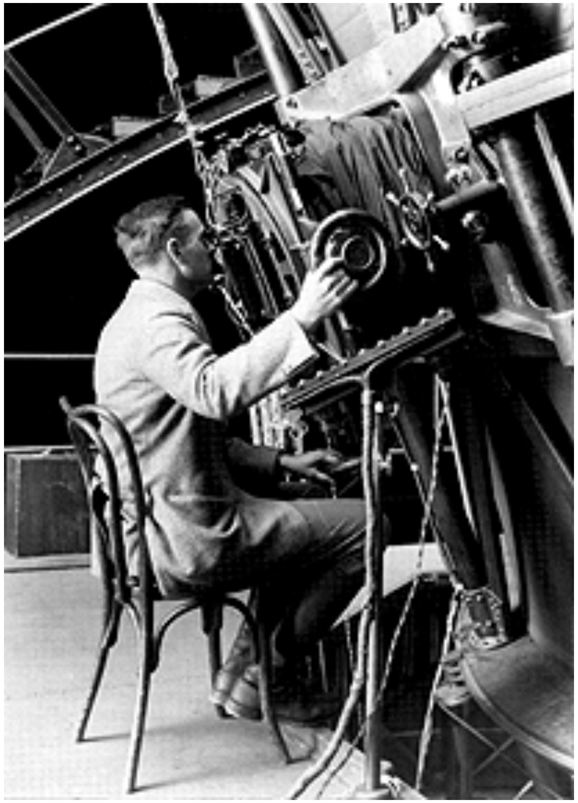
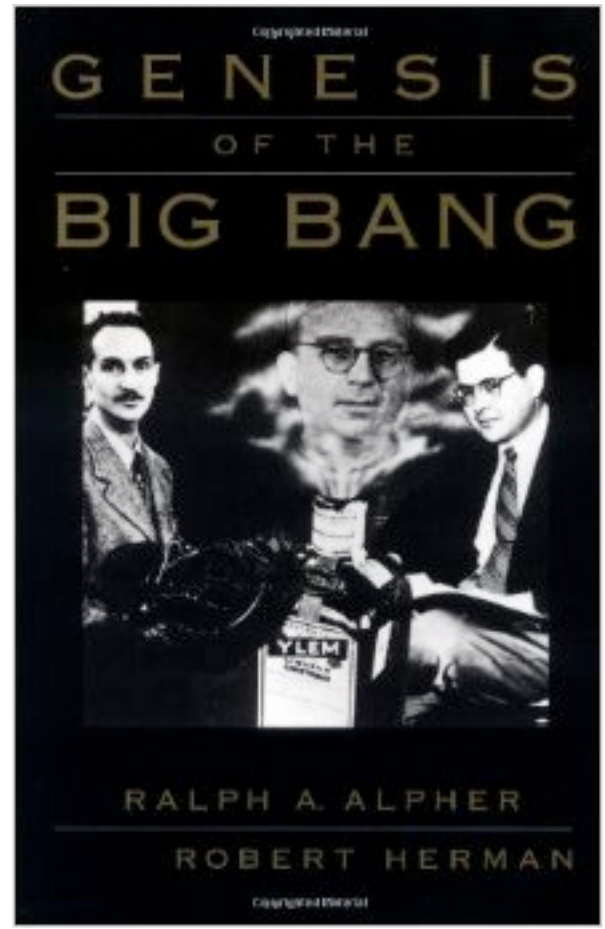


FIGURE 1



Birth of Big Bang Nucleosynthesis

- In late 1940's Gamow, Alpher and Hermann were developing theories of element formation by neutron capture in first few minutes after big bang
- Implicit that thermal photon field present…



BB Radiation in expanding universe

- The Planck function specifies not just the distribution, but also the absolute number density of photons in a thermal radiation field
- The energy density in J m^{-3} Hz^{-1} is

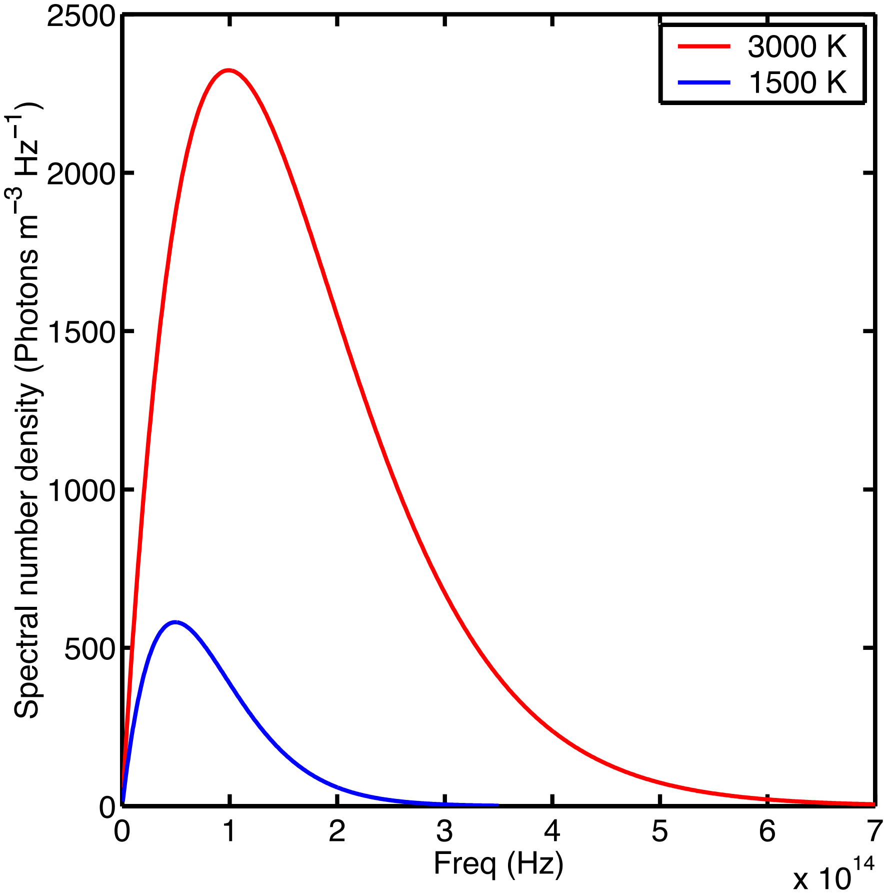
$$I(\nu) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{h\nu/kT}-1}$$

- Dividing by the energy per photon $E = h\nu$ the photon number density in ptcles. m^{-3} Hz^{-1} is

$$I(\nu) = \frac{8\pi\nu^2}{c^3}\frac{1}{e^{h\nu/kT}-1}$$

BB Radiation in expanding universe

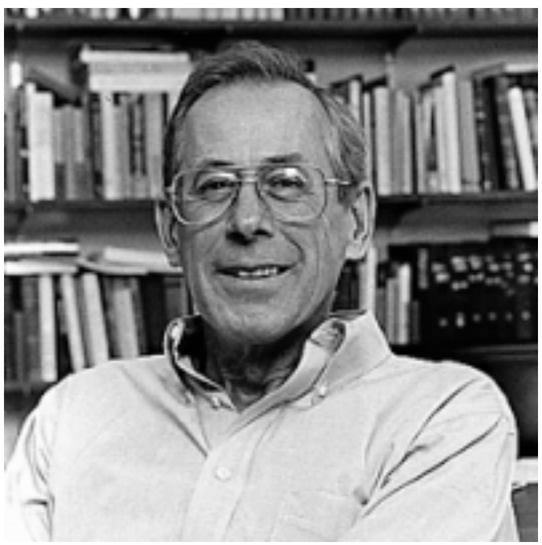
- Stretch space by factor 2:
  - Each photon goes to nu/2
  - Each bin in Hz now has twice as many…
  - …but diluted into 8x the space
- Net effect of this is the same as T goes to T/2
- If it was anything other than nu^2 the photon field would not remain thermal



Conference at Princeton last summer:

cosmic microwave background @50

2015 june | 10 - 12 | princeton university



- Jim Peebles gave a talk
- Emphasized that this was first pointed out by Tolman in 1934

Penzias and Wilson 1965

A MEASUREMENT OF EXCESS ANTENNA TEMPERATURE
AT 4080 Mc/s

Measurements of the effective zenith noise temperature of the 20-foot horn-reflector antenna (Crawford, Hogg, and Hunt 1961) at the Crawford Hill Laboratory, Holmdel, New Jersey, at 4080 Mc/s have yielded a value about 3.5° K higher than expected. This excess temperature is, within the limits of our observations, isotropic, unpolarized, and

free from seasonal variations (July, 1964–April, 1965). A possible explanation for the observed excess noise temperature is the one given by Dicke, Peebles, Roll, and Wilkinson (1965) in a companion letter in this issue.

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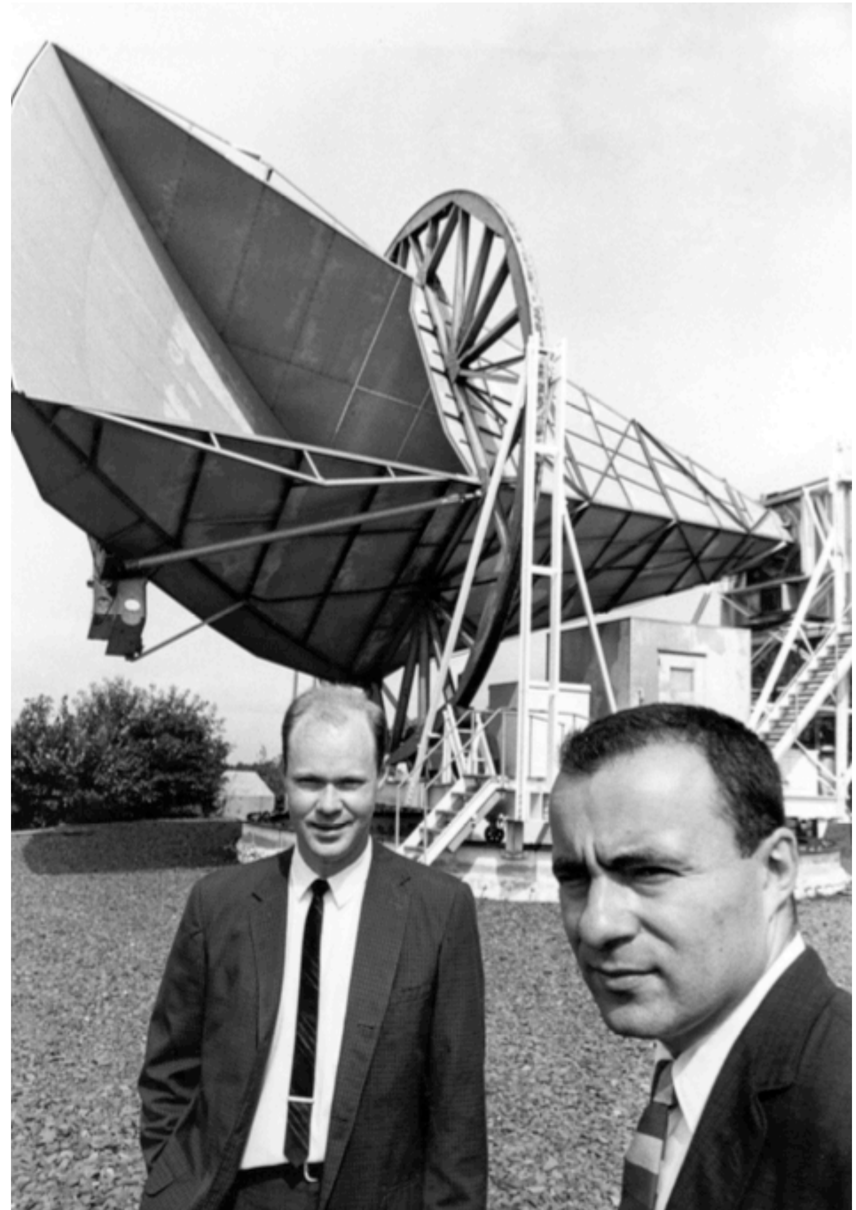
A. A. Penzias
R. W. Wilson

May 13, 1965

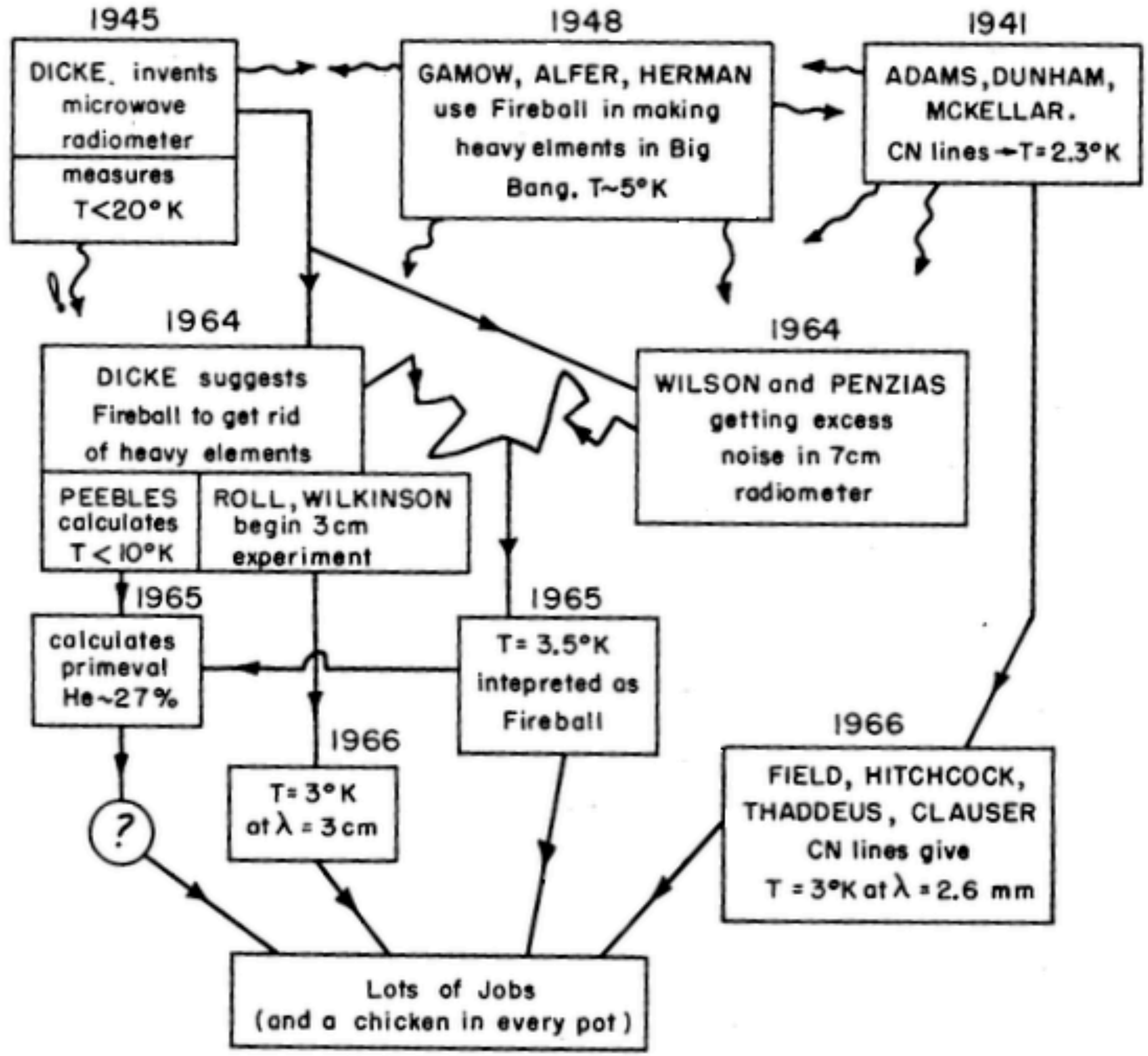
REFERENCES

- Fresh radio astronomy PhD's
- Found excess isotropic signal
- Turned out to be CMB!
- Paper *is* a letter



Finding the CMB

CMB@50
June 2015
PJE Peebles



The negative for this figure is marked December 1966.