OLBERS’ PARADOX: why is the night sky so dark?

Were the succession of stars endless, then the background of the sky would present us a uniform luminosity, like that displayed by the Galaxy – since there could be absolutely no point, in all that background, at which would not exist a star. The only mode, therefore, in which, under such a state of affairs, we could comprehend the voids which our telescopes find in innumerable directions, would be by supposing the distance of the invisible background so immense that no ray from it has yet been able to reach us at all.
The local universe

2MASS infrared galaxy survey: $10^6$ galaxies
Why the sky is dark at night

Olbers’ Paradox

Divide universe into shells of galaxies
Each shell contributes according to its area ($\sim r^2$)
and its contribution decreases as $1/r^2$

So each shell contributes equally

There is no limit if the universe is infinite
Resolution:
The universe has a finite age, 13.7 billion years otherwise there would be too many stars
RELICS FROM THE ORIGIN OF SPACE-TIME

• the fundamental forces of nature
THE BEGINNING

INFLATION $10^{-35}$

HERE WE ARE $10^{10}$ yr

LHC

$10^6$ GeV

$10^9$ GeV

ENERGY

PLANCK SCALE

GRAND UNIFICATION
RELICS FROM $10^{-36}$ second AFTER THE BIG BANG
The distant universe

COBE DMR Microwave Sky at 53 GHz
The distant universe (ctd)

Planck satellite: cosmic microwave background fluctuations at 1 part in $10^5$
• Age of the universe from the expansion
accelerating model
open
critical density

13.7 x 10^9 yr
• Age of the universe from the expansion
• Age from radioactive chemistry
old  young  "new-born"

\[ \text{U}^{238} \text{ decays with half life } 4 \times 10^9 \text{ yr} \]

\[ \text{Pb}^{205} \rightarrow \text{U}^{238} \]

radiogenic isotope of lead

only formed by this decay process

\[ \text{Th}^{232} \rightarrow \text{Pb}^{208} \quad 13.9 \times 10^9 \text{ yr} \]

\[ \text{U}^{235} \rightarrow \text{Pb}^{207} \quad 0.7 \times 10^9 \text{ yr} \]
ORIGIN OF THE LIGHT ELEMENTS
predicted origin of light elements & fossil radiation in 1949

The Origin of Chemical Elements

R. A. Alpher*
Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland

AND

H. Bethe
Cornell University, Ithaca, New York

AND

G. Gamow
The George Washington University, Washington, D.C.

February 18, 1948

half an hour of creation...
predicted origin of light elements & fossil radiation in 1949

ROBERT HERMAN, GEORGE GAMOW, RALPH ALPHER

- helium
- deuterium
- lithium
ORIGIN OF THE HEAVY ELEMENTS

We are the ashes of stars
A massive star evolves.

Hydrogen, helium, carbon, nitrogen, oxygen, iron.

And explodes.

From its ashes, our solar system formed.
Relic of an exploding star recorded by Chinese astronomers in 1054
CIRCULATION OF THE DEBRIS
GALACTIC DISRUPTION
A computer simulation of a disrupted infalling dwarf galaxy

Bonnell 2015
A nearby galaxy
A computer simulation

A nearby galaxy

Cooper et al 2010

Martinez-Delgado et al 2008
THE FIELD OF STREAMS
ULTRAFAINT DWARF GALAXIES
A gallery of S0/S0a dwarf galaxies

Canes Venatici I

- $D = 220$ kpc
- $r_h = 550$ pc
- $M_V = -7.9$ mag

Bootes

- $D = 60$ kpc
- $r_h = 220$ pc
- $M_V = -5.8$ mag

Canes Venatici II

- $D = 150$ kpc
- $r_h = 140$ pc
- $M_V = -4.8$ mag

Coma Berenices

- $D = 44$ kpc
- $r_h = 70$ pc
- $M_V = -3.7$ mag
GALAXY COLLISIONS
Grav. instability forms massive clusters

Pile up in a massive TDG
some typical galaxies
Searching for evidence of a collision between galaxies... its like a crime scene
The sausage cluster
The toothbrush cluster
GAMMA RAY FOSSIL CLOSE TO HOME
GAMMA RAY FOSSIL CLOSE TO HOME

gamma ray sources as seen by the FERMI satellite
The diffuse gamma ray background

A GIGANTIC EXPLOSION OCCURRED A MILLION YEARS AGO AT THE CENTRE OF THE MILKY WAY
How we do cosmology

By looking far away, into the remote past
By searching for nearby fossils
How we do cosmology
By looking far away, into the remote past
By searching for nearby fossils

The questions we pose
Where do we come from?
What is the universe made of?
Where are we going?
How we do cosmology

By looking far away, into the remote past
By searching for nearby fossils

The questions we pose
Where do we come from?
What is the universe made of?
Where are we going?

We are still searching...