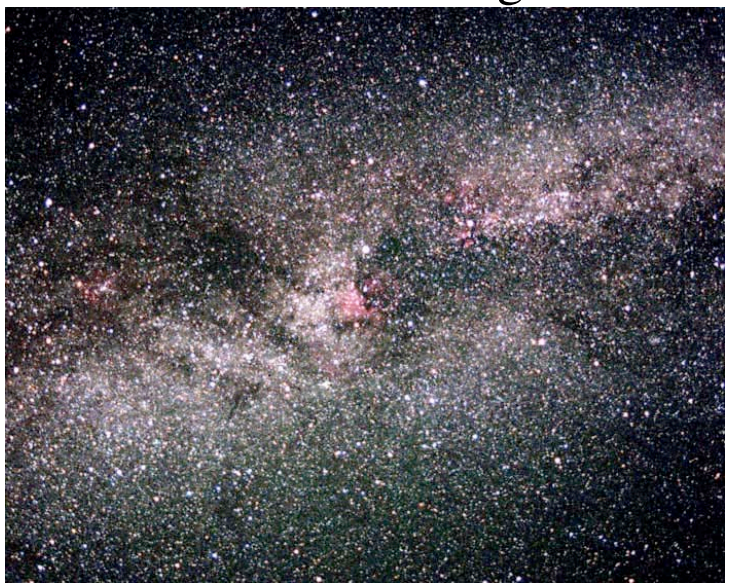
Darkness At Night



Darkness At Night?

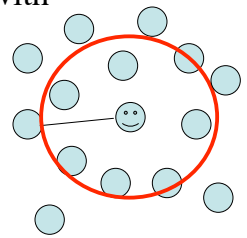
- Why is the night sky dark?
  - Suppose that the universe is infinite.
  - Suppose that stars are uniformly distributed.
  - The number of stars in the entire universe under these two assumptions would be infinite.
  - We should see the infinite number of stars on the sky at night.
  - But we don't!
- What did we do wrong?
  - The universe is finite?
  - The stars are not evenly distributed?
  - Have we taken into account the particle horizon?
  - Or, are we missing something more important?

Olbers' Paradox

- "Why is the night sky dark?" riddle is often called "Olbers' Paradox", but it had been known before Hinrich Olbers who analyzed it in 1823.
- Olbers' argument
  - Each star must have a finite size.
  - As there are so many stars out there, every line-of-sight would intersect the surface of stars.
  - Therefore, the number of stars that we see on the sky would be finite. (We don't see infinite number of stars regardless of the size of the universe.) The line-of-sight would be intercepted by these foreground stars.
  - **However, the night sky would still be bright, as every line of sight is intercepted by the surface of stars.**

Was Olbers Right?

- Notice that his argument is only "qualitative". He did not have the justification for his statement, "**every** line of sight would be intercepted by the surface of stars".
- "Quantitative" study must be performed with some calculations.
- Look-out Limit Distance
  - a.k.a. Mean-free Path of Light
  - $D = 1/(s*n)$
    - $s=\pi R^2$ is the typical surface area of stars.
    - n is the number density of stars.
  - The average distance that light can travel without hitting intervening materials with finite size.
  - Each line-of-sight intercepts the surface of stars at D, on average.



Olbers Was Wrong!

- The number density of stars in the universe, *n*
  - There are about 100 billion galaxies witin the current horizon.
  - There are about 100 billion stars within one galaxy.
  - Therefore, there are (100 billion)x(100 billion) = 10^{22} stars within the current horizon.
  - The volume of the current horizon is about (40 billion light years)^3 ~ 10^{31} light-years^3.
  - The average number density of stars in the universe is therefore, **n = 10^{-9} light-years^{-3}**.
- The typical surface area of stars, *s*
  - The radius of the Sun, R, is 700 million meters.
  - s = πR^2 ~ 1.5x10^{18} m^2 ~ **10^{-14} light-years^2**
- The look-out limit distance = 1/(s*n) ~ **10^{23} light years.**
- It's HUGE! This result implies that it is very rare to have our line-of-sight intercepted by the surface of any stars.

So, Why Is The Night Sky Dark?

- The size of the entire universe is irrelevant.
  - We see stars within the current horizon only.
  - It does not matter whether or not the universe is infinite.
- Maybe there are many stars out there, but the volume of the observable universe is also very large.
  - Therefore, the average number density of stars is such that there is only one star per one billion light-years^3.
  - Most of our lines of sight never hit the surface of stars.
- Once the question was formulated in a quantitative way, there was no "paradox".