

Cosmological Principle

Principle:

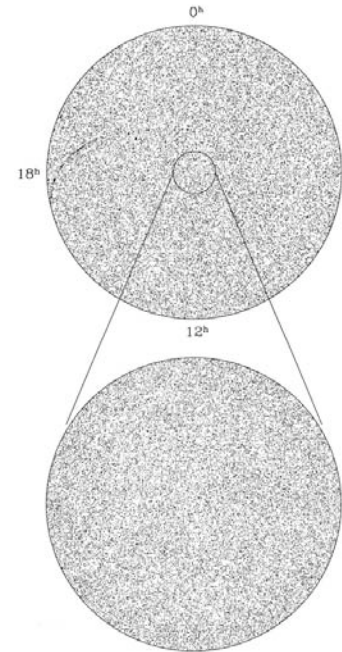
*The universe is **homogeneous and isotropic on large scales.***

Implication:

No center or special point exists in the universe

- Homogeneity
 - All places look alike. No special location.
- Isotropy
 - All directions look alike. No special direction.
- Would it be possible that the universe is...
 - Homogeneous but anisotropic?
 - Inhomogeneous but isotropic?
 - Inhomogeneous and anisotropic?

Evidence for Isotropy

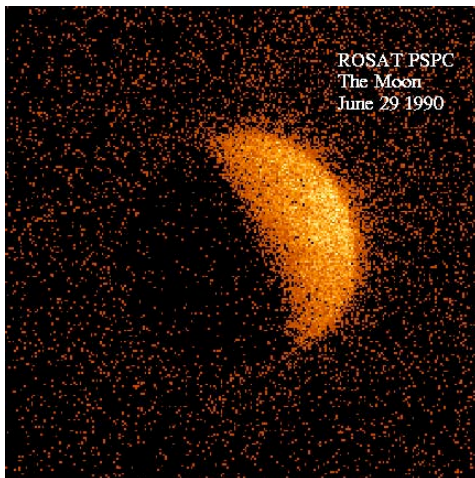


- **Distribution of radio galaxies**
- Observed with the *Very Large Array* (VLA) in New Mexico
- There are 40,000 bright radio galaxies in the upper panel
 - Distribution is isotropic
- There are about the same number of fainter radio galaxies in the bottom panel, which is a zoom-up of the small region in the upper panel

• Distribution of diffuse X-ray light

– Cosmic X-ray Background

- Distribution of AGNs

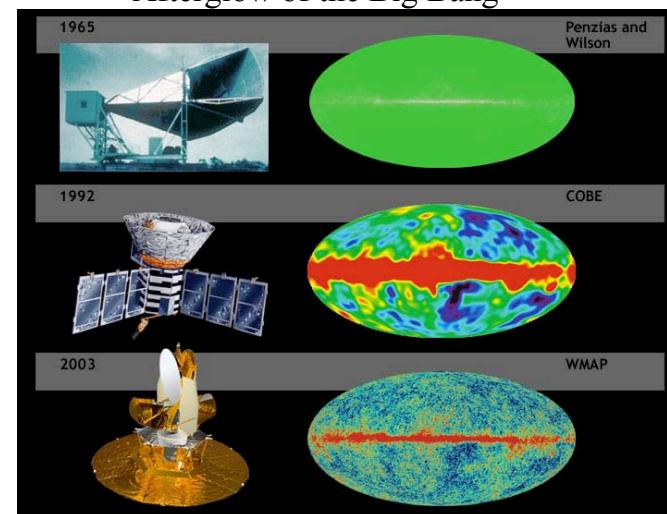


- The bright part of the Moon reflects X-rays from the Sun.
- The dark part blocks any X-rays from behind of the Moon.
- Isotropic “Cosmic X-ray Background” is seen around the Moon.
- This diffuse X-ray light comes from the AGNs that we don’t resolve out individually.

• Distribution of diffuse microwave light

– Cosmic Microwave Background

– Afterglow of the Big Bang



Temperature = 2.73K in all directions

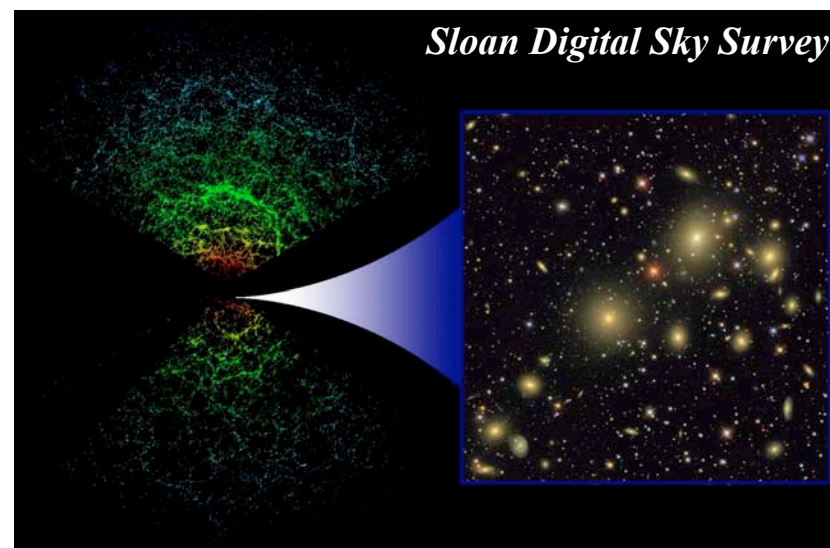
Anisotropy ~ 1/100,000

Anisotropy ~ 1/100,000

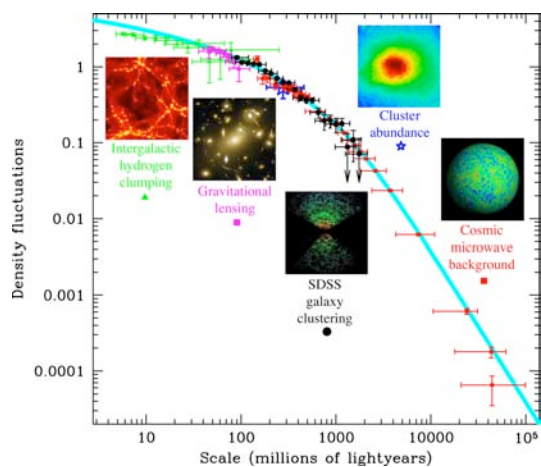
The Universe is Isotropic, but Is It...

- **Homogeneous?**
 - If one place is isotropic, all the other places must be isotropic as well.
- **Inhomogeneous?**
 - One place might be isotropic, but the other places could be anisotropic.
 - Thus, one place being isotropic does not prove homogeneity; however, inhomogeneity requires the existence of “special locations”.
- Isotropy is easier to test from one place in the universe -- our place.
 - Homogeneity is more difficult to test, but it is possible to test homogeneity in the limited region in the universe.

Does This Look Homogeneous?



Homogeneity on large scales



- To see homogeneity, one has to “smear out” the irregularities at small distances (such as galaxies and clusters of galaxies)
- Inhomogeneity decreases at large distances
 - Homogeneous on **large scales!**
- The structure becomes clumpier at small distances.