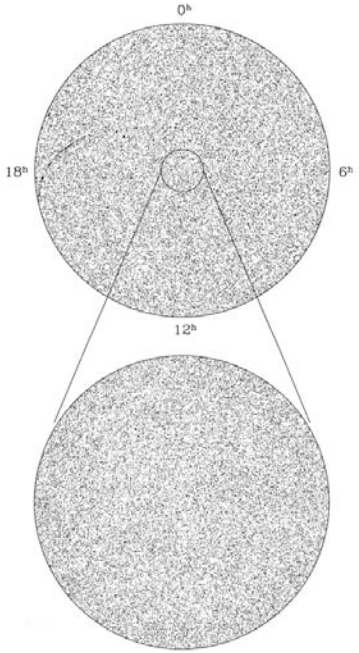
Cosmological Principle

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

Implication: No center or special point exists in the universe

- What do we mean by "homogeneous"?
  - Homogeneous ←→ Inhomogeneous
- What do we mean by "isotropic"?
  - Isotropic ←→ Anisotropic
- Would it be possible that the universe is…
  - Homogeneous but anisotropic?
  - Inhomogeneous but isotropic?
  - Inhomogeneous and anisotropic?
- *Principle*: Something we demand and rely on, but is difficult to verify.

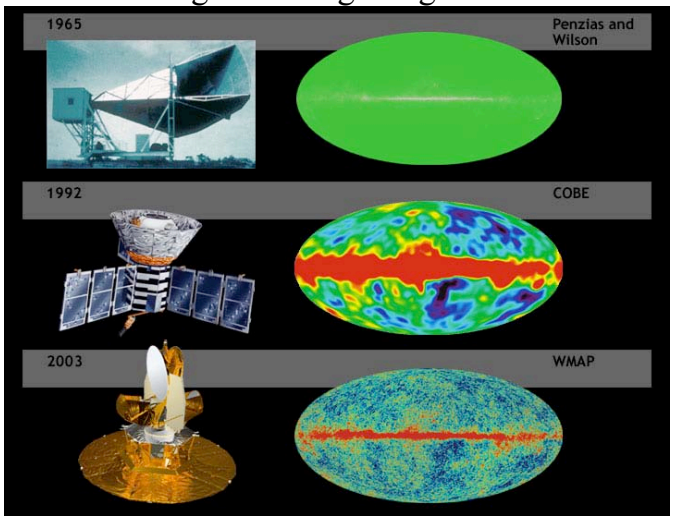
- In a homogeneous universe, if one place is isotropic, then all other places are isotropic.
- In an inhomogeneous universe, one place might be isotropic, but other place are anisotropic.
  - Thus, one place being isotropic does not prove homogeneity; however, inhomogeneity requires the existenec of "special points".
- Isotropy is easier to test from one place in the universe -- our place.
  - Homogeneity is more difficult to test because we have to travel to other places in the universe!



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 microwave light
  - **Cosmic Microwave Background**
  - Afterglow of Big Bang

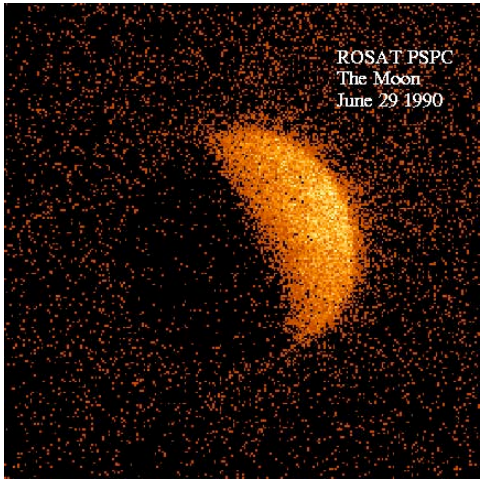


Temperature = 2.73K in all directions

Anisotropy ~ 1/100,000

Anisotropy ~ 1/100,000

- Distribution of diffuse X-ray light
  - **Cosmic X-ray Background**
  - Superposition of AGNs



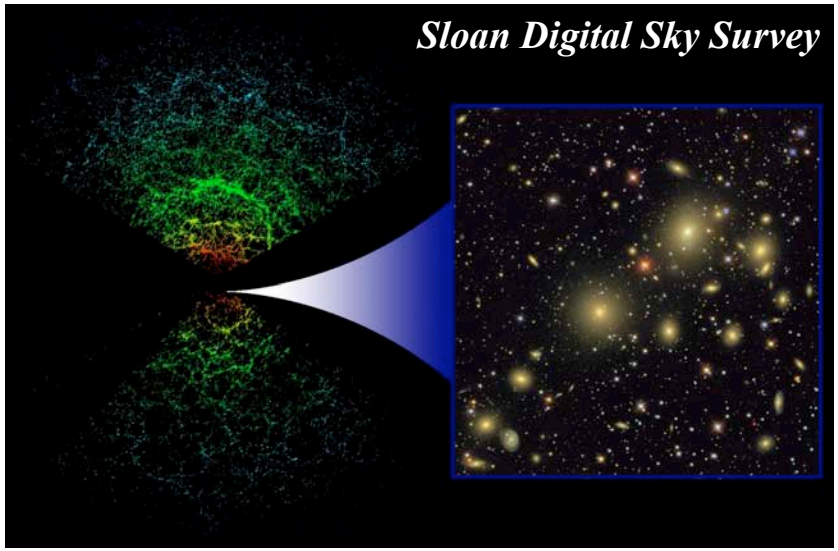
•The bright part of the Moon reflects X-rays from the Sun.

•The dark part blocks any X-rays from behind of the Moon.

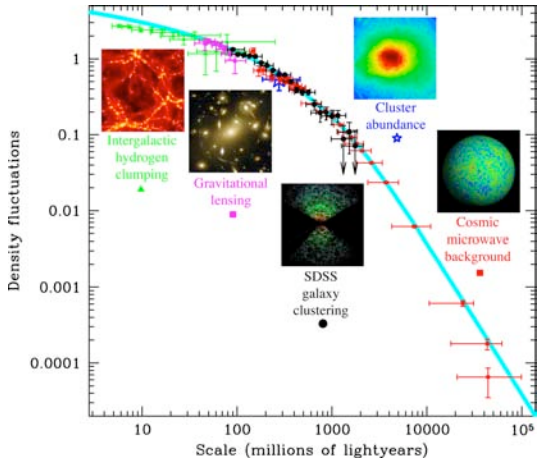
•Isotropic "Cosmic X-ray Background" is seen around the Moon.

•This diffuse X-ray light comes from AGNs which we don't resolve out individually.

Homogeneity?



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 does decrease at large distances
  - Homogeneous on **large scales**!