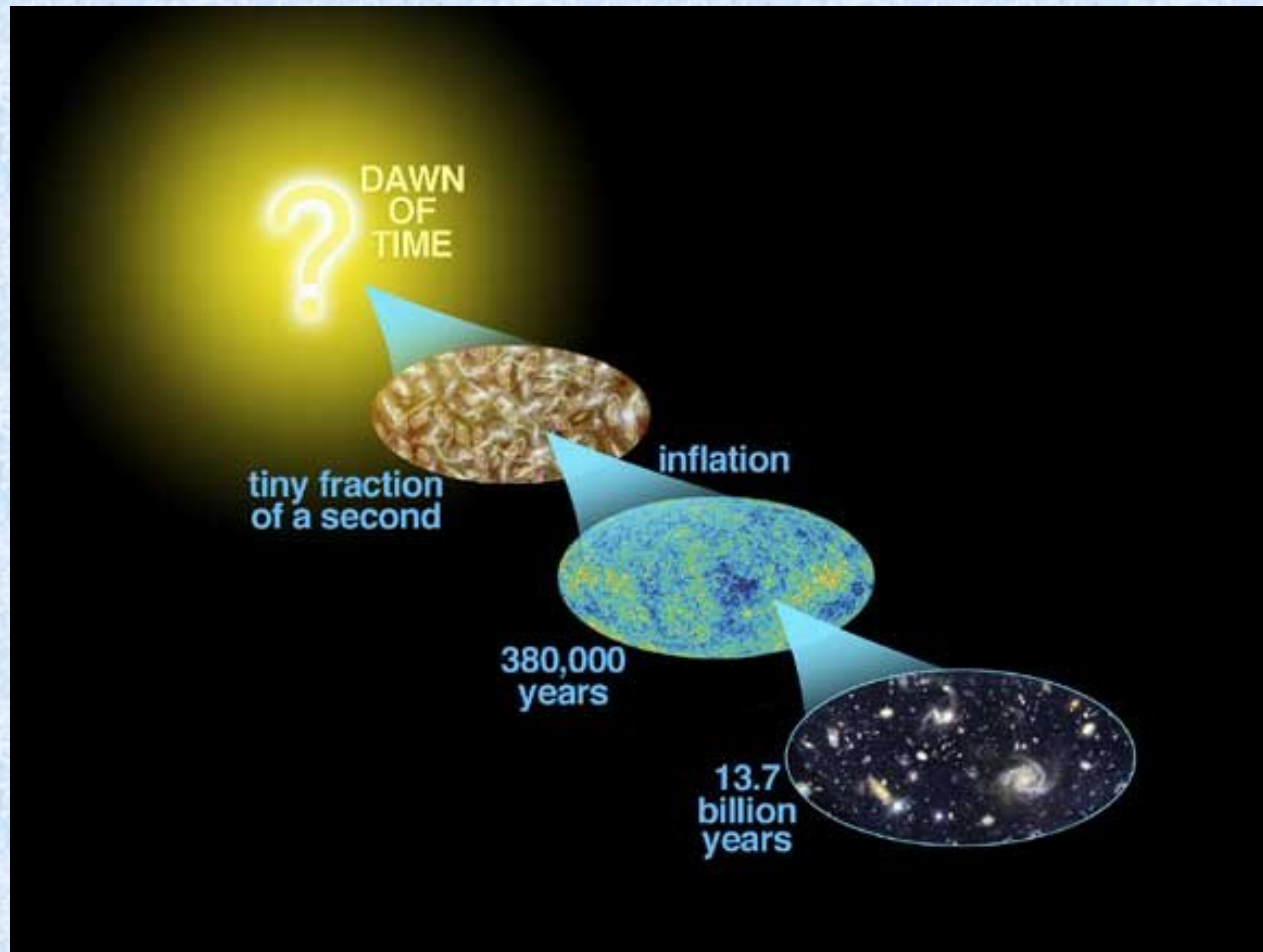


# Origins



Lecture 10; May 1 2014

# Previously... on Origins: Is Earth a special/unique place?

- What does the question mean?
- How do we find planets?
- What are habitable planets?
  - Selection effects

# Outline:

## Is Earth a special/unique place?

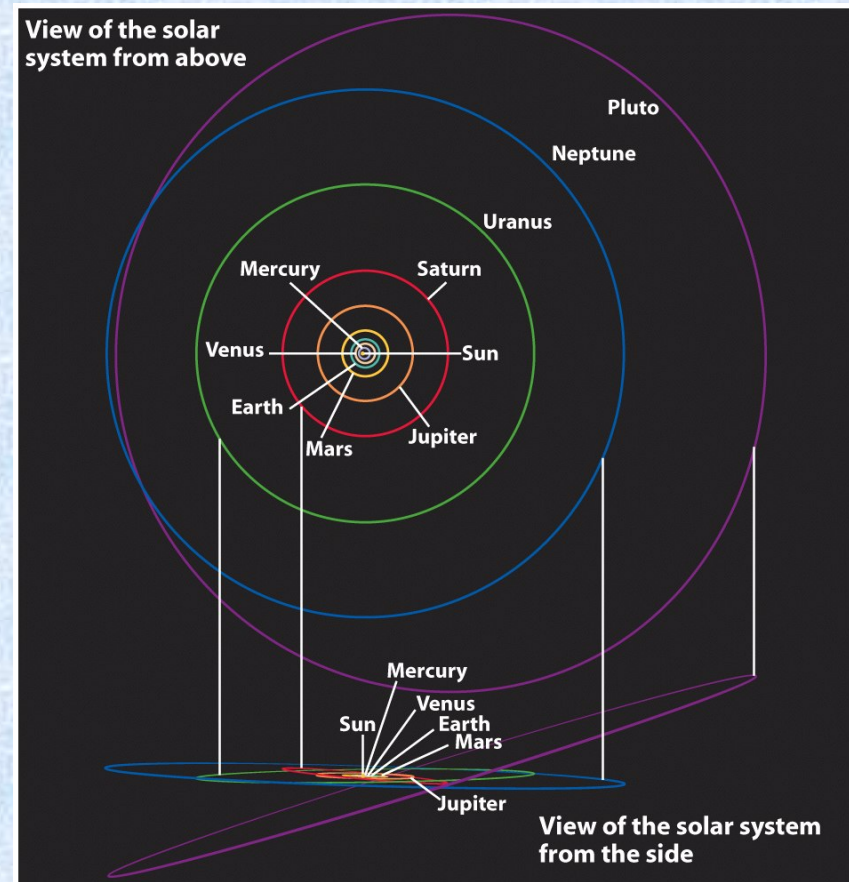
- Drake's equation
- Is Earth special?
  - Heliocentrism vs. Geocentrism
  - How about in our Galaxy?
- Is our Galaxy special?
- Is there *any* special place?
  - Observations
- The cosmological principle and its consequences:
  - Cosmic Time

# A physicist's answer

- We phrase the question in statistical terms:
  - Is the location of the Earth in the Universe special in anyway?
  - Is it at the “center” of something?
- Let's take a look! Let's measure!

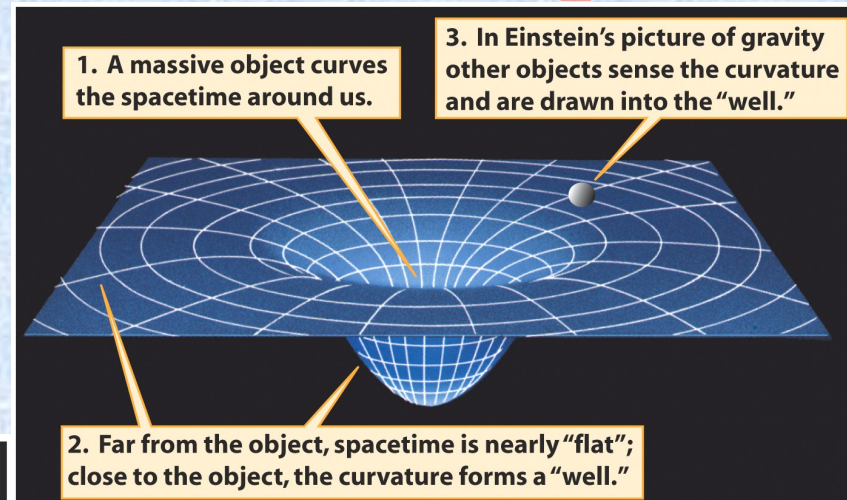
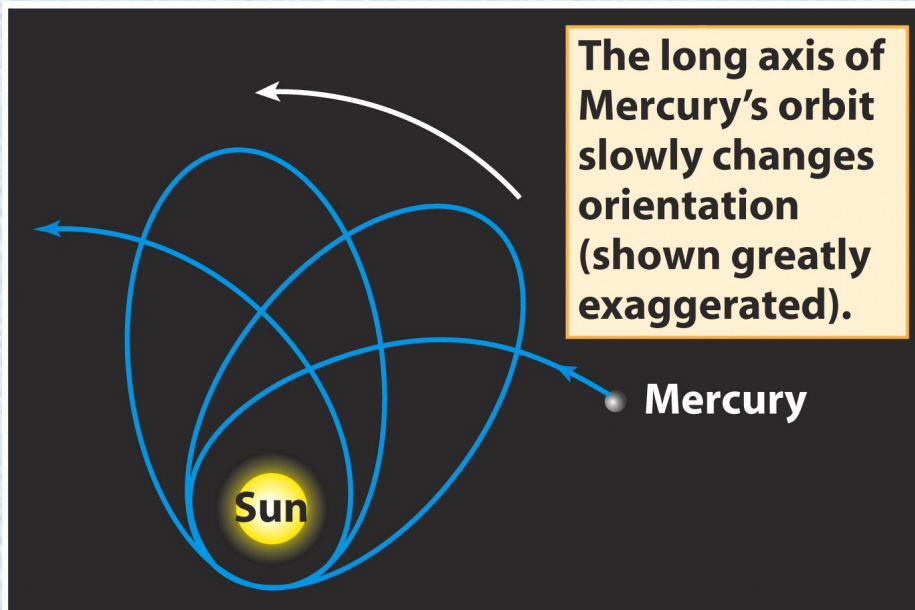
# Modern “Copernicanism”: Current solar system description

- Newton:
  - The Sun and the other bodies orbit around a common center of mass
  - The Sun is so massive that it is very close to the center of mass and moves very little
  - Orbits are elliptical, but very slightly so



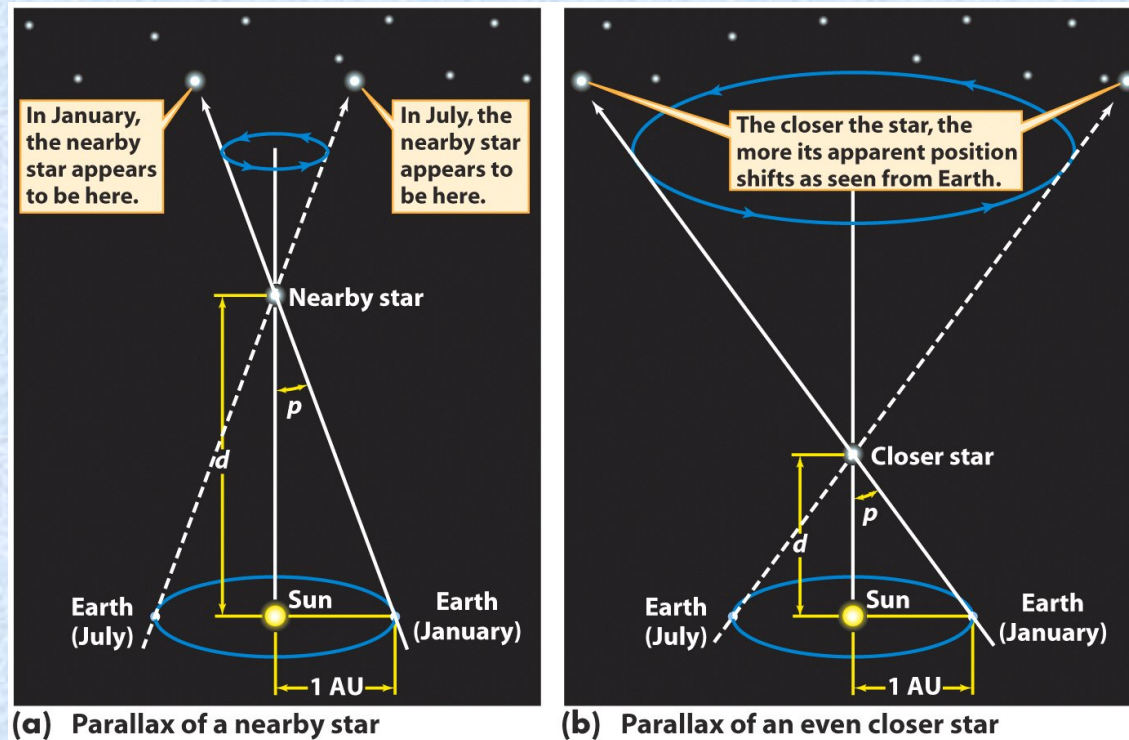
# Modern “Copernicanism”: Current solar system description

- Einstein:
  - Mass perturbs local geometry
  - Space time is curved
  - Objects move freely in curved space time



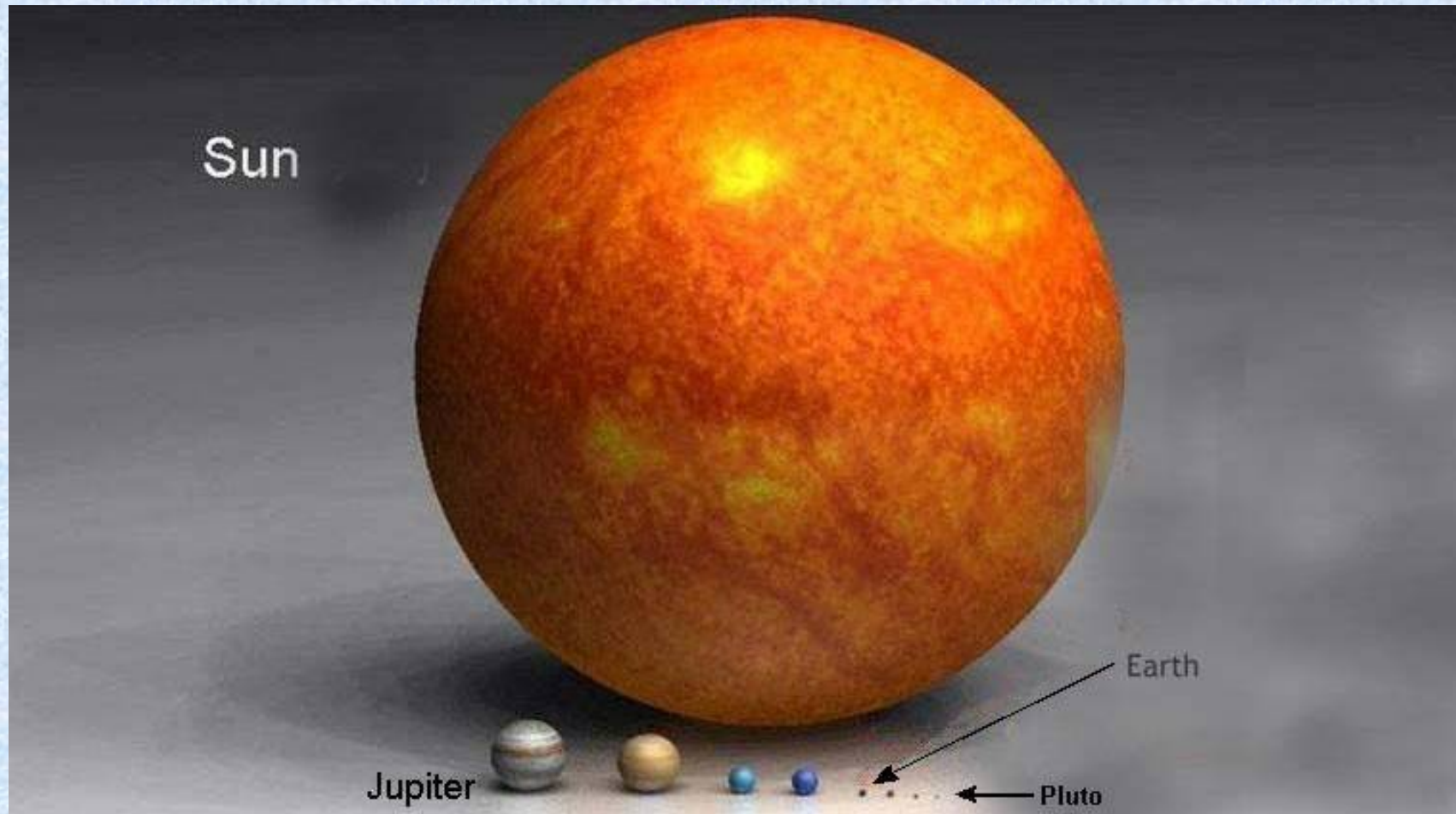
43s per century!  
Another test of  
general relativity!

# Modern “Copernicanism”: Parallax and distances



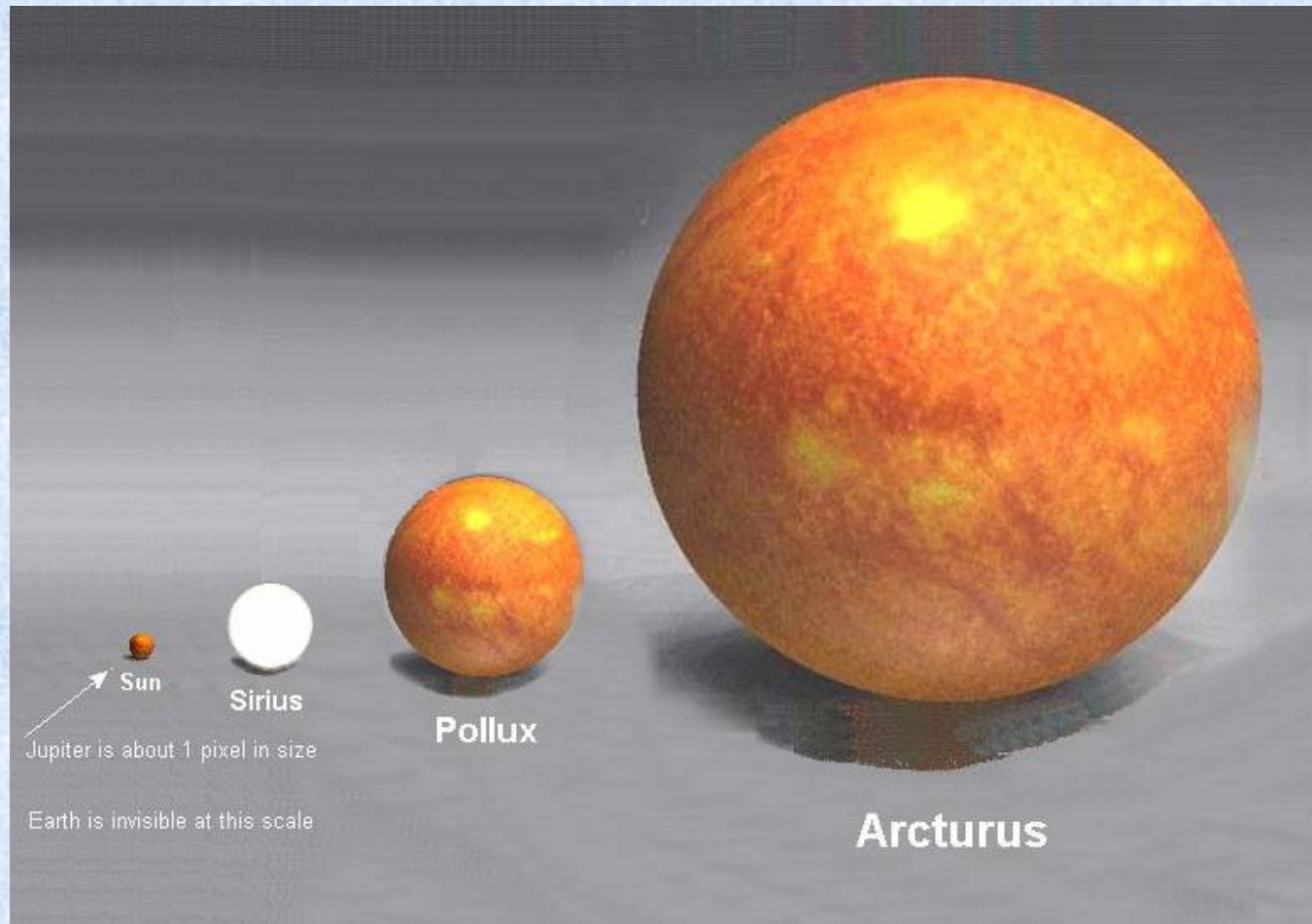
- Measurements of stellar parallax indicate that the closest stars are a few light years away! How far is the sun?
- They also indicate that the Earth “moves” (eppur si muove). With respect to what? How fast?

# Modern “Copernicanism”: planets, Sun and other stars

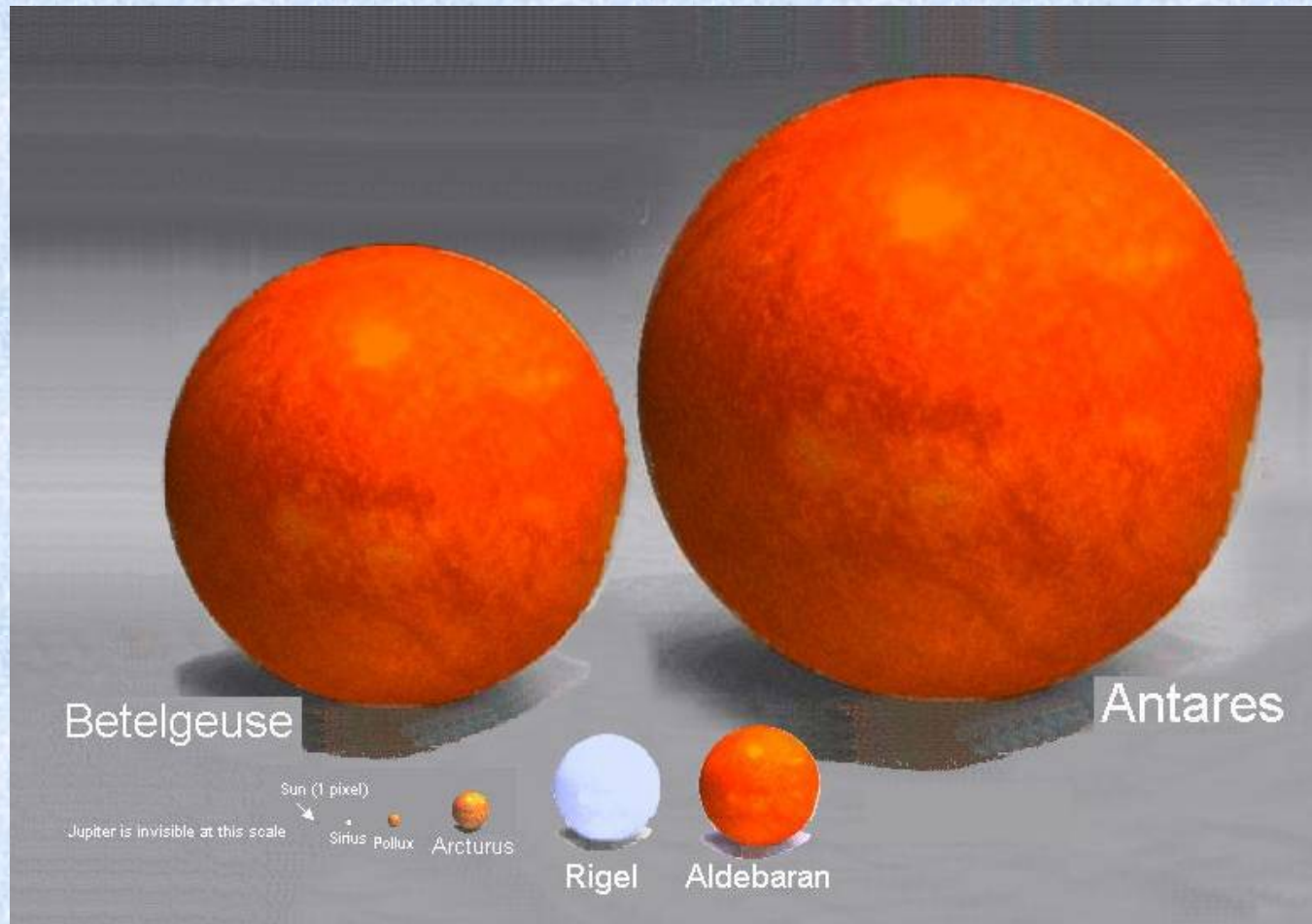




# Modern “Copernicanism”: planets, Sun and other stars



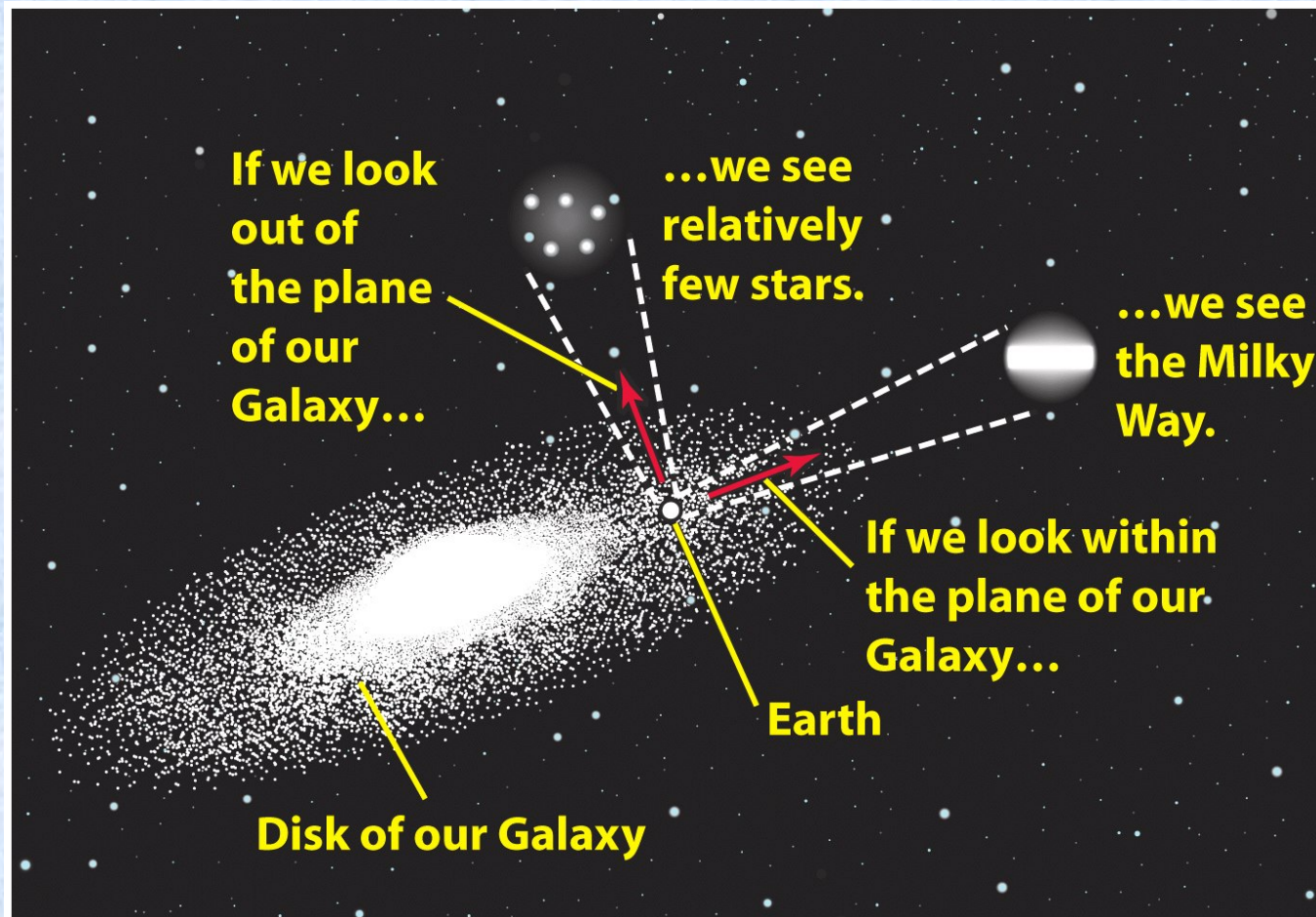
# Modern “Copernicanism”: planets, Sun and other stars



# Modern “Copernicanism”: Where are we in our Galaxy?

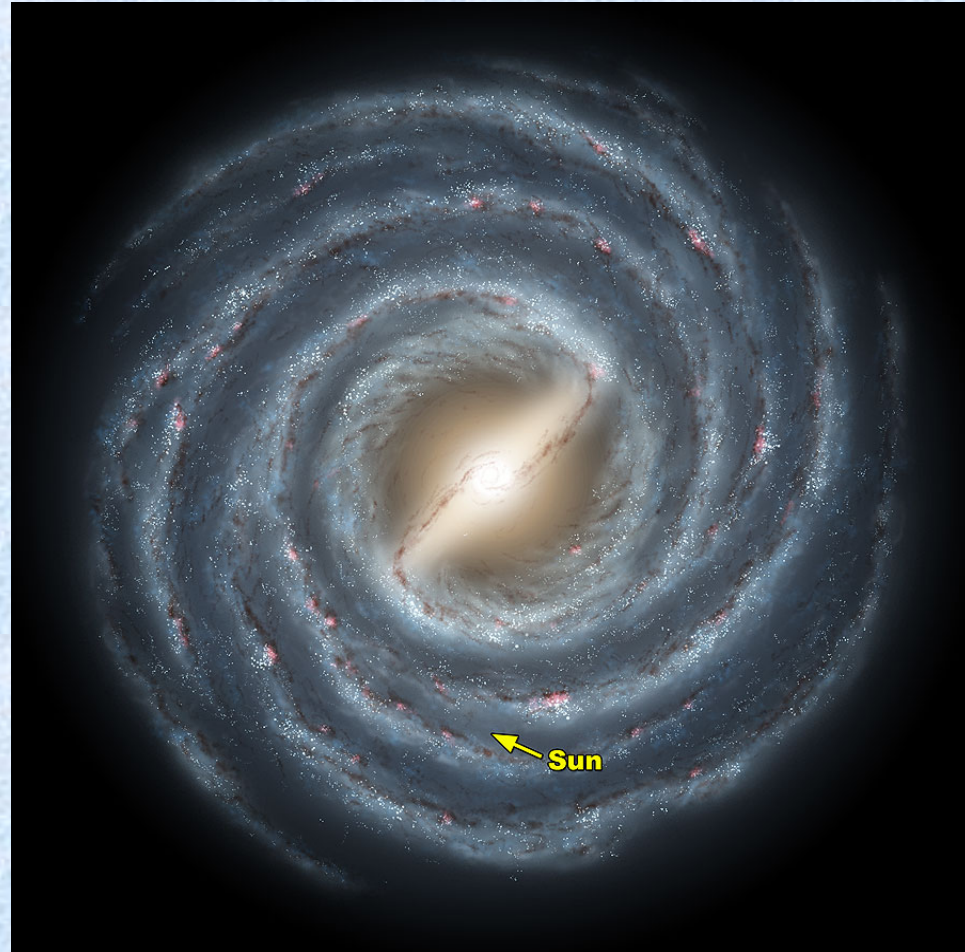


# Modern “Copernicanism”: Current view



# Modern “Copernicanism”: Where are we in our Galaxy?

- Somewhat in the outskirts...
- 25,000 ly away from the center
- Moving at about 200 km/s around the center of the Milky Way
- TRUMPLER's (1930) discovery of dust

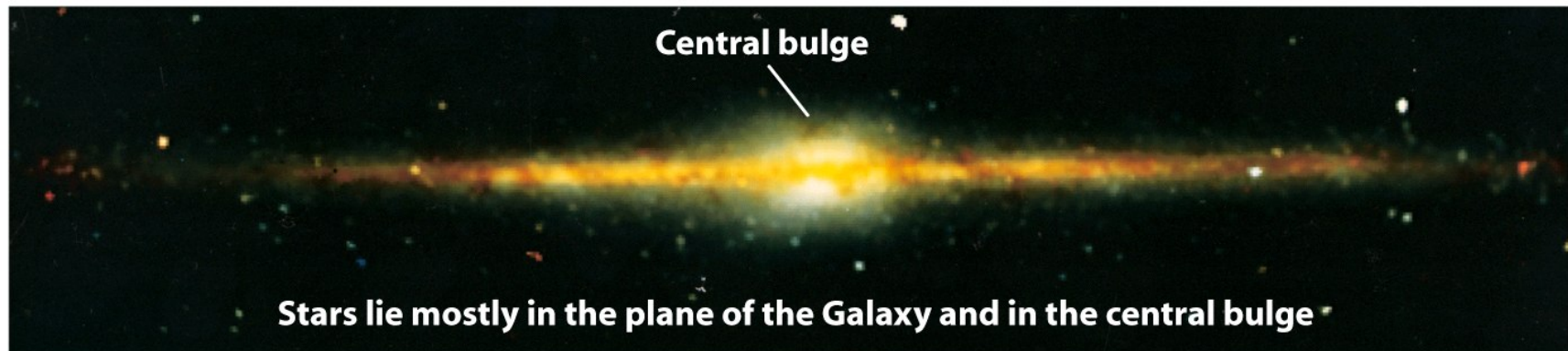


# Modern “Copernicanism”: Evidence



Dust lies mostly in the plane of the Galaxy (seen edge-on)

**(a)** Infrared emission from dust at wavelengths of 25, 60, and 100  $\mu\text{m}$



Stars lie mostly in the plane of the Galaxy and in the central bulge

**(b)** Infrared emission from dust at wavelengths of 1.2, 2.2, and 3.4  $\mu\text{m}$

The Galaxy is more than a 100,000 lyrs in diameter  
There are 10,000,000,000 solar masses inside the Sun's orbit!

# Modern “Copernicanism”: Galaxies



What are they? How far are they? How big are they?

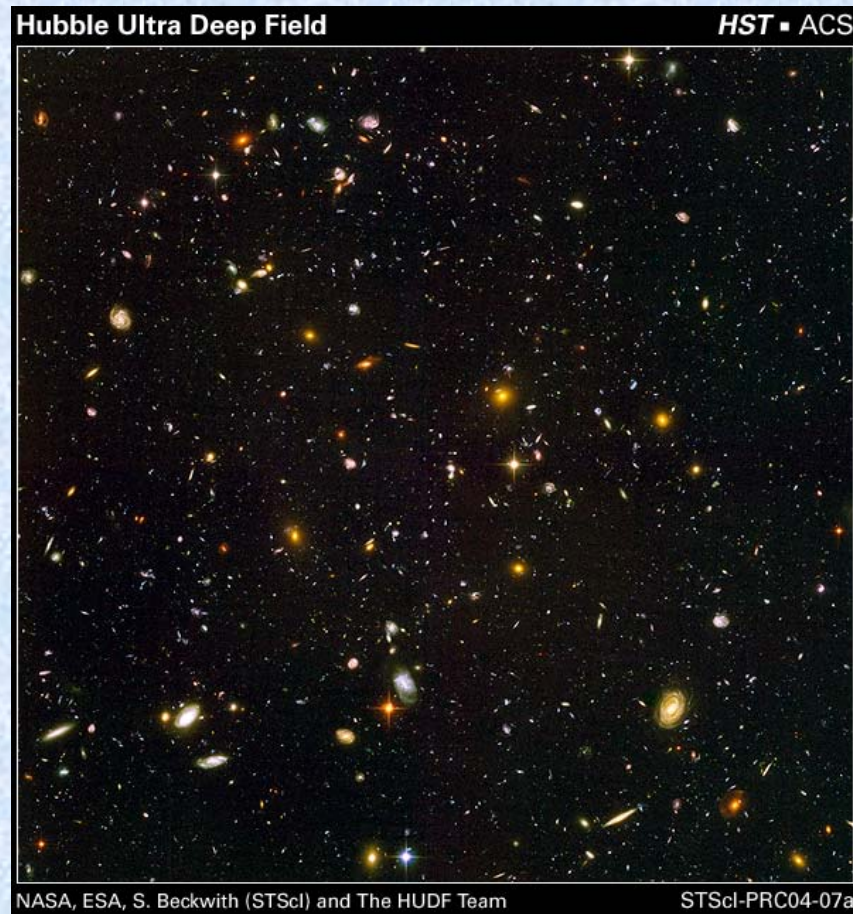
# Modern “Copernicanism”: Galaxies

- Until 1923 there was a debate on the distance of “nebulae” (galaxies)
- Are they small objects inside our galaxy or are they “external”?
- Hubble settled this by measuring the distance to Andromeda
  - A whopping 2.5 million light years!



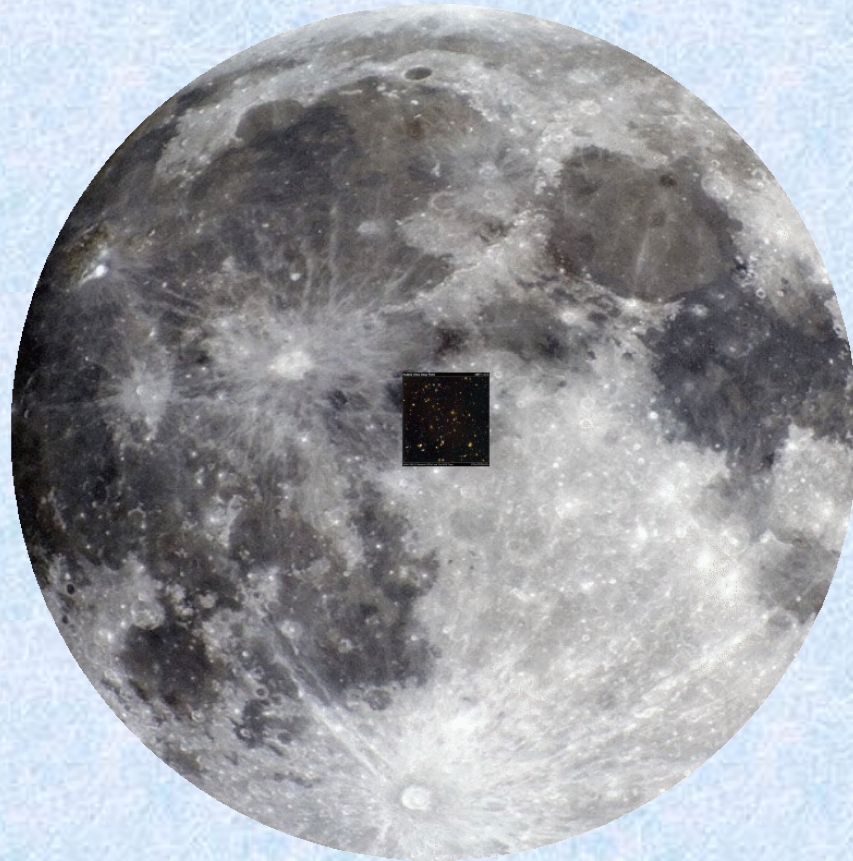


# Modern “Copernicanism”: The Universe is full of galaxies!



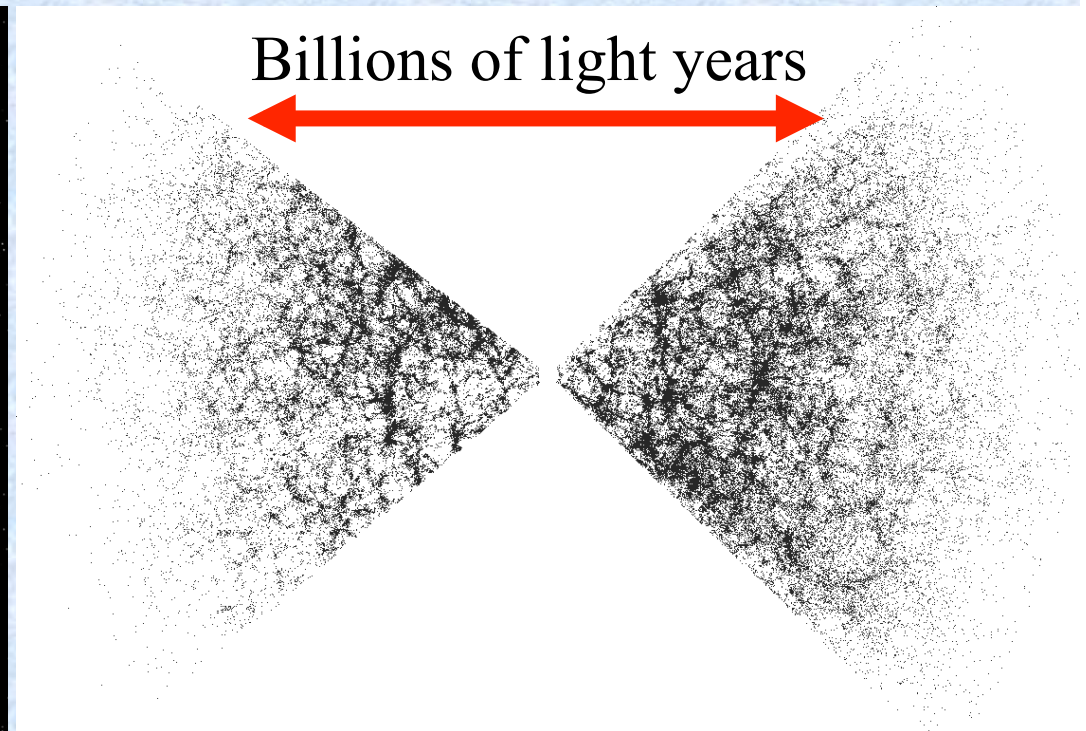
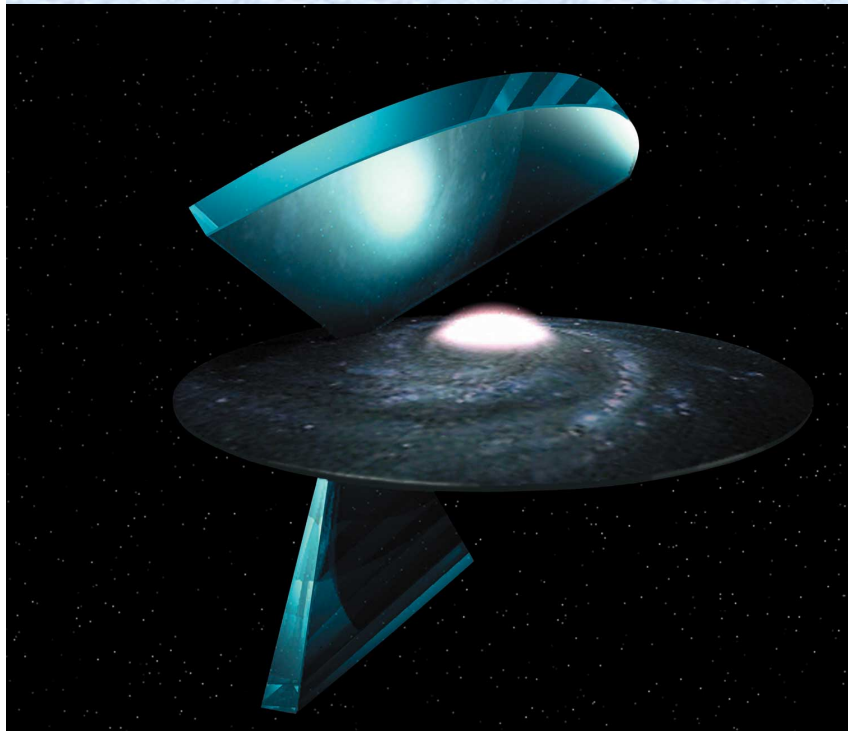
10,000 galaxies in a tiny piece of sky! 1/150,000 of the sky

# Modern “Copernicanism”: How many galaxies?



Based on the deep fields we estimate of order a billion visible galaxies

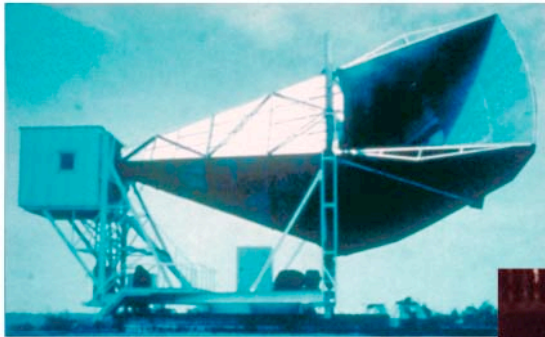
# Modern “Copernicanism”: Large scale structures



SDSS and 2dF mapped the positions of about 1,000,000 galaxies

# COSMIC MICROWAVE BACKGROUND

## DISCOVERY OF COSMIC BACKGROUND

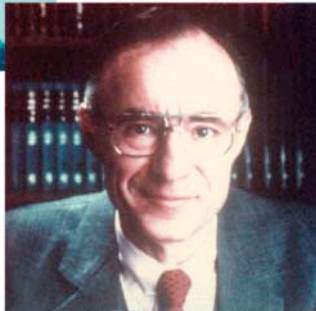


Microwave Receiver

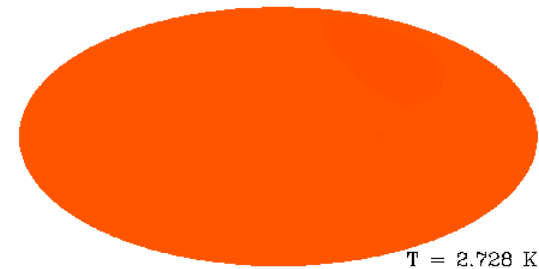


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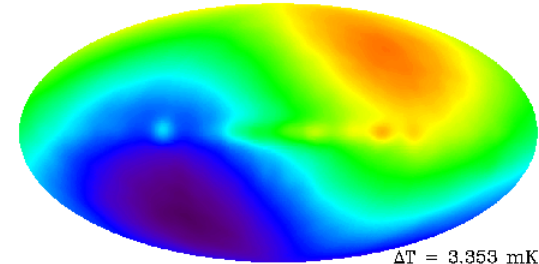
Robert Wilson



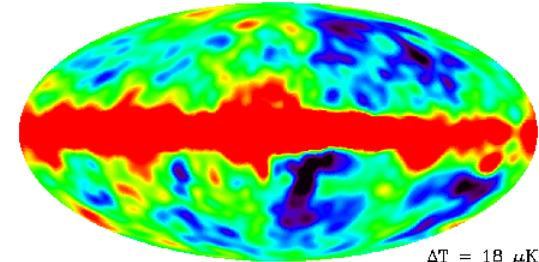
Arno Penzias



$T = 2.728 \text{ K}$



$\Delta T = 3.353 \text{ mK}$



$\Delta T = 18 \mu\text{K}$

# Modern “Copernicanism”: Summary

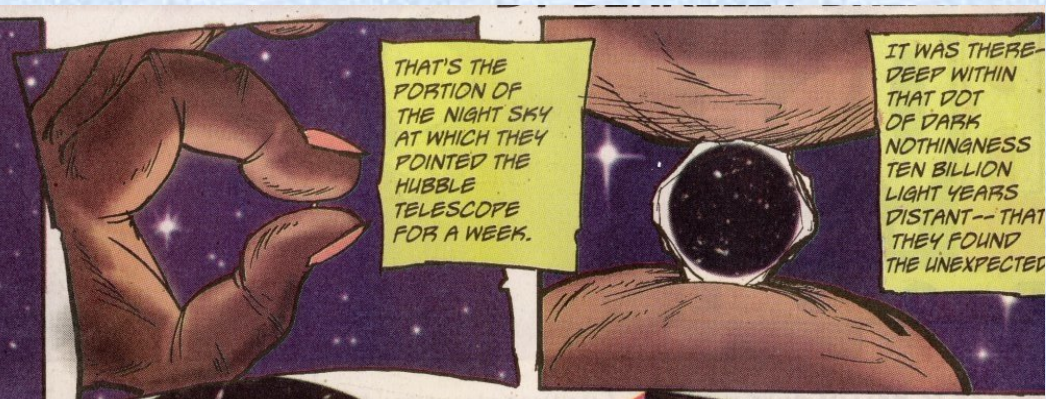
- Our planet orbits around an average star in the outskirts of an average galaxy
- All directions in the universe look the same
- All places in the universe look the same if you average over large enough volumes (100,000,000 light years or so)
- **THE UNIVERSE IS HOMOGENEOUS AND ISOTROPIC (Cosmological Principle)**
- This scientific hypothesis build on observational evidence allows us to construct a simple theory of the universe, including define a cosmic time



I LOVE THESE SUMMER EVENING REALITY CHECKS FROM OLIVER!

HOLD OUT A SPECK OF SAND AT ARM'S LENGTH...

BERKELEYBREATHED.COM -- WASHINGTON POST UNIVERSE GROUP

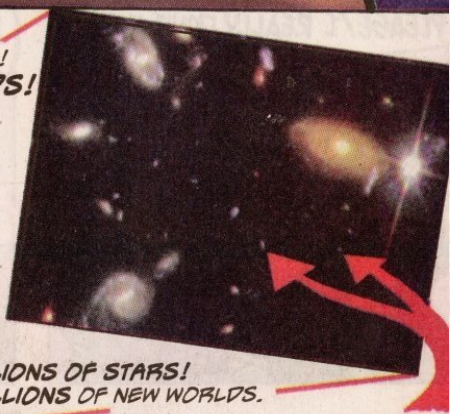


THAT'S THE PORTION OF THE NIGHT SKY AT WHICH THEY POINTED THE HUBBLE TELESCOPE FOR A WEEK.

IT WAS THERE-- DEEP WITHIN THAT DOT OF DARK NOTHINGNESS TEN BILLION LIGHT YEARS DISTANT-- THAT THEY FOUND THE UNEXPECTED



GALAXIES! THOUSANDS! THOUSANDS!



...WITH BILLIONS OF STARS!  
... AND TRILLIONS OF NEW WORLDS.

AND BEYOND THOSE... MORE!



ALL IN THE SPACE OF A SINGLE GRAIN OF SAND ON THE VAST BEACH OF THE COSMOS.



WHICH NICELY FRAMES THE QUESTION MAN HAS BEEN ASKING FOR MILLENNIA.

WHAT QUESTION?



WHAT'S THE CENTER OF IT ALL?

ME.

ME, BABY.

**The End**

See you on Tuesday