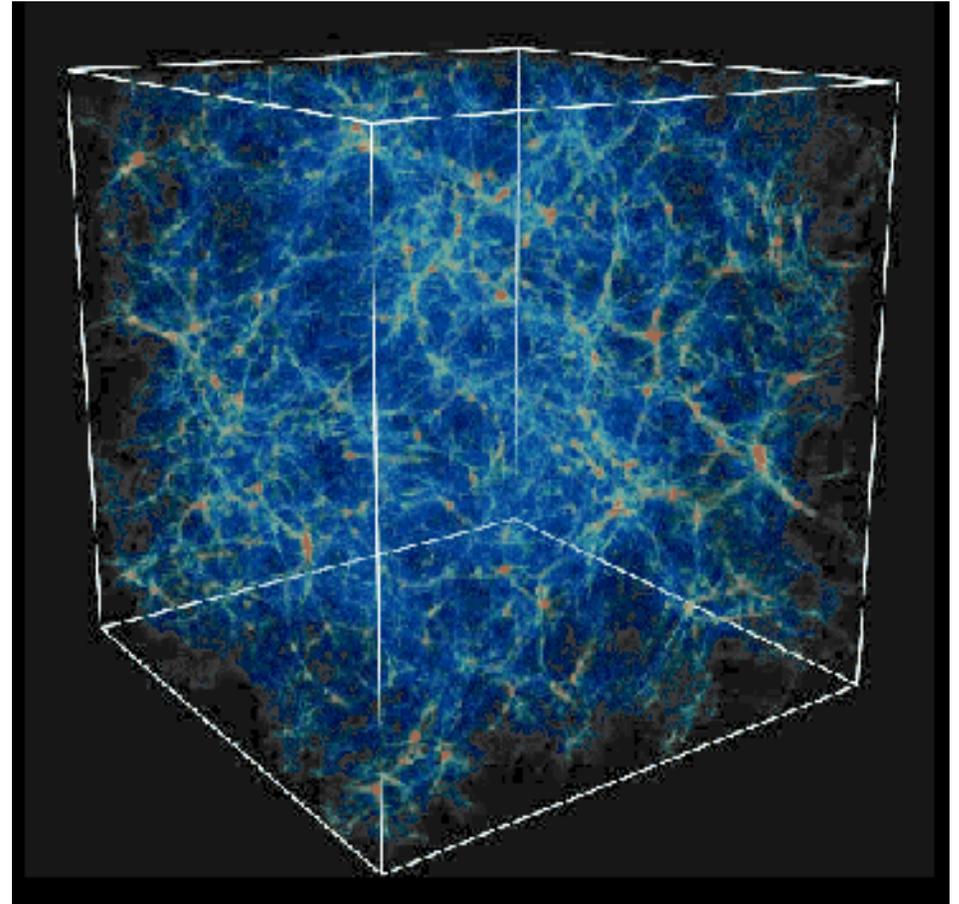


What's Cosmology?

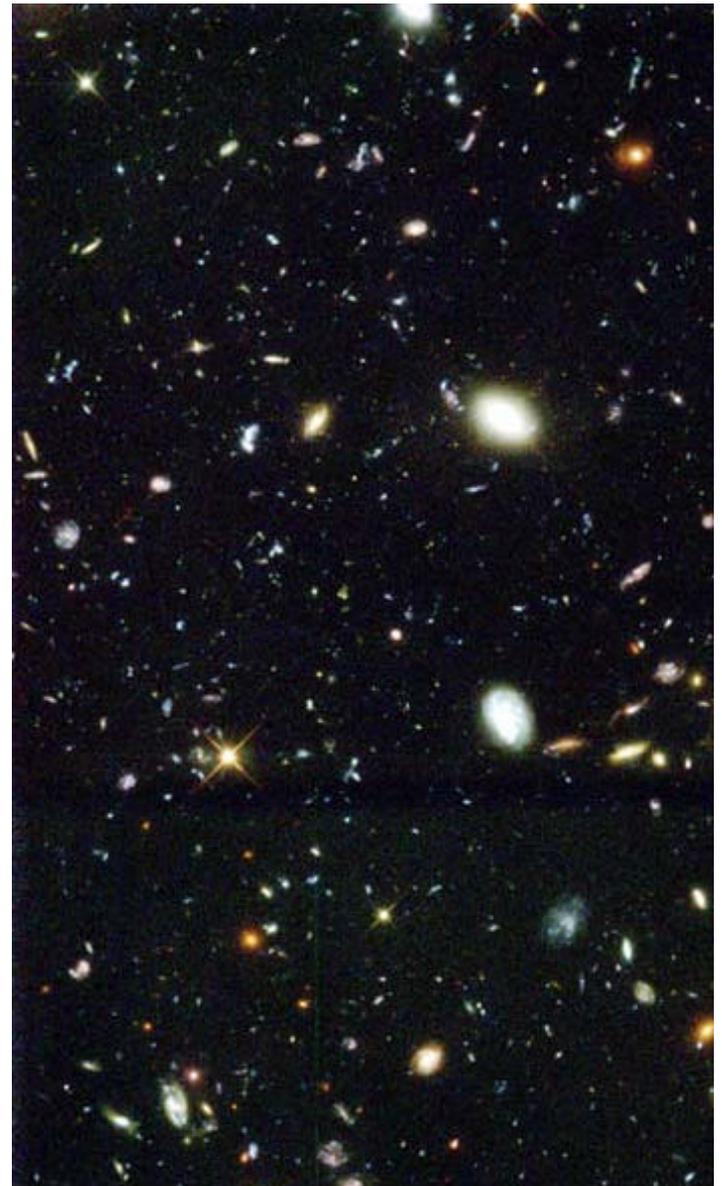
- **Cosmology** = study of the whole Universe!
- **The Universe** is everything that exists -- stars, planets, galaxies -- everything!
 - We can see only a tiny fraction of it all from Earth.



A computer simulation showing a large chunk of our universe

What fills the Universe?

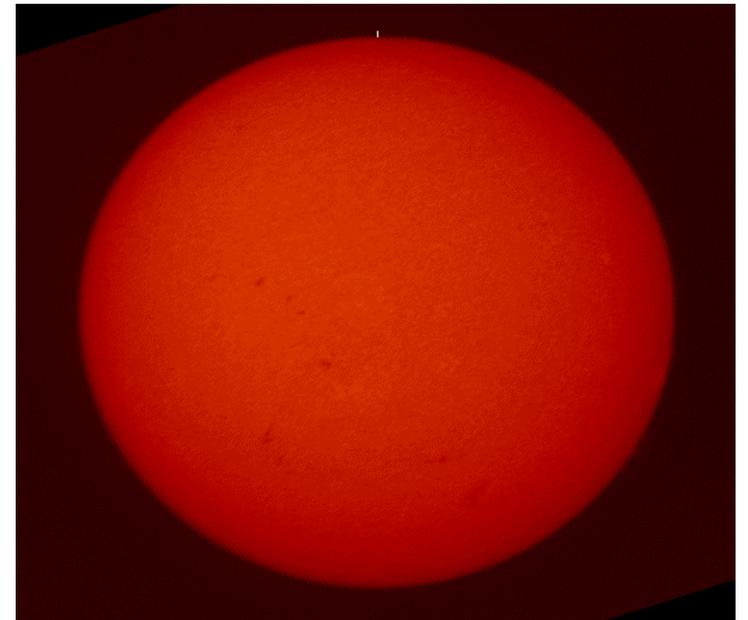
- Stars
- Galaxies
- Star dust (nebulae)
- Strange stuff!



Stars



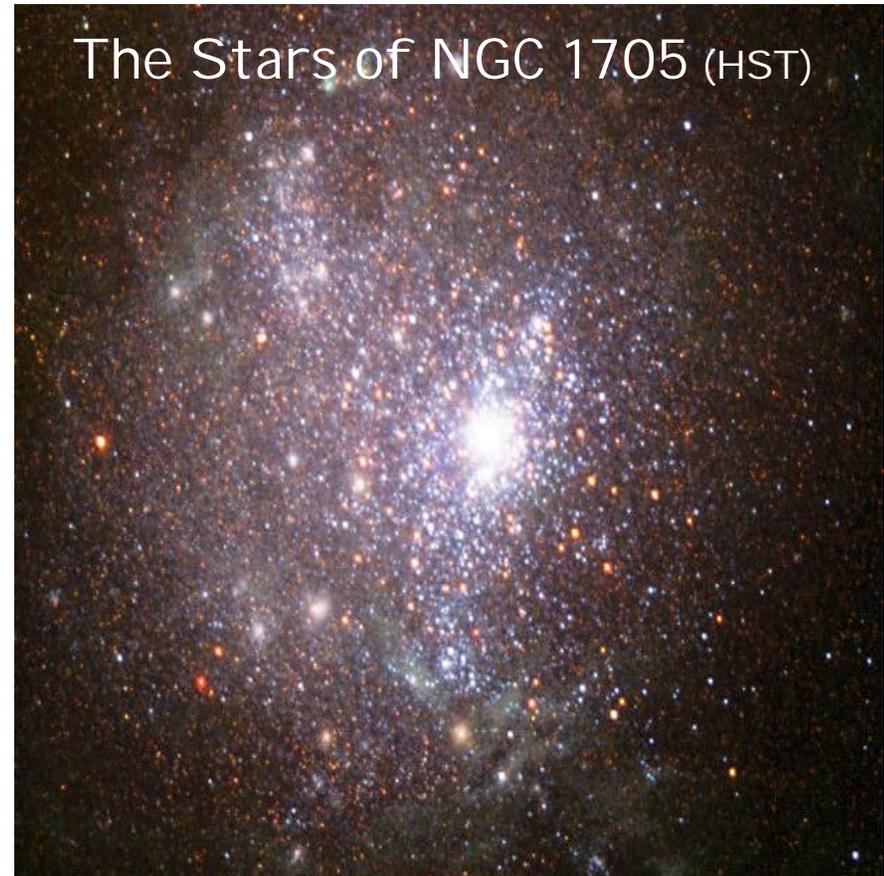
- **Stars** are giant balls of gas in space that shine through the darkness



- **The Sun** is an average star!

Galaxies

- A **Galaxy** is a collection of billions of stars
- Galaxies come in different shapes and sizes
 - **Elliptical** - shaped like an egg
 - **Spiral** - shaped like a pinwheel
 - **Irregular** - shaped in a weird way



The Pinwheel Spiral Galaxy (CFHT)



NGC 4636 Elliptical Galaxy (DDS)



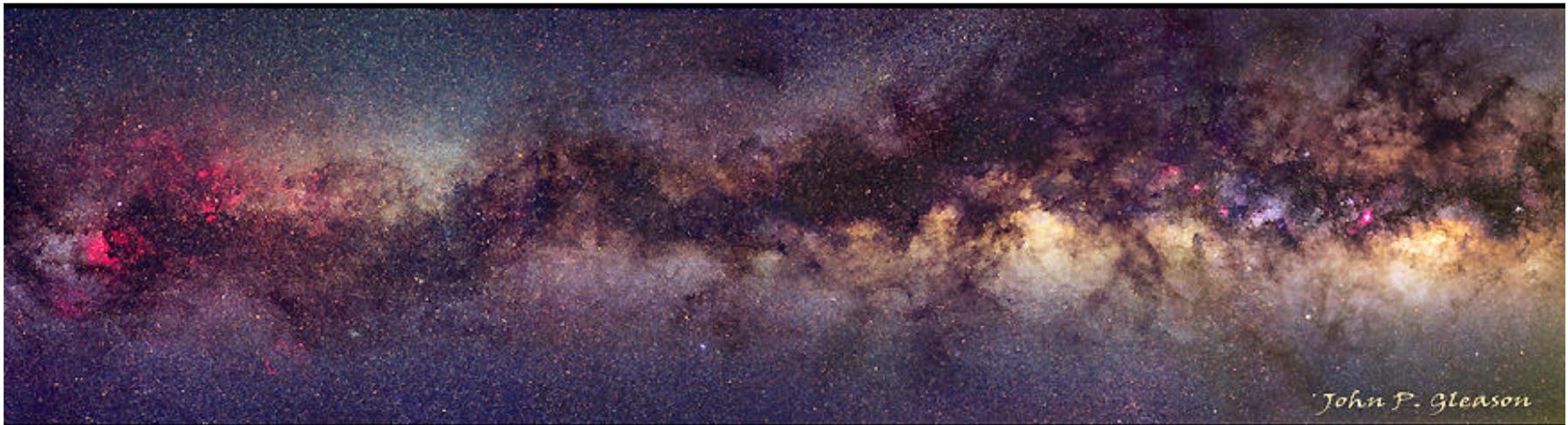
M82: The Cigar Galaxy (CfA)



Our very own galaxy

- We live at the outskirts of a huge disk-like collection of stars:

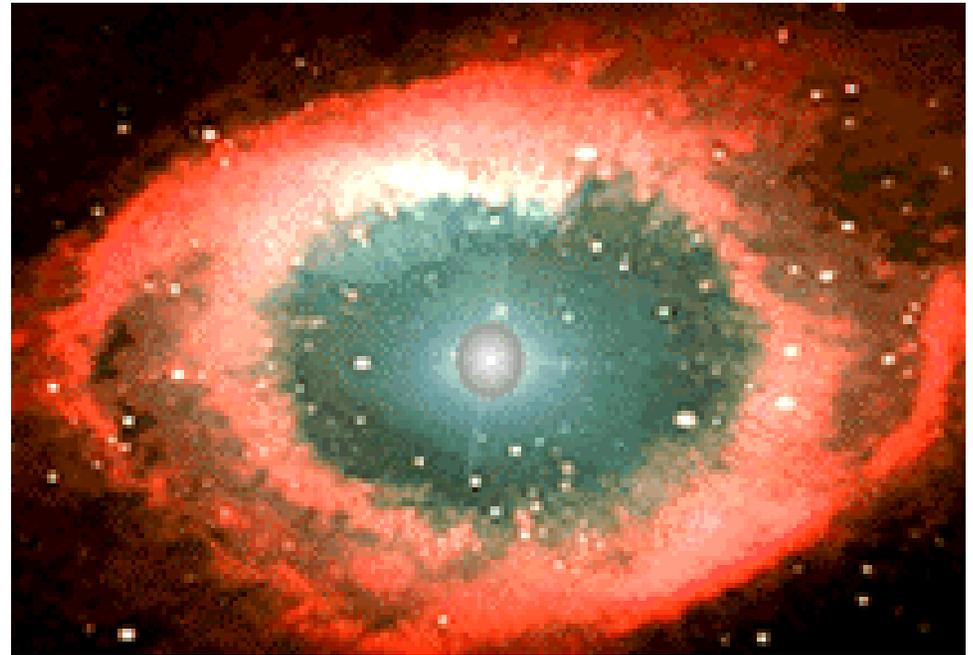
the Milky Way galaxy



- The Milky Way contains about **one trillion stars!**

Galactic dust

- As stars get older, their outer gas layers blow off
- That stardust is called a **nebula**



☀ Water is at least 1,000,000,000,000,000 times as dense as the gas found in nebulae!

The Orion Nebula (CFHT)



The Witch's Broom Nebula (WIYN, NOAO, AURA, NSF)

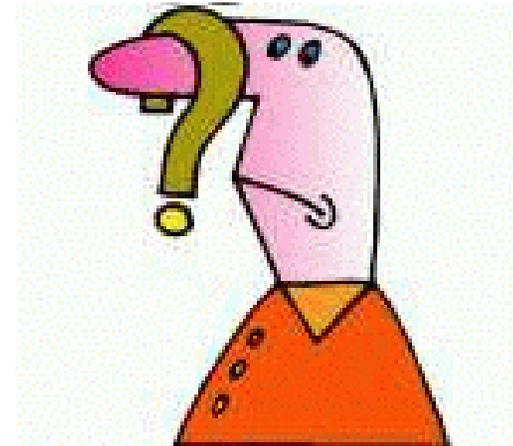


The Horsehead Nebula (CFHT)



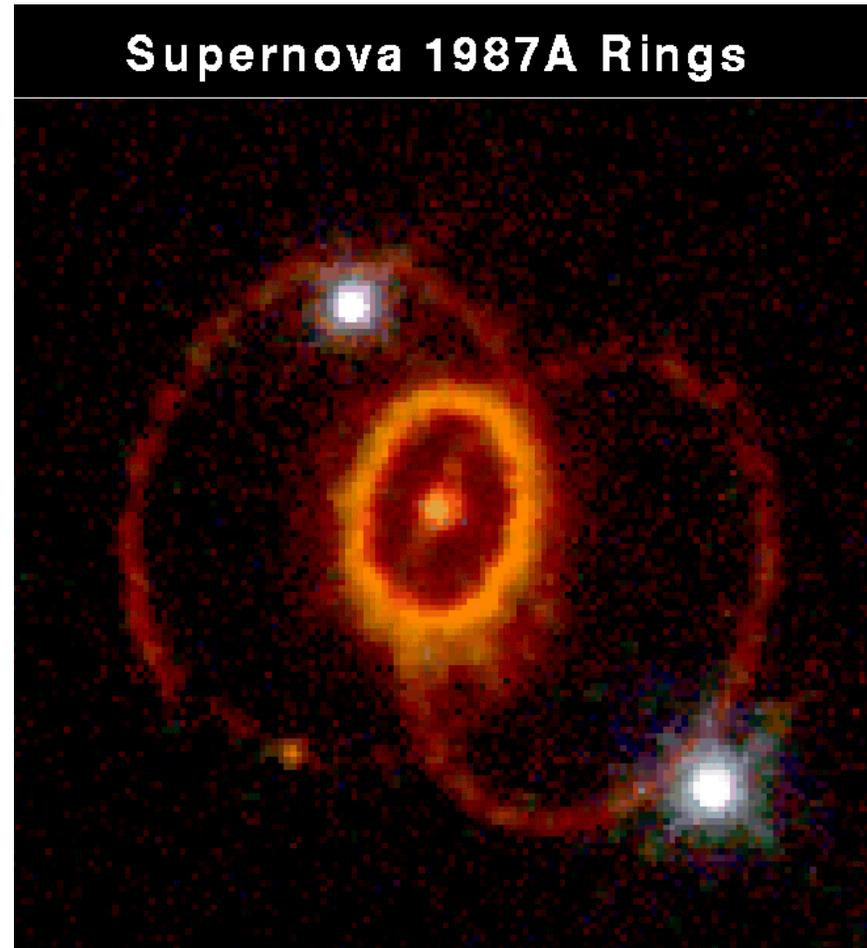
Strange stuff

- Apart from "normal" things like stars and galaxies, there is some pretty strange stuff out there!
 - White dwarfs
 - Supernovae
 - Neutron stars
 - Black holes
 - Stuff we can't even see!



Supernovae

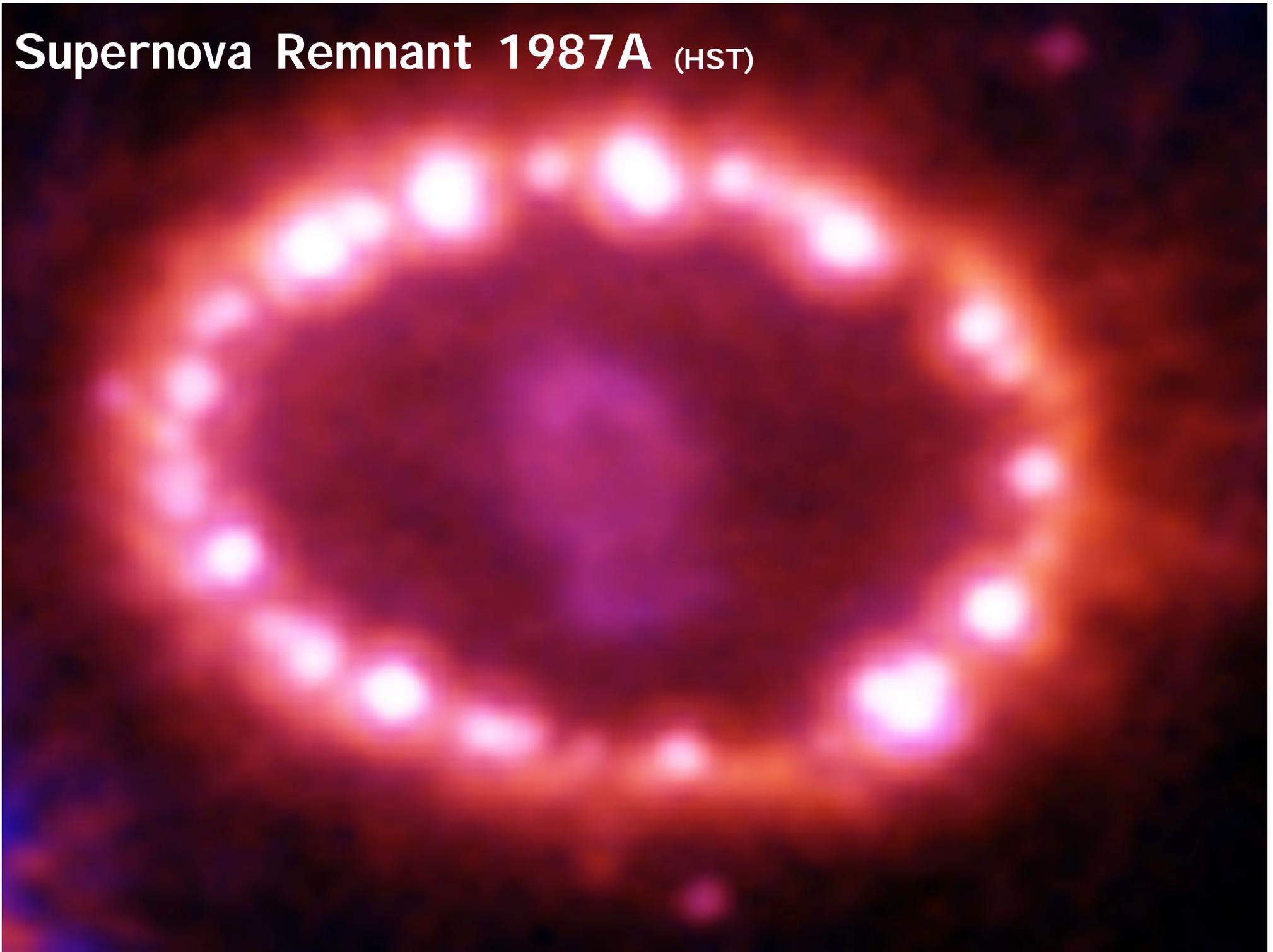
- Sometimes a star bigger than our Sun ends its life in a huge explosion called a **supernovae**
- A supernova can shine bigger than a whole galaxy for a while!



Supernova Remnant IC 443 (CFHT)

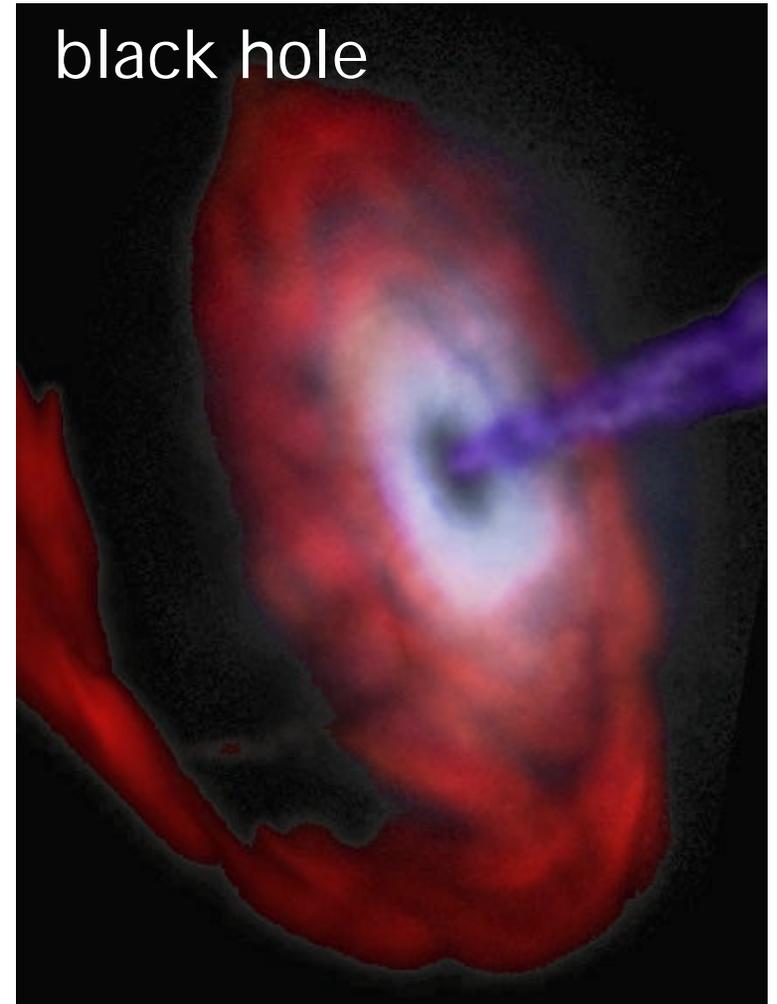


Supernova Remnant 1987A (HST)



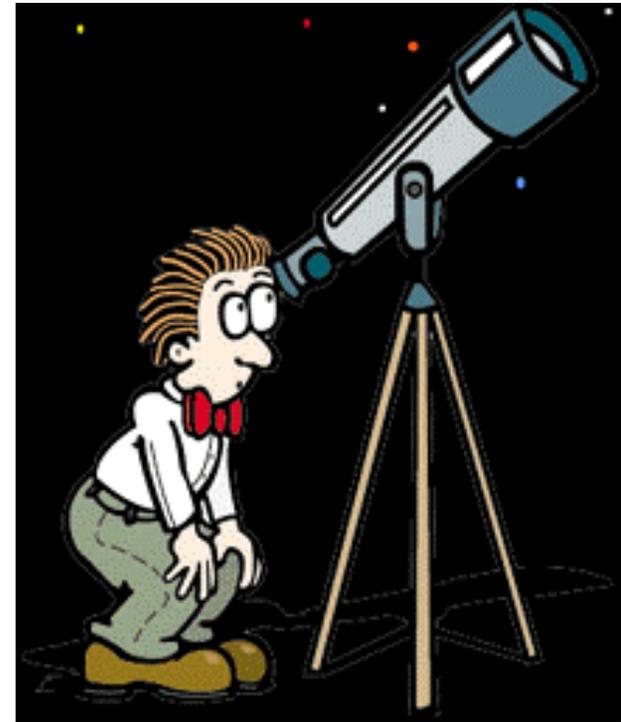
What's left after a supernova?

- Either a **neutron star** or a **black hole**
 - A **neutron star** is the size of a small city, but it's super-heavy!
 - A **black hole** is a very strange object whose gravity is so strong, not even light can escape it!

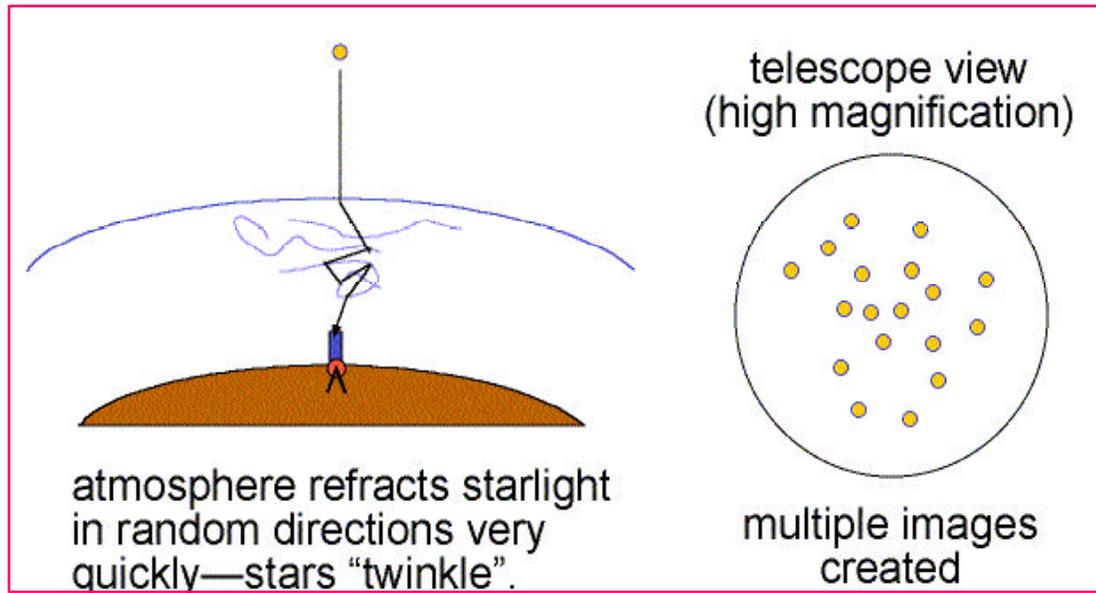


How do we study the Universe?

- We use **telescopes**, devices to visualize distant objects
- Most modern telescopes are located in **observatories**, high on mountain tops

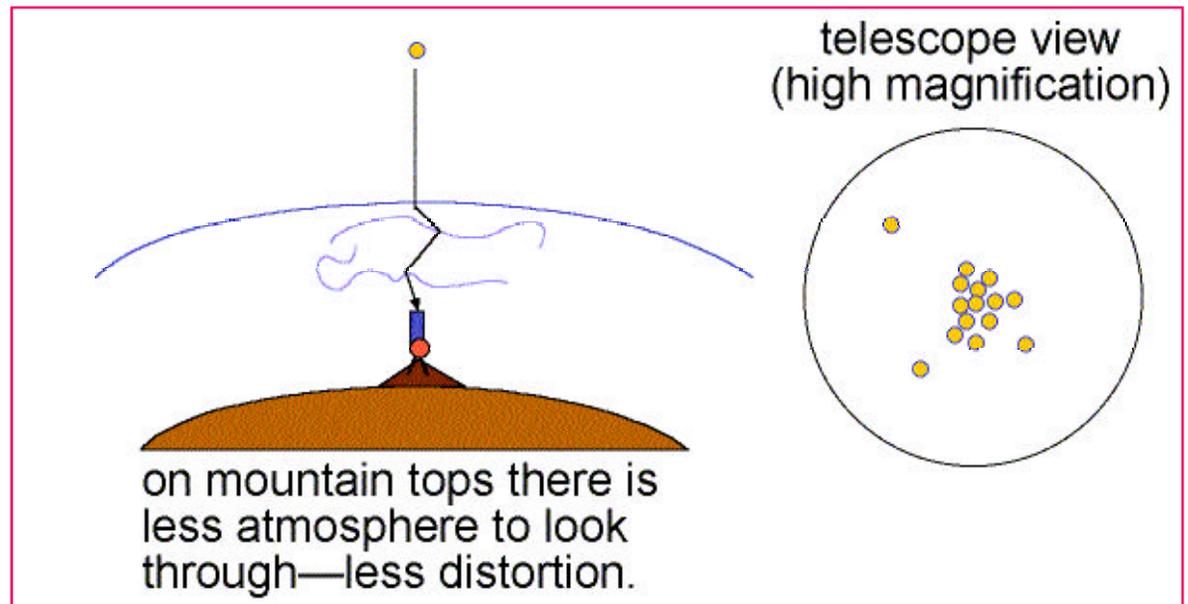


Why go to the mountains?



Because the Earth's
atmosphere
constantly shuffles
light around!

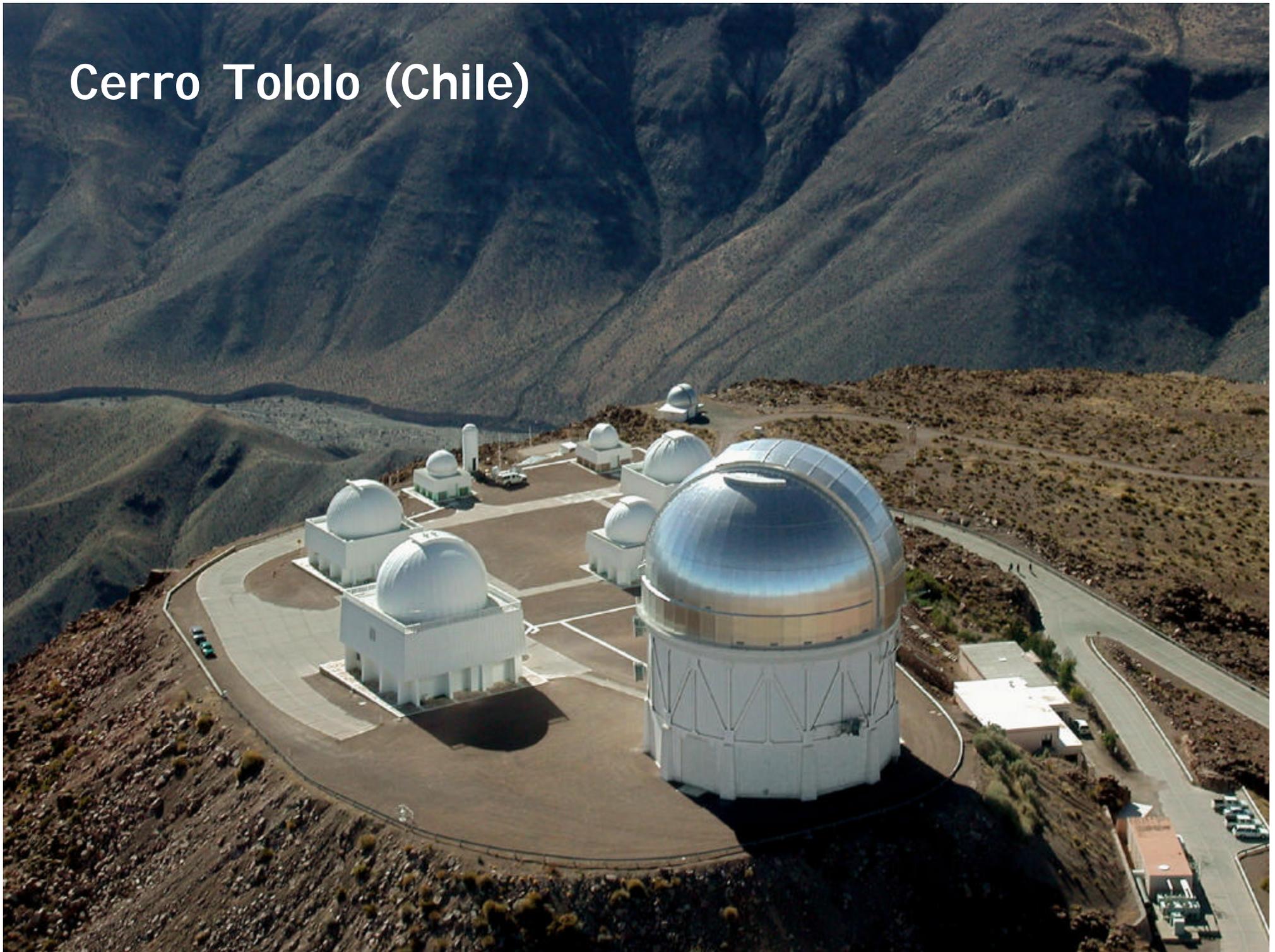
So you want to
go where there
isn't as much
atmosphere



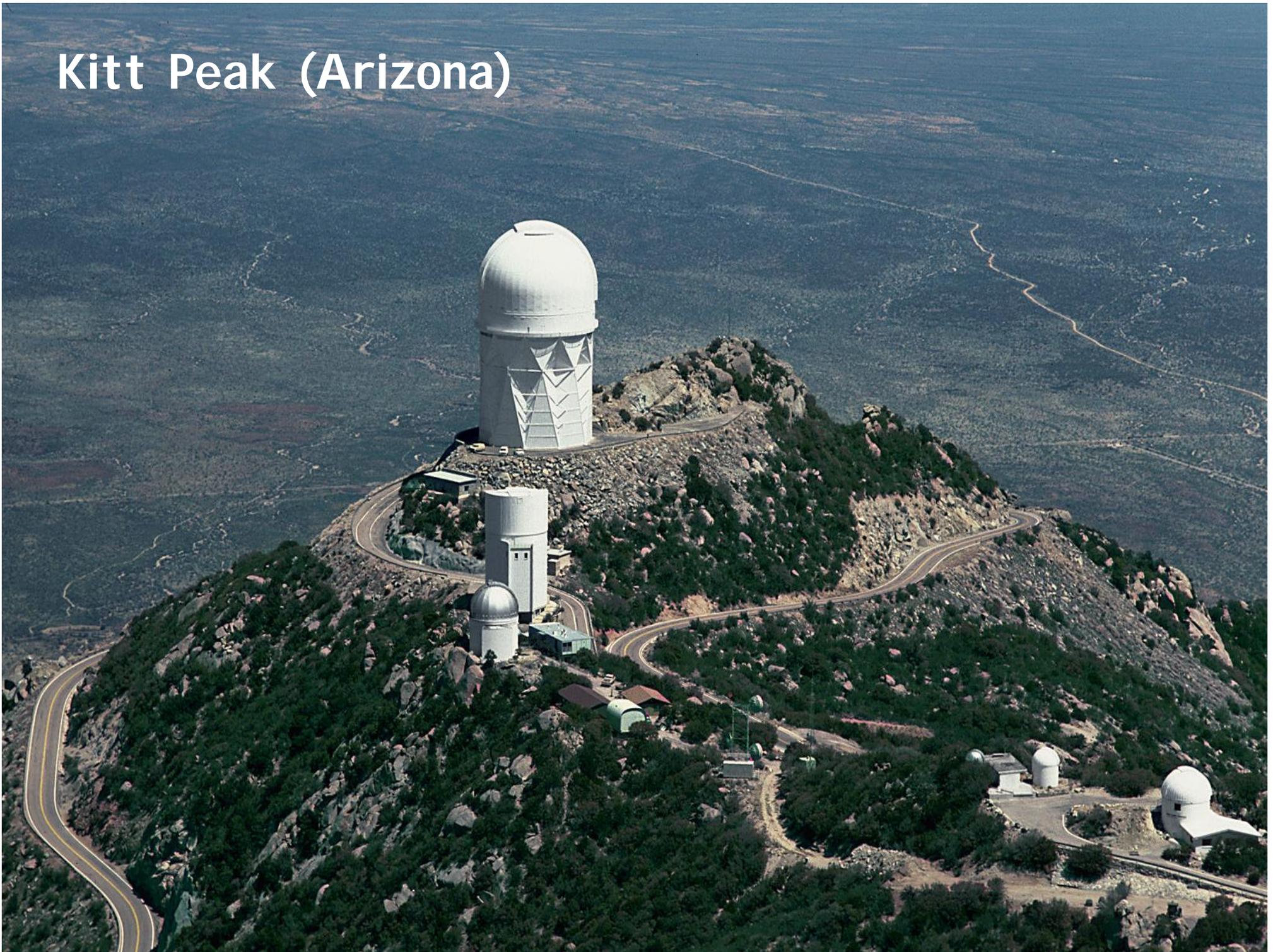
Mauna Kea (Hawaii)



Cerro Tololo (Chile)



Kitt Peak (Arizona)



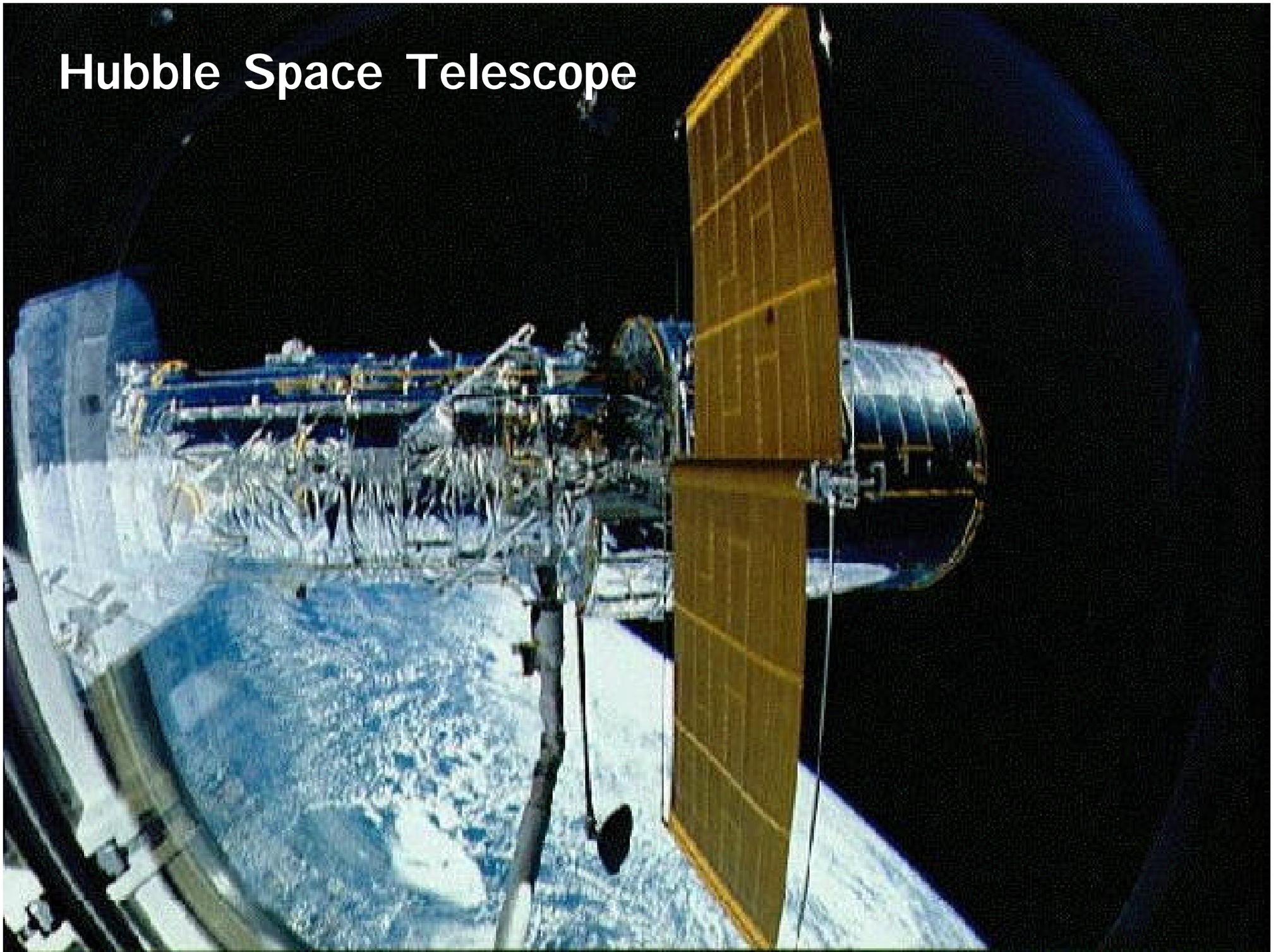
A Modern Telescope

- Modern telescopes used for astronomy research are large and sophisticated
 - Just the camera attached to this telescope weights 500 pounds!
- Astronomers nowadays rely on computers to operate these things

Kitt Peak's 0.9m telescope



Hubble Space Telescope



Hubble Ultra Deep Field



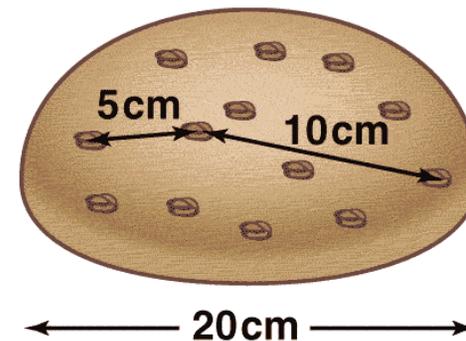
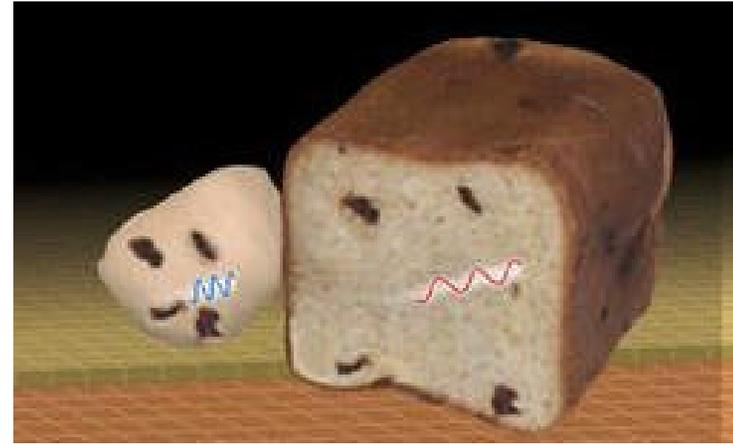
What do we know about the Universe?



- We know that the Universe is filled with galaxies
- In 1924, Edwin Hubble showed that the Universe is expanding!

What does "expanding" mean?

- The space itself in between galaxies is getting bigger
- So everything sees everything else moving away!



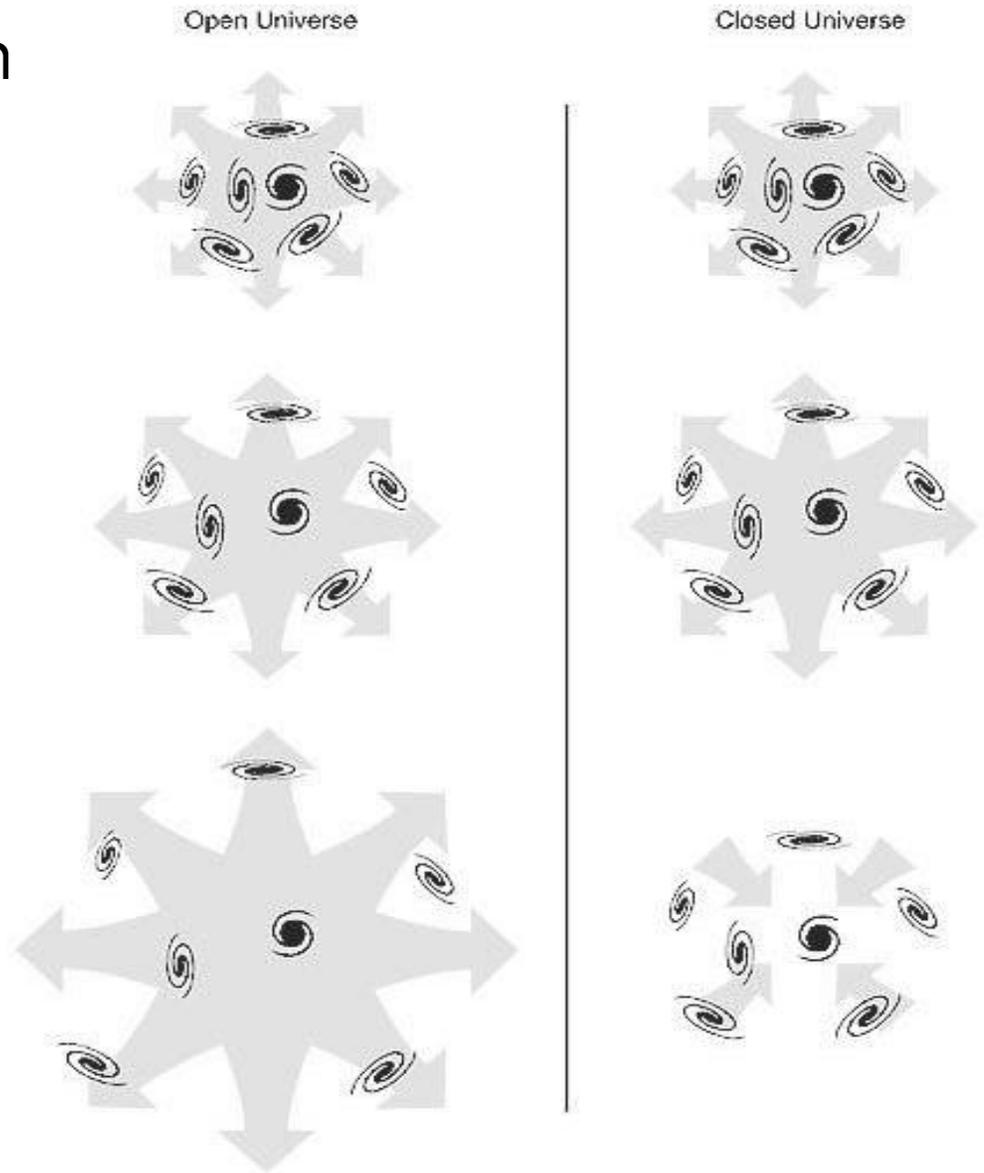
Big Bang

- The simplest explanation for how the Universe came to be is the **Big Bang** theory
- Our Universe is about 10-20 billion years old

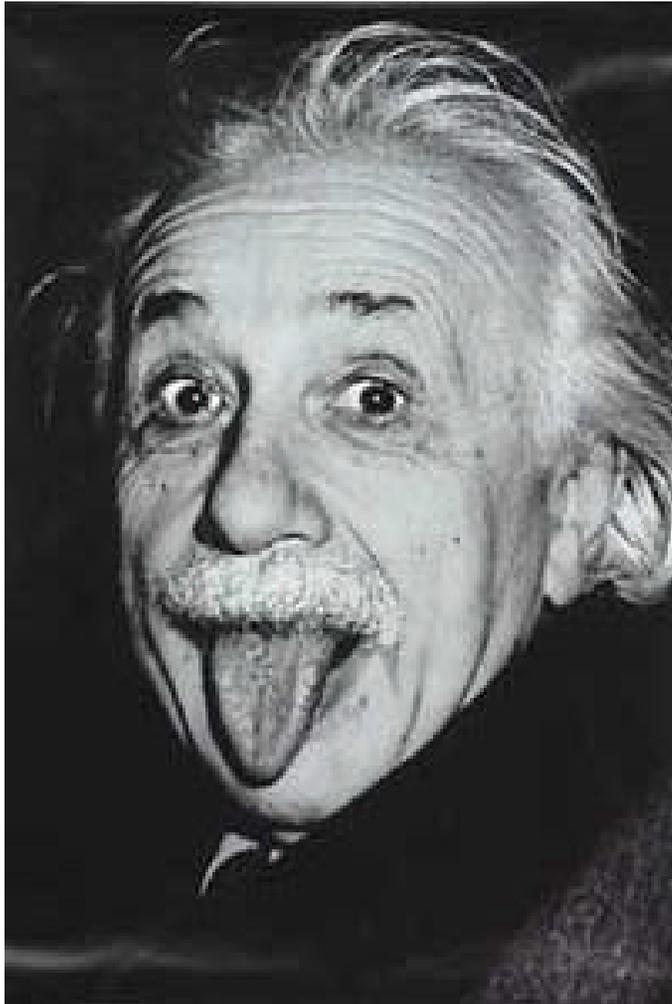


What will happen to the Universe?

- That depends on how much stuff there is in the Universe
- If there's lots of stuff, it will overcome gravity and the Universe will continue to expand forever
- If there isn't enough, gravity wins and the Universe collapses again!



So how much stuff is there?

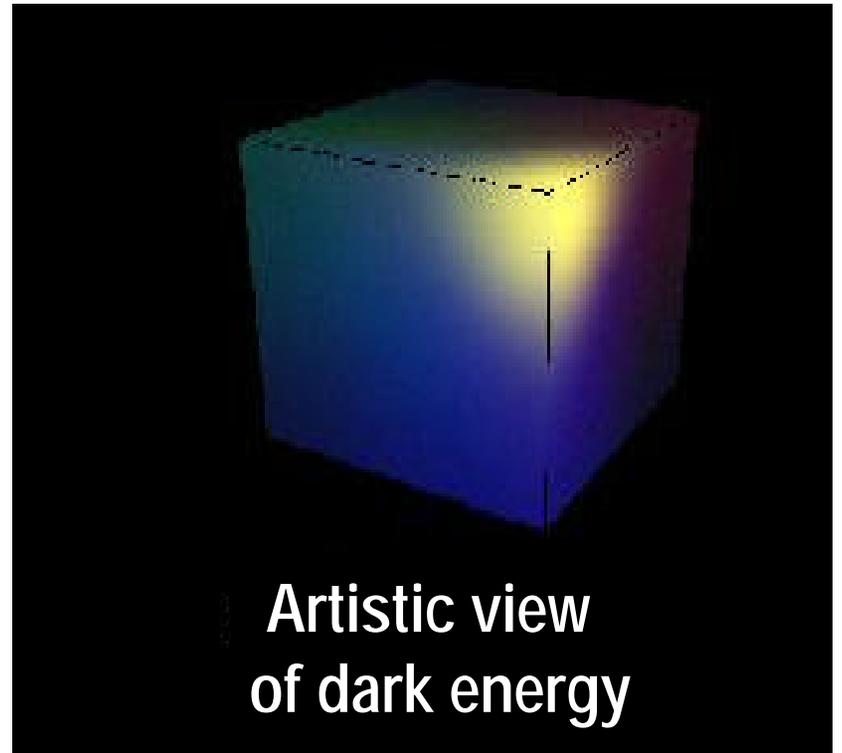


Gravity is described by
Einstein's Theory of Relativity

- Well, **we don't know** exactly...
- There may be some stuff in the Universe that is invisible and transparent
- We only detect it through gravity!

Dark Energy!

- Recently, cosmologists discovered that most of the stuff out there is in fact invisible and transparent
- It's called **Dark Energy**
- Its nature is completely mysterious



SNAP

- Here at Berkeley Lab, we are building a satellite called **SNAP** that will explore the properties of this dark energy

