Common thread: technology enables us to see more...
Storyline

- The Universe is **14.6 billion years** old; it is **awesome and mysterious**

- Your career as an astronomer may only span **50 years** or so.

- How much can our **understanding** of the Universe change in 50 years?
25 years ago...

1987
This was (and is) our home. 
In 1987, the Earth and the other planets in the solar system were the only planets known...
Pluto was still a planet!
The 5m (200”) Hale Telescope on Mount Palomar was the largest telescope in the world for 39 years. It had been built in 1948...
There was no Hubble Space Telescope.

It was launched in 1990.
Dobsonians were changing amateur astronomy... but they were mostly solid tubes.
Astrophotography was done on film...

... “hypered” on your own at home.
The most distant object known was a quasar at a redshift of $z = 4$, 12.9 billion lightyears away.

Quasars were the most energetic objects known. We had no idea where the power comes from!
The last supernova near or in the Milky Way was Kepler’s Supernova in 1604, before the invention of the telescope!
In astronomy, the frontier is always on the move...

23 February 1987
SN 1987A exploded in the Large Magellanic Cloud, only 168,000 lightyears from Earth!
All stars die...

... from their deaths come everything we know
In a supernova, almost every proton crashes into an electron, making a neutron and a neutrino.
We detected neutrinos from Supernova 1987A — 24 out of $\sim 10^{57}$

This is one of the first times we do astronomy without light.
24 neutrinos out of 1,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000

This is the beginning of precision astronomy... enabled by technology!
Fast forward to today...

2012
Hubble stared at an empty spot on the sky for 10 days, an area about the size of the eyeball on a dime, if held at arms length...
Hubble found galaxies...

lots of galaxies!

There may be 600 billion galaxies in the Cosmos
Supermassive black holes power the quasars...

...and are harbored in the hearts of many galaxies.
Black holes are central to our thinking about many astrophysical phenomena...
After the Big Bang, the Universe is HOT, and atoms can’t form. Photons scatter off charges...

When the Universe cools enough for atoms to form, photons fly free...
The most distant thing we’ve seen is the Cosmic Microwave Background, emitted when atoms formed 400,000 years after the Big Bang.
The largest effective telescope are the twin 10m Keck Telescopes in Hawaii, which work as one.

There are 18 telescopes larger than the Hale Telescope...
Large aperture Dobsonians are common!

...enabled by “technology” — truss designs.
Digital technology also enables stunning amateur astrophotography...
Technology allows amateurs to participate in SCIENCE.
Everything we’ve seen is made of 92 naturally occurring elements — ATOMS.
The Universe is only 4% of stuff like me and you.
We have no idea what the other 96% is!
Pluto is no longer a planet...
We know of 834 planets around other stars!

Our ideas about planets are changing everyday.
Imagining the future...

2037
Computing and simulations will be more capable and more important than they are today.
Exploding stars

Entire Galaxies

Colliding black holes
The largest telescopes will be enormous...
We will have detected planets like Earth around other stars...

...detected, and characterized atmospheres
We probably still won’t know what Dark Energy and Dark Matter are... but we’ll be much better at observing it!
We will use gravity instead of light to observe the Cosmos...
Gravitational waves are emitted by moving mass, and change the distances between parts of our detectors...
LIGO will measure small distance changes equivalent to changing the distance to alpha Centauri (4.3 lightyears) by 10 μm.

10μm is about the width of a human hair. This is the new precision astronomy...
10 solar mass + 10,000 solar mass black holes

Gravitational Waves
The Music of the Cosmos

Circular Orbit
Eccentric Orbit
You are living on the frontiers.
We are the new explorers.

The things that will be discovered in your lifetimes, we haven’t even imagined yet.