LECTURE 27:
A TALE OF 3 TELESCOPES, PART I

27.1 CCDs

Over the last 25 years, the most important technological development in optical astronomy has been the use of CCDs (charge-coupled devices), silicon-based, electronic light detectors. These are now used in cameras and spectrographs on most large telescopes.

A CCD counts the number of photons that hit in each "pixel" (picture element) of a grid.

CCDs are about 100 times more sensitive than the best photographic film, so for many purposes it has the same effect as making the telescope mirror 100 times bigger ($10\times$ the diameter).

CCDs produce data in digital form, suitable for computer analysis.

Their main drawback is small size $\longrightarrow$ cannot image a large area at one go. The largest astronomical CCDs today are about 2 inches on a side, 2000×2000 pixels.

27.2 HUBBLE SPACE TELESCOPE (HST)

Orbits earth every 90 minutes, at an altitude of 300 miles.

Main mirror: 2.4-meter diameter, not especially large by ground-based standards.

Instruments: two cameras, two spectrographs.

Launched in 1990. Major "refurbishment" in 1993, extremely successful. Two new instruments were installed this winter.

HST's major strength is *high angular resolution*, which it gets because it is above the blurring effects of earth's atmosphere. This allows it to make images nearly a factor of 10 sharper than the best ground-based telescopes.

HST can also measure ultraviolet light, which does not penetrate the earth's atmosphere.

27.3 EXAMPLES OF HST SCIENCE

1. Classifying distant galaxies

High angular resolution $\longrightarrow$ HST can distinguish between elliptical, spiral, and irregular galaxies even if they are billions of light years away.

We can thus examine the galaxy content of the universe at a time when it was a small fraction of its present age.

Initial results: irregular galaxies were much more common when the universe was young. Rich galaxy clusters, which are full of ellipticals today, were once full of spirals.

2. Faint stars in the Milky Way

Use resolution to distinguish faint stars from faint galaxies. Count faint stars.

Goals: learn about how stars form; determine whether faint, hydrogen-burning stars can be the "dark" matter.

Initial results: stars of about $0.3M_\odot$ are the most common. Not enough faint stars to make up the Milky Way's dark corona. "Failed" stars that don't fuse hydrogen would have been too faint to detect, so they could still be the dark matter.

27.4 THE KECK TELESCOPE

On Mauna Kea, Hawaii, altitude of 14,000 feet.

Main mirror: 10-meter diameter, the world's largest.

Started operation in 1993.

Keck's major strength is its *light gathering power*, which comes from its enormous main mirror. It can take very deep images, but its greatest importance is for measuring spectra of faint objects, where every photon counts.

27.5 EXAMPLES OF KECK SCIENCE

1. Abundances of rare elements

Lots of photons $\longrightarrow$ Keck can measure very weak absorption lines in stellar spectra and hence detect the presence of rare chemical elements.

Goal: combine with stellar ages and the theory of supernovae to deduce the history of star formation in the Milky Way.

2. Quasar absorption lines

Quasars are the most luminous objects in the universe. They can thus be seen at enormous distances, in light they emitted when the universe was much younger.

Hydrogen gas clouds at different redshifts produce absorption lines in spectra of background quasars.

Keck can examine these absorption lines with unprecedented accuracy and detail.

Goals: follow what happens to hydrogen gas as universe ages, learn about formation of galaxies. Compare results to predictions of cosmological simulations to test hypotheses about dark matter, Ω, physics of early universe.

NOTE: Summary is at end of lecture 27.