Lecture 29: Ellipticals and Irregulars
Readings: Section 26-3

Key Ideas
Elliptical Galaxies
Irregular Galaxies
Dwarf Galaxies
- Dwarf ellipticals, dwarf spheroidals, dwarf irregulars

Galactic Content
- H-R Diagrams
- Integrated Color/Light

Summary of Properties of Galaxies

Elliptical Galaxies
<u>Properties:</u>
- Mass: 10^5-10^{13} M_{Sun}
- Diameter: 1-200 kpc
- Luminosity: 10^6-$10^{12} L_{Sun}$

<u>Structure & Dynamics</u>
- Spheroid of old stars with little gas or dust
- Supported by random motion of stars with some very slow rotation

Measuring Mass in Ellipticals
The motions of globular clusters, for example, tell us about the mass inside their orbits.
We can map the distribution of mass in the galaxy and compare it to the light.

Dark Matter in Elliptical Galaxies
Elliptical galaxies have little or no rotation, so we can't measure their masses from their rotation curves.
Motions of objects reveal the strength of the gravity confining them to the galaxy.
Tracers: planetary nebulae, globular clusters, integrated spectra of stars.
Elliptical galaxies have lots of dark matter too!
Up to 90% in extended dark matter halos.

Velocity Dispersion

Doppler shifts of stars result in broadening of absorption lines of integrated spectrum.

Range of Doppler shifts=velocity dispersion

High velocity dispersion = **High** mass M(R)
Low velocity dispersion = **Low** mass M(R)

Irregular Galaxies

Properties:

Mass: 10^6-10^{11} M_{Sun}
Diameter: 1-10 kpc
Luminosity: 10^6-few x 10^9 L_{Sun}

Structure & Dynamics:

Chaotic structure, lots of young blue stars
Moderate rotation in Irregulars, but very chaotic motions as well.

Type I: Irregulars

Have irregular, often chaotic structures

Little evidence of systematic rotation

Catch-all class:

Proposed systematic subclasses, but many irregulars defy classification.

Significant dwarf irregular population, classified as “dI”

Examples: Large and Small Magellanic Clouds

Irregulars in the early Universe

Irregulars were more common in the early Universe. Important information for understanding the formation of galaxies.

Dark Matter in Irregular Galaxies

Methods

Doppler shifts in gas or stars
Rotation curves if rotation is important
Velocity dispersion if not

Results

Irregular galaxies have lots of dark matter, up to 90%

Dwarf Galaxies

Low-luminosity Ellipticals & Irregulars

Significant number of dwarfs

Most common type of galaxy by number

There are no (convincing) Dwarf Spirals

Ellipticals divided into

Dwarf ellipticals (dEs) 10^8-10^{11} M_{Sun}

Dwarf spheroidals (dSphs) 10^5-10^8 M_{Sun}

<u>Possibilities:</u>

Small versions of their cousings

Different populations of objects with superficial similarities to larger E's and Irr's

Dwarf Galaxy Discoveries

Large and Small Magellanic Clouds easily visible to the naked eye

First preserved mention

Persian astronomer Al Sufi in 964

White Ox of the southern Arabs

Visible from the strait of Bab el Mandeb

1781 – M32 discovered by LeGentil

19th Cent – numerous dwarfs in NGC and IC catalogs

1938—Sculptor & Fornax dSph discovered by Shapley

Dwarfs at a Distance

Dwarf galaxies are small and low luminosity. It is difficult to see dwarf galaxies outside of the local area.

Cosmic Building Blocks

Galaxies of all types are the basic "units" of luminous matter in the Universe.

Basic units of larger, organized structures

Sites of star formation from raw gas

Factories that synthesize heavy elements from Hydrogen and Helium

Differences in the types of galaxies reflect differences in their star formation histories and environments.

What's in Galaxies?

Methods of learning about what's in galaxies:

Images: use blue and red filters to measure colors and make H-R diagram from individual stars

Integrated light/spectra

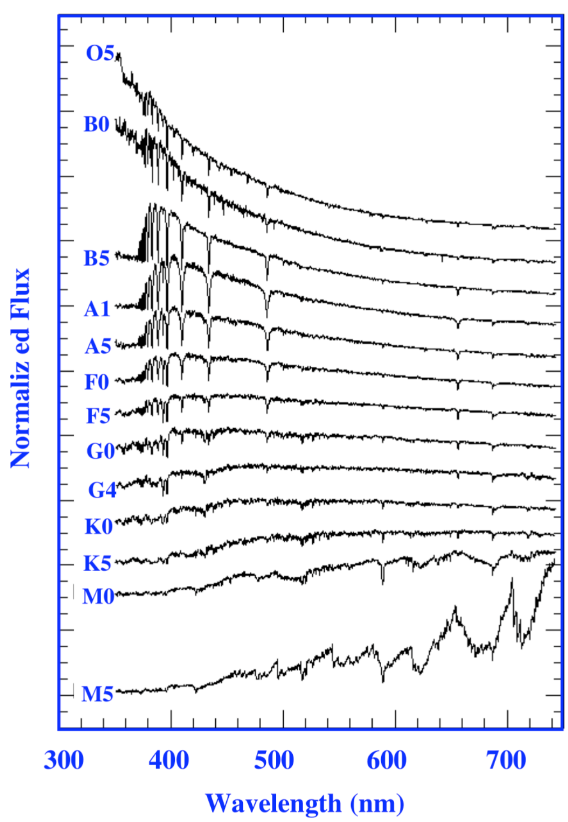
Emission lines, particularly from neutral hydrogen and molecular gas.

H-R Diagrams: Leo A Example

Integrated Light/Spectra

Reminder of what Stellar Spectra look like

Spectra of Dwarf Stars (Luminosity Class V)



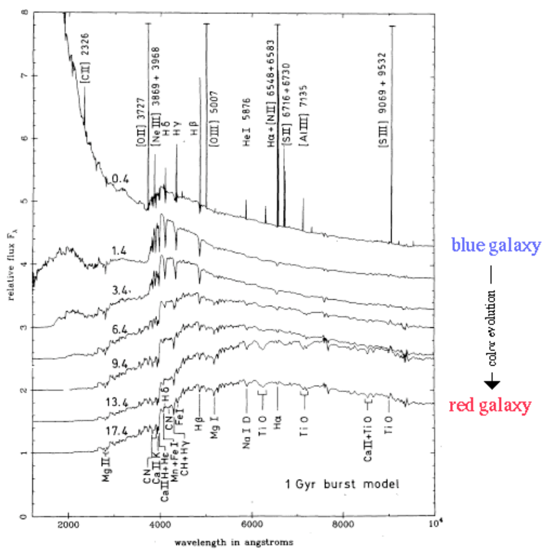
The appearance of a stellar spectrum is determined mostly by the star's *temperature.*

Hot stars live short lives, therefore must be young.

Spectra with O and B star features indicate a young stellar population

In addition, lines from nebulae, particularly ionized H regions, can be present as well

Spectra of Galaxies



The age of the stars (at least the most luminous stars) can be determined from the spectra. As the stars in the galaxy age, the hot, blue stars are the first to die, so the galaxy gradually becomes redder and the spectrum changes.

Relative Stellar & Gas Content

<u>Spirals</u>

Range is ~10-20% gas
On-going star formation in the disks
Mix of old and young stars

<u>Ellipticals</u>

Very little or no gas or dust
Star formation ended billions of years ago

See only old stars, some quite metal-rich

Irregulars

Up to 90% gas content

Much on-going star formation

Dominated by young stars

Gas Content in Dwarf Galaxies

The gas content of dwarf galaxies can be studied by the emission lines.

21-cm from neutral hydrogen

Radio and millimeter lines from molecules

Results: dIrr are gas-rich, with 25-50% of their total mass still in the form of gas

dE and dSph are gas-poor. Only one dSph (Sculptor) has any gas detected.

Summary of Properties of Galaxies

Type of Galaxy	**Gas**	**Stars**	**Rotation**	**Dark Matter**	**Dwarf Varieties?**
Spiral	Some	Mix of old and young	Important	Yes	No
Elliptical	No	Mostly old	Not important	Yes	dE dSph
Irregular	Lots	A few old and lots of young	Not important	Yes	dIrr

Big Questions

How do spirals, ellipticals and irregulars form?

Why are so many bright galaxies spirals?

Why are the shapes of galaxies and their stellar populations/gas content related?

What is the connection between the different types? Can a galaxy change type over its lifetime? Dwarf elliptical to dwarf spheroidal? Spiral to elliptical?