Galaxies

Relativity and Astrophysics
Lecture 16
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Outline

- Discovering Galaxies
- Classifying Galaxies
  - Hubble (morphological) classification
  - Different types of galaxies

Note:
- Most galaxy photos from Astronomy Picture of the Day (APOD) on the web – you can find them (and credits for images) by searching the name of the object.
Galaxies

- A **galaxy** is a collection of stars, gas and dust along w/ associated starlight, magnetic fields and cosmic rays.
- Four broad categories based on morphology (appearance):
  - E  elliptical
  - S  spiral (normal & barred)
  - S0  lenticular
  - I  irregular

Ellipticals Galaxies

- Range from spherical to highly flattened
  - with designations E0 to E7
- Contain old stars (Pop II)
- Very little gas and dust
- 1-200 kpc in diameter
- Mostly found in clusters of galaxies
- Average spectral type: K
- $10^6$ to $10^{13} M_{\odot}$
Spiral Galaxies

- Flattened systems which have a thin disk
- Display spiral structure
- Divided into barred (SB) and unbarred (S) spirals
- Further subdivided into classes a, b, and c; e.g. SBB, Sc, ... where
  - a ⇒ large nuclear bulge & tightly wound spiral arms
  - c ⇒ small nuclear bulge & loosely wound spiral arms
- Young (Pop I) and old (Pop II) stars
- Copious amounts of gas and dust
- 5-50 kpc in diameter
- Found mostly in the "field" (outside clusters of galaxies)
- Average spectral type: A, F, G, K
- $10^9$ to $10^{11}$ M$_\odot$
Lenticulars (S0 Galaxies)

- Like spiral galaxies in shape and color but no spiral arms
- Flattened systems which are morphologically between ellipticals and spirals.
Irregulars

- By definition, irregular in shape
- Mostly young stars (Pop I)
- Lots of gas and dust
- 1-10 kpc in diameter
- Found in the field (outside clusters)
- Average spectral type: A, F
- $10^8$ to $10^{10} M_\odot$

Hubble Tuning Fork – For classifying galaxies

- The classification scheme is strictly morphological and does not necessarily imply an evolutionary sequence.
Other Types of Galaxies

- Dwarfs \(10^6\) to \(10^8\) stars
- Peculiar Exploding, Rings, Disrupted
- Seyfert Very Bright Nucleus
- Interacting Tidal Effects, Tails (pairs)
- QSO Collapsed Nuclei?
Dwarf Galaxies

Leo I

NGC 1313

Interacting Galaxies

Cartwheel Galaxy

The Antennae (NGC 4038 and NGC 4039)
Interacting Galaxies

Arp 104 – NGC 5216 (top right) and NGC 5218

Arp 273

The Local Group

LMC
SMC
Milky Way

M31
M33

100 kpc
Nearby galaxies – SMC

SMC (Dwarf)
50kpc

47 Tuc Globular Cluster

Nearby galaxies – LMC

LMC (Dwarf)
50kpc
Notes on Classifying Galaxies

- Classifying of galaxies by their morphology is a bit problematic
  - Appearance can depend on exposure time, wavelength, and angular resolution.
  - Thus can change with redshift – even if no intrinsic evolution
- Classification Requirements
  - Homogeneous data set
  - Unique classification
  - Flexible and unambiguous notation
- Unfortunately these requirements are often violated
  - Can get ambiguities and inconsistencies
- Some examples of how galaxy morphology can change with exposure time and wavelength are given in the next slide.
Cen A: Two Different Scales

The image of the peculiar galaxy Cen A (NGC 5128) but with different image display scales. How would YOU classify this galaxy? The same effect could be achieved with different exposure times. [Image is IIIa-J, 4680A from the Digital Sky Survey (DSS) via NASA Extragalactic Database (NED).]

Cen A: Two Different Wavelengths

The image of Cen A (NGC 5128) but with two different wavelengths. Both images are from APOD (Astronomy Picture of the Day)

Left image: antwrp.gsfc.nasa.gov/apod/ap030806.html
Right image: antwrp.gsfc.nasa.gov/apod/ap040624.html
Centaurus A (Peculiar Galaxy)

Nearest Radio Galaxy

In the Infrared
M81 at different wavelengths

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Image Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.23 um (yellow), 0.16 um (blue)</td>
<td>B Color visual</td>
</tr>
<tr>
<td>3.6 um</td>
<td>8.0 um</td>
</tr>
<tr>
<td>70 um</td>
<td>160 um</td>
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<tr>
<td>24 um</td>
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M81: H-alpha emission

<table>
<thead>
<tr>
<th>Image Description</th>
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<tbody>
<tr>
<td>V image from NED</td>
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<tr>
<td>H-alpha in blue, V in red + green</td>
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Galaxies

M81: Blue light

Color enhanced image using B & V bands. Color mix is V=red, B=green, B/V=blue.

Ratio of B to V images

Galaxy Classification Systems

- Hubble System (of Classification)
  - Introduced in by Edwin Hubble in 1936 book, The Realm of the Nebulae

- A number of other classification systems exist
  - De Vaucouleurs’ Extension of the Hubble System, 1959
  - David Dunlap Observatory (DDO) System (S. van den Bergh 1960, 1976)

- Note – these system are based on visual appearance