Active Galaxies
Lecture 24

APOD: M82 (The Cigar Galaxy)

Lecture Topics

- Active Galaxies
  - What powers these things?
- Potential exam topics
**Active Galaxies**

<table>
<thead>
<tr>
<th>&quot;Galaxies&quot;</th>
<th>Luminosity ($L_{MW}^*$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>$&lt; 10$</td>
</tr>
<tr>
<td>Seyfert</td>
<td>$0.5 - 50$</td>
</tr>
<tr>
<td>Radio</td>
<td>$0.5 - 50$</td>
</tr>
<tr>
<td>QSO</td>
<td>$100 - 5000$</td>
</tr>
</tbody>
</table>

*where $L_{MW}^*$ = Luminosity of the Milky Way

$\sim 2 \times 10^{10} L_{\odot}$

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**Seyfert Galaxies**

- Spectral lines don’t resemble normal stars.
  - Highly ionized heavy elements, e.g. iron!
  - Lines very “wide” $\Rightarrow$ tremendously hot ($>10^8$ K) or rapidly rotating ($\sim 1000$ km/s)
- Nearly all emission comes from the galactic nucleus (a small central region).
  - $\sim 10^4$ times brighter than the center of our galaxy
Seyfert Galaxies (cont’d)

- Most energy emitted in infrared and radio parts of the spectrum.
  - Look very much the same as normal galaxies in the visual.
- Emitted energy varies with time!
  - ⇒ Compact source of energy
  - ⇒ Emitting region < 1 lyr across
- Some emit more light than the Milky Way from this small region!

Radio Galaxies

- Very bright in the radio
  - Cosmic rock stations?
- Core-Halo radio galaxies
  - Most emission from a very small core (< 1 parsec across)
- Extended (or Lobe) radio galaxies
  - Emission extends hundreds of kiloparsecs!
Core-Halo Radio Galaxies

M87

- Jet
- $v \sim 0.1\ c$ in jet
- Extended halo
- Bright core

Optical Image

HST Image

Optical Jet
Extended Radio Galaxies

Cygnus A

“Original” extragalactic radio source, Cygnus A.
Centaurus A (Peculiar Galaxy)

Nearest Radio Galaxy

Centaurus A (Peculiar Galaxy)

In the Infrared
Centaurus A (Peculiar Galaxy)

Radio emission (green)

Centaurus A - rising

Radio image of Centaurus A overlaid on optical view showing size relative to full Moon. Dots are distant radio bright galaxies.

Also shown is the Australian Telescope Compact Array (ATCA).

From APOD
Quasi-Stellar Objects (QSOs)

- Galaxies with extremely luminous sources
  - Look like stars in photographs.
  - Some evidence of faint “parent” galaxy
- Energy originates in a very small region
  - QSOs are variable
- Can see to great distances
  - Most distant objects seen in the universe
- Such a source at 50 pc would appear as bright as the Sun!

What powers these objects?

- We need to produce up to 5000 times the luminosity of the M.W.
  - But within a region ~ 1 pc in size !!!!
- Leading theory is a black hole with an accretion disk:
  - Material gains energy as it falls towards the black hole.
  - The gas heats up, and radiates energy.
Accretion disk model

- Gas falling onto disk
- Accretion disk
- Black hole
- Jets of high speed particles

Accretion Disks

Black Hole Disk Model

NGC 4261
Energetics

- Material needs to keep flowing onto the black hole to power the source.
- For $1 \, M_{\text{sun}} / \text{decade} \Rightarrow \sim 10 \, L_{\text{MW}}$
- For $10,000 \, L_{\text{MW}} \Rightarrow 100 \, M_{\text{sun}} / \text{year}!!$
- Large black holes ($10^8 - 10^9 \, M_{\text{sun}}$) are needed, otherwise the accretion disks blow themselves apart.
Potential Exam Topics

- Types of star clusters and properties
  - Open (Galactic), Globular, O/B Association
- H-R diagram
  - Of a cluster of stars
  - Movement of star as it evolves
- Energy generation in stars
  - CNO cycle, P-P chain
  - Nucleosynthesis
- Stellar evolution
  - From birth to death

Potential Exam Topics (cont’d)

- Stellar end-products
  - White dwarfs, neutron stars and black holes
  - What’s left and why?
- Supernovae and the collapse of stars
  - What happens?
- Neutron Stars and Pulsars
- Special Relativity
  - Postulates and Consequences
  - Rough velocity addition
Potential Exam Topics (cont’d)

- General Relativity and Black Holes
  - Postulates and Consequences
  - “Proofs” of GR
  - Schwarzchild radius & event horizon
- Properties of the Milky Way
  - Components & shape
  - Motions (rotation curve), etc.