Starburst and AGNs

Starburst Galaxies

- More than 100 stars/year are formed
- Look funny due to high number of star forming clouds
- Higher birth rate means higher death rate
  - Leads to fast galactic winds
  - Galactic winds in small galaxies causes star formation to halt

Causes

- Structure implies collisions
  - Streamers
  - Dusty molecular clouds
  - Two distinct clumps of stars in center
- Close encounters

Strange Objects

- Start in 1936 with Grote Reber
- Built first Radio Telescope
  - Backyard in Illinois
- By 1944 he had 3 strong radio sources
- These objects are labeled with constellation name and a letter
  - Sagittarius A
  - Cassiopeia A
  - Cygnus A

Active Galaxies

Quasars
What Were These Objects?

- Further investigation found Sag A and Cas A were within the Milky Way:
  - Sag A was the center of the Milky Way
  - Cas A was found to be a supernova remnant
- But what about Cyg A?
- Walter Baade and Rudolph Minkowski
  - Palomar 200” telescope
  - They found a strange looking galaxy

The Spectrum of Cyg A

- Instead of finding the absorption spectrum of a normal galaxy they found emission lines
- The lines were redshifted 5.7% (17,000 km/sec)
- Using Hubble’s Law puts this object at about 750 Billion ly = 230 million pc

Distance and Output

- How can an amateur telescope find an object so far away?
- It turns out that Cyg A puts out 10 million x’s more radio energy than M31
- What could be putting out that much energy from an apparently normal galaxy?

3C Catalogue

- In 1959 the 3C catalogue was published
- In contained 471 strong radio sources
- In 1960 Allen Sandage looked at 3C 48
- Instead of finding a strange galaxy at the coordinates he found a ‘star’

A Star?

- Stars don’t put out strong radio signals
- A spectrum was once again taken
  - This again showed emission lines
  - Couldn’t identify the lines this time
- Some thought it was just a strange star in our own galaxy
The Mystery

• In 1962 astronomers looked at 3C 273 and found what appeared to be a blue star
  – Unfortunately the emission spectrum was unidentifiable
• In 1963 Maarten Schmidt at CalTech realized the emission lines were known lines
  – Redshifted Hydrogen lines
  – About 15% the speed of light
  – This implies 2 billion ly = 614 million pc

Quasars

• A star 614 million pc away could never be seen
  – 3C 48 was found to be 4 billion ly (1.2 billion pc) away
• These objects had two main characteristics
  – Strong Radio Sources
  – Looked like stars

Quasars

• Names:
  – 1) Quasi-stellar Radio Sources
  – 2) Quasars
  – 3) Quasi-stellar Objects
  – 4) QSO's
• We now know only about 10% of quasars are 'radio-loud'
• However the name has stuck
• More than 10,000 quasars are now known to exist

Quasar Redshifts

• The current QSO redshift range: 0.06 < z < 7.00
• Most have redshifts of 0.3 or more
• Example
  – The redshift of PC1247+3406 is 4.897 or 94% of the speed of light
  – This is roughly 3 billion pc (10 billion ly) from the Earth
  – The light left 5 billion years before the Sun was formed!

Quasar Redshifts

• There are no nearby quasars
• The closest is 800 million ly = 245.27 Mpc
• Quasars are objects from an earlier era in the history of the Universe
• They give us clues to the early Universe

Clues to the Nature of Quasars?

• Quasar have turned out to be associated with remote galaxies from HST photos
  – Radio-quiet quasars in spirals
  – Radio-loud quasars in ellipticals
Clues to the Nature of Quasars?

• Spectra of Quasars are unique in the fact that they show non-blackbody emission
  – They have energy source other than thermal radiation
• This can come from Synchrotron Radiation
  – Production of synchrotron radiation could be evidence for an accretion disk around a blackhole

Other Active Galaxies

• To further our understanding of the nature of quasars we need to look at other active galaxies
• We will discuss
  – Seyferts
  – Radio Galaxies
  – Blazars

Closer Quasars?

• Are there any objects similar to quasars which are closer?
• Yes
  – Seyfert galaxies, radio galaxies, blazars
  – We will start with Seyfert galaxies which provide a logical bridge between quasars and normal galaxies

Seyfert Galaxies

• About 10% of the brightest spirals are Seyferts
• 700 Currently known
• Range in brightness from the faintest quasars down to normal galaxies

Seyfert Galaxies

• Spiral galaxies with very compact nuclei
  – Extra bright nuclei
  – They had strong emission lines like the quasars
• Other characteristics
  – Radio Emission (on the quiet side)
  – X-ray emission

Radio Galaxies

• Seyferts have a counterpart
• Active elliptical galaxies are called Radio Galaxies
• The first of these galaxies was discovered in 1918 by Heber Curtis
• He found a bright nucleus and a jet of material
M87

- From HST images we know that the jet extends

Radio Lobes

- In the 1960's and 1970's astronomers systematically examined extragalactic radio sources
  - Most radio galaxies have two Radio Lobes with a giant elliptical galaxy at the center
  - The lobes were 5 to 10 times the size of the parent galaxy
  - These are sometimes called Double Radio Sources

Blazars

- These are similar to quasars with extraordinary variability
  - The first of these new objects was BL Lacertae
- However, BL Lac had no features in its spectrum
- Images showed a faint fuzz around BL Lac which turned out to be an elliptical galaxy

Blazars

- They also show variations which can be as large as 5 magnitudes
- They are radio sources
- They are probably double lobe sources seen end on so we are looking down the jet

The Engines

- What kind of object could drive all these amazing galaxies?
- The variability of Blazars gives us a clue
- The period of variation is related to the size of the changing object
  - If the period is 1 year then the size of the object can't be larger than 1 lightyear
- This is called a Light Time Argument
The Engines

• In 1968 Donald Lynden-Bell theorized about blackholes lurking in the center of galaxies
  – The potential energy of material falling into the blackhole could be turned into radiation
• This blackhole would be about the size of our solar system
• This would explain the Active Galactic Nuclei

A Unified Model

• Could the various AGN’s be explained by the presence of a blackhole in their centers?
• The fact that there are no nearby Quasars might simply be that the fuel has run out or decreased enough to lessen the output

Viewing Directions - Elliptical

• End on jet - Blazar (BL Lac)
• From end on jet to about 45 degrees - Quasar
• Close to edge on - Radio Galaxy

Viewing Directions – Spirals

• Two types of Seyfert galaxies
  – Type I
    • Have both broad and narrow spectral lines
    • An end-on view
    • Sees the blackhole
  – Type II
    • Have only narrow emission lines
    • Edge-on seeing the disk

GRB

• Unknown cause until recently
• Supernovae viewed end-on