Galaxy Collisions

AST 200

Evans
“Normal” massive galaxy types – elliptical & spiral galaxies

- **Elliptical**
  - Bulge of old stars
  - Large black hole
  - Very little gas & dust

- **Spiral**
  - Bulge of old stars + large black hole
  - Disk of young stars & gas
Infrared emission

- Stars are very hot & emit the most energy in the visible
- People are warm & emit the most energy at 10 microns
- Dust in galaxies is cool-to-warm & emit the most energy at 2 – 100 microns

Visible (0.55 micron) light

10 micron light
Other Examples -

Visible

Infrared
And...

- Observed the sky at 12, 25, 60, 100 microns
- Emission from dust
- Revealed imbedded star formation
- And…

Orion Star Formation Regions

Andromeda Galaxy (M 31)
... Some other, unknown sources.

IRAS – 60 micron images
Optical follow-up revealed a population of infrared bright, interacting galaxies
How do we know that they are interacting/merging?
Why were these galaxies easy for IRAS to detect?
• Dust is Efficient at Absorbing Ultraviolet & Optical Light
• Optical Light from Embedded Stars is Absorbed by Dust and Reradiated as Infrared Light.
• But Infrared Light from this Warm Dust has a much Higher Chance of Escaping.
Molecular gas in a nearby spiral galaxy – star formation rate: few solar masses/year
... Compared with molecular gas in infrared galaxies. SFR = 100 Solar masses/year

1000 light years
Compression of gas in merger = star formation

2. Gas Only
Star formation signatures also seen in optical spectroscopy

Produced by gas heated by young stars
Late 1980s: … But often, Quasar-like signatures are seen in spectra…

- … And bright, compact Quasar-like nuclei
- … And a few Quasars have distorted host galaxies
- … And many nearby Quasars were detected by IRAS
- … And Quasars are about as common as the intrinsically brightest IRAS galaxies

- Maybe the intrinsically brightest IRAS galaxy mergers evolve into quasars
The Model

**Progenitors**

- **Merger phase**
  - Gas compression
  - Star formation
  - Black hole fueling/building

- **Quasar phase**

- **Elliptical**

Time

- 100 million years
- 1 billion years
## Infrared Galaxies vs. Quasars

<table>
<thead>
<tr>
<th></th>
<th>Infrared galaxies</th>
<th>Quasars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signs of galaxy collision</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Star-forming gas</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Young, bright star clusters</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Quasar-like gas heating</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Bright, compact nucleus</td>
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Do stars or Quasars energize bright infrared galaxies? Problem 1: Dust.

- **Optical light** from the center of the galaxy does not escape the galaxy, but optical light from stars in the outer galaxy can.

**Young stars**  
**Dust**  
**Feeding black hole**
Thus, Quasars can hide beneath the dust.

The effects of dust.

Ultraviolet (0.1-0.2 µm)

Near-Infrared (1 – 2 µm)

(Note: Optical = 0.55 µm)

Thus, Quasars can hide beneath the dust.
Problem 2 - Imaging Quasar host galaxies:

- Problem – The brightness of the Quasar makes it difficult to see the underlying galaxy
Addressing the IRAS Galaxy – Quasar Connection

- **Approach 1** – Image IRAS galaxies in the near-infrared and look for bright, compact nuclei.

- **Approach 2** – Image a large sample of Quasars and look for evidence of galaxy merger-like signatures.

- **Approach 3** – Look for molecular gas in Quasar host galaxy that must be left over from earlier, IRAS-bright phase.
Imaging galaxies: High Resolution

Hubble Space Telescope

• To get clear images, we go to space, or we go to a high mountaintop.
• Why? To lessen the blurring effects of the dense atmosphere.

Mauna Kea Observatories, Hawaii (14,000 ft)
Hubble Space Telescope Near-Infrared Camera

Quasar-Like nucleus

Extended distribution of star clusters
HST Data

Lots of star clusters

Inner spirals

Embedded compact nuclei
QSOs: Diverse Morphologies
Detecting Molecular Gas: Millimeter-wave Telescopes

Owens Valley Millimeter Array

Plateau de Bure – Grenoble France
Looking for molecular gas in nearby Quasars
Launch date: April 2003

SIRTF will probe deep into the dusty regions of galaxies

The Future –– Space Infrared Telescope Facility (SIRTF)

SIRTF will probe deep into the dusty regions of galaxies
Half of the energy emitted since the Big Bang is observed at infrared wavelengths.
SIRTF will routinely detect early universe galaxies

The Hubble Deep Field

Optical – Hubble Space Telescope (HST)

850 microns – Submillimeter Common User Bolometer Array (SCUBA)
Molecular gas in a galaxy at 80% look-back times

... About 20 galaxies at these distances detected to date
The Future (Part 2) – Atacama Large Millimeter Array will routinely detect star-forming gas in early universe galaxies at high resolution.

The Present – Owens Valley Millimeter Array:
Six 10m dishes.

ALMA: 64 12m dishes.