Introductory Astronomy

Week 7: Galaxies

Clip 11: Galactic Evolution

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Galactic Interactions

- Most galaxies are in clusters and fill more of the space
- Interactions are important
- Elliptical galaxies common in interior of dense clusters
- Collisions and mergers can destabilize disk structure
- Clusters contain hot gas comprising half the mass
- Likely removed from galaxies in repeated collisions

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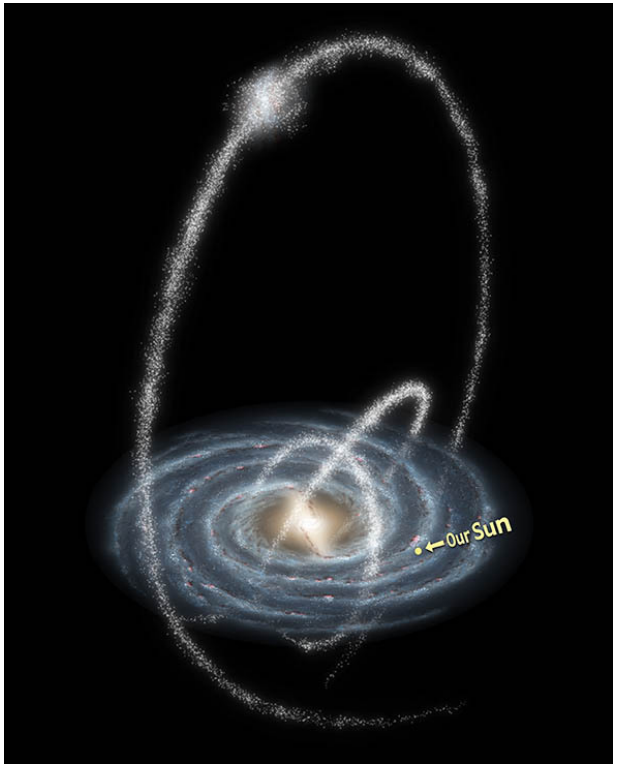
Slow Collisions

- Collisions between galaxies are gravitational
- Dynamical Friction slows down a cluster moving through a galaxy $f_d \sim \frac{G^2 M^2 \rho}{v_M^2}$
- In closer encounters tidal forces break it spreading into stellar stream



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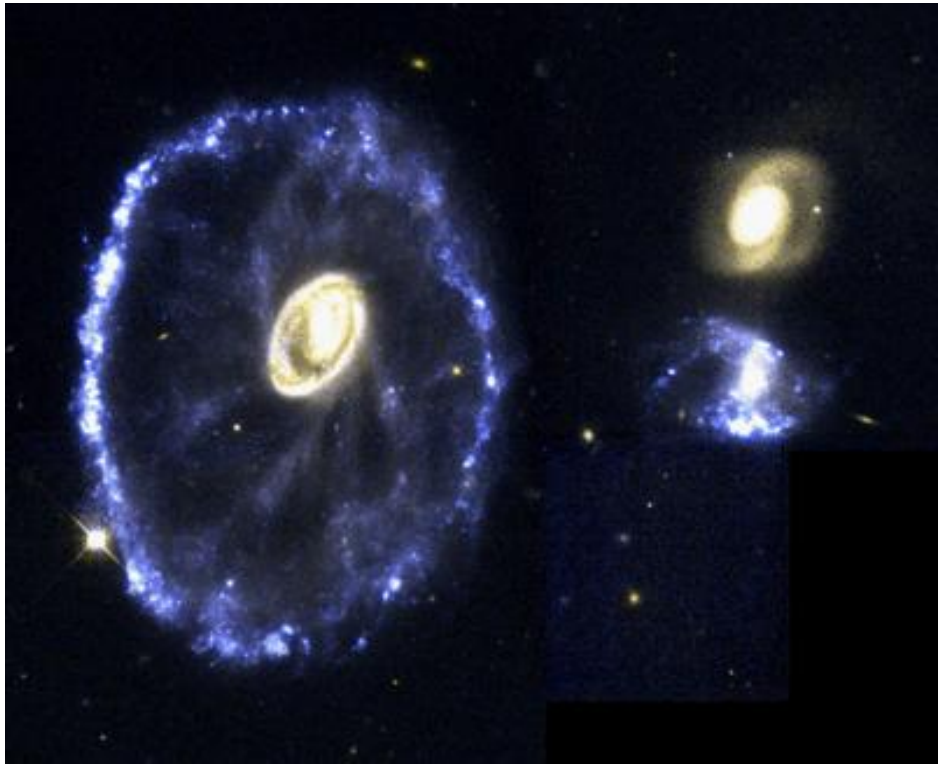
Fast Collisions

- In rapid collisions gas ejected in high-velocity ring
- Used to verify dark matter halo distribution



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Tidal Collisions

Can initiate starburst

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Largest Spiral Known

- NGC 6872 is huge
- Shows tidal tail possibly due to collision
- Is a dwarf forming?

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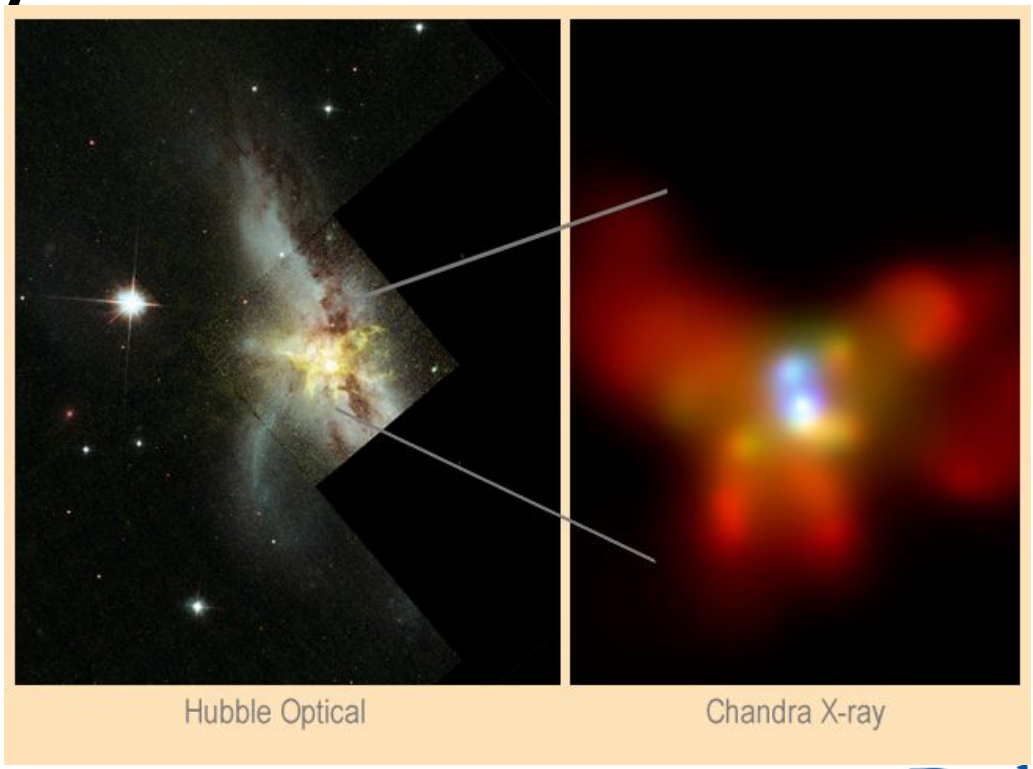
Binary Black Holes

- After merger black holes migrate to center of merged galaxy
- NGC 6240 has binary black holes separated by



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ELS Model of Galaxy Formation

- Eggen, Lynden-Bell, Sandage 1962: Collapse of a "protogalactic cloud" (top-down)
- Old stars formed before angular momentum flattening to disk or ISM enrichment

- Issues:
  - Halo clusters in retrograde orbits
  - Age spread in halo clusters
  - Distant clusters are younger, metal poor
  - Age spread in disk components

Heirarchical Merger Model

- In collapse form protogalactic fragments
- More with mass $10^6\ M_\odot$ than $10^{12}\ M_\odot$
- Merge to spheroidal mass distribution forming stars and globular clusters in dense centers
- Chemistry varies by history
- Collisions and tidal forces disrupted some – halo field stars, bared globular clusters of others
- 90% of clusters – all the most massive ones - destroyed
- Bulge forms early in dense center
- In distant reaches left with dwarf satellites

Can We See This?

- Ellipticals may form from mergers of spirals or at bottom of deepest gravitational wells
- Hubble deep field may show us early protogalaxies: blue, irregular
- Galaxy formation far from understood

Credits

- Coma Cluster: NASA, ESA, and G. Bacon (STScI) http://hubblesite.org/newscenter/archive/releases/2008/24/video/b/
- MW Streams: NASA/JPL-Caltech/R. Hurt (SSC/Caltech) http://www.spitzer.caltech.edu/images/2138-sig07-008-Rings-Around-the-Galaxy-Annotated-
- Cartwheel Galaxy: Kirk Borne (STScI), and NASA http://hubblesite.org/newscenter/archive/releases/1995/02/
- NGC 4650A: The Hubble Heritage Team (AURA/STScI/NASA) http://hubblesite.org/newscenter/archive/releases/1999/16/image/a/
- M51: NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA) http://hubblesite.org/newscenter/archive/releases/2005/12/image/a/
- NGC 6240: Optical: R.P.van der Marel & J.Gerssen (STScI), NASA; X-ray: S.Komossa & G.Hasinger (MPE) et al., CXC, NASA http://apod.nasa.gov/apod/ap021128.html
- NGC 6872 NASA's Goddard Space Flight Center/ESO/JPL-Caltech/ DSS http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA16613
- Extreme Deep Field: NASA, ESA, G. Illingworth, D. Magee, and P. Oesch (UCSC), R. Bouwens (Leiden Obs.), and the XDF Team http://apod.nasa.gov/apod/ap121014.html

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