Starbursts, AGN, and Interacting Galaxies

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Galaxy Interactions

Galaxy Interactions – Major and Minor

- Major interactions are interactions in which the interacting galaxies have similar (i.e. within an order of magnitude) masses
  - Causes significant tidal disruption of both galaxies
- Minor interactions involve galaxies with significantly different masses
  - Parent (larger galaxy) not significantly affected
  - Includes satellite interactions

Galaxy interactions – Satellite interactions

- Most large galaxies have satellites
- Close-orbiting satellites of gas-rich galaxies often are stripped of their gas by the interaction
- May eventually result in the satellite being absorbed into larger galaxy

Galaxy Name	M_V (mag)	σ_* (km s^{-1})	$D_\odot$ (kpc)
Bootes	−6.3	6.6	60
Canes Venatici II	−4.9	4.6	150
Carina	−9.4	6.8	100
Coma	−4.1	4.6	45
Canes Venatici I	−8.6	7.6	220
Draco	−8.75	10.0	80
Fornax	−13.2	10.5	138
Hercules	−6.6	5.1	130
Leo I	−11.5	8.8	250
Leo II	−9.6	6.7	205
Leo IV	−5.0	3.3	160
LMC	−18.6	···	49
Sagittarius	−12.1	11.4	24
Sculptor	−11.1	6.6	80
Sextans	−9.5	6.6	86
Segue 1	−1.5	4.3	23
SMC	−17.2	···	58
Ursa Minor	−9.0	9.3	66
Ursa Major I	−5.5	7.6	100
Ursa Major II	−4.2	6.7	30
Willman I	−2.7	4.3	40

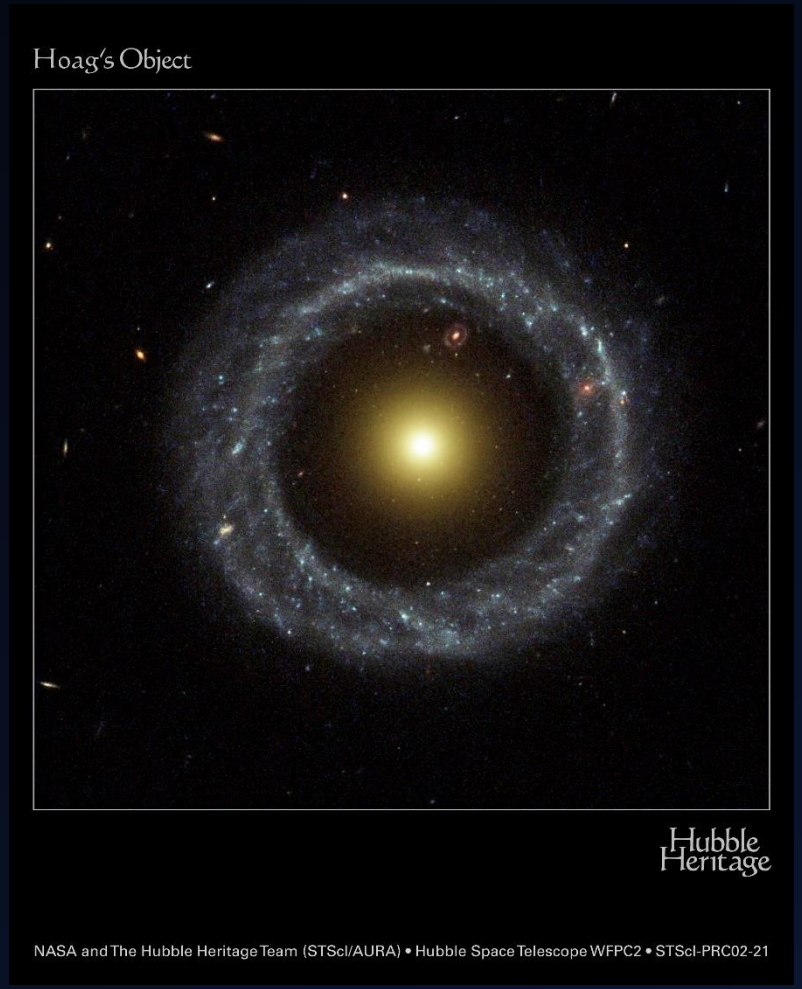
Some Satellites of the Milky Way, Koposov et al. 2009

Galaxy interactions – Collisions

- The stars within colliding galaxies collide only rarely
- Lensing experiments have shown that the dark matter halos are also “collisionless”
- The gas and dust components of galaxies collide, resulting in regions of high density and subsequent star formation
- Head-on collisions can result in the collision of the two supermassive black holes
- Galaxy collision simulation – Dubinski

Galaxy interactions – Example Interaction Products

- Polar-Ring galaxies and dust-lane ellipticals
  - Normal galaxies orbited by rings of gas dust and stars stripped from passing galaxies
- Tidal-tail galaxies (eg. M51 Whirlpool)
  - Bridge of stars and gas from a galaxy to its neighbor
- Ring galaxy
  - Created in head-on merger



Ring Galaxy - Hubble Heritage

Toomre Sequence

- Peculiar galaxies are transient phenomena
- Colliding spirals generally produce an elliptical galaxy
  - Note that this is the opposite of the Hubble tuning fork
- Will deal more with this on the assignment

Starburst Galaxies

Starburst Galaxies

- Starbursts are typically quite blue in optical because of a burst of star formation within the last few Gyr
- Typically produce the majority of their luminosity in IR

Antennae galaxies, Hubble Heritage

Starburst Galaxies II

Antennae galaxies, Hubble Heritage

Wide-field of Antennae, APoD

Active Galactic Nuclei

AGN Classification - I

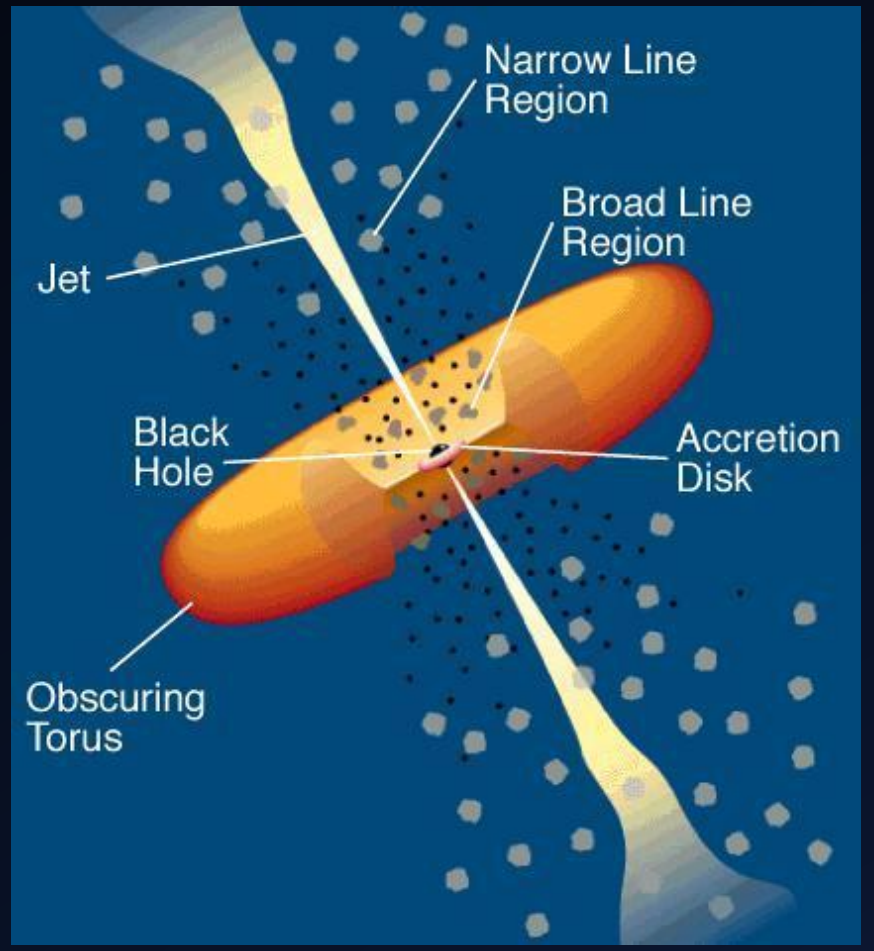
- Seyfert
  - Seyfert 1: Both permitted and forbidden emission lines, lines Doppler broadened by velocities of 1000-5000 $\mathrm{km}\ s^{-1}$
  - Seyfert 2: Both permitted and forbidden emission lines, lines Doppler broadened by velocities of $\sim 500\ \mathrm{km}\ s^{-1}$
  - Both types are usually strong x-ray emitters and radio-quiet
- QSO
  - QSO-1 Similar to Seyfert 1, AGN outshines host galaxy in optical
  - QSO-2 Originally predicted by AGN unification, similar to Seyfert 2 but brighter in optical

AGN Classification - II

- Low-Ionization Nuclear Emission line Region (LINER) galaxy
  - Like Seyfert 2 but forbidden lines come from less highly ionized atoms
  - Thought to be low-luminosity relatives of Seyfert galaxies
  - Most common in Sa, Sb, SBa, SBb spirals
- Fanaroff & Riley Radio Galaxy
  - High radio power relative to bolometric luminosity
  - FRI – Core brightened, low luminosity
  - FRII – Edge brightened, high luminosity, large radio lobes
- And more…

AGN Unification

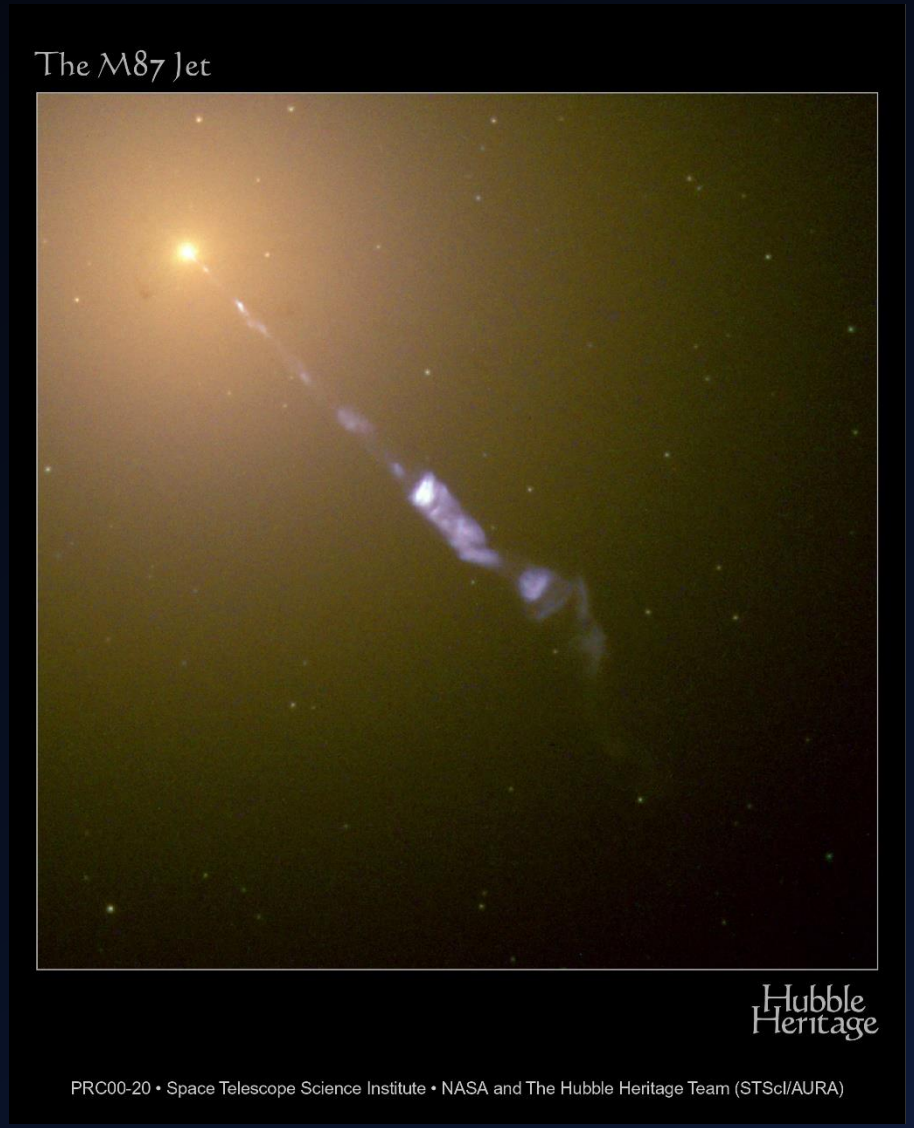
- A family of models that is intended to explain the vast diversity of AGN classes with a similar set of structures
- Includes:
  - Supermassive black hole
  - Accretion disk
  - Obscuring clouds
  - Outflows/Jets



AGN Unification Model Urry & Padovani 1995

AGN – related phenomena

- Jet
  - Relativistic outflow
  - Typically show power-law synchrotron spectra
- Narrow Line Region
  - Line emission from accretion disk, not Doppler-broadened
- Broad Line Region
  - Doppler-broadened emission from accretion disk
- Lobes
  - Large, amorphous, diffuse low-energy radio gas hundreds to millions of parsecs from host galaxy



Sidenote - Eddington Luminosity

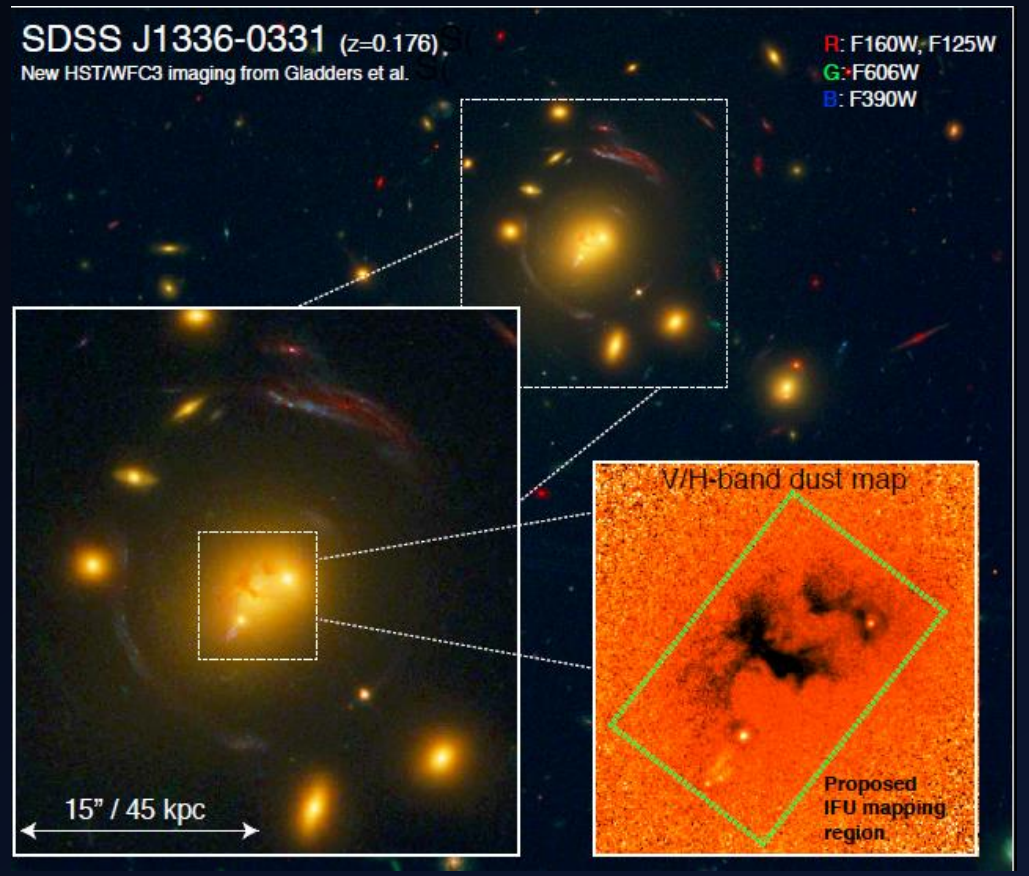
- The maximum luminosity of a stable, spherical, self-gravitating body
- Found by equating pressure due to gravity and radiation pressure
- AGN sometimes exceed this limit because of geometry and relativistic beaming

$$L_{Edd} = \frac{4\,\pi G c}{\bar{\kappa}}$$

Equation source: Carroll & Ostlie, 2nd ed., p. 341

Connection to my research

- IR spectroscopy to investigate the possibility of toroidal obscuration in the AGN of a sample of nearby Fanaroff & Riley class I (FR-I) radio galaxies. These are relatively low-power objects which are brightest in the radio. The radio excess is predominantly in the core.
- My next project will study the kinematics of the dust formations in the centre of SDSS J1336-0331, which has recently undergone a merger



The End

Sources

- Koposov, S.E., Yoo, J., Rix, H.-W., et al. 2009, ApJ, 696, 2179
- Urry, C.M., & Padovani, P. 1995, PASP, 107, 803
- Carroll, B.W., & Ostlie, D.A. 1996, Institute for Mathematics and Its Applications
- Sparke & Gallagher
- Binney & Merrifield