Galaxies Lec 5

AGN and SMBH

AGN

AGN was discovered when we looked at a galaxy noticed that the spectrum of the spiral galaxy but it had strong emission lines that was super broad.

We also found they were of great distances with high redshifts

Some properties:

- Non-stellar UV and optical continuum
- High luminosity
- Strong xray and gamma
- Broad lines
- Variable

There are many types of AGN

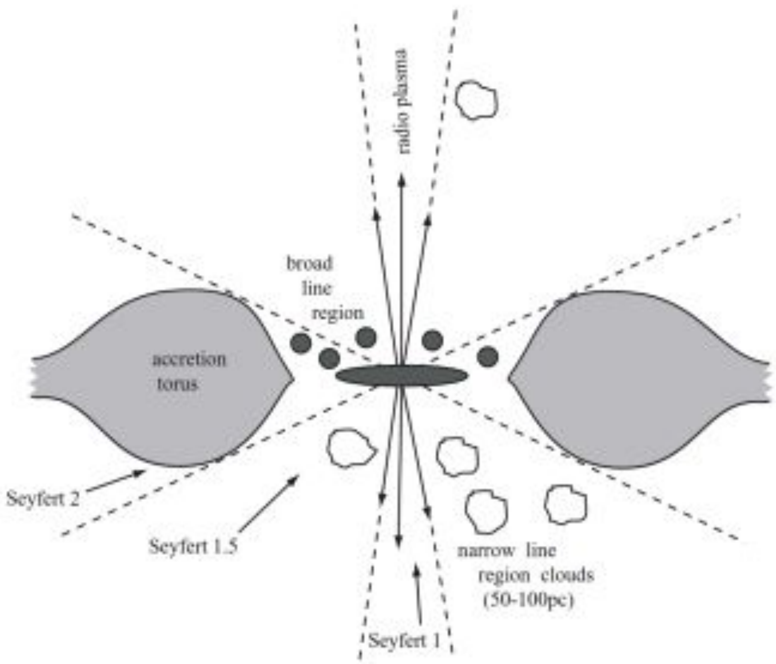
1. Seyfert galaxies are galaxies with spectra of nuclear region that show emission lines that require ionizing source that produces higher energy photons than massive stars.

2. Radio galaxies are extremely strong radio sources (Lr>2x108 L☉), powered by synchrotron emission from jets emanating from AGN. These tend to be associated with elliptical galaxies.

3. Quasars are extremely luminous AGNs, so luminous that they outshine their host galaxy in visible light, appearing as compact point-like source in optical images.

4. Blazers are radio-luminous objects with significant variability

Central Engines of AGN all described!



- **AGN unification** schemes have been presented to explain many of the differences in the properties in terms of inclination effects
- **Seyfert 1** galaxies (+quasars, radio galaxies) are those where the disk+BLR is visible, as expected with viewing angle shown at left.
- **Seyfert 2** galaxies are those for which the dusty torus obscures the view of the central engine + BLR. No broad lines seen!

DRIVEN BY SUPERMASSIVE BLACK HOLES

For Seyfert 1 (face on)

- **Permitted Lines (HI, HeI, HeII):** Show extremely **broad**
- **Forbidden Lines ([O III], [N II]):** Remain **narrow**.

For Seyfert 2 (edge/disk on):

- **Permitted** Lines: Are **narrow**.
- **Forbidden Lines ([O III], [N II]):** Remain **narrow**.

Forbidden lines probe the outside and thus look unaffected. Permitted lines probe the INSIDE HOT STUFF thus showing doppler broadening

Supermassive blackholes

Measure the blackholes sphere of influence.

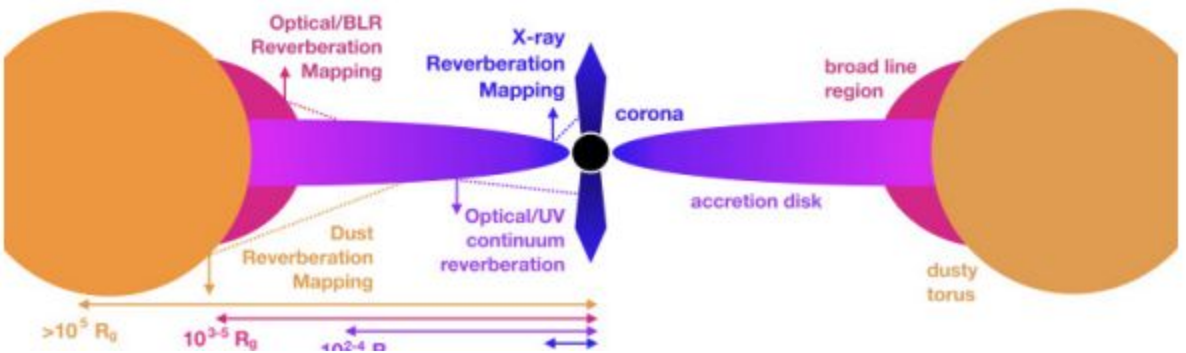
$$r = GM_{BH}/\sigma^2$$

We need to get mass!

Get the region of the broadline region by looking at time delays between the disk and the broadline luminosity uptick.

$$v^2 \sim \frac{GM_{BH}}{R_{BLR}} \longrightarrow M_{BH} = f\,\frac{R_{BLR}\,\Delta v^2}{G}$$

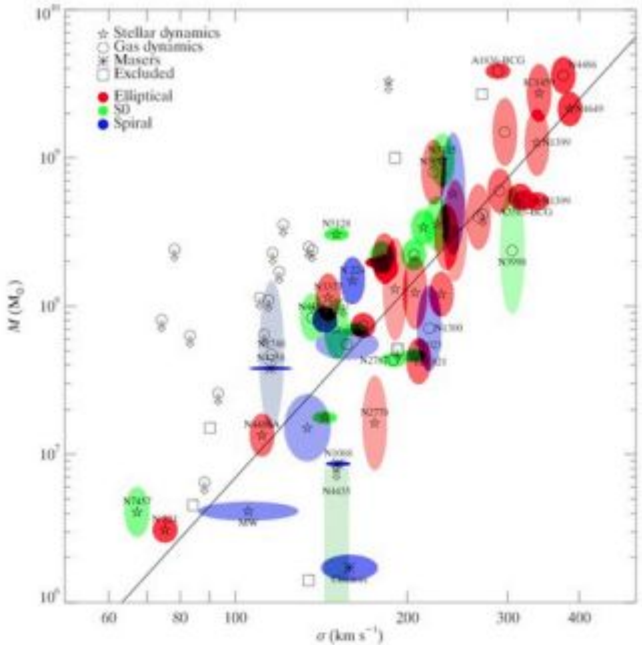
Then measure velocity dispersion to then get the mass



Mass and sigma relationship

$$\mathcal{M}_{\rm BH} \approx 2 \times 10^8 \mathcal{M}_\odot \times \left(\frac{\sigma_c}{200\,\mathrm{km\,s^{-1}}} \right)^{4.86} .$$

Relationship was found by JWST and similar Integral field spectra



•**fast** accretion: **quasar**-mode feedback

radiative feedback: mediated by photons

• **Slow** accretion: **radio**-mode feedback (dominated by mechanical feedback mode)
(maintains the hot gas around it preventing cold accretion)

mechanical (kinetic) feedback: mediated by outflows of particles

The AGN energy output in radiation goes as

$$E_\bullet = \langle \epsilon_{\rm rad} \rangle \mathcal{M}_\bullet c^2,$$

We compare this to the binding energy of the stars, which we estimate as

$$E_\star \approx \mathcal{M}_\star \, \sigma^2.$$

Taking the ratio of the two, we find

$$\frac{E_\bullet}{E_\star} \approx \frac{\langle \epsilon_{\rm rad} \rangle \mathcal{M}_\bullet c^2}{\mathcal{M}_\star \sigma^2}$$

$$\simeq 100 \left(\frac{\langle \epsilon_{\rm rad} \rangle}{0.1} \right) \left(\frac{\sigma}{300\,{\rm km\,s^{-1}}} \right)^{-2} \left(\frac{\mathcal{M}_\bullet / \mathcal{M}_\star}{0.001} \right)$$

Energy release of AGN can be much larger than that of host bulge!!

AGN's are super important for many things…

1. Feedback & Quenching (stopping Star Formation)

Heating the Halo: AGN jets and winds inject energy into the circumgalactic medium (CGM), preventing hot gas from cooling and falling onto the galaxy.
Blowout: Powerful outflows can physically eject cold molecular gas (the fuel for star formation) entirely out of the galactic potential well.
Maintaining "Red and Dead": Without AGN heating (radio mode feedback), massive elliptical galaxies would form cooling flows and reignite star formation, contradicting observations.

2. Structural Co-evolution

M-sigma Relation: The tight correlation between the mass of the central supermassive black hole (SMBH) and the velocity dispersion of the host bulge suggests they regulate each other's growth.

Bulge Formation: AGN feedback likely limits the maximum mass a galaxy's bulge can attain by shutting down supply lines during major mergers.
Size Growth: "Puffing up" of galaxies—rapid mass loss from AGN winds can cause the stellar distribution to expand adiabatically.

3. Cosmological Impact

Reionization: High-redshift quasars ($z > 6$) contributed to the reionization of the intergalactic medium (IGM), ending the cosmic "Dark Ages."
Metal Enrichment: AGN outflows transport heavy metals produced in the distinct nuclear region out into the IGM, enriching the intergalactic gas.
The "Downsizing" Phenomenon: AGN activity explains why the most massive galaxies formed their stars early and quickly (high redshift) while smaller galaxies continued forming stars until today.