Host Galaxies of AGN at Low Redshift

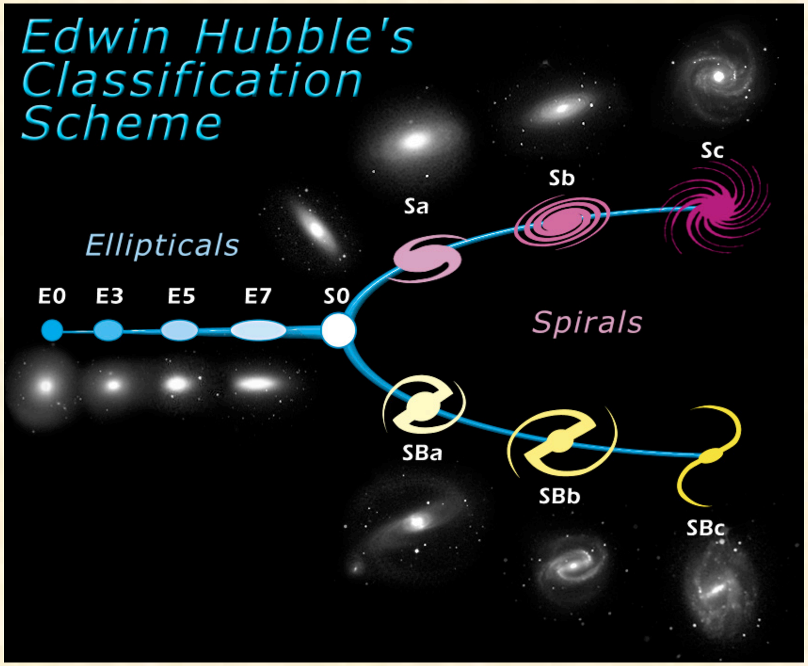
- Morphologies and companions
- Star Formation
- Bars in host galaxies

(Koss et al. 2011)

Lectures available at:
http://www.chara.gsu.edu/~crenshaw/beijing_agn.html

Morphologies

"early"

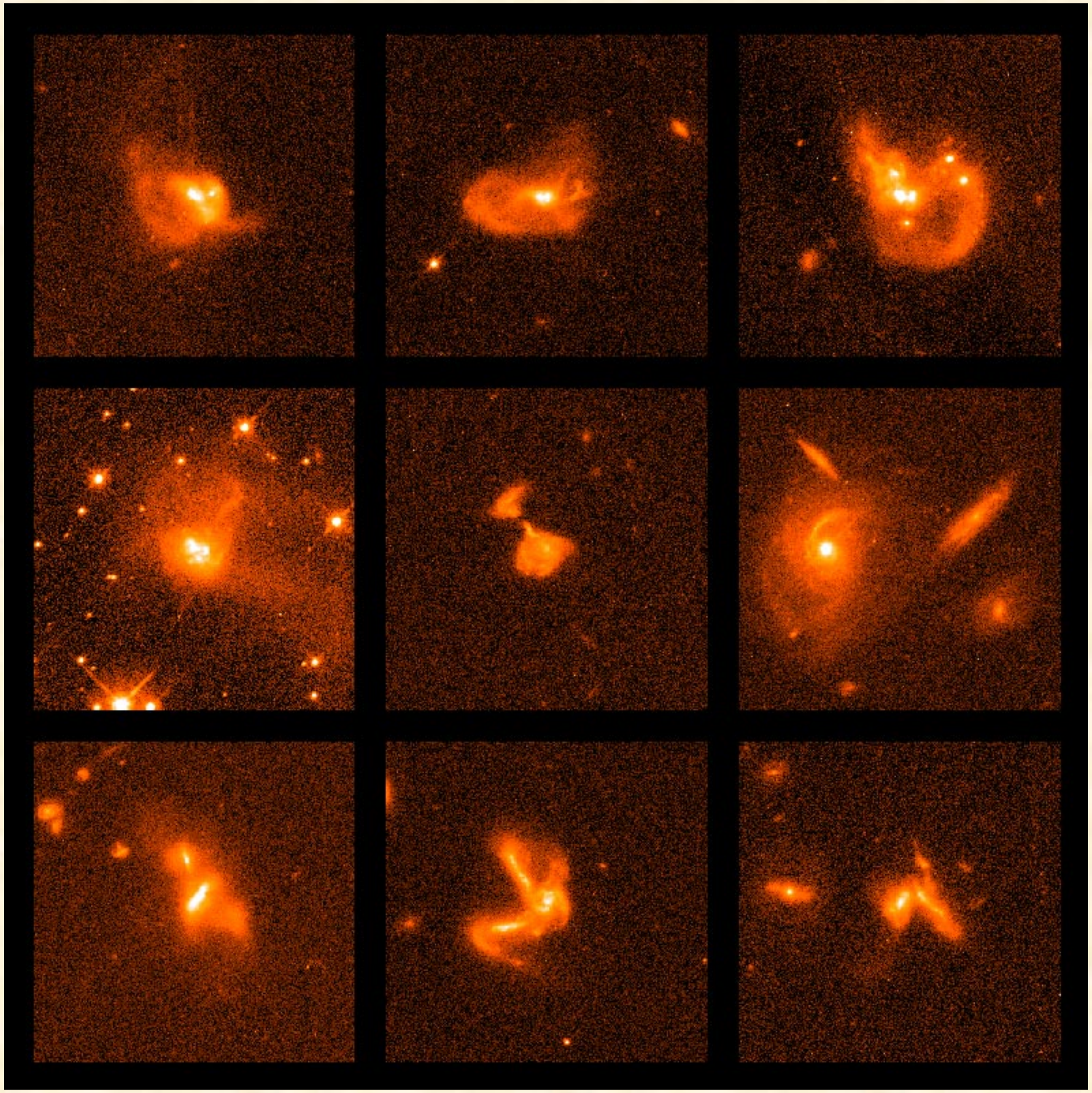


"late"

Irregulars

- Seyfert galaxies are found primarily in early type (large bulge) spirals.
  - Consistent with larger black hole masses and higher possible luminosities
- LINERs are found in all types of spirals and even some ellipticals
- "Dwarf" Seyferts (e.g., NGC 4395 with $M \approx 10^5 M_{\odot}$) found in late type spirals and even dwarf galaxies.
- **In general, AGN host galaxies and inactive galaxies have similar, if not identical, morphologies at low z (< 0.1).**

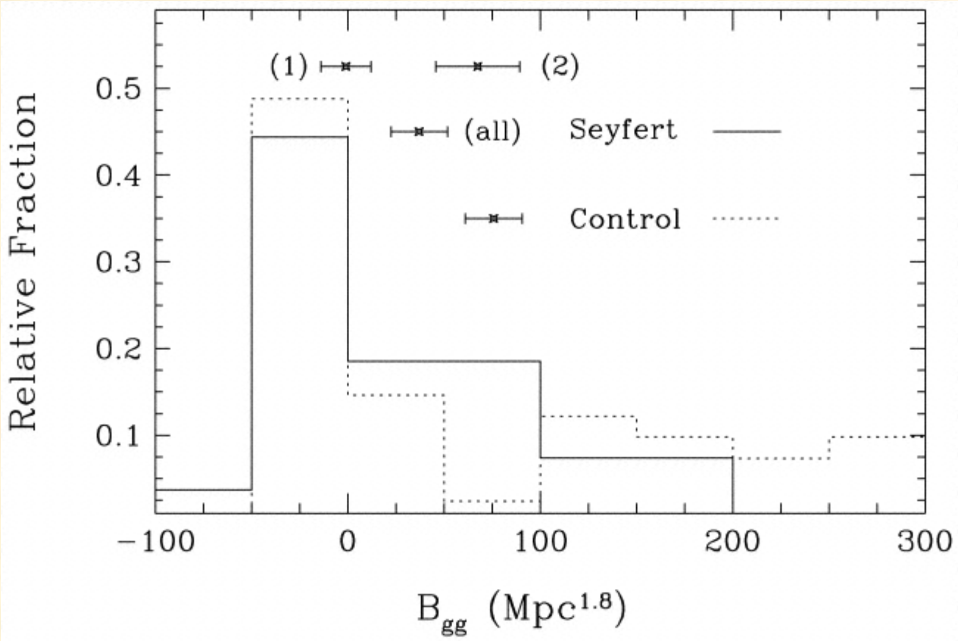
Companions and Mergers



ULIRGS

Companions and Mergers

- Most ULRIGs are found in merging systems, often **major mergers** (two large galaxies).
- Quasars and radio galaxies also prefer companions compared to inactive galaxies.
- Results on Seyfert galaxies have been contradictory.



(De Robertis et al. 1998, ApJ, 496, 93)

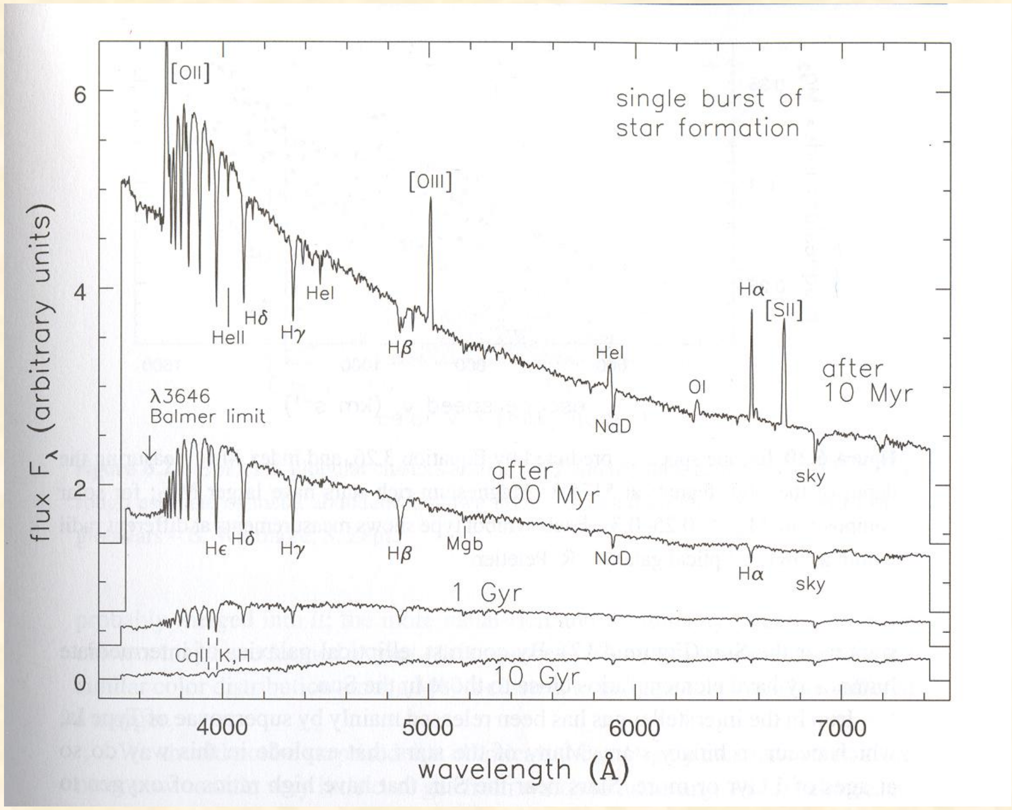
Covariance amplitudes for companion galaxies are similar for Seyferts and inactive galaxies.

Local AGN activity likely arises from minor mergers (i.e., large galaxies absorbing smaller ones like their own satellites).

Star Formation

- Is there a correlation between AGN activity and star formation?
- One might expect a correlation because both can be fueled by the same event (e.g., mergers, bars).

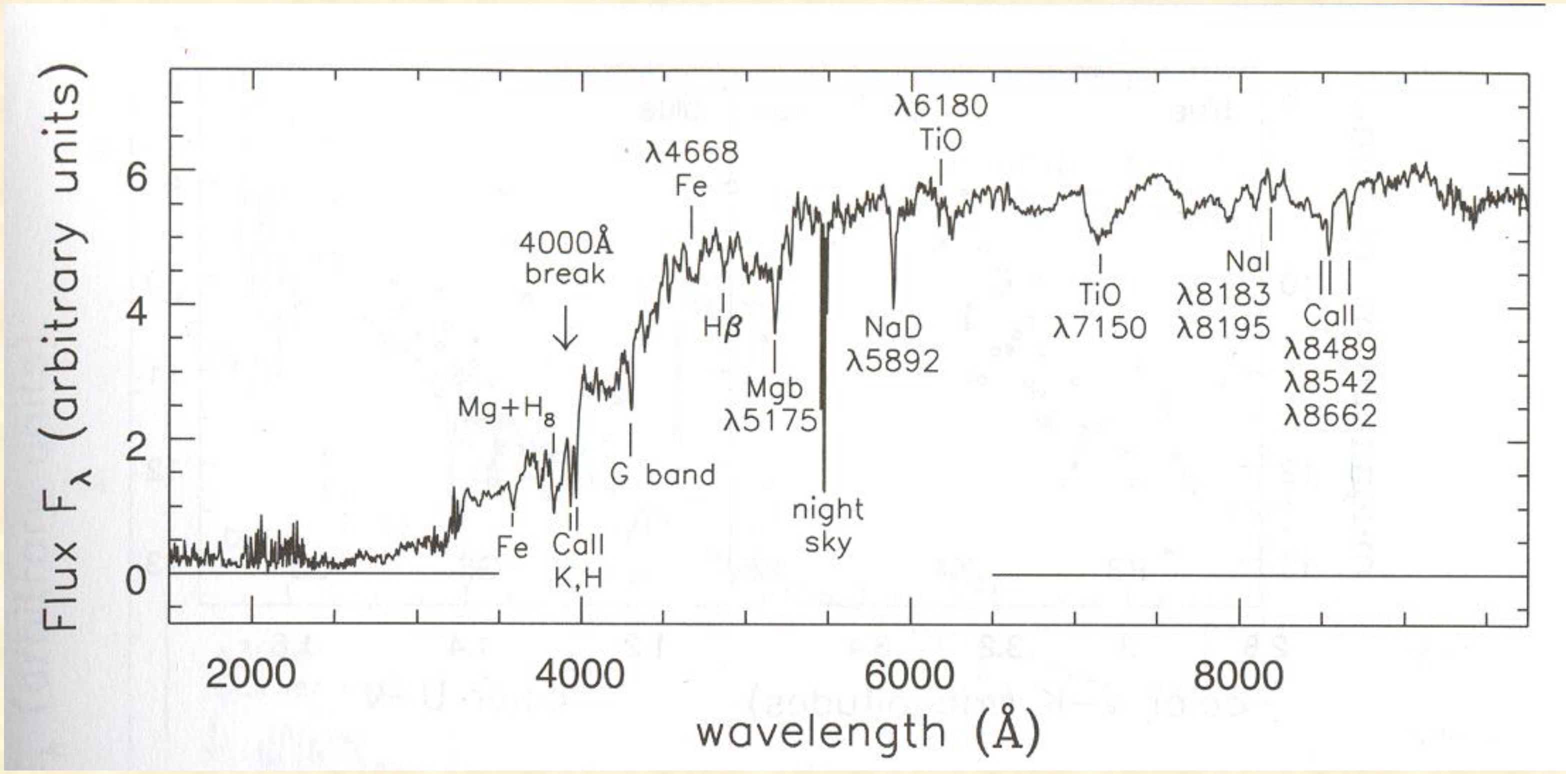
Stellar Populations



(Sparke & Gallagher, p. 268)

- Young populations (< 1 Gyr) revealed by strong UV continuum flux, Balmer absorption lines, Hα emission, [OII] emission
- Star formation also indicated by mid-IR PAH features, far-IR emission
- The star formation rate (SFR) scales with these strengths of these features

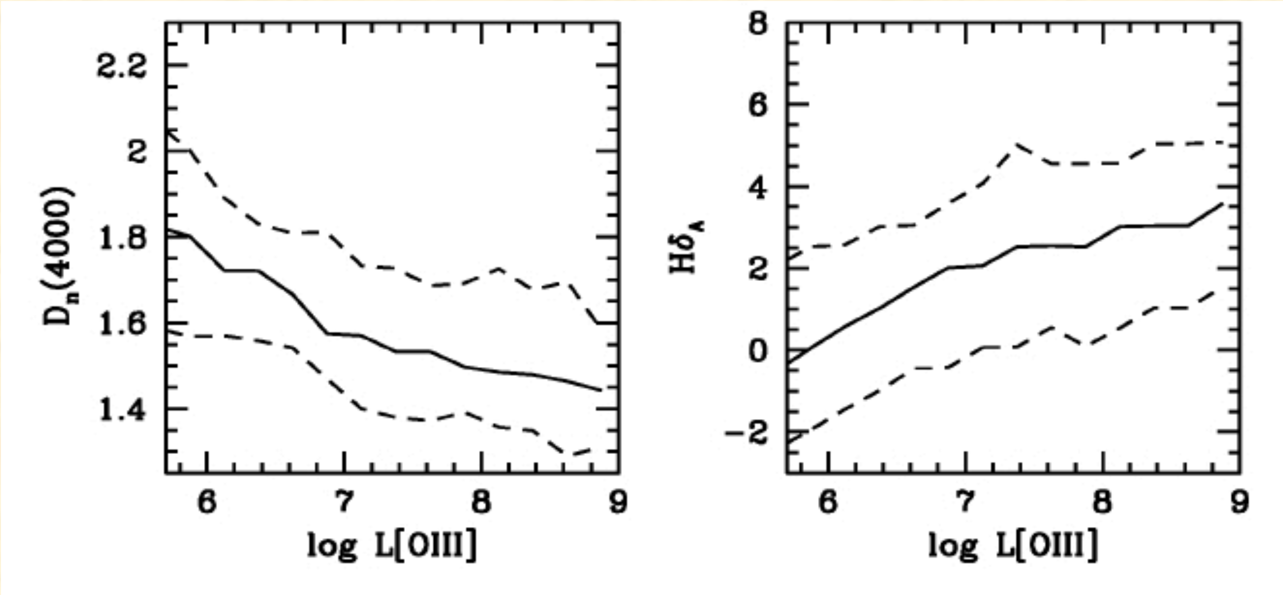
Older Populations



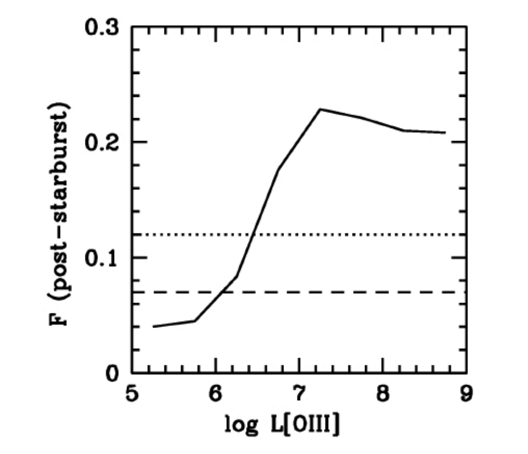
(Sparke and Gallagher, p. 267)

- Strength of 4000 Å break given by parameter D4000 (Kauffmann et al. 2003)
- For stars < 1 Gyr in age, the opacity from metal lines at 4000 Å is low, due to ionization, and thus D4000 is low.

Results from SDSS

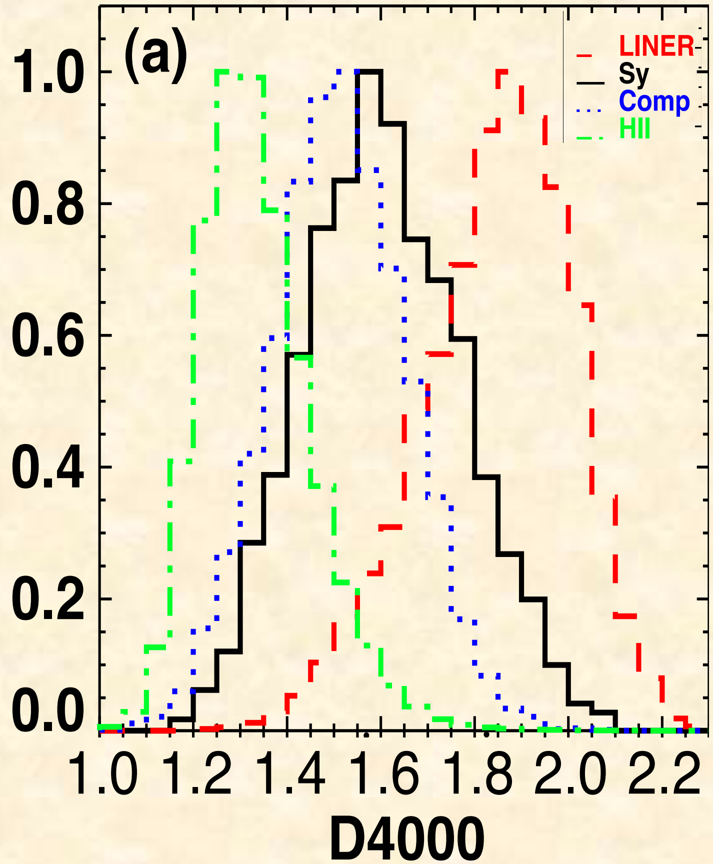


Kauffmann et al 2003, MNRAS, 346, 1055



- SFR correlated with L[O III] (AGN luminosity)
- Fraction of hosts with stellar populations < 1 Gyr increases with AGN luminosity (see also Veilleux 2008, astro-ph)

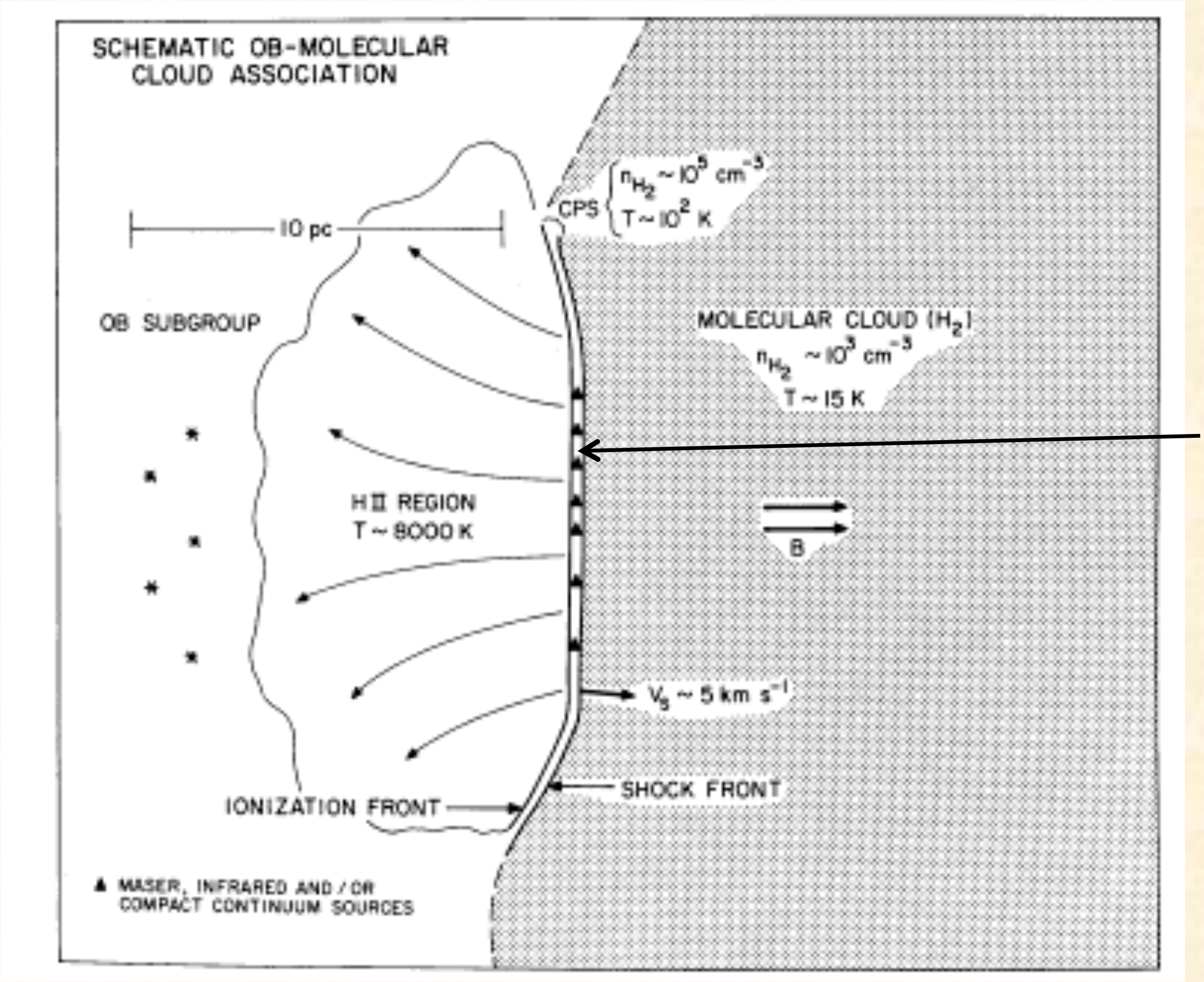
SDSS Results: Seyferts vs. LINERs



(Kewley et al. 2006, MNRAS, 372, 961)

- LINERs have larger D4000, and thus older populations.
- LINERs are also more massive and less dusty and than Seyferts

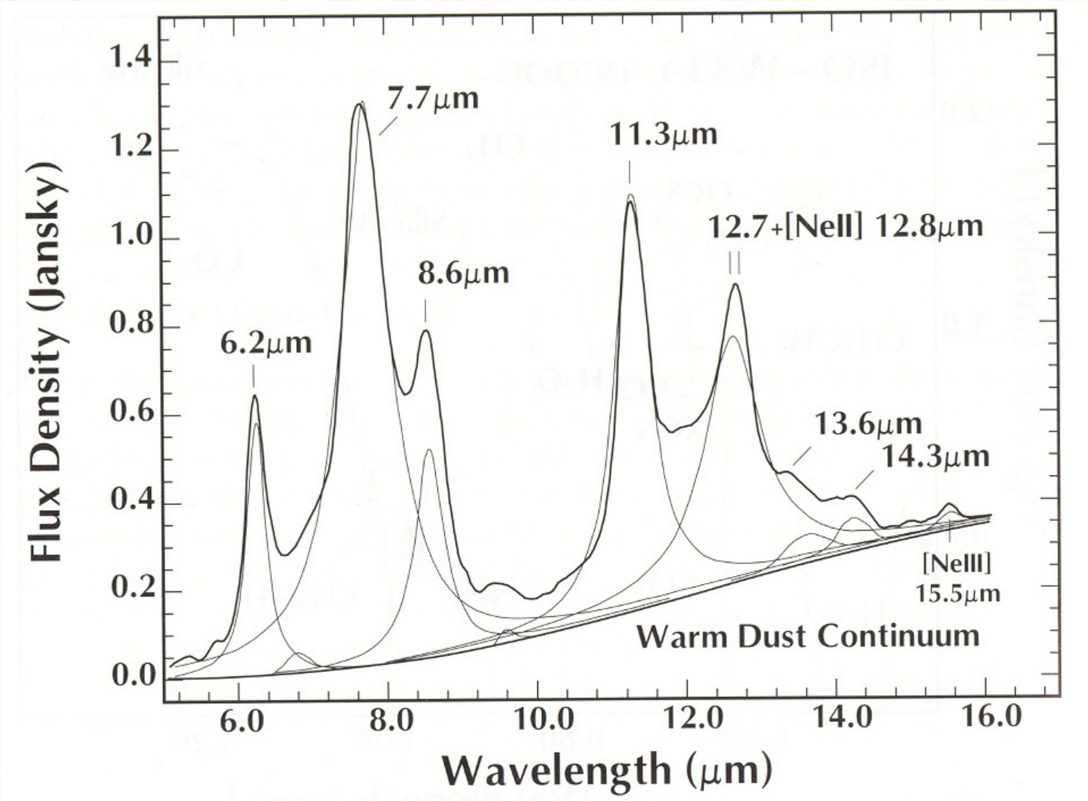
Star Formation – The "Blister" Model



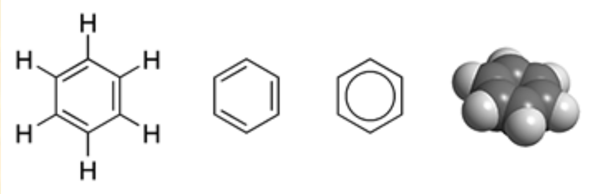
photodissociation region (PDR)

(Elmegreen and Lada, 1977, ApJ, 214, 725)

Mid-IR: PAH Emission Features

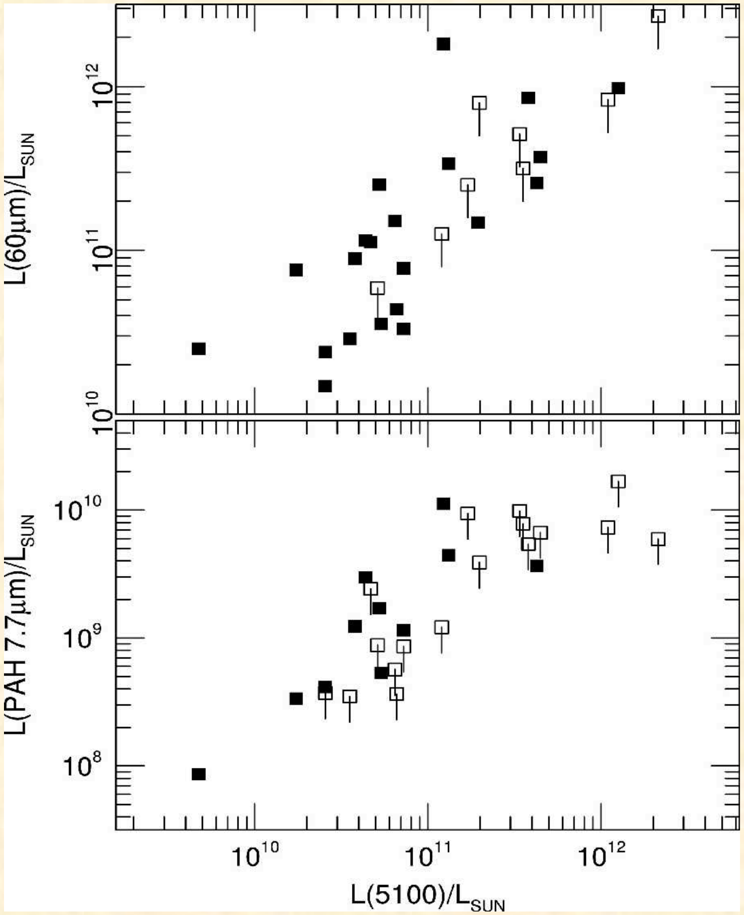


ISO spectrum of starburst region in M82



- Polycyclic Aromatic Hydrocarbons (PAHs): linked benzene (C_6H_6) rings: naphthalene ($C_{10}H_8$) … ovalene ($C_{32}H_{14}$) …
- Seen in emission in photodissociation regions (PDRs)

Spitzer Observations: Star Formation



(Netzer et al. 2007, ApJ, 666, 806)

- Far-IR continuum and PAH features measure SFR.
- Optical continuum radiation primarily from AGN.
- Strong correlation between SF and AGN activity

Stellar Bars

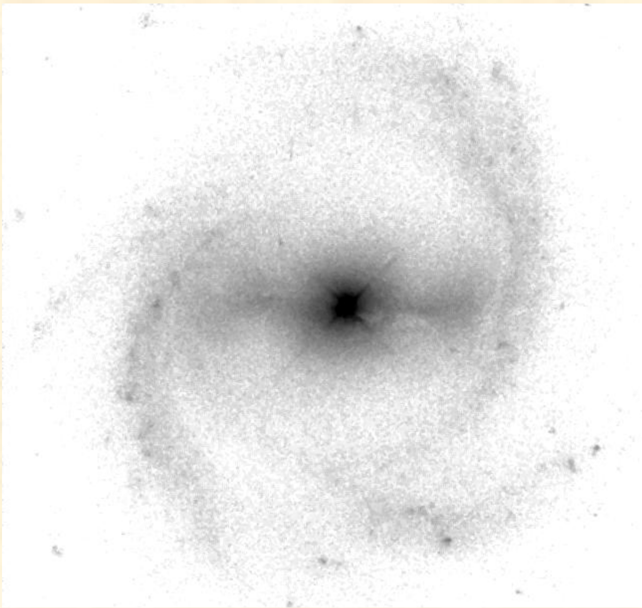
- Large-scale stellar bars can funnel gas (and dust) into the nucleus..

Stellar Bars – A Case Study

- Bars should provide an efficient means to fuel the nuclei of active galaxies (Shlosman et al. 1990, Nature, 345, 679).
- Most studies find a similar fraction of bars in Seyferts and normal spiral galaxies (e.g., Hunt & Malkan, 1999, ApJ, 516, 660).
- What happens if we look at subtypes? – BLS1s and NLS1s
- Most NLS1s are accreting near their Eddington limits (Pounds et al., 1995, MNRAS, 277, L5).
- Is there a connection between NLS1s and properties of their host galaxies (i.e., to support the high accretion rates)?
- Krongold et al. (2001, AJ, 121, 702) found no difference in the frequency of companion galaxies in NLS1s and BLS1s.
- What about bars inNLS1 and BLS1 host galaxies ?

Sample

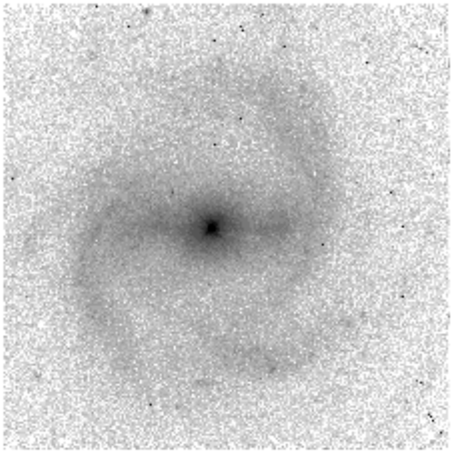
- HST/WFPC2 optical images from the STScI archives
  - 91 Seyfert 1 galaxies (13 NLS1s) at $z < 0.035$ (Malkan et al. 1998, ApJS, 117, 25)
  - 6 NLS1s at $z < 0.085$ (Veron-Cetty et al. (2001, A&A, 372, 730)
- Measurements of FWHM (Hβ) emission from the literature



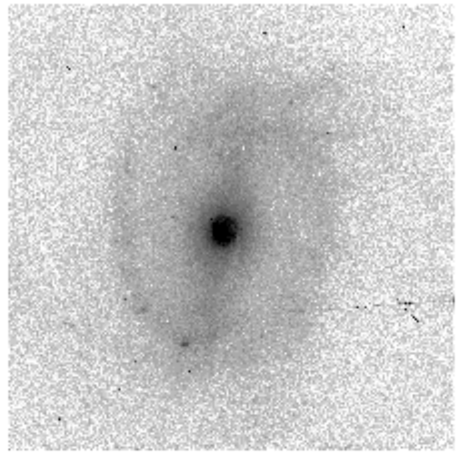
(Crenshaw et al. 2003, AJ, 126, 1690)

MCG 6-26-12 (NLS1)
HST/WFPC2
F606W filter
PC chip - 34" x 34"

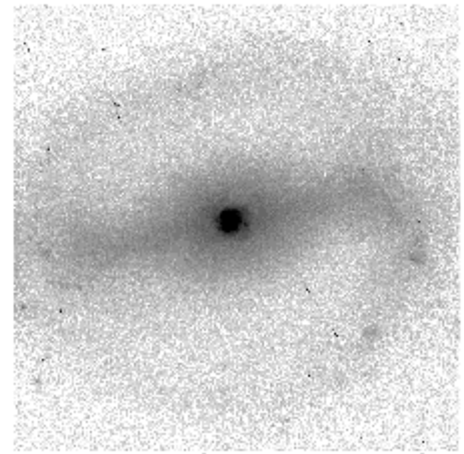
NLS1 Images



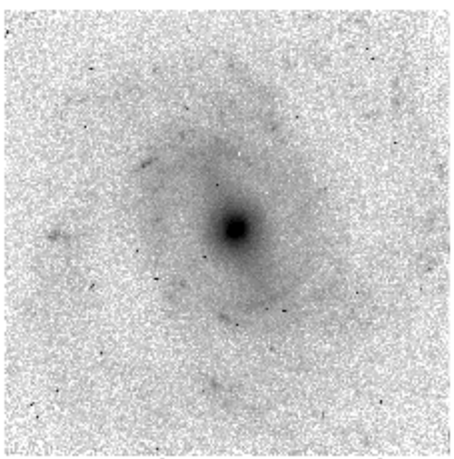
MCG 6−26−12 (22.7 x 22.7 pc)



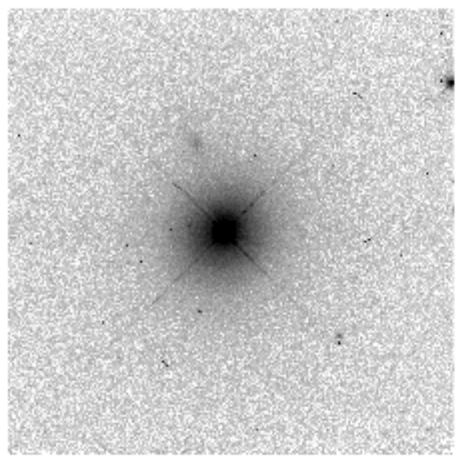
Mrk 42 (17.0 x 17.0 kpc)



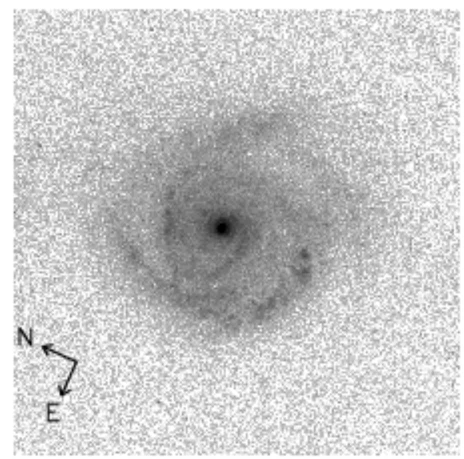
Mrk 493 (22.0 x 22.0 kpc)



Mrk 382 (24.1 x 24.1 kpc)



Mrk 335 (17.8 x 17.8 kpc)



MS 01442−0055 (28.3 x 28.3 kpc)

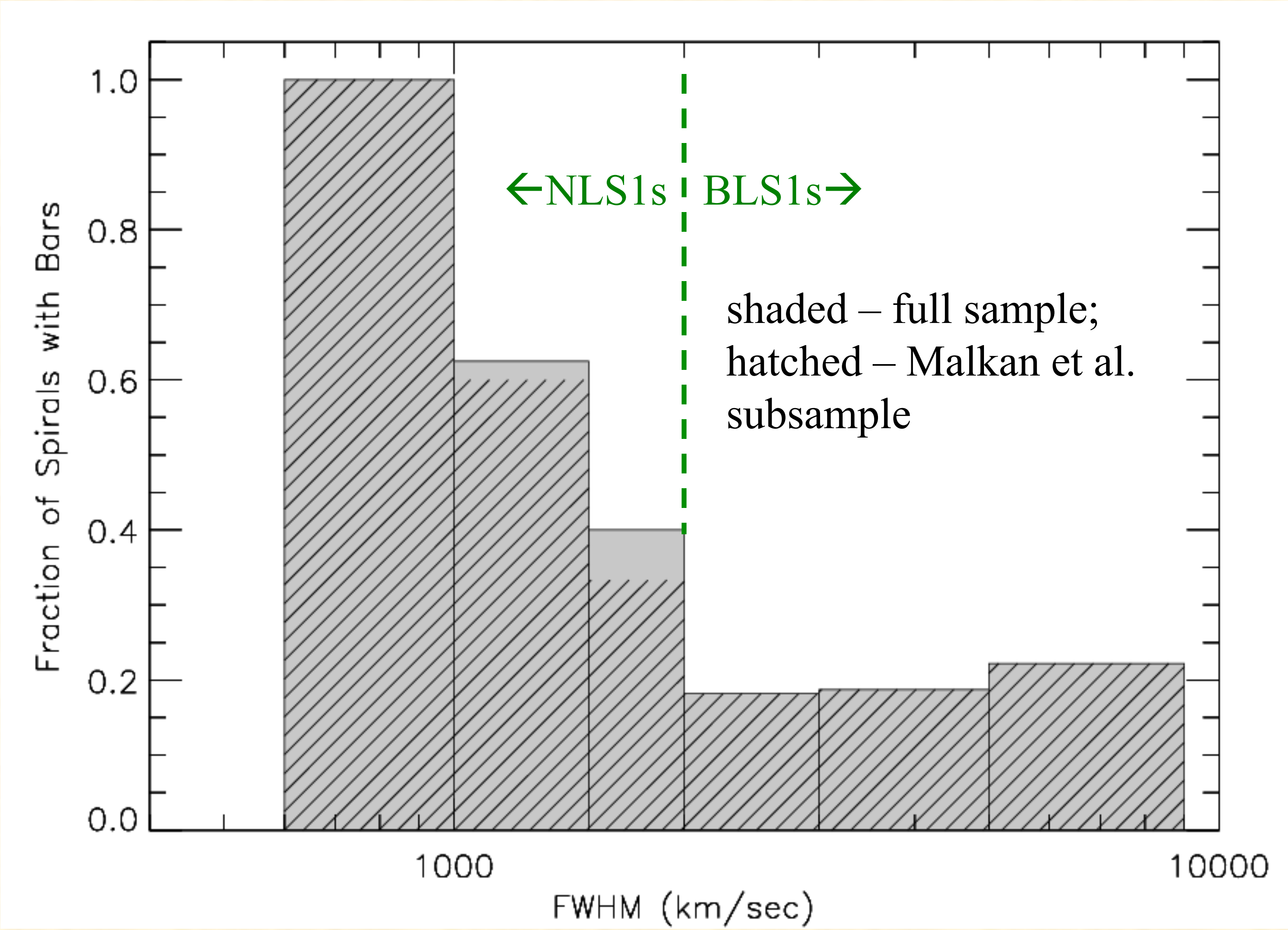
Results

- 91% of the Seyfert 1s are spirals
- 33% of the Seyfert 1 spirals have bars (similar to normal spiral galaxies)

  - The bars begin at ~1 kpc from the nucleus and extend to 5 – 10 kpc.

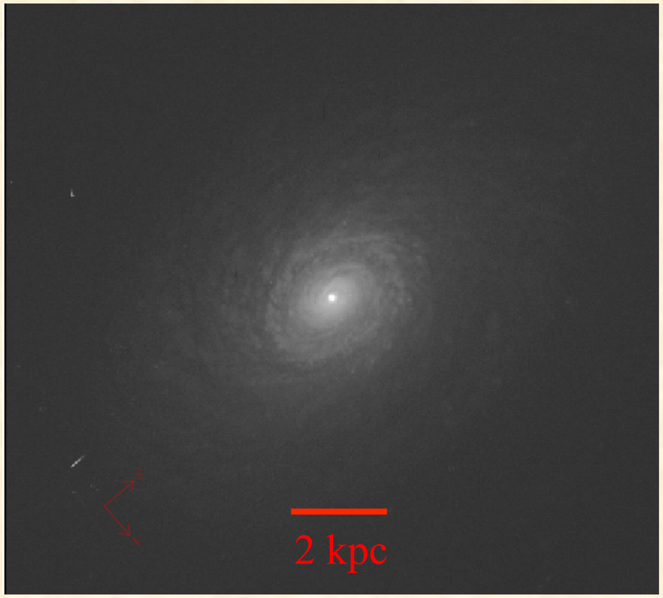
- 65% of the NLS1 spirals have bars
- 25% of the BLS1 spirals have bars
- The fraction of Seyfert 1 spirals with bars decreases with increasing FWHM (Hβ)

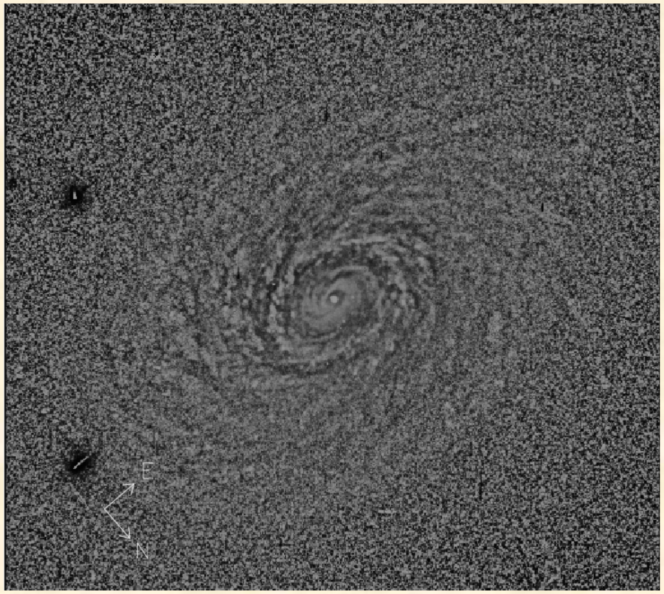
Seyfert 1s - Fraction with Bars vs. FWHM (Hβ)



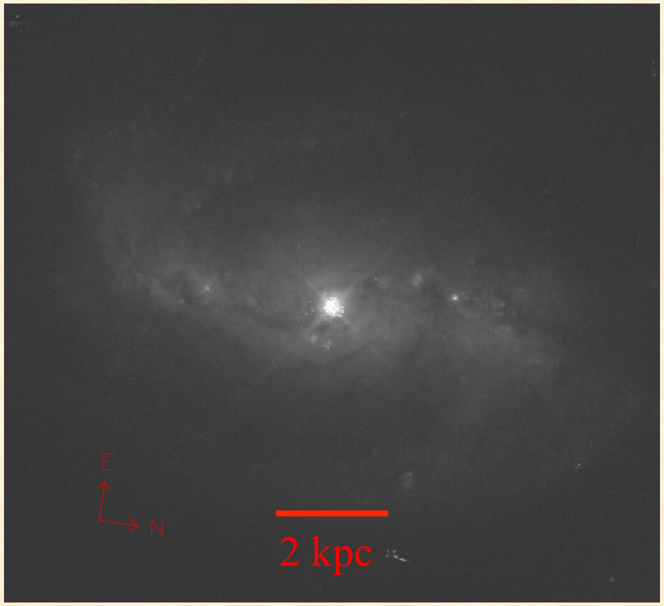
(Crenshaw et al. 2003, AJ, 126, 1690)

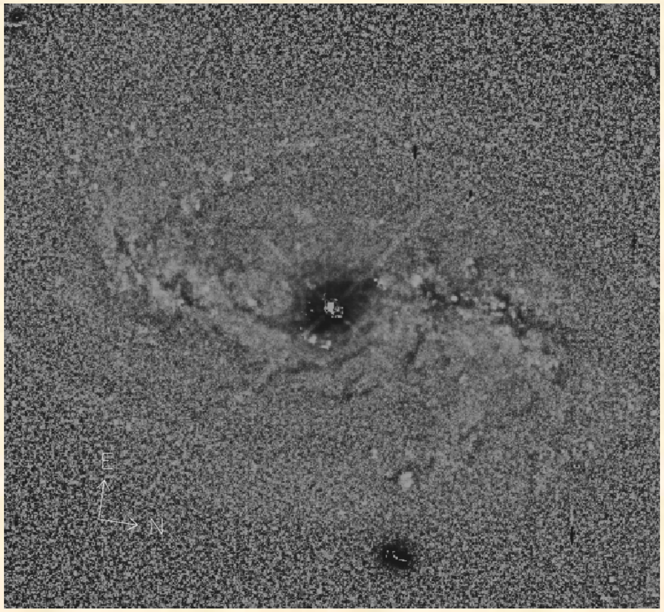
Dust Morphologies in the Nuclear Regions of Seyfert 1s
Direct Images and Structure Maps (Pogge & Martini 2002, ApJ, 569, 624)





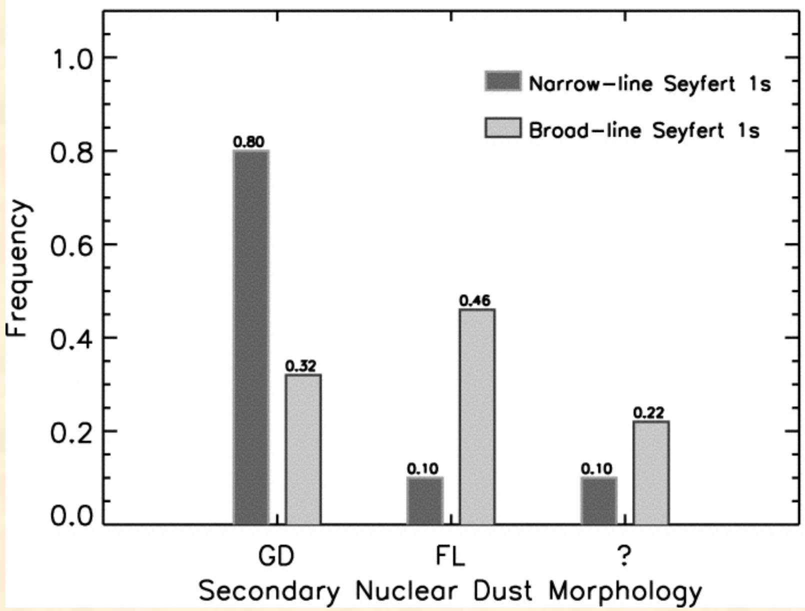
NGC 6212
- Flocculent dust spiral

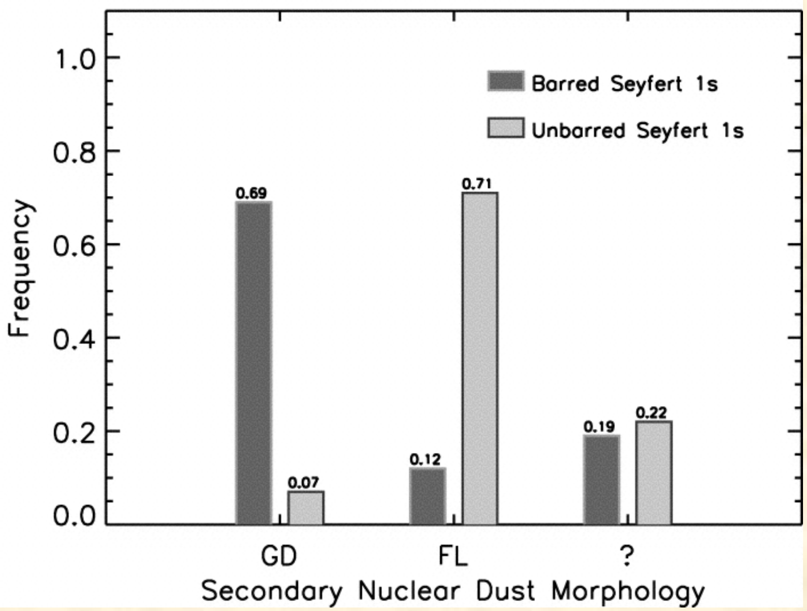




ESO 438-G9
- Grand design dust spiral

Nuclear Dust Spirals





(Deo et al. 2006, 132, 321)

- NLS1s show higher fraction of grand design nuclear dust spirals
- NLS1s show higher fraction of nuclear star forming rings
- Consistent with more efficient fueling of their nuclei compared to BLS1s to support their claimed higher Eddington ratios.

Speculation – Evolutionary Scenario

- NLS1s show evidence of recent bursts of star formation (Mathur, 2000, MNRAS, 314, L17), from high N V/ C IV ratios (Wills et al., 1999, ApJ, 515, L53) and high mid-IR brightness (Moran et al. 1996, ApJ, 106, 341).
- NLS1s appear to have smaller SMBH mass to bulge mass ratios (Wandel, 2002, ApJ, 565, 762).
- Outer rings are much more common in BLS1s (~ 40%) than normal galaxies (~ 10%) (Hunt & Malkan, 1999, ApJ, 516, 660).

1. Start with a small SBMH in an inactive galaxy.
2. A stellar bar forms in a few x 10^8 years due to a tidal disruption or asymmetrical distribution of gas in the inner disk (Combes & Elmegreen, 1993, A&A, 271, 391).
3. The bar drives gas into the nucleus, initiating star bursts and the NLS1 phase over ~10^8 years .
4. Once ~5% of the disk's mass has been redistributed into the nucleus, the bar is destroyed (Norman et al., 1996, ApJ, 462, 114) .
5. The mass of the SMBH has increased by several to 10 times, but the fueling flow has been reduced, so that the AGN is now a BLS1. The outer rings take several x 10^9 years to form, and are the remnants of the earlier disturbance.