Space Astronomy: The UV window to the Universe
Dedicated to Dr. Willem Wamsteker
El Escorial 2007

The Starbursts-AGN connection: The role of stellar clusters in AGNs

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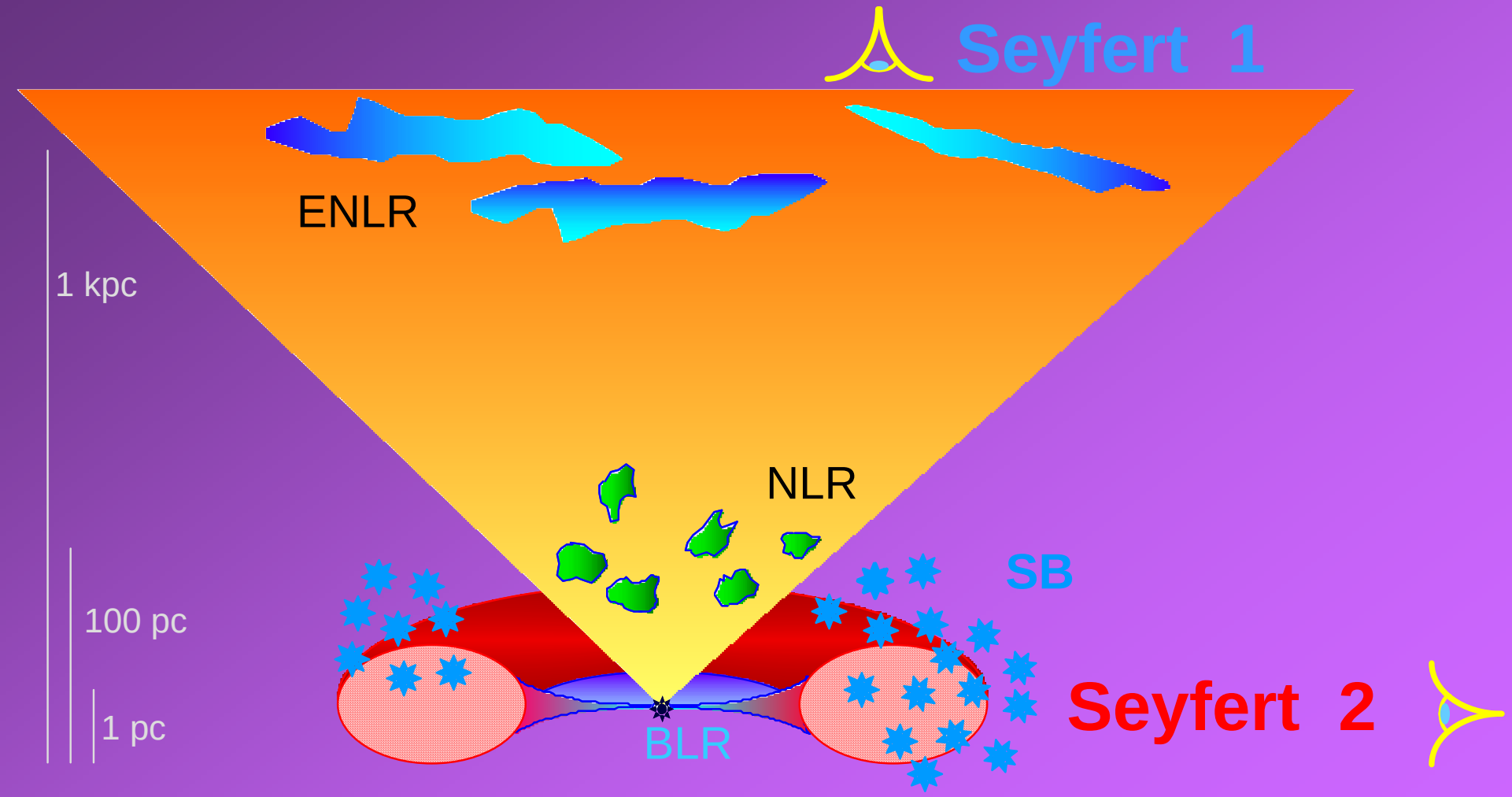
- Seyferts: HST+ACS (F330W)
- LLAGNs: HST+ WFPC2 (Optical) + ACS (F330W)
- LLAGNs: NGC 4303 (HST+STIS)

Unified Model



Unified Model

- **Ionization Cones** (Tadhunter & Tsvetanov 1989)
- **Deficit of ionizing photons**
- $N_H > 10^{24}$ cm^{-2} (Risaliti et al 1999)
- **Broad components (H, He, FeII) in polarized light** (Antonucci 1993)

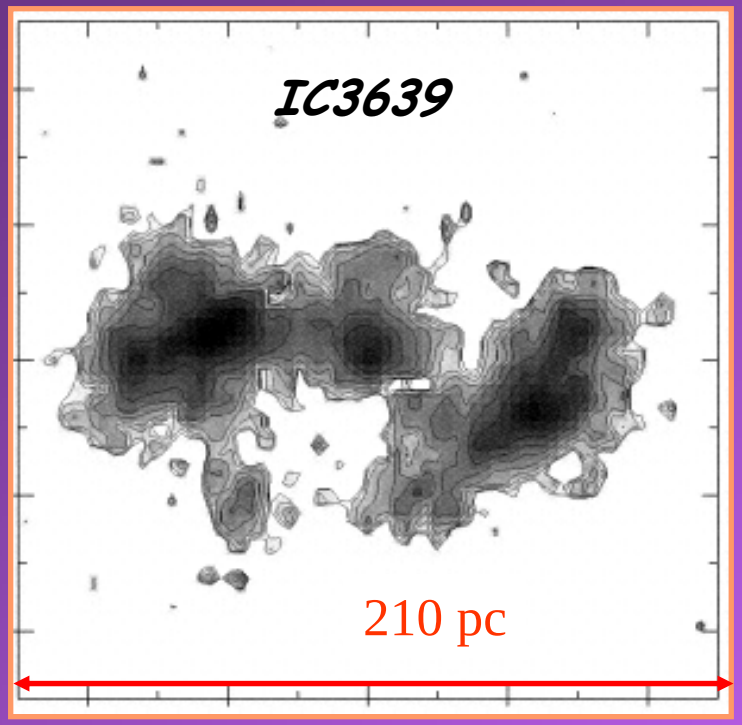
- **Sy2 continuum =**

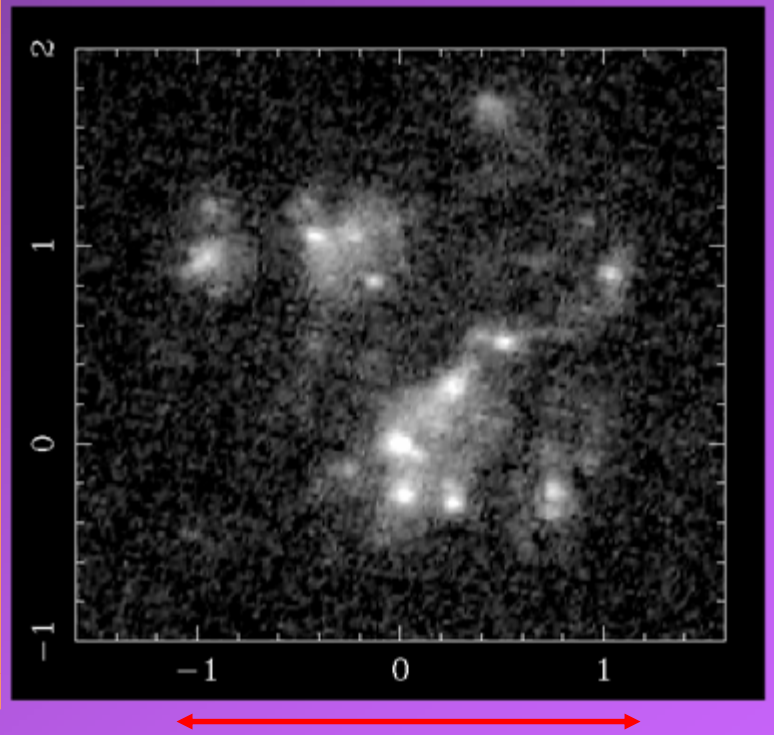
  old population (red continuum) + scattered light (blue continuum) from Sy1 hidden nucleus
- **The continuum is less polarized than the recombination lines** (Tran 1995)
- **Additional Component (FC2) = Thermal emission from warm gas heated by the Sy1** (Tran 1995)
- FC2 = **Starburst** (Cid Fernandes & Terlevich 1995, Heckman et al 1995)

Circinus Galaxy (Wilson et al 2001)

Previous work:
Nuclear Starburst in Seyfert 2

HST+FOC





1arcsec=550 pc

NGC 5135

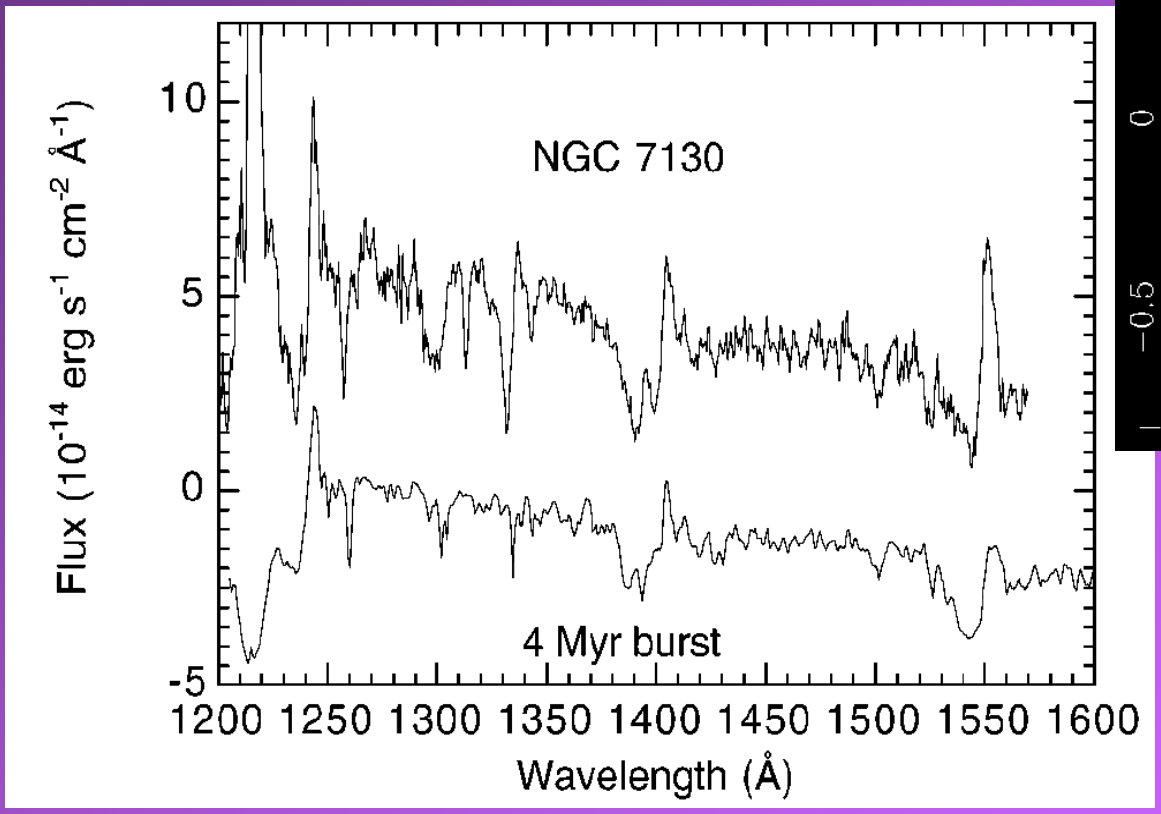
González Delgado et al (1998)

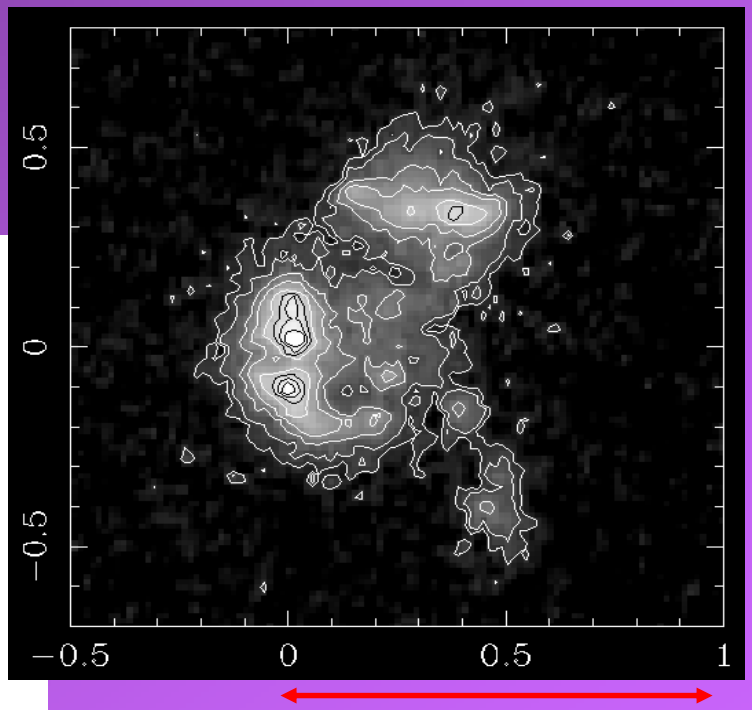
Heckman et al (1997)

- *Nuclear Starburst of size a few 100 pc (similar size to NLR)*
- *Compact sources: similar to SSC detected in Starbursts*

Nuclear Starburst in AGNs: UV morphology in Seyfert 2 galaxies

- *Starburst dominates the UV light*
- *Ages: 3-5 Myr*
- *$10^{10} < L_{Bol} < 10^{11}$ $L_{\odot}$: Similar to the estimated AGN luminosity*





1arcsec=310 pc

González Delgado et al (1998)

Heckman et al (1997)

LLAGNs: Open Questions

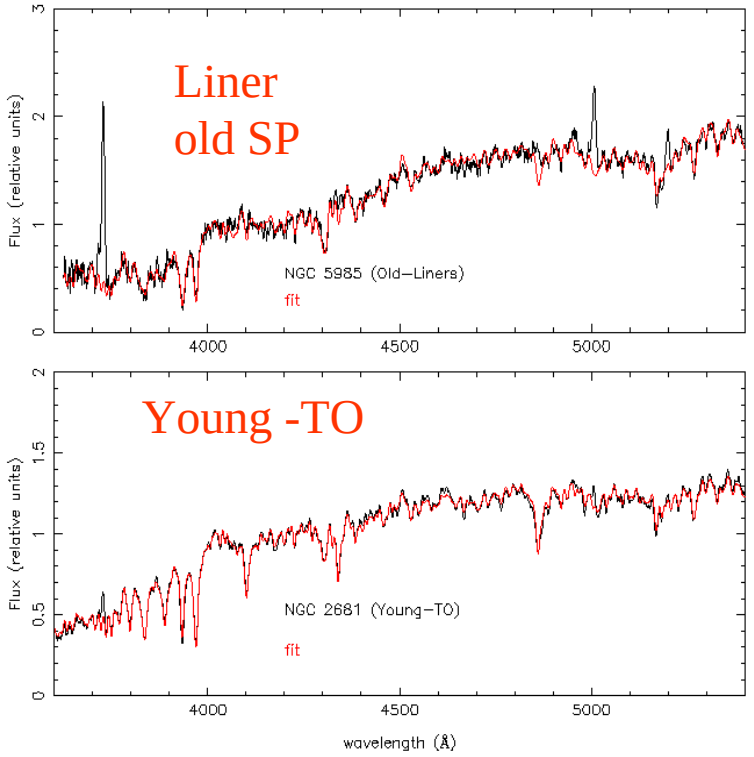
They are located in about 30% of the nearby and luminous galaxies (B_T< 12.5)
(Ho, Filippenko & Sargent 1995)

- Liners/HII (Transitions Objects=TO) (weak Liners): weak [OI]/Hα (< 0.25)
- Classical Liners : strong [OI] 6300/Hα (>0.25)

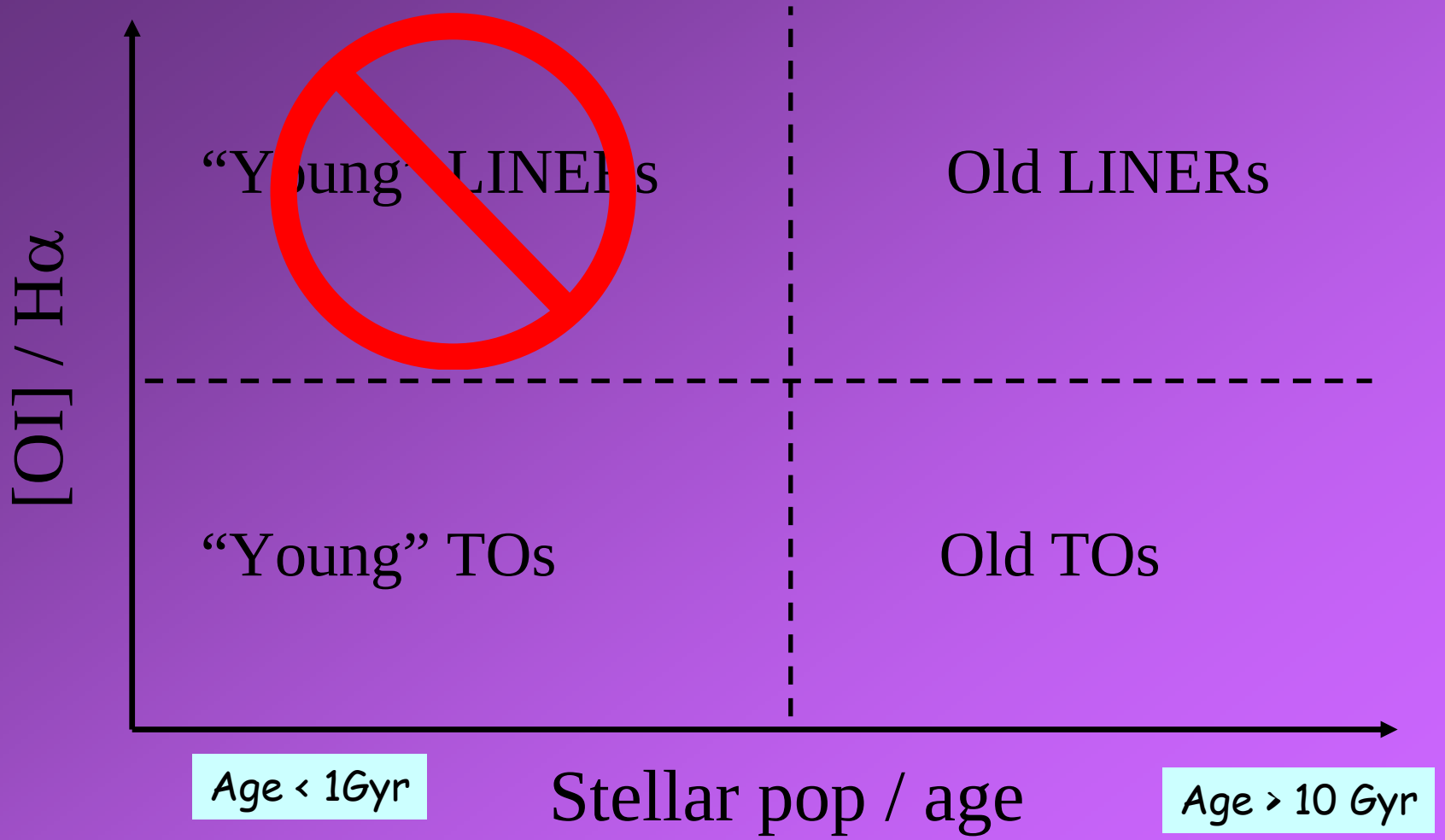
- Do LINERs & Transition Objects also have nuclear starbursts?
- Are they similar to those in Seyfert 2s?
- Is there a link between stellar population & ionization?

Stellar population Synthesis: ages

- High Order Balmer Absorption Lines are very common (~ 50% of TOs)
- No WR bump
- Intermediate age populations (10^8 – 10^9 yr) are very common (~ 50% of TOs)
- Very young starbursts (≤ 10^7 yr), if present, are very weak at optical wavelengths



Summary of the Optical nuclear spectra



Stellar clusters in galaxies

- Nuclear stellar clusters are a common phenomenon in spirals (Carollo et al 2002; Boeker et al 2002)
- HST survey in Virgo have detected compact nuclear source in a comparable fraction of ellipticals (Ferrarese et al 2006; Cote et al 2006)
- Their masses scale directly with the galaxy mass, in the same way as the BH masses do in high luminosity galaxies (Ferrarese et al 2006; Ferrarese & Merrit 2000)

A link between massive BH and bulge formation in galaxies:

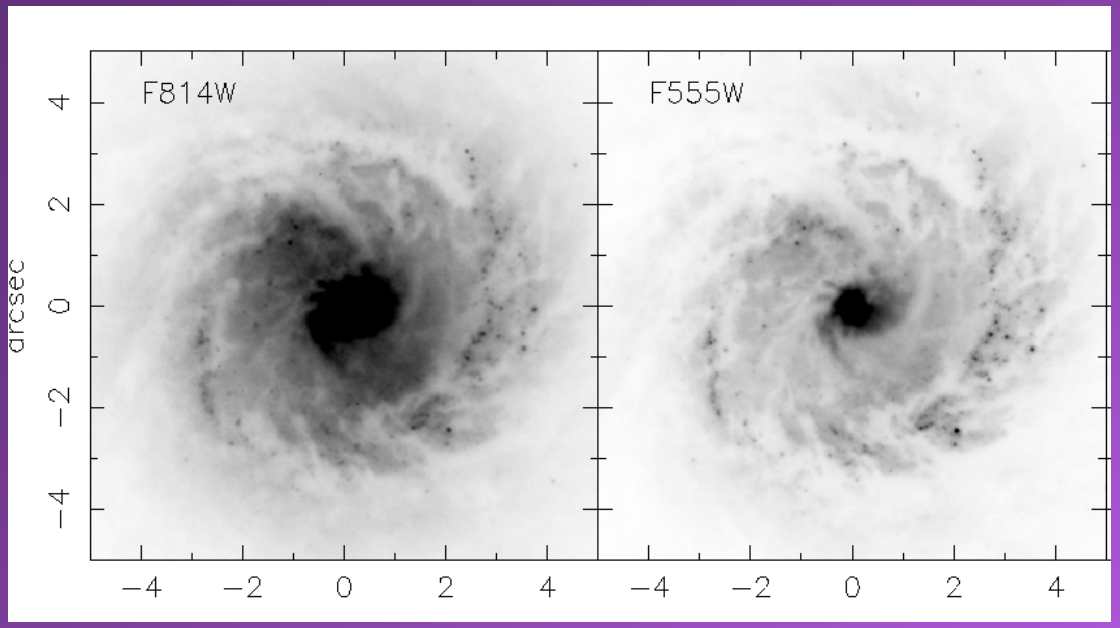
Starburst-AGN connection

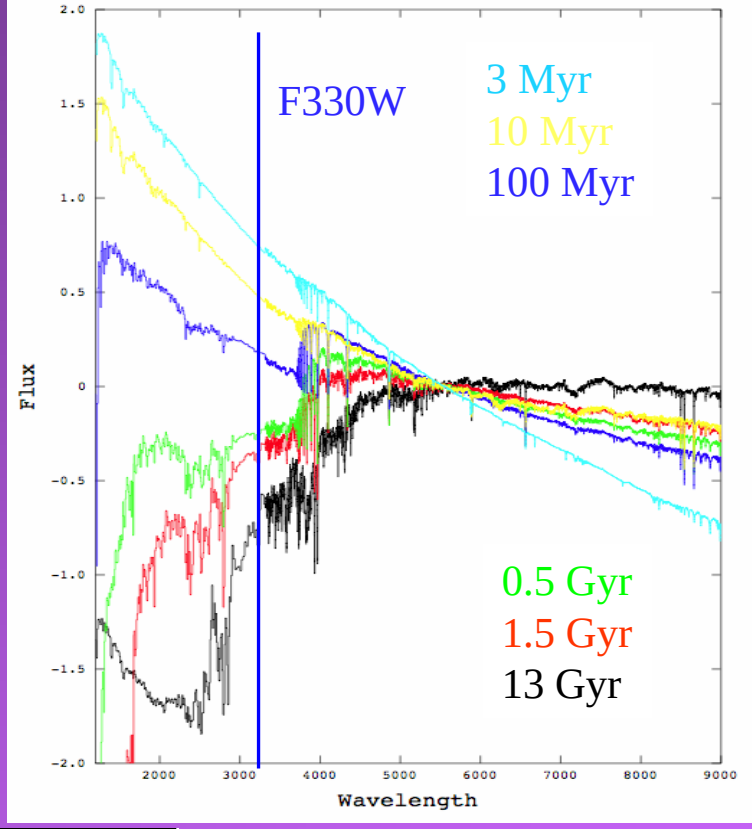
Open Questions

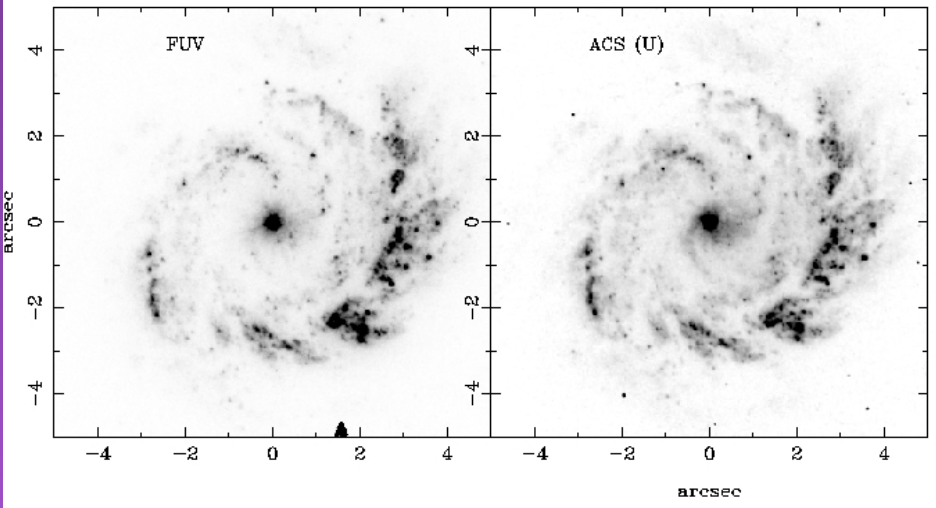
- Investigate nuclear unresolved sources that can be attributed to an AGN
- Determine the frequency of nuclear and circumnuclear stellar clusters
- Characterize their size, luminosity, mass and age
- Determine if nuclear (and circumnuclear) clusters are more common in Seyfert 1 and in Seyfert 2, and Liners and Transitions Objects (TOs)
- Investigate whether there could be an evolution from Seyferts to TOs and Liners

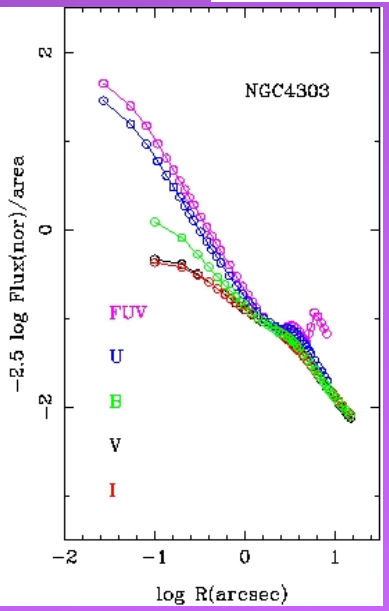
Stellar clusters have size of a few pc: HST is needed

FUV vs. NUV vs. Optical wavelengths









Observational Program

- *HST + ACS:*

0.027 arcsec/pixel
cluster sizes (few pcs)

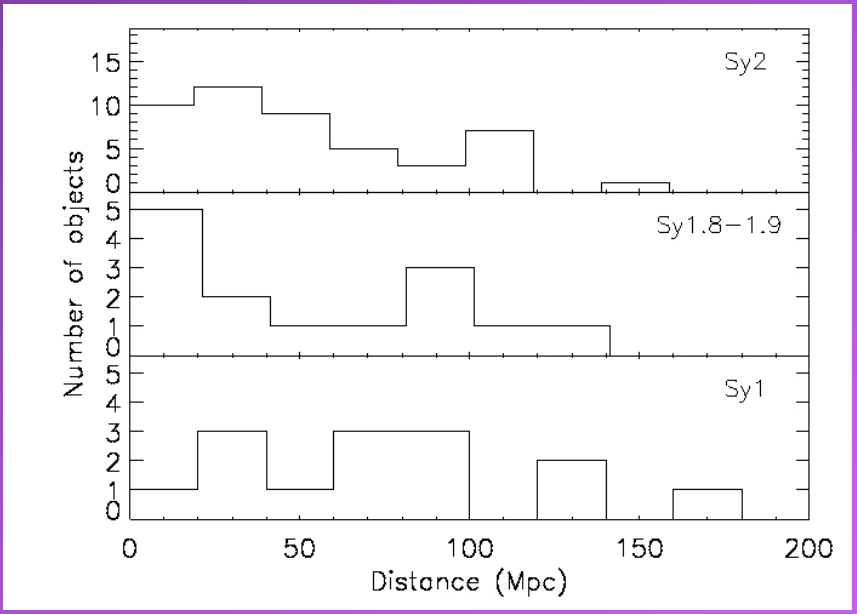
- *F330W:*

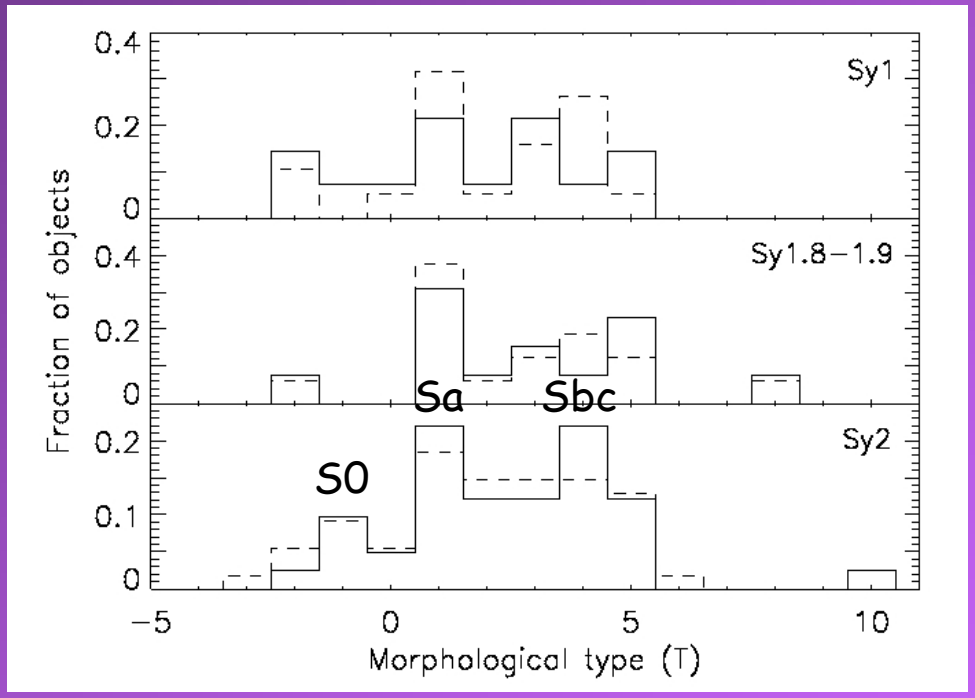
trace well the young and intermediate age cluster distribution

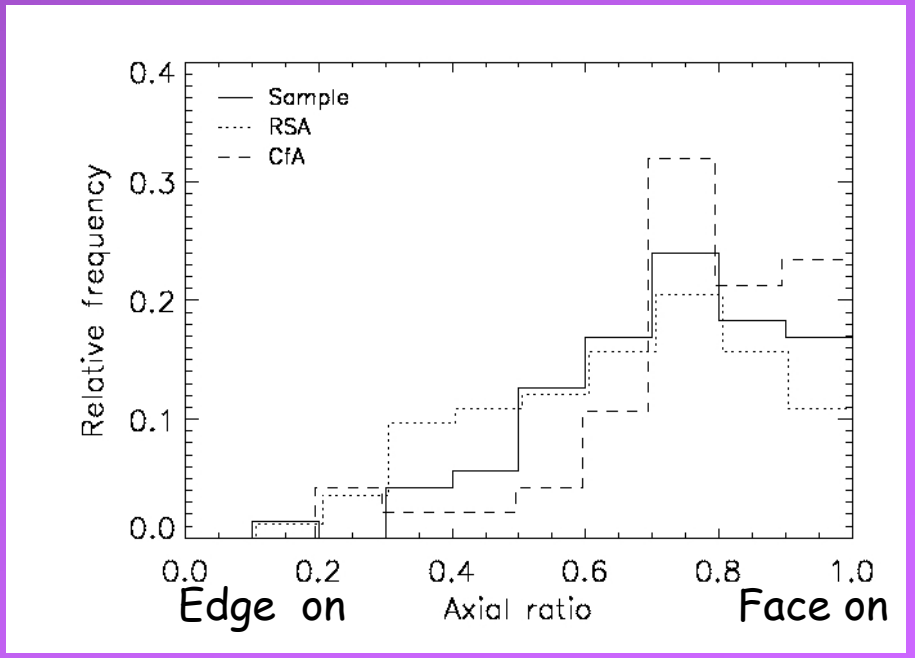
Seyfert sample

HST+ACS (F330W) observations:

- 75 Seyferts (63% Sy2 + 37% Sy1.8-1)
- 50% from CfA + 42% RSA Seyfert samples
- At their distances: mean value of 6pc/pixel (1-20 pc/pixel)
- Morpholgy: early types to Sc
- Axial ratio distribution in between the CfA and the RSA samples.



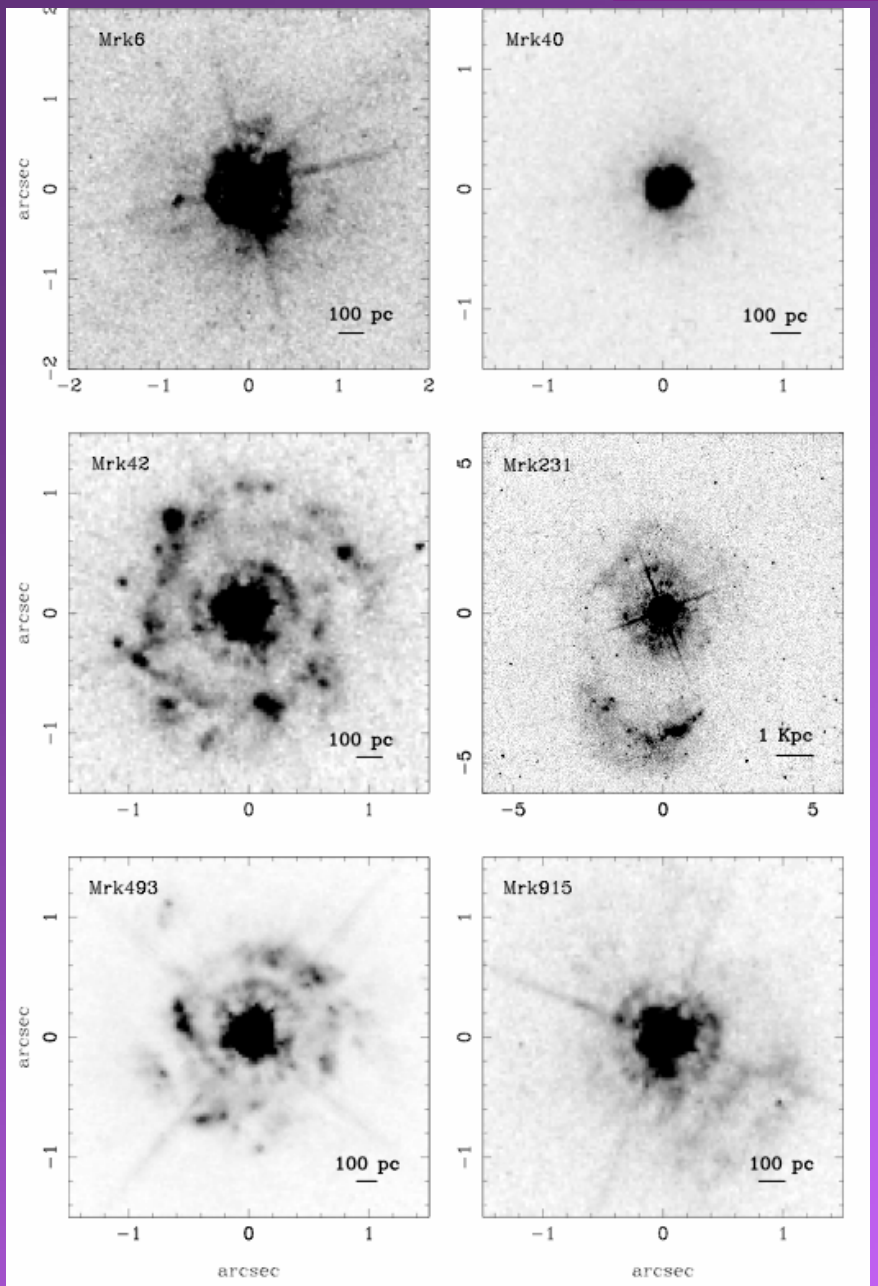


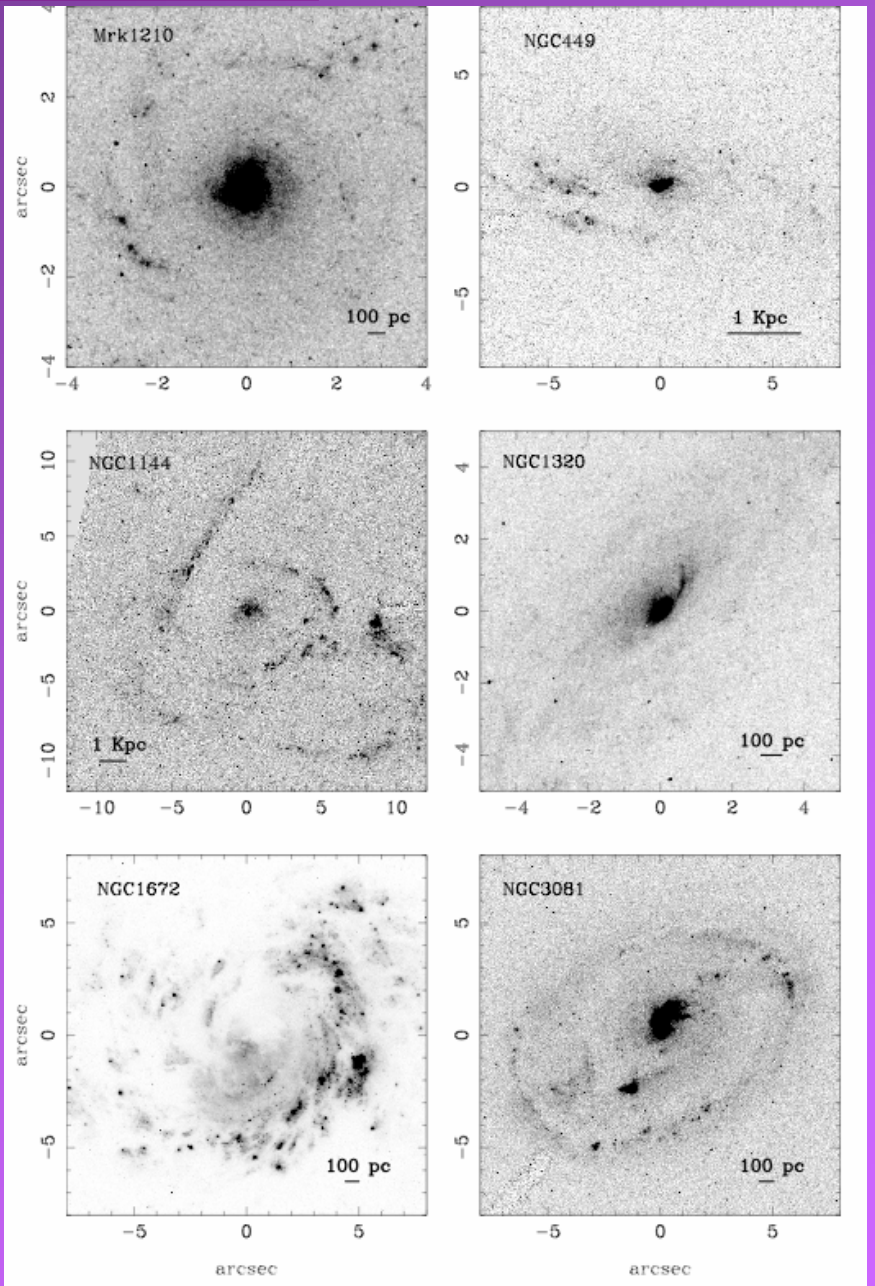


Seyfert 1

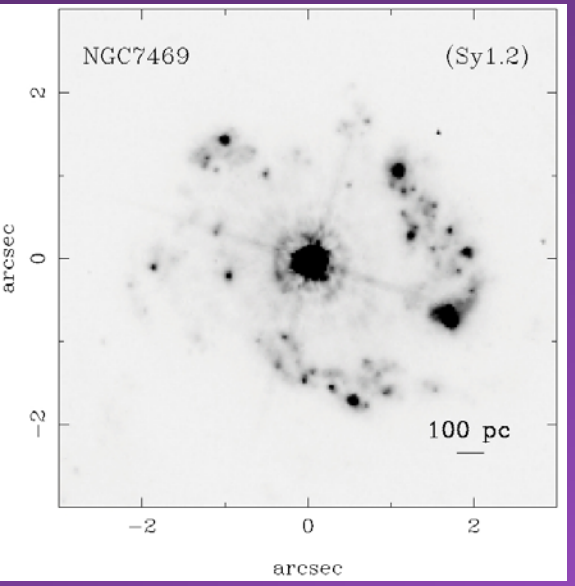
HST +ACS (F330W)

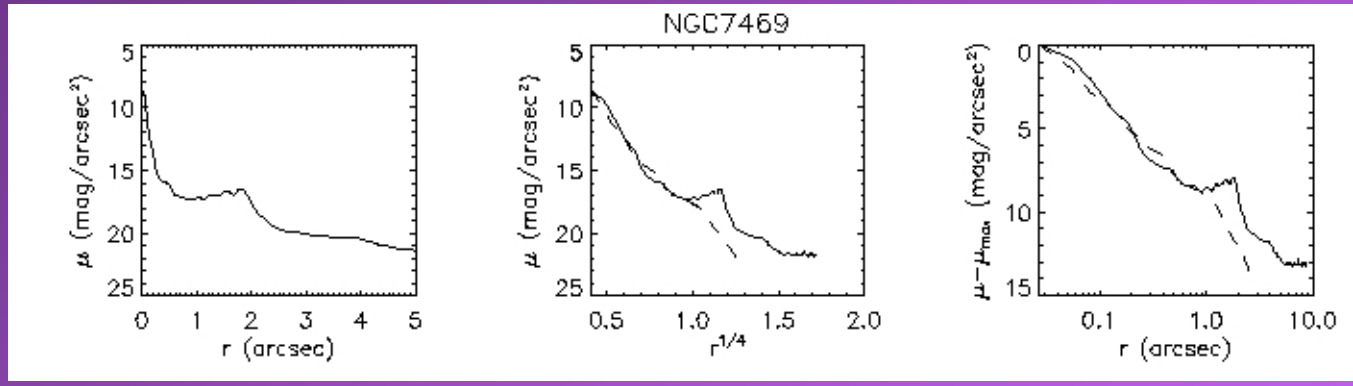
Seyfert 2



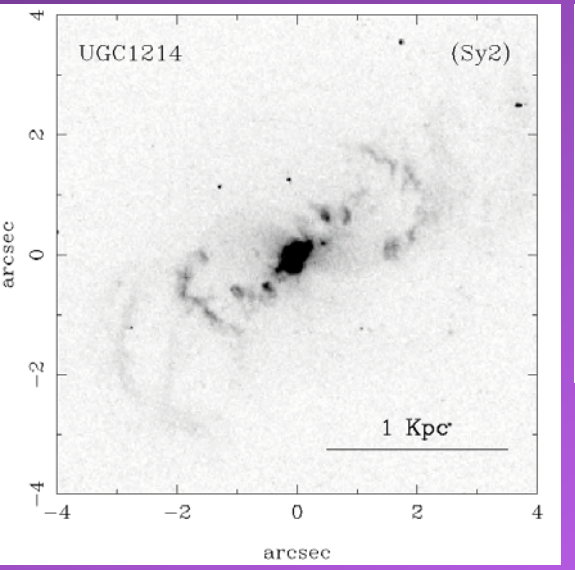


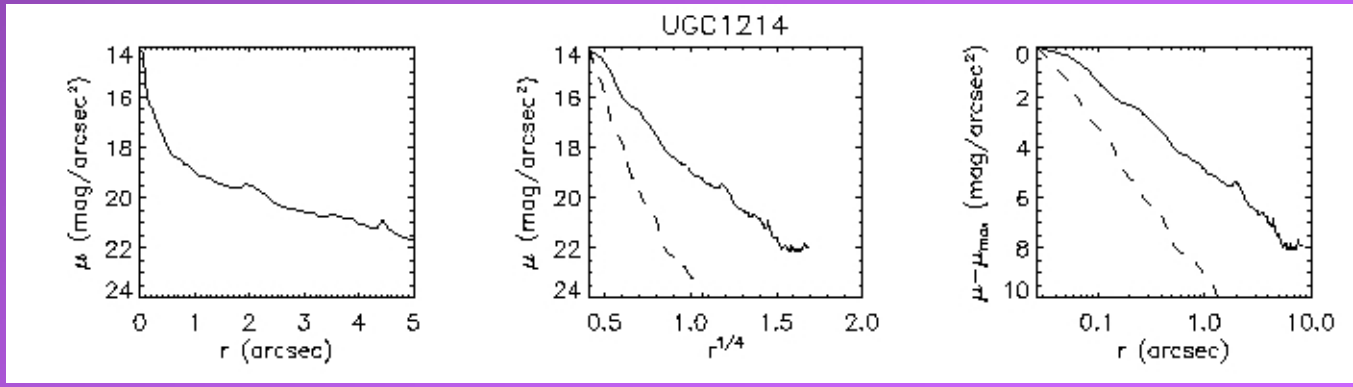
HST+ACS results





- *Sy1 are PSF dominated objects*
- *No nucleus is resolved for any of the Sy 1 galaxies*

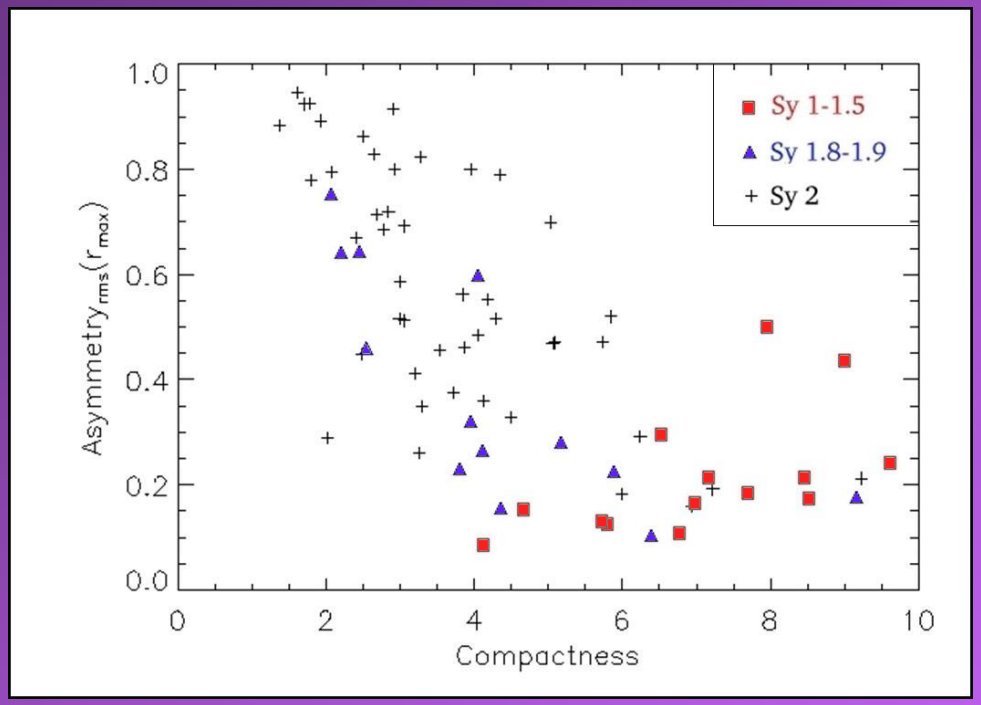


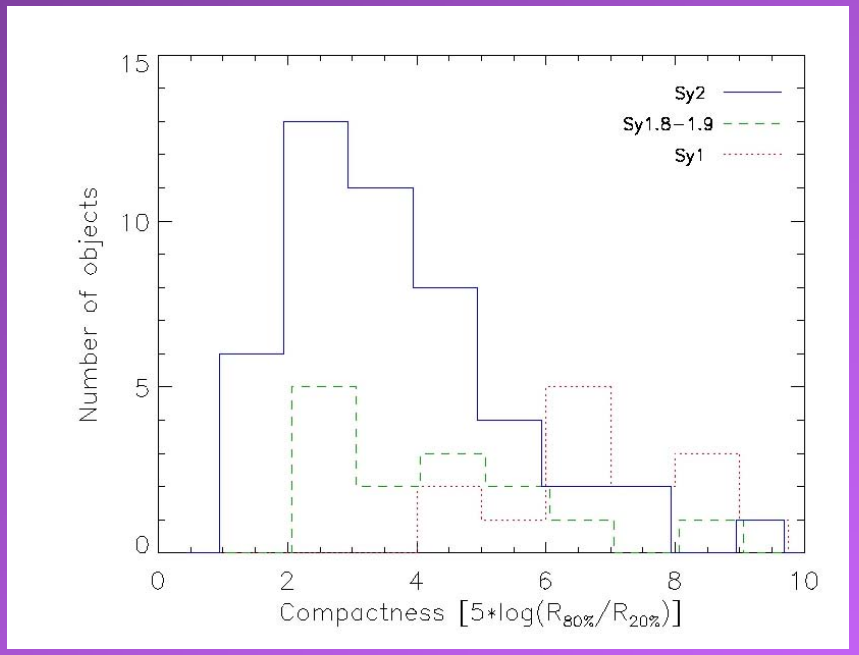


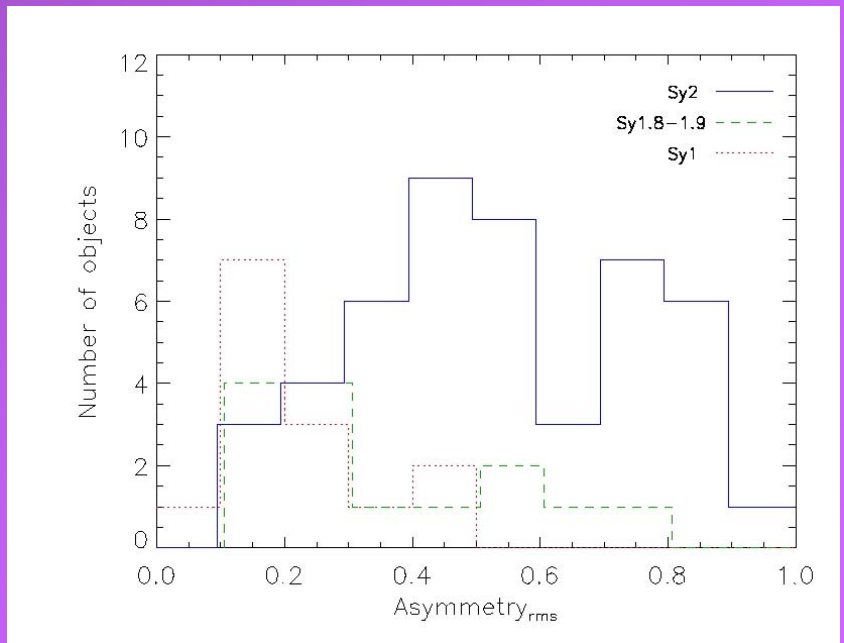
- *Almost all Sy2 have a resolved nucleus*

HST+ACS (F330W) results

- Sy 1 are more compact than Sy2
- Sy 1 have low value of the asymmetry

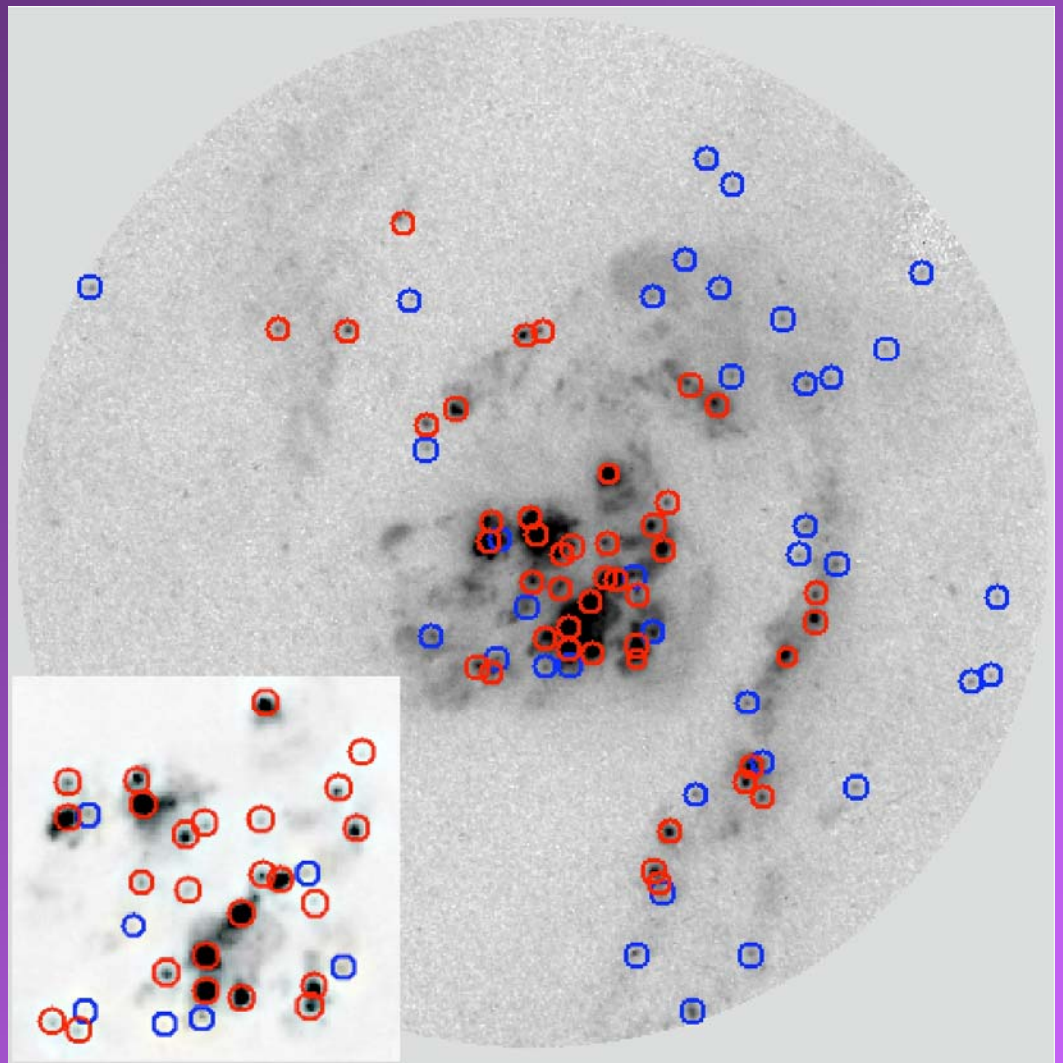


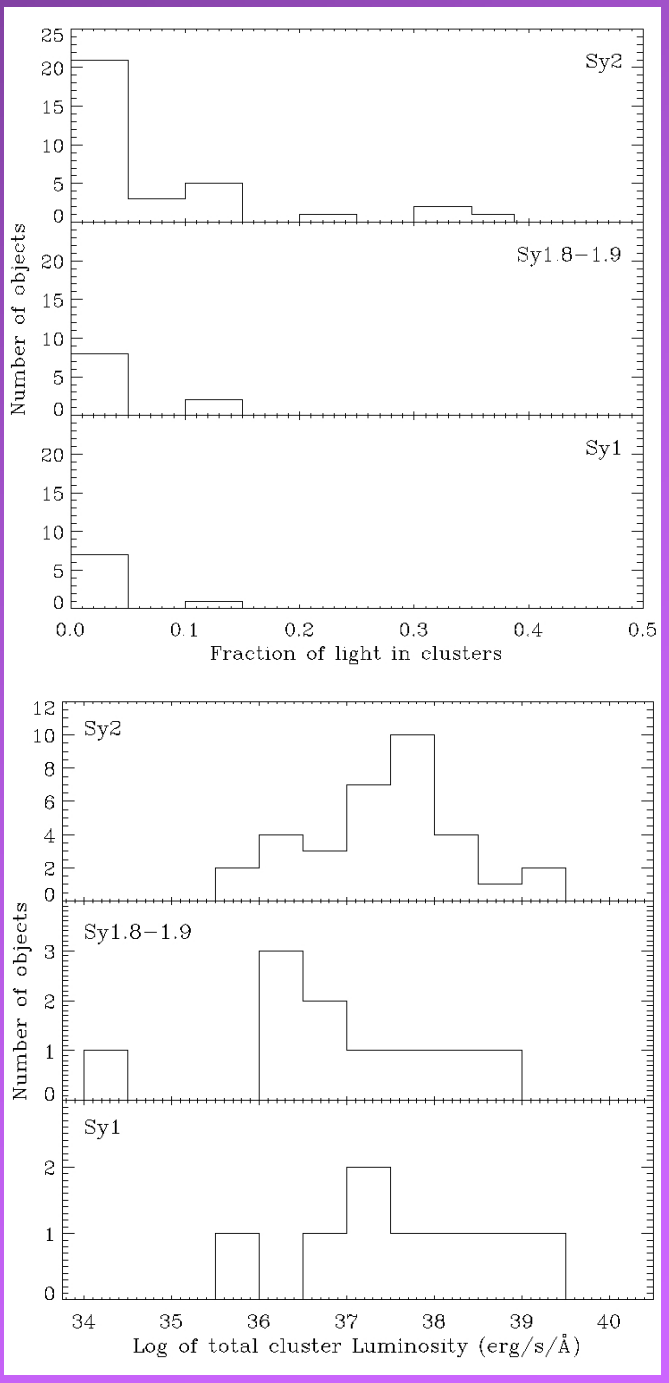




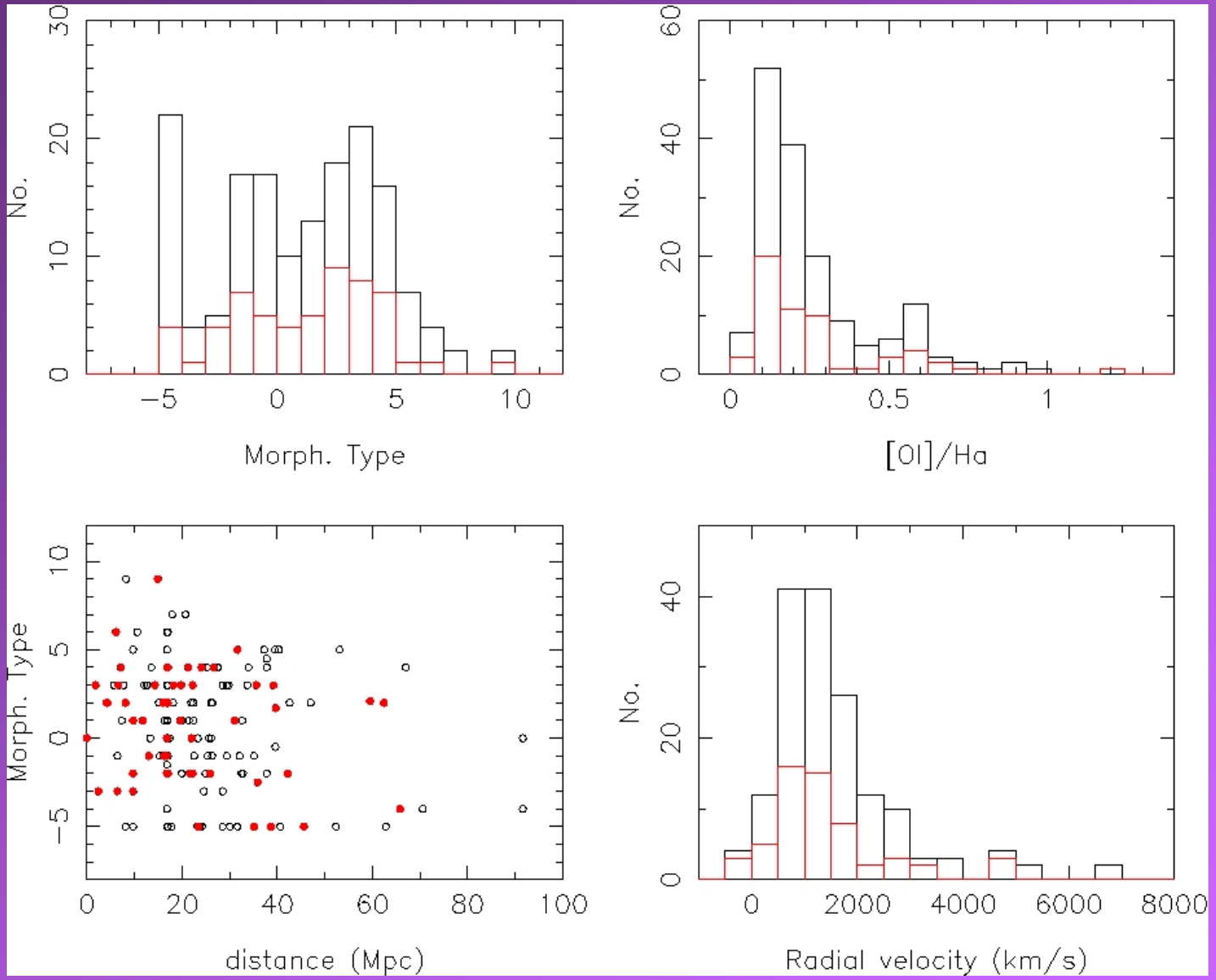
HST+ACS (F330W) Seyfert results: Stellar clusters contribution

Stellar clusters more common in Sy2 than in Sy1



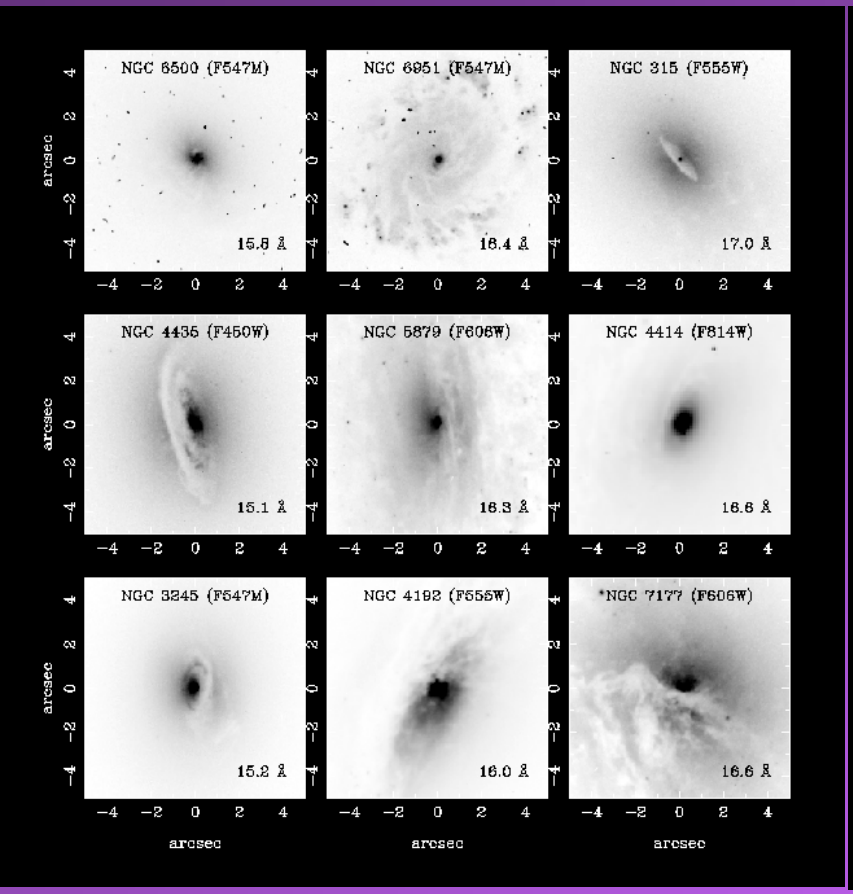


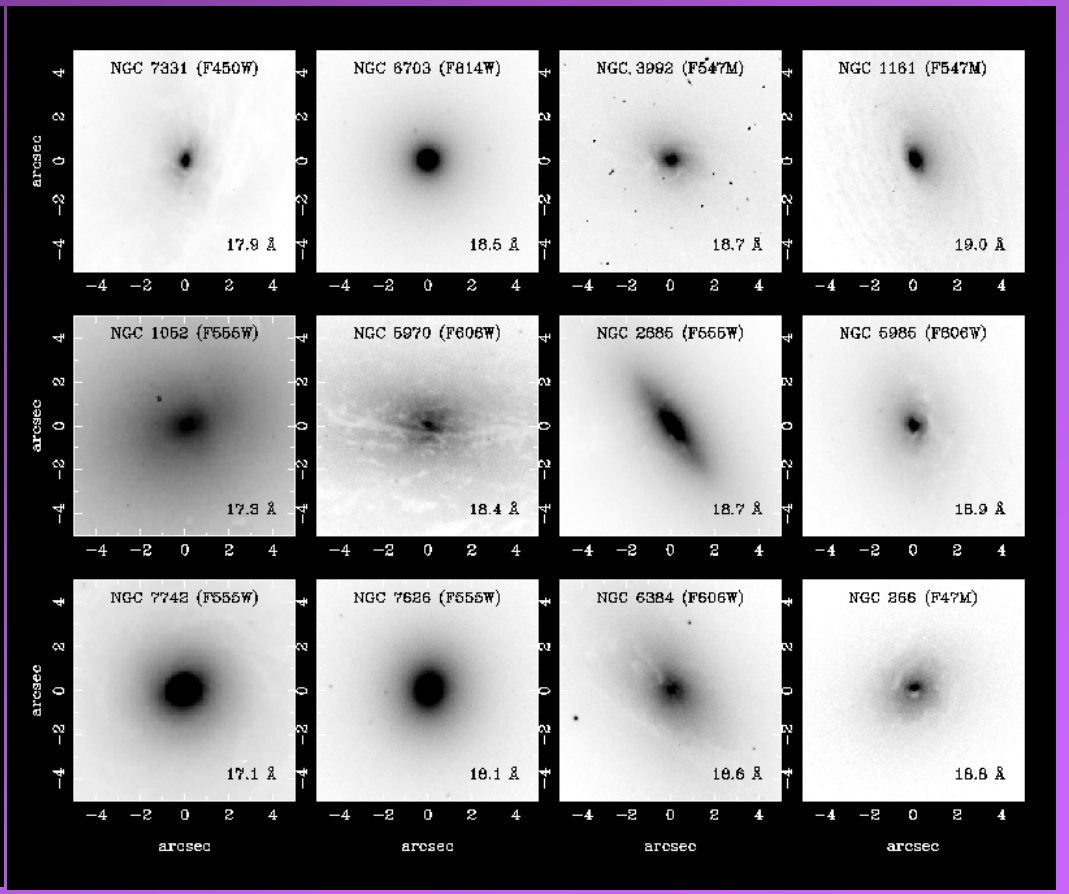
LLAGN sample: Optical and NUV wavelengths



LLAGN sample: from Ho, Flippenko & Sargent 1995

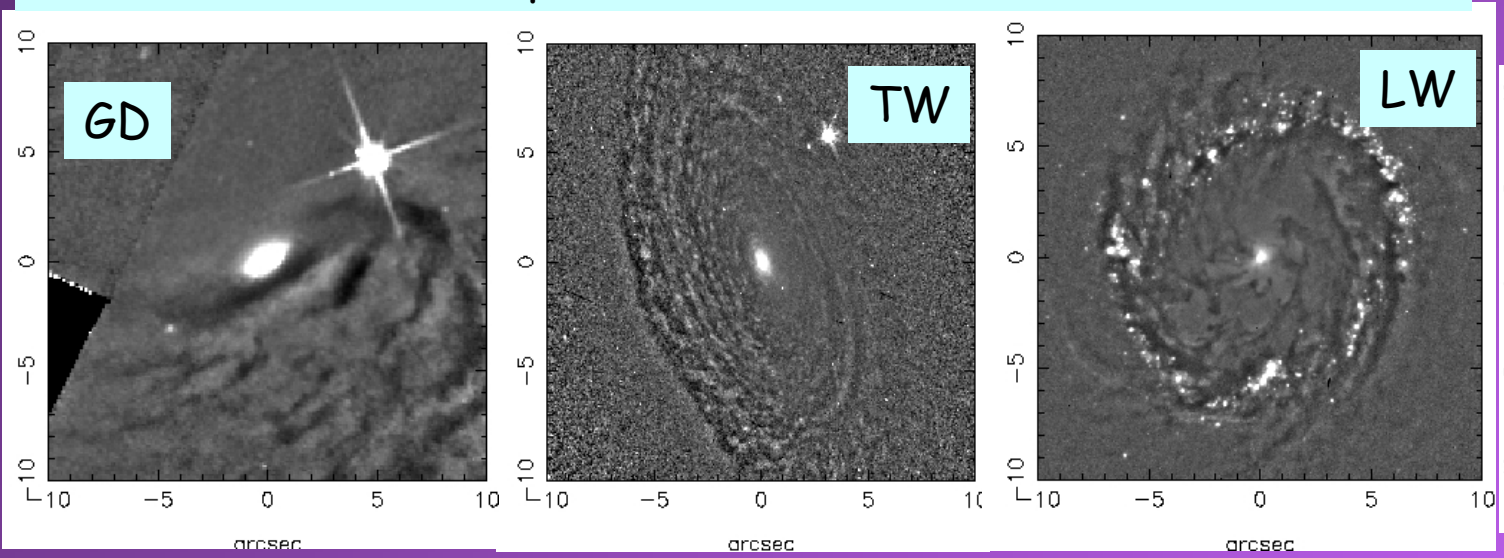
Central morphology: HST+WFPC2 (optical filter)



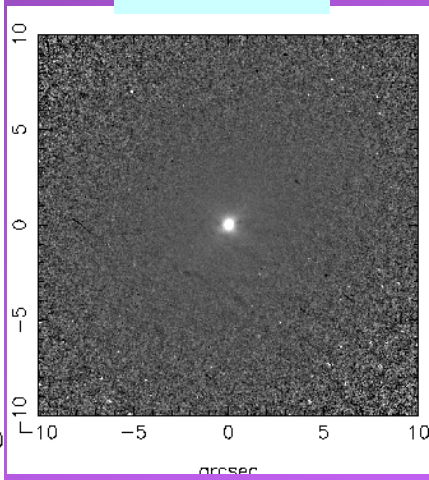


Dust morphology: unsharp WFPC2 images (optical filter)

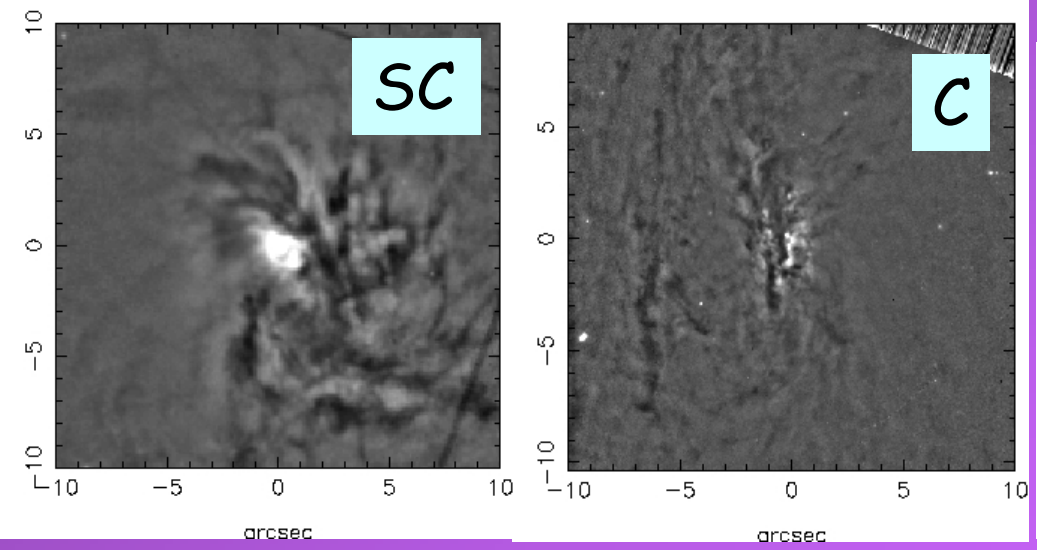
Spiral dust structures



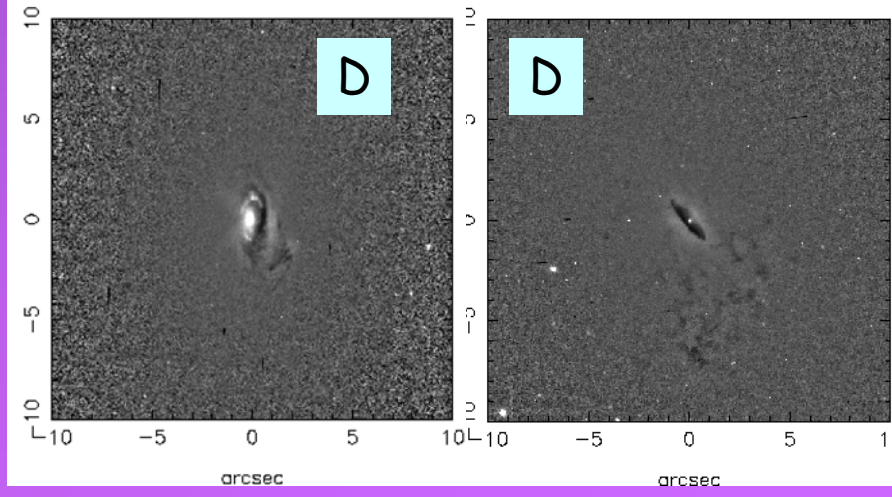
No dust



Chaotic circumnuclear dust structures

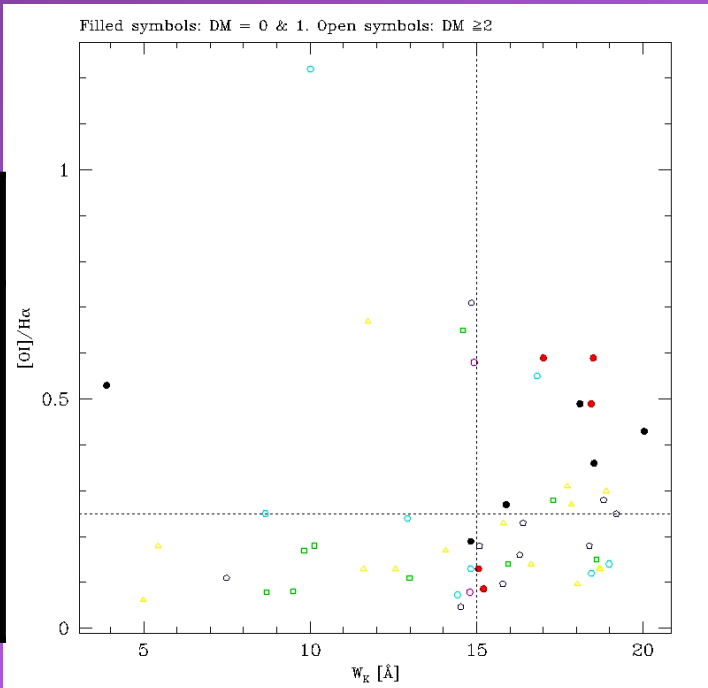


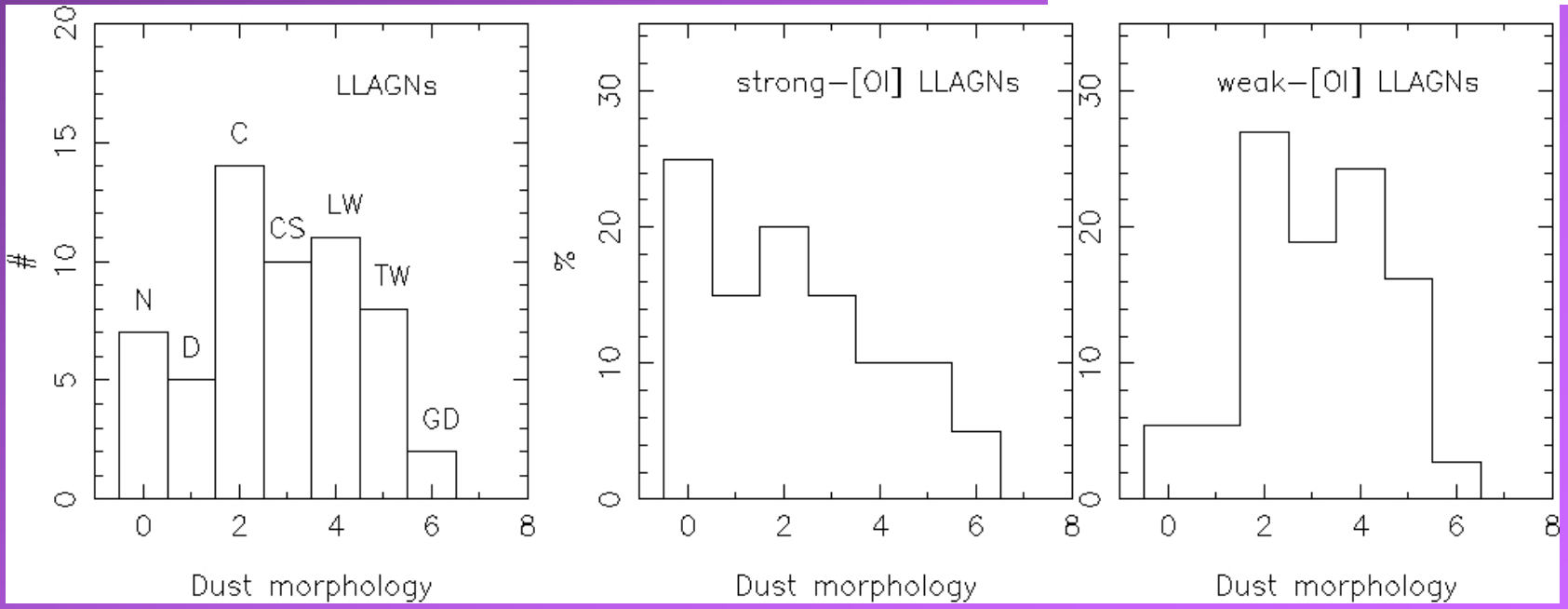
Nuclear disk dust structures



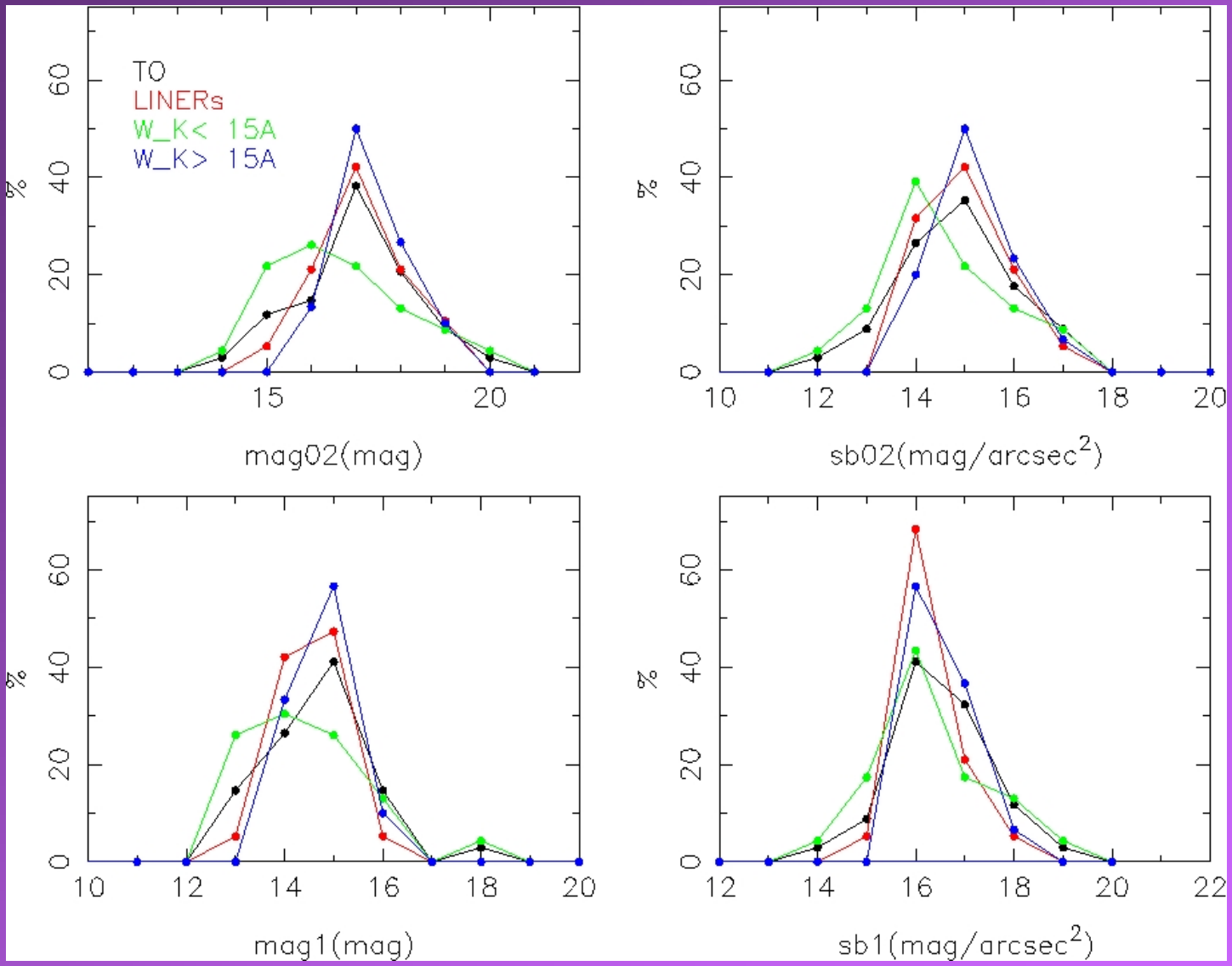
LLAGNs: dust morphology

Dust morph.	LLAGN strong-[OI]	LLAGN weak-[OI]	Seyferts	Early type galaxies
No dust	25%	5%	2%	45%
Dust Disk	15%	5%	0%	22%
Chaotic dust	35%	46%	38%	24%
Spiral dust	25%	43%	60%	9%





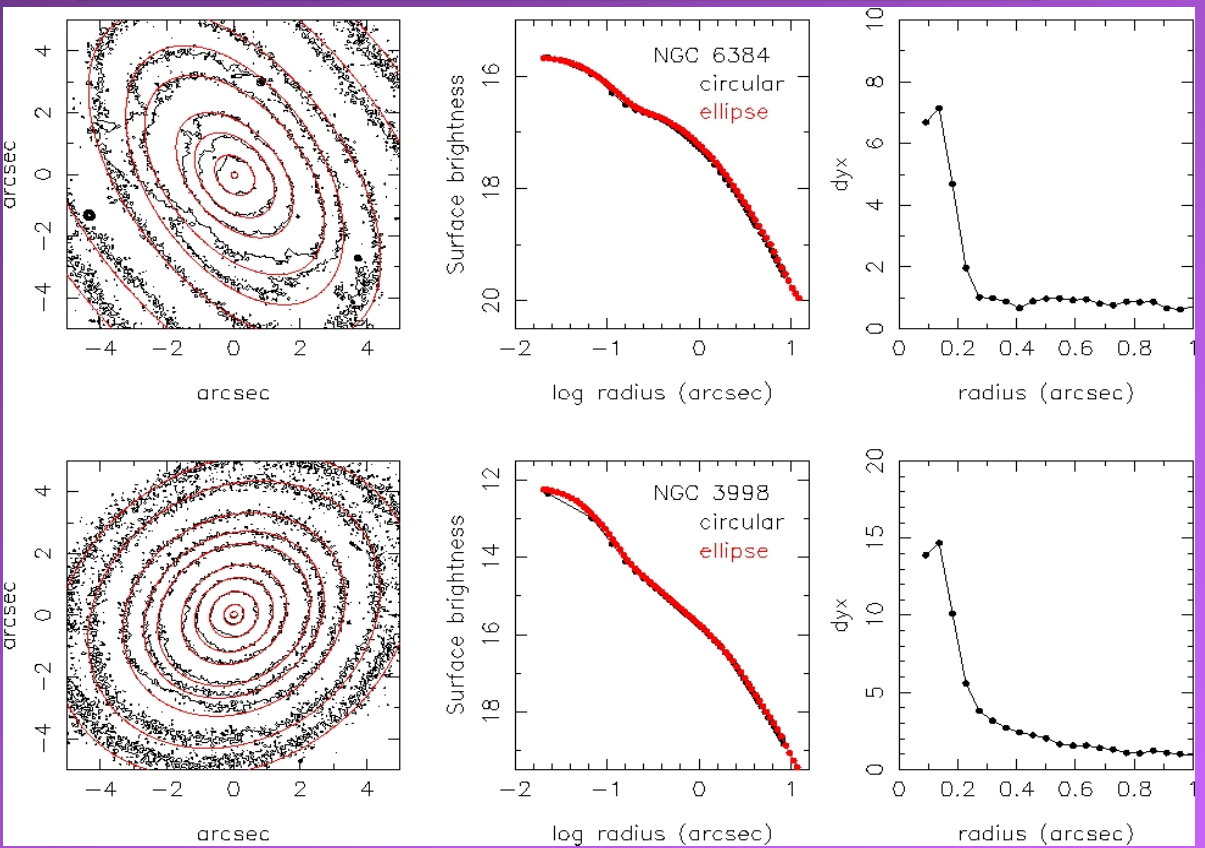
LLAGNs: distribution of the central magnitude and surface brigthness

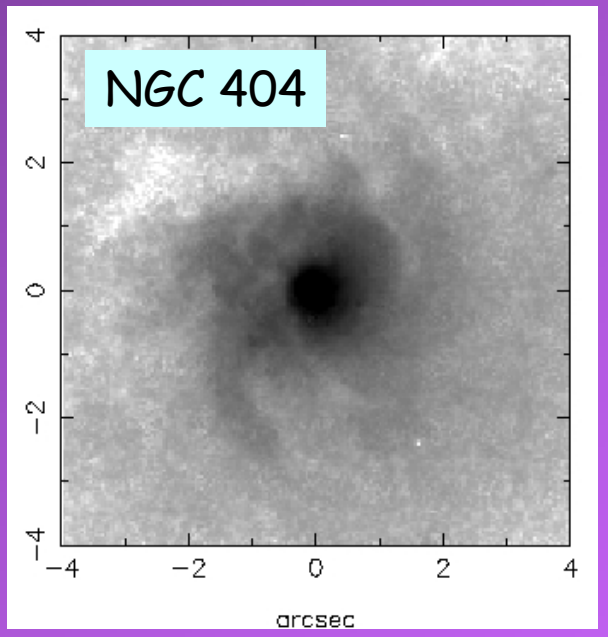


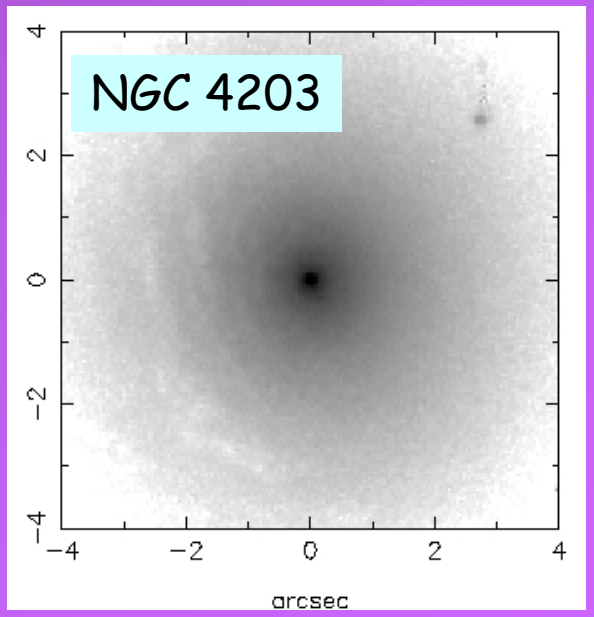
- *The nuclei of Young-TOs are brighter than old-TOs and Liners*
- *Young-TOs are separated from other LLAGNs classes in term of their central Stellar Populations and brightness*

LLAGNs: frequency of compact sources

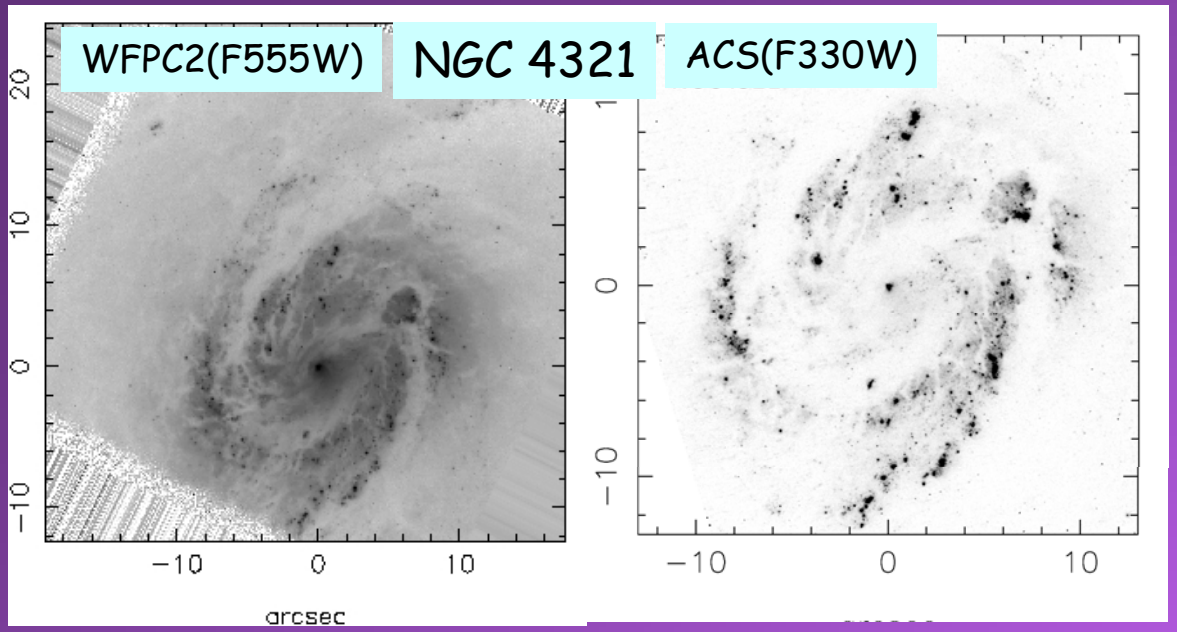
	No nucleated	Nucleated	Clusters+dust
Strong-[OI]	40%	50%	10%
Weak-[OI]	41%	51%	8%
YTO	22%	67%	11%
OTO	58%	37%	5%
OL	44%	55%	0%

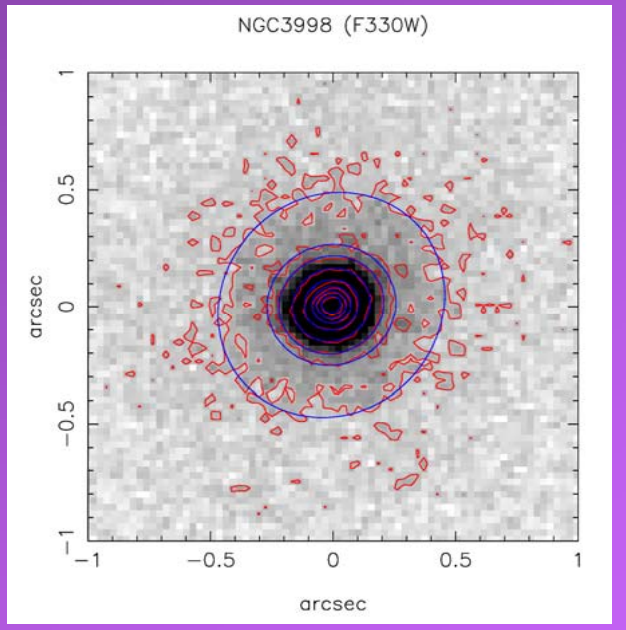


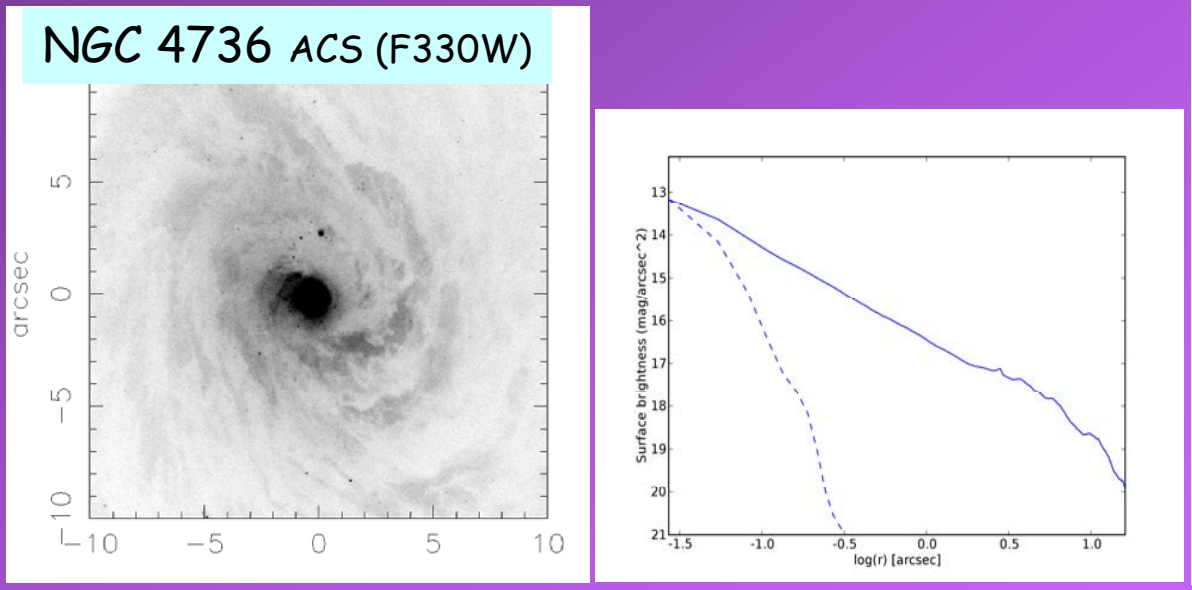


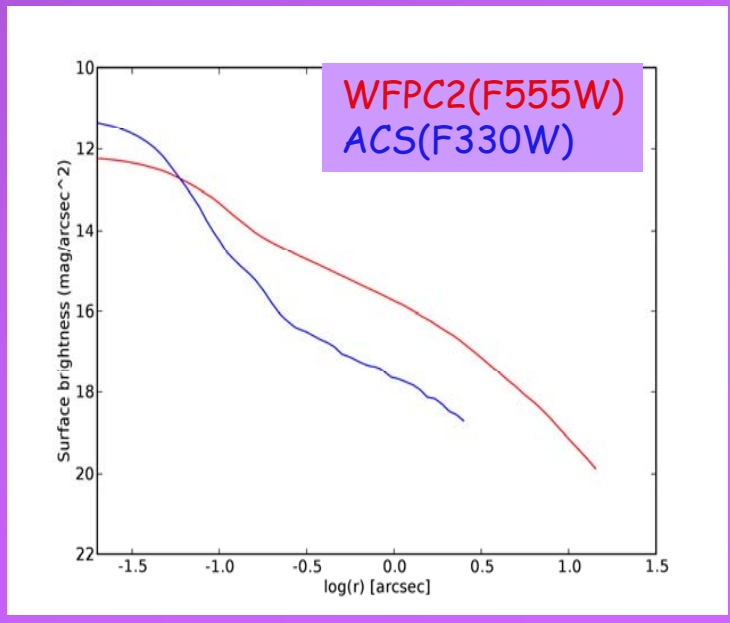


LLAGNs: HST+ ACS(F330W)

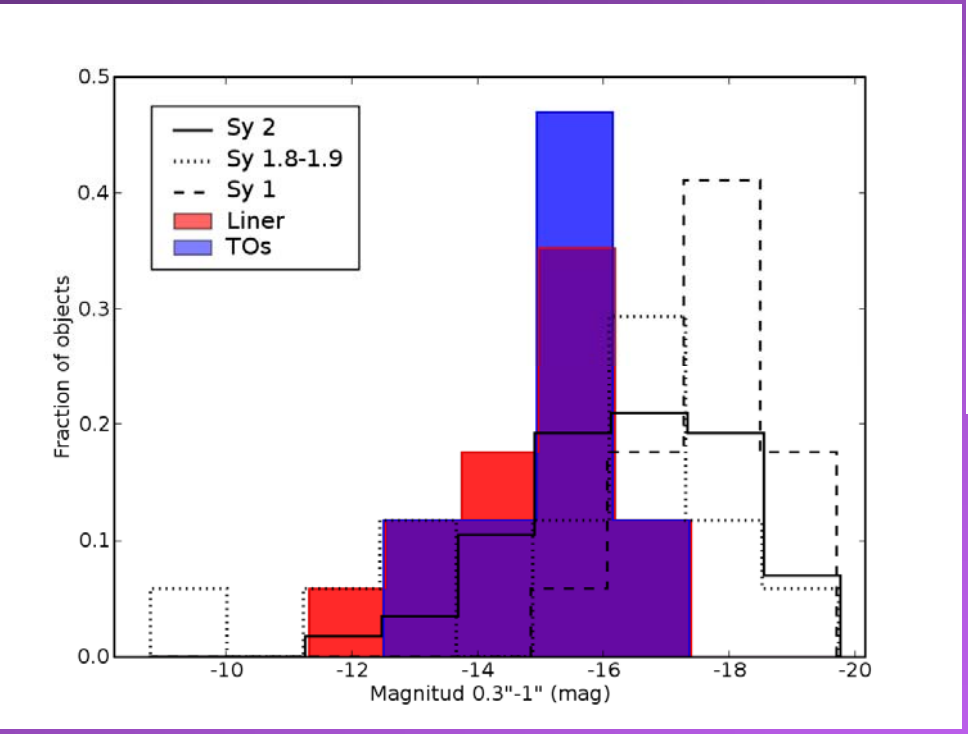


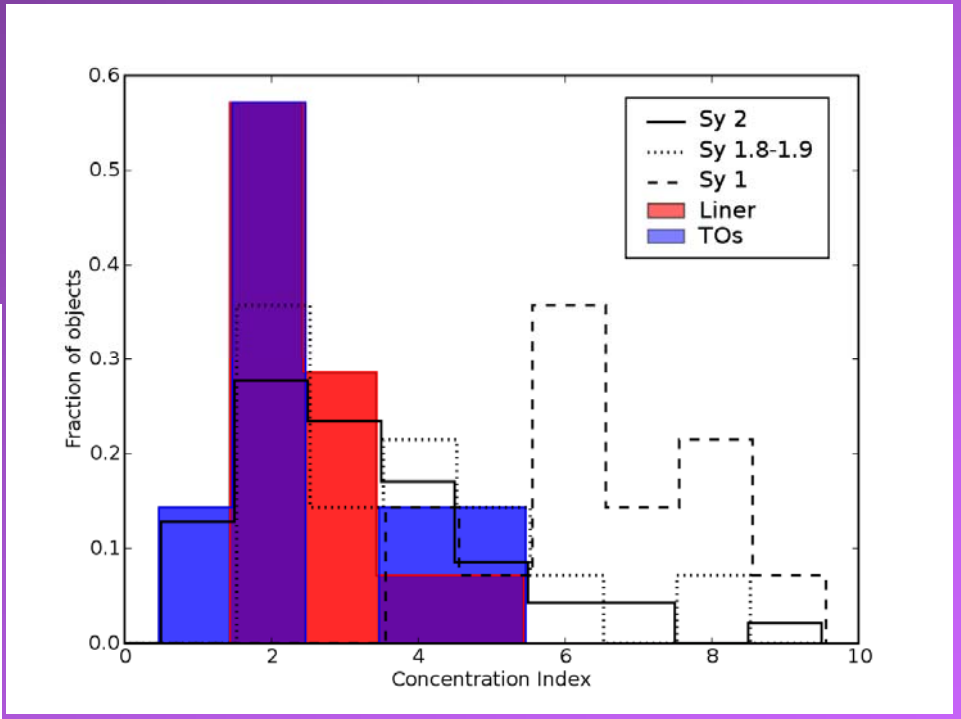




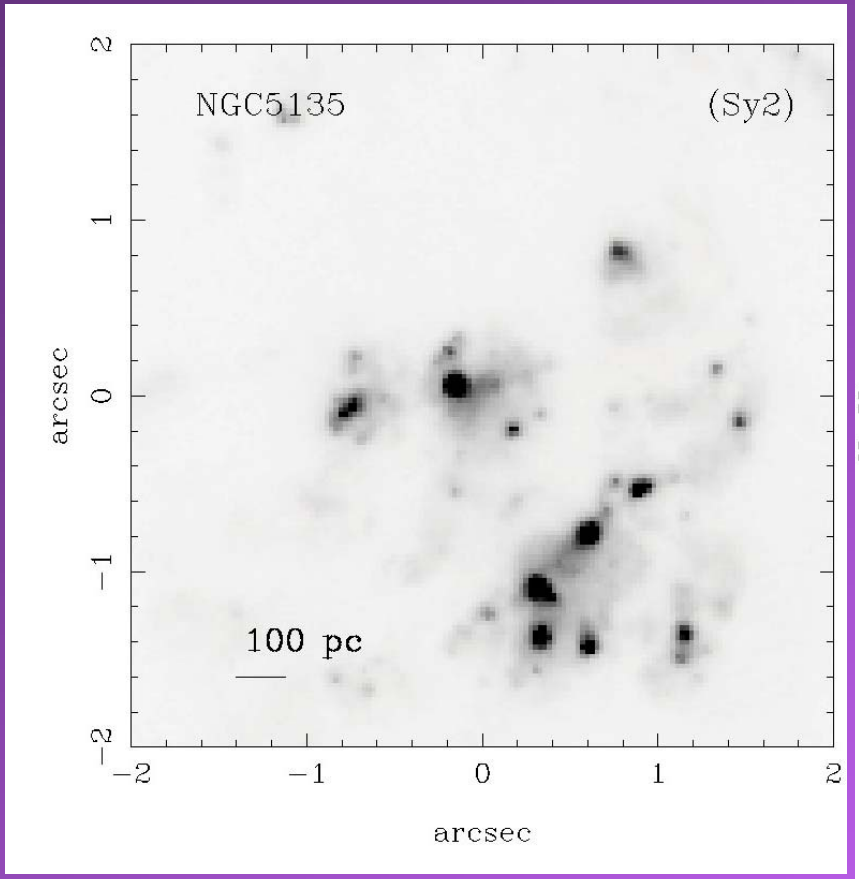


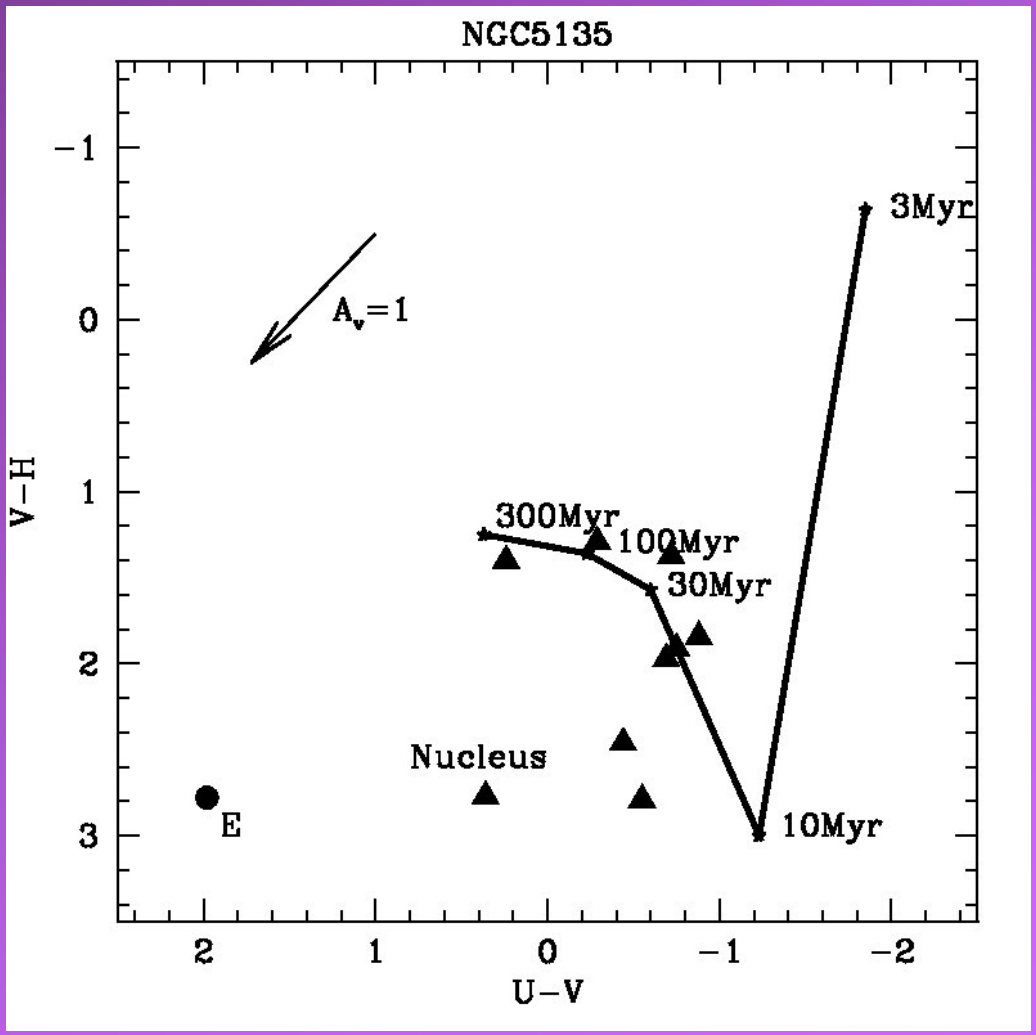
LLAGNs: HST+ ACS(F330W)



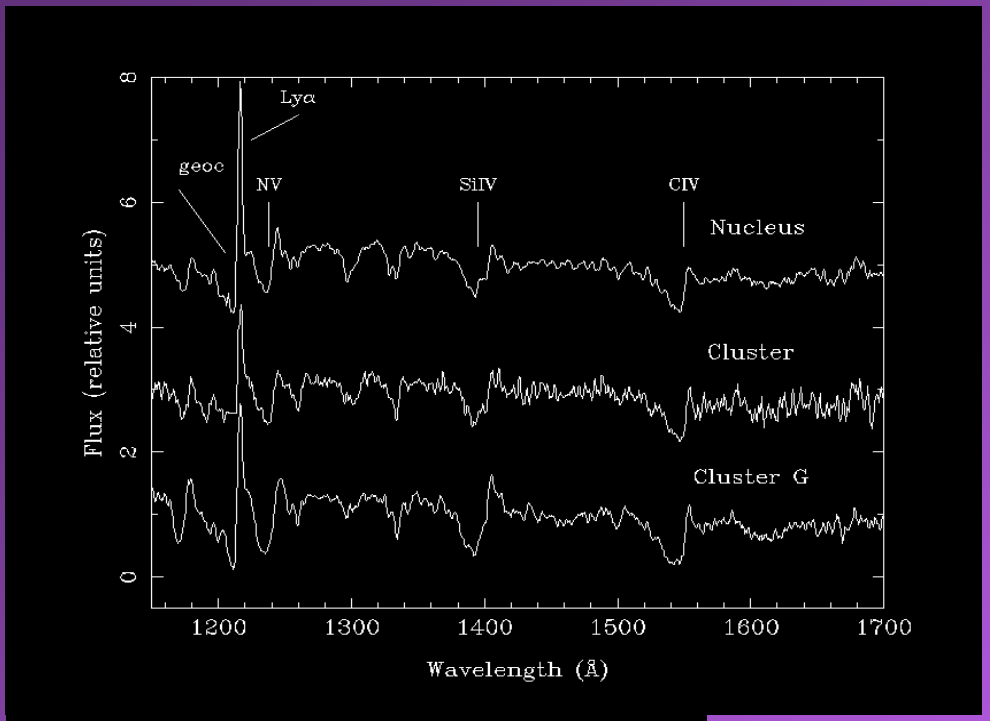


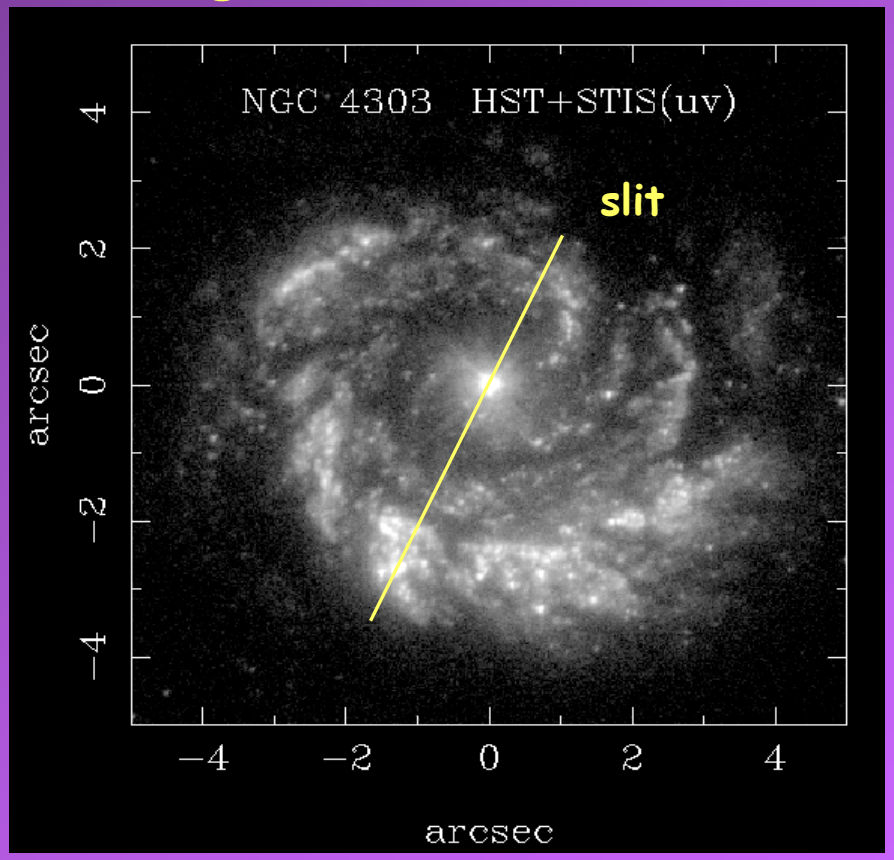
Future prospects: Analysis of F330W, F555W and H band

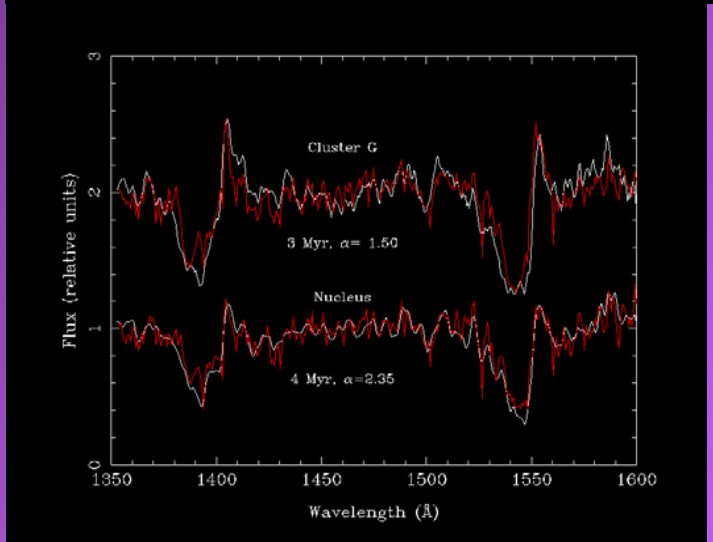




Is the star formation proceed at a residual level? UV emission in the core of some Young-TO: NGC 4303







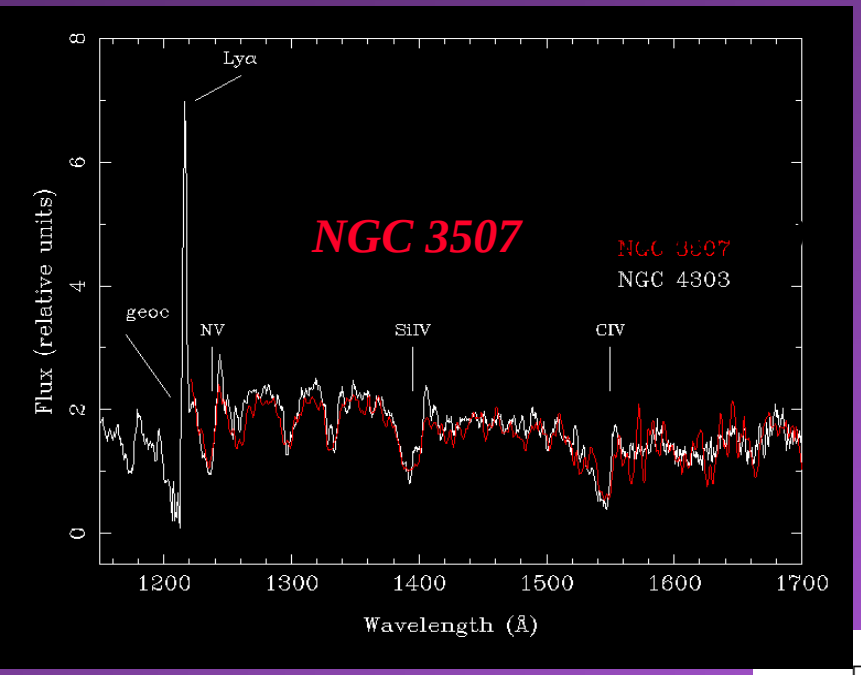
STIS/MAMA (FUV)

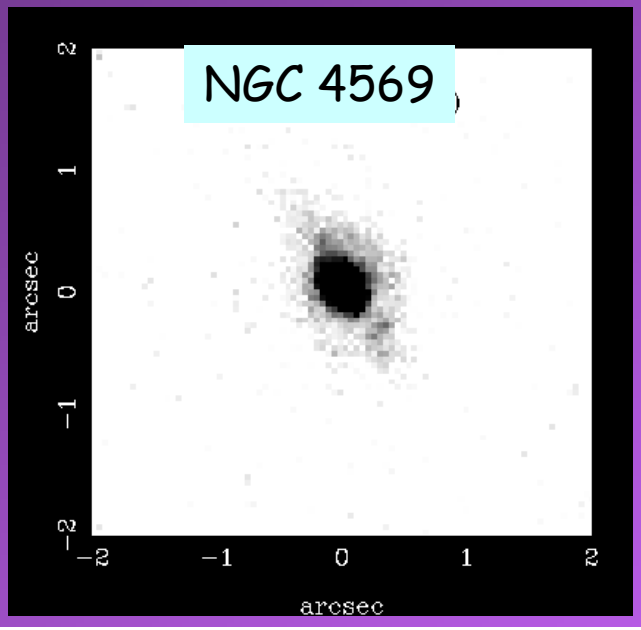
- E(B-V)= 0.1
- Age= 4 Myr
- Mass= 2-3 x 10^5 M_{sol}
- Lbol= 2 x 10^8 L_{sol}

Size of the central knot (nucleus): 3 pc

Colina, González Delgado, Mas-Hesse, Leitherer, Jiménez Bailón, 2002, ApJ, 579, 545

UV emission: evidence that the star formation proceeds at some level in Young-TO

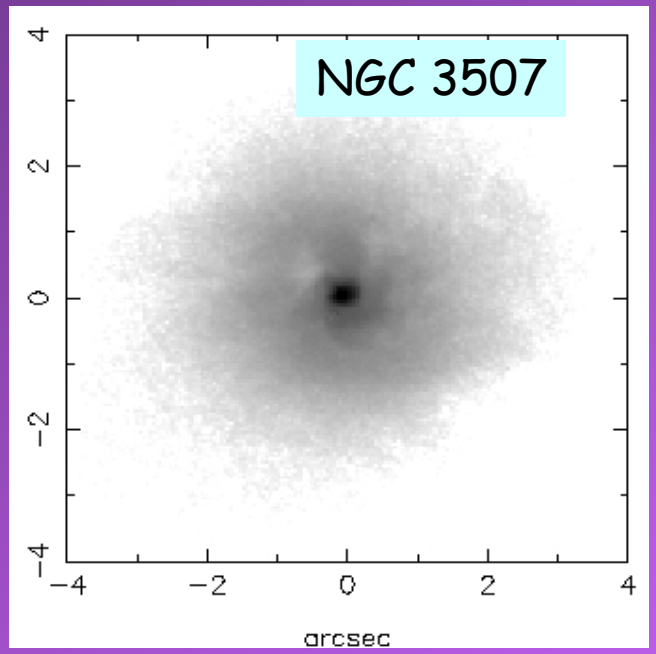


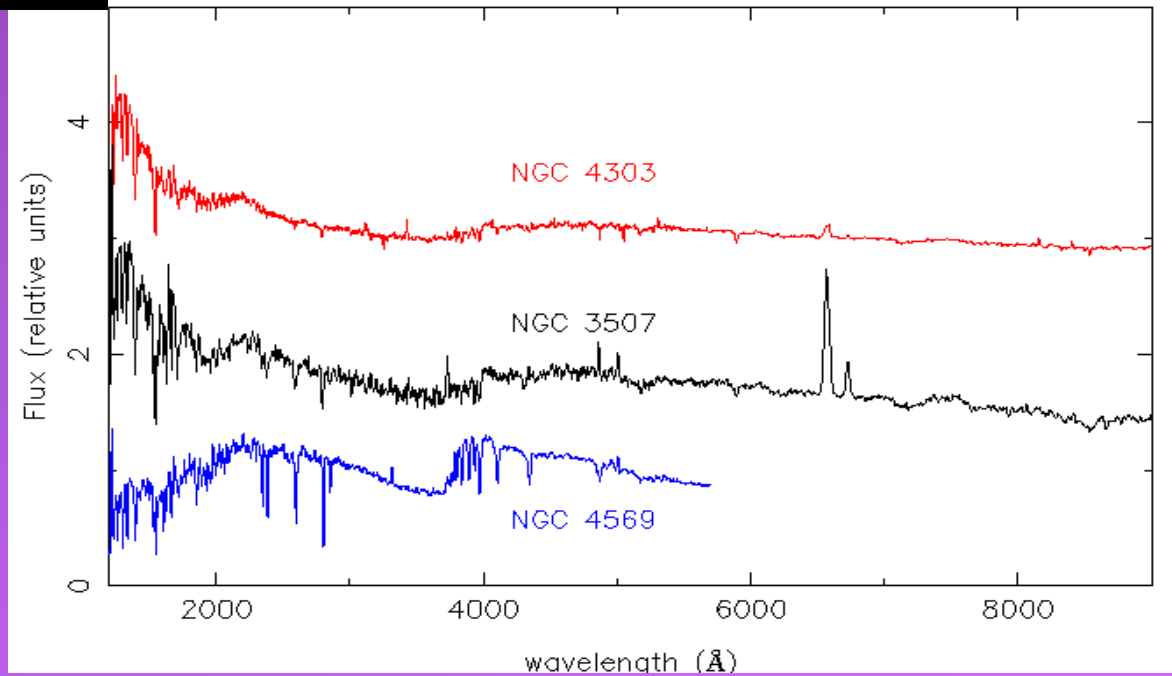


NGC 4569

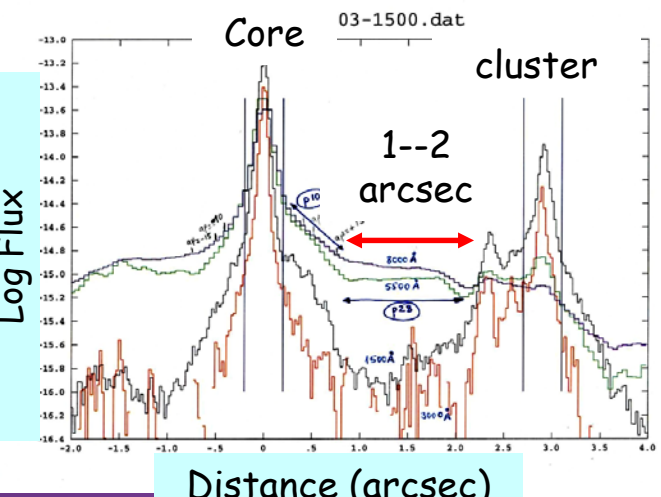
WFPC2 (F220W)

A compact but resolved source: Stellar cluster?



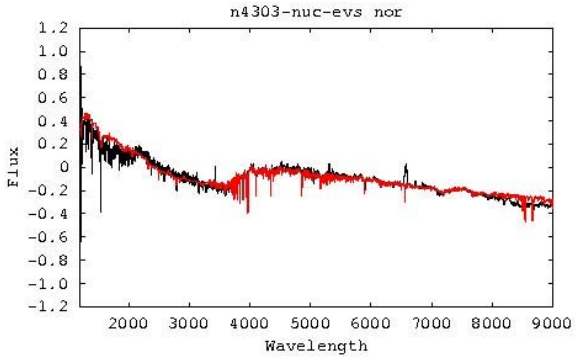


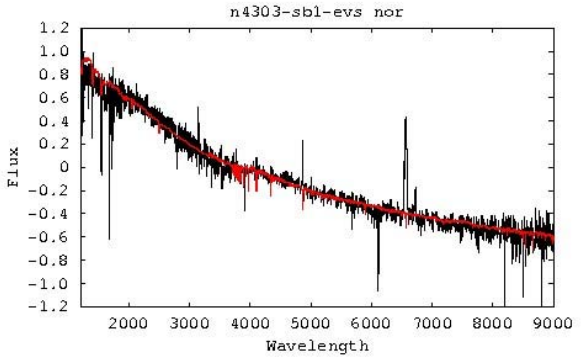
LLAGNs (NGC 4303)
SED: STIS spectra



Core (central 0.4 arcsec)
F_{4020}: 50%(4Myr)+(50%inter. Age)

Cluster in the ring
F_{4020}: 90%(3Myr)+10%(inter. Age)

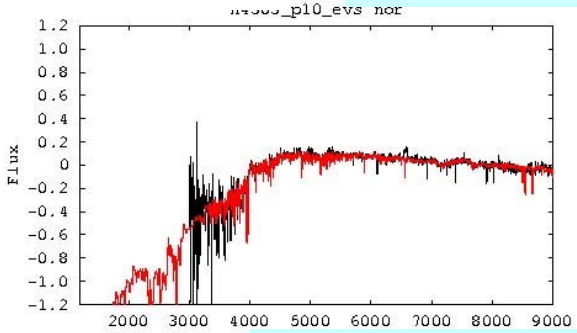


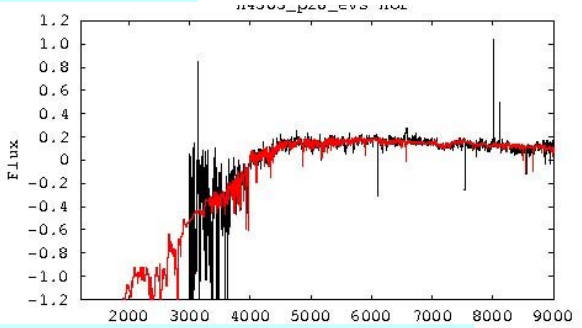


0.5--1 arcsec

Extinction Av=0.4-0.6

1--2 arcsec





Regions between the core and the ring
F_{4020}: 80%(0.9 Gyr)+20%(10 Gyr)

Summary and Conclusions

- NUV light in Seyfert galaxies (HST+ACS)
  - Sy1 are dominated by their bright and compact unresolved nucleus.
  - Almost no unresolved nucleus is found in Sy2 galaxies.
  - Sy1 and Sy2 are well segregated in the asymmetry-compactness plot, beeing Sy1 more compact and less asymmetry than Sy2.
  - The contribution of stellar clusters to the total NUV light is much more important in Sy2 than Sy1.
- The circumnuclear structure of LLAGNs (HST+WFPC2):
  - We have not found any correlation between the presence of nuclear compact sources and the LLAGN classes (Liners, TOs).
  - The nuclei of Young-TOs are brighter than the nuclei of Old-TOs and Liners.
  - Circumnuclear dust is detected in 88% of LLAGNs , beeing almost ubiquitous inTos
  - Dust morphology is complex and varied. Chaotic filaments are as frequent as dust spirals, but nuclear disks are mainly seen in Liners.
  - There is an evolutionary sequence of dust in LLAGNs, beeing Liners more evolved systems than TOs.
- NUV light in LLAGN galaxies (HST+ACS): still in progress
- NGC 4303 (LLAGN):
  - Young clusters dominated the UV continuum.
  - STIS UV+Optical spectra are needed to constrain the SFH in these systems.