Isabel Márquez
(IAA-CSIC)

Coll.:
J. Masegosa,
O. González-Martín,
S. Cazzoli,
L. Hermosa

Most relevant recent results from the studies of LINER nuclear sources

Santander, July 2019

1. Introduction

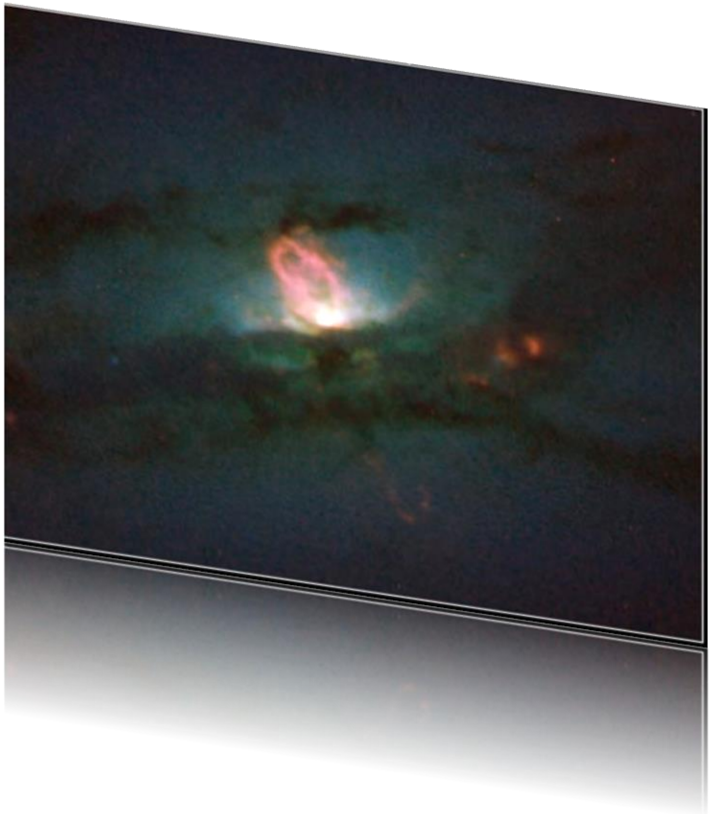
- Properties
- LINERs vs. LIERs

2. AGN LINERs

- X-ray properties and variability
- MIR spectroscopy. The dusty torus?
- HST Hα imaging
- The BLR in LINERs revisited. Outflows?

3. Conclusions

4. Most luminous LINERS @ z=0.04-0.11



LINERs: Low Ionization Emission-line Regions

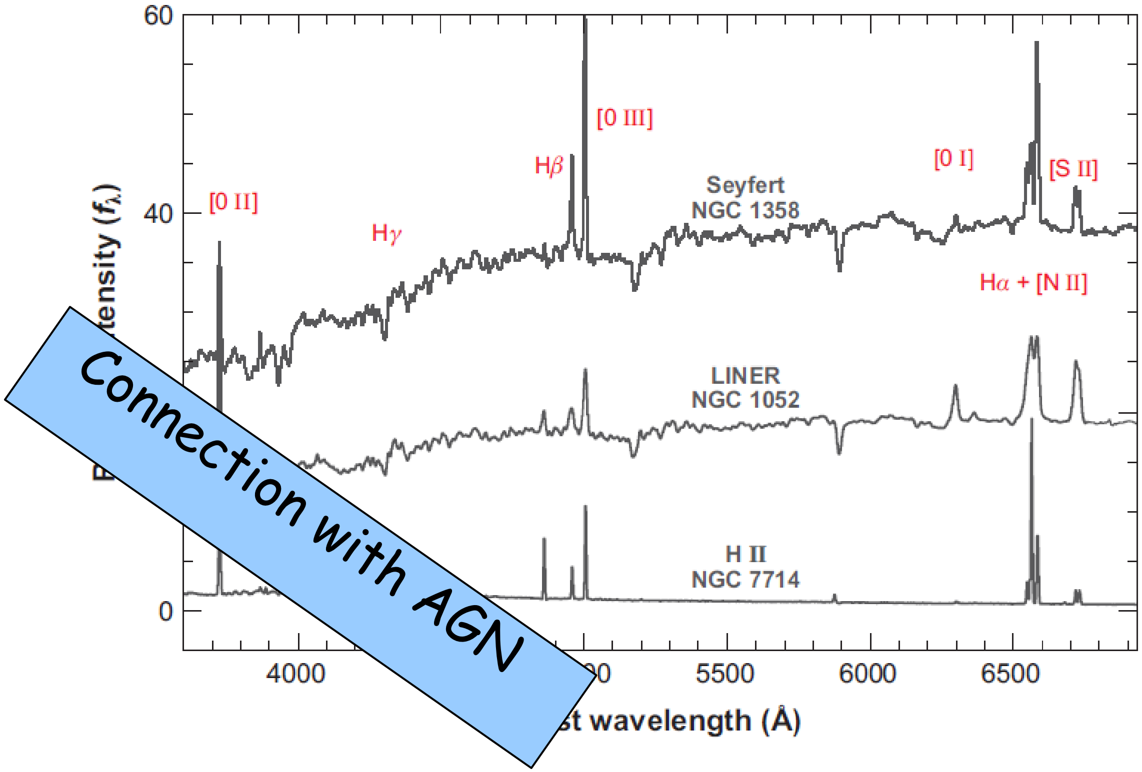
Spectral Classification (Heckman 1980)

- Optical spectra dominated by emission lines from low ionization Species ([OI],[NII][SII])

- Early types

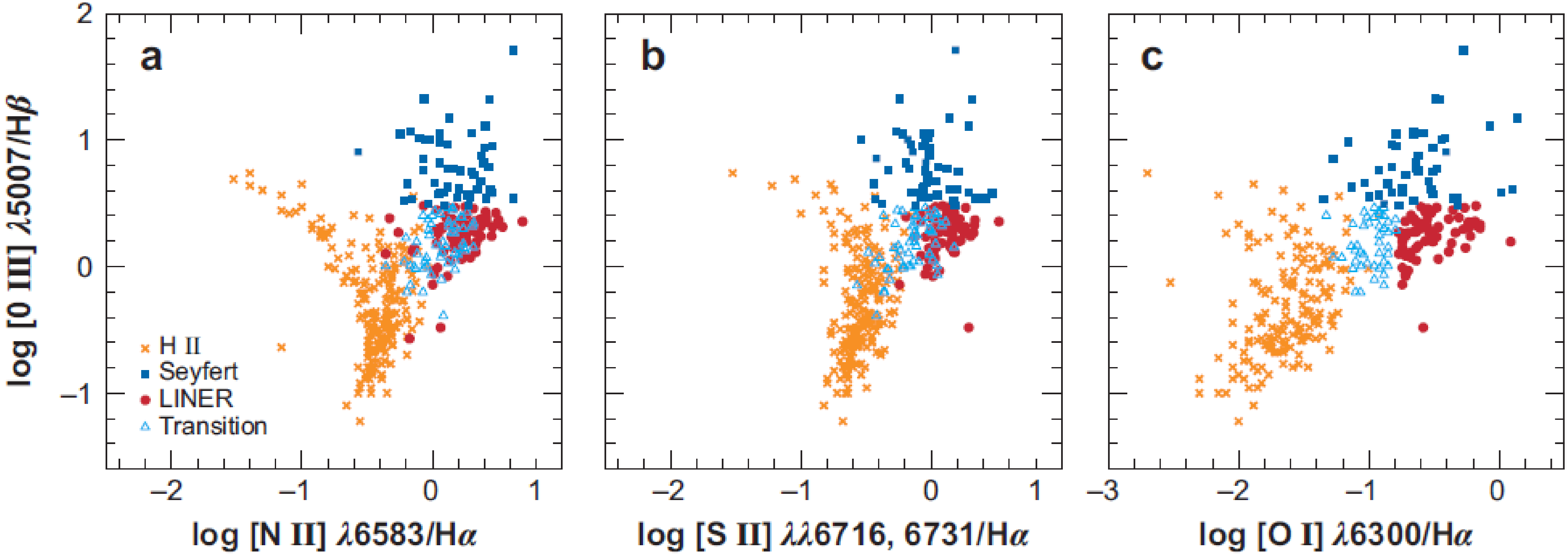
- Lower luminosities than Seyferts

- Continuity ionization state and electron temperature



BUT, difficult detection due to extinction and contamination by circumnuclear star formation

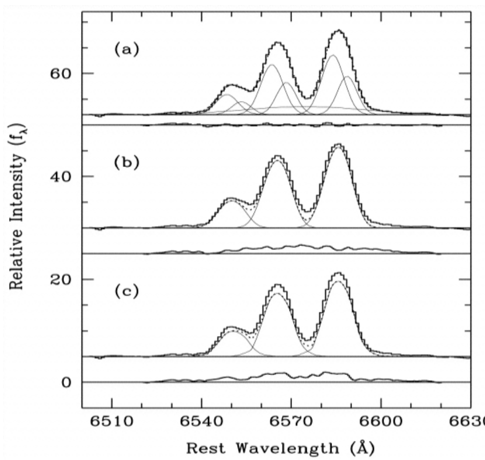
Ho (2008)



Warning:

broad line LINERs must be AGN powered

LINERs 1.9 **(Ho et al. 1997)**



- Non Stellar Photoionization

(Osterbrock 1959, Ferland & Netzer 1983, Halpern & Steiner 1983,Ho,Filipenko & Sargent 1993, **Allen+2008**)

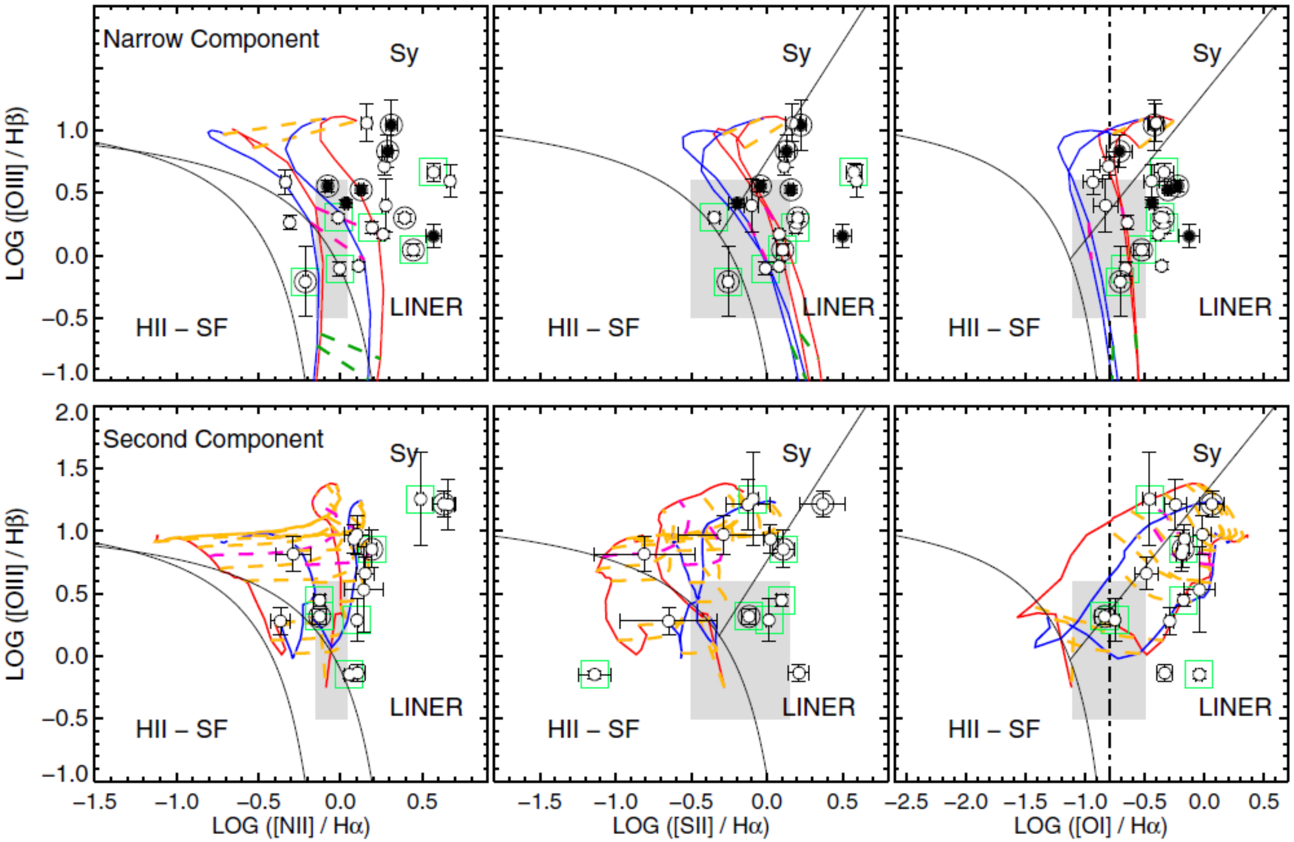
- Shock induced

(Dopita & Sutherland 1996, Aldrovandi & Contini, Kewley+2001, **Groves+2004**)

- Stellar Photoionization

(Terlevich, Melnick 1985, **Binette+1994**, Stasinska+2008, Sarzi+2010, Singh+2013, Papaderos+2013, Belfiore+2017, Byler+2019)

Cazzoli et al. (2008)



EXCELENCIA SEVERO OCHOA

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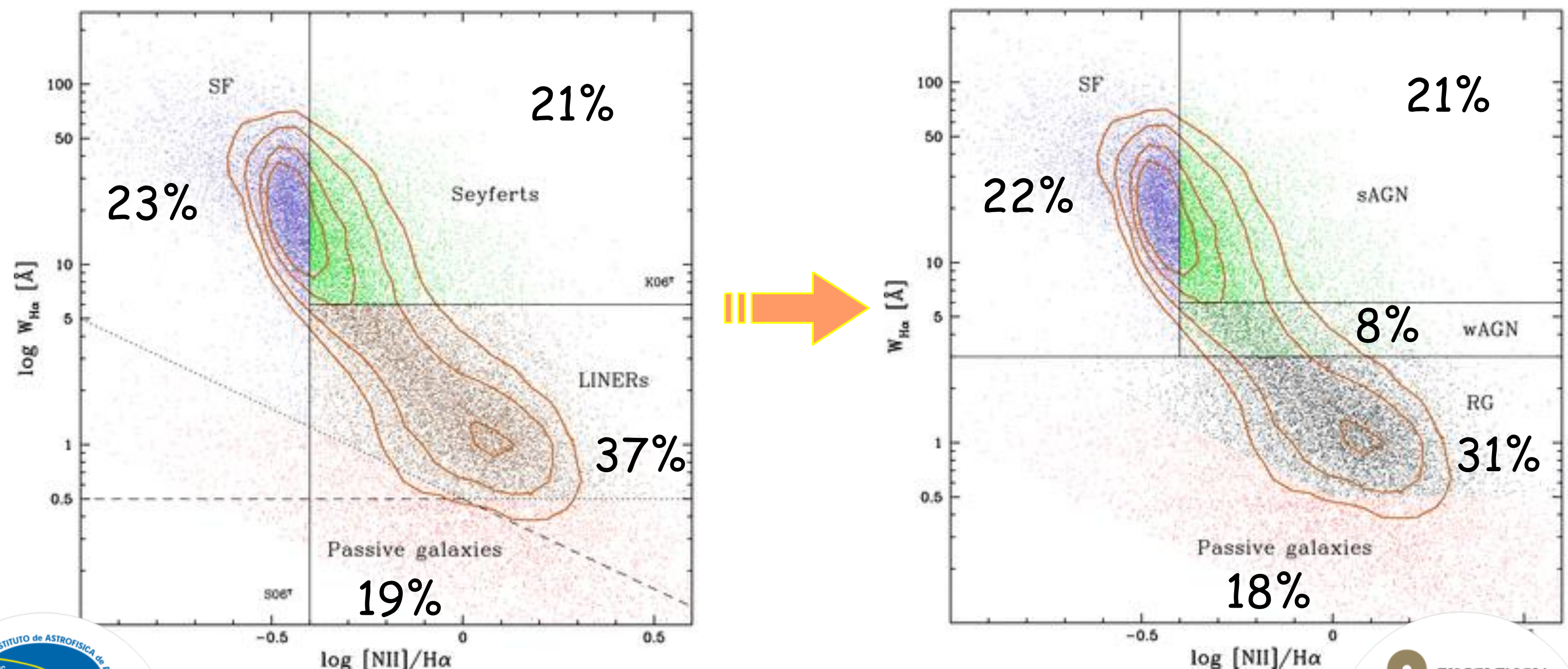
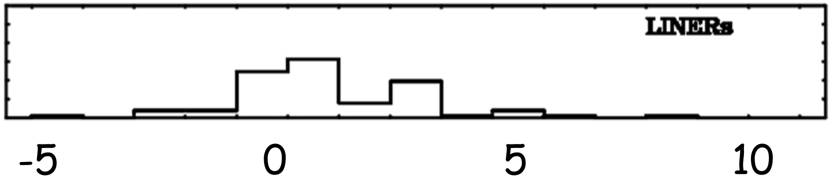
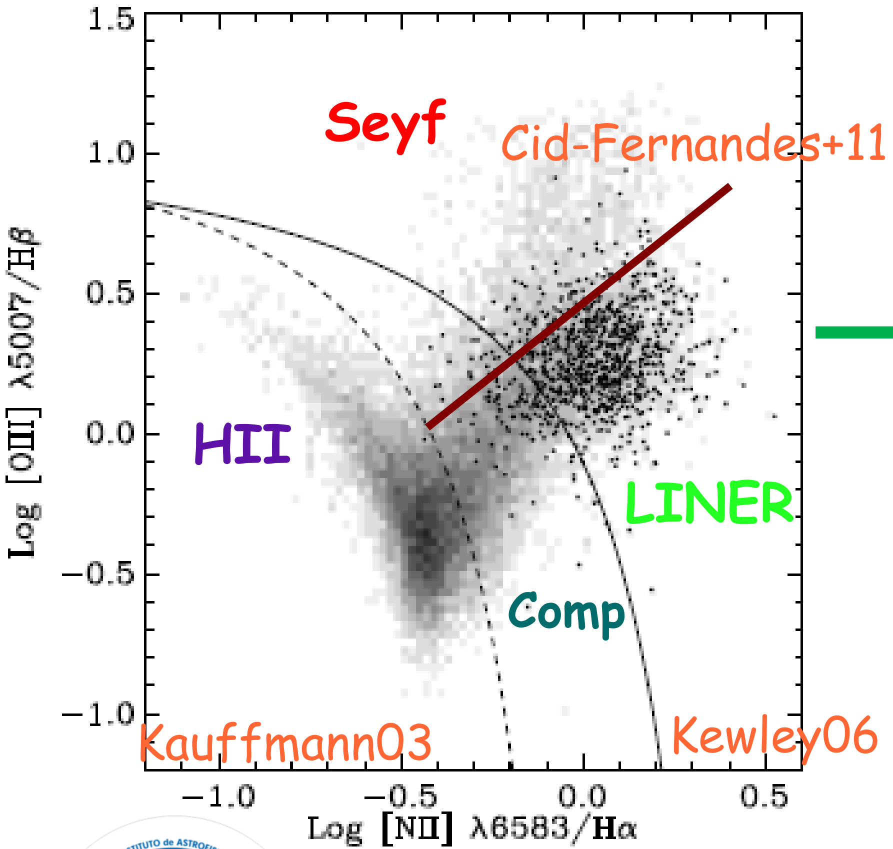
(Cid-Fernandes+2011)



MORPHOLOGY & ENVIRONMENT





SAMPLE: Palomar Sky Survey

LINERs:from E to Sb,

irrespective of the interaction class

(Márquez et al. 2010)

Passive red galaxies (0.09 < z < 0.1)

are mostly LINERs (color-cut selected)

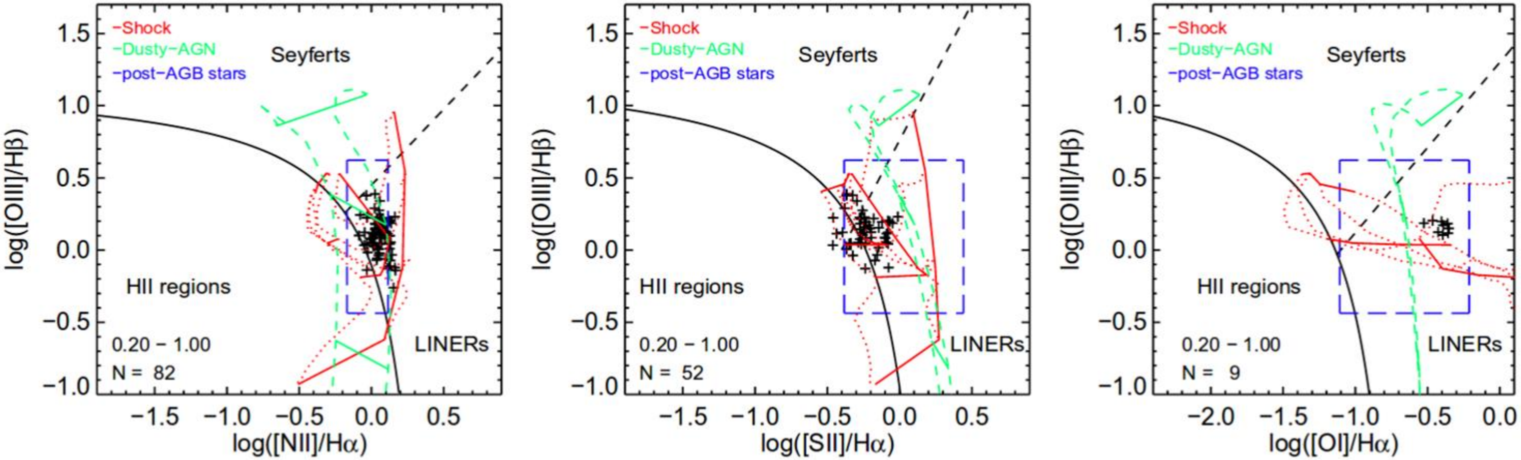
(Yan et al. 2012)

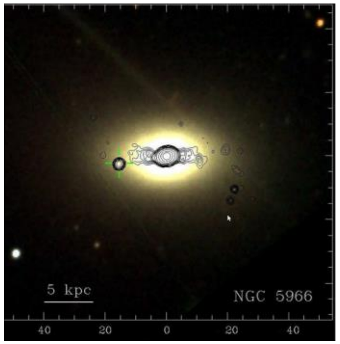
LINERs in lower density environments

(Coldwell et al. 2017)

LINERs older and redder

(Coldwell et al. 2018)

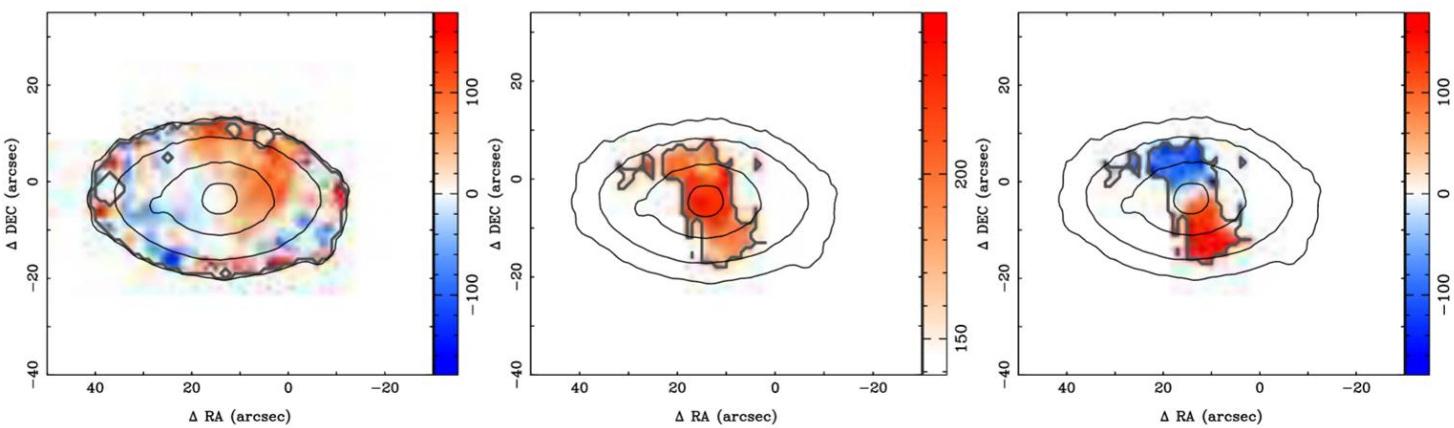




NGC 5966 (Kehrig+ 12)

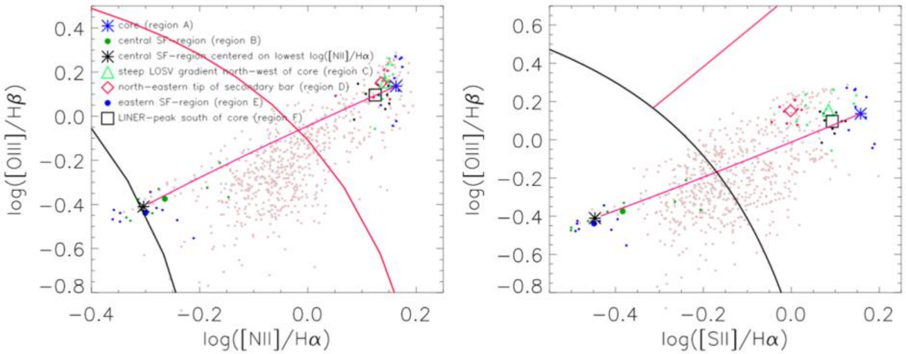
SB Kewley+01
Sy/LINER Kewley+06
Shock grid Allen+08
AGN phot. Groves+04
pAGB Binette+94

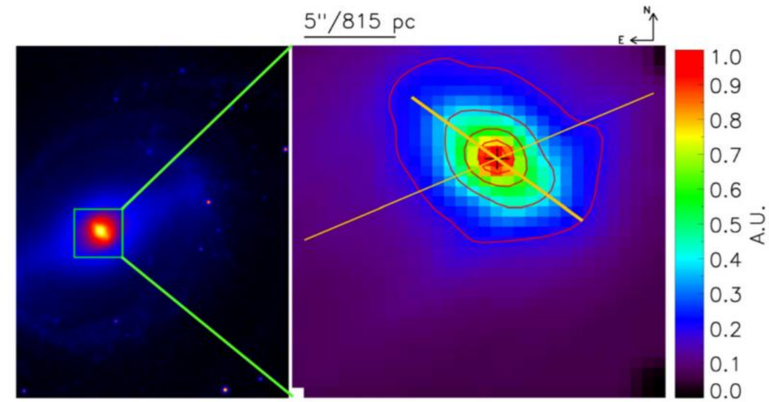
Vstars (km/s) σ(Hα) (km/s) v(Hα) (km/s)

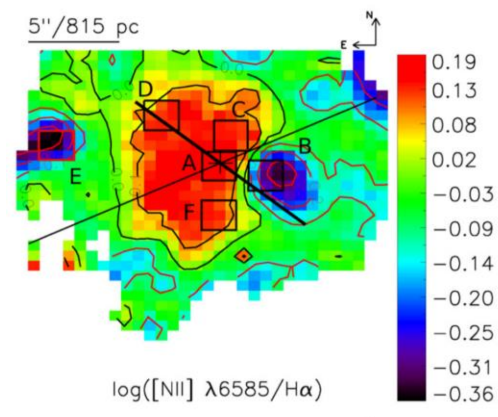


(see also Papaderos+12, Singh+ 13)

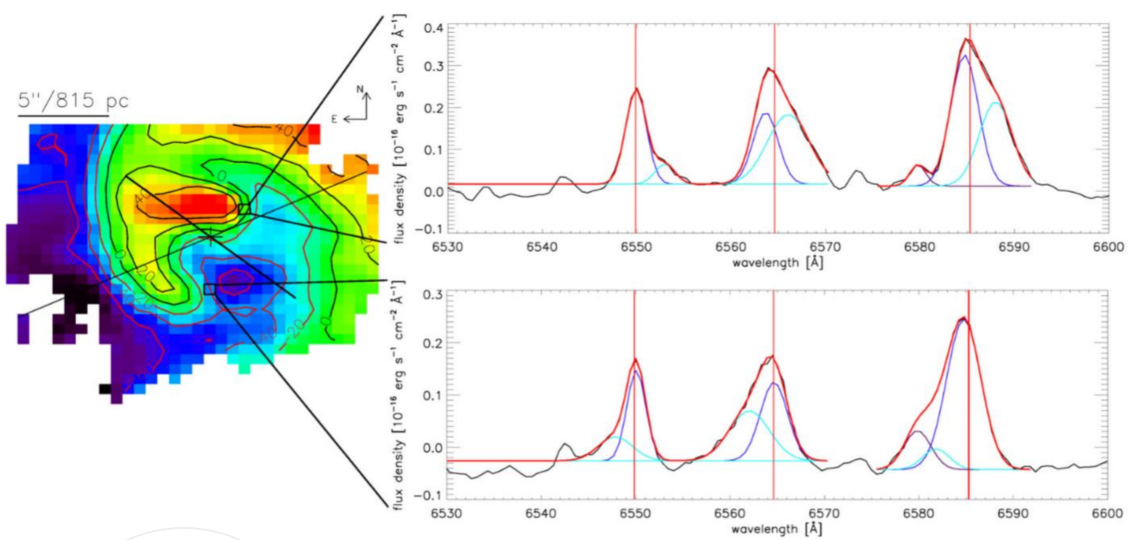
INTRODUCTION – LIERS (non-nuclear)







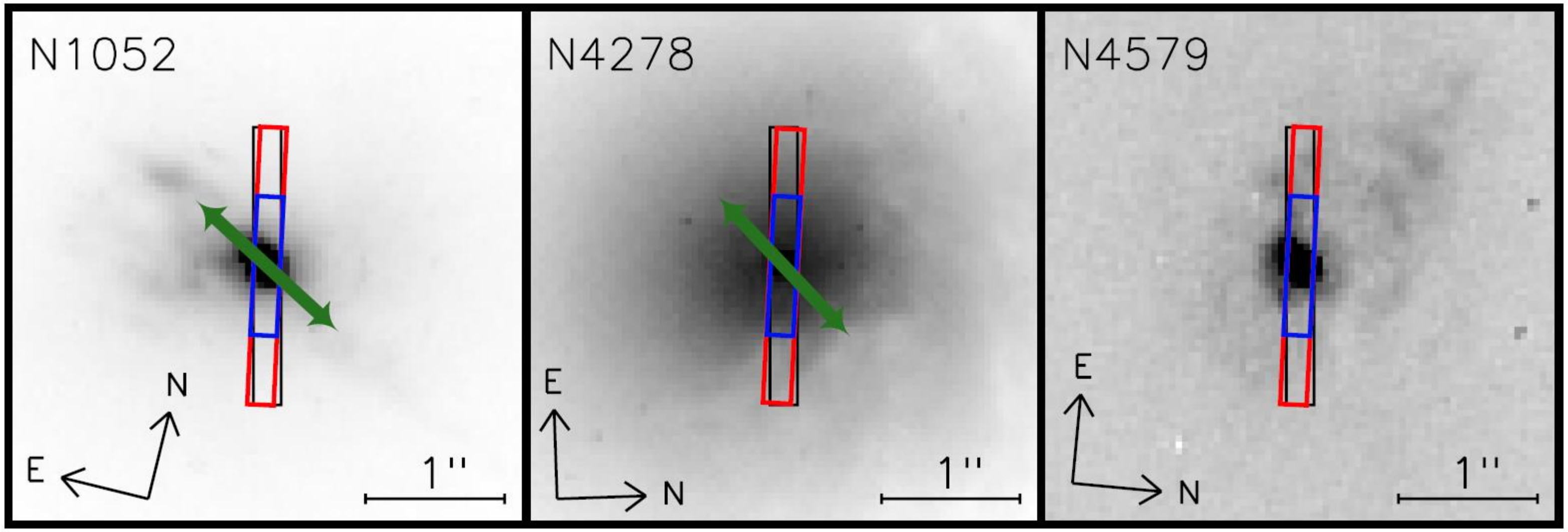
NGC 5850 (Bremer+ 13)



AGN-powered nucleus?

Line asymmetries

Non Stellar Photoionization, Shock induced, Stellar Photoionization



The shocking power sources of LINERS (Molina et al. 2018)

- *"The best model that best described the data comprises an AGN that photoionize the gas near the nucleus and shocks that ionize the gas at larger distances from the nucleus"*
- *"A single mechanism may not fully explain observed line strengths in LINER emission on scales of 100 ps or larger"*

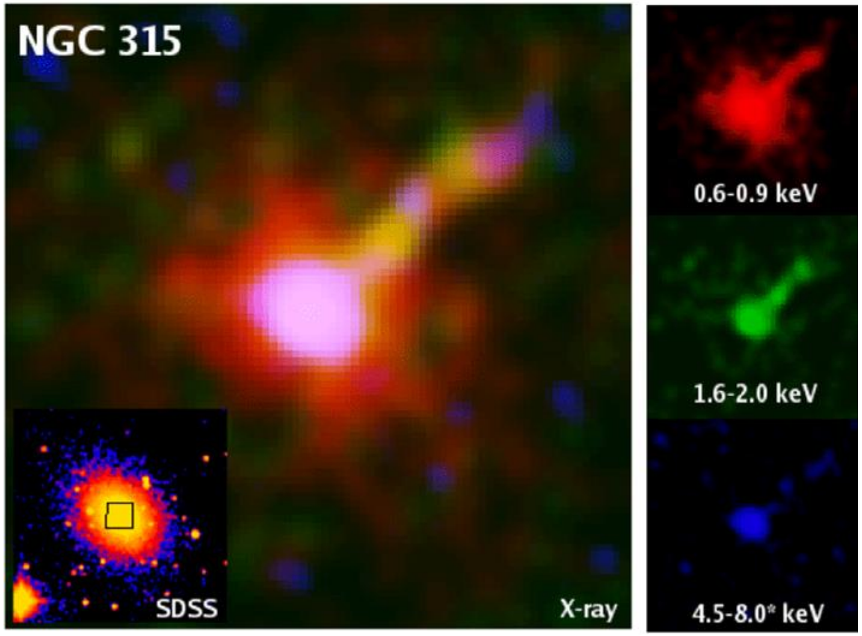
Important caveat: single-zone models, several mechanisms coexisting

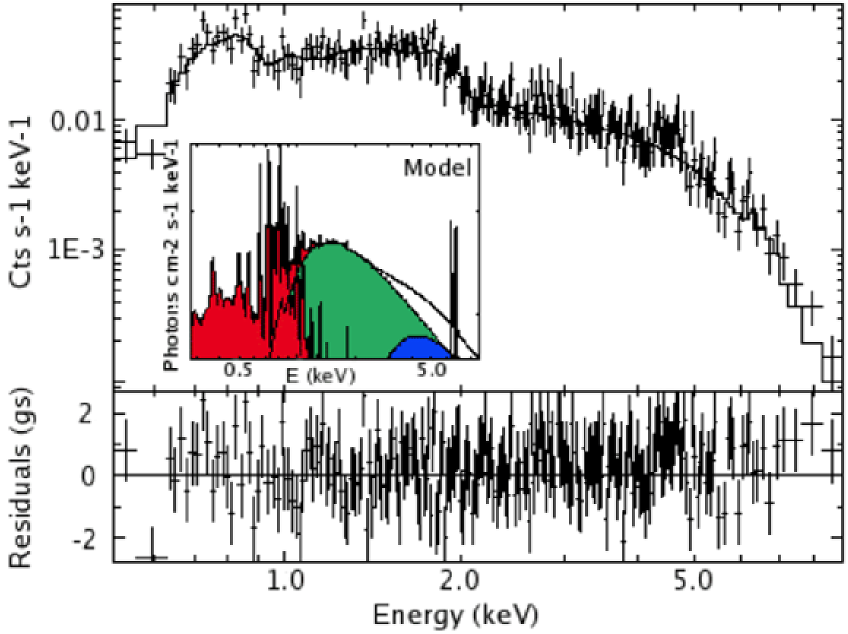
multi-zone & multi-process models needed

SAMPLE: from multi-λ catalogue of **476 LINERs** (Carrillo + 1999)

82 LINERs: **68** with *Chandra*, **54** with *XMM-Newton* (40 in common)

Gonzalez-Martín's PhD (González-Martín+2006a, 2009a, 2009b)





(González-Martín+2009a)

MEPL, two absorbers: Γ = 2.11 (σ =0.52), kT = 0.54 (σ =0.52)

log NH1 = 21.32 (σ =0.71), log NH2 = 21.93 (σ =1.36)

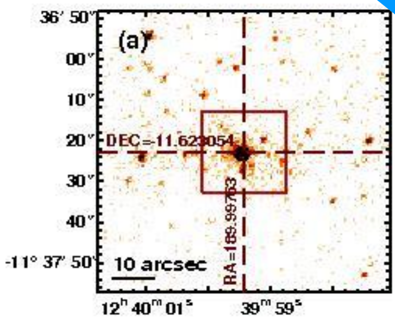
AGN LINERs – X-rays

AGN candidate: With a **point-like source at 4.5-8.0 keV**

Non-AGN candidate: Without point-like source at 4.5-8.0 keV

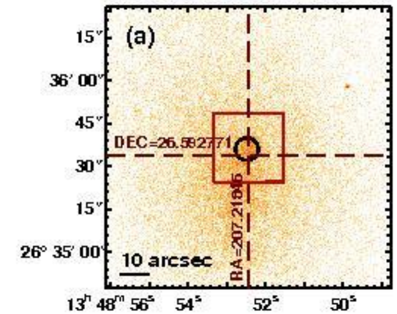
48/82

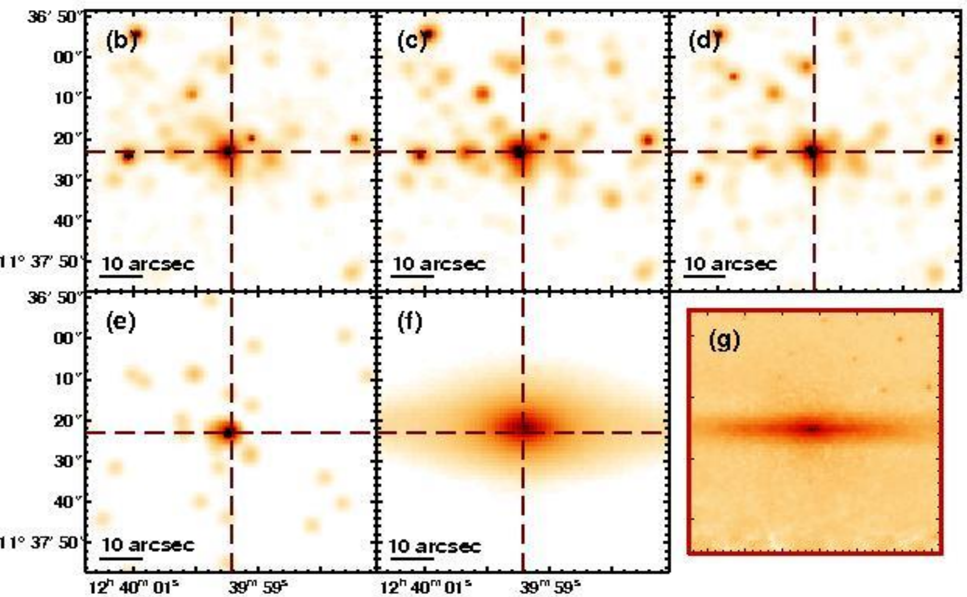
(60%)

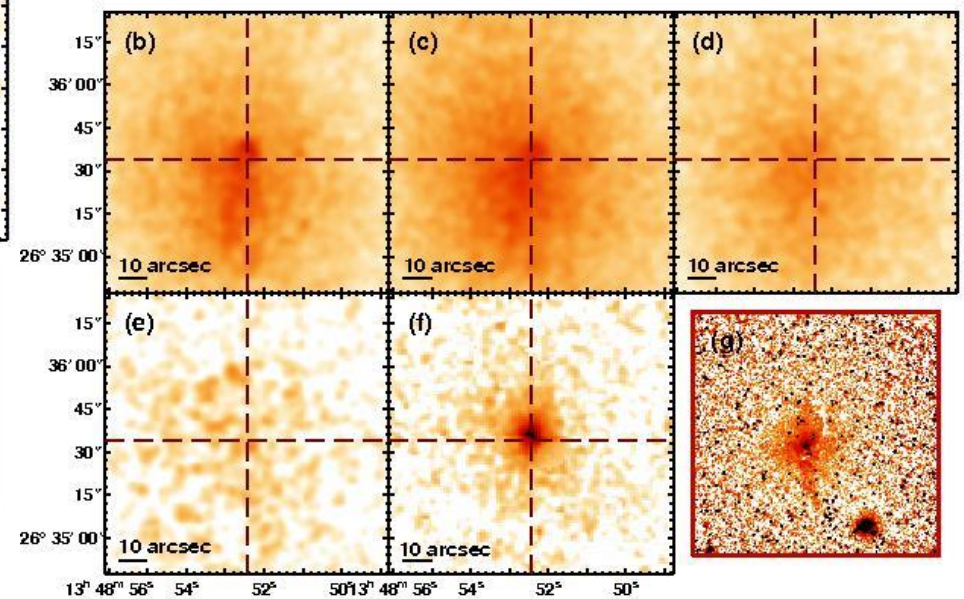


34/82

(40%)



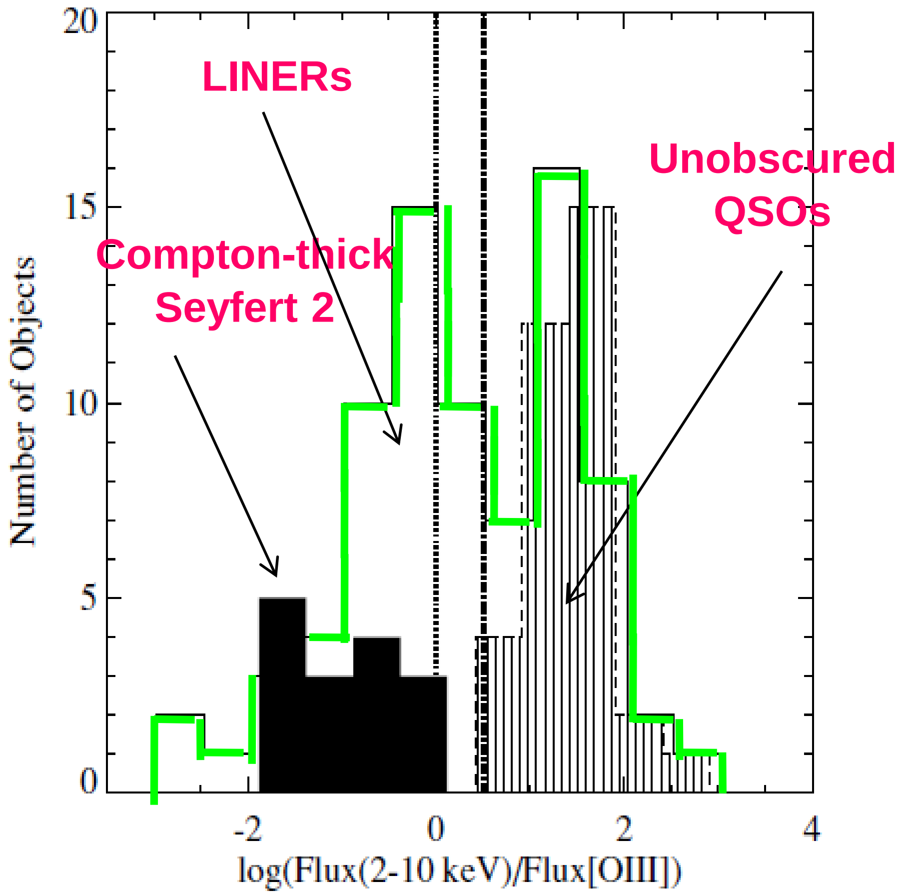




(González-Martín+2009a)

AGN candidates: 90% when including other wavelengths

Why LINERs are so Dim with M_BH of 10^8 - 10^9 Mo ?



Compton thick indicator

✓L([OIII])/L(2-10 keV)

LINERS: **<u>63%</u>** Compton-thick
(52/82)

Seyfert 2: **23%** Compton thick

(Panessa et al. 2006)

(González-Martín+2009b)

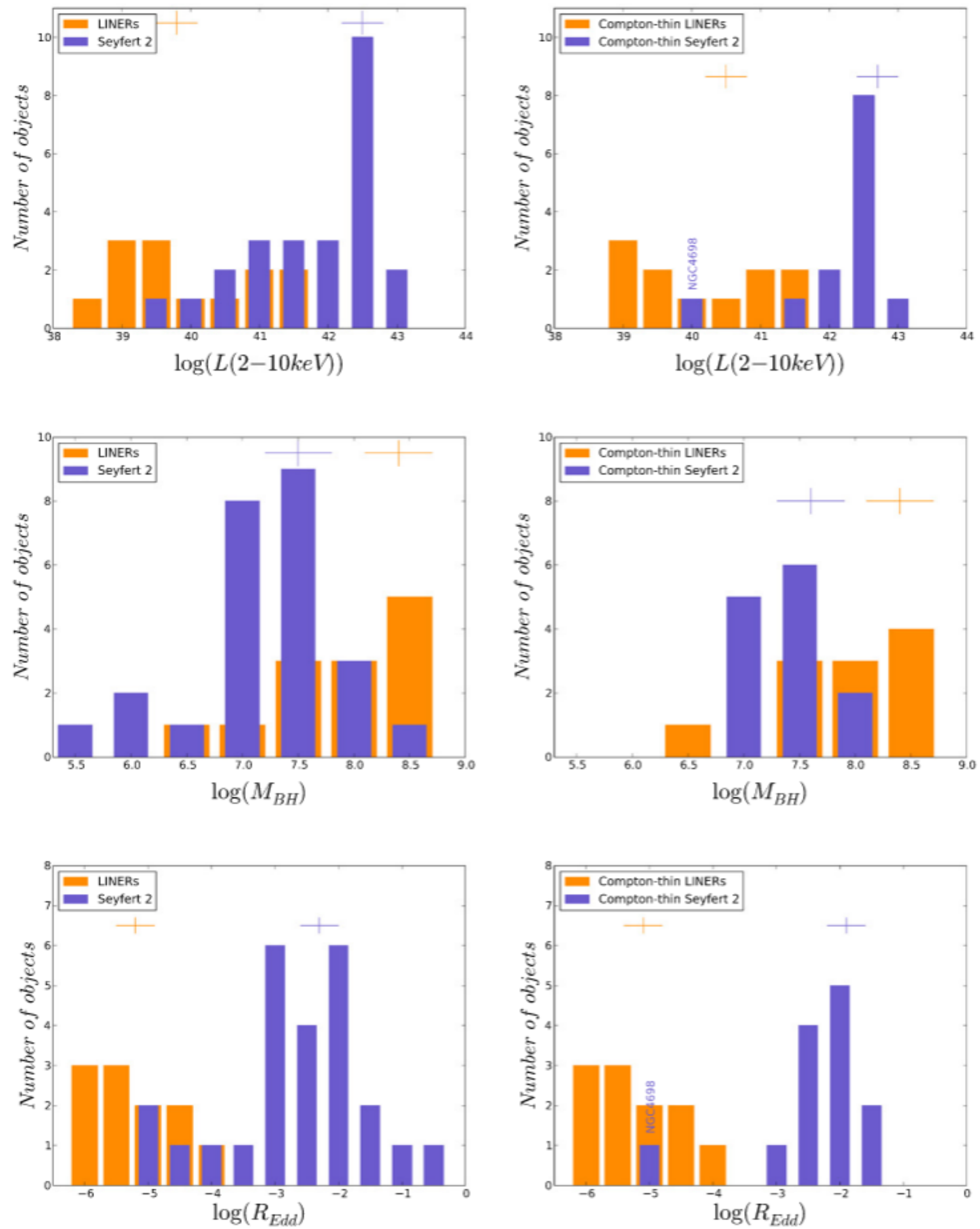
LINERS *versus* Seyfert 2s

LINERS have

- lower X-ray luminosities

- lower Eddington ratios

(Hernández-García+2016)



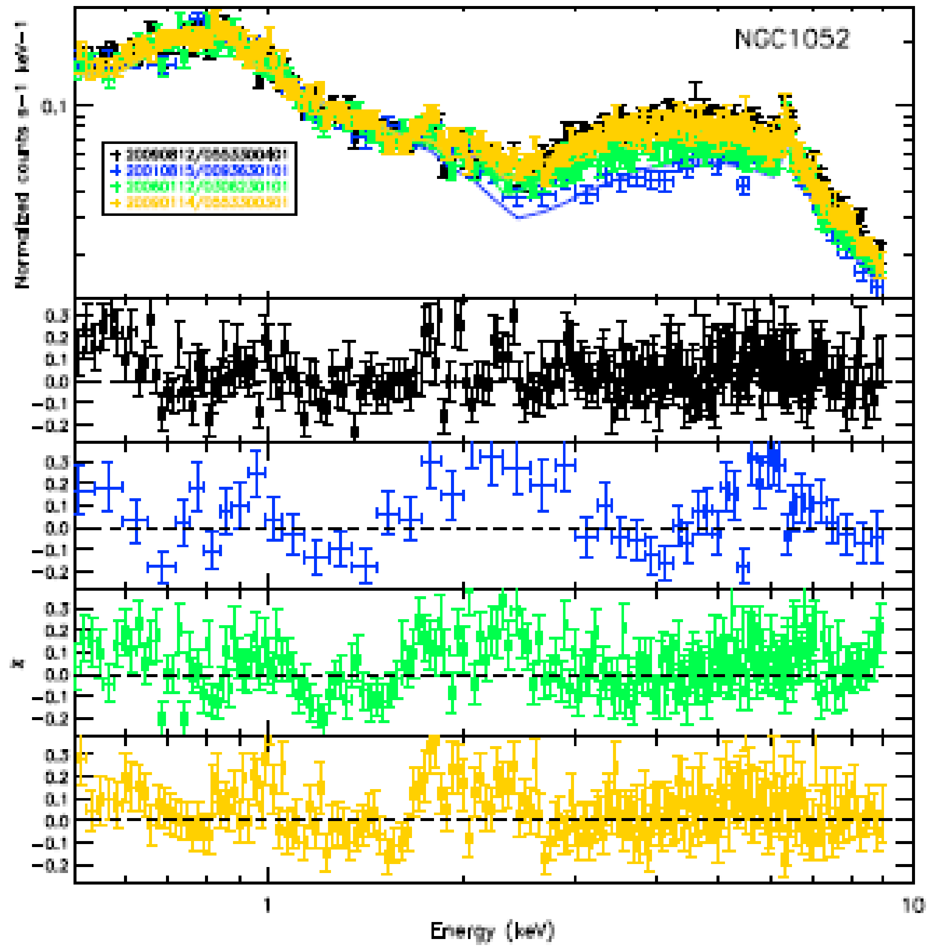
Sample: **17 AGN-LINERs** with multi-epoch XMM-Newton and/or Chandra obs

Long and short term variations studied **7 LINER1.8-1.9, 9 LINER2**

Model:

wabs[NHgal](zwabs[NH1]*mekal[kT,Norm1] + zwabs[NH2]*plaw[gamma,Norm2])

- No short-term variations
- 50% with long-term variations
- **Flux variations due to Norm2 and NH2** (one case)
- **Variable at UV**



(Hernández-García +2013, 2014, 2016)

LINERS *versus* Seyfert 2s

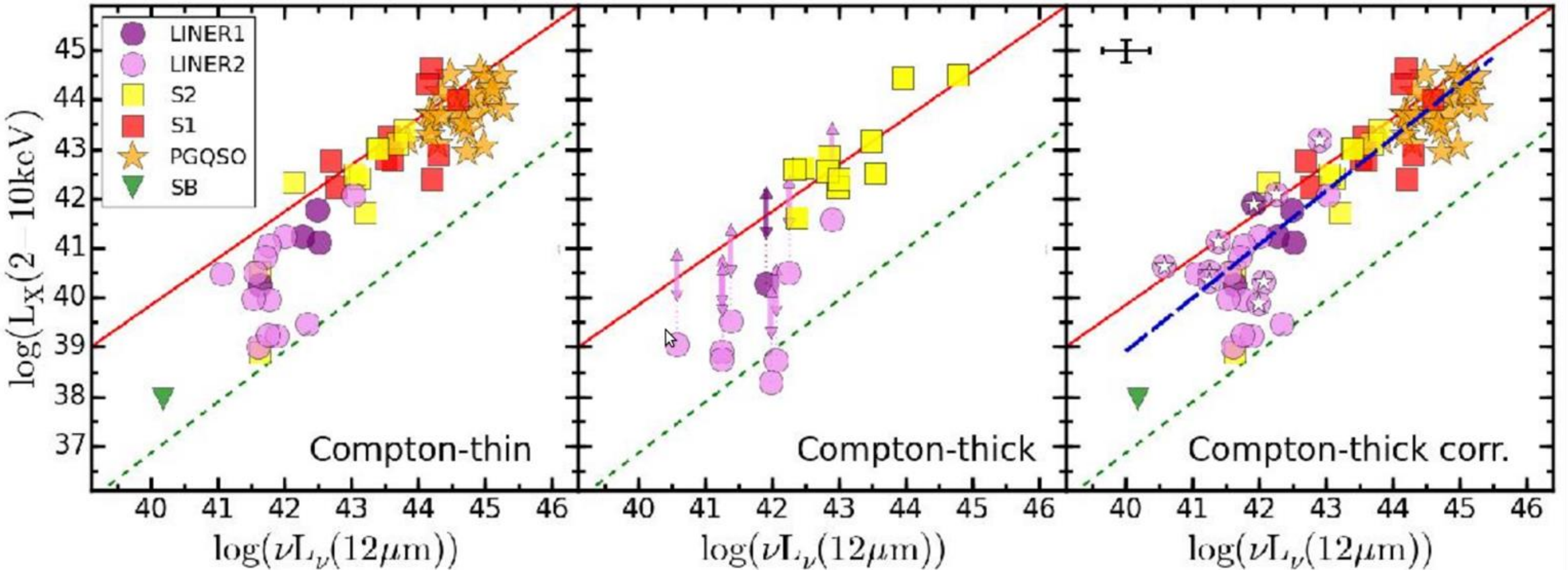
Variation due to **absorbers at hard X-ray** energies were much **more frequent in Seyfert 2s** than in LINERs

No LINER changing-look candidates were reported BUT SEE Frederick et al. 2019 !!

UV long-term variations were common in LINERs (not detected in Sey2)

	LINER	Seyfert 2
Short-tem var.	No	No
Long-term var.	Yes	Yes
Variable parameters	Norm2 (NH2 in one case)	Norm2 NH2
Long-term UV	Yes	No

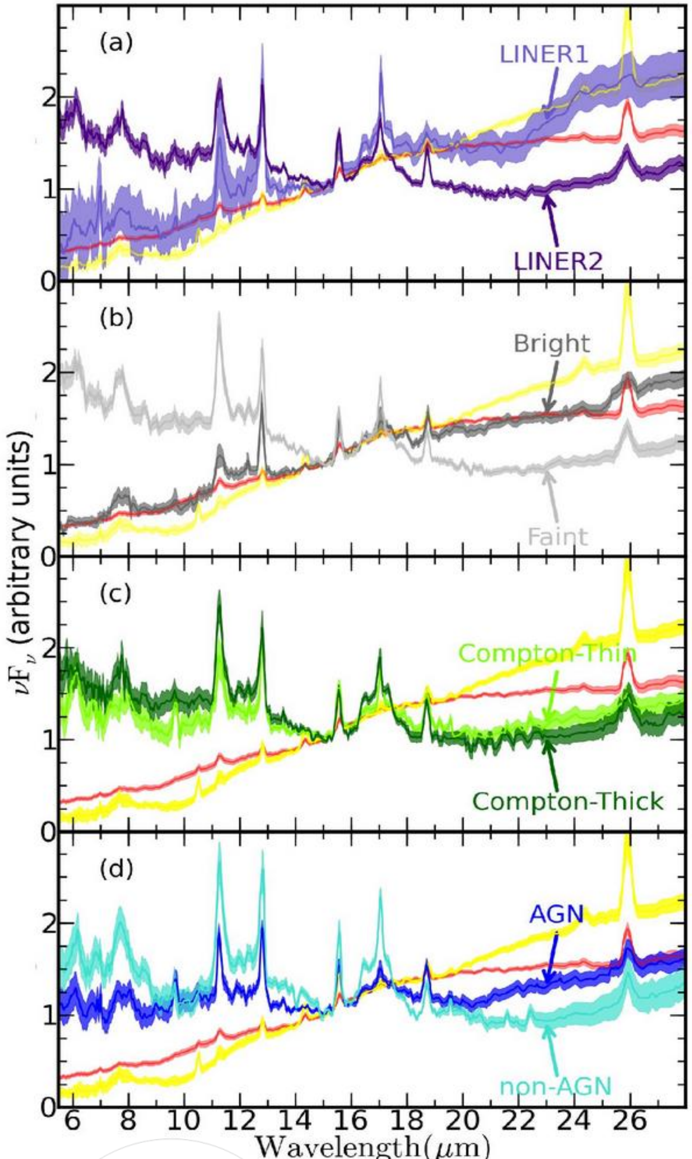
(Hernández-García+2016)



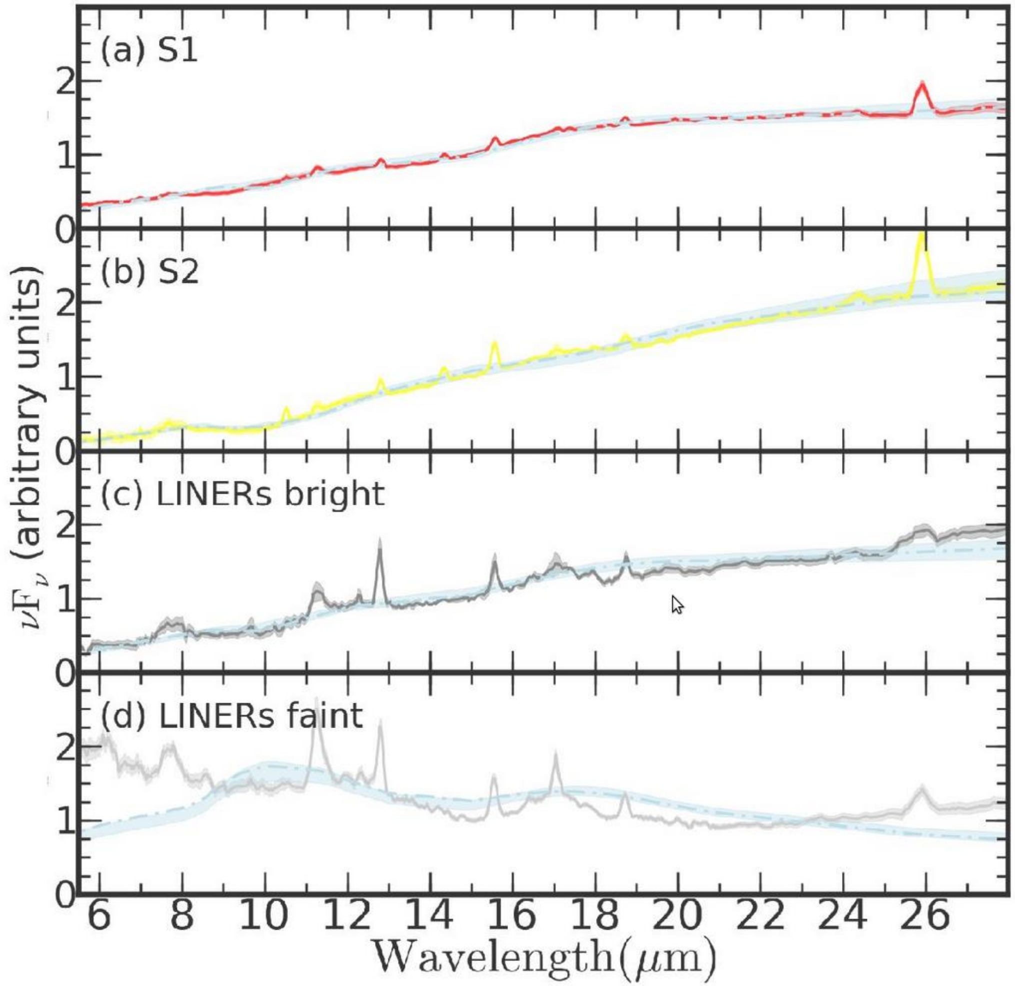
Asmus et al. (2011) correlation from high spatial resolution similar to ours (Spitzer/IRS spectra) suggests that **AGN contrib. may dominate**

(González-Martín et al. 2015)

AGN LINERs – MIR spectroscopy



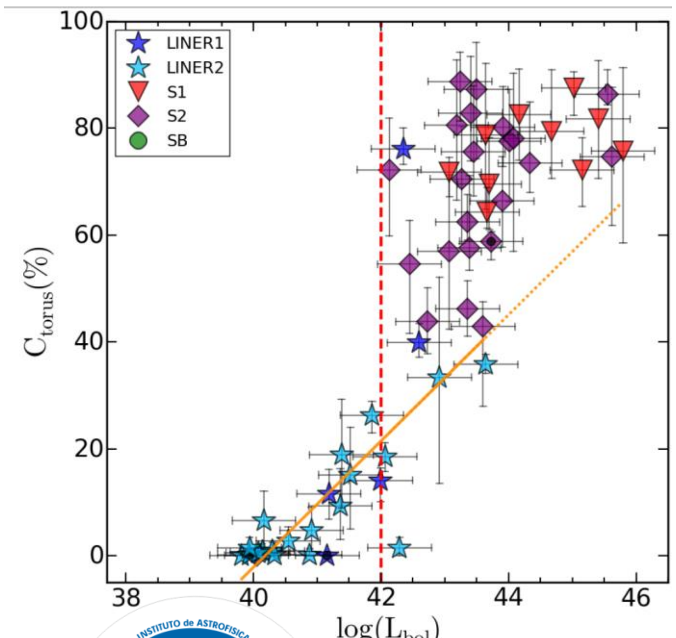
Bright LINERS L_X(2-10 keV) > 10^{41} erg/s

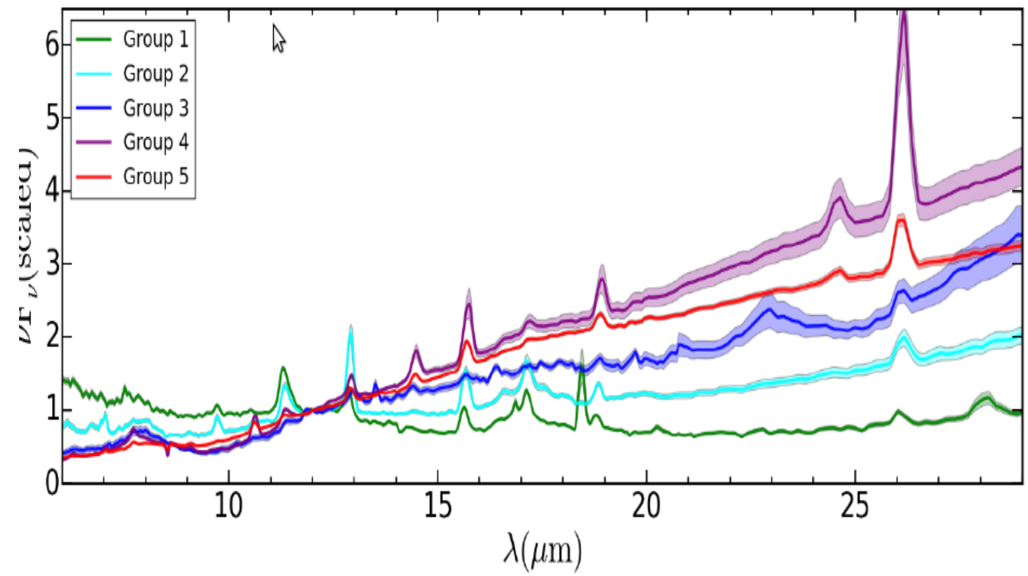


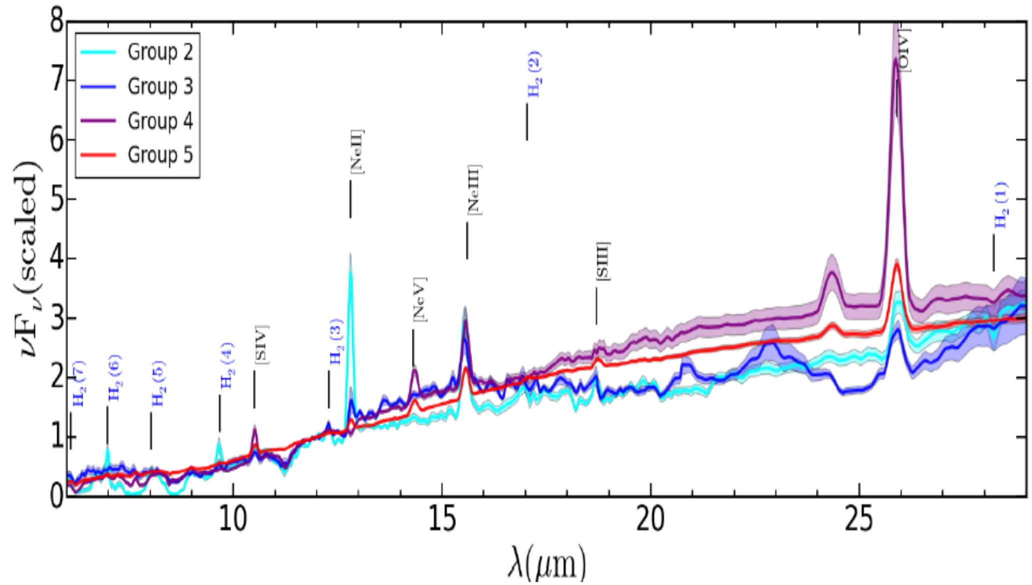
(González-Martín et al. 2015)

AGN LINERs – MIR spectroscopy

- Spec. decomp.: **torus, ISM, stellar**
- High resolution MIR images, Xray luminosity
- Affinity propagation method for **grouping**
- **LINERS in groups 1 and 2**
- Torus contribution negligible for **L_{BOL} ~ 10^{41} erg/s**







(González-Martín et al. 2017)

Hα HST imaging:

32 LINERs

Hα imaging of (multi-λ)

confirmed AGN

favours

core-halo

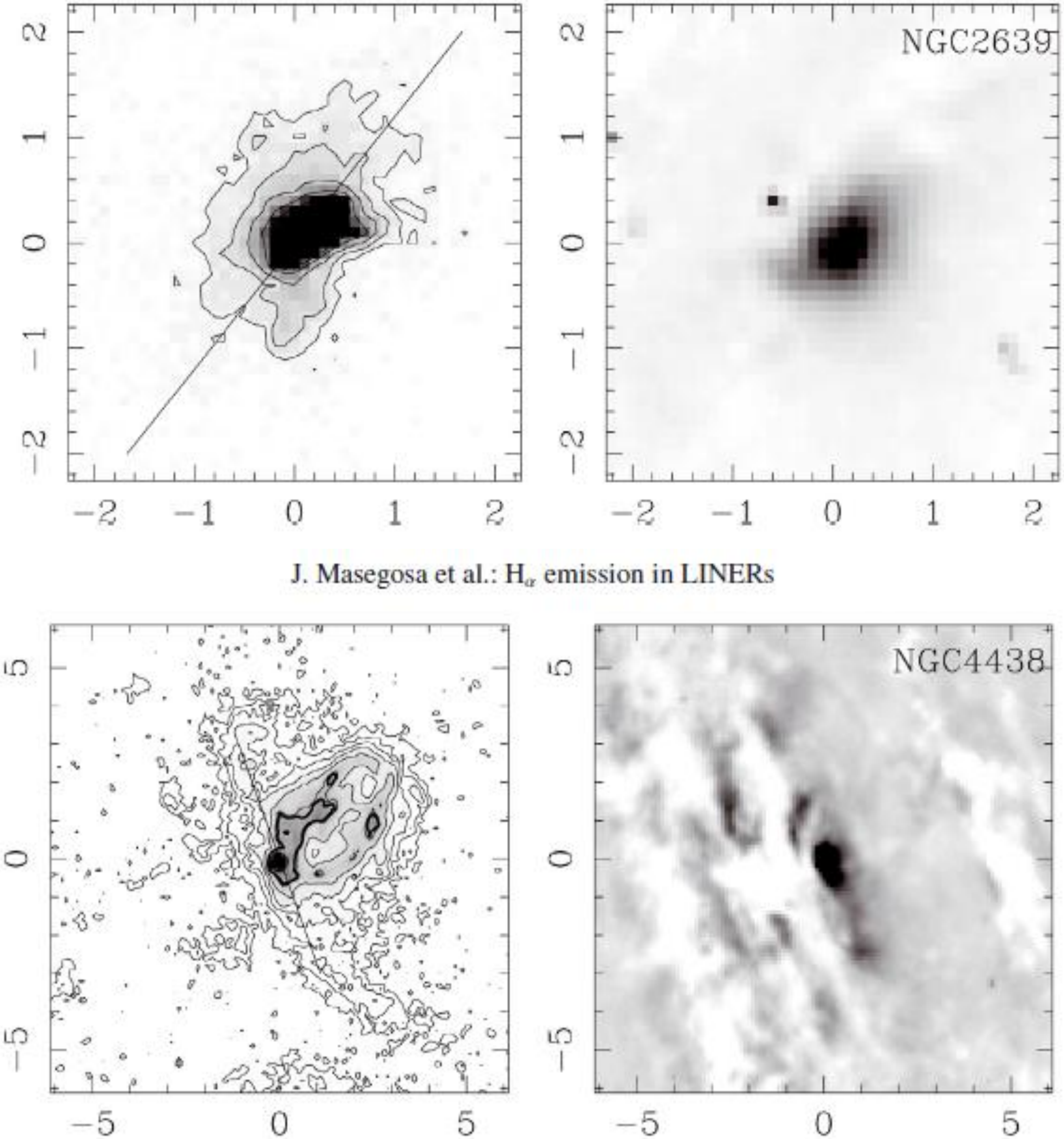
and

outflow

morphologies

(65%)

(Masegosa+2011)



AGN LINERs – The BLR in LINERs revisited. Outflows?

Optical spectroscopy of nearby LINERs:

Type 1 (1.9)……………………….….talk by **Sara Cazzoli** (IAA-CSIC)

Type 2…………………………………..talk by **Laura Hermosa** (IAA-CSIC)

STIS HST versus ground-based

Spectral decomposition in several kinematic components

Very broad Hα lines? Always?

Other components, outflows?

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CONCLUSIONS

X-rays:

60%-90% AGN

Compton-thickness

Comparison with Sey2 properties and variability

MIR spectroscopy:

Bright LINERs similar to Sey2

Torus contribution negligible $L_{BOL} \sim 10^{41}$ erg/s

HST Hα imaging:

Outflow/core-halo morphologies

BLR in LINERs 1.9 revisited:

....

Most luminous LINERs @ z = 0.04 – 0.11

Local LINERs are hosted by **massive and old early-type galaxies**, with **low extinctions, massive SMBHs, old stellar populations**, and **little or no star-formation**

- MLLINERs studied in this work have:

all morphologies, higher extinctions, much higher SFRs

- This kind of LINERs first detected @ z ~ 0.3

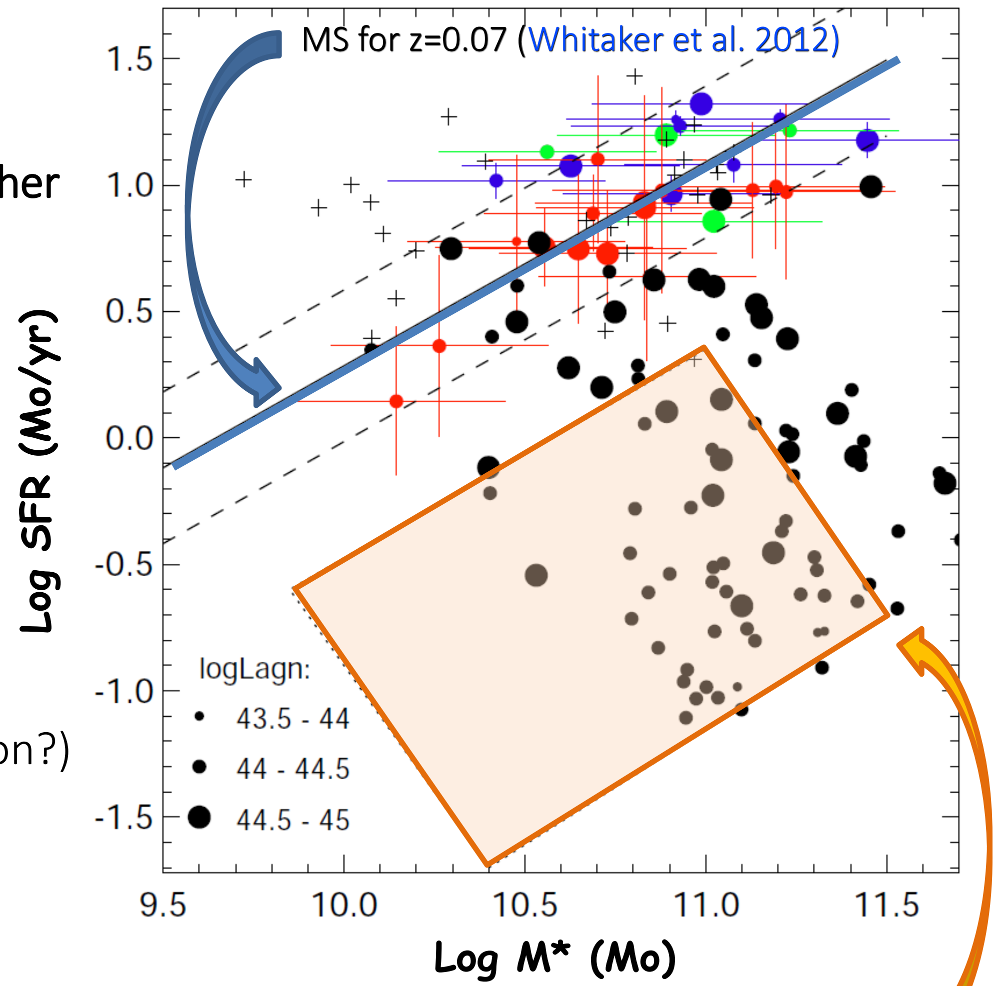
their existence **confirmed in the local universe** (@z = 0.04 – 0.11) **so ~~evolutionary scenario~~**

- Same M*, SFRs, and LAGN at both redshifts

- They lie **along the LAGN = LSF line** (co-evolution?)

- Most of them lie on the MS of SF galaxies, with M* > 10^{10}Mo

- The **fraction of LINERs on the MS depends on their AGN luminosity**



> 60% of all low-redshift LINERs (Leslie et al. 2016)

(Povic et al. 2016)