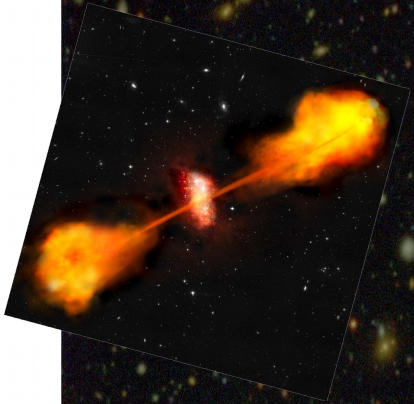
Star formation and AGN activity in the most luminous LINERs in the local universe



Mirjana Pović

Ethiopian Space Science and Technology Institute (EORC-ESSTI), Ethiopia

&

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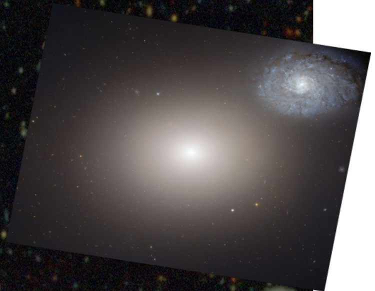

SFDE17: from Local Clouds to Distant Galaxies,
06 - 12 of August, 2017, Quy Nhon, Vietnam

Star formation and AGN activity in the most luminous LINERs in the local universe

Pović et al. 2016, MNRAS, 462, 2878

In collaboration with:

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Raanan Nordon (Tel Aviv University, Israel)
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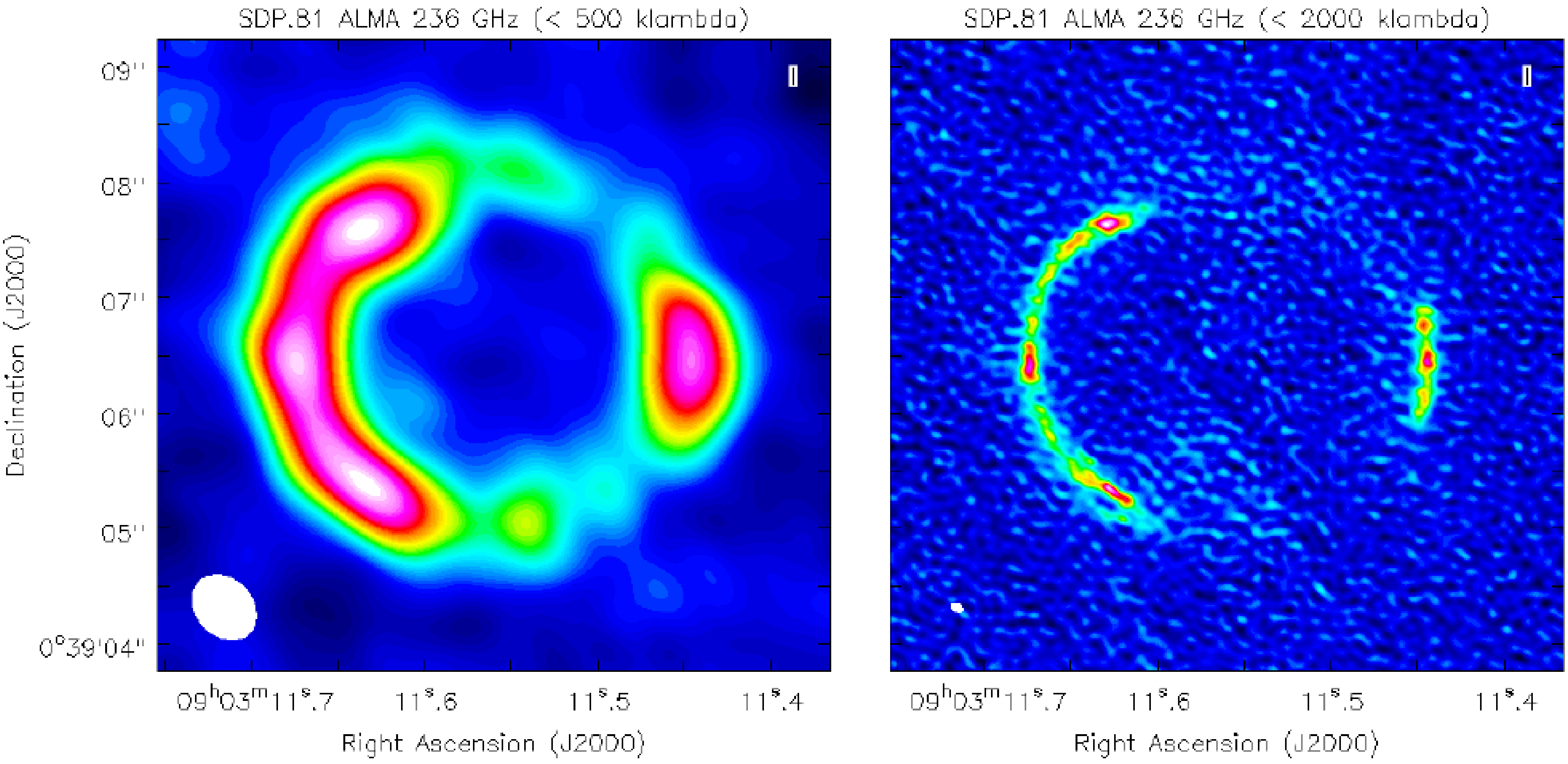
ALMA image of the continuum emision at 236 GHz of SDP 81



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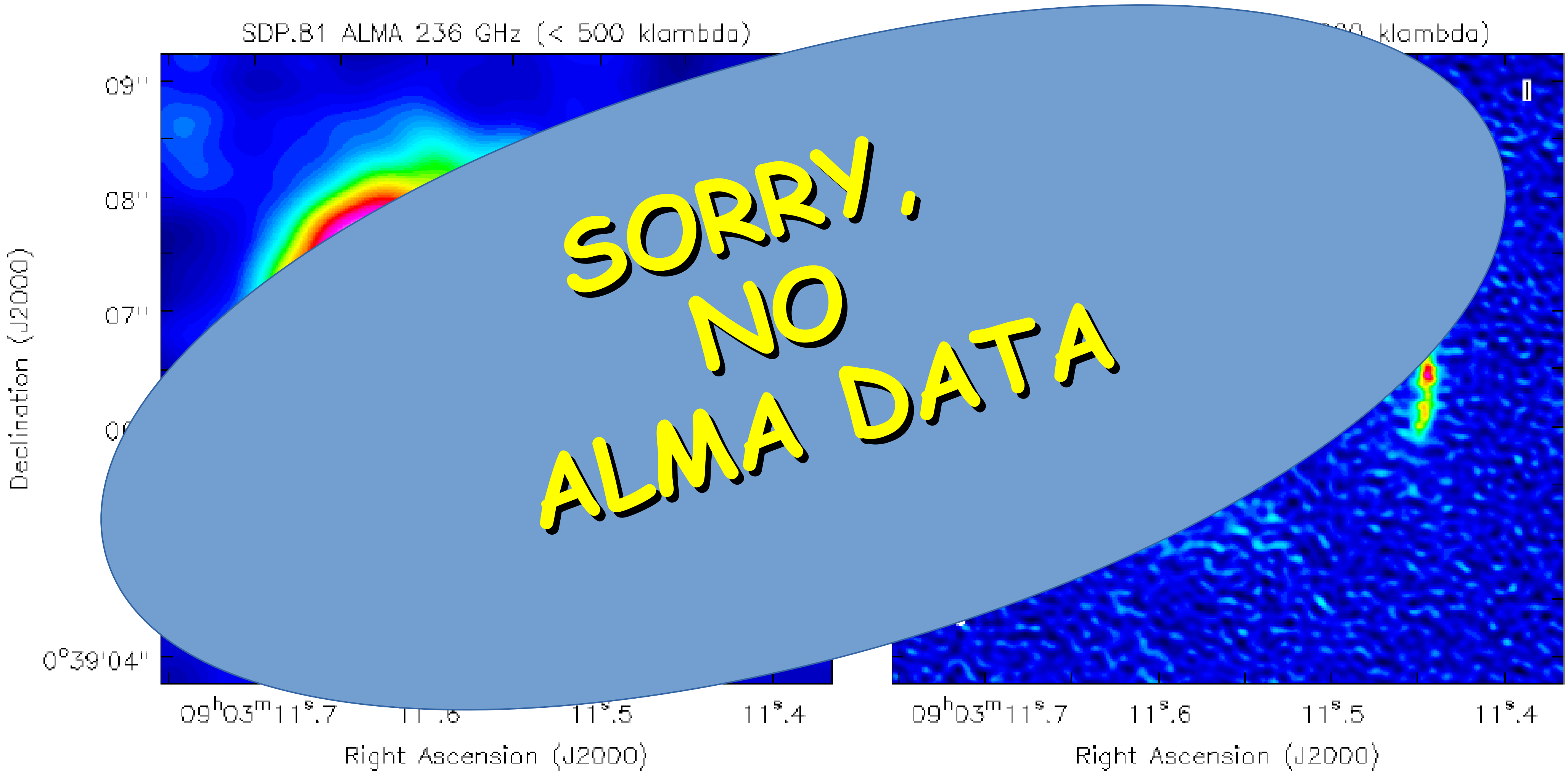


Introduction: LINERs

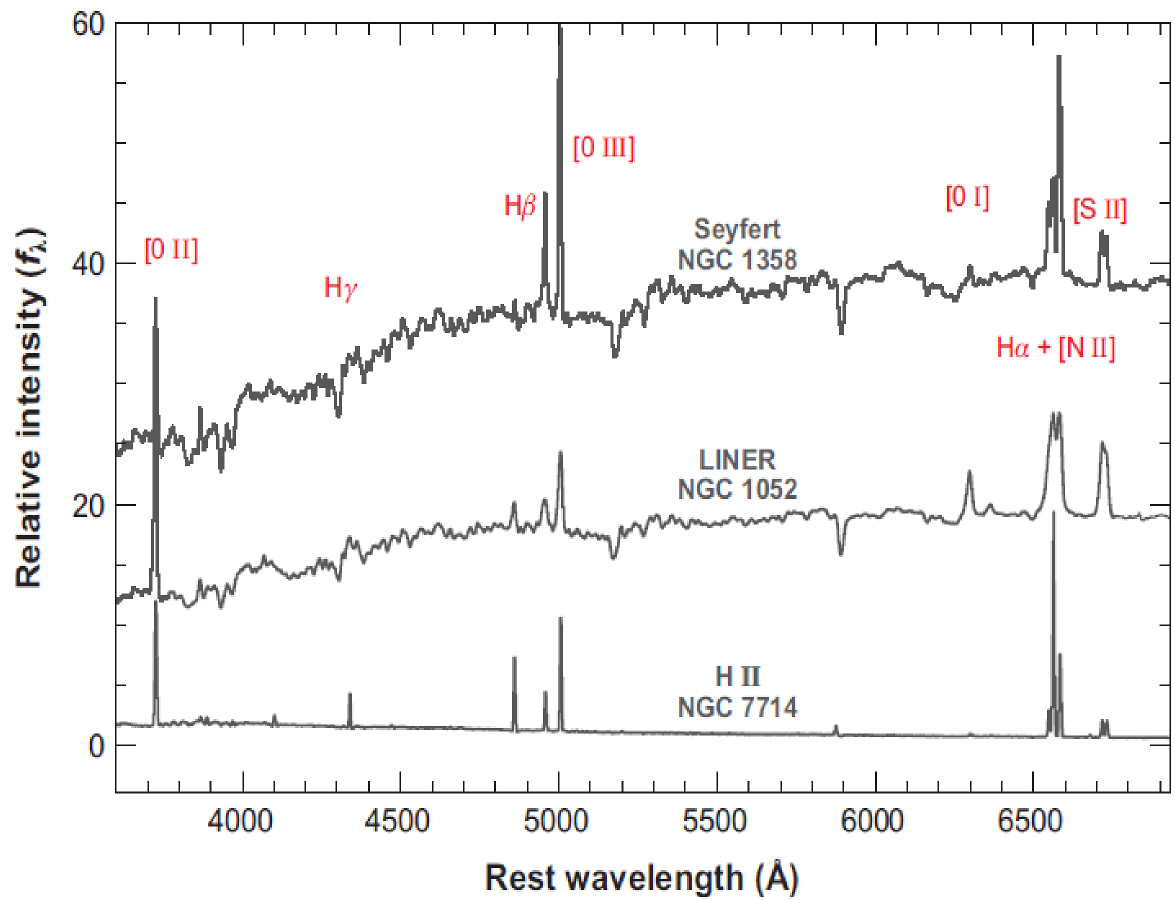
LINERs = Low Ionization Nuclear Emission-line Regions

Spectral Classification (Heckman 1980)

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

- Early-type galaxies

- Lower luminosities than Seyferts



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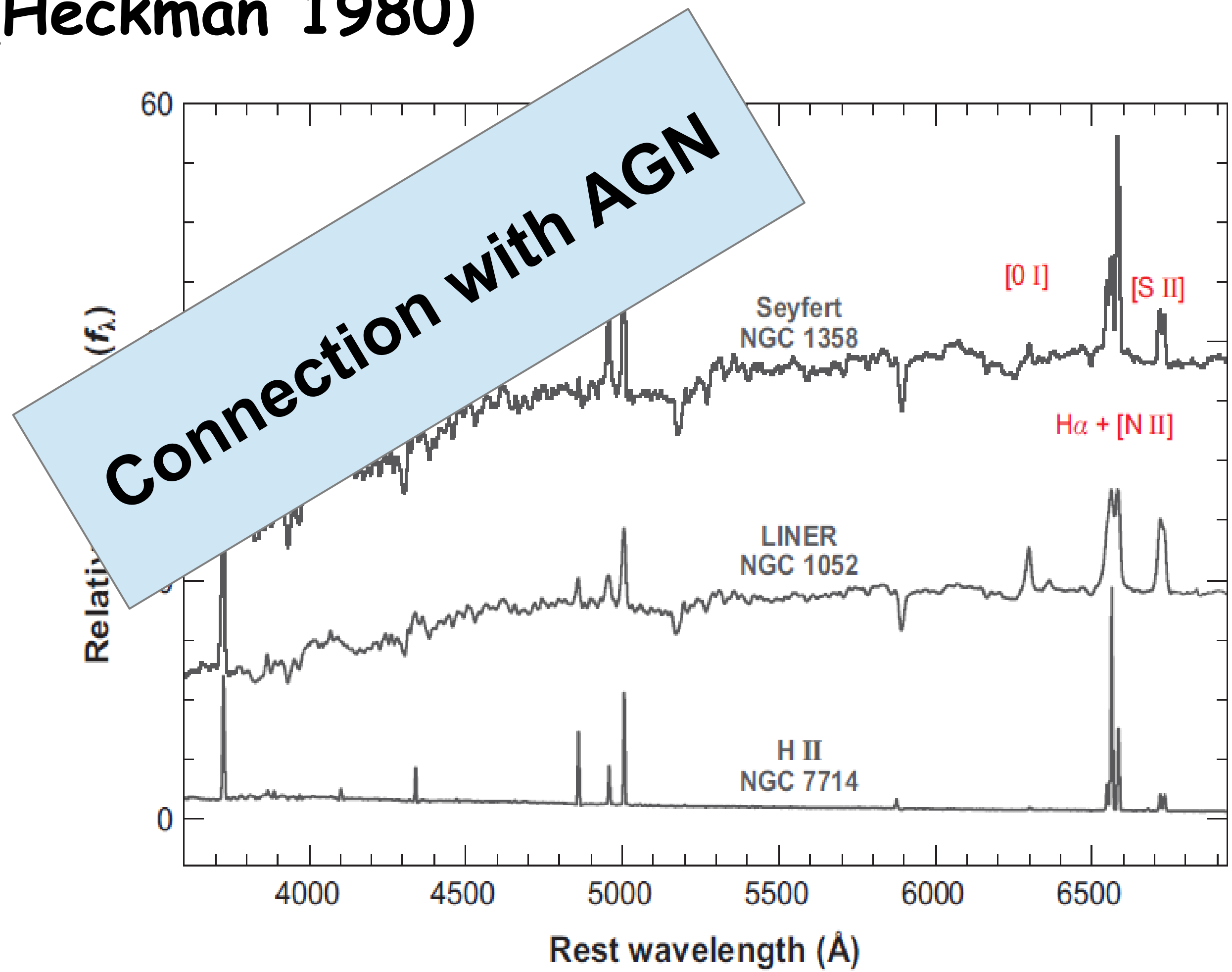


Introduction: AGN properties

AGN (Active Galactic Nuclei) :

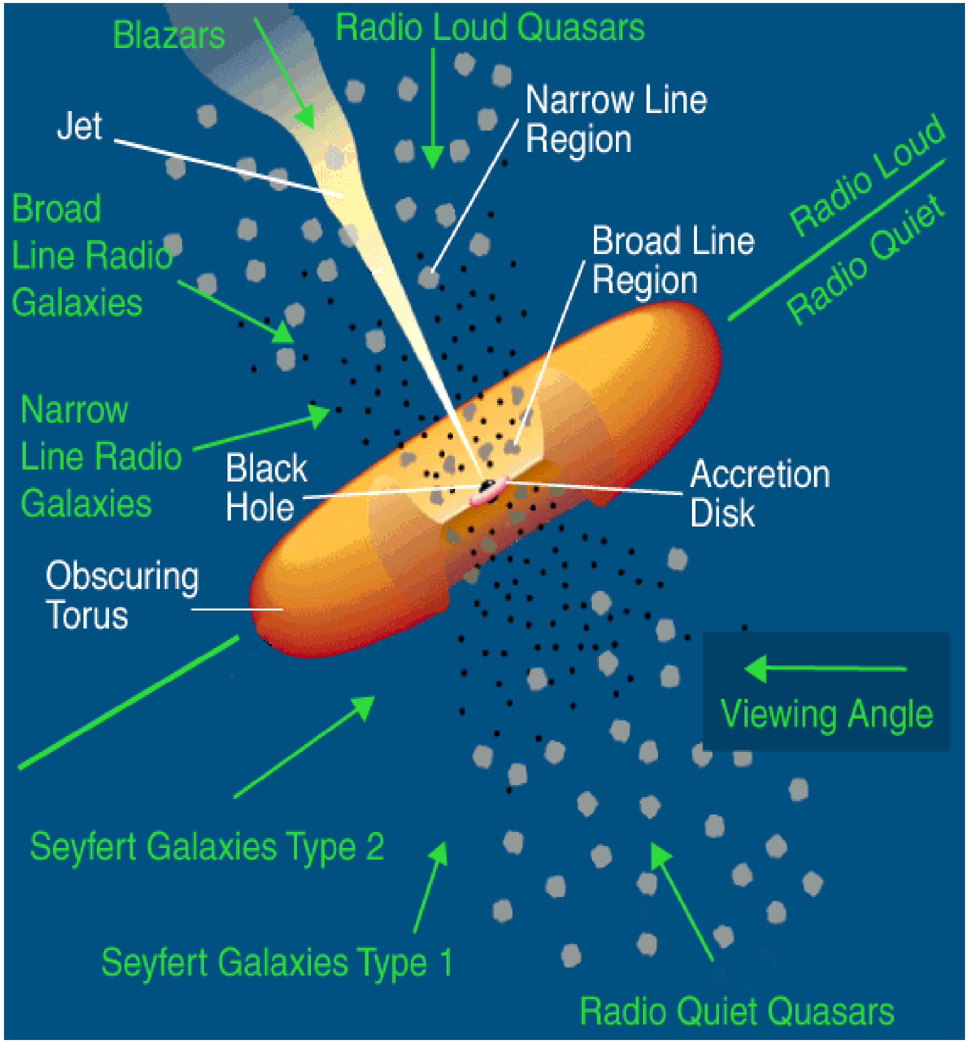
- high luminosities
- very compact regions
- usually temporaly variable (from hours to years)
- more efficient energy/mass than normal stellar processes (Fabian 79)

How normal galaxy becomes active?

Connection between active and non-active nuclei?

Fundamental for understanding the picture of galaxy formation and evolution.

Unification scheme due to orientation: Urry and Padovany (1995)



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1. High Luminosity AGNs (HLAGN):

$L > 10^{43}$ erg/sec

2. Low luminosity AGNs (LLAGN):

- $L \sim 10^{42} - 10^{43}$ erg/sec
- most of AGN population
- eventual connection active/non-active nuclei

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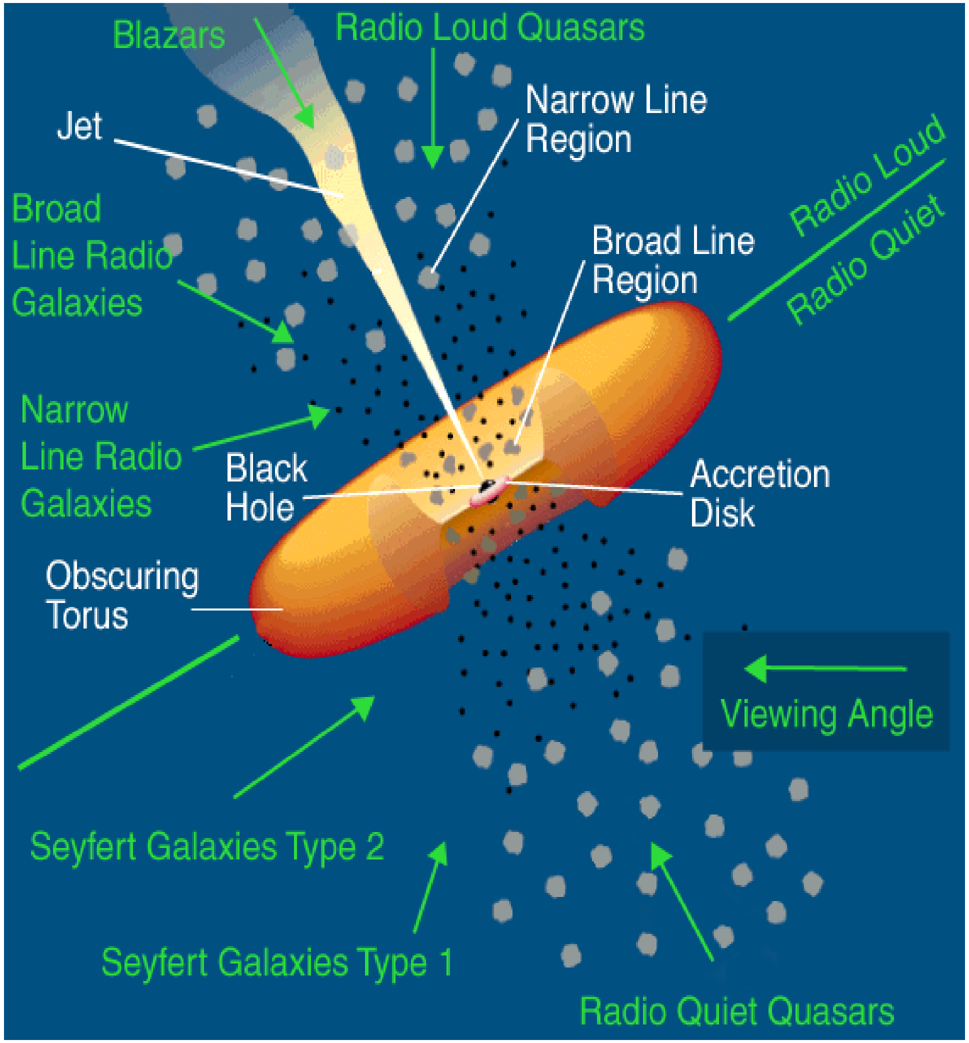

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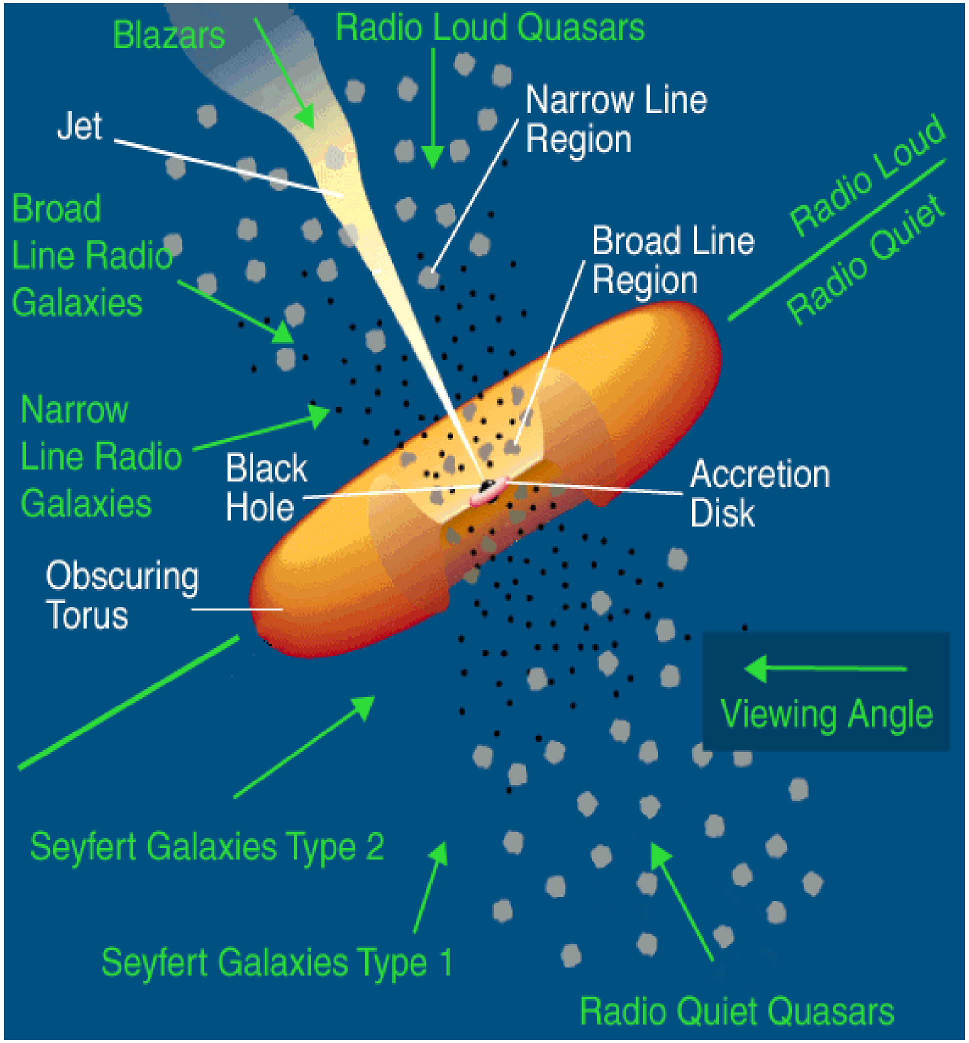

BUT, difficult detection due to extinction and contamination by circumnuclear star formation.

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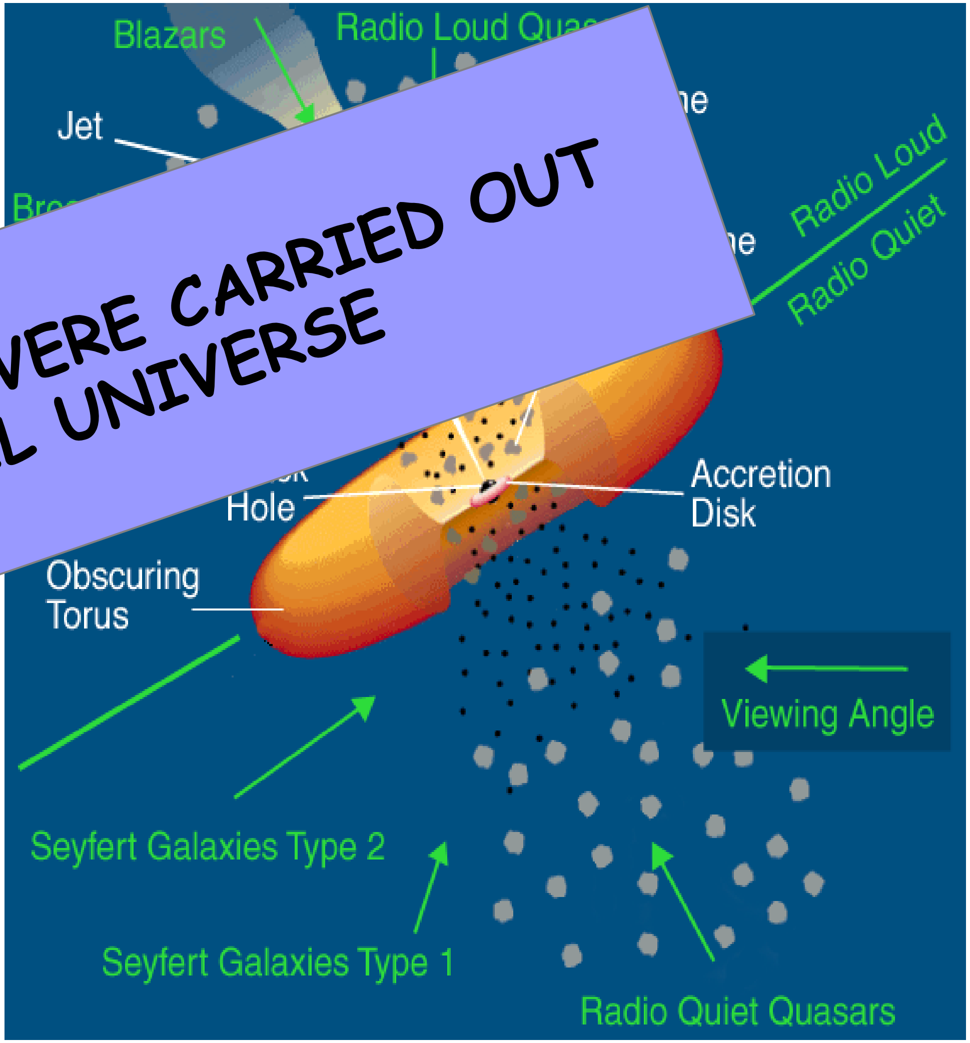

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L > $10^{4\ 3}$

2. ... **ON):**
... y/sec
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MOST OF LINERs STUDIES WERE CARRIED OUT ONLY IN THE LOCAL UNIVERSE

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

Introduction: AGN properties

From previous studies in the local universe:

(Heckman & Best 2014 review, and references therein)

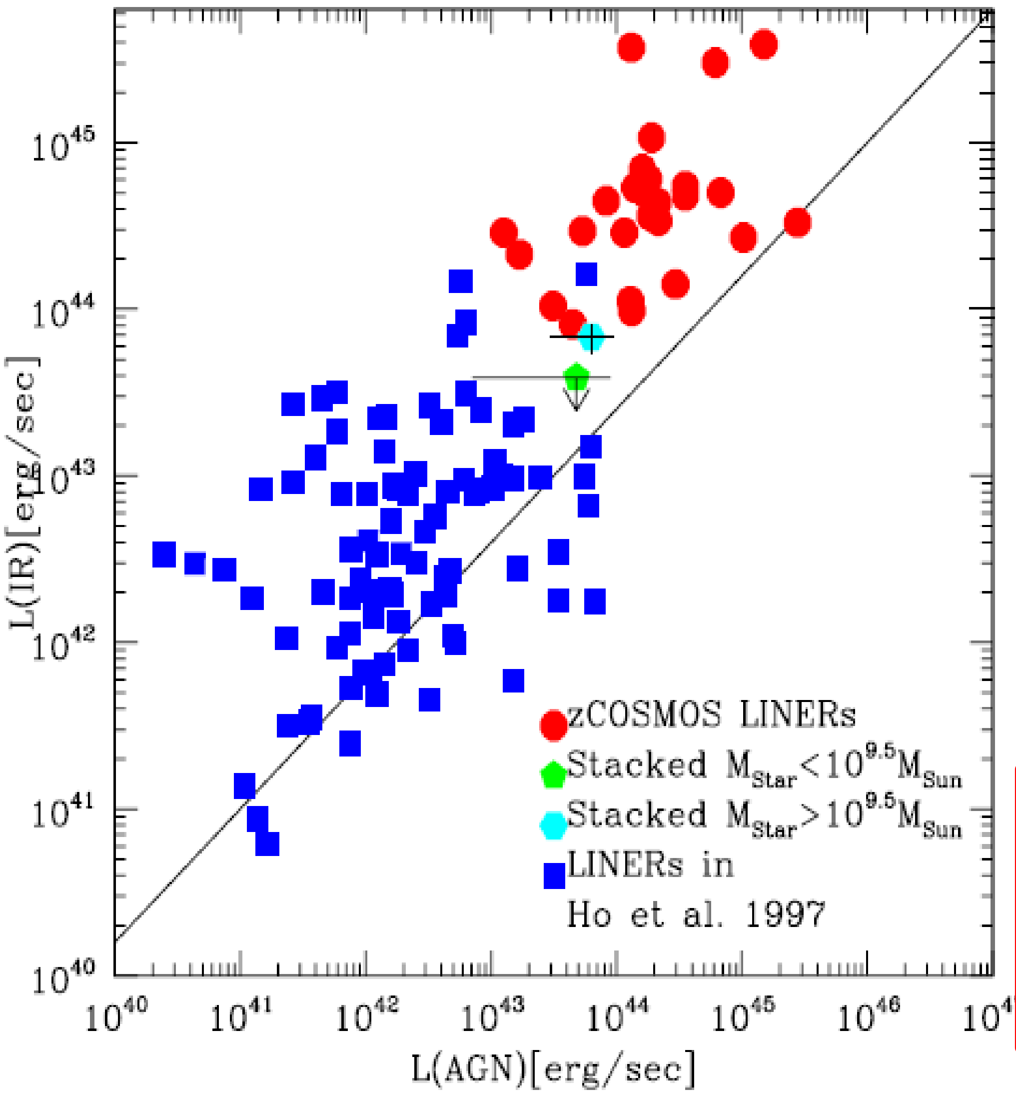
$L/L_{Edd} \lesssim 0.01$ ⟷ $L/L_{Edd} \gtrsim 0.01$

	Jet mode	Radiative mode Type 2	Radiative mode Type 1
Radio Loud	**Low–excitation radio source** * Very massive early–type galaxy * Very massive black hole * Old stellar population; little SF * Moderate radio luminosity * FR1 or FR2 radio morphology * Weak (or absent) narrow, low ionisation emission lines	**High–excitation radio source** * Massive early–type galaxy * Massive black hole * Old stellar population with some on–going star formation * High radio luminosity * Mostly FR2 morphology * Strong high–ionisation narrow lines	**Radio–loud QSO** Host galaxy properties like high–excitation radio source, but with addition of: * Direct AGN light * Broad permitted emission lines * Sometimes, beamed radio emission
Radio Quiet	**AGN LINER** * Massive early–type galaxy * Massive black hole * Old stellar population; little SF * Weak, small–scale radio jets * Moderate strength, low–ionisation narrow emission lines	**Type 2 QSO / Seyfert 2** * Moderately massive early–type disk galaxy with pseudo–bulge * Moderate mass black hole * Significant central star–formation * Weak or no radio jets * Strong high–ionisation narrow lines * QSOs more luminous than Seyferts	**Radio Quiet QSO / Seyfert 1** Host galaxy properties like Type–2 QSO and Seyfert 2, respectively, but with addition of: * Direct AGN light * Broad permitted emission lines * Bias towards face–on orientation

Light dominated by host galaxy ⟷ Direct AGN light

Star formation in LINERs

Tommasin et al. 2012



LINERs from zCOSMOS at

z ~ 0.3 (Herschel-PACS FIR data)

- L(IR) from 10^{44} erg/s

and higher AGN luminosities

- later morphological types (82% of their sample)

- LINERS at z ~ 0.3 have LFIR 2 orders of magnitude higher than those for nearby LINERs

Star formation in LINERs

Tommasin et al. 2012

Their interpretation:

- smaller nuclear regions in nearby LINERs

- selection effects in FIR (35 out of 97 LINERs)

- insufficient population studied systematically with sensitive FIR instruments in the local universe

- real evolution in the AGN and SF properties between z ~ 0 and z ~ 0.3

  (or the combination of several)

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Our proposal

To conduct a **detailed**, **spatially resolved**, **ground based spectroscopic** study of the nuclear regions of the **most luminous local LINERs (MLLINERs)** and to use **different methods** to measure their SFRs

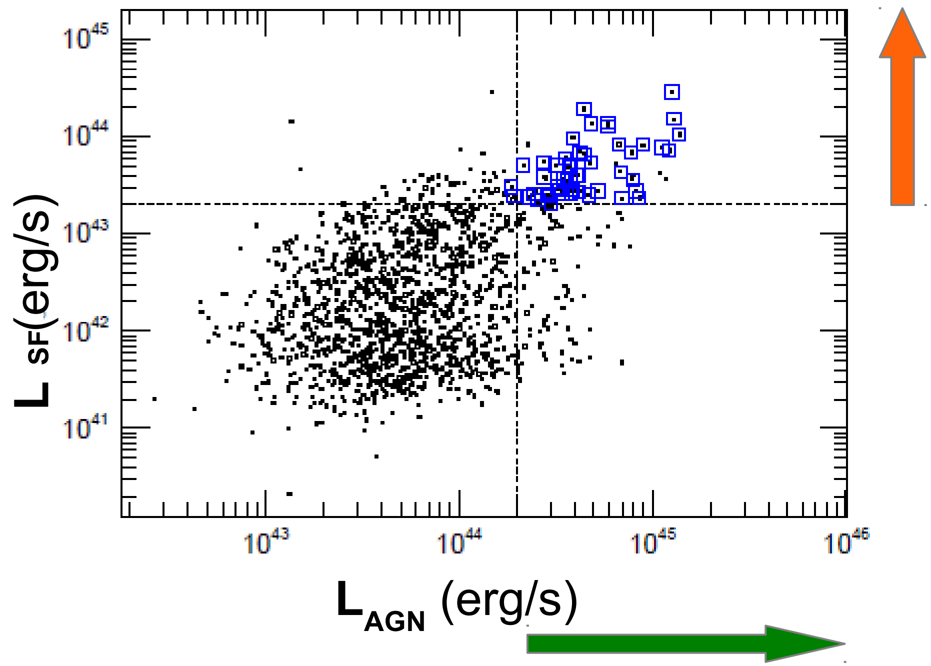
Sample selection

- SDSS/DR4 MPI-JHU catalogue (Kauffmann et al. 2003; Brinchmann et al. 2004)

- classification: BPT-NII and BPT-OI diagrams (Kewley et al. 2006)

- redshift selection: 0.04 < z < 0.11

- EW(Ha) > 2.5A (Cid-Fernandes et al. 2011)



<u>Luminous LINERs (LLINERs) selection, in terms of their AGN luminosity:</u>

- LAGN measured through [OIII] and [OI] (Netzer 2009)
  → ~ 150 LLINERs with logLAGN > 44.3 (erg/sec)

<u>The most luminous LINERs (MLLINERs) selection, in terms of their AGN and SF luminosity:</u>

- SFR measured with *Dn4000* method → LSF (Brinchmann et al. 2004)
  → selected 47 sources with logLSF > 43.3 (erg/sec)

The data: optical spectroscopy

CAHA/TWIN data (PI. I. Márquez)
- 24 nights (6 runs from October 2013 to July 2014)
- long-slit spectra for 35 (+7) sources
- spectral range: in red 6700 – 8300 A, and in blue 3500 – 6500 or 3700 – 7000 A
- slit size: 1.2 or 1.5 arcsec

NOT/ALFOSC data (PI. I. Márquez)
- 4 nights (May 2013)
- long-slit spectra for 7 (+3) sources
- spectral range: in red 5825 – 8350 A and in blue 3200 – 5550 A
- slit size: 1.3 arcsec

→ 42 MLLINERs observed in total (out of 47)

The data: FIR

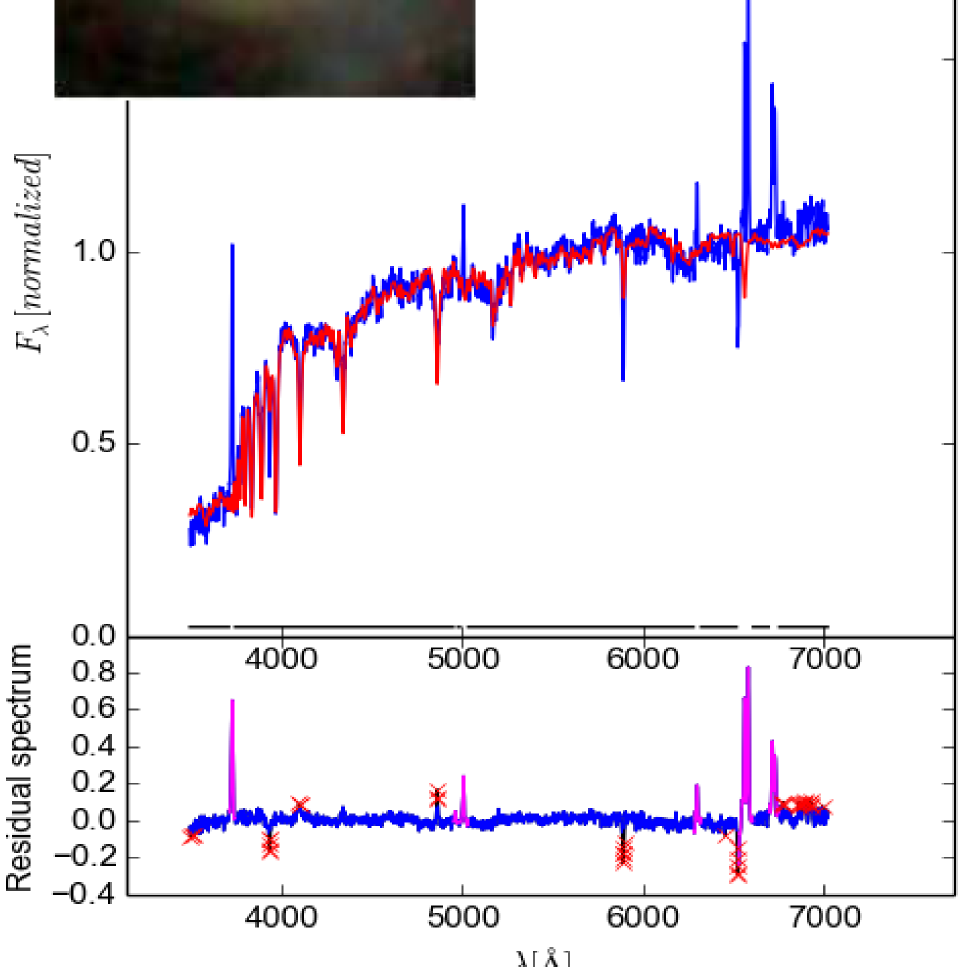
Herschel/PACS data *(PI. H. Netzer)*
- observations carried out for 6 sources
- 70 and 100 μm
- standard data reduction using HIPE tools

IRAS data
- public data available for 13 sources
(3 overlap with Herschel observations)
- flux densities available in: 12, 25, 60, and 100 μm

→ FIR data available for 16 MLLINERs in total

Analysis and measurements: STARLIGHT fittings of nuclear regions

An example



χ^2 = 0.95

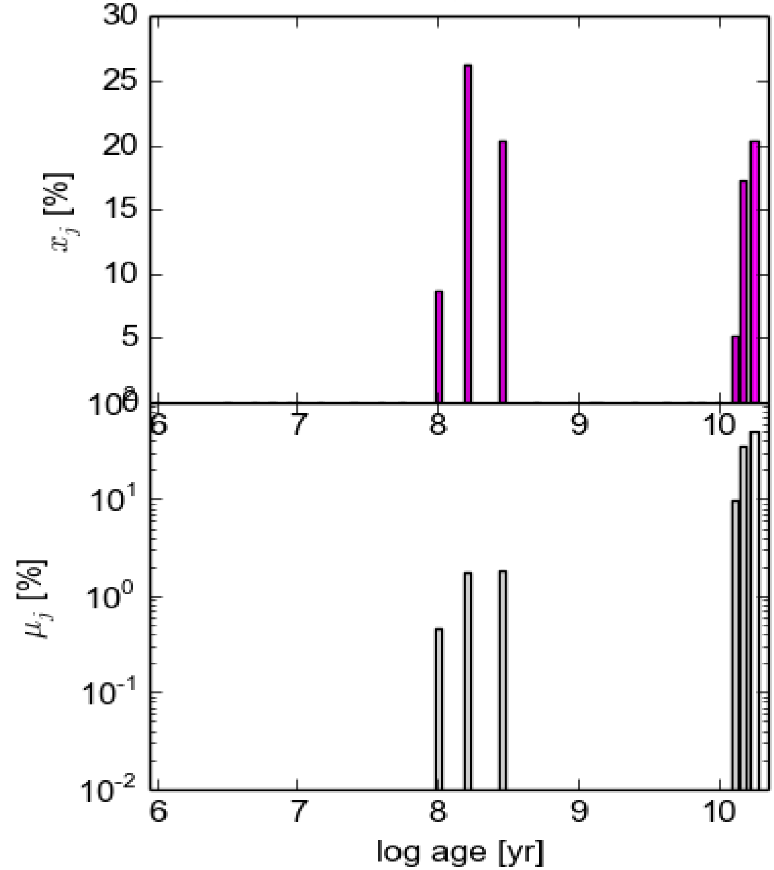
adev = 2.68

S/N = 45.25

A_V = 1.21

$\sigma_\star$ = 239.40 km/s $v_\star$ = −0.49 km/s

STARLIGHT also provides M*, SFR, LSFR



Analysis and measurements: AGN luminosity (LAGN), AGN/SF contribution, and SFRs

LAGN

LogLAGN = logL(Hβ) + 3.75 + max[0, 0.31 x (log(L([OIII])/L(Hβ)) – 0.6)]
(Netzer 2009)

AGN/SF contribution

$$SFR[M_\odot/yr] = 5.5\times10^{-42}\,L(H\alpha)\,[erg\ s^{-1}],$$

Not for SFR

→ in all except 4 MLLINERs the contribution of AGN to Hα luminosity is > 60% → neither L(Hα) nor L([OII]) were used for SFR estimations

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SFRs

1. Through STARLIGHT best fits:
(Cid-Fernandes et al. 2013)

$$SFR(t_{SF}) = 1/t_{SF} \sum M_{t},$$

2. Through Dn4000 measurements and Brinchmann et al. (2004) models

3. Using FIR data and assuming LSF = L(TIR)
   - Herschel/PACS → L(TIR) measured through SED fits
   - IRAS → L(TIR) measured as in Sanders & Mirabel (1996)

$$F_{FIR} = 1.26\times10^{-14}(2.58\times F(60\mu m) + F(100\mu m))\,[W\ m^{-2}],$$

General properties of MLLINERs

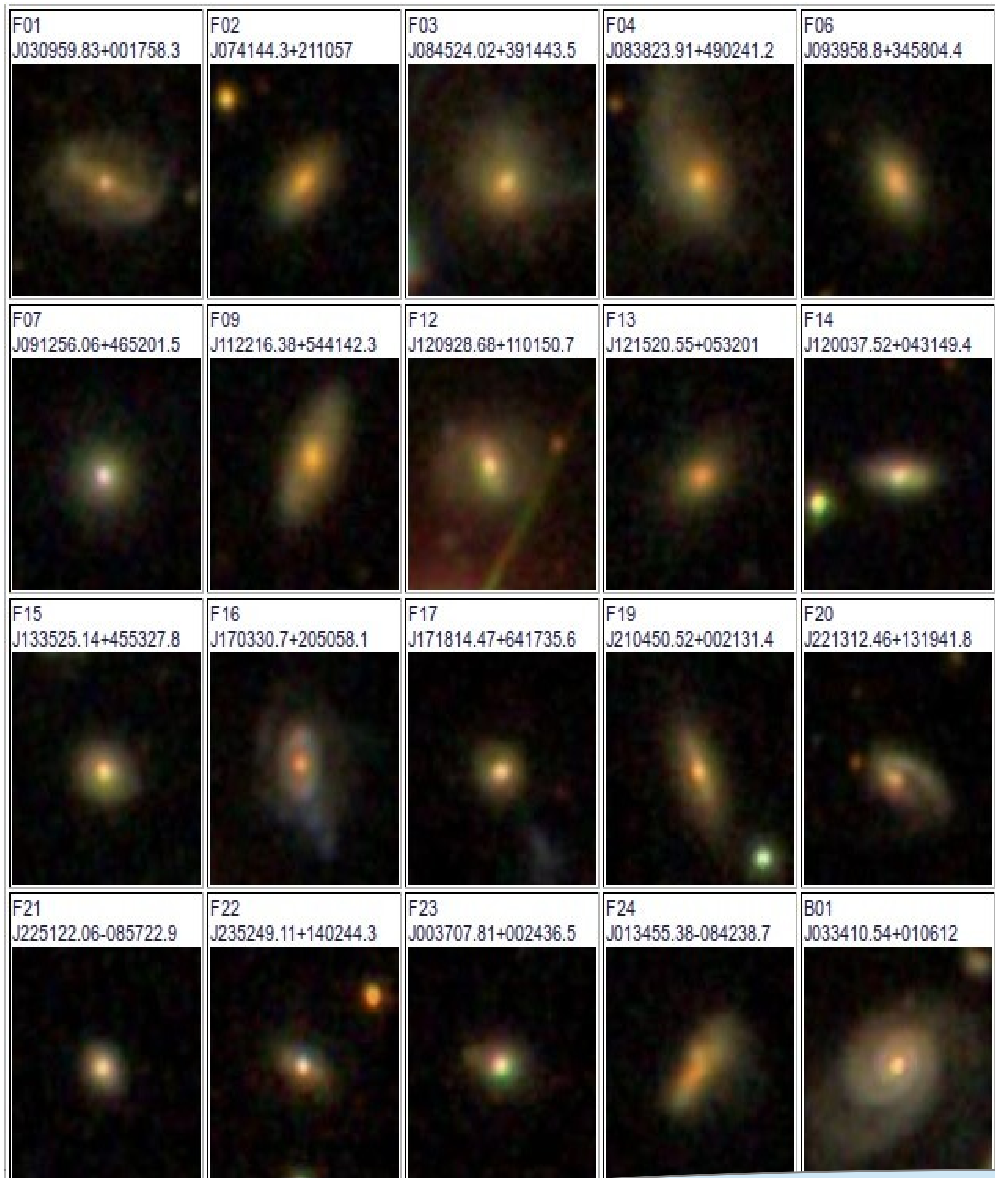
SFRs
and stellar populations

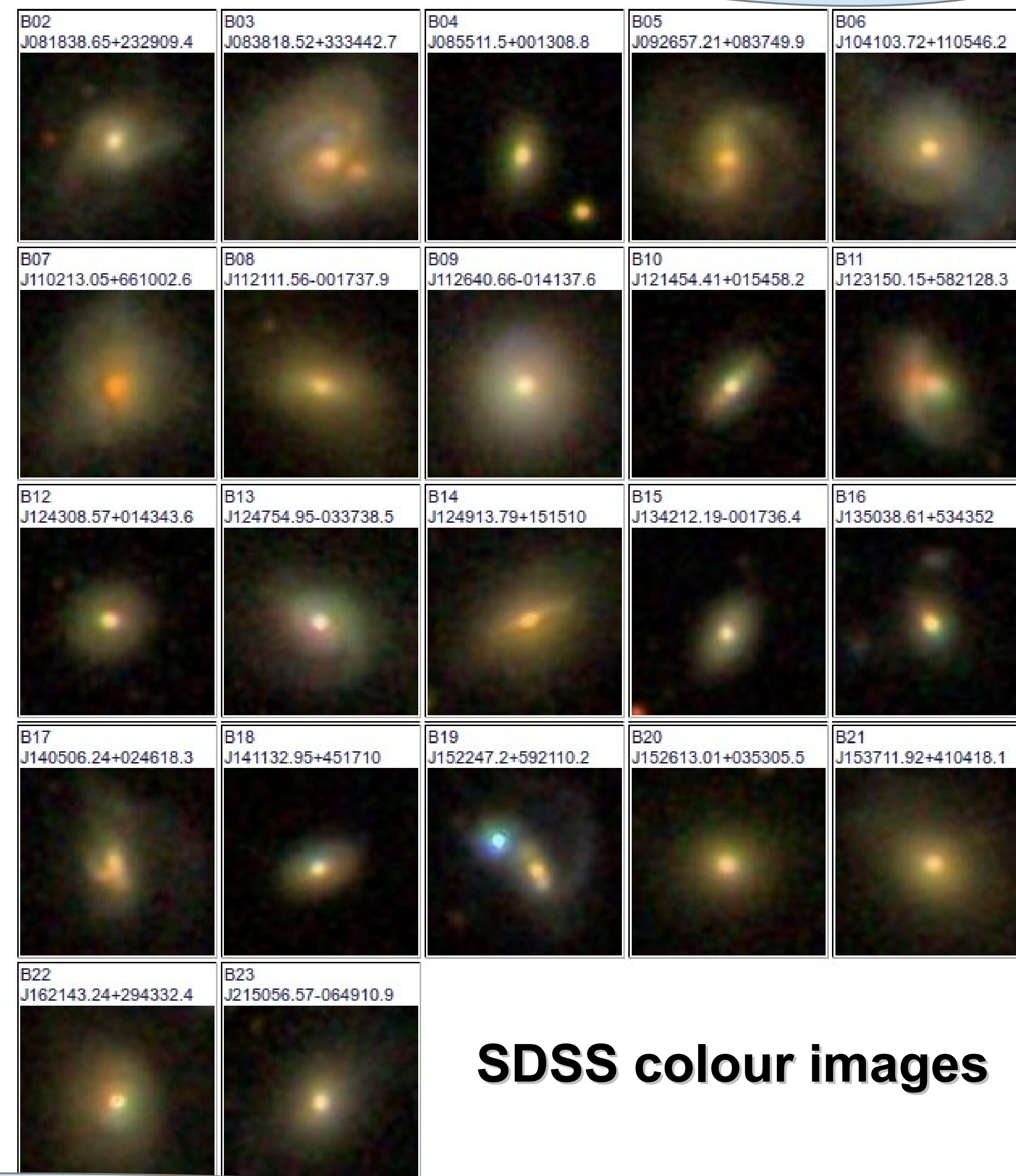
Intermediate and old stellar populations
dominate the central regions of MLLINERs

- <SFR> ~ 3 [Mo/yr] Dn4000 and STARLIGHT (nuclear spectra)
- <SFR> ~ 13 [Mo/yr] in FIR (entire galaxy)
- <SFR> ~ 10 [Mo/yr] Dn4000 and STARLIGHT (entire galaxy)

General properties of MLLINERs

Morphology





SDSS colour images

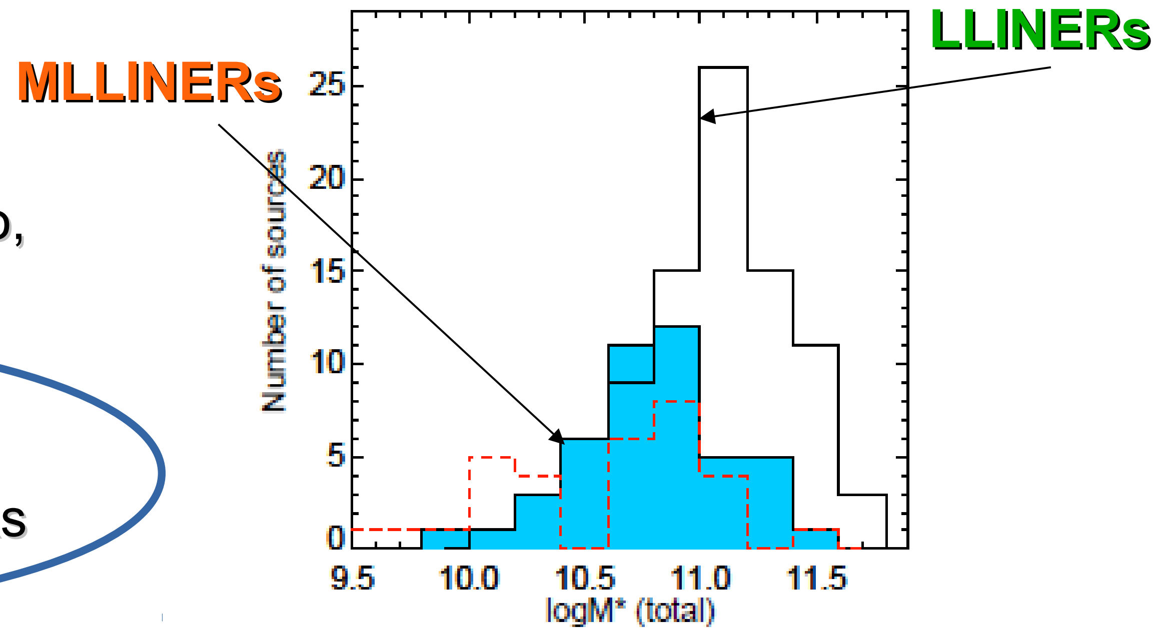
ALL MORPHOLOGIES:
40% E, 20% S, 25% peculiar (15% unclassified)
→ higher population of E galaxies (~ 10%) than for LLINERs

General properties of MLLINERs

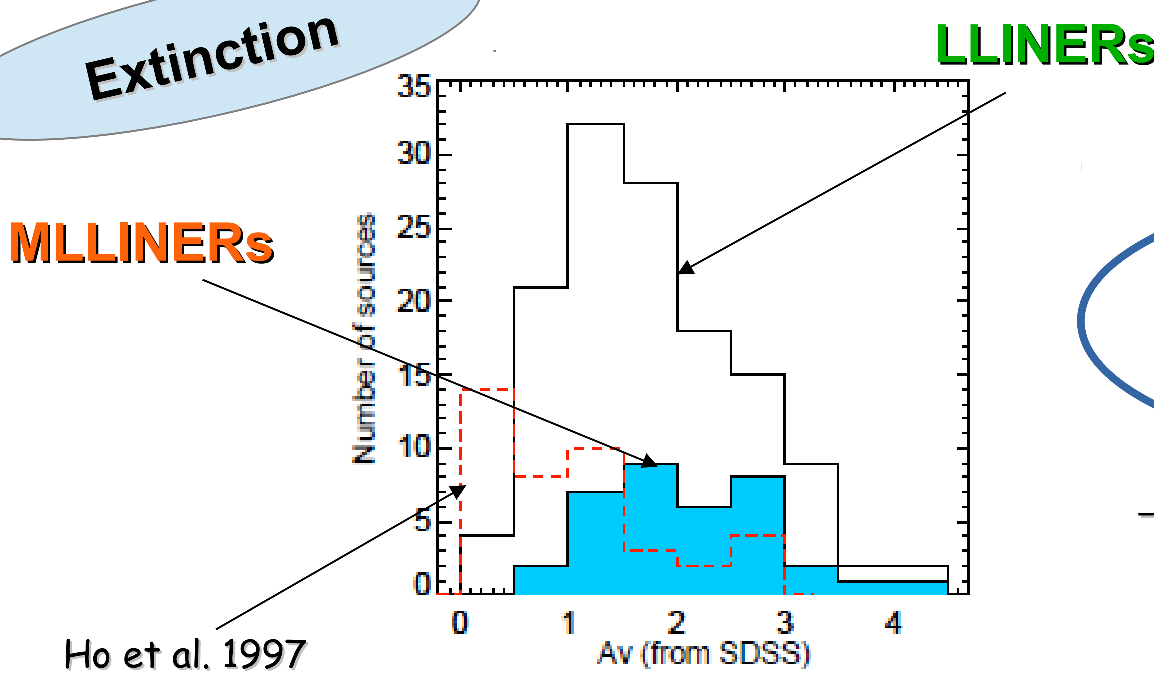
M* and MBH

- median nuclear M* = 1.52 x 10^{10} Mo,
median total M* = 6.58 x 10^{10} Mo

- median log(MBH/Mo) = 7.45 for MLLINERs
and log(MBH/Mo) = 8.04 for LLINERs



Extinction



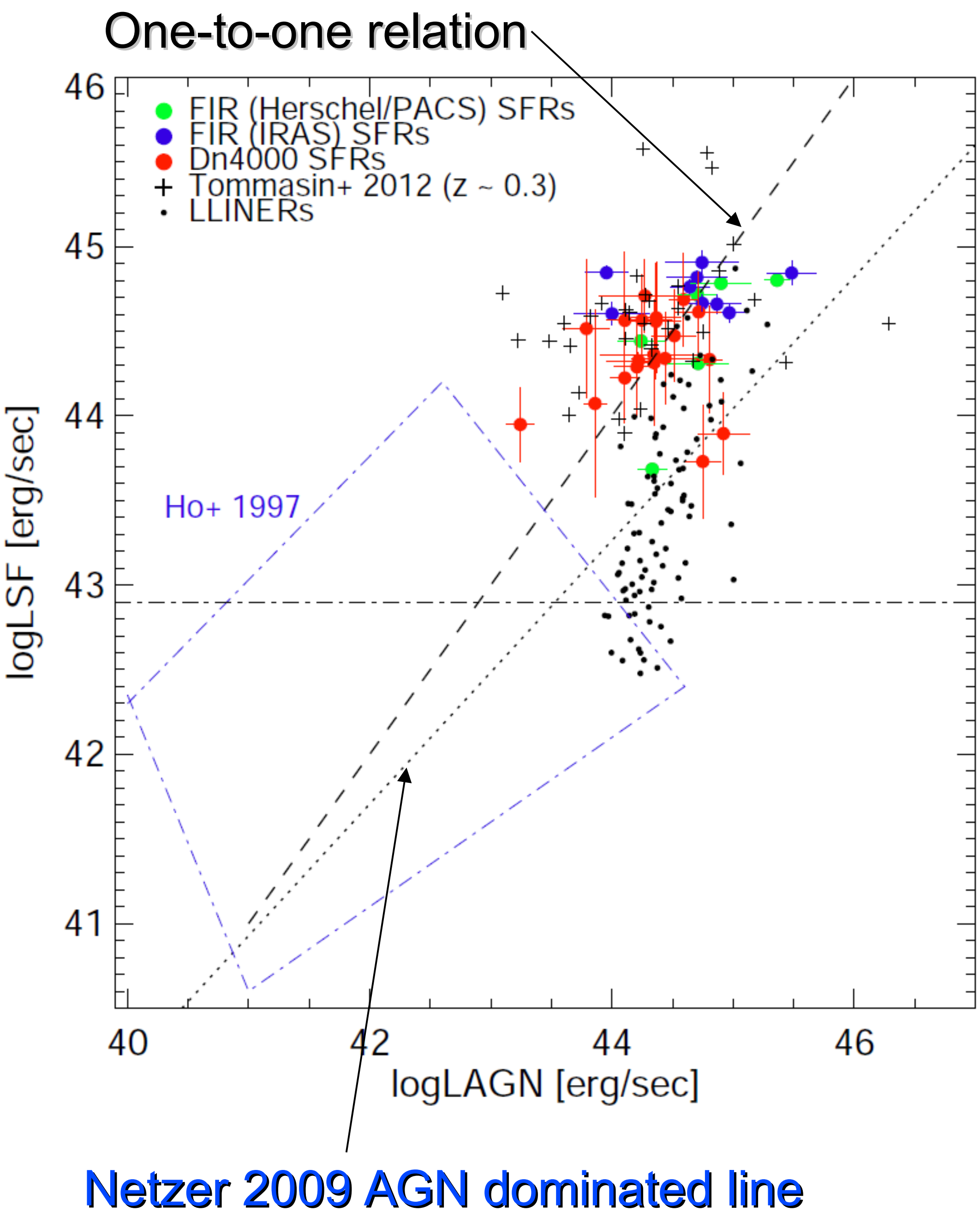
- wide range of extinctions

- median Av = 1.65 mag

- in general higher than for nearby LINERs (median Av = 0.97 mag)

→ consistent with the general finding that extinction increases with SFR
(e.g., Kauffmann et al. 2003)

AGN and SF luminosities of MLLINERs



- co-evolution between LAGN and LSF in MLLINERs

- same LAGN and LSF as for z ~ 0.3 LINERs

In addition to Tommasin et al. (2012) results:

- confirmed the existence of these sources in the local universe

- with the same ranges of M*, AGN and SF properties

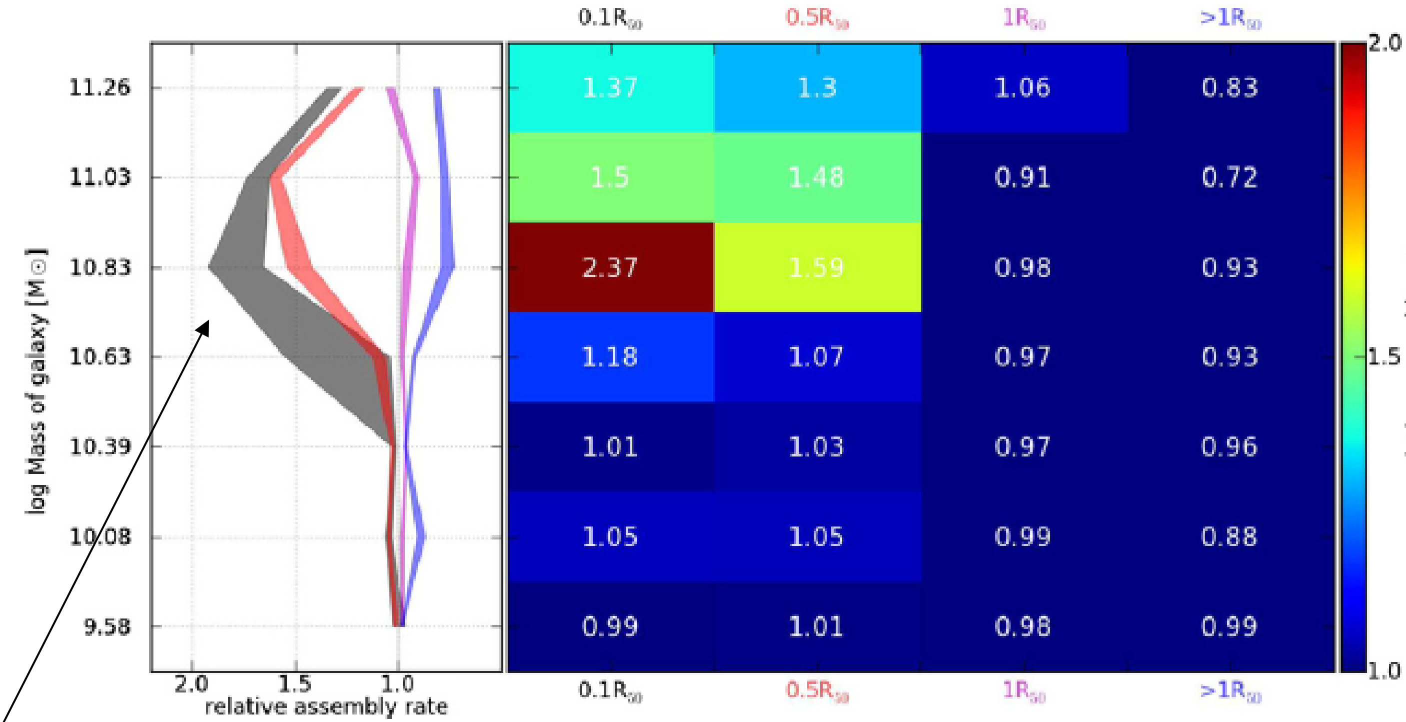
- the evolutionary scenario is discarded

General properties of MLLINERs

Why earlier-types and lower stellar masses than LLINERs, but higher SFRs?

Critical mass for the growth rate of stellar populations: ~ 6 x 10^{10}Mo

(e.g., Kauffmann et al. 2003; Mateus et al. 2006; Leauthaud et al. 2012; Pérez et al. 2013)



Pérez et al. 2013

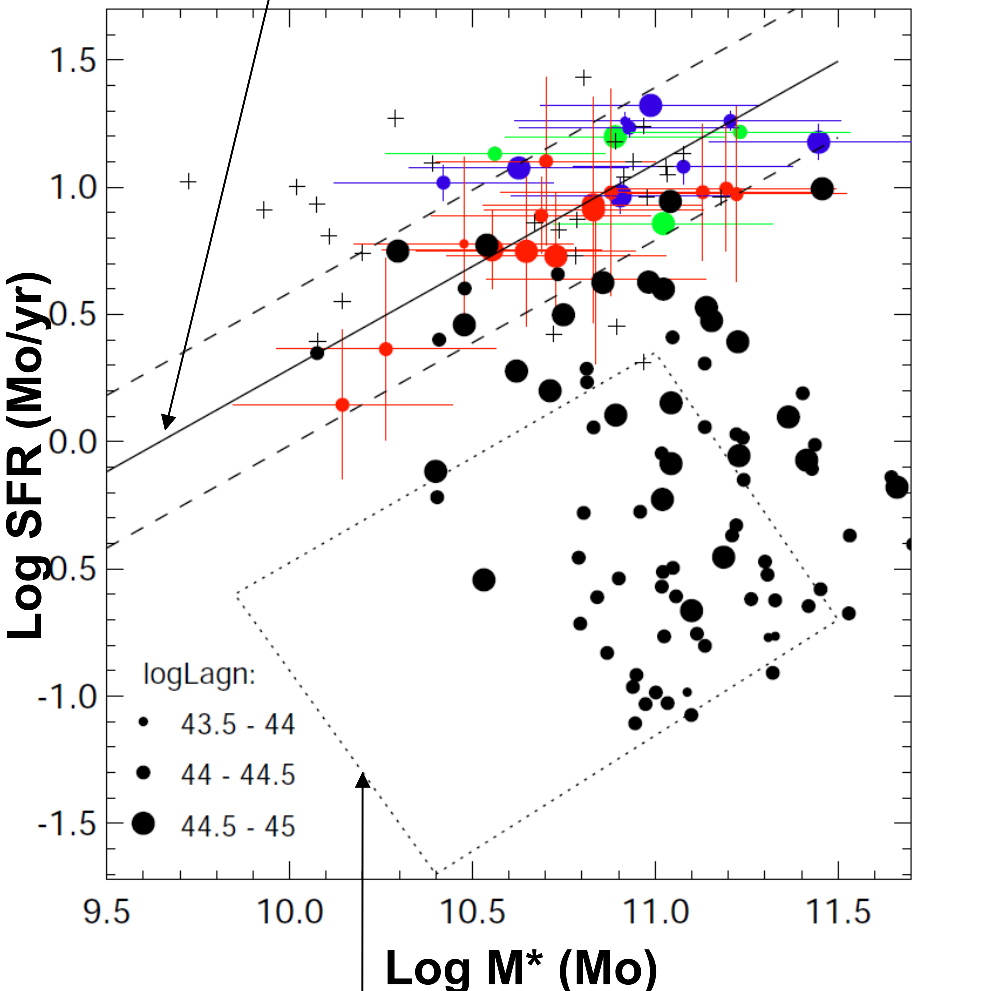
=> peak of relative growth rates of inner and outer galaxy regions correspond to the stellar mass of 6 – 7 x 10^{10} M⊙

For MLLINERs the median total M* = 6.58 x 10^{10} Mo
→ corresponds to the peak of relative rate of transforming gas into stars → highest SFRs

MLLINERs and the main sequence (MS) of SF galaxies

- > 90% of MLLINERs lie along the MS of SF galaxies
- all morphological types present on the MS
- same location as in the case of the most luminous LINERs at z ~ 0.3; important differences regarding the majority of low-redshift LINERs

MS of Whitaker et al. 2012
(for z = 0.07)



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

The fraction of SF galaxies among the low-redshift LINERs is LAGN-dependent

LINERS located on the MS:
2% for logLAGN = 43 – 43.5,
3% for logLAGN = 43.5 – 44 ,
11% for logLAGN = 44 – 44.5,
and 37% for logLAGN = 44.5 – 45

More similar to Sy2 than to LINERs regarding LAGN and LSF

Summary and main conclusions

Previous works characterised local LINERs as:
Hosted by massive and old early-type galaxies, with low extinctions, massive BHs, old stellar populations, and little or no star-formation
(Ho 1997, 2008; Kauffmann et al. 2003; Heckman & Best 2014)

- **MLLINERs studied in this work have:**
  * **all morphologies**
  * **higher extinctions**
  * **much higher SFRs**

- **This kind of LINERs first were detected at z ~ 0.3**

- **Their existence confirmed in the local universe (@z = 0.04 – 0.11) discarding an evolutionary scenario**

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

- **They lie along the LAGN = LSF line hinting for co-evolution of the two properties**

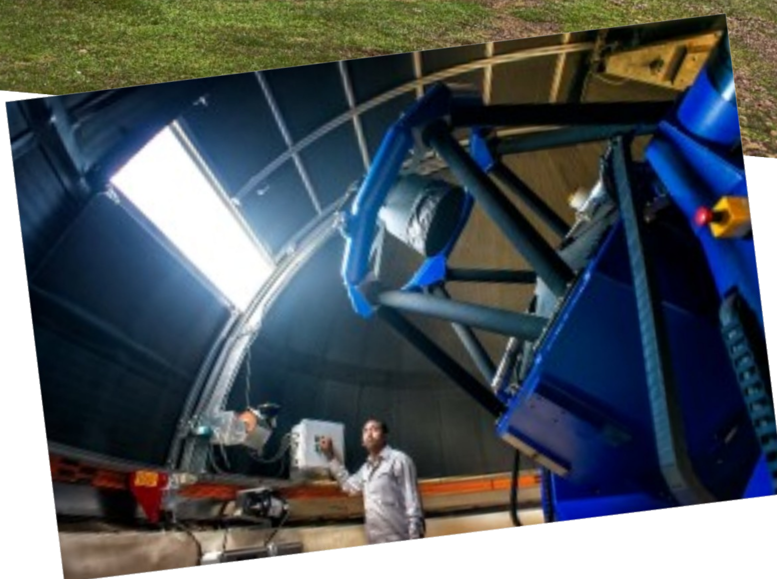
- **Most of them lie on the MS of SF galaxies, with M* > 10^{10}Mo**

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

- **The median stellar mass of MLLINERs corresponds to the peak of relative growth rate of stellar populations**

Ethiopian Space Science and Technology Institute (ESSTI)

Entoto Observatory and Research Center (EORC)



… and more initiatives in African context

- New MSc and PhD programs in A&A and space physics → e.g., Kenya, Uganda, Rwanda, Sudan, Ghana, Nigeria, Madagascar, Egypt, Algeria, etc.

- New institutional developments → e.g., GSSTI in Ghana, NASRDA in Nigeria, NARSS in Egypt, ESSTI in Ethiopia, etc.

- New continental initiatives → African Union Space Strategy (in line with the UN Post-2015 development Agenda)

- New long-term projects → SKA-Africa (South Africa + 8 Sub-Saharan African countries)

- New collaborations → e.g.,African – European Radio Astronomy Platform (AERAP)

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SHARE OF YOUR KNOWLEDGE WOULD BE VERY MUCH APPRECIATED


Thanks for your attention!
And have a nice day!