Investigating the relationship between AGN activity and stellar mass in zCOSMOS galaxies at 0<z<1 using emission line diagnostic diagrams

Vitale et al. 2013 (astro-ph:1304.2776)
• Introduction
• Database (zCOSMOS survey)
• Spectral Analysis
• Stacking technique
• Emission lines measurements
• Diagnostic Diagrams
• Discussions
• Conclusions
Introduction

- Local galaxies present a **bimodality color distribution** (e.g., Kauffmann03).
- **Downsizing scenario** (Cowie et al. 1996)
- **Number density** of early-type is constant and late-type increases between $0<z<1$ (Bundy et al. 2004).
- **Quenching** mechanisms → passive evolution → growing abundances

- Several mechanisms to **quench**: gas exhaustion, major mergers, AGN feedback, etc.

Pozzetti et al. (2009)
Introduction

- AGNs releasing large amount of energy
- **AGN feedback** (trigger or quench star forming?)
- According to some calculations, \(~1\% \text{ of the released energy}\) is enough to **heat/blow away the gas content** (Cattaneo et al. 2009).
- The gas consumption is coupled to the **SN-driven winds and AGN-feedback to quench the star formation**.
- Ho et al. 1997a show that \(~50-70\% \text{ of E-Sb galaxies}\) can be considered **nucleus active**.
- The AGN detection drops towards later Hubble types (Sc and later), where about 80% host a star forming nucleus.
- **Emission-line diagnostic diagrams** (eg Baldwin et al. 1981)
- AGN \(\rightarrow\) **non-thermal mechanism** of ionization.
- There is some evidence of AGN activity in suppressing star-formation?
- Some AGN activity trend on stellar mass?
COSMOS and zCOSMOS survey

- The **COSMOS survey** is a large HST-ACS survey with I-band exposure down to $I_{\text{AB}} = 28$ on a 2deg$^2$ (Scoville et al 2007)
- Bands: X-ray, UV, optical/IR, mid-infrared, submillimeter and radio (~30 bands).
- **zCOSMOS - BRIGHT FINAL RELEASE**: 20k of galaxies with $I_{\text{AB}} < 22.5$ between 0<z<2.0
- **Wavelength range**: 5650A - 9550A

http://irsa.ipac.caltech.edu/data/COSMOS/

Lilly et al. (2007)
COSMOS and zCOSMOS survey

- The COSMOS survey provides photometric redshift (Hyperzmass, Bolzonella et al. 2010) of galaxies without secure spectroscopic redshift flag: $0.007(1+z)$ for $I_{AB} < 22.5$ (Ilbert et al. 2009)

- **Mass completeness**: Pozzetti et al. (2010) have defined minimum mass ($M_{\text{min}}$) which is the upper limit of the 20% faintest galaxies at each redshift.

- **Remove Seyfert 1 + low flags**: exclude broad line objects, i.e., ~892+35 objects.

- **Final sample**: 15.715 galaxies.

**Samples in logM,z bins**

- Investigate average properties of galaxies as function of mass and redshift -> divide this final sample in mass and redshift bins, considering mass completeness.

- Size of mass and redshift bins -> Compromise with statistics (large enough samples in bins and good redshift sampling)
Spectral Analysis

- **Redshift bins**: 8 bins with $\Delta z = 0.1$
- **Mass bins**: 9 bins with $\Delta \log M = 0.25$ dex
- At higher redshift roughly half of the bins are placed below the confidence curves ($M_{\text{min}}$).

- Bins with $\log M < 9$ and $\log M > 11.25$ are poorly represented.
- Filaments and Voids are identified through redshift.
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- $0.117 < z < 0.436$ (lowz)
- $0.548 < z < 0.884$ (highz)
Stacking

- **Stacking** → the gain in S/N is considerable and allows a more accurate line fitting.
- The spectra are always normalized in wavelength ranges without prominent spectroscopic features.

![Stacking diagram](image)

Many low S/N spectra + + + + 

representative spectrum with higher S/N ratio

*logM,z bins represent galaxy samples with similar properties*
Stacking

- **Stacking → the gain in S/N is considerable and allows a more accurate line fitting.**
- The spectra are always normalized in wavelength ranges without prominent spectroscopic features.
- 5300A - 5800A -> 0.177<z<0.371
- 4500A - 4800A -> 0.371<z<0.716
- 3400A - 3700A -> 0.716<z<0.884

- low-ionization emission lines such as [NII] and [OIII]
- strong recombination lines: Balmer series
- D4000 as indicative of age for stellar populations.
- **Downsizing scenario**
Emission lines measurements

- **Continuum subtraction** by using Bruzual & Charlot (2003) SSPs with 5 values of extinction, being 234 stellar templates.
- The most suitable is used to subtract the continuum from zCOSMOS spectrum.
- The emission line measurements provides flux of [OII], Hgamma, Hbeta, [OIII], Halpha, [NII] and [SII].

- Observed fluxes need to be corrected by extinction.
- **Extinction correction**
  - Halpha/Hbeta = 2.86
  - Hgamma/Hdelta = 0.47
  - Calzetti et al (1994)
Diagnostic Diagrams

- \([\text{[NII]}/\text{Halpha} \times \text{[OIII]}/\text{Hbeta}]\) - Baldwin et al. (1981) (BPT diagram) - \(z<0.436\)
- \([\text{[OII]}/\text{Hbeta} \times \text{[OIII]}/\text{Hbeta}]\) - Tresse et al (1996) - \(z>0.548\)
- MEx diagram - Juneau et al (2011) – \(z>0.117\)
- The redshift range \(0.436<z<0.548\) has been excluded because \([\text{NII}]\) and Halpha are redshifted outside the optical spectra and \([\text{OII}]\) is not visible in the blue part of the spectral range.

Low-z diagrams

- \([\text{[NII]}/\text{Halpha}]\) is a linear function of the nebular metallicity and it presents a saturation point.
- Further increase in the \([\text{NII}]/\text{Halpha}\) value is only due to AGN contribution (e.g. Kewley et al 2006, Stasinska et al 2006).
- Several works determined the limit between star forming and AGNs.
- Kewley et al 2001 - theoretical limit -> models of star forming galaxies.
- Kauffmann et al 2003 - observational limit -> SDSS emission-line galaxy samples
Diagnostic Diagrams

- \([\text{NII}]/\text{Halpha} \times [\text{OIII}]/\text{Hbeta}\) - Baldwin et al. (1981) (BPT diagram) - \(z<0.436\)

0.177<z<0.242 0.242<z<0.306 0.306<z<0.371 0.371<z<0.436

- Progressive migration from SF “wing” to AGN one
- Highest mass bin is already placed in AGN/composite regions
- Objects with logM>10.2 start being classified as composite or AGN, in agreement to Kauffmann et al (2003).
Diagnostic Diagrams

- \([\text{SII}]/\text{Halpha} \times [\text{OIII}]/\text{Hbeta}\)

0.177<z<0.242 0.242<z<0.306 0.306<z<0.371 0.371<z<0.436

- Objects classified as AGN in \([\text{NII}]-\text{diagram}\) can be classified as SF in \([\text{SII}]-\text{diagrams}\).
- \([\text{SII}]\) ionization is due to shock winds of SNs or accretion of SMBHs?
- \([\text{SII}]\)-diagram is more affected by errors (lines blending: 6716A and 6730A)
Diagnostic Diagrams

- \([\text{OII}]/\text{H}\beta \times [\text{OIII}]/\text{H}\beta\) - Tresse et al (1996) - \(z > 0.548\)
- Lamareille et al (2004) involve the [OII] line making an high-redshift option to the more classic red diagnostic diagrams. However Lamareille et al 2010 show that it is biased to composite objects, i.e., overlap between star forming and (Low Ionization Nuclear Emission Regions) LINERS. \(0.548 < z < 0.632\) \(0.632 < z < 0.716\) \(0.716 < z < 0.8\) \(0.8 < z < 0.884\)

- High mass means, in most of the cases, a shift towards higher values of [OII]/Hbeta.
- As shown in BPT diagram, almost all the objects are located in SF region.
- Higher mass galaxies are located in mixed contributions.
- Poor ability to classify AGNs, however it is more sensitive to shocks.
Diagnostic Diagrams

- **MEx diagram** - Juneau et al (2011) - \( z > 0.548 \)
- \([\text{NII}]/\text{Halpha}\) traces the metallicity in SF galaxies.
- **Correlation between mass and metallicity** (Tremonti et al. 2004).
- \([\text{NII}]/\text{Halpha}\) → logM: MEx diagram
- This diagram suffers more from blending between LINERS and Seyfert 2 with respect to the latter diagram.

\[
\begin{align*}
0.117 < z < 0.242 & \quad 0.242 < z < 0.306 & \quad 0.306 < z < 0.371 \\
0.371 < z < 0.436 & \quad 0.548 < z < 0.632 & \quad 0.632 < z < 0.716 \\
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\end{align*}
\]

- At logM\( > 10.2 \), the galaxies **leave the SF region and enter the composite region** of the diagram.
- logM increases then [OIII]/Hbeta decreases up to the point where are classified as composite.
- Systematically **offset towards the AGN region and metal enhancement**.
Discussion

- **Median versus Average Stacking**
- **Average stacking** → strong lines dominates the signal over weak objects.
- Seyferts present stronger lines (in particular [OIII]) compared to SF and LINERS with the same logM
- **Few percents of Seyfert** dominate the signal of [OIII] on the stacked spectrum.
- However there is **NO substantial difference** between median and average stacking.
- **Two reasons for this similarity:**
  - AGN fraction is low, compared to SF galaxies
  - trend is lost in **measurement errors**
- **Visual extinction**
- ULIRGs (*Ultra Luminous Infra Red Galaxies*), AGN feedback and downsizing.
- **E(B-V)** are higher at higher redshifts
- No difference between high and low logM.

\[
0.117 < z < 0.242 \quad 0.242 < z < 0.306 \quad 0.306 < z < 0.371 \\
0.371 < z < 0.436 \quad 0.548 < z < 0.632 \quad 0.632 < z < 0.716 \\
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\]
Discussion

Diagnostic Diagrams

- **MEx diagram** provides **larger time interval to probe evolutionary effects**.
- **[NII]-diagram** nicely shows that **the mass can determine the galaxy classification**.
- **[SII]-diagram** does not show the same trend and **classify all the stacked galaxies as SF**.
- **[OII]-diagram** leaves us with **big uncertainties** (rather sensitive to shocks → **starbursts** or AGNs?).

**Quenching of the star formation**

- Massive objects (logM>11) are already formed and their number density is constant between 0<z<1.
- Massive objects are formed earlier → they have more time to evolve → older stellar population.
- Mechanism to quench star formation → **AGN feedback**?
- **Older stellar population after AGN active phase** (Sarzi et al. 2005).
- Observational evidences are still needed!
- **X-ray** as another observational source to test this diagrams.
Conclusions

- **Visual extinction of galaxies** (from Balmer ratio) does not show any strong trend on mass but with redshift.
- Galaxy stellar population are older for more massive objects (**downsizing**).
- Objects with logM>10.2 are classified as composite objects.
- **Highest masses → composite to AGN regions** (MEx, [NII]-diagram but not in [OII]-diagram).
- [OII]-diagram is not effective to distinguish SF, composite and AGNs (more sensitive to shocks than AGN photoionization).
- There is no clear trend in BPT diagram but there is a trend on the MEx diagram (offset).
- **High-redshift stack galaxies** display more composite and AGN-like spectra → evolutionary or bias sample effects?
- Link between stellar population age and stellar mass, combined to the increasing AGN detection rate for increasing mass and redshift.
- AGN could act to quench the star formation and contribute to the transformation from young blue late-type to old read early-type.