What’s the fuss about AGN?

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Outline

• What is an Active Galactic Nucleus (AGN)?
• AGN role and importance
• AGN evolutionary models and feedback
• Star-formation and AGN activity at high redshifts and luminosities
• Feedback signatures and implications on models
Active Galactic Nuclei
Components and Taxonomy

AGN observed properties are orientation-dependent

<table>
<thead>
<tr>
<th>λ</th>
<th>Type 1</th>
<th>Type 2</th>
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<tr>
<td>Optical spectrum</td>
<td>Broad lines</td>
<td>Narrow lines</td>
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<tr>
<td>Optical continuum</td>
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<td>Red</td>
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(Antonucci 1993)

Illustration: CXC/Weiss
Active Galactic Nuclei
Components and Taxonomy

AGN observed properties are orientation-dependent

\[ \lambda \quad \text{Type 1} \quad \text{Type 2} \]

Optical
- Broad lines
- Narrow lines

Optical continuum
- Blue
- Red

Mid-infrared
- Hot dust
- Warm dust

X-ray
- Soft/ unabsorbed
- Hard/ absorbed

(Antonucci 1993)

Illustration: CXC/Weiss
Active Galactic Nuclei
Components and Taxonomy

AGN observed properties are orientation-dependent

Unobscured AGN (Type 1)

Obscured AGN (Type 2)

Torus emission (Hönig et al. 2006)

(Antonucci 1993)

Illustration: CXC/Weiss
Active Galactic Nuclei
Components and Taxonomy

AGN observed properties are orientation-dependent

The Effects of X-ray Absorption by Solar Abundance Gas
Column densities of $10^{20}$, $10^{21}$, $10^{22}$, $10^{23}$ cm$^{-2}$

Unabsorbed AGN (Type 1)
Absorbed AGN (Type 2)

X-ray
Soft/unabsorbed
Hard/absorbed

(Antonucci 1993)

Illustration: CXC/Weiss
Galaxies host black holes of mass proportional to their bulge mass, luminosity, velocity dispersion.

Fossil evidence that BHs regulated galaxies growth or vice versa.

(Kormendy & Richstone 1995; Magorrian et al. 1998; Ferrarese & Merritt 2000; Gebhard et al. 2000; Marconi & Hunt 2003; Häring & Rix 2004)
Star Formation and Accretion share a similar "history"

Star Formation Rate (SFR) density vs z

AGN Space Density vs z (X-ray and optically selected)

Decrease in fuel supply and/or fueling rate?

Growth phase of SMBH?

(Silverman et al. 2004)

(Hopkins & Beacom 2006)
The role of AGN in galaxy evolution

AGN through a feedback process regulates star formation in their host galaxies

Quasar mode
- High luminosities
- Rare
- \( z \sim 2 \)
- Wind/Outflow
- Starbursting host
- Standard thin disk
- Radiatively efficient
- Cold gas blowout

Radio mode
- Radio loud AGN
- Common
- \( z \leq 1 \)
- Jet
- Radiatively inefficient
- ADAF/ADIOS
- Regulates star formation
- Hot gas bubbles

The role of AGN in galaxy evolution

AGN through a feedback process regulates star formation in their host galaxies.

Quasar mode
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Galaxy Merger simulation with AGN feedback

The role of AGN in galaxy evolution

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The role of AGN in galaxy evolution

AGN through a feedback process regulates star formation in their host galaxies

Quasar mode
High luminosities
Rare
z~2
Wind/Outflow
Starbursting host
Standard thin disk
Radiatively efficient
Cold gas blowout

Radio mode
Radio loud AGN
Common
z≤1
Jet
Radiatively inefficient
ADAF/ADIOS
Regulates star formation
Hot gas bubbles

A laboratory to test and study the proposed scenario

Quasar mode laboratory:

Starburst & obscured AGN

Obscured QSO

Unobscured AGN.

Columns Evolve

Angle-dependent effect (classical unification)

Evolution-dependent effect

“Blowout” phase

Bolometric

AGN luminosity and absorption evolution

Time [Gyr]

Starburst Bulge & SMBH growth

Merger of large galaxies

AGN feedback
Fuel exhaustion
Halt of star-formation

(Hopkins et al. 2005)

(Di Matteo et al. 2005)
High-z luminous Infrared Galaxies

**SWIRE** to sample large volumes
**Spitzer** to identify starburst and AGNs

### Selection
**Fields:** SWIRE Lockman Hole & XMM-LSS fields (20 deg$^2$)
- $F(3.6\mu m)/F(r') > 25 \Leftrightarrow$ high-z
- $F(24\mu m) \sim 0.3-6$ mJy $\Leftrightarrow$ high-L

**SED types:**
1) **Starbursts** [peak at 5.8$\mu$m]
2) **AGN** [red and smooth mid-IR SEDs]
3) **Composite** (AGN+starburst) [24$\mu$m excess on extrapolated IRAC power-law or peak at 5.8$\mu$m]
The Spitzer Wide Area Infrared Extragalactic Survey (SWIRE)

Spitzer Space Telescope
3.6, 4.5, 5.8, 8.0μm
24, 70, 160μm
+ multi-band optical data

2 Million Galaxies up to z=3 & hundreds of 100 Mpc scale cells

Lonsdale et al. 2003
High-z luminous Infrared Galaxies

SWIRE to sample large volumes
Spitzer to identify starburst and AGNs

Spitzer/MIPS & IRAM/MAMBO
(70μm, 160μm, 1.2mm)

Far-infrared luminosity L(FIR)
Star formation rate (SFR)
Millimeter emission of AGN and starbursts

**Starbursts (33) 39% det.**  
**AGN (43) 22% det.**  
**Composites (10) 10% det.**

- **1.2mm-detected**
- **1.2mm undetected**

AGNs are brighter at 24μm

1.2mm detection does not depend on z
Infrared properties of SWIRE/MAMBO sources and comparison with SMGs

Is an AGN contributing to the 24μm flux in the starbursts?

SWIRE sample: Distinct IRAC colors for different source types
SMGs: wider range of IRAC colors

Starbursts
AGN
Composites

F(1.2mm)/F(24μm) decreases

SMGs→Starbursts→AGNs

(Lacy et al. 2004)
AGN contribution in SWIRE/MAMBO starbursts

Mid-IR spectra (Spitzer/IRS):
6/8 sources are PAH-dominated with no warm dust continuum, 2/8 show PAHs+ continuum
an AGN might be present in 25% of the sample

(Lonsdale, Polletta et al., 2008)
AGN contribution in SWIRE/MAMBO starbursts

- ~30% of SWIRE-selected z~2 starbursts contain an AGN

vs 30-46% in z~2 SMGs (Alexander et al. 2005; Pope et al. 2008)

In most of the cases the starburst is the main energy source!

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Star formation rates in high-z obscured QSOs

AGNs detected at 70 or 160\(\mu\)m \(\rightarrow\) evidence for starburst component

Starburst with \(L(\text{FIR}) \sim 10^{12.5-13.2} \, L_\odot \Rightarrow \text{SFR} \sim 600-3000 \, M_\odot/yr\)

Conclusion N.2: \(\sim20-40\%\) of obscured AGNs at \(z\sim2\) are hosted by extreme starbursts

(Polletta et al., 2008a)
A closer look at these obscured QSOs

The brightest mm sources of the entire SWIRE/sample:
2 powerful and obscured AGN and starbursts at z~3.5

$L(\text{AGN}) \sim 10^{13} \, L_\odot \text{ & } L(\text{SB}) \sim 10^{12.5-13.2} \, L_\odot$

(Polletta et al. 2008b)
Ultraviolet & optical rest-frame spectra

| Line FWHM, flux ratios and equivalent widths | type 2 AGN |

- Strong NV
- Asymmetric CIV
- Optical spectrum (Australian Telescope)
- Near-Infrared spectra (ISAAC Telescope)
- z offset ~ 500 km/s
- Line ratios ➔ High metallicity or shock-heated gas

(Polletta et al. 2008b)
AGN-driven radio activity: feedback signature?

16 radio-detected sources (13 AGNs, 3 starbursts)

Radio-loud vs radio-quiet diagnostic:

\[ q - \frac{L(\text{FIR})}{L(1.4 \text{ GHz})} < 1.6 \] (Yun et al. 2001)

\[ \Rightarrow 8/16 = 50\% \text{ are radio-`active'} \]
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AGN-driven radio emission

\[ 8/16 = 50\% \text{ are radio-`active'} \]

Conclusion N.3: A significant fraction of AGNs show AGN-driven moderate radio activity

- Radio activity might be a signature of AGN feedback (important for QSOs?)
Summary

FIR-mm observations of **SWIRE ULIRGs** at z~2 (43 AGN, 33 Starbursts, 10 Composites)

≥30% of starburst galaxies contain an AGN. The AGN is moderately luminous and obscured and contributes ~30-40% to the total luminosity.

~20-40% of obscured AGNs are hosted by powerful starburst galaxies.

The peak of AGN activity is shorter than the starburst phase ➔ more chances to detect a moderately luminous AGN than a QSO in a starburst galaxy

A significant fraction of AGNs show AGN-driven moderate radio activity that might be a signature of feedback.
Final thoughts....

E con questa astro siesta
spero vi sia entrato in testa
che qualunque sia il vostro campo
senza AGN non c'è scampo.
Tu che degli ammassi prendi la temperatura
o che sulle galassie metti la fenditura;
tu che del cosmo misuri il fondo
o che guardi l'universo profondo;
tu che costruisci il rivelatore
o che programmi con il calcolatore;
tu che cerchi le binarie
o sbrighi faccende universitarie;
di AGN non si può evitare di parlare
per poter tanti misteri svelare.