Signatures of Obscured Supermassive Black Hole Growth in High Redshift Dusty Galaxies (Including SMGs)

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Image credit: NASA/JPL-Caltech
Why should we talk about AGN?
Why should we talk about AGN?

Credit: K. Cordes & S. Brown (STScI)

Madau & Dickinson 2014
1. Looking for AGN in SMGs was an obvious idea given the proposed merger scenario

Hopkins et al. 2007
Alexander & Hickox 2012

Theories for triggering AGN

- Merger
- Secular
- Hot halo

Cosmic time
2. Looking for AGN in SMGs was an obvious idea given the local ULIRGs.

Why should we talk about AGN at SMG20?

Log $[L_{IR}(L_\odot)]$ vs. SB fraction.

SMGs

Tran et al. 2001
Why should we talk about AGN at SMG20?

3. AGN were found in some of the first SMGs


A hyperluminous galaxy at $z = 2.8$ found in a deep submillimetre survey

R. J. Ivison, 1 Ian Smail, 2 J.-F. Le Borgne, 3 A. W. Blain, 4 J.-P. Kneib, 3 J. Bézecourt, 3 T. H. Kerr 5 and J. K. Davies 5

From the abstract:

... The emission line widths, FWHM~1000–1500 km/s, and line ratios, along with the compact morphology and high luminosity of the galaxy, indicate that SMM 02399-0136 contains a rare dust-embedded, narrow-line or type-2 active galactic nucleus (AGN) ...
SMG20 - Twenty years of Submillimetre Galaxies:
STAR-FORMING GALAXIES AT HIGH REDSHIFTS.

Why should we talk about AGN?

Credit: K. Cordes & S. Brown (STScI)

Why are we not talking about AGN?
Why should we talk about AGN?

SMGs are dominated by intense star formation
(e.g. Fabian et al., 2000; Alexander et al., 2005a,b; Pope et al., 2006, 2008; Valiante et al. 2007; Menendez-Delmestre et al. 2009, Laird et al., 2010; Lutz et al., 2010; Georgantopoulos et al., 2011; Gilli et al., 2011; Hill & Shanks, 2011; Bielby et al., 2012; Johnson et al., 2013; Wang et al., 2013a,b)
SMGs may not be dominated by AGN ...
but AGN will still be crucial for their evolution

Image credit: NASA/MIT

Alexander & Hickox 2012

Feedback – Quenching – Triggering
How do we observe AGN?

- X-ray spectra and imaging
- Mid-IR spectra and imaging
- Radio spectra and imaging
- Optical spectroscopy
- Submm/radio spectroscopy


S. Juneau et al. in prep.

Image credit: NASA/JPL-Caltech
AGN in SMGs: X-ray insight

AGN in SMGs: X-ray insight

Laird et al. 2010
Star formation heats the interstellar medium

Hollenbach & Tielens 1997
Active Galactic Nuclei heat the interstellar medium

Warm dust
[NeV]
[OIV]
Etc.
Mid-infrared is a good tracer of AGN

Chen et al. 2017
Mid-infrared spectral signature of AGN

Star-forming

AGN

[NeII] [NeV]

PAHs

Local ULIRGs: Stierwalt et al. 2013
Pope et al. 2008; Riechers et al. 2014
Pope et al. 2008; Riechers et al. 2014
Pope et al. 2008; Riechers et al. 2014
Mid-IR picks up obscured AGN

Alexander et al. 2008
Pope et al. 2008; Riechers et al. 2014
AGN in SMGs: Mid-infrared color diagnostics

Coppin et al. 2010; see also Ivison et al. 2004; Pope et al. 2008
What is the impact of the AGN on the full IR SED?
Simulations show AGN heating the ISM

The AGN can heat the ISM throughout the galaxy

Roebuck et al. (2016)
What is the impact of the AGN on the full IR SED?

Empirical SED templates based on *Spitzer* (IRS spectroscopy) and *Herschel* observations of 343 dusty galaxies from \( z = 0.5 - 4 \)

Goal: Understand the impact of the mid-IR diagnosed AGN on the full IR SED

Kirkpatrick, Pope, et al. 2015
http://daisy.astro.umass.edu/~pope/Kirkpatrick2015/
Observations of AGN heating the ISM

Kirkpatrick, Pope, et al. 2015
Are AGN an epidemic in dusty galaxies?

What to do with AGN in dusty galaxies?

Step 1: Identify

Step 2: Quantify AGN luminosity
   (-> Eddington ratio)

Step 3: Determine impact of
   AGN on host galaxy ISM

Step 4: Quantify black hole mass
What to do with AGN in dusty galaxies?

Step 1: Identify ✔

Step 2: Quantify AGN luminosity (-> Eddington ratio) ✔

Step 3: Determine impact of AGN on host galaxy ISM

Sort of
Need resolved studies

Step 4: Quantify black hole mass TBD
Open questions

1. **What is the sphere of influence of AGN within galaxies?** How much does it contribute to heating the gas and dust on galaxy scales? How does this contribute to triggering or quenching the star formation?

2. **How does the M-sigma relation evolve over cosmic time?** How does it vary in individual galaxies over their lifetime?

**SMGs/DSFGs are excellent laboratories for addressing these broad questions in galaxy evolution**
Black hole masses from mid-IR spectroscopy

Spinoglio et al. 2012

Dasyra et al. 2008
JWST can see PAHs back to cosmic noon and AGN diagnostic lines (Ne lines) only out to $z \sim 1$
SPICA and Origins Space telescope can see the AGN diagnostic lines out to cosmic dawn
NASA Mission concept: a Far-Infrared Surveyor for the 2020 Decadal review

~10 μm – 1000 μm, cold, large aperture ~8-15 m

launch ~2030
Tracing the signatures of life and the ingredients of habitable worlds

Origins will trace the trail of water from interstellar clouds, to proto-planetary disks, to Earth itself facilitating understanding of the abundance and availability of water for habitable planets.

Charting the Rise of Metals, Dust, and the First Galaxies

Origins will trace the metal enrichment history of the Universe, probe the first cosmic sources of dust, the earliest star formation, and the birth of galaxies.

Unveiling the Growth of Black Holes and Galaxies over Cosmic Time

Origins will reveal the co-evolution of super-massive black holes and galaxies, energetic feedback, and the dynamic interstellar medium from which stars are born.

Characterizing Small Bodies in the Solar System

Origins will chart the role of comets in delivering water to the early Earth, and conduct a survey of thousands of ancient Trans Neptunian Objects (TNOs) in the outer reaches of the Solar System.
Unveiling the Growth of Black Holes and Galaxies over Cosmic Time

Origins will reveal the co-evolution of super-massive black holes and galaxies, energetic feedback, and the dynamic interstellar medium from which stars are born.
Summary

- AGN may not dominate the bolometric luminosity of dusty galaxies, but they are lurking in a significant fraction (~25%) of the population.

- We can exploit SMGs/DSFGs to understand the coevolution of star formation and supermassive black hole growth at early times.

- JWST – SPICA – OST will be crucial for weighing the black holes in these active systems.

Image credit: NASA/JPL-Caltech