

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



Alexandra Pope (UMass Amherst)  
SMG20 – Durham, UK  
August 2, 2017

Image credit: NASA/JPL-Caltech



# SMG20 - Twenty years of Submillimetre Galaxies:

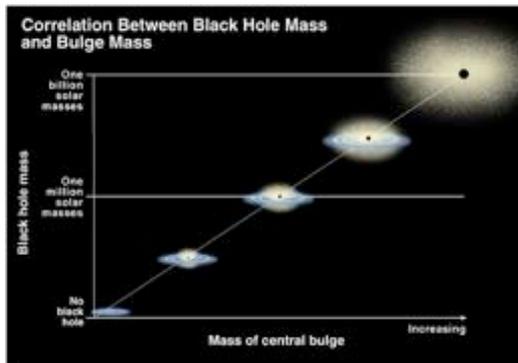
STAR-FORMING GALAXIES AT HIGH REDSHIFTS.

**Why should we talk about AGN?**

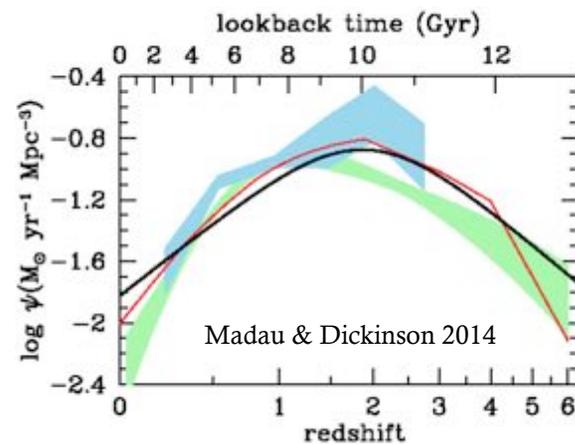
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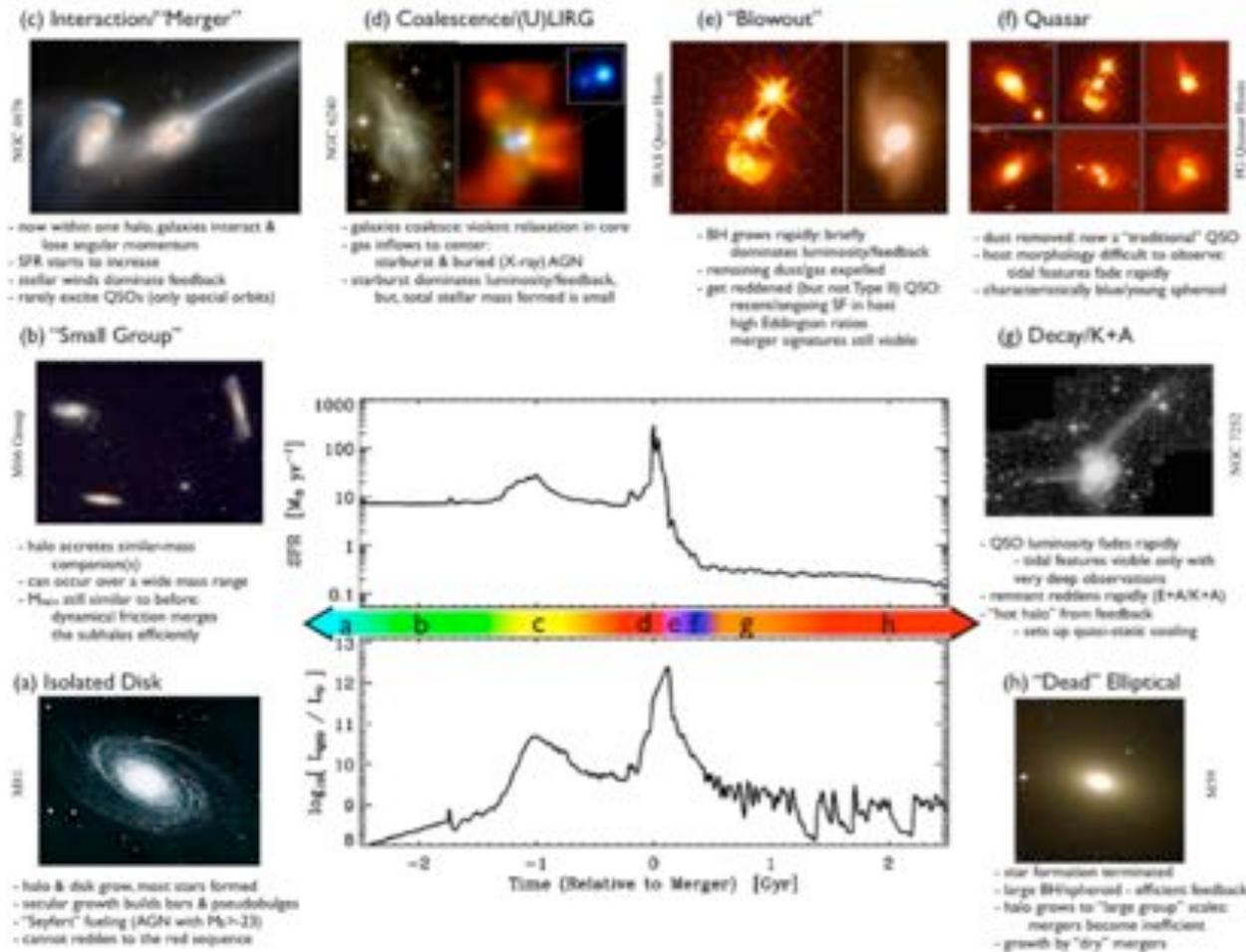


Credit: K. Cordes & S. Brown (STScI)

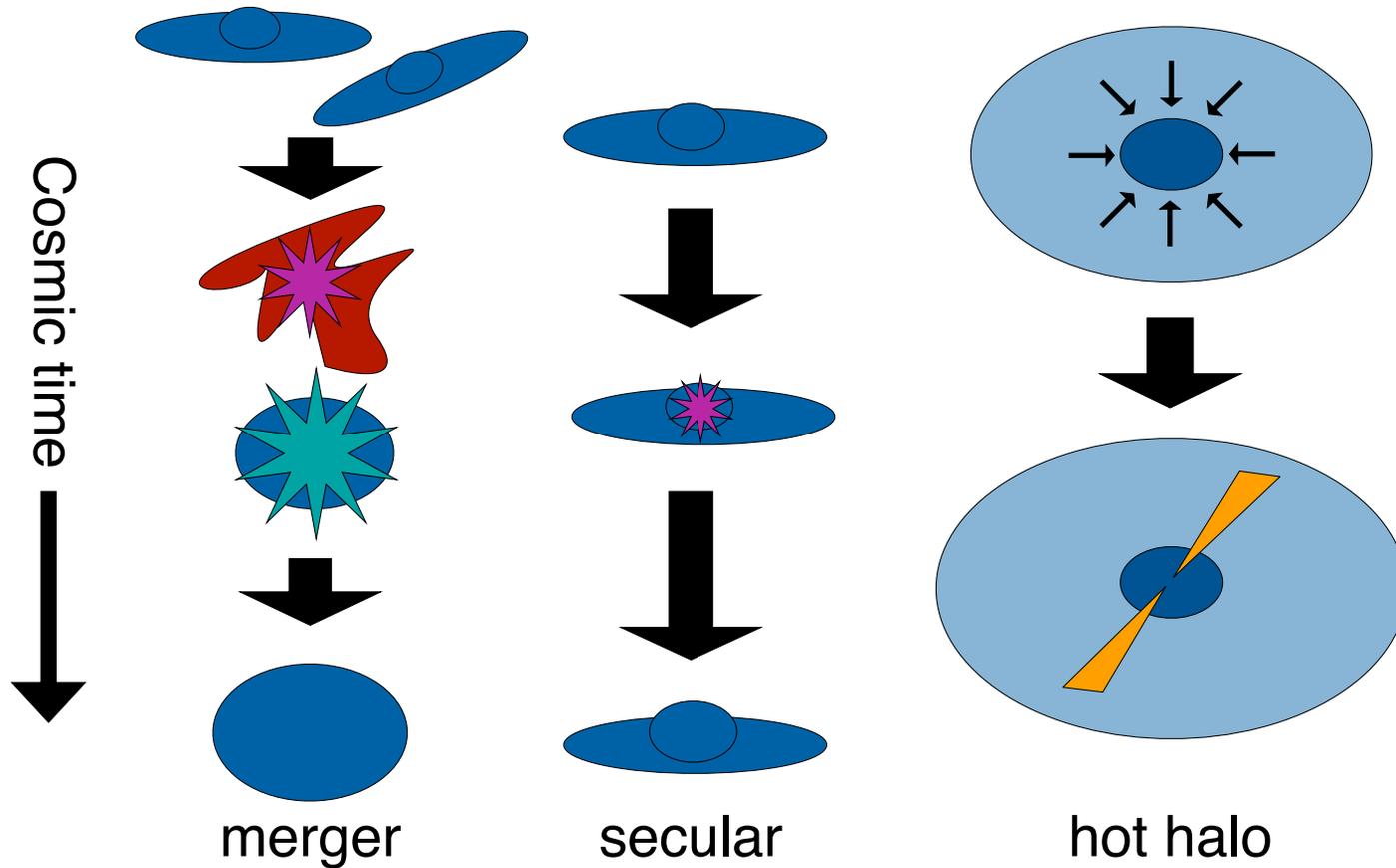


Why should we talk about AGN at SMG20?

# 1. Looking for AGN in SMGs was an obvious idea given the proposed merger scenario

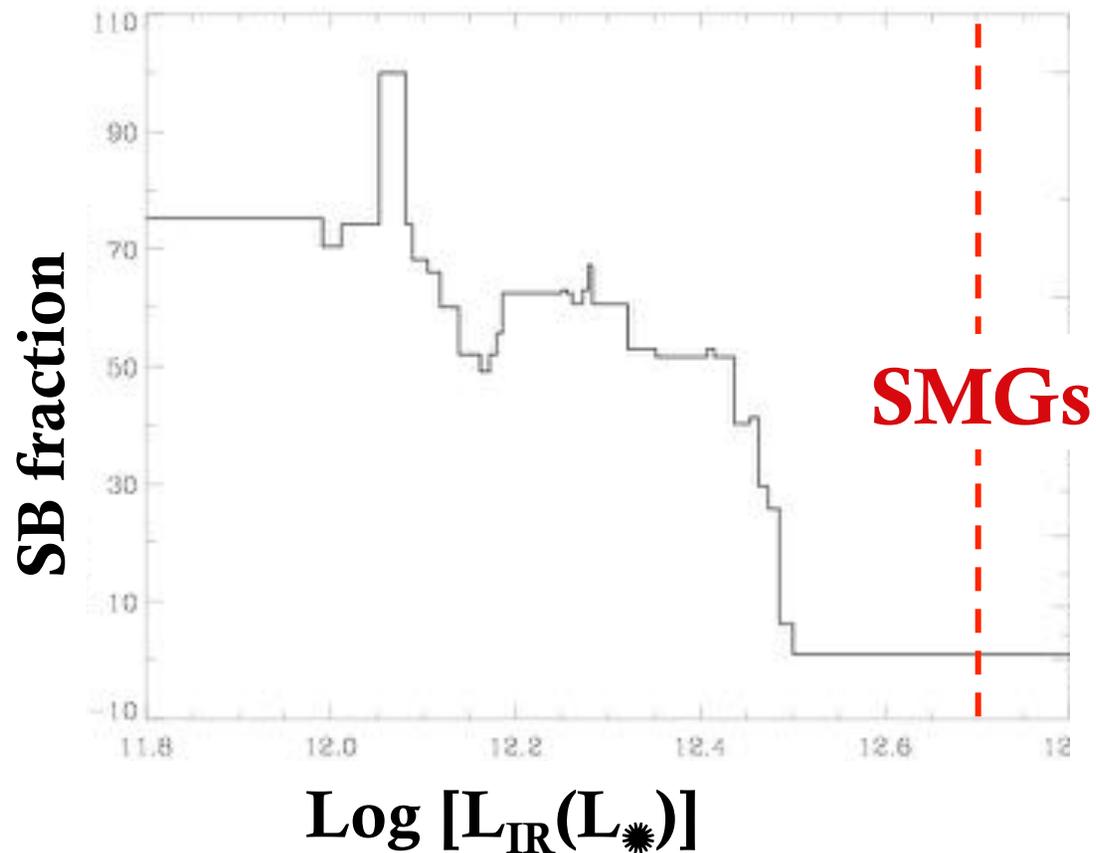


# Theories for triggering AGN



Why should we talk about AGN at SMG20?

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



Why should we talk about AGN at SMG20?

### 3. AGN were found in some of the first SMGs

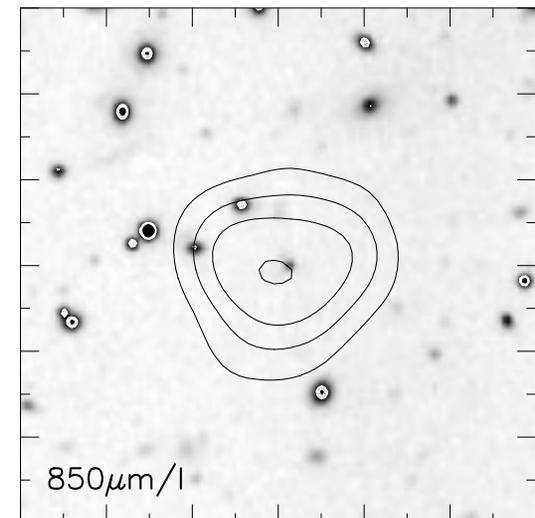
Mon. Not. R. Astron. Soc. **298**, 583–593 (1998)

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

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

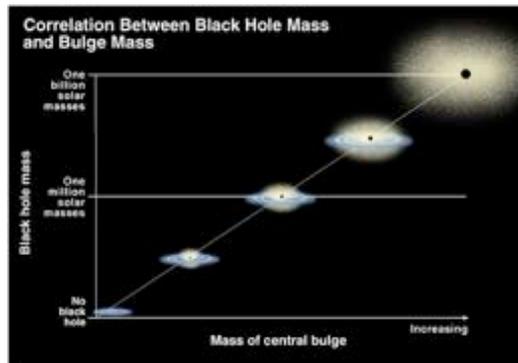
From the abstract:

... 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)** ...

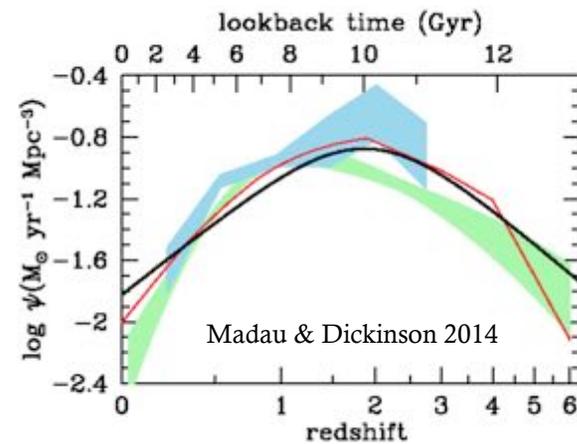


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## Why should we talk about AGN?



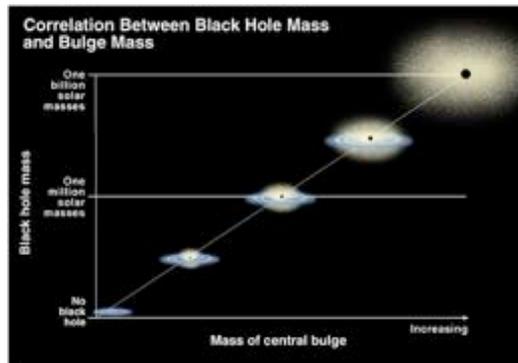
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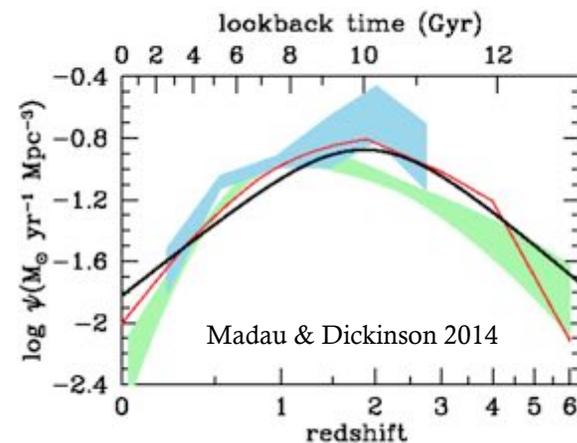
## Why are we not talking about AGN?

# SMG20 - Twenty years of Submillimetre Galaxies: STAR-FORMING GALAXIES AT HIGH REDSHIFTS.

## Why should we talk about AGN?



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

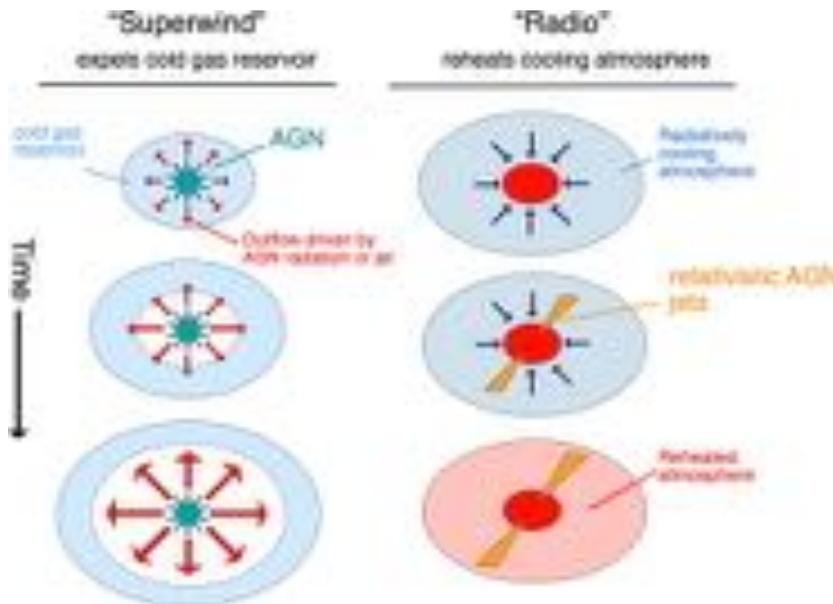


## Why are we not talking about AGN?

### 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



Alexander & Hickox 2012

## Feedback - Quenching - Triggering

# How do we observe AGN ?

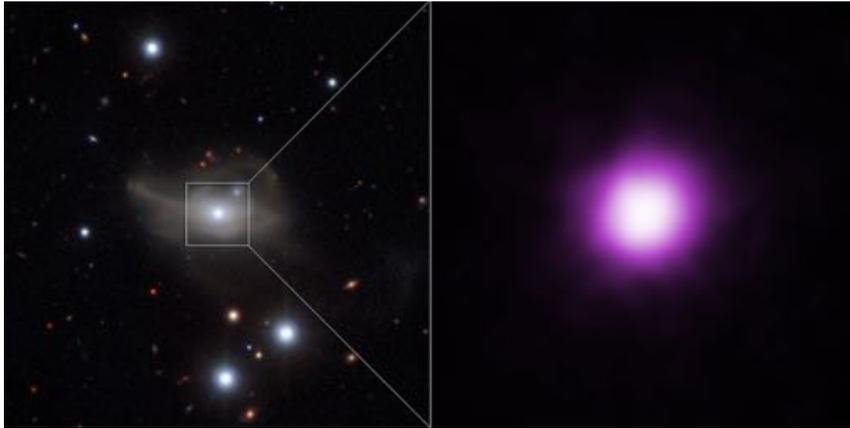


Image credit: X-ray: NASA/CXC/Univ of Sydney/R.McElroy et al,  
Optical: ESO/CARS Survey.

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

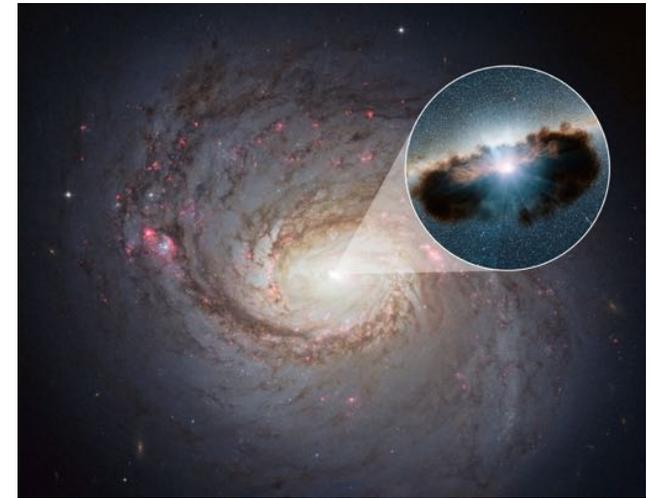
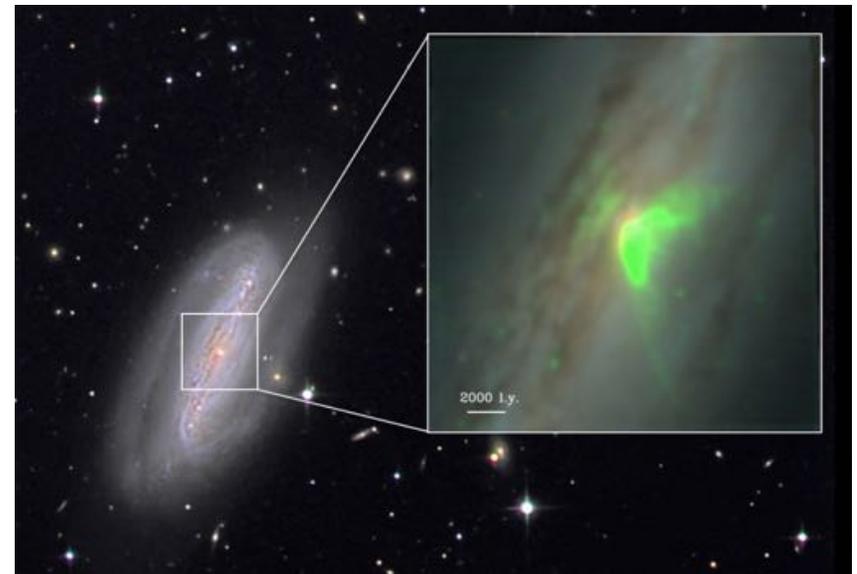
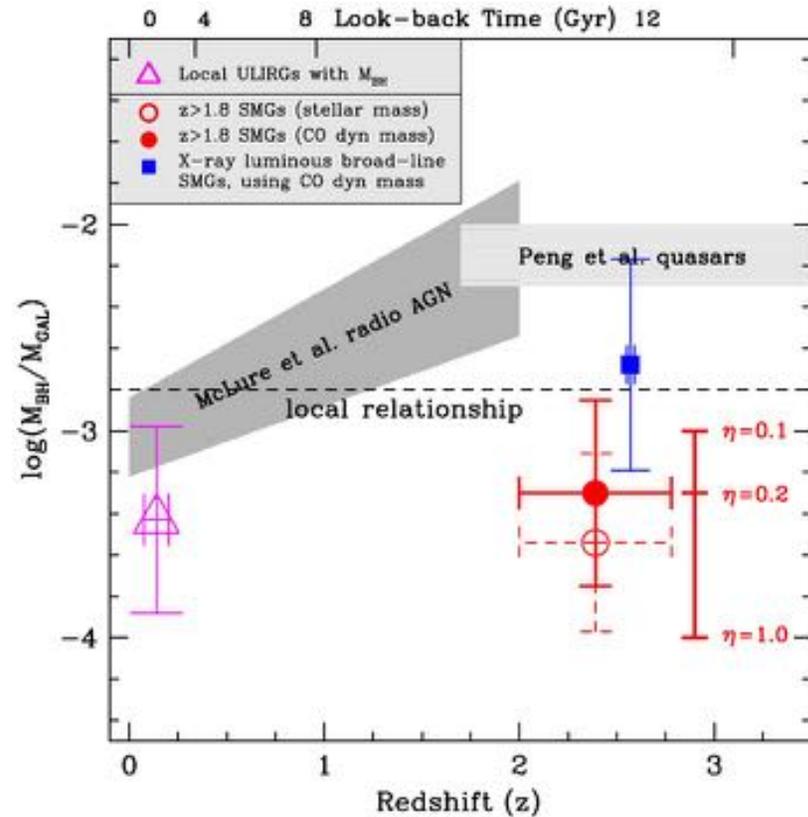
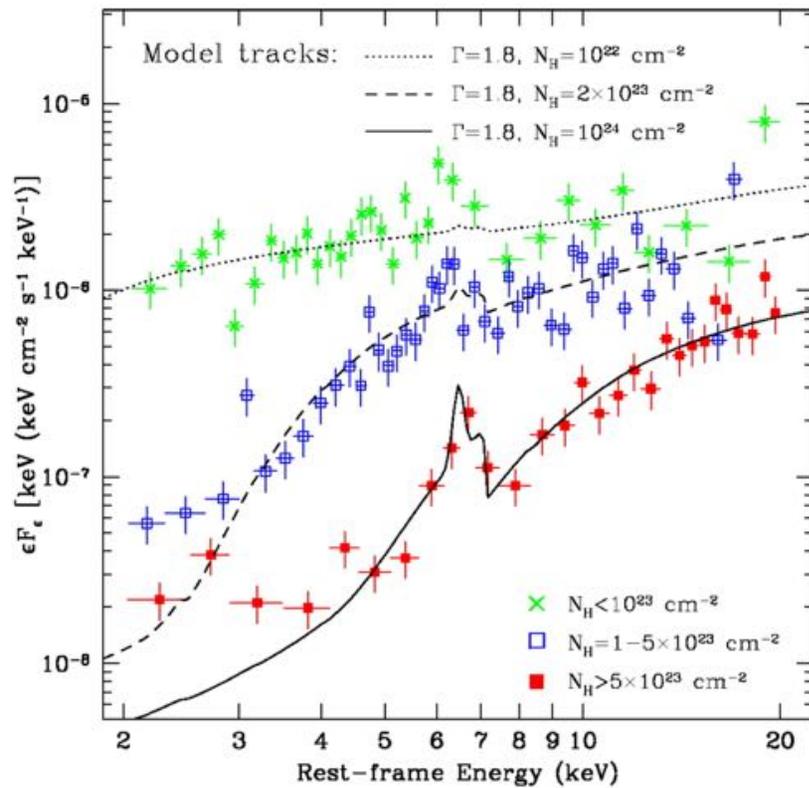


Image credit: NASA/JPL-Caltech

S. Juneau et al. in prep.

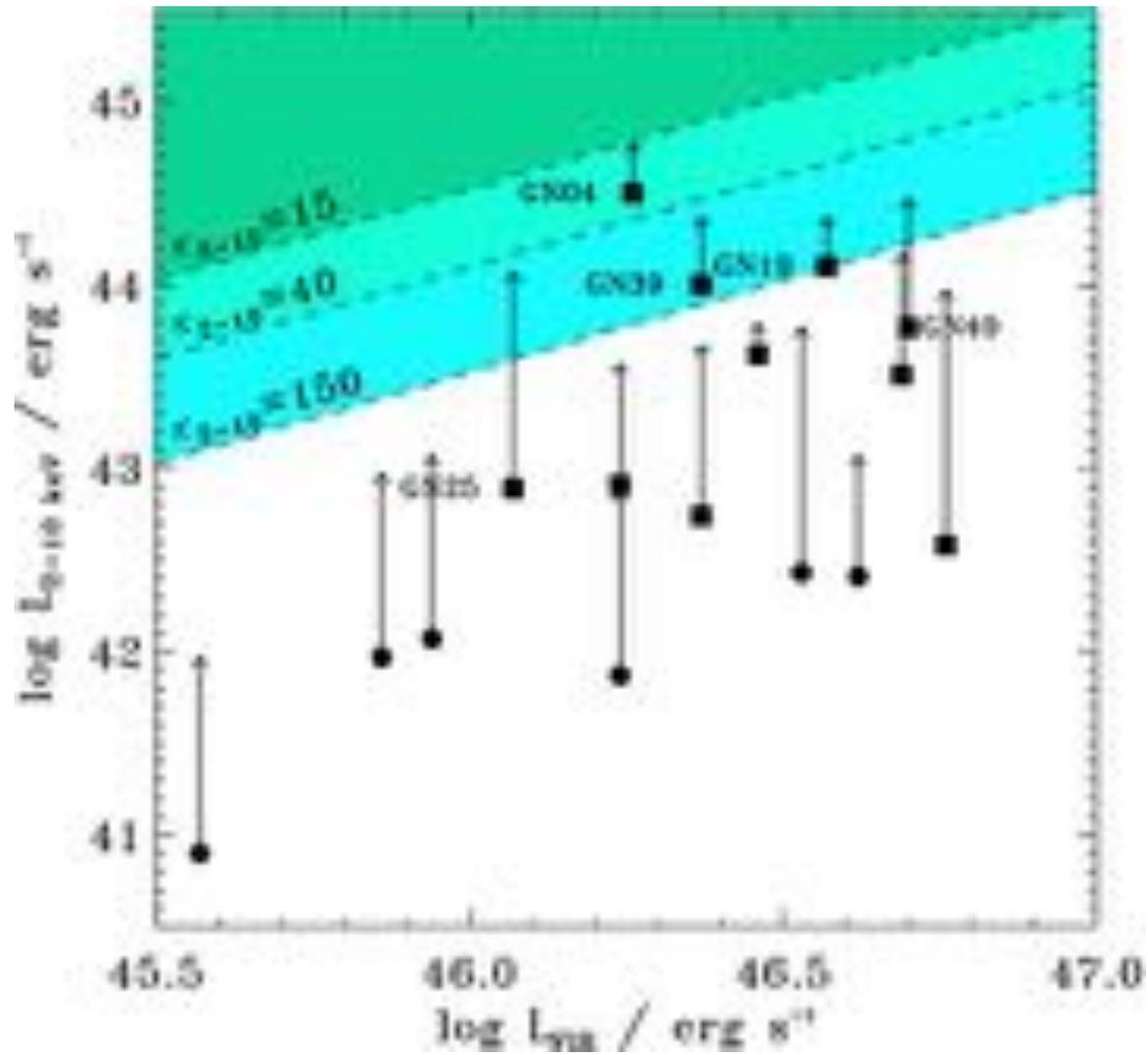


# AGN in SMGs: X-ray insight



Alexander et al. 2005, 2008

# AGN in SMGs: X-ray insight

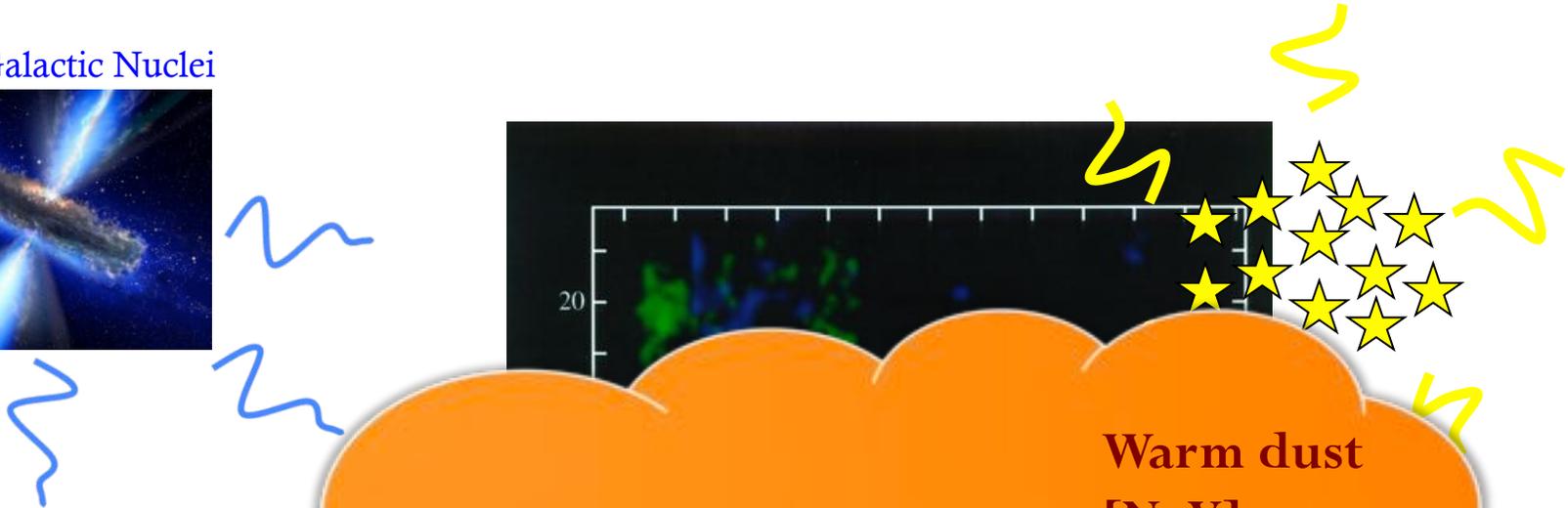
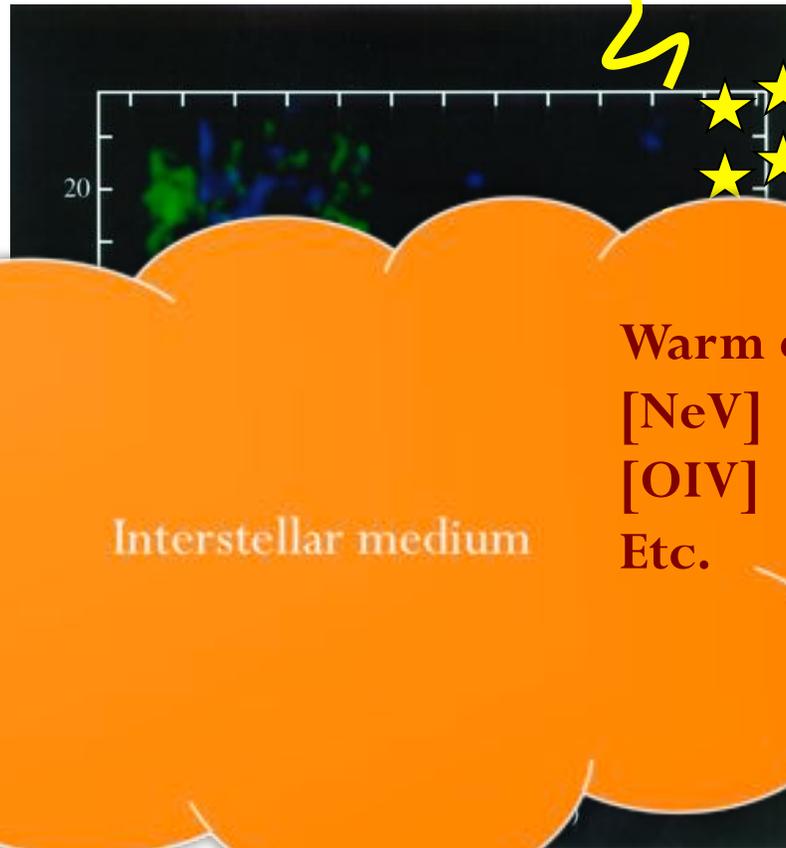
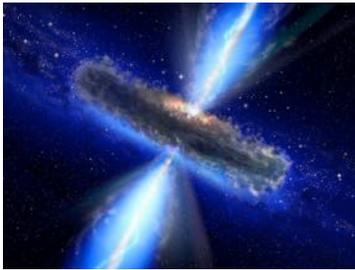


Laird et al. 2010

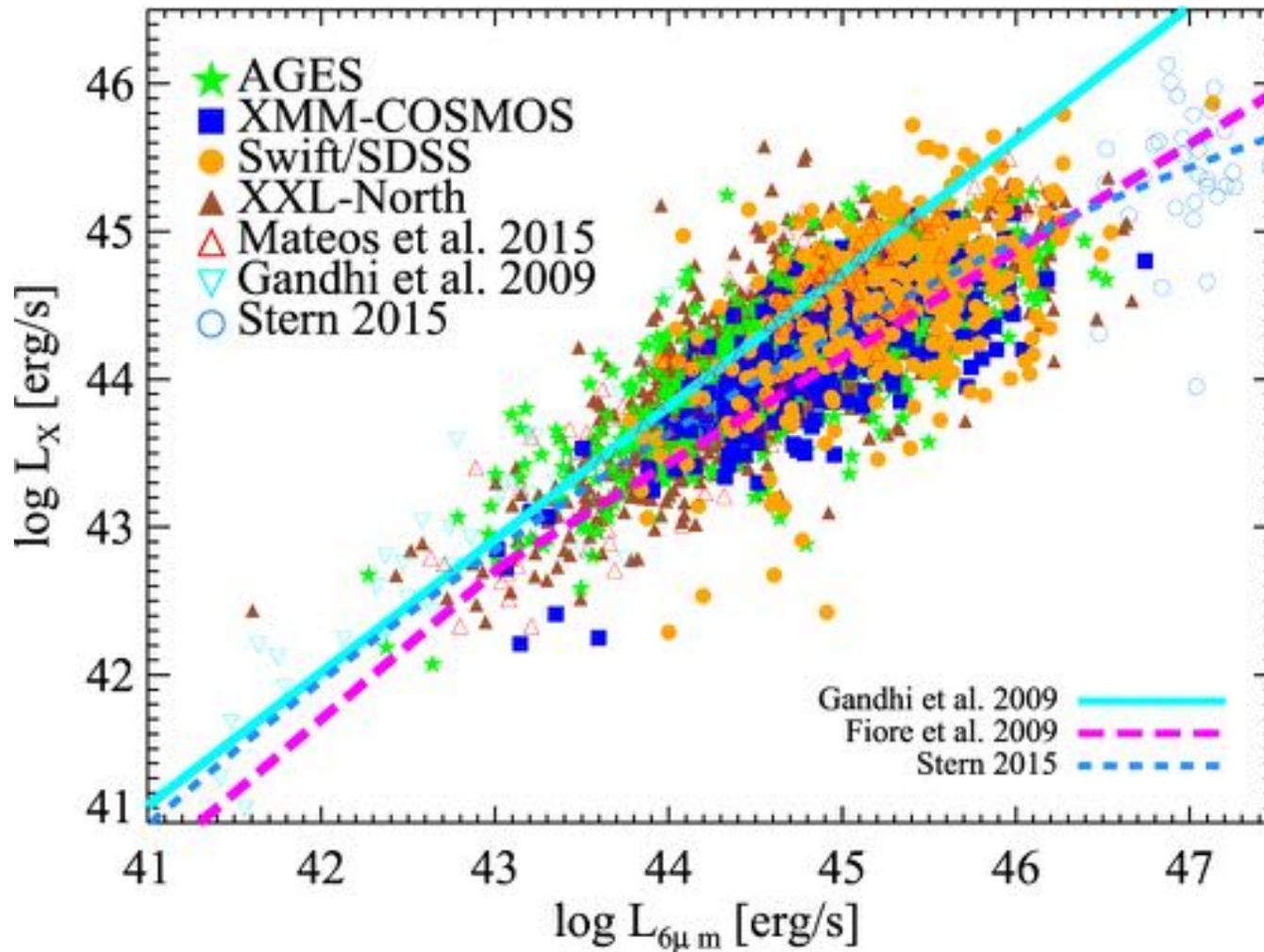


# Active Galactic Nuclei heat the interstellar medium

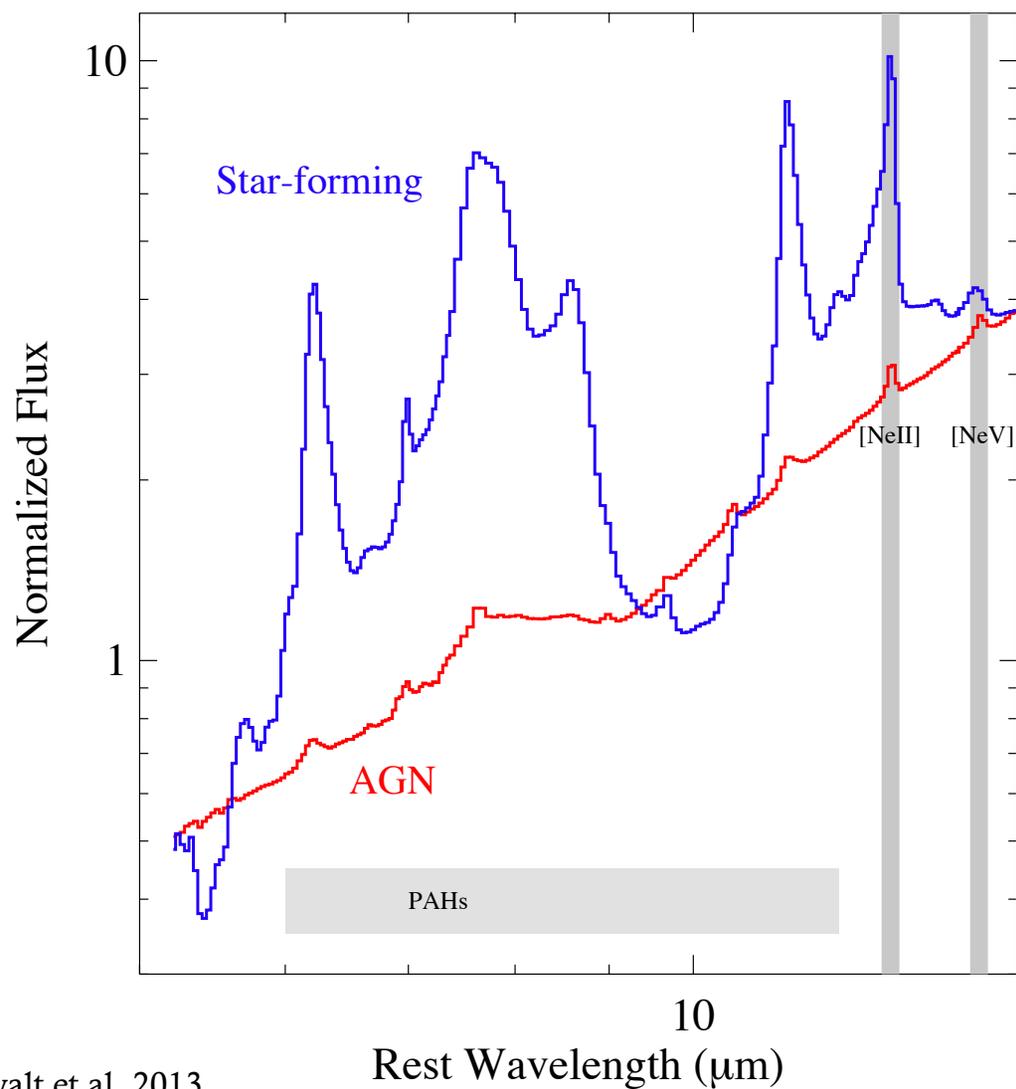
Active Galactic Nuclei



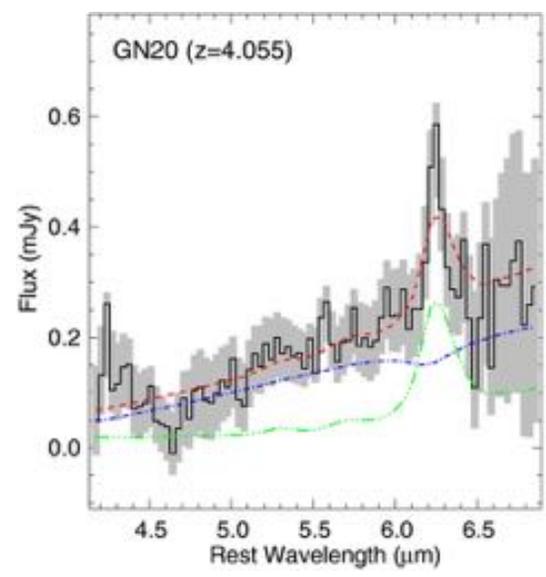
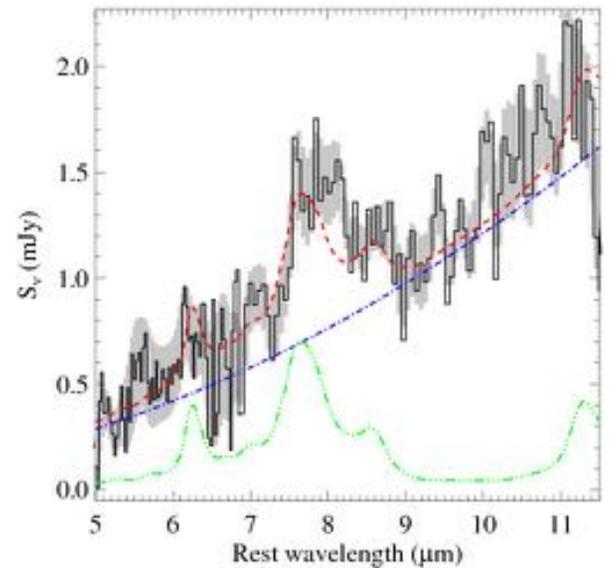
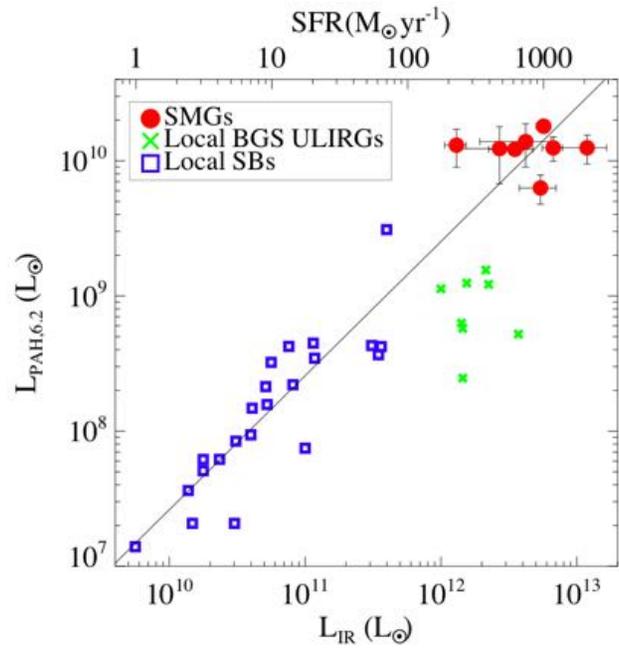
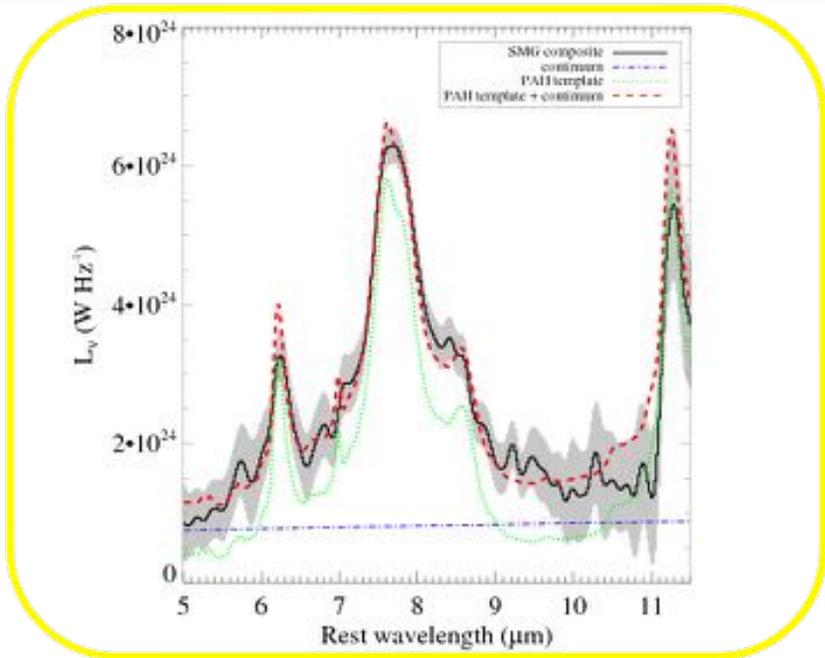
# Mid-infrared is a good tracer of AGN



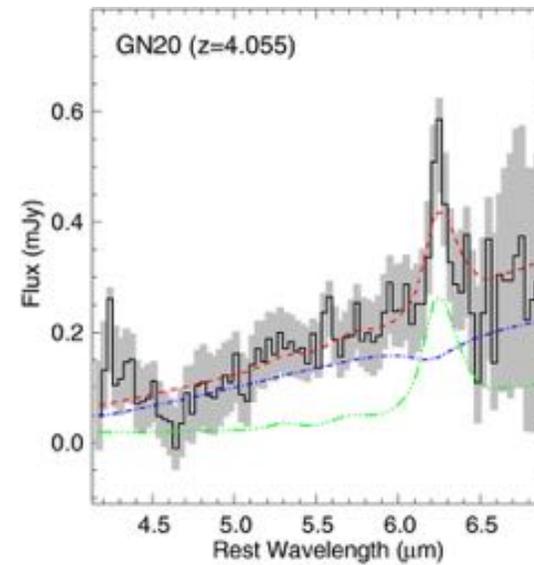
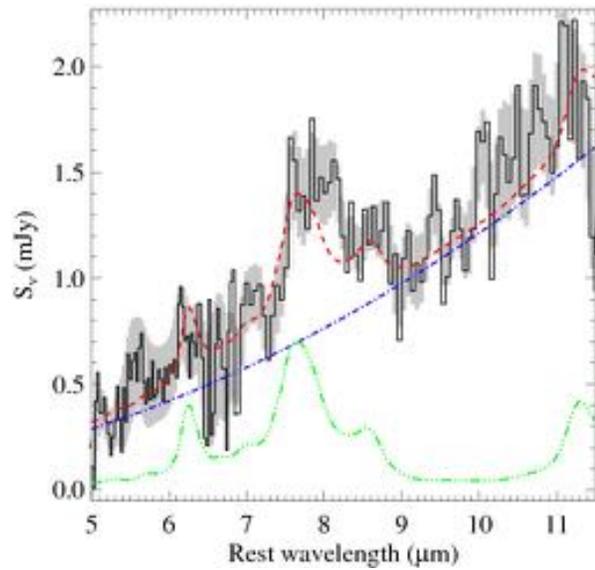
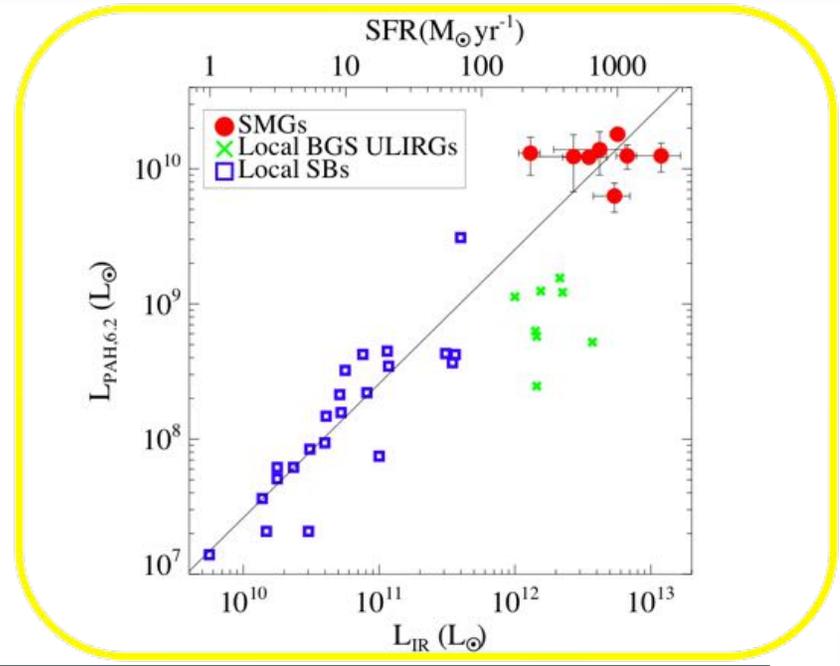
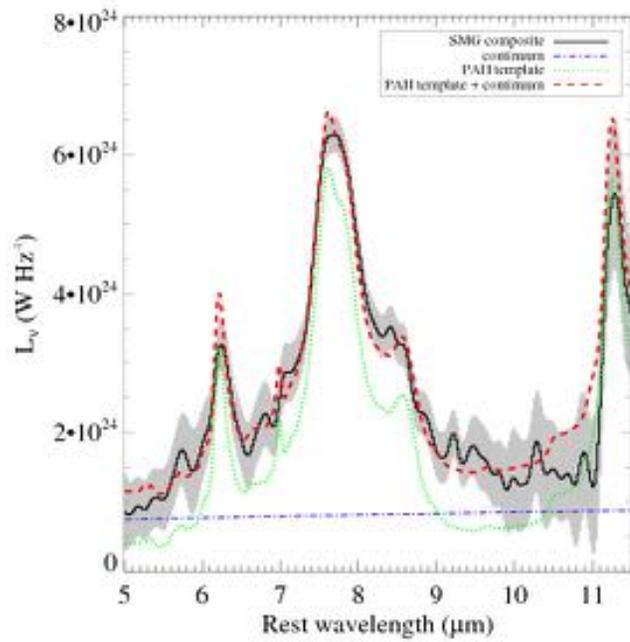
# Mid-infrared spectral signature of AGN



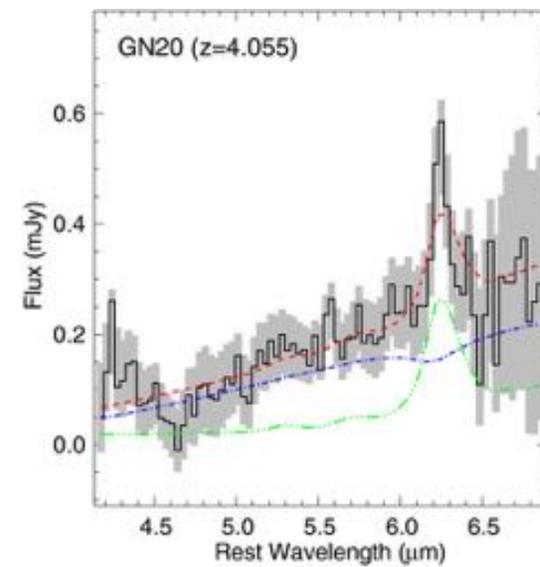
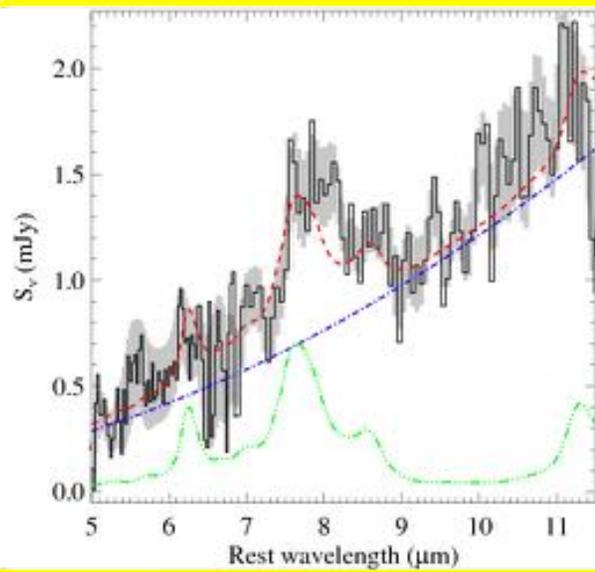
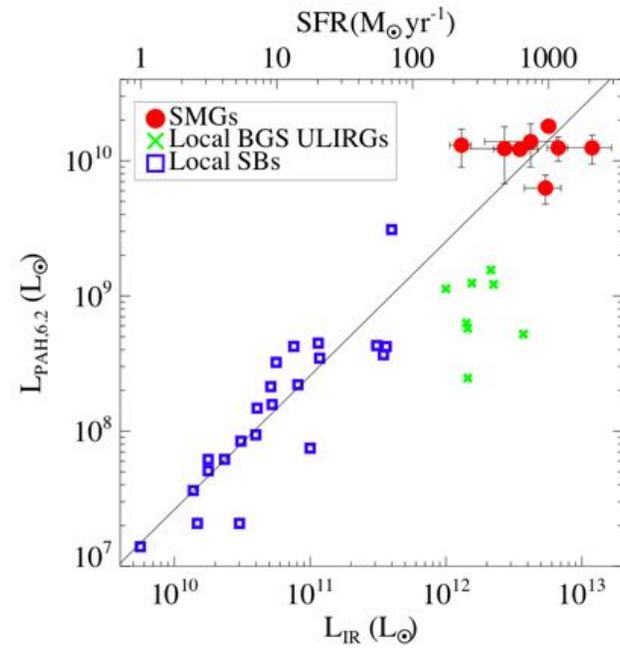
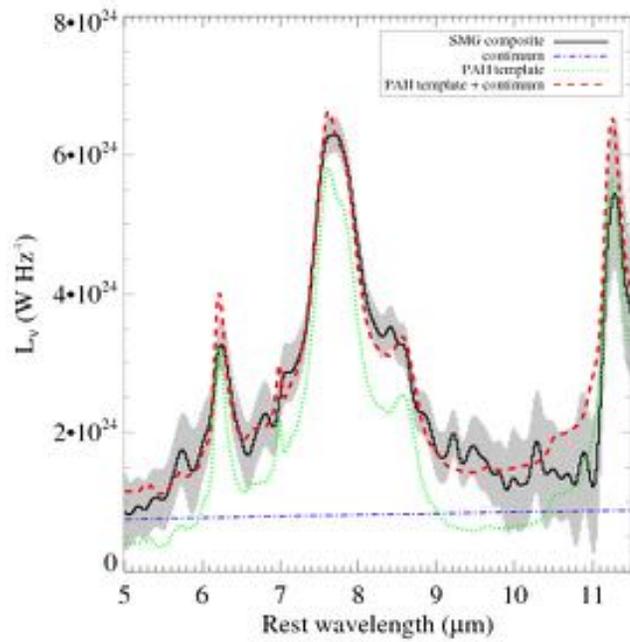
Local ULIRGs: Stierwalt et al. 2013



Pope et al. 2008; Riechers et al. 2014

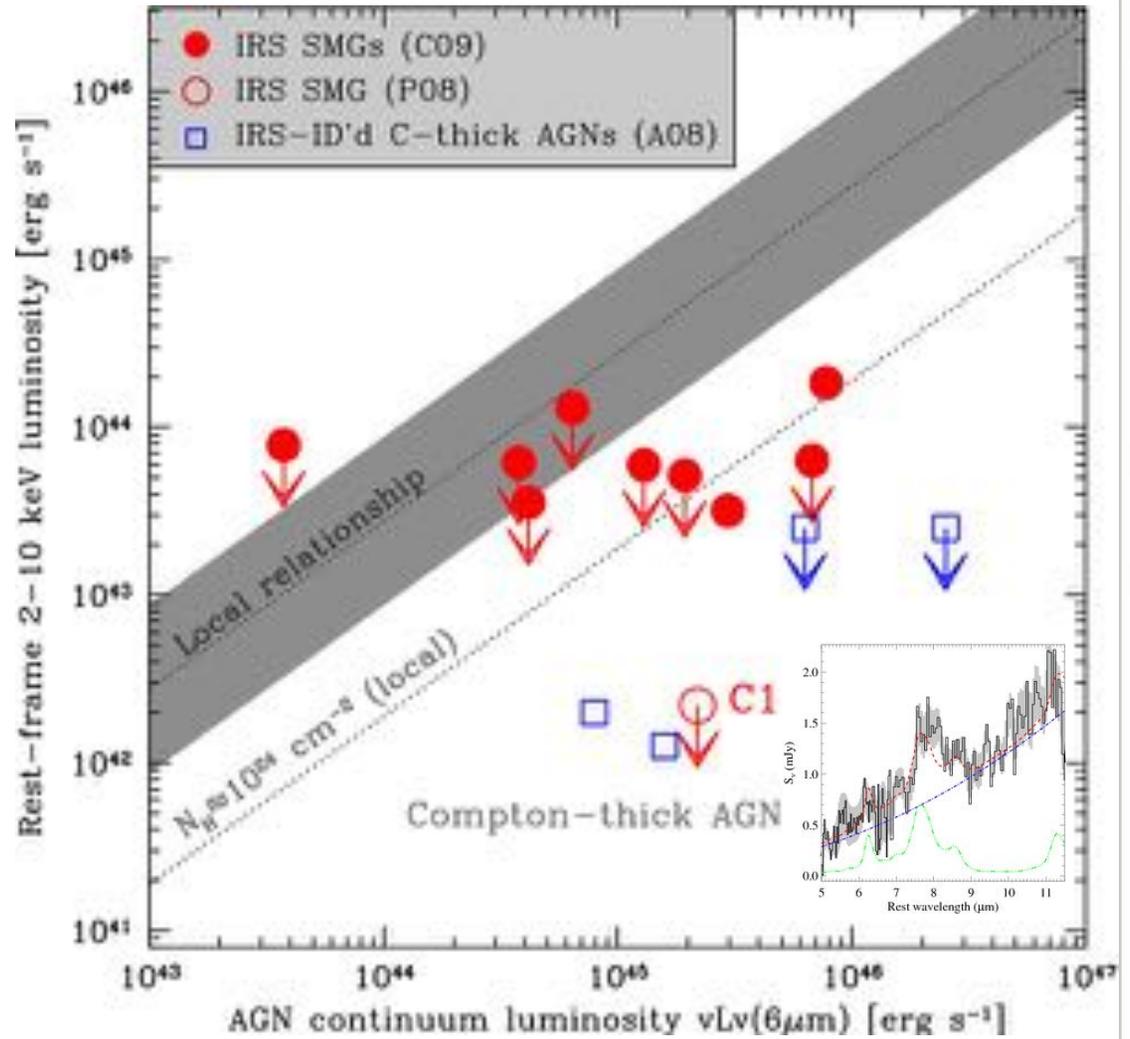
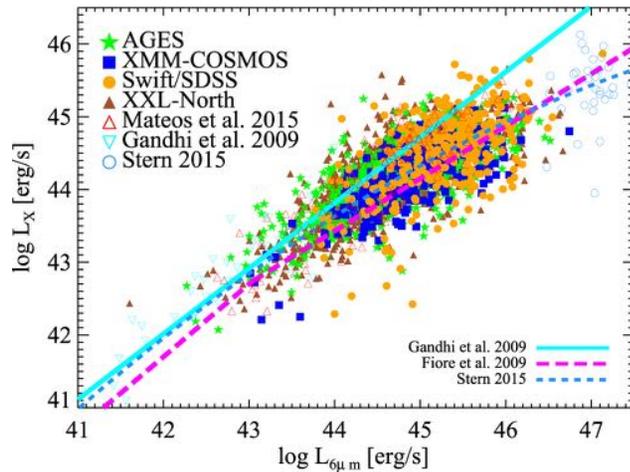


Pope et al. 2008; Riechers et al. 2014

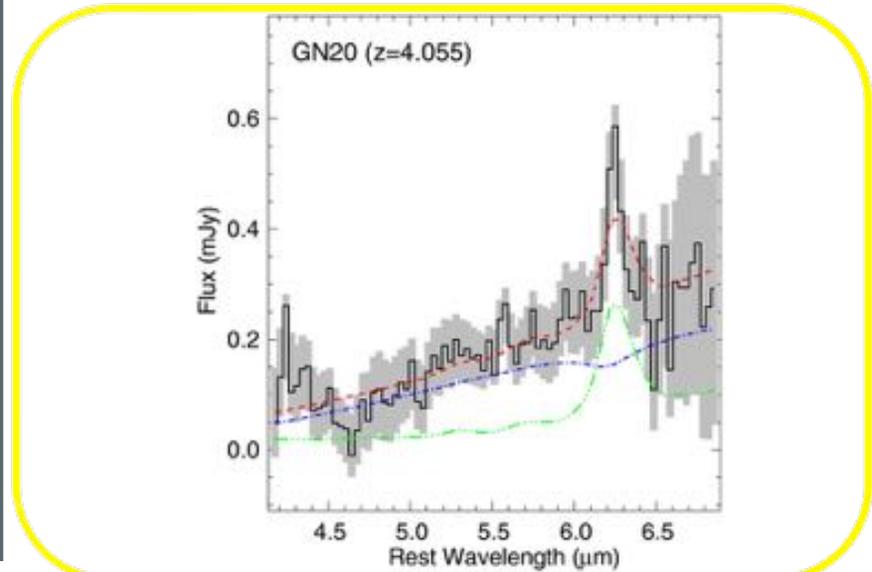
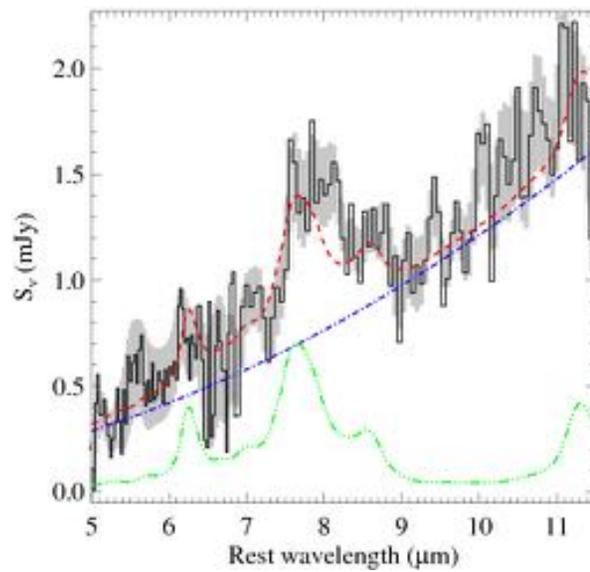
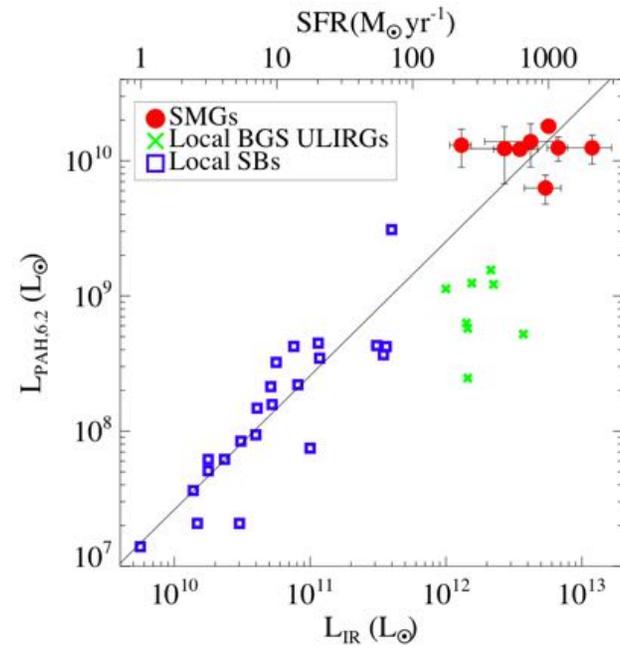
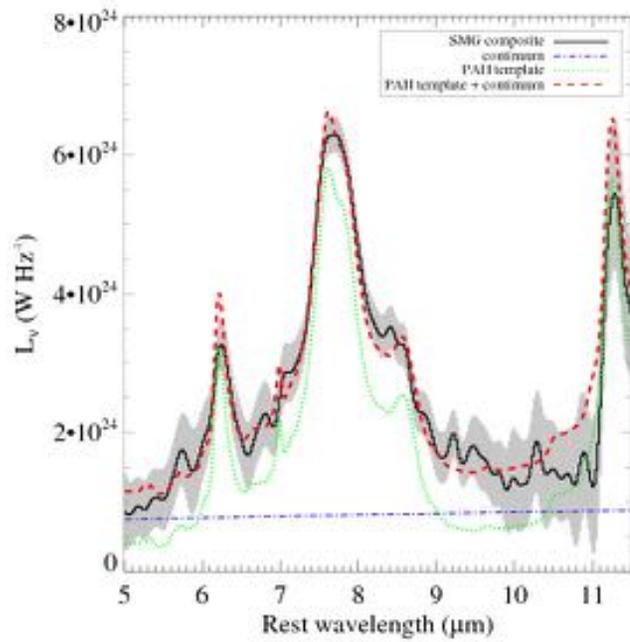


Pope et al. 2008; Riechers et al. 2014

# Mid-IR picks up obscured AGN

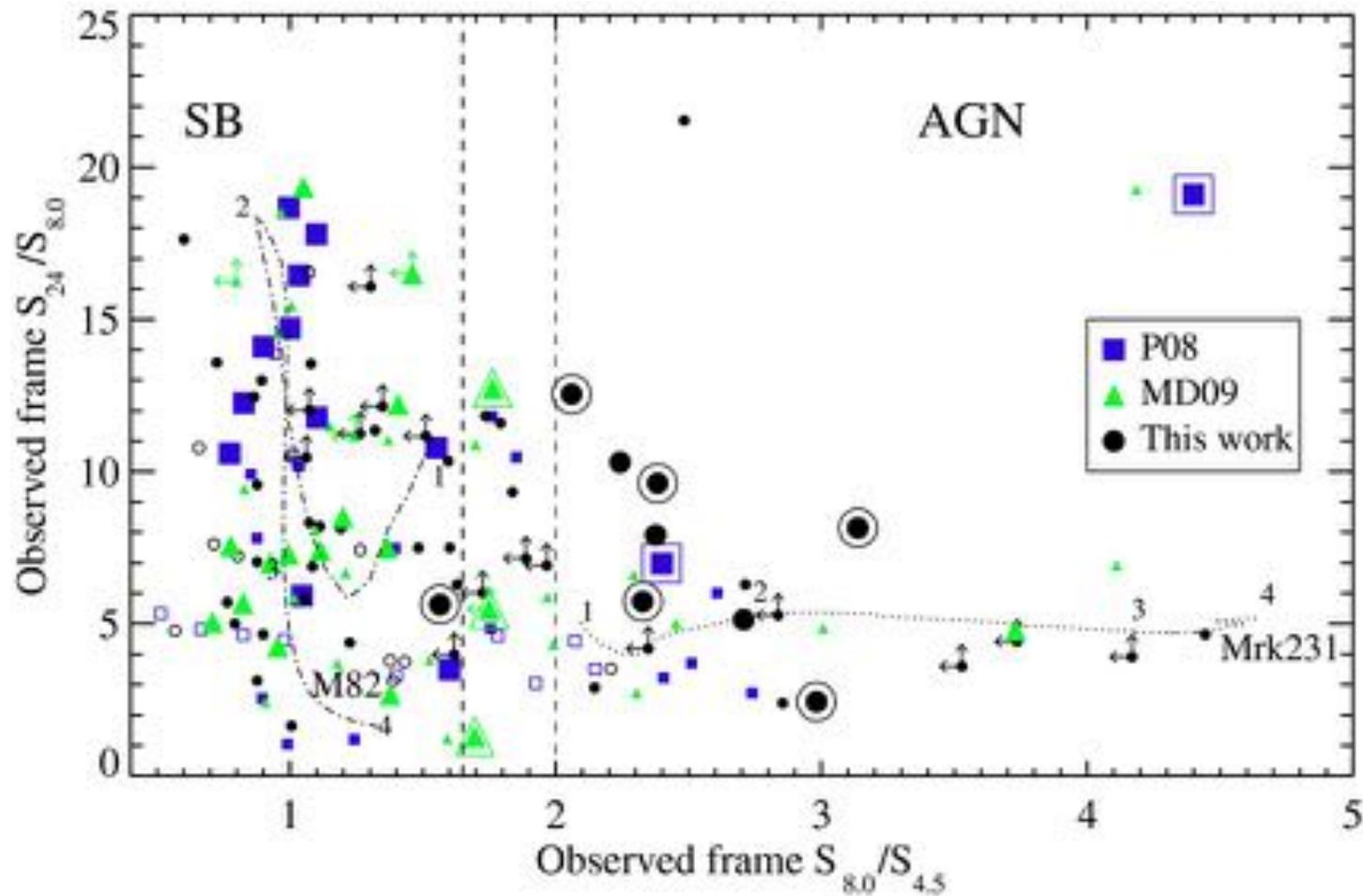


Alexander et al. 2008



Pope et al. 2008; Riechers et al. 2014

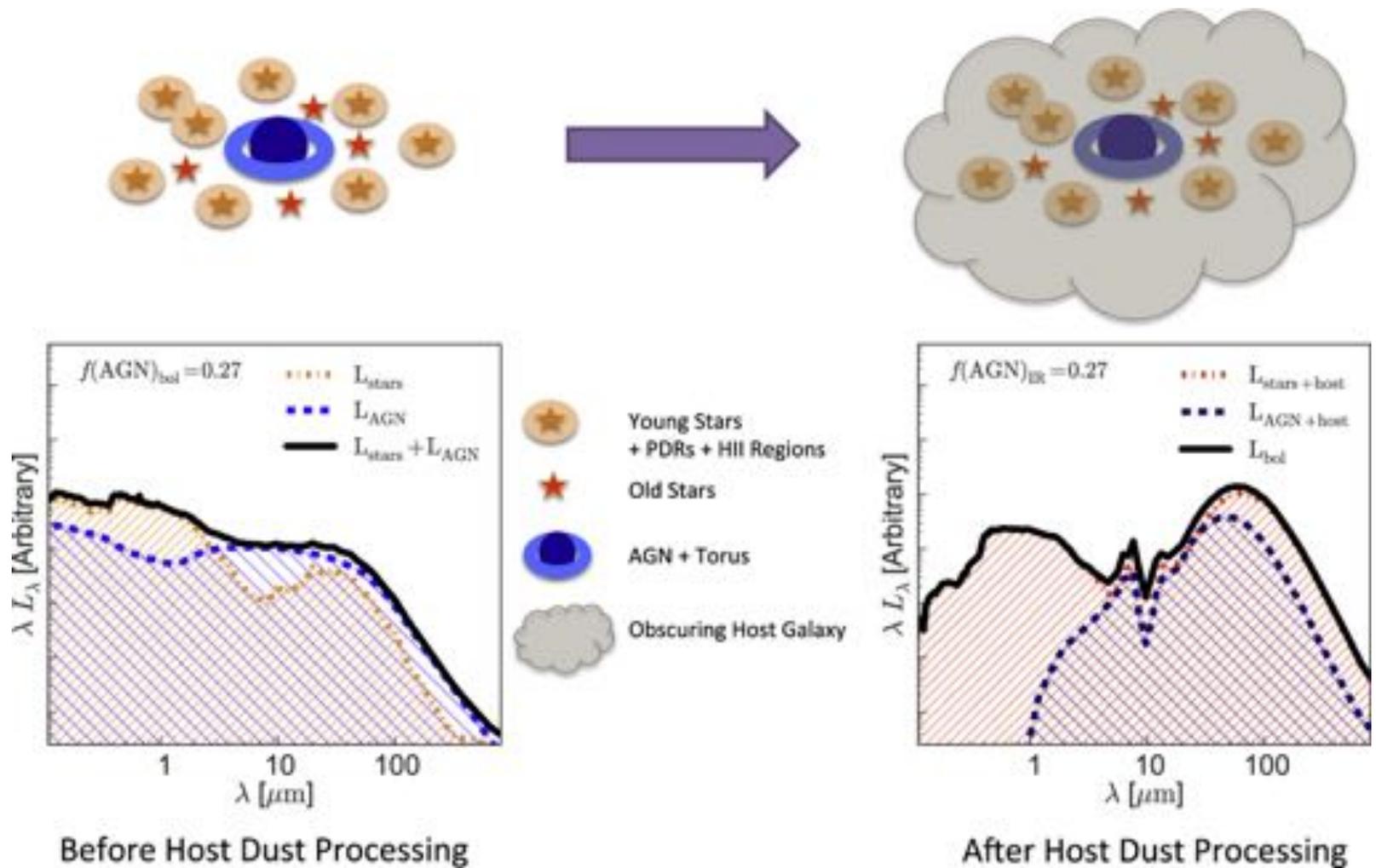
# AGN in SMGs: Mid-infrared color diagnostics



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

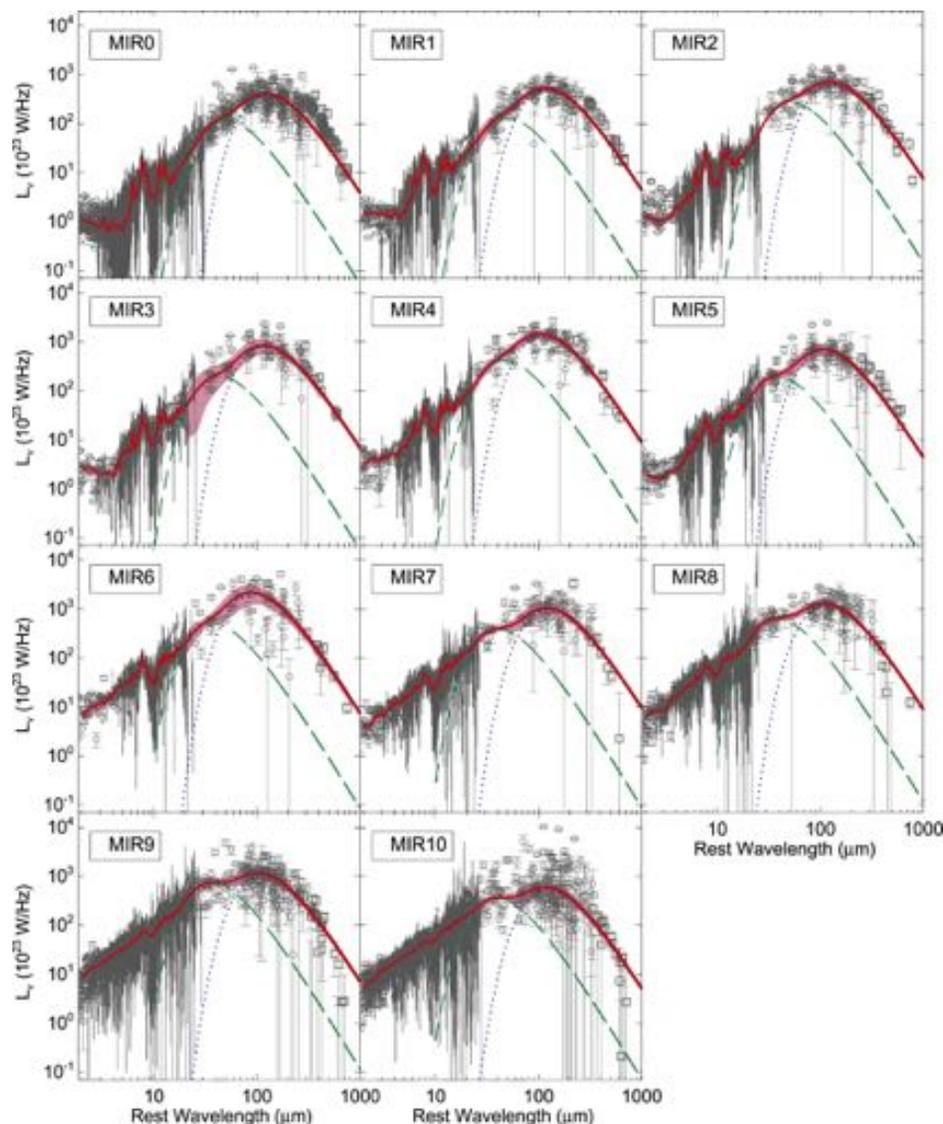


The AGN can heat the ISM throughout the galaxy

# 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  $z=0.5-4$

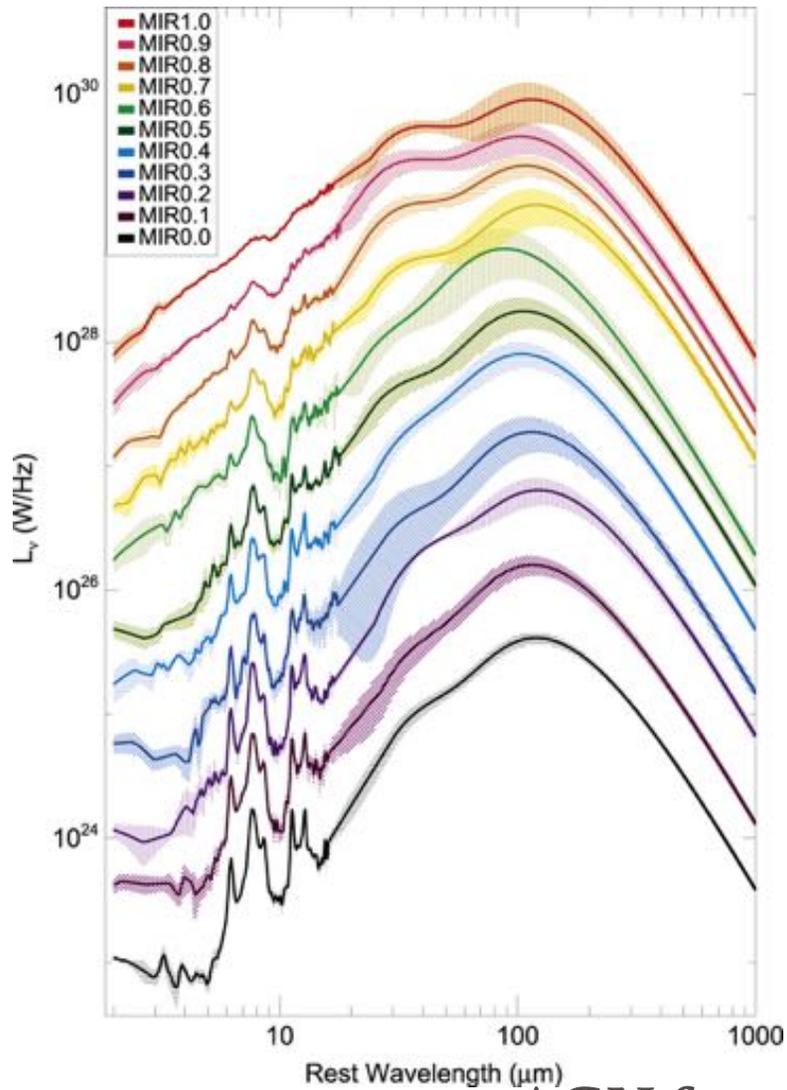
Goal: Understand the impact of the mid-IR diagnosed AGN on the full IR SED



Kirkpatrick, Pope, et al. 2015

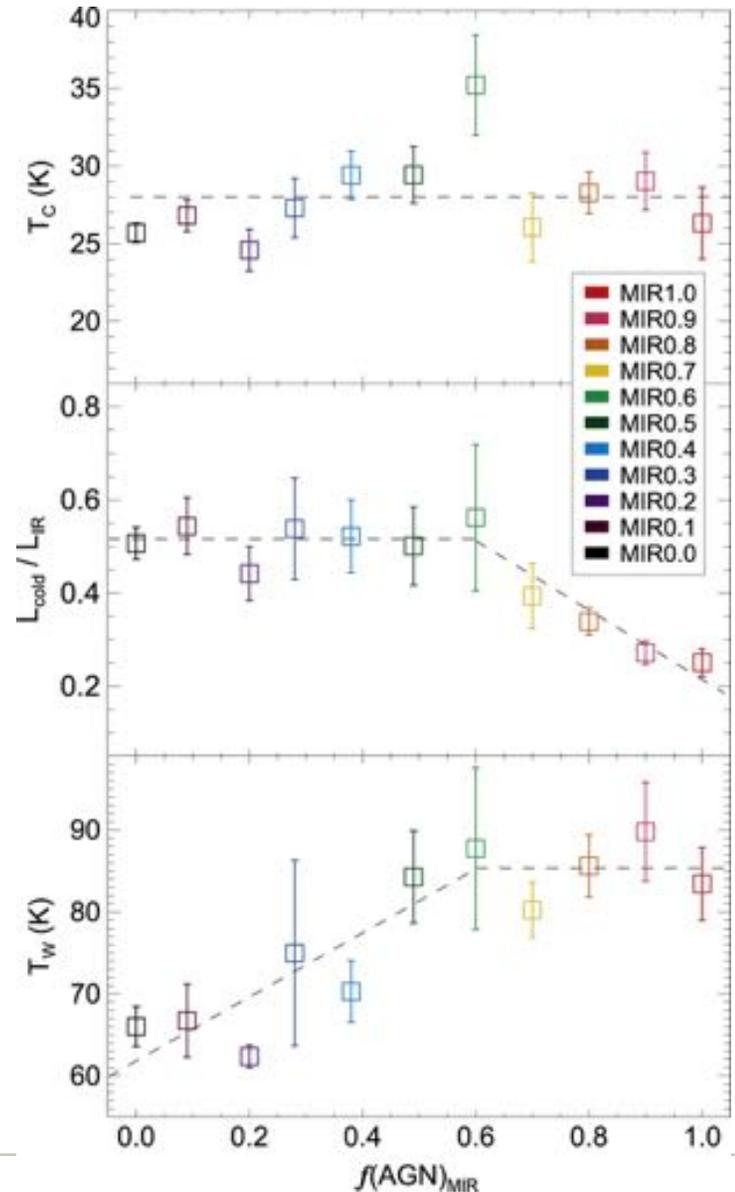
<http://daisy.astro.umass.edu/~pope/Kirkpatrick2015/>

# Observations of AGN heating the ISM

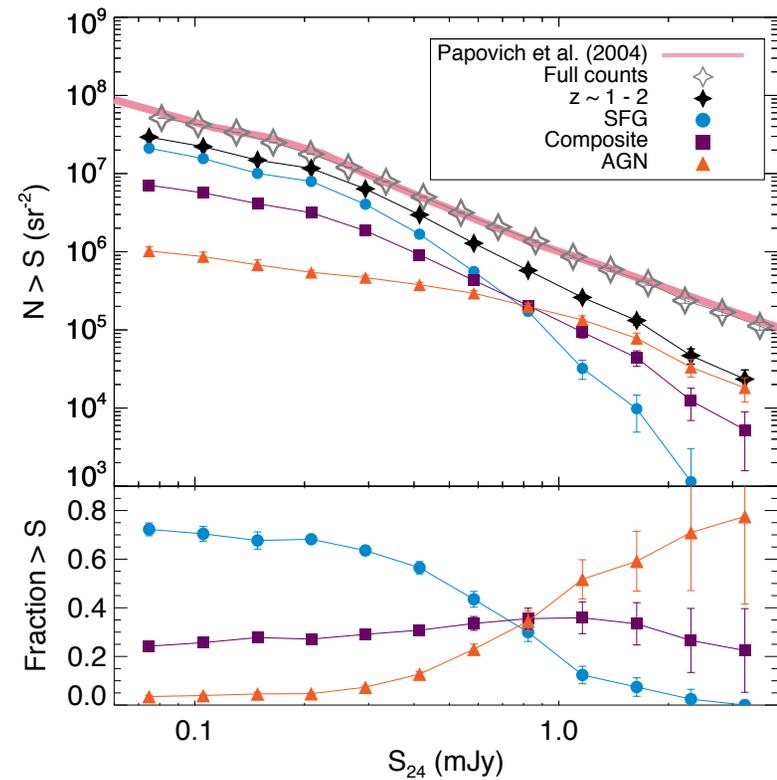
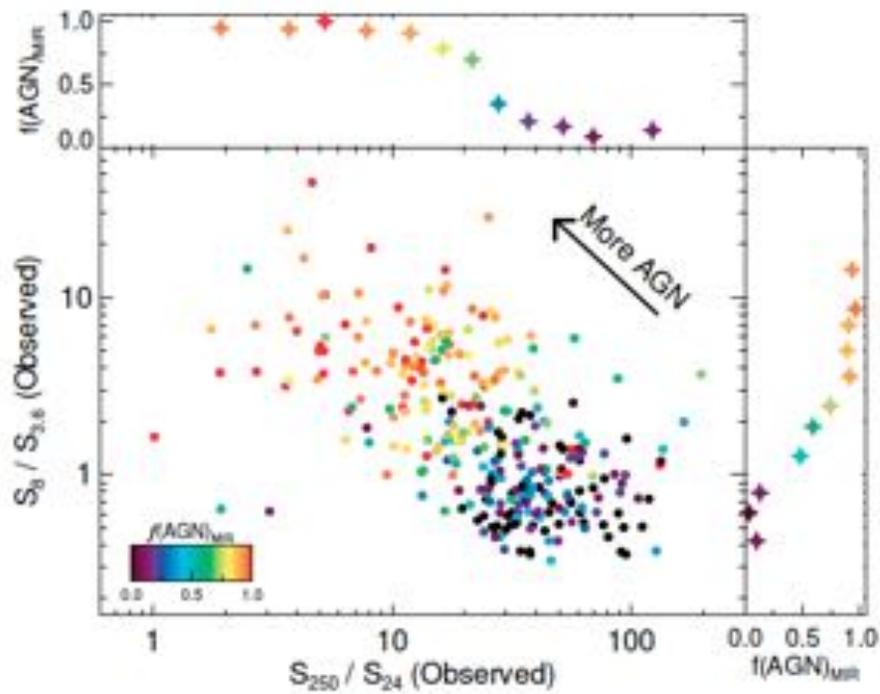


Kirkpatrick, Pope, et al. 2015

AGN fraction



# 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

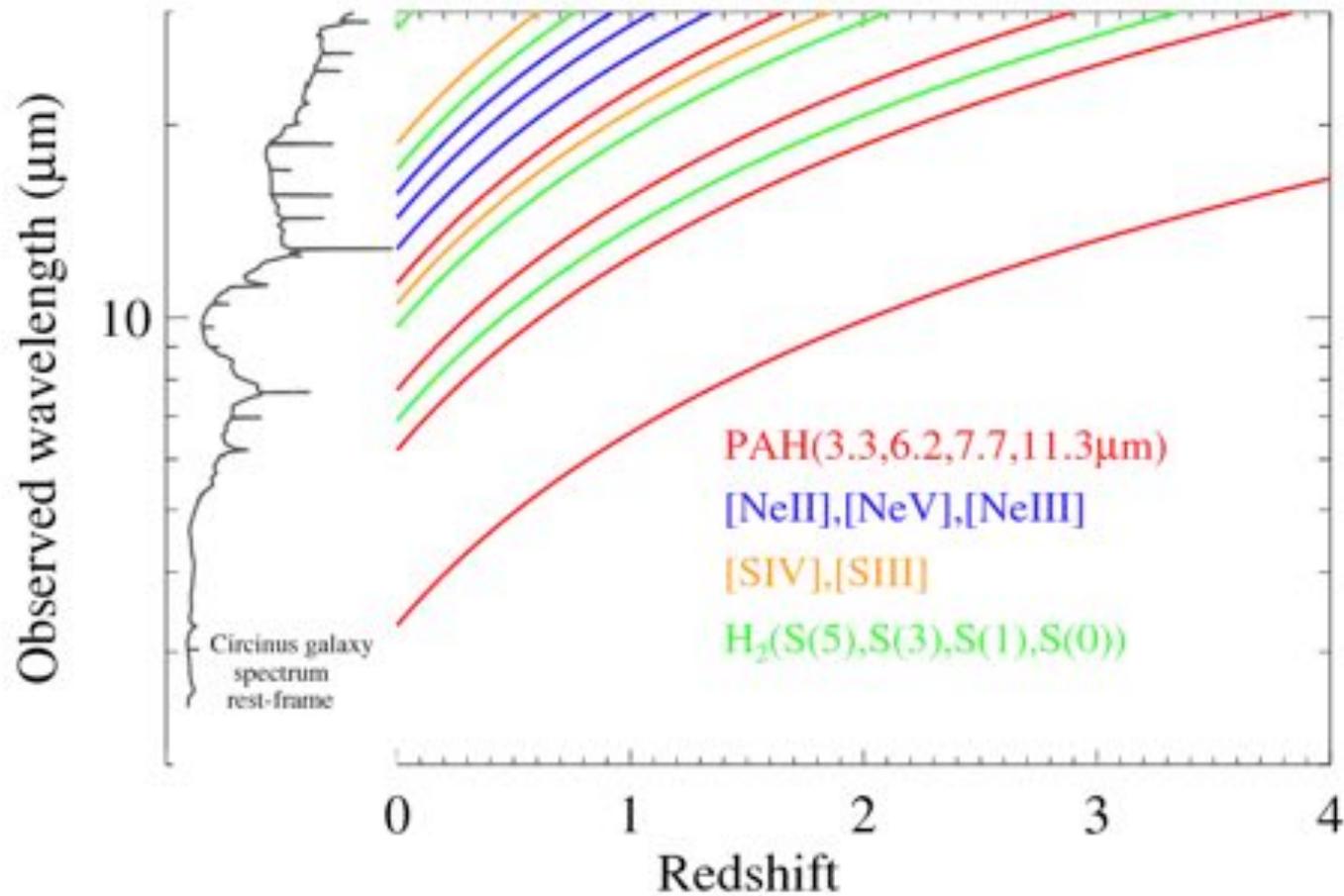
# Open questions

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?

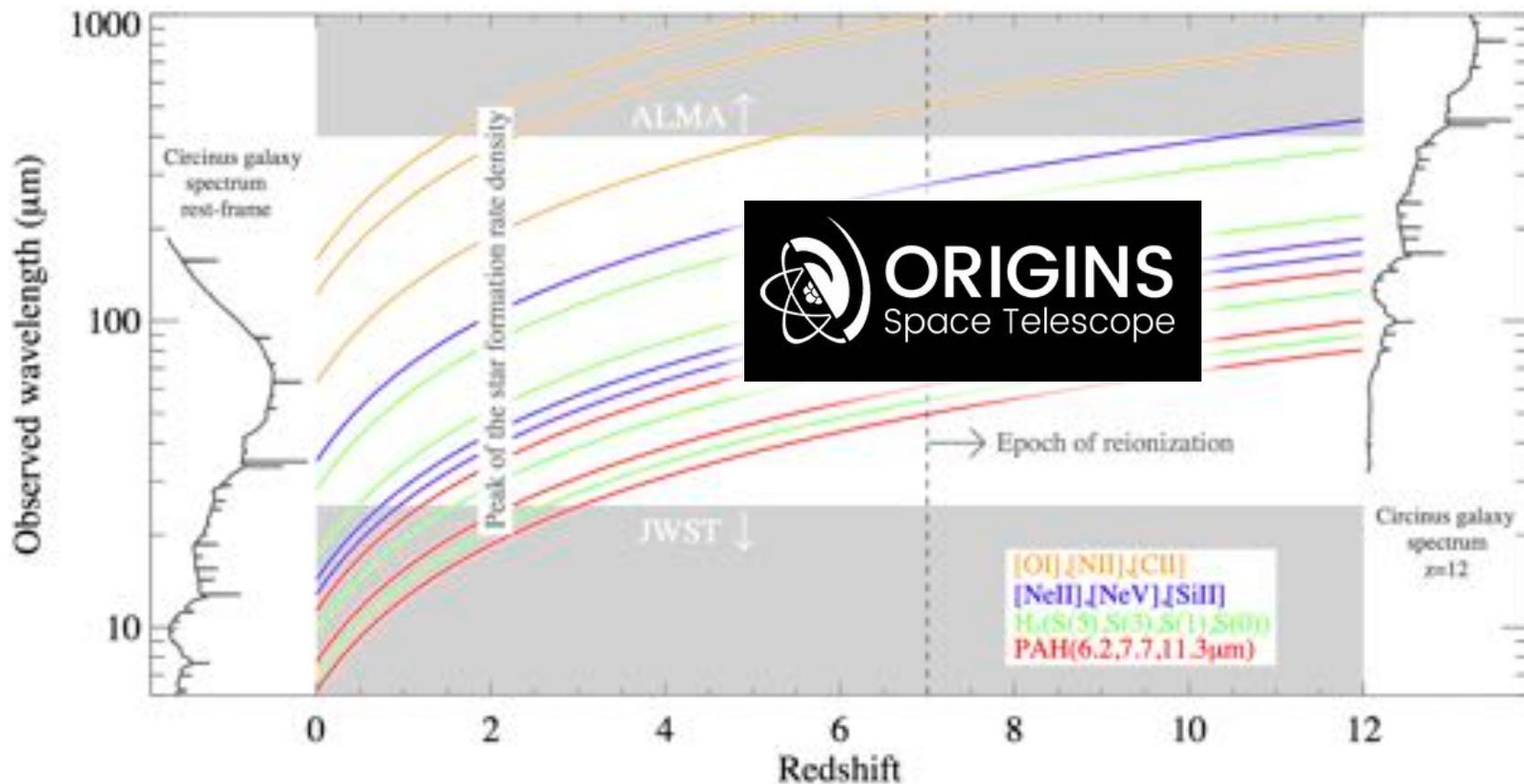
**SMGs/DSFGs are excellent laboratories for addressing these broad questions in galaxy evolution**



*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*





Tracing the rise of dust & metals in galaxies  
and the path of water across cosmic time to  
Earth and other habitable planets.



## **NASA Mission concept: a Far-Infrared Surveyor for the 2020 Decadal review**

~10  $\mu\text{m}$  – 1000  $\mu\text{m}$ , cold, large aperture ~8-15 m  
launch ~2030





# ORIGINS

Space Telescope

Tracing the rise of dust & metals in galaxies  
and the path of water across cosmic time to  
Earth and other habitable planets.



## 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.



## 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.



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.

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



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.



## Characterizing Small Bodies in the Solar System



**ORIGINS**  
Space Telescope

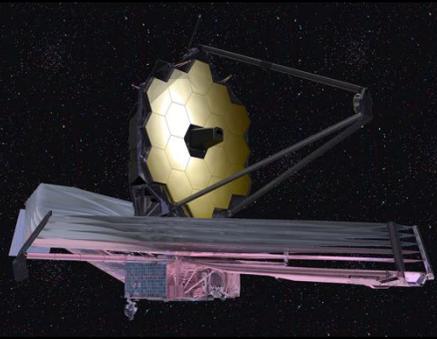
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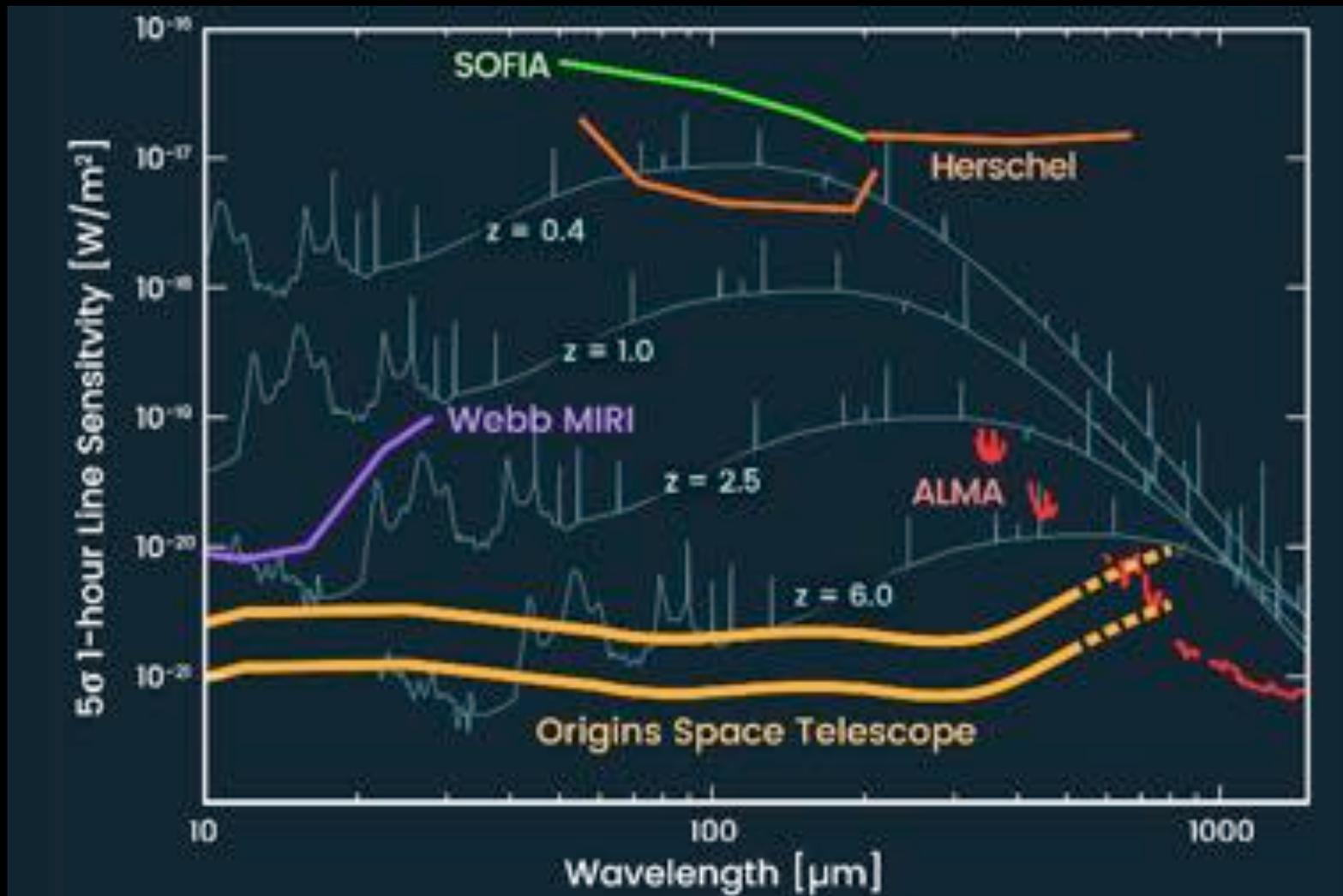




# ORIGINS

Space Telescope

## Technical Specifications



# Summary

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

