BAT AGN prefer circumnuclear star formation

Dieter Lutz
MPE

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The many faces of AGN obscuration

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What is the size and structure of star formation (or cold gas) in galaxies as a function of SFR, $M^*$, $z$, AGN content...

- Inside-out growth of star forming galaxies?
- Compaction in gas rich instable disks?
- Gas inward transport in mergers?
- Relation of star formation to Black Hole accretion?
- ...

[Diagram showing relationships between star formation rate and stellar mass.
Main sequence shift for larger gas fraction at higher redshift,
Stellar mass axis,
Outliers, Main sequence, Passive galaxies,
Methods

- Rest-UV/optical continuum, Hα
  Obscured for massive dusty galaxies and outliers, AGN contamination

More extinction insensitive:
- Mid-IR imaging or long-slit spectra
  e.g., Soifer+00,01, Diaz-Santos+10,11
  Sample sizes, AGN contamination

- Radio interferometry
  e.g., Condon+90,91, Barcos-Munoz+17
  Sample sizes, AGN contamination

- (sub)mm interferometry of dust or CO
  e.g., Sakamoto+99
  Sample sizes, have to assume star formation law

- Far-infrared imaging
  No sensitive far-infrared interferometry in the foreseeable future
Herschel FIR sizes for hundreds of galaxies

Ugly but highly stable PSF

\[ \text{FWHM}_{\text{Source}} = \sqrt{\left(\text{FWHM}_{\text{obs}}^2 - \text{FWHM}_{\text{PSF}}(\alpha)^2\right)} \]

Overall FWHM, not a detailed map, simplifying
Consistently available for hundreds of targets

N3184
Kingfish
Scaling relations for $R_e$ and $\Sigma_{\text{FIR}}$, link to [CII] deficit, candidates for molecular outflows...

Lutz et al. 2016, 2019 in prep
Herschel: Link of flickering BHAR and SFR – ‘unsynchronized coevolution’

Average BHAR for samples selected in bins of SFR, M*, z (Delvecchio+15)

Average SFR for samples selected in bins of instantaneous BHAR, z (Rosario+12)

Shao+10, Rosario+12,13, Santini+12, Mullaney+12ab, Chen+13, Hickox+14, Stanley+15, Delvecchio+15...
Structural differences favouring AGN, if BHAR and SFR fed from same gas reservoir?

To establish the role of intriguing features, such data would be needed for very large samples of AGN and reference galaxies!
Difficult to have a **tight** link SFR/BHAR

Star formation up to kpc and 10kpc scale

BH sphere of influence ~tens of pc
Event horizon ~μpc
PG QSO hosts agree with galaxy scalings

.. But limited by distance, faintness, and sample size – Different AGN sample?

Optically thin AGN-heated FIR emission would be larger than observed size... FIR from host SF!
Swift-BAT sample to the rescue

Selected by extremely hard 14-195keV X-ray – will catch all but the most obscured AGN

$z < 0.05$ BAT AGN from 58 month version observed with Herschel PACS & SPIRE photometers:
Mushotzky+14
Melendez+14
Shimizu+15,16,17

→ Apply the tuned ‘Herschel-PACS size measurement’ machine to BAT sample and as large as possible reference sample
Sample

\[ N(\text{Comparison}) = 515 \]

\[ N(\text{BAT}) = 277 \]

Typical \[ \log(L_{\text{bol}}) \sim 44.5 \]
Huge scatter, but modest SFR AGN hosts are on average more compact
kpc scale gas reservoir/SF and accretion know about each other... but due to the many intermediary transport steps they barely understand each other.
Are we fooled by compact AGN-heated dust?

$$\Delta R_e = \log(R_{e,70,AGN}) - \log(\text{Median}(R_{e,70,\text{Comparison}}))$$
Why no size difference at higher SFR?

For limited gas content of local galaxies, high SFR needs compact gas in the first place?
What can we expect from a gas distribution experiment at 10pc ‘torus’ resolution?
(NIR adaptive optics, Alma)

- Obviously and naively a tighter link, but

- Dynamical times are still large compared to AGN flickering/accretion variations
- Any non-AGN reference sample is contaminated by yesterday’s and tomorrow’s AGN, with ~same structural properties

- Hopefully not “it’s all very complex”
Thank you!

- Characteristic size and surface brightness of FIR emission (star formation) in several hundred local AGN and normal or IR-luminous galaxies

- At same SFR, local AGN prefer more compact circumnuclear star formation (but note large scatter!)

- Accretion and SF feed from galaxy’s gas reservoir, with more efficient AGN feeding if reservoir is more concentrated – some link is left over the many orders of magnitude inward transport