LLAMA and obscuration
Local Luminous AGN with Matched Analogs

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Garching
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Sample and rationale
A complete, hard X-ray selected local sample

Davies, LB + 2015
A complete, hard X-ray selected local sample

- Local Luminous Agn with Matched Analogs
- CT fraction in local universe ~ 30%; we have 3/20 = 15%, i.e. miss ~ 3 sources

Davies, LB + 2015
Sample and rationale

A complete, hard X-ray selected local sample

The most luminous local sources: AGN activity is more than just "weather"
Sample and rationale

A complete, hard X-ray selected local sample

The most luminous local sources: AGN activity is more than just "weather"
Sample and rationale
A complete, hard X-ray selected local sample

All BAT-58 detected galaxies with DEC < +15 deg

Local Luminous Agn with Matched Analogs

AGNs inactive

$\log L_H [L_{sun}]$ vs number

Axis Ratio vs number

Hubble Stage vs number

Davies, LB + 2015

4.2. How Common are X-Ray Unabsorbed Seyfert 2s?

Figure 3.

The Astrophysical Journal,

Comparing the AGNs in our sample to the left edge of

The most luminous

The joint optical/X-ray classification is due to the large fraction of AGNs classified as Sy 2 and X-ray absorbed; only three are just X-ray absorbed. These exceptions are

The classification is based on the ranges shown in Figure 6.

Panessa & Bassani 2001

Thus, despite their rather low Eddington ratios, these AGNs are relatively inactive

The most luminous AGNs have been identified as Sy 2, but large dispersion prevents BLR clouds from surviving

These authors also showed that these AGNs are relatively minor

The six objects identified

Objects are also known as pure or true Sy 2s

The unusual amplitude variations typical of Sy 1s. Subsequent X-ray observations of three by Gliozzi et al.

These objects are also known as pure or true Sy 2s

The reason that they may not be more optically obscured

The CT fraction in local universe ~

Rather low Eddington ratios

since they are all close to the boundary

The X-ray absorbed AGN NGC 1365 is absorbed threshold and so is on the borderline in both

As a Sy 2 which we have revised to Sy 1.9. The Sy 1.8

and has only weak broad Hα

classify it as Sy 1. Similarly MCG-05-23-016 is X-ray absorbed taken to be a Sy 2, here we adopt a strict de

Optically classified

between the regimes.
The torus: more than obscuration

A starburst-AGN connection?

Davies+ 2007
The torus: more than obscuration

A starburst-AGN connection?

powerful AGN activity only in post-starburst nuclei?

Davies+ 2007
The next steps
A complete, hard X-ray selected local sample

- SINFONI IFU cubes to analyze gas inflow / outflow

see poster B9 by Ming-Yi Lin
The next steps
A complete, hard X-ray selected local sample

- SINFONI IFU cubes to analyze gas inflow / outflow
- X-SHOOTER spectra to robustly analyze the star formation histories
The next steps

A complete, hard X-ray selected local sample

- SINFONI IFU cubes to analyze gas inflow / outflow
- X-SHOOTER spectra to robustly analyze the star formation histories
- APEX data to probe molecular inventory (+ trying to get ALMA + HST...)

![LLAMA](image)

### References

1. Cappellari et al. (2007) & Krajnovic et al. (2010). The M/L ratio can help us to explain as an additional inner component.
4. A complete volume-limited sample, selected from their intrinsic luminosity. The criteria are: X-ray luminosity $L_X > 10^{42.5}$ keV; $z < 0.01$; declination <15° (Davies et al. 2015).
5. A complete, hard X-ray selected local sample.
First results: BLR properties and obscuration

NGC1365

Panel 1: Broad Line Region in local Seyferts

- Observed Hα, Hβ, Paβ, Paγ, Paδ, HeI, FeII, [OIII], Hell, [NeVII]
- Broad line profiles from an integrated spectrum of the inner 1 arcsec
- Panel, broad He I was subtracted from the spectrum
- Differences between the observed and fitted profiles are due to the references between the observed and fitted profiles

Figure 9.

Schnorr-Müller+ 2016 (re-submitted)
First results: BLR properties and obscuration

<table>
<thead>
<tr>
<th>Object</th>
<th>Extinction to the NLR</th>
<th>Uncertainty on the derived parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCG0630</td>
<td>18.0</td>
<td>≫20%</td>
</tr>
<tr>
<td>NGC6814</td>
<td>19.5</td>
<td>≫20%</td>
</tr>
<tr>
<td>NGC4593</td>
<td>17.5</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>NGC4235</td>
<td>2.8</td>
<td>≪20%</td>
</tr>
<tr>
<td>NGC4593</td>
<td>17.5</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>NGC2992</td>
<td>2.2</td>
<td>≫20%</td>
</tr>
</tbody>
</table>

In the case of the H I lines, determining A

...
First results: BLR properties and obscuration

![Graph showing hydrogen emitting clouds and obscuration](image)

<table>
<thead>
<tr>
<th>Object</th>
<th>$r_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCG–05-14-012</td>
<td>1.0</td>
</tr>
<tr>
<td>MCG–05-23-16</td>
<td>0.5</td>
</tr>
<tr>
<td>MCG–06-30-015</td>
<td>1.0</td>
</tr>
<tr>
<td>NGC1365</td>
<td>0.7</td>
</tr>
<tr>
<td>NGC2992</td>
<td>0.8</td>
</tr>
<tr>
<td>NGC3783</td>
<td>0.8</td>
</tr>
<tr>
<td>NGC4235</td>
<td>1.8</td>
</tr>
<tr>
<td>NGC4593</td>
<td>0.9</td>
</tr>
<tr>
<td>NGC6814</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Schnorr-Müller+ 2016 (re-submitted)
A near-IR high-resolution atlas of local AGNs

Dilution of stellar light by the AGN continuum
Spectral decomposition

NGC 1386 (Sy 2)

Flux density

rest wavelength $\mu$m

FWHM 1 = 298 km/s
FWHM 2 = 325 km/s

Stars

Hot dust
A robust way to estimate the obscuration

K band color temperature

K−N

Seyfert 1
Seyfert 1i
Seyfert 2
LINER

Burtscher+ 2015
A robust way to estimate the obscuration

- color temperature consistent with optical appearance → obscuration

Burtscher+ 2015
A robust way to estimate the obscuration

- color temperature consistent with optical appearance $\rightarrow$ obscuration
- normalization consistent with observed radii of hot/warm dust

Burtscher+ 2015
Obscuration: Torus vs. BLR

X-ray column $[\log N_H / \text{cm}^{-2}]$

Torus obscuration $A_V$ [mag]

- Blue: Seyfert 1-1.5
- Purple: Seyfert 1.8/1.9/1i
- Red: Seyfert 1h/2
- White: NH variable
- Green: Galactic ratio

Uncertainty in $A_V$
Obscuration: Torus vs. BLR

X-ray column $[\log N_H / \text{cm}^{-2}]$ vs. Torus obscuration $A_V$ [mag]

Legend:
- Seyfert 1-1.5
- Seyfert 1.8/1.9/1i
- Seyfert 1h/2
- NH variable
- Galactic ratio

Uncertainty in $A_V$
Obscuration: Torus vs. BLR

X-ray column ($\log N_H / \text{cm}^{-2}$) vs. Torus obscuration $A_V$ [mag]

Maiolino+2010

Burtscher+2016
Obscuration: Torus vs. BLR

Absorption in the dust-free BLR

Absorption in the dusty torus

Torus obscuration $A_V$ [mag] vs. X-ray column $\log N_H / \text{cm}^{-2}$

Maiolino+2010
Burtscher+ 2016

X-ray source
cometary cloud A

$N_H \sim 10^{23} \text{ cm}^{-2}$
$N_H \sim 3 \times 10^{22} \text{ cm}^{-2}$

$V_c > 3000 \text{ km/s}$

$R_X$

$\theta < 1.2^\circ$

$L_{\text{tag}} > 2 \times 10^{13} \text{ cm}$

Maiolino+2010

Burtscher+ 2016
Obscuration: Torus vs. BLR

![Graph showing the relationship between X-ray column and BLR obscuration.]

- The graph represents the relationship between the X-ray column and BLR obscuration for various galaxies.
- The X-axis represents BLR obscuration $A_V$ in magnitudes, while the Y-axis represents the X-ray column $\log N_H / cm^{-2}$.
- The data points for NGC6814, NGC2992, MCG-05-23-016, and other objects are plotted.
- The shaded area indicates the range of data points for different galaxies.
- The graph is used to compare the obscuration of the broad line region (BLR) with the X-ray absorbing columns, which can be due to dusty structures that are more compact than the BLR.
Obscuration: Torus vs. BLR

Hot dust obscuration:
Uncertainties (<~ 5 mag) due to intrinsic temperature of hot dust

- Hot dust obscuration $A_v$ [mag]
- BLR obscuration $A_v$ [mag]
Outlook for local, high-resolution AGN studies
Outlook

for local, high-resolution AGN studies

• GRAVITY; MATISSE: 2\textsuperscript{nd} generation VLTI instrument offering phases (imaging), higher resolution (\(L\) band, and \(N\)) and more efficiency (4 beams)
Outlook

for local, high-resolution AGN studies

- GRAVITY; MATISSE: 2nd generation VLTI instrument offering phases (imaging), higher resolution ($L$ band, and $N$) and more efficiency (4 beams)

- E-ELT/METIS
Outlook for local, high-resolution AGN studies

- GRAVITY; MATISSE: 2nd generation VLTI instrument offering phases (imaging), higher resolution (L band, and N) and more efficiency (4 beams)

- E-ELT/METIS

- resolve large-scale "torus" component found with MIDI: determine the kinematics of the wind launching region
Outlook for local, high-resolution AGN studies

- GRAVITY; MATISSE: 2nd generation VLTI instrument offering phases (imaging), higher resolution (L band, and N) and more efficiency (4 beams)
- E-ELT/METIS
  - resolve large-scale „torus“ component found with MIDI: determine the kinematics of the wind launching region
  - resolve stellar populations very close to nearby AGNs
AGN NIR luminosity relations

\[ \log L^\text{NIR} \approx 7 \times \log L^\text{MIR} \]

\[ \log L^\text{NIR} \approx 10 \times \log L^\text{X} \]

Burtscher+ 2015
Leonard Burtscher: Where is the torus?

Black hole and accretion disk

(1) inflow + starburst

e.g. Norman & Scoville 1988
Leonard Burtscher: Where is the torus?

Black hole and accretion disk

OB late-type stars

(1) inflow + starburst

(2) supernovae + turbulence

e.g. Norman & Scoville 1988
Leonard Burtscher: Where is the torus?

1. Inflow + starburst
2. Supernovae + turbulence
3. AGB stars and stellar winds

E.g. Norman & Scoville 1988
Leonard Burtscher: Where is the torus?

Physical torus models

Schartmann+ 2009
Physical torus models

Figure 2: Density distribution of our effort to model the stellar mass loss from the nuclear star cluster in the nearby Seyfert galaxy NGC 1068 after an evolution time of (a) $7 \times 10^4$ yr and (b) $6 \times 10^5$ yr. Panel (c) shows the corresponding temperature distribution of the large scale component, whereas panel (d) displays a zoom-in into the central 2 pc region, where a dense disc builds up. Figure adapted from *Schartmann et al. (2010).*

Radiation feedback on dusty clouds during Seyfert activity

As described above, our scenario of the evolution from a nuclear star cluster towards the formation of discs and tori in nearby Seyfert galaxies leads to a clumpy or filamentary infall of gas towards the centre during the pre-active phase. A hot inner accretion disc will form and the central activity will start, while matter still gets accreted towards the central region. So far, we only concentrated on the pre-active phase. As soon as the illumination starts, radiation pressure forces can become of similar magnitude as gravitational forces. To investigate these processes in great detail, we performed two-dimensional high-resolution radiation-hydrodynamical simulations of idealised, dusty clouds, illuminated by a typical AGN spectrum and subject to gravitational forces due to the central black hole and nuclear star cluster. To this end, we have implemented a one-dimensional multi-wavelength, approximate equilibrium radiative transfer algorithm into the PLUTO code, which comes at moderate costs and reasonable accuracy. We find three distinct phases of the evolution of an infalling gas clump that experiences the radiation pressure force of the central engine: (i) formation of a lenticular shape with dense inner rim caused by the interaction of gravity and radiation pressure (the lense phase), (ii) formation of a clumpy sickle-shaped structure as the result of a converging flow (the clumpy sickle phase) and (iii) a filamentary phase caused by a rapidly varying optical depth along the sickle (see Fig. 3).

Depending on its column density, the clump will either be completely pushed outwards or its central (highest column density) parts move inwards, while its diffuse outer regions are pushed outwards by radiation pressure effects. A stationary state cannot be found. The general dynamical evolution of the cloud can approximately be described by a simple analytical model. The corresponding paper has recently been submitted to MNRAS (*Schartmann, Krause & Burkert 2011*).
Leonard Burtscher: Where is the torus?

Physical torus models

Where is the torus?

Andreas Burkert: ISM-SPP Proposal

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3 component model of the dust emission in the Circinus galaxy