Using High-Spatial Resolution to Uncover Elusive AGN and Disentangle them from Shocks

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With: Vivian U, Anne Medling, Thomas Bohn, Laura Sales, and KOALA team
Main take away:

High spatial resolution studies can help us uncover elusive AGN
OSIRIS + NIRC2 + LGS AO

- K (or H) band, sampling at 0.035” and 0.1”/spaxel
- Targeted ~20 (U)LIRGs at z < 0.08
- 20-50 pc/spaxel
Case Study: Mrk 273
U+ 2013

ULIRG ($L_{IR} = 10^{12.21} L_\odot$)
z = 0.04; 1" ~ 800 pc

Underlying image:
I band (green) + H band (red)

Contours:
VLA 8.4 GHz

Hard X-ray (blue) + Soft X-ray (yellow)

Iwasawa+11, Scoville+00, Condon+91, etc.
Is there a second (elusive) AGN in Mrk 273?

(cf. talks by Sara Ellison, Anca Constantin, Andy Goulding, and Laura Blecha)
NIRC2 LGS AO images (0.01"/px, or 8pc/px)

NIR lines give us clues to the nature of the three sources
Clue #1: There is a very massive object in clump N!

Keplerian disk model of [Fe II] gas shows there is a mass of $1.04 \pm 0.1 \times 10^9 \, M_\odot$ enclosed within 26 pc -> SMBH!

(cf. Dave Sanders’ talk)
Clue #2: Suppressed Brγ and He I near the center of N – ionized by obscured AGN?
Clue #2: Suppressed Br$\gamma$ and He I near the center of N – ionized by obscured AGN?
Spatially resolved spectra (OSIRIS: K band, 0.1" or 80pc/px)

Clue #3: [Si VI] is detected in SE and SW, but not in N... hmm....

(cf. Anca Constantin’s talk)
Spatially resolved spectra (OSIRIS: K band, 0.1" or 75pc/px)
[Si IV]
- Detected only in SE and SW
- Extended coronal line region
Clue #4: Gradient in [Si VI]/Br\(\gamma\) decreasing toward SE suggests photoionization from AGN in N

[CLOUDY models confirm AGN located at N could produce these ratios]
Bonus: We see biconical molecular outflows from N and directed toward SE

Increased velocity dispersion for H$_2$ along the minor axis
Shock or AGN?

Models using SHOCKPLOT (Allen+2008)

Only fast shocks in the densest material, if at all, could reproduce the observed line ratios
[Si VI] line in the SE

Two kinematic components (broad and narrow)
Summary for Mrk 273

- **SW**: Hard X-ray AGN
- **N**: SMBH, obscured AGN
- **SE**: clump of gas or tidal feature, photoionized by obscured AGN in N and shock-heated by outflows from AGN
- **Bridge**: outflow

... *Dual AGN system*
• $H_2/Br\gamma$ quantifies the relative contributions from UV vs. X-ray radiation or shocks.

• $H_2/Br\gamma > 2$ indicates regions dominated by shocks.

(cf. Anca Constantin’s talk)
Blue – outflow
Green – shocked gas
Yellow – both

H₂ Velocity Dispersion (km/s)
Blue – outflow
Green – shocked gas
Yellow - both
Blue – outflow
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Coherent structure

$\text{H}_2$ Velocity Dispersion (km/s)
Summary from KOALA survey (U+2017):

• Outflows are present in nearly every object
• Shocks are commonly found in LIRGS and ULIRGs (> 50%)
• About half of AGN show shocked outflows, often in biconical shape
• Shocked outflows with coherent structure can be present in objects with no detected AGN. Either
  • They are powered by central starbursts
  • They betray the presence of very elusive AGN
AGN in Bulgeless Galaxies

- The study of the BH population in bulgeless galaxies sheds light on alternative growth mechanisms for BHs that are not strictly connected to mergers
- Another way to look at “fossil record” of BH seeds (cf. Jon Trump’s talk)
- Comparison to Illustris simulations (cf. Colin DeGraf’s talk) allow us to trace back the growth history of these objects
Bulgeless galaxies potentially hosting AGN

Following Satyapal+2014, we selected galaxies:

- $z < 0.05$
- $B/T = 0$ (Simard+2011)
- BPT composite or AGN

Two problems (at least):
- Host subtraction (cf. Ingyin Zaw’s talk)
- Shocks
Lick 3-meter spatially resolved spectroscopy:

solution to host dilution in some cases

Will follow up with NIR observations
Summary:

High spatial resolution studies can help us uncover elusive AGN

• Sometimes even a modest improvement in spatial resolution can make all the difference!
- There is observational evidence that shock velocity is correlated with velocity dispersion (Ho+2015)