

The Starburst-AGN Connection:

Integral Field Spectroscopy of Merging and Seyfert 2 Galaxies

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Distinguishing Spectral Lines:

- [Fe II] 1.644 μm
- Paschen α 1.876 μm
- H₂ 1-0 S(3), S(2), S(1) 1.1.958, 2.034, 2.122 μm
- [Si VI] 1.963 μm
- Brackett γ 2.166 μm
- CO absorption band head 2.294 μm

Luminous galaxies can be powered by two different mechanisms. In one mechanism matter is accreted onto a super-massive black hole at the galactic nucleus. The other mechanism involves a rapid burst of star formation that produces many luminous young stars, a "starburst." Both events occur inside a large optical depth of dust: an active galactic nuclei within its dusty torus as a Seyfert 2 and starbursts through their dusty cocoons. At 2 microns the obscuration due to dust is ten times less than at visible wavelengths making it possible to see through the clouds of dust to the luminous source hidden within. Spectral features found in the K-band can be used to distinguish starburst activity from an AGN:

1. Paschen α , Brackett γ : broad for AGNs, narrow for star formation
2. [Si VI]: can only be observed near an AGN due to high ionization potential
3. CO absorption band: formed in the atmospheres of giants stars that have just evolved off of the upper main sequence, can be used to constrain the star formation history of the galaxy
4. [Fe II]: associated with supernovae activity and also used to constrain the star formation history

5. H₂ 1-0 transitions: show position, shape, and kinematics of shocked molecular hydrogen important in post-merger starbursts

The spectroscopic CO index as defined in Doyon et al. 1994 and the equivalent width of Brackett γ can be used in the stellar population synthesis model Starburst99 (Leitherer et al., 1999) in order to constrain the luminosity contributed by the starburst to the total luminosity of the galaxy.

K-band observations of a sample of twenty galaxies were made on April 19-23, 2003 using the United Kingdom Infrared Telescope Imager-Spectrometer integral field unit. The integral field unit, with a resolution of 900 and a field of $6 \times 3.3 \text{ arcsec}^2$, allows us to use the infrared spectral diagnostics listed above, shown for six of the twenty galaxies. The sample includes galaxies identified as merging starbursts and galaxies identified as Seyfert 2s to investigate the presence of both starbursts and AGNs in both sets of galaxies and look for evidence of the starburst-AGN connection.

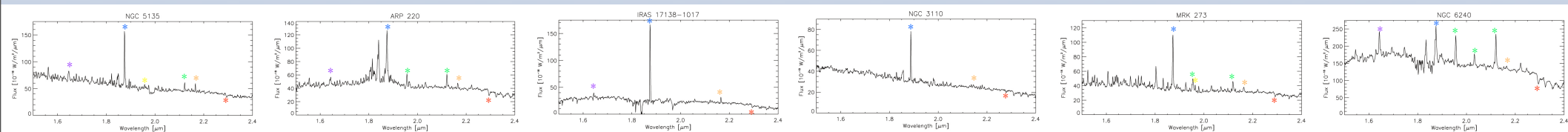


Figure 1. The spectra averaged over the spatial pixels of the IFU datacube for each galaxy.

NGC 5135

ARP 220

IRAS 17138-1017

NGC 3110

MRK 273

NGC 6240

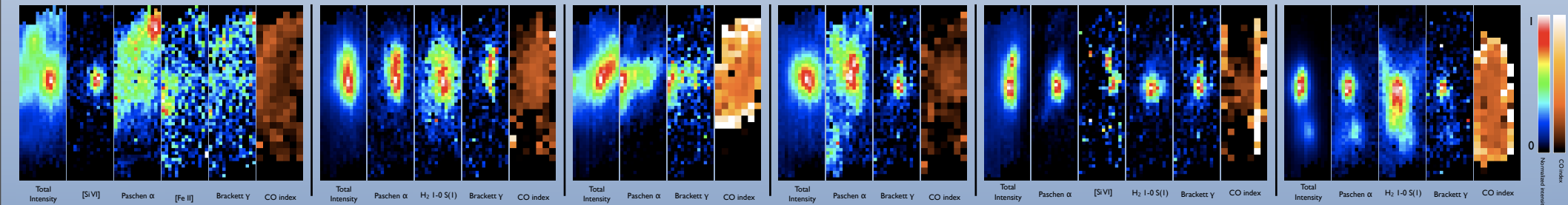


Figure 2. Distribution of the continuum intensity and the most important spectral diagnostics for each galaxy in order of wavelength.

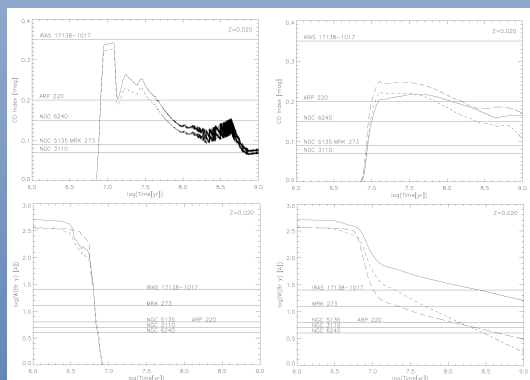


Figure 3. The most common value of the CO index ± 0.05 (top) and $\log[\text{Br } \gamma] \pm 0.5$ (bottom) compared to the time evolution of the quantities from the Starburst 99 models for instantaneous (left) and continuous (right) star formation for $Z=0.020$ (figures 88, 89, 95, and 96 from Leitherer et al. 1999)

Results and Conclusions:

Two of the galaxies of the six selected show starburst and AGN features simultaneously. NGC 5135 is the archetypal Seyfert 2-starburst galaxy. The IFU captures the galaxy nucleus and one of the bright spiral arms curving to the top right corner. NGC 5135 betrays its AGN identity with bright [Si VI] emission consistent with the position of the brightest continuum source. Paschen α and Brackett γ reveal a bright clump along the spiral arm not identified with any continuum source which seems a likely candidate for AGN excited star formation. The CO band strength traces the edge of the spiral arm, revealing off-nuclear star formation and evolution off the main sequence.

The tidal tails and Seyfert 2 pair of MRK 273 are suggestive of the close interaction of two galaxies. There are two clear sources of [Si VI] which correspond closely with the galactic nuclei shown by the continuum, confirming the results presented by many authors since 1992. The secondary source appears very weakly at other wavelengths and does not harbor the same level of activity as its companion. Emission from the star formation indicators Paschen α and Brackett γ as well as from the H₂ transitions correspond with the primary continuum source.

The CO index and $\log[\text{Br } \gamma]$ are shown in comparison to the Starburst99 dataset in figure 3. Neither NGC 5135 or MRK 273 have exceedingly strong CO bands, which may be indicative of a very recent starburst or an older remnant of a starburst that has evolved. The AGN pair may also contribute considerable flux to the Brackett γ line in MRK 273 so this measure may not be as accurate, however this galaxy has an especially strong [Fe II] emission, meaning that many supernovae have recently occurred and that a burst of star formation only recently ended.

Future Work:

There are many more galaxies in this sample to inspect in detail. Light contributions from possible starburst populations need to be estimated and compared with the total galactic emission in the infrared. Using the strength of the 2.29 μm CO band and the width of Brackett γ combined with the more time sensitive 1.62 μm CO absorption band and the 1.59 μm Si absorption line as in Oliva et al. 1999 should increase the confidence of the star formation timescale.

REFERENCES

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Leitherer, C., et al. 1999, *ApJS*, 123, 3
Oliva, et al. 1999, *A&A*, 350, 9