Rebecca Davies is a 2nd year undergraduate student at the Australian National University

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Nature or Nurture?

Starburst and AGN in NGC 7130

Australian National University

We investigate the relationship between star-formation and AGN activity in NGC 7130, a starburst-AGN composite galaxy, by studying the correlation between the ionisation properties of the gas in the galaxy and its distance from the central active galactic nucleus.

Rebecca L. Davies[1], Jeffrey A. Rich[2] Lisa J. Kewley[1], Michael A. Dopita[1,3,4]

Email: Rebecca.Davies@anu.edu.au, Webpage: http://www.mso.anu.edu.au/~rebeccad/

1. *Research School of Astronomy and Astrophysics, Australian National University*
2. *Carnegie Observatories*
3. *Institute for Astronomy (IfA), University of Hawaii*
4. *King Abdulaziz University, Saudi Arabia*

The Starburst-AGN Connection

It is well known that in bulge-dominated galaxies, the mass of the central black hole scales with the stellar velocity dispersion, stellar mass and luminosity of the central bulge (e.g. Magorrian et al 1998, Ferrarese & Merritt 2000). This suggests that black holes may co-evolve with their host galaxies. Theoretical studies have also indicated that AGN feedback is pivotal for determining when, where and how galaxies build up stellar mass (e.g. Torrey et al. 2013).

However, in order to determine whether the relationship between black holes and their host galaxies is causal (and if so, what drives this link) it is necessary to study how star formation and AGN activity are connected using indicators which are resolved in both space and time. In order to achieve this, we analyse the spatial variation of strong emission line ratios from Integral Field Spectroscopic data.

Starburst-AGN Mixing Sequences

Traditionally, the power sources of galaxies have been classified using Baldwin, Philips and Terlevich (BPT) diagrams, which compare the ratios of strong emission lines (e.g. [NII]/Hα and [OIII]/Hβ) to separate the spectral signatures of star formation and AGN activity (BPT 1981). Pure star-forming galaxies form a metallicity sequence on the [NII]/Hα diagnostic, because [NII]/Hα increases with metallicity whilst [OIII]/Hβ decreases with metallicity. However, [NII]/Hα is strongly enhanced by the extreme ultraviolet (EUV) radiation field of active galactic nuclei. This causes galaxies with some contribution from an AGN to lie along a starburst-AGN mixing sequence, starting at the high metallicity end of the star-forming sequence and reaching to high values of [NII]/Hα and [OIII]/Hβ (e.g. Kewley et al. 2006).

Integral Field Unit (IFU) data have provided the opportunity to analyse how emission line ratios vary as a function of radius in galaxies. In particular, we now have the tools necessary to probe how the relative contributions of star formation and AGN activity change as a function of distance from the centre of the galaxy.

NGC 7130

NGC 7130 is a local (z = 0.016) Luminous Infrared Galaxy (LIRG) which has been identified as a starburst-AGN composite galaxy over a wide range of wavelengths including X-ray, UV, optical and infrared bands (e.g. Gonzalez Delgado et al. 2001, Spinoglio et al. 2002, Levenson et al. 2002, Mulchaey et al. 1997). We obtained IFU data for this galaxy using the Wide Field Spectrograph (WiFeS) on the ANU 2.3m telescope at Siding Spring Observatory. We show maps of the principle strong line ratios in Figure 1. The line ratios (with the exception of [SII]/Hα) all peak in the centre of the galaxy, pointing to the location of the central AGN. The absence of this peak in the [SII]/Hα map is most likely due to low signal-to-noise on the [SII] line. The spatial extent of the [NII]/Hα and [SII]/Hα detections compared to that of [OI]/Hα indicate the significance of star formation activity in the disk of the galaxy. A star-forming ring is also visible just inside the edges of the [NII]/Hα map.

We investigate starburst-AGN mixing in NGC 7130 in Figure 2. The [NII]/Hα and [SII]/Hα BPT diagrams are plotted on the left hand side of the figure (top and bottom respectively). In both cases, there is a smooth distribution of points from the pure star-forming region to the AGN region, branching from the high metallicity end of the star-forming sequence. This matches theoretical expectations for starburst-AGN mixing. We further investigate the starburst-AGN mixing scenario by colour-coding maps of the galaxy according to the distance of each spaxel (spectral pixel) up the mixing sequence.

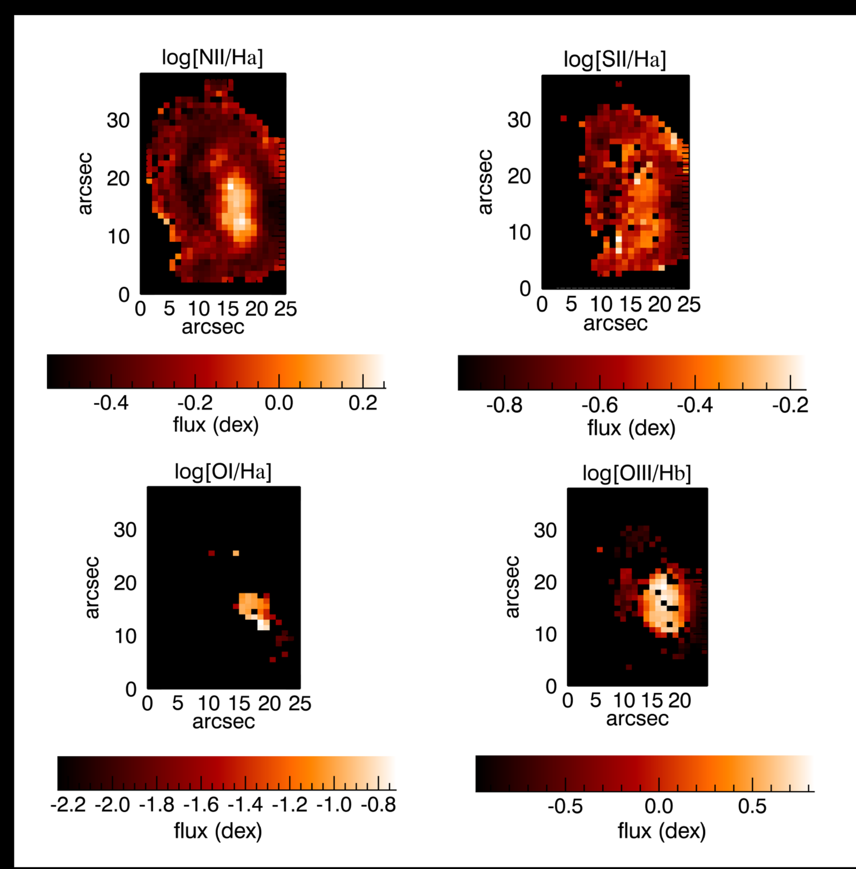

Figure 1: Maps of [NII]/Hα, [SII]/Hα, [OI]/Hα and [OIII]/Hβ for NGC 7130

It is clear that there is a strong relationship between the location of points on the mixing sequence and their distance from the centre of the galaxy. The pink points on the [NII]/Hα BPT diagram, which have the highest line ratios, are also found to lie the closest to the centre of the galaxy. The purple and blue points form a clean ring around the pink points, and likewise, the green points form a clean ring around the purple and blue points. This indicates that the contribution of the AGN is highest in the centre of the galaxy (at the location of the AGN), and gradually decreases with distance from the centre of the galaxy. Very similar behaviour is observed in the second map. This provides strong evidence that starburst-AGN mixing is significant in NGC 7130.

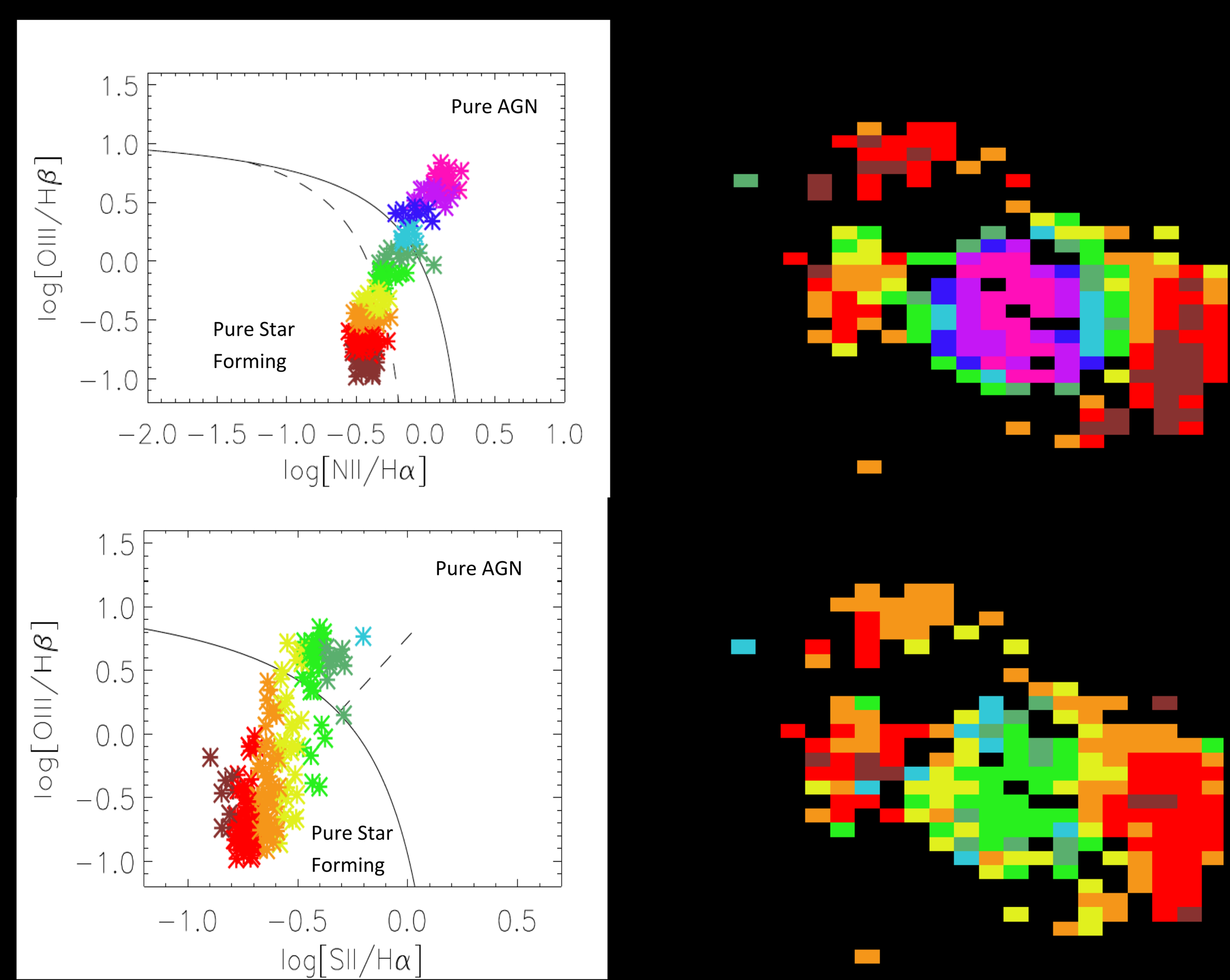

Figure 2: (Top) [NII]/Hα vs [OIII]/Hβ BPT diagram for NGC 7130, colour-coded by distance up the mixing sequence, and map of the galaxy produced using the same colour-scheme. (Bottom) same but for the [SII]/Hα vs [OIII]/Hβ BPT diagram. In this case, colour-coding traces the value of the [SII]/Hα ratio.

We use the observation of mixing to quantify the contribution of the AGN and the star formation activity to the Hα and [OIII] luminosities. In Figure 3 we plot the [NII]/Hα vs [OIII]/Hβ BPT diagram in linear space, and divide the mixing sequence into ten sections, indicated by the green lines. These divisions represent 10% increments in AGN fraction. Although this technique is purely empirical, it is motivated by models of starburst-AGN mixing. Using these divisions, we assign each spaxel an AGN fraction. This allows us to calculate that the AGN is responsible for 35% of the Hα luminosity and 71% of [OIII], whilst the star formation is responsible for 65% of Hα and 29% of [OIII]. This highlights the need to account for AGN activity when calculating star formation rates from Hα.

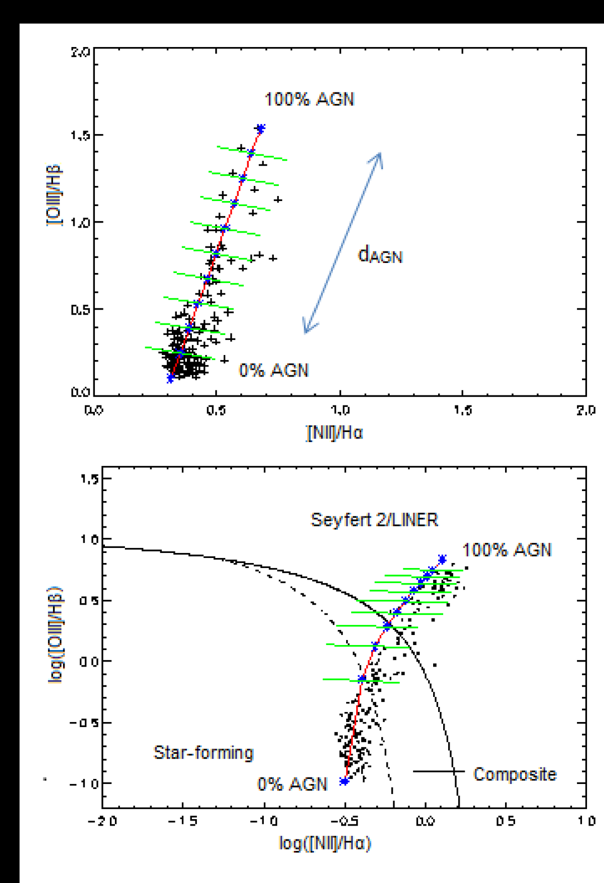

Figure 3: Empirical divisions on the [NII]/Hα vs [OIII]/Hβ diagnostic diagram indicating 10% increments in AGN fraction

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