Studying gas flows in the SUNBIRD starburst galaxies and LIRGs

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Abstract

Gas flows are an important aspect of galactic feedback and the regulation of star formation in galaxies. Nearby starburst galaxies and LIRGs provide an extreme environment where feedback and the changes due to it can be studied in great detail. The aim of my project is to search for traces of outflows and inflows in a sample of nearby starburst galaxies and LIRGs in the SUNBIRD survey, and to characterize them using observations of multi-phase gas and stellar kinematics. The relationship between the gas flows, star formation and other galaxy properties will be used to study feedback and the fueling of star formation, which in turn will help us to understand galaxy evolution. As a first step, the gas flows in the galaxies were studied using long-slit spectra from the Southern African Large Telescope (SALT). Here, I will present preliminary results from the data of one galaxy (NGC 6000) where the ionized gas kinematics were traced through the Hα emission line. The gas was modelled with single and multiple components of Gaussian and Gauss-Hermite functions. The best-fit models were compared in order to identify the gas flows in and around the galaxy.

Introduction

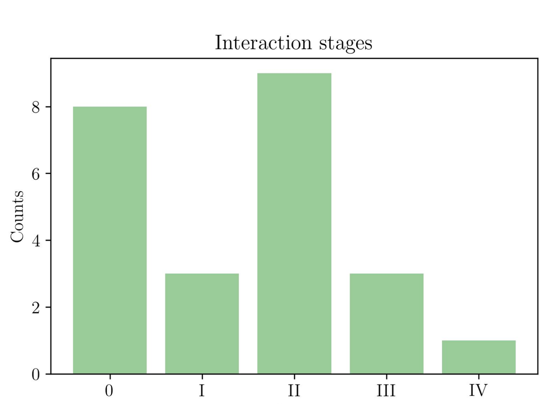
Starburst galaxies and Luminous InfraRed Galaxies (LIRGs) are galaxies with a star formation rate (SFR) several orders of magnitude higher compared to galaxies like the Milky Way and were considered "normal" in the early universe. The high star-formation rates in the nearby starburst galaxies and LIRGs create an extreme environment where the baryon cycle, in particular feedback and the changes due to feedback, is easier to observe and study with Earth-based observations (Veilleux et al., 2005).

The baryon cycle describes the inflow and outflow of gas. Gas flows into a galaxy through accretion from the intergalactic medium which makes it possible for stars to form. Gas that flows out from the galaxy are recycled back into the galaxy, flows into the circumgalactic medium, or it leaves the galaxy completely if it has a velocity greater than the escape velocity of the galaxy (Veilleux et al., 2005; Tumlinson et al., 2017). Star formation can either be enhanced or quenched depending on the inflow and outflow of gas. This is the reason for the bimodal distribution of galaxies observed today (e.g., Strateva et al., 2001).

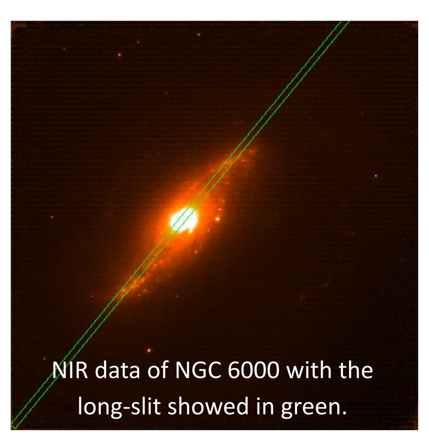
Outflows in particular are generally driven by star formation or AGN activity. Outflows are also multi-phase and can be studied with various tracers (Veilleux et al., 2005). For example, in the optical regime, stellar absorption and outflowing neutral gas can be traced with the sodium doublet (NaD) absorption lines and ionized gas with the Hα emission line (e.g., Cazzoli et al., 2016).

Sample

The starburst galaxies and LIRGs studied in this project are a sub-sample of galaxies in the SUperNovae and starBurst in the InfraReD (SUNBIRD) survey (Väisänen et al., 2014). There are more than 40 galaxies in the survey.

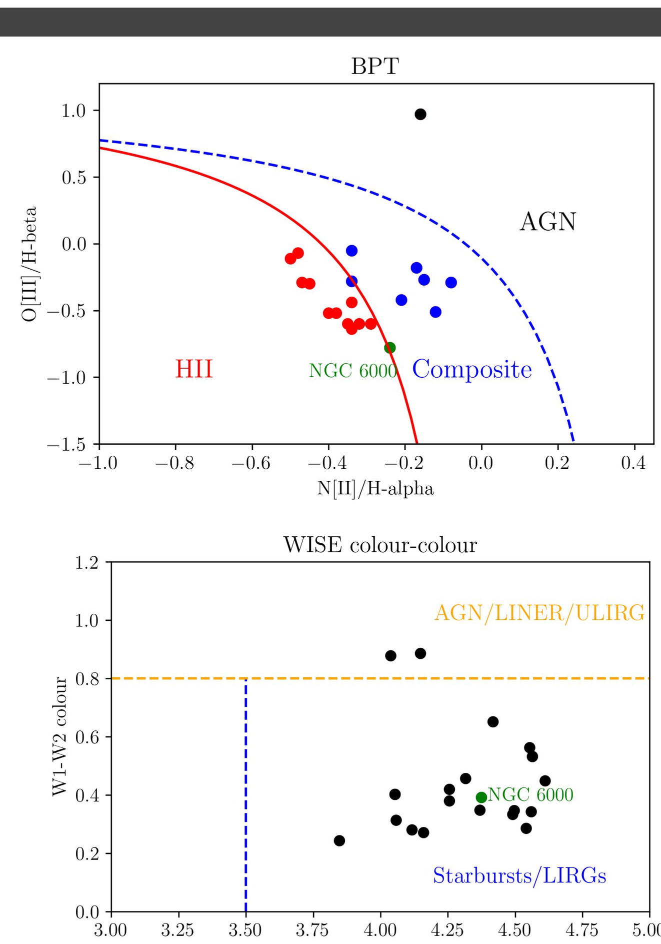


The interaction stages of the sub-sample.



The sub-sample:

- Chosen based on the availability of low- and high-resolution long-slit spectra from previous studies
- 24 starburst galaxies and LIRGs, of which 5 have nearby companions
- Redshift: $0.0073 \leq z \leq 0.0482$
- Various interaction stages



BPT diagram (top) and WISE colour-colour plot (bottom) differentiating the star-forming galaxies and the AGN. NGC 6000 is indicated in green.

Aims of the study

Using a sub-sample of starburst galaxies and LIRGs in the SUNBIRD survey:

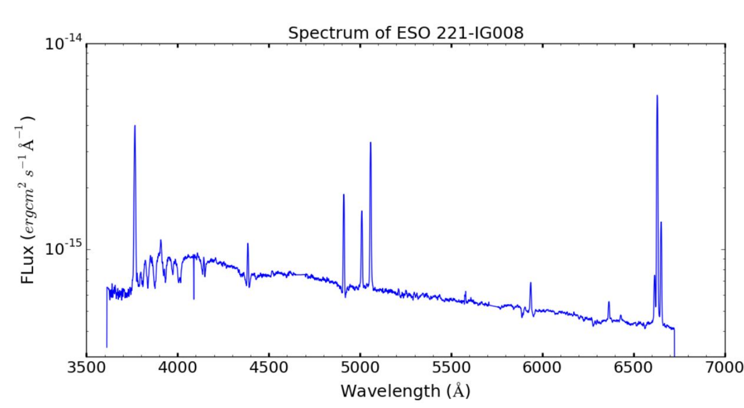
- Search for traces of outflows, inflows and extraplanar gas using resolved long-slit and multi-wavelength data.
- Characterize them using observations of neutral and ionized gas kinematics, as well as stellar kinematics.
- Determine the line diagnostics and characterise the interstellar medium. Through this determine if the outflows are driven by star formation, AGN activity or interaction from a nearby companion.

Previous work

The starburst galaxies and LIRGs in the SUNBIRD survey have been previously studied by a PhD (Ramphul, 2018) and MSc student (Tafere, 2018). Our work aims to extend and improve their studies.

Ramphul (2018)

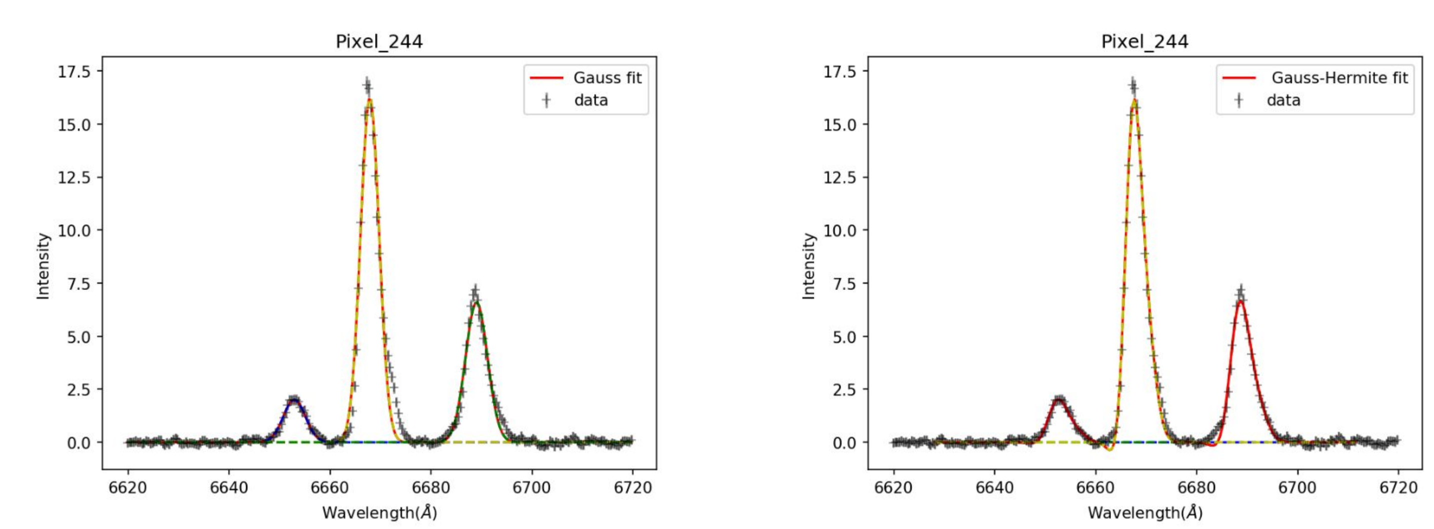
- 52 starburst galaxies and LIRGs
- Stellar population modelling and the properties of ISM
- PG0900 SALT Robert Stobie Spectrograph (RSS) long-slit data
  - Low resolution
  - 3640−6740 Å



Example of a spectrum from Ramphul (2018)

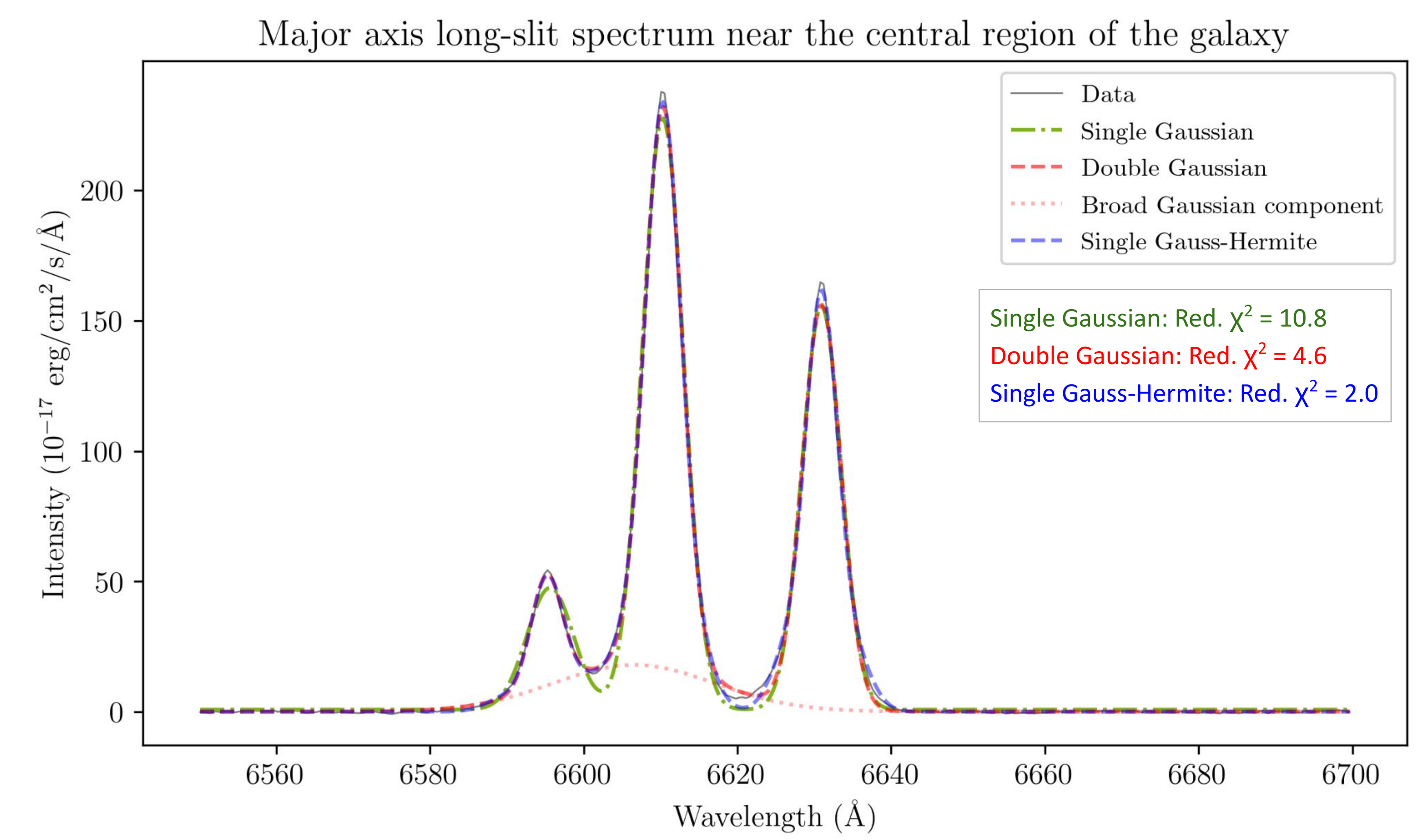
Tafere (2018)

- 40 starburst galaxies and LIRGs
- Outflows studied by looking at the kinematics of the ionized and neutral gas traced through the Hα emission line and the NaD absorption lines, respectively.
- Kinematics determined through fitting Gaussian and Gauss-Hermite models and choosing the best fit
- Outflows detected as deviations from regular galaxy rotation.
- Stellar contribution to the spectra was not traced and subtracted
- PG1800 SALT RSS long-slit data
  - High resolution
  - 5600 - 6930 Å



Gaussian and Gauss-Hermite fit from Tafere (2018). Further analysis was performed using the best fit.

Preliminary results of emission line modelling



Continuum-subtracted spectrum of NGC 6000 near the centre of the galaxy. Three emission lines are plotted: Hα and the two [NII] lines. Various models are shown: a single Gaussian model in green, a double Gaussian model in red and a single Gauss-Hermite in blue.

In order to expand and improve the studies of Ramphul (2018) and Tafere (2018) and perform more complex emission line modelling, we used the existing high resolution (PG1800) data from SALT.

The plot above shows the continuum-subtracted spectrum near the centre of galaxy NGC 6000, as well as the line modelling of the Hα and [NII] emission lines. As an initial estimate, the continuum was modelled using the *specutils* Astropy package and subtracted from the spectrum. In the future, we will model the continuum and stellar component of the spectra with a Penalized Pixel-Fitting method (pPXF; Cappellari and Emsellem, 2004). This will allow us not only to extract the stellar kinematics but also to disentangle the stellar absorption from the neutral gas in the NaD absorption lines. The emission line modelling was performed through the non-linear least squares *kmpfit* package from the Kapteyn Python module.

From the reduced χ^2 of the models, the Gauss-Hermite function fits the spectrum the best. However, we are taking the analysis of Tafere (2018) one step further by comparing the different models instead of continuing the analysis with the best fit. If, for example, a double Gaussian fits the Hα line better compared to a single Gaussian or Gaussian-Hermite, then it tells us that there might be multiple gas components, some of which could be outflow, inflow or extraplanar gas. In the plot shown above, the slightly blue shifted second Gaussian component (in red) might suggest and outflow, extraplanar gas or it could just be scattered light from the instruments.

As a next step, we will perform a more in-depth study by calculating the rotation curves, as well as emission line ratios to characterise the gas flows.

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