Spectral-cube fitting software for Spitzer & JWST studies of active galaxies

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Introduction

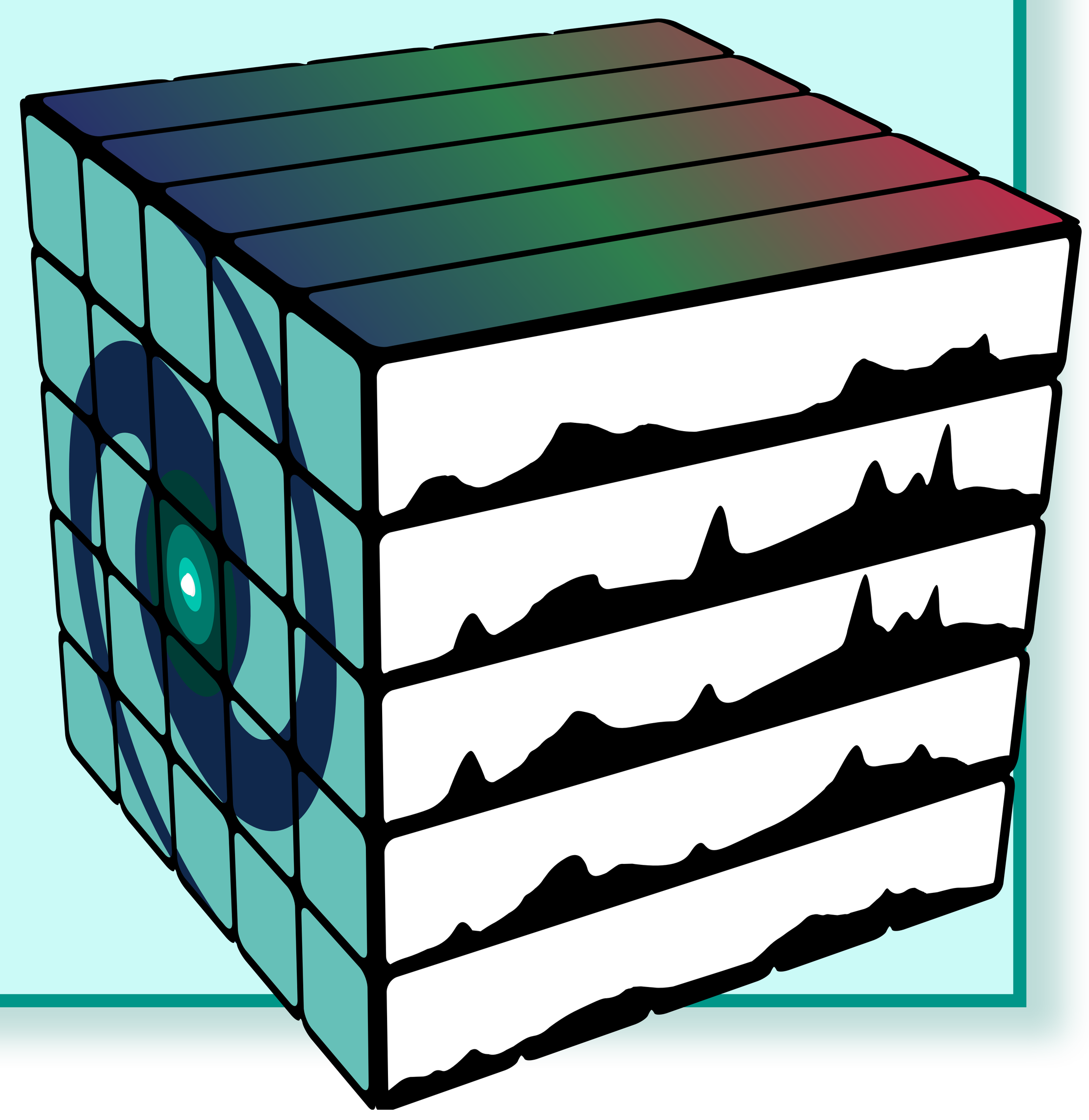
Spitzer mid-infrared spectral maps of the nearby galaxy M58 reveal that the physical conditions of the interstellar medium in molecular gas and star-forming regions are impacted by **AGN feedback**. In particular, the strong H_2 emission in this galaxy appears to trace a large mass of jet-shocked molecular gas.

We developed a flexible spectral-cube fitting tool to fit the infrared spectra of galaxies. We are using this tool to search for extended H_2 emission in nearby galaxies so we can study the effects of AGN feedback on molecular gas and how this affects the **star formation** process in galaxy bulges.

Multi-Purpose Fitting tool

MPF can fit spectral cubes of galaxies observed with Spitzer IRS, and will be easily modified to work with JWST MIRI MRS and NIRSpec IFUs.

- Coded in python, using the *lmfit* package with Levenberg-Marquardt method.
- Uses **parallel processing** to fit every spaxel with a different process, at a rate of $(1.4/N_{cores})$ seconds per spaxel. When run on a typical 7-core laptop, it fits a 900-spaxel cube in 2.5 minutes.
- Uses *astropy* to read FITS files.
- Models included: continuum, PAH features, gaussian lines, extinction, silicate emission, and more models can be added.
- Calculates integrated fluxes and luminosities.
- Makes FITS format maps of emission features from the model fitting.



Case study

M 58 (or NGC 4579) hosts a low-luminosity AGN with a moderate power radio jet. Strong H_2 emission is found in the central 1.5 kpc region, indicating **shock-heated** molecular gas. This region shows enhanced soft X-ray and Hα emission, consistent with shock heating as we can see in Figure 1.

We ran MPF for Spitzer observations of this galaxy and we obtained emission maps like the close up RGB in Figure 1. Also, in Figure 2 we extracted spectra information for different regions of interest.

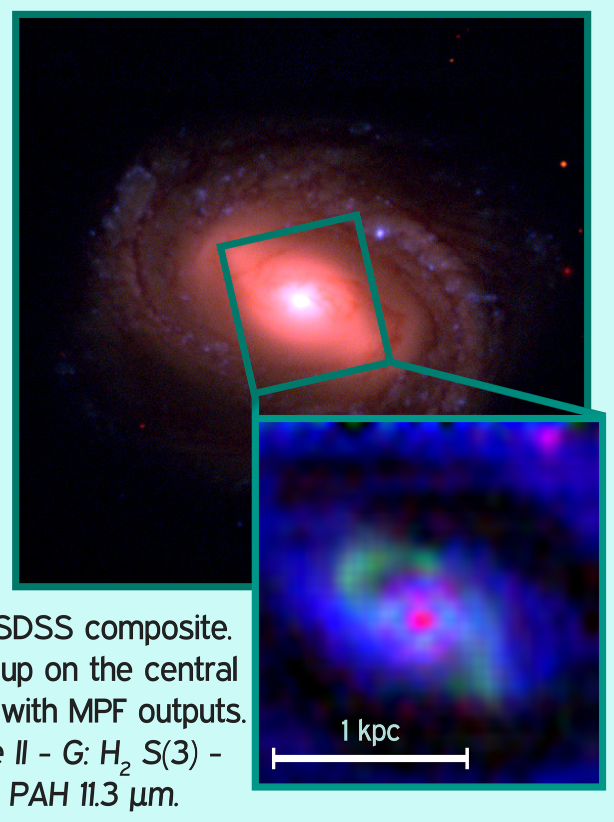


Fig 1: SDSS composite. Close up on the central region with MPF outputs. R: Ne II - G: H_2 S(3) - B: PAH 11.3 μm.

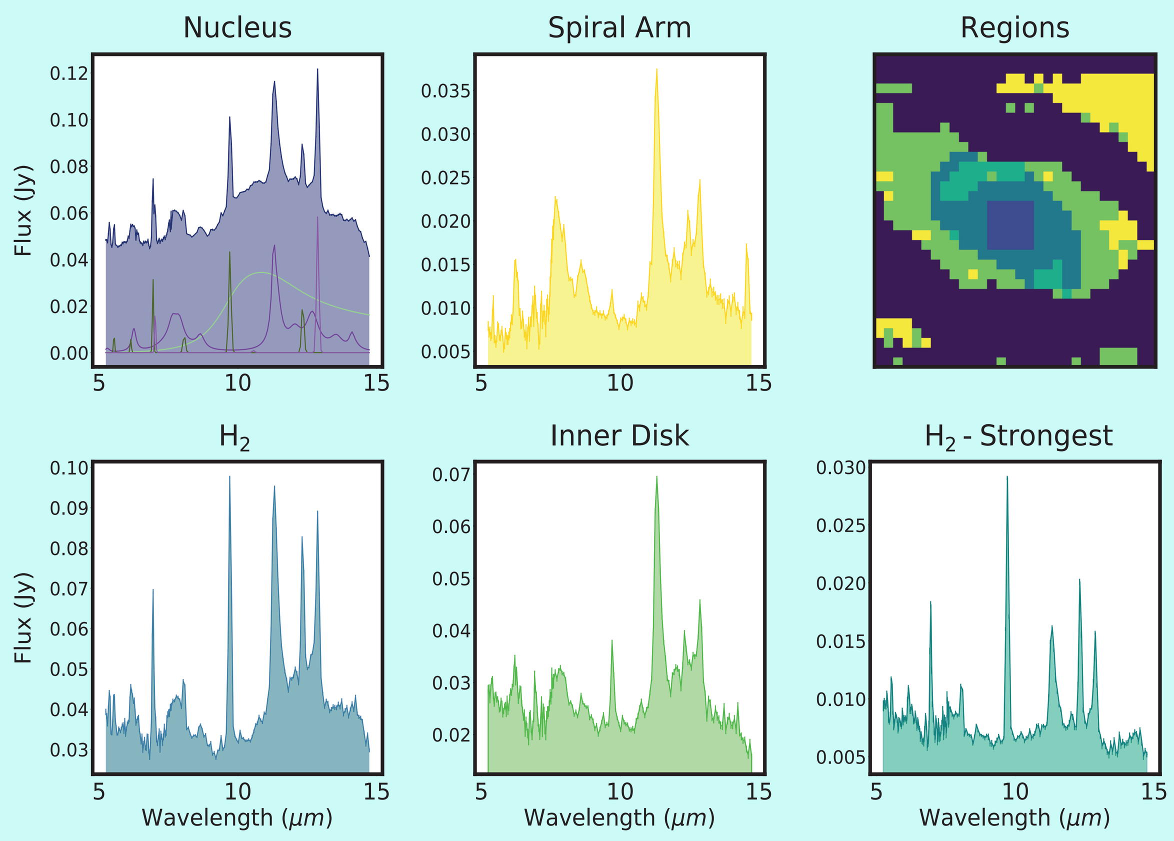


Fig 2: MPF can separate regions based on emission line and PAH ratios, and models the spectrum of each of these regions, as shown for the nucleus.

We also find evidence of a depressed PAH 7.7 μm/ PAH 11.3 μm ratio, which may indicate either the destruction of small dust grains or a weak UV field from a lack of star formation.

Conclusions

- MPF has good performance and is a powerful tool to fit spectral cubes.
- M58 has a large mass of warm molecular gas that appears to be shock-heated by its radio jet and where star formation appears to be suppressed.
- These shocked regions emit strongly in H_2 pure-rotational lines, and have low PAH 7.7 μm/PAH 11.3 μm dust emission feature ratios.

Future work

- We plan to analyze Herschel Far-IR imaging to determine if the low PAH 7.7 μm dust emission is associated with low star formation rates.
- We have been awarded time to observe the radio jet at higher dynamic range with the Jansky-VLA to better study its interaction with the ISM.
- MPF has revealed other nearby galaxies with strong H_2 emission that we will study in the future.