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ICTP PWF: Bangladesh Internship Program
Bangladesh Extragalactic Explorers(BEE)

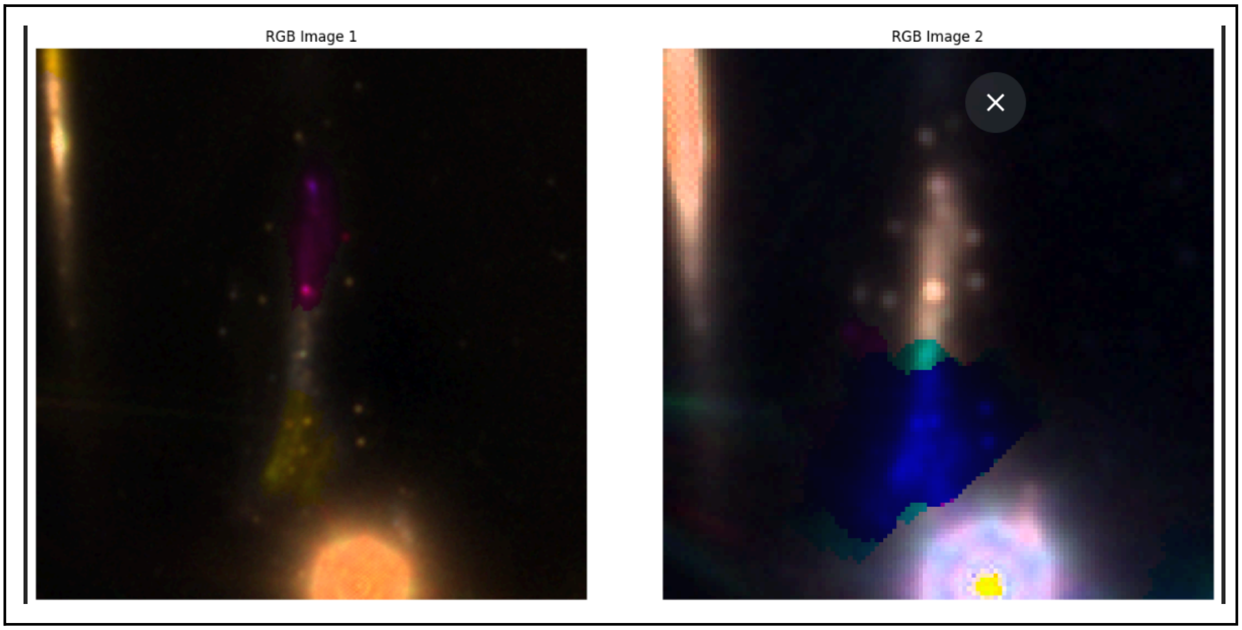
Project Name: RGB making and SED fitting with photometric data of sparkler galaxy

INTRODUCTION:

During this project I had the incredible opportunity to work with JWST NIRCam mosaics to study the Sparkler galaxy, a high-redshift galaxy at z ≈ 1.38 which is known for its complex structure and gravitational lensing features.The main tasks involved creating clear RGB images for visualization, performing background subtraction and masking, extracting precise fluxes through photometry, and finally performing SED fitting using BAGPIPES to study the galaxy's stellar population and star formation history.

Methodologies:

I first loaded the JWST science mosaics in multiple filters, ranging from F090W to F444W, from my Google Drive into Colab and carefully verified their flux units, which were in nJy, to ensure consistent measurements across all bands. I then visualized the full-frame mosaics to inspect the overall structure and quality of the images. To focus on the target galaxy, I created smaller cutouts using `Cutout2D`, making sure to preserve the World Coordinate System (WCS) information so that spatial alignment and astrometry were maintained accurately.Following the creation of cutouts, I performed background reduction using `Background2D` to remove large-scale variations and enhance faint sources. I then generated segmentation maps to detect individual sources and applied deblending techniques to effectively separate overlapping objects, ensuring that the photometry of the target galaxy was not contaminated by nearby sources.Finally, I combined selected filters to produce RGB images, allowing for a visually intuitive inspection of the galaxy and its surroundings.



To ensure consistent analysis across all filters, I performed PSF-matching with JWST UNCOVER project data so that the point spread functions were aligned, enabling accurate photometry. I then extracted flux measurements from the galaxy in each band, preparing the data for subsequent spectral energy distribution (SED) fitting. This workflow allowed me to systematically uncover the galaxy's intrinsic properties while minimizing contamination and observational artifacts.

After preparing the cutouts and performing PSF-matching across all filters, I carried out elliptical photometry on the target galaxy to measure its flux in each band. Elliptical apertures were defined to match the galaxy's shape and orientation, ensuring accurate flux capture while minimizing contamination from nearby sources. The resulting flux measurements in nJy for the different JWST filters are as follows: F090W: 4033.19 ± 6.28, F115W: 5944.55 ± 12.46, F150W: 6657.89 ± 17.59, F200W: 6864.40 ± 16.65, F277W: 7212.41 ± 15.49, F356W: 7688.28 ± 13.85, and F444W: 7626.53 ± 15.02. These measurements provide a reliable multi-band photometric dataset that can be used for further analysis, such as spectral energy distribution (SED) fitting, and help uncover the intrinsic properties of the galaxy.The fluxes and the errors have been saved in a CSV file for further use.

Next, I set up a spectral energy distribution (SED) modeling workflow using Bagpipes. I defined the galaxy model components, starting with an exponential star formation history

(SFH), specifying its age, timescale, stellar mass formed, and metallicity. I also included a dust component using the Calzetti law with a visual extinction parameter, and a **nebular** emission component with an ionization parameter. Additional parameters such as birth cloud lifetime and stellar velocity dispersion were incorporated. I then loaded the filter transmission curves corresponding to the JWST NIRCam filters (F090W–F444W) and generated the model galaxy using `pipes.model_galaxy`. I visualized the resulting spectrum and SFH, experimenting with more complex SFHs such as double power-law models and multiple bursts to better capture the galaxy's star formation history.

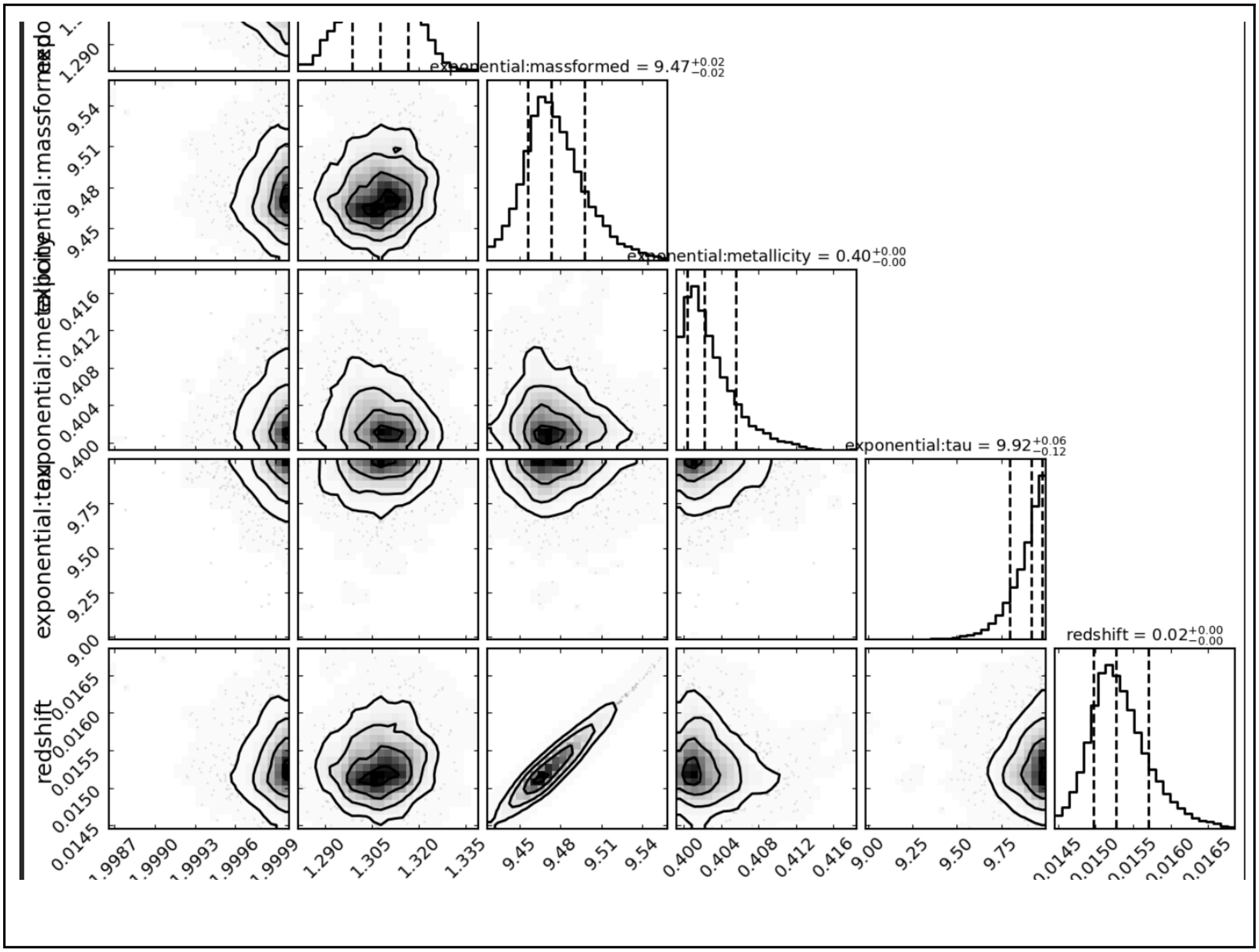
Finally, I performed photometry fitting using the measured fluxes and uncertainties of the Sparkler galaxy in nJy. The photometric data were loaded directly from CSV, ensuring invalid or missing entries were properly handled. I created a Bagpipes fit object and ran the fit, generating posterior distributions for all model parameters. The fitting outputs included posterior percentiles for redshift, dust extinction, stellar mass, SFH age, metallicity, and timescale, providing a comprehensive characterization of the galaxy's physical properties. The fit was also visualized through spectrum, SFH, and corner plots for thorough inspection of uncertainties and correlations.

RESULTS AND DISCUSSION:

The Bagpipes SED fitting of the Sparkler galaxy provides a clear picture of its stellar population and star formation history. The stellar mass formed in the exponential component is approximately $\log_{10}(M^*/M_\odot) = 9.47$, with a small uncertainty ranging from 9.45 to 9.54. This indicates that the galaxy has formed a significant amount of stars over its history.

The metallicity of the galaxy is measured to be $Z = 0.40 \pm 0.016$, showing a relatively enriched stellar population, with values spanning 0.400 to 0.416.

The star formation timescale (τ) is found to be around 9.92 Gyr, with posterior samples roughly between 9.75 and 9.92 Gyr. This long timescale suggests a slow, sustained star formation in the galaxy.



These values can be used as input for further analysis in other applications or modeling tools, allowing for comparisons with different stellar population synthesis codes or galaxy evolution models. For instance, using these parameters, one could generate model SEDs in other software to check for consistency or explore alternative star formation histories.

Additionally, a quantitative comparison can be made by calculating the chi-square (χ^2) value between the observed photometry and model predictions. This allows an assessment of the goodness-of-fit and helps determine whether the chosen model components adequately describe the galaxy's stellar population. By combining Bagpipes results with other codes or datasets, a more comprehensive understanding of the galaxy's formation and chemical enrichment history can be achieved.

References

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Approval

The internship report titled “RGB making and SED fitting with photometric data of sparkler galaxy” submitted by Abantika Maytra Oishee, a participant of the ICTP PWF: Physics for Bangladesh Online Summer Internship, has been found satisfactory in partial fulfillment of the requirements of the internship program. The internship was conducted under the supervision of **Lamiya Mowla** during the period **15 July 2025** to **15 October 2025**.

Supervisor

Lamiya Mowla
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