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The $z = 0$ Multiwavelength Galaxy Synthesis (z0MGS) Data Release 1 GALEX-WISE Atlas Data Delivery Document

1. INTRODUCTION

This document provides an overview of the delivered data products from the z0MGS GALEX-WISE atlas (Leroy et al. 2019) Data Release 1 (DR1). This includes GALEX and WISE imaging for a sample of 15,748 local galaxies ($D \lesssim 50$ Mpc) as well as best-effort masks that can be used to help remove stars and other galaxies from the images. We also provide a table of integrated galaxy properties, measured and calibrated as described in Leroy et al. (2019).

There are 15,748 galaxies in DR1. This consists of the main sample of $\sim 11,000$ galaxies that are deemed to have $> 10\%$ probability of being within $D < 50$ Mpc and of having $M_B < -18$[1]. In addition, in the course of iterating on distance estimates when creating the atlas, we generated images for $\sim 5,000$ additional galaxies. We also include these in the delivery, although they do not meet our formal selection criteria.

We have generated images in each WISE and GALEX band for each of these galaxies where data were available. All galaxies included in the atlas have WISE 1 coverage, at minimum. In total, out of the 15,748 galaxies in DR1, 15,716 have coverage in all WISE bands, 11,687 have GALEX NUV and 10,754 have GALEX FUV.

Future z0MGS deliveries will include maps of star formation rate surface density and stellar mass surface density for these galaxies. Additional multiwavelength datasets for sub-samples will be the subject of future data releases as well. For a full description of the GALEX-WISE atlas creation and the z0MGS super-sample please refer to Leroy et al. (2019).

2. CONTENTS OF DR1

DR1 consists of the following products:

1. GALEX-WISE image atlas at $7\farcs5$ resolution, containing the GALEX NUV and FUV bands and WISE 1-3, plus associated data products.
2. GALEX-WISE image atlas at $15''$ resolution, containing all of the above plus WISE 4 and associated data products.
3. An "index" stored as a FITS table that describes the $15''$ resolution data for each galaxy. The table summarizes the data characteristics for each band and each galaxy. It also includes photometry, integrated galaxy stellar mass (M_*) estimates, and star formation rate (SFR) estimates. A more limited second index describes the data for the $7\farcs5$ resolution data but does not include photometry or physical property estimates. Those should be taken from the $15''$ resolution index.

[1] We base this selection on LEDA's corrected B magnitude (Makarov et al. 2014), which attempts to correct for the effects of internal and Galactic extinction.

3. IMAGE ATLASES

The image atlas consists of a set of background subtracted images on matched astrometry with matched resolution. We provide two sets of images with different PSFs. Both PSFs are Gaussian in shape. The first set of images has FWHM 7″.5, the second of images has FWHM 15″.

All data products are sampled on the same pixel grid at a given resolution. We use 2″.5 pixels for the 7″.5 resolution atlas, and 5″.5 pixels for the 15″ resolution atlas. The image size is set to the larger of ± 4 r_{25} or $\pm 120''$.

For each galaxy we deliver the following products:

1. `PGCnumber_band_resolution.fits` - the image of the galaxy in the given band at the given resolution.

2. `PGCnumber_band_resolution_weight.fits` - the GALEX weight image (for FUV and NUV bands only), see Section 3.3 for details.

3. `PGCnumber_band_resolution_stars.fits` - a mask that can be used to eliminate bright stars from the image. The star masks have the same pixel grid as the images and have values of 1 in pixels which are dominated by a bright foreground star and 0 otherwise.

4. `PGCnumber_resolution_galaxies.fits` - a mask that can be used to eliminate other resolved galaxies from the image. This mask does not exist unless there is another known, resolved galaxy overlapping the image field of view.

Here `PGCnumber` refers to a galaxy's PGC designation with no leading 0's, e.g., `PGC39002`, not `PGC039002`. The `band` refers to either `w1`, `w2`, `w3`, `w4`, `fuv`, or `nuv`. Finally, `resolution` is given by either `gauss7p5` for 7″.5 resolution or `gauss15` for 15″.

3.1. *Units*

All intensity images have units of MJy sr^{-1}. Details of the conversion from the raw data units to MJy sr^{-1} are provided in Leroy et al. (2019).

3.2. *Convolution Caveats*

The images were convolved from their native point spread function to have a Gaussian point spread function with FWHM of either 7″.5 or 15″. This convolution used the kernels from Aniano et al. (2011).

Given the native resolution of the images, only GALEX FUV and NUV, and WISE 1-3 bands could be convolved to 7″.5 resolution. All bands can be convolved to 15″ resolution.

Use of "aggressive" kernels: In convolving the WISE 3 to 7″.5, we have used kernels considered by Aniano et al. (2011) to be "aggressive." This indicates that there are negative values in the kernel due to the necessity of moving some power from large to small angular scales in the convolution, primarily due to the wings of the WISE PSF. The use of "aggressive" kernels can lead to artifacts in the case of bright point sources and can amplify the noise in the images. This same concern applies, but to a lesser extent, to the WISE 4 convolution to to 15″ resolution.

We strongly recommend that users of the atlas work at the lowest resolution feasible for their science and exercise particular caution when using the WISE 3 band at 7″.5 resolution.

3.3. *GALEX Images*

Imaging at GALEX FUV and NUV bands exists for 10,754 and 11,687 galaxies, respectively. There are 10,696 galaxies with imaging in both GALEX bands. Below we provide a brief overview of the GALEX image processing.

3.3.1. *Processing Overview*

The GALEX image cutouts were created by combining all of the individual tiles covering the galaxy that were obtained by GALEX during its mission. The initial processing aligned all tiles to a matched astrometric grid with 1.″5-sized pixels and spanning the larger of 1800″ or 6 r_{25}. The raw counts per second images were converted to MJy sr^{-1} and the edges of the field of view were masked due to the decline in sensitivity. The images were then combined, weighting by the effective integration time (contained in the GALEX pipeline `rrhr` file). A combined weight image was also produced to capture the effective integration time appropriate for each pixel.

Next the images and weight images were convolved to the 7.″5 and 15″ resolutions. Star masks were constructed as described in Leroy et al. (2019) based on the 2MASS and GAIA catalogs. Last, we removed the background from the images by masking all data within 2 r_{25} of the galaxy center, all stars in the star mask, and any resolved nearby galaxies. We then performed an iterative process to find the median in the remaining sky pixels, rejecting outliers. We note that the background fitting is done at 15″ resolution and applied to both the 7.″5 and 15″ images. The additional averaging supplied by the convolution to 15″ leads to sufficient counts per 15″ beam that we can safely use Gaussian statistics for the GALEX data.

3.4. *WISE Images*

Imaging at WISE 1 is available for all galaxies in the atlas. There are 15,716 galaxies that have coverage in all four WISE bands. Below is a brief description of the WISE atlas image processing.

3.4.1. *Processing Overview*

The WISE cutouts for each galaxy were generated from the unWISE reprocessing of the WISE all-sky datasets (Lang 2014). The initial images have the same 2.″75 pixel scale as used in Lang (2014) and an astrometric grid spanning the larger of 1800″ or 6 r_{25} on each side. The images at WISE 3 and 4 (12 and 22 μm, respectively) were created without median filtering to remove backgrounds. This filtering is the standard unWISE processing; we disable it here in order to avoid oversubtracting the diffuse, extended emission from large, nearby galaxies. After creating the cutouts, we performed our own background removal by iteratively fitting a tilted plane to regions outside 2 r_{25} that were not masked in the star or galaxy masks. After conversion from original units to MJy sr^{-1}, the images were convolved and resampled to the final pixel grids.

3.5. *Star and Galaxy Masks*

Included with the atlas are masks that can be used to eliminate bright foreground stars and other resolved galaxies from the images. The galaxy mask was created by locating any galaxies in the image field of view out to $z \sim 0.3$ from the LEDA database. The mask removes pixels within the either 1.25 r_{25} or 7.″5 from the center of any identified galaxies, depending on which radius is larger. For galaxies with unknown r_{25} the mask defaults to a 7.″5 radius. The star masks are created with a

combination of 2MASS and GAIA information to predict the positions of bright foreground stars in the images as described in Section 4.4 of Leroy et al. (2019).

We caution the user of the atlas that neither mask is complete—e.g. there are potentially contaminating stars that are not identified by the 2MASS/GAIA predictions and there are galaxies beyond $z \sim 0.3$ or that are not in the LEDA catalog that can potentially overlap the target. In addition, by-hand masking may be necessary to deal with image artifacts in some galaxies. Future data releases are likely to include updates to the masks.

3.6. *Final Image Atlas*

Both the GALEX and WISE data were put on matched astrometric grids using the common pixel scales mentioned above. During this stage, the field of view was reduced to its final value. Both steps reduce the overall data volume of the atlas. The final images cover at least ± 4 r_{25} but never less than $\pm 120''$. The delivered `fits` image headers contain some useful parameters described below.

3.6.1. *Image Atlas Fits Header Information*

The fits headers of the delivered data include the following potentially useful parameters beyond the standard WCS information:

- `RMS` – a robust estimate of the noise in the image. The robust estimate attempts to capture the statistical noise, suppressing the influence of, e.g., foreground stars.
- `STDDEV` – the standard deviation of the image away from the galaxy without any masking. This calculation does not suppress bright sources, and so will deviate from the RMS in regions with many foreground stars.
- `SATURATE` – indicates whether saturation appears likely to occur inside the image. Thresholds for saturation are taken to be 100 MJy sr^{-1} for WISE1 and WISE2 and 300 MJy sr^{-1} for WISE3 and WISE4. See the paper for more details.
- `GALFRAC` – fraction of the footprint of the galaxy that is flagged due to the presence of other galaxies.
- `GALFLAG` – a flag indicating whether $> 10\%$ of the galaxy footprint is flagged due to the presence of other galaxies.
- `STARFLUX` – the fraction of the flux inside the galaxy footprint flagged due to the presence of foreground stars.
- `STARAREA` – the fraction of the area inside the galaxy footprint flagged due to the presence of foreground stars.
- `STARFLAG` – a flag indicating whether $> 20\%$ of the flux inside the galaxy footprint is flagged due to the presence of stars.

Parameters unique to GALEX images include:

- `MEANINT` – the mean effective integration time across the GALEX image.
- `FRACCOV` – the fraction of the galaxy covered by the image.
- `MWEXT` – the adopted and applied foreground Milky Way extinction, in magnitudes.

4. DR1 INDEX AND INTEGRATED GALAXY PROPERTY MEASUREMENTS

In addition to the image atlas, we deliver a fits data table that includes an overview of the dataset and the integrated stellar mass and star formation rate measured for each galaxy. The fits table `z0mgs_dr1_index.fits` contains the following columns:

- Galaxy Identifying Information:
  - `PGCNAME` - galaxy PGC name (as a string) with no leading 0s
  - `PGC` - PGC number (as an integer)
  - `RA_DEG`, `DEC_DEG` - Right Ascension and Declination of the galaxy center (in degrees)
  - `GL_DEG`, `GB_DEG` - Galactic latitude and longitude of the galaxy center (in degrees)
- Atlas Contents:
  - `RESOLUTION` - resolution of the atlas (as a string), e.g. `gauss15`.
  - `HAS_band` - availability of data in the atlas (0 for no data, 1 for data exists) where `band` is one of `WISE1`, `WISE2`, `WISE3`, `WISE4`, `FUV` or `NUV`
- GALEX-only information:
  - `TIME_FUV`, `TIME_NUV` - mean integration time in the GALEX bands in seconds (equivalent to the header keyword `MEANINT` described in Section 3.6.1)
  - `AFUV`, `ANUV` - the applied extinction value for the FUV and NUV bands in magnitudes (equivalent to the header keyword `MWEXT` described in Section 3.6.1)
- Noise Characterization:
  - `STD_band` - standard deviation of the background pixels for each `band`, equivalent to the header keyword `STDDEV` as described in Section 3.6.1 (in MJy sr^{-1})
  - `RMS_band` - RMS of the background pixels for each `band`, equivalent to the header keyword `RMS` as described in Section 3.6.1 (in MJy sr^{-1})
- Masks and Saturation:
  - `SAT_EFFECTS_band` - flag for saturation in the image, 0 for no saturation, 1 for saturation effects likely (equivalent to the header keyword `SATURATE` described in Section 3.6.1)
  - `STAR_AREA_band` - fraction of the area inside the galaxy footprint flagged due to foreground star contamination (equivalent to the header keyword `STARAREA` described in Section 3.6.1)
  - `STAR_FLUX_band` - fraction of the flux inside the galaxy footprint flagged due to the presence of foreground stars (equivalent to the header keyword `STARFLUX` described in Section 3.6.1)
  - `STAR_FLAG_band` - flag indicating that $> 20\%$ of the flux inside the galaxy footprint is flagged due to the presence of stars (equivalent to the header keyword `STARFLAG` described in Section 3.6.1)
  - `GALAXY_MASK_OVERLAP` - fraction of the footprint of the galaxy that is flagged due to the presence of other galaxies (equivalent to the header keyword `GALFRAC` described in Section 3.6.1)

  - GALAXY_OVERLAP_FLAG - a flag indicating whether > 10% of the galaxy footprint is flagged due to the presence of other galaxies (equivalent to the header keyword GALFLAG described in Section 3.6.1)

- Integrated Photometry:
  - FLUX_band - integrated flux in Jy at the given band for the galaxy
  - RMS_FLUX_band - uncertainty on the flux implied by the RMS of background regions of the image
  - STD_FLUX_band - uncertainty on the flux implied by the standard deviation of background regions of the image

- Sample Definition Parameters:
  - DIST_MPC - distance to the galaxy in Mpc, obtained as described in Section 2.2 of Leroy et al. (2019)
  - E_DIST_DEX - distance uncertainty in dex
  - ABSBTC - absolute B magnitude from LEDA computed from the "btc" corrected total apparent magnitude
  - COMPLETE_SAMPLE - a flag indicating whether the galaxy is part of the formal z0MG sample (1 for yes, 0 for no), i.e. is within $d < 50$Mpc and $M_B < -18$

- Derived Parameters:
  - MTOL - WISE1 mass-to-light ratio, with units $M_\odot/L_\odot$.
  - METHOD_MTOL - Method used to determine MTOL, options include W4W1 or SSFRLIKE, described in Appendix A.5 of Leroy et al. (2019).
  - LOGMASS - logarithm of the derived stellar mass, $\log_{10}(M_*)$, where M_* is in units of $M_\odot$
  - E_LOGMASS - uncertainty on the stellar mass in dex
  - METHOD_SFR - method used to determine star formation rate, options include FUV+WISE4, NUV+WISE4 or WISE4, as described in Appendix A.6 and A.7 of Leroy et al. (2019)
  - LOGSFR - derived star formation rate, $\log_{10}(\mathrm{SFR})$, where SFR is in units of $M_\odot$ yr^{-1}
  - E_LOGSFR - uncertainty on the star formation rate in dex
  - DELTAMS - offset from the "star-forming main sequence" as described in Section 8.2 of Leroy et al. (2019)

4.1. *Simple Index for the 7.″5 Resolution Atlas*

Included in DR1 is an additional index fits table (called simple_index_gauss7p5.fits) that describes the contents of the 7.″5 atlas. This includes the same information as the main DR1 index file for the 7.″5 images, but it does not include "Integrated Photometry", "Sample Definition Parameters" and "Derived Parameters". These values should be taken from the main DR1 index file.

REFERENCES

Aniano, G., Draine, B. T., Gordon, K. D., & Sandstrom, K. 2011, PASP, 123, 1218

Lang, D. 2014, AJ, 147, 108

Leroy, A., Sandstrom, K., Lang, D., et al. 2019, ApJS, in press

Makarov, D., Prugniel, P., Terekhova, N., Courtois, H., & Vauglin, I. 2014, A&A, 570, A13