# The FENIKS Survey: Catalogs of Photometry, Redshifts, and Stellar Population Properties

This document describes the Version 1 (v1) release of the FENIKS UDS catalog. Please refer to Zaidi et al. (2024) for the details of the catalog construction. In the following, we describe the PSF-matched photometric catalog in §1, the `eazy-py` derived redshift catalog (includes stellar population parameters too) in §2, and the dedicated catalogs of stellar population properties derived using `FAST` in §3 and `Dense Basis` in §4. The segmentation map and masks are mentioned in §5.

## 1. PSF-matched photometric catalog

We release two almost identical photometry catalogs, one with zeropoint corrections applied and one without (see below). The zeropoint corrected catalog - `feniks_uds_v1.0_zpcor.cat` is the preferred catalog to use. We provide the non-zeropoint corrected catalog - `feniks_uds_v1.0.cat` only for completion.

**Photometry Catalog files:**
`feniks_uds_v1.0_zpcor.cat` (zeropoint corrected, recommended catalog to use)
`feniks_uds_v1.0.cat` (non-zeropoint corrected)

**Table 1**. Contents of the Photometric catalog

| Column | Description | units/range |
|---|---|---|
| `ID` | Object identifier | - |
| `X, Y` | X and Y image coordinates. Pixel scale = 0.2684″/pixel | pixel |
| `RA, DEC` | Right Ascension and Declination | J2000 deg |
| `fcol_X, ecol_X` | color aperture flux and error. ZP = 25 AB | - |
| `w_X` | "weight": relative coverage | 0 - 1 |
| `fauto_Kuds, eauto_Kuds` | Flux and error in the UDS $K$-band within the Kron-like elliptical aperture. ZP = 25 AB | - |
| `ftot_Kuds, etot_Kuds` | Total flux and error in the UDS $K$-band. ZP = 25 AB | - |
| `auto_to_tot_corr` | correction factor to multiply fauto_Kuds or eauto_Kuds to get the total flux or error | > 1 |
| `fD3_Kuds, eD3_Kuds` | Flux and error in the UDS $K$-band within the aperture diameter of 3″. ZP = 25 AB | - |
| `fD5_Kuds, eD5_Kuds` | Flux and error in the UDS $K$-band within the aperture diameter of 5″. ZP = 25 AB | - |
| `Kronradius_Kuds` | circularized Kron radius | ″ |
| `aper` | Diameter of the color aperture | ″ |
| `aper_tot` | Diameter of the AUTO FLUX aperture, the Kron-like aperture | ″ |
| `aper_to_tot_corr` | correction factor to multiply `fcol_X` or `ecol_X` to get the total flux or error | > 1 |
| `r50_Kuds` | Half-light radius in the UDS $K$-band given by `SExtractor` | ″ |
| `ellipticity_Kuds` | Ellipticity in the UDS $K$-band as output by `SExtractor` | - |
| `PA_Kuds` | Position Angle (east of north) in the UDS $K$-band as output by `SExtractor` | deg |

**Table 1** *continued on next page*

**Table 1** *(continued)*

| Column | Description | units/range |
|---|---|---|
| flags_Kuds | SExtractor flags in the UDS $K$-band as output by SExtractor | - |
| class_star | Star/Galaxy classifier of SExtractor | 0 - 1 |
| star | Binary flag for stars; | |
| | star=0 means that the object is classified as a star | 0 or 1 |
| gaia_star | Binary flag for stars classified in the Gaia catalog[2] with > 95% confidence; | |
| | not included in the star flag above | 0 or 1 |
| opt_nir_maxflags | maximum of the FLAGS output by SExtractor in each band | |
| det_contam | Binary flag indicating contamination in the detection band (UDS-$K$) | 0 or 1 |
| use_phot | Binary flag indicating galaxies with reliable photometry having star = 0, | |
| | det_contam = 0, $S/N$ (calculated using color aperture flux/error in the | |
| | UDS $K$-band) > 3, and nusefilt (parameter in the eazy-py output catalog | |
| | quoting the number of filters with data) > 7 | 0 or 1 |
| z_grism | Binary flag indicating if the corresponding z_spec came from grism spectroscopy | 0 or 1 |
| z_spec | Spectroscopic redshift | - |

## 2. eazy-py derived photometric redshifts

**Redshift Catalog files:**
feniks_uds_v1.0.eazypy.zout.ecsv - eazy-py output described in Table 2 below
feniks_uds_v1.0.eazypy.zout.fits - same as feniks_uds_v1.0.eazypy.zout.ecsv but in '.fits' format
feniks_uds_v1.0.eazypy.data.fits - contains fitting metadata (see §2.2 for an example on how to extract pdf(z) from this file)

eazy-py **version:** 0.6.3

### 2.1 Main output catalog - feniks_uds_v1.0.eazypy.zout.ecsv

The columns in the feniks_uds_v1.0.eazypy.zout.ecsv file are mostly the same as described in the eazy-py API documentation[3] with a few additions. All of the stellar population properties such as rest-frame fluxes, stellar masses, star formation rates, etc. are derived at the best available redshift: spectroscopic redshift (z_spec) if available, otherwise at the maximum likelihood photometric redshift (z_ml). The table below describes all the information available.
The rest-frame magnitudes [AB] from the rest-frame fluxes, such as in the U-band (restU), can be calculated as follows: $-2.5*\log_{10}(\text{restU}) + 25$

[2] https://www.cosmos.esa.int/web/gaia/dr3
[3] https://eazy-py.readthedocs.io/en/latest/eazy/zout_columns.html

**Table 2**. Contents of the eazy-py catalog

| Column | Description | units/range |
|---|---|---|
| id | Object identifier | - |
| ra, dec | Right Ascension and Declination | J2000 deg |
| z_spec | Spectroscopic redshift | -1 if not available |
| nusefilt | Number of filters used for photo-z | - |
| z_ml | Maximum likelihood redshift (the equivalent of z_peak) from | |
| | the non-python version of eazy-py | -1 if not available |
| z_ml_chi2 | chi-squared at z==z_ml | - |
| z_ml_risk | R(z_ml), "Risk" parameter defined by Tanaka et al. (2017) , evaluated at z_ml | - |
| lc_min | Minimum effective wavelength of valid filters | Å |
| lc_max | Maximum effective wavelength of valid filters | Å |
| z_phot | This is the best redshift available: z_spec if available, otherwise z_ml | - |
| z_phot_chi2 | chi-squared at z==z_phot | - |
| z_phot_risk | Risk evaluated at z_phot | - |
| z_min_risk | Redshift where R(z) is minimized | - |
| min_risk | R(z_min_risk) | - |
| z_raw_chi2 | Redshift where $\chi^2$ is minimized | - |
| raw_chi2 | Minimized $\chi^2$ | - |
| z025 | 2.5 percentile of pdf(z) (2-$\sigma$) | - |
| z160 | 16 percentile of pdf(z) (1-$\sigma$) | - |
| z500 | 50 percentile of pdf(z) | - |
| z840 | 84 percentile of pdf(z) (1-$\sigma$) | - |
| z975 | 97.5 percentile of pdf(z) (2-$\sigma$) | - |
| restU | Rest-frame U-band flux; magnitude [AB] = -2.5*$\log_{10}$(restU) + 25 | - |
| restU_err | Uncertainty in restU | - |
| restB | Rest-frame B-band flux; magnitude [AB] = -2.5*$\log_{10}$(restB) + 25 | - |
| restB_err | Uncertainty in restB | - |
| restV | Rest-frame V-band flux; magnitude [AB] = -2.5*$\log_{10}$(restV) + 25 | - |
| rest_Verr | Uncertainty in restV | - |
| restJ | Rest-frame J-band flux; magnitude [AB] = -2.5*$\log_{10}$(restJ) + 25 | - |
| rest_Jerr | Uncertainty in restJ | - |
| dL | Luminosity distance at z_phot | Mpc |
| Lv | Rest-frame V-band luminosity | $L_\odot$ |
| mass | Stellar mass | $M_\odot$ |
| sfr | Star formation rate over last 100 Myr | $M_\odot$ yr$^{-1}$ |
| LIR | Total 8–1000 µm luminosity | $L_\odot$ |
| energy_abs | Implied absorbed energy associated with $A_V$ | $L_\odot$ |
| Av | Extinction in V-band | mag |
| lw_age_V | Light-weighted Age (V-band) | Gyr |
| MLv | Mass-to-light ratio in V-band | $M_\odot/L_\odot$ |
| Lv_p | 2.5, 16, 50, 84, 97.5 Percentiles of rest-frame V-band luminosity | $L_\odot$ |
| mass_p | 2.5, 16, 50, 84, 97.5 Percentiles of stellar mass | $M_\odot$ |

**Table 2** *continued on next page*

**Table 2** *(continued)*

| Column | Description | units/range |
|---|---|---|
| LIR_p | 2.5, 16, 50, 84, 97.5 Percentiles of total 8–1000 µm luminosity | $L_\odot$ |
| sfr_p | 2.5, 16, 50, 84, 97.5 Percentiles of star formation rate over last 100 Myr | $M_\odot$ yr$^{-1}$ |
| Av_p | 2.5, 16, 50, 84, 97.5 Percentiles of extinction in V-band | mag |
| ssfr_p | 2.5, 16, 50, 84, 97.5 Percentiles of specific SFR (sfr/mass) | yr$^{-1}$ |
| rest414 | Rest-frame synthetic u-band (Antwi-Danso et al. 2023) flux; | |
| | magnitude [AB] = -2.5*log$_{10}$(rest414) + 25 | - |
| rest414_err | Uncertainty in rest414 | - |
| rest415 | Rest-frame synthetic g-band (Antwi-Danso et al. 2023) flux; | |
| | magnitude [AB] = -2.5*log$_{10}$(rest415) + 25 | - |
| rest415_err | Uncertainty in rest415 | - |
| rest416 | Rest-frame synthetic i-band (Antwi-Danso et al. 2023) flux; | |
| | magnitude [AB] = -2.5*log$_{10}$(rest416) + 25 | - |
| rest416_err | Uncertainty in rest416 | - |

### 2.2 Example showing how to get probability distribution functions of redshift - pdf(z) from uds.eazypy.data.fits

```
#imports
from astropy.io import fits
import eazy
import numpy as np
import matplotlib.pyplot as plt

#read in the data.fits file
hdu=fits.open('uds.eazypy.data.fits')

#display its contents
hdu.info()

#get redshift grid eazy-py used
ZGRID = hdu[2].data

#get chi-squared array
CHI2 = hdu[3].data

#Below, we'll get pdf(z) of an object with ID = 20
ID = 20

#In general, with such fits, log-likelihood = chi-squared/(-2)
ln_pz = CHI2[ID-1]/(-2)

#convert from log-likelihood to likelihood
pz = np.exp(ln_pz)

#plot to show the pdf(z) of object with ID=20.  You can of course store these as you want
```

```
plt.plot(ZGRID, pz)
plt.show()
```

## 3. FAST derived Stellar population properties

**Stellar Population Properties Catalog file:** `feniks_uds_v1.0.fout`

**FAST version:** 1.0
**Template error function:** TEMPLATE_ERROR.fast.v0.2
**Stellar population library:** Bruzual & Charlot (2003)
**Star formation history function:** Delayed exponential: SFR $\sim$ t $\times$ exp(-t/tau)
**Stellar IMF:** Chabrier (2003)
**Dust law:** Calzetti et al. (2000)
**metallicity:** $Z = Z_{\odot} = 0.0200$ (fixed at solar)

**Table 3**. Contents of the FAST catalog

| Column | Description | units/range |
|---|---|---|
| `col1` | id: Object identifier | - |
| `col2` | z: redshift | 0.01 - 8.00 ($\Delta = 0.01$) |
| `col3` | ltau: log[tau/yr] | 7.0 - 10.0 dex ($\Delta = 0.1$ dex) |
| `col4` | metal: metallicity | fixed at 0.02 |
| `col5` | lage: log(age/yr) | 7.0 - 10.1 dex ($\Delta = 0.1$ dex) |
| `col6` | Av: extinction in V-band | 0.0 - 10.0 mag ($\Delta = 0.1$ mag) |
| `col7` | lmass: log($M_*/M_{\odot}$) | dex |
| `col8` | lsfr: log[sfr/($M_{\odot}yr^{-1}$)]; -99 if sfr=0 | dex |
| `col9` | lssfr: log[ssfr $yr^{-1}$] | dex |
| `col10` | la2t: log[age/tau] - indicator of how evolved/quenched is the stellar population | dex |
| `col11` | reduced $\chi^2$ | - |

## 4. Dense Basis derived Stellar population properties

**Stellar Population Properties Catalog file:** `feniks_uds_v1.0.db`

**Stellar population library:** `FSPS` (Conroy & Gunn 2010; Conroy et al. 2009) using the MIST isochrones (Choi et al. 2016), and MILES spectral library (Sánchez-Blázquez et al. 2006)
**Nebular emission lines:** `CLOUDY` (Ferland et al. 2017; Byler et al. 2017)
**Star formation history:** non-parametric using the model in Iyer et al. (2019)
**Star formation history constrained at lookback times:** $t_{25}$, $t_{50}$, and $t_{75}$ at which 25%, 50%, and 75% of stellar mass had been assembled, respectively.
**Stellar IMF:** Chabrier (2003)
**Dust law:** Calzetti et al. (2000)
**metallicity ($Z/Z_{\odot}$):** 0.01 - 2.0

**Table 4**. Contents of the Dense Basis catalog

| Column | Description | units/range |
|---|---|---|
| ID | Object identifier | - |
| logM_50 | $50^{th}$ percentile of $\log_{10}$ of stellar mass [$M_*/M_\odot$] | dex |
| logM_16 | $16^{th}$ percentile of $\log_{10}$ of stellar mass [$M_*/M_\odot$] | dex |
| logM_84 | $84^{th}$ percentile of $\log_{10}$ of stellar mass [$M_*/M_\odot$] | dex |
| logSFRinst_50 | $50^{th}$ percentile of $\log_{10}$ of instantaneous star-formation rate [$M_\odot yr^{-1}$] | dex |
| logSFRinst_16 | $16^{th}$ percentile of $\log_{10}$ of instantaneous star-formation rate [$M_\odot yr^{-1}$] | dex |
| logSFRinst_84 | $84^{th}$ percentile of $\log_{10}$ of instantaneous star-formation rate [$M_\odot yr^{-1}$] | dex |
| logZsol_50 | $50^{th}$ percentile of $\log_{10}$ of metallicity [$Z/Z_\odot$] | dex ($Z/Z_\odot$: 0.01 - 2.0) |
| logZsol_16 | $16^{th}$ percentile of $\log_{10}$ of metallicity [$Z/Z_\odot$] | dex ($Z/Z_\odot$: 0.01 - 2.0) |
| logZsol_84 | $84^{th}$ percentile of $\log_{10}$ of metallicity [$Z/Z_\odot$] | dex ($Z/Z_\odot$: 0.01 - 2.0) |
| Av_50 | $50^{th}$ percentile of extinction in V-band | 0 - 4 mag |
| Av_16 | $16^{th}$ percentile of extinction in V-band | 0 - 4 mag |
| Av_84 | $84^{th}$ percentile of extinction in V-band | 0 - 4 mag |
| zfit_50 | $50^{th}$ percentile of the best-fit redshift | - |
| zfit_16 | $16^{th}$ percentile of the best-fit redshift | - |
| zfit_84 | $84^{th}$ percentile of the best-fit redshift | - |
| logMt_50 | $50^{th}$ percentile of $\log_{10}$ of total mass formed (i.e. without including mass loss for old stars while calculating stellar mass); same units as stellar mass | dex |
| logMt_16 | $16^{th}$ percentile of $\log_{10}$ of total mass formed (i.e. without including mass loss for old stars while calculating stellar mass); same units as stellar mass | dex |
| logMt_84 | $84^{th}$ percentile of $\log_{10}$ of total mass formed (i.e. without including mass loss for old stars while calculating stellar mass); same units as stellar mass | dex |
| t25_50 | $50^{th}$ percentile of the time when 25% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t25_16 | $16^{th}$ percentile of the time when 25% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t25_84 | $84^{th}$ percentile of the time when 25% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t50_50 | $50^{th}$ percentile of the time when 50% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t50_16 | $16^{th}$ percentile of the time when 50% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t50_84 | $84^{th}$percentile of the time when 50% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t75_50 | $50^{th}$ percentile of the time when 75% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t75_16 | $16^{th}$ percentile of the time when 75% of the total mass was assembled, as a fraction of the age of the universe at zfit_50 | 0 - 1 |
| t75_84 | $84^{th}$ percentile of the time when 75% of the total mass was assembled, | |

**Table 4** *continued on next page*

**Table 4** *(continued)*

| Column | Description | units/range |
|---|---|---|
| | as a fraction of the age of the universe at `zfit_50` | 0 - 1 |
| `nparam` | number of lookback time parameters used | fixed at 3: $t_{25}$, $t_{50}$, and $t_{75}$ |
| `nbands` | number of bands utilized | - |
| `chi2` | reduced $\chi^2$ | - |

## 5. Detection Segmentation map and Masks

**UDS-K band's (detection band) segmentation map:** `feniks_uds_v1.0_UDS_K_seg.fits`

**Region file of UDS-K detected object centroids:** `feniks_uds_v1.0_UDS_K_obj_centroids.reg`

**Masks for bright stars and other artifacts for optical-NIR bands:** `feniks_uds_v1.0_masks.tar.gz`
Pixels with the value '0' are unmasked regions devoid of bright stars and other artifacts, whereas '1' means masked. Only in the detection band mask - `UDS_K_Mask.fits`, regions with no data are marked with '100'. This is useful for calculating the total effective area with good quality data which is covered by pixels not equal to '1' or '100' (which is the same as pixels equal to '0').

REFERENCES


Antwi-Danso, J., Papovich, C., Leja, J., et al. 2023, ApJ, 943, 166, doi: 10.3847/1538-4357/aca294

Bruzual, G., & Charlot, S. 2003, MNRAS, 344, 1000, doi: 10.1046/j.1365-8711.2003.06897.x

Byler, N., Dalcanton, J. J., Conroy, C., & Johnson, B. D. 2017, ApJ, 840, 44, doi: 10.3847/1538-4357/aa6c66

Calzetti, D., Armus, L., Bohlin, R. C., et al. 2000, ApJ, 533, 682, doi: 10.1086/308692

Chabrier, G. 2003, PASP, 115, 763, doi: 10.1086/376392

Choi, J., Dotter, A., Conroy, C., et al. 2016, ApJ, 823, 102, doi: 10.3847/0004-637X/823/2/102

Conroy, C., & Gunn, J. E. 2010, ApJ, 712, 833, doi: 10.1088/0004-637X/712/2/833

Conroy, C., Gunn, J. E., & White, M. 2009, ApJ, 699, 486, doi: 10.1088/0004-637X/699/1/486

Ferland, G. J., Chatzikos, M., Guzmán, F., et al. 2017, RMxAA, 53, 385, doi: 10.48550/arXiv.1705.10877

Iyer, K. G., Gawiser, E., Faber, S. M., et al. 2019, ApJ, 879, 116, doi: 10.3847/1538-4357/ab2052

Sánchez-Blázquez, P., Gorgas, J., Cardiel, N., & González, J. J. 2006, A&A, 457, 809, doi: 10.1051/0004-6361:20064845

Zaidi, K., Marchesini, D., Papovich, C., et al. 2024, arXiv e-prints, arXiv:2401.03107, doi: 10.48550/arXiv.2401.03107