Abstract

- Context: Photometry of astrophysical sources, galaxies and stars, in crowded field images.
- Our purpose: estimate the flux in a low resolution band using prior information (position and shape) from a better resolved band, in a Bayesian approach under the Poisson noise assumption.
- Expectation-Maximization (EM) algorithm for solving the photometry.
- Prior shapes deblending in high resolution images.
- Astrometry correction, PSF optimization, background correction from the residual.
- Application: Deep Imaging Survey (DIS) of the GALEX mission, which observes in two UV bands with long exposure times (~3000 sec) and produces deep sky images of 1 square degree, with hundreds of thousands of galaxies or stars.
- Priors are computed from CHYFS data.
- Very faint signal dominated by the photon shot noise, with background level around 100 (resp. 10) counts in the near (resp. far) UV band.

Maximum Likelihood parametric estimation with Priors: Expectation-Maximization (EM)

- \( x_i \): observed value on pixel \( i \) of the UV image, considered as a sample of the random variable \( X \), following a Poisson statistics law.
- \( \mu_i = f(X) \): expected value.
- \( h_{ki} \): known relative value of object \( k \) on pixel \( i \), results from the convolution between each object and the PSF of the GALEX imaging system.
- \( a_{ki} \): unknown fluxes of these objects.
- \( b_{ki} \): known background level value.
- \( r_k \): relative instrument response taking into account exposure time and efficacy of GALEX system.

We define the model for the UV image as follows:

\[
\mathbb{V}(i) \sim \sum_{k} h_{ki} \mu_i + b_{ki} + r_k.
\]

The expectation-maximization iterative scheme (EM) gives the iterative algorithm:

\[
a_{(m+1)i} = a_{mi} \frac{\sum_{k} h_{ki} \mu_i}{\sum_{k} h_{ki}}, \quad \mu_{(m+1)i} = \frac{\sum_{k} h_{ki} a_{(m+1)i}}{\sum_{k} h_{ki}}.
\]

The step compares the data image \( x_i \) to the projection \( \mu_{(m+1)i} \) of the \( a_{(m+1)i} \) estimates. The result is introduced in the \( m \)-step as the corrective ratio needed for the new set of \( a_{(m+1)i} \) estimates.

Features

- Prior shape:
  - Deblending using SExtractor ellipses to define objects contour. Central symmetry is used to determine the flux assigned to each object blended in one pixel.
  - Deblending of the resolution of the image to that of the GALEX image.
- Astrometry correction:
  - Cross-correlate the positions of the brightest objects (detected with SExtractor) with the brightest objects of the prior catalog and warp with a 2nd order polynomial fitting.
- Image processed by tiles, typically 64x64 margins for PSF convolution.
- Initial fluxes \( a_{i1} \), use i-band value or estimate from the image using a PSF weighted sum:

\[
a_{i} = \sum_{k} h_{ki} \mu_i + b_{ki} + r_k.
\]

- Prior flux constraint from i-band magnitude to avoid faint sources taking the flux of a nearby stronger source, using this relation: \( \log_{10}(a_{i1}) > \log_{10}(F_{i}) + 2 \sigma_{i} \).
- PSF rescaling:
  - The PSF is not deconvolved from the optical (priors) and is averaged over imprecise recentering which causes an artificial enlargement.
  - We find an optimally rescaled PSF using a maximum-likelihood algorithm with a parametrized PSF and fixed fluxes.
- Error estimation from the residual:

\[
\sigma_{\text{res}} = \sqrt{\sum_{k} h_{ki} (x_i - \mu_i)^2}.
\]

Background correction: mask and do the in-painting around objects artifacts in the residual, filter high frequencies and redo \( K \) iterations with this new background.

- Post-processing of the output catalog: flag objects inside GALEX and CHYFS masks, compute statistics on nearest neighbors, compare with GALEX catalog.

Simulations

- Error estimation is done using Monte-Carlo simulations:
  - adding simulated objects to the real image,
  - simulating all the objects, using the number counts from [Xu et al., ApJ. 2005].
- Simulations use astrometry corrections, stamps or an optimal PSF scale value to be consistent with the processing.

Results

- Histogram of magnitudes estimated by EM algorithm and GALEX pipeline (NUV).
- Histogram of magnitudes estimated by EM algorithm and GALEX pipeline (FUV).
- Histogram of estimated mag and the repartition compared to simulated mag, 1032 objects, 63 non detected, 301 flagged.
- Study of the dispersion of estimated mag vs simulated mag.

In development / Prospects

- PSF parametrization.
- Gaussian noise (PSF), application to HERCULES.
- Model selection method for reducing prior number.
- Astrometry improvement with a maximum-likelihood recentering.

References


CeSAM

The “Centre de données UV Astronomiques de Marseille” (CeSAM) from “Laboratoire d’Astrophysique de Marseille” (LAM) has been set up to provide access to quality controlled data via web based applications, tools, pipelines developments and vO compliant applications to astrophysical community. See poster M33 at AGNAS for details.