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PRESENTING DAWIS : DETECTION ALGORITHM WITH WAVELETS FOR INTRA-CLUSTER LIGHT SURVEYS

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Abstract.
We present a new detection code named DAWIS - standing for Detection Algorithm with Wavelets for Intra-cluster light Surveys -, created specially to detect and characterize the optical diffuse light component in galaxy clusters. The code is based on a multi-scale approach of astronomical images, and uses wavelet convolutions to decompose them into several planes, each plane corresponding to a specific spatial scale. The detection is made in those planes, and the objects are then reconstructed using a conjugate gradient algorithm. DAWIS is highly optimized and parallelised in order to be run on large images and to detect intra-cluster light in big surveys. We test the code on simulations of galaxies in order to estimate its efficiency to decorrelate large diffuse sources from bright ones.

Keywords: galaxies, galaxy clusters, photometry

1 Introduction

The Intracluster Light (ICL) is a diffuse component of galaxy clusters or groups, composed of stars that do not belong to any specific galaxy, but that are more generally linked to the global gravitational potential of their cluster/group. While its existence has been known for almost seventy years - the first mention of it was made by Zwicky in 1951 (Zwicky 1951) - the ICL has been a rather forgotten field of research, mainly for instrumental and technical reasons. Indeed, the very low surface brightness of this diffuse component (a few percent of the sky background) makes it easy to be contaminated by various phenomena (scattered light, galactic cirrus, blending into galaxy luminosity profiles), and hard to detect. Here we choose a multi-scale approach to the problem, considering the galaxy cluster optical images as a mix of bright sources (galaxies and foreground Milky Way stars) superposed on diffuse low luminosity sources (ICL). We present a Detection Algorithm with Wavelets for Intra-cluster Surveys (DAWIS) in order to detect and separate such sources, keeping in mind the fact that wavelet based image processing algorithms, while being efficient, are very CPU time consuming. Taking this into account, DAWIS is optimized and parallelised, making it possible to run on large photometric surveys and images. For now, the code is tested on simulations of galaxies.

2 Wavelet transform and noise modeling

DAWIS is based on Mallat's a trous algorithm (Starck et al. 1999). The concept is fairly simple : the original image is smoothed several times using a B-spline kernel. This corresponds to a wavelet transform, with the wavelet planes given by the difference between two additional scales i and i+1. Those wavelet planes form the 3D wavelet space that contains the details of the image.

The noise estimation is done in the 3D wavelet space, at each scale. For gaussian noise, the thresholding is done by comparing the pixel value to the standard deviation of the noise σ_j at the scale j multiplied by a factor k (usually $k = 3$). The value of σ_j depends on the standard deviation of the original image σ, and on the standard deviation at each scale $\sigma_{j,1}$ of a 1σ gaussian distribution when is applied a wavelet transform : $\sigma_j = \sigma_{j,1}.\sigma$. A pixel value larger than $k\sigma$ is considered as significant.

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3 Object detection and reconstruction

Once the statistically significant pixels have been estimated, we create the support of the image : we give them a boolean value of 1, while non-significant ones are given a value of 0. We then segment the support into labelled regions (packs of 1-value pixels surrounded by 0-value pixels). After this, we analyse the interscale connectivity: informations about an object are found in several consecutive wavelet planes, with regions at the same spatial position. We link those regions together before reconstructing the object using an iterative conjugate gradient algorithm (Starck et al. 1999).

4 Validation on simulations

In order to validate DAWIS, we run it on a sample of 900 simulated galaxies, once without noise, and once with a gaussian background noise typical of space-based optical images. The galaxies are created using single Sérsic profiles (Sérsic 1963), with a magnitude range of 18-22, and feature satellite galaxies as faint as magnitude 27. Each galaxy is reconstructed by DAWIS. We then fit Sérsic profiles to the reconstructed images and compare their index to the Sérsic index of the simulations (see Fig. 1). In the case without noise, the reconstruction is consistent with simulations, even if for high Sérsic indexes a bias appears. For the case with noise, some low surface brightness galaxies show a big discrepancy with simulations, and the sample features the same bias around high Sersic indexes.

5 Conclusions

We presented DAWIS, an algorithm using wavelets to detect sources and reconstruct them, and tested it on simulations and some data. The results are promising, beside some bias implied by the reconstruction of objects. The real challenge is now to apply it to ICL detection. Such diffuse sources need a pre-DAWIS processing in order to be detected : exquisite estimation of the PSF of the instrument, deep enough data to reach high magnitudes, high quality flat-fielding, etc. We plan on running DAWIS on the data of the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS) that has been processed by J-C.Cuillandre's Elixir-LSB pipeline, which is a pipeline created specifically to conserve low surface brightness features. We also plan on applying it to the Hubble Space Telescope Frontier Field clusters, in order to compare our results to other previous works on ICL (Montes & Trujillo 2018),(DeMaio et al. 2018).

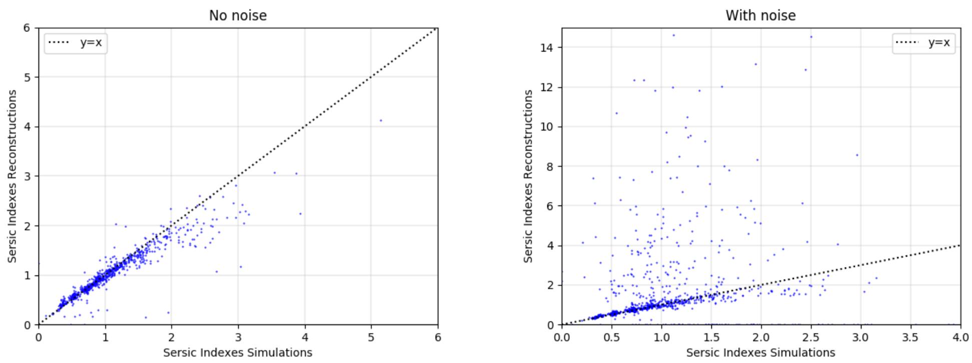

Fig. 1. Left: Reconstruction of simulated galaxies without noise. **Right:** Reconstruction of simulated galaxies with noise.

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