

# Weak Lensing Data Analysis : Mask interpolation using Inpainting

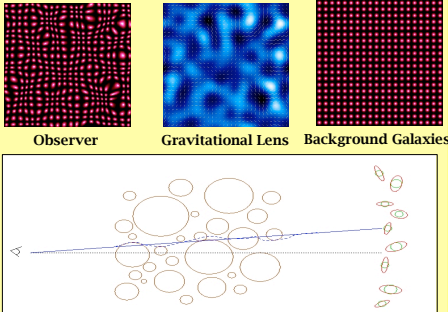
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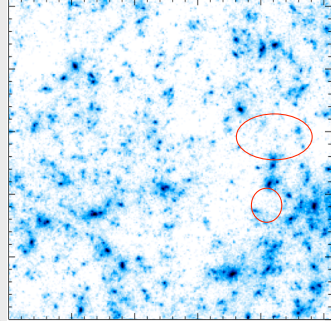
With increasingly large data sets, weak lensing measurements are able to measure cosmological parameters with great precision.

But the analysis of weak lensing data requires to account for missing data such as masking out of bright stars.

## Weak gravitational lensing



## Simulated weak lensing mass map



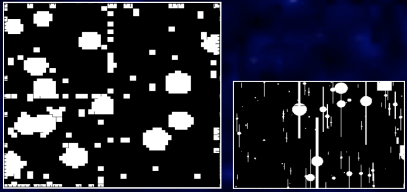
## WEAK GRAVITATIONAL LENSING

Weak gravitational lensing provides a unique method to map directly the distribution of dark matter in the Universe. According to General Relativity, matter deflects the trajectory of the light beam. This deflection changes the size and the shape of the observed galaxies. The mass that causes this distortion is called gravitational lens.

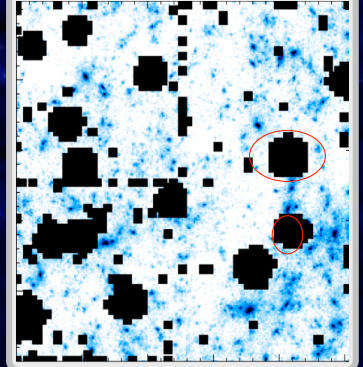
By measuring these distortions (or shear), we can map the distribution of mass in the Universe but we need to account for missing data. The mask for saturated stars is applied to the shear field and we want to reconstruct the dark matter mass map from the incomplete shear field.

Missing data in weak lensing data can be due to camera CCD defect or from bright stars in the field of view that saturate the image.

Two different mask patterns :  
CFHTLS survey of  $1^\circ \times 1^\circ$  (left)  
SUBARU of  $0.575^\circ \times 0.426^\circ$  (right)



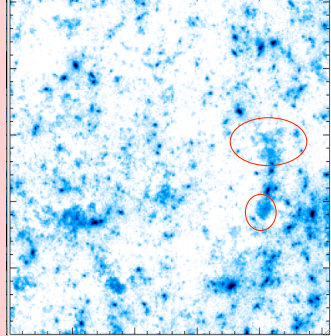
## Map derived from masked shear maps



## INPAINTING

Image inpainting also termed image interpolation consists in restoring an image from a masked subregion of the image. Recently, considerable interest has been generated for the digital inpainting problem. Elad (2005) introduced a new inpainting approach relying on sparse representation of both texture and smooth image contents. This algorithm is a direct extension of MCA (Morphological Component Analysis) (Starck 2005) that allows the separation of features contained in an image when these features present different morphological aspects. Representing the image to be inpainted in an appropriate sparse dictionary is the main issue. Integrating the mass inversion problem, we found that the sparsest representation for weak lensing data is obtained with a local DCT.

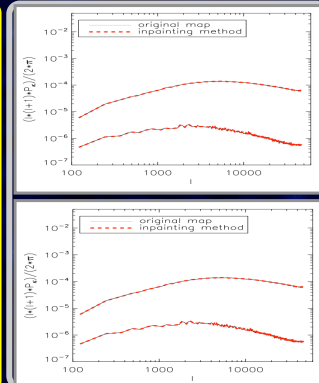
## Inpainted mass maps



## STANDARD WEAK LENSING ANALYSIS

❖ **Two-point statistics** to constrain Gaussian signal that is to say large scales: Two-point correlation function (too long to be estimated) and power spectrum (biased by mask).

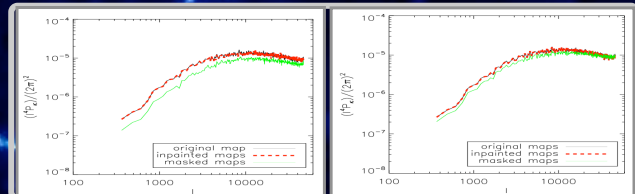
❖ **Three-point statistics** to constrain Non-Gaussian structures that is to say small scales: Three-point correlation function (too long to be estimated) and bispectrum (biased by mask).



Upper panel, result for CFHTLS mask.: Two-upper curves (almost superposed) correspond to the mean power spectrum computed from complete mass maps (black-continuous line) and from inpainted masked maps (red-dashed line) and the two lower curves are the corresponding standard deviation. Lower panel, results for Subaru mask.

## CONCLUSIONS

We have addressed the problem of statistic analysis of Weak Lensing data in the case of incomplete shear field. We propose an algorithm that solves both the problem of mass inversion and of missing data. It relies strongly on the ideas of sparsity of the signal in a given basis. We have shown that our inpainting method enables to use the power spectrum and higher-order statistics in future large weak lensing surveys by filling in the gaps in weak lensing mass maps. Our inpainting method enables to reach an accuracy on the power spectrum of about 1% with the CFHTLS mask and about 0.3% with Subaru mask and an accuracy on the bispectrum of about 3% with the CFHTLS mask and about 1% with Subaru mask.



Left, result for CFHTLS and right, for Subaru mask: The two curves almost superposed correspond to the mean bispectrum computed from complete mass maps (black-continuous line) and from inpainted masked maps (red-dashed line) and the lower from incomplete mass maps.

- References : [1] Pires, S., Starck, J.-L., Amara, A., Teyssier, R., Réfrégier, A., Fadili, J., FASTLens : Fast method for Weak Lensing Statistics and map making, to be submitted in A&A  
[2] Elad, M., Starck, J.-L., Donoho, D., Querre, P., Simultaneous Cartoon and Texture Image Inpainting using Morphological Component Analysis (MCA), ACHA, Vol. 9, p.340-358, 2005  
[3] Starck, J.-L., Elad, M., Donoho, D., Image Decomposition Via The Combination of Sparse Representations and Variational Approach, IEEE T. Im. Proc., Vol.10, p.1570-1582, 2005  
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[5] Massey, R., Rhodes, J., Ellis, R., ..., Pires, S., Réfrégier, A., ..., Starck, J.-L., Dark matter maps reveal cosmic scaffolding, Nature, Vol.445, p.286-290, 2007