Shapelet analysis of weak lensing surveys

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with
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Shapelets

Refregier 2003, Refregier & Bacon 2003, Massey & Refregier 2005

Complete orthogonal basis functions
Capture all shape information of an object
Simple and analytic form for convolution and shear
Adapted to cosmic shear

\[ f(r, \theta) = \sum_{n=0}^{\infty} \sum_{m=-n}^{n} f_{n,m} \chi_{n,m}(r, \theta; \beta) \]
\[ f_{n,m} = \int_{\mathbb{R}} \int_{\theta} f(r, \theta) \chi_{n,m}(r, \theta; \beta) r \, dr \, d\theta. \]
Shapelets decomposition pipeline

Least-square fitting of an analytical model (pixellised and convolved with the PSF) to observed data.

Galaxy to be fitted

Shapelet model of the PSF

Shapelet model of the observed galaxy

Residuals

Convolution in shapelets space

Shapelet model of the galaxy, deconvolved from the PSF
Shapelets decomposition pipeline

Least-square fitting of an analytical model (pixellised and convolved with the PSF) to observed data.

Galaxy to be fitted

Shapelet model of the observed galaxy

Residuals

Shear estimator
PSF model

- Stars selected then decomposed into shapelets, the order of decomposition depending on data.
PSF spatial variations

- Polynomial interpolation of each shapelet coefficients of stars

- Possibility to characterize spatial variations of PSF shape information

Coefficients $f_{nm}$

Flux

$$F \equiv \int_{\mathbb{R}} \int f(x) d^2x = (4\pi)^{1/2} \beta \sum_{n} f_{n0}^{\text{even}}$$

Size

$$R^2 = \frac{(16\pi)^{1/2} \beta^3}{F} \sum_{n} (n + 1) f_{n0}^{\text{even}}$$

Ellipticity, order by order

$$\varepsilon = \frac{F_{11} - F_{22} + 2iF_{12}}{F_{11} + F_{22}} = \sum_{n} \varepsilon_n^{\text{even}}$$

$$\varepsilon_n = \frac{(16\pi)^{1/2} \beta^3}{FR^2} [n(n+2)]^{1/2} f_{n2}^{\text{even}}$$
Shapelet coefficients

Shapelet measure

Polynomial model

Residuals
Size

$R^2 = \frac{(16\pi)^{1/2} \beta^3}{F} \sum_{n}^{\text{even}} (n + 1) f_{n0}$

Shapelet measure

Polynomial model

20% variation of the size across the image
Ellipticity $n=2$

$$\epsilon_n = \frac{(16\pi)^{1/2} \beta^3}{FR^2} [n(n+2)]^{1/2} f_{n2}$$

Shapelet measure

Polynomial model

Residuals

$<e_1> = 0.00848$

$<e_2> = -0.00237$

$<e_1> = 0.00078$

$<e_2> = -8.3 \times 10^{-5}$
Ellipticity $n=6$

\[ \varepsilon_n = \frac{(16\pi)^{1/2}\beta^3}{FR^2} \left[ n(n+2) \right]^{1/2} f_{n2} \]

**Shapelet measure**

<table>
<thead>
<tr>
<th>$e_1$</th>
<th>$e_2$</th>
<th>$e_3$</th>
<th>$e_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0197</td>
<td>0.0014</td>
<td>0.0011</td>
<td>-0.0192</td>
</tr>
</tbody>
</table>

**Polynomial model**

**Residuals**

$\langle e_1 \rangle = 0.0197$

$\langle e_2 \rangle = -0.0192$

$\langle e_3 \rangle = 0.0014$

$\langle e_4 \rangle = -0.0011$
Ellipticity $n=18$

\[ \epsilon_n = \frac{(16\pi)^{1/2} \beta^3}{FR^2} \left[ n(n+2) \right]^{1/2} f_{n2} \]

Shapelet measure

Polynomial model

Residuals

$\langle e_1 \rangle = 0.00728$

$\langle e_2 \rangle = -0.00151$

$\langle e_1 \rangle = 0.00097$

$\langle e_2 \rangle = 0.00019$
CFHTLS/Megacam data : maps

Shapelets

Luminosity map
(courtesy Chiara Marmo)
CFHTLS/Megacam data: maps

X-ray map (courtesy Florian Pacaud)

Shapelets

“Luminosity” (courtesy C. Marmo)

XMM-LSS clusters, Pacaud et al. 2006
CFHTLS/Megacam data: maps

Shapelets

KSB (Gavazzi & Soucail 2006)

XMMLSS clusters, Pacaud et al 2006

“Luminosity” (courtesy C. Marmo)

KSB (Gavazzi & Soucail 2006)
Conclusions

- Full model of the PSF on CFHTLS D1 field
- Mass map on CFHTLS D1 field
- Comparison with XMMLSS-detected X-ray clusters: some common clusters, even if some detections remain untrustworthy
- In progress: comparison with two independent KSB techniques
- In progress: analysis of CFHTLS W1 field

Software package and documentation

http://www.astro.caltech.edu/~rjm/shapelets/
http://www.astro.caltech.edu/~jberge/shapelets/