05-06 March, 2020

PPGFis, UFES
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Gradient Pattern Analysis:

Applications in Astrophysics & Cosmology

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FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO

1999

International Journal of Modern Physics C, Vol. 10, No. 1 (1999) 147–163

CHARACTERIZATION OF ASYMMETRIC FRAGMENTATION PATTERNS IN SPATIALLY EXTENDED SYSTEMS

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2018

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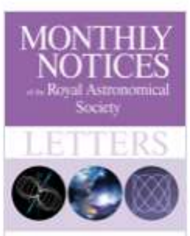

Volume 477, Issue 1
June 2018

Gradient pattern analysis applied to galaxy morphology

R R Rosa, R R de Carvalho, R A Sautter, P H Barchi, D H Stalder, T C Moura, S B Rembold, D R F Morell, N C Ferreira

Monthly Notices of the Royal Astronomical Society: Letters, Volume 477, Issue 1, 11 June 2018, Pages L101–L105, https://doi.org/10.1093/mnrasl/sly054

Published: 04 April 2018 **Article history** ▾

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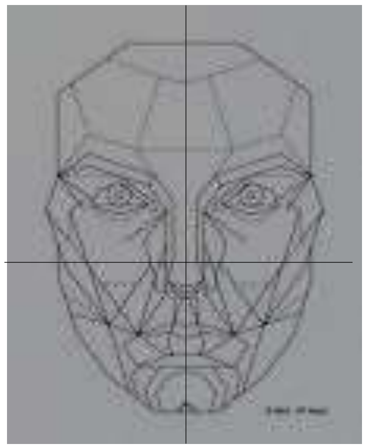
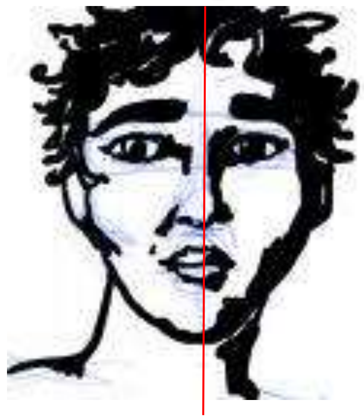
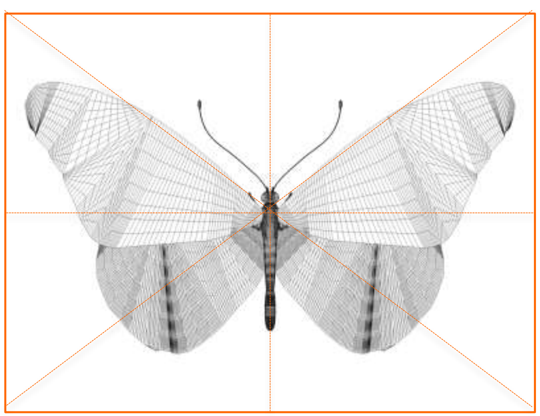
Bilateral Asymmetry Patterns:

Where do I find asymmetry patterns?

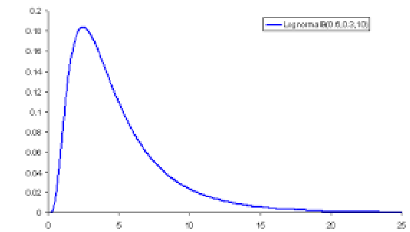


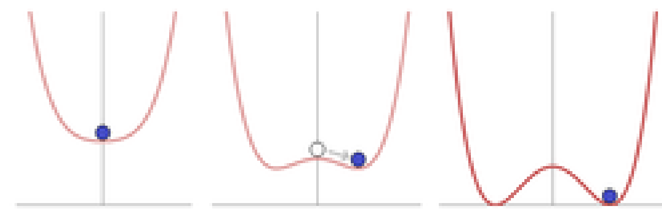


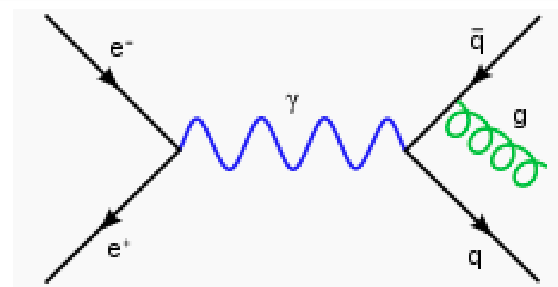


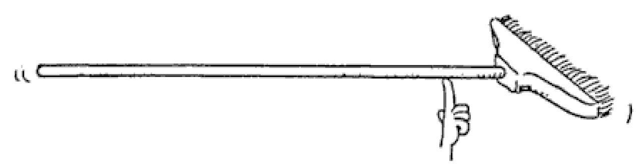
$$\forall a, b \in X : aRb \rightarrow \neg(bRa).$$

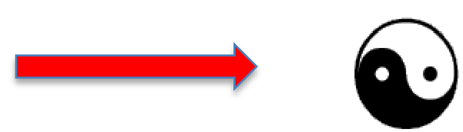
$$(x - x_1)/a \neq (y - y_1)/b$$





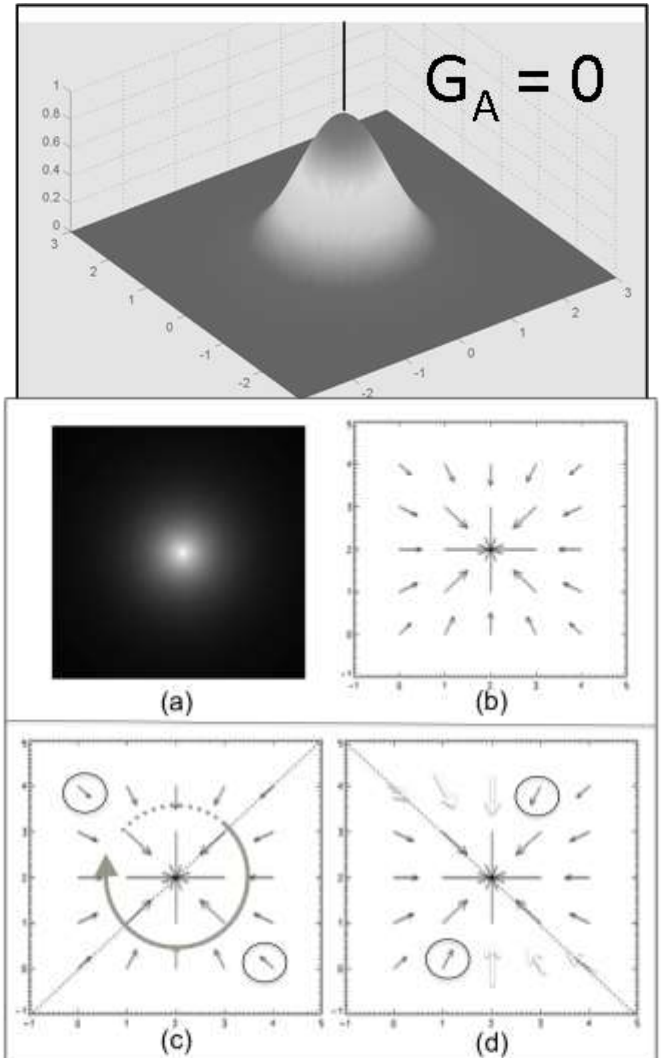


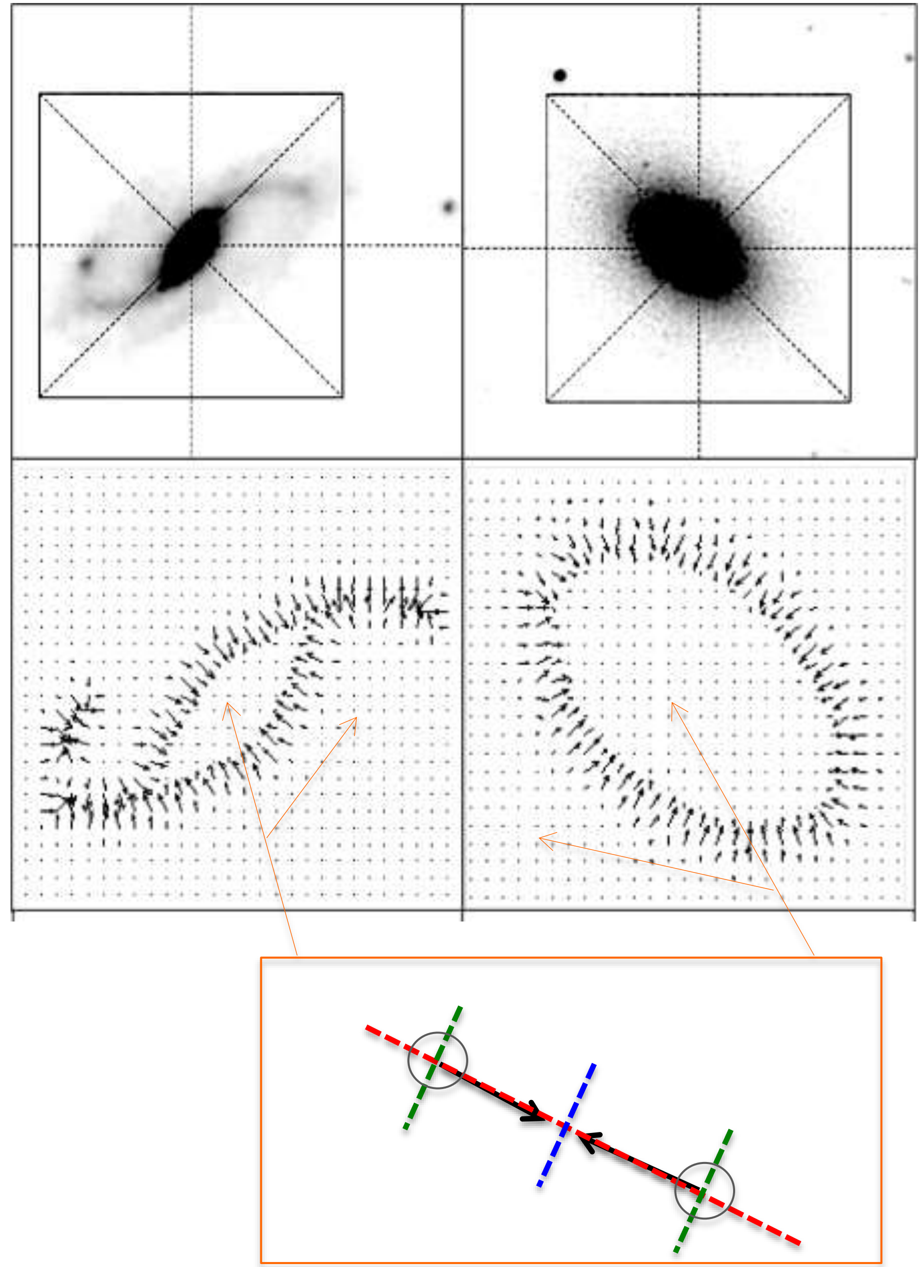


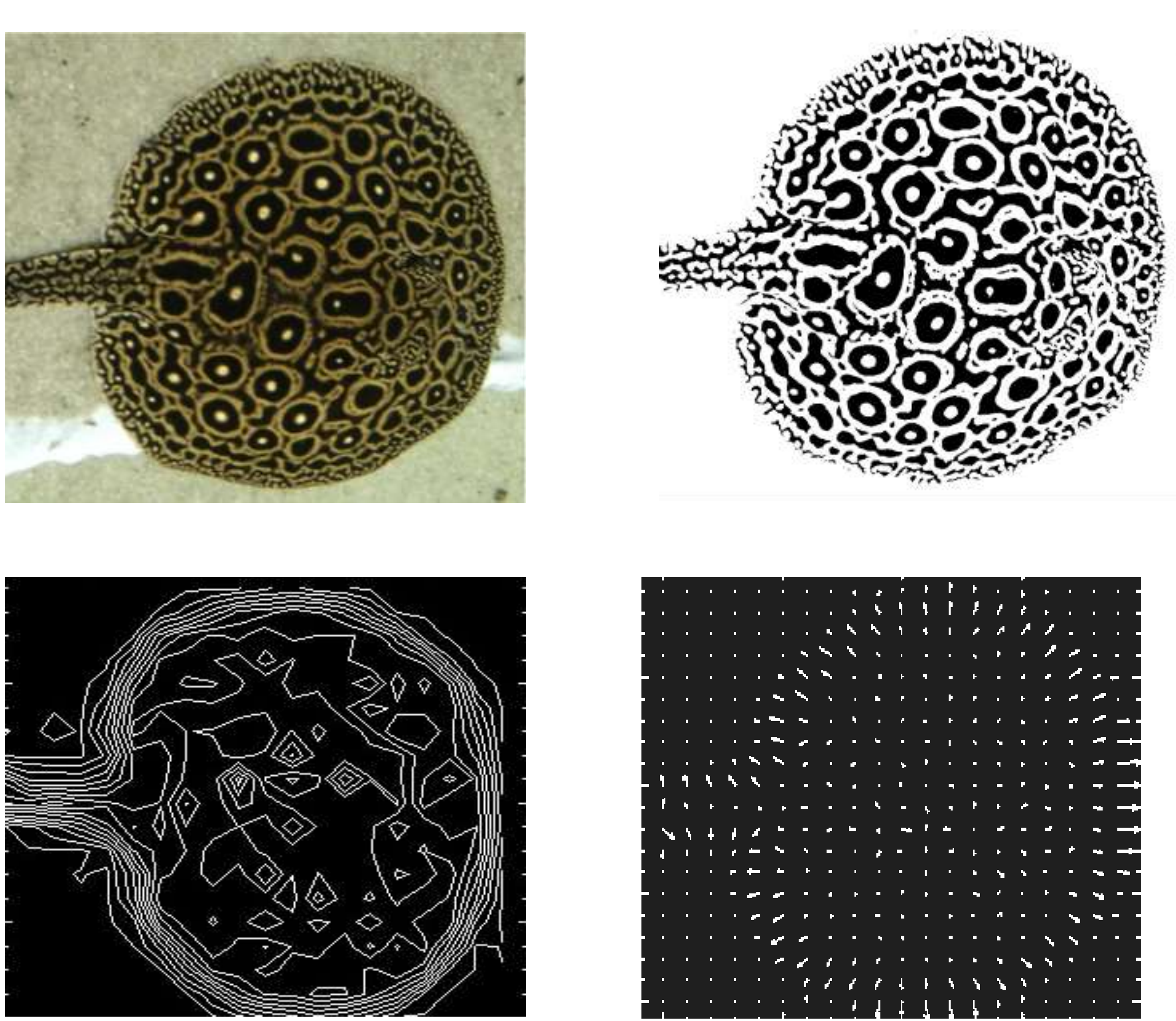


Gradient Pattern Analysis (GPA

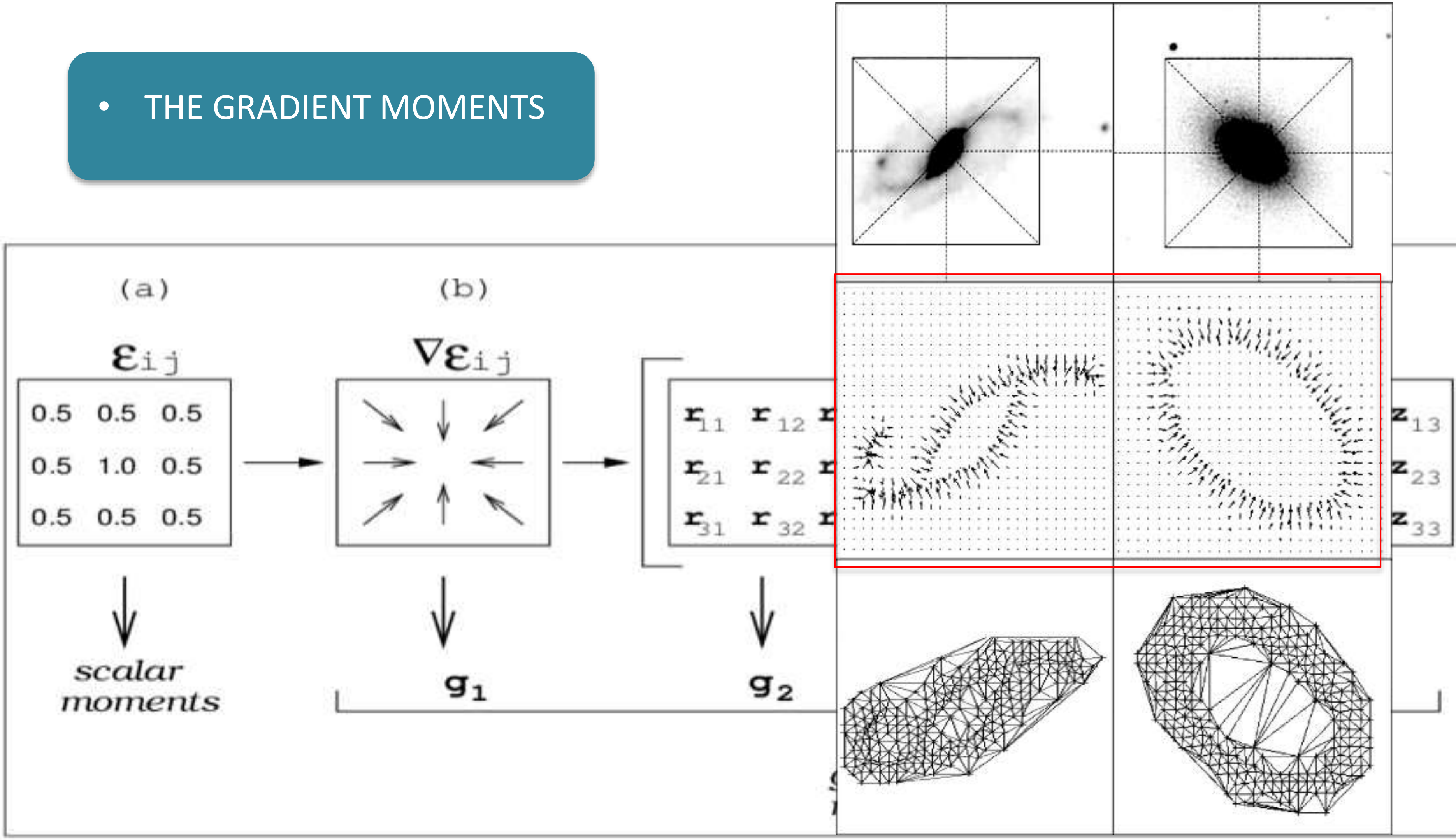
Starting from
Canonical Symmetric Patterns







- THE GRADIENT MOMENTS

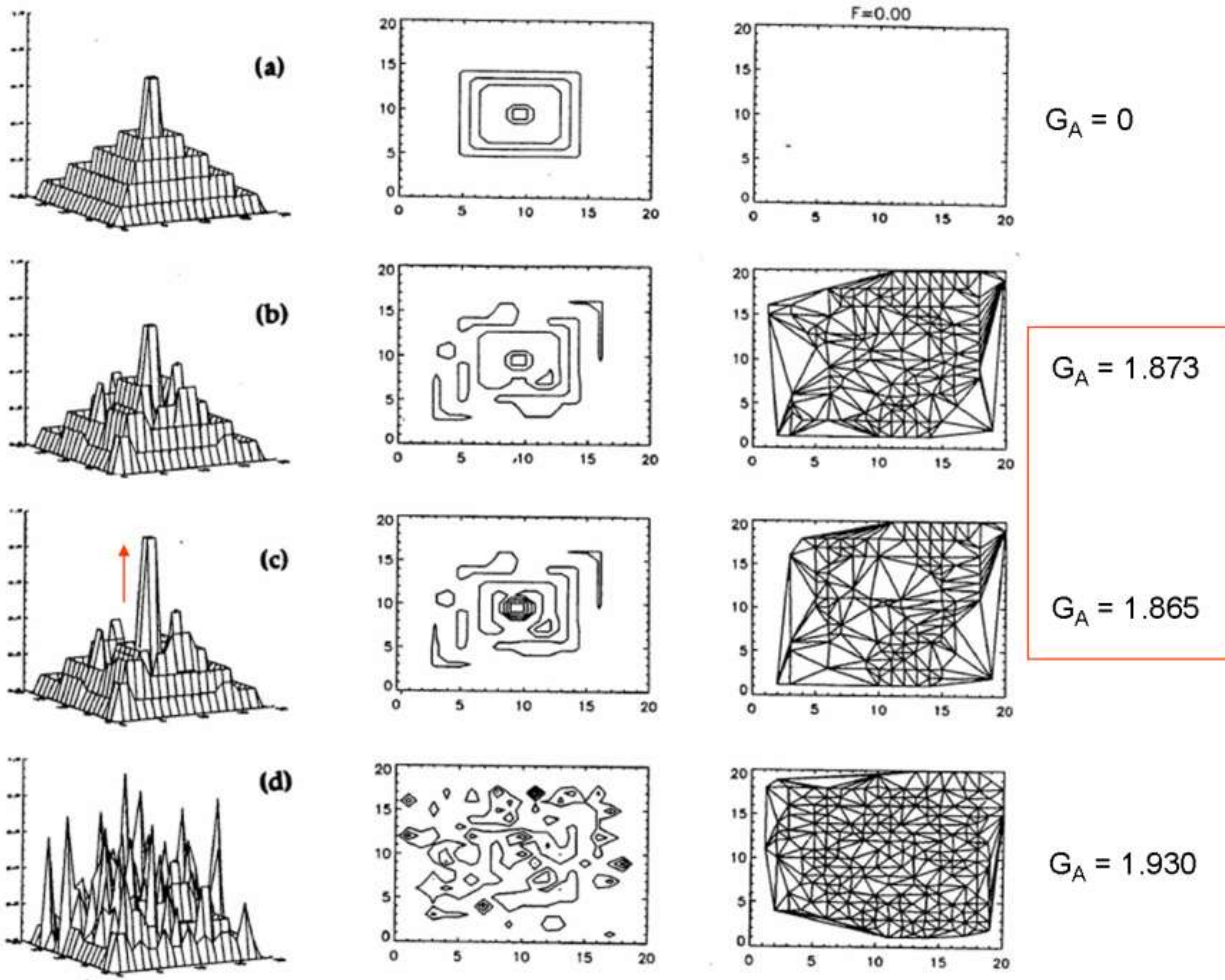


$$G_1 = \frac{T_A - V_A}{V_A}$$

$$G_2 = \frac{V_A}{N}\left(2 - \frac{\left|\sum_i^{V_A} r_i\right|}{\sum_i^{V_A} |r_i|}\right)$$

$$G_3 = \frac{V_A}{N}\left(2 - \frac{\left|\sum_i^{V_A} \varphi_i\right|}{\sum_i^{V_A} |\varphi_i|}\right)$$

$$G_4 = H = -\sum_{i,j} \frac{\varphi_i}{r_i} \ln\left(\frac{\varphi_i}{r_i}\right)$$



(a)
(b)
(c)
(d)
F=0.00
G_A = 0
G_A = 1.873
G_A = 1.865
G_A = 1.930

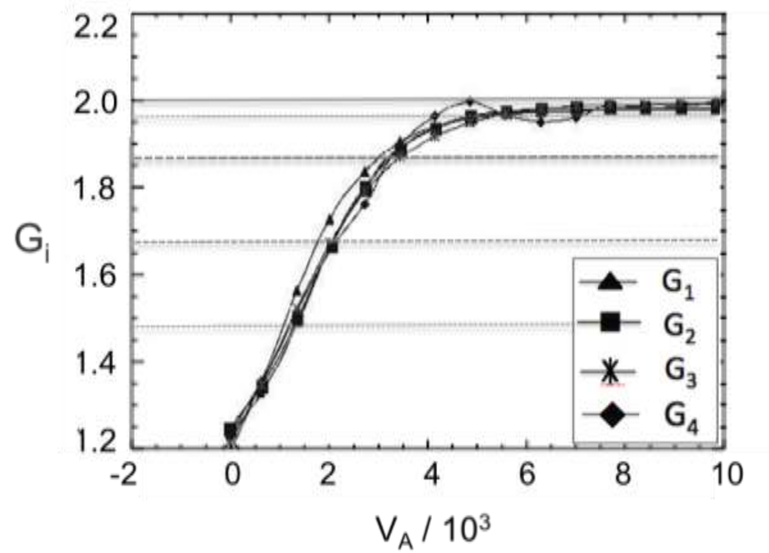
NxN	$\langle V_A \rangle$	$\langle T_A \rangle$	$\langle G_1 \rangle$	σ
3×3	9	18	1.2200	0.2200
5×5	25	65	1.6500	0.1700
10×10	100	285	1.8600	0.0120
20×20	400	1186	1.9575	0.0076
30×30	900	2685	1.9833	0.0031
40×40	1600	4781	1.9881	0.0016
64×64	4096	12269	1.9954	0.0009
80×80	6400	19199	1.9968	0.0003
100×100	10000	29975	1.9974	0.0002
128×128	16384	49140	1.9992	0.0001

$$G_1 = \frac{T_A - V_A}{V_A}$$

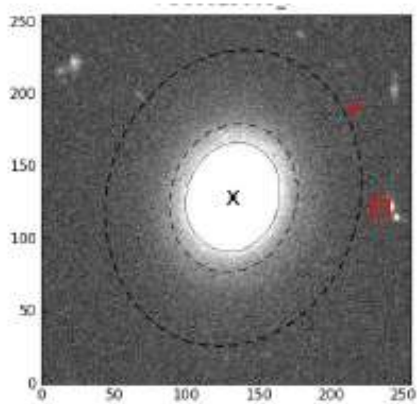
$$G_2 = \frac{V_A}{N}\left(2 - \frac{\left|\sum_i^{V_A} v_i\right|}{\sum_i^{V_A} |v_i|}\right)$$

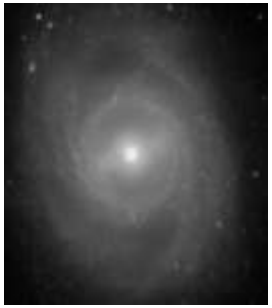
$$G_3 = \frac{V_A}{N}\left(2 - \frac{\left|\sum_i^{V_A} \varphi_i\right|}{\sum_i^{V_A} |\varphi_i|}\right)$$

$$G_4 = H = -\sum_{i,j} \frac{\varphi_i}{r_i} \ln\left(\frac{\varphi_i}{r_i}\right)$$

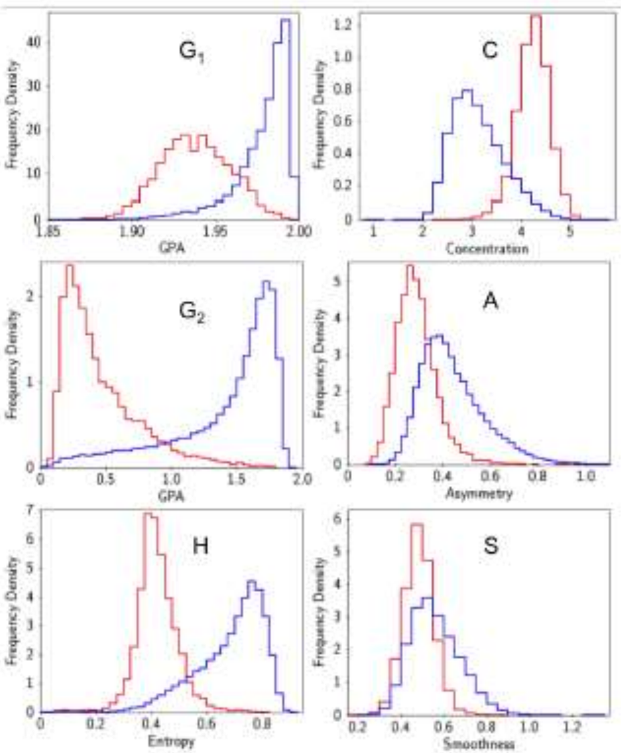


Background → Segmentation → Resampling → star masking → stamp → analysis





- Color and Magnitudes
- Sersic Parameters
- CAS + H + GPA
- Geometrical Moments
- Luminosity Profile

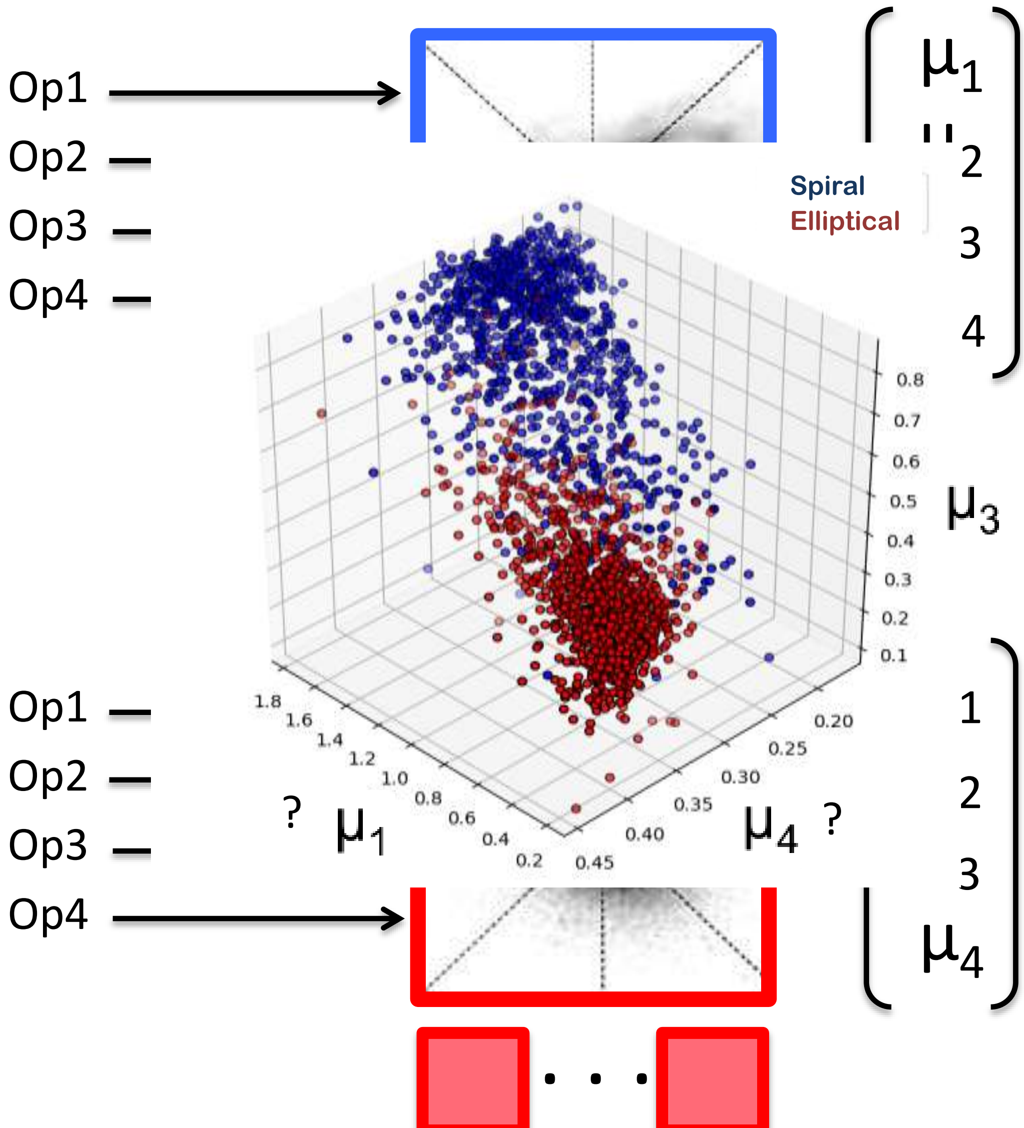


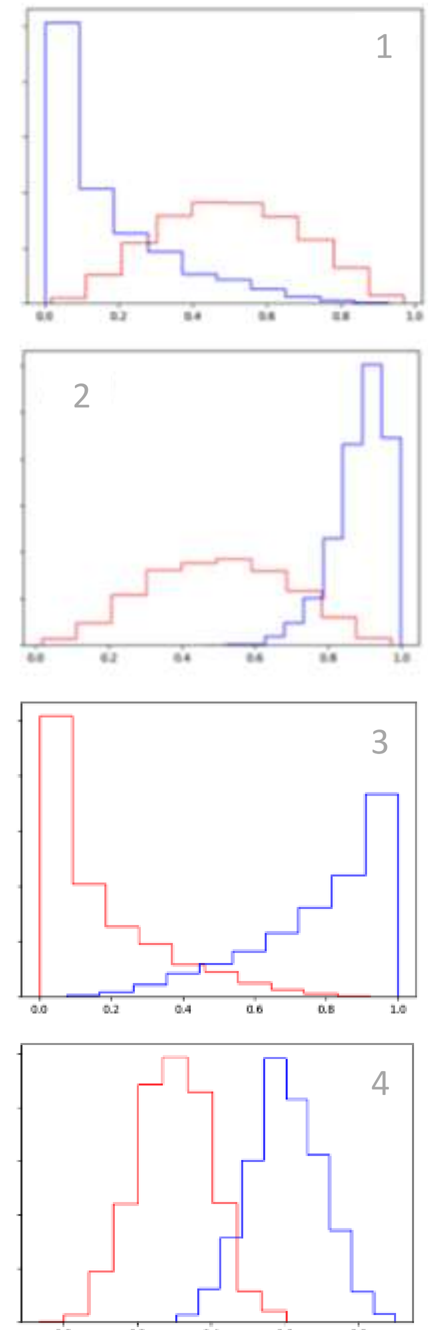
Gradient Pattern Analysis Applied to Galaxy Morphology
R.R.Rosa et al. MNRASL, 2018.
https://doi.org/10.1093/mnrasl/sly054

Parameter	$\delta_{GHS}(\%)$	$\langle t \rangle$ **(s)**	$P(s^{-1})$
GPA ($\mathbf{G_2}$)	90.4	**1.840**	49.1
Entropy (H)	86.9	2.035	42.7
GPA ($\mathbf{G_1}$)	82.3	**1.915**	42.9
Concentration (C)	78.9	2.262	34.9
Asymmetry (A)	49.6	1.854	26.8
Smoothness (S)	42.7	1.852	23.1

• Discriminant Analysis from Big Data

Tao Li, Shenghuo Zhu, and Mitsunori Ogihara. Using Discriminant Analysis for Multi-Class Classification: An Experimental Investigation. Knowledge and Information Systems 10, no. 4 (2006): 45372.)





Astronomy and Computing

Volume 30, January 2020, 100334

Full length article

Machine and Deep Learning applied to galaxy morphology - A comparative study

P.H. Barchi [a, b], R.R. de Carvalho [c, d], R.R. Rosa [a], R.A. Sautter [a], M. Soares-Santos [b], B.A.D. Marques [e], E. Clua [e], T.S. Gonçalves [f], C. de Sá-Freitas [f], T.C. Moura [g]

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https://doi.org/10.1016/j.ascom.2019.100334

• Why Gx Morph is so important?

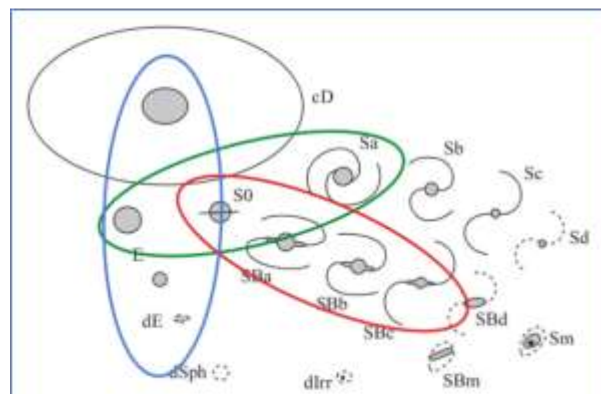
From large surveys we need to know more about ...

Hierarchical Merging? Dark halo?
Gas Infall? Isothermal spheres?
Nongaussianity?

- Galaxy formation mechanisms
- Galaxy evolutionary paths
- Galaxy morphology at different environments
- Galaxies dynamics $f(\mathbf{r}, \mathbf{v}, t)$
- Galaxy and Universe evolution
- spheroid $\times$ disc dispute over z
- Elliptical galaxies

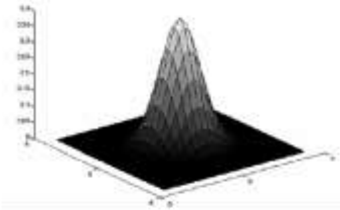
Physical size x redshift
Angular size x redshift
Age x redshift
Morphology x redshift

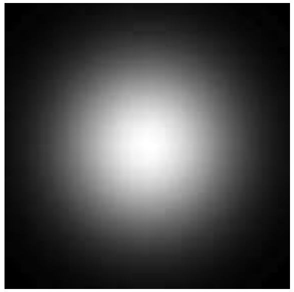
- Hubble time
- Dynamical time
- Cooling time
- Star formation time (rate)
- Merging time
- Dynamical friction time

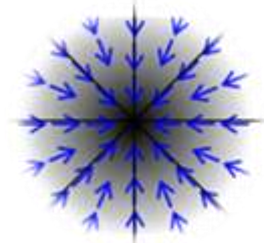


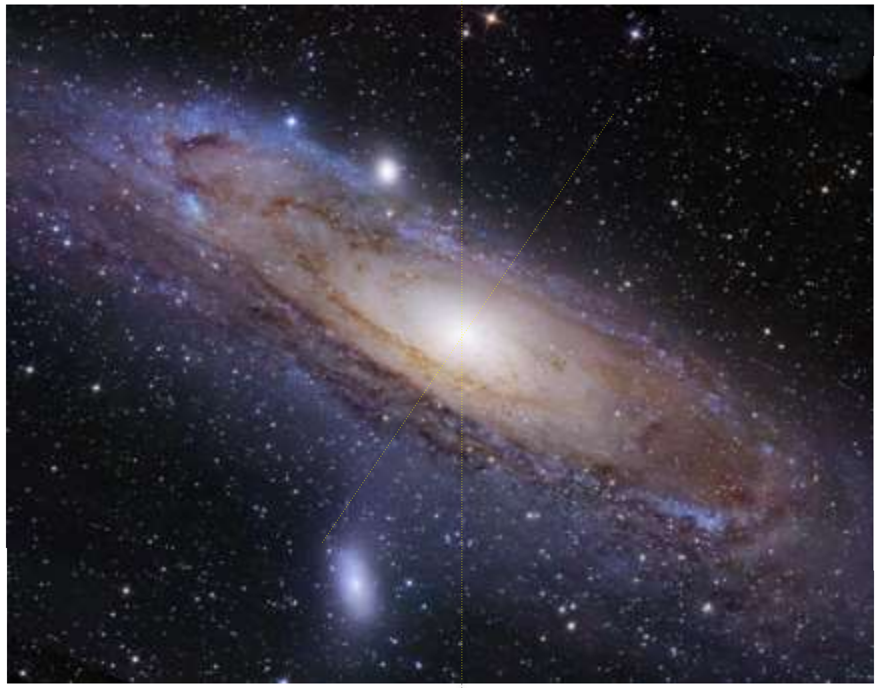
adapted from Sparke & Gallagher 2007

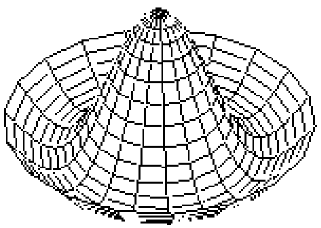
$$k_{2D}(\vec{x}) = \frac{1}{2\pi\sigma^2}\exp(-\frac{\vec{x}\cdot\vec{x}}{2\sigma^2})$$

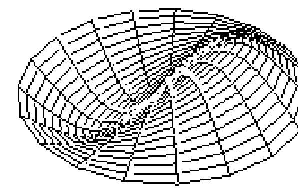


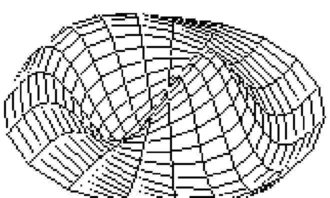


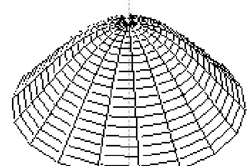


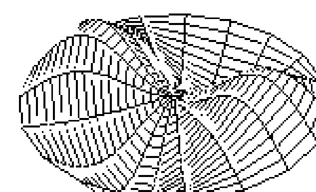












COSMOLOGY

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Physica D 223 (2006) 139–145
PHYSICA D
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Gradient pattern analysis of cosmic structure formation: Norm and phase statistics

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Received 9 December 2005; received in revised form 9 August 2006; accepted 16 August 2006

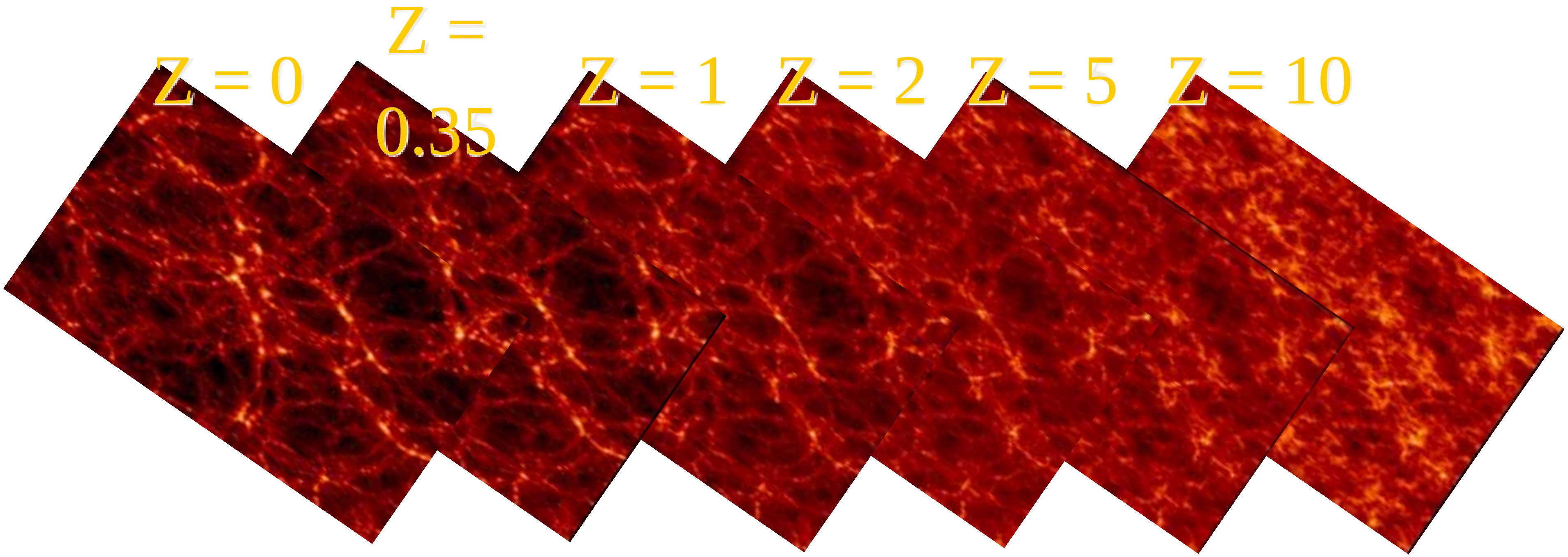
Communicated by C.K.R.T. Jones

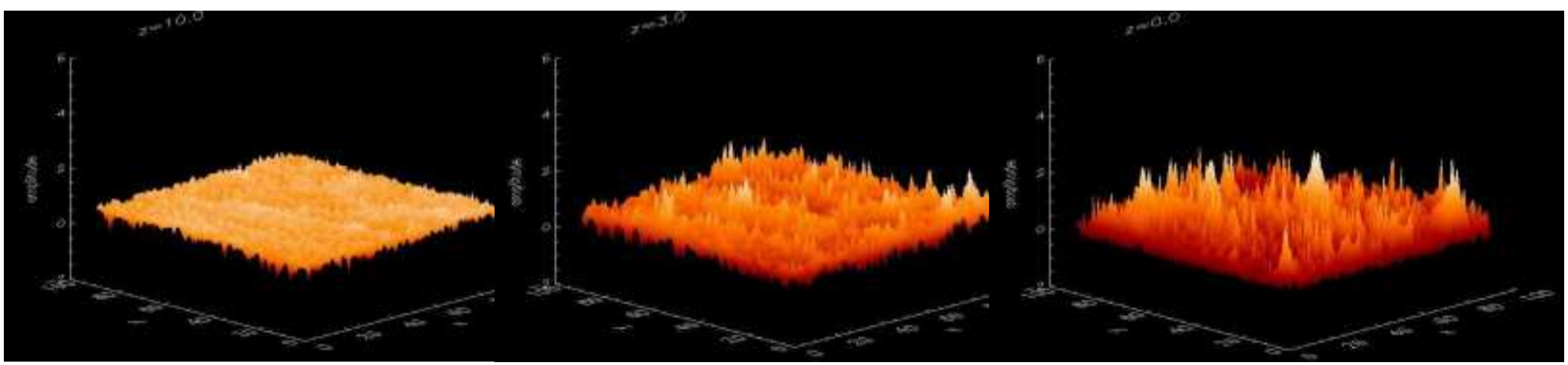
Abstract

This paper presents the preliminary results of the characterization of pattern evolution in the process of cosmic structure formation. We are applying to N-body cosmological simulations data the technique proposed by Rosa et al. [R.R. Rosa, A.S. Sharma, J.A. Valdivia, Int. J. Modern Phys. C 10 (1999) 147] and Ramos et al. [F.M. Ramos, et al., Physica A 283 (2000) 171] to estimate the time behaviour of asymmetries in the gradient field. The gradient pattern analysis is a well tested tool, used to build asymmetrical fragmentation parameters estimated over a gradient field of an image matrix able to quantify a complexity measure of nonlinear extended systems. In this investigation we work with the high resolution cosmological data simulated by the Virgo consortium, in different time steps, in order to obtain a diagnostic of the spatio-temporal disorder in the matter density field. We perform the calculations of the gradient vectors statistics, such as mean, variance, skewness, kurtosis, and correlations on the gradient field. Our main goal is to determine different dynamic regimes through the analysis of complex patterns arising from the evolutionary process of structure formation. The results show that the gradient pattern technique, specially the statistical analysis of second and third gradient moment, may represent a very useful tool to describe the matter clustering in the Universe.

Keywords: Pattern formation; Gradient moments; Cosmic structure formation

GRADIENT PATTERN ANALISYS IN STRUCTURE FORMATION





Gradient Asymmetry

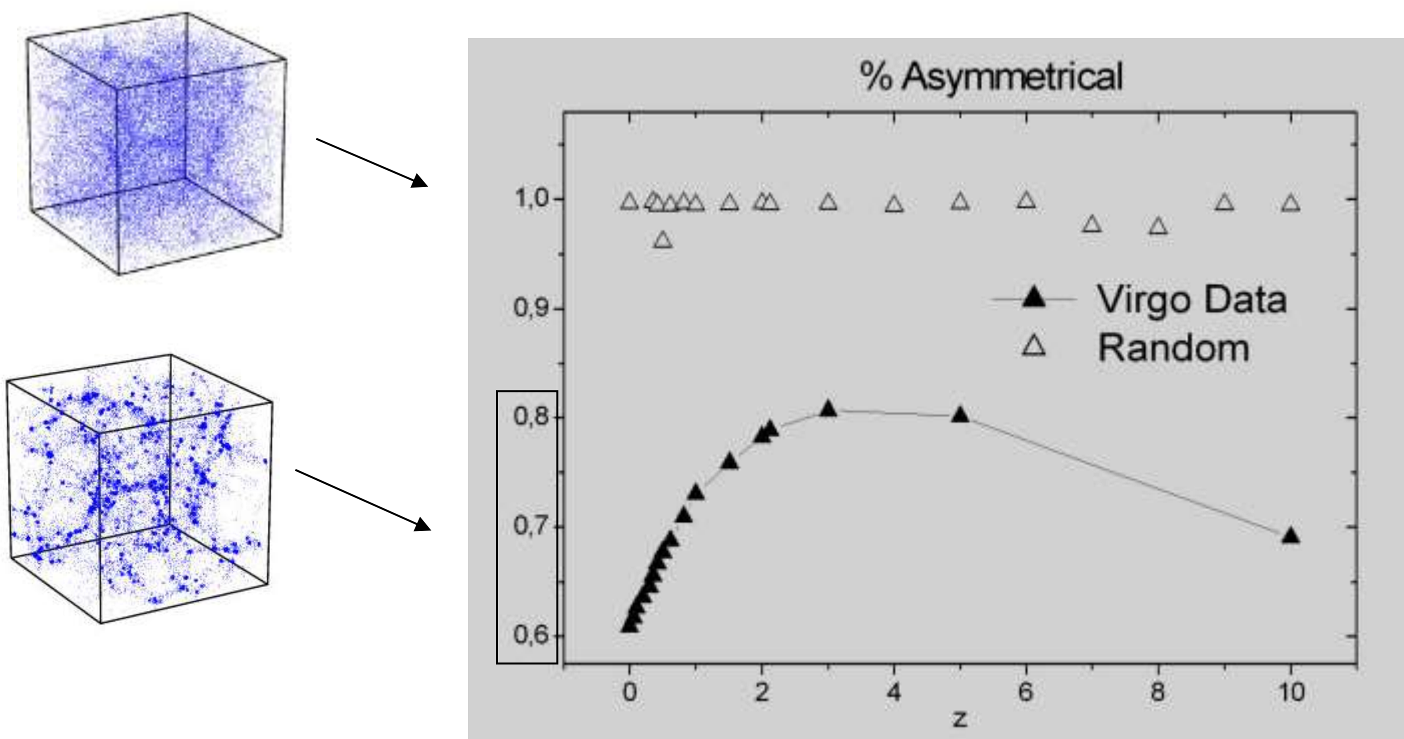
Andrade, Ribeiro, Rosa, Physica D 223(2006)139-145

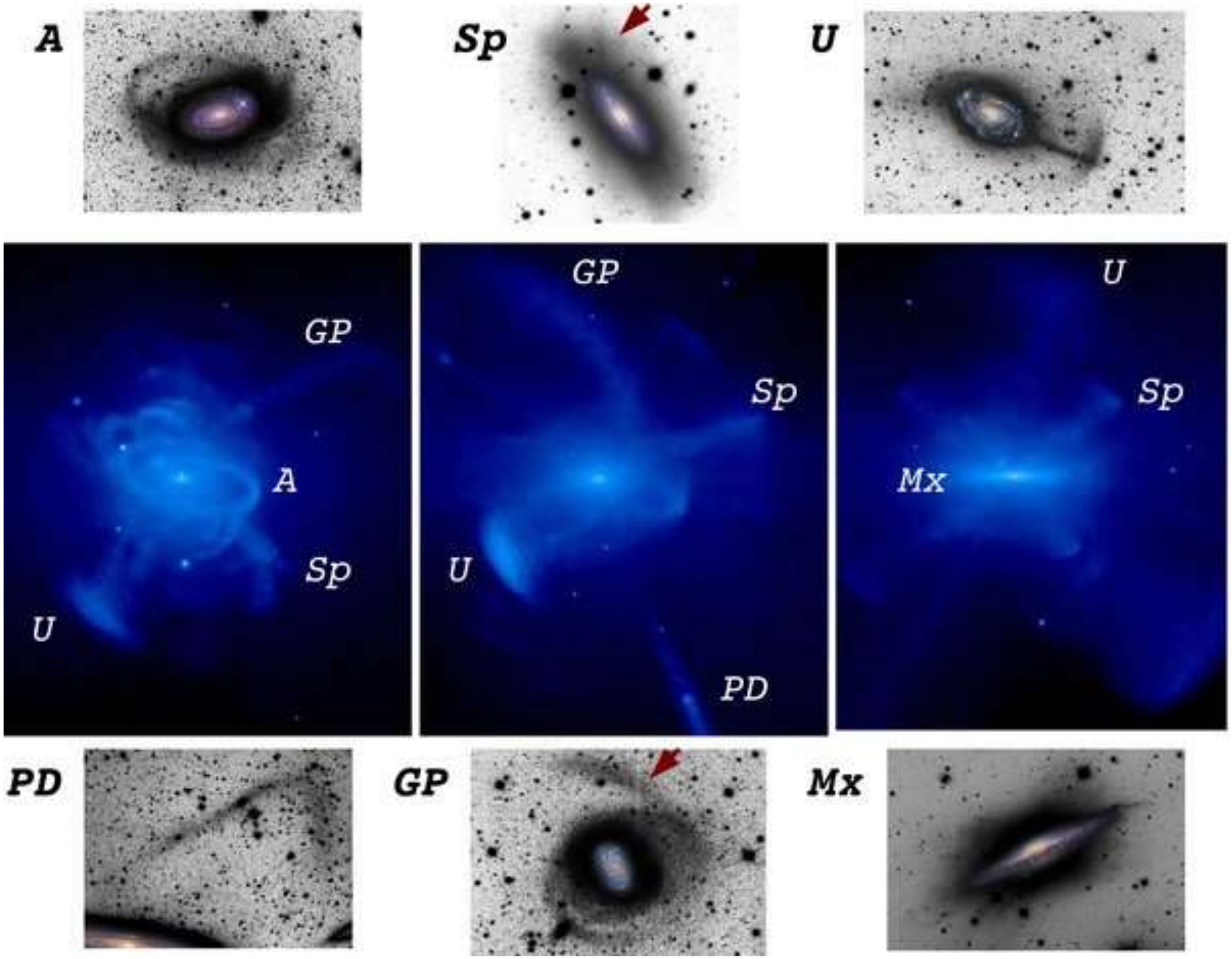
Rosa & Zaniboni, Nonlinear Analysis (in press)

Random Patterns: > 90%

Typical range for Turbulence Patterns: 60-85%

Quasi-Symmetric Patterns: 1-40%





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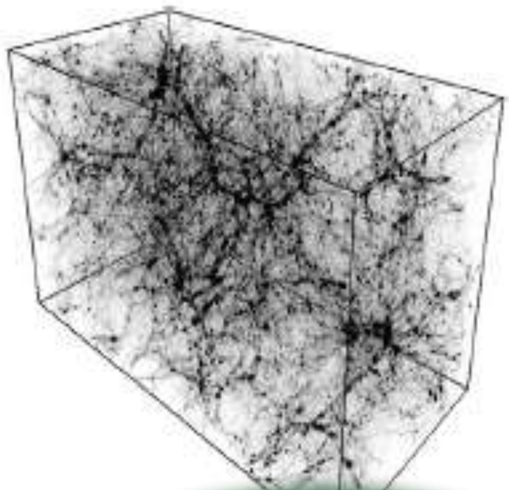


Fig. 1. A snapshot … Virgo consortium da… …r particles).

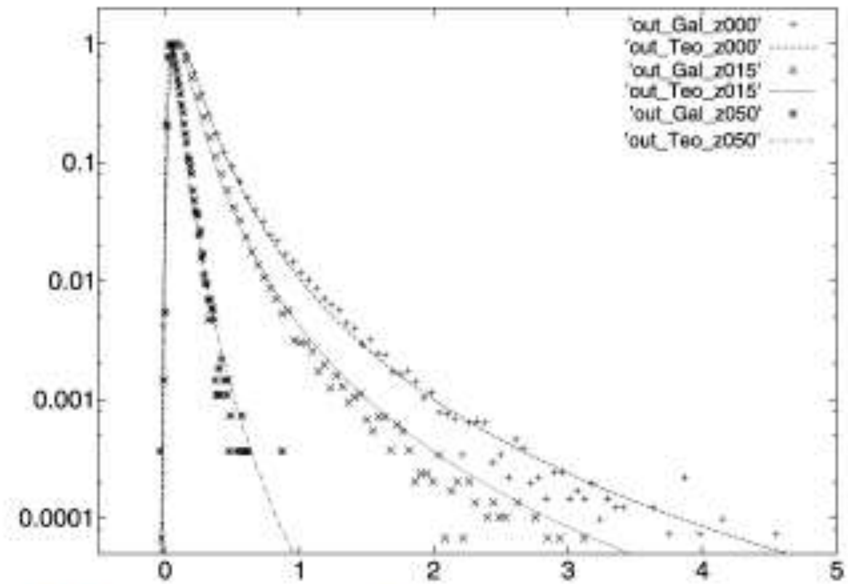
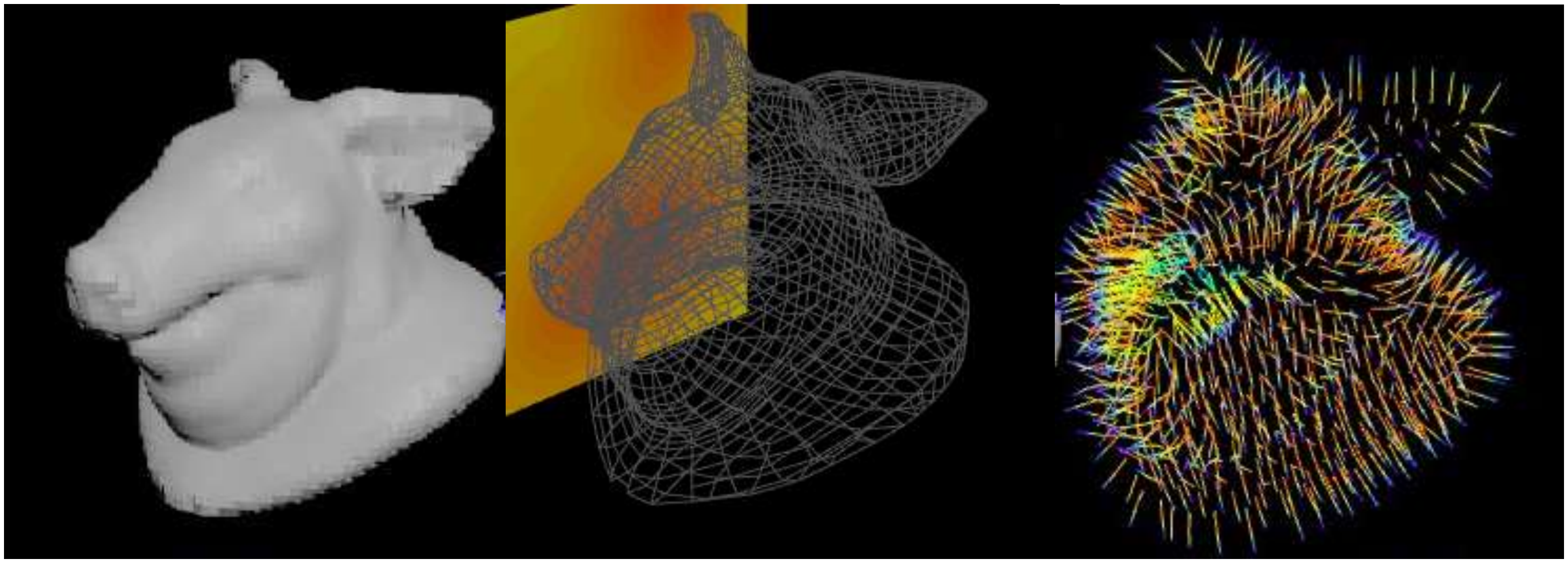
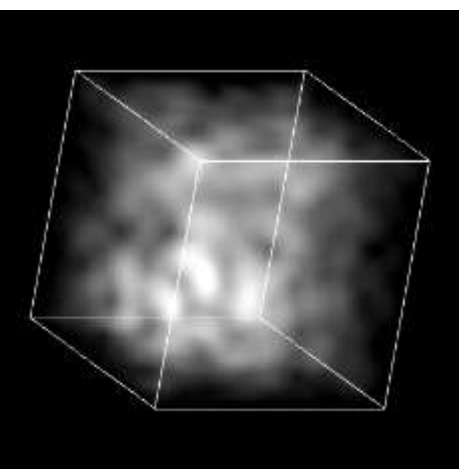


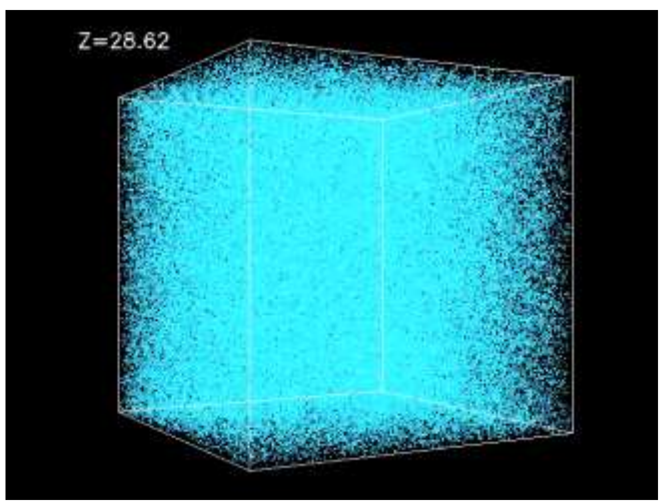
Fig. 2. Empirical and theoretical (GEV model) rescaled energy histograms, for redshifts z = 0, 1.5 and 5.0.

Concluding Remarks

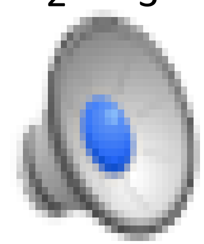
GPA
Theory & Applications
Santiago, 2018



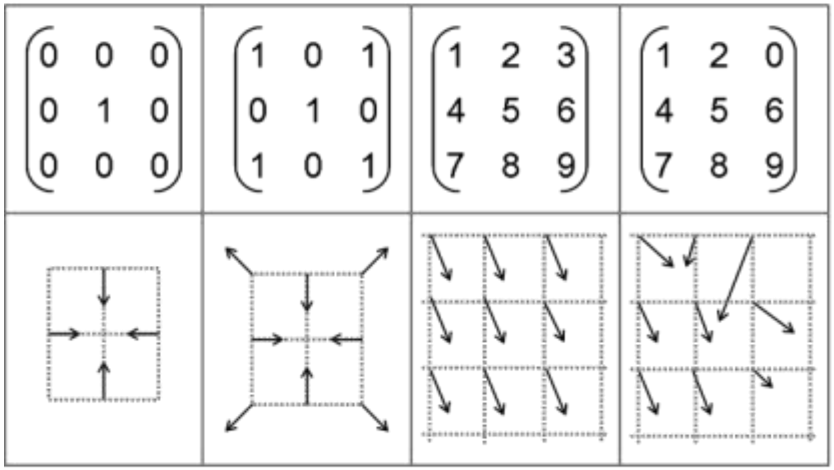


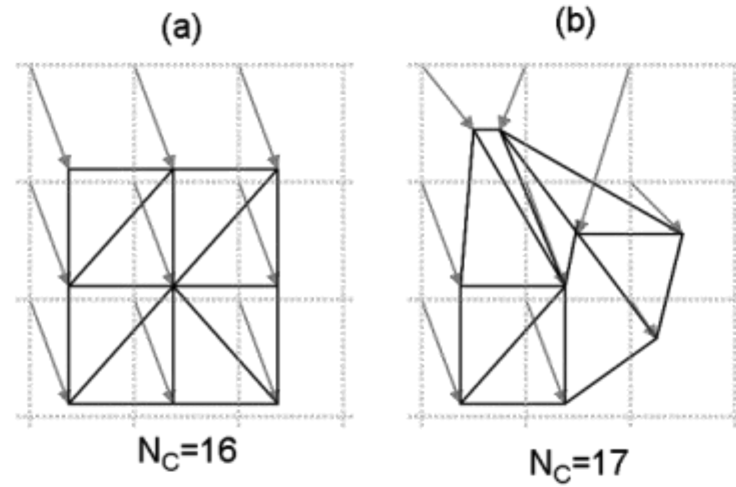


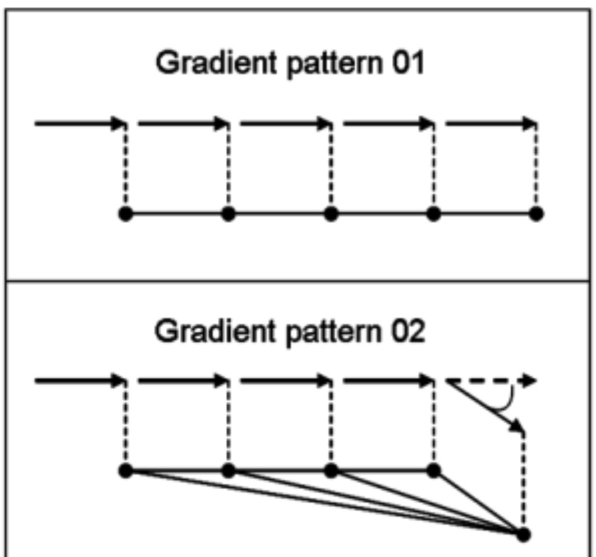
$\{G_1, G_2, G_3, G_4\}$



Rosa, R.R.; Sharma, A.S.and Valdivia, J.A. *Int. J. Mod. Phys. C*, **10**, 147 (1999), doi:10.1142/S0129183199000103.





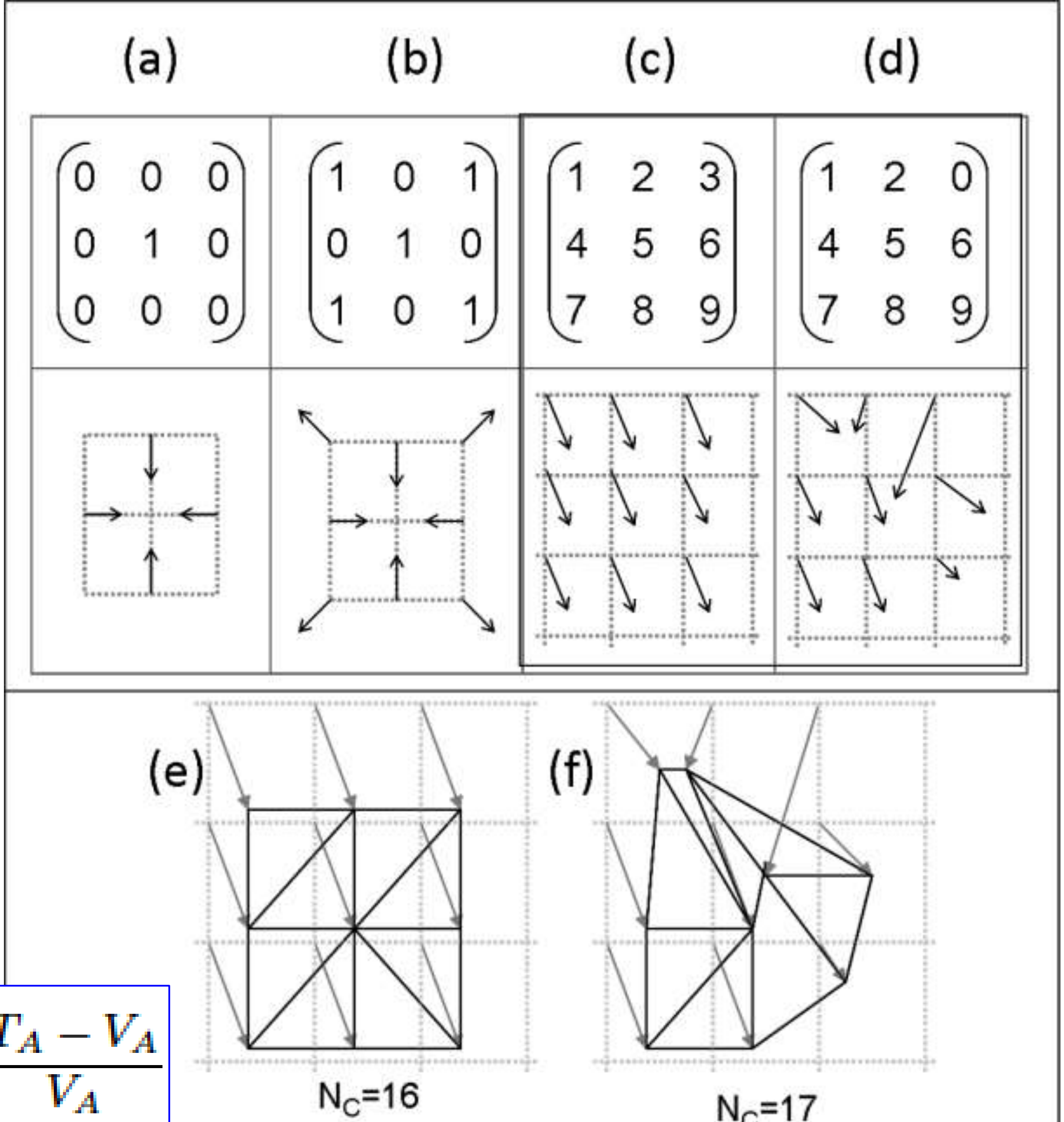


Gradient Asymmetry Coefficient

$$G_1 = \frac{T_A - V_A}{V_A}$$

$$G_A = [\, N_C - N_V \,] \,/\, N_V$$

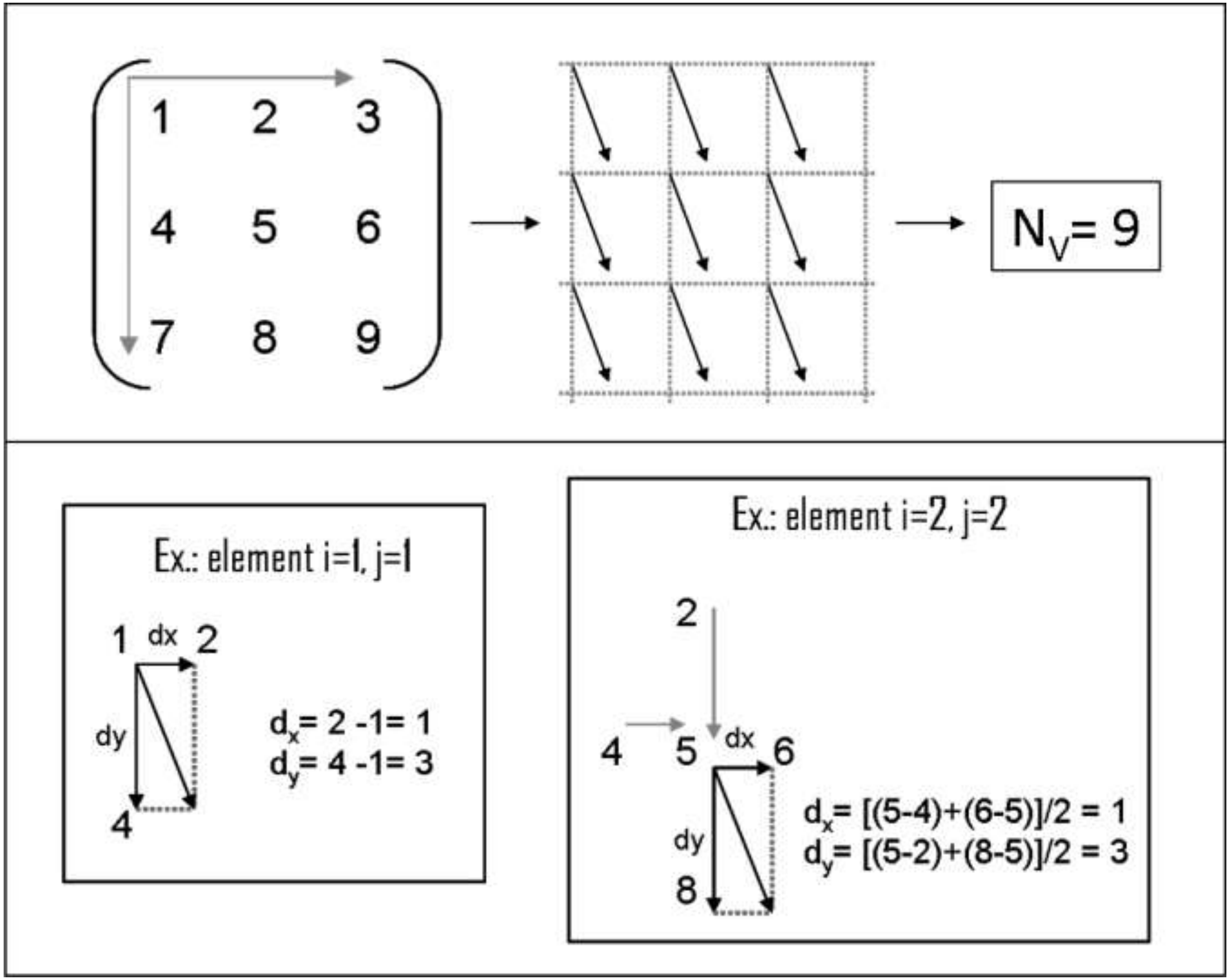
http://en.wikipedia.org/wiki/Gradient_pattern_analysis



$$G_1 = \frac{T_A - V_A}{V_A}$$

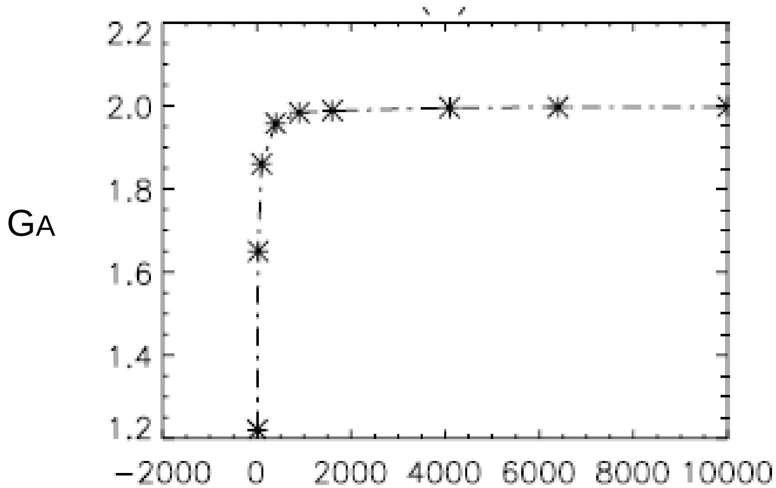
(16-9)/9=0.778 =0.78

(17-9)/9=0.889 =0.89



1 2 3
4 5 6
7 8 9
N_V= 9
Ex.: element i=1, j=1
1 dx 2
dy
4
d_x= 2 -1= 1
d_y= 4 -1= 3
Ex.: element i=2, j=2
2
4 5 dx 6
dy
8
d_x= [(5-4)+(6-5)]/2 = 1
d_y= [(5-2)+(8-5)]/2 = 3

International Journal of Modern Physics C, Vol. 10, No. 1 (1999) 147–163



' ASYMMETRIC FRAGMENTATION
IALLY EXTENDED SYSTEMS

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$I = T_A$
$L = V_A$

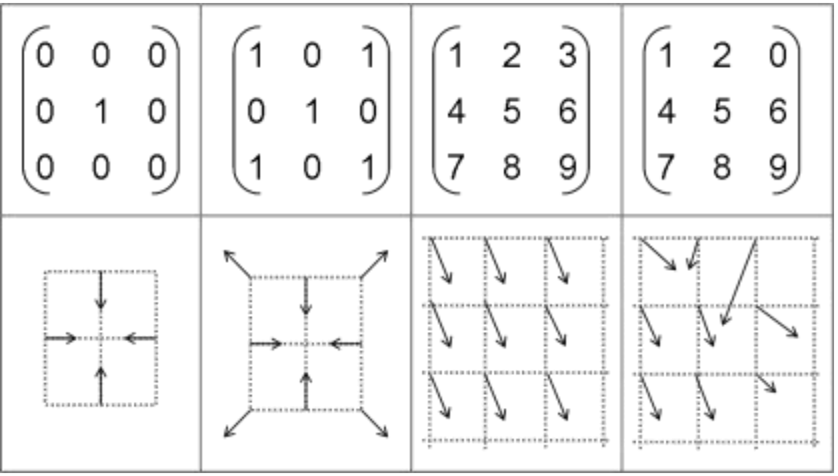
$$\boxed{G_1 = \frac{T_A - V_A}{V_A}}$$

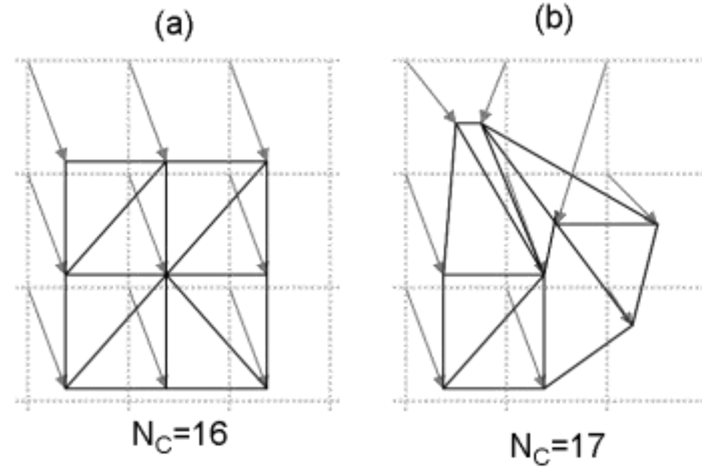
In this case, the difference $(I - L)$ will increase with L as follows:

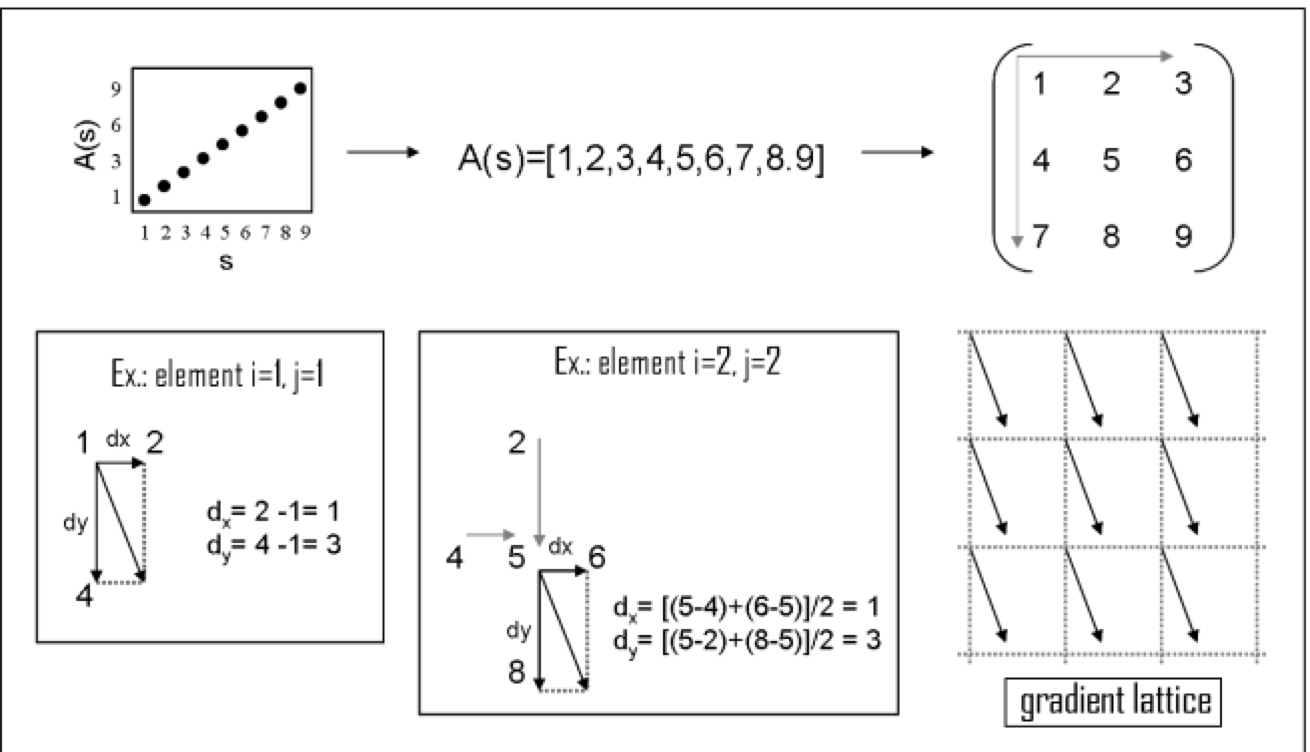
$$\lim_{L\to\infty} (I - L) \simeq 2L. \tag{1}$$

Therefore, given a $n \times n$ size matrix, for which $L \approx n^2$, the $(I - L)/L$ ratio for a big n, tends to 2. This asymptotic regime implies a very high accuracy of the value $(I - L)/L$ to compare different matrices of the same size for $L > 100$.

Gradient Pattern Analysis



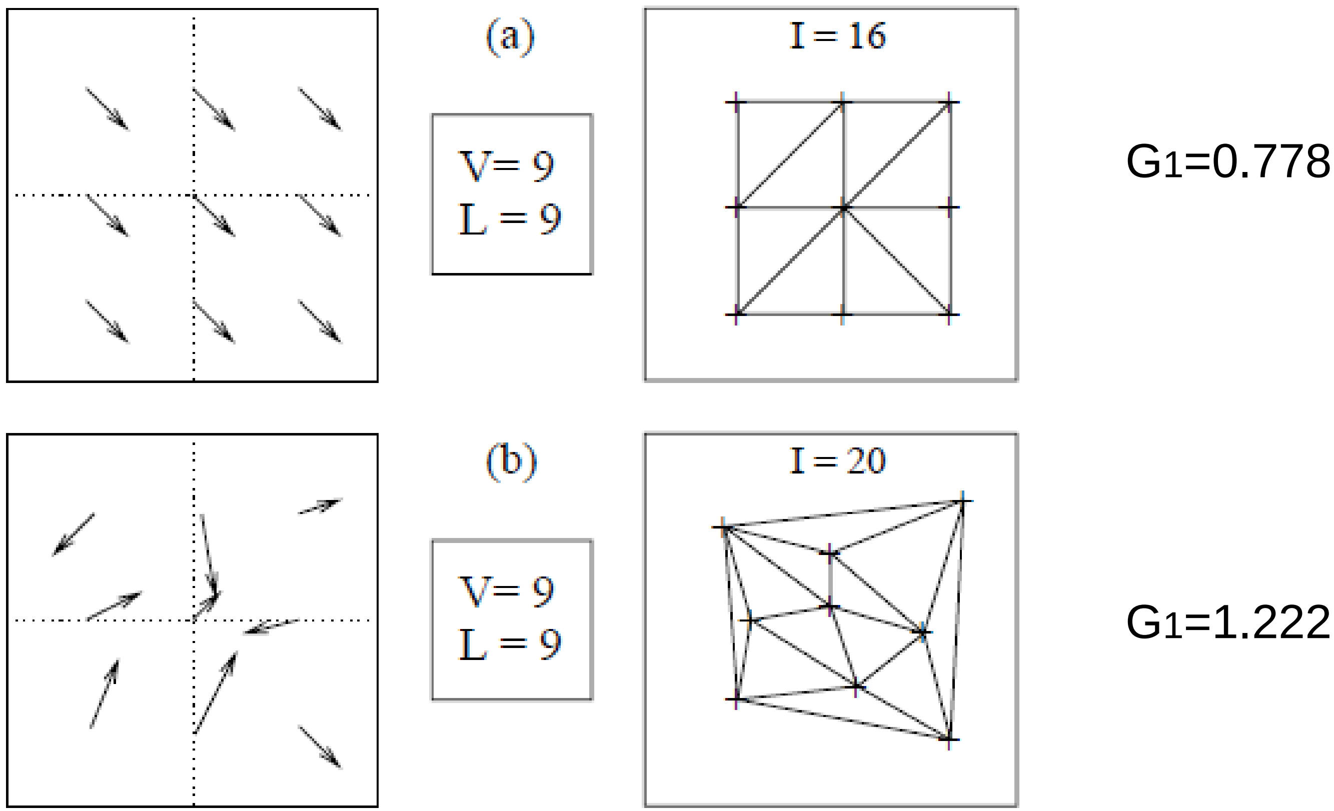


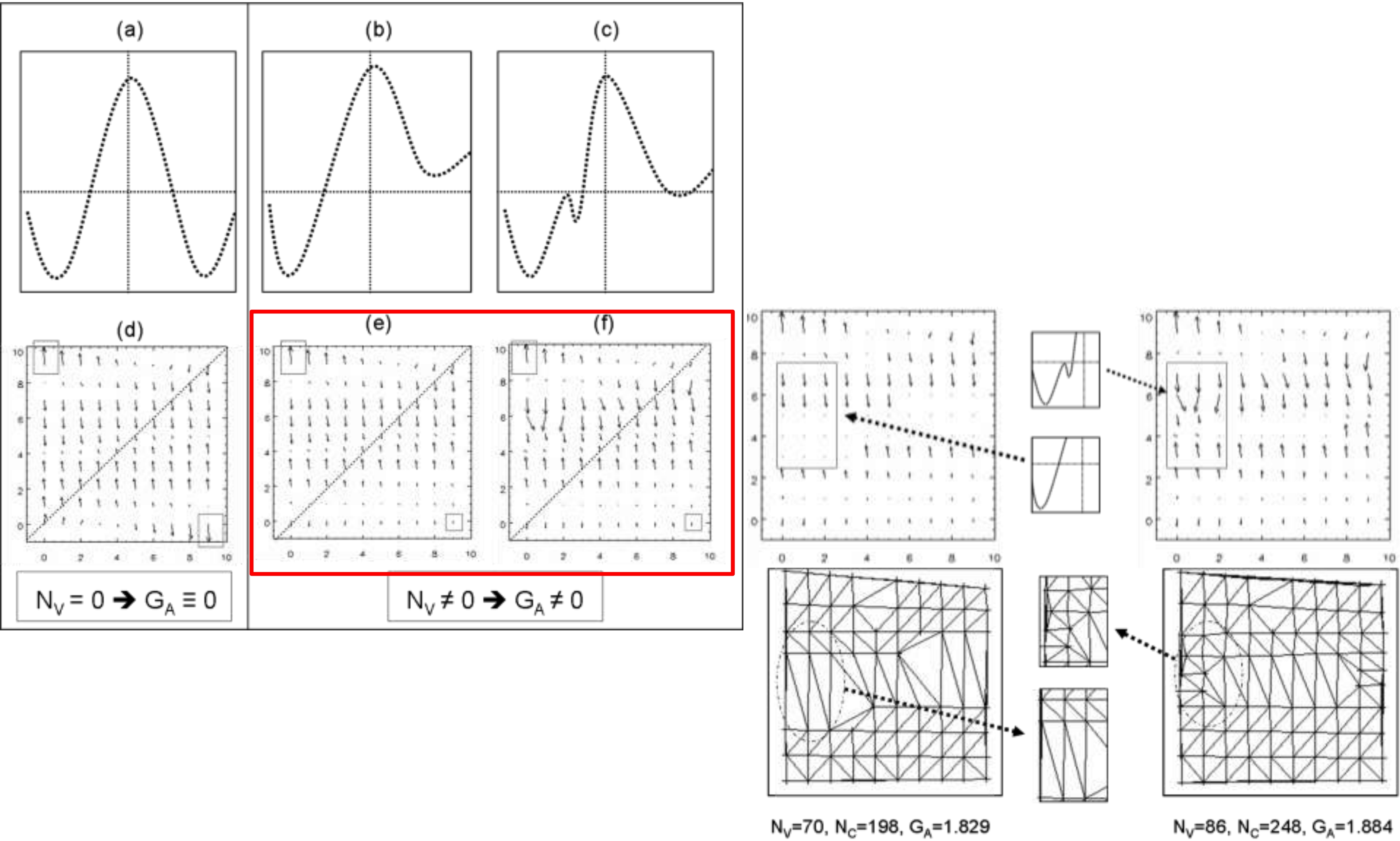


$$G_A = \frac{N_C - N_V}{N_V},$$

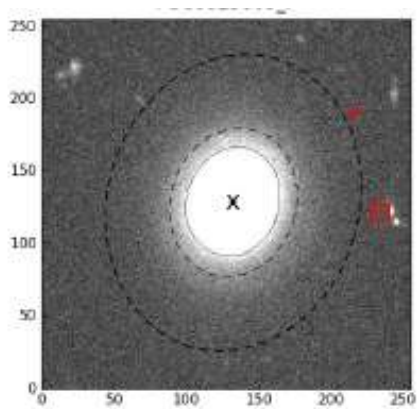
Ex.: Elementar ramp

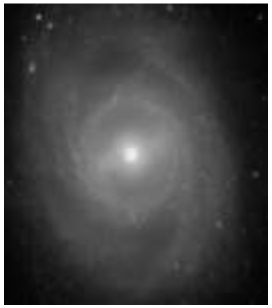
GA=(16-9)/9=0.7777


(a)
V= 9
L = 9
I = 16
G1=0.778
(b)
V= 9
L = 9
I = 20
G1=1.222

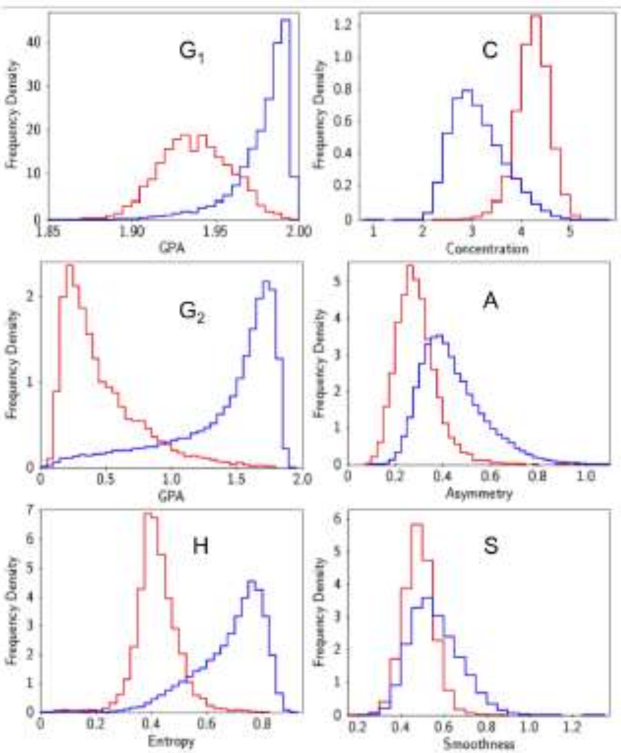

(a)
(b)
(c)
(d)
(e)
(f)
$N_V = 0 \rightarrow G_A \equiv 0$
$N_V \neq 0 \rightarrow G_A \neq 0$
N_V=70, N_C=198, G_A=1.829
N_V=86, N_C=248, G_A=1.884

Background → Segmentation → Resampling → star masking → stamp → analysis





- Color and Magnitudes
- Sersic Parameters
- CAS + H + GPA
- Geometrical Moments
- Luminosity Profile

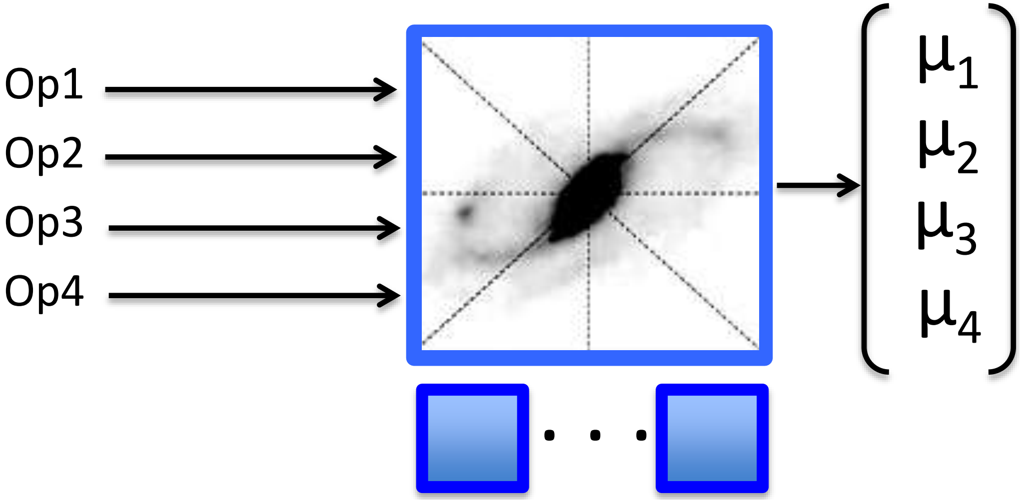


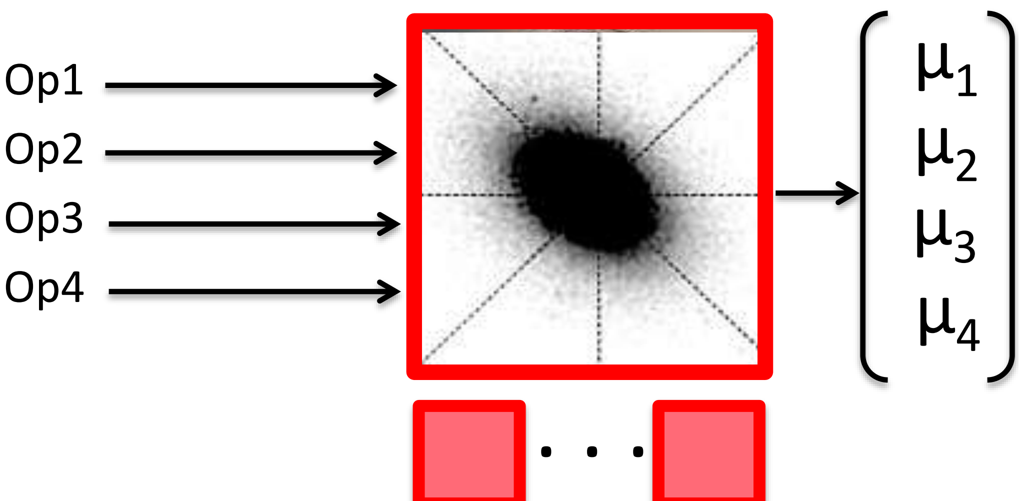
Gradient Pattern Analysis Applied to Galaxy Morphology
R.R.Rosa et al. MNRASL, 2018.
https://doi.org/10.1093/mnrasl/sly054

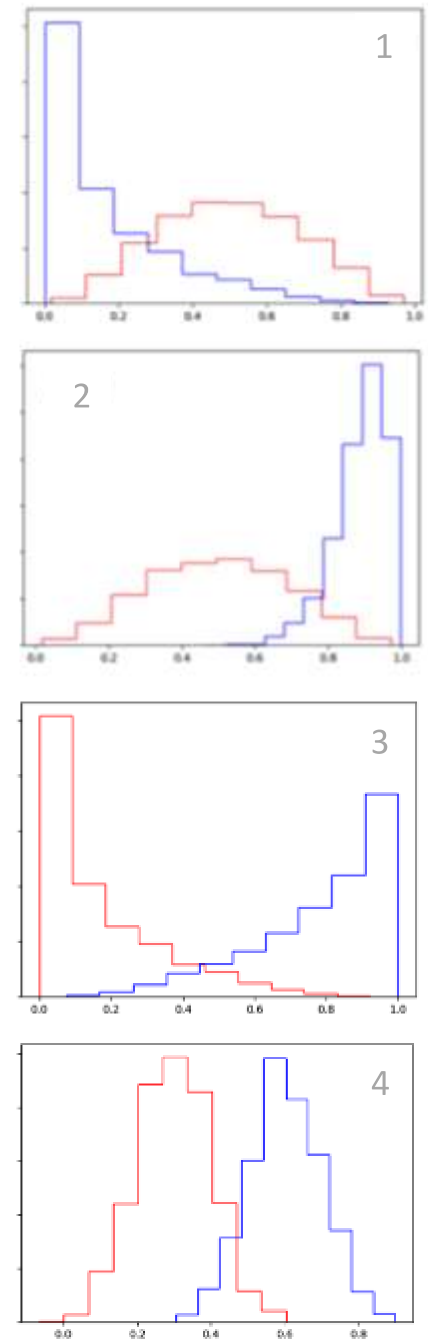
Parameter	$\delta_{GHS}(\%)$	$\langle t \rangle$ (s)	$P(s^{-1})$
GPA (G_2)	90.4	**1.840**	49.1
Entropy (H)	86.9	2.035	42.7
GPA (G_1)	82.3	**1.915**	42.9
Concentration (C)	78.9	2.262	34.9
Asymmetry (A)	49.6	1.854	26.8
Smoothness (S)	42.7	1.852	23.1

• Discriminant Analysis from Big Data

Tao Li, Shenghuo Zhu, and Mitsunori Ogihara. Using Discriminant Analysis for Multi-Class Classification: An Experimental Investigation. Knowledge and Information Systems 10, no. 4 (2006): 45372.)



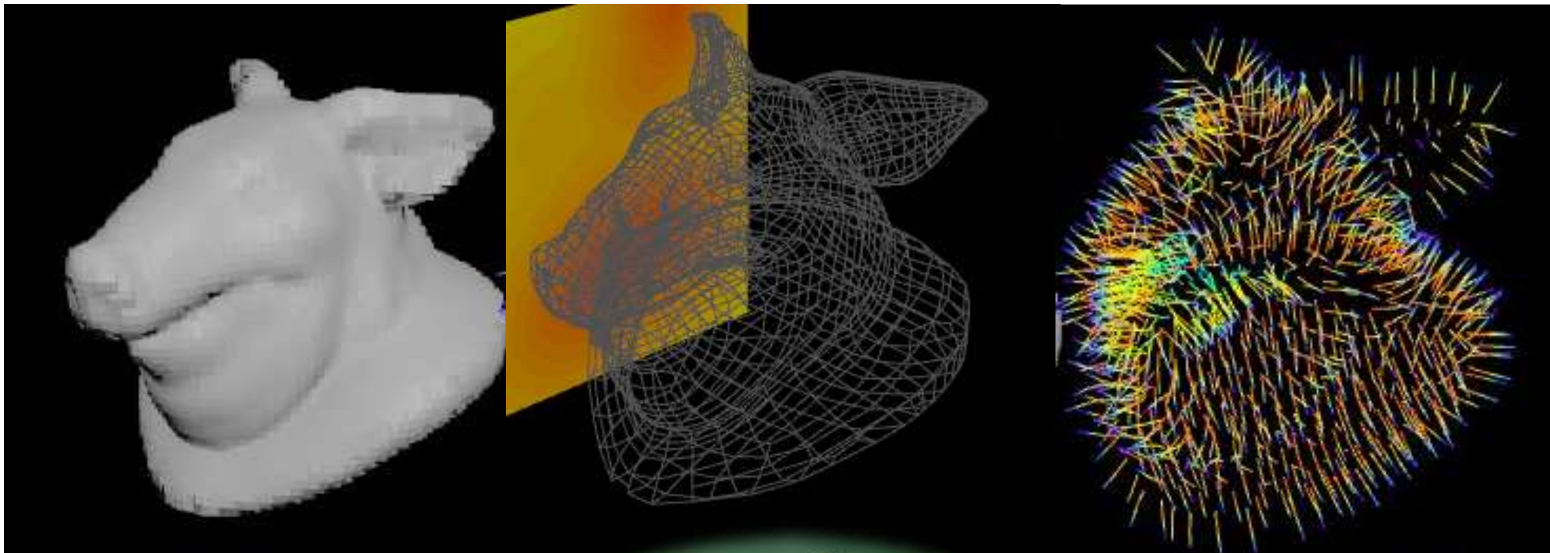




Concluding Remarks

GPA
Theory & Applications
Santiago, 2018

reinaldo.rosa@inpe.br



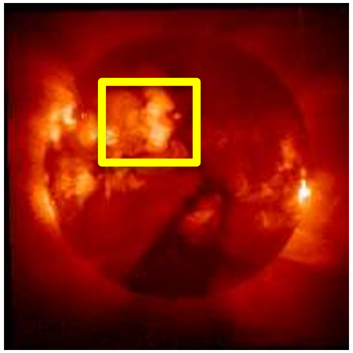
Future Challenges: ... , G_2, G_3, G_4}

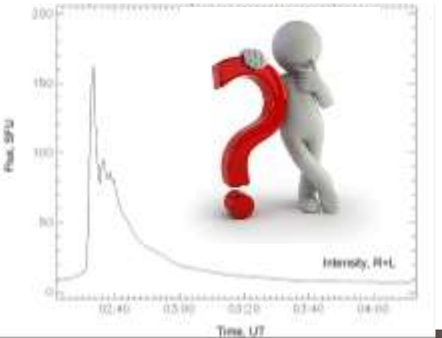
- GPA FOR HYPE...
- GPA OpenACC ... tions

Part A: **Reminiscences** & Theory

- The Need for Spatiotemporal Analytic Tools (Matrix Operation)

GPA
Theory & Applications
Santiago, 2018





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Physica A 257 (1998) 509–514

PHYSICA A

Characterization of localized turbulence in plasma extended systems

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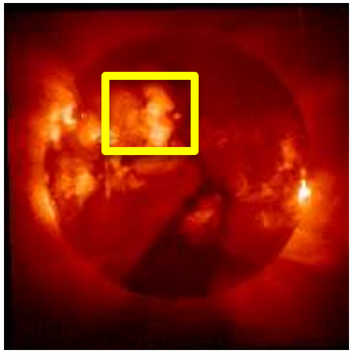
Part A: **Reminiscences** & Theory

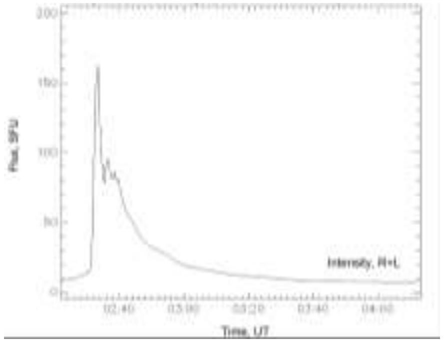
- The Need for Spatiotemporal Analytic Tools (Matrix Operation)

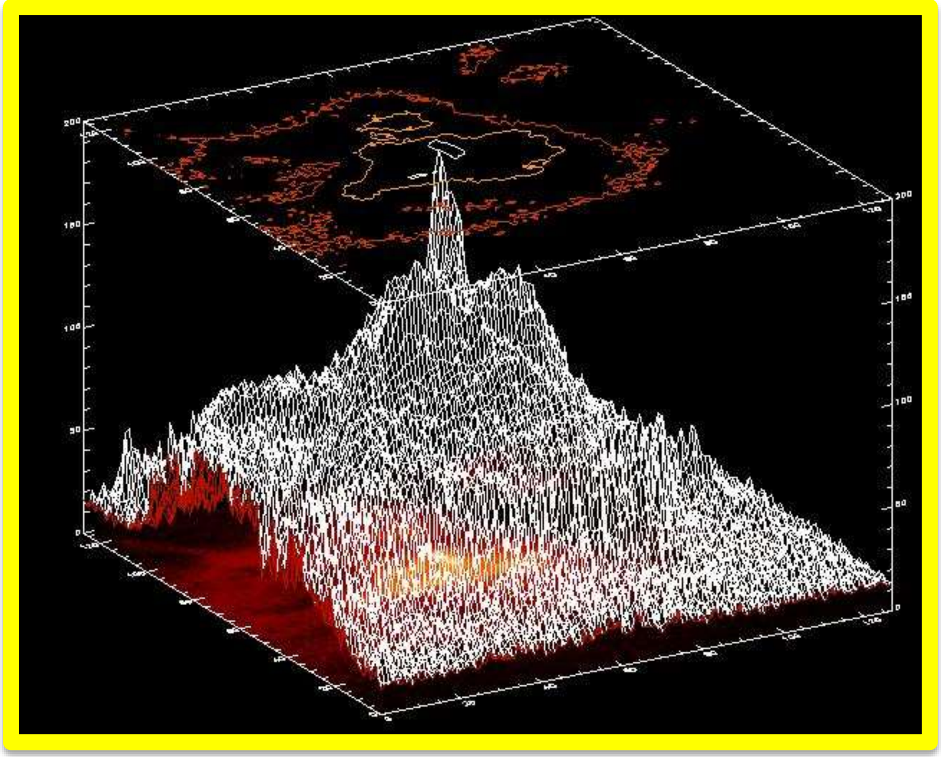
GPA

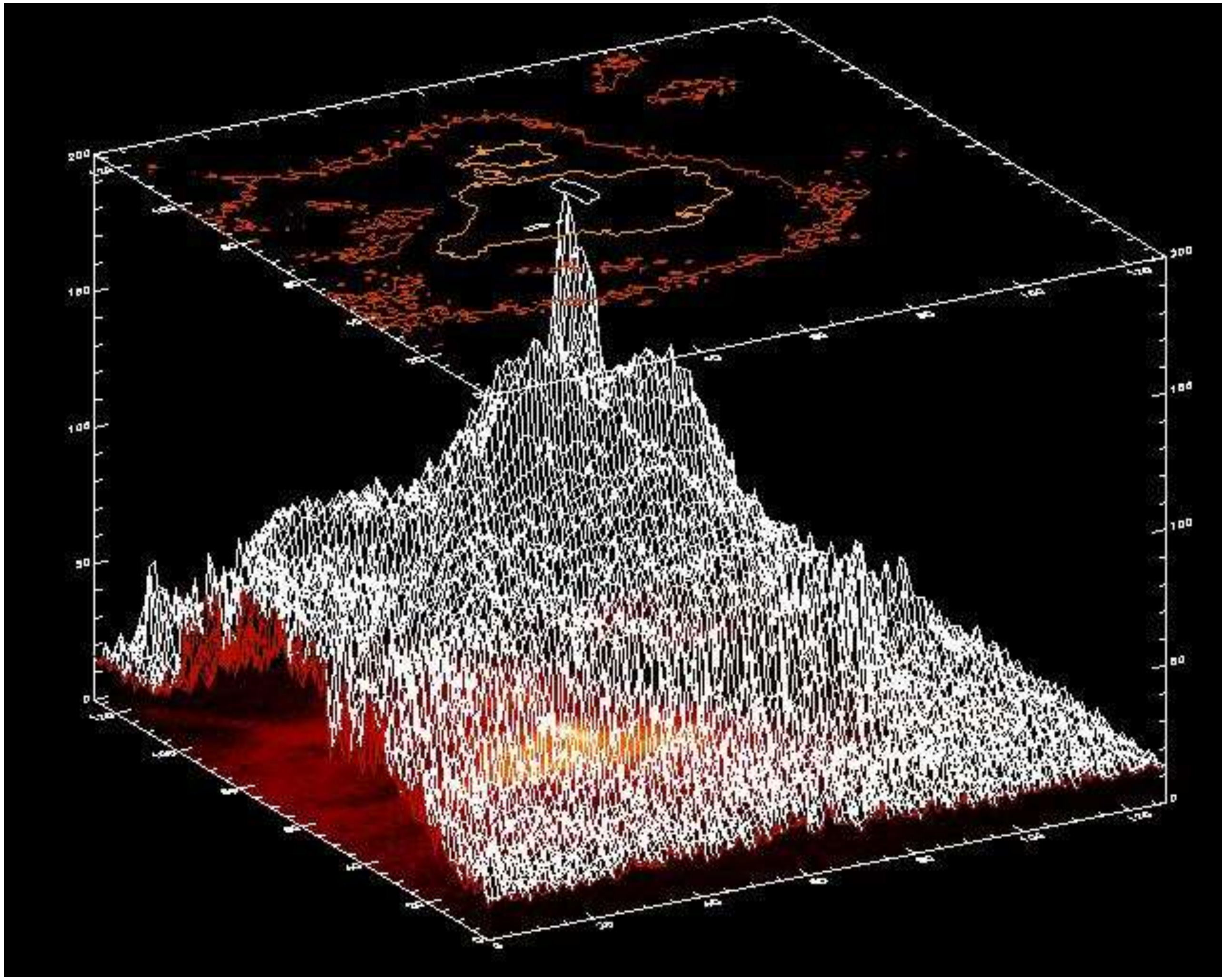
Theory & Applications

Santiago, 2018



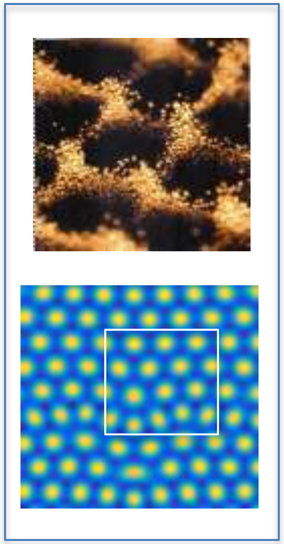




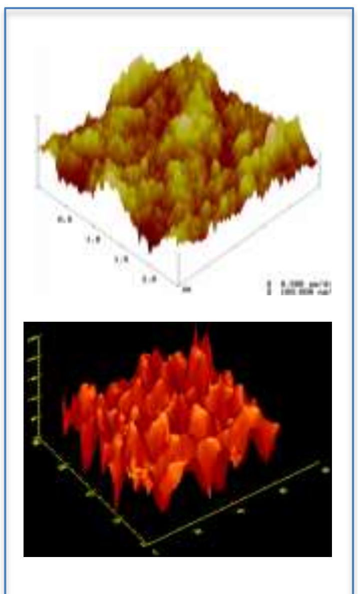

200
150
100
50
0

Examples for Modeling Validation

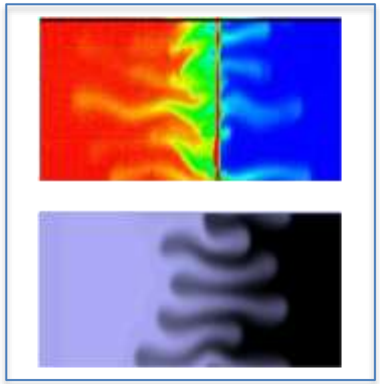
(a)



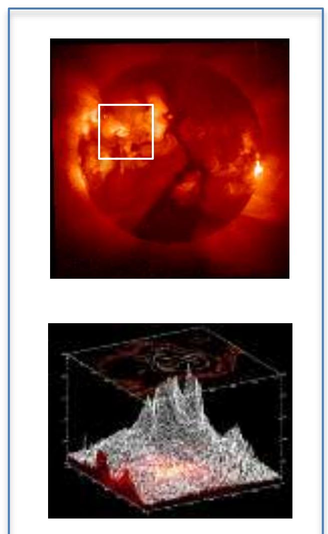
(b)



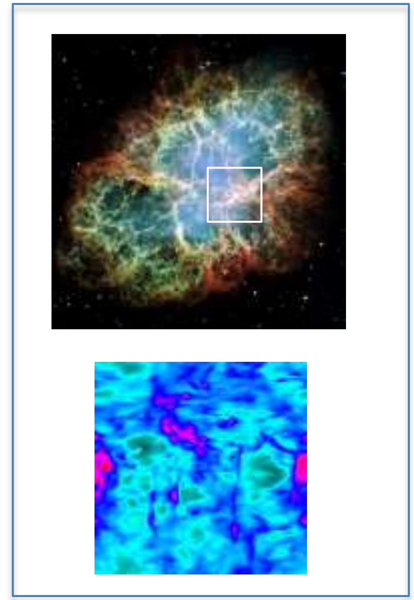
(c)



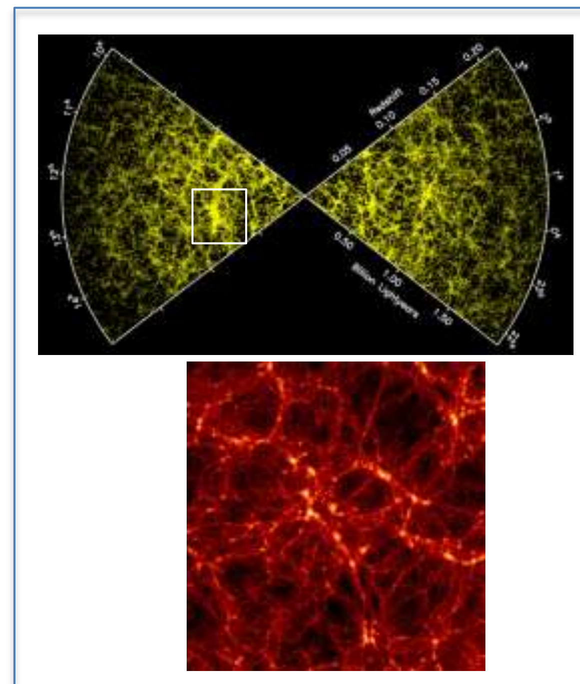
(d)



(e)



(f)



- Spatiotemporal Data:
  from simple to complex

EX. de Sistema Simples
Equação da Membrana
(Coordenadas Polares)

$$A_{tt} = (1/c^2)\,(A_{rr} + r^{-1} A_r + r^{-2} A_{\theta\theta})$$

A(t,r,θ) é um deslocamento ➔ uma solução (EDO) para a variável radial

Prova-se, analiticamente, que existe uma família de funções que admitem Soluções do tipo:

$$S_{n,k}(t,r,\theta) = J_n(b_{n,k})\cos(n\theta t)$$ (*Funções Especiais de Bessel*)

Onde n indica a quantidade de *diâmetros nodais* e k a ordem da função.