

Machine Learning techniques applied to Astronomy: The Merging Systems Identification (MeSsl) Algorithm.

Martín de los Ríos (ICTP-SAIFR/IFT-UNESP)

November 6, 2019

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- A267.
- Statistical analysis of the magnetic fields in merging clusters.
- DM- γ interactions.

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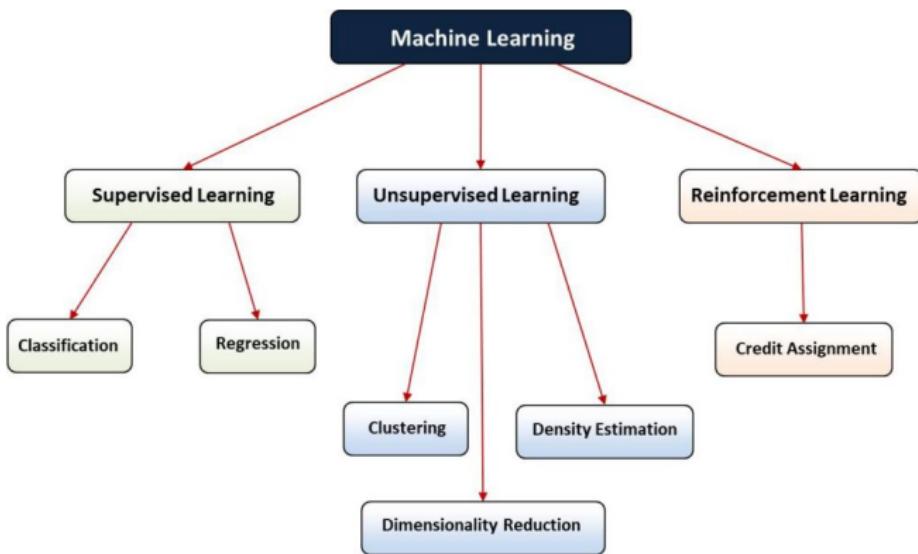
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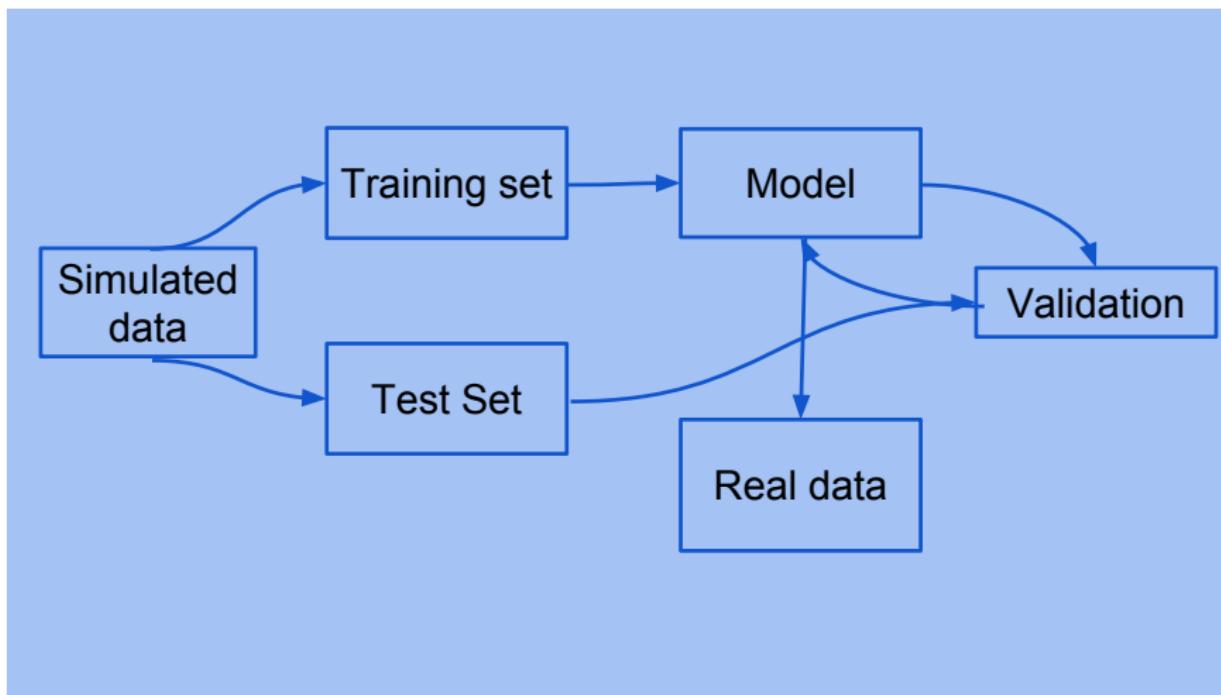
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A computer program learns to perform a task T , based on a training E and taking into account a measure P of its performance, if this measure P when making T improves with the training E.

Thomas M. Mitchell. Machine Learning.



Supervised Learning.



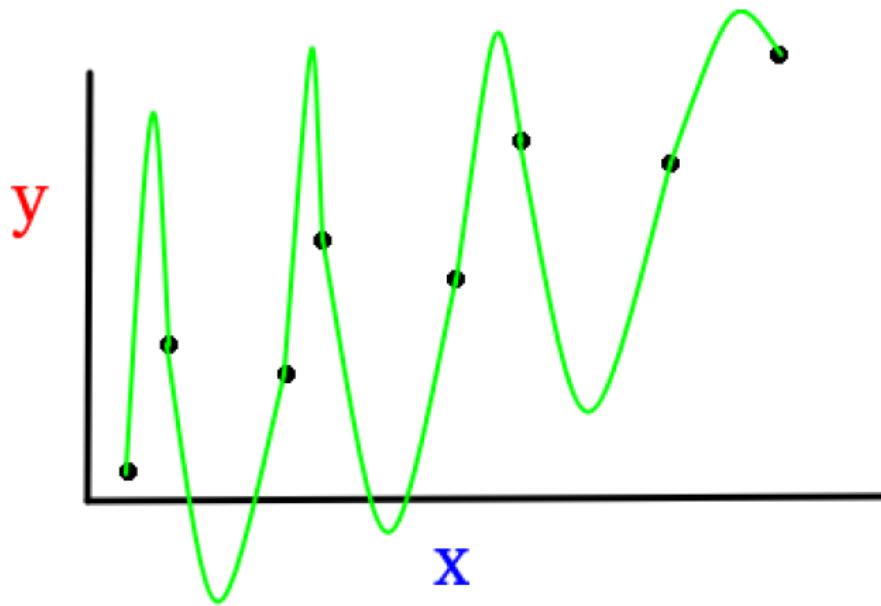
	a	b	...	z
1				
2				
...				
n				

	a	b	...	z
1				
2				
...				
n				

$$y = f(x)$$

↓

Machine Learning



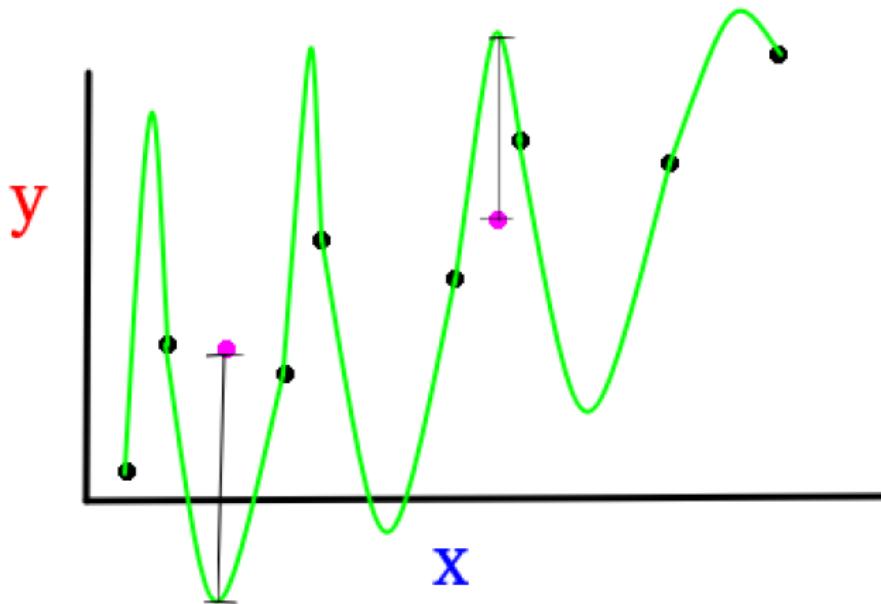
	a	b	...	z
Training-set	1			
Test-set	2			
...				
Training-set	n			

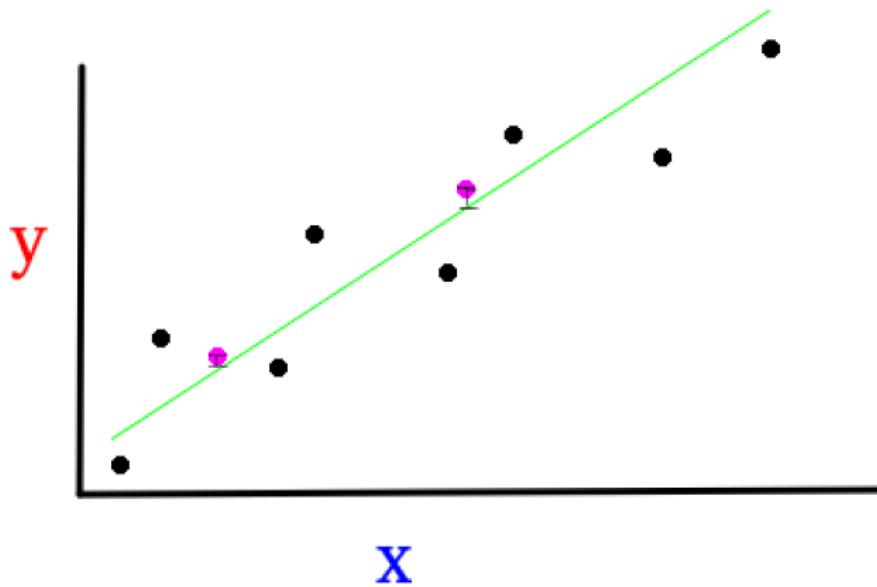
$$\min |y_i - f(x_i)|$$

↓
Training

$$y_i - f(x_i)$$

↓
Testing





		a	b	...	z
Training-set	1				
Test-set	2				
	...				
Training-set	n				
New data		?	b	...	z

1 Introduction to Machine Learning techniques.

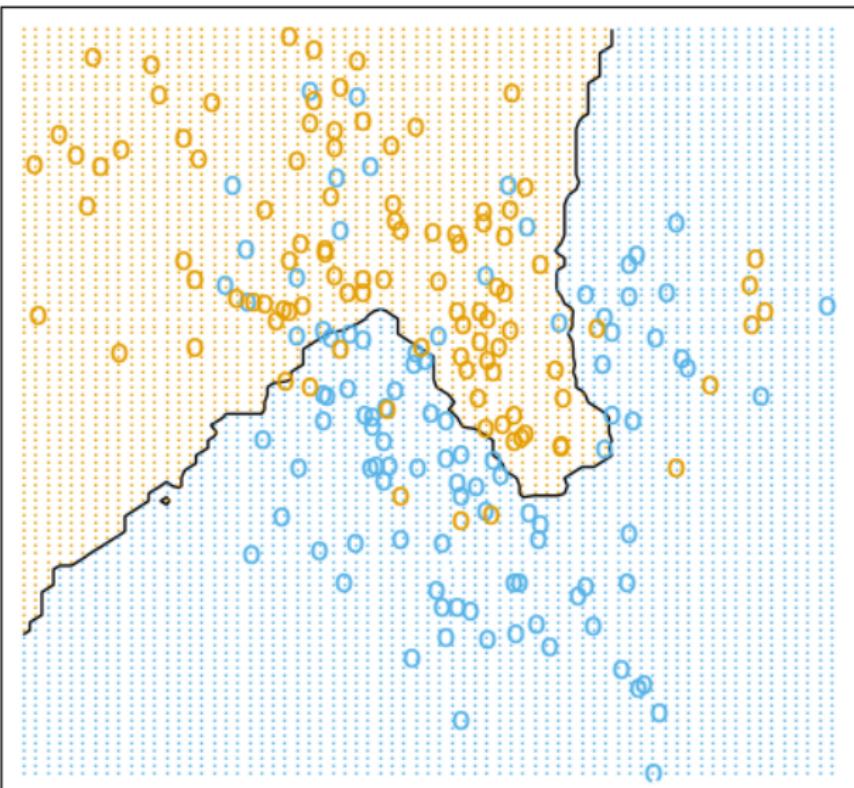
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K-Nearest Neighbour



Random Forest

Support Vector Machines

Deep Learning

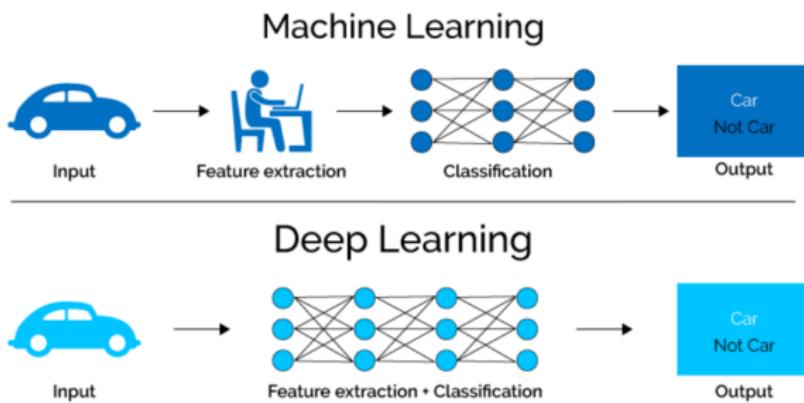


Figure 1: Machine Learning VS Deep Learning

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Classification Problems

- The S-PLUS: a star/galaxy classification based on a Machine Learning approach. [Costa-Duarte et al. \(1909.08626\)](#)
- A Neural Network Gravitational Arc Finder based on the Mediatrix filamentation Method. [Bom et al. \(1607.04644\)](#)
- Circumventing Lens Modeling to Detect Dark Matter Substructure in Strong Lens Images with Convolutional Neural Networks. [Diaz Rivero & Dvorkin. \(1910.00015\)](#)
- Distinguish standard and MOG with ML and weak lensing. [Peel et al. \(1810.11030\)](#)

Regression Problems

- A Hybrid Deep Learning Approach to Cosmological Constraints From Galaxy Redshift Surveys. [Ntampaka et al. \(1909.10527\)](#)
- An improved cosmological parameter inference scheme motivated by deep learning. [Ribli et al. \(1806.05995\)](#)
- Cosmological parameter estimation from large-scale structure deep learning. [Pan et al. \(1908.10590\)](#)
- Estimating Cosmological Parameters from the Dark Matter Distribution. [Ravanbakhsh et al. \(1711.02033\)](#)

Other applications

- CosmoGAN: creating high-fidelity weak lensing convergence maps using Generative Adversarial Networks. [Mustafa et al. \(1706.02390\)](#)
- From Dark Matter to Galaxies with Convolutional Networks. [Zhang et al. \(1902.05965\)](#)
- Learning to Predict the Cosmological Structure Formation. [He et al. \(1811.06533\)](#)
- CosmicNet I: Physics-driven implementation of neural networks within Boltzmann-Einstein solvers. [Albers et al. \(1907.05764\)](#)

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Mon. Not. R. Astron. Soc. **000**, 1–7 (2015)

Printed 17 December 2015

(MN LATEX style file v2.2)

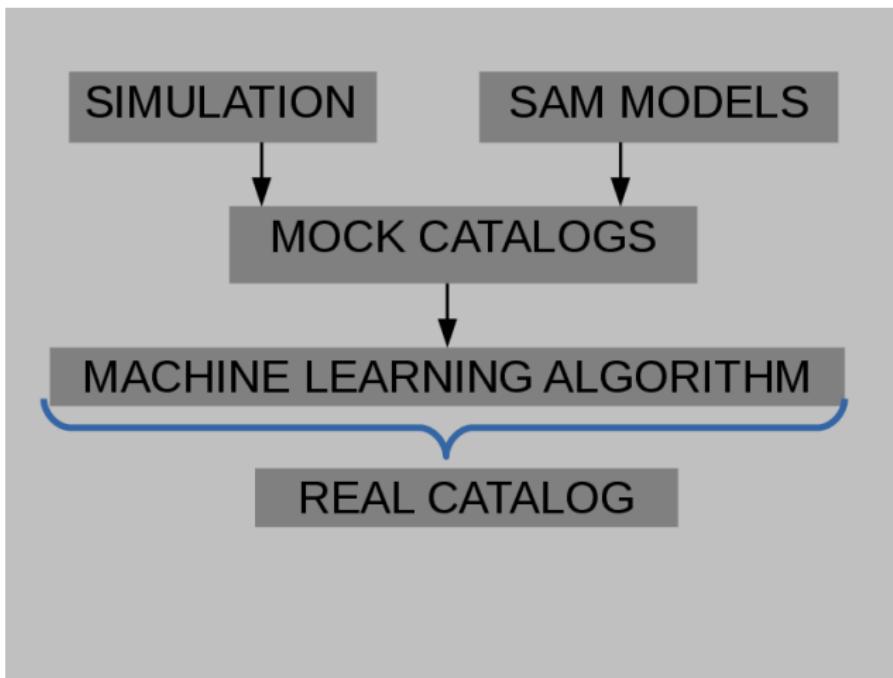
The MeSSI (Merging Systems Identification) Algorithm & Catalogue.

Martín de los Ríos*, Mariano J. Domínguez R.*¹, Dante Paz, Manuel Merchán^{1,2,3}.

¹ Instituto de Astronomía Teórica y Experimental (CCT Córdoba, CONICET, UNC), Laprida 854, X5000BGR, Córdoba, Argentina.

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Clusters identification.

- We construct a mock catalogue based on the results of the application of the SAM Model of Guo et al. 2010 to the Millennium simulation.

Clusters identification.

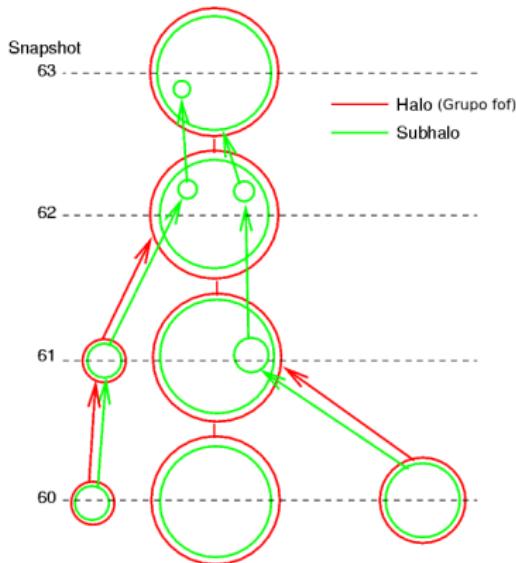
- We construct a mock catalogue based on the results of the application of the SAM Model of Guo et al. 2010 to the Millenium simulation.
- We Perform a friend-of-friend algorithm (*Merchan & Zandivares 2002*) to the mock catalog in order to identify the clusters.

Clusters identification.

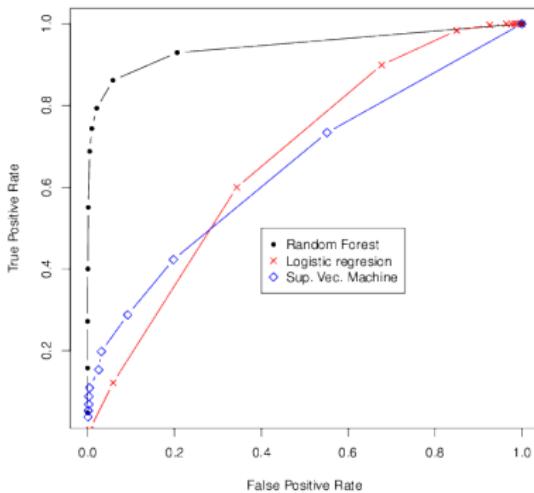
- We construct a mock catalogue based on the results of the application of the SAM Model of Guo et al. 2010 to the Millennium simulation.
 - We Perform a friend-of-friend algorithm (*Merchan & Zandivares 2002*) to the mock catalog in order to identify the clusters.
 - We assign each identified cluster with a fof-group in the simulation.

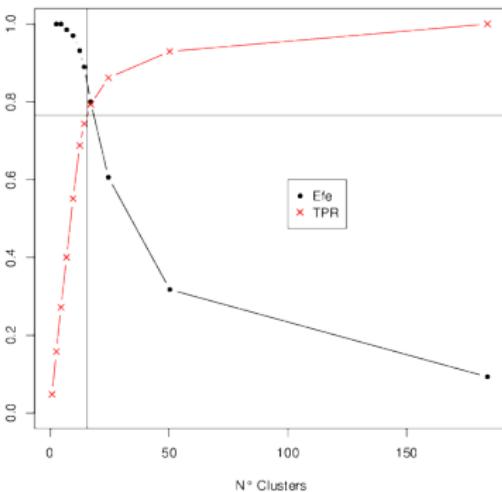
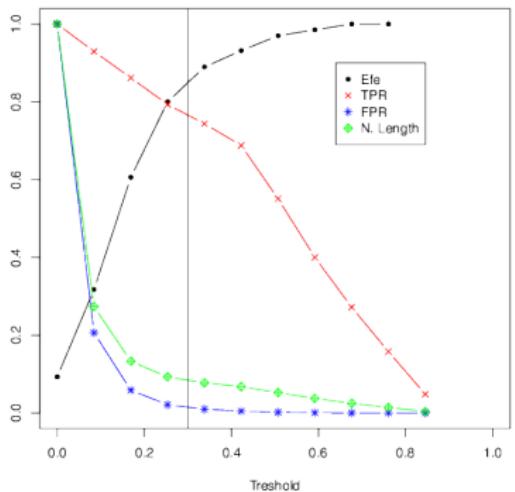
Study of the merger trees.

- Based on the subhalos merger trees, we study the merger tree for every galaxy cluster in the mock catalog.



- Dressler-Shectman test.
- Non gaussianity test.
- Color.
- Number of galaxies.





Study of the identified substructures.

- We ran a second stage of a random forest algorithm, applied to the galaxies.

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- In order to define substructures we identify clumps of galaxies based on their proximity, using a mixture of gaussians weighted by the probability of each galaxy of being part of a substructure, calculated with the RF.

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- We ran a second stage of a random forest algorithm, applied to the galaxies.
- In order to define substructures we identify clumps of galaxies based on their proximity, using a mixture of gaussians weighted by the probability of each galaxy of being part of a substructure, calculated with the RF.
- After that, we estimate the velocity dispersion and the virial radius.

Application of the MeSsl Algorithm to spectroscopy catalogues

- We find 12 Clusters with high probability of been in a merger in the SDSS DR7.

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- We find 29 spatially coincident merging system candidates.

Application of the MeSsl Algorithm to spectroscopy catalogues

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- We find 4 Clusters with high probability of been in a merger in the WINGS Clusters.
- We find 16 Clusters with high probability of been in a merger in the HECs Clusters.
- We find 29 spatially coincident merging system candidates.
- 21 previously reported merging clusters and 40 new candidates to merging systems.

<https://github.com/Martindelosrios/MeSsI>

```
library('devtools')
install_github('MartindelosRios/MeSsI')
```

Example

```
# Loading the MeSsI library.
library('MeSsI')

# Loading the data
data('GalaxiesDataset')

# Let's see the structure of this dataset
str(GalaxiesDataset)

# As you can see this dataset already have all the properties of the galaxies precomputed.
# We will remove this properties and start with a dataset with only the angular positions (ra, dec),
# the redshift (z), the identification of the cluster to which the galaxy belongs (id), the color (color)
# and the r apparent magnitude (mag).

cat <- GalaxiesDataset[, (1:6)]
colnames(cat)[1] <- 'id'
str(cat)

# Then we just can apply the messi functions to this catalog, optionally given a name to the folder where all
# outputs file will be saved.

messi(cat, folder = 'test')
```

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Astronomy & Astrophysics manuscript no. merger1_v3
December 4, 2017

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I. Analysis of candidates for interacting galaxy clusters

A1204 and A2029/A2033

Elizabeth Johana Gonzalez ^{1,2}, Martín de los Ríos^{1,2}, Gabriel A. Oio^{1,2}, Daniel Hernández Lang⁴, Tania Paez Tagliaferro^{1,2}, Mariano J. Domínguez R.^{1,2}, José Luis Nilo Castellón^{3,4}, Héctor Cuevas L.⁴, and Carlos A. Valotto^{1,2}

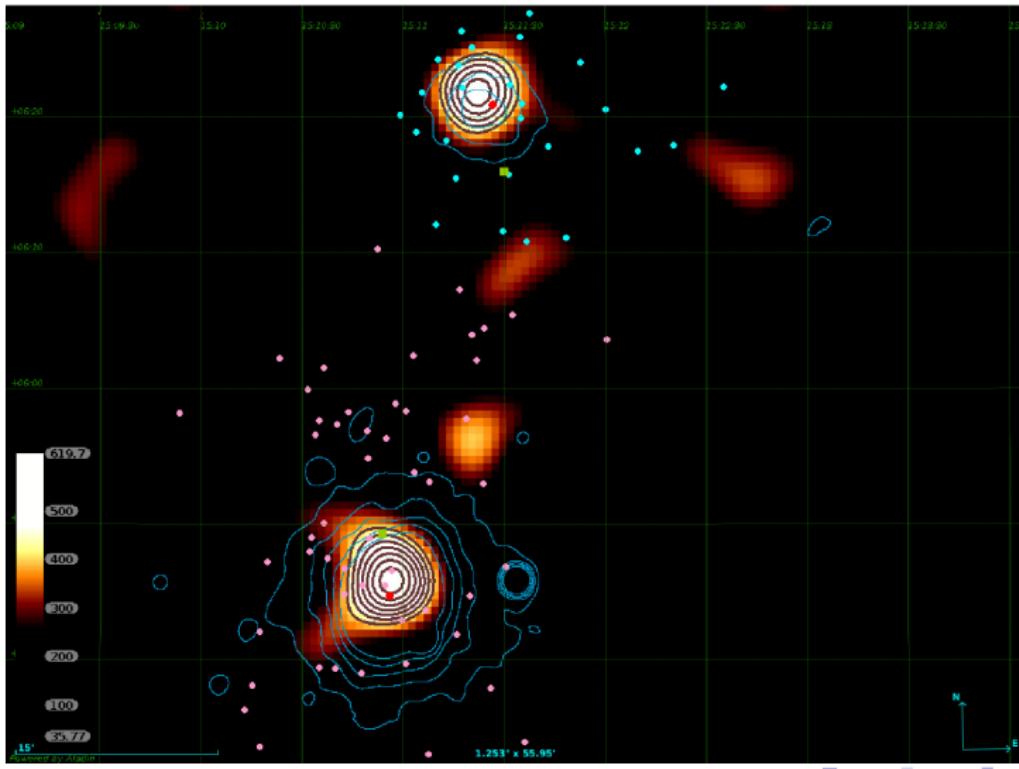
¹ Instituto de Astronomía Teórica y Experimental, (IATE-CONICET), Laprida 854, X5000BGR, Córdoba, Argentina.

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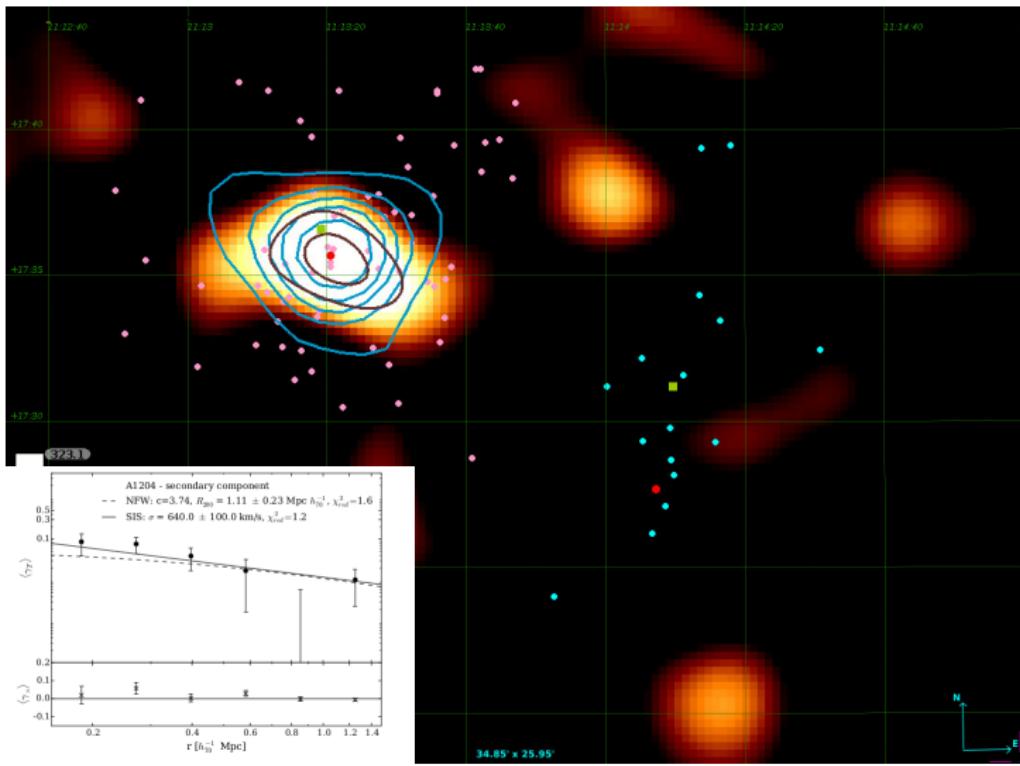
³ Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, Universidad de La Serena. Benavente 980, La Serena, Chile.

⁴ Departamento de Física y Astronomía, Facultad de Ciencias, Universidad de La Serena. Av. Juan Cisternas 1200, La Serena, Chile.

A2029/2033



A1204



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II. Analysis of candidates for interacting galaxy clusters: A267, a merging fossil group.

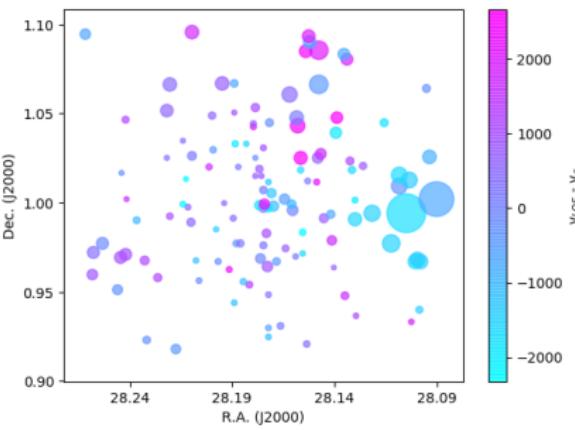
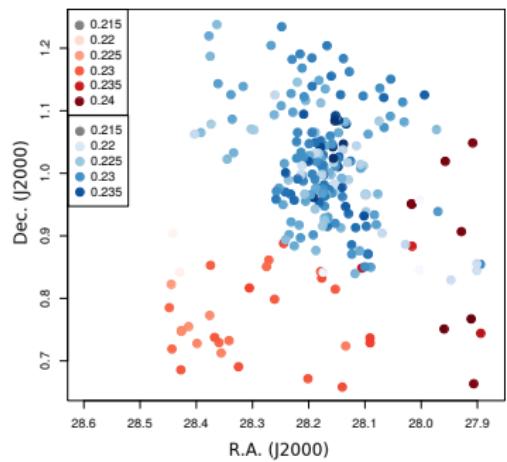
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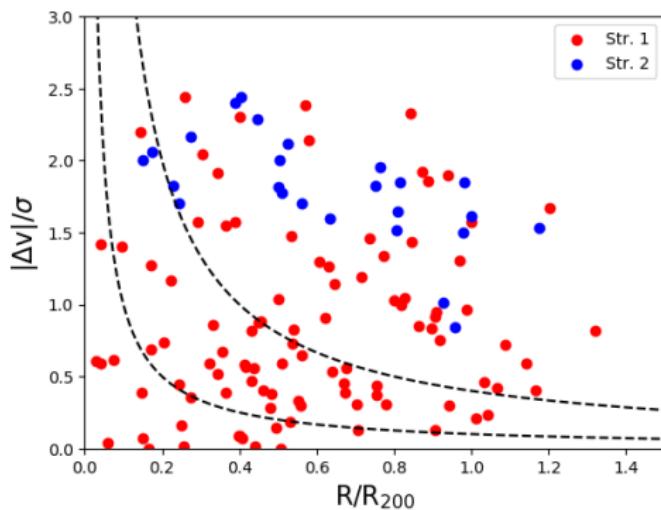
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- $\approx 40\%$ Fossil groups have a major merger $z < 0.8$.
- $\approx 15 - 25\%$ Fossil groups have a major merger $z < 0.3$.

Noble et al. 2013

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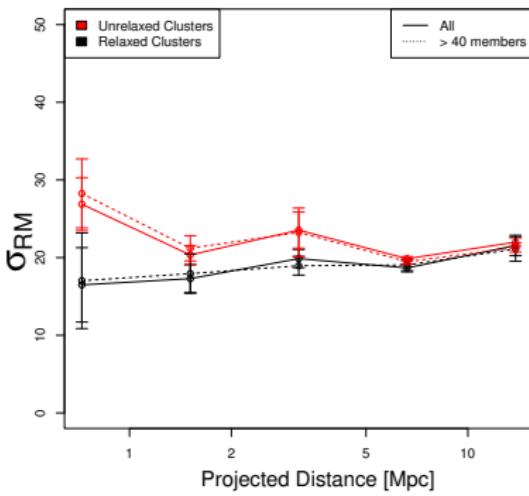
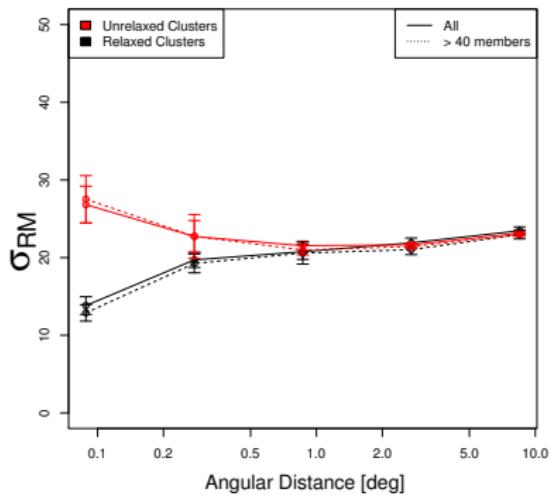
Faraday Rotation Measure dependence with galaxy clusters dynamics

F.A. Stasyszyn^{1,2*} & M. de los Rios^{1,2,3}

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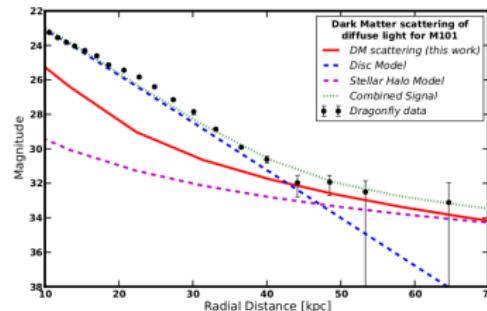
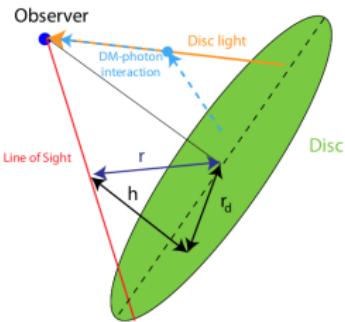
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Davis & Silk (1410.5423)

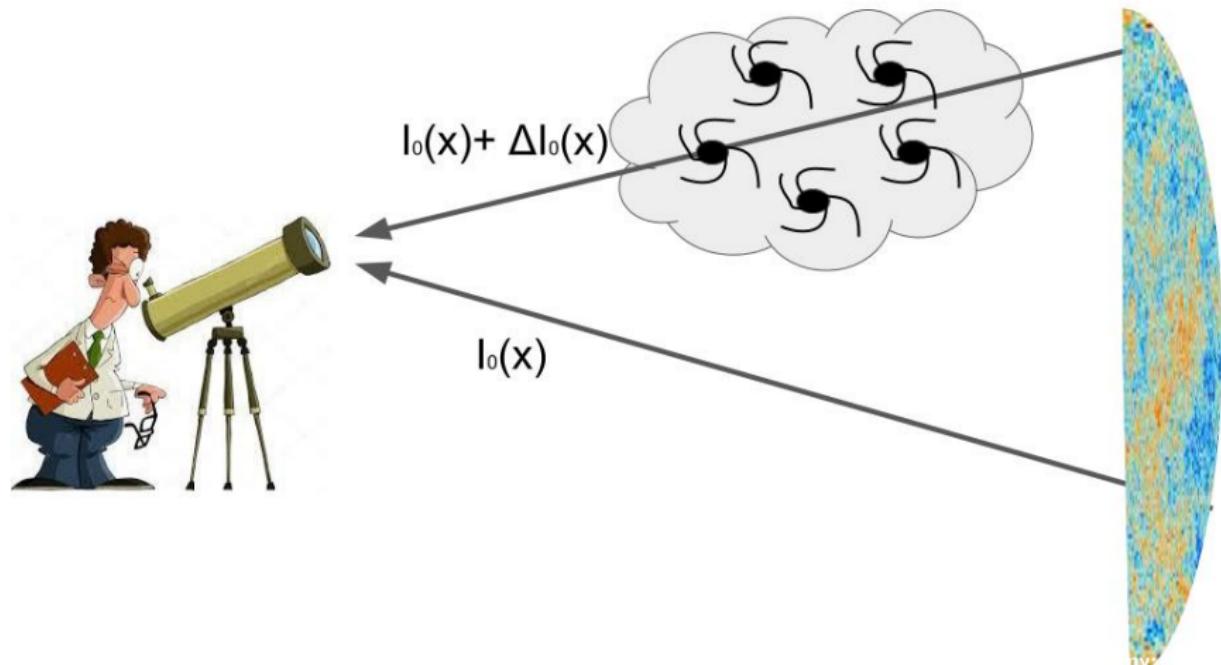


- Bøhm et al. (1404.7012)
- Schewtschenko et al. (1512.0677)
- Stadler & Bøhm (1802.06589)

$$\sigma_{DM\gamma} \leq 2.25 \times 10^{-6} \sigma_{Th} (mDM / \text{GeV})$$

DM- γ interactions (work in progress)

In collaboration with Dra. Celine Bœhm





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- Study the physical properties of the galaxies that belong to the identified substructures.
- Construct a catalog of relaxed clusters in order to study the dark matter equation of state (Serra & Dominguez 2011).
- Study the candidate to merging cluster A376 (HSC SUBARU Images).

Future Work

- Estimate the CMB Masked Bispectra using Machine Learning techniques.

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- Estimate the Dark matter Distribution of spiral galaxies using Deep Learning.

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- Estimate the CMB Masked Bispectra using Machine Learning techniques.
- Estimate the Dark matter Distribution of spiral galaxies using Deep Learning.
- Identifying backsplash galaxies in the phase-space using Machine Learning.



THANK YOU

