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

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

October 31, 2019

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   - A1204.
   - A267.
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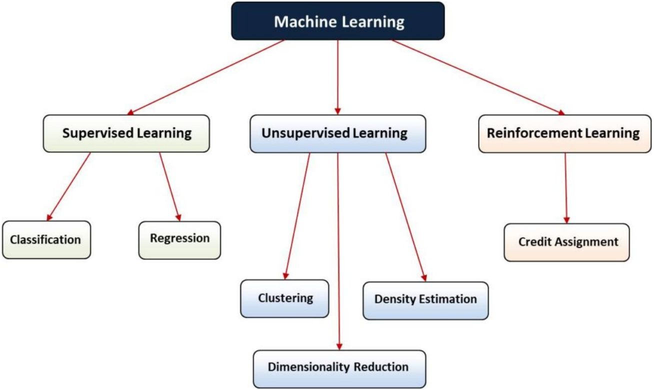
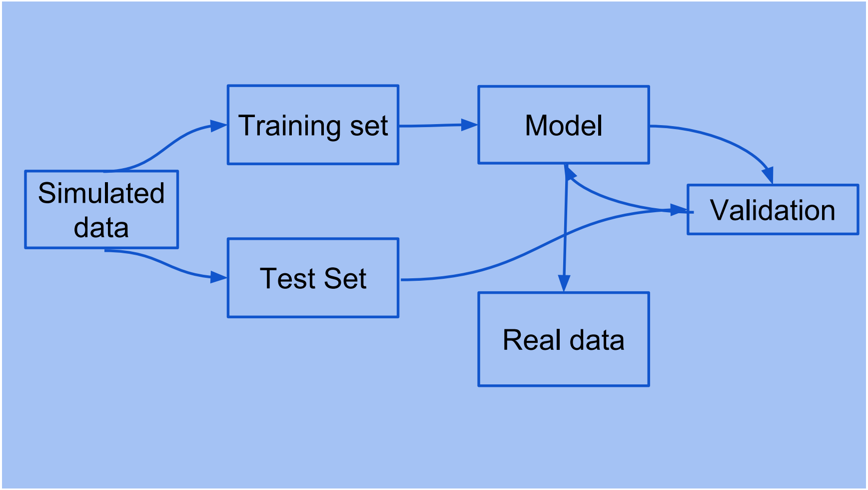
   - DM-γ interactions.
3. Future Work

> 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.


Machine Learning
Supervised Learning
Unsupervised Learning
Reinforcement Learning
Classification
Regression
Clustering
Density Estimation
Dimensionality Reduction
Credit Assignment

Supervised Learning.

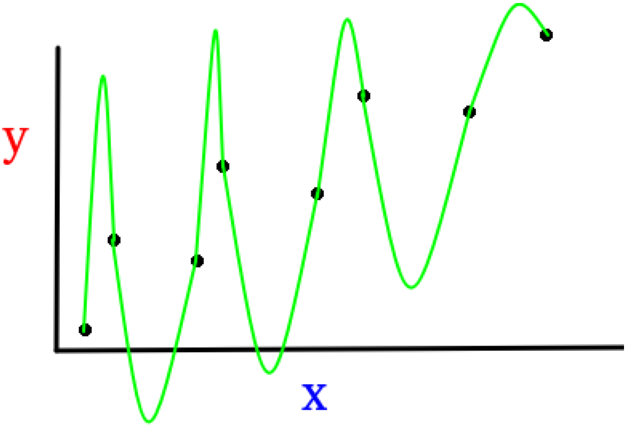


	a	b	...	z
1				
2				
...				
n				

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

$$y = f(x)$$

Machine Learning


y
x

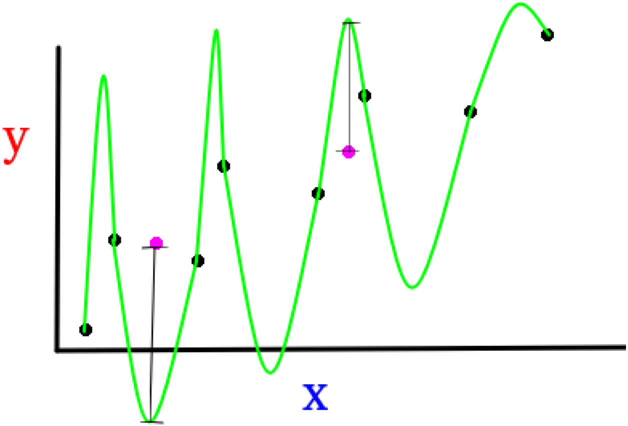
		a	b	...	z
Training-set	1				
Test-set	2				
	...				
Training-set	n				

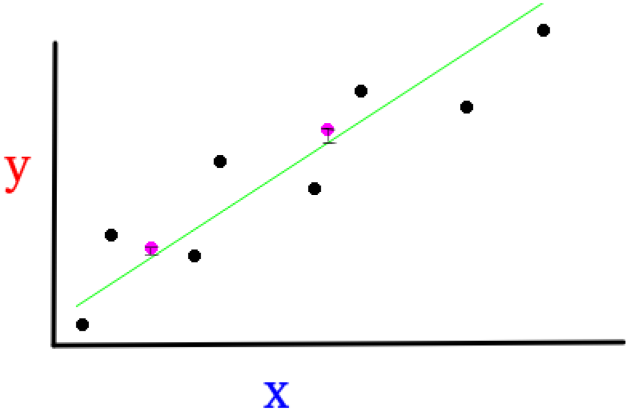
$$\min|y_i - f(x_i)|$$

Training

$$y_i - f(x_i)$$

Testing


y
x


y
x

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

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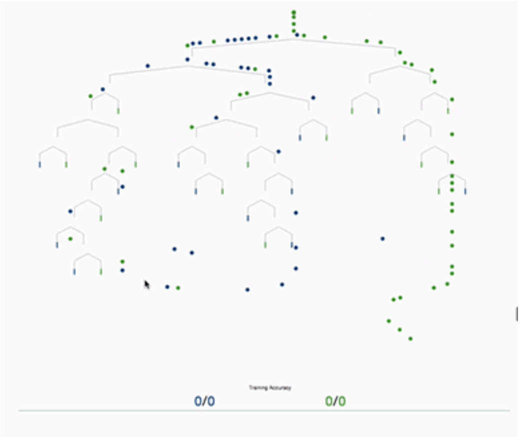
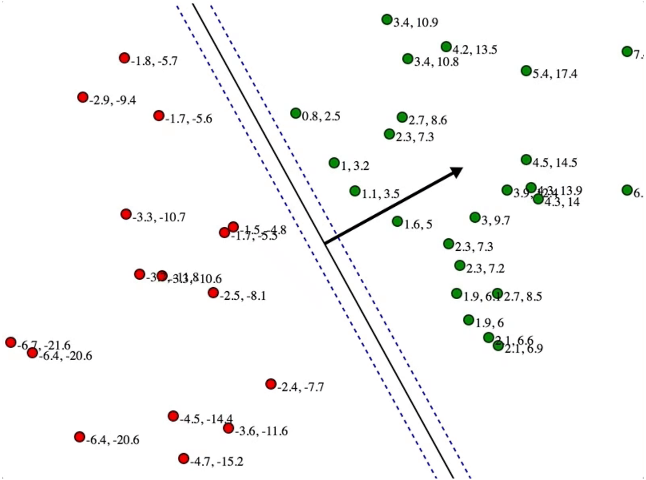
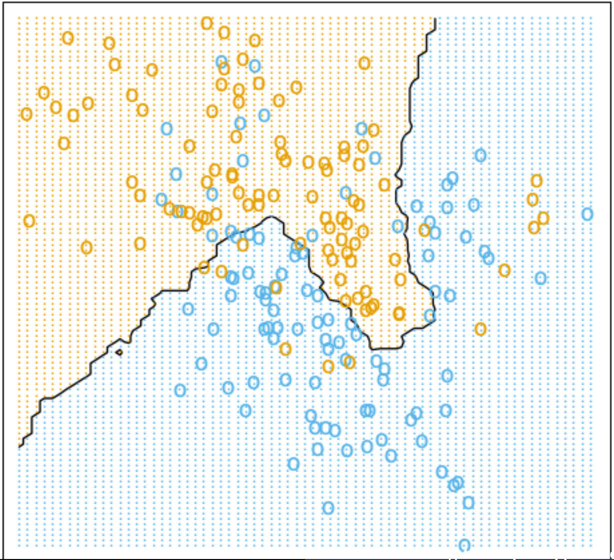
Random Forest



Support Vector Machines



K-Nearest Neighbour



Deep Learning

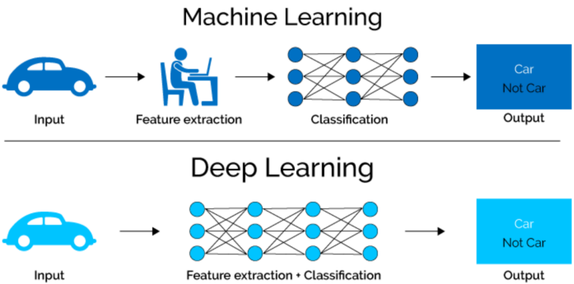


Figure 1: Machine Learning VS Deep Learning

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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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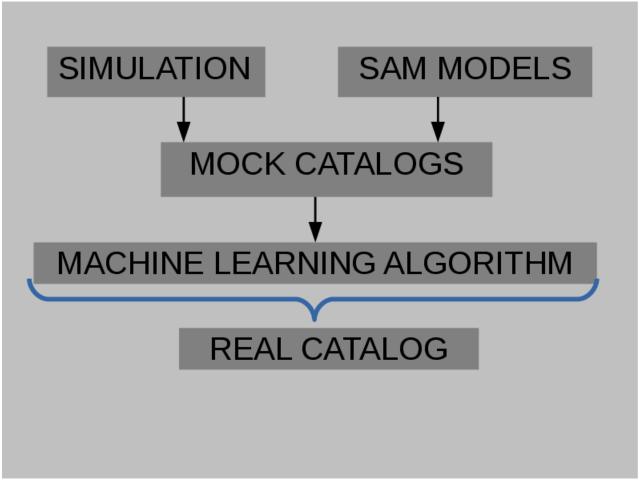
Mon. Not. R. Astron. Soc. **000**, 1–7 (2015) Printed 17 December 2015 (MN LaTeX style file v2.2)

The MeSsI (Merging Systems Identification) Algorithm & Catalogue.

Martín de los Rios⋆, Mariano J. Domínguez R.⋆, Dante Paz, Manuel Merchán [1,2,3].
[1] *Instituto de Astronomía Teórica y Experimental (CCT Córdoba, CONICET, UNC), Laprida 854, X5000BGR, Córdoba, Argentina.*
[2] *Observatorio Astronómico de Córdoba, Universidad Nacional de Córdoba, Laprida 854, X5000BGR, Córdoba, Argentina.*
[3] *Consejo Nacional de Investigaciones Científicas y Técnicas, Rivadavia 1917, C1033AAJ Buenos Aires, Argentina.*


SIMULATION
SAM MODELS
MOCK CATALOGS
MACHINE LEARNING ALGORITHM
REAL CATALOG

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.

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- We Perform a friend-of-friend algorithm (*Merchan & Zandivares 2002*) to the mock catalog in order to identify the clusters.

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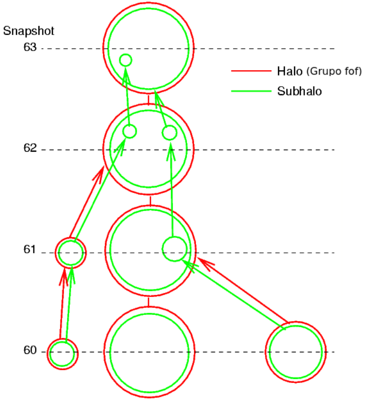
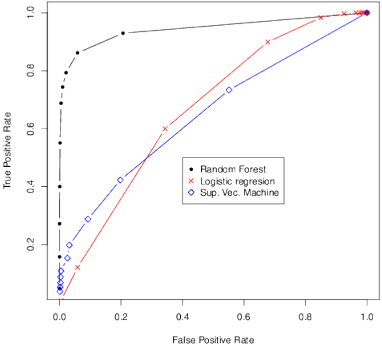
- We construct a mock catalogue based on the results of the application of the SAM Model of Guo et al. 2010 to the Millenium simulation.
- We Perform a friend-of-friend algorithm (*Merchan & Zandivares 2002*) to the mock catalog in order to identify the clusters.
- We assign each identified cluster with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

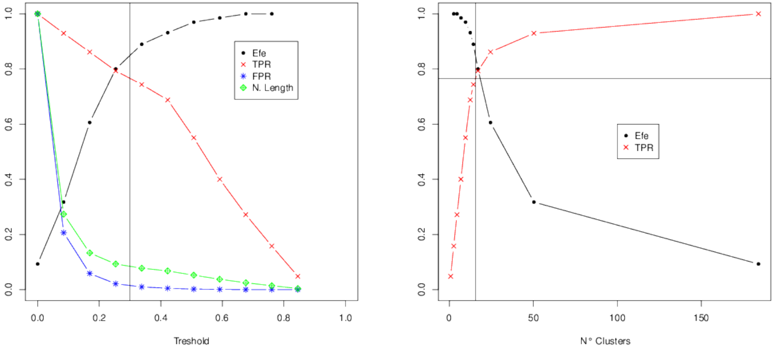
Study of the merger trees.

- 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.




Efe
TPR
FPR
N. Length
Treshold
Efe
TPR
N° Clusters

Study of the identified substructures.

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

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Study of the identified substructures.

- 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 MeSsI 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 12 Clusters with high probability of been in a merger in the SDSS DR7.
- We find 7 Clusters with high probability of been in a merger in the WINGS Clusters.
- We find 15 Clusters with high probability of been in a merger in the HECs Clusters.

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 al
#  outputs file will be saved.

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

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Astronomy & Astrophysics manuscript no. merger1_v3
December 4, 2017

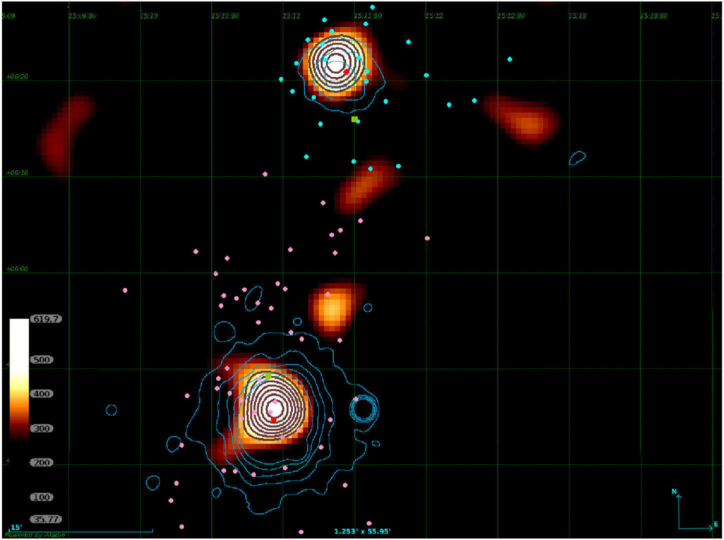
I. Analysis of candidates for interacting galaxy clusters

A1204 and A2029/A2033

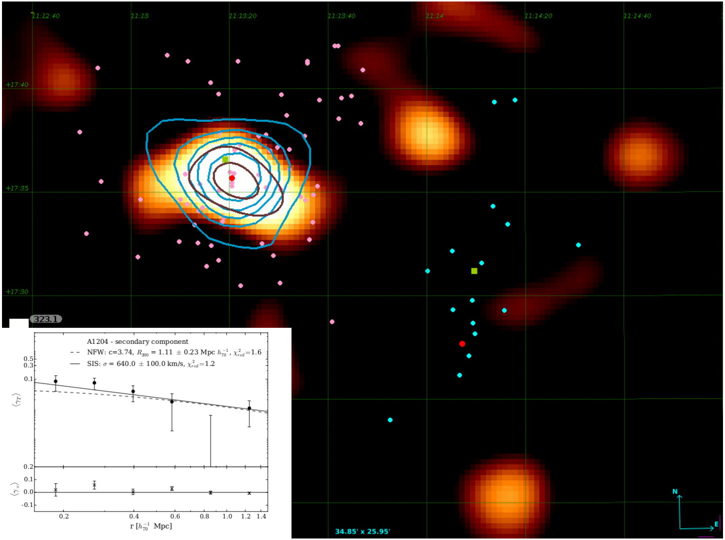
Elizabeth Johana Gonzalez ⋆[1,2], Martín de los Rios[1,2], Gabriel A. Oio[1,2], Daniel Hernández Lang[4], Tania Paez Tagliaferro[1,2], Mariano J. Domínguez R.[1,2], José Luis Nilo Castellón[3,4], Héctor Cuevas L.[4], and Carlos A. Valotto[1,2]

[1] Instituto de Astronomía Teórica y Experimental, (IATE-CONICET), Laprida 854, X5000BGR, Córdoba, Argentina.
[2] Observatorio Astronómico de Córdoba, Universidad Nacional de Córdoba, Laprida 854, X5000BGR, Córdoba, Argentina.
[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


619.7
500
400
300
200
100
35.77
15'
Powered by Aladin
1.253° x 55.95'
N
E

A1204


11:12:40
11:13
11:13:20
11:13:40
11:14
11:14:20
11:14:40
+17:40
+17:35
+17:30
323.1
A1204 - secondary component
NFW: c=3.74, R_{200} = 1.11 ± 0.23 Mpc h_{70}^{-1}, χ^2_{red}=1.6
SIS: σ = 640.0 ± 100.0 km/s, χ^2_{red}=1.2
$\langle \gamma_T \rangle$
$\langle \gamma_\times \rangle$
r [h_{70}^{-1} Mpc]
N
E
34.85' x 25.95'

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II. Analysis of candidates for interacting galaxy clusters:

A267, a merging fossil group.

Elizabeth Johana Gonzalez ⋆[1,2], María Jose Kanagusuku[1,2], Martín de los Rios[1,2], Gabriel A. Oio[1,2], Daniel Hernández Lang[4], Tania Aguirre 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]

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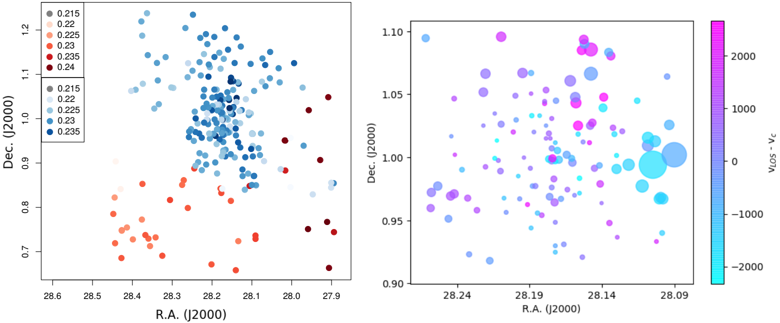
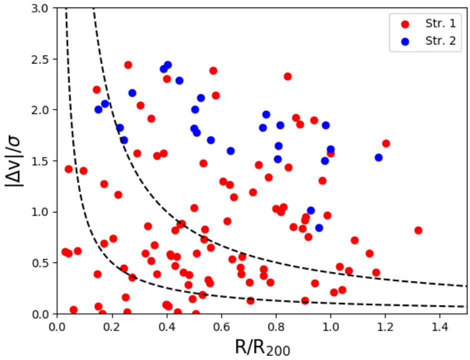

0.215
0.22
0.225
0.23
0.235
0.24
0.215
0.22
0.225
0.23
0.235
Dec. (J2000)
R.A. (J2000)
Dec. (J2000)
R.A. (J2000)
v_{LOS} - v_c



- $\approx 40\%$ 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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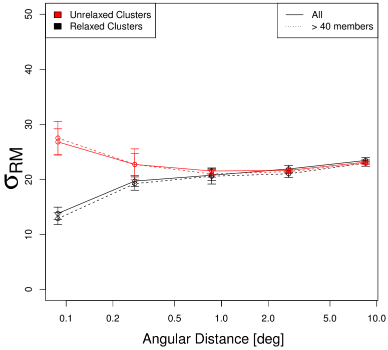
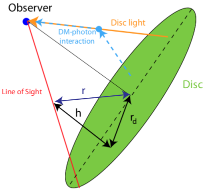
Faraday Rotation Measure dependence with galaxy clusters dynamics

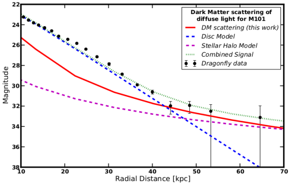
F.A. Stasyszyn[1,2⋆] & M. de los Rios[1,2,3]
[1] *Instituto de Astrofísica Teórica y Experimental (IATE), Laprida 854, Córdoba, Argentina*
[2] *Observatorio Astronómico de Córdoba, Universidad Nacional de Córdoba, Laprida 854, X5000BGR, Córdoba, Argen*
[3] *Consejo Nacional de Investigaciones Científicas y Técnicas, Rivadavia 1917, C1033AAJ Buenos Aires, Argentina.*



Unrelaxed Clusters
Relaxed Clusters
All
> 40 members
σ_{RM}
Angular Distance [deg]
Projected Distance [Mpc]

Davis & Silk (1410.5423)



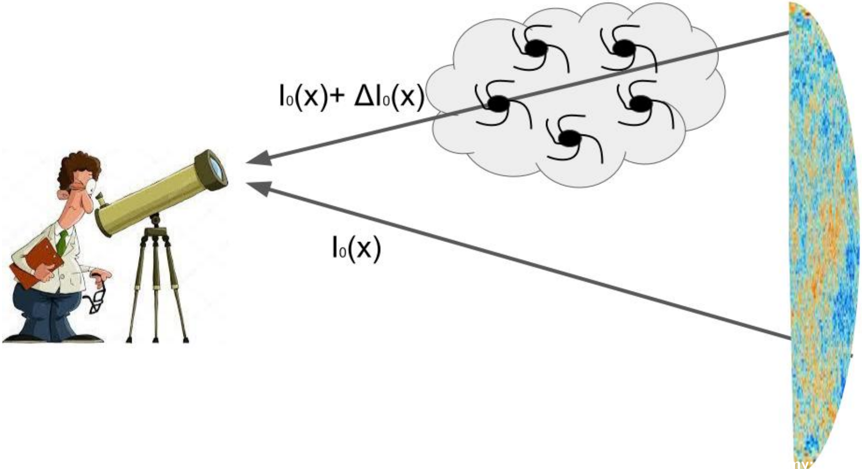


- Boœm et al. (1404.7012)
- Schewtschenko et al. (1512.0677)
- Stadler & Boœm (1802.06589)

$$\sigma_{DM\gamma} \leq 2.25x10^{-6}\sigma_{Th}(mDM/GeV)$$

DM-γ interactions (work in progress)

In collaboration with Dra. Celine Bœhm




CMB
SZ
?
?

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- Perform astrophysical test over our sample of colliding cluster candidates of the catalog looking for impose some constraints on dark matter particle properties.

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- Study the physical properties of the galaxies that belong to the identified substructures.
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- 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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- Identifying backsplash galaxies in the phase-space using Machine Learning.


THANK YOU