



Centro Brasileiro de Pesquisas Físicas  
Brazilian Center For Research in Physics

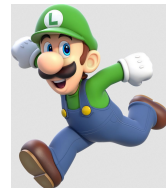
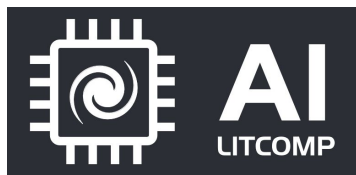


# Galaxy Morphology in the DECam Local Volume Exploration Survey: first results and perspectives

Luidhy Santana-Silva

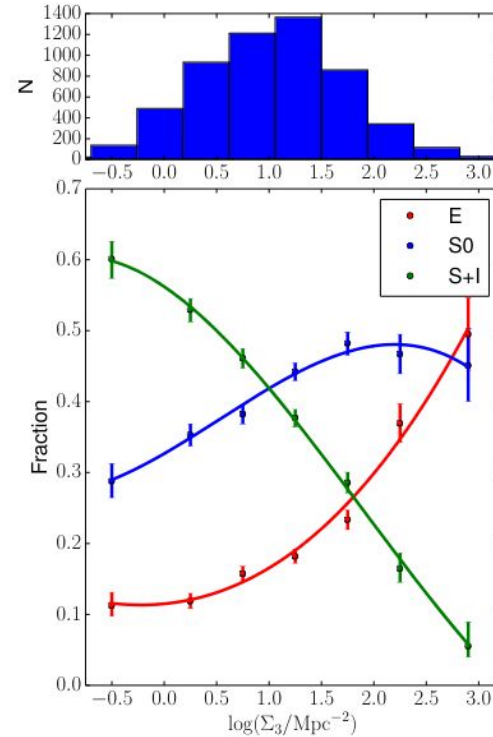
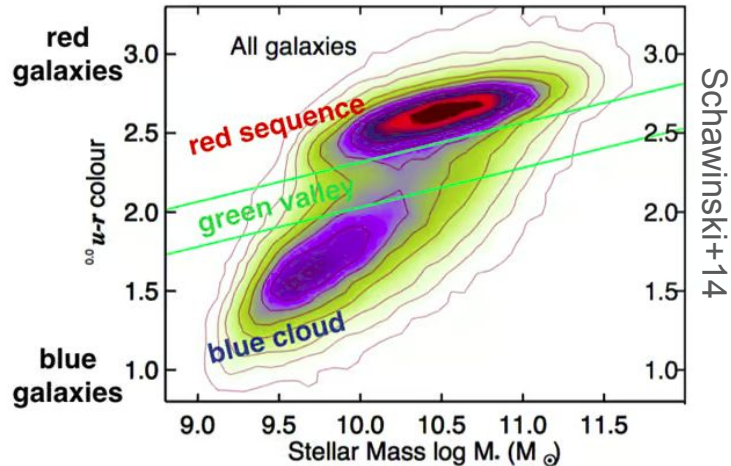
[luidhy@cbpf.br](mailto:luidhy@cbpf.br)

On behalf of the DELVE Collaboration

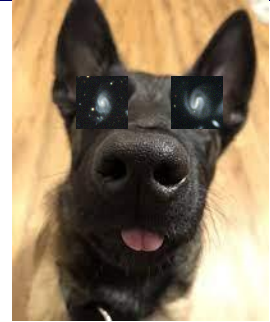


# Galaxy Morphology: why we care?

- Morphology is strongly correlated to galaxy properties.
- Colors, Star-formation, stellar mass..
- Morphology-Density relation (Dressler, 1989).



Houghton+15

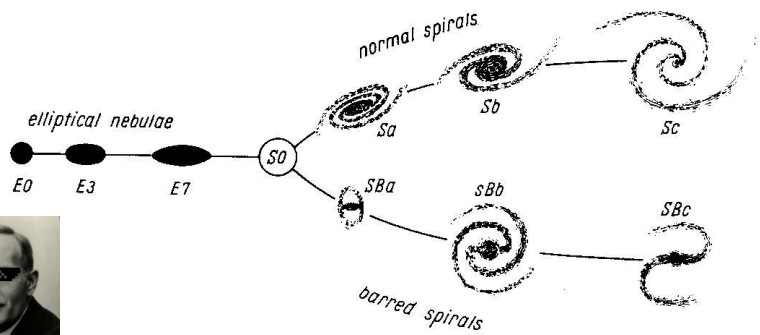


# How to classify galaxies?

- Visual Classification.
- ETG & LTG.
- Timeband consuming in the scale of surveys such as DELVE, DES, DESI.....

## Alternative Methods

- Galaxy Zoo (Lintott+08,+11).
- Machine Learning (Clarke+20,Barchi+20..).
- Deep Learning and Deep Neural Networks (.....Bom+21)

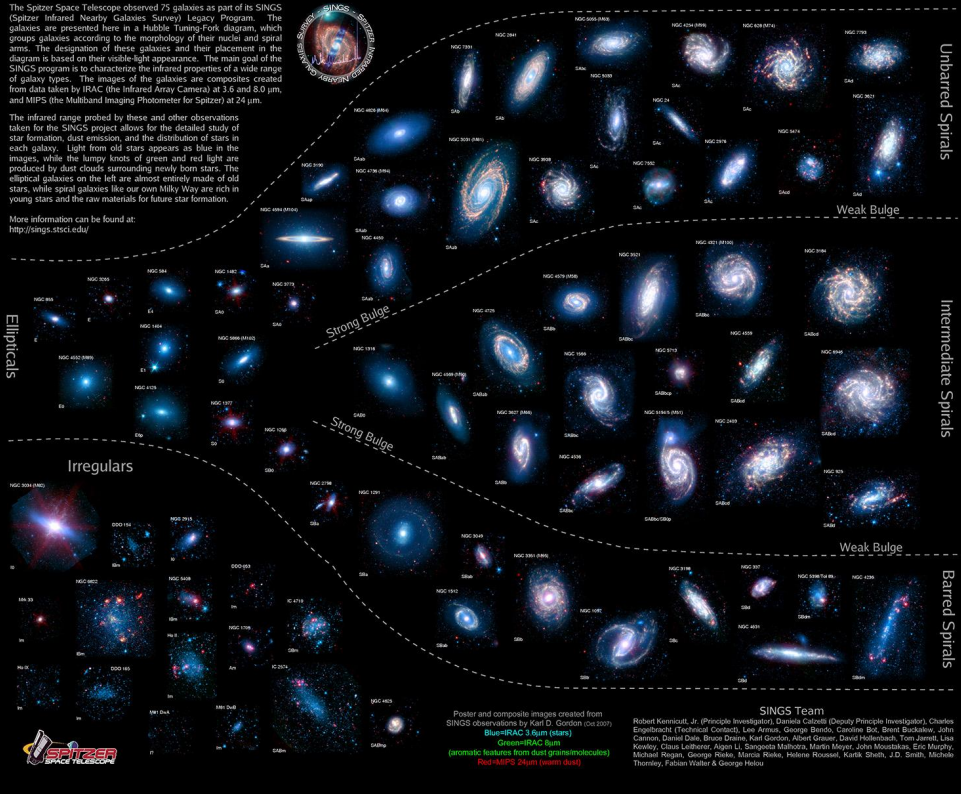


## The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0  $\mu\text{m}$ , and MIPS (the Multiband Imaging Photometer for Spitzer) at 24  $\mu\text{m}$ .

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the hazy looks of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at: <http://sings.stsci.edu/>

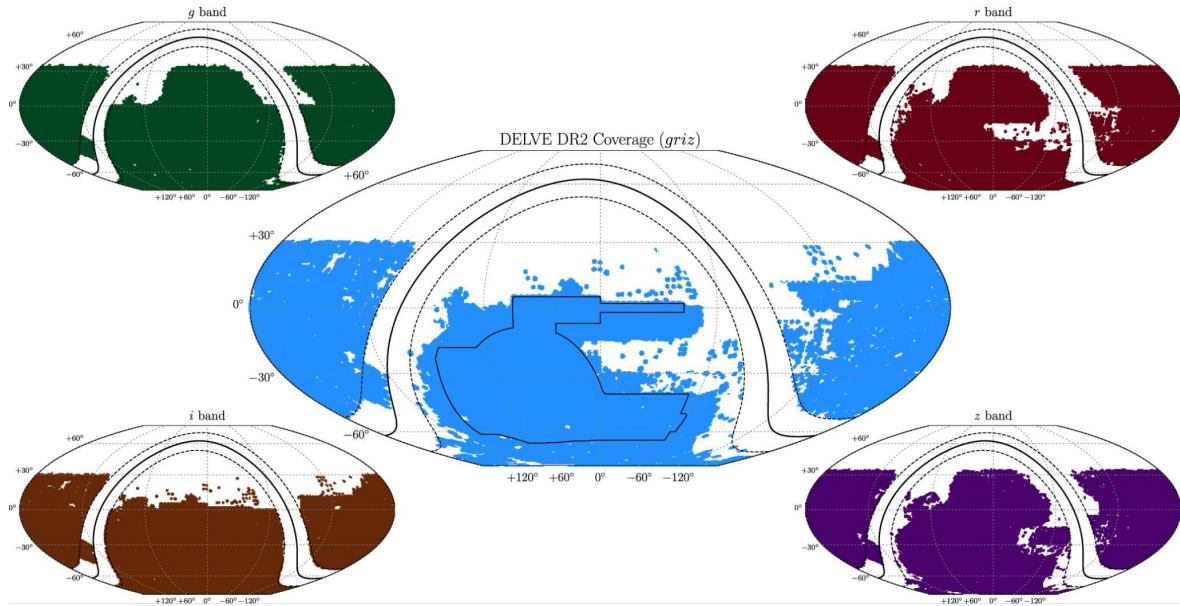
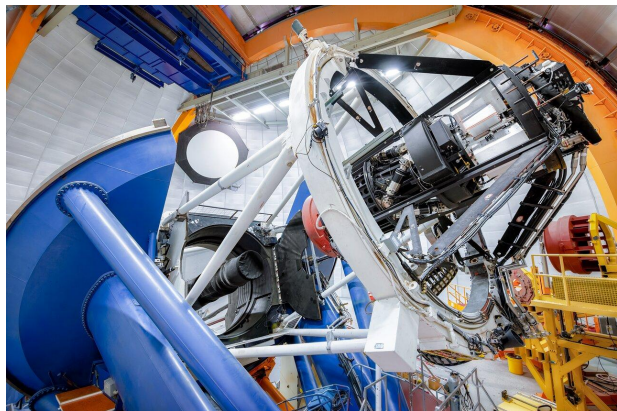


Poster and composite images created from SINGS observations by Karl D. Gordon (2012) (Blue+IRAC 3.6um stars) Green+IRAC 8um (aromatic features from dust grains+relics) Red+MIPS 24um (new stars)

SINGS Team  
 Robert Kennicutt, Jr. (Principal Investigator), Daniela Calzetti (Co-principal Investigator), Charles Engelbracht, Eric Ostriker, George Bendo, Swaminath Bal, Brent Brinkman, John Carron, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grais, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Alton Li, Sanyal Malhotra, Hans Meier, John Moustakas, Eric Mumford, Michael Ragan, George Rieke, Marcos Rieke, Helene Roussel, Karik Sheth, J.D. Smith, Michele Throner, Fabian Voigt & George Helou

# DECam Local Volume Exploration Survey (DELVE)

- 4 filters (g,r,i,z).
- Dark Energy Camera, Blanco Telescope, 0.26 arcsec/pixel.
- 17000 deg<sup>2</sup> (~23.5 mag).
- ~ 3 billion unique objects.



Drlica-Wagner & DELVE collaboration +21,22

# DECam Local Volume Exploration Survey (DELVE)

May 22:

**Searching for the Universe's Faintest Galaxies in our Galactic Neighborhood** (William Cerny).

*Lightning IV:*

**A measurement of the Hubble constant using dark sirens from the first four LIGO/Virgo observing runs with galaxy information from DELVE and DESI Legacy Survey** (Viviane Alfradique)

**Satellites of dwarf galaxies with the MADCASH+DELVE survey**  
(Amandine Doliva-Dolinsky)

# Galaxy Morphology on DELVE

## Main Goals:

- Provide reliable morphological classification for galaxies observed by DELVE down to magnitude 22 (g-band), and  $S/N > 5$ .
- Model I: Disk and Spheroids.
- Model II: Disturbed, Round-Smooth, Barred Spiral, Unbarred Spiral, Edge-on galaxies (work in progress).
- Investigate galaxy morphology across different environments and redshifts.

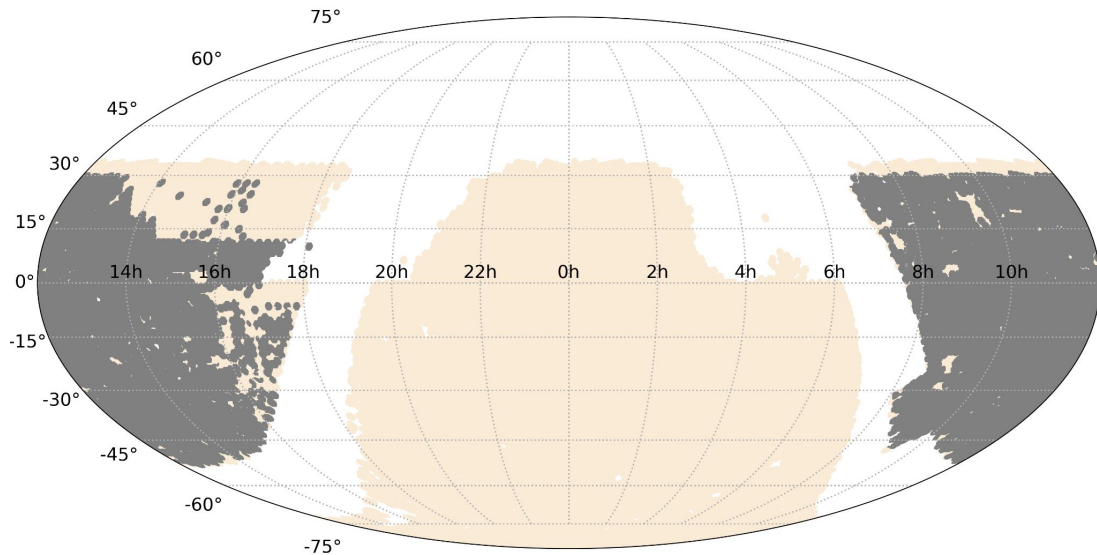


Santana-Silva (in prep.)

# Galaxy Morphology on DELVE

## Selection:

- Main catalog:  $g < 22.5$ ,  $b > 0$ , *Extendend\_Class* = 3, images ( $g,r,i,z$ ), Flags = 0.
- Main catalog:  $\sim 20$  million galaxies ( $\sim 20$  Tb of cutout data).
- Logistics: stamp production (DES machines), Training models (Scimind - CBPF).

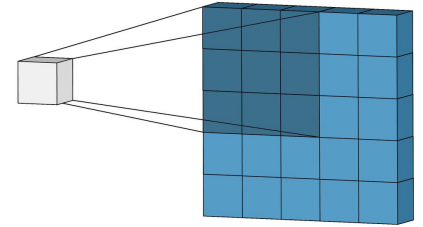


Santana-Silva (in prep.)

# Convolutional Neural Networks (CNN)

- It learn features by using filter (kernel) applications.
- Widely used in image recognition problems.
- Need a good training sample.

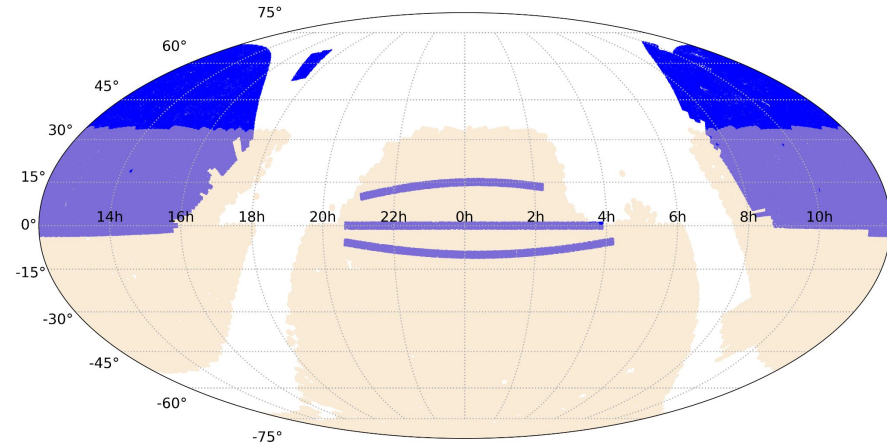
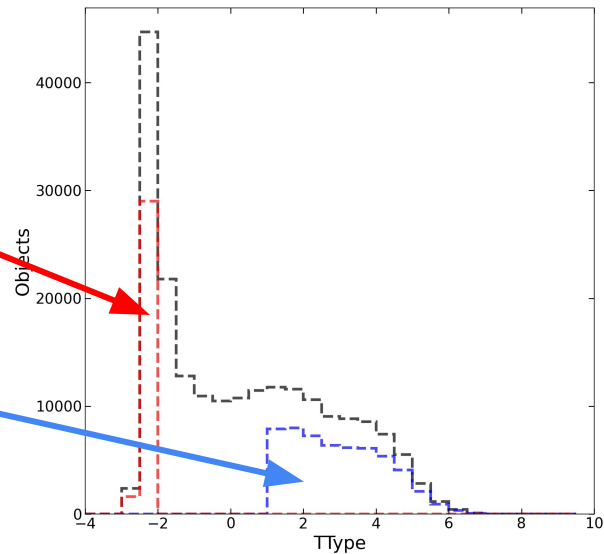
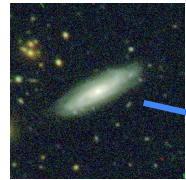
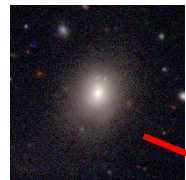
**How to confuse  
machine learning:**





# Galaxy Selection to training

- Training sample: Dominguez+18 (TType selection)
- Overlap with 200k objects available at Dominguez+18.



# CNN applied to morphology classification

- 60000 galaxies.
- Binary classification: Disk and Spheroids.
- 70% (train), 20% (validation), 10% (test).
- Hardware: 8 GPUs (Nvidia A5000)



SCI.MIND-CBPF

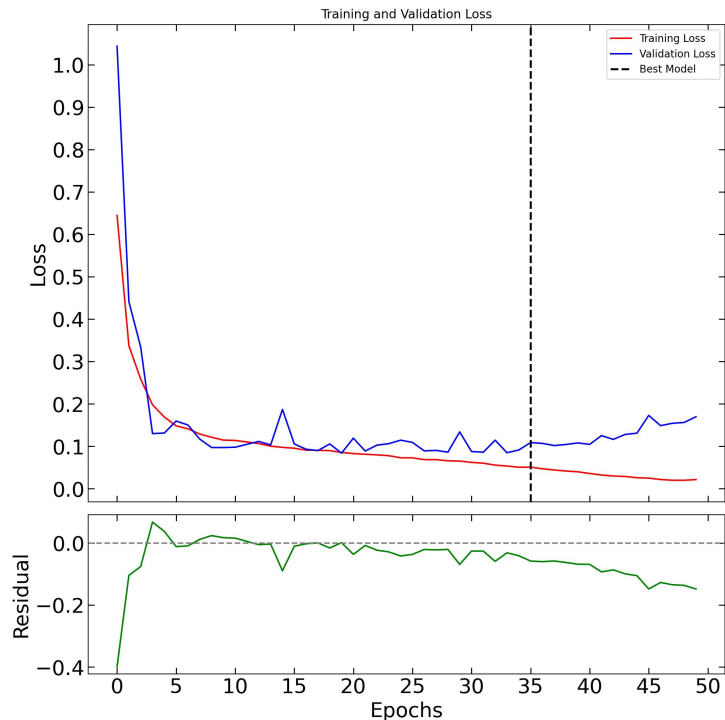
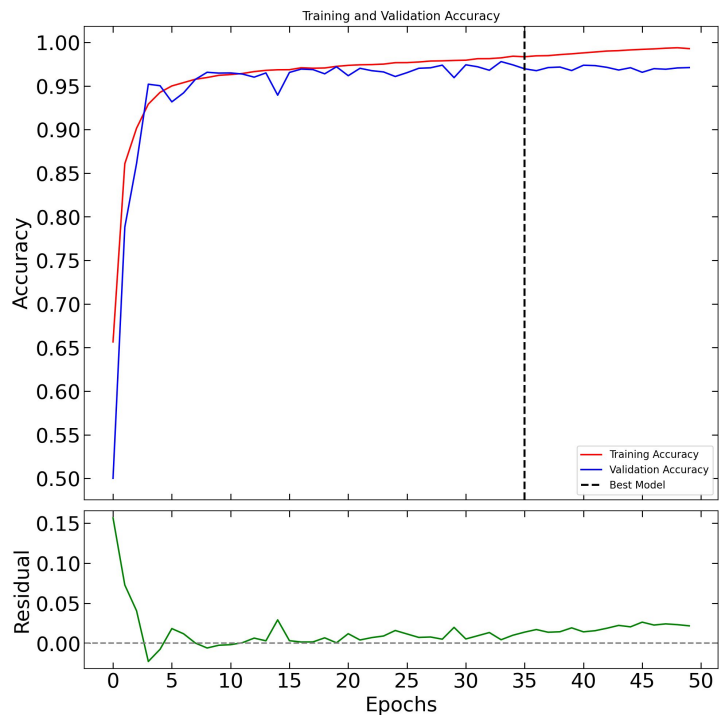


Santana-Silva (.in prep)



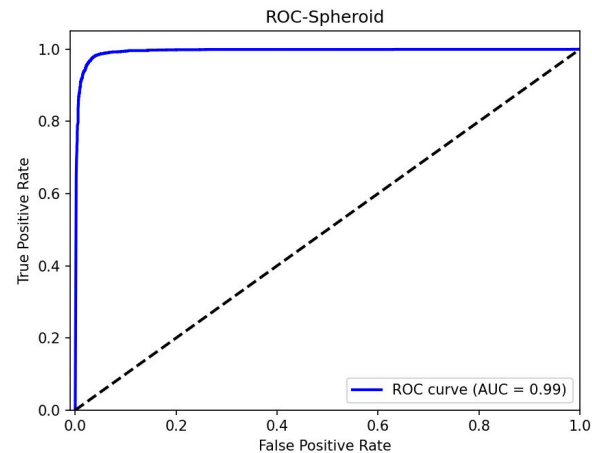
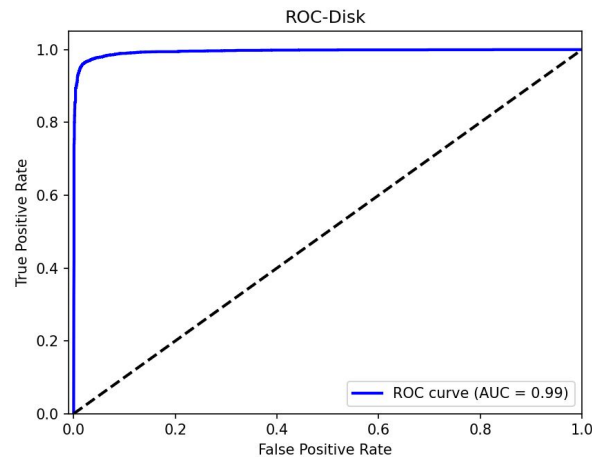
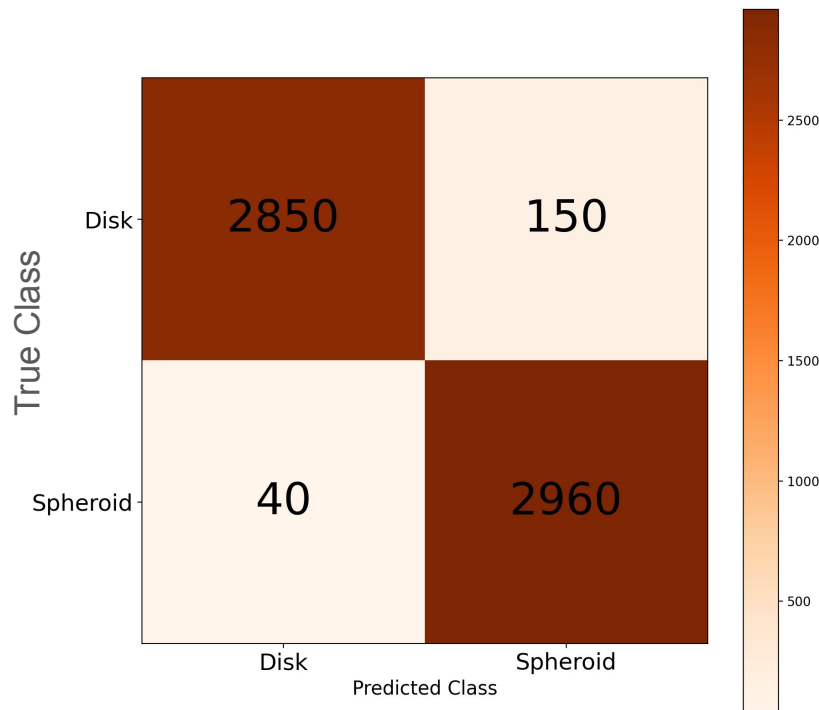
# CNN Results

- 60000 galaxies.
- Binary classification: Disk and Spheroids.
- 70% (train), 20% (validation), 10% (test).



# CNN Results

- Binary classification: Disk and Spheroids.
- 6000 for testing.
- Precision = 98,67 , Recall = 95,18

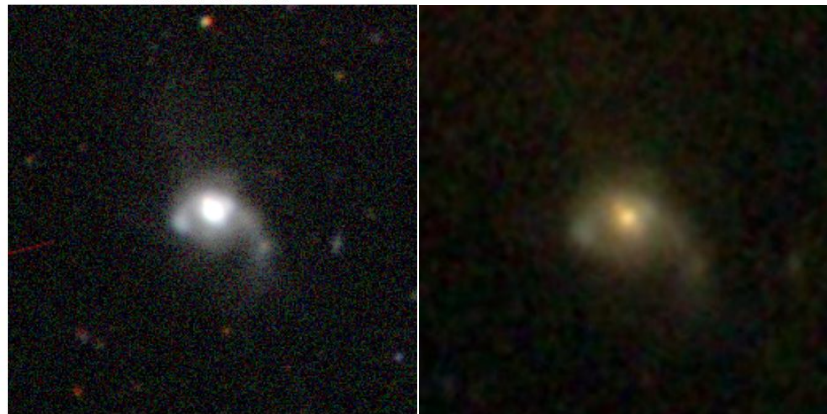


# CNN (wrong classifications)

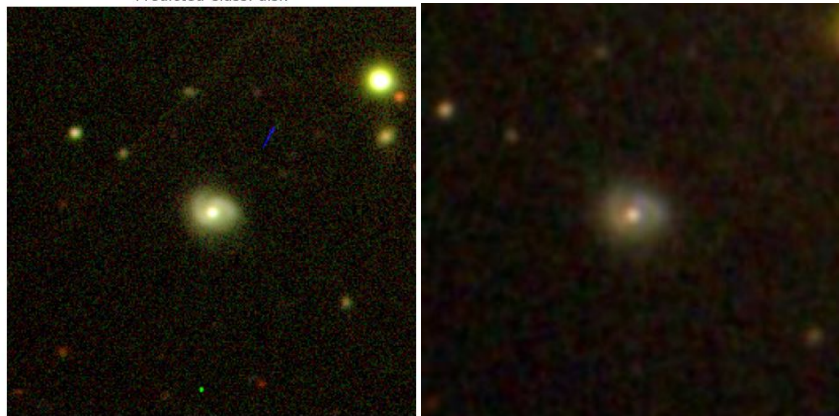
QUICK\_OBJECT\_ID: 10305200037838  
Class: disk  
Predicted Class: spheroid



QUICK\_OBJECT\_ID: 10369100065202  
Class: spheroid  
Predicted Class: disk



QUICK\_OBJECT\_ID: 10397500055712  
Class: spheroid  
Predicted Class: disk



QUICK\_OBJECT\_ID: 10526600166629  
Class: spheroid  
Predicted Class: disk



# Summary

- Galaxy morphology plays an important role to understand galaxy formation and evolution.
- The amount of data in modern astronomy turns infeasible the classification using visual inspection.
- The model is efficient to classify galaxies observed on DELVE with precision  $\sim 98\%$ .
- 4 million galaxies already done.
  
- *Release the morphology catalog with the binary classification.*
- *Implement the model with more complex classification.*
- *Connect the morphology classification with the photometric measurements in order to investigate the environment.*

# For now, that's all folks!!!

Special Thanks to:

