Identification and annotation of numerical simulations of galaxy collisions.

Proto-cluster from TNG50 simulation.

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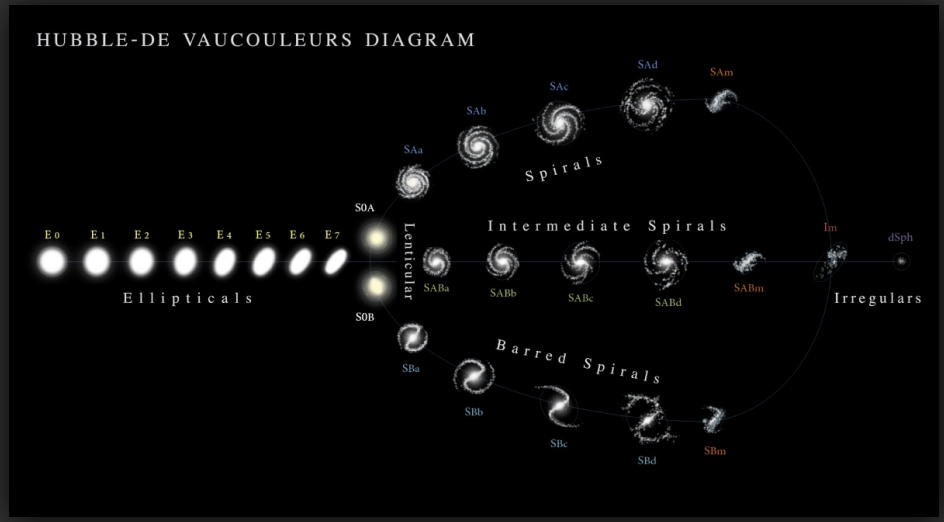
Introduction

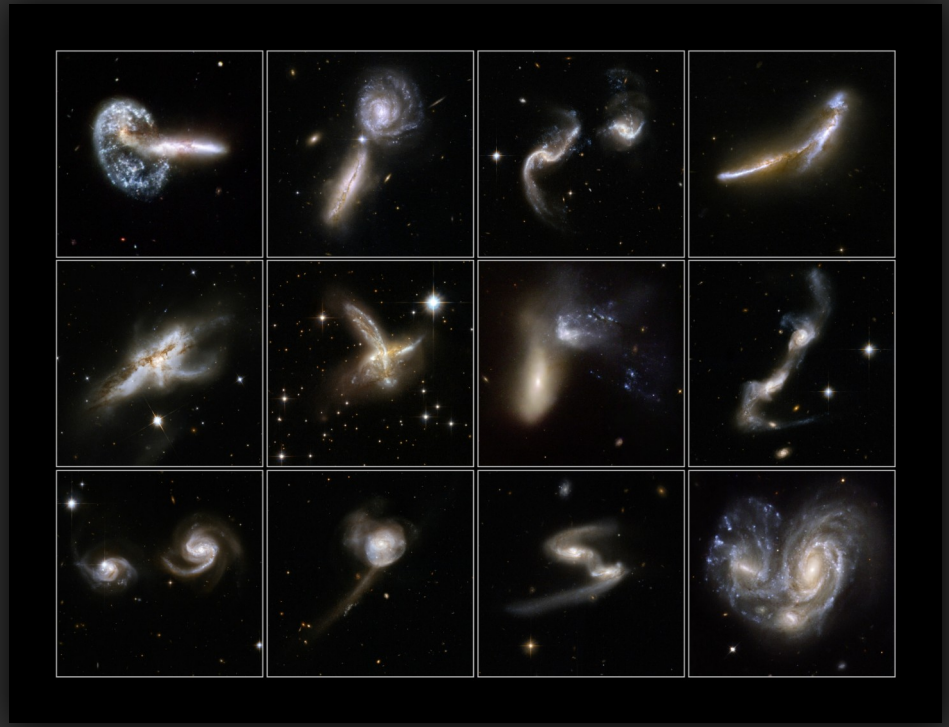
- Galaxy: stars, gas, dust, dark matter
- Two main families: spiral and elliptical
- Diversity of morphologies and internal properties



https://en.wikipedia.org/wiki/File:Hubble-Vaucouleurs.png

Introduction

- Tend to interact, collide and merge
- Source of the observed diversity
- Gravitational interaction:
  - Deformation of galaxies
  - Apparition of tidal debris

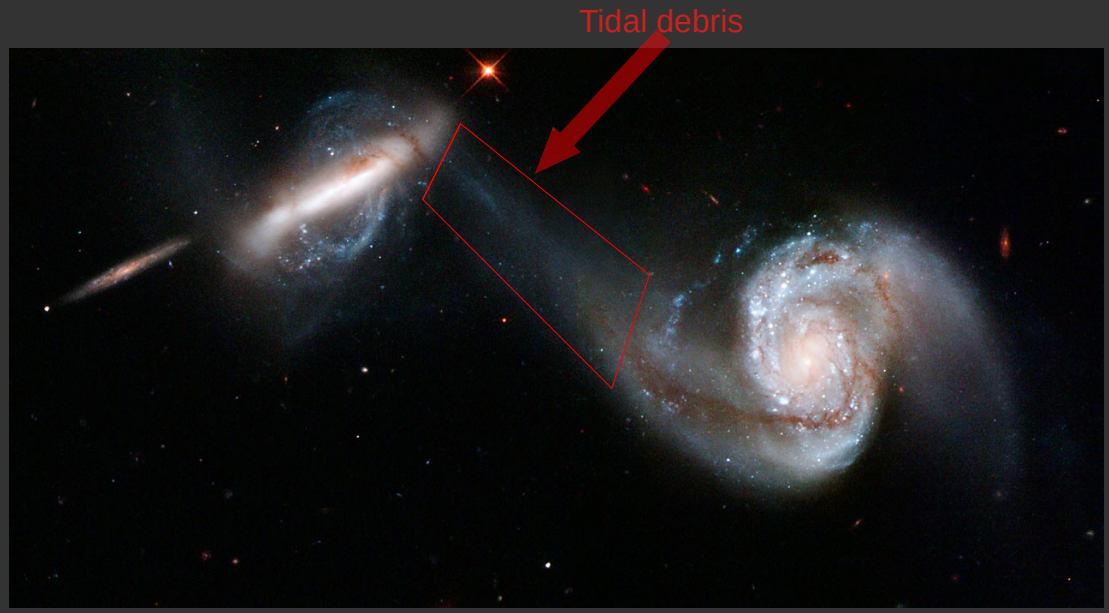


NASA/ESA

Introduction

- Tidal debris: directly linked to galaxies history
- Problem:
  - Faint and extended
  - Low contrast

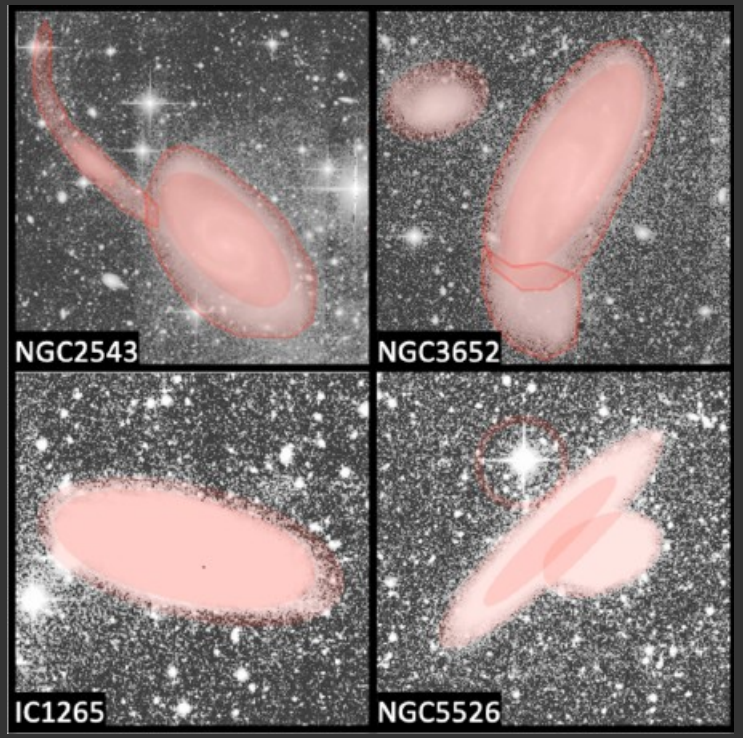
  ⇨ Hard to observe
- Each image of galaxy must be characterized by hand: long process



Arp 87, NASA/ESA

Annotation and previous works

- Development of an annotation tool
- Intuitive and visual annotation
- Goal:
  - Identify, highlight and label tidal structures on galaxy images
  - Extract properties of this debris
- Large number of annotations already performed



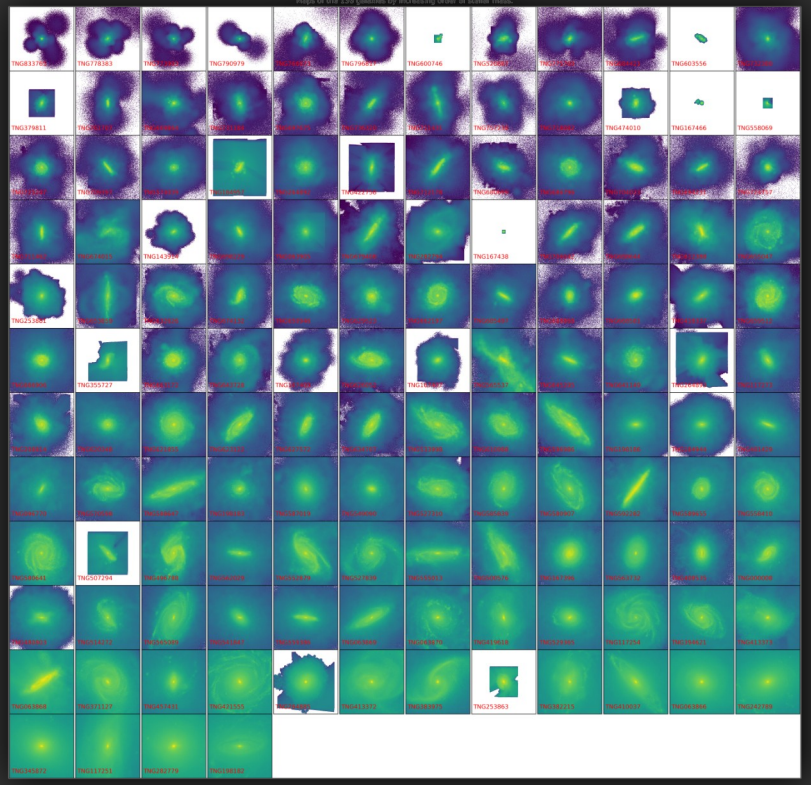
E.Sola et al.

Goals of the project

- Annotate images from simulation
- Interest of simulation:
  - Understand plurality of observations
  - Constrain models of galaxy evolution
- Adapt and characterize a sample of simulated galaxies, annotate them and extract properties of tidal debris

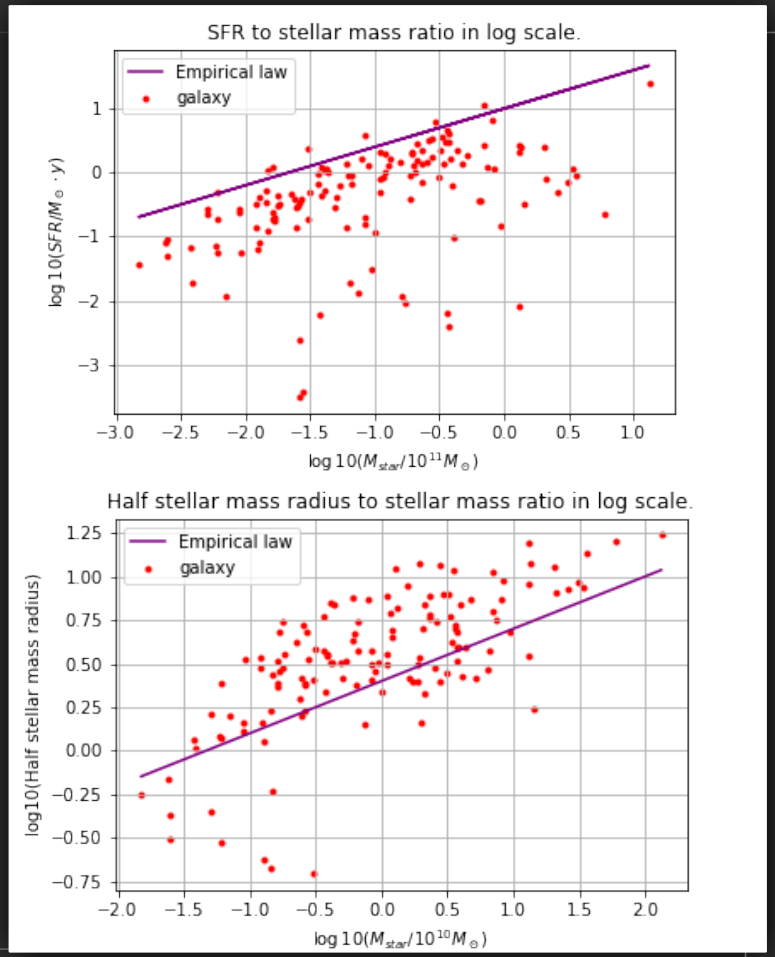
Characterization

- Our initial sample: 136 galaxies
- First step: check if our sample is consistent with observed galaxies
- Visual inspection:
  - Realistic aspect
  - Mainly spirals
  - Some very large galaxies



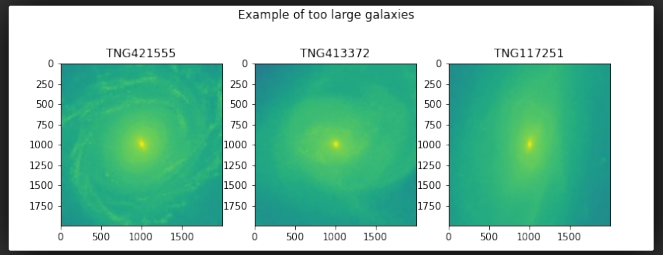
Characterization and scale relations

- Scale relation: link a “size” properties (radius, mass, etc…) to an other property
- Empirical relation.
- Our sample: consistent with this relation



Characterization

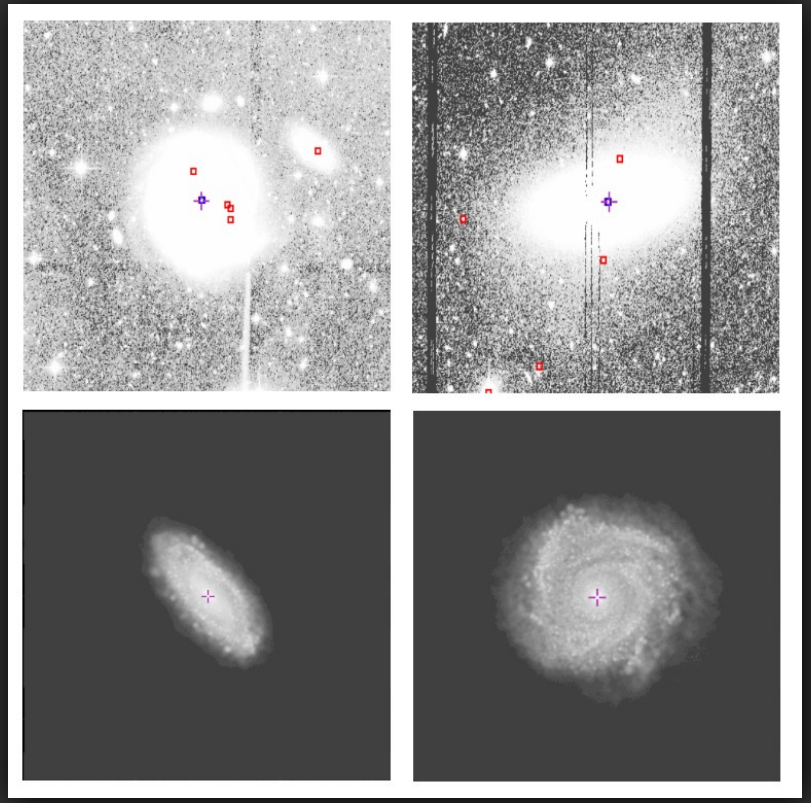
- Advantages:
  - Realistic aspects
  - Realistic shapes
  - Scale relations
- Counterparts:
  - Large number of spiral galaxies
  - Small FOV



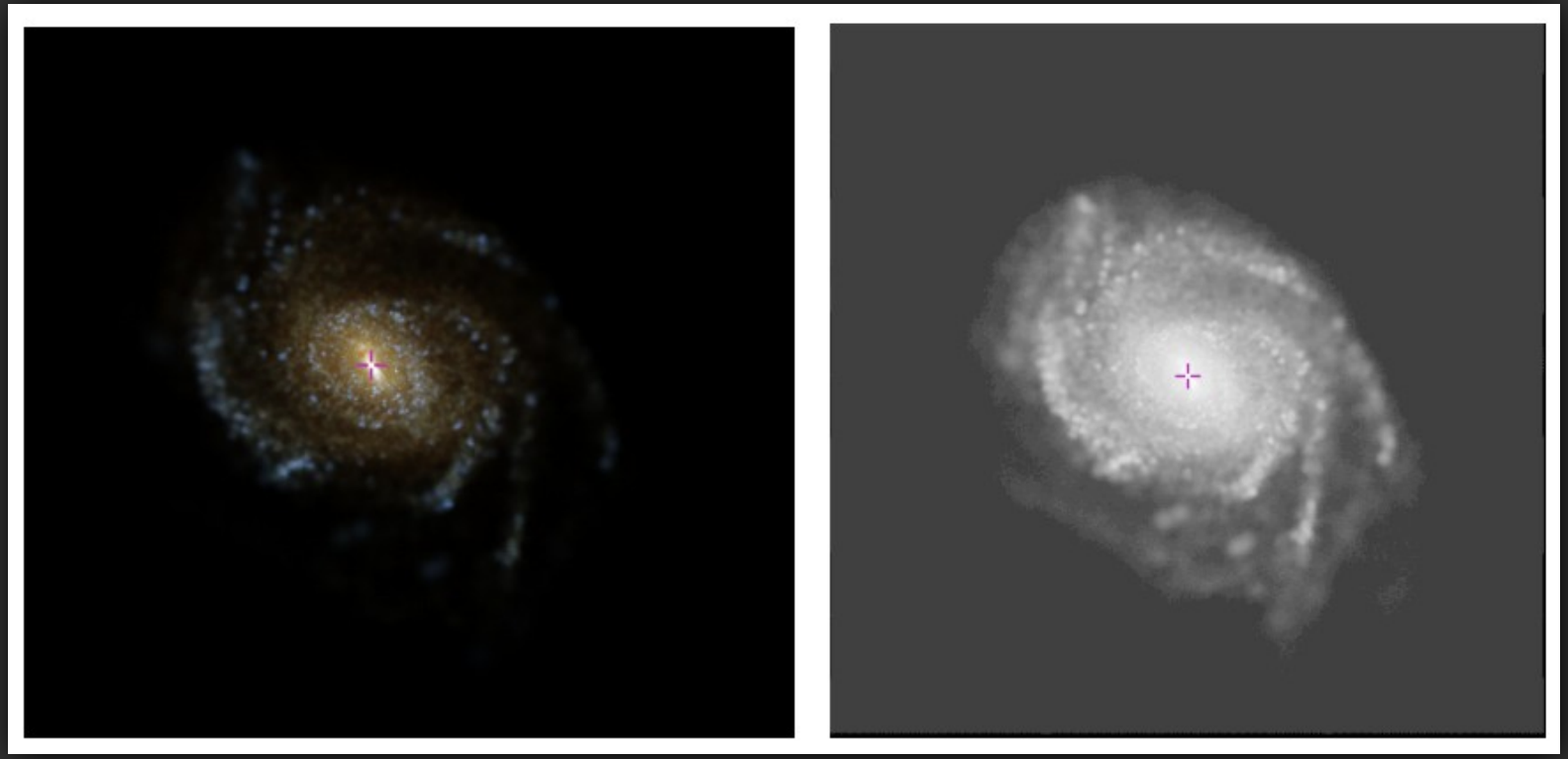
- Physical properties: consistent with observations

Preparation of the images

- Annotation tool: support only a specific extension ⇨ Need to convert raw images.
- Adapt to look like real images ⇨ Find optimal parameters.
- We kept 53 images from the 136.

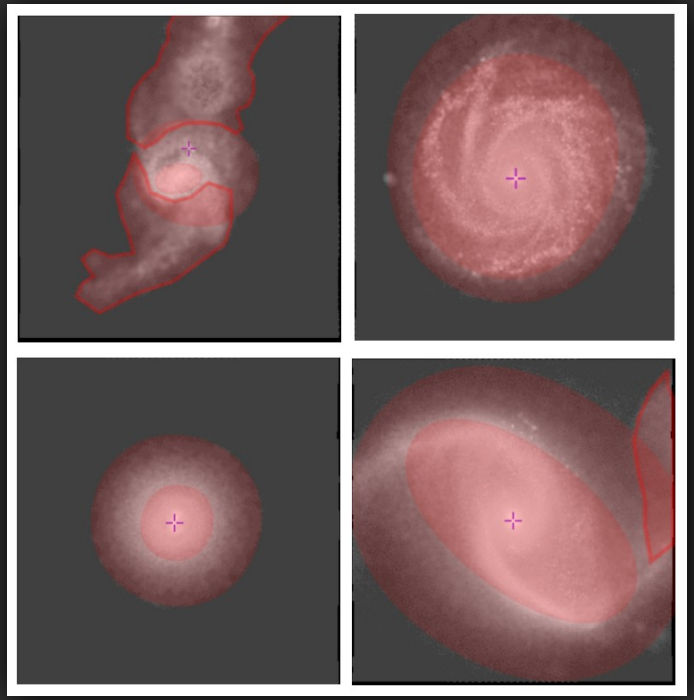


Preparation of the images

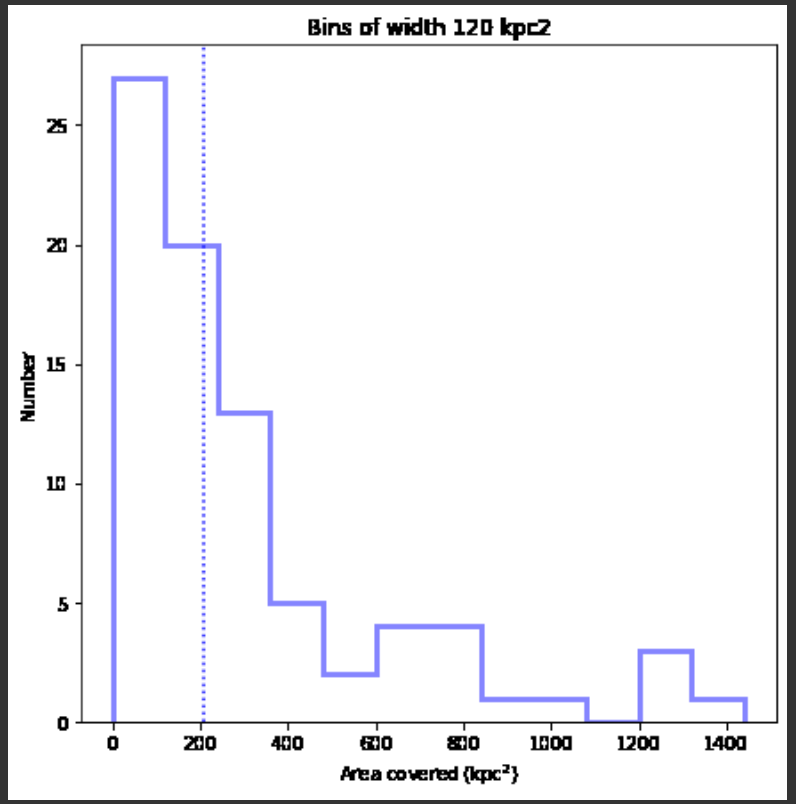


Annotation and preliminary results

- Highlight main galactic components and tidal features:
  - Brightest part
  - Halo
  - Tails/plumes
- Allow access to their main properties:
  - Area
  - Size
  - Surface brightness
- Quantitative analysing of tidal debris



Annotation and preliminary results



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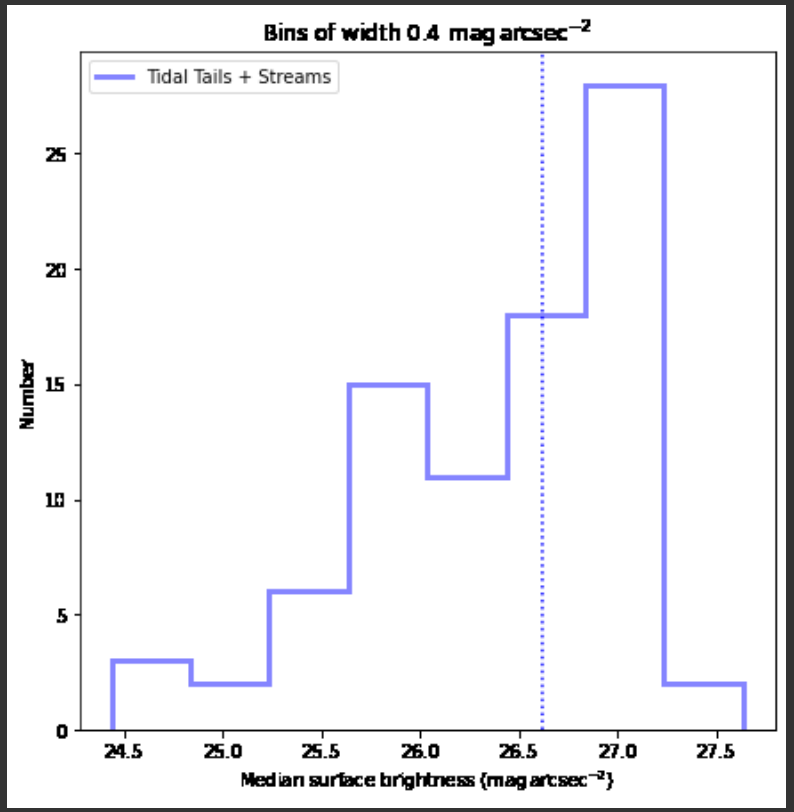

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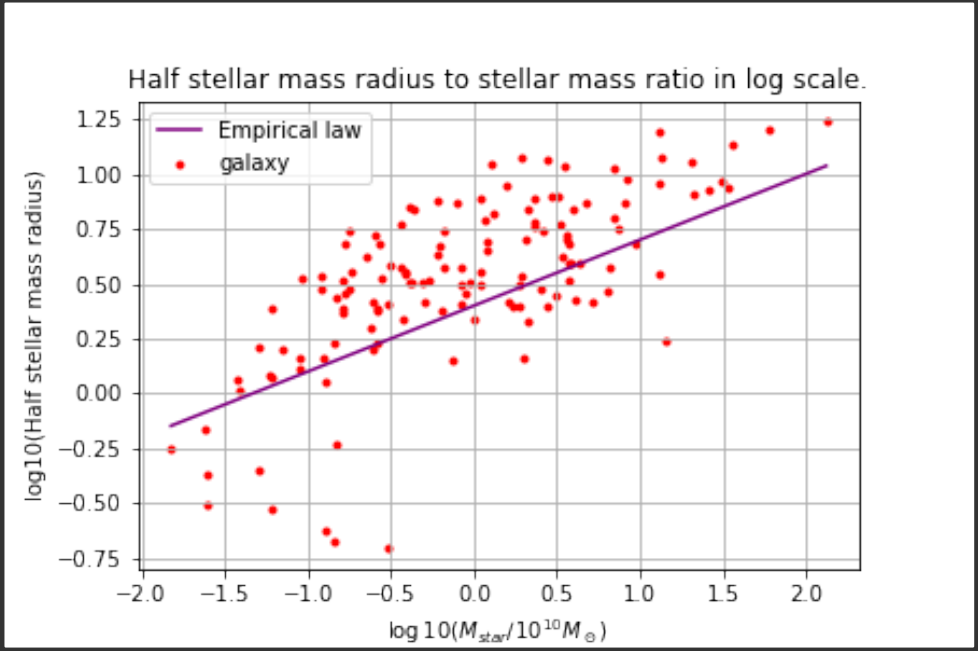
Conclusion and future prospects

- Heart of the project:
  - Characterize a sample of simulated galaxies
  - Annotation
  - Extraction of informations
- Properties of tidal debris ⇨ Redraw the history of the galaxy

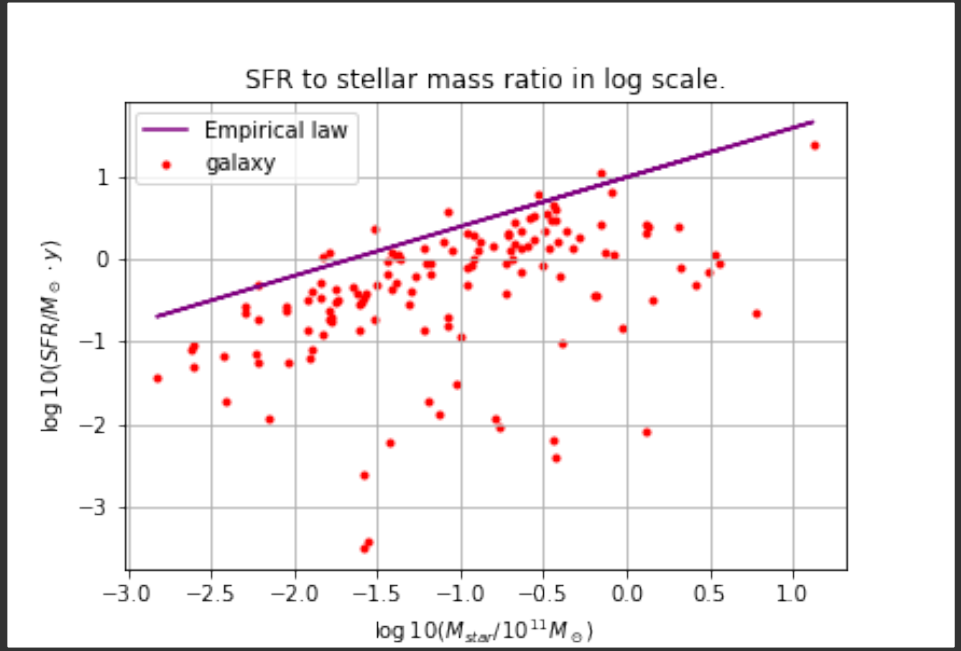
Conclusion and future prospects

- Next steps:
  - Better sample, much representative
  - Annotate more galaxies
  - Compare with annotations from real images
- Final goals: machine learning and automatization of the process

Annexe: Scale relations

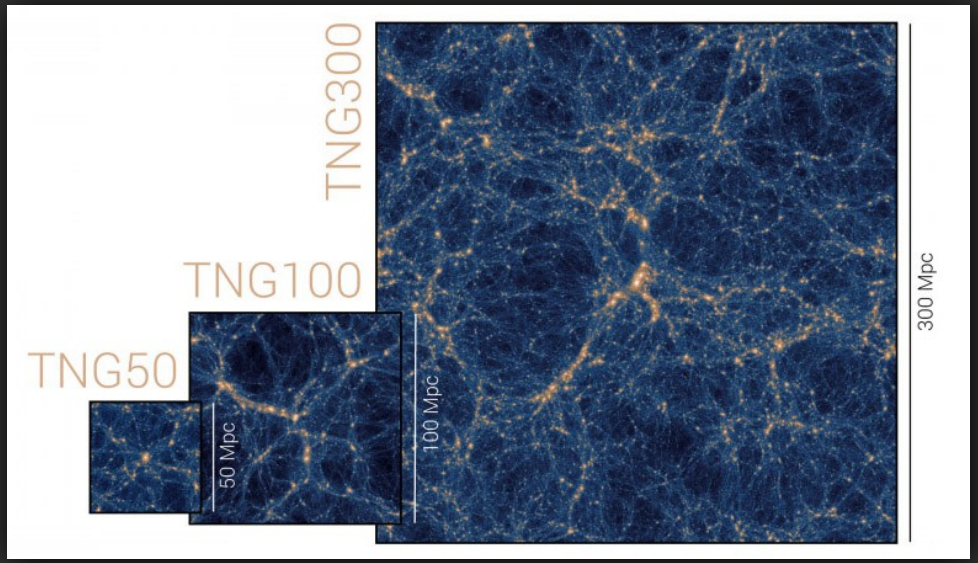


$$\log_{10}\left(\frac{R_d}{1\,kpc}\right) = H + \xi \log_{10}\left(\frac{M_{star}}{10^{10}\,M_{sun}}\right), H \approx 0{,}4\,, \kappa \approx 0{,}6$$



$$\log_{10}\left(\frac{SFR}{M_{sun}\,year^{-1}}\right) = Y + \kappa \log_{10}\left(\frac{M_{star}}{10^{11}\,M_{sun}}\right), Y \approx 1\,, \xi \approx 0{,}2$$

Annexe: The *Illustris TNG* simulations

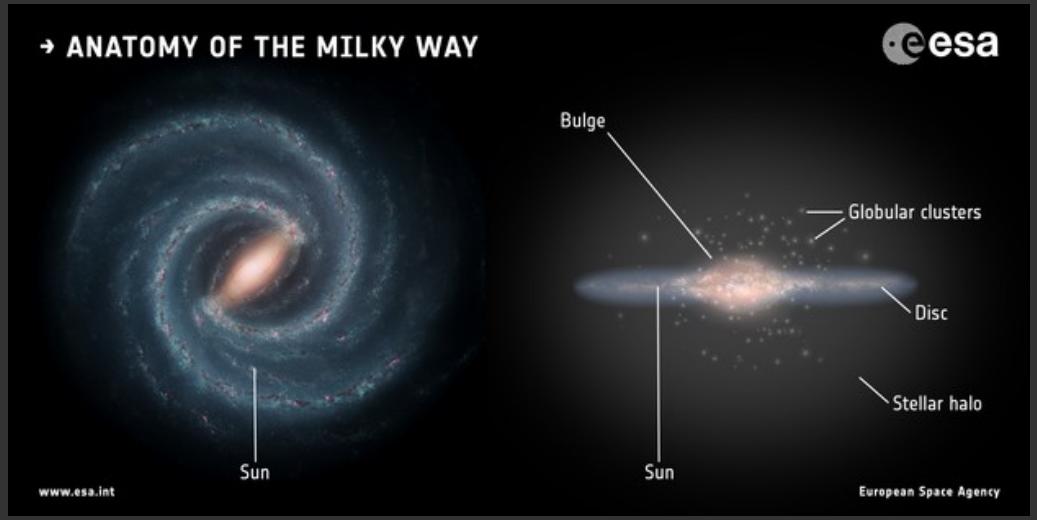


Illustris TNG

- Cosmological simulations of galaxies formation
- Hydrodynamical simulation
- 18 simulations
- Different size of simulated universe
- TNG50: $51,7^3$ Mpc

Reminder: 1pc=3.26 al

Annexe: Substructures of a galaxy.



ESA/NASA

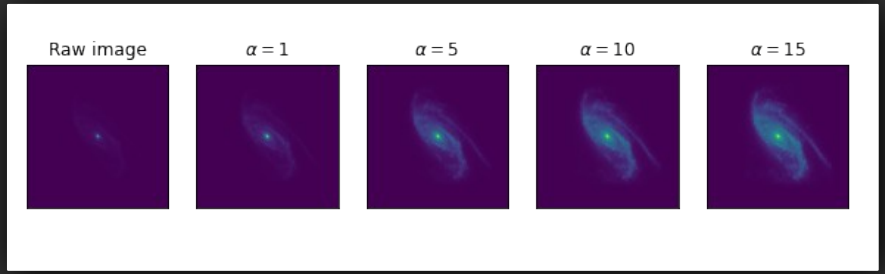
- Different sub-structures:
  - Main galaxy
  - Stellar halo
  - Dark matter halo
- Components:
  - Dark matters
  - Stars
  - Gas
  - Dust

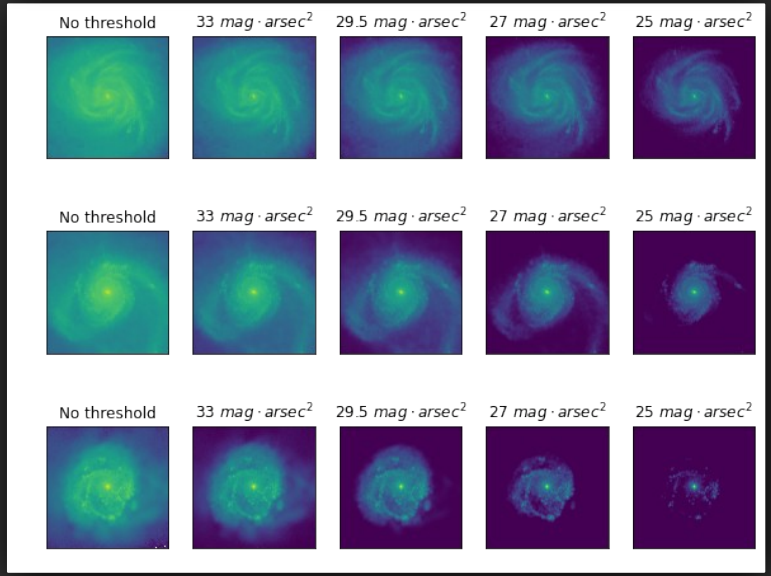
Annexe: optimization of conversion

- Conversion:

$$y = \log_{10}\left(\alpha(x-\beta) + \sqrt{\alpha^2(x-\beta)^2 + 1}\right), \alpha, \beta \in \mathbb{R}$$

- Contrast and dynamics of images
- Here: α=10, β=0
- Adapt the brightness threshold of the images





Annexe: Glitch and artefacts