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Taking a look through the Incliscope

A Probabilistic Neural Network to estimate galactic Inclinations

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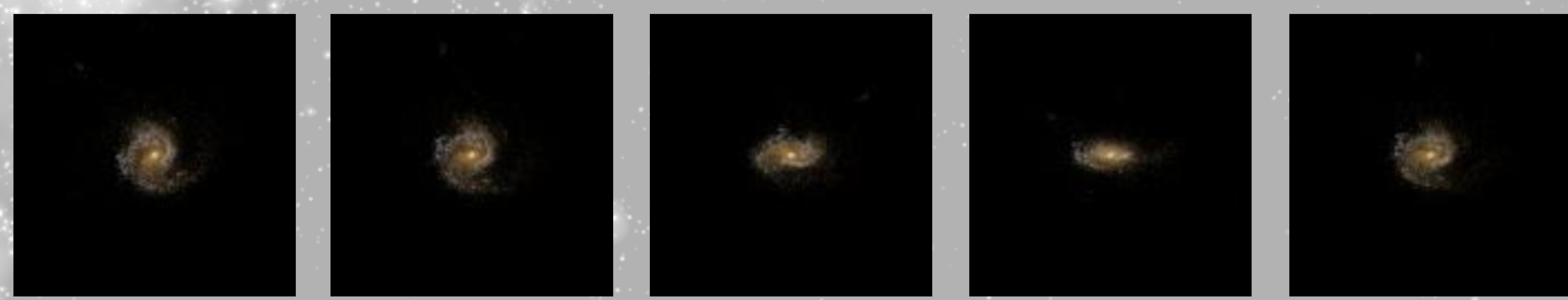
Abstract

Determining a galaxy's inclination i from an optical image is a challenging task. Currently, it relies on fitting an elliptic shape (isophote) with semimajor axis a and semiminor axis b to the disk; then solving the intrinsic axis ratio as defined by Hubble and Holmberg.

$$\cos i = \sqrt{\frac{(b/a)^2 - \alpha^2}{1 - \alpha^2}}$$

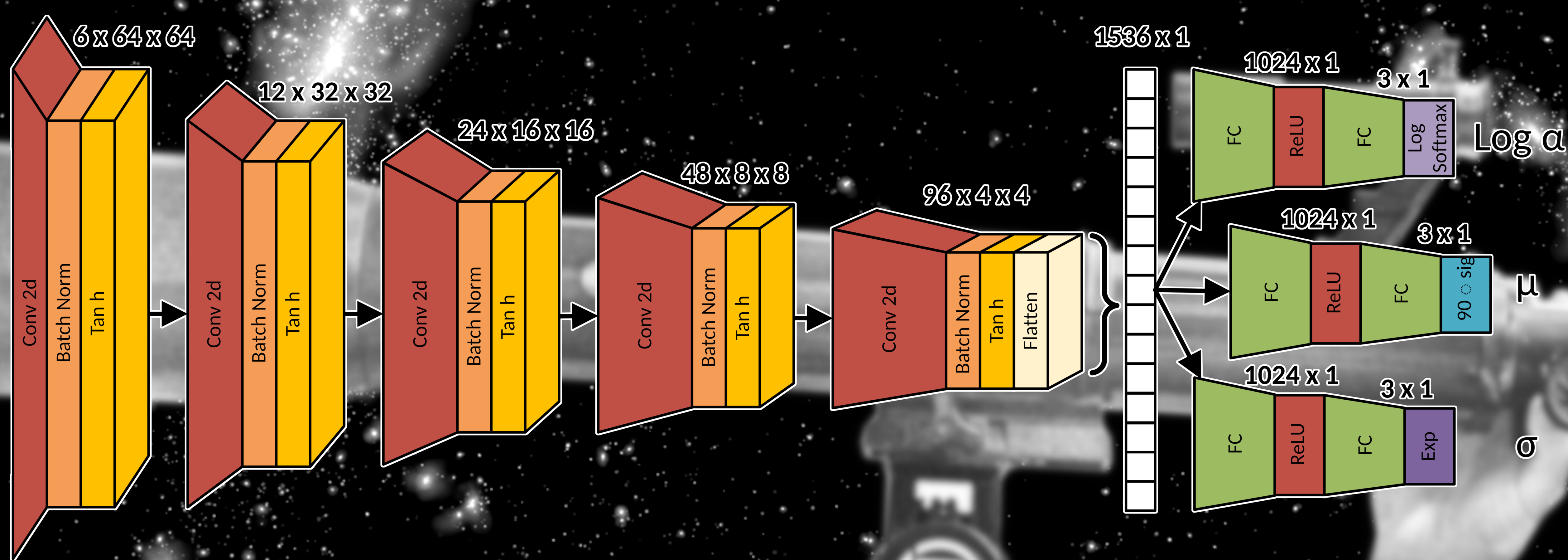
However, the method is limited by neglecting the degeneracy between 3D shape and inclination. We present the Bayesian framework **Incliscope**, a novel way to estimate inclinations of galaxies based on optical images. By collecting properly-calibrated posterior distributions among inclinations from simulated galaxies, we are able to train a **D**eep **C**onvolutional **M**ixture **D**ensity **N**etwork (**DCMDN**).

Method

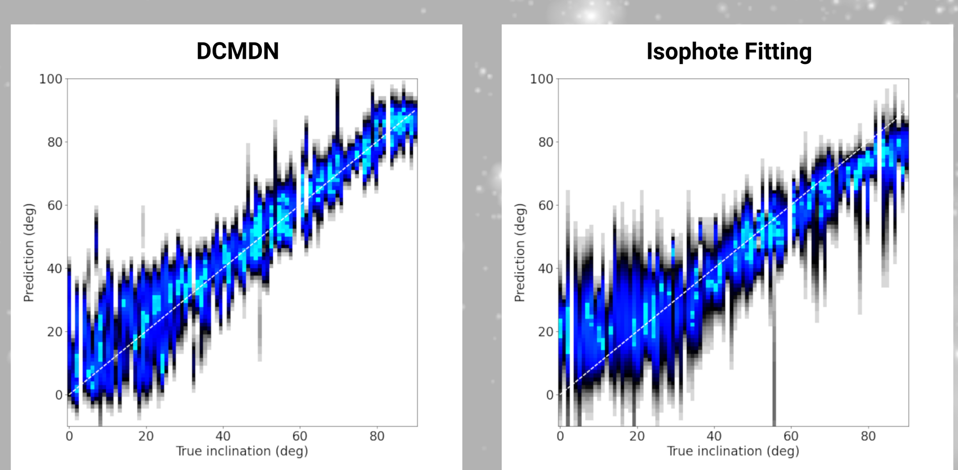


Mock images of a simulated galaxy from Illustris TNG in different orientations.

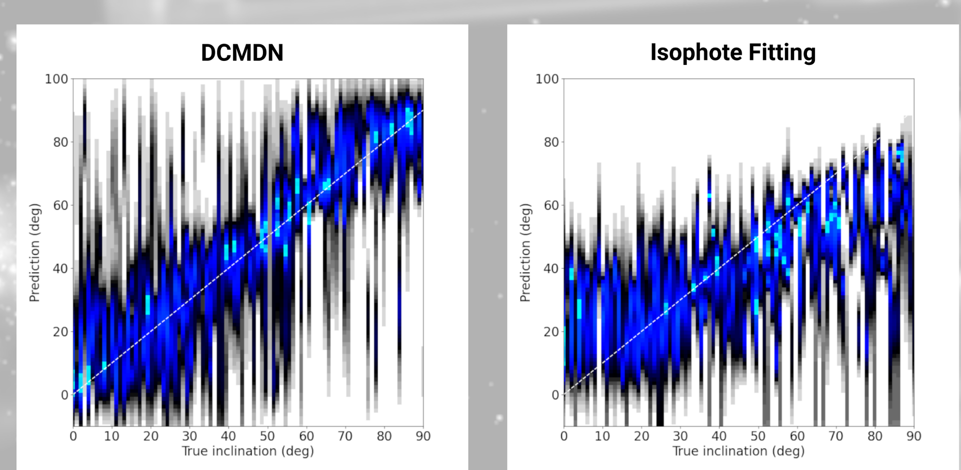
1. Collect **2,500** galaxies with at least **3000** stellar particles from **IllustrisTNG**.
2. Render **33** different **RBG images** from each galaxy by randomly changing its orientation.
3. Receive ground truth inclination distributions by bootstrapping the angular momentum.
4. Use final data set of **85,000** image-distribution tuples to train a DCMDN with **3 components**.
5. Test the model with two distinct data sets: Galaxies **with disks** and galaxies **without disks**.



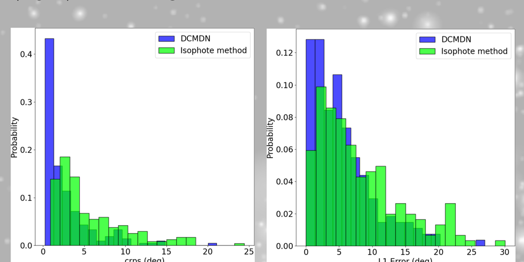
Results



Binned probability densities of the DCMDN predictions (left) and isophote fitting estimates (right) for **disk galaxies**.

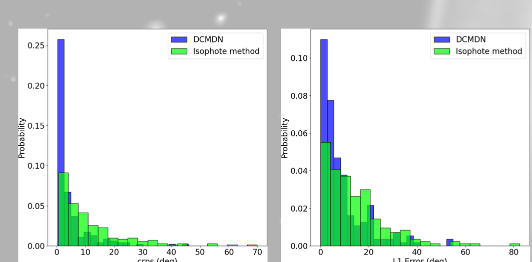


Binned probability densities of the DCMDN predictions (left) and isophote fitting estimates (right) for **non-disk galaxies**.

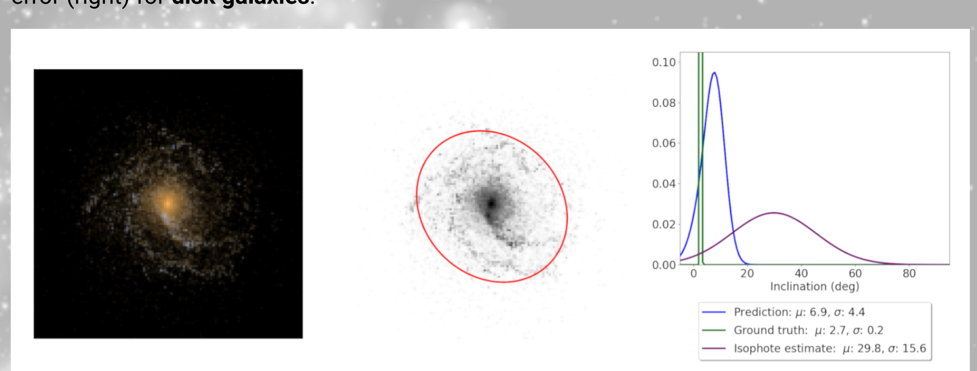


Histograms of the CRPS (left) and the absolute error (right) for **disk galaxies**.

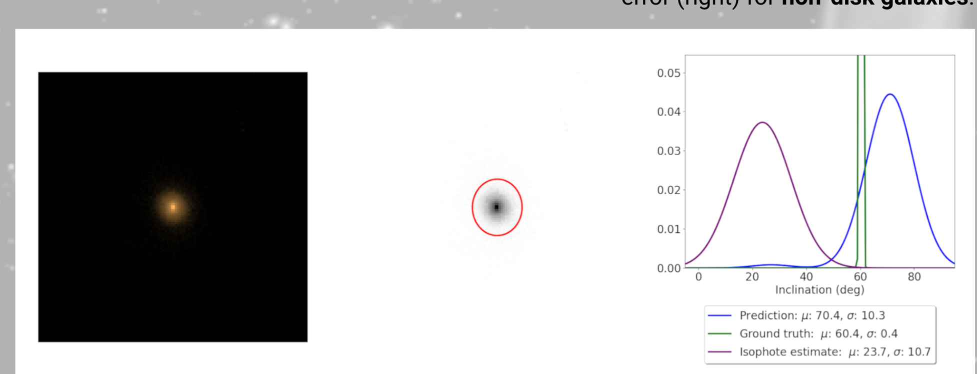
The predictions of our model on the test data were compared with the bootstrapped ground-truth, as well as with inclination estimates gathered from applying isophote fitting to the images.



Histograms of the CRPS (left) and the absolute error (right) for **non-disk galaxies**.



Results for an example **disk galaxy**. *Left:* Synthetical input image. *Center*: Ellipse fit for the isophote method. *Right:* Probability distributions describing the inclination in the image with the DCMDN prediction in blue, grount truth in green and isophote estimate in violet.



Results for an example **non-disk galaxy**. *Left:* Synthetical input image. *Center*: Ellipse fit for the isophote method. *Right:* Probability distributions describing the inclination in the image with the DCMDN prediction in blue, grount truth in green and isophote estimate in violet.

Conclusions

- ✔ DCMDN predictions accurate within 5° for disk and within 8° for non-disk galaxies
- ✔ Properly calibrated uncertainties
- ✔ DCMDN outperforms isophote fitting, especially in extreme inclinations
- ✔ The model gives stable and decent predictions for non-disk galaxies
- ✔ Predicting with a trained model is significantly faster than fitting isophotes

Learn more

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Incliscope Sources:
https://github.com/SirrahErydya/Incliscope