Mapping Dark Matter in Galaxy Clusters with Artificial Intelligence and Machine Learning

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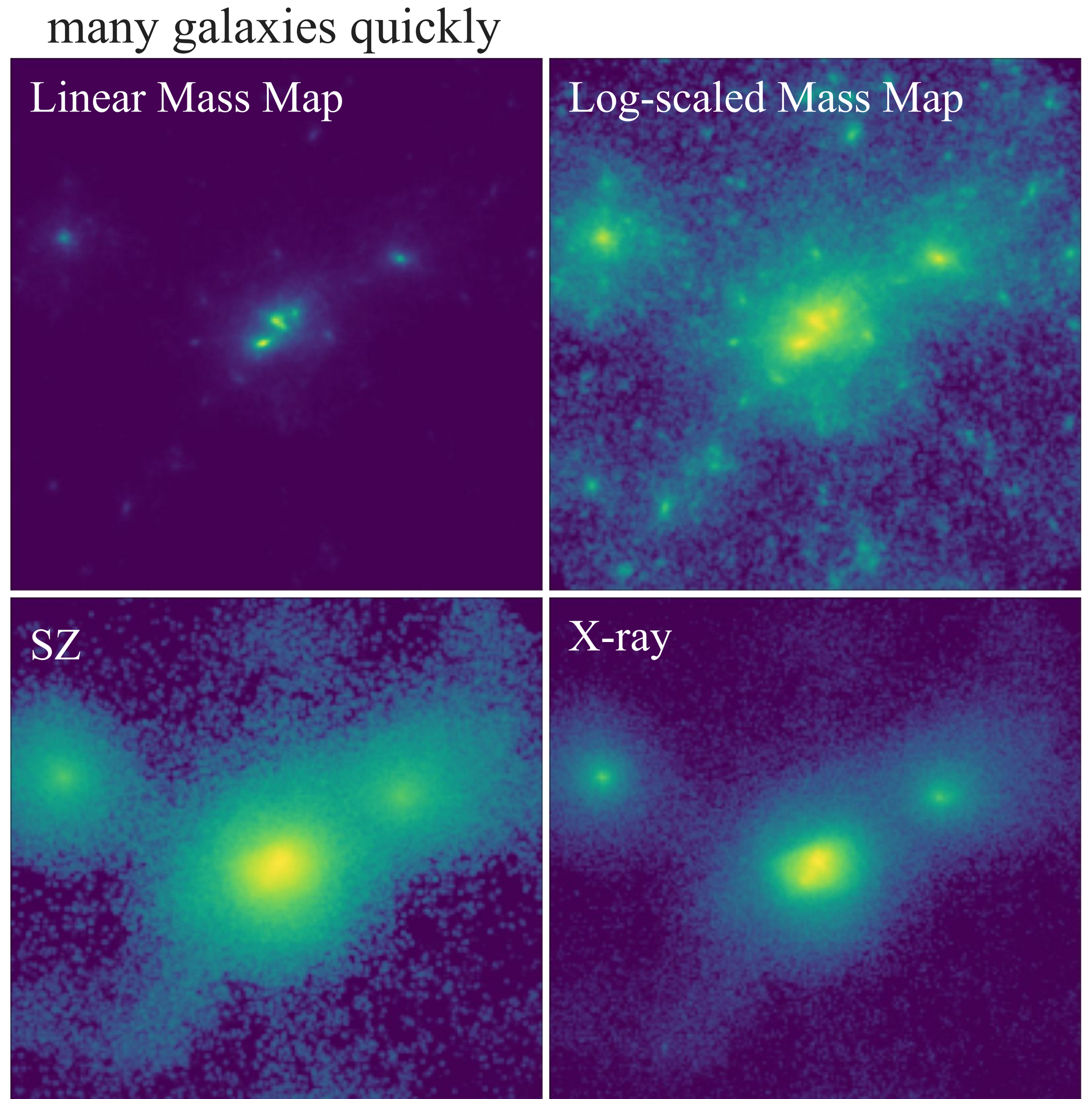
Introduction

- Dark Matter makes up more than 80% of matter in galaxy clusters and can only manifest in a few ways
- Galaxy cluster mass can be indirectly measured through observations of weak-lensing, X-ray emission, or SZ effects
- *Weak lensing:* characterized by the distortion such as magnification and shearing of images of background galaxies from massive objects like galaxy clusters
- *X-ray:* emitted from the hot, ionized gas that exist in galaxy clusters
- *Sunyaev-Zel'dovich Effect (SZ):* a scattering of CMB photons scattering in hot, ionized gas

HYPER

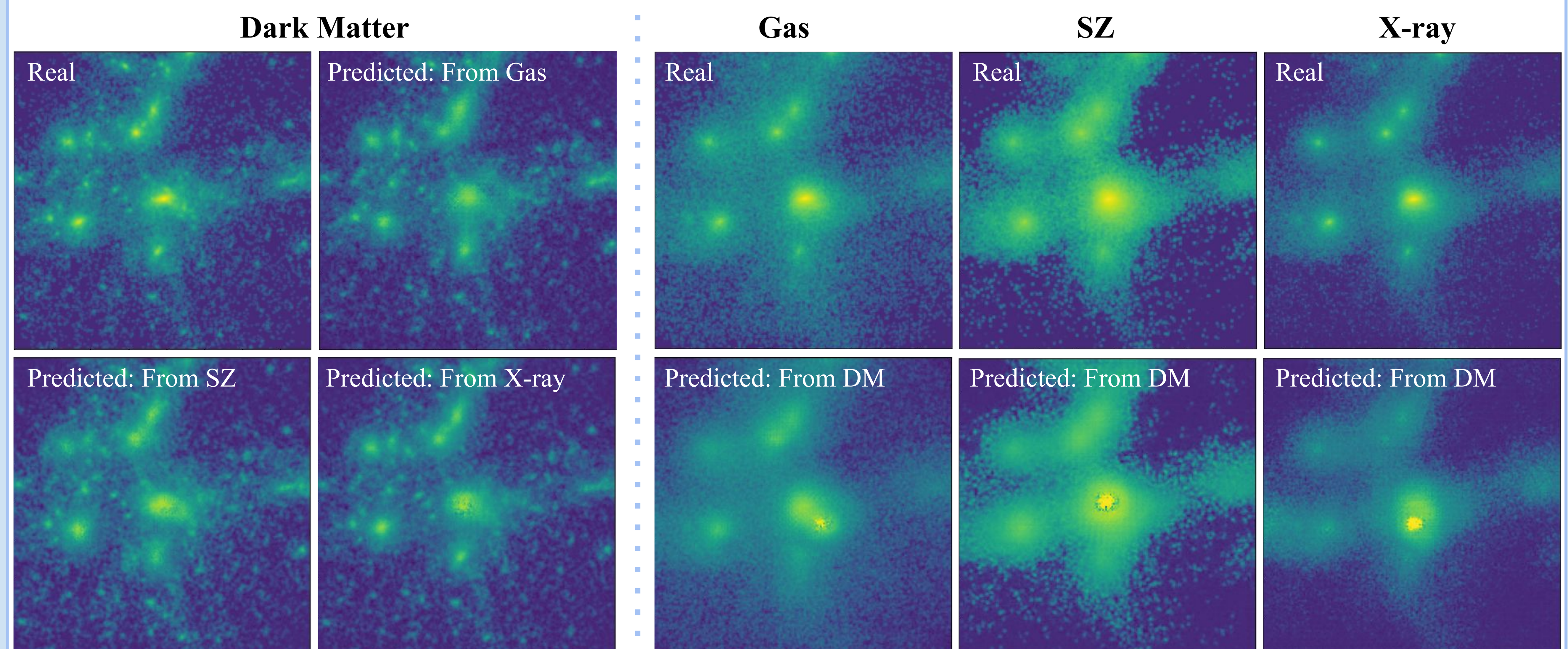
- Simulation of dark matter and gas particles
- Standard modern cosmological parameters
- Able to create large volume simulations containing many galaxies quickly



(Plots): Images of the center of the largest halo (Total Mass: 1.25x10^{15} M$_{\odot}$) simulated by HYPER

Results

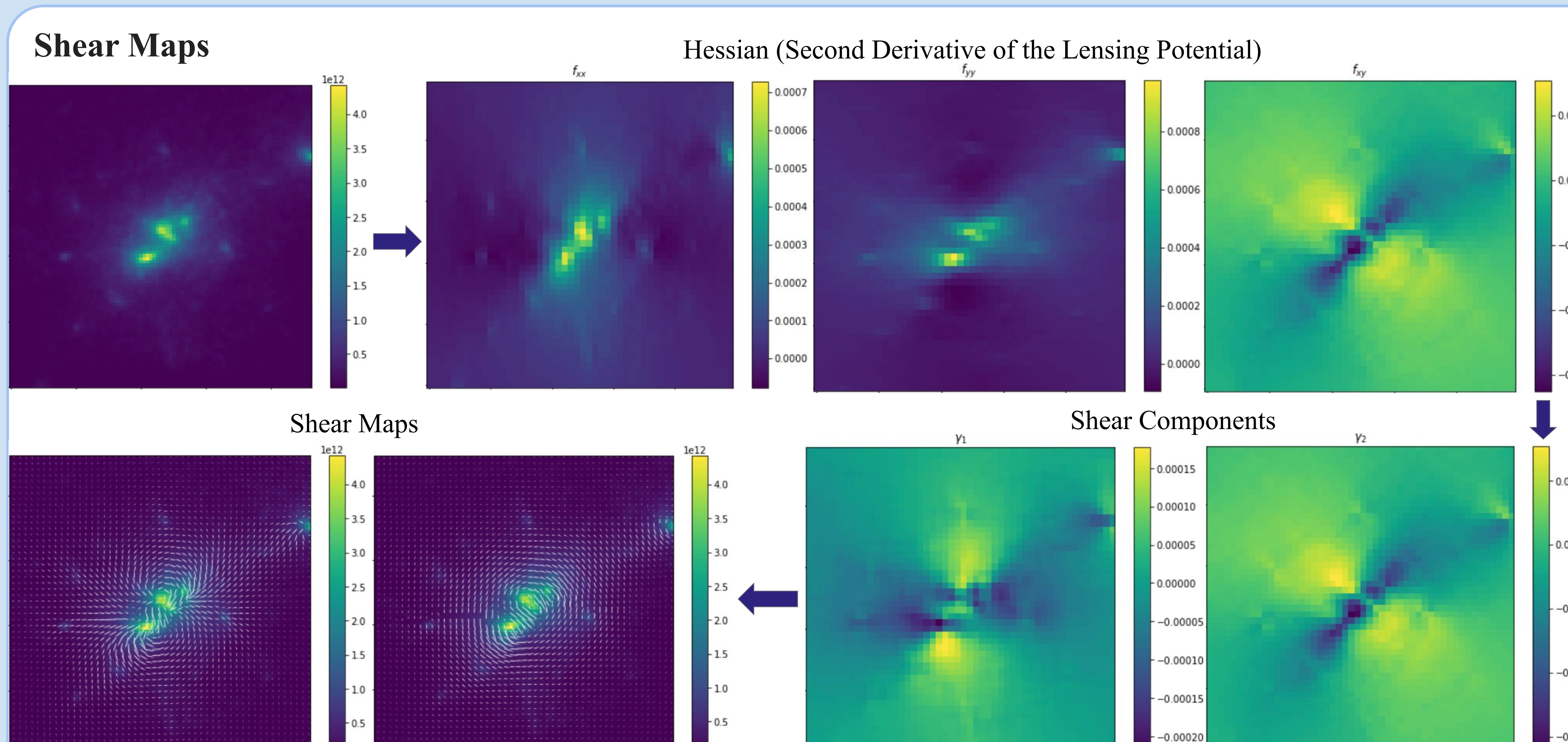
→ **Goal: Predict Dark Matter distribution in galaxy clusters from measured observables such as SZ, X-Ray, and Lensing (shear) maps using machine learning**



(Plots): Selected images from three different Astro-cycleGAN results by mapping dark matter to and from gas, SZ, x-ray data calculated from HYPER simulations

→ **Future Work: Use multi-channel machine learning with SZ, X-ray, and shear maps as inputs to learn the distribution of dark matter and apply to observations as well as dynamic measurements such as those from Vera Rubin Observatory, eRosita, or the Simons Observatory, etc.**

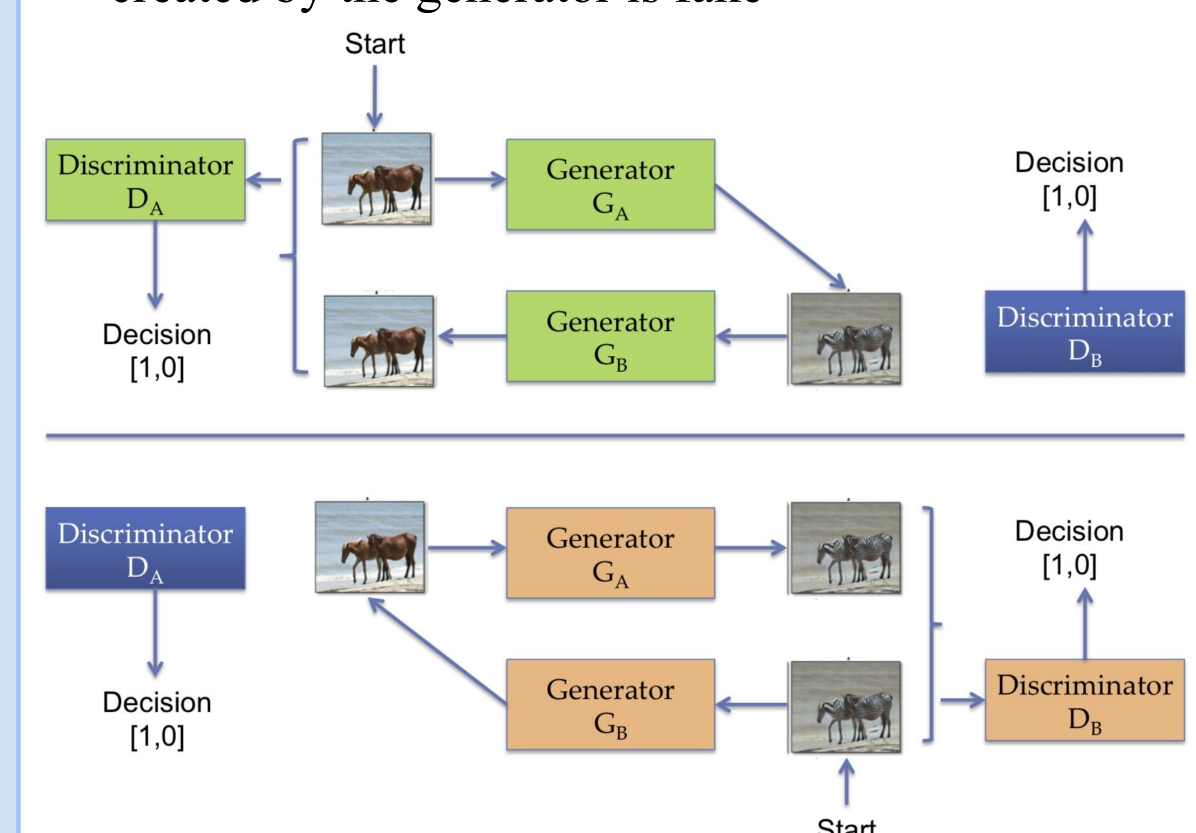
Shear Maps



(Diagram): process to create a shear map - starting from a mass map, calculate the lensing potential, take the second partial derivatives, calculate the shear components, plot and adjust the angle for the shear maps

Astro-CycleGAN

- CycleGAN: a type of Generative Adversarial Network (GAN) consisting of two generators and discriminators that have a mutualistic relationship that allow for mapping between two types of images (or arrays) - e.g. Dark Matter & Gas
- Generator: sole purpose is to create fake images to trick the discriminator
- Discriminator: determines whether or not an image created by the generator is fake



(Diagram) - showing the cyclic relation between two generators and two discriminators

References

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