Extragalactic Astrophysics

Group lead: Prof. Tim Schrabback

Senior Scientist: SG

Independent FWF Fellow: Dr. Laila Linke

Currently 8 PhD candidates among which
Niko Zimmermann
Benjamin Csizi

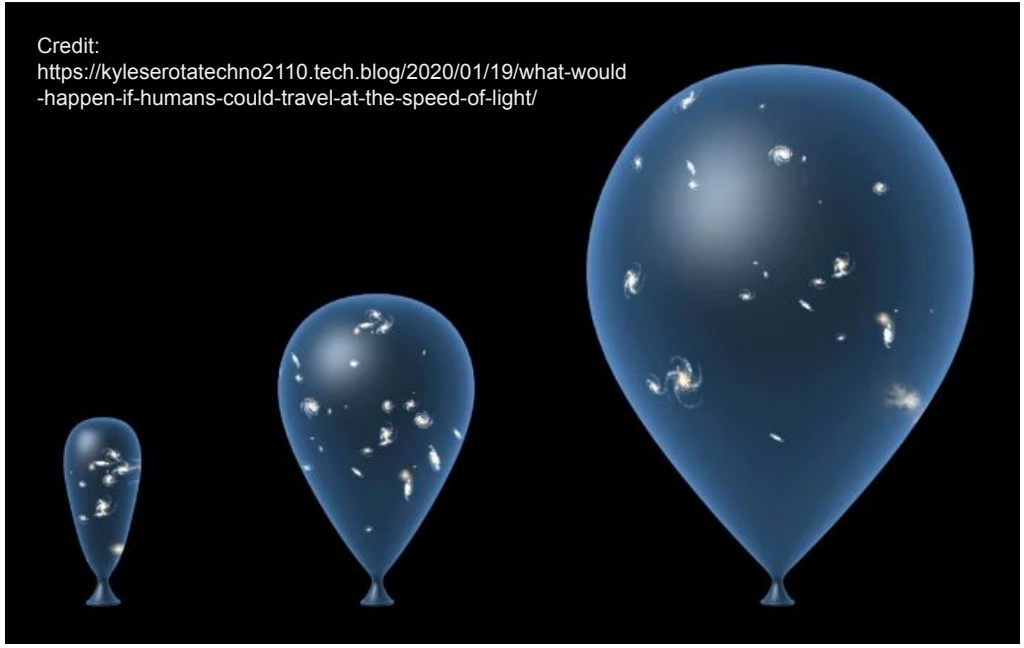
Offering three Bachelor thesis topics

Credit: H.Jansen

Extragalactic Astrophysics

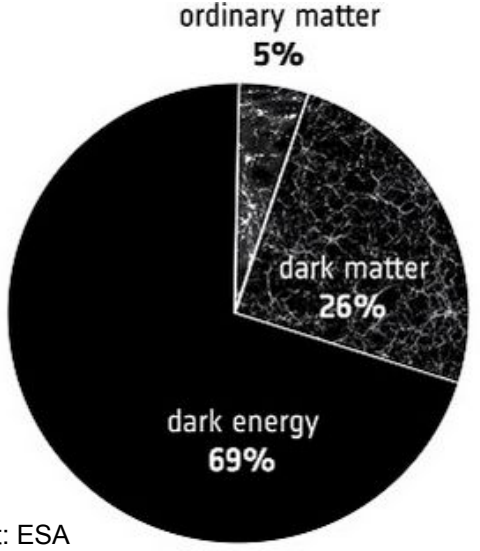
Main research goal: observational study of the structure and composition of the Universe

The space between distant galaxies is expanding



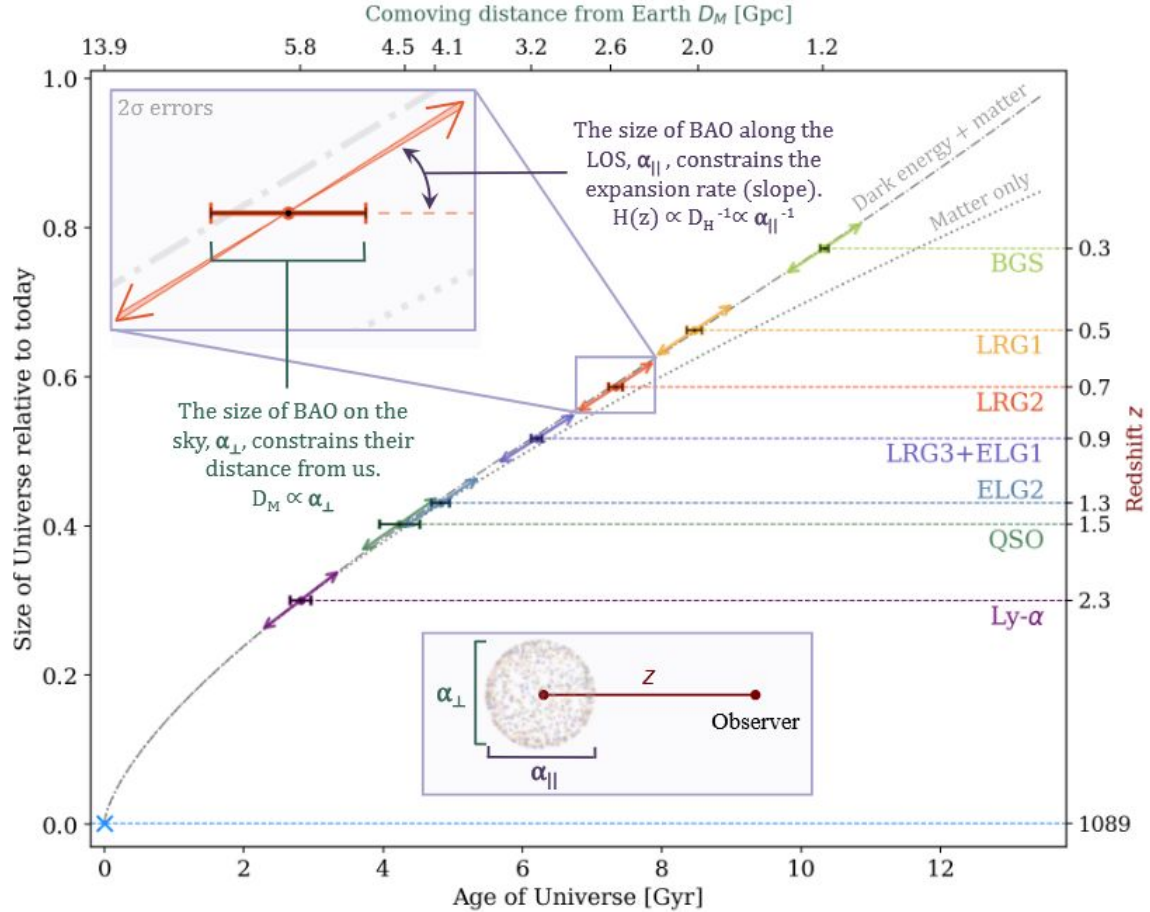
This expansion is a natural prediction of Einstein Theory of Relativity

Yet, the speed of the expansion as a function of cosmic time implies the presence of two unknown quantities



Credit: ESA

Topic 1: the Dark Universe



Reanalyse the latest observation of the Dark Energy Spectroscopic Instrument (DESI)

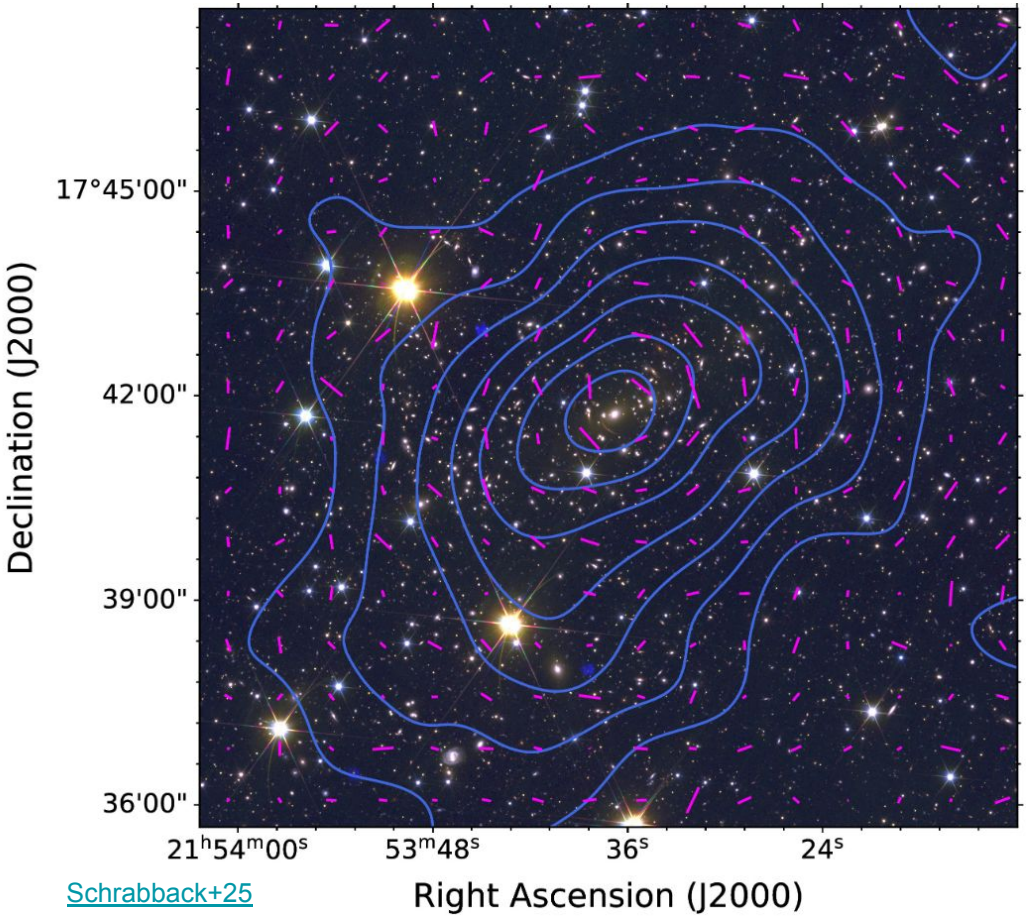
Prove the presence of Dark Matter and Dark Energy, and investigate their properties

Requires some python coding, good theoretical physics skills to explain and understand the results

You will learn how to use Bayesian statistics

Direct supervision: Sebastian Grandis

Galaxy clusters and gravitational lensing



Schrabback+25

Main research goal: observational study of distribution of matter in the Universe

Clusters of galaxies appears a groups of >100 galaxies, gravitationally bound together

Their large masses (> 1e14 Msol) distort the shape of background galaxies via **gravitational lensing**

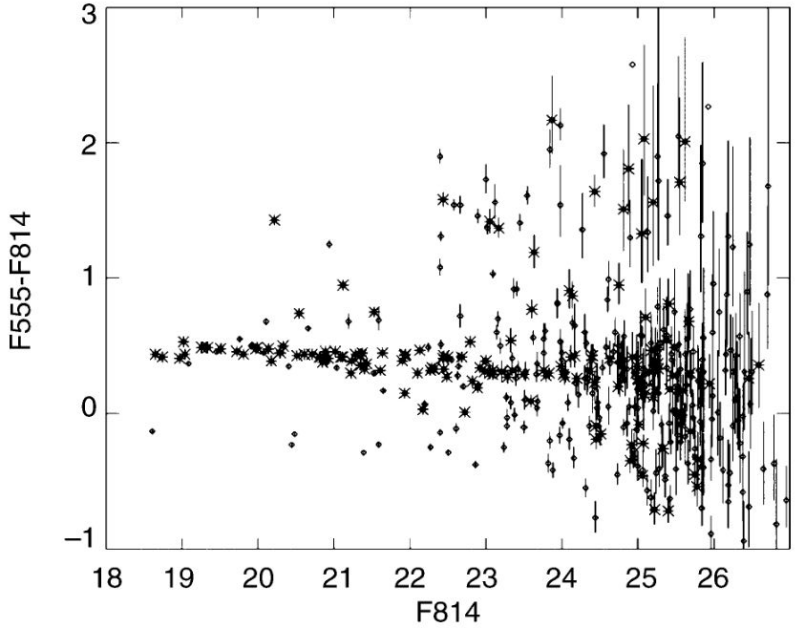
Photometrie von Galaxienhaufen mit hoher Rotverschiebung in *Euclid* Q1-Daten

https://euclid.caltech.edu/image/euclid20250319e-euclid-deep-field-south-16x-zoom

Photometrie von Galaxienhaufen mit hoher Rotverschiebung mit *Euclid* Q1-Daten

Galaxien in einem Haufen bei verschiedenen Rotverschiebungen zeigen ein starken Farben-Helligkeits-Zusammenhang, die rote Sequenz.
z.B. Abell 2390 (z = 0.228):

Abell 2390, aufgenommen mit *Euclid* VIS, *Y*, *H*.
Quelle: https://www.esa.int/ESA_Multimedia/Images/2024/05/



HST Farben-Helligkeits-Diagramm von Abell 2390.
Quelle: Gladders & Yee 2000

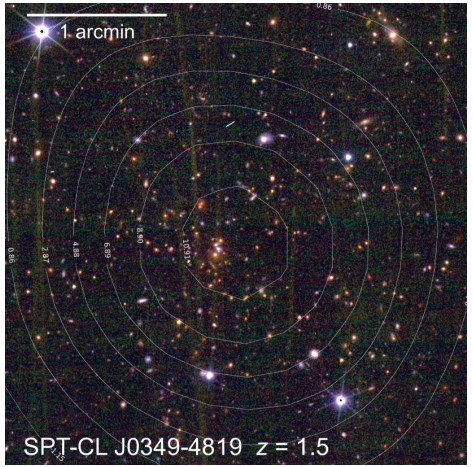
Photometrie von Galaxienhaufen mit hoher Rotverschiebung mit *Euclid* Q1-Daten

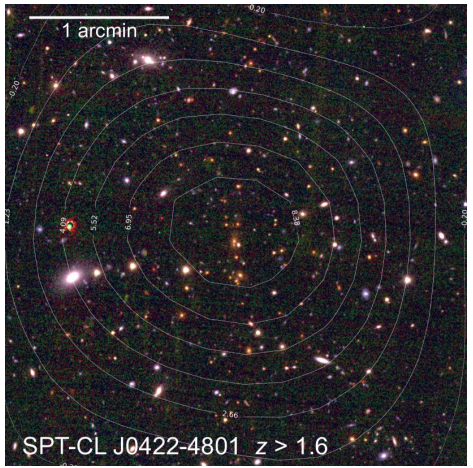
- Die rote Sequenz von Galaxienhaufen bei gleicher Rotverschiebung scheint stets die gleiche Farbe zu haben und wird bei steigender Rotverschiebung immer röter.
  → Aus der Farbe der roten Sequenz kann man die Rotverschiebung des Haufens abschätzen.

- Die scheinbare Helligkeit der roten Sequenz nimmt bei zunehmender Rotverschiebung ab
  → zur Beobachtung werden sensitive Instrumente benötigt
  → z.B. das Hubble Space Telescope (Sichtfeld Infrarot: 2.3 x 2.1 Bogenminuten) → "targeted"
  → z.B. *Euclid* (Sichtfeld Infrarot: 45.78 x 43.32 Bogenminuten) → "Survey"

- *Euclid* Quick Release 1 (Q1): Fläche: 63.1deg^2, Tiefe: 24.5 mag$_{AB}$

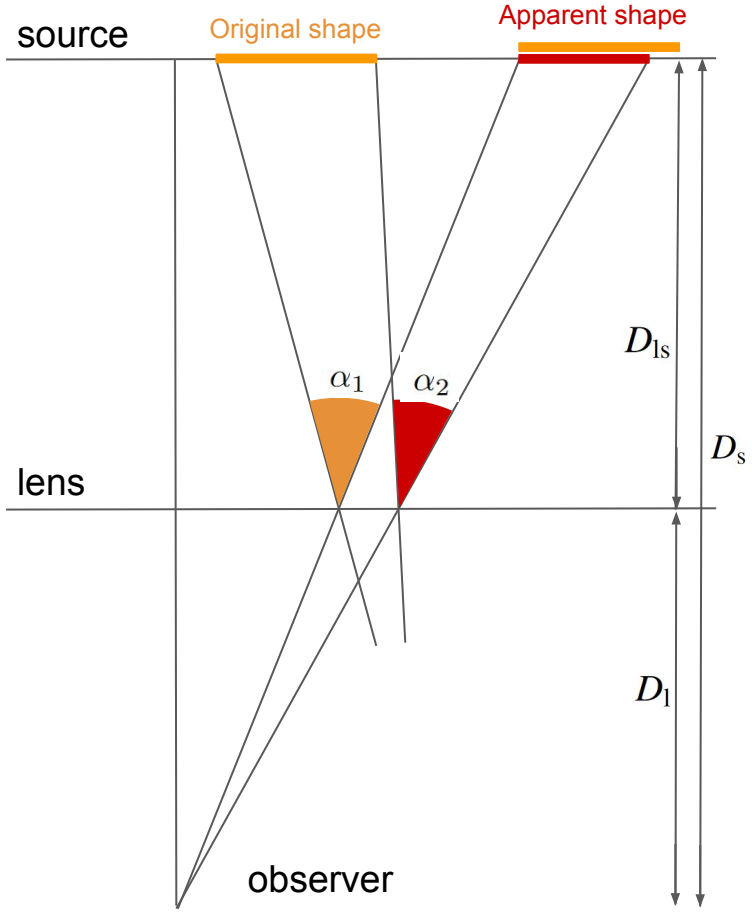
- Bekannte Galaxienhaufen bei hoher Rotverschiebung (z.B. SPT-CL J 0349-4819) liegen in Q1
  → Haben weit entfernte Galaxienhaufen in Euclid Q1 einen Farben-Helligkeits-Zusammenhang?





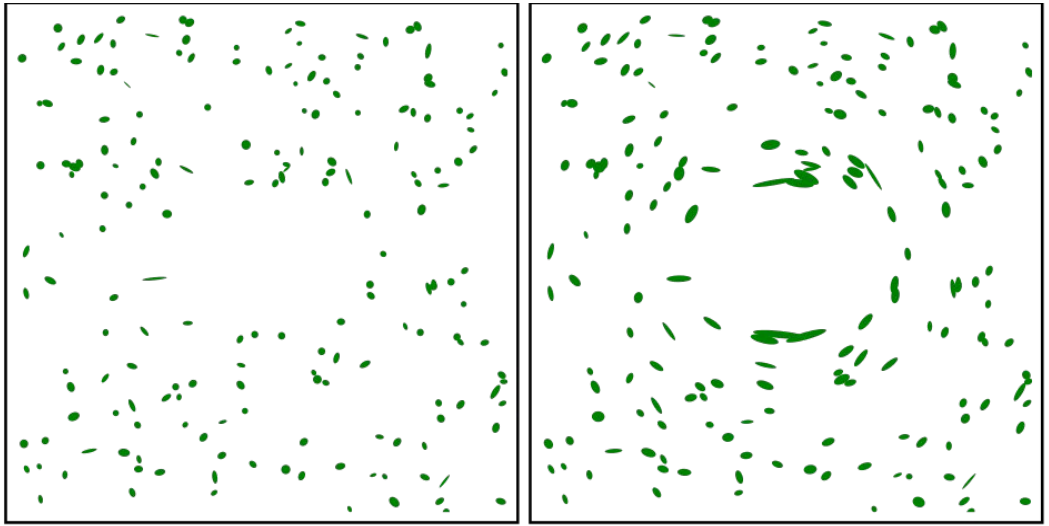
Quelle: Archipley et al. 2025

Gravitational Lensing



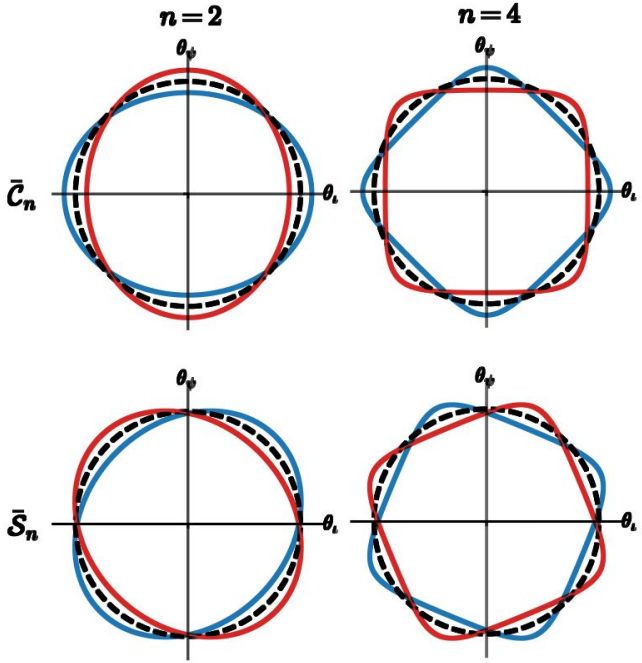
Main research method: measurement of coherent distortion in shape of background galaxies to detect also invisible matter

Source: Wikipedia



Typically done with ellipticity of galaxies, which shows tangential distortion around massive objects

BSc Topic: Measuring the shape noise in galaxy boxiness with simulated galaxy images



Kogai et al. 2021

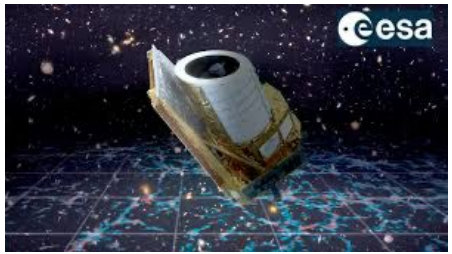
Weak lensing acts upon the observed shape of galaxies like a **distortion** and a magnification.

The shape function of a galaxy can be described via spin-*n* components, of which the spin-2 component is known as **shear.**

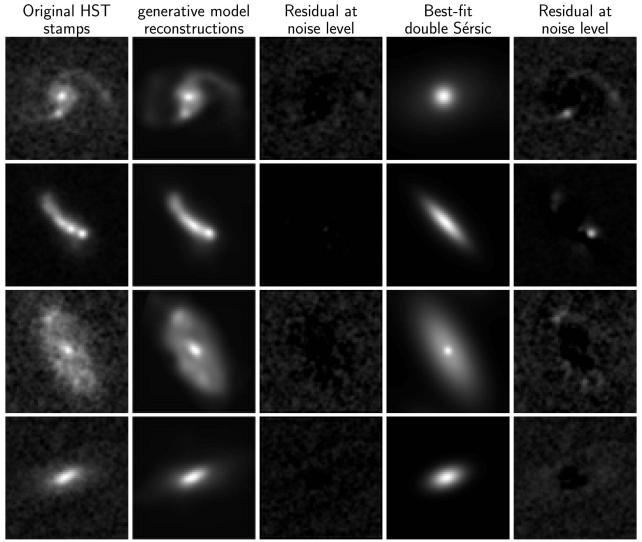
Higher-order distortions are so far not well explored.

We are now interested if the **spin-4 component ("boxiness")** could yield additional cosmological constraining power, as it is sensitive to tidal fields and primordial non-Gaussianity. For that we need to understand its distribution.

In this project you will use **a deep learning generative model** to create **simulated images of galaxies** in a *Euclid*-like setup.



ESA



Csizi et al. 2025

You will then measure the **boxiness distribution** of these simulations and quantify its intrinsic shape noise.

This will provide a first estimate if galaxy boxiness could be a potential observable for future weak lensing surveys.

Requirements: some python experience, experience with AI and cosmology welcome