In **two** steps over the two semesters

1. Learn the specific tools of astrophysics on a set of prepared exercises
2. Apply this knowledge to real research projects

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Register to IS-Academia NOW
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Astrophysics is the study of our Universe as a whole and its components at all scales but also … planets, dust, gas, etc …
Open Questions

- Expansion rate of the Universe
- Dark Energy
- Dark Matter
- First Stars, First Galaxies
- Coevolution of Large Structures and Galaxies
LASTRO 2022
SKA

2020
JWST + Euclid

LASTRO

LASTRO
20 April 2020: EPFL joined the giant radio telescope SKA for the Swiss community
First Stars, First Galaxies?

- Universe was dark & neutral = Dark Ages.
- Universe is now bright and ionized.
- When re-ionization started?
- What are the sources of re-ionization?
- How different are the properties of the first systems from what we know?
- Strong UV radiation from the first galaxies and quasars are likely responsible.
- Future powerful radio observation (SKA) will also help probing re-ionization epoch by mapping the Hydrogen 21 cm line at z~7

Robertson et al. (2013)

Zitrin et al. (2015)
- **~1930**: First evidence by Zwicky studying galaxy velocities in the Coma cluster.
- **1987**: Discovery of giant arcs: cluster lensing requires dark matter.
- **1996**: Bullet cluster: **Separating Dark Matter and Baryons** => Limit on the interaction cross-section.
- **Probe nature of DM? Self Interacting?**
  - use galaxy clusters as DM laboratories!
  - use dwarf galaxies as testbed
Dark Energy?

- **1930**: E. Hubble first measured the Universe expansion.

\[
\frac{H^2}{H_0^2} = \Omega_R a^{-4} + \Omega_M a^{-3} + \Omega_k a^{-2} + \Omega_\Lambda
\]

- **1990**: Key project of the *Hubble Space Telescope*: measuring $H_0$ with high precision (today known at ~1-2%).

- **1998-2003**: CMB favor a flat Universe.

- **1999**: Supernovae Type Ia confirmed accelerated expansion => Nobel Prize (2011).

- **2000**: **Dark Energy** (DE) concept put forward to explain Accelerated expansion.

- **2011**: Physics Nobel Prize

**What is the nature of DE? new component? or is Gravitation different on large scale? Fractal Geometry???
Open Questions

Addressed by new observations, new techniques of analysis, and new technologies.

Involve:

• Instrumentation (ground-based observatory or with space missions)
• Observational strategy (ground- and space-based telescopes)
• (Big) Data flow and processing
• (Big) data analysis (imaging, photometry and spectroscopy)
• Modelling (theory, analytical calculations to numerical simulations)

Research is conducted in a very international context. LASTRO is connected worldwide.
Monitor gravitational lenses to find how fast the Universe grows.
Massive Redshift Surveys

- **Hubble (1930):** expanding Universe
- **CfA Redshift Survey (1985):** first large scale structures
- **2dF (2000-6):** 1500 deg²
- **SDSS (2002-9):** 5700 deg²
- **VVDS/DEEP2 (2004):** deep Universe ~1 deg²
- **zCOSMOS (2005-10):** 2 deg²
- **WiggleZ (2011):** 800 deg² (BAO)
- **SDSS-III/BOSS (2014):** 10,000 deg² BAO/LSS (BAO)
- **e-BOSS (2014-2020):** BAO/LSS: 7,500deg² w/ LRG+QSO & 1,500deg² of ELGs
- **DESI (2019), 4MOST (2021) Optical**
- **MOONS (2020) Infrared**
- **Euclid (2020) Space mission**
- **SKA (2025) Radio Telescope**
Galaxy Power Spectrum

3D mapping of the position of galaxies

Size of the Horizon: mass-radiation equilibrium

non-gaussian initial fluctuations

Dark Energy: Baryonic Acoustic Oscillation

Dark Matter Warm/Cold

Neutrinos Masses

Galaxy halo occupation distribution (HOD)

Growth of structure

Distribution of galaxies (SDSS)
First Stars in the MW: Pristine

Looking for the imprint of the very first stars by looking deep in the Milky Way!

New observational strategy!

New filter that preselect the metal-poor candidates

2 – Spectroscopic follow-up:

Hardly any metals!

WEAVE
4MOST
Numerical simulations

Unveiling how galaxies form and evolve

- Nature of the dark matter?
- Initial conditions?
- Physics of baryons?
- Nature of the first galaxies?

- gravity
- hydrodynamics
- gas cooling
- star formation
- SNe explosions (stellar feedback)
- chemical evolution
**Instrumentation: Astrobots**

Aims:
- contribute to the building of the next generation instruments worldwide
- Contribute to the observational strategy
- Get primary access to the new datasets.

- **Interdisciplinary Group** formed in 2013, with members of LSRO, REACT and LASTRO.
- **Goal**: develop high-precision fiber positioner robotic system for massive spectroscopic surveys
- **Projects**: DESI & VLT/MOONS & SDSS-V, Megamapper?
- **Group and Equipment funded by**: SNF+Innosuisse+EPFL+Sloan Foundation

[http://astrobots.epfl.ch/](http://astrobots.epfl.ch/)
The Sloan Telescope & Spectrograph

- 90 cm aluminium plate with 1000 holes for fibers,
- 45 min to plug for typical 1 hour observation on sky
- up to 9 plates observed per (good) night
- 1.5 millions redshifts in ~4 years  
 sdss.org
- The best multiplexing spectroscopic facility still
**SDSS-V** (2020-2025)

- Project started fall 2017
- 2 telescopes (New-Mexico+Chile)
- Fast development, for on-sky in 2020.
- EPFL responsible of the robotic fiber positioner systems, contract with industry
- Production this year by a Swiss company, validation done at EPFL
(eBOSS), DESI, 4MOST

- Spectroscopic survey
- From 4 millions to 35 millions
- Explore redshift window $0.2 < z < 3.5$
- Use 4 tracers: LRG, ELG, QSO & Ly-alpha forest
- Perform observations on telescopes (USA+Chili)
MOONS (2022-2027)

- Approved by ESO in 2014: 1000 fiber NIR spectrograph at VLT (3rd generation of instruments) to start observing in 2019.
- Study of galaxy evolution and formation at 1<z<5
- Measure ~1 million galaxies over 50-100 deg$^2$. Much higher density than DESI, and Euclid.
- Will also probe the z>7 Universe and will constrain Dark Ages
Euclid (2022-2025)

- Euclid is a major wide-field imaging and spectroscopy space mission, lead by ESA with NASA participation (1 B$).
  - J.P. Kneib Cluster Lensing.
  - F. Courbin Galaxy Lensing.
- Machine Learning on Strong Lensing finder (tensorflow)
- modeling with GPU for fast computing (CUDA)
- Ultimately contribute to the science of Euclid.
Square Kilometer Array

- Participate in the SKA at Swiss level (EPFL leading the Swiss effort)  [http://ska.epfl.ch/](http://ska.epfl.ch/)
- Interest in the Astrophysics (Reionization, Dark Energy)
- Algorithm (Raw reduction - Data Analysis)
- Big-data (Data server - Machine Learning) - IBM DOME project
- Connections with South-Africa & Australia (Possibility to go there for a master projects/internships)
• Lot’s to do in Astrophysics & Cosmology! (Strong links with STI, IC possible)

• TP-IVa (learning) - b (practise)

• If you are interested, please contact us: jean-paul.kneib@epfl.ch, frederic.courbin@epfl.ch, pascale.jablonka@epfl.ch

• For TP-IV please register to IS-Academia NOW. Responsible: frederic.courbin@epfl.ch