NPAC course on Astroparticles

0 - INTRODUCTION
The course and the exam

First part of the course: *Astroparticles* (7 classes, 3h each)
Second part: *Cosmology* (14 classes, 3h each)

Written exam -> final mark is $\frac{1}{3} \times \text{Astro} + \frac{2}{3} \times \text{Cosmo}$
If final mark <10 and Astro < 10 -> oral exam
Introduction

Probably, the most complete textbook on **High Energy Astrophysics** is Malcolm Longair’s “High Energy Astrophysics” (Cambridge University Press).

According to Longair, High Energy Astrophysics is “the astrophysics of high energy processes and their application in astrophysical and cosmological contexts. For example, we need to explain:

- how the massive black holes present in the nuclei of active galaxies can be studied,
- how charged particles are accelerated to extremely high energies in astronomical environments,
- the origins of enormous fluxes of high energy particles and magnetic fields in active galaxies,
- the physical processes in the interiors and environments of neutron stars,
- the nature of the dark matter,
- the expected fluxes of gravitational waves in extreme astronomical environments, and so on… “
Introduction

Probably, the most complete textbook on High Energy Astrophysics is Malcolm Longair’s “High Energy Astrophysics” (Cambridge University Press).

According to Longair, High Energy Astrophysics is “the astrophysics of high energy processes and their application in astrophysical and cosmological contexts. For example, we need to explain:

✓ how the massive black holes present in the nuclei of active galaxies can be studied,
✓ how charged particles are accelerated to extremely high energies in astronomical environments,
✓ the origins of enormous fluxes of particles and magnetic fields in active galaxies,
✓ the physical processes in the interiors and environments of neutron stars,
✓ the nature of the dark matter,
✓ the expected fluxes of gravitational waves in extreme astronomical environments, and so on…”
**Galactic cosmic rays**

Victor Hess got the Noble Prize for the discovery of cosmic rays (1912)

Cosmic rays are a flux of energetic particles (mainly protons) that hits the Earth’s atmosphere from above.

- Cosmic ray particles are accelerated to extreme energies (up to $10^{20}$ eV!)
- The Galaxy is filled of cosmic rays
- Most of them are accelerated within the Galaxy
- Where are they from?
Radiation processes in astrophysics

- Class 0 [0.5h] — Introduction
- Class 1 [1.5h] — Astronomy: the Milky Way
- Class 2 [1.5h] — Particle interactions: cosmic rays, γ-rays, neutrinos
- Class 3 [1.5h] — Astrophysics: SuperNova Remnants
- Class 4 [1.5h] — Plasma physics: MagnetoHydroDynamics
- Class 5 [1.5h] — Particle propagation in turbulent magnetic fields
- Class 6 [1.5h] — Particle acceleration: diffusive shock acceleration at SNRs
- Conclusions [0.5h] — What did we learn?
Radiation processes in astrophysics

- Class 0 [0.5h] — Introduction
- Class 1 [1.5h] — Astronomy: the Milky Way
- Class 2 [1.5h] — Particle interactions: cosmic rays, γ-rays, neutrinos
- Class 3 [1.5h] — Astrophysics: SuperNova Remnants
- Class 4 [1.5h] — Plasma physics: MagnetoHydroDynamics
- Class 5 [1.5h] — Particle propagation in turbulent magnetic fields
- Class 6 [1.5h] — Particle acceleration: diffusive shock acceleration
- Conclusions [0.5h] — What did we learn?
Radiation processes in astrophysics

- Class 0 [0.5h] — Introduction
- Class 1 [1.5h] — Astronomy: the Milky Way
- Class 2 [1.5h] — Particle interactions: cosmic rays, γ-rays, neutrinos
- Class 3 [1.5h] — Astrophysics: SuperNova Remnants
- Class 4 [1.5h] — Plasma physics: MagnetoHydroDynamics
- Class 5 [1.5h] — Particle propagation in turbulent magnetic fields
- Class 6 [1.5h] — Particle acceleration: diffusive shock acceleration

Conclusions [0.5h] — What did we learn?

Total = ~10h of theoretical classes
Radiation processes in astrophysics

- Class 0 [0.5h] — Introduction
- Class 1 [1.5h] — Astronomy: the Milky Way
- Class 2 [1.5h] — Particle interactions: cosmic rays, γ-rays, neutrinos
- Class 3 [1.5h] — Astrophysics: SuperNova Remnants
- Class 4 [1.5h] — Plasma physics: MagnetoHydroDynamics
- Class 5 [1.5h] — Particle propagation in turbulent magnetic fields
- Class 6 [1.5h] — Particle acceleration: diffusive shock acceleration
- Conclusions [0.5h] — What did we learn?

Total = ~10h of theoretical classes

- Exam simulation [3h]
- Exercises [8h]

Total = ~11h of practical classes
Bibliography

General reference

- Longair, High Energy Astrophysics

Radiative processes

- Rybiki & Lightman, Radiative processes in astrophysics
- Ghisellini, Radiative processes in high energy astrophysics
- Aharonian, Very high energy cosmic gamma radiation
- Gaisser, Cosmic rays and particle physics
Bibliography

Plasma physics

- Shu, Gas dynamics
- Kulsrud, Plasma physics for astrophysics
- Vietri, Foundations of high energy astrophysics

Particle acceleration/propagation

- Gaisser, Vietri, Kulsrud (see above)
- Berezinskii et al., Astrophysics of cosmic rays