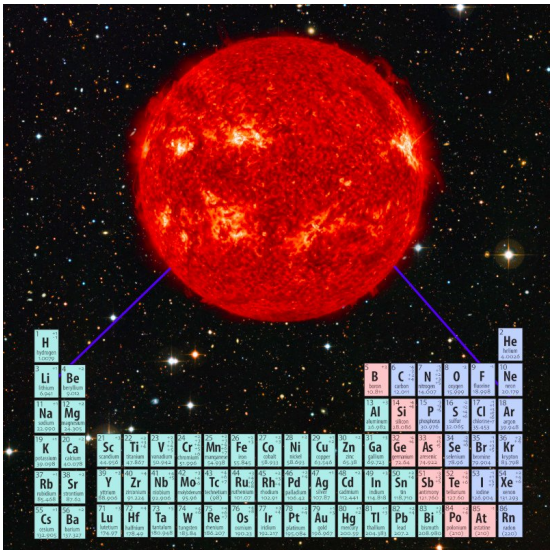
Chemical composition of very metal-poor stars



SUMMARY.
Very metal-poor stars, those that have chemical elements in amounts that are 100 times or less than what is found in the Sun, are among the oldest stars in the Galaxy. Such old stars are fossils that can reveal details about the early stages of the Milky Way formation and evolution. In particular, the chemical elements in some of these extant metal-poor stars may come from a single or from very few nucleosynthetic sources, including the explosion of the first stars to form in the Universe (the so called Population III stars) and mergers of neutron stars. Interestingly, some of these very old stars have been found to be enriched in r-process elements. The rapid neutron capture process (r-process) is a nucleosynthetic mechanism that produces the heaviest elements in the periodic table, but that is still not well understood. In this METEOR, the student will perform the analysis to determine the detailed chemical abundance pattern of a sample of very metal-poor stars candidates of being rich in r-process elements. The results will then be used to investigate the origins of the potential enrichment based on stellar nucleosynthesis models. Gaia data will also be used to determine to which stellar population the stars belong.

OBJECTIVES

- **Knowledge**
  Introduction to the physics of stellar spectra and spectral line formation; fundaments of stellar nucleosynthesis and stellar populations;
- **Skills**
  Practical and critical use of tools for the analysis of high-resolution stellar spectra; use of Gaia data to compute kinematics and stellar orbits; comparison to theoretical models of stellar nucleosynthesis.

INSTITUTE

- Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences
- https://www.camk.edu.pl/en/
- Bartycka 18, Warsaw, Poland
- SAGA (Stellar Abundances and Galactic Archaeology) Team
- Research at the SAGA Team

THEORY

by Rodolfo Smiljanic

- **Stellar spectra**

First, we will have an introduction to the physics of stellar spectra formation, including an overview of continuous opacities, model atmospheres, and the formation of absorption lines. This will include a look into how the overall spectra and selected lines change as a function of stellar parameters and chemical composition.

- **Stellar populations**

Second, we will discuss the different stellar populations of the Milky Way (thin and thick discs, bulge, and halo). We will look into the main differences of their stars in terms of ages, chemical composition, kinematics, and orbits. This will then be contextualized in terms of their most probable histories of chemical enrichment.

APPLICATIONS

by R. Smiljanic and team

The student will learn to use tools for the analysis of stellar spectra and work to determine the chemical composition of a sample of metal-poor stars. The main focus will be on spectral lines of elements heavier than Fe. The resulting abundances will be compared to models of stellar nucleosynthesis. The student will also use Gaia data (proper motions, parallaxes, and radial velocities) to compute stellar orbits and investigate to which Galactic stellar population the stars belong.

MAIN PROGRESSION STEPS

- `Week 1-3`: Lectures on stellar spectra and stellar populations
- `Week 4-8`: Research project
- `Week 9`: Project presentation

EVALUATION

- `Theory grade [30%]`
  - Oral exam (50%): theoretical questions based on reading material
  - Discussion of an article (50%): critical spirit, clarity, answering questions
- `Practice grade [30%]`
  - Project: initiative, progress, analysis
- `Defense grade [40%]`
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

- da Silva & Smiljanic 2025
- Giribaldi & Smiljanic 2023
- Bonifacio et al. 2025

CONTACT

Rodolfo Smiljanic
☎ +48 223 296 115
✉ rsmiljanic@camk.edu.pl