



NETZWERK
TEILCHENWELT

NUCLEAR ASTROPHYSICS MASTERCLASSES

A journey through the elements



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CONCEPT OF MASTERCLASSES

- One day program held by (young) physicists, e.g. PhD students
- Lectures, hands-on activities, analysis of real data
- High school students (15 – 19) are „scientists for one day“
- At a research institute or university or classroom

Act as a "scientist for a day"

- Close to current research
- Own "hands-on" activities (listen = forget, see = remember, do = understand)

Authentic experiences

- Analysis of real scientific data
- Meeting and discussion with scientists

Get insight into the research process

- Use of relevant methods and tools
- Comparisons between experiment and theory



CONCEPT OF MASTERCLASSES

Netzwerk Teilchenwelt

- Organizing multiple activities in particle & nuclear physics for students, e.g. different masterclasses
- Teaching materials, events, ...



WHAT ARE WE WORKING ON?

- Development of two Nuclear Astrophysics Masterclasses
 - First masterclass available @ mc.chetec-infra.eu
 - Second masterclass coming end of 2023
- **Languages**
 - **German, English, French, Italian, Czech, Bulgarian, Sorbian,** Spanish, Romanian, Swedish, Hungarian, Lithuanian, Hebrew, *Catalan, Welsh*
- **Learning Goals**
 - Teaching the basic principles of nuclear physics & astrophysics
Nuclei structure, nuclear reactions, nucleosynthesis, stellar evolution
 - Conveying the basic idea of this science field
What questions does nuclear astrophysics?
 - Depicting how physical knowledge develops
Dynamics, evolution & open questions of nuclear astrophysics
 - Insight into the work of nuclear astrophysicists



“Education is that which remains when one has forgotten everything he learned in school.”



INSIGHT INTO THE **CONTENT AND MATERIALS**



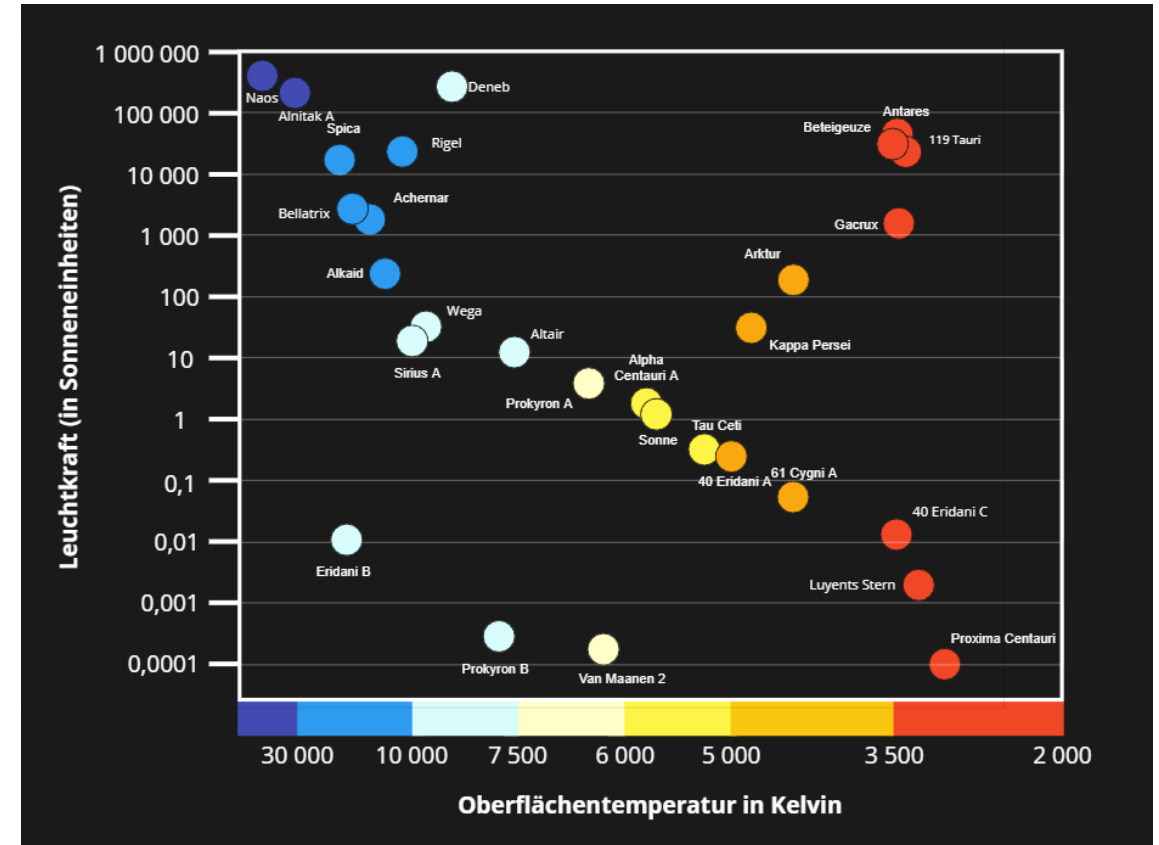
CONTENT & MATERIALS

- **Multiple Activities** with Gamification Elements, e.g. ...
 - Building a Hertzsprung–Russell diagram together
 - Primordial nucleosynthesis puzzle
 - Playful Challenges
 - Nuclei Race
- **Videos & Visualizations**
- **Various Lectures** linking the activities



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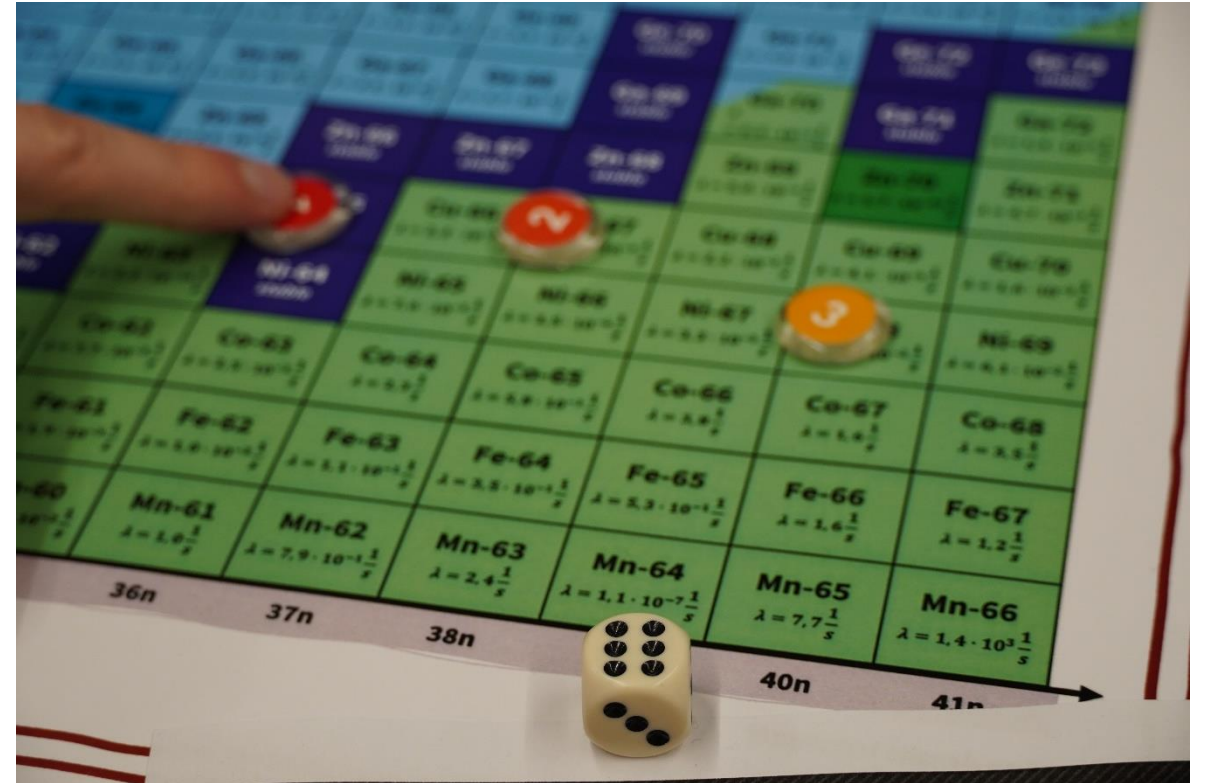
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Nuclides	Stars	Galaxies	Universe
\$ 100	\$ 100	\$ 100	\$ 100
\$ 200	\$ 200	\$ 200	\$ 200
\$ 300	\$ 300	\$ 300	\$ 300
\$ 500	\$ 500	\$ 500	\$ 500

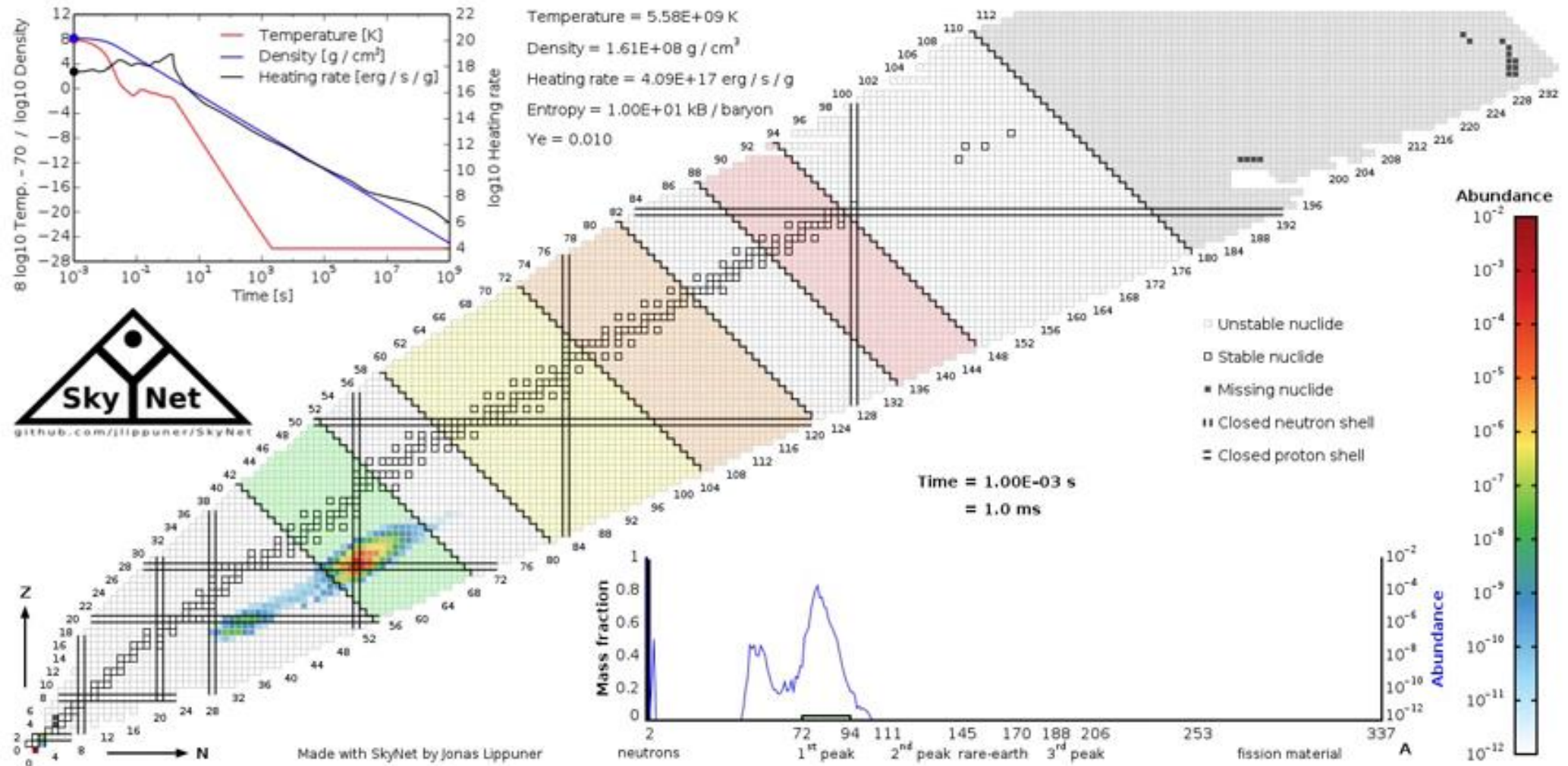


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NUCLEOSYNTHESIS OF HEAVY ELEMENTS

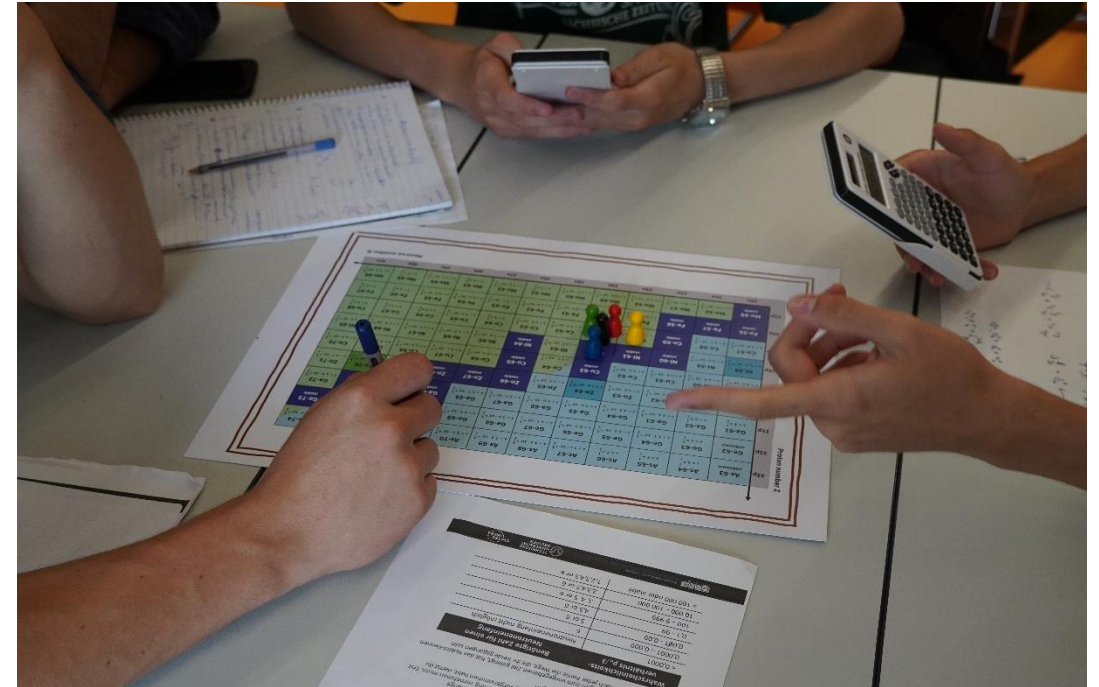


NUCLEOSYNTHESIS OF HEAVY ELEMENTS

➤ The Nuclei Race:

Recreating s- and r-processes in a board game

- Calculate the probability ratio between neutron capture and beta conversion
- Tracing the steps on a nuclide chart
- Clarify the difference between the s- & r-process as well as the stochastic character



CONTENT & MATERIALS

- **Multiple Activities** with Gamification Elements
- **Videos & Visualizations**
 - Camera tour through an underground ion accelerator lab
 - slice of the life of an astronomer
 - Astronuclear Nibbles – Video series
- **Various Lectures** linking the activities



Felsenkeller Laboratory



Astronuclear Nibbles:

<https://youtu.be/L6NMurf64-4>

CONTENT & MATERIALS

- **Multiple Activities** with Gamification Elements
- **Videos & Visualizations**
- **Various Lectures** linking the activities, e.g.
 - Development of the understanding of chemical elements over history
 - The life story of our sun – from protostar to white dwarf



CONTENT & MATERIALS

Centerpiece of the Masterclass:
Analysis & evaluation of a **nuclear astrophysics experiment**

1. Masterclass

- Nuclear Reaction Measurements carried out at the Felsenkeller Laboratory, Dresden
- Data analysis of $^{14}\text{N}(\alpha, \gamma)^{18}\text{F}$
 - Gamma spectroscopy & peak measurements
 - usage of a term diagram
 - Consideration of the underground
 - Determination of the cross section & reaction rate

2. Masterclass

- Stellar Spectra Analysis
- Analysis of **Lithium Abundances**
 - Astronomical Spectroscopy
 - Deriving stellar parameters
 - Calculating Abundances with WebSME
 - Reconstructing the cosmological lithium problem

Goals:

- Working as a Physicist for one day
- Gain an Insight into the Laboratory and the working methods of Nuclear & Astrophysicists



CONTENT & MATERIALS

Centerpiece of the Masterclass: Analysis & evaluation of a **nuclear astrophysics experiment**

1. Masterclass

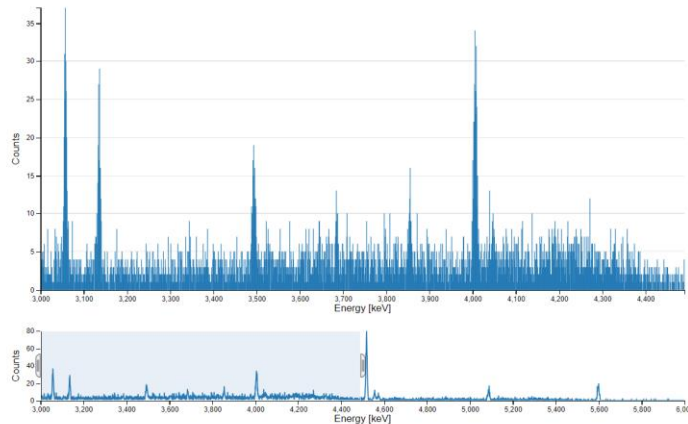
1. Choose the interval

Photon energies from 0 to 16300 keV were measured. Choose the energy range in which you want to analyze the spectrum.

Minimum keV
Maximum keV

2. Choose the Measurement series

Several series of Measurements were carried out. Here you can choose between four exemplary runs.



2. Masterclass

Stellar Analysis Pipeline

Select spectrum file

Upload spectrum in FITS or CSV format. FITS files containing 2D data are collapsed along y-axis. CSV files or FITS files in binary table format must contain the columns "Wavelength" and "Normalized_Flux". Note that the spectrum must be **normalized** and the radial velocity (VRAD) must be provided, either by entering VRAD in the text input field below or by providing a spectrum that is already shifted.

User info (optional)	Source (optional)	Stellar parameters	Derive abundance	References
<p>User name</p> <input type="text"/>	<p>Gaia DR3 ID</p> <input type="text"/>	<p>Teff</p> <input type="checkbox"/> 5800	<p>Select elements</p> <div>Fe Li Mg Ca Ti Ba Eu Pb Sr Th</div>	<p>Solar ref. composition</p> <p><input checked="" type="radio"/> Asplund 2021</p> <p><input type="radio"/> Asplund 2009</p> <p><input type="radio"/> Grevesse 2007</p> <p><input type="radio"/> Lodders 2003</p>
<p>Email address</p> <input type="text"/>	<p>Vrad</p> <input type="text"/>	<p>logg</p> <input type="checkbox"/> 4.4	<p>monh</p> <input type="checkbox"/> 0.0	<p>Linelist</p> <p><input checked="" type="radio"/> Gaia-ESO</p> <p><input type="radio"/> Gaia-ESO (Y,Y[U])</p> <p><input type="radio"/> VALD (F-type stars)</p> <p><input type="radio"/> VALD (G-type stars)</p> <p><input type="radio"/> VALD (K-type stars)</p> <p><input type="radio"/> VALD (red clump)</p> <p><input type="radio"/> VALD (sel. el. unconstr.)</p>
		<p>Vmic</p> <input checked="" type="checkbox"/> 0.0	<p>Vmac</p> <input checked="" type="checkbox"/> 0.0	<p>Reported abundances are log10 of the fraction of nuclei of each element in any form relative to the number of hydrogen in any form plus an offset of 12. For the Sun, the nuclei abundance values of H, He, and Li are approximately 12, 10.9, and 1.09.</p> <p>Checked: Parameter p will be derived by SME using an initial guess provided through the textbox. Unchecked: p is fixed to the value provided in the textbox.</p>

Goals:

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GENERAL **DESIGN ASPECTS** OF THE MASTERCLASSES



GENERAL DESIGN ASPECTS

1. Low Threshold

- Previous knowledge in astrophysics and nuclear physics not mandatory
- Target Group: Age 15+

2. Accessibility

- Masterclass available in both online and live formats
- Open Access to all materials online
- No software installations necessary
- Analog materials can be recreated easily

3. Reproducibility

- Complete materials & instructions for educators open access
- Making it as easy as possible, to be a Nuclear Astrophysics Facilitator

4. Two different Masterclasses

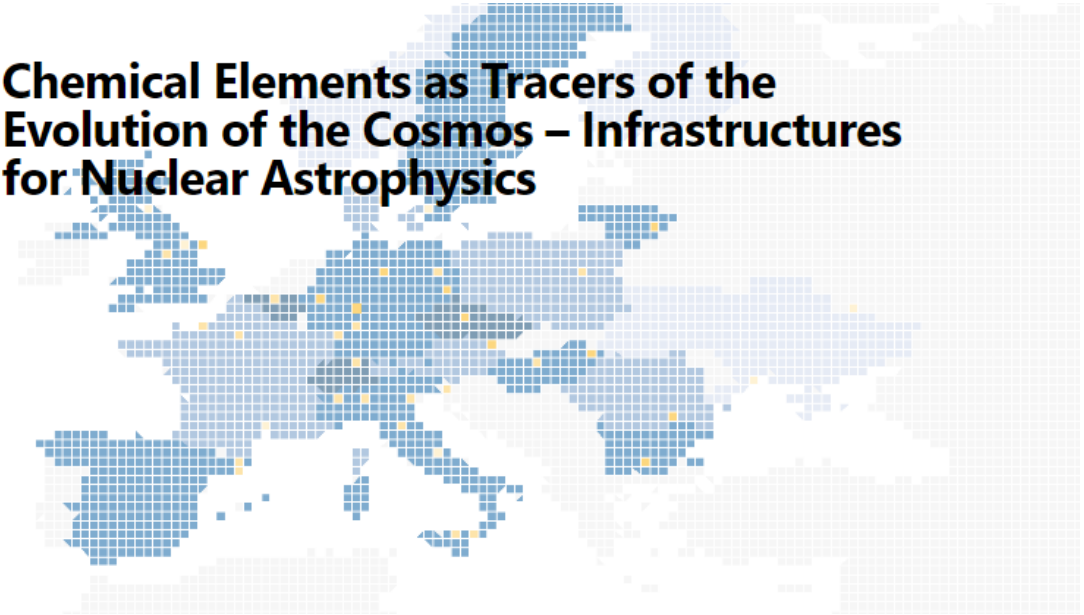
- Access to nuclear astrophysics with different Points of View
- No Necessity to visit the first Masterclass to understand the second
- Two independent Masterclasses: Each Scientist can choose their preferred topic



PROJECT STATUS

- First Masterclass tested and evaluated
- Second MC in the pipeline
- Multiple Run-throughs in german schools
- **We are aiming for ...**
 - ... a international Masterclass
 - Creating a Network of Nuclear Astrophysics **Facilitators** with the help of the Masterclass
 - Giving every interested physicist the opportunity to be a educator

Chemical Elements as Tracers of the Evolution of the Cosmos – Infrastructures for Nuclear Astrophysics





Masterclass can be found online @

<http://mc.chetec-infra.eu>

Thank you for your attention.

