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**HZDR**  
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# Chemical Elements as Tracers of the Evolution of the Cosmos — Infrastructures for Nuclear Astrophysics



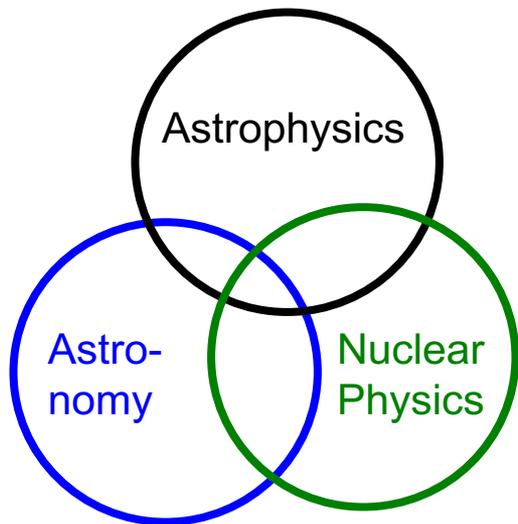
Talk for Europlanet 2024 RI Council Meeting  
14.10.2021 (online)

Daniel Bemmerer  
HZDR Dresden, DE

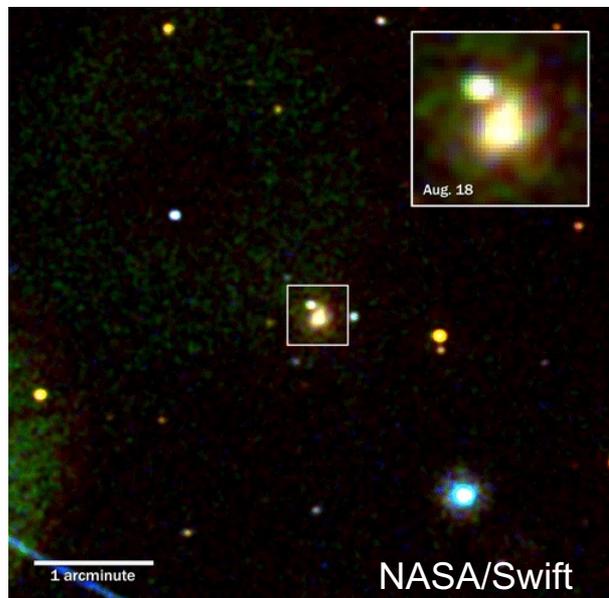
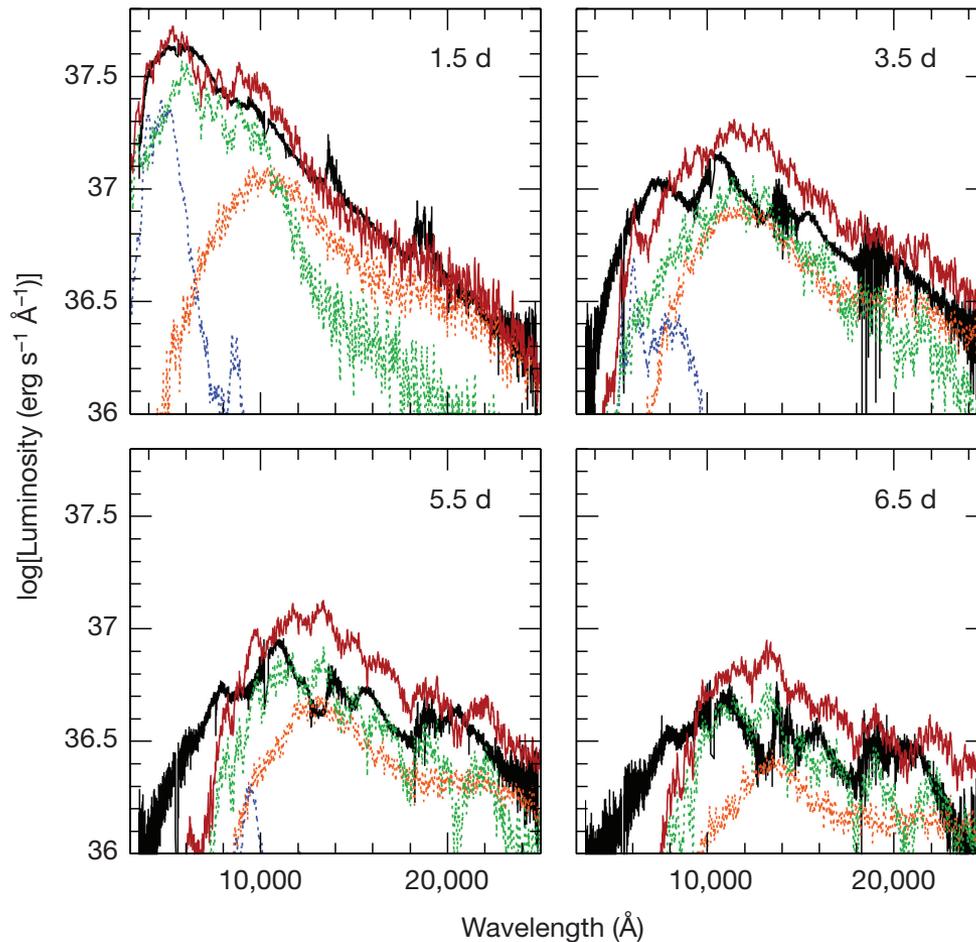
[www.chetec-infra.eu](http://www.chetec-infra.eu)



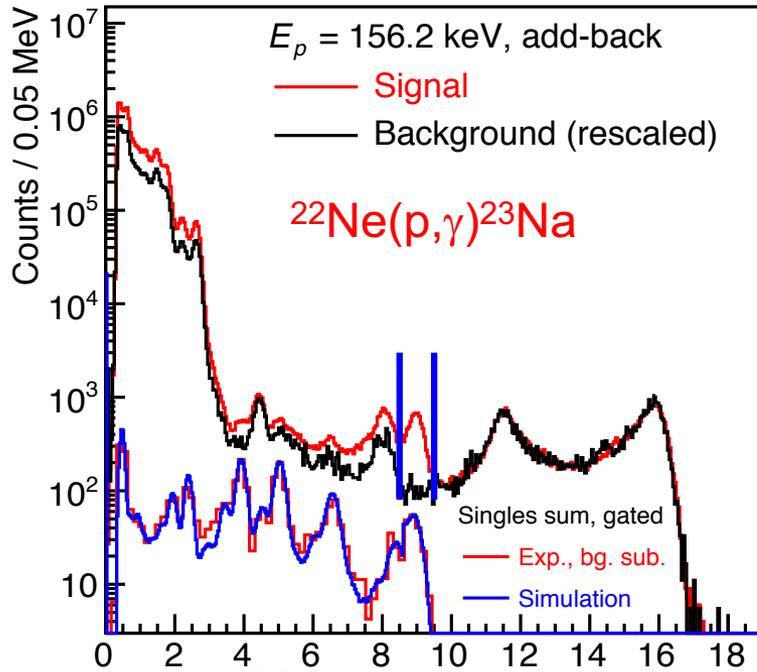
# Nuclear astrophysics at the intersection of three disciplines



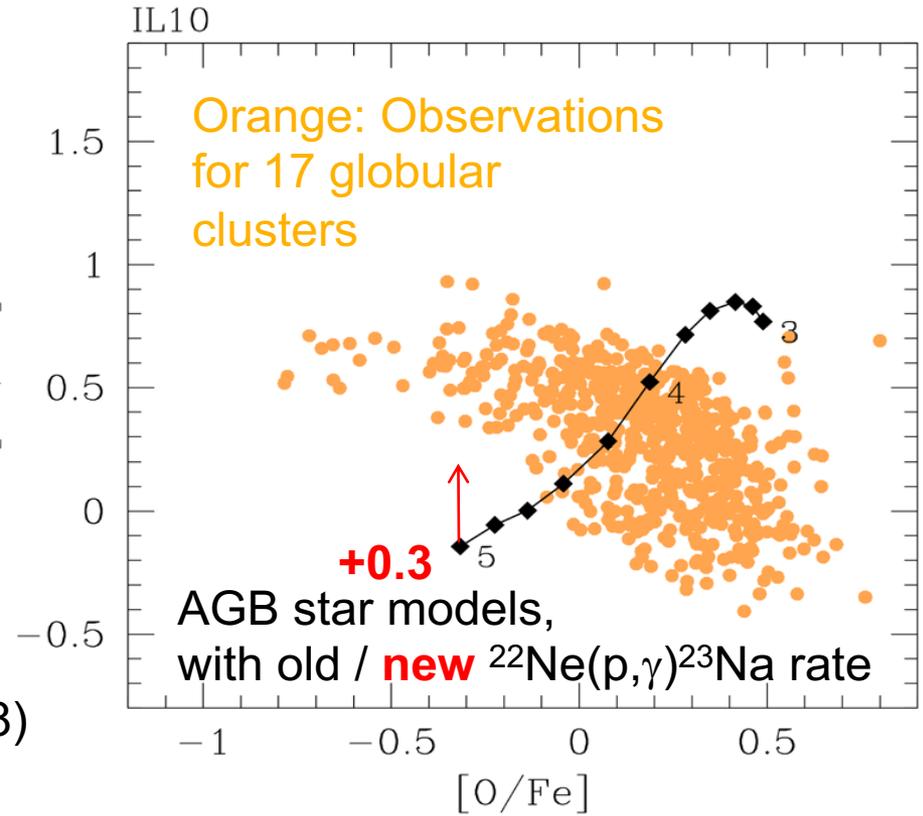
GW170817 and its kilonova  
E. Pian *et al.* (2017)



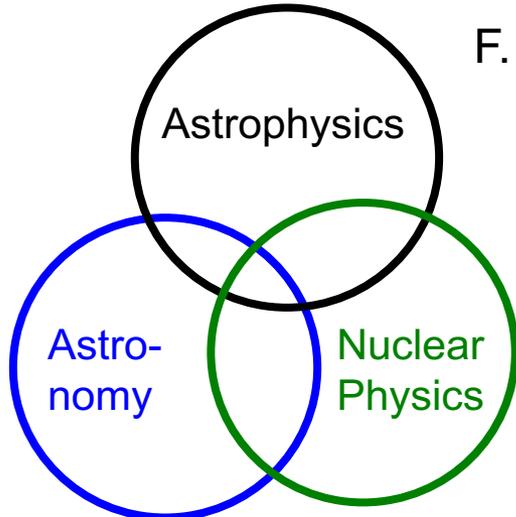
# Nuclear astrophysics at the intersection of three disciplines



F. Ferraro *et al.* (2018)



A. Slemer *et al.* (2017)



# COST action ChETEK [ketek] on Nuclear Astrophysics

## Chemical Elements as Tracers of the Evolution of the Cosmos

A network to bring European research, science and business together to further our understanding of the early universe

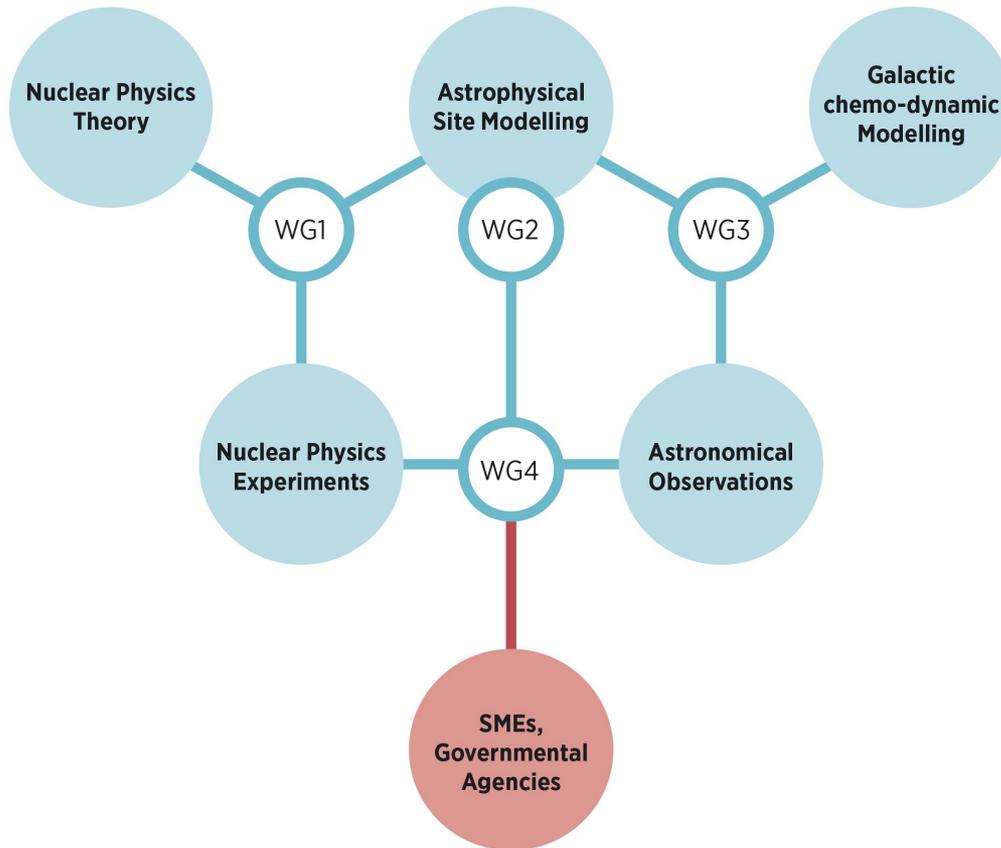


<http://www.chetec.eu>

- ◆ May 2017 - October 2021
- ◆ 30 European countries

Chair:

- ◆ Raphael Hirschi, Keele/UK



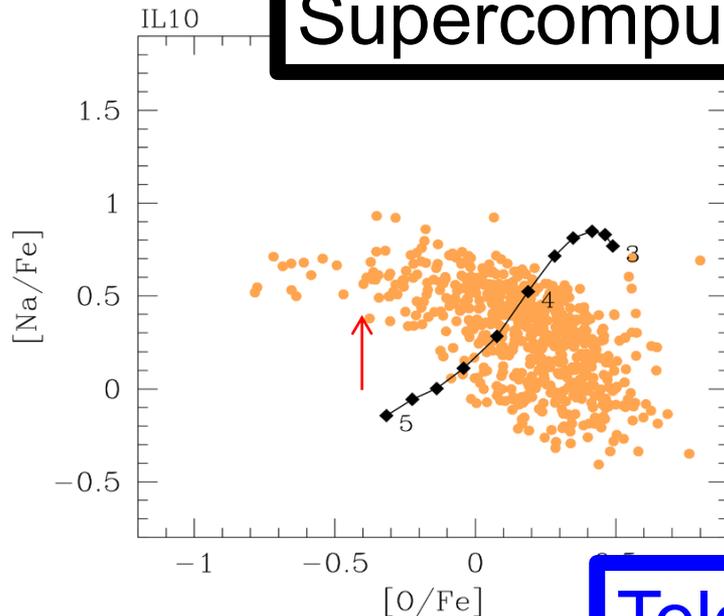
# Nuclear astrophysics, the three types of infrastructures needed for progress

## Astrophysics:

Models of asymptotic giant branch stars including  $^{22}\text{Ne}(p,\gamma)^{23}\text{Na}$  nuclear reaction rate Slemer+ 2017

## Nuclear laboratories

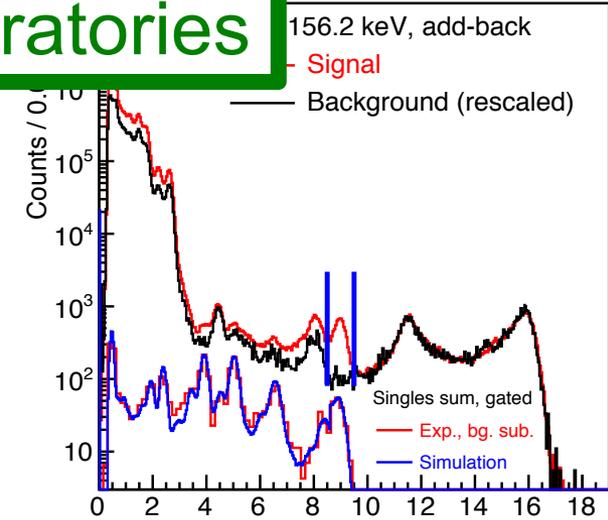
## Supercomputers



Astrophysics

Astronomy

Nuclear Physics



## Nuclear Physics:

Rate of the  $^{22}\text{Ne}(p,\gamma)^{23}\text{Na}$  nuclear reaction 10 times higher  
Ferraro+ 2018

## Telescopes

## Astronomy:

Observed  $^{23}\text{Na}$  and oxygen abundances in globular cluster stars Carretta+ 2009

## Nuclear astrophysics – challenges

- ◆ Many small university groups, often just one or two PIs per institution
- ◆ Nuclear astrophysicists are embedded in larger disciplines with their own agendas
  - ◆ Nuclear physics
  - ◆ Astronomy
  - ◆ Astrophysics
- ◆ Many EU countries have only a small or even no nuclear astrophysics community, with limited access to resources for researchers

## How to address these challenges of nuclear astrophysics?

- ◆ Start at the crucial intersection of researchers, the research **infrastructures**
- ◆ Provide EU-funded access to a set of key national and regional infrastructures
- ◆ Improve coherence and networking inside the field
- ◆ Address outreach inside and beyond the field

# ChETEC-INFRA, an EU-supported Starting Community of Research Infrastructures for Nuclear Astrophysics

5.0 M€ EU HORIZON2020 support (2021-2025)

TNA Transnational Access	JRA Joint Research Activities	NA Networking Activities
<b>Infrastructure <b>access</b></b> <ul style="list-style-type: none"><li>• 8 nuclear labs</li><li>• 4 telescopes</li><li>• 1 computer</li></ul>	<b>Infrastructure <b>usability</b></b> <ul style="list-style-type: none"><li>• Targets</li><li>• Neutron detectors</li><li>• Abundance corrections</li><li>• Analysis pipelines</li></ul>	<b>Infrastructure <b>networking</b></b> <ul style="list-style-type: none"><li>• Complementary Experiments</li><li>• Solar fusion+model</li><li>• Geochemistry/Astrophysics</li><li>• Nuclear astrophysics schools</li><li>• Outreach</li></ul>

32 partners, 17 countries, largest EU project for nuclear astrophysics yet

# First pillar: TA Transnational Access to Research Infrastructures

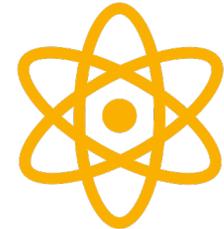
## ★ Astronuclear High Performance Computing

- 8 million cpu hours access
- University of Hull (UHULL) viper HPC, **United Kingdom**



## ★ Astronuclear Laboratories

- 3763 beam hours access
- HZDR Felsenkeller underground ion beam, **Germany**
- HZDR Accelerator Mass Spectrometry, **Germany**
- Vienna VERA Accelerator Mass Spectrometer, **Austria**
- Frankfurt Van de Graaff neutron beam, **Germany**
- PTB PIAF neutron and ion beam, **Germany**
- University of Cologne 10MV Tandem accelerator, **Germany**
- ATOMKI Cyclotron, **Hungary**
- IFIN-HH 3MV Tandetron, **Romania**



## ★ Astronuclear Telescopes

- 172 observation nights access
- IANA O Rozhen NAO 2m telescope, **Bulgaria**
- ASU Perek 2m Telescope, **Czech Republic**
- Aarhus University NOT Telescope La Palma, **Spain**
- Vilnius University Molėtai Observatory, **Lithuania**



# ChETEC-INFRA: all work packages at a glance

## ChETEC-INFRA partner institutions (funding applied for here)

### TA nuclear labs

- **HZDR, UNIVIE, GUF, PTB, UoC, ATOMKI, IFIN-HH**
- JRA1 Astronuclear Lab
- **INFN, HZDR, UNIVIE, CNRS, GUF, PTB, TUD, UoC, ATOMKI, UKE, UMIL, UNIPD, NCBJ, IFIN-HH**

### TA HPC

- **UHULL**
- JRA2 Astronuclear HPC
- **UHULL, ULB, GUF, CSFK, CSIC, UPC, KEELE**

### TA telescopes

- **ASU, AU-NOT, VU, IANAO**
- JRA3 Astronuclear Abundances
- **VU, IANAO, ASU, AU-NOT, AIP, MPG, INAF, UU**

### NA1 Comprehensive Nucl. Astro.

- **UPC, HZDR, ULB, MPG, HUJI, INAF, VU, CSIC, UU, UHULL**

### NA2 Dissemination/Outreach/Innovation

- **TUD, HZDR, CNRS, GANIL, GUF, INFN, UNIPD, VU, IFIN-HH, UU, KEELE, UHULL**

### NA3 Astronuclear Library

- **CSIC, HZDR, CNRS, IPGP, GUF, ATOMKI, INFN, UKE, UMIL**

### NA4 Mass Spectrometry Network

- **CSFK, HZDR, UNIVIE, IPGP, ETHZ, UHULL**

## ChETEC-INFRA associated (unfunded) partners in EU/associated countries

- CAEN, GLOBE Copenhagen, Edinburgh, EPS Nucl. Phys. Board, Heidelberg, L'Aquila, Manchester, Montpellier, Oslo, Odessa, SCIONIX, Turku, Warsaw, York

## ChETEC-INFRA partners outside Europe

- JINA-CEE/IReNA (US), CINA (China), JaFNA (Japan)

## ChETEC COST action

30 countries

100 additional institutions

500 additional scientists

# ChETEC-INFRA SNAQs [snacks]



## Schools on Nuclear Astrophysics Questions

- ★ **Goal:** Provide the same interdisciplinary background for nuclear astrophysicists
- ★ **3** successful editions with a total of
  - ★ **536** participants from **35** countries all over the world
  - ★ **7** lecturers
  - ★ **6** scientific talks by young scientists
- ★ **1** of **3** participants is female
- ★ **2** of **3** participants are young scientists



### Great thanks to the organising team!

- ★ Rosanna **Depalo** (*University of Padua, Italy*)
- ★ Camilla Juul **Hansen** (*Max Planck Institute for Astronomy Heidelberg, Germany*)
- ★ Marcel **Heine** (*Hubert Curien Pluridisciplinary Institute, France*)
- ★ Ann-Cecilie **Larsen** (*University of Oslo, Norway*)
- ★ Andreas **Korn** (*Uppsala University, Sweden*)
- ★ Arūnas **Kučinskas** (*Vilnius University, Lithuania*)
- ★ Mohamad **Moukaddam** (*University of Strasbourg, France*)
- ★ Sara **Palmerini** (*University of Perugia, Italy*)
- ★ Gianluca **Pizzone** (*Laboratori Nazionali del Sud, Italy*)
- ★ Konrad **Schmidt** (*Helmholtz-Zentrum Dresden-Rossendorf, Germany*)
- ★ Olivier **Sorlin** (*Grand Accélérateur National d'Ions Lourds, France*)
- ★ Livius **Trache** (*Horia Hulubei National Institute for Physics & Nuclear Engineering, Romania*)
- ★ Aurora **Tumino** (*Kore University of Enna, Italy*)



0 50 100 150

# Cross-cutting goals

**Educate** the next generation of scientists

- ◆ Start with high school students
- ◆ SNAQs for PhD students running since February 2021, reach+activate several 100 participants

**Increase participation** across Europe+, across genders, nationalities, ...

- ◆ Conference outreach, web page, ...
- ◆ Top-level Gender and Inclusiveness Coordinator

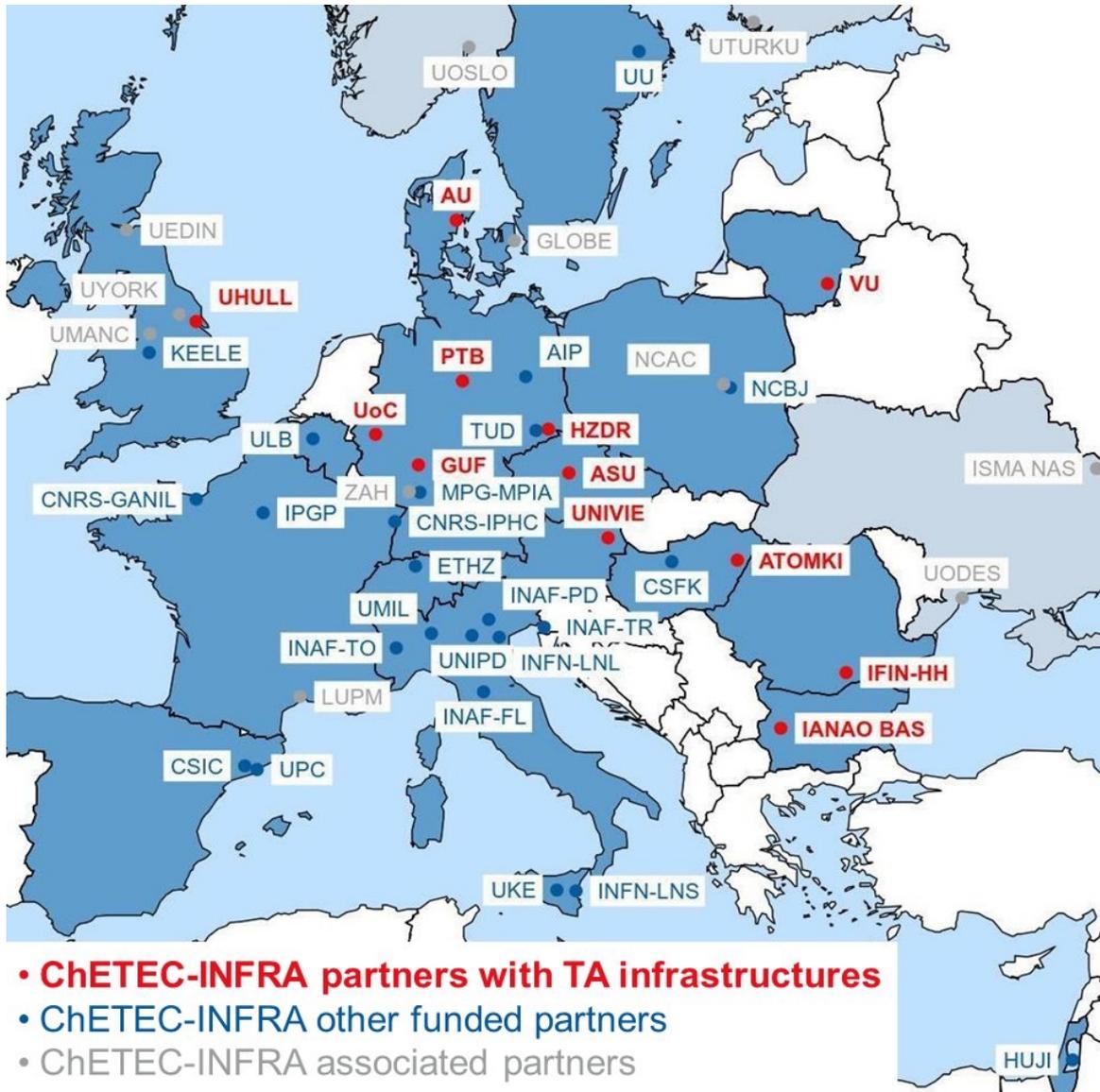
**Synergies and coherence** with neighboring communities

- ◆ Large telescopes, labs, and supercomputers
- ◆ **Links between astro and planetary sciences**
- ◆ Links to US IRENA, China, Japan, ...
- ◆ Links to COST actions **ChETEC**, GAIA-MW, PHAROS, ...

**Interdisciplinary** approaches

- ◆ TNA proposals using more than one type of infrastructure are encouraged
- ◆ Education of one PhD student in all three disciplines (observation, nuclear, astro)

# ChETEC-INFRA, 32 partners in 17 countries



# ChETEC-INFRA and Europlanet 2024 RI (1)

## We are happy to collaborate!

- ◆ Talk by Nigel Mason at ChETEC-INFRA kick-off meeting in May 2021
- ◆ Contact me any time at [d.bemmerer@hzdr.de](mailto:d.bemmerer@hzdr.de)
- ◆ ChETEC-INFRA is a Starting Community... we are meant to learn!

Overlap on **small telescopes** in both ChETEC-INFRA and Europlanet

- ◆ Moletai / Lithuania
- ◆ Rozhen / Bulgaria
- ◆ Ondrejov / Czech Republic

**Data** as a possible point of common interest

- ◆ Nuclear data
- ◆ Computational data
- ◆ Stellar spectra and abundances

# ChETEC-INFRA and Europlanet 2024 RI (2)

**Meteors** as tracers of galactic chemical evolution and planetary evolution

- ◆ ChETEC-INFRA NA4 „Mass Spectrometry Network“
- ◆ Maria Lugaro, Konkoly Observatory Budapest/Hungary (chair)
- ◆ Maria Schönbachler (ETHZ Switzerland), Marc Chaussidon (IPGP France), and several other partners

Strong **complementarity**

- ◆ Nuclear astrophysics studies production of the isotopes found in meteorites
- ◆ Planetary science uses these isotopes as tracers

**Example studies** planned in ChETEC-INFRA NA4

- ◆ Codes to be used both by nuclear astrophysicists and by cosmochemists
- ◆ Stable isotopes in bulk meteoritic samples and the s-process in AGB stars
- ◆ Xenon anomalies: Theory and single grain mass spectrometric analyses
- ◆ Extinct radionuclides and core-collapse supernovae
- ◆ Live radionuclides and Accelerator Mass Spectrometry

# ChETEC-INFRA, takeaway messages



## Basic facts

- ◆ 32 partners in 17 EU+ countries
- ◆ ChETEC-INFRA runs 01 May 2021 – 30 April 2025
- ◆ 5.0 M€ support from EU research infrastructure networking budget
- ◆ We are a **starting** community, meaning we are meant to **learn**

## Selected possible avenues for collaboration

- ◆ Small but manageable overlap in partners (small telescopes, NA4) between the projects
- ◆ Development/update of an interdisciplinary approach to store, manage, and make findable and accessible the research data produced
- ◆ Education of nuclear astrophysics students, and researchers, about planetary science
- ◆ ....